

**TREATABILITY STUDY WORK PLAN FOR
OPERABLE UNIT 1 OCTOBER 1991**

DOCUMENT DATE 10-01-91

2425

TREATABILITY STUDY WORK PLAN FOR OPERABLE UNIT 1

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION and FEASIBILITY STUDY



OCTOBER 1991

U.S. DEPARTMENT OF ENERGY
FERNALD OFFICE

DRAFT

1

TREATABILITY STUDY WORK PLAN FOR OPERABLE UNIT 1

**FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO**

REMEDIAL INVESTIGATION and FEASIBILITY STUDY

OCTOBER 1991

**U.S. DEPARTMENT OF ENERGY
FERNALD OFFICE**

DRAFT

TABLE OF CONTENTS

	<u>Page</u>
List of Tables	iii
List of Figures	iv
List of Acronyms/Abbreviations	v
List of Chemical Abbreviations	vii
Distribution List	viii
1.0 Project Description	1-1
1.1 Purpose	1-1
1.2 Background Information	1-2
1.2.1 Site Description	1-2
1.2.2 Operable Unit Description	1-3
1.2.3 Nature and Extent of Contamination	1-9
1.2.4 Remedial Action Objectives	1-16
1.2.5 EPA Guidance	1-17
1.3 Treatability Study Goals	1-24
1.4 Treatability Study Description	1-24
1.4.1 Approach	1-24
1.4.2 Cement Stabilization	1-30
1.4.3 Vitrification	1-31
1.4.4 General Selection Criteria	1-31
2.0 Remedial Technology Description	2-1
3.0 Test and Data Quality Objectives	3-1
3.1 Performance Objectives and Desired Data	3-9
3.2 Data Quality Objectives	3-12
4.0 Experimental Design and Procedures	4-1
4.1 Cement Stabilization Experiment Design	4-1
4.1.1 Preliminary Phase - Stage 1	4-5
4.1.2 Preliminary Phase - Stage 2 (Composite Samples)	4-5
4.1.3 Advanced Experiments - Stage 1	4-6
4.1.4 Advanced Experiments - Stage 2	4-6
4.1.5 Advanced Experiments - Optional	4-6
4.1.6 Procedures	4-6
4.1.7 Data Required	4-7
4.2 Vitrification Experiment Design	4-8
4.2.1 Preliminary Phase - Stage 1 (Composite Samples)	4-10
4.2.2 Advanced Phase - Stage 1	4-10
4.2.3 Advanced Phase - Stage 2	4-12
4.2.4 Advanced Phase - Optional	4-12

TABLE OF CONTENTS
(continued)

	<u>Page</u>
4.2.5 Procedures	4-12
4.2.6 Data Required	4-13
5.0 Equipment and Materials	5-1
6.0 Sampling and Analysis	6-1
7.0 Data Management	7-1
7.1 General	7-1
7.2 Stabilization	7-2
7.3 Vitrification	7-2
8.0 Data Analysis and Interpretation	8-1
8.1 Effectiveness of Waste Forms	8-1
8.2 Stabilization	8-1
8.3 Vitrification	8-2
8.4 Procedures Used to Assess Data Precision, Accuracy, and Completeness	8-3
9.0 Health and Safety	9-1
10.0 Residuals Management	10-1
10.1 Stabilized Waste	10-1
10.2 Leachate	10-1
11.0 Community Relations	11-1
12.0 Reports	12-1
13.0 Schedule	13-1
14.0 Management and Staffing	14-1
References	
Appendix A - Justification for Using a Minimum UCS Value of 500 psi and a Portland Cement/Fly Ash Mixture	A-1
Appendix B - Technology Development Laboratory Standard Operating Procedures	B-1
Appendix C - Other Operating Procedures	C-1
Appendix D - Health and Safety Plan for the Fernald Environmental Management Project Waste Pits 1, 2, 3, 4, 5, and 6 and the Clearwell and the Burn Pit Treatability Study - Remedial Screening, Remedy Selection Phases	D-1
Appendix E - Radiological and Chemical Constituents of the Waste Pits	E-1

LIST OF TABLES

2425

<u>Table</u>	<u>Title</u>	<u>Page</u>
1-1	Estimated Waste Storage Inventory in Operable Unit 1	1-6
1-2	Radionuclides and Chemicals of Potential Concern for Operable Unit 1	1-10
1-3	Estimated Number of Experiments by Phase - Cement Stabilization	1-25
1-4	Estimated Number of Experiments by Phase - Vitrification	1-26
1-5	Analytical Tests - Cement Stabilization of Untreated Waste Material	1-27
1-6	Analytical Tests - Vitrification of Untreated Waste Material	1-28
1-7	Relationship of Treatability Data to FS Evaluation Criteria	1-33
3-1	Comparison of ARARs, TBCs, Preliminary Remediation Goals, Derived Leachate Reference Levels, FEMP Background Concentrations, and Contract Lab Required Detection Limits for Water and Surface Soils	3-2
3-2	Comparison of Preliminary Remediation Goals, Derived Leachate Reference Levels, FEMP Background Concentrations, and Contract Lab Required Detection Limits for Soil	3-4
3-3	Comparison of ARARs, TBCs, Preliminary Remediation Goals, Derived Leachate Reference Levels, FEMP Background Concentrations, and Contract Lab Required Detection Limits for Water	3-7
3-4	Chemical and Radiological Information to be Acquired - Preliminary Phase	3-10
3-5	Summary of Analytical Levels	3-13
3-6	Stabilization Test DQOs	3-14
3-7	Vitrification Test DQOs	3-16
4-1	Cement Stabilization Experiment Matrices (Stage 1)	4-2
4-2	Vitrification Experiment Matrix Preliminary Phase (Stage 1)	4-11
5-1	Equipment and Materials	5-2
6-1	Analytical Characterization Parameters for Operable Unit 1	6-3
6-2	Geotechnical/Physical Tests	6-4

LIST OF FIGURES

2425

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1-1	Operable Unit 1 Study Area	1-4
1-2	Major Features of the FEMP	1-5
1-3	Remedial Action Objectives	1-18
1-4	The Role of Treatability Studies in the RI/FS and RD/RA Process	1-21
1-5	Relationship of the Operable Unit 1 Treatability Studies to the RI/FS Process	1-22
4-1	Cement Stabilization Laboratory Screening Flowchart	4-4
4-2	Vitrification Laboratory Screening Flowchart	4-9
6-1	Sample Borehole Locations	6-2
8-1	General QA/QC Report	8-5
13-1	Treatability Study Schedule	13-2
14-1	Treatability Study Management and Staffing	14-2

LIST OF ACRONYMS/ABBREVIATIONS

ARAR	applicable or relevant and appropriate requirements
ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHP	Chemical Hygiene Plan
CIS	Characterization Investigation Study
CLP	contract laboratory program
CLRDL	contract laboratory required detection limit
d	day
DDT	dichlorodiphenyl trichloroethane
DLRL	derived leachate reference level
DOE	U.S. Department of Energy
DQO	data quality objective
EPA	U.S Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FFCA	Federal Facilities Compliance Agreement
FMPC	Feed Materials Production Center
FS	feasibility study
HEPA	high efficiency particulate air
IC	ion chromatography
L	liter
μ Ci	microCuries
MCL	maximum contaminant level
mrem	millirem
MTCLP	modified toxicity characteristics leaching procedure
NPDES	National Pollutant Discharge Elimination System

**LIST OF ACRONYMS
(Continued)**

PCBs	polychlorinated biphenyls
pCi	picoCurie
PCT	nuclear waste glass product consistency test
ppm	parts per million
PRG	preliminary remediation goals
psi	pounds per square inch
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
QCC	Quality Control Coordinator
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RfD	(toxicity based) reference dose
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
TBC	to be considered
TCLP	toxicity characteristics leaching procedure
RME	reasonable maximum exposure
SAP	Sampling and Analysis Plan
SOP	standard operating procedures
TDL	Technology Development Laboratory
UCS	unconfined compressive strength
WEMCO	Westinghouse Environmental Management Company of Ohio
WL	working level
WMCO	Westinghouse Materials Company of Ohio

LIST OF CHEMICAL ABBREVIATIONS

U	uranium
Th	thorium
Al	aluminum
As	arsenic
Ba	barium
Be	beryllium
B	boron
Ca	calcium
Cd	cadmium
Cr	chromium
Cs	cesium
Cu	copper
Mn	manganese
Np	neptunium
Pu	plutonium
Ra	radium
Se	selenium
Sr	strontium
Tc	technetium
Tl	thallium
V	vanadium
Zn	zinc
NaOH	sodium hydroxide

DISTRIBUTION LIST

Project Director - John Wood, Fernald
Deputy Project Director, John Razor, Fernald
Site Characterization Director - Douglas Harmel, Fernald
Technical Integration Director - Briand Wu, Fernald
Operable Unit/Task Managers - Mike Higgins, Knoxville
Dan Smith, Oak Ridge
David Smith, Fernald
Susan Rhyne, Knoxville
Robin Smith, Pittsburgh
Sam Wolinsky, Fernald
John Frazier, Knoxville
John Martin, Fernald
Sue Wolinsky, Fernald
Ernie Stine, Knoxville

Project QA Officer - Larry Sexton, Fernald
Technical QA Officer - Steve Alvanas, Knoxville
Site Project Files - Fernald
IT-Monroeville Project Central Files
IT-Knoxville Project Central Files
ASI-Oak Ridge Project Files

DOE COR - Jack Craig, Fernald
- OU Manager - Oba Vincent
WMCO - Dennis Carr, Fernald OU Manager
- OU Manager - Ike Diggs
Parsons - OU Manager - Scott Mallette

EPA, Region 5 - James Saric, Chicago
OEPA - Graham Mitchell, Dayton

1.0 PROJECT DESCRIPTION

The Fernald Environmental Management Project (FEMP) is a contractor-operated federal facility for the production of pure uranium for the U.S. Department of Energy (DOE). The FEMP is located on 1050 acres in a rural area approximately 18 miles northwest of downtown Cincinnati, Ohio. On July 18, 1986, a Federal Facilities Compliance Agreement (FFCA) was jointly signed by the U.S. Environmental Protection Agency (EPA) and DOE to ensure that human health and environmental impacts associated with past and present activities at the FEMP are thoroughly investigated so that appropriate remedial actions can be assessed and implemented. A remedial investigation/feasibility study (RI/FS) has been initiated to develop these remedial actions.

The FEMP was divided into five operable units to facilitate remediation. Operable Unit 1 consists of the Waste Pits 1 through 6, the Clearwell, and the Burn Pit. Radioactive waste, consisting of naturally occurring radionuclides left over from uranium ore processing, and various chemicals were stored in this operable unit. The waste in the pits, the Clearwell, and soil surrounding and between the pits are to be remediated. Both in situ and removal alternatives have been proposed. Removal options are expected to include some of the contaminated soils surrounding the waste. The total amount of material to be treated is approximately 1.4 million cubic yards. The scope of the treatability study discussed in this document is the laboratory screening of treatment technologies for the waste in Waste Pits 1 through 6, the Burn Pit, and the Clearwell. This work plan was prepared in accordance with EPA's "Guide for Conducting Treatability Studies Under CERCLA" (EPA 1989a) and the Fernald quality assurance project plan (QAPP).

1.1 PURPOSE

The initial screening of alternatives has been conducted (DOE 1991a) for Operable Unit 1 with cement stabilization and vitrification being identified as two potential treatment technologies to be promoted for further consideration. However, to adequately evaluate alternatives in the detailed analysis, additional data obtained through treatability studies are needed on each of these technologies to better evaluate their performance.

Due to the lack of available data for the vitrification and stabilization technologies, treatability tests for both technologies are needed. Literature surveys provide limited data for these technologies or contain information that is not specific to the waste forms common to Operable Unit 1. Treatability testing will provide data specific to the Operable Unit 1 waste, which will aid in the selection of the final waste form. Vital information such as bulking factors (percent change in waste volumes), unconfined compressive strengths (UCSs), leachate characteristics, as well as permeability and durability of the final waste forms will be developed.

This treatability work plan outlines the objectives, procedures, and techniques for conducting a screening of cement stabilization and vitrification technologies for Waste Pits 1 through 6, the Burn Pit, and the Clearwell of Operable Unit 1. The data resulting from this screening will be used to support the FS by establishing or identifying the following:

- Proof of principle for each technology's applicability to Operable Unit 1 waste
- Compliance of technology with applicable or relevant and appropriate requirements (ARARs)
- Fate and transport modeling
- Leachability data to support residual risk calculations in support of the effectiveness criteria evaluation for the detailed evaluation of alternatives
- Refinement of process requirements for cost estimation purposes
- Initial database for use in subsequent bench- and pilot-scale studies used in support of remedial design

1.2 BACKGROUND INFORMATION

1.2.1 Site Description

A variety of chemical and metallurgical processes were utilized at the FEMP for manufacturing uranium products. During the manufacturing process, uranium compounds were introduced into the FEMP processes at several points. Impure starting materials were dissolved in nitric acid, and the uranium was purified through solvent extraction to yield a solution of uranyl nitrate. Evaporation and heating converted the nitrate solution to uranium trioxide (UO₃) powder. This compound was reduced with hydrogen to uranium dioxide (UO₂) and then converted to uranium tetrafluoride (UF₄) by reaction with anhydrous hydrogen fluoride. Uranium metal was produced by reacting UF₄ and magnesium metal in a refractory-lined vessel. This primary uranium metal was then remelted with scrap uranium metal to yield a purified uranium ingot.

From 1953 through 1955, the FEMP refinery processed pitchblende ore from the Belgian Congo. Pitchblende ore contains all daughter products of the uranium decay chains and is particularly high in radium. No chemical separation or purification was performed on the ore before its arrival at the FEMP. Beginning in 1956, the refinery feedstock consisted of uranium concentrates (yellowcake) from Canada and the United States. Canadian concentrates were not processed after 1960. In the production of these concentrates, most of the uranium daughters had been removed. However, radium-226 (Ra-226) and thorium-230 (Th-230) remained in the yellowcake in amounts that varied with the process.

Small amounts of thorium were produced at the FEMP on several occasions from 1954 through 1975. Thorium operations were performed in the metals fabrication plant, the recovery plant, the special projects plant, and the pilot plant. The FEMP currently serves as the thorium repository for DOE and maintains long-term storage facilities for a variety of thorium materials.

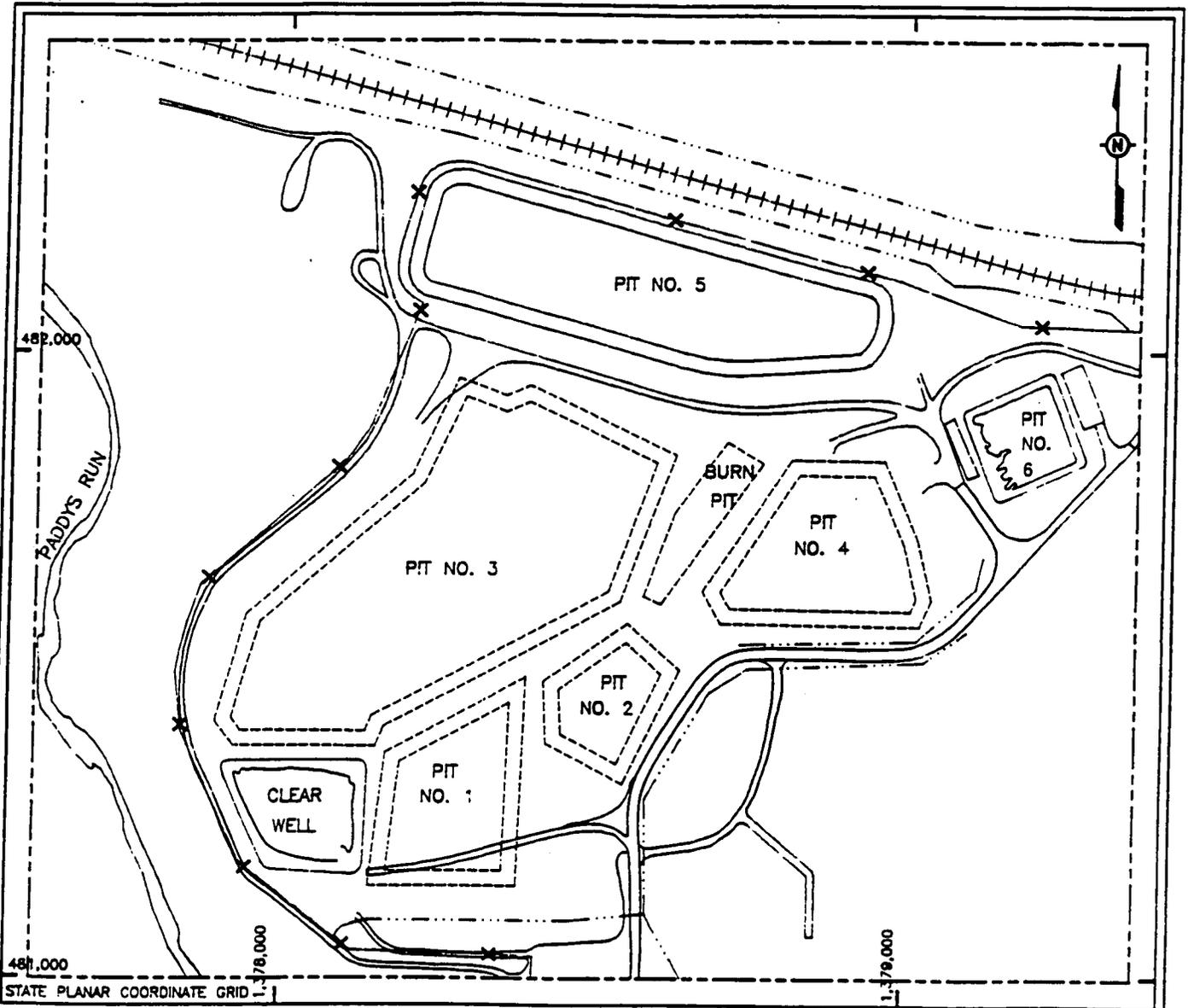
Large quantities of liquid and solid waste were generated by the various operations at the FEMP. Before 1984, disposal of solid and slurried waste from FEMP processes was in the on-property waste storage area. This area, which is located west of the production facilities, includes seven low-level radioactive waste storage pits and a clearwell; two earthen-bermed concrete silos containing K-65 wastes that are high-specific activity and low-level radium-bearing residues resulting from the pitch-blende refining process; one concrete silo containing metal oxides (raffinate solids disposed of in the pits are similar to those initially dried and pneumatically transferred to that silo) and one unused concrete silo; two lime sludge ponds; and a sanitary landfill. The waste storage area is addressed under Operable Units 1, 2, and 4.

An inactive fly ash disposal area and an active fly ash pile, addressed under Operable Unit 2, are located approximately 3000 feet south-southeast of the waste storage area. One pile remains active for the disposal of fly ash from the FEMP coal-fired boiler plant. Fly ash from this area will be tested in the Operable Unit 1 treatability studies. An area between and adjacent to the fly ash areas, known as the Southfield, is believed to be the disposal site for construction debris and possibly other types of solid waste from FEMP operations. The Southfield is also being addressed as a solid waste unit under Operable Unit 2.

1.2.2 Operable Unit Description

The waste pits consist of Pits 1 through 6, the Burn Pit, and Clearwell (Figure 1-1). Figure 1-2 shows where Operable Unit 1, the waste storage area, is in relation to the FEMP site. They are numbered chronologically in their order of construction. Pits 3 and 5 are referred to as "wet" because they received waste in mostly slurry form. Pits 1, 2, 4, and 6 are referred to as "dry" because they received mostly dry solid waste from trucks. Table 1-1 describes the characteristics of the waste pits and provides an approximate inventory of stored waste based on the limited amount of available historical information. Appendix E contains more detailed information on the radiological, organic, and inorganic constituents of the waste pits.

Waste Pit 1, constructed in 1952, was excavated into an existing clay lens and has a capacity of 33,676 cubic yards. The waste material that was placed in the waste pit consisted primarily of neutralized waste filter cakes, production plant sump cakes, depleted slag, scrap graphite, contaminated brick, and sump liquor. Although the majority of the waste was dry solids, decant pipes were constructed through the west berm. These pipes were rarely used. The quantity of uranium placed in the



NOTES:

OPERABLE UNIT 1 CONSISTS OF THE 6 WASTE STORAGE PITS, THE CLEAR WELL, AND THE BURN PIT.

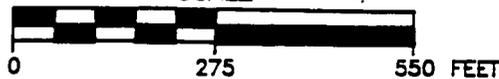
PITS 1, 2, AND 3 ARE COVERED. PIT 4 HAS AN INTERIM CAP.

THE OUTLINES OF THE COVERED PITS ARE APPROXIMATE.

LEGEND:

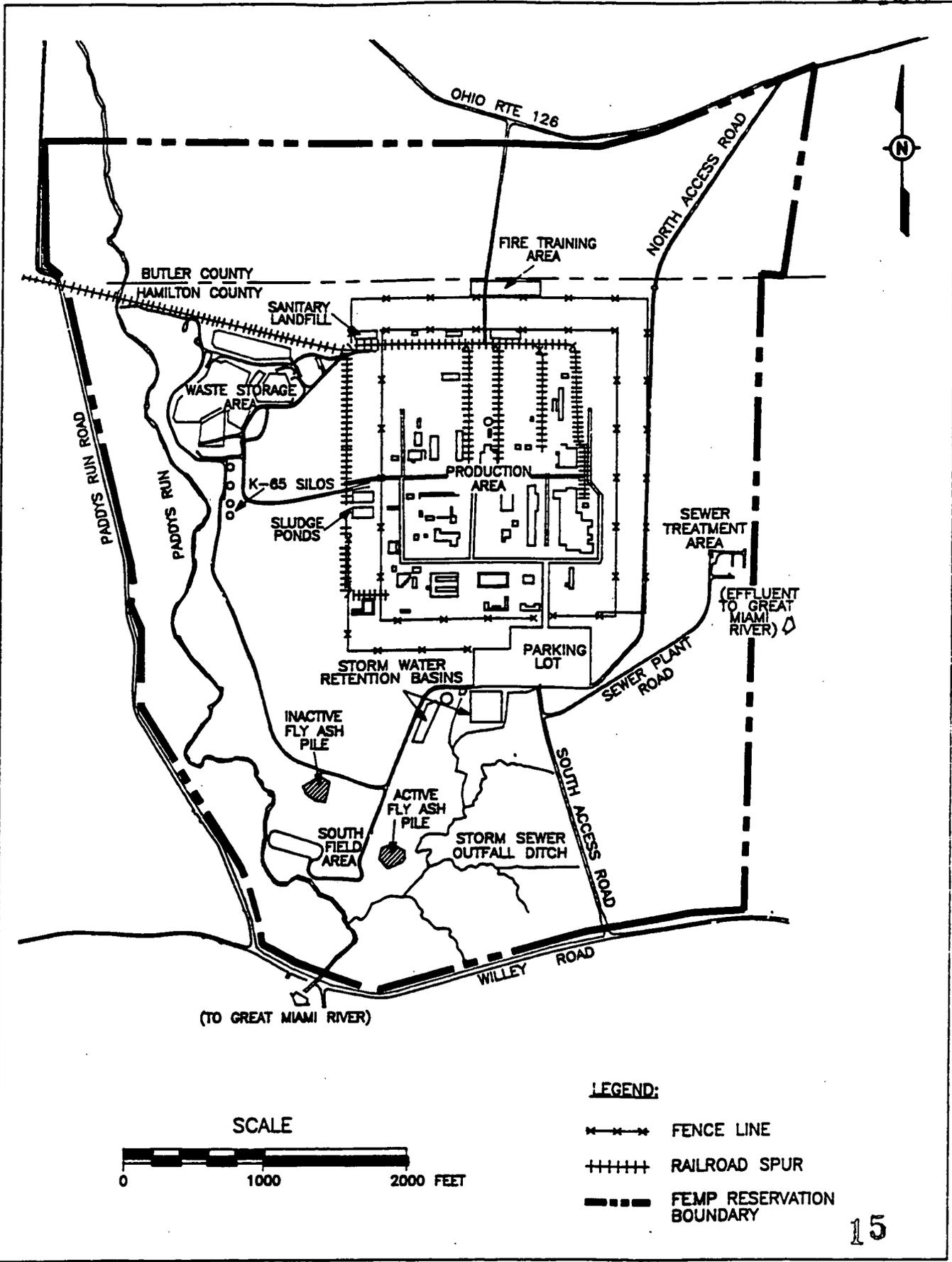
- OPERABLE UNIT 1 STUDY AREA
- ===== ROADWAY
- - - - - DRAINAGEWAY
- x-x-x-x- FENCE
- + + + + + RAILROAD

SCALE



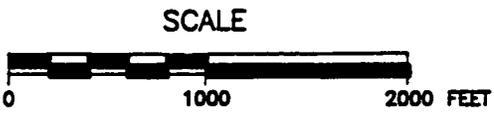
303317-A-C239/OU1-TS/KNOX

FIGURE 1-1. OPERABLE UNIT 1 STUDY AREA



303317-A-C253/OUT18/KNOX

(TO GREAT MIAMI RIVER)



- LEGEND:**
- x—x— FENCE LINE
 - + + + + + RAILROAD SPUR
 - - - - - FEMP RESERVATION BOUNDARY

FIGURE 1-2 MAJOR FEATURES OF THE FEMP

TABLE 1-1. ESTIMATED WASTE STORAGE INVENTORY IN OPERABLE UNIT 1^a

Waste Pit	Estimated Waste Quantity (cu yd)	Depth (ft)	Contents	Estimated Radioactive Material (kg)	Construction	Operational Period	Current Status
Pit No. 1	33,676	17	Neutralized waste filter cakes, graphite, brick scrap, sump liquor and cakes, depleted slag	Uranium - 52,000	Excavated in clay lens and lined with clay	1952-59	Covered with clean fill dirt
Pit No. 2	18,478	13	Dry low-level radioactive wastes: neutralized waste filter cakes, sump liquor and cakes, brick, scrap, depleted slag	Uranium - 1,206,000 Thorium - 400	Lined with a compacted on-site native clay layer	1957-64	Covered with clean fill dirt
Pit No. 3	237,053	27	Lime neutralized raffinate concentrate, slag leach residues, filter cakes, fly ash, and lime sludge	Uranium - 129,000 Thorium - 400	Excavated into clay lens and lined with clay along the pit walls	1959-77	Covered with clean fill dirt
Pit No. 4	53,706	24	Process residues, trailer cakes, slurries, raffinates, depleted graphite, asbestos, nonburnable trash, barium chloride	Uranium - 3,000,000 Thorium - 61,800	Same as Pit No. 3	1960-86	Interim RCRA cap

FER/OU1-6/DK.350.1A/10-05-91

TABLE 1-1 (Continued)

Waste Pit	Estimated Waste Quantity (cu yd)	Depth (ft)	Contents	Estimated Radioactive Material (kg)	Construction	Operational Period	Current Status
Pit No. 5	98,841	30	Solids from neutralized raffinate, slag leach slurry, lime sludge, arsenic	Uranium - 50,309 Thorium - 17,000	Lined with 60 mil Royal-Seal EPDM elastomeric membrane	1968-87	Uncovered
Pit No. 6	11,556	24	Depleted slag, sump green salt, process residue, filter cake	Uranium - 843,142	Same as Pit No. 5	1979-85	Uncovered
Burn Pit	9074	20	Reactive chemicals, pyrophoric chemicals, oils, combustible wastes, scrap iron, wood, tin cans, ashes, and gravel	Unknown	Excavated in clay Excavated clay used to line Pits 1 and 2	1957-86	Backfilled
Clearwell	5008	27	Clear process effluents and surface runoff	Unknown	Lined with clay	1959	In use

*Information generated by WEMCO, Weston, and Dames & Moore.

PER/MP350.1/ATK.OUI-6/10-05-91

17

pit is estimated at 52,000 kilograms (kg). Waste Pit 1 was closed in 1959, backfilled, and covered with clean fill dirt. Surface water runoff is diverted to the Clearwell before being discharged to the Great Miami River.

Waste Pit 2 was constructed in 1957 and lined with a compacted on-property native clay layer. Waste Pit 2 received primarily dry, low-level radioactive waste consisting of neutralized filter cakes, sump cakes, depleted slag, contaminated brick, sump liquor, and concentrated raffinate residues. As with Pit 1, decant pipes were installed through the west berm. The pit holds approximately 18,478 cubic yards of waste that contain approximately 1,206,000 kg of uranium and approximately 400 kg of thorium. The waste pit was covered with clean uncontaminated fill and graded to direct surface drainage to the Clearwell for subsequent discharge to the Great Miami River.

Waste Pit 3 was constructed in 1959 by excavating into the underlying clay lens and placing a layer of clay along the pit walls. This pit was the first "wet" pit built for the purpose of settling solids from wet waste streams. The pit received wet waste streams consisting of radioactive, lime-neutralized, raffinate concentrate from the recovery plant and the general sump and slag leach residue, filter cakes, fly ash, and lime sludges. The principal waste contained in Pit 3 is lime-neutralized radioactive raffinate concentrate. The pit contains an estimated 237,053 cubic yards of waste, including 129,000 kg of uranium and 400 kg of thorium. The pit was retired in 1977 and clean fill was placed over the waste. Surface water runoff from the mounded pit cover is diverted to the Clearwell before discharge to the Great Miami River.

Waste Pit 4 was constructed in 1960 and used until May 1986. This pit was constructed in a similar manner as Pit 3 with a liner consisting of two feet of compacted clay on the sides and bottom. Waste Pit 4 received process residues, filter cakes, slurries, raffinates, graphite, noncombustible trash, and asbestos. The pit contains an estimated 53,706 cubic yards of waste (23 percent of Pit 3) but has more than 3 million kg of uranium and 61,800 kg of thorium. Between May 1981 and April 1983, Pit 4 also received 10,681 kg of low-level radioactive waste containing barium chloride salt. The pit is covered with an interim Resource Conservation and Recovery Act (RCRA) cover at the present time and is no longer in service.

Waste Pit 5 was constructed in 1968 and operated from 1968 to 1983. The pit was lined with a 60-mil-thick elastomeric membrane. As with Pit 3, this waste pit received liquid waste slurries from the refinery and the recovery plant, including neutralized raffinate settled solids, slag leach slurry, sump slurries, and lime sludge. The waste volume consists of approximately 98,841 cubic yards, containing 50,309 kg of uranium and 17,000 kg of thorium. From 1983 to February 1987, when it was taken out

of service, Pit 5 received only clear decant from the general sump, filtrate from the recovery plant, or nonradioactive slurries, such as blowdown from the boiler plant and water treatment plant.

Waste Pit 6 was constructed in 1979 and operated until 1985. Pit 6 was constructed in the same manner as Waste Pit 5 and lined with a similar synthetic liner. Fine-grained solid waste, including green salt, filter cakes, and process residues containing elevated levels of uranium, have been stored in the pit. Until March 1987, rainfall that had collected in the pit was pumped to Waste Pit 5 for settling before discharge via the Clearwell. Since then, collected rainfall is pumped to the Bionitrification Surge Lagoon. The current waste volume is approximately 11,556 cubic yards, which consists of 843,142 kg uranium. The capacity of Waste Pit 6 has not been reached; however, the pit is currently retired.

The Burn Pit was constructed in 1953 as a site to excavate clay to line Waste Pits 1 and 2. Beginning in 1957, the resulting excavation was used to dispose of laboratory chemicals and to burn combustible materials, including pyrophoric and reactive chemicals, oils, and other low-level contaminated combustible materials. The current waste volume is estimated to be 9074 cubic yards. The actual inventory of materials or chemicals that were disposed of in the Burn Pit is unknown. The boundaries of the Burn Pit are no longer discernible from the covered Pit 4.

The Clearwell receives surface runoff from the waste pit area. The Clearwell was used until March 1987 as a final settling basin before discharge to the Great Miami River via the FEMP National Pollutant Discharge Elimination System (NPDES) discharge point. The Clearwell still receives decanted water from Pit 5. Presently the Clearwell is estimated to contain 1,546,265 gallons of water.

1.2.3 Nature and Extent of Contamination

The RI data and data from previous studies show that releases to the environment from Operable Unit 1 have occurred. The surface soils, the glacial overburden, and the groundwater beneath the waste pits are contaminated. The principal environmental concern associated with Operable Unit 1 is contaminant migration and transport in surface water and groundwater. Previous radionuclides and chemicals of concern are listed in Table 1-2. Additional compounds are being analyzed under the new EPA-approved sampling analysis plan (SAP). This plan involved taking 13 soil borings from Waste Pits 1 through 4 and the Burn Pit. The types of samples taken and the analyses conducted on the samples are summarized in Section 6.0. Composite samples were taken from Waste Pits 5, 6, and the Clearwell. This was necessary due to the consistency of the contained materials. These samples will be analyzed for the same parameters as those for Waste Pits 1 through 4 and the Clearwell. Results from the RI are briefly presented in the following paragraphs.

TABLE 1-2. RADIONUCLIDES AND CHEMICALS OF POTENTIAL CONCERN FOR OPERABLE UNIT 1

ENVIRONMENTAL MEDIA: WASTE PIT		
Radionuclides	Inorganics	Organics
U-234	Arsenic	Acenaphthene
U-235/236	Barium	Anthracene
U-238	Beryllium	Benzo(a)anthracene
Th-228	Cadmium	Benzo(b)fluoranthene
Th-230	Chromium	Benzo(k)fluoranthene
Th-232	Cobalt	Benzo(g,h,i)perylene
Pu-238	Copper	Benzo(a)pyrene
Pu-239/240	Lead	Chrysene
Tc-99	Magnesium	Ethyl benzene
Sr-90	Manganese	Fluoranthene
Np-237	Mercury	Fluorene
Cs-137	Nickel	Indeno(1,2,3-cd)pyrene
Ra-226	Selenium	2-methylnaphthalene
Ra-228	Silver	Naphthalene
Pb-210	Thallium	Pentachlorophenol
	Vanadium	Phenanthrene
	Zinc	Phenol
		Pyrene
		Toluene
		Xylenes
		Acetone
		2-butanone
		PCBs (Aroclors-1242, 1248, 1254, 1260)
		DDT
		Ethyl parathion

TABLE 1-2 (Continued)

ENVIRONMENTAL MEDIA: WASTE PIT		
Radionuclides	Inorganics	Organics
		Methyl parathion
		Bis(2-ethylhexyl)phthalate
		Di-n-butyl phthalate
		Di-n-octyl phthalate
		Chloroform
		Methylene chloride
		1,1,1-trichloroethane
		Trichloroethene
ENVIRONMENTAL MEDIA: GROUNDWATER		
Radionuclides	Inorganics	Organics
U-234	Aluminum	Butyl benzyl phthalate
U-235	Arsenic	Di-n-butyl phthalate
U-238	Barium	1,1-dichloroethane
Total uranium	Copper	1,1,1-trichloroethane
Th-228	Magnesium	Trichloroethene
Th-230	Manganese	Toluene
Th-232	Molybdenum	Acetone
Tc-99	Nickel	cis-1,2-dichloroethene
Sr-90	Vanadium	2-propanol
Ra-226	Zinc	Tetrachloroethene
Ra-228		2-butanone ^a
Pb-210		Chloroform ^a
		Ethyl parathion ^a
		Methyl parathion ^a
		Phenol ^a
		Methylene chloride ^a

TABLE 1-2 (Continued)

ENVIRONMENTAL MEDIA: SURFACE WATER		
Radionuclides	Inorganics	Organics
U-234	Aluminum	Bis(2-ethylhexyl) phthalate
U-235	Beryllium	Di-n-butyl phthalate
U-238	Cobalt	
Total uranium	Manganese	
Tc-993	Vanadium	
Ra-226		
Ra-228		
Pb-210		
ENVIRONMENTAL MEDIA: SURFACE SOIL		
Radionuclides	Inorganics	Organics
U-238	(No data available)	(No data available)
Th-232		
Ra-226		
Pb-210		
ENVIRONMENTAL MEDIA: SUBSURFACE SOIL		
Radionuclides	Inorganics	Organics
U-234	(No data available)	2-butanone ^b
U-235		Carbon disulfide ^b
U-238		Ethyl benzene ^b
Total uranium		Acetone ^b
Th-228		Xylenes ^b
Th-230		
Th-232		
Tc-99		
Sr-90		
Ra-226		
Pb-210		

TABLE 1-2 (Continued)

ENVIRONMENTAL MEDIA: SEDIMENT		
Radionuclides	Inorganics	Organics
Total uranium	None	Acetone
Ra-226		Methylene chloride
ENVIRONMENTAL MEDIA: DIRECT RADIATION		
Radionuclides	Inorganics	Organics
Penetrating radiation	Not applicable	Not applicable
ENVIRONMENTAL MEDIA: AIR		
Radionuclides	Inorganics	Organics
U-238	(No data available)	(No data available)
Th-232		
Ra-226		
Radon		

^aChemicals expected to reach aquifer within 500 years based on preliminary fate and transport calculations.

^bOrganic data for surface soil were taken from the one sample available.

Waste Pit Contents

The contents of the waste pits were sampled under the Characterization Investigation Study (CIS) program conducted by Roy F. Weston in 1986 (Weston 1987). Data from the CIS sampling program indicate that the concentration of uranium-238 (U-238) was relatively high in Pits 2, 4, and 6 with concentrations ranging between 53 and 17,900 pCi/g, 509 and 15,800 pCi/g, and 12,500 and 18,700 pCi/g, respectively. Samples from the Burn Pit contained the lowest uranium concentrations, which ranged from 22 to 454 pCi/g. Pits 3 and 5 contained higher concentrations of Th-230 than the other pits with concentrations ranging from 15 to 21,900 pCi/g and 3,080 to 20,200 pCi/g, respectively. The Clearwell and Pit 5 contained higher concentrations of Ra-226 than the other pits with concentrations ranging between 22 and 458 and 235 and 999 pCi/g, respectively.

Results from the CIS for the inorganic chemical analysis show that all pit residues had elevated concentrations of aluminum, calcium, iron, and magnesium. Pits 3 and 5 had elevated concentrations of arsenic with a maximum concentration of 3049 parts per million (ppm) in Pit 3. Vanadium was present in all pits with concentrations ranging up to 9696 ppm in Pit 3. Pits 2, 3, 6, and the Burn Pit had elevated lead concentrations. These ranged from detection limits to 613 ppm, which was found in Pit 3. Pits 3 and 5 and the Clearwell had elevated mercury concentrations. These ranged from detection limits to 4.0 ppm, which was found in Pit 3 and the Clearwell. Pits 4, 6, and the Burn Pit had the higher silver concentrations, which measured 444,158, and 506 ppm, respectively. Pit 4 had fluoride and barium with concentrations ranging from 47,812 ppm to 124,576 ppm and from 444 to 6,669 ppm, respectively.

Results from the organic chemical analysis identified the presence of polychlorinated biphenyls (PCBs) in Pits 1 through 6 and the Burn Pit. The PCBs most frequently detected were Aroclor-1254, Aroclor-1248, and Aroclor-1260. The concentrations of PCBs in the waste storage area ranged from detection limits to 10.0 ppm with Pit 1 containing the highest concentrations. Various organic chemicals found in other storage areas outside Operable Unit 1 were also detected in individual pits. In Pit 1, chrysene and phenanthrene were detected and ranged in concentration up to 0.51 and 2.3 ppm, respectively. In Pits 1 and 2, 4,4-DDT was detected in concentrations ranging up to 1.6 and 1.4 ppm, respectively. In Pit 4, tetrachloroethene was detected at 30.0 ppm. In Pit 6, a concentration of 29.0 ppm 1,1,2,2-tetrachloroethane was detected.

Surface Soils

A review of the surface soil data obtained during the CIS program shows that uranium and thorium are the predominant and most widespread radionuclides in the waste pit area. Surface U-238 concentrations are elevated around the perimeter of Pit 6 and east of Pits 1 and 2. Several locations within the waste pit area had concentrations greater than 35 pCi/g and at some locations as high as

10,900 pCi/g. The majority of sampling locations show Th-232 concentrations to range between 1 and 5 pCi/g.

