Westinghouse

SOIL SURVEY PLAN

DOCUMENT #: DO-04-006, Rev. 1

NRC License SNM-33, Docket No. 70-36

HEMATITE, MISSOURI

January 2005

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ABBREVIATIONS AND ACRONYMS

ALARA	as low as reasonably achievable
Am-241	americium-241
ARAR	Applicable or Relevant and Appropriate Requirement
BKG	background
CFR	Code of Federal Regulations
cpm	counts per minute
DQO	Data Quality Objective
DCGL	derived concentration guideline level
$DCGL_{EMC}$	DCGL for small areas of elevated activity
$DCGL_W$	DCGL for average concentrations over a wide area
DP	Decommissioning Plan
DSR	dose-to-source ratio
EMC	elevated measurement comparison
EPA	Environmental Protection Agency
H_0	null hypothesis
H_a	alternative hypothesis
LBGR	lower bound of the gray region
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
mrem/yr	millirem per year
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
NCP	National Contingency Plan
NaI	sodium iodide
Np-237	neptunium-237
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
pCi/g	picocuries per gram
Pu-239	plutonium-239
QA	quality assurance
QC	quality control
RI/FS	Remedial Investigation/Feasibility Study
RSO	Radiation Safety Officer
SNM	special nuclear material
Tc-99	technetium-99
Th-232	thorium-232
TEDE	total effective dose equivalent
U-234	uranium-234
U-235	uranium-235
U-238	uranium-238
WRS	Wilcoxon Rank Sum

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PREFACE

This soil survey plan was prepared in accordance with the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (Ref. 2) jointly developed by the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), the Department of Energy, and the Department of Defense. In addition to the investigations referenced in this soil survey plan, a larger set of investigations and evaluations have been conducted at the Hematite site in accordance with the National Contingency Plan (NCP) (Ref. 6), including a Remedial Investigation/Feasibility Study (RI/FS) Work Plan (Ref. 7). The RI/FS Work Plan, which has been reviewed and conditionally approved by the Missouri Department of Natural Resources, serves as the overall template for site characterization activities. To the greatest extent practicable, Westinghouse intends to coordinate implementation of this soil survey plan with the activities undertaken pursuant to the RI/FS Work Plan.

In addition, as part of the *Hematite Decommissioning Plan* (Ref. 1), Westinghouse established derived concentration guideline levels (DCGLs) for soil in accordance with NRC protocol. These DCGLs are relied upon in this soil survey plan. Under the NCP process, the approved DCGLs will be included in the consideration of Applicable or Relevant and Appropriate Requirements (ARARs) and the establishment of cleanup levels.

Finally, as noted in the *Hematite Decommissioning Plan*, the final status survey for the Hematite site referenced in this soil survey plan will be designed to be in accordance with MARSSIM and will, to the greatest extent practicable, be conducted in a manner consistent with the objectives and process established in the NCP and underlying EPA regulations and guidance. See Appendix F of MARSSIM.

1.0 INTRODUCTION

1.1 Scope

This soil survey plan is designed to support site-wide survey activities described in the *Hematite Decommissioning Plan* (Ref. 1) submitted by Westinghouse Electric Company LLC (Westinghouse) for the Hematite Former Fuel Cycle Facility (Hematite). This plan addresses both remedial action support surveys and the final status survey for land areas at the Hematite site.

1.2 Overview

This soil survey plan provides direction for implementing site-wide radiological survey actions necessary to demonstrate that the Westinghouse Hematite site has been remediated and decommissioned in accordance with U.S. Nuclear Regulatory Commission (NRC) regulations in Title 10 of the Code of Federal Regulations, Part 20.1402 (10 CFR 20.1402). This plan is based on the guidance provided by the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (Ref. 2) and NUREG-1757, *Consolidated NMSS Decommissioning Guidance*, Vol. 2 (Ref. 3). This plan also is based on the final status survey plan previously approved by the NRC and implemented for the soil remediation conducted at the Westinghouse Waltz Mill Site (License No. SNM-770). The lessons learned from the implementation of that plan have been incorporated into this document.

The following discussion provides a summary description of the major elements of this plan and discusses the basis for the document. It provides a general roadmap on how the plan will be implemented and identifies where deviations have been made from the guidance documents.

The primary intent of this document is to define an overall process that will be followed. It is based on an approach that allows flexibility in the actual implementation. For example, a final determination has not been made as to the appropriate allocation of the basic NRC license termination criterion of 25 mrem/yr among the anticipated dose components. At the time of license termination, three possible dose components are anticipated: 1) residual soil contamination above natural background levels, 2) groundwater contamination by radionuclides, and 3) residual contamination above natural background levels in any buildings that remain on site at time of license termination. While this document describes a process to allocate the dose limit among the three components, specific information is provided only for the soil component. Additional information is being gathered to establish the existing levels of radiological contamination in groundwater, which will provide the technical basis for the allocation of that dose component. No final decision has been made as to whether some existing process buildings will be left on site at license termination. If a decision is made to leave certain buildings, additional documents will be prepared to establish building surface criteria and a final status survey plan for the buildings.

This plan addresses only the radiological contamination of soils on the site. Chemical contamination is not addressed.

Relationship to Other Westinghouse Documents

This document is based on the assumption that the derived concentration guideline levels (DCGLs) are those that are derived in "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility," (Ref. 4) and presented in Table 4-1 of this plan. If NRC review of the referenced DCGL report results in changes to the DCGL values presented in Table 4-1, changes will also be required to this plan. Depending on the magnitude of change to the DCGLs, it is possible that necessary changes to this plan could be substantial. Thus timely approval of the DCGL report by the NRC is necessary.

Adherence to MARSSIM and NUREG-1757 Guidance

Except as noted in the following section, this plan adheres to the guidance provided in MARSSIM and NUREG-1757, Vol. 2. The approach utilized is based on the presence of multiple radionuclides with some serving as surrogates for others. The plan covers the following elements:

- Organization and responsibilities
- Remediation criteria including the basis for allocation of dose and the establishment of operational criteria
- Criteria for area classification and survey unit sizes
- Change process for area classification changes
- Statistical test for decision making
- Reference areas for background determination
- Use of surrogate radionuclides and methods to adjust criteria to include the effect of other radionuclides
- Methods to determine number of samples and grid spacing
- Survey instrumentation to conduct surface scans
- Quality Assurance (QA) program

- Data assessment process

Deviation from MARSSIM and NUREG-1757 Guidance

MARSSIM is based on the concept that the residual radionuclide contamination is within a depth of six inches of the soil surface following remediation. This plan incorporates volumetric soil DCGLs that are applicable when the final distribution of residual radionuclides is within a soil horizon that is thicker than six inches. To adjust the requirements for scans and soil sampling, this plan is based on allowing for backfilling deep excavations with soil that meets the volumetric soil DCGL criteria. The process described is to backfill the excavation in lifts up to three feet thick and then conduct MARSSIM-based scan and soil sampling on each lift prior to the placement of the next lift. For each lift, the soil sample will be averaged over the entire thickness of that lift. This concept is in general accordance with the recommendation provided in NUREG-1757, Vol. 2, Appendix G, Paragraph G.2.1 with the added factor that scans are conducted on each lift of soil.

While not anticipated at this time, it is possible that some volumetric contamination might be identified that can be left in place because it meets the volumetric DCGL values. If this situation is identified, the plan calls for the preparation of a technical basis document (Section 1.5) based on the "ARR approach" to sample and assess the soil concentration present. This additional document will be submitted to the NRC for approval.

Implementation of DCGLs

The values for the DCGLs given in Table 4-1 are each based on the 25 mrem/yr criterion. Thus the resulting dose at the peak year, based on the exposure model utilized, would be 25 mrem for each radionuclide if the soil was contaminated to the level given in the table. It is therefore necessary to use the "sum-of-the-fractions" rule when a mixture of radionuclides is present. This necessarily reduces the allowable DCGL values for the radionuclides to allow for the mixture of radionuclides such that the sum-of-the-fractions for all the radionuclides present in the soil is less than one.

This plan is also specifically limited to the radiation dose associated with the concentrations of residual radionuclides present in the soil at time of the final status survey. There are also other dose components that must be accounted for such that the total radiation dose is less than the overall site criterion of 25 mrem/yr in the peak year. As noted above, it is anticipated that there will be a dose associated with the existing groundwater contamination that is not considered in the derivation of the soil DCGLs. It is also possible that some site buildings might be left at time of license termination. A dose allocation approach is described in this document to account for the other dose components. In order to implement this approach, operational DCGLs (Section 4.2.3) will be established and incorporated into decommissioning procedures that account for the following:

- The dose component that is allocated to the soil component
- The ratio of the radionuclides present, such as a composite operational DCGL for enriched uranium that accounts for the various enrichments possible
- The reduction in the DCGL for surrogate radionuclides as described in this document, if utilized

Final Dose Assessment

The DCGLs presented in this document were derived using a deterministic calculation approach. This method is considered appropriate for the derivation of the DCGLs but does not necessarily incorporate all of the parameter uncertainty that might exist. While the data evaluation section of this document is based on the statistical test approach incorporated in MARSSIM, Westinghouse believes it is also appropriate to consider the recalculation of the RESRAD model using the probabilistic method available. The DCGL report provides the probability distributions that would be utilized along with the actual concentration of residual radionuclides above background levels that are present at time of license termination, including the uncertainty of measurements. This recalculation of the soil dose component will be combined with the appropriate dose for all other dose components in order to demonstrate that the dose criterion of 10 CFR 20.1402 is met in accordance with the regulations.

1.3 Remediation Objectives

The soil remediation objectives were established in the decommissioning plan (DP) and are summarized as follows:

- Reduce the concentration of radionuclides in the soil to levels that are consistent with the "as low as reasonably achievable" (ALARA) principle.
- Reduce the concentration of radionuclides in the soil to levels that would result in a total effective dose equivalent (TEDE) that does not exceed 25 mrem/yr and allow the site to meet the criteria for unrestricted use as specified by 10 CFR 20.1402.
- Justify termination of NRC License No. SNM-33 (Ref. 5).
- Minimize the volume of soil that must be disposed as radioactive waste.
- Minimize the risk to human health and the environment in accordance with the National Contingency Plan (NCP) (Ref. 6) and the Remedial

Investigation/Feasibility Study (RI/FS) Work Plan (Ref. 7) prepared for the Hematite site.

1.4 Survey Objectives

The primary objectives of this soil survey plan are to:

- Define the radiological survey actions that will be taken to guide and monitor soil remediation activities.
- Define the radiological survey measurements that will be made in order to document the post-remediation radiological status of the site and demonstrate that radiological parameters satisfy the established guideline values and conditions.
- Define a plan for assessing radiological contamination that is supportive of and consistent with the larger set of investigations currently being conducted in accordance with the RI/FS Work Plan developed for the Hematite site.

1.5 Technical Basis Documents

This soil survey plan will be supplemented by technical basis documents. In some cases, these documents will be used to present various detailed calculations required by the soil survey plan. In other cases, the documents will be used to address technical issues that might arise during the course of the soil surveying and sampling. For example, if water cover is present in an area to be surveyed, a technical basis document will be prepared to justify an acceptable approach. The planned or potential uses of technical basis documents are identified in the applicable sections of the soil survey plan. If necessary, technical basis documents will be submitted to the NRC for approval; otherwise, all technical basis documents will be available for regulatory inspection.

The following is a list of topics that will or could potentially be addressed in technical basis documents:

1. When adequate characterization data is available, a conceptual model will be developed to determine the dose resulting from groundwater and building contamination. (Section 4.2.3)

2. If it is determined that a volumetric source of contamination exists that does not need to be excavated to meet the volumetric source DCGLs, a site-specific evaluation of the subsurface soil averaging criteria for the Hematite site will be developed based on the survey method that was prepared by the NRC in conjunction with the NRC's review of the AAR Site. (Section 4.2.4)

3. If water cover is present in an area to be surveyed and water removal actions are not adequate to allow surveying and sampling, an alternate approach will be developed and justified. (Section 5.2.1.3)

4. Background concentrations for the radionuclides of interest will be established to identify and evaluate residual contamination attributable to site operations. (Section 5.3)

5. Characterization data will be used to evaluate the use of surrogate radionuclides and determine associated scaling factors. (Section 5.4)

6. Relative dose contribution fractions will be calculated based on analytical results from characterization samples. (Section 6.1)

7. An analysis of survey instruments and detector capabilities will be performed prior to the start of survey activities. (Section 6.2)

8. Minimum detectable concentrations (MDCs) will be calculated for field and laboratory instrumentation. (Sections 6.2 and 6.3)

9. Calculations will be made to determine if scan MDC values for selected detectors are adequate to detect the operational $DCGL_W$ levels and if additional sample points will be required. (Section 6.2)

10. If the discrete point measurement approach is used, details will be provided on how the approach will be implemented and to determine the scan MDC to be used. (Section 6.4.1.2)

2.0 SOIL REMEDIATION ORGANIZATION

The direct responsibility for operational oversight of project activities, including soil remediation and survey, conducted under License No. SNM-33 and the DP rests with the Hematite Project Director. The Project Director is supported by a decommissioning project organization, which includes operations, licensing, quality assurance, radiological protection, criticality safety, environmental health and safety, material control and accountability, and security. The Hematite project organization, along with descriptions of management positions and qualifications, is described in the Hematite *Project Management Plan* (Ref. 8) and in License No. SNM-33.

The Operations Project Manager reports to the Project Director and will have responsibility for oversight of contractors performing soil remediation. The soil remediation contractor(s) will have responsibility for soil operations and for soil surveying and data management. The Hematite Radiation Safety Officer (RSO) is responsible for the establishment and guidance of programs in radiation protection. The RSO also evaluates potential and/or actual radiation exposures, establishes appropriate control measures, approves written procedures, and assures compliance with pertinent policies and regulations. The Hematite Waste Management Manager is responsible for waste packaging and transport.

The organization chart for soil remediation is shown in Figure 2-1. Changes to the organization can be made by the Project Director and the Operations Project Manager as required. One or more of the positions shown on the organization chart and described in the following can be held by the same person, as appropriate.

2.1 Soil Operations Responsibilities

Organizational responsibilities currently planned for the soil operations contractor are described as follows:

Soil Operations Manager - Responsible for analysis and coordination of schedules, costs, and changes to the contract; field activities, including oversight of field personnel; interface with Hematite management; and overall control of work plan preparation, including assurance that site requirements are incorporated.

General Superintendent – Responsible for control of work in the field, ensuring that work plan and change notice directions are implemented or that the necessary changes are obtained prior to implementation; identification of remediation hold points, assuring that radiation work permits and other applicable permits are initiated and in place; and scheduling resources and providing man-hour estimates.

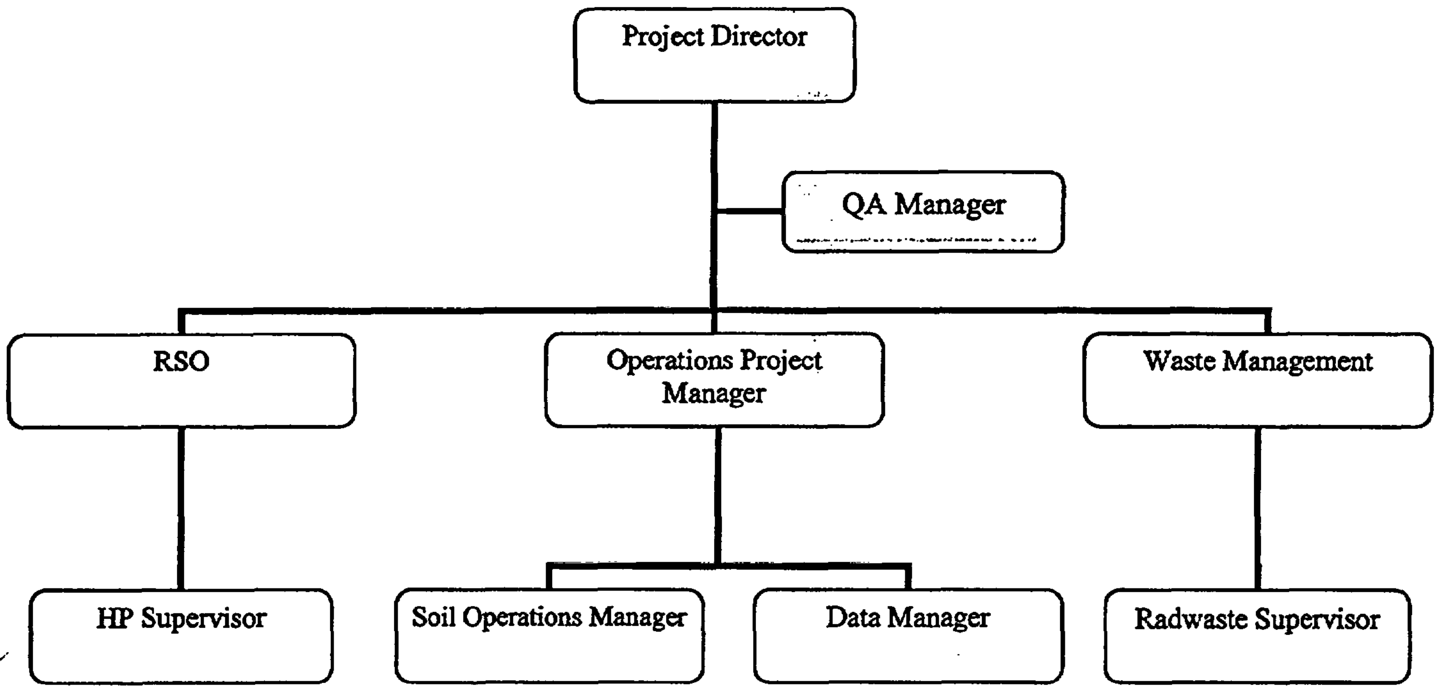

Figure 2-1 Soil Remediation Organization Chart

Project Engineer – Responsibilities include the development of work plans, coordination of design documents, engineering support, review of work plans, and supervision of field engineers.

Health and Safety Supervisor – Responsible for implementation of the contractor health and safety program plan, maintaining safety records, environmental and personnel sampling, personnel safety training, direct leadership/coordination of site safety with workers and supervision, and interfacing with Hematite safety personnel.

Soil Superintendent – Responsible for day-to-day field supervision of contractor workers, identification of resource needs, and field implementation of the work plan directions, including change notices. The Soil Superintendent reports directly to the General Superintendent.

Field Engineer – Responsible for writing work plans, resolving all comments, compiling all associated documentation (drawing, clearances, etc.) necessary to control the work, and ensuring that the work plan is issued in a timely manner to support remediation. The Field Engineer is also responsible for coordinating any revisions or changes to work plans, reviewing completed work plans, and coordinating work plan closeout. The Field Engineer(s) report directly to the Project Engineer.

Crew Foreman – Responsible for assisting the Soil Superintendent in day-to-day field operations, providing field leadership and a point of contact for contractor workers, and promoting safety, quality, and good workmanship.

Contractor workers – Responsible for performing assigned field tasks in a safe manner and using good workmanship.

2.2 Soil Survey and Data Management Responsibilities

Organizational responsibilities currently planned for the soil survey and data management contractor are described as follows:

Data Manager – Responsible for ensuring that implementation of the soil survey plan is consistent with the data quality objectives (DQOs) and survey design; reviewing soil survey data to determine the effectiveness of soil remediation activities; conducting data review, including a review of quality control (QC) and QA of the sampling and analytical program; selecting and applying statistical tests; verifying the assumptions of statistical tests; determining validity of the derived scaling factors and surrogate values; and summarizing results of data for review.

Data Management Engineer – Responsible for providing technical support to the Data Manager.

Soil Survey Supervisor – Responsible for coordinating the remediation of affected soil areas with operations personnel, directing the Soil Survey Technicians in the performance of soil surveys in accordance with the soil survey plan; supervising the collection of soil samples for laboratory analysis; and monitoring the laboratory chain of custody.

Soil Survey Technicians – Responsible for conducting soil surveys in accordance with procedures and training.

2.3 Radiological Support Responsibilities

Radiological support for soil remediation will be provided in the areas of health physics, dose and contamination monitoring, and radioactive waste management. Organizational responsibilities currently planned are described as follows:

Health Physics Supervisor – Responsibilities include directing the health physics personnel in the performance of their assigned work activities and assisting the RSO in maintaining proper radiological controls for soil remediation. The Health Physics Supervisor reports to the RSO.

