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U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Reference: (a) License No. DPR-3 (Docket No. 50-29)

Subject: Calculations for Contaminated Concrete for the License Termination Plan (LTP)

This letter provides a hardcopy of two calculations in support of the LTP[1] for the Yankee Nuclear Power Station (YNPS). In support of Section 6 of the LTP, the specific calculations provided are:

(1) YA-CALC-00-002-04, "RESRAD 6.21 Sensitivity Analysis and DGCL for Concrete Debris"
(2) YA-CALC-00-003-04, "Assessment of Radionuclide Release from Contaminated Concrete at the Yankee Nuclear Power Station"

YA-CALC-00-002-04 determines the derived concentration guideline levels (DCGLs) for all significant radionuclides for concrete debris. The RESRAD code was used to determine doses based on a resident farmer scenario with consideration also given to a possible future intruder scenario for future use of the Yankee site. Sensitivity analyses were performed to determine those input parameters that have the greatest impact on dose and this information was subsequently utilized in the DCGL determination.

YA-CALC-00-003-04 evaluates the rate of release of residual radioactive contaminants, including H-3, C-14, Co-60, Ni-63, Sr-90, and Cs-137, from subsurface structures and concrete debris placed in these structures and the resulting dose in the groundwater pathway.

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[1] YAEC Letter to USNRC, "Submittal of YNPS License Termination Plan and Proposed Revision to Possession Only License," dated November 24, 2003, BYR 2003-080.

These calculations are provided for your review. If you have any questions, please contact us.

Sincerely,

YANKEE ATOMIC ELECTRIC COMPANY

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Attachments

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Calculation Title Page

Assessment of Radionuclide Release from Intact Structures Backfilled with Contaminated Concrete at the Yankee Nuclear Power Station

Title

YA-CALC-00-003-04

Calculation Number

Approvals		(Print & Sign Name)	
Preparer:	Terry Sullivan	[signature]	Date: 9/1/04
Reviewer:	Eric Darois		Date:
Reviewer:	Alice Carson	[signature]	Date: 9/1/04
Approval(Cognizant Manager):		[signature] for GMB	Date: 9/2/04

Calculation Title Page

Assessment of Radionuclide Release from Intact Structures Backfilled with Contaminated Concrete at the Yankee Nuclear Power Station

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YA-CALC-00-003-04

Calculation Number

Approvals		(Print & Sign Name)	
Preparer:	Terry Sullivan		Date:
Reviewer:	Eric Darois		Date: 9/2/04
Reviewer:	Alice Carson		Date:
Approval(Cognizant Manager):			Date:

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List of Tables

Assessment of Radionuclide Release from Intact Structures Backfilled with Contaminated Concrete at the Yankee Rowe Nuclear Power Station

Purpose

This calculation determines the release of residual radioactivity (including H-3, C-14, Co-60, Ni-63, Sr-90, and Cs-137), from subsurface structures filled with concrete debris at the Yankee Nuclear Power Station. Analyses were performed to assess the rate of release from the source of contamination and the resulting dose in the groundwater pathway.

Summary of Results

Two mechanisms were considered, diffusive release from the concrete structures (walls and floors) that remain intact and sorption onto concrete backfill placed within these structures.

RESRAD was used to calculate the predicted maximum dose assuming a unit loading of 1 pCi/g on the intact structures. To the extent possible, the same assumptions in the soil DCGL calculations performed for Yankee Atomic were used in the calculation. However, modifications to some input parameter values were needed to represent the geometry of the subsurface facilities, flow through these facilities, and releases from the backfill and intact structures. Input parameters specific to these calculations included the leach rate, disposal geometry, pumping rate, porosity and bulk density. The dose results for a unit loading of 1 pCi/g on intact structures showed that Sr-90 had the highest dose (3.67E-02 mrem/yr).

References

[Carson, 2004]
A. Carson, "Basis for Selection of Concrete Kd Values," YA-REPT-01-003-03, August 2004.

[Darman, 2004],
YAEC Internal Communication, J. Darman to AP-0831 File, "IX-Pit Sample Plan Close-Out," January 7, 2004 (also filed as RP 04-008., Darman to Heath, dated March 4, 2004).

[Sullivan, 2004]
Sullivan, T.M., "Assessment of Radionuclide Release from Contaminated Concrete at the Yankee Nuclear Power Station," YA-CALC-00-001-04, March 2004.

[YA 2004]
YA-CALC-01-002-03, "Derived Concentration Guideline Levels for Soil at the Yankee Rowe Site," January 2004.

[Yu, 2001]
Yu, C, A.J. Zielen, J.-J. Cheng, D.J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III,* W.A. Williams, and H. Peterson, Users Manual for RESRAD Version 6, ANL/EAD-4, Argonne National Laboratory, 2001.

Method of Calculation

Yankee Nuclear Power Station (YNPS) is undergoing decontamination and decommissioning (D&D) and, eventually, license termination. As a part of the process, the YAEC is required to demonstrate that any radioactivity that remains at the time of license termination will not cause exposure to exceed the limits stated in Subpart E to 10CFR20.

Yankee Rowe has identified four structures that may remain, in part, and be backfilled with concrete debris resulting from D&D activities or other fill, at the time of license termination:

a. Primary Auxiliary Building (PAB) drain collection tank (PDCT) cubicle
b. PAB gravity drain tank (GDT) cubicle
c. Spent Fuel Pit (SFP)
d. Waste Disposal Building (WDB) cubicle

Because these partial structures and the backfill may contain residual radioactivity, the possible dose attributable to these must be evaluated. A separate calculation addresses the dose from the concrete debris backfill, and, thus, the focus of this study is the dose from the subsurface structures. The resulting dose depends upon the distribution of radionuclides in the remaining material and the mechanisms by which radionuclides in the material migrate into groundwater. This calculation addresses the potential release of radionuclide contamination from subsurface concrete structures and the associated dose.

Body of Calculation

1.0 Introduction

The YNPS is undergoing the process of decontamination and decommissioning (D&D) and license termination. In doing so, a number of concrete structures will be demolished, with the debris potentially used as backfill onsite. Other structures will be partially demolished, with their subsurface foundations left intact. The demolition debris may be used as backfill in these partially intact subsurface structures. Part of the license termination process requires analyses that demonstrate that any radioactivity that remains will not cause exposure to radioactive contaminants to exceed acceptable limits. This requires knowledge of the distribution of radionuclides in the remaining material and their potential release mechanisms from the material to the contacting groundwater.

This study concerns the potential release of radionuclide contamination from the partially intact subsurface structures. A separate calculation assesses the dose from the concrete debris.

1.1 Objective

To determine the potential dose that may result from subsurface contaminated concrete as a function of initial contamination levels in the remaining partial structures for selected radionuclides.

1.2 Approach

YNPS has four subsurface partial structures that may remain and may be backfilled with concrete debris. These partial structures are:

1. Primary Auxiliary Building (PAB) drain collection tank room
2. PAB gravity drain tank room
3. Spent Fuel Pit (SFP)
4. Waste Vault

Release of the contaminants from the facilities will occur through diffusion out of the concrete into the groundwater. Diffusion-controlled release from each of the four facilities was modeled independently using DUST-MS (Sullivan, 2004). The total release from the walls of the subsurface structures will be combined to form a single source to be used by RESRAD. RESRAD will calculate exposure from the various pathways using the resident farmer scenario. The details of this approach are provided in the following sections.

2.0 Subsurface Structures Geometry

To calculate the magnitude of the source, the maximum potential volume of contaminated concrete is needed. Dimensions of the walls for facilities that may be left in situ are in Table 1. To estimate the mass of concrete, the density of concrete is needed.

This value is not known, but a density of 2.5 g/cm^3 is assumed. The actual value is expected to be less than the assumed value based on other concretes. Therefore, mass and total contamination will be overestimated.

Table 1 Dimensions of Subsurface Structures After Removal of Above Grade Sections.

		Below-Grade Dimensions (ft)					
Structure	Component	Component Height	Component Width	Component Thickness	Area (ft^2)	Volume (ft^3)	Mass (g)
PAB	Floor			2.50	193.8	484.4	3.4E+07
(drain collection tank room)	wall 1	18.50	12.50	1.00	231.25	231.25	1.6E+07
	wall 2	18.50	12.50	1.00	231.25	231.25	1.6E+07
	wall 3	18.50	15.50	1.00	286.75	286.75	2.0E+07
	wall 4	18.50	15.50	1.75	286.75	501.81	3.6E+07
PAB	Floor			2.50	157.6	394.1	2.8E+07
(gravity drain tank room)	wall 1	18.50	10.17	1.00	188.15	188.15	1.3E+07
	wall 2	18.50	10.17	1.00	188.15	188.15	1.3E+07
	wall 3	18.50	15.50	1.00	286.75	286.75	2.0E+07
	wall 4	18.50	15.50	1.00	286.75	286.75	2.0E+07
SFP	Floor			3.00	555.5	1666.7	1.2E+08
	wall 1	14.67	16.50	6.00	242.06	1452.33	1.0E+08
	wall 2	14.67	16.50	6.00	242.06	1452.33	1.0E+08
	wall 3	14.67	33.67	6.00	493.94	2963.63	2.1E+08
	wall 4	14.67	33.67	6.00	493.94	2963.63	2.1E+08
Waste Vault	Floor			1.17	126	147.4	1.0E+07
	wall 1	9.83	9.00	1.00	88.47	88.47	6.3E+06
	wall 2	9.83	9.00	1.00	88.47	88.47	6.3E+06
	wall 3	9.83	14.00	1.00	137.62	137.62	9.7E+06
	wall 4	9.83	14.00	1.00	137.62	137.62	9.7E+06

2.1 Contaminant Initial Concentrations

The total release from the concrete walls to the backfill region is assumed to be independent of the contamination levels in the backfill. It is assumed that the initial contamination level is 1 pCi/g for all radionuclides in the walls and floors of the subsurface structures. Thus the results can be scaled up or down to determine the dose for the actual levels of residual radioactivity in the structures.

3.0 Modeling Release from Contaminated Concrete

The radionuclides in the concrete will eventually be released to the surrounding backfill. The contaminants will move through the backfill undergoing sorption and eventually reach a receptor well. Therefore, the contaminant concentration in the well is a function of the release rate from the concrete and the transport to the well. For conservatism, all four subsurface areas will be combined, assuming that one well withdraws all the water from each area.

An important outcome of modeling diffusion controlled releases is the ability to obtain a diffusion profile that can be used to help develop characterization data needs. An analysis of these profiles is presented in this section.

3.1 Key Radionuclides

Measurable levels of tritium were found throughout the entire core of the wall between the IX Pit and the SFP. Average concentrations in the concrete for tritium were 25 pCi/g (Darman, 2004). Several radionuclides including Cs-137, Co-60, Ni-63, Sr-90, and C-14 were found within the first inch of the interface of the wall and the SFP. Contamination levels ranged from 1075 pCi/g for Cs-137 down to 0.91pCi/g for Sr-90 (Darman, 2004). All of these radionuclides will be simulated.

