# U.S. Department of Energy

Oakland Operations Office, Oakland, California

# FINAL
# SAMPLING AND ANALYSIS PLAN FOR THE DOE DISPOSAL BOX AREA CONFIRMATION DATA GAPS

at the

LABORATORY FOR ENERGY-RELATED HEALTH RESEARCH
UNIVERSITY OF CALIFORNIA, DAVIS

*Prepared for:*

**United States Department of Energy**
Oakland Operations Office
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*Prepared by:*

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April 5, 2002
Rev. 0

DOE Oakland Operations Contract DE-AC03-96SF20686

Weiss Associates
Environmental Science, Engineering and Management

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# APPENDIX

Appendix A. DOE Box Area Confirmation Data Gaps Sampling Design

Appendix B. Soil Quality Control Blank Preparation Procedure

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| bgs | below ground surface |
| COC | Constituents of Concern |
| DOE | United States Department of Energy |
| EPA | United States Environmental Protection Agency |
| ft | foot/feet |
| HDPE | high-density polyethylene |
| ID | identification (number) |
| LEHR | Laboratory for Energy-Related Health Research |
| pCi/g | picoCuries per gram |
| QA/QC | quality assurance/quality control |
| QAPP | Quality Assurance Project Plan |
| RA | removal action |
| Ra-226 | radium-226 |
| SAP | Sampling and Analysis Plan |
| SOP | Standard Operating Procedure |
| Sr-90 | strontium-90 |
| WA | Weiss Associates |

# 1. INTRODUCTION

This Sampling and Analysis Plan (SAP) is designed to address confirmation data gaps at the United States Department of Energy (DOE) Disposal Box Area (DOE Box Area) at the Laboratory for Energy-Related Health Research (LEHR), University of California, Davis (UC Davis) (Figure 1). This document presents the approach, procedures and rationale for sampling activities. In addition, it discusses the procedures for fieldwork, quality assurance/quality control (QA/QC), and data management.

Confirmation samples were previously collected in 1996 following a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) time-critical removal action (RA) performed by DOE at the DOE Box Area (DOE-OAK, 1996). Data gaps at the DOE Box Area exist because the original confirmation sampling plan design was not statistically based and the confirmation samples were not analyzed for all potential constituents of concern. This SAP is designed to provide additional confirmation data necessary to support future risk assessment and remedial action decisions for the DOE Box Area. The confirmation data will be compared to site background levels, risk-based action standards (RBAS) and preliminary remediation goals (PRGs) in a future remedial investigation (RI) report addendum.

## 1.1 Background

The LEHR Site began operating at its present location in 1958. Research at LEHR through the mid-1980s focused on the health effects from chronic exposure to radionuclides, primarily strontium-90 (Sr-90) and radium-226 (Ra-226). During this time period, the DOE Box Area was used as a repository by the LEHR facility for the disposal of miscellaneous low-level radioactive wastes associated with research.

In 1996, a time-critical RA was conducted at the DOE Box Area. A backhoe was used to excavate a series of trenches to determine the actual location of the DOE Box. The trenching activities did not find any evidence of an actual box buried beneath the surface, but did locate buried gravel and laboratory waste. The disposal area was approximately 36 feet (ft) by 9 ft with an exterior boundary defined by metal runway matting and plywood (Weiss [WA], 1997). The waste material was encountered two to three feet below ground surface (bgs), beneath a layer of gravel/soil overburden to a depth of approximately nine feet bgs.

During the 1996 RA, approximately 110 cubic yards of waste was removed from the DOE Box Area. The waste included soil, gravel, steel matting, plywood, syringes, bottles and vials. This waste was packaged in 33 B-25 boxes and disposed as low-level radioactive waste at Hanford. Seventy-two bottles, each containing between two ounces and one gallon of unidentified fluids, were

recovered from the north end of the excavation. Although most of the bottles appeared to be intact, eleven bottles showed signs of leakage. The 72 bottles were sent to Lockheed Analytical Services in Las Vegas and their contents were consumed during radiological analyses.

Samples were collected from the waste at various locations and depths during the trenching activities for disposal purposes. Analytical laboratory results showed elevated levels of Ra-226 and Sr-90 in the DOE Box waste (PNNL, 1996). Ra-226 concentrations ranged from 0.29 to 9.7 picoCuries per gram (pCi/g) and reported activities for Sr-90 ranged from 0.67 to 36.7 pCi/g.

Following removal of the waste, the DOE Box Area was over-excavated to remove approximately six inches of native soil from the excavation side walls and floor to ensure that no residual contamination remained. Additional soil was also removed from the north end of the disposal box area where the bottles were located. The final excavation dimensions for the DOE Box Area were approximately 43 ft long by 12 ft wide and 10 ft deep.

Once excavation of the DOE Box Area was complete, nine soil samples were collected from the native soil along the excavation side walls and floor. Results of analyses of these soil samples are presented in Table 1 and the sample locations are shown on Figure 2. The excavation was lined with 20 mil high-density polyethylene (HDPE) sheeting and backfilled to grade with soil generated during previous removal activities at LEHR.

The soil used for the DOE Box Area backfill was generated in 1993 during removal of buried drain lines in Animal Hospital Nos. 1 and 2. The drain lines conveyed radiological waste from the former dog cages to the Ra/Sr treatment systems. Soil surrounding the drain lines was excavated, placed in drums, and stored in the Co-60 field pending analytical testing. Following drain line removal, the trenches were radiologically surveyed and visually inspected for evidence of pipe leaks. No leaks or radiological contamination were detected during this inspection.

Scientech, Incorporated analyzed 12 composite samples of the drummed soil for radiological constituents. No chemical analyses were deemed necessary based on process knowledge and the leak inspection results. The analytical data for the drummed soil are presented in Table 2. As shown, the soil activities were either at or below site background or well below the risk-based action standards and preliminary remediation goals except for Ra-226. Of 12 samples, 10 contained Ra-226 below site background (0.75 pCi/g) and 2 were slightly above background (0.88 and 1.08 pCi/g).

Based on the analytical results, the lack of evidence of pipe leaks, and process knowledge, the drummed soil was deemed suitable for reuse as backfill material for the DOE Box Area excavation.

# 2. FIELD ACTIVITIES

## 2.1 Land Survey

Prior to sampling activities, a land survey crew will be mobilized to the site to determine the former location of the DOE Box Area. The survey crew will use the field coordinates obtained from the 1996 excavation boundary corners to determine the former location of the DOE Box. Upon completion of drilling and sampling activities, the sample locations and elevations will be surveyed by a land survey crew.

## 2.2 Excavation

To ensure the excavation limits of the DOE Box Area are properly located by the land survey, two shallow excavations will be performed by hand to expose the northeast and southwest corners of the HDPE liner placed in the original excavation area prior to backfilling. The liner is expected to be less than six inches below the existing asphalt surface.

Upon locating the southwest corner of the HDPE liner, the origin of the sampling grid will be established with an offset of approximately three to six inches as shown in Figure 3. The orientation of the confirmation sample grid area with respect to its origin will be established based on the exposed northeast and southwest corners of the liner. The resulting sample grid area perimeter will be outside the HDPE liner.

# 3. SAMPLING AND ANALYSIS

## 3.1 Data Quality Objectives

The sampling and analysis program presented in this section and in Appendix A was developed using the data quality objectives (DQOs) process described in Guidance for the Data Quality Objectives Process, United States Environmental Protection Agency (EPA) document number QA/G-4 (US EPA, 2000, EPA/600/R-96/055). The DQO process is a systematic planning tool for establishing criteria for DQOs and for developing data collection designs. The following sections demonstrate how the seven steps of the DQO process were used in designing the DOE Box Area sampling and analysis program.

### *3.1.1 Statement of the Problem*

Under the Federal Facility Agreement between DOE and EPA (EPA, 1999), DOE is the lead agency for cleanup of soil contamination associated with LEHR-related activities. DOE-OAK will make the final decisions on all CERCLA activities associated with the DOE Box based on recommendations from the planning team. The planning team consists of DOE-OAK; RPMs from EPA Region IX, the California Department of Toxic Substances Control, the Central Valley Regional Water Quality Control Board, and the California Department of Health Services; UC Davis; the Davis South Campus Superfund Oversight Committee; and WA and its subcontractors, IT Corp. and EMS.

As described in Section 1, a time-critical RA was conducted under National Contingency Plan guidelines to minimize and reduce the threat posed by environmental contaminants in the DOE Box area. Analytic results for soil samples collected from the excavation boundary suggested the analytes were present at levels representative of background. However, as described in Section 1, the data do not adequately define the nature and extent of all potential contaminants of concern in soil at the excavation boundary.

Therefore, the fundamental question to be answered by this sampling and analysis program is: "What is the distribution of potential contaminants of concern in native soil at the DOE Box excavation boundaries?" The sampling program described in this section and in Appendix A is designed to provide DOE-OAK and the planning team with the data needed to answer this question.

### *3.1.2 Identification of Decisions*

The decision statements for the DOE Box sampling are:

- Determine whether or not chemical or radionuclide concentrations statistically above site background levels remain in soil adjacent to the DOE Box excavation area.
- For chemicals and radionuclides statistically above background, determine whether or not the constituent distribution is related to the location of the 72 bottles described in Section 1.1, or has any other obvious spatial pattern.

### *3.1.3 Identify Inputs to Decisions*

Existing data that will be used to resolve the decision statements include LEHR RBASs and background levels. New environmental measurement inputs will include:

- Field observations;
- Soil sampling at appropriate locations and depths;
- Soil sample description using the Unified Soil Classification System;
- Laboratory analyses of confirmation sampling; and,
- Laboratory data validation.

