Westinghouse

Westinghouse Electric Company
Hematite Facility
3300 State Road P
Festus, MO 63028

January 28, 2005

Mr. Amir Kouhestani
U.S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Mail Stop T7 F27
Rockville, MD 20852-2738

Subject: Submittal of additional information to support application for approval of Hematite Decommissioning Plan, SNM-33, Docket No. 70-36

Reference: Westinghouse letter dated April 30, 2004 from Karen Ann Craig to Amir Kouhestani, USNRC, transmitting Decommissioning Plan and supporting documents.

Dear Mr. Kouhestani:

The Westinghouse Electric Company hereby submits this additional information to support our application of April 30, 2004 for approval of the Decommissioning Plan for License Number SNM-33 (Docket No. 070-036). During the period since the initial submittal Westinghouse has continued to conduct work associated with removal and cleanout of process equipment (source term removal) and to gather additional characterization information for the buildings and site. In addition, a number of informal discussions have been held with NRC staff to explain the general concept of the approach taken by Westinghouse. This submittal incorporates clarifications identified during those informal discussions which are intended to aid the formal technical review of the Decommissioning Plan (DP) and supporting documents.

Enclosed are two hard copies and 10 copies on CD as you requested.

As discussed in the prior submittal, Westinghouse requested an alternate schedule for submittal of the subsequent tasks of the decommissioning. A more complete discussion of the additional submittals that are anticipated to be made during decommissioning leading to license termination is provided in Attachment 1 to this letter.

If you have any additional questions concerning this submittal, please feel free to contact me at (314)810-3306.

Regards,

Karen Ann Craig
Manager, Regulatory and Licensing
Electronically Approved in EDMS 2000

Attachments:

- Attachment 1 - Anticipated Future Submissions to Support Decommissioning Plan and License Termination
- Decommissioning Project Documents
  - DO-04-004 Revision 1, *Hematite Decommissioning Plan* (Nonproprietary)
  - DO-04-003 Revision 1, *Decommissioning Plan Checklist* (Nonproprietary)
  - DO-04-006 Revision 1, *Soil Survey Plan* (Nonproprietary)
  - DO-04-012 Revision 1, *Derivation of Site-Specific DCGLs* (Nonproprietary)
- Decommissioning Project Supplements
  - DO-02-001 Revision 0, *Historical Site Assessment* (Nonproprietary)
  - EO-04-001 Revision 1, *Gamma Walkover Data Evaluation Report* (Nonproprietary)
  - DO-03-005 Revision 0, *Site Specific Soil Parameters* (Nonproprietary)
  - DO-03-006 Revision 0, *Determination of Distribution Coefficients for Radionuclides of Concern* (Nonproprietary)
  - DO-04-010 Revision 0, *Radiological Characterization Report* (Nonproprietary)

ATTACHMENT 1

Anticipated Future Submissions to Support Decommissioning Plan and License Termination

Anticipated Future Submissions to Support Decommissioning Plan and License Termination

As explained in Section 1.0 of the DP, the decommissioning project has been divided into five phases. This submittal covers Phase A of the project. The projected submittal dates for amendment requests for the remaining phases is provided in Figure 8-1 of the DP. In addition a number of Technical Basis Documents are identified in Section 1.5 of the Soil Survey Plan. These documents will be prepared as the necessary information is developed or, in some cases, the need develops. As appropriate, these documents will be approved internally and provided to the NRC upon request or submitted for NRC approval.

During the conduct of the decommissioning project reports will be generated to document final status survey results for designated survey areas. These reports, individually or grouped as appropriate, will be submitted in a timely manner to the NRC to provide the necessary information to demonstrate that the work is being conducted in a manner sufficient to assure that the goal of the decommissioning project will be accomplished.

Upon completion of the decommissioning project a final report will be prepared and submitted for approval that incorporates a summary of the results of previous submittals and requests termination of the license. This report will incorporate the results of the Final Dose Assessment as described in Section 14.6 of the DP to demonstrate that the requirements of 10 CFR Part 20, Subpart E has been met and that the license can be terminated.

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HEMATITE DECOMMISSIONING PROJECT DOCUMENTS

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

HEMATITE, MISSOURI

DOCUMENTS ENCLOSED:

DO-04-004, ***Decommissioning Plan***
DO-04-006, ***Site Wide Soil Survey Plan***
DO-04-003, ***NUREG 1757, Appendix "D" Checklist***
DO-04-012, ***Site Wide DCGL Report***

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HEMATITE DECOMMISSIONING PLAN

DOCUMENT #: DO-04-004 Rev. 1

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

HEMATITE, MISSOURI

January 2005

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ABBREVIATIONS AND ACRONYMS

ABB	Asea Brown Boveri
ACM	asbestos-containing material
AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
ALI	annual limit on intake
Am-241	americium-241
ARAR	Applicable or Relevant and Appropriate Requirement
CAM	continuous air monitor
CAPs	Corrective Action Process
CDE	committed dose equivalent
CE	Combustion Engineering
CEDE	committed effective dose equivalent
cfs	cubic feet per second
CFR	Code of Federal Regulations
cpm	counts per minute
DAC	derived air concentration
DCGL	derived concentration guideline level
D&D	decontamination and decommissioning
DP	Decommissioning Plan
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
DQO	data quality objective
DSCC	deeper, silty clay/clay
EDMS	Electronic Document Management System
EH&S	Environmental Health and Safety
EPA	U.S. Environmental Protection Agency
EMC	elevated measurement comparison
FEMA	Federal Emergency Management Agency
FNMC	Fundamental Nuclear Material Control
GERT	General Employee Radiation Training
gpm	gallons per minute
GWS	gamma walkover survey
HEU	high-enriched uranium
HP	health physics
HQAPP	Hematite Quality Assurance Program Plan
HSA	Historical Site Assessment
ISA	Integrated Safety Analysis
LEU	low-enriched uranium
LLD	lower limit of detection
LLRW	low-level radioactive waste
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MC&A	material control and accountability
µCi/ml	microcuries per milliliter

MDA	minimum detectable activity
MDC	minimum detectable concentration
MDNR	Missouri Department of Natural Resources
mrem/y	millirem per year
M&TE	measuring and test equipment
NCP	National Contingency Plan
NCSA	nuclear criticality safety analysis
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
Np-237	neptunium-237
NRC	U.S. Nuclear Regulatory Commission
NSSSC	near-surface silt, silty clay
OSL	optically stimulated luminescence
PCB	polychlorinated biphenyls
PCE	perchloroethylene
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PPE	personal protective equipment
PRG	Preliminary Remediation Goal
Pu-239	Plutonium-239
QA	quality assurance
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactive Material Guidelines computer code
RI/FS	Remedial Investigation/Feasibility Study
RSO	Radiation Safety Officer
RWP	radiation work permit
SAA	site accumulation area
SNM	special nuclear material
Tc-99	technetium-99
TCE	trichloroethylene
TEDE	total effective dose equivalent
Th-232	thorium-232
TLD	thermo-luminescent dosimeter
TSCA	Toxic Substances Control Act
U-234	uranium-234
U-235	uranium-235
U-238	uranium-238
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UNC	United Nuclear Corporation
UO_2	uranium dioxide
VOC	volatile organic compound
WP	work plan

REFERENCES

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26. Westinghouse Electric Co., Hematite's *Training Plan*, PO-GM-002.
27. Westinghouse Electric Co., *Hematite Quality Assurance Program Plan*, PO-QA-001.

28. Westinghouse Electric Co., *Radiation Work Permit*, PR-HP-001.
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34. Westinghouse Electric Co., *Quality Management System*, Rev. 5.
35. Westinghouse Electric Co., "Remedial Investigation/Feasibility Study Work Plan," Rev. 0, May 9, 2003.
36. Westinghouse Electric Company, "Westinghouse Hematite Site Radiological Characterization Report," DO-04-010, January 2005.
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PREFACE

This Decommissioning Plan (DP) was prepared using the guidance in NUREG-1757 (Ref. 1) as well as other applicable or relevant documents and guidance identified in the reference section of this DP. This DP also has been prepared so as to be in accord with the Remedial Investigation/Feasibility Study (RI/FS) Work Plan (Ref. 35), the National Contingency Plan (NCP), 40 CFR 300 (Ref. 2), and related guidance. The RI/FS Work Plan, which has been reviewed and approved by the Missouri Department of Natural Resources (MDNR), serves as the overall template for site characterization.

It should be noted that although Westinghouse is following the NCP process in achieving site remediation objectives, the Hematite site is not listed or proposed for listing on the National Priorities List, and the U.S. Environmental Protection Agency (EPA) is not actively involved in overseeing activities at the site. In addition to NRC involvement, MDNR is overseeing implementation of the RI/FS Work Plan.

Pursuant to the NRC regulations, the DP must designate whether the licensee intends to decommission the site for unrestricted use or whether some future restrictions will be included. Westinghouse's intention and objective is to meet the criteria for unrestricted use, but it will continue to evaluate this objective as more information is gathered through implementation of the characterization and RI/FS Work Plan.

As part of this DP, Westinghouse has established soil derived concentration guideline levels (DCGLs) in accordance with NRC protocol. 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.

The final status survey for the Hematite site will be designed using the guidance contained in *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (Ref. 21) 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 EXECUTIVE SUMMARY

Westinghouse Electric Company LLC (Westinghouse) is proposing to decommission the Hematite Former Fuel Cycle Facility (Hematite). This site-wide Decommissioning Plan (DP) and subsequent amendments will provide the decommissioning information necessary to allow license termination and unrestricted release in accordance with the requirements of the License Termination Rule at 10 CFR 20.1402. This DP was prepared using guidance in NUREG-1757, *Consolidated NMSS Decommissioning Guidance*, Vol. 1–3 (Ref. 1). Westinghouse plans to perform this decommissioning in compliance with U.S. Nuclear Regulatory Commission (NRC) regulations. Accordingly, this DP is being submitted to the NRC for review and approval.

Throughout its history, Hematite's primary function was to manufacture uranium metal and uranium compounds from natural and enriched uranium for use as nuclear fuel. The entire site covers an area of approximately 228 acres, but licensed activities were restricted to process buildings and grounds within an approximately 10-acre central site tract. The land areas outside the central site tract have no known history of licensed activities and no evidence of soil contamination.

The decommissioning project has been divided into phases as follows:

a. Outlying Land Areas
b. Subsurface Soil Areas
c. Surface Soil and Water
d. Non-contaminated Buildings
e. Groundwater

Following approval of this DP and associated submittals, work will begin on Phase a., Outlying Land Areas. An alternate schedule has been requested to submit plans for the remaining phases (Phases b. – e.) of work under the DP. Plans and information necessary to obtain approval for the remaining phases will be submitted as amendment requests to the DP.

The overall scope of decommissioning work under this DP and its subsequent amendments will include remediation of impacted soil and water and performance of a final status survey. Characterization and remediation of soil and other impacted material will be performed consistent with approved derived concentration guideline levels (DCGLs) and the remedial goals and objectives established through the National Contingency Plan (NCP) (Ref. 2) process.

1.1 Site and Licensee Information

The Hematite facility of Westinghouse Electric Company LLC is located on a site in Jefferson County, Missouri, approximately 3/4 mile northeast of the unincorporated town of Hematite, Missouri and 35 miles south of the city of St. Louis, Missouri.

The name and address of the site licensee are:

Westinghouse Electric Company LLC
P.O. Box 355
Pittsburgh, PA 15230

The address of the site is:

Westinghouse Electric Company LLC
Hematite Site
3300 State Road P
Festus, MO 63028

All correspondence pertaining to this license should be addressed to:

Mr. A. Joseph Nardi, License Administrator
Westinghouse Electric Company LLC
P.O. Box 355
Pittsburgh, PA 15230

Phone: (412) 374-4652
Email: nardiaj@westinghouse.com
Fax: (412) 374-3357

1.2 Summary of Licensed Activities

From its inception in 1956 through 1974, the Hematite facility was used primarily in support of government contracts that required production of high-enriched uranium (HEU) products. From 1974 through the plant closure in 2001, the focus changed from government contracts to commercial fuel production. Specifically, operations included the conversion of uranium hexafluoride (UF_6) gas of various uranium-235 (U-235) enrichments to uranium oxide, uranium carbide, uranium dioxide pellets, and uranium metal. These products were manufactured for use by the federal government and government contractors and by commercial and research reactors approved by the Atomic Energy Commission (AEC) and its successor, the NRC. Research and development was also conducted at the plant, as were uranium scrap recovery processes. Over the lifetime of the facility, there have been seven owners. Mallinckrodt Chemical Works, Mallinckrodt Nuclear Corporation, United Nuclear Corporation, Gulf United Nuclear Fuels Corporation, and General Atomic Company owned the plant for the government-focused phase of operations. Combustion Engineering Inc. (CE) and

Westinghouse Electric Company LLC owned the plant during the commercial phase of operations.

1.3 Nature and Extent of Site Radiological Contamination

As a result of past activities, enriched uranium (principally) and technetium (minimally) have been released to the soils in the central site tract. Due to the unknowns associated with government activities on the site, other radionuclides that will be considered isotopes of concern until proven otherwise include americium-241 (Am-241), plutonium-239 (Pu-239), neptunium-237 (Np-237), and thorium-232 (Th-232) in equilibrium with its progeny, i.e., radium-228 (Ra-228) and thorium-228 (Th-228).

A *Historical Site Assessment* (HSA) (Ref. 3) completed in 2003 identified building, soil, and environmental locations where these radionuclides are known to be or potentially exist. The soil and environmental locations are being targeted during continuing characterization to better define remediation and work control requirements. Contaminated buildings have been vacated and equipment, machinery, and furniture are being removed under the site license so as to facilitate site characterization requirements.

Based on results from the HSA and site characterization performed to date (Section 14.2), the land areas outside the central site tract show no documented evidence of activities that might have contaminated these areas. As such, these areas are not expected to be radiologically impacted.

The groundwater in the overburden has historical radiological contamination in the form of technetium-99 (Tc-99). The groundwater aquifers have shown no detectable levels of radiological contamination, but volatile organic compounds (VOCs) have been found in the soil and groundwater. Trichloroethylene (TCE) was used in the U.S. Navy fuel processes. Perchloroethylene (PCE) was used at the facility in the HEU scrap processing operations. These VOCs are being addressed in a manner that is in substantial compliance with the NCP.

1.4 Decommissioning Objective

It is the objective of Westinghouse to decommission the Hematite site in a manner that is consistent with its license requirements, NRC regulations, and the goals and objectives established through the NCP process (see Preface). Through implementation of the approved DP, all areas of the site are expected to meet the criteria for unrestricted use as specified by 10 CFR 20.1402, which will allow for the termination of NRC License No. SNM-33.

1.5 Site-Specific DCGLs

The soil DCGLs are presented in a report, "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility" (Ref. 4), which is being submitted to the NRC along with this DP. Surface and volumetric soil DCGLs were derived for radionuclides of concern potentially present at the Hematite site, 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.

The proposed site-specific soil $DCGL_W$ values for the radionuclides of concern at the Hematite site are shown in Table 1-1 below. 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.

The values for the DCGLs given in Table 1-1 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.

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 the *Hematite Soil Survey Plan* (Ref. 5) 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 decision has been made as to whether 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.

In order to implement the dose allocation approach, operational DCGLs will be established and incorporated into decommissioning procedures. Apportionment of the dose in this manner will have the effect of reducing the "base-case" soil DCGLs in Table 1-1.

Table 1-1 Site-Specific 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)

1.6 ALARA Analysis

Because the site objective is to remediate to unrestricted use criteria and to use site-specific dose modeling to relate concentrations to dose, the results of an ALARA analysis are known on a generic basis and an analysis is not necessary. However, because Westinghouse actively promotes the ALARA philosophy, a simplified analysis will be developed. Because the pre-remediation ALARA analysis cannot be completed until the site characterization and the related NCP process are completed, an example analysis is being provided in Section 7.0 of this DP to demonstrate the methodology that will be used for the final analysis. The example analysis was completed in the context of NUREG-1757, Vol. 2, Appendix N. The analysis is based upon release criteria derived from site-specific dose modeling, that is, the DCGLs referenced in Sections 1.5 and 5.0 of this DP.

1.7 Start and End Dates

Decommissioning activities addressed by this DP are scheduled to start at the beginning of August 2005, following NRC approvals of this DP, soil DCGLs, and the soil survey plan. The initial phase of work, Phase a., consists of a final survey of surface soils in the outlying land areas of the site. Phase a. is scheduled to be completed by the end of

November 2005. An alternate schedule has been requested to submit plans for the remaining phases (Phases b. – e.) of work under the DP. Projected submittal dates for DP amendment requests for the remaining phases are shown in Figure 8-1. Schedules for the remaining phases of work will be included in the DP amendment requests. Periodic schedule updates will be submitted as the work progresses.

1.8 Post-Remediation Activities

No post-remediation activities have been identified. If required, post-remediation activities will be identified in subsequent amendment requests for this DP.

1.9 Amendment to License to Incorporate DP

The licensee is requesting the NRC to amend License No. SNM-33 to incorporate this DP.

2.0 FACILITY OPERATING HISTORY

2.1 License Number, Status, and Authorized Activities

By application dated September 11, 2001, Westinghouse notified the NRC that all principal activities, specifically those related to the manufacture of nuclear reactor fuel utilizing low-enriched uranium (LEU), at the Hematite site had ceased. Westinghouse requested an amendment to License No. SNM-33 to change the scope of licensed activities to those associated with decommissioning activities. Amendment 42 to License No. SNM-33 was issued on April 11, 2002 to reduce the possession limits for source and special nuclear material and to change the scope of authorized activities to the performance of decommissioning activities. Amendment 43 to the license issued on October 17, 2003 further reduced the possession limits to the current levels shown in Table 2-1.

Table 2-1 Special, Source, and Byproduct Material Under License SNM-33

Item	Material	Chemical and/or Physical Form	Maximum Amount
A	Uranium enriched to a maximum of 5.0 weight percent in the U-235 isotope	Any (excluding metal powders)	1,250 kilograms U-235
B	Uranium, enriched to any enrichment in the U-235 isotope	Any (excluding metal powders)	350 grams U-235
C	Uranium (natural or depleted)	Any (excluding metal powders)	2,000 kilograms
D	Cobalt-60	Sealed sources	40 millicuries
E	Cesium-137	Sealed sources	500 millicuries
F	Byproduct material, including americium-241	Any	400 microcuries
G	Special, source, and byproduct material	Any (residual contamination)	Existing at the Hematite site on July 1, 2001
H	Californium-252	Sealed sources	23.77 micrograms

The above materials are being used as follows:

1. Item A, B and C – possession of this special nuclear material and source material is limited to those activities necessary to process and package the materials into forms suitable for transfer to other licensed operations. Receipt of any additional materials in these categories is limited to that necessary to complete the decommissioning of the site and facilities. Examples of such receipts would be calibration sources and residual contamination on shipping containers and packages.

2. Items D and H – for instrument calibration and testing.

3. Item E – for possession only pending transfer to other licensed operations.

4. Item F – for instrument calibration and testing and as residual contamination on shipping containers and packages.

5. Item G – possession of this residual contamination is limited to the activities associated with the decommissioning of the site.

Current locations of radionuclide use at the site are inside the central site tract shown in Figures 3-3 and 3-4.

Table 2-2 is a list of amendments to License No. SNM-33 since its renewal on July 28, 1994.

Table 2-2 List of Amendments to License No. SNM-33

Amend. No.	Subject	Issued
1	Schedule of the Standby Trust Agreement	12/8/94
2	Organization changes	3/14/95
3	Delay in starting 1995 physical inventory	3/29/95
4	Evaporation Ponds decommissioning	5/4/95
5	Increase in possession limit	5/11/95
6	Revised Fundamental Nuclear Material Control (FNMC) Plan	5/17/95
7	Delay in completion of biennial MC&A assessment	5/18/95
8	Temporary change of UF_6 sampling procedure	8/23/95
9	Request for delay in conducting emergency exercise	11/27/95
10	Branch Technical Positions	12/20/95
11	Request for R-3 oxide conversion reactor change	1/31/96
12	Temporary change to UF_6 receipt sampling procedure	4/15/96
13	Request for validation of criticality calculational method	6/21/96
14	Transitional Facility Attachment	7/18/96

Amend. No.	Subject	Issued
15	Increase possession limit	11/18/96
16	Temporary change to UF_6 receipt sampling procedure	2/6/97
17	Organizational changes	8/13/97
18	Request to update decommissioning plan for Hematite Evaporation Ponds	1/26/98
19	Revisions of the FNMC Plan	2/12/98
20	Authorize release of hydrofluoric acid	2/26/98
21	Changes in Chapter 4, "Nuclear Criticality Safety," of the license application	7/23/98
22	Extension to certain commitments in the FNMC Plan	1/27/99
23	Revision to Hematite Emergency Plan	3/18/99
24	Change of mailing addresses for corporate offices and facility	4/9/99
25	Request to amend the FNMC Plan	5/99
26	Time extension to report the results of the April 1999 physical inventory	6/2/99
27	Transfer and amend materials licenses, QA program approval, and COCs	6/23/99
28	Licensee name change	8/19/99
29	Temporary change to UF_6 receipt sampling procedure	10/19/99
30	Physical Security Plan changes	12/2/99
31	Credit for neutron absorbers contained in fuel pellets	12/17/99
32	Temporary change to UF_6 receipt sampling procedure	2/3/00
33	Licensee name change	3/13/00
34	Licensee name change	7/13/00
35	Delete certain license and license application commitments	8/31/00
36	Request for extension to certain commitments in the FNMC Plan	1/5/01
37	Licensee name change	4/10/01
38	Request for time extension to conduct SNM physical inventory	5/7/01
39	Plan for completion of CSPU analyses and DP for Hematite Plant	5/30/01
40	Organizational changes, name changes	10/15/01
41	Authorize exemption to fissile materials classification and package standards in transport	4/15/02
42	Change possession limits and change authorized activities to decommissioning activities	4/11/02
43	Delete Emergency Plan and two license conditions, change possession limits and authorized activities, approve new Site Manager, and designate a RSO	10/22/02
44	Change of Site Manager	1/28/04
45	Update Hematite Site Physical Security Plan and incorporate commitments	4/14/04
46	Alternate Schedule request for Decommissioning Plan submittals	8/25/04
47	Chapter 2 license amendment	9/7/04
48	Rev. 5 to FNMCP	11/24/04
49	Revision to Section 3.2.2	1/3/05

2.2 License History

Throughout its history, Hematite's primary function has been to manufacture uranium metal and uranium compounds from natural and enriched uranium for use as nuclear fuel. Specifically, Hematite was primarily used to convert government-owned and -leased UF_6 gas of various U-235 enrichments to uranium oxide, uranium carbide, uranium dioxide pellets, and uranium metal. These products were manufactured for use by the federal government, government contractors, and commercial and research reactors approved by the AEC. Research and development was also conducted at the plant, as were uranium scrap recovery processes.

In 1955, Mallinckrodt Chemical Works purchased the parcel of farmland on which the plant sits. The plant became operational in July of 1956, producing uranium products for use in the U.S. Navy nuclear fuel program. Mallinckrodt Chemical Works, or the affiliated Mallinckrodt Nuclear Corporation, operated the facility until approximately May 1961 at which time ownership was transferred to the United Nuclear Corporation (UNC). UNC provided uranium products to the federal government.

In 1970, UNC and Gulf Nuclear Corporation entered into a joint venture, forming Gulf United Nuclear Fuels Corporation (Gulf), which owned and operated the facility until the spring of 1973 when Gulf closed the plant and began decommissioning. In January 1974, Gulf transferred the property to General Atomic Company. Combustion Engineering Inc. (CE) purchased the property in May 1974. In 1989, Asea Brown Boveri (ABB) acquired the stock of CE and began operating the facility. In April 2000, Westinghouse purchased the nuclear operations of ABB, which included the Hematite facility. In 2001, Westinghouse announced the shutdown of the facility.

During the period prior to CE's purchase of the facility in 1974, government projects dominated the operations at the site. During this time period, the government owned all the national uranium supply and leased it to facilities as needed. In order to obtain uranium, even for government projects, a facility had to submit a request for allocation to the AEC, describing the amount and enrichment of uranium needed. A review of the requests for allocation from 1959 through 1966 (the only such documents located to date) indicates that approximately 7,576 kg of uranium were requested for government-related projects and 1,887 kg of uranium were requested for commercial projects.

Much of the work on behalf of the government at the site was classified, and therefore, specific details regarding the exact nature of the processes are not known. Generally, the government work began under Mallinckrodt's supervision and then dominated Hematite production during the ownership and operation by UNC and Gulf. Examples of government projects during this time include:

- Production of uranium metal for nuclear submarines and a D1G destroyer reactor

- Supply of specialized uranium oxides for the Army Package Power Reactor
- Supply of high-enriched oxides for a General Atomics gas-cooled reactor in Fort St. Vrain, Colorado
- Production of high-enriched metal for materials test reactors utilized by the U.S. Navy
- Supply of uranium-beryllium pellets for use in the SL-1 reactor
- Production of high-enriched uranium-zirconia pellets under contract to Bettis Laboratory
- Production of high-enriched oxides for General Atomics for use in the NERVA nuclear rocket projects

Hematite also contracted directly with the Oak Ridge AEC office and other government contractors for the recovery of uranium from scrap materials. Scrap recovery projects at Hematite included the recovery of uranium from scrap generated by a variety of U.S. Navy projects and CUNO filter scrap generated by the Aircraft Nuclear Propulsion program.

Although the physical design of the plant was modified over the years, certain areas of the plant were dedicated to particular production processes as well as certain types of work, i.e., low-enrichment processes versus high-enrichment processes. (The layout of the facility buildings is shown in Figure 3-4.) For example, Building 240 was historically dedicated to the chemical conversion of uranium into compounds, solutions, and metal. Building 240 was further divided into areas for high-enrichment and low-enrichment uranium processes—the "Red Room" (area 240-2) contained high-enrichment conversion processes, and the "Green Room" (area 240-3) contained low-enrichment conversion processes and high-enrichment scrap processing. The Red Room was specifically used for the reduction of UF_6 to uranium tetrafluoride (UF_4), the conversion of UF_4 to uranium metal, high-enrichment uranium scrap recovery, and other chemical conversion processes using highly or fully enriched uranium.

Building 255 of the plant is understood to have been used for the fabrication of uranium compounds into physical shapes. Again, this building was segregated into areas of high enrichment and low enrichment, with area 255-2 containing the low-enrichment pellet plant and area 255-3 containing the "Item Plant." The Item Plant work was classified, and products coming out of the plant were referred to only as "items." Thus, the area received its name as the Item Plant. The Item Plant was dedicated solely to classified government-related work and specifically, U.S. Navy fuel production work. The Item Plant was specifically designed to process uranium dioxide into a U.S. Navy fuel product. Other activities within the Item Plant included the blending of uranium dioxide (UO_2) with other chemical compounds.

Other areas of the Hematite facility were used for storage and again were separated primarily by degree of enriched material or product stored. High-enrichment storage areas included Buildings 235, 250, and 252. Also, high-enrichment scrap was held in an outdoor, fenced, 75-ft. x 120-ft. area to the south of the plant.

A review has been conducted of those license application and approval documents that are available on site for the period from the initial issuance of License No. SNM-33 (July 18, 1956) until 1974 when the license was transferred to CE and the facility converted to the fabrication of LEU fuel for nuclear power plants. In general, the available records for the early years are incomplete. Because much work was done on classified projects, the available information is limited to generalized statements. In summary, the review identified that, during this period, the facility was licensed to possess enriched uranium at all enrichments up to fully enriched. The description of the chemical and physical form of the material possessed is limited to general statements that include "metals, oxides, and other uranium compounds." Thus, this search did not produce any information that was not already included in the HSA.

The quantities of special, source, and byproduct material authorized under License No. SNM-33 (Amendment 15, approved November 18, 1996) prior to the termination of nuclear fuel manufacturing operations in 2002 are listed in Table 2-3. A complete history of special, source, and byproduct material authorized for use at the site is not available.

Table 2-3 Authorized Material Prior to Plant Shutdown in 2002

Material	Chemical and/or Physical Form	Maximum Amount
Uranium enriched to a maximum of 5.0 weight percent in the U-235 isotope	Any (excluding metal powders)	20,000 kilograms U-235
Uranium, enriched to any enrichment in the U-235 isotope	Any (excluding metal powders)	350 grams U-235 *
Source material (uranium and thorium)	Any (excluding metal powders)	50,000 kilograms
Cobalt-60	Sealed sources	40 millicuries
Cesium-137	Sealed sources	500 millicuries
Mixed activation and fission product calibration sources including Am-241	Solid sources	200 microcuries
Californium-252	Sealed sources	4 milligrams

* Higher quantities were authorized during earlier periods of nuclear fuel manufacturing operations.

2.3 Previous Decommissioning Activities

2.3.1 Former Evaporation Ponds

Formal decommissioning and decontamination efforts on the Evaporation Ponds were undertaken in 1984, as specified and ordered by the NRC in a March 8, 1984 letter (Ref. 6). In response, CE submitted a decommissioning plan to the NRC by letter dated May 31, 1984 (Ref. 7). The NRC approved the plan by letter dated October 3, 1984 (Ref. 8). As a result of the 1984 decontamination, approximately 2,800 ft.^{3} of sludge, rock, and dirt were removed from the primary pond in August 1985. Detailed sampling of the primary pond was performed during the period of August through October 1986. Additional sampling, following the remediation effort, determined the average uranium contamination of the soil in the ponds was below the 250-pCi/g decontamination limit set by the NRC. However, contamination levels in excess of the average limit remained.

In a status report dated May 20, 1988 (Ref. 9) to NRC, CE provided further information concerning the remediation of the ponds. CE reported that core samples from the sides and bottom of the primary pond were taken and analyzed. The samples revealed an average contamination of approximately 60 pCi/g, with one sample as high as 674 pCi/g. Approximately 1,200 ft.^{3} of soil and rock were also removed from the secondary pond during 1987, and detailed surface soil samples were taken. The average contamination from these 150 samples was 173 pCi/g, and the highest reported level was 745 pCi/g.

During the period of 1991–1992, CE commissioned a contractor to plan and execute a soil and water study of residual contamination in the ponds. The results of this study were not consistent with the previous analyses. Rather, in this testing, the near surface soil samples from both ponds showed higher total uranium activity, and further characterization of this area was required.

A status update to the NRC on the ponds dated August 13, 1999 (Ref. 10) indicated that, since a decommissioning plan for the ponds was incorporated by amendment into the site license on May 4, 1995, approximately 6,000 ft.^{3} of additional soil had been removed and disposed. Surveys in 1999 of the pond area indicated an average concentration of 170 pCi/g. Uranium concentrations of approximately 100 pCi/g were detected at depths of 10 ft. below ground surface, greater than originally assumed. Remediation efforts in and around the Evaporation Ponds were suspended to investigate other remedial options.

Additional details on the Evaporation Ponds are provided in Section 4.4.2 of this DP.

2.3.2 Red Room, Item Plant, and Related Areas

Because these areas were used for high-enriched fuel production processes from at least the 1950's to the early 1970's, they are highly likely to contain nuclear contamination above currently applicable limits. In fact, these areas were identified as contaminated or "hot" areas during the transition of ownership of the plant from Gulf to CE in 1974. At that time, partial decontamination was undertaken. Specifically, equipment was removed, duct work and exhaust fans were removed, the floors were scarified, and both rooms were vacuumed, steam cleaned, and painted. In the Red Room, three inches of concrete were added to the floor and the roof was removed and supposedly buried on-site. However, these decontamination efforts are probably not in compliance with current regulations for free release. Moreover, additional contamination has been identified in the areas under the Red Room floor and immediately outside the Red Room. These buildings are described in Section 4.1 of this DP.

2.3.3 Site Creek

In mid-1995, it was determined that the site sewage treatment plant was having a number of upsets during routine operations, which resulted in sewage sludge collecting in the Site Creek. The sewage effluent enters the Site Creek directly below the dam, which creates the Site Pond. The sludge settled out between the dam and the railroad that crosses the site property.

A decision was made to remove the settled material. A back-hoe was used to remove silt to a depth that varied from 0.5 to 3 ft. in the area between the site dam and the railroad tracks. The removed material was dried and placed into "super sacks," which were shipped to a licensed disposal facility.

The objective of the remediation was to remove the sewage sludge and contaminated soil so that the average contamination remaining would be less than 30 pCi/g, with no single sample above 90 pCi/g. This was not a free release survey, because licensed activities continued at the site.

2.3.4 Contaminated Buildings

Decontamination and removal of systems and components inside contaminated site buildings are being performed under the current site license. Removal of these systems, components, and buildings will be protective of human health and the environment by addressing releases or threatened releases into the environment (i.e., by removing radioactive materials from the facilities) and will facilitate further characterization of soils and structures (e.g., sewer lines) pursuant to the NCP process.

2.4 Spills

Building 240 is described in Section 4.1.6 of this DP. Past operations in this building included the conversion of HEU using a wet conversion process and wet recovery of scrap. The effluent streams were piped to the retention ponds for settling and evaporation. The piping system likely contains HEU. Numerous spills and leaks likely occurred in these areas and parts of the slab were re-poured in 1974 over some existing contaminated flooring. Additionally, sub-slab contamination was found during the 1989 construction of Building 253.

Other spills associated with routine fuel fabrication operations have occurred in the process buildings. These buildings contain fixed and removable contamination above the release criteria established in the site license.

2.5 Prior On-site Burials

Beginning no later than 1965, and perhaps as early as 1958 or 1959, and continuing at least until November 1970, on-site burial was used as a means of disposal of contaminated materials and wastes at Hematite. From 1965 until 1971, up to 40 large, unlined pits were dug northeast of the plant buildings. Each pit is approximately 20 ft. by 40 ft. and 12 ft. deep. These pits were used to dispose of materials and waste generated by the plant processes. This on-site burial was a formally authorized activity, conducted pursuant to a former policy and memoranda describing the size and spacing of the pits, the thickness of the cover, and the quantity of radioactive material that could be buried in each pit.

UNC and Gulf maintained detailed logs of burials for the period of July 1965 through November 1970. The entries contain dates, descriptions of the waste buried, the weight of the uranium measured for that waste, and a cumulative total of the uranium buried in particular pits. Some entries also list percent enrichment for the uranium.

The logs show a wide variety of wastes being buried in the pits. Although the number of entries is too great to include, some examples of entries include:

- Tile (Red Room floor)
- Contam. 5 gal. Endshake oil
- B.D. Chlorotherm
- 97% Acid H_2
- R.S. oil
- UO_2 ThO_2 Paper Towels
- Unknown Oil
- R.S. Acid Insoluable
- Mixed Acid Residues
- vac. Oil
- KOH Insoluables
- pentachloride from vaporizer
- Used Magnorite
- TCE u. metal wash
- chlorothene – can cleanup
- TCE Rags
- Oily rags from Item floor
- $NbCl_5$ vap. Cleanout

- MB Rafinate Sample bottles
- Bottle unknown organics
- Pickling Solution
- 1 Drum of TCE #930 unknown enr
- Item 51 Poison equipt.
- TCE-Oil-Rags
- Perclene
- press oil

No records of burials exist prior to July 1965. However, an untitled memorandum has been located indicating that burial pits might have been used as early as 1958 or 1959 and that as many as three or four pits were used each year prior to 1965. Accordingly, it is estimated that an additional 20–25 pits might exist for which there are no records. There is no information to indicate the nature of the material buried in these other pits. These pits are being investigated during the characterization. Interviews from former plant employees indicate that these pits are located next to the process buildings between the process buildings and the known pit area.

On-site burial of radioactive material was terminated in November of 1970 as a result of an AEC citation issued for failure to adhere to AEC regulations concerning the quantity of material that could be buried on site. It appears, however, that Gulf did not cover the final pit until 1974, when it sold the property.

3.0 FACILITY DESCRIPTION

3.1 Site Location and Description

The Hematite facility is located on a site of about 228 acres in Jefferson County, Missouri, approximately 3/4 mile northeast of the unincorporated town of Hematite, Missouri and 35 miles south of the city of St. Louis, Missouri.

Jefferson County is predominately rural and characterized by rolling hills with many sizable woodland tracts. The land area is classified as 51% forest, 33% agricultural with crops such as grain and hay, and approximately 16% urban, suburban, commercial, and unused or undeveloped. Although extensive development in the county has resulted from urban growth around St. Louis, agricultural land use is still predominant in the site's environs. Some areas, generally ½ to 5 miles from the plant site, have been developed as small- to moderate-sized subdivisions.

A map showing the general location of the site is presented in Figure 3-1. The area within a 5-mile radius of the site is presented in Figure 3-2. The current site boundaries and the central site tract are depicted in Figure 3-3, and a site map with building locations and other infrastructure features is included as Figure 3-4.

The site is situated between hills to the northwest and a terrace/floodplain of Joachim Creek, located along the southeast site boundary. Activities with special nuclear materials were conducted within an approximately 10-acre, central site tract adjacent to the site access road, State Road P. The central site tract is developed with buildings, infrastructure, and maintained landscaping. The remaining property is woods and farmland, with no documented evidence of historic operations by Westinghouse or pervious owners. An active railroad line runs across the site southeast of the central site tract. The highest elevation on the site is approximately 560 ft. above mean sea level. The site topography drops to approximately 420 ft. above mean sea level along the banks of Joachim Creek. Topographic contours around the site are shown in Figure 3-5.

Figure 3-3 illustrates several surface water features present on or in close proximity to the site. These features are described in Section 3.6 of this DP.

The area immediately surrounding the site is primarily woods, farmland, and suburban residential. Three private residences are located on the site property, and other residences are located within 1/4 mile of the site. Groundwater is widely used within five miles of the site as the primary source of household water. According to Water Resources Report 30, 1974 (Ref. 11), domestic and industrial water wells in the vicinity produce water from the Powell-Gasconade aquifer group, which includes the Jefferson City Dolomite, the uppermost bedrock unit at the site. Wells in the area might penetrate the Jefferson City Dolomite if it is present but presumably do not derive significant quantities of water from it due to its poor storability. There are 763 wells within a 5-mile radius of the Hematite facility. There are 721 private drinking wells, 38 public wells, 4 industrial wells, and no irrigation wells. There are 29 wells within 0 to 1 mile of the site, 111 wells within 1 to 2 miles, 112 wells within 2 to 3 miles, 231wells within 3 to 4 miles, and 280 wells within 4 to 5 miles. The locations of private wells used by nearby residents down gradient of the site and four proposed/contingent monitoring wells are shown in Figure 3-6. Not all wells in Missouri are registered with the state. There might be wells in existence near the facility that are not documented by the state.

According to an EPA field investigation report, "Preliminary Assessment, Hematite Radioactive Site, Hematite, Jefferson County, Missouri," 1990 (Ref. 12), most of the residents in the community of Hematite and nearby Lake Virginia receive their drinking water from Public Water District No. 5. The report also states that surface water is not used for drinking water within a four-mile radius of the site. Public Water District No. 5 operates five public wells located in the Desoto and Festus quadrangles. Residents in Mapaville receive their public drinking water supply from Public Water District No. 7. Eight public wells service customers in Mapaville, Festus, Hillsboro, and Pevely (approximately 9 miles northeast of the site). The wells are located in the Festus and Desoto quadrangles. The nearest active public well (Well #3) to the Hematite site is located approximately 2 miles south/southeast of the plant site on Carron Road. There is a standby public well (Well #5) located approximately ¼ mile from the site in the Lake Virginia subdivision. This standby well is currently not in use.

There is a Head Start pre-school in the community of Hematite. A county school for handicapped children is located in Mapaville. There is a high school/middle school/elementary school complex in Festus.

Figure 3-1 General Location of the Hematite Site

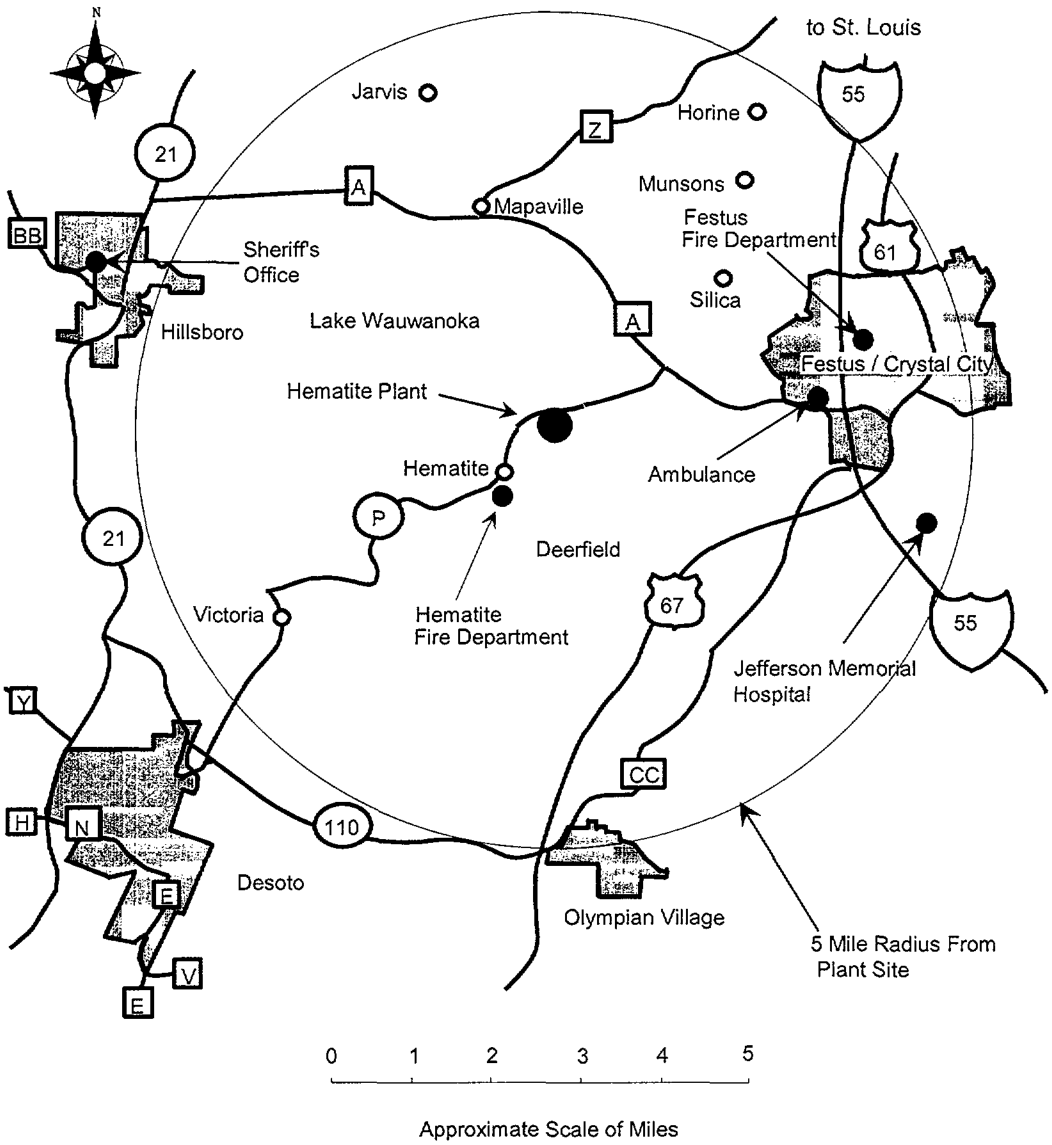


Figure 3-2 Area Within 5-Mile Radius of the Hematite Site

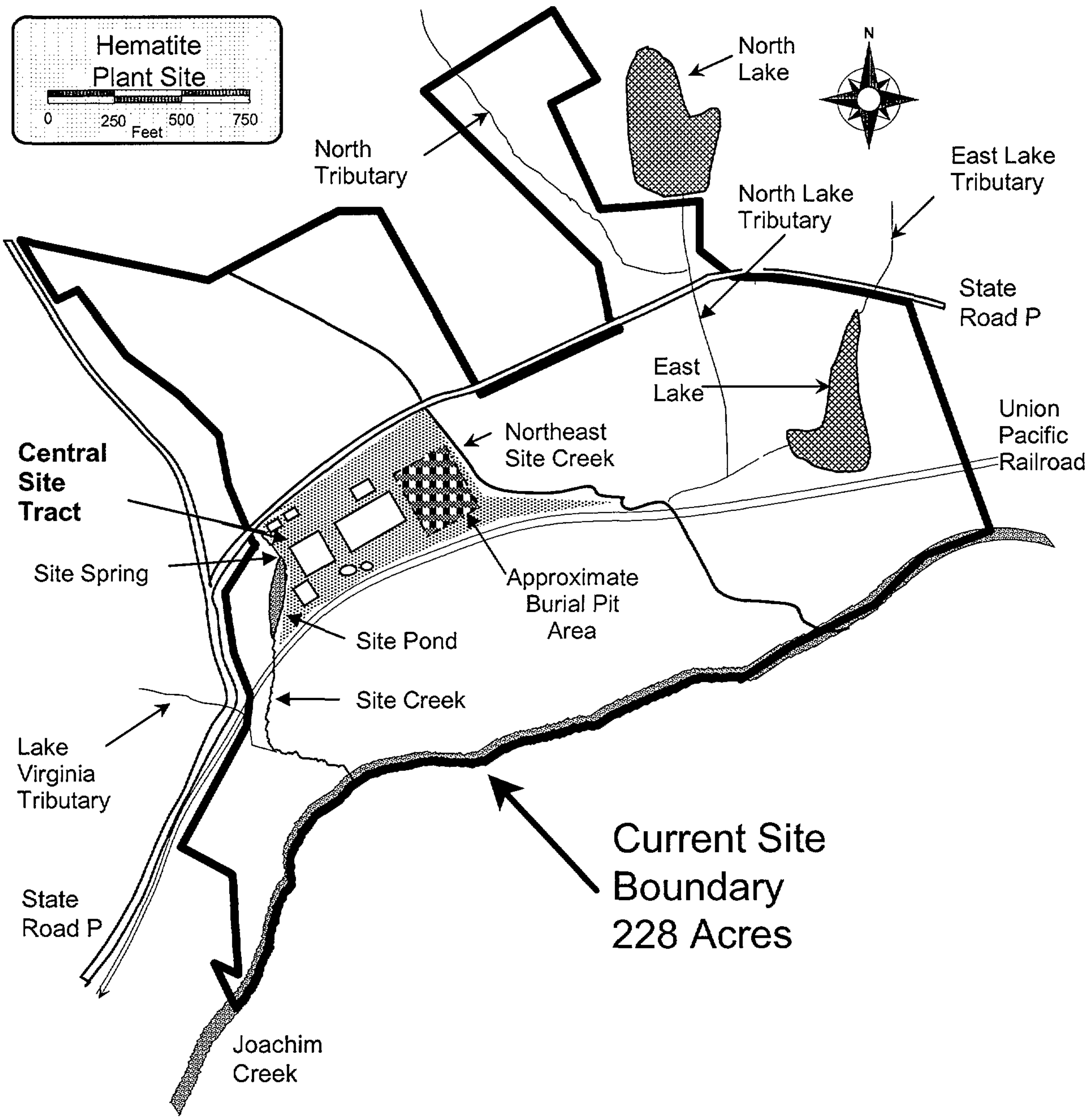


Figure 3-3 Hematite Site Boundaries

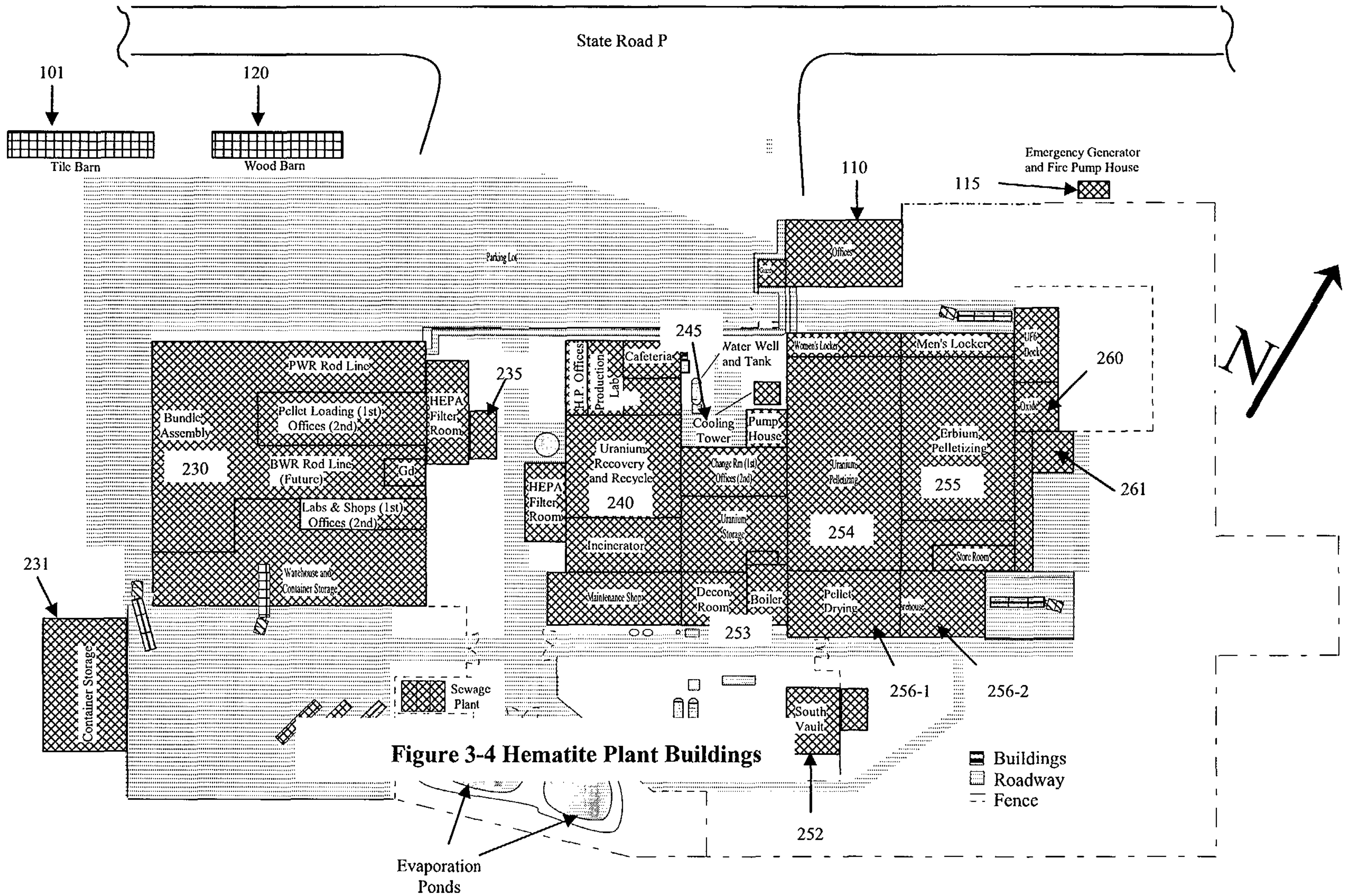


Figure 3-4 Hematite Plant Buildings

Figure 3-4 Hematite Plant Buildings

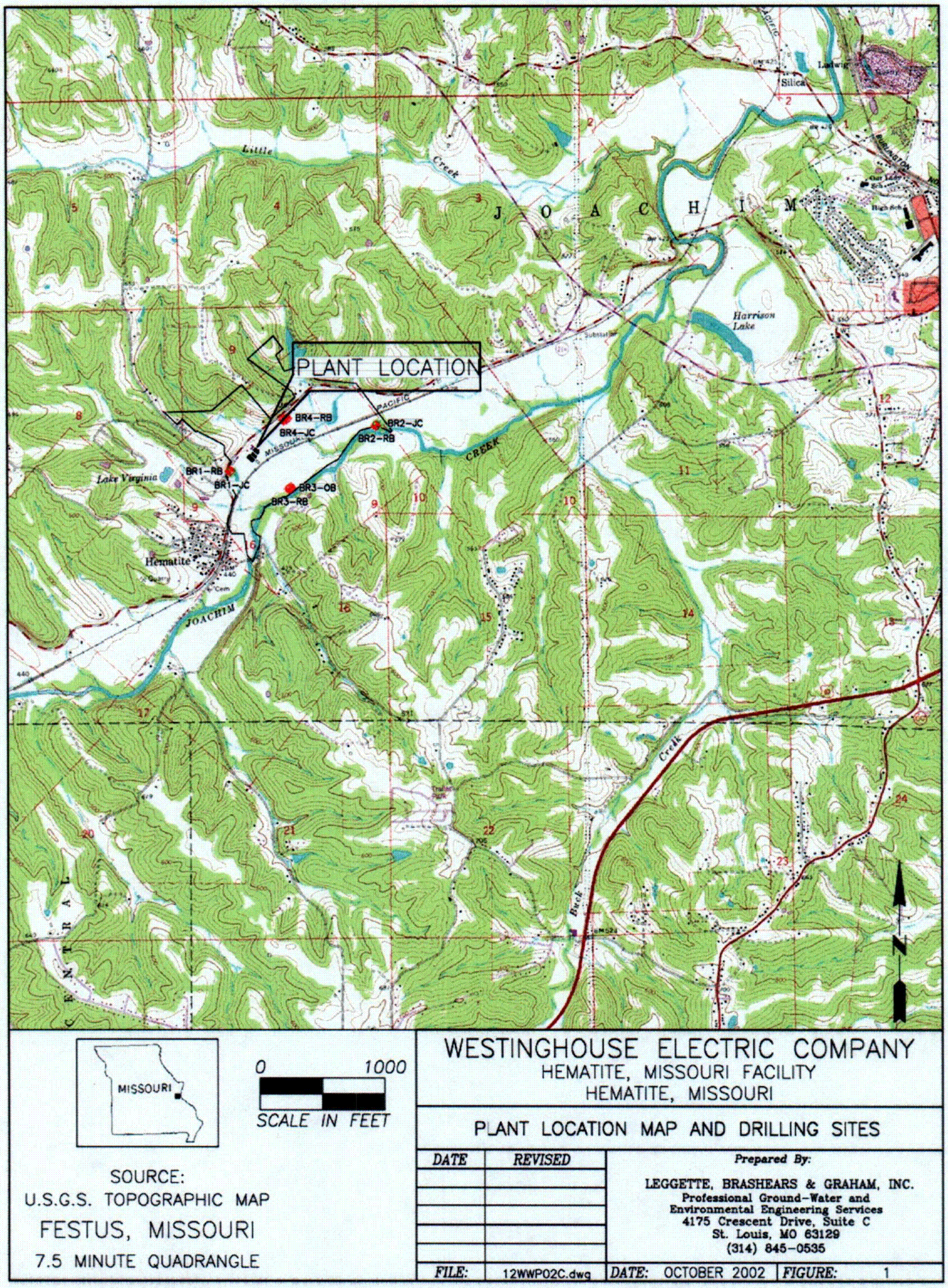


Figure 3-5 Topographic Contours Around the Hematite Site

C01

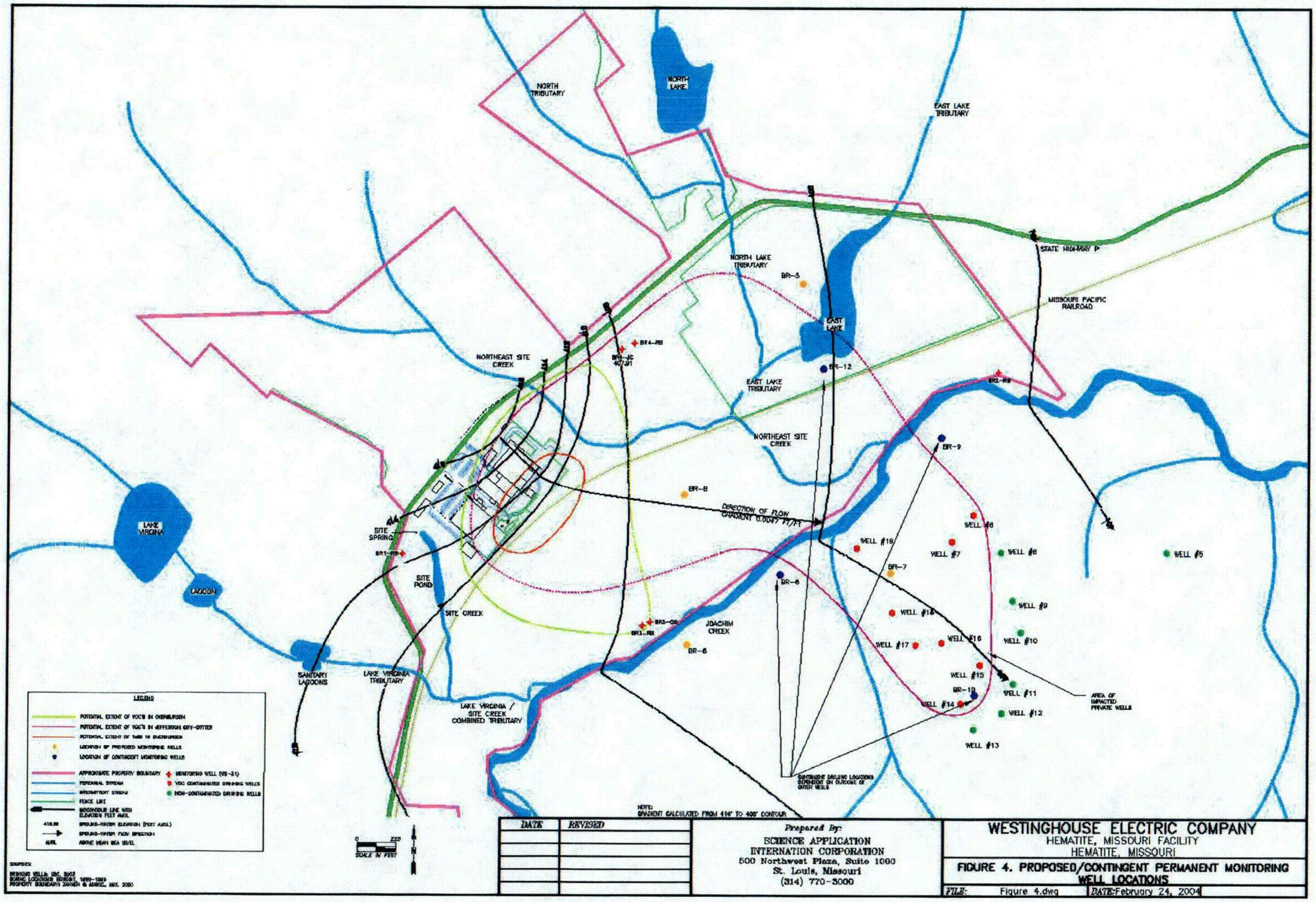


Figure 3-6 Nearby Drinking Water Wells

C02

3.2 Population Distribution

Several towns and unincorporated settlements are wholly or partly within a 5-mile radius of the Hematite plant. Hematite is the closest settlement and is a bedroom community of about 125 people. Festus and Crystal City, located 3.5 miles east of the site and having a combined population of about 13,900 people, are the nearest towns of significant size. They are the county's second largest incorporated community and include a substantial number of commercial and retail businesses. The locations of nearby communities are shown in Figure 3-2, and information on these communities is provided in Table 3-1.

Table 3-1 Communities Within 5 Miles of the Hematite Site

Town or Settlement	Direction from Plant	Distance from Plant (miles)	1990 Census	2000 Census
Crystal City	E	4.5	4,088	4,247
DeSoto	SW	5	5,993	6,375
Festus	E	3.5	8,105	9,660
Hematite	SW	0.5	125	
Hillsboro	NW	5	1,625	1,675
Horine	NE	5	1,043	923
Mapaville	N	3.5	100	
Olympian Village	S	5	669	669
Victoria	SW	3	100	

The county's average population density is 301 people per square mile based on the total estimated 2000 census population of 198,099 persons and an area of 657 square miles. Most of the population is White (193,102), followed by Black or African American (1,354), Asian (708), American Indian or Alaska Native (577), and other races. The median annual income is approximately $45,000. Owner-occupied housing units outnumber renter-occupied units by a ratio of approximately 6 to 1. The average size of an owner-occupied household is 2.81 people, and the average size of a renter-occupied household is 2.42 people.

Estimates provided by the Missouri Census Data Center indicate the population of Jefferson County is projected to increase by approximately 31% between 2000 and 2025.

3.3 Current and Future Land Use

The current land use in the surrounding area is a mixture of farming, light industry, and suburban residential. Current land use within the site boundaries consists of characterization and decommissioning activities, primarily in the central site tract. Part of the site property outside the process plant area is leased to residents and to farmers.

It is anticipated that future uses of the land in and around the site will remain roughly consistent with its current use, i.e., residential, agricultural, and light industrial.

3.4 Meteorology and Climatology

The *Missouri Water Atlas*, 1986 (Ref. 13) was referenced to determine local precipitation. The area receives an average of 38 inches of precipitation per year, with 12 inches of average annual runoff. The maximum 10-day event expected precipitation is 9 inches in a given 25-year period. Snowfall has averaged less than 20 inches per winter season since 1930. The three winter months are the driest, the spring months are normally the wettest, and it is not unusual to have extended periods (1 to 2 weeks or more) without appreciable rainfall from the middle of the summer into the fall. Thunderstorms occur on average between 40 to 50 days per year. The U.S Department of Commerce reports a mean annual frequency of about 8 tornadoes per year for a 30-year period. The probability of a tornado striking the site location is computed as 7.51×10^{-4}, and the recurrence interval is 1,331 years.

General climatological characteristics of the site area can be approximated by those of St. Louis, the location of the nearest U.S. Weather Bureau recording station. The region experiences a modified continental climate without prolonged periods of extreme cold, extreme heat, or high humidity. To the south, the warm, moist air comes off the Gulf of Mexico, and to the north, Canada is a source of cold air masses. The alternate invasion of the region by air masses from these sources produces a variety of weather conditions, none of which is likely to persist for any length of time. Winters are brisk but seldom severe. Minimum temperatures remain as cold as 32°F or lower fewer than 20 to 25 days in most years. Summers are warm with a maximum temperature of 90°F or higher an average of 35 to 40 days per year.

3.5 Geology and Seismology

The Hematite site is on the north, northeast flank of the Precambrian age St. Francis Mountains uplift, which created the Ozark Dome. Cambrian, Ordovician, Silurian, Devonian, and Mississippian age sedimentary formations of various depositional environments are draped on the flanks of the Ozark Dome. The site is situated over these sedimentary formations. Based on the "Missouri Geologic Map," 1979 (Ref. 14) and the "Bedrock Geologic Map of the Festus 7.5 Minute Quadrangle, Jefferson County, Missouri" (Ref. 15) the uppermost bedrock beneath the site is the lower Ordovician Canadian series, Jefferson City Dolomite.