3.2 Diffusion- Controlled Release from Intact Structures

Calculations of diffusion controlled release from the subsurface structures has been previously reported (Sullivan, 2004). In these calculations, conservative values for the diffusion coefficients were selected based on literature values. The initial distribution of contaminants for the release calculation is a uniform concentration of 1 pCi/g. The maximum yearly release rate occurs in the first year and continually declines afterwards. This analysis uses the first year release rates for conservatism. Table 2 presents the diffusion coefficient, fractional release of the inventory and the peak release rate for the six radionuclides under consideration.

Table 2 Average Fractional Release and Total Release from All Subsurface Facilities for Initial Uniform Contamination of 1 pCi/g in All Walls and Floors.

Radionuclide	Diffusion Coefficient (cm^2/s)	Average fractional release	Peak Release Rate (pCi/yr)
H-3	5.5 E-07	6.29E-02	6.45E+07
C-14	1.0E-12	3.02E-04	3.10E+05
Co-60	4.0E-11	1.02E-03	1.05E+06
Ni-63	1.1E-09	4.88E-03	5.00E+06
Sr-90	5.2E-10	3.41E-03	3.49E+06
Cs-137	3.0E-09	7.82E-03	8.02E+06

Using the assumption that the groundwater concentration is controlled by sorption onto the backfill with the total mass defined from the peak release rate in Table 2, the maximum activity released within a year and the maximum contaminated zone concentration for each radionuclide from the subsurface structures are presented in Table 3. The maximum concentration is calculated as follows:

$$C_{cz} = M_r/(V*\beta*\eta*R_d) \text{ (in pCi/L)} \quad (1)$$

Where M_r = mass released
V= Volume of the fill (m^3)
β =1000 conversion factor for m^3 to liters.
η = saturated zone porosity = 0.31
R_d = retardation coefficient = $1 + \rho K_d/\eta$

This approach does not account for dilution that will occur due to groundwater flow.

Table 3 Activity and contaminated zone concentrations through diffusion release from intact subsurface structures.

Radionuclide	Activity Released through Diffusion (pCi)	Maximum Contaminated Zone Concentration (pCi/L)
H-3	6.45E+07	4.36E+02
C-14	3.10E+05	5.95E-03
Co-60	1.05E+06	5.05E-03
Ni-63	5.00E+06	1.91E-01
Sr-90	3.49E+06	4.44E-01
Cs-137	8.02E+06	7.96E-02

4.0 Modelling the Source Term for RESRAD

The modeling performed above was used as the basis for assessing dose using RESRAD. RESRAD assumes that the source is controlled by the sorption properties of the contaminated zone. RESRAD also assumes that the contaminated zone is above the water table, whereas in this case, the source is below the water table. These conceptual model differences lead to the need to make assumptions about parameter values to make the calculations in RESRAD match the desired release rates, geometry, and dilution effects.

4.1 Matching release rates

RESRAD assumes that release from contaminated material is controlled by the following equation (Yu, 2001).

$$R(t) = L(t)*\rho_b*A*T*S(t) \quad (1)$$

Where R(t) is the time-dependent release rate (pCi/yr)

L(t) is the leach rate (1/yr) for the contaminant

ρ_b is the bulk density of the source zone (kg/m^3)

A is the area of the contaminated zone (m^2)

T is the thickness of the contaminated zone (m)

S(t) is the average concentration of the radionuclide available for leaching (pCi/kg).

The RESRAD Leach Rate, L (t), is calculated from the following expression (Yu, 2001),

$$L(t) = I/(\theta*T*R_{dcz}) \quad (2)$$

Where I = infiltration rate (m/y)

θ = moisture content in the contaminated zone

R_{dcz} = retardation coefficient in the contaminated zone (dimensionless)

$$R_{dcz} = 1 + \rho_b K_d/\theta \quad (3)$$

Where ρ_b = bulk density of the concrete backfill = 1.54 g/cm^3

K_d = radionuclide distribution coefficient (g/cm^3)

θ = moisture content (porosity in the saturated zone) = 0.31

4.2 Selection of Contaminated Zone Geometry for RESRAD

RESRAD treats the source of contamination as a single region. Therefore, for modeling purposes, the different building structures are combined to form a single source. RESRAD requires three parameters to define the geometry of the contaminated zone: area, thickness, and length parallel to aquifer flow. The most conservative assumption is that all of the facilities are lined up with the longest dimension in the direction of flow. Using only the interior dimensions of the intact structures (Table 1), the distance parallel to flow is 24 m. The average height of the structures is 4.7 m. The volume of the backfill region of the contaminated structures is 450 m^3. Therefore, the effective width is 4 m. The area perpendicular to groundwater flow is the product of the average height and effective width and is 18.8 m^2.

Table 4 Contaminated zone geometry factors

Area (m^2)	Height (m)	Length parallel to flow (m) (thickness)	Volume (m^3)
18.8	4.7	24	450

4.3 Leach Rates

RESRAD assumes that the contaminated zone is above the water table and uses unsaturated flow parameters (infiltration rate and moisture content) to calculate leach rates. In this simulation, the source of contamination is below the water table and, therefore, the flow parameters of the aquifer and the geometry relative to flow in the aquifer should be used to calculate the leach rates. Equation (2) and (3) were used to calculate the "effective" leach rates for use in RESRAD using the K_d values in Table 2, the geometry values in Table 4, and a moisture content of 0.31 and bulk density of 1.54 g/cm^3. Table 5 presents the effective leach rate for each radionuclide.

Table 5 Effective leach rates for RESRAD.

Radionuclide	Effective Leach Rate (yr^{-1})
H-3	3.368E+01
C-14	9.56E-02
Co-60	2.40E-02
Ni-63	1.90E-01
Sr-90	6.34E-01
Cs-137	4.94E-02

The effective leach rate for H-3 is much greater than 1. This reflects the lack of sorption and high groundwater flow velocity. This high effective leach rate suggests that all of the contamination is released within much less than 1 year. The effective leach rates in Table 5 were used as the contaminated zone leach rate in RESRAD. Use of the leach rate for the contaminated zone overrides the use of a distribution coefficient in the contaminated zone. Therefore, the input for this parameter in RESRAD does not effect the calculations

4.4 Source Inventory

In RESRAD, all concentrations are directly proportional to the initial concentration in the contaminated zone. The source inventory is presented in Table 6 for the intact structures with an initial concentration of 1 pCi/g.

Table 6 Activity released from subsurface structures contaminated to 1 pCi/g and the effective concentration for RESRAD calculations.

Radionuclide	Activity Released from subsurface structures (pCi)	Effective Contaminated Zone Soil Concentration (pCi/g)
H-3	6.45E+07	8.78E-02

C-14	3.10E+05	4.22E-04
Co-60	1.05E+06	1.42E-03
Ni-63	5.00E+06	6.81E-03
Sr-90	3.49E+06	4.75E-03
Cs-137	8.02E+06	1.09E-02

5.0 RESRAD Dose Modelling

Using the effective leach rates in Table 5 and the effective initial concentrations in Table 6 RESRAD was used to calculate peak concentration and dose.

A few parameter values used in the analysis differ from those used by Yankee Rowe in calculating soil DCGLs (YA, 2003) These were changed to fit the conditions being simulated for release controlled by diffusion from intact concrete and sorption on concrete debris used as backfill in the saturated zone.

In calculating soil DCGLs, the cover thickness is zero. However, in this analysis, the depth to the water table will be at least 2 feet and, because of the assumption that the source is in the aquifer, a cover thickness of 2 feet (0.6 m) is used. In the soil DCGLs, the depth for root penetration was 1.17 m and the unsaturated zone thickness was 1.82 m. Therefore, the roots did not penetrate the saturated zone. Retaining the root depth value used in the soil DCGL analysis implies the roots penetrate the saturated zone. The root depth value of 1.17 m will be changed to 0.5 m for this analysis. This prevents the non-water pathways from being non-zero, which is appropriate for the conditions being modeled. The non-water pathways assume that the entire inventory in the contaminated zone is available for transfer to plants modified by the thickness of the cover divided by the thickness of the root zone. However, this is not the situation being modeled as most of the contamination will be bound in the cement and unavailable for release to the plants even if the roots were near the concrete.

A second difference between the assumption used in the analyses of the soil DCGLs and the concrete release model is that the water table drop rate is set to 0. In the soil DCGLs analysis (YA, 2003), a RESRAD default value of 0.001 m/y was used. That analysis had a 1.8 m unsaturated zone, and the results were not sensitive to the water table drop rate. In the current analysis, the unsaturated zone has zero thickness and a non-zero water table drop rate causes a non-zero unsaturated zone thickness to form. This leads to RESRAD calculating transport through the unsaturated zone to reach the aquifer. This effect is not desired because the source is assumed to reside in the saturated zone.

The saturated zone K_ds were set to zero. This assumption was used to provide an upper bound on well concentrations.

The contaminated zone geometry was changed to fit the conditions for release from the partial subsurface structures as defined in Table 4. A bulk density of 1.54 g/cm^3 was

used as being representative of the expected average for backfilled concrete and an effective porosity of 0.31 was used.

In the following analysis, the deterministic model in RESRAD was used. The deterministic model was selected because the calculated well concentrations are conservative. This is because the entire source was considered to be in the aquifer, the release rate calculations were biased high due to the use of the largest value of diffusion coefficient found in the literature, a K_d of zero is used in the saturated zone, and the mass balance model which takes all of the radionuclides released and places them in the well was used in place of the non-dispersion model.

Table 7 summarizes the results for the peak well concentrations and dose using the release rates calculated for diffusion controlled release, Table 2, the leach rate parameters in Table 5 and the parameters used in the analysis for soil DCGLs, with the exceptions noted above. The results suggest that Sr-90 is the radionuclide of highest dose. The RESRAD prediction for H-3 appeared to be low considering it released an order of magnitude more mass than any other radionuclide. As a basis of comparison, the concentration that would occur if all of the mass released was put into the volume of water that flows through the contaminated zone in one year was calculated. This value is almost a factor of 3 higher than predicted by RESRAD. The cause for this discrepancy is that physically the H-3 is modeled to be released instantly. The contaminant flow velocity is the volumetric low rate per unit area (250.6 m/yr) divided by the porosity and retardation factor. For H-3, the retardation factor is 1 ($K_d = 0$) and its transport velocity is 808 m/yr. Therefore, the residence time of H-3 in the 24 meters of contamination is 0.03 years. RESRAD does not allow time steps smaller than 1 year and this limitation leads to large inaccuracy when the residence time is on the order of 1 year or less. Several attempts were made to change input parameters to RESRAD (leach rate, geometry, precipitation rate, etc) to obtain concentrations that were closer to those obtained using a simple mass balance. However, due to the interrelationships between parameters and other restrictions in RESRAD (e.g., maximum precipitation rate is 10 m/yr) this was not possible.