Radwaste Supervisor – Responsibilities include coordinating waste packaging, waste shipments, and the preparation of shipping manifests for soil remediation. The Radwaste Supervisor reports to the Hematite Waste Management Manager.

Health Physics Technicians – Responsible for personnel, equipment, and environmental monitoring, contamination control, and radwaste support.

3.0 DATA QUALITY OBJECTIVES

The DQOs implement the rational decision making process for soil surveys. It is a systematic planning tool that identifies the data type, quality, and quantity needed to ensure the DCGL values are met. The seven-step DQO process for soil surveying is as follows:

State the Problem

Westinghouse seeks to terminate License No. SNM-33 and to remediate the site in a manner that protects human health and the environment. In order to successfully achieve these objectives, Westinghouse must perform a soil survey of the Hematite site that will demonstrate compliance with release criteria.

Identify the Decision

Following remediation of a survey unit or area at the Hematite site, it must be determined if the site-specific operational DCGLs have been met or if further remediation is required. Alternative actions that could result from the decision statement include further remediation, reevaluation of the modeling assumptions used to develop the operational DCGLs, and reassessment of the survey unit. The decision can be stated: "Do the soils that remain after remediation meet the established operational DCGLs?"

Identify Inputs to the Decision

Inputs to the decision include the type, quality, and quantity of data that, as a whole, will allow the decision to be made. 'Type' refers to the radiological data needed for the survey unit or area. 'Quality' refers to precision, accuracy, representativeness, comparability, and completeness. 'Quantity' refers to the amount of data necessary to confirm compliance with the established DCGL and is determined as part of the design process. Inputs involve developing estimates of the median residual radioactivity concentrations and maximum residual radioactivity concentrations.

Define the Study Boundaries

The study is to be performed within the boundaries of the Hematite site, including impacted areas designated 1, 2, and 3.

Develop Decision Rule

If data indicate a survey unit or area meets or exceeds the remedial objectives based on the operational DCGLs, remediation efforts are complete and the null hypothesis is rejected.

Limits on Decision Errors

The Type I decision error has been established as 0.05 and the Type II decision error is 0.10 or 0.25, depending on the survey unit size. The Type II decision error can be changed if it is found that more fixed measurements than necessary are being made to demonstrate compliance with the release criterion.

Optimize Design

The DCGL is defined in MARSSIM as a radionuclide-specific concentration that could result in a member of the public receiving dose at the allowed limit or meeting a specific allowed risk. This step includes optimization of the data collection process and meeting the DQOs. Operational details and theoretical assumptions of the survey design are used to ensure optimum design during soil survey.

4.0 CLASSIFICATION OF SURVEY AREAS AND UNITS

4.1 Survey Areas

As shown in Figure 4-1, the entire Hematite site has been divided into survey areas governed by physical boundaries and soil residual radioactivity concentrations. Detailed characterization data is being developed for these survey areas under the Remedial Investigation/Feasibility Study (RI/FS) Work Plan discussed in the Preface to this survey plan. An initial report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 9) presents results from the characterization of surface soil, surface water, sediment, and subsurface soil. Limited site groundwater sampling was also addressed in this report. The results from site-wide groundwater and background soil/groundwater sampling will be presented in separate reports.

The site survey areas are listed as follows:

- Area 1 – central site tract.
- Area 2 – buffer area surrounding the central site tract on three sides, including adjacent surface water features.
- Area 3 – outlying land areas.

Area 1 is the central site tract where licensed activities with special nuclear materials were conducted when the Hematite facility was in operation. Area 1 is bounded by State Road P on the northwest side, a creek on the northeast side, a pond and creek on the southwest side, and a railroad track on the southeast side. It should be noted that a number of buildings on the central site tract currently interfere with the characterization and potential remediation of soil in this area. Westinghouse currently is evaluating the best method to address these issues, including building demolition, through the license amendment and NCP processes. If any site buildings are left in place as discussed in Section 8.1 of the DP, their dose contribution will be addressed as described in Section 4.2.3 of this plan.

Area 2 is a buffer area between the central site tract and the outlying land areas. Area 2 surrounds the central site tract except for the portion bounded by State Road P. Area 2 also includes the adjacent surface water features.

Area 3 is composed of the remainder of the Hematite site. These outlying land areas are woods and farmland with no documented evidence of historic operations by Westinghouse or previous owners.

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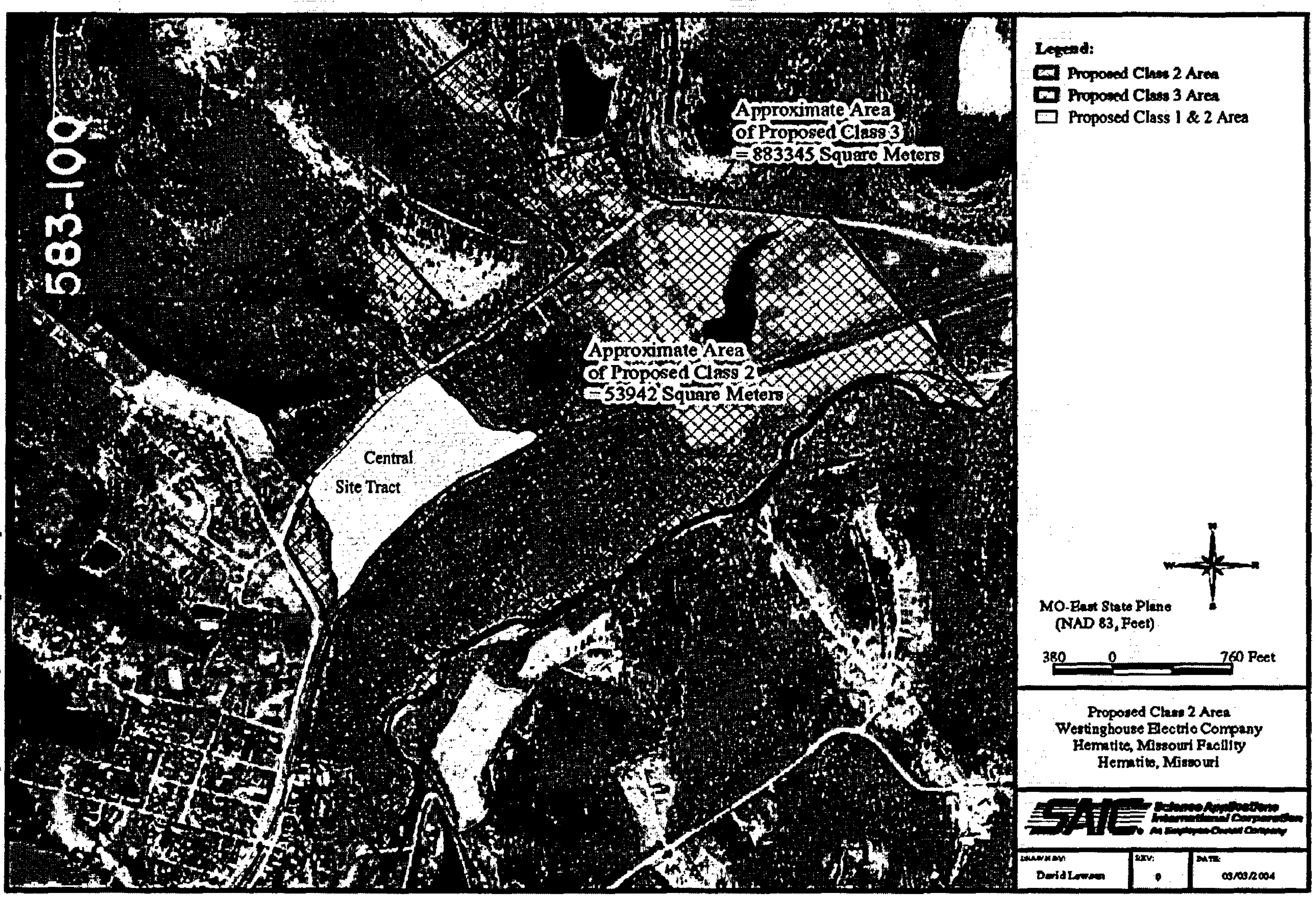

Figure 4-1 Soil Survey Areas

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4.2 Remediation Criteria

4.2.1 Dose Limit

The site remediation criteria have been established based on unrestricted use of the site using a residential farmer scenario. For purposes of guiding the remediation efforts, operational DCGLs for soil will be established.

4.2.2 $DCGL_W$

The modeling performed to derive surface and volumetric soil DCGLs for radionuclides of concern at the Hematite site is described in, "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility", which has been provided as a separate submittal to the NRC. The DCGLs were derived using a residential-farmer scenario. The NRC's primary dose limit of 25 mrem in any year in excess of natural background radiation dose was used as the basis for each derivation. A DCGL established for the average residual radioactivity evenly distributed over a large area is called a $DCGL_W$. The site-specific surface and volumetric soil $DCGL_W$ values for the radionuclides of concern at the Hematite site are shown in Table 4-1.

The $DCGL_W$ values labeled "surface source" are applicable to situations where the residual concentrations, above background, of radionuclides are located in the near surface (within approximately 0–15 cm) of the final remediated surface. Because the calculations do not assume the presence of a cover material, which might actually exist, the final remediated surface will not necessarily correspond to the actual restored surface.

The "volumetric source" $DCGL_W$ values are applicable to those situations where the thickness of the soil zone containing residual concentrations, above background, of radionuclides is greater than 15 cm. Such situations will occur, for example, if excavations are backfilled with soils that contain radionuclides above background but less than the volumetric source $DCGL_W$ values.

Table 4-1 Soil $DCGL_W$ Values

Radionuclide	Surface Source $DCGL_W$ (pCi/g)	Volumetric Source $DCGL_W$ (pCi/g)
Am-241	117	40
Np-237+D	1.4	0.11
Pu-239	129	43
Tc-99	140	23
Th-232+C	2.9	1.5
U-234	518	188
U-235+D	63	35
U-238+D	224	127

D = short-lived decay products
C = entire decay chain (Th-232 assumed to be in equilibrium with Ra-228+D and Th-228+D)

4.2.3 Operational $DCGL_W$

The Hematite site has both soil and groundwater residual contamination. One or more buildings containing some residual contamination might also be left in place. Implementation of the soil DCGLs in Table 4-1 will involve Westinghouse internally approved administrative controls to apportion the 25 mrem/y criteria among the remaining final dose components of residual soil, groundwater, and building contamination (if any buildings are left in place).

For survey areas where all three dose components are present, the total dose, H_{Total}, can be expressed as:

$$H_{Total} = H_{Soil} + H_{GW} + H_{Building} \qquad \text{(Equation 4-1)}$$

Where:

H_{Total} = Total dose from all components, i.e., 25 mrem/yr

H_{Soil} = Dose component for soil

H_{GW} = Dose component for groundwater

$H_{Building}$ = Dose component for building(s)

Apportionment of the dose in this manner will have the effect of reducing the "base-case" soil DCGLs in Table 4-1. The reduced or "operational" DCGLs for soil will be calculated based on the value of H_{Soil}, which will be determined after the values of H_{GW} and $H_{Building}$ are derived from the analysis of site characterization data for groundwater and buildings. A conceptual model will be developed to determine the dose resulting from groundwater and building contamination, and the results will be provided in a technical basis document.

The operational soil $DCGL_W$ for an individual radionuclide i is related to the base-case $DCGL_W$ as follows:

$$H_{Soil} = 25 \times \frac{DCGL^i_{OP}}{DCGL^i_{Base}} \qquad \text{(Equation 4-2)}$$

Where:

$DCGL^i_{OP}$ = Operational $DCGL_W$ for radionuclide i

$DCGL^i_{Base}$ = Base-case $DCGL_W$ for radionuclide i (from Table 4-1)

Solving for $DCGL^i_{OP}$ gives the following relationship:

$$DCGL^i_{OP} = \frac{H_{Soil}}{25} \times DCGL^i_{Base} \qquad \text{(Equation 4-3)}$$

4.2.4 $DCGL_{EMC}$

The $DCGL_{EMC}$ (EMC refers to "elevated measurement comparison") is the DCGL value used when residual radioactivity appears in small areas of elevated activity within a larger area. The $DCGL_{EMC}$ is derived separately for these areas based on the calculation of area factors as discussed in MARSSIM Section 5.5.2.4. The area factor is used to adjust the $DCGL_W$ to estimate the $DCGL_{EMC}$. The area factor is the magnitude by which the residual radioactivity within a small area of elevated activity can exceed the $DCGL_W$. $DCGL_{EMC}$ is defined as:

$$DCGL_{EMC} = \text{Area Factor} \times DCGL_W \qquad \text{(Equation 4-4)}$$

In determining the area factors for the Hematite site, the RESRAD scenario used for determining DCGLs was used as the basis. The contaminated area parameter used to determine DCGLs was 77,458 m^2. Area factors were derived for the following areas

(m^2): 2000, 100, 50, 30, 10, 5, 3, and 1. Area factors were derived by comparing the radionuclide-specific dose-to-source ratio (DSR) for the specific area to the DSR for the DCGL area (77,458 m^2) using the following equation:

$$AF = \frac{DSR_{DCGL}}{DSR_{AREA}} \quad \text{(Equation 4-5)}$$

Where:

AF = Area Factor

DSR_{DCGL} = radionuclide-specific dose-to-source ratio based on 77,458 m^2

DSR_{AREA} = radionuclide-specific dose-to-source ratio based on the selected area

DSRs were determined by using the same RESRAD parameters that were used for determining the DCGLs with the exception of the area parameter. By changing the area parameter in RESRAD, new DSRs were derived. Surface and volumetric DSRs and area factors are presented in Table 4-2. An evaluation of the sensitivity to the parameter "length parallel to the aquifer" indicates that the derivation is not sensitive to this parameter. Therefore, the parameter was not varied in the calculation of DSR_{AREA}.

The area factor to be used for the evaluation of a specific survey unit will be established as follows:

1. An area factor will be interpolated from Table 4-2 based on the actual area of the survey unit (i.e., AF_{2000} for a 2,000 m^2 survey unit).

2. An area factor will be interpolated from Table 4-2 based on the actual area of the elevated area (i.e., AF_1 for a 1 m^2 elevated area).

3. The area factor used for the evaluation of the single elevated area within the survey unit will be calculated as the ratio of the two values established above (i.e., Area Factor = AF_1/AF_{2000}).

The area factors established here for the volumetric source DCGLs are intended for use when an area has been excavated and subsequently backfilled with soil that contains acceptable levels of residual contamination and is surveyed in accordance with Section 7.2.2. If it is determined that a volumetric source of contamination exists that does not need to be excavated to meet the volumetric source operational DCGLs, a technical basis document will be prepared and submitted to the NRC for approval. That technical basis document will be based on the survey method that was prepared by the NRC in conjunction with the NRC's review of the AAR Site, "Method for Surveying and Averaging Concentrations of Thorium in Contaminated Subsurface Soil" (Ref. 10).

Table 4-2 Surface and Volumetric DSRs and Area Factors

Surface DSRs
mrem/yr per pCi/g

Area (m^2)	77,458	2000	100	50	30	10	5	3	1
Am-241	2.14E-01	2.11E-01	1.17E-01	1.10E-01	1.06E-01	1.00E-01	9.63E-02	9.41E-02	9.10E-02
Np-237	1.97E+00	1.96E+00	1.83E+00	1.80E+00	1.76E+00	1.69E+00	1.64E+00	1.61E+00	1.56E+00
Pu-239	1.93E-01	1.92E-01	1.02E-01	9.69E-02	9.48E-02	9.26E-02	9.20E-02	9.18E-02	9.15E-02
Ra-228	4.61E+00	4.48E+00	3.97E+00	3.70E+00	3.41E+00	2.81E+00	2.38E+00	2.15E+00	1.80E+00
Tc-99	1.79E-01	1.79E-01	1.79E-01	1.79E-01	1.79E-01	1.79E-01	1.79E-01	1.79E-01	1.79E-01
Th-228	3.54E+00	3.39E+00	2.79E+00	2.47E+00	2.13E+00	1.45E+00	9.57E-01	6.92E-01	3.07E-01
Th-232	4.21E-01	4.11E-01	3.11E-01	2.92E-01	2.73E-01	2.37E-01	2.11E-01	1.97E-01	1.77E-01
U-234	4.83E-02	4.81E-02	4.08E-02	4.03E-02	4.01E-02	3.99E-02	3.98E-02	3.98E-02	3.97E-02
U-235	3.94E-01	3.81E-01	3.28E-01	3.01E-01	2.70E-01	2.02E-01	1.47E-01	1.16E-01	7.23E-02
U-238	1.12E-01	1.09E-01	9.21E-02	8.62E-02	7.98E-02	6.68E-02	5.69E-02	5.16E-02	4.38E-02

Surface Area Factors

Area (m^2)	77,458	2000	100	50	30	10	5	3	1
Am-241	1.0	1.01	1.8	1.9	2.0	2.1	2.2	2.3	2.3
Np-237	1.0	1.01	1.1	1.1	1.1	1.2	1.2	1.2	1.3
Pu-239	1.0	1.00	1.9	2.0	2.0	2.1	2.1	2.1	2.1
Tc-99	1.0	1.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Th-232	1.0	1.02	1.2	1.3	1.5	1.9	2.4	2.8	3.7
U-234	1.0	1.00	1.2	1.2	1.2	1.2	1.2	1.2	1.2
U-235	1.0	1.03	1.2	1.3	1.5	1.9	2.7	3.4	5.4
U-238	1.0	1.03	1.2	1.3	1.4	1.7	2.0	2.2	2.6

Table 4-2 Surface and Volumetric DSRs and Area Factors (Cont.)

Volumetric DSRs
mrem/yr per pCi/g

Area (m^2)	77,458	2000	100	50	30	10	5	3	1
Am-241	6.19E-01	6.17E-01	5.21E-01	5.15E-01	5.11E-01	5.05E-01	5.01E-01	4.99E-01	4.96E-01
Np-237	1.25E+01	1.24E+01	1.23E+01	1.22E+01	1.22E+01	1.21E+01	1.20E+01	1.20E+01	1.19E+01
Pu-239	5.88E-01	5.87E-01	4.96E-01	4.91E-01	4.89E-01	4.87E-01	4.86E-01	4.86E-01	4.86E-01
Ra-228	1.18E+01	1.16E+01	1.11E+01	1.09E+01	1.06E+01	9.98E+00	9.45E+00	9.15E+00	8.73E+00
Tc-99	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00
Th-228	4.11E+00	3.85E+00	3.33E+00	3.04E+00	2.70E+00	1.96E+00	1.33E+00	9.87E-01	4.91E-01
Th-232	1.13E+00	1.12E+00	1.02E+00	1.00E+00	9.85E-01	9.48E-01	9.17E-01	9.00E-01	8.75E-01
U-234	1.33E-01	1.33E-01	1.25E-01	1.25E-01	1.25E-01	1.24E-01	1.24E-01	1.24E-01	1.24E-01
U-235	7.17E-01	4.28E-01	3.06E-01	2.91E-01	2.75E-01	2.42E-01	2.13E-01	1.97E-01	1.73E-01
U-238	1.97E-01	1.92E-01	1.77E-01	1.72E-01	1.66E-01	1.52E-01	1.41E-01	1.35E-01	1.26E-01

Volumetric Area Factors

Area (m^2)	77,458	2000	100	50	30	10	5	3	1
Am-241	1.0	1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Np-237	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Pu-239	1.0	1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Tc-99	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Th-232	1.0	1.0	1.1	1.1	1.2	1.3	1.5	1.5	1.7
U-234	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1
U-235	1.0	1.67	2.3	2.5	2.6	3.0	3.4	3.6	4.1
U-238	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6

Because that document is limited to thorium contamination, it will be necessary to provide a site-specific evaluation of the subsurface soil averaging criteria for the Hematite site.

4.3 Area Classifications

Each of the survey areas described in Section 4.1 has been assigned an initial classification based on characterization surveys, a gamma walkover survey, and the *Historical Site Assessment* (Ref. 11) completed in 2003. All areas have been designated as impacted. Area 3 has no historical record of licensed use, but in the interest of conservatism, it has been designated as a Class 3 impacted area.

4.3.1 Area Classification Definitions

The definitions used for the area classifications are shown in Table 4-3, along with the area limits used to establish survey units.

