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April 14, 2005April 14, 2005

Kenneth L. Kalman
Decommissioning Branch
Division of Waste Management
Office of Nuclear Materials Safety and Safeguards
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

**Re: Transmittal of Deliverable (License No. SMB-743, Control No. 132074)**

Dear Mr. Kalman:

On February 23, 2005, Shieldalloy Metallurgical Corporation (SMC) submitted a schedule for completing three key components of our revised decommissioning plan as part of a phased approach.[1] Those deliverables are: (1) a Draft of Chapter 5 of the revised plan (entitled "Dose Modeling Evaluations") which is due to the USNRC on April 15, 2005; (2) a draft environmental report which is due to the USNRC on May 27, 2005; and (3) a draft of Chapter 6 of the revised plan (entitled "ALARA Analysis") which is due to the USNRC on September 2, 2005. This letter transmits the Chapter 5 draft (enclosed).

As you will see during your review of the enclosure, there are a number of blank spaces in the text. Many of the parameters and descriptive elements that will eventually fill them in have not been finalized as they are dependent upon the results of work in progress. However, the text as written is how we intend to treat this important topic. We are sending Chapter 5 to you with those blank spaces to ensure that its scope, contents and approach will be satisfactory for technical review when we submit it again as part of the entire plan (due to you at the end of September).

We also intend to schedule a meeting with our Site Specific Advisory Board between May 27 and September 9, 2005, depending upon the SSAB's availability. The purpose of that meeting will be to present the three deliverables and give the SSAB an opportunity to comment on them before the September 30th submission of Rev. 1 of the Decommissioning Plan. Once the date for the SSAB meeting is set, I will formally invite the USNRC to attend and participate in that meeting.

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[1] Shieldalloy Metallurgical Corporation, Report No. 94005/G-28247 (Rev. 1), "Decommissioning Plan for the Newfield Facility".

I look forward to your comments and suggestions on the attached draft. Your feedback will help SMC meet its goals of submitting a decommissioning plan that is accepted for technical review. This will allow the decommissioning of the Newfield site proceeds expeditiously and effectively. Please don't hesitate to call me at (856) 692-4201, extension 1-226 if you have any questions or need further information.

Sincerely,

David R. Smith,
Radiation Safety Officer

cc: Eric Jackson
Joe Diegel
Charles L. Harp, Esq. - Archer & Greiner
Carol D. Berger, CHP - Integrated Environmental Management, Inc.
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# 5 Radiation Dose Modeling

A critical aspect of this decommissioning plan is an assessment of the potential future dose that could be caused by the residual radioactivity at the Newfield site after all decommissioning activities are completed. This Chapter of the Plan provides the results of the assessment for realistic exposure scenarios and demonstrates that the following dose limits applicable to restricted release of the site will indeed be met when decommissioning is complete:[1]

> "A site will be considered acceptable for license termination under restricted conditions if: . . . (e) Residual radioactivity at the site has been reduced so that if the institutional controls were no longer in effect, there is reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group is as low as reasonably achievable and would not exceed either– (e)(1) 100 mrem (1 mSv) per year–, . . ."

In order to complete the assessment, information on the source term, exposure scenarios, conceptual models, numerical analyses and uncertainty are required. The following subsections of this chapter contain this information. Included herein is a brief description of the methodology used to perform the dose assessments, a detailed description of the site conceptual model which includes the source term used as input to the assessment, the exposure scenarios deemed applicable under conditions of restricted release, applicable exposure scenarios when the controls specified as part of the terms of the release fail, a presentation of the uncertainty associated with the input parameters, and the findings (results) of the assessment demonstrating that the requirements for restricted release will be met once the decommissioning is complete.

## 5.1 Assessment Methodology

The process of assessing the potential radiation dose involves defining the source(s), the site conceptual model, the pathways for potential human exposure, and the availability of a receptor to receive a dose. However, the relationships between factors involved in defining the mechanisms for human exposure are complex and often interdependent. Therefore, a computer program to model the plausible human exposure scenarios and to perform the complex sets of computations was employed for the Newfield site.

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[1] US Nuclear Regulatory Commission, *Criteria For License Termination Under Restricted Conditions*, Title 10 CFR 20.1403, July 21, 1997.

The computer code, RESRAD (Version 6.22) was used to model radionuclide fate and transport of residual radioactivity at the site and to assess the radiation dose incurred by the hypothetical people who may occupy the site after decommissioning is complete.[2] This code provides the radiation dose expected to be received by the hypothetical member of the public beginning immediately after termination of the license for restricted release and extending for 1,000 years into the future.[3]

The RESRAD code is widely accepted as an industry-standard tool for performing radiological dose assessments and for deriving concentration guideline values. However, there are several important features of the code that should be taken into account in interpreting any results that are generated. These include the following:

- The radiation dose conversion factors (DCFs) used in RESRAD 6.22 are taken from Federal Guidance Reports (FGRs) No. 11 and 12, which are derived from dosimetry model promulgated by the International Commission on Radiation Protection (ICRP);[4,5,6,7]

- Short-lived radioactive progeny (e.g. halflife less than 180 days) are accounted for using the "parent+D" DCFs;

[2] Yu, C, Zielen, A.J, et al, *User's Manual for RESRAD Version 6*, ANL/EAD-4, Argonne National Laboratory, Argonne, Illinois, July, 2001.

[3] The RESRAD code was chosen primarily because it can adequately depict the key site-specific features of SMC's site. It is also able to derive values for exposure parameters based on built-in fate and transport computations using well-defined site-specific data. In addition, the code is able to integrate radiation dose projections over time taking into account transient conditions that may occur.

[4] U.S. Environmental Protection Agency, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, Federal Guidance Report Number 11, EPA 520/1-88-20, September, 1988.

[5] U.S. Environmental Protection Agency, *External Exposure to Radionuclides in Air, Water and Soil*, Federal Guidance Report Number 12, EPA 402 R-93-081, September, 1993.

[6] International Council on Radiation Protection, *Report of the Task Force on Reference Man*, ICRP Report 23, 1981.

[7] The bio-kinetic dosimetry model accounts for particle fractioning that might occur following exposure. For example, the DCFs for particle inhalation account for the dose to the GI tract from the fraction of respired particles that are ingested. As a result, there is no need to independently account for biological fractioning in the dose calculations.

- RESRAD integrates and normalizes exposure factors based on the fraction of time a receptor is exposed over the exposure period;[8] and

- RESRAD uses single-point estimates for values of every parameter to evaluate complete pathways in the deterministic module of the code.

A final feature of the RESRAD code is that the user may select from two types of risk assessment methods: deterministic and probabilistic.[9] Most professionals are familiar with the deterministic approach because it has been, until recently, the most widely used of the two. It is designed to capture the reasonable maximum exposure (RME) condition for a receptor using single point estimates of parameter values used to calculate dose. Such a calculation provides a single point estimate of radiation dose that could result from a given concentration of radioactivity. However, few parameters used to calculate future dose potential are so well known that they can be described by a single value, thus common practice is to use unrealistically-conservative input parameters in order to bound the inherent uncertainty in the deterministic approach.

In contrast, the probabilistic methodology for risk assessment addresses the potential for exposure through what is essentially an uncertainty analysis, taking both the range and distribution of individual parameters into consideration.[10] The probabilistic method provides a substantially clearer picture of the potential future dose corresponding to a residual radioactivity concentration for the risk manager to evaluate. Because the USNRC has established their decision-making criteria on the use of probabilistic assessment methods and the resulting mean or "most likely" exposure to an

[8] For example, a soil ingestion rate of 100 mg/d for a receptor who is exposed on Site for only 50-percent of one day would result in an ingestion intake of 50 mg.

[9] Table ___ summarizes the principal differences that exist between the deterministic and probabilistic methods.

[10] U.S. Nuclear Regulatory Commission, *Consolidated NMSS Decommissioning Guidance, Decommissioning Process for Materials Licensees*, NUREG 1757, Vol. 1, Rev. 1, September, 2003.

average member of the critical exposure group, this is the approach used by SMC in its assessment of the dose potential at the decommissioned Newfield site.[11,12,13,14]

### *5.2 Site Conceptual Model*

The site conceptual model has three fundamental components that must be described in terms that can be used to calculate (or model) the potential future dose to a receptor at or near the decommissioned SMC site. The first component is the source term itself.[15] The second is the physical characteristics of the site.[16] The third component is the range of plausible human exposure scenarios, which are described primarily by factors that are associated with human behavior and metabolic physics. Each of these fundamental components is discussed in the subsections that follow.

#### *5.2.1 Source Term*

The source term abstraction used by the RESRAD code to project potential future dose is derived from knowledge about the source material itself, and previously completed radiological assessments of the residual radioactivity at the site. The source term is defined by its radionuclide composition, as well as its lateral and vertical deposition (spatial configuration).

The source term at SMC's Newfield site has a variety of contributors. Those that will be present in the closed and capped restricted area are boulders of vitreous, radionuclide-bearing slag, a lime dust pile with exempt source material concentrations, soil and surface-contaminated building rubble. The radionuclide contents of the source term in its entirety, normalized for all of the contributors, is described in Section 4.4, above, and summarized in Table ____.

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[11] The average member of the critical group is used rather than using the RME for the entire population. In a typical deterministic risk, the RME is used for the entire population.

[12] As defined in 10 CFR 20.1003, the critical group is a group of individuals expected to receive the greatest exposure to residual radioactivity for any applicable set of conditions.

[13] U.S. Nuclear Regulatory Commission, *Radiological Criteria for License Termination*, Volume 62, Federal Register, page 39058, July 21, 1997.