Table 7 Peak Dose for initial partial structure concentrations of 1 pCi/g

Radionuclide	Peak Dose (mrem/yr)
H-3	1.42E-03
H-3*	3.67E-03
C-14	2.14E-04
Co-60	1.45E-04
Ni-63	2.05E-04
Sr-90	3.67E-02
Cs-137	8.73E-03

* H-3 concentration determined by mass balance of the total inventory divided by the annual flow rate through the contaminated region.

6.0 Discussion and Conclusions

Release of residual radioactive contaminants, including H-3, C-14, Co-60, Ni-63, Sr-90, and Cs-137, from subsurface concrete structures at the Yankee Nuclear Power Station is of concern. Consideration is being given to the effect of using demolition debris containing residual radioactivity as backfill in four subsurface structures (PAB drain collection tank room, PAB gravity drain tank room. Spent Fuel Pit, and the Waste Vault). These facilities may have residual contamination in their walls and floors that may contribute to release to the groundwater. As the dose from the backfill is being calculated separately, this analysis was performed to assess the peak dose and well water concentration that could occur as a result of the residual radioactivity in the partially intact subsurface structures. Two mechanisms were considered, diffusive release from the intact concrete and equilibrium sorption onto the concrete backfill that fills the facilities. The majority of the volumes of the concrete walls and floors that may remain are below the water table. Thus, for these analyses it is assumed the entire facility is below the water table. Using these assumptions and appropriate parameters, the calculations showed that Sr-90 had the highest predicted dose rate (3.67E-02 mrem/yr).

CALCULATION TITLE PAGE

RESRAD 6.21 Sensitivity Analysis and Derived Concentration Guideline Levels (DCGLs) for Concrete Debris

Title

YA-CALC-00-002-04

Calculation Number

Executive Summary:

Derived Concentration Guideline Levels (DCGLs) were determined for all significant radionuclides for concrete debris. The RESRAD code was used to determine doses based on a resident farmer scenario with consideration given to a possible intruder for the Yankee site. Sensitivity analyses were performed to determine those input parameters that have the greatest impact on dose and this information was subsequently utilized in the DCGL determination.

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Preparer:			Date:
Reviewer:		Section:	Date:
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Approver (Cognizant Manager):			Date:

CALCULATION TITLE PAGE

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Reviewer:		Section:	Date:
Reviewer:		Section:	Date:
Reviewer:		Section:	Date:
Approver (Cognizant Manager):			Date:

CALCULATION TITLE PAGE

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Preparer:			Date:
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Reviewer:		Section:	Date:
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Approver (Cognizant Manager):	Gregory M Babineau [signature]		Date: 8/31/04

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TABLES

FIGURES

ATTACHMENTS

A. PURPOSE:

The purpose of this calculation is to determine the Derived Concentration Guideline Levels (DCGL) for concrete debris for the list of nuclides identified as important at the Yankee Rowe site. The DCGL values are determined using RESRAD Version 6.21 and the resident farmer scenario. The calculation involves performing a sensitivity analysis to identify sensitive stochastic parameters in the RESRAD resident farmer scenario that have the greatest influence on the dose. Sensitive parameters are identified using the probabilistic analysis in the RESRAD Version 6.21 computer code. The RESRAD output parameter, the Partial Rank Correlation Coefficient (PRCC), provides a measure of the sensitivity of the dose to variations in the input parameter. DCGL values are determined by performing deterministic RESRAD scenario runs using conservative 25/75 percentile values for sensitive parameters.

B. SUMMARY OF RESULTS:

The radiological criteria for license termination established in 10CFR20, Subpart E [1] requires that (i) the annual total effective dose equivalent (TEDE) from residual radioactivity to an average member of the critical group does not exceed 25 mrem and (ii) residual radioactivity be reduced to a level that is as low as reasonably achievable (ALARA). The approach used in this calculation is based on and consistent with NRC guidance provided in NUREG-1727 [2] and the NUREG-1757 [3].

Table 1 summarizes the nuclide specific DCGL values based on the annual dose limit of 25 mrem/year.

Table 1: Nuclide-Specific DCGL Values for Concrete Debris

Nuclide	DCGL (pCi/g)	Nuclide	DCGL (pCi/g)
H-3 cellar hole	100	Cs-134	4.9
H-3 site grading	300	Cs-137	7.1
C-14	7.6	Eu-152	10
Fe-55	150	Eu-154	9.6
Co-60	4.5	Eu-155	400
Ni-63	110	Pu-238	10
Sr-90	0.8	Pu-239	9.3
Nb-94	7.4	Pu-241	150
Tc-99	64	Am-241	4.3
Ag-108m	7.4	Cm-243	4.9
Sb-125	33		

C. REFERENCES:

1. CFR Title 10, Section 20.1402, "Radiological Criteria for Unrestricted Uses."
2. NUREG-1727. "NMSS Decommissioning Standard Review Plan," September 2000.
3. NUREG-1757. "Consolidated NMSS Decommissioning Guidance," Volume 2: Characterization, Survey and Determination of Radiological Criteria," September 2003.
4. YA-REPT-00-001-03, "Radionuclide Selection for DCGL Determination," November 2003.
5. Correspondence between J. Lynch and P. Littlefield, "RE. Concrete Debris," August 4, 2004 (attached).
6. Telecon: Joseph Lynch and Peter Littlefield, July 15, 2004 (attached).
7. NUREG/CR-5512, "Residual Radioactive Contamination From Decommissioning,"
   - Volume 1: "Technical Basis for Translating Contamination Levels to Annual TEDE," October 1992
   - Volume 2: "User's Manual DandD Version 2.1," April 2001
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9. YA-REPT-00-008-03, "Evaluation of GeoTesting Express Soil Testing and Determination of Depth to Groundwater," December 2003.
10. NUREG/CR-6676, "Probabilistic Dose Analysis Using Parameter Distributions Developed for RESRAD and RESRAD-BUILD Codes", Kamboj S., et al. US Department of Energy- Argonne National Laboratory, May 2000.
11. NUREG/CR-6692, "Probabilistic Modules for the RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes", LePoire, D., et al., US Department of Energy- Argonne National Laboratory, November 2000.
12. NUREG/CR-6697, "Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes", Yu, C. et al., US Department of Energy-Argonne National Laboratory, November 2000.
13. YA-REPT-00-002-03, "Hydrogeological Parameter Estimates for Radiation Dose Modeling," May 2003.
14. YA-REPT-01-003-03, "Basis for Selection of Concrete Kd Values," August 2004.
15. ANL/EAD-4, "Users Manual for RESRAD Version 6.0," Yu, C. et al., July 2001.
16. Yu, C., et al, Argonne National Laboratory, April 1993, Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil.
17. YA-CALC-02-001-03, "RESRAD 6.21 Sensitivity Analysis for Resident Farmer Scenario – Soil," February 2004.

D. ASSUMPTIONS:

1. Radionuclide List

The RESRAD sensitivity analysis and DCGL runs were performed for the radionuclides listed in Table 2. This list of radionuclides was developed by consideration of historical site data, waste stream analyses and source terms in NUREG guidance to encompass the radionuclides that may present a significant dose impact [4].

Table 2
YNPS Radionuclide List

H-3	Tc-99	Eu-155
C-14	Ag-108m	Pu-238
Fe-55	Sb-125	Pu-239
Co-60	Cs-134	Pu-241
Ni-63	Cs-137	Am-241
Sr-90	Eu-152	Cm-243
Nb-94	Eu-154	

2. Concrete Debris Use at Yankee Rowe

Several of the remaining concrete buildings and structures at the Yankee site will be demolished with the resulting concrete debris being used for fill material on site. Some part of these structures may have low levels of radioactivity present. Thus, it is necessary to determine appropriate DCGLs for use with this concrete debris. However, no credit will be taken for slowed release of radionuclides from large concrete pieces (i.e. diffusion). The concrete debris may be placed in cellar holes or used as grading material for the site. Clean cover will be placed over all concrete debris used on the site. This cover will consist of clean fill materials or topsoil and will have a minimum depth of 3' [6].

3. Dose Model: The Resident Farmer / Intruder Scenarios

The dose model used to perform the sensitivity analyses and to calculate subsequent concrete debris DCGLs is based upon the Resident Farmer Scenario defined in NUREG/CR-5512 Volumes 1, 2 and 3 [7]. The dose model translates residual radioactivity into potential radiation dose and is defined by the scenario, exposure pathways and the critical group. The resident farmer scenario is considered to be a reasonably conservative bounding scenario, which generally overestimates potential dose. NUREG/CR-5512 discusses the development of scenarios to estimate the dose from radioactivity in soil and Section 4, below, describes the modifications made in order for this calculation to model and estimate the dose from radioactivity in concrete debris.

In addition, this calculation considers the possible site intrusion and subsequent removal of all of the required cover. The intruder scenario incorporated into the model is based on NUREG-1757, Appendix J [8] and very conservatively assumes that no cover exists on the site.

The residual radioactivity in this scenario is assumed to be uniformly contained in a concrete layer on the property that can be used for residential and light farming activities. The residential farming family is assumed to live onsite, raise crops and livestock for consumption and drink water from a ground water source onsite. The dose from residual radionuclides in the concrete debris is evaluated for the average member of the critical group as required by 10CFR Part 20, Subpart E and as described in NUREG-1727 and -1757 [2, 3]. The critical group represents the group reasonably expected to receive the greatest exposure, given the scenario, to residual radioactivity.

The potential exposure pathways that define the residential farmer scenario are:

a. Direct exposure to external radiation from radionuclides in the soil
b. Internal dose from inhalation of airborne radionuclides, and
c. Internal dose from ingestion of radionuclides in
   - Crops grown on the property and irrigated with water obtained onsite,
   - Meat and milk obtained from livestock fed fodder produced onsite and water obtained onsite,
   - Drinking water from an onsite well,
   - Fish from an onsite pond and
   - Concrete debris dust

4. Conceptual Model Underlying the Dose Model

The conceptual model is based on the site characteristics expected at the time of license termination. The model includes the use of concrete debris for filling cellar holes and site grading. It also assumes the presence of a potential intruder who removes all of the clean material that will cover the concrete debris. The use of the resident farmer scenario in RESRAD assumes that normal farm activities will take place on the concrete debris including the growing of food crops and the raising of livestock.