### *3.1.4 Definition of Study Boundaries*

The geographical area addressed by the sampling and analysis program consists of the native soil within one ft of the DOE Box excavation area (Figure 3). The sampling and analysis program focuses on all COCs potentially introduced after 1958, when DOE first began operations at the Site (Table 3).

### *3.1.5 Development of Decision Rules*

The primary decision rule for this confirmation sampling is:

- If a chemical or radionuclide in soil adjacent to the DOE Box excavation area is statistically above site background levels, then that chemical or radionuclide will be included in the Site-Wide Risk Assessment for this area.

A secondary decision rule is:

- For chemicals and radionuclides statistically above background, if the spatial distribution indicates a discrete area with the highest concentrations, then additional excavation in that area will be considered.

### *3.1.6 Specification of Limits on Decision Errors*

As described in Appendix A, the sampling is designed to attain Type I and II errors of 20% and 10% or lower, respectively. The number of estimated samples was based on the expected highest coefficients of variability (COVs, defined as the standard deviation divided by the mean) for the potential COC concentrations. The sampling and analysis design is expected to limit Type I and Type II error to maxima of 20% and 10%, respectively, for all constituents.

### *3.1.7 Sample Design Optimization*

The output from each of the first six DQO steps described in Section 3.1.1 through 3.1.6 was used to optimize the sampling and analysis program summarized here and described in more detail in Appendix A. This sampling design is based on methods used in other LEHR non-time critical RAs (Appendix A).

Soil samples will be collected for a full suite of analytes (Table 3) on a low-density grid and a limited suite of analytes on a high-density grid as shown in Figure A-1 of Appendix A. Significantly more samples are necessary to prevent decision errors for the limited suite analytes, because their COVs are expected to be much larger than the remainder of full suite analytes. The rationale and procedures used to determine the sample locations, number of samples, and analytes to include in the limited and full-suite analyses are described in detail in Appendix A.

Organic analyte sample design is based on the results of previously collected samples. Organic compounds were not detected in significant concentrations in prior DOE Box area samples or in samples collected at other LEHR waste disposal areas. However, as an extra precaution, seven samples will be analyzed for organic analytes and two additional discretionary samples will be collected at the former location of the 72 bottles to confirm that no organic releases have occurred in this previously unsampled location. In the event that organic or other mobile constituents are identified in the confirmation samples, additional samples will be collected at a later date to define their vertical extent.

Thirty soil samples will be collected from the DOE Box area (Figure 3). The sample grid origin will be placed approximately three inches to six inches outside the southwest corner based of the visually identified location of the HDPE liner. Because the 72 bottles were a potential source of chemical and radiological releases, two discretionary samples will be collected in the northern area as shown in Figure 3. Soil samples will be collected from each boring location at depths ranging from

4.4 to 10 ft bgs as specified on Table 4. All of the sample locations listed in Table 4 will be outside or below the HDPE liner and collected within the first foot of native soil.

Conditions that may cause deviation from this planned sampling and analysis include:

- Physical obstructions, such as buildings and underground utilities, that prevent excavation and sampling in selected locations;
- Field screening measurements indicating that the work environment, or some aspect of it, is unsafe for human or environmental health and/or welfare; and,
- Equipment required to perform the intended work safely is unavailable.

These conditions are considered very unlikely. If one or more of these conditions occur, potential impact on achieving DQOs will be evaluated and addressed.

## 3.2 Sample Collection Procedures

A direct-push drill rig will be used to collect the samples. All soil samples will be collected in accordance with Standard Operating Procedure (SOP) 3.2, Subsurface Soil Sampling While Drilling (WA, 2001).

A sample preparation area will be established adjacent to the sampling location. The work surface will be covered with plastic sheeting to minimize the potential spread of contamination. The following equipment will be staged in the sample preparation area:

- Spill kit,
- Sample containers,
- Demineralized water,
- Sampling tools,
- Custody seals, and
- Chain-of-custody forms.

Soil samples will be collected in a core barrel with a clear acetate liner, to enable visual inspection of the material. To ensure that all confirmation samples are only collected in native soil, each core shall be carefully inspected for remnants of the acetate liner or other characteristics (e.g., color, moisture content, texture) which would be indicative of the backfill material. All occurrences of the plastic liner or backfill in the core shall be noted in the geologic log.

The samples will be screened by a radiological control technician for indications of contamination, then logged by the field geologist and transferred into the appropriate containers for shipping. Table 5 summarizes the container type, volume and holding time for each analyte. Sample handling, packaging and shipping are described in SOP 2.1, Sample Handling, Packaging and Shipping.

For quality control, one duplicate sample will be collected for every 10 samples (10%) and one soil blank will be sent with each shipment from the field. The location of field duplicates will be

determined in the field based on the observations of the field geologist. The soil quality control blank will be prepared as described in Appendix B. An equipment rinsate field blank will also be collected at the completion of sampling activities and analyzed for a full suite of parameters.

At the conclusion of soil sampling, all boreholes will be filled with cement grout to a depth of one ft bgs. After the grout has set, the top ft of the borehole will be filled with soil, and the location will be marked and surveyed. Drilling equipment utilized for sample collection will be decontaminated between each sample borehole location according to SOP 6.2, Drilling Equipment Decontamination.

## 3.3 Sample Documentation

The usability of the data obtained during this investigation will depend on its quality. Following proper procedures for both sample collection and analysis reduces sampling and analytical error. To ensure sample integrity, samples will be handled using complete chain-of-custody documentation and preserved using proper sample preservation techniques, holding times, and shipment methods. Obtaining valid and comparable data also requires adequate QA/QC procedures and documentation.

The components of the sample documentation and custody system will include:

- Chain-of-custody,
- Field logbook,
- Sample numbers,
- Sample labels, and
- Custody seals.

### *3.3.1 Chain-of-Custody*

Chain-of-custody forms will be completed by the sample team members to track sample custody, as well as to specify the requested analyses. Chain-of-custody forms will be completed in accordance with the requirements of SOP 1.1, Chain-of-Custody.

### *3.3.2 Field Logbook*

Descriptions and observations made during field sampling activities will be documented in the field logbook. In addition, boring logs with detailed lithologic descriptions will be prepared in accordance with SOP 15.1, Lithologic Logging, for all soil borings. The following will be recorded in the field logbook:

- Project name and number;
- Site location;

- Purpose of sampling;
- Description of field activities;
- Names of sampling personnel;
- Date and time of entries;
- Sample medium description using the Unified Soil Classification System;
- Date and time of sample collection;
- Sample location, identification (ID) number and sampling methodology;
- Field observations;
- Results of field measurements; and,
- Results of field instrument calibrations.

### *3.3.3 Sample Numbers*

All sample numbers will be assigned a unique sample ID number (i.e., sample designation) using the following format:

SSDBCXXX.

Where,

SS = soil sample, refers to the sample matrix;

DB = Disposal Box, designating the area at the site;

C = Confirmation sample; and

XXX = Chronological sample number (e.g., 001, 002, 003).

### *3.3.4 Sample Labels*

Sample labels will be attached to individual sample containers and will contain the following information:

- Project number,
- Sample ID number,
- Date and time collected,
- Initials of sampler, and
- Requested analyses.

### *3.3.5 Custody Seals*

Custody seals will be used to detect tampering and will be placed over the lid of the container and annotated with the following information:

- Project number,
- Sample ID number, and
- Date and time collected.

## 3.4 Analytical Plan

Thirty primary soil samples will be collected from the disposal Box Area for off-site analysis. Nine soil samples will be analyzed for a full suite of parameters and 21 will be analyzed for a limited suite. More samples are necessary for limited suite analytes (i.e., cadmium, chromium, hexavalent chromium, mercury and nitrate) because their COV is significantly larger than it is for the remainder of analytes. The rationale and procedure for determining which analytes to include in limited suite and full suite analyses are discussed in detail in Appendix A. Table 3 lists the analytical methods for the DOE Box Area confirmation data gaps samples and Table 4 lists the suite of analytes for each sample location. General Engineering Laboratory of Charleston, South Carolina will perform the analysis on a standard 45-day turnaround time.

Duplicate soil samples will be collected in the field at a rate of 10% and will reflect the ratio of full suite to limited suite analysis. Specifically, three field duplicate soil samples will be collected one full suite and two limited suites).

# 4. QUALITY ASSURANCE AND DATA MANAGEMENT

The quality assurance requirements applicable to the sampling activities at the DOE Box Area are detailed in the Quality Assurance Project Plan (QAPP) for the environmental restoration activities at the LEHR site (WA, 2000). This plan is based upon the requirements of DOE Order 414.1A *Quality Assurance* and EPA QAMS-005/80 *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* as they are applicable to the DOE Box Area scope of work. Additional task-specific quality assurance requirements are detailed in the SOPs.

Laboratory reports (hard copies and electronic files) will be forwarded from the laboratories to the WA Project Chemist. These results will be validated by the project chemist or qualified designee according to SOP 21.1 "Data Validation" and transferred to the project database by the Database Manager in accordance with procedures described in the QAPP (WA, 2000).

# 5. REFERENCES

United States Department of Energy, Oakland Operations Office (DOE-OAK), 1996, Action Memorandum, Removal Action of the Laboratory for Energy-Related Health Research, University of California, Davis, July.