The Jefferson City Dolomite is described in Martin et al (Ref. 16) as mostly light-brown to medium-brown, medium to finely crystalline dolomite and argillaceous dolomite. Chert, which is not abundant, is typically oolitic, banded, mottled, or sandy. Lithologic succession within the formation is complex and varies among locations. The Jefferson City Dolomite typically is 125 to 325 ft. thick. It is bounded above by the overlying Cotter Formation, also mostly a dolomite, and beneath by the Roubidoux Formation, which is dominantly a sandy dolomite with lesser beds of dolomitic sandstone and dolomite. The indurated sedimentary rocks in this area dip gently and uniformly to the north, northeast.

Several test borings have been made in connection with past construction activities at the site. The borings were drilled to depths of approximately 35 ft. The soil profile thus obtained shows upper alluvial soils of stiff, very silty clays containing some sand, underlain by silty clays of firm to stiff consistency to depths of 10 to 13.5 ft. Very stiff, highly plastic clay with limestone fragments were next encountered to depths of approximately 22 ft. Firm to stiff, sandy, silty clay was then found until auger refusal was obtained on boulders or limestone bedrock at an approximate depth of 36 ft.

The southeastern area of Missouri is quite active seismically and also contains a portion of the New Madrid Fault that caused the "great earthquakes" of 1811 and 1812. There were three quakes of Epicentral Intensity XII Modified Mercalli scale (M.M.) that took place on December 6, 1811 and January 23 and February 7, 1812 near New Madrid. In 1962, a quake measuring V (M.M) was recorded in the New Madrid area. A quake with a magnitude of 4-1/2 was recorded in the New Madrid area in 1963. A quake reported as "the strongest in years" occurred near Caruthersville, Missouri, 150 miles southeast of Hematite, on December 3, 1980. Figure 3-7 shows the location of mapped faults and folds in the Hematite, Missouri area. Figure 3-8 illustrates measured earthquakes in and near southeast Missouri from roughly 1900 to present. The closest earthquake to the Hematite facility of 3.0 magnitude or greater was centered roughly 10 miles south/southeast of the facility.

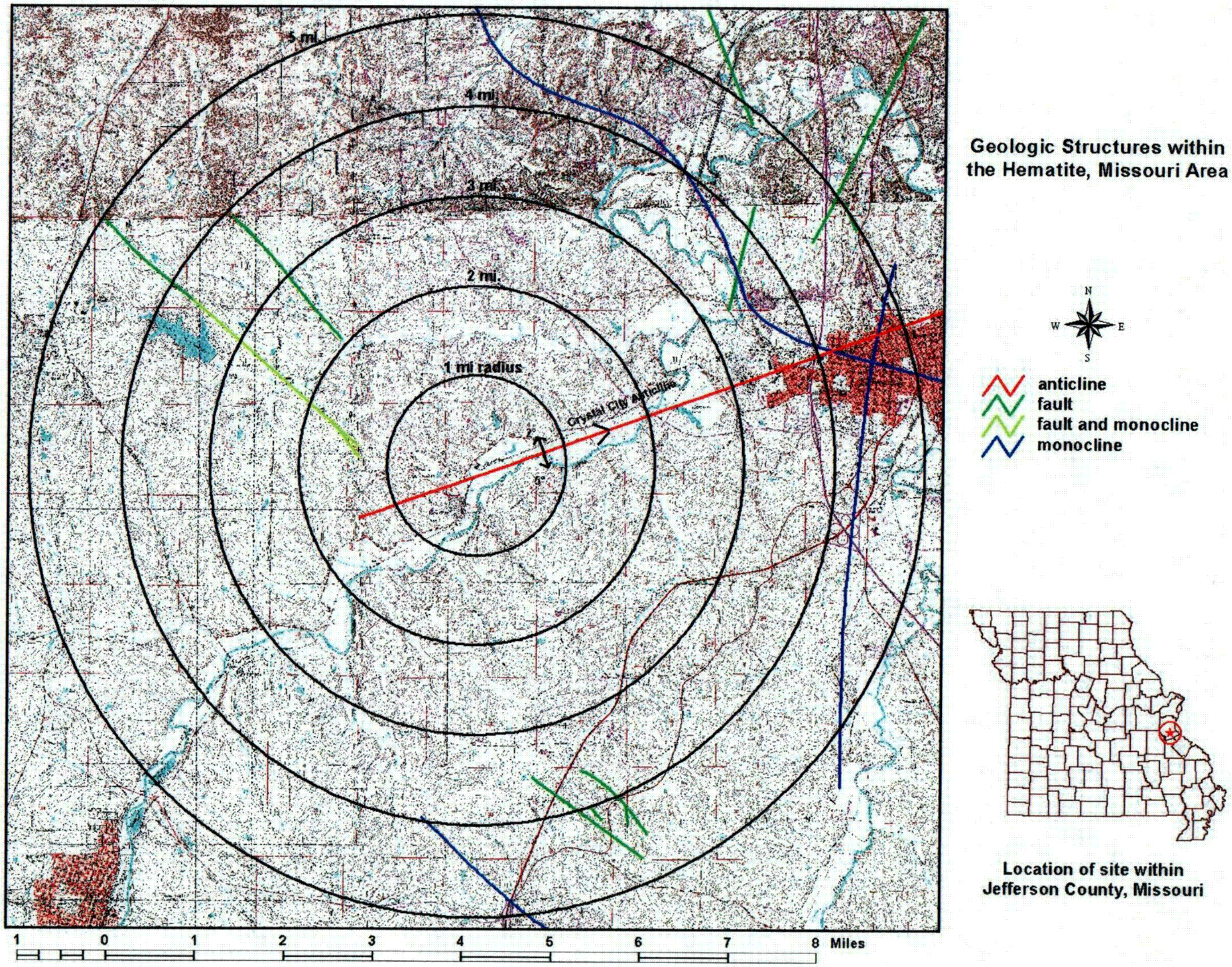
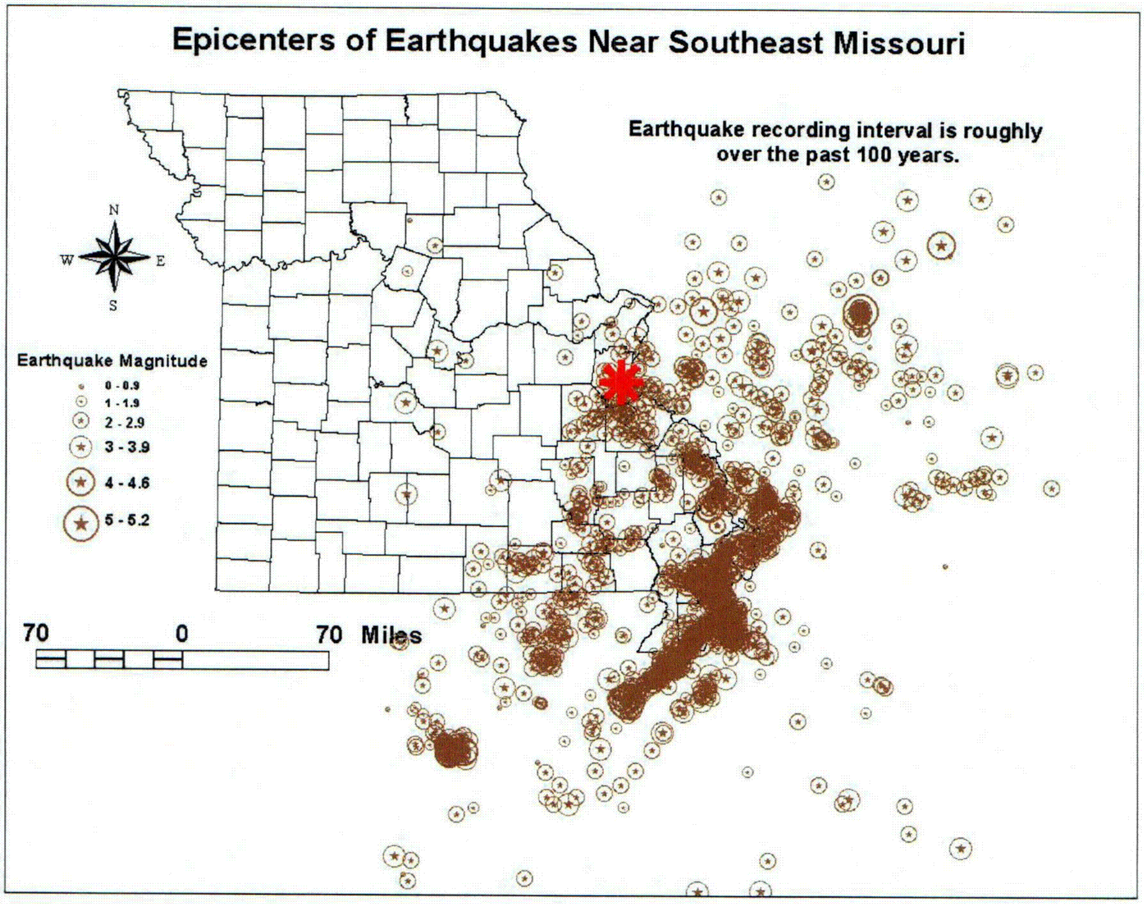


Figure 3-7 Hematite Area Faults

C03



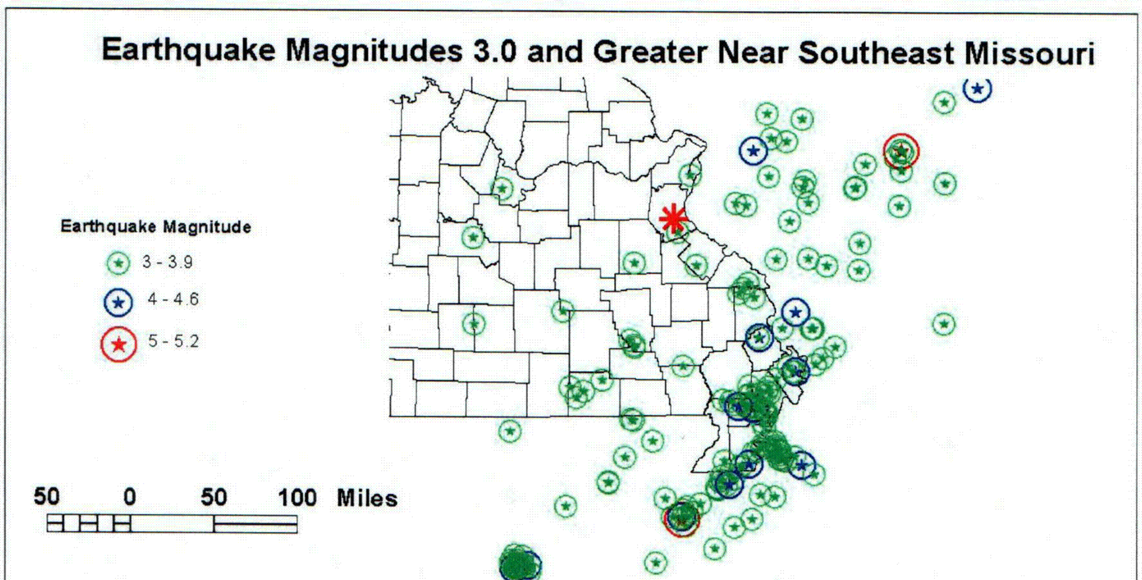


Figure 3-8 Earthquakes Near Southeast Missouri

C04

3.6 Surface Water Hydrology

The "Missouri Water Atlas," 1986 (Ref. 17) was referenced to determine local stream characteristics. The atlas shows that Joachim Creek, located along the southeast site boundary, is a permanent flowing stream. There are several other surface water features present on or near the site, including a spring, intermittent perennial and ephemeral streams, a lake, and ponds. These features are listed as follows:

- Site Spring flows an estimated 1 to 10 gpm most of the year. The spring is likely a result of fracture flow in the Jefferson City/Cotter Formation, which receives its source water from the hills northwest of the site.
- Site Pond is a small concrete dam impoundment southwest of the plant. It receives flow from the Site Spring and storm water runoff from the plant area.
- Site Creek is the effluent from below the dam of the Site Pond that receives discharge from the sanitary and storm water system. It flows through a culvert beneath the railroad track and joins the effluent from the Lake Virginia drainage basin.
- Lake Virginia/Site Creek Combined Tributary flows east to Joachim Creek.
- Northeast Site Creek flows southeast to the east of the Burial Pits and then east to its confluence with the effluent of East Lake tributary and then to the Joachim Creek.
- East Lake east of the site is an earth impoundment lake used as a water supply for cattle. It is reported to never have been used in conjunction with plant operations.
- North Lake is located just outside the northeast site boundary. It is an earth impoundment lake used as a water supply for cattle.
- North Lake Tributary is the effluent drainage from North Lake and North Tributary. This tributary crosses the terrace, west of East Lake.
- North Tributary is an intermittent stream west of North Lake.

Quantitative data regarding flow quantity, duration, peak discharge, etc. is not available for all of these features. However, some observations can be made.

- The Site Spring flows continually.
- The ponds and lake on the site hold water year round. (Flow is measured at the Site Pond dam and reported quarterly to the MDNR Water Pollution Control Program.)
- The streams flow intermittently.
- Joachim Creek is perennial. Based on flow gauge information from the U.S. Geological Survey, the annual mean flow is approximately 132 cubic feet per second (cfs). The seasonal mean flows are: 330 cfs (spring), 12 cfs (summer), 16 cfs (fall), and 169 cfs (winter). Joachim Creek flows into the Mississippi River near Herculaneum, Missouri. MDNR reports that there are no registered major water users that take water from Joachim Creek, and there are no public water systems listed in the "Census of Missouri Public Water Systems 2004" that take water from the creek.

There are two water control structures on the site—the Site Pond dam and the East Lake dam. The Site Pond dam is made of concrete and is approximately 32 ft. long, 16 in. wide, and 40 in. from the footing to the top of the dam. The East Lake has an earthen dam, which is approximately 175 ft. long.

There are two lakes within a one mile radius of the site that have water control structures. North Lake is located northeast of the site and has an earthen dam of approximately 200 ft. in length. Lake Virginia is located southwest of the site and has an earthen dam structure. With the exception of Lake Virginia (actually a small pond), there are no known water obstructing barriers within 5 miles upstream of the Hematite facility.

The drainage channels for all of the above structures cross through the site boundaries and empty into Joachim Creek.

Floods that might occur at the site will produce different flood levels depending upon the flow rate of Joachim Creek. While historical records (maximum observed level of 431 ft. above mean sea level) and analysis by the Federal Emergency Management Agency (FEMA) show that a site flood is not likely, it is still considered remotely possible. If a flood of larger magnitude (greater than 432 ft. above mean sea level) were to occur, water at the plant site would rise, but there is not expected to be any significant water velocity associated with the flooding. The reason for the minimal water velocity is that the railroad track, which is located between Joachim Creek and the plant, would serve to isolate the plant area from the main stream flow. Figure 3-9 shows the 100- and 500-year flood boundaries for Joachim Creek.

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THAT CAN BE VIEWED AT THE RECORD TITLED:

"FIRM FLOOD INSURANCE MAP JEFFERSON, MISSOURI (UNINCORPORATED AREAS)"
PANEL 110 OF 275
COMMUNITY-PANEL NUMBER 290808 0110 B
EFFECTIVE DATE: MAY 16, 1983

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3.7 Groundwater Hydrology

The near-surface hydrostratigraphic units at the site were characterized in *Hydrogeological Investigation and Groundwater, Soil and Stream Characterization*, 1998 (Ref. 18). In that investigation, groundwater monitoring wells were installed to serve the purposes of discrete geologic unit mapping and sampling and to provide vertical hydraulic gradient information.

As part of the hydrogeologic studies, single-well hydraulic conductivity tests were performed to characterize the horizontal hydraulic conductivity of distinct geologic horizons. From these tests, the average hydraulic conductivities of the unconsolidated materials above bedrock were found to be 3×10^{-5} cm/sec and 8×10^{-4} cm/sec for the near-surface silt, silty clay (NSSSC) and deeper, silty clay/clay (DSCC) units, respectively. Single-well testing of the Jefferson City Dolomite showed a hydraulic conductivity of 8×10^{-4} cm/sec. Fracturing and other features causing secondary porosity and permeability in the rock affect the hydrogeologic characteristics of the Jefferson City Dolomite and other bedrock formations. The primary permeability of the bedrock (i.e., through the solid rock matrix) is measured to be low, thus slow groundwater velocity would be predicted. However, groundwater flowing discretely through fractures, partings, or other secondary permeability features can do so at a much higher velocity. The size, density, and orientation of these fractures and partings determine the effective hydraulic conductivity of the bedrock.

Potentiometric surface (groundwater elevation) maps were constructed for the NSSSC, DSCC, and Jefferson City units to determine groundwater flow direction and hydraulic gradient. In the NSSSC unit, groundwater flows to the northeast and southeast. In the DSCC and Jefferson City units, groundwater flows to the southeast. Recent work shows the Roubidoux Formation's pieziometric surface as also indicating southeast flow direction. The orientation of the fractures and other secondary permeability features influence groundwater flow directions and gradients in the Jefferson City and other bedrock formations. Figure 3-10 shows groundwater flow direction and gradient in the vicinity of the site buildings.

In 1996, a site investigation by MDNR revealed the presence of volatile organic compounds (VOCs) in several monitoring wells located on site. Four private domestic wells located east of the site were sampled at that time, and no contaminants were found. In December 2001, the Missouri Department of Health and Senior Services conducted annual monitoring of the four private wells near the site. Results of that sampling revealed that one of the private wells (located on the site property) had VOCs—primarily perchloroethylene (PCE), trichloroethylene (TCE), and their degradation by-products—significantly above drinking water standards. In 2002, the need for more hydrogeologic data was prompted by the discovery of the VOCs in private domestic wells. Additional drilling and characterization were accomplished, adding to the hydrogeologic body of knowledge. In response to the information gathered, the affected private wells have been taken out of service, and the residents have been switched to a public water supply. This information is summarized in *Engineering Evaluation and Cost Analysis for Response Action for Off-Site Groundwater*, January 2003 (Ref. 19).

Hydrogeologic evaluations and private domestic well sampling data indicate that groundwater flow is to the east/southeast and that the most distant private wells with VOC contamination are approximately 0.6 miles from the plant site. Except for one private well located northeast of the plant at a residence on the site property, all affected wells (a total of eight) are at residences located southeast of the site.

Public water supply wells are not located in an area that is expected to be impacted by VOCs. Public or industrial water supply wells are typically constructed to withdraw water from a deeper part of the aquifer than private wells. For example, the closest active public well on Carron Road is approximately 1,000 ft. deep and the Hematite plant well is approximately 600 ft. deep, while residential wells in the affected area are typically only 250 to 350 ft. deep. Data from the Hematite plant well confirms that the identified contamination has not extended to that depth (600 ft. below ground surface); thus, the public water supply wells are expected to remain free of VOC contamination.

There are thirty-four existing monitoring wells and piezometers installed to monitor the unconsolidated and bedrock aquifers at the site. The shallow wells/piezometers range from approximately 14 to 60 ft. in depth below ground surface. The deeper wells range from 105 to 335 ft. in depth below ground surface. Selected wells are sampled periodically as part of the site's environmental monitoring program. Some wells/piezometers have not been developed/sampled in several years and might require development (i.e., removal of excessive silt/sand accumulation) for the additional site characterization. The locations of monitoring wells in the vicinity of the site buildings are shown in Figure 3-10.

Additional information on groundwater will be developed and summarized in the site characterization.

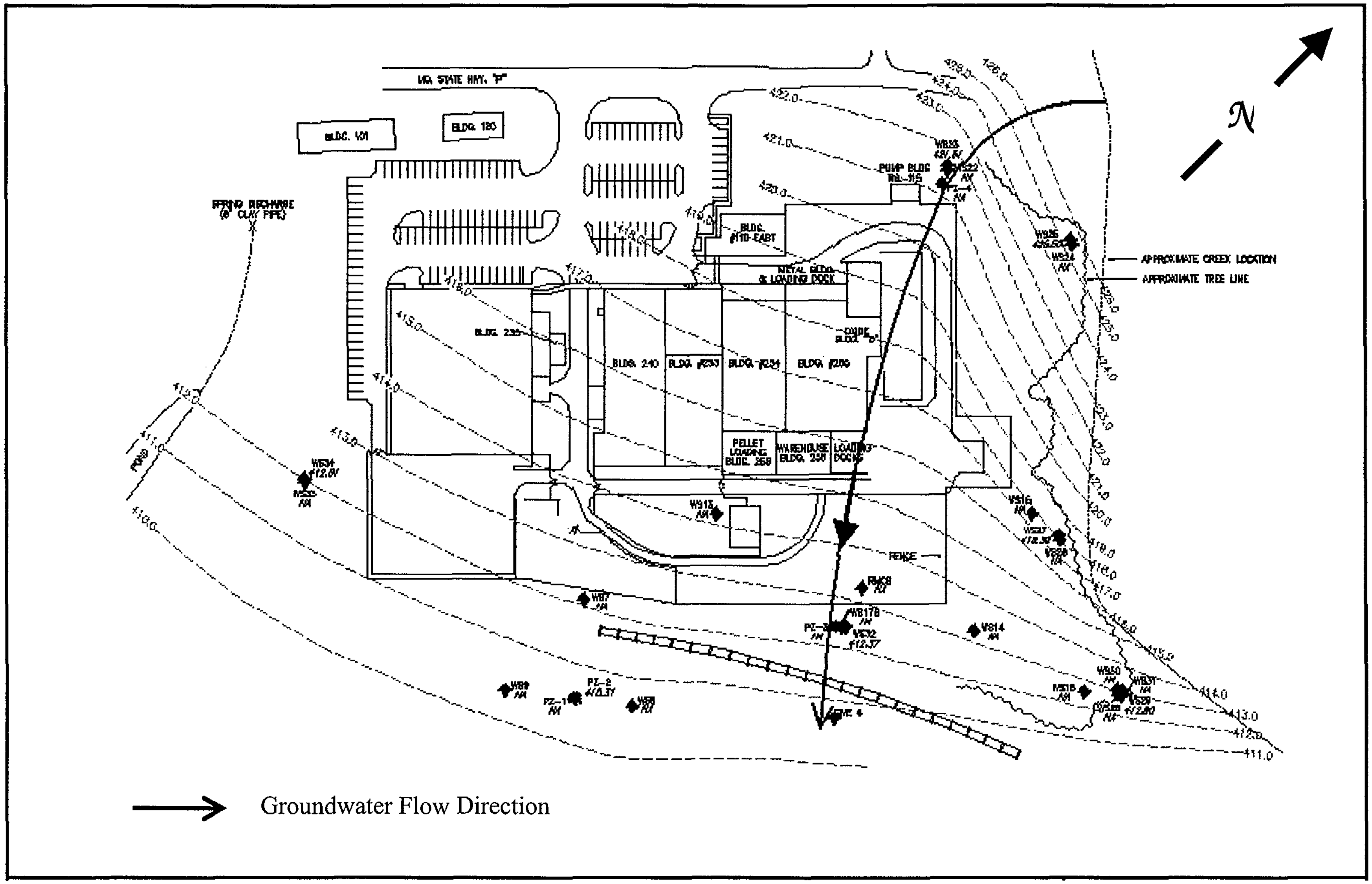

Figure 3-10 Groundwater Flow Direction and Gradient

3.8 Natural Resources

The primary natural resources occurring at or near the site are agricultural lands, surface water ponds and streams, and groundwater. There are some wooded areas on and surrounding the site, but the low quality of the timber makes any major harvesting unlikely.

The surface water features on and near the site are described in Section 3.6 of this DP. These surface water features are not used for drinking water, but some are used for watering livestock. Groundwater is widely used as the primary source of household water.

There are 33 surface mines within 5 miles of the Hematite site. The closest are two limestone quarries, less than two acres in size, that are approximately 1 mile southwest of the site. The other mines consist of 1 copper, 11 lead, 2 other limestone, and 17 sandstone quarries. Most of these lie outside of a 2-mile radius from the site.

4.0 RADIOLOGICAL STATUS OF FACILITY

The descriptions in this section are summarized from the same or equivalent information presented in the Historical Site Assessment (HSA), the Gamma Walkover Survey (GWS) described in the "Gamma Survey Data Evaluation Report" (Ref. 20), and other characterization efforts, i.e., soil sampling for soil distribution coefficient (K_d) determination, "Deul's Mountain" characterization, and characterization of soil under site buildings. The "Gamma Survey Data Evaluation Report" has been provided as a separate submittal to the NRC.

The HSA assessed the potential radiological impacts of historic operations at the site and provides a history of site activities that might have resulted in the release of licensed material. The HSA was prepared in accordance with NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (Ref. 21) to address the following:

- Identify the potential, likely, and known sources of radioactive material and radioactive contamination based on existing or derived information
- Differentiate impacted from non-impacted areas
- Identify whether or not areas pose a threat to human health and the environment
- Provide an assessment for the likelihood of contaminant migration
- Provide input to scoping and characterization surveys

The GWS was performed in 2003 at the Hematite site to identify the presence of natural uranium, LEU, HEU, technicium-99, and thorium contamination in surface or near-surface soils to aid in area classification and future characterization planning at the site. The GWS was designed to follow the guidance for scoping surveys presented in Section 5.2 of MARSSIM.

Soil characterization was performed in selected locations inside the central site tract in 2003 to facilitate K_d determination. The results of this characterization are described in Section 14.2.2.

Soil samples from Deul's Mountain were collected and analyzed in 2002 to characterize the stockpiled soil resulting from building construction. The results are described in Section 4.3.1.

Soil samples from underneath site buildings have also been collected and analyzed as described in Section 4.3.1.

4.1 Contaminated Structures

Structures that have been or might be radiologically impacted by historic licensed activities at the Hematite site are described in this section. Figure 3-4 shows the layout for the site buildings.

4.1.1 Building 101 – Tile Barn

The Tile Barn formerly functioned as the emergency operations center. The building has been used to store both clean and radiologically contaminated equipment.

4.1.2 Building 115 – Generator/Fire Pump Building

A diesel-powered emergency generator was located in this building. No work with radioactive materials was reportedly performed in this building. A diesel fire water pump currently remains in the building.

4.1.3 Building 120 – Wood Barn

The wood barn has been used to store both clean and contaminated equipment. The floor is dirt and might have residual contamination in low concentrations.

4.1.4 Building 230 Rod Loading

Finished pellets (standard, erbium and gadolinium) were loaded into fuel rods and assemblies for shipment offsite from Building 230. Radiological contamination levels are less than the restricted and controlled area limits of SNM-33. This building was built circa 1992.

4.1.5 Building 231 – Warehouse

Building 231 was used to store shipping containers. Some shipping container refurbishment was performed in this area. A small potential for UO_2 contamination exists.

4.1.6 Building 235 – West Vault

The West Vault was most recently used to store depleted and natural uranium. It was historically used to store HEU. The interior of the building was painted in 1994, and contamination might be present under the paint.

4.1.7 Building 240 – Recycle Recovery (Red Room, Green Room, Blue Room)

This building contains laboratory and maintenance areas, a recycle recovery area, a waste incinerator area, and the former health physics laboratory. Support operations were conducted for conversion, pelletizing, and fuel assembly, including material recycle, scrap recovery, cylinder heel recovery, quality control, analytical laboratory, maintenance, waste consolidation, and disposal preparation. This building was integral to the historic operations of the facility. Past operations included the conversion of HEU using a wet conversion process and wet recovery of scrap. The effluent streams were piped to the retention ponds for settling and evaporation. The piping system is likely to contain HEU. Numerous spills and leaks likely occurred in these areas, and parts of the slab were re-poured in 1974 over some existing contaminated flooring. Additionally, sub-slab contamination was found during the 1989 construction of Building 253.

Building 240-1 currently houses the health physics and production laboratories, lunchroom, and laundry for radiologically contaminated personal protective equipment (PPE). It historically housed the lunchroom, offices, locker rooms, and laundry.

Building 240-2 (Red Room) was used for recycle and recovery operations. It historically included high-enrichment powder and metal operations, including recycle and recovery.

Building 240-3 (Green Room) is currently used for the incinerator and associated support operations. It historically included low-enriched powder operations, including ammonium diurinate and oxidation/reduction furnaces.

Building 240-4 (Blue Room) currently houses the maintenance shop. It also housed the production laboratory until 1993 when it was moved to 240-1. It formerly housed low-enriched powder operations.

4.1.8 Building 245 – Well House

The Well House is the block building attached to the potable water tank by the double doors into the laundry room. Currently, chlorinating of potable water occurs in the building using sodium hypochlotite (bleach), and the tank marked "potable water" is used to ensure appropriate contact time. This building and the attached tank are connected to the 200,000-gallon gravity tank on the hill across State Road P. The elevation of the gravity tank creates a 50-psig static head throughout the system. A pressure switch in the Well House automatically activates the well pump when static pressure drops below 50 psig.

Formerly, the existing chlorine contact tank was used as a pressure tank to create the static head by adding nitrogen as necessary. That operation ended when the gravity tank was built in 1991. The Well House formerly contained a mop water boil-down tank immediately east of the chlorinating tank with a storm drain under the tank for overflow. The boil-down tank was eliminated around 1993, and the storm drain was capped with concrete.

4.1.9 Building 252 – South Vault

The South Vault was used for storage of low- and high-enrichment nuclear material. It was most recently used for storage of chemicals and low-level radioactive wastes.

4.1.10 Building 253 – Offices, Storage, and Mechanical Operations

This building contained offices, various site utilities, a uranium storage facility, processing areas, and decontamination facilities. Within Building 253 is Building 250, which was formerly a stand-alone structure. In 1958, rooms 250-2 and 250-3 were added to Building 250. Building 250 became room 250-1 and continued to be used for the storage of uranium hexafluoride (UF_6) cylinders and mechanical operations such as boilers, cooling tower pumps, and recycle hopper make-up. Building 250-2 was used as a general storage area, and Building 250-3 was the blending room for low-enriched uranium oxide. Characterization surveys indicate that building and equipment surfaces are contaminated.

4.1.11 Building 254 – Pellet Plant

In the pelletizing buildings, granules of UO_2 or uranium oxide (U_3O_8) were fed into a mill (micronizer) that produced fine powder for pressing. A starch and die lubricant were added and blended into a batch and subsequently pressed into pellets. The "Green" fuel pellets were processed through a de-waxing furnace to remove the additives and then passed through a sintering furnace where they were made into a ceramic. These furnaces were electrically heated and used disassociated ammonia to provide a reducing atmosphere.

4.1.12 Building 255 – Erbia Plant

The most recent use of this building was for the special product line making erbium pellets. It was the main pellet plant from 1974 through the opening of Building 254 in 1989. This process area included agglomeration, which used cranko and freon, instead of the slugging presses, to increase particle size between the micronization/blending and pellet pressing. Additionally, Building 255-3, the most recent erbium recycling area, was historically called the Item

Plant in which high-enrichment shot to be used as reactor fuel was sized and coated.

4.1.13 Building 256 – Pellet Drying and Warehouse

Building 256-1 was used for pellet drying. Pellet trays were loaded into pans, dried in an electric oven using disassociated ammonia as a cover gas, and either stored or transferred to Building 230. This structure was originally used as warehouse space.

Building 256-2 was the main site warehouse for shipping and receiving pellets and powder and for receiving site supplies.

4.1.14 Building 260 – Oxide and Oxide Loading Dock

The Oxide Building was built in approximately 1968 and is a four-story Butler-type building. This building was used for the conversion of uranium compounds into uranium oxide granules.

4.1.15 Building 261 – Limestone Building

Building 261 was used for the storage of unused limestone. Historically, the building contained a limestone storage bin, conveyor system, preheat furnace, and a heat trace. All contents have been removed from this building.

4.2 Contaminated Systems and Equipment

All contaminated systems and equipment are being removed from contaminated building. The buildings are being stripped to bare walls and floors. This work is being performed under the current site license and will facilitate the additional characterization of soils and potential structures under the buildings. These steps will also be protective of human health and the environment by removing radioactive impacts from the facility. Demolition of the buildings is being evaluated under a license amendment and will support the required characterization of soils underlying these structures.

4.3 Surface Soil Contamination

Based on historical operations and supporting data from the GWS, the surface soils in the central site tract (around and under the plant buildings) are considered to be Class 1 or Class 2 impacted areas. The exact classification of the areas inside the central site tract and the precise extent of these impacted areas will be defined during characterization efforts and during decommissioning. A perimeter area around three sides of the central site tract has been categorized as a Class 2 impacted area. The outlying land areas of the site have been categorized as a Class 3 impacted area. Figure 4-1 shows the locations of

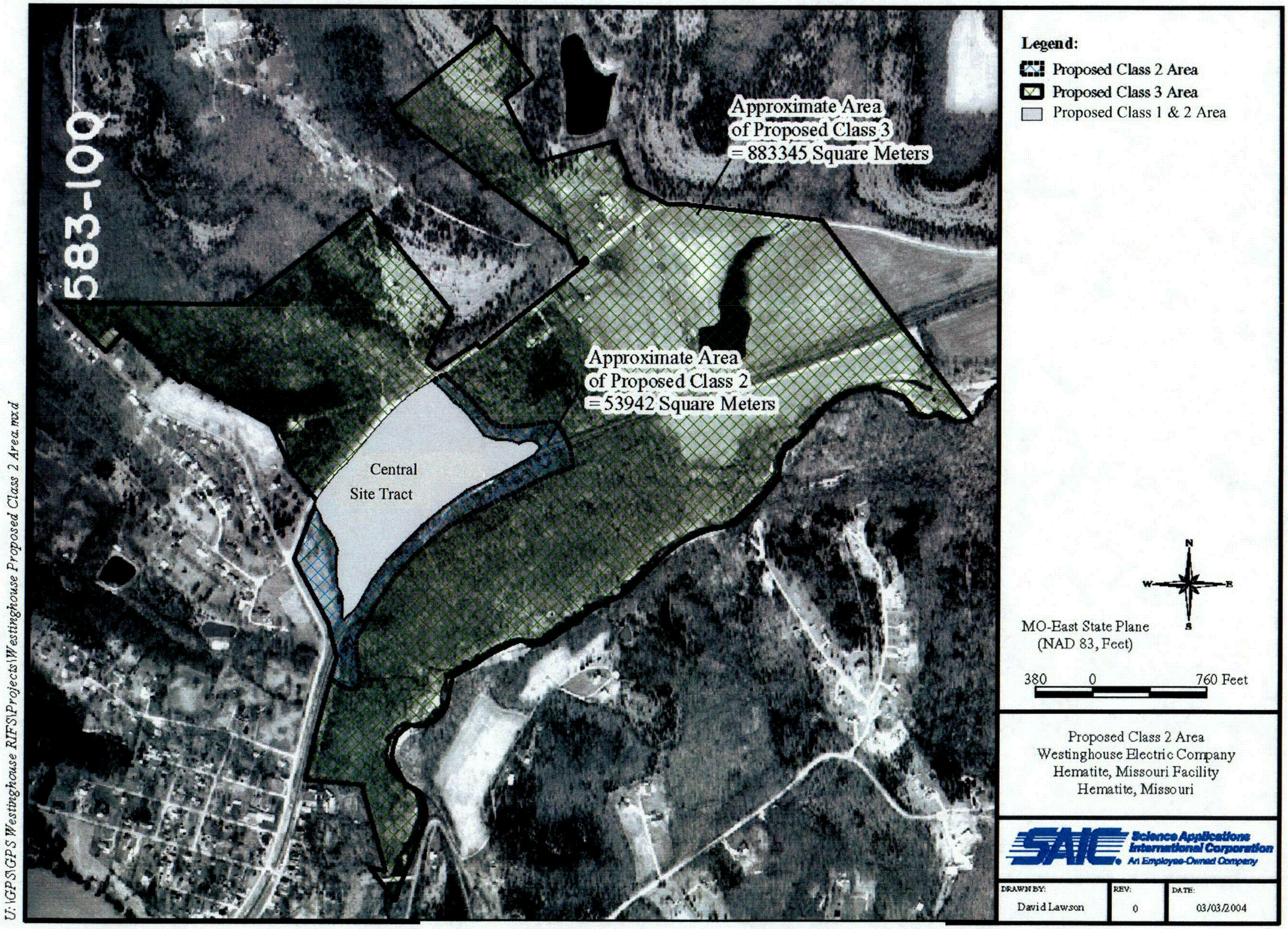

Figure 4-1 Map of Site Soil Areas

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the central site tract, the Class 2 impacted perimeter area, and the Class 3 impacted outlying land areas.

4.3.1 Central Site Tract

The GWS in the central site tract was designed to provide 100% coverage of all accessible areas that were not beneath buildings or covered with asphalt or concrete. Contaminated areas of special interest inside the central site tract are described as follows:

Former Leach Field
The former Leach Field and septic system were used until 1977 when a water treatment plant was built and placed into service. Located west of the water treatment plant and Evaporation Ponds, the leach field and septic system might have been used for sanitary waste and liquid waste from the operation and maintenance of the facility.

Spent Limestone Pile
The Hematite plant used crushed limestone rock chips in dry scrubbers to facilitate the removal of hydrogen fluoride from off-gas streams associated with the UF_6 to UO_2 conversion process. The limestone chips are partially converted to calcium fluoride in the scrubbers, and the waste limestone chips are referred to as "spent limestone." After removal from the scrubbers, the spent limestone was tested to determine the level of radiological activity.

Prior to 1979, all spent limestone with radiological activity above 100 dpm/100 cm^2 was quarantined in a pile located in the southeast corner of the current fenced area of the plant. Since 1979, all spent limestone with radiological activity below 100 dpm/100 cm^2 has been used, with NRC approval, as onsite landfill, while spent limestone with activity greater than 100 dpm/100 cm^2 has been quarantined in piles in the southeast corner. All spent limestone with activity greater than 1,000 dpm/100 cm^2 has been sent to a licensed burial facility. Sampling and testing of the material has been performed periodically, revealing uranium contamination concentrations in the piles and the soils adjacent to and/or beneath the piles.

During the GWS, no indication of elevated gamma radiation was identified due to the existence of the spent limestone pile within the fenced area or in two fill locations outside the fence—one near the Site Spring and the other in the northeast section of the Burial Pits. The GWS was not specifically performed on the spent limestone pile within the fence but only along the edges of the pile.

Deul's Mountain

During the construction of the Building 256 warehouse, a large area of potentially contaminated soil was removed and stored along the southeast corner of the fence line. This pile has become known as "Deul's Mountain." The volume of the pile is estimated at 1,250 cubic yards. The GWS found no elevated gamma radiation levels during the walkover of this stockpiled soil; however, a significant area of elevated activity was identified at the foot of the pile where a piece of sheet plastic was found protruding from the soil.

In 2002, a characterization of the soil pile was performed, as described in a report entitled "Characterization Report for Deul's Mountain" (Ref. 22), and samples revealed the presence of U-238, U-235, and U-234. No other isotopes were detected above natural background. The characterization was performed by drilling 12 bore holes into the pile for the purpose of collecting radiological data at various depths and to collect soil samples. The bore holes were drilled to a depth of three feet, and three discrete samples, containing one foot of soil each (~454 g), were taken from each bore hole.

The soil concentration background levels for the three uranium isotopes were derived from a sample collected within two miles of the Hematite facility and are as follows:

- 7.70E-01 pCi/g for U-238
- <2.95E-02 pCi/g for U-235
- 5.92E-01 pCi/g for U-234

Through laboratory analysis, it was found that collected samples contained uranium concentrations higher than the above stated backgrounds. These are preliminary background values.

Soil Beneath Site Buildings

Soil samples were collected from eight (8) locations beneath building foundations during a site characterization effort in 2003. Bore hole and sampling locations were selected based on input from previous employees and historical knowledge of site operations to provide biased sampling locations most likely to be impacted by radioactive materials. The radiological results of the samples collected are presented in Table 4-1. Sampling and analysis for chemical constituents of potential concern were also conducted as part of the project.

The following issues must be considered when evaluating Table 4-1:

- Samples from the concrete foundations themselves were removed from the data set. They do not represent the soils under the foundation.

- Data for the hard-to-detect radionuclides (Am-241, Np-237, and Pu-239) were not available or not of sufficient quality to allow evaluation.
- There is limited data on Tc-99. Tc-99 can be highly mobile in soils and groundwater.
- There is limited data on U-234.

Table 4-1 Soil Samples Underneath Site Buildings

Sample ID	Units	Tc-99	U-234	U-235	U-238
BLD240-01-01	pCi/g	NA	NA	0.12	1.1
BLD240-01-09	pCi/g	NA	NA	0.23	0.9
BLD240-01-Fill	pCi/g	NA	NA	5.9	17
BLD240-03-04	pCi/g	NA	NA	0.44	1.32
BLD240-03-19	pCi/g	NA	NA	0.36	0.7
BLD240-03-Fill	pCi/g	NA	NA	17.9	71
BLD240-04-02	pCi/g	NA	NA	0.02	1.7
BLD240-04-04	pCi/g	NA	NA	0.3	0.9
BLD240-04-Fill	pCi/g	NA	NA	0.7	2.59
BLD240-05-01	pCi/g	NA	NA	-0.08	1.37
BLD240-05-02	pCi/g	NA	NA	-0.4	1.6
BLD253-02-01	pCi/g	NA	NA	0.9	3.7
BLD253-02-04	pCi/g	7.5	172	9.5	11.7
BLD253-02-Fill	pCi/g	NA	NA	1.2	2.6
BLD255-05-Fill	pCi/g	NA	NA	0.17	1.7
BLD255-07-02	pCi/g	NA	NA	0.06	1.7
BLD255-07-15	pCi/g	NA	NA	0.37	1.1
BLD255-07-Fill	pCi/g	NA	NA	0.17	0.8
BLD255-08-01	pCi/g	30.2	604	23.1	13.8
BLD255-08-08	pCi/g	NA	NA	0.34	0.85
BLD260-06-01	pCi/g	NA	17.8	0.87	5.04
BLD260-06-03	pCi/g	NA	NA	0.12	0.6
BLD260-06-FILL	pCi/g	NA	NA	3.34	16.4

NA – not analyzed

Based upon the sampling information gathered through this effort, it is apparent that no clear pattern of soil impacts under the buildings has been formed and that additional characterization of these soils and potential underground structures will be needed. As noted elsewhere in this DP, contaminated equipment and structures and the contaminated buildings themselves will need to be removed in order to properly complete site characterization work and to address releases or threatened releases of radioactive impacts into the environment.

Tile Barn
Several areas (soils within the original fence line and soil adjacent to the barns) are known to have surface or near-surface uranium contamination. Adjacent to the Tile Barn is an area that was used to store excess contaminated equipment. The GWS detected several areas of elevated gamma radiation around the Tile Barn, adjacent to the original fence line, and in nearby drainage ditches.

Red Room Roof
The old roof of the Red Room (Building 240) was buried in an area south of the Tile Barn. The GWS identified elevated areas of contamination south/southwest of the Tile Barn; however, it could not be confirmed that this was due to the presence of the Red Room roof burial. Additional characterization will be performed in this area.

Cistern Burn Pit
The Cistern Burn Pit near the Tile Barn was used historically to burn contaminated wood and pallets. In early 1993, the cistern was cleaned to less than 30 pCi/g uranium. Additional characterization will be needed to assess the effectiveness of the prior remediation efforts.

4.3.2 Outlying Land Areas

The outlying land areas comprise all the site land outside the central site tract and its Class 2 perimeter area. The GWS was designed to cover approximately 10% of the outlying land areas. The GWS concluded that surface soil contamination appears to be confined to the central site tract. Surface contamination does not appear to have migrated a great distance from the building facility area in any of the normal topographical transport modes. With the exception of a few anomalies, the GWS data indicate that there is no obvious surface soil contamination in the outlying land areas.

The railroad easement that cuts through the site is not considered a potential Area of Concern; however, a portion of the ballast used to construct the railroad is Rhyolite. The Rhyolite deposit is known to have naturally occurring radioactivity. The GWS confirmed increased gamma radiation levels associated with the Rhyolite. The railroad easement that cuts through the site exhibited elevated count rates in the range of 14,000–16,000 cpm. In addition, the railroad adjacent to the United States National Guard Armory exhibited similar count rates. The Rhyolite on the site does exhibit elevated levels of gamma radiation consistent with Rhyolite on the non-impacted railroad adjacent to the armory.

4.4 Subsurface Soil Contamination

In addition to surface soils and buildings, as discussed above, two subsurface soil areas within the central site tract are known to be radiologically impacted—the Burial Pits and the Evaporation Ponds. A third area, the natural gas pipeline, is a potential conduit for subsurface soil contamination. A description of these areas is provided as follows:

4.4.1 Burial Pits

Additional information on the Burial Pits is provided in Section 2.5 of this DP. The Burial Pits remain in substantially the same condition as when Gulf ended on-site burial activity in November 1970. There has been no substantial investigation or analysis of the extent of the contamination of the Burial Pits and the surrounding area. In the GWS, individual elevated count rates were identified and confirmed in the general vicinity of the area where the Burial Pits are expected to be located.

4.4.2 Former Evaporation Ponds

As discussed in Section 2.3.1, the two former filtrate disposal Evaporation Ponds were used for on-site disposal of low-level contaminants and both high-enrichment and low-enrichment uranium materials. The two ponds consisted of a primary pond and a larger secondary/overflow pond. When constructed, the ponds were excavated to a depth of 3 ft., 4 in., and the soil removed was used to construct a 1½-ft. high berm around each pond. The ponds were then lined with a 6-in. bed of 3-in. diameter rock, followed by a 4-in. bed of ½-in. diameter rock. The original size of the primary pond was 30 ft. by 40 ft., and the secondary pond was 30 ft. by 85 ft. Twelve feet separated the two ponds.

The Evaporation Ponds were primarily used for the disposal of low-level liquid wastes containing insoluble uranium bearing precipitates and other solids. The precipitates and solids were allowed to settle, and the water evaporated naturally. As additional liquids were added to the primary pond, the overflow flowed through a pipe into the secondary pond. The ponds were originally built to receive filtrates from the low-enrichment ammonium diurinate conversion facility but were later used for the disposal of both high- and low-enrichment recovery waste liquid. The logs from the burial pits also contain a number of entries reflecting disposal of various materials in the ponds. Examples of such entries include:

- Filtered Perclene
- Liquid from Sump
- TCE from Metal Wash
- Filtered Reactor Cleanout
- Filtered KOH Solution
- Acid Water Cleanup
- HCl Solution
- TCE Cleanup
- Oil from Vac. Pump
- Mop Water
- TCE and Oil
- TCE (u. Metal Wash)
- Acetic Acid & H_2O
- H_2O and Perclene
- Filtrate
- Nitric Acid Wash Water
- Pickling Hood Cleanup

Immediately after CE purchased the plant in 1974, use of the ponds was curtailed so as to allow only disposal of spent potassium hydroxide scrubber solution from the uranium dry recycle process and liquids from startup testing of the wet recovery process. Use of the ponds was discontinued altogether in September 1978. Following the discontinued use of the ponds, 700 $ft.^3$ of sludge were pumped out of the primary pond on October 1979. The sludge was dried and shipped to licensed burial during 1982, 1983, and early 1984.

4.4.3 Gas Pipeline

Missouri Natural Gas (MNG), a subsidiary of Laclede Gas in St. Louis, Missouri, owns and operates a high-pressure natural gas transmission line located on a right-of-way that parallels the railroad track. Because this line runs beneath or adjacent to the Evaporation Ponds, Burial Pits, and former Leach Field, it might be acting as a conduit for contaminant transport in the subsurface.

4.5 Surface Water

The surface water features on the site are described in Section 3.6 of this DP. Five intermittent tributaries (North Lake Tributary, East Lake Tributary, Northeast Site Creek, Site Creek, and Lake Virginia/Site Creek Tributary) and one perennial stream (Joachim Creek) flow across or run adjacent to the site. Two ponds/lakes, including East Lake and Site Pond are also on the property. These water resources are under the jurisdiction of the federal government and the State of Missouri.

The potential for radioactive contamination in Site Creek on the west side of the plant is discussed in Section 2.3.3 of this DP. Northeast Site Creek also has a high potential for radioactive contamination due to the visible surface runoff and the proximity of the tributary to the Burial Pits. The extent of surface water contamination on the site will be further characterized.

4.6 Groundwater

The groundwater in the overburden has historical contamination of Tc-99. A field investigation to determine the source of the Tc-99 contamination was performed in 1996. The results of this investigation are presented in "Investigation to Determine the Source of Technetium-99 in Groundwater Monitoring Wells 17 and 17B," September 27, 1996 (Ref. 23). This investigation revealed that Tc-99 entered the groundwater system in the area behind Building 256 and traveled down gradient. Based upon site-specific groundwater flow information and groundwater quality data, the investigation concluded that it is doubtful that elevated gross-beta concentrations from Tc-99 would reach Joachim Creek before diluting to background concentration.

Table 4-2 shows gross-alpha and gross-beta averages during 2003 for groundwater from six of the site monitoring wells. These monitoring wells are sampled quarterly. Tc-99 has been identified in wells WS-17 and WS-17B. The limit for uranium in 10 CFR 20, Appendix B, Table 2 is 3.00E+02 pCi/L.

Table 4-2 Sample Results From Groundwater Monitoring Wells

Monitoring Well	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
WS-7 (North)	3.76E+01	3.40E+02
WS-8 (Southeast)	5.60E+00	2.42E+00
WS-9 (Southwest)	7.94E+00	2.67E+01
WS-15 (Burial Pits)	5.63E-01	1.12E+01
WS-16 (Burial Pits)	3.96E+00	8.08E+00
WS-17B (Burial Pits)	1.06E+02	3.00E+03

Additional characterization of groundwater will be performed. The aquifers have shown no detectable levels of radioactive contamination.

As discussed in Section 3.7 of this DP, VOCs were discovered in private domestic wells on and near the site. The affected wells have been taken out of service, and the residents have been switched to a public water supply (Ref. 19).

5.0 DOSE MODELING

5.1 Unrestricted Release Using Site-Specific Information

5.1.1 Building Surface Evaluation Criteria

As discussed in Section 8.1, the aboveground structures of contaminated site buildings will be removed under the site license to facilitate further characterization of soils under the buildings. For any non-impacted buildings that are left in place, evaluation criteria will be developed to demonstrate that the buildings meet the criteria for unrestricted use.

5.1.2 Soil Evaluation Criteria

Surface and volumetric soil DCGLs have been determined (as described in Section 1.5) for radionuclides of concern potentially present in soil (including sediment) at the Hematite site. The DCGLs were determined to meet requirements set forth by the NRC. The NCP process will also be followed to establish Preliminary Remediation Goals (PRGs), which will be considered in concert with the approved DCGLs. The NRC has promulgated a primary limit of 25 mrem total effective dose equivalent (TEDE) in any one year, in excess of natural background, for releasing a radiologically contaminated site.

Radionuclides of concern for the site have been identified as U-234, U-235, U-238, Tc-99, Th-232 and progeny, Am-241, Np-237, and Pu-239. DCGLs were derived using dose modeling and the RESRAD code Version 6.21. The modeling, in most cases, used site-specific values and values presented in NRC's NUREG guidance documents for a residential-farmer scenario.

Sensitivity analyses were performed by examining the model input parameters related to intake assumptions for the receptor. Fruits, vegetables, and grain consumption is the most sensitive parameter for most of the radionuclides of concern at the site.

The site has both surface soil and groundwater contamination. The soil DCGLs were derived using groundwater as an indirect (modeled) pathway without the use of actual groundwater data. 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 the *Hematite Soil Survey Plan* to account for the other dose components. In order to implement this approach, operational DCGLs will be established and incorporated into decommissioning procedures.

6.0 ENVIRONMENTAL INFORMATION

The site characterization implemented in 2004 includes plans to investigate and evaluate the effects decommissioning and remediation of the Hematite facility might have on wetlands and surface water, threatened and endangered species, and cultural resources.

6.1 Wetlands and Surface Water

Jurisdictional wetlands and surface water issues will be considered in operations and actions related to decommissioning and remediation of the Hematite facility.

6.1.1 Wetlands

Wetlands are believed to be present on the Hematite site and the surrounding properties. This natural resource is under the jurisdiction of the federal government, jointly administered by the U.S. Army Corps of Engineers and the EPA. At the state level, jurisdiction is administered by participating state agencies including the MDNR and the Missouri Department of Conservation Wetlands Management Program. The site characterization will address the effects decommissioning and remediation might have on this natural resource.

6.1.2 Surface Water

Five intermittent tributaries (North Lake Tributary, East Lake Tributary, Northeast Site Creek, Site Creek, and Lake Virginia/Site Creek Tributary) and one perennial stream (Joachim Creek) flow across or run adjacent to the site. Two ponds/lakes, East Lake and Site Creek Pond, are also on the property. These water resources, just as wetlands, are under the jurisdiction of the federal government and the State of Missouri. The site characterization will address the effects decommissioning and remediation might have on these tributaries and ponds/lakes.

6.2 Threatened and Endangered Species

The site characterization will evaluate the potential effects the site's decommissioning and remediation might have on threatened and endangered species. Threatened and endangered species are protected under federal and state statutes and are often key indicators to the overall health of an ecosystem.

An evaluation of the potential presence of threatened and endangered species within the project area and assessment of potential impacts to these species and/or their habitats will utilize a multi-phased approach. First, listed species potentially occurring within the project area will be identified through consultation with the Missouri Department of Conservation and from the list of threatened, endangered, and proposed species provided by the U.S. Fish and Wildlife Service. Second, existing site-specific and regional information will be collected and reviewed to assess the potential of the project area to provide the habitat requirements of threatened or endangered species. This information, in addition to existing data regarding the range and habitat preferences of potential threatened and endangered species, will be used to determine the potential for occurrence of these species in the project area and to determine the need and focus of field surveys. Once a review of existing information is completed, a field reconnaissance of the project area will be conducted to verify project area habitats, assess current habitat conditions, and identify any unique habitat features. The final step in the evaluation process will be a determination of effects for those species that might occur within the project area or be affected by offsite or indirect impacts such as changes in downstream water quality. If a potential listed species is not expected to be present or affected by the proposed project, evidence or rationale for supporting this conclusion will be presented. A final impact assessment report will be prepared addressing all state and federal listed threatened and endangered species potentially affected by proposed decommissioning activities.

6.3 Cultural Resources Management

The Antiquities Act of 1906 and Historic Sites Act of 1935 seek to preserve historic sites, buildings, and objects of national significance for the inspiration and benefit of the people of the United States. As part of the characterization, Cultural Resource Management activities will be carried out in three phases. Phase I consists of a records and literature review along with a pedestrian survey. Phase II includes archaeological test excavations at selected sites that might be significant, and Phase III investigations are full-scale data recovery efforts at identified significant sites. A vast number of archaeological sites and historic resources that are initially located are deemed non-significant, that is, further investigations of the site would not contribute new or significant information about the past. These would be recommended as requiring no further evaluation at the Phase I level. A few archaeological sites might require further evaluation through Phase II excavations to make a recommendation of significance or non-significance. Finally, if a site is determined to be historically significant, Phase III data recovery would occur if the site cannot be avoided by construction or remediation.

7.0 ALARA ANALYSIS

7.1 Introduction

A pre-remediation ALARA analysis will be conducted to demonstrate that the dose criteria in 10 CFR 20.1402 have been met and whether it is feasible to further reduce the levels of residual radioactivity to levels below those necessary to meet the dose criteria (i.e., to levels that are ALARA). The analysis will encompass the approximately 228 acres of land located at the Hematite Site. Because the pre-remediation ALARA analysis cannot be completed until the site characterization and related NCP process are completed, an example analysis is being provided to demonstrate the methodology that will be used for the final analysis.

As noted previously, it is the intention of the licensee to remediate soil such that the site meets the unrestricted use criteria presented in 10 CFR 20.1402, that is, the TEDE to an average member of the critical group does not exceed 25 mrem/y.

Because the site objective is to remediate to unrestricted use criteria and to use appropriate dose modeling to relate concentrations to dose, the licensee can apply Section N.1.5, Appendix N of NUREG-1757, Vol. 2, which states "In certain circumstances, the results of an ALARA analysis are known on a generic basis and an analysis is not necessary. For residual radioactivity in soil at sites that may have unrestricted release, generic analyses show that shipping soil to a low-level waste disposal facility is unlikely to be cost effective for unrestricted release, largely because of the high costs of waste disposal. Therefore, shipping soil to a low-level waste disposal facility generally does not have to be evaluated for unrestricted release."

With this in mind, the results of an ALARA analysis are "known on a generic basis and an analysis is not necessary." However, because Westinghouse actively promotes the ALARA philosophy, a simplified analysis (possible benefits and costs relating to decommissioning, a determination of residual radioactivity levels that are ALARA, and cost versus soil activity levels) will be performed. NUREG-1757, Vol. 2, Appendix N provides information outlining a simplified method to estimate when a proposed remediation guideline is cost effective. Possible benefits, as well as possible costs, are derived and compared. If the desired beneficial effects (benefit) from the remediation action are greater than the undesirable effects (cost) of the action, the remediation action being evaluated is cost-effective and should be performed. Conversely, if the benefits are less than the cost, the level of residual radioactivity is already ALARA without taking additional remediation action. A list of possible benefits and costs to be considered in the analysis is shown in Table 7-1.

Table 7-1 Possible Benefits and Costs Related to Decommissioning

Possible Benefits	Possible Costs
• Collective Dose Averted • Regulatory Costs Avoided • Changes in Land Values • Aesthetics • Reduction in Public Opposition	• Remediation Costs • Additional Occupational/Public Dose • Occupational Non-radiological Risks • Transportation Direct Costs and Implied Risks • Environmental Impacts • Loss of Economic Use of Site/Facility

During the analysis, results from an appropriate dose modeling method will be used to relate concentration to dose. Information used for the analysis, regarding concentration-to-dose values, will be obtained from the Westinghouse report on "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility." The following is an example analysis that demonstrates the methodology that will be used in the final analysis. The values used in this example analysis are not representative of the values that will be determined for the final ALARA analysis. As noted above, cleanup goals will also be developed and evaluated through implementation of the NCP process.

7.2 Determination of Benefits

7.2.1 Collective Dose Averted Benefit

Remediation of site soils to levels that meet the unrestricted use criteria in 10 CFR 20.1402, using appropriate dose modeling to relate concentrations to dose, is known on a generic basis to demonstrate that these levels are ALARA. Therefore, calculation of the collective dose averted is not required in this analysis. However, collective dose costs are determined and evaluated in Section 7.3.

7.2.2 Regulatory Cost Avoided Benefit

Based on the site objective to remediate the site to unrestricted use criteria, costs associated with a decision to remediate the site to a restricted release level (additional licensing fees, financial assurance related to both the decommissioning fund and the site restriction, cost associated with public meetings or the community review committee, and future liability to release the site) are avoided and not taken into account in this analysis.

7.2.3 Changes in Land Value Benefit

Land released for unrestricted use from this site would be primarily suited for agricultural, residential, and light-industrial uses due to its current status, geographical location, and proximity to other similar use areas. Remediation to unrestricted use criteria levels (operational DCGLs) will allow for any and all land use scenarios, including the most restrictive Suburban Residential scenario (Child). In light of this, changes in land value can occur without adverse effect on the remediation activities planned for the site. Thus no additional land value benefit is gained with additional remediation activities.

7.2.4 Esthetics Benefit

If contaminated soil is removed to meet the operational DCGL soil activity values, the excavation will be refilled and contoured to the surroundings and vegetation will be restored for erosion control. However, if a decision was made to remediate below the operational DCGL value, an increasing quantity of previously undisturbed land might be disrupted and removed. This additional remedial action would increase the overall environmental disturbance of the land and prove to be a negative esthetics benefit overall.

7.3 Determination of Costs

The determination of costs includes all possible costs (excluding Environmental Impacts and Loss of Economic Use of Site/Facility costs, which need not be considered due to the site objective of remediation to unrestricted use criteria presented in 10 CFR 20.1402). This level of remediation ensures that the site will be available for any future proposed activity, hence eliminating the loss of economic use. In addition, land contours and vegetation will be restored in site remediation areas for the purpose of erosion control. These costs are unavoidable regardless of the remediation method and, therefore, are excluded.

7.3.1 Determination of Total Costs

The total cost of a decommissioning alternative is determined in accordance with Equation N-3 of NUREG-1757, Vol. 2, Appendix N, which states:

$$Cost_T = Cost_R + Cost_{WD} + Cost_{Acc} + Cost_{TF} + Cost_{WDose} + Cost_{PDose} + Cost_{Other}$$

Where:

$Cost_T$ = Total cost

$Cost_R$ = Monetary cost of the remediation action

$Cost_{WD}$	=	Monetary cost for transport and disposal of the waste generated by the action
$Cost_{Acc}$	=	Monetary cost of worker accidents during the remediation action
$Cost_{TF}$	=	Monetary cost of traffic fatalities during transport of the waste
$Cost_{WDose}$	=	Monetary cost of dose received by workers performing the remediation action and transporting waste to the disposal facility
$Cost_{PDose}$	=	Monetary cost of the dose to the public from excavation, transport, and disposal of the waste
$Cost_{Other}$	=	Other costs as appropriate for the particular situation

The cost of the remedial action (removal of contaminated soil to an operational DCGL value) does not include land restoration costs. The cost of remediation action ($Cost_R$) and the cost for transport and disposal of the waste generated by the action ($Cost_{WD}$) are combined into one value for this assessment. The $Cost_T$ is calculated as follows:

$Cost_{R+WD}$ = $Cost_R + Cost_{WD}$
= (Volume of waste produced) x (cost of remediation, disposal, and transportation per unit volume)
= [10,000] m^3 x [$800]/$m^3$
= [$8,000,000]

$Cost_{Acc}$ = (Monetary value of a fatality equivalent to $2000/person-rem) x (workplace fatality rate in fatalities/hour worked) x (worker time required for remediation in units of worker-hours)
= ($3,000,000/fatality) x ($4.2 \times 10^{-8}$ fatalities/person-h) x ([10,000] m^3 x 1.62 person-h/m^3)
= [$2,041]

$Cost_{TF}$ = (Monetary value of a fatality equivalent to $2000/person-rem) x (volume of waste produced/volume of a shipment) x (fatality rate per kilometer traveled) x (distance traveled)
= ($3,000,000/fatality) x ([10,000] m^3 / 13.6 m^3/shipment) x (3.8×10^{-8} fatalities/km) x ([2500] km)
= [$209,559]

$Cost_{WDose}$	–	This cost is not applicable. Based on dose modeling performed, dose to an average construction worker is estimated to be 8 mrem/y at a soil concentration of 1500 pCi/g Total U. At $2000 per person-rem x 0.008 rem/y = $16/y/construction worker. This dollar value is insignificant and will not add significant cost to the total cost of remediation and need not be evaluated for the different alternatives
$Cost_{PDose}$	–	This cost is not applicable. Dose to the public from excavation, transport, and disposal of the waste is negligible; hence, monetary cost of the dose to the public from excavation, transport, and disposal of the waste is negligible and will not add a significant cost to the total cost of remediation.
$Cost_{Other}$	–	This cost is not applicable. Land restoration costs are not included in this analysis.
$Cost_T$	=	[$8,211,600]

Note: [ ] – Highlighted values are for demonstration purposes only. These values are not representative of actual values.