[14] NUREG-1757, September, 2003.

[15] The size, thickness, and radiological composition of the source must be conceptualized in the source term abstraction.

[16] The site must be described in a physical abstraction that includes physical and hydraulic characteristics of the site and its potentially impacted environs.

In describing the source term for input to RESRAD, the area (size) of the contaminated zone parameter (AREA) is represented by a loguniform distribution with a minimum value of ____ $m^2$ and a maximum value of ____ $m^2$ corresponding to the entire area.. The use of the loguniform distribution provides a realistic, yet conservative, description of the lateral variability in the size of the source term in that it assigns the most likely size (____ $m^2$) as the minimum size and allows for the possibility (albeit with lower probability of occurrence) of larger sizes up to the entire area covered by the cap. Vertically, the radiologically significant material is assumed to be located beneath the cover. A triangular distribution describes well the observed variability in the depth profile and thus the thickness of the contaminated zone or source term.

In describing the source term for input to RESRAD, the thickness of the contaminated zone parameter (THICKO) is represented by a triangular distribution, with the central tendency (CT) value conservatively set to a thickness of ____ feet (____ meters). This thickness is conservative in that the mean source thickness over the entire footprint of the cell, the impacted area, is considerably less than ____ feet.

As described in Chapter 4, radionuclide composition of the source term (the radionuclides of interest) is defined by both measured isotopic ratios in samples collected from within the contaminated volume and by historical knowledge of the origin of the radioactivity found within the volume. The relatively longer-lived progeny of $^{232}$Th and $^{238}$U are assumed to be in secular equilibrium with their parent. This assumption is not only conservative but it is supported by the results of analytical measurements. Therefore, the source term input to RESRAD includes all of the isotopes in the $^{238}$U and $^{232}$Th decay series with half-lives longer than 180 days in the concentrations shown in Table ____.[17]

### *5.2.2 Site Physical Parameters*

The second major conceptual component of the dose assessment is the physical abstraction of the site, which must capture and express the important physical, hydraulic, and geological conditions at the site. It is also used to place the source term in the context of the environment and systems that surround it.[18]

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[17] Isotopes with half-lives shorter than 180 days are assumed to be in equilibrium with their first parent with a half-life greater than 180 days and a re accounted for in dose calculations through the use of "parent+D" dose conversion factors.

[18] The physical, hydraulic, and geologic conditions must be described and input into RESRAD. RESRAD is not a comprehensive model for the fate and transport of groundwater and surface water. It does, however, model the vertical migration of radiological contaminants from the surface or near surface soils to ground water sources of drinking water and surface water bodies for the purpose of calculating the potential exposure to human receptors who may use such water.

Conceptually, the restricted area at the Newfield site after decommissioning is complete will be composed of four "layers" that are important to the dose modeling objective. These are:

- Engineered Cover Layer - a thick layer of unimpacted native soil, a geomembrane liner, rip rap (as necessary), topsoil and vegetation brought onto the site to form a cap over the contaminated zone and underlying waste layer;[19]

- Contaminated Zone - a layer generally lying just beneath the engineered cover in which radionuclide-bearing materials are placed and formed;

- Undisturbed Surface Layer - a relatively thick, dense, undisturbed native deposit of gravel/sands of the Bridgeton Formation (thickness ranging from zero to 28 feet), underlain by the fine- to coarse-grained sands of the Cohansey Sand; and

- Deep Aquifer Saturated Zone - the saturated Cohansey Sand to the depth of the confining Kirkwood formation (i.e., 120 feet or more).

The various parameters describing the composition in each "layer" are defined within RESRAD with probabilistic variables included in order to account for the variability and uncertainty inherent in hydrogeological features. The parameters defining each layer used as input to the code are described in detail in the subsections that follow.

#### *5.2.2.1 Engineered Cover Layer*

The cover layer overlies the radionuclide-bearing slag is an engineered soil and geomembrane membrane cap made of native materials brought onto the site and installed. It is designed to encapsulate the residual radioactivity currently in the Storage Yard. The thickness of the engineered cover layer is ____ meters thick. A triangular distribution with a central tendency value of ____ meters and a minimum and maximum of ____ and ____ meters, respectively, is used to represent the thickness of this layer in RESRAD model.

The engineered soil cover is designed to have a low hydraulic conductivity. Soil density is assumed to be equivalent to the native soil in the region (____ g/cm$^3$). When modeling the subsurface-soil source term in RESRAD, this layer is identified as the "cover layer" since it overlies the contamination zone. Cover degradation is accounted for in RESRAD by a surface soil erosion rate parameter (VCV). The value used as input to the code, 0.5 feet over a 1,000-year period, was

[19] The cap includes a geomembrane to divert surface water.

derived using the Revised Universal Soil Loss Equation computer program, version 2 (RUSLE 2) and conservative input parameters.[20] Appendix ___ contains the findings from this analysis.

#### 5.2.2.2 Contaminated Zone

Contamination in the form of ferrocolumbium slag, baghouse dust, soil and contaminated building rubble will be consolidated within the Storage Yard and then capped with the engineered cover described previously. The contaminated zone will consist of ____ cubic meters of material, with a mean density of ___ and a hydraulic conductivity of ____. The dimensions of the contaminated zone are ____ by ____ by____ meters.

#### 5.2.2.3 Undisturbed Surface Layer

The third layer is the gravel/sand layer of the Bridgeton Formation, underlain by the fine- to coarse-grained sands of the Cohansey Sand. This layer is estimated to range in thickness between 8 and 10 feet (___ to ___ meters) with a nominal or typical thickness of approximately ___ ft.(___ meter). RESRAD identifies this layer as the "unsaturated layer" when modeling the source term. The thickness of this zone is described with the RESRAD, bounded with a triangular distribution, having a central tendency value of ___ meter bounded at a minimum of ___ meter and a maximum of ___ meters. Measured soil density is ___ g/cm$^3$ and measured hydraulic conductivity is ___ m/yr. The radionuclide distribution coefficients described in Section ___ were used for all isotopes.[21]

#### 5.2.2.4 Deep Aquifer Layer

The lower-most (deepest) layer is described as the deep aquifer layer. It is not important from a dose modeling perspective if groundwater beneath the site is not used for drinking water. Still, the RESRAD model will calculate the potential for radioactive material "breakthrough" and evaluate the potential impacts on groundwater even if the drinking water pathway is not used for a given scenario.

### 5.3 Potential Exposure Scenarios

In order to demonstrate compliance with applicable requirements for restricted release of the SMC site, and to ensure a realistic correlation between radiation dose and residual radioactivity, it is critical that the model portrayed in the RESRAD code be sufficiently representative of actual (site-specific) cases. To determine the setup of the RESRAD code, SMC first envisioned and then characterized plausible exposure scenarios that a potential future receptor may encounter.

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[20] TRC Environmental Corporation, *Estimated Soil Loss from Soil Cap*, Project Number 26770-0000, January, 2005.

[21] Berger, C. (IEM), written communication to D. R. Smith (SMC), *Radionuclide Leachability from Newfield Slag*, ____, 2005.

A number of physical and demographic properties pertinent to the site contribute to the conception of plausible and realistic conditions under which an individual might be exposed at the site in the future. In addition, the future use of the property as described in Chapter 3, above, was also taken into account. For the foreseeable future (100 years), the following is deemed likely for the SMC property:

- The property will retain industrial (light industry) zoning.
- Residential encroachment up to the property boundary is possible but not likely because of the deed restrictions to be filed with Gloucester County, the requirements of the Long Term Control license held by the property owner, and anticipated land use factors.
- Farming encroachment up to the property boundary is not likely due anticipated land use factors in areas that border the deed-restricted SMC property.
- The property will remain intact (i.e.,. will not be subdivided), such that the "releasable" portion of the property will remain associated with the restricted area.[22]
- Under conditions of restricted release, all controls specified in Chapter ___ of this Plan and in the Long Term Control license that is eventually issued to SMC, will remain in force.
- If a control fails, it is reasonable to assume that it does not fail instantly and completely (i.e., if cap maintenance should cease, the cap will erode over time as opposed to instantaneous and complete loss of the cap over the contaminated zone).
- Excavating the residual radioactivity from beneath the engineered cap is considered unlikely because the cap will camouflage its contents, the lack of economic value of the residual radioactivity, and the unappealing physical form of the majority of the residual radioactivity (large, vitrified and irregularly-shaped rocks).
- Excavating some or all of the engineered cap as a source of fill, thus partially- or fully-exposing the residual radioactivity therein, is not likely due to the relative

[22] Kallman, KL (USNRC), letter to D. Smith (SMC), "Nuclear Regulatory Commission Staff Guidance for a Long Term Control Possession Only license at the Shieldalloy Metallurgical Corporation Site in Newfield, New Jersey", May 15, 2004.

difficulty of scavenging fill from a sloped surface as compared to a nearby flat surface.

- The presence of the institutional and regulatory controls at the site for a reasonable period of time after decommissioning is complete would create a land area buffer (i.e., a natural separation) that would not be conducive to construction in close proximity to the engineered cap. Furthermore, there are existing site use restrictions due to the natural resource restoration requirements to a large portion of the Newfield site (i.e, required maintenance of tree-planting areas), as well as potential future residential use restrictions due to soil contaminant levels under the CERCLA that would result in a land buffer to prevent construction in close proximity to the cap.