Table 4-3 Area Classification Definitions

Classification	Definition	Survey Unit Area
Class 1 Land Areas	Areas known or expected to have radionuclide concentrations above the operational $DCGL_W$	$< 2{,}000\ m^2$
Class 2 Land Areas	Areas with the potential for contamination or known contamination not expected to be above the operational $DCGL_W$	$2{,}000\ m^2 \leq$ area $\leq 10{,}000\ m^2$
Class 3 Land Areas	Areas that are not expected to have any residual radioactivity or have radionuclide concentrations at a small fraction of the operational $DCGL_W$	No limit

4.3.2 Initial Area Classifications

Descriptions of the initial area classifications provided in Section 4.1 are presented in Table 4-4.

Table 4-4 Initial Area Classifications

Area (See Fig. 4-1)	Description	Classification
Central Site Tract	Specific areas of the central site tract that require remediation based on characterization data, including a surrounding buffer zone at least 3 meters wide.	1
Central Site Tract	Remaining areas of the central site tract that do not require remediation based on characterization data.	2
Buffer Area Around Central Site Tract	Entire buffer area	2
Outlying Area	Entire outlying area	3

4.3.3 Area Classification Change Process

The initial area classifications established in Section 4.3.2 are based on a combination of characterization data and historical information. Characterization is an ongoing effort throughout the decommissioning and remediation process, and it might become necessary to change an area classification on the basis of new characterization information or impacts from decommissioning and remediation activities.

4.3.3.1. Classification Upgrades

Any area classification can be upgraded (e.g., from Class 2 to Class 1) based on the receipt of additional survey or measurement information that justifies the need for the higher classification (see Section 9.2).

4.3.3.2. Classification Downgrades

An area classification will not be downgraded (e.g., from Class 1 to Class 2) without NRC approval.

4.3.3.3. Documentation of Area Classification Changes

All changes to the initial area classifications, as established in Section 4.3.2, will be documented in the final soil remediation documentation.

4.3.4 Selection of Survey Units

A survey area consists of one or more survey units. Each survey area will be divided into a sufficient number of survey units based on the area classification definitions and surface area limits described in Section 4.3.1. A survey unit is a physical land area of specific size and shape that will be subject to a final status survey. Selection of the survey units will be based on areas having similar operational history or similar potential for residual radioactivity to the extent practical. Survey units will also be selected to have relatively compact shapes unless an unusual shape is appropriate for the site operational history or site topography.

Area 3 has been divided into three survey units as shown in Figure 4-2. Survey units will be established for Areas 1 and 2 prior to performing final status surveys in those areas.

A survey unit can have only one classification. Thus, situations might arise where it is necessary to create new survey units by subdividing areas within an existing unit or to upgrade the classification of the entire unit. The process described in Section 4.3.3 will be followed when making such changes.

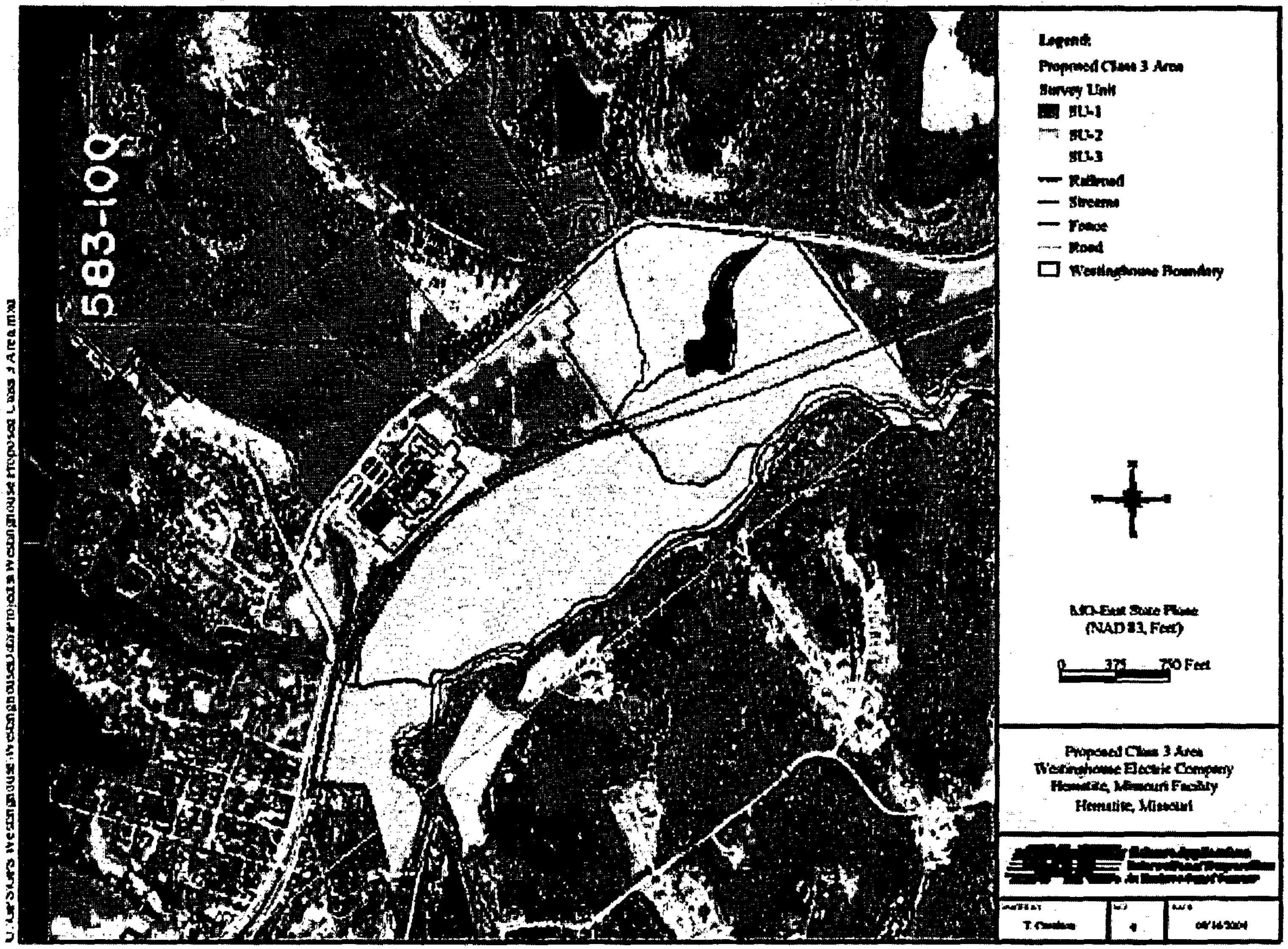

Figure 4-2 Area 3 Survey Units

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5.0 FINAL STATUS SURVEY DESIGN

5.1 Survey Objective

The objective of the final status survey is to document the post-remediation radiological status of the site and demonstrate that radiological parameters satisfy the established guideline values and conditions.

5.2 Design Basis

5.2.1 MARSSIM Statistical Tests

The MARSSIM methodology for evaluating whether a survey unit meets its applicable release criterion is based on using non-parametric statistical tests for data assessment. The final status survey will use discrete soil sampling to determine the average radionuclide concentration in a survey unit and gross-gamma scans to screen the survey unit for "hot spots." Fixed measurements might be used to supplement scanning surveys. The methods of MARSSIM are based on two statistical tests: the Wilcoxon Rank Sum (WRS) test and the Sign test. Selection of the required minimum number of data points depends on the statistical test used, which in turn depends on the type of measurements to be made (gross measurement, net measurement, or radionuclide specific) and on whether the radionuclides of interest appear in background. Because radionuclides of interest do appear in background at the Hematite site, the WRS statistical test will be used unless otherwise indicated and justified.

5.2.1.1. Discrete Soil Sampling

The results of discrete soil sampling will be used to verify that the average soil concentration is less than the operational $DCGL_W$. Regardless of the survey unit classification (Class 1, Class 2, or Class 3), a predetermined minimum number of samples will be collected in each survey unit. Where a systematic grid is used (Class 1 or Class 2), a random-start, triangular-grid pattern will be used.

5.2.1.2. Scanning Surveys

Scanning surveys will be used to identify small areas of elevated activity. The percentage of the survey unit to be covered by scans will be based upon the survey unit classification in accordance with Table 5-1.

Table 5-1 Scanning Survey Coverage

Survey Unit Classification	Scanning Coverage
Class 1	100 percent
Class 2	10 to 100 percent Systematic and judgmental
Class 3	Judgmental

One-hundred percent coverage means that the entire surface area of the survey unit will be covered by the field of view of the detector. The scanning coverage for Class 2 areas will be adjusted based on the level of confidence supplied by existing data. Whenever less than 100 percent of the survey unit is scanned, the degree of scan coverage and which areas are to be scanned will be determined.

5.2.1.3. Surveys of Water Courses and Water-Filled Excavations

There are several water courses on the site that will require surveying and sampling. In addition, it is anticipated that excavations will experience in-leakage of groundwater. This survey plan is based on the approach that the areas to be surveyed will be sufficiently "dry" to permit surveying and sampling in accordance with this plan. If water cover is present in an area to be surveyed, then actions will be taken that could include but are not limited to:

- Diversion of the water source for a period of time
- Conducting surveys during a dry period
- Active pumping to maintain an area sufficiently free of water

If it is determined that such techniques do not allow for adequate surveying and sampling in accordance with this plan, a separate technical basis document will be prepared and submitted for approval that presents and justifies an alternate approach.

5.2.1.4. Fixed Measurements

Fixed measurements might be collected at random locations in a survey unit or at systematic locations to supplement scanning surveys for the identification of small areas of elevated activity. Fixed measurements might also be collected at locations identified by scanning surveys as part of an investigation to determine the source of the elevated instrument response. Judgment might also be used to identify locations for fixed measurements to further define the areal extent of contamination.

5.2.2 Null Hypothesis

With respect to final status surveys, the null hypothesis (H_0) will be that the survey unit of interest contains residual contamination in excess of the release criterion. The null hypothesis is assumed to be true in the absence of strong evidence to the contrary. The alternative hypothesis (H_a) will be that the residual contamination meets the remedial objective. Decision errors refer to making incorrect decisions by either rejecting a null hypothesis when it is true (Type I error) or accepting a null hypothesis when it is false (Type II error). The probability of making a Type I error is referred to as alpha (α). The probability of making a Type II error is denoted as beta (β).

5.2.3 Decision Error Rates

The decision error possibilities are demonstrated in the following matrix:

TRUE CONDITION OF SURVEY UNIT	OUTCOME OF STATISTICAL TEST	
	Reject H_0	Accept H_0
Meets remedial objective (below operational $DCGL_W$)	No decision error. (probability = $1-\alpha$)	Incorrectly fail to release survey unit. Type II error (probability = β)
Exceeds remedial objective (exceeds operational $DCGL_W$)	Incorrectly release survey unit. Type I error (probability = α)	No decision error. (probability = $1-\beta$)

Examination of this matrix highlights the importance of limiting the Type I error rate (α) in terms of protection of human health and the environment. The DQO selected for α is 0.05. The DQO selected for β is 0.10 or 0.25, depending on the survey unit size. The value for β can be changed if it is determined to be appropriate to adjust the number of required soil samples, recognizing that this increases the probability of false positives.

5.3 Reference Areas

Because uranium and other naturally occurring radionuclides might be present at significant levels in the environment, establishing background concentrations that describe a distribution of measurement data is necessary to identify and evaluate contributions attributable to site operations. A reference area provides a location to determine these background concentrations that are used for comparisons with sampling activities. Physical, chemical, geological, radiological, and biological characteristics of the reference area should match those of the investigation area to the degree possible. The background soil sampling locations for the Hematite site were chosen because they have similar characteristics to soils in the investigation area, were historically unrelated to plant activities, and were not impacted by industrial development. A technical basis document will be prepared to establish appropriate background concentrations for the radionuclides of interest.

5.4 Surrogate Radionuclides

Soil characterization and historical assessment at the Hematite site have identified a range of radionuclides of various decay schemes, activity concentrations, and dose consequences. Not all radionuclides present can be identified by real-time gamma surveys or by gamma spectroscopy of soil samples, which are the most efficient and cost effective measurements. In addition, each radionuclide contributes to the total dose in varying magnitudes. In order to save both time and resources, it is desirable to select surrogate radionuclides to demonstrate compliance for all the radionuclides and to guide remediation activities. The data used to evaluate the use of surrogate radionuclides is a compilation of characterization data acquired in the areas to be surveyed.

A technical basis document will be prepared to evaluate the use of surrogate radionuclides and calculate the associated parameters discussed below.

5.4.1 Selection of Surrogate Radionuclides

When using a surrogate measurement for multiple radionuclides, it is necessary to determine if the radionuclide activity concentrations have a fairly constant ratio throughout the survey unit. In accordance with Appendix I of MARSSIM, the correlation coefficient, r, will be computed for the activity concentrations of selected surrogates and each of the additional radionuclides and compared to applicable acceptance criteria. In order to improve the correlation among radionuclide activity concentrations, the radionuclides of concern will be separated into appropriate groups for evaluation. For example, U-235 might be analyzed as a surrogate radionuclide for other radionuclides, including U-234, U-238, and Tc-99. Similarly, a surrogate radionuclide might be selected for Th-232 and its decay chain and for the transuranic radionuclides. Calculation of the correlation coefficient, r, will reveal if the selected surrogate radionuclide has an acceptable correlation with the other radionuclides in its group.

Because there is not a simple, fixed ratio of the various radionuclides to a single radionuclide, it will be necessary to use a combination of the methods for related and unrelated radionuclides, described in Appendix I of MARSSIM, to accommodate the use of multiple surrogate radionuclides.

5.4.2 Scaling Factors

Scaling factors are the calculated ratios of a correlated radionuclide activity concentration to that of the surrogate radionuclide activity concentration. It is necessary to develop values for scaling factors that are representative of the situation that will exist at the final cleanup stage. MARSSIM recommends calculating scaling factors at the 95 percent confidence level. If the scaling factor is underestimated (i.e., low), then the contribution of the related radionuclide to the final dose estimate will be underestimated. For purposes of initial planning and development of the sampling plan, it is better to over estimate the value of the scaling factor. Later it will be possible to reevaluate the radionuclide distribution, based on the final sample results, for the purpose of determining a final dose estimate.

Data will be grouped as detailed in Section 5.4.1. The ratios of the correlated radionuclide activity concentrations to that of the surrogate radionuclide activity concentration will then be calculated. The following parameters will then be determined for each radionuclide ratio:

- average
- median
- minimum
- maximum
- standard deviation (σ)
- percent coefficient of variation (%CV)

Using the above information, the radionuclide specific scaling factors will then be calculated at the 95 percent confidence level using the following equation:

$$SF_i = R_i + 1.96\,\sigma_i \qquad \text{(Equation 5-1)}$$

Where:

SF_i = scaling factor of radionuclide i to the surrogate radionuclide

R_i = average activity concentration ratio of radionuclide i to the surrogate radionuclide

σ_i = standard deviation of the average activity concentration ratio

5.4.3 Relative Contribution to Final Dose

It is necessary to determine the relative importance of each of the radionuclides of interest with respect to the final dose to determine the appropriate radionuclides to include in the $DCGL_{total}$ calculation and which radiochemical analyses are appropriate.

The following process will be used to determine which radionuclides will be included in the $DCGL_{total}$:

- Determine the activity for the related radionuclides by multiplying the measured activity of the surrogate by the appropriate scaling factor determined in Section 5.4.2 for each related radionuclide.
- Divide the activity for each surrogate and related radionuclides by their respective DCGL value to determine the fraction of the DCGL.
- Determine the percentage contribution for each radionuclide to total dose by taking the sum of the fractions of the DCGLs for all radionuclides and dividing each radionuclide's fraction of the DCGL by the sum of the fractions to obtain the relative dose contribution fraction for that radionuclide.
- Determine which radionuclides account for 90% of the total dose and include these radionuclides when determining the $DCGL_{total}$.

This approach is consistent with NUREG-1757, Volume 2, Section 3.2 and Appendix O.

5.4.4 $DCGL_{total}$

$DCGL_{total}$ is the $DCGL_W$ value of the surrogate radionuclide adjusted to account for the activity concentration of the other radionuclides that will be calculated (scaled) from the surrogate radionuclide activity concentration (Appendix I, Page I-32 of MARSSIM). Scaling factors are used in the calculation of $DCGL_{total}$.

$$DCGL_{total} = \frac{1}{\frac{1}{D_S} + \sum_{i=1}^{n} \frac{SF_i}{D_i}} \qquad \text{(Equation 5-2)}$$

Where:

D_S = $DCGL_W$ value for the surrogate radionuclide

D_i = $DCGL_W$ values (i = 1,2,…,n) of radionuclides that are related to the surrogate radionuclide

SF_i = scaling factors (i = 1,2,...,n) of radionuclides that are related to the surrogate radionuclide

5.4.5 Unity Rule and Elevated Measurement Evaluation

When multiple, unrelated radionuclides are present, the individual radionuclide DCGLs need to be adjusted to account for the other radionuclides contributing to the total dose. The use of the unity rule requires that the sum of ratios of the concentration of each radionuclide to its respective DCGL must not exceed 1 (MARSSIM).

When multiple surrogate radionuclides and other radionuclides not related to a surrogate are present, the unity rule can be applied as shown in Equation 5-3. (For radionuclides not related to a surrogate, $DCGL_{W_i}$ values for these radionuclides will be substituted for $DCGL_{total_i}$.)

$$\sum_{i=1}^{n} \frac{C_i}{DCGL_{total_i}} \leq 1 \qquad \text{(Equation 5-3)}$$

Where:

C_i = activity concentrations (i = 1,2,...,n) of the surrogate radionuclides and other radionuclides not related to a surrogate

$DCGL_{total_i} = DCGL_{total}$ values (i = 1,2,...,n) for the surrogate radionuclides from Equation 5-2 (Substitute $DCGL_{W_i}$ values for radionuclides not related to a surrogate.)

Small areas of elevated activity will be evaluated using the elevated measurement comparison ($DCGL_{EMC}$). The $DCGL_{EMC}$ is equal to the $DCGL_W$ times the appropriate area factor. Use of area factors is described in Section 4.2.4.

For a single elevated measurement area containing surrogate radionuclides and other radionuclides not related to a surrogate, the unity rule can be applied as shown in Equation 5-4. (For radionuclides not related to a surrogate, $DCGL_{EMC_i}$ values for these radionuclides will be substituted for $DCGL_{E_i}$.)

$$\sum_{i=1}^{n} \frac{C_i}{DCGL_{E_i}} \leq 1 \qquad \text{(Equation 5-4)}$$

Where:

$DCGL_{E_i}$ = $DCGL_{EMC}$ values (i = 1,2,...,n) for the surrogate radionuclides (Substitute $DCGL_{EMC_i}$ values for radionuclides not related to a surrogate.)

$DCGL_{E_i}$ for a surrogate radionuclide is calculated as follows:

$$DCGL_{E_i} = \frac{1}{\dfrac{1}{AF_i \times DCGL_{W_i}} + \sum_{j=1}^{n} \dfrac{SF_j}{AF_j \times DCGL_{W_j}}} \qquad \text{(Equation 5-5)}$$

Where:

i – refers to surrogate radionuclide i

j – refers to the radionuclides (j = 1,2,...,n) related to the surrogate radionuclide i

AF_i = the area factor for surrogate radionuclide i

$DCGL_{W_i}$ = $DCGL_W$ for surrogate radionuclide i

SF_j = the scaling factors (j = 1,2,...,n) for the radionuclides related to the surrogate radionuclide i

AF_j = the area factors (j = 1,2,...,n) for the radionuclides related to the surrogate radionuclide i

$DCGL_{W_j}$ = $DCGL_W$ values (j = 1,2,...,n) for the radionuclides related to the surrogate radionuclide i

(Note: If Equation 5.5 is substituted into Equation 5.4, the resulting equation is equivalent to the inequality I-18 in Appendix I of MARSSIM for the elevated measurement comparison.)

Where there are multiple elevated measurement areas within a survey unit, the following inequality will be used:

$$\sum_{i=1}^{n} \frac{C_i}{DCGL_{total_i}} + \sum_{x=1}^{m} \sum_{i=1}^{n} \frac{\left(C_{EMC_i} - C_i\right)}{DCGL_{E_i}} \le 1 \qquad \text{(Equation 5-6)}$$

Where:

i – refers to the surrogate radionuclides and other radionuclides not related to a surrogate (i = 1,2,...,n)

n = total number of radionuclides, including surrogate radionuclides and other radionuclides not related to a surrogate

C_i = the average concentration of radionuclide i over the entire survey unit

C_{EMC_i} = the average concentration of radionuclide i over the elevated measurement area x within the survey unit

$DCGL_{total_i}$ = $DCGL_{total}$ values (i = 1,2,...,n) for the surrogate radionuclides from Equation 5-2 (Substitute $DCGL_{W_i}$ values for radionuclides not related to a surrogate.)