Several locations that are associated with elevated U-238 activity show Th-232 concentrations ranging from 5 to 15 pCi/g. The areal extent of Ra-226 concentrations greater than background levels of 1.5 pCi/g is quite low. The Th-232 levels range between 1 and 5 pCi/g in the majority of the waste storage area surface samples.

Subsurface Soils

A total of 26 subsurface soil samples were collected from various depths from the wells installed within the Operable Unit 1 study area during the RI/FS. These samples were analyzed for a full range of radionuclides. Ra-226, Ra-228, Th-228, Th-230, Th-232, U-234, and U-238 were consistently detected in these samples. The concentration ranges for these radionuclides in pCi/g are: 0.4 to 1210 for Ra-226; <0.5 to 160 for Ra-228; <0.6 to 22.9 for Th-228; <0.6 to 710 for Th-230; <0.6 to 33.1 for Th-232; <0.6 to 112 for U-234; and <0.6 to 320 for U-238.

Surface Water

Surface water samples were collected at 12 locations along drainageways within Operable Unit 1. Data from this RI sampling program, as well as data from previous studies, indicate the presence of radionuclides in the storm water runoff from the waste pits. Most of the radionuclides are present at background concentrations. Total uranium concentrations range from 54 to 9318 micrograms/liter ($\mu\text{g/L}$). Concentrations of U-234 and U-238 in two samples exceed the proposed 20 $\mu\text{g/L}$ MCL for total uranium in drinking water. These samples contained 597 and 653 pCi/L of U-234 and 2840 and 2506 pCi/L of U-238, which convert to values of 8520 $\mu\text{g/L}$ and 7520 $\mu\text{g/L}$ for U-238 (the concentration of U-235 is insignificant with respect to the MCL compared to the concentration of U-238). Radium and thorium concentrations in all the samples were well within the DOE guidelines. Radium and thorium were not detected in any surface water samples with the exception of a single sample, which had a radium level of 6.1 pCi/L. Thorium was not detected in any samples.

Sediments

No sediment samples were collected within Operable Unit 1 during the RI. However, several drainage ditches within Operable Unit 1 were sampled during the CIS program. Review of the CIS data indicates widespread uranium contamination in most of the drainage ditches. A sample from a drainage ditch that flows parallel and adjacent to the south berm of Pit 5 contained U-238 activity concentrations ranging from 46 to 728 pCi/g. The radium and thorium concentrations were low in all the drainageway samples, with the concentrations ranging from nondetectable to slightly greater than detection limits (approximately 1 pCi/g). A shallow drainage ditch flowing north and south over the Burn Pit area contained U-238 activity concentrations ranging from 170 to 408 pCi/g. A minor

drainage ditch flowing east of Pit 4 contained U-238 activity concentrations ranging from 96 to 746 pCi/g.

Groundwater

The perched groundwater in the glacial till overburden is contaminated with uranium as a result of leaking waste pits. A sample from a well in this region contained 15,330 µg/L of total uranium. Many other wells contained high concentrations of uranium greater than 1000 µg/L. All the wells that contain high concentrations of uranium are located in the east central part of the waste storage pits. Leakage from the waste pits is suspected of being the source of contamination in the eastern groundwater plume. Contaminants from the heavily contaminated overburden have infiltrated into the Great Miami Aquifer from the perched groundwater zones as evidenced by uranium levels of up to 218 µg/L found in deeper wells.

Biological Resources

The investigation of biological resources conducted during the RI determined that there is uptake of radionuclides by both plants and animals within the FEMP. Total uranium concentrations in samples of vegetation collected within the Operable Unit 1 study area ranged from 1.8 to 31.3 pCi/g. Results from background uranium concentrations obtained from macroinvertebrate (taken from the vicinity of Paddys Run, north of the FEMP) have been reported as nondetectable. This site is upstream of the FEMP. At another site just above the confluence of Paddys Run and the Great Miami River, uranium concentrations in a bluegill sample ranged from below detection limits of 1.8 to 3.7 pCi/g.

1.2.4 Remedial Action Objectives

The overall program goals, (i.e., remedial action objectives [RAOs]), are medium-specific cleanup goals for protecting human health and the environment. They address the contaminants of concern as well as exposure routes and receptors identified in the baseline risk assessment. The primary purposes of RAOs are to ensure site-wide compliance with:

- Chemical-specific ARARs and to be considered (TBC) guidelines
- EPA guidance for risk to public health from hazardous chemicals
- Regulatory standards for control of radiation and radioactivity in the environment

The RAOs for Operable Unit 1 must cover all constituents (radiological and chemical) that contribute to a reasonable maximum exposure (RME) scenario. Alternatives for remediation must meet airborne RAOs at a point immediately adjacent to the waste pits or at a location determined by an RME scenario to be of greatest risk to human and environmental receptors, as well as drinking water RAOs in the aquifer that might be encountered directly below Operable Unit 1.

RAOs were developed based on chemical-specific and radionuclide-specific criteria. The media for which RAOs were developed included: air, soils, sediments and surface water, groundwater, and pit waste. RAOs are presented in Figure 1-3. Treatability study goals are developed in Section 1.3.

1.2.5 EPA Guidance

The EPA's "Guide for Conducting Treatability Studies Under CERCLA" (EPA 1989a) outlined a three-tiered approach to conducting treatability studies for a Superfund site. The original interpretation of the approach can be seen in Figure 1-4. The remedy evaluation phase of the RI/FS, in accordance with proposed revised EPA guidance, may require a maximum of three tiers of treatability testing:

- Remedy screening
- Remedy selection
- Remedy design

Figure 1-5 reflects the approach recommended by DePercin, Bates, and Smith of EPA in their article, "Designing Treatability Studies for CERCLA Sites: Three Critical Issues," which appeared in the May 1991 issue of the Journal of the Air Waste Management Association. The figure illustrates three levels of treatability testing and how this treatability plan compares with these requirements.

The three levels of treatability testing are divided into pre-Record of Decision (ROD) and post-ROD studies. The remedy screening and remedy selection testing are pre-ROD studies, and the remedy design studies are post-ROD.

Pre-ROD treatability studies provide the critical performance and cost data needed to (1) evaluate all potentially applicable treatment alternatives and (2) select an alternative for remedial action based on the nine RI/FS evaluation criteria. The detailed analysis of alternatives phase of the RI/FS follows the development and screening of alternatives and precedes the actual selection of a remedy in the ROD. During the detailed analysis, all remedial alternatives are evaluated based on nine RI/FS evaluation criteria. These criteria are as follows:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

MEDIA	REMEDIAL ACTION OBJECTIVES
1. PIT WASTES	<u>For Human Health:</u>
	1-1
	Prevent exposures to non-carcinogens which would result in a Hazard Index greater than or equal to unity (1), and/or combined risks from exposure to carcinogens greater than 1.0E-04, using 1.0E-06 as the point of departure.
	1-2
	Prevent migration of contaminants which would result in groundwater concentrations greater than the MCLs or that would result in a Hazard Index greater than or equal to unity (1), and/or combined risks from exposure to carcinogens greater than 1.0E-04, using 1.0E-06 as the point of departure.
1-3	Prevent current and future direct radiation doses from exceeding 100 mrem/yr.
1-4	<u>For Environmental Protection:</u>
1-5	Prevent migration of contaminants that would result in surface water levels greater than ambient water quality criteria.
1-5	Prevent current and future direct radiation doses from causing detectable chronic effects.
2. AIR	<u>For Human Health:</u>
	2-1
	Prevent inhalation of contaminants which would result in a Hazard Index greater than or equal to unity (1), and/or combined risks from exposure to carcinogens greater than 1.0E-04, using 1.0E-06 as the point of departure.
2-2	Prevent doses from radionuclide emissions at the FEMP from exceeding 10 mrem/yr, and radon flux from exceeding 20pCi/square meter/second.
2-3	<u>For Environmental Protection:</u>
Prevent current and future radiation emissions from causing detectable chronic effects.	

FL/FMPC-0105-B/1-3a

28

FIGURE 1-3. REMEDIAL ACTION OBJECTIVES

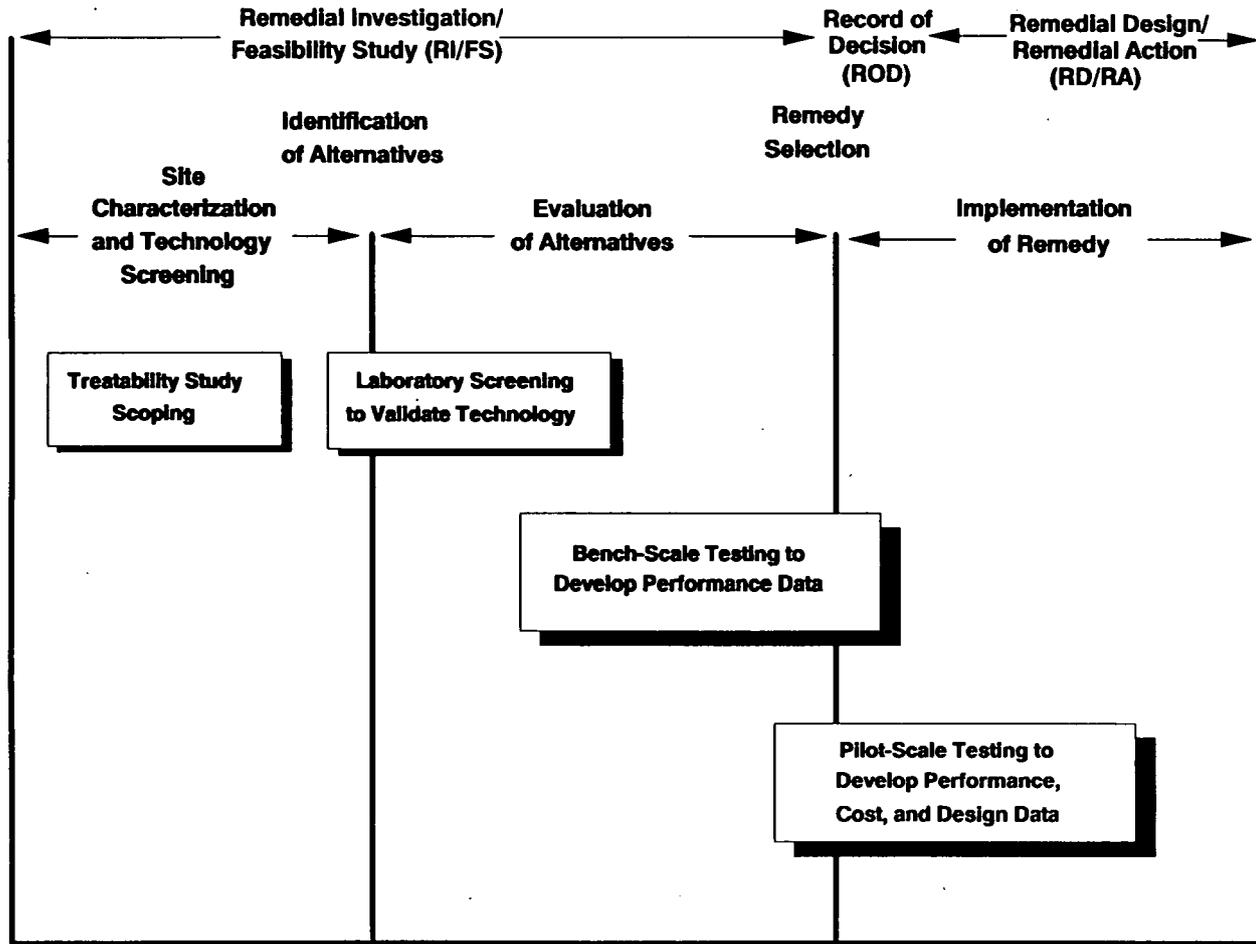
MEDIA	REMEDIAL ACTION OBJECTIVES	
3. SOILS	3-1	<p><u>For Human Health:</u> Prevent inhalation of/ingestion of/direct contact with soils surrounding the waste pits which would result in a Hazard Index greater than or equal to unity (1), and/or combined risks from exposure to carcinogens greater than 1.0E-04, using 1.0E-06 as the point of departure.</p>
	3-2	<p>Prevent migration of contaminants which would result in groundwater concentrations greater than the MCLs or that would result in a Hazard Index greater than or equal to unity (1), and/or combined risks from exposure to carcinogens greater than 1.0E-04, using 1.0E-06 as the point of departure.</p>
	3-3	<p>Prevent contact with radium and thorium above 5 pCi/g in the first 15 cm of soil, and 15 pCi/g at lower depths. Prevent contact with other nuclides at concentrations resulting in doses greater than 100 mrem/yr.</p>
	3-4	<p><u>For Environmental Protection:</u> Prevent migration of contaminants that would result in surface water contamination levels greater than ambient water quality criteria.</p>
4. SEDIMENTS	4-1	<p><u>For Human Health:</u> Prevent ingestion of/direct contact with sediment contaminants which would result in a Hazard Index greater than or equal to unity (1), and/or combined risks from exposure to carcinogens greater than 1.0E-04, using 1.0E-06 as the point of departure.</p>
	4-2	<p><u>For Environmental Protection:</u> Prevent releases of contaminants from sediments that would result in surface water contamination levels greater than ambient water quality criteria.</p>

29

FIGURE 1-3.
(CONTINUED)

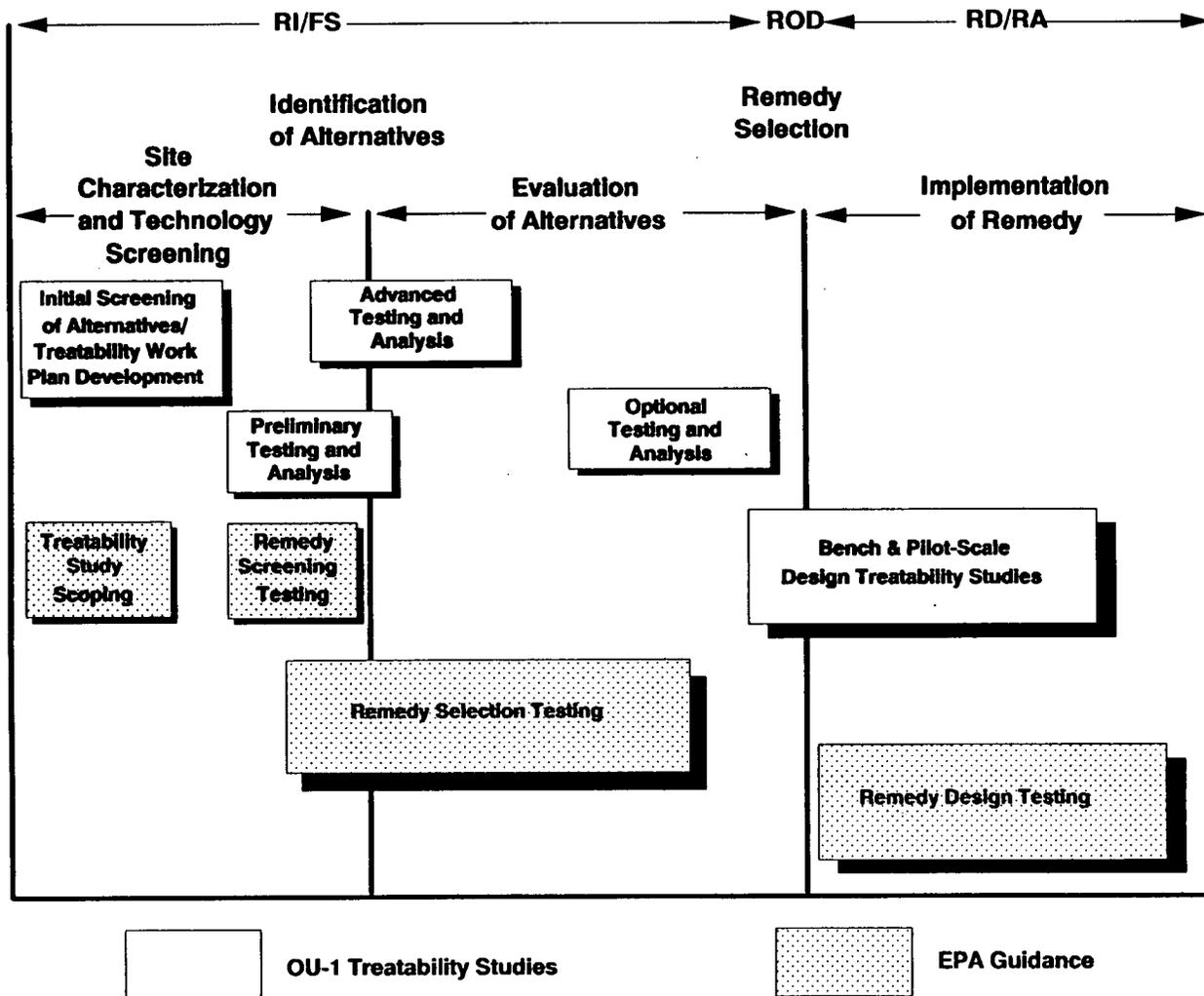
MEDIA	REMEDIAL ACTION OBJECTIVES
5. SURFACE WATER	5-1 <u>For Human Health:</u> Prevent exposures to non-carcinogens which would result in a Hazard Index greater than or equal to unity (1), and/or combined risks from exposure to carcinogens greater than 1.0E-04, using 1.0E-06 as the point of departure.
	5-2 <u>For Environmental Protection:</u> Restore surface water to below ambient water quality criteria.
6. GROUNDWATER	6-1 <u>For Human Health:</u> Prevent ingestion of water having contaminant levels greater than the MCLs or TBCs, or which would result in a Hazard Index greater than or equal to unity (1), and/or combined risks from exposure to carcinogens greater than 1.0E-04, using 1.0E-06 as the point of departure.
	6-2 <u>For Environmental Protection:</u> Restore groundwater aquifer to contaminant concentrations below the MCLs.

FIGURE 1-3.
(CONTINUED)



Source: Guide for Conducting Treatability Studies Under CERCLA. Interim Final 12/89.

FIGURE 1-4. THE ROLE OF TREATABILITY STUDIES IN THE RI/FS AND RD/RA PROCESS



Source for EPA Guidance: DePercin, P., E. Bates, D. Smith, 1991, "Designing Treatability Studies for CERCLA Sites: Three Critical Issues," Journal of the Air and Waste Management Association, Vol.41, No. 5.

FIGURE 1-5. RELATIONSHIP OF THE OPERABLE UNIT 1 TREATABILITY STUDIES TO THE RI/FS PROCESS

32
FL/FMPC-0105-9/1-5

These criteria are described in detail in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988).

Remedy screening is the first step in the tiered approach. Its purpose is to determine the feasibility of a treatment alternative for the contaminants/matrix of interest. These tests are typically conducted under conditions that are favorable to the technology. These small-scale studies are designed to provide a qualitative evaluation of the technology and are conducted with minimal levels of quality assurance/quality control (QA/QC). Tests conducted under this tier are generic in nature (not vendor specific). If the feasibility of the treatment cannot be demonstrated, the alternative should generally be screened out at this time.

The remedy selection tier of the treatability study program is designed to determine whether a treatment alternative can meet the operable unit's cleanup criteria and at what cost. The purpose of this tier is to generate the performance and cost data necessary for remedy evaluation in the detailed analysis of alternatives phases of the FS. The cost data developed in this tier should support cost estimates of +50 percent/-30 percent accuracy. The performance data will be used to determine if this technology will meet ARARs or cleanup goals. Remedy selection studies are typically small-scale, incorporating generic tests using bench- or pilot-scale equipment in either the laboratory or field. The study costs are higher than those encountered in the remedy screening tier and require longer durations to complete. The levels of QA/QC are moderate to high because the data from these studies will be used to support the ROD.

In the post-ROD remedy design tier treatability study, detailed scale-up, design, performance, and cost data are generated to implement and optimize the selected remedy. Remedy design studies are performed after the ROD, usually as part of the remedy implementation. These studies are performed on full-scale or near full-scale equipment with the purpose of generating detailed, scale-up design and cost data. The study should focus on optimizing process parameters, which are not a part of this treatability study. These studies require moderate to high QA/QC and are typically vendor specific.

This work plan covers the remedy screening and remedy selection tiers of the treatability studies as described in the EPA guidance. The remediation screening is performed in the preliminary phase study, and the remediation selection is performed in the advanced phase treatability study. The remedy selection phase involves an optional stage treatability study task. This optional treatability task will be used if necessary to develop additional data for incorporation in the Final Review of the FS. This testing will be done as a task that is not on the critical path, and the data will be provided as an addendum to the FS and not as part of the treatability study report.

The estimated number of experiments by phase and stage are in Table 1-3 for cement stabilization and Table 1-4 for vitrification. Tables 1-5 and 1-6 list the actual tests that will be conducted in each stage and phase.

1.3 TREATABILITY STUDY GOALS

The primary goal of the treatability study is to support remedy selection during the FS. It supports the FS by providing data about the waste treatment under consideration by the FS. This information is used to select the most promising treatment technologies for further consideration, in conjunction with other aspects of the proposed alternative designs.

Preliminary remediation goals have been determined for chemicals and radionuclides. These are listed in Section 3.0. This treatability study is designed to provide data to determine if attainment of these goals is feasible using the technologies of cement stabilization and vitrification. The intent of these treatment methods is to chemically fix the contaminants in an altered waste matrix and thereby lower its leachability. It is not the intent of these treatment methods to reduce the apparent leachability of radioactive and Hazardous Substance List (HSL) constituents by diluting the waste with stabilizing reagents.

1.4 TREATABILITY STUDY DESCRIPTION

1.4.1 Approach

Treatability studies on the pit materials will be performed in accordance with 40CFR261.4(e) and (f), and OAC3745-51-04(e) and (f). The study aids in the selection of a remedial action alternative that is feasible, implementable, and cost-effective. Cement stabilization and vitrification technologies are proposed for application to the Operable Unit 1 waste. Reagent formulations for cement stabilization and vitrification of the waste material will be determined. For cement stabilization, binding agents being considered are portland cement, fly ash, and sodium silicate. Clay (attapulgite and clinoptilolite) will be added to reduce the leachability of metals in the waste. Various ratios of waste to binder will be tested to minimize the amounts of binder required to produce an acceptable stabilized waste form. Glass formers and modifiers being considered for vitrification are fly ash, soil, and sodium hydroxide.

The cement stabilization of the treatability study consists of the following:

- Preliminary Phase - Stage 1 on composite samples
- Preliminary Phase - Stage 2 on composite samples
- Advanced Phase - Stage 1
- Advanced Phase - Stage 2
- Advanced Phase - Optional

**TABLE 1-3. ESTIMATED NUMBER OF EXPERIMENTS BY PHASE
CEMENT STABILIZATION**

Waste Pit Number	Remedy Screening (Preliminary Phase)		Remedy Selection (Advanced Phase)		
	Stage 1	Stage 2 ^a	Stage 1	Stage 2 ^a	Optional ^b
1	20	0 to 5	6	6 to 8	
2	20	0 to 5	6	6 to 8	
3	20	0 to 5	6	6 to 8	
4	20	0 to 5	6	6 to 8	
5	20	0 to 5	2	2 to 3	
6	20	0 to 5	2	2 to 3	
Burn Pit	20	0 to 5	6	6 to 8	
Clearwell	20	0 to 5	2	2 to 3	
Subtotal	160	0 to 40	36	36 to 49	
Duplicate	0	0	7	0 to 10	
Total	160	0 to 40	43	36 to 59	

^aThe total number of experiments in Stage 2 will depend on the results from the previous stage.

^bThe scope of the optional stage will be based on the results from the remedy selection Stages 1 and 2.

**TABLE 1-4. ESTIMATED NUMBER OF EXPERIMENTS BY PHASE
VITRIFICATION**

Waste Pit Number	Remedy Screening (Preliminary Phase)	Remedy Selection (Advanced Phase)		
	Stage 1	Stage 1	Stage 2 ^a	Optional ^b
1	6	6	6 to 8	
2	6	6	6 to 8	
3	6	6	6 to 8	
4	6	6	6 to 8	
5	6	2	2 to 3	
6	6	2	2 to 3	
Burn Pit	6	6	6 to 8	
Clearwell	6	2	2 to 3	
Subtotal	48	36	36 to 49	
Duplicate	0	7	0 to 10	
Total	48	43	36 to 59	

^aThe total number of experiments in Stage 2 will depend on the results from the previous stage.

^bThe scope of the optional stage will be based on the results from the remedy selection Stages 1 and 2.

TABLE 1-5. ANALYTICAL TESTS - CEMENT STABILIZATION OF UNTREATED WASTE MATERIAL

	Preliminary Phase		Advanced Phase	
	Stage 1	Stage 2	Stage 1	Stage 2
Bulking factor	X	X	X	X
UCS	X	X	X	X
Temperature rise	X	X	X	X
Shear strength	X	X	X	X
MTCLP - metals	X	X		
MTCLP - gross alpha - beta	X	X		
MTCLP - U by IC	X	X		
TCLP - organic			X	X
TCLP - metals			X	X
TCLP - radionuclide			X	X
TCLP - general chemistry			X	X
5-Day Static - metals ^a			X	X
5-Day Static - radionuclide			X	X
5-Day Static - general chemistry			X	X
Radon emanation			X	X
Permeability			X	X

^aOptionally, after extraction for 5 days, the samples will be soaked for an additional 85 days. The sample will be inspected for physical degradation.

TABLE 1-6. ANALYTICAL TESTS - VITRIFICATION OF UNTREATED WASTE MATERIAL

	Preliminary Phase	Advanced Phase	
	Stage 1	Stage 1	Stage 2
Fly ash, soil, and waste characterization	X		
Bulking factor	X	X	X
MTCLP - metals	X		
MTCLP - gross alpha - beta	X		
MTCLP - U by IC	X		
TCLP - organic		X	X
TCLP - metals		X	X
TCLP - radionuclide		X	X
TCLP - general chemistry		X	X
PCT - metals	X	X	X
PCT - radionuclide		X	X
PCT - general chemistry		X	X
PCT - gross alpha - beta	X		
PCT - U by IC	X		
Radon emanation		X	X

This approach is consistent with that currently recommended by DePercin, Bates, and Smith (1991).
The preliminary phase corresponds to remedy screening. The advanced phase or strata sample
experiments, which correspond to the remedy selection testing, are expected to provide sufficient data
to perform detailed analysis of alternatives so that remedy selection can be made. This treatability
study will not provide enough data for remedy design. Further testing may be conducted as part of the
post-ROD. To implement and optimize the selective remedy, remedy design will develop data for:

- Detailed scale-up
- Design
- Performance
- Cost data

The objectives of the treatability study are to identify formulations that will have a UCS of approxi-
mately 500 psi, decrease leachability of metals and radionuclides as measured with toxicity characteris-
tic leaching procedure (TCLP) and modified TCLP (MTCLP) near the TCLP standards, and a relat-
ively low bulking factor. Detailed objectives and desired data are presented in Sections 3.0 and 4.0.

The preliminary phase Stage 1 for cement stabilization was designed to take advantage of some
samples that were collected in 1989-1990. These tests were designed to range-find the reagent levels
necessary to meet the UCS requirement of approximately 500 psi. The MTCLP test will be added to
this stage to augment the UCS results, thus providing additional information on the fixation as well as
the solidification of the waste matrices. Composite samples will be used in the remedy screening
phase to minimize the total number of experiments, and therefore, costs and generation of laboratory
waste. The most promising formulations from this stage will have metal concentrations in the MTCLP
near or less than the TCLP standards, a relatively low bulking factor, and UCS values of approximate-
ly 500 psi or greater. The 500 psi value is a recommended value for low-level waste set forth by
NRC in "Technical Position on Waste Form" (Revision 1), prepared by Low-Level Waste Management
Branch Division of Low-Level Waste Management and Decommissioning, January 1991. An excerpt
of the document that describes the reasoning is in Appendix A. Where possible, these experiments
will be based on a statistically designed matrix to maximize the information gained in the fewest
experiments.

The preliminary phase, Stage 2 screening will test additional reagent mixtures in the event that the
preliminary phase, Stage 1 was unsuccessful, or to refine the formulation of those successful mixtures.
This stage is designed to achieve a greater level of confidence in the data. The most promising
formulations, from this stage, will have UCS values of approximately 500 psi, metal concentrations in
the MTCLP at or below the TCLP standards, and a relatively low bulking factor.

The advanced phase, the strata sample experiments, will apply the best formulations discovered in the previous stages to strata samples. It is important to test the individual layers of the waste pits because much of the material was added in batch to the pits (i.e., truck loads) over an extended period of time, so it is highly likely that the waste pits are heterogeneous. The effect of waste material variability will be tested in this stage.

The vitrification screening will have only two phases:

- Preliminary phase for remedy screening
- Advanced phase - Stages 1, 2, and Optional for detailed analysis of alternatives and remedy selection

The design, reasoning, and intent of the vitrification laboratory screening is similar to the cement stabilization laboratory screening.

1.4.2 Cement Stabilization

The composite and strata samples will be treated with varying combinations of cement, sodium silicate, clay, zeolite, and fly ash from the active fly ash pile to determine the viability of the cement stabilization option. Portland Type I and II cements, PQ Corporation Type N sodium silicates, and Type F and site fly ash, attapulgitite, clinoptilolite, and water will be used in various combinations to determine the optimum overall mix. Site fly ash from the active fly ash pile in Operable Unit 2 will be used as an additional pozzolanic agent in the screening in an effort to determine its effectiveness in achieving an adequate stabilized waste form. This will allow for the stabilization of contaminated material from two operable units in the same treatment system. The analytical tests to be performed in each phase and stage of the project are listed in Table 1-5. Section 4.0 contains more details on the experimental design.

From the available analytical data and process history of the waste, the organic compound concentrations should be low. The work plan was written to reflect the known constituents in the waste. It is expected that the inorganic inhibitors (e.g., MgF_2 and inorganic or organic phosphate compounds) will cause more problems than the organic contaminants. Due to the anticipated problems resulting from the inorganic inhibitors and the potential organic constituents, a wide range of cement and fly ash concentrations will be investigated in the preliminary phase. In Stage 1, the proposed range of reagents in Table 4-1 will be investigated. The experiments were designed such that trends could be identified and utilized in the subsequent experiments in this treatability study. When possible, graphs of UCS and MTCLP results versus reagent loadings will be created to aid in visualization of the trends. Based on the results of the tests, the ranges for each reagent may be adjusted before Stage 2. In Stage 2, graphs will also be used. The graphs will separately plot UCS, bulking factor, and MTCLP results versus reagent loadings.

The general procedure of this work plan is an iterative process where the results from matrices of experiments are used to determine the course of the next set of experiments.

1.4.3 Vitrification

The first step of the vitrification screening will be to determine the glass-forming characteristics of the waste without the addition of vitrifying reagents. This step will be performed in a simple laboratory furnace. Following this test, glass-forming agents such as fly ash from the site (Operable Unit 2), soil/sand from the site, and modifiers such as sodium hydroxide will be added separately to the waste and the mix vitrified to determine the best combination of waste and glass-forming/modifying agents. The analytical tests to be performed in each phase and stage of the project are listed in Table 1-6. Section 4.0 contains more details on the experimental design.

The general procedure of this work plan is an iterative process where the results from matrices of experiments are used to determine the course of the next set of experiments.

1.4.4 General Selection Criteria

During these pre-ROD treatability studies, the most promising cement-based formulations will meet, at a minimum, the following requirements: a UCS of approximately 500 psi, meet or exceed TCLP standards, and have a minimum volume increase after treatment. The third criteria will be a secondary requirement. For vitrification, the formulations should meet the TCLP leaching standards, form a durable glass, and have minimum volume increase. In addition, the leaching data will also be inspected from a risk perspective to assist in the selection of the most promising formulations.

The best technology will be determined by comparison of multiple criteria during the detailed analysis. The detailed analysis of alternatives phase of the RI/FS follows the development and screening of alternatives and precedes the actual selection of a remedy in the ROD. During the detailed analysis, all remedial alternatives are evaluated based on nine RI/FS evaluation criteria. These criteria are as follows:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

The relationship between the evaluation criteria and the data that will be generated during treatability studies is shown in Table 1-7. For example the ability of a particular waste formulation or technology (cement stabilization versus vitrification) to provide protection of human health and the environment would be determined by evaluating factors such as concentration of contaminants in the leachate, the durability of the waste form, its compressive strength as it relates to disposal and handling, permeability, and intrinsic properties of the waste form (glass versus cement).

Compliance with ARARs would be determined by whether the treated material meets compressive strength requirements for disposal, whether the leachate exceeds established discharge standards, and on factors relating to waste form. A full evaluation of the technology for compliance with ARARs will be performed in the FS.

Treatability testing that relates to a technology's long-term effectiveness and permanence includes its shear strength and durability for handling and disposal purposes, its solubility as measured by leachability, and the extent to which it transmits water based on permeability. The waste form itself (glass or cement) also influences long-term stability. A glass, for instance, would tend to be a more stable waste form provided the glass is of good quality.

The ability of a technology or formulation to reduce the toxicity, mobility, or volume will be measured by indicators such as bulking factor for volume reduction; leachate analysis for toxicity and mobility, and permeability; and waste form for mobility reduction.

Short-term effectiveness is impacted primarily by bulking factor, which is an indicator of the volume of treated waste that must be handled and disposed of and by the specific technology chosen. The short-term impacts associated with implementing cement stabilization would be different from vitrification because they have significantly different requirements to construct, operate, and maintain during remediation.

The implementability of a particular technology is influenced by the volume of waste to be handled as measured by bulking factor and by the waste form itself (glass versus cement). As with implementability, cost is impacted by the technology selected and the volume of waste to be generated. Because cement stabilization and vitrification are radically different processes, each will require different equipment and facilities.

The final two evaluation criteria, state and community acceptance, are influenced by the results of all the data and by the other seven criteria.

TABLE 1-7. RELATIONSHIP OF TREATABILITY DATA TO FS EVALUATION CRITERIA

FS Evaluation Criteria	TREATABILITY DATA					
	Compressive Strength - UCS	Leachate Analysis - MTCLP - TCLP - 5-Day Static Leach Test ^a	Bulking Factor (% volume change)	Permeability ^a	Durability - PCT ^b - Shear Strength ^a - Temperature Rise ^a	Treatment Method - Cement Stabilization - Vitrification
• Overall protection of human health and the environment	X	X		X	X	X
• Compliance with ARARs	X	X				X
• Long-term effectiveness and permanence	X	X		X	X	X
• Reduction of toxicity, mobility, or volume through treatment		X	X	X		X
• Short-term effectiveness			X			X
• Implementability			X		X	X
• Cost			X			X
• State acceptance	X	X	X	X	X	X
• Community acceptance	X	X	X	X	X	X

^aCement stabilization only.

^bVitrification only.

Additional information on use of the evaluation criteria and treatability data in the FS process can be found in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988).

1
2
3

2.0 REMEDIAL TECHNOLOGY DESCRIPTION

Several remediation technologies are being considered for the Operable Unit 1 RI/FS. These alternatives have been described in detail in the DOE "Initial Screening of Alternatives for Operable Unit 1, Task 12 Report, January 1991" (DOE 1991a).

Summary of Alternatives

In addition to the no-action alternative, seven distinct remedial action alternatives were developed for Operable Unit 1. These alternatives are briefly described in the following sections.

Alternative 0 - No Action

The no-action alternative provides no remediation of any sort and simply leaves the waste pits in their present condition.

Alternative 1 - Nonremoval, Slurry Wall, and Cap

The first nonremoval alternative for Operable Unit 1 is intended to isolate the waste from the environment and to minimize the generation and release of contaminated leachate to the underlying Great Miami Aquifer. This alternative includes removing and treating any standing water, installing subsurface flow control measures, building a closure cap, and providing storm water runoff and run-on control measures. The subsurface flow control measures combine a slurry wall, subsurface drains, and a temporary groundwater extraction system.

Alternative 2 - Nonremoval, Physical Stabilization, Slurry Wall, and Cap

The second nonremoval alternative for Operable Unit 1 is identical to Alternative 1 with the addition of a waste stabilization step. The purpose of this additional process is to promote the compaction (densification) of the waste to minimize both the potential for long-term settlement and the release of contaminated waste pit water into the underlying till. The need for continuing maintenance of the cap due to settling will be correspondingly reduced.

Alternative 3 - Nonremoval, In Situ Vitrification, and Cap

Because a waste immobilization step has been incorporated into the nonremoval scenario, this alternative is similar to Alternative 2. However, this solidification/stabilization step specifies that a vitrification technology be used rather than physical stabilization technologies. A second important difference: the subsurface control measures are not included in this alternative. It is reasoned that the resultant vitrified mass precludes the future release of contaminated water from the waste.

Alternative 4 - Removal, Waste Treatment, and On-Property Disposal

The alternatives for Operable Unit 1, which include removing the waste material, are intended to completely eliminate the waste source from its current location above the Great Miami Aquifer and to obviate future problems through the treatment and disposal of the wastes. This alternative utilizes technologies that include removing and treating the standing water, removing the waste, waste segregation and treatment, and on-property disposal. The waste treatment portion of this alternative retains two distinct process options: cement stabilization and continuous vitrification. Treatment of residual water will be handled by the existing FEMP wastewater treatment facility and the FEMP advanced wastewater treatment facility. If any pretreatment is necessary, it will consist of waste segregation/separation.

Alternative 5 - Removal, Waste Treatment, and Off-Site Disposal

This alternative is identical to Alternative 4 except that the treated and packaged waste is to be transported to and disposed of at an approved off-site location.

Alternative 6 - Waste Removal, Treatment, On-Property Disposal, and Cap

This alternative, like Alternative 4, addresses the removal and treatment of the waste pit caps (or standing surface water on those pits without caps) and pit wastes from each of the waste pits including the Burn Pit and the Clearwell. However, in this alternative, the contaminated soils that make up and surround the pits will be left in place and fitted with a closure cap. The treated and packaged waste is to be housed on property in an engineered waste management facility.

Alternative 7 - Waste Removal, Treatment, On-Property Disposal, Soil Treatment, and Cap

This alternative is identical to Alternative 6, except that the soil in the pits will be treated by in situ technologies following the excavation of the waste materials.

The following alternatives were removed from further consideration during initial screening of alternatives because of concerns about technology implementability and reliability:

- Alternative 1 Nonremoval - Slurry Wall and Cap
- Alternative 3 Nonremoval - In Situ Vitrification and Cap

No treatability testing is planned for Alternatives 1, 2, or 3.

3.0 TEST AND DATA QUALITY OBJECTIVES

The purpose for this screening is to assess the performance of various stabilization technologies on the Operable Unit 1 waste in support of the RI/FS. To select a preferred alternative for the Operable Unit 1 RI/FS, a waste treatment technology must be screened to support evaluations of the alternative during the detailed analysis of alternatives. Also, data for risk assessment studies and ARARs determination must be generated and the foundation for the subsequent treatability studies must be set. In addition, the level of QA applied during experimentation and analysis must be established.

This section will establish the performance objectives for the treatment tests, the additional data desired for use in subsequent stages of the RI/FS, and the data quality objectives (DQOs).

Concentration-based performance objectives and the resulting DQOs for the advanced phase of the treatability testing are driven by the remediation goals (RGs) established for the site. RGs are chemical-specific, medium-specific numerical concentration limits that should address all contaminants and all pathways found to be of concern during the baseline risk assessment process. The baseline risk assessment for Operable Unit 1 has not been completed, but preliminary remediation goals (PRGs) based on chemical-media-specific concentrations have been developed using results of the RI/FS investigation presently available. These PRGs are based on a 10^{-6} risk level (as a point of departure) and are presented in Tables 3-1, 3-2, and 3-3 for radiological and chemical constituents, respectively.

Although these PRGs are used to provide preliminary goals for evaluating the effectiveness of the treatment technology, they are not intended to provide final action levels for contaminants in leachate, soils, or waste residues. Therefore, if the technology does not achieve individually specified levels, it should not be judged ineffective solely for that reason. The technology may later be determined to be the best available technology for treating the Operable Unit 1 materials.