With these parameters in mind, the following subsections describe the most realistic post-decommissioning exposure scenarios assuming all controls remain in place, and when all controls fail. These exposure scenarios are consistent with Commission recommendations to rely upon parameters that are conservative yet realistic to conditions at the site.[23] They were presented to the USNRC in advance of the preparation of this Plan, and a general indication of acceptability was obtained.[24]

### *5.3.1 Exposure Scenarios Under Restricted Release Conditions*

Once decommissioning is complete, SMC will apply for (and presumably receive) a Long Term Control license from the USNRC. The conditions of this license will include a variety of regulatory and institutional controls, including but not limited to the following:

- Deed restrictions to prevent construction in or near the restricted area.
- ____
- ____

Under these conditions, the most likely exposure scenario for many years into the future would be a maintenance worker who is required to periodically traverse the capped Storage Yard to inspect

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[23] U.S. Nuclear Regulatory Commission, *Results of the License Termination Rule Analysis*, SECY-03-0069, May 2, 2003.

[24] Smith, D. (SMC), written communication to K. Kalman (USNRC), "Teleconference Summary (License No. SMB-743, Control No. 132074)", October 7, 2004.

and repair (as necessary) the engineered cover.[25] Other realistic scenarios would be an industrial worker present during normal business hours somewhere on the SMC property but without access to the restricted area, and an occasional trespasser who climbs over the fence and traverses the restricted area for brief periods of time. The following subsections describe these scenarios.

#### *5.3.1.1 Maintenance Worker*

Description of the Critical Group

SMC will inspect and maintain the cap installed over the Storage Yard. A worker will inspect the cover by walking or driving over the surface of the cap.[26] It is assumed that the maintenance worker will inspect the entire surface and repair any evidence of erosion or intrusion in the cover. It is reasonable to assume that the inspection and maintenance will require no more than eight (8) days per year (8 hours per day) or no more than 64 hours per year since the cap will be installed in a manner that minimizes erosion and enhances the growth of vegetation on its surface. Once established, the inspection and maintenance efforts are likely to be minimal.

Pathways included in the Maintenance Worker Scenario

RESRAD identifies the potential pathways for exposure to the critical group. Three (3) pathways are used for the maintenance worker scenario, including:

- direct radiation exposure;
- particulate inhalation; and
- direct ingestion.

The other pathways are inapplicable and are turned off for the purpose of the RESRAD model. Table 5.7 identifies the pathways that have been retained for the analysis and provides an explanation for those pathways that were not retained. Table 5.8 describes the specific parameters that were used in the RESRAD model; this table lists the parameters specifically used in the model

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[25] The use of realistic exposure scenarios, rather than those that are unduly conservative, was approved by the Commission in a November 17, 2003 memorandum from A. L. Vietti-Cook to W. D. Travers, "Staff Requirements - SECY-03-069 - Results of the License Termination Rule Analysis". In that memorandum it states in part that "The Commission has approved the staff's recommendation for use of realistic exposure scenarios as described in attachment 6".

[26] Mechanical equipment will be limited on the surface of the cover. Mechanized equipment such as a "four wheel ATV" or light tracked equipment may be used. Heavy equipment that may cause damage to the cover and/or the vegetation will be specifically prohibited.

for the maintenance worker.[27] The tables are organized such that key parameters common to the assessment of both the surface and subsurface soil source terms are presented first. Subsequent tables present key parameters that are unique to the source term. Table 5.9 describes the parameters used in the RESRAD model that depict the physical parameters of the cover, slag and the undisturbed layer conditions; these parameters are common to each of the scenarios used in this chapter.

The exposure pathway for potential exposure to radon gas was eliminated in this assessment and all potential exposure scenarios. The USNRC documented their concurrence with this approach in the Statement of Consideration for the License Termination Rule:[28]

> *Following the approach taken in the proposed rule, this final rule includes radiological criteria for residual radioactivity that is distinguishable from background. Because of natural transport of radon gas in outdoor areas due to diffusion and air currents, doses from exposure to radon in outside areas due to radium in the soil are negligible... Therefore, in implementing the final rule, licensees will not be expected to demonstrate that radon from licensed activities is indistinguishable from background on a site-specific basis...*

Description of the Parameters Used in the Analysis

It is assumed that the maintenance worker does not spend anytime indoors; there are no buildings located on the Storage Yard. The outdoor fraction, 0.007, is derived by dividing the 64 hours per year by the total number of hours in a year, 8,760 hours. The inhalation rate for the maintenance worker is assumed to be a short term exposure for adult males averaging 8,400 cubic meters per year. It is also assumed that the maintenance worker ingests soil from the cover as a result of incidental contact with the soil in the Storage Yard. The maintenance worker does not eat any animals or vegetables from the Storage Yard; he does not drink any surface water or ground water.

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27 A comprehensive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for each scenario is provided in the RESRAD output files (reports) in appendices ___ through ___.

28 U.S. Nuclear Regulatory Commission, *Radiological Criteria for License Termination*, Federal Register, Volume 62, Number 139, July 21, 1997.

### *5.3.1.2 Industrial Worker*

Description of the Critical Group

SMC anticipates that industrial operations will be located on the property adjacent to the fenced Storage Yard. Industrial workers will visit the site to work each day; at no time will any workers enter the fenced area or walk on the cap over the Storage Yard. For purposes of conservatism, it is assumed that the industrial worker will work immediately adjacent to the Storage Yard even though it is not likely that the industrial operations will be located close to the fence. It is also assumed that the industrial worker will work at the industrial site five (5) days per week for fifty (50) weeks per year. It is assumed that the work day will last for eight (8) hours per day, with a fraction of that time spent outdoors.

Pathways included in the Industrial Worker Scenario

RESRAD identifies the potential pathways for exposure to the critical group. Two (2) pathways are used for the industrial worker scenario, including:

- direct radiation exposure; and
- particulate inhalation.

Table 5.10 identifies the pathways that have been retained for the analysis and provides an explanation for those pathways that were not retained. The other pathways are inapplicable and are turned off for the purpose of the RESRAD model. Table 5.11 describes the specific parameters that were used in the RESRAD model; this table lists the parameters specifically used in the model for the industrial worker.[29] Table 5.9 describes the parameters used in the RESRAD model that depict the physical parameters of the cover, slag and the undisturbed surface conditions; these parameters are common to each of the scenarios used in this chapter.

Description of the Parameters Used in the Analysis

It is assumed that the industrial worker does not spend anytime indoors. The outdoor fraction, 0.23, is derived by dividing the 2,000 hours per year by the total number of hours in a year, 8,760 hours. The inhalation rate for the industrial worker is assumed to be a short term exposure for adult males averaging 8,400 cubic meters per year. The industrial worker does not enter the fenced Storage Yard; it is assumed that he does not ingest soil from the Storage Yard. In addition: The industrial

[29] A comprehensive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for each scenario is provided in the RESRAD output files (reports) in appendices ___ through ___.

worker does not eat any animals or vegetables from the Storage Yard; he does not drink any surface water or ground water.[30]

#### 5.3.1.3 Occasional Trespasser

Description of the Critical Group

The capped Storage Yard will be fenced and signs will be posted that prohibit trespassers from entering the property. SMC will maintain the conditions at the site in its entirety, as well as the fence and cap on the Storage Yard. The likelihood that a trespasser will enter the property when the institutional controls are in place is remote. However, it is possible since it is unlikely there will be provision for round-the-clock security at the site. Therefore, it is reasonable to assume that a trespasser might be present on the surface of the cap for no more than an average of 3.5 hours per day for a nominal 12 days per year, for a total of 42 hours in a year.[31]

Pathways included in the Trespasser Scenario

RESRAD identifies the potential pathways for exposure to the critical group. Three (3) pathways are used for the trespasser scenario, including:

- direct radiation exposure;
- particulate inhalation; and
- direct ingestion.

The other pathways are inapplicable and are turned off for the purpose of the RESRAD model. Table 5.12 identifies the pathways that have been retained for the analysis and provides an explanation for those pathways that were not retained. Table 5.13 describes the specific parameters that were used in the RESRAD model; this table lists the parameters specifically used in the model for the trespasser.[32] Table 5.9 describes the parameters used in the RESRAD model that depict the physical parameters of the cover, slag and the undisturbed surface conditions; these parameters are common to each of the scenarios used in this chapter.

[30] Drinking water is provided by a publicly-owned water system where there is testing for compliance with drinking water standards for radionuclides, and there are no surface water sources or ground water wells inside of the Storage Yard. Furthermore, the cover does not erode while institutional controls are in place and the cap is being maintained.

[31] U. S. Environmental Protection Agency, EPA/600/P-95/002Fc, "Exposure Factors Handbook Volume III - Activity Factors", August, 1997, Table 15-86.

[32] A comprehensive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for each scenario is provided in the RESRAD output files (reports) in appendices ___ through ___.

Description of the Parameters Used in the Analysis

It is assumed that the trespasser does not spend anytime indoors; there are no buildings located on the Storage Yard. The outdoor fraction, 0.005, is derived by dividing the 42 hours per year by the total number of hours in a year, 8,760 hours. The inhalation rate for the trespasser is assumed to be a short term exposure for adult males averaging 8,400 cubic meters per year. It is also assumed that the trespasser ingests soil from the cover as a result of incidental contact with the soil in the Storage Yard. The trespasser does not eat any animals or vegetables from the Storage Yard; he does not drink any surface water or ground water. The cover does not erode while institutional controls are implemented by SMC and while the cap is being maintained.