$DCGL_{E_i}$ = $DCGL_{EMC}$ values (i = 1,2,...,n) for the surrogate radionuclides from Equation 5-5 (Substitute $DCGL_{EMC_i}$ values for radionuclides not related to a surrogate.)

x – refers to the elevated areas (x = 1,2,...,m) within the survey unit

m = total number of elevated areas within the survey unit

5.5 Method to Determine Number of Samples

An example calculation of relative shift using characterization data has been performed. The data used for the example calculation is preliminary data that was available at the time the calculations were performed. It is appropriate to use data that is expected to be representative of the soil concentrations after remediation has occurred. To obtain such a representative data set from the existing characterization data, all radionuclide results above the soil DCGL values were deleted from the data set. Remediation typically addresses most, if not all, soil above the operational DCGL values. The data set used to generate the statistics necessary for the example calculations is provided in Appendix A.

For the purposes of these example calculations, the only nuclides considered were Tc-99, Th-232, U-234, U-235, and U-238. Am-241, Np-237, and Pu-239 were not included due to the lack of adequate data to address these nuclides. The values for Tc-99 and U-235 are results as reported from the laboratory. The Th-232 values were obtained from the reported Ac-228 results. The U-238 values were obtained from the reported Th-234 results. There were nine U-238 alpha spectroscopy results available; however, the highest value reported was 11.2 pCi/g, which is less than the standard deviation. The gamma spectroscopy results from Th-234 resulted in a larger data set with more realistic deviations across the population. The U-234 values are from nine alpha spectroscopy results. MARSSIM recommends using site-specific data if available, reference area data if available, or if data is not readily available, assuming a 30% standard deviation of the DCGL as a default value. Table 5-2 shows the nuclides considered, standard deviations, number of samples used for statistical purposes, and the DCGL value used for each parameter.

Table 5-2 Data for Relative Shift Calculation

Nuclide	Standard Deviation (pCi/g)	Number of Samples	DCGL (pCi/g)
Tc-99	26.58	111	140
Th-232 (Ac-228)	0.44	114	2.9
U-234	35.96	9	518
U-235	10.66	120	63
U-238 (Th-234)	25.31	111	224

5.5.1 Determining Relative Shift

The relative shift (Δ/σ) is a parameter that quantifies the concentrations to be measured in a survey unit relative to the variability in these measurements. Delta (Δ) or shift is equal to the $DCGL_W$ minus the lower bound of the gray region (LBGR) value.

Example delta (Δ):

$$\Delta = DCGL_W - LBGR \qquad \text{(Equation 5-7)}$$

Because unity is the $DCGL_W$ when multiple radionuclides are present:

$DCGL_W = 1$
$LBGR = 0.5 * DCGL_W = 0.5$

$\Delta = 1 - 0.5 = 0.5$

This is an example. The final LBGR will be based on characterization results and the need to consider both the LBGR and σ to balance a reasonable sample size against the probability of a Type II error.

The standard deviation (σ) is either the expected standard deviation of the measurements to be made in the survey unit (σ_s) or the standard deviation established for the corresponding reference area (σ_r). Sigma (σ_s or σ_r) is calculated from the following expression (MARSSIM App. I):

$$\sigma = \sqrt{[\sigma(C_1)/D_1]^2 + [\sigma(C_2)/D_2]^2 + ... + [\sigma(C_n)/D_n]^2} \qquad \text{(Equation 5-8)}$$

Where:

$\sigma(C_{1,2,...,n})$ = the expected standard deviations of the radionuclides (1,2,...n)

$D_{1,2,...,n}$ = the calculated $DCGL_W$ values for the radionuclides (1,2,...n). [$DCGL_{total}$ values will be substituted for $DCGL_W$ values if surrogate radionuclides are used.]

Example sigma (σ):

The specific characterization data standard deviation values are listed in Table 5-2.

The surface source $DCLG_W$ values for radionuclides are also listed in Table 5-2.

$$\sigma = \sqrt{[26.58/140]^2 + [0.44/2.9]^2 + [35.96/518]^2 + [10.66/63]^2 + [25.31/224]^2}$$

$$\sigma = (.036 + .023 + .005 + .029 + .013)^{1/2}$$

$$\sigma = (.106)^{1/2}$$

$$\sigma = 0.325$$

Example relative shift:

Relative shift = Δ/σ

$\Delta = 0.5$

$\sigma = 0.325$

Relative shift (Δ/σ) = 0.5/0.325 = 1.54

MARSSIM recommends a range of 1 to 3 for Δ/σ. If the value calculated is outside that range, the LBGR can be adjusted to provide a relative shift in that recommended range; however, no adjustments are necessary based on these calculations.

5.5.2 Selecting the Required Number of Samples for the WRS Test

The minimum number of samples to be obtained from each reference area/survey unit pair for the WRS test is computed by the following equation:

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{3(P_r - 0.5)^2} \qquad \text{(Equation 5-9)}$$

where:

N = the minimum number of samples required for each reference area/survey unit pair

$Z_{1-\alpha}$ = the percentile represented by the α decision error (α error of 0.05 = 1.645 from Table 5.2 in MARSSIM)

$Z_{1-\beta}$ = the percentile represented by the β decision error (β error of 0.10 = 1.282 from Table 5.2 in MARSSIM)

P_r = the probability that a random sample measurement from the survey unit exceeds a random sample measurement from the reference area by less than the $DCGL_W$ when the survey unit median concentration is equal to the LBGR concentration above background (relative shift of 1.54 = 0.8617302 from Table 5.1 in MARSSIM)

An example calculation of the number of samples (N) is provided as follows:

$$N = \frac{(1.645 + 1.282)^2}{3(.8617302 - 0.5)^2} = \frac{8.567}{0.393} = 22$$

MARSSIM recommends increasing the number of calculated samples by 20% to account for a reasonable amount of uncertainty in the parameters used to calculate N and still allow flexibility to account for some lost or unusable data. This gives a value of 27 samples for the reference area/survey area pair. To distribute this value between the survey unit and the reference area, half of the samples are assigned to the survey unit and half to the reference area. This would result in 14 samples being taken in each area.

5.6 Determination of Grid Spacing

A systematic triangular sampling grid pattern with a random starting point will be used to establish the soil sampling points within each Class 1 or Class 2 survey unit. The distance between the grid nodes (L) will be determined by the following equation:

$$L = \sqrt{\frac{A}{0.866N}} \qquad \text{(Equation 5-10)}$$

where A is the area to be covered by the grid and N is the number of samples.

An example calculation of L is provided as follows:

A = 1854 square meters (Class 1)

N = 14 required samples

$$L = \sqrt{\frac{A}{0.866N}} = \sqrt{\frac{1854\ m^2}{0.866 \cdot 14}} = \sqrt{\frac{1854}{12.124}} = 12.37\ m$$

For this example of a Class 1 survey unit of 1854 square meters, each sample would represent 132 square meters. A random starting point would be selected in this survey unit. The grid coordinates of all locations within this survey unit would be identified at intervals of 12.3 meters along the same east-west reference grid line as the initial random starting point. The next line of sample locations would start 10.7 meters (L*0.866) south or north and 6.1 meters (L/2) east or west of the initial reference grid line. This process is repeated until the entire survey unit is covered by the triangular pattern.

5.7 Adjustment of Grid Spacing Based on Scan MDC

The triangular grid pattern has an approximately 90 percent chance of detecting a circular hot spot of radius equal to one half the grid spacing. The hot spot size indicates the appropriate area factor for calculating the $DCGL_{EMC}$ from the $DCGL_W$. Area factors are presented in Section 4.2.4.

The scanning instrument MDC required to detect an area of elevated activity is given by the following expression:

$$\text{Scan MDC (required)} = DCGL_W \times A_m \qquad \text{(Equation 5-11)}$$

where A_m is the area factor corresponding to the hot spot area detected by the systematic triangular grid (Section 5.6).

If the instrument Scan MDC (actual) is <Scan MDC (required), then the survey instrument will be sufficient to detect areas of elevated activity. If not, then it is necessary to calculate the area factor that corresponds to the actual scan MDC:

$$\text{Area Factor} = \text{Scan MDC (actual)} / DCGL_W \qquad \text{(Equation 5-12)}$$

The corresponding size of an area of elevated activity is then obtained from Table 4-2 shown in Section 4.2.4. The number of samples (N) is now calculated by dividing the survey unit area by the area of elevated activity that can be detected by the scanning instrument, and the grid spacing is recalculated as in Section 5.6.

5.8 Approval Process for Changes to Survey Design

As data is collected and evaluated, revisions to the survey plan might become necessary. If the survey plan design will not meet the limits on decision errors within the budget or other constraints, it might be necessary to relax one or more constraints. For example, if the data variability is much greater than that initially used to determine the number of samples required for each survey unit, the Type I (α) error rate might have to be increased to maintain the number of samples required at a reasonable number. Other examples include:

- Revising the exposure pathway model used to develop site-specific DCGLs
- Increasing the width of the gray region by decreasing the LBGR

Westinghouse will request approval from the NRC for any proposed change to the agreed upon value of the Type I (α) error rate. Westinghouse will notify the NRC in writing within 30 days of any change to the survey plan that requires a recalculation of the DCGLs. DCGLs and related MDCs (for both scan and fixed measurement methods) will not be increased without NRC approval. Submittals will include a description of and justification for the revision. Other changes to the survey plan allowed by Section 9.6 of the DP will be documented in the final status survey report.

6.0 SURVEY INSTRUMENTATION AND MEASUREMENT TECHNIQUES

This chapter presents a summary of field instrumentation and laboratory analyses that will be used during remediation. To better understand the selection and use of survey meters and analytical analyses, the relationship of radionuclide concentration to dose must be examined.

6.1 Radionuclide Relationship to Dose

The relative dose contribution fraction represents the individual radionuclide's contribution to the total dose. The fractions will be calculated based on analytical results from characterization samples. The relative dose contribution fractions will be compiled in a technical basis document.

As an example, Table 6-1 shows an example of a realistic mixture of radionuclides (not for the Hematite site) where the surrogate radionuclides are those that can be measured by relatively inexpensive gamma spectrometry analysis techniques. In this table only the concentrations of the surrogate radionuclides are based on the measured values. The concentrations of the related radionuclides are calculated using the conservative values determined for the scaling factors. For example, the scaling factor is equal to 3 for the Sr-90 to Cs-137 ratio. This approach is similar to that utilized in other applications, such as waste disposal, where it is cost prohibitive to make the full compliment of possible analyses for each waste package or shipment.

Table 6-1 Relative Dose Contribution Fraction

Surrogate Radionuclide	Related Radionuclide	Scaling Factor	DCGL ($Bq\ g^{-1}$)	Measured Activity ($Bq\ g^{-1}$)	Fraction of the DCGL	Relative Dose Contribution Fraction (%)
Co-60	-	-	0.14	11	7.89×10^{-1}	4.00
	H-3	0.3	4.1	3	8.18×10^{-1}	0.041
	Fe-55	3	370	33	9.00×10^{-2}	0.005
	Ni-63	1	78	11	1.43×10^{-1}	0.007
Cs-137	-	-	0.41	37	9.09×10^{1}	4.60
	Sr-90	3	0.06	111	1.76×10^{3}	89.35
Am-241	-	-	0.078	2	2.38×10^{1}	1.21
	Pu-239	0.5	0.09	1	1.09×10^{1}	0.55
	Pu-241	7	2.7	13	4.86×10^{0}	0.25
				Total	1.98×10^{3}	100

The relative dose contribution fractions are calculated as described in Section 5.4.3. This analysis will identify which radionuclides deliver the highest percentage of dose. The analysis is conservative because the majority of non-gamma-emitting radionuclide data is calculated using scaling factors calculated at the 95 percent confidence level. This information will be used to select field survey instrumentation and establish the requirements for laboratory analyses.

6.2 Field Instrumentation

Surrogate radionuclides will be selected that can be detected using survey instruments. Analysis of survey instruments and detector capabilities will be evaluated in an instrumentation technical basis document prior to the start of survey activities. Examples of field instruments to be used will be based on MARSSIM recommendations and other evaluated instruments and can include gamma scintillators, in situ gamma spectrometry systems, and gas flow proportional counters (β mode). Scanning for gross-gamma activity will be used to guide remediation activities and as part of the final status survey when remediation is complete. Typical detectors that might be used for gamma surveys are listed in Table 6-2.

Table 6-2 Radiation Detectors for Gamma Surveys

Detector Type	Description	Application	Remarks
Scintillation	NaI(Tl) scintillator; up to 5 cm by cm	Surface scanning; exposure rate correlation	High sensitivity; cross calibrate with PIC (or equivalent) or for specific site gamma energy mixture for exposure rate measurements.
	CsI or NaI(Tl) scintillator; thin crystal	Scanning; low-energy gamma and x-rays	Detection of low-energy radiation
Gas Ionization	Pressurized ionization chamber; non-pressurized ionization chamber	Exposure rate measurements	
Geiger-Mueller	Pancake (<2 mg/cm^2 window) or side window (~30 mg/cm^2)	Surface scanning; exposure rate correlation (side window in closed position)	Low relative sensitivity to gamma radiation

Use of these field instruments will be evaluated against the objective of achieving MDCs of less than the operational $DCGL_W$ values for direct measurements and/or scanning measurements. MDCs will be calculated for scanning instruments using the method provided in MARSSIM for calculating MDCs that address both Type I and Type II errors (i.e., elimination of false negatives and false positives), as follows:

$$Scan\ MDCR_{surveyor} = \frac{MDCR}{\sqrt{p}\ \epsilon_i} \qquad \text{(Equation 6-1)}$$

where MDCR is the minimum detectable count rate in counts per minute (cpm), ε_i is the instrument efficiency (cpm/μR/hour), and p is the surveyor efficiency. The calculation of MDCs using the above equation will be provided in a technical basis document. The approaches described in the paper by E.W. Abelquist, "Scan MDCs for Multiple Radionuclides in Class 1 Areas" (Ref. 12), will be used to guide the development of scan MDCs.

Based on laboratory studies (Ref. 13 and Ref. 14), the value of p has been estimated to be between 0.5 and 0.75. The value of 0.5 is conservative. In addition:

$$\mathrm{MDCR} = s_i \times (60/i) \qquad \text{(Equation 6-2)}$$

where s_i is the minimal number of net source counts required for a specified level of performance for the interval i, in seconds, and:

$$s_i = d'\sqrt{b_i} \qquad \text{(Equation 6-3)}$$

where d′ is the value selected from MARSSIM Table 6.5 based on the required true positive (1-β) and false positive rates (α), and b_i is the number of background counts in the intervals. The value of d′ used to calculate the detector sensitivity values is 1.9, corresponding to an alpha of 0.05 and beta of 0.40. This value of d′ will result in about 60 percent true positives and about 5 percent false positives.

To account for the multiple radionuclides, both gamma emitters and non-gamma emitters on site, scan MDCs will be evaluated against the operational $DCGL_W$ values by the calculation of a weighted DCGL value that represents the fraction of the total activity concentration that can be detected by a gamma scan. This calculation is conservative in that the majority of the non-gamma-emitting radionuclide data are calculated using scaling factors calculated at the 95 percent confidence level.

$$DCGL_{SCAN} = F / \sum (f_i / DCGL_i) \qquad \text{(Equation 6-4)}$$

where F is the fraction of the sample activity that emits gamma (i.e., is detectable), f_i is the fraction of the sample activity from radionuclide i and $DCGL_i$ is the DCGL value for radionuclide i. An average of the $DCGL_{SCAN}$ values will be calculated for Areas 1, 2, and 3. These values will be compared to the MDC_{SCAN}, a weighted average of the MDC values for the surrogate gamma-emitting radionuclides, calculated as follows:

$$MDC_{SCAN} = 1 / \Sigma\,(fg_i / MDC_i) \qquad \text{(Equation 6-5)}$$

where fg_i is the fraction of the activity concentration of radionuclide i (gamma emitters only) and MDC_i is the calculated MDC value of radionuclide i. It is generally considered good practice to select survey instruments with a MDC of 10 to 50 percent of the DCGL.

This calculation will determine which survey area is most limiting for the MDC, assuming various background levels. This calculation will determine if scan MDC values for selected detectors are adequate to detect the operational $DCGL_W$ and if additional sample points will be required based on Section 5.7. The results for the survey areas will be summarized in a technical basis document.

6.3 Laboratory Analysis

Each soil sample collected will be analyzed by gamma spectroscopy either by an onsite laboratory or offsite laboratory. The surrogate radionuclides will be identified and compared to their respective $DCGL_{total}$ values and the acceptance criteria of unity via the unity summation. Ten percent of the samples collected will undergo additional laboratory analyses for specific radionuclides. For those radionuclides that are determined to have a negligible relative dose contribution, specific analyses for these radionuclides will only be performed to the extent necessary to properly classify the waste per 10 CFR 61. The minimum MDCs required for analytical analyses are 25 percent of the operational $DCGL_{total}$ values for the surrogate radionuclides and 25 percent of the operational $DCGL_W$ values for the additional radionuclides. The required MDCs for laboratory analysis will be determined in a technical basis document.

6.4 Sampling and Measurement Technique

6.4.1 Field Survey

A combination of the following techniques can be used to achieve the desired survey requirements for an area.

6.4.1.1. Surface Scans

Depending on the area classification (Class 1, Class 2, or Class 3), scanning coverage of an area will range from judgmental to 100 percent. Surface scans will be used to detect gamma-emitting radionuclides and will most likely employ survey instruments equipped with sodium iodide (NaI) scintillation crystal detectors. When scanning soil, the detector is held close to the ground (1 to 2 inches) and moved in a serpentine pattern. A scan rate of 0.5 meter per second will be used. In the scanning mode, the audio response should be used to help prevent failure to detect an elevated area due to meter response time.

6.4.1.2. Discrete Point Measurements

An alternate to scanning is to perform discrete point (fixed) measurements comparable to the scan coverage required by the area classification. A fixed gross-gamma measurement and global positioning system reading will be taken in each grid or predetermined interval. The fixed reading count time will be determined based on the current background count rate in the area and the required sensitivity.

An in situ gamma spectroscopy measurement can be substituted for a fixed gross-gamma count. If a single-channel analyzer (calibrated for a selected nuclide) is used, a weighted threshold value for the selected nuclide, based on the area specific relative fractions of the gamma emitting surrogate radionuclides and their respective $DCGL_{total}$ values, will be used to evaluate the results. If a multi-channel analyzer is used, the results of the surrogate radionuclides can be evaluated by dividing by their $DCGL_{total}$ values and a unity summation calculation. A multi-channel analyzer might also be used in lieu of soil sample gamma spectroscopy results.

If the discrete point measurement approach is used, a technical basis document will be developed to provide details on how the approach will be implemented and to determine the scan MDC to be used.

6.4.2 Soil Sampling

6.4.2.1. Surface Sampling

Soil sampling will be conducted to assess the effectiveness of the remediation efforts. Surface samples will be collected from the top 15 centimeters (6 inches) of soil, which corresponds to the soil mixing or plow depth in several environmental pathway models. Grass, rocks, sticks, and foreign objects will be removed from the soil samples to the degree practical at the time of sampling. If there is reason to believe these materials contain activity, they will be retained as separate samples.

6.4.2.2. Composite Sampling

Composite sampling will be conducted during remediation activities for soils potentially to be used as backfill. Soil will be randomly collected and uniformly mixed (e.g., a sample from each excavating equipment bucket). A number of samples per lift (layer) will be collected to evaluate the suitability of that soil to be used as backfill.

6.4.2.3. Three-foot Backfill Layer Sampling

Soil samples will be collected during backfilling activities as described in Section 7.2.2. For purposes of a final status survey, every 3-foot layer will be considered a survey unit. The predetermined number of soil samples (Section 5.5) will be collected in a 3-foot depth interval to encompass the entire layer. A composite sample of the 3-foot interval will be submitted for analysis.

6.4.3 Reference Coordinate Systems

Measurement and sample locations can be identified in one of two ways—using a benchmark location or a global positioning system (GPS). If benchmark is used, the benchmark (origin) will be provided on the map or plot included in the final status survey package. Any coordinate systems used for surveys will typically take the form of a grid of intersecting, perpendicular lines, but other patterns (e.g., triangular and polar) might be used as convenient. Physical application of a grid to a survey unit will only be done in cases where it is beneficial and cost effective to do so. When a physical grid is used, benchmark locations will be designated by setting an iron pin (or equivalent). If needed, grid lines or measurement location will be marked (e.g., with chalk lines, paint, or surveyor's flags), as appropriate. Global positioning systems can also be used as practical.