7.4 Determination of Residual Radioactivity Levels That Are ALARA

The purpose of this section is to determine whether the DCGLs selected for remediation action are ALARA. Because the intent of the calculation is to determine whether additional soil should be remediated in order to lower the radiological dose, only the cost associated with the additional remediation is used as input for this section.

Soil concentrations that are ALARA are determined in accordance with Equation N-8 of NUREG-1757, Vol. 2, Appendix N, where:

$$\frac{Conc}{DCGL_W} = \frac{Cost_T}{\$2000 \times P_D \times 0.025 \times F \times A} \times \frac{r + \lambda}{1 - e^{-(r+\lambda)N}}$$

Where:

Conc	=	Average concentration of residual radioactivity in the area being evaluated
$DCGL_W$	=	Derived concentration guideline level equivalent to the average concentration of residual radioactivity per unit volume

$Cost_T$	=	[$8,211,600] (See calculation in Section 7.3.1.)
r	=	Monetary discount rate (0.03/y for soil)
λ	=	Radiological decay constant for the radionuclide
P_D	=	Population density (0.0004 person/m^2 for land)
F	=	Fraction of the residual radioactivity removed by the remediation action ([0.8]—assuming [80%] of the source term removed during remediation activities)
A	=	Area being evaluated ([90,000] m^2)
N	=	Number of years over which the collective dose will be evaluated (1000 y for soil)

This calculation allows the licensee to estimate a concentration at which a remediation action will be cost effective prior to starting remediation. Results less than one (1) indicate the remediation action is warranted to meet the ALARA requirement. Results greater than one (1) indicate the remediation action is not warranted to meet the ALARA requirement.

$$\frac{Conc}{DCGL_W} = \frac{\$8{,}211{,}600}{\$2{,}000 \times \left(4 \times 10^{-4}\right) \times 0.025 \times 0.8 \times 90{,}000} \times \frac{0.03+0}{1-e^{-(0.03+0)1000}}$$

$$\frac{Conc}{DCGL_W} = 171$$

Because this value is greater than one (1), it is determined that the remedial action DCGL is ALARA, and no additional remediation action is warranted.

Note: [ ] – Highlighted values are for demonstration purposes only. These values are not representative of actual values.

7.5 Conclusion

This pre-remediation ALARA analysis demonstrates that the dose criteria in 10 CFR 20.1402 will be met using the remedial action DCGL, concludes whether it is feasible to further reduce the levels of residual radioactivity to levels below those necessary to meet the dose criteria, and demonstrates that the remedial action DCGL is ALARA.

As presented in Section 7.2, because the site objective is to remediate to unrestricted use values, all possible benefits are realized with no comparison against cost for the benefit.

As presented in Section 7.3, costs were determined for the remedial action.

As presented in Section 7.4, an example ALARA analysis for the remedial action was performed. The ratio of conc to $DCGL_W$ was calculated to be [171]. Because this value is greater than one, it is determined that the $DCGL_W$ for the remedial action for unrestricted release of the area is ALARA, and no additional remediation for the area is justified.

Note: [ ] – Highlighted values are for demonstration purposes only. These values are not representative of actual values.

8.0 PLANNED DECOMMISSIONING ACTIVITIES

Decommissioning activities will be performed in phases as follows:

a. Outlying Land Areas
b. Subsurface Soil Areas
c. Surface Soil and Water
d. Non-contaminated Buildings
e. Groundwater

Phase a. will be done under this DP. An alternate schedule will be requested to begin the remaining phases (Phases b.– e.) of work under the DP. Plans and information necessary to obtain approval for the remaining phases will be submitted as amendment requests to the DP, pending completion of the site characterization and related NCP process.

The overall scope of decommissioning includes the following:

- Removal of pavement, concrete slabs, foundations, and below-grade utilities left from the demolition of contaminated buildings (Phase c.)
- Removal of contaminated soil (consistent with operational DCGLs and the NCP process)
- Remediation of surface water and groundwater, as determined by the characterization results and the NCP process
- Transportation of waste
- Site restoration
- Final status surveys and sampling

During the operations phase of the plant, a number of Integrated Safety Analyses (ISAs) were conducted. These ISAs covered various portions of the fuel fabrication process. All fuel fabrication and associated operations have ceased, and the equipment and systems have been cleaned of special nuclear material to the extent possible. In addition, the bulk chemicals (i.e., ammonia and liquid nitrogen) associated with the processing operations have been removed from the site. The considerations covered by the ISAs are therefore not applicable to the work that will be done under the DP beyond the general issues of external events such as severe weather.

8.1 Contaminated Structures

Decontamination and demolition of contaminated, above-grade structures will be conducted under the site license. This work will be performed so as to facilitate additional site characterization activities and to remove or reduce radioactive contamination from the facilities consistent with the NCP objectives and license termination efforts.

The plan for non-contaminated structures, Phase d., will be submitted in a separate amendment request for this DP if the buildings are to remain in place. Building 110 is an office building, and no work with radioactive or chemical compounds was reportedly undertaken in this building. Building 230 is the Rod Loading building. Finished pellets (standard, erbium, and gadolinium) were loaded into fuel rods and assemblies for shipment offsite from Building 230. The plans for these two buildings are being evaluated. These buildings do not contain any contamination above the license's limits for free release. The final status of these buildings will be determined based on the results of the characterization of the soils beneath the buildings. If it is determined that the buildings can remain, DCGLs for the buildings will be submitted with the Phase d. amendment request for this DP.

8.2 Contaminated Systems and Equipment

To accomplish the objectives set forth above, contaminated systems and equipment are being removed from contaminated buildings under the current site license.

8.3 Soil

8.3.1 Outlying Land Areas (Phase a.)

Phase a. addresses the remediation of surface soils in outlying land areas, i.e., outside the central site tract and perimeter area. The outlying land areas have no documented evidence of contamination. As such, these areas are conservatively classified as Class 3 impacted.

Removal/Remediation Tasks

Activities in Phase a. for the outlying land areas will be limited to performing a final status survey of the Class 3 impacted area in accordance with MARSSIM methodology. The final status survey plan for soils is described in the *Hematite Soil Survey Plan*, which has been provided as a separate submittal to the NRC. This plan was developed to demonstrate, within acceptable limits of uncertainty, that residual radioactivity in the soil does not exceed the operational DCGLs or PRGs as determined by the NCP process.

Techniques Employed to Remove or Remediate Surface Soil

No soil removal will be performed during Phase a. If any soil removal is indicated in these outlying land areas based on the operational DCGLs, the affected areas will be marked for remediation during Phase c. following development of soil remediation alternatives under the NCP evaluation process. Techniques that will be used for soil removal will be described in an amendment to this DP for Phase c.

Radiation Protection Methods

Radiation protection methods that will be used for decommissioning activities, including Phase a. surveys, are addressed in Section 10.0.

Procedures Authorized Under the Existing License
NRC License No. SNM-33 does not authorize remediation of contaminated soils without NRC approval via a specific license amendment or a Decommissioning Plan.

Use of Procedures
All decommissioning activities involving licensed material will be conducted in accordance with approved, written procedures as described in License No. SNM-33.

8.3.2 Subsurface Soil Areas (Phase b.)

The plan for remediation of subsurface soil areas will be submitted in a separate amendment request for this DP after additional characterization information is gathered. The potential to find HEU in the Burial Pits represents a unique remediation issue that will be addressed in the amendment.

8.3.3 Surface Soils Inside the Central Site Tract (Phase c.)

The plan for remediation of surface soils inside the central site tract will be submitted in a separate amendment request for this DP.

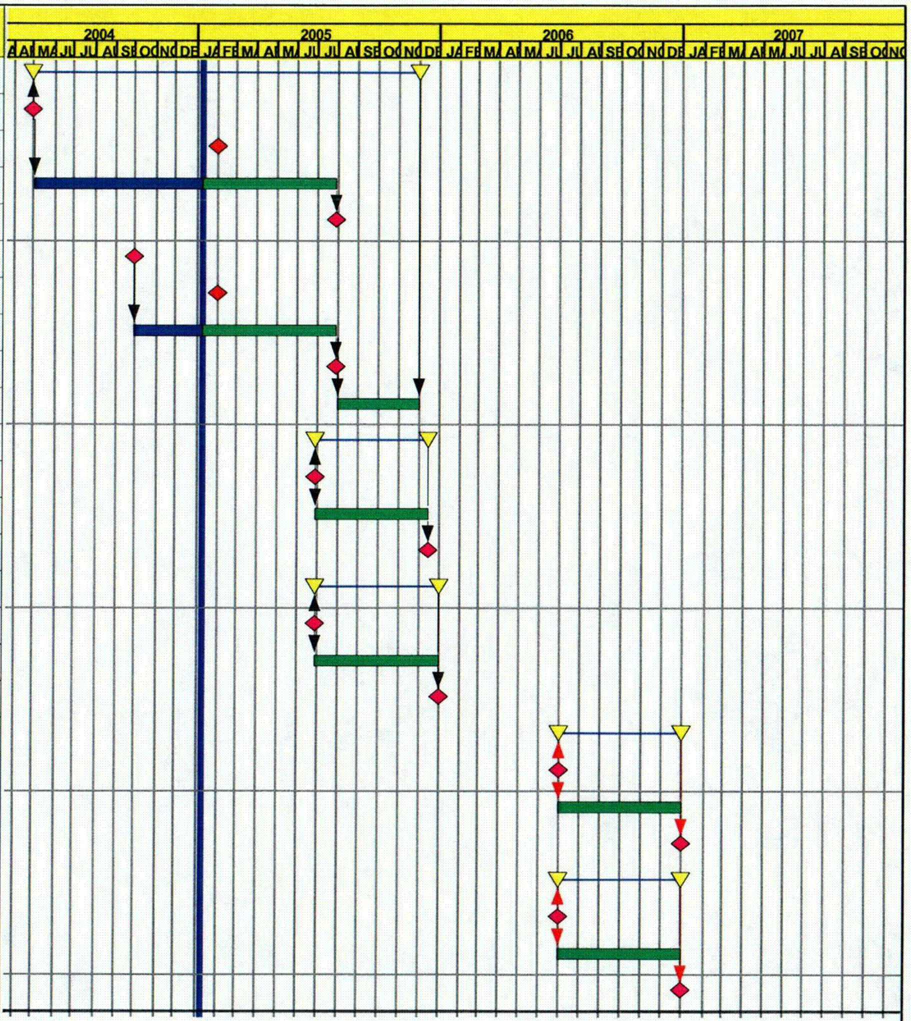
8.4 Surface and Groundwater

The plans for remediation of surface water and groundwater will be submitted in separate amendment requests for this DP. Surface water remediation will be performed in Phase c. in conjunction with surface soil remediation. Groundwater remediation will be performed in Phase e. in accordance with the amended DP and the NCP process.

8.5 Schedules

The projected schedule for decommissioning, Figure 8-1, identifies decommissioning milestones and tasks. The milestones and tasks are organized according to the planned work sequence. The dates are contingent on NRC approval of this DP and approvals of other submittals to the NRC (e.g., DCGL report and soil survey plan). Circumstances can change during decommissioning, and if the licensee determines that the decommissioning cannot be completed as outlined in the schedule, the licensee will provide an updated schedule to NRC. If the decommissioning is not expected to be completed within the timeframes outlined in NRC regulations, a request for an alternative schedule for completing the decommissioning will be submitted. Periodic updates to the schedule also will be submitted to the NRC. Schedules for subsequent decommissioning phases will be provided with the respective amendment requests for this DP.

Activity ID	Activity Description	Early Start	Early Finish
000060	Outlying Land Areas	30APR04A	30NOV05
000070	Submit Decomissioning Plan (DP) to NRC	30APR04A	
000075	Submit DP Rev 1		31JAN05*
000080	NRC Review of DP	03MAY04A	29JUL05
000090	DP Approved		29JUL05
000100	Submit Soil Survey Plan (SSP)		29SEP04A
000102	Submit Soil Survey Plan Rev 1		31JAN05*
000105	NRC Review SSP	01OCT04A	29JUL05
000110	SSP Approved		29JUL05
000115	Final survey of Outlying Land Areas	01AUG05	30NOV05
000120	Subsurface Soil Areas	30JUN05	14DEC05
000130	Submit DP to NRC	30JUN05*	
000140	NRC Review of DP	30JUN05	14DEC05
000150	DP Approved		14DEC05
000160	Surface Soil and Water	30JUN05	30DEC05
000170	Submit DP to NRC	30JUN05*	
000180	NRC Review of DP	30JUN05	30DEC05
000190	DP Approved		30DEC05
000200	Noncontaminated Buildings	30JUN06	29DEC06
000210	Submit DP to NRC	30JUN06*	
000220	NRC Review of DP	30JUN06	29DEC06
000230	DP Approved		29DEC06
000240	Groundwater	30JUN06	29DEC06
000250	Submit DP to NRC	30JUN06*	
000260	NRC Review of DP	30JUN06	29DEC06
000270	DP Approved		29DEC06



Start Date	11FEB04	Projected Decommissioning Plan Schedule
Finish Date	29DEC06	
Data Date	10JAN05	

Figure 8-1 Projected Decommissioning Plan Schedule

C06

9.0 PROJECT MANAGEMENT AND ORGANIZATION

Amendment 47 to SNM-33 incorporated the project management and organization requirements of NUREG-1757 into Chapter 2 of SNM-33. The project management and organization for decommissioning shall be in compliance with Section 2.0 of SNM-33.

Adjustments to the Decommissioning Process

Westinghouse can make justified changes related to the decommissioning process without filing an application for an amendment to the license to change the DP and supporting documents provided the following conditions are satisfied:

a. The change does not conflict with requirements specifically stated in License No. SNM-33 nor impair Westinghouse's ability to meet all applicable NRC regulations.
b. There is no degradation in safety or environmental commitments addressed in the NRC-approved DP for the activity being performed.
c. The change will not significantly affect the quality of work, the remediation objectives, or health and safety in an adverse way.
d. The change is consistent with the conclusion of actions analyzed in the Environmental Assessment issued by the NRC.
e. There is reasonable assurance that adequate funds for decommissioning remain.
f. The coverage requirements for scan measurements and/or sample density will not be reduced.
g. The DCGLs and related minimum detectable concentrations (MDC) (for both scan and fixed measurement methods) will not be increased.
h. The radioactivity level, relative to the applicable DCGLs, at which an investigation occurs will not be increased.
i. The statistical test applied to a final status survey will not be other than a Sign test, a Wilcoxon Rank Sum test, or those described in NUREG-1505.
j. The Type I decision error (for Scenario A of NUREG-1505) or the Type II decision error (for Scenario B) will not be increased beyond 0.05.
k. A final status survey area classification will not be decreased, e.g., from impacted to non-impacted; Class 1 to Class 2; Class 2 to Class 3; or Class 1 to Class 3, without NRC approval.
l. Following failure of a final status survey, a survey unit will not be subdivided and reclassified without NRC approval.
m. Scenario B of NUREG-1505 will not be used unless approved by the NRC.

Verification that conditions *a* through *m* have been met and approval of each change will done in accordance with the change approval process in License No. SNM-33. Hematite will retain records of each authorized change to the decommissioning process that provide the basis for determining that conditions *a* through *m* have been met. The records will be maintained in accordance with License No. SNM-33 requirements.

10.0 HEALTH AND SAFETY PROGRAM DURING DECOMMISSIONING

Occupational dose will be kept as low as reasonably achievable (ALARA). To this end, Hematite's *Radiation Protection Plan* has been established commensurate with the scope and extent of licensed activities at the site. This plan and associated procedures are the primary means used to administratively establish safe radiation work practices and ensure compliance with the requirements of the NRC. Radiation safety controls and monitoring for workers will be conducted in accordance with the site license and the *Radiation Protection Plan*.

10.1 Workplace Sampling Program

The HP staff will perform measurements of radioactive material concentrations in air for areas where radioactive materials are handled or processed in unsealed form and when operations could expose workers, without credit for respiratory protection, to the inhalation of quantities of radioactive material exceeding 10% of DAC. Special requirements for airborne monitoring can be made as a condition of the RWP.

Air sampling will be conducted while work is in progress if the concentration of radioactive material is likely to exceed 0.1 DAC. The air sampling frequency, if not continuous, will be based on the nature of the radiological work involved and the likelihood that airborne radioactive material will be present. If the airborne concentration is likely to exceed 0.1 DAC, the air sampling will be representative of the breathing zone. This is normally accomplished using lapel samplers.

General area air sampling will be performed during work operations that are likely to cause airborne concentrations in excess of 0.1 DAC. This general area sampling will be used to evaluate potential radiation hazards and to determine the effectiveness of engineering controls and procedures in confining radioactivity, measuring the general or average airborne radioactivity in the workplace, and detecting any releases into the workplace. These air samples will be collected at least weekly, and an investigation will be conducted whenever any sample result exceeds 1.0 DAC.

A continuous air monitor (CAM) might be used to provide a warning signal that the concentration of airborne radioactivity has become unexpectedly high. A CAM will be provided if it is likely that, in the absence of an appropriate air monitor alarm, accidental conditions could cause an intake of radioactive material exceeding 10% of an annual limit on intake (ALI).

Air samplers used for quantitative measurements will have a means to determine the volume of air sampled. Airflow meters for fixed-location samplers, portable samplers, and lapel samplers will be calibrated at intervals not exceeding 12 months. Additional calibrations will be performed after repairs or modifications to the meter or if the meter is believed to have been damaged. The calibration methods will be consistent with Section 5 of Regulatory Guide 8.25, "Air Sampling in the Workplace."

In the event that a specific radionuclide activity is required for air samples, an off-site commercial analytical laboratory will be used. The commercial laboratory selected from the approved vendors list will state the MDA/lower limit of detection (LLD) on the analytical report.

10.2 Respiratory Protection Program

Various engineering and administrative controls will be used to limit the amount of airborne contamination. Facilities and equipment will be kept in safe working order, and good housekeeping will be maintained to provide a safe work environment. Licensed radioactive materials will be used and stored in radiologically controlled areas. PPE, fixatives, temporary ventilation, remote handling equipment, storage containers, shielding, fume hoods, ventilation systems, administrative controls, and other items can be used for controlling exposures from licensed radioactive materials. Areas containing radioactive materials and/or contamination will be posted and controlled in accordance with 10 CFR 20.

The primary objective of the Respiratory Protection Program is to limit the inhalation of airborne radioactive material when the application of engineering or process controls is not practicable and to maintain occupational radiation exposures ALARA. The RSO or other qualified individual as appointed by the Project Director will administer the Respiratory Protection Program.

Only respiratory protection equipment certified by the National Institute for Occupational Safety and Health (NIOSH) will be used to limit the intake of radioactive material. Pursuant to Subpart H of 10 CFR 20, Westinghouse will assign and take credit for the use of respiratory protection equipment to limit intakes of airborne radioactive material. The assigned protection factor will be consistent with Appendix A to 10 CFR 20. The Respiratory Protection Program will include, as a minimum, all the requirements contained in 10 CFR 20.1703 and 29 CFR 1910.134.

Written procedures for respiratory protection will be in place. These procedures will address and implement the following elements:

- Radiological monitoring, including air sampling and bioassays
- Supervision of the program, including program audits
- Training and minimum qualifications of respirator program supervisors and implementing personnel
- Training of respirator users, including the requirement for each user to inspect and perform a user seal check (for face-sealing devices) or an operational check (non-face-sealing devices) on a respirator each time it is donned

- Fit testing
- Selecting respirators
- Maintaining breathing air quality
- Inventory and control of respiratory protection equipment
- Storage, issuance, maintenance, repair, testing, and quality assurance of respiratory protection equipment
- Recordkeeping
- Limitations on periods of respirator use and relief from respirator use

An initial medical evaluation to determine a worker's fitness to use respirators will be performed prior to respirator fit testing for tight-fitting face pieces and before the first field use for loose-fitting devices. Each user will be reevaluated medically every 12 months thereafter or at some frequency consistent with ANSI-Z88.6-1984. A grace period of up to 30 days can be approved by the program administrator in unusual circumstances for a fully qualified respirator user whose medical screening has expired within the last 30 days.

The wearer of a respirator will inspect it daily whenever it is in use. EH&S will periodically spot check respirators for proper fit, usage, and condition. If a defective respirator is found during inspection, it will be returned for repair or proper disposal. An out of service tag will be placed upon the respirator until it is repaired. During cleaning and maintenance, respirators that do not pass inspection will be repaired or properly disposed of. Repair of respirators will be done with the original manufacturer's parts in accordance with the manufacturer's instructions. No attempt will be made to replace components or make adjustments, modifications, or repairs beyond the manufacturer's recommendation. Respirators not discarded after one shift use will be stored in a manner and location where they are protected from sunlight, dust, heat, cold, moisture, damaging chemicals, and deformation of the face piece and exhalation valve. Standard-issue respirators will be stored in the HP office or similar location.

User training will be performed prior to respirator fit testing for tight-fitting face pieces and before the first field use for loose-fitting devices. Refresher training will be performed every 12 months thereafter. As a minimum, the training objectives will be consistent with Regulatory Guide 8.15, Section 5.2.

A quantitative fit test will be performed for tight-fitting face pieces before the first field use. The fit-testing protocol will be consistent with Regulatory Guide 8.15, Section 5.3.1. The worker will be fit tested with the same make, model, style, and size of respirator that will be used in the field. Retesting will be performed every 12 months thereafter or as otherwise indicated in Regulatory Guide 8.15, Section 5.3.5. If necessary, a grace period of up to 30 days can be approved by the program administrator in unusual circumstances for a fully qualified respirator user whose fit test has expired within the last 30 days.

10.3 Internal Exposure Determination

All employees with the potential to exceed 500 millirem committed effective dose equivalent (CEDE) or 5,000 millirem committed dose equivalent (CDE) from internal sources will participate in a routine internal radiation monitoring program. This program can consist of direct or indirect bioassay sampling at the beginning and end of employment and on a planned, periodic basis.

Employees will be encouraged to declare pregnancy to the RSO. An evaluation will be performed by the RSO to determine the potential for a declared pregnant female to exceed the regulatory exposure limit during the nine-month gestation period. If the potential to exceed the limit exists or if an employee's request for transfer is approved, the employee will be transferred to a job assignment that would reduce the employee's radiation dose. Declared pregnant females with the potential to exceed 50 millirem CEDE during the calendar year or 100 mrem deep dose equivalent will be monitored for internal and/or external exposure as appropriate.

Special monitoring might be performed whenever an administrative limit is reached or exceeded or a nasal smear reveals the presence of detectable radioactivity. Special monitoring also will be performed whenever the RSO deems it appropriate. Routine monitoring methodologies and frequencies will be appropriate for detecting the types and quantities of radioactive materials in use by the employee and will be determined by the RSO. A formal investigation will be performed by the RSO or designee in the event that a monitoring result is unexpected. A written report will be submitted to the Project Director within ten working days for review and approval of follow-up actions intended to prevent the exposure from reoccurring.

Employees and contractors who have received medical treatments with radioactive isotopes must notify the RSO prior to entering the facility for work. The RSO will be provided information on the specific isotope and quantity that was used for treatment or diagnosis.

An internal exposure monitoring program will be maintained consistent with the requirements of Subpart F of 10 CFR 20. The internal exposure monitoring program is accomplished through air sampling and the implementation of a system of periodic and special whole-body counts and/or urinalysis.

10.3.1 Bioassay Monitoring

Bioassay monitoring will include baseline, periodic, and termination sampling as determined by the RSO. Bioassay measurements will be performed at least annually for individuals likely to exceed 0.02 of ALI (40 DAC-hrs). Periodic measurements will be made when an individual's cumulative exposure to airborne radioactivity since the most recent bioassay measurement is >0.04 ALI

(80 DAC-hr). For single intakes by inhalation, ingestion, or wounds that are greater than 10% ALI, an investigation of the exposure will be performed.

Bioassays will be performed according to established procedures. The methods and techniques prescribed by these procedures will follow the provisions of applicable Regulatory Guides and accepted industry standards (NUREG-1556, Vol.11, Table 8.2). Whole-body counting, urinalysis, and/or fecal analyses will be performed for bioassay measurements.

Special bioassay measurements will be performed as determined by the RSO to evaluate intakes of radioactive material. Examples of circumstances requiring special bioassays include:

- The presence of unusually high levels of facial and/or nasal contamination
- Entry into airborne radioactivity areas without appropriate controls
- Operational events with a reasonable likelihood that a worker was exposed to unknown quantities of airborne radioactive material
- Known or suspected incidents of a worker ingesting radioactive material
- Incidents that result in contamination of wounds or other skin absorption
- Evidence of damage to or a failure of respiratory protection

10.3.2 Measurements of Radioactive Material Concentrations in Air

The Health Physics staff will perform measurements of radioactive material concentrations in air for areas where radioactive materials are handled or processed in unsealed form and when operations could expose workers, without credit for respiratory protection, to the inhalation of quantities of radioactive material exceeding 10% of DAC. Special requirements for airborne monitoring can be made as a condition of the RWP.

Air sampling will be conducted while work is in progress if the concentration of radioactive material is likely to exceed 0.1 DAC. The air sampling frequency, if not continuous, will be based on the nature of the radiological work involved and the likelihood that airborne radioactive material will be present. If the airborne concentration is likely to exceed 0.1 DAC, the air sampling will be representative of the breathing zone. This is normally accomplished using lapel samplers.

General area air sampling will be performed during work operations that are likely to cause airborne concentrations in excess of 10% of DAC. This general area sampling will be used to evaluate potential radiation hazards and to determine the effectiveness of engineering controls and procedures in confining radioactivity, measuring the general or average airborne radioactivity in the workplace, and detecting any releases into the workplace. These air samples will be collected at least weekly and an investigation will be conducted whenever any sample result exceeds 1 DAC.

A CAM can be used to provide a warning signal that the concentration of airborne radioactivity has become unexpectedly high. A CAM will be provided if it is likely that, in the absence of an appropriate air monitor alarm, accidental conditions could cause an intake of radioactive material exceeding 10% of an ALI.

10.4 External Exposure Determination

A personnel monitoring program will be maintained consistent with the requirements of Subpart F of 10 CFR 20. The RSO will provide monitored personnel with a primary dosimetry device capable of measuring the individual's deep dose equivalent, shallow dose equivalent, and eye dose equivalent from external sources. The primary dosimetry device will be approved by the RSO. Other Westinghouse employees or contractors can be issued a primary dosimetry device at the discretion of the RSO. The personnel monitoring program will be accomplished using optically stimulated luminescence (OSL) dosimeters, thermo-luminescent dosimeters (TLDs), and/or pocket dosimeters or equivalent devices. The official and permanent record of accumulative external dose received by individuals is obtained normally from the OSL or TLD.

Dose information from sources other than a dosimeter can supplant or supplement dosimeter results. Such action might be necessary if the dosimeter result is unavailable due to loss or damage or if the dosimeter result is suspect. In these cases, the action taken and the justification for such action will be documented by the RSO.

At a minimum, personnel monitoring devices will be assigned and worn by all individuals likely to exceed 100 mrem of external dose during the calendar year. Individuals who enter a restricted area under circumstances where they are likely to receive a dose to an extremity in excess of 10% of the applicable regulatory limit will be issued and required to wear an appropriate extremity exposure monitoring device. The most common form of extremity monitoring provided for workers will be the TLD ring dosimeter.

Routine exposure rate surveys and contamination surveys of radiologically controlled areas will be performed on a planned and periodic basis. Non-routine surveys can be performed at the discretion of the RSO or any time there is reason to suspect that radiation or contamination levels might have changed unexpectedly. The methodology for performing surveillance activities will be as described in an approved procedure.

Unrestricted areas adjacent to restricted areas will be surveyed at intervals not exceeding 45 days to ensure that radiation and radioactive material are adequately confined in restricted areas. Removable surface contamination surveys in unrestricted areas will be performed and recorded at frequencies consistent with the potential for spreading contamination but not less frequently than quarterly. Radiation surveys in unrestricted areas will be performed and recorded at frequencies consistent with the types and quantities of materials in use in adjacent areas but not less frequently than quarterly.

The administrative exposure limits for monitored personnel will be less than 2,000 millirem TEDE per calendar year. The Project Director will ensure that sufficient trained personnel are made available to perform each operation such that administrative exposure limits are generally not exceeded. Contractors are also required to provide adequate qualified staff. The Project Director and RSO can grant extensions to the administrative limit. Persons under 18 years of age are not permitted access to radiologically controlled areas at the Hematite site.

10.5 Summation of Internal and External Exposures

The RSO will determine if monitoring is required for both internal and external exposures in accordance with 10 CFR 20.1502. If it is determined that monitoring is required for both external and internal exposures, compliance with the occupational dose limits will be demonstrated by summing the external and internal doses. The CEDE will be determined from a combination of representative air sampling typically using lapel air sampling and the results of bioassay measurements, as deemed appropriate by the RSO.

The RSO will maintain records in accordance with approved procedures to document implementation of the Hematite *Radiation Protection Plan* and to demonstrate compliance with project requirements. Radiation protection records include personnel radiation exposure documentation, effluent and airborne monitoring data, survey results, RWPs, waste manifests, and training documentation. Records will be maintained in accordance with 10 CFR 20 requirements and retained for 3 years or until the materials license is terminated.

10.6 Contamination Control Program

Equipment, components, or surfaces where loose or total (loose plus fixed) contamination is detected will be quantified to facilitate decommissioning operations. Materials and surfaces contaminated above release criteria will be defined and posted. Loose and fixed radioactive contamination will be maintained at concentrations that are ALARA in unrestricted areas.

10.6.1 Control of Work

A RWP will be issued in order to ensure that individuals observe the proper precautions while work is being performed in any area where hazards exist due to radiation, contamination, and/or airborne radioactivity. Unless specifically excepted by the RSO, a RWP is required for all radiological work. The RWP will contain information describing the job, assigned workers, hazards evaluations, dosimetry, stay times, protective clothing and equipment requirements, health physics monitoring, and other additional safety-related information. A written description of RWP requirements is contained in the Hematite's *Radiation Work Permit* procedure (Ref. 28).

Individuals authorized to work under an RWP will read the RWP and print and sign their name on the original copy of the RWP, indicating they have read and understand the RWP requirements. Individuals will sign in and out on the RWP each time they enter or exit the RWP area.

A copy of the RWP will be posted at the job site, unless the job site is in a restricted area, in which case the copy of the RWP will be posted at the entrance point to the restricted area. Changes made to a non-terminated RWP will be authorized by the RSO, HP Supervisor, or designee on the original RWP, and a new copy of the RWP will be posted.

Health physics will perform surveillances at least monthly to ensure that access controls are properly posted, legible, and operative. Signs, labels, postings, or notices found to be missing will be replaced promptly.

10.6.2 Contamination Surveys

Surveys will be performed to comply with 10 CFR 20.1501. Surveys will be used to evaluate:

- External exposure to personnel
- Concentrations of airborne radioactive materials in the facility
- Surface contamination levels
- Radioactive effluents from the facility
- Environmental conditions of the site and surrounding areas

The frequency of routine surveys will depend on the nature, quantity, and use of radioactive materials, as well as the specific protective facilities, equipment, and procedures that are designed to protect the worker from external and internal exposure. Active restricted area work locations will be surveyed at least monthly with intervals between surveys not exceeding 45 days. Routine surveys might be supplemented as part of the RWP program. Supplemental surveys typically include measurements of radiation, contamination, and airborne radioactivity as the work progresses. Surveys will also be conducted after changes in the conditions that existed at the time of the most recent survey, including changes in the quantities of radioactive material handled or in protective equipment and procedures. Survey records will be maintained in a clear and legible format as required by 10 CFR 20.2103.

Monitoring for radioactive contamination on surfaces of floors, walls, furnishings, and equipment will be part of the survey program. Surveys will be performed in locations where individuals are working with an unsealed form of radioactive material in an amount greater than or equal to 10% of the smallest ALI. These surveys will be performed at least monthly with intervals between surveys not exceeding 45 days. Methods and instruments used in surface contamination surveys will be sufficiently sensitive to detect the nuclides being monitored.

A standardized method for smear evaluation of a relatively uniform area will be used to aid in comparing contamination at different places. A dry smear collected from an area of about 100 cm^2 will be used to indicate levels of removable contamination. Large area wipes using masselin cloth or equivalent can also be used as a qualitative measure of removable contamination. Removable surface contamination limits are based on the requirement to avoid transfer of contamination to unrestricted areas and to maintain exposures ALARA. Higher levels of contamination are permitted within designated work areas, containment devices, or upon approval by the RSO. Limits for removable contamination in decontamination work areas are not established. Fixatives will be used as appropriate during decommissioning operations to support the ALARA philosophy.

Surface contamination surveys will be conducted for both removable and fixed contamination before contaminated equipment or facilities are released for unrestricted use. Release limits for equipment will be in accordance with the NRC "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," April 1993 (Ref. 29). The survey methodology will be sufficient to detect the release limits specified. Equipment and facilities will be decontaminated to levels that are ALARA prior to release.

10.6.3 Leak Testing of Sealed Sources

Each sealed source containing licensed material will be leak tested at least every six months while in use. Sealed sources not in use, but in storage, do not have to be tested. Prior to transferring a source from storage to use or to another person, it will be tested for leakage if a leakage test has not been performed within the last six months.

The source will be removed from its container, and the container will be checked for loose contamination. If leak test results show that there is contamination of 0.005 microcuries (6,600 dpm) or greater on the source container, the following actions will be taken:

- Immediately remove the sealed source from use and notify the RSO
- Forward completed leak test surveys to the RSO

10.7 Instrumentation Program

Instrumentation used for decommissioning will be of sufficient sensitivity and accuracy to assess radiation exposure levels and detect the presence of radioactivity on tools, equipment, clothing, and personnel. Instrumentation will be of sufficient quantity to support ongoing and planned operations. Descriptions of the types of radiation monitoring instruments needed to support decommissioning operations are provided in Table 10-1. Additions, deletions, or equivalent substitutions can occur at the discretion of the RSO or in accordance with the recommendations of the POC.

Table 10-1 Radiation Monitoring Instruments Used to Support Decommissioning

TYPE	RADIATION DETECTED	DETECTION METHOD
Laboratory counter (automatic)	Alpha, Beta	Gas flow proportional
Portable survey	Beta, Gamma Up to 5 R/hr	Ionization
Portable survey	Gamma Up to 5000 μR/hr	Scintillation
Portable survey	Neutron 1 to 10,000 mrem/hr	BF_3
Contamination survey	Beta, Gamma	Geiger-Muller
Contamination survey	Alpha	Scintillation
Continuous air monitor	Alpha	PIPS/Equivalent
Lapel air sampler	N/A (sample collection at 0 to 1 cfm)	N/A
Low-volume air sampler	N/A (sample collection at 0 to 5 cfm)	N/A

TYPE	RADIATION DETECTED	DETECTION METHOD
High-volume air sampler	N/A (sample collection at 0 to 40 cfm)	N/A

MDA/MDC and/or LLD values for laboratory instruments used to analyze soil samples will be provided by the contract laboratory along with soil analysis results. The analysis results will also include associated uncertainty bounds and limits, as appropriate. The contract laboratory will have an approved QA program and approved procedures.

10.7.1 Instrument Calibration

Radiation monitoring and measurement instruments used for decommissioning activities will be calibrated in accordance with approved procedures or by calibration facilities operating with an approved QA Program. Instruments that are in need of calibration or repair will be appropriately identified as such and removed from the work area to prevent inadvertent use. Calibrated instruments available for use will be segregated from damaged or out-of-calibration instruments and maintained in an area accessed by authorized personnel only.

Radiation monitoring instrument calibration will address the type, geometry, intensity, and energy spectrum of the radiation field in which the instrument is to be calibrated and will be appropriate to the instrument's intended use. Uncalibrated scales or ranges will be identified on the instrument with a suitable tag (or label) attached to the instrument. Records of instrument calibrations will be maintained for a three-year period unless otherwise required by 10 CFR 20.

Instruments will be calibrated using procedures consistent with Appendix Q of NUREG 1556, Vol. 11 or by a vendor that is licensed by the NRC or an agreement state to perform instrument calibrations and is on the Westinghouse approved vendors list. The calibration frequency will be at least annually or as recommended by the instrument manufacturer or after maintenance, repair, or adjustment likely to affect the calibration.

For hand-held radiation survey instruments, the readout scale and linearity calibration and adjustment will be performed according to ANSI N323A-1997, "Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments" (Ref. 30), using a standard source or sources having traceability to the National Institute of Standards and Technology (NIST). For each scale normally used for radiation protection surveys, a periodic performance test as described in ANSI N323A-1997 will be applied to each survey instrument in order to check its operability and its response relative to the reference readings recorded at the last calibration. Each day that a survey 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.

For fixed-station personnel contamination monitors (if applicable) and friskers, check sources will be used daily and after gas change outs to check that the monitor responds properly. Recalibration will be performed if the source check is not within the normal response range.

For laboratory instruments, check source and background counts will be made daily and after gas change outs. A recalibration will be performed if a source or background check is not as expected (i.e., statistically normal).

Air samplers used for quantitative measurements will have a means to determine the volume of air sampled. Airflow meters for fixed-location samplers, portable samplers, and lapel samplers will be calibrated at intervals not exceeding 12 months. Additional calibrations will be performed after repairs or modifications to the meter or if the meter is believed to have been damaged. The calibration methods will be according to Section 5 of Regulatory Guide 8.25, "Air Sampling in the Workplace" (Ref. 31).

10.7.2 Instrument Quality Assurance

In addition to the measuring and test equipment (M&TE) requirements of License No. SNM-33, control systems will be established and implemented to ensure that tools, gauges, instruments, and other measuring and test devices that affect or evaluate the quality of activities are controlled, calibrated, and adjusted at specific intervals so that the necessary accuracies are maintained.

Measurement reference standards used for calibrating M&TE will be traceable to nationally recognized standards and have calibration ranges, accuracies, and environmental conditions documented, so that the M&TE can be calibrated and maintained within the required tolerances. When practical and possible, the bias or uncertainty of the measurement reference standard would contribute no more than one-fourth of the allowable M&TE tolerance for each characteristic being calibrated.

Certificates or reports of measurement reference standards will include the following minimum information:

- Individual who performed the calibration and name of organization
- Identification or serial number
- Identification of the calibration source and report number

- Date of the calibration
- Calibration values assigned, with a statement of accuracy (uncertainties)
- Relevant environmental conditions (temperature, gravity, air buoyancy, etc.) under which the calibration was performed for which the assigned accuracies are valid
- Correction that will be applied if standard conditions (temperature, gravity, buoyancy, etc.) are not met or differ from those during the calibration
- A statement that the standards used are traceable, if the laboratory is other than NIST

M&TE and measurement reference standards will be transported, stored, and calibrated in environments that will not adversely affect their accuracy. Environmental factors that will be considered include heat, humidity, vibration, radio frequency interference, electrostatic discharge, dust, cleanliness, and fumes. When inaccuracy of M&TE caused by systematic environmental effects cannot be avoided, compensating corrections will be determined and applied.

The calibration and control program will require that all M&TE and measurement reference standards needing recalibration be recalled at prescribed intervals. The intervals can either be expressed as calendar time or be related to usage. Factors to consider when selecting calibration intervals include past experience, inherent stability, purpose of use, manufacturers' recommendations, characteristics of the equipment, and accuracy required. Historical records that contain experience data for evaluating and adjusting calibration intervals should be maintained.

M&TE will be calibrated using measurement reference standards with calibrations traceable to nationally recognized standards if such standards exist, or to accepted values of natural physical constants. When no national standard exists, the basis for calibration will be documented.

Measurement reference standards will be identified on calibration data records and supported by certificates, reports, or data sheets attesting to the calibration data, calibration facility, and relevant environmental conditions showing compliance with requirements for accuracy.

M&TE and measurement reference standards will be labeled to indicate their calibration status. The label will include the date of last calibration and the due date for the next calibration. When size or functional characteristics prevent the application of a label, an identifying code can be used, or the label can be affixed to the instrument container. When neither labeling nor coding is practical, the procedures will provide for the monitoring of records to assure control. M&TE with use limitations will be identified and controlled (such as a multi-scale instrument for which only one scale was calibrated).

M&TE and measurement reference standards found to be out of tolerance, past due (out of calibration), improperly maintained or calibrated, or subjected to possible damage, will be identified and removed from service until corrective measures can be taken. The equipment should be tagged or segregated to prevent inadvertent use. An evaluation of equipment tested or calibrated since the last calibration will be performed to establish the acceptability of the equipment and the work or to confirm a non-conformance. The results of the investigation will be documented. The QA organization will be notified of any M&TE or measurement reference standards that were used in a significantly out-of-tolerance condition. When equipment is calibrated and controlled for another organization, the user organization will be notified of the nonconformance so that it can then initiate corrective action and investigation of the condition. When appropriate to the specific M&TE, the use of trending should be considered.

Before placing M&TE and measurement reference standards in inactive, out-of-service, or retired status, the M&TE and measurement reference standards will be calibrated to verify accuracy and to close the calibration cycle. The calibration record and labeling will indicate the status of the equipment.

Subcontracted calibration services suppliers, other than NIST or government laboratories, will be evaluated to determine their capability to perform calibrations. Compliance with these requirements will be included in the procurement documents.

10.8 Nuclear Criticality Safety

NRC License No. SNM-33, Section 4.0 contains requirements for nuclear criticality safety during decommissioning.

10.9 HP Audits, Inspections, and Recordkeeping Program

An audit program will be conducted to monitor the effectiveness of the Radiation Protection Program. Areas reviewed include the following:

- ALARA program development and implementation
- Environmental monitoring and effluent releases
- Qualification and radiological safety training
- Performance of the RSO and HP staff
- Incident investigation reports, non-conformance reports, and corrective actions
- Status reports and audits
- Contractor oversight results

The POC will conduct an annual audit of licensed activities as described in Section 2.5 of License No. SNM-33.

Limited-scope audits/assessments of the radiation protection program will be conducted by the RSO (or designee) to determine compliance with applicable federal/state regulations and the Hematite *Radiation Protection Plan*. The RSO, or his designated alternate, will conduct quarterly inspections of areas where licensed materials are in use to ensure compliance with radiation protection requirements. A written report will be issued to the Project Director.

The RSO will make a written annual report to the POC and executive management having responsibility for the license reviewing the employee exposures and effluent release data. This report will include a review of audits, inspections, and radiological measurements performed during the past calendar year with emphasis on the data collected from the following areas: employee exposures; bioassay results; in-plant airborne radioactivity; and environmental monitoring. Reportable incidents (see 10 CFR 20, Subpart M) will also be identified in the report.

Events specified by applicable regulations or license conditions will be investigated and reported to the NRC. The Licensing Manager will be responsible for conducting the investigation and documentation of reportable events. Non-reportable occurrences will be investigated and documented as appropriate. Such reports will be available for NRC inspection.

Records that are generated by audit activities will be retained for three years from the date of record. Records pertaining to a particular audit will be filed together as an audit package. Audit records will include audit plans, reports, written responses, and records of completion of corrective actions.

11.0 ENVIRONMENTAL MONITORING AND CONTROL PROGRAM

Decommissioning activities will be conducted in a manner that protects the environment and the health and safety of the public and employees. This includes development of programs and procedures that provide for monitoring, detection, and control of releases of radioactive material into the environment as a result of decommissioning activities. Protection of human health and the environment will also be considered through implementation of the NCP process.

Hematite's radiological environmental monitoring program will be conducted in accordance with the site license and Hematite's *Radiation Protection Plan*. Activities related to environmental monitoring and control will comply with the HQAPP. The program will be reviewed and revised as necessary during the decommissioning process. The license commitment for environmental monitoring and control serves as a minimum commitment. As remediation activities begin, the monitoring program will be revised as necessary to ensure adequate environmental monitoring and controls are in place. These revisions will be addressed in the subsequent amendments to this DP.

11.1 Environmental ALARA Evaluation Program

In accordance with Hematite policy, every effort will be made to ensure that operations are conducted in accordance with ALARA principles, consistent with Regulatory Guide 8.37, "ALARA Levels for Effluents from Materials Facilities" (Ref. 32). A radiological environmental monitoring program will be conducted in accordance with Table 11-1 to periodically monitor the Hematite site and surrounding areas to determine if there has been any increase, above natural background conditions, in the radiation level or radioactive material content of air, water, soil, or other representative environmental samples. Locations of air particulate, soil, vegetation, well water, surface water, and liquid effluent sampling stations will be established and documented. Monitoring locations can be changed as decommissioning operations progress to ensure decommissioning operations do not impact off-site releases.

Environmental samples will be collected and analyzed as show in Table 11-1. Sample frequency can vary due to inclement weather, operating conditions, or a variance in decommissioning activities. More frequent or additional samples can be taken as required for special studies and evaluations. Should a significant continuous upward trend be noted in any of the sampling data, actions will be taken to investigate the cause and remedial actions will be taken as appropriate.

Table 11-1 Radiological Environmental Monitoring Program

Exposure Pathway and/or Sample	Samples/Sampling				Analysis
	Number	Location	Method (Duration)	Frequency	
AIR	Three	Air stations	Continuous	Weekly filter change	Gross α
	Currently Eighteen	Exhaust	Continuous	Weekly filter change	Gross α
WATER	Three	Surface – Septic outfall, dam, storm drain outfall	Grab	Weekly	Gross β Gross α
	Two	Surface – Joachim Creek upstream & downstream	Grab	Monthly	Gross β Gross α
	One	Surface – West Creek confluence with Joachim Creek	Grab	Quarterly	Gross β Gross α
	Seven	Well – offsite, evaporation ponds, south vault, burial pits	Grab	Quarterly	Gross β Gross α
SOIL	Seven	*	Grab	Annually	Gross β Gross α
VEGETATION	Four	*	Grab	Annually	Gross β Gross α

* Location not fixed

11.2 Effluent Monitoring Program

Airborne effluents from monitored release points (i.e., monitored stacks, discharges, and vents) will be monitored or sampled as determined by the RSO. Portable and fixed station air samplers will be used for an ambient air monitoring. Samples will be collected weekly or as determined by the RSO. Air samples will be analyzed after suitable decay of radon daughters. The sampling program will be designed based on the potential that the effluent from an area has for contributing to the dose to a member of the general public. Airborne effluent monitoring systems, if used, will be calibrated at intervals not to exceed 12 months.

Members of the HP staff will evaluate the stack monitoring data monthly, and the average discharge concentration will be determined. If the concentration of radioactivity in the effluent exceeds 75% of the applicable limit averaged over one week, the RSO will take corrective action. The RSO will give notification to the cognizant facility manager, and a review of previous and current operations will be conducted to determine the cause of the increase in concentration. The information obtained from this review will be documented, including appropriate recommendations aimed at preventing a recurrence.

Liquid effluent samples will be collected via representative grab samples of batch discharges or by sampling of continuous discharges or both. Samples will be collected at or prior to discharge from the waste handling system. Samples will be analyzed by the following methods:

- Alpha activity measurements
- Uranium fluorimetry
- Kpa
- Mass spectroscopy
- Beta measurements
- Gamma spectroscopy
- Neutron activation analysis

Other approved analytical methods for sample analysis can be authorized by the RSO.

The control limits for alpha and beta activity in liquid effluents will be 3.0×10^{-7} µCi/ml average for alpha and 5.0×10^{-6} µCi/ml average for beta. The stated control limits for alpha and beta activity will apply at the site boundary and are average values for the year. If the control limits are exceeded, averaged over a calendar quarter, an investigation will be conducted and corrective action taken.

Gross-alpha and gross-beta analyses are performed on liquid effluent samples. Gross-alpha analysis is performed on air effluent (stack) samples. The average concentrations for 2003 are shown in Table 11-2:

Table 11-2 Average Effluents for 2003

Effluent	Gross Alpha	Gross Beta	10 CFR 20 App. B Limit
Liquid	1.52E-8 µCi/ml	2.07E-8 µCi/ml	3.00E-7 µCi/ml
Air (stacks)	2.27E-15 µCi/ml	N/A	6.00E-14 µCi/ml

Background and baseline concentrations of radionuclides in environmental media will be determined during site characterization. A significant amount of environmental monitoring data has been accumulated during the history of the site license. The environmental monitoring data was prepared and generally reported without subtracting natural background. Therefore, the historical environmental monitoring data can be used to supplement the results obtained during the site characterization efforts.

Effluent samples are collected in accordance with approved site procedures. Analyses of effluent samples are performed by a contract laboratory selected from the approved vendors list. Analyses of physical and chemical characteristics of radionuclides in effluents have not been performed. Air samples are analyzed for particulates. Water samples are analyzed for filtered and unfiltered fractions.

11.3 Effluent Control Program

Environmental air emissions were monitored for 19 stacks during fuel production operations of the facility. The 2002 radiological results for the air emissions were loaded into COMPLY Code–V1.6 and executed at Level 1, the most conservative level. The results of the COMPLY run indicated that the Hematite facility was in compliance with 40 CFR 61, National Emissions Standards for Hazardous Air Pollutants and 10 CFR 20.1101. During decommissioning activities, air emissions will not approach the release levels observed during fuel production operations. Execution of the COMPLY Code can be re-implemented if deemed appropriate.

12.0 RADIOACTIVE WASTE MANAGEMENT PROGRAM

12.1 Program Description

Radioactive waste management will be performed in accordance with Hematite's *Waste Management and Transportation Plan* (Ref. 33) and the site license. The waste streams generated as a result of the decommissioning effort will be characterized by sampling and analysis to establish profile, packaging, and disposal criteria. Characterization can encompass a combination of process knowledge, radiological survey, volumetric sampling, and direct sampling. Direct sampling can be performed utilizing direct radiological and hazardous constituent reading instruments to survey the material before and after removal. Characterization data will provide information to support health and safety operations, as well as waste packaging and transportation requirements. The sampling protocol will be adequate to meet the waste acceptance criteria of the approved disposal facility. Each waste stream is unique and will require specific handling, containerization, labeling, transportation, and disposal requirements. Based on characterization data, the waste will be segregated and analyzed as required by the disposal facility's waste acceptance criteria. If the analytical results show an out-of-compliance condition, an alternate disposal facility will be used.

12.2 Solid Radioactive Waste

12.2.1 Low-Level Radioactive Waste (LLRW) Solids

LLRW solids might include soil, brick, concrete, masonry, paper, wood, glass, metal, plastics, sheetrock, mineral material, equipment, tables, wire, pipe, ductwork, chairs, desks, roofing, filing cabinets, laboratory fume hoods, and any other debris or material normally found in the facilities being demolished. LLRW will be characterized, containerized, transported, and disposed at a permitted disposal facility as described in the waste profile. LLRW will be stored/staged in the appropriate container depending on the volume of waste. Metal boxes can be utilized for small volumes, while intermodal or gondola containers can be utilized for large volumes, depending on method of transportation.

If contaminated soil or other loose, solid radioactive waste is excavated, a storm water control plan will be implemented to control erosion and mitigate the entry of any contaminants from the work area into the storm drain system or onto other off-site areas. Best management practices will be used to control re-distribution of contamination, including silt fencing and straw bales, work sequencing, and re-seeding of exposed soil areas. Spill containment and cleanup materials will be kept for ready use in the work area. Silt controls will remain in place until disturbed soil is covered with gravel or stabilized with seeding.

Projected volumes of solid radioactive waste and the names and locations of potential disposal facilities being considered for solid radioactive waste will be provided, as appropriate, in the plans for the subsequent phases of decommissioning work to be submitted as amendment requests for this DP. Class B, C, or greater-than-C solid radioactive waste will not be generated at the site.

12.2.2 LLRW Asbestos-Containing Material

LLRW asbestos-containing material (ACM) will be handled as radioactive waste. The LLRW ACM will be double wrapped, labeled both "asbestos" and "radioactive", containerized, transported, and disposed at a permitted facility. LLRW ACM that is bagged will be stored/staged in the appropriate container depending on the volume of waste. Metal boxes and drums can be utilized for small volumes, while roll-offs or intermodal containers can be utilized for large volumes. LLRW ACM, such as transite, will be double wrapped, placed on pallets, or packaged and staged for transport.

The projected volume of LLRW ACM and the names and locations of potential disposal facilities being considered for LLRW ACM will be provided, as appropriate, in the plans for the subsequent phases of decommissioning work to be submitted as amendment requests for this DP.

12.3 Liquid Radioactive Waste

LLRW liquids such as sludge, oil, and wastewater will be sampled, characterized, containerized, labeled, transported, and disposed at a permitted disposal or process facility. LLRW liquids will be stored/staged in the appropriate container, depending on the volume and type of waste. Filled and partially filled containers will be staged on spill pallets or in a bermed area. The containers will be filled so that the weight does not exceed the maximum weight specified by the manufacturer.

LLRW liquids will be stored in an area that provides secondary containment of such size so as to contain 10 percent of the volume of all containers or the volume of the largest container (whichever is greater). LLRW liquids will be segregated from uncontaminated wastes to minimize the amount of contaminated liquid generated. LLRW liquids can be absorbed to meet the disposal facility's waste acceptance criteria.

The projected volume of LLRW liquids and the names and locations of potential disposal facilities being considered for LLRW liquids will be provided, as appropriate, in the plans for the subsequent phases of decommissioning work to be submitted as amendment requests for this DP. Class B, C, or greater-than-C liquid radioactive waste will not be generated at the site.

12.4 Mixed Waste

Mixed waste that meets the EPA definition of a hazardous waste that is also radiologically contaminated will be disposed of at a permitted disposal facility. If mixed waste is found during decommissioning, it will be identified via characterization and volumetric sampling. Analytical data will delineate the specific hazardous material, the levels of contamination, and the radioactive isotopes. In the event the material exceeds the land disposal restrictions set forth by the EPA, the material will be treated at a permitted facility prior to disposal.

Mixed waste will be stored/staged in the appropriate container depending on the volume and type of waste. One-gallon containers, 55-gallon drums, or metal boxes can be used for smaller volumes of hazardous waste, while intermodal containers can be utilized for larger volumes.

Suspect/unknown material will be sampled and sent to a laboratory for analysis for hazardous materials outlined in Table 1 of 40 CFR 261.24. Upon receipt of the analytical data and in the event the suspect/unknown material meets the definition of a hazardous waste or a mixed waste, the material will be managed in a Site Accumulation Area (SAA) near the point of generation until a quantity of 55 gallons is generated. While being stored in the SAA, the container will be labeled, and the label will identify the container's contents, contaminants, and the contaminant waste code(s). Within 3 days of generating 55 gallons of waste, the waste will be moved to a less than 90-day storage area or transported for treatment and/or disposal.

Mixed wastes (LLRW/RCRA or LLRW/TSCA) will be managed in an area that meets the requirements of a LLRW staging area and SAA or LLRW staging area/PCB storage area according to waste characterization. PCB waste will be treated within one year of generation unless covered by a regulatory agreement allowing longer storage. The Westinghouse EPA identification number is MOR000012724. The State of Missouri ID number is 032741.

The estimated volume of mixed wastes and the names and locations of potential disposal facilities being considered for mixed wastes will be provided, as appropriate, in the plans for the subsequent phases of decommissioning work to be submitted as amendment requests for this DP. There is potential for mixed waste in the Burial Pits based on information found in the burial logs. No Class B, C, or greater-than-C mixed waste will be generated at the site.

12.5 Waste Segregation

Demolition debris and the various waste streams will be segregated, size reduced if necessary, packaged in accordance with the appropriate waste acceptance criteria, and staged in the immediate vicinity of the structure being decontaminated or demolished. Demolition, radiological, and hazardous materials might not be containerized immediately but could be staged for sampling and characterization prior to being placed in the appropriate shipping container. Radioactive wastes will be staged to the greatest extent possible in remaining structures. In the event that a structure is not available, radioactive wastes will be containerized in intermodal containers, metal boxes, or roll-off boxes to minimize runoff. Erosion controls will be established, as required, around waste material that is stored outside.

Co-mingling will be strictly prohibited and controlled through containerization and segregation. Co-mingling will be prevented to the extent possible through the use of tarps, discrete barriers, and containerization. Staging areas will be established to control waste packages that are ready for transportation and disposal. Staging areas will be identified and posted in accordance with approved procedures.

13.0 QUALITY ASSURANCE PROGRAM

Amendment 47 to SNM-33 incorporated the quality assurance requirements of NUREG-1757 into Chapter 2 of SNM-33. The quality assurance program for decommissioning shall be in compliance with Section 2.8 of SNM-33.

14.0 FACILITY RADIATION SURVEYS

14.1 Release Criteria

The unrestricted release criteria for soils and sediments that remain on site will be in accordance with the DCGLs described in Sections 1.5 and 5.0 of this DP. Information on area factors, $DCGL_{EMC}$ (elevated measurement comparison), treatment of multiple nuclides, and use of operational DCGLs is provided in the *Hematite Soil Survey Plan*, which is being submitted to the NRC along with this DP.

If any non-impacted buildings are left in place, evaluation criteria will be developed to demonstrate that the buildings meet the criteria for unrestricted use.

Release criteria for equipment will be in accordance with the NRC "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," April 1993.

14.2 Characterization Surveys

Detailed characterization data is being developed for the site under the Remedial Investigation/Feasibility Study (RI/FS) Work Plan (Ref. 35) discussed in the Preface to this DP. An initial report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) 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 HSA and previous characterization efforts, as described in the following sections, provide adequate information for beginning work on Phase a., Outlying Land Areas, as no licensed activities have been associated with these areas. Plans and characterization data necessary to obtain approval for the remaining phases will be submitted as amendment requests to the DP, pending completion of the site characterization and related NCP process.

14.2.1 Gamma Walkover Survey

The Gamma Walkover Survey (GWS) was performed at the Hematite site to identify the presence of natural uranium, LEU, HEU, Tc-99, and thorium contamination in surface or near-surface soils to aid in area classification and future characterization planning at the site. The GWS also attempted to locate buried trenches and other Areas of Concern known or suspected to be on site. The GWS was designed to cover 100% of the central site tract and approximately 10% of the outlying land areas.

The GWS was also conducted with the intent of maximizing the use of all data collected in future site evaluations. Although the GWS was conducted to aid in classification of site areas as impacted or non-impacted and therefore should not be considered a scoping survey, the GWS was designed to follow the guidance for scoping surveys presented in Section 5.2 of MARSSIM.

The GWS data has helped verify the conclusions of the Historical Site Assessment (HSA) and provided input for the design of the site characterization.

14.2.2 Soil Characterization for K_d Determination

Because higher-than-background levels of uranium isotopes (U-234, U-235, and U-238) and technetium (as Tc-99) have been measured during previous characterization events, site-specific K_d factors for these radionuclides were measured in the laboratory using soil samples collected from the Hematite site. This work is described in a report entitled "Determination of Distribution Coefficients for Radionuclides of Concern at the Westinghouse Hematite Facility" (Ref. 37), which was provided in a separate submittal to the NRC. Six bore holes were drilled to refusal or bedrock (~30 to 35 ft.), and 18 soil samples (3 depth intervals per bore hole) were collected for K_d testing, radionuclide analysis, and general soil characterization procedures. The bore holes were located based on site history, previous subsurface characterization, and the GWS. Bore hole locations are described as follows:

- Deul's Mountain—refers to a pile of excavated and potentially contaminated soil stored along the southeast corner of the fence line.
- Burial Pits—approximately 40 burial pits are known to exist
- Tile Barn Cistern Burn Pit—the roof of the Red Room (referring to Building 240, formerly used highly enriched uranium conversion processes) was reportedly buried in an area south of the Tile Barn.
- Fenced Area No. 1—this bore hole is located where elevated gamma radiation was detected during the GWS.
- Fenced Area No. 2— this bore hole is located where elevated gamma radiation was detected during the GWS.
- Evaporation Ponds—past waste management practices have included the disposal of radioactive waste water in these ponds.

Uranium activities were detected at significant levels in samples from the fenced areas and in the shallowest sample from the Tile Barn/Cistern Burn Pit area. A summary of activities in the soil samples is provided in Table 14-1:

Table 14-1 Activities in Soil Samples for K_d Determination

Location	Upper Limit of Sample Interval (ft.)	Lower Limit of Sample Interval (ft.)	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)	Tc-99 (pCi/g)
Deul's Mountain	4	8.6	6.14	0.26	1.48	6.6
	23	28	1.79	N.D.	1.04	6.23
	28	33	0.92	N.D.	0.73	2.84
Burial Pits	4	10	4.97	0.18	1.22	N.D.
	13	17	0.85	N.D.	0.93	N.D.
	23	34	0.72	N.D.	0.78	N.D.
Tile Barn/Cistern Burn Pit	8	13	21.5	1.31	12	N.D.
	16	20	1.48	0.15	0.93	N.D.
	23	27	1.63	0.24	1.01	N.D.
Fenced Area #1	2	14	3	N.D.	0.99	2.8
	14	21	20.2	0.66	3.32	13.8
	24	30	1.38	N.D.	0.94	0.82
Fenced Area #2	1	12	218	9.8	33.6	2.52
	19	24	90	4.12	14.5	1.18
	27	31	75.8	2.67	6.57	0.91
Evaporation Ponds	1	8	11.6	0.45	2.06	2.55
	11	16	1	N.D.	0.91	2
	26	30	1.14	N.D.	0.66	5.86

N.D. – none detected

14.2.3 Characterization of Soil Under Site Buildings

The results of soil characterization under site buildings are described in Section 4.3.1.

14.2.4 Deul's Mountain Characterization

The characterization results on Deul's Mountain are described in Section 4.3.1.

14.3 Remedial Action Support Surveys

14.3.1 General

Radiation surveys will be conducted to 1) support remediation activities, 2) determine when a survey unit is ready for the final status survey, and 3) provide updated estimates of parameters used for planning the final status survey. These surveys can be performed on building and equipment surfaces and bulk materials.