Key assumptions of the conceptual model:

a. The concrete debris contains residual radioactivity. This concrete is used to fill cellar holes and grade the site and is identified as the contaminated zone. The total area comprising the cellar holes is 170 m^2 based on the YR drawings referenced in Attachment 1, Table 1-1. The area of grading, 5020 m^2, is defined to be an area of approximately 300 ft in the north-south direction by 180 ft in the east-west direction [5] as determined for the site grading plan.

b. The model uses the very conservative assumption that the entire contaminated zone extends into the water table. The range of depths to ground water on the site is 0.76 meters to 3.8 meters below grade. The contaminated zone thickness is conservatively set at 3.8 meters, the maximum depth to groundwater. Attachment 1, Table 1-1, lists the vertical extent of the site buildings with cellar spaces.

c. The volume of concrete debris to fill the total volume in the conceptual model is 19076 m^3 (5020 m^2 x 3.8 m). The actual volume of concrete debris expected to be available from building demolition is 13500 m^3 [6].

d. Massachusetts Department of Environmental Protection requires 3 feet of uncontaminated cover over the concrete fill. However, to incorporate an intruder scenario into the conceptual model according to Reference 8, no cover is assumed.

e. The on-site well for drinking, crop irrigation and livestock is drilled within the concrete debris field as part of the Mass Balance water transport model.

The RESRAD code is designed to estimate doses from a contaminated zone above the water table. Because the YR conceptual model includes a contaminated zone that extends above and into the water table, the following RESRAD parameters have been modified to develop a dose model consistent with the conceptual model of the site.

- The Mass Balance model (MB) used for water transport
- No unsaturated zones
- No dilution of groundwater by using a well pumping rate equal to 250 m^3/y (RESRAD default)

5. Conceptual Model for H-3

Because of the conservative assumption that the entire contaminated zone extends into the saturated zone, the DCGL values obtained using the model described above may be applied to concrete debris that will be placed either in the cellar hole area or used for site grading. For H-3, two separate conceptual models are developed based on more realistic site assumptions, primarily that the cellar hole area is potentially in contact with ground water and that the larger site area to be graded is above the water table. Two RESRAD dose models are applied to obtain separate H-3 DCGL values for each scenario.

The first model, described in Section 4, modifies the RESRAD parameters to reflect a contaminated zone within the saturated zone, in this case, the combined area of the cellar hole spaces. For the H-3 cellar hole scenario, all the other key elements discussed in Section 4 are maintained with the exception of the contamination fractions. This parameter represents the fraction of ingested food assumed to be contaminated and is assigned the RESRAD default value, -1. This allows RESRAD to calculate the fraction based on the smaller area of the cellar holes. This small area cannot support the production of all the food products (plant, meat, milk) used by the resident farmer.

The second model reflects the site grading scenario where the larger site grading area comprises the contaminated zone and is located above the water table.

Key parameters for the H-3 site grading scenario that differ from the cellar hole scenario are as follows:

- The Nondispersion model (ND) is used for water transport
- One unsaturated zone
- Well pumping rate value determined for the soil-resident farmer scenario [17]

E. METHOD / BODY OF CALCULATION:

1. Parameter Selection Process

The dose and conceptual models are quantified by a set of input parameters that are listed in Attachment 3, Table 3-1 and Table 3-2 under the following categories.

- Soil Concentration
- Distribution Coefficients
- Calculation Time
- Contaminated Zone
- Cover and Contaminated Zone Hydrological Data
- Saturated Zone Hydrological Data
- Unsaturated Zone Hydrological Data
- Occupancy
- Ingestion, Dietary
- Ingestion, Non-dietary
- Storage Times of Contaminated Foodstuffs
- Special Radionuclides (C-14)
- Dose Conversion Factors (Inhalation and Ingestion)
- Transfer Factors (Plant, Meat, Milk)
- Bioaccumulation Factors (Fish, Crustacea/Mollusks)

Most H-3 input parameter values for the site grading scenario are unchanged from the soil sensitivity analysis and are discussed in Reference 17. Input parameter values that are different from the soil analysis are listed in Attachment 3, Table 3-2.

Incorporated within RESRAD Version 6.21 are probabilistic modules that allow the evaluation of dose as a function of parameter distributions. The code output report provides a measure of the sensitivity of the dose to variations in parameter values. The parameter values are defined by the statistical parameters of an assigned probability distribution. To aid in selecting which parameter sensitivities to evaluate, a process was followed in this calculation that was developed in accordance with guidance from NUREG/CR-6676, -6692, and -6697 [10, 11, 12]. A schematic flow diagram of the parameter selection process is provided in Figure 1. Each step of the selection process is discussed below.

Classification (Type):

The parameters were classified as behavioral, metabolic or physical consistent with NUREG/CR-6697. Behavioral parameters depend on the behavior of the receptor and the scenario definition. Metabolic parameters represent the

metabolic characteristics of the receptor and are independent of the scenario definition. Physical parameters are the parameters that would not change if a different group of receptors were considered.

Prioritization:

The NUREG/CR-6697 approach to prioritizing parameters was applied in this calculation. The priority of a particular parameter is based upon:

a. The relevance of the parameter in dose calculations,
b. The variability of the dose as a result of changes in the parameter value,
c. The parameter type and
d. The availability of parameter-specific data.

Priority 1 parameters are considered to be high priority; Priority 2 parameters are considered to be medium priority; and Priority 3 parameters are considered to be low priority.

Treatment:

Input parameters are treated as either "deterministic" -assigned a single value, or "stochastic" -assigned a probability distribution. The treatment depends on parameter type, priority, availability of site-specific data and the relevance of the parameter in dose calculations.

a. Behavioral and metabolic parameters are treated as deterministic and are assigned values from NUREG/CR-5512, Volume 3, NUREG/CR-6697, or the RESRAD default library.
b. Physical parameters for which site-specific data is available are treated as deterministic based on information in YA-REPT-00-008-003 [9] and YA-REPT-00-002-003 [13].
c. The remaining physical parameters, for which no site-specific data is available, are assigned values based on priority. Priority 1 and 2 parameters are treated as stochastic and are assigned a probability distribution from NUREG/CR-6697. The priority 3 physical parameters are treated as deterministic and are assigned values from NUREG/CR-5512, Volume 3, NUREG/CR-6697, or the RESRAD default library.

2. Basis for Concrete Debris Parameter Values

The basis and determination of appropriate values for the elemental distribution coefficients, Kd, to be used by RESRAD to predict the release of residual radioactivity from the concrete debris are discussed in detail in Reference 14. Where possible, industry concrete Kd values obtained from specific Kd studies are used. If an element is not specifically included in an industry study, literature values are used or chemical analogies are made. Attachment 3, Table 3-1 provides the basis for nuclide specific distribution coefficients.

The calculation of the plant transfer factor (ptf) for concrete is based on the correlation of the Kd and the root uptake factor (CR) defined in Reference 12. The plant transfer factor distributions are derived from the distributions assigned to the Kd in Reference 14. The use of equation 3.9.2 from Reference 12 to calculate concrete plant transfer factors is discussed in Attachment 2. A summary of the distributions assigned is provided below and in Attachment 3, Table 3-1.

a. A Uniform Distribution is assigned to Ag, Cm, Co, Cs, Fe, Ni, Sr and Tc.
b. A Loguniform Distribution is assigned to Ac, Am, C, Eu, Gd, Nb, Np, Pa, Pu and Th.
c. A Lognormal Distribution is assigned to Pb, Sb, and U.
d. A Truncated Lognormal Distribution from Reference 12 is assigned to H-3 and Ra-226 to allow stochastic treatment of this parameter for the sensitivity analysis.

The equilibrium groundwater concentration for principle nuclides is calculated using equations derived from the relationship of the nuclide concentration in the solid and liquid portions of the contaminated zone discussed in Reference 15, Appendices H and L. Using the value for Kd as determined above and an initial nuclide concentration of 1pCi/gm the groundwater concentration under saturated equilibrium conditions are calculated.. A discussion of the calculation is included in Attachment 2.

3. Sensitivity Analysis

The probabilistic module of the RESRAD Version 6.21code was used to perform analyses designed to identify stochastic parameters having the greatest influence on the resultant dose and the associated DCGLs. The code was run for each nuclide listed in Table 2 at a concentration of 1 pCi/gram. Prior to use, the operability of the RESRAD Version 6.21 code was verified in accordance with YNPS Procedures.

Sample Specifications:

The analyses were run using 2000 observations and 1 repetition. The Latin Hypercube Sampling (LHS) technique was used to sample the probability distributions for each of the stochastic input parameters. The correlated or uncorrelated grouping option was used to preserve the prescribed correlations, and a random seed of 1000 was used to preserve the prescribed sampling technique.

Input Rank Correlations:

Input correlations were assigned between correlated parameters based on guidance provided in NUREG/CR-6676 and NUREG/CR-6697.

Output Specifications:

All of the output options were specified.

The Partial Rank Correlation Coefficient (PRCC) for the peak of the mean dose was used as the measure of the sensitivity of each parameter to the peak of the mean dose.

For the scenario defined above, a parameter was identified as sensitive if the absolute value of its PRCC (|PRCC|) was greater than or equal to 0.25 and non-sensitive if the |PRCC| value was less than 0.25. These thresholds were selected based on the guidance included in NUREG/CR-6676.

Results of Sensitivity Analysis:

The RESRAD Uncertainty Report provides regression and correlation coefficients for the peak of the mean dose. The PRCC has been used to identify sensitive parameters with the limit set at 0.25. Parameter values are further identified as being positively or negatively correlated to dose by assessing whether the PRCC value is greater than zero or less than zero.

NUREG/CR-6692 and 6697 recommend the use of the PRCC or SRRC for cases where a non-linear relationship and widely disparate scales exists between the inputs and outputs. The NUREG/CR guidance further recommends the use of the PRCC if the strong correlation exists between input parameters.

Table 5 identifies for each radionuclide the sensitive parameters in order of rank, the PRCC values and the R-Squared value. R-Squared, the coefficient of determination presents a measure of the variation in the peak dose explained by the regression on the input parameters involved in the analysis, and varies between 0 and 1. The conservative percentile values, representing either the 25th or the 75th percentiles of the parameter distributions are also listed.

4. DCGL Determination for Concrete Debris

This analysis is performed to calculate nuclide-specific residual radioactivity levels or DCGL values for concrete debris that will provide assurance that the radiological criteria for license termination established in 10CFR20, Subpart E are met at the Yankee Rowe site. For unrestricted release of a site, 10 CFR Part 20 requires that (i) the annual total effective dose equivalent (TEDE) from residual radioactivity to an average member of the critical group does not exceed 25 mrem and (ii) residual radioactivity be reduced to a level that is as low as reasonably achievable (ALARA). The approach used in this calculation is based on and consistent with NRC guidance provided in NUREG-1727 [2] and the draft NUREG-1757 [3].

Assignment of Parameter Values:

Behavioral Parameters were assigned the deterministic values in Attachment 3, Table 3-1 and Table 3-2.

Metabolic Parameters were assigned the deterministic values in Attachment 3, Table 3-1 and Table 3-2.

Priority 3 and site specific Physical Parameters were assigned the deterministic values given in Attachment 3, Table 3-1 and Table 3-2.

Priority 1 and 2 parameters found to be non-sensitive (PRCC < 0.25) were assigned the median value of the distribution or the 50% quantile values listed in Attachment 3, Table 3-1 and Table 3-2.