7.0 REMEDIAL ACTION SUPPORT AND FINAL STATUS SURVEYS

As noted in Section 4.1, detailed site characterization data is being developed under the RI/FS Work Plan. This characterization data and information developed through this soil survey plan, as well as through other investigative steps being taken pursuant to the NCP process, will be used to determine the most appropriate approaches for site remediation and facility decommissioning. With respect to soil remediation, several alternative approaches might be considered, including the removal of soil with activity concentrations above the operational $DCGL_W$. This section provides the details of how remediation action support surveys and final status surveys will be performed if soil removal is the ultimate soil remediation approach selected.

7.1 Remedial Action Support Surveys

Remedial action support surveys will be performed while remediation is being conducted and will guide the cleanup in a real-time mode. These surveys will be used to determine when a survey unit is ready for the final status survey and provide updated estimates of site-specific parameters used for planning the final status survey. The remedial action surveys will rely principally on direct radiation measurements using gamma sensitive instrumentation described in Section 6.0.

Under this approach, soil or debris will be characterized into one of four categories based on physical description and/or radiological survey:

- Contaminated soil—soil with activity concentrations above the operational surface $DCGL_W$ (or above the operational volumetric $DCGL_W$ if the soil is from an excavation that will be backfilled with acceptable backfill soil).
- Acceptable backfill soil—soil with activity concentrations below the operational volumetric $DCGL_W$
- Suspect contaminated soil—soil that requires additional characterization to determine if the activity concentrations are below the operational volumetric $DCGL_W$
- Debris—non-soil material that is oversized, e.g., concrete fragments, bricks

Debris will be segregated from soil to the extent practical by visual inspection. Disposition of the debris will be in accordance with applicable requirements.

Based on survey instrument MDC_{SCAN} and $DCGL_{SCAN}$ (Section 6.0), two survey instrumentation threshold values will be determined. The lower-bound threshold is the value below which surveyed soil is acceptable to leave in place. The upper-bound threshold is the value above which surveyed soil is contaminated soil. The two threshold values will be conservatively set based on empirical data. For example, the lower-bound threshold value will be set at the average net-counts-per-minute value corresponding to the $DCGL_{SCAN}$ less one standard deviation and the upper-bound threshold will be set at the average plus one standard deviation. The average net-counts-per-minute value will be derived from empirical data and will be continually checked as survey and analytical data is collected. Soil surveyed with results between the two threshold values will be stockpiled as suspect contaminated soil and will be sampled for analytical laboratory analysis to determine if the soil is acceptable backfill or contaminated.

Two situations that require remedial action support surveys are detailed in this section. The first involves the remediation of areas of contaminated surface soil, and the second involves the removal of overburden soil in order to remediate contaminated subsurface soil.

7.1.1 Surveys During Removal of Surface Contaminated Materials

Prior to remediation, the location of surface contaminated soil will be visually marked in the field based on existing site maps and the surveyed coordinates (northings and eastings) for each surface contaminated soil sample location. If there are areas where there have been significant ongoing activities since the historical assessment and characterizations were completed, the historical information will be supplemented by field gamma surveys to determine if additional areas have been contaminated. Field gross-gamma scanning will occur at the time of remediation to establish the initial remediation boundaries around contaminated soil sample locations.

As soil is removed, operational gross-gamma scans will be used to guide soil removal and segregation. When scanning indicates that the soil remaining in the excavation area is below the lower-bound threshold value, the area will be ready for the final status survey.

7.1.2 Surveys During Removal of Overburden Materials

Prior to removal of overburden, the location of the excavation areas will be visually marked in the field based on existing site maps. Prior to the removal of the surface layer and as each subsequent layer is removed in 3-foot lifts, gross-gamma scans will be performed to screen for hot spots. Hot spots will be removed. Random samples of soil will be taken from each excavation equipment bucket. These samples will be combined and uniformly mixed. A representative number of samples from the composite will be analyzed per Section 6.3. Soil will be stockpiled and marked. When the "bottom" is reached, remedial action surveys will be conducted in accordance with Section 7.1.1. If the excavation is to be backfilled with acceptable backfill material, the lower-bound threshold will be set to the value below which surveyed soil is acceptable backfill soil.

7.2 Final Status Surveys

The final status survey will be used to select/verify survey unit classification and to demonstrate that the survey objectives have been achieved. Two situations that require final status surveys are detailed in this section. The first involves the final status survey of remediation areas, and the second involves the final status survey of removed overburden soil after the soil is returned in 3-foot layers. The surveys will be performed using gamma-sensitive instrumentation and laboratory analyses described in Section 6.0.

7.2.1 Post-remediation Surveys

The final status survey units will be defined and marked per Section 4.3 prior to remediation activities. When remediation activities in a survey unit are completed the following will be performed:

- A gamma scan as defined by area classification will be performed per Sections 5.2.1.2 and 6.4.1.
- The sample grid and starting location will be established per Section 5.6.
- The number of samples determined per Section 5.5 will be taken and analyzed per Sections 6.3 and 6.4.
- The data will be evaluated per Section 9.0.

7.2.2 Post-remediation Surveys for Returned Overburden Material

When remediation activities in a survey unit that required the excavation of substantial overburden soil (e.g., >50 m^3) are completed, the following will be performed:

- The bottom of the excavation will be surveyed as detailed in Section 7.2.1.
- A 3-foot layer of acceptable backfill will be placed in the excavation.
- A gamma scan as defined by area classification will be performed per Sections 5.2.1.2 and 6.4.1.
- The sample grid and starting location will be established per Section 5.6.
- The number of samples determined per Section 5.5 will be taken and analyzed per Sections 6.3 and 6.4.
- The data will be evaluated per Section 9.0.

- The sequence of 3-foot layers of acceptable backfill, and subsequent surveying and sampling, will be repeated as necessary to fill the excavation.

A visual depiction of this process is shown in Figure 7-1.

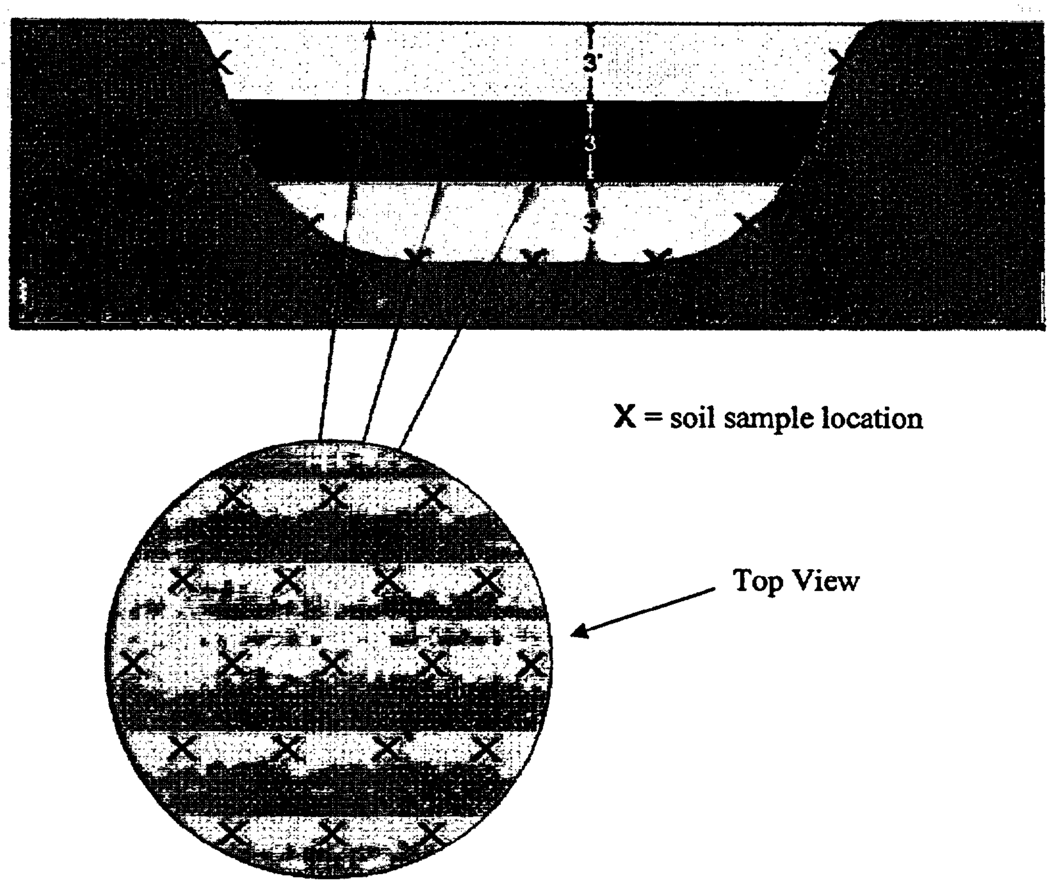

Figure 7-1 Surveying and Sampling for Returned Overburden Soil

7.3 Records Management

Records required to be generated for soil surveys will be defined in written procedures. Records will be signed, or otherwise authenticated, and dated. Methods of correcting errors will be identified along with a means of documenting the authorized individual who made the corrections. Soil survey records will be maintained in accordance with the records management requirements in Chapter 2 of License No. SNM-33.

C10

8.0 QUALITY ASSURANCE AND CONTROL

8.1 Introduction

The goal of quality assurance and quality control (QA/QC) is to identify and implement sampling and analytical methodologies that limit the introduction of error into analytical data. This section establishes the system necessary to ensure that radiation surveys produce results that are of the type and quality needed and expected for their intended use. QA/QC covers all aspects of data collection, including both field radiation instrument surveys and soil sampling for laboratory analysis, from planning through the documentation of the results. The evaluation of measurement results is covered in Section 9.0.

8.2 Instrumentation

For all counting systems and instruments used to generate measurement data, the following QA/QC principles will be applied at a minimum.

8.2.1 Procedures

Counting systems and instruments will be used in accordance with approved procedures.

8.2.2 Source and Instrument Checks

Each day that a counting system or instrument is used, the response will be checked a minimum of two times per day (e.g., before and after use) using an appropriate source. Additional response checks might be necessary depending on the counting system used and the length of time the instrument is in use during the day. In addition:

- For laboratory counting systems, source check acceptance criteria, e.g., $\pm 2\sigma$ of the average response determined after the most recent calibration or otherwise linking the response to the current calibration, will be established prior to using the counting system. Control charts will be used to evaluate the data.

- For field instrumentation, source check acceptance criteria, e.g., $\pm 2\sigma$ for direct (integrated) measurements and ±20 percent for rate measurements, will be established.

- For field instruments of increased complexity (e.g., single-channel analyzers), additional checks such as energy calibration and efficiency checks will be performed and documented.

- All source check results will be documented.

- Failed source checks will be repeated. Consecutive failure will result in additional testing of the counting system in accordance with the applicable procedure and ultimately removing the counting system from service.

- Survey data acquired prior to an instrument failing a source check will be reviewed to determine the validity of the data. This review will be documented.

- All instrument failures in the field will be followed by an investigation of suspect data. All investigations will be documented.

8.2.3 Background Determination

Each day that an analysis is performed, the ambient background will be determined and documented at least once daily, depending on the counting system and instrument used and the variability in the background.

8.2.4 Calibration

All counting systems and instruments will be calibrated with a National Institute of Standards and Technology (NIST) traceable source at intervals specified in License No. SNM-33. The source used will be appropriate for the type and the energy of the radiation to be detected. All calibrations will be documented and include the source data.

8.3 Sample Collection

8.3.1 Procedure

Soil samples will be collected in accordance with written procedures. Sampling tools will be cleaned and monitored, as appropriate, after each use. Samples will be collected in clean/unused sealable containers.

8.3.2 Documentation

Sample containers will be permanently labeled/marked in the field at the time of collection by the technician collecting the sample. At a minimum, the sample identification number and the sample location will be recorded on the sample container. Additional information on the sample, such as the surveyor's name/initials, date/time of sample collection, and instrument used, will be specified and documented in accordance with written procedures.

Sample identification numbers will consist of an alphanumeric code that further defines the sample type, location, and depth at which the sample was taken. All samples that might contain radionuclide levels in excess of 100 times the baseline concentration or that, because of their form, might be a potential laboratory contamination concern will be identified on the outside of the container with a "radioactive material" caution label.

8.3.3 Chain of Custody

An approved procedure will be used for chain of custody to ensure that the integrity of the sample is maintained throughout sampling, transportation, analysis, and archiving.

8.3.4 Analysis Requirements

For each type of laboratory analysis requested, a specification, including at a minimum the following, will be made:

- Required analyses and/or analytical methodology
- The required MDC value for each radionuclide
- Any result presentation requirements
- Sample disposition
- Turnaround time required to support the project

8.4 Analytical Laboratory

For onsite laboratories and any analytical laboratories (vendors) used, at a minimum, the following QA/QC principles will be applied:

- Proper maintenance, storage, and archiving of samples after transfer to laboratory will be practiced.
- An approved internal QA program will be in place.

8.5 Analytical QC

A number of samples equal to, at a minimum, 5 percent of the total number of samples for a specific laboratory analysis will be submitted for the purposes of QA/QC. Of these samples, approximately one third will be duplicate samples, one third will consist of background soil, and one third will consist of soil containing a known quantity of one or more radionuclides, when possible. The results of these QA/QC samples will be reviewed to assess the accuracy and precision of the laboratory counting system as follows:

- The results of duplicate samples and samples of soils of known activity concentrations will be reviewed against the original analysis results ±2σ.

- The results of background soil analysis will be reviewed against the desired MDCs for specified radionuclides. The MDCs reported should be less than the desired MDCs.

- The results of these samples and their review will be included in the final report.

8.6 Personnel

8.6.1 Training

All individuals, including subcontractors, who collect samples and/or operate survey instruments or analytical counting systems will be trained accordingly, and such training will be documented. Training will be commensurate with the education, experience, and proficiency of the individual and the scope, complexity, and nature of the assigned activity.

8.6.2 Qualification

All individuals, including subcontractors, who collect samples and/or operate survey instruments or analytical counting systems will be qualified, and such qualification will be documented. Qualification requirements will be commensurate with the scope, complexity, and nature of the assigned activity.

8.6.3 Documentation

All steps of the process, including, but not limited to, training, calibration of the instrumentation, daily checks, surveys, sampling, and results analysis and interpretation, will be documented such that all records will be auditable. Records will be maintained in accordance with the records management requirements in Chapter 2 of License No. SNM-33.

8.7 Audits

An audit program will be established and implemented that covers all aspects of the survey plan. Audits will be conducted in accordance with the surveillance and audit requirements specified in Chapter 2 of License No. SNM-33.

9.0 DATA ASSESSMENT

Data will be reviewed to ensure that the requirements stated in the survey plan are implemented as prescribed and results of the data collection activities support the objectives of the survey or permit a determination that these objectives should be modified. It will be determined if the data are of the right type, quality, and quantity to demonstrate compliance with the plan objective. The review will check that the appropriate number of samples were taken in the correct locations and were analyzed with measurement systems with appropriate sensitivity. After the data are analyzed, a sample estimate of data variability, namely the sample standard deviation (σ) and actual number of valid measurements, will be used to determine that the sampling design provides adequate power to determine that the objectives of the survey design are met. A review will be conducted to ensure radionuclide relationships used to calculate surrogate DCGLs are appropriate.

9.1 Preliminary Data Review

QA/QC reports will be reviewed, graphs of the data will be prepared, and basic statistical quantities will be calculated, as applicable, to analyze the structure of the data and identify patterns, relationships, or potential anomalies. The survey data will be reviewed as it is collected. The preliminary data examination includes:

- Evaluation of data completeness
- Verification of instrument calibration
- Verification of sample identification and traceability back to sampling location
- Measurement of precision using duplicates, replicates, or split samples
- Measurement of bias using reference materials or spikes examination of blanks for contamination
- Assessment of adherence to method specifications and QC limits
- Evaluation of method performance in the sample matrix
- Applicability and validation of analytical procedures for site-specific measurements
- Assessment of external QC measurement results and QA assessments

9.2 Investigation Levels

Radionuclide-specific investigation levels will be used to indicate when additional investigations might be necessary. Investigation levels will also serve as a QC check to determine when a measurement process begins to get out of control. Table 9-1 lists the investigation levels that will be used.

Table 9-1 Post-Remediation Survey Investigation Levels

Survey Unit Classification	Flag Direct Measurement or Sample Result When:	Flag Scanning Measurement Result When:
Class 1	>operational $DCGL_{EMC}$ or >operational $DCGL_W$ and > mean + 3 std. dev.	>operational $DCGL_{EMC}$
Class 2	>operational $DCGL_W$	>operational $DCGL_W$ or >MDC
Class 3	>fraction of operational $DCGL_W$	>operational $DCGL_W$ or >MDC

A measurement that exceeds an investigation level might indicate that the survey unit has been improperly classified or it might indicate a failing instrument. When an investigation level is exceeded, the first step will be to confirm that the initial measurement/sample actually exceeds the particular investigation level. This might involve taking further measurements to determine that the area and level of the elevated residual radioactivity are such that the resulting dose or risk meets the release criterion.

Once it is confirmed that a survey unit fails to demonstrate compliance with the release criterion, the process described in Section 8.5.3 of MARISSM will be followed. If additional sampling is determined to be appropriate, the double-sampling approach in Appendix C of NUREG-1757, Vol. 2 will be used. Site-specific information will be reviewed to fully evaluate all of the possible reasons for failure, their causes, and their remedies. The DQO process will be used to identify and evaluate potential solutions to the problem. Alternatives will be evaluated against the DQOs, and a survey design that meets the objectives of the project will be selected.

9.3 Data Evaluation and Conversion

For comparison of survey data to operational DCGLs, the survey data from field and laboratory measurements will be converted to DCGL units. It will be ensured that data measurements retain traceability to NIST and conversion factors are appropriate for the radiation quantity. The preliminary data reports will be reviewed to ensure adequate measurement sensitivity is being achieved and to resolve any detector sensitivity problems.

An evaluation will be made to determine that the data are consistent with the underlying assumptions made for survey plan statistical procedures. The basic statistical quantities that will be calculated for the survey unit are as follows:

- mean
- standard deviation
- median
- minimum
- maximum

A review will be conducted to ensure that the relationship between radionuclides used to determine surrogate values for DCGLs remains valid. If the radionuclide ratios and associated correlations are determined to be invalid, the surrogate DCGLs will be re-determined and the statistical tests will be conducted using the revised surrogate DCGL values or specific radionuclide concentration measurements when available for a sample location.

The value of the sample standard deviation will be used to determine if a sufficient number of samples were collected to achieve the desired power of the statistical test. A verification that the sample sizes determined for the tests are sufficient to achieve the DQOs set for the Type I (α) and Type II (β) error rates will be completed. Additionally, verification of the power of the tests ($1-\beta$) to detect adequate remediation will be performed. If an insufficient number of samples were taken, a resurvey will be performed. A resurvey will be performed only if the sample size must be increased by more than 20 percent, because MARSSIM Table 5.5 includes a correction factor of 20 percent to allow for lost or unusable data.

Graphical data review will consist of a posting plot and histogram to potentially reveal heterogeneities in the data. If the posting plot reveals systematic spatial trends in the survey unit, the cause of the trends will be investigated. A frequency plot will be used for examining the general shape of a data distribution. The frequency plot will be used to reveal any obvious departures from symmetry in the data distributions for the survey unit. Methods for checking the assumptions of statistical tests are listed in Table 9-2.

Table 9-2 Methods for Checking the Assumptions of Statistical Tests

Assumption	Diagnostic
Spatial independence	Posting plot
Symmetry	Histogram
Data variance	Sample standard deviation
Power is adequate	Retrospective power chart

Certain departures from the survey plan assumptions might be determined to be acceptable when given the actual data and other information. More sophisticated tools for determining the extent of the validity of the survey data can be used (e.g., Ref. 15). These evaluations will be documented. If it is not possible to show that the DQOs were met with reasonable assurance, a resurvey will be performed.

9.4 Data Analysis

The first step in evaluating the data for a given survey unit is to draw simple comparisons between the measurement results and the release criterion. The initial comparisons made for the results for a given survey unit depend on whether or not the results are to be compared against a background reference area. If the survey data are in the form of gross (non-radionuclide-specific) measurements or if the radionuclide of interest is present in background in a concentration that is a relevant fraction of the operational $DCGL_W$, then the initial data evaluation will be as described in Table 9-3.