### *5.3.2 Exposure Scenario if Controls Should Fail*

In the event that all controls associated with the post-decommissioning Long Term Control license fail, it is unreasonable to assume anyone would take up residence on the capped Storage Yard simply because its shape/form would not be conducive to building construction. It is equally unreasonable to assume that truck farming or small-scale agriculture would go on directly on the capped Storage Yard again because of its configuration. The most likely exposure scenario if the controls fail would be (1) a hunter could hunt game on the capped pile, (2) a family living near the Storage Yard, (3) a trespasser who traverses the capped pile where some or all of the cover has been excavated thus exposing the contents, and (4) an industrial worker who works at a manufacturing facility on the SMC property.[33]

#### *5.3.2.1 Recreational Hunter Scenario*

Description of the Critical Group

The critical exposure group for the recreational hunter scenario is described by hypothetical subpopulation that frequently hunts for recreation and consumes a considerable amount of game meat culled from the site. This hunter (as conservatively described) is likely to spend a large fraction of his available outdoor recreational time engaged in hunting and who returns to the SMC site, where the fencing around the restricted area has failed thus permitting the egress of game, each time rather than visiting other sites in search of prey. This scenario is unlikely because of the lack of shelter for animals to hide and forage and because hunting is not allowed within Newfield borough limits. Hunters are not likely to use the small property as a source of game because of the realistically-small animal population in its vicinity.

[33] As described in Section 5.3, removing some or all of the engineered cap as a source of fill, thus partially- or fully-exposing the residual radioactivity therein, is not likely due to the relative difficulty of scavenging fill a sloped surface as compared to a nearby flat surface. And even if surface mining did occur, the radionuclide concentration in the excavated material would be small since it is comprised of radiologically-inert soil and possibly small amounts of the baghouse dust that was placed below the native soils as void filler. (The baghouse dust contains less than 0.05% source material.) Therefore, this scenario does not present dosimetric significance.

Pathways Included in the Recreational Hunter Scenario

RESRAD identifies the potential pathways for exposure to the critical group. Four (4) pathways are used for the trespasser scenario, including:

- direct radiation exposure;
- particulate inhalation;
- meat ingestion; and
- direct ingestion.

The other pathways are inapplicable and are turned off for the purpose of the RESRAD model. Table 5.14 identifies the pathways that have been retained for the analysis and provides an explanation for those pathways that were not retained. Table 5.15 describes the specific parameters that were used in the RESRAD model; this table lists the parameters specifically used in the model for the recreational hunter.[34] Table 5.9 describes the parameters used in the RESRAD model that depict the physical parameters of the cover, slag and the undisturbed surface conditions; these parameters are common to each of the scenarios used in this chapter.

Description of the Parameters Used in the Analysis

The recreational hunter scenario involves relatively conservative exposure factors attributable to members of the critical group, hunting enthusiasts, who may spend a considerable amount of time hunting and whose annual diet of meat is composed of a large fraction of game culled from the site. Key parameters used to define the recreational hunter exposure scenario are presented in a series of three tables along with specific remarks explaining the values' selection. Table 5.15 contains common parameters describing the receptor's exposure and behavioral patterns (e.g., exposure time, inhalation rate, etc.) as well as common parameters describing the general and weather-related parameters relevant to the site. Table 5.9 contains parameters specific to the Storage Yard and the slag, covered by the engineered cap (i.e., geotechnical parameters and parameters describing the source term itself).

#### *5.3.2.2 Suburban Resident Scenario*

Description of the Critical Group

The critical exposure group for the suburban resident scenario is described by hypothetical family occupies a house located near the Storage Yard. As a result of the design of the cover, it is not feasible for a house to be built directly on top of the Storage Yard. The cover is elevated from the ground surface and covers slag which does not allow excavation or trenching for typical construction

[34] A comprehensive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for each scenario is provided in the RESRAD output files (reports) in appendices ___ through ___.

of footers or utility trenches, commonly used in the construction of a house. It is assumed that the house is located approximately 100 yards from the Storage Yard. The family who lives in the house uses water provided by a publicly owned water supply and does not grow a significant amount of food or vegetables near the Storage Yard (i.e., food is purchased at a nearby grocery store). This scenario is unlikely because of the lack of available space to construct a house and parking, and because the majority of the area surrounding the Storage Yard is assigned for natural resource damage mitigation (tree planting) and could only be developed for housing if the controls maintaining the conservation should fail.

Pathways Included in the Suburban Resident Scenario

RESRAD identifies the potential pathways for exposure to the critical group. Three (3) pathways are used for the suburban resident scenario, including:

- direct radiation exposure;
- particulate inhalation; and
- direct ingestion.

The other pathways are inapplicable and are turned off for the purpose of the RESRAD model. Table 5.14 identifies the pathways that have been retained for the analysis and provides explanation for those pathways that were not retained. Table 5.15 describes the specific parameters that were used in the RESRAD model; this table lists the parameters specifically used in the model for the suburban resident.[35] Table 5.9 describes the parameters use in the RESRAD model that depict the physical parameters of the cover, slag and the subsurface conditions; these parameters are common to each of the scenarios used in this chapter.

Description of the Parameters Used in the Analysis

The suburban resident scenario involves relatively conservative exposure factors attributable to a suburban family who live near the covered Storage Yard, after controls fail. Key parameters used to define the suburban family exposure scenario are presented in a series of three tables along with specific remarks explaining the values' selection. Table 5.15 contains common parameters describing the receptor's exposure and behavioral patterns (e.g., exposure time, inhalation rate, etc.) as well as common parameters describing the general and weather-related parameters relevant to the site. Table 5.9 contains parameters specific to the Storage Yard and the slag, covered by the engineered cap (i.e., geotechnical parameters and parameters describing the source term itself).

[35] A comprehensive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for each scenario is provided in the RESRAD output files (reports) in appendices ___ through ___.

### *5.3.2.3 Cover Excavation Scenario*

Description of the Critical Group

The critical exposure group for the cover excavation scenario is described by a hypothetical person who excavates the cover and moves the noncontaminated cover soil to a different location.[36] The person who excavates the cover soil is assumed to spend each work day at the site until a portion of the cover is removed, thus exposing a portion of the residual radioactivity. This scenario is unlikely because of the difficulty in removing the cover and the limited access for heavy equipment to support such an excavation.

Pathways Included in the Cover Excavation Scenario

RESRAD identifies the potential pathways for exposure to the critical group. Three (3) pathways are used for the excavation scenario, including:

- direct radiation exposure;
- particulate inhalation; and
- direct ingestion.

The other pathways are inapplicable and are turned off for the purpose of the RESRAD model. Table 5.14 identifies the pathways that have been retained for the analysis and provides explanation for those pathways that were not retained. Table 5.15 describes the specific parameters that were used in the RESRAD model; this table lists the parameters specifically used in the model for the excavation scenario.[37] Table 5.9 describes the parameters use in the RESRAD model that depict the physical parameters of the cover, slag and the subsurface conditions; these parameters are common to each of the scenarios used in this chapter.

Description of the Parameters Used in the Analysis

The excavation scenario involves relatively conservative exposure factors attributable to a person who may attempt to excavate the cover and reuse the soil for other purposes, away form the site. It is assumed that the person uses heavy equipment to excavate soil for ninety (90) days; it is assumed that each work day is eight (8) hours long. Key parameters used to define the excavation exposure scenario are presented in a series of three tables along with specific remarks explaining

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[36] It assumed that the cover may be excavated after institutional controls fail and that there is no maintenance or inspection of the cover over time. It is assumed that the cover construction materials have intrinsic value and may be used at a different location for landscaping or fill at a different location.

[37] A comprehensive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for each scenario is provided in the RESRAD output files (reports) in appendices ___ through ___.

the values' selection. Table 5.15 contains common parameters describing the receptor's exposure and behavioral patterns (e.g., exposure time, inhalation rate, etc.) as well as common parameters describing the general and weather-related parameters relevant to the site. Table 5.9 contains parameters specific to the Storage Yard and the slag, covered by the engineered cap (i.e., geotechnical parameters and parameters describing the source term itself).

### *5.3.2.4 Industrial Worker Scenario*

Description of the Critical Group

SMC anticipates that industrial operations will be located on the property adjacent to the fenced Storage Yard. For the purposes of this scenario, it is assumed that industrial workers travel to the site to work each day; it is assumed that there are no controls in place and there is no prohibitions to enter the area. Workers may walk on the cap over the Storage Yard. It is assumed that the industrial worker will work immediately adjacent to the Storage Yard even though it is not likely that the industrial operations will be located there. It is also assumed that the industrial worker will work at the industrial site five (5) days per week for fifty (50) weeks per year, and that the work day will last for eight (8) hours per day.

Pathways included in the Industrial Worker Scenario

RESRAD identifies the potential pathways for exposure to the critical group. Three (3) pathways are used for the industrial worker scenario, including:

- direct radiation exposure;
- direct ingestion; and
- particulate inhalation.

Table 5.10 identifies the pathways that have been retained for the analysis and provides explanation for those pathways that were not retained. The other pathways are inapplicable and are turned off for the purpose of the RESRAD model. Table 5.11 describes the specific parameters that were used in the RESRAD model; this table lists the parameters specifically used in the model for the industrial worker.[38] Table 5.9 describes the parameters use in the RESRAD model that depict the physical parameters of the cover, slag and the subsurface conditions; these parameters are common to each of the scenarios used in this chapter.

Description of the Parameters Used in the Analysis

It is assumed that the industrial worker does not spend anytime indoors. The outdoor fraction, 0.23, is derived by dividing the 2,000 hours per year by the total number of hours in a year, 8,760 hours.

