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TREATABILITY STUDY WORK PLAN FOR OPERABLE UNIT 5 SOIL WASHING AUGUST 1992

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TREATABILITY STUDY WORK PLAN FOR OPERABLE UNIT 5 SOIL WASHING

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION and FEASIBILITY STUDY

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U.S. DEPARTMENT OF ENERGY
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LIST OF ACRONYMS

AA	atomic absorption
ACGIH	American Conference of Governmental Industrial Hygienists
ARAR	applicable or relevant and appropriate requirement
ASI	Advanced Sciences, Inc.
ASTM	American Society for Testing and Materials
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHP	Chemical Hygiene Plan
CLP	Contract Laboratory Program
CSF	cancer slope factor
DAC	derived air concentration
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DQO	data quality objective
EDTA	ethylenediaminetetraacetic acid
EPA	U.S. Environmental Protection Agency
ETDC	Environmental Technology Development Center
FEMP	Fernald Environmental Management Project
FFCA	Federal Facility Compliance Agreement
FMPC	Feed Materials Production Center
FS	feasibility study
GC	gas chromatography
GC/MS	gas chromatography/mass spectrometry
HEAST	Health Effects Assessment Summary Table
HSL	Hazardous Substance List
HSP	Health and Safety Plan
IC	ion chromatography
ICP	inductively coupled plasma
ID	Integrated Demonstration
IT	International Technology Corp.
MCL	maximum contaminant level
MSDS	material safety data sheets
MTCLP	modified toxicity characteristic leaching procedure
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission

LIST OF ACRONYMS
(Continued)

OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
PEL	permissible exposure limit
PPE	personal protective equipment
PRG	preliminary remediation goal
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	reference dose
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision
RPD	relative percent difference
RSD	relative standard deviation
SAP	Sampling and Analysis Plan
SOP	standard operating procedure
STEL	short-term exposure limit
SVOC	semivolatile organic compound
TCLP	toxicity characteristics leaching procedure
TCL	target compound list
TDL	[IT] Technology Development Laboratory
TLD	thermoluminescent dosimeter
TLV	threshold limit value
TOC	total organic compound
TWA	time-weighted average
VOC	volatile organic compound
WEMCO	Westinghouse Environmental Management Company of Ohio
XRF	x-ray diffraction

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1.0 PROJECT DESCRIPTION

1.1 INTRODUCTION

The Feed Materials Production Center (FMPC), renamed on August 23, 1991 and hereinafter called the Fernald Environmental Management Project (FEMP), is a contractor-operated federal facility for the production of purified uranium metal located on 1050 acres in a rural area approximately 18 miles northwest of downtown Cincinnati, Ohio. Owned by the U.S. Department of Energy (DOE), production operations at the FEMP were suspended in July 1989 and the facility was formally closed in June 1991.

On July 18, 1986, a Federal Facility 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 activities at the FEMP are thoroughly investigated so that appropriate remedial actions can be assessed and implemented. In response to the FFCA, a remedial investigation/feasibility study (RI/FS) has been initiated to develop these remedial actions.

The 1986 FFCA was amended by a Consent Agreement under Section 120 and 106(a) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Consent Agreement was signed on April 9, 1990 and became effective on June 29, 1990. In 1991, a renegotiation of the Consent Agreement was initiated to establish a revised schedule for cleanup of the FEMP. This Amended Consent Agreement was signed in September, and became effective on December 19, 1991.

The technical strategy adopted under the RI/FS was to divide the site into five operable units to facilitate remedial actions (Figure 1-1). As a result of the renegotiations of the 1990 Consent Agreement, the scope of Operable Unit 5, which is the focus of this work plan, has been modified. The broad definition of Operable Unit 5 remains unchanged and still includes those environmental media that represent pathways and/or environmental receptors presently or potentially affected by FEMP contaminants. However, soil and perched groundwater previously identified as components of Operable Unit 3 are now included within the scope of Operable Unit 5. The soils within Operable Unit 5 have been identified as an area of concern requiring remediation and are the focus of this treatability study. Radionuclides, other inorganics, and organics are present in these soils. A summary of the extent of this soil contamination is presented in Section 1.2.2.

1.1.1 Soil Washing Process Option

Technology process options were identified for the remediation of soils within the final Operable Unit 5 Initial Screening of Alternatives document, December 1990. Technology process options for

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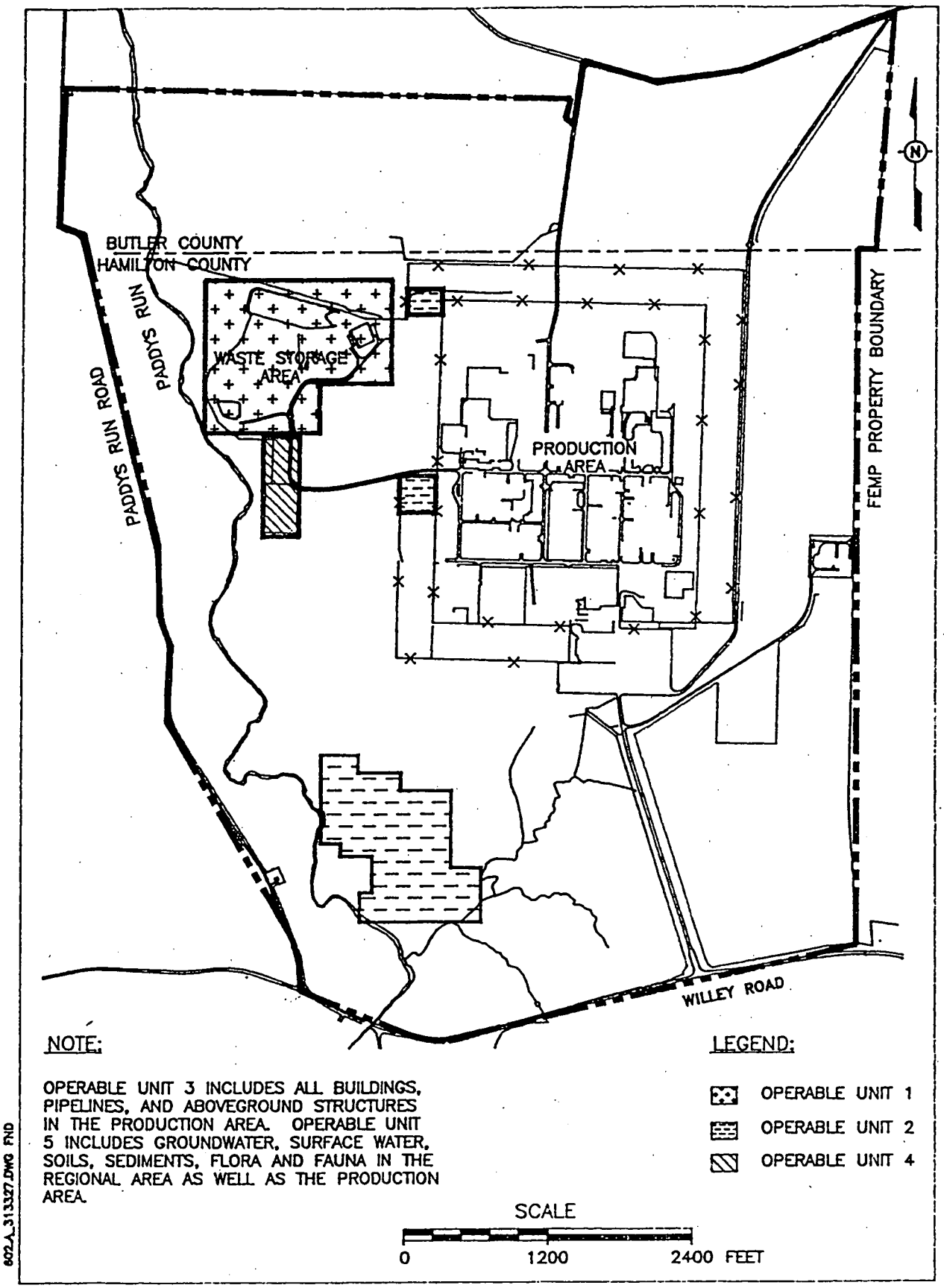

FIGURE 1-1. RI/FS OPERABLE UNITS

the remediation of soils were also identified during the preparation of the draft initial screening document for Operable Unit 3. These documents were prepared within the schedule and scope of the 1990 Consent Agreement. Because of the changes in operable unit definitions during the renegotiation of the Amended Consent Agreement, a new initial screening document will be prepared for Operable Unit 5.

Several viable treatment technology process options have been identified for the remediation of soils. These include soil washing, vitrification, vapor extraction, plasma arc incineration, hydrocyclonic separation, and cement stabilization. A literature review has been completed for the soil washing process. This review revealed that water washing with extractive agents is applicable for cleaning nonvolatile hydrophilic and hydrophobic organics and heavy metals from soils (EPA 1989a) and has been successfully used on soil contaminated with radionuclides. Information was not found on its application to soils containing the radionuclides, inorganics and organics that characterize the Operable Unit 5 soils. Therefore, due to the lack of information available to adequately address the overall effectiveness of this process, as well as the other EPA remedy evaluation criteria necessary during the detailed analysis of alternatives, a decision was made to proceed with treatability testing of the soil washing process.

Literature reviews are currently underway for the other technologies identified as potentially applicable for Operable Unit 5. If this review provides sufficient data for evaluation of these processes within the detailed analysis, no other treatability studies will be conducted. Currently, no other treatability work plans are being prepared.

1.1.2 Organization of the Work Plan

This treatability study work plan is being prepared in accordance with EPA's "Guide for Conducting Treatability Studies Under CERCLA" (EPA 1989b) and the Fernald RI/FS Quality Assurance Project Plan (QAPP) (DOE 1988). In addition to the 14 sections suggested by the treatability guidance document, this work plan includes six appendices. Appendix A provides additional information on the nature and extent of contamination in Operable Unit 5 soils. Appendix B contains standard operating procedures for laboratory procedures and other non-standard procedures. Appendix C is the health and safety plan (HSP) for field sampling and Appendix D is the HSP for the remedy screening and remedy selection phases of the treatability study. Appendix E contains the Integrated Demonstration's (ID) soil sampling project information. The ID project is a parallel program, being conducted outside the FEMP RI/FS, for evaluating alternative technologies for treatment of FEMP soils. Information, including results, will be shared between the ID and RI/FS programs as they become available. Appendix F is a list of organic analytes.

The work plan outlines the objectives and procedures for conducting treatability testing for soil washing. The data resulting from these studies will be used to support the FS by establishing or identifying the following:

- Confirmation of technology applicability to Operable Unit 5 soils
- Compliance of technology with applicable or relevant and appropriate requirements (ARARs)
- Fate and transport modeling input parameters
- Data for residual risk calculations that support the effectiveness criteria evaluation for the detailed analysis of alternatives
- Refinement of process requirements for cost estimation purposes
- Initial database for use in potential subsequent studies in support of remedial design

1.2 SITE DESCRIPTION

1.2.1 Site History

A variety of chemical and metallurgical processes were used at the FEMP for the manufacture of uranium products. These manufacturing processes occurred largely within the former production area, which covers approximately 136 acres near the center of the FEMP and consists of several processing plants and waste storage areas. The pilot plant was completed in 1951 and was the first operational facility at the FEMP. The pilot plant housed many different processes including thorium metal production, uranium metal production, and uranium hexafluoride reduction. The metals fabrication plant, Plant 6, began operations in 1952. The metal production plant, Plant 5; the green salt plant, Plant 4; the recovery plant, Plant 8; the sampling plant, Plant 1; and the refinery (Plant 2/3) began operating in 1953. A uranium hexafluoride reduction plant, Plant 7, and the special products plant, Plant 9, were operational in 1954.

Production peaked in 1960 at approximately 10,000 metric tons of uranium (mtu) per year. A production decline began in 1964, to a low of about 1230 mtu in 1975. During the 1970s, consideration was given to closing the FEMP; therefore, capital improvements and staffing were minimized. In 1981 the FEMP began to accommodate increased production requirements. Production levels significantly increased and there was a rapid staff buildup for several years; implementation of a major facilities restoration program followed. Then production ceased in the summer of 1989 to focus plant resources on the environmental restoration program. The FEMP was officially closed in June 1991.

1.2.2 Nature and Extent of Soil Contamination

Surface soil in the vicinity of the FEMP has become contaminated from a variety of sources. Overall, the site has received a dusting of airborne uranium from the stacks in the production area. Additional airborne material has been released in the waste storage area by dust blown from the disposal pits and

tracking of contamination by vehicles. The incinerator in the sewage treatment plant area was also a source of airborne contamination. Additionally, leaks and spills from processing activities within the former production area have resulted in soil contamination.

Currently, no standards exist for radiological contamination levels in soil (other than radium). Radiological contamination levels used as preliminary action levels for soil in uncontrolled areas of the FEMP are consistent with levels set by the Nuclear Regulatory Commission (NCR) in a branch technical position paper (NRC 1981) and published in the Federal Register on October 23, 1981. The levels are consistent with what is used throughout the DOE complex and are below the levels used for residual contamination in surface soil for most unrestricted locations in the United States. The levels are documented in FEMP site policy and procedures, which have been provided to the (EPA). The RI/FS process will be the vehicle for determination of final cleanup levels, including radiological levels in soil. Cleanup levels will be based on considerations that include a risk basis, but will not be based solely on risk. Cleanup levels cannot be determined at the treatability study stage of the RI/FS process.

The value of 35 pCi/g will be used as a preliminary action level in this treatability study. The work plan uses this level (35 pCi/g) to provide perspective for comparison to soil contamination levels to ensure that soil samples collected for use in the treatment tests exhibit significant contamination (it is desirable to test the effectiveness of treatment on significantly contaminated soil).

The data used to characterize the nature and extent of soil contamination at the FEMP were collected and analyzed from the spring of 1988 through 1990. In general, concentrations of total uranium in soil samples from outside the production area and the waste storage area are below 35 pCi/g. The exceptions to this are in suspect areas, such as the fire training area, the sewage treatment plant area, and the rubble mound west of the K-65 silos. Each of these areas has surface contamination in excess of 35 pCi/g of total uranium.

As shown in Figure 1-2, large portions of the production area have total uranium concentrations in soil from 0.0 to 1.5 feet at greater than 50 µg/g, which is roughly equivalent to 35 pCi/g. Figure 1-3, which shows the total uranium concentrations for samples collected in the 1.5 to 3.0-foot interval, illustrates that in large part the uranium contamination is a surface contamination problem. A comparison of the 50 µg/g contours in Figures 1-2 and 1-3 indicates that below 1.5 feet total uranium values greater than 50 µg/g are restricted to the northern end of Plant 6, scattered points around the garage and heavy equipment building, the Plant 2/3 area, the southwest corner of the pilot plant, the northwest corner of the maintenance building, and the southeast corner of Plant 9. Within the production area leaks and spills from process equipment have resulted in deeper migration of

contamination at higher concentrations than is due to airborne deposition. Although uranium is the indicator parameter for contamination at the FEMP, many samples have been analyzed for other radionuclides. To better focus the investigation of this complex production network into a manageable technical framework, the production area was separated into four distinct quadrants. Table 1-1 summarizes, by quadrant, the maximum concentrations for radionuclides in soil samples from the production area.

Contaminated soils, which contained the maximum detected concentrations of 11 radionuclides in the Southeast Quadrant (Table 1-1), were removed as part of a construction program that was initiated in August 1988 to connect the health and safety building with the services building. Soils located between these buildings were removed during the construction activities after initial sampling of these areas had been conducted under the RI/FS program.

The maximum total uranium value found in soils from throughout the production area was detected in a sample collected just below the concrete floor of the Plant 6 waste water treatment area (Table 1-1). More detailed information as to the extent and level of contamination, including summaries of other inorganics and organics, is given in Appendix A.

Although the data used to develop the soil contour figures and Table 1-1 were collected and analyzed from the spring of 1988 through 1990, the intent of these figures and this summary table is to provide a brief overview of the contamination in site soils based on existing data. The work plan proposes further characterization of soils before to collecting samples that will be used in the treatability testing. This ensures that samples are representative of site conditions.

1.2.3 Summary

Uranium is the indicator parameter for contamination at the FEMP. Uranium has also been present in samples containing concentrations above background levels for other inorganic constituents including radionuclides and metals, and concentrations above detection limits for organics. The level of contamination in surface soil is generally less than the level of contamination of soil under or near certain process buildings. The highest levels of uranium have been detected near Plant 6 and Plant 2/3. Acids were used to digest or pickle material in these locations.

Organic contamination occurs near plants where chemicals were used for process development or in conjunction with machining and maintenance operations. The exceptions to this are the fire training area, the graphite furnace and oil burner, and the coal pile.

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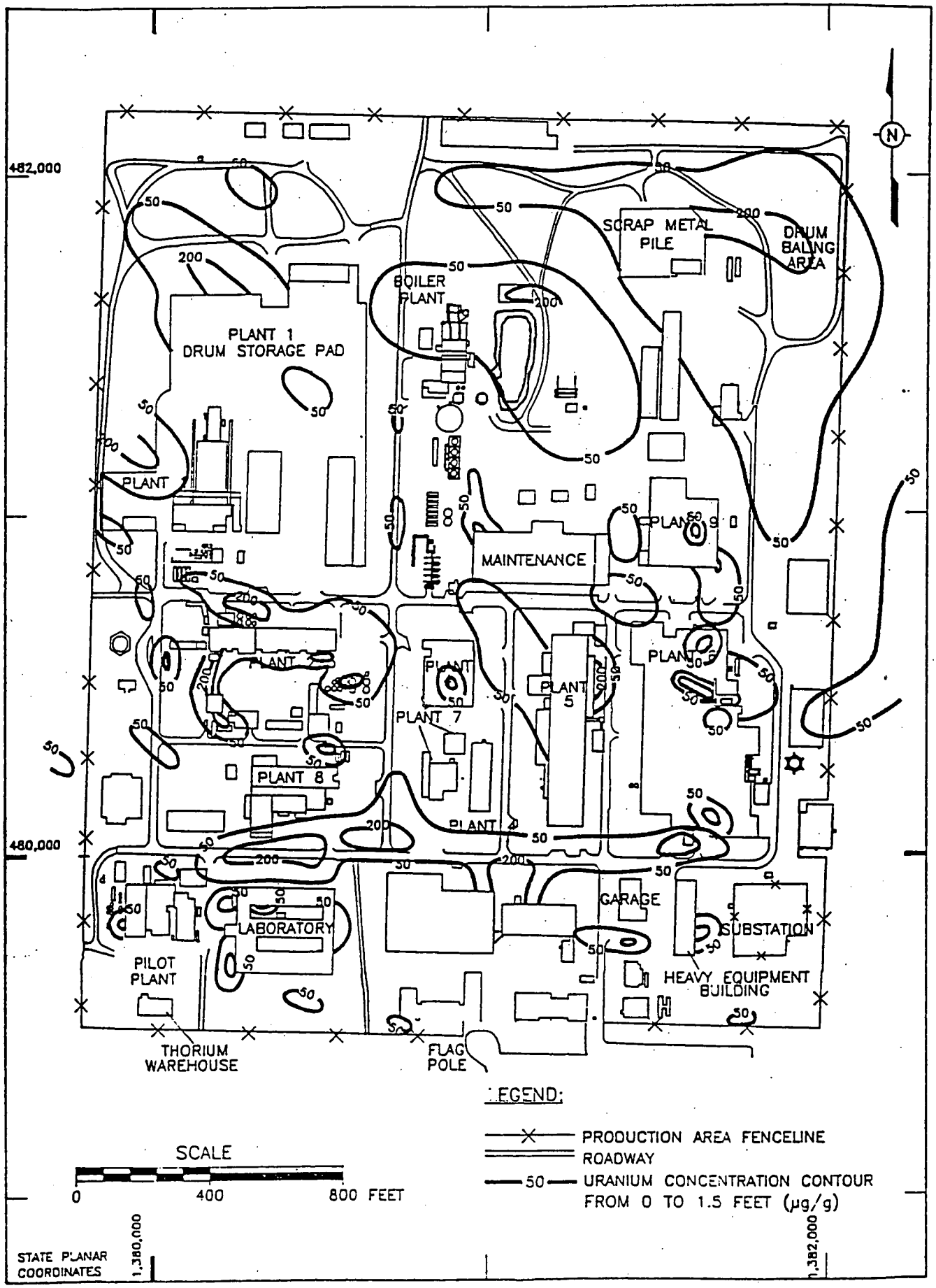

FIGURE 1-2. URANIUM CONCENTRATION CONTOURS IN SOIL – 0.0 TO 1.5 FEET

802.A_SOILCON_OU3RL_FND

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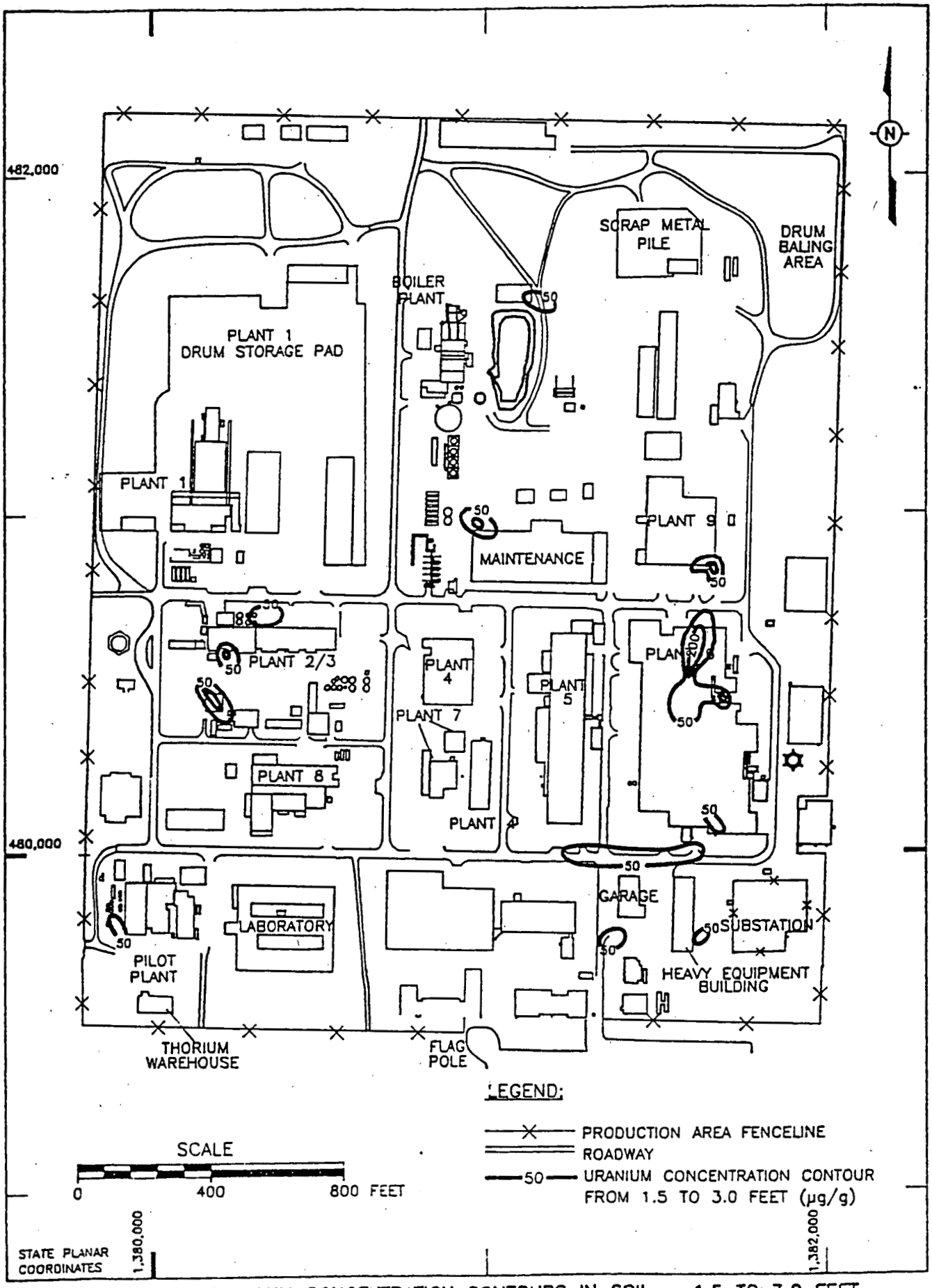


FIGURE 1-3. URANIUM CONCENTRATION CONTOURS IN SOIL – 1.5 TO 3.0 FEET

TABLE 1-1
MAXIMUM CONCENTRATIONS OF RADIONUCLIDES IN SOIL
FROM THE FEMP PRODUCTION AREA
Results are in pCi/g

Element	Northwest Quadrant	Northeast Quadrant	Southwest Quadrant	Southeast Quadrant	Fire Training Area	Incinerator/ Sewage Treatment Plant
Total uranium[a]	457	465	7450	90,350	67.9	4210
Total thorium[a]	NA[b]	NA	NA	NA	NA	NA
Uranium-234	3857	177	13,262	970[c]	361	10,977
Uranium-235/236	204	14.3	950	41.6[c]	0.7	1730
Uranium-238	4108	179	14,321	986[c]	10.0	25,670
Thorium-228	31.2	40.9	315	7.5[c]	0.9	24.8
Thorium-230	2749	17	288	40.3[c]	1.6	806
Thorium-232	31.4	34	283	9.1[c]	0.8	61.9
Radium-226	2720	1.4	27.2	2.2[c]	1.2	57.4
Radium-228	56.2	105	546	5.4[c]	1.2	18.0
Cesium-137	0.5	1.0	2.9	14.4[c]	0.7	1.1
Technetium-99	1.4	8.1	78.8	2.0[c]	--	228
Strontium-90	3.1	2.7	26.3	3.6[c]	5.0	1.9
Neptunium-237	--[d]	--	2.6	--	--	--
Plutonium-238	--	--	6.1	--	--	--
Plutonium-239/240	--	1.5	0.9	--	--	--

[a]Results in µg/g.
[b]NA - Not analyzed.
[c]Soil removed during a construction program to connect the health and safety building and the services building.
[d]No detected concentrations were noted.

1.3 Operable Unit 5 Soil Washing Treatability Study

1.3.1 EPA Treatability Guidance

The EPA's "Guide for Conducting Treatability Studies Under CERCLA" (1989b) outlines 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. Since publication, the terminology of this approach has been revised as follows (dePercin et al. 1991) and as shown in Figure 1-5:

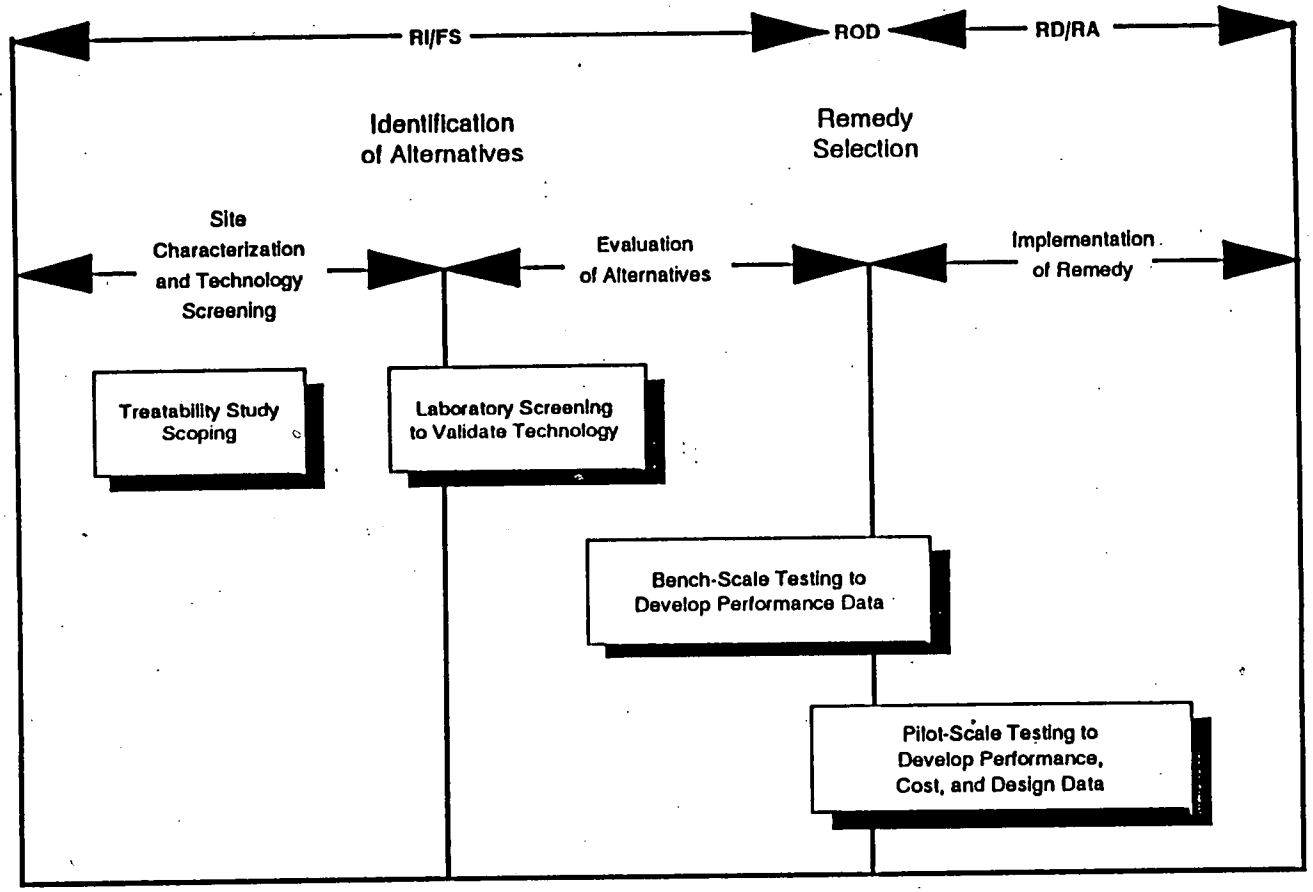
- Remedy screening
- Remedy selection
- Remedy design

The three tiers of treatability testing are divided into pre-record of decision (ROD) and post-ROD studies. The remedy screening and remedy selection testing are generally pre-ROD studies, and the remedy design studies are generally post-ROD. However, the appropriateness and levels of treatability testing required are flexible, and remedy design studies, on a site-specific basis, may be conducted before to issuance of the ROD.

The remedy screening and remedy selection treatability studies provide the 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

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



Source: Guide to Conducting Treatability Studies Under CERCLA. December 1989.

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

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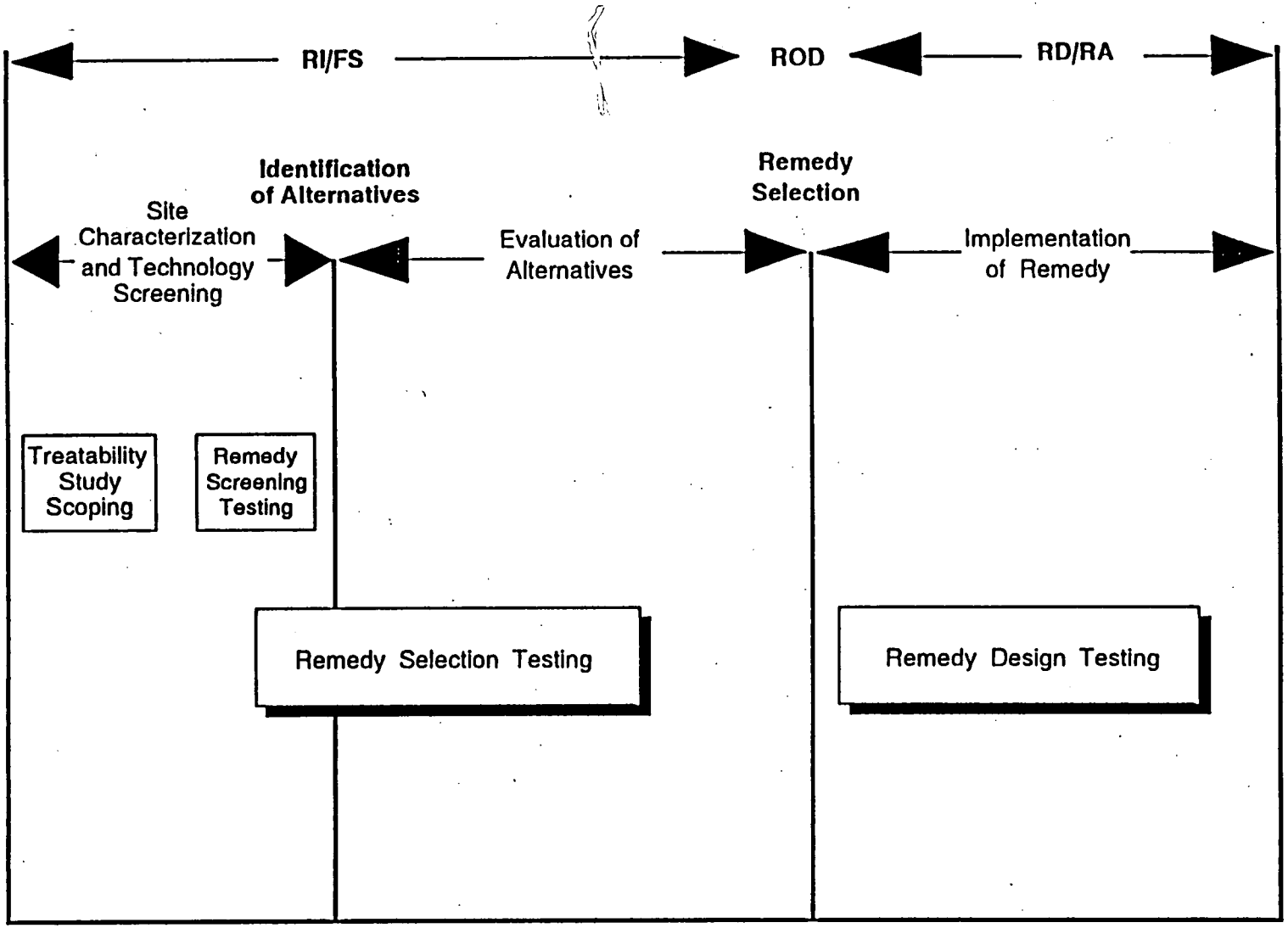

Source: dePercin et al., 1991, "Designing Treatability Studies for CERCLA Sites," J. of the Air and Waste Management Assn., Vol. 41, No. 45.

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

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 purpose of the remedy selection 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 to -30 percent accuracy. The performance data will be used to determine whether this technology will meet remedial action objectives (RAOs). Remedy selection studies are typically small-scale, incorporating generic tests using bench- or pilot-scale equipment in either the laboratory or the field. The study costs are higher than those encountered in the remedy screening tier and the tests 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 remedy design tier, detailed scale-up design, performance, and cost data are generated to implement and optimize the selected remedy (Figure 1-5). Remedy design studies are usually performed as part of remedy implementation on full-scale or near-full-scale equipment. These studies should focus on optimizing process parameters, which are not a part of this treatability study. The levels of QA/QC are moderate to high and are typically vendor specific.

1.3.2 Purpose of Treatability Study

The purpose of this treatability study is to generate data for the detailed analysis of alternatives in the FS. A primary consideration is to integrate the soil washing treatability technology being evaluated in this study with other technology evaluations being conducted for on-site remediation of Operable Unit 5 soils.

This treatability work plan outlines the objectives, procedures, and techniques for conducting screening of soil washing technologies. 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 5
- 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

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- 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

1.3.3 Operable Unit 5 Soil Washing Treatability Approach

The proposed approach for these Operable Unit 5 studies, which can be seen in Figure 1-6, is consistent with EPA's tiered system for conducting treatability studies and consists of the following:

- Remedy Screening - Stage I, Stage II
- Remedy Selection

Two-tiered treatability approach is planned for evaluation of the soil washing process for Operable Unit 5 and will incorporate the ID treatability program as part of the total scope of work. A general description of the soil washing technology is presented in Section 2.0.

In the EPA document "Guide for Conducting Treatability Studies Under CERCLA" (EPA/540/2-89/058), it is recommended that target compounds be used during the Remedy Screening phase. Remedy Screening-Stage I testing will use uranium as the target radioactive and metal compound. In addition, the radiological activity will be tracked by analyzing for gross alpha and gross beta in the extracted soils and washing solutions. Target organic compounds will also be tracked. During the Remedy Screening-Stage II tests, uranium and gross alpha and gross beta will be used to track the radioactive compounds. In addition, target metals and target organic compounds will be analyzed. A more detailed analysis, using data quality objective (DOQ) Level 4 analytical procedures, will be conducted in the Remedy Selection phase.

Soil washing is a physical/chemical treatment process that initially involves the separation of a soil into different particle-size fractions. Reagent formulations in the washing solutions are used in the extraction of radionuclides and organic and inorganic compounds from these different size fractions. The contaminants may be separated from the wash stream into a concentrated residue for further treatment (e.g., stabilization or vitrification).

A parallel remedy screening phase is incorporated in Stage I and includes physical separation and chemical extraction tests. The physical separation tests will identify the soil size fractions with which

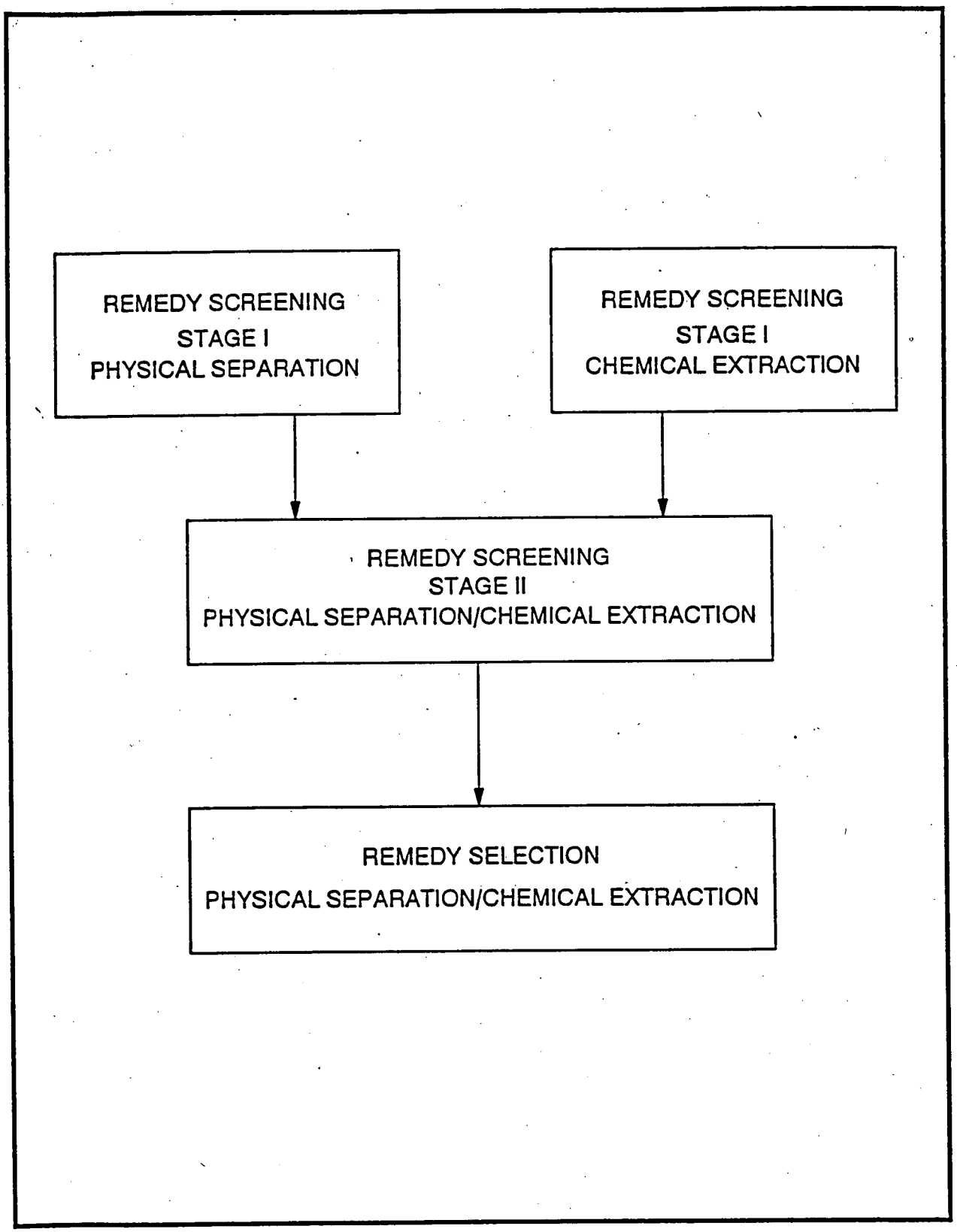

FIGURE 1-6.
SOIL WASHING EXPERIMENTAL DESIGN

each of the types of contamination (i.e., radionuclides, organics, metals) are associated. The chemical extraction tests will be performed on samples that have not been separated into specific-size fractions. Extractants are screened to identify those most promising for separating the contaminants from the soil. Stage II will incorporate the use of selected individual soil size fractions and the most effective washing solutions as determined in Stage I testing. The remedy selection phase incorporates the results of the Stage II testing into a scaled version of the soil washing treatment system.

1.3.3.1 Remedy Screening

The Remedy Screening-Stage I chemical extraction experiments are designed to look for gross effects. The conditions are selected to yield favorable results, i.e., what reagents have a reasonable probability of working. The conditions chosen are high temperature (80° C), relatively high reagent concentrations (e.g., 1:1), and relatively high dose rate (10:1). (The high temperature and reagent concentration will increase the rate of metal compound dissolution. The high dose rate will minimize the effects of common ion effect and ionic strength on the dissolution of the desired material.) In Stage II, after the number of extractants are decreased, the effect of extractant concentration, multiple extractions, and dose rate will be determined on each soil size fraction.

The physical separation component of Remedy Screening-Stage I is designed to elucidate the association of contaminants with specific soil size fractions. This is accomplished by first mechanically separating soil samples received from the field into specific soil size fractions using a wet sieving technique. Each soil fraction, dispersing solution, and washing solution are collected and analyzed for selected contaminants, as detailed in Section 3.0.

The Stage I chemical extraction testing is conducted on a parallel track with the physical separation testing. Multiple extractants will be tested on the less than 2-mm soil size fraction samples. The most effective extractants will be determined by evaluating the percent reduction of selective contaminants in the soil after each extraction.

Within Stage II of the remedy screening, the results of Stage I physical separation and chemical extraction experiments are combined. Those soil size fractions that are shown to retain the greatest levels of contaminants will be selected for use in a series of chemical extraction tests. Again, the extractants found to be most effective as a result of Stage I testing will be used in Stage II. If soil contamination is shown to be easily removed from the sand-size fraction by the wet sieving process conducted in Stage I physical separation, then chemical extractants will be tested only on the clay and fine silt fractions within Stage II. If, however, significant contamination is found in the sand fraction as well as the fine silt and clay fraction, the separate extraction experiments will be conducted on both

fractions within Stage II. Each soil size fraction, dispersing solution, and washing solution are collected and analyzed for selected contaminants, as detailed in Section 3.0.

The loaded extractant solutions, wash solutions, and rinse solutions will contain material leached from the soil. Preliminary precipitation experiments will be performed. These tests will determine which type(s) of precipitating and flocculating reagents are necessary to remove the majority of the hazardous and radioactive metals before the liquid is sent to the site-wide water purification system.

1.3.3.2 Remedy Selection

The remedy selection component of the treatability program incorporates specific equipment (e.g., multigravity separators, centrifugal jigs, and centrifuges) in the soil washing system. Only the most successful chemical extracting solutions are incorporated into this system. It is expected that a combination of chemical extractants will be necessary to remove the metals and organic compounds from the soil. Each soil size fraction, dispersing solution, and washing solution were collected and analyzed for selected contaminants, as detailed in Section 3.0.

1.3.4 Relationship of Treatability Data to FS Evaluation Criteria

The following information will be obtained or can be calculated as a result of the treatability study testing:

- Volume of soils requiring disposal relative to the initial volume of untreated waste
- Amount of contaminant removed from soil, extractants, and washwater
- Cost of implementing the technology
- Volume of wash water for treatment and/or disposal relative to the initial volume of untreated waste
- Volume of extracting reagents for disposal relative to the initial volume of untreated waste
- Volume of soil in which uranium content was reduced to $\leq$35 pCi/g.

This information will be used to evaluate the soil washing technology and compare it to other soil technologies during the detailed analysis of alternatives phase of the RI/FS.

The alternatives are evaluated in regard to each of the nine RI/FS evaluation criteria as previously discussed in Section 1.3.1. The relationship between the data generated during the remedy screening and remedy selection soil washing treatability studies and these evaluation criteria is presented in Table 1-2.

TABLE 1-2

RELATIONSHIP OF SOIL WASHING TREATABILITY DATA TO FEASIBILITY STUDY EVALUATION CRITERIA

	Soil Washing Treatability Data				
FS Evaluation Criteria	Leachate Analyses	Volume Reduction (%)	Radionuclide Removal (%)	Organic Removal (%)	Inorganic Removal (%)
Overall protection of human health and the environment	X		X	X	X
Compliance with ARARs	X		X	X	X
Long-term effectiveness and permanence	X		X	X	X
Reduction of toxicity, mobility, or volume through treatment	X	X	X	X	X
Implementability		X	X	X	X
Short-term effectiveness		X			
Cost		X			
State acceptance	X	X	X	X	X
Community acceptance	X	X	X	X	X

The ability of soil washing to provide protection of human health and the environment will be determined by considering such factors as the results of toxicity characteristics leaching procedure (TCLP) of the leachate, which establishes cross-media impacts, and the percent removal of soil contamination, which establishes the potential risk reduction. In addition, the overall assessment of human health and environmental protection will incorporate the assessment of long-term effectiveness, short-term effectiveness, and compliance with ARARs. Compliance with chemical-specific ARARs will be determined by whether the leachate meets or exceeds established or proposed discharge standards, and whether the treated soil meets or exceeds established cleanup levels. Treatability testing parameters that will be evaluated to assess the ability of soil washing to provide long-term effectiveness and permanence to include the effectiveness of the process to permanently reduce radionuclide, organic, and inorganic contaminant concentrations in soil. These parameters will permit the assessment of residual risk remaining from untreated waste or treatment residuals at the conclusion of remedial activities. The effectiveness of soil washing will also be evaluated via TCLP testing as to the leachability of contaminants from the treated soil.

The ability of soil washing to reduce the toxicity, mobility, or volume of contaminated waste will be measured by parameters such as TCLP leachate analysis, which will determine toxicity and mobility reduction, percent volume reduction, and percent contaminant removal in the treated soils, which will assess the reduction of toxicity.

Short-term effectiveness is impacted primarily by volume reduction, which indicates the amount of waste that must be treated and the amount of treated waste that must be handled and disposed of. The volume of soil that requires handling and treatment will impact the operation and maintenance requirements during implementation of the technology.

The implementability of soil washing is influenced primarily by the volume of waste to be handled. As with implementability, cost is also impacted by the volume of waste to be treated.

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

The information required from the soil washing treatability study for use in the detailed analysis will be generated utilizing various analytical methods and various tiers of treatability testing. Various media (i.e., initial soil, treated soil, and washing solution) will be tested for radionuclide, organic, and other inorganic parameters within both the remedy screening and remedy selection stages of the treatability study.

2.0 REMEDIAL TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY JUSTIFICATION

Based on characterization data, it has been determined that a relatively large quantity of FEMP surface soils may contain radioactive components. In isolated cases, nonradioactive components may exist in conjunction with radioactive components. To address the cases where these components are present at levels exceeding risk-based action levels, soil washing was selected as the technology to be evaluated within this treatability study. A general soil washing extraction system is illustrated in Figure 2-1. Soil washing, if successful, produces large volumes of remediated soil which can be returned to the site from which it was excavated, while significantly reducing the final volume of material requiring selective handling. This soil may be designated a solid waste per State of Ohio ARARs, and may require an exemption from the OEPA before returning the soil to the site. The success of the technology must also be assessed based on the final volume of washing solutions requiring selective storage and/or disposal practices. In essence, the sum of the final soil and washing solution (leachate) volumes must be significantly less than the initial volume of contaminated soil. The overall implementability and effectiveness of this technology will be evaluated within the FS.

A review of soil washing technologies and their applicability to Superfund sites (EPA 1989a) reported that water washing with extractant reagents is applicable for cleaning nonvolatile hydrophilic and hydrophobic organics and heavy metals from soils. The report concluded that although extraction of organics and toxic metal contaminants from excavated sandy/silty soil that is low in clay and humus content has been successfully demonstrated at several pilot-plant test facilities, extraction from clay and humus soil fractions is more complicated.

Kunze and Gee (1989) demonstrated greater than 90 percent removal of a large number of contaminants from a CERCLA-site soil using various surfactant, organic solvent and acid washing solutions. They determined that both aqueous surfactant and aqueous citrate-based solutions are effective for high removals of all classes of the organic compounds tested. Their bench-scale soil washing study also showed that with high levels of contamination at a site, several washings may be required and used solutions would have to be treated before reuse.

Soil washing is not a new technology, but its application to a mixed waste (organics, inorganics and radionuclides) contamination problem such as exists at the FEMP site extends the application of such a technology to a relatively new dimension. Soil washing has been successfully used on soil contaminated with radionuclides. Richardson et al. (1989) conducted soil washing studies on the removal of radium-226 and thorium-230 from two soils. The results of their wet-sieving and water-

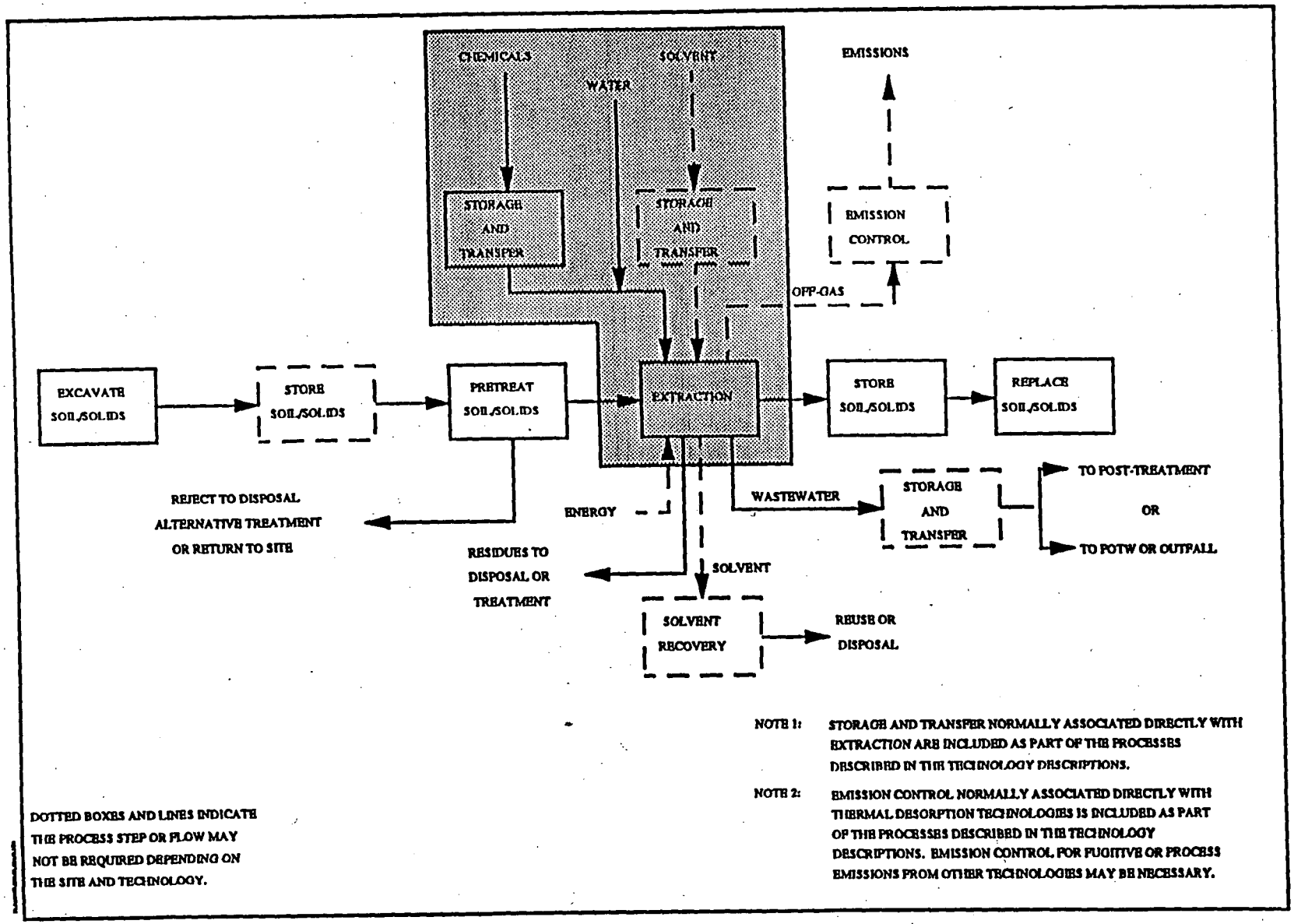

FIGURE 2-1. GENERAL SOIL EXTRACTION SYSTEM

washing studies indicated that the combination of the two processes can significantly reduce the radionuclide levels in soils.

2.2 PHYSICAL SEPARATION

Soil washing is a physical/chemical treatment process that initially involves the separation of a soil into different particle-size fractions. Those size fractions that actually constitute soil particles include clays (< 2 μm), silts (2-50 μm), and sands (50 μm to 2 mm). Other constituents of the soil may include cobbles and stones (2 mm to 50 mm) and rocks, debris and trash (> 50 mm [2 inches]). All constituents of the soil may be contaminated with organics, metals and radionuclides. However, it is the soil particles (< 2 mm) that are of primary concern, and in particular those particle-size fractions that include the silts and clays (< 50 μm). It is within this size fraction that contaminants are bound to soil particles by specific mechanisms such as ionic, covalent and hydrogen bonding, responsible for the absorption of metals and radionuclides (ionic species) and Van der Waals forces and nonspecific bonding, responsible for the affinity of organic molecules.

Soil washing techniques that employ the use of extraction reagents (such as proposed in this treatability plan) consist of soil excavation, aboveground treatment, isolation and removal or destruction of the contaminant, and redeposit of the cleaned soil. Techniques like those used in solution mining and mineral extraction have been proposed for use in this soil washing operation for the removal of contaminants from soil. This process is accomplished through a combination of particle separation by size and/or density. The proposed process uses conventional equipment (e.g., hydroclones, hydrogravimetric separators, scalping screens, trommels, mineral jigs, and centrifuges) for scrubbing, size reduction, washing, and dewatering of soils. Large objects (e.g., rocks and debris) are removed by screening and then cleaned separately. The soil is mixed thoroughly with water and extraction agents to remove the contaminants from the soil. This is followed by solid/liquid separation where the coarse fraction of the soil is separated. The extraction agent with contaminant and smaller soil particles (clay and fine silt) undergoes further solid/liquid separation where fine soil fractions are separated as much as possible. The extraction agent is cleaned and recycled. The separated soil fraction undergoes posttreatment where it is cleaned of any residual extraction fluid. A more detailed description of this process is provided in Section 4.0.

2.3 CHEMICAL EXTRACTION

Water and/or reagent formulas are used as the washing or leaching solutions in the extraction of organic compounds and inorganics and radionuclides from different soil size fractions. Water washing with extractive agents includes basic aqueous solutions (caustic, lime, slaked lime, or industrial alkali-based washing compounds); acidic aqueous solutions (sulfuric, hydrochloric, nitric, phosphoric, or carbonic acids); or solutions with surfactant or chelating agents. Hydrogen peroxide, sodium hypochlorite, and other strong oxidizing agents can chemically change the contaminants and enhance

their removal from soil. The removal of organics from soil can be enhanced by strong basic or surfactant solutions, while the extraction of metals is best facilitated by chelating agents or strongly acid solutions.

The treatment technique basically mobilizes the contaminants physically by mass action, or chemically by complexing, chelating, reducing, oxidizing, or ion exchange mechanisms. The washing solution, which now contains the disassociated contaminants, is then separated from the soil/water slurry. The soil is monitored for the presence of residual contaminants and either returned to the site as decontaminated soil or washed further using additional reagent solutions. The washing solution or leachate, which now contains the contaminants, is processed through a series of chemical extraction steps (e.g., complexing, chelating, reducing, oxidizing and/or exchange resins) to concentrate the contaminants into a finite volume of solution or onto a resin bed for ultimate disposal off site. The remaining solution is monitored to determine if the contaminants have been removed, and are then either released to the site treatment works or further processed to remove residual contaminants. A more detailed description of this process is provided is Section 4.0.

3.0 TEST AND DATA QUALITY OBJECTIVES

The purpose of this treatability study is to assess the performance of the soil washing technology on Operable Unit 5 soil in support of the RI/FS. Soil washing treatability testing will be conducted to elucidate the various levels of contaminant removal that can be achieved with increasing cleaning levels or numbers of washing processes (e.g., washing or chemical extraction steps) associated with the soil washing operation. Information obtained from this study will be used to support the detailed analysis of alternatives within the FS process.

This section establishes the performance objectives and the data desired from the soil washing tests. This section also establishes the DQOs for this program. The baseline risk assessment for Operable Unit 5 has not been completed, but site-wide leachate action levels have been developed for treatability studies using results of the RI/FS presently available. These leachate action levels include a 10^{-6} risk level as a point of departure and are presented in Tables 3-1 and 3-2 for chemical and radiological constituents; background concentrations and instrument contract required detection limits are provided for comparison purposes only.

The EPA has recently provided additional guidance on the initially proposed site-wide preliminary remediation goals (PRGs) (EPA 1991). The new guidance is specific on the definition of PRGs and that definition does not include goals for leachate; therefore, the leachate goals presented in this report are referred to as "leachate action levels" in order to minimize confusion when referring to the values.

Leachate action levels are developed to act as reference points for evaluating treatability data and are designed to be protective of human health and the environment and to comply with ARARs. They are developed early in the process and are based on readily available information (EPA 1991). These action levels are used by engineers as design criteria during development and selection of remedial alternatives. Leachate action levels are a subset of RAOs that are site-specific (qualitative goals that define the extent of cleanup required to achieve a CERCLA response action) (EPA 1988). RAOs address contaminants of concern, media of concern and potential exposure pathways as well as leachate action levels. Leachate action levels 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.

Although these leachate action levels are used to provide targets for aiding in the determination of the effectiveness of soil washing, they are not intended to provide final cleanup levels for removing contaminants from soil. However, if the technology does not achieve individually specified levels, it should not be judged ineffective. The technology may eventually be determined to be the best available technology for remediation of soil on the FEMP site. The final concentrations of contaminants in the soils resulting from the remedy selection testing will be compared to leachate action levels during the detailed analysis of alternatives.