Table 9-3 Initial Evaluation of Survey Results (Background Reference Area Used)

Survey Result	Conclusion
Difference between the maximum concentration measurement for the survey unit and the minimum reference area concentration is less than the operational $DCGL_W$	Survey unit meets release criterion
Difference between the average concentration measured for the survey unit and the average reference concentration is greater than the operational $DCGL_W$	Survey unit does not meet release criterion
Difference between any individual survey result and any individual reference area concentration is greater than the operational $DCGL_W$ and difference between the average concentration and the average for the reference area is less than the operational $DCGL_W$	Conduct appropriate statistical test and elevated measurement comparison

If the survey data are in the form of radionuclide-specific measurements and the radionuclides of interest are not present in background in a concentration that is a relevant fraction of the operational $DCGL_W$, then the initial data evaluation will be as described in Table 9-4.

Table 9-4 Initial Evaluation of Survey Results (Background Reference Area Not Used)

Survey Result	Conclusion
All measured concentrations less than the operational $DCGL_W$	Survey unit meets release criterion
Average concentration is greater than the operational $DCGL_W$	Survey unit does not meet release criterion
Individual measurement result(s) exceeds the operational $DCGL_W$ and the average concentration is less than the operational $DCGL_W$	Conduct Sign test and elevated measurement comparison

Both measurements at discrete locations and scans will be subject to the EMC. Because the results of gamma spectroscopy analyses are evaluated against surrogate radionuclide $DCGL_{total}$ values, corresponding surrogate radionuclide $DCGL_{EMC}$ values are calculated as discussed in Section 5.4.4. The result of the EMC will be used as a trigger for further investigation. The investigation might involve taking further measurements to determine that the area and level of the elevated residual radioactivity are such that the resulting dose meets the release criterion. The investigation will provide adequate assurance, using the DQO process, that there are no other undiscovered areas of elevated residual radioactivity in the survey unit that might otherwise result in a dose exceeding the release criterion. In some cases, this might lead to reclassifying all or part of a survey unit.

If residual radioactivity is found in a localized area of elevated activity—in addition to the residual radioactivity distributed relatively uniformly across the survey unit—the unity rule will be used to ensure that the release criterion has been met in accordance with Section 5.4.5.

Rather than, or in addition to, taking further measurements, the investigation might involve assessing the adequacy of the exposure pathway model used to obtain the operational DCGLs and area factors and the consistency of the results obtained with the characterization and remedial action support surveys.

9.5 Final Status Survey Report

A final status survey report will be prepared to document the final conditions of the site. A list of the information to be included in the final status survey is provided in Section 14.5 of the DP.

10.0 APPENDICES

Appendix A	Data Set Used for Example Calculation of Relative Shift
Appendix B	Information Relative to Uranium Enrichment Level and Its Effect on Activity Distribution of the Isotopes and Composite DCGLs

Appendix A

Data Set Used for Example Calculation of Relative Shift

Table A-1 Tc-99 Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
GS-01-00-SL-FD	04/30/2004	Tc-99	-0.429	1.02	U	0.577
NB-08-00-SL	04/30/2004	Tc-99	-0.293	0.837	U	0.473
NB-07-00-SL-FD	04/30/2004	Tc-99	-0.241	0.877	U	0.499
NB-17-00-SL	04/30/2004	Tc-99	-0.166	0.836	U	0.478
NB-27-00-SL	04/29/2004	Tc-99	-0.147	1.18	U	0.679
NB-16-00-SL	04/30/2004	Tc-99	-0.135	0.892	U	0.512
GS-02-00-SL	05/03/2004	Tc-99	-0.112	0.973	U	0.56
NB-06-00-SL	04/30/2004	Tc-99	-0.0905	0.888	U	0.512
GS-03-00-SL	04/30/2004	Tc-99	-0.0783	0.941	U	0.543
GS-04-00-SL	05/03/2004	Tc-99	0.0157	1.15	U	0.669
BP-08-00-SL	04/28/2004	Tc-99	0.0335	0.792	U	0.462
NB-21-00-SL	05/03/2004	Tc-99	0.0628	0.808	U	0.473
OA-30-00-SL	04/28/2004	Tc-99	0.145	0.805	U	0.476
NB-10-00-SL	05/03/2004	Tc-99	0.148	0.903	U	0.533
OA-31-00-SL	04/28/2004	Tc-99	0.154	0.831	U	0.491
NB-05-00-SL	04/30/2004	Tc-99	0.154	1.3	U	0.764
NB-02-00-SL	04/29/2004	Tc-99	0.158	0.865	U	0.512
BP-12-00-SL	04/29/2004	Tc-99	0.175	0.828	U	0.491
RR-03-00-SL	04/27/2004	Tc-99	0.179	0.82	U	0.486
OA-27-00-SL	05/03/2004	Tc-99	0.223	0.854	U	0.509
NB-20-00-SL	04/28/2004	Tc-99	0.24	0.822	U	0.491
OA-37-00-SL	04/29/2004	Tc-99	0.278	0.82	U	0.493
NB-23-00-SL	05/03/2004	Tc-99	0.289	0.919	U	0.551
BP-11-00-SL	04/29/2004	Tc-99	0.295	0.81	U	0.488
GS-05-00-SL	05/03/2004	Tc-99	0.326	0.993	U	0.596
OA-32-00-SL	04/28/2004	Tc-99	0.333	0.807	U	0.489
NB-27-00-SL-FD	04/29/2004	Tc-99	0.361	1.09	U	0.655
SW-04-00-SL	04/27/2004	Tc-99	0.366	0.823	U	0.501
OA-05-00-SL	04/28/2004	Tc-99	0.371	0.849	U	0.516
NB-07-00-SL	04/30/2004	Tc-99	0.377	0.858	U	0.522
OA-03-00-SL	04/27/2004	Tc-99	0.396	0.98	U	0.594
NB-18-00-SL	04/30/2004	Tc-99	0.401	0.834	U	0.509
NB-24-00-SL	05/03/2004	Tc-99	0.401	0.918	U	0.558
NB-12-00-SL	05/03/2004	Tc-99	0.407	0.946	U	0.574
OA-06-00-SL	05/06/2004	Tc-99	0.41	0.792	U	0.486
GS-01-00-SL	04/30/2004	Tc-99	0.431	1.04	U	0.63
OA-33-00-SL	04/28/2004	Tc-99	0.437	0.882	U	0.539
NB-09-00-SL	04/30/2004	Tc-99	0.452	0.926	U	0.566
BP-09-00-SL	04/28/2004	Tc-99	0.495	0.819	U	0.508
NB-26-00-SL	04/29/2004	Tc-99	0.509	0.876	U	0.541
BP-10-00-SL	04/29/2004	Tc-99	0.546	0.886	U	0.549
OA-04-00-SL	04/28/2004	Tc-99	0.588	0.859	U	0.537
BP-01-00-SL	04/28/2004	Tc-99	0.593	0.797	U	0.502

Table A-1 Tc-99 Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
OA-09-00-SL	05/06/2004	Tc-99	0.695	0.855	U	0.543
OA-40-00-SL	04/29/2004	Tc-99	0.703	0.859	U	0.546
NB-19-00-SL	05/03/2004	Tc-99	0.774	0.85	U	0.547
NB-01-00-SL	04/29/2004	Tc-99	0.807	1.09	U	0.689
SW-03-00-SL	04/27/2004	Tc-99	0.808	0.81	U	0.527
NB-25-00-SL	05/03/2004	Tc-99	0.818	0.92	U	0.59
NB-03-00-SL	04/29/2004	Tc-99	0.891	1.01	U	0.647
OA-34-00-SL	04/29/2004	Tc-99	0.9	0.919	U	0.597
LF-02-00-SL	05/05/2004	Tc-99	0.902	0.836	LT	0.55
OA-29-00-SL	04/28/2004	Tc-99	0.907	0.806	LT	0.534
OA-28-00-SL	04/28/2004	Tc-99	0.928	0.81	LT	0.538
OA-38-00-SL	04/29/2004	Tc-99	0.929	0.934	U	0.607
NB-04-00-SL	04/30/2004	Tc-99	0.952	2.44	U	1.49
BP-02-00-SL	05/03/2004	Tc-99	1.13	1.13	LT	0.733
NB-13-00-SL	05/03/2004	Tc-99	1.2	1.01	LT	0.675
OA-39-00-SL	04/29/2004	Tc-99	1.45	0.908	LT	0.642
LF-03-00-SL	05/05/2004	Tc-99	1.56	0.866	LT	0.63
OA-35-00-SL	04/29/2004	Tc-99	1.57	0.969	LT	0.687
PL-02-00-SL	04/29/2004	Tc-99	1.58	0.926	LT	0.664
OA-07-00-SL	05/06/2004	Tc-99	1.59	0.839	LT	0.619
OA-36-00-SL	04/29/2004	Tc-99	1.59	0.906	LT	0.654
OA-12-00-SL	05/04/2004	Tc-99	1.74	0.973	LT	0.706
RR-02-00-SL	04/27/2004	Tc-99	1.76	0.881	LT	0.66
NB-15-00-SL	05/03/2004	Tc-99	1.81	1.05	LT	0.756
NB-22-00-SL	05/03/2004	Tc-99	2.34	2.5	U	1.61
LF-04-00-SL	05/05/2004	Tc-99	2.38	1.02	LT	0.801
BP-05-00-SL	05/03/2004	Tc-99	2.81	0.897	LT	0.79
PL-03-00-SL	04/29/2004	Tc-99	2.96	1.04	LT	0.88
CB-01-00-SL	04/27/2004	Tc-99	5.15	0.85		1.09
CB-01-00-SL-FD	04/27/2004	Tc-99	5.23	0.876		1.11
EP-05-00-SL	05/06/2004	Tc-99	5.24	0.855		1.1
LF-01-00-SL	05/05/2004	Tc-99	5.49	0.84		1.13
OA-13-00-SL	05/04/2004	Tc-99	5.85	0.957		1.23
BP-06-00-SL	04/28/2004	Tc-99	6.36	0.809		1.25
OA-02-00-SL	04/27/2004	Tc-99	7.39	0.864		1.42
NB-14-00-SL	05/03/2004	Tc-99	7.43	3.31	M3	2.57
OA-15-00-SL	05/04/2004	Tc-99	8.22	1.02		1.6
BP-03-00-SL	05/03/2004	Tc-99	8.83	0.898		1.65
OA-01-00-SL	04/27/2004	Tc-99	10.3	1.04		1.92
LF-05-00-SL	05/05/2004	Tc-99	12.3	0.785		2.15
OA-14-00-SL	05/04/2004	Tc-99	12.4	0.887		2.2
NB-11-00-SL	05/03/2004	Tc-99	12.7	1.09		2.3
OA-24-00-SL	05/04/2004	Tc-99	13.1	1		2.35

Table A-1 Tc-99 Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
RR-01-00-SL	04/27/2004	Tc-99	14.9	0.802		2.56
EP-03-00-SL	05/06/2004	Tc-99	17.2	0.841		2.94
SW-02-00-SL	04/27/2004	Tc-99	18.4	0.81		3.12
BD-11-00-SL	05/06/2004	Tc-99	19	5.79	M3	5.22
OA-10-00-SL	05/04/2004	Tc-99	20.8	0.853		3.5
OA-16-00-SL	05/04/2004	Tc-99	21.3	0.871		3.59
SW-01-00-SL	04/27/2004	Tc-99	22.3	0.865		3.74
LS-03-00-SL	05/06/2004	Tc-99	22.7	0.86		3.81
EP-07-00-SL	05/05/2004	Tc-99	23.5	0.909		3.94
BP-07-00-SL	04/29/2004	Tc-99	26.3	0.977		4.41
DM-01-00-SL	05/06/2004	Tc-99	35.8	6.2	M3	7.69
PL-01-00-SL	04/29/2004	Tc-99	37.9	0.858		6.22
EP-06-00-SL	05/05/2004	Tc-99	51	0.866		8.29
OA-20-00-SL	05/04/2004	Tc-99	52.6	0.823		8.54
OA-11-00-SL	05/04/2004	Tc-99	53	0.81		8.6
OA-08-00-SL	05/06/2004	Tc-99	58.1	0.996		9.45
EP-12-00-SL	05/05/2004	Tc-99	59.9	1.25		9.79
BP-04-00-SL	05/03/2004	Tc-99	68.3	0.855		11
BD-09-00-SL	05/05/2004	Tc-99	86.9	0.743		14
OA-25-00-SL	05/05/2004	Tc-99	87.6	0.844		14.1
LS-02-00-SL	05/06/2004	Tc-99	93.6	0.808		15.1
LS-01-00-SL	05/06/2004	Tc-99	94.1	0.827		15.1
OA-26-00-SL	05/06/2004	Tc-99	109	3.08	M3	18
EP-09-00-SL	05/05/2004	Tc-99	111	1.4		18
EP-11-00-SL	05/05/2004	Tc-99	112	3.27	M3	18.5
		Std. Dev. =	**26.58**	**111**	**= Number**	

Note: U = Result is less than the sample specific MDC
LT = Result is less than requested MDC, greater than sample specific MDC
M3 = The requested MDC was not met, but the reported activity is greater than the reported MDC

Table A-2 Th-232 (by Ac-228) Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
DM-02-00-SL	05/06/2004	AC-228	-0.0535	0.987	U,G	0.547
OA-21-00-SL	05/04/2004	AC-228	0.0815	0.944	U,G	0.509
LS-01-00-SL	05/06/2004	AC-228	0.092	0.671	U	0.388
OA-20-00-SL	05/04/2004	AC-228	0.12	0.871	U,G	0.47
NB-02-00-SL	04/29/2004	AC-228	0.121	0.677	U,G	0.375
NB-26-00-SL	04/29/2004	AC-228	0.134	0.434	U,G	0.251
LS-02-00-SL	05/06/2004	AC-228	0.172	0.508	U	0.296
OA-22-00-SL	05/04/2004	AC-228	0.217	0.532	U	0.319
GS-03-00-SL	04/30/2004	AC-228	0.226	0.682	U,G	0.399
BD-09-00-SL	05/05/2004	AC-228	0.242	0.798	U,G	0.46
LF-02-00-SL	05/05/2004	AC-228	0.313	0.793	U,G	0.353
BD-10-00-SL	05/06/2004	AC-228	0.342	0.669	U,G	0.412
OA-35-00-SL	04/29/2004	AC-228	0.383	0.935	U,G	0.562
NB-03-00-SL	04/29/2004	AC-228	0.384	0.631	U,G	0.403
EP-06-00-SL	05/05/2004	AC-228	0.4	1.42	U,G	0.823
EP-10-00-SL	05/05/2004	AC-228	0.47	1.14	U,G	0.685
OA-25-00-SL	05/05/2004	AC-228	0.474	0.886	U,G	0.407
OA-15-00-SL	05/04/2004	AC-228	0.488	1.13	U,G	0.683
OA-12-00-SL	05/04/2004	AC-228	0.503	0.977	U,G	0.609
OA-23-00-SL	05/04/2004	AC-228	0.509	0.606	U	0.419
NB-27-00-SL	04/29/2004	AC-228	0.584	0.691	U,G	0.36
BP-02-00-SL	05/03/2004	AC-228	0.587	0.542	G,TI	0.315
OA-16-00-SL	05/04/2004	AC-228	0.61	0.958	U,G	0.616
OA-26-00-SL	05/06/2004	AC-228	0.62	0.615	TI	0.455
NB-25-00-SL	05/03/2004	AC-228	0.632	0.622	G,TI	0.439
NB-14-00-SL	05/03/2004	AC-228	0.645	1.07	U,G	0.666
EP-07-00-SL	05/05/2004	AC-228	0.648	1.21	U,G	0.764
LF-03-00-SL	05/05/2004	AC-228	0.679	1.11	U,G	0.519
LS-03-00-SL	05/06/2004	AC-228	0.714	0.578	G	0.338
GS-05-00-SL	05/03/2004	AC-228	0.726	0.524	G,TI	0.418
GS-01-00-SL	04/30/2004	AC-228	0.735	0.753	U,G	0.392
NB-01-00-SL	04/29/2004	AC-228	0.743	0.469	G,TI	0.324
OA-07-00-SL	05/06/2004	AC-228	0.746	0.55	G	0.331
OA-31-00-SL	04/28/2004	AC-228	0.747	0.558	G	0.323
OA-11-00-SL	05/04/2004	AC-228	0.75	0.89	U,G	0.613
NB-08-00-SL	04/30/2004	AC-228	0.784	0.728	G	0.382
LF-05-00-SL	05/05/2004	AC-228	0.789	0.908	U,G	0.645
NB-24-00-SL	05/03/2004	AC-228	0.791	0.506	G	0.343
BP-06-00-SL	04/28/2004	AC-228	0.793	0.382	G	0.292
BD-11-00-SL	05/06/2004	AC-228	0.795	0.686	G	0.433
PL-03-00-SL	04/29/2004	AC-228	0.818	0.557	G	0.319
NB-05-00-SL	04/30/2004	AC-228	0.82	0.936	U,G	0.467
EP-08-00-SL	05/05/2004	AC-228	0.836	0.86	U,G	0.606

Table A-2 Th-232 (by Ac-228) Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
EP-12-00-SL	05/05/2004	AC-228	0.857	1.17	U,G	0.609
BP-03-00-SL	05/03/2004	AC-228	0.866	0.613	G	0.34
OA-03-00-SL	04/27/2004	AC-228	0.911	0.98	U,G	0.683
NB-22-00-SL	05/03/2004	AC-228	0.915	0.657	G	0.42
BP-04-00-SL	05/03/2004	AC-228	0.915	0.614	G,TI	0.484
OA-14-00-SL	05/04/2004	AC-228	0.941	0.904	G,TI	0.663
OA-24-00-SL	05/04/2004	AC-228	0.941	0.78	G	0.474
OA-38-00-SL	04/29/2004	AC-228	0.944	0.651	G	0.36
OA-30-00-SL	04/28/2004	AC-228	0.952	0.696	G	0.406
OA-40-00-SL	04/29/2004	AC-228	0.956	0.49	G	0.387
NB-16-00-SL	04/30/2004	AC-228	0.959	0.7	G	0.42
GS-02-00-SL	05/03/2004	AC-228	0.962	0.629	G	0.372
NB-11-00-SL	05/03/2004	AC-228	0.975	0.473	G	0.341
BP-01-00-SL	04/28/2004	AC-228	0.977	1.14	U,G	0.613
OA-09-00-SL	05/06/2004	AC-228	0.983	0.795	G	0.424
GS-04-00-SL	05/03/2004	AC-228	0.993	0.476	G	0.385
OA-10-00-SL	05/04/2004	AC-228	0.996	0.675	G	0.451
NB-23-00-SL	05/03/2004	AC-228	1	0.627	G	0.374
NB-21-00-SL	05/03/2004	AC-228	1.01	0.62	G	0.403
OA-36-00-SL	04/29/2004	AC-228	1.02	0.641	G	0.437
OA-06-00-SL	05/06/2004	AC-228	1.03	0.67	G	0.345
OA-05-00-SL	04/28/2004	AC-228	1.04	0.575	G	0.432
OA-32-00-SL	04/28/2004	AC-228	1.04	0.476	G	0.338
OA-37-00-SL	04/29/2004	AC-228	1.04	1.12	U,G	0.766
NB-13-00-SL	05/03/2004	AC-228	1.05	0.674	G	0.344
NB-20-00-SL	04/28/2004	AC-228	1.06	0.618	G	0.374
OA-01-00-SL	04/27/2004	AC-228	1.07	0.821	G	0.694
OA-08-00-SL	05/06/2004	AC-228	1.08	0.457	G	0.376
OA-28-00-SL	04/28/2004	AC-228	1.08	0.575	G	0.403
NB-18-00-SL	04/30/2004	AC-228	1.09	0.453	G	0.39
OA-27-00-SL	05/03/2004	AC-228	1.1	0.746	G	0.414
NB-15-00-SL	05/03/2004	AC-228	1.11	0.752	G	0.364
NB-07-00-SL	04/30/2004	AC-228	1.12	0.642	G	0.471
OA-02-00-SL	04/27/2004	AC-228	1.13	1.05	G	0.799
EP-05-00-SL	05/06/2004	AC-228	1.13	0.609	G	0.346
OA-04-00-SL	04/28/2004	AC-228	1.14	0.781	G	0.493
OA-39-00-SL	04/29/2004	AC-228	1.14	0.625	G	0.371
BP-09-00-SL	04/28/2004	AC-228	1.15	0.611	G	0.376
NB-10-00-SL	05/03/2004	AC-228	1.16	0.597	G	0.43
OA-34-00-SL	04/29/2004	AC-228	1.17	0.551	G	0.403
BP-10-00-SL	04/29/2004	AC-228	1.18	0.597	G	0.402
OA-29-00-SL	04/28/2004	AC-228	1.19	0.498	G	0.38
NB-19-00-SL	05/03/2004	AC-228	1.21	0.479	G	0.356