Additional information has been provided in Tables 3-1, 3-2, and 3-3 to give some perspective on how the listed PRGs compare with detection limits, background concentrations, and existing ARARs. These tables also contain a column titled "DLRL," which stands for Derived Leachate Reference Level. The DLRL numbers were calculated using the same methodology as that used by EPA to determine the regulatory levels of toxic constituents published in Table IV-3 of the Federal Register (FR Vol. 55, No. 61, pp. 11796-11877). The DLRL concentrations may be used as minimum performance criteria during the remedy selection phase, keeping in mind that the PRGs are the current proposed action levels for the FEMP. Background concentrations and detection limits are provided for comparative purposes only.

TABLE 3-1. COMPARISON OF ARARs, TBCs, PRELIMINARY REMEDIATION GOALS, DERIVED LEACHATE REFERENCE LEVELS, FEMP BACKGROUND CONCENTRATIONS, AND CONTRACT LAB REQUIRED DETECTION LIMITS FOR WATER AND SURFACE SOILS

FERROU-6/TK-350.3A/10-05-91

Radionuclides	Water Concentrations					Surface Soil Concentrations			
	TBC/ARAR Based ^a (pCi/L)	PRGs ^b (pCi/L)	DLRL ^c (pCi/L)	FEMP Background ^d (pCi/L)	QAPP Detection Limits (pCi/L)	ARAR Based ^e (pCi/g)	PRGs ^f (pCi/g)	Background ^g (pCi/g)	QAPP Detection Limits (pCi/g)
Cs-137	102	0.7	700	0	NA	215000	515	0	NA
Np-237	1 ^h	0.072	72	0	NA	13.0	0.28	0	NA
Pb-210	1 ^h	0.03	30	~1	NA	5	0.6	~1	NA
Pu-238	2 ^h	0.070	70	0	NA	18	0.23	0	NA
Pu-239/240	2 ^h	0.63	630	0	NA	18	0.23	0	NA
Ra-224	5 ^h	0.41	410	3	NA	NA	8.2	1	NA
Ra-226	5 ⁱ	0.16	160	1	1	j	0.33	1.5	0.3
Ra-228	5 ⁱ	0.2	200	3	3	j	3.9	1	0.5
Rn-220	NA	NA	NA	NA	NA	k	NA	0	NA
Rn-222	1	1.5	300	~1	NA	k	NA	0	NA
Sr-90	8	0.59	590	0	NA	5270	175	0	NA
Tc-99	914	15	15000	0	NA	822000	1200	0	NA

TABLE 3-1 (Continued)

Radionuclides	Water Concentrations					Surface Soil Concentrations			
	TBC/ARAR Based ^a (pCi/L)	PRGs ^b (pCi/L)	DLRL ^c (pCi/L)	FEMP Background ^d (pCi/L)	QAPP Detection Limits (pCi/L)	ARAR Based ^e (pCi/g)	PRGs ^f (pCi/g)	Background ^g (pCi/g)	QAPP Detection Limits (pCi/g)
Th-228	14 ^h	1.3	1300	1	1	20	0.13	1	0.6
Th-230	10 ^h	0.82	820	0.1	1	21	0.32	1.4	0.6
Th-232	2 ^h	0.89	890	1	1	4	0.32	1	0.6
U-234	^m	0.14	140	0.3	1	52	0.36	1.4	0.6
U-235	^m	0.15	150	0.02	1	56	0.39	0.06	0.6
U-238	^m	0.15	150	0.3	1	58	0.41	1.4	0.6

NA - not available.

^aMCLs for radionuclides in community water supplies, as defined in 40CFR141.5 and 141.6.

^bRisks of 1×10^{-6} from the drinking water pathway using HEAST methodology and assuming 730 L/year for 70 years.

^cDerived leachate reference level. Calculated using the same methodology as that used by EPA to determine regulatory levels found in 40CFR261 et al. (Federal Register Vol. 55, No. 61, 11796 - 11877).

^dSite-specific RI/FS data from the FEMP groundwater report.

^eBased on doses from inhalation of resuspended dust. Calculated using an inhalation rate of 7300 m³/year, a dust loading rate of 0.0002 mg/m³, and the 40CFR61 dose limit of 10 mrem/year.

^fRisks of 1×10^{-6} from the inhalation and soil ingestion pathways using HEAST methodology and assuming 51100 m³ of air inhaled or 2660 g of soil ingested per lifetime.

^gAll fission products and transuranics are assumed to be zero. Ra-226, Th-232, and U-238 concentrations are from Myrick, T.E., et al., (1983). All daughter nuclides are assumed to be in equilibrium with their long-lived progenitors. Natural isotopic ratios are assumed for uranium.

^hBased on doses from drinking water pathway. Calculated using 4 mrem/year dose limit from DOE Order 5400.5 and assuming 730 L/year for 70 years.

ⁱCombined radium limit in community water systems 40CFR141.15 and 141.16.

^j40CFR192 combined limit for Ra-226 and Ra-228 in surface soil is 5 pCi/g.

^k40CFR61 fluence limit for radon is 20 pCi/m²-s.

^lProposed MCL for radon in drinking water is 300 pCi/L (1×10^{-6} risk).

^m20 mg/L total uranium is the published preliminary maximum concentration.

TABLE 3-2. COMPARISON OF PRELIMINARY REMEDIATION GOALS, DERIVED LEACHATE REFERENCE LEVELS, FEMP BACKGROUND CONCENTRATIONS, AND CONTRACT LAB REQUIRED DETECTION LIMITS FOR SOIL

Chemical	PRGs ^a (mg/kg)	DLRL ^b (mg/kg)	FEMP ^c Background (mg/kg)	CLRDL ^d (mg/kg)
Aluminum	e	e	57000	20
Arsenic	8.00 x 10 ¹	8000	7.4	1
Barium	4.00 x 10 ³	400000	420	20
Beryllium	1.63 x 10 ⁻¹	16	0.85	0.5
Cadmium (soil)	8.00 x 10 ¹	8000	1.7	0.5
Chromium	4.00 x 10 ²	40000	52	1
Cobalt	e	e	9.2	5
Copper	e	e	22	2.5
Lead	5.60 x 10 ¹	5600	17	0.5
Magnesium	e	e	4600	500
Manganese	8.00 x 10 ³	800000	640	1.5
Mercury	2.40 x 10 ³	2400	0.12	0.02
Nickel	1.60 x 10 ³	160000	18	4
Selenium	e	e	0.45	0.5
Silver	2.40 x 10 ²	24000	2.8	1
Thallium	5.60	560	NA	1
Uranium	2.40 x 10 ²	24000	4.2	NA
Vanadium	5.60 x 10 ²	56000	66	5
Zinc	1.60 x 10 ⁴	1600000	52	2
1,1,1-Trichloroethane	7.20 x 10 ³	7.20 x 10 ⁵	NA	0.005
2-Butanone	4.00 x 10 ³	4.00 x 10 ⁵	NA	0.01
2-Methylnaphthalene	e	e	NA	0.33
Acenaphthalene	4.80 x 10 ³	4.80 x 10 ⁵	NA	0.33
Acetone	8.00 x 10 ³	8.00 x 10 ⁵	NA	0.01

TABLE 3-2 (Continued)

Chemical	PRGs ^a (mg/kg)	DLRL ^b (mg/kg)	FEMP ^c Background (mg/kg)	CLRDL ^d (mg/kg)
Anthracene	2.40 x 10 ⁴	2.40 x 10 ⁶	NA	0.33
Aroclor-1242	9.09 x 10 ⁻²	9.09	NA	0.08
Aroclor-1248	9.09 x 10 ⁻²	9.09	NA	0.08
Aroclor-1254	9.09 x 10 ⁻²	9.09	NA	0.16
Aroclor-1260	9.09 x 10 ⁻²	9.09	NA	0.16
Benzo(a)anthracene	e	e	NA	0.33
Benzo(a)pyrene	e	e	NA	0.33
Benzo(b)fluoranthene	e	e	NA	0.33
Benzo(g,h,i)perylene	e	e	NA	0.33
Benzo(k)fluoranthene	e	e	NA	0.33
Bis(2-ethyl hexyl)phthalate	5.00 x 10 ¹	5.00 x 10 ³	NA	0.33
Carbon disulfide	8.00 x 10 ³	8.00 x 10 ⁵	NA	0.005
Chloroform	1.15 x 10 ²	1.15 x 10 ⁴	NA	0.005
Chrysene	e	e	NA	0.33
DDT	2.06	2.06 x 10 ²	NA	0.016
Di-n-butyl-phthalate	8.00 x 10 ³	8.00 x 10 ⁵	NA	0.33
Di-n-octyl-phthalate	1.60 x 10 ³	1.60 x 10 ⁵	NA	0.33
Ethyl parathion	e	e	NA	NA
Ethyl benzene	8.00 x 10 ³	8.00 x 10 ⁵	NA	0.005
Fluoranthene	3.20 x 10 ³	3.20 x 10 ⁵	NA	0.33
Fluorene	3.20 x 10 ³	3.20 x 10 ⁵	NA	0.33
Indeno(1,2,3-cd)pyrene	e	e	NA	0.33
Methyl parathion	2.00 x 10 ¹	2.00 x 10 ³	NA	NA
Methylene chloride	9.33 x 10 ¹	9.33 x 10 ³	NA	0.005
Naphthalene	3.20 x 10 ²	3.20 x 10 ⁴	NA	0.33

TABLE 3-2 (Continued)

Chemical	PRGs ^a (mg/kg)	DLRL ^b (mg/kg)	FEMP ^c Background (mg/kg)	CLRDL ^d (mg/kg)
Pentachlorophenol	5.83	5.83×10^2	NA	1.6
Phenanthrene	^e	^e	NA	0.33
Phenol	4.80×10^4	4.80×10^6	NA	0.33
Pyrene	2.40×10^3	2.40×10^5	NA	0.33
Toluene	1.60×10^4	1.60×10^6	NA	0.005
Trichloroethene	6.36×10^1	6.36×10^3	NA	0.005
Xylenes (total)	1.60×10^5	1.60×10^7	NA	0.005

NA - not available.

^aRAO for a noncarcinogen in soil calculated from: Cleanup Level = (RFD * Body Weight)/(Intake * Absorption Factor); for an intake of 0.2 gram/day for a 16 kg child and an absorption factor of 1. Federal Register, 7/27/90, Vol. 55, No. 145, p. 30870. RAO for a carcinogen in soil calculated from: Cleanup Level = (Risk Level * Body Weight * Assumed Lifetime)/(CSF * Intake * Absorption Factor * Exposure Duration); for a soil intake of 0.1 gram/day for a 70 kg adult/70-year lifetime exposure. The risk level used was 10^{-6} , the absorption factor was 1, and the exposure duration was 70 years. Lowest resulting soil concentration is reported as preliminary remediation goal (PRG).

^bDerived leachate reference level. Calculated using the same methodology used by EPA to determine regulatory levels found in 40CFR261. The dilution attenuation factor used was 100 (Federal Register Vol. 55, No. 61, 11796 - 11877).

^cFurther site-specific data being developed.

^dContact Lab Required Detection Limit (CLRDL).

^eToxicity data were inadequate for risk-based calculation.

TABLE 3-3. COMPARISON OF ARARs, TBCs, PRELIMINARY REMEDIATION GOALS, DERIVED LEACHATE REFERENCE LEVELS, FEMP BACKGROUND CONCENTRATIONS, AND CONTRACT LAB REQUIRED DETECTION LIMITS FOR WATER

Chemical	TBC/ARAR ^a (mg/L)	PRGs ^b (mg/L)	DLRL ^c (mg/L)	FEMP ^d Background (mg/L)	CLRDL ^e (mg/L)
Arsenic	0.050	3.50 x 10 ⁻²	3.5	NA	0.01
Barium	2.000	1.75	175	0.0795	0.2
Beryllium	0.001 ^f	8.14 x 10 ⁻⁶	0.0008	NA	0.005
Cadmium	0.005	1.75 x 10 ⁻²	0.5	0.0057	0.005
Chromium	0.100	1.75 x 10 ⁻¹	10	0.0177	0.01
Copper	1.300 ^g	^h	130	0.0102	0.025
Lead	0.005	2.45 x 10 ⁻²	0.5	NA	0.005
Manganese	NA	3.50	350	0.0482	0.015
Mercury	0.002	1.05 x 10 ⁻²	0.2	0.0018	0.0002
Nickel	0.100 ^f	7.00 x 10 ⁻¹	10	0.0178	0.004
Selenium	0.050	^h	5	NA	0.005
Thallium	0.001 ^f	2.45 x 10 ⁻³	0.1	NA	0.01
Uranium	0.020 ^f	1.05 x 10 ⁻¹	2	1.0	NA
Vanadium	NA	2.45 x 10 ⁻¹	2.45	NA	0.05
Zinc	NA	7.00	700	NA	0.02

NA - not available

^aARARs are from 7/18/91 memo, "Drinking water MCLs and HAs," from J. Dee.

^bRAO for a noncarcinogen in water calculated from: Cleanup Level = (RFD * Body Weight)/Intake; for an intake of 2 liters/day for 70 kg adult (HEAST). RAO for a carcinogen in water calculated from: Cleanup Level = (Risk Level * Body Weight)/(CSF * Intake); for a water intake of 2 liters/day for a 70 kg adult and a risk level of 10⁻⁶ (HEAST). Lowest resulting water concentration was reported as the preliminary remediation goal (PRG).

^cDerived leachate reference level. Calculated using the same methodology used by EPA to determine regulatory levels found in 40CFR261. The dilution attenuation factor used was 100 (Federal Register Vol. 55, No. 61, 11796 - 11877).

TABLE 3-3 (Continued)

^dFurther site-specific data being developed.

^eContract Lab Required Detection Limit (CLRDL).

^fProposed maximum contaminant level.

^gCurrent drinking water standard.

^hToxicity data were inadequate for risk-based calculation.

3.1 PERFORMANCE OBJECTIVES AND DESIRED DATA

Specific test objectives have been established so that the performance of the various stabilization mixtures can be evaluated in the areas of leachability, UCS, and final waste form volume. These performance objectives will be used to determine if a particular reagent mixture produces an acceptable waste form. The specific objectives of the treatability study are as follows:

- To develop a database of stabilization reagents and corresponding hazardous and radioactive materials leachability for stabilized waste forms
- To determine the cement stabilization and vitrification reagents and relative quantities required to minimize leachable concentrations of radionuclides and HSL constituents from the final waste form
- To determine the cement stabilization reagents and relative quantities required so that the final waste form achieves a UCS of approximately 500 psi
- To minimize the final volume of treated waste
- To estimate the volumes of treated waste that will be generated by each process
- To provide leaching characteristics for use in fate and transport modeling
- To develop preliminary reagent mixtures for use in future treatability studies
- To develop process parameters for use in future treatability studies
 - For cement general stabilization: shear strength, waste form temperature rise with reagent addition, general description of waste before and after reagent addition, permeability of stabilized waste percent of water in the waste, pH of the leachate solutions, and evolution of gas during mixing or during curing process
 - For vitrification: percent moisture in the raw waste
- To provide the chemical and radiological data as shown in Table 3-4
- To establish the proof of process and applicability of the selected stabilization technology
- To screen a large number of parameters and identify those that will be critical for future bench-scale studies
- To provide data for evaluation of alternatives:
 - 4 - Removal, waste treatment, and on-property disposal
 - 5 - Waste removal, treatment, and off-site disposal
 - 6 - Waste removal, treatment, on-property disposal, and cap
 - 7 - Waste removal, treatment, on-property disposal, soil treatment, and cap

**TABLE 3-4. CHEMICAL AND RADIOLOGICAL INFORMATION TO BE ACQUIRED
PRELIMINARY PHASE**

Modified TCLP List for Vitrification		PCT ^a List for Vitrification		Modified TCLP List for Cement Stabilization	
Metals	Radionuclides	Metals	Radionuclides	Metals	Radionuclides
Arsenic (As) Barium (Ba) Cadmium (Cd) Chromium (Cr) Lead (Pb) Selenium (Se) Silver (Ag)	Uranium by IC ^b Gross alpha Gross beta	Aluminum (Al) Boron (B) Iron (Fe) Potassium (K) Sodium (Na)	Uranium by IC ^b Gross alpha Gross beta	Arsenic (As) Barium (Ba) Cadmium (Cd) Chromium (Cr) Lead (Pb) Selenium (Se) Silver (Ag)	Uranium by IC ^b Gross alpha Gross beta
		<u>General chemistry</u> Chloride Nitrate Sulfate			
<u>Physical parameters</u> Bulking factor Temperature of oven Time of sample heating				<u>Physical parameters</u> Bulking factor Temperature rise Unconfined compressive strength Shear strength	

TABLE 3-4 (continued)

ADVANCED PHASE

TCLP Organic List ^c	Five-Day Static Leach Test, PCT, and TCLP Inorganic List			
	Metals	Radionuclides	General Chemistry	
TCL ^d Volatiles TCL Semivolatiles TCL Pesticides/PCBs	Aluminum (Al) Antimony (Sb) Arsenic (As) Barium (Ba) Beryllium (Be) Boron (B) Calcium (Ca) Cadmium (Cd) Chromium (Cr) Cobalt (Co) Copper (Cu) Cyanide (CN) Lead (Pb)	Magnesium (Mg) Manganese (Mn) Mercury (Hg) Molybdenum (Mo) Potassium (K) Nickel (Ni) Selenium (Se) Silicon (Si) Silver (Ag) Sodium (Na) Thallium (Tl) Vanadium (V) Zinc (Zn)	Cs-137 Np-237 Pb-210 Pu-238 Pu-239/240 Ra-226 Ra-228 Sr-90 Tc-99 Th-total U-total Radon	alkalinity chloride reactivity fluoride ammonia nitrate pH phosphorus sulfate
<p><u>Physical Parameters :</u></p> <p>Bulking factor Temperature rise (cement only) Shear Strength (cement only) UCS (cement only) Permeability (cement only) Temperature of oven (vitrification only) Time of sample heating (vitrification only)</p>				

^aProduct Consistency Test (see Appendix C for SOP).

^bIon chromatography.

^cTCLP organics will not be analyzed if the compounds are not found in the characterization study portion of the work plan (Section 6.0).

^dTarget Compound List (TCL).

3.2 DATA QUALITY OBJECTIVES

DQO analytical levels are defined in EPA's "Guide for Conducting Treatability Studies Under CERCLA" (EPA 1989a). This guide states that the requisite analytical levels are dictated by the types and magnitudes of decisions to be made based on the data and the objective of the screening. A description of the analytical levels is presented in Table 3-5, an excerpt from EPA's guide. A discussion of the DQOs for each stage of the treatability study for cement stabilization and vitrification follows.

Data quality needs are used to establish DQOs. The implementation of an appropriate QA/QC program is required to ensure that data of known and documented quality are generated. The DQOs will define the level of QA/QC for the treatability testing and analysis. A list of tests and associated DQOs for cement stabilization and vitrification are listed in Tables 3-6 and 3-7. In addition, the appendices that contain the descriptions of the procedures are listed. Standard Operating Procedures (SOPs) and nonstandard test methods are described in Appendices B and C, respectively. In Tables 3-6 and 3-7, two appendices are listed for bulking factor. If the untreated waste is a slurry, the bulking factor will be determined according to the SOP in Appendix B. If the untreated waste is a solid, the bulking factor will be calculated using densities in accordance with Appendix C.

Composite samples will be used in the initial stage(s) to minimize the total number of experiments, cost, and waste generation. These preliminary phase experiments will aid in the resolution of general ranges of reagent formulations needed to stabilize and vitrify the waste and to elucidate on potential problems with different stabilization schemes. Experiments with strata samples will be conducted to determine the effects of waste material variability on the stabilization and vitrification processes. See Section 4.0 for a detailed discussion of the experimental design and lists of desired data.

TABLE 3-5. SUMMARY OF ANALYTICAL LEVELS

Level I	
Type of analysis	Field screening or analysis with portable instruments.
Limitations	Usually not compound-specific, but results are available in real time. Not quantifiable.
Data quality	Can provide an indication of contamination presence. Few QA/QC requirements.
Level II	
Type of analysis	Field analysis with more sophisticated portable instruments or mobile laboratory. Organics by GC; inorganics by AA, ICP, or XRF.
Limitations	Detection limits vary from low parts per million to low parts per billion. Tentative identification of compounds. Techniques/instruments limited mostly to volatile organics and metals.
Data quality	Depends on QA/QC steps employed. Data typically reported in concentration ranges.
Level III	
Type of analysis	Organics/inorganics performed in an off-site analytical laboratory. May or may not use CLP procedures. Laboratory may or may not be a CLP laboratory.
Limitations	Tentative compound identification in some cases.
Data quality	Detection limits similar to CLP. Rigorous QA/QC.
Level IV	
Type of analysis	HSL organics/inorganics by GC/MS, AA, ICP. Low parts-per-billion detection limits. CLP analysis.
Limitations	Tentative identification of non-HSL parameters. Validation of laboratory results may take several weeks.
Data quality	Goal is data of known quality. Rigorous QA/QC.
Level V	
Type of analysis	Analysis by nonstandard methods.
Limitations	May require method development or modification. Method-specific detection limits. Will probably require special lead time.
Data quality	Method-specific

Source: EPA, "Guide for Conducting Treatability Studies under CERCLA," December 1989.

TABLE 3-6. STABILIZATION TEST DQOS

PRELIMINARY (REMEDY SCREENING)			
TEST	APPENDIX	DQO/COMMENT	DQO LEVEL
Bulking Factor	B or C	Minimize waste volume increase. To estimate the volume of waste that will be generated.	V
Modified Toxicity Characteristic Leaching Procedure (MTCLP)	C	During the screening phases, to determine the relative leachability of hazardous and radiological constituents associated with the various stabilization reagent formulations.	V
Waste Form Temperature Rise	C	Preliminary process parameters	I
Shear Strength	C	Preliminary process parameters	I
Unconfined Compressive Strength (UCS)	B	To determine the unconfined compressive strength associated with each of the reagent formulations	II
pH, Eh	C	Preliminary process parameter	I

TABLE 3-6 (Continued)

ADVANCED (REMEDY SELECTION)			
TEST	APPENDIX	DQO/COMMENT	DQO LEVEL
Bulking Factor	B or C	Minimize waste volume increase. To estimate the volume of waste that will be generated.	V
Unconfined Compressive Strength	B	To determine the unconfined compressive strength associated with each of the stabilization reagent formulations.	III
Full TCLP	See QAPP	To determine leachability of each of the stabilization reagent formulations. To provide data for the FS risk assessment calculations.	IV
5-Day Static Leach Test	C	To provide data for the FS risk assessment calculations	V
Permeability	C	To provide data for the FS risk assessment calculations	III
Waste Form Temperature Rise	C	To provide preliminary process parameters	I
Shear Strength	C	To provide preliminary process parameters	I
Radon Emanation	C	To determine effect of stabilization on radon emanation	V
pH, Eh	C	Preliminary process parameter	I

FER/OU1-6/JK.350.3F/10-05-91

TABLE 3-7. VITRIFICATION TEST DQOs

PRELIMINARY (REMEDY SCREENING)			
TEST	APPENDIX	DQO/COMMENT	DQO Level
Bulking Factor	B or C	Minimize waste volume increase. To estimate the volume of water.	V
MTCLP	C	During the screening phases, to determine stabilization reagent formulations so that the final waste form meets the TCLP metal leaching criteria. In addition, the test data will indicate the relative leachability of uranium with the various reagent formulations.	V
PCT	C	To provide data for the FS risk assessment calculations. To provide data on the relative leachability of uranium and glass components with the various reagent formulations.	V
ADVANCED (REMEDY SELECTION)			
Bulking Factor	B or C	Minimize waste volume increase. To estimate the volume of waste that will be generated.	V
Radon emission	C	Estimate effectiveness of treatment in reducing radon emissions	V
Full TCLP	See QAPP	To determine stabilization reagent formulations so that the final waste form meets the TCLP metal leaching criteria. To provide data for the FS risk assessment calculations.	IV
PCT	C	To provide data for the FS risk assessment calculations. To provide data on the relative leachability of uranium and glass components with the various reagent formulations	V

ERR/OU1-6/IR.350.36/10-05-91

62

4.0 EXPERIMENTAL DESIGN AND PROCEDURES

4.1 CEMENT STABILIZATION EXPERIMENT DESIGN

There are many unknown variables regarding the behavior and activity of the waste and the performance of the stabilizing reagents with the waste. Therefore, this treatability study will consist of three distinct stages. The first or preliminary phase will be divided into two sets of experiments: the first will involve a statistically designed mixture experiment (Group I experiments in Table 4-1); the second will involve five single variable experiments (Groups II through V experiments in Table 4-1). The statistically-designed matrix was developed through a statistical analysis of the variable parameters and the practical ranges of these parameters. The stabilization matrix is based on the extreme vertices design for mixtures that have constraints on the values of each factor (McLean and Anderson 1966; Diamond 1981). Because this is a screening study, and to decrease the number of experiments, only the matrix vertices and center point of the complete matrix values will be used. The single variable matrices, Group II, III, IV, and V experiments, are similar in structure to the Group I experiments but differ in that a single variable is changed for each experiment group. All of these experiments will be conducted on the composite samples. The preliminary studies on the composite samples will entail up to 160 experiments (8 composite samples x 20 experiments/sample). Preliminary characterization of the samples is discussed in Section 6.0.

Mathematical models relating results from UCS, MTCLP, and bulking factor to reagent loading will be generated from the data gathered during the Group I experiments of the preliminary phase. These models will aid in the interpretation of data and in the formulation of reagent combinations for the additional testing phase of the screening.

The second stage of the preliminary phase will consist of 0 to 5 experiments depending on the success of the preliminary phase. This stage will use new combinations of reagents if the preliminary phase is unsuccessful in producing adequate waste forms or it will refine the mixtures of those successful experiments run in the preliminary phase. The preliminary phase experiments will be run on composite samples.

The advanced phase will apply the two most promising mixtures discovered in the preliminary Stages I and II to each of the 15 strata composite samples from Pits 1 through 4 and the Burn Pit, and 3 composite samples from Pits 5 and 6 and the Clearwell. This will determine if the successful mixtures from the preliminary phase will work on the strata samples. These two formulations will result in approximately 43 samples. See Figure 4-1 for the logic of the cement stabilization screening and Table 1-3 for the estimated number of experiments per phase and stage. Experimental conditions

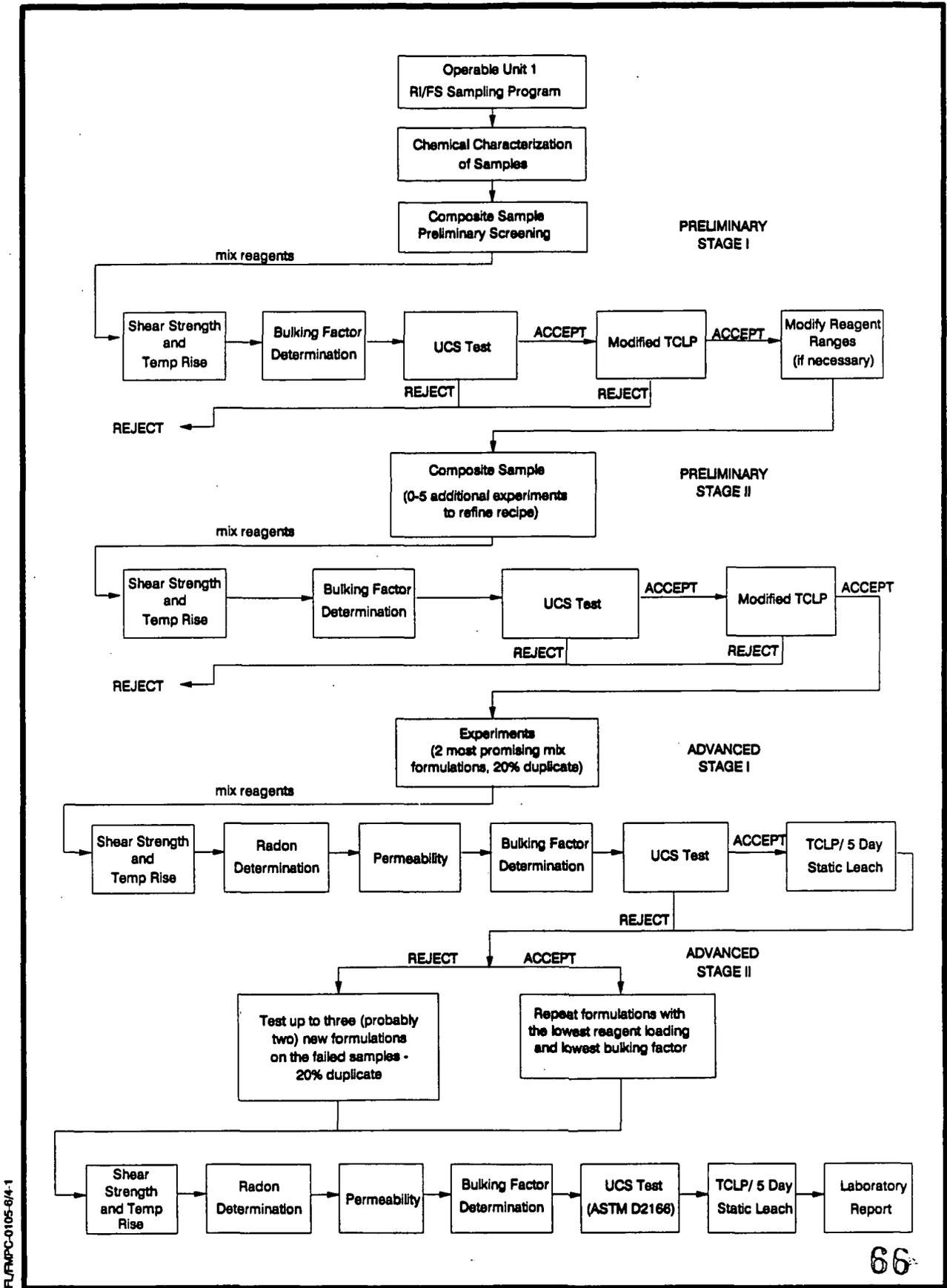
TABLE 4-1. CEMENT STABILIZATION EXPERIMENT MATRICES (STAGE 1)

GROUP I EXPERIMENTS-STATISTICALLY-BASED MATRIX						
Run Number	Waste (g)	Portland Cement Type II (g)	Fly Ash Type F (g)	Sodium Silicate Type N (g)	Attapulgite and Clinoptilolite Each (g)	Potential Range of Water Needed (g)
1	100	64	64	0	6	9 - 65
2	100	68	68	7	6	11 - 71
3	100	51	31	0	6	0 - 35
4	100	54	33	7	6	0 - 38
5	100	31	51	0	6	0 - 35
6	100	33	54	7	6	0 - 38
7	100	26	26	0	6	0 - 15
8	100	27	20	7	6	0 - 16
9	100	43	43	4	6	0 - 37
GROUP II EXPERIMENTS-SINGLE VARIABLE MATRIX, EFFECT OF SITE FLY ASH						
Run Number	Waste (g)	Portland Cement Type II (g)	Site Fly Ash (active) (g)	Sodium Silicate Type N (g)	Attapulgite and Clinoptilolite Each (g)	Potential Range of Water Needed
10	100	43	43	0	6	0 - 37
11	100	43	43	4	6	0 - 37
GROUP III EXPERIMENTS-SINGLE VARIABLE MATRIX, EFFECT OF ADSORBENT						
Run Number	Waste (g)	Portland Cement Type II (g)	Fly Ash Type F (g)	Sodium Silicate Type N (g)	Attapulgite or * Clinoptilolite (g)	Potential Range of Water Needed (g)
12	100	43	43	4	12A	0 - 37
13	100	43	43	4	12C	0 - 37
14	100	26	26	0	0	11 - 71
15	100	64	64	0	0	11 - 71

TABLE 4-1. (Continued)

GROUP IV EXPERIMENTS-SINGLE VARIABLE MATRIX, EFFECT OF CEMENT TYPE						
Run Number	Waste (g)	Portland Cement Type I (g)	Fly Ash Type F (g)	Sodium Silicate Type N (g)	Attapulgitite and Clinoptilolite Each (g)	Potential Range of Water needed (g)
16	100	43	43	4	6	0 - 37
17	100	43	43	0	6	0 - 37
18	100	43	43	0	0	0 - 37
GROUP V EXPERIMENTS-CEMENT ONLY						
Run Number	Waste (g)	Portland Cement Type II (g)	Fly Ash Type F (g)	Sodium Silicate Type N (g)	Attapulgitite and Clinoptilolite Each (g)	Potential Range of Water needed (g)
19	100	60	0	0	0	11 - 71
20	100	80	0	0	0	11 - 71

*12A and 12C: Add 12 grams of attapulgitite and clinoptilolite, respectively.
 Total number of experiments is 160. (160 experiments = 8 composite samples x 20 runs/sample.)



FL/FMPC-0105-6/4-1

FIGURE 4-1. CEMENT STABILIZATION LABORATORY SCREENING FLOWCHART

of the optional stage of the advanced phase will be determined based on results from the preceding stages.

4.1.1 Preliminary Phase - Stage 1

The Group I experiments will treat each composite sample with a combination of portland Type-II cement, PQ Corporation Type N sodium silicate, Type F fly ash, clay and zeolite (attapulgite and/or clinoptilolite), and water according to the matrix shown in Table 4-1.

The Groups II, III, IV, and V experiments will change a single variable in the reagent mixture. The Group II experiments will substitute site fly ash from the active fly ash pile (Operable Unit 2) for the commercial Type F fly ash. This will allow for the stabilization of contaminated material from two operable units in the same treatment system. The Group III experiments will modify the type and level of adsorbents that may affect the leachability of the heavy metals and radionuclides in the treated waste. In the Group IV experiments, portland Type I cement will be substituted for Type II cement. This is being done due to the cost difference between the two types of cement. In Group V experiments, portland Type II cement with water will be the only additive.

For each of the test runs, the waste form temperature rise, bulking factor, shear strength, and general appearance will be recorded. The waste form temperature rise and shear strength will be measured within 10 minutes of when reagents and waste are mixed. These temperature measurements are relative values only because they are performed in an open, plastic container. The shear strength will be measured with a Soiltest Torvane. The UCS, MTCLP, and bulking factor will be measured on day 28. It is expected that 20 to 30 percent of the samples will meet the UCS and leaching requirements. In addition, the following observations, measurements, or tests will be performed: general description of waste before and after reagent addition, percent water in waste, pH of stabilized waste analytical leachate solutions, and indication if there is gas evolution during mixing or during the curing process.

4.1.2 Preliminary Phase - Stage 2 (Composite Samples)

The preliminary phase may not yield a successful mixture or it may indicate a promising reagent combination that requires more data for adequate evaluation. Additionally, analysis of the preliminary phase data may indicate that lesser quantities of reagents will yield adequate results. If any of these are the case, an additional experimental matrix will be designed to gather this data. The mathematical models developed from the Group I experiment data will be used to aid in the development of this additional experiment matrix. It is expected that this additional testing could consist of 0 to 5 experiments.

The same data will be required for these experiments as was required for the preliminary phase, Stage 1.

4.1.3 Advanced Experiments - Stage 1

The two most promising stabilization formulations encountered during the preliminary phase will be applied to the top, middle, and bottom strata of strata composites from the borings to determine the effect of varying waste composition. (See Section 6.0 for more information on the sampling effort.) The two most promising formulations will also be applied to the composite samples from Pits 5, 6, and the Clearwell. The most promising formulations are those with a high UCS, low leachability of hazardous and radioactive contaminants, minimum volume increase of the resultant waste form, and lowest cost of reagents. It is expected that two formulations per strata per pit and per composite sample from Pits 5, 6, and the Clearwell, will be tested with 20 percent of testing in duplicate resulting in approximately 43 experiments performed. The mathematical models developed from the Group I experiment data will also be used to aid in the development of these experiments.

For this phase, a full TCLP, a bulking factor, permeability test, shear strength, temperature rise, and a five-day static leachability test will be run in addition to a UCS test. Radon emissions from the final waste form will also be determined. In addition, the following observations, measurements, or tests will be performed: general description of waste before and after reagent addition, percent water in waste, pH of stabilized waste analytical leachate solutions, and indication if there is gas evolution during mixing or during the curing process.

4.1.4 Advanced Experiments - Stage 2

The successful formulations from Stage 1 of advanced experiments with the lowest reagent loading and lowest bulking factor will be repeated in Stage 2. If any formulations fail in Stage 1 of the advanced experiments, two or three new formulations will be tested on each of the failed samples (Stage 2). Twenty percent duplicate runs will be made with the new formulations.

The same tests as in advanced phase, Stage 1 will be conducted.

4.1.5 Advanced Experiments - Optional

It is possible that some waste forms that appear to be promising will fail TCLP, or exhibit other traits casting doubt on the formulations. If this occurs, optional experiments might be designed. Waste forms from optional tests would, as a minimum, be subjected to the same tests used in Stages 1 and 2 of the advanced experiments. The treated sample from the 5-day static leach test may be inspected for physical degradation after 90 days of leaching. The leachate may be analyzed during the advanced phase.

4.1.6 Procedures

The procedures described in Appendices B and C are listed below:

Appendix B Procedures

	1
• Laboratory Notebook Recording Procedure	2
• Analytical Logbook Recording Procedure	3
• Standard Laboratory Sieves: Specification, Calibration, and Maintenance	4
• Bulking Factor Measurement for Pourable Sludge	5
• Calibration of Thermometers	6
• Unconfined Compressive Strength	7

Appendix C Procedures

	8
• Nuclear Waste Glass Product Consistency Test - Version 3.0 (U)	9
• Bulking Factor Procedure for Non-sludge Type Waste	10
• 5-Day Static Leach Test Procedure	11
• Modified TCLP Leach Test Procedure	12
• Waste and Reagent Mixing Procedure	13
• Stabilization Waste Form Temperature Rise Generic Procedure	14
• Permeability	15
• Generic pH and Eh Procedure	16
• Proposed Radon Emissions from Stabilized Solids	17
• Shear Strength	18
• Vitrification of Waste	19
• Generic Uranium by Ion Chromatography with Post-Column Reactions and Phosphorescence or Fluorescence Detection	20
	21

4.1.7 Data Required

The following data will be recorded during cement stabilization preliminary and advanced phases: 23

• UCS measured by a soiltest U-590 or U-610 instruments (SOP No. TCL 1109, Appendix B)	24
	25
• Permeability (for advanced phase)	26
• MTCLP (for preliminary phase), or TCLP and 5-day static leach test (for advanced phase) on those mixtures with a compressive strength of approximately 500 psi	27
	28
• Bulking factor	29
• Waste form temperature rise after waste and reagents are mixed, and the time between mixing and temperature measurements	30
	31
• Approximate shear strength measured within 10 minutes of when waste and reagents are mixed	32
	33
• Physical characteristics: percent moisture, bulk density	34

- Amount of water added to each waste form 1
- The maximum particle size treated; weight and percentage of material sieved from the raw waste before treatment 2
3
- General description of the waste form before and after reagents are mixed. This includes a description of any grinding of the sample to meet particle size requirements for UCS 4
5
6
- Description of vapor released during mixing and during curing of mixture 7
- Physical appearance of mold after 90-day soak in deionized water in optional phase 8
- pH and Eh of the reagent waste mixture before adding mixture to molds 9
- pH of MTCLP and TCLP extraction fluids, pH of TCLP extraction fluid determination test 10
11
- pH of 5-day static leach solution and 90-day leach solution (if required) 12
- pH and Eh of slightly wet water waste mixture 13
- Radon emissions from each waste form 14
- TCLP metals results for reagents combined with clean sand or quartz 15

4.2 VITRIFICATION EXPERIMENT DESIGN

This screening will consist of two phases: preliminary phase and advanced phase. There will be approximately 48 experiments (8 composites samples x 6 experiments/sample) in the preliminary screening. There will be several range-finding experiments where various amounts of sodium hydroxide are added to the mixture of waste, fly ash, and soil to determine the sodium hydroxide concentration needed to lower the melting point temperature to approximately 1250°C. The effects of the addition of sodium hydroxide, site fly ash, and site soil will be demonstrated. The advanced phase will apply the most promising mixtures discovered in the preliminary phase to each of the samples. This will determine if the successful mixtures will work on the strata samples. These formulations will be applied to each of the 18 samples (1 strata composite each from Pits 1 through 4 and the Burn Pit x 3 strata per pit plus composite samples from Pits 5 and 6 and the Clearwell) resulting in approximately 36 experiments with 20 percent duplication giving 43 experiments possible for Stage 1. See Figure 4-2 for the logic of the vitrification screening and Table 1-4 for estimated number of experiments per phase and stage.