United States Environmental Protection Agency (EPA), 1999, California Department of Toxic Substances Control, Central Valley Regional Water Quality Control Board, California Department of Health Services, and DOE, *Federal Facility Agreement Under CERCLA Section 120 Administrative Docket Number: 99-17, In the Matter of: The U.S. Department of Energy Laboratory for Energy-Related Health Research.*

Pacific Northwest Laboratories (PNNL), 1996, Approval of Waste Certification Summary for LEHR's DOE Box (Trench) Waste for the Laboratory for Energy-Related Health Research, University of California, Davis, September.

Weiss Associates (WA), 1997, Draft Final DOE Disposal Box Area Closure Report for the Laboratory for Energy-Related Health Research, University of California, Davis, March, Rev. 0.

WA, 2000, Final Quality Assurance Plan for the Laboratory for Energy-Related Health Research, University of California, Davis, June.

WA, 2001, Final Standard Operating Procedures for the Laboratory for Energy-Related Health Research, University of California, Davis, September.

# TABLES

Table 1. 1996 DOE Box Excavation Confirmation Soil Sampling Analytical Results

| Radionuclide | Units | Sample ID LEHR-S-503 | | | Sample ID LEHR-S-504 | | | Sample ID LEHR-S-505 | | | Sample ID LEHR-S-506 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Value | Uncert | MDA | Value | Uncert | MDA | Value | Uncert | MDA | Value | Uncert | MDA |
| Actinium-228* | pCi/g | 0.61 | 0.128 | 0.15 | 0.58 | 0.11 | 0.12 | 0.57 | 0.11 | 0.12 | 0.65 | 0.17 | 0.2 |
| Bismuth-212* | pCi/g | 0.16 | 0.2 | 0.27 | 0.34 | 0.18 | 0.2 | 0.32 | 0.2 | 0.24 | 0.25 | 0.3 | 0.39 |
| Bismuth-214* | pCi/g | 0.522 | 0.091 | 0.079 | 0.424 | 0.076 | 0.072 | 0.384 | 0.077 | 0.075 | 0.74 | 0.13 | 0.11 |
| Carbon-14 | pCi/g | -0.39 | 0.553 | 1.1 | -0.25 | 2.56 | 1.1 | -0.61 | 0.53 | 1.1 | 0.27 | 0.65 | 1.1 |
| Cesium-137* | pCi/g | -0.007 | 0.014 | 0.035 | 0.014 | 0.023 | 0.031 | 0.008 | 0.021 | 0.028 | -0.04 | 0.028 | 0.068 |
| Cobalt-60* | pCi/g | -0.006 | 0.011 | 0.034 | -0.001 | 0.013 | 0.03 | 0.001 | 0.016 | 0.033 | 0.011 | 0.026 | 0.051 |
| Gross Alpha | pCi/g | 13.5 | 6.2 | 6.8 | 5.4 | 4.4 | 6.3 | 5.4 | 5.17 | 6.4 | 8.7 | 5.1 | 6.4 |
| Gross Beta | pCi/g | 14.4 | 4.2 | 5.7 | 13.1 | 4 | 5.6 | 10.6 | 4.02 | 5.6 | 14 | 3.9 | 5.3 |
| Lead-210* | pCi/g | 2.4 | 8 | 11 | 1.8 | 2.5 | 3.4 | 0.6 | 2.6 | 3.7 | 1.11 | 0.9 | 1.3 |
| Lead-212* | pCi/g | 0.535 | 0.083 | 0.063 | 0.532 | 0.078 | 0.053 | 0.527 | 0.079 | 0.06 | 0.7 | 0.11 | 0.079 |
| Lead-214* | pCi/g | 0.494 | 0.074 | 0.073 | 0.471 | 0.068 | 0.062 | 0.576 | 0.075 | 0.061 | 0.75 | 0.11 | 0.098 |
| Potassium-40* | pCi/g | 11.2 | 1.4 | 0.52 | 11 | 1.4 | 0.39 | 10.7 | 1.3 | 0.37 | 12.1 | 1.7 | 0.61 |
| Radium-223* | pCi/g | -0.1 | 0.18 | 0.61 | -0.15 | 0.12 | 0.53 | -0.03 | 0.18 | 0.57 | -0.11 | 0.21 | 0.94 |
| Radium-226 ** | pCi/g | 0.68 | 0.24 | 0.24 | 0.36 | 0.283 | 0.29 | 0.65 | 0.26 | 0.22 | 0.51 | 0.2 | 0.13 |
| Radium-226* | pCi/g | 1.1 | 0.53 | 0.69 | 0.53 | 0.47 | 0.66 | 0.69 | 0.48 | 0.66 | 1.41 | 0.7 | 0.93 |
| Strontium-90 | pCi/g | 0.28 | 0.33 | 0.59 | -0.09 | 1.66 | 0.62 | 0.28 | 0.34 | 0.57 | -0.09 | 0.3 | 0.54 |
| Thallium-208* | pCi/g | 0.16 | 0.04 | 0.04 | 0.174 | 0.039 | 0.036 | 0.173 | 0.039 | 0.035 | 0.224 | 0.059 | 0.057 |
| Thorium-234* | pCi/g | 0.32 | 0.39 | 1.1 | 0.4 | 0.41 | 1.3 | 0.18 | 0.41 | 1.3 | 0.91 | 0.43 | 1.2 |
| Tritium | pCi/L | 90 | 135 | 200 | 40 | 110 | 200 | 50 | 110 | 200 | 70 | 120 | 200 |
| Uranium-235* | pCi/g | -0.096 | 0.086 | 0.22 | 0.06 | 0.12 | 0.18 | 0.04 | 0.12 | 0.19 | -0.08 | 0.13 | 0.24 |

Table 1. 1996 DOE Box Excavation Confirmation Soil Sampling Analytical Results (continued)

| Radionuclide | Units | Sample ID LEHR-S-507 | | | Sample ID LEHR-S-508 | | | Sample ID LEHR-S-509 | | | Sample ID LEHR-S-510 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Value | Uncert | MDA | Value | Uncert | MDA | Value | Uncert | MDA | Value | Uncert | MDA |
| Actinium-228* | pCi/g | 0.59 | 0.17 | 0.2 | 0.7 | 0.18 | 0.21 | 0.57 | 0.12 | 0.13 | 0.56 | 0.18 | 0.25 |
| Bismuth-212* | pCi/g | 0.27 | 0.24 | 0.37 | 0.15 | 0.28 | 0.37 | 0.37 | 0.2 | 0.23 | 0.57 | 0.28 | 0.37 |
| Bismuth-214* | pCi/g | 0.57 | 0.12 | 0.1 | 0.41 | 0.11 | 0.11 | 0.402 | 0.079 | 0.073 | 0.42 | 0.11 | 0.11 |
| Carbon-14 | pCi/g | 0.16 | 0.59 | 1 | 0.03 | 0.56 | 1 | 0.09 | 0.58 | 1 | 0.0 | 0.56 | 1 |
| Cesium-137* | pCi/g | 0.006 | 0.036 | 0.05 | -0.032 | 0.023 | 0.063 | -0.006 | 0.013 | 0.033 | -0.007 | 0.022 | 0.056 |
| Cobalt-60* | pCi/g | 0.002 | 0.024 | 0.054 | 0.01 | 0.027 | 0.055 | 0.008 | 0.015 | 0.027 | -0.011 | 0.02 | 0.056 |
| Gross Alpha | pCi/g | 5 | 5.1 | 8 | 11.6 | 5.7 | 6.5 | 7.4 | 4.9 | 6.5 | 6.2 | 4.6 | 6.3 |
| Gross Beta | pCi/g | 16.2 | 4.2 | 5.5 | 17.8 | 4.3 | 5.5 | 15.3 | 4.2 | 5.6 | 13.7 | 4 | 5.5 |
| Lead-210* | pCi/g | 0.97 | 0.86 | 1.2 | 0.79 | 0.93 | 1.4 | -0.9 | 2.5 | 3.6 | 0.71 | 0.86 | 1.3 |
| Lead-212* | pCi/g | 0.76 | 0.12 | 0.087 | 0.68 | 0.11 | 0.086 | 0.59 | 0.085 | 0.06 | 0.72 | 0.12 | 0.092 |
| Lead-214* | pCi/g | 0.66 | 0.11 | 0.11 | 0.594 | 0.1 | 0.1 | 0.568 | 0.077 | 0.067 | 0.56 | 0.11 | 0.12 |
| Potassium-40* | pCi/g | 11.3 | 1.7 | 0.52 | 11.4 | 1.7 | 0.59 | 12.2 | 1.5 | 0.41 | 11.6 | 1.7 | 0.44 |
| Radium-223* | pCi/g | -0.2 | 0.26 | 1 | -0.11 | 0.24 | 0.95 | -0.06 | 0.23 | 0.58 | -0.3 | 0.33 | 1 |
| Radium-226 ** | pCi/g | 0.3 | 0.18 | 0.22 | 0.43 | 0.2 | 0.2 | 1.13 | 0.34 | 0.26 | 0.56 | 0.23 | 0.23 |
| Radium-226* | pCi/g | 1.3 | 0.76 | 1 | 0.24 | 0.73 | 0.99 | 0.16 | 0.49 | 0.65 | 0.46 | 0.73 | 0.99 |
| Strontium-90 | pCi/g | 0.0 | 0.26 | 0.45 | -0.02 | 0.33 | 0.58 | 0.27 | 0.37 | 0.62 | 0.11 | 0.35 | 0.61 |
| Thallium-208* | pCi/g | 0.199 | 0.057 | 0.055 | 0.18 | 0.059 | 0.063 | 0.206 | 0.042 | 0.034 | 0.189 | 0.059 | 0.061 |
| Thorium-234* | pCi/g | 0.66 | 0.44 | 1.2 | 0.85 | 0.47 | 1.4 | 0.51 | 0.43 | 1.4 | 0.83 | 0.45 | 1.2 |
| Tritium | pCi/L | 80 | 120 | 200 | -20 | 100 | 200 | 130 | 130 | 200 | 90 | 120 | 200 |
| Uranium-235* | pCi/g | -0.03 | 0.14 | 0.26 | 0.04 | 0.16 | 0.25 | 0.08 | 0.13 | 0.19 | 0.04 | 0.16 | 0.24 |