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TABLE 3-1
LEACHATE ACTION LEVELS FOR CHEMICALS IN SOIL

Site: Fernald Environmental Management Project
Location: Fernald, Ohio
Medium: Leachate

Land Use: Resident Farmer
Transport Routes: Leaching to Groundwater

Chemical	Risk-Based Action Levels[a]			ARAR-Based Action Levels[a]		Other Considerations	
	HI=0.20 RfD-Based Action Levels[b]	10-5 CSF-Based Action Levels[c]	10-6 CSF-Based Action Levels[c]	MCL-Based Limit[d]	TCLP Regulatory Limit[e]	Background Concentration[f]	Contract Required Detection Limit[g]
Inorganics (mg/ℓ)							
Aluminum						0.14	0.2
Antimony	0.3						0.06
Arsenic	0.7			5	5	0.39	0.01
Barium	37			200	100	1.0	0.2
Beryllium	4	0.01	0.001	0.1 (P)		0.001	0.005
Boron	66						
Cadmium	0.4			0.50	1	0.003	0.005
Chromium	3.7			10	5	0.039	0.01
Cobalt	1.9						0.05
Copper							0.025
Iron						4.1	0.1
Lead	0.5			0.50	5	0.051	0.005
Magnesium						47	5
Manganese	73.0					0.27	0.015
Mercury	0.2			0.20	0.2		0.0002
Molybdenum	3					0.014	
Nickel	15						0.04
Selenium	4			5	1		0.005
Silver	2			5	5		0.01
Thallium	0.1						0.01
Uranium	2			2			
Vanadium	5					0.02	0.05
Zinc	150					0.045	0.02
Cyanide	15			20 (P)			0.01

TABLE 3-1
(Continued)

Chemical	Risk-Based Action Levels[a]			ARAR-Based Action Levels[a]		Other Considerations	
	HI=0.20 RfD-Based Action Levels[b]	10-5 CSF-Based Action Levels[c]	10-6 CSF-Based Action Levels[c]	MCL-Based Limit[d]	TCLP Regulatory Limit[e]	Background Concentration[f]	Contract Required Detection Limit[g]
Organics (mg/ℓ)							
1,1,2-Trichloro-1,2,2-trifluoroethane	2190						
1,1,2,2-Tetrachloroethane		0.18	0.02				0.005
1,1,1-Trichloroethane	66			20			0.005
1,1-Dichloroethane	73						0.005
1,1-Dichloroethene	7	0.06	0.01	0.70	0.7		0.005
1,2-Dichloroethane		0.40	0.04	0.50	0.5		0.005
1,2-cis-Dichloroethene	7.3			7			
1,2-trans-Dichloroethene	15			10			0.005
2,4-Dimethylphenol	15						0.01
2-Butanone	37				200		0.01
2-Methylnaphthalene							0.01
2-Methylphenol							0.01
4-Methyl-2-pentanone	37						0.01
4-Methylphenol							0.01
Acenaphthene	44						0.01
Acetone	73						0.01
Anthracene	219						0.01
Aroclor-1242		0.005	0.0005	0.05			0.0005
Aroclor-1248		0.005	0.0005	0.05			0.0005
Aroclor-1254		0.005	0.0005	0.05			0.001
Aroclor-1260		0.005	0.0005	0.05			0.001
Benzene		1.26	0.13	0.50			0.005
Benzo(a)anthracene[h]							0.01
Benzo(a)pyrene		0.003	0.0003				0.01
Benzo(b)fluoranthene[h]							0.01

TABLE 3-1
(Continued)

Chemical	Risk-Based Action Levels[a]			ARAR-Based Action Levels[a]		Other Considerations	
	HI=0.20 RfD-Based Action Levels[b]	10-5 CSF-Based Action Levels[c]	10-6 CSF-Based Action Levels[c]	MCL-Based Limit[d]	TCLP Regulatory Limit[e]	Background Concentration[f]	Contract Required Detection Limit[g]
Benzo(g,h,i)perylene[h]							0.01
Benzo(k)fluoranthene[h]							0.01
Benzoic acid	2920						0.05
Benzyl alcohol	220						0.01
Bis(2-ethylhexyl)phthalate	15	2.61	0.26			0.015	0.01
Butyl benzyl phthalate	150						0.01
Carbon disulfide	73.0						0.005
Carbon tetrachloride	0.5	0.28	0.03	0.50	0.5		0.005
Chlordane	0.04	0.03	0.003	0.20	0.03		0.0005
Chlorobenzene	15				100		0.005
Chloroethane							0.01
Chloroform	7	5.98	0.60	10	6		0.005
Chrysene[h]							0.01
DDT	0.4	0.11	0.01				0.0001
Di-n-butyl Phthalate	73.0						0.01
Di-n-octyl Phthalate	15						0.01
Dibenzo(a,h)anthracene[h]							0.01
Dibenzofuran							0.01
Ethyl parathion							0.0001
Ethylbenzene	7			70			0.005
Fluoranthene	29						0.01
Fluorene	29						0.01
beta-Hexachlorocyclohexane		0.02	0.002				0.00005
Indeno(1,2,3-cd)pyrene[h]							0.01
Methyl parathion	2						
Methylene chloride	44	5	0.5			0.018	0.005

TABLE 3-1
(Continued)

Chemical	Risk-Based Action Levels[a]			ARAR-Based Action Levels[a]		Other Considerations	
	HI=0.20 RfD-Based Action Levels[b]	10-5 CSF-Based Action Levels[c]	10-6 CSF-Based Action Levels[c]	MCL-Based Limit[d]	TCLP Regulatory Limit[e]	Background Concentration[f]	Contract Required Detection Limit[g]
N-nitrosodiphenylamine		7	0.7			0.013	0.01
Naphthalene	3						0.01
Pentachlorophenol	22	0.30	0.03	0.10	100		0.05
Phenanthrene							0.01
Phenol	440						0.01
Pyrene	22						0.01
Tetrachloroethene	7	0.7	0.07	0.50	0.7		0.005
Toluene	150			100			0.005
Trichloroethene		3.3	0.3	0.50	0.5		0.005
Vinyl Chloride		0.02	0.002	0.20	0.2		0.01
Xylenes (total)	1500			1000			0.005

[a]Leachate action levels are developed based on the potential for chemicals in those zones to leach into the bedrock aquifer or a receiving surface water body, thus equating water in the shallow zones to "leachate." Leachate is regulated by the U.S. EPA under 40CFR261 with the use of the toxicity characteristic leaching procedure (TCLP). TCLP regulatory levels are based on the acceptable drinking water concentrations multiplied by a dilution attenuation factor (DAF), which accounts for the degree of attenuation and dilution that a compound is expected to undergo during transport to the drinking water aquifer or receiving stream (U.S. EPA 1986).
[b]Based on a Hazard Index-based groundwater preliminary remediation goal and a DAF of 100. Blank spaces in the table indicate information is not available to determine a value.
[c]Based on cancer risk-based groundwater preliminary remediation goal and a DAF of 100.
[d]Based on maximum contaminant level (MCL) times DAF of 100.
[e]From 40CFR261, 55FR11798.
[f]In most cases, concentrations represent upper 95% tolerance level from background concentrations found in the Shandon Flow at the FEMP. In cases where data were not available to calculate UTL, mean value is reported.
[g]From CLP Statement of Work, U.S. EPA OLM01.08.
[h]Risk-based level developed using cancer slope factor for benzo(a)pyrene.

TABLE 3-2
LEACHATE ACTION LEVELS FOR RADIONUCLIDES IN SOIL

Site: Fernald Environmental Management Project
Location: Fernald, Ohio
Medium: Leachate

Land Use: Resident Farmer
Transport Routes: Leaching to Groundwater

	Risk-Based Action Levels[a]			ARAR-Based Action Levels[a]		Other Considerations	
Radionuclides (pCi/ℓ)	HI=0.20 RfD-Based Action Levels[b]	10-5 CSF-Based Action Levels[c]	10-6 CSF-Based Action Levels[c]	MCL-Based Limit[d]	TCLP Regulatory Limit[e]	Background Concentration[f]	Contract Required Detection Limit[g]
Ac-227		70	7				
Cs-137		700	70	10200			102
Pb-210		40	4	100			
Np-237		90	9	100			1
Pa-231		200	20				
Pu-238		90	9	200			2
Pu-239		90	9	200			
Pu-240		90	9	200			
Pu-239/240		90	9	200			2
Ra-226		200	20	2000 (P)			5
Ra-228		200	20	2000 (P)		<3	5
Rn-220							
Rn-222		15000	1500	30000			
Sr-90		600	60	800			8
Tc-99		16000	1600	91400			914
Th-228		90	90	1400		<1	14
Th-230		1200	120	1000		<1	10
Th-232		1300	130	200			2
U-234		1000	100			<1	
U-235		1000	100				
U-238		1000	100	700 (P)		<1	

[a]Leachate action levels are developed based on the potential for chemicals in those zones to leach into the bedrock aquifer or a receiving surface water body, thus equating water in the shallow zones to "leachate." Leachate is regulated by the U.S. EPA under 40CFR261 with the use of the toxicity characteristic leaching procedure (TCLP). TCLP regulatory levels are based on the acceptable drinking water concentrations multiplied by a dilution attenuation factor (DAF), which accounts for the degree of attenuation and dilution that a compound is expected to undergo during transport to the drinking water aquifer or receiving stream (U.S. EPA 1986).
[b]Based on a Hazard Index-based groundwater preliminary remediation goal and a DAF of 100. Blank spaces in the table indicate information is not available to determine a value.
[c]Based on cancer risk-based groundwater preliminary remediation goal and a DAF of 100.
[d]Based on maximum contaminant level (MCL) times DAF of 100.
[e]From 40CFR261, 55FR11798.
[f]In most cases, concentrations represent upper 95% tolerance level from background concentrations found in the Shandon Flow at the FEMP. In cases where data were not available to calculate UTL, mean value is reported.
[g]From CLP Statement of Work, U.S. EPA OLM01.08.

3.1 PERFORMANCE OBJECTIVES

Test objectives have been established so that the performance of soil washing techniques can be evaluated on the basis of volume reduction, contaminant removal from individual soil fractions, and contaminant removal from the wash solutions. These performance objectives will be used to determine if a particular series of physical/chemical processes will effectively and efficiently remove contaminants from soil. Only selected constituents found during the initial soil characterization in this study (Section 6.0) will be targeted and followed through the treatability study.

In the EPA document "Guide for Conducting Treatability Studies Under CERCLA" (EPA 1986b), it is recommended that target compounds be used during Remedy Screening. Remedy Screening-Stage I testing will use uranium as the target radioactive and metal compound. In addition, the radiological activity will be tracked by analyzing for gross alpha and gross beta in the extracted soil and washing solutions. If specific organic compounds are detected in the soil during the initial characterization, four target organic compounds will be selected and tracked (Table 3-3). During the Remedy Screening-Stage II tests, uranium and gross alpha and gross beta will be used to track the radioactive compounds and seven metals (Table 3-4) will be targeted and used to track inorganic compounds (Table 3-4). If specific organic compounds are detected during the initial characterization, eight target organic compounds (four volatiles and four semivolatiles) will be selected and tracked (Table 3-4). Initial volatile and semivolatile compounds have been chosen because of their reported presence in site soil and their distinct separation peaks in chromatographic analysis. A more detailed analysis will be conducted in the Remedy Selection phase (Table 3-5).

The minimum performance criteria for Remedy Screening-Stage I are that the uranium concentration, or target organic concentration or measured gross alpha and gross beta, in the extracted soil is decreased by 40 percent. During Remedy Screening-Stage II, the minimum performance criteria are that the extracted soil passes the TCLP leaching standard for targeted metals or the measured gross alpha/gross beta, uranium concentration, or target organic compound concentrations are decreased by 80 percent. During the Remedy Selection phase, the minimum performance criteria are that the extracted soil passes the TCLP leaching standard for As, Ba, Cd, Cr, Pb, Se, and Ag, or that the soil contains less than 35 pCi/g uranium.

The specific objectives of the soil washing treatability study are as follows:

- To determine the levels of targeted contaminants associated with various soil size fractions
- To determine the amount of radionuclides and Hazardous Substance List (HSL) constituents removed from the soil during washing
- To determine the leachability of all radionuclides and HSL constituents from the treated (washed) soils

TABLE 3-3

TARGET ANALYTES FOR REMEDY SCREENING - STAGE I

Analyses for Fractioned and Extracted Soils		Analyses for Soil Washing Solutions	
4 Target Organics[a]	Inorganics	4 Target Organics[a]	Inorganics
Semivolatiles	Radionuclides	Semivolatiles	Radionuclides
Benzo(a)pyrene	Uranium by IC[b]	Benzo(a)pyrene	Uranium by IC[b]
Benzo(g,h,i)perylene	Gross alpha	Benzo(g,h,i)perylene	Gross alpha
Fluorene	Gross beta	Fluorene	Gross beta
Naphthalene		Naphthalene	

[a]If the initial characterization does not show a specific organic compound to be present, a replacement organic compound will be chosen as appropriate. If no specific organic compounds are detected during the initial characterization, target organics will not be analyzed.
[b]IC is ion chromatography using a phosphorescence detector.

TABLE 3-4

TARGET ANALYTES FOR REMEDY SCREENING - STAGE II

Analytes for Fractioned and Extracted Soils		Analyses for Soil Washing Solutions		MTCLP[a] List for Extracted Soil	
8 Target Organics[b]	Inorganics	4 Target Organics[b]	Inorganics	Metals	Inorganics
Volatiles	Radionuclides	Semivolatiles	Radionuclides	Metals by ICP	Radionuclides
Benzene	Uranium by IC[c]	Benzo(a)pyrene	Uranium by IC[c]	Arsenic	Uranium by IC[c]
Toluene	Gross alpha	Benzo(g,h,i)perylene	Gross alpha	Barium	Gross alpha
Total xylenes	Gross beta	Fluorene	Gross beta	Cadmium	Gross beta
Trichloroethene		Naphthalene		Chromium	
				Lead	
Semivolatiles	Metals by ICP[d]		Metals by ICP	Selenium	
Benzo(a)pyrene	Arsenic		Arsenic	Silver	
Benzo(g,h,i)perylene	Barium		Barium		
Fluorene	Cadmium		Cadmium		
Naphthalene	Chromium		Chromium		
	Lead		Lead		
	Selenium		Selenium		
	Silver		Silver		

[a]The Modified TCLP (MTCLP) differs from the standard TCLP as follows: the MTCLP uses only 2.5 grams of material rather than 100 grams; the MTCLP generates only 50 milliliters of leachate rather than 2 liters; and the leachate from the MTCLP is analyzed for metals only, rather than metals and organics.

[b]If the initial characterization does not show a specific organic compound to be present, a replacement organic compound will be chosen as appropriate. If no specific organic compounds are detected during the initial characterization, target organics will not be analyzed.

[c]IC is ion chromatography using a phosphorescence detector.

[d]ICP is inductively coupled plasma.

TABLE 3-5
TARGET ANALYTES FOR REMEDY SELECTION TESTING

	Initial, Fractioned, and Extracted Soils and Soil Washing Solutions		
Organics[a]	Inorganics-TCLP and HSL Metals		Radionuclides
TCLP Volatiles	Aluminum (Al)	Magnesium (Mg)	Cesium-137
TCLP Semivolatiles	Antimony (Sb)	Manganese (Mn)	Neptunium-237
TCLP Pesticides/PCBs	Arsenic (As)	Mercury (Hg)	Plutonium-238
	Barium (Ba)	Molybdenum (Mo)	Plutonium-239/240
HSL Volatiles	Beryllium (Be)	Potassium (K)	Radium-224
HSL Semivolatiles	Boron (B)	Nickel (Ni)	Radium-226
HSL Pesticides/PCBs	Calcium (Ca)	Selenium (Se)	Radium-228
	Cadmium (Cd)	Silicon (Si)	Ruthenium-106
	Chromium (Cr)	Silver (Ag)	Strontium-90
	Cobalt (Co)	Sodium (Na)	Technetium-90
	Copper (Cu)	Thallium (Tl)	Thorium-228
	Cyanide (CN)	Vanadium (V)	Thorium-230
	Lead (Pb)	Zinc (Zn)	Thorium-232
			Uranium-234
			Uranium-235/236
			Uranium-238
			Gross alpha
			Gross beta

[a]Specific organic analytes are listed in Appendix F.

- To evaluate reagents and their effect on the removal of contaminants from soil and washing solutions
- To determine the volume of soil from which contaminants are removed
- To determine the volume of waste produced as a result of individual soil washing processes
- To develop the following preliminary process data for use in potential future remedy design treatability studies:
  - Chemical and physical characterization of waste streams before and after particle size separation and reagent addition (chemical extraction)
  - System design description identifying the number and kinds of treatment steps in the soil washing operation
- To provide preliminary cost and design data for the RI/FS
- To acquire the chemical and radiological information as shown in Tables 3-3, 3-4, and 3-5
- To integrate the soil washing treatability technology being evaluated with other technology evaluations for on-site remediation of Operable Unit 5 soils.

3.2 DATA QUALITY OBJECTIVES

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. The DQOs for this remedy screening are quantitative in nature because the final soil washing products must meet specific performance criteria, namely TCLP and contaminant and radionuclide concentration criteria.

DQO analytical levels are defined in EPA's "Guide for Conducting Treatability Studies Under CERCLA" (EPA 1989b). 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 objectives of the screening. A description of the analytical levels is presented in Table 3-6, an excerpt from EPA's guide. A discussion of the DQOs for each stage of the remedy screening for soil washing follows.

To ensure that the level of detail and data quality needed for evaluating the soil-washing technology as a viable alternative for treating soils is achieved, DQO tables were prepared based on guidance given in "Data Quality Objectives for Remedial Response Activities (Development Process)" (EPA 1987).

The general soil washing DQO tables appear as Tables 3-7, 3-8, and 3-9 and they summarize the technical focus or activity for the study. These tables are organized to provide DQO criteria based on the various phases of remedy screening and remedy selection.

A list of analyses for each phase of the treatability study is included as part of these series of DQO tables and are presented in accordance with the following:

TABLE 3-6
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 analyses 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 identification of compounds in some cases.
Data quality	Detection limits similar to CLP. Rigorous QA/QC.
Level IV	
Type of analysis	Hazardous Substances List (HSL) organics/inorganics by GC/MS, AA, ICP. Low parts-per-billion detection limits.
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.

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TABLE 3-7
DATA QUALITY OBJECTIVES (DQOs) FOR THE SOIL WASHING TREATABILITY STUDY
REMEDY SCREENING - STAGE I

Activity	Purpose/Criteria
Objectives	Physical Separation: To determine the concentration of targeted contaminants that are associated with various soil size fractions.
	Chemical Extraction: To determine effective reagents in removing contaminants from soils.
Prioritized Data Use(s)	Physical Separation: The level of targeted contaminants associated with specific soil size fractions will be determined to allow for additional soil washing and chemical extraction steps to focus on those size fractions retaining must of the contaminants.
	Chemical Extraction: Initial screening of extraction reagents will select only those chemicals that significantly effect removal of targeted contaminants from soil.
Appropriate Analytical Level	I and V - See Table 3-6.
Target Analytes	See Table 3-3.
Level of Concern	Physical separation test will only characterize soil particle/contaminant relationships. Chemical extraction effectiveness will be determined by a 40% reduction constant.

TABLE 3-8
DATA QUALITY OBJECTIVES (DQOs) FOR THE SOIL WASHING TREATABILITY STUDY
REMEDY SCREENING - STAGE II

Activity	Purpose/Criteria
Objectives	1) To use most effective extraction reagents from Stage I on those soil size fractions determined to retain significant amounts of contaminants. 2) To determine the level of targeted contaminant removal from specific soil size fractions based on the use of various extraction reagents and their sequence of use required to effectively remove contaminants. 3) To determine the level of contaminants associated with each washing solution (leachate) and to elucidate those reagents effective in removal of targeted contaminants from those solutions.
Prioritized Data Use(s)	1) Data will provide preliminary estimates on volume reduction of contaminated soil with initial soil washing treatment processes. 2) Results from these tests will determine the process design most effective in removing contaminants from both soil and wash solutions. Process design will illustrate the number and sequence of washing (extracting) steps (for soils and wash solutions), and the extraction reagents in the soil washing operation.
Appropriate Analytical Level	I and V - See Table 3-6.
Target Analytes	See Table 3-4.
Level of Concern	Chemical extraction effectiveness will be determined by an 80 percent reduction constant.

TABLE 3-9
DATA QUALITY OBJECTIVES (DQOs) FOR THE SOIL WASHING TREATABILITY STUDY
REMEDY SELECTION

Activity	Purpose/Criteria
Objectives	1) To incorporate the use of specific soil washing equipment (e.g., gravity separators, trommels, centrifugal jigs, centrifuges, etc.,) into a mini-pilot plant system that will simulate actual field system operations. 2) To incorporate the series of washing steps and respective reagents determined to be most effective in removal of targeted contaminants from both soils and wash solutions. 3) To determine soil washing reagent formulation so that the washed soil meets TCLP criteria.
Prioritized Data Use(s)	This data will be used to determine the volume of soil that can be cleaned to targeted cleanup levels and returned to the site as decontaminated soil. Data will include volume of soil cleaned during initial soil washing step. Remedy selection testing data will be used to determine that applicability of soil washing is an efficient and effective treatability alternative for FEMP soils.
Appropriate Analytical Level	IV - Table 3-6.
Target Analytes	See Table 3-5.

- Remedy Screening-Stages I and II initial sample preparation is in Table 3-10.
- Remedy Screening-Stage I physical separation and chemical extraction is in Table 3-3.
- Remedy Screening-Stage II physical separation and chemical extraction is in Table 3-4.
- Remedy Selection physical separation and chemical extraction is in Table 3-5.

Listings of the tests performed during remedy screening and remedy selection are provided in Tables 3-11 and 3-12. These tables also provide the analytical level appropriate for each test. Tests conducted during remedy screening will follow analytical DQO Levels I or V. Standard Operating Procedures (SOPs) and nonstandard test methods for this phase of the study are provided in Appendix B as noted in Table 3-11. The analyses conducted at ORL in support of the remedy selection testing program will be conducted at a DQO analytical level of IV and in accordance with the detection levels as stated in the RI/FS QAPP (DOE 1988). The required detection limits are listed in Tables 3-1 and 3-2.

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TABLE 3-10
TARGET ANALYTES FOR INITIAL SOIL PREPARATION

Analyses for Initial Soil Preparation	
Target Organics[a]	Inorganics
Volatiles	Radionuclides
Benzene	Uranium by IC[b] (50-400 µg/kg)[c]
Toluene	Gross alpha
Total xylenes	Gross beta
Trichloroethene	
Semivolatiles	Metals by ICP[d]
Benzo(a)pyrene	Arsenic (0.200 mg/l)
Benzo(g,h,i)perylene	Barium (0.005 mg/l)
Fluorene	Cadmium (0.010 mg/l)
Naphthalene	Chromium (0.015 mg/l)
General Chemistry	Lead (0.250 mg/l)
Acidity[e]	Selenium (0.500 mg/l)
Alkalinity[e]	Silver (0.020 mg/l)

[a]If the initial characterization does not show a specific organic compound to be present, a replacement organic compound will be chosen as appropriate.
[b]IC is ion chromatography using a phosphorescence detector.
[c]To be done for Stages I and II analyses.
[d]ICP is inductively coupled plasma.
[e]Detection limits for individual analytes are given in ( ).

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TABLE 3-11
SOIL WASHING PROCEDURES AND ANALYTICAL DQO LEVELS
REMEDY SCREENING

Test	Procedure	Comment	DQO Analytical Level
Alkalinity/Acidity	Other procedures;[a] Appendix B	Performed on soil samples so that proper dosage of extractant can be estimated before testing.	I
Uranium by IC	Other procedures; Appendix B	Nonstandard test used to measure uranium in solutions. Results used to quantitatively compare effectiveness of washing solutions.	V
Volatiles/Semivolatiles by GC	Other procedures; Appendix B	Used to measure targeted organics. Results will be used to qualitatively compare the effectiveness of soil washing solutions.	V
Gross alpha and gross beta	SOP; Appendix B	Performed on solid and liquid samples. Used to determine relative effectiveness of soil washing solutions.	I
Metals by ICP	Other procedures; Appendix B	Used to determine the effectiveness of soil washing solutions.	V
MTCLP	Other procedures; Appendix B	Scaled down version of TCLP. Used to determine the relative leachability of hazardous and radiological constituents of washed soils.	V
pH	Other procedures; Appendix B	Preliminary process parameter.	I
See footnote at end of table.			I

TABLE 3-11
(Continued)

Test	Procedure	Comment	DQO Analytical Level
Turbidity	SOP; Appendix B	Qualitative indication of presence of precipitate in filtrate. Used to determine if precipitate is filterable.	I

[a]A nonstandard operating procedure.

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TABLE 3-12
DETECTION LIMITS AND ANALYTICAL DQO LEVELS
REMEDY SELECTION

Test	Detection Limits	Comment	DQO Analytical Level
TCLP	Table 3-1; Table 3-2	Used to determine leachability of hazardous and radiological constituents of washed soil. Results will be used to compare effectiveness of processes, and will also be used in risk assessment calculations.	IV
Radiological	Table 3-2	Used to quantify residual radionuclide concentrations in washed soil, wash solutions, and TCLP extract. Results will be used to compare effectiveness of processes, and will also be used in risk assessment calculations.	IV
Volatiles/Semivolatiles	Table 3-1	Used to quantify residual organics concentrations in washed soil and wash solutions. Results will be used to compare effectiveness of processes, and will also be used in risk assessment calculations.	IV
HSL Metals	Table 3-1	Used to quantify residual metals in extractants and wash water. Results will be used to compare relative effectiveness of processes.	IV

4.0 EXPERIMENTAL DESIGN AND PROCEDURES

Soil washing has been selected as a treatment technology to be considered for the remediation of Operable Unit 5 soils. Soil washing (previously illustrated in Figure 2-1) involves dislodging contaminants bound to soil particles by a physical/chemical process using aqueous washing solutions. Dislodged contaminants (concentrated in the washing solution) and soil particles still retaining associated contaminants are separated from the remaining soil matrix by a series of physical processes. Subsequent processes may involve further separation and isolation of contaminants from the residual soil and wash solutions. Contaminants and residues may be further concentrated through continued washing and separation processes or subjected to alternative treatment technologies (e.g., stabilization or vitrification).

Soils in Operable Unit 5 have been reported in earlier site characterization data (1988 RI/FS Work Plan and the 1989-1990 Additional Suspect Areas Addendum to the RI/FS Work Plan) to contain radioactive components as well as other inorganic and organic chemical constituents. The experimental design of this work plan will focus on washing soils contaminated with (1) radionuclides and (2) radionuclides plus chemical constituents.

The following subsections explain the soil washing experimental design for treatability testing of FEMP soils following their collection and characterization, as described in Section 6.0. The design outlines the following:

- Soil Preparation for Remedy Screening - Stage I and Stage II
- Remedy Screening - Stage I
- Remedy Screening - Stage II
- Soil Preparation for Remedy Selection Testing
- Remedy Selection Testing
- Optional Phase Testing

4.1 SOIL WASHING EXPERIMENTAL DESIGN

Figure 4-1 shows the series of treatment stages that comprise the experimental design. This design for soil washing incorporates a tiered approach in determining 1) the binding association of radionuclides and other inorganic and organic chemical constituents within the soil matrix and 2) the physical separation and chemical extraction processes necessary for soil washing and wash solution (leachate) recovery. This design incorporates the two parallel testing phases of physical separation and chemical extraction as part of the Stage I study, selectively separating soils into five individual soil size fractions (19.5 to 9.5 mm, 9.5 to 2 mm, 2 mm to 53 μm, 53 to 2 μm, and <2 μm).

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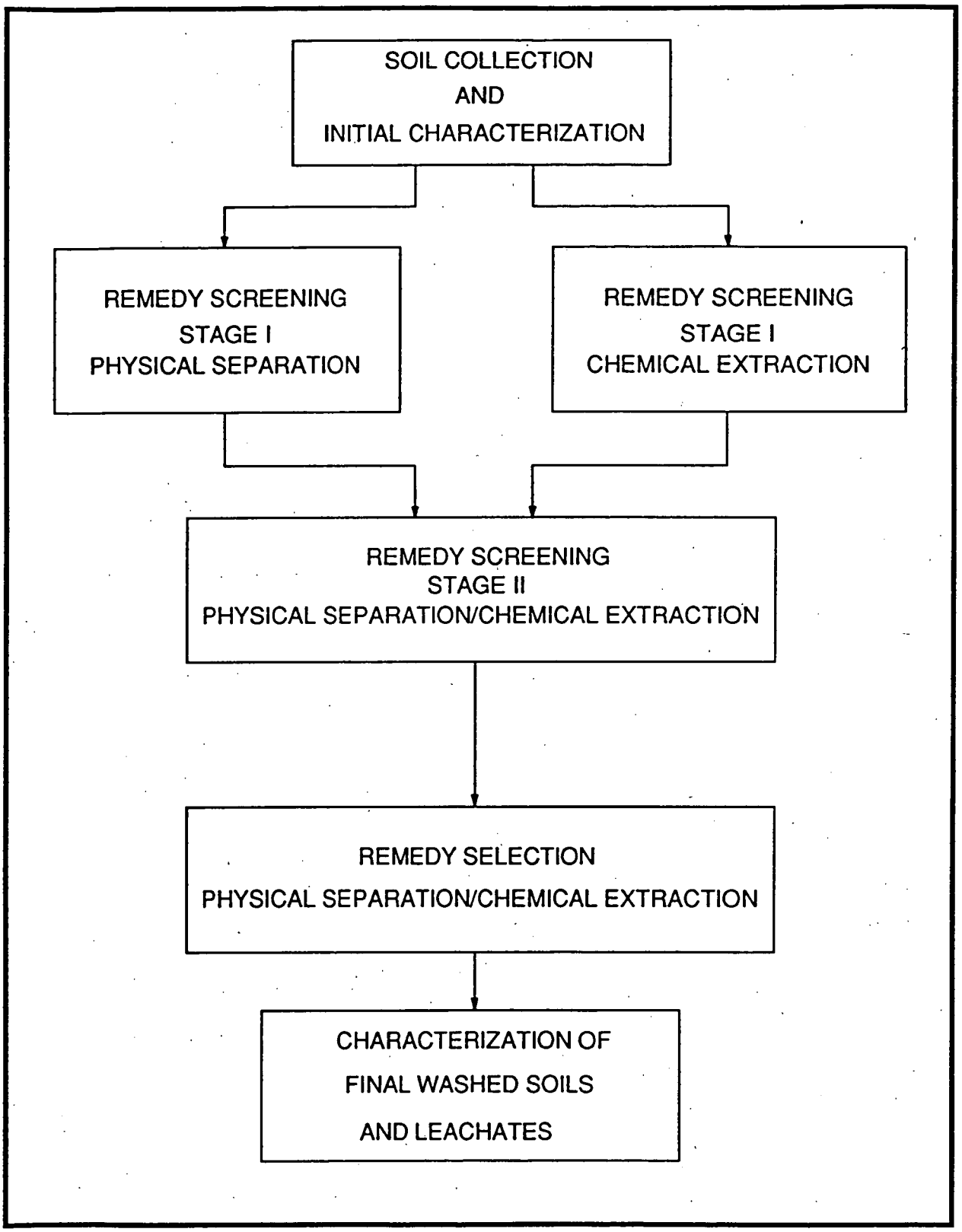

FIGURE 4-1. TREATMENT PHASES
SOIL WASHING EXPERIMENTAL DESIGN

The Remedy Screening-Stage I chemical extraction experiments are designed to look for gross effects on the less than 2 mm soil size fraction. The conditions were selected to yield favorable results, i.e., reagents that have a reasonable probability of working. The conditions chosen are high temperature (80°C), relatively high reagent concentrations (e.g., 1:1) and relatively high dose rate (10:1). The high temperature and reagent concentration will increase the rate of metal compound dissolution. The high dose rate will minimize the effects of common ion effect and ionic strength on the dissolution of the desired material.

Initial screening tests conducted during Stage I studies will allow for refinement of the Stage II approach for soil washing. The physical separation tests will identify the soil size fractions with which each type of contaminant (e.g., radionuclides, organic and inorganic compounds) is associated. Stage II remedy screening will focus on these individual soil size fractions as part of the test matrix. The most effective washing solutions, as determined in Stage I chemical extraction testing, will be used for washing these selected soil size fractions. The effect of extractant concentration and dose rate will be determined.

Results from Stage II studies will demonstrate those extraction reagents and concentrations that are most effective in removing radionuclides and other chemical constituents from selected soil size fractions. These results will help to establish the series of steps during physical separation and chemical extraction necessary to achieve a particular action level for contaminant removal. Also, the results from chemical extraction tests could help determine the effectiveness of iterative chemical extractions in removing additional contaminants from soils and wash solutions or leachates. These remedy screening results will, in turn, be incorporated into the remedy selection advance phase testing and the scaled version of the soil washing treatment system.

4.2 SOILS USED IN THE SOIL WASHING TREATABILITY STUDY

4.2.1 Initial Selection of Soils

The Operable Unit 5 soil washing study requirements include the initial collection and characterization of soils used for treatability testing. Soils chosen for soil washing will be selected from four locations that are considered to be representative of the contamination problem at the FEMP. The basic criteria for the type of soil selected, described in Section 6.0, focuses on four soils with moderate to high uranium contamination. The selection of soils from two of these locations that also contain other inorganic and organic constituents will allow for soil washing treatability testing to address other specific contamination problems of soils at FEMP.

Soils contaminated primarily with radionuclides (specifically uranium) will be noted as "ID" soils. These soils will be used in both the treatability testing and the Integrated Demonstration (ID) program. Soils contaminated with radionuclides plus other inorganic and organic chemicals will be noted as

"OU5" soils because they are unique to the Operable Unit 5 Treatability Study Work Plan program. Two soils will be selected from each program and will be denoted as soils A and B. Further specific reference to the four soils used in this treatability study will use the following four soil identifications: ID-A, ID-B, OU5-A, and OU5-B. This system will also enhance the subsequent reporting of results relative to the treatability testing of these soils.

The locations of the two ID soils (ID-A and ID-B) selected for soil washing are illustrated in Figures 6-1 and 6-2. Their selection was based on the results of an initial characterization of 10 locations at the FEMP (Appendix E). The two Operable Unit 5 soils (OU5-A and OU5-B) unique to this study will be selected based on the presence of HSL inorganic and organic compounds as well as radionuclides. The locations of these two soils will be based on the results of an initial sampling and screening of soils from four locations as described in Section 6.4, Initial Soil Sampling and Characterization.

4.2.2 Initial Analysis and Characterization of Soils

Soils from each of the four locations will be initially screened, homogenized, and placed into separate 55-gallon metal drums in accordance with Section 6.0 procedures. All drums containing soil from a single location will be individually sampled and analyzed to determine if the characteristics of soil contained in a single drum are significantly different than the characteristics of soil contained in the set of drums. The standard operating procedure for this homogeneity testing is given in Appendix E.

After determining that the soil within any single drum is homogeneous to all the soil contained in the set of drums for a single location, the drums will again be sampled. An aliquot of soil from each drum for a single location will be collected and placed into a stainless steel bucket and further homogenized using a stainless steel hand trowel. This soil will be sent to a CLP laboratory for analysis as described in Section 6.0.

A physical and chemical characterization of all four soils (ID-A, ID-B, OU5-A and OU5-B) will be conducted following collection and preceeding treatability testing. A list of the parameters to be tested in this initial baseline characterization is presented in Table 6-1. HSL and TCLP analyses in the initial soil characterization and the remedy selection studies are necessary to address the criteria for targeted action levels and to comply with RCRA guidelines for returning treated soil to the site. This characterization will be conducted in accordance with guidelines established in Section 3.0, Test and Data Quality Objectives, and Section 6.0, Sampling and Analysis. These analyses will provide the initial baseline characterization of the soil for each location to be used in all subsequent treatability studies.

4.2.3 Stage I - Laboratory Preparation Of Soil

Soils to be used in Remedy Screening - Stage I testing (Section 4.3) will be removed from the aforementioned drums and sent to the laboratory for bench-scale soil washing treatability studies. Because the soil contained in these drums will be prepared in a manner representative of the bulk preparation of soil quantities in excess of 1000 kilograms, there will be a need to further prepare the small quantities of soil sent to the laboratory before use in these soil washing studies. The following procedure for preparing soil is illustrated in Figure 4-2.

Soil that was sent to the laboratory in 5-gallon metal cans will be transferred to metal drying racks confined in a hood and allowed to air dry for 48 hours. The soil will be stirred as needed during this 48-hour period to ensure even drying. Air-dried soil will be physically attenuated with a wooden roller before screening through a 9.5- and 2.0-mm series of screens. Soil passing the 2.0-mm screen will be placed into a plastic bucket, and the soil collected on the 9.5- and 2-mm screens will be transferred to separate plastic buckets. To enhance homogenization of the soil for Stage I testing, each of the three different sizes of fractions of soil will be separately mixed in a rotating jar mixer for approximately 30 minutes. Each soil fraction will be separately transferred to a sample splitter, with the resulting split sample recombined and placed back into the bucket. This process should ensure a homogeneous soil with a constant moisture content for each of the three size fractions (19 to 9.5 mm, 9.5 to 2 mm, and <2 mm).

Loss of volatiles experienced during this homogenizing process will be similar to losses that normally occur during the handling of soil in the washing process. It is necessary in bench-scale studies using small aliquots of soil (e.g., 30 to 50 g) to properly prepare the soil before testing. Although this process may accentuate normal field operations, it is extremely critical in understanding the true distribution of radiological and chemical constituents in the various soil size fractions. The knowledge of chemical distribution and the resulting chemical extraction treatments can then be better utilized in remedy selection testing. In support of the remedial design efforts, a qualitative visual evaluation of the dust produced during handling and mixing of the soil, relative to the moisture content of soil, will be recorded as part of the laboratory notes.

4.2.4 Stage I - Initial Analysis And Characterization Of Soils

Baseline concentration and activities will be acquired for the less than 2-mm size fraction. The data will be used in the chemical extraction experiments. A baseline analysis will be conducted for each of the four soils (ID-A, ID-B, OU5-A, and OU5-B), and will consist of the following:

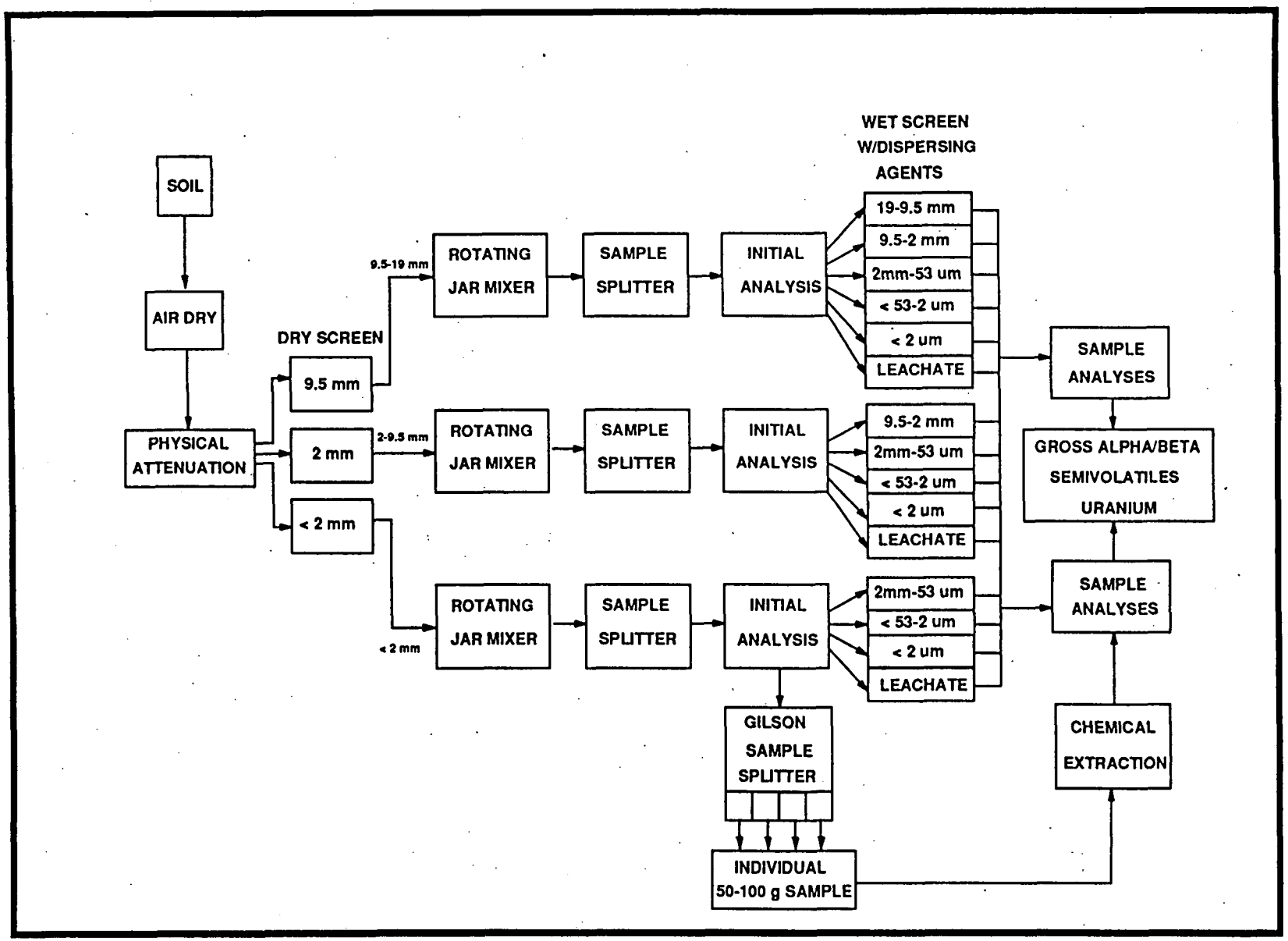

FIGURE 4-2. PROPOSED SOIL PARTICLE SIZE SEPARATION PROCEDURE
REMEDY SCREENING - STAGE I

- Gross alpha/gross beta
- Uranium
- Alkalinity or acidity
- Target organic compounds

The average activity for each homogenized soil fraction will be determined by analyzing six 400-mg aliquots for gross alpha and gross beta. Soil from each location drum will be considered homogeneous if the six gross alpha and six gross beta values have a percent relative standard deviation (RSD) less than or equal to 30 percent. If the percent RSD is greater than 30 percent, the sample will be remixed (see Section 4.2.3) and tested again for homogeneity.

After the soil sample is determined to be homogeneous, it will be analyzed for uranium content, alkalinity, acidity, and target organic compound content. Random aliquots will be collected from each of the homogenized samples for the analyses.

Alkalinity or acidity will initially be determined in soils to aid in determining the quantity of certain extraction reagents necessary to overcome buffering effects and effectively remove contaminants. The average alkalinity or acidity of six 3-g aliquots of the soil will be determined by titration with 1 normal hydrochloric acid (1N HCl) or 1 molar sodium hydroxide (1M NaOH). The test will be conducted at ambient temperature. The proposed weights of the soil and extraction fluid in initial chemical extraction tests will be reevaluated after analysis of the average gross alpha/gross beta and alkalinity or acidity of the soil.

The average concentration of eight selected target organic compounds in six samples will be determined. These concentrations will serve as baseline values for monitoring the efficiency of organic compound extraction. The eight organic compounds will consist of four volatile organic compounds and four semivolatile organic compounds. Initial volatile and semivolatile compounds have been chosen because of their reported presence in site soils and their distinct separation peaks in chromatographic analysis. Alternative compounds will be selected if the initial characterization shows that the compounds initially selected are not present at significant levels within the soil to be treated. If no specific organic compounds are detected during the initial characterizations, target organics will not be analyzed.

The four volatile organics are benzene, toluene, total xylene, and trichloroethene; the four semivolatile organics are benzo(a)pyrene, benzo(g,h,i)perylene, fluorene, and naphthalene. Six 10-g aliquots of the soil will be analyzed for volatile organics by either purge and trap gas chromatography (GC) analysis or a combination of solvent extraction (e.g., methanol) followed by purge and trap GC analysis. Additionally, six 10-g aliquots of soil will be extracted with a solvent (e.g., methylene chloride) and

analyzed for the targeted semivolatile organics. The analytical parameters will depend on the concentration of volatile organic compounds and semivolatile organic compounds in the sample.

4.2.5 Stage II - Laboratory Preparation of Soil

Soils to be used in Remedy Screening - Stage II testing (Section 4.4) will be transferred from 55-gallon metal drums to 5-gallon metal cans and sent to the laboratory for bench-scale soil washing treatability studies. Because the soil contained in the 5-gallon cans is representative of the bulk soil to be used in the remedy selection testing, minimal additional preparation of soil before Stage II testing will be conducted. Approximately 10-kg batches of feed soil used in Stage II tests will be slurried using a 1:4 (wt:wt) ratio of soil to washing solution. This slurry will then be processed through the physical separation and chemical extraction steps described in Stage II testing (Section 4.4). This method will closely simulate process conditions expected in remedy selection stage testing.

4.2.6 Stage II - Initial Analysis and Characterization of Soils

Soil received in 5-gallon cans from the FEMP site (<19.5 mm) will not be initially separated into specific size fractions. Five 100-g aliquots of soil from each approximate 10-kg soil batch (before the addition of washing solution) will be collected, recombined and air dried. The sample will be ground using a ceramic mortar and pestle to pass a 2-mm screen. This material will then be homogenized using a rotating jar mixer and sample splitter.

Initially, this soil will be analyzed and characterized in accordance with procedures similar to those described in Section 4.2.4 of Stage I analysis. Alkalinity and acidity will not be determined at this stage; data obtained in Stage I testing will be used as a reference source. However, the following analyses (refer to Table 3-4) will be performed on this soil before physical separation and chemical extraction tests in Stage II studies:

- Gross alpha/gross beta
- Uranium by IC
- Target semivolatiles
- Target volatiles
- Target metals

4.2.7 Remedy Selection - Preparation of Soil Used in Advanced Stage Tests

The soils from the four locations (ID-A, ID-B, OU5-A, and OU5-B) stored in the 55-gallon drums on the Plant 1 pad at the FEMP will be used in remedy selection testing. No additional preparation of this soil will be conducted before its use in remedy selection studies.

4.2.8 Remedy Selection - Initial Analysis and Characterization of Soils

A complete physical and chemical characterization of soils in these drums was conducted when the soil was initially placed into the drums. This information, described in Sections 4.2.2 and 6.0, is the baseline characterization data for all four soils used in the remedy selection stage tests.

4.3 REMEDY SCREENING - STAGE I

4.3.1 Stage I - Physical Separation

Physical separation studies in Remedy Screening - Stage I will focus on a qualitative and quantitative characterization of the distribution of target analytes (Table 3-3) relative to specific soil size fractions. Soils shipped from the FEMP site, having already passed a 19-mm screen on site, will be further prepared at the laboratory in accordance with Section 4.2.2.1. Figure 4-2 illustrates the sequential procedure for this screening portion of the bench-scale soil washing treatability study. Five size fractions (19 to 9.5 mm, 9.5 to 2 mm, 2 mm to 53 µm, 53 to 2 µm, and <2 µm), will be treated independently throughout this stage of testing. Initial characterization of three size fractions (19 to 9.5 mm, 9.5 to 2 mm, and <2 mm) was described in Section 4.2.2.2. The two smallest fractions cannot be initially characterized, but will be characterized as a final product of Stage I physical separation testing.

A 250-g sample of soil from each size fraction will be subjected to a modified version of the "mineral fractionation for soils procedure" by M. L. Jackson (1975) (Appendix B). A variation of this procedure will incorporate the use of sodium bicarbonate ($NaHCO_3$) and sodium hydroxide (NaOH) as alternative dispersing reagents selected in addition to the recommended sodium carbonate (Na_2CO_3). Potable water and a modified method incorporating the use of a sodium citrate-sodium bicarbonate-sodium dithionite (CBD) mixture (Lee and Marsh 1992) will also be tested. Potable water will be used for all reagent solutions as well as in the fractionating procedure. The five solutions are listed in Table 4-1. All dispersing solutions will be used as approximately 1 millimolar (1 Mm) concentrations. The investigation of alternative dispersing reagents is necessary to evaluate the efficacy of contaminant removal relative to the incorporation of these reagents into the initial washing solution.

Dispersing agents may be critical in providing a single grain product of the soil used in the Stage I tests. The importance of this lies in the need to determine the association of contaminants with individual size fractions of the soil. This association will be the basis for all further mechanical separation parameters as well as the focus of all chemical extractions tests.

The use of dispersing agents in subsequent testing may present a problem during the chemical extraction tests relative to the interferences of the dispersing agent with the chemical extraction of uranium and other contaminants. This is the primary reason for the listing of the five dispersing agents as potential deflocculants during the particle size separation tests.

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TABLE 4-1

TEST PROGRAM FOR CHEMICAL EXTRACTANTS

Typical Extractants	Concentration	Dose (wt extractant/wt initial sample)	Temperature (degrees C)
Acids/Bases/Salts			
H_2SO_4	1:1[a]	10:1	80
HCl	1:1[a]	10:1	80
HNO_3	1:1[a]	10:1	80
H_3PO_4	1:1[a]	10:1	80
$Na_2CO_3/NaHCO_3$	60/20 g/L[b]	10:1	80
NaOH	4N	10:1	80
$(NH_4)_2CO_3/NH_4HCO_3$	60/20 g/L[c]	10:1	80
NaCl	Various[d]	10:1	80
KCl	Various[d]	10:1	80
Chelants			
EDTA	30%	10:1	80
NSI	Commercial Concentration	10:1	80
Citraklean	Commercial Concentration	10:1	80
Surfactants			
Anionic	Various	10:1	Ambient
Cationic	Various	10:1	Ambient
Noionic	Various	10:1	Ambient
Alcohol			
Octanol	Various	10:1	Ambient

[a] Mixture of equal volumes of concentrated acid and water.
[b] 60 g of Na_2CO_3 plus 20 g of $NaHCO_3$ in each liter of solution.
[c] 60 g of $(NH_4)_2CO_3$ plus 20 g of NH_4HCO_3 in each liter of solution.
[d] NaCl and KCl will be tested alone and in combination with other extractants.

In consideration of the interferences noted above, a physical means of aggregate dispersion will also be investigated. Mechanical mixing or ultrasonic dispersion will be investigated in addition to the five dispersing agents.

The soil fractions derived from the addition of dispersing reagents and from separation by physical means using only potable water will be analyzed for uranium by IC. A comparison of the uranium in each soil fraction will be made.

If dispersing reagents appear to be necessary, they will be carried forward into Remedy Screening-Stage II to determine their effects on the chemical extractions. Before proceeding to the Remedy Selection phase, it will be determined if chemical dispersing reagents are necessary.

The fractionation method by Jackson uses a 53 μm sieve to initially separate the sand fraction from the soil/dispersing reagent slurry. A 4:1 solution-to-soil (weight:volume) ratio will then be shaken for 30 minutes on a reciprocating laboratory shaker before sieving. Separation of the silt from the clay fraction incorporates the use of centrifugation. Fractionating the two size fractions greater than 2 mm (19 to 9.5 mm and 9.5 to 2 mm) will also require the use of a 2-mm screen to determine the mass of soil constituents greater than 2 mm in size.

The washing (dispersing) solution will be separated from the clay fraction in the final step by centrifugation and then collected. Uranium, gross alpha/gross beta, and targeted semivolatiles will be analyzed for in the wash solution and in each of the four particle-size fractions (>2 mm, 2 to 53 μm, 53 to 2 μm and <2 μm) of the washed soil. This characterization of the soils will determine the type and amount of targeted contaminants and the level of radioactivity associated with each of the particle size fractions isolated from each soil sample from the four locations. Contaminants found in the solutions will be considered readily removable contaminants and therefore loosely or freely associated with the soil matrix. Those contaminants still present in selected particle-size fractions following washing and sieving will be considered strongly bound or occluded contaminants and will be the primary focus in development of the chemical extraction processes.

4.3.2 Stage I - Chemical Extraction

4.3.2.1 Background for Extraction Testing

The purpose of Stage I chemical extraction is to determine potentially successful extractants and to eliminate ineffective extractants from the study. The effectiveness of various acids, bases, chelants, surfactants and alcohol extractant solutions in removing radionuclides and targeted metal and organic compounds from soil will be determined. An extractant is considered potentially successful if the uranium concentration, target organic compound concentration, or measured gross alpha/gross beta in the extracted and rinsed soil is decreased by 40 percent (see Table 3-3). A flow diagram for chemical extraction - Stage I is illustrated in Figure 4-3.

Remedy Screening - Stage I testing will use uranium as the target radioactive and metal chemical constituent. In addition, the radiological activity will be tracked by analyzing for gross alpha/gross beta in the extracted soils and washing solutions. Results from Stage I testing will be used to refine the experimental approach used in Stage II. A number of extractants will be eliminated from Stage II studies as a result of Stage I testing. This will allow for a more thorough investigation of the remaining potentially successful extractants during Stage II testing.

Certain soils used in this study have been reported to contain various metals besides uranium (e.g., arsenic, barium, and lead) and organic compounds. Tables in Appendix A (A-1, A-2, A-3, and A-4) show the results of these earlier investigations. The extractants have been selected to test the removal efficiencies for these metals and organic compounds, which are listed in Section 3.0 of this work plan.

The FEMP soils have been reported to contain a relatively high clay content. It is anticipated that a certain amount of the uranium and other metals present in soil will be tightly bound to the clay portion of the soil. In addition, Lee and Marsh (1992) have reported that a significant amount of the uranium (present in the particulate form) is associated with the larger soil size fractions. Aggressive extractants were therefore selected for this early stage of the chemical extraction process.

A brief rationale for selection of each extractant follows. Sulfuric acid, hydrochloric acid, nitric acid, and the carbonate solutions are used in uranium mining and contaminated water purification. Phosphoric acid was selected due to potential phosphate complexes that may form. These acids may also protonate some organic compounds, making them more soluble. Sodium hydroxide is used to increase the pH, which should increase the solubility of certain metals like lead. Sodium hydroxide may also increase the solubility of certain organic compound via a deprotonation mechanism. Sodium and potassium chloride have been used to convert the less soluble RaSO4 into the more soluble RaCl2

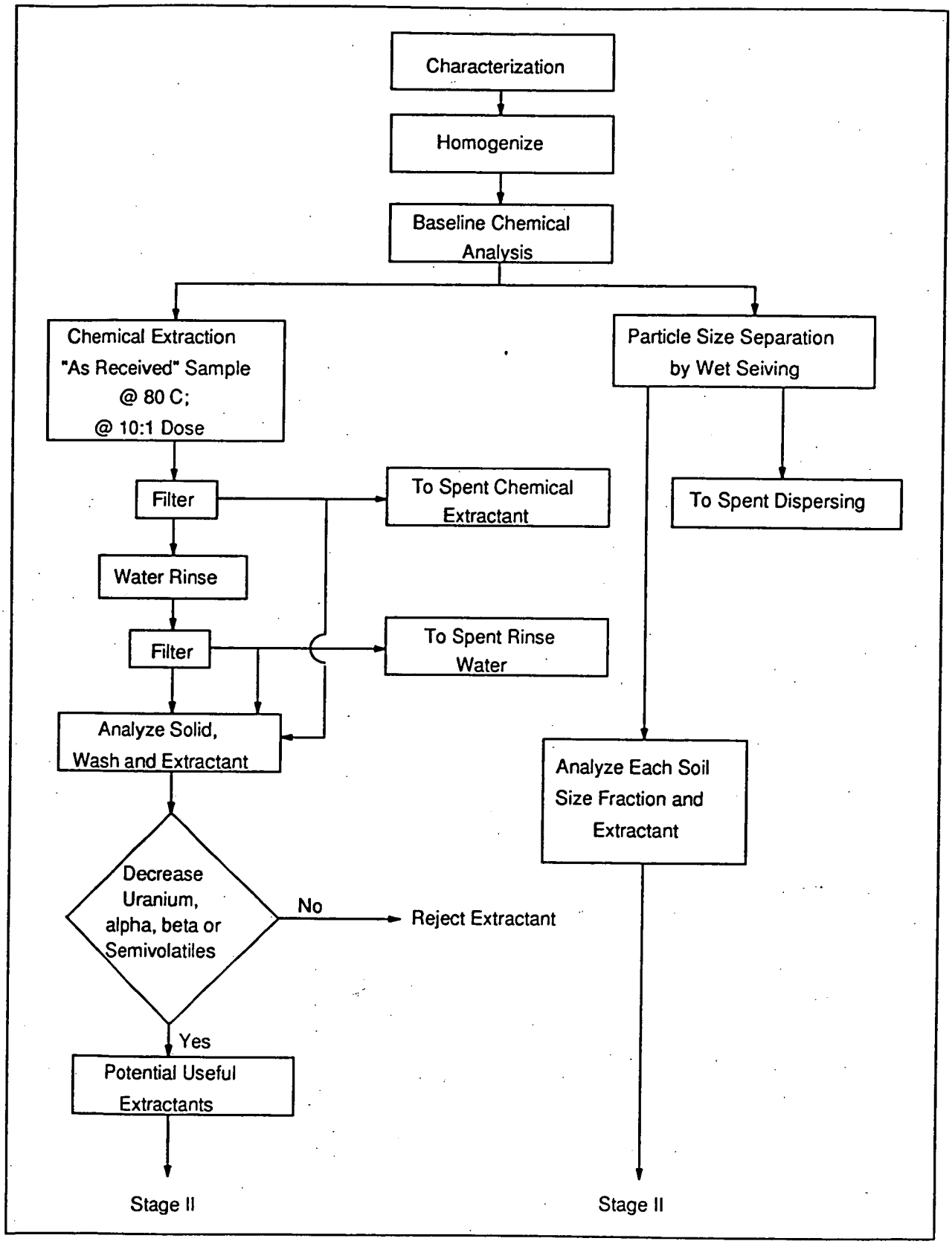

FIGURE 4-3. REMEDY SCREENING - STAGE I - CHEMICAL AND PHYSICAL EXTRACTION

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so that it could be extracted. Chelants have been successfully used to extract metals from ores. Surfactants and alcohols are used to increase the solubility of organic constituents in the soil matrix (Katz 1951; Kirk-Othmer 1978; Mattus n.d.; Merritt 1971).

The rationale for the reagent concentration used in Stage I is given below:

- Acids: The 1:1 acid concentrations are chosen as a reasonable compromise of acid strength and having adequate water for dissolution. The IT Technology Development Laboratory (TDL) experience on the extraction of uranium and other hazardous metals from mixed waste biological and wastewater sludges and from the Fernald Silos 1 and 2 waste material has shown that the efficiencies of extractions with acids were highest with acid concentrations between concentrated acids and solutions that were diluted by 50 percent with water.

- Sodium hydroxide: 4N sodium hydroxide concentration is a compromise between total alkalinity, water content of the extractant, and viscosity of the extractant.

- Carbonate solutions, NS1 and Citraklean™: These extractants are being used at typical commercial concentrations.

- EDTA: The ethylenediaminetertraacetic acid (EDTA) concentration is selected to provide a significant excess of exchange equivalents for favorable extraction ability.

- Chloride salts, surfactants, and alcohols: The correct range of concentrations for NaCl, KCl, surfactants, and alcohols cannot be determined without experimentation.

4.3.2.2 Experimental Procedure

The <2-mm size fraction of this homogenized soil will be used in this stage of testing (see Section 4.2.3). Each extractant will be tested at a 10:1 (wt:wt) dose rate of extractant to soil on approximately 50-gram aliquots of this homogenized soil and at extractant concentrations according to Table 4-1. The extractants are acidic or basic solutions and solutions that contain chelants, surfactants, chlorides, and/or alcohols. Soil and extractant mixtures will be stirred or agitated for four hours during chemical extraction. Soil will be extracted at either 80°C or ambient temperature depending on the extractants used (see Table 4-1).

After cooling to room temperature, the samples will be filtered and slurry rinsed with a volume of deionized water equal to approximately 20 percent of the original extractant volume. Slurry rinsing is a step in the extraction and filtration process in which a sufficient quantity of liquid is used to rinse the extraction vessel and, when transferred to the filter, serves as a flushing solution to the soil sample that was just extracted and filtered.

The ethylenediaminetetraacetic acid EDTA solutions will be tested at three different pH values. The metal-EDTA stability constant is a strong function of Ph. For a complex mixture of metals, the pH of

the solution must be varied to maximize the solubilities of all the metals of concern (Dow 1981, 1985). By vendor description, the NS1 and Citraklean reagents are buffered solutions whose pH is optimized for their application. The pH will not therefore be varied for these two extractants. The surfactants will be tested at three different concentrations. The other extractants, noted in the table, may be tested at various pH values if the standard pH values being tested give unsatisfactory results.

The radiological activity of the extracted solid, extractant solution, and rinse water will be determined by performing uranium, gross alpha, and gross beta analyses. The concentrations of the four target semivolatile compounds in the extracted solid, extractant solutions, and rinse water will be determined by performing GC analyses as described in Section 4.2.4. The percent radiological and organic compound removal will be calculated.

4.4 REMEDY SCREENING - STAGE II

4.4.1 Introduction

Stage II treatability testing incorporates the findings of Stage I physical separation and chemical extraction testing. A flow diagram of Stage II is presented in Figure 4-4. A primary function of Stage II testing in the experimental design is to serve as a transition phase between Stage I testing and the remedy selection stage testing. Because the soil sent from the FEMP site to the laboratory is representative of the site soil to be used in the remedy selection testing, no additional preparation of the soil will be done before its incorporation into the study. Also, those extractants evaluated to have been most effective in contaminant removal for soil will be selectively chosen for use in this stage of testing. This process decreases the number of extractants to be considered in Stage II.