Soil survey activities designed to support this DP are described in the *Hematite Soil Survey Plan.*

14.3.2 Survey Design

Random and biased surveys will be performed. Biased sampling will be based on results of historical surveys, walk-downs, historical use of the item or area, and professional judgment.

14.3.3 Conducting Surveys

Support surveys will include one or more of the following:

- Surface scans
- Direct static measurements
- In situ gamma measurements
- Material sampling
- Removable sampling

Surface scans and direct static measurements will be performed with portable radiation detection instrumentation (e.g., gas proportional detector, alpha/beta scintillation detector, gamma detectors). Samples of material will be collected to identify and quantify radionuclide concentrations. Measurements of removable radioactivity will be performed on surfaces using standard smear techniques.

14.3.4 Evaluating Survey Results

Survey data (e.g., surface activity levels and radionuclide concentrations in media) will be converted to standard units and compared to the operational DCGLs. If results of these surveys indicate that remediation has been successful in meeting the operational DCGLs, decontamination efforts will cease. Otherwise, additional remediation will be performed.

14.4 Final Status Survey Design

14.4.1 Overview

NRC regulation, 10 CFR 30.36(g)(4)(iv), requires a description of the final radiation survey. The final status survey plan for soils is described in the *Hematite Soil Survey Plan.* The final status survey report will be submitted after the final radiological survey has been completed. For license termination, the final design will encompass consideration for the entire site. The final status survey for the Hematite site will be designed using the guidance contained in MARSSIM. The surveys will demonstrate that the residual radioactivity in each survey unit satisfies the applicable criteria for unrestricted release, as described in Sections 1.5 and 5.0 of this DP. The surveys will provide data to demonstrate that radiological parameters do not exceed the operational DCGLs.

Survey Design

The survey designs will begin with the development of data quality objectives (DQOs). The DQOs will be developed using guidance provided in the DQO process in Appendix D of MARSSIM. On the basis of these objectives and the known or anticipated radiological conditions at the site, the numbers and locations of measurement and sampling points used to demonstrate compliance with the release criterion will be determined. Finally, survey techniques appropriate for development of adequate data will be selected and implemented.

Radionuclides of Concern

Enriched uranium (principally) and technetium (minimally) have been identified in the soils in the central site tract. Due to the unknowns associated with government activities on the site, other radionuclides that will be considered isotopes of concern until proven otherwise include Am-241, Pu-239, Np-237, and Th-232 in equilibrium with its progeny, i.e., Ra-228, and Th-228.

Derived Concentration Guideline Levels (DCGL)

Sections 1.5 and 5.0 of this DP discuss the DCGLs that will be used to design the soil surveys. Detailed information on the use of DCGLs is provided in the *Hematite Soil Survey Plan.*

Classification of Areas Based on Contamination

All areas of the site do not have the same potential for contamination and, accordingly, do not need the same level of survey coverage to demonstrate that residual radioactivity in the area satisfies the applicable criteria. The surveys will be designed so that areas with higher potential for contamination receive a higher degree of survey effort. The survey designs fall into one of two categories, non-impacted and impacted. In the interest of conservatism, all soil areas on the Hematite site are being treated as impacted areas, i.e., have some potential for containing residual contamination. Impacted areas are subdivided into three classes according to known or suspected levels of contamination with regard to the classification guidance of MARSSIM. Specific and thorough consideration will be given to site operating history and/or known contamination based on site characterization efforts:

- Class 1 areas have, or had prior to remediation, a potential for radioactive contamination (based on site operating history) or known contamination (based on radiological surveys). Areas that are suspected of containing contamination in excess of the operational DCGLs will be classified as Class 1.
- Class 2 areas have, or had prior to remediation, a potential for radioactive contamination or known contamination but are not expected to exceed the operational DCGLs.
- Class 3 areas are potentially impacted but are not expected to contain any residual radioactivity or are expected to contain levels of residual radioactivity at a small fraction of the operational DCGL, based on site operating history and previous radiological surveys. These are areas with very low potential for residual contamination but insufficient information to justify a non-impacted classification.

Class 1 areas have the greatest potential for contamination and, therefore, receive the highest degree of survey effort, followed by Class 2, and then Class 3 areas. Areas can be further subdivided into survey units in accordance with the guidance in MARSSIM to better facilitate assessment of the areas.

14.4.2 Investigation Levels

Radionuclide-specific investigation levels will be used to indicate when additional investigations might be necessary. The investigation levels will also serve as a quality control check for the measurement process. The investigation levels to be used at the site are provided in Table 14-2.

Table 14-2 Final Status Survey Investigation Levels

Survey Unit Classification	Investigate When Sample Result:	Investigate When Scanning Measurement:
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

14.4.3 Instruments and Methods

The instruments and calibration and operational checks to be used during the final status survey are described in Section 10.7.

Measurement techniques used to generate data during the surveys can be classified into four categories commonly known as scanning surveys, direct measurements, sampling, and fixed measurements. These techniques will be combined in an integrated survey design. Descriptions of these techniques are as follows:

- Scanning surveys will be performed to identify areas of elevated activity that might not be detected by other measurement methods. Scanning will be performed of structure surfaces and land areas. Structure surfaces will be scanned for both alpha and beta/gamma radiations. Land areas will be scanned for gross-gamma radiation.
- Direct and removable measurements will be made to determine average activity in a survey area or unit. These measurements will only be made on structural surfaces and will be limited to alpha and beta/gamma measurements.
- Sampling will be limited to land areas. Samples of soil will be collected and analyzed for the radionuclides of concern, as applicable.
- Fixed measurements might be used to supplement scanning surveys for the identification of small areas of elevated activity.

14.4.4 Reference Areas

The reference areas used for the conduct of the final status surveys for land areas will be as described in the *Hematite Soil Survey Plan.* The reference for structural surfaces will be determined at the time of the survey as part of instrument calibration.

14.4.5 Reference Coordinate System

Reference coordinate systems will be used to facilitate selection of measurement and sampling locations and to provide a mechanism for relocating a survey point. Land area scanning surveys and soil sample locations will be referenced to State Plane.

14.4.6 Summary of Statistical Tests

Measurements from a survey unit will be compared to equivalent measurements from the reference areas. In general, the comparison will be whether the survey unit exceeds the reference area by more than the DCGL. The MARSSIM Wilcoxon statistical test will be used unless otherwise indicated and justified. Additional information on statistical tests and associated Type I and Type II errors is provided in the *Hematite Soil Survey Plan.*

In addition, an elevated measurement comparison will be performed against each measurement in a Class 1 unit to ensure that the measurement result does not exceed the specified investigation level, i.e., the $DCGL_{EMC}$. If any measurement exceeds the $DCGL_{EMC}$, then additional investigation will be completed regardless of the outcome of the statistical test.

14.4.7 Control and Handling of Samples for Laboratory Analysis

Sample collection and laboratory analyses will be conducted in accordance with written procedures. A written chain-of-custody procedure will be used to ensure integrity of samples and data from sample collection through data reporting.

14.5 Final Status Survey Report

A report will be prepared to document the final conditions of the site. The report will include information concerning:

- An overview of the results of the final status survey
- A discussion of any changes that were made in the survey from what was proposed in the DP
- A description of the method by which the number samples was determined for each survey unit
- A summary of values used to determine the number of samples and justification for these values
- The survey results for each survey unit including:
  - Number of samples taken for the survey unit
  - A map or drawing of the survey unit showing the reference system and random start systematic sample locations
  - Measured sample concentrations
  - Statistical evaluation of measured concentrations
  - Judgmental and miscellaneous sample data sets reported separately from those samples collected for performing the statistical evaluation
  - A discussion of anomalous data including any areas of elevated direct radiation detected during scanning that exceeded the investigation level or measurement locations in excess of the operational $DCGL_W$
  - A statement that a given survey unit satisfied the operational $DCGL_W$ and the elevated measure comparison if any sample points exceeded the operational $DCGL_W$
  - A description of any changes in initial survey unit assumptions relative to the extent of residual radioactivity
- Results of investigations, including causes and impacts of any failed survey units
- A summary of conclusions

14.6 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. The data evaluation section of the *Hematite Soil Survey Plan* provides the methods to determine that the DCGL criteria have been met based on the measured soil concentrations collected during the final status survey. This method for determining compliance conforms to the method described in Section 2.5.2 of NUREG-1757, Volume 2, termed the "DCGL and FSS Approach." This method is based on the statistical test approach incorporated in MARSSIM. Section 2.5.1 of NUREG-1757, Volume 2 also provides for a second approach to compliance demonstration. The second allowed method is termed the "Dose Modeling Approach."

In order to both control the decommissioning effort and to establish the most realistic assessment of dose for the site upon completion of the remediation, a combination of the two approaches will be used:

- During the decommissioning effort, the "DCGL and FSS Approach" will be used to control the operations and to establish confidence that the decommissioning effort will be successful, thereby minimizing the possibility that additional iterations of remediation will be required.
- Upon completion of the decommissioning, the "Dose Modeling Approach" will be used to establish the most realistic measure of the potential dose from the site. This method will constitute the demonstration that the decommissioning has been completed in accordance with the requirements of 10 CFR 20, Subpart E.

Implementation of the "Dose Modeling Approach" will be as follows. The final dose estimate will be recalculated by the same RESRAD model used to derive the DCGLs included in this DP. However, this calculation will use the probabilistic method available in RESRAD Version 6.22. Appendix D of the DCGL report provides the probability distributions that would be utilized. The actual concentration of residual radionuclides above background levels that is present at time of license termination, including the uncertainty of measurements, will be used. 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. This "Dose Modeling Approach" has the following advantages:

- The modeling is more realistic and is based on actual site conditions existing at time of license termination, including the measured concentrations of residual radionuclides and locations and depths of contaminated materials.
- The method accounts for the time of peak dose for the mixture of radionuclides present.
- The probabilistic calculation method includes the uncertainty of the parameters.

The final dose calculation for the soil component will be performed with the following requirements:

1. The calculations will be performed using the uncertainty/probabilistic mode for RESRAD Version 2.22. The parameter uncertainty and probabilistic distributions given in Appendix D of the DCGL report will be used. If justified and approved by the NRC, certain pathways might be turned off.
2. The uncertainty and distribution of the final residual radionuclides will be based on the measurements made during the final status survey. All radionuclides identified from the measurements made during the final status survey will be included. If a specific radionuclide has been eliminated from consideration during the final status survey, a concentration for the radionuclide will be used based on the best available information.
3. The geometry for the contaminated soil zone will be based on actual final conditions, including area of the contaminated area, contaminated zone depth and thickness, and soil cover depth.
4. For the survey units designated as Class I, a calculation will be performed for each survey unit and the average potential dose will be determined as the area weighted average over all of the Class I survey units.
5. Separate calculations will be performed for those soil areas designated as Class II and Class III. These results will be presented separately so as not to dilute the average result for the Class I areas.
6. The result will be reported as the peak dose and the time of occurrence.

The above approach will account for the dose component associated with residual radionuclides present in the soil.

A similar approach can be used to calculate the dose associated with any buildings remaining on site at time of license termination using RESRAD-BUILD. If the dose component associated with the buildings is very small, a realistic but simplified approach might be utilized. Such a simplified approach would include the "sum of fractions" for DCGLs approved for remaining building surfaces.

The dose associated with the existing contaminated groundwater will be calculated separately using an appropriate groundwater model.

15.0 FINANCIAL ASSURANCE

The Westinghouse Electric Company has established and submitted to the NRC a Decommissioning Funding Plan for the Hematite site. In June 2004, this funding plan was increased from $9,926,184 to $40,500,000 based on the decommissioning forward cost estimate shown in Table 15-1. An updated Continuing Certification of Financial Assurance was provided with the plan revision. The funding plan is based on a realistic estimate of the costs associated with the radiological issues for decommissioning the site. As further characterization information is obtained and evaluated in conjunction with submission of amendments to the DP, the decommissioning cost estimate will be re-evaluated and adjusted as appropriate.

A financial assurance mechanism in the form of a Letter of Credit and the associated Standby Trust have been established and provided to the NRC in accordance with regulatory requirements.

Table 15-1 Decommissioning Cost Estimate

Cost Element	Costs as of 4/04 (000)	Forward Total (000)
Project Management	$ 7,000	$ 5,500
Remedial Investigation	$ 1,000	
Mobilization	$ 2,000	
Facility Cleanout	$ 10,000	
Building Preparation	$ 3,000	
Contractor Costs		
Equipment Removal and Disposal		$ 8,500
Building Demolition and Disposal		$ 12,000
Burial Pit Excavation and Disposal		$ 10,000
Surface Soil Excavation and Disposal		$ 3,000
Final Status Survey and Documentation		$ 1,500
Prior Costs	$ 23,000	
Projected Additional Costs		$ 40,500
Existing Financial Assurance		$ 9,926
Additional Financial Assurance		$ 30,574

Westinghouse

NUREG-1757, App. D
DECOMMISSIONING PLAN CHECKLIST

DOCUMENT #: DO-04-003, Rev. 1

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

HEMATITE, MISSOURI

January 2005

DECOMMISSIONING PLAN CHECKLIST

I. EXECUTIVE SUMMARY

- ***The name and address of the licensee or owner of the site***

  Section 1.1

- ***The location and address of the site***

  Section 1.1

- ***A brief description of the site and immediate environs***

  Sections 1.0 and 1.1

- ***A summary of the licensed activities that occurred at the site***

  Section 1.2

- ***The nature and extent of contamination at the site***

  Section 1.3

- ***The decommissioning objective proposed by the licensee (i.e., restricted or unrestricted use)***

  Section 1.4

- ***The DCGLs for the site, the corresponding doses from these DCGLs, and the method that was use to determine the DCGLs***

  Section 1.5

- ***A summary of the ALARA evaluations performed to support the decommissioning***

  Section 1.6

- ***If the licensee or responsible party requests license termination under restricted conditions, the restrictions the licensee intends to use to limit doses as required in 10 CFR Part 20.1403 or 20.1404, and a summary of institutional controls and financial assurance***

Not applicable. Licensee is not requesting license termination with restriction.

- ***If the licensee requests license termination under restricted conditions or using alternate criteria, a summary of the public participation activities undertaken by the licensee to comply with 10 CFR Part 20.1403(d) or 20.1404(a)(4)***

  Not applicable. Licensee is not requesting license termination with restriction nor does it propose alternate radiological criteria.

- ***The proposed initiation and completion dates of decommissioning***

  Section 1.7

- ***Any post-remediation activities (such as groundwater monitoring) that the licensee proposes to undertake prior to requesting license termination***

  Section 1.8

- ***A statement that the licensee is requesting that its license be amended to incorporate the decommissioning plan***

  Section 1.9

II. FACILITY OPERATING HISTORY

II.a. LICENSE NUMBER/STATUS/AUTHORIZED ACTIVITIES

- ***The radionuclides and maximum activities and quantities of radionuclides authorized and used under the current license***

  Section 2.1 - Table 2-1

- ***The chemical forms of the radionuclides authorized and used under the current license***

  Section 2.1 - Table 2-1

- ***A detailed description of how the radionuclides are currently being used at the site***

  Section 2.1 - paragraph 2

- ***The location(s) of use and storage of the various radionuclides authorized under current licenses***

  Section 2.1 - paragraph 3

- ***A scale drawing or map of the building or site and environs showing the current locations of radionuclide use at the site***

  Section 3.1 - Figures 3-3 and 3-4

- ***A list of amendments to the license since the last license renewal***

  Section 2.1 - Table 2-2

II.b. LICENSE HISTORY

- ***The radionuclides and maximum activities of radionuclides authorized and used under all previous licenses***

  Section 2.2 - paragraph 10 and Table 2-3 (A complete history of special, source, and byproduct material authorized for use at the site is not available.)

- ***The chemical forms of the radionuclides authorized and used under all previous licenses***

  Section 2.2 - Table 2-3 (A complete history of special, source, and byproduct material authorized for use at the site is not available.)

- ***A detailed description of how the radionuclides were used at the site***

  Section 2.2

- ***The location(s) of use and storage of the various radionuclides authorized under all previous licenses***

  Section 2.1 - paragraph 3

- ***A scale drawing or map of the site, facilities and environs showing previous locations of radionuclide use at the site***

  Section 3.1 - Figures 3-3 and 3-4

II.c. PREVIOUS DECOMMISSIONING ACTIVITIES

- ***A list or summary of areas at the site that were remediated in the past***

  Sections 2.3.1–2.3.4

- ***A summary of the types, forms, activities and concentrations of radionuclides that were present in previously remediated areas***

  Section 1.3 - paragraph 1, Sections 2.31–2.3.4

- ***The activities that caused the areas to be contaminated***

  Section 2.2 - paragraphs 1, 5, 6, 7, 8, and 9, Sections 2.3.1–2.3.3, Section 4.4.2

- ***The procedures used to remediate the areas and the disposition of radioactive material generated during the remediation***

  Sections 2.3.1–2.3.3

- ***A summary of the results of the final radiological evaluation of the previously remediated area including the locations and average radionuclide concentrations in the previously remediated area***

  Sections 2.3.1–2.3.3

- ***A scale drawing or map of the site, facilities and environs showing the locations of previously remedial activity***

  Section 3.1 - Figures 3-3 and 3-4

II.d. SPILLS

- ***A summary of areas at the site where spills (or uncontrolled releases) of radioactive material occurred in the past***

  Section 2.4

- ***The types, forms, activities and concentrations of radionuclides involved in the spill or uncontrolled release***

  Section 1.3 - paragraph 1, Section 2.4

- ***A scale drawing or map of the site, facilities, and environs, showing the locations of spills***

  Section 3.1 - Figure 3-4

II.e. PRIOR ON-SITE BURIALS

- ***A summary of areas at the site where radioactive material has been buried in the past***

  Section 2.5

- ***The types, forms, activities and concentrations of waste and radionuclides in the former burial(s)***

  Section 1.3 - paragraph 1, Section 2.5

- ***A scale drawing or map of the site, facilities and environs showing the locations of former burials***

  Section 3.1 - Figure 3-3

III. FACILITY DESCRIPTION

III.a. SITE LOCATION AND DESCRIPTION

- ***The size of the site in acres or square meters***

  Section 3.1 - paragraph 1

- ***The State and county in which the site is located***

  Section 3.1 - paragraph 1

- ***The names and distances to nearby communities, towns and cities***

  Section 3.1 - Figures 3-1 and 3-2, Section 3.2 - Table 3-1

- ***A description of the contours and natural features of the site***

  Section 3.1 - paragraphs 1 and 2

- ***The elevation of the site***

  Section 3.1 - paragraph 1

- ***A description of property surrounding the site, including the location of all off-site wells used by nearby communities or individuals***

Section 3.1 - paragraphs 4 and 5, Figure 3-6

- ***The location of the site relative to prominent features such as rivers and lakes***

  Section 3.1 - paragraph 2, Figure 3-3

- ***A map that shows the detailed topography of the site using a contour interval***

  Section 3.1 - Figure 3-5

- ***The location of the nearest residences and all significant facilities or activities near the site***

  Section 3.1 - paragraphs 4, 5, and 6

- ***A description of the facilities (e.g., buildings, parking lots, and fixed equipment) at the site***

  Section 3.1 - paragraphs 1 and 2, Figures 3-3 and 3-4, Section 4.1

III.b. POPULATION DISTRIBUTION

- ***A summary of the current population in and around the site, by compass vectors***

  Section 3.2. - paragraphs 1 and 2, Table 3-1

- ***A summary of the projected population in and around the site by compass vectors***

  Section 3.2 - paragraph 2 (Information is provided for Jefferson County. Information is not available by compass vectors.)

III.c. CURRENT/FUTURE LAND USE

- ***A description of the current land uses in and around the site***

  Section 3.3 - paragraph 1

- ***A summary of anticipated land uses***

  Section 3.3 - paragraph 2

III.d. METEOROLOGY AND CLIMATOLOGY

- ***A description of the general climate of the region***

  Section 3.4 - paragraphs 1 and 2

- ***Seasonal and annual frequencies of severe weather phenomena***

  Section 3.4 - paragraphs 1 and 2

- ***Weather-related radionuclide transmission parameters***

  Section 3.4 - paragraphs 1 and 2 and Section 3.6 – paragraph 3

- ***Routine weather-related site deterioration parameters***

  Section 3.4 - paragraphs 1 and 2 and Section 3.6 – paragraph 3

- ***Extreme weather-related site deterioration parameters***

  Section 3.4 - paragraphs 1 and 2 and Section 3.6 – paragraph 3

- ***A description of the local (site) meteorology***

  Section 3.4 - paragraphs 1 and 2

- ***The national Ambient Air Quality Standards Category of the area in which the facility is located and, if the facility is not in a Category 1 zone, the closest and first downwind Category 1 Zone***

  This information has not been identified.

III.e. GEOLOGY AND SEISMOLOGY

- ***A detailed description of the geologic characteristics of the site and the region around the site***

  Section 3.5 - paragraphs 1–3

- ***A discussion of the tectonic history of the region, regional geomorphology, physiography, stratigraphy, and geochronology***

  Section 3.5 - paragraphs 1–4

- ***A regional tectonic map showing the site location and its proximity to tectonic structures***

  Section 3.5 – paragraph 1-4 (A regional tectonic map is not included in the DP.)

- ***A description of the structural geology of the region and its relationship to the site geologic structure***

  Section 3.5 - paragraphs 1–3

- ***A description of any crustal tilting, subsidence, karst terrain, landsliding, and erosion***

  There is no significant occurrence of these conditions at the site.

- ***A description of the surface and subsurface geologic characteristics of the site and its vicinity***

  Section 3.5 - paragraphs 1–3

- ***A description of the geomorphology of the site***

  Section 3.5 - paragraphs 1–3

- ***A description of the location, attitude, and geometry of all known or inferred faults in the site and vicinity***

  Section 3.5 – paragraph 4 and Figure 3-7

- ***A discussion of the nature and rates of deformation***

  Deformation in the vicinity of the site is negligible.

- ***A description of any man-made geologic features such as mines or quarries***

  Section 3.8 - paragraph 3

- ***A description of the seismicity of the site and region***

  Section 3.5 - paragraph 4 and Figure 3-8

- ***A complete list of all historical earthquakes that have a magnitude of 3 or more, or a modified Mercalli intensity of IV or more within 200 miles of the site***

  Section 3.5 - paragraph 4 and Figure 3-8

III.f. SURFACE WATER HYDROLOGY

- ***A description of site drainage and surrounding watershed fluvial features***

  Section 3.6 - paragraphs 1 and 2

- ***Water resource data, including maps, hydrographs, and stream records from other agencies (e.g., U.S. Geological Survey and U.S. Army Corps of Engineers)***

  Section 3.6 - paragraph 2

- ***Topographic maps of the site that show natural drainages and man-made features***

  Figures 3-5 and 3-9

- ***A description of the surface water bodies at the site and surrounding areas***

  Section 3.6 - paragraph 1

- ***A description of existing and proposed water control structures and diversions (both upstream and downstream) that may influence the site***

  Section 3.6 - paragraphs 3 and 4 (Existing structures are described. There are no proposed structures and diversions.)

- ***Flow-duration data that indicate minimum, maximum, and average historical observations for surface water bodies in the site areas***

  Section 3.6 - paragraphs 1 and 2

- ***Aerial photography and maps of the site and adjacent drainage areas identifying features such as drainage areas, surface gradients, and areas of flooding***

  Figures 3-5 and 3-9

- ***An inventory of all existing and planned surface water users, whose intakes could be adversely affected by migration of radionuclides from the site***

  Section 3.6 – paragraph 2

- ***Topographic and/or aerial photographs that delineate the 100-year floodplain at the site***

Figure 3-9

- ***A description of any man-made changes to the surface water hydrologic system that may influence the potential for flooding at the site***

  No man-made changes have been identified that would influence the potential for flooding at the site.

III.g. GROUNDWATER HYDROLOGY

- ***A description of the saturated zone***

  Section 3.7 - paragraphs 1–4, Figure 3-7

- ***Descriptions of monitoring wells***

  Section 3.7 - paragraph 7

- ***Physical parameters***

  Section 3.7 - paragraphs 1–5, Figure 3-7

- ***A description of groundwater flow directions and velocities***

  Section 3.7 - paragraphs 2, 3, and 5, Figure 3-7

- ***A description of the unsaturated zone***

  Section 3.7 - paragraphs 1–3

- ***Information on all monitor stations including location and depth***

  Section 3.7 - paragraph 7

- ***A description of the numerical analyses techniques used to characterize the unsaturated and saturated zones***

  Section 3.7 - paragraph 2

- ***The distribution coefficients of the radionuclides of interest at the site***

  Section 14.2.2

III.h. NATURAL RESOURCES

- ***A description of the natural resources occurring at or near the site***

  Section 3.8 - paragraphs 1 and 2

- ***A description of potable, agricultural, or industrial ground or surface waters***

  Section 3.8 - paragraphs 1 and 2

- ***A description of economic, marginally economic, or subeconomic known or identified natural resources as defined in U.S. Geological Survey Circular 831***

  Section 3.8 - paragraphs 1 and 2

- ***Mineral, fuel, and hydrocarbon resources near and surrounding the site which, if exploited, would affect the licensee's or responsible party's dose estimates***

  There are no known resources that, if exploited, would affect dose estimates.

IV. RADIOLOGICAL STATUS OF FACILITY

IV.a. CONTAMINATED STRUCTURES

This section is not applicable to the DP. Decommissioning of contaminated structures will be performed under an amendment to the site license. Section 4.1 provides a short description of each of the contaminated structures on the site.

IV.b. CONTAMINATED SYSTEMS AND EQUIPMENT

This section is not applicable to the DP. Section 4.2 indicates that all contaminated systems and equipment are being removed from contaminated building under the current site license.

IV.c. SURFACE SOIL CONTAMINATION

- ***A list or description of all locations at the facility where surface soil contains residual radioactive material in excess of site background levels***

  Sections 4.3 and 4.3.1 (This item also is being addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for surface soil areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

- ***A summary of the background levels used during scoping or characterization surveys***

Section 4.3.1- section on Deul's Mountain (The "Gamma Survey Data Evaluation Report" (Ref. 20), which has been provided as a separate submittal to the NRC, contains information on background levels. This item also was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for surface soil areas.)

- ***A summary of the radionuclides present at each location, the maximum and average radionuclide activities in pCi/gm, and, if multiple radionuclides are present, the radionuclide ratios***

  Sections 4.3.1 and 14.2.2 (Additional information will be provided in the site characterization performed for the Site Remedial Investigation/Feasibility Study for surface soil areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

- ***The maximum and average radiation levels in mrem/hr at each location***

  Section 4.3.1 (The "Gamma Survey Data Evaluation Report" (Ref. 20), which has been provided as a separate submittal to the NRC, contains information on surface soil radiation levels. This item also was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for surface soil areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

- ***A scale drawing or map of the site showing the locations of radionuclide material contamination in surface soil***

  Section 4.3.1 (The "Gamma Survey Data Evaluation Report" (Ref. 20), which has been provided as a separate submittal to the NRC, contains information on locations of surface soil contamination. This item also was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for surface soil areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

IV.d. SUBSURFACE SOIL CONTAMINATION

- ***A list or description of all locations at the facility where subsurface soil contains residual radioactive material in excess of site background levels***

  Sections 4.4, 4.4.1, 4.4.2, and 4.4.3 (This item also was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for subsurface soil areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

- ***A summary of the background levels used during scoping or characterization surveys***

  Section 4.3.1- section on Deul's Mountain (The "Gamma Survey Data Evaluation Report" (Ref. 20), which has been provided as a separate submittal to the NRC, contains information on background levels. This item also was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for subsurface soil areas.)

- ***A summary of the radionuclides present at each location, the maximum and average radionuclide activities in pCi/gm, and, if multiple radionuclides are present, the radionuclide ratios***

  Sections 2.3.1 and 14.2.2 (This item also was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for subsurface soil areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

- ***The depth of the subsurface soil contamination at each location***

  Sections 2.3.1 and 14.2.2 (This item also was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for subsurface soil areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

- ***A scale drawing or map of the site showing the locations of subsurface soil contamination***

  Figures 3.3 and 3.4 (This item also was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for subsurface soil areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

IV.e. SURFACE WATER

- ***A list or description and map of all surface water bodies at the facility that contain residual radioactive material in excess of site background levels***

  Section 4.5 - paragraphs 1 and 2, Figure 3-3

- ***A summary of the background levels used during scoping or characterization surveys***

  This item was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for surface water areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

- ***A summary of the radionuclides present in each surface water body and the maximum and average radionuclide activities in becquerel per liter (Bq/L) (picocuries per liter (pCi/L))***

  This item was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for surface water areas. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.

IV.f. GROUNDWATER

- ***A summary of the aquifer(s) at the facility that contain residual radioactive material in excess of site background levels***

  Section 4.6 - paragraph 1

- ***A summary of the background levels used during scoping or characterization surveys***

  This item was addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for groundwater. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.

- ***A summary of the radionuclides present in each aquifer and the maximum and average radionuclide activities in becquerel per liter (Bq/L) (picocuries per liter (pCi/L))***

  Section 4.6 and Section 1.3 – paragraph 3 (This item also will be addressed in the site characterization performed for the Site Remedial Investigation/Feasibility Study for groundwater.

V. DOSE MODELING

V.a. UNRESTRICTED RELEASE USING SITE-SPECIFIC INFORMATION

- ***Source term information including nuclides of interest, configuration of the source, areal variability of the source***

  Section 5.1.2 provides an overview. Detailed information can be found in Westinghouse's report on "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility" (Ref. 4), which has been provided as a separate submittal to the NRC.

- ***Description of the exposure scenario including a description of the critical group***

  Section 5.1.2 provides an overview. Detailed information can be found in Westinghouse's report on "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility" (Ref. 4), which has been provided as a separate submittal to the NRC.

- ***Description of the conceptual model of the site including the source term, physical features important to modeling the transport pathways, and the critical group***

  Section 5.1.2 provides an overview. Detailed information can be found in Westinghouse's report on "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility" (Ref. 4), which has been provided as a separate submittal to the NRC.

- ***Identification/description of the mathematical model used (e.g., hand calculations, DandD Screen v1.0, RESRAD v5.81)***

  Section 5.1.2 provides an overview. Detailed information can be found in Westinghouse's report on "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility" (Ref. 4), which has been provided as a separate submittal to the NRC.

- ***Description of the parameters used in the analysis***

  Section 5.1.2 provides an overview. Detailed information can be found in Westinghouse's report on "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility" (Ref. 4), which has been provided as a separate submittal to the NRC.

- ***Discussion about the effect of uncertainty on the results.***

  Section 5.1.2 provides an overview. Detailed information can be found in Westinghouse's report on "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility" (Ref. 4), which has been provided as a separate submittal to the NRC.

- ***Input and output files or printouts, if a computer program was used***

  Section 5.1.2 provides an overview. Detailed information can be found in Westinghouse's report on "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility" (Ref. 4), which has been provided as a separate submittal to the NRC.

VI. ENVIRONMENTAL INFORMATION

- ***Environmental information described in NUREG-1748***

  Section 6.0 (The Remedial Investigation/Feasibility Study Work Plan implemented in 2004 includes plans to investigate and evaluate the effects decommissioning might have on wetlands and surface water, threatened and endangered species, and cultural resources.

VII. ALARA ANALYSIS

- ***A description of how the licensee or responsible party will achieve a decommissioning goal below the dose limit***

  Section 7 (An example analysis is provided to estimate whether remediation to satisfy DCGLs proposed in Section 5 would also be as low as reasonably achievable (ALARA). A commitment is made to finalize the analysis when information from the Remedial Investigation/Feasibility Study and related NCP process is available.)

- ***A quantitative cost-benefit analysis***

  Sections 7.2 and 7.3 (An example cost/benefit analysis, which demonstrates the methodology that will be used for the final analysis, is provided.)

- ***A description of how costs were estimated***

  Section 7.3 (An example cost analysis, which demonstrates the methodology that will be used for the final analysis, is provided.)

- ***A demonstration that the doses to the average member of the critical group are ALARA***

  Sections 7.4 and 7.5 (An example analysis, which demonstrates the methodology that will be used for the final analysis, is provided.)

VIII. PLANNED DECOMMISSIONING ACTIVITIES

VIII.a. CONTAMINATED STRUCTURES

This section is not applicable to the DP. Decommissioning of contaminated structures will be performed under an amendment to the site license. The plan for non-contaminated structures, Phase d., will be submitted in a separate amendment request for this DP if it is decided to leave these structures in place.

VIII.b. CONTAMINATED SYSTEMS AND EQUIPMENT

This section is not applicable to the DP. Decommissioning of contaminated systems and equipment is being performed under the current site license.

VIII.c. SOIL

- ***A summary of the removal/remediation tasks planned for surface and subsurface soil at the site in the order in which they will occur including which activities will be conducted by licensee staff and which will be performed by a contractor***

  Section 8.3 (Section 8.3.1- paragraph 2 indicates that activities during the initial phase of soil remediation (Phase a., Outlying Land Areas) will be limited to performing a final status survey of the Class 3 impacted area in accordance with MARSSIM methodology. The plans for subsequent phases will be submitted in separate amendment requests for the DP.)

- ***A description of the techniques that will be employed to remove or remediate surface and subsurface soil at the site***

  Section 8.3 (Section 8.3.1- paragraph 3 indicates that no soil removal will be performed during Phase a. If any soil removal is indicated during Phase a. based on the approved DCGLs, the affected areas will be marked for remediation during Phase c. (surface soil inside the central site tract and perimeter area), following development of soil remediation alternatives under the NCP evaluation process. Techniques that will be used for soil removal will be described in an amendment request for the DP for soil remediation in Phase c.)

- ***A description of the radiation protection methods (such as PPE, or area exit monitoring) and control procedures (such as the use of HEPA vented enclosures during excavation or covering soil piles to prevent wind dispersion) that will be employed during soil removal/remediation.***

  Sections 8.3.1 and 10 (Any additional control procedures will be identified in an amendment request for the DP for soil remediation in Phase c.)

- ***A summary of the procedures already authorized under the existing license and those for which approval is being requested in the decommissioning plan***

  Section 8.3.1 - paragraph 5

- ***A commitment to conduct decommissioning activities in accordance with written, approved procedures***

  Section 8.3.1 - paragraph 6

- ***A summary of any unique safety or remediation issues associated with remediating the soil***

  Section 8.3.2

- ***For Part 70 licensees, a summary of how the licensee will ensure that the risks addressed in the facility's Integrated Safety Analysis will be addressed during decommissioning***

  Section 8.0 – paragraph 4

VIII.d. SURFACE AND GROUNDWATER

Section 8.4 (Plans for remediation of surface water and groundwater will be submitted in separate amendment requests for this DP. Surface water remediation will be performed in Phase c. in conjunction with surface soil remediation. Groundwater remediation will be performed in Phase e.)

VIII.e. SCHEDULES

- ***A Gantt or PERT chart detailing the proposed remediation tasks in the order in which they will occur***

  Section 8.5 - Figure 8-1

- ***A statement acknowledging that the dates in the schedule are contingent on NRC approval of the decommissioning plan***

  Section 8.5

- ***A statement acknowledging that circumstances can change during decommissioning, and, if the licensee determines that the decommissioning cannot be completed as outlined in the schedule, the licensee or responsible party will provide an updated schedule to NRC***

  Section 8.5

- ***If the decommissioning is not expected to be completed within the timeframes outlined in NRC regulations, a request for alternative schedule for completing the decommissioning***

  Section 8.5

IX. PROJECT MANAGEMENT AND ORGANIZATION

IX.a. DECOMMISSIONING MANAGEMENT ORGANIZATION

- ***A description of the decommissioning organization***

  SNM-33 Section 2.1 and 2.2

- ***A description of the responsibilities of each of these decommissioning project units***

  SNM-33 Section 2.1 and 2.2

- ***A description of the reporting hierarchy within the decommissioning project management organization***

  SNM-33 Section 2.1, 2.2 and figure on page 2-30.

- ***A description of the responsibility and authority of each unit to ensure that decommissioning activities are conducted in a safe manner and in accordance with approved written procedures***

  SNM-33 Section 2.1 and 2.2

IX.b. DECOMMISSIONING TASK MANAGEMENT

- ***A description of the manner in which the decommissioning tasks are managed***

  SNM-33 Section 2.2

- ***A description of how individual decommissioning tasks are evaluated and how the Radiation Work Permits (RWPs) are developed for each task***

  Section 10.6.1

- ***A description of how the RWPs are reviewed and approved by the decommissioning project management organization***

  SNM-33 Section 3.1.2

- ***A description of how RWPs are managed throughout the decommissioning project***

  SNM-33 Section 3.1.2 and DP Section 10.6.1

- ***A description of how individuals performing the decommissioning tasks are informed of the procedures in the RWP***

  Section 10.6.1

IX.c. DECOMMISSIONING MANAGEMENT POSITIONS AND QUALIFICATIONS

- ***A description of the duties and responsibilities of each management position in the decommissioning organization and the reporting responsibility of the position***

  SNM-33 Section 2.1 and 2.2

- ***A description of the duties and responsibilities of each chemical, radiological, physical, and occupational safety-related position in the decommissioning organization and the reporting responsibility of each position***

  SNM-33 Section 2.1 and 2.2

- ***A description of the duties and responsibilities of each engineering, quality assurance, and waste management position in the decommissioning organization and the reporting responsibilities of each position***

  SNM-33 Section 2.1 and 2.2

- ***The minimum qualifications for each of the positions described above, and the qualifications of the individuals currently occupying the positions***

  SNM-33 Section 2.1 and 2.2

- ***A description of all decommissioning and safety committees***

  SNM-33 Section 2.5

IX.d. Radiation Safety Officer

- ***A description of the health physics and radiation safety education and experience required for individuals acting as the licensee's or responsible party's RSO***

  SNM-33 Section 2.1.3

- ***A description of the responsibilities and duties of the RSO***

  SNM-33 Section 2.1.3

- *A description of the specific authority of the RSO to implement and manage the licensee's or responsible party's radiation protection program*

  SNM-33 Section 2.1.3

IX.e. TRAINING

- *A description of the radiation safety training that the licensee will provide to each employee*

  SNM-33 Section 2.6

- *A description of any daily worker "jobside" or "tailgate" training that will be provided at the beginning of each workday or job task to familiarize workers with job-specific procedures or safety requirements*

  SNM-33 Section 2.6

- *A description of the documentation that will be maintained to demonstrate that training commitments are being met*

  SNM-33 Section 2.6.6

IX.f. CONTRACTOR SUPPORT

- *A summary of decommissioning tasks that will be performed by contractors*

  SNM-33 Section 2.3

- *A description of the management interfaces that will be in place between the licensee or responsible party's management and on-site supervisors, and contractor management and on-site supervisors*

  SNM-33 Section 2.3

- *A description of the oversight responsibilities and authority that the licensee or responsible party will exercise over contractor personnel*

  SNM-33 Section 2.3

- *A description of the training that will be provided to contractor personnel by the licensee or responsible party, and the training that will be provided by the contractor*

  SNM-33 Section 2.3 and 2.6.5

- *A commitment that the contractor will comply with all radiation safety and license requirements at the facility*

  SNM-33 Section 2.3

X. HEALTH AND SAFETY PROGRAM DURING DECOMMISSIONING: RADIATION SAFETY CONTROLS AND MONITORING FOR WORKERS

X.a. Workplace Sampling Program

- *A description which demonstrates that the air sampling program is representative of the workers' breathing zones*

  Section 10.1

- *A description of the criteria which demonstrates that air samplers with appropriate sensitivities will be used; and that samples will be collected at appropriate frequencies*

  Sections 10.1 and 10.3.2

- *A description of the conditions under which air monitors will be used*

  Sections 10.1 and 10.3.2

- *A description of the criteria used to determine the frequency of calibration of the flow meters on the air samplers*

  Section 10.1

- *A description of the action levels for air sampling results*

  Sections 10.1 and 10.3.2

- *A description of how minimum detectable activities (MDA) for each specific radionuclide that may be collected in air samples are determined*

  Section 10.1 - paragraph 6

X.b. Respiratory Protection Program

- *A description of the process controls, engineering controls, or procedures to control concentrations of radioactive materials in air*

Section 10.2

- ***A description of the evaluation which will be performed when it is not practical to apply engineering controls or procedures***

  Conditions have not been foreseen where engineering controls or procedures could not be employed to minimize personnel radiation exposure.

- ***A description of the considerations used which demonstrates respiratory protection equipment is appropriate for a specific task, based on the guidance on assigned protection factors***

  Section 10.2

- ***A description of the medical screening and fit testing required before workers will use any respirator that is assigned a protection factor***

  Section 10.2

- ***A description of the written procedures maintained to address all the elements of the respiratory protection program***

  Section 10.2

- ***A description of the use, maintenance, and storage of respiratory protection devices***

  Section 10.2

- ***A description of the respiratory equipment users training program***

  Section 10.2

- ***A description of the considerations made when selecting respiratory protection equipment***

  Section 10.2

X.c. Internal Exposure Determination

- ***A description of the monitoring to be performed to determine worker exposure***

  Sections 10.3, 10.3.1, and 10.3.2

- ***A description of how worker intakes are determined using measurements of quantities of radionuclides excreted from, or retained in the human body***

  Section 10.3.1

- ***A description of how worker intakes are determined by measurements of the concentrations of airborne radioactive materials in the workplace***

  Section 10.3.2

- ***A description of how worker intakes for an adult, a minor, and a declared pregnant woman are determined using any combination of the measurements above, as may be necessary***

  Sections 10.3, 10.3.1, and 10.3.2

- ***A description of how worker intakes are converted into committed effective dose equivalent***

  Section 10.3

X.d. External Exposure Determination

- ***A description of the individual-monitoring devices which will be provided to workers***

  Section 10.4 - paragraphs 1 and 2

- ***A description of the type, range, sensitivity, and accuracy of each individual-monitoring device***

  Section 10.4 - paragraph 1 (As determined by the RSO)

- ***A description of the use of extremity and whole body monitors when the external radiation field is non-uniform***

  Section 10.4 - paragraph 3

- ***A description of when audible-alarm dosimeters and pocket dosimeters will be provided***

  Section 10.4 - paragraph 1

- ***A description of how external dose from airborne radioactive material is determined***

  Section 10.4

- *A description of the procedure to insure that surveys necessary to supplement personnel monitoring are performed*

  Section 10.4 - paragraphs 4 and 5

- *A description of the action levels for worker's external exposure, and the technical bases and actions to be taken when they are exceeded*

  Section 10.4 - paragraph 6

X.e. Summation of Internal and External Exposures

- *A description of how the internal and external monitoring results are used to calculate TODE and TEDE doses to occupational workers*

  Section 10.5

- *A description of how internal doses to the embryo/fetus, which is based on the intake of an occupationally-exposed DPW will be determined*

  Section 10.3 - paragraph 2

- *A description of the monitoring of the intake of a DPW, if determined to be necessary*

  Section 10.3 - paragraph 2

- *A description of the program for the preparation, retention, and reporting of records for occupational radiation exposures*

  Section 10.5 - paragraph 2

X.f. Contamination Control Program

- *A description of the written procedures to control access to, and stay time in, contaminated areas by workers, if they are needed*

  Section 10.6.1

- *A description of surveys to supplement personnel monitoring for workers during routine operations, maintenance, clean-up activities, and special operations*

  Section 10.6.2

- ***A description of the surveys which will be performed to determine the baseline of background radiation levels and radioactivity from natural sources for areas where decommissioning activities will take place***

  This item will be addressed during site characterization for the Site Remedial Investigation/Feasibility Study.

- ***A description in matrix or tabular form which describes contamination action limits (that is, actions taken to either decontaminate a person, place, or area, restrict access, or modify the type or frequency of radiological monitoring)***

  Section 10.6.2 (not in matrix or tabular form)

- ***A description (included in the matrix or table mentioned above) of proposed radiological contamination guidelines for specifying and modifying the frequency for each type of survey used to assess the reduction of total contamination***

  Section 10.6.2 (not in matrix or tabular form)

- ***A description of the procedures used to test sealed sources, and to insure that sealed sources are leak tested at appropriate intervals***

  Section 10.6.3

X.g. Instrumentation Program

- ***A description of the instruments to be used to support the health and safety program***

  Section 10.7 and Table 10-1

- ***A description of instrumentation storage, calibration, and maintenance facilities for instruments used in field surveys***

  Section 10.7 - paragraph 2

- ***A description of the method used to estimate the MDC or MDA (at the 95 percent confidence level) for each type of radiation to be detected***

  Section 10.7- paragraph 3

- ***A description of the instrument calibration and quality assurance procedures***

  SNM-33 Section 2.8.5 and DP Sections 10.7.1 and 10.7.2

- ***A description of the methods used to estimate uncertainty bounds for each type of instrumental measurement***

  Section 10.7- paragraph 2

- ***A description of air sampling calibration procedures or a statement that the instruments will be calibrated by an accredited laboratory***

  Section 10.7.1 - paragraph 7

X.h. NUCLEAR CRITICALITY SAFETY

NRC License No. SNM-33, Chapter 4 contains requirements for nuclear criticality safety during decommissioning.

X.i. HEALTH PHYSICS AUDITS, INSPECTIONS AND RECORDKEEPING PROGRAM

- ***A general description of the annual program review conducted by executive management***

  Section 10.9

- ***A description of the records to be maintained of the annual program review and executive audits***

  Section 10.9

- ***A description of the types and frequencies of surveys and audits to be performed by the RSO and RSO staff***

  Section 10.9 (Requirements for annual Project Oversight Committee audits of licensed activities are in Section 2.5 of License No. SNM-33.)

- ***A description of the process used in evaluating and dealing with violations of NRC requirements or license commitments identified during audits***

  Section 10.9

- ***A description of the records maintained of RSO audits***

  Section 10.9

XI. ENVIRONMENTAL MONITORING AND CONTROL PROGRAM

XI.a. ENVIRONMENTAL ALARA EVALUATION PROGRAM

- ***A description of ALARA goals for effluent control***

  Section 11.1

- ***A description of the procedures, engineering controls, and process controls to maintain doses ALARA***

  Section 11.1

- ***A description of the ALARA reviews and reports to management***

  Sections 10.9 and 11.1

XI.b. EFFLUENT MONITORING PROGRAM

- ***A demonstration that background and baseline concentrations of radionuclides in environmental media have been established through appropriate sampling and analysis***

  Section 11.2

- ***A description of the known or expected concentrations of radionuclides in effluents***

  Section 11.2 - Table 11-2

- ***A description of the physical and chemical characteristics of radionuclides in effluents***

  Section 11.2

- ***A summary or diagram of all effluent discharge locations***

  Sections 11.1 and 11.2 - Table 11-1

- ***A demonstration that samples will be representative of actual releases***

  Sections 11.1 and 11.2

- ***A summary of sample collection and analysis procedures***

  Sections 11.1 and 11.2

- ***A summary of the sample collection frequencies***

Sections 11.1 and 11.2

- ***A description of the environmental monitoring recording and reporting procedures***

  Sections 11.1 and 11.2

- ***A description of the quality assurance program to be established and implemented for the effluent monitoring program***

  Section 11.0 – paragraph 2

XI.c. EFFLUENT CONTROL PROGRAM

- ***A description of the controls that will be used to minimize releases of radioactive material to the environment***

  Sections 11.1 and 11.2

- ***A summary of the action levels and description of the actions to be taken should a limit be exceeded***

  Sections 11.1 and 11.2

- ***A description of the leak detection systems for ponds, lagoons, and tanks***

  Such leak detection systems are not required at the site.

- ***A description of the procedures to ensure that releases to sewer systems are controlled and maintained to meet the requirements of 10 CFR 20.2003***

  There are no releases to sewer systems at the site.

- ***A summary of the estimates of doses to the public from effluents and a description of the method used to estimate public dose***

  Section 11.3

XII. RADIOACTIVE WASTE MANAGEMENT PROGRAM

XII.a. SOLID RADIOACTIVE WASTE

- ***A summary of the types of solid radioactive waste that are expected to be generated during decommissioning operations***

Section 12.2

- ***A summary of the estimated volume, in cubic feet, of each solid radwaste type summarized Line a above***

  Section 12.2.1 – paragraph 3

- ***A summary of radionuclides (including the estimated activity of each radionuclide) in each estimated solid radwaste type summarized in Line a above***

  This information will be provided with the waste estimates, as appropriate, in the plans for the subsequent phases of decommissioning work to be submitted as amendment requests for the DP.

- ***A summary of the volumes of Class A, B, C, and greater-than-Class-C solid radwaste that will be generated by decommissioning operations***

  Section 12.2.1 – paragraph 3

- ***A description of how and where each of the solid radwastes summarized Line a above will be stored on site prior to shipment for disposal***

  Sections 12.2 and 12.5

- ***A description of how each of the solid radwastes summarized in Line a above will be treated and packaged to meet disposal site acceptance criteria prior to shipment for disposal***

  Sections 12.2 and 12.5

- ***If appropriate, how the licensee or responsible party intends to manage volumetrically contaminated material***

  Sections 12.2 and 12.5

- ***A description of how the licensee or responsible party will prevent contaminated soil, or other loose solid radioactive waste, from being re-distributed after exhumation and collection***

  Section 12.2.1 – paragraph 2 (Additional information will be provided, as appropriate, in the plans for the subsequent phases of decommissioning work to be submitted as amendment requests for the DP.)

- ***The name and location of the disposal facility that the licensee intends to use for each solid radwaste type summarized in Line a above***

  Section 12.2.1 – paragraph 3

XII.b. LIQUID RADIOACTIVE WASTE

- ***A summary of the types of liquid radwaste that are expected to be generated during decommissioning operations***

  Section 12.3

- ***A summary of the estimated volume, in liters, of each liquid radwaste type summarized in Line a above***

  Section 12.3 – paragraph 3

- ***A summary of the radionuclides (including the estimated activity of each radionuclide) in each liquid radwaste type summarized in Line a above***

  This information will be provided with the waste estimates, as appropriate, in the plans for the subsequent phases of decommissioning work to be submitted as amendment requests for the DP.

- ***A summary of the estimated volumes of Class A, B, C, and Greater-than-Class-C liquid radwaste that will be generated by decommissioning operations***

  Section 12.3 – paragraph 3

- ***A description of how and where each of the liquid radwastes summarized in Line a above will be stored on site prior to shipment for disposal***

  Sections 12.3 and 12.5

- ***A description of how each of the liquid radwastes summarized in Line a above will be treated and packaged to meet disposal site acceptance criteria prior to shipment for disposal***

  Sections 12.3 and 12.5

- ***The name and location of the disposal facility that the licensee intends to use for each liquid radwaste type summarized in Line a above***

  Section 12.3 – paragraph 3

XII.c. MIXED WASTE

- ***A summary of the types of solid and liquid mixed waste that are expected to be generated during decommissioning operations***

  This information will be provided, as appropriate, in the plans for the subsequent phases of decommissioning work to be submitted as amendment requests for the DP.

- ***A summary of the estimated volumes in cubic feet of each solid mixed waste type summarized in Line a above, and in liters for each liquid mixed waste***

  Section 12.4 – paragraph 5

- ***A summary of the radionuclides (including the estimated activity of each radionuclide) in each mixed waste type summarized in Line a above***

  This information will be provided, as appropriate, in the plans for the subsequent phases of decommissioning work to be submitted as amendment requests for the DP.

- ***A summary of the estimated volumes of Class A, B, C, and Greater-than-Class-C mixed waste that will be generated by decommissioning operations***

  Section 12.4 – paragraph 5

- ***A description of how and where each of the mixed wastes summarized in Line a above will be stored on site prior to shipment for disposal***

  Sections 12.4 and 12.5

- ***A description of how each of the mixed wastes summarized in Line a above will be treated and packaged to meet disposal site acceptance criteria prior to shipment for disposal***

  Sections 12.4 and 12.5

- ***The name and location of the disposal facility that the licensee intends to use for each mixed waste type summarized in Line a above***

  Section 12.4 – paragraph 5

- ***A discussion of the requirements of all other regulatory agencies having jurisdiction over the mixed waste***

This information will be provided, as appropriate, in the plans for the subsequent phases of decommissioning work if mixed wastes are found at the site.

- ***A demonstration that the licensee possesses the appropriate EPA or State permits to generate, store, and/or treat the mixed wastes***

  Section 12.4 - paragraph 4

XIII. QUALITY ASSURANCE PROGRAM

XIII.a. ORGANIZATION

- ***A description of the QA program management organization***

  SNM-33 Section 2.8

- ***A description of the duties and responsibilities of each unit within the organization and how delegation of responsibilities is managed within the decommissioning program***

  SNM-33 Section 2.8 (There are no units established within the QA program at Hematite.)

- ***A description of how work performance is evaluated***

  SNM-33 Section 2.8.4 (Work performance is evaluated by surveillance and audits.)

- ***A description of the authority of each unit within the QA program***

  There are no units within the QA program at Hematite.

- ***An organization chart of the QA program organization***

  SNM-33 organization chart on page 2-30

XIII.b. QUALITY ASSURANCE PROGRAM

- ***A commitment that activities affecting the quality of site decommissioning will be subject to the applicable controls of the QA program and activities covered by the QA program are identified on program defining documents***

  SNM-33 Section 2.8

- ***A brief summary of the company's QA policies***

  SNM-33 Section 2.8

- ***A description of provisions to ensure that technical and quality assurance procedures required to implement the QA program are consistent with regulatory, licensing, and QA program requirements and are properly documented and controlled***

  SNM-33 Section 2.8

- ***A description of the management reviews, including the documentation of concurrence in these quality-affecting procedures***

  SNM-33 Section 2.3

- ***A description of the quality-affecting procedural controls of the principal contractors***

  SNM-33 Section 2.3 and 2.8

- ***A description of how NRC will be notified of changes (a) for review and acceptance in the accepted description of the QA program as presented or referenced in the DP before implementation and (b) in organizational elements within 30 days after the announcement of the changes***

  This description is provided in the license amendment to SNM-33, Section 2.8. Organizational changes shall be managed in accordance with Section 2.4 of SNM-33

- ***A description is provided of how management regularly assesses the scope, status, adequacy, and compliance of the QA program***

  SNM-33 Section 2.8.4 (QA program compliance is assessed through surveillance and audit)

- ***A description of the instruction provided to personnel responsible for performing activities affecting quality***

  SNM-33 Section 2.8

- ***A description of the training and qualifications of personnel verifying activities***

  SNM-33 Section 2.8.4

- ***For formal training and qualification programs, documentation includes the objectives and content of the program, attendees, and date of attendance***

  SNM-33 Section 2.6.6 and 2.8

- ***A description of the self-assessment program to confirm that activities affecting quality comply with the QA program***

  SNM-33 Section 2.1.3 and 2.8.4

- ***A commitment that persons performing self-assessment activities are not to have direct responsibilities in the area they are assessing***

  SNM-33 Section 2.8.4 (Persons performing self-assessments are not required to have independence from the areas they are assessing. Audits do require independence of the auditor from the area they are auditing.)

- ***A description of the organizational responsibilities for ensuring that activities affecting quality are (a) prescribed by documented instructions, procedures, and drawings and (b) accomplished through implementation of these documents***

  SNM-33 Section 2.8.1

- ***A description of the procedures to ensure that instructions, procedures, and drawings include quantitative acceptance criteria and qualitative acceptance criteria for determining that important activities have been satisfactorily performed***

  SNM-33 Section 2.8.1

XIII.c. Document Control

- ***A summary of the types of QA documents that are included in the program***

  SNM-33 Section 2.8.2

- ***A description of how the licensee or responsible party develops, issues, revises and retires QA documents***

  SNM-33 Section 2.7 and 2.8.2

XIII.d. Control of Measuring and Test Equipment

- ***A summary of the test and measurement equipment used in the program***

  SNM-33 Section 2.8.5

- ***A description of how and at what frequency the equipment will be calibrated***

This description is provided in Section 2.8.5 of SNM-33 and in Section 3.2.4 of SNM-33 for radioactivity measurement instruments.

- ***A description of the daily calibration checks that will be performed on each piece of test or measurement equipment***

  Section 10.7.1

- ***A description of the documentation that will be maintained to demonstrate that only properly calibrated and maintained equipment was used during the decommissioning***

  SNM-33 Section 2.8.5 and DP Section 10.7.1

XIII.e. Corrective Action

- ***A description of the corrective action procedures for the facility, including a description of how the corrective action is determined to be adequate***

  SNM-33 Section 2.8.7

- ***A description of the documentation maintained for each corrective action and any follow-up activities by the QA organization, after the corrective action is implemented***

  SNM-33 Section 2.8.7

XIII.f. Quality Assurance Records

- ***A description of the manner in which QA records will be managed***

  SNM-33 Section 2.8.3

- ***A description of the responsibilities of the QA organization***

  The responsibilities of the records management organization are provided in SNM-33 Section 2.8.3

- ***A description of the QA records storage facility***

  SNM-33 Section 2.8.3 –(The QA records storage facility is the Westinghouse Electronic Database Management System (EDMS). The description of this system was previously provided in an amendment request to the NRC dated February 3, 2004 from Karen Craig to G. Mike McCann (RIII).

XIII.g. Audits and Surveillances

- ***A description of the audit program***

  SNM-33 Section 2.8.4

- ***A description of the records and documentation generated during the audits and the manner in which the documents are managed***

  SNM-33 Section 2.8.4

- ***A description of all follow-up activities associated with audits or surveillances***

  SNM-33 Section 2.8.4

- ***A description of the trending/tracking that will be performed on the results of audits and surveillances***

  SNM-33 Section 2.8.4

XIV. FACILITY RADIATION SURVEYS

XIV.a. RELEASE CRITERIA

- ***A summary table or list of the DCGLw for each radionuclide and impacted medium of concern***

  Section 1.5 (Additional information can be found in Westinghouse's report on "Derivation of Site-Specific DCGLs for Westinghouse Electric Co. Hematite Facility" (Ref. 4) and the *Hematite Soil Survey Plan* (Ref. 5), which have been provided as separate submittals to the NRC.)

- ***If Class 1 survey units are present, a summary table or list of area factors that will be used for determining a $DCGL_{EMC}$ for each radionuclide and media of concern***

  Section 14.1 (This information can be found in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***If Class 1 survey units are present, the $DCGL_{EMC}$ values for each radionuclide and medium of concern***

  Section 14.1 (This information can be found in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***If multiple radionuclides are present, the appropriate $DCGL_W$ for the survey method to be used***

  Section 14.1 (This information can be found in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

XIV.b. CHARACTERIZATION SURVEYS

- ***A description and justification of the survey measurements for impacted media***

  Section 14.2 (Information on previous characterization efforts is provided. Further information will be provided of the site characterization performed for the Remedial Investigation/Feasibility Study. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

- ***A description of the field instruments and methods that were used for measuring concentrations and the sensitivities of those instruments and methods***

  This information will be provided of the site characterization performed for the Remedial Investigation/Feasibility Study. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.

- ***A description of the laboratory instruments and methods that were used for measuring concentrations and the sensitivities of those instruments and methods***

  This information will be provided upon completion of the site characterization performed for the Remedial Investigation/Feasibility Study. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.

- ***The survey results, including tables or charts of the concentrations of residual radioactivity measured***

  Sections 4.3.1 and 14.2. (Information on previous characterization efforts is provided. Further information is being provided of the site characterization performed for the Remedial Investigation/Feasibility Study. A report from this work, "Westinghouse Hematite Site Radiological Characterization Report," (Ref. 36) has been submitted to the NRC.)

- ***Maps or drawings of the site, area, or building, showing areas classified as non-impacted or impacted***

  Section 4.3 - Figure 4-1

- ***The justification for considering areas to be non-impacted***

  No areas of the site have been designated as non-impacted.

- ***A discussion of why the licensee considers the characterization survey to be adequate to demonstrate that it is unlikely that significant quantities of residual radioactivity have gone undetected***

  Sections 4.3.2 and 14.2 (These sections address this for the outlying land areas. Further information will be provided upon completion of the site characterization that is being performed for the Remedial Investigation/Feasibility Study.)

- ***For areas and surfaces that are inaccessible or not readily accessible, a discussion of how they were surveyed or why they did not need to be surveyed***

  No such areas have been identified for the outlying land areas. If any such areas are identified, they will be addressed in the site characterization performed for the Remedial Investigation/Feasibility Study.

- ***For sites, areas, or buildings with multiple radionuclides, a discussion justifying the ratios of radionuclides that will be assumed in the final status survey or an indication that no fixed ratio exists and each radionuclide will be measured separately***

  This information is provided in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.

XIV.c. REMEDIAL ACTION SUPPORT SURVEYS

- ***A description of the field screening methods and instrumentation***

  Section 14.3.3 (Additional information on soil surveys is provided in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***A demonstration that field screening should be capable of detecting residual radioactivity at the DCGL***

  This is addressed in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.

XIV.d. FINAL STATUS SURVEY DESIGN

- ***A brief overview describing the final status survey design***

  Section 14.4.1

- ***A description and map or drawing of impacted areas of the site, area, or building classified by residual radioactivity levels (Class 1, 2, or 3) and divided into survey units, with an explanation of the basis for division into survey units***

  Section 4.3, Figure 4-1 (A map showing the survey units for the outlying land areas is provided in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***A description of the background reference areas and materials, if they will be used, and a justification for their selection***

  Section 14.4.4 (Additional information on reference areas is provided in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***A summary of the statistical tests that will be used to evaluate the survey results***

  Section14.4.6 (Additional information on statistical tests is provided in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***A description of scanning instruments, methods, calibration, operational checks, coverage, and sensitivity for each media and radionuclide***

  Sections 10.7 and 14.4.3 (Additional information on instruments is provided in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***For in-situ sample measurements made by field instruments, a description of the instruments, calibration, operational checks, sensitivity, and sampling methods, with a demonstration that the instruments, and methods have adequate sensitivity***

  Sections 10.7 and 14.4.3 (Additional information on instruments is provided in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***A description of the analytical instruments for measuring samples in the laboratory, including the calibration, sensitivity, and methodology for evaluation, with a demonstration that the instruments and methods have adequate sensitivity***

  Sections 10.7 and 14.4.3 (Additional information on instruments is provided in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***A description of how the samples to be analyzed in the laboratory will be collected, controlled, and handled***

  Section 14.4.7 (Additional information on soil sample collection is provided in the *Hematite Soil Survey Plan* (Ref. 5), which has been provided as a separate submittal to the NRC.)