Table 1. 1996 DOE Box Excavation Confirmation Soil Sampling Analytical Results (continued)

| Radionuclide | Units | Sample ID LEHR-S-511 | | |
|---|---|---|---|---|
| | | Value | Uncert | MDA |
| Actinium-228* | pCi/g | 0.51 | 0.16 | 0.16 |
| Bismuth-212* | pCi/g | 0.2 | 0.28 | 0.28 |
| Bismuth-214* | pCi/g | 0.425 | 0.1 | 0.1 |
| Carbon-14 | pCi/g | -0.57 | 0.5 | 0.5 |
| Cesium-137* | pCi/g | 0.007 | 0.031 | 0.031 |
| Cobalt-60* | pCi/g | -0.004 | 0.018 | 0.018 |
| Gross Alpha | pCi/g | 7.7 | 5.2 | 5.2 |
| Gross Beta | pCi/g | 13 | 3.9 | 3.9 |
| Lead-210* | pCi/g | 0.6 | 0.77 | 0.77 |
| Lead-212* | pCi/g | 0.626 | 0.096 | 0.096 |
| Lead-214* | pCi/g | 0.493 | 0.087 | 0.087 |
| Potassium-40* | pCi/g | 11.3 | 1.6 | 1.6 |
| Radium-223* | pCi/g | -0.11 | 0.21 | 0.21 |
| Radium-226 ** | pCi/g | 0.48 | 0.2 | 0.2 |
| Radium-226* | pCi/g | 0.94 | 0.62 | 0.62 |
| Strontium-90 | pCi/g | -0.02 | 0.35 | 0.35 |
| Thallium-208* | pCi/g | 0.152 | 0.048 | 0.048 |
| Thorium-234* | pCi/g | 0.84 | 0.39 | 0.39 |
| Tritium | pCi/L | 280 | 150 | 150 |
| Uranium-235* | pCi/g | 0.12 | 0.14 | 0.14 |

**Abbreviations**

| | |
|---|---|
| * | Gamma scan results |
| ** | Alpha scan results |
| ID | identification (number) |
| MDA | Minimum Detectable Activity |
| pCi/g | picoCuries per gram |
| pCi/L | picoCuries per liter |
| Uncert | Uncertainty or Error |

Table 2. DOE Box Area Backfill Soil Analysis

| Sample Identification | Analyte | Activity | Error | Detection Limit | RBAS [1] | PRG [2] | Background [3] 0 - 4 ft bgs | Background [3] > 4 ft bgs |
|---|---|---|---|---|---|---|---|---|
| | | < | | | pCi/g | | | > |
| **WAS-COMP-AH1-AO-3** | Ra-226 | 0.60 | 0.178 | 0.20 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.50 | 0.71 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.131 | 0.045 | 0.04 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.158 | 0.044 | 0.03 | - | - | 1.04 | |
| | Th-232 | 0.120 | 0.040 | 0.03 | 0.022 | 24 | 0.63 | 0.80 |
| **WAS-COMP-AH1-AO-4** | H-3 | .244 | 1.17 | 0.002 | 5.4 | 11000 | 1.2 | 1.2 |
| **WAS-COMP-AH1-AO-5** | H-3 | 0.00 | 1.15 | 0.002 | 5.4 | 11000 | 1.2 | 1.2 |
| **WAS-COMP-AH1-A1-4** | H-3 | 0.00 | 1.16 | 0.002 | 5.4 | 11000 | 1.2 | 1.2 |
| **WAS-COMP-AH1-A3-1** | Ra-226 | 0.688 | 0.211 | 0.30 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.00 | 0.650 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.148 | 0.052 | 0.05 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.084 | 0.040 | 0.04 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.137 | 0.040 | 0.01 | 0.022 | 24 | 0.63 | 0.80 |
| **WAS-COMP-AH1-C1-1** | Ra-226 | 0.720 | 0.131 | 0.10 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.00 | 0.610 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.140 | 0.061 | 0.03 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.203 | 0.081 | 0.07 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.140 | 0.061 | 0.03 | 0.022 | 24 | 0.63 | 0.80 |

Table 2. DOE Box Area Backfill Soil Analysis (continued)

| Sample Identification | Analyte | Activity | Error | Detection Limit | RBAS [1] | PRG [2] | Background [3] 0 - 4 ft bgs | Background [3] > 4 ft bgs |
|---|---|---|---|---|---|---|---|---|
| | | < | | | pCi/g | | | > |
| **WAS-COMP-AH1-DO-1** | Ra-226 | 0.720 | 0.153 | 0.10 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.140 | 0.41 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.087 | 0.039 | 0.05 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.061 | 0.036 | 0.05 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.087 | 0.030 | 0.02 | 0.022 | 24 | 0.63 | 0.80 |
| **WAS-COMP-AH1-D1-1** | Ra-226 | **0.88** | 0.132 | 0.05 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.00 | 0.60 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.288 | 0.085 | 0.04 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.156 | 0.065 | 0.04 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.252 | 0.078 | 0.03 | 0.022 | 24 | 0.63 | 0.80 |
| **WAS-COMP-AH1-GO-1** | Ra-226 | 0.679 | 0.122 | 0.06 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.99 | 0.67 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.092 | 0.051 | 0.04 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.092 | 0.046 | 0.03 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.109 | 0.050 | 0.03 | 0.022 | 24 | 0.63 | 0.80 |
| **WAS-COMP-AH1-G3-1** | Ra-226 | 0.688 | 0.170 | 0.2 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.00 | 0.59 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.182 | 0.069 | 0.05 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.211 | 0.070 | 0.03 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.182 | 0.065 | 0.03 | 0.022 | 24 | 0.63 | 0.80 |

Table 2. DOE Box Area Backfill Soil Analysis (continued)

| Sample Identification | Analyte | Activity | Error | Detection Limit | RBAS [1] | PRG [2] | Background [3] 0 - 4 ft bgs | Background [3] > 4 ft bgs |
|---|---|---|---|---|---|---|---|---|
| | | < | | | pCi/g | | | > |
| **WAS-COMP-AH1-G3-1** | H-3 | 0.00 | 1.12 | 0.002 | 5.4 | 11000 | 1.2 | 1.2 |
| **WAS-COMP-AH2-AO-3** | Ra-226 | **1.08** | 0.248 | 0.3 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.00 | 0.830 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.220 | 0.052 | 0.04 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.144 | 0.042 | 0.03 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.132 | 0.038 | 0.02 | 0.022 | 24 | 0.63 | 0.80 |
| **WAS-COMP-AH2-A1-1** | H-3 | 2.325 | 1.42 | 0.003 | 5.4 | 11000 | 1.2 | 1.2 |
| **WAS-COMP-AH2-B0-2** | H-3 | 1.46 | 1.405 | 0.003 | 5.4 | 11000 | 1.2 | 1.2 |
| **WAS-COMP-AH2-C0-1** | Ra-226 | 0.711 | 0.150 | 0.08 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.00 | 0.720 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.204 | 0.056 | 0.04 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.278 | 0.064 | 0.04 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.243 | 0.055 | 0.01 | 0.022 | 24 | 0.63 | 0.80 |
| **WAS-COMP-AH2-E0-1** | Ra-226 | 0.623 | 0.171 | 0.20 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.00 | 0.640 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.192 | 0.055 | 0.05 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.177 | 0.056 | 0.05 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.192 | 0.049 | 0.02 | 0.022 | 24 | 0.63 | 0.80 |
| **WAS-COMP-AH2-F0-1** | H-3 | 1.62 | 1.375 | 0.003 | 5.4 | 11000 | 1.2 | 1.2 |
| **WAS-COMP-AH2-F1-3** | H-3 | 2.05 | 1.415 | 0.003 | 5.4 | 11000 | 1.2 | 1.2 |

Table 2. DOE Box Area Backfill Soil Analysis (continued)

| Sample Identification | Analyte | Activity | Error | Detection Limit | RBAS [1] | PRG [2] | Background [3] 0 - 4 ft bgs | Background [3] > 4 ft bgs |
|---|---|---|---|---|---|---|---|---|
| | | < ---------- | ---------- | ---------- | pCi/g | ---------- | ---------- | ---------- > |
| **WAS-COMP-AH2-F2-3** | Ra-226 | 0.707 | 0.171 | 0.20 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.020 | 0.840 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.155 | 0.453 | 0.030 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.227 | 0.051 | 0.030 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.155 | 0.041 | 0.010 | 0.022 | 24 | 0.63 | 0.80 |
| **WAS-COMP-AH2-F2-4** | Ra-226 | 0.656 | 0.130 | 0.070 | 0.0042 | 1.5 | 0.752 | 0.752 |
| | Sr-90 | 0.00 | 0.61 | 1.0 | 10 | 14 | 0.056 | 0.056 |
| | Th-228 | 0.060 | 0.036 | 0.040 | 0.032 | 0.041 | 0.627 | 0.771 |
| | Th-230 | 0.069 | 0.036 | 0.040 | - | - | 1.04 | 1.04 |
| | Th-232 | 0.069 | 0.030 | 0.010 | 0.022 | 24 | 0.63 | 0.80 |

**Abbreviations**

| | | | |
|---|---|---|---|
| bgs | below ground surface | RBAS | Risk-Based Action Standard |
| ft | feet | Sr-90 | strontium-90 |
| H-3* | tritium | Th-228 | thorium-228 |
| pCi/g | picoCuries per gram | Th-230 | thorium-230 |
| PRG | Preliminary Remediation Goal [2] | Th-232 | thorium-232 |
| Ra-226 | radium-226 | | |

**Notes**

[1] RBAS derived from WA 1997 Draft Final Determination of Risk-Based Action Standards for the DOE Areas for the Laboratory for Energy-Related Health Research at UC Davis, CA. (August, Rev C)

[2] PRG derived from RISKCALC computer software based on RAGS HHEM Part B with its default scenario values and the 1997 Health Effects Assessment Summary Tables, Steve M. Dean , April, 1998

[3] Background = 80% lower confidence limit on the 95$^{th}$ quantile determined from background data, Appendix C, Draft Final Work Plan For Removal Actions in the Southwest Trenches, Ra/Sr Treatment Systems, and Domestic Septic System Areas, (WA, 1998, rev C).