Priority 1 and 2 parameters found to be sensitive (PRCC ≥ 0.25) were assigned 25% or 75% quantile values dependent on whether the parameter was negatively or positively correlated to the dose. Also, for positively correlated parameters the mean of the distribution was compared to the 75% values. The mean value was assigned to the parameter if it was greater than the 75%. The values assigned for the DCGL analysis are presented in Attachment 3, Table 3-3.

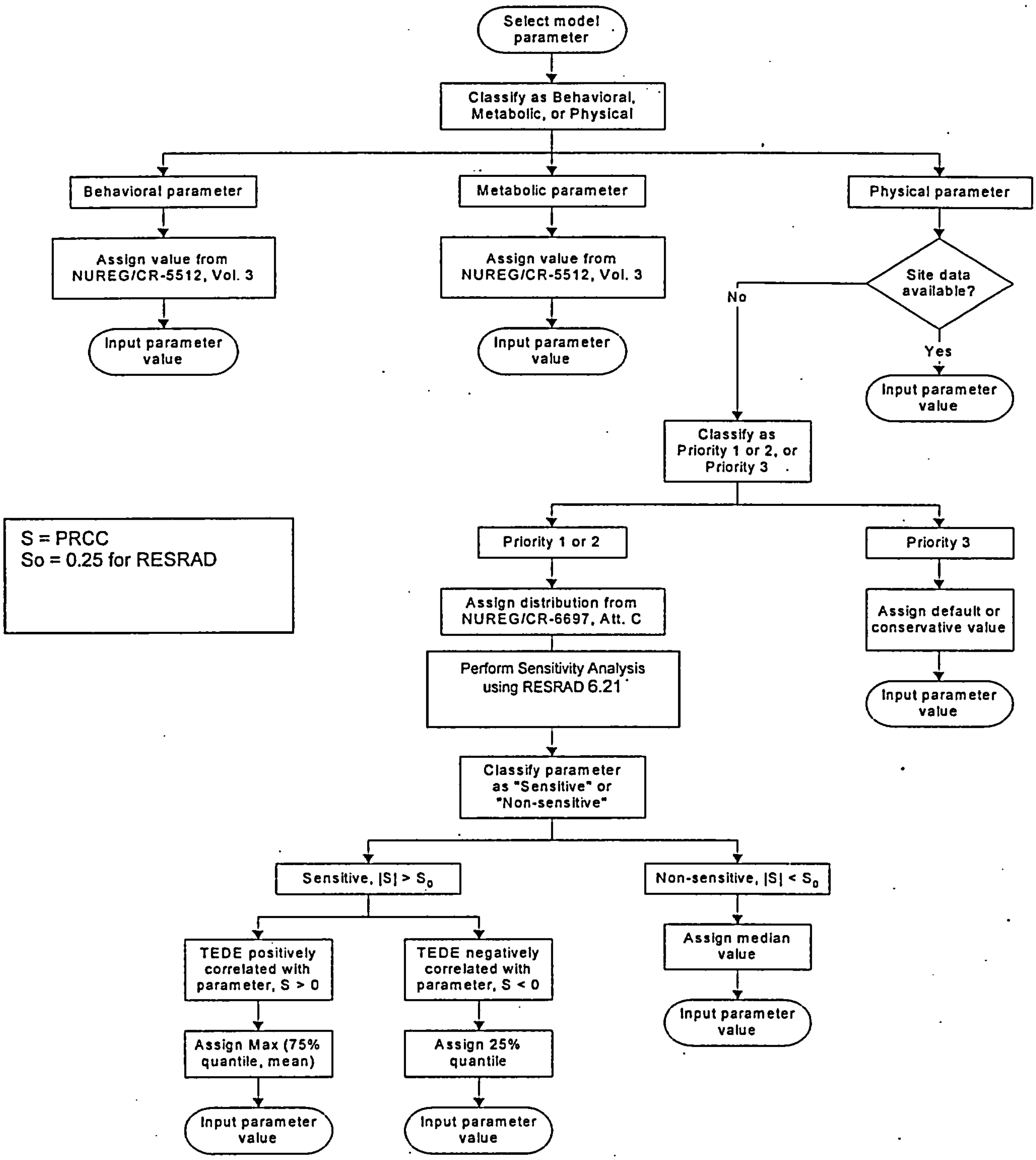
Concrete Debris DCGL Values:

The nuclide specific DCGL values were calculated using the maximum total dose in mrem/yr per pCi/gm provided in the RESRAD summary report and are based on the annual dose limit of 25mrem. Attachment 4, Table 4-1 presents the DCGL and the time of the maximum dose along with the dose contribution from each exposure pathway considered in the scenario.

Comparison of the Well Water Concentration to the Equilibrium Groundwater Concentration:

The RESRAD "CONCENT.rep" report provides the well water concentration for each principle radionuclide as calculated by RESRAD (at T=1 year). This concentration was compared to the equilibrium groundwater concentration calculated in accordance with Attachment 2.B, Equation 4. The contaminated zone concrete concentrations, which are also used in Equation 4 of Attachment 2, were obtained from the RESRAD concentration reports. The RESRAD well water concentration is greater than or equal to the calculated equilibrium groundwater concentration for all nuclides. The results are listed in Attachment 4, Table 4-2.

Figure 1- Parameter Selection Process



Attachment 1

Table 1-1: Vertical Extent of Remaining Subsurface Structures
and Reference 5 –
"Correspondence between J. Lynch and P. Littlefield, "RE. Concrete Debris," August 4, 2004"
and Reference 6 –
Telecon July 15, 2004 "regarding Preliminary Estimate of Concrete and Soil Borrow and Fill Volumes"

A. Buildings identified as potentially having subsurface spaces at the completion of the DEMCO Phase 1 Demolition Plan and/or the email communication with J. Lynch [5]

Table 1-1 Vertical Extension of Remaining Below-Grade Structures

Building	YR drawing reference	Wall elevations msl, ft (wrt plant grade)	Vertical Extension of Structure, meters (wrt plant grade)	Area m^2
PAB TK-30	PAB 9699-FM-57A	1022'8"-1004'2" = 18'6"	5.6	18
PAB, TK-27	PAB 9699-FM-57A	1022'8"-1004'2" = 18'6"	5.6	14.6
Spent Fuel Pool	Fuel Pit 9699-FC-45B	1022'8"-1008'0" = 14'8"	4.5	51.6
Waste Vault	PAB 9699-FC-43A	1020'6"-1010'8" = 9'10"	3.0	11.7
Elevator Pit	PAB 9699-FC-43A	1022'8"-1016'2" = 6'6"	1.9	6.5
IX Pit	PAB 9699-FC-40A, 40K,40L	1022' 8' - 1012' 6" = 6' 6"	3.1	67.5

B. Reference 5: Correspondence between J. Lynch and P. Littlefield, "RE. Concrete Debris," August 4, 2004

----- Original Message -----
From: Joe Lynch
To: 'Pete Littlefield'
Sent: Monday, July 12, 2004 10:38 AM
Subject: RE: Concrete Debris

Pete:

I sent you the Site Grading Plan under a separate message.

To address your questions, the building the subject of fill are the PAB (south wall towards the VC), the Fuel Pool excavation and the Ion Exchnage Pit excavation.

Concrete debris will be 8" in size or less.....uniformly distributed.

The majority of the fill will be used in the area extending from the southern end of the diesel generator building north to the northern end of the turbine building. In the east-west direction the fill zone would be from the east edge of the diesel generator/fuel storage building to the west edge of that building. This area is approximately 300 feet in the north-south direction and 180 feet in the east-west direction. The fill area will be approximately triangular in cross-section and will vary from 10 feet deep at the southern edge to approximately zero depth at the northern end (an average of 5 feet of depth). As a volume calculation this would equate to 300x180x5/27=10,000cy. This is an approximate number at this stage, but there is some science behind it. The fill area could potentially extend easterly along the ledge cut line approximately 200 feet. However, if we can dispose of the entire volume of ABC fill within the area described above, it may be better to keep it confined to a smaller footprint.

If you need any further information or clarification please let me know.

Regards,

Joe

I have listed the contact inforamtion for the designers of the Site Grading Plan if you have more questions or need clarification.

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C. Telecon: Joseph Lynch and Peter Littlefield, July 15, 2004, regarding "Preliminary Estimate of Concrete and Soil Borrow and Fill Volumes."

Preliminary Estimates of Concrete and Soil Borrow and Fill Volumes
Yankee Nuclear Power Station
Rowe, MA

WORKING DRAFT - FOR DISCUSSION PURPOSES ONLY

Category	Type	Source	Compacted Volume (cubic yards)	Subtotal (cubic yards)	Total (cubic yards)	Source	Comments
Borrow	Concrete	Structures to Grade	13,105	17,705	69,805	1	
		Structures 0 - 18 inches below grade	4,600			2	Not all may need to be removed if greater than 3 feet of fill planned.
	Pavement	Not quantified.	1,200	1,200			
	Soil	ISFSI soils on SCFA	10,000	50,900		3	
		ISFSI soils in mid-parking lot	11,000			4	
		SCFA Removal	29,000			5	
		Detention Basin Excavation	900			5	
Fill	ABC	Building Voids	4,800	18,300	58,850	1	Based on information provided by Yankee.
		Shaping material (< 3 feet) for H&A Plan	10,800	slopes		5	
		Shallow Foundations	2,700			2	Assumes all structures removed to 18 inches below grade.
	ABC?	Screenwell Foundation	3,400	10,500		1	Use of ABC will require USGen approval.
		Circulating Water Pipes	600			1	Method of placing ABC will need to be evaluated.
		SCFA Below 3 feet	6,500			5	Does YAEC want to place ABC in SCFA?
	Soil	Service Building Foundation	350	24,050		2	
		Cap for H&A Plan	18,700			5	
		SCFA Upper 3 feet	5,000			5	
	Engineered Soils	Dam Extension	6,000	6,000		5	

Notes:
Volume estimates are preliminary and for discussion purposes only - not intended for contracting or design purposes.
Assumes 3 feet of soil will be required over ABC fill or structures left in-place.
Volume of pavement has not been quantified.
Assumes that no net fill or borrow for shoreline activities.
Assumes volume of soil in borrow area will be same as in fill area (fluff factor would be negligible).
Assumes soil on-site is suitable for use as topsoil.

ABC - asphalt, Brick, Concrete 6" or less

Sources:
1 - Yankee Waste Optimization Estimates
2 - Concrete volume estimates prepared by Joe McCumber, April 2004
3 - Volume estimate reported in SCFA CSA
4 - Estimate prepared by Ken Dow
5 - ERM preliminary volume estimates

Attachment 2

Plant Transfer Factor for Concrete Debris
and
Equilibrium Groundwater Concentration

A. The calculation of the plant transfer factor (ptf) for concrete is based on the correlation of the Kd and the root uptake factor (CR) defined in Reference 12 Equation 3.9-2, as shown below

$$Ln(Kd) = 4.62 + stex - 0.56[ln(CR)] \qquad \text{Equation 1}$$

Where:

Kd = distribution coefficient for concrete
stex = -2.52 for sand soil (coarsest medium in Reference 12 and site soil type)
CR = Root Uptake Transfer Factor (pCi/g plant per pCi/g medium) or the RESRAD soil/plant transfer coefficient (Reference 15, Section H, p. H-13).