- ***A description of the final status survey investigation levels and how they were determined***

  Section 14.4.2

- ***A summary of any significant additional residual radioactivity that was not accounted for during site characterization***

  To be provided in Final Status Survey Report, as described in Section 14.5

- ***A summary of direct measurement results and/or soil concentration levels in units that are comparable to the DCGL, and if data is used to estimate or update the survey unit***

  To be provided in Final Status Survey Report, as described in Section 14.5

- ***A summary of the direct measurements or sample data used to both evaluate the success of remediation and to estimate the survey unit variance***

  To be provided in Final Status Survey Report, as described in Section 14.5

XIV.e. FINAL STATUS SURVEY REPORT

- ***An overview of the results of the final status survey***

  Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

- ***A discussion of any changes that were made in the final survey from what was proposed in the DP or other prior submittals***

  Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

- ***A description of the method by which the number of samples was determined for each survey unit***

Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

- ***A summary of the values used to determine the numbers of sample and a justification for these values***

Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

- ***The survey results for each survey unit include:***

— ***The number of samples taken for the survey unit;***

Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

— ***A map or drawing of the survey unit showing the reference system and random start systematic sample locations for Class 1 and 2 survey units, and random locations shown for Class 3 survey units and reference areas;***

Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

— ***The measured sample concentrations;***

Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

— ***The statistical evaluation of the measured concentrations***

Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

— ***Judgmental and miscellaneous sample data sets reported separately from those samples collected for performing the statistical evaluation;***

Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

— ***A discussion of anomalous data including any areas of elevated direct radiation detected during scanning that exceeded the investigation level or measurement locations in excess of DCGLw; and***

Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

— ***A statement that a given survey unit satisfied the DCGLW and the elevated measurement comparison if any sample points exceeded the DCGLW.***

Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

- ***A description of any changes in initial survey unit assumptions relative to the extent of residual radioactivity***

  Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

- ***If a survey unit fails, a description of the investigation conducted to ascertain the reason for the failure and a discussion of the impact that the failure has on the conclusion that the facility is ready for final radiological surveys***

  Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

- ***If a survey unit fails, a discussion of the impact that the reason for the failure has on the other survey unit information***

  Specification of incorporation of this item in the Final Status Survey Report is provided in Section 14.5.

XV. DECOMMISSIONING FINANCIAL ASSURANCE

XV.a. Cost Estimate

- ***A cost estimate that appears to be based on documented and reasonable assumptions***

  Section 15

XV.b. Certification Statement

- ***The certification statement is based on the licensed possession limits and the applicable quantities specified in 10 CFR 30.35, 40.36, or 70.25***

  Section 15

- ***The licensee is eligible to use a certification of financial assurance and, if eligible, that the certification amount is appropriate***

  Section 15

XV.c. Financial Mechanism

- ***The financial assurance mechanism supplied by the licensee of responsible party consists of one or more of the following instruments:***
  - Trust fund;
  - Escrow account;
  - Government fund;
  - Certificate of deposit;
  - Deposit of government securities;
  - Surety bond;
  - Letter of credit;
  - Line of credit;
  - Insurance policy;
  - Parent company guarantee;
  - Self guarantee;
  - External sinking fund;
  - Statement of intent; or
  - By special arrangements with a government entity assuming custody or ownership of the site.

  Section 15

- ***The financial assurance mechanism is an originally signed duplicate***

  Section 15

- ***The wording of the financial assurance mechanism is identical to the recommended wording provided in Appendix F of this document***

  Section 15

- ***For a licensee regulated under 10 CFR Part 72, a means is identified in the DP for adjusting the financial assurance funding level over any storage and surveillance period***

  Section 15

- ***The amount of financial assurance coverage provided by the licensee for site control and maintenance is at least as great as that calculated using the formula provided in this SRP***

  Section 15

Westinghouse

Derivation of Site Specific DCGLs for Westinghouse Electric Company Hematite Facility

Document #: DO-04-012

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

HEMATITE, MISSOURI

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ACRONYMS & ABBREVIATIONS

ABB	Asea, Brown, and Boveri
ALARA	as low as reasonably achievable
Am-241	americium-241
AEC	Atomic Energy Commission
bgs	below ground surface
cm/sec	centimeters per second
cm^3/g	cubic centimeters per gram
CE	Combustion Engineering Inc.
CFR	code of federal regulations
cm	centimeter
CSM	conceptual site model
CSSG	clayey, silty, sandy-gravel unit
d/yr	days per year
DCGL	derived concentration guideline level
DSCC	deeper, silty clay/clay unit
DSR	dose-to-source ratio
DOE	U.S. Department of Energy
$Dose_{GW}$	dose contribution from groundwater
EPA	U. S. Environmental Protection Agency
EU	enriched uranium
f(p)min	minimum dose related to input parameter
f(p)max	maximum dose related to input parameter
g/cm^3	grams per cubic centimeter
g/m^3	grams per cubic meter
g/yr	grams per year
Gulf	Gulf United Nuclear Fuels Corporation
HEU	highly enriched uranium
hr/d	hours per day
kg/d	kilogram per day
kg/m^2	kilogram per square meter
kg/yr	kilogram per year
K_d	distribution coefficient
LEU	low enriched uranium
L/hr	liters per hour
L/d	liters per day
LBG	Leggette, Brashears, and Graham, Inc.
m	meters
m^2	square meters
m/sec	meters per second
m/yr	meters per year
m^3/hr	cubic meters per hour
m^3/yr	cubic meters per year
MB	mass balance
MDNR	Missouri Department of Natural Resources

ACRONYMS & ABBREVIATIONS (Con't)

mg/d	milli-grams per day
mrem	millirem
mrem/yr	millirem per year
MTR	materials test reactor
NA	not applicable
N/A	not available
ND	non-dispersion
NRC	U. S. Nuclear Regulatory Commission
Np-237	neptunium-237
NSSSC	near surface silt, silty clay unit
pCi/g	picocuries per gram
pCi/L	picocuries per liter
Pu-239	plutonium-239
Ra-228	radium-228
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
SAIC	Science Applications International Corporation
SI	sensitivity index
site	The Westinghouse Electric Co. Hematite site
SNM	special nuclear material
TEDE	total effective dose equivalent
Tc-99	technetium-99
TcO_4	pertechnetate anion
Th-228	thorium-228
Th-232	thorium-232
U	uranium
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2	uranium dioxide
UNC	United Nuclear Corporation
U-234	uranium-234
U-235	uranium-235
U-238	uranium-238
wt%	weight percent

EXECUTIVE SUMMARY

This report presents the derived concentration guideline levels ($DCGL_W$; hereafter referred to as DCGL) for radionuclides of concern that are potentially present in soil at Westinghouse Electric Co. Hematite site (site). DCGLs are derived radionuclide-specific activity concentrations that correspond to the site-wide soil release criteria (or remedial goal).

The site has been impacted by licensed activities and has been in operation since 1956. The plant was primarily used for the manufacturing of uranium metal and uranium compounds for nuclear fuel, using processed and enriched uranium. Numerous research and development activities were also conducted at the site. Because of these past activities, enriched uranium (principally) and technetium may have been released to the soils at the site. Other radionuclides that may be present at the site include americium-241 (Am-241), plutonium-239 (Pu-239), neptunium-237 (Np-237), and thorium-232 (Th-232) in equilibrium with its progeny (i.e., radium-228 (Ra-228), and thorium-228 (Th-228)).

The U.S. Nuclear Regulatory Commission (NRC) is the regulatory licensing authority for the site. The NRC has promulgated a primary limit of 25 mrem total effective dose equivalent (TEDE) in any one year, in excess of natural background, for releasing a radiologically contaminated site. This radiological criterion was used in the derivation of soil DCGLs. As noted in the Decommissioning Plan, Westinghouse has established these DCGLs in accordance with NRC guidance and protocol. Under the NCP process (Ref 4), the approved DCGLs will be included in the consideration of applicable or relevant and appropriate requirements (ARARs) and the establishment of cleanup levels.

The Hematite site has both soil and groundwater residual contamination. In addition, one or more buildings containing some residual contamination might also be left in place. Implementation of the soil DCGLs will involve administrative controls to apportion the 25 mrem/yr 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:

$$H_{Total} = H_{Soil} + H_{GW} + H_{Building} \quad \text{(Equation 5-1)}$$

Where:

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

H_{Soil} = Dose component from soil

H_{GW} = Dose component from groundwater

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

Apportionment of the dose in this manner will have the effect of reducing the "base-case" soil DCGLs in Tables 1 through 4. "Base case" soil DCGLs were derived assuming that all dose (i.e., 25 mrem/yr) results from exposure to surface or volumetric soils (i.e., no contribution from residual contamination on buildings left in place or groundwater). 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.
The operational soil $DCGL_W$ for an individual radionuclide "*i*" is related to the base-case $DCGL_W$ as follows:

$$H_{Soil} = 25 \times \frac{DCGL^i_{OP}}{DCGL^i_{Base}} \qquad \text{(Equation 5-2)}$$

Where:

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

$DCGL^i_{Base}$ = Base-case $DCGL_W$ for radionuclide "*i*" (from Tables 1 through 4)

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

$$DCGL^i_{OP} = \frac{H_{Soil}}{25} \times DCGL^i_{Base} \qquad \text{(Equation 5-3)}$$

In other words, the "operational" DCGLs will be derived for soil after taking into account residual dose from other applicable components (i.e., buildings and groundwater).

Soil DCGLs were derived using dose modeling and the RESRAD code Version 6.21 (Ref 25). In the modeling, a residential farmer was considered as the critical receptor for the site. The resident farmer is assumed to move onto the site after the site was released for unrestricted use. The farmer builds a home and raises crops & livestock on the property for consumption. As a result, the farmer will be exposed to the residual radioactive contamination. Both surface (top 15 cm) and volumetric (0-2 meters) sources were considered during DCGL calculations; however, only the surface or volumetric DCGL will be implemented in any one survey unit to demonstrate compliance with the primary dose limit of 25 mrem/yr.

In the derivation of the soil DCGLs, surface and subsurface dose assessments were performed by using a unit concentration of 1 picocurie per gram (1 pCi/g) for each of the radionuclides of concern. The output of RESRAD "runs" could then be interpreted as an estimate of the dose per unit activity (millirem/year per pCi/g), also called a dose-to-source ratio (DSR). The primary limit was then divided by DSR to yield a DCGL for that radionuclide, in units of pCi/g.

Sensitivity analyses were performed by examining the model input parameters related to intake assumptions for the receptor. The results of the sensitivity analyses showed that the fruits, vegetables, and grain consumption is the most sensitive parameter for most of the radionuclides of concern at the site.

Table ES-1 presents the proposed site-specific soil DCGLs for the radionuclides of concern at the Hematite site. Each DCGL represents a concentration (based on the presented model) that would produce 25 mrem/yr. Note that DCGLs are presented for individual uranium isotopes. These concentrations do not represent realistic soil conditions given that the relative concentration of each uranium isotope is dependent on the degree of enrichment.

Table ES-2 presents an example calculation of the soil DCGLs for total uranium based upon a given degree of enrichment. These calculated values are based on DCGLs presented for NRC approval in ES-1. Given the site's history with enriched uranium, a range of DCGLs is presented to match the range of potential conditions that may be encountered at the site. These total uranium soil DCGLs may be more useful for planning characterization and/or remedial activities. The relative contributions of each uranium isotope to the total uranium DCGL are provided in table ES-2 as well.

TABLE ES-1. Site-Specific, Radionuclide-Specific, Soil DCGLs

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

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

TABLE ES-2. Example Calculation of Site-Specific Soil DCGLs for Uranium, by Enrichment

Isotope	Units	Percent Enrichment				
		0.72%	3.5%	20%	75%	90%
Surface Source DCGL						
Total U(1)	pCi/g	**298**	**338**	**372**	**416**	**427**
U-234(2)		*53.0%*	*78.0%*	*92.0%*	*96.5%*	*97.0%*
U-235(2)		*2.1%*	*4.2%*	*4.9%*	*3.4%*	*3.0%*
U-238(2)		*44.9%*	*17.8%*	*3.1%*	*0.2%*	*0.1%*
Volumetric Source DCGL						
Total U(1)	pCi/g	**148**	**157**	**165**	**173**	**175**
U-234(2)		*53.0%*	*78.0%*	*92.0%*	*96.5%*	*97.0%*
U-235(2)		*2.1%*	*4.2%*	*4.9%*	*3.4%*	*3.0%*
U-238(2)		*44.9%*	*17.8%*	*3.1%*	*0.2%*	*0.1%*

(1) Total uranium (Total U) = sum of individual isotopic concentrations. Each Total U concentration corresponds to 25 mrem/yr.

(2) Relative percent contribution of the isotope to the total U DCGL, taken to one decimal place.

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this report is to calculate derived concentration guideline levels ($DCGL_W$; hereafter referred to as DCGL) for the radionuclides of concern that are potentially present in soil (including sediment) at the Westinghouse Electric Co. Hematite site (site). The DCGLs meet the "radiological criteria for unrestricted use" requirements set forth by the U.S. Nuclear Regulatory Commission (NRC). These criteria can be found in the code of federal regulations (CFR) 10 CFR Part 20.1402 (Ref 15) and state:

> "A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal."

The 25 mrem/yr value is a primary limit. The DCGLs represent remedial goals that, if met, will ensure that the primary limit is satisfied. These are known as secondary or derived limits. As a result, demonstrating compliance with the DCGLs presented in this report would allow release of the site without institutional controls. As noted in the Decommissioning Plan, Westinghouse has established these DCGLs in accordance with NRC guidance and protocol. 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.

1.2 SCOPE

The scope of this document is limited to soils (including sediment) that may have been impacted by licensed activities. This document addressed the following radionuclides of potential concern:

- uranium-234 (U-234),
- uranium-235 (U-235),
- uranium-238 (U-238),
- technetium-99 (Tc-99),
- thorium-232 (Th-232) and progeny,
- americium-241 (Am-241),
- neptunium-237 (Np-237), and
- plutonium-239 (Pu-239).

This report does not address the impact of non-radiological contaminants present at the site nor does it address the derivation of DCGLs for any structures (i.e., non-environmental media) that are present at the site. These issues may be addressed in greater detail in the RI/FS process that is currently ongoing. To the extent possible, this report uses information from available site-specific documents to ensure consistency in the dose models.

RESRAD Version 6.21 (Ref 25) was used during the derivation of DCGLs for each radionuclide of potential concern. RESRAD is a computer code developed at Argonne National Laboratory for the U.S. Department of Energy (DOE) to determine site-specific residual radiation guidelines and dose to a future hypothetical on-site receptor at sites that are contaminated with residual radioactive materials.

2.0 REGULATORY FRAMEWORK FOR DEVELOPMENT OF THE DCGL

The NRC has the regulatory authority over the NRC license issued for the site. The NRC's regulations that are applicable to licensing, license termination, and release of real property with residual radioactive material are contained in the CFR, Title 10, "Energy," Parts 20, 30, 40, 50, 51, and 70. These regulations are ARARs under the NCP process that is currently underway (Ref 4).

The NRC regulations present a performance-based standard that requires the responsible party (licensee) to demonstrate compliance with the primary limit (25 mrem in any one year), from all credible sources and pathways for exposure. In addition, the licensee must demonstrate that potential future doses arising from residual radioactivity at the site have been reduced to levels that are as low as reasonably achievable (ALARA).

3.0 SITE HISTORY AND DESCRIPTION

3.1 SITE HISTORY

In 1955, Mallinckrodt Chemical Works purchased the parcel of farmland on which the Hematite plant resides. The plant became operational in July of 1956, producing uranium for use in the navy nuclear fuel program. Mallinckrodt Chemical Works and its affiliate, Mallinckrodt Nuclear Corporation, operated the facility until May of 1961, at which time ownership was transferred to the United Nuclear Corporation (UNC). UNC provided uranium products to the federal government. Figure 1 illustrates the location of the plant.

In 1970, UNC and Gulf Nuclear Corporation entered into a joint venture, forming Gulf United Nuclear Fuels Corporation (Gulf). Gulf owned and operated the facility until the spring of 1973, when Gulf closed the plant and began decommissioning. The property was conveyed to General Atomic Company in January 1974, and Combustion Engineering Inc. (CE) purchased the property in May of 1974. In 1989, Asea Brown Boveri (ABB) acquired the stock of CE and CE began operating the facility as ABB Combustion Engineering. In April of 2000, Westinghouse Electric Co. purchased the nuclear operations of ABB, which include the Hematite facility, and shortly thereafter initiated the decommissioning process.

Throughout its history, the site's primary function was the manufacture uranium metal and uranium compounds from processed and enriched uranium (EU) for use as nuclear fuel. Specifically, operations included the conversion of uranium hexafluoride (UF_6) gas of various U-235 enrichments to uranium oxide, uranium carbide, uranium dioxide (UO_2) pellets, and uranium metal. From its inception in 1956 through 1974, the facility was used primarily in support of government contracts that required production of EU products. Much of the work on behalf of the government at the site was classified, and therefore specific details regarding the exact nature of the processes are not known.

Examples of known projects during this time include:

- production of uranium metal for nuclear submarines and a D1G destroyer reactor,
- the supply of specialized uranium oxides for the Army Package Power Reactor,
- the supply of high enriched oxides for a General Atomics gas-cooled reactor,
- the production of highly enriched metal for materials test reactors (MTR) utilized by the Navy,
- the supply of uranium-beryllium pellets for use in the "SL-1" reactor,
- the production of high enrichment uranium zirconia pellets for a naval reactor, and
- and the production of highly enriched oxides to General Atomics for use in nuclear rocket projects.

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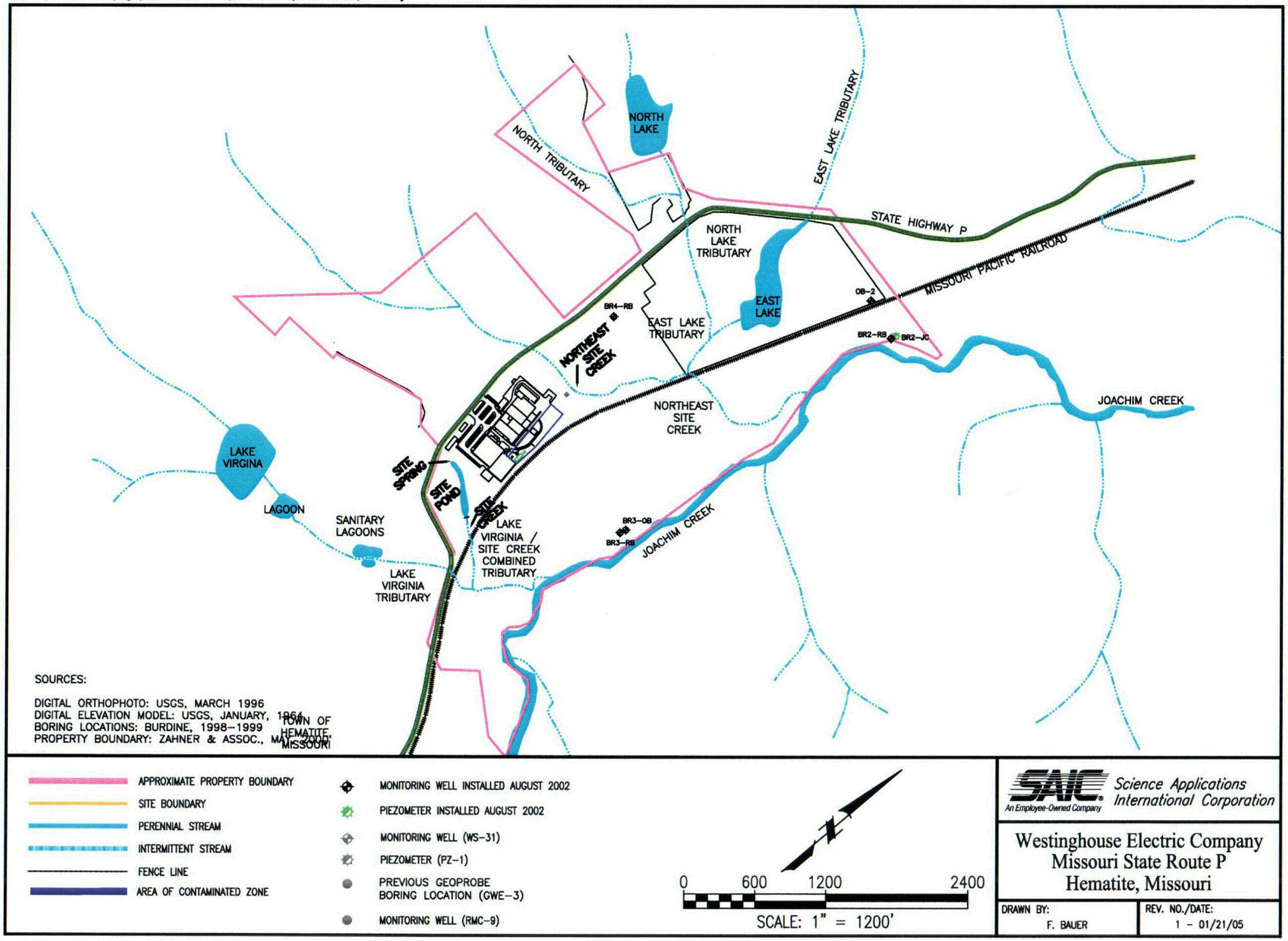

Figure 1. Site Location and Area of Contaminated Zone

C07

These products were manufactured for use by the federal government, government contractors, and by commercial and research reactors approved by the Atomic Energy Commission (AEC). Research and development was also conducted at the plant, as were uranium scrap recovery efforts. From 1974 through the plant closure in 2001, the focus changed from government contracts to commercial fuel production contracts. Although the physical design of the plant has changed over the years, certain areas of the plant were dedicated to particular production processes (i.e., low enrichment processes versus high enrichment processes). For example, Building 240 was historically dedicated to the chemical conversion of uranium into compounds, solutions, and metal.

Building 240 was further divided into areas for highly enriched uranium (HEU) and low enriched uranium (LEU) processes:

- the "Red Room" (Area 240-2) containing HEU conversion processes, and
- the "Green Room" (Area 240-3) containing LEU conversion processes and scrap processing.

The Red Room was specifically used for the reduction of UF_6 to uranium tetrafluoride (UF_4), the conversion of UF_4 to uranium metal, HEU scrap recovery, and other chemical conversion processes using HEU. Building 255 of the plant was used for the fabrication of uranium compounds into physical shapes. Other activities within the plant included the blending of UO_2 with other chemical compounds. Figure 2 presents the locations of the buildings within the plant.

Other areas of the plant were used for storage, and again were separated primarily by degree of enrichment or product stored. HEU storage areas included Buildings 235, 250, and 252. Also, HEU scrap was held in an (outdoor) fenced 75 ft by 120 ft area to the south of the plant.

3.2 PHYSICAL SITE CHARACTERISTICS

3.2.1 Site Specific Bedrock Stratigraphy

In 1956, Mallinckrodt Chemical Company installed an industrial water supply well for the plant. The *Missouri Geological Survey and Water Resources Log* (Ref 14) documents the bedrock stratigraphy encountered by the well. Unconsolidated sediments were present to 35 feet below ground surface (bgs). The Jefferson City-Cotter Dolomite extended from 35 to 125 feet bgs, the Roubidoux Formation from 125 to 255 feet bgs, the Gasconade Formation from 255 to 470 feet bgs, the Gunter Sandstone Member of the Gasconade Formation from 455 to 470 feet bgs and the Eminence Dolomite, from 470 to the total depth of the well, which was 600 feet bgs.

3.2.2 Unconsolidated Sediments (Pleistocene and Quaternary)

The site is positioned in the valley of the Joachim Creek, which has incised the surrounding Cotter and Jefferson City Formations. During late Pleistocene glacial regression, terrace units were deposited in the Joachim Creek valley. These units are chiefly derived from loess and

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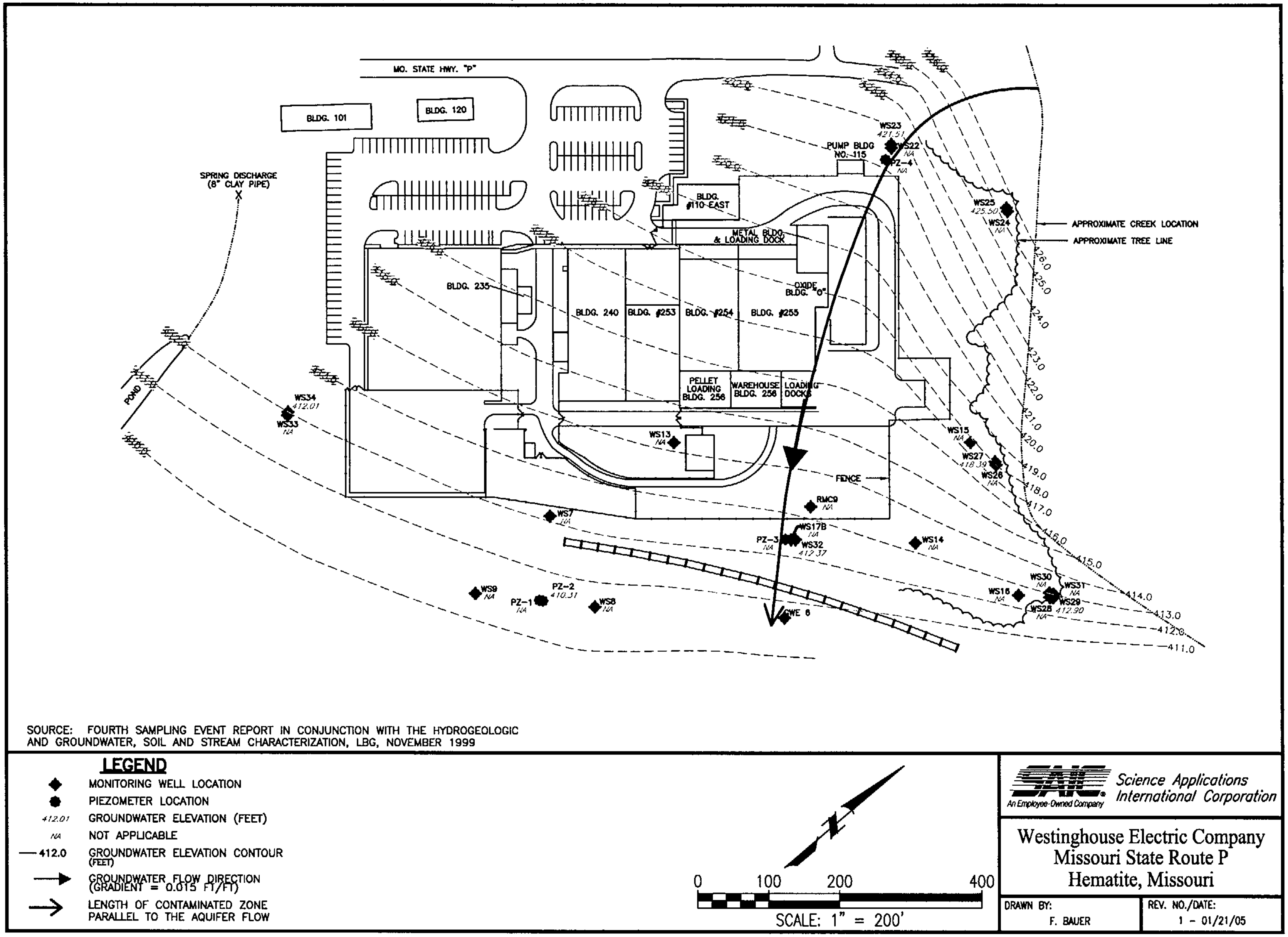

Figure 2. Location of the Buildings, Groundwater Flow and Gradient

colluvium. Later during the Holocene period, alluvium was deposited in the Joachim Creek valley.

A more comprehensive geologic investigation performed by Leggette, Brashears & Graham, Inc., (LBG) provides more site-specific information regarding the unconsolidated subsurface (Ref 8). The study supports the concept of a sand/gravel unit present in the subsurface above the uppermost bedrock unit. Soil collected during the investigation was analyzed for physical properties (i.e., permeability, distribution coefficient, etc.) and/or chemical laboratory parameters. Generally, the geologic information collected during this investigation corroborated geologic data obtained during previous studies.

Specifically, six unique hydrostratigraphic units are located beneath the plant portion of the site:

- a near surface silt, silty-clay (NSSSC),
- a fat clay,
- a deeper, silty clay/clay (DSCC),
- a clayey, silty, sandy-gravel (CSSG) sometimes later in this document is referred to as the sandy-gravel unit,
- The Jefferson City-Cotter Dolomite, and
- The Roubidoux formation.

3.2.3 Regional Bedrock and Geologic Structures

The site is on the north-northeast flank of the Precambrian-age St. Francis Mountains uplift, which created the Ozark Dome. Cambrian, Ordovician, Silurian, Devonian and Mississippian age sedimentary formations of various depositional environments are draped on the flanks of the Ozark Dome. The site is situated over these sedimentary formations. Based upon the *Missouri Geologic Map* (Ref 15) and the *Bedrock Geologic Map of the Festus 7.5 Minute Quadrangle* (Ref 26) the uppermost bedrock beneath the site is the lower Ordovician Canadian series, Jefferson City-Cotter Dolomite.

The Jefferson City-Cotter Dolomite is described as mostly light-brown to medium-brown, medium to finely crystalline dolomite and argillaceous dolomite (Ref 15). Chert, which is not abundant, is typically oolitic, banded, mottled or sandy. Lithologic succession within the formation is complex and varies among locations. The Jefferson City Dolomite typically is 125 to 325 feet thick, and is bounded by the overlying Cotter Formation (also mostly a dolomite), and beneath by the Roubidoux formation that is dominantly a sandy dolomite with lesser beds of dolomitic sandstone and dolomite.

The indurated sedimentary rocks in this area dip gently and uniformly to the north-northeast. There are no mapped or suspected faults within several miles of the site.

3.3 HYDROGEOLOGY, HYDROLOGY AND WATER SUPPLY

3.3.1 Hydrogeology

LBG characterized the near-surface hydrostratigraphic units at the site (Ref 8). In that investigation, two ground-water monitoring wells were installed to provide discrete geologic unit mapping, sampling, and vertical hydraulic gradient information.

As part of LBG's hydrogeologic studies, single-well hydraulic conductivity tests were performed to characterize the horizontal hydraulic conductivity of distinct geologic horizons. From these

tests, the average hydraulic conductivities of the unconsolidated materials above bedrock were found to be 3 x 10^{-5} cm/sec and 8 x 10^{-4} cm/sec for the NSSSC and DSCC units, respectively. Single-well testing of the Jefferson City Dolomite showed a hydraulic conductivity of 8 x 10^{-4} cm/sec. Fracturing and other features causing secondary porosity and permeability in the rock affect the hydrogeologic characteristics of the Jefferson City Dolomite and other bedrock formations. The primary permeability of the bedrock (i.e., through the solid rock matrix) is measured to be low, thus, slow ground-water velocity would be predicted. However, ground water flowing discretely through fractures, partings, or other secondary permeability features may have a much higher velocity. The size, density, and orientation of these fractures and partings determine the effective hydraulic conductivity of the bedrock.

Potentiometric surface (ground-water elevation) maps were constructed for the NSSSC, DSCC, and Jefferson City units to determine groundwater flow direction and horizontal hydraulic gradient. In the NSSSC unit, ground water flows to the northeast and southeast. In the DSCC and Jefferson City units, ground water flows to the southeast. An interim hydrogeologic investigation, performed by LBG during 2002 (Ref 8), shows that the Roubidoux unit also flows in the southeast direction.

3.3.2 Hydrology, Precipitation and Stream Characteristics

The *Missouri Water Atlas* (Ref 16) was referenced to determine local precipitation and stream characteristics. The area receives an average of 38 inches of precipitation per year, with 12 inches of average annual runoff. The maximum 10-day event expected precipitation is 9 inches in a given 25-year event. The Atlas shows that Joachim Creek, located along the southeast site boundary, is a permanent flowing stream. There are several other surface water features present on the site, including a spring, intermittent perennial and ephemeral streams, a lake, and ponds.

3.3.3 Water Supply

Water for the Plant is supplied by a well located north of Building 253, within the fenced manufacturing area. During site operations, up to 36,000 gallons were withdrawn from this well daily. Well water is stored in an elevated 200,000-gallon tank and distributed as needed within the plant, primarily for process water.

According to the *Water Resources Report of the St. Louis Area* (Ref 13), domestic and industrial water wells in the vicinity produce water from the Powell - Gasconade aquifer group. This includes the Jefferson City Dolomite; the uppermost bedrock unit at the site. Wells in the area may penetrate the Jefferson City Dolomite if it is present, but presumably do not derive significant quantities of water from it due to its poor storativity.

There are no public water supply intakes on Joachim Creek. According to an U.S. Environmental Protection Agency (EPA) field investigation report *Preliminary Assessment, Hematite Radioactive Site* (Ref 12), most of the residents of Hematite receive their drinking water from Rural Water District No. 5. The report also states that surface water is not used for drinking within at least a four-mile radius of the site.

4.0 RADIOLOGICAL CHARACTERISTICS OF FEED STOCK AND ENRICHED URANIUM

The mix of radionuclides found in EU is governed by the physical and chemical processes used to produce the EU and by the laws of physics describing radioactive decay. The same physical laws govern the relative concentrations of these radionuclides, making their proportions at a given U-235 mass enrichment known with a reasonable degree of certainty. The EU fuel stock used at the site is known to have come from gaseous diffusion enrichment processes. There is no indication that EU fuel stock derived from other enrichment processes (e.g., centrifuge, laser) was ever used at the site.

In the enrichment process, the smaller U-234 atoms are more readily separated than the heavier U-235 or U-238 atoms. Likewise, U-235 atoms are more readily separated than U-238 atoms. As a result, at a given uranium enrichment, the mass of U-234 will be roughly equal to the mass of U-235 and both should be less than the mass of U-238 that is present.

U-234 has a specific activity (activity per mass, or pCi/g) that is about four orders of magnitude greater that U-238 and U-235, therefore U-234 dominates the total uranium activity concentration for EU. The percent of uranium enrichment reflects the amount of U-235 that is present, and is calculated from the activity concentrations of the uranium isotopes in the fuel mixture.

Typical commercial grade LEU fuel stock was produced at about 3.5% enrichment. HEU with enrichments greater than 90% was used to manufacture special nuclear fuels for the federal government. Thus, a wide range of uranium isotopic ratios might occur on the site, and could vary from one location to another depending upon the deposition source.

Uranium that was recycled from spent nuclear fuel was fed back into the enrichment process at some gaseous diffusion facilities, resulting in the presence of transuranics and Tc-99 (in trace quantities) in the uranium stock used at the site. Quantities of Tc-99 have been detected in some of the environmental monitoring wells at the site.

A review of the characteristics of recycled uranium is provided in the DOE Project Overview and Field Site Reports entitled "A Preliminary Review of the Flow and Characteristics of Recycled Uranium Throughout the DOE Complex 1951-1999". This publication notes that most of the fission products and transuranic isotopes were disposed of as high level waste during spent nuclear fuel reprocessing. It further notes that trace concentrations of Tc-99, Am-241, Pu-239, and Np-237 remained with the recovered uranium. The gaseous diffusion plants (enrichment plants) then blended the recycled uranium with processed uranium, the predominant feed to the gaseous diffusion enrichment process, further diluting any contaminants.

Since Tc-99 forms volatile and semi-volatile chemical compounds that tend to migrate toward the top of the gaseous diffusion cascade, it is reasonable to assume that technetium would tend to end up in the enriched product. Due to their higher atomic weight, Am-241, Pu-239, and Np-237 would generally migrate towards the bottom of the gaseous diffusion cascade along with much of

the U-238. Since uranium at nearly any enrichment contains U-238, there is a potential for Am-241, Pu-239, and Np-237 to be present in the EU used at the Hematite site.
Enriched product, such as 3.5 wt% of U-235 that is likely to be encountered at the site, would tend to favor the lower mass isotopes (i.e. Tc-99). Tc-99 is a low energy beta emitter and is found in the environment primarily as the pertechnetate anion (TcO_4). This form is highly water soluble and mobile in soil and groundwater (Ref 10).

In addition, a limited amount of work was performed with thorium compounds as part of early research into the use of thorium in the fuel cycle. Any thorium present at the site is assumed to be derived from naturally occurring Th-232 in secular equilibrium with its progeny.

Am-241, Pu-239, Np-237, and Th-232 are all alpha and gamma radiation emitters and are heavy metals that would behave similar to EU in the environment. These radionuclides are expected to be at concentrations that are insignificant to the uranium concentrations found at the site.

5.0 DEVELOPMENT OF THE DERIVED CONCENTRATION GUIDELINE LEVELS

5.1 SELECTION OF THE ANNUAL PUBLIC DOSE LIMIT

The annual dose limit for the site corresponds to the radiological criteria for unrestricted use given in 10 CFR Part 20.1402 as described in Sections 1.1 and 2.1 of this report.

5.2 CONCEPTUAL SITE MODEL

The conceptual site model (CSM) identifies the relationship between the sources of contamination, source areas, transport mechanisms, exposure routes, and the receptor. The CSM provides a description of how contaminants enter into the environment, how they are transported within the environment, and the routes of exposures to humans. Figure 3 illustrates the CSM for residual soil contamination at the site.

The residual radioactive material in this CSM is defined as contaminated soil subdivided into a surface source (top 15 cm) and a volumetric source (0-2 meters). The surface source conservatively represents the most likely contaminant geometry across the site assuming most contamination, if any, was distributed through stack emissions. The volume source represents potential smaller portions of the site where contamination extends beyond the first several centimeters of soil. Environmental pathways include external gamma radiation, inhalation of suspended dust, ingestion of impacted flora and fauna, ingestion of impacted groundwater, and ingestion of contaminated soil. Note that RESRAD models migration of contaminants into groundwater and subsequent dispersal though water dependent pathways. This modeling component is included in soil DCGL calculations. Specific exposure pathways include external gamma, inhalation, and ingestion although, as noted, the ingestion pathway includes multiple routes. The critical receptor for the site is a subsistence (resident) farmer. This receptor incurs a radiological dose from all complete exposure pathways and is the subject of DCGL calculations. The following sections of the report provide additional details on the critical receptor and the exposure pathways modeled by the RESRAD code.

5.2.1 Selection of Critical Receptor Scenario

NRC guidance document *Decision Methods for DOE Assessment to Comply with Radiological Criteria for License Termination* (Ref 18) recommends the use of a residential farmer scenario as the basis for the DCGLs for residual contamination in site-wide soils. This scenario was utilized for the soil DCGL derivations for surface and volumetric soils. Under the scenario, a resident is assumed to move onto the site after it has been released for use without radiological restrictions, builds a home, and raises crops and livestock for consumption. Appendix A presents the scenario-specific RESRAD parameters used in the DCGL calculations.

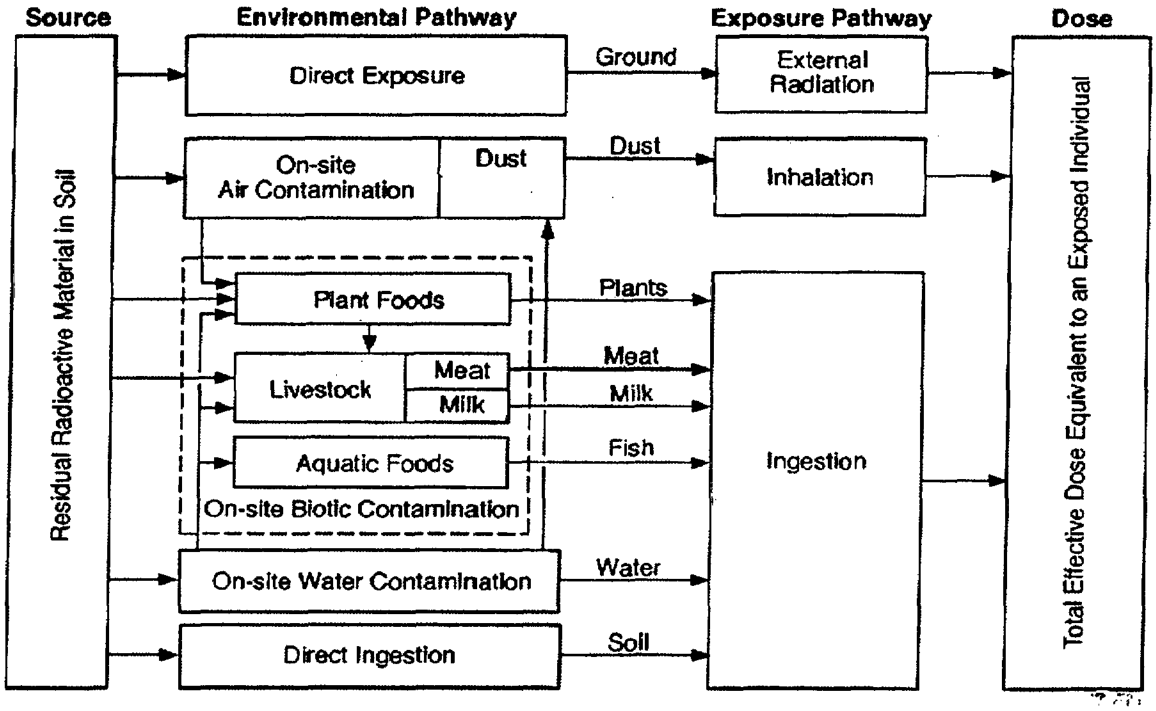

Figure 3. Conceptual Site Model for Hematite Facility Soils (Ref 2)

5.2.2 Selection of Exposure Pathways

The resident farmer may be exposed to radioactive contamination through several exposure pathways relative to site soils. Members of the resident farmer critical group can incur a radiation dose via the following pathways:

(1) Direct radiation from radionuclides in the soil,
(2) Inhalation of resuspended dust (if the contaminated area is exposed at the ground surface),
(3) Ingestion of food from crops grown in contaminated soil,
(4) Ingestion of milk from livestock raised in the contaminated area,
(5) Ingestion of fish from a nearby pond contaminated by water percolated through the contaminated area,
(6) Ingestion of meat from livestock raised in the contaminated area,
(7) Ingestion of water from a well contaminated by water percolated through the contaminated zone, and
(8) Direct ingestion of contaminated soil.

Radium-226 (the parent of radon-222) is not a radionuclide of concern due to licensed activities at the site. The NRC's radiological criteria for unrestricted use specifies that radioactivity that is distinguishable from background is to be considered in the 25 mrem/yr primary limit. Since radon may be present at some concentration from natural background, but should not be present due to licensed activities, exposure due to radon was not considered for the site.

5.3 RECOMMENDED VALUES FOR RESRAD PARAMETERS

The following hierarchy was implemented in selecting the RESRAD input parameters presented in Appendix A. In general, the preference was to use site-specific information first, followed by NRC recommended values, EPA recommended values, and finally RESRAD defaults:

(1) First Preference – Site Specific Parameter: Site-specific information is the first preference for selection of values for RESRAD input parameters. The following two site-related documents were used during the selection process.

   a. *Site-Specific Soil Parameters Westinghouse Former Fuel Cycle Facility D & D Project.* (Ref 10)

   b. *Determination of Distribution Coefficients for Radionuclides of Concern at the Westinghouse Hematite Facility.* (Ref 24)

(2) Second Preference – NRC Documents: When site-specific data is not available, the values provided in NRC documents were chosen for the RESRAD input parameters. Between the three applicable NRC documents, NUREG/CR-5512 (Ref 20) defines the residential farmer scenario, and was given first preference. The remaining documents define the values for a residential scenario.

a. *Comparison of the Models and Assumptions used in DandD 1.0, RESRAD 5.61, and RESRAD-Build 1.50 Computer Codes with Respect to the Resident Farmer and Industrial Occupant Scenarios*; NUREG/CR-5512 Volume 4 (Ref 20)

b. *Residual Radioactive Contamination From Decommissioning - Parameter Analysis, Draft Report for Comments*; NUREG/CR-5512 Volume 3 (Ref 21)

c. *Residual Radioactive Contamination From Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent* NUREG/CR-5512 Volume 1 (Ref 18)

d. *Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes* NUREG/CR-6697 (Ref 22).

(3) Third Preference – EPA's Guidance documents: The following EPA documents were mainly used for comparison purposes and for selection of conservative values for intake parameters.

a. *Soil Screening Guidance Document for Radionuclides: User's Guide* (Ref 6)

b. *Exposure Factors Handbook* (Ref 5).

(4) Fourth Preference – RESRAD Default: When no site-specific, NRC, and EPA values for the RESRAD parameters is available, the following document was used for selection of RESRAD default values:

Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil, Environmental Assessment and Information Sciences Division, Argonne National Laboratory (Ref 1).

There was one exception to this hierarchy. The NUREG/CR-5512 (Ref 20) value of 18.3 g/yr for the resident adult soil ingestion rate was conservatively replaced with the EPA's assigned value of 36.5 g/yr. This is supported by the fact that the EPA lists a value of 18.3 g/yr for an adult in an industrial worker scenario (Ref 5).

5.4 METHODOLOGY TO DETERMINE DCGLS

The RESRAD model was used to calculate soil DCGLs from exposure to direct and indirect pathways. Direct pathways include soil ingestion, dust inhalation and external gamma. Indirect pathways include flora and fauna ingestion and water dependent pathways (e.g., groundwater ingestion and use of groundwater for irrigation). The dose from all complete exposure pathways

was included in soil DCGLs. The Hematite site has both soil and groundwater residual contamination. In addition, one or more buildings containing some residual contamination might also be left in place. Implementation of the soil DCGLs will involve administrative controls to apportion the 25 mrem/yr 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:

$$H_{Total} = H_{Soil} + H_{GW} + H_{Building} \quad \text{(Equation 5-1)}$$

Where:

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

H_{Soil} = Dose component from soil

H_{GW} = Dose component from groundwater

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

Apportionment of the dose in this manner will have the effect of reducing the "base-case" soil DCGLs in Tables 1 through 4. 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.

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

$$H_{Soil} = 25 \times \frac{DCGL^i_{OP}}{DCGL^i_{Base}} \quad \text{(Equation 5-2)}$$

Where:

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

$DCGL^i_{Base}$ = Base-case $DCGL_W$ for radionuclide "*i*" (from Tables 1 through 4)

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

$$DCGL^i_{OP} = \frac{H_{Soil}}{25} \times DCGL^i_{Base} \quad \text{(Equation 5-3)}$$

5.4.1 Dose Due to Groundwater Contamination

The dose contribution from groundwater contamination was estimated as part of the soils DCGL derivation using the RESRAD's soil-to-groundwater transport model. This method considers groundwater-related exposures as indirect exposure pathways. Direct calculations of groundwater impacts will be considered as described above in Section 5.4. In addition, the background concentrations for those radionuclides that are also present in nature have not been established. Groundwater sampling and the collection of natural background data will be conducted at the site during the Remedial Investigation (RI, Ref 9).

5.4.2 Determination of Site-Specific Soil DCGLs

RESRAD 6.21 (Ref 25) was used to perform the dose assessments for both the surface and volumetric soil sources. Both surface (top 15 cm) and volumetric (0-2 meters) sources were considered during DCGL calculations; however, only the surface or volumetric DCGL will be implemented in any one survey unit to demonstrate compliance with the primary dose limit of 25 mrem/yr. The actual fractional concentrations of the radionuclides of concern for the site are not currently available. Therefore, a unit concentration of each radionuclide of concern (1 pCi/g) along with the recommended model input parameters provided in Appendix A were used during the dose assessments. The dose resulting from a unit concentration for a given radionuclide is defined as the dose-to-source ratio (DSR) The maximum DSR (in units mrem/yr per pCi/g) over the 1000-year evaluation period for each radionuclide of concern was then divided into the 25 mrem/yr primary limit to determine the soil DCGLs. Appendix B presents the results of the surface soil RESRAD "run" for Am-241, Np-237, Pu-239, Th-232 and its progeny, Tc-99 and uranium isotopes. Appendix C presents the RESRAD "run" for the volumetric source term.
Table 1 lists the surface soil DCGLs for individual radionuclides. All radionuclides except Np-237 produce a maximum dose at year zero. Neptunium produces a maximum dose at year 100 due to the water dependent pathways (groundwater ingestion, fish ingestion, etc.), because the distribution coefficient of 2 cm^3/g allows for rapid migration of soil contaminants to groundwater. Without the water dependent pathways, the neptunium DCGL would be approximately 13 pCi/g with the maximum dose occurring at year zero. Note also that DCGLs are presented for individual uranium isotopes. These concentrations do not represent realistic soil conditions given that the relative concentration of each isotope is dependent on the enrichment.

Table 2 presents an example of calculated total uranium DCGLs, given a range of enrichments. These calculated values are based on isotopic uranium DCGLs presented for NRC approval in Table 1. Soils found to be contaminated at this total uranium concentration would produce a dose of 25 mrem/yr. These total uranium DCGLs may be more useful for planning future characterization and/or remedial activities, if necessary.

All uranium isotopes produced a maximum dose at year zero, thus all total uranium surface DCGLs listed in Table 2 are also for year zero. Total uranium results indicate that the DCGLs are smaller (more restrictive) for lower enrichments, noting that 0.72% represents natural uranium. Assuming a single total uranium enrichment is desirable, the 338 pCi/g value for 3.5% enrichment is conservative and reasonable given the site's operational history.

Table 1. Determination of Single-Nuclide Surface Soil DCGLs

Radionuclides of Concern	Dose-to-source Ratio (mrem/yr per pCi/g)	Year of Maximum dose	Surface Soil DCGLs (pCi/g)
Am-241	2.136E-01	0	117
Np-237+D	1.834E+01	100	1.4
Pu-239	1.932E-01	0	129
Tc-99	1.790E-01	0	140
Th-232+C	8.569E+00	0	2.9
U-234	4.825E-02	0	518
U-235+D	3.940E-01	0	63
U-238+D	1.116E-01	0	224

Notes:
"+D" = plus short-lived decay products
"+C" = plus entire decay chain (Th-232 assumed to be in equilibrium with Ra-228+D and Th-228+D)
DCGL = 25 mrem/yr divided by the dose-to-source ratio
Np-237 DCGL at year zero = 12.7 pCi/g

Table 2. Example Uranium Surface Soil DCGLs by Enrichment

Isotope	Units	Percent Enrichment				
		0.72%	3.5%	20%	75%	90%
U-234	[redacted]	*53.0%*	*78.0%*	*92.0%*	*96.5%*	*97.0%*
U-235	[redacted]	*2.1%*	*4.2%*	*4.9%*	*3.4%*	*3.0%*
U-238	[redacted]	*44.9%*	*17.8%*	*3.1%*	*0.2%*	*0.1%*
Total U	**pCi/g**	**298**	**338**	**372**	**416**	**427**

Table 3 lists the volumetric soil DCGLs for individual radionuclides. All radionuclides except Np-237 and U-235 produce a maximum dose at year zero. Neptunium produces a maximum dose at year 100 due to the water dependent pathways (groundwater ingestion, fish ingestion, etc.) likely because the distribution coefficient of 2 cm^3/g allows for rapid migration of soil contaminants to groundwater. Without the water-dependent pathways the neptunium DCGL would be approximately 2.0 pCi/g with the maximum dose occurring at year zero. Uranium-235 produces a maximum dose at 1000 years. As with Np-237, U-235 would also produce a maximum dose at year zero without the water-dependent pathway. The corresponding year-zero DCGL for U-235 would be approximately 52 pCi/g. The DCGL for U-235 being submitted for NRC approval (i.e., 35 pCi/g) is based on dose in year 1000.

As with the surface soil DCGLs, Table 4 presents an example of calculated total uranium DCGLs given a range of enrichments. Volumetric DCGLs listed in Table 4 are based on dose in year zero.

In addition to the U-235 producing a maximum dose at year 1000, the combination of all uranium isotopes also produces a maximum dose at year 1000, regardless of enrichment. Therefore, all total uranium volumetric DCGLs listed in Table 4 are also for year 1000. As with surface soils, the total uranium results indicate that the DCGLs are more restrictive for lower enrichments. Assuming a single total uranium enrichment is desirable, the 157 pCi/g value for 3.5% enrichment is conservative and reasonable given the site's operational history.

Table 3. Determination of Single-Nuclide Volumetric Soil DCGLs

Radionuclides of Concern	Dose-to-source Ratio (mrem/yr per pCi/g)	Year of Maximum dose	Subsurface Soil DCGLs (pCi/g)
Am-241	6.188E-01	0	40
Np-237+D	2.371E+02	100	0.11
Pu-239	5.877E-01	0	43
Tc-99	1.082E+00	0	23
Th-232+C	1.704E+01	0	1.5
U-234	1.327E-01	0	188
U-235+D	7.166E-01	1000	35
U-238+D	1.972E-01	0	127

Notes:
"+D" = plus short-lived decay products
"+C" = plus entire decay chain (Th-232 assumed to be in equilibrium with Ra-228+D and Th-228+D)
DCGL = 25 mrem/yr divided by the dose-to-source ratio
Np-237 DCGL at year zero = 2.01 pCi/g
U-235 DCGL at year zero = 51.8 pCi/g

Table 4. Example Uranium Volumetric Soil DCGLs by Enrichment

Isotope	Units	Percent Enrichment				
		0.72%	**3.5%**	**20%**	**75%**	**90%**
U-234	[redacted]	*53.0%*	*78.0%*	*92.0%*	*96.5%*	*97.0%*
U-235	[redacted]	*2.1%*	*4.2%*	*4.9%*	*3.4%*	*3.0%*
U-238	[redacted]	*44.9%*	*17.8%*	*3.1%*	*0.2%*	*0.1%*
Total U	**pCi/g**	**148**	**157**	**165**	**173**	**175**

The DCGLs for surface soil range from approximately two to twelve times the volumetric values. This is primarily due to the thickness of the modeled contamination zone in combination with two other factors. First, produce ingestion is a major pathway for almost all radionuclides, but the modeled root depth of 0.9 m extends well beyond the surface soil contamination zone of 0.15 m (see Appendices B and C). This limits the plant intake of contamination and the subsequent receptor dose. The volumetric source extends beyond the root depth thus plant uptake is maximized. Second, the erosion rate of 0.0006 m/yr assures that the 0.15 m surface soil contaminated zone is completely eroded in 250 years. There is still 1.4 m of the volumetric source left after 1000 years. In spite of these differences, the DCGLs were derived based on the CSM and still conservatively represent the defined source geometries.

Three outstanding issues may prompt a revision to the "operational" soil DCGL values (see Section 5.4) at some point during the project. These issues are briefly summarized as follows:

When the groundwater data and natural background data become available, a dose assessment should be performed to assess the contribution from known groundwater contamination (if any, due to licensed activities), and the "operational" soils DCGL values will be revised, if needed.
If impacted buildings are left in place, characterization of the residual surface and/or volumetric contamination present in the buildings will need to be conducted and a dose assessment performed to assess the dose contribution of residual contamination from buildings (if any, due to licensed activities), and the "operational" soils DCGL values will be revised, if needed.

1. The very low DCGL anticipated for Np-237 may necessitate the use of advanced laboratory analytical techniques to demonstrate compliance. Np-237 is only a potential trace contaminant in EU, and may not be present at all in site soils. NUREG-1757 Section 3.3 (Ref 23) may be used to evaluate the dose contribution from Np-237 and other radionuclides present in trace quantities. If relevant criteria are met, and following regulator concurrence, Np-237 and/or other trace contaminants may be eliminated from further survey, sampling, and evaluation efforts. The dose contribution from these trace contaminants will still need to be accounted for, therefore the soils DCGLs will need to account for the dose contribution from these trace radionuclides.

5.5 SENSITIVITY ANALYSIS

A sensitivity analysis was performed for each radionuclide of concern using the RESRAD sensitivity graphic utility on input parameters related to intake assumptions for the receptors. The following intake parameters were selected for the sensitivity analyses:

(1) Inhalation Rate,
(2) Fruits, Vegetables, and Grains Consumption,
(3) Leafy Vegetables Consumption,
(4) Milk Consumption,
(5) Meat and Poultry Consumption,
(6) Fish Consumption,
(7) Soil Ingestion Rate, and
(8) Drinking Water Intake.

The RESRAD sensitivity utility operates by both reducing and increasing the selected input parameter by a common factor. During the sensitivity analyses, the common factor was selected in such a way that the maximum and minimum value related to the parameter includes the uncertainty range associated with the parameter. For parameters for which there is no uncertainty range, a common factor of two was used. The dose was then calculated for each perturbed parameter value. The output, including dose with the parameter unperturbed, dose with parameter reduced, and dose with parameter increased, was graphically displayed with time as the independent variable. A sensitivity index (SI) was calculated to determine which parameters have the greatest influence on the calculated DCGLs by using the following formula.

$$SI = 1 - (f(p)_{min} / f(p)_{max}),$$

where f(p) are the minimum and maximum dose resulted due to increased and reduced value related to certain intake parameter.

Sensitivity analyses were performed for both surface soil and volumetric soil by using a unit concentration of 1 pCi/g for each radionuclide of concern. Table 5 presents the results of the sensitivity analysis for radionuclide specific intake parameters. The table presents the average sensitivity index, determined based on the dose results examined over a 1000-year period. A positive value of the sensitivity index indicates that the DCGL is directly proportional to the parameter of interest, whereas a negative value indicates the DCGL is inversely proportional to the parameter of interest. A value of < 0.01 indicates that the DCGL is independent of the parameter. The higher the value of SI, the more sensitive is the intake value. A SI value of greater than 10% was used in the selection of the most sensitive parameters.

The results of the sensitivity analysis summarized in Table 5 shows that the fruits, vegetables, and grain consumptions is the most sensitive intake parameter for most of the radionuclides of concern. Drinking water intake, leafy vegetable consumption, and soil ingestion intake parameters are also sensitive for some radionuclides. However, inhalation, meat and poultry consumption, and fish consumption are the least sensitive intake parameters for all radionuclides. Milk consumption is sensitive to Tc-99 and uranium isotopes. Conservative values were assigned for the intake parameters that are most sensitive to the radionuclides of concern under current site conditions.

TABLE 5. SENSITIVITY INDICES FOR RECEPTOR INTAKE PARAMETERS

Intake/Analytes	Soil	Radionuclides of Concern (Unit is unitless)							
		Am-241	**Np-237**	**Pu-239**	**Tc-99**	**Th-232 +D**	**U-234**	**U-235**	**U-238**
Inhalation	Surface	NS	NS	0.01	NS	NS	0.02	NS	NS
	Volume	NS	NS	NS	NS	NS	NS	NS	NS
Fruits, vegetable, and grain consumption	Surface	**0.41**	**0.39**	**0.44**	**0.79**	**0.24**	**0.45**	0.08	**0.21**
	Volumetric	**0.74**	**0.45**	**0.75**	**0.4**	**0.58**	**0.68**	**0.34**	**0.54**
Leafy vegetable consumption	Surface	0.08	**0.11**	0.09	**0.19**	0.03	0.07	0.02	0.03
	Volumetric	**0.17**	**0.13**	**0.17**	**0.12**	**0.11**	**0.15**	0.06	0.1
Milk consumption	Surface	NS	0.02	NS	**0.14**	0.05	**0.45**	0.05	**0.2**
	Volumetric	NS	NS	NS	0.10	0.08	**0.23**	0.06	**0.16**
Meat and poultry consumption	Surface	0.03	0.04	0.07	NS	0.01	0.09	0.01	0.04
	Volumetric	0.01	0.02	0.03	0.01	0.01	0.04	0.02	0.02
Fish consumption	Surface	0.02	0.04	0.01	NS	NS	NS	0.01	0.02
	Volumetric	NS	0.05	NS	0.05	NS	NS	NS	NS
Soil Ingestion	Surface	**0.37**	0.03	**0.4**	NS	0.02	**0.21**	0.02	0.08
	Volumetric	**0.21**	NS	**0.22**	NS	0.01	0.08	0.02	0.05
Drinking water intake	Surface	**0.13**	**0.32**	**0.12**	NS	NS	NS	**0.12**	0.02
	Volumetric	NS	**0.3**	NS	**0.43**	NS	0.03	0.04	0.03

NS = Not Significant (S.I. value less than 0.01).

6.0 UNCERTAINTY ANALYSIS

6.1 TYPES OF UNCERTAINTY

Uncertainty is inherent in all dose and risk assessment calculations and should be considered in determining whether a selected DCGL concentration will satisfy the regulatory decision-making criteria. In general, there are three primary sources of uncertainty in a dose/risk assessment (Ref 3). The following sections explain each of the source of uncertainty, and summarize how the project handled the associated uncertainties.

6.1.1 Uncertainty in the models

A number of computer software models are available to characterize the site-specific fate and transport mechanisms of contaminants in the environment, and to assess the residual dose presented by contamination from licensed activities at the site. Models are simplifications of reality, and in general, are not able to fully characterize the physical condition of the site. During this project, the RESRAD code is used for estimating the dose to human receptors from exposure to soil contaminated with residual radioactivity. The DOE and NRC have approved the use of RESRAD for dose evaluation and waste disposal at licensed nuclear facilities. The EPA also used the code in rule making for sites contaminated with radioactivity. Therefore, the uncertainty associated with the RESRAD model is considered to be acceptable.

6.1.2 Uncertainty in the scenario

Uncertainty in scenarios is the result of lack of absolute knowledge about the future uses of the site. Based on NRC regulatory guidance and recommendations, a residential farmer scenario was chosen for determining the soil DCGLs at the site. This is the most conservative receptor scenario. However, it is important to recognize that the model evaluation time period (next 1000 years) is not intended to predict the future scenarios in these 1000 years. It is intended to evaluate the continued protectiveness of a given DCGL for 1000 years into the future given the reasonable and plausible future uses of the site in today's social and economic conditions. Since the residential farmer scenario is considered the most conservative scenario, the uncertainty associated with this scenario is considered to be acceptable.

6.1.3 Uncertainty in the parameters

Uncertainty in parameters was limited by using, whenever possible, site-specific values. However, there are no site-specific values for many of the parameters, thus conservative NRC/EPA reference values were used to assure that doses would be over rather than underestimated. The selection of prudently conservative parameters was conducted based on the hierarchy presented in Section 5.3 and was designed to utilize broadly accepted values while adhering to the CSM and particular nuances of the RESRAD code. Because of the established hierarchy and tendency toward prudently conservative parameters values that tend to overestimate doses, the uncertainties associated with parameter selection is considered to be acceptable.

RESRAD allows users to consider parameters as point estimates (deterministic) or as distributions (probabilistic). A sensitivity analysis on point estimate values may be used to determine which parameters have the largest impact on dose results. This analysis was performed as described in Section 5. Knowledge of sensitivity analysis results helps modelers limit uncertainty by focusing on the most sensitive parameters, if possible. When the probabilistic module is used, modelers can represent parameters as distributions (e.g., with a mean and standard deviation) to limit the conservatism in using NRC/EPA reference values. In some cases there is sufficient site-specific data to utilize the probabilistic module, or NRC default definitions can be used. In either case, the selection of probabilistic inputs can limit uncertainty assuming those inputs are representative of site conditions. If a probabilistic module is populated with default distributions the uncertainty may or may not be reduced depending on the overlap of modeled versus actual conditions.