* Tritium results converted from pCi/L to pCi/g using an estimated 20% moisture content.

Table 3. DOE Box Area Confirmation Data Gaps Sampling Analytical Methods

| Parameter | Analytical Method | Required Detection Limit (pCi/g for radionuclides, mg/kg for chemicals) |
|---|---|---|
| **Full Suite of COCs** | **Laboratory** | |
| Radionuclides: | | |
| Americium-241 | Lab SOP | 0.01 |
| Carbon-14 | Lab SOP | 0.1 |
| Gamma Emitters | Lab SOP | — |
| Actinium-228 | Lab SOP | 0.1 |
| Bismuth-212 | Lab SOP | 0.1 |
| Bismuth-214 | Lab SOP | 0.1 |
| Cesium-137 | Lab SOP | 0.01 |
| Cobalt-60 | Lab SOP | 0.005 |
| Lead-210 | Lab SOP | 0.5 |
| Lead-212 | Lab SOP | 0.1 |
| Lead-214 | Lab SOP | 0.1 |
| Potassium-40 | Lab SOP | 1 |
| Radium-223 | Lab SOP | 2 |
| Radium-228 | Lab SOP | 0.1 |
| Radium-226 | Lab SOP | 0.1 |
| Thallium-208 | Lab SOP | 0.05 |
| Thorium-228 | Lab SOP | 0.1 |
| Thorium-230 | Lab SOP | 0.05 |
| Thorium-232 | Lab SOP | 0.05 |
| Thorium-234 | Lab SOP | 0.5 |
| Gross Alpha | EPA Method 900.0 | 1 |
| Gross Beta | EPA Method 900.0 | 1 |
| Plutonium-241 | Lab SOP | 0.5 |
| Strontium-90 | EPA Method 905.0 | 0.05 |
| Tritium | EPA Method 906.0 | 1 |
| Uranium-233/234 | Lab SOP | 0.025 |
| Uranium-235 | Lab SOP | 0.01 |
| Uranium-238 | Lab SOP | 0.025 |
| Metals/Other Inorganics: | | |
| Antimony | CLP SOW ILM 02.1 | 0.5 |
| Arsenic | CLP SOW ILM 02.1 | 2 |
| Barium | CLP SOW ILM 02.1 | 40 |
| Beryllium | CLP SOW ILM 02.1 | 1 |
| Cadmium | CLP SOW ILM 02.1 | 0.25 |
| Chromium (total) | CLP SOW ILM 02.1 | 1 |
| Cobalt | CLP SOW ILM 02.1 | 10 |
| Copper | CLP SOW ILM 02.1 | 0.25 |
| Iron | CLP SOW ILM 02.1 | 20 |
| Lead | CLP SOW ILM 02.1 | 0.3 |

Table 3. DOE Box Area Confirmation Data Gaps Sampling Analytical Methods (continued)

| Parameter | Analytical Method | Required Detection Limit (pCi/g for radionuclides, mg/kg for chemicals) |
|---|---|---|
| Manganese | CLP SOW ILM 02.1 | 3 |
| Mercury | CLP SOW ILM 02.1 | 0.1 |
| Molybdenum | CLP SOW ILM 02.1 | 0.1 |
| Nickel | CLP SOW ILM 02.1 | 1 |
| Selenium | CLP SOW ILM 02.1 | 1 |
| Silver | CLP SOW ILM 02.1 | 0.1 |
| Thallium | CLP SOW ILM 02.1 | 0.5 |
| Vandium | CLP SOW ILM 02.1 | 1 |
| Zinc | CLP SOW ILM 02.1 | 4 |
| General Chemistry | | |
| Nitrate | EPA Method 300.0 | 1 |
| Chromium (+6) | EPA Method 3060A/7196 | 0.05 |
| Organics: | | |
| Volatile Organic Compounds | CLP SOW OLM 4.2 | Exhibit C of SOW OLM 4.2 |
| Semi-Volatile Organic Compounds | CLP SOW OLM 4.2 | Exhibit C of SOW OLM 4.2 |
| Organochlorine Pesticides (and PCBs) | CLP SOW OLM 4.2 | Exhibit C of SOW OLM 4.2 |

**Abbreviations**

| | |
|---|---|
| CLP SOW | Contract Laboratory Program Statement of Work |
| EPA | United States Environmental Protection Agency |
| ILM | Inorganic Laboratory Method |
| mg/kg | milligrams per kilogram |
| OLM | Organic Laboratory Method |
| pCi/g | picoCuries per gram |
| SOP | Standard Operating Procedure |

Table 4. DOE Box Area Confirmation Data Gaps Sample Locations

| x (feet) | y (feet) | Depth (feet) | Analyses |
|---|---|---|---|
| 0.0 | 2.8 | 5.5 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 0.0 | 10.2 | 5.5 | Full Suite |
| 0.0 | 17.5 | 5.5 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 0.0 | 24.9 | 5.5 | Full Suite |
| 0.0 | 32.2 | 5.5 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 0.0 | 39.6 | 5.5 | Full Suite |
| 2.9 | 0.0 | 5.4 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 2.9 | 2.8 | 10 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 2.9 | 10.2 | 10 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 2.9 | 17.5 | 10 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 2.9 | 24.9 | 10 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 2.9 | 32.2 | 10 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 2.9 | 39.6 | 10 | Full Suite |
| 2.9 | 43.5 | 6.6 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 6.6 * | 35.9 | 10 | Full Suite |
| 6.6 * | 41.6 | 10 | Full Suite |
| 10.2 | 0.0 | 5.4 | Full Suite |
| 10.2 | 2.8 | 10 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 10.2 | 10.2 | 10 | Full Suite |
| 10.2 | 17.5 | 10 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 10.2 | 24.9 | 10 | Full Suite |
| 10.2 | 32.2 | 10 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 10.2 | 39.6 | 10 | Full Suite |
| 10.2 | 43.5 | 6.6 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 12 | 2.8 | 4.4 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 12 | 10.2 | 4.4 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 12 | 17.5 | 4.4 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 12 | 24.9 | 4.4 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 12 | 32.2 | 4.4 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |
| 12 | 39.6 | 4.4 | Cd, Cr, Hg, $Cr^{6+}$, Nitrate |

**Notes**
*Discretionary sample location
Full Suite refers to all of the parameters listed in Table 5.

**Abbreviations**
Cd cadmium
Cr chromium
$Cr^{6+}$ hexavalent chromium
Hg mercury

Table 5. Containers and Holding Times for Laboratory Analytical Methods for the DOE Box Area Confirmation Data Gaps Sampling

| Parameter | Container Type | Holding Time |
|---|---|---|
| Radionuclides: | 1 x 2-L P | |
| Americium-241 | | 6 months |
| Carbon-14 | | 6 months |
| Gamma Emitters | | 6 months |
| Actinium-228 | | |
| Bismuth-212 | | |
| Bismuth-214 | | |
| Cesium-137 | | |
| Cobalt-60 | | |
| Lead-210 | | |
| Lead-212 | | |
| Lead-214 | | |
| Potassium-40 | | |
| Radium-223 | | |
| Radium-228 | | |
| Radium-226* | | |
| Thallium-208, 234 | | |
| Thorium-228, 230, 232 | | 6 months |
| Gross Alpha | | 6 months |
| Gross Beta | | 6 months |
| Plutonium-241 | | 6 months |
| Strontium-90 | | 6 months |
| Tritium | | 6 months |
| Uranium-233/234, 235/236, 238 | | 6 months |
| Metals/Other Inorganics: | 1 x 4-oz G | |
| Antimony | | 6 months |
| Arsenic | | 6 months |
| Barium | | 6 months |
| Beryllium | | 6 months |
| Cadmium | | 6 months |
| Chromium (total) | | 6 months |
| Cobalt | | 6 months |
| Copper | | 6 months |
| Iron | | 6 months |
| Lead | | 6 months |
| Manganese | | 6 months |
| Mercury | | 28 days |