The effectiveness of extractants relative to their concentration and dose rate will be more thoroughly evaluated in Stage II testing. Operating conditions for these potentially successful extractants will also be more thoroughly investigated and optimized during this stage of the study. The selection of extractants from this stage of testing for use in the remedy selection stage testing will be based on the extractants' effectiveness. An extractant will be considered effective if targeted organic compound concentrations in the soil are decreased by 80 percent or if the extracted soil passes the TCLP leaching standard for one of the following:

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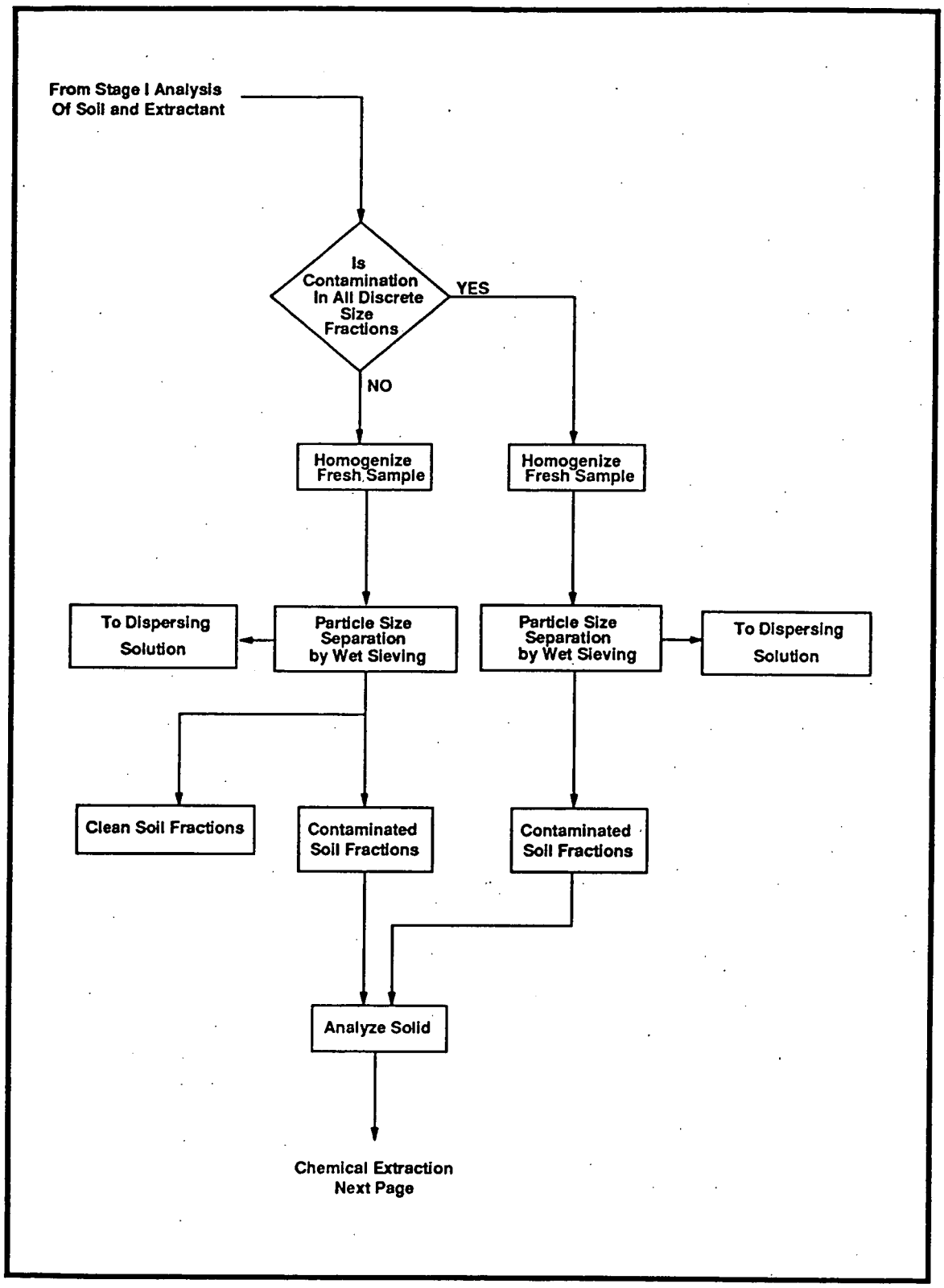

FIGURE 4-4. REMEDY SCREENING - STAGE II - PHYSICAL SEPARATION AND CHEMICAL EXTRACTION

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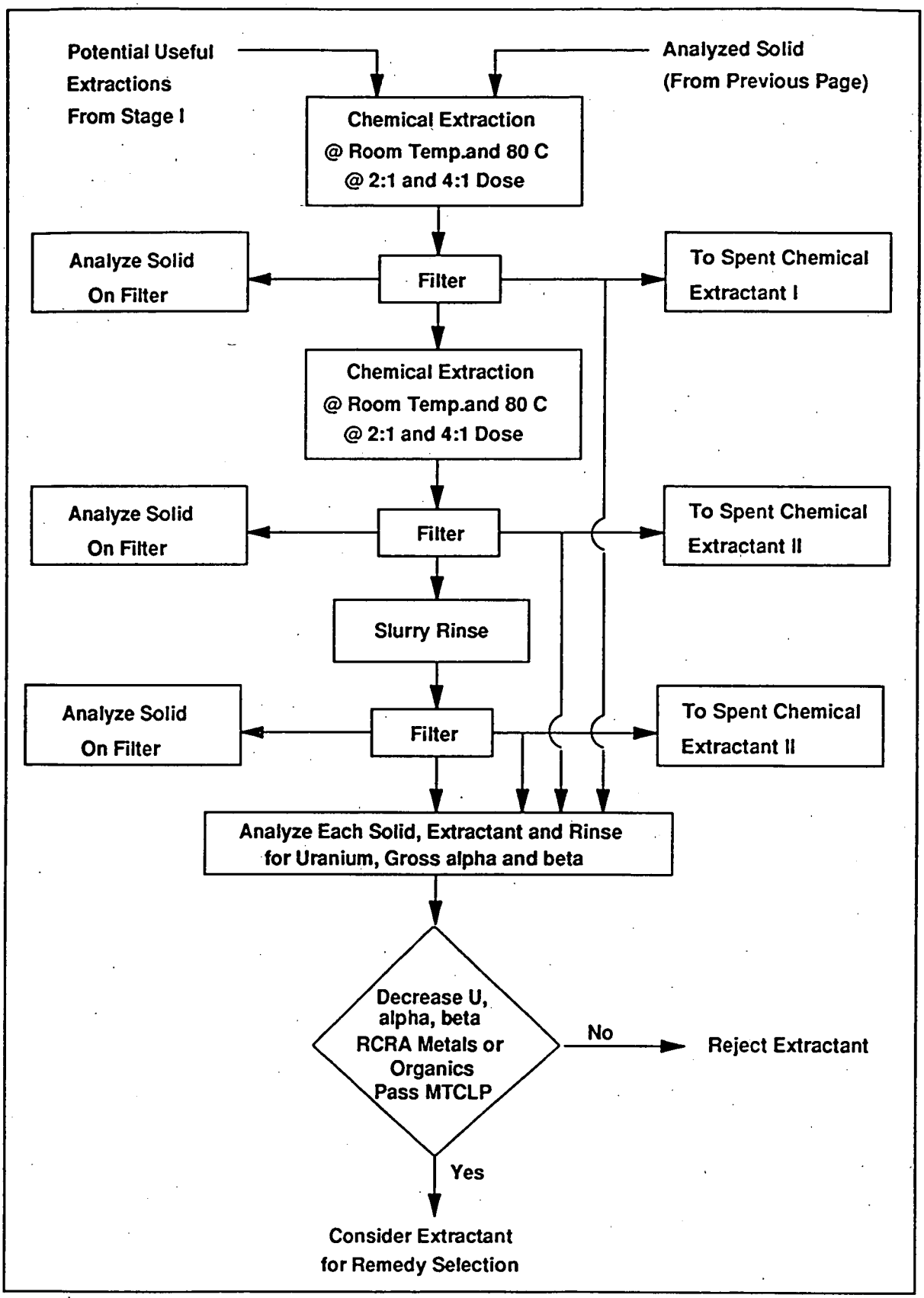

FIGURE 4-4. (CONTINUED)

- Targeted metals
- Measured gross alpha/gross beta
- Uranium concentration

4.4.2 Stage II - Physical Separation and Chemical Extraction

4.4.2.1 Physical Separation

The approximate 10-kg batches of feed soil that have been analyzed and characterized, as described in Section 4.2.6, will be used in Remedy Screening - Stage II tests. This quantity of soil will be mixed into a 1:4 (wt:wt) soil to washing solution slurry using a Hobart mixer. Mixing time will be approximately 4 hours. The washing solutions will be composed of the most effective dispersing reagents evaluated in Stage I testing. In addition, the washing solutions may incorporate selected chemical extractants determined to be effective in contaminant removal during Stage I testing. A combination of a dispersing reagent and chemical extractant reagent in the washing solution will be dependent on the results from Stage I testing and the chemical compatibility of the two reagents in a single solution.

This slurry will then be screened through a series of three stainless steel sieves (9.5 mm, 2 mm and 53 µm) connected to a motor-driven sieve shaker. Each of the four size fractions (19 to 9.5 mm, 9.5 to 2 mm, 2 mm to 53 µm, and <53 µm) and the washing solution will be separately collected. Each soil size fraction will be transferred to a separate glass beaker and slurried using potable water at a 1:4 (wt:wt) soil to water ratio. Each slurry will be mixed on a shaker table for 4 hours. This rinsing solution will be separated from each size fraction by transferring the entire volume of the beaker to each soil size fraction's respective sieve.

Aliquots of the initial washing solution and rinsates will be taken and analyzed for the following:

- Uranium
- Gross alpha/gross beta
- Target semivolatiles
- Target metals

A 50-g aliquot of each soil size fraction will be taken and analyzed for the following:

- Uranium
- Gross alpha/gross beta
- Target volatiles
- Target semivolatiles
- Target metals

A 2.5-g aliquot of each soil size fraction will be taken, subjected to the modified TCLP (MTCLP) and analyzed for the following:

- Uranium
- Gross alpha/gross beta
- Target metals

Those soil size fractions that have not achieved an action level of cleanup for individual contaminants will be subjected to additional chemical extraction tests. The chemical extraction tests for Remedy Screening-Stage II are described in the following sections.

4.4.2.2 Chemical Extraction

The effects of temperature, extractant concentration, extractant to soil ratios (dose rates), and the multiple extractions will be investigated according to Tables 4-2 and 4-3 in two steps during this stage of testing. In Step 1, the dose rate (4:1), time of extraction (4 hours), and number of extractions (1) will be constant for the concentrations and extractions listed in Table 4-2. The temperature will be maintained at 80°C for all extractants except for the surfactants and alcohol. Ambient temperature will be used for the latter two extractants. The chloride salts, surfactants, and alcohols will be used at similar levels determined in Stage I in all Stage II experiments. The chemical analyses for Stage II are listed in Table 3-4.

The most effective extractant concentrations determined from the experiments in Step 1 will be used in the temperature, dose rates, and multiple extractions experiments (see Table 4-3). Two temperatures (ambient and 80°C) and two dose rates (2:1 and 4:1) will be tested. The soil will be extracted two times with virgin extractants. Fifty- to 100-g aliquots of soil will be treated for 4 hours in each extraction. After each extraction cools to room temperature, the sample will be filtered. The sample will be slurry rinsed twice with deionized water after the second extraction.

The radiological activity of the extracted solid, extractant solution, and rinse water will be determined by gross alpha and gross beta analyses. The concentration of the eight volatile organics and semivolatile organics in the extracted soil will be determined. The concentration of the semivolatile organics in the extractant solution and rinse water will also be determined. Uranium will be measured by IC, and percent removal efficiencies will then be calculated. MTCLP will also be performed on the extracted soil (see Table 3-4). Those extractants that decrease gross alpha and beta activity, metals, or organics by at least 80 percent will be considered for the remedy selection phase.

TABLE 4-2

STAGE II EXTRACTANTS AND CONCENTRATIONS

Extractant	Concentration
Acids	Concentrated, 1:1, 1:3 (v/v)
NaOH	4 N, 2 N, 1 N
NS1, Citraklean	Commercial, 1:1, 1:3 (v/v)
EDTA	30%, 15%, 7.5%

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TABLE 4-3

PROPOSED REMEDY SCREENING - STAGE II TESTS

Run Number	Dose Wt Extractant/Wt Initial Sample	Temperature (°C)	No. of Extractions
1	2:1	Ambient	1
2	2:1	Ambient	2
3	4:1	Ambient	1
4	4:1	Ambient	2
5	2:1	80	1
6	2:1	80	2
7	4:1	80	1
8	4:1	80	2

The most promising extraction treatment test will be repeated for an extended run time of 8 hours. The slurry will be sampled while stirring at 1, 2, 3, 5, and 8 hours. Solids will be rinsed twice, and the solids and liquids will be analyzed separately for uranium, gross alpha/gross beta, and target metals and organics according to Table 3-4.

Contaminant Removal from Washing Solution - Stage IIA and IIB

Precipitation experiments will be performed on the leachates to remove contaminants from the washing solution as illustrated in Figure 4-5. The most promising treatments from the remedy screening phase of extraction testing will be used. The precipitation program will be divided into two parts: preliminary screening (Remedy Screening - Stage IIA) and confirmational testing (Remedy Screening - Stage IIB). The screening tests (using 10- to 20-mℓ samples) will be used to eliminate obviously deficient treatments and to establish dosages. The confirmatory tests (using 100-mℓ samples) will be used to demonstrate treatments on a larger scale for settling tests and more extensive analyses.

Precipitation of Metals in the Leachate Solutions - Stage IIA

This part of the Remedy Screening-Stage II incorporates the use of scintillation vials and small aliquots of the extractant solution (10 to 15 mℓ) in precipitating tests. The first set of tests uses single reagents as 10 to 30 percent solutions. The second set of tests uses dual reagents and sequential addition to evaluate the effectiveness of precipitating reagents on removing contaminants from the soil washing solution. Both sets of tests are described below.

Acid or Base Extraction Solutions Decontamination - Stage IIA

Precipitation reagents will be added to aliquots (10 to 15 mℓ) of the leachate solutions from the most promising treatments resulting from Stage I. The wash solutions will contain radionuclides and other metals (see Appendix A). Precipitating and flocculating reagents known to work with metals potentially present in the wash solution will be investigated. The reagents to be investigated are the sodium or potassium salt solutions of hydroxide, sulfide, sulfate, carbonate, and phosphate. Aluminum sulfate, ferric sulfate, and aqueous sodium silicate (Na_2O: SiO_2) will also be investigated. Aluminum sulfate and ferric sulfate additions will be preceded and/or followed by the appropriate pH adjustments. Slurries of magnesium oxide, calcium hydroxide, and dolomitic lime will also be tested. A preliminary series of tests using the aforementioned reagents is listed in Table 4-4. Tests 1 through 11 use single-reagents and Tests 12 through 26 use dual reagents (i.e., the reagents are added sequentially). In the sequential tests, the "first addition" reagent is added and allowed to react before the "second addition" reagent is added.

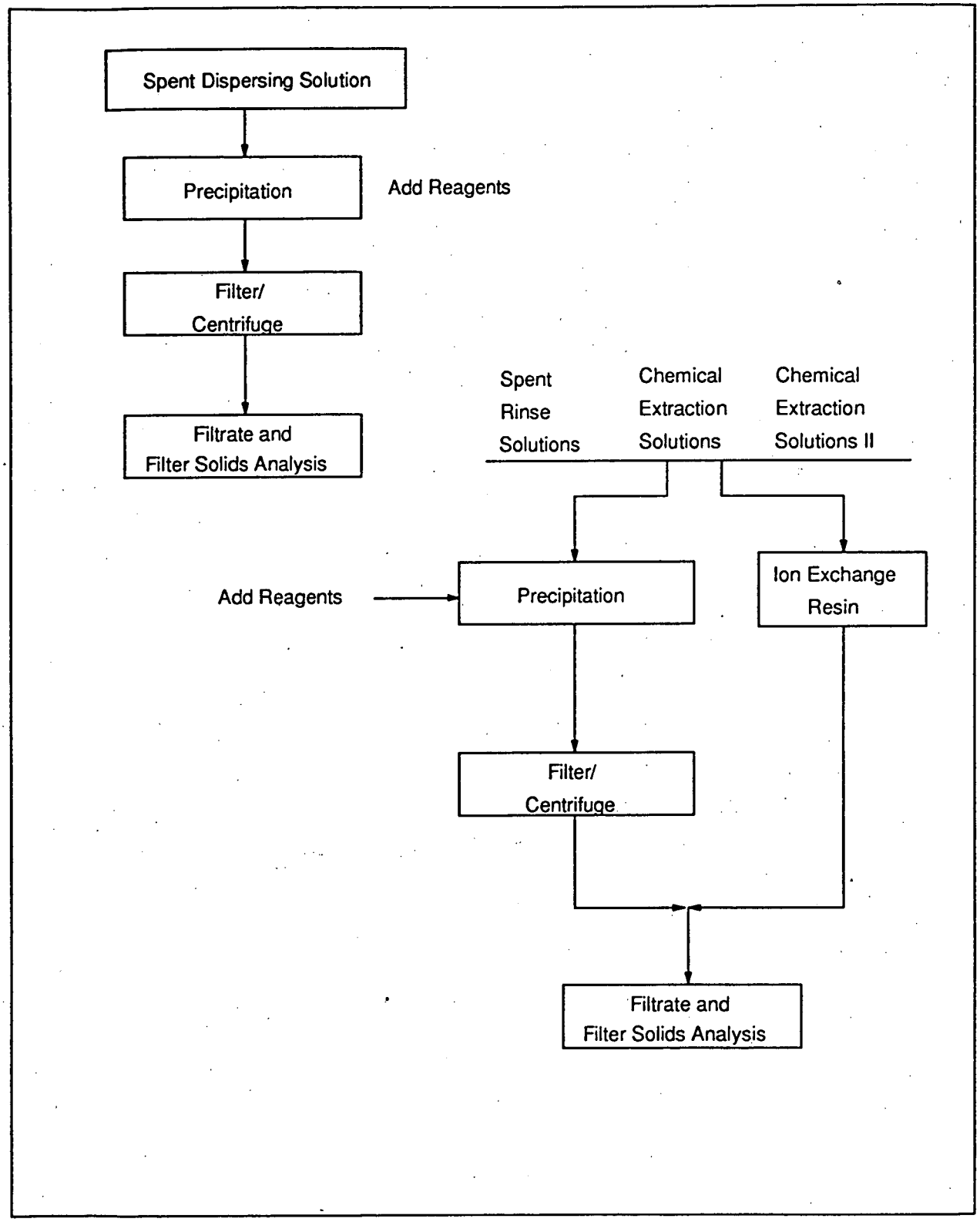

FIGURE 4-5. CONTAMINANT REMOVAL FROM WASH SOLUTION STAGE IIA AND IIB

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TABLE 4-4

PRECIPITATION OF EXTRACTION SOLUTIONS

Test Number	First Addition	Second Addition
1	NaOH	Not Applicable
2	Na_3PO_4	Not Applicable
3	Na_2CO_3	Not Applicable
4	Na_2S	Not Applicable
5	MgO	Not Applicable
6	$Ca(OH)_2$ tech lime	Not Applicable
7	Dolomitic lime	Not Applicable
8	Na_2SO_4	Not Applicable
9	Na_2S	Not Applicable
10	$Fe_3(SO_4)_3$	Not Applicable
11	$Al_2(SO_4)_3$	Not Applicable
12	$Na_2O:SiO_2$	NaOH
13	$Na_2O:SiO_2$	Na_3PO_4
14	$Na_2O:SiO_2$	Na_2CO_3
15	$Na_2O:SiO_2$	Na_2S
16	$Na_2O:SiO_2$	MgO
17	$Na_2O:SiO_2$	$Ca(OH)_2$
18	MgO	Na_3PO_4
19	MgO	Na_2CO_3
20	MgO	Na_2S
21	NaOH	Na_3PO_4
22	NaOH	Na_2CO_3
23	NaOH	Na_2S
24	Na_3PO_4	NaOH
25	Na_3PO_4	MgO
26	Na_3PO_4	$Ca(OH)_2$

Single Reagent Tests - Stage IIA

The single reagent tests (1 through 11) will involve addition of the reagent as a 10 to 30 percent solution to a 20-mℓ scintillation vial containing 10 to 15 mℓ of sample. The leachate will be neutralized with the appropriate acid or base. In the case where the leachate is basic, the neutralization agent will be sulfuric, hydrochloric, or nitric acid. In the case where the leachate is acidic, sodium hydroxide or lime will be used for neutralizing the leachate. Certain tests may also be deleted because of excessive precipitate formation between extraction liquids and the precipitation reagents to be used. After neutralization, the appropriate reagent listed in Table 4-4 will be incrementally added according to the flocculation mini-jar test procedure. The treated leachate solutions will be gently shaken on an orbital shaker at 10 to 80 rpm. At 1, 4, and 24 hours, the treated solutions will be observed for the appearance of turbidity, and 0.5-mℓ sample aliquots will be removed, filtered through a 0.45-micron filter, and analyzed for uranium. If no turbidity has developed within 24 hours, the treatment will be considered as failing. The tests will be terminated at 24 hours, and the whole test solution will be filtered through a 0.45-micron filter. The filtered liquid will be analyzed for gross alpha/gross beta, U, As, Ba, Cd, Cr, Pb, Se, Ag, pH, and turbidity. If a metal is determined not to be in the parent liquid, that metal may not be analyzed for in the filtrate. If there is enough solid present, the filter cake will be analyzed for gross alpha/gross beta and uranium. The 0.45-micron filter is also used to determine if a removable precipitate is formed. If larger particulates are needed to improve filtrations, polymer addition may be used. Due to sample size, the filtrates from this Stage IIA may require dilution before analysis. Final analyte concentrations will be corrected for reagent dilutions during treatment as well as analytical dilutions. The effectiveness of the treatment will be determined by analysis of the uranium and metals results.

Dual Reagent Test (Sequential Addition) - Stage IIA

Tests 12 through 26 will be performed as listed in Table 4-4, after evaluation of results from Tests 1 through 11. In the dual reagent tests, the first reagent will be added and allowed to react for a period of time determined by the previous tests (1 through 11). Then, the second reagent will be added incrementally (as in the single reagent tests) and allowed to react for up to 24 hour, sampling for uranium analysis and noting turbidity at 1, 4, and 24 hours as before (in Tests 1 through 11). Final filtered test liquids will also be analyzed for gross alpha/gross beta, U, As, Ba, Cd, Cr, Pb, Se, Ag, pH, and turbidity as in Tests 1 through 11. If there is enough solid present, the filter cake will be analyzed for gross alpha/gross beta and uranium.

The experiments will note the appearance of turbidity and precipitation in the solution. Correlations between change in pH and onset of turbidity and precipitation, and correlations of pH with volume or weight of titrant added will be noted. The experiments will also note the rate of settling and which reagents significantly lower the concentrations of uranium and lead. 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.

EDTA Chelant Extraction Liquid Decontamination - Stage IIA

The metal-laden chelant solution from the most promising extraction treatment will be treated for metals removal from the liquid by the following methods. The methods are listed in order of testing sequence. If one of the bulleted methods work, the methods listed in subsequent bullets may not be tested.

- Alkaline precipitation - Tests will be performed in 20-mℓ scintillation vials in the same manner as outlined in single reagent tests in Stage IIA of precipitation testing. Reagents to be tested will include NaOH, Na_2CO_3, or Na_3PO_4 to the liquid. Filtration and subsequent analysis of the treated liquid will determine the effectiveness of the treatment. If none of the above are successful, a preliminary treatment with Fe^{3+} (to displace other metals) will be used, followed by alkaline precipitation.

- Insoluble chelant treatment - Tests will include treatment with and without Fe^{3+} preliminary addition at pH 3 to 6 (to displace other metals), followed by addition of another organic chelant that forms a stronger insoluble complex. The correct pH (using sodium hydroxide addition) will be determined empirically based on previous experience.

- Electrochemical treatment - An electrochemical cell can be used to remove metals while regenerating the chelant extraction liquid. This process consists of an electrochemical cell divided into two chambers by a cationic ion exchange membrane. One chamber contains the cathode and metal chelate solution, and the second contains Na_2CO_3 and the anode. During the process, metals are plated at the cathode while Na^+ ions migrate across the cationic exchange membrane to place the working chelant in the Na^+ form.

- Sodium sulfide treatment - If none of the above treatments are successful, sodium sulfide will be added to the metal chelate liquid to produce the insoluble metal sulfides. After filtration of the precipitate, samples will be analyzed for metals.

Precipitation of Metals in the Leachate Solutions - Stage IIB

Larger aliquots (50 to 100 cc) of the leachate solution will be tested with the most promising precipitation reagents from Stage IIA. The procedure to be used for these tests will be ASTM procedure 2035-80, Coagulation-Flocculation Jar Test of Water with the following modifications:

- The test sample size will be 100-mℓ instead of 1000 mℓ.
- 150-mℓ beakers will replace 1500-mℓ beakers.
- Agitator and reagent rack tube sizes will be reduced accordingly.

Settling rates will be determined as noted in the settling rate procedure. After settling rates have been determined, mixtures will be filtered per the filtration testing procedure. Solutions from the latter two

operations will be tested for As, Ba, Cd, Cr, Pb, Se, Ag, pH, and turbidity. The filtrate and filter cake will be analyzed for gross alpha/gross beta and uranium. If three or more precipitation tests are necessary, then further composite waste samples (presumably 300 to 500 grams) will have to be extracted to finish the tests.

Settling - Polymer - Stage IIB

If settling or filtration rates of treated leachates are very slow, then jar tests using inorganic coagulants (such as ferric sulfate) and/or organic polymers (such as Nalco #7768 anionic polymer) will be used. Preliminary range-finding tests will be performed with up to 10 different reagent combinations, incrementally adding the reagents until the appearance of floc. The most promising treatment, based on dosage versus sludge volume and effluent quality, will be tested per the modified ASTM Jar Test Procedure (Appendix B) at four different dosages to determine the most effective reagent dosage. A settling test will be run on the best treatment and dosage, as listed in the Settling Rate Procedure (Appendix B). The clear supernatant liquid will be sampled and analyzed for As, Ba, Cd, Cr, Pb, Se, Ag, pH, and turbidity. The filtrate and filter cake will be analyzed for gross alpha/gross beta and uranium.

Settling - Filter Aid - Preliminary Phase - Stage IIB

If the filtration rates are slow, these tests will be conducted. The feed solids concentration will be adjusted to pumpable solids concentration and the body feed concentrations to three different dosages of John Manville celite filter aid. Filter aid concentrations will be those recommended by the manufacturer. The treated samples will be filtered per the Filtration Testing Procedure (Appendix B). The optimum dose of reagents will be which produces the driest cake and the most filtrate in the shortest time. The filtrate will be analyzed to determine if the process successfully lowered the metal content. The filtrate and filter cake will be analyzed for gross alpha/gross beta and uranium.

Ion Exchange - Stage IIB

Ion exchange will be tested as a final step for precipitation/filtration-treated extraction liquid. This testing will include preliminary isotherm screening tests followed by column experiments using the most effective ion exchange resins. The ion exchange isotherm/kinetics experiments will be used to determine type of resin, column size, and flow rate for the column tests to follow. A minimum of 600-mℓ batch size will be required per study based on the minimum column size needed for use with 20 to 50 mesh resins and analytical sampling requirements.

Ion exchange isotherm screening tests will be performed by weighing milligram (±0.1 mg) quantities of different ion exchange resins into 20 mℓ scintillation vials. Fifteen mℓ of treated filtered leachate solution will be added to each of the vials. Some of the resins may be tested at more than one pH per

manufacturers recommendations, by pH adjustment of the liquid before addition to the resins. The isotherms will be shaken on an orbital shaker for 24 hours. A 0.5-mℓ aliquot of the liquids will be filtered at 1, 2, 3, 4, and 24 hours. The aliquots will be analyzed for uranium by IC.

Based on results of isotherm testing, an ion exchange (IX) column(s) will be sized (0.5 to 1 inch in diameter) and packed with the resin(s) of choice. The resin bed will be slurry-packed and rinsed with Type I water. Then, not less than 600 mℓ of treated leachate liquid will be pumped through the IX column at a flow rate of 2.5 to 10 mℓ per minute (based on column size) using a Masterflex tubing pump. The column effluent will be collected in at least five cuts and analyzed for uranium by IC.

4.5 REMEDY SELECTION

The remedy selection testing will combine particle-size physical separation and chemical extraction into the single operation of soil washing. Findings from Stage I and Stage II testing will be incorporated into a scaled version of this soil washing system.

Each of the four soils (ID-A, ID-B, OU5-A and OU5-B) collected at the onset of the treatability study program will be separately washed during this Remedy Selection testing. After collection, the soils are stored in 55-gallon drums on the Plant 1 pad at the FEMP until being sent to the laboratory for analysis. No additional preparation of these soils will be performed before their incorporation into the soil washing system.

A physical and chemical characterization of these soils (Table 6-1) is performed at the time the soils are excavated, screened and placed into the drums. These analyses, described in Section 4.2.2 and Section 6.0, provide the baseline characterization data for each of the four soils to be used in the Remedy Selection phase of soil washing. This baseline data will be used to describe the starting physical characteristics of the soil and the initial concentration of analytes in the soil.

4.5.1 Soil Size Physical Separation

The process flow sheet for the scaled version of the soil washing system used in Remedy Selection testing is illustrated in Figure 4-6. The system design illustrates a proposed operation based on the information derived from earlier soil sampling and analyses indicating the presence of radionuclides and other inorganic and organic chemicals.

For purposes of simplifying the explanation of the flow sheet, only uranium will be mentioned as the contaminant. The uranium is considered to be present in several forms, including ionic, particulate, and as soil-particulate coatings (Lee and Marsh 1992). Selective forms of the uranium are also

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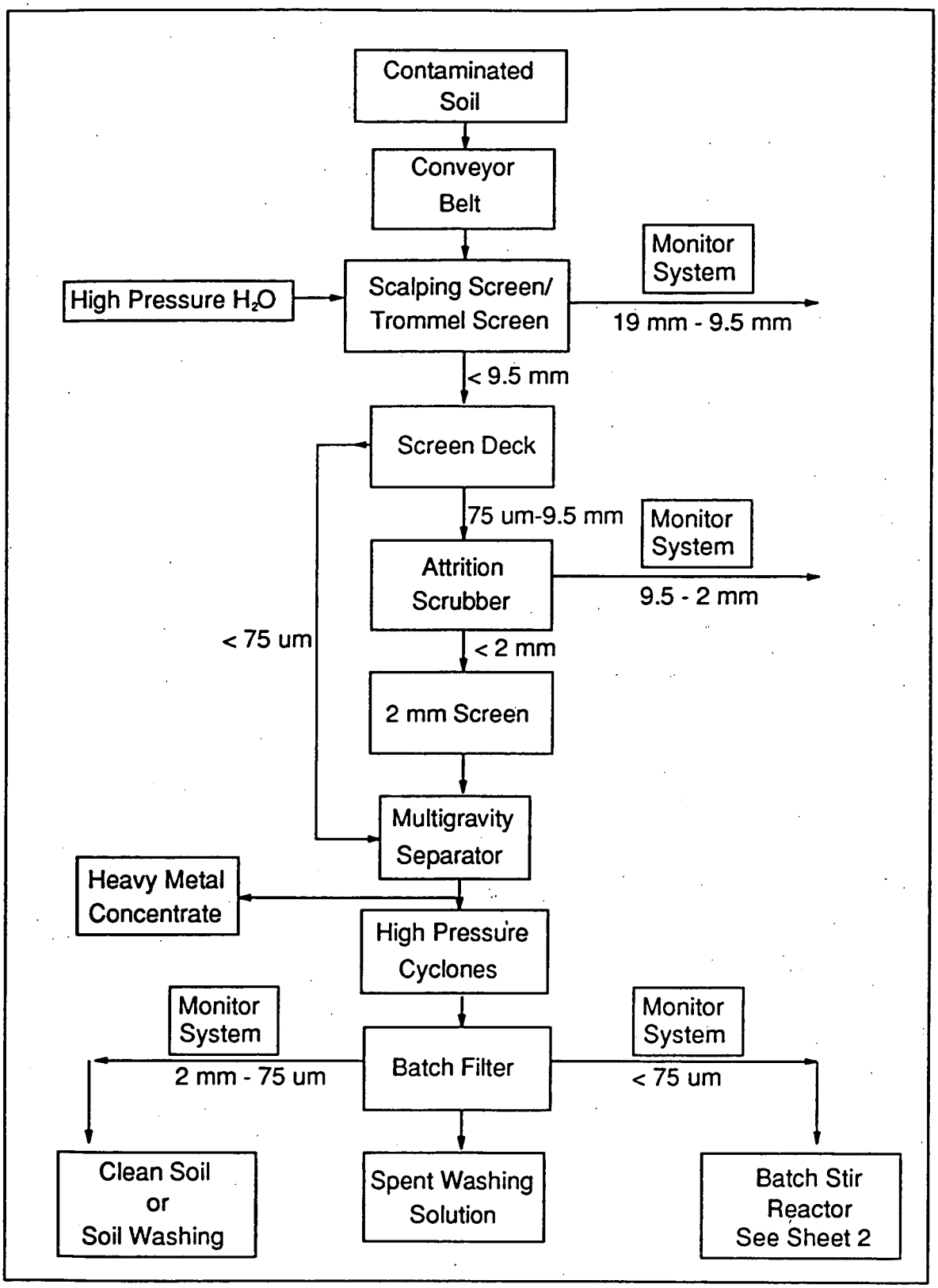

FIGURE 4-6. PROPOSED PROCESS FLOWSHEET FOR SOIL WASHING

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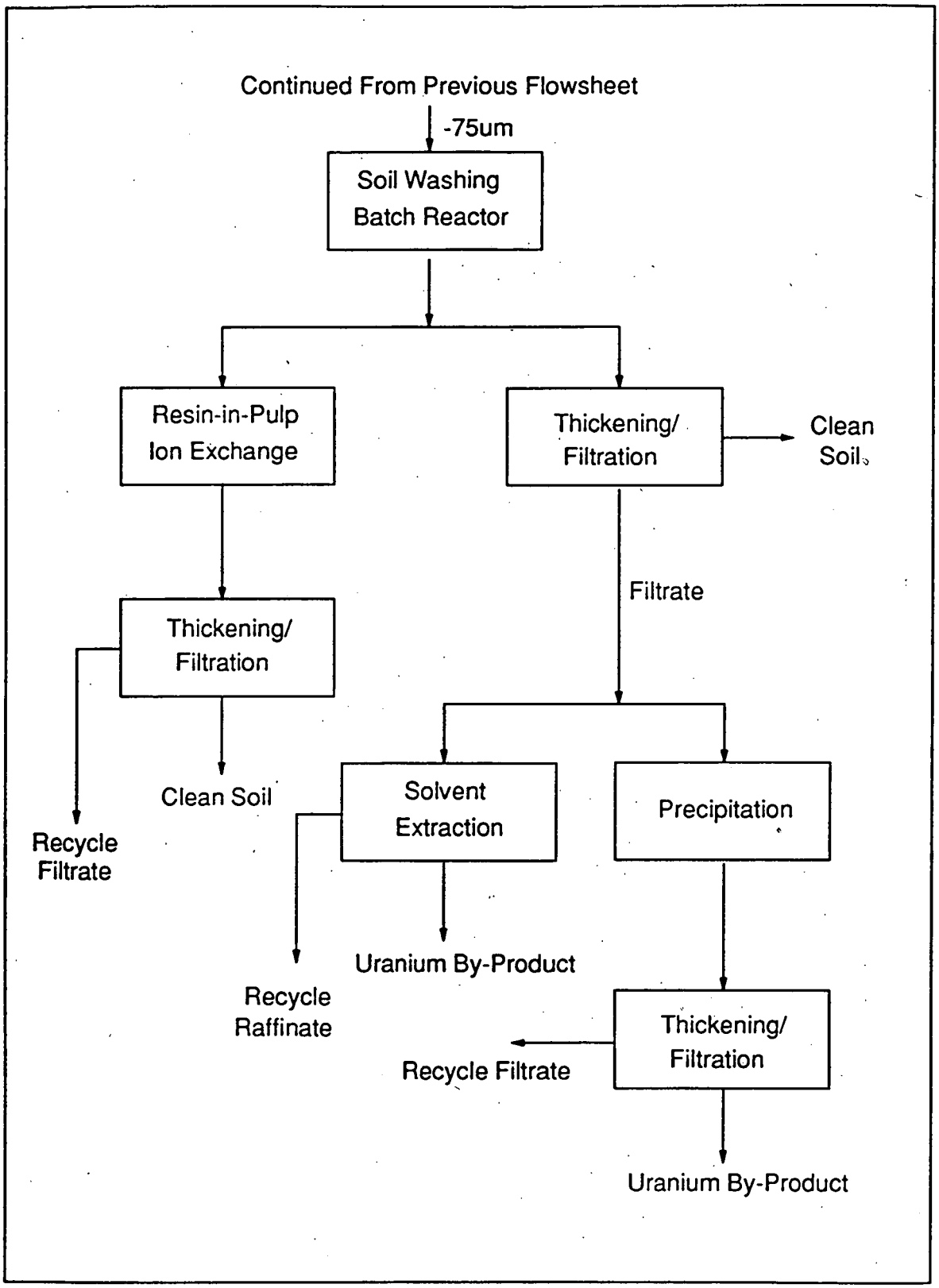

FIGURE 4-6. PROPOSED PROCESS FLOWSHEET (CONTINUED)

considered to be associated with specific soil size fractions. It is therefore understood that all soil size fractions need to be addressed relative to soil washing and monitoring before release to the site as noncontaminated soil.

Contaminated soil, in approximately 100- to 250-kg batches, will be removed from the drums and first fed into a 500-gallon slurry batch reactor containing the initial aqueous soil washing solution. The composition of this washing solution will be elucidated during the Remedy Screening tests but will probably contain either a dispersing agent or a dilute extractant reagent or both. This slurry, a 1:4 (wt:wt) soil to washing solution ratio, will be reacted for a predetermined amount of time (extrapolated from Stage II studies) and transferred to a combination two-inch scalping and 9.5-mm trommel screen.

The scrubbing trommel is equipped with a spray bar that will wash the soil fines from the coarse soil particle. The tumbling and lifting action ensures that the fine material will be broken into discrete particles. The plus-9.5-mm material will be removed from the trommel screen and monitored using a sodium iodide detector. All plus-9.5-mm material will be collected for each batch test and homogenized. An aliquot of this homogenized material will be collected and analyzed for uranium by IC and for gross alpha/gross beta. If it is determined that the uranium has been removed to the preliminary action level of 35 pCi/g then a representative aliquot of the material will be taken and analyzed for all chemical constituents in accordance with Table 3-10. If it is determined that uranium has not been removed to 35 pCi/g, then the material will be transferred back to the slurry batch reactor and given a second washing before being analyzed for all chemical constituents.

The minus-9.5-mm fraction plus washing solution will be collected into an attrition scrubber. Additional washing solution or concentrated extractant may be added to the scrubber at this time. Results from the Stage II testing as well as on-site evaluation of the washing solution during this remedy selection phase of testing will be used to determine the appropriate action. Scrubbing time will also be determined during on-site inspection as well as being evaluated from remedy screening test results.

Material from the attrition scrubber will be transferred to a 2-mm screen. The plus-2-mm material will be rinsed with high pressure water, removed from the screen and monitored using a sodium iodide detector. All plus-2-mm material will be collected for each batch test and homogenized. An aliquot of this homogenized material will be taken and analyzed for uranium by IC and for gross alpha/gross beta. If it is determined that the uranium has been removed to 35 pCi/g then a representative aliquot of the material will be taken and analyzed for all chemical constituents in accordance with Table 3-10. If it is determined that uranium has not been removed to this level, then the material will be transferred back to the slurry batch reactor and given a second washing before being analyzed for all chemical constituents.

The minus-2-mm material will be collected in a batch stir reactor. Additional washing solutions or concentrated extractants may be added to the scrubber at this time. Results from the Stage II testing as well as on-site evaluation of the washing solution during this remedy selection phase of testing will be used to determine the appropriate action. Reaction time will also be determined during on-site inspection as well as being evaluated from remedy screening test results.

This final slurry will then be transferred to either a multigravity separator or a high-pressure cyclone. The multigravity separator separates materials by density through stratification in the washing solution. Hydrocyclonic separation incorporates centrifugal separation of particles by size or specific gravity. These machines will produce a light-gravity and heavy-gravity product. The light-gravity product may need a soil washing treatment. The heavy-gravity product can be disposed of or treated for uranium recovery, which will produce a final product and a recyclable uranium product.

It is at this stage of the soil washing process that discrete particles of uranium (heavy metal concentrate) should be separated from the soil/washing solution matrix and recovered. The final separation of the soil into the minus-75-µm size fractions is also achieved at this step in the soil washing process. The minus-2-mm by plus-75-µm material will first be monitored using a sodium iodide detector, and collected and homogenized for each batch test. An aliquot of this homogenized material will be taken and analyzed for uranium by IC and for gross alpha/gross beta. If it is determined that the uranium has been removed to the preliminary action level of 35 pCi/g then the material will be transferred back to the batch stir reactor and given a second washing before being analyzed for all chemical constituents.

The minus-75-µm material will also be collected and analyzed for uranium and gross alpha/gross beta. If this size fraction of soil contains contaminants above an acceptable action level, it will have to be processed by the chemical extraction techniques described in Section 4.5.2, Chemical Extraction. In addition, any soil size fraction that during the course of specific physical separation soil washing steps do not reach the level of 35 pCi/g (based on the sequence of washing steps described above), that size fraction will also be subjected to further chemical extraction processes as described below.

4.5.2 Chemical Extraction

The most effective chemical extraction solutions will be tested on soil samples from various locations. It is expected that a combination of chemical extractants and leachates will be necessary to remove the metals, organics, and radionuclides from the soil. As an example, the soil could first be extracted with a basic mixture containing surfactants (e.g., $(NH_4)_2CO_3$ combined with a nonionic surfactant) to remove organic compounds and some metals followed by an acid extraction enhanced with KCl (e.g.,

HCl, HNO_3, or H_2SO_4 combined with KCl) to remove metals and radionuclides. Depending on the results from the earlier phases, each extraction process may involve one or more stages. In this context, a stage consists of an extraction followed by a filtration.

The radioactive constituents will be analyzed in the extracted soils, extractant solutions, and wash water. In addition, a full TCLP with radionuclide constituents will be performed on the extracted solids. The concentration of the HSL metals and organic compounds in extractant and wash water will be determined by SW-846 methods. The percent removal efficiencies will be calculated.

4.6 OPTIONAL PHASE TESTING - RESIDUAL ORGANIC AND SURFACTANT REMOVAL

The organic compound removal technology is contingent on identification of the types of organic compounds found in the liquid. The scope of the organic compound removal study cannot be defined at this time.

4.7 DATA REQUIRED

A summary table of the approximate number of sample analyses required during remedy screening and remedy selection testing are shown in Table 4-5. The following data will be acquired during soil washing studies:

- Soil characterization data including moisture content, specific gravity, plasticity index, particle size distribution, total organic carbon (TOC), cation exchange capacity (CEC), chemical characterization, and radiological analyses for radionuclides identified in the characterization study (Section 6.0).
- Percent by weight of the amount of soil within each particle-size fraction
- Concentration of target organic compounds associated with each particle-size fraction
- Concentration of target organic compounds in extracted soil, extractant, and rinse water during remedy screening
- Concentration of target metals from MTCLP during remedy screening
- Percent decrease in gross alpha and gross beta in soil
- Gross alpha and gross beta in the extractant, rinse, and in extracted soil during remedy screening
- Effectiveness of washing solution additives, expressed as amount of contaminant removed per amount of soil treated and volume of washing solution used
- Percent by weight of the amount of volume of soil reduced
- Full TCLP on extracted soils during remedy selection

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TABLE 4-5
NUMBER OF SAMPLE ANALYSES[a] REQUIRED DURING REMEDY SCREENING AND REMEDY SELECTION TESTING

	Remedy Screening					
Tests	Uranium by Ion Chromato-graphy	Gross Alpha/ Gross Beta	Volatiles	Semi-Volatiles	Metals	Modified Toxicity Characteristic Leaching Procedure
Stage I						
Physical Separation[b]	300	300	NA[c]	150	NA	NA
Chemical Extraction[b]	200	168	NA	100	NA	NA
Stage 2						
Physical Separation[d] and Chemical Extraction[d]	800-1600	800-1600	900-1800	900-1800	1800-3600	400
Precipitation	300-600	500-800	250-400	150-300	500-800	NA

	Remedy Selection		
Soil Washing Fractions	Uranium by Ion Chromato-graphy	Complete Analysis	Quality Assurance/ Quality Control
9.5 - 19mm	4	4	1
2 - 9.5mm	4	4	1
0.053 - 2mm	4	4	1
Wash H_2O	4	4	1
Heavy Metal Concentrate	4	4	1
< 53µm	4	4	1
Extractant	4	4	1
< 53µm[e]	4	4	1
Extractant	4	4	1
Rinse H_2O	4	4	1

[a]Represents an approximate number of analyses
[b]Includes solid and aqueous matrices
[c]NA= Not applicable
[d]Approximate number of tests dependent on Stage I results
[e]Dependent on whether a second extraction step is included in the remedy selection testing

- Radionuclide concentration in soil, extractants, and wash water during remedy selection
- Uranium in cleaned wash solution (by IC fluorescence)
- Organics in extractants and wash water during remedy selection
- Temperature of wash solution
- Resin type and effectiveness
- Types of filter aids
- Volume of wash water for treatment and/or disposal relative to the initial volume of untreated waste
- Volume of extracting reagents for disposal relative to the initial volume of untreated waste
- Volume of soil in which uranium content was reduced to $\leq$35 pCi/g.

5.0 EQUIPMENT AND MATERIALS

A variety of equipment, materials, and reagents will be used in conducting the soil washing treatability studies and performing the associated analyses. This includes the equipment and materials necessary for leachate analyses, MTCLP analyses, and TCLP analyses. The reagents required are not listed here since they are described in detail within Section 4.0, Experimental Design and Procedures.

Table 5-1 lists the major equipment which will be used during the remedy screening and remedy selection soil washing testing.

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TABLE 5-1
EQUIPMENT AND MATERIALS[a]

No. of Items	Item Description
Multiple	Plastic containers, 8 oz. and 5 oz.
Multiple	Spatulas
1	Digital pH meter
1	Soiltest Laboratory vibrating shaker
3	Thermometer, calibrated and traceable
1	Balance, calibrated
1	Forced air drying oven
1	Multigravity separator
2	Batch Reaction Vessels, 500 gal.
1	Feeder
1	Concentrating Table
1	Scalping screen
1	Trommel screen
1	RO-TAP sieve shaker
2 Sets	Standard testing sieves, 8" (stainless steel series)
1	Stainless steel soil sampler
1	High pressure cyclone
1	Sedimentation cylinders
1	Hydrometers
1	Mechanical stirring apparatus
4	Pump
4	Tank, 500 gal.

[a]This equipment list does not include analytical instrumentation for leachate analyses, equipment for TCLP, or general laboratory equipment.

6.0 SAMPLING AND ANALYSIS

The Sampling and Analysis Plan (SAP) for treatability studies on site soil is defined in this section of the Treatability Study Work Plan. It describes the incorporation of the ID soil sampling program with the SAP for the Soil Washing Treatability Study Work Plan for Operable Unit 5. The SAP ensures that samples obtained for characterization and testing are representative and that the quality of the analytical data generated is known and appropriate. This SAP addresses initial site selection, initial soil sampling and characterization, and the field sampling plan.

6.1 OVERVIEW

The collection of soil samples for soil washing treatability studies is a critical function within the experimental design. The rationale for selecting the location of soils and the number of samples to be collected is based on the objectives and constraints placed on the soil washing program. A primary consideration in this work study plan is to integrate the soil washing treatability technology being evaluated with other technology evaluations for on-site remediation of Operable Unit 5 soils. Part of this integration is to use soils common to the Uranium Soil Integrated Demonstration Treatability Sampling Plan (in revision). Therefore, this SAP for soils will incorporate the ID's sampling plan as part of the total scope of the Operable Unit 5 treatability study work plan (see Appendix E).

The sampling program's primary objective is to first select locations on site that contain soil that is representative of the contamination problem at the FEMP. These selected locations will then be sampled in a manner to retrieve a representative sample of soil for each location. A physical/chemical characterization of these soils will be conducted. Based on the results of these initial analyses, a final selection will be made as to the four locations to be used in the soil washing treatability study. A subsequent objective of this sampling program will then be to collect a sufficient quantity of soil from each of the four locations that will be homogenized (per location) and completely characterized (physically and chemically) for use in treatability testing.

The primary constraints within the soil sampling program will be sample size restrictions and personnel exposure limitations. The personnel exposure limits are presented in Tables C.3-1 and C.3-2 of Appendix C. The sample size restrictions are based on the level of radioactivity per sample that the analytical laboratory is licensed to accept. Both of these constraints will be determined during the initial sample collection and characterization part of the sampling program.

This SAP identifies the procedures specific to the ID sampling program as well as those procedures applicable to the Operable Unit 5 sampling program. The locations selected for initial soil sampling and characterization have been previously reported in initial site characterization data to contain a

specific level and range of contaminants. Five soil locations were selected for the ID program based on the criteria for a soil with high levels of radionuclides and low levels of other inorganic and organic contaminants. Four additional locations have been selected in support of the Operable Unit 5 program for soils containing radionuclides and high levels of organic and inorganic contaminants. This selection of nine Operable Unit 5 soils will provide a range in soils, contaminants and contamination levels that are considered to be representative of the soil contamination problem on the FEMP site.

6.1.1 Initial Selection of Soils

Soils contaminated with primarily radionuclides (uranium specifically) will be noted as "ID" soils since they are soils in common with treatability testing conducted under the DOE's Integrated Demonstration (ID) program. Soils contaminated with radionuclides plus other inorganic and organic chemicals will be noted as "OU5" soils since they are soils unique to the Operable Unit 5 Treatability Study Work Plan program. Two soils will be selected from each program and will be denoted as soils A and B. Further specific reference to the four soils used in this treatability study will use the following four soil identifications: 1) ID-A, 2) ID-B, 3) OU5-A, and 4) OU5-B. This system will also enhance the subsequent reporting of results relative to the treatability testing of these soils.

The location of the two ID soils (ID-A and ID-B) selected for soil washing is illustrated in Figures 6-1 and 6-2. Their selection was based on the results of an initial characterization of ten locations at the FEMP (Appendix E). The two soils (OU5-A and OU5-B) unique to this study were selected based on the presence of HSL inorganics and organics as well as radionuclides. The locations of these two soils will be based on the results of an initial sampling and screening of soils from four locations as described in Section 6.4, Initial Soil Sampling and Characterization.

6.1.2 Initial Analysis and Characterization of Soils

Soils from each of the four locations will be initially screened, homogenized and placed into separate 55-gallon metal drums in accordance with these procedures. All drums containing soil from a single location will be individually sampled and analyzed to determine if the characteristics of soil contained in a single drum are significantly different than the characteristics of soil contained in the set of drums. The standard operating procedure for this homogeneity testing is given in Appendix E.

After it is determined that the soil within any single drum is homogeneous relative to all the soil contained in the set of drums for a single location, the drums will again be sampled. An aliquot of soil from each drum for a single location will be collected and placed into a stainless steel bucket and

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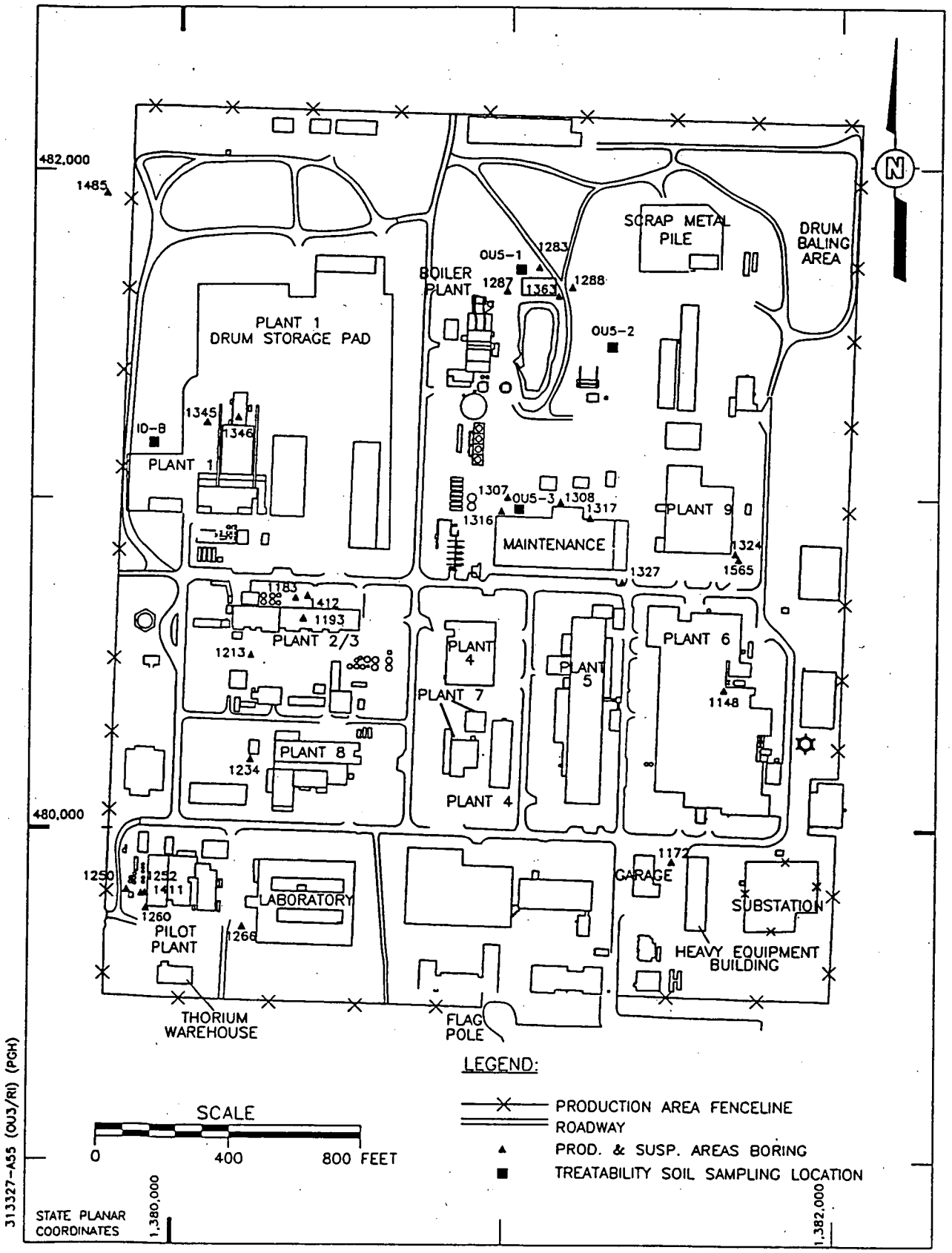

FIGURE 6-1. TREATABILITY SOIL SAMPLING LOCATIONS - PRODUCTION AREA

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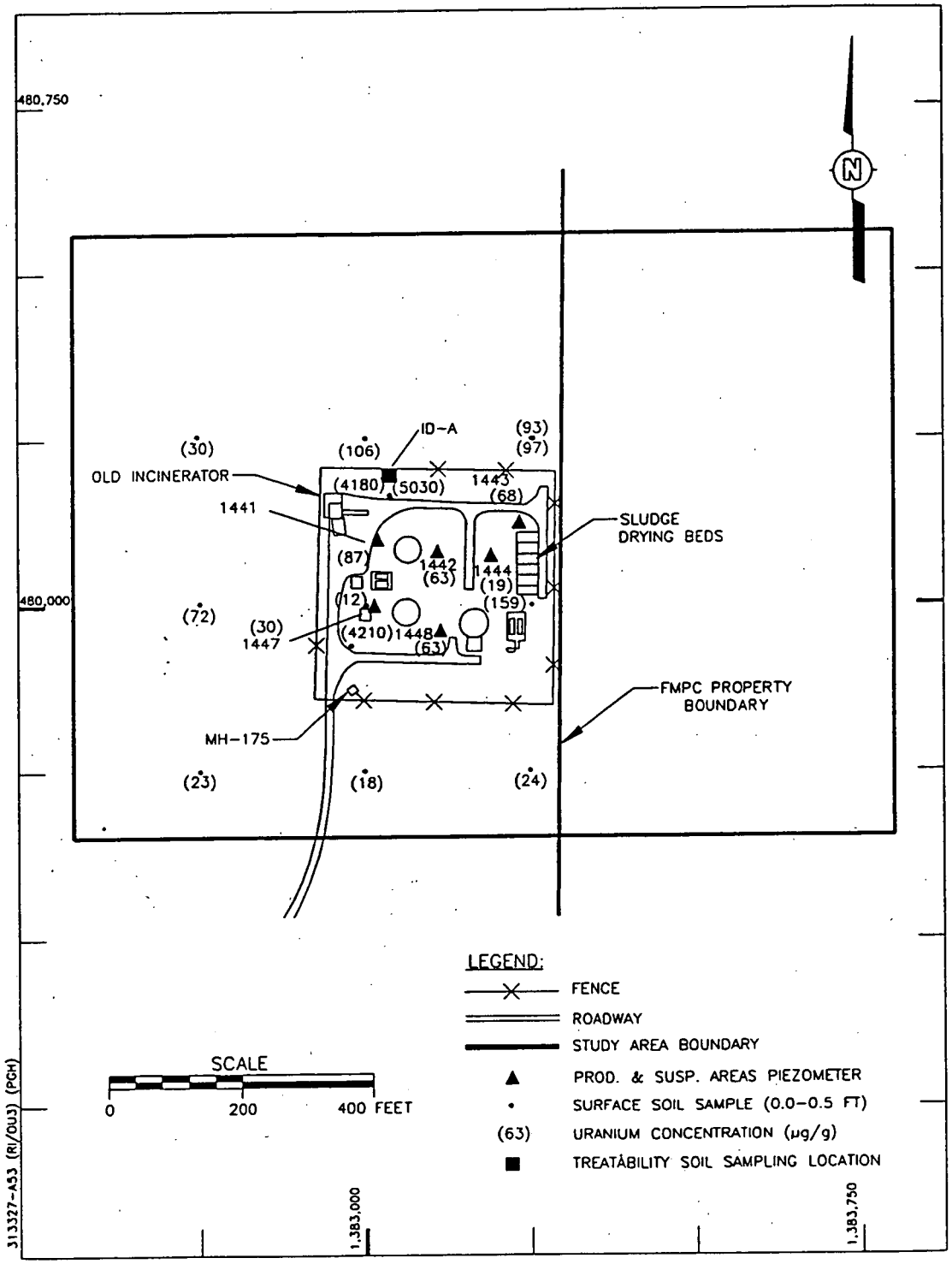

FIGURE 6-2. TREATABILITY SOIL SAMPLING LOCATIONS - SEWAGE TREATMENT PLANT

further homogenized by using a stainless steel hand trowel. This soil will be sent to a contract laboratory for complete analysis.

A complete physical and chemical characterization of all four soils (ID-A, ID-B, OU5-A and OU5-B) will be conducted following collection and before treatability testing. A list of the parameters to be tested in this initial baseline characterization is presented in Table 6-1. The conductance of both HSL and TCLP analyses in the initial soil characterization and the advanced stage studies of remedy selection testing is necessary to address the criteria for targeted action levels and to comply with RCRA guidelines for returning treated soil to the site. This characterization will be conducted in accordance with guidelines established in Section 3.0, Test and Data Quality Objectives, and this section, Sampling and Analysis. These analyses will provide the initial baseline characterization of the soil for each location to be used in all subsequent treatability studies.

6.2 ID SAMPLING PLAN FOR SOILS

Five locations representing three characteristic waste forms (aqueous uranium waste, solid uranium product particulate, and airborne uranium waste particulate) were selected based on preliminary studies of site data. Four of the five following locations listed below are illustrated in Figure 6-1:

Plant 2/3 Area
Plant 1 Storage Pad Area
Decontamination Pad/Drum Baling Area
Plant 6 Area
Old Incinerator Area (not shown)

In June 1991, screening samples were obtained from these five locations in accordance with the RI/FS QAPP. The objective was to determine some specific physical/chemical data on the soil and uranium waste forms. Data tables from the "Characterization of Uranium Contaminated Soils from DOE Fernald Environmental Management Project Site: Results of Phase I Characterization," describing the results of this initial characterization, are contained in Appendix E. Based on the results of this report, two locations, the Plant 1 Storage Pad Area and the Old Incinerator Area, were selected for the collection of soils for ID treatability tests.

Each location will be staked out to delineate the boundaries of the effective area. A grid of the area will be laied out so that volatile levels and radioactivity levels can be measured to determine homogeneity of surface soil within each location. Surface monitoring of soil within each location for volatiles will be done using a photoionizing detector while radiation levels will be measured using a beta-gamma frisker or a sodium iodide detector.

TABLE 6-1
CHEMICAL AND PHYSICAL ANALYSES FOR CHARACTERIZATION STUDY OF OPERABLE UNIT 5 SOILS

Organic Analyses[a]	TCLP and HSL Metals Analyses	Radiological Analyses[b]	Physical Analyses
TCLP Volatiles	Aluminum	Cesium-137	Moisture content
TCLP Semivolatiles	Antimony	Neptunium-237	Specific gravity
TCLP Pesticides/PCBs	Arsenic	Plutonium-238	Atterberg limits
	Barium	Plutonium-239/240	Particle size
HSL Volatiles	Beryllium	Radium-224	Total organic carbon
HSL Semivolatiles	Boron	Radium-226	Cation exchange capacity
HSL Pesticides/PCBs	Calcium	Radium-228	
	Cadmium	Ruthenium-106	
	Chromium	Strontium-90	
	Cobalt	Technetium-99	
	Copper	Thorium-228	
	Cyanide	Thorium-230	
	Lead	Thorium-232	
	Magnesium	Uranium-234	
	Manganese	Uranium-235/236	
	Mercury	Uranium-238	
	Molybdenum	Gross alpha	
	Potassium	Gross beta	
	Nickel	Total uranium	
	Selenium		
	Silicon		
	Silver		
	Sodium		
	Thallium		
	Vanadium		
	Zinc		

[a]List of organic analytes is given in Appendix F.
[b]Radiological analyses will be performed on soils and TCLP extracts.

To provide a comprehensive and systematic method of survey that ensures appropriate coverage, the area will be marked to establish a refined grid for use in the conduct of a walkover radiation and volatile survey. The boundaries for each location will be delineated and subdivided into 4-foot grids. and will be surveyed. Radiation detection will be conducted using a Ludlum Model 12 Beta-gamma frisker or a Model ESP-2 Sodium Iodide Detector, or an equivalent field instrument. The frisker will be held to the surface of the soil until a stable or average reading can be taken. Monitoring time for each point will be approximately 10 seconds per point. Volatile organic determinations will be performed using a Model PI 101 HNu with a photoionization detector. The tip, or air inlet part of the wand will be held to the surface of the soil in a similar manner to the frisker. Monitoring time for each point will be approximately 10 seconds per point.

Soil samples for volatile organic analyses will then be collected first from each undisturbed location before excavation of the soil for treatability testing. Discrete point samples of soil for volatile analysis will be necessary in order to minimize volatile loss during sampling. Four sampling points will be selected based on surface monitoring results in order to obtain representative soil from each location. All vegetation will be removed before to the excavation of the soil.

The soil will be excavated to a depth of 15 to 20 centimeters by the use of a backhoe. A radiological survey utilizing sodium iodide detectors will be conducted in conjunction with soil removal to ensure that material being removed exceeds the action level of 35 pCi/g (see Section 1.2.2). The soil will then be screened through a 3/4-inch mesh. Material not passing the screen will be collected and stored for possible future analysis. Soil passing the screen will be collected and blended to obtain homogeneous samples representing the location.

Blending of soil will be conducted using a cement mixer. After initial blending, a coring device will be used to collect representative aliquots of soil from each drum. A screening test will be conducted to determine homogeneity of the soil among the drums. This testing procedure is contained in Appendix E, Testing for Homogeneity. Soil homogeneity will be determined by first determining the distribution of soil particles into three diameter size classes (>2, 2-0.075, and <0.075 mm). Each size class will then have total uranium activity determined by a direct counting method. If it is determined that homogeneity of the soil among the drums does not exist, the soil will be removed from the drums and further blended. This will be followed again by testing for homogeneity.

Once homogenized, representative aliquots of the soil will be collected and completely analyzed to provide both a physical and chemical baseline of the material for future treatability testing. All the analyses in Table 6-1 will be conducted on this soil.