DCGLs for the Hematite site were calculated using the deterministic and not the probabilistic approach. However, Appendix E presents (for reference) probabilistic parameters along with the selected deterministic values. Potential probabilistic parameter values were selected from available site-specific and literature values are follows:

(1) First Preference: Site-Specific Information. If site-specific sampling information is available, the minimum and maximum sampling results for that parameter were defined as the uncertainty range.
(2) Second Preference: NRC Documents. NUREG/CR-6697 (Ref 22) assigned values for uncertainty ranges for most of the RESRAD parameters under a residential scenario. When site-specific values were not available, values defined in NUREG/CR-6697 were used. NUREG/CR-5512 assigned values were also chosen for parameters that are directly proportional to dose.

Should DCGLs be calculated based on these probabilistic or similar parameters, it is likely that similar but different results would be produced. However, the uncertainty associated with these revisions may not necessarily be reduced.

7.0 SUMMARY AND CONCLUSIONS

Surface and volumetric soil DCGLs were derived for the radionuclides of concern potentially present at the site, 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. Surface and volumetric DCGLs will be used separately when demonstrating compliance with the primary dose limit (i.e., only one or the other will be used in a single survey unit).

The site has both soil and groundwater residual contamination. In addition, one or more buildings containing some residual contamination might also be left in place. Implementation of the soil DCGLs derived in this report will involve administrative controls to apportion the 25 mrem/yr criteria among the remaining final dose components of residual soil, groundwater, and building contamination (if any buildings are left in place). RESRAD 6.21 (Ref 25) was used during the dose assessments for soil contamination. The modeling, in most cases, used site-specific values and values presented in NRC's dose assessment guidance documents for a residential farmer scenario. Sensitivity analyses were performed to determine the impact of the receptor intake parameters on the total dose. Conservative values were assigned to the parameters that are most sensitive to the total dose to account for the uncertainty associated with those parameters.

Tables 1 and 3 present (for NRC approval) the proposed site-specific soil DCGLs for the potential radionuclides of concern at the Hematite Site. Tables 2 and 4 are calculated values of total uranium DCGLs using the values in Tables 1 and 3. Each DCGL represents the concentration (based on the presented model) that would produce 25 mrem/yr.

NUREG-1757 Section 3.3 (Ref 23) may be used to evaluate the dose contribution from Np-237 and other radionuclides present in trace quantities. If relevant criteria are met, and following regulator concurrence, Np-237 and/or other trace contaminants may be eliminated from further survey, sampling, and evaluation efforts. The dose contribution from these trace contaminants will still need to be accounted for, therefore the "operational" soils DCGLs will need to account for the dose contribution from these trace radionuclides.

Although the DCGLs provided in this report translate to the full 25 mrem/yr dose criterion, the ALARA criterion can also be demonstrated. Experience with other sites has shown that soils are rarely contaminated to levels equal to the DCGLs. Soils are generally found to be near background levels or (prior to remediation) well in excess of remedial goals. When soil remediation is conducted through soil removal actions, the remaining excavation surfaces are also generally found to be near background levels. As a result, using DCGLs as provided in this report will generally result in a residual site dose that is well below the 25 mrem/yr dose criterion.

8.0 REFERENCES

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APPENDIX A

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD			Recommendations			
Parameter	Code	Default Value	Value	Units	Justification	Reference
Area of contaminated zone	AREA	10,000	77458	m^2	Site-specific value was determined for this parameter	LBG 2003
Thickness of contaminated zone	THICK0	2	0.15	m	Conservative site-specific value based on conceptual site model for surface soil.	NA
			2.0		RESRAD default used for volumetric source.	ANL 1993
Length parallel to aquifer flow	LCZPAQ	100	291	m	Site-specific value was used. No NRC and EPA value could be located for this parameter.	LBG 2003
Time since placement of material	TI	0	1,3,10,30, 100, 300, 1000	yr	This is RESRAD model-related parameter. No NRC and EPA value could be located for this parameter.	ANL 1993
Cover depth	COVER0	0	0	m	The project assumed no cover as a conservative approach.	NA
Density of cover material	DENSCV	1.5	NA	g/m^3	No value is assigned for this parameter due to no soil cover.	NA
Cover depth erosion rate	VCV	0.001	NA	m/yr	No value is assigned for this parameter due to no soil cover.	NA
Density of contaminated zone	DENSCZ	1.5	1.69	g/m^3	Site-specific value was determined based on silty clay soil.	LBG 2003
Contaminated zone erosion rate	VCZ	0.001	0.0006	m/yr	No site-specific data is available. No NRC and EPA value for this parameter could be located. Assuming 2% slope and significant farming and gardening activities at the site, 0.0006 m/yr was assigned for this parameter.	ANL 1993
Contaminated zone total porosity	TPCZ	0.4	0.45	unitless	Site-specific value was determined based on silty clay soil.	LBG 2003
Contaminated zone field capacity	FCCZ	0.2	0.17	unitless	The value was calculated per ANL, 1993 by using site-specific total and effective porosity for the site.	LBG 2003
Contaminated zone hydraulic conductivity	HCCZ	10	14.56	m/yr	Site-specific value was determined based on silty clay soil.	LBG 2003
Contaminated zone b parameter	BCZ	5.3	10.4	unitless	Site-specific value was determined based on silty clay soil.	ANL 1993
Average annual wind speed	WIND	2	2	m/sec	Site-specific data, NRC and EPA value could not be located. Hence, RESRAD default value was assigned.	ANL 1993

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS (CONT'D)

RESRAD			Recommendations			
Parameter	**Code**	**Default Value**	**Value**	**Units**	**Justification**	**Reference**
Humidity in air	HUMID	8	NA	g/m^3	No value was assigned, as Tritium is not a radionuclide of interest for this site. Humidity input only required if Tritium is present.	NA
Evapotranspiration coefficient	EVAPTR	0.5	0.5	unitless	No site-specific data is available. NRC and EPA value could not be located. Hence, RESRAD default value was assigned for this parameter.	ANL 1993
Precipitation	PRECIP	1	0.965	m/yr	The value was calculated based on 38" annual average rainfall for the site.	LBG 2003
Irrigation	RI	0.2	0.2	m/yr	No site-specific data is available. NRC and EPA value could not be located. Hence, RESRAD default value was assigned for this parameter.	ANL 1993
Irrigation mode	IDITCH	Overhead	Overhead	unitless	Site-specific. No NRC and EPA value could be located.	LBG 2003
Runoff coefficient	RUNOFF	0.2	0.305	unitless	The value for this parameter was calculated based on 12" annual average runoff	LBG 2003
Watershed area for nearby stream or pond	WAREA	1.00E+06	998939	m^2	Site-specific.	LBG 2003
Accuracy for water/soil computations	EPS	0.001	0.001	unitless	This is RESRAD model-related parameter. No NRC and EPA value could be located for this parameter.	ANL 1993
Saturated zone density	DENSAQ	1.5	1.69	g/m^3	Site-specific value was determined based on silty clay soil.	LBG 2003
Saturated zone total porosity	TPSZ	0.4	0.45	unitless	Site-specific value was determined based on silty clay soil.	LBG 2003
Saturated zone effective porosity	EPSZ	0.2	0.29	unitless	Site-specific value was determined based on silty clay soil.	LBG 2003
Saturated zone field capacity	FCSZ	0.2	0.17	unitless	Site-specific value was determined based on silty clay soil.	LBG 2003
Saturated zone hydraulic conductivity	HCSZ	100	169.58	m/yr	Site-specific value was determined based on silty clay soil.	LBG 2003
Saturated zone hydraulic gradient	HGWT	0.02	0.015	unitless	Site-specific value was determined for this parameter	LBG 2003
Saturated zone b parameter	BSZ	5.3	10.4	unitless	Site-specific value was determined based on silty clay soil.	ANL 1993
Water table drop rate	VWT	0.001	0.001	m/yr	No site-specific data is available. NRC and EPA value could not be located. Hence, RESRAD default value was assumed.	ANL 1993

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS (CONT'D)

RESRAD			Recommendations			
Parameter	**Code**	**Default Value**	**Value**	**Units**	**Justification**	**Reference**
Well pump intake depth (m below water table)	DWIBWT	10	16	m	Site-specific; Calculated using the available extrapolated data from the private wells (3, 14, 15, and 18).	LBG 2003
Model: Nondispersion (ND) or Mass-Balance (MB)	MODEL	ND	ND	unitless	Area of contamination is greater than 1000 m^2, hence non-dispersion model was assumed.	LBG 2003
Well pumping rate	UW	250	913	m^3/yr	Site-specific value was determined for this parameter.	LBG 2003
Number of unsaturated zone strata #	NS	1	1	unitless	No site-specific data is available for this parameter. Both NRC & RESRAD default used the same value.	NUREG/CR-5512 (Vol. 4)
Unsaturated zone thickness	H(1)	4	4.5	m	Site-specific value was assigned for this parameter.	LBG 2003
Unsaturated zone density	DENSUZ(1)	1.5	1.69	g/m^3	Site-specific value was determined based on silty clay soil.	LBG 2003
Unsaturated zone total porosity	TPUZ(1)	0.4	0.45	unitless	Site-specific value was determined based on silty clay soil.	LBG 2003
Unsaturated zone effective porosity	EPUZ(1)	0.2	0.29	unitless	Site-specific value was determined based on silty clay soil.	LBG 2003
Unsaturated zone field capacity	FCUZ(1)	0.2	0.17	unitless	The value was calculated per ANL, 1993 by using site-specific total and effective porosity for the site.	LBG 2003
Unsaturated zone hydraulic conductivity	HCUZ(1)	10	14.56	m/yr	Site-specific value was determined based on silty clay soil.	LBG 2003
Unsaturated zone b parameter	BUZ(1)	5.3	10.4	unitless	Site-specific value was determined based on silty clay soil.	ANL 1993
Distribution coefficients						
Uranium	D-1	50	175	cm^3/g	Site-specific derived value. The kd value for each radionuclide of interest were justified in "Determination of Distribution Coefficients for Radionuclides of Concern at the Westinghouse Hematite Facility. The default value was used radium, plutonium, and thorium.	ANL 1993 SAIC 2003
Plutonium	D-1	2,000	2,000	cm^3/g		
Radium	D-1	70	70	cm^3/g		
Technetium	D-1	0	106	cm^3/g		
Thorium	D-1	60,000	60,000	cm^3/g		
Neptunium	D-1	-1	2	cm^3/g		
Americium	D-1	20	1,000	cm^3/g		
Inhalation rate	INHALR	8,400	8,600 (see note)	m^3/yr	Site-specific value for this parameter is not available. Hence, time-weighted inhalation rate was calculated based on NRC defined inhalation rates for different activities, and the time, receptor will spend for each activity.	NUREG/CR-5512 (Vol. 4)

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS (CONT'D)

RESRAD			Recommendations			
Parameter	**Code**	**Default Value**	**Value**	**Units**	**Justification**	**Reference**
Mass loading for inhalation	MLINH	0.0001	5.9E-6 (see note)	g/m^3	Site-specific value for this parameter is not available. Hence, time-weighted mass loading for inhalation rate was calculated based on NRC defined mass loading factor for different activities, and the time, receptor will spend for each activity. Indoor = 1.4E-6; Outdoor=3.14E-6; Gardening = 4E-4; (g/m^3)	NUREG/CR-5512 (Vol. 4)
Exposure duration	ED	30	30	yr	RESRAD default. Exposure duration not relevant to DCGL calculations.	ANL 1993
Indoor Dust Filtration Factor	SHF3	0.4	0.4	unitless	No site-specific, NRC and EPA value for this parameter could be located; hence, RESRAD default was assigned.	ANL 1993
External gamma shielding factor	SHF1	0.7	0.5512	unitless	No site-specific value is available. Hence, NRC value was assigned.	NUREG/CR-5512 (Vol. 4)
Fraction of time spent indoors	FIND	0.5	0.6571	unitless	No site-specific value is available. (15.77 hr/day for 350 days/yr)	NUREG/CR-5512 (Vol. 4)
Fraction of time spent outdoors (on site)	FOTD	0.25	0.1181	unitless	No site-specific value is available. (2.756 + 0.2 hr/day for 350 days/yr)	NUREG/CR-5512 (Vol. 4)
Shape of the contaminated zone: Circular; Non-Circular	FS	Circular	Circular	unitless	No site-specific, NRC and EPA value for this parameter could be located; hence, RESRAD default was assigned.	ANL 1993
Fruits, vegetables and grain consumption	DIET(1)	160	112	kg/yr	No site-specific value is available. NUREG/CR-5512 default value was chosen for this parameter. The value is almost equal to the most likely value defined in NUREG/CR-6697. This value is more conservative than EPA value. (Fruits = 52.8; Grains = 14.4; Roots = 4.6; kg/yr)	NUREG/CR-5512 (Vol. 4)
Leafy vegetable consumption	DIET(2)	14	21.4	kg/yr	No site-specific value is available. Hence, NRC value was used for this parameter.	NUREG/CR-5512 (Vol. 4)
Milk consumption	DIET(3)	92	233	L/yr	No site-specific value is available. NUREG/CR-5512 default value was chosen for this parameter.	NUREG/CR-5512 (Vol. 4)

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS (CONT'D)

RESRAD			Recommendations			
Parameter	Code	Default Value	Value	Units	Justification	Reference
Meat and poultry consumption	DIET(4)	63	65.1	kg/yr	No site-specific value is available. Hence, NRC value was used.	NUREG/CR-5512 (Vol. 4)
Fish consumption	DIET(5)	5.4	20.6	kg/yr	No site-specific value is available. Hence, NRC value was used.	NUREG/CR-5512 (Vol. 4)
Other seafood consumption	DIET(6)	0.9	0.9	kg/yr	No site-specific value is available. No NRC and EPA value could be located. Hence, RESRAD default value was assigned.	ANL 1993
Soil ingestion rate	SOIL	36.5	36.5	g/yr	Soil ingestion rate Both RESRAD default and EPA use the same value for this parameter for adult receptor. Adult = 100 mg/day	EPA 1997
Drinking water intake	DWI	510	478.5	L/yr	No site-specific value is available. Hence, NRC value was used.	NUREG/CR-5512 (Vol. 4)
Contamination fraction of drinking water	FDW	1	1	unitless	No site-specific value is available. Hence, the maximum NRC value was used for this parameter. No EPA value could be located.	NUREG/CR-6697
Contamination fraction of household water	FHHW	1	NA	unitless	Radon pathway is not selected; hence this parameter is not applicable	NA
Contamination fraction of livestock water	FLW	1	1	unitless	No site-specific value is available. Hence, maximum NRC value was used for this parameter. No EPA value could be located.	NUREG/CR-6697
Contamination fraction of irrigation water	FIRW	1	1	unitless	No site-specific value is available. Hence, the maximum NRC value was used for this parameter. No EPA value could be located.	NUREG/CR-6697
Contamination fraction of aquatic food	FR9	0.5	1	unitless	No site-specific value is available. Hence, the maximum NRC value was used for this parameter. No EPA value could be located.	NUREG/CR-6697
Contamination fraction of plant food	FPLANT	-1 **	1	unitless	No site-specific value is available. Hence, NRC value was used for this parameter. No EPA value for this parameter could be located.	NUREG/CR-6697
Contamination fraction of meat	FMEAT	-1 **	1	unitless	No site-specific value is available. Hence, NRC value was used for this parameter. No EPA value for this parameter could be located.	NUREG/CR-6697

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS (CONT'D)

RESRAD			Recommendations			
Parameter	Code	Default Value	Value	Units	Justification	Reference
Contamination fraction of milk	FMILK	-1**	1	unitless	No site-specific value is available. Hence, the maximum NRC value was used for this parameter. No EPA value could be located.	NUREG/CR-6697
Livestock fodder intake for meat	LFI5	68	26.8	kg/day	No site-specific value is available. Hence, NRC value was used for this parameter. No EPA value for this parameter could be located.	NUREG/CR-5512 (Vol. 3)
Livestock fodder intake for milk	LFI6	55	63.25	kg/day	No site-specific value is available. Hence, NRC value was used for this parameter. No EPA value for this parameter could be located.	NUREG/CR-6697
Livestock water intake for meat	LWI5	50	50	L/day	No site-specific value is available. Hence, NRC value was used for this parameter. No EPA value for this parameter could be located.	NUREG/CR-6697
Livestock water intake for milk	LWI6	160	60	L/day	No site-specific value is available. Hence, NRC value was used for this parameter. No EPA value for this parameter could be located.	NUREG/CR-6697
Livestock soil intake	LSI	0.5	0.5	kg/day	No site-specific value is available. No NRC and EPA value could be located. Hence, RESRAD default value was assigned.	ANL 1993
Mass loading for foliar deposition	MLFD	0.0001	0.0001	g/m^3	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD Default value is assigned.	ANL 1993
Depth of soil mixing layer	DM	0.15	0.15	m	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value is assigned for this parameter.	ANL 1993
Depth of roots	DROOT	0.9	0.9	m	Site-specific value is not available. No EPA value could be located. Hence RESRAD default value is assigned for this parameter.	ANL 1993
Drinking water fraction from ground water	FGWDW	1	1	unitless	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Household water fraction from ground water	FGWHH	1	NA	unitless	Radon pathway is not selected; hence this parameter is not applicable	NA
Livestock fraction from ground water	FGWLW	1	1	unitless	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS (CONT'D)

RESRAD			Recommendations			
Parameter	Code	Default Value	Value	Units	Justification	Reference
Irrigation fraction from ground water	FGWIR	1	1	unitless	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Wet weight crop yield for non-leafy vegetables	YV(1)	0.7	0.7	kg/m^2	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Wet weight crop yield for leafy	YV(2)	1.5	1.5	kg/m^2	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Wet weight crop yield for fodder	YV(3)	1.1	1.1	kg/m^2	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Growing season for non-leafy	TE(1)	0.17	0.17	years	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Growing season for leafy	TE(2)	0.25	0.25	years	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Growing season for fodder	TE(3)	0.08	0.08	years	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Translocation factor for non-leafy	TIV(1)	0.1	0.1	unitless	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 3)
Translocation factor for leafy	TIV(2)	1	1	unitless	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 3)
Translocation factor for fodder	TIV(3)	1	1	unitless	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 3)
Dry foliar interception fraction for non-leafy vegetables	RDRY(1)	0.25	0.25	unitless	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS (CONT'D)

RESRAD			Recommendations			
Parameter	Code	Default Value	Value	Units	Justification	Reference
Dry foliar interception fraction for leafy vegetables	RDRY(2)	0.25	0.25	unitless	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Dry foliar interception fraction for fodder	RDRY(3)	0.25	0.25	unitless	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Wet foliar interception fraction for non-leafy vegetables	RWET(1)	0.25	0.25	unitless	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Wet foliar interception fraction for leafy	RWET(2)	0.25	0.25	unitless	Site-specific value is not available. Most likely value defined in NUREG/CR was assigned. No EPA value could be located.	ANL 1993
Wet foliar interception fraction for fodder	RWET(3)	0.25	0.25	unitless	Site-specific value is not available. Most likely value defined in NUREG/CR was assigned. No EPA value could be located.	ANL 1993
Weathering removal constant for vegetation	WLAM	20	20	unitless	Site-specific value is not available. No NRC and EPA value could be located. Hence RESRAD default value was assigned.	ANL 1993
Storage time: fruits, non-leafy vegetables, and grain	STOR_T(1)	14	14	days	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Storage time: leafy vegetables	STOR_T(2)	1	1	days	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Storage time: milk	STOR_T(3)	1	1	days	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Storage time: meat and poultry	STOR_T(4)	20	20	days	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Storage time: fish	STOR_T(5)	7	7	days	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Storage time: crustacea and mollusks	STOR_T(6)	7	7	days	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS (CONT'D)

RESRAD			Recommendations			
Parameter	Code	Default Value	Value	Units	Justification	Reference
Storage time: well water	STOR_T(7)	1	1	days	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Storage time: surface water	STOR_T(8)	1	1	days	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Storage time: livestock fodder	STOR_T(9)	45	45	days	Both NRC and RESRAD values for this parameter are the same; hence that value was assigned. No EPA value could be located.	NUREG/CR-5512 (Vol. 4)
Thickness of building foundation	FLOOR1	0.15	NA	m	No Radon pathway, hence this parameter is not applicable.	NA
Bulk density of building foundation	DENSFL	2.4	NA	g/cm^3	No Radon pathway, hence this parameter is not applicable.	NA
Total porosity of the cover material	TPCV	0.4	NA	unitless	No Radon pathway, hence this parameter is not applicable.	NA
Total porosity of the building foundation	TPFL	0.1	NA	unitless	No Radon pathway, hence this parameter is not applicable.	NA
Volumetric water constant of the cover material	PH2OCV	0.05	NA	unitless	No Radon pathway, hence this parameter is not applicable.	NA
Volumetric water constant of the foundation	PH2OFL	0.03	NA	unitless	No Radon pathway, hence this parameter is not applicable.	NA
Diffusion coefficient for radon gas in cover material	DIFCV	2.00E+06	NA	m/sec	No Radon pathway, hence this parameter is not applicable.	NA
Diffusion coefficient for radon gas in foundation material	DIFFL	3.00E-07	NA	m/sec	No Radon pathway, hence this parameter is not applicable.	NA
Diffusion coefficient for radon gas in contaminated zone soil	DIFCZ	2.00E-06	NA	m/sec	No Radon pathway, hence this parameter is not applicable.	NA
Radon vertical dimension of mixing	HMIX	2	NA	m	No Radon pathway, hence this parameter is not applicable.	NA
Average building air exchange rate	REXG	0.5	NA	1/hour	No Radon pathway, hence this parameter is not applicable.	NA
Height of the building (room)	HRM	2.5	NA	m	No Radon pathway, hence this parameter is not applicable.	NA
Building interior area factor	FAI	0	NA	unitless	No Radon pathway, hence this parameter is not applicable.	NA

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS (CONT'D)

RESRAD			Recommendations			
Parameter	Code	Default Value	Value	Units	Justification	Reference
Building depth below ground surface	DMFL	-1	NA	m	No Radon pathway, hence this parameter is not applicable.	NA
Emanating power of Rn-222 gas	EMANA(1)	0.25	NA	unitless	No Radon pathway, hence this parameter is not applicable.	NA
Emanating power of Rn-220 gas	EMANA(2)	0.15	NA	unitless	No Radon pathway, hence this parameter is not applicable.	NA
Pathway – external gamma	NA	active	active	unitless	NA	NA
Pathway – inhalation (w/o radon)	NA	active	active	unitless	NA	NA
Pathway – plant ingestion	NA	active	active	unitless	NA	NA
Pathway – meat ingestion	NA	active	active	unitless	NA	NA
Pathway – milk ingestion	NA	active	active	unitless	NA	NA
Pathway – aquatic foods	NA	active	active	unitless	NA	NA
Pathway – drinking water	NA	active	active	unitless	NA	NA
Pathway – soil ingestion	NA	active	active	unitless	NA	NA
Pathway – radon	NA	active	inactive	unitless	NA	NA

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NUREG/CR-5512

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Residual Radioactive Contamination From Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent, Volume 1, IV) PNL-7994

EPA, 1997. Exposure Factors Handbook, Volumes I, II, and III, EPA/600/P-95/002Fa-c, Office of Research and Development, Washington, DC, August.

EPA, 2000. *Soil Screening Guidance for Radionuclides: User's Guide*, EPA/540-R-00-007, Office of Radiation and Indoor Air/Office of Solid Waste and Emergency Response, Washington, DC, October.

LBG, 2003. *Site-Specific Soil Parameters Westinghouse Former Fuel Cycle Facility D & D Project.*

NUREG/CR-6697, 2000. *Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes.*

SAIC, 2003. *Determination of Distribution Coefficients for Radionuclides of Concern at the Westinghouse Hematite Facility (Draft).*

NA = Not Applicable

N/A = Not Available

** specifies that the contaminated fraction will be calculated from the appropriate area factor in RESRAD.

Inhalation Rate =((0.9 m^3/hr x 15.77 hrs/day) + (1.4 m^3/hr x 2.756 hrs/day) + (1.7 m^3/hr x 0.20 hrs/day)) x 8760 hrs/yr / (24 hrs/day) = 6710 m^3/yr, where 15.77, 2.756, and 0.2 hrs/day are indoor, outdoor, and gardening activities for the receptor. Rate must also account for time off-site because of way the RESRAD the occupancy factor is applied. Therefore, using weighted average approach based on given hourly fractions: =((0.9 m^3/hr x 4.44 hrs/day) + (1.4 m^3/hr x 0.78 hrs/day) + (1.7 m^3/hr x 0.06 hrs/day)) x 8760 hrs/yr / (24 hrs/day) = 1890 m^3/yr. Total rate = 6710 + 1890 = 8600 m^3/yr.

Mass loading for inhalation =[(1.4 E-6 g/m^3 x {15.77 + 4.44} hrs/day) + (3.14E-06 g/m^3 x {2.64 + 0.78} hrs/day) + (4E-04 g/m^3 x {0.20 + 0.06} hrs/day)] /24 hrs/day = 5.9E-06 g/m^3. As with inhalation rate, the mass loading estimate must also account for time off-site because of way the RESRAD the occupancy factor is applied.

APPENDIX B

SURFACE SOIL DOSE ASSESSMENT SUMMARY REPORT

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ac-227+D	6.720E+00	6.720E+00	DCF2(1)
B-1	Am-241	4.440E-01	4.440E-01	DCF2(2)
B-1	Np-237+D	5.400E-01	5.400E-01	DCF2(3)
B-1	Pa-231	1.280E+00	1.280E+00	DCF2(4)
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(5)
B-1	Pu-239	4.290E-01	4.290E-01	DCF2(6)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(7)
B-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(8)
B-1	Tc-99	8.330E-06	8.330E-06	DCF2(9)
B-1	Th-228+D	3.450E-01	3.450E-01	DCF2(10)
B-1	Th-229+D	2.160E+00	2.160E+00	DCF2(11)
B-1	Th-230	3.260E-01	3.260E-01	DCF2(12)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(13)
B-1	U-233	1.350E-01	1.350E-01	DCF2(14)
B-1	U-234	1.320E-01	1.320E-01	DCF2(15)
B-1	U-235+D	1.230E-01	1.230E-01	DCF2(16)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2(17)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ac-227+D	1.480E-02	1.480E-02	DCF3(1)
D-1	Am-241	3.640E-03	3.640E-03	DCF3(2)
D-1	Np-237+D	4.440E-03	4.440E-03	DCF3(3)
D-1	Pa-231	1.060E-02	1.060E-02	DCF3(4)
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(5)
D-1	Pu-239	3.540E-03	3.540E-03	DCF3(6)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(7)
D-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(8)
D-1	Tc-99	1.460E-06	1.460E-06	DCF3(9)
D-1	Th-228+D	8.080E-04	8.080E-04	DCF3(10)
D-1	Th-229+D	4.030E-03	4.030E-03	DCF3(11)
-1	Th-230	5.480E-04	5.480E-04	DCF3(12)
-1	Th-232	2.730E-03	2.730E-03	DCF3(13)
D-1	U-233	2.890E-04	2.890E-04	DCF3(14)
D-1	U-234	2.830E-04	2.830E-04	DCF3(15)
D-1	U-235+D	2.670E-04	2.670E-04	DCF3(16)
D-1	U-238+D	2.690E-04	2.690E-04	DCF3(17)
D-34	Food transfer factors:			
D-34	Ac-227+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(1,1)
D-34	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,2)
D-34	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,3)
D-34				
D-34	Am-241 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(2,1)
D-34	Am-241 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-05	5.000E-05	RTF(2,2)
D-34	Am-241 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-06	2.000E-06	RTF(2,3)
D-34				
D-34	Np-237+D , plant/soil concentration ratio, dimensionless	2.000E-02	2.000E-02	RTF(3,1)
D-34	Np-237+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,2)
D-34	Np-237+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(3,3)
D-34				

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
D-34	Pa-231 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(4,1)
D-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-03	5.000E-03	RTF(4,2)
D-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(4,3)
D-34				
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(5,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(5,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(5,3)
D-34				
D-34	Pu-239 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(6,1)
D-34	Pu-239 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(6,2)
D-34	Pu-239 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-06	1.000E-06	RTF(6,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(7,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(7,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(7,3)
D-34				
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(8,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(8,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(8,3)
D-34				
D-34	Tc-99 , plant/soil concentration ratio, dimensionless	5.000E+00	5.000E+00	RTF(9,1)
D-34	Tc-99 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(9,2)
D-34	Tc-99 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(9,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(10,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(10,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(10,3)
D-34				
D-34	Th-229+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(11,1)
D-34	Th-229+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(11,2)
˥-34	Th-229+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(11,3)
34				
34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(12,1)
D-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(12,2)
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(12,3)
D-34				
D-34	Th-232 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(13,1)
D-34	Th-232 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(13,2)
D-34	Th-232 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(13,3)
D-34				
D-34	U-233 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(14,1)
D-34	U-233 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(14,2)
D-34	U-233 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(14,3)
D-34				
D-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(15,1)
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(15,2)
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(15,3)
D-34				
D-34	U-235+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(16,1)
D-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(16,2)
D-34	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(16,3)

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(17,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(17,2)
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(17,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ac-227+D , fish	1.500E+01	1.500E+01	BIOFAC(1,1)
D-5	Ac-227+D , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(1,2)
D-5				
D-5	Am-241 , fish	3.000E+01	3.000E+01	BIOFAC(2,1)
D-5	Am-241 , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(2,2)
D-5				
D-5	Np-237+D , fish	3.000E+01	3.000E+01	BIOFAC(3,1)
D-5	Np-237+D , crustacea and mollusks	4.000E+02	4.000E+02	BIOFAC(3,2)
D-5				
D-5	Pa-231 , fish	1.000E+01	1.000E+01	BIOFAC(4,1)
D-5	Pa-231 , crustacea and mollusks	1.100E+02	1.100E+02	BIOFAC(4,2)
D-5				
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(5,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(5,2)
D-5				
D-5	Pu-239 , fish	3.000E+01	3.000E+01	BIOFAC(6,1)
D-5	Pu-239 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(6,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(7,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(7,2)
D-5				
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(8,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(8,2)
D-5				
D-5	Tc-99 , fish	2.000E+01	2.000E+01	BIOFAC(9,1)
D-5	Tc-99 , crustacea and mollusks	5.000E+00	5.000E+00	BIOFAC(9,2)
5				
5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(10,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(10,2)
D-5				
D-5	Th-229+D , fish	1.000E+02	1.000E+02	BIOFAC(11,1)
D-5	Th-229+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(11,2)
D-5				
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(12,1)
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(12,2)
D-5				
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(13,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(13,2)
D-5				
D-5	U-233 , fish	1.000E+01	1.000E+01	BIOFAC(14,1)
D-5	U-233 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(14,2)
D-5				
D-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(15,1)
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(15,2)
D-5				

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
D-5	U-235+D , fish	1.000E+01	1.000E+01	BIOFAC(16,1)
D-5	U-235+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(16,2)
D-5				
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIOFAC(17,1)
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(17,2)

Site-Specific Parameter Summary

Menu	Parameter		User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)		7.746E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)		1.500E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)		2.910E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)		2.500E+01	2.500E+01	---	BRDL
R011	Time since placement of material (yr)		0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)		1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)		3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)		1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)		3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)		1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)		3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)		1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)		not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)		not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g):	Am-241	1.000E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g):	Np-237	1.000E+00	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g):	Pu-239	1.000E+00	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g):	Ra-228	1.000E+00	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g):	Tc-99	1.000E+00	0.000E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g):	Th-228	1.000E+00	0.000E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g):	Th-232	1.000E+00	0.000E+00	---	S1(13)
R012	Initial principal radionuclide (pCi/g):	U-234	1.000E+00	0.000E+00	---	S1(15)
R012	Initial principal radionuclide (pCi/g):	U-235	1.000E+00	0.000E+00	---	S1(16)
R012	Initial principal radionuclide (pCi/g):	U-238	1.000E+00	0.000E+00	---	S1(17)
R012	Concentration in groundwater (pCi/L):	Am-241	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L):	Np-237	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L):	Pu-239	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L):	Ra-228	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L):	Tc-99	not used	0.000E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L):	Th-228	not used	0.000E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L):	Th-232	not used	0.000E+00	---	W1(13)
R012	Concentration in groundwater (pCi/L):	U-234	not used	0.000E+00	---	W1(15)
R012	Concentration in groundwater (pCi/L):	U-235	not used	0.000E+00	---	W1(16)
R012	Concentration in groundwater (pCi/L):	U-238	not used	0.000E+00	---	W1(17)
R013	Cover depth (m)		0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)		not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)		not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)		1.690E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)		6.000E-04	1.000E-03	---	VCZ
R013	Contaminated zone total porosity		4.500E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity		1.700E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)		1.456E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter		1.040E+01	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)		2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)		not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient		5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)		9.650E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)		2.000E-01	2.000E-01	---	RI
R013	Irrigation mode		overhead	overhead	---	IDITCH

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R013	Runoff coefficient	3.050E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	9.989E+05	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.690E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.500E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.900E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	1.700E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.696E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	1.500E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	1.040E+01	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.600E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	9.130E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	4.500E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.690E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.500E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.900E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	1.700E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	1.040E+01	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.456E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Am-241				
R016	Contaminated zone (cm**3/g)	1.000E+03	2.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+03	2.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	1.000E+03	2.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.717E-03	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Np-237				
R016	Contaminated zone (cm**3/g)	2.000E+00	-1.000E+00	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+00	-1.000E+00	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	2.000E+00	-1.000E+00	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.702E-01	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for Pu-239				
R016	Contaminated zone (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCU(6,1)
R016	Saturated zone (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCS(6)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.586E-04	ALEACH(6)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(6)
R016	Distribution coefficients for Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(8,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(8)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.445E-02	ALEACH(8)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(8)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Tc-99				
R016	Contaminated zone (cm**3/g)	1.060E+02	0.000E+00	---	DCNUCC(9)
R016	Unsaturated zone 1 (cm**3/g)	1.060E+02	0.000E+00	---	DCNUCU(9,1)
R016	Saturated zone (cm**3/g)	1.060E+02	0.000E+00	---	DCNUCS(9)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.617E-02	ALEACH(9)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(9)
R016	Distribution coefficients for Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(10)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(10,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(10)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.862E-05	ALEACH(10)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(10)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(13)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(13,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(13)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.862E-05	ALEACH(13)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(13)
R016	Distribution coefficients for U-234				
R016	Contaminated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCC(15)
R016	Unsaturated zone 1 (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCU(15,1)
R016	Saturated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCS(15)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.800E-03	ALEACH(15)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(15)
R016	Distribution coefficients for U-235				
R016	Contaminated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCC(16)
R016	Unsaturated zone 1 (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCU(16,1)
~016	Saturated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCS(16)
16	Leach rate (/yr)	0.000E+00	0.000E+00	9.800E-03	ALEACH(16)
J16	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(16)
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCC(17)
R016	Unsaturated zone 1 (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCU(17,1)
R016	Saturated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCS(17)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.800E-03	ALEACH(17)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(17)
R016	Distribution coefficients for daughter Ac-227				
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.489E-02	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Pa-231				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	3.419E-02	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.713E-02	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
R016	Distribution coefficients for daughter Ra-226				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(7,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.445E-02	ALEACH(7)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(7)
R016	Distribution coefficients for daughter Th-229				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(11)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(11,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(11)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.862E-05	ALEACH(11)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(11)
R016	Distribution coefficients for daughter Th-230				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(12)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(12,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(12)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.862E-05	ALEACH(12)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(12)
R016	Distribution coefficients for daughter U-233				
R016	Contaminated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCC(14)
R016	Unsaturated zone 1 (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCU(14,1)
R016	Saturated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCS(14)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.800E-03	ALEACH(14)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(14)
R017	Inhalation rate (m**3/yr)	8.600E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	5.900E-06	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	5.512E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	6.571E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	1.181E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.120E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	2.140E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	2.330E+02	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.510E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	2.060E+01	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	4.785E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	1.000E+00	5.000E-01	---	FR9
R018	Contamination fraction of plant food	1.000E+00	-1	---	FPLANT
R018	Contamination fraction of meat	1.000E+00	-1	---	FMEAT
R018	Contamination fraction of milk	1.000E+00	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	2.680E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	6.325E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	6.000E+01	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
^14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
:4	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
14	DCF correction factor for gaseous forms of C14	not used	8.894E+01	---	CO2F
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Contaminated Zone Dimensions	
Area:	77458.00 square meters
Thickness:	0.15 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Am-241	1.000E+00
Np-237	1.000E+00
Pu-239	1.000E+00
Ra-228	1.000E+00
Tc-99	1.000E+00
Th-228	1.000E+00
Th-232	1.000E+00
U-234	1.000E+00
U-235	1.000E+00
U-238	1.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	1.168E+01	1.048E+01	9.463E+00	8.490E+00	2.533E+01	2.430E+01	1.039E-04	5.634E-02
M(t):	4.671E-01	4.191E-01	3.785E-01	3.396E-01	1.013E+00	9.722E-01	4.157E-06	2.254E-03

Maximum TDOSE(t): 2.554E+01 mrem/yr at t = 32.99 ± 0.07 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.299E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Am-241	1.866E-02	0.0007	1.385E-03	0.0001	0.000E+00	0.0000	6.341E-02	0.0025	4.635E-03	0.0002	6.716E-04	0.0000	7.981E-02	0.0031
Np-237	1.304E-08	0.0000	2.060E-09	0.0000	0.000E+00	0.0000	5.907E-08	0.0000	1.191E-08	0.0000	7.638E-08	0.0000	3.079E-08	0.0000
Pu-239	1.310E-04	0.0000	1.452E-03	0.0001	0.000E+00	0.0000	6.691E-02	0.0026	9.780E-03	0.0004	3.543E-04	0.0000	8.421E-02	0.0033
a-228	7.086E-02	0.0028	1.575E-05	0.0000	0.000E+00	0.0000	8.912E-03	0.0003	4.650E-04	0.0000	2.098E-03	0.0001	5.319E-04	0.0000
-99	3.470E-05	0.0000	1.690E-08	0.0000	0.000E+00	0.0000	8.185E-02	0.0032	1.098E-04	0.0000	9.146E-03	0.0004	2.082E-05	0.0000
h-228	2.152E-05	0.0000	6.500E-09	0.0000	0.000E+00	0.0000	8.502E-08	0.0000	1.243E-08	0.0000	2.251E-09	0.0000	1.070E-07	0.0000
Th-232	5.295E+00	0.2073	6.712E-03	0.0003	0.000E+00	0.0000	9.829E-01	0.0385	5.513E-02	0.0022	2.212E-01	0.0087	1.122E-01	0.0044
U-234	1.438E-04	0.0000	3.317E-04	0.0000	0.000E+00	0.0000	9.863E-03	0.0004	2.000E-03	0.0001	1.300E-02	0.0005	4.998E-03	0.0002
U-235	2.483E-01	0.0097	3.123E-04	0.0000	0.000E+00	0.0000	1.007E-02	0.0004	2.456E-03	0.0001	1.227E-02	0.0005	4.832E-03	0.0002
U-238	4.617E-02	0.0018	2.963E-04	0.0000	0.000E+00	0.0000	9.373E-03	0.0004	1.901E-03	0.0001	1.236E-02	0.0005	4.748E-03	0.0002
Total	5.679E+00	0.2223	1.051E-02	0.0004	0.000E+00	0.0000	1.233E+00	0.0483	7.648E-02	0.0030	2.711E-01	0.0106	2.913E-01	0.0114

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.299E+01 years

Radio-Nuclide Nuclide	Water Dependent Pathways: Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Am-241	2.982E-05	0.0000	4.715E-06	0.0000	0.000E+00	0.0000	4.622E-06	0.0000	3.936E-07	0.0000	1.254E-08	0.0000	1.686E-01	0.0066
Np-237	1.354E+01	0.5302	2.146E+00	0.0840	0.000E+00	0.0000	2.105E+00	0.0824	1.817E-01	0.0071	5.762E-03	0.0002	1.798E+01	0.7040
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.628E-01	0.0064
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.289E-02	0.0032
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.116E-02	0.0036
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.173E-05	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.673E+00	0.2612
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.034E-02	0.0012
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.782E-01	0.0109
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.485E-02	0.0029
Total	1.354E+01	0.5302	2.146E+00	0.0840	0.000E+00	0.0000	2.105E+00	0.0824	1.817E-01	0.0071	5.762E-03	0.0002	2.554E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	2.082E-02	0.0018	1.781E-03	0.0002	0.000E+00	0.0000	8.153E-02	0.0070	5.959E-03	0.0005	8.635E-04	0.0001	1.026E-01	0.0088
Np-237	3.502E-01	0.0300	1.513E-03	0.0001	0.000E+00	0.0000	1.403E+00	0.1202	1.242E-01	0.0106	2.626E-03	0.0002	8.745E-02	0.0075
Pu-239	1.369E-04	0.0000	1.723E-03	0.0001	0.000E+00	0.0000	7.939E-02	0.0068	1.160E-02	0.0010	4.204E-04	0.0000	9.992E-02	0.0086
Ra-228	3.021E+00	0.2587	2.315E-04	0.0000	0.000E+00	0.0000	1.200E+00	0.1028	6.020E-02	0.0052	2.881E-01	0.0247	4.135E-02	0.0035
Tc-99	5.933E-05	0.0000	3.319E-08	0.0000	0.000E+00	0.0000	1.608E-01	0.0138	2.155E-04	0.0000	1.796E-02	0.0015	4.090E-05	0.0000
Th-228	3.499E+00	0.2996	1.163E-03	0.0001	0.000E+00	0.0000	1.521E-02	0.0013	2.223E-03	0.0002	4.027E-04	0.0000	1.914E-02	0.0016
Th-232	1.740E-01	0.0149	6.598E-03	0.0006	0.000E+00	0.0000	1.311E-01	0.0112	1.212E-02	0.0010	1.757E-02	0.0015	7.957E-02	0.0068
U-234	1.898E-04	0.0000	5.277E-04	0.0000	0.000E+00	0.0000	1.570E-02	0.0013	3.183E-03	0.0003	2.070E-02	0.0018	7.952E-03	0.0007
U-235	3.486E-01	0.0298	4.918E-04	0.0000	0.000E+00	0.0000	1.483E-02	0.0013	3.021E-03	0.0003	1.953E-02	0.0017	7.506E-03	0.0006
U-238	6.593E-02	0.0056	4.717E-04	0.0000	0.000E+00	0.0000	1.492E-02	0.0013	3.026E-03	0.0003	1.967E-02	0.0017	7.559E-03	0.0006
Total	7.480E+00	0.6405	1.450E-02	0.0012	0.000E+00	0.0000	3.117E+00	0.2669	2.258E-01	0.0193	3.878E-01	0.0332	4.531E-01	0.0388

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.136E-01	0.0183
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.969E+00	0.1686
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.932E-01	0.0165
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.611E+00	0.3948
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.790E-01	0.0153
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.537E+00	0.3029
h-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.210E-01	0.0360
-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.825E-02	0.0041
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.940E-01	0.0337
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.116E-01	0.0096
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.168E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	2.075E-02	0.0020	1.768E-03	0.0002	0.000E+00	0.0000	8.094E-02	0.0077	5.915E-03	0.0006	8.572E-04	0.0001	1.019E-01	0.0097
Np-237	1.620E-01	0.0155	6.977E-04	0.0001	0.000E+00	0.0000	6.503E-01	0.0621	5.792E-02	0.0055	1.219E-03	0.0001	4.032E-02	0.0038
Pu-239	1.368E-04	0.0000	1.714E-03	0.0002	0.000E+00	0.0000	7.900E-02	0.0075	1.155E-02	0.0011	4.183E-04	0.0000	9.943E-02	0.0095
Ra-228	3.595E+00	0.3431	5.256E-04	0.0001	0.000E+00	0.0000	1.040E+00	0.0992	5.259E-02	0.0050	2.484E-01	0.0237	4.100E-02	0.0039
Tc-99	5.838E-05	0.0000	3.253E-08	0.0000	0.000E+00	0.0000	1.576E-01	0.0150	2.113E-04	0.0000	1.761E-02	0.0017	4.008E-05	0.0000
Th-228	2.433E+00	0.2322	8.061E-04	0.0001	0.000E+00	0.0000	1.054E-02	0.0010	1.541E-03	0.0001	2.792E-04	0.0000	1.327E-02	0.0013
Th-232	5.771E-01	0.0551	6.619E-03	0.0006	0.000E+00	0.0000	2.644E-01	0.0252	1.876E-02	0.0018	4.940E-02	0.0047	8.422E-02	0.0080
U-234	1.880E-04	0.0000	5.205E-04	0.0000	0.000E+00	0.0000	1.548E-02	0.0015	3.140E-03	0.0003	2.041E-02	0.0019	7.843E-03	0.0007
U-235	3.451E-01	0.0329	4.851E-04	0.0000	0.000E+00	0.0000	1.468E-02	0.0014	3.018E-03	0.0003	1.926E-02	0.0018	7.409E-03	0.0007
U-238	6.523E-02	0.0062	4.652E-04	0.0000	0.000E+00	0.0000	1.472E-02	0.0014	2.984E-03	0.0003	1.940E-02	0.0019	7.455E-03	0.0007
Total	7.198E+00	0.6871	1.360E-02	0.0013	0.000E+00	0.0000	2.327E+00	0.2221	1.576E-01	0.0150	3.772E-01	0.0360	4.029E-01	0.0385

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.121E-01	0.0202
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.125E-01	0.0871
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.922E-01	0.0183
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.977E+00	0.4751
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.755E-01	0.0167
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.459E+00	0.2347
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.001E+00	0.0955
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.759E-02	0.0045
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.899E-01	0.0372
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.103E-01	0.0105
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.048E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	2.062E-02	0.0022	1.742E-03	0.0002	0.000E+00	0.0000	7.975E-02	0.0084	5.829E-03	0.0006	8.447E-04	0.0001	1.004E-01	0.0106
Np-237	3.469E-02	0.0037	1.483E-04	0.0000	0.000E+00	0.0000	1.382E-01	0.0146	1.231E-02	0.0013	2.591E-04	0.0000	8.572E-03	0.0009
Pu-239	1.364E-04	0.0000	1.697E-03	0.0002	0.000E+00	0.0000	7.822E-02	0.0083	1.143E-02	0.0012	4.142E-04	0.0000	9.846E-02	0.0104
Ra-228	3.751E+00	0.3964	7.418E-04	0.0001	0.000E+00	0.0000	7.762E-01	0.0820	3.971E-02	0.0042	1.845E-01	0.0195	3.622E-02	0.0038
Tc-99	5.651E-05	0.0000	3.124E-08	0.0000	0.000E+00	0.0000	1.513E-01	0.0160	2.029E-04	0.0000	1.691E-02	0.0018	3.849E-05	0.0000
Th-228	1.176E+00	0.1242	3.874E-04	0.0000	0.000E+00	0.0000	5.067E-03	0.0005	7.406E-04	0.0001	1.342E-04	0.0000	6.377E-03	0.0007
Th-232	1.479E+00	0.1563	6.725E-03	0.0007	0.000E+00	0.0000	4.788E-01	0.0506	2.963E-02	0.0031	1.006E-01	0.0106	9.288E-02	0.0098
U-234	1.844E-04	0.0000	5.063E-04	0.0001	0.000E+00	0.0000	1.506E-02	0.0016	3.054E-03	0.0003	1.986E-02	0.0021	7.630E-03	0.0008
U-235	3.381E-01	0.0357	4.722E-04	0.0000	0.000E+00	0.0000	1.437E-02	0.0015	3.007E-03	0.0003	1.874E-02	0.0020	7.220E-03	0.0008
U-238	6.386E-02	0.0067	4.525E-04	0.0000	0.000E+00	0.0000	1.431E-02	0.0015	2.903E-03	0.0003	1.888E-02	0.0020	7.252E-03	0.0008
Total	6.864E+00	0.7253	1.287E-02	0.0014	0.000E+00	0.0000	1.751E+00	0.1851	1.088E-01	0.0115	3.611E-01	0.0382	3.650E-01	0.0386

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.092E-01	0.0221
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.942E-01	0.0205
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.904E-01	0.0201
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.789E+00	0.5060
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.685E-01	0.0178
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.188E+00	0.1256
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.188E+00	0.2312
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.629E-02	0.0049
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.819E-01	0.0404
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.077E-01	0.0114
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.463E+00	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	2.014E-02	0.0024	1.653E-03	0.0002	0.000E+00	0.0000	7.571E-02	0.0089	5.533E-03	0.0007	8.018E-04	0.0001	9.529E-02	0.0112
Np-237	1.574E-04	0.0000	6.593E-07	0.0000	0.000E+00	0.0000	6.121E-04	0.0001	5.453E-05	0.0000	1.252E-06	0.0000	3.799E-05	0.0000
Pu-239	1.352E-04	0.0000	1.639E-03	0.0002	0.000E+00	0.0000	7.553E-02	0.0089	1.104E-02	0.0013	4.000E-04	0.0000	9.507E-02	0.0112
Ra-228	1.898E+00	0.2236	4.389E-04	0.0001	0.000E+00	0.0000	2.756E-01	0.0325	1.432E-02	0.0017	6.502E-02	0.0077	1.568E-02	0.0018
Tc-99	5.044E-05	0.0000	2.711E-08	0.0000	0.000E+00	0.0000	1.313E-01	0.0155	1.761E-04	0.0000	1.467E-02	0.0017	3.340E-05	0.0000
Th-228	9.222E-02	0.0109	2.979E-05	0.0000	0.000E+00	0.0000	3.897E-04	0.0000	5.696E-05	0.0000	1.032E-05	0.0000	4.904E-04	0.0001
Th-232	3.874E+00	0.4563	7.055E-03	0.0008	0.000E+00	0.0000	8.666E-01	0.1021	4.950E-02	0.0058	1.928E-01	0.0227	1.112E-01	0.0131
U-234	1.729E-04	0.0000	4.593E-04	0.0001	0.000E+00	0.0000	1.366E-02	0.0016	2.771E-03	0.0003	1.801E-02	0.0021	6.922E-03	0.0008
U-235	3.148E-01	0.0371	4.294E-04	0.0001	0.000E+00	0.0000	1.331E-02	0.0016	2.932E-03	0.0003	1.700E-02	0.0020	6.589E-03	0.0008
U-238	5.925E-02	0.0070	4.106E-04	0.0000	0.000E+00	0.0000	1.299E-02	0.0015	2.634E-03	0.0003	1.712E-02	0.0020	6.579E-03	0.0008
Total	6.259E+00	0.7373	1.212E-02	0.0014	0.000E+00	0.0000	1.466E+00	0.1727	8.902E-02	0.0105	3.258E-01	0.0384	3.379E-01	0.0398

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.991E-01	0.0235
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.640E-04	0.0001
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.838E-01	0.0217
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.270E+00	0.2673
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.462E-01	0.0172
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.320E-02	0.0110
-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.101E+00	0.6008
-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.200E-02	0.0049
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.550E-01	0.0418
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.898E-02	0.0117
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.490E+00	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	1.885E-02	0.0007	1.418E-03	0.0001	0.000E+00	0.0000	6.493E-02	0.0026	4.746E-03	0.0002	6.876E-04	0.0000	8.172E-02	0.0032
Np-237	1.235E-08	0.0000	2.139E-09	0.0000	0.000E+00	0.0000	6.164E-08	0.0000	1.243E-08	0.0000	7.973E-08	0.0000	3.199E-08	0.0000
Pu-239	1.316E-04	0.0000	1.476E-03	0.0001	0.000E+00	0.0000	6.801E-02	0.0027	9.941E-03	0.0004	3.601E-04	0.0000	8.560E-02	0.0034
Ra-228	1.097E-01	0.0043	2.461E-05	0.0000	0.000E+00	0.0000	1.393E-02	0.0006	7.270E-04	0.0000	3.280E-03	0.0001	8.314E-04	0.0000
Tc-99	3.643E-05	0.0000	1.798E-08	0.0000	0.000E+00	0.0000	8.709E-02	0.0034	1.168E-04	0.0000	9.731E-03	0.0004	2.215E-05	0.0000
Th-228	6.382E-05	0.0000	1.945E-08	0.0000	0.000E+00	0.0000	2.544E-07	0.0000	3.719E-08	0.0000	6.736E-09	0.0000	3.202E-07	0.0000
Th-232	5.287E+00	0.2087	6.798E-03	0.0003	0.000E+00	0.0000	9.925E-01	0.0392	5.569E-02	0.0022	2.234E-01	0.0088	1.135E-01	0.0045
U-234	1.470E-04	0.0000	3.462E-04	0.0000	0.000E+00	0.0000	1.030E-02	0.0004	2.088E-03	0.0001	1.357E-02	0.0005	5.217E-03	0.0002
U-235	2.561E-01	0.0101	3.257E-04	0.0000	0.000E+00	0.0000	1.047E-02	0.0004	2.528E-03	0.0001	1.281E-02	0.0005	5.036E-03	0.0002
U-238	4.771E-02	0.0019	3.093E-04	0.0000	0.000E+00	0.0000	9.784E-03	0.0004	1.984E-03	0.0001	1.290E-02	0.0005	4.957E-03	0.0002
Total	5.720E+00	0.2258	1.070E-02	0.0004	0.000E+00	0.0000	1.257E+00	0.0496	7.782E-02	0.0031	2.767E-01	0.0109	2.968E-01	0.0117

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	1.722E-05	0.0000	2.718E-06	0.0000	0.000E+00	0.0000	2.663E-06	0.0000	2.245E-07	0.0000	7.178E-09	0.0000	1.724E-01	0.0068
Np-237	1.332E+01	0.5260	2.111E+00	0.0833	0.000E+00	0.0000	2.071E+00	0.0818	1.785E-01	0.0070	5.663E-03	0.0002	1.769E+01	0.6984
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.655E-01	0.0065
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.285E-01	0.0051
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.699E-02	0.0038
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.446E-05	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.679E+00	0.2637
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.166E-02	0.0013
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.873E-01	0.0113
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.765E-02	0.0031
Total	1.332E+01	0.5260	2.111E+00	0.0833	0.000E+00	0.0000	2.071E+00	0.0818	1.785E-01	0.0070	5.663E-03	0.0002	2.533E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Am-241	1.487E-02	0.0006	7.655E-04	0.0000	0.000E+00	0.0000	3.505E-02	0.0014	2.562E-03	0.0001	3.712E-04	0.0000	4.411E-02	0.0018
Np-237	2.281E-08	0.0000	8.733E-10	0.0000	0.000E+00	0.0000	2.256E-08	0.0000	4.471E-09	0.0000	2.738E-08	0.0000	1.280E-08	0.0000
Pu-239	1.156E-04	0.0000	9.445E-04	0.0000	0.000E+00	0.0000	4.353E-02	0.0018	6.364E-03	0.0003	2.305E-04	0.0000	5.479E-02	0.0023
Ra-228	3.680E-06	0.0000	6.557E-10	0.0000	0.000E+00	0.0000	3.709E-07	0.0000	1.935E-08	0.0000	8.730E-08	0.0000	2.214E-08	0.0000
Tc-99	1.147E-05	0.0000	3.948E-09	0.0000	0.000E+00	0.0000	1.913E-02	0.0008	2.566E-05	0.0000	2.138E-03	0.0001	4.864E-06	0.0000
Th-228	5.249E-16	0.0000	1.278E-19	0.0000	0.000E+00	0.0000	1.672E-18	0.0000	2.444E-19	0.0000	4.427E-20	0.0000	2.105E-18	0.0000
Th-232	4.613E+00	0.1898	4.635E-03	0.0002	0.000E+00	0.0000	6.825E-01	0.0281	3.827E-02	0.0016	1.537E-01	0.0063	7.760E-02	0.0032
U-234	9.678E-05	0.0000	1.191E-04	0.0000	0.000E+00	0.0000	3.542E-03	0.0001	7.171E-04	0.0000	4.655E-03	0.0002	1.794E-03	0.0001
U-235	1.195E-01	0.0049	1.129E-04	0.0000	0.000E+00	0.0000	3.791E-03	0.0002	1.010E-03	0.0000	4.395E-03	0.0002	1.762E-03	0.0001
U-238	2.129E-02	0.0009	1.061E-04	0.0000	0.000E+00	0.0000	3.357E-03	0.0001	6.808E-04	0.0000	4.426E-03	0.0002	1.700E-03	0.0001
Total	4.769E+00	0.1962	6.683E-03	0.0003	0.000E+00	0.0000	7.909E-01	0.0325	4.963E-02	0.0020	1.699E-01	0.0070	1.818E-01	0.0075

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Am-241	2.617E-04	0.0000	4.146E-05	0.0000	0.000E+00	0.0000	4.067E-05	0.0000	3.507E-06	0.0000	1.113E-07	0.0000	9.808E-02	0.0040
Np-237	1.381E+01	0.5682	2.189E+00	0.0900	0.000E+00	0.0000	2.147E+00	0.0883	1.853E-01	0.0076	5.877E-03	0.0002	1.834E+01	0.7544
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.060E-01	0.0044
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.180E-06	0.0000
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.131E-02	0.0009
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.291E-16	0.0000
ι-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.569E+00	0.2292
234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.092E-02	0.0004
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.306E-01	0.0054
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.156E-02	0.0013
Total	1.381E+01	0.5682	2.189E+00	0.0901	0.000E+00	0.0000	2.147E+00	0.0883	1.853E-01	0.0076	5.877E-03	0.0002	2.430E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	7.145E-05	0.6876	1.133E-05	0.1090	0.000E+00	0.0000	1.111E-05	0.1069	9.599E-07	0.0092	3.044E-08	0.0003	9.488E-05	0.9130
Np-237	4.605E-06	0.0443	1.955E-07	0.0019	0.000E+00	0.0000	7.134E-07	0.0069	2.099E-08	0.0002	2.349E-07	0.0023	5.769E-06	0.0555
Pu-239	3.860E-14	0.0000	7.552E-15	0.0000	0.000E+00	0.0000	5.969E-15	0.0000	1.025E-17	0.0000	6.520E-17	0.0000	5.220E-14	0.0000
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	2.417E-06	0.0233	4.729E-07	0.0046	0.000E+00	0.0000	3.738E-07	0.0036	6.430E-10	0.0000	4.087E-09	0.0000	3.268E-06	0.0315
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	7.847E-05	0.7552	1.199E-05	0.1154	0.000E+00	0.0000	1.220E-05	0.1174	9.816E-07	0.0094	2.694E-07	0.0026	1.039E-04	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Am-241	1.701E-05	0.0003	2.695E-06	0.0000	0.000E+00	0.0000	2.644E-06	0.0000	2.283E-07	0.0000	7.251E-09	0.0000	2.258E-05	0.0004
Np-237	4.599E-06	0.0001	1.995E-07	0.0000	0.000E+00	0.0000	7.125E-07	0.0000	2.093E-08	0.0000	2.340E-07	0.0000	5.766E-06	0.0001
Pu-239	3.870E-09	0.0000	6.503E-10	0.0000	0.000E+00	0.0000	5.995E-10	0.0000	5.020E-11	0.0000	5.638E-12	0.0000	5.176E-09	0.0000
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-234	2.084E-07	0.0000	1.549E-07	0.0000	0.000E+00	0.0000	3.238E-08	0.0000	2.410E-09	0.0000	9.422E-09	0.0000	4.075E-07	0.0000
U-235	4.213E-02	0.7478	7.013E-03	0.1245	0.000E+00	0.0000	6.527E-03	0.1158	5.771E-04	0.0102	6.080E-05	0.0011	5.631E-02	0.9995
U-238	3.894E-11	0.0000	3.314E-11	0.0000	0.000E+00	0.0000	6.237E-12	0.0000	4.904E-13	0.0000	1.546E-12	0.0000	8.035E-11	0.0000
Total	4.215E-02	0.7482	7.016E-03	0.1245	0.000E+00	0.0000	6.530E-03	0.1159	5.774E-04	0.0102	6.105E-05	0.0011	5.634E-02	1.0000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Am-241	Am-241	1.000E+00	2.136E-01	2.121E-01	2.092E-01	1.991E-01	1.723E-01	9.773E-02	0.000E+00	0.000E+00
Am-241	Np-237	1.000E+00	3.395E-07	7.783E-07	1.066E-06	1.095E-06	2.379E-05	3.480E-04	9.488E-05	2.258E-05
Am-241	U-233	1.000E+00	1.225E-14	6.243E-14	2.127E-13	7.723E-13	2.207E-12	5.185E-11	2.120E-10	3.142E-10
Am-241	Th-229	1.000E+00	4.739E-18	5.994E-17	5.203E-16	6.749E-15	5.926E-14	4.418E-13	1.451E-13	1.022E-12
Am-241	ΣDSR(j)		2.136E-01	2.121E-01	2.092E-01	1.991E-01	1.724E-01	9.808E-02	9.488E-05	2.258E-05
Np-237	Np-237	1.000E+00	1.969E+00	9.125E-01	1.942E-01	8.637E-04	1.769E+01	1.834E+01	0.000E+00	0.000E+00
Np-237	U-233	1.000E+00	9.841E-08	1.971E-07	2.563E-07	2.489E-07	4.933E-07	4.856E-06	5.763E-06	5.741E-06
Np-237	Th-229	1.000E+00	5.572E-11	3.166E-10	1.150E-09	4.414E-09	1.233E-08	2.703E-08	6.266E-09	2.447E-08
Np-237	ΣDSR(j)		1.969E+00	9.125E-01	1.942E-01	8.640E-04	1.769E+01	1.834E+01	5.769E-06	5.766E-06
Pu-239	Pu-239	1.000E+00	1.932E-01	1.922E-01	1.904E-01	1.838E-01	1.655E-01	1.060E-01	0.000E+00	0.000E+00
Pu-239	U-235	1.000E+00	1.938E-10	5.789E-10	1.335E-09	3.839E-09	9.862E-09	2.076E-08	0.000E+00	0.000E+00
Pu-239	Pa-231	1.000E+00	1.431E-14	1.045E-13	5.468E-13	4.353E-12	2.559E-11	8.181E-11	0.000E+00	9.342E-10
Pu-239	Ac-227	1.000E+00	8.046E-17	1.020E-15	1.012E-14	1.927E-13	2.258E-12	1.180E-11	5.220E-14	4.242E-09
Pu-239	ΣDSR(j)		1.932E-01	1.922E-01	1.904E-01	1.838E-01	1.655E-01	1.060E-01	5.220E-14	5.176E-09
Ra-228	Ra-228	1.000E+00	3.957E+00	3.416E+00	2.545E+00	9.078E-01	4.760E-02	1.487E-06	0.000E+00	0.000E+00
Ra-228	Th-228	1.000E+00	6.539E-01	1.561E+00	2.244E+00	1.362E+00	8.092E-02	2.693E-06	0.000E+00	0.000E+00
Ra-228	ΣDSR(j)		4.611E+00	4.977E+00	4.789E+00	2.270E+00	1.285E-01	4.180E-06	0.000E+00	0.000E+00
Tc-99	Tc-99	1.000E+00	1.790E-01	1.755E-01	1.685E-01	1.462E-01	9.699E-02	2.131E-02	0.000E+00	0.000E+00
Th-228	Th-228	1.000E+00	3.537E+00	2.459E+00	1.188E+00	9.320E-02	6.446E-05	5.291E-16	0.000E+00	0.000E+00
Th-232	Th-232	1.000E+00	1.557E-01	1.551E-01	1.539E-01	1.495E-01	1.369E-01	9.315E-02	0.000E+00	0.000E+00
Th-232	Ra-228	1.000E+00	2.377E-01	6.792E-01	1.388E+00	2.694E+00	3.245E+00	2.622E+00	0.000E+00	0.000E+00
Th-232	Th-228	1.000E+00	2.756E-02	1.663E-01	6.462E-01	2.258E+00	3.296E+00	2.854E+00	0.000E+00	0.000E+00
Th-232	ΣDSR(j)		4.210E-01	1.001E+00	2.188E+00	5.101E+00	6.679E+00	5.569E+00	0.000E+00	0.000E+00
U-234	U-234	1.000E+00	4.825E-02	4.759E-02	4.629E-02	4.200E-02	3.165E-02	1.087E-02	0.000E+00	0.000E+00
U-234	Th-230	1.000E+00	1.497E-07	4.324E-07	9.804E-07	2.748E-06	6.651E-06	1.105E-05	0.000E+00	0.000E+00
U-234	Ra-226	1.000E+00	3.941E-09	2.767E-08	1.434E-07	1.174E-06	7.634E-06	3.395E-05	0.000E+00	1.014E-07
U-234	Pb-210	1.000E+00	1.480E-11	1.950E-10	2.029E-09	4.353E-08	6.523E-07	4.855E-06	0.000E+00	3.061E-07
U-234	ΣDSR(j)		4.825E-02	4.759E-02	4.629E-02	4.200E-02	3.166E-02	1.092E-02	0.000E+00	4.075E-07
U-235	U-235	1.000E+00	3.939E-01	3.898E-01	3.816E-01	3.542E-01	2.857E-01	1.296E-01	0.000E+00	0.000E+00
U-235	Pa-231	1.000E+00	4.532E-05	1.382E-04	3.107E-04	7.843E-04	1.377E-03	8.286E-04	0.000E+00	1.075E-02
U-235	Ac-227	1.000E+00	3.064E-07	1.814E-06	8.098E-06	4.842E-05	1.576E-04	1.382E-04	3.268E-06	4.556E-02
U-235	ΣDSR(j)		3.940E-01	3.899E-01	3.819E-01	3.550E-01	2.873E-01	1.306E-01	3.268E-06	5.631E-02
U-238	U-238	1.000E+00	1.116E-01	1.103E-01	1.077E-01	9.898E-02	7.764E-02	3.156E-02	0.000E+00	0.000E+00
U-238	U-234	1.000E+00	6.823E-08	2.022E-07	4.592E-07	1.250E-06	2.737E-06	3.099E-06	0.000E+00	0.000E+00
U-238	Th-230	1.000E+00	1.458E-13	9.673E-13	4.908E-12	4.034E-11	2.736E-10	1.321E-09	0.000E+00	0.000E+00
U-238	Ra-226	1.000E+00	2.770E-15	4.181E-14	4.802E-13	1.170E-11	2.219E-10	3.208E-09	0.000E+00	1.313E-11
U-238	Pb-210	1.000E+00	8.726E-18	2.363E-16	5.269E-15	3.343E-13	1.499E-11	3.940E-10	0.000E+00	6.723E-11
U-238	ΣDSR(j)		1.116E-01	1.103E-01	1.077E-01	9.898E-02	7.765E-02	3.156E-02	0.000E+00	8.035E-11