Table A-2 Th-232 (by Ac-228) Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
SW-03-00-SL	04/27/2004	AC-228	1.22	0.998	TI,G	0.744
PL-02-00-SL	04/29/2004	AC-228	1.22	0.849	G,TI	0.492
LF-04-00-SL	05/05/2004	AC-228	1.24	0.788	G,TI	0.504
EP-11-00-SL	05/05/2004	AC-228	1.26	1.02	G,TI	0.821
CB-01-00-SL	04/27/2004	AC-228	1.26	0.981	G	0.475
BP-05-00-SL	05/03/2004	AC-228	1.27	0.552	G	0.395
BP-07-00-SL	04/29/2004	AC-228	1.27	0.656	G	0.423
EP-03-00-SL	05/06/2004	AC-228	1.29	0.488	G	0.403
EP-09-00-SL	05/05/2004	AC-228	1.29	1.79	U,G	1.18
OA-33-00-SL	04/28/2004	AC-228	1.33	0.399	G	0.364
NB-06-00-SL	04/30/2004	AC-228	1.33	0.6	G	0.4
NB-09-00-SL	04/30/2004	AC-228	1.37	0.807	G	0.483
NB-12-00-SL	05/03/2004	AC-228	1.37	0.697	G	0.491
LF-01-00-SL	05/05/2004	AC-228	1.4	0.891	G,TI	0.801
RR-01-00-SL	04/27/2004	AC-228	1.41	1.12	G	0.746
OA-13-00-SL	05/04/2004	AC-228	1.41	1.24	G	0.647
RR-02-00-SL	04/27/2004	AC-228	1.42	1.21	G	0.631
BP-12-00-SL	04/29/2004	AC-228	1.42	0.517	G	0.432
BP-11-00-SL	04/29/2004	AC-228	1.45	0.634	G	0.494
NB-17-00-SL	04/30/2004	AC-228	1.46	0.618	G	0.464
SW-01-00-SL	04/27/2004	AC-228	1.47	1.03	TI,G	0.813
NB-04-00-SL	04/30/2004	AC-228	1.5	0.611	G	0.446
SW-02-00-SL	04/27/2004	AC-228	1.62	1.5	G	0.761
RR-03-00-SL	04/27/2004	AC-228	1.65	1.21	TI,G	0.974
EP-02-00-SL	05/06/2004	AC-228	1.68	1.52	G,TI	0.68
BD-12-00-SL	05/05/2004	AC-228	1.81	0.986	G,TI	0.853
EP-01-00-SL	05/05/2004	AC-228	1.91	1.1	G	0.607
EP-04-00-SL	05/06/2004	AC-228	2.75	1.64	G	0.922
		Std. Dev. =	**0.44**	**114**	**=Number**	

Note: U = Result is less than the sample specific MDC
G = Sample density did not match calibration density to within +/- 15%
TI = Tentatively identified—nuclide identification is tentative

Table A-3 U-238 (by Th-234) Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
GS-03-00-SL	04/30/2004	TH-234	-0.484	1.47	U,G	0.793
OA-15-00-SL	05/04/2004	TH-234	-0.473	3.52	U,G	1.95
NB-01-00-SL	04/29/2004	TH-234	-0.454	2.35	U,G	1.3
NB-26-00-SL	04/29/2004	TH-234	0.156	1.38	U,G	0.78
GS-01-00-SL	04/30/2004	TH-234	0.308	1.95	U,G	1.15
NB-06-00-SL	04/30/2004	TH-234	0.399	1.7	U,G	1
OA-39-00-SL	04/29/2004	TH-234	0.468	1.99	U,G	1.17
OA-31-00-SL	04/28/2004	TH-234	0.47	2.44	U,G	1.44
LF-03-00-SL	05/05/2004	TH-234	0.516	3.52	U,G	2.04
NB-03-00-SL	04/29/2004	TH-234	0.566	1.98	U,G	1.18
OA-37-00-SL	04/29/2004	TH-234	0.613	3.01	U,G	1.76
LF-02-00-SL	05/05/2004	TH-234	0.64	1.91	U,G	1.15
OA-10-00-SL	05/04/2004	TH-234	0.671	2.84	U,G	1.66
OA-03-00-SL	04/27/2004	TH-234	0.685	2.65	U,G	1.56
NB-24-00-SL	05/03/2004	TH-234	0.712	2.02	U,G	1.2
NB-09-00-SL	04/30/2004	TH-234	0.715	2.51	U,G	1.49
NB-27-00-SL	04/29/2004	TH-234	0.764	2.09	U,G	1.26
NB-02-00-SL	04/29/2004	TH-234	0.766	1.34	U,G	0.831
GS-02-00-SL	05/03/2004	TH-234	0.785	1.26	U,G	0.665
OA-40-00-SL	04/29/2004	TH-234	0.857	1.89	U,G	1.15
NB-23-00-SL	05/03/2004	TH-234	0.891	1.67	U,G	0.792
OA-35-00-SL	04/29/2004	TH-234	0.942	3.29	U,G	1.97
RR-03-00-SL	04/27/2004	TH-234	1.03	2.14	U,G	1.09
OA-09-00-SL	05/06/2004	TH-234	1.03	2.46	U,G	1.49
BP-02-00-SL	05/03/2004	TH-234	1.03	1.6	U,G	1
NB-21-00-SL	05/03/2004	TH-234	1.06	2.03	U,G	1.01
GS-05-00-SL	05/03/2004	TH-234	1.13	1.67	U,G	0.797
NB-25-00-SL	05/03/2004	TH-234	1.22	1.9	U,G	1.18
LF-04-00-SL	05/05/2004	TH-234	1.23	3.18	U,G	1.9
OA-38-00-SL	04/29/2004	TH-234	1.27	1.8	U,G	1.13
NB-12-00-SL	05/03/2004	TH-234	1.28	2	U,G	0.917
SW-03-00-SL	04/27/2004	TH-234	1.3	2.76	U,G	1.68
OA-12-00-SL	05/04/2004	TH-234	1.34	3.5	U,G	2.1
PL-02-00-SL	04/29/2004	TH-234	1.35	1.98	U,G	0.971
OA-24-00-SL	05/04/2004	TH-234	1.47	2.86	U,G	1.75
NB-04-00-SL	04/30/2004	TH-234	1.48	2.3	U,G	1.43
NB-19-00-SL	05/03/2004	TH-234	1.5	1.58	U,G	1.02
OA-27-00-SL	05/03/2004	TH-234	1.51	1.71	U,G	0.901
OA-29-00-SL	04/28/2004	TH-234	1.57	2	U,G	1.01
NB-20-00-SL	04/28/2004	TH-234	1.57	2.01	U,G	1
NB-16-00-SL	04/30/2004	TH-234	1.58	2.51	U,G	1.56
GS-04-00-SL	05/03/2004	TH-234	1.61	1.7	U,G	0.967
NB-13-00-SL	05/03/2004	TH-234	1.65	1.93	U,G	1.23

Table A-3 U-238 (by Th-234) Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
NB-10-00-SL	05/03/2004	TH-234	1.7	2	U,G	1.28
OA-36-00-SL	04/29/2004	TH-234	1.71	2.22	U,G	1.4
SW-04-00-SL	04/27/2004	TH-234	1.72	2.82	U,G	1.32
NB-05-00-SL	04/30/2004	TH-234	1.72	2.19	U,G	1.38
OA-30-00-SL	04/28/2004	TH-234	1.74	2	U,G	1.12
NB-07-00-SL	04/30/2004	TH-234	1.75	2.26	U,G	1.19
NB-15-00-SL	05/03/2004	TH-234	1.75	2.8	U,G	1.73
OA-33-00-SL	04/28/2004	TH-234	1.76	2.38	U,G	1.51
OA-34-00-SL	04/29/2004	TH-234	1.77	2.58	U,G	1.61
BP-11-00-SL	04/29/2004	TH-234	1.77	1.88	U,G	1.22
LS-02-00-SL	05/06/2004	TH-234	1.88	1.96	U	1.3
NB-18-00-SL	04/30/2004	TH-234	1.91	1.54	G,TI	1.05
BP-05-00-SL	05/03/2004	TH-234	1.97	2.12	U,G	1.37
OA-06-00-SL	05/06/2004	TH-234	2.02	1.87	G	1.07
BP-09-00-SL	04/28/2004	TH-234	2.03	1.85	G	1.01
PL-03-00-SL	04/29/2004	TH-234	2.04	1.96	G	0.978
LS-01-00-SL	05/06/2004	TH-234	2.07	1.76		0.958
BP-10-00-SL	04/29/2004	TH-234	2.09	2.44	U,G	1.56
OA-28-00-SL	04/28/2004	TH-234	2.14	2.77	U,G	1.75
LF-01-00-SL	05/05/2004	TH-234	2.2	2.99	U,G	1.38
BP-01-00-SL	04/28/2004	TH-234	2.27	2.25	G	1.17
NB-22-00-SL	05/03/2004	TH-234	2.32	2.2	G	1.18
BP-06-00-SL	04/28/2004	TH-234	2.33	1.67	G	0.855
LF-05-00-SL	05/05/2004	TH-234	2.38	2.29	G,TI	1.51
OA-20-00-SL	05/04/2004	TH-234	2.93	2.63	G	1.55
OA-32-00-SL	04/28/2004	TH-234	2.94	1.72	G	1.04
BP-12-00-SL	04/29/2004	TH-234	3.15	2.43	G,TI	1.61
NB-08-00-SL	04/30/2004	TH-234	3.21	2.47	G,TI	1.69
NB-14-00-SL	05/03/2004	TH-234	3.36	3.91	U,G	2.47
NB-17-00-SL	04/30/2004	TH-234	3.38	3.28	G	1.93
OA-16-00-SL	05/04/2004	TH-234	3.4	3.51	U,G	2.02
OA-05-00-SL	04/28/2004	TH-234	3.64	2.37	G	1.32
EP-07-00-SL	05/05/2004	TH-234	4.12	2.94	G	1.58
BD-09-00-SL	05/05/2004	TH-234	4.26	3.93	G,TI	2.59
BP-04-00-SL	05/03/2004	TH-234	4.43	1.98	G	1.21
LS-03-00-SL	05/06/2004	TH-234	4.51	1.93	G	1.22
OA-25-00-SL	05/05/2004	TH-234	4.73	2.24	G	1.4
RR-02-00-SL	04/27/2004	TH-234	4.87	3.64	G	2.19
OA-14-00-SL	05/04/2004	TH-234	5.22	3.75	G,TI	2.64
OA-07-00-SL	05/06/2004	TH-234	5.76	2.16	G	1.42
PL-01-00-SL	04/29/2004	TH-234	8.15	2.33	G	1.7
OA-22-00-SL	05/04/2004	TH-234	8.43	2.57		2.13
OA-11-00-SL	05/04/2004	TH-234	9.04	3.93	G	2.77

Table A-3 U-238 (by Th-234) Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
OA-02-00-SL	04/27/2004	TH-234	9.1	2.8	G	2.01
EP-11-00-SL	05/05/2004	TH-234	9.45	3.4	G	2.27
SW-01-00-SL	04/27/2004	TH-234	9.81	3.84	G	2.88
NB-11-00-SL	05/03/2004	TH-234	9.88	2.7	G	1.9
OA-13-00-SL	05/04/2004	TH-234	10.8	5.48	G	3.74
EP-09-00-SL	05/05/2004	TH-234	13.8	3.68	G	2.71
OA-01-00-SL	04/27/2004	TH-234	16.5	3.09	G	2.78
OA-21-00-SL	05/04/2004	TH-234	17.6	4.01	G	3.55
CB-01-00-SL	04/27/2004	TH-234	18.4	3.97	G	3.44
EP-12-00-SL	05/05/2004	TH-234	20.3	4.72	G	4.13
BP-03-00-SL	05/03/2004	TH-234	27	4.69	G	4.18
EP-08-00-SL	05/05/2004	TH-234	27.1	5.94	G	5.33
EP-03-00-SL	05/06/2004	TH-234	28.3	3.42	G	4.3
BP-08-00-SL	04/28/2004	TH-234	31.4	4.98	G,TI	5.2
SW-02-00-SL	04/27/2004	TH-234	32	4.49	G	4.86
OA-23-00-SL	05/04/2004	TH-234	34.4	17.5		9.67
BD-12-00-SL	05/05/2004	TH-234	36.2	7.73	G	6.63
EP-06-00-SL	05/05/2004	TH-234	52.1	7.28	G,SI	7.3
BP-07-00-SL	04/29/2004	TH-234	53.9	6.19	G,SI	7.23
EP-02-00-SL	05/06/2004	TH-234	86.7	5.92	G	11
EP-05-00-SL	05/06/2004	TH-234	88.5	4.07	G	10.8
OA-08-00-SL	05/06/2004	TH-234	90.5	4.92	G	11.6
EP-01-00-SL	05/05/2004	TH-234	92.3	8.49	G	12.8
DM-01-00-SL	05/06/2004	TH-234	102	11.6	G,SI	13.5
OA-26-00-SL	05/06/2004	TH-234	165	8.06		20.6
		Std. Dev. =	**25.31**	**111**	**=Number**	

Note: U = Result is less than the sample specific MDC
G = Sample density did not match calibration density to within +/- 15%
TI = Tentatively identified—nuclide identification is tentative
SI = Spectral interference—nuclide identification and/or quantization is tentative

Table A-4 U-235 Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
NB-16-00-SL	04/30/2004	U-235	-0.285	0.655	U,G	0.339
NB-05-00-SL	04/30/2004	U-235	-0.236	0.838	U,G	0.465
BP-10-00-SL	04/29/2004	U-235	-0.217	0.714	U,G	0.383
GS-03-00-SL	04/30/2004	U-235	-0.182	0.62	U,G	0.322
GS-05-00-SL	05/03/2004	U-235	-0.121	0.682	U,G	0.369
NB-20-00-SL	04/28/2004	U-235	-0.118	0.789	U,G	0.437
GS-02-00-SL	05/03/2004	U-235	-0.0665	0.767	U,G	0.423
NB-13-00-SL	05/03/2004	U-235	-0.0421	0.689	U,G	0.383
GS-04-00-SL	05/03/2004	U-235	-0.0399	0.65	U,G	0.358
NB-04-00-SL	04/30/2004	U-235	-0.0282	0.712	U,G	0.395
NB-01-00-SL	04/29/2004	U-235	-0.0274	0.659	U,G	0.363
NB-22-00-SL	05/03/2004	U-235	-0.0238	0.877	U,G	0.492
LS-02-00-SL	05/06/2004	U-235	-0.0204	0.973	U	0.555
OA-09-00-SL	05/06/2004	U-235	0	0.831	U,G	0.472
OA-30-00-SL	04/28/2004	U-235	0	0.79	U,G	0.443
OA-29-00-SL	04/28/2004	U-235	0.0188	0.698	U,G	0.395
NB-18-00-SL	04/30/2004	U-235	0.0214	0.661	U,G	0.369
NB-02-00-SL	04/29/2004	U-235	0.026	0.0222	LT	0.0205
NB-23-00-SL	05/03/2004	U-235	0.0327	0.629	U,G	0.354
NB-17-00-SL	04/30/2004	U-235	0.0328	0.029	LT	0.0239
PL-03-00-SL	04/29/2004	U-235	0.0394	0.681	U,G	0.388
NB-06-00-SL	04/30/2004	U-235	0.0565	0.025	LT	0.0305
NB-23-00-SL	05/03/2004	U-235	0.0606	0.017	LT	0.0298
OA-35-00-SL	04/29/2004	U-235	0.0614	1.1	U,G	0.641
OA-36-00-SL	04/29/2004	U-235	0.0674	0.814	U,G	0.465
NB-27-00-SL	04/29/2004	U-235	0.0688	0.862	U,G	0.501
OA-38-00-SL	04/29/2004	U-235	0.0721	0.688	U,G	0.392
NB-12-00-SL	05/03/2004	U-235	0.08	0.0194	LT	0.0368
BP-12-00-SL	04/29/2004	U-235	0.0808	0.0289	LT	0.0369
GS-01-00-SL	04/30/2004	U-235	0.104	0.764	U,G	0.447
NB-17-00-SL	04/30/2004	U-235	0.106	0.689	U,G	0.396
OA-06-00-SL	05/06/2004	U-235	0.11	0.604	U,G	0.35
LF-04-00-SL	05/05/2004	U-235	0.118	0.88	U,G	0.496
OA-37-00-SL	04/29/2004	U-235	0.127	0.0301		0.048
NB-15-00-SL	05/03/2004	U-235	0.142	0.602	U,G	0.352
OA-37-00-SL	04/29/2004	U-235	0.154	0.928	U,G	0.532
NB-12-00-SL	05/03/2004	U-235	0.155	0.76	U,G	0.442
NB-26-00-SL	04/29/2004	U-235	0.156	0.433	U,G	0.257
NB-08-00-SL	04/30/2004	U-235	0.161	0.692	U,G	0.403
NB-24-00-SL	05/03/2004	U-235	0.169	0.569	U,G	0.335
LF-02-00-SL	05/05/2004	U-235	0.17	0.658	U,G	0.39
OA-03-00-SL	04/27/2004	U-235	0.172	0.801	U,G	0.461
OA-24-00-SL	05/04/2004	U-235	0.174	0.878	U,G	0.507

Table A-4 U-235 Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
OA-31-00-SL	04/28/2004	U-235	0.182	0.647	U,G	0.381
BP-11-00-SL	04/29/2004	U-235	0.183	0.799	U,G	0.467
OA-27-00-SL	05/03/2004	U-235	0.184	0.672	U,G	0.396
OA-28-00-SL	04/28/2004	U-235	0.185	0.644	U,G	0.38
BP-05-00-SL	05/03/2004	U-235	0.189	1.64	U,G	1.22
NB-25-00-SL	05/03/2004	U-235	0.215	0.573	U,G	0.343
BP-09-00-SL	04/28/2004	U-235	0.217	0.647	U,G	0.385
NB-09-00-SL	04/30/2004	U-235	0.228	0.699	U,G	0.414
BP-01-00-SL	04/28/2004	U-235	0.242	0.879	U,G	0.514
OA-32-00-SL	04/28/2004	U-235	0.247	0.616	U,G	0.37
SW-04-00-SL	04/27/2004	U-235	0.253	1.08	U,G	0.621
LF-03-00-SL	05/05/2004	U-235	0.284	0.938	U,G	0.551
NB-06-00-SL	04/30/2004	U-235	0.3	0.702	U,G	0.425
NB-10-00-SL	05/03/2004	U-235	0.311	0.648	U,G	0.396
BP-12-00-SL	04/29/2004	U-235	0.32	0.679	U,G	0.414
NB-19-00-SL	05/03/2004	U-235	0.323	0.553	U,G	0.344
OA-39-00-SL	04/29/2004	U-235	0.325	0.59	U,G	0.365
NB-02-00-SL	04/29/2004	U-235	0.334	0.579	U,G	0.361
OA-34-00-SL	04/29/2004	U-235	0.342	0.619	U,G	0.383
SW-03-00-SL	04/27/2004	U-235	0.345	0.847	U,G	0.51
OA-10-00-SL	05/04/2004	U-235	0.35	0.859	U,G	0.517
OA-40-00-SL	04/29/2004	U-235	0.352	0.724	U,G	0.443
PL-02-00-SL	04/29/2004	U-235	0.388	0.885	U,G	0.536
BP-02-00-SL	05/03/2004	U-235	0.404	0.516	U,G	0.334
NB-21-00-SL	05/03/2004	U-235	0.422	0.713	U,G	0.443
NB-07-00-SL	04/30/2004	U-235	0.427	0.788	U,G	0.487
BP-06-00-SL	04/28/2004	U-235	0.459	1.06	U,G	0.669
OA-12-00-SL	05/04/2004	U-235	0.486	0.85	U,G	0.532
LS-01-00-SL	05/06/2004	U-235	0.537	1.35	U	1.01
LF-05-00-SL	05/05/2004	U-235	0.559	0.777	U,G	0.501
OA-20-00-SL	05/04/2004	U-235	0.575	0.697	U,G	0.462
RR-02-00-SL	04/27/2004	U-235	0.58	1.92	U,G	1.39
LF-01-00-SL	05/05/2004	U-235	0.585	0.896	U,G	0.57
NB-14-00-SL	05/03/2004	U-235	0.606	1.2	U,G	0.731
OA-15-00-SL	05/04/2004	U-235	0.631	2.28	U,G	1.64
OA-33-00-SL	04/28/2004	U-235	0.638	0.65	U,G	0.433
NB-03-00-SL	04/29/2004	U-235	0.682	0.564	G,TI	0.4
EP-07-00-SL	05/05/2004	U-235	0.736	1.08	U,G	0.685
OA-05-00-SL	04/28/2004	U-235	0.783	2.15	U,G	1.59
RR-03-00-SL	04/27/2004	U-235	0.833	0.973	U,G	0.647
BP-08-00-SL	04/28/2004	U-235	0.867	1.83	U,G	1.11
OA-16-00-SL	05/04/2004	U-235	1.03	0.675	G,TI	0.516
OA-14-00-SL	05/04/2004	U-235	1.14	0.951	G	0.673