6.3 INITIAL LOCATION SELECTIONS FOR OPERABLE UNIT 5 SOIL

Four additional locations were selected for potential use in soil washing treatability studies, based on data generated during earlier soil sampling and characterization programs. These four locations, illustrated in Figures 6-1 and 6-3, are described in Table 6-2. Two previous soil sampling programs have been conducted as part of the RI/FS to characterize the extent and level of contamination in the soils within the Production Area. The first, a surface soil sampling program completed in the Spring of 1988, was conducted under the RI/FS Work Plan (DOE 1988). The second, a subsurface soil sampling program started in 1989, was conducted under the Production and Additional Suspect Areas Addendum to the RI/FS Work Plan. Appendix A contains the location of the borings and the supportive chemical analyses for the soils in the four locations selected for initial characterization. Results from these past sampling programs have provided the basis for the selection of representative sampling locations for soils to be used in the soil washing treatability testing.

Sampling bias in this SAP will be necessary to retrieve soil that has a designated range or level of contamination for each contaminant type, including radionuclides, organics, and inorganics. This type of sampling should provide the soil washing study with a "worst case" scenario: a soil with elevated levels of radionuclides (in particular, uranium concentrations greater than 200 μg/g) and elevated levels of organic and inorganic contaminants. This type of sampling should also provide a soil with elevated levels of organic and inorganic contaminants with uranium concentrations less than 50 μg/g. This range in the concentration of contaminants should enable the evaluation of soil washing efficiency on soils with both high and low levels of uranium contamination.

6.4 INITIAL SOIL SAMPLING AND CHARACTERIZATION OF OPERABLE UNIT 5 SOIL

The first objective of this SAP is to collect representative soil samples from the four targeted locations. Two of the four locations will be selected based on high levels of uranium (>200 μg/g) and elevated levels of organic and inorganic contaminants, and two locations will be selected based on the soil containing low levels of uranium (<50 μg/g) but high levels of organic and inorganic contaminants. Sufficient soil will be collected to conduct a radiological and chemical characterization of each location.

A set of analyses consisting of a rad screen, gross alpha/gross beta, VOCs and SVOCs will initially be conducted on the soils from the four locations. The rad screen and gross alpha/gross beta will provide sufficient radiological characterization for evaluating the soil from these locations. The VOC and SVOC tests will be used to determine the presence of organics in these soils.

Each location will first be staked out, based on the findings of earlier sampling reports, to delineate the boundaries of the effective area. A grid of the area will be layed out so that volatile levels

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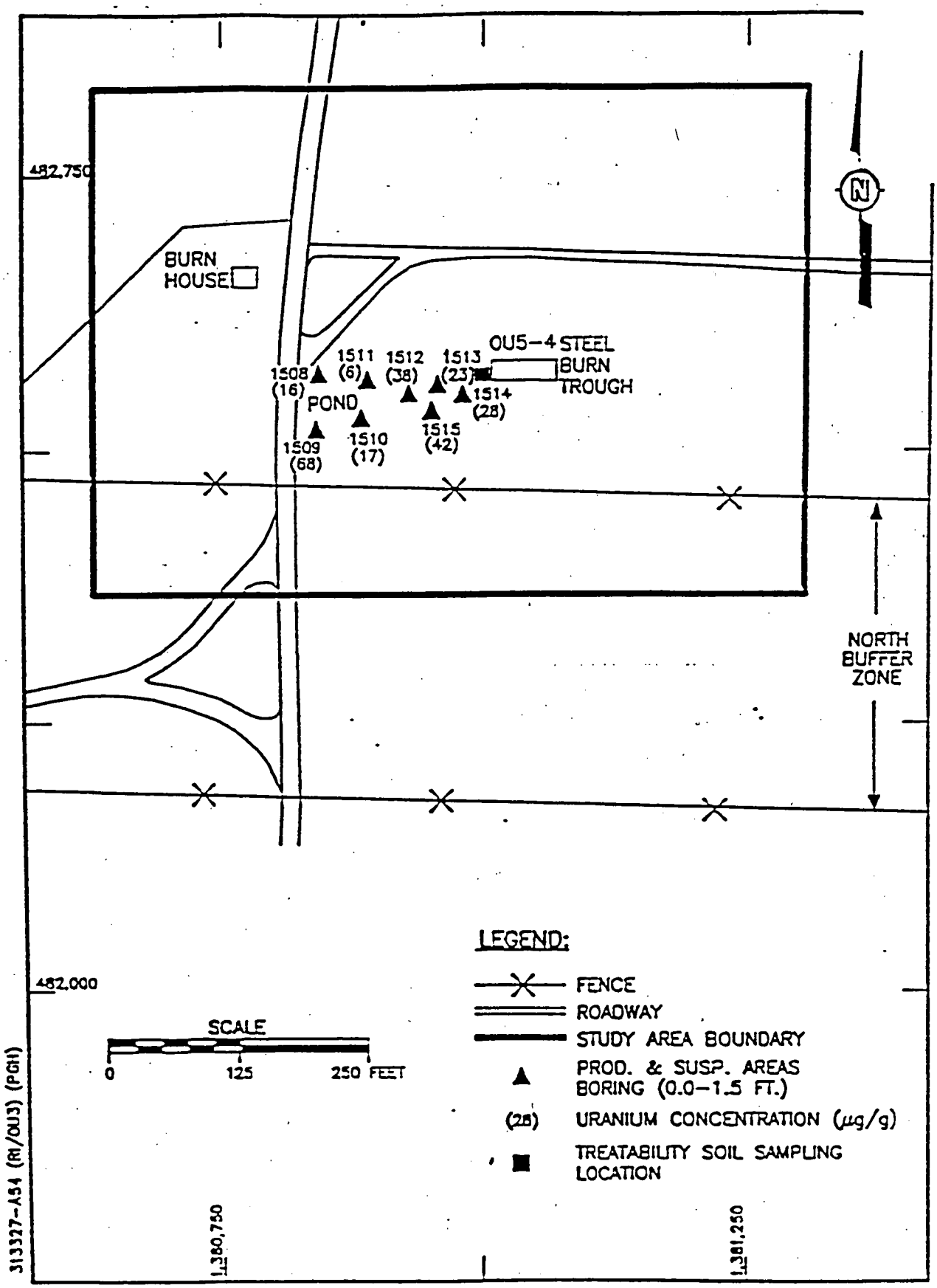

FIGURE 6-3. TREATABILITY SOIL SAMPLING LOCATIONS — FIRE TRAINING AREA

TABLE 6-2
POTENTIAL SAMPLING LOCATIONS WITHIN THE PRODUCTION AREA AND CORRESPONDING ANALYTICAL ESTIMATES

Identification Number	Location	Uranium	Volatiles[a]	Semivolatiles[a]	PCBs[a]
OU5-1	North of Graphite Furnace Oil Burner near Boring 1283	467 µg/g	Medium Levels	Medium Levels	Low levels
OU5-2	East of Boiler Plant's Coal Pile	114[b] µg/g	Low levels[b]	Low levels[b]	Low levels[b]
OU5-3	Northeast Quadrant near Maintenance Building Boring 1307	330 µg/g	High levels	Medium levels	Low levels
OU5-4	Fire Training Area	50 µg/g	Low levels	Low levels	Low levels

[a]Analytical estimates based on range of analytes and concentrations from borehole data.
[b]Extrapolated estimates from surrounding boreholes.

(photoionization detector) and radioactivity levels (beta-gamma frisker) can be measured to determine homogeneity of surface soil within each location. Six discrete soil samples within each location will be collected from the upper 30 cm (12 inches) of the soil using a beta-gamma frisker or a sodium iodide detector.

To provide a comprehensive and systematic method of survey that ensures appropriate coverage, the area will be marked to establish a refined grid for use in the conduct of a walkover radiation and volatile survey. The boundaries for each location will be delineated and subdivided into 4-foot grids and surveyed. Radiation detection will be conducted using a Ludlum Model 12 Beta-gamma frisker or a Model ESP-2 Sodium Iodide Detector, or an equivalent field instrument. The estimated lower limit of detection for uranium-238 in soil using a frisker is approximately 35 pCi/g. The frisker will be held to the surface of the soil until a stable or average reading can be taken. Monitoring time for each point will be approximately 10 seconds per point. Volatile organic determinations will be performed using a Model PI 101 HNu with a photoionization detector. The tip, or air inlet part of the wand will be held to the surface of the soil in a similar manner to the frisker. Monitoring time for each point will be approximately 10 seconds per point. Ambient conditions (e.g., temperature, humidity and wind speed) during the survey will be recorded.

Six discrete soil samples within each location will be collected from the upper 30 cm (12 inches) of the soil using a stainless steel 1 1/2-inch split-spoon sampler. A centroid will be located within each effective area. An equal distance will be measured and marked in six directions from this centroid, each direction emitting from 60 degree intervals around the centroid. The distance for each discrete sampling point will be a uniform length from the centroid to the edge of the delineated boundaries to approximate a midpoint of the total length. The six split-spoon samples from each location will be capped with teflon-lined caps and chilled to 4°C before shipment.

Once at the laboratory, the soil will be maintained in a refrigerator at 4°C during the mixing of the soil within each stainless steel can using a stainless steel spoon. The final mixture will consist of representative homogeneous soil composites for that location. These homogeneous composites will be taken and maintained at 4°C until analyzed for gross alpha/gross beta, VOCs and SVOCs.

TABLE 6-3
ANALYTICAL METHODS AND CRITERIA FOR OPERABLE UNIT 5 SOIL SAMPLING

Analysis	Volume	Container	Preservative	Holding Times	Method
RAD screen	1 - 15 g	VOA vial - 40 ml	None	None	SOP:RSL 308
TCLP and HSL volatiles	2[a] - 85 g	VOA vial - 40 ml	Cool 4°C	14 days	624 CLP
TCLP and HSL semivolatiles (base neutral/acid)	1 - 200 g	Amber glass Teflon-lined cap	Cool 4°C	14 days until extraction 40 days after extraction	625 CLP
TCLP and HSL pesticides/PCBs	1 - 200 g	Amber glass Teflon-lined cap	Cool 4°C	14 days until extraction 40 days after extraction	608 CLP
TCLP and HSL metals	1 - 200 g	Amber glass	None	6 months	200 CLP
Cyanide	1 - 100 g	Amber glass	Cool 4°C	14 days	335.2 CLP
Total organic carbon	1 - 100 g	Glass	Cool 4°C	28 days	MOSA[b] 29-3.5
Radiological	1 kg	Amber glass	None	6 months	Appendix B
Physical parameters	1 kg	Clear glass	None	None	
Moisture content					ASTM D2216
Specific gravity					ASTM D854
Atterburg limits					ASTM 4318
Particle size					ASTM 422
Cation exchange capacity					SW-846 9081

[a]3 if matrix spike or matrix spike duplicate
[b]MOSA - Methods of Soil Analysis

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6.5 SAMPLING FOR TREATABILITY STUDIES OF OPERABLE UNIT 5 SOIL

The sampling or collection of soils that are representative of the contamination problem at the FEMP for use in treatability studies is a primary purpose of this sampling and analysis section of the Work Plan. The initial chemical and physical characterization of the four locations described previously will provide the fundamental information to select two primary locations where the soil is considered optimum for use in soil washing treatability studies. Based on these results, this part of the SAP describes the procedures to be followed to collect a sufficient volume of representative soil for use in the soil washing studies.

Before the collection of soils in the two primary designated locations, each will be monitored again to determine the "hot spot" within the delineated areas. A beta-gamma frisker will be used to monitor for radionuclides and a photoionization detector for volatile organics. An approximately 200-square-foot area will be marked off as the area from which to collect the soil within each location. VOC and SVOC analyses will have been completed during initial soil sampling and characterization, before this excavation of the soil for treatability testing. These discrete point samples of soil for volatile analysis minimize volatile loss during sampling. Sampling points will be selected based on surface monitoring results in order to obtain representative soil from each location. All vegetation will be removed before the excavation of the soil.

A tiller will be used to loosen the surface soil and to provide a vertical mixing of the soil within the 200-square-foot sampling location before collection. The use of a tiller or similar device to prepare soil for collection and placement into drums will serve two functions. It first loosens the soil and breaks down the coarse aggregates that can pass a 19-mm screen. It also serves as a method for homogenizing the soil while it is still on the ground. This process may accentuate volatile losses compared to the actual mechanical removal of soil during a full-scale soil washing operation. However, loss of volatile organics occurring during this process could possibly be evaluated by comparison of volatile organic levels in the soil during the initial volatile organic sampling before excavation with targeted volatile organic levels analyzed in Stage II testing. All soil will be collected from within the 0 to 30-cm (0 to 12-inch) portion of the soil profile. The area will be monitored for volatiles using HNu during the tilling and excavating processes. The observations will be recorded to evaluate volatile loss during these processes.

A steel shovel will be used to transfer the soil from the ground to a 19-mm screen. The material not passing the screen will be collected and stored in 55-gallon drums for future analysis. Soils passing the screen will be further homogenized on site (using a one-cubic-yard cement mixer or bobcat). (Note: Use of equipment may pose slight increases in certain metals; e.g., iron and nickel, or residual contaminants such as calcium: the level of increase in compounds bearing these elements is

considered to be insignificant, relative to the need to provide a homogenous soil for use in treatability studies.) The soil will be screened onto a sheet of Herculite plastic. When sufficient soil to fill five 55-gallon drums and five 5-gallon buckets has been collected on the plastic sheet, an additional mixing of the soil will be done using the stainless steel shovel. Based upon visual inspection of this material for homogeneity, the final soil composite for that location will then be transferred to the five 55-gallon drums and five 5-gallon buckets using the shovel. Volatile organic compounds may be lost from the soil during this process; these losses are considered standard with the normal preparation of soil within the soil washing process. A homogeneity test (Appendix E) will be performed on the drummed soil. Once the soil has been determined to be homogeneous, aliquots of the drummed soil will be collected and sent to the laboratory for physical and chemical characterization (Table 6-1). Table 6-3 identifies the analytical method, aliquot size, and the criteria relative to drum sampling. The five 5-gallon buckets will be sealed and prepared for shipment to the soil washing treatability testing laboratory. The five 55-gallon drums will be secured and properly labeled for storage. A WEMCO drum number will be assigned to each drum and a chain-of-custody form attached. A chain-of-custody and request for analysis form will be completed for each set of five 5-gallon buckets to be sent for soil washing treatability testing. All drums will be stored on FEMP property until needed for remedy selection soil washing studies. A summary of the sample locations and number of analyses required for this program are presented in Table 6-4.

6.6 QA/QC REQUIREMENTS FOR SAMPLING PROGRAMS

QA/QC protocols will be based on the RI/FS QAPP, Revision 3, Volume 5 (DOE 1988) sampling requirements. These protocol requirements describe instrument calibrations, duplicates, trip blanks, matrix spikes and sampling equipment rinsates as related to site characterization activities. Treatability study activities, including sampling, will be derived from these protocols, and will be implemented as appropriate for individual activities within the treatability study. All sampling equipment will follow chemical and radiological decontamination procedures as stipulated in the QAPP. Additional QA/QC guidelines for data management and analyses are described in Sections 7.0 and 8.0.

6.7 HEALTH AND SAFETY

Site-specific health and safety procedures for the SAP are described in Appendices C and D of this work plan. All soil sampling will be monitored by a health physics technician.

6.8 WASTE MANAGEMENT

Waste management, handling, and packaging requirements for the soil, residue and debris are part of the soil washing treatability study, and will be provided for by Westinghouse Environmental Management Company of Ohio (WEMCO) in accordance with their Procedure SOP-65-C-106. The

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TABLE 6-4

SOIL SAMPLING LOCATIONS AND NUMBER OF ANALYSES

X denotes variable number of measurements or analyses

Analyses	Locations					
	ID-A	ID-B	OU5-1	OU5-2	OU5-3	OU5-4
Initial Survey						
Beta/Gamma frisker	X	X	X	X	X	X
HNu volatiles	X	X	X	X	X	X
Initial analyses						
RAD screen	-	-	X	X	X	X
Gross alpha/gross beta	-	-	X	X	X	X
VOC	X	X	X	X	X	X
SVOC	-	-	X	X	X	X

	ID-A	ID-B	OU5-A[a]	OU5-B
Initial Drummed Soil Characterization				
HSL VOCs	4	4	4	4
HSL SVOCs	4	4	4	4
HSL PCBs/Pesticides	4	4	4	4
HSL metals	4	4	4	4
Radiological	4	4	4	4
TCLP VOCs	4	4	4	4
TCLP SVOCs	4	4	4	4
TCLP PCBs/Pesticides	4	4	4	4
TCLP metals	4	4	4	4
TCLP radiological	4	4	4	4
Physical analyses	4	4	4	4
QA/QC samples[b]	-	-	-	-

[a]Soil from two of the four OU5 sample locations will be selected for the treatability study and complete characterization based on the results of the initial analyses.
[b]QA/QC samples will be determined as appropriate (e.g., matrix spike, matrix spike duplicate and trip blanks).

generated waste will be handled as radioactive waste, packaged in appropriately labeled containers, and transferred to WEMCO for further handling and/or disposal. No liquid wastes, other than decontamination fluids, are expected to be generated during the sampling program. However, if any liquid waste is generated, it will be handled in accordance with WEMCO provisions and transferred to WEMCO for disposal after appropriate containment and packaging.

7.0 DATA MANAGEMENT

Two types of laboratory notebooks will be used for this project. All laboratory notebooks are uniquely numbered and have sequentially numbered pages. The Technology Development Laboratory Standard Operating Procedure No. 1503 identifies the notebook criteria on data logging procedures (Appendix B).

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.

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 instruments (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 data will be written in standard laboratory notebooks or on standard formatted data entry sheets. All records management and reporting will follow standard QA/QC protocol. 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 - All raw data entries, transcriptions, and calculations are checked.
- 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.
- Use of trained personnel conducting tests - All technicians are trained in the application of standard laboratory procedures for analyses as well as in the QA measures implemented for internal QC checks.

8.0 DATA ANALYSIS AND INTERPRETATION

8.1 EFFECTIVENESS OF REAGENTS

A determination of potentially successful extractants and conditions will be made by using the minimum performance criteria. The minimum performance criteria for Remedy Screening-Stage I are that the uranium concentration, or target organic concentration or measured gross alpha and gross beta in the extractant, is decreased by 40 percent. During Remedy Screening-Stage II, the minimum performance criteria are that the extracted soil pass the MTCLP standard for targeted metals, or the measured gross alpha/gross beta, uranium concentration, or target organic compound concentrations are decreased by 80 percent. During Remedy Selection, the minimum performance criteria are that the extracted soil pass the TCLP standard for As, Ba, Cd, Cr, Pb, Se, and Ag, or that the soil contains less than 35 pCi/g uranium.

The results of the leaching tests will be used to evaluate the effectiveness of the soil washing. The concentrations of radioactive and hazardous constituents in the leachate will be used as input into the geochemical models described in the RI/FS Risk Assessment Work Plan Addendum (DOE 1992). These models will be used in conjunction with groundwater fate and transport models to generate data that will then be used to calculate concentrations of contaminants in the aquifer at the location of the reasonable maximum exposure. These concentrations will in turn be used to calculate the magnitude of that exposure, and the resulting risks to human health and the environment.

8.2 SOIL WASHING

For Remedy Screening - Stages I and II, and remedy selection testing, the reagent formulation, inorganics, organics, and radionuclide concentrations will be presented in a tabular format for each test run. The results of the MTCLPs and TCLPs will also be listed.

8.3 REQUIRED DATA

The following data will be acquired during soil washing studies:

- Soil characterization data including moisture content, specific gravity, plasticity index, particle size distribution, total organic carbon (TOC), cation exchange capacity (CEC), and chemical characterization as described in Section 6.0.
- Percent by weight of the amount of soil within each particle-size fraction.
- Concentration of target organic compounds associated with each particle-size fraction.
- Concentration of target organic compounds in extracted soil, extractant, and rinse water during remedy screening.

- Concentration of target metals from MTCLP during remedy screening.
- Percent decrease in gross alpha and gross beta in soil.
- Gross alpha and gross beta in the extractant, rinse, and in extracted soil during remedy screening.
- Effectiveness of washing solution additives, expressed as amount of contaminant removed per amount of soil treated and volume of washing solution used.
- Percent of weight of the amount of volume of soil reduced.
- Full TCLP on extracted soils during remedy selection.
- Radionuclide concentration in soil, extractants, and wash water during remedy selection.
- Uranium in cleaned wash solution (by IC fluorescence).
- Organics in extractants and wash water during remedy selection.
- Temperature of wash solution.
- Resin type and effectiveness.
- Types of filter aids.
- Volume of wash water for treatment and/or disposal relative to the initial volume of untreated waste.
- Volume of extracting reagents for disposal relative to the initial volume of untreated waste.
- Volume of soil in which uranium content was reduced to $\leq$35 pCi/g.

8.4 DATA PRECISION, ACCURACY, AND COMPLETENESS

The following procedures will be used to assess data precision, accuracy, and completeness. Calculations of precision, accuracy, and completeness will be used to assess data quality.

Example of calculation 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 of 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
V	=	number of measurements judged valid
n	=	total number of measurements necessary to achieve a specified statistical level of confidence in decision making

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

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FIGURE 8-1

GENERAL QA/QC REPORT

Analyte:
Matrix:
Sample Number:

		Concentration (mg/ℓ)
Precision of Duplicates Spike Value (b)= Spike Dup. Value (a)=		
Precision (RPD[a])	$\frac{\lvert a-b \rvert}{(a+b)/2} \times 100\% =$	
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 =	$\frac{b-a}{c} \times 100\% =$	

[a]RPD - Relative percent difference.

9.0 HEALTH AND SAFETY

Appendix C contains the Health and Safety Plan for the Operable Unit 5 Treatability Field Sampling. These procedures will be implemented and followed by personnel involved in all field sampling activities related to the Operable Unit 5 treatability program.

Appendix D contains the Health and Safety Plan for the Operable Unit 5 Treatability Study Remedy Screening and Remedy Selection Phases, which describes the procedures. These will be implemented and followed by personnel involved in the soil washing treatability study.

These HSPs ensure that all activities are conducted so that the health and safety of all personnel involved are protected, and the hazards associated with field sampling, treatability studies and associated analyses are properly identified.

10.0 RESIDUALS MANAGEMENT

All treatability tests conducted in the ETDC will comply with the Tennessee Hazardous Waste Management Regulations for treatability study samples (TN Rule Chapter 1200-1-11-.02-16) and samples undergoing treatability studies at laboratories and testing facilities (TN Rule Chapter 1200-1-11-.02-19) when applicable.

All waste forms (solids and liquids) from this treatability study program will be analyzed to develop the data necessary for evaluation of the efficacy of the process. These data will be used in the detailed evaluation of alternatives phase of the FS to determine the feasibility of the proposed technology and disposal alternatives for the waste forms generated in the proposed full scale treatment process.

As an ongoing process during the treatability study program all process wastes will be returned to the FEMP site for storage pending disposal at the permitted facility. The FEMP is currently operating under RCRA rules through the 1988 OEPA/DOE Consent Decree. The first Part A Permit Application was submitted on July 6, 1984, to the U.S. EPA. There have been 3 revisions to the Part A Permit since the 1984 submittal, the first of which was sent for informational purposes only. The most recent Part A Permit revision was submitted on October 31, 1991. The revised RCRA Part B Permit Application was also submitted on October 31, 1991 to the U.S. EPA and to the Ohio EPA for review. The FEMP has been permitted for interim storage in accordance with requirements. Final disposition of these wastes will be conducted in accordance with CERCLA, under the Amended Consent Agreement.

10.1 TREATABILITY STUDY WASHED SOIL

The soil washing treatability studies will use approximately three 55-gallon drums of contaminated soil per sampling location. Two to four 55-gallon drums of solid residue from tests on each soil type will be returned to the site for storage pending disposal at the permitted facility. All waste and residue shipments will comply with Dept. of Transportation (DOT) regulations.

10.2 TREATABILITY STUDY LEACHATES

All aqueous streams from the remedy screening stages of the treatability study program including washing, leaching, filtering solutions and all extracts from the MTCLP and TCLP extractions will be placed in 55-gallon drums (estimated to be ten to twelve 55-gallon drums), over-packed and transported according to DOT regulations to the FEMP for interim storage in accordance with RCRA requirements.

11.0 COMMUNITY RELATIONS

Treatability studies and community information and involvement activities are required in the CERCLA process. Community relations activities will be conducted: 1) to support site-wide soil-washing treatability studies in Operable Unit 5 and to explain the role of treatability studies in the RI/FS and 2) 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 5 will comply with the "Community Relations Plan - Remedial Investigation/Feasibility Study and Removal Actions at the Department of Energy Feed Materials Production Center, Fernald, Ohio," August 1990. At a minimum, information appropriate to the Operable Unit 5 treatability studies will be transferred to the community via the following community relations activities:

- 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. During the July 1991 community meeting, an initial discussion made the community aware of treatability studies underway.

- Publications - RI/FS materials such as progress reports, fact sheets, a community newsletter *(Fernald Site Cleanup Report)*, and updates of CERCLA-related activities at the FEMP will include information on treatability study activities for this operable unit.

- 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 work plan to EPA
- EPA approval of work plan
- Treatability testing
- Submittal of treatability testing report

Other activities identified in Section 4.0 of the Community Relations Plan may be used 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 will be issued following the completion of the remedy screening phase of the treatability testing and will document the results of the physical separation and chemical extraction procedures. This report will identify those reagent combinations that yielded the best results for use in the remedy selection phase of testing. In addition, all raw data will be included and presented in a tabular format.

A final treatability study report will be prepared after the remedy selection of the study has been completed. The final report will incorporate information from the interim draft report. The following outline will be used as a guide when preparing this report.

SUGGESTED ORGANIZATION OF TREATABILITY STUDY REPORT

1.0 Introduction
- 1.1 Site description
  - 1.1.1 Site name and location
  - 1.1.2 History of operations
  - 1.1.3 Prior removal and remediation activities
- 1.2 Waste stream description
  - 1.2.1 Waste matrices
  - 1.2.2 Pollutants/chemicals
- 1.3 Remedial technology description
  - 1.3.1 Treatment process and scale
  - 1.3.2 Operating features
- 1.4 Previous treatability studies at the site

2.0 Conclusions and recommendations
- 2.1 Conclusions
- 2.2 Recommendations

3.0 Treatability Study Approach
- 3.1 Test objectives and rationale
- 3.2 Experimental design and procedures
- 3.3 Equipment and materials
- 3.4 Sampling and analysis
  - 3.4.1 Waste stream

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3.4.2 Treatment process
3.5 Data management
3.6 Deviations
4.0 Results and discussion
4.1 Data analysis and interpretation
4.1.1 Analysis of waste stream characteristics
4.1.2 Analysis of treatability study data
4.1.3 Comparison to test objectives
4.2 Quality assurance/quality control
4.3 Costs/schedule for performing the treatability study
4.4 Key contacts
References
Appendices
A. Data summaries
B. Standard operating procedures

13.0 SCHEDULE

The schedule to complete all soil washing treatability-related activities is shown in Figure 13-1. The activities and dates are based on the Operable Unit 5 Amended Consent Agreement schedule.

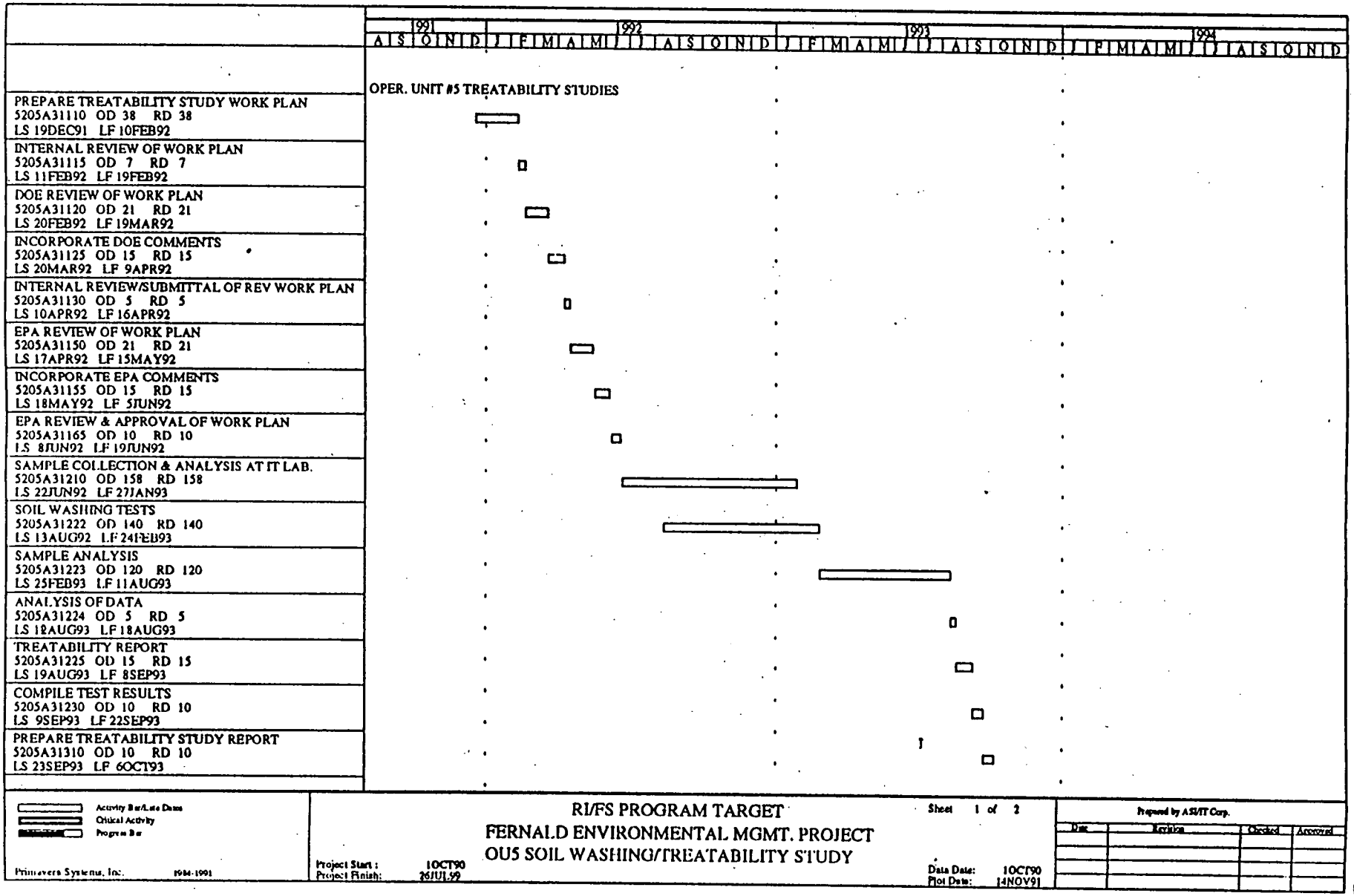

FIGURE 13-1. OPERABLE UNIT 5 TREATABILITY SCHEDULE

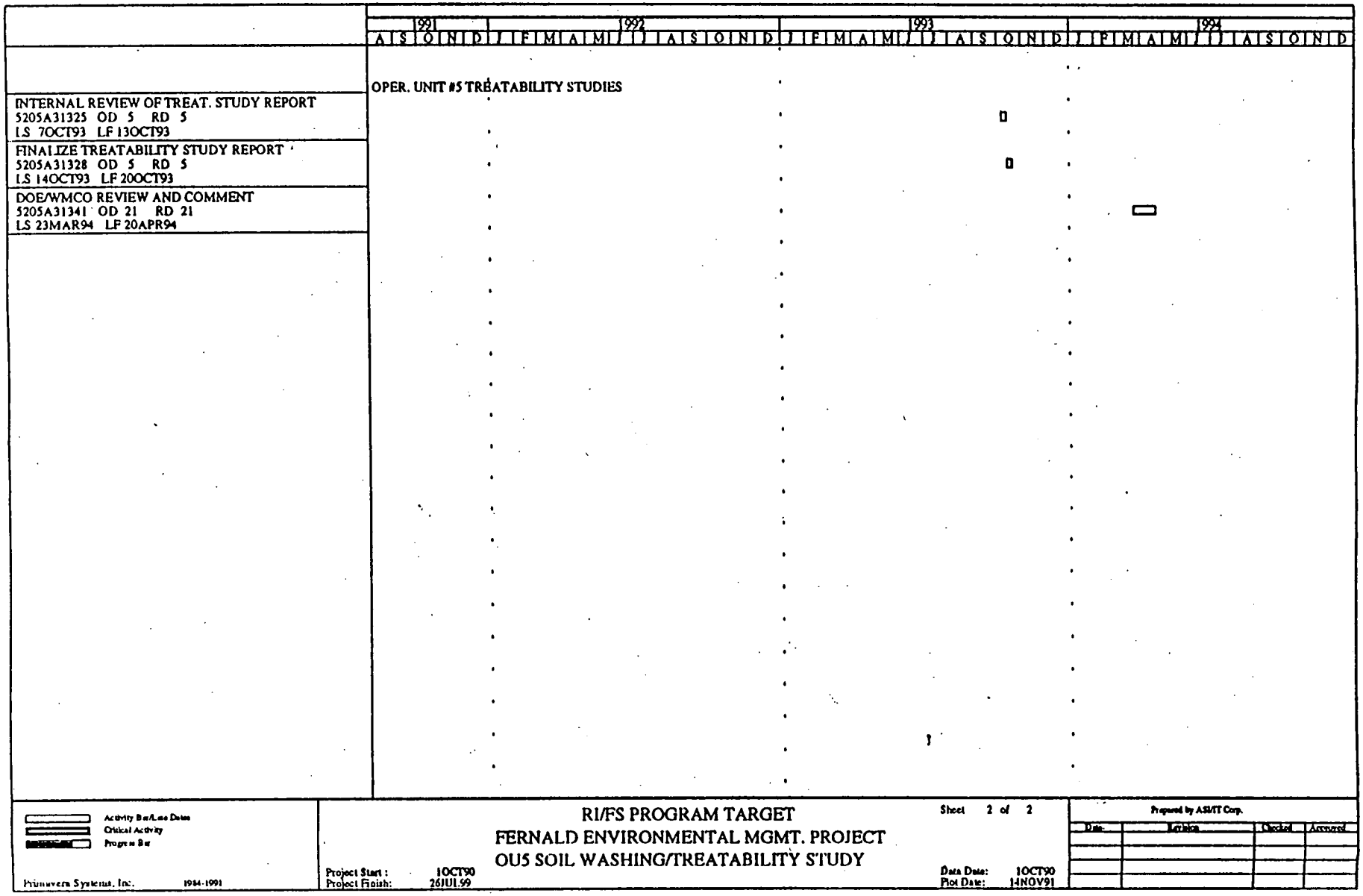

FIGURE 13-1. CONTINUED

14.0 MANAGEMENT AND STAFFING

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. 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.

Those personnel specifically involved in Operable Unit 5 include Carlos J. Fermaintt, DOE Operable Unit manager; Dave Brettschneider, WEMCO's (the integration contractor) Operable Unit 5 manager; and Brent Harvey, Operable Unit 5 manager for Parsons (the remedy design contractor). John Martin of ASI/IT serves as the RI/FS consultant's Operable Unit 5 manager and is the focal point for technical communication with the laboratory performing the treatability study.

The IT Technology Development Laboratory 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 the laboratory and the site. Ernie Stine, Operations Supervisor, and Michael Krstich, Environmental Scientist, are responsible for the technical aspects of the soil washing treatability program at the laboratory. Ken Sadler and Michael Krstich will perform most of the experiments. These personnel and their lines of communication are shown in Figure 14-1.

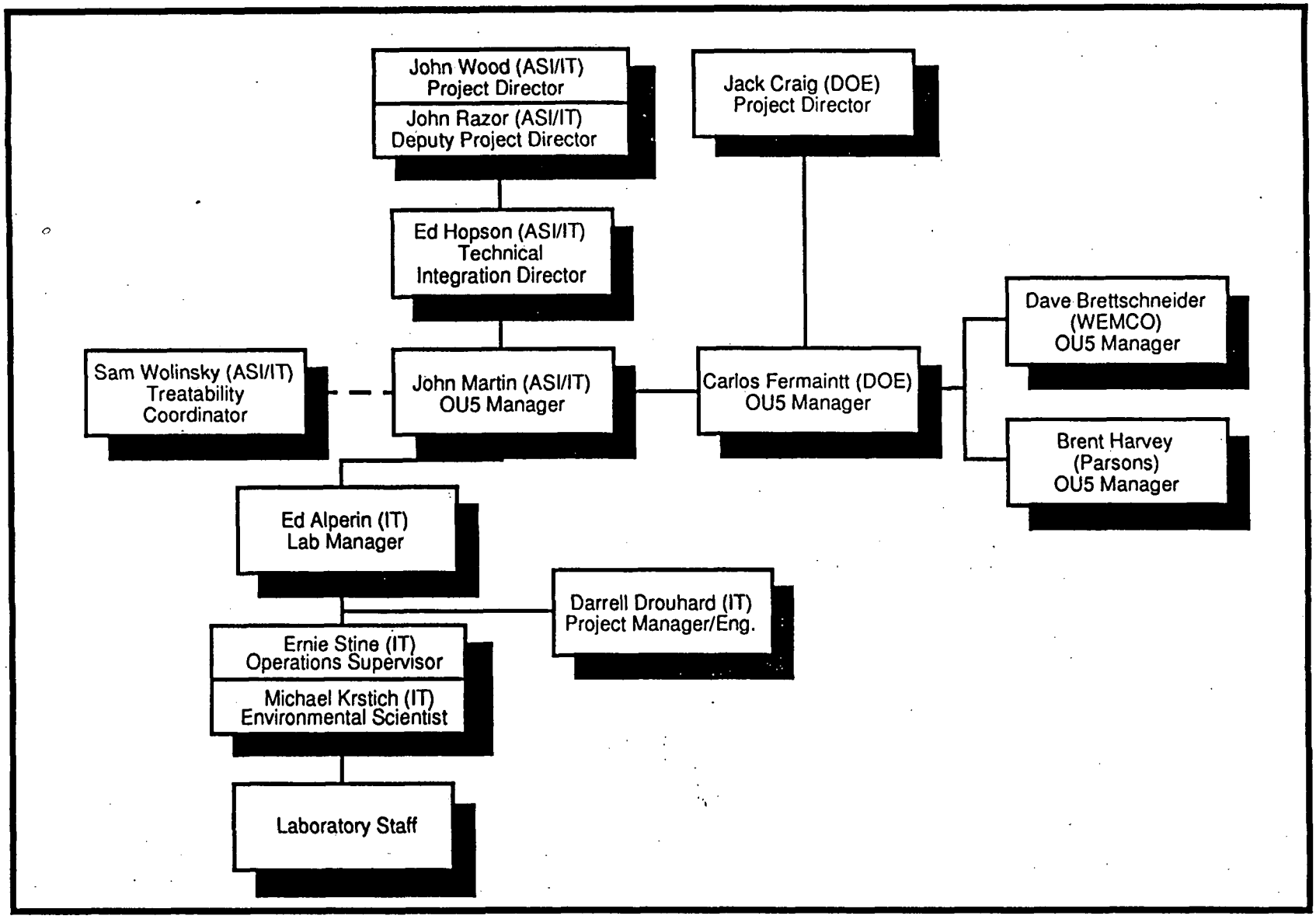

FIGURE 14-1. TREATABILITY STUDY MANAGEMENT AND STAFFING

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APPENDIX A

ADDITIONAL INFORMATION ON THE NATURE AND EXTENT OF CONTAMINATION OF OPERABLE UNIT 5 SOIL

NATURE AND EXTENT OF CONTAMINATION

In describing the soil contamination present at the FEMP, an examination of the RI data collected from the production area reveals that the majority of soils that contain uranium at levels exceeding 35 pCi/g are located in the top 1.5 feet of surficial material. Approximately 50 percent of the former production area soils contain uranium contamination exceeding 35 pCi/g.

In addition, the RI/FS soil sampling program includes the analysis of a number of samples for several radionuclides in addition to (total) uranium. Samples were analyzed for isotopes of uranium, thorium, radium, plutonium, cesium, technetium, strontium, and neptunium (see Table 1-1 for a specific list of radionuclides analyzed). Each of the isotopes included in the analysis was detected at least once in the production area. In all but a few instances, the maximum detected concentration in each area exceeds the natural background concentration of that radionuclide.

A detailed description of contaminated soil areas is presented in Table A-1. The maximum detected concentrations of U-234, -235/236 and -238, Th-230 and -228, and Ra-226 and -238 are presented for each specific area within a given quadrant. These results indicate that, as in the case of total uranium, each of these radionuclides is widely distributed throughout the production area. The remaining radionuclides presented in Table 1-1, including Cs-137, Tc-99, Sr-90, Np-237, Pu-238 and Pu-239/240, are not as prevalent across the site, nor do they generally occur at such high concentrations. However, because uranium contamination is so pervasive throughout the production and suspect areas, each of the areas of concern identified in Table A-1 is also considered an area of concern with respect to total uranium.

Figure A-1 shows the southeast quadrant of the production area. The total uranium values for samples from all borings in the quadrant are shown adjacent to the boring numbers. (This is the data that was used to generate the contours in Figure 1-2 in Section 1.0.) Figure A-1 illustrates the variability of uranium values over relatively short distances. Within the northern half of Plant 6 samples range from less than the detection limit (11 g/g) to several hundred µg/g over distances of 50 to 100 feet. Outside of buildings there is a similar variability, probably due to surface water transporting the airborne materials.

Also within the southeast quadrant, organic chemical contamination has been found in shallow soil in Piezometer 1148 in Plant 6, as illustrated in Figure A-2. The volatile organic compounds

TABLE A-1

ISOTOPIC DISTRIBUTION OF RADIOACTIVE ELEMENTS IN PRODUCTION AREA SOILS[a]

Location	U-234	U-235/236	U-238	Th-230	Th-228	Th-232	Ra-226	Ra-228
			Southeast Quadrant					
West of Plant 6	31.3	2.0	35.2	3.8	0.7	<0.6	0.9	0.9
East of Plant 5	1.5	<0.6	1.5	1.0	0.6	<0.6	0.6	0.8
Between Service Building and Health and Safety Building	970	41.6	986	40.3	7.5	9.1	2.2	5.4
Engine House/Garage and Heavy Equipment Building	41.5	3.3	52.3	6.3	1.5	1.7	1.8	1.3
			Southwest Quadrant					
North of Plant 2/3	2039	398	2014	127	2.85	2.29	21.9	2.27
East of Plant 8	44.8	3.5	41.6	1.7	0.9	0.7	0.7	0.7
West of Plant 8	26.3	1.3	24.7	23.9	1.3	1.0	1.1	1.2
West of Pilot Plant	222	21	238	55.6	26.1	20.4	27.2	28.5
Northeast of Pilot Plant	55.2	4.3	47.4	0.8	<0.6	<0.6	0.6	1.3
North of Pilot Plant	29.2	2.7	27.4	3.8	5.3	5.2	0.9	5.0
South of Pilot Plant	8.4	0.9	7.6	1.3	2.0	1.0	1.0	1.2
Laboratory	13262	950	14321	288	315	283	2.0	546
Along First Street	114	5.5	116	22.2	5.9	5	2.6	5.3

TABLE A-1
(Continued)

Location	U-234	U-235/236	U-238	Th-230	Th-228	Th-232	Ra-226	Ra-228
				Northeast Quadrant				
Graphite Furnace/Oil Burner Area	177.0	14.3	179	17.0	2.0	1.8	1.4	1.8
Drum Baling Area	24.8	2.4	27.9	12.8	29.3	34.0	0.9	105
North of Maintenance Building	117	8.6	118	6.7	1.8	1.8	1.2	1.8
Southwest Corner of Plant 9	40.3	2.5	35.0	<0.6	2.3	2.2	0.9	4.6
South-Southeast of Plant 9	NA	NA	NA	1.9	1.1	1.0	0.9	0.9
Northwest of Building 65	19.3	1.3	19.9	12.6	40.9	39.5	1.3	42.3
South of Buildings 64 and 65	24.8	2.4	27.9	12.8	29.3	34	1.0	105
				Northwest Quadrant				
Plant 1 Pad	3857	204	4108	2749	31.2	31.4	2720	56.2

*This table presents the maximum detected concentration of each isotope in a given area. Units are in picocuries per gram. "<0.6" means sample tested at or below detection limits. See Figures A-1, A-3, A-4, A-6, and A-8 for approximate locations of buildings/facilities within each quadrant.

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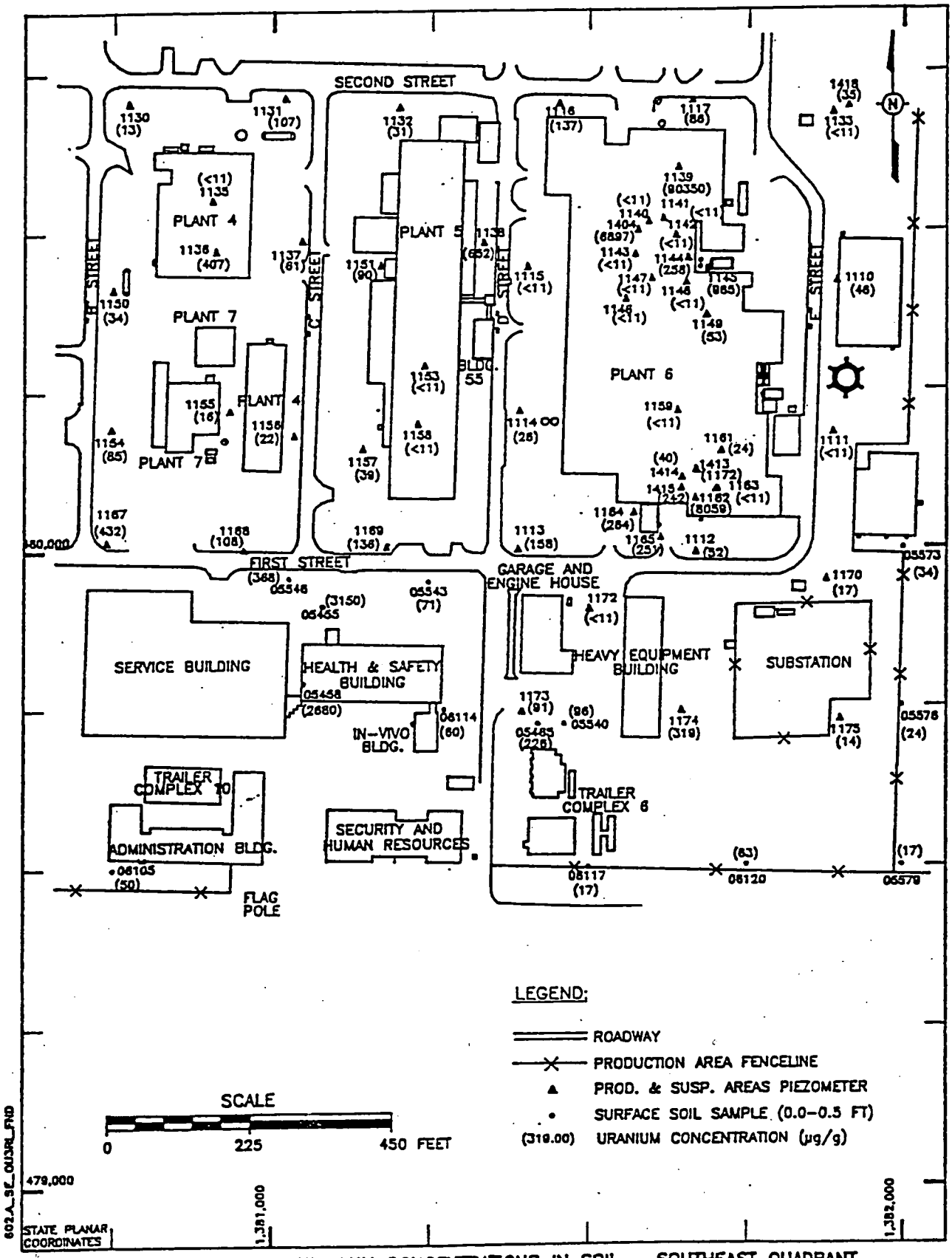

FIGURE A-1. TOTAL URANIUM CONCENTRATIONS IN SOIL - SOUTHEAST QUADRANT

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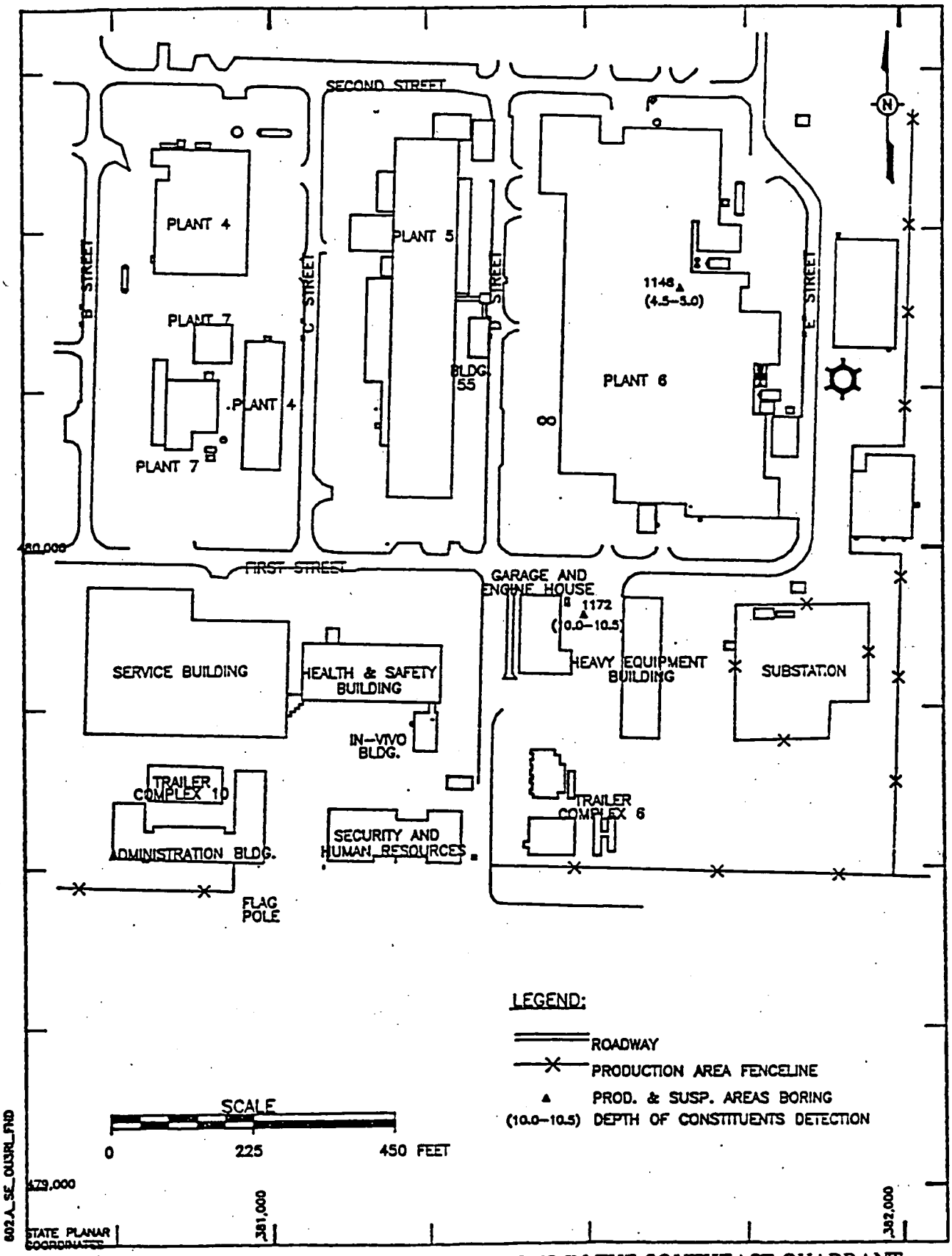

FIGURE A-2. CHEMICAL SAMPLING LOCATIONS IN THE SOUTHEAST QUADRANT

1,2-dichloroethylene and trichloroethene were found at 55 and 200 µg/g, respectively. Further sampling has been conducted; however, results are not available at this time.

Figure A-3 shows the total uranium contamination in surface soil for the upper part of the southwest quadrant of the production area. Surface soil contamination is highest in the vicinity of Plant 2/3. Figure A-4 shows the total uranium concentrations in surface soil in the lower half of the southwest quadrant. Total uranium concentrations are highest near the southwest corner of the pilot plant and along the west side of the laboratory.

Because organic chemicals were used in some of the facilities within the southwest quadrant, several soil samples were analyzed for hazardous substance list (HSL) parameters. Figure A-5 shows these sampling locations. Table A-2 lists chemical concentrations from surface soil samples in the pilot plant area. Table A-3 lists chemical concentrations from soil samples in the Plant 2/3 area. These analyses indicate the range of contaminants that are found in these relatively small areas.

Figure A-6 shows the total uranium in surface soil in the northeast quadrant. Chemical contamination (Figure A-7) was detected in two areas within this quadrant: the graphite furnace and oil burner area near the northeast corner of the boiler plant and the area along the north side of the maintenance building. Tables A-4 and A-5 present the results of chemical analyses for samples in these respective areas. Between these two areas lie the coal pile and the runoff retention basin for the coal pile. Additional sampling for chemical contamination has been conducted between the graphite furnace and the maintenance building; however, the data are not currently available. It is quite possible that the area bounded by the graphite furnace and the maintenance building is the largest contiguous area where chemical contamination exists on site.

Figure A-8 shows the concentration of total uranium in the surface soil in the northwest quadrant. Concentrations of total uranium in this area ranged from 7 µg/g to 211 µg/g. Limited chemical analysis has been conducted on the soils in this area as illustrated in Figure A-9.

The sewage treatment plant area contains the highest levels of total uranium contamination outside the production area or the Waste Storage Area. Figure A-10 shows the total uranium concentration in surface soil samples from this area.

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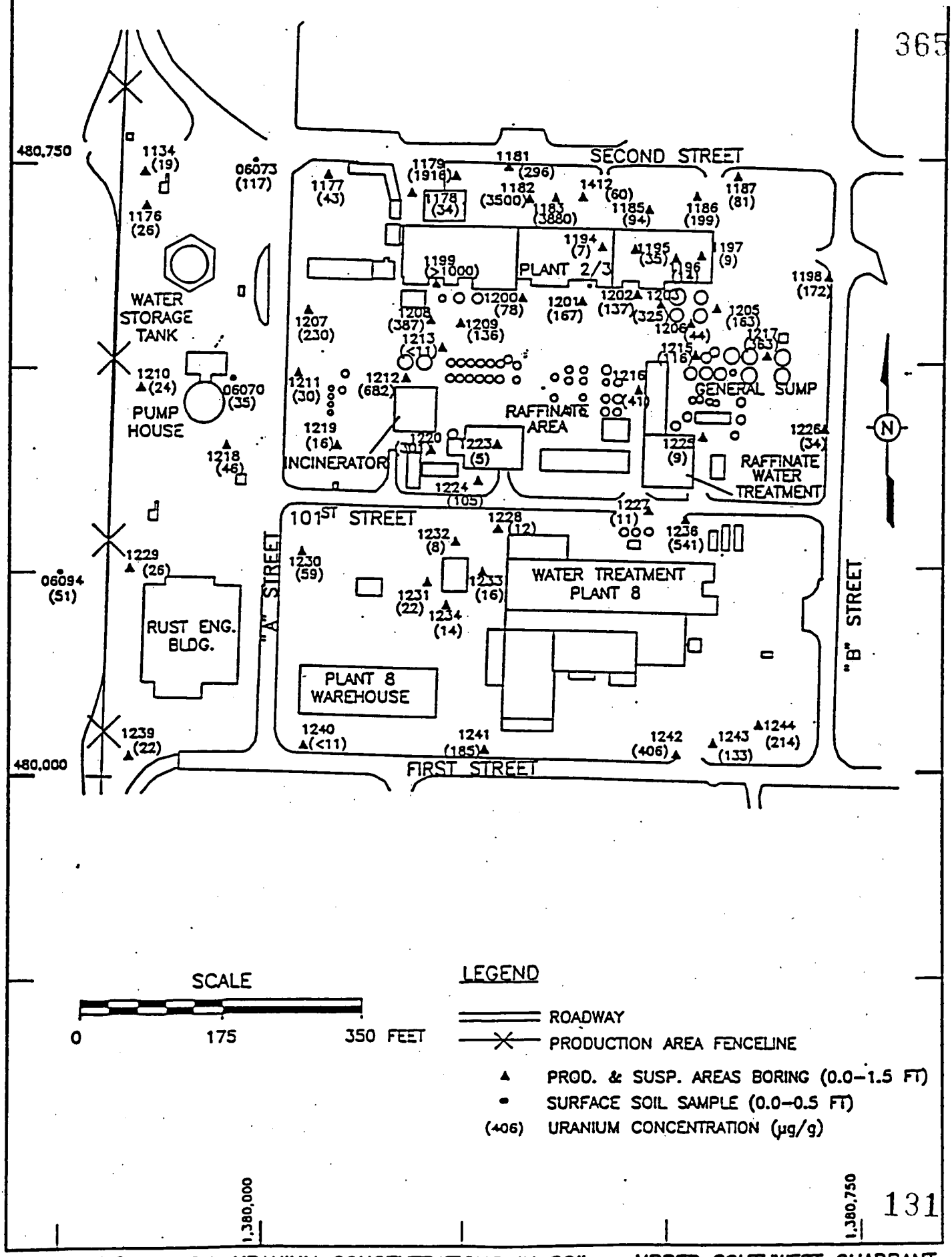

FIGURE A-3. TOTAL URANIUM CONCENTRATIONS IN SOIL – UPPER SOUTHWEST QUADRANT

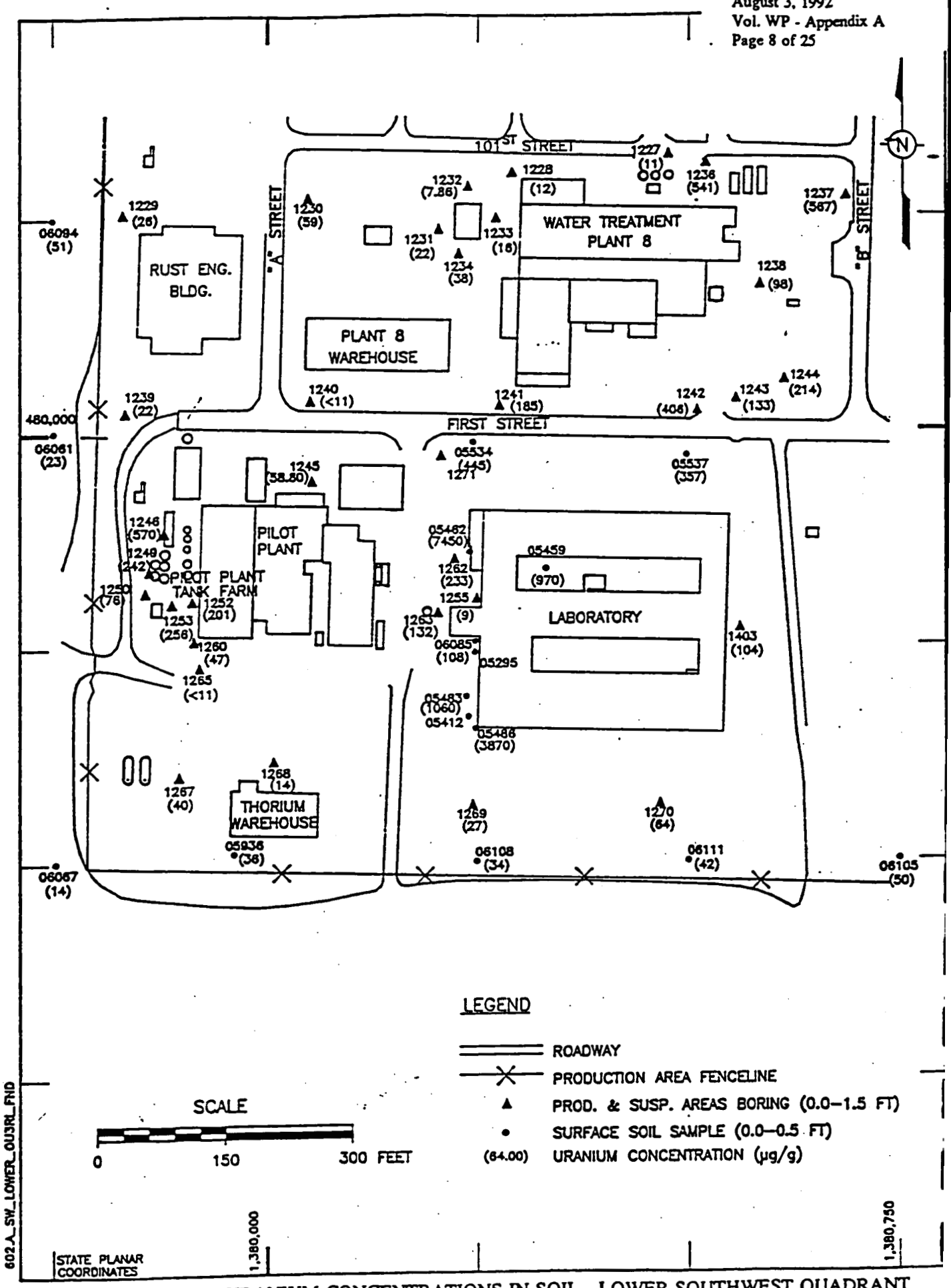

FIGURE A-4. TOTAL URANIUM CONCENTRATIONS IN SOIL - LOWER SOUTHWEST QUADRANT

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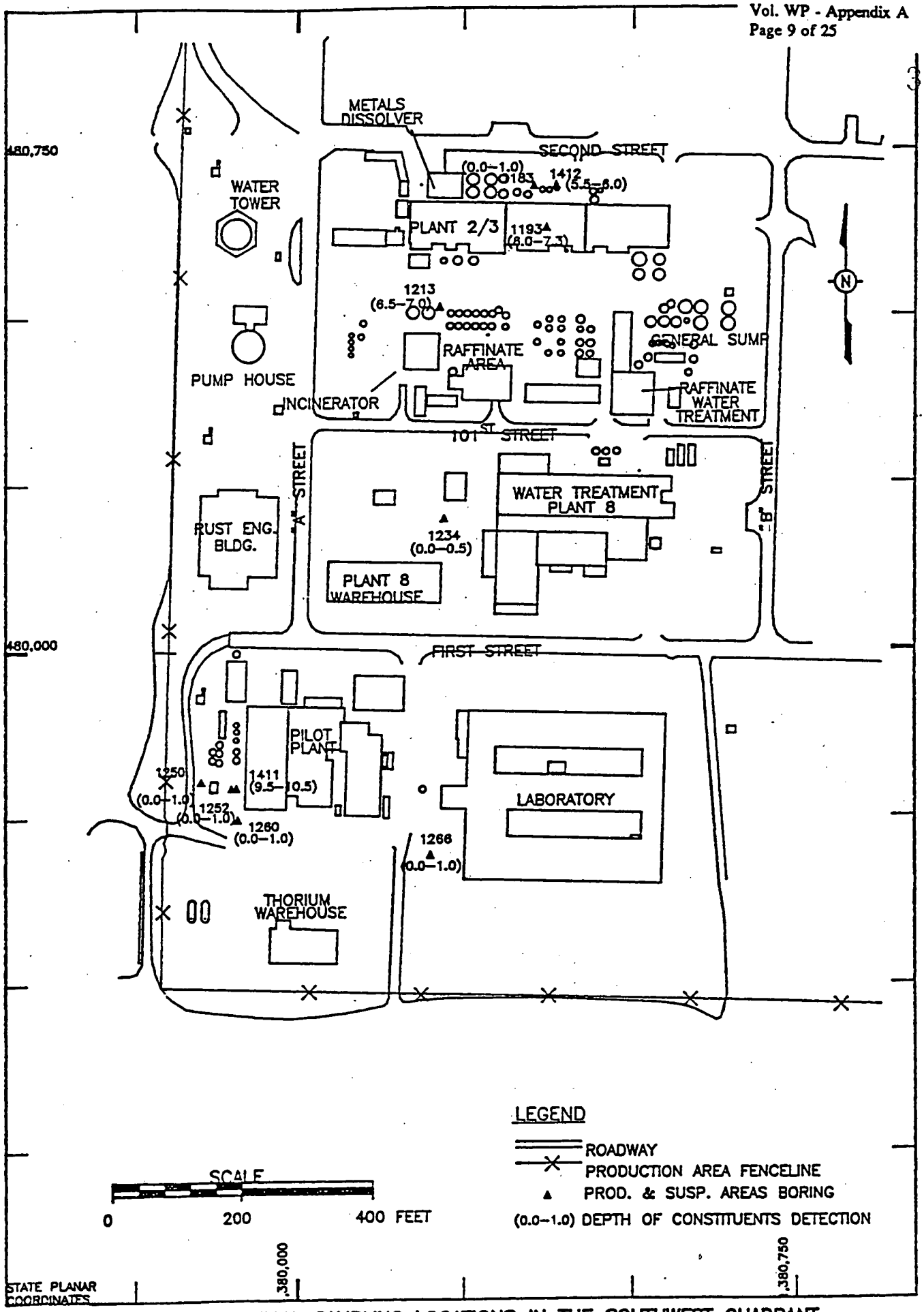

FIGURE A-5. CHEMICAL SAMPLING LOCATIONS IN THE SOUTHWEST QUADRANT

TABLE A-2

CHEMICAL CONCENTRATIONS IN SOIL FROM THE PILOT PLANT AREA IN THE SOUTHWEST QUADRANT[a]

Constituents	Location Sample ID Depth (ft)	1250 18071 0.5-1.0	1250 18069 0.0-0.5	1252 52753 0.0-0.5	1252 52754 0.5-1.0	1260 18289 0.0-0.5	1260 18290 0.5-1.0	1411 54995 9.5-10.0	1411 54996 10.0-10.5
Inorganics (mg/kg)									
Arsenic		--	--	7.4	--	--	--	--	--
Barium		--	--	--	--	--	--	--	3610
Beryllium		1.7	1.5	1.2	0.94	1.2	0.82	0.93	0.99
Cadmium		4.5	3.4	4.7	3	5.4	3.4	4.5	4.2
Calcium		115,000	35,200	86,600	8440	181,000	103,000	77,100	89,400
Cobalt		16.5	13.8	13.9	14	13.3	--	9.9	10.4
Copper		22.3	27.1	--	25.3	28.9	--	--	--
Iron		--	--	--	--	27,300	--	--	--
Lead		--	30.3	--	26.7	117	--	--	--
Magnesium		26,000	9740	20,200	4680	11,400	20,700	26,600	20,000
Manganese		--	835	--	--	--	--	--	--
Nickel		41.9	39.8	40.5	34.7	35.1	29.2	27.4	25.9
Silver		--	--	--	--	--	3.1	--	--
Thallium		--	--	--	0.34	0.33	0.26	0.46	0.37
Zinc		--	60.8	219	242	207	210	209	213
Organics (µg/kg)									
Volatiles									
1,1-Dichloroethene		--	--	--	4	--	--	NA	--
1,1,2,2-Tetrachloroethane		--	--	--	--	--	--	NA	350
1,2-Dichloroethylene		2	--	--	--	--	--	NA	1600
2-Butanone		49	10	8	9	1	4	NA	2400
2-Propanone		--	9	--	12	6	6	NA	--
4-Methyl-2-pentanone		--	--	--	--	--	--	NA	330
Benzene		--	--	--	5	--	--	NA	--
Chlorobenzene		--	--	--	5	--	--	NA	--
Methylene chloride		10	7	20	20	20	19	NA	6700
Tetrachloroethene		--	-	1	--	2	--	NA	17,000
Toluene		1	--	--	5	--	--	NA	31,000
Trichloroethene		4	5	--	5	3	--	NA	2000

(Continued)

Constituents	Location Sample ID Depth (ft)	1250 18071 0.5-1.0	1250 18069 0.0-0.5	1252 52753 0.0-0.5	1252 52754 0.5-1.0	1260 18289 0.0-0.5	1260 18290 0.5-1.0	1411 54995 9.5-10.0	1411 54996 10.0-10.5
Semivolatiles									
Acenaphthene		--	--	1600	--	110	110	--	--
Anthracene		--	--	2800	60	170	290	--	--
Benzo(a)anthracene		--	--	5400	430	660	580	--	--
Benzo(a)pyrene		--	--	5100	320	470	520	--	--
Benzo(b)fluoranthene		--	--	4700	--	--	540	--	90
Benzo(g,h,i)perylene		--	--	3700	230	400	440	--	--
Benzo(k)fluoranthene		--	--	5000	550	730	510	--	--
bis(2-ethyl hexyl)phthalate		--	71	--	58	46	--	810	1100
Chrysene		--	--	7200	550	860	790	--	--
Dibenzofuran		--	--	640	--	55	72	--	--
Dibenzo(a,h)anthracene		--	--	1500	420	--	140	--	--
Di-n-butyl phthalate		--	--	--	--	--	46	1400	1400
Fluoranthene		--	43	10,000	940	1500	1600	94	190
Fluorene		--	--	1700	44	130	160	--	--
Indeno(1,2,3-cd)pyrene		--	--	2900	160	280	330	--	--
Phenanthrene		--	--	8800	480	950	1300	140	240
Phenol		69	--	--	--	--	--	--	--
Pyrene		--	--	10,000	860	1400	1300	83	150
Pesticides and PCBs (µg/kg)									
beta-BHC		--	--	220	--	--	46	--	--
PCB-1254		--	120	1000	170	200	--	--	--
PCB-1260		--	--	1000	270	340	--	830	1100

[a]Data presented by location, sample number, and sample depth

NA - Not analyzed

-- Dash indicates concentrations for inorganics were below background

-- Dash indicates concentrations for organics, pesticides, and PCBs were below the contract-required detection limit

TABLE A-3

CHEMICAL CONCENTRATIONS IN SOIL FROM THE PLANT 2/3 AREA IN THE SOUTHWEST QUADRANT

Data presented by location, sample number, and sample depth.
NA indicates not available. For inorganic constituents, dashes indicate concentrations below background; for organic constituents, pesticides, and PCBs, dashes indicate no detection.