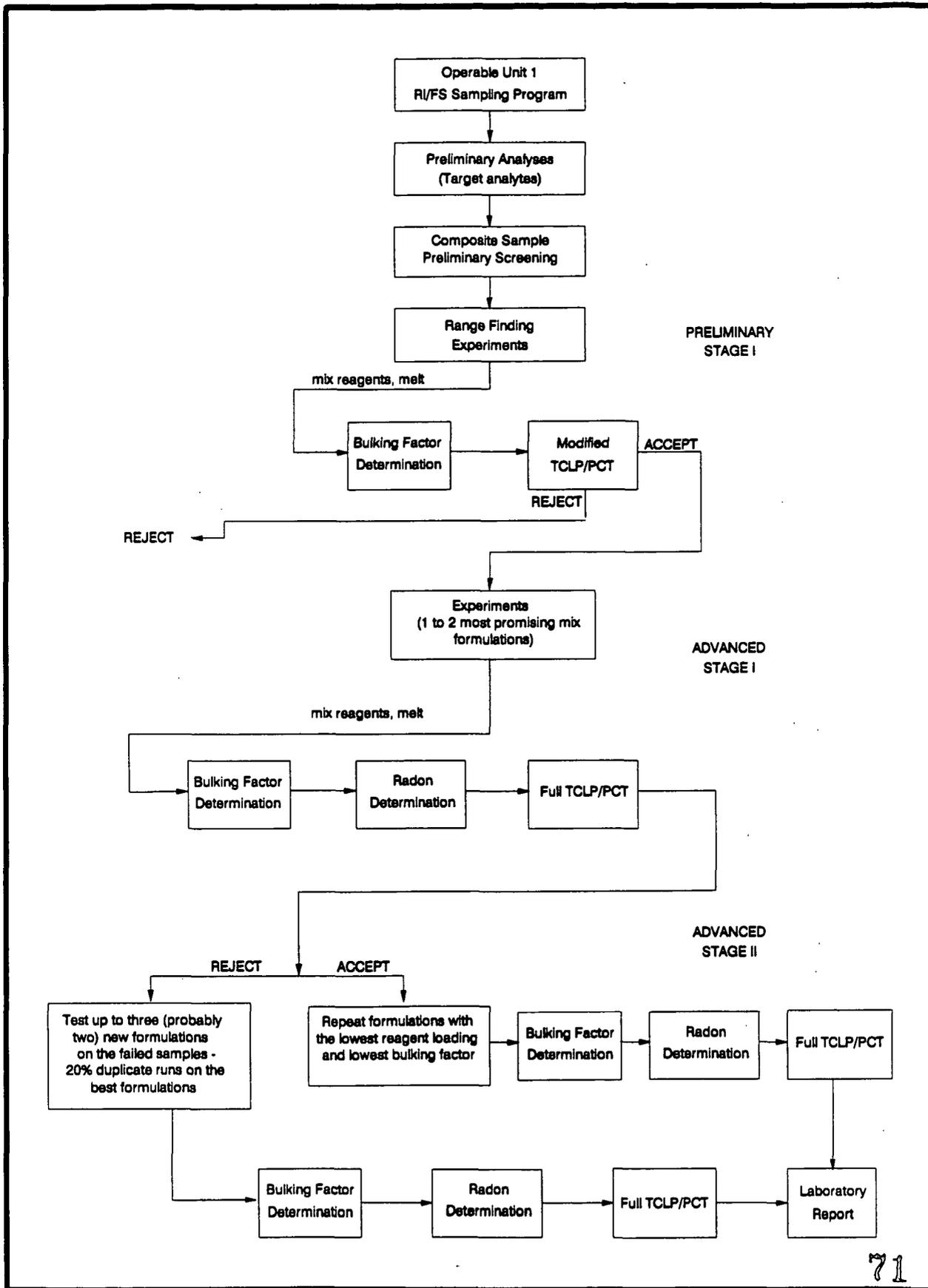


FIGURE 4-2. VITRIFICATION LABORATORY SCREENING FLOWCHART

FL/FMFC-0105-8/4-2

4.2.1 Preliminary Phase - Stage 1 (Composite Samples)

The effects of adding sodium hydroxide, site fly ash, and site soil will be demonstrated (except for tests on the raw waste, no experiments will be conducted until the chemical characterization of the soil and fly ash are completed). As a target, the reagent waste mixture will have between 40 and 60 percent combined SiO_2 and Al_2O_3 content and 10 to 20 percent sodium oxide content when dried. It is expected that this range of SiO_2 and Al_2O_3 content will produce durable glass. The melting point of the glass mixture can be lowered by increasing the sodium oxide content of the glass. Sodium hydroxide may be added to the mixture before heating to increase the sodium oxide content of the vitrified waste. (Sodium hydroxide is converted to sodium oxide during the vitrification process.) Enough sodium hydroxide will be added to cause the mixture to melt at 1250°C in a muffle furnace. This temperature was chosen to give a reasonable compromise between the cost of adding sodium oxide content to lower the melting point, the expected increase in leachability as the melting point of mixture is lowered, and the energy cost to melt and form the vitrified material. If this process is carried forward to the remedy design phase, the effect of metal temperature may be investigated.

The waste will be analyzed on a dry basis for the content of total aluminum as alumina, silicon as silica, and sodium as sodium oxide. Using the chemical analyses of the raw waste, fly ash, and soil as guides, a series of range-finding experiments will be performed. Various amounts of sodium hydroxide will be added to mixtures of waste, fly ash, and soil to determine the sodium hydroxide concentration needed to lower the melting point temperature to about 1250°C . These range-finding experiments will be followed by an experimental matrix similar to Table 4-2. The ranges given in Table 4-2 may be changed after completion of the range-finding experiments and consideration of the chemical analysis of the soil and fly ash.

According to Table 4-2, sodium hydroxide will be added at three levels: 0 percent, 10 percent, and 20 percent of the dry weight of the waste. The site fly ash and soil will be added at 50 percent of the dry weight of the waste.

4.2.2 Advanced Phase - Stage 1

The one to two most promising vitrification formulations encountered during the composite sample preliminary phase will be applied to the top, middle, and bottom strata of each boring from Pits 1 through 4 and the Burn Pit, to determine the effect of varying waste composition. In addition, the one

**TABLE 4-2. VITRIFICATION EXPERIMENT MATRIX
PRELIMINARY PHASE (STAGE 1)**

Run Number	Sodium Hydroxide^a (w/w)%	Active Site Fly Ash^a (w/w)%	Site Soil^a (w/w)%
1	0	0	0
2	0	50	0
3	0	0	50
4	10	50	0
5	10	0	50
6	20	50	0
7	20	0	50

^aWeight of reagent to dry weight of waste.

or two most promising formulations will also be applied to composite samples from Pits 5 and 6 and the Clearwell. The most promising formulations are those that meet the leachability criteria and that minimize the volume increase of the resultant waste and the cost of reagents.

For this stage, full TCLP, bulking factor, and PCT tests will be run. Radon emissions will also be determined.

4.2.3 Advanced Phase - Stage 2

Successful formulations from advanced Stage 1 with the lowest reagent loading and lowest bulking factor will be repeated. Vitrified samples will be subjected to PCT, and bulking factor will be determined. If any formulations from advanced Stage 1 fail, two or three new formulations will be tested on each failed sample. Vitrified samples with the new formulations will be tested for TCLP, PCT, and bulking factor. Radon emissions will also be determined.

4.2.4 Advanced Phase - Optional

Experimental conditions of the optional stage will be determined based on the results of the first two stages.

4.2.5 Procedures

The procedures described in Appendices B and C are listed below:

Appendix B Procedures

- Laboratory Notebook Recording Procedure
- Analytical Logbook Recording Procedure
- Standard Laboratory Sieves: Specification, Calibration, and Maintenance
- Bulking Factor Measurement for Pourable Sludge
- Calibration of Thermometers
- Unconfined Compressive Strength

Appendix C Procedures

- Nuclear Waste Glass Product Consistency Test - Version 3.0 (U)
- Bulking Factor Procedure for Non-sludge Type Waste
- 5-Day Static Leach Test Procedure
- Modified TCLP Leach Test Procedure
- Waste and Reagent Mixing Procedure
- Stabilization Waste Form Temperature Rise Generic Procedure
- Permeability
- Generic pH and Eh Procedure
- Proposed Radon Emissions from Stabilized Solids
- Shear Strength

- Vitrification of Waste 1
- Generic Uranium by Ion Chromatography with Post-Column Reactions and Phosphorescence or Fluorescence Detection 2
3

4.2.6 Data Required 4

The following data will be recorded during the vitrification screening: 5

- MTCLP (for preliminary phase), or TCLP and PCT (for strata sample experiments) leach procedure 6
7
- Weights of reagents and waste in final waste form 8
- Temperature of oven 9
- Time heating sample 10
- Bulking factor 11
- General description of the waste before and after melting 12
- Physical characteristic: percent moisture, bulk density 13
- Metal characterization (SiO_2 , Al_2O_3 , Na_2O) of the site soil, site fly ash, and successfully vitrified samples 14
15
- Radon emissions 16

5.0 EQUIPMENT AND MATERIALS

See Table 5-1 for a listing of the major equipment to be used during the laboratory screening.

TABLE 5-1. EQUIPMENT AND MATERIALS^a

No. of Items	Item Description
Multiple	Plastic containers, 8 oz. and 5 oz.
Multiple	Spatulas
Multiple	Crucibles
1	HACH digital pH meter
3	Glass melter furnace
1	Soiltest Laboratory vibrating shaker
1	Thermometer, calibrated and traceable
1	Scale, calibrated
1	Soiltest Torvane
Multiple	2 X 4 Jatco Co. plastic molds for UCS
1	Hobart ASTM Grade Planetary Mixer or equivalent
1	Soiltest U-590 or U-610 instrument
1	Drying oven
Multiple	High temperature gloves
Multiple	Crucible tongs

^aThis equipment list does not include analytical instrumentation for leachate analyses; equipment for TCLP, PCT, radon emissions analysis, or 5-day static leach test; or general laboratory equipment.

6.0 SAMPLING AND ANALYSIS

1

The data from the CIS sampling program were used to estimate the amount of waste in the pits. The results obtained were significantly different from the waste inventory records. This discrepancy may have resulted from the inability to sample the full waste column in the pits. A review of the CIS data revealed additional data requirements. These data are needed for the final design of the remedial actions and also for the evaluation of the risks associated with remediation. Consequently, two Sampling and Analysis Plans (SAPs) for Operable Unit 1 have been prepared and approved by the EPA. Actual field sampling for Pits 1 through 4 and the Burn Pit began in June 1991. The samples taken in this sampling program and samples taken from Waste Pits 5, 6, and the Clearwell will be used for this laboratory screening.

2

3

4

5

6

7

8

9

10

A total of 13 borings were taken from Waste Pits 1 through 4 and the Burn Pit under the first sampling program (Figure 6-1). The borings were sectioned into top, middle, and bottom zones that consist of three tubes collected at 1/3, 1/2, and 2/3 of the estimated depth of each pit (from which 39 strata samples will be taken). These demarcations will be used on the following estimated depths: Pit 1 - 20 feet, Pit 2 - 22 feet, Pit 3 - 27 feet, Pit 4 - 24 feet, and the Burn Pit - 13 feet. If a greater number of strata were observed, more samples were taken from the boring. A total of five composite samples were prepared, one each from Pits 1 through 4 and the Burn Pit. The composites were collected based on details as described in the SAP. These samples consisted of waste material from each identified stratum in the boring such that a representative sample was prepared. In the second sampling program (handled by WEMCO), composite samples were collected from Pits 5 and 6 and the Clearwell for support of the treatability study. Composite samples were collected because of the consistency of the Waste Pits and Clearwell material. (Additional site-specific characterization is underway, but will not provide samples for this study.)

11

12

13

14

15

16

17

18

19

20

21

22

23

According to the SAP for Pits 1 through 4 and the Burn Pit, a full range of radionuclide, organic, and inorganic analyses are being conducted on the retrieved samples. These analyses are listed in Table 6-1. Similar analyses will be conducted on the untreated samples from Waste Pits 5, 6, and the Clearwell as part of the treatability study characterization because the SAP concerning these areas did not include characterization. For the material to be treated, this laboratory screening requires that the presence and concentrations of a number of analytes be known as well as a number of physical parameters. The analytes and physical parameters are of interest because their presence and or high concentrations may have adverse effects on the proposed cement stabilization and vitrification testing. All of the composite and strata samples were analyzed for these parameters. The physical parameters are listed in Table 6-2.

24

25

26

27

28

29

30

31

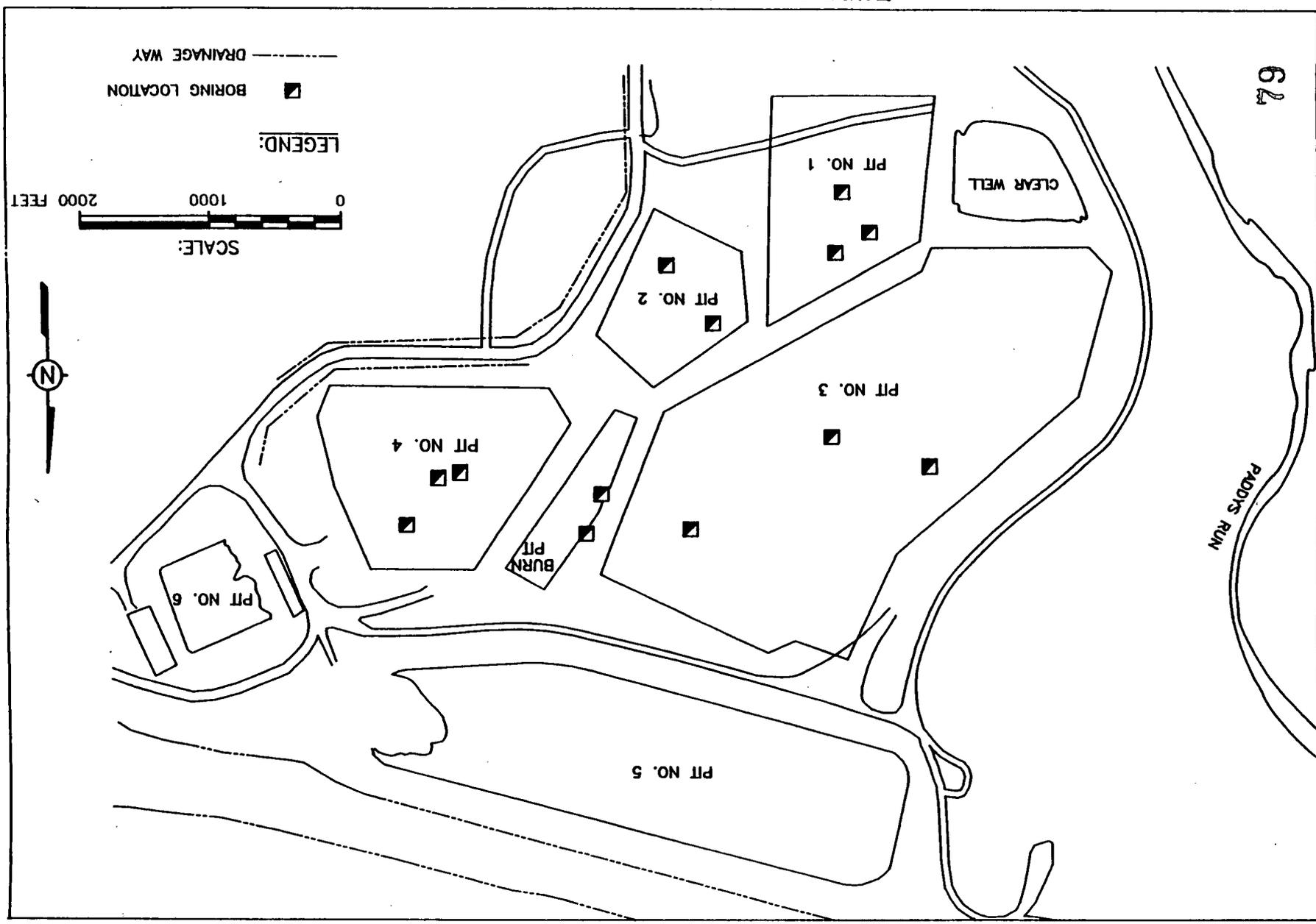
32

33

78

2425

FIGURE 6-1. SAMPLE BOREHOLE LOCATIONS



303317X3 09/20/91 8:20am SAT

**TABLE 6-1. ANALYTICAL CHARACTERIZATION PARAMETERS
FOR OPERABLE UNIT 1**

PER/OU1-6/JTK-350.6A/10-05-91

Location	Required Analyses	No. of Samples
Composite of Interval 3 in each boring	Full Radiological ^b Full HSL ^c less VOA General Chemistry ^d Dioxins and Furans ^e	13
Composite of Interval 2 in each boring	Parameters listed above plus Appendix IX less volatiles and semivolatiles	13
One sample from each boring ^a	Appendix IX volatiles/semivolatiles	13
Discreet 6-inch samples from Intervals 1, 2, and 3 in each boring	HSL volatiles TCLP VOA on Interval 2	39 13
Composite of entire boring, less Shelby Tube interval, for each boring	TCLP Extraction: Full Radiological/BNA/Pesticides/PCB/Metals Total Organic Carbon Grain Size Analysis	13
All monitoring wells	Full Radiological ^b Appendix IX Full HSL ^c Dioxins and Furans ^e General Chemistry ^f	13

^aVolatiles and semivolatiles will be tested for in the interval displaying the highest HNu readings. If no preference is indicated, the second interval will be analyzed.

^bParameters listed in RI/FS QAPP Table 4.3.

^cFull HSL plus boron, cobalt, thallium, and tributyl phosphate.

^dTotal phosphorous, ammonia, pH, total Kjeldahl nitrogen, total organic nitrogen, oil and grease, bromide, chloride, nitrate, fluoride, and sulphate.

^eTotal dioxin and furan and 2,3,7,8-TCDD isomeric breakdown.

30

TABLE 6-2. GEOTECHNICAL/PHYSICAL TESTS

ASTM Designation	Method Title	Minimum No. of Tests
D2216-80	Water Content Determination	39
D4318-84	Atterberg Limits	39
D854-83	Specific Gravity Determination	39
D422-63	Grain Size Distribution with Hydrometer Analysis	39
D2435-80	One-Dimensional Consolidation	6
D2850-82	Unconsolidated Undrained Triaxial	6
D2434	Permeability of Granular Soils	6
No ASTM Designation	In Situ Soils Density Determination	39

7.0 DATA MANAGEMENT

7.1 GENERAL

This section pertains to work performed at the Technology Development Laboratory (TDL) only. Two types of laboratory notebooks will be used for this project. All laboratory notebooks are uniquely numbered and permanently bound with sequentially numbered pages.

Project-specific notebooks will be signed out by the facility quality control coordinator (QCC) to the individuals working on the project. All daily laboratory activities associated with the project will be recorded in the project-specific notebooks. Refer to the SOP in Appendix B.

Separate nonproject-specific logbooks will be used to record the injection or introduction of samples into analytical instrumentation. These logbooks are also used to record maintenance or problems with the instrument. Refer to the SOP in Appendix B.

At the completion of the project, the project-specific laboratory notebooks and logbooks will be returned to the facility QCC for retention. Instrument logbooks are returned to the facility QCC when the books are filled.

All records management and reporting will follow standard, QA/QC protocol in the QAPP and Volume 4 of the RI/FS Work Plan. Standard QA/QC protocol, as it applies to testing within the laboratory, will adhere to the following guidelines:

- One hundred percent verification on all numerical results - transcriptions, and calculations are checked and recalculated.
- Data validation through test reasonableness - summaries of all test results for individual reports are reviewed to determine the overall reasonableness of data and to determine the presence of any data that may be considered outliers.
- Routine instrument calibration - will be performed under guidance from the QAPP.
- Use of trained personnel conducting tests - all technicians are trained in the application of standard laboratory procedures for analyses as well as the QA measures implemented for internal QC checks.

7.2 STABILIZATION

Spikes

- TCLP - During the site characterization, the TCLP leachate from the sample will be spiked. Spike recovery will be calculated separately for each waste pit and for each zone (A, B, C). These spike recovery values will be used with all subsequent TCLP results.

Blanks

- Reagent blank - Solidify sand or quartz, run TCLP on solidified mass
- Radionuclide test will use a water blank
- TCLP will use the Oak Ridge Laboratory (ORL) blank

Duplicate Analysis

- There will be a 20 percent experimental duplicate of all tests during the advanced phase.

7.3 VITRIFICATION

Spikes

- TCLP - During the site characterization, the TCLP leachate from the sample will be spiked. Spike recovery will be calculated separately for each waste pit and for each zone (A, B, C). These spike recovery values will be used with all subsequent TCLP results.

Blanks

- Radionuclide test will use a water blank
- TCLP will use the ORL laboratory blank

Duplicate Analysis

- There will be a 20 percent experimental duplicate of all tests during the advanced phase.

8.0 DATA ANALYSIS AND INTERPRETATION

8.1 EFFECTIVENESS OF WASTE FORMS

The results of the leaching tests (MTCLP, TCLP, PCT, and 5-day static) will be used to evaluate the long-term effectiveness of each waste form. The concentrations of radioactive and hazardous constituents in the standard TCLP leachate will be used as input into the geochemical models described in the draft RI/FS Work Plan Addendum on risk assessment methodology. These models will be used with groundwater fate and transport models to estimate the concentrations of contaminants in the aquifer at the RME. These concentrations will in turn be used to calculate the magnitude of that exposure, and the resulting risks to human health and the environment. Fate and transport models are discussed in the DOE draft "Risk Assessment Work Plan Addendum" (DOE 1991b).

8.2 STABILIZATION

The reagent formulation along with the following data will be presented in tabular form:

- Waste form temperature rise after waste and reagents are mixed, and time between mixing and temperature measurements
- General descriptions of the waste before and after reagent addition. This includes a description of any grinding of the sample to meet particle size requirements for UCS.
- Approximate shear strength measured within 10 minutes of when waste and reagents are mixed
- Physical characteristics: percent moisture, bulk density
- Amount of water added to each waste form
- UCS (SOP TDL 1109)
- Permeability (for advanced screening)
- Bulking factor
- The maximum particle size treated; weight and percentage of material sieved from the raw waste before treatment
- Description of gases or vapors released during mixing and during curing of mixture
- Physical appearance of mold after 90-day soak in deionized water in optional phase
- pH and Eh of the reagent waste mixture before adding mixture to molds

- pH of MTCLP and TCLP extraction fluids, pH of TCLP extraction fluid determination test 1
2
- pH of 5-day static leach solution 3
- pH and Eh of slightly wet water mixture 4
- pH of 90-day leach solution in optional phase 5
- Radon emission test results in advanced phase 6
- MTCLP (for preliminary phase) 7
- 5-day static (for advanced phase) 8
- TCLP (for advanced phase) results will be reported three ways: (1) actual analysis of extract, (2) results adjusted for spike recovery, and (3) results adjusted for spike recovery and dilution by stabilization reagents 9
10
11
- TCLP metals results from reagents combined with clean sand or quartz 12

8.3 VITRIFICATION

The following data will be tabulated for the vitrification screening:

- MTCLP (for preliminary phase) 15
- PCT 16
- Weights of reagents and waste in final waste form 17
- Temperature of oven 18
- Heating time of sample 19
- Bulking factor 20
- General description of the waste before and after melting 21
- Physical characteristics: percent moisture, bulk density 22
- Radon emissions test results 23
- TCLP (for advanced phase) results will be reported three ways: (1) actual analysis of extract, (2) results adjusted for spike recovery, and (3) results adjusted for spike recovery and dilution by vitrified reagents 24
25
26

8.4 PROCEDURES USED TO ASSESS DATA PRECISION, ACCURACY, AND COMPLETENESS

The following are procedures used to assess data precision, accuracy, and completeness:

Calculations of precision, accuracy, and completeness will be used to assess data quality. These formulas can be found in the EPA guidance document "Preparing Perfect Project Plans" (EPA 1989b).

Example calculations of precision:

$$RPD = \frac{(C_1 - C_2) \times 100\%}{(C_1 + C_2)/2}$$

where

- RPD = relative percent difference
- C_1 = larger of the two observed values
- C_2 = smaller of the two observed values

Example calculation of accuracy:

$$\%R = \frac{100\% \times (S - U)}{C_{sa}}$$

where

- $\%R$ = percent recovery
- S = measured concentration in spiked aliquot
- U = measured concentration in unspiked aliquot
- C_{sa} = actual concentration of spike added

Example of calculation of completeness:

$$\%C = 100\% \times \frac{V}{n}$$

where

- %C = percent completeness 1
- V = number of measurements judged valid 2
- n = total number of measurements necessary to achieve a specified statistical level of confidence in decision making 3

An example of the TDL form used for reporting precision of duplicates and accuracy of spikes is given in Figure 8-1. 4

**Figure 8-1
 General QA/QC Report**

Analyte:
 Matrix:
 Sample Number:

		Concentration. ()
Precision of Duplicates		
Spike Value (b)=		
Spike Dup. Value (a)=		
Precision (RPD ^a)	$\frac{ a-b }{(a+b)/2} \times 100\% =$	
Accuracy of Spike		
Original Value (a)=		
Observed Spike Value (b)=		
Spike Level (c)=		
Accuracy=	$\frac{b-a}{c} \times 100\% =$	
Accuracy of Spike Dup.		
Original Value (a)=		
Observed Spike Dup. Value (b)=		
Spike Level (c) =		
Accuracy =	$\frac{b-a}{c} \times 100\% =$	

9.0 HEALTH AND SAFETY

1

See Appendix D for the Health and Safety Plan.

2

10.0 RESIDUALS MANAGEMENT

10.1 STABILIZED WASTE

This project will generate approximately 220 kg of cement stabilized waste and approximately 150 kg of vitrified waste. There may also be waste samples that have not undergone treatment that must also be handled as residual waste. These residuals will be shipped to the Fernald site for disposal. All waste and residual shipments must comply with the provisions of the Federal Treatability Study Sample Exemption Rule (see Section 3.9 of "Guide for Conducting Treatability Studies Under CERCLA" [EPA 1989a]). All disposal of materials conducted by the FEMP environmental remediation management contractor will be in accordance with requirements of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), RCRA, and the waste management requirements of the FEMP.

All treatability studies will be conducted in accordance with Tennessee's Hazardous Waste Management Regulations for treatability study samples (Tennessee Rule Chapter 1200-1-11-.02-16) and samples undergoing treatability studies at laboratories and testing facilities (Tennessee Rule Chapter 1200-1-11-.02-19).

10.2 LEACHATE

As a result of the MTCLP, TCLP, and 5-day static leaching procedures, approximately 1100 liters of stabilized waste leachate, a RCRA waste, will be generated. This leachate will be sent to the IT Oak Ridge Laboratory in Oak Ridge, Tennessee, or other QAPP laboratory for analysis and then will be shipped to FEMP for disposal. All waste and residual shipments must comply with the provisions of the Federal Treatability Study Sample Exemption Rule (see Section 3.9 of "Guide for Conducting Treatability Studies Under CERCLA" [EPA 1989a]).

All treatability studies will be conducted in accordance with Tennessee's Hazardous Waste Management Regulations for treatability study samples (Tennessee Rule Chapter 1200-1-11-.02-16) and samples undergoing treatability studies at laboratories and testing facilities (Tennessee Rule Chapter 1200-1-11-.02-19).

11.0 COMMUNITY RELATIONS

Treatability studies and community information and involvement activities are required in the CERCLA process. Community relations activities shall be conducted: (1) to support treatability studies in Operable Unit 1, (2) to explain the role of treatability studies in the RI/FS, and (3) to raise the public's confidence in cleanup alternatives and technologies identified in the alternatives screening/analysis process and in the preferred alternative for this operable unit. The Treatability Study Community Relations activities for Operable Unit 1 will comply with the Community Relations Plan, "RI/FS and Removal Actions at the DOE FEMP, Fernald, Ohio," August 1990. At a minimum, the following community relations activities will be conducted to explain treatability studies for Operable Unit 1.

- Community Meetings - Held a minimum of three times per year to provide status on cleanup issues, and to ensure that interested area residents have a routine public forum for receiving new information, expressing their views, and getting answers to their questions, the meetings will focus on operable unit updates, removal actions, major RI/FS documents, and other appropriate topics.
- Publications - RI/FS materials such as progress reports, factsheets, a community newsletter (*Fernald Site Cleanup Report*), and updates of CERCLA-related activities at the FEMP and will include information on treatability study activities for this Operable Unit 1.
- Presentations to Community Groups - Information about treatability studies for this operable unit will be included in briefings to community groups in Ross, Crosby, and Morgan townships, and to Fernald Residents for Environment Safety and Health, as appropriate. Also, this information will be included in presentations to other organizations, as requested.

Key milestones in treatability studies will be identified and progress reported to the community in these presentations and publications. These milestones include:

- Submittal of the work plan to DOE and EPA
- EPA approval of work plan
- Treatability testing
- Submittal of the treatability study report

Other activities identified in Section 4.0 of the community relations plan may be utilized as appropriate to effectively communicate treatability information to the community. Such activities may include workshops and community roundtables.

12.0 REPORTS

An interim draft report, which will document the results of the stabilization and leaching tests, will be issued following the completion of the preliminary phase. This report will identify the promising stabilization formulation and extraction solutions and will recommend whether those procedures be further tested in the advanced treatability program. To determine the success of the recommended stabilization formulations and extraction solutions, it will be necessary to have the residues and leachates analyzed for radium and thorium at IT's Oak Ridge Laboratory or other QAPP laboratory. In addition, all raw data will be presented in a tabular format.

The advanced phase report will be issued following the completion of the experimental portion of the advanced tests. This report will identify the stabilization formulations and extraction procedures that are promising and that identify any problems. To determine the success of the recommended stabilization formulations and extraction solutions in removing contaminants, it will be necessary to have the residues analyzed at IT's Oak Ridge Laboratory or other QAPP laboratory. The following outline can be used as a guide when preparing the reports.

SUGGESTED ORGANIZATION OF TREATABILITY STUDY REPORT

1.0	Introduction	16
1.1	Site description	17
1.1.1	Site name and location	18
1.1.2	History of operations	19
1.1.3	Prior removal and remediation activities	20
1.2	Waste stream description	21
1.2.1	Waste matrices	22
1.2.2	Pollutants/chemicals	23
1.3	Remedial technology description	24
1.3.1	Treatment process and scale	25
1.3.2	Operating features	26
1.4	Previous treatability studies at the site	27
2.0	Conclusions and recommendations	28
2.1	Conclusions	29
2.2	Recommendations	30
3.0	Treatability Study Approach	31
3.1	Test objectives and rationale	32

3.2	Experimental design and procedures	1
3.3	Equipment and materials	2
3.4	Sampling and analysis	3
3.4.1	Waste stream	4
3.4.2	Treatment process	5
3.5	Data management	6
3.6	Deviations	7
4.0	Results and discussion	8
4.1	Data analysis and interpretation	9
4.1.1	Analysis of waste stream characteristics	10
4.1.2	Analysis of treatability study data	11
4.1.3	Comparison to test objectives	12
4.2	Quality assurance/quality control	13
4.3	Costs/schedule for performing the treatability study	14
4.4	Key contacts	15
	References	16
	Appendices	17
A.	Data summaries	18
B.	Standard operating procedures	19

13.0 SCHEDULE

1

The schedule to complete all treatability-related activities is shown in Figure 13-1. The activities and dates are based on the Operable Unit 1 amended Consent Agreement Schedule.

2

3

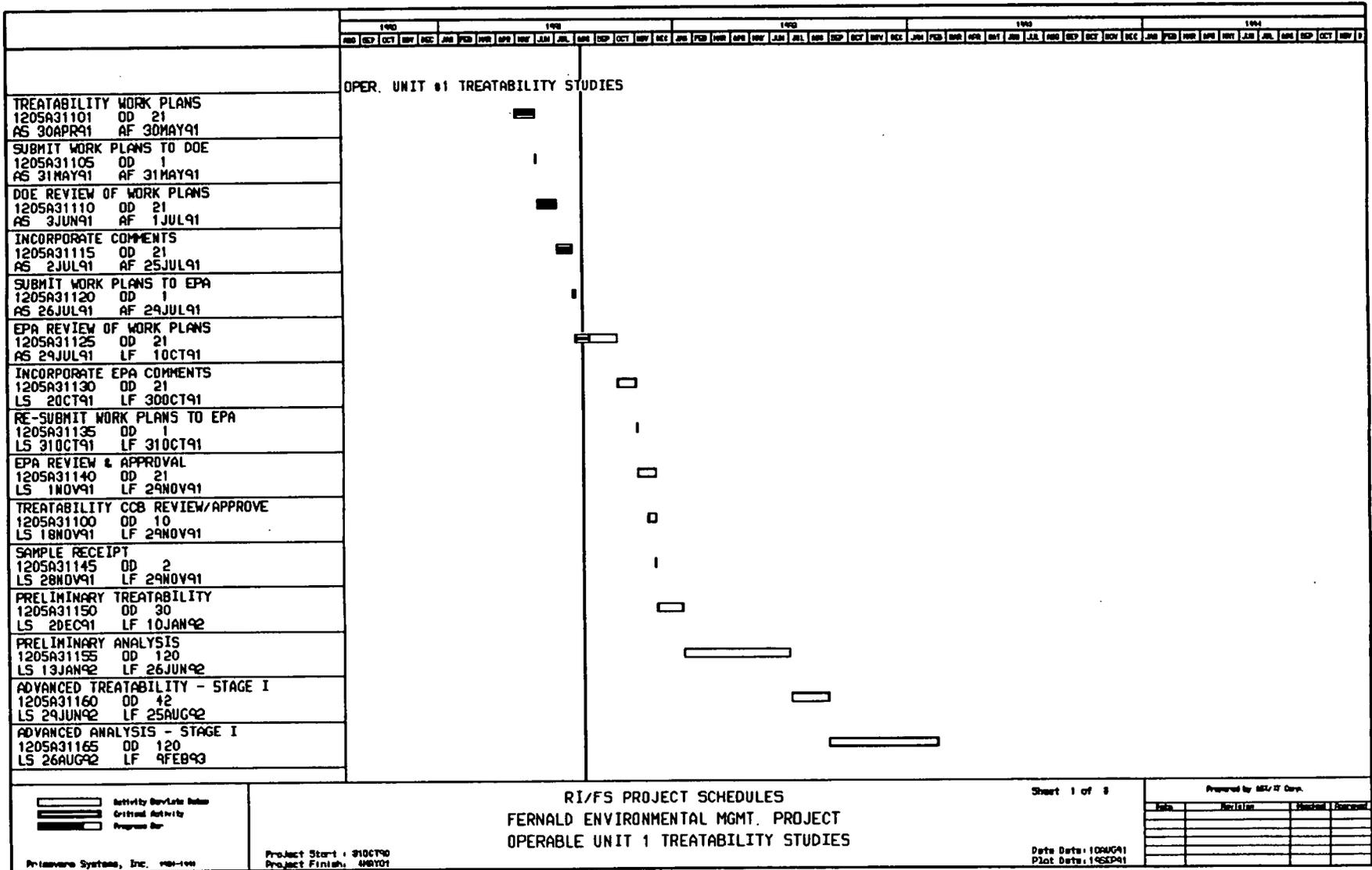
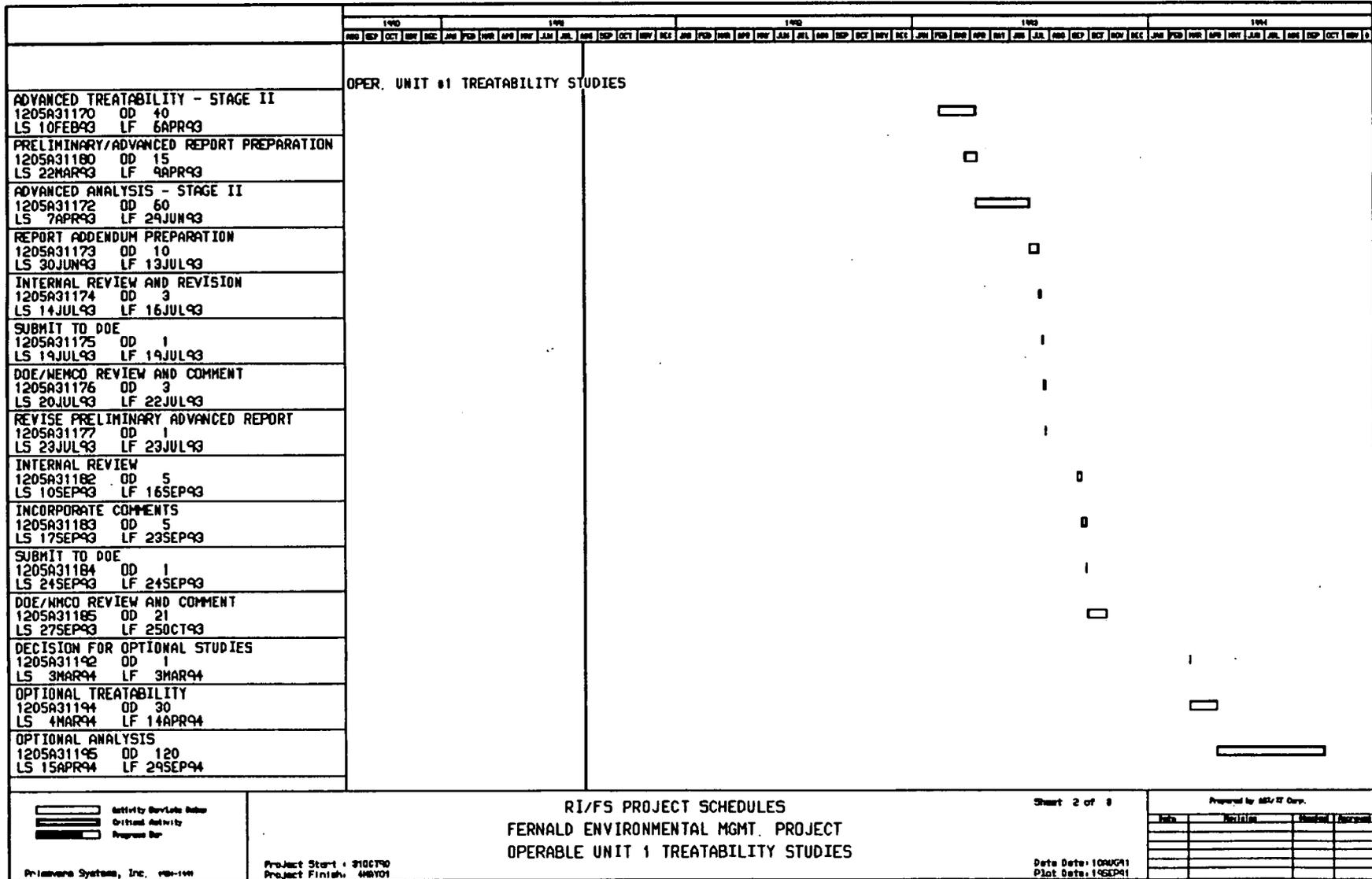
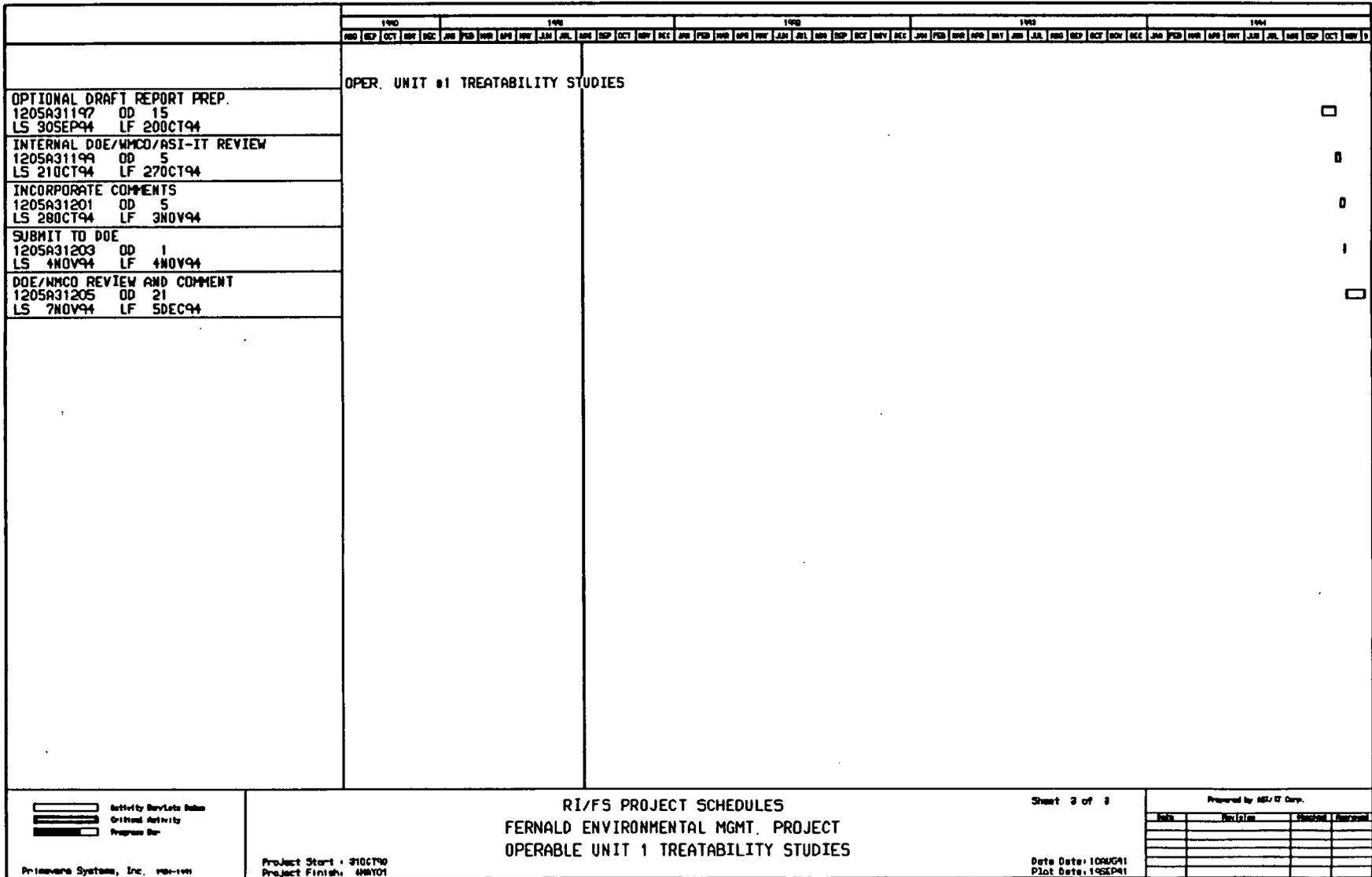


FIGURE 13-1. TREATABILITY STUDY SCHEDULE



66

FIGURE 13-1.
(CONTINUED)



97

**FIGURE 13-1.
(CONTINUED)**

14.0 MANAGEMENT AND STAFFING

1

Personnel involved in the management of the entire RI/FS include: Jack Craig, DOE Project Director, who is responsible for the RI/FS; John Wood, ASI/IT's Project Director for the RI/FS consultant; and ASI/IT's John Razor, who serves as Deputy Project Director and is responsible for the technical content of the RI/FS consultant's documents.