Table 5. Containers and Holding Times for Laboratory Analytical Methods for the DOE Box Area Confirmation Data Gaps Sampling (continued)

| Parameter | Container Type | Holding Time |
|---|---|---|
| Molybdenum | | 6 months |
| Nickel | | 6 months |
| Selenium | | 6 months |
| Silver | | 6 months |
| Thallium | | 6 months |
| Vandium | | 6 months |
| Zinc | | 6 months |
| General Chemistry: | 1 x 4-oz. G | |
| Chromium (VI) | | 24 hours |
| Nitrate | | 48 hours |
| Organics: | | |
| Volatile Organic Compounds | EPA 5035 Pre-Weighed, Pre-Preserved Vials | 14 days |
| Semi-Volatile Organic Compounds | 1 x 4-oz G | 14 days to extraction, 40 days to analysis of extract |
| Organochlorine Pesticides/PCBs | 1 x 4-oz G | 14 days to extraction, 40 days to analysis of extract |

**Abbreviations**

| | |
|---|---|
| * | Requires 30-day ingrowth-time and 1,000-minute count-time |
| CLP SOW | Contract Laboratory Program Statement of Work |
| G | Glass |
| ILM | Inorganic Laboratory Method |
| OLM | Organic Laboratory Method |
| oz | ounces |
| P | Plastic |

# FIGURES

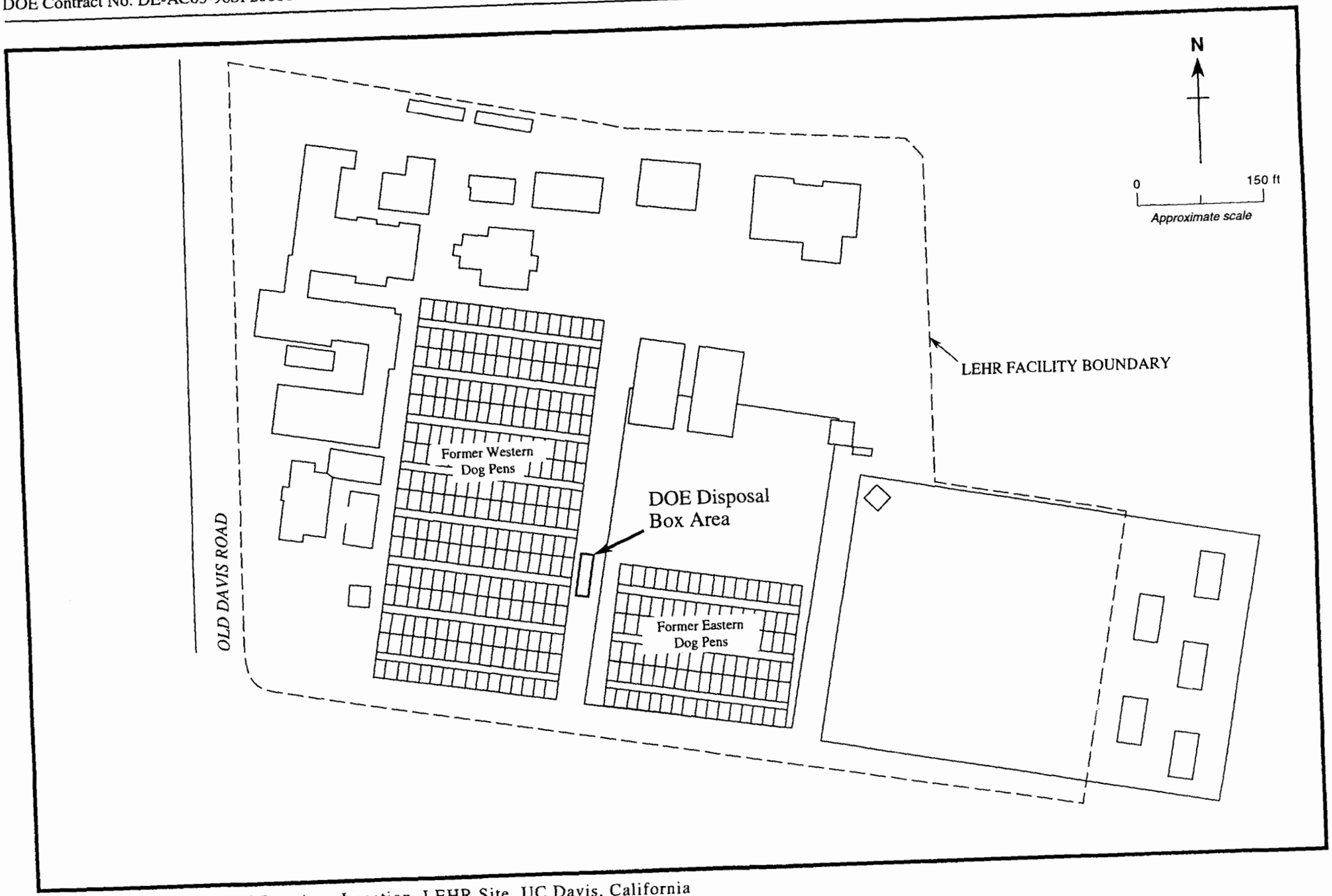


Figure 1. DOE Disposal Box Area Location, LEHR Site, UC Davis, California

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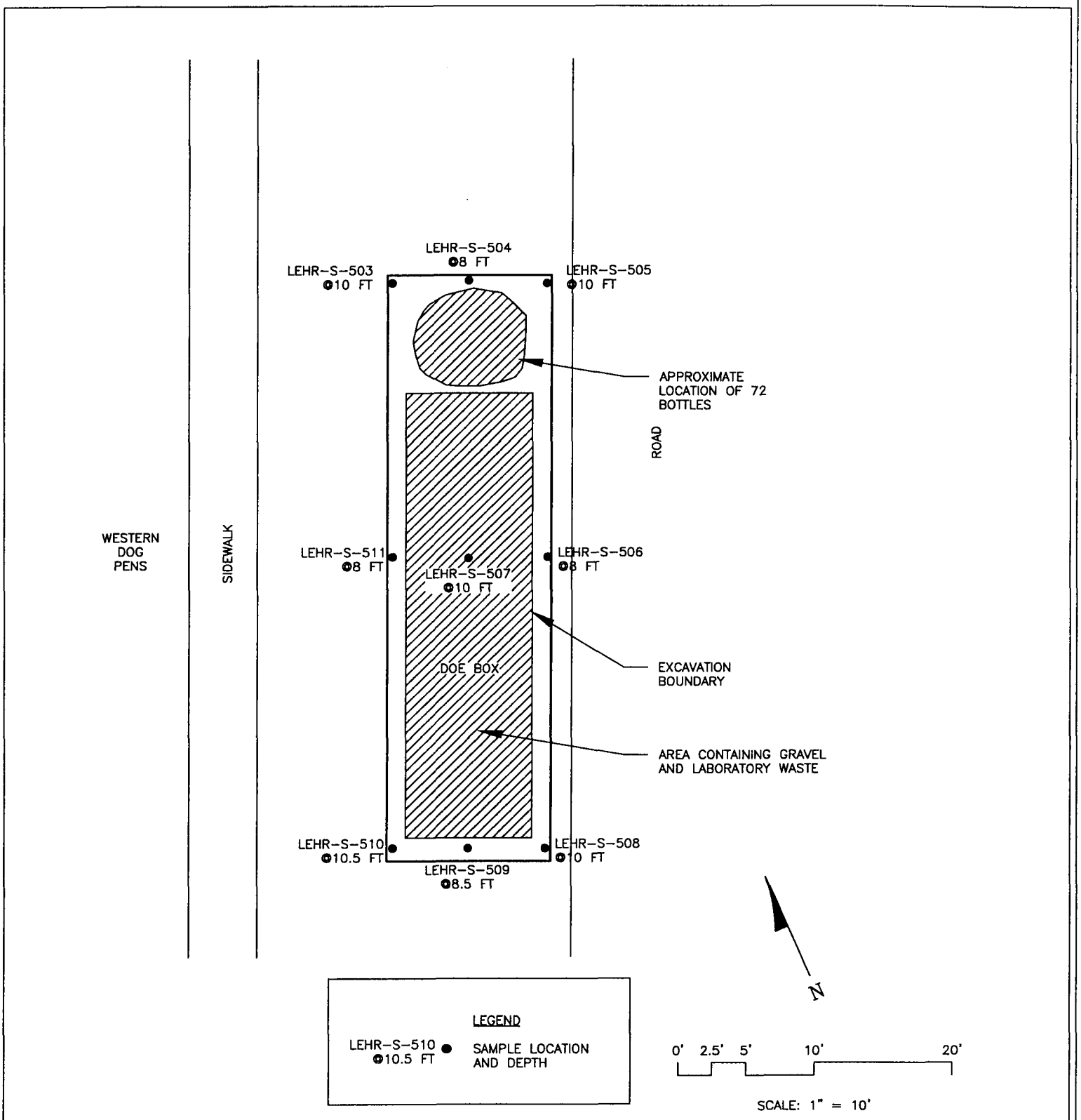


Figure 2. Excavation Limits and Confirmation Sample Locations for the 1996 DOE Box Area Removal Action, LEHR Site, UC Davis, California