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Am-241	1.171E+02	1.179E+02	1.195E+02	1.255E+02	1.450E+02	2.549E+02	2.635E+05	1.107E+06
Np-237	1.269E+01	2.740E+01	1.287E+02	2.894E+04	1.413E+00	1.363E+00	4.333E+06	4.336E+06
Pu-239	1.294E+02	1.300E+02	1.313E+02	1.360E+02	1.510E+02	2.359E+02	*6.212E+10	4.830E+09
Ra-228	5.422E+00	5.023E+00	5.221E+00	1.102E+01	1.945E+02	5.981E+06	*2.726E+14	*2.726E+14
Tc-99	1.396E+02	1.425E+02	1.483E+02	1.710E+02	2.578E+02	1.173E+03	*1.696E+10	*1.696E+10
Th-228	7.067E+00	1.017E+01	2.104E+01	2.682E+02	3.879E+05	*8.192E+14	*8.192E+14	*8.192E+14
Th-232	5.939E+01	2.499E+01	1.143E+01	4.901E+00	3.743E+00	4.489E+00	*1.096E+05	*1.096E+05
U-234	5.182E+02	5.253E+02	5.401E+02	5.952E+02	7.895E+02	2.289E+03	*6.245E+09	6.134E+07
U-235	6.346E+01	6.412E+01	6.546E+01	7.042E+01	8.703E+01	1.914E+02	*2.160E+06	4.440E+02
U-238	2.241E+02	2.267E+02	2.322E+02	2.526E+02	3.220E+02	7.920E+02	*3.360E+05	*3.360E+05

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose =   32.99 ± 0.07 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Am-241	1.000E+00	0.000E+00	2.136E-01	1.171E+02	1.686E-01	1.483E+02
Np-237	1.000E+00	102.8 ± 0.2	1.840E+01	1.359E+00	1.798E+01	1.390E+00
Pu-239	1.000E+00	0.000E+00	1.932E-01	1.294E+02	1.628E-01	1.535E+02
Ra-228	1.000E+00	1.522 ± 0.003	5.017E+00	4.983E+00	8.289E-02	3.016E+02
Tc-99	1.000E+00	0.000E+00	1.790E-01	1.396E+02	9.116E-02	2.742E+02
Th-228	1.000E+00	0.000E+00	3.537E+00	7.067E+00	2.173E-05	1.151E+06
Th-232	1.000E+00	30.46 ± 0.06	6.679E+00	3.743E+00	6.673E+00	3.747E+00
U-234	1.000E+00	0.000E+00	4.825E-02	5.182E+02	3.034E-02	8.241E+02
U-235	1.000E+00	0.000E+00	3.940E-01	6.346E+01	2.782E-01	8.986E+01
U-238	1.000E+00	0.000E+00	1.116E-01	2.241E+02	7.485E-02	3.340E+02

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Am-241	Am-241	1.000E+00	2.136E-01	2.121E-01	2.092E-01	1.991E-01	1.723E-01	9.773E-02	0.000E+00	0.000E+00
Np-237	Am-241	1.000E+00	3.395E-07	7.783E-07	1.066E-06	1.095E-06	2.379E-05	3.480E-04	9.488E-05	2.258E-05
Np-237	Np-237	1.000E+00	1.969E+00	9.125E-01	1.942E-01	8.637E-04	1.769E+01	1.834E+01	0.000E+00	0.000E+00
Np-237	ΣDOSE(j)		1.969E+00	9.125E-01	1.942E-01	8.648E-04	1.769E+01	1.834E+01	9.488E-05	2.258E-05
U-233	Am-241	1.000E+00	1.225E-14	6.243E-14	2.127E-13	7.723E-13	2.207E-12	5.185E-11	2.120E-10	3.142E-10
U-233	Np-237	1.000E+00	9.841E-08	1.971E-07	2.563E-07	2.489E-07	4.933E-07	4.856E-06	5.763E-06	5.741E-06
U-233	ΣDOSE(j)		9.841E-08	1.971E-07	2.563E-07	2.489E-07	4.933E-07	4.856E-06	5.763E-06	5.742E-06
Th-229	Am-241	1.000E+00	4.739E-18	5.994E-17	5.203E-16	6.749E-15	5.926E-14	4.418E-13	1.451E-13	1.022E-12
Th-229	Np-237	1.000E+00	5.572E-11	3.166E-10	1.150E-09	4.414E-09	1.233E-08	2.703E-08	6.266E-09	2.447E-08
Th-229	ΣDOSE(j)		5.572E-11	3.166E-10	1.150E-09	4.414E-09	1.233E-08	2.703E-08	6.266E-09	2.447E-08
Pu-239	Pu-239	1.000E+00	1.932E-01	1.922E-01	1.904E-01	1.838E-01	1.655E-01	1.060E-01	0.000E+00	0.000E+00
U-235	Pu-239	1.000E+00	1.938E-10	5.789E-10	1.335E-09	3.839E-09	9.862E-09	2.076E-08	0.000E+00	0.000E+00
U-235	U-235	1.000E+00	3.939E-01	3.898E-01	3.816E-01	3.542E-01	2.857E-01	1.296E-01	0.000E+00	0.000E+00
U-235	ΣDOSE(j)		3.939E-01	3.898E-01	3.816E-01	3.542E-01	2.857E-01	1.296E-01	0.000E+00	0.000E+00
Pa-231	Pu-239	1.000E+00	1.431E-14	1.045E-13	5.468E-13	4.353E-12	2.559E-11	8.181E-11	0.000E+00	9.342E-10
Pa-231	U-235	1.000E+00	4.532E-05	1.382E-04	3.107E-04	7.843E-04	1.377E-03	8.286E-04	0.000E+00	1.075E-02
Pa-231	ΣDOSE(j)		4.532E-05	1.382E-04	3.107E-04	7.843E-04	1.377E-03	8.286E-04	0.000E+00	1.075E-02
Ac-227	Pu-239	1.000E+00	8.046E-17	1.020E-15	1.012E-14	1.927E-13	2.258E-12	1.180E-11	5.220E-14	4.242E-09
Ac-227	U-235	1.000E+00	3.064E-07	1.814E-06	8.098E-06	4.842E-05	1.576E-04	1.382E-04	3.268E-06	4.556E-02
Ac-227	ΣDOSE(j)		3.064E-07	1.814E-06	8.098E-06	4.842E-05	1.576E-04	1.382E-04	3.268E-06	4.556E-02
Ra-228	Ra-228	1.000E+00	3.957E+00	3.416E+00	2.545E+00	9.078E-01	4.760E-02	1.487E-06	0.000E+00	0.000E+00
-228	Th-232	1.000E+00	2.377E-01	6.792E-01	1.388E+00	2.694E+00	3.245E+00	2.622E+00	0.000E+00	0.000E+00
-228	ΣDOSE(j)		4.195E+00	4.095E+00	3.933E+00	3.602E+00	3.293E+00	2.622E+00	0.000E+00	0.000E+00
Th-228	Ra-228	1.000E+00	6.539E-01	1.561E+00	2.244E+00	1.362E+00	8.092E-02	2.693E-06	0.000E+00	0.000E+00
Th-228	Th-228	1.000E+00	3.537E+00	2.459E+00	1.188E+00	9.320E-02	6.446E-05	5.291E-16	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	2.756E-02	1.663E-01	6.462E-01	2.258E+00	3.296E+00	2.854E+00	0.000E+00	0.000E+00
Th-228	ΣDOSE(j)		4.219E+00	4.187E+00	4.079E+00	3.713E+00	3.377E+00	2.854E+00	0.000E+00	0.000E+00
Tc-99	Tc-99	1.000E+00	1.790E-01	1.755E-01	1.685E-01	1.462E-01	9.699E-02	2.131E-02	0.000E+00	0.000E+00
Th-232	Th-232	1.000E+00	1.557E-01	1.551E-01	1.539E-01	1.495E-01	1.369E-01	9.315E-02	0.000E+00	0.000E+00
U-234	U-234	1.000E+00	4.825E-02	4.759E-02	4.629E-02	4.200E-02	3.165E-02	1.087E-02	0.000E+00	0.000E+00
U-234	U-238	1.000E+00	6.823E-08	2.022E-07	4.592E-07	1.250E-06	2.737E-06	3.099E-06	0.000E+00	0.000E+00
U-234	ΣDOSE(j)		4.825E-02	4.759E-02	4.629E-02	4.200E-02	3.165E-02	1.088E-02	0.000E+00	0.000E+00
Th-230	U-234	1.000E+00	1.497E-07	4.324E-07	9.804E-07	2.748E-06	6.651E-06	1.105E-05	0.000E+00	0.000E+00
Th-230	U-238	1.000E+00	1.458E-13	9.673E-13	4.908E-12	4.034E-11	2.736E-10	1.321E-09	0.000E+00	0.000E+00
Th-230	ΣDOSE(j)		1.497E-07	4.324E-07	9.804E-07	2.748E-06	6.651E-06	1.105E-05	0.000E+00	0.000E+00

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	U-234	1.000E+00	3.941E-09	2.767E-08	1.434E-07	1.174E-06	7.634E-06	3.395E-05	0.000E+00	1.014E-07
Ra-226	U-238	1.000E+00	2.770E-15	4.181E-14	4.802E-13	1.170E-11	2.219E-10	3.208E-09	0.000E+00	1.313E-11
Ra-226	ΣDOSE(j)		3.941E-09	2.767E-08	1.434E-07	1.174E-06	7.634E-06	3.395E-05	0.000E+00	1.015E-07
Pb-210	U-234	1.000E+00	1.480E-11	1.950E-10	2.029E-09	4.353E-08	6.523E-07	4.855E-06	0.000E+00	3.061E-07
Pb-210	U-238	1.000E+00	8.726E-18	2.363E-16	5.269E-15	3.343E-13	1.499E-11	3.940E-10	0.000E+00	6.723E-11
Pb-210	ΣDOSE(j)		1.480E-11	1.950E-10	2.029E-09	4.353E-08	6.523E-07	4.855E-06	0.000E+00	3.062E-07
U-238	U-238	1.000E+00	1.116E-01	1.103E-01	1.077E-01	9.898E-02	7.764E-02	3.156E-02	0.000E+00	0.000E+00

BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

0Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Am-241	Am-241	1.000E+00	1.000E+00	9.967E-01	9.901E-01	9.673E-01	9.052E-01	7.174E-01	3.693E-01	3.613E-02
Np-237	Am-241	1.000E+00	0.000E+00	2.254E-07	3.763E-07	4.084E-07	3.823E-07	3.030E-07	1.560E-07	1.526E-08
Np-237	Np-237	1.000E+00	1.000E+00	4.629E-01	9.921E-02	4.520E-04	9.237E-11	3.562E-34	0.000E+00	0.000E+00
Np-237	ΣS(j):		1.000E+00	4.629E-01	9.921E-02	4.524E-04	3.824E-07	3.030E-07	1.560E-07	1.526E-08
U-233	Am-241	1.000E+00	0.000E+00	5.541E-13	3.316E-12	1.510E-11	4.377E-11	9.660E-11	9.003E-11	1.028E-11
U-233	Np-237	1.000E+00	0.000E+00	3.033E-06	5.014E-06	5.212E-06	4.286E-06	2.158E-06	3.036E-07	3.174E-10
U-233	ΣS(j):		0.000E+00	3.033E-06	5.014E-06	5.212E-06	4.286E-06	2.158E-06	3.037E-07	3.277E-10
Th-229	Am-241	1.000E+00	0.000E+00	1.852E-17	3.648E-16	6.460E-15	6.323E-14	5.578E-13	2.449E-12	4.658E-12
Th-229	Np-237	1.000E+00	0.000E+00	1.617E-10	9.703E-10	4.466E-09	1.339E-08	3.367E-08	5.042E-08	4.898E-08
Th-229	ΣS(j):		0.000E+00	1.617E-10	9.703E-10	4.466E-09	1.339E-08	3.367E-08	5.043E-08	4.898E-08
Pu-239	Pu-239	1.000E+00	1.000E+00	9.991E-01	9.973E-01	9.912E-01	9.737E-01	9.151E-01	7.663E-01	4.117E-01
U-235	Pu-239	1.000E+00	0.000E+00	9.796E-10	2.908E-09	9.339E-09	2.524E-08	5.965E-08	7.883E-08	4.549E-08
U-235	U-235	1.000E+00	1.000E+00	9.902E-01	9.710E-01	9.066E-01	7.453E-01	3.753E-01	5.286E-02	5.543E-05
U-235	ΣS(j):		1.000E+00	9.902E-01	9.710E-01	9.066E-01	7.453E-01	3.753E-01	5.286E-02	5.548E-05
Pa-231	Pu-239	1.000E+00	0.000E+00	1.026E-14	8.967E-14	8.993E-13	6.116E-12	2.909E-11	4.870E-11	2.888E-11
Pa-231	U-235	1.000E+00	0.000E+00	2.070E-05	5.943E-05	1.702E-04	3.354E-04	2.970E-04	4.579E-05	4.805E-08
Pa-231	ΣS(j):		0.000E+00	2.070E-05	5.943E-05	1.702E-04	3.354E-04	2.970E-04	4.579E-05	4.808E-08
Ac-227	Pu-239	1.000E+00	0.000E+00	1.062E-16	2.649E-15	7.530E-14	1.045E-12	7.265E-12	1.327E-11	7.938E-12
Ac-227	U-235	1.000E+00	0.000E+00	3.193E-07	2.587E-06	2.021E-05	7.480E-05	8.593E-05	1.363E-05	1.431E-08
Ac-227	ΣS(j):		0.000E+00	3.193E-07	2.587E-06	2.021E-05	7.480E-05	8.593E-05	1.363E-05	1.431E-08
Ra-228	Ra-228	1.000E+00	1.000E+00	8.650E-01	6.473E-01	2.346E-01	1.291E-02	5.043E-07	1.283E-19	0.000E+00
Ra-228	Th-232	1.000E+00	0.000E+00	1.122E-01	2.932E-01	6.362E-01	8.201E-01	8.291E-01	8.244E-01	8.081E-01
-228	ΣS(j):		1.000E+00	9.772E-01	9.405E-01	8.708E-01	8.330E-01	8.291E-01	8.244E-01	8.081E-01
Th-228	Ra-228	1.000E+00	0.000E+00	2.817E-01	5.169E-01	3.465E-01	2.148E-02	8.407E-07	2.139E-19	0.000E+00
Th-228	Th-228	1.000E+00	1.000E+00	6.960E-01	3.372E-01	2.669E-02	1.901E-05	1.835E-16	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	0.000E+00	1.849E-02	1.213E-01	5.209E-01	8.129E-01	8.291E-01	8.244E-01	8.081E-01
Th-228	ΣS(j):		1.000E+00	9.962E-01	9.753E-01	8.942E-01	8.344E-01	8.291E-01	8.244E-01	8.081E-01
Tc-99	Tc-99	1.000E+00	1.000E+00	9.840E-01	9.527E-01	8.507E-01	6.156E-01	1.985E-01	7.822E-03	9.502E-08
Th-232	Th-232	1.000E+00	1.000E+00	1.000E+00	9.999E-01	9.997E-01	9.991E-01	9.971E-01	9.915E-01	9.718E-01
U-234	U-234	1.000E+00	1.000E+00	9.902E-01	9.710E-01	9.066E-01	7.452E-01	3.752E-01	5.282E-02	5.528E-05
U-234	U-238	1.000E+00	0.000E+00	2.807E-06	8.258E-06	2.570E-05	6.338E-05	1.064E-04	4.494E-05	1.569E-07
U-234	ΣS(j):		1.000E+00	9.902E-01	9.710E-01	9.066E-01	7.453E-01	3.753E-01	5.286E-02	5.543E-05
Th-230	U-234	1.000E+00	0.000E+00	8.958E-06	2.661E-05	8.573E-05	2.338E-04	5.725E-04	8.628E-04	8.877E-04
Th-230	U-238	1.000E+00	0.000E+00	1.268E-11	1.126E-10	1.195E-09	9.459E-09	6.815E-08	2.091E-07	2.576E-07
Th-230	ΣS(j):		0.000E+00	8.958E-06	2.661E-05	8.573E-05	2.338E-04	5.726E-04	8.630E-04	8.880E-04

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	U-234	1.000E+00	0.000E+00	1.927E-09	1.695E-08	1.739E-07	1.255E-06	6.941E-06	1.450E-05	1.548E-05
Ra-226	U-238	1.000E+00	0.000E+00	1.822E-15	4.812E-14	1.650E-12	3.588E-11	6.528E-10	3.280E-09	4.490E-09
Ra-226	ΣS(j):		0.000E+00	1.927E-09	1.695E-08	1.739E-07	1.255E-06	6.942E-06	1.450E-05	1.548E-05
Pb-210	U-234	1.000E+00	0.000E+00	1.979E-11	5.127E-10	1.647E-08	3.014E-07	3.420E-06	9.128E-06	9.984E-06
Pb-210	U-238	1.000E+00	0.000E+00	1.406E-17	1.097E-15	1.192E-13	6.786E-12	2.758E-10	1.980E-09	2.896E-09
Pb-210	ΣS(j):		0.000E+00	1.979E-11	5.127E-10	1.647E-08	3.014E-07	3.420E-06	9.130E-06	9.987E-06
U-238	U-238	1.000E+00	1.000E+00	9.902E-01	9.710E-01	9.066E-01	7.453E-01	3.753E-01	5.286E-02	5.543E-05

BRF(i) is the branch fraction of the parent nuclide.

RESCALC.EXE execution time = 81.21 seconds

APPENDIX C

VOLUMETRIC DOSE ASSESSMENT SUMMARY REPORT

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ac-227+D	6.720E+00	6.720E+00	DCF2(1)
B-1	Am-241	4.440E-01	4.440E-01	DCF2(2)
B-1	Np-237+D	5.400E-01	5.400E-01	DCF2(3)
B-1	Pa-231	1.280E+00	1.280E+00	DCF2(4)
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(5)
B-1	Pu-239	4.290E-01	4.290E-01	DCF2(6)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(7)
B-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(8)
B-1	Tc-99	8.330E-06	8.330E-06	DCF2(9)
B-1	Th-228+D	3.450E-01	3.450E-01	DCF2(10)
B-1	Th-229+D	2.160E+00	2.160E+00	DCF2(11)
B-1	Th-230	3.260E-01	3.260E-01	DCF2(12)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(13)
B-1	U-233	1.350E-01	1.350E-01	DCF2(14)
B-1	U-234	1.320E-01	1.320E-01	DCF2(15)
B-1	U-235+D	1.230E-01	1.230E-01	DCF2(16)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2(17)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ac-227+D	1.480E-02	1.480E-02	DCF3(1)
D-1	Am-241	3.640E-03	3.640E-03	DCF3(2)
D-1	Np-237+D	4.440E-03	4.440E-03	DCF3(3)
D-1	Pa-231	1.060E-02	1.060E-02	DCF3(4)
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(5)
D-1	Pu-239	3.540E-03	3.540E-03	DCF3(6)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(7)
D-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(8)
D-1	Tc-99	1.460E-06	1.460E-06	DCF3(9)
D-1	Th-228+D	8.080E-04	8.080E-04	DCF3(10)
-1	Th-229+D	4.030E-03	4.030E-03	DCF3(11)
1	Th-230	5.480E-04	5.480E-04	DCF3(12)
-1	Th-232	2.730E-03	2.730E-03	DCF3(13)
D-1	U-233	2.890E-04	2.890E-04	DCF3(14)
D-1	U-234	2.830E-04	2.830E-04	DCF3(15)
D-1	U-235+D	2.670E-04	2.670E-04	DCF3(16)
D-1	U-238+D	2.690E-04	2.690E-04	DCF3(17)
D-34	Food transfer factors:			
D-34	Ac-227+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(1,1)
D-34	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,2)
D-34	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,3)
D-34				
D-34	Am-241 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(2,1)
D-34	Am-241 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-05	5.000E-05	RTF(2,2)
D-34	Am-241 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-06	2.000E-06	RTF(2,3)
D-34				
D-34	Np-237+D , plant/soil concentration ratio, dimensionless	2.000E-02	2.000E-02	RTF(3,1)
D-34	Np-237+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,2)
D-34	Np-237+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(3,3)
D-34				

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
D-34	Pa-231 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(4,1)
D-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-03	5.000E-03	RTF(4,2)
D-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(4,3)
D-34				
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(5,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(5,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(5,3)
D-34				
D-34	Pu-239 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(6,1)
D-34	Pu-239 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(6,2)
D-34	Pu-239 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-06	1.000E-06	RTF(6,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(7,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(7,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(7,3)
D-34				
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(8,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(8,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(8,3)
D-34				
D-34	Tc-99 , plant/soil concentration ratio, dimensionless	5.000E+00	5.000E+00	RTF(9,1)
D-34	Tc-99 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(9,2)
D-34	Tc-99 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(9,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(10,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(10,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(10,3)
D-34				
D-34	Th-229+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(11,1)
D-34	Th-229+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(11,2)
·34	Th-229+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(11,3)
34				
34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(12,1)
D-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(12,2)
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(12,3)
D-34				
D-34	Th-232 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(13,1)
D-34	Th-232 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(13,2)
D-34	Th-232 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(13,3)
D-34				
D-34	U-233 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(14,1)
D-34	U-233 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(14,2)
D-34	U-233 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(14,3)
D-34				
D-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(15,1)
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(15,2)
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(15,3)
D-34				
D-34	U-235+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(16,1)
D-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(16,2)
D-34	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(16,3)

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(17,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(17,2)
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(17,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ac-227+D , fish	1.500E+01	1.500E+01	BIOFAC(1,1)
D-5	Ac-227+D , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(1,2)
D-5				
D-5	Am-241 , fish	3.000E+01	3.000E+01	BIOFAC(2,1)
D-5	Am-241 , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(2,2)
D-5				
D-5	Np-237+D , fish	3.000E+01	3.000E+01	BIOFAC(3,1)
D-5	Np-237+D , crustacea and mollusks	4.000E+02	4.000E+02	BIOFAC(3,2)
D-5				
D-5	Pa-231 , fish	1.000E+01	1.000E+01	BIOFAC(4,1)
D-5	Pa-231 , crustacea and mollusks	1.100E+02	1.100E+02	BIOFAC(4,2)
D-5				
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(5,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(5,2)
D-5				
D-5	Pu-239 , fish	3.000E+01	3.000E+01	BIOFAC(6,1)
D-5	Pu-239 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(6,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(7,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(7,2)
D-5				
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(8,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(8,2)
D-5				
D-5	Tc-99 , fish	2.000E+01	2.000E+01	BIOFAC(9,1)
D-5	Tc-99 , crustacea and mollusks	5.000E+00	5.000E+00	BIOFAC(9,2)
-5				
-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(10,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(10,2)
D-5				
D-5	Th-229+D , fish	1.000E+02	1.000E+02	BIOFAC(11,1)
D-5	Th-229+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(11,2)
D-5				
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(12,1)
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(12,2)
D-5				
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(13,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(13,2)
D-5				
D-5	U-233 , fish	1.000E+01	1.000E+01	BIOFAC(14,1)
D-5	U-233 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(14,2)
D-5				
D-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(15,1)
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(15,2)
D-5				

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: FGR 13 Morbidity

Menu	Parameter	Current Value	Default	Parameter Name
D-5	U-235+D , fish	1.000E+01	1.000E+01	BIOFAC(16,1)
D-5	U-235+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(16,2)
D-5				
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIOFAC(17,1)
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(17,2)

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	7.746E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	2.000E+00	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	2.910E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	2.500E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Am-241	1.000E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Np-237	1.000E+00	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Pu-239	1.000E+00	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Ra-228	1.000E+00	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): Tc-99	1.000E+00	0.000E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g): Th-228	1.000E+00	0.000E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): Th-232	1.000E+00	0.000E+00	---	S1(13)
R012	Initial principal radionuclide (pCi/g): U-234	1.000E+00	0.000E+00	---	S1(15)
R012	Initial principal radionuclide (pCi/g): U-235	1.000E+00	0.000E+00	---	S1(16)
R012	Initial principal radionuclide (pCi/g): U-238	1.000E+00	0.000E+00	---	S1(17)
R012	Concentration in groundwater (pCi/L): Am-241	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Np-237	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Pu-239	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): Tc-99	not used	0.000E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(10)
12	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(13)
12	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(15)
012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(16)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(17)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.690E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	6.000E-04	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.500E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	1.700E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.456E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	1.040E+01	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	9.650E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R013	Runoff coefficient	3.050E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	9.989E+05	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.690E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.500E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.900E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	1.700E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.696E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	1.500E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	1.040E+01	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.600E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	9.130E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	4.500E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.690E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.500E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.900E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	1.700E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	1.040E+01	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.456E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Am-241				
R016	Contaminated zone (cm**3/g)	1.000E+03	2.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+03	2.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	1.000E+03	2.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.288E-04	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
16	Distribution coefficients for Np-237				
R016	Contaminated zone (cm**3/g)	2.000E+00	-1.000E+00	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+00	-1.000E+00	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	2.000E+00	-1.000E+00	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.776E-02	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for Pu-239				
R016	Contaminated zone (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCU(6,1)
R016	Saturated zone (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCS(6)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.439E-05	ALEACH(6)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(6)
R016	Distribution coefficients for Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(8,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(8)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.834E-03	ALEACH(8)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(8)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Tc-99				
R016	Contaminated zone (cm**3/g)	1.060E+02	0.000E+00	---	DCNUCC(9)
R016	Unsaturated zone 1 (cm**3/g)	1.060E+02	0.000E+00	---	DCNUCU(9,1)
R016	Saturated zone (cm**3/g)	1.060E+02	0.000E+00	---	DCNUCS(9)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.212E-03	ALEACH(9)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(9)
R016	Distribution coefficients for Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(10)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(10,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(10)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.147E-06	ALEACH(10)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(10)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(13)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(13,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(13)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.147E-06	ALEACH(13)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(13)
R016	Distribution coefficients for U-234				
R016	Contaminated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCC(15)
R016	Unsaturated zone 1 (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCU(15,1)
R016	Saturated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCS(15)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.350E-04	ALEACH(15)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(15)
R016	Distribution coefficients for U-235				
R016	Contaminated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCC(16)
R016	Unsaturated zone 1 (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCU(16,1)
R016	Saturated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCS(16)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.350E-04	ALEACH(16)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(16)
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCC(17)
R016	Unsaturated zone 1 (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCU(17,1)
R016	Saturated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCS(17)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.350E-04	ALEACH(17)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(17)
R016	Distribution coefficients for daughter Ac-227				
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.367E-03	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Pa-231				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.564E-03	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.285E-03	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
R016	Distribution coefficients for daughter Ra-226				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(7,1)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.834E-03	ALEACH(7)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(7)
R016	Distribution coefficients for daughter Th-229				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(11)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(11,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(11)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.147E-06	ALEACH(11)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(11)
R016	Distribution coefficients for daughter Th-230				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(12)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(12,1)
016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(12)
)16	Leach rate (/yr)	0.000E+00	0.000E+00	2.147E-06	ALEACH(12)
?016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(12)
R016	Distribution coefficients for daughter U-233				
R016	Contaminated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCC(14)
R016	Unsaturated zone 1 (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCU(14,1)
R016	Saturated zone (cm**3/g)	1.750E+02	5.000E+01	---	DCNUCS(14)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	7.350E-04	ALEACH(14)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(14)
R017	Inhalation rate (m**3/yr)	8.600E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	5.900E-06	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	5.512E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	6.571E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	1.181E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.120E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	2.140E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	2.330E+02	9.200E+01	---	DIET(3)
18	Meat and poultry consumption (kg/yr)	6.510E+01	6.300E+01	---	DIET(4)
18	Fish consumption (kg/yr)	2.060E+01	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	4.785E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	1.000E+00	5.000E-01	---	FR9
R018	Contamination fraction of plant food	1.000E+00	-1	---	FPLANT
R018	Contamination fraction of meat	1.000E+00	-1	---	FMEAT
R018	Contamination fraction of milk	1.000E+00	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	2.680E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	6.325E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	6.000E+01	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
4	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
4	DCF correction factor for gaseous forms of C14	not used	8.894E+01	---	CO2F
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Contaminated Zone Dimensions	
Area:	77458.00 square meters
Thickness:	2.00 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Am-241	1.000E+00
Np-237	1.000E+00
Pu-239	1.000E+00
Ra-228	1.000E+00
Tc-99	1.000E+00
Th-228	1.000E+00
Th-232	1.000E+00
U-234	1.000E+00
U-235	1.000E+00
U-238	1.000E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	3.260E+01	3.188E+01	3.055E+01	2.695E+01	8.482E+01	2.568E+02	1.924E+01	1.863E+01
M(t):	1.304E+00	1.275E+00	1.222E+00	1.078E+00	3.393E+00	1.027E+01	7.695E-01	7.452E-01

Maximum TDOSE(t): 2.585E+02 mrem/yr at t = 115.5 ± 0.2 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.155E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Am-241	1.707E-02	0.0001	1.462E-03	0.0000	0.000E+00	0.0000	3.980E-01	0.0015	5.109E-03	0.0000	7.821E-04	0.0000	8.425E-02	0.0003
Np-237	6.390E-04	0.0000	2.723E-06	0.0000	0.000E+00	0.0000	1.464E-02	0.0001	3.719E-04	0.0000	1.319E-05	0.0000	1.555E-04	0.0000
-239	1.383E-04	0.0000	1.708E-03	0.0000	0.000E+00	0.0000	4.680E-01	0.0018	1.201E-02	0.0000	4.599E-04	0.0000	9.909E-02	0.0004
-228	6.857E-06	0.0000	1.453E-09	0.0000	0.000E+00	0.0000	5.420E-06	0.0000	1.053E-07	0.0000	6.989E-07	0.0000	5.165E-08	0.0000
Tc-99	5.190E-05	0.0000	2.912E-08	0.0000	0.000E+00	0.0000	8.458E-01	0.0033	1.111E-03	0.0000	9.360E-02	0.0004	3.588E-05	0.0000
Th-228	2.705E-18	0.0000	7.883E-22	0.0000	0.000E+00	0.0000	6.130E-20	0.0000	1.573E-21	0.0000	3.012E-22	0.0000	1.298E-20	0.0000
Th-232	7.446E+00	0.0288	7.988E-03	0.0000	0.000E+00	0.0000	8.058E+00	0.0312	1.567E-01	0.0006	9.919E-01	0.0038	1.399E-01	0.0005
U-234	2.990E-04	0.0000	4.891E-04	0.0000	0.000E+00	0.0000	8.708E-02	0.0003	3.271E-03	0.0000	2.395E-02	0.0001	7.370E-03	0.0000
U-235	3.298E-01	0.0013	5.018E-04	0.0000	0.000E+00	0.0000	1.172E-01	0.0005	8.478E-03	0.0000	2.266E-02	0.0001	8.113E-03	0.0000
U-238	6.544E-02	0.0003	4.363E-04	0.0000	0.000E+00	0.0000	8.247E-02	0.0003	3.102E-03	0.0000	2.275E-02	0.0001	6.992E-03	0.0000
Total	7.860E+00	0.0304	1.259E-02	0.0000	0.000E+00	0.0000	1.007E+01	0.0390	1.901E-01	0.0007	1.156E+00	0.0045	3.459E-01	0.0013

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.155E±02 years

Water Dependent Pathways

Radio- Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	3.992E-03	0.0000	6.326E-04	0.0000	0.000E+00	0.0000	6.207E-04	0.0000	5.350E-05	0.0000	1.697E-06	0.0000	5.119E-01	0.0020
Np-237	1.799E+02	0.6959	2.851E+01	0.1103	0.000E+00	0.0000	2.798E+01	0.1082	2.415E+00	0.0093	7.657E-02	0.0003	2.389E+02	0.9241
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.814E-01	0.0022
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.313E-05	0.0000
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.406E-01	0.0036
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.782E-18	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.680E+01	0.0650
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.225E-01	0.0005
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.868E-01	0.0019
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.812E-01	0.0007
Total	1.799E+02	0.6959	2.852E+01	0.1103	0.000E+00	0.0000	2.798E+01	0.1082	2.415E+00	0.0093	7.657E-02	0.0003	2.585E+02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	rem/yr	fract.	mrem/yr	fract.
Am-241	2.085E-02	0.0006	1.786E-03	0.0001	0.000E+00	0.0000	4.860E-01	0.0149	6.238E-03	0.0002	9.552E-04	0.0000	1.029E-01	0.0032
Np-237	5.034E-01	0.0154	2.112E-03	0.0001	0.000E+00	0.0000	1.153E+01	0.3537	2.927E-01	0.0090	8.913E-03	0.0003	1.221E-01	0.0037
Pu-239	1.397E-04	0.0000	1.727E-03	0.0001	0.000E+00	0.0000	4.731E-01	0.0145	1.214E-02	0.0004	4.649E-04	0.0000	1.002E-01	0.0031
Ra-228	3.368E+00	0.1033	2.339E-04	0.0000	0.000E+00	0.0000	7.289E+00	0.2236	1.406E-01	0.0043	9.578E-01	0.0294	4.188E-02	0.0013
Tc-99	5.973E-05	0.0000	3.351E-08	0.0000	0.000E+00	0.0000	9.733E-01	0.0299	1.278E-03	0.0000	1.077E-01	0.0033	4.129E-05	0.0000
Th-228	3.998E+00	0.1226	1.165E-03	0.0000	0.000E+00	0.0000	9.059E-02	0.0028	2.325E-03	0.0001	4.451E-04	0.0000	1.918E-02	0.0006
Th-232	1.929E-01	0.0059	6.612E-03	0.0002	0.000E+00	0.0000	7.879E-01	0.0242	1.597E-02	0.0005	4.999E-02	0.0015	7.975E-02	0.0024
U-234	1.917E-04	0.0000	5.311E-04	0.0000	0.000E+00	0.0000	9.442E-02	0.0029	3.552E-03	0.0001	2.604E-02	0.0008	8.005E-03	0.0002
U-235	3.574E-01	0.0110	4.950E-04	0.0000	0.000E+00	0.0000	8.922E-02	0.0027	3.375E-03	0.0001	2.457E-02	0.0008	7.555E-03	0.0002
U-238	7.123E-02	0.0022	4.748E-04	0.0000	0.000E+00	0.0000	8.975E-02	0.0028	3.376E-03	0.0001	2.476E-02	0.0008	7.609E-03	0.0002
Total	8.512E+00	0.2611	1.514E-02	0.0005	0.000E+00	0.0000	2.190E+01	0.6718	4.816E-01	0.0148	1.202E+00	0.0369	4.892E-01	0.0150

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.188E-01	0.0190
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.246E+01	0.3822
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.877E-01	0.0180
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.180E+01	0.3619
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.082E+00	0.0332
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.111E+00	0.1261
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.133E+00	0.0348
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.327E-01	0.0041
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.826E-01	0.0148
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.972E-01	0.0060
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.260E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	2.081E-02	0.0007	1.783E-03	0.0001	0.000E+00	0.0000	4.852E-01	0.0152	6.228E-03	0.0002	9.536E-04	0.0000	1.027E-01	0.0032
Np-237	4.751E-01	0.0149	1.994E-03	0.0001	0.000E+00	0.0000	1.089E+01	0.3414	2.766E-01	0.0087	8.419E-03	0.0003	1.152E-01	0.0036
Pu-239	1.397E-04	0.0000	1.727E-03	0.0001	0.000E+00	0.0000	4.730E-01	0.0148	1.214E-02	0.0004	4.648E-04	0.0000	1.001E-01	0.0031
Ra-228	4.119E+00	0.1292	5.390E-04	0.0000	0.000E+00	0.0000	6.482E+00	0.2033	1.253E-01	0.0039	8.477E-01	0.0266	4.253E-02	0.0013
Tc-99	5.965E-05	0.0000	3.347E-08	0.0000	0.000E+00	0.0000	9.721E-01	0.0305	1.276E-03	0.0000	1.076E-01	0.0034	4.124E-05	0.0000
Th-228	2.783E+00	0.0873	8.109E-04	0.0000	0.000E+00	0.0000	6.305E-02	0.0020	1.619E-03	0.0001	3.098E-04	0.0000	1.335E-02	0.0004
Th-232	6.495E-01	0.0204	6.660E-03	0.0002	0.000E+00	0.0000	1.613E+00	0.0506	3.165E-02	0.0010	1.569E-01	0.0049	8.486E-02	0.0027
U-234	1.916E-04	0.0000	5.308E-04	0.0000	0.000E+00	0.0000	9.435E-02	0.0030	3.549E-03	0.0001	2.602E-02	0.0008	7.999E-03	0.0003
U-235	3.571E-01	0.0112	4.947E-04	0.0000	0.000E+00	0.0000	8.946E-02	0.0028	3.428E-03	0.0001	2.455E-02	0.0008	7.556E-03	0.0002
U-238	7.118E-02	0.0022	4.745E-04	0.0000	0.000E+00	0.0000	8.968E-02	0.0028	3.373E-03	0.0001	2.474E-02	0.0008	7.603E-03	0.0002
Total	8.476E+00	0.2658	1.501E-02	0.0005	0.000E+00	0.0000	2.125E+01	0.6664	4.652E-01	0.0146	1.198E+00	0.0376	4.820E-01	0.0151

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.177E-01	0.0194
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.176E+01	0.3689
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.877E-01	0.0184
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.162E+01	0.3644
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.081E+00	0.0339
-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.862E+00	0.0898
-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.543E+00	0.0797
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.326E-01	0.0042
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.826E-01	0.0151
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.970E-01	0.0062
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.188E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	2.074E-02	0.0007	1.776E-03	0.0001	0.000E+00	0.0000	4.835E-01	0.0158	6.206E-03	0.0002	9.503E-04	0.0000	1.024E-01	0.0034
Np-237	4.233E-01	0.0139	1.776E-03	0.0001	0.000E+00	0.0000	9.698E+00	0.3174	2.464E-01	0.0081	7.501E-03	0.0002	1.026E-01	0.0034
Pu-239	1.397E-04	0.0000	1.726E-03	0.0001	0.000E+00	0.0000	4.729E-01	0.0155	1.214E-02	0.0004	4.647E-04	0.0000	1.001E-01	0.0033
Ra-228	4.479E+00	0.1466	7.873E-04	0.0000	0.000E+00	0.0000	5.103E+00	0.1670	9.884E-02	0.0032	6.638E-01	0.0217	3.931E-02	0.0013
Tc-99	5.951E-05	0.0000	3.339E-08	0.0000	0.000E+00	0.0000	9.697E-01	0.0317	1.273E-03	0.0000	1.073E-01	0.0035	4.114E-05	0.0000
Th-228	1.348E+00	0.0441	3.929E-04	0.0000	0.000E+00	0.0000	3.055E-02	0.0010	7.842E-04	0.0000	1.501E-04	0.0000	6.468E-03	0.0002
Th-232	1.708E+00	0.0559	6.827E-03	0.0002	0.000E+00	0.0000	3.003E+00	0.0983	5.855E-02	0.0019	3.382E-01	0.0111	9.481E-02	0.0031
U-234	1.914E-04	0.0000	5.300E-04	0.0000	0.000E+00	0.0000	9.421E-02	0.0031	3.544E-03	0.0001	2.599E-02	0.0009	7.987E-03	0.0003
U-235	3.566E-01	0.0117	4.943E-04	0.0000	0.000E+00	0.0000	8.994E-02	0.0029	3.534E-03	0.0001	2.452E-02	0.0008	7.559E-03	0.0002
U-238	7.108E-02	0.0023	4.738E-04	0.0000	0.000E+00	0.0000	8.955E-02	0.0029	3.368E-03	0.0001	2.470E-02	0.0008	7.592E-03	0.0002
Total	8.407E+00	0.2752	1.478E-02	0.0005	0.000E+00	0.0000	2.003E+01	0.6557	4.346E-01	0.0142	1.194E+00	0.0391	4.689E-01	0.0153

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.156E-01	0.0201
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.048E+01	0.3430
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.875E-01	0.0192
-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.038E+01	0.3399
99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.078E+00	0.0353
-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.387E+00	0.0454
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.210E+00	0.1705
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.324E-01	0.0043
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.827E-01	0.0158
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.968E-01	0.0064
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.055E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Am-241	2.049E-02	0.0008	1.755E-03	0.0001	0.000E+00	0.0000	4.777E-01	0.0177	6.132E-03	0.0002	9.388E-04	0.0000	1.011E-01	0.0038
Np-237	2.825E-01	0.0105	1.185E-03	0.0000	0.000E+00	0.0000	6.473E+00	0.2402	1.644E-01	0.0061	5.007E-03	0.0002	6.851E-02	0.0025
Pu-239	1.396E-04	0.0000	1.725E-03	0.0001	0.000E+00	0.0000	4.726E-01	0.0175	1.213E-02	0.0005	4.644E-04	0.0000	1.001E-01	0.0037
Ra-228	2.605E+00	0.0966	5.392E-04	0.0000	0.000E+00	0.0000	2.182E+00	0.0810	4.238E-02	0.0016	2.819E-01	0.0105	2.006E-02	0.0007
Tc-99	5.900E-05	0.0000	3.311E-08	0.0000	0.000E+00	0.0000	9.615E-01	0.0357	1.262E-03	0.0000	1.064E-01	0.0039	4.079E-05	0.0000
Th-228	1.067E-01	0.0040	3.110E-05	0.0000	0.000E+00	0.0000	2.418E-03	0.0001	6.208E-05	0.0000	1.188E-05	0.0000	5.120E-04	0.0000
Th-232	4.777E+00	0.1772	7.428E-03	0.0003	0.000E+00	0.0000	5.908E+00	0.2192	1.149E-01	0.0043	7.144E-01	0.0265	1.196E-01	0.0044
U-234	1.914E-04	0.0000	5.274E-04	0.0000	0.000E+00	0.0000	9.373E-02	0.0035	3.526E-03	0.0001	2.585E-02	0.0010	7.947E-03	0.0003
U-235	3.548E-01	0.0132	4.933E-04	0.0000	0.000E+00	0.0000	9.167E-02	0.0034	3.902E-03	0.0001	2.440E-02	0.0009	7.576E-03	0.0003
U-238	7.071E-02	0.0026	4.713E-04	0.0000	0.000E+00	0.0000	8.909E-02	0.0033	3.351E-03	0.0001	2.457E-02	0.0009	7.553E-03	0.0003
Total	8.217E+00	0.3049	1.416E-02	0.0005	0.000E+00	0.0000	1.675E+01	0.6215	3.521E-01	0.0131	1.184E+00	0.0439	4.330E-01	0.0161

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Am-241	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.082E-01	0.0226
Np-237	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.994E+00	0.2595
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.872E-01	0.0218
-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.132E+00	0.1904
-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.069E+00	0.0397
-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.098E-01	0.0041
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.164E+01	0.4319
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.318E-01	0.0049
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.829E-01	0.0179
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.958E-01	0.0073
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.695E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	1.979E-02	0.0002	1.695E-03	0.0000	0.000E+00	0.0000	4.615E-01	0.0054	5.924E-03	0.0001	9.069E-04	0.0000	9.769E-02	0.0012
Np-237	8.898E-02	0.0010	3.734E-04	0.0000	0.000E+00	0.0000	2.039E+00	0.0240	5.180E-02	0.0006	1.578E-03	0.0000	2.158E-02	0.0003
Pu-239	1.394E-04	0.0000	1.722E-03	0.0000	0.000E+00	0.0000	4.718E-01	0.0056	1.211E-02	0.0001	4.636E-04	0.0000	9.988E-02	0.0012
Ra-228	2.391E-01	0.0028	5.067E-05	0.0000	0.000E+00	0.0000	1.891E-01	0.0022	3.673E-03	0.0000	2.439E-02	0.0003	1.802E-03	0.0000
Tc-99	5.759E-05	0.0000	3.231E-08	0.0000	0.000E+00	0.0000	9.384E-01	0.0111	1.232E-03	0.0000	1.038E-01	0.0012	3.981E-05	0.0000
Th-228	7.607E-05	0.0000	2.217E-08	0.0000	0.000E+00	0.0000	1.724E-06	0.0000	4.425E-08	0.0000	8.469E-09	0.0000	3.649E-07	0.0000
Th-232	7.212E+00	0.0850	7.939E-03	0.0001	0.000E+00	0.0000	7.873E+00	0.0928	1.531E-01	0.0018	9.681E-01	0.0114	1.381E-01	0.0016
U-234	1.969E-04	0.0000	5.199E-04	0.0000	0.000E+00	0.0000	9.239E-02	0.0011	3.475E-03	0.0000	2.548E-02	0.0003	7.834E-03	0.0001
U-235	3.499E-01	0.0041	4.930E-04	0.0000	0.000E+00	0.0000	9.687E-02	0.0011	4.906E-03	0.0001	2.405E-02	0.0003	7.660E-03	0.0001
U-238	6.968E-02	0.0008	4.645E-04	0.0000	0.000E+00	0.0000	8.780E-02	0.0010	3.303E-03	0.0000	2.422E-02	0.0003	7.443E-03	0.0001
Total	7.980E+00	0.0941	1.326E-02	0.0002	0.000E+00	0.0000	1.225E+01	0.1444	2.395E-01	0.0028	1.173E+00	0.0138	3.820E-01	0.0045

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	4.215E-05	0.0000	6.641E-06	0.0000	0.000E+00	0.0000	6.505E-06	0.0000	5.423E-07	0.0000	1.740E-08	0.0000	5.875E-01	0.0069
Np-237	4.733E+01	0.5580	7.481E+00	0.0882	0.000E+00	0.0000	7.335E+00	0.0865	6.231E-01	0.0073	1.986E-02	0.0002	6.499E+01	0.7662
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.861E-01	0.0069
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.581E-01	0.0054
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.044E+00	0.0123
-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.824E-05	0.0000
-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.635E+01	0.1928
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.299E-01	0.0015
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.838E-01	0.0057
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.929E-01	0.0023
Total	4.733E+01	0.5580	7.481E+00	0.0882	0.000E+00	0.0000	7.335E+00	0.0865	6.231E-01	0.0073	1.986E-02	0.0002	8.482E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	1.753E-02	0.0001	1.502E-03	0.0000	0.000E+00	0.0000	4.088E-01	0.0016	5.247E-03	0.0000	8.033E-04	0.0000	8.654E-02	0.0003
Np-237	1.561E-03	0.0000	6.591E-06	0.0000	0.000E+00	0.0000	3.576E-02	0.0001	9.086E-04	0.0000	2.954E-05	0.0000	3.791E-04	0.0000
Pu-239	1.385E-04	0.0000	1.711E-03	0.0000	0.000E+00	0.0000	4.687E-01	0.0018	1.203E-02	0.0000	4.606E-04	0.0000	9.923E-02	0.0004
Ra-228	4.554E-05	0.0000	9.651E-09	0.0000	0.000E+00	0.0000	3.599E-05	0.0000	6.992E-07	0.0000	4.642E-06	0.0000	3.430E-07	0.0000
Tc-99	5.289E-05	0.0000	2.967E-08	0.0000	0.000E+00	0.0000	8.619E-01	0.0034	1.132E-03	0.0000	9.537E-02	0.0004	3.656E-05	0.0000
Th-228	7.354E-16	0.0000	2.143E-19	0.0000	0.000E+00	0.0000	1.666E-17	0.0000	4.277E-19	0.0000	8.187E-20	0.0000	3.528E-18	0.0000
Th-232	7.446E+00	0.0290	7.988E-03	0.0000	0.000E+00	0.0000	8.058E+00	0.0314	1.567E-01	0.0006	9.919E-01	0.0039	1.399E-01	0.0005
U-234	2.719E-04	0.0000	4.945E-04	0.0000	0.000E+00	0.0000	8.799E-02	0.0003	3.306E-03	0.0000	2.421E-02	0.0001	7.451E-03	0.0000
U-235	3.333E-01	0.0013	5.003E-04	0.0000	0.000E+00	0.0000	1.140E-01	0.0004	7.911E-03	0.0000	2.291E-02	0.0001	8.040E-03	0.0000
U-238	6.618E-02	0.0003	4.413E-04	0.0000	0.000E+00	0.0000	8.341E-02	0.0003	3.138E-03	0.0000	2.301E-02	0.0001	7.071E-03	0.0000
Total	7.866E+00	0.0306	1.264E-02	0.0000	0.000E+00	0.0000	1.012E+01	0.0394	1.903E-01	0.0007	1.159E+00	0.0045	3.486E-01	0.0014

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	3.202E-03	0.0000	5.074E-04	0.0000	0.000E+00	0.0000	4.978E-04	0.0000	4.289E-05	0.0000	1.361E-06	0.0000	5.247E-01	0.0020
Np-237	1.785E+02	0.6953	2.830E+01	0.1102	0.000E+00	0.0000	2.777E+01	0.1081	2.396E+00	0.0093	7.598E-02	0.0003	2.371E+02	0.9234
Pu-239	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.823E-01	0.0023
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.723E-05	0.0000
-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.585E-01	0.0037
-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.563E-16	0.0000
h-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.680E+01	0.0654
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.237E-01	0.0005
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.867E-01	0.0019
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.833E-01	0.0007
Total	1.785E+02	0.6953	2.830E+01	0.1102	0.000E+00	0.0000	2.777E+01	0.1081	2.396E+00	0.0093	7.598E-02	0.0003	2.568E+02	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	1.240E-02	0.0006	1.062E-03	0.0001	0.000E+00	0.0000	2.891E-01	0.0150	3.711E-03	0.0002	5.681E-04	0.0000	6.119E-02	0.0032
Np-237	1.410E-06	0.0000	4.909E-08	0.0000	0.000E+00	0.0000	7.237E-06	0.0000	2.564E-07	0.0000	1.639E-06	0.0000	7.111E-07	0.0000
Pu-239	1.360E-04	0.0000	1.679E-03	0.0001	0.000E+00	0.0000	4.600E-01	0.0239	1.181E-02	0.0006	4.521E-04	0.0000	9.740E-02	0.0051
Ra-228	1.068E-15	0.0000	2.263E-19	0.0000	0.000E+00	0.0000	8.439E-16	0.0000	1.640E-17	0.0000	1.088E-16	0.0000	8.044E-18	0.0000
Tc-99	4.147E-05	0.0000	2.327E-08	0.0000	0.000E+00	0.0000	6.758E-01	0.0351	8.873E-04	0.0000	7.479E-02	0.0039	2.867E-05	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	7.443E+00	0.3869	7.984E-03	0.0004	0.000E+00	0.0000	8.055E+00	0.4187	1.566E-01	0.0081	9.915E-01	0.0515	1.398E-01	0.0073
U-234	8.437E-04	0.0000	4.289E-04	0.0000	0.000E+00	0.0000	7.781E-02	0.0040	2.900E-03	0.0002	2.106E-02	0.0011	6.479E-03	0.0003
U-235	2.900E-01	0.0151	5.007E-04	0.0000	0.000E+00	0.0000	1.421E-01	0.0074	1.311E-02	0.0007	1.990E-02	0.0010	8.525E-03	0.0004
U-238	5.714E-02	0.0030	3.812E-04	0.0000	0.000E+00	0.0000	7.205E-02	0.0037	2.710E-03	0.0001	1.987E-02	0.0010	6.108E-03	0.0003
Total	7.804E+00	0.4057	1.204E-02	0.0006	0.000E+00	0.0000	9.772E+00	0.5079	1.917E-01	0.0100	1.128E+00	0.0586	3.195E-01	0.0166

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	3.562E-03	0.0002	5.646E-04	0.0000	0.000E+00	0.0000	5.540E-04	0.0000	4.782E-05	0.0000	1.516E-06	0.0000	3.727E-01	0.0194
Np-237	4.419E-03	0.0002	6.938E-04	0.0000	0.000E+00	0.0000	6.880E-04	0.0000	5.915E-05	0.0000	4.974E-06	0.0000	5.876E-03	0.0003
Pu-239	7.488E-14	0.0000	1.465E-14	0.0000	0.000E+00	0.0000	1.158E-14	0.0000	1.987E-17	0.0000	1.264E-16	0.0000	5.715E-01	0.0297
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.045E-15	0.0000
c-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.516E-01	0.0391
-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
h-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.679E+01	0.8730
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.095E-01	0.0057
U-235	4.907E-06	0.0000	9.602E-07	0.0000	0.000E+00	0.0000	7.590E-07	0.0000	1.305E-09	0.0000	8.295E-09	0.0000	4.741E-01	0.0246
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.583E-01	0.0082
Total	7.986E-03	0.0004	1.259E-03	0.0001	0.000E+00	0.0000	1.243E-03	0.0001	1.070E-04	0.0000	6.499E-06	0.0000	1.924E+01	1.0000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	3.687E-03	0.0002	3.158E-04	0.0000	0.000E+00	0.0000	8.596E-02	0.0046	1.103E-03	0.0001	1.689E-04	0.0000	1.820E-02	0.0010
Np-237	3.589E-06	0.0000	6.108E-08	0.0000	0.000E+00	0.0000	6.082E-06	0.0000	1.983E-07	0.0000	9.863E-07	0.0000	8.395E-07	0.0000
Pu-239	1.276E-04	0.0000	1.573E-03	0.0001	0.000E+00	0.0000	4.310E-01	0.0231	1.106E-02	0.0006	4.235E-04	0.0000	9.125E-02	0.0049
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Tc-99	1.771E-05	0.0000	9.936E-09	0.0000	0.000E+00	0.0000	2.886E-01	0.0155	3.789E-04	0.0000	3.193E-02	0.0017	1.224E-05	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	7.432E+00	0.3989	7.972E-03	0.0004	0.000E+00	0.0000	8.043E+00	0.4317	1.564E-01	0.0084	9.900E-01	0.0531	1.396E-01	0.0075
U-234	4.246E-03	0.0002	2.624E-04	0.0000	0.000E+00	0.0000	5.836E-02	0.0031	2.032E-03	0.0001	1.362E-02	0.0007	4.106E-03	0.0002
U-235	1.755E-01	0.0094	3.663E-04	0.0000	0.000E+00	0.0000	1.273E-01	0.0068	1.393E-02	0.0007	1.202E-02	0.0006	6.635E-03	0.0004
U-238	3.416E-02	0.0018	2.284E-04	0.0000	0.000E+00	0.0000	4.317E-02	0.0023	1.624E-03	0.0001	1.191E-02	0.0006	3.659E-03	0.0002
Total	7.650E+00	0.4106	1.072E-02	0.0006	0.000E+00	0.0000	9.077E+00	0.4872	1.865E-01	0.0100	1.060E+00	0.0569	2.635E-01	0.0141