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[38] A comprehensive list of the input parameters used in the execution of the RESRAD dose modeling code to evaluate the potential future radiation dose for each scenario is provided in the RESRAD output files (reports) in appendices ___ through ___.

The inhalation rate for the industrial worker is assumed to be a short term exposure for adult males averaging 8,400 cubic meters per year. The industrial worker may enter the Storage Yard and it is assumed that he may ingest soil from the Storage Yard. In addition, the worker does not eat any animals or vegetables from the Storage Yard, and drinking water is provided by a publicly-owned water system where there is testing for compliance with drinking water standards for radionuclides since there are no surface water sources or ground water wells inside of the Storage Yard. However, because failure of institutional controls means cover maintenance may cease, the cover does erode.

## *5.4 Uncertainty Analysis*

### *5.4.1 Managing Uncertainty*

There is an inherent uncertainty in any projection of a future condition. Thus, tools were developed to model or project a future condition and to understand the uncertainty associated with such projections. In the past, dose assessments in support of USNRC decommissioning requirements relied primarily on the use of deterministic (single point estimate) analyses. The deterministic approach has the advantage of being simple to implement and easy to communicate to a non-specialist audience. However, it has a significant drawback in not allowing consideration of the combined effects of uncertainty in input parameters. It also fails to provide information on the degree of uncertainty in the model results, which would be helpful to the decision maker. To overcome these weaknesses and to ensure that a deterministic analysis had a high probability of erring conservatively, it was common practice to rely on the use of worst-case (grossly conservative) estimates of each parameter of the model, typically leading to overly conservative evaluations and unnecessarily restrictive release criteria.

The alternative to the deterministic approach is the probabilistic approach in which the overall uncertainty in the assessment is evaluated to arrive at a better estimate of the correspondence between residual radioactive concentration and the extent of incremental dose to an exposed receptor. Uncertainty analysis imparts more information to the decision maker than deterministic analysis. It characterizes a range of potential doses and the likelihood that a particular dose would be exceeded.

Regardless of the method, uncertainty is inherent in all dose and risk assessment calculations and should be considered in determining whether a selected release criteria will satisfy the regulatory decision-making criteria. In general, there are three primary sources of uncertainty in a dose/risk assessment:[39]

[39] Bonano, E.J, Davis, P.A., *A Review of Uncertainties Relevant in Performance Assessment of High Level Radioactive Waste Repositories*, NUREG/CR-5211, September, 1988.

- Uncertainty in the models;
- Uncertainty in scenarios; and
- Uncertainty in the parameters.

Models are simplifications of reality and, in general, several alternative models may be consistent with available data. Computer modeling codes have permitted the analyst to increasingly refine the models they use because the computer is handling the complex calculations that result. The RESRAD dose modeling code used in this evaluation has been developed and maintained using a stringent version control process. The models (or components of them) are tested for mathematical correctness, verified, and benchmarked against comparable models, when available. Modeling in and of itself implies a degree of uncertainty in that direct measurements or standards are typically not available to compare to modeled results. It is in such cases that risk managers resort to models. Perhaps the most important factor in building confidence in the predictions of a model is selecting the model that most closely approximates the scenario to be evaluated.

Uncertainty in scenarios is the result of our lack of absolute knowledge about the future uses of the site. It is important to recognize that the outlook evaluation time criterion (1,000 years) is not intended to predict future scenarios for the next 1,000 years, but to evaluate the continued protectiveness of a given release criterion for 1,000 years into the future given the reasonable and plausible future uses of the site in today's social and economic conditions.

Parameter uncertainty results from incomplete knowledge of the coefficients that describe the model. However, with the selection of a suitable model for the site conditions and scenarios to be considered, and configuring the model with realistic and most probable input parameters, one may be reasonably confident in the model's predictions.

The current regulatory philosophy is to evaluate the uncertainty in an estimate along with the severity of consequence and probability of exceeding a deterministic regulatory limit. Such a decision method is termed "risk-informed decision making." The advent of powerful personal computers and increasingly capable software tools coupled with increased knowledge of key physical, behavioral, and metabolic parameters used to make dose/risk assessments, have brought probabilistic analysis to the state of the art. While not all regulating agencies currently expect that assessments will employ the probabilistic approach, with a quantitative assessment of the associated uncertainties, the USNRC has adopted a risk-informed approach to regulatory decision making, suggesting that an assessment of uncertainty be included in dose assessments.[40] The USNRC's Probabilistic Risk Assessment (PRA) Policy Statement states, in part,

> *The use of PRA technology should be increased in all regulatory matters to the extent supported by the state of the art in PRA methods and data, and in a manner that complements the USNRC's deterministic approach.*[41]

Even with the use of probabilistic analyses, it should be recognized that not all sources of uncertainty could be, or need to be, considered in a dose assessment. The primary emphasis in uncertainty analysis is to identify the important assumptions and parameter values that, when altered, could change the decision.

Sensitivity analysis performed in conjunction with the uncertainty analysis is used to identify parameters and assumptions that have the largest effect on the overall result and provides a tool for understanding and explaining the influence of these key assumptions and parameter values on the variability of the estimated dose.

### 5.4.2 How Sources of Uncertainty are Addressed

As mentioned above, an important issue in uncertainty and sensitivity analysis is that not all sources of uncertainty can be easily quantified. Of the three primary sources of uncertainty in dose assessment analyses, parameter uncertainty analysis is most mature and will be dealt with quantitatively in this section.

However, mathematical approaches for quantifying the uncertainty in the site conceptual models and future use scenarios are not well developed. For example, it is difficult to predict with absolute certainty the characteristics of a future society. For these reasons, no attempt to formally quantify model or scenario uncertainty is made.

To confront these uncertainties a suite of scenarios capturing the plausible range of future uses for this site, given the nature and site-specific impediments to future land development, has been developed and is considered in the assessment. In addition, conceptual site models have been designed and selected to represent the existing features at the site and to conservatively represent the conditions that might be encountered in each scenario. In reality, the uncertainties in the

[40] NUREG-1757, September, 2003.

[41] U.S. Nuclear Regulatory Commission, *Probabilistic Risk Assessment Policy Statement*, Commission Policy Statement, August, 1995.

conceptual site model and the scenario selections are captured, to a certain extent, in the parameter uncertainty analysis.

### *5.4.3 Uncertainty Evaluation*

SMC has selected the most current version of the RESRAD dose modeling code (version 6.22, February, 2004) to evaluate uncertainty in accordance with USNRC guidance.[42] It contains a probabilistic module that is used to assess the uncertainty in the relationship between a concentration of radioactivity in soil and the dose it might produce. It uses an enhanced random sampling algorithm called Latin Hypercube sampling in which input parameter values are selected randomly from probability distribution functions (PDF).

The uncertainty module in the code permits the analyst to define the PDF for each variable of interest by selecting the distribution and its parameters, and to identify the parameter as either independent or correlated to other input variables. The following describes the process used to evaluate uncertainty:

- Each scenario was evaluated using the deterministic module to identify a concentration in soil corresponding to the deterministic regulatory limits. Additionally, coarse scale sensitivity analysis was performed to zero in on the parameters that had the greatest potential to impact the dose.

- Pathways of interest were identified through preliminary runs of the deterministic module in the code for all the scenarios. These identified the scenario specific pathways that most significantly contributed to dose. The direct exposure pathway, or "ground" pathway was consistently the dominant pathway for exposure to the source term, and by a significant margin.

- Where site-specific knowledge was lacking, where the dose response was not sensitive to variability in a given parameter, or where the default parameter distributions were reasonably representative of site conditions or conditions being portrayed in the exposure scenario, the default was used. Where no default distribution is recommended or where discrete knowledge of site-specific conditions exists, an appropriate distribution considering the degree of knowledge of site-specific conditions was selected.

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[42] NUREG-1757, September, 2003.

- The Latin-Hypercube sampling algorithm (a variant of the Monte Carlo sampling technique which has an advantage in that it forces the sampling to occur over the entire range of possible values in the PDF rather than rely on pure random sampling) was set to obtain 1,500 samples (300 samples, repeated five times).

Parameters to which probability density functions were assigned in order to evaluate their impact on uncertainty are listed in the following subsections. They are organized such that the receptor exposure parameters are presented first, followed by the geotechnical parameters describing the various soil layers starting with the cover and concluding with the contaminated zone.

### *5.4.3.1 Exposure Factors*

Outdoor Time Fraction

RESRAD uses fractions of a whole year spent on site to calculate annual dose to a receptor. The total fraction of a year spent on site is divided between two parameters: indoor time fraction (FIND) and outdoor time fraction (FOTD). Fractions of time spent on site are wholly dependent upon the scenario under consideration. The value used to describe the on site, outdoor time fraction for each of the use scenarios is derived from conservative assumptions attributed to members of the critical exposure group and designed to be conservative for the general population of potentially exposed individuals.

Sensitivity analysis indicates that total annual dose is sensitive to variability in the FOTD parameter as the penetrating gamma (ground) exposure pathway dominates and is strongly dependent on exposure duration. In setting up the uncertainty analysis, the FOTD parameter is represented with a triangular distribution.

Inhalation Rate

Inhalation rate (INHALR) is the air volume inhaled over time and is used to calculate the radiation dose from the inhalation pathway.[43] The parameter represents the annual average breathing rate for a receptor from the critical exposure group subpopulation performing tasks under evaluation in a given scenario.