Constituents	Location Sample ID Depth (ft)	1183 16595 0.0-0.5	1183 16597 0.5-1.0	1213 17276 6.0-7.0	1193 51954 6.0-7.5	1412 55089 5.5-6.0
Inorganics (mg/kg)						
Arsenic		8.4	--	NA	NA	26.5
Beryllium		2.4	1.7	NA	NA	1
Cadmium		6.9	5.2	NA	NA	4.1
Calcium		105,000	115,000	NA	NA	48,200
Chromium		75.5	--	NA	NA	--
Cobalt		17.4	14.3	NA	NA	12.8
Copper		38.5	--	NA	NA	--
Lead		334	440	NA	NA	161
Magnesium		38,600	21,400	NA	NA	17,500
Molybdenum		2.9	--	NA	NA	--
Nickel		50	42.3	NA	NA	38
Silver		17.2	5.9	NA	NA	3.9
Zinc		247	89	NA	NA	65.5
Organics (µg/kg)						
Volatiles						
1,1-Dichloroethane		--	--	--	--	14
1,1,1-Trichloroethane		--	--	--	--	6
2-Butanone		4	4	--	10	110
2-Propanone		14	5	9	29	98
Methylene chloride		8	5	17	17	78
Toluene		2	2	--	2	--
Semivolatiles						
Benzoic acid		--	88	NA	NA	--
bis(2-Ethylhexyl)phthalate		180	--	NA	NA	--
Fluoranthene		--	--	NA	NA	81
N-Nitrosodiphenylamine		100	130	NA	NA	630
Phenanthrene		--	--	NA	NA	88
Pesticides and PCBs (mg/kg)						
PCB-1254		360	--	NA	NA	--

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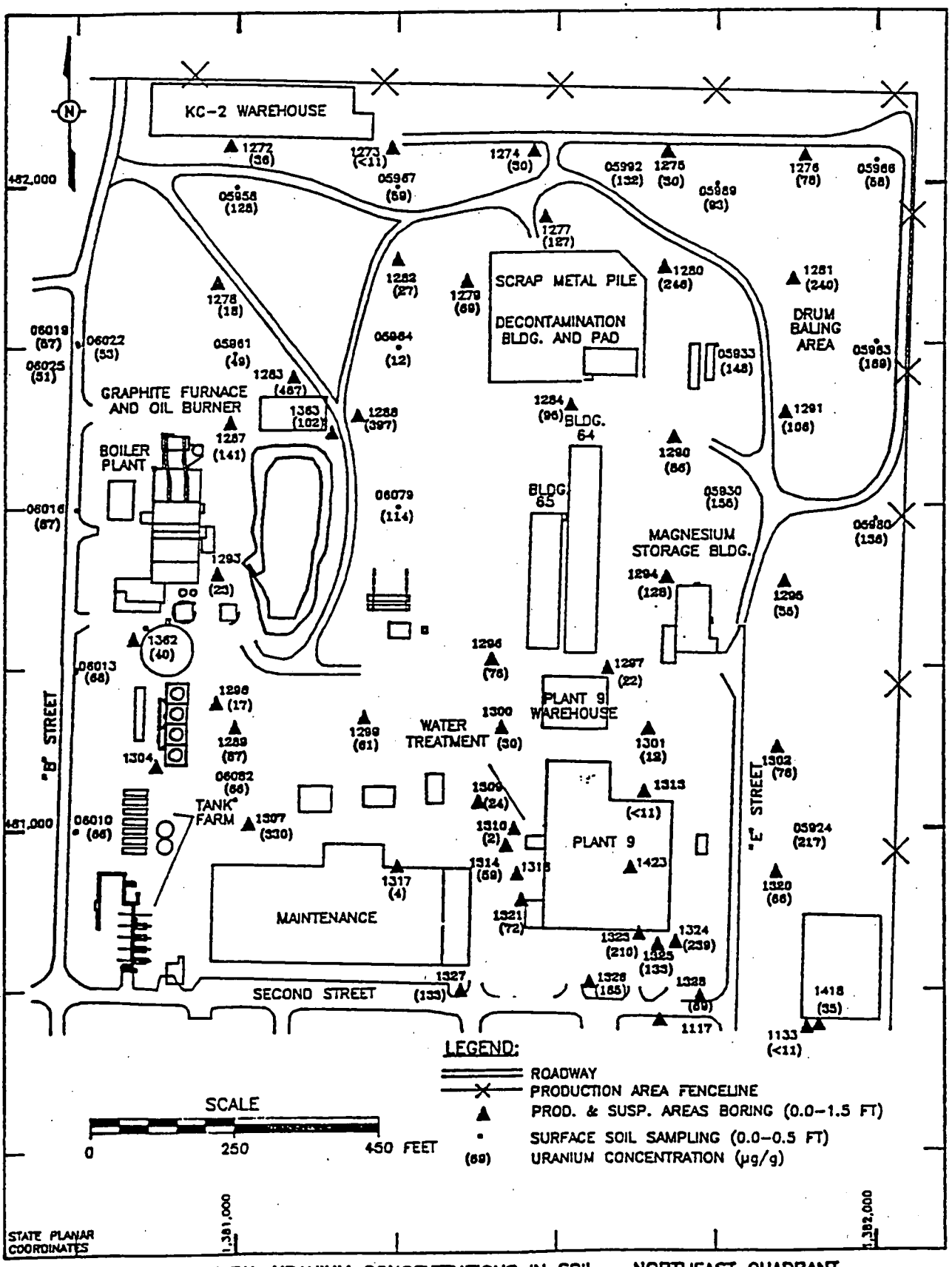

FIGURE A-6. TOTAL URANIUM CONCENTRATIONS IN SOIL – NORTHEAST QUADRANT

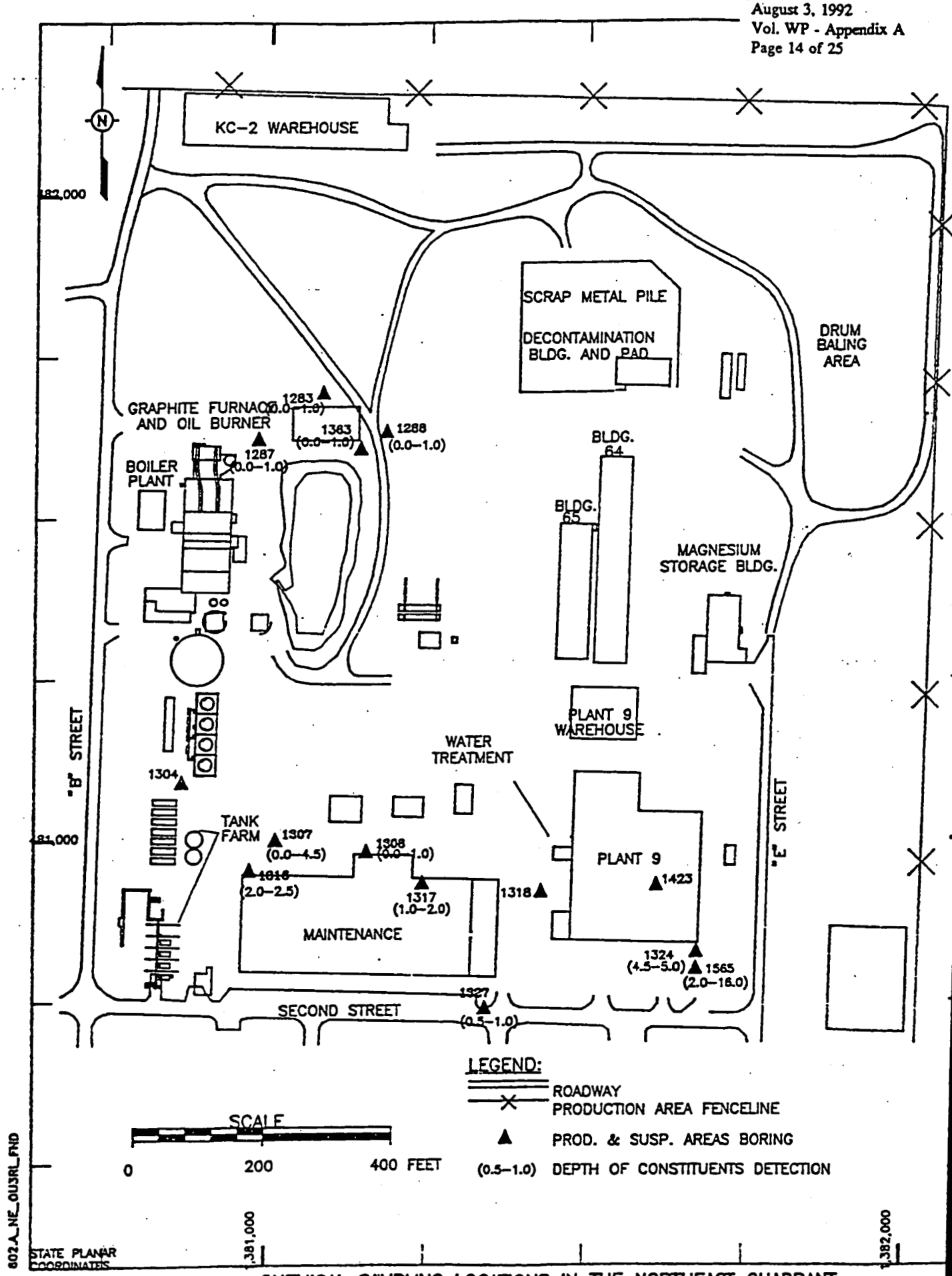

FIGURE A-7. CHEMICAL SAMPLING LOCATIONS IN THE NORTHEAST QUADRANT

CHEMICAL CONCENTRATIONS IN SOIL FROM THE GRAPHITE FURNACE AND OIL BURNER AREA IN THE NORTHEAST QUADRANT OF THE FEMP PRODUCTION AREA

Constituents	Location Sample ID Depth (ft)	1283 18795 0.0-0.5	1283 18796 0.5-1.00	1287 18883 0.0-0.5	1287 18884 0.5-1.0	1288 53473 0.0-0.5	1288 53474 0.5-1.0	1363 50554 0.0-0.5	1363 50555 0.5-1.0
Inorganics (mg/kg)									
Arsenic		7.5	17.2	22.6	12	8.7	--	7.6	--
Barium		--	--	--	523	512	456	--	--
Beryllium		1.8	1.2	--	1.3	1.2	1.2	0.98	0.87
Cadmium		6.2	3.9	3.5	2.9	4	4.4	4.7	4.9
Calcium		205,000	110,000	21,000	8000	44,200	42,700	88,100	162,000
Cobalt		11.8	11.4	15.7	12.6	13.4	16.1	12.6	10.4
Copper		--	--	24.9	--	--	--	--	--
Iron		--	--	--	--	--	--	--	--
Lead		50.3	29.4	57.2	27	25.3	--	--	38.2
Magnesium		45,100	19,600	6710	--	13,200	15,000	20,800	29,300
Manganese		--	--	--	818	--	661	--	--
Mercury		0.16	0.16	0.22	--	0.28	0.32	--	--
Molybdenum		2.3	--	--	--	--	--	--	--
Nickel		30.5	32	40.7	44.8	37.5	44.3	35	28.2
Silver		--	2.3	--	--	4	2.9	--	--
Thallium		--	0.24	0.57	--	0.42	0.42	--	--
Zinc		194	203	248	285	270	232	233	145
Organics (µg/kg)									
Volatiles									
1,1,1-Trichloroethane		--	120	--	--	--	--	7	7
1,1-Dichloroethene		--	--	--	--	--	--	1	--
2-Butanone		--	67	2	6	12	1	3	--
2-Propanone		13	--	17	--	--	7	16	16
Chloroform		--	--	--	--	9	7	--	2
Ethyl benzene		--	140	--	--	--	--	--	--
Methylene chloride		22	640	24	13	24	27	28	27
Tetrachloroethene		12	140	10	12	--	--	5	7
Toluene		2	160	2	--	--	--	1	3
Total xylenes		--	120	--	--	--	--	--	--
Trichloroethene		12	52	5	2	--	--	1	2

TABLE A-4
(Continued)

Constituents	Location Sample ID Depth (ft)	1283 18795 0.0-0.5	1283 18796 0.5-1.00	1287 18883 0.0-0.5	1287 18884 0.5-1.0	1288 53473 0.0-0.5	1288 53474 0.5-1.0	1363 50554 0.0-0.5	1363 50555 0.5-1.0
Semivolatiles									
2-Methylphthalate		280	590	320	--	150	--	100	--
Benzo(a)anthracene		--	--	--	--	51	--	--	--
Benzo(b)fluoranthene		--	--	--	--	95	--	--	310
Benzo(k)fluoranthene		--	--	--	--	81	--	--	--
bis(2-ethyl hexyl)phthalate		--	--	--	--	--	--	--	--
Chrysene		--	--	--	--	83	--	--	--
Dibenzofuran		--	--	81	--	--	--	--	--
Di-n-butyl phthalate		240	--	--	--	--	--	--	--
Fluoranthene		--	--	81	--	150	--	--	--
Naphthalene		--	390	190	--	89	--	--	--
N-Nitrosodiphenylamine		530	370	--	--	--	--	120	--
Phenanthrene		310	330	190	--	180	--	79	--
Pyrene		--	--	--	--	140	--	--	--
Pesticides and PCBs (µg/kg)									
beta-BHC		--	--	--	--	--	--	100	--
PCB-1254		1200	370	1200	85	--	--	--	--
PCB-1260		560	150	2800	--	230	--	--	150

-- Dash indicates concentrations for inorganic were below background
-- Dash indicates concentrations for organics, pesticides, and PCBs were below the contract-required detection limit

TABLE A-5

CHEMICAL CONCENTRATIONS IN SOIL FROM THE MAINTENANCE BUILDING AREA
IN THE NORTHEAST QUADRANT OF THE FMPC PRODUCTION AREA

Constituents	Location Sample ID Depth (ft)	1307 19323 0.0-0.5	1307 19324 0.5-1.0	1307 53853 3.0-4.5	1307 53854 1.5-3.0	1308 19345 0.0-0.5	1308 19346 0.5-1.0	1316 19525 2.0-2.5	1317 54053 1.0-1.5	1317 54054 1.5-2.0	1327 19763 0.0-0.5	1327 19764 0.5-1.0
Inorganics (mg/kg)												
Arsenic		12.6	--	NA[a]	NA	--	--	--	--	--	--	--
Barium		434	456	NA	NA	--	--	--	--	--	--	--
Beryllium		--	--	NA	NA	1.2	1.1	0.99	1.1	0.96	1.7	1.7
Cadmium		6.7	5.4	NA	NA	8	7.1	4	5.1	4.6	7.2	6.3
Calcium		91,900	132,000	NA	NA	157,000	180,000	139,000	126,000	111,000	178,000	189,000
Chromium		67.5	--	NA	NA	--	53	--	--	--	--	--
Cobalt		16.8	11.7	NA	NA	12.2	9.7	--	13.8	11.5	10.2	12.9
Copper		48.9	--	NA	NA	65.2	46.2	--	--	--	30.3	--
Iron		25,800	--	NA	NA	26,900	--	--	--	--	--	--
Lead		334	32.2	NA	NA	182	165	--	--	--	116	22.8
Magnesium		24,900	35,100	NA	NA	42,200	55,100	35,100	35,600	34,500	46,000	41,600
Manganese		0.65	0.46	NA	NA	0.53	0.18	--	--	--	0.37	--
Mercury		--	--	NA	NA	--	--	--	--	--	5.7	3.6
Molybdenum		72.2	36.7	NA	NA	67.8	70.5	20.6	49.3	33.6	63.3	38.1
Nickel		4.5	--	NA	NA	--	--	--	--	--	--	--
Silver		0.38	0.39	NA	NA	--	--	--	0.34	--	--	--
Thallium		767	292	NA	NA	431	324	--	--	--	119	--
Zinc												
Organics (µg/kg)												
Volatiles												
1,1-Dichloroethylene		--	--	310	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane		210	110	--	--	--	--	--	--	--	--	--
2-Butanone		1100	430	1200	1100	26	3	--	7	35	3	4
2-Propanone		2300	70	2700	2500	18	8	5	5	--	--	11
4-Methyl-2-pentanone		160	--	--	--	--	--	--	--	--	--	--
Chloroform		--	--	--	--	--	--	--	--	--	14	46
Methylene chloride		3000	1200	4200	4600	21	9	3	50	3	6	5
Tetrachloroethene		3300	2000	--	1600	--	--	--	--	--	--	--
Toluene		190	--	--	--	4	--	--	2	2	3	4
Trichloroethene		89,000	56,000	150,000	120,000	18	7	--	--	--	--	--

TABLE A-5
(Continued)

Constituents	Location Sample ID Depth (ft)	1307 19323 0.0-0.5	1307 19324 0.5-1.0	1307 53853 3.0-4.5	1307 53854 1.5-3.0	1308 19345 0.0-0.5	1308 19346 0.5-1.0	1316 19525 2.0-2.5	1317 54053 1.0-1.5	1317 54054 1.5-2.0	1327 19763 0.0-0.5	1327 19764 0.5-1.0
Semivolatiles												
2-Methylnaphthalene		320	--	NA	NA	760	--	--	--	--	--	--
Acenaphthene		--	--	NA	NA	4800	570	--	--	--	--	--
Anthracene		--	--	NA	NA	6200	880	--	--	--	330	--
Benzo(a)anthracene		660	--	NA	NA	19,000	2900	--	--	--	2000	--
Benzo(a)pyrene		640	--	NA	NA	24,000	3700	--	--	--	2300	--
Benzo(b)fluoranthene		840	--	NA	NA	39,000	4200	--	--	--	2300	--
Benzo(g,h,i)perylene		--	--	NA	NA	12,000	1500	--	--	--	1900	--
Benzo(k)fluoranthene		790	--	NA	NA	--	3100	--	--	--	2600	--
bis(2-ethyl hexyl)phthalate		500	--	NA	NA	--	--	--	--	38	780	--
Chrysene		900	--	NA	NA	18,000	3000	--	--	--	1900	--
Dibenzofuran		--	--	NA	NA	2000	210	--	--	--	610	--
Dibenzo(a,h)anthracene		--	--	NA	NA	6900	690	--	--	--	--	--
Fluoranthene		1600	--	NA	NA	33,000	5900	--	--	--	4000	--
Fluorene		--	--	NA	NA	3300	380	--	--	--	--	--
Indeno(1,2,3-cd)pyrene		--	--	NA	NA	13,000	1500	--	--	--	1700	--
Naphthalene		--	--	NA	NA	1300	--	--	--	--	--	--
N-Nitrosodiphenylamine		580	130	NA	NA	--	--	--	--	--	200	99
Phenanthrene		1400	--	NA	NA	22,000	3700	--	--	--	1500	--
Phenol		--	--	NA	NA	--	200	--	--	--	--	--
Pyrene		1400	--	NA	NA	22,000	4300	--	--	--	4400	--
Pesticides and PCBs (µg/kg)												
PCB-1254		8600	1200	NA	NA	--	1700	200	--	--	460	--
PCB-1260		--	--	NA	NA	--	2100	--	--	--	--	--
Other (mg/kg)												
Cyanide		--	--	NA	NA	22.8	20.6	8.6	--	--	0.59	1.3

*NA - Not analyzed
-- Dash indicates concentrations for inorganics were below background
-- Dash indicates concentrations for organics, pesticides, and PCBs were below the contract-required detection limit

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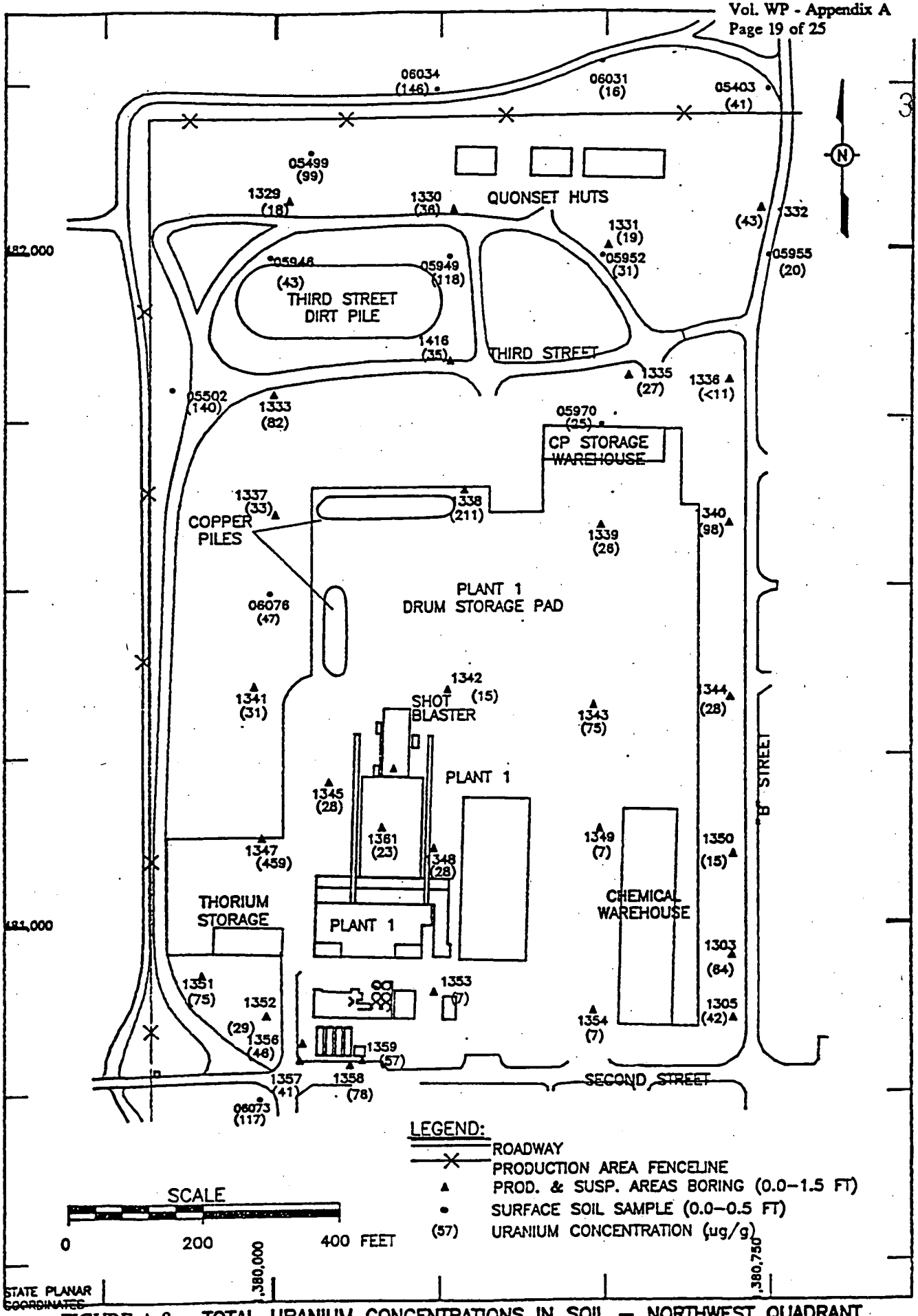

FIGURE A-8. TOTAL URANIUM CONCENTRATIONS IN SOIL — NORTHWEST QUADRANT

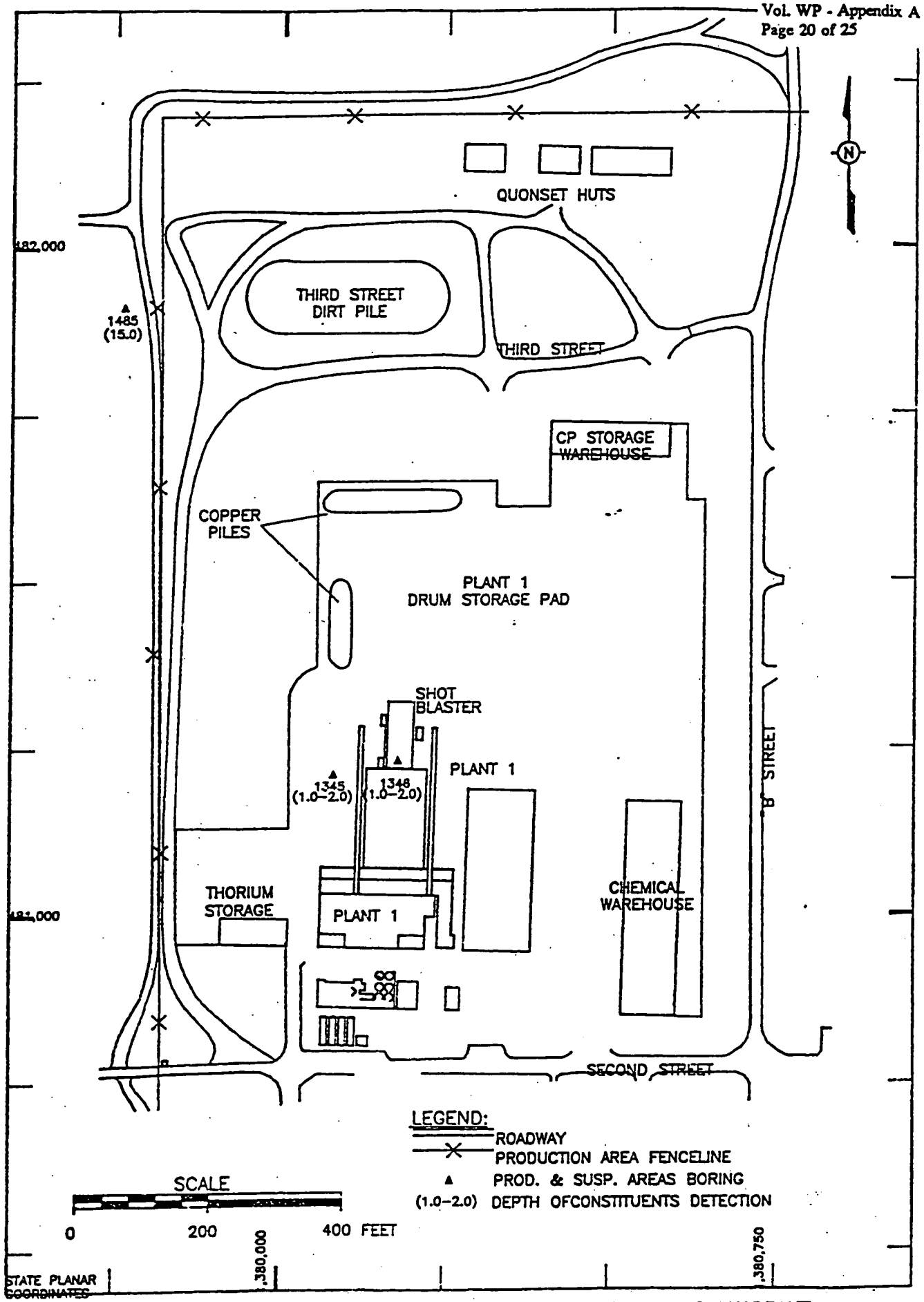

FIGURE A-9. CHEMICAL SAMPLING LOCATIONS IN THE NORTHWEST QUADRANT

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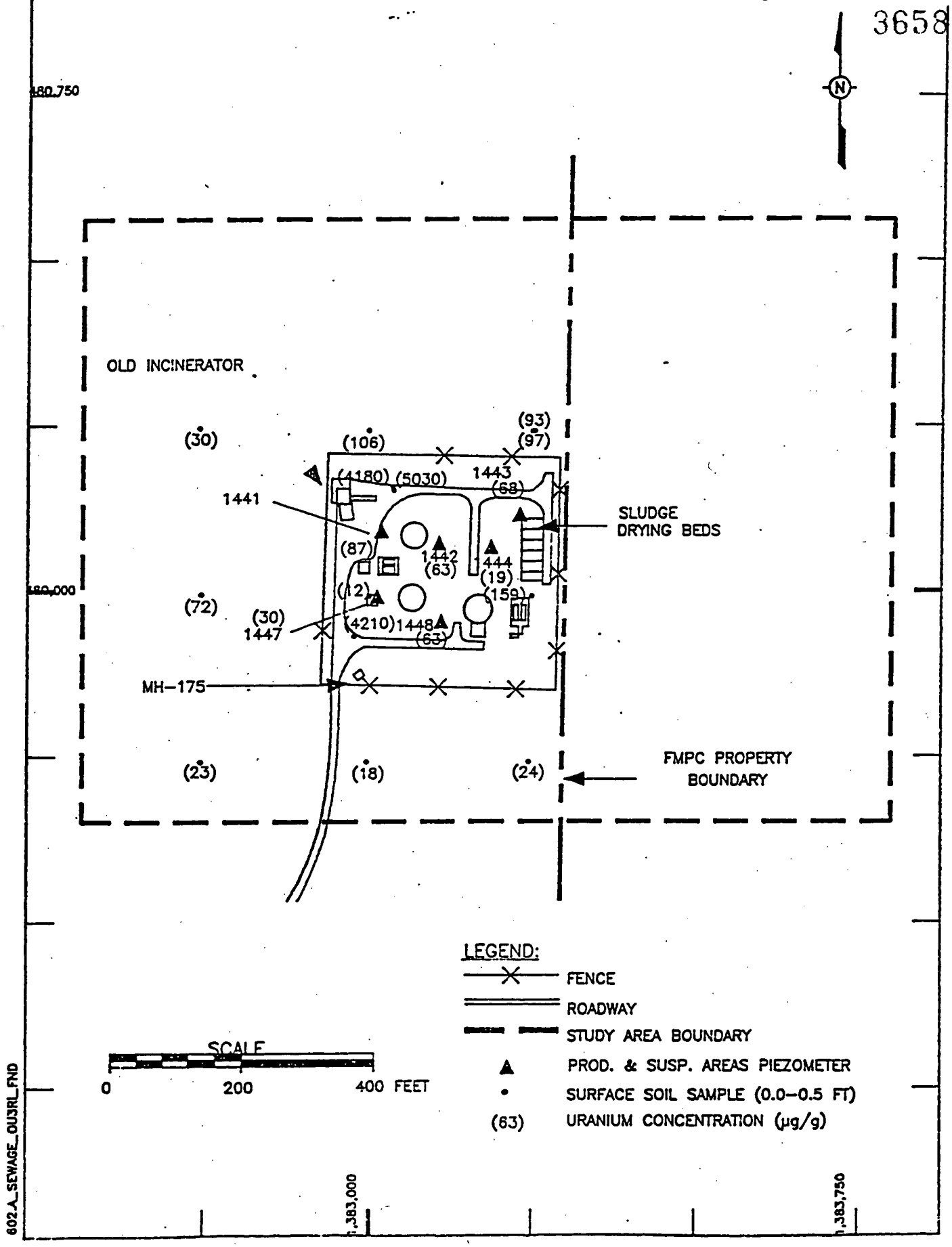

FIGURE A-10. TOTAL URANIUM CONCENTRATIONS IN SOIL – SEWAGE TREATMENT PLANT

The fire training area is located immediately beyond the security fence that runs along the north side of the production area (Figure A-11). This area contains the burn house, an oil-fire pond, a metal trough containing water and oil, and a sump that was used to dispose of waste fluids from the oil-fire pond.

The radiological analytical results for the fire training area are presented in Table A-6. These data show that in the upper 18 inches of soil, the dominant contaminant is uranium.

The results of organic and inorganic analysis show elevated levels of heavy metals as well as isolated hits of volatile organics, semivolatile organics, and Aroclor 1260. These results are presented in Table A-7. The source of the organic chemicals is likely the oils and solvents used in the fire fighting exercises.

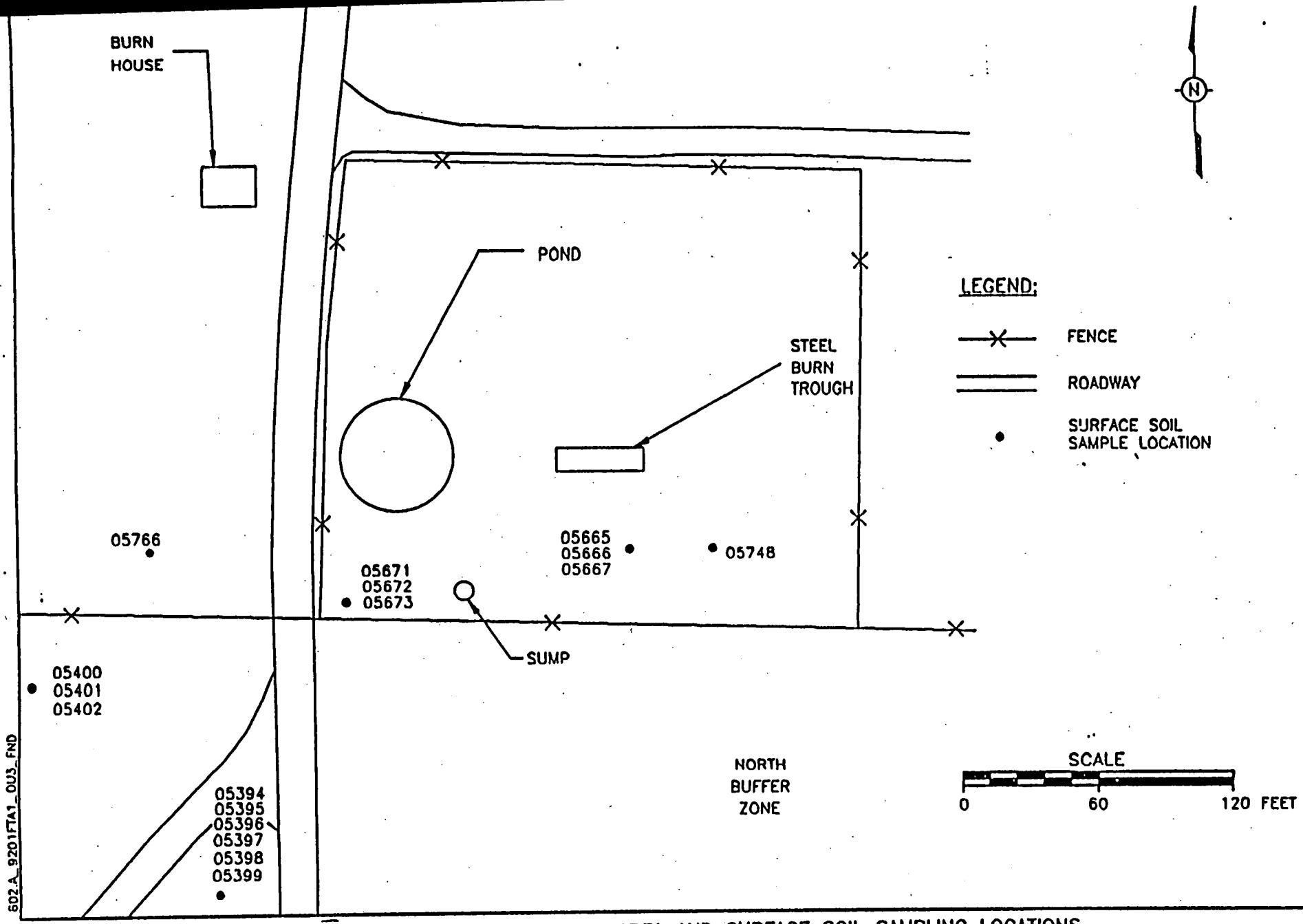

FIGURE A-11 FIRE TRAINING AREA AND SURFACE SOIL SAMPLING LOCATIONS

TABLE A-6
RADIOLOGICAL RESULTS FOR SURFACE SOIL IN THE FIRE TRAINING AREA

Results in picocuries per gram (pCi/g). Data presented by sample number and depth in inches. NA indicates not analyzed; a number preceded by a "less than" (<) symbol indicates that the compound was not present above the detection limit of the analytical instrument.

Radiological Parameters	Sample ID Depth (in.)	05394 0-6	Duplicate 05395 0-6	05396 6-12	Duplicate 05397 6-12	05398 12-18	Duplicate 05399 12-18	05400 0-6	05401 6-12	05402 12-18
Cesium 137		0.4	0.3	<0.2	<0.2	0.2	<0.2	1.0	<0.2	<0.2
Plutonium 238		2.2	0.9	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium 239/240		<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium 226		2.3	1.9	0.9	1.3	1.6	1.0	0.7	0.4	0.5
Radium 228		30.5	22.6	8.2	12.3	16.4	10.1	<0.5	<0.5	<0.5
Strontium 90		<0.5	<0.5	2.1	0.9	1.0	0.6	<0.5	0.5	<0.5
Technetium 99		<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
Thorium 238		38.9	21.9	10.2	14.2	24.0	12.2	0.7	<0.6	<0.6
Thorium 230		15.1	13.6	5.4	6.8	9.2	5.8	2.5	1.3	1.1
Thorium 232		11.4	8.4	1.8	2.5	3.8	1.7	<0.6	<0.6	<0.6
Uranium 234		87.9	73.8	17.4	29.1	47.7	21.5	30.3	3.9	5.9
Uranium 235/236		7.1	4.3	1.6	2.6	4.3	1.7	1.4	<0.6	<0.6
Uranium 238		387.0	350.0	94.8	154.0	270.0	110.0	131.0	12.8	21.3
Total Uranium *		NA	NA	308.0	410.0	413.0	324.0	NA	32.0	59.0

Radiological Parameters	Sample ID Depth (in.)	05665 0-2	05666 2-4	05667 4-6	05671 0-2	05672 2-4	05673 4-6	05748 0-6	05766 0-6
Cesium 137		NA	<0.2	<0.2	1.4	0.7	0.9	0.7	<0.2
Plutonium 238		NA	<0.6	<0.6	1.3	<0.6	<0.6	<0.6	<0.6
Plutonium 239/240		NA	<0.6	<0.6	<0.6	2.9	1.9	<0.6	<0.6
Radium 226		NA	0.4	0.5	1.2	0.7	1.0	1.2	0.4
Radium 228		NA	<0.5	0.5	5.8	2.3	2.0	1.1	<0.5
Strontium 90		NA	<0.5	<0.5	<0.5	<0.5	<0.5	5.0	0.5
Technetium 99		NA	10.5	8.7	11.9	18.4	27.3	0.9	<0.9
Thorium 238		NA	<0.6	0.6	6.2	2.4	1.3	0.9	<0.6
Thorium 230		NA	1.0	1.7	13.5	4.3	5.4	1.6	1.2
Thorium 232		NA	<0.6	0.7	5.2	1.3	1.2	0.8	<0.6
Uranium 234		361.0	38.3	44.5	251.0	250.0	74.2	9.9	1.5
Uranium 235/236		19.1	2.1	1.9	17.0	12.0	5.4	0.7	<0.6
Uranium 238		348.0	37.4	45.4	334.0	295.0	80.9	10.0	2.1
Total Uranium *		NA	78.0	100.0	1170.0	835.0	213.0	36.0	5.0

TABLE A-7

CHEMICAL CONCENTRATIONS IN SOIL IN THE FIRE TRAINING AREA

Data presented by location, sample number, and sample depth.

NA indicates not analyzed. For inorganic constituents, dashes indicate concentration below background; for organic constituents, pesticides, and PCBs, dashes indicate no detection.

Constituents	Location Sample ID Depth (ft)	1508 51160 2.0-2.5	1509 51161 2.0-2.5	1510 53259 2.0-2.5	1511 54439 2.0-2.5	1512 51679 2.0-2.5	1513 53519 2.0-2.5	1514 53782 2.0-2.5	1515 52259 2.0-2.5
Inorganics (mg/kg)									
Arsenic		--	--	8.7	7.6	--	--	10	--
Beryllium		1.4	1.6	1.5	1.5	1.8	1.8	1.9	1.7
Cadmium		2.6	4.2	3.4	3.9	3.3	3.4	3.4	2.9
Calcium		44900	97700	7010	28600	20600	10100	--	--
Cobalt		12.3	10.2	26	18.6	14.7	13.4	20.3	16.9
Iron		--	--	28700	26500	--	29900	30200	26900
Lead		--	21.1	20.9	21	25.4	20.9	--	18.5
Magnesium		6190	24600	4620	12100	7660	4900	--	--
Manganese		--	--	660	833	678	--	1080	765
Mercury		0.18	0.18	--	--	--	--	--	--
Nickel		34.1	67.1	39.6	43.2	36.8	50.5	50	28.7
Silver		--	--	--	--	5.6	--	--	--
Zinc		52.2	--	67	64.8	75.3	74.8	74.7	54.8
Organics (µg/kg)									
Volatiles									
1,1-Dichloroethane		--	6	--	--	--	--	--	--
1,1,1-Trichloroethane		--	3	--	--	--	--	--	--
1,2-Dichloroethylene		--	2	--	--	--	--	--	--
2-Butanone		76	--	--	--	--	--	--	--
Chloroform		--	--	--	--	--	--	--	2
Tetrachloroethene		--	2	--	--	--	--	--	--
Toluene		--	2	--	--	--	--	--	--
Trichloroethene		--	1	--	--	--	--	--	--
Semivolatiles									
Benzoic acid		--	--	--	NA	--	--	--	--
bis(2-Ethylhexyl)phthalate		--	--	--	NA	--	--	96	--
N-Nitrosodiphenylamine		--	--	--	NA	--	--	--	--
Pentachlorophenol		--	--	--	NA	--	98	260	--
Pesticides and PCBs (µg/kg)									
Aroclor 1260		240	--	--	--	2200	--	--	--
Other (mg/kg)									
Cyanide		--	0.5	--	--	--	--	--	--

APPENDIX B
STANDARD OPERATING PROCEDURES AND OTHER PROCEDURES

Standard Operating Procedures

Turbidity

Standard Laboratory Sieves

Analytical Logbook Recording Procedures

Laboratory Notebook Recording Procedures

Calibration of Thermometers

Radiological Procedures

STANDARD OPERATING PROCEDURE

ITAS-TECHNOLOGY DEVELOPMENT LABORATORY

TITLE:	SOP NO: TDL1102
TURBIDITY	DATE INITIATED: 7/28/89
	REVISION NO: 1
	DATE REVISED:
	PAGE 1 OF 4

PREPARED BY	APPROVED BY	DATE	QA CONCURRENCE	DATE
C E Moore	John T. McGahan	4/4/90	Janet M. Jones	4-4-90

1.0 Purpose and Application

1.1 This method is based upon a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension. The higher the intensity of scattered light, the higher the turbidity.

1.2 This method is applicable to drinking, surface, and saline waters.

2.0 References

2.1 Annual Book of ASTM Standards, Part 31, "Water", Standard D1889-71, p223 (1976).

2.2 Standard Methods for the Examination of Water and Wastewater. 1987. 16th Ed. American Public Health Association.

2.3 Hach Water Analysis Handbook. 1986. Hach Co. Loveland, CO. p. 2-311, 2-312.

3.0 Associated SOPs and Applicable Methods

3.1 ASTM D1889-81.

3.2 Standard Methods 214A.

3.3 EPA 1979 Method 180.1.

4.0 Definitions

4.1 Turbidity - reduction of transparency of a sample due to the presence of particulate matter.

4.2 Nephelometric Turbidity - an empirical measure of turbidity based on a measurement of the light-scattering characteristics (Tyndall effect) of the particulate matter in the sample.

5.0 Procedure

5.1 Hach Water Analysis Handbook Method for Turbidity.

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.

TURBIDITY
Range: 0-400 FTU
Absorptometric Method*
For Water and Sea Water

Introduction

Refer to the Turbidity, Nephelometric Method.

Sampling and Storage

Refer to the Turbidity, Nephelometric Method.

> *WARNING*
>
> *Some of the chemicals used in this procedure may be hazardous to the health and safety of the user if inappropriately handled or accidentally misused. Please read all warnings on the reagent labels and read the safety section of this manual. If you have questions or would like a reprint of the safety section, please contact Hach. In the procedure, hazardous substances appear in italic typeface wherever they are used in the test and deserve extra care in handling. It is always good practice to wear safety glasses when handling chemicals. Wash thoroughly if contact occurs. Follow instructions carefully.*

Procedure

1. Take a water sample by filling a clean sample cell to the 25 mark.
2. Fill another sample cell to the 25 mark with clear, colorless water and place it in the cell holder. Close the light shield. *See Note A*. Insert the Turbidity (Absorptometric Method) Meter Scale (Cat. No. 41978-00) into the meter and adjust the Wavelength Dial to 450 nm.
3. Set the Mode Switch to LEFT SET and check the left set adjustment. If necessary, adjust the LEFT SET control to align the meter needle with the extreme left mark on the meter scale arc.
4. Set the Mode Switch to NORM and adjust the RIGHT SET controls for a meter reading of zero units.
5. Place the sample in the cell holder and close the light shield. Read the formazin turbidity units (FTU).

DREL/5

Notes

A. Filtering is recommended for highly colored samples. The filtered water is then used in place of the clear, colorless water called for in Step 2.

B. The meter scale has been calibrated using a milky white suspension of a polymer called formazin. Standard formazin solutions for checking the accuracy of the test can be prepared using the following procedure:

   1. Dissolve 1.000 gram of *Hydrazine Sulfate* in demineralized water and dilute to the mark in a 100-mL volumetric flask.
   2. Dissolve 10.00 grams of *Hexamethylenetetramine* in demineralized water and dilute to the mark in a 100-mL volumetric flask.
   3. Mix 5.0 mL of each solution in a 100-mL volumetric flask and allow to stand undisturbed for 24 hours at 25 ± 3°C (77° ± 5°F).
   4. Dilute to the mark and mix.

   The turbidity of this stock solution is 400 FTU and it should be prepared monthly. Dilutions used for standard solutions must be prepared fresh daily. A more convenient prepared Formazin Stock Solution rated at 4000 NTU (or 4000 FTU) is available from Hach.

*FWPCA Methods for Chemical Analysis of Water and Wastes, 275 (1969)

C. For the most precise turbidity measurements, the Hach Model 2100A Laboratory Turbidimeter or Model 18900 Ratio Turbidimeter is recommended. These instruments are true nephelometers that meet all the performance requirements for turbidity measurement described in APHA *Standard Methods*, the EPA's *Methods of Chemical Analysis of Water and Wastes* and the *Federal Register*.

Reagents and Apparatus — See Part 3, How to Order

Optional Reagents

Cat. No.	Description	Unit
742-26	*Hydrazine Sulfate*	100 g
1878-34	*Hexamethylenetetramine*	500 g
2461-11	Formazin Stock Solution, 4000 NTU	473 mL (pt)

INTERNATIONAL TECHNOLOGY CORPORATION

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: Tom Leist Date: 3/6/91
Technical Specialist

Patti B. Carswell Date: 3/13/91
Quality Control Coordinator

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

Approved by: John M. Hall Date: 7/5/91
Laboratory Director

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

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Date	03/05/91					

Regional Office
1570 Bear Creek Road • Oak Ridge, Tennessee 37830-1329 • 615-482-7075 and 1-800-727-7075

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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

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.

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: 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

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

Approved by: R S Miller Date: 6/7/91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: Logbook, Notebook

Revision #	0					
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 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.

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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: 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

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

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

Controlled Copy No: Uncontrolled Copy

Key Words: NOTEBOOK

Revision #	0					
Date	1-21-91					

Technology Development Laboratory
304 Directors Drive • Knoxville, Tennessee 37923 • (615) 690-3211 • FAX (615) 694-9573
IT Corporation is a wholly owned Subsidiary of International Technology Corporation.

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: CALIBRATION OF THERMOMETERS

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

Reviewed by: Walter W. [illegible] **Date:** 5/29/91
Technical Specialist

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

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

Approved by: James [illegible] **Date:** 6-27-91
Laboratory Director

Controlled Copy No: Uncontrolled Copy

Key Words: CALIBRATION, THERMOMETER, NBS

Revision #	1					
Date	02/27/91					

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:

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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 (± 1°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 (± 1°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.

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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: _____

RADIOLOGICAL PROCEDURES

Parameter	Methods
CS-137	RSL-201 and RSL-112
Np-237	RSL-304, RSL-201
Pu-239	RSL-304, RSL-201
Pu-240	RSL-304, RSL-201
Ra-226	RSL-309, RSL-201
Ra-228	RSL-309, RSL-201
Ru-106	RSL-201, RSL-112
Sr-90	RSL-305, RSL-201
Tc-99	RSL-310, RSL-201
Th-230	RSL-304, RSL-201
Th-232	RSL-304, RSL-201
U-234	RSL-304, RSL-201
U-235	RSL-304, RSL-201
U-238	RSL-304, RSL-201
Gross Alpha	RSL-308
Gross Beta	RSL-308

Other Procedures

Procedure for Alkalinity or Acidity

Soil Sample Digestion for ICU

Uranium by IC

Volatile and Semivolatile Organics

Metals by ICP

Modified Toxicity Characteristic Leaching Procedure

Generic pH Procedure

Procedure for Flocculation Mini Jar Test

Procedure for Settling Rate

Procedure for Filtration Testing

Separation of Minerals by Sieve and Centrifugation
(The Modified M.L. Jackson Procedure)

Procedure for Alkalinity or Acidity

Procedure for Alkalinity:

This is a typical procedure. The pH measurements and the autotitrations will be conducted on an Orion 960 Autochemistry System. In general, the sample will be titrated with 1 N HCl until the pH remains at 2.5. The samples will be gently heated for 10 minutes, then allowed to cool. The room temperature samples will be back-titrated with a standard NaOH to pH 7 to determine the amount of acid consumed by the base in the samples. Alkalinity will be calculated as the milli-equivalents per gram of the 1 N HCl added, minus the milli-equivalents per gram of NaOH used to back-titrate.

Procedure for Acidity:

This is a typical procedure. The pH measurements and the autotitrations will be conducted on an Orion 960 Autochemistry System. In general, the sample will be titrated with a standard NaOH solution to pH 7. Acidity is calculated as milli-equivalents of NaOH used in the titration.

GENERIC PROCEDURES[a] FOR SOIL SAMPLE DIGESTION FOR ICU

1. Weigh out approximately 0.2 g of sample and place it in a vial.

2. Add approximately 0.5 ml of concentrated HNO_3 to the sample in the vial.

3. Swirl the vial gently until the acid and soil are well mixed.

4. Heat at 525° C approximately 10-15 minutes.

5. Allow the sample to cool to room temperature.

6. Repeat Step 2 through 5, four times.

7. Add approximately 1 ml of 25% HNO_3.

8. Swirl gently until the acid and soil are well mixed.

9. Sonicate for 1.5 hours at 40 to 60° C.

10. Allow the sample to cool to room temperature.

11. Add approximately 19 mls of 0.2% Phosphoric Acid.

12. Shake the vial to ensure that the Phosphoric Acid is well mixed with the HNO_3 extract.

13. Analyze the sample on the ion chromatograph (IC).

[a]This procedure may be modified due to matrix effects.

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 uL
- 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.

Volatile and Semi Volatile Organics

During the preliminary testing, the following methods, with modified QC/QA, will be used for organics analysis. The methods are subject to change if the target organics change, or if a more suitable method is found.

Soils -- SW-846 Methods
Method 8020 -

Method 8100 -

Solutions -- EPA Methods
Method 602 -

Method 610 -

METALS

During the preliminary testing, the following methods, with modified QA/QC, will be used for metal analysis. The methods are subject to change if the target metals change, or if a more suitable method is found.

Sample Preparation – SW-846 Methods

Method 3010 - Acid digestion for solutions

Method 3050 - Acid digestion for soils

Analysis – SW-846 Methods

Method 6010 - ICP

MODIFIED TOXICITY CHARACTERIZATION LEACHING PROCEDURE

The modified toxicity characteristic leaching procedure (MTCLP) is a modification of the TCLP test. The TCLP is in the Federal Register, Vol. 55, No. 126, pages 26,986 through 26,998. 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 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.

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.

Procedure For Flocculation Mini Jar Tests

Application:

This method is used to determine the optimum condition, i.e., coagulant dosage and operating conditions, for maximum removal or coagulation of the desired wastewater constituents. Generally, the selected coagulant is added to the wastewater under specified conditions, such as dosage, pH, temperature, etc., and then the mixture is rapidly mixed followed by the addition of a coagulant aid and gentle flocculation. After determining the best coagulant and the optimum conditions of applications, other design parameters, such as settling properties and sludge production should be determined. This procedure has been modified to use small samples from 5-20 ml in cases of limited sample quantity. It uses 20 ml sample vials as reaction vessels and hand mixing or an orbital shaker as a mixing device.

Procedure:

1. Select coagulants and/or flocculants based on knowledge of the sample matrix. Then make reagent solutions at concentrations of 100 to 1,000 ppm for polymers, 1,000 to 10,000 ppm for inorganic coagulants, and 1-30% for acid or base neutralization reagents.

2. Determine the approximate minimum dosage of each coagulant for which a floc will be formed. This may be accomplished by adding the coagulant in 0.05 ml increments to 5-20 ml of the raw waste water and slowing mixing (by capping and inverting the vial several times) until the first evidence of a floc is observed.

3. After repeating Step #2 for each reagent of interest, set up multiple vials with the same amounts of liquid sample for comparison testing. Then set up multiple 1 ml syringes with the respective amounts of reagents for floc formations. Add the reagents to their respective vials in as narrow a time frame as possible.

4. Rapid mix the samples on an orbital shaker at approximately 200-400 rpm for 1-2 minutes and then flocculate slowly at 5-50 rpm for 15 minutes. The rate of flocculation should be slow enough that floc shear does not occur. Record the time for a visible floc to form in each sample and after flocculation, shut off the shaker and allow the samples to settle. Note the relative depths of clear liquids in each of the vials with time.

5. Determine the residual parameters of interest, e.g., TOC, color, metals, turbidity, etc. in the supernatent. Also measure the pH after the material has settled and use this as the pH level for subsequent correlation. A slow settling rate will be considered as less than 0.5-1" per minute.

6. If necessary, repeat Steps #3-#5 using organic polymers. Again, record the time of formation of the visual floc. If polyelectrolytes are to be added, a cationic polymer should be added toward the end of the rapid mix. Anionic polymers should be added about the middle of the flocculation step.

References:

ASTM Method 2035-80, Standard Procedure forCoagulation-Flocculation Jar Test

Development of Criteria for Wastewater Treatment Processes,Chapter XI, "Coagulation and Precipitation", Proceedings of a Seminar Sponsored by Vanderbilt University Nashville, TN, 1976.