2

3

4

5

Additional personnel involved in the management of RI/FS treatability programs for all operable units include Briand Wu, ASI/IT's Technical Integration Manager who is responsible for the RI, NEPA, and treatability work tasks. Sam Wolinsky serves as Treatability Coordinator for all operable unit treatability studies performed by the RI/FS consultant and serves as the focal point for RI/FS administrative communication with the laboratory.

6

7

8

9

10

Those personnel specifically involved in Operable Unit 1 include Oba Vincent, DOE Operable Unit manager; Ike Diggs, WEMCO's (the integration contractor) Operable Unit 1 manager; and Scott Mallett, Operable Unit 1 manager for Parsons (the remedy design contractor). Mike Higgins of ASI/IT serves as the RI/FS consultant's Operable Unit 1 manager and is the focal point for technical communication with the laboratory performing the treatability study.

11

12

13

14

15

The IT TDL personnel will perform the actual treatability testing. Those personnel include Ed Alperin, Laboratory Manager, who is responsible for all of the treatability testing programs within the treatability laboratory. Darrell Drouhard, Project Manager/Engineer, coordinates all treatability laboratory work between labs and site. Ernie Stine, Operations Supervisor, is responsible for the technical aspects of the treatability programs at the laboratory. Arie Groen and Chanley Morgan perform most of the experiments. Patti Carswell is responsible for all QA activities. These personnel and their lines of communication are shown in Figure 14-1.

16

17

18

19

20

21

22

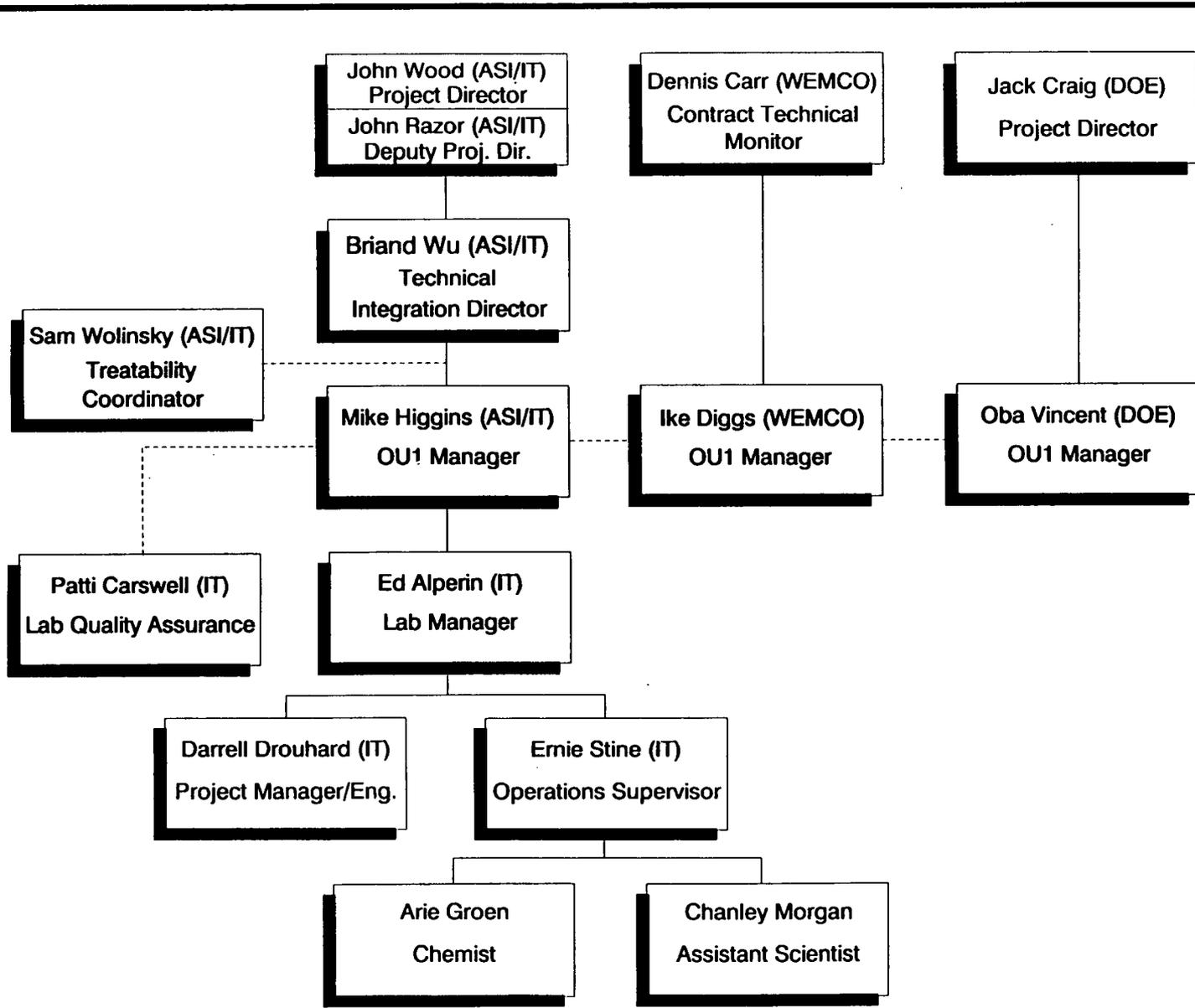


FIGURE 14-1. TREATABILITY STUDY MANAGEMENT AND STAFFING

REFERENCES

American National Standard Institute, 1986, "American National Standard Measurement of the Leachability of Solidified Low-Level Radioactive Wastes by a Short-Term Procedure," ANSI/ANS-16.1-1986.

Army Corps of Engineers, Engineers Manual, EM 1110-2-1906, Laboratory Soils Testing, Appendix VII.

American Society for Testing and Materials (ASTM) D2166-85, Standard Test Method for Unconfined Compressive Strength of Cohesive Soil.

Diamond, W. J., 1981, Practical Experimental Designs for Engineering and Scientists, Von Nostrand Reinhold Co., New York, NY.

DePercin, P., E. Bates and D. Smith, 1991, "Designing Treatability Studies for CERCLA Sites: Three Critical Issues," J. of the Air and Waste Management Assn., Vol. 41, No. 45.

Jantzen, C. M. and N. E. Bibler, 1990, "Nuclear Waste Glass Product Consistency Test (PCT) - Version 3.0 (u)," WSRC-7R-90-539, Rev. 1, prepared by Westinghouse Savannah River Co. for the U.S. Dept. of Energy.

McLean, R. A. and V. L. Anderson, 1966, "Extreme Vertices Design of Mixture Experiments," Techometrics, Vol. 8, No. 3.

Method 1311 Toxicity Characteristic Leaching Procedure (TCLP), Federal Register, Vol. 55, No. 126, pp. 26986-26998.

U.S. Dept. of Energy, 1988, "Remedial Investigation and Feasibility Study, Feed Materials Production Center, Fernald, Ohio, Work Plan Requirements," Revision 3, DOE, Oak Ridge Operations Office, Oak Ridge, TN.

U.S. Dept. of Energy, 1991a, "Initial Screening of Alternatives for Operable Unit 1," DOE, Oak Ridge Operations Office, Oak Ridge, TN.

U.S. Dept. of Energy, 1991b, "Risk Assessment Work Plan Addendum (draft)," DOE, Oak Ridge Operations Office, Oak Ridge, TN.

U.S. Environmental Protection Agency, 1986, "Test Methods for Evaluating Solid Wastes, Method 9100," EPA SW-846, EPA, Washington, D.C.

U.S. Environmental Protection Agency, 1988, "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA," EPA/540-G-89/004, EPA, Office of Emergency and Remedial Response, Washington, D.C.

U.S. Environmental Protection Agency, 1989a, "Guide for Conducting Treatability Studies Under CERCLA," EPA/540/2-89/058, Office of Emergency and Remedial Response, Washington, D.C. 100

U.S. Environmental Protection Agency, 1989b, "Preparing Perfect Project Plans," EPA/600/9-89/087, EPA, Risk Reduction Engineering Laboratory, Cincinnati, OH.

U.S. Environmental Protection Agency, 1989c, "Stabilization/Solidification of CERCLA and RCRA Wastes," EPA/625/6-89/022, EPA, Office of Research and Development, Cincinnati, OH.

U.S. Nuclear Regulatory Commission, January 1991, "Technical Position on Waste Form," prepared by Low-Level Waste Management Branch, NRC, Washington, D.C.

Weston, Inc., Roy F., 1986, "Site Characterization of the Waste Storage Areas, Part 1: Evaluation of the Current Situation, U.S. Department of Energy Feed Materials Production Center, Fernald, Ohio," Weston, Inc., Westchester, PA, prepared for Westinghouse Materials Company of Ohio, Cincinnati, OH.

Weston, Inc. Roy F., 1987, "Characterization Investigation Study Volume 2: Chemical and Radiological Analyses of the Waste Storage Pits," FMPC/56B008 prepared for the Feed Materials Production Center, Westinghouse Materials Company of Ohio, Cincinnati, OH.

APPENDIX A

**JUSTIFICATION FOR USING A MINIMUM UCS VALUE OF 500 psi
AND A PORTLAND CEMENT/FLY ASH MIXTURE**

APPENDIX A
TABLE OF CONTENTS

	<u>Page</u>
A.1.0 Justification for Using a Minimum UCS Value of 500 psi	1
A.2.0 Justification for Using a Portland Cement/Fly Ash Mixture	2
A.2.1 Introduction	2
A.2.2 Types of Solidification	2
A.2.2.1 Portland Cement-Based Process	2
A.2.2.2 Portland Cement/Soluble Silicate Process	3
A.2.2.3 Lime Fly-Ash Based Process	3
A.2.2.4 Portland Cement/Fly Ash Process	4
A.2.2.5 Kiln Dust and Fly Ash-Based Process	4
A.2.2.6 Polyethylene Process	5
A.2.2.7 Magnesium-Based Cement	6
A.2.2.8 Modified Sulfur Cement Encapsulation	7
A.2.3 Literature Search	10
A.2.3.1 INEL Literature	10
A.2.3.2 ORNL Literature	10
A.2.3.3 BNL Literature	11
A.2.3.4 Soliditech, Incorporated Literature	11
A.3.0 Solidification Process Chosen for Operable Unit 1	12
A.4.0 Conclusions and Recommendations	13

A.1.0 JUSTIFICATION FOR USING A MINIMUM UCS VALUE OF 500 psi

Portland cement mortars, which comprise mixtures of cement, lime, silica, sand, and water, are readily capable of achieving compressive strengths of 5000 to 6000 pounds per square inch (psi); that is approximately two orders of magnitude greater than the minimum compressive strength required to resist deformation under load in current low-level waste burial trenches. Therefore, to provide greater assurance that there will be sufficient cementitious material present in the waste form to not only withstand the burial loads, but also to maintain general "dimensions and form" (i.e., to not disintegrate) over time, it is recommended that cement-stabilized waste forms possess compressive strengths that are representative of the values that are reasonably achievable with current cement solidification processes. Taking into consideration the fact that low-level radioactive waste material constituents are not in most cases capable of providing the physical and chemical functions of silica sand in a cement mortar, a mean compressive strength equal to or greater than 500 psi is recommended for waste form specimens cured for a minimum of 28 days. This value of compressive strength is recommended as a practical strength value that is representative of the quality of cementitious material that should be used in the waste form to provide assurance that it will maintain integrity and thus possess the long-term structural capability required by Part 61.

A.2.0 JUSTIFICATION FOR USING A PORTLAND CEMENT/FLY ASH MIXTURE

A.2.1 INTRODUCTION

This appendix provides additional justification for choosing stabilization/solidification using a portland cement/fly ash mixture as the treatment process option to treat the pits. The wastes would be solidified using the fly ash from the active fly ash pile, although solidification using fly ash from the inactive fly ash disposal area will be examined on a limited basis.

The additional justification will be provided by discussing results from a literature search of solidification technology. The literature search provides information that indicates solidification of the wastes will provide a waste form that could pass toxicity characteristics leaching procedure (TCLP) tests and allows mixed wastes to be disposed of as nonhazardous or low-level wastes. Also discussed in this appendix will be the reasoning for using the cement to fly ash ratios and water to cement ratios indicated in this study.

A.2.2 TYPES OF SOLIDIFICATION

Various solidification processes exist that could be used to solidify waste. Systems that could be used for solidification are the portland cement-based process, the portland cement/soluble silicate process, the lime/fly ash-based systems, the kiln dust and fly ash-based process, and the portland cement/fly ash process.

A.2.2.1 Portland Cement-Based Process

With the portland cement process, water from the waste reacts chemically with the cement to form a hardened concrete-like material. Depending upon the amount of cement added, the final product may be a monolithic solid or may have a crumbly soil-like consistency (EPA 1985). The optimum combination of waste, water, and portland cement will vary with waste type and composition. The minimum water to cement ratio is about 0.40, by weight, for portland cement, but this also depends upon the moisture content of the waste. The addition of too much water may result in free-standing water on the surface of the solidified product, as well as a reduction in its strength and an increase in the permeability of the final product (Conner 1990).

The bulk density of cement-based waste forms varies between 1.25 and 1.75 g/cm³, with water contents ranging from about 15 to 60 percent. The unconfined compressive strength (UCS) varies also, depending upon the mix ratio.

Most products range from 15 to 1000 psi but can be strengthened by other additives. Permeability is influenced by solidification of the waste. The permeability of cement-based waste forms is similar to that of clay (Conner 1990).

The chemical properties of cement-based forms are described in terms of leachability. The interaction of organic and inorganic substances in cement affects the setting and hardening of the cement matrix. Salts of manganese, tin, zinc, copper, and lead tend to reduce the strength of the waste form. Cement solidification can immobilize metals; but if the waste form is subjected to even a mild acidic solution, leaching could take place (EPA 1985). Because of these limitations, portland cement is normally used as a setting agent in combination with other solidification processes.

The cost of the portland cement-based process is low and the equipment for the process is readily available.

A.2.2.2 Portland Cement/Soluble Silicate Processes

The Portland Cement Soluble Silicate (PCSS) process is based on the reactions between soluble silicates and portland cement to produce a solid matrix. This process depends on three different reactions, the first being a rapid reaction between the soluble silicate (such as sodium silicate) and metal ions to produce a low-solubility metal silicate. The second set of reactions occurs between the soluble silicate and portland cement. The third set of reactions occurs among the cement, waste, and water. The soluble silicate functions as a surfactant (keeping retarders such as oil or particulates in suspension), which helps in the setting and hardening of the waste.

By adding soluble silicate to the portland cement, low-solid waste can be solidified without the addition of massive amounts of bulking agents. This is a cost-effective approach, but the water content of the waste form is high, which increases the porosity of the solid. Higher water content also causes reduced strength and higher permeability. The UCS ranges between 15 and 100 psi, but stronger products can be prepared (with the addition of cement). The advantages of this process include relatively low cost and small volume increase; however, the UCS is lower than the 500 psi proposed by the Nuclear Regulatory Commission (NRC 1991).

A.2.2.3 Lime, Fly Ash-Based Process

Combining lime and fly ash with water forms a cementitious material. Initially a noncrystalline gel, which eventually becomes a calcium silicate hydrate, is formed. The reactions that occur are similar to cement-based systems. The reactions are slower however and do not produce the same products as the cement-based system in terms of physical and chemical properties. A problem with the lime/fly ash process is that fly ash is a by-product of coal-burning power plants and its composition depends

upon the type of coal burned and how the plant was operated. Unburned organics in the fly ash can reduce the cementing action by covering reactive surfaces. Also, the lime-based process is not as effective in reducing leachability as the cement-based systems, due in part to its high pH. Much of the lime/fly ash treatment used has been in nonhazardous waste applications.

A.2.2.4 Portland Cement/Fly Ash Process

Portland cement and fly ash have been used in applications for many years. When fly ash is used with cement in an application, the percentage of cement required is reduced significantly. Because fly ash itself is a waste, it is desirable to use it as a component in solidification systems.

Fly ash in portland cement acts as a bulking agent and as a pozzolan. The reaction between the two materials produces a product that may have higher strength than when portland cement is used alone. The fly ash also helps to bind additional water and decrease pH, as well as acting as an adsorbent for metal ions. The greatest disadvantage of this process is the volume increase associated with large additions of fly ash. The range of the fly ash to cement ratio (by weight) is two to four, with total weight increases of 50 to 150 percent. Where increase in volume is not important, the cement/fly ash process is the optimum choice (Conner 1990).

In a pure water-cement system, the permeability is essentially zero at a water to cement ratio of 0.32. The water to cement ratio can be increased when a bulking agent such as fly ash is added to the process.

Several vendors use the cement/fly ash process and many studies have been performed. One such program was performed on waste at the Idaho National Engineering Laboratory (INEL).

A.2.2.5 Kiln Dust and Fly Ash-Based Process

Kiln dust and fly ash have been used in several solidification projects. They function primarily as adsorbents or bulking agents. The kiln dusts are highly alkaline, which gives them the ability to remove free water by hydration of calcium oxide to calcium hydroxide. This process can produce hard, strong solids that continue to harden with time. The actual setting reactions of the kiln dust and fly ash are pozzolanic and resemble those of portland cement. A limitation of the use of these materials is that they contain significant amounts of metals, which leach at levels above regulatory standards. These materials are available, and their costs are low compared to portland cement. The cost of these materials however has been increasing; if the trend continues, they could be replaced by more expensive but more efficient reagents (Conner 1990).

A.2.2.6 Polyethylene Process

Brookhaven National Laboratory (BNL) has also developed a process for the solidification of salt wastes, incinerator ash, and ion-exchange resins in polyethylene. Although the most common solidification agents used in solidification of low-level radioactive waste (LLW) are portland cement, bitumen, and thermo settling polymers, operational difficulties such as incompatibility with waste constituents, low loading efficiency, premature setting, or formulation of solidified products with poor performance properties have been observed with these materials (Franz 1987).

The choice of polyethylene as an improved solidification agent was based on such considerations as compatibility with waste, solidification efficiency, material properties, availability of materials, economic feasibility, and ease of processibility. Because the solidification process is not dependent upon complex chemical reactions as it is in the case of hydraulic cements and thermosetting polymers, the processing is simplified and solidification of the waste is ensured.

Polyethylene is a thermoplastic organic polymer of crystalline-amorphous structure formed through the polymerization of ethylene gas. At elevated temperatures thermoplastic polymers change from a hard material to a rubbery flowable liquid. On cooling, the polymers revert to their original form.

Polyethylene is resistant to most acids, bases, and organics normally encountered in waste streams. The superior mechanical properties of polyethylene (i.e., compressive strength) allow higher waste loading than normally can be incorporated into other materials such as cement or bitumen, without compromising the integrity of the waste form.

Some of the more important factors that affect the properties of polyethylene are density, molecular weight, molecular weight distribution, melt index, and cross linking. Low-density polyethylene (0.910 to 0.925 g/cm³). The process parameters investigated included temperature, pressure, mixing kinetics, and volumetric efficiency. In general, polyethylenes with a density of 0.924 g/cm³ and melt indices of 35.0 to 55.0 g/10 minutes were able to incorporate greater quantities of waste. In the case of the incinerator ash, the maximum amount of waste was 40 weight percent (dry) that represents the maximum amount of waste that can be incorporated to form a monolithic solid. For the determination of the release of radionuclides through leach tests, radioactive tracers were added to the incinerator ash. The radioisotopes used were cobalt-60, strontium-85, and cesium-137 because these are the radionuclides of greatest concern in low-level wastes. Results of this study indicated a clear dependence of leachability upon increased waste loadings for all three isotopes for the incinerator ash samples. With increased waste loading, the average leaching of the radioisotopes decreased. Results of the polyethylene studies indicate that polyethylene is a viable solidification agent for various types of low-level waste (Franz 1987).

A.2.2.7 Magnesium-Based Cement

The magnesium-based cement technology discussed here is one developed by Envirotite Incorporated (ETI). ETI literature states that approximately 65 percent of the stabilization products marketed use portland cement or a mixture of portland cement and catalysts. ETI identified only three corporations that used magnesium-based cements for stabilization. Magnesium-based cements have been formulated and perfected to possess physical properties similar to ceramics. The ETI literature also states that due to the improved qualities of magnesium cement, it can meet more disposal needs than other stabilization products and offer some unique properties significantly different than those provided through the use of portland cement (ETI 1991).

ETI provides the following table to show the comparison of portland cement versus magnesium cement:

Standards for Comparison	Portland Cement	Magnesium Cement
Compressive strength	hard	very hard
Finished surface	smooth	glass-like
Acid resistance	mild reaction	no reaction
Free water	visible	not visible
Miscibility in oil	no	yes

The magnesium-based cement offered by ETI are CERAMAG-S1 and CERAMAG-L1.

CERAMAG-S1

CERAMAG-S1 is a magnesium-based concrete specifically formulated to stabilize hazardous wastes present in solid matrices such as clay, dirt, sand, gravel, ash, and sludge. CERAMAG-S1 reduces TCLP values less than regulatory limits for a wide variety of inorganic and organic wastes. Stabilized products meet applicable land disposal restriction (LDR) treatment standards.

CERAMAG-L1

CERAMAG-L1 is also a magnesium-based concrete specifically formulated to stabilize hazardous waste present in liquid matrices including acids, caustic, solutions of inorganic wastes, solutions of organic wastes, and petroleum products. CERAMAG-L1 reduces TCLP values less than regulatory

limits for a wide variety of inorganic and organic wastes. Stabilized products meet applicable LDR treatment standards. 1
2

The performance data by ETI for the magnesium-based concrete indicate that there would be no free-standing water in the stabilized product that the UCS would be far greater than the 500 psi UCS quoted by the Nuclear Regulatory Commission technical position paper (NRC 1991). Specific data from a particular site was not provided but the chemical characteristics of the stabilized waste provided by ETI indicate that TCLP values for organic and inorganics are below regulatory limits. 3
4
5
6
7

A.2.2.8 Modified Sulfur Cement Encapsulation 8

Modified sulfur cement is a thermoplastic material that can be easily melted, combined with waste components in a homogeneous mixture, and cooled to form a solid monolithic waste form. Compared with portland cements, sulfur cement has several advantages. For example, no chemical reactions are required for solidification, eliminating the possibility that elements in the waste can interfere with setting and thereby limit the range of waste materials that can be encapsulated successfully. Sulfur concrete compressive and tensile strengths twice those of comparable portland concretes have been achieved, and full strength is attained in several hours rather than weeks. Sulfur concretes are resistant to attack by most acids and salts, e.g., sulfates that can severely degrade hydraulic cement have little or no effect on the integrity of sulfur cement (Kalb 1991). 9
10
11
12
13
14
15
16
17

As a result of defense and research activities the U.S. Department of Defense (DOD) generates a broad range of waste types, including hazardous/radioactive waste, one of which is incinerator ash. In an effort to develop new methods of stabilizing/solidifying mixed wastes generated at DOE facilities, work is being performed at BNL to encapsulate incinerator fly ash waste. 18
19
20
21

The incinerator fly ash in this study are generated in the Waste Experimental Reduction Facility (WERF) at INEL. This fly ash contains a total of 40 pCi/g of activity consisting of fission products (Cs-137) and activation products (Co-57 and Sb-125). The ash was analyzed for 12 elements and the results are shown below: 22
23
24
25

Elemental Composition of INEL
 Incinerator Fly Ash

Element	Weight Percentage
Zinc	36.0
Lead	7.5
Sodium	5.5
Potassium	2.8
Calcium	0.8
Copper	0.7
Iron	0.5
Cadmium	0.2
Chromium	BDL*
Barium	BDL
Silver	BDL
Nickel	BDL

*Below detection limits (<0.05 wt. percent)

The incinerator fly ash contains zinc, lead, sodium compounds, and highly soluble metal chloride salts that creates an acidic environment in the presence of moisture. The presence of these element and compounds have been shown to impede or interfere with cement solidification by reducing the ultimate mechanical strength of the waste form, by causing cracking and could greatly increase the mobility of contaminants (Kalb 1991).

As stated above, however, modified sulfur cement is resistant to attack by acids and salts.

The modified sulfur cement is a thermoplastic material that means that thermal input is required for processing. Also, when the sulfur cement is mixed with dry waste materials, a thick paste is formed. Therefore, a mixing system would be required to mix the waste and binder to form a homogeneous mixture. Several mixing systems were investigated and based on the processing requirements of modified sulfur cement/waste combinations, a double planetary orbital mixer was chosen as the most appropriate system.

Formulation and process development work was concluded to determine the limits and ease of processibility, while at the same time producing waste forms that conform to regulatory criteria.

111

Maximum waste loadings were determined by first processing at waste loading above the limits of workability (i.e., extremely dry mixtures that yielded friable products with little structural integrity) and then adding additional increments of modified sulfur cement until acceptable workability and product integrity were achieved. Reported waste loadings represent weight percent of dry ash, after all residual moisture has been removed. Using this procedure, a maximum waste loading of 55 weight percent INEL incinerator fly ash was determined. Due to its low pH and high chloride content, the maximum waste loading using portland cement achieved at INEL was 16 weight percent (Kalb 1991).

Among the tests conducted on the waste forms were compressive strength and leachability to provide information on structural integrity and waste form behavior in a disposal environment. Modified sulfur cement is a brittle material and tends to shatter under axial compressive load.

Compressive strength testing of waste form specimens containing 40 and 55 weight percent INEL fly ash encapsulated in modified sulfur cement were compared with modified sulfur cement specimens containing no waste. The results indicated that compressive strength were not highly dependent upon waste loading (4053 psi to 40 weight percent ash and 4118 psi at 55 weight percent ash) "but both waste loadings displayed more than two times greater strength than the binder material alone (1800 psi)."

The INEL incinerator ash and samples of encapsulated ash at various waste loadings were tested using both the Extraction Procedure Toxicity (EP Tox) and TCLP.

The TCLP leachate data from the INEL incinerator ash show that cadmium and lead were present in concentration well above the EPA allowable limits for each chemical. The TCLP leachate from waste encapsulated in plan modified sulfur indicated that cadmium and lead above the allowable limits. (Leachate concentrations for encapsulated waste samples tested by the EP Tox method were found to be considerably lower, which demonstrates the conservative nature of the TCLP test.)

Based on results of scoping experiments and other considerations, sodium sulfide was selected as an additive to further reduce mobility of toxic heavy metals in the incinerator ash and to comply with EPA TCLP hazardous waste concentration limits. Sodium sulfide reacts with the toxic metals salts to form metal sulfides of extremely low solubility. Sodium sulfide has been used extensively in the related field of wastewater treatment, and has been identified as an effective treatment technology by EPA. A ratio of sodium sulfide/fly ash of 0.175 was used based on the results of an experiment to determine the effectiveness of this additive on cadmium mobility under EPA leaching conditions. Optimization of INEL incinerator fly ash waste loading with added sodium sulfide (while maintaining

additive/ash ratio constant) yielded a maximum waste loading of 43 weight percent fly ash, 49.5 weight percent modified sulfur cement, and 7.5 weight percent sodium sulfide (Kalb 1991).

By using the optimal INEL incinerator ash with sodium chloride in modified sulfur cement, 2.7 times more incinerator ash can be used per drum (55 gallon) than when using portland cement as the binder. INEL incinerator ash is difficult to stabilize using ordinary portland cement mixtures and the waste loading is limited to 16 weight percent. Modified sulfur cement is not susceptible to interference from the high concentrations of zinc, lead, sodium, and chloride as portland cement. The waste loading is increased significantly using modified sulfur cement. A process demonstration using production-scale equipment to encapsulate the incinerator fly ash in modified cement is being planned in conjunction with INEL.

A.2.3 LITERATURE SEARCH

A literature search was conducted to determine whether the performance of stabilization/solidification have been sufficiently documented on similar wastes and the number of times the technology has been used.

The literature search for Operable Unit 1 involved calling various laboratories that have been involved in stabilization/solidification and reviewing various other available literature. Those laboratories contacted were the INEL, Oak Ridge National Laboratory (ORNL), and BNL.

A.2.3.1 INEL Literature

INEL representatives were contacted and they indicated that published information on stabilization/solidification is not available because none has been performed. INEL however provided the name of a private company, Halliburton-NUS Environmental Company, with whom they had worked with previously. The contact person at Halliburton indicated he had performed work for the Savannah River Plant using stabilization/solidification; however, he did not know how to get the report. He further stated that a lot of this type information is difficult to obtain because it is proprietary. During the course of the conversation, he also stated that it is his experience that a treatability study would be needed to indicate the type of inhibitors present in the waste. Although a complete analysis of the raw waste may be performed, sometimes those compounds that inhibit the stabilization/solidification process are not found until the treatability testing is done.

A.2.3.2 ORNL Literature

ORNL was also contacted. ORNL provided a list of reports that provided remedial techniques for various waste sites at ORNL. A review of the list and of some reports indicate that they do not provide information with regards to ex situ stabilization/solidification.

A.2.3.3 BNL Literature

BNL also provided a list of references that used stabilization/solidification methods to treat various wastes. The results of the analysis performed on the solidified products produced by the two methods indicate that both methods are viable for solidification agents for low-level waste. The portland cement/fly ash process however is the chosen method for solidifying Operable Unit 1 wastes. Therefore, the results offered by the sulfur cement encapsulation and solidification using polyethylene is not relevant for comparison to portland cement/fly ash method.

A.2.3.4 Soliditech, Incorporated Literature

The literature search also included a paper presented at the Forum of Innovative Hazardous Treatment Technologies by Soliditech, Incorporated. The paper described the Soliditech process, which is a mixing process based on the use of pozzolans or cement and various additives that enhance the ability of the mixture to incorporate organic compounds into the matrix and reduce the potential for these compounds to leach from the solidified product.

The Soliditech process solidifies wastes by use of URRICHEM (a proprietary chemical reagent, U.S. patent pending), additives, pozzolanic solids, and water. The proportions of reagent, additives, and pozzolan are optimized for each particular waste requiring treatment. The solidified material displays properties of excellent unconfined compressive strength, high stability, and a rigid texture similar to that of concrete (Brassow 1989).

Three different waste streams were treated as part of the demonstration, which included a soil contaminated with oily sludge, a filter media with a high percentage of hydrocarbons and an oily tank bottom sludge. The latter stream was co-treated with the filter media during the demonstration.

Untreated waste samples were collected for each test parameter from each of the three waste streams. These samples were analyzed for total chemical constituents, physical characteristics and the amount of solubles removed by leaching/extractions. The results allow a direct comparison of physical and chemical properties between the treated and untreated waste and a determination of effectiveness of the treatment process (Brassow 1989). The information presented below is from the results of Brassow 1989.

Untreated waste -- Untreated waste from the site consisted of contaminated soil, filter cake, and filter cake/oily sludge. These wastes contained 2.8 to 17 percent oil and grease, with relatively low levels of other organic compounds. PCB (Aroclors 1242 and 1260) concentrations ranged from 28 to 43 mg/g; arsenic concentrations from 14 to 94 mg/kg; lead concentrations ranged from 650 to 2470 mg/kg; and zinc concentrations from 26 to 151 mg/kg.

Treated Waste -- The Soliditech stabilization process produced solidified waste with high structural stability and low permeability. UCS values ranged from 392 to 856 psi. Permeability values ranged from 8.9×10^{-9} to 4.5×10^{-7} cm/s. Because of the cementitious additives in the Soliditech process, pH values of the solidified wastes ranged from 11.7 to 12.0. Arsenic concentrations ranged from 28 to 92 mg/kg; lead concentrations from 480 to 850 mg/kg; zinc concentrations from 23 to 95 mg/kg; and PCB (Aroclors 1242 and 1260) concentrations from approximately 15 to 41 mg/kg. Low concentrations of phenol and p-cresol were found in solidified filter cake and filter cake/oily waste samples. These compounds were not detected in the untreated wastes.

Extract of Untreated Waste -- Arsenic, lead, and zinc were found in EP, TCLP, and BET extracts of the untreated wastes. No PCBs were detected in the TCLP extracts of the untreated wastes. Total concentrations of up to 1.3 mg/L of volatile organic compounds and up to 0.38 mg/L of semivolatile organic compounds were detected in TCLP extract of the untreated waste. Oil and grease concentrations of 1.4 to 1.9 mg/L were detected in the TCLP extract of the untreated waste. Untreated wastes could not be tested by ANS 16.1.

Extract of Treated Waste -- Significantly reduced amounts of metals were detected in the TCLP, EP, BET, and ANS 16.1 extracts of the treated waste. No PCBs or volatile organic compounds were detected in the TCLP extract of the treated waste. Phenol, p-cresol, o-cresol, and 2,4-dimethylphenol were detected in the post-treatment TCLP waste extracts. Oil and grease concentrations of 2.4 to 12.0 mg/L were detected in the TCLP extracts.

The range of UCS and low permeabilities verify the solidification objective.

The change in volume ranged from 0 to 60 percent but the median appeared to be less than 30 percent. This is an important parameter when estimating disposal volume of treated waste and this level is probably an acceptable increase now (Brassow 1989).

A.3.0 SOLIDIFICATION PROCESS CHOSEN FOR OPERABLE UNIT 1

Section 2.0 contains descriptions of the various types of stabilization/solidification methods and their associated advantages or disadvantages. As a result of reviewing these methods, the portland cement/fly ash process is the technology that has been chosen to solidify the waste in Operable Unit 1.

The modified sulfur cement encapsulation method, which appears to be a viable technology but data results from other studies using this method are not documented, to verify its success rate. Also, the use of the modified sulfur cement requires the use of an additive, such as sodium sulfide, to reduce the mobility of toxic metals. The results from the laboratory study for modified sulfur indicate that it is a better binder than portland cement in that the modified sulfur cement would have higher waste loadings than the portland cement. Studies using portland cement/fly ash have however been performed is pozzolonic and acts as an adsorbent for metal ions. Therefore, by using portland cement/fly ash, an existing waste can be used as resource to aid in treating other wastes at the site.

A.4.0 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this additional literature search was to provide additional justification for choosing stabilization/solidification using a portland cement/fly ash mixture as the treatment process option.

One of the main criteria to determine whether a treatability study is required is to determine from a literature search whether sufficient documentation of results exist for the treatment method being proposed.

Based on the results of this literature search, it can be concluded that sufficient documentation of results of stabilization/solidification of wastes similar to Operable Unit 1 is not available. Therefore, the treatability study for Operable Unit 1 should be conducted.

**APPENDIX A
REFERENCES**

- Boehmer, A.M., 1986, "Waste Characterization and Analysis Activities Conducted in Support of the Solidification Development Program at the Idaho National Laboratory," prepared for the U.S. Department of Energy Idaho Operations Office by Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, ID. 1
2
- Boehmer, A.M. and M.M. Larsen, 1986, "Hazardous and Mixed Waste Solidification Development Conducted at the Idaho National Engineering Laboratory," prepared for the U.S. Department of Energy Idaho Operations Office by Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, ID. 3
4
5
6
- Brassow, C.L., J.T. Healy and R.A. Bruckdorfer, June 1989, "Fixation of Organic and Inorganic Wastes/Intimate Mixing Technique" presented at Forum on Innovative Hazardous Waste Treatment Technologies: Domestic and International, Atlanta, GA. 7
8
9
10
- Conner, J.R., 1990, Chemical Fixation and Solidification of Hazardous Wastes, Van Nostrand Reinhold, New York, NY. 11
12
13
- Envirotite Incorporated, May 1991, "Summary of Waste Stabilization Technology and Services," St. George, UT. 14
15
- Franz, E.M., J.H. Heiser and P. Colombo, 1987, "Solidification of Commercial and Defense Low-Level Radioactive Waste in Polyethylene," Proceeding of the Ninth Annual Doe Low-Level Waste Management Conference. CONF-870859, Session VI, Denver, CO. 16
17
18
19
20
- Hunt, L.F. and A.M. Boehmer, 1987, "Development Process for the Stabilization of Incineration Bottom Ash and Sizing Baghouse Dust Material," prepared for the U.S. Dept. of Energy Idaho Operations Office by Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, ID. 21
22
23
- Kalb, P.D., J.H. Heiser, and P. Colombo, 1991, "Modified Sulfur Cement Encapsulation of Mixed Waste Contaminated Incinerator Fly Ash," Waste Management, Vol. 11, pp. 147-153. 24
25
- U.S. Environmental Protection Agency, Oct. 1985, "Handbook of Remedial Action at Waste Disposal Sites (Revised)," EPA/625/6-85/006, EPA, Office of Research and Development, Cincinnati, OH, and EPA, Washington, D.C. 26
27
28
- U.S. Nuclear Regulatory Commission, 1991, "Technical Position on Waste Form (Revision 1)," prepared for the NRC Office of Nuclear Safety and Safeguards by the Low-Level Waste Management Branch, Division of Low-Level Waste Management and Decommissioning, NRC, Washington, D.C. 29
30
31

APPENDIX B
TECHNOLOGY DEVELOPMENT LABORATORY
STANDARD OPERATING PROCEDURES

APPENDIX B
TABLE OF CONTENTS

2425

Laboratory Notebook Recording Procedures
Analytical Logbook Recording Procedure
Standard Laboratory Sieves: Specification, Calibration, and Maintenance
Bulking Factor Measurement for Pourable Sludge
Calibration of Thermometers
Unconfined Compressive Strength



IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: Laboratory Notebook Recording Procedures

Prepared by: Patti B. Carswell **Date:** 2/7/91

Reviewed by: Bruce F. Wagner **Date:** 2/7/91
Technical Specialist

Patti B. Carswell **Date:** 2/7/91
Quality Control Coordinator

Jane M. Jones **Date:** 3-26-91
Director, Quality and Compliance, ITAS

Approved by: P. Miller **Date:** 3/27/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: NOTEBOOK

Revision #	0					120
Date	1-21-91					

1.0 Purpose and Application

- 1.1 The purpose of this method is to describe the required methods of data entry in Technology Development Laboratory notebooks.
- 1.2 This procedure applies to laboratory notebooks used for project-specific and non-project-specific documentation.
- 1.3 The purpose of each entry in your notebook is to provide a complete record of your work, one that would enable a co-worker to repeat, if necessary, exactly what you did and produce the same results, without having to ask any questions.