Rearranging and solving equation 1 for CR results in the following equation to calculate CR for given values of Kd:

$$ln(CR) = \frac{ln(Kd) - 4.62 - (stex)}{-0.56}$$

$$ln(CR) = \frac{ln(Kd)}{-0.56} + 3.75$$

$$CR = 42.52\ (EXP(ln(Kd)/-0.56)) \qquad \text{Equation 2}$$

Specifically:

e. A Uniform Distribution is assigned to Ag, Cm, Co, Cs, Fe, Ni, Sr and Tc. The minimum and maximum Kd values are substituted into Equation 2.

f. A Loguniform Distribution is assigned to Ac, Am, C, Eu, Gd, Nb, Np, Pa, Pu and Th. The minimum and maximum Kd values are substituted into Equation 2.

g. A Lognormal Distribution is assigned to Pb, Sb, and U. The mean and standard deviation of the lognormal distribution were determined following the calculation of CR using equation 2 and the natural log transformation of CR.

h. A Truncated Lognormal Distribution from Reference 12 is assigned to H-3 and Ra-226 to allow stochastic treatment of this parameter for the sensitivity analysis.

B. Equilibrium Groundwater Concentration

RESRAD uses the linear relationship in Equation 3, taken from Reference 15, Section H, to estimate the ground water concentration resulting from concentrations in concrete (soil) particles.

$$S = Kd*C \qquad \text{Equation 3}$$

Equation 4 expresses the ground water concentration under equilibrium conditions in a saturated environment based on the relationships defined by Equation 3. This equation is used to compare the RESRAD well water concentration to the equilibrium ground water concentration.

$$C = \frac{1000\ S_o \rho_b}{[1 + (k_d \rho_b / n)]\ n} \qquad \text{Equation 4}$$

where:

C = Equilibrium groundwater concentration (pCi/L)
So = Initial principal radionuclide concentration in the concrete (pCi/gm)
ρ_b = Bulk density of the contaminated zone (gm/cm^3)

Kd = Distribution coefficient of the contaminated zone (cm^3/gm)

n = Total porosity of the contaminated zone

1000 cm^3 per liter

Attachment 3

Table 3-1 - Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris

Table 3-2 - Input Parameters for Sensitivity Analysis, H-3 Graded Concrete Debris

Table 3-3 - Sensitivity Analysis Summary, Percentile Values and Assignment of Conservative Values for Concrete Debris DCGL Determination

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Soil Concentrations										
Basic radiation dose limit (mrem/yr)		3	D	25	10 CFR 20.1402 [1]	NR	NR	NR	NR	
Initial principal radionuclide (pCi/g)	P	2	D	1	Unit Value	NR	NR	NR	NR	
Distribution Coefficient										
Ac-227+D	P	1	S	Loguniform	Chemical analogy to Am [3]	200	5000			1.00E+03
Ag-108m	P	1	S	Uniform	Chemical analogy to Cu [3]	3000	10000			6.5E+03
Am-241	P	1	S	Loguniform	[3]	200	5000			1.00E+03
Am-243+D	P	1	S	Loguniform	[3]	200	5000			1.00E+03
C-14	P	1	S	Loguniform	[3]	10	500			7.07E+01
Cm-243	P	1	S	Uniform	[3]	200	1000			6.00E+02
Co-60	P	1	S	Uniform	[3]	181	383			2.82E+02
Cs-134	P	1	S	Uniform	[3]	34	240			1.37E+02
Cs-137+D	P	1	S	Uniform	[3]	34	240			1.37E+02
Eu-152	P	1	S	Loguniform	Chemical analogy to Am [3]	200	5000			1.00E+03
Eu-154	P	1	S	Loguniform	Chemical analogy to Am [3]	200	5000			1.00E+03
Eu-155	P	1	S	Loguniform	Chemical analogy to Am [3]	200	5000			1.00E+03
Fe-55	P	1	S	Uniform	[3]	7	18			1.25E+01
Gd-152	P	1	S	Loguniform	Chemical analogy to Am [3]	200	5000			1.00E+03
H-3	P	1	D	0.00	[3]					
Nb-94	P	1	S	Loguniform	[3]	100	1000			3.16E+02
Ni-63	P	1	S	Uniform	[3]	10	61			3.55E+01
Np-237+D	P	1	S	Loguniform	[3]	100	5000			7.07E+02
Pa-231	P	1	S	Loguniform	Chemical analogy to Nb [3]	100	1000			3.16E+02
Pb-210+D	P	1	S	Lognormal-n	[3]	10.77	0.88			4.76E+04
Pu-238	P	1	S	Loguniform	[3]	500	5000			1.58E+03

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Pu-239	P	1	S	Loguniform	[3]	500	5000			1.58E+03
Pu-241+D	P	1	S	Loguniform	[3]	500	5000			1.58E+03
Ra-226+D	P	1	D	100	[3]					
Sb-125	P	1	S	Lognormal-n	[3]	7.35	1.11			1.55E+03
Sr-90+D	P	1	S	Uniform	[3]	10	11			1.05E+01
Tc-99	P	1	S	Uniform	[3]	6	21			1.35E+01
Th-229+D	P	1	S	Loguniform	[3]	500	5000			1.58E+03
Th-230	P	1	S	Loguniform	[3]	500	5000			1.58E+03
U-233	P	1	S	Lognormal-n	[3]	4.99	2.37			1.47E+02
U-234	P	1	S	Lognormal-n	[3]	4.99	2.37			1.47E+02
U-235+D	P	1	S	Lognormal-n	[3]	4.99	2.37			1.47E+02
Initial concentration of radionuclides present in groundwater (pCi/l)	P	3	D	0	Ground water uncontaminated	NR	NR			
Calculation Times										
Time since placement of material (yr)	P	3	D	0		NR	NR	NR	NR	
Time for calculations (yr)	P	3	D	0, 1, 3, 10, 30, 100, 300, 1000	RESRAD Default	NR	NR	NR	NR	
Contaminate Zone										
Area of contaminated zone (m**2)	P	2	D	5020 170	Area of site to be graded with concrete [5] Combined area of the cellar holes used for H-3	NR	NR	NR	NR	
Thickness of contaminated zone (m)	P	2	D	3.8	Corresponds to maximum depth to groundwater [6]					
Length parallel to aquifer flow (m)	P	2	D	80 14.7	Length corresponds to area of 5020m^2 Based on area of cellar holes used for H-3	NR	NR	NR	NR	

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Cover and Contaminated Zone Hydrological Data										
Cover depth (m)	P	2	D	0	NUREG-1757 Intruder Scenario conservative assumption that required MA State DEP cover is removed [7]	NR	NR	NR	NR	
Density of Cover material (g/cm**3)	P	1	S	NA	No cover					
Cover erosion rate (m/yr)	P	2	D	NA	No cover					
Density of contaminated zone (g/cm**3)	P	1	S	Uniform	Distribution derived using total porosity range for coarse gravel [4] & concrete particle density of 2.2 g/cm3 [4, equation 2.3 p 16]	1.41	1.67	NR	NR	1.54
Contaminated zone erosion rate (m/yr)	P	2	D	8.5E-04	Calculated value based on site-specific slope of 2.9% [8]	NR	NR	NR	NR	
Contaminated zone total porosity	P	2	S	Uniform	Range for coarse gravel [4]	0.24	0.36	NR	NR	0.3
Contaminated zone field capacity	P	3	D	0.07	Calculated using Equation 4.4 [4] and arithmetic means for SZ total and effective porosity [8]	NR	NR	NR	NR	
Contaminated zone hydraulic conductivity (m/yr)	P	2	S	Loguniform	Range for gravel [8]	1.E+04	1.E+07	NR	NR	3.16E05
Contaminated zone b parameter	P	2	S	Bounded Lognormal n	NUREG 6697 dist for site soil type - sand [2] Coarsest media listed	- 0.0253	0.216	0.501	1.90	0.975
Humidity in air (g/m**3)	P	3	D	6.1	Regional value [8]	NR	NR	NR	NR	
Evapotranspiration coefficient	P	2	S	Uniform	NUREG/CR-6697 Att. C [2]	0.5	0.75	NR	NR	0.625
Average annual wind speed (m/sec)	P	2	D	2.03	Site-specific value calc. from site meteorological data [8]	NR	NR	NR	NR	
Precipitation (m/yr)	P	2	D	1.2	Site-specific value calculated from site geographical area ppt. [8]	NR	NR	NR	NR	
Irrigation (m/yr)	B	3	S	Uniform	NUREG/CR-6697, Att C methodology [2, 8]	0.252	0.618	NR	NR	0.435
Irrigation mode	B	3	D	Overhead	Site-specific - overhead vs. ditch irrigation is standard practice in Eastern U. S.	NR	NR	NR	NR	
Runoff coefficient	P	2	D	0.6	NUREG/CR-6697, Att. C section 4.2 methodology [2, 8]	NR	NR	NR	NR	

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Watershed area for nearby stream or pond (m**2)	P	3	D	7.77E+05	Site-specific- drainage area [8]	NR	NR	NR	NR	
Accuracy for water/soil computations	-	3	D	1.00E-03	RESRAD Default	NR	NR	NR	NR	
Saturated Zone Hydrological Data										
Density of saturated zone (g/cm**3)	P	1	D	1.54	Value derived using total porosity range for coarse gravel [4] & concrete particle density of 2.2 g/cm3 [4, Eqn 2.3 p 16]	NR	NR	NR	NR	
Saturated zone total porosity	P	1	D	0.28	Arithmetic mean for coarse gravel [4, Section3]	NR	NR	NR	NR	
Saturated zone effective porosity	P	1	D	0.21	Arithmetic mean for coarse gravel [4, Section 3]l	NR	NR	NR	NR	
Saturated zone field capacity	P	3	D	0.07	Calculated using equation 4.4 and porosity values from [4	NR	NR	NR	NR	
Saturated zone hydraulic conductivity (m/yr)	P	1	D	3.16E5	Median value for gravel [4]	NR	NR	NR	NR	
Saturated zone hydraulic gradient	P	2	D	0.1	Site gradient [8]	NR	NR	NR	NR	
Saturated zone b parameter	P	2	D	0.975	Median from NUREG-6697 distrbution for sand [2]	NR	NR	NR	NR	
Water table drop rate (m/yr)	P	3	D	1.00E-03	RESRAD Default	NR	NR	NR	NR	
Well pump intake depth (m below water table)	P	2	D	10	RESRAD Default (not used with MB model)	NR	NR	NR	NR	
Model: Nondispersion (ND) or Mass-Balance (MB)	P	3	D	MB	MB model selected to minimize dilution in saturated zone	NR	NR	NR	NR	
Well pumping rate (m**3/yr)	P	2	D	250 50	RESRAD Default selected to ensure no dilution in saturated zone in MB model Assures no dilution in saturated zone in MB model for H-3	NR	NR	NR	NR	
Unsaturated Zone Hydrological Data										
Number of unsaturated zone strata	P	3	D	0	Contaminated zone extends below the water table	NR	NR	NR	NR	
Occupancy										
Inhalation rate (m**3/yr)	B	3	D	8400	NUREG/CR-6697, Att C [2]	NR	NR	NR	NR	