Procedure for Settling Rate

Application:

This method is used to determine the rate of settling of solids or floc in a sludge or wastewater containing suspended solids. Generally, the sludge or wastewater is tested "as is" or it may undergo flocculation treatment as a preliminary step. The procedure is adapted for 100 ml samples where quantities are limited.

Procedure:

1. Pour the gently mixed sample ("as is" or flocculated) into a 100 ml graduate.

2. Immediately after the swirling has ceased, start a stop watch at time 0.

3. Record the volume of clear liquid or of the sludge blanket with time, taking more measurements earlier in the test and fewer as the rate of settling appears slower.

4. Calibrate the graduate with a ruler such that ml may be converted to inches, and make that conversion.
5. Plot the inches of settling with time. A slow settling rate will be considered as less than 0.5-1" per minute.

References:

ASTM Method 2035-80, Standard Procedure forCoagulation-Flocculation Jar Test

Development of Criteria for Wastewater Treatment Processes,Chapter XI, "Coagulation and Precipitation", Proceedings of a Seminar Sponsored by Vanderbilt University Nashville, TN, 1976.

Procedure for Filtration Testing

Application:

This method is used to perform simple vacuum filter clarification of samples or to develop engineering data as to the rate of liquid processing and filtered solids production.

Procedure:

The method uses a standard 4.7 cm Millipore Filter Apparatus with a 300 ml graduated Feed reservoir and a 1000 ml clear liquid receiver. However, larger or smaller filtering systems may be substituted. The wastewater or sludge is poured "as is" directly into the feed reservoir or treated by flocculation techniques before pouring into the feed reservoir. Next, vacuum is applied to vacuum take-off on the receiver at 10-15 inches of mercury (Hg), and the vacuum held constant. Immediately, measurements of liquid fed from top feed reservoir are noted with time. A slow filtration rate is considered to 100 ml per 10 minutes. Filtration is considered complete when the vacuum set-point cannot be maintained or when there is no free liquid atop the filter cake or when the filter cake becomes cracked. The filtrate and filter cake are measured by volume and/or weight. In addition the turbidity of the filtrate and the bulk density and moisture content or total solids content of the filter cake may be determined.

References:

U.S. Environmental Protection Agency, "Methods of Chemical Analyses of Water and Washes".

Development of Criteria for Wastewater Treatment Processes, Chapter X, "Coagulation and Precipitation", Proceedings of a Seminar Sponsored by Vanderbilt University, Nashville, TN, 1976.

SEPARATION OF MINERALS BY SIEVE AND CENTRIFUGATION (THE MODIFIED M.L. JACKSON PROCEDURE)

The sieve type of separation of cleaned mineral particles can be employed down to a particle diameter of about 50 µm. Wet sieving involves some decrease in nominal sieve opening. Centrifugation is employed for the purpose of increasing the gravitational force and hence the rate of particle sedimentation, which becomes important in the separation of clay-size particles.

1.0 SEPARATION OF MINERALS BY SIEVING

1.1 Apparatus

Needed apparatus includes: a large stainless steel funnel; a series of 9.5 mm, 2 mm, and 53 m sieves; two-liter beakers; Ro-Tap shaker; high pressure sprayer (0-80 psi); and glass collection (storage) vessels with teflon-lined caps.

1.2 Reagents

Reagents needed include potable water and dispersing agents as noted in Section 4.

1.3 Procedure

This procedure is used for separation of sands from silts and clays (at 50 µm). To facilitate the separations of the various finer-size fractions by centrifugation later, the sand fraction (grains greater than 50 µm in diameter) are removed from the suspension of dispersed soil by wet sieving. First, the soil in the centrifuge tube or beaker is thoroughly dispersed by wet sieving. Approximately 125 grams of soil is added to a 2-liter beaker. The beaker is then filled with 500 m,ℓ of potable water. A concentrated dispersing agent is added to provide an approximately 1 millimolar concentration in the slurry. The soil/dispersing agent slurry is placed on a shaker table and shaken at low speed for thirty minutes or shaken until all visible aggregates are broken up and the individual particles seem discrete. A 9.5-mm, 2-mm and 53- m series of stainless steel sieves (including catch pan and lid) are placed on a Ro-Tap shaker. The slurry is quantitatively transferred to the top 9.5 mm sieve and the lid secured. The slurry is shaken for one hour.

After shaking, the bottom catch pan is removed from the series of sieves. The <53 m-size fraction in the catch pan is transferred to a 2-ℓ beaker. The series of sieves are transferred to and supported on a stainless funnel, so as to deliver to the side of the 2-ℓ beaker. A high pressure sprayer (operating at 25 psi) is used to spray 250 mL of potable water over the individual soil size fractions contained on the sieves. Any remaining silt and clay are washed from the larger soil size fractions on the series of sieves by means of this coarse jet of water. Finally, the bottom of the sieve is washed clean with a jet of water.

Soil remaining on each sieve is oven dried at 105°C for twelve hours; quantitatively transferred to glass collection vessels with teflon-lined caps, and stored until analyzed. The soil and water slurry in the 2-ℓ beaker is processed according to the procedure described in the following section, "Separation of Minerals by Centrifugation."

2.0 SEPARATION OF MINERALS BY CENTRIFUGATION

2.1 Apparatus

Apparatus needed for the size segregation procedure includes: an International No. 2 centrifuge (International Equipment, Boston, MA) with No. 240 head; speed indicator; time clock, a rack of eight 100-mℓ centrifuge tubes fitted with rubber stoppers (a shaker* for the rack of centrifuge tubes is a great convenience), glass rod with rubber ball plunger (Fig. 2-1, page 34); glass rod with policeman; and a 6-ℓ flask.

2.2 Reagents

Needed reagents include distilled water, potable water and dispersing agents (as noted above).

2.3 Procedure

The centrifuge separation procedure to be followed removes the clay particles less than 2 m from the medium and fine silt, then the medium silt is separated from the fine silt. The following paragraphs further describe the separation of silt from clay at 2 m. The suspension of silt and clay consists of the combined decants in the 2-L beaker from the sieving procedure.

Potable water or the selected dispersing agent is added to the <53 um soil size fraction in the 2-L beaker to make a soil-water slurry of approximately 1800 mL. This slurry is thoroughly mixed by placing the beaker on a stir plate using a magnetic stir bar. Approximately 100 mL of slurry are transferred to 200-mℓ centrifuge tubes. Potable water or dispersing solution is added to each centrifuge tube to approximate a volume that would provide a 1:10 soil:water composition. This slurry is centrifuged at 800 rpm for seven minutes. The supernatant (containing the <2 um soil size fraction) is decanted into a 2-L beaker. The soil solids in the centrifuge tube are resuspended by adding either more potable water or dispersing agent. The processes of resuspension, centrifugation, and decantation are continued until the supernatant suspension is fairly clear after the centrifuging periods. Usually eight to ten sequences are required to produce a supernatant that appears clear after the shaking process to resuspend solids. It has been determined in earlier studies that over 90 percent of the clay yield is obtained in the first three centrifugings and that 97 to 99 percent of the clay yield is obtained in the first five centrifugings. More than 10 centrifugings should never be required. Because of the gradual breaking up of the finer silt particles (particularly of mica and kaolinite) during the process of resuspension, the suspension does not become entirely clear even with a very large number of centrifugings. Segregation of various minerals into separate fractions is probably more complete if the number of repetitions is limited to five to eight so as to keep the physical fracture of the particles at a minimum.

The solids (2-53 m soil size fraction) in the bottom of each centrifuge tube are quantitatively transferred to a 2-ℓ beaker at the conclusion of the centrifuging. This soil is dried at 105°C for 12 hours and stored in glass containers (with teflon-lined caps) until analyzed. A 200-mℓ aliquot of the supernatant slurry (<2 m size fraction) in the 2- ℓ beaker is collected and centrifuged at 3000 rpm for one hour. The liquid and solid fractions are collected and analyzed separately. The remainder of the slurry in the 2-ℓ beaker is dried at 105°C for 24 hours and stored until analyzed.

APPENDIX C

HEALTH AND SAFETY PLAN

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
OPERABLE UNIT 5 TREATABILITY FIELD SAMPLING

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C.1.0 TASKS TO BE PERFORMED

This Health and Safety Plan (HSP) establishes the work practices necessary to help ensure protection of ASI/IT personnel during sampling at the six locations within Operable Unit 5.

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

All site operations will be performed in accordance with applicable state, local, and ASI/IT regulations and procedures, Occupational Safety and Health Administration (OSHA) requirements, and any client requirements.

The work to be performed involves the retrieval of representative soil samples from six locations within Operable Unit 5 for use in treatability studies. Samples will be obtained from an area southwest of the pilot plant, north of Plant 2/3, southeast of the graphite furnace, and from an area northeast, north, and southeast of the maintenance building. Samples will be obtained at depths of 0 to 1.5 feet at each sampling location. Samples will be obtained using a stainless steel drive tube sampler.

Based on screening of these six samples, four locations will be selected. Samples at these four locations will be obtained using a shovel and will be placed in lined 55-gallon drums.

C.2.0 RESPONSIBILITIES

SITE HEALTH & SAFETY MANAGER: Steve Duce

The Site Health & Safety Manager is responsible for the technical development and coordination of the HSP. Inquiries regarding the HSP, ASI/IT health and safety procedures, and other technical or regulatory items shall be addressed to this individual.

SITE PROJECT SUPERVISOR: Michael Krstich

The Site Project Supervisor shall be responsible for field implementation of the HSP. This shall include communication of site requirements to all field personnel and interaction with client representatives and regulatory agencies. Additional communication may include consultation with the Site Health & Safety Manager regarding the execution of the project and the HSP.

TEAM MEMBERS:

All team members shall be responsible to understand and comply with all site health and safety requirements. Each team member shall be provided training on the requirements of this HSP before the beginning of the project.

Note: The Health & 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.

C.3.0 SITE HISTORY

A variety of chemical and metallurgical processes were used at the Fernald Environmental Management Project (FEMP) for the manufacture of uranium products. During the manufacturing process, high quality 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 (UO_3) powder. This compound was reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal was produced by reacting UF_4 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.

Operable Unit 5 consists of those environmental media that represent pathways and/or environmental receptors presently or potentially affected by FEMP contaminants. The media within Operable Unit 5 include groundwater, surface water, soils, sediments, flora and fauna. Operable Unit 5 specifically covers the soils associated with the former Production Area and nine suspect areas. The Production Area includes the buffer zones, the scrap piles, and the miscellaneous discarded materials and equipment overlying the former drum baling area. The nine suspect areas currently being addressed are:

- Clearwell
- Fire training area
- Main effluent line
- Rubble mound west of the K-65 silos
- South flagpole area
- Sewage treatment plant/incinerator area
- K-65 slurry line
- Suspected rubble mound south of the K-65 slurry line
- Rubble mound west of the northwest corner of the Production Area (north rubble mound)

C.4.0 TASK-SPECIFIC HAZARD ASSESSMENT

The following hazard assessment is based on historical information and defined task activities. Field 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 & Safety Officer to determine the degree of hazard and if any changes to the HSP are needed.

C.4.1 PHYSICAL HAZARDS

The potential physical hazards involved with Operable Unit 5 may include:

- Heat stress
- Bending/Lifting hazards
- Slip/Trip/Fall

All ASI/IT employees shall be aware of these hazards, and shall use protective equipment and proper work procedures.

C.4.2 RADIOLOGICAL HAZARDS

The soil data from the areas to be sampled indicate areas where uranium is present due to surface deposition. Subsurface contamination appears to decrease significantly at depths greater than 1.5 to 2.0 feet.

The potential radiation hazards are from uranium (ranging from depleted to 2 percent enriched in uranium-235) and short-lived decay products. Uranium is the controlling radionuclide and was observed at concentrations up to 330 parts per million (ppm) at the maintenance building and 570 ppm west of the pilot plant. Gross activity levels will be referred to as uranium. Thorium was also found at concentrations up to 184 ppm at the pilot plant.

Uranium has an exposure route through inhalation or ingestion. The background level in ambient air is less than 2×10^{-12} microcuries/milliliter (μCi/mℓ). Action levels are described in Table C.4-1.

C.4.3 CHEMICAL HAZARDS

The potential chemical hazards involved at the Operable Unit 5 site are related to hydrocarbons. Preliminary soil sample analyses indicated concentrations of volatile hydrocarbons ranging from 0.005 parts per million (ppm) to 150 ppm. The contaminants in highest concentrations were methylene chloride, xylene, trichloroethene and polynuclear aromatic hydrocarbons. Lower concentrations of polychlorinated biphenyls (PCB) were also found in soil samples.

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TABLE C.4-1

ACTION LEVELS FOR RADIOACTIVE CONTAMINANTS

Instrument	Need	Interval	Level	Action[a]
Alpha probe	Yes	Prejob and intermittent	20 cpm[b]	HP Review
Beta/gamma probe	Yes	Prejob and intermittent	500 cpm[b]	HP Review
External radiation	Yes	Prejob	>1 mrem/hour	HP Review
Thermoluminescent dosimetry badge	Yes	Continuous	NA, no real time results	

[a]Health Physics (HP) review of the work will be initiated when the action level is reached. At 10 times these levels, work will be stopped until the new conditions can be evaluated by Health and Safety personnel.
[b]Above background.

Currently, exposure guidelines to pesticides and other chemical substances are regulated by OSHA. These exposures are based upon the time-weighted average (TWA) concentration for a normal 8-hour workday. Several chemical substances have short-term exposure limits or ceiling values which allow a maximum concentration to which workers can be exposed continuously for a short period of time without suffering from (1) irritation, (2) chronic or irreversible tissue damage, and/or (3) narcosis of a sufficient degree to result in accidental injury, impair self rescue, or substantially reduce work efficiency.

Threshold limit values (TLVs) refer to airborne concentration of substances which represent conditions that nearly all employees may be repeatedly exposed to day after day without adverse effect. These threshold limits are prescribed by the American Conference of Governmental Industrial Hygienists (ACGIH). They are based upon the best available information from industrial experience and animal or human studies. Because of the wide variation in individual susceptibility, a small percentage of workers may experience discomfort from some substances at concentrations below the recommended values. It has been policy to use these guidelines for good hygienic practices; however, whenever applicable, stricter guidelines may be used.

The short-term exposure limit (STEL) is defined by the ACGIH and OSHA as a 15-minute TWA-exposure which should not be exceeded within a two-hour time period during a workday even if the 8-hour TWA is within applicable limits. OSHA requires that a 15 minute "ceiling" concentration never be exceeded for that chemical constituent. This notation appears as the letter "C" preceding the exposure standard.

Under certain chemical substance listings, there may appear a "skin" notation. This refers to the potential contribution to the overall exposure by the cutaneous route, including mucous membranes and eyes, either airborne or by direct contact. Little quantitative data are available describing absorption as a function of the concentration to which the skin is exposed. Biological monitoring may be considered to determine the relative contribution of dermal exposure to the total dose.

The ACGIH and OSHA have recognized that certain chemical substances may have the potential to be carcinogenic in humans from epidemiological studies, toxicology studies and, to a lesser extent, case histories. Because of the long latency period for many carcinogens, it is often impossible to base timely risk management decisions on the results of such information. Two categories of carcinogens are designated, based upon the most current literature and information. These include confirmed human carcinogens and suspected human carcinogens. These chemical categories are based on either limited epidemiologic evidence or demonstration of carcinogens in one or more animal species by appropriate methods. The worker potentially exposed to a known human carcinogen must be properly

equipped to insure virtually no contact with the chemical constituents. In the case of a suspected human carcinogen, worker exposure by all routes must be carefully controlled by the use of personal and respiratory protection, and administrative or engineering controls.

Table C.4-2 lists exposure standards for some contaminants which may be encountered.

TABLE C.4-2

EXPOSURE GUIDELINES

	PEL[a]		TLV[b]	
Contaminant	OSHA TWA[c]	OSHA STEL[d]	ACGIH TWA	ACGIH STEL
Methylene chloride	500 ppm[e]	C[f] 1000 ppm[e]	50 ppm, A2[g]	NE[h]
Xylene	100 ppm	150 ppm	100 ppm	150 ppm
Trichloroethene	50 ppm	200 ppm	50 ppm	200 ppm
PCB	0.5 mg/m^3	NE	0.5 mg/m^3	NE

[a]PEL - Permissible exposure limit, or maximum airborne exposure allowed by the Occupational Safety and Health Administration (OSHA). Types of PELs include TWAs, STELs, and Ceilings.
[b]TLV - Threshold limit value as prescribed by the American Conference of Government Industrial Hygienists (ACGIH).
[c]TWA - Time-weighted average, or average exposure allowed over an 8-hour shift.
[d]STEL - Short-term exposure limit, or maximum average exposure during a 15-minute period
[e]In the process of 6(b) rulemaking.
[f]C - Ceiling, or maximum exposure allowed, even instantaneously.
[g]A2 - suspected human carcinogen.
[h]NE - None established.

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C.5.0 MONITORING

C.5.1 GOALS

Air monitoring will be performed to ensure contaminant concentrations in the breathing zone do not exceed the concentrations specified by established exposure levels. The air monitoring program will consist of monitoring for long-lived radioactive particulates and for volatile organic vapors.

ASI/IT policy requires engineering controls, if feasible, or the use of personal protective equipment (PPE) to reduce on-site exposures to the action limit values. It is advisable to keep exposures to chemicals as low as possible because there are insufficient data to predict the combined effects of most chemical mixtures.

C.5.2 MONITORING METHODOLOGY (AIRBORNE CONTAMINANTS)

Long-lived airborne radioactivity will be monitored using a portable, battery-powered air pump with a 37 millimeter (mm) membrane filter with an 8-mm pore size. At a minimum, samples will be taken at the start of each workshift and hourly thereafter. Samples shall be taken in the breathing zone of the worker to obtain samples representative of the airborne concentrations to which the worker is exposed. Samples shall be collected and counted for gross alpha and beta activity using a gas proportional counter in accordance with Westinghouse Environmental Management Company of Ohio (WEMCO) procedure SP-P-35-026-Occupational Air Sampling.

Volatile organic vapors will be monitored using an HNU photoionization instrument. Both samples and excavated areas should be monitored to determine the presence of volatile organics. If organic vapors are detected, the concentrations will be compared to exposure limits or guidelines, with the stricter value of the two being used in the comparison. Draeger tubes may also be used to determine levels of specific organic vapors. Breathing zone action levels are listed in Table C.4-1.

C.5.3 RADIATION/CONTAMINATION MONITORING

The Health and Safety Field Technician shall monitor each selected sample location for contamination and/or radiation before work begins using a Ludlum Model 9 Ion Chamber or equivalent to determine if protective clothing requirements are adequate. Radiation and contamination surveys will also be performed periodically during the performance of work, using a Ludlum Model 2 Survey Meter with a GM pancake probe or equivalent, to verify that levels have not changed significantly. All personnel involved in work on site are required to wear thermoluminescent dosimeters (TLDs) to monitor for external radiation exposure. Equipment used for the sampling effort will be monitored for contamination at the completion of work and decontaminated or disposed of as required.

Sample duration and intervals are based on potential exposure as work progresses, not on minimum detection limits. Flexibility in the sampling regime is required to allow monitoring personnel to react to changing status.

Soil samples will be monitored for radioactive contamination and organics as collected. Measurement results are used to assess potential worker exposure.

C.5.4 HEAT/COLD STRESS

HEAT STRESS

Site project work conducted in summer months or in chemical protective clothing may cause heat-related symptoms in some individuals. One or more of the following control measures can be used to help control heat related disorders:

- Provision of adequate liquids to replace lost body fluids. Employees must replace water and salt lost from sweating. Employees must be encouraged to drink more than the amount required to satisfy thirst. Thirst satisfaction is not an accurate indicator of adequate salt and fluid replacement.
- Replacement fluids can be a 0.1 percent salt water solution. Commercial mixes such as Gatorade are effective.
- Establishment of a work regimen that will provide adequate rest periods for cooling down. This may require additional shifts for workers.
- Cooling devices such as vortex tubes or cooling vests can be worn beneath protective garments.
- All breaks are to be taken in a cool rest area (77° F is best).
- All employees shall be informed of the importance of adequate rest, acclimation, and proper diet in the prevention of heat stress.

During periods of high temperature and/or humidity, project personnel should be alert for symptoms of heat stress, especially in areas where protective clothing is being worn. If the body's physiological process to maintain a normal body temperature fails, or is overburdened due to excessive heat exposure, a number of physical reactions can occur ranging from mild symptoms such as fatigue, irritability, and/or anxiety to decreases in mental concentration. Heat-related problems are presented below:

Heat Rash - This is caused by continual exposure to heat and humid air, and aggravated by chaffing clothes. Heat rash decreases a person's ability to tolerate heat as well as becoming an irritating nuisance.

Heat Cramps - This is caused by profuse perspiration with inadequate water intake and chemical electrolyte imbalance. This results in muscle spasm and pain in the extremities and abdomen.

Heat Exhaustion - Stress on various organs to meet increasing demands to cool the body will result in signs and symptoms including: shallow breathing; pale, cool, moist skin; profuse sweating; dizziness and lassitude.

Heat Stroke - This is the most severe form of heat stress which must be treated immediately by cooling the body or death may result. Signs and symptoms include: red, hot, dry skin; no perspiration; nausea; dizziness and confusion; strong, rapid pulse; and coma.

Supervisors will observe workers for signs and symptoms of heat/cold stress and adjust work schedules as required. Monitoring for heat (wet bulb globe temperature) and cold stress will be performed by the Health and Safety Field Technicians as needed to ensure compliance with the ACGIH limits established in the most recent edition of the TLV booklet.

COLD STRESS

Procedures for recognizing and avoiding cold stress must be implemented when the ambient temperature is below 40° F. Cold stress effects may range from frostbite to severe hypothermia. The following signs and symptoms in project personnel may indicate cold stress, and appropriate action should be taken if the signs are present:

Frostbite: Pain in the affected extremities, reddening of tissue, loss of dexterity; a tingling or lack of sensation in the affected area.

Hypothermia: Pain in the extremity, and loss of dexterity; severe or uncontrollable shivering; inability to maintain normal rate of activity; excessive fatigue, drowsiness or euphoria.

Severe Hypothermia: Clouded consciousness, low blood pressure, cessation of shivering, dilated pupils, unconsciousness.

If these symptoms are observed, remove the individual to a warm, dry place. Remove any wet clothing and replace with dry clothing. Keep patient warm, but warm gradually. If patient is conscious

and alert, give warm liquids, but no caffeine. Warm affected extremities with moist, lukewarm compresses; gradually increase the temperature until normal circulation and temperature return. Seek medical attention for all but minor cold stress cases.

C.6.0 PERSONAL PROTECTIVE EQUIPMENT

Equipment for personnel protection will be determined based on the potential contact and/or airborne levels of any contaminant.

LEVELS OF PROTECTION

Specific levels of protection will be used to safeguard ASI/IT employees and subcontractors from potential hazards. Two distinct levels of protection may be required for this project. The final determination for ASI/IT personnel and subcontractors of any required level of protection will be based upon the hazards and current conditions of the work site. The situations requiring specific levels of protection are described in the following sections. No one is permitted to downgrade levels of PPE without authorization of the Health and Safety Manager.

LEVEL C PROTECTION

Level C protection will be required when the airborne concentration of suspected contaminants is known to be one half the ACGIH TLV or the OSHA permissible exposure limit (PEL) or wherever airborne radioactive contaminants exceed 25 percent of a derived air concentration (DAC). For mixtures of airborne radioactive contaminants, the sum of the DAC fractions will be used, and when the fractions sum is greater than 0.25, Level C protective clothing will be required. This may occur during the excavation of heavily contaminated soil.

The following equipment will be used for Level C protection:

- Full-face, air-purifying respirators with organic vapor cartridge in combination with high efficiency particulate filters which are NIOSH/MSHA approved. Half-face respirators may be utilized if accompanied by chemical splash goggles.
- Hooded, chemical resistant suit such as polyethylene-coated Tyvek.
- Gloves - (outer) - chemical resistant nitrile or neoprene.
- Gloves - (inner) - chemical resistant (latex).
- Boots - (outer) - chemical resistant neoprene with steel toes or double latex booties over steel-toed shoes.
- Hard hat
- Hearing protection (if necessary)

LEVEL D PROTECTION

The minimal level of protection that will be required of ASI/IT personnel and subcontractors at the site will be Level D. The following equipment will be used for Level D protection:

- Coveralls or work clothing
- Boots/shoes - with steel toes, latex overboots if area is heavily contaminated.
- Safety glasses or goggles
- Hard hat
- Chemical resistant nitrile or PVC protective gloves with surgical latex undergloves.
- Hearing protection (if necessary)

RESPIRATORY PROTECTION

A comprehensive respiratory protection program has been established by ASI/IT. This program is required in all locations where use of such equipment could lessen the potential for adverse health affects to any employee.

As part of the respiratory training program, each employee is instructed in the following elements:

- Nature of the respiratory hazard on the work site and the appraisal of potential consequences if the respiratory protection is not used.
- Use and proper fitting of the respirator.
- Cleaning, disinfecting, inspection, maintenance, and storage of the respirator.
- Proper selection of a respirator and its capabilities and limitations.

Employees must demonstrate proper fit of the equipment in a test atmosphere.

Routinely used respiratory equipment will be inspected, cleaned, and disinfected daily to help assure proper hygienic practices. An inspection of these breathing devices will include the following:

- Examination of the head straps for breaks, loss of elasticity, broken or malfunctioning buckles, and other attachments.
- Examination of the facepiece for excessive dirt, cracks, tears, distortion, holes, or inflexibility.

- Examination of the exhalation and inhalation valves for any foreign material, cracks, tears, or distortion in the valve, and proper installation.
- Examination of air-purifying elements for incorrect cartridge, expired shelf-life of the cartridge, cracks or dents in the cartridge or cartridge holder.
- Examination of proper insertion of the cartridge into the facepiece and a check of the gaskets inside the cartridge holder.

When Level C protection is required, respirator cartridges will be changed daily. All respirators will be inspected before each day's use. If broken or malfunctioning parts are found during the cleaning process, these parts will be replaced or new respiratory equipment will be issued to the user.

C.7.0 SITE CONTROL

A site control program has been developed to control worker exposure to radioactive and hazardous materials and to prevent the spread of contamination. The FEMP site access is controlled by WEMCO security. The Operable Unit 5 treatability sampling sites will have access restricted during operations by use of boundary rope. Only properly authorized and trained personnel will be allowed access.

For each sampling location, the work area will include three separate zones: an exclusion ("hot") zone, a contamination reduction zone, and a support zone.

The exclusion zone will consist of the entire area of suspected contamination during excavation. All employees will use proper ppe when working in those areas. The exclusion zone will be a defined area where there is a possible respiratory and/or contact health hazard. In most instances this area will be immediately adjacent to the sample excavation area. The location of the exclusion zone will be identified by cones, tape, or other appropriate means.

A contamination reduction zone will be established and decontamination will be performed in this zone. All personnel entering or leaving the exclusion zone will pass through this area in order to prevent any cross contamination and for the purpose of accountability. Tools and any equipment or machinery will be decontaminated in a specific location. The decontamination of all personnel will be performed on site adjacent to the exclusion zone. Personal protective outer garments and respiratory protection will be removed in the contamination reduction zone and properly labelled.

The support zone will consist of an area outside the contamination reduction zone. The support zone will be located to prevent employees from being exposed to any organic vapors or dust levels above regulatory limits. Eating, drinking, or smoking will be permitted in the support area only after washing face and hands.

Work zones will be identified as necessary to prevent the spread of contamination from the sample collection site to the surrounding area.

C.8.0 HAZARD CONTROL PROGRAM

The following procedures are mandatory for all ASI/IT and subcontractors' personnel. All site visitors entering exclusion zones must follow these procedures. Personnel not following procedures will be warned. If they refuse to follow these procedures, they will be escorted from the site.

C.8.1 GENERAL PRACTICES

All information regarding work to be performed, emergency procedures, and health and safety hazards will be reviewed before the work begins during a daily Tailgate Safety meeting. No work will be performed before this meeting has taken place. At least one copy of this plan shall be available at the work site.

Only authorized personnel will be permitted in the work area. These authorized individuals must have successfully completed a medical exam and have been properly trained in the use of respiratory protective equipment and specific health and safety hazards. All visitors shall check in with the ASI/IT or client representative.

All personnel entering the site shall be thoroughly briefed on the hazards, equipment requirements, safety practices, emergency procedures, and communication methods.

Protective clothing and respiratory protective equipment will be used for various stages of the operation as needed. The level of protection as specified in Section C.6.0, Personal Protective Equipment, will depend upon the degree of hazard.

At least one person trained in a minimum of both American Red Cross first-aid techniques and cardiopulmonary resuscitation will be on site whenever remediation activities occur. As an alternative, this requirement is satisfied when a 911 emergency responder can respond within five (5) minutes to the site.

No food, beverages, tobacco products shall be present, consumed or used in contaminated areas or potentially contaminated areas. Taking medication, smoking or applying cosmetics are also prohibited. These activities are allowed only in the established clean room and clean areas.

Before eating, drinking, or smoking employees shall wash their hands and remove outer protective garments.

At the end of each work shift, before leaving the site, personnel who worked in contaminated zones shall thoroughly shower or wash themselves to remove any contaminants.

Containers shall be moved only with the proper equipment and shall be secured to prevent dropping or loss of control during transport.

Emergency equipment shall be located in readily accessible uncontaminated locations. A complete first-aid kit will be readily available on site. A fire extinguisher will be at the work site. In the event of an emergency, it will be readily available for the team's use. It shall be located not more than 25 feet from the work activity. At least one eyewash will be maintained in the contamination reduction zone.

Employee entrance and exit routes shall be planned and emergency escape routes designated.

All operators of equipment used on site will be familiar with the requirements for inspection and operation of such equipment. Unfamiliar operations shall be discussed with affected employees before beginning work. The site supervisor will be responsible to check the proficiency of the operator. Perimeter barricades will be placed around the particular equipment used in a fixed location. Audio and/or visual backup alarms will be used on all heavy equipment on site.

Personnel will be prohibited from being transported by any other means than those prescribed for movement of personnel. When trucks or other heavy equipment enters or leaves the site, an individual shall direct the driver.

Any employee not willing to comply with this or any other health & safety procedure will be subject to disciplinary action.

No electrical equipment will be permitted in areas where a flammable atmosphere may exist. All static ignition sources will be identified and eliminated by the use of bonding and grounding techniques.

Material safety data sheets (MSDS) will be obtained for every chemical product used on site. This information will be made readily available to all employees upon request and stored in a central location. MSDSs or applicable information will be available with regard to materials used in the soil collection. All containers of any chemical products will be properly labeled to comply with the OSHA Hazard Communication Standard (29CFR1910.1200).

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C.8.1.1 Buddy System

All on-site personnel shall use the buddy system. Buddies shall maintain visual contact with each other. Personnel must observe each other for signs of heat stress or toxic exposure such as:

1. Changes in complexion and skin discoloration
2. Changes in coordination or demeanor
3. Excessive salivation and pupillary response
4. Changes in speech pattern

Personnel shall inform their supervisor of nonvisual effects of toxic exposure such as:

1. Headaches, dizziness, blurred vision
2. Nausea, cramps
3. Irritation of eyes, skin or respiratory tract

C.8.1.2 Fall Protection

The walking and working surfaces may become wet and slippery during these tasks. Extra caution is to be used when working on these surfaces. In addition, visible barriers will be erected around any open excavations to prevent personnel from falling into these holes.

C.8.2 PROJECT-SPECIFIC REQUIREMENTS

C.8.2.1 Bioassay Program

A bioassay program will be implemented to monitor employees for internal radiation exposure and to determine the amount and distribution of internally deposited radioactive material should an intake occur as a result of project operations. The bioassay program will be designed to assess potential chronic exposures and single exposure events. A baseline bioassay will be performed for each employee before beginning work on the project. The history of each worker's previous exposures to radioactive materials will be reviewed and documented with the results of the baseline bioassay. Sampling frequency will be determined so as not to miss intakes greater than 50 percent of an annual limit on intake for class W and class Y uranium, and greater than 50 percent of the air concentration limit for chemical toxicity for class D uranium. [Note: The air concentration limit for chemical toxicity for class D depleted uranium is approximately the same as the DAC for class Y uranium.] The urinalysis frequency for the routine bioassay program will be determined from the following table according to the measured airborne concentrations of uranium in the breathing zones for workers on this project:

TABLE C.8-1
MEASURED AIRBORNE CONCENTRATIONS OF URANIUM

Quarterly Average (Bq/m^3)	Maximum for a Single Quarter (Bq/m^3)	Urinalysis Frequency[a]
<0.15	<0.6	quarterly
	0.6 - 6	monthly
	>6	biweekly
0.15-0.3	<0.6	monthly
	0.6 - 6	biweekly
	>6	weekly
>0.3	≤6	biweekly
	>6	weekly

[a]This table is an adaptation of the frequency table from the DOE report, Health Physics Manual of Good Practices for Uranium Facilities (June 1988). The values of the DAC for uranium isotopes has been included and consideration has been given to limiting concentrations based on chemical toxicity of uranium.

In addition to the routine bioassay program, any circumstances that could have resulted in any intake of radioactive materials by ingestion, inhalation, or skin absorption will require that the affected employees report immediately to their supervisor and then to WEMCO Medical at the end of that shift and submit an incident-type urine sample and complete an Incident Investigation Report. The affected employee will also be required to submit another follow-up urine sample at the start of the next shift and at additional time intervals deemed appropriate by the project Health and Safety personnel.

C.8.2.2 Medical Monitoring

In accordance with 29CFR1910.120 OSHA requirements, all ASI/IT and subcontractor personnel are required to participate in a medical monitoring program that includes:

- Baseline medical examination
- Annual medical examination
- Medical examinations that may be required after potential exposures
- Respirator physical

C.8.2.3 Training Requirements

All ASI/IT and subcontractor personnel assigned to site tasks will be trained to meet OSHA and site-specific requirements including:

- 40-hour OSHA training
- 8-hour refresher training
- 8-hour supervisory training (supervisors)
- 24-hour supervised field experience
- Review of this HSP
- Site-specific training, required by WEMCO (radiation safety, etc.)

C.8.2.4 Sanitation

ASI/IT employees will keep the work and support areas neat and orderly and free of trash and debris.

An area will be established that is upwind from the sampling area and outside the contamination reduction zone where personnel can take a break. The area must be clearly marked and no contaminated personnel or equipment is permitted there. An adequate number of toilet facilities will be made available to employees.

If the facility does not have a water supply available then potable water will be carried to the site for use in decontamination and employee cleanup.

C.8.2.5 Illumination

Sampling activities will take place during daylight hours; therefore, the work areas will be illuminated to a minimum of 20 foot candles. Supplementary lighting may be necessary inside buildings, tanks, at night, or in other poorly lit areas.

C.8.2.6 Drum Handling

The following requirements will be adhered to when working with drums and containers:

- When practical, containers will be inspected and their integrity evaluated before being moved.

- Containers whose contents are unknown will be considered to contain hazardous substances and handled accordingly until the contents are positively identified.

- Site operations will be organized to minimize the amount of drum or container movement.
- Before opening, transfer of contents, removal, or other operations that may involve employee contact with contaminants (direct or airborne), all potentially exposed personnel shall be warned of the potential hazards associated with the contents of the container and the operation in which they are participating.

C.9.0 SITE ENTRY PROCEDURES

Site entry procedures will consist of the following:

- The site crew will radio CONTROL daily to establish radio contact, location, start time, and stop time.

- Procure radiation work permit for daily operations, if required, which

  - Identifies degree of radiological hazard
  - Limits allowable work time
  - Specifies minimum PPE requirements

- All safety equipment is required to undergo a safety inspection by WEMCO Fire and Safety personnel upon initial entry to the FEMP.

- Perform tailgate meeting to familiarize team with site-specific hazards. Identify contamination zones and break area. Discuss alternate communications signals (if applicable).

- Calibrate instruments and log calibrations.

- Visually scan the site for signs of contamination.

- Perform respirator checkout and fit test before use.

- Enter potentially contaminated areas with monitoring. Monitoring instrumentation is identified in Section C.5.0.

- Monitor for radiation using radiation meters for alpha and beta/gamma.

- Use buddy system

  - Teams of at least two people will be used for all activities within a Contamination Control Area. Team members will monitor each other for signs of heat stress or other distress and will render aid, if required.

Note: The ASI/IT Site Safety Officer and any member of the Field 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 a level deemed acceptable by the Site Safety Officer (or designee) and the Project Manager.

C.10.0 SITE EXITING PROCEDURE

10.1 CONTAMINATION DETECTION

All site personnel are required to decontaminate themselves and then confirm the effectiveness of the decontamination. The effectiveness will be determined by frisking with a hand-held radiation monitor. A Radiation Safety Technician shall monitor any visitors to the site.

Personnel monitoring will be performed using portable survey instruments equipped with either a GM Detector (beta/gamma) or a Zinc Sulfide Scintillation Detector (alpha). For beta/gamma monitoring, the detector will he held within 1/2 inch of the surface being frisked and surveyed at a rate of 2 to 3 inches per second. Background levels while frisking for beta/gamma contamination must be less than 300 counts per minute (cpm). In cases where background exceeds 300 cpm, monitoring will be performed using alpha scintillation detectors. For alpha contamination monitoring, the detector should be held as close as possible to the surface being frisked (not in contact) and surveyed at a rate of 1 to 2 inches per second. All personnel will perform a whole body frisk upon exit from a contamination area.

In the event that contamination cannot be removed to below the action level (100 cpm beta/gamma or detectable alpha above background), contact Health Physics personnel. Health Physics should be notified of any contamination incidents.

Vehicles and other equipment used on site must be monitored for contamination (and decontaminated if necessary) before moving them to noncontaminated areas. Health Physics personnel will determine when the equipment is safe to move to clean areas.

10.2 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: Remove disposable protective equipment at the exclusion zone. Personnel leaving the process area are required to wash hands, face, and any other exposed skin. Detergent and water should be used to gently scrub skin surfaces that have contacted potentially contaminated wastes. The effectiveness of decontamination must be confirmed by frisking or the use of hand and foot monitors.

Heavy Equipment: Heavy equipment generally requires decontamination at the WEMCO Decontamination Pad. Frisking and/or wipe tests will be performed to confirm the effectiveness of decontamination.

C.11.0 SAMPLING-DERIVED WASTES

Sampling-derived wastes are those generated in the performance of on-site activities and will be handled in accordance with site procedures. These wastes include, but are not limited to:

- Disposable PPE such as Tyvek coveralls, gloves, and booties
- Excess sample materials
- Used glovebags and decontamination materials

All potentially contaminated waste materials resulting from site activities will be collected and placed in drums or other containers specified by WEMCO. Protective clothing will be placed in plastic bags and disposed of as compactable, potentially contaminated waste through WEMCO. Wastes will be segregated as much as practical to aid in disposal.

Sampling-derived wastes are the property of the client and are to be left on site.

C.12.0 CONFINED SPACE ENTRY

No confined space entry is permitted.

C.13.0 CONTINGENCY PLANS

Emergency response procedures will be developed for extraordinary conditions that may occur at the work site; they will be covered during the Tailgate Safety Meeting.

Emergencies must be dealt with in a manner to minimize the health and safety risk to all project personnel. All ASI/IT personnel shall be aware of emergency procedures, evacuation routes, and "safe" areas.

ASI/IT team leaders have the following responsibilities in an emergency:

- Assess the emergency situation and notify appropriate response personnel (e.g., fire department, ambulance, police)
- Determine the required response measures and inform the client representative.
- Determine and coordinate ASI/IT personnel actions for the particular emergency.
- Immediately complete the Supervisor Injury Report form upon occurrence of an accident or incident.

EMERGENCY TELEPHONE NUMBERS

		Radio
Ambulance: Radio to Control	(513) 738-6511	CONTROL
Hospital: Radio to Control	(513) 738-6511	CONTROL
Fire: Radio to Control	(513) 738-6511	CONTROL

	Work	Home	Radio
John Wood: Project Director	(513) 738-3100	[redacted]	
Steve Duce, H.P.	(513) 738-3100		
Bill Kwoka, H&S (WMD)	(615) 483-1274		
Alvin Luttrell, V.P. (WMD)	(615) 483-1274		
Bruce Myers, Field Manager	(513) 738-3100		
Lee Vittitow, Sr. IH	(513) 738-3100		
Dan Stropes	(513) 738-3100		
Susan Birner, Personnel	(505) 883-0959		
Greg McAnarney, H&S (Corp.)	(505) 883-0959		

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Mark Turner, H.P.	(513) 738-3100	[redacted]
Ron Gill, H&S	(513) 738-3100	
John Simak (DOE)	(513) 738-6009	
EMERGENCY RESPONSE	(513) 738-6511	CONTROL
Leo Singleton (WEMCO)	(513) 738-8908	
Dick Kasparek (WEMCO)	(513) 738-6899	
Industrial Hygiene (WEMCO):	(513) 738-6207	357
Radiation Safety (WEMCO):	(513) 738-6889	355
Fire and Safety (WEMCO):	(513) 738-6235	303
Utility Engineer (WEMCO)	(513) 738-6295	202
PROJECT CONTACTS		
ASI/IT Deputy Project Director - John Razor	(1) 738-3100	
ASI/IT Ops. Supervisor - Doug Harmel	(1) 738-3100	
WEMCO Health Physics Supervisor -	(513) 738-6672	
Don Spahr	Beeper-844-5893	

PUBLIC RESPONSE AGENCIES

Before the start of site work, the project supervisor will develop a list of response agencies which may be contacted depending on the nature of the emergency. This list of contact agencies will include the name, address, and telephone number of the following:

NATIONAL HOTLINES FOR EMERGENCY REPORTING AND INFORMATION

Center for Disease Control	404-633-5313
Chemtrec	800-424-9300
CMA Chemical Referral Center	800-262-8200
DOT Hazardous Materials Information	202-366-4488
Emergency Planning and Community Right-to-Know	800-535-0202
Federal Emergency Management Agency	817-898-9104
National Response Center Hotline	800-424-8802
Occupational Safety and Health Administration	800-582-1708
American Chemical Society Library - Contact: Henry Saxe	(202) 872-4511
Substance Identification	(800) 848-6538
National Safety Council	(312) 527-4800

HOSPITALS

The nearest medical facility is the WEMCO medical department (Figure C.13-1). It is the primary choice for on-site injuries. First aid and ambulance service is available at the WEMCO medical department. Radio or call 6511 to contact CONTROL. WEMCO maintains an emergency response capability which includes an ambulance and trained emergency medical technicians. The WEMCO ambulance will transport the injured workers to the nearest hospital if necessary.

ACCIDENTS AND NONROUTINE EVENTS

The types of emergencies outlined below are not all inclusive and the corresponding response procedures will not be considered inflexible. Each accident presents a unique event that must be dealt with by key trained personnel. The objective is to provide the appropriate initial response to assist those in jeopardy without placing other personnel at unnecessary risk.

WORKER INJURY

If a person working in an area is physically injured, American Red Cross first-aid procedures will be followed. Depending upon the severity of the injury or illness, emergency medical response may be obtained accordingly. If the person can be moved, that person will be taken to a location away from the work area where emergency first aid treatment can be administered. An ambulance should be summoned and the local emergency medical facility should be contacted.

The site supervisor will prepare a written report detailing the particular accident, its causes, and consequences within 24 hours of the accident.

If the injury to the worker is of a chemical nature, the following first-aid procedures will be instituted as soon as possible:

- Eye Exposure - If contaminated material gets into the eyes, the eyes will be flushed immediately at the eyewash station using copious amounts of water while lifting up the lower and upper eyelids.

- Skin Exposure - If contaminated sludge or corrosive liquid material gets on the skin, the affected area will be washed with soap or mild detergent.

- Inhalation - If an individual inhales a volume of toxic or corrosive vapors, the employee will be removed to fresh air at once. If breathing has stopped, artificial respiration will be performed on the affected individual until medical attention can arrive on the scene and transport the patient to the nearest medical facility.

- Ingestion - In the event a person ingests a toxic liquid or solid material, medical attention shall be obtained at once.

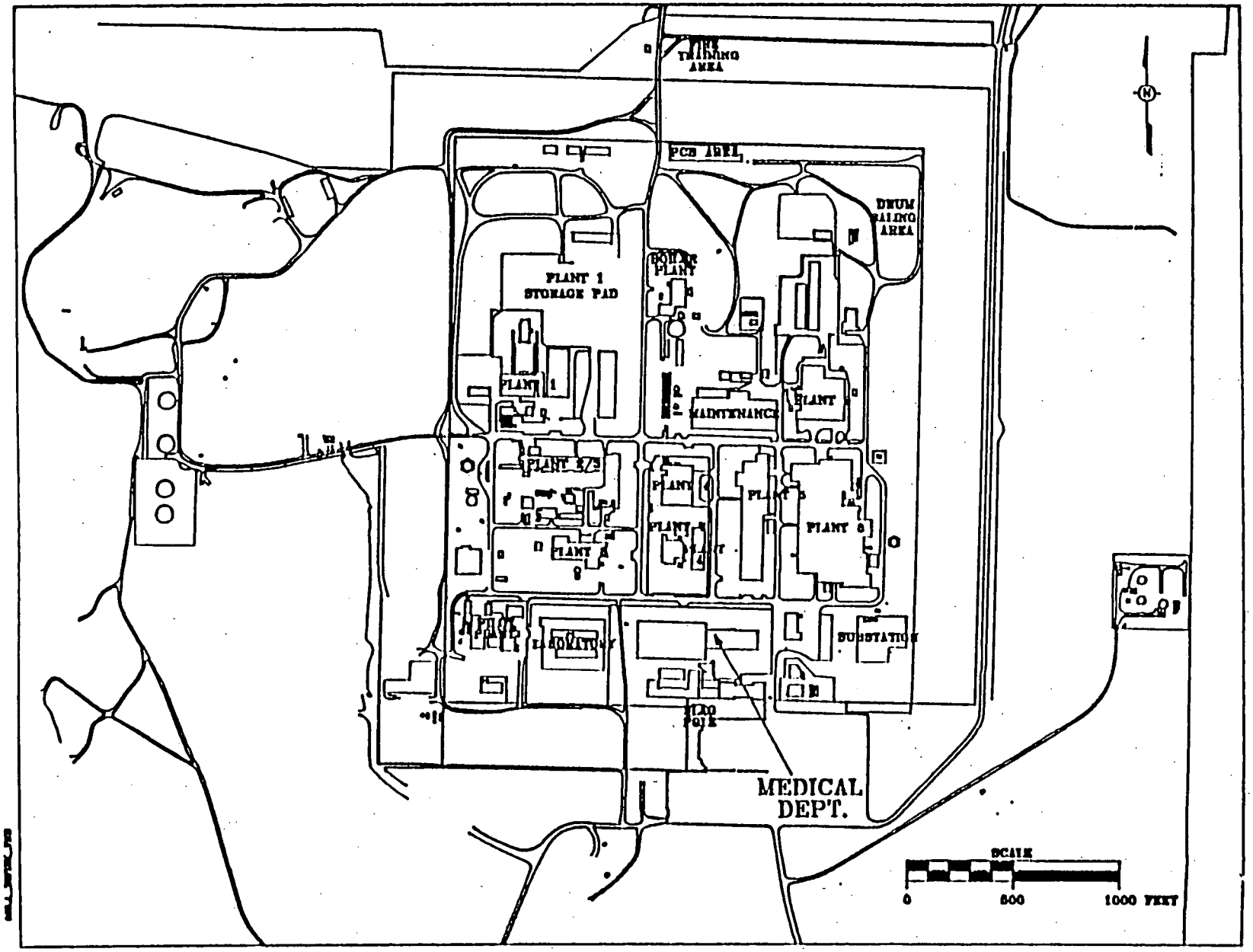

FIGURE C.13-1. LOCATION OF MEDICAL DEPARTMENT

SITE HEALTH AND SAFETY PLAN ACKNOWLEDGEMENT

I have read, understand, and agree to abide by the provisions as detailed in this Site-Specific Health and Safety Plan prepared by ASI/IT. Failure to comply with these provisions may lead to disciplinary action and/or my dismissal from the work site. .

Printed Name	Employee Number	Signature	Date

APPENDIX D

HEALTH AND SAFETY PLAN
FOR THE
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
OPERABLE UNIT 5 TREATABILITY STUDY
REMEDY SCREENING, REMEDY SELECTION PHASES

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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 personnel during the Operable Unit 5 laboratory screening to be performed at the 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 Occupational Safety and Health Administration (OSHA) requirements.

D.1.1 SCOPE OF WORK

This laboratory screening will involve washing the soil obtained under the Operable Unit 5 treatability Sampling and Analysis Plan (SAP) using two fundamental processes: froth flotation and hydro-gravimetric separation. The washing solutions will then be treated through a series of precipitation and ion exchange reaction steps for removal of contaminants. The soils will be analyzed for gross alpha and gross beta before treatment. This will establish a baseline value for comparison against treated soils. The average alkalinity will also be determined before treatment. Samples will be analyzed for volatile and semivolatile organic compounds. All analyses will be run on the extracted solid, extractant, and wash water after treatment and will be compared against the original soil parameters. Two similar phases will follow this first phase with the addition of a modified toxicity characteristic leaching procedure (MTCLP) analysis and a full TCLP being conducted on the extracted solids. Concentration of the Resource Conservation and Recovery Act (RCRA) hazardous metals and organic compounds in extractant and water wash will be determined by SW-846 methods.

D.1.1.1 Preliminary Characterization

The samples drawn under the Operable Unit 5 SAP will be composited at the Feed Materials Production Center in Ross, Ohio. These activities will be governed by the HSP for the SAP (Appendix C).

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 Officer (Keith Hood) - responsible for the technical development and coordination of the HSP. Inquiries regarding the HSP, corporate health & safety 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 Health & Safety Manager regarding the execution of the project and the HSP.

- Laboratory personnel - responsible for understanding and complying with all site health & safety requirements. Each team member shall be provided training on the requirements of this HSP before beginning the project.

- Emergency Coordinators (Tom Geisler, Rick Greene) - 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

A variety of chemical and metallurgical processes were used at the FEMP for the manufacture of uranium products. During the manufacturing process, high quality 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 (UO_3) powder. This compound was reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal was produced by reacting UF_4 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.

Operable Unit 5 consists of those environmental media that represent pathways and/or environmental receptors presently or potentially affected by FEMP contaminants. The media within Operable Unit 5 include groundwater, surface water, soils, sediments, flora, and fauna. Operable Unit 5 also specifically covers the soils associated with the former Production Area and nine suspect areas. The Production Area includes the buffer zones, the scrap piles, and the miscellaneous discarded materials and equipment overlying the former drum baling area. The nine suspect areas currently being addressed are:

- Clearwell
- Fire training area
- Main effluent line
- Rubble mound west of the K-65 silos
- South flagpole area
- Sewage treatment plant/incinerator area
- K-65 slurry line
- Suspected rubble mound south of the K-65 slurry line
- Rubble mound west of the northwest corner of the production area (north rubble mound)

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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 RADIOLOGICAL HAZARDS

- U-238

Contaminant	MPC In Air* 40 Hr. Week	Action Level
Uranium-238	7×10^{-11} µCi/mℓ	4 MPC* hrs. of U-238

*Maximum permissible concentration

D.4.2 CHEMICAL HAZARDS

The following chemicals will be present, either in the samples or in the reagents, and will pose potential hazards. Other materials, such as ethylenediaminetetraacetic acid (EDTA), NS1 and citraclean, will be present but will pose no significant hazard due to their relatively low toxicity and the use of small quantities.

TABLE D.4-2

EXPOSURE GUIDELINES

	PEL[a]	
Contaminants	OSHA TWA[b]	OSHA STEL[c]
Methylene chloride	500 ppm[d]	C[e] 1000 ppm
Xylene	100 ppm	150 ppm
Trichloroethene	50 ppm	200 ppm
PCB	0.5mg/m^3	NE
Sulfuric acid	1 mg/m^3	NE
Hydrochloric acid, as HCl	NE[f]	C 5 ppm
Nitric acid	2 ppm	4 ppm
Phosphoric acid	1 mg/m^3	3 mg/m^3
Sodium carbonate	NE	NE

	PEL[a]	
Contaminants	OSHA TWA[b]	OSHA STEL[c]
Sodium bicarbonate	NE	NE
Sodium hydroxide	None	C 2 mg/m^3
Potassium chloride	NE	NE
Uranium	0.05 mg/m^3 0.02 mg/m^3[g]	0.6 mg/m^3

[a]PEL - Permissible exposure limit, or maximum airborne exposure allowed by the Occupational Safety and Health Administration (OSHA). Types of PELs include TWAs, STELs, and ceilings.
[b]TWA - Time-weighted average, or average exposure allowed over an eight-hour shift.
[c]STEL - Short-term exposure limit, or maximum average exposure during a 15-minute period.
[d]Soluble compounds
[e]C - Ceiling, or maximum exposure allowed, even instantaneously.
[f]NE - None established.
[g]Insoluble compounds

D.4.3 POTENTIAL ROUTES OF EXPOSURE AND HAZARD ASSESSMENT

The identified site contaminants are solid 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. Radioisotopes in the sample pose an external and internal exposure hazard. The internal hazard is largely eliminated by the procedures to be used. 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 soil 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 samples or the reagents. To minimize the potential for radiation exposure, air monitoring will be conducted to quantify the exposure and to ensure that the procedures in use are appropriate.

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. The frequency of the monitoring is determined by the operation being performed. The work areas are cleaned after each eight-hour shift and surveyed for contamination. Intermittent surveys may be performed during the shift but are not required by this work plan. No work will be allowed until the area has been declared free of contamination by a health physics technician.

When concentrations exceed the one millirem (mrem)/hour action level, 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.5.2.1 Action Levels for Radiation

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

Instrument	Need	Interval	Level	Action[a]
Alpha probe	Yes	Prejob and intermittent	20 dpm/100 cm^2[b]	HP Review
Beta/gamma probe	Yes	Prejob and intermittent	200 dpm/100 cm^2[b]	HP Review
External radiation	Yes	Prejob	>1 mrem/hour	HP Review
Thermoluminescent dosimetry	Yes	Continuous	N/A, no real time results	
Alpha CAM	Yes	Continuous	4 MPC hrs. of U-238	Withdraw

[a]Health Physics (HP) review of the work will be initiated when the action level is reached. At 10 times these levels, work will be stopped until the new conditions can be evaluated by Health and Safety personnel.
[b]Above background.

D.6.0 PERSONAL PROTECTIVE EQUIPMENT AND EXPOSURE REDUCTION

D.6.1 PERSONAL PROTECTIVE EQUIPMENT

D.6.1.1 Respiratory Protection

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

A comprehensive respiratory protection program has been established by IT. This program is required in all locations where use of such equipment could lessen the potential for adverse health effects to any employee.

As part of the respiratory training program, each employee is instructed in the following elements:

- Nature of the respiratory hazard on the work site and the appraisal of potential consequences if the respiratory protection is not utilized
- Use and proper fitting of the respirator
- Cleaning, disinfecting, inspection, maintenance, and storage of the respirator
- Proper selection of a respirator and its capabilities, and limitations

Employees must demonstrate proper fit of the equipment in a test atmosphere.

Routinely used respiratory equipment will be inspected, cleaned, and disinfected daily to help assure proper hygienic practices. An inspection of these breathing devices will include the following:

- Examination of the head straps for breaks, loss of elasticity, broken or malfunctioning buckles, and other attachments
- Examination of the facepiece for excessive dirt, cracks, tears, distortion, holes, or inflexibility
- Examination of the exhalation and inhalation valves for any foreign material, cracks, tears or distortion in the valve, and proper installation
- Examination of air purifying elements for incorrect cartridge, expired shelf-life of the cartridge, and cracks or dents in the cartridge or cartridge holder
- Examination of proper insertion of the cartridge into the facepiece and a check of the gaskets inside the cartridge holder

When Level C protection is required, respirator cartridges will be changed daily. All respirators shall be inspected before each day's use. If broken or malfunctioning parts are found during the cleaning process, these parts will be replaced or new respiratory equipment will be issued to the user.

D.6.1.2 Eye Protection

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

D.6.1.3 Protective Clothing

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.

D.6.2 EXPOSURE REDUCTION

D.6.2.1 Engineering Controls

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 that is also under negative ventilation. A slant manometer or magnehelic gauge will be utilized to measure and indicate the pressure differential created by the air flow.

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.

D.6.2.2 Administrative Controls

Control Access to Work Area

Access to contamination work areas will be regulated and will be 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:

- 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.

- Contamination reduction zone - This zone includes all areas immediately adjacent to the exclusion zone. Personnel contamination monitoring will take place in this zone.

- Support zone - This area covers all areas outside of the contamination reduction zone. Exposure to harmful chemicals or radioactive materials in this zone is highly unlikely.

D.6.2.3 Safe Work Practices

All personnel will follow the safe work practices outlined in the CHP for the ETDC.

D.6.2.4 Equipment Inspection

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

D.7.0 LABORATORY ACCESS AND ENTRY PROCEDURES

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

D.7.1 BIOASSAY SAMPLING

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

Additional urine samples will be required if air samples indicate an acute exposure of 40 DAC-hours (2 percent of the annual limit of intake). This correlates to a gross alpha activity for U-238 of 6×10^{-10} µCi/mℓ averaged over a one-hour exposure. No respirator protection factors are built into these action levels.

D.7.2 MEDICAL MONITORING

In accordance with 29CFR1910.120 OSHA requirements, all personnel involved in the treatability study are required to participate in a medical monitoring program that includes:

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

D.7.3 TRAINING REQUIREMENTS

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

- CHP
- ETDC Emergency Contingency Plan
- General employee training - rad worker training
- Hazard communication training

D.7.4 CONTAMINATION ZONES

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.

A contamination reduction zone will be established and decontamination will be performed in this zone. All personnel entering or leaving the exclusion zone will pass through this area in order to prevent any cross contamination and for the purpose of accountability. Tools and any equipment or machinery will be decontaminated in a specific location. The decontamination of all personnel will be

performed on site adjacent to the exclusion zone. Personal protective outer garments and respiratory protection will be removed in the contamination reduction zone and properly labelled.

The support zone will consist of an area outside the environmental containment cubicle. The support zone will be located to prevent employees from being exposed to any organic vapors or dust levels above regulatory limits. Eating, drinking, or smoking will be permitted in the support area only after washing face and hands.

D.7.5 LABORATORY ENTRY PROCEDURES

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

- Perform respirator check out and negative/positive pressure checks before use
- Locate the nearest eyewash/shower and fire extinguisher before 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 1/2-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.

If contamination cannot be removed to below the action levels (100 cpm beta/gamma or detectable alpha radiation above background), notify the Health & 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 with a 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. Exposure to low levels of radioactivity do not produce acute exposure symptoms. The exposures may cause delayed effects such as cancer. Because biological effects from radiation exposures are cumulative, exposures are to be kept as low as reasonably achievable.

No treatment is anticipated for the predicted contaminants and concentrations. Any emergencies arising during the performance of work will covered by an emergency contingency plan prepared for the ETDC.

D.10.0 OPERATIONALLY DERIVED WASTES

Operationally derived wastes are those 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 compatible, potentially contaminated waste by 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

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

APPENDIX E

INTEGRATED DEMONSTRATION
SOIL SAMPLING PROJECT INFORMATION

SAMPLING PLAN

EM-SMPLPN-SMS-
REQ-91-080.2
REV-0

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

PREPARED BY: Jerome A. Brown (ENGINEER/TECHNOLOGIST) DATE: 9-23-91

REVIEWED BY: Lawrence Dove Jr. (ENGINEER/TECHNOLOGIST) DATE: 9-24-91

APPROVED BY: Thomas E. Buhlage (MANAGER SMS) DATE: 9-25-91

APPROVED BY: Donald A. Bu (QA/QC) DATE: 9/30/91

Note : This document applies to activities to be conducted for Phase II of the Integrated Technology Demonstration Project.

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

A request for Environmental Media Sampling (Sample Request # EM-SMS-080) has been forwarded to Environmental Monitoring - Site Media Sampling (EM-SMS) for soil sampling and characterization in support of the Uranium Soils Integrated Demonstration Treatability Project - Phase II.

In June 1991, SMS conducted soil sampling activities in support of the Uranium Soils Integrated Demonstration Treatability Project - Phase I. A total of 10 soil cores were collected from five suspect areas at the Fernald Environmental Management Project (FEMP) facility. The soil cores were shipped to the Oak Ridge National Laboratory in Oak Ridge, Tennessee to determine their physical and chemical properties.

Based on data collected during Phase I, two areas were selected for Phase II operations. The areas selected are: Area A - the grassy area north of the Incinerator near the Sewage Treatment facility, and Area B - the grassy area west of Plant 1 Pad.

Phase II of the Uranium Soils Integrated Demonstration Treatability Project will be split into the following tasks: 1) pre-sampling (soil excavation, sifting, and blending), and 2) sampling and analyses.

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

1.2 PURPOSE OF SAMPLING

EM-SMS has received a sampling request SMS-REQ-080 to collect soil samples for homogeneity testing and verification of Resource Conservation and Recovery Act (RCRA) contaminant concentrations. The objective of sampling and characterization is to determine the homogeneity and chemical constituents of the soils in the previously identified areas. Homogenous, non-RCRA soils will be shipped to the appropriate companies participating in the Uranium Soils Integrated Demonstration Treatability Project to improve/validate remediation technology components and systems in terms of risk-reduction, effectiveness, cost savings, regulatory and public acceptability, and duration.

2.0 IDENTIFICATION OF KNOWN/SUSPECTED CONTAMINANTS

The contaminants of concern include a variety of radiological, chemical, and metallic elements and compounds. Radiological contaminants such as Uranium-238, and Uranium-235 are known to be present. The following contaminants may be present: volatile and semi-volatile hydrocarbons, pesticides and herbicides, and metals .

3.0 SAMPLE FIELD SITE

The areas selected for Phase II operations are: Area A - the grassy area north of the Incinerator near the Sewage Treatment facility, and Area B - the grassy area west of Plant 1 Pad. Soil materials for each area will be excavated, sieved using a 3/4-inch screen, blended using a concrete mixing device, and transferred to a total of 12 55-gallon storage drums.