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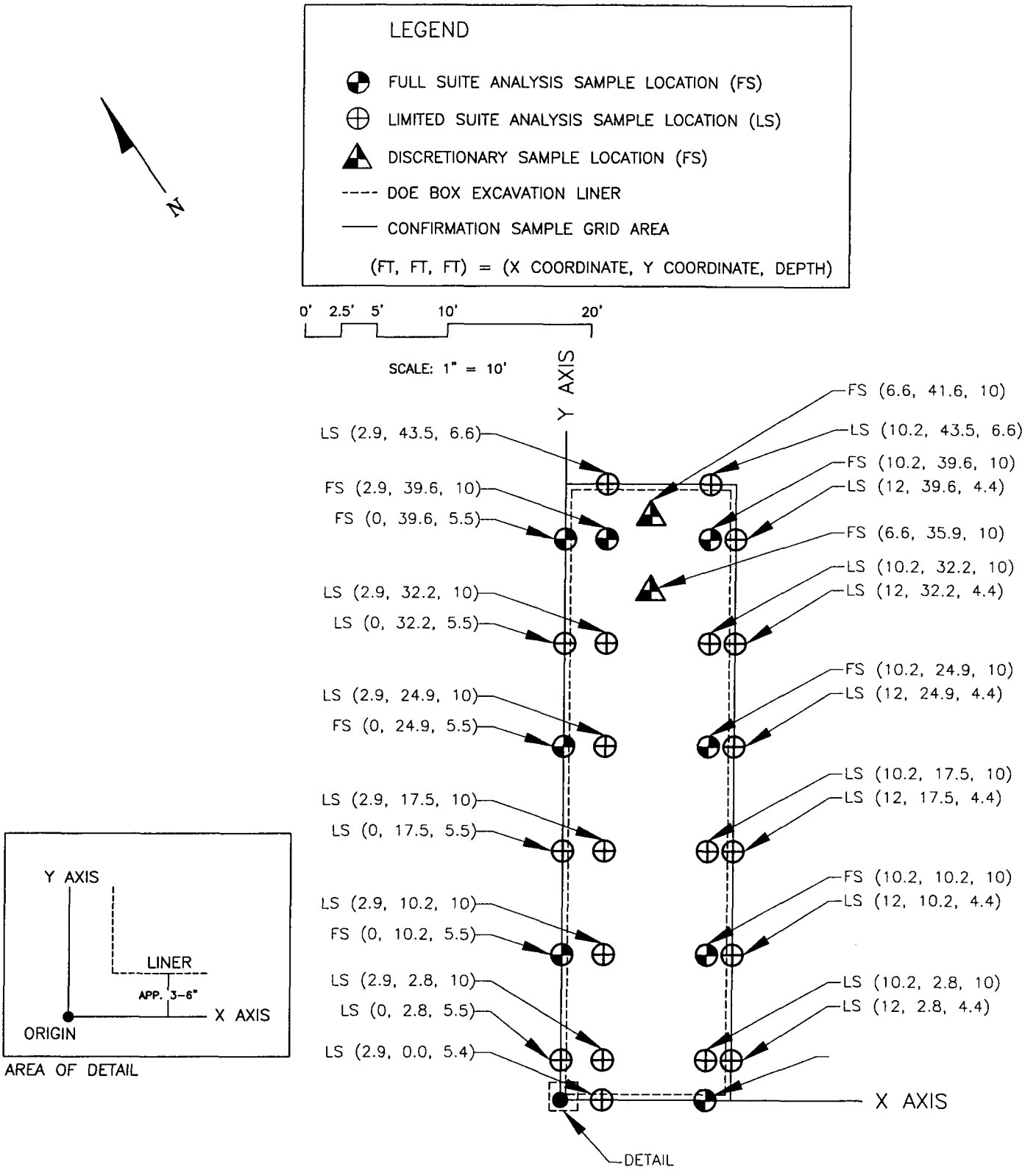


Figure 3. Plan View of DOE Box Area Confirmation Data Gaps Sample Locations, LEHR Site, UC Davis, California

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# APPENDIX A

## DOE BOX AREA CONFIRMATION DATA GAPS SAMPLING DESIGN

# A. DOE BOX AREA CONFIRMATION DATA GAPS SAMPLING DESIGN

## A.1 Statistical Basis for the Removal Action Confirmation Data Gaps Sampling Design

Statistical methods were used for the United States Department of Energy (DOE) Box Area sampling design to ensure that decisions regarding attainment of cleanup standards are scientifically valid. A statistical approach cannot declare with 100% certainty that cleanup standards are achieved. However, it is reasonable to assume cleanup criteria have been met if statistical tests show that the reference-based cleanup standards were achieved with an acceptable level of certainty. The statistical approach described in this appendix was taken from Statistical Methods for Evaluating the Attainment of Cleanup Standards (USEPA, 1994) and is intended for use for those contaminants for which cleanup at or near background is desired (e.g., radium-226 [Ra-226]).

The statistical hypothesis testing procedure begins with the statement of null hypothesis ($H_o$) and alternative hypothesis ($H_a$). These are:

- $H_o$: The median concentration of residual radioactivity in the survey unit is indistinguishable from the median background concentration; and,
- $H_a$: The median concentration of residual radioactivity in the survey unit is greater than the median background concentration.

Based on the power curve for this hypothesis, the lower bound on the gray region is zero and the upper bound on the gray region is 1/3 of the background value. The background value is defined as the 80% lower confidence limit on the 95$^{th}$ quantile determined from uncontaminated background samples collected near the DOE areas at LEHR.

The null and alternative hypotheses allow some cleanup unit measurements to be larger than reference area (background data set) measurements without rejecting $H_o$. In addition, the statistical tests recommended in USEPA (1994) are designed to determine whether cleanup unit measurements are significantly larger, as a whole, than reference area (background) measurements.

Associated with $H_o$ are Type I and Type II decision errors. A Type I decision error ($\alpha$) is the probability of rejecting $H_o$ when it is true. In the context of the DOE Box Area, $\alpha$ is the probability that the statistical tests will indicate the cleanup standard was not achieved when it actually was. A Type II decision error ($\beta$) is the probability of accepting $H_o$ when it is false. In the context of the DOE Box Area, $\beta$ is the probability that the statistical tests will indicate cleanup standard was achieved when it actually was not achieved. Table A-1 illustrates the relationship between $\alpha$, $\beta$, the actual condition of the cleanup unit, and the results of the statistical tests.

Table A-1. Decision Error Relationships

| Result of Statistical Test, Based on Sample Data from Cleanup Unit | Actual Condition of Cleanup Unit | |
|---|---|---|
| | Standard Achieved | Standard Not Achieved |
| Test Indicates Standard was Achieved | Correct Test Result (Probability = $1 - \alpha$) | Incorrect Test Result Type II Error (Probability = $\beta$) |
| Test Indicates Standard was Not Achieved | Incorrect Test Result Type I Error (Probability = $\alpha$) | Correct Test Result (Probability = $1 - \beta$) |

Table A-1 illustrates how often a statistical test may produce incorrect results. The test will be correct 100% of the time if $\alpha$ and $\beta$ are equal to zero. However, the required number of samples approaches infinity as $\alpha$ and $\beta$ approach zero. Therefore, the test cannot be correct 100% of the time because an infinite number of samples cannot be collected.

To demonstrate achievement of the null hypothesis, $H_o$, a compromise must be made between the decision error rates of $\alpha$ and $\beta$ and the number of samples required to conduct the test. Decision error rates of $\alpha$=0.2 and $\beta$=0.1 were accepted by the LEHR Remedial Project Managers in the *Draft Final Sampling and Analysis Plan for Removal Actions in the Southwest Trenches, Ra/Sr Treatment Systems, and Domestic Septic Systems Areas* (WA, 2000). Estimates of the required number of samples based on these allowable decision errors are described in detail in Section A.2.

## A.2 Estimation of the Required Number of Confirmation Data Gaps Samples

A minimum number of confirmation samples is required to maintain decision errors below the established limits for $\alpha$ and $\beta$ when applying a statistical test to compare the distribution of cleanup unit concentrations with the distribution of reference unit concentrations. The required number of cleanup unit and reference unit samples is different for each COC and is a function of the coefficient of variation (COV) which is the standard deviation divided by mean. The required number of confirmation samples is not determined for individual COCs because the sample grid design would be different for each COC, which would make the sample collection effort too costly. Thus, indicator COCs are selected to determine the number of confirmation samples to use in the sample design. The indicator COC is the COC with the highest COV. COCs with lower COVs are then grouped with the indicator COC to simplify sample grid design while ensuring $\alpha$ and $\beta$ decision errors are maintained for all COCs.

The sample design was separated into high and low COV groups based on review of the reference unit COVs. The groups were separated because five COCs have significantly higher COVs than the majority of COCs. Mercury is the indicator COC of the high COV group and Ra-226 is the indicator COC for the low COV group. Mercury and Ra-226 have the highest COV in their

groups. The high COV group consists of mercury, cadmium, chromium, hexavalent chromium, and nitrate. The low COV group consists of Ra-226 and all other COCs.

As recommended by the USEPA (1994), the Wilcoxon Rank Sum (WRS) test, a non-parametric statistical comparison of two data distributions to determine whether there is a difference in the mean, will be the primary method to determine whether COC levels are below background. The WRS test requires a minimum number of samples, n, to be statistically valid based on the decision errors $\alpha$ and $\beta$. The Quantile test will also be run if the Null Hypothesis is confirmed using the WRS test. A secondary Hot Measurement Comparison that compares data suspected to be "hot" to determine if the data is in agreement with hot measurement standards, will be used as necessary and appropriate to further confirm whether cleanup criteria have been met. However, that comparison does not have a minimum sample number requirement.