2.0 References

- 2.1 Writing the Laboratory Notebook, Howard M. Kanare, 1985.

3.0 Associated SOPs and Applicable Methods

- 3.1 ITAS SOP No. TDL1503, "Analytical Logbook Recording Procedures."

4.0 Definitions

- 4.1 None

5.0 Procedure

5.1 Safety

5.1.1 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

5.1.2 All laboratory notebooks must be kept free of chemical contamination while being used on benchtops, in field settings, etc.

5.2 Summary

5.2.1 All laboratory notebooks are the property of the International Technology Corporation (IT) Technology Development Laboratory (TDL). It is assigned to you so that you may keep a complete, careful, chronological record of your work. The work which you do and the data which you enter in the notebook are confidential; they must not be disclosed to unauthorized persons. The notebook's security and maintenance are your responsibility. In case of damage, loss, or disappearance, report the

5.0 Procedure (continued)

facts to your supervisor at once. When the notebook is filled or upon termination of your employment, it must be returned to the laboratory quality/operation files.

5.3 Procedure

5.3.1 All data is to be recorded directly into the notebook. Recording of original data on loose pieces of paper for later transcription into the logbook is to be avoided. Should loose paper be necessary for proper conduct of an experiment:

5.3.1.1 Write on the logbook page itself identification of what is affixed to that page.

5.3.1.2 Firmly affix the loose paper with clear tape

5.3.1.3 Initial and date over the edge of the tape.

5.3.2 All entries must be made in black ink. Red ink is reserved for Quality Control (QC) checking purposes only. Erasures, blacking out, or use of correction fluid is not permitted. If a mistake is made, draw a single line through the erroneous material and make a corrected entry, initial, and date the correction.

5.3.3 It is necessary to fill each page and keep the sequence of entries in chronological order. Several pages may be reserved for a particular experiment. However, if the continuity of pages for a particular experiment is broken for lack of reserved space, notations will be made on both sides of the break. The unused balance of a page will be cancelled by a diagonal line. Spaces intentionally left blank in tables or logs will contain horizontal lines.

5.3.4 Stock or standard solutions must reference:

5.3.4.1 Source

5.3.4.2 Lot number

5.3.4.3 Date received

5.3.4.4 Notebook and page numbers whenever available.

5.3.5 When reference is made to samples, the TDL sample number must be used. Additional sample identification may be offered, but not to the exclusion of the TDL sample number.

5.3.6 A co-worker performs a QC check on your calculations by recalculating 20 percent and verifying the formula used. Have him make a check in red ink beside each answer which was recalculated and sign and date

5.0 Procedure (continued)

calculations that lead to the generation of a result which is reported to the client either verbally or in writing. Any values which have not had a 20 percent QC check (one of every five calculations has been checked) are considered "preliminary" and will be marked as such on any material leaving the TDL lab. If an error is found during the 20 percent check, then a 100 percent QC check will be performed.

5.3.7 If one of your co-workers has witnessed an experiment you have conducted, to an extent that enables him to state of his own knowledge what you did and what results you secured, have him sign and date the notebook page(s) as "Witnessed and understood by." If the experiment seems to you to be of sufficient importance (i.e., is potentially patentable), arrange to have it witnessed for content and date of entry.

5.4 Project Documentation Requirements

5.4.1 Every page of the notebook will contain project name, project number, date, and initials of persons entering data. Each project will then be described by the following entries:

5.4.1.1 Objective - briefly describe the planned experiment and the expected or desired result.

5.4.1.2 Plan - give an overview of what you intend to do.

5.4.1.3 Calibrations and Standards - list frequency of calibration, acceptance limits, and concentrations.

5.4.1.4 Analytical Methods - state SOP, standard reference or give a brief description.

5.4.1.5 Experimental Set-ups - sketch and describe the set-up.

5.4.1.6 Data and Observations - provide tables including units and space for observations within or below.

5.4.1.7 Results - include formula and calculations which are necessary to produce results from raw data.

5.4.1.8 Conclusion - how objective was met and any interpretation of results.

6.0 Nonconformance and Corrective Action

6.1 A nonconformance is a deficiency in procedure sufficient to render the quality of an item unacceptable or indeterminate or any event which is beyond the limits documented and established for laboratory operation. A nonconformance may include data recording errors, transcription errors, and failure to document. A nonconformance memo associated with this procedure will be filed with the QC Coordinator.

7.0 Records Management

7.1 TDL Notebooks are the property of IT Corporation.

7.2 Document control of TDL Notebooks is handled by the QC Coordinator (QCC). The QCC will issue all notebooks. All completed notebooks will be returned to the QCC.

7.3 All returned Laboratory Notebooks are filed in TDL Central Files.



IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: Analytical Logbook Recording Procedures

Prepared by: Patti B. Carswell **Date:** 2/7/91

Reviewed by: Bruce F. Wagner **Date:** 2/7/91
Technical Specialist

Patti B. Carswell **Date:** 2/7/91
Quality Control Coordinator

James M. Jones **Date:** 3-26-91
Director, Quality and Compliance, ITAS

Approved by: Pat Miller **Date:** 6/7/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: Logbook, Notebook

Revision #	0					
Date	1-21-91					125

1.0 Purpose and Application

- 1.1 The purpose of this method is to describe the required methods of data entry in Technology Development Analytical Logbooks.
- 1.2 This procedure applies to analytical logbooks such as instrument injection logbooks, maintenance logbooks, and balance logs.

2.0 References

- 2.1 Writing the Laboratory Notebook, Howard M. Kanare, 1985.

3.0 Associated SOPs and Applicable Methods

- 3.1 ITAS SOP No. TDL1504, "Laboratory Notebook Recording Procedures."

4.0 Definitions

- 4.1 None

5.0 Procedure

5.1 Safety

5.1.1 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

5.1.2 All analytical logbooks must be kept free of chemical contamination while being used on benchtops, in field settings, etc.

5.2 Summary

5.2.1 All logbooks are the property of the International Technology Corporation (IT) Technology Development Laboratory (TDL). It is assigned to you so that you may keep a complete, careful, chronological record of your work. The work which you do and the data which you enter in this book are confidential; they must not be disclosed to unauthorized persons. The logbook's security and maintenance are your responsibility. In case of damage, loss, or

5.0 Procedure (continued)

disappearance, report the facts to your supervisor at once. When the logbook is filled, or upon termination of your employment, it must be returned to the laboratory quality/operation files.

5.3 Procedure

- 5.3.1 Briefly define in the front pages of the book what type of log is contained within. Definitions of column headings, references, and acceptance limits will be addressed on the first pages as well.
- 5.3.2 All entries are to be recorded directly into the logbook. Recording of original data on loose pieces of paper for later transcription into the logbook is to be avoided. Should loose paper be necessary for proper conduct of an experiment:
- 5.3.2.1 Write on the logbook page itself identification of what is affixed to that page
- 5.3.2.2 Firmly affix the loose paper with clear tape
- 5.3.2.3 Initial and date over the edge of the tape.
- 5.3.3 All entries must be made in black ink. Red ink is reserved for Quality Control (QC) checking purposes only. Erasures, blacking out, or use of correction fluid is not permitted. If a mistake is made, draw a single line through the erroneous material and make a corrected entry, initial, and date the correction.
- 5.3.4 It is necessary to fill each page and keep the sequence of entries in chronological order. Any unused section of a page will be cancelled with a diagonal line. Spaces intentionally left blank in tables or logs will contain horizontal lines.
- 5.3.5 When reference is made to samples, the TDL sample number will be used. Additional sample identification may be offered, but not to the exclusion of the TDL sample number.
- 5.3.6 Use a ruler to draw lines defining columns. Label columns including units when appropriate. Injection logs, balance logs, and other similar logs will include columns for the operators' initials and date.
- 5.3.7 Each entry in an analytical logbook is to be initialed and dated. The "Completed by" is signed by the last person to make entry on a given page and indicates that the page has been checked for completeness of entries.

6.0 Nonconformance and Corrective Action

6.1 A nonconformance is a deficiency in procedure sufficient to render the quality of an item unacceptable or indeterminate or any event which is beyond the limits documented and established for laboratory operation. A nonconformance may include data recording errors, transcription errors, and failure to document. A nonconformance memo associated with this procedure will be filed with the QC Coordinator.

7.0 Records Management

7.1 TDL Analytical Logbooks are the property of IT Corporation.

7.2 Document control of TDL Logbooks is handled by the QC Coordinator (QCC). The QCC will issue all notebooks. All completed logbooks will be returned to the QCC.

7.3 All returned Laboratory Logbooks are filed in TDL Central Files.



IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: STANDARD LABORATORY SIEVES : SPECIFICATION, CALIBRATION,
AND MAINTENANCE

Prepared by: Coy A. Lauer **Date:** March 5, 1991

Reviewed by: *[Signature]* **Date:** 3/6/91
Technical Specialist

[Signature] **Date:** 3/13/91
Quality Control Coordinator

[Signature] **Date:** 6-24-91
Director, Quality and Compliance, ITAS

Approved by: *[Signature]* **Date:** 7/5/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: Sieve, ASTM E 11-87, Geotechnical

Revision #	0					
Date	03/05/91					129

SOP No.: TDL1113
Date Initiated: March 5, 1991
Revision No.: 0
Date Revised: N/A
Page 2 of 4

LABORATORY SIEVES
SPECIFICATION, CALIBRATION, AND MAINTENANCE

1.0 Purpose and Application

1.1 This SOP defines the standards for standard laboratory sieves used in the Geotechnical Analysis Laboratory. It also describes calibration requirements and maintenance of the sieves.

2.0 References

2.1 ASTM E 11-87, Standard Specification For Wire Cloth Sieves For Testing Purposes.

3.0 Associated SOPs

3.1 None.

4.0 Definitions

4.1 None.

5.0 Procedure

5.1 All standard sieves will meet the specifications in ASTM E 11-87, Standard Specifications for Wire Cloth Sieves For Testing Purposes. Upon receipt, each sieve will be checked for a label which has the ASTM specification, sieve size, and a identification number or serial number. If the ASTM specification is not on the sieve, that sieve will be returned to the vendor and not used. If the sieve size or a serial number is not on the label, prepare a permanent label with the appropriate information and affix it to the side of the sieve. Due to the corrosive nature of some samples, brass sieves with stainless steel mesh are preferred.

5.2 Sieves put into use prior to this SOP do not require a serial number.

5.3 Calibration certificates should be provided by the manufacturer. If a calibration certificate did not come with the sieve, either return it, or get a certificate from the vendor. Calibration certificates will be kept in the Quality/Operations files maintained

SOP No.: TDL1113
Date Initiated: March 5, 1991
Revision No.: 0
Date Revised: N/A
Page 3 of 4

by the lab QC Coordinator.

- 5.4 If a sieve calibration is suspect, it shall be either checked or replaced. Due to the amount of time involved in checking sieve calibration, replacement is usually the preferred alternative. AASHTO proficiency samples may also be used as an indication of sieve calibration. If the results from a proficiency sample are too far out of line (as determined by the lab supervisor), the suspect sieve shall be pulled for calibration or replacement.
- 5.5 Sieves with a mesh size of #200 or smaller will be replaced one year after initially being placed into service. Each sieve will be labeled with the replacement date at the time it is placed into service.
- 5.6 Prior to use, each sieve will be visually inspected for holes, broken mesh, or any other condition which may make the sieve unsuitable for use. Sieves which are clogged will be cleaned with a suitable brush. Caution shall be used when cleaning fine sieves with a wire bristle brush as this may damage the sieve. Any sieve deemed unsuitable for use will be immediately discarded.
- 5.7 Sieves used in washing samples or sieves used with corrosive samples will be cleaned with water and a brush after use. It may be useful to place the sieve in a drying oven (<120 °C) to dry. This will help to keep corrosion to a minimum.
- 5.8 Sieves will be stored in a clean, dry environment.

6.0 Nonconformance and Corrective Action

- 6.1 Sieves which do not meet the required specifications, are damaged, or otherwise unsuitable for use will be discarded or returned to the vendor if newly purchased. If a sieve is discovered nonuseable during use, the sample(s) will be retested and a nonconformance memo generated to describe the problem with the sieve and the fact that the sample(s) are being retested.

SOP No.: TDL1113
Date Initiated: March 5, 1991
Revision No.: 0
Date Revised: N/A
Page 4 of 4

7.0 Records Management/Documentation

- 7.1 Sieve calibration records will be kept in the Quality/Operations files by the QA coordinator.

IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: Bulking Factor Measurement

Prepared by: Charley Morgan Date: 2/7/91

Reviewed by: Ed Opeck Date: 2/8/91
Technical Specialist

Patti B. Carswell Date: 2/8/91
Quality Control Coordinator

James M. Jones Date: 3-26-91
Director, Quality and Compliance, ITAS

Approved by: Pat Miller Date: 3/27/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words:

Revision #	0					
Date	9/16/90					133

1.0 Purpose and Application

- 1.1 The purpose of this SOP is to determine the volume increase when additives are mixed with homogenized sludge. This procedure proves to be the best test instead of trying to read the volume increase directly from a plastic or glass container because the sludge tends to stick to the sides, therefore giving an erroneous result.

2.0 References

- 2.1 ITAS-TDL Chemical Hygiene Plan.

3.0 Associated SOPs and Applicable Methods

- 3.1 None

4.0 Definitions

4.1 Container Volume (A)

The volume of deionized water that the container will hold.

4.2 Volume of Water Plus Sludge (B)

The amount of deionized water it takes to fill container with a known weight of sludge

4.3 Initial Volume (I)

Initial volume of sludge in cm^3 .

4.4 Volume of Water with Treated Sludge (C)

Amount of deionized water needed to fill container that contains treated sludge.

4.5 Treated Sludge

Raw sludge that has been mixed with additives.

4.6 Treated Volume (D)

Treated volume amount of sludge.

4.7 Change in Volume (BF)

Difference of initial volume (I) of sludge and treated volume (D) of sludge.

5.0 Procedure

5.1 Summary

5.1.1 A known volume of deionized water is added to a known weight of a sludge sample. A percent volume change is then calculated.

5.2 Interferences

5.2.1 No known interferences.

5.3 Sample Handling, Preservation, and Holding Time

5.3.1 Application of these procedures on hazardous waste samples must consider the known or suspected hazardous compounds present. Project-specific selection of work area, safe working practices, and personal protective equipment shall be made based upon exposure potential to the hazardous components.

5.3.2 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

5.3.3 There are no holding times applicable to this procedure.

5.3.4 There are no preservation requirements applicable to this procedure.

5.4 Required Equipment

5.4.1 Two 5-oz. S/P Dispo® polypropylene container or equivalent.

5.4.2 Graduated cylinder.

5.5 Reagents/Standards

5.5.1 Deionized water.

5.5.2 Additives.

5.0 Procedure (continued)

5.6 Calibration

5.6.1 Determine the container volume (A). For example, a 5-oz. S/P Dispo® polypropylene container which is graduated from 10 to 140 ml is used. Calibrate the 5-oz container by filling the container with deionized water using a graduate cylinder.

5.7 Analysis/Operation

5.7.1 Add a known weight in grams of raw sludge to a 5-oz container. Tap container with raw sludge to release air bubbles. Add deionized water by a graduate into container until full. Designate the volume of deionized water added as the volume of water plus sludge (B).

5.7.2 In another 5-oz container, add same weight as above of raw sludge plus the percent additives and mix well. Tap container to release air pockets. Fill rest of container using a graduate with deionized water. Designate the volume of deionized water added as volume of water with treated sludge (C).

5.8 Calculations

5.8.1 Initial volume (I) of sludge is equal to (A-B) and units are in cm³.

$$A - B = I$$

where: A = container volume and
B = volume of water plus sludge.

5.8.2 (A-C) equals treated volume (D).

$$A - C = D$$

where: A = container volume,
C = volume of water with treated sludge, and
D = treated volume.

5.8.3 Calculate the difference of initial volume (I) and treated volume (D). Designate this amount as change in Volume (BF).

$$D - I = BF$$

where: I = initial volume,
D = treated volume, and
BF = change in volume.

5.0 Procedure (continued)

5.8.4 To get percent change in volume, take (BF) divided by initial volume (I) and multiply by 100.

$$\% \text{ Change in Volume} = \text{BF}/\text{I} \times 100$$

where: BF = change in volume and
I = initial volume.

5.9 Quality Control

5.9.1 None

6.0 Nonconformance and Corrective Action

6.1 Any failure to follow this procedure will be noted on a nonconformance memo. The corrective action will be verified by the Quality Control Coordinator and approved by the appropriate Operations Manager.

7.0 Records Management

7.1 All data will be recorded in standard laboratory notebooks.



IT Analytical Services

Technology Development Laboratory Standard Operating Procedure

Title: CALIBRATION OF THERMOMETERS

Prepared by: David McNeil **Date:** 5/17/91

Reviewed by: Walter W. L. **Date:** 5/29/91
Technical Specialist

Patti B. Caswell **Date:** 5/29/91
Quality Control Coordinator

Gene M. Jones **Date:** 6-24-91
Director, Quality and Compliance, ITAS

Approved by: Janet Hall **Date:** 6-22-91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: CALIBRATION, THERMOMETER, NBS

Revision #	1				
Date	02/27/91				138

1.0 Purpose and Application

- 1.1 The purpose of this SOP is to detail proper procedures for the calibration of all laboratory thermometers, such that temperature measurements are accurate and traceable.
- 1.2 This procedure applies to any thermometer used in the laboratory directly or indirectly in the preparation, storage or analysis of samples.
- 1.3 Working thermometers in the laboratory shall be calibrated annually against reference thermometers that have initial NBS traceability and that are recertified every three years with equipment directly traceable to the NBS.

2.0 References

- 2.1 ITAS-SW SOP No. MW104R0, "Calibration of Thermometers."

3.0 Associated SOPs and Applicable Methods

- 3.1 ITAS System Procedure No. 9014-HSC-01, "General Health and Safety Practices for Tasks Performed in the Laboratory."

4.0 Definitions

- 4.1 None.

5.0 Procedure

- 5.1 Copies of the NBS traceable certification of reference thermometers will be kept in the Quality/Operations files.
- 5.2 Every three years reference thermometers will be recertified with equipment directly traceable to the NBS. A record of the date of this certification will be kept in the Equipment Maintenance and Calibration files by the QCC.
- 5.3 Each working thermometer in use in the laboratory will be assigned a unique number and will be calibrated annually against a reference thermometer using the calibration methods listed below as appropriate for the specific use of the thermometer:

5.0 Procedure (continued)

5.3.1 Calibration Method 1:

5.3.1.1 Working thermometer and reference thermometers are allowed to remain together in the same room for at least 24 hours. The bulbs are then put together on desk top for at least 30 minutes and read.

5.3.2 Calibration Method 2:

5.3.2.1 A one-liter beaker is filled with regular refrigerator ice cubes prepared with deionized water. The remainder of space in beaker is filled with deionized water. The working thermometer and reference thermometer are immersed with bottom of bulbs at same level. Wait at least 30 minutes and read.

5.3.3 Calibration Method 3:

5.3.3.1 Fill a one liter glass beaker with deionized water and bring to a boil on a hot plate. The working and reference thermometer are immersed with bottom of bulbs at same level. At least the whole bulb on each thermometer must be completely immersed. Wait 5 minutes and read.

5.3.4 Calibration Method 4:

5.3.4.1 Working thermometers and a reference thermometer are allowed to remain together in a freezer for at least one hour. After one hour, read the thermometers.

5.4 A Thermometer Calibration form (Figure TDL102-1) shall be completed for each working thermometer calibrated and placed in the Quality/Operation files.

5.5 Any thermometer that does not meet the acceptance criteria ($\pm 1^{\circ}\text{C}$) shall be tagged to prevent inadvertent use. New thermometers that do not meet the acceptance criteria will be sent back to the vendor. Old thermometers that do not meet the acceptance criteria will be removed from the lab.

5.6 All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped in the event of a known or potential compromise to the health or safety of any ITAS Associate, and must be reported immediately to a laboratory supervisor.

6.0 Nonconformance and Corrective Action

- 6.1 Any thermometer that does not meet the acceptance criteria ($\pm 1^{\circ}\text{C}$) shall be tagged to prevent inadvertent use. New thermometers that do not meet the acceptance criteria will be sent back to the vendor. Old thermometers that do not meet the acceptance criteria will be removed from the lab.

7.0 Records Management

- 7.1 A Thermometer Calibration form (Figure TDL102-1) shall be completed for each working thermometer calibrated and placed in the Quality/Operation files.

FIGURE TDL102-1
ITAS TECHNOLOGY DEVELOPMENT LABORATORY
THERMOMETER CALIBRATION

Date: _____
 Number of thermometer being calibrated: _____
 Description of thermometer being calibrated: _____

Date last calibrated: _____
 Time since last calibration _____
 Description of reference thermometer: _____

Calibration Method Number	Temperature Reading	
	Reference Thermometer	Thermometer Being Calibrated

Working range: _____
 Acceptance criteria: _____ ± _____ °C
 Signed: _____

STANDARD OPERATING PROCEDURE
ITAS-TECHNOLOGY DEVELOPMENT LABORATORY

TITLE:

UNCONFINED COMPRESSIVE STRENGTH

SOP NO: TDL1109

DATE INITIATED: 7/31/89

REVISION NO: 1

DATE REVISED: 3/28/90

PAGE 1 OF 18

PREPARED BY

APPROVED BY

DATE

QA CONCURRENCE

DATE

John F. Dye, Graham E. Moran *3/28/90* *Janet M. Jones* *9-4-90*

1.0 Purpose and Application

- 1.1 This test method covers the determination of the unconfined compressive strength of cohesive soil in the undisturbed, remolded, or compacted condition using strain-controlled application of the axial load.
- 1.2 This test method provides an approximate value of the strength of cohesive soils in terms of total stresses.
- 1.3 This test method is applicable only to cohesive materials which will not expel bleed water during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils.

2.0 References

- 2.1 Annual Book of ASTM Standards. 1988. "Soil and Rock; Building Stones; Geotextiles. Vol. 4.08.

3.0 Associated SOPs and Applicable Methods

- 3.1 ASTM D-422.
- 3.2 ASTM D-854.
- 3.3 ASTM D-2216.
- 3.4 ASTM D-2850.

3.0 Associated SOPs and Applicable Methods (continued)

3.5 ASTM D-4220.

3.6 ASTM D-4318.

4.0 Definitions

4.1 Unconfined compressive strength - the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test.

4.2 Shear strength - for unconfined compressive strength test specimens, the shear strength is calculated to be one-half of the compressive stress at failure.

4.3 Bleed water - water expelled from the soil due to deformation or compaction.

5.0 Procedure

5.1 ASTM Standard Method D-2166.

6.0 Nonconformance and Corrective Action

6.1 If this procedure cannot be followed for any reason, a nonconformance memo will be filed with the Quality Control Coordinator. Corrective action will be approved by the Operations or Project Manager.

7.0 Records Management

7.1 Data is to be recorded in a standard laboratory notebook with the project it pertains to clearly labeled on the notebook page.



Standard Test Method for Unconfined Compressive Strength of Cohesive Soil¹

This standard is issued under the fixed designation D 2166; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 This test method covers the determination of the unconfined compressive strength of cohesive soil in the undisturbed, remolded, or compacted condition, using strain-controlled application of the axial load.

1.2 This test method provides an approximate value of the strength of cohesive soils in terms of total stresses.

1.3 This test method is applicable only to cohesive materials which will not expel bleed water (water expelled from the soil due to deformation or compaction) during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils. Dry and crumbly soils, fissured or varved materials, silts, peats, and sands cannot be tested with this method to obtain valid unconfined compression strength values.

NOTE 1—The determination of the unconsolidated, undrained strength of cohesive soils with lateral confinement is covered by Test Method D 2850.

1.4 This test method is not a substitute for Test Method D 2850.

1.5 The values stated in SI units are to be regarded as the standard. The values stated in inch-pound units are approximate.

1.6 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- D 422 Method for Particle-Size Analysis of Soils²
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids²
- D 854 Test Method for Specific Gravity of Soils²
- D 1587 Practice for Thin-Walled Tube Sampling of Soils²
- D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures²
- D 2487 Test Method for Classification of Soils for Engineering Purposes²

¹ This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.05 on Structural Properties of Soils.

Current edition approved July 26, 1985. Published September 1985. Originally published as D 2166 - 63T. Last previous edition D 2166 - 66 (1979)¹.

² Annual Book of ASTM Standards, Vol 04.08.

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²

D 2850 Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression²

D 4220 Practices for Preserving and Transporting Soil Samples²

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils²

3. Terminology

3.1 Refer to Terminology D 653 for standard definitions of terms.

3.2 Descriptions of Terms Specific to this Standard:

3.2.1 *unconfined compressive strength* (q_u)—the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In this test method, unconfined compressive strength is taken as the maximum load attained per unit area or the load per unit area at 15 % axial strain, whichever is secured first during the performance of a test.

3.2.2 *shear strength* (s_w)—for unconfined compressive strength test specimens, the shear strength is calculated to be ½ of the compressive stress at failure, as defined in 3.2.1.

4. Significance and Use

4.1 The primary purpose of the unconfined compression test is to quickly obtain the approximate compressive strength of soils that possess sufficient cohesion to permit testing in the unconfined state.

4.2 Samples of soils having slickensided or fissured structure, samples of some types of loess, very soft clays, dry and crumbly soils and varved materials, or samples containing significant portions of silt or sand, or both (all of which usually exhibit cohesive properties), frequently display higher shear strengths when tested in accordance with Test Method D 2850. Also, unsaturated soils will usually exhibit different shear strengths when tested in accordance with Test Method D 2850.

4.3 If both an undisturbed and a remolded test are performed on the same sample, the sensitivity of the material can be determined. This method of determining sensitivity is suitable only for soils that can retain a stable specimen shape in the remolded state.

NOTE 2—For soils that will not retain a stable shape, a vane shear test or Test Method D 2850 can be used to determine sensitivity.

5. Apparatus

5.1 *Compression Device*—The compression device may be a platform weighing scale equipped with a screw-jack-activated load yoke, a hydraulic loading device, or any other

D 2166

compression device with sufficient capacity and control to provide the rate of loading prescribed in 7.1. For soil with an unconfined compressive strength of less than 100 kPa (1.0 ton/ft²) the compression device shall be capable of measuring the compressive stress to within 1 kPa (0.01 ton/ft²). For soil with an unconfined compressive strength of 100 kPa (1.0 ton/ft²) or greater, the compression device shall be capable of measuring the compressive stress to the nearest 5 kPa (0.05 ton/ft²).

5.2 *Sample Extruder*, capable of extruding the soil core from the sampling tube in the same direction of travel in which the sample entered the tube, at a uniform rate, and with negligible disturbance of the sample. Conditions at the time of sample removal may dictate the direction of removal, but the principal concern is to keep the degree of disturbance negligible.

5.3 *Deformation Indicator*—The deformation indicator shall be a dial indicator graduated to 0.03 mm (0.001 in.) or better and having a travel range of at least 20 % of the length of the test specimen, or some other measuring device, such as an electronic deformation measuring device, meeting these requirements.

5.4 *Dial Comparator*, or other suitable device, for measuring the physical dimensions of the specimen to within 0.1 % of the measured dimension.

NOTE 3—Vernier calipers are not recommended for soft specimens, which will deform as the calipers are set on the specimen.

5.5 *Timer*—A timing device indicating the elapsed testing time to the nearest second shall be used for establishing the rate of strain application prescribed in 7.1.

5.6 *Balance*—The balance used to weigh specimens shall determine the mass of the specimen to within 0.1 % of its total mass.

5.7 *Equipment*, as specified in Method D 2216.

5.8 *Miscellaneous Apparatus*, including specimen trimming and carving tools, remolding apparatus, water content cans, and data sheets, as required.

6. Preparation of Test Specimens

6.1 *Specimen Size*—Specimens shall have a minimum diameter of 30 mm (1.3 in.) and the largest particle contained within the test specimen shall be smaller than one tenth of the specimen diameter. For specimens having a diameter of 72 mm (2.8 in.) or larger, the largest particle size shall be smaller than one sixth of the specimen diameter. If, after completion of a test on an undisturbed specimen, it is found, based on visual observation, that larger particles than permitted are present, indicate this information in the remarks section of the report of test data (Note 4). The height-to-diameter ratio shall be between 2 and 2.5. Determine the average height and diameter of the test specimen using the apparatus specified in 5.4. Take a minimum of three height measurements (120° apart), and at least three diameter measurements at the quarter points of the height.

NOTE 4—If large soil particles are found in the sample after testing, a particle-size analysis performed in accordance with Method D 422 may be performed to confirm the visual observation and the results provided with the test report.

6.2 *Undisturbed Specimens*—Prepare undisturbed specimens from large undisturbed samples or from samples secured in accordance with Practice D 1587 and preserved and transported in accordance with the practices for Group C samples in Practices D 4220. Tube specimens may be tested without trimming except for the squaring of ends, if conditions of the sample justify this procedure. Handle specimens carefully to prevent disturbance, changes in cross section, or loss of water content. If compression or any type of noticeable disturbance would be caused by the extrusion device, split the sample tube lengthwise or cut it off in small sections to facilitate removal of the specimen without disturbance. Prepare carved specimens without disturbance, and whenever possible, in a humidity-controlled room. Make every effort to prevent any change in water content of the soil. Specimens shall be of uniform circular cross section with ends perpendicular to the longitudinal axis of the specimen. When carving or trimming, remove any small pebbles or shells encountered. Carefully fill voids on the surface of the specimen with remolded soil obtained from the trimmings. When pebbles or crumbling result in excessive irregularity at the ends, cap the specimen with a minimum thickness of plaster of paris, hydrostone, or similar material. When sample condition permits, a vertical lathe that will accommodate the total sample may be used as an aid in carving the specimen to the required diameter. Where prevention of the development of appreciable capillary forces is deemed important, seal the specimen with a rubber membrane, thin plastic coatings, or with a coating of grease or sprayed plastic immediately after preparation and during the entire testing cycle. Determine the mass and dimensions of the test specimen. If the specimen is to be capped, its mass and dimensions should be determined before capping. If the entire test specimen is not to be used for determination of water content, secure a representative sample of cuttings for this purpose, placing them immediately in a covered container. The water content determination shall be performed in accordance with Method D 2216.

6.3 *Remolded Specimens*—Specimens may be prepared either from a failed undisturbed specimen or from a disturbed sample, providing it is representative of the failed undisturbed specimen. In the case of failed undisturbed specimens, wrap the material in a thin rubber membrane and work the material thoroughly with the fingers to assure complete remolding. Avoid entrapping air in the specimen. Exercise care to obtain a uniform density, to remold to the same void ratio as the undisturbed specimen, and to preserve the natural water content of the soil. Form the disturbed material into a mold of circular cross section having dimensions meeting the requirements of 6.1. After removal from the mold, determine the mass and dimensions of the test specimens.

6.4 *Compacted Specimens*—Specimens shall be prepared to the predetermined water content and density prescribed by the individual assigning the test (Note 5). After a specimen is formed, trim the ends perpendicular to the longitudinal axis, remove from the mold, and determine the mass and dimensions of the test specimen.

NOTE 5—Experience indicates that it is difficult to compact, handle, and obtain valid results with specimens that have a degree of saturation that is greater than 90 %.



7. Procedure

7.1 Place the specimen in the loading device so that it is centered on the bottom platen. Adjust the loading device carefully so that the upper platen just makes contact with the specimen. Zero the deformation indicator. Apply the load so as to produce an axial strain at a rate of 1/2 to 2%/min. Record load, deformation, and time values at sufficient intervals to define the shape of the stress-strain curve (usually 10 to 15 points are sufficient). The rate of strain should be chosen so that the time to failure does not exceed about 15 min (Note 6). Continue loading until the load values decrease with increasing strain, or until 15% strain is reached. The rate of strain used for testing sealed specimens may be decreased if deemed desirable for better test results. Indicate the rate of strain in the report of the test data, as required in 9.1.7. Determine the water content of the test specimen using the entire specimen, unless representative cuttings are obtained for this purpose, as in the case of undisturbed specimens. Indicate on the test report whether the water content sample was obtained before or after the shear test, as required in 9.1.2.

NOTE 6—Softer materials that will exhibit larger deformation at failure should be tested at a higher rate of strain. Conversely, stiff or brittle materials that will exhibit small deformations at failure should be tested at a lower rate of strain.

7.2 Make a sketch, or take a photo, of the test specimen at failure showing the slope angle of the failure surface if the angle is measurable.

7.3 A copy of a sample data sheet is included in Appendix X1. Any data sheet can be used, provided the form contains all the required data.

8. Calculations

8.1 Calculate the axial strain, ϵ_1 , to the nearest 0.1%, for a given applied load, as follows:

$$\epsilon_1 = \Delta L / L_0$$

where:

ΔL = length change of specimen as read from deformation indicator, mm (in.), and

L_0 = initial length of test specimen, mm (in.).

8.2 Calculate the average cross-sectional area, A , for a given applied load, as follows:

$$A = A_0 / (1 - \epsilon_1)$$

where:

A_0 = initial average cross-sectional area of the specimen, mm² (in.²), and

ϵ_1 = axial strain for the given load, %.

8.3 Calculate the compressive stress, σ_c , to three significant figures, or nearest 1 kPa (0.01 ton/ft²), for a given applied load, as follows:

$$\sigma_c = (P/A)$$

where:

P = given applied load, kPa (ton/ft²),

A = corresponding average cross-sectional area mm² (in.²).

8.4 *Graph*—If desired, a graph showing the relationship between compressive stress (ordinate) and axial strain (ab-

scissa) may be plotted. Select the maximum value of compressive stress, or the compressive stress at 15% axial strain, whichever is secured first, and report as the unconfined compressive strength, q_u . Whenever it is considered necessary for proper interpretation, include the graph of the stress-strain data as part of the data reported.

8.5 If the unconfined compressive strength is determined, the sensitivity, S_T , is calculated as follows:

$$S_T = \frac{q_u \text{ (undisturbed specimen)}}{q_u \text{ (remolded specimen)}}$$

9. Report

9.1 The report should include the following:

9.1.1 Identification and visual description of the specimen, including soil classification, symbol, and whether the specimen is undisturbed, remolded, compacted, etc. Also include specimen identifying information, such as project, location, boring number, sample number, depth, etc. Visual descriptions shall be made in accordance with Practice D 2488,

9.1.2 Initial dry density and water content (specify if the water content specimen was obtained before or after shear, and whether from cuttings or the entire specimen),

9.1.3 Degree of saturation (Note 7), if computed,

NOTE 7—The specific gravity determined in accordance with Test Method D 854 is required for calculation of the degree of saturation.

9.1.4 Unconfined compressive strength and shear strength,

9.1.5 Average height and diameter of specimen,

9.1.6 Height-to-diameter ratio,

9.1.7 Average rate of strain to failure, %,

9.1.8 Strain at failure, %,

9.1.9 Liquid and plastic limits, if determined, in accordance with Test Method D 4318,

9.1.10 Failure sketch or photo,

9.1.11 Stress-strain graph, if prepared,

9.1.12 Sensitivity, if determined,

9.1.13 Particle size analysis, if determined, in accordance with Method D 422, and

9.1.14 *Remarks*—Note any unusual conditions or other data that would be considered necessary to properly interpret the results obtained, for example, slickensides, stratification, shells, pebbles, roots, or brittleness, the type of failure (that is, bulge, diagonal shear, etc.).

10. Precision and Bias

10.1 No method presently exists to evaluate the precision of a group of unconfined compression tests on undisturbed specimens due to specimen variability. Undisturbed soil specimens from apparently homogeneous soil deposits at the same location often exhibit significantly different strength and stress-strain properties.

10.2 A suitable test material and method of specimen preparation have not been developed for the determination of laboratory variances due to the difficulty in producing identical cohesive soil specimens. No estimates of precision for this test method are available.

SOP NO: TDL1109
DATE INITIATED: 7/31/89
REVISION NO: 1
DATE REVISED: 3/28/90
PAGE 7 OF 18

 D 2166

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

EM 1110-2-1906
30 Nov 70

APPENDIX XI:

UNCONFINED COMPRESSION TEST

1. INTRODUCTION. The unconfined compression test is used to measure the unconfined compressive strength of a cohesive soil. The unconfined compression test is applicable only to coherent materials such as saturated clays or cemented soils that retain intrinsic strength after removal of confining pressure; it is not a substitute for the Q test. Dry or crumbly soils, fissured or varved materials, silts, and sands cannot be tested meaningfully in unconfined compression. In this test, a laterally unsupported cylindrical specimen is subjected to a gradually increased axial compression load until failure occurs. The unconfined compression test is a form of triaxial test in which the major principal stress is equal to the applied axial stress, and the intermediate and minor principal stresses are equal to zero. The unconfined compressive strength, q_u , is defined as the maximum unit axial compressive stress at failure or at 15 percent strain, whichever occurs first. The undrained shear strength, s_u , is assumed to be equal to one-half the unconfined compressive strength. The axial load may be applied to the specimen either by the controlled strain procedure, in which the stress is applied to produce a predetermined rate of strain, or by the controlled stress procedure, in which the stress is applied in predetermined increments of load.