3.1 SAMPLE LOCATIONS

At each area identified in section 3.0, approximately 250 cubic feet of soil will be removed from the following excavations:

Area A - 50' long, 10' wide and 0.5' deep
Area B - 25' long, 20' wide and 0.5' deep

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

3.1.1 SAMPLES PER LOCATION

Per Environmental Media Sampling Request #SMS-REQ-080 a soil core will be extracted from each 55-gallon storage drum per each sample area. The soil cores will be split into five (5) equal subsamples. Four subsamples from each drum per each area (total of 48 subsamples/area) will be retained for homogeneity analyses. The remaining subsample for each drum per each area will be retained to produce a composite sample for each respective area.

3.1.2 ANALYTICAL PARAMETERS N/A if not applicable

CONCURRENCE REQUESTOR [signature]

HOMOGENEITY ANALYSES*
1. GRAIN SIZE
2. RAD. ACTIVITY

RCRA CHARACTERIZATION**
1. TCLP VOLATILES
2. TCLP SEMI-VOLATILES
3. TCLP METALS
4. TCLP PEST./HERB.
5. ALPHA/BETA/GAMMA SCREENING

Note :
* - For the four subsamples for each drum per sample area.
** - For the composite sample for each sample area.

3.1.3 REQUIRED SAMPLE VOLUME

CONCURRENCE ~~FMPC~~ FEMP ANALYTICAL [signature] 9-23-91

HOMOGENEITY ANALYSES

TO BE PERFORMED BY FEMP ANALYTICAL FACILITY

PARAMETER	VOLUME	CONTAINER TYPE	HOLDING TIME	PRESERVATIVE
1. GRAIN SIZE	250 grams	Glass/Plastic	none	none
2. RAD. ACT.	Note 1	Glass/Plastic	none	none

Note :
1 - Only one (1) sample container will be required to allow for Grain size and radiological activity analyses.

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

RCRA ANALYSES

TO BE ANALYZED BY A SUBCONTRACTED LABORATORY

PARAMETER	VOLUME	CONTAINER TYPE	HOLDING TIME*	PRESERVATIVE
1. TCLP VOLATILES	Note 1	Glass	14 days	cool 4 deg C
2. TCLP SEMI-VOL.	1 pint	Glass	14 days	cool 4 deg C
3. TCLP METALS	1 pint	Glass	Note 2	none
4. TCLP PEST./HERB.	1 pint	Glass	14 days	cool 4 deg C
5. ALPHA/BETA/GAMMA	4 ounces	Glass	none	none

Note :

1 - Samples will be retained in three 4 ounce jars with teflon lined closures.

2 - 6 month holding time for all metals except mercury (28 days).

* - Period from time of sample collection to sample extraction by laboratory facility.

4.0 QA/QC REQUIREMENTS

Environmental Monitoring will adhere to the QA/QC requirements as outlined in procedure EM-CS-001 "ENVIRONMENTAL MONITORING ON-SITE MEDIA SAMPLING" for trip blanks, field blanks, and duplicate sampling. Trip and field blanks (deionized water) will be prepared prior to each day of sampling activities and will accompany each sample set to the designated laboratory facility for RCRA analyses indicated in Section 3.1.2.

Equipment rinsate blanks will be collected (on a daily basis) at the completion of sampling activities and will accompany each sample set to the designated laboratory facility for RCRA analyses indicated in Section 3.1.2.

EM-SMS may extract a duplicate sample for this project for RCRA analyses. The duplicate extraction will be noted in the permanent field logbook. The duplicate sample will be contained, sealed, and labeled in such a way that the receiving laboratory will not know that the sample is a duplicate.

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

5.0 EQUIPMENT NEEDED

5.1 Task 1 - Pre-sampling

The following equipment will be required as a minimum:

- Bulldozer or Bobcat
- Mechanical Shaker/Sifter
- Conveyor
- Concrete Mixer
- PPE as determined by FEMP Health and Safety groups
- 24 55-gallon storage drums

5.2 Task 2 - Sampling and Analysis

The following equipment will be required as a minimum:

- Hand Auger or Coring Device, Stainless Steel Scoop/Spoon
- Sample Containers indicated in Section 3.1.3
- PPE as determined by FEMP Health and Safety groups
- RO-TAP and Sieves (No. 10, No. 200, and collection pan)
- Drying Oven
- Geiger-Mueller or Sodium Iodide detector

6.0 DECONTAMINATION OF EQUIPMENT

6.1 Task 1 - Pre-sampling

All equipment (except for PPE and drums) will be decontaminated at the FEMP Decontamination Pad using Standard Operating Procedures developed by the Decontamination and Demolition (D&D) facility.

6.2 Task 2 - Sampling and Analysis

All sampling equipment used will be decontaminated as per procedure EM-CS-001. Equipment used by the laboratories will be decontaminated in accordance to their respective Standard Operating Procedures.

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

7.0 METHODOLOGY

7.1 Task 1 - Pre-sampling

7.1.1 Using the Bobcat or bulldozer blade remove as much of the grass as possible from the designated sample area.

7.1.2 Excavate the soil at the designated area to a total depth of no more than 6 inches below surface grade. If the soil appears to be moist or saturated, then stockpile excavated soils on plastic sheeting materials and cover with Herculite. Allow the soils a period of 12 to 16 hours to dry.

7.1.3 Transfer dry soil materials to the shaker/sifter device and operate for a period of at least 15 minutes to allow for segregation of materials of less than 3/4-inches in diameter.

7.1.4 Transfer sifted materials to the conveyor system to fill the mixer device.

7.1.5 Operate the mixer device for a period of at least 4 hours to ensure that a homogenous blend of soil materials has been created.

7.1.6 Transfer blended soil materials to the drum containers specified for the designated sample area.

7.1.7 Decontaminate equipment at the FEMP D&D facility and proceed to the next designated sample area.

7.2 Task 2 - Sampling and Analysis

7.2.1 Drummed Soil Sampling

7.2.1.1 Using a hand auger or coring device, collect a soil core from the top to the

base of the given drum.

7.2.1.2 Transfer soil core from the collection device to a piece of clean plastic sheeting and divide into 5 equal subsamples.

7.2.1.3 Place the subsamples in glass quart-sized containers. Retain and label four of these containers for homogeneity analyses. Retain the remaining container to produce a composite sample for RCRA analyses for the designated sample area.

Note : Indicate the EM number, the Sample area (A or B), the drum number (1 to 12), and the depth interval on the label for each container retained for homogeneity analyses.

7.2.1.4 Decontaminate all equipment used in the sample collection process.

7.2.1.5 Move to the next drum and repeat steps 7.2.1.1 through 7.2.1.4 until all drums for the designated sample area have been sampled.

7.2.1.6 To produce a composite sample for the designated sample area, combine all subsamples retained for RCRA analyses in the following manner: 1) place four clean stainless steel pans (labeled in accordance to the respective TCLP parameter to be analyzed) on clean plastic sheeting, 2) divide each subsample into four equal portions, 3) transfer a portion of each subsample to each stainless steel pan, and 4) combine the portions in each pan and transfer to the appropriate container specified in Section 3.1.3. Transfer any remaining soil materials to the container labeled

for Alpha/Beta/Gamma screening analysis.

7.2.1.7 Decontaminate the stainless steel pans and equipment used to transfer samples to the appropriate containers.

7.2.1.8 Deliver all samples collected to the FEMP analytical laboratory facility with the appropriate Chain-of-Custody documentation.

7.2.1.9 Proceed to the next sample area and repeat steps 7.2.1.1 through 7.2.1.8.

7.2.2 Homogeneity Analyses

7.2.1.1 The homogeneity analyses will be performed by the FEMP analytical laboratory facility using the procedures provided in Attachment A. The proceduralized steps for conducting grain size analyses are taken and modified from ASTM Method D422-63 "Standard Method for Particle-Size Analysis of Soils" and "Petrology of Sedimentary Rocks"; Robert L. Folk, 1974.

8.0 HEALTH AND SAFETY

The work to be performed and outlined in this sampling plan will be accomplished in accordance with the FEMP Site Health and Safety Plan, the Environmental Monitoring Health and Safety Plan, and the Project Specific Health and Safety Plan.

EM-SMS technicians will comply to all precautionary surveys performed by the FEMP employees representing Industrial Hygiene, Radiological Safety, and Safety Engineering. EM-SMS shall obtain a FEMP Work Permit and a Radiation Work Permit, which will be posted at the job site. Concurrence to all applicable safety permits (indicated by signature of the EM-SMS technicians assigned to the project) is expected in the performance of their assigned duties.

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

The responsible sampling team lead will insure that all EM-SMS technicians performing sampling related to this project has read and understands all applicable surveys that protect worker safety and health. EM-SMS technicians who do not sign the applicable health and safety survey forms will not participate in the execution of sampling activities related to the completion of assigned project responsibilities. A copy of all applicable safety surveys issued for worker safety and health shall be stored for easy reference in the applicable project files maintained by ENVIRONMENTAL MONITORING.

9.0 DEPARTMENT OF TRANSPORTATION (DOT) PACKAGING, MARKING/LABELING REQUIREMENTS

CONCURRENCE DOT INTEGRATION Betty Bunter 9/25/91

As specified in 49 CFR 173.421, the following criteria will be evaluated to determine the appropriate DOT packaging, marking and labeling requirements:

1) If the package does not contain more than 15 grams of uranium 235, or the radiation level at any point on the external surface does not exceed 0.5 millirem per hour, then use:

   * **Proper Shipping Name for Liquids or Solids:**
     Radioactive Material, Limited Quantity, N.O.S. (laboratory specimen for analysis)

   * **Hazard Class:**
     Radioactive Material

   * **Identification Number:**
     UN2910

   * **Labeling/Marking:**
     The word "Radioactive" shall be on each bottle. Each container shall have "Radioactive Material, Limited Quantity" and "Danger, Cargo Aircraft Only".

   * **Packaging:**
     The materials shall be packaged in strong, tight packages that will not leak any of the radioactive materials during conditions normally incident to transportation.

2) If the package contains more than 15 grams of Uranium 235, or the radiation level at any point on the external surface of the package exceeds 0.5 millirem per hour, use:

* **Proper Shipping Name for Liquids or Solids:**
  Radioactive Material, LSA, N.O.S.
  (laboratory specimen for analysis)

* **Hazard Class:**
  Radioactive Material

* **Identification Number:**
  UN2912

* **Labeling/Marking:**
  Radioactive Yellow II or Radioactive Yellow III label (determined by radiation monitoring levels at a distance of one meter from the surface of the outer container) and "Danger, Cargo Aircraft Only".

* **Packaging:**
  DOT 7A, Type A packaging must be used. The exterior of each package must be marked "USA DOT 7A Type A" and "Radioactive". DOT 17-C (5 gallon pail) is an approved package.

EM-SMS will comply with **49 CFR 173.421** regulations for sample overpackaging to maintain sample preservation temperatures per EPA regulations contained within SW-846.

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

ATTACHMENT A

STANDARD OPERATING PROCEDURE FOR HOMOGENEITY ANALYSIS

EM-SMPLPN-SMS-
REQ-91-080.2
REV-0

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

STANDARD OPERATING PROCEDURES FOR HOMOGENEITY ANALYSES BY FEMP ANALYTICAL LABORATORY

Author: Jerome A. Gnoose 9-22-91
Jerome A. Gnoose Jr. / EM-SMS

Approved By: _____
Raymond J. Danahy, FEMP Laboratory

Approved By: _____
Victor R. Gill, FEMP Laboratory

Approved By: _____
W. J. Neyer, FEMP Laboratory

1.0 OBJECTIVE

1.1 To determine if the characteristics of soil contained in a single drum are significantly different than the characteristics of soil contained in a set of drums. Homogeneity testing is required to assure that the characteristics of soil being prepared for treatability studies do not differ significantly between drums.

2.0 SCOPE

2.1 This procedure applies to all work being performed by the Fernald Environmental Management Project (FEMP) Analytical Laboratory facility for soil homogeneity analyses.

3.0 DEFINITIONS

3.1 *Balance* - An instrument sensitive to 0.01 grams for weighing the materials retained by No. 10 (2.00 mm) and No. 200 (0.075 mm) sieves, and materials passing through the No. 200 sieve.

3.2 *Oven* - A device of sufficient size, capable of maintaining a uniform temperature of 110 +/- 5 degrees Celsius.

3.3 *Ro-Tap* - A mechanical shaker device (capable of vertical and lateral movement) that aids in segregation of particulate materials.

3.4 *Sieves* - A series of square-mesh woven-wire cloth, conforming to the requirements of ASTM Specification E-11. Sieves to be used for homogeneity analyses are:

No. 10, 2.00 millimeters (mm); and
No. 200, 0.075 millimeters (mm).

4.0 RESPONSIBILITIES

4.1 Environmental Monitoring - Site Media Sampling

4.1.1 Collect soil samples from drum containers for homogeneity analyses.

4.1.2 Deliver soil samples to the FEMP Analytical Laboratory facility with the appropriate Chain-of-Custody documentation.

4.1.3 Provide technical assistance and supervision for homogeneity analyses, when required.

4.2 FEMP Analytical Laboratory

4.2.1 Receive and log all samples collected for homogeneity analyses.

4.2.2 Conduct grain-size analyses in accordance with this procedure.

4.2.3 Conduct radiological activity screening measurements in accordance with this procedure.

4.2.4 Submit analytical results to the appropriate personnel indicated on the Chain-of-Custody documentation.

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

5.0 GENERAL

5.1 Soil cores will be obtained from a minimum of twelve (12) 55-gallon drums for two sample areas located at the FEMP facility. Each soil core will be divided into four subsamples for homogeneity analyses. A total of 96 subsamples shall be submitted to the FEMP Analytical Laboratory facility for homogeneity analyses.

5.2 Each soil subsample will be dried in ovens (maximum temperature of 110 degrees Celsius) for a period of at least 6 hours to remove soil moisture.

5.3 Subsequent to soil drying operations, 250 grams of each subsample shall be placed in the sieves and mechanically separated using a Ro-Tap device for a period of at least 10 minutes. The percentage of materials retained by No. 10 and No. 200 sieves, and the percentage of materials passing through the No. 200 sieve will be calculated.

5.4 For each subsample, the materials retained by the No. 10 and No. 200 sieves, and the materials passing through the No. 200 sieve will be screened for radiological activity using a Geiger-Mueller or Sodium Iodide detection device.

5.5 For each sample area, the grain-size and radiological activity data for each drum will be compared to determine the homogeneity of the set of drummed materials. If the set of drummed materials for the given sample area is not homogenous, the drummed materials will be re-blended and resampled for homogeneity analyses.

6.0 PROCEDURE

6.1 Sample Preparation

6.1.1 Sort subsamples by the appropriate depth intervals (indicated on sample container labels) for each sample area into four (4) batches.

Note : Each batch should contain 12 subsamples with identical depth intervals.

6.1.2 Remove the sample container lids for each container for the first batch of subsamples to be dried.

6.1.3 Place the batch of subsamples in an oven (maximum temperature of 110 degrees Celsius) for a period of at least 6 hours to remove excess soil moisture.

6.1.4 Remove the batch of subsamples from the oven. After cooling, transfer approximately 250 grams of each subsample from their original sample containers to clean, pre-weighed containers. Re-weigh containers and subsample contents. Record weights on the appropriate Homogeneity Analysis Form.

6.1.5 Select the next batch of subsamples to be dried. Repeat steps 6.1.2 through 6.1.5 until all batches of subsamples for a given sample area are dried.

6.2 Grain-Size Analysis

6.2.1 Transfer approximately 250 grams of subsample to the series of sieves.

Note : The sieves should be stacked as follows (from top to bottom):

No. 10 (2.00 mm) sieve;
No. 200 (0.075 mm) sieve; and
Collection Pan.

6.2.2 Place the cover lid and rubber protection cover on top of the No. 10 sieve. Place the series of sieves in the Ro-Tap device.

6.2.3 Operate Ro-Tap device for a minimum period of at least 10 minutes to ensure

that all materials have been properly sieved.

6.2.4 Remove the series of sieves from the Ro-Tap device. Remove rubber protection cover and cover lid from the No. 10 sieve.

6.2.5 Transfer the contents from the sieves and collection pan to clean, pre-weighed containers with an known geometry.

6.2.6 Re-weigh containers and sieved contents. Record weights on the appropriate Homogeneity Analysis Form. Retain containers and sieved contents for radiological activity screening analyses.

6.2.7 Decontaminate the sieves, lids and Ro-Tap device using an Alconox + deionized water solution, followed by a deionized water rinse.

6.2.8 Repeat steps 6.2.1 through 6.2.7 until each subsample for a given sample area has been analyzed.

6.2.9 Calculate the percentages of grain-size fractions for a given subsample by dividing the weight of each grain-size fraction by the initial weight of the dried subsample and multiplying by 100%. Record percentages of grain-size fractions on the appropriate Homogeneity Analysis Form.

6.2.10 Repeat step 6.2.9 for each subsample for a given sample area.

6.3 Radiological Activity Screening Analysis

6.3.1 For each grain-size fraction of a given subsample, slowly move the Geiger-Mueller or Sodium Iodide detector above the surface of the sieved materials. Record

the radiological activity screening reading for each grain-size fraction on the appropriate Homogeneity Analysis Form.

Note : The detection device should be kept approximately 1/4-inches above the surface of the sieved materials.

6.3.2 Repeat step 6.3.1 for each subsample for a given sample area.

7.0 APPLICABLE DOCUMENTS

7.1 ASTM Methods D421-85, D422-63, D546-88.

7.2 Appendix A, Uranium Soils Integrated Demonstration Treatability Sampling Plan, August 1991.

7.3 Petrology of Sedimentary Rocks, Robert L. Folk, 1974.

8.0 ATTACHMENTS

8.1 Homogeneity Analysis Form.

SITE MEDIA SAMPLING PLAN

INTEGRATED TECHNOLOGIES DEMONSTRATION PROJECT

HOMOGENEITY ANALYSIS FORM

Sample No.:_____ Date Sample Received:_____
Sample Area:_____ Initial Sample Wt.:_____
Drum No.:_____ Time Drying Started:_____
Depth Int.:_____ Time Drying Stopped:_____

SAMPLE PREPARATION RESULTS Analyst:_____

Weight of Clean Container:_____ grams
Weight of Container and
Dried Soil Contents: _____ grams
Weight of Dried Soil: _____ grams

Weight of Dried Soil = Weight of Container and Dried Soil - Weight of Container

GRAIN-SIZE ANALYSIS RESULTS Analyst:_____

Grain-Size Fraction	Wt. of Container	Wt. of Soil + Container	Wt. of Soil	% of Grain Size Frct.
> No. 10	_____ g	_____ g	_____ g	_____ %
> No. 200	_____ g	_____ g	_____ g	_____ %
< No. 200	_____ g	_____ g	_____ g	_____ %

Wt. of Soil = Wt. of Soil + Container - Wt. of Container

$$\% \text{ Grain Size Frct.} = \frac{\text{Wt. of Soil (per grain size fraction)}}{\text{Weight of Dried Soil}}$$

RADIOLOGICAL ACTIVITY SCREENING RESULTS
Analyst:_____

Grain-Size Fraction	Radiological Activity Reading
> No. 10	_____ cpm
> No. 200	_____ cpm
< No. 200	_____ cpm

RESULTS OF PHASE I CHARACTERIZATION

ornl

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

3658
ORNL/TM-11980

Characterization of Uranium Contaminated Soils from DOE Fernald Environmental Management Project Site: Results of Phase I Characterization

S. Y. Lee
J. D. Marsh, Jr

Environmental Sciences Division
Publication No. 3786

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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ORNL/TM-11980

ENVIRONMENTAL SCIENCES DIVISION

CHARACTERIZATION OF URANIUM CONTAMINATED SOILS FROM DOE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT SITE: RESULTS OF PHASE I CHARACTERIZATION

S. Y. Lee
J. D. Marsh, Jr.

Environmental Sciences Division

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Characterization Group
Integrated Demonstration
Vincent Tidwell (SNL), Group Leader
James Cunnane (ANL) S. Y. Lee (ORNL) Vic Gil (FEMP)
Mark Nichelson (HAZWRAP) Dale Perry (LBL)

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ABSTRACT

LEE, S. Y. and J. D. MARSH, Jr. 1992. Characterization of uranium contaminated soils from DOE Fernald Environmental Management Project Site: Results of Phase I characterization. ORNL/TM-11980. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 70 pp.

The Integrated Demonstration (ID) for remediation of uranium-contaminated soils has been established by the DOE Office of Technology Development. The Fernald site was selected as the DOE facility for the field demonstration. The principle objective of this ID is to evaluate and compare the versatility, efficiency, and economics of various technologies that may be combined into systems for the removal of uranium from contaminated soils.

The ID Characterization Task group designed a study to obtain basic information relating to soil properties and the nature of uranium contamination at the site soil. Such information is essential for the selection of (1) contaminated soils for use in treatability studies, (2) a field demonstration area at the site, and (3) integrated technologies. The task group selected five areas and collected two core samples from each area.

The nature of soil contamination was investigated by examining (1) uranium distribution with soil depth, (2) soil particle size distributions and their uranium contribution, (3) soil chemical and physical properties, (4) particle density of soil and contaminant, (5) mineralogical and microscopic properties of soil and contaminant, (5) chemical leaching characteristics, and (6) background soil uranium content and soil properties.

The results indicated: (1) except in an area contaminated by acidic solution spills, the contamination depth of most areas was shallow (usually <10 cm containing from 10 to 2800 pCi/g); (2) background uranium concentration of off-site soils was <4 pCi/g; (3) the sand and silt size fraction of soils contained from 48 to 79% of the uranium in soils; (4) the dominant form of uranium was sand and silt-sized particulate often associated with

calcium, phosphorous, iron, and silicon; (5) most of the uranium particulates had a density >2.9 g/mL, however; and (6) considerable amounts of soil uranium, 10 to 49% and 20 to 75%, could be extracted using 2% solutions of ammonium carbonate and citric acid, respectively.

On the basis of the soil characterization results, two areas, Plant 1 Drum Storage area and the Incinerator area, were selected for use in treatability studies and insitu characterization demonstration areas. The Plant 1 Drum Storage area was contaminated by uranium product spills and the Incinerator area was contaminated by airborne uranium materials during incineration of contaminated materials. Particulate uranium was the dominant form associated with the sand and silt fractions of both soils (see attached micrograph plate). Some uranium in the soils was not readily extractable. Therefore, simple chemical extraction alone would not be effective for waste volume reduction as soil remediation. Development of more effective and selective extraction technology and density-based physical separation technology is needed to meet the cleanup goal for the Integrated Demonstration.

CHARACTERIZATION OF URANIUM-CONTAMINATED SOILS FROM DOE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT SITE: RESULTS OF PHASE I CHARACTERIZATION

S. Y. LEE AND J. D. MARSH, JR.
Environmental Sciences Division
Oak Ridge National Laboratory

INTRODUCTION

The Integrated Demonstration (ID) for uranium-contaminated soils remediation has been established by the DOE Office of Technology Development. The principle objective of this ID is to evaluate and compare the versatility, efficiency, and economics of various technologies that may be combined into systems for the removal of uranium from contaminated soils. Because the scope of the ID program is to address remedial alternatives for uranium-contaminated soils, the Fernald Site was selected as the DOE facility for the field demonstration. The draft RI/FS report (DOE, 1990) of the site concluded that the majority of uranium-contaminated soils were located within the Operable Unit 3, including the Sewage Treatment Plant/Old Incinerator area (Figs. 1 and 2). Therefore, the ID team selected Operable Unit 3 as the source of contaminated soils for the field demonstration (Note: After the renegotiation of the CERCLA Consent Agreement, the management of all soils became the responsibility of Operable Unit 5.)

The Phase I soil sampling/characterization task was established by the Characterization Group to obtain basic information related to soil properties and the nature of uranium contamination. Such information is essential for:

- the selection of contaminated soils for use in treatability studies,
- the selection of a field demonstration area or areas within Operable Unit 3, and
- the preliminary screening of integrated technologies (Tidwell's Memorandum, 1991).

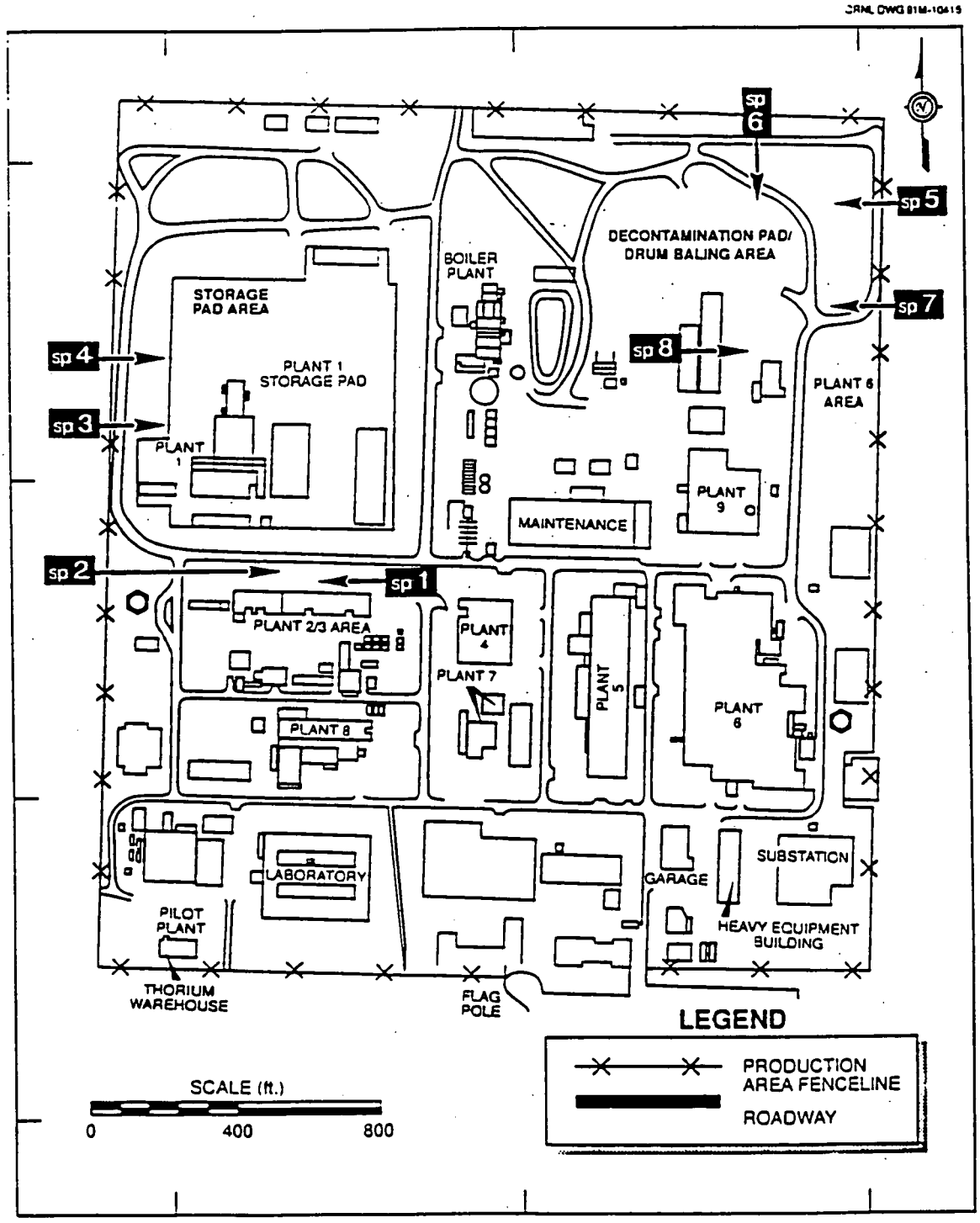

Figure 1. Sampling locations in Operable Unit 3 of Fernald Operation Site.

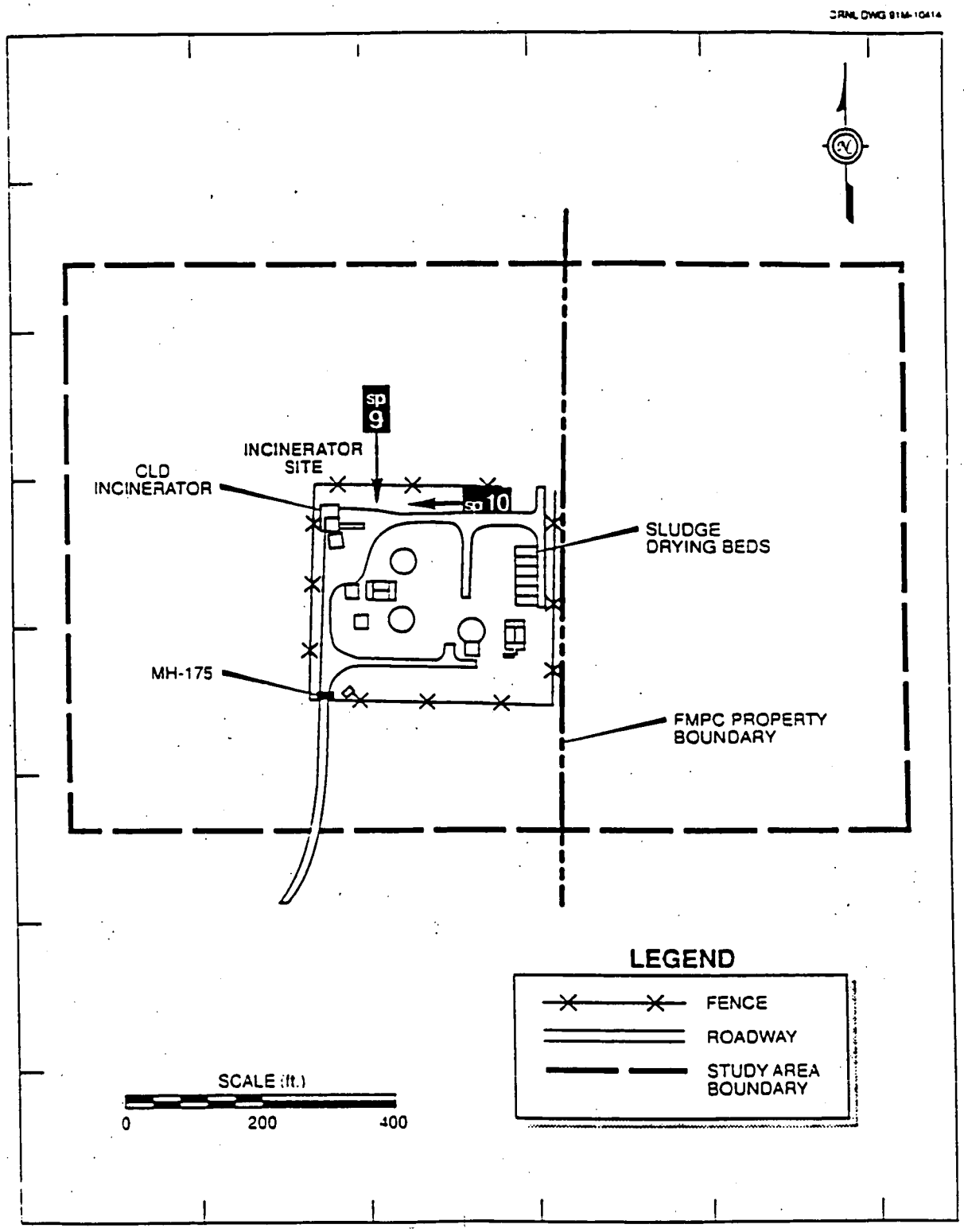

Figure 2. Sampling locations in the incinerator area of Fernald Operation Site.

Table 1 is a list of the information needs. More detailed characterization will be conducted in the Phase II investigation that will follow the Phase I investigation. This Phase I investigation is intended to be finished within 2 1/2 months because of the schedule established by DOE for preliminary treatability tests at Nevada.

This preliminary investigation will, however, provide critical information related to: (1) the nature of uranium contamination, (2) important soil properties related to uranium retention, (3) guide the direction on the next phase of the investigation, and (4) narrow the scope of technology investigations.

Table 1. Characterization information needs for the Integrated Demonstration Program

Properties	Where the information is needed
1. Uranium distribution with depth:	Excavation, Risk assessment
2. Soil particle size distribution:	Treatability, Risk assessment, Waste Disposal
3. Uranium distribution with particle size:	Treatability, Risk Assessment
4. Soil chemical and physical properties:	Excavation, Treatability
5. Specific gravity soil/contaminant:	Treatability
6. Soil solution chemistry:	Treatability, Risk Assessment, Site Operation
7. Mineralogical analysis:	Treatability, Waste Disposal
8. Microscopic analysis:	Treatability
9. Uranium form identification:	Treatability, Risk Assessment
10. Chemical leaching test:	Treatability, Waste Disposal, Risk Assessment
11. Reference soil characterization:	Risk Assessment, Treatability, Regulation

Characterization Group members agreed to select soil sampling areas based on the contamination source term characteristics, that is, aqueous uranium wastes, solid uranium product spills, and airborne uranium wastes (dust, aerosols) (Tidwell's Memorandum, 1991). The decontamination Pad/Drum Baling area and north of the Plant 2/3 area have

been selected to represent the soils contaminated by aqueous uranium wastes. The Plant 1 Drum Storage area was selected for the soils contaminated by uranium product spills. And, the Incinerator and Plant 6 areas were selected to represent the soils contaminated by airborne releases of uranium. Two reference soils, Fincastle and Henshaw Series located about 1 mile and 1.5 miles west of the Fernald Site, respectively, were collected for base line data establishment (Fig. 3).

METHODS

Collection of soil core samples for the Phase I Sampling Program was performed according to the protocols and procedures established for the RI/FS Operable Unit 3 program, the RI/FS Quality Assurance Project Plan, and the Project Specific Health and Safety Plan (Tidwell's Memorandum, 1991).

Characterization Group representatives (S. Y. Lee and Mark Nichelson) with the aid of the Fernald RI/FS sampling team and Health Physics personnel performed site surveys with a sodium-iodide survey meter at selected sampling sites. Specific sampling points were selected according to areas exhibiting a high activity. Prior to collecting sample, gravel or grass covers were removed before setting up a hand-driven auger. A stainless steel auger with one or three 12-in.-long polybutyrate sleeve (2 in. diam) was used for sample collection. After retrieval of the auger by a hydraulic jack, soil cores were cut at the joints of sleeves and capped for shipment. Supplemental undisturbed samples were collected by pushing down an 8.5-cm-diam × 3.5-cm-deep plastic dish and cutting the bottom of the soil block with a knife for microscopic analyses. Samples were shipped to the Oak Ridge National Laboratory for characterization.

The soil cores were described according to the standard soil description methodology (Soil Survey Staff, 1975) and then cut into 2- to 4-in. segments. Each soil core segment was given an identification number in the following way; SP#-1-A, "SP#" representing sampling site, "-1" representing the order of sleeve from the top or the order of sampling when three 12-in. cores were taken instead of one 36 in. core per each sampling location, and "-A" representing the order of each soil segment starting from the top of each sleeve.

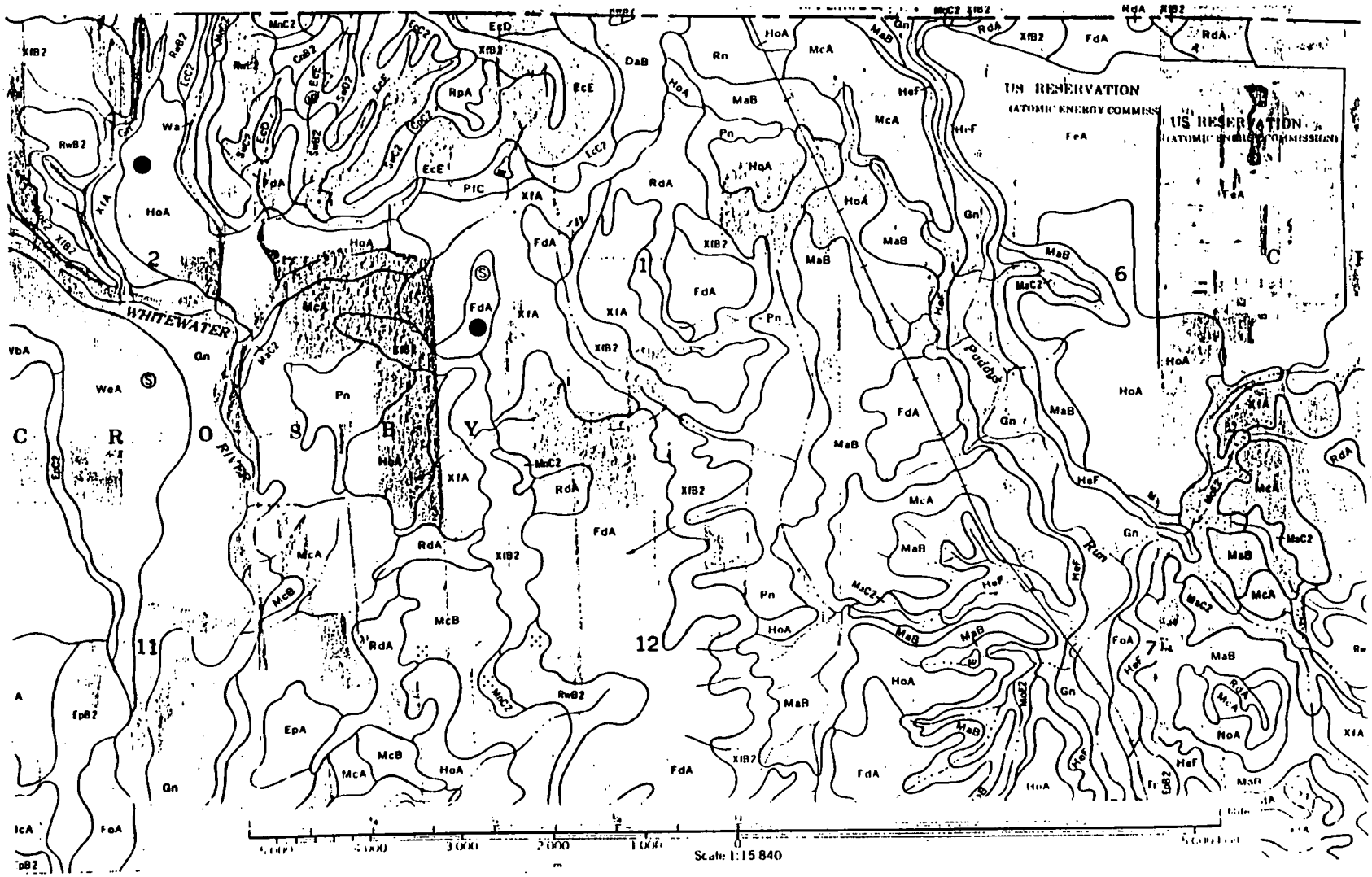

Figure 3. Reference soil sampling locations on soil survey map of Hamilton County, Ohio. (FdA = Fincastle Series; HoA = Henshaw Series)

Soil pH measurements were made using a PHM 84 Research pH meter with a combination pH electrode. The meter and electrode were calibrated with standard pH buffers of pH 7 and 10 to encompass the pH range of the soil samples. The soil samples were prepared by adding 5 ml of distilled water to 5 g of soil, stirring, and allowing the soil and water to set in contact for about 6 h before beginning pH measurements. The electrode was left in the soil/water mixture until the reading had stabilized and the measurement recorded.

The soil core segments (3 to 4 in.) were transferred to 8.5-cm-diam (internal) by 3-cm-high plastic containers for gamma spectroscopy. Gamma analysis was done on all the samples prior to particle size separation. The samples were counted on a high resolution, solid state, coaxial, intrinsic, germanium (IG) detector coupled to an ND6700 multichannel analyzer with 4096 channels. The gamma system had previously been calibrated with a Amershan QCY44 certified mixed gamma standard with traceability to National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), in the geometry used to contain the soil samples. In addition, weekly and daily sources were counted to verify that the detectors were remained calibration. Samples were counted down the soil column from 1 h to overnight depending on their level of activity. The ^{238}U concentration was determined using the 1001-keV line for ^{234}Pa, which is a daughter of ^{238}U assumed to be in secular equilibrium with the uranium isotope. At equilibrium the activities of the two nuclides should be the same and the measurement of one determines the activity of the other. The ^{235}U was determined using its 143-keV peak. The activity ratio of $^{235}U/^{238}U$ for natural uranium is 4.6. Cesium-137 at 661 keV and ^{40}K at 1460 keV were also measured down the soil column. For those samples with activities below detectable levels, a minimum detectable activity (MDA) is reported. This is the minimum activity of the radionuclide which have to be present 95% of the time to be detected in the presence of the sample compton continuum.

After gamma spectroscopy, soil segments from the SP22, SP2-3, SP4, SP5, SP8, and SP9 cores were selected. The selected segments from each core were combined as needed to obtain enough sample for characterization. For example, a soil sample identification number such as SP2-2-ABC represents a mixed sample of A, B, and C segments from the

SP2-2 sleeve and SP4-1A/2A represents a mixed soil of the first segment of the first sleeve and the first segment of the second sleeve from SP4.

Particle size separation of the selected soil samples was performed by dry sieving with 4- and 2-mm sieves (size fractions larger than 2 mm were designated as gravel). The <2-mm fractions were further separated into 2 to 0.053 mm (sand), 0.053 to 0.002 mm (silt), and <0.002 mm (clay) by wet sieving and centrifugation method (Jackson 1975). Water samples produced during particle-size separation and soil samples were submitted to the Environmental Analysis Laboratory located at the Y-12 Plant in Oak Ridge, Tennessee, for the following analyses; total uranium by mass spectroscopy, isotopic uranium by alpha spectroscopy, trace element analysis by inductively coupled plasma atomic emission spectroscopy (ICP-AES), anions by ion chromatography (IC), and alkalinity by acid titration to pH 4.5. Due to the sensitivity of the alpha spectroscopy method for uranium, only those soils and leachates with very low levels of uranium (<10 pCi/g for solid and <100 pCi/L for liquid) could be analyzed by this method. For this reason, the high-level uranium samples were done by mass spectroscopy. Prior to the uranium and metal analyses, 1 to 3 g of soil was digested at 90 to 95°C with nitric acid and 30% hydrogen peroxide, centrifuged, and filtered. The filtrates were diluted before spectroscopy analyses.

Several leaching solutions were employed to determine their effectiveness in extracting uranium from the soil. The extractants and their means of preparation were:

- 0.1 *N* nitric acid [HNO_3]: 6.25 mL of concentrated nitric acid was diluted to 1 L with distilled water.
- 2% ammonium carbonate [$(NH_4)_2CO_3$]: 20 g of $(NH_4)_2CO_3$ was dissolved in distilled water and diluted to 1 L.
- 5% sodium hypochlorite (NaOCl): 50 mL of NaOCl reagent (Cl < 6%) was diluted to 1 L with distilled water.
- 0.1 M ethylenediaminetetraacetic acid, disodium salt (EDTA): 37.224 g of EDTA was dissolved in distilled water and diluted to 1 L.

- 2% citric acid monohydrate solution ($H_3C_6H_5O_7 \cdot H_2O$): 20 g of citric acid was diluted to 1 L with distilled water.
- 0.1 *M* hydroxylamine-hydrochloride ($NH_2OH.HCl$) in 0.01 *N* nitric acid: 6.95 g ($NH_2OH \cdot HCl$) was dissolved and diluted to 1 L with 0.01 *N* HNO_3. The 0.01 *N* nitric acid was prepared by diluting 3 mL concentrated nitric acid to 5 L with distilled water.

The procedure for each extraction was the same except for the extractant used. The soils extracted were ones that had been sieved and consisted of particles <2 mm in size. Those samples were: SP2-2-ABC, SP2-3-ABC, SP4-1A/2A, SP5-1-AB, SP8-1A/2A/3A, and SP9-1A/3A. Forty milliliters of the extractant were added to 5 g of each soil (1:8 soil/solution ratio) and mixed for 2 h in a shaker. The samples were then centrifuged for 6 min at about 3000 rpm in an IEC HN-SII centrifuge. The liquid was decanted and filtered through a 0.45-μm, 25-mm, Acrodisc. This leachate was then submitted to the Y-12 Environmental Analysis Laboratory for total uranium analysis by mass spectroscopy and trace element analysis by inductively coupled plasma atomic emission spectroscopy (ICP-AES). In addition to the leachates, some unleached soil was also submitted for analysis so that the percent of uranium and trace metals extracted could be calculated.

One additional extraction was conducted employing the citrate-bicarbonate-dithionite (CBD) method. This method is summarized as follows.

- Sodium citrate-bicarbonate-dithionite (CBD) method: 0.3 *M* sodium citrate (88 g tribasic sodium citrate, $Na_3C_6H_5O_7.2H_2O$, per liter); 1 *M* sodium bicarbonate (84 g $NaHCO_3$ per liter); and 5 g sodium dithionite, $Na_2S_2O_4$.

For the CBD extraction, 800 mL of sodium citrate were mixed with 100 mL sodium bicarbonate for an 8:1 citrate/bicarbonate solution. Sixty milliliters of this solution were added to 15 g of soil in a 200-mL centrifuge bottle. The soil plus citrate/bicarbonate solution was then heated in a water bath to 75-80°C. At about 78°C, 5 g of sodium dithionite were added and the mixture stirred for 15 min. After digestion, the mixture was centrifuged, the solution decanted, and filtered through a 0.45-μ, 25-mm, Acrodisc. This

leachate was also submitted to the Y-12 Environmental Analysis Laboratory for total uranium by mass spectroscopy and trace element analysis by inductively coupled plasma atomic emission spectroscopy (ICP-AES).

The CBD treatment soil samples were separated into sand-, silt-, and clay-sized fractions by the wet sieving and centrifugation methods for mineralogical analysis by x-ray powder diffraction (XRD) and heavy liquid density separation. Clay fractions were saturated with magnesium and potassium and excess salts were removed by washing. Oriented clay specimen slides, two for magnesium-saturated clay and three for potassium-saturated clay were prepared using the filter membrane peel technique (Drever 1973). One of the magnesium-saturated clay slides was solvated with ethylene glycol and the second and third sets of potassium-saturated clay slides were heated at 300 and 550°C. XRD scans began and ended at 2 and 30 degrees, two theta, respectively, using copper K alpha radiation on a Norelco-Philips x-ray diffractometer.

The dry, undisturbed, surface soil samples collected in plastic dishes and soil clumps from the subsurface were embedded in epoxy resin under a vacuum allowing the solution to move into soil micropores. After resin polymerization, microscopic specimens about 2 × 3.5 cm), were prepared by cutting the soil resin blocks perpendicular to the soil surface by a diamond saw. The specimens were polished with silicon carbide powder. Scanning electron microscopy (SEM), utilizing both secondary electron imaging (SEI) and backscattered electron imaging (BEI) in conjunction with energy dispersive X-ray analysis (EDX), was used for analysis of morphology, particle size, and elemental distributions (Lee 1990).

Lithium metatungstate solution with density 2.8 g/mL was used for the heavy liquid density separation. About 10 mL of the lithium metatungstate solution was transferred into a 20-mL plastic centrifuge tube and to about 3 g of sand fractions separated after CBD treatment to the solution. After mixing for 5 min and centrifugation for 10 min (2000 rpm), the bottom of the tube containing heavy particles was placed in liquid nitrogen to freeze the bottom, thus allowing the upper (floating) part to be poured off to separate the fractions. Both the heavy and floating fractions were collected on filter

papers (0.45 μm) and washed with distilled water using a vacuum filtering apparatus. The fractions were placed in petri dishes, and uranium concentrations were determined by gamma spectroscopy as described above. A portion of the floating and heavy fractions was embedded in epoxy resin solution for SEM, EDX, and XRD analyses (in progress). These analyses would provide information related to elemental composition and crystalline phase of uranium containing particles.

RESULTS AND DISCUSSION

Soil Description and Gamma Spectroscopic Analysis

Reference Soils: Undisturbed soils on and around the Fernald Site are classified as either Fincastle or Henshaw series. The Henshaw series consists of deep, somewhat poorly drained, moderately permeable soils that formed in alluvium from calcareous loess (SCS 1982). Henshaw soils would be on a stream terrace as seen from the southeast portion of the Fernald Site. The Fincastle series consists of deep, somewhat poorly drained soils that formed in loess and in the underlying loam till. Permeability of Fincastle soils is moderate in the upper solum and moderately slow in the underlying glacial till. Current usage of the lands is farming. The results of gamma spectroscopic analysis are in Table 2. Uranium contents of the background soils were very close to the lower detection limit of the gamma spectroscopic analysis. Both mass and alpha spectroscopies were performed for reference soil uranium analysis.

Plant 2/3 Area: The area surrounding Plant 2/3 has been highly disturbed from past construction and decontamination activities. Limestone gravels were on the surface and mixed into the soil as deep as 30 in. from the surface. Two soil core samples, SP1 and SP2, were taken from the area (Fig. 1). Both core samples had a very high gravel content, and bulk density of the soils ranged from 1.2 to 1.9 g/cm^3 depending on the clay and moisture contents of particular core segments. Soil ranged from light yellowish brown (10YR 4/2) to yellowish gray (2.5YR 5/0). The SP1 core had a clay layer at the bottom (18+ in.) and had a very low uranium content (Table 3). The SP2 core was selected for the characterization study because the soil was contaminated uniformly down to 32 in.

Table 2. Radionuclide concentrations in reference soils at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
Fincastle Soil											
FS-1	0-6	2.56E+00	30.10	8.20E-02	39.95	3.20	1.60	1.24E+01	1.53	1.13E-01	6.54
FS-2	6-12	9.94E-01	MDA	5.16E-02	MDA			1.14E+01	1.20	9.52E-03	MDA
FS-3	12-18	1.53E+00	35.76	3.71E-02	67.84	2.42	1.85	1.46E+01	1.17	3.57E-03	122.17
FS-4	18-24	1.46E+00	55.81	1.62E-01	33.67	11.10	7.23	1.52E+01	1.90	1.67E-02	MDA
FS-5	24-30	2.70E+00	41.47	7.62E-02	51.82	2.82	1.87	1.58E+01	1.45	1.41E-02	MDA
FS-6	30-36	5.74E-01	90.49	7.71E-02	37.48	13.44	13.16	1.35E+01	1.21	9.33E-03	MDA
Henshaw Soil											
HS-1	0-6	2.50E+00	24.71	6.27E-02	51.46	2.51	1.43	1.24E+01	1.60	9.76E-02	6.89
HS-2	6-12	1.69E+00	55.24	3.12E-02	146.55	1.85	2.90	1.28E+01	2.05	2.71E-02	51.69
HS-3	12-18	1.77E+00	54.73	3.51E-02	98.65	1.98	2.23	1.24E+01	2.27	1.57E-02	MDA
HS-4	18-24	9.57E-01	MDA	4.19E-02	55.90			1.41E+01	1.00	7.16E-03	MDA
HS-5	24-30	2.24E+00	60.92	4.23E-02	65.59	1.89	1.69	1.62E+01	1.86	1.52E-02	MDA
HS-6	30-36	1.06E+00	59.76	5.57E-02	56.49	5.24	4.31	1.71E+01	1.34	1.08E-02	MDA

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Table 3. Radionuclide concentrations in SP1 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP1-1-A	0-4	5.07E+02	2.53	3.27E+01	2.35	6.44	0.222	1.73E+00	28.11	2.48E-01	24.61
SP1-1-B	4-7	1.50E+03	1.68	1.05E+02	1.10	7.01	0.141	4.07E+00	19.00	3.28E-01	24.38
SP1-1-C	7-10	2.86E+01	16.52	2.25E+00	10.36	7.86	1.533	1.08E+01	6.03	4.63E-02	MDA
SP1-2-A	10-14	5.77E+02	2.42	3.73E+01	2.21	6.47	0.212	3.33E+00	12.54	1.49E-01	39.80
SP1-2-B	14-18	4.29E+02	2.55	2.96E+01	2.30	6.90	0.237	7.15E+00	8.03	1.61E-01	31.51
SP1-2-C	18-22	5.80E-00	MDA	2.43E-01	MDA	4.18	0.000	1.42E+01	5.27	4.85E-02	MDA
SP1-3-A	22-25	1.85E+01	21.67	8.22E-01	21.36	4.44	1.352	1.13E+01	6.17	4.16E-02	MDA
SP1-3-B	25-28	7.37E+00	MDA	8.25E-01	34.56	11.21	3.872	1.37E+01	5.69	4.47E-02	MDA
SP1-3-C	28-33	3.02E+00	MDA	2.09E-01	MDA	6.91	0.000	1.10E+01	6.11	3.74E-02	MDA
SP1-3-D	33-36	3.83E-00	MDA	1.85E-01	MDA	4.82	0.000	1.22E+01	4.99	2.58E-02	MDA

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Table 4 gives the activities of individual segments. In order to examine uniformity of contamination characteristics, two soil samples were chosen at the different depths from the SP2 core. The SP2-2 and SP2-3 samples were prepared by combining A, B, and C segments of the core sections from 10 to 20 in. and 20 to 31 in. depth, respectively.

Plant 1 Drum Storage Area: This area is located in the northwestern part of the plant, and the underlaying soils should be Fincastle series if they have not been too deeply disturbed. Soil sampling sites are located on the west side of the Drum Storage Area. The soil sampling area was covered by fescue grass. Most of the area was mowed but the northern portion of the grass area was left alone because the area was designated as a regulated zone. The SP3 core was taken near the concrete pad in the south and the SP4 core was taken from the unmowed area in the north (Fig. 1). The unmowed area was a surface water receiving area from the Drum Storage Pad. Soil in the SP3 core had a light yellowish brown (10YR 6/4) to brown (10YR 5/3) color with weakly developed soil structure and about 30 to 60% limestone gravels. The presence of the angular limestone gravel indicated that the SP3 core area had been highly disturbed from past activities. The gamma spectroscopy results of the core indicated that the level of uranium contamination (Tables 5 and 6) was <100 pCi/g in the upper 4 in. and <10 pCi/g below 7 in. Soil in the upper part of the SP4 core had a light to dark brown color with a lower dark gray (2.5Y 4/0) clay reducing zone. Gravel content in the soil core was less than 8%. The soil had relatively abundant plant roots, loam texture in the surface horizon (Ap), and clay loam textured subsurface horizons. Depth of considerable contamination (91 pCi/g) was above 7 in. The SP3 core was selected for the Phase I investigation because of the high contamination level of the soil core.

Decontamination Pad/Drum Baling Area: This area is located in the northeast corner of the site and is used as a storage area for contaminated materials (Fig. 1). Two soil core samples were taken from the area. The SP5 core was taken from the area where the surface was covered by gravel-sized contaminated slag materials. The field survey indicated that the slag materials were the major source of the radioactivity in the area. Smaller-sized slag material was mixed into soil down to 9 in. of the core and soil had pale brown to yellowish brown color and silt loam to clay loam texture. Considerable

Table 4. Radionuclide concentrations in SP2 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP2-1-A	0-4	5.41E+02	3.00	3.26E+01	2.70	6.02	0.243	5.64E+00	11.66	3.28E-01	35.71
SP2-1-B	4-6	1.07E+03	2.26	6.12E+01	2.16	5.72	0.179	5.52E+00	14.77	2.64E-01	27.92
SP2-1-C	6-10	5.84E+02	2.73	3.54E+01	2.39	6.05	0.220	5.53E+01	12.34	3.18E-01	18.90
SP2-2-A	10-13	2.10E+02	4.85	1.17E+01	6.45	5.59	0.451	6.74E+00	11.94	1.00E-01	MDA
SP2-2-B	13-16	2.37E+02	5.41	1.34E+01	4.90	5.68	0.414	7.87E+00	12.72	1.22E-01	MDA
SP2-2-C	16-20	4.75E+02	3.56	2.56E+01	3.57	5.38	0.271	5.54E+00	18.88	1.06E-01	58.25
SP2-3-A	20-24	5.75E+02	2.35	3.22E+01	2.48	5.59	0.191	4.08E+00	17.67	2.27E-01	26.06
SP2-3-B	24-27	1.83E+02	4.65	1.07E+01	5.02	5.88	0.402	1.09E+01	7.32	8.58E-02	MDA
SP2-3-C	27-31	5.29E+02	2.69	2.79E+01	2.69	5.28	0.201	6.74E+00	9.82	9.20E-02	46.61
SP2-3-D	31-32	2.63E+02	6.65	1.57E+01	5.80	5.98	0.528	1.11E+01	10.21	1.60E-01	MDA

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Table 5. Radionuclide concentrations in SP3 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP3-1-A	0-4	9.08E+01	7.56	4.74E+00	8.37	5.23	0.589	9.59E+00	7.61	2.29E-01	17.70
SP3-1-B	4-7	1.67E+01	21.54	1.33E+00	14.05	7.98	2.053	1.25E+01	6.08	5.25E-02	MDA
SP3-1-C	7-10	6.40E+00	60.34	4.62E-01	45.14	7.21	5.434	1.33E+01	6.04	4.56E-02	MDA
SP3-2-A	10-13	6.88E+00	MDA	2.26E-01	MDA	3.29	0.000	1.31E+01	6.12	4.26E-02	MDA
SP3-2-B	13-16	5.82E+00	MDA	2.39E-01	MDA	4.11	0.000	1.24E+01	5.56	4.47E-02	MDA
SP3-2-C	16-18	5.33E+00	MDA	2.21E-01	MDA	4.14	0.000	1.14E+01	6.83	3.43E-02	MDA
SP3-3-A	18-21	4.60E+00	MDA	2.07E-01	MDA	4.50	0.000	9.91E+00	6.69	3.87E-02	MDA
SP3-3-B	21-24	5.98E+00	MDA	1.46E-01	84.89	2.45	2.081	1.09E+01	5.77	3.16E-02	MDA
SP3-3-C	24-27	4.76E+00	MDA	2.06E-01	MDA	4.33	0.000	9.98E+00	6.41	3.33E-02	MDA
SP3-3-D	27-30	5.80E+00	MDA	2.00E-01	MDA	3.45	0.000	1.20E+01	5.74	3.74E-02	MDA

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Table 6. Radionuclide concentrations in SP4 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP4-1-A	0-4	2.77E+03	1.16	1.19E+02	1.08	4.31	0.068	1.55E+01	8.59	9.77E-01	12.48
SP4-2-A	4-7	1.05E+02	6.42	3.98E+00	7.96	3.79	0.388	1.07E+01	6.53	6.79E-02	MDA
SP4-2-B	7-10	1.98E+01	16.73	9.03E-01	17.32	4.55	1.096	7.34E+00	7.19	3.55E-02	MDA
SP4-2-C	10-13	8.57E+00	37.72	1.49E-01	19.88	1.73	0.739	6.38E+00	7.76	2.65E-02	MDA
SP4-2-D	13-16	4.48E+00	52.85	4.94E-01	21.78	11.02	6.297	7.83E+00	8.13	2.88E-02	MDA
SP4-3-A	16-19	5.47E+00	MDA	2.05E-01	52.30	3.75	1.963	1.29E+01	5.61	4.58E-02	MDA
SP4-3-B	19-22	4.67E+00	MDA	1.49E-01	90.01	3.20	2.876	1.19E+01	5.85	4.39E-02	MDA
SP4-3-C	22-25	4.75E+00	MDA	1.77E-01	MDA	3.73	0.000	1.15E+01	6.24	3.80E-02	MDA
SP4-3-D	25-28	6.72E+00	MDA	2.37E-01	MDA	3.53	0.000	1.13E+01	7.03	4.34E-02	MDA

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

radioactivity was detected from the top 8 in. of the core. The SP6 core was taken near the railroad track and east of the Decontamination Pad (Fig. 1). The soil had yellowish brown color with clay loam texture and contained limestone fragments throughout the soil core. Gamma spectroscopy showed that uranium contamination of the SP6 soil core was relatively lower than the SP5 soil core (Tables 7 and 8). Therefore, the 0- to 9-in. segment of the SP5 soil core was chosen for characterization.

Plant 6 Area: The initial sampling plan was to collect samples from the northeast side of Plant 6. An alternate area was selected because the proposed area was disturbed by construction activities. The SP7 and SP8 core sampling sites were located further north of the initially planned area (Fig. 1). The SP7 site was considerably contaminated by waste spills or dumping activities in the area (Table 9). However, the area selected for SP8 soil core was relatively undisturbed. The area was selected to obtain a soil sample which had been contaminated by airborne uranium waste. Therefore, the SP8 soil core was investigated in this phase of characterization. The SP8 soil had light brown color, well developed soil horizons, silt loam texture, and high organic matter content contributed by growing grass in the area for considerable time. The uranium contamination was limited to only a few inches below the surface (Table 10). Therefore, a composite soil sample was prepared by combining the top 3 in. from three soil cores.

Incinerator Area: The surface soil was contaminated by the past incinerating activities of the old primitive incinerator located in the area. The contaminated area was covered by fescue grass and three 12-in. cores per site were obtained from near the curb of the asphalt-paved driveway (Fig. 2). The SP9 sampling site was relatively closer to the old incinerator than the SP10 sampling site. Field survey results indicated that the level of surface soil contamination decreased with increasing distance from the incinerator (Tables 11 and 12). The soil core samples had a well developed Ap horizon with dark grayish brown color, fine granular structure, but had small limestone gravels throughout the cores. The top 3-in. segments of the SP9 cores were used for this investigation.