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Mass loading for inhalation (g/m**3)	P	2	S	Continuous linear	NUREG/CR-6697, Att. C [2]					2.33E-05
Exposure duration	B	3	D	30	RESRAD Default	NR	NR	NR	NR	
Indoor dust filtration factor	P	2	S	Uniform	NUREG/CR-6697, Att. C [2]	0.15	0.95			0.55
Shielding factor, external gamma	P	2	S	Bounded lognormal-n	NUREG/CR-6697, Att. C [2]	-1.3	0.59	0.044	1	0.2725
Fraction of time spent indoors	B	3	D	0.6571	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Fraction of time spent outdoors (on site)	B	3	D	0.1181	NUREG/CR-5512, Vol. 3 Table 6.87 (outdoors + gardening) [9]	NR	NR	NR	NR	
Shape factor flag, external gamma	P	3	D	Circular	RESRAD Default - Circular contaminated zone assumed	NR	NR	NR	NR	
Ingestion, Dietary										
Fruits, vegetables, grain consumption (kg/yr)	B	2	D	112	NUREG/CR-5512, Vol. 3 (other vegetables + fruits + grain) [9]	NR	NR	NR	NR	
Leafy vegetable consumption (kg/yr)	B	3	D	21.4	NUREG/CR-5512, Vol. 3 [9]	NR	NR	NR	NR	
Milk consumption (L/yr)	B	2	D	233	NUREG/CR-5512, Vol. 3 [9]	NR	NR	NR	NR	
Meat and poultry consumption (kg/yr)	B	3	D	65.1	NUREG/CR5512, Vol. 3 (beef + poultry) [9]	NR	NR	NR	NR	
Fish consumption (kg/yr)	B	3	D	20.6	NUREG/CR-5512, Vol. 3 [9]	NR	NR	NR	NR	
Other seafood consumption (kg/yr)	B	3	D	0.9	RESRAD Default	NR	NR	NR	NR	
Soil ingestion rate (g/yr)	B	2	D	18.26	NUREG/CR-5512, Vol. 3 [9]	NR	NR	NR	NR	
Drinking water intake (L/yr)	B	2	D	478.5	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Contamination fraction of drinking water	P	3	D	1	RESRAD Default - all water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of household water (if used)	P	3		NA						
Contamination fraction of livestock water	P	3	D	1	RESRAD Default - all water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of irrigation water	P	3	D	1	RESRAD Default - all water assumed contaminate	NR	NR	NR	NR	
Contamination fraction of aquatic food	P	2	D	1	NUREG/CR-5512, Vol. 3 [9]	NR	NR	NR	NR	

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Contamination fraction of plant food	P	3	D	1 -1	Used w/ NUREG/CR-5512, Vol. 3 [9] regional homegrown consumption rate RESRAD calculates fraction based on cellar hole area for H-3	NR	NR	NR	NR	
Contamination fraction of meat	P	3	D	1 -1	Used w/ NUREG/CR-5512, Vol. 3 [9] regional homegrown consumption rate RESRAD calculates fraction based on cellar hole area for H-3	NR	NR	NR	NR	
Contamination fraction of milk	P	3	D	1 -1	Used w/ NUREG/CR-5512, Vol. 3 [9] regional homegrown consumption rate RESRAD calculates fraction based on cellar hole area for H-3	NR	NR	NR	NR	
Ingestion, Non-dietary										
Livestock fodder intake for meat (kg/day)	M	3	D	27.1	NUREG/CR5512, Vol. 3 Table 6.87, beef cattle + poultry + layer hen [9]	NR	NR	NR	NR	
Livestock fodder intake for milk (kg/day)	M	3	D	63.2	NUREG/CR5512, Vol. 3 Table 6.87, forage + grain + hay [9]	NR	NR	NR	NR	
Livestock water intake for meat (L/day)	M	3	D	50.6	NUREG/CR5512, Vol. 3 Table 6.87, beef cattle + poultry + layer hen [9]	NR	NR	NR	NR	
Livestock water intake for milk (L/day)	M	3	D	60	NUREG/CR5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Livestock soil intake (kg/day)	M	3	D	0.5	RESRAD Default	NR	NR	NR	NR	
Mass loading for foliar deposition (g/m**3)	P	3	D	4.00E-04	NUREG/CR-5512, Vol. 3 Table 6.87, gardening [9]	NR	NR	NR	NR	
Depth of soil mixing layer (m)	P	2	S	Triangular	NUREG/CR-6697, Att. C [2]	0	0.15	0.6		0.23
Depth of roots (m)	P	1	S	Uniform	Min. from NUREG/CR-6697, Att. C [2] Max. is site specific depth to water table [6]	0.3	3.8			2.05
Drinking water fraction from ground water	P	3	D	1	RESRAD Default - all water assumed to be supplied from groundwater	NR	NR	NR	NR	
Household water fraction from ground water (if used)	P	3		NA						
Livestock water fraction from ground water	P	3	D	1	RESRAD Default - all water assumed to be supplied from groundwater	NR	NR	NR	NR	
Irrigation fraction from ground water	P	3	D	1	RESRAD Default - all water assumed to be supplied from groundwater	NR	NR	NR	NR	

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Wet weight crop yield for Non-Leafy (kg/m**2)	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	0.56	0.48	0.001	0.999	1.75
Wet weight crop yield for Leafy (kg/m**2)	P	3	D	2.88921	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Wet weight crop yield for Fodder (kg/m**2)	P	3	D	1.8868	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Growing Season for Non-Leafy (years)	P	3	D	0.246	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Growing Season for Leafy (years)	P	3	D	0.123	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Growing Season for Fodder (years)	P	3	D	0.082	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Translocation Factor for Non-Leafy	P	3	D	0.1	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Translocation Factor for Leafy	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Translocation Factor for Fodder	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Weathering Removal Constant for Vegetation (1/yr)	P	2	S	Triangular	NUREG/CR-6697, Att. C [2]	5.1	18	84		33
Wet Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Wet Foliar Interception Fraction for Leafy	P	2	S	Triangular	NUREG/CR-6697, Att. C [9]	0.06	0.67	0.95		0.58
Wet Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 [9]	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 [9]	NR	NR	NR	NR	
Storage Times of contaminated Foodstuffs (days)										
Fruits, non-leafy vegetables, and grain	B	3	D	14	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Leafy vegetables	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	
Milk	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87 [9]	NR	NR	NR	NR	

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Meat and poultry	B	3	D	20	NUREG/CR-5512, Vol. 3 Table 6.87 (holdup period for beef) [9]	NR	NR	NR	NR	
Fish	B	3	D	7	RESRAD Default	NR	NR	NR	NR	
Crustacea and mollusks	B	3	D	7	RESRAD Default	NR	NR	NR	NR	
Well water	B	3	D	1	RESRAD Default	NR	NR	NR	NR	
Surface water	B	3	D	1	RESRAD Default	NR	NR	NR	NR	
Livestock fodder	B	3	D	45	RESRAD Default	NR	NR	NR	NR	
Special Radionuclides (C-14)										
C-12 concentration in water (g/cm**3)	P	3	D	2.00E-05	RESRAD Default	NR	NR	NR	NR	
C-12 concentration in contaminated soil (g/g)	P	3	D	3.00E-02	RESRAD Default	NR	NR	NR	NR	
Fraction of vegetation carbon from soil	P	3	D	2.00E-02	RESRAD Default	NR	NR	NR	NR	
Fraction of vegetation carbon from air	P	3	D	9.80E-01	RESRAD Default	NR	NR	NR	NR	
C-14 evasion layer thickness in soil (m)	P	2	S	Triangular	NUREG/CR-6697, Att. C [2]	0.2	0.3	0.6		0.3
C-14 evasion flux rate from soil (1/sec)	P	3	D	7.00E-07	RESRAD Default	NR	NR	NR	NR	
C-12 evasion flux rate from soil (1/sec)	P	3	D	1.00E-10	RESRAD Default	NR	NR	NR	NR	
Fraction of grain in beef cattle feed	B	3	D	0.2500	NUREG/CR-6697, Att. B [2]	NR	NR	NR	NR	
Fraction of grain in milk cow feed	B	3	D	0.1000	NUREG/CR-6697, Att. B [2]	NR	NR	NR	NR	
Dose Conversion Factors (Inhalation mrem/pCi)										
Ac-227+D	M	3	D	6.72E+00	FGR11 (RESRAD Dose Conversion Library)	NR	NR	NR	NR	
Ag-108m	M	3	D	2.83E-04	FGR11	NR	NR	NR	NR	
Am-241	M	3	D	4.44E-01	FGR11	NR	NR	NR	NR	
Am-243+D	M	3	D	4.40E-01	FGR11	NR	NR	NR	NR	
C-14	M	3	D	2.09E-06	FGR11	NR	NR	NR	NR	
Cm-243	M	3	D	3.07E-01	FGR11	NR	NR	NR	NR	
Co-60	M	3	D	2.19E-04	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	4.63E-05	FGR11	NR	NR	NR	NR	

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Cs-137+D	M	3	D	3.19E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	2.21E-04	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	2.86E-04	FGR11	NR	NR	NR	NR	
Eu-155	M	3	D	4.14E-05	FGR11	NR	NR	NR	NR	
Fe-55	M	3	D	2.69E-06	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	2.43E-01	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
Nb-94	M	3	D	4.14E-04	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	6.29E-06	FGR11	NR	NR	NR	NR	
Np-237+D	M	3	D	5.40E-01	FGR11	NR	NR	NR	NR	
Pa-231	M	3	D	1.28E+00	FGR11	NR	NR	NR	NR	
Pb-210+D	M	3	D	1.38E-02	FGR11	NR	NR	NR	NR	
Pu-238	M	3	D	3.92E-01	FGR11	NR	NR	NR	NR	
Pu-239	M	3	D	4.29E-01	FGR11	NR	NR	NR	NR	
Pu-241+D	M	3	D	8.25E-03	FGR11	NR	NR	NR	NR	
Ra-226+D	M	3	D	8.60E-03	FGR11	NR	NR	NR	NR	
Sb-125	M	3	D	1.22E-05	FGR11	NR	NR	NR	NR	
Sr-90+D	M	3	D	1.31E-03	FGR11	NR	NR	NR	NR	
Tc-99	M	3	D	8.33E-06	FGR11	NR	NR	NR	NR	
Th-229+D	M	3	D	2.16E+00	FGR11	NR	NR	NR	NR	
Th-230	M	3	D	3.26E-01	FGR11	NR	NR	NR	NR	
U-233	M	3	D	1.35E-01	FGR11	NR	NR	NR	NR	
U-234	M	3	D	1.32E-01	FGR11	NR	NR	NR	NR	
U-235+D	M	3	D	1.23E-01	FGR11	NR	NR	NR	NR	
Dose Conversion Factors (Ingestion mrem/pCi)										
Ac-227+D	M	3	D	1.48E-02	FGR11 (RESRAD Dose Conversion Library)	NR	NR	NR	NR	
Ag-108m	M	3	D	7.62E-06	FGR11	NR	NR	NR	NR	
Am-241	M	3	D	3.64E-03	FGR11	NR	NR	NR	NR	
Am-243+D	M	3	D	3.63E-03	FGR11	NR	NR	NR	NR	
C-14	M	3	D	2.09E-06	FGR11	NR	NR	NR	NR	
Cm-243	M	3	D	2.51E-03	FGR11	NR	NR	NR	NR	