According to the USEPA statistical methods (USEPA, 1994), "cleanup unit" refers to the area undergoing cleanup while "reference area" refers to an off-site area representing the background. The minimum required number of confirmatory samples is determined using the following steps:

1. Determine the permissible Type I error ($\alpha$) and Type II error ($\beta$) for the statistical hypothesis. Values of $\alpha = 0.2$ and $\beta = 0.1$ were established for confirmation sampling in previously completed RA areas at the Site (WA, 2000).
2. A shift ($\Delta$) equal to 30% of the background value was established (WA, 2000) for previously completed RAs at the Site.
3. Calculate the standard deviation ($\sigma$) of previously collected representative data.
4. Calculate the relative shift ($\Delta/\sigma$).
5. Determine the probability ($P_r$) that a measurement performed at a random location in the survey area will result in a larger value than a measurement performed at a random location in the reference (background) area. $P_r$ is a function of the relative shift.
6. Determine the percentiles $Z_{1-\alpha}$ and $Z_{1-\beta}$, represented by the selected decision error levels, $\alpha$ and $\beta$, respectively. These values can be found in tables of the cumulative normal distribution.
7. Calculate the total number of data points (N) for the cleanup unit (n) and reference area (m), where N = n + m. The formula for calculating N is:

$$N = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{3\left(P_r - 0.5\right)^2}$$

where parameter values independent of the constituent were:

$Z_{1-\alpha} = 0.8418$;

$Z_{1-\beta} = 1.282$; and,

The mercury (Hg) specific value used to predict N was:

$P_r = 0.6903$,

The Ra-226 specific value used to predict N was:

$P_r = 1.005$.

8. Calculate the minimum number of data points required in the cleanup unit and reference area using the equation n = m = N/2.

Once the confirmation data are collected, the data set from the DOE Box will be evaluated independently against the reference area data set using the WRS test. If the data passes the WRS test, the Quantile Test will be used. As stated above, the Hot Measurement Comparison will be used to further confirm whether cleanup goals have been met. The combined results of the WRS test, Quantile test, and Hot Measurement Comparison will determine whether residual contaminants in the cleanup unit exceed the target cleanup goals.

### *A.2.1 Sample Number Calculation*

The Noether calculation, which determines the number of samples required in the background and cleanup units based on constituent concentration statistical parameters, was run for Hg and Ra-226. Deep (>four feet below ground surface [bgs]) Hg background data were selected for the large n prediction because Hg is stratified with depth and all DOE Box samples will be collected at depths between 3 and 10 feet bgs.

Ra-226 concentration data were selected from background investigation results and results from the Western Dog Pens RA confirmation samples collected in August 2001. Ra-226 is not stratified with depth at LEHR.

The results of the Noether calculations indicated that at least 21 samples are required for Hg, and 3 samples are required for Ra-226. The recommended sample count was increased to 24 for constituents with high variance and 6 for the remaining constituents to provide additional statistical power.

The samples will be collected at positions defined by two overlying rectangular grids with a random start as described in Section A.3.

## A.3 Removal Action Confirmation Data Gaps Sample Locations and Grid Spacing

Post-RA confirmation sampling will be performed to verify that residual contaminant levels in the DOE Box Area are below the cleanup standards, defined as either background or the Risk-Based Action Standards (RBAS). The RBAS is selected as the cleanup criterion when background is zero for a COC (as is the case for most organic compounds), or when the background value is below the RBAS.

A random-start, rectangular grid sampling approach was used to plan the sample locations. These locations were determined by projecting the floor and walls of the DOE Box excavation onto a planar coordinate system (Figure A-1). As shown in Figure A-1, the floor and walls are located outside of the excavation liner and within native soil. The dimensions of the grid area are 43.5 feet (ft) long and 12 ft wide with 7-ft high walls. The grid area has slightly larger dimensions than the original excavation. The top of the DOE box was located approximately three feet bgs and its base was approximately ten feet bgs. Grid samples located in the floor will be collected in native soil below the high-density polyethylene liner.

The random start was determined by placing the origin of the coordinate system at the lower left corner of the laid out grid area and using a random number generator to produce the start coordinates. The random start coordinate $X'_1$ (17.2 ft) was determined by multiplying the planar layout width (W') by a random number between 0 and 1. Similarly, the random start coordinate $Y'_1$ (2.4 ft) was the product of a random number and the length (L') of the grid layout. The spacing between sampling points (a) in the rectangular grid was determined from the equation $a = (A/n)^{0.5}$ where A is total grid area and n (determined in Section A.2.1) is the required number of samples. The calculated grid spacing for the DOE Box confirmation sampling is 7.36 ft for high COV constituents and 14.71 ft for lower COV constituents. The low COV grid spacing is exactly twice the high COV grid spacing to enable laying the grids over each other and using a common random start. The grid calculation is attached in spreadsheet form.

Due to the random start location, one low variance sample and four high variance samples landed within the grid area in addition to those recommended in Section A.2.1. The extra samples were included in the sampling design because they will increase the statistical power without significantly increasing sampling and analysis costs. A plan view of the proposed DOE Box confirmation sample design is shown in Figure 3 of the work plan and three dimensional sample coordinates are summarized in Table 2 of the work plan.

## A.4 References

United States Environmental Protection Agency (USEPA), 1994, Statistical Methods for Evaluating the Attainment of Cleanup Standards, Vol. 3, EPA 230-R-94-004.

WA, 2000, Sampling and Analysis Plan for Removal Actions in the Southwest Trenches, Ra/Sr Treatment Systems, and Domestic Septic Systems Areas for the Laboratory for Energy-Related Health Research, University of California, Davis, Rev. 0, July.

WA, 2001, Final Engineering Evaluation/Cost Analysis for the Western and Eastern Dog Pens at the Laboratory for Energy-Related Health Research, University of California, Davis, Rev. 0, February.

## Table A-2. Confirmation Grid Calculation, DOE Box, LEHR Site, UC Davis

| DOE Box Dimensions | |
|---|---|
| length (ft) | 43.5 |
| width (ft) | 12 |
| height (ft) | 7 |

| A ($ft^2$) | n | a (ft) | Grid Type |
|---|---|---|---|
| 1299 | 24 | 7.36 | Limited suite grid |
| 1299 | 6 | 14.71 | Full suite grid |

Definitions:
A = Area of 2-D DOE box Layout
n = approximate number of samples to be collected
a = side dimension of squares in grid
Formulas:
A = length x width + 2 x length x height + 2 x width x height
a = (A/n)^.5

| Random Number | W' (ft) | $X'_1$ (ft) |
|---|---|---|
| 0.6631703 | 26 | 17.2 |

| Random Number | L' (ft) | $Y'_1$ (ft) |
|---|---|---|
| 0.042607865 | 57.5 | 2.4 |

(See Figure 1.)

Definitions:
Random Number = Number between 0 and 1 generated by Excel random number generator
W' = Width of 2-D DOE Box layout
L' = Length of 2-D DOE Box layout
$X'_1$ = Grid point of random start on X' axis
$Y'_1$ = Grid Point of random start on Y' axis

Full Suite Grid Points

| X' (ft) | Y' (ft) |
|---|---|
| 2.5 | 17.2 |
| 2.5 | 31.9 |
| 2.5 | 46.6 |
| 17.2 | 2.4 |
| 17.2 | 17.2 |
| 17.2 | 31.9 |
| 17.2 | 46.6 |

Limited Suite Grid Points

| X' (ft) | Y' (ft) |
|---|---|
| 2.5 | 9.8 |
| 2.5 | 24.5 |
| 2.5 | 39.2 |
| 9.9 | 2.4 |
| 9.9 | 9.8 |
| 9.9 | 17.2 |
| 9.9 | 24.5 |
| 9.9 | 31.9 |
| 9.9 | 39.2 |
| 9.9 | 46.6 |
| 9.9 | 53.9 |
| 17.2 | 9.8 |
| 17.2 | 24.5 |
| 17.2 | 39.2 |
| 17.2 | 53.9 |
| 24.6 | 9.8 |
| 24.6 | 17.2 |
| 24.6 | 24.5 |
| 24.6 | 31.9 |
| 24.6 | 39.2 |
| 24.6 | 46.6 |

# APPENDIX B

## SOIL QUALITY CONTROL BLANK PREPARATION PROCEDURE

# B. SOIL QUALITY CONTROL BLANK PREPARATION PROCEDURE

**Materials Needed:**

- Quality Control (QC) blank soil,
- trowel,
- aluminum foil,
- bench or table top,
- heat lamps on common switch,
- digital thermometer,
- field notebook, and
- two, four-ounce (oz) glass sample containers with Teflon-lined lids.

**Preparation Steps:**

1) Collect approximately eight oz of soil from the container labeled "QC blank soil" located on the table in the onsite lab.
2) Lay the soil evenly over a 1 ft x 1 ft square of aluminum foil and place it under the heat lamps.
3) Adjust the lamps so that the soil temperature stabilizes at approximately 115 degrees (°) Celsius (C), ±15° (240° Fahrenheit [F], ±30°).
4) Shut the lamps off and measure the temperature of the soil with the digital thermometer after temperature stabilization. Record the temperature in a field notebook and turn the lamps back on.
5) Heat the soil for one hour.
6) After the one-hour period, shut the lamps off and measure the temperature again. If the second temperature measurement is above 100° C (212° F), then record the temperatures in a field notebook and proceed to Step 7. If the second measurement is below 100° C (212° F), then adjust the lamps to achieve greater than 100° C for one hour and measure the beginning and ending temperatures. Record the temperatures in a field notebook.
7) Immediately transfer the soil into two 4-oz glass jars from the same stock to be used for actual samples and seal them with the Teflon-lined lids.
8) Assign the sample an identification number that is indistinguishable from the rest of the soil samples to be collected so the blank will be blind for the laboratory.
9) Ship the Soil QC blank with other soil samples on the same chain-of-custody form.