Population normalized inhalation rates vary depending upon the tasks that are being performed. For the land user, the inhalation rate used is the RESRAD default, which is derived from ICRP and EPA

[43] The air volume is measured in cubic meters of air per year.

recommendations for adults engaged in short-term (episodic) exposure scenarios.[44,45,46] Sensitivity analysis shows that the total annual dose is not sensitive to this parameter, because the inhalation pathway is not a significant contributor to total annual dose. Inhalation rate is represented with a triangular distribution, using the default provided by RESRAD.

Contaminated Fraction of Meat Diet

The meat ingestion pathway is unique to the recreational hunter scenario. Evaluation of the potential dose from this pathway considers both the annual consumption of meat and poultry, DIET(4) (using the RESRAD default value of 63 kilograms per year), and the fraction of that annual meat diet that is potentially impacted with residual radioactivity from the site (FMEAT). A triangular distribution was selected to represent the range and variability in the fraction of the receptor's meat diet that might have been culled from among game animals that grazed on the site. The mode of the distribution (the most likely value) was selected based upon the typical dressed weight of a white-tail deer (40 pounds or 19 kilograms), the most abundant game species in the area.[47] The contaminated fraction is estimated to range between 0 (no game meat harvested) and 0.5 (half of the entire annual meat diet consumed is derived from game grazed on the SMC site). The fraction modeled is conservative in that the size of the site is small relative to the grazing land required to support game habitat. Sensitivity analysis shows that the total annual dose is not sensitive to this parameter, because the meat ingestion pathway is not a significant contributor to total annual dose for the undisturbed surface soil source terms.

Mass Loading for Inhalation

Mass loading for inhalation (MLINH) is the soil/air concentration ratio. It is used to calculate the dose from the particle inhalation pathway. The parameter represents the dust (mass) loading on site conservatively assuming that all airborne dust is generated on Site and is radioactive. Other parameters, derived by the RESRAD code and based upon the site-specific parameters input, are used to modify this assumption, as appropriate. Mass loading does vary from season to season and depends upon the activities that are being performed at the Site. The RESRAD default continuous

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[44] ICRP Report 23, 1981.

[45] U.S. Environmental Protection Agency, *Development of Statistical Distributions or Ranges of Standard Factors used in Exposure Assessments*, EPA 600/8-85-010, 1985.

[46] U.S. Environmental Protection Agency, *Exposure Factors Handbook, Volume I, General Factors*, EPA 600/P-95-002Fa, August, 1997.

[47] RESRAD, ANL/EAD-4, July, 2001.

liner distribution and fit with a central tendency value of 0.00003 g/m$^3$ (30 micrograms/m$^3$) and ranging up to 100 micrograms/m$^3$ are used for each of the scenarios evaluated. The use of the RESRAD default is conservative as PM10 monitoring in the area indicates annual average dust loading to be approximately ___ micrograms/m$^3$, which is ____ of those used in the default. **insert results of air modeling once complete** Sensitivity analysis shows that the inhalation pathway and total annual dose are insensitive to this parameter when the radioactivity is effectively isolated from the receptor by the in-place cover material. However, under the cover excavation scenario, such isolation will not exist.

Soil Ingestion Rate

RESRAD uses the annual average soil ingestion rate (SOIL) to calculate the dose from the direct soil ingestion pathway. The soil ingestion rate used in deriving the soil release criteria for the site is represented by a triangular distribution centered at 18.3 g/yr (50 mg/d) and ranging from 0 to 36.5 g/yr (0 to 100 mg/d), the RESRAD default. Sensitivity analysis again shows that neither the soil ingestion pathway nor the annual effective dose equivalent is sensitive to this parameter because the radioactivity is effectively isolated from the receptor by the in place cover material. However, under the cover excavation scenario, such isolation will not exist.

### *5.4.3.2 Geophysical Parameters for the Cover*

Evapotranspiration Coefficient

The evapotranspiration coefficient (EVAPTR) is the fraction of total precipitation that is released back to the atmosphere via plant "respiration." Evapotranspiration varies with geographic region and to some extent with soil type. Evapotranspiration rates in the Newfield region are estimated to be approximately ___ inches per year, corresponding to a most likely evapotranspiration coefficient of approximately ___ (average annual precipitation in the region is ___ inches).[48,49]

The evapotranspiration coefficient is conservatively represented with a uniform distribution ranging between 0.5 and 0.75 (the RESRAD default). Sensitivity analysis showed that annual dose is insensitive to values of evapotranspiration coefficient over the entire RESRAD default range.

Wind Speed

Average annual wind speed is used to calculate the dose from the inhalation pathway. The wind speed is used to transport airborne dust generated on site in a standard air dispersion model.

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[48] Yu, C, et al, *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil*, ANL/EAIS-8, Argonne National Laboratory, Argonne, Illinois, April, 1993.

[49] ______. National Climatological Data Center, Wind speed, Precipitation, _____.

Through the transport calculations, the radioactive fraction of the total dust loading in air is derived. The fraction is then used to calculate particle inhalation intake.

While wind speeds do vary from day-to-day and season-to-season, the annual average wind speed is reasonably steadfast. Data from the National Climate Data Center from Philadelphia, Pennsylvania were reviewed from 1961 through 1990. The mean annual wind speed was reported to be 9.6 miles per hour (4.3 meters/sec). Sensitivity analysis shows that the inhalation pathway is insensitive to this parameter because, the residual radioactivity is effectively isolated by the covering layer such that radioactive particle suspension is minor. As a result, the inhalation pathway is not a significant contributor to total annual dose. Wind speed is represented with the RESRAD default (4.25 m/sec), bounded lognormal-N distribution.

Runoff Coefficient

The runoff coefficient is one of a number of parameters used to calculate radionuclide leaching from the contaminated zone. It is the fraction of precipitation that does not penetrate the top soil layer. The runoff coefficient (RUNOFF) varies with topography, amount of pavement, precipitation patterns in the region, and soil type.

Runoff coefficient is represented with the RESRAD default parameter distribution, a uniform distribution ranging between 0.1 and 0.8 (10% to 80% of precipitation runs off without penetrating the surface). Considering the mounded topography of the site and the presence of the engineered soil cover over the cell, the true range is likely to be much narrower and near the maximum value (80%) considered in the probability distribution. For the purposes of conservatism, the RESRAD default (0.45) was used in the code. Sensitivity analysis showed that annual dose is insensitive to values of runoff coefficient over the entire range of plausible values.

Depth of Soil Mixing Layer

This parameter (DM) is used in calculating the depth factor for the dust inhalation and soil ingestion pathways and for foliar deposition for the ingestion pathways. The depth factor is the fraction of resuspendable soil particles at the ground surface that are contaminated, which is calculated by assuming that mixing of the soil will occur within a layer of thickness, DM, at the surface. The RESRAD default distribution (triangular) and range (0 to 0.6 m) was used.

Cover Depth (Thickness)

When modeling the source term, the cover depth (thickness) is a key parameter in assessing the protectiveness of the chosen decommissioning alternative as it provides a barrier to potential physical contact with residual radioactivity in the slag materials located within the cell, and a substantial degree of gamma radiation attenuation for the penetrating gamma radiation exposure pathway, the dominant, or critical dose pathway. RESRAD does not suggest a default probability distribution for cover depth (COVERO) as it is highly dependant upon site-specific conditions and for many sites does not exist at all. Thus SMC has conservatively chosen to represent this parameter with a triangular distribution ranging between ___ and ___ meters thick and with a most likely value of ___ meters (___ ft.). This representation is conservative in that the thickness value used does not include the topsoil layer to support natural succession vegetation as an erosion control mechanism. Sensitivity analysis reveals that the "cover penetrating gamma radiation dose" pathway, and as a result the total annual effective dose equivalent, is sensitive to this parameter.

Cover Soil Density

The engineered cover is comprised of ___. The soil density at the site was measured to arrive at a site-specific estimate of the soil density of both the cover material and the undisturbed surface layer. The measured soil density was found to be ___ g/cm$^3$. Sensitivity analysis showed that annual dose was insensitive to a wide range of soil densities. Since site-specific data was available for the materials at the site, these were used to describe the density of the cover soil layer. Cover soil density (DENSCV) was represented with a truncated normal distribution (the RESRAD default). The Mean was set equal to the measured density of ___ g/cm$^3$ and allowed to range between approximately ___ and ___ g/cm$^3$.

Surface Soil Erosion Rate

**insert summary of TRC report and site the specific variables used in this section**

When modeling the surface soil source term, no cover layer is assumed. Thus, the surface soil is the surface soil contaminated zone and the surface soil erosion rate is captured in the RESRAD model as the contaminated zone erosion rate (VCZ). In recognition of the relatively flat topographic features present at the site, the general meteorological signature for the area, and the non-invasive nature of the future use scenarios, all of which argue for lower than average soil erosion potentials, the contaminated zone erosion rate was conservatively modeled with a deterministic value (___ m/yr) over 300 times slower than the RESRAD default value.[50] Annual dose is not particularly sensitive to this parameter since the peak annual dose occurs in the first year after deposition, and decreases each year thereafter, regardless of the surface soil erosion rate used.

When modeling the source term, the conceptual site model includes a relatively thick cover layer that is engineered to resist the forces of erosion. In this case, the surface soil layer is the engineered cover layer and the surface soil erosion rate is captured in two important parameters within the RESRAD model. The cover layer erosion rate (VCV) is important because as cover erosion occurs,

[50] This may not be true as described for the excavation scenario, where some of the radioactive materials could be exposed.

the underlying contaminated zone is exposed, increasing the potential for human exposure to radiation.[51] Once the cover layer has been eroded, RESRAD further accounts for the effect of surface soil erosion through the contaminated zone erosion rate parameter (VCZ).