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	9.208E-04	0.0000	1.459E-04	0.0000	0.000E+00	0.0000	1.432E-04	0.0000	1.236E-05	0.0000	3.924E-07	0.0000	1.107E-01	0.0059
Np-237	6.182E-05	0.0000	2.680E-06	0.0000	0.000E+00	0.0000	9.578E-06	0.0000	2.814E-07	0.0000	3.146E-06	0.0000	8.926E-05	0.0000
Pu-239	3.624E-08	0.0000	6.264E-09	0.0000	0.000E+00	0.0000	5.612E-09	0.0000	3.894E-10	0.0000	5.428E-11	0.0000	5.354E-01	0.0287
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Tc-99	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.209E-01	0.0172
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-232	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.677E+01	0.9001
U-234	2.614E-07	0.0000	1.928E-07	0.0000	0.000E+00	0.0000	4.060E-08	0.0000	3.026E-09	0.0000	1.192E-08	0.0000	8.263E-02	0.0044
U-235	2.846E-01	0.0153	4.813E-02	0.0026	0.000E+00	0.0000	4.409E-02	0.0024	3.552E-03	0.0002	4.172E-04	0.0000	7.166E-01	0.0385
U-238	5.976E-11	0.0000	5.085E-11	0.0000	0.000E+00	0.0000	9.686E-12	0.0000	7.850E-13	0.0000	2.477E-12	0.0000	9.475E-02	0.0051
Total	2.856E-01	0.0153	4.828E-02	0.0026	0.000E+00	0.0000	4.424E-02	0.0024	3.565E-03	0.0002	4.207E-04	0.0000	1.863E+01	1.0000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Am-241	Am-241	1.000E+00	6.188E-01	6.177E-01	6.156E-01	6.081E-01	5.874E-01	5.203E-01	3.680E-01	1.094E-01
Am-241	Np-237	1.000E+00	1.925E-06	5.822E-06	1.299E-05	3.225E-05	1.133E-04	4.314E-03	4.774E-03	1.236E-03
Am-241	U-233	1.000E+00	4.907E-14	2.737E-13	1.234E-12	9.007E-12	5.351E-11	7.371E-10	4.971E-09	1.150E-08
Am-241	Th-229	1.000E+00	8.883E-18	1.223E-16	1.348E-15	3.195E-14	6.023E-13	1.114E-11	1.073E-10	7.558E-10
Am-241	ΣDSR(j)		6.188E-01	6.177E-01	6.156E-01	6.082E-01	5.875E-01	5.247E-01	3.727E-01	1.107E-01
Np-237	Np-237	1.000E+00	1.246E+01	1.176E+01	1.048E+01	6.994E+00	6.499E+01	2.371E+02	5.788E-03	1.549E-20
Np-237	U-233	1.000E+00	3.959E-07	9.687E-07	1.985E-06	4.733E-06	9.234E-06	5.909E-05	8.469E-05	8.216E-05
Np-237	Th-229	1.000E+00	1.050E-10	6.878E-10	3.443E-09	2.689E-08	1.639E-07	8.288E-07	2.652E-06	7.100E-06
Np-237	ΣDSR(j)		1.246E+01	1.176E+01	1.048E+01	6.994E+00	6.499E+01	2.371E+02	5.876E-03	8.926E-05
Pu-239	Pu-239	1.000E+00	5.877E-01	5.877E-01	5.875E-01	5.872E-01	5.861E-01	5.823E-01	5.715E-01	5.354E-01
Pu-239	U-235	1.000E+00	2.356E-10	7.101E-10	1.659E-09	4.967E-09	1.431E-08	4.583E-08	1.263E-07	3.197E-07
Pu-239	Pa-231	1.000E+00	5.426E-14	4.002E-13	2.161E-12	1.942E-11	1.607E-10	1.616E-09	1.164E-08	7.255E-08
Pu-239	Ac-227	1.000E+00	2.403E-16	3.102E-15	3.251E-14	7.613E-13	1.513E-11	3.134E-10	3.116E-09	6.105E-08
Pu-239	ΣDSR(j)		5.877E-01	5.877E-01	5.875E-01	5.872E-01	5.861E-01	5.823E-01	5.715E-01	5.354E-01
Ra-228	Ra-228	1.000E+00	1.100E+01	9.732E+00	7.619E+00	3.235E+00	2.798E-01	5.326E-05	1.249E-15	0.000E+00
Ra-228	Th-228	1.000E+00	7.989E-01	1.885E+00	2.766E+00	1.897E+00	1.783E-01	3.397E-05	7.965E-16	0.000E+00
Ra-228	ΣDSR(j)		1.180E+01	1.162E+01	1.038E+01	5.132E+00	4.581E-01	8.723E-05	2.045E-15	0.000E+00
Tc-99	Tc-99	1.000E+00	1.082E+00	1.081E+00	1.078E+00	1.069E+00	1.044E+00	9.585E-01	7.516E-01	3.209E-01
Th-228	Th-228	1.000E+00	4.111E+00	2.862E+00	1.387E+00	1.098E-01	7.824E-05	7.563E-16	0.000E+00	0.000E+00
Th-232	Th-232	1.000E+00	4.601E-01	4.601E-01	4.601E-01	4.601E-01	4.601E-01	4.600E-01	4.598E-01	4.591E-01
Th-232	Ra-228	1.000E+00	6.386E-01	1.880E+00	3.961E+00	8.279E+00	1.119E+01	1.146E+01	1.146E+01	1.144E+01
Th-232	Th-228	1.000E+00	3.439E-02	2.025E-01	7.887E-01	2.901E+00	4.703E+00	4.878E+00	4.876E+00	4.868E+00
Th-232	ΣDSR(j)		1.133E+00	2.543E+00	5.210E+00	1.164E+01	1.635E+01	1.680E+01	1.679E+01	1.677E+01
U-234	U-234	1.000E+00	1.327E-01	1.326E-01	1.324E-01	1.318E-01	1.298E-01	1.233E-01	1.064E-01	6.347E-02
U-234	Th-230	1.000E+00	4.487E-07	1.289E-06	2.958E-06	8.779E-06	2.524E-05	8.097E-05	2.250E-04	5.878E-04
U-234	Ra-226	1.000E+00	8.127E-09	5.914E-08	3.176E-07	2.849E-06	2.362E-05	2.395E-04	1.767E-03	1.065E-02
U-234	Pb-210	1.000E+00	7.315E-11	9.532E-10	1.005E-08	2.381E-07	4.857E-06	1.068E-04	1.140E-03	7.920E-03
U-234	ΣDSR(j)		1.327E-01	1.326E-01	1.324E-01	1.318E-01	1.299E-01	1.237E-01	1.095E-01	8.263E-02
U-235	U-235	1.000E+00	4.824E-01	4.821E-01	4.814E-01	4.789E-01	4.719E-01	4.483E-01	3.870E-01	2.313E-01
U-235	Pa-231	1.000E+00	1.716E-04	5.326E-04	1.255E-03	3.744E-03	1.054E-02	3.100E-02	6.727E-02	1.455E-01
U-235	Ac-227	1.000E+00	9.163E-07	5.581E-06	2.687E-05	2.108E-04	1.370E-03	7.405E-03	1.984E-02	3.397E-01
U-235	ΣDSR(j)		4.826E-01	4.826E-01	4.827E-01	4.829E-01	4.838E-01	4.867E-01	4.741E-01	7.166E-01
U-238	U-238	1.000E+00	1.972E-01	1.970E-01	1.968E-01	1.957E-01	1.929E-01	1.832E-01	1.582E-01	9.455E-02
U-238	U-234	1.000E+00	1.881E-07	5.640E-07	1.314E-06	3.922E-06	1.123E-05	3.513E-05	9.067E-05	1.803E-04
U-238	Th-230	1.000E+00	4.435E-13	2.915E-12	1.495E-11	1.311E-10	1.089E-09	1.140E-08	9.237E-08	7.342E-07
U-238	Ra-226	1.000E+00	5.631E-15	8.859E-14	1.058E-12	2.826E-11	6.817E-10	2.289E-08	5.102E-07	1.035E-05
U-238	Pb-210	1.000E+00	4.346E-17	1.163E-15	2.619E-14	1.822E-12	1.102E-10	8.578E-09	3.014E-07	7.467E-06
U-238	ΣDSR(j)		1.972E-01	1.970E-01	1.968E-01	1.958E-01	1.929E-01	1.833E-01	1.583E-01	9.475E-02

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Am-241	4.040E+01	4.047E+01	4.061E+01	4.111E+01	4.255E+01	4.765E+01	6.707E+01	2.259E+02
Np-237	2.007E+00	2.125E+00	2.386E+00	3.574E+00	3.847E-01	1.054E-01	4.255E+03	2.801E+05
Pu-239	4.254E+01	4.254E+01	4.255E+01	4.258E+01	4.266E+01	4.294E+01	4.374E+01	4.669E+01
Ra-228	2.119E+00	2.152E+00	2.407E+00	4.871E+00	5.457E+01	2.866E+05	*2.726E+14	*2.726E+14
Tc-99	2.310E+01	2.313E+01	2.318E+01	2.338E+01	2.396E+01	2.608E+01	3.326E+01	7.790E+01
Th-228	6.081E+00	8.736E+00	1.803E+01	2.278E+02	3.195E+05	*8.192E+14	*8.192E+14	*8.192E+14
Th-232	2.206E+01	9.832E+00	4.798E+00	2.148E+00	1.529E+00	1.488E+00	1.489E+00	1.491E+00
U-234	1.883E+02	1.885E+02	1.888E+02	1.897E+02	1.925E+02	2.021E+02	2.283E+02	3.026E+02
U-235	5.180E+01	5.180E+01	5.180E+01	5.177E+01	5.167E+01	5.137E+01	5.273E+01	3.489E+01
U-238	1.268E+02	1.269E+02	1.271E+02	1.277E+02	1.296E+02	1.364E+02	1.580E+02	2.638E+02

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 115.5 ± 0.2 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Am-241	1.000E+00	0.000E+00	6.188E-01	4.040E+01	5.119E-01	4.883E+01
Np-237	1.000E+00	115.4 ± 0.2	2.389E+02	1.046E-01	2.389E+02	1.046E-01
Pu-239	1.000E+00	0.000E+00	5.877E-01	4.254E+01	5.814E-01	4.300E+01
Ra-228	1.000E+00	0.000E+00	1.180E+01	2.119E+00	1.313E-05	1.904E+06
Tc-99	1.000E+00	0.000E+00	1.082E+00	2.310E+01	9.406E-01	2.658E+01
Th-228	1.000E+00	0.000E+00	4.111E+00	6.081E+00	2.782E-18	*8.192E+14
Th-232	1.000E+00	90.3 ± 0.2	1.680E+01	1.488E+00	1.680E+01	1.488E+00
U-234	1.000E+00	0.000E+00	1.327E-01	1.883E+02	1.225E-01	2.042E+02
U-235	1.000E+00	1.000E+03	7.166E-01	3.489E+01	4.868E-01	5.136E+01
U-238	1.000E+00	0.000E+00	1.972E-01	1.268E+02	1.812E-01	1.380E+02

*At specific activity limit

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Am-241	Am-241	1.000E+00	6.188E-01	6.177E-01	6.156E-01	6.081E-01	5.874E-01	5.203E-01	3.680E-01	1.094E-01
Np-237	Am-241	1.000E+00	1.925E-06	5.822E-06	1.299E-05	3.225E-05	1.133E-04	4.314E-03	4.774E-03	1.236E-03
Np-237	Np-237	1.000E+00	1.246E+01	1.176E+01	1.048E+01	6.994E+00	6.499E+01	2.371E+02	5.788E-03	1.549E-20
Np-237	ΣDOSE(j)		1.246E+01	1.176E+01	1.048E+01	6.994E+00	6.499E+01	2.371E+02	1.056E-02	1.236E-03
U-233	Am-241	1.000E+00	4.907E-14	2.737E-13	1.234E-12	9.007E-12	5.351E-11	7.371E-10	4.971E-09	1.150E-08
U-233	Np-237	1.000E+00	3.959E-07	9.687E-07	1.985E-06	4.733E-06	9.234E-06	5.909E-05	8.469E-05	8.216E-05
U-233	ΣDOSE(j)		3.959E-07	9.687E-07	1.985E-06	4.733E-06	9.235E-06	5.909E-05	8.469E-05	8.217E-05
Th-229	Am-241	1.000E+00	8.883E-18	1.223E-16	1.348E-15	3.195E-14	6.023E-13	1.114E-11	1.073E-10	7.558E-10
Th-229	Np-237	1.000E+00	1.050E-10	6.878E-10	3.443E-09	2.689E-08	1.639E-07	8.288E-07	2.652E-06	7.100E-06
Th-229	ΣDOSE(j)		1.050E-10	6.878E-10	3.443E-09	2.689E-08	1.639E-07	8.288E-07	2.652E-06	7.101E-06
Pu-239	Pu-239	1.000E+00	5.877E-01	5.877E-01	5.875E-01	5.872E-01	5.861E-01	5.823E-01	5.715E-01	5.354E-01
U-235	Pu-239	1.000E+00	2.356E-10	7.101E-10	1.659E-09	4.967E-09	1.431E-08	4.583E-08	1.263E-07	3.197E-07
U-235	U-235	1.000E+00	4.824E-01	4.821E-01	4.814E-01	4.789E-01	4.719E-01	4.483E-01	3.870E-01	2.313E-01
U-235	ΣDOSE(j)		4.824E-01	4.821E-01	4.814E-01	4.789E-01	4.719E-01	4.483E-01	3.870E-01	2.313E-01
Pa-231	Pu-239	1.000E+00	5.426E-14	4.002E-13	2.161E-12	1.942E-11	1.607E-10	1.616E-09	1.164E-08	7.255E-08
Pa-231	U-235	1.000E+00	1.716E-04	5.326E-04	1.255E-03	3.744E-03	1.054E-02	3.100E-02	6.727E-02	1.455E-01
Pa-231	ΣDOSE(j)		1.716E-04	5.326E-04	1.255E-03	3.744E-03	1.054E-02	3.100E-02	6.727E-02	1.455E-01
Ac-227	Pu-239	1.000E+00	2.403E-16	3.102E-15	3.251E-14	7.613E-13	1.513E-11	3.134E-10	3.116E-09	6.105E-08
Ac-227	U-235	1.000E+00	9.163E-07	5.581E-06	2.687E-05	2.108E-04	1.370E-03	7.405E-03	1.984E-02	3.397E-01
Ac-227	ΣDOSE(j)		9.163E-07	5.581E-06	2.687E-05	2.108E-04	1.370E-03	7.405E-03	1.984E-02	3.397E-01
Ra-228	Ra-228	1.000E+00	1.100E+01	9.732E+00	7.619E+00	3.235E+00	2.798E-01	5.326E-05	1.249E-15	0.000E+00
Ra-228	Th-232	1.000E+00	6.386E-01	1.880E+00	3.961E+00	8.279E+00	1.119E+01	1.146E+01	1.146E+01	1.144E+01
Ra-228	ΣDOSE(j)		1.164E+01	1.161E+01	1.158E+01	1.151E+01	1.147E+01	1.146E+01	1.146E+01	1.144E+01
Th-228	Ra-228	1.000E+00	7.989E-01	1.885E+00	2.766E+00	1.897E+00	1.783E-01	3.397E-05	7.965E-16	0.000E+00
Th-228	Th-228	1.000E+00	4.111E+00	2.862E+00	1.387E+00	1.098E-01	7.824E-05	7.563E-16	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	3.439E-02	2.025E-01	7.887E-01	2.901E+00	4.703E+00	4.878E+00	4.876E+00	4.868E+00
Th-228	ΣDOSE(j)		4.945E+00	4.950E+00	4.941E+00	4.909E+00	4.881E+00	4.878E+00	4.876E+00	4.868E+00
Tc-99	Tc-99	1.000E+00	1.082E+00	1.081E+00	1.078E+00	1.069E+00	1.044E+00	9.585E-01	7.516E-01	3.209E-01
Th-232	Th-232	1.000E+00	4.601E-01	4.601E-01	4.601E-01	4.601E-01	4.601E-01	4.600E-01	4.598E-01	4.591E-01
U-234	U-234	1.000E+00	1.327E-01	1.326E-01	1.324E-01	1.318E-01	1.298E-01	1.233E-01	1.064E-01	6.347E-02
U-234	U-238	1.000E+00	1.881E-07	5.640E-07	1.314E-06	3.922E-06	1.123E-05	3.513E-05	9.067E-05	1.803E-04
U-234	ΣDOSE(j)		1.327E-01	1.326E-01	1.324E-01	1.318E-01	1.298E-01	1.233E-01	1.065E-01	6.365E-02
Th-230	U-234	1.000E+00	4.487E-07	1.289E-06	2.958E-06	8.779E-06	2.524E-05	8.097E-05	2.250E-04	5.878E-04
Th-230	U-238	1.000E+00	4.435E-13	2.915E-12	1.495E-11	1.311E-10	1.089E-09	1.140E-08	9.237E-08	7.342E-07
Th-230	ΣDOSE(j)		4.487E-07	1.289E-06	2.958E-06	8.780E-06	2.525E-05	8.098E-05	2.250E-04	5.885E-04

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	U-234	1.000E+00	8.127E-09	5.914E-08	3.176E-07	2.849E-06	2.362E-05	2.395E-04	1.767E-03	1.065E-02
Ra-226	U-238	1.000E+00	5.631E-15	8.859E-14	1.058E-12	2.826E-11	6.817E-10	2.289E-08	5.102E-07	1.035E-05
Ra-226	ΣDOSE(j)		8.127E-09	5.914E-08	3.176E-07	2.849E-06	2.362E-05	2.395E-04	1.768E-03	1.066E-02
Pb-210	U-234	1.000E+00	7.315E-11	9.532E-10	1.005E-08	2.381E-07	4.857E-06	1.068E-04	1.140E-03	7.920E-03
Pb-210	U-238	1.000E+00	4.346E-17	1.163E-15	2.619E-14	1.822E-12	1.102E-10	8.578E-09	3.014E-07	7.467E-06
Pb-210	ΣDOSE(j)		7.315E-11	9.532E-10	1.005E-08	2.381E-07	4.857E-06	1.068E-04	1.141E-03	7.927E-03
U-238	U-238	1.000E+00	1.972E-01	1.970E-01	1.968E-01	1.957E-01	1.929E-01	1.832E-01	1.582E-01	9.455E-02

BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Am-241	Am-241	1.000E+00	1.000E+00	9.983E-01	9.948E-01	9.828E-01	9.494E-01	8.409E-01	5.947E-01	1.768E-01
Np-237	Am-241	1.000E+00	0.000E+00	3.144E-07	8.898E-07	2.437E-06	4.466E-06	4.843E-06	3.438E-06	1.022E-06
Np-237	Np-237	1.000E+00	1.000E+00	9.439E-01	8.409E-01	5.612E-01	1.768E-01	3.100E-03	2.979E-08	8.197E-26
Np-237	ΣS(j):		1.000E+00	9.439E-01	8.409E-01	5.612E-01	1.768E-01	3.105E-03	3.467E-06	1.022E-06
U-233	Am-241	1.000E+00	0.000E+00	6.942E-13	6.006E-12	5.844E-11	3.756E-10	1.825E-09	4.899E-09	7.439E-09
U-233	Np-237	1.000E+00	0.000E+00	4.248E-06	1.203E-05	3.308E-05	6.145E-05	7.099E-05	6.143E-05	3.661E-05
U-233	ΣS(j):		0.000E+00	4.248E-06	1.203E-05	3.308E-05	6.145E-05	7.099E-05	6.144E-05	3.662E-05
Th-229	Am-241	1.000E+00	0.000E+00	2.196E-17	5.756E-16	1.929E-14	4.023E-13	7.664E-12	7.312E-11	5.084E-10
Th-229	Np-237	1.000E+00	0.000E+00	2.025E-10	1.754E-09	1.714E-08	1.115E-07	5.707E-07	1.798E-06	4.737E-06
Th-229	ΣS(j):		0.000E+00	2.025E-10	1.754E-09	1.714E-08	1.115E-07	5.707E-07	1.798E-06	4.737E-06
Pu-239	Pu-239	1.000E+00	1.000E+00	9.999E-01	9.997E-01	9.991E-01	9.972E-01	9.907E-01	9.724E-01	9.110E-01
U-235	Pu-239	1.000E+00	0.000E+00	9.845E-10	2.951E-09	9.808E-09	2.918E-08	9.451E-08	2.613E-07	6.622E-07
U-235	U-235	1.000E+00	1.000E+00	9.993E-01	9.978E-01	9.927E-01	9.782E-01	9.291E-01	8.021E-01	4.795E-01
U-235	ΣS(j):		1.000E+00	9.993E-01	9.978E-01	9.927E-01	9.782E-01	9.291E-01	8.021E-01	4.795E-01
Pa-231	Pu-239	1.000E+00	0.000E+00	1.041E-14	9.345E-14	1.030E-12	9.064E-12	9.311E-11	6.748E-10	3.795E-09
Pa-231	U-235	1.000E+00	0.000E+00	2.112E-05	6.316E-05	2.081E-04	6.040E-04	1.795E-03	3.907E-03	4.621E-03
Pa-231	ΣS(j):		0.000E+00	2.112E-05	6.316E-05	2.081E-04	6.040E-04	1.795E-03	3.907E-03	4.621E-03
Ac-227	Pu-239	1.000E+00	0.000E+00	1.094E-16	2.894E-15	9.989E-14	2.233E-12	4.816E-11	4.839E-10	3.070E-09
Ac-227	U-235	1.000E+00	0.000E+00	3.322E-07	2.909E-06	2.943E-05	2.066E-04	1.146E-03	3.087E-03	3.888E-03
Ac-227	ΣS(j):		0.000E+00	3.322E-07	2.909E-06	2.943E-05	2.066E-04	1.146E-03	3.087E-03	3.888E-03
Ra-228	Ra-228	1.000E+00	1.000E+00	8.848E-01	6.927E-01	2.941E-01	2.544E-02	4.842E-06	1.135E-16	0.000E+00
Ra-228	Th-232	1.000E+00	0.000E+00	1.135E-01	3.027E-01	6.953E-01	9.599E-01	9.848E-01	9.844E-01	9.829E-01
Ra-228	ΣS(j):		1.000E+00	9.983E-01	9.954E-01	9.894E-01	9.853E-01	9.848E-01	9.844E-01	9.829E-01
Th-228	Ra-228	1.000E+00	0.000E+00	2.850E-01	5.368E-01	4.038E-01	3.839E-02	7.312E-06	1.714E-16	0.000E+00
Th-228	Th-228	1.000E+00	1.000E+00	6.961E-01	3.372E-01	2.670E-02	1.903E-05	1.840E-16	0.000E+00	0.000E+00
Th-228	Th-232	1.000E+00	0.000E+00	1.863E-02	1.241E-01	5.610E-01	9.471E-01	9.848E-01	9.844E-01	9.829E-01
Th-228	ΣS(j):		1.000E+00	9.997E-01	9.981E-01	9.915E-01	9.855E-01	9.848E-01	9.844E-01	9.829E-01
Tc-99	Tc-99	1.000E+00	1.000E+00	9.988E-01	9.964E-01	9.879E-01	9.642E-01	8.855E-01	6.944E-01	2.965E-01
Th-232	Th-232	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	9.999E-01	9.998E-01	9.994E-01	9.979E-01
U-234	U-234	1.000E+00	1.000E+00	9.993E-01	9.978E-01	9.926E-01	9.781E-01	9.289E-01	8.014E-01	4.781E-01
U-234	U-238	1.000E+00	0.000E+00	2.833E-06	8.486E-06	2.814E-05	8.319E-05	2.634E-04	6.819E-04	1.357E-03
U-234	ΣS(j):		1.000E+00	9.993E-01	9.978E-01	9.927E-01	9.782E-01	9.291E-01	8.021E-01	4.795E-01
Th-230	U-234	1.000E+00	0.000E+00	8.999E-06	2.698E-05	8.968E-05	2.670E-04	8.673E-04	2.418E-03	6.327E-03
Th-230	U-238	1.000E+00	0.000E+00	1.275E-11	1.147E-10	1.270E-09	1.131E-08	1.215E-07	9.913E-07	7.899E-06
Th-230	ΣS(j):		0.000E+00	8.999E-06	2.698E-05	8.968E-05	2.671E-04	8.674E-04	2.419E-03	6.335E-03

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	U-234	1.000E+00	0.000E+00	1.948E-09	1.750E-08	1.930E-07	1.703E-06	1.765E-05	1.311E-04	7.916E-04
Ra-226	U-238	1.000E+00	0.000E+00	1.841E-15	4.961E-14	1.825E-12	4.837E-11	1.679E-09	3.778E-08	7.686E-07
Ra-226	ΣS(j):		0.000E+00	1.948E-09	1.750E-08	1.930E-07	1.703E-06	1.765E-05	1.311E-04	7.924E-04
Pb-210	U-234	1.000E+00	0.000E+00	2.003E-11	5.313E-10	1.853E-08	4.250E-07	9.739E-06	1.051E-04	7.319E-04
Pb-210	U-238	1.000E+00	0.000E+00	1.422E-17	1.135E-15	1.334E-13	9.444E-12	7.768E-10	2.770E-08	6.896E-07
Pb-210	ΣS(j):		0.000E+00	2.003E-11	5.313E-10	1.853E-08	4.250E-07	9.739E-06	1.051E-04	7.326E-04
U-238	U-238	1.000E+00	1.000E+00	9.993E-01	9.978E-01	9.927E-01	9.782E-01	9.291E-01	8.021E-01	4.795E-01

BRF(i) is the branch fraction of the parent nuclide.

RESCALC.EXE execution time =   57.45 seconds

APPENDIX D

RECOMMENDED VALUES AND UNCERTAINTY RANGES ASSOCIATED WITH RESRAD INPUT PARAMETERS

RESRAD Parameter	Recommended Value	Units	Uncertainty Range			
			Value	Statistics	Distribution	Reference: NUREG/CR-6697
Area of contaminated zone	77458	m^2	NA	NA	NA	NA
Thickness of contaminated zone	0.15	m	NA	NA	NA	NA
	2					
Length parallel to aquifer flow	291	m	NA	NA	NA	NA
Time since placement of material	1,3,10,30, 100, 300, 1000	yr	NA	NA	NA	NA
Cover depth	0	m	NA	NA	NA	NA
Density of cover material	NA	g/m^3	NA	NA	NA	NA
Cover depth erosion rate	NA	m/yr	NA	NA	NA	NA
Density of contaminated zone	1.69	g/m^3	1.39	Lower value	Truncated Normal	LBG, 2003
			2.11	Upper value		
Contaminated zone erosion rate	0.0006	m/yr	4.00E-04	Minimum	Bounded Normal	LBG, 2003
			8.00E-04	Maximum		
Contaminated zone total porosity	0.45	unitless	0.408	Lower value	Truncated Normal	LBG, 2003
			0.483	Upper value		
Contaminated zone field capacity	0.17	unitless	NA	NA	NA	NA
Contaminated zone hydraulic conductivity	14.56	m/yr	1.38E-03	Lower value	Bounded lognormal-n	LBG, 2003
			1.45E+02	Upper value		
Contaminated zone b parameter	10.4	unitless	2.29	Mean	Bounded lognormal-n	Table 3.5-1 (Silty Clay)
			0.259	Std. Dev		
			4.43	Lower value		
			22	Upper value		
Average annual wind speed	2	m/sec	1.445	Mean	Bounded lognormal-n	Section 4.5
			0.2419	Std. Dev		
			1.4	Lower value		
			13	Upper value		
Humidity in air	NA	g/m^3	NA	NA	NA	NA
Evapotranspiration coefficient	0.5	unitless	0.5	Minimum	Uniform	Section 4.3
			0.75	Maximum		
Precipitation	0.965	m/yr	NA	NA	NA	NA
Irrigation	0.2	m/yr	NA	NA	NA	NA
Irrigation mode	Overhead	unitless	NA	NA	NA	NA
Runoff coefficient	0.305	unitless	0.1	Minimum	Uniform	Section 4.2
			0.8	Maximum		
Watershed area for nearby stream or pond	998939	m^2	NA	NA	NA	NA

RESRAD Parameter	Recommended Value	Units	Uncertainty Range			
			Value	Statistics	Distribution	Reference: NUREG/CR-6697
Accuracy for water/soil computations	0.001	unitless	NA	NA	NA	NA
Saturated zone density	1.69	g/m^3	1.39	Lower value	Truncated Normal	LBG, 2003
			2.11	Upper value		
Saturated zone total porosity	0.45	unitless	0.408	Lower value	Truncated Normal	LBG, 2003
			0.483	Upper value		
Saturated zone effective porosity	0.29	unitless	0.281	Lower value	Truncated Normal	LBG, 2003
			0.425	Upper value		
Saturated zone field capacity	0.17	unitless	NA	NA	NA	NA
Saturated zone hydraulic conductivity	169.58	m/yr	1.56E+01	Lower value	Bounded lognormal-n	LBG, 2003
			8.51E+02	Upper value		
Saturated zone hydraulic gradient	0.015	unitless	0.021	Mean	Bounded lognormal-n	Table 3.6-1 (National Average)
			0.006	Median		
			0.046	Std Dev		
			0.006	Geo Mean		
Saturated zone b parameter	10.4	unitless	2.29	Mean	Bounded lognormal-n	Table 3.5-1 (Silty Clay)
			0.259	Std. Dev		
			4.43	Lower value		
			22	Upper value		
Water table drop rate	0.001	m/yr	NA	NA	NA	NA
Well pump intake depth (m below water table)	16	m	6	Minimum	Triangular	Section 3.11
			30	Maximum		
			10	Most Likely		
Model: Nondispersion (ND) or Mass-Balance (MB)	Nondispersion	unitless	NA	NA	NA	NA
Well pumping rate	913	m^3/yr	NA	NA	NA	NA
Number of unsaturated zone strata #	1	unitless	N/A	N/A	N/A	N/A
Unsaturated zone thickness	4.5	m	2.296	Mean	Bounded lognormal-n	Section 3.7
			1.276	Std Dev		
Unsaturated zone density	1.69	g/m^3	1.39	Lower value	Truncated Normal	LBG, 2003
			2.11	Upper value		
Unsaturated zone total porosity	0.45	unitless	0.408	Lower value	Truncated Normal	LBG, 2003
			0.483	Upper value		
Unsaturated zone effective porosity	0.29	unitless	0.289	Mean	Truncated Normal	Table 3.3-1 (Silty Clay)
			0.0735	Std. Dev		
			0.0623	Lower value		
			0.517	Upper value		
Unsaturated zone field capacity	0.17	unitless	NA	NA	NA	NA

RESRAD Parameter	Recommended Value	Units	Uncertainty Range			
			Value	Statistics	Distribution	Reference: NUREG/CR-6697
Unsaturated zone hydraulic conductivity	14.56	m/yr	-1.238	Mean	Bounded lognormal-n	Table 3.4-1 (Silty Clay)
			1.31	Std. Dev		
			0.00506	Lower value		
			16.6	Upper value		
Unsaturated zone b parameter	10.4	unitless	2.29	Mean	Bounded lognormal-n	Table 3.5-1 (Silty Clay)
			0.259	Std. Dev		
			4.43	Lower value		
			22	Upper value		
Distribution coefficients						
Uranium	175	cm^3/g	7.2	Min	Truncated lognormal-n (Clay)	SAIC, 2003
			964	Max		
Plutonium	2,000	cm^3/g	316	Min	Truncated lognormal-n (Clay)	SAIC, 2003
			190,000	Max		
Technetium	106	cm^3/g	15.1	Min	Truncated lognormal-n (Clay)	SAIC, 2003
			172.9	-Max		
Thorium	60,000	cm^3/g	244	Min	Truncated lognormal-n (Clay)	SAIC, 2003
			160000	Max		
			5800	Geo mean		
Neptunium	2	cm^3/g	0.4	Min	Truncated lognormal-n (Clay)	SAIC, 2003
			2575	Max		
			55	Geo mean		
Americium	1,000	cm^3/g	25	Min	Truncated lognormal-n (Clay)	SAIC, 2003
			400000	Max		
			8400	Geo mean		
Inhalation rate	8,600	m^3/yr	4,380	Minimum	Triangular	Section 5
			13,100	Maximum		
			8,400	Most likely		
Mass loading for inhalation	5.9E-06	g/m^3	2.00E-04	Indoor and outdoor time fraction	Empirical	RESRAD
Exposure duration	30	yr	NA	NA	NA	NA
Indoor Dust Filtration Factor	0.4	unitless	0.15	Minimum	Uniform	Section 7.1
			0.95	Maximum		
External gamma shielding factor	0.5512	unitless	-1.3	Mean	Bounded lognormal-n	Section 7.10
			0.59	Std. Dev		
			0.044	Lower value		
			1	Upper value		
Fraction of time spent indoors	0.6571	unitless	NA	NA	NA	NA

RESRAD Parameter	Recommended Value	Units	Uncertainty Range			
			Value	Statistics	Distribution	Reference: NUREG/CR-6697
Fraction of time spent outdoors (on site)	0.1181	unitless	NA	NA	NA	NA
Shape of the contaminated zone: Circular; Non-Circular	Circular	unitless	NA	NA	NA	NA
Fruits, vegetables and grain consumption	112	kg/yr	135	Minimum	Triangular	Section 5.4
			318	Maximum		
			178	Most likely		
Leafy vegetable consumption	21.4	kg/yr	NA	NA	NA	NA
Milk consumption	233	L/yr	60	Minimum	Triangular	Section 5.3
			200	Maximum		
			102	Most likely		
Meat and poultry consumption	65.1	kg/yr	NA	NA	NA	NA
Fish consumption	20.6	kg/yr	NA	NA	NA	NA
Other seafood consumption	0.9	kg/yr	NA	NA	NA	NA
Soil ingestion rate	36.5	g/yr	0	Minimum	Triangular	Section 5.6
			36.5	Maximum		
			18.3	Most likely		
Drinking water intake	478.5	L/yr	510	Mean	Truncated lognormal-n	Table 5.2-2 (Adult) (EPA, 1997)
			478.5	50th Percentile		
			840	90th Percentile		
Contamination fraction of drinking water	1	unitless	NA	NA	NA	NA
Contamination fraction of household water	NA	unitless	N/A	N/A	N/A	N/A
Contamination fraction of livestock water	1	unitless	NA	NA	NA	NA
Contamination fraction of irrigation water	1	unitless	NA	NA	NA	NA
Contamination fraction of aquatic food	1	unitless	0	Minimum	Triangular	Section 5.5
			1	Maximum		
			0.39	Most Likely		
Contamination fraction of plant food	1	unitless	NA	NA	NA	NA
Contamination fraction of meat	1	unitless	NA	NA	NA	NA
Contamination fraction of milk	1	unitless	NA	NA	NA	NA
Livestock fodder intake for meat	26.85	kg/day	NA	NA	NA	NA
Livestock fodder intake for milk	63.25	kg/day	NA	NA	NA	NA

RESRAD Parameter	Recommended Value	Units	Uncertainty Range			
			Value	Statistics	Distribution	Reference: NUREG/CR-6697
Livestock water intake for meat	50	L/day	NA	NA	NA	NA
Livestock water intake for milk	60	L/day	NA	NA	NA	NA
Livestock soil intake	0.5	kg/day	NA	NA	NA	NA
Mass loading for foliar deposition	0.0001	g/m^3	NA	NA	NA	NA
Depth of soil mixing layer	0.15	m	0.00	Minimum	Triangular	Section 3.12
			0.60	Maximum		
			0.15	Most Likely		
Depth of roots	0.9	m	NA	NA	NA	NA
Drinking water fraction from ground water	1	unitless	N/A	N/A	N/A	N/A
Household water fraction from ground water	NA	unitless	NA	NA	NA	NA
Livestock fraction from ground water	1	unitless	NA	NA	NA	NA
Irrigation fraction from ground water	1	unitless	NA	NA	NA	NA
Wet weight crop yield for non-leafy vegetables	0.7	kg/m^2	0.56	Mean	Truncated lognormal-n	Section 6.5
			0.48	Std Dev		
Wet weight crop yield for leafy	1.5	kg/m^2	NA	NA	NA	NA
Wet weight crop yield for fodder	1.1	kg/m^2	NA	NA	NA	NA
Growing season for non-leafy	0.17	years	NA	NA	NA	NA
Growing season for leafy	0.25	years	NA	NA	NA	NA
Growing season for fodder	0.08	years	NA	NA	NA	NA
Translocation factor for non-leafy	0.1	unitless	NA	NA	NA	NA
Translocation factor for leafy	1	unitless	NA	NA	NA	NA
Translocation factor for fodder	1	unitless	NA	NA	NA	NA
Dry foliar interception fraction for non-leafy vegetables	0.25	unitless	NA	NA	NA	NA
Dry foliar interception fraction for leafy vegetables	0.25	unitless	NA	NA	NA	NA
Dry foliar interception fraction for fodder	0.25	unitless	NA	NA	NA	NA
Wet foliar interception fraction for non-leafy vegetables	0.25	unitless	NA	NA	NA	NA
Wet foliar interception fraction for leafy	0.25	unitless	0.06	Minimum	Triangular	Section 6.7
			0.95	Maximum		
			0.67	Most Likely		

RESRAD Parameter	Recommended Value	Units	Uncertainty Range			
			Value	Statistics	Distribution	Reference: NUREG/CR-6697
Wet foliar interception fraction for fodder	0.25	unitless	NA	NA	NA	NA
Weathering removal constant for vegetation	20	unitless	5.1	Minimum	Triangular	Section 6.6
			84	Maximum		
			18	Most Likely		
Storage time: fruits, non-leafy vegetables, and grain	14	days	NA	NA	NA	NA
Storage time: leafy vegetables	1	days	NA	NA	NA	NA
Storage time: milk	1	days	NA	NA	NA	NA
Storage time: meat and poultry	20	days	NA	NA	NA	NA
Storage time: fish	7	days	NA	NA	NA	NA
Storage time: crustaceans and mollusks	7	days	NA	NA	NA	NA
Storage time: well water	1	days	N/A	N/A	N/A	N/A
Storage time: surface water	1	days	NA	NA	NA	NA
Storage time: livestock fodder	45	days	NA	NA	NA	NA
Thickness of building foundation	NA	m	N/A	N/A	N/A	N/A
Bulk density of building foundation	NA	g/cm^3	N/A	N/A	N/A	N/A
Total porosity of the cover material	NA	unitless	N/A	N/A	N/A	N/A
Total porosity of the building foundation	NA	unitless	N/A	N/A	N/A	N/A
Volumetric water constant of the cover material	NA	unitless	N/A	N/A	N/A	N/A
Volumetric water constant of the foundation	NA	unitless	N/A	N/A	N/A	N/A
Diffusion coefficient for radon gas in cover material	NA	m/sec	N/A	N/A	N/A	N/A
Diffusion coefficient for radon gas in foundation material	NA	m/sec	N/A	N/A	N/A	N/A
Diffusion coefficient for radon gas in contaminated zone soil	NA	m/sec	N/A	N/A	N/A	N/A
Radon vertical dimension of mixing	NA	m	N/A	N/A	N/A	N/A
Average building air exchange rate	NA	1/hour	N/A	N/A	N/A	N/A
Height of the building (room)	NA	m	N/A	N/A	N/A	N/A
Building interior area factor	NA	unitless	N/A	N/A	N/A	N/A
Building depth below ground surface	NA	m	N/A	N/A	N/A	N/A
Emanating power of Rn-222 gas	NA	unitless	N/A	N/A	N/A	N/A
Emanating power of Rn-220 gas	NA	unitless	N/A	N/A	N/A	N/A

NA = Not Available
N/A = Not Applicable

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.

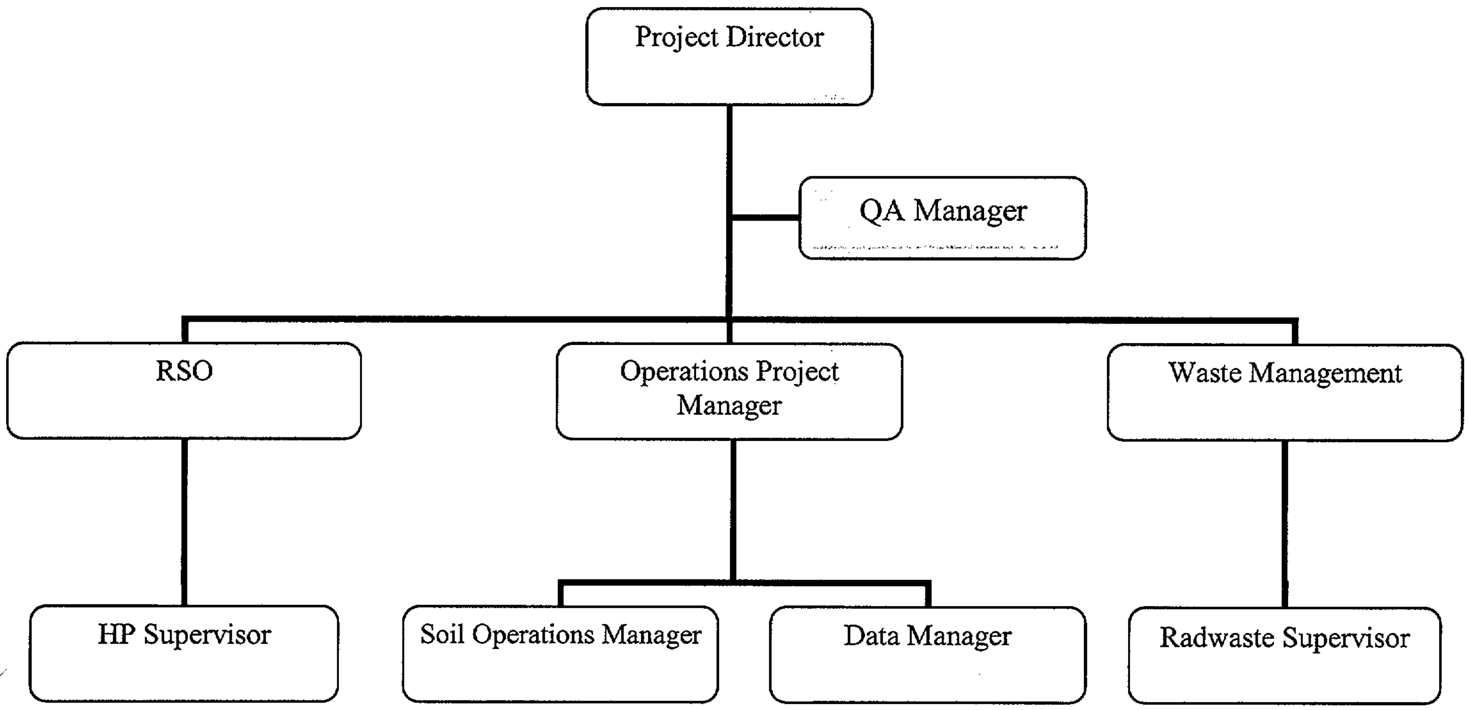

Figure 2-1 Soil Remediation Organization Chart

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.

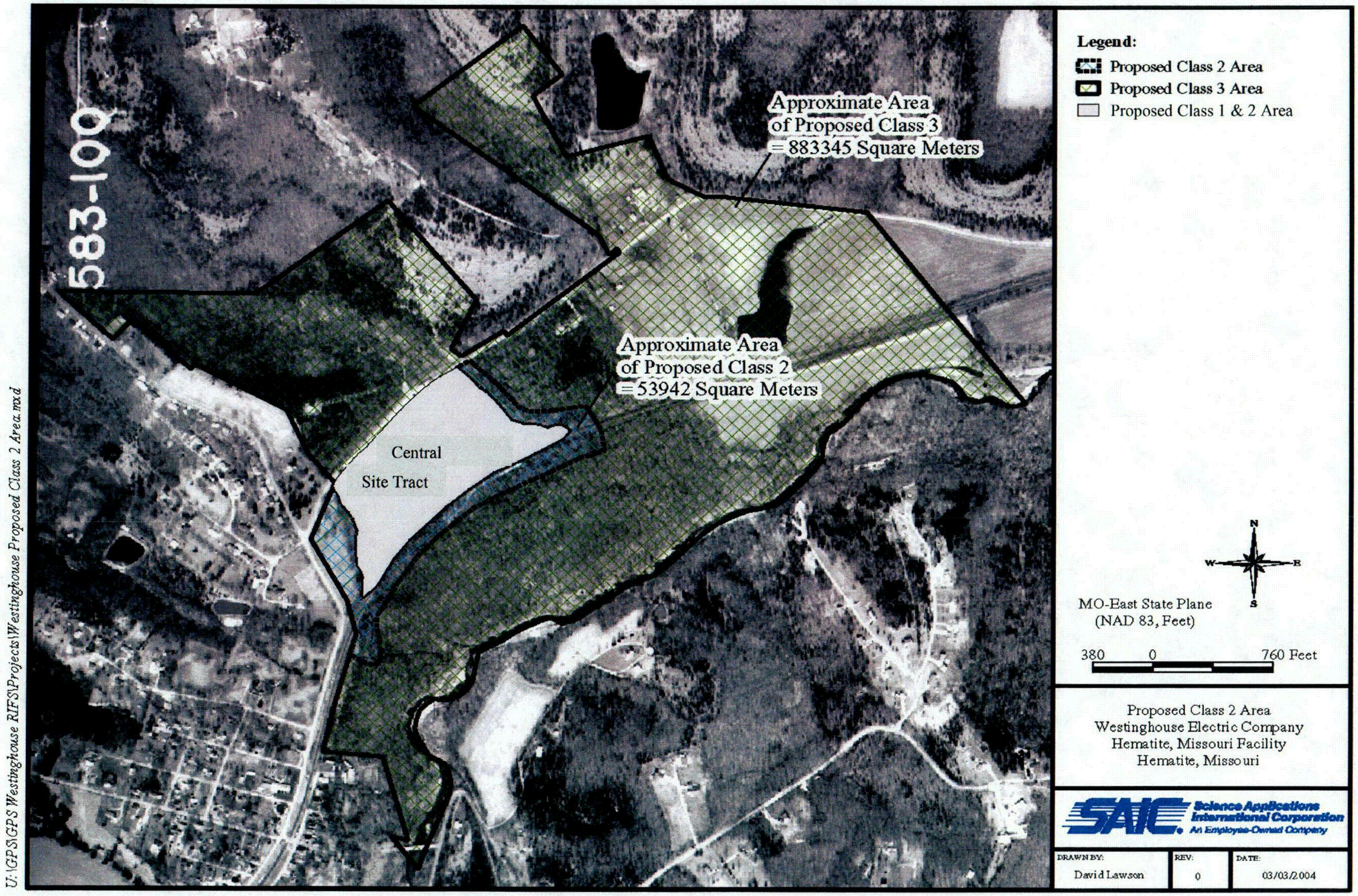

Figure 4-1 Soil Survey Areas

C08

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:

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

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:

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

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:

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

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:

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

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:

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

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 $DCGL_W$	$2{,}000\ m^2 \leq \text{area} \leq 10{,}000\ m^2$
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.

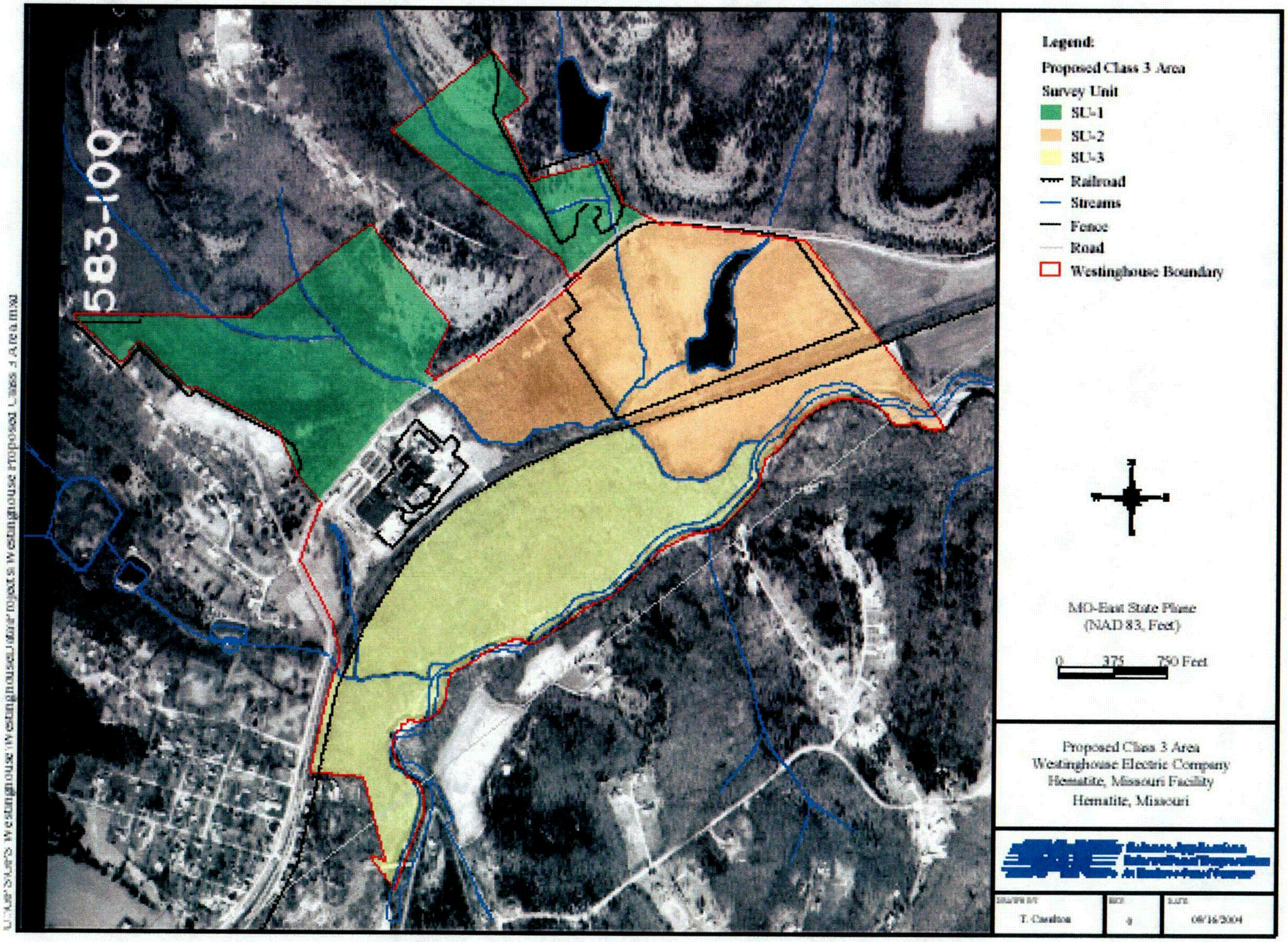

Figure 4-2 Area 3 Survey Units

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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- α)	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- β)

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(TI) 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(TI) 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.

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

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:

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

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.

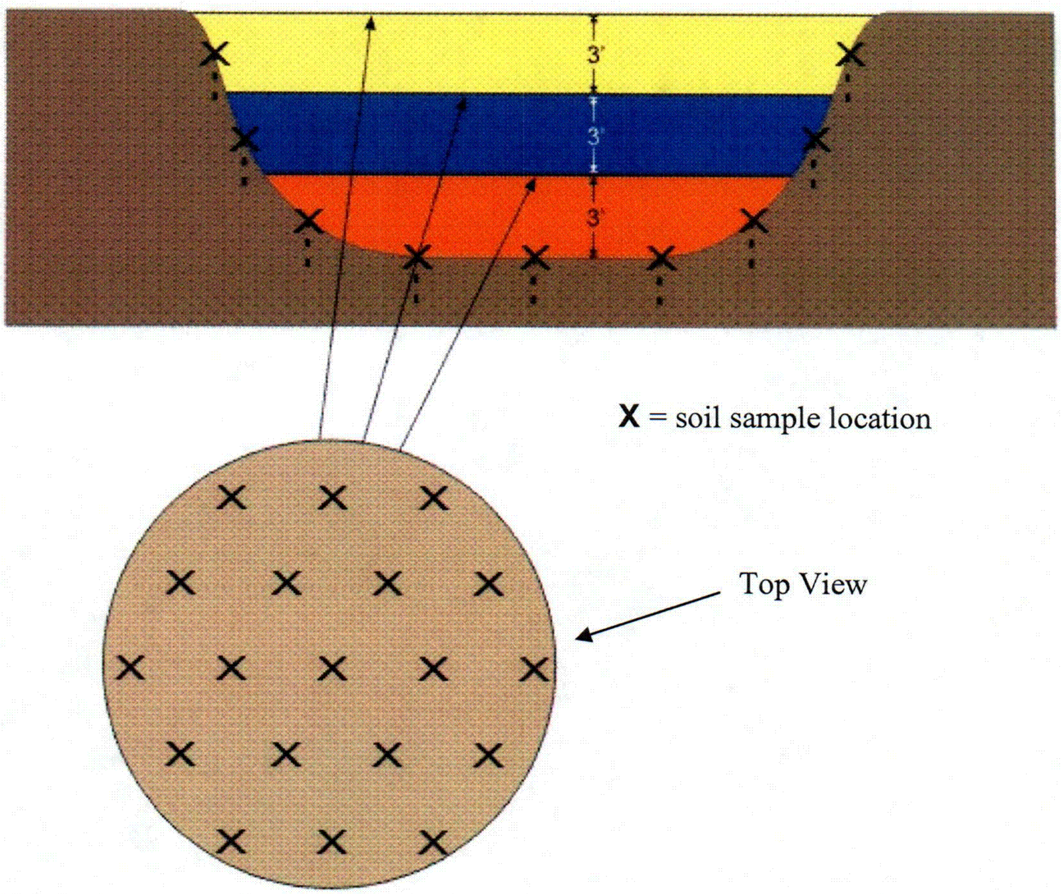

Figure 7-1 Surveying and Sampling for Returned Overburden Soil

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 $\pm 2\sigma$.
- 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.

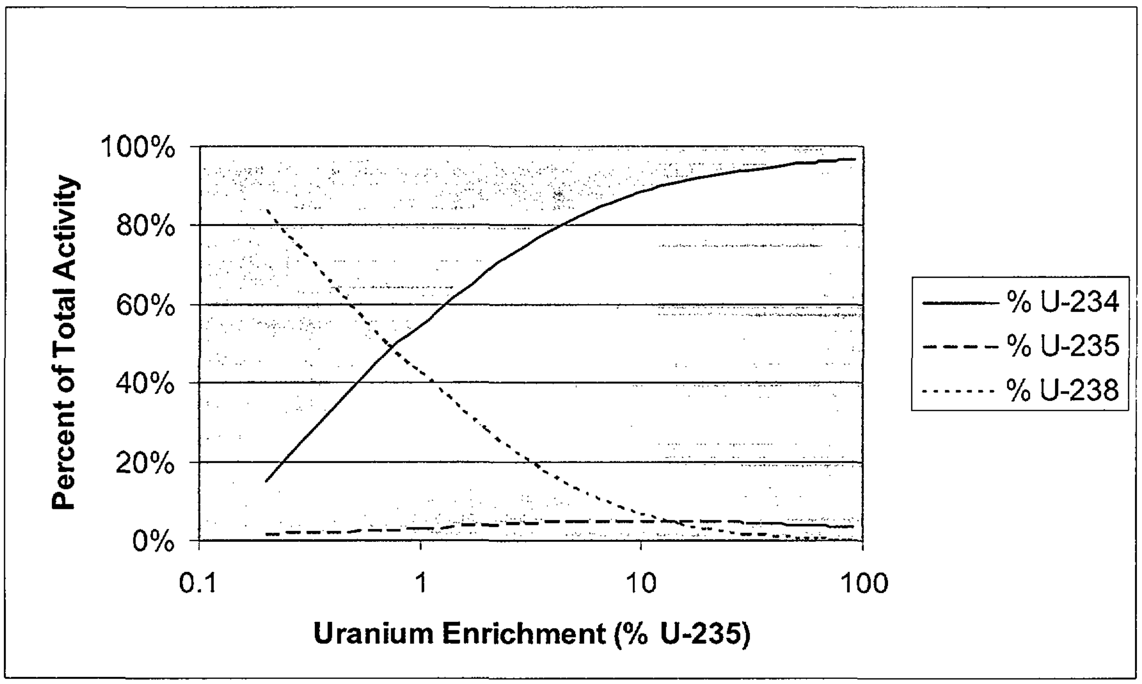

Figure B-1 Percentage of Total Uranium Activity

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

Enrichment (% U-235)	Percentage of Total Activity		
	% 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.

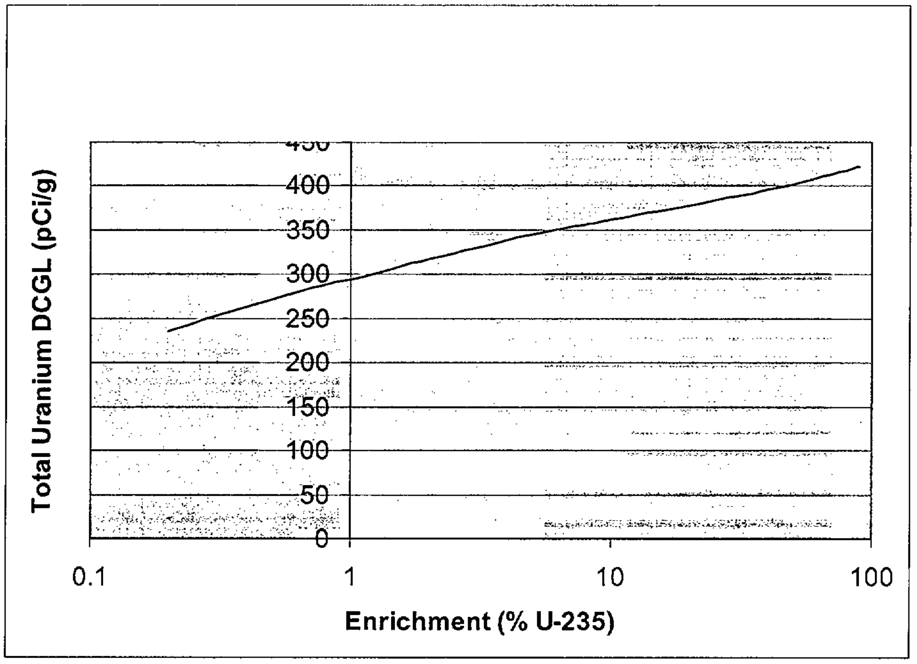

Figure B-2 Composite Surface Source DCGL

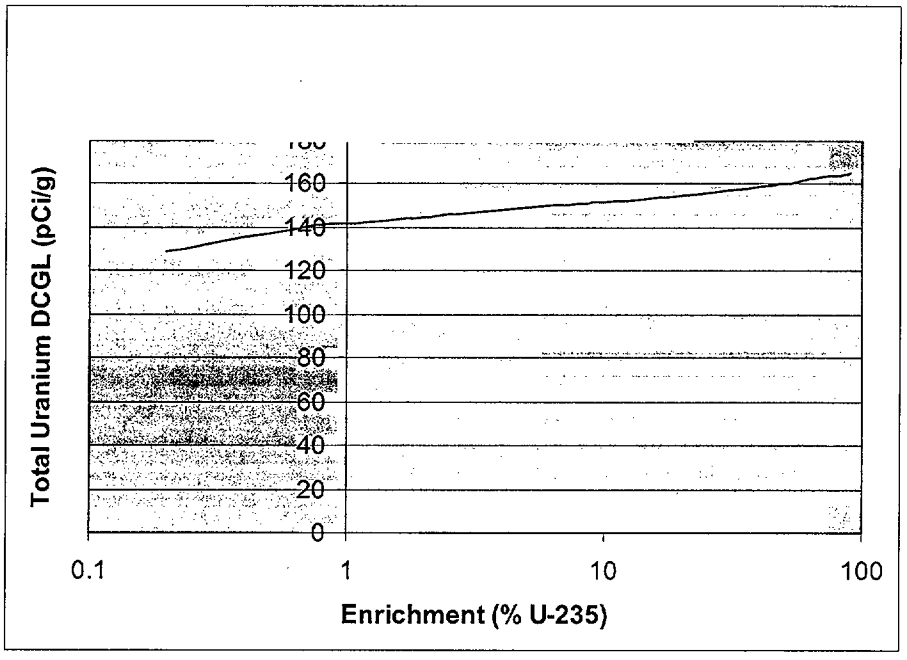

Figure B-3 Volumetric Source DCGL

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.

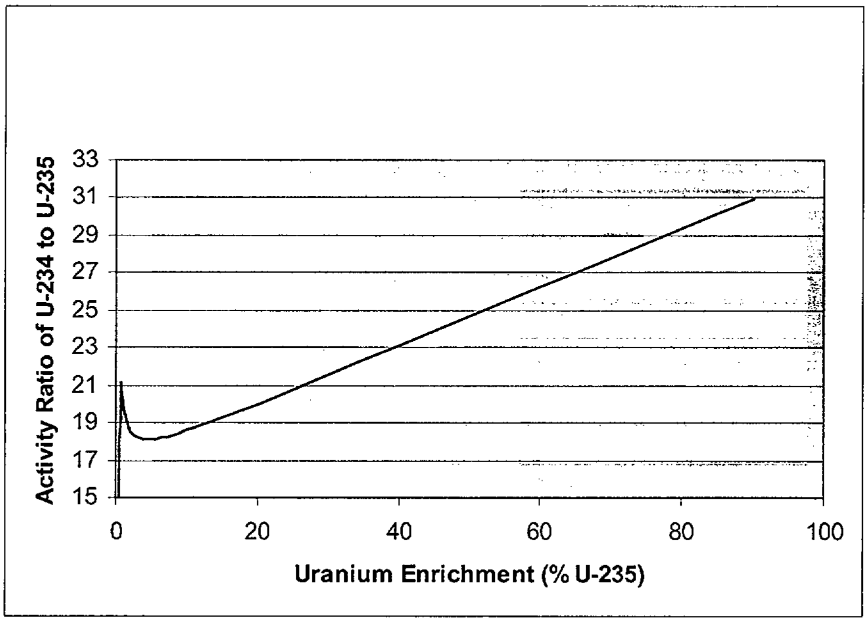

Figure B-4 Ratio of U-234/U-235 to % U-235

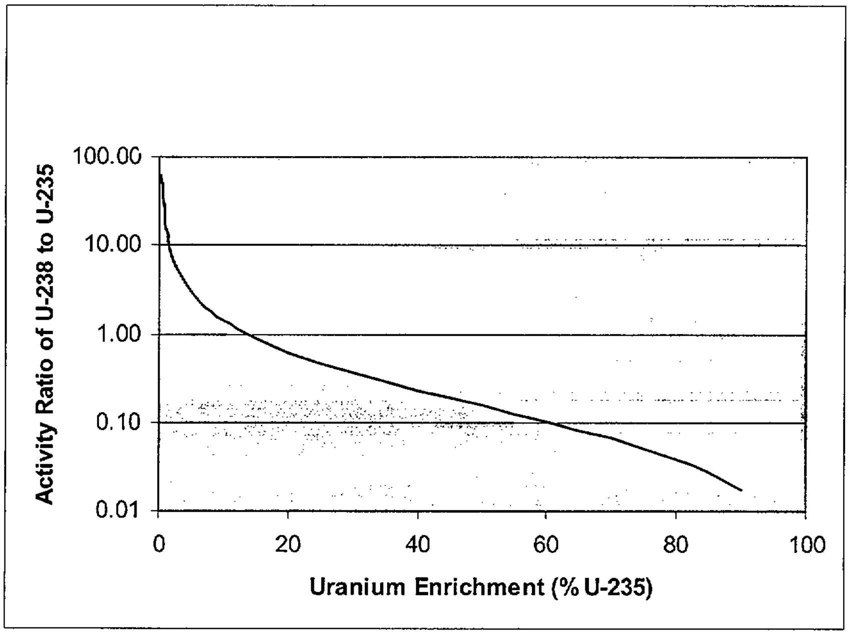

Figure B-5 Ratio of U-238/U-235 to % U-235

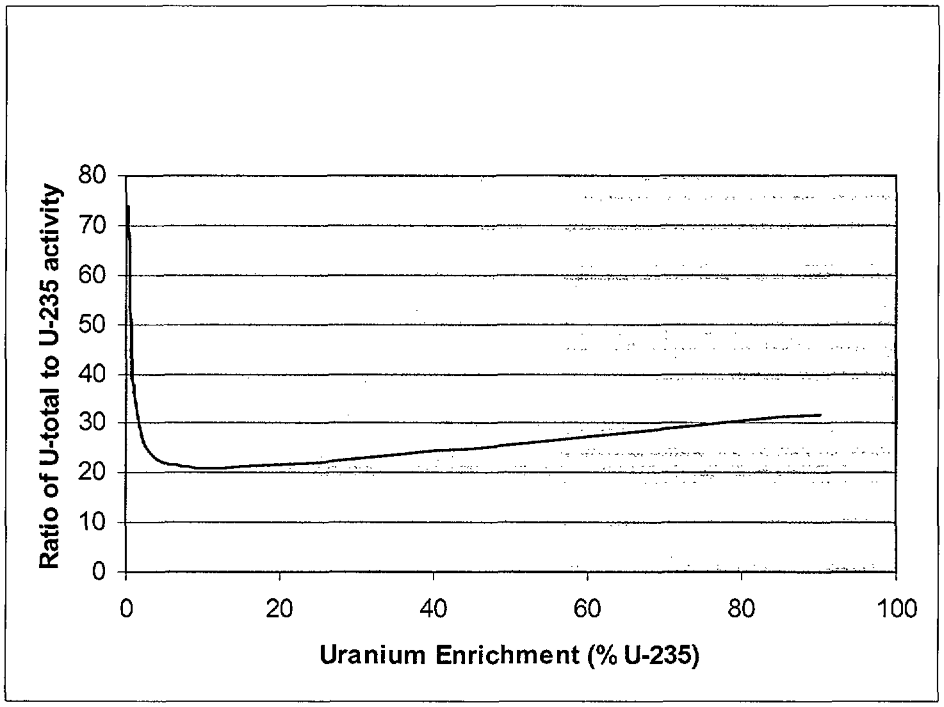

Figure B-6 Ratio of U-total/U-235 to % U-235

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.

WITHIN THIS PACK THIS THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE

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Hematite, Missouri facility
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