2. APPARATUS. The apparatus consists of the following:

a. Equipment for Preparing Specimen. A trimming frame as described in paragraph 3e of Appendix X, TRIAXIAL COMPRESSION TESTS, or a trimming cylinder with beveled cutting edges may be used for trimming specimens. The equipment should include wire saws and knives of various sizes and types for use with the trimming frame. A motorized soil lathe may be used advantageously under certain circumstances. A miter box or cradle is required to trim the specimen to a fixed length and to ensure that the ends of the specimen are parallel with each other and perpendicular to the vertical axis of the specimen.

b. Loading Device. A number of commercially available controlled-strain or controlled-stress types of loading devices are suitable for applying the axial loads in the unconfined compression test. In

EM 1110-2-1906
Appendix XI
30 Nov 70

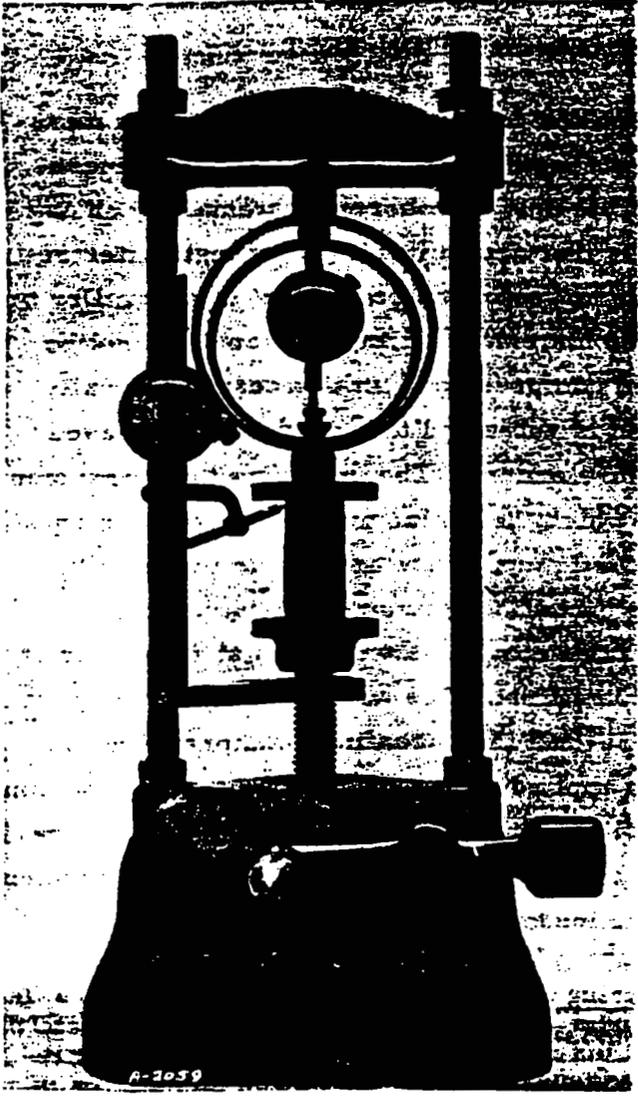


Figure 1. Typical unconfined compression test apparatus

general, controlled-strain type loading devices are preferable, and the procedures described herein are based on the use of this type of equipment. If available, an automatic stress-strain recorder may be used to measure and record applied axial loads and displacements. A typical loading device is shown in Figure 1. Any equipment used should be calibrated so that the loads actually applied to the soil specimen can be determined. The required sensitivity of stress-measuring equipment for both controlled-stress and controlled-strain testing will vary with the strength characteristics of the soil. For relatively weak soils (compressive strengths less than 1.0 ton per sq ft), the unit load should be measurable to within 0.01 ton per

sq ft. For soils with compressive strengths of 1.0 ton per sq ft or greater, the loads should be measurable to the nearest 0.05 ton per sq ft.

c. Measuring equipment, such as dial indicators and calipers, suitable for measuring the dimensions and axial deformation of a specimen

to the nearest 0.001 in.

- d. Timing device, either a watch or clock with second hand.
- e. Balances, sensitive to 0.1 g.
- f. Other. Apparatus necessary to determine water content and specific gravity (see Appendixes I, WATER CONTENT - GENERAL, and IV, SPECIFIC GRAVITY).

3. PREPARATION OF SPECIMENS. a. Specimen Size. Unconfined compression specimens shall have a minimum diameter of 1.0 in. (preferably 1.4 in.), and the largest particle in any test specimen will be no greater than one-sixth the specimen diameter. The height-to-diameter ratio shall be not less than 2.1. Commonly used diameters of unconfined compression specimens are 1.4 and 2.8 in. Specimens of 1.4-in. diameter are generally used for testing cohesive soils which contain a negligible amount of gravel.

b. Undisturbed Specimens. Generally, undisturbed specimens are prepared from undisturbed tube or chunk samples of a larger size than the test specimen. Core or thin-wall tube samples of relatively small diameter may be tested without further trimming except for squaring the ends, if the condition of the soil requires this procedure. Specimens must be handled carefully to prevent remolding, changes in cross section, or loss of moisture. To minimize disturbance caused by skin friction between samples and metal sampling tubes, the tubes should be cut into short lengths before ejecting the samples. Sample ejection should be accomplished with a smooth continuous, and fairly rapid motion in the same direction that the sample entered the tube. All specimens shall be prepared in a humid room to prevent evaporation of moisture. The specimen shall be prepared as follows:

- (1) From the undisturbed sample cut a section somewhat larger in length and diameter than the desired specimen size.

EM 1110-2-1906
Appendix XI
30 Nov 70

It is generally desirable to prepare duplicate specimens for unconfined compression testing, and selection of material for testing should be made with this in mind.

(2) Carefully trim the specimen to the required diameter using a trimming frame and various trimming tools (see Fig. 7, Appendix X, TRIAXIAL COMPRESSION TESTS). Remove any small shells or pebbles encountered during the trimming operations. Carefully fill voids on the surface of the specimen with remolded soil obtained from the trimmings. Cut the specimen to the required length, using a miter box (see Fig. 8, Appendix X, TRIAXIAL COMPRESSION TESTS). Where the presence of pebbles or crumbling results in excessive irregularity at the ends, cap the specimens with a minimum thickness of plaster of Paris, hydrostone, or other support material. Care must be taken to insure that the ends of the specimen are parallel with each other and perpendicular to the vertical axis of the specimen.

(3) From the soil trimmings obtain 200 g of material for specific gravity and water content determinations (see Appendixes I, WATER CONTENT - GENERAL, and IV, SPECIFIC GRAVITY).

(4) Weigh the specimen to an accuracy of ± 0.01 g for 1.4-in.-diameter specimens and ± 0.1 g for 2.8-in.-diameter specimens. If specimens are to be capped, they should be weighed before capping.

(5) Measure the height of the specimen with calipers or a scale and the diameter with calipers or circumference measuring devices. If the specimen is cut to a fixed length in a miter box, the length of the miter box can be taken as the height of specimen for routine tests, and additional height measurements are not usually necessary. It is always advisable to measure the diameter of the specimen after trimming, even though specimens are cut to a nominal diameter in a trimming frame. Make all measurements to the nearest ± 0.01 in. Determine the average initial diameter, D_o , of the specimen using the diameters measured at the top, D_t , center, D_c , and bottom, D_b , of the specimen, as follows:

$$D_o = \frac{D_t + 2D_c + D_b}{4}$$

(6) If the specimen is not tested immediately after preparation, precautions must be taken to prevent drying and consequent development of capillary stresses. When drying before or during the test is anticipated, the specimen may be covered with a thin coating of grease such as petrolatum. This coating cannot be used if the specimen is to be used in a subsequent remolded test.

c. Remolded Specimens. Remolded specimens usually are prepared in conjunction with tests made on undisturbed specimens after the latter has been tested to failure. The remolded specimens are tested to determine the effects of remolding on the shear strength of the soil. The remolded specimen should have the same water content as the undisturbed specimen in order to permit a comparison of the results of the tests on the two specimens. The remolded specimen shall be prepared as follows:

(1) Place the failed undisturbed specimen in a rubber membrane and knead it thoroughly with the fingers to assure complete remolding of the specimen. Take reasonable care to avoid entrapping air in the specimen and to obtain a uniform density.

(2) Remove the soil from the membrane and compact it in a cylindrical mold with inside dimensions identical with those of the undisturbed specimen. The compaction effort is not critical since the water contents of soils subjected to remolded tests are always considerably wetter than optimum. Care must be taken, however, to insure uniform density throughout the specimen. A thin coat of petrolatum on the inside of the molding cylinder will assist in the removal of the specimen after compaction.

(3) Carefully remove the specimen from the mold, preferably by means of a close fitting piston, and plane off the top of the specimen. The specimen is then ready for testing.

EM 1140-2-1906
Appendix XI
30 Nov 70

(4) Follow the steps outlined in paragraphs 3b(4) and 3b(5).

4. PROCEDURE. The procedure shall consist of the following steps:

a. Record all identifying information for the sample such as project, boring number, visual classification, and other pertinent data on the data sheet (see Plate XI-1 which is a suggested form). The data sheet is also used for recording test observations described below.

b. Place the specimen in the loading device so that it is centered on the bottom platen; then adjust the loading device carefully so that the loading ram or upper platen barely is in contact with the specimen. If a proving ring is used for determining the axial load, contact of the platen and specimen is indicated by a slight deflection of the proving ring dial. Attach a dial indicator, sensitive to 0.001 in., to the loading ram to measure vertical deformation of the specimen. Record the initial reading of the dial indicator on the data sheet (Plate XI-1). Test the specimen at an axial strain rate of about 1 percent per minute. For very stiff or brittle materials which exhibit small deformations at failure, it may be desirable to test the specimen at a slower rate of strain. Observe and record the resulting load corresponding to increments of 0.3 percent strain for the first 3 percent of strain and in increments of 1 or 2 percent of strain thereafter. Stop the test when the axial load remains constant or when 20 percent axial strain has been produced.

c. Record the duration of the test, in minutes, to peak strength (time to failure), type of failure (shear or bulge), and a sketch of specimen after failure on the data sheet (Plate XI-2).

d. After the test, place the entire specimen or a representative portion thereof in a container of known weight and determine the water content of the specimen in accordance with Appendix I, WATER CONTENT - GENERAL.

5. COMPUTATIONS. The computations consist of the following steps:

a. From the observed data, compute and record on the data sheet (Plate XI-1) the water content, volume of solids, void ratio, degree of

EM 1110-2-1906
Appendix XI
30 Nov 70

saturation, and dry density, using the formulas presented in Appendix II, UNIT WEIGHTS, VOID RATIO, POROSITY, AND DEGREE OF SATURATION.

b. Compute and record on the data sheet the axial strain, the corrected area, and the compressive stress, at each increment of strain by using the following formulas:

$$\text{Axial strain, } \epsilon = \frac{\Delta H}{H_0}$$

$$\text{Corrected area of specimen, } A_{\text{corr}}, \text{ sq cm} = \frac{A_0}{1 - \epsilon}$$

$$\text{Compressive stress, tons per sq ft} = \frac{P}{A_{\text{corr}}} \times 0.465$$

where

ΔH = change in height of specimen during test, cm

H_0 = initial height of specimen, cm

A_0 = initial area of specimen, sq cm

P = applied axial load, lb

6. PRESENTATION OF RESULTS. The results of the unconfined compression test shall be recorded on the report form shown as Plate XI-2. Pertinent information regarding the condition of the specimen, method of preparing the specimen, or any unusual features of each specimen (such as slickensides, stratification, shells, pebbles, roots, or brittleness) should be shown under "Remarks." The applied compressive stress shall be plotted versus the axial strain in Plate XI-2. The unconfined compressive strength, q_u , of the specimen shall be taken as the maximum or peak compressive stress. For tests continued to 20 percent strain without reduction of axial load occurring, the unconfined compressive strength as a rule shall be taken as the compressive stress at 15 percent strain.

EM 1110-2-1906
Appendix XI
30 Nov 70

Where the unconfined compressive strength of a specimen is also obtained after remolding, the sensitivity ratio, S_t , shall also be calculated and reported. The sensitivity ratio is defined as follows:

$$S_t = \frac{q_u \text{ (undisturbed)}}{q_u \text{ (remolded)}}$$

7. POSSIBLE ERRORS. Following are possible errors that would cause inaccurate determinations of unconfined compressive strength:

a. Test not appropriate to type of soil.

b. Specimen disturbed while trimming.

c. Loss of initial water content. A small change in water content can cause a larger change in the strength of a clay, so it is essential that every care be taken to protect the specimen against evaporation while trimming and measuring, during the test, and when remolding a specimen to determine the sensitivity.

d. Rate of strain or rate of loading too fast.

8. USE OF OTHER TYPES OF EQUIPMENT FOR UNDRAINED SHEAR STRENGTH DETERMINATIONS. Various other types of laboratory equipment, such as cone penetrometers and vane shear apparatus, may be used advantageously in the laboratory as a supplement to the basic unconfined compression test equipment for determining the undrained shear strength of cohesive soils. The use of these testing devices generally results in savings in cost and time. However, the devices should be used with caution until sufficient data and procedural details are established to assure their successful application. Use of such testing apparatus, as a rule,

SOP NO: TDL1109
DATE INITIATED: 7/31/89
REVISION NO: 1
DATE REVISED: 3/28/90
PAGE 16 OF 18

2425

EM 1110-2-1906
Appendix XI
30 Nov 70

should be preceded by careful correlations with the results of tests with the basic unconfined compression test equipment on the same type of soil, and correlations developed for a given type of soil should not be used indiscriminately for all soils.

EM 1110-2-1906
 Appendix XI
 30 Nov 70

Failure Sketches

Compressive Stress, T/sq ft

Axial Strain, %

Controlled stress
 Controlled strain

Test No.			
Type of specimen			
Initial	Water content	v_o	\$ \$ \$ \$
	Void ratio	e_o	
	Saturation	S_o	\$ \$ \$ \$
	Dry density, lb/cu ft	γ_d	
Time to failure, min		t_f	
Unconfined compressive strength, T/sq ft		q_u	
Undrained shear strength, T/sq ft		s_u	
Sensitivity ratio		S_t	
Initial specimen diameter, in.		D_o	
Initial specimen height, in.		H_o	
Classification			
LL	FL	PI	C_u
Remarks		Project	
		Area	
		Boring No.	Sample No.
		Depth	Date
		EL	

UNCONFINED COMPRESSION TEST REPORT

APPENDIX C
OTHER OPERATING PROCEDURES

**APPENDIX C
TABLE OF CONTENTS**

	<u>Page</u>
Nuclear Waste Glass Product Consistency Test - Version 3.0 (U)	1
Bulking Factor Procedure for Non-sludge Type Waste	4
5-Day Static Leach Test Procedure	7
Modified TCLP Leach Test Procedure	8
Waste and Reagent Mixing Procedure	9
Stabilization Waste Form Temperature Rise Generic Procedure	10
Permeability	11
Generic pH and Eh Procedure	13
Proposed Radon Emissions from Stabilized Solids	14
Shear Strength	19
Vitrification of Waste	24
Generic Uranium by Ion Chromatography with Post-Column Reaction and Phosphorescence or Fluorescence Detection	25

NUCLEAR WASTE GLASS PRODUCT CONSISTENCY TEST - VERSION 3.0 (U)

A durability test, designated for Product Consistency Test (PCT), has been developed for glasses produced in the Defense Waste Processing Facility (DWPF).¹ The test is designed to meet the requirements of the Waste Acceptance Preliminary Specifications (WAPS) 1.3 and 1.4.² Specification 1.3 requires the DWPF to demonstrate control of the radionuclide release properties of the final waste form. Changes in phase composition due to devitrification do not greatly alter the rate of release of material from the glass³ of the type that will be produced in DWPF. The WAPS Specification 1.4 however requires that the release properties of devitrified glass be similar to those determined in Specification 1.3. The DWPF is responsible for relating the results of the PCT to a repository site-specific release test, or alternatively, for performing the repository site-specific release tests.

The PCT has been developed, in part, to satisfy the WAPS requirements by providing a test that is (1) sensitive to glass composition and homogeneity, and (2) has the potential to be related to repository site-specific release tests. The test was designed to provide confirmation of the consistency of DWPF glass under the following considerations:

- Sensitivity of the test to glass composition and homogeneity
- Time necessary to demonstrate product quality
- Ease of sample preparation for radioactive glass
- Ease of test procedure for remote operation
- Precision of the test results
- Acceptance of waste form developers and repository projects

During PCT development, sample size was limited to 100-200 mesh (149-74 m) crushed glass because leaching of finer mesh sizes can cause overestimation of saturation concentrations, e.g. if finer powders are used, mass balance calculations need to be used to determine the maximum saturation concentration expected from a given particle size.⁴ Fine particles also contribute larger errors to the estimation of the sample surface area than coarser sized samples. Moreover, use of a coarser mesh crushed glass simplifies sample preparation for radioactive service.

One test temperature, 90°C, was chosen for the PCT. This temperature is representative of the anticipated temperature in a repository because of the heat of decay of the radionuclides in DWPF waste glass. A single leachant, American Society for Testing and Materials (ASTM) Type I water, was specified so that the test would be dominated by elemental species leached from the glass.

The $v_{\text{soln}}/m_{\text{solid}}$ ratio for the PCT was chosen as 10 mL/g and test durations of 1, 3, 7, 14, and 28 days were evaluated. Seven days was chosen as the minimum test duration that optimized test precision but did not sacrifice discrimination.¹

Leachate filtration to $<0.45\mu\text{m}$ was determined to improve the precision of the PCT. Filtering is advantageous because it removes colloidal species that would otherwise dissolve during the leachate acidification step and erroneously be measured as soluble elemental species. Filtering the leachate also removes the potential for fine glass particulates to become entrained in the leachate acidification.⁵ Such a dissolved particulate of glass would give an erroneously high soluble leachate concentration or contribute excessive radioactivity to the leachate.

PCT sample preparation specifies that the sieved glass should be washed in ASTM Type I water and absolute ethyl alcohol to remove electrostatically adhering fine particles. Comparisons of B.E.T. specific surface area measurements of alcohol washed and unwashed crushed basalt demonstrated that there was less than a 5 percent difference in the total surface area.⁵ Other studies⁶⁻⁹ have demonstrated that the $<1\mu\text{m}$ fine particles only affect the initial non-linear kinetics of dissolution, e.g. the first 24-hour period. Thereafter, the fines are consumed with no further effect on the bulk dissolution. The amount of fines adhering to a glass sample however, is an uncontrollable quantity and, hence, sample washing was included in the PCT. Later experimental studies verified that sample washing improved the precision and the accuracy of the PCT.

An Savannah River Laboratory (SRL) internal round robin¹ and a seven-laboratory external round robin were completed¹⁰ to determine the precision and accuracy of the PCT. Confirmatory testing on radioactive samples was also performed.¹¹ These studies indicated that the PCT was very reproducible, yielded reliable results rapidly, and could be easily performed in shielded cell facilities with radioactive samples.

This draft was submitted to ASTM subcommittee C26.13 on Repository Waste Package Materials Testing in January 1990.

REFERENCES

1. C. M. Jantzen and N. E. Bibler, "Product Consistency Test (PCT) and Test Protocol," U.S. Dept. of Energy Report DPST-87-575, Savannah River Laboratory, Aiken, SC (1987). 1 2 3
2. Waste Acceptance Preliminary Specifications for the Defense Waste Processing Facility High-Level Waste Form, U. S. Dept. of Energy, Office of Civilian Radioactive Waste Management, USDOE Document OGR/B-8, Washington, D.C (1988). 4 5 6
3. C. M. Jantzen and D. F. Bickford, "Leaching of Devitrified Glass Containing Simulated SRP Nuclear Waste," Specific Basis for Nuclear Waste Management, VIII, C. M. Jantzen, J. A. Stone and R. C. Ewing (Eds.), Materials Research Society, Pittsburgh, PA, pp. 135-146 (1985). 7 8 9 10
4. P. B. Macedo and A. Barkatt, "Mechanisms of Defense Waste Glass Corrosion: Dissolution of Glass Matrix," PNL-5157, Pacific Northwest Laboratories, Richland, WA, p. 1.1-1.63 (August 1984). 11 12 13
5. G. L. Pine and C. M. Jantzen, "Implications of a One-Year Basalt Weathering/Reactivity Study for a Basalt Repository Environment," DP-1742, E.I. duPont de Nemours & Co., Savannah River Laboratory, Aiken, SC (March 1987). 14 15 16
6. G. R. Holdren, Jr. and R. A. Burner, "Mechanism of Feldspar Weathering I. Experimental Studies," Geochim. Cosmochim. Acta, 43, pp. 1161-1171 (1979). 17 18
7. D. E. Grindstaff, "The Dissolution Rate of Forsterite Olivine from Hawaiian Beach Sand," Proceedings of the Third International Symposium on Water-Rock Interactions, Alberta Research Council, Edmonton, pp. 72-74 (1980). 19 20 21
8. P. M. Tole, A. C. Lasaga, C. Pantano and W. B. White, "The Kinetics of Dissolution of Nepheline (NaAlSiO₄)," Geochim. Cosmochim. Acta, 50[3], pp. 379-392 (1986). 22 23
9. V. N. Fleer, "The Dissolution Kinetics of Anorthite (CaAl₂Si₂O₈) and Synthetic Strontium Feldspar (SrAl₂Si₂O₈) in Aqueous Solutions at Temperatures Below 100°C: With Applications to the Geological Disposal of Radioactive Wastes" Ph.D. Thesis, The Pennsylvania State University, University Park (1982). 24 25 26 27
10. G. F. Piepel, T. E. Jones, D. L. Eggett, G. B. Mellinger, "Product Consistency Test Round Robin Conducted by the Materials Characterization Center - Summary Report," U.S. Dept. of Energy Report PNL-6967, Materials Characterization Center, Battelle Pacific Northwest Laboratories, Richland, WA (1989). 28 29 30 31
11. N. E. Bibler and J. K. Bates, "Product Consistency Leach Tests of Savannah River Site Radioactive Waste Glasses," Scientific Basis for Nuclear Waste Management, XIII, V. M. Oversby and P. W. Brown (Eds.), Materials Research Society, Pittsburgh, PA, pp. 327-338 (1990). 32 33 34 35

BULKING FACTOR PROCEDURE FOR NONSLUDGE TYPE WASTE

The bulking factor is the measured percent volume increase/decrease of the treated waste, relative to the original waste volume. The bulking factor measurement for a pourable waste sludge will follow the Standard Operating Procedure (SOP) in Appendix B. For a nonsludge material, the bulking factor will be determined by using bulk density values. The bulking factor will be calculated by using the following equation:

$$BF = 100 * \frac{[(100 + A)/P_t - 100/P_r]}{100/P_r} \quad (1)$$

where

- BF = percent change in volume relative to untreated waste
- A = percent additives relative to untreated waste (weight to weight)
- P_t = density of treated waste
- P_r = density of raw waste

The bulk density of the raw waste will be determined in the site characterization. The bulk density of the treated waste will be calculated by dividing the weight of the unconfined compressive strength (UCS) solid cylinder (e.g., 1.5 by 3 or 2 by 4 inches) by its volume. (See "Stabilization/Solidification of CERCLA and RCRA Wastes," [EPA/625/6-89/022], Section 4.2.4 for a description of bulk density measurement of stabilized waste.)

Bulk density of the raw waste values used in the treatability study will be averaged values from several locations in each pit. These average values will be used in the bulking factor calculation.

The BF equation was derived as follows:

BF is defined as the percent change in volume resulting from treatment to the initial volume. This change can be presented mathematically as follows:

$$BF = 100 \frac{V_t - V_r}{V_r} \quad (2)$$

where

- V_t = volume of waste after treatment

V_r = volume of waste before treatment

1

Volume can be expressed as a function of density.

2

$$V = \frac{m}{P} \quad (3)$$

where

3

m = mass of waste

4

P = density of waste

5

Equation (2) can be used to express V_i and V_r

6

$$V_r = \frac{m}{P_r} \text{ and} \quad (4)$$

$$V_i = \frac{m + t}{P_i} \quad (4)$$

where

7

t = mass of reagents added

8

Substituting equations (3) and (4) into (1) gives:

9

$$BF = 100 \frac{[(m + t)/P_i - m/P_r]}{m/P_r} \quad (5)$$

This can be reduced as follows:

10

$$BF = 100 \frac{[(1 + \frac{t}{m})/P_i - 1/P_r]}{1/P_r} \quad (6)$$

$\frac{t}{m}$ is the fraction of reagents relative to the untreated waste. This can also be expressed as a percentage and redefined as follows:

1
2

$$\frac{100 t}{m} = A \quad (7)$$

Using equation (7) in (6) gives

3

$$BF = 100 \frac{[(100 + A)/P_t - 100/P_r]}{100/P_r} \quad (8)$$

5-DAY STATIC LEACH TEST PROCEDURE

The 5-day static leach test uses a monolith and demineralized water. These conditions are more representative of what would be expected for waste placed in a disposal facility. The 5-day static leach test is a modification of the American National Standard Measurement of the Leachability of Solidified Low-Level Radioactive Waste by a Short-Term Procedure. The 5-day static leach test differs from the ANSI/ANS-16.1-1986 as follows: the treated sample is leached for a 5 days continuously instead of 12 wash-leach periods over 90 days, the sample is supported in the leaching solution by a permeable polymeric material or a Teflon® cage, the effective diffusion coefficient will not be calculated, and the concentration of the metals in the treated sample before leaching will not be analyzed. Optionally, the sample may be soaked in another batch of deionized water leachant for an additional 85 days. The physical appearance of the sample would be noted after the cumulative 90-day leaching. The leaching solution may be analyzed as with the 5-day leaching solution.

The data obtained from the 5-day static leach test may be used during the risk assessment modeling segment of the RI/FS. The data will also help determine the effects of the pH of the leachate (which has an initial low ionic strength) on the leachability of the stabilized waste.

MODIFIED TCLP LEACH TEST PROCEDURE

The modified toxicity characteristic leaching procedure (MTCLP) leach test is a modification of the TCLP test. The TCLP procedure is in Federal Register, Vol. 55, No. 126, pages 26986 through 26998. The MTCLP screening data will be acquired in the initial stage(s) to minimize costs and waste generation.

The same leachant to solid ratio and leachants (TCLP Type 1 and 2) are used in both procedures. The MTCLP differs from the standard TCLP as follows: the MTCLP uses 2.5 grams of material instead of 100 grams; the MTCLP generates 50 milliliters of leachate instead of 2 liters; and the leachate from the MTCLP is analyzed for metals only rather than metals and organics.

WASTE AND REAGENT MIXING PROCEDURE

The waste will be sieved through a 3/8-inch-mesh screen before testing. Obvious debris such as chunks of wood and metal will be removed. The percent weight and visual observation of removed debris will be noted. The waste will be ground to one-tenth the inner diameter of the UCS before mixing, if necessary. In the preliminary phase, 100 to 110 grams of waste and correct amounts of reagents will be mixed in a plastic container or a metal mixing bowl. The amount of water added will be determined empirically. Enough water will be added to make the mixture into a paste. Mixing will be done by hand with a spatula until the mixture has an even consistency without any lumps or mixed in a Planetary mixer. The mixture will be compacted using a vibrating table. The plastic container will be filled approximately half full and vibrated at least 1 minute. The remainder of the container will be filled and vibrated for another 1 minute. The vibrating table will be set at approximately 38 percent maximum power. The container will be sealed with a lid and taped. The treated samples will be cured at room temperature for 28 days in the sealed containers.

In the advanced phase, approximately 300 grams of waste per mold will be mixed with the correct amount of reagents in Planetary mixer. The mixture will be placed into a 2- by 3-inch Jatco plastic cylinder in three to six aliquots. The mixture will be compacted using a vibratory table. After the molds are loaded, they will be capped and sealed with tape until the sample is tested on day 28.

The specified quantity of waste to use in the test may be changed due to the radiological activity of the waste.

STABILIZATION WASTE FORM TEMPERATURE RISE GENERIC PROCEDURE

1. Measure room temperature (A). 2
2. Mix waste and reagents thoroughly to homogenize the mixture. 3
3. Place 50 to 100 grams of homogenized mixture in a separate container. If the sample is cohesive, press the mixture into a mass along the side of the container. Place the thermometer near the center of the mass. 4
5
6
4. Monitor the mixture temperature. Record the temperature when the temperature reaches a peak and starts to decline (B). 7
8
5. Calculate the temperature rise (dT): $dT = B - A$. 9

The measured temperature rise is a qualitative test. It is conducted as a screening test to alert of potential problems and hazards during scale-up. Further investigations of the actual temperature rise may be made during the remedy design phase when larger equipment, which has a design similar to the full-scale equipment, will be used. 10
11
12
13

PERMEABILITY

The permeability of the treated samples will be determined by using procedures in EPA SW-846 and EM-1110-2-1906 as guidelines. There are several methods to choose from, depending on the sample matrix, and sample constraints (e.g., radioactivity and hazardous contaminants, sample condition on receipt, and clients' end use).

The method of choice for determining permeability of treated samples is described in SW-846, Method 9100, Section 2.8. This is the constant-head method using a triaxial-cell with back pressure. This method is applicable to cohesive samples, which are supplied in a molded form.

The constant head triaxial cell method may take a couple of days longer to run, but there is more control over sample conditions during the test, and a wide range of field conditions can be simulated.

There will be one slight modification to the method. A permeability cell will be substituted for the triaxial cell. The permeability cell is similar to the triaxial cell but does not have the plunger for applying a load to the sample. This plunger is not used in permeability testing, and its absence has no effect on the test.

It is anticipated that all of the samples for permeability testing will be of the cohesive, molded type. If a sample is in a form that precludes the above test, there are several options available in the referenced method. Items that would preclude the above test may include: small sample size due to radioactivity level, noncohesive sample, loose sample requiring remolding, and chemicals in the sample that are incompatible with the latex membrane.

A small sample size may require permeability testing in a consolidation cell. This method is not addressed in SW-846, but is found in the Army Corps of Engineers Manual EM 1110-2-1906, Appendix VII, paragraph 8.

Noncohesive samples will require the use of a solid wall permeameter, such as a compaction or standard permeameter. These methods are found in SW-846, Method 9100, Sections 2.5, 2.6, and 2.7, and include both constant-head and falling-head methods. The selection of constant- or falling-head methods is not critical as both methods provide similar results. These methods are also applicable to samples containing chemicals incompatible with the latex membrane.

If a sample requires remolding, a remolding density should be supplied. A moisture/density relationship curve can be generated to aid in the determination of remolding density. The permeability of remolded samples may be determined by any of the aforementioned methods. If the sample is

cohesive, the constant-head method, using a triaxial cell with back pressure, is again the method of choice.

1

2

GENERIC pH AND Eh PROCEDURE

I. Single Component Sample

1. Calibrate electrode as specified by the vendor. Record calibration data.
2. Place a few grams of material in a container (e.g., a 5-ounce plastic container).
3. Add water to mixture and stir with a spatula until a wet slurry is produced. There should be free water present. Enough water must be added to allow insertion of electrode in liquid phase with minimal contact with the solid phase. This procedure will minimize damage to the electrode.
4. Insert pH or Eh probe in liquid phase.
5. Take reading when measurement stabilizes.

II. Multicomponent Sample

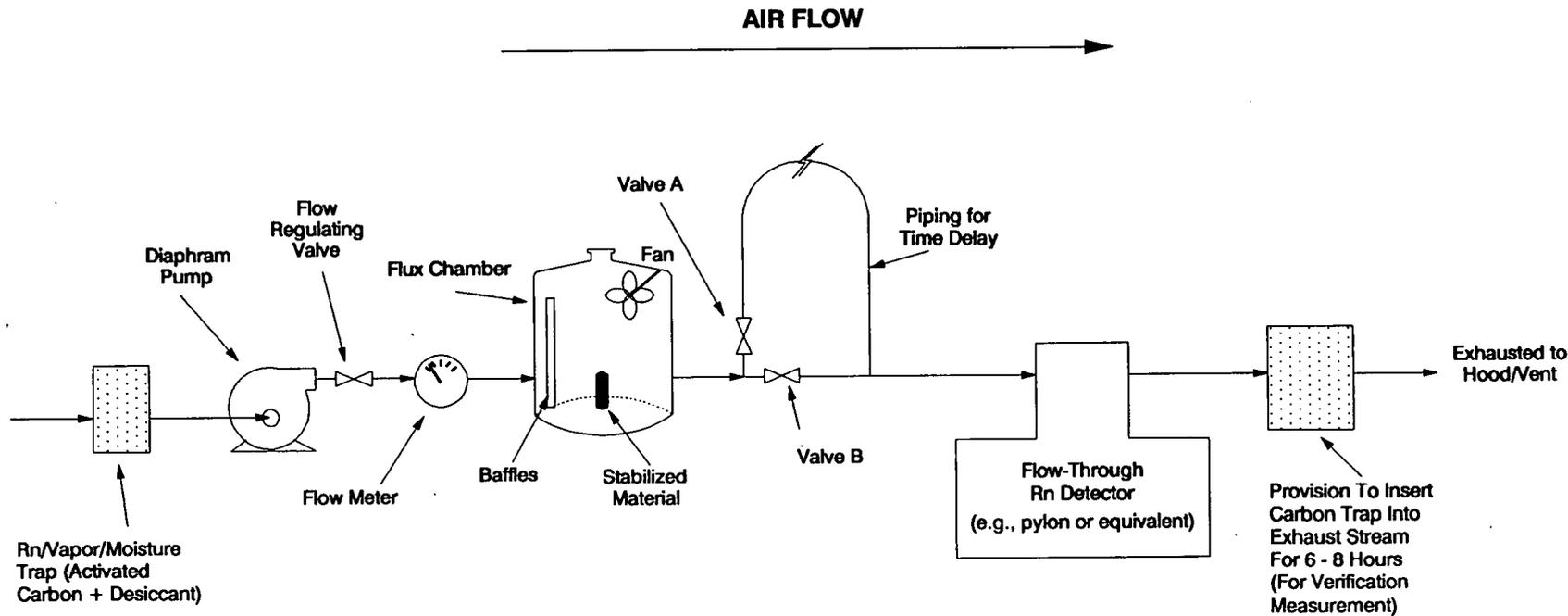
The procedure is the same with the single component sample except that the sample is mixed before it is added to the container.

PROPOSED RADON EMISSIONS FROM STABILIZED SOLIDS

		1
1.0	Purpose and Application	2
	A radon emission measurement technique is proposed for determining radon emissions from treated Operable Unit 1 materials. The test will determine the activity of radon emitted from the material's final form by measuring the radon activity in the air flowing through a chamber containing the waste form.	3 4 5 6
2.0	Definitions	7
2.1	See Figure C-1	8
3.0	Procedure	9
3.1	Summary	10
3.1.1	A cylinder of solidified material, having a known volume and surface area, is placed in a sealed container having one inlet and one outlet. Air is pumped through the chamber until equilibrium is reached. The radon in the exhaust stream is then measured. The radon emitted from the solidified material during a known time will be equal to the radon removed in the chamber's exhaust stream.	11 12 13 14 15
3.2	Interference No known interferences.	16 17
3.3	Sample Handling, Preservation, and Holding Time	18
3.3.1	Application of these procedures on hazardous waste samples must consider the known or suspected hazardous compounds present. Project-specific selection of work area, safe working practices, and personal protective equipment shall be made based upon exposure potential to the hazardous components.	19 20 21 22
3.3.2	All applicable safety and compliance guidelines set forth by IT Corporation and by federal, state, and local regulations must be followed during performance of this procedure. All work must be stopped if a known or potential compromise to the health or safety of any IT Analytical Services (ITAS) Associate, and must be reported immediately to a laboratory supervisor.	23 24 25 26 27

3.3.3	There are no holding times applicable to this procedure.	1
3.3.4	There are no preservation requirements applicable to this procedure.	2
3.4	Required equipment	3
3.4.1	Air-tight test chamber of known volume.	4
3.4.2	One (1) small fan.	5
3.4.3	One (1) diaphragm pump (Brailsford TD-3LL or equivalent).	6
3.4.4	One (1) rotameter.	7
3.4.5	Two (2) activated carbon radon canisters.	8
3.4.6	One (1) desiccant canister.	9
3.4.7	One (1) metering valve (Swagelok B-SS4 or equivalent).	10
3.4.8	Tubing, fitting, and connectors.	11
3.4.9	One (1) continuous flow radon detector (Pylon AB-5 or equivalent).	12
3.5	Operation	13
3.5.1	Assemble test equipment as shown in Figure C-1.	14
3.5.2	Place treated solid in test chamber with fan.	15
3.5.3	Start fan.	16
3.5.4	Open valve "A," and close valve "B."	17
3.5.5	Start pump.	18
3.5.6	Start radon detector in continuous counting mode.	19

- 3.5.7 Monitor detector until counts stabilize. 1
- 3.5.8 Switch detector to integrated count and count for 10 minutes. Record count. 2
- 3.5.9 Repeat step 3.5.7 two (2) times and record counts each time, for a total of three recorded measurements. 3
4
- 3.5.10 Open valve "B" and close valve "A." 5
- 3.5.11 Repeat steps 3.5.6 through 3.5.8. 6
- 3.5.12 Remove solid and store in air-tight container. 7
- 3.5.13 Switch radon detector to continuous mode. 8
- 3.5.14 Continue operating system until count rate returns to background levels. 9
- 3.5.6 Quality Control 10
- 3.5.6.1 None. 11
- 4.0 Nonconformance and Corrective Action 12
- 4.1 Any failure to follow this procedure will be noted on a nonconformance memo. The corrective action will be verified by the quality control coordinator and approved by the appropriate operations manager. 13
14
15
- 5.0 Records Management 16
- 5.1 All data will be recorded in standard laboratory notebooks. 17



FL/FMPC/0105-8/C-1

179

FIGURE C-1. PROPOSED RN-222 COLLECTION/MEASUREMENT SYSTEM

Calculations: 1

The radon emitted from the solidified form will be calculated using the following equation: 2

$$A \text{ (pCi)} = C \text{ (pCi/L)} * Q \text{ (L/min)} * T \text{ (min)}/M \text{ (g)} \quad (1) \quad 3$$

where 4

- A = Radon activity emitted per gram of sample over time, t (pCi/g) 5
- C = Measured concentration of radon in exhaust air at equilibrium (pCi/L) 6
- M = Initial mass of sample in solidified material (g) 7
- Q = Flow rate (L/min) 8
- T = Time of count (10 min) 9

Example calculation: 10

Assuming the measured concentration of radon from a 200 gram sample (M = 200) is 100 pCi/L (C = 100) during a 10-minute count (T = 10) at a flow rate of 1 L/min (Q = 1), A becomes: 11 12

$$A = 100 \text{ pCi/L} * 1 \text{ L/min} * 10 \text{ min}/200 \text{ g} \quad 13$$

and 14

$$A = 5 \text{ pCi/g} \quad 15$$

SHEAR STRENGTH

1

The following is a procedure to determine shear strength.

2

MODEL ~~CL 600A~~ 2425

~~TORVANE SHEAR DEVICE~~

Technical Data



Soiltest, Inc. • 86 Albrecht Drive • P.O. Box 8004
Lake Bluff, Illinois 60044-8004 U.S.A.

Telephone (708) 295-9400
Telex: 687-1537 SOILT UW • FAX (708) 295-9414

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
1	GENERAL	1-1
	PROCEDURE	1-2
	LAB USES	1-3

1. GENERAL

2425

The CL-600A Torvane is a scientifically designed soil testing instrument for the rapid determination of shear strength of cohesive soils, either in the field or in the laboratory.

The Torvane permits the rapid determination of a large number of strength values with different orientation of failure planes. It is simple to use and sample trimming is eliminated. All that is required is a reasonably flat two-inch minimum diameter surface.

The Torvane, ideally suited to field usage, is an invaluable addition to the inspector's kit or to the consulting engineer. Here are some suggested applications for evaluation of shear strength.

1. Ends of Shelby tube samples.
2. Standard penetration samples.
3. Split spoon samples.
4. Chunk samples from test pits and backhoe excavations.
5. Sides of test pits.

The instrument has a stress range of zero to 2.5 kg./sq. cm (tons/sq. ft.). This is also the approximate range of torque that can be easily applied by the fingers. It should be used only for fully saturated cohesive soils whose undrained strength is independent of normal pressure. The stress range permits it to be used for clays varying in consistency from very soft to stiff. The dial head is equipped with a mechanism to hold the maximum reading after release. The instrument is supplied with three vanes. The standard vane (1 inch diameter) is for a range of 0 to 1.0 kg./sq. cm. The sensitive vane (1 7/8 inch diameter) is for a range of 0 to 0.2 kg./sq. cm. When this vane is used, multiply the scale reading by 0.2 to get the shear strength of the material. The high capacity vane (3/4 inch diameter) is for the range of 0 to 2.5 kg./sq. cm. When this vane is used, multiply the reading by 2.5.

184

The Torvane was developed in connection with an investigation of ²⁴²⁵ several massive landslides which occurred as a result of the Alaska earthquake in 1964. Its original purpose was to speed up the job of determining the shear strength of cohesive soil at the ends of Shelby tube samples rather than resort to conventional compression testing methods.

Tests performed with the Torvane also provide excellent supplemental data for extensive foundation investigation programs. The results of such tests are rapid and accurate. The Torvane also can be used successfully in evaluating site conditions in the planning of laboratory investigations.

The shear strength of a cohesive soil is dependent upon many factors, including rate of loading, progressive failure, orientation of the failure plane and pore water migration during testing. The Torvane does not eliminate the effects of any of the variables. Homogeneous clay and extensive laboratory testing indicates excellent agreement between the unconfined compression test and the Torvane. The smallest division on the dial is in units of 0.05 kg./sq. cm., permitting visual interpolation to the nearest 0.01 kg./sq. cm. The graph showing the correlation between readings of the Torvane and shear strength values by unconfined compression tests and triaxial tests are given in Figure 1.