Sensitivity analysis shows that all pathways are sensitive to this parameter when represented with chronic and extreme erosion values such as those that might be observed in arid desert climates or where continual loosening of the surface soils occurs, such as might be expected for land used for agricultural purposes. In every scenario, the greatest annual dose occurs in the out years (year 1,000) when the cumulative effect of long-term soil erosion impacts the thickness of the cover layer and thus its attenuating affect.

The cover erosion rate (VCV) has been conservatively estimated with a range of possible values to represent the likely and extreme erosion rates typical for conditions and activities expected at the site. Surface soil erosion is represented with a continuous logarithmic distribution (the RESRAD default) and ranging over approximately two decades from ___ to ___ m/yr. The most probable range for a site in a humid climate, with a slope of approximately ___ percent, and natural succession vegetation extends from ___ to ___ m/yr. Extreme surface soil erosion potential has been accounted for by estimating that there is as much as a 50% probability that the soil erosion rate will exceed this range, with estimates ranging to ___ m/yr (the predicted maximum for sites used for permanent pasture).

<u>Weathering Removal Constant</u>
The weathering removal constant is used to account for the natural removal of soil and dust that have been deposited on consumable plants. It is relevant only for the recreational user scenarios (scenarios in which the consumption of plants by game animals is considered). Sensitivity analysis showed that annual dose was insensitive to the weathering removal constant (WLAM), thus the RESRAD default distribution (triangular) and range were used when modeling the source term. The RESRAD deterministic default (20/yr) is used when modeling the surface soil source term.

### *5.4.3.3 Geophysical Parameters for Sub-cover Zones*

<u>Area of Contaminated Zone</u>
The area of the contaminated zone (AREA) describes the areal size, in square meters, of the region in which elevated concentrations of residual radioactivity are located. As described in Section ___,

[51] It is important to note that once the cover soil is eroded, the underlying contaminated zone will not be immediately exposed due to the presence of the geomembrane. And if jsut a small area of geomembrane were to be exposed, it is unlikely that the protective nature of the geomembrane would be degrated or compromised or a very long time.. However, if a larger area of geomembrane was exposed, it is possible that an edge of the geomembrane could come loose thus exposing the underlying contaminated zone.

the areas describing the source terms are related to one another but they are not necessarily equal to one another. In defining the probability density function for the AREA parameter when modeling the source term, it was conservatively assumed that the contaminated zone area is no smaller than the ___ $m^2$ estimate derived from characterization survey data, but might be as large as the entire area circumscribed by the slag pile ___ $m^2$. RESRAD does not offer a default distribution for this parameter. A loguniform distribution ranging from the most likely value, ___ $m^2$, to a maximum value of ___ $m^2$ was selected to represent the area of the contaminated zone within the probabilistic module of RESRAD. Sensitivity analysis showed that annual dose was insensitive to the area of the contaminated zone.

Contaminated Zone Thickness

Thickness of the contaminated zone (THICKO) describes the depth profile of the residual radioactivity. Vertically, the radiologically significant material associated with the source term is located just beneath the cover (approximately ___ feet below the ground surface) and lies in a lens that is nominally about ___ feet (___ meters) thick (Figure ___). The amount of source material deposited rapidly depletes as the depth increases and terminates at a maximum thickness of approximately 30 feet. RESRAD does not offer a recommended (or default) distribution for the thickness of contaminated zone parameter (THICKO).

A lognormal-N distribution best describes the observed variability in the depth profile for the source term and thus the thickness of the contaminated zone. In describing the source term for input to RESRAD, the thickness parameter is represented by a bounded lognormal-N distribution, with the central tendency (CT) value conservatively set to a thickness of ___ feet (___ meters). This thickness is conservative in that the mean source thickness over the entire footprint of the cell, the impacted area, is considerably less than ___ feet. The distribution is bounded at a minimum value of 0 feet (0 meters), and a maximum value of ___ feet (___ meters). Sensitivity analysis showed that annual dose was insensitive to the thickness of the contaminated zone. This is the result of the self-attenuating effect of source thicknesses greater than approximately 12 inches (0.3 meters) coupled with the attenuating capacity of the engineered cover.

Contaminated Zone Density

The density of the slag, baghouse dust, soil and surface-contaminated building rubble is ___, ___, ___ and ___, respectively, with a volumetrically-normalized density of ____. It is conservatively assumed that the contaminated zone has a soil density (and other hydrogeologic soil properties) equal to that of the native sand materials at the site. The measured sandy soil density was found to be 1.68 g/cm3, a number typical of sandy soils. Sensitivity analysis showed that annual dose was insensitive to a wide range of soil densities. The contaminated zone density (DENSCZ) was represented with a truncated normal distribution (the RESRAD default). The mean was set equal to the measured density of sandy materials at the site (___ g/cm3) and allowed to range between approximately ____ and ____ g/cm3. Figure 5-29 graphically illustrates the distribution from which values of the contaminated zone density were sampled.

Contaminated Zone Hydraulic Conductivity
RESRAD uses vertical hydraulic conductivity to model the potential vertical movement of water through the contaminated layer and any underlying strata. Hydraulic conductivity is a key parameter used to assess the downward vertical migration potential of radioactivity released from the contaminated zone layer. This allows RESRAD to calculate the potential concentration of residual radioactivity in a useable subsurface saturated zone. Sensitivity analysis showed that annual dose is insensitive to a wide range of hydraulic conductivities in the contaminated zone, largely because the thorium and other radionuclides in the contaminated zone are physically and chemically bound up in the slag and because the slag is very insoluble.

Hydraulic conductivity in the residual radioactivity layer is described with a probabilistic distribution. Hydraulic conductivity was specifically measured for the native sand materials found at the site and was determined to be 6.4 x $10^{-3}$ cm/s (2000 m/yr). Hydraulic conductivity in the contaminated zone (HCCZ) and the underlying unsaturated zone 1 (HCUZ(I)) is represented with bounded lognormal-N distributions (the RESRAD default) having central tendency values at 2,000 meters per year and with values conservatively ranging over two decades between 200 and 20,000 meters per year

Soil Specific b-Parameter
The soil-specific exponential b-parameter is one of several hydrogeologic parameters used to calculate radionuclide transport from the contaminated zone. Sensitivity analysis showed that annual dose was insensitive to both the contaminated zone and saturated zone b-parameters (BCZ and BSZ, respectively), thus, the RESRAD default distribution (bounded lognormal-N) and parameters were used when modeling the source term.

Distribution Coefficient, Contaminated Zone
Distribution coefficients ($K_d$) describe the partitioning between solid (soil) and liquid phases of soluble concentrations of radionuclides introduced to a soil column. It is a key parameter influencing the migration of radioactivity from contaminated zone soils to groundwater. Distribution coefficients for a given chemical species (e.g., uranium) can vary over many orders of magnitude depending on the soil type, pH, redox potential, and presence of other ions. Observed $K_d$ values for thorium are somewhat less subject to extreme variability.

The distribution coefficient, $K_d$, is the ratio of the mass of solute species adsorbed or precipitated on the solids per unit of dry mass of the soil to the solute concentration in liquids within the pore spaces in the soil. The key component of this definition as it relates to the site-specific conditions at the site and the RESRAD groundwater transport model is that it assumes that the radionuclide is introduced to the soil column as a solute. While this classical approach may be appropriate to describe the retardation of soluble contaminant migration in the soil column beneath the contaminated soil layer, it fails to address the situation encountered for the so-called "contaminated zone."

The site specific condition encountered at the SMC site is that the physical composition of the contaminant is a vitreous slag that is essentially insoluble even under the most extreme in-situ conditions that might reasonably be encountered. Analysis of the distribution coefficient of the slag, where the greatest radionuclide concentration will reside within the capped pile, results in the values shown in Table ____. These are the parameters used as input to the RESRAD code. Bounds have been established on the range of values sampled during probabilistic analysis (a bounded lognormal-N distribution). The central tendency value for the distribution has been set to match the default, single-point estimate used in the RESRAD deterministic module, ____ $cm^3/g$.[52] Probabilistic sampling is bounded between ____ and ____ $cm^3/g$, the lowest and highest geometric mean values for various soils as reported in literature and summarized in the "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil".[53]

Thickness of the Undisturbed Surface Layer

The thickness of the undisturbed surface layer (unsaturated layer #2 [H(2)] when modeling the source term, and unsaturated layer #3 [H(3)] when modeling the surface soil source term) varies from eight (8) to 10 feet in the Storage Yard. Sensitivity analysis showed that annual dose equivalent was insensitive to variability in the thickness of the undisturbed surface layer. The thickness is represented with a bounded lognormal-N distribution (the RESRAD default), with a most likely value (____ meters) near the lower end of the range that extends from ____ to ____ meters.

Density, Undisturbed Surface Layer

As described earlier, the unsaturated zone is comprised of the undisturbed layer underlying the entire area. The measured soil density was found to be ___ $g/cm^3$, a number that is typical of soils. Sensitivity analysis showed that annual dose was insensitive to a wide range of soil densities. Since site-specific data was available for the density of the materials at the site, it was used to describe the density of the undisturbed layer. Unsaturated layer soil density (DENSUZ(1)) was represented with a truncated normal distribution (the RESRAD default). The Mean was set equal to the measured

[52] Yu,C., et al, ANL/EAIS-8, April, 1993.

[53] Yu,C., et al, ANL/EAIS-8, April, 1993.

density of ___ $g/cm^3$ and allowed to range between approximately ___ and ___ $g/cm^3$. This is the same distribution used to represent the soil density of the engineered cover and is presented in Figure 5-21.