Table 7. Radionuclide concentrations in SP5 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP5-1-A	0-4	1.51E+02	4.94	6.92E+00	5.92	4.59	0.354	3.24E+00	14.27	3.65E-01	12.84
SP5-1-B	4-9	1.32E+02	6.38	6.63E+00	6.90	5.02	0.472	7.88E+00	7.55	1.83E-01	22.87
SP5-2-A	9-12	6.68E+00	12.45	3.22E-01	11.68	4.82	0.822	1.36E+01	1.33	1.13E-02	MDA
SP5-2-B	12-16	6.75E+00	14.93	3.22E-01	16.55	4.77	1.064	1.42E+01	1.61	1.60E-02	MDA

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Table 8. Radionuclide concentrations in SP6 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP6-1-A	0-4	9.30E+01	10.64	3.33E+00	16.78	3.58	0.71	1.23E+01	8.97	3.54E-01	24.90
SP6-1-B	4-8	1.35E+01	32.65	7.01E-01	23.95	5.20	2.11	1.21E+01	5.92	3.36E-02	MDA
SP6-1-C	8-12	8.84E+00	14.59	1.63E-01	27.88	1.84	0.58	1.32E+01	1.79	1.47E-02	MDA
SP6-2-A	12-16	2.86E+00	20.72	1.26E-01	22.81	4.41	1.36	1.36E+01	1.44	1.08E-02	MDA
SP6-2-B	16-20	2.85E+00	26.22	1.83E-01	18.62	6.44	2.07	1.32E+01	1.44	1.08E-02	MDA
SP6-2-C	20-24	2.13E+00	33.12	1.59E-01	19.48	7.48	2.87	1.34E+01	1.43	1.12E-02	MDA

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Table 9. Radionuclide concentrations in SP7 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP7-1-A	0-3	3.57E+02	4.19	1.84E+01	4.18	5.15	0.305	9.39E+00	10.53	3.03E-01	20.04
SP7-1-B	3-6	1.51E+02	6.98	7.91E+00	7.22	5.24	0.526	1.37E+01	8.12	7.69E-02	43.91
SP7-1-C	6-9	7.40E+01	8.34	3.10E+00	8.34	4.18	0.494	1.44E+01	5.37	5.66E-02	MDA
SP7-1-D	9-12	5.37E+01	9.84	2.77E+00	10.30	5.17	0.736	1.22E+01	5.68	3.38E-02	MDA
SP7-2-A	0-2	3.75E+02	1.09	1.78E+01	1.24	4.73	0.078	1.01E+01	2.97	3.01E-01	6.29
SP7-2-B	2-5	1.46E+02	1.54	7.39E+00	1.63	5.08	0.114	1.22E+01	1.81	1.51E-01	7.30
SP7-2-C	5-8	7.72E+01	1.96	3.63E+00	2.05	4.70	0.133	1.20E+01	1.65	1.39E-02	MDA
SP7-2-D	8-11	4.61E+01	5.12	2.05E+00	4.28	4.44	0.296	1.31E+01	2.66	1.95E-02	MDA
SP7-3-A	0-3	6.00E+02	3.28	2.91E+01	3.39	4.85	0.229	1.21E+01	12.50	7.36E-01	13.73

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Table 10. Radionuclide concentrations in SP8 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP8-1-A	0-2	7.60E+01	3.31	4.51E+00	2.41	5.94	0.243	1.52E+01	2.09	8.47E-01	2.96
SP8-1-B	2-5	3.02E+01	16.94	1.91E+00	13.26	6.34	1.364	1.38E+01	6.17	3.82E-01	12.79
SP8-1-C	5-8	1.41E+01	8.29	7.15E-01	7.34	5.08	0.566	1.49E+01	1.60	1.38E-01	7.89
SP8-1-D	8-11	5.92E+00	20.61	1.70E-01	30.04	2.87	1.045	1.60E+01	1.49	5.66E-02	MDA
SP8-2-A	0-3	6.30E+01	4.48	3.81E+00	3.67	6.05	0.350	1.43E+01	2.72	7.44E-01	3.49
SP8-2-B	3-6	1.38E+01	11.41	7.21E-01	10.68	5.20	0.813	1.40E+01	2.55	1.05E-01	10.63
SP8-2-C	6-9	6.64E+00	28.34	2.95E-01	24.18	4.44	1.656	1.47E+01	2.49	6.15E-02	29.64
SP8-2-D	9-12	7.05E+00	26.29	4.07E-01	24.25	5.78	2.066	1.55E+01	3.21	3.63E-02	MDA
SP8-3-A	0-3	6.85E+01	13.21	4.09E+00	13.39	5.97	1.122	1.42E+01	8.03	9.02E-01	10.08

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Table 11. Radionuclide concentrations in SP9 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP9-1-A	0-3	1.68E+03	1.80	8.17E+01	1.85	4.87	0.126	1.12E+01	9.86	6.31E-01	26.45
SP9-1-B	3-6	4.67E+02	3.68	2.53E+01	3.43	5.43	0.273	8.37E+00	11.69	4.61E-01	24.30
SP9-1-C	6-9	1.67E+02	6.13	8.90E+00	6.58	5.33	0.480	1.24E+01	7.15	1.33E-01	42.06
SP9-1-D	9-11	3.95E+01	3.60	2.10E+00	3.76	5.33	0.277	1.14E+01	1.99	4.86E-02	20.21
SP9-3-A	0-3	1.93E+03	1.84	9.42E+01	1.66	4.88	0.121	1.32E+01	10.04	7.70E-01	21.99
SP9-3-B	3-6	3.69E+02	3.62	1.97E+01	3.99	5.33	0.287	1.10E+01	7.11	2.58E-01	29.04
SP9-3-C	6-9	7.35E+01	9.33	3.41E+00	9.44	4.63	0.615	1.17E+01	6.60	7.74E-02	40.91
SP9-3-D	9-12	1.47E+01	22.36	1.56E+00	19.77	10.59	3.161	1.01E+01	7.45	7.80E-02	34.46

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Table 12. Radionuclide concentrations in SP10 soil core samples at varying depths

ID	Depth (in.)	^{238}U[a] (pCi/g)	1 sigma % error	^{235}U[b] (pCi/g)	1 sigma % error	%5/8 ActRatio	1 sigma % error	^{40}K[c] (pCi/g)	1 sigma % error	^{137}Cs[d] (pCi/g)	1 sigma % error
SP10-1-A	0-2	3.26E+02	4.51	1.71E+01	4.76	5.24	0.343	1.08E+01	9.47	5.12E-01	17.49
SP10-1-B	2-5	2.58E+02	4.24	1.31E+01	5.13	5.05	0.336	1.07E+01	8.15	3.85E-01	21.53
SP10-1-C	5-8	5.25E+01	10.39	2.52E+00	10.86	4.79	0.721	1.17E+01	6.28	1.38E-01	24.46
SP10-1-D	8-10	3.13E+01	4.65	1.68E+00	4.26	5.36	0.338	1.31E+01	1.77	8.40E-02	10.59
SP10-2-A	0-2	2.20E+02	1.43	1.16E+01	1.21	5.27	0.099	1.18E+01	2.19	4.89E-01	4.23
SP10-2-B	2-4	1.24E+02	2.14	6.14E+00	2.08	4.95	0.148	1.13E+01	2.27	3.48E-01	4.59
SP10-2-C	4-7	4.40E+01	3.40	2.20E+00	3.55	5.00	0.246	1.23E+01	1.71	1.37E-01	8.03
SP10-2-D	7-10	2.00E+01	3.86	9.67E-01	4.18	4.84	0.275	7.89E+00	1.53	5.99E-02	8.87

[a] ^{238}U activity based on the 100.00-keV (0.92%) gamma energy line for ^{234m}Pa.
[b] ^{235}U activity based on the 143.77-keV (10.50%) gamma energy line.
[c] ^{40}K activity based on the 1460.73-keV (10.70%) gamma energy line.
[d] ^{137}Cs activity based on the 661.65-keV (85.10%) gamma energy line.

Note: The natural 5/8 activity ration is 4.6% for 0.72% ^{235}U.
Normal atmospheric fallout from ^{137}Cs is around 1 pCi/g.

Soil Particle Size Distributions

The results of the particle size fractionation are in Table 13. The >2-mm gravel fractions were probably overestimated because of surface coating of finer materials on coarse fragments. The SP2-2 and SP2-3 samples had a similar particle size distribution pattern. Gravel fractions constituted about 56 to 59% by weight and other fractions were less than 20%. The SP4 sample had 8% gravel, 20% sand, 54% silt, and 18% clay that, if the gravel fraction is discounted, is similar to the surface texture of local loess soils (see reference soils). The SP5-1 sample had 54% gravel, 15% sand, 25% silt, and 16% clay, with the high gravel content reflecting the presence of the coarse slag materials in the soil surface layer. The surface soil of the SP8 sample had 34% sand, 47% silt, and 19% clay. This soil had a similar texture as the reference soils, indicating that the sampling area had been minimally disturbed (Table 13). The surface soil of the SP9 cores had 13% gravel, 21% sand, 53% silt, and 13% clay. The mixing with limestone gravel altered the soil texture somewhat, but the texture of the SP9 soil was similar to other less disturbed soils inside the plant.

The results of the particle size distribution suggest that (1) soils inside the plant boundary were highly disturbed from past construction activities; (2) most of the coarse fragments (>2 mm) were limestone that was used as fill, cover, and road construction materials; (3) the presence of limestone fragment is reflected in the relatively high pH of the surface soils in the sampling areas (Table 14); and (4) the weak alkaline pH and carbonate mineral availability would contribute to a high uranium concentration in perched water zones in the soils. The amounts of uranium, cation, and anions dissolved during size separation were given in Table 15.

Uranium Distribution with Particle Size in Soils

Analytical results of uranium in the soils (Table 13) were expressed in concentration of each fraction (μg/g) as well as contribution of each fraction to total soil concentration (%).

Table 13. Soil particle size distribution and uranium distribution with particle size of the soil samples

Soil Location	Size Fraction (mm)	% Particle Size	U Conc. (μg/g)	Particle Size Conc. (μg/g)	% U Contribution by Size Fraction
SP2-2-ABC	>4	48	134	64.32	8.21
SP2-2-ABC	4 - 2	11	297	32.67	4.17
SP2-2-ABC	2 - 0.053	14	1070	149.8	19.12
SP2-2-ABC	0.053 - 0.002	19	1990	378.1	48.27
SP2-2-ABC	<0.002	8	1980	158.4	20.22
SP2-3-ABC	>4	46	197	90.62	2.52
SP2-3-ABC	4 - 2	10	207	20.7	0.58
SP2-3-ABC	2 - 0.053	12	13900	1668	46.47
SP2-3-ABC	0.053 - 0.002	18	5290	952.2	26.53
SP2-3-ABC	<0.002	14	6130	858.2	23.91
SP4-1A/2A	>2	8	50.1	4.008	0.06
SP4-1A/2A	2 - 0.053	20	15900	3180	47.84
SP4-1A/2A	0.053 - 0.002	54	4560	2462.4	37.04
SP4-1A/2A	<0.002	18	5560	1000.8	15.06
SP5-1-AB	>4	39	159	62.01	13.61
SP5-1-AB	4 - 2	15	924	138.6	30.42
SP5-1-AB	2 - 0.053	25	653	163.25	35.83
SP5-1-AB	0.053 - 0.002	16	386	61.76	13.56
SP5-1-AB	<0.002	5	600	30	6.58
SP8-1A/2A/3A	2 - 0.053	34	283	96.22	46.78
SP8-1A/2A/3A	0.053 - 0.002	47	125	58.75	28.56
SP8-1A/2A/3A	<0.002	19	267	50.73	24.66
SP9-1A/3A	>2	13	791	102.83	2.71
SP9-1A/3A	2 - 0.053	21	8770	1841.7	48.47
SP9-1A/3A	0.053 - 0.002	53	2220	1176.6	30.97
SP9-1A/3A	<0.002	13	5220	678.6	17.86

Table 14. pH measurements of contaminated and reference soils

Sample Name	pH	Sample Name	pH
SP1-1-A	8.2	SP6-1-A	8.2
SP1-1-B	8.3	SP6-1-B	8.6
SP1-1-C	8.1	SP6-1-C	8.3
SP1-3-A	8.2	SP6-2-A	8.4
SP1-3-B	8.1	SP6-2-B	8.2
SP1-3-C	7.8	SP6-2-C	8.4
SP2-1-A	7.8	SP7-1-A	8.2
SP2-2-A	8.1	SP7-1-B	8.2
SP2-3-A	8.0	SP7-1-C	8.2
		SP7-1-D	8.2
SP3-1-A	8.3	SP8-1-A	6.1
SP3-1-B	8.4	SP8-1-B	6.9
SP3-2-A	8.1	SP8-1-C	7.3
SP3-2-B	8.4	SP8-1-D	7.6
SP3-2-C	8.5		
SP3-2-D	8.3	SP9-1-A	7.2
SP3-3-A	8.2	SP9-3-B	7.8
SP3-3-B	8.1	SP9-3-C	8.0
SP3-3-C	8.1	SP9-3-D	8.2
SP3-3-D	8.0		
SP4-1-A	7.9	SP10-1-A	7.3
SP4-2-A	8.3	SP10-1-B	7.6
SP4-2-B	8.4	SP10-1-C	8.0
SP4-2-C	8.5	SP10-1-D	8.3
SP4-2-D	8.2		
SP4-3-A	8.2	Henshaw	6.3
SP4-3-B	8.2	Fincastle	5.4
SP4-3-C	8.3		
SP4-3-D	7.6		
SP5-1-A	8.3		
SP5-2-A	7.9		
SP5-2-B	7.9		

Table 15. Uranium, cations, and anions dissolved during particle size separation

	Uranium (μg/g)	Al (μg/g)	Ba (μg/g)	Ca (μg/g)	Fe (μg/g)	Mg (μg/g)	Mn (μg/g)	P (μg/g)	Na (μg/g)	Sr (μg/g)	Alk (μg/g)	F (μg/g)	SO_4 (μg/g)
SP2-2-ABC	17.2	0	9.3	1404	0	128	0	11.6	26.1	3.7	812	0	0
SP2-3-ABC	214.9	0	12.5	1344	0	161	0	0	45.5	3.4	1330	126	0
SP4-1A/2A	145.3	0	13.2	1402	0	168	0	0	47.5	3.5	1241	113	0
SP5-1-AB	5.83	0	4.5	896	0	144	0	0	21.6	2.8	1080	0	295
SP8-1A/2A/3A[a]	0.61	43.0	12.9	1063	39.4	222	1.7	0	14.3	2.3	100	0	0
SP9-1A/3A[a]	1.22	38.6	8.1	934	22.5	174	0	32.2	16.1	1.5	354	0	0
Fincastle Soil[a]	0.40	0	28.1	756	0	144	8.3	0	0	2.5	0	0	0
Henshaw Soil[a]	0.01	0	15.0	807	0	147	0	0	110	2.6	0	0	0

[a]Uranium values for these soils are preliminary.

Note: A "0" value means not detected.

The gravel fractions (limestone fragments) of the SP2-2 and SP2-3 samples had low uranium contamination and their contribution to total uranium was less than 13%. The sand fraction of SP2-2 had a moderate level of contamination and contribution to total uranium concentration, but the sand fraction of SP2-3 contributed about 46% to the total soil uranium concentration, although the soil sample had only 12% sand by weight. On the other hand, the silt fraction of SP2-2 was the largest contributor of uranium to the soil, although the sample had only 19% silt by weight. The clay fractions of the both sample had a moderate contribution (20 to 24%).

The SP4 sample had the highest contamination among the samples (0.665%). The uranium contribution by the gravel fraction was minimal (0.06%). The sand fraction had the highest concentration (15.9 mg/g) as well as the highest contribution (48%) to the total uranium in the soil. The silt and clay fraction had a considerable amount of uranium but their contributions were lower than the sand fraction (Table 13).

The uranium distribution pattern of the SP5 sample was distinctively different from other samples. The SP5 sample had a large amount of gravel fractions (54%) and the gravel fractions were the major uranium contributor (44%). The second largest contributor was the sand fraction (36%). In other samples, gravel fractions were minor uranium contributors regardless of the amount of limestone gravel in the soil.

The uranium concentration of the SP8 sample was the lowest among the samples, but it was still much higher than the background level. The sand and clay fractions had a higher concentration than that of the silt fraction. The sand fraction contributed about 47% of the total uranium in the soil. The uranium distribution in the SP9 size fractions was similar to other samples such as SP4 and SP8. The sand fraction had a higher uranium concentration and was a major contributor although it was a minor size fraction of the soil.

The results of the uranium distribution with size fractions indicate that (1) the majority of uranium in the soils was as individual discrete particles or as smaller particles cemented to silt, sand, and gravel fractions rather than an adsorbed form on clay minerals;

(2) the dominant size fraction for uranium contribution would be sand for the SP2-3, SP4, SP8, and SP9, silt for the SP2-2, and gravel for the SP5; and (3) separation and removal of a particular size range would not help a great deal for the waste volume reduction for most samples except the separation of the gravel fraction from the SP2 soil.

Microscopic Analyses

Polished sections of soil aggregates embedded in epoxy resin were examined by SEM and EDX. Most of the uranium containing clumps in the SP2 samples consisted of aggregates of fine silt or clay particles. The uranium containing aggregates were composed of silicon, aluminum, calcium, phosphorous, and iron (Plate 1 and 2). In the micrographs, individual uranium particles are brighter than silicate minerals. The SP4 specimen contained a wide variety of sizes and shapes of particles containing uranium (Plates 3 and 4). Some particles were composed entirely of uranium and others had iron, calcium, and/or silicon.

The slag material in the SP5 samples was the major source of uranium. Uranium occurred as a coating on the slag surface or as an occluded form in the calcium silicate matrix (Plates 5, 6, and 7). Silicon and calcium were the major elemental components in the slag matrix (Plate 5). The presence of occluded uranium in the slag would cause problems for the development of a decontamination strategy. The uranium-rich particles were much less abundant in the SP8 specimen. Most of the uranium particles were aggregated with silicate minerals. Phosphorous was commonly associated with the uranium particles (Plate 8). Numerous uranium particles having different morphology and composition were observed from the SP9 specimen (Plates 9, 10, and 11). Calcium and phosphorous were detected in some of the particles. Other particles had only uranium (possibly uranium oxides). Some of the particles were mixed with silicate particles as an aggregate form and others were a form of grain separated from a silicate matrix.

Heavy Liquid Separation

The soil samples (<2 mm) were treated with CBD solution to remove amorphous iron coatings. The CBD treatment removed some of the uranium associated with coatings and precipitated/adsorbed on the surface of soil particles (see Chemical Leaching Experiment section). The removal of iron coatings and disaggregation of soil clays would assist in evaluating the effectiveness of heavy liquid separation and mineralogical analysis of the soils. The results of the heavy liquid separation are given in Table 16.

Table 16. Weight and uranium distribution of sand-size fractions after heavy liquid density separation in lithium metatungstate solution with a density 2.8 g/mL.

Sample	Fraction	Weight Distribution (%)	Uranium Distribution (%)
SP2-2-ABC	Floating	83	49
	Heavy	17	51
SP2-3-ABC	Floating	79	64
	Heavy	21	36
SP4-1A/2A	Floating	63	30
	Heavy	37	70
SP9-1A/3A	Floating	82	49
	Heavy	18	51

The data presented in the table were the first separation test results for the sand-sized fraction in the lithium metatungstate solution at density 2.8 g/mL. The separation

procedure such as solid to liquid ratio, tube size, and liquid density will be modified for future experiments. The weight percent of heavy (sink) fractions varied from 17 to 37% and the percent of contribution by the heavy fraction to total concentration varied from 36 to 70%. The results indicated that the heavy liquid density separation is a relatively effective method for the removal of uranium containing particles from the soils. However, the method may not be practical for massive amounts of soils in an engineering scale. Therefore, a new separation technology based on the difference of particle density should be developed for this ID program. Readjustment of the procedure after microscopic and X-ray diffraction examination of the heavy fraction would improve the separation. The heavy liquid separation will be continued for silt and clay fractions and the results will be reported in the final report of this Phase 1 Characterization project.

Mineralogical Analyses

For mineralogical analysis, clay fractions of the soil samples were separated from sand and silt fractions after CBD treatment by the centrifugation method of Jackson (1975). The six contaminated soils had very similar clay mineral compositions. The X-ray diffraction patterns (XRD) of the contaminated soil clays were remarkably similar to those of the Fincastle and Henshaw clay samples. The XRD patterns of clay fractions from SP4-1A/2A and Henshow soils were shown in Fig. 4 as examples. The XRD after magnesium and ethylene glycerol solvation showed very weak 18-, 14-, 10-, 7-, and 3.34-Å peaks with other second order peaks. After heating K saturated samples to 550°C, the 7-Å peak disappeared. The XRD results indicated that the clay fractions were composed of smectite, vermiculite, mica, kaolinite, and quartz. Swelling clays consisting of smectite and vermiculite were a minor component in the soils. Since clay minerals control many chemical and physical properties of soil, clay mineral composition could influence treatability of soils, dewatering after soil washing, and disposal of secondary waste. Since the clay mineral composition of all core samples was similar, these soil clays should respond about the same to decontamination treatments.

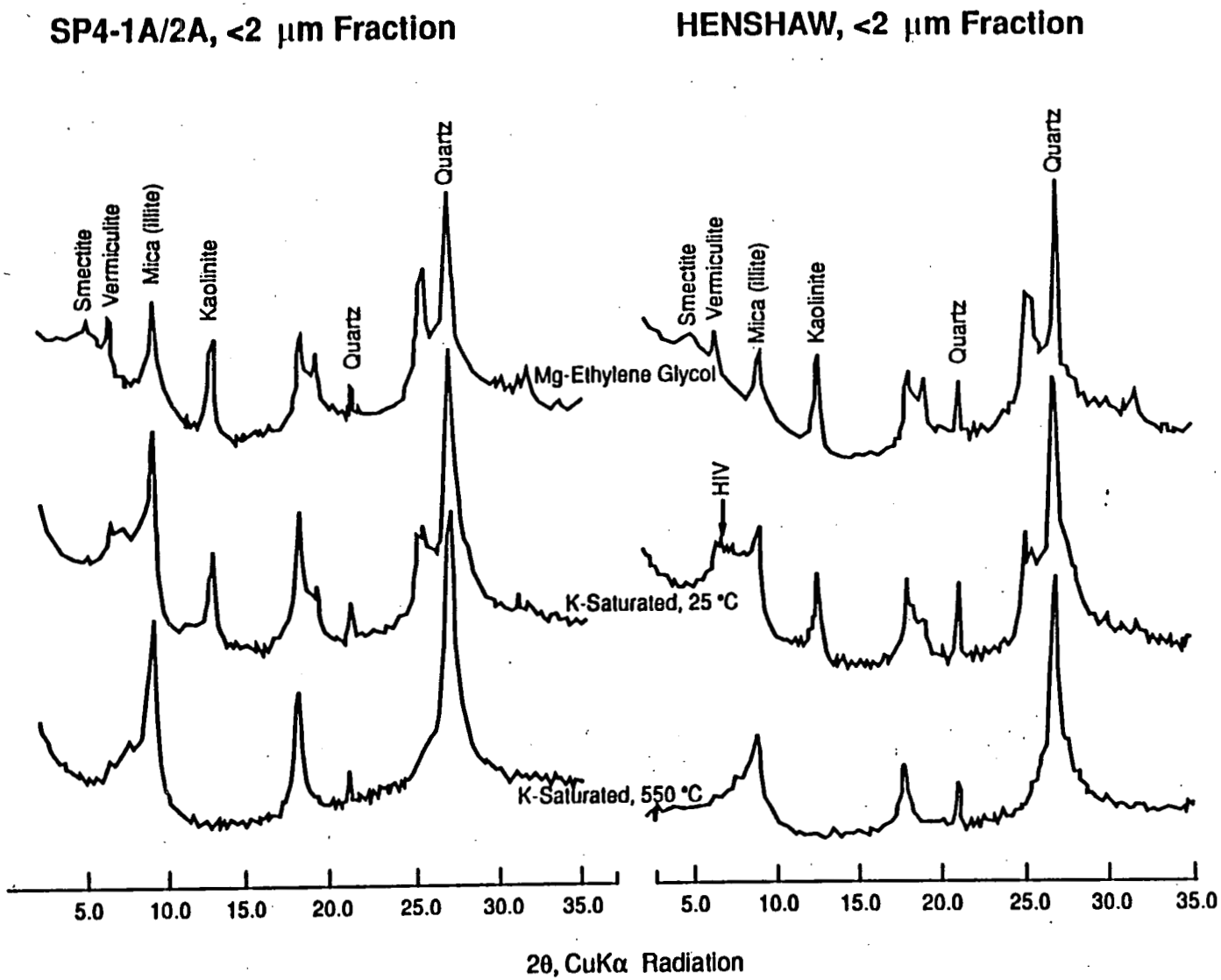

Figure 4. XRD of clay fractions of SP4-1A/2A and Henshaw soils

Chemical Leaching Experiments

The chemical leaching experiments were conducted to provide general information to the Treatability Task Group. The mild acid (0.1 *N* nitric acid) treatment would remove uranium precipitates on the soil mineral surfaces and dissolve some uranium associated with carbonates. However, the mineral acid treatment was not effective because the contaminated soils contained too many limestone gravels (Table 17). The hydroxylamine hydrochloride treatment would remove uranium associated with manganese coatings in the contaminated soils. The nominal effectiveness of this treatment suggested that extraction of manganese would not have an effect on uranium leaching. Sodium hypochlorite is an effective oxidant for a reduced form of uranium. Oxidation of the reduced uranium would promote leaching by inducing complexation with soil carbonates. The experimental results showed some positive but minimal effects. EDTA is a well known chelating ligand for metals. The treatment was very effective for the SP4 soil sample but was not effective for the other soil samples. CBD treatment is a standard method for removing amorphous sesquioxides (iron and aluminum) in soils. As expected, considerable amounts of uranium (10 to 30%) were removed by this treatment. The bicarbonate and citrate in the solution could be complexed with uranium when the sesquioxides were dissolved by the treatment. The citric acid and ammonium carbonate treatments were the most effective, particularly for the SP4, for removing uranium. Urnium in the soils might be dissolved from solid phase by the citric acid and then complexed as citrate. The excess carbonates in the ammonium carbonate solution would promote complexation of uranium in the contaminated soils.

SUMMARY AND RECOMMENDATIONS

The Phase I soil sampling and characterization task was established by the Characterization Group to obtain basic information related to soil properties and the nature of uranium contamination. The results of this preliminary investigation were intended for (1) the selection of contaminated soils for use in treatability studies, (2) the selection of a field demonstration area or areas within Operable unit 3, and (3) the preliminary screening of integrated decontamination technology.

Table 17. Percent extractable uranium and total uranium concentrations in the soil samples

Sample ID	pH	Extractants							Total U ($\mu g/g$)
		0.1 N HNO_3 1.7	0.1M $NH_3OH \cdot HCl$ 2.4	2% Citric Acid 2.5	0.1M EDTA 4.6	2% $(NH_4)2CO_3$ 9.5	5% NaOCl 11.7	CBD 8.5	
SP2-2-ABC		2.32	2.09	32.04	1.77	21.66	7.82	28.83	2220
SP2-3-ABC		3.77	2.59	32.05	3.18	20.20	7.11	29.76	2970
SP4-1A/2A		12.43	23.51	74.86	45.41	48.78	25.27	31.28	5920
SP5-1-AB		8.43	6.12	20.45	8.96	9.79	5.58	11.27	575
SP8-1A/2A/3A		14.71	0.11	32.36	9.04	47.14	34.57	27.68	224
SP9-1A/3A		6.31	0.03	43.55	5.44	14.12	6.06	25.10	5290

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Ten soil sampling locations were selected from five different areas: Plant 2/3 area, storage Pad Area, Decontamination Pad/Drum Baling Area, Plant 6 Area, and Incinerator Area (Figs. 1 and 2). After examining general soil properties such as pH, texture, morphology, and radionuclide survey by gamma scanning, five sampling locations (SP2, SP4, SP5, SP8, and SP9) representing each area were selected for detailed characterization. Surface soil samples with varying depths were prepared for characterization because of a higher uranium contamination, except the SP2 location. Two subsurface soil samples were selected from SP2 core, one from 10 to 20 in. (SP2-2) and from 20 to 31 in. (SP2-3). Two reference soils representing undisturbed plant area soils were also collected from about 1 to 2 miles west of Fernald Operation Site (Fig. 3).

Selection of Contaminated Soils for Use in Treatability Studies and Demonstration Areas

Three areas, Plant 2/3 represented by SP1 and SP2 samples, Plant 1 Drum Storage Area representing by SP3 and SP4 samples, and Incinerator Area representing SP9 and SP10 samples, have potential to be used for treatability studies. The other two areas, Decontamination Pad/Drum Baling Area and Plant 6 area investigated, are not good candidates because the uranium concentration is too low for technology evaluation and/or the depth of contamination is too shallow for excavation without mixing with uncontaminated soils. In addition, the presence of contaminated slag material in the Decontamination Pad/Drum Baling Area would be a negative element for the effectiveness of decontamination demonstration.

Plant 2/3 Area: The history of contamination, depth of contamination, and nature of contamination suggested that the area was contaminated by aqueous uranium waste. However, the characterization results indicated that silt and sand size fractions were the major uranium contributor in the soil. The microscopic analysis and density separation also indicated that some of the uranium in the soil was in particulate form having a density higher than 2.8 g/mL. Leaching experiment showed relatively low uranium extractabilty although the uranium particulates appeared as amorphous precipitate forms (Plates 1 and 2). EDX analysis showed that most uranium-containing particles also had calcium and phosphorous as elemental components. Since the contaminated zone had a fairly high

content of slightly contaminated but easily cleaned limestone gravel, a combination of extraction and physical size separation treatment would achieve more than 60% of waste volume reduction.

Plant 1 Drum Storage Area: The area was suspected to be contaminated by uranium product spills. As expected, the nature of the contamination is very complex. More than 80% of uranium was associated with sand and silt fractions coprising about 74% of the soil. However, the citric acid and ammonium carbonate solutions were able to extract about 75 and 49% of uranium from the soil, respectively (Table 17). The uranium particles were associated with iron, calcium, phosphorous, and silicon (Plate 3). Others had only uranium (oxide or metallic ?) (Plate 4). Density-based separation was also successful in isolating uranium-containing heavy particles from the sand fraction (Table 16). This is an excellent candidate area for demonstration of decontamination technologies based on chemical extraction and density separation.

Incinerator Area: This area was suspected to have been contaminated by airborne uranium material. As expected, uranium-containing particles having different composition, shape, and sizes were in the soil samples collected from the area (Plates 9, 10, and 11). Chemical leaching of uranium by citric acid was moderately effective (43%) but was not very effective by ammonium carbonate solution (14%) (Table 17). Heavy liquid density separation was also moderately effective (Table 16). It will be a very difficult engineering challenge to remove uranium or reduce waste volume because the most abundant size fractions (sand and silt) had the most uranium (79% of total uranium) in the soil.

Preliminary Screening of Integrated Technology

Preliminary leaching test results indicated that (1) citric acid dissolution/complexation and carbonate complexation were the most effective methods for removing adsorbed or leachable uranium in the contaminated soils, (2) oxidant and inorganic mineral acid were the least effective leachate solutions, (3) the amount of extracted uranium did not correlate with either total amounts of uranium in soils or in clay fractions. Therefore, chemical extraction alone cannot be expected to accomplish soil remediation. Particle size

distribution and uranium distribution with particle size fractions suggested that simple size separation would not always be effective for waste volume reduction. However, density-based separation showed some degree of success for removing uranium-containing particles. Therefore, the integrated technology to be developed should be based on both chemical extraction and physical separation technologies.

Characterization Group: (1) need more sampling and characterization to verify the preliminary investigation results (e.g., soil samples underneath structures); (2) should investigate on-going geochemical processes to evaluate decontamination impacts; (3) should establish sample preparation and analytical methods as a part of the QA procedure; and (4) should prepare evaluation protocol for the treatment effectiveness and secondary waste disposal technology.

Treatability Group: (1) technologies should be able to remove both particulate form and leachable forms of uranium in these soils, (2) proposed technologies should recycle leaching solution after removal of uranium, (3) should prepare several decontamination schemes reflecting the area specific conditions, and (4) decontamination products to be returned to the site should not include a carbonate source.

Excavation Group: (1) need development of a depth sensing remote control devise to remove the contaminated surface soils (<8 in.).

Risk Assessment and Regulation Group: (1) need early establishment of a lower limit of uranium concentration for candidate soils and upper limit for treated soil to be returned to the field.

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APPENDIX

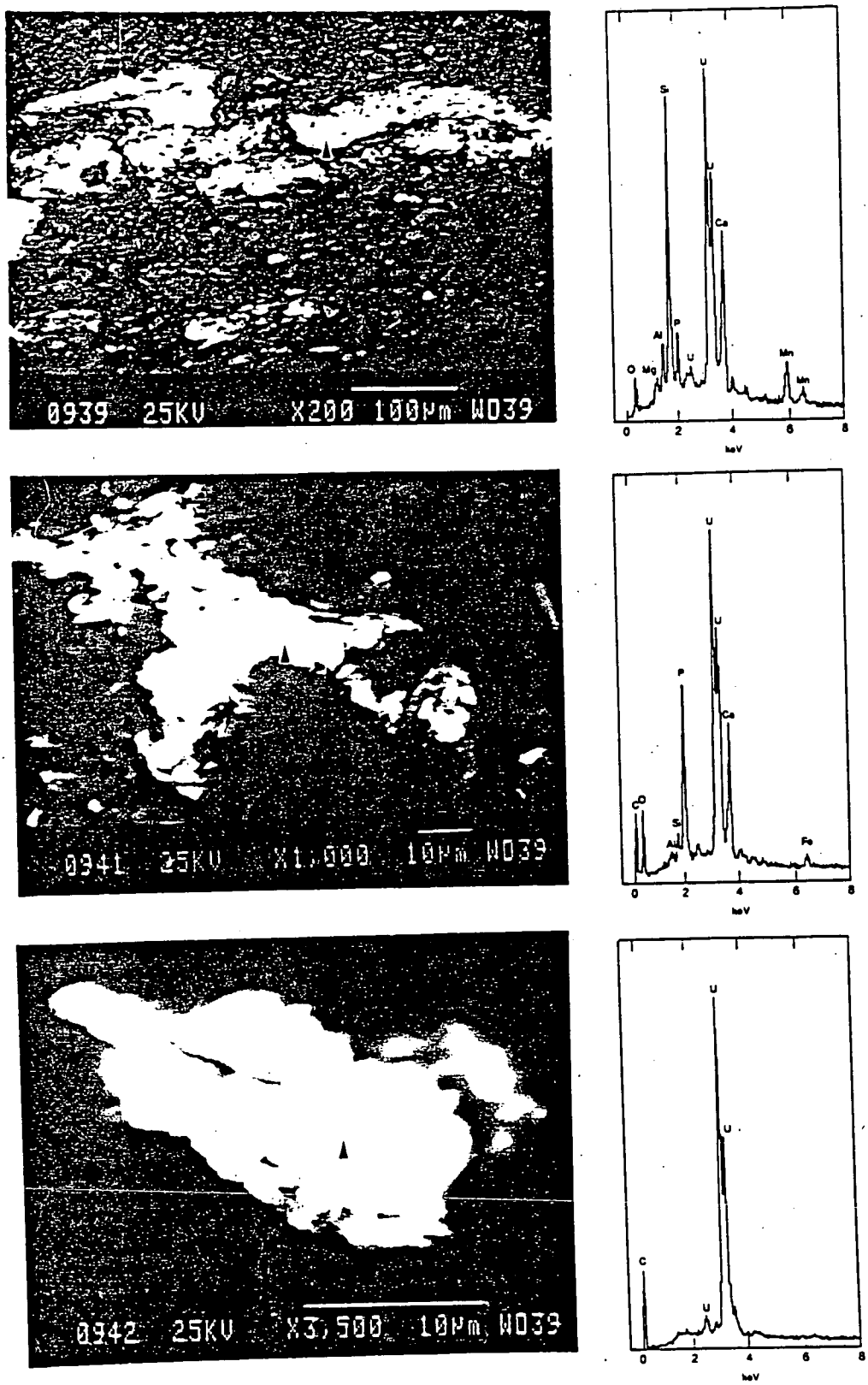


Plate 1. SEM and EDX of uranium-containing particles from SP2 soil sample.

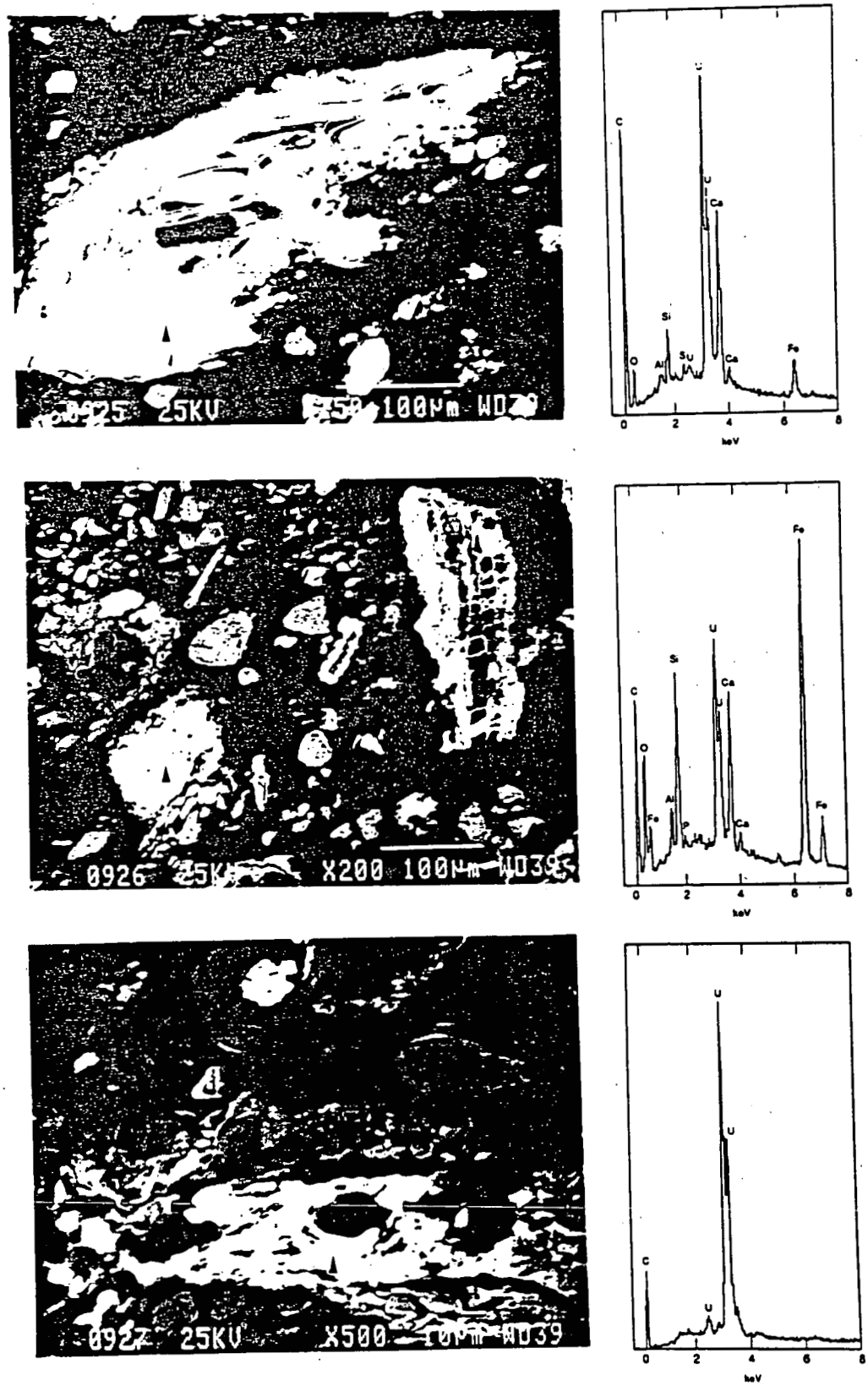


Plate 2. SEM and EDX of uranium-containing particles from SP4 soil sample.

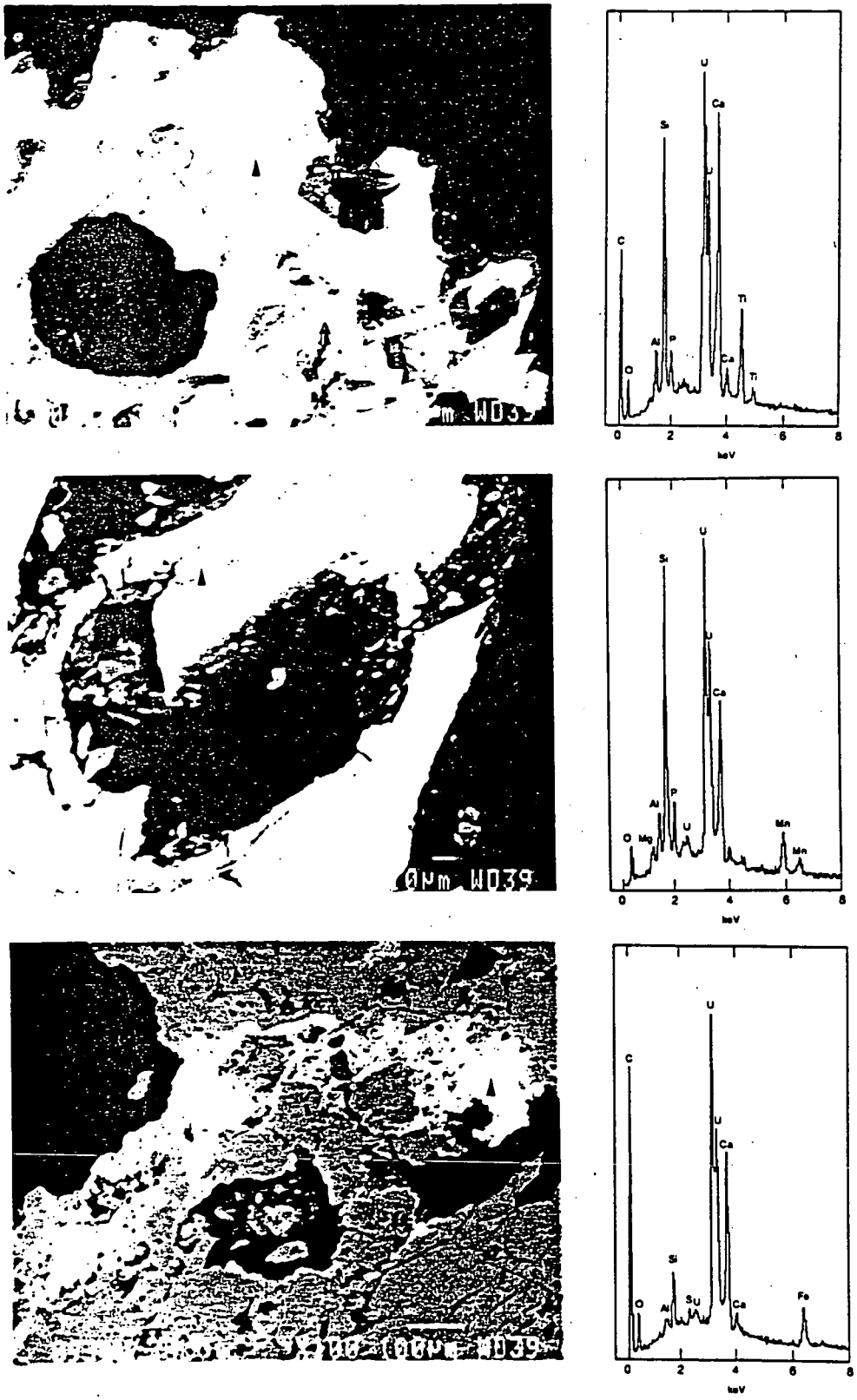
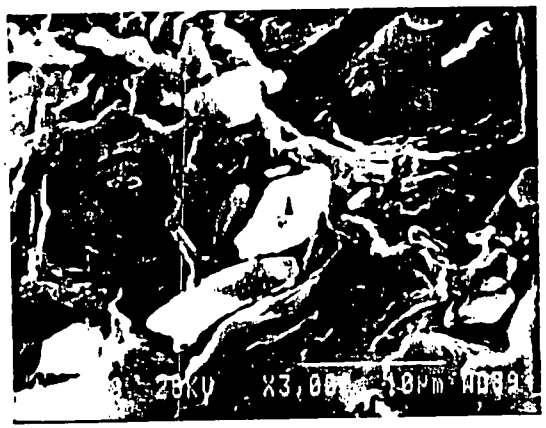
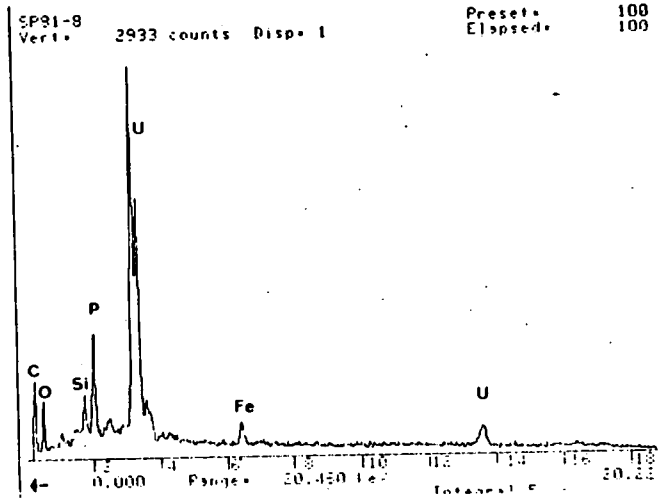
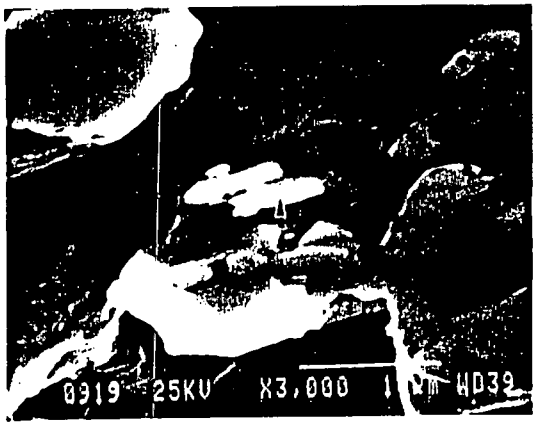


Plate 3. SEM and EDX of uranium-containing particles from SP5 soil sample.







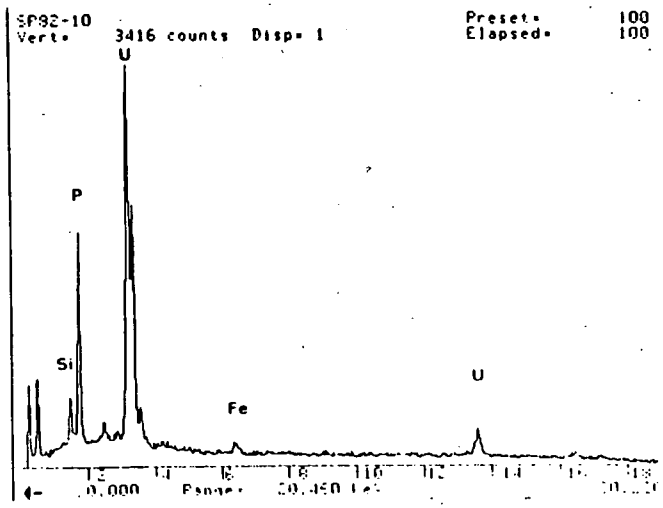


Plate 4. SEM and EDX of uranium-containing particles from SP8 soil sample.

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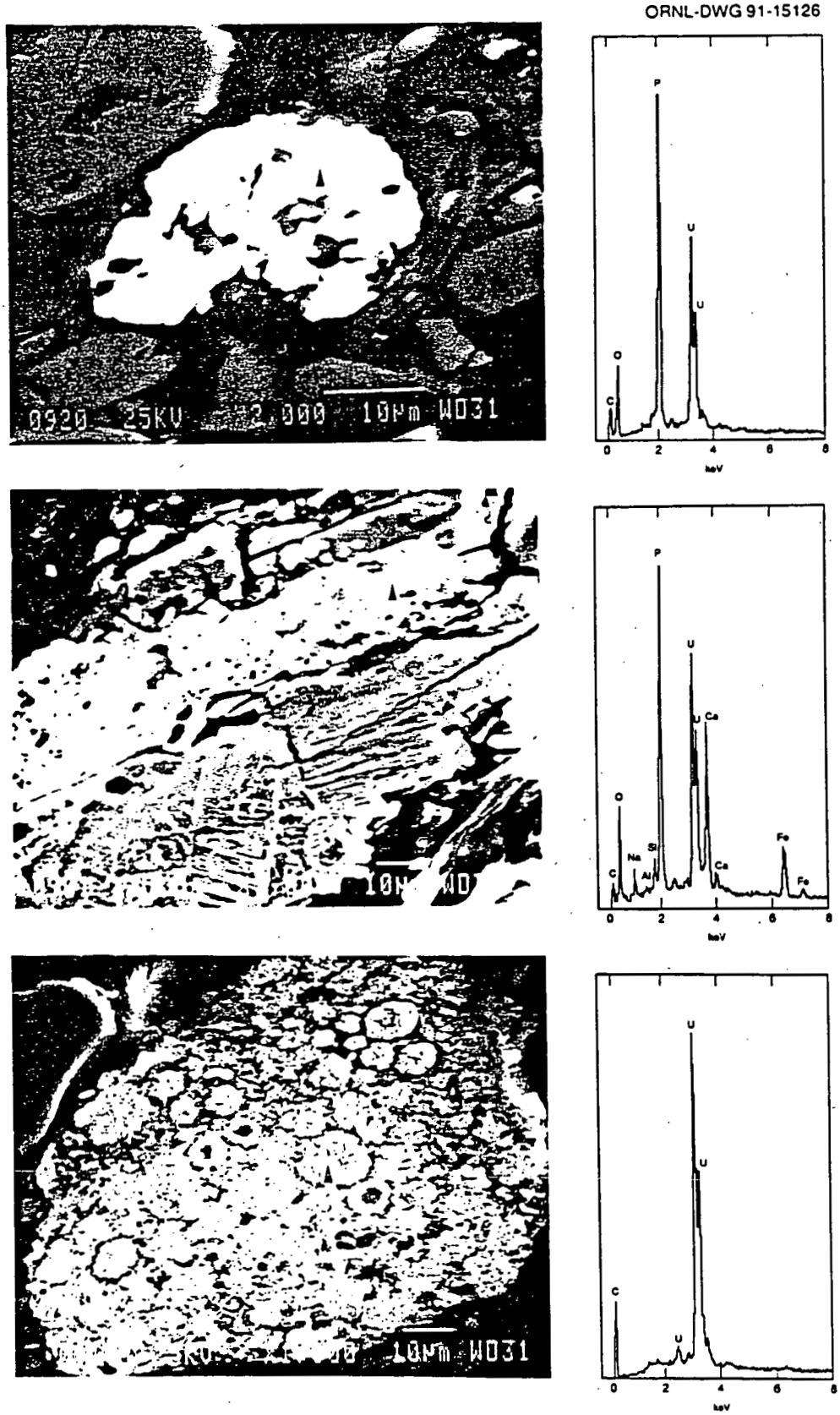

Plate 5. SEM and EDX of uranium-containing particles from SP9 soil sample.

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94. M. Fuhrmann, Brookhaven National Laboratory, Building 703M, Upton, NY 11973
95. A. Gatchett, RREL, 26 W. Martin Luther King Drive, Cincinnati, OH 45268
96. Richard Gay, Rockwell International, 6633 Canoga Avenue, Canoga Park, CA 91303
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100. J. Gnosse, WEMCO/FEMP, P. O. Box 398704, Cincinnati, OH 45239-8704
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105. B. F. Harvey, 6120 South Gilmore Road, Fairfield, OH 45014
106. J. Haugen, U.S. Department of Energy, Chicago Field Office, 9800 South Cass Avenue, Argonne, IL 60439
107. K. Hayes, U.S. Department of Energy, EM-424, 12800 Middlebrook Road, Germantown, MD 20874
108. M. A. Heiskell, DOE/ORD, Waste Management Division (EW92), 200 Adminstration Road, Oak Ridge, TN 37831-8620
109. J. E. Helt, Ph.D., Director, Office of Waste Management Programs, 9700 South Cass Avenue, Argonne, IL 60439-4837
110. J. M. Hennig, U.S. Department of Energy, Richland Field Office, 825 Jadwin Avenue, P. O. Box 550, MS A5-21, Richland, WA 99352
111. D. Herman, WEMCO/FEMP, P. O. Box 398704, Cincinnati, OH 45239-8704
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115. J. Hyde, U.S. Department of Energy, EM-55, 12800 Middlebrook Road, Germantown, MD 20874
116. D. Jacoboski, WEMCO/FEMP, P. O. Box 398704, Cincinnati, OH 45239-8704
117. R. Jacobson, Ph.D., University of Nevada, Water Resources Center, Suite 1, 2505 Chandler Avenue, Las Vegas, NV 89120
118. S. James, RREL, 26 W. Martin Luther King Drive, Cincinnati, OH 45268
119. R. J. Janke, U.S. Department of Energy-FO, P. O. Box 398705, Cincinnati, OH 45239-8705
120. G. Y. Jordy, Director, Office of Program Analysis, Office of Energy Research, ER-30, G-226, U.S. Department of Energy, Washington, DC 20545
121. P. G. Kaplan, Division 6312, Sandia National Laboratory, Albuquerque, NM 87185
122. T. R. Kato, WEMCO/FEMP, P. O. Box 398704, Cincinnati, OH 45239-8704
123. K. Koller, EG&G Idaho, Inc., P. O. Box 1625, Idaho Falls, ID 83402-3970
124. M. Krsitch, IT Corporation, 312 Directors Drive, Knoxville, TN 37923
125. D. Layton, Lawrence Livermore National Laboratory, P. O. Box 5507 (L-453), Livermore, CA 94550
126. D. Maiers, EG&G Idaho, Inc., Technology Development Dept., P. O. Box 1625, Idaho Falls., ID 83415-3940
127. L. W. McClure, Westinghouse Idaho Nuclear Company, Inc., P. O. Box 4000, Idaho Falls, ID 83403-4000
128. T. McEvilly, 5OE-111, Lawrence Berkeley Laboratory, 1 Cyclotron Road, Berkeley, CA 94720
129. K. Merrill (Acting), EG&G Idaho, Inc., P. O. Box 1625, Idaho Falls, ID 83415-3970
130. E. Merz, Waste Policy Institute, 12850 Middlebrook Road, Germantown, MD 20874
131. J. Mohiuddin, BDM Int., 12850 Middlebrook Road, Germantown, MD 20874
132. J. O. Moore, TPO, U.S. Department of Energy, Oak Ridge Operations Waste Management, P. O. Box 2001, Oak Ridge, TN 37831-8620
133. D. Morris, LANL-INC-4, MS C346, P. O. Box 1663, Los Alamos, NM 87545

134. H. D. Murphy, ET-AET, Los Alamos National Laboratory, MS D446, Los Alamos, NM 87545
135. M. Nickelson, HAZWRAP, P. O. Box 2003, Oak Ridge, TN 37831-7606
136. T. Noble, Center for Advanced Technology Development, Iowa State University, Ames, IA 50011
137-139. K. Nuhfer, WEMCOP/FEMP, P. O. Box 398704, Cincinnati, OH 45239-8704
140. R. Olexsey, RREL, 26 Martin Luther King Dr., Cincinnati, OH 45268
141. R. H. Olsen, Vice President for Research, University of Michigan, Medical Science Building II, #5605, 1301 East Catherine Street, Ann Arbor, MI 48109-0620
142. M. O'Rear, U.S. Department of Energy, Savannah River Field Office, RFD #1, Building 703A, Room E208 North, P. O. Box A, Aiken, SC 29802
143. A. Patrinos, Acting Director, Environmental Sciences Division, Office of Health and Environmental Research, ER-74, U.S. Department of Energy, Washington, DC 20585
144. R. W. Perkins, PNL, Battelle Boulevard, Richland, WA 99352
145. D. L. Perry, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720
146. M. Peterson, Battelle Pacific NW Laboratory, P. O. Box 999, MSINP7-41, Richland, WA 99352
147. F. Poucher, Energy Programs & Advanced Planning, P. O. Box 1449-D/6222, T038, 6633 Canoga Avenue, Canoga Park, CA 91304
148. L. Rogers, EG&G/EM, P. O. Box 1812, Las Vegas, NV 89125
149. R. R. Ryan, LANL-INC-4, MS C346, P. O. Box 1663, Los Alamos, NM 87545
150. J. Sattler, WEMCO/FEMP, P. O. Box 398704, Cincinnati, OH 45239-8704
151. P. A. Saxman, TPO/AL, U.S. Department of Energy, P. O. Box 5400, Albuquerque, NM 87115
152. A. Schilk, PNL, Nuclear Chemistry Department, Battelle Boulevard, Richland, WA 99352
153. J. Schnoor, 1134 Engineering Building, University of Iowa, Iowa City, Iowa 52242
154. J. Schwing, WEMCO/FEMP, P. O. Box 398704, Cincinnati, OH 45239-8704
155. R. S. Shirley, WEMCO/FEMP, P. O. Box 398704, Cincinnati, OH 45239-8704
156. S. C. Slate, Pacific Northwest Laboratory, MSIN KI-25, Office of Environmental Tech., P. O. Box 999, Richland, WA 99352
157. R. Snipes, Martin Marietta-HAZWRAP, P. O. Box 2003, Oak Ridge, TN 37831-7606
158. S. Spence, Kaiser Engineering, MS E6-22, P. O. Box 888, Richland, WA 99352
159. R. Stead, WEMCO/FEMP, P. O. Box 398704, Cincinnati, OH 45239-8704
160. J. L. Steele, P.E., Waste Environmental Remediation Programs, Savannah River Site, SRL, 733A, A208, Aiken, SC 29802
161. S. Stein, Deputy General Manager, Environmental Management Organization, Pacific Northwest Division, 4000 N.E. 41st Street, Seattle, WA 98105
162. K. Stevenson, U.S. Department of Energy, 376 Hudson Street, New York, NY 10014-3621
163. R. S. Stiger, Waste Technology Development, EG&G Idaho, Inc., P. O. Box 1625, Idaho Falls, ID 83415-3940
164. T. M. Sullivan, Brookhaven National Laboratory, Building 830, Upton, NY 11973
165. R. E. Swatzell, HAZWRAP, P. O. Box 2003, Oak Ridge, TN 37831-7606

166. J. Throckmorton, ASI, P. O. Box 475, Ross, OH 45061-0475
167. V. C. Tidwell, Sandia National Laboratory, MS 6315, P. O. Box 5800, Albequerque, NM 87185
168. J. Tipton, Assistant Operations Manager, Remote Sensing Laboratory, P. O. Box 1912, MS D-12, Las Vegas, NV 89125
169. A. E. Torma, EG&G Idaho, Inc., P. O. Box 1625, Idaho Fall, ID 83415-3940
170. L. D. Tyler, Sandia National Laboratory, Division 6621, Box 5800, Albuquerque, NM 87185
171. R. Tyler, U.S. Department of Energy, Rocky Flats Office, DOE Building 116, Golden, CO 80402-0928
172. C. L. Valle, Allied Signal Aerospace, Kansas City Plant, P. O. Box 419159, D/272, FV43, Kansas City, KS
173. E. M. Van Eeckhout, Los Alamos National Laboratory, P. O. Box 1663, Los Alamos, NM 87545
174. G. Voelker, U.S. Department of Energy, EM-55, 12800 Middlebrook Road, Germantown, MD 20874
175. T. L. Walton, Westinghouse SRC, SRL, P. O. Box 616, Aiken, SC 29802
176. P. Wichlacz, EG&G Idaho, Inc., P. O. Box 1625, MS 3940, Idaho Falls, ID 83415
177. F. J. Wobber, Environmental Sciences Division, Office of Health and Environmental Research, ER-74, U.S. Department of Energy, Washington, DC 20585
178. S. Wolinsky, ASI, P. O. Box 475, Ross, OH 45061-0475
179. J. L. Yow, P. O. Box 808, 7000 East Avenue, MS L-207, Livermore, CA 94550
180. C. Zeh, Morgantown Energy Technology Center, 3610 Collins Ferry Road, Morgantown, WV 26507-0880
181. Office of Assistant Manager for Energy Research and Development, Oak Ridge Operations, P. O. Box 2001, U.S. Department of Energy, Oak Ridge, TN 37831-8600

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APPENDIX F
LIST OF ORGANIC ANALYTES FOR TCLP AND HSL ANALYSES

FULL HSL - ANALYTICAL PARAMETERS

PESTICIDES/PCBs

4,4'-DDD
4,4'-DDE
4,4'-DDT
Aldrin
alpha-BHC
alpha-Chlordane
Aroclor 1016
Aroclor 1221
Aroclor 1232
Aroclor 1242
Aroclor 1248
Aroclor 1254
Aroclor 1260
beta-BHC
delta-BHC
Dieldrin
Endosulfan sulfate
Endosulfan-I
Endosulfan-II
Endrin
Endrin aldehyde
Endrin ketone
gamma-Chlordane
Heptachlor
Heptachlor epoxide
Methoxychlor
Toxaphene

VOLATILE ORGANICS

1,1-Dichloroethane
1,1-Dichloroethene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
1,1,2,2-Tetrachloroethane
1,2-Dichloroethane
1,2-Dichloroethene (total)
1,2-Dichloroethylene
1,2-Dichloropropane
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
cis-1,3-Dichloropropene
Dibromochloromethane
Ethylbenzene
Methylene chloride
Styrene
Tetrachloroethene
Toluene
Total xylenes
trans-1,3-Dichloropropene

SEMIVOLATILE ORGANICS

1,2-Dichlorobenzene
1,2,4-Trichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methylphenol
2-Nitroaniline
2-Nitrophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,6-Dinitrotoluene
3-Nitroaniline
3,3'-Dichlorobenzidine
4-Bromophenyl phenylether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl-phenylether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
4,6-Dinitro-2-methylphenol
Acenaphthene
Acenaphthylene
Anthracene
Benzoic acid
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Benzyl alcohol
bis(2-Chloroethoxy)methane
bis(2-Chloroethyl)ether
bis(2-Chloroisopropyl) ether
bis(2-Ethylhexyl)phthalate
Butyl benzyl phthalate
Carbazole
Chrysene
Dibenzofuran
Dibenzo(a,h)anthracene
Diethylphthalate
Dimethylphthalate
Di-n-butyl phthalate
Di-n-octyl phthalate
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Naphthalene
Nitrobenzene
N-Nitroso-di-n-propylamine
N-Nitrosodiphenylamine
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Phenanthrene
Phenol
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