Table A-4 U-235 Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
BP-04-00-SL	05/03/2004	U-235	1.2	1.02	G,TI	0.607
OA-25-00-SL	05/05/2004	U-235	1.26	1.56	U,G	0.835
OA-07-00-SL	05/06/2004	U-235	1.51	0.821	G	0.537
LS-03-00-SL	05/06/2004	U-235	1.67	0.813	G	0.495
OA-22-00-SL	05/04/2004	U-235	1.86	0.816		0.506
NB-14-00-SL	05/03/2004	U-235	1.98	0.0107		0.357
PL-01-00-SL	04/29/2004	U-235	2.43	0.812	G	0.579
EP-11-00-SL	05/05/2004	U-235	2.43	2.82	U,G	1.24
OA-11-00-SL	05/04/2004	U-235	2.71	1.86	G	1.05
SW-01-00-SL	04/27/2004	U-235	2.86	0.949	G	0.726
CB-01-00-SL	04/27/2004	U-235	2.87	1.29	G	0.795
OA-21-00-SL	05/04/2004	U-235	2.88	1.05	G	0.721
NB-11-00-SL	05/03/2004	U-235	3	0.775	G	0.631
OA-13-00-SL	05/04/2004	U-235	3.6	1.12	G	0.898
OA-02-00-SL	04/27/2004	U-235	3.61	1.17	G	0.906
BD-09-00-SL	05/05/2004	U-235	3.63	0.905	G	0.74
EP-11-00-SL	05/05/2004	U-235	4.26	0.0173		0.7
OA-01-00-SL	04/27/2004	U-235	4.57	1.15	G	0.988
EP-12-00-SL	05/05/2004	U-235	4.81	2.29	G	1.32
EP-09-00-SL	05/05/2004	U-235	4.95	3.1	G	1.94
EP-03-00-SL	05/06/2004	U-235	6.97	0.893	G	1.05
EP-08-00-SL	05/05/2004	U-235	8.87	1.23	G	1.42
SW-02-00-SL	04/27/2004	U-235	11.8	3.68	G	2.43
OA-04-00-SL	04/28/2004	U-235	12.2	3.03	G	2.19
EP-05-00-SL	05/06/2004	U-235	18.5	1.82	G	2.58
BD-12-00-SL	05/05/2004	U-235	20.2	1.82	G	2.78
OA-08-00-SL	05/06/2004	U-235	23.2	1.29	G	2.95
EP-02-00-SL	05/06/2004	U-235	30.3	1.82	G	3.94
EP-01-00-SL	05/05/2004	U-235	31.2	1.73	G	3.99
BP-03-00-SL	05/03/2004	U-235	35.3	1.75	G	4.37
OA-26-00-SL	05/06/2004	U-235	39	2.12		4.88
EP-10-00-SL	05/05/2004	U-235	51.4	2.56	G	6.39
BP-07-00-SL	04/29/2004	U-235	53.5	2.03	G	6.51
RR-01-00-SL	04/27/2004	U-235	57.9	2.79	G	7.24
		Std. Dev. =	**10.66**	**120**	**= Number**	

Note: U = Result is less than the sample specific MDC
G = Sample density did not match calibration density to within +/- 15%
LT = Result is less than requested MDC, greater than sample specific MDC
TI = Tentatively identified—nuclide identification is tentative

Table A-5 U-234 Characterization Data Used for FSSP Example Statistics

SampleID	SampleDate	ParamName	Result	MDL	Qualifier	Error
OA-37-00-SL	04/29/2004	U-234	1.93	0.0315		0.337
NB-02-00-SL	04/29/2004	U-234	0.759	0.0309		0.152
NB-06-00-SL	04/30/2004	U-234	0.888	0.0233		0.173
NB-12-00-SL	05/03/2004	U-234	1.45	0.0223		0.263
NB-14-00-SL	05/03/2004	U-234	52.3	0.0177		8.23
NB-17-00-SL	04/30/2004	U-234	1.09	0.0316		0.204
NB-23-00-SL	05/03/2004	U-234	1.1	0.0215		0.203
BP-12-00-SL	04/29/2004	U-234	2.22	0.0326		0.381
EP-11-00-SL	05/05/2004	U-234	103	0.0199		16
		Std. Dev. =	35.96	9.00	= Number	

Appendix B

Information Relative to Uranium Enrichment Level and Its Effect on Activity Distribution of the Isotopes and Composite DCGLs

During the course of operations conducted at the Hematite site, the U-235 percentages ranged from depleted up to fully enriched. A review of site characterization data indicates that it is more realistic to anticipate enrichment levels in the range of 3% to 35% rather than the full possible range. Because the uranium was processed through the gaseous diffusion plants, a reasonable distribution of the three uranium isotopes (U-234, U-235, and U-238) is known. Figure B-1 and Table B-1 show respectively the graphical and numerical percent distribution of the three isotopes as a function of the percentage of U-235. Although the activity percentage for U-234 is dominant for enriched uranium, the U-234 contribution to the mass percentage is small. At 90% enrichment the U-234 contributes only 1% to the mass. Therefore, it is reasonable, within the uncertainty of analytical measurements, to ignore the U-234 contribution to the mass and calculate the enrichment (% by mass of the U-235) using only the measured activity levels of U-235 and U-238.

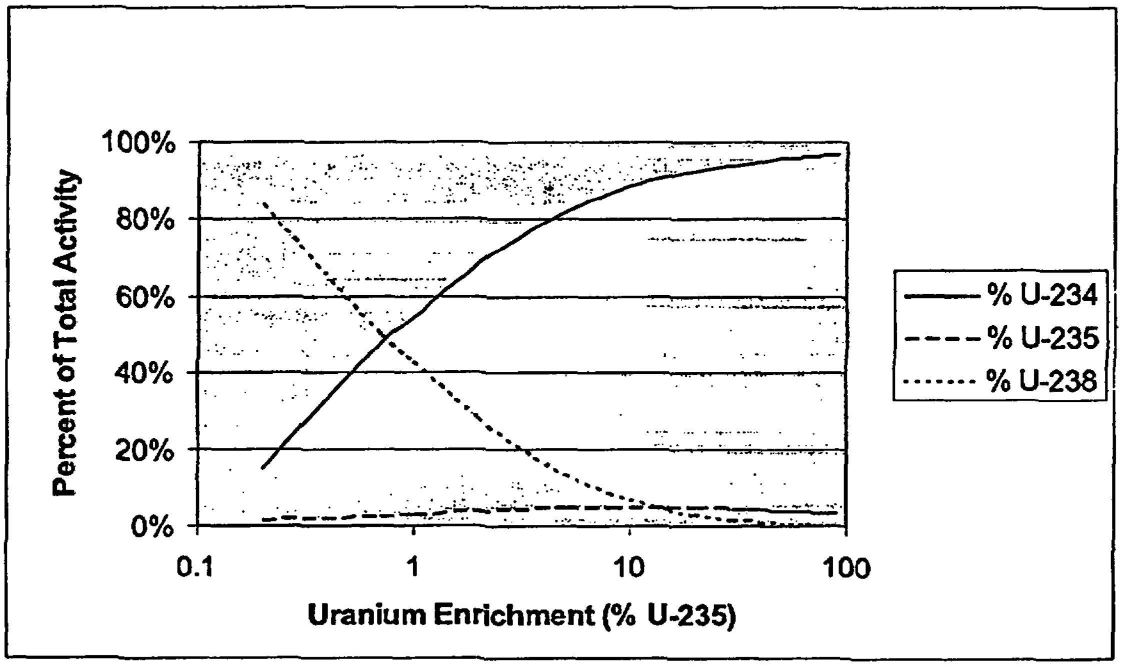

Figure B-1 Percentage of Total Uranium Activity

Table B-1 Distribution of Uranium Isotope Activity as a Function of Enrichment

Enrichment	Percentage of Total Activity		
(% U-235)	% U-234	% U-235	% U-238
0.2	14.86%	1.35%	83.75%
0.71	48.03%	2.28%	49.68%
1	54.78%	2.76%	42.46%
2	68.26%	3.68%	28.06%
3	75.12%	4.13%	20.75%
5	82.09%	4.53%	13.38%
8	86.82%	4.73%	8.45%
10	88.58%	4.76%	6.66%
15	91.12%	4.72%	4.16%
20	92.51%	4.62%	2.87%
25	93.41%	4.49%	2.10%
30	94.05%	4.36%	1.58%
35	94.54%	4.23%	1.22%
40	94.93%	4.11%	0.96%
45	95.25%	3.99%	0.76%
50	95.53%	3.87%	0.60%
55	95.76%	3.76%	0.48%
60	95.96%	3.66%	0.38%
65	96.14%	3.56%	0.30%
70	96.30%	3.46%	0.23%
75	96.45%	3.37%	0.17%
80	96.58%	3.29%	0.13%
85	96.70%	3.21%	0.09%
90	96.82%	3.13%	0.05%

Given the individual DCGL of Table 4-1 for each uranium isotope, it is possible to derive a composite DCGL for the uranium mixture as a function of the percentage of U-235. This is shown in Figures B-2 and B-3 for the surface and volumetric DCGLs, respectively.

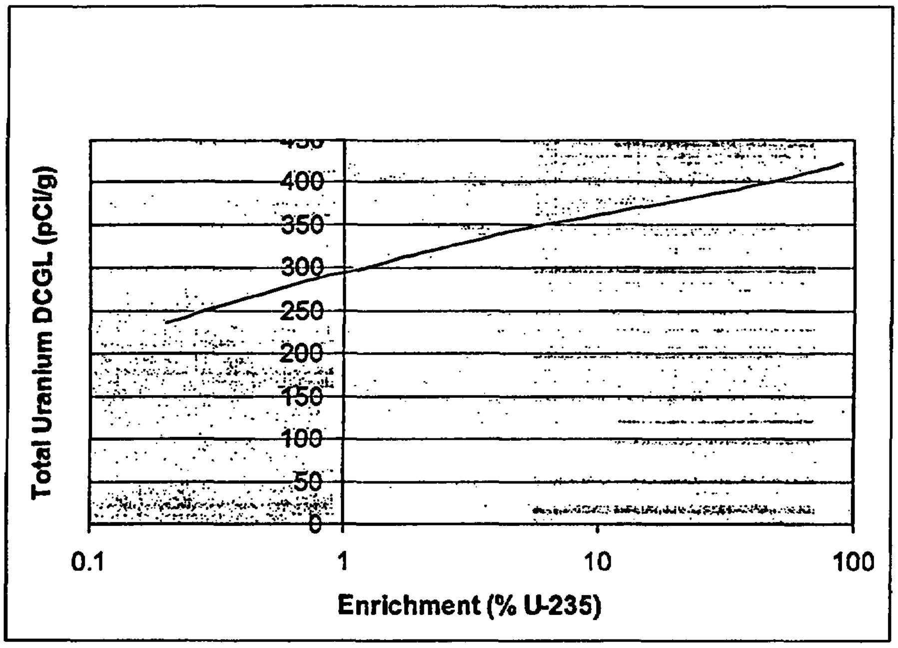

Figure B-2 Composite Surface Source DCGL

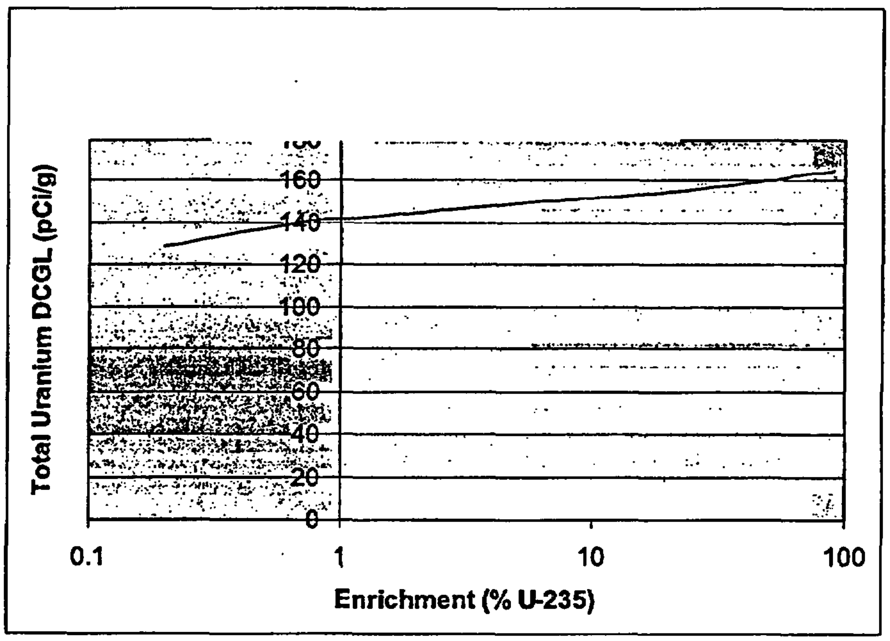

Figure B-3 Volumetric Source DCGL

Such a composite DCGL would be used only if the uranium isotope activities were to be added together for the statistical evaluation of the data. Another approach is to consider one isotope as the surrogate and utilize the activity ratios of the other isotopes to the surrogate. Figures B-4, B-5, and B-6 present graphically the ratios of U-234, U-238, and U-total to the U-235 isotope as a function of U-235 enrichment.

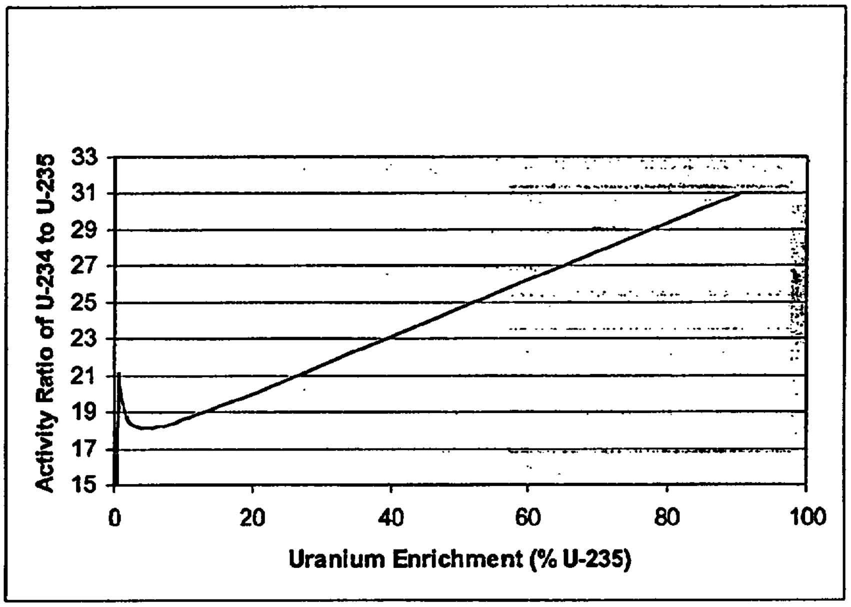

Figure B-4 Ratio of U-234/U-235 to % U-235

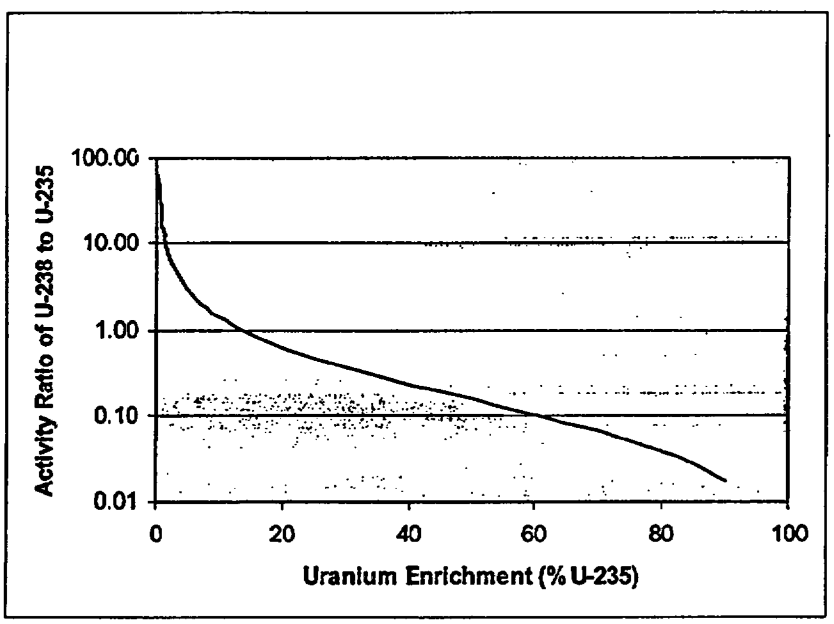

Figure B-5 Ratio of U-238/U-235 to % U-235

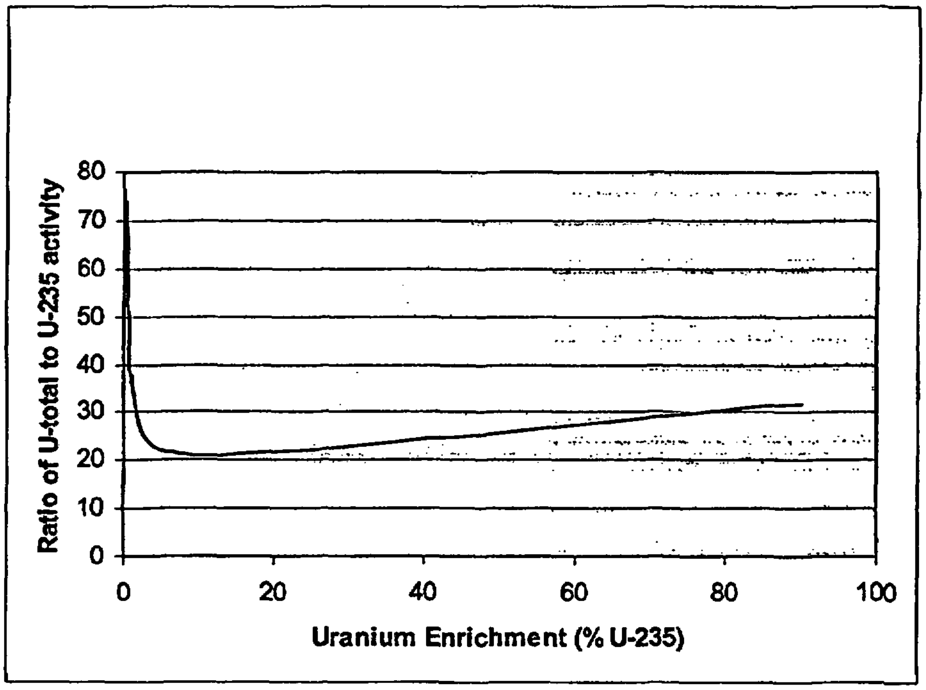

Figure B-6 Ratio of U-total/U-235 to % U-235

A review of the previous three figures indicates that the ratio of U-234 to U-235 as a function of enrichment is relatively flat, varying only from about 18 to 22 for the range of enrichments anticipated. Whereas the ratio of U-238 to U-235 is a strong function of enrichment, varying by nearly a factor of 100 for the range of enrichments anticipated. The activity ratio of total uranium to U-235 varies only from about 21 to 24 over the range of enrichments anticipated.

The above information can be used to aid the design of the final status survey with respect to the uranium activity.

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