Hydraulic Conductivity, Undisturbed Surface Layer

Hydraulic conductivity was specifically measured for the native materials found at the site and was determined to be ___ cm/s (___ m/yr).[54] Hydraulic conductivity in undisturbed layer [HCUZ(1)] is represented with a bounded lognormal-N distribution (the RESRAD default) having a central tendency value at ____ meters per year and with values conservatively ranging over two decades between ___ and ___ centimeters per year. Sensitivity analysis showed that annual dose was insensitive to a wide range of hydraulic conductivities, largely because the radionuclides in the contaminated zone are physically and chemically bound up in the slag and because the slag itself is not readily soluble.

Density, Saturated Zone

The RESRAD default distribution and fit for the saturated zone density is used in the uncertainty analysis because no site-specific data was collected explicitly for this parameter. The truncated normal distribution is centered at the most likely value of 1.52 $g/cm^3$ and ranges between values of less than 1 and 2.2 g/cm3. Variability in the saturated zone soil density was shown to have no affect on the projected annual dose in the uncertainty analysis.

Hydraulic Conductivity, Saturated Zone

The saturated zone hydraulic conductivity (HCSZ) for the site is ______.[55] The bounded lognormal-N distribution is centered at the most likely value of 16,000 m/yr (for the Cohansey Sand) and ranges over more than five decades of possible values between approximately ___ cm/yr and more than ___ m/yr.[56] Variability in the saturated zone hydraulic conductivity was shown to have no measurable impact on the projected annual dose in the uncertainty analysis.

Saturated Zone Hydraulic Gradient

The hydraulic gradient is one of several hydrogeologic parameters used to calculate radionuclide transport from the contaminated zone. Sensitivity analysis, again, showed that annual dose was insensitive to the hydraulic gradient parameter (HGWT). A site-specific value of ____ is used when

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[54] TRC Remedial Investigation Technical Report, _____ April, 1995.

[55] TRC Remedial Investigation Technical Report, _____ April, 1995, pg. 48.

[56] TRC Environmental Consultants, *Remedial Investigation Technical Report*, Report No. ____, April, 1995, pg. 48.

modeling the source term. The central tendency value is estimated to be 0.004 (for the Cohansey Sand) and the distribution is allowed to range over approximately 4 decades from ___ to ___.[57]

Saturated Zone Thickness

When modeling the surface soil source term, the RESRAD default deterministic value was used. The depth to the Kirkwood Formation clays in the Storage Yard area varies from approximately 121 to 144 feet below the ground surface. Subtracting the depth of the unsaturated zone (about eight to 10 feet), the average thickness of the saturated zone in the Storage Yard area would range from about 110 to 135 feet, with 130 to 135 feet being a more typical range for boring locations closest to the storage yard.

### *5.4.4 Interpreting Uncertainty Analysis Results*

Since the results of the uncertainty analyses provide a distribution of annual doses, it must be recognized that some percentage of the calculated doses may exceed the regulatory limit. At the same time, because not all parameter distributions are symmetrical and because some parameters are correlated, the mean dose calculated in the uncertainty analysis is not necessarily equal to a deterministic dose calculated using single point estimates of the various parameters. A further phenomenon observed in the probabilistic modeling is that the mean dose for a particular series of repetitions is frequently higher than the 90th or even the 95th percentile estimates of probable dose. This results when all but the rarest combinations of very conservative estimates of the individual parameters result in little or no dose. In the very few cases in which the Monte Carlo sampling technique selects combinations of values from the outermost extremes of the proposed parameter distributions, projected annual dose is large compared to the majority of cases sampled.

A key issue that must be addressed in the treatment of uncertainty is specifying how to interpret the results from an uncertainty analysis in the context of the deterministic regulatory limit. There is no such thing as absolute assurance that the regulatory limit will be met, so regulatory compliance must be stated in terms of a metric of the distribution. Even for a deterministic analysis, it should be recognized that the reported dose is simply one of a range of possible doses that could be calculated for the Site and scenario. In this analysis, the peak of the mean dose for the critical exposure group (the most exposed subpopulation) is presented for comparison with the deterministic regulatory limit as required by regulation. Since the severely skewed cumulative distribution phenomenon occurs repeatedly in the annual dose modeled for the Newfield site using the probabilistic approach, a suite of projected annual doses corresponding to the 50th, 90th, 95th, and maximum is reported along with the traditional compliance measure, peak mean annual dose. In addition, the deterministic estimate of projected annual dose is provided for comparison.

[57] TRC Environmental Consultants, *Remedial Investigation Technical Report*, Report No. ____, April, 1995, pg. 49.

The parameters used to perform the assessment were selected to represent the critical exposure group (analogous to the Reasonable Maximum Exposure concept), and as such already overstate the expected dose to the average receptor at the Site. Results of both the deterministic and probabilistic dose modeling including an evaluation of the uncertainty analyses are presented in sections that follow.

## 5.5 Results

The RESRAD code was iteratively run for each of the selected scenarios to arrive at the highest uniform concentration of residual radioactivity in soil that results in a peak mean annual dose estimate to a single receptor in the critical exposure group that is equal to the regulatory limit (100 mrem/yr).

The computer code was set up to model each scenario with the input parameters identified and explained in this section. A separate set of soil release criteria are presented for each scenario and for each source term.

** Introduce the DCGLs for the remainder of the site (outside of the restricted area) here, once determined.***

The following subsections present the results of the dose modeling, relating residual radiouclide concentration with potential future doses in each of the four scenarios evaluated.

***The preponderance of this section will be completed after all of the dose modeling is performed. From the RESRAD summary reports we will be able to summarize key isotopes, associated radiation doses, key pathways and error bars.***

### 5.5.1 Maintenance Worker Scenario (Controls in Place)

description of the scenario
why is it likely to be encountered
summary of the dominat source of future exposure
% dose by isotope
% dose by pathway
refer to table XX

### 5.5.2 Industrial Worker Scenario (Controls In Place)

description of the scenario
why is it likely to be encountered
summary of the dominat source of future exposure
% dose by isotope

% dose by pathway
refer to table XX

### *5.5.3 Trespasser Scenario (Controls In Place)*

description of the scenario
why is it likely to be encountered
summary of the dominat source of future exposure
% dose by isotope
% dose by pathway

refer to table XX

### *5.5.4 Recreational Hunter Scenario (Controls Failed)*

The recreational hunter scenario is considered, perhaps, to be the most likely among the future use scenarios considered for this site. Whereas the variety of persons who engage in recreational hunting on the site might spend little time actually on the site, the critical exposure group receptor for this scenario is a conservatively assumed to spend a relatively large fraction of his/her available recreational hunting time actually on the site where the greatest exposure potential occurs. This naturally provides a conservative evaluation of the potential future dose for a more typical hunter making use of the site.

Table 5-XX summarizes the results of modeling the projected future exposure potential for the scenario involving exposure while engaged in recreational hunting at the Site. A review of the computer modeling printouts for the recreational hunter scenario (Appendix XX) reveals that exposure from gamma radiation dominates the potential future dose. The $^{232}$Th and $^{228}$Th isotopes are the most significant contributors to total effective annual dose.

% dose by isotope
% dose by pathway

### *5.5.5 Suburban Resident Scenario (Controls Failed)*

description of the scenario
why is it likely to be encountered
summary of the dominat source of future exposure
% dose by isotope
% dose by pathway

refer to table XX

### 5.5.6 Cover Excavation Scenario (Controls Failed)

description of the scenario
why is it likely to be encountered
summary of the dominat source of future exposure
% dose by isotope
% dose by pathway

refer to table XX

## 5.6 Summary of Dose Modeling and Comparison to Release Criteria

The estimates of peak mean dose to the critical exposure groups in each of the foregoing scenarios have been derived with industry standard modeling tools specifically designed to assess exposures to residual radioactivity. The RESRAD modeling code is recognized as an industry standard, and is accepted for use by the USNRC, USDOE, and USEPA for modeling dose and risk to individuals exposed to radioactivity originating in soils.

Conservatism has been built into the modeling by conscientiously selecting exposure factor values that err on the side of safety when confronted with uncertainty in the selection of input parameters. In order to provide the risk managers and decision makers with insight as to the degree of conservatism associated with the dose modeling, projected annual doses have been calculated with both deterministic and probabilistic techniques.

Based on the results presented above, the source term in each of the scenarios considered is projected to produce a peak mean annual dose well below the annual public dose limits identified by the USNRC even when the residual radioactivity concentration is set at the specific activity limit for each isotope.[58] The dose evaluation described in this report provides the substantive basis necessary to set and approve site-specific permissible concentration standards (release criteria) derived from the applicable regulatory limits for public dose.

The projected annual dose arising from the source term is not constrained by the permissible decommissioning dose standard of 25 mrem/yr but rather, the potential annual dose is constrained to a value substantially lower than the decommissioning annual dose limit by virtue of the physically limiting specific activity for the residual radioactivity. That the residual radioactivity concentration in the source term could safely approach the specific activity limit without impacting compliance,

[58] Title 10, Code of Federal Regulations, Part 20, Section 1403, *Criteria for License Termination under Restricted Conditions*, December 31, 2003.

provides the risk managers and decision makers with a clear margin of safety upon which to evaluate public health impacts resulting from exposure to residual radioactivity at the site.

The release criteria are constrained by the permissible decommissioning dose standard of 100 mrem/yr. Additionally, the projected peak annual dose for each scenario has been derived with a level of conservatism commensurate with the extent of the hazard and uncertainty in the estimation tools.