2. PROCEDURE

- 2.1 Prepare a flat surface on the cohesive undisturbed material.
- 2.2 Attach the standard vane of suitable range to the stem by pressing the end of the stem into the square recess on the vane all the way.
- 2.3 Check that the zero of the circular scale coincides with the index on the head. If not, rotate the dial with finger tip on the embossed numbers in the counter clockwise direction until it stops at the index.

2.4 Press the Torvane carefully into the soil with the stem at right angles to the surface, to the depth of the blades.

2.5 Maintaining a constant vertical load by finger pressure, slowly turn the knob at a constant rate to provide a torque on the vane. Note: A rate of rotation such that failure develops in 5 to 10 seconds is recommended.

2.6 After sample fails, read Torvane shear strength on the circular scale just against the index.

2.7 Multiply the reading by the proper scale factor to get the shear strength. (For the high capacity vane, the smallest, the scale factor is 2.5; for the sensitive vane, the largest, the scale factor is 0.2; for the standard vane, medium size, the scale factor is 1.)

2.8 Before making another test, re-zero the scale by rotating it with finger tip in the counter clockwise direction until it stops at the index.

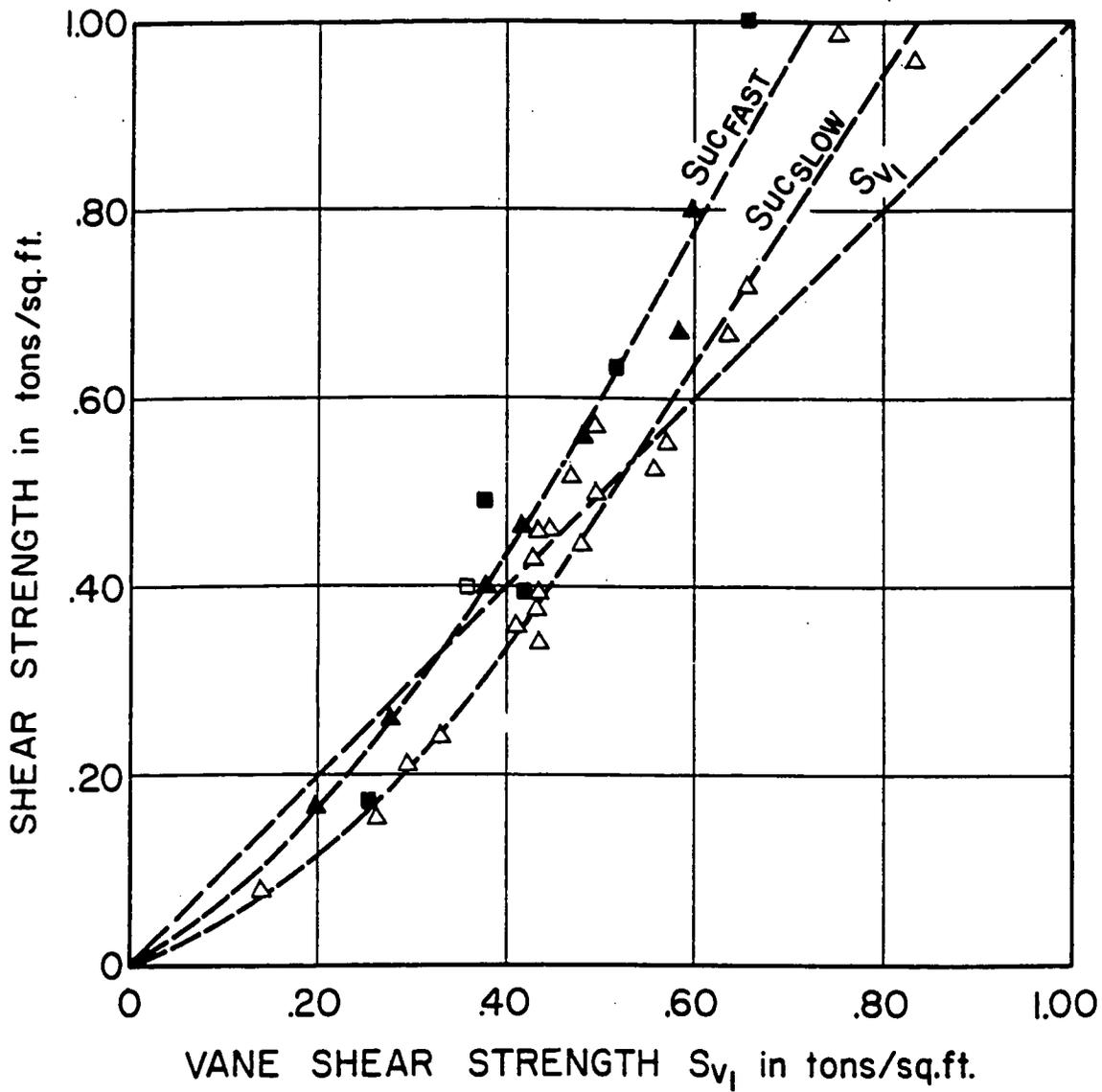
2.9 Take readings at different spots (if possible) on the surface and calculate the average value.

3. LAB USES

3.1 Before conducting unconfined compression tests or triaxial tests on undisturbed samples, cut the sample into segments 1/2 inch longer than the desired length, and perform Torvane test on each end. Then trim the material disturbed by the test. It is easier to do the test while the specimen is in the sampling tube, after trimming at one end.

3.2 Use the Torvane test as a control test to determine the shear strength prior to other testing.

3.3 In consolidation testing, after the specimen has been consolidated under a desired normal stress, remove the upper porous stone and determine the consolidated shear strength of the specimen using the Torvane.



LEGEND

- Δ S_{UCSLOW} - Unconfined compression test, slow test: $S_{uc} = 1/2 q_u$
- \blacktriangle S_{UCFAST} - Unconfined compression test, quick test: $S_{uc} = 1/2 q_u$
- \blacksquare S_Q - Triaxial compression test, Q test: $S_Q = 1/2 (\sigma_1 - \sigma_3)_{max}$.

Figure 1

VITRIFICATION OF WASTE

The waste will be analyzed to determine the metals and silica concentrations. This will be used to estimate the quantities of glass-making reagents required. Reagents will be mixed in by hand and placed in a crucible. The mixture will be melted in the muffle furnace at approximately 1250°C.

This temperature was chosen to give a reasonable compromise between the cost of adding sodium oxide content to lower the melting point, the expected increase in leachability as the melting point of mixture is lowered, and the energy cost to melt and form the material.

**GENERIC URANIUM BY ION CHROMATOGRAPHY
WITH POST-COLUMN REACTION AND
PHOSPHORESCENCE OR FLUORESCENCE DETECTION**

This method uses ion chromatography in the cation-exchange mode to separate the uranium as UO_2^{+2} (uranyl ion) from interferences. As the uranyl ion leaves the analytical column it is mixed with 39 percent H_3PO_4 to give a final concentration of approximately 19 percent H_3PO_4 . The addition of H_3PO_4 enhances the fluorescence of the uranyl ion. Finally, the post-column reaction mixtures pass through a flow-through cell mounted in a fluorescence detector. Response has been found to be linear over the range studies (10 to 500 parts per billion [ppb]). The equipment and conditions for this method are listed below:

- High performance liquid chromatography (HPLC) pump - LDC/Milton Roy Constametric III
- Post-column reagent pump - LDC/Milton Roy Constametric III
- Injection valve - Altex 210
- Sample loop size - 147 μL
- Analytical columns - Dionex HPIC-CG2 Cation Guard
- Analytical columns - Dionex HPIC-CG2 Cation Analytical
- Post-column reactor (PCR) - 1/16-inch SS low dead volume "TEE" and 12-inch coil, heated 60°C with a water bath
- Detector - Perkin Elmer 204 - S Fluorescence Detector
- Detector excitation wavelength - 275 nm
- Detector emission wavelength - 515 nm
- Eluant - 0.1 M H_3PO_4
- Eluant Flow - 1.5 mL/min
- PCR reagent - 39 percent weight H_3PO_4 (1 volume 85 percent H_3PO_4 to two volumes H_2O)
- PCR reagent flow rate - 1.1 mL/min

The concentrations of H_3PO_4 and brands of equipment are for examples only. They may be modified during the study.

APPENDIX D

HEALTH AND SAFETY PLAN
FOR THE
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
WASTE PITS 1, 2, 3, 4, 5, 6, the CLEARWELL, AND
THE BURN PIT TREATABILITY STUDY
REMEDIAL SCREENING, REMEDY SELECTION PHASES

TABLE OF CONTENTS

	<u>Page</u>
D.1.0 Introduction	1
D.1.1 Scope of Work	1
D.1.1.1 Preliminary Characterization	1
D.1.1.2 Cement Stabilization	1
D.1.1.3 Vitrification	2
D.2.0 Responsibilities	3
D.3.0 Site History	4
D.4.0 Task Specific Hazard Assessment	5
D.4.1 Physical Hazards	5
D.4.2 Chemical Hazards	5
D.4.3 Potential Routes of Exposure and Hazard Assessment	6
D.5.0 Monitoring	8
D.5.1 Goals	8
D.5.2 External Radiation Hazard Monitoring	8
D.5.3 Action Limits	8
D.6.0 Personal Protective Equipment and Exposure Reduction	9
D.6.1 Personal Protective Equipment	9
D.6.1.1 Respiratory Protection	9
D.6.1.2 Eye Protection	9
D.6.1.3 Protective Clothing	9
D.6.2 Exposure Reduction	9
D.6.2.1 Engineering Controls	9
D.6.2.2 Administrative Controls	9
D.6.2.3 Safe Work Practices	10
D.6.2.4 Equipment Inspection	10
D.7.0 Laboratory Access and Entry Procedures	11
D.7.1 Bioassay Sampling	11
D.7.2 Medical Monitoring	11
D.7.3 Training Requirements	11
D.7.4 Contamination Zones	11
D.7.5 Laboratory Entry Procedures	12
D.8.0 Laboratory Exiting Procedure	13
D.8.1 Contamination Detection	13
D.8.2 Decontamination	13
D.9.0 Exposure Symptoms	14
D.10.0 Operationally Derived Wastes	15
D.11.0 Contingency Plans	16

D.1.0 INTRODUCTION

This Health and Safety Plan (HSP) in conjunction with the laboratory Chemical Hygiene Plan (CHP) establishes the work practices necessary to help ensure protection of IT Corporation (IT) personnel during the Operable Unit 1 (Operable Unit 1) laboratory screening to be performed at IT's Environmental Technology Development Center (ETDC) Laboratory in Oak Ridge, Tennessee.

The objective of this plan is to provide a mechanism for the establishment of safe and healthy working conditions at the laboratory. The safety procedures have been established following an analysis of potential hazards at the laboratory, and procedures have been developed to minimize the potential of accident or injury.

All laboratory operations will be performed in accordance with applicable state, local and IT Corporate regulations and procedures and OSHA requirements.

D.1.1 SCOPE OF WORK

This laboratory screening will involve mixing Operable Unit 1 waste pit samples with various reagents to conduct cement stabilization and vitrification testing. Cement stabilized wastes will then be tested for unconfined compressive strength (UCS) using a Soiltest U-590 or U-610. Following compressive strength testing, the waste forms will be tested for leaching characteristics using a modified toxicity characteristics leaching procedure (TCLP) test, a full TCLP test, and five-day static leach test. Vitrified waste will be subjected to MTCLP, full TCLP, and PCT tests. This testing will be performed at IT's ETDC Laboratory.

D.1.1.1 Preliminary Characterization

The samples drawn under the Operable Unit 1 SAP will be composited at the Fernald Environmental Management Project (FEMP) in Ross, Ohio. These activities will be governed by the Health and Safety Plan for the SAP.

D.1.1.2 Cement Stabilization

The cement stabilization laboratory screening will consist of mixing cement stabilization reagents (portland cement, fly ash, sodium silicate, attapulgite, clinoptilolite, water) in varying quantities with waste pit material. These stabilization reagents will be mixed with 100 grams of composited pit waste in a graduated plastic cup. Mixing will be performed by hand with a spatula until the mixture is homogeneous (approximately two minutes). After a prescribed setting period the stabilized wastes will be tested for compressive strength and leachability characteristics.

D.1.1.3 Vitrification

The vitrification laboratory screening will consist of first attempting to vitrify the waste pit material in a laboratory furnace without the benefit of vitrifying agents. Waste pit material will then be mixed with vitrifying agents (sodium hydroxide, site/commercial fly ash, and site soil) in varying quantities in a manner identical to that described in the previous section and vitrified. After a prescribed cooling period the stabilized wastes will be tested for leachability characteristics.

1
2
3
4
5
6

D.2.0 RESPONSIBILITIES

The following is a listing of those personnel responsible for various activities in the Health and Safety program and their responsibilities:

- ETDC Health & Safety (H&S) Officer (Keith Hood) - responsible for the technical development and coordination of the Health and Safety Plan (HSP). Inquiries regarding the HSP, IT Corporate H&S Procedures, and other technical or regulatory items shall be addressed to the Health and Safety Officer.
- Laboratory Project Supervisor (Ernie Stine) - responsible for implementation of the HSP. This shall include communication of requirements to all personnel and interaction with client representatives and regulatory agencies. Additional communication may include consultation with the H&S Manager regarding the execution of the project and the HSP.
- Laboratory personnel - responsible for understanding and complying with all site H&S requirements. Each team member shall be provided training on the requirements of this HSP prior to the beginning of the project.
- Emergency Coordinators (Tom Geisler, Rick Greene) - shall be responsible for and have the full authority to commit any personnel or equipment necessary for response and recovery operations during spills, disasters, or other emergencies.

D.3.0 SITE HISTORY

1

A variety of chemical and metallurgical processes were utilized at the Fernald Environmental Management Project (FEMP) for the manufacture of uranium products. During the manufacturing process, high quality uranium compounds are introduced into the processes at several points. Impure starting materials are dissolved in nitric acid, and the uranium is purified through solvent extraction to yield a solution of uranyl nitrate. Evaporation and heating convert the nitrate solution to uranium trioxide (UO_3) powder. This compound is reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal is produced by reacting UF_4 and magnesium metal in a refractory-lined vessel. This primary uranium metal is then remelted with scrap uranium metal to yield a purified uranium ingot.

2

3

4

5

6

7

8

9

10

The waste pits to be studied consist of Pits 1 through 4 and the Burn Pit. They are numbered chronologically in their order of construction. Pits 3, 5, and 6 and the Clearwell are referred to as "wet" because they received mostly waste in slurry form. Pits 1, 2 and 4 and the Burn Pit are referred to as "dry" because they received mostly dry solid waste from trucks. These low-level radioactive waste storage pits received varying quantities of neutralized waste filter cakes, graphite, brick scrap, sump liquor and cakes, depleted slag, process residues, slurries and raffinates. The volumes of waste in the pits range from a low of 11,556 cubic yards (cy) in Pit 6 to a high of 237,053 cy in Pit 3.

11

12

13

14

15

16

17

D.4.0 TASK SPECIFIC HAZARD ASSESSMENT

The following hazard assessment is based on historical information and defined task activities. The laboratory personnel routinely reassess the hazards before starting work to ensure that conditions have not changed. All newly identified hazards will be addressed with the Health and Safety Officer to determine the degree of hazard and if any changes to the HSP are needed.

D.4.1 PHYSICAL HAZARDS

- Radiological Hazards
- U-238 and daughters
- U-235 and daughters

<u>Contaminant</u>	<u>Derived Air Concentration</u>	<u>Action Limit .25DAC</u>
Thorium-230	$3 \times 10^{-12} \mu\text{Ci/mL}$	$7.5 \times 10^{-13} \mu\text{Ci/mL}$
Uranium-238	$2 \times 10^{-11} \mu\text{Ci/mL}$	$5 \times 10^{-12} \mu\text{Ci/mL}$
Uranium-235 (trace levels of actinium series)	$2 \times 10^{-11} \mu\text{Ci/mL}$	$5 \times 10^{-12} \mu\text{Ci/mL}$
Uranium-234	$2 \times 10^{-11} \mu\text{Ci/mL}$	$5 \times 10^{-12} \mu\text{Ci/mL}$

D.4.2 CHEMICAL HAZARDS

The following chemicals will be present, either in the samples, or in the reagents, and pose potential hazards. Other materials, such as fly ash, lime, and cement/sodium silicate will be present but pose no significant hazard due to their relatively low toxicity and small quantities.

<u>Chemical</u>	<u>PEL</u>		
	<u>TWA</u>	<u>STEL</u>	
Reagents			
Acetic Acid	10 ppm	None	
1,1,1-Trichloroethane	350 ppm	450 ppm	
Sodium hydroxide	None	2 mg/m ³ (C)	
Uranium	0.05 mg/m ³ *		
	0.02 mg/m ³ **	0.6 mg/m ³ **	

PEL - Permissible exposure limit, or maximum airborne exposure allowed by OSHA.

Types of PELs include TWAs, STELs, and ceilings.

TWA - Time weighted exposure limit, or average exposure allowed over an 8-hour shift.

STEL - Short term exposure limit, or maximum average exposure during a 15-minute period

C - Ceiling, or maximum exposure allowed, even instantaneously.

* - Soluble compounds

** - Insoluble compounds

D.4.3 POTENTIAL ROUTES OF EXPOSURE AND HAZARD ASSESSMENT

The identified site contaminants are solids in nature and the majority of the reagents to be used are liquids. The potential routes of entry into the body are inhalation, absorption, and ingestion, in their order of importance. Radioisotopes in the sample pose an external and internal exposure hazard. The internal hazard is largely eliminated by the procedures to be utilized. The external hazard will be controlled through air monitoring. Direct skin contact with the corrosives may result in destruction of skin tissue and absorption of other contaminants if in solution.

To minimize the potential exposure hazards, nearly all of the operations to be carried out during this project will be performed inside a laboratory exhaust hood, which is located inside an environmental containment cubicle. These operations include sample preparation, pouring reagents, and packaging for disposal. The only operations planned to be performed outside the hood are transport of the waste pit samples to and from the hood and transport of reagents to the hood. All container opening will be done only inside the hood. Reagents have been prepared and packaged off-site to further minimize on-site handling.

The use of the hood greatly minimizes any potential for exposure to the hazards associated with the pit 1
samples or the reagents. To minimize the potential for radiation exposure, air monitoring will be 2
conducted to quantify the exposure and ensure that the procedures in use are appropriate. 3

D.5.0 MONITORING

D.5.1 GOALS

Air monitoring will be performed to ensure that contaminant concentrations in the breathing zone do not exceed the concentrations specified by established exposure levels.

Exposures to chemicals should be kept as low as possible because there are insufficient data to predict the combined effects of most chemical mixtures.

D.5.2 EXTERNAL RADIATION HAZARD MONITORING

A health physics technician will monitor all locations before start of work and will frequently monitor exposures in all areas that exceed the one millirem (mrem)/hour action limit. Measures such as increasing shielding, increasing distance, or reducing exposure time will be taken to minimize exposures. Radiation monitoring instruments include:

- Ludlum Model 177, or equivalent, with a G-M pancake probe
- Ludlum Model 3, or equivalent, with a ZnS alpha scintillation probe
- Eberline Model Alpha-5A alpha air monitor, or equivalent.

D.5.3 ACTION LIMITS

The following table provides types, scheduling, and actions for monitoring.

Instrument/chem.	Need	Interval	Limit	Action
Alpha probe	Y	Pre-job and intermittent	20 cpm ^a	HP Review
Beta/gamma probe	Y	Pre-job and intermittent	500 cpm ^a	HP Review
External radiation	Y	Pre-job	>1 mrem/hour	HP Review
Continuous air monitor (CAM)	Y	Continuous	4 MPC-hrs of Th-230	Withdraw
Thermoluminescent dosimetry (TLD) badge	Y	Continuous	N/A, no real time results	
TLD ring	Y	Continuous	N/A, no real time results	

^aAbove background

D.6.0 PERSONAL PROTECTIVE EQUIPMENT AND EXPOSURE REDUCTION 1

D.6.1 PERSONAL PROTECTIVE EQUIPMENT 2

D.6.1.1 Respiratory Protection 3

The need for respiratory protection will be evaluated by a professional industrial hygienist and health physicist before activities begin. 4
5

D.6.1.2 Eye Protection 6

A face shield with goggles is required when performing the tests due to the potential for splash when using concentrated acids and bases. 7
8

D.6.1.3 Protective Clothing 9

A rubber apron and long sleeves are required when performing tests due to the potential for splash when using concentrated acids and bases. Additionally, chemical-resistant gloves will be worn when performing tests. 10
11
12

D.6.2 EXPOSURE REDUCTION 13

D.6.2.1 Engineering Controls 14

The operations will be performed under a laboratory exhaust hood in an environmental containment cubicle that is under negative ventilation. This cubicle is located in the environmental containment cubicle room which is also under negative ventilation. A slant manometer or magnehelic gage will be utilized to measure and indicate the pressure differential created by the air flow. 15
16
17
18

The laboratory exhaust hoods are in the work area and will be kept free of materials placed where they will block the vents, reducing air flow. 19
20

D.6.2.2 Administrative Controls 21

Control Access to Work Area 22

Access to contamination work areas will be regulated and limited to authorized personnel. Warning signs will be affixed in readily visible locations in or near the work area as required by applicable regulations. The work area shall be divided into the following three zones: 23
24
25

- Exclusion zone - This zone will include the highest potential concentrations of contamination. This zone has the highest potential for skin contamination and inhalation exposures. The exclusion zone will be the environmental containment cubicle. 26
27
28

- Contamination reduction zone - This zone includes all areas immediately adjacent to the exclusion zone. Personnel contamination monitoring will take place in this zone. 1
2
- Support zone - This area covers all areas outside of the contamination reduction zone. 3
Exposure to harmful chemicals or radioactive materials in this zone is highly unlikely. 4

D.6.2.3 Safe Work Practices 5

All personnel will follow the safe work practices outlined in the chemical hygiene plan for the ETDC. 6

D.6.2.4 Equipment Inspection 7

All equipment used in the testing will be inspected prior to use. Defective equipment will reported to the Project Manager and repaired prior to use. 8
9

D.7.0 LABORATORY ACCESS AND ENTRY PROCEDURES 1

Access to the environmental containment cubicles during treatability studies will be limited to personnel who have completed required training and have had required medical exams. 2
3

D.7.1 BIOASSAY SAMPLING 4

A baseline 24-hour urine sample will be taken before starting treatability activities and a post-work 24-hour urine sample will be submitted upon completion of activities. 5
6

A post-work, 24-hour urine sample will be submitted upon completion of work and will be analyzed for uranium and Ra-226. If significant uptake of radioactivity is suspected, fecal samples will be analyzed for Th-230. 7
8
9

Additional urine samples will be required if air samples indicate an acute exposure of 40 DAC-hours (two percent of the annual limit of intake [ALI]). A one-hour exposure leading to 40 DAC-hours for radon daughters is 12.0 WL or 1,200 pCi/L for Rn-222 in 100 percent equilibrium with its daughters. A point worth noting is that no respirator protection factors are built into these action levels. 10
11
12
13

D.7.2 MEDICAL MONITORING 14

In accordance with 20 CFR 1910.120 OSHA requirements, all personnel involved in the treatability study are required to participate in a medical monitoring program that includes: 15
16

- A baseline medical examination 17
- Annual medical examination 18
- Medical examinations that may be required after potential exposures 19

D.7.3 TRAINING REQUIREMENTS 20

All personnel at the ETDC involved in the treatability study have the following training: 21

- IT Chemical Hygiene Plan 22
- ETDC Emergency Contingency Plan 23
- General Employee Training - Rad Worker Training 24
- Hazard Communication Training 25

D.7.4 CONTAMINATION ZONES 26

The Exclusion Zone is the zone of high potential hazard due to physical, chemical, or radiological dangers. Access to the Exclusion Zone is restricted to employees who are required to enter to perform their job functions. The area inside the environmental containment cubicles is considered to be the Exclusion Zone. 27
28
29

D.7.5 LABORATORY ENTRY PROCEDURES

The following activities shall be conducted prior to and during the work day, as appropriate:

- Perform respirator check out and fit test prior to use
- Locate the nearest eyewash/shower and fire extinguisher prior to initiating activities

- Verify all instruments are calibrated
- Visually scan the laboratory for signs of contamination

Note: The Health and Safety Manager and any member of the team have the authority to stop work when imminent or serious safety hazards or conditions exist. Restart of work will be allowed only after the hazard or condition has been abated or reduced to an acceptable level.

D.8.0 LABORATORY EXITING PROCEDURE

D.8.1 CONTAMINATION DETECTION

All personnel are required to follow decontamination procedures themselves and then confirm the effectiveness of the decontamination. The effectiveness will be determined by frisking with a hand held radiation monitor.

The monitor must be held within one-half inch of the surface and moved at a rate of approximately one inch per second for effective radiation monitoring. If frisking count exceeds DETECTABLE, additional decontamination is required. This decontamination will be conducted by gently scrubbing with soap and water.

In the event that contamination cannot be removed to below the action levels (100 cpm beta/gamma or detectable alpha radiation above background), notify the Health and Safety Manager.

D.8.2 DECONTAMINATION

Decontamination reduces contaminant concentrations to acceptable levels, but does not generally remove it totally. Try to avoid contamination where possible by making minimum contact with the contaminant.

Personnel: Dry removal of disposable protective equipment; wash hands, face and any other exposed skin. Detergent and tepid water should be used to gently scrub skin surfaces that have contacted potentially contaminated wastes.

Equipment: Any exposed areas of the equipment surface will be wiped with a damp paper towel/cloth to remove contamination. Wiping and cloth dampened with detergent solution may be necessary to remove greasy materials.

The effectiveness of decontamination must be confirmed by frisking.

D.9.0 EXPOSURE SYMPTOMS

Acute exposure to solvents and corrosives may produce dizziness and/or irritation. Exposures to low levels of radioactivity do not produce acute exposure symptoms. The exposures may cause delayed effects such as cancer. Since biological effects from radiation exposures are cumulative, exposures are to be kept As Low As Reasonably Achievable (ALARA).

No treatment is anticipated for the predicted contaminants and concentrations. Any emergencies arising during the performance of work will be covered by IT's Emergency Contingency Plan (ECP) prepared for the ETDC.

D.10.0 OPERATIONALLY DERIVED WASTES

Operationally derived wastes are wastes generated in the performance of various activities. These wastes include, but are not limited to:

- Disposable PPE such as Tyvek coveralls, gloves, booties.
- Disposable decontamination supplies.

Protective clothing will be placed in plastic bags, placed in a B-25 box or metal drum for disposal as compactible, potentially contaminated waste by Westinghouse Environmental Management Company of Ohio (WEMCO).

Operationally derived wastes are the property of the client and are to be shipped back to WEMCO unless otherwise specified in the written contract.

The client will be responsible for proper transport, shipment or disposal unless otherwise specified in the written contract.

D.11.0 CONTINGENCY PLANS

1

Contingency plans for injuries, spills, releases, fires, and explosions are given in the ECP for the
ETDC. The ECP identifies ETDC emergency coordinators. Agencies that may be requested to
provide assistance in an emergency are also listed along with phone numbers. Copies of the ECP will
be available on site to all personnel.

2

3

4

5

APPENDIX E
RADIOLOGICAL AND CHEMICAL CONSTITUENTS
OF THE WASTE PITS

TABLE E-1. SUMMARY OF RADIOLOGICAL CONSTITUENT RESULTS FOR THE WASTE PITS^a
(Concentration Ranges in pCi/g)

Radionuclide (pCi/g)	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Background (Average)
Cs-137	<0.2 - 1.10	<0.2 - 3.6	<0.2 - <6.0	<0.2 - <0.5	2.0 - 76	0.8
Np-237	<0.1 - 0.3	<0.1 - <0.4	<0.1 - 2.1	<0.1 - 0.4	0.3 - 23	--
Pu-238	<0.1 - 0.1	<0.1 - 0.1	<0.05 - 1.0	0.1 - 0.5	0.1 - 4.4	--
Pu-239	<0.1 - 0.1	<0.1 - 0.6	<0.05 - 14.0	0.1 - 0.4	0.1 - 13	--
Ra-226	12 - 60.2	12.2 - 412	3.1 - 369	5 - 20	235 - 999	1.5
Ru-106	<2.0 - <4.0	<2.0 - 35	<2.0 - <35	<2.0 - <4.0	<13 - <35	<1.0
Sr-90	<0.3 - <0.6	<0.3 - <1.0	<0.5 - 26	<0.4 - <1.0	0.8 - 23	--
Tc-99	<1 - 15	<1 - 618	<1 - 1110	6.8 - 225	423 - 2990	--
Th-228	1.8 - 18.0	0.3 - 73	1.0 - 82	0.3 - 22.0	41 - 191	--
Th-230	122 - 1980	1.2 - 3980	15 - 21,900	2.2 - 566	3080 - 20,200	1.4
Th-232	1.8 - 17.0	0.1 - 88	1.0 - 121	0.3 - 21.0	21 - 90	1.0
U-234	244 - 1180	39 - 18,200	27 - 475	149 - 2320	310 - 1250	1.4
U-235	16 - 151	1 - 8780	2.5 - 21	35 - 426	14 - 79	0.063
U-238	360 - 6980	53 - 17,900	134 - 1380	509 - 15,800	387 - 1230	1.4

FERROU-6/MP350/EI/0-05-91

209

R/FS Treatability Work Plan
October 10, 1991
Vol. WP-Appendix E
Page 1 of 8
2425

TABLE E-1. (Continued)

Radionuclide (pCi/g)	Pit 6	Burnpit	Clearwell	Background (Average)
Cs-137	4.0 - 31	<0.2 - <0.6	18.0 - 450	0.8
Np-237	0.9 - 4.5	0.1 - 0.7	<0.4 - 2.7	-
Pu-238	0.4 - 1.4	0.1 - 0.5	<0.1 - <0.1	-
Pu-239	4.0 - 15	0.1 - 0.4	<0.1 - 0.4	-
Ra-226	<16 - <30	<2.0 - 3.9	21.6 - 458	1.5
Ru-106	35.0 - 35.0	2.0 - 2.0	<3 - <24	<1.0
Sr-90	0.5 - 4.0	<0.5 - <0.9	1.3 - 26	-
Tc-99	84 - 164	<0.4 - 64.0	0.4 - 278	-
Th-228	0.2 - 2.0	0.1 - 9.6	0.2 - 41	-
Th-230	14 - 41	0.1 - 26.0	0.3 - 5600	1.4
Th-232	0.2 - 1.2	0.1 - 7.7	0.1 - 39	1.0
U-234	2000 - 5330	9.9 - 415.0	242 - 376	1.4
U-235	350 - 1750	0.5 - 27.0	24 - 49	0.063
U-238	12,500 - 18,700	22 - 454	548 - 670	1.4

^aSummarized from the CIS Volume 2 (Weston 1987b).

TABLE E-2. SUMMARY OF INORGANIC CHEMICAL CONSTITUENT RESULTS FOR THE WASTE PITS^a
(Concentration Ranges in ppm)

Inorganics (ppm)	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Background (Average)
Arsenic	14 - 15	3 - 10	514 - 3116	5 - 5 ^c	139 - 2800	7.4
Beryllium	2 - 2 ^c	2 - 9	3 - 24	13 - 13 ^c	3 - 18	0.8
Cadmium	1 - 5	3 - 10	2 - 13	2 - 29	4 - 17	1.7
Chromium	6 - 46	16 - 91	16 - 152	8 - 94	26 - 223	52.0
Cobalt	28 - 28 ^c	14 - 451	-- ^b	84 - 84 ^c	16 - 44	9.2
Copper	19 - 161	26 - 329	80 - 2333	20 - 188	672 - 3370	22.0
Lead	5 - 90	21 - 190	26 - 613	14 - 63	60 - 236	17.0
Manganese	145 - 2915	495 - 917	407 - 10,571	1383 - 3596	346 - 4740	640.0
Mercury	0.26 - 0.36	0.2 - 0.7	0.5 - 4.0	0.2 - 0.6	0.4 - 1.8	0.12
Nickel	9 - 65	29 - 609	22 - 504	21 - 50	53 - 202	18.0
Potassium	165 - 2564	667 - 4319	810 - 2894	303 - 1920	611 - 1490	-- ^b
Selenium	-- ^b	2 - 10	2 - 90	-- ^b	3 - 7	-- ^b
Silver	2.25 - 33.1	6 - 23	4 - 8	3 - 444	8 - 9	2.8
Sodium	386 - 3639	411 - 2303	1192 - 7640	255 - 1238	1426 - 9980	--
Thallium	-- ^b	-- ^b	6 - 12	-- ^b	3 - 3 ^c	--
Vanadium	14 - 67	27 - 106	50 - 9696	14 - 235	792 - 5380	6.6
Zinc	6 - 58	54 - 3247	38 - 311	14 - 84	117 - 212	52

FEER/OU1-6/MP/350/EE/10-05-91

211

TABLE E-2. (Continued)

Inorganics (ppm)	Pit 6	Burn Pit	Clearwell	Background (Average)
Arsenic	8 - 8 ^c	4 - 21	8 - 18	7.4
Beryllium	2 - 6	1 - 16	9 - 9 ^c	0.8
Cadmium	0.6 - 6	1 - 35	5 - 7	1.7
Chromium	5 - 30	18 - 88	41 - 76	52.0
Cobalt	26 - 26 ^c	22 - 104	18 - 18 ^c	9.2
Copper	13 - 222	12 - 167	195 - 1119	22.0
Lead	5 - 60	7 - 53	32 - 83	17.0
Manganese	35 - 35 ^c	119 - 1717	761 - 1660	640.0
Mercury	0.03 - 0.07	0.1 - 0.2	0.4 - 4.4	0.12
Nickel	8 - 51	9 - 60	47 - 67	18.0
Potassium	913 - 913 ^c	486 - 1452	1690 - 3653	-- ^b
Selenium	-- ^b	-- ^b	4 - 4 ^c	-- ^b
Silver	158 - 158 ^c	7 - 506	3 - 3 ^c	2.8
Sodium	600 - 600 ^c	356 - 1265	1293 - 3501	-- ^b
Thallium	-- ^b	-- ^b	-- ^b	-- ^b
Vanadium	100 - 100 ^c	16 - 290	100 - 2596	6.6
Zinc	5 - 51	15 - 75	82 - 194	52

^aSummarized from the CIS Volume 2 (Weston 1987).

^bData not available.

^cAll samples taken reported identical concentrations.

TABLE E-3. SUMMARY OF ORGANIC CHEMICAL CONSTITUENT RESULTS FOR THE WASTE PITS^a
(Concentration Ranges in ppb)

Volatile Organics (ppb)	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Burn Pit	Clearwell
Acetone ^b	BDL	BDL	BDL	BDL	470 - 630	BDL	BDL	BDL
2-Butanone ^b	1900 - 3800	2600 - 2700	3600	<100 - 7900	NR	BDL - 530	BDL	NR
Ethyl benzene	BDL	BDL	NR	NR	NR	NR	270	NR
Methylene chloride ^b	BDL	BDL	420	BDL	<42 - 350	BDL - 280	BDL	BDL
1,1,1-trichloroethane	BDL	BDL	NR	BDL	NR	NR	NR	NR
1,1,2,2-tetrachloroethane	NR	NR	NR	NR	NR	BDL - 29,000	NR	NR
Vinyl chloride	NR	670	NR	NR	NR	NR	NR	NR
Toluene	BDL	NR	NR	BDL	NR	BDL	<50	NR
Total xylenes	NR	BDL	NR	NR	NR	BDL	890	NR
Tetrachloroethene	BDL	NR	NR	530 - 30,000	NR	NR	<170 - 260	NR
Trichloroethene	NR	NR	NR	300	NR	BDL	NR	NR

ERR/OU1-6/NP/350 EA/10-05-91

213

TABLE E-3. (Continued)

Semivolatile Organics (ppb)	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Burn Pit	Clearwell
Acenaphthene	NR	BDL	NR	BDL	NR	NR	NR	NR
Anthracene	BDL	<58 - 120,000	NR	<260 - 510	NR	NR	NR	NR
Benzo(a)anthracene	BDL	<55 - 180,000	BDL	<52 - 750	NR	NR	61 - 64	BDL
Benzo(a)pyrene	NR	<110 - 140,000	NR	<320 - 550	NR	NR	BDL	NR
Benzo(k)fluoranthene	BDL	<180 - 750,000	NR	<330 - 560	NR	NR	NR	NR
Benzo(b)fluoranthene	BDL	<110 - 760	BDL	<250 - 510	NR	NR	69 - 170	NR
Benzo(g,h,i)perylene	NR	BDL	NR	BDL	NR	NR	85	NR
Chrysene	<64 - 510	<74 - 180,000	BDL	<70 - 760	NR	NR	73 - 77	BDL
Dibenzo(a,h)anthracene	NR	BDL	NR	BDL	NR	NR	NR	NR
Fluoranthene	BDL	<160 - 2300	BDL	<170 - 2200	NR	NR	74 - 220	NR
Fluorene	NR	BDL	NR	BDL	NR	NR	NR	NR
Indeno (1,2,3-cd)pyrene	NR	<340 - 52,000	NR	BDL	NR	NR	BDL	NR

PER/OU1-6/MP/350 EA/10-05-91

TABLE E-3. (Continued)

Semivolatile Organics (ppb)	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Burn Pit	Clearwell
2-Methyl naphthalene	BDL	7,000	NR	NR	NR	NR	50	NR
Naphthalene	BDL	<190 - 16,000	NR	BDL	NR	NR	NR	NR
Phenanthrene	<97 - 2300	<98 - 370,000	BDL	<110 - 2100	NR	NR	<49 - 190	BDL
Pyrene	BDL	<88 - 1600	BDL	<93 - 1400	NR	NR	79 - 140	BDL
Phenol	NR	BDL	NR	NR	BDL	NR	<100 - 650	NR
4-Chlorophenyl-phenylether	NR	NR	NR	NR	NR	NR	NR	NR
2,4-Dimethyl phenol	NR	BDL	NR	NR	NR	NR	NR	NR
4-Methylphenol	NR	BDL	NR	NR	NR	NR	NR	NR
bis(2-ethylhexyl) phthalate ^b	<330 - 1700	BDL	<250 - 1100	BDL	84 - 2300	BDL	340 - 2000	BDL
Chloroform	210	NR	NR	<40 - 1300	NR	NR	NR	NR
Di-n-butyl phthalate	BDL	BDL	BDL	<60 - 490	56 - 200	NR	<54 - 210	BDL
Di-n-octyl phthalate ^b	<150 - 830	BDL	NR	BDL	NR	NR	<67 - 130	NR
Dibenzofuran	NR	<78 - 36,000	NR	BDL	NR	NR	NR	NR
Pentachlorophenol (2)	NR	NR	BDL	NR	NR	NR	1200 - 2600	NR

FER/OU1-6/MP350,EA/10-05-91

TABLE E-3. (Continued)

Pesticides (ppb)	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Burn Pit	Clearwell
Aroclor-1016	NR	NR	NR	NR	NR	NR	290	NR
Aroclor-1242	NR	NR	NR	99 - 1034	NR	NR	<70 - 290	NR
Aroclor-1248	3500	321	NR	460 - 854	BDL	NR	200	308
Aroclor-1254	720 - 10,000	323	BDL	<296 - 1008	<330- 750	BDL	<77 - 2700	<132 - 737
Aroclor-1260	7000	740 - 1800	NR	NR	NR	NR	NR	NR
4,4'-DDT	1,600	580 - 1400	NR	NR	NR	NR	NR	NR
Ethyl parathion	NR	NR	NR	150 - 860	NR	NR	NR	NR
Methyl parathion	NR	NR	NR	370 - 2100	NR	NR	NR	NR
Malathion	NR	NR	NR	670	NR	NR	NR	NR

^aSummarized from the CIS Volume 2 (Weston 1987b).

^bCommon laboratory contaminants.

NR - Not reported.

BDL - Below detection limit.

FER/OUI-6/WP/350.BA/10-05-91

346

2422