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Co-60	M	3	D	2.69E-05	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	7.33E-05	FGR11	NR	NR	NR	NR	
Cs-137+D	M	3	D	5.00E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	6.48E-06	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	9.55E-06	FGR11	NR	NR	NR	NR	
Eu-155	M	3	D	1.53E-06	FGR11	NR	NR	NR	NR	
Fe-55	M	3	D	6.07E-07	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	1.61E-04	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
Nb-94	M	3	D	7.14E-06	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	5.77E-07	FGR11	NR	NR	NR	NR	
Np-237+D	M	3	D	4.44E-03	FGR11	NR	NR	NR	NR	
Pa-231	M	3	D	1.06E-02	FGR11	NR	NR	NR	NR	
Pb-210+D	M	3	D	5.37E-03	FGR11	NR	NR	NR	NR	
Pu-238	M	3	D	3.20E-03	FGR11	NR	NR	NR	NR	
Pu-239	M	3	D	3.54E-03	FGR11	NR	NR	NR	NR	
Pu-241+D	M	3	D	6.85E-05	FGR11	NR	NR	NR	NR	
Ra-226+D	M	3	D	1.33E-03	FGR11	NR	NR	NR	NR	
Sb-125	M	3	D	2.81E-06	FGR11	NR	NR	NR	NR	
Sr-90+D	M	3	D	1.53E-04	FGR11	NR	NR	NR	NR	
Tc-99	M	3	D	1.46E-06	FGR11	NR	NR	NR	NR	
Th-229+D	M	3	D	4.03E-03	FGR11	NR	NR	NR	NR	
Th-230	M	3	D	5.48E-04	FGR11	NR	NR	NR	NR	
U-233	M	3	D	2.89E-04	FGR11	NR	NR	NR	NR	
U-234	M	3	D	2.83E-04	FGR11	NR	NR	NR	NR	
U-235+D	M	3	D	2.67E-04	FGR11	NR	NR	NR	NR	
Plant Transfer Factors (pCi/g plant)/(pCi/g soil										
Ac-227+D	P	1	S	Loguniform	Chemical analogy to Am [3]	1.06E-05	3.31E-03			1.87E-04
Ag-108m	P	1	S	Uniform	Chemical analogy to Cu [3]	3.06E-06	2.63E-05			1.47E-05

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Am-241	P	1	S	Loguniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.06E-05	3.31E-3			1.87E-04
Am-243+D	P	1	S	Loguniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.06E-05	3.31E-3			1.87E-04
C-14	P	1	S	Loguniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	6.44E-04	6.96E-01			2.12E-02
Cm-243	P	1	S	Uniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.87E-04	3.31E-03			1.75E-03
Co-60	P	1	S	Uniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.04E-03	3.95E-03			2.50E-03
Cs-134	P	1	S	Uniform	Mean and Std Dev calculated using [3] and [2, Eqn 3.9-2]	2.39E-03	7.83E-02			4.03E-02
Cs-137+D	P	1	S	Uniform	Mean and Std Dev calculated using [3] and [2, Eqn 3.9-2]	2.39E-03	7.83E-02			4.03E-02
Eu-152	P	1	S	Loguniform	Chemical analogy to Am Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.06E-05	3.31E-03			1.87E-04
Eu-154	P	1	S	Loguniform	Chemical analogy to Am Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.06E-05	3.31E-03			1.87E-04
Eu-155	P	1	S	Loguniform	Chemical analogy to Am Min and Max values calculated [3] and [2, Eqn 3.9-2]	1.06E-05	3.31E-03			1.87E-04
Fe-55	P	1	S	Uniform	Mean and Std Dev calculated using [3] and [2, Eqn 3.9-2]	2.44E-01	1.32E+00			7.80E-01
Gd-152	P	1	S	Loguniform	Chemical analogy to Am [3]	1.06E-05	3.31E-03			1.87E-04
H-3	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	1.57	1.1	0.001	0.999	4.8
Nb-94	P	1	S	Loguniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.87E-04	1.14E-02			1.46E-03
Ni-63	P	1	S	Uniform	Mean and Std Dev calculated using [3] and [2, Eqn 3.9-2]	2.76E-02	6.96E-01			3.62E-01
Np-237+D	P	1	S	Loguniform	Min and Max values calculated [3] and [2, Eqn 3.9-2]	1.06E-05	1.14E-02			3.47E-04

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Pa-231	P	1	S	Loguniform	Chemical analogy to Nb [3]	1.87E-04	1.14E-02			1.46E-03
Pb-210+D	P	1	S	Lognormal-n	Mean and Std Dev calculated using [3] and [2, Eqn 3.9-2]	-15.48	1.57			1.88E-07
Pu-238	P	1	S	Loguniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.06E-05	6.44E-04			8.24E-05
Pu-239	P	1	S	Loguniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.06E-05	6.44E-04			8.24E-05
Pu-241+D	P	1	S	Loguniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.06E-05	6.44E-04			8.24E-05
Ra-226+D	P	1	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-3.22	0.9	0.001	0.999	4.0E-02
Sb-125	P	1	S	Lognormal-n	Mean and Std Dev calculated using [3] and [2, Eqn 3.9-2]	-9.37	1.98			8.50E-05
Sr-90+D	P	1	S	Uniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	5.87E-01	6.96E-01			6.42E-01
Tc-99	P	1	S	Uniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.85E-01	1.73E+00			9.60E-01
Th-229+D	P	1	S	Loguniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.06E-05	6.44E-04			8.24E-05
Th-230	P	1	S	Loguniform	Min and Max values calculated using [3] and [2, Eqn 3.9-2]	1.06E-05	6.44E-04			8.24E-05
U-233	P	1	S	Lognormal-n	Mean and Std Dev calculated using [3] and [2, Eqn 3.9-2]	-5.17	4.23			5.71E-03
U-234	P	1	S	Lognormal-n	Mean and Std Dev calculated using [3] and [2, Eqn 3.9-2]	-5.17	4.23			5.71E-03
U-235+D	P	1	S	Lognormal-n	Mean and Std Dev calculated using [3] and [2, Eqn 3.9-2]	-5.17	4.23			5.71E-03
Meat Transfer Factors (pCi/kg per pCi/d)										
Ac-227+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-10.82	1.0	0.001	0.999	2.0E-05
Ag-108m	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.21	0.7	0.001	0.999	2.0E-03

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Am-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.90	0.2	0.001	0.999	5.0E-05
Am-243+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.90	0.2	0.001	0.999	5.0E-05
C-14	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-3.47	1.0	0.001	0.999	3.1E-02
Cm-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-10.82	1.0	0.001	0.999	2.0E-05
Co-60	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-3.51	1.0	0.001	0.999	3.0E-02
Cs-134	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-3.00	0.4	0.001	0.999	5.0E-02
Cs-137+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-3.00	0.4	0.001	0.999	5.0E-02
Eu-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.21	1.0	0.001	0.999	2.0E-03
Eu-154	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.21	1.0	0.001	0.999	2.0E-03
Eu-155	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.21	1.0	0.001	0.999	2.0E-03
Fe-55	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-3.51	0.4	0.001	0.999	3.0E-02
Gd-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.21	1.0	0.001	0.999	2.0E-03
H-3	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-4.42	1.0	0.001	0.999	1.2E-02
Nb-94	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-13.82	0.9	0.001	0.999	1.0E-06
Ni-63	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-5.30	0.9	0.001	0.999	5.0E-03
Np-237+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.91	0.7	0.001	0.999	1.0E-03
Pa-231	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-12.21	1.0	0.001	0.999	5.0E-06
Pb-210+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-7.13	0.7	0.001	0.999	8.0E-04
Pu-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.21	0.2	0.001	0.999	1.0E-04
Pu-239	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.21	0.2	0.001	0.999	1.0E-04

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Pu-241+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.21	0.2	0.001	0.999	1.0E-04
Ra-226+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.91	0.7	0.001	0.999	1.0E-03
Sb-125	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.91	0.9	0.001	0.999	1.0E-03
Sr-90+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-4.61	0.4	0.001	0.999	1.0E-02
Tc-99	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.21	0.7	0.001	0.999	1.0E-04
Th-229+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.21	1.0	0.001	0.999	1.0E-04
Th-230	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.21	1.0	0.001	0.999	1.0E-04
U-233	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-7.13	0.7	0.001	0.999	8.0E-04
U-234	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-7.13	0.7	0.001	0.999	8.0E-04
U-235+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-7.13	0.7	0.001	0.999	8.0E-04
Milk Transfer Factors (pCi/L)/(pCi/d										
Ac-227+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-13.12	0.9	0.001	0.999	2.0E-06
Ag-108m	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-5.12	0.7	0.001	0.999	6.0E-03
Am-241	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-13.12	0.7	0.001	0.999	2.0E-06
Am-243+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-13.12	0.7	0.001	0.999	2.0E-06
C-14	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-4.4	0.9	0.001	0.999	1.2E-02
Cm-243	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-13.12	0.9	0.001	0.999	2.0E-06
Co-60	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.21	0.7	0.001	0.999	2.0E-03
Cs-134	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-4.61	0.5	0.001	0.999	1.0E-02

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Cs-137+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-4.61	0.5	0.001	0.999	1.0E-02
Eu-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.72	0.9	0.001	0.999	6.0E-05
Eu-154	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.72	0.9	0.001	0.999	6.0E-05
Eu-155	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.72	0.9	0.001	0.999	6.0E-05
Fe-55	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-8.11	0.7	0.001	0.999	3.0E-04
Gd-152	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.72	0.9	0.001	0.999	6.0E-05
H-3	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-4.6	0.9	0.001	0.999	1.0E-02
Nb-94	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-13.12	0.7	0.001	0.999	2.0E-06
Ni-63	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-3.91	0.7	0.001	0.999	2.0E-02
Np-237+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-11.51	0.7	0.001	0.999	1.0E-05
Pa-231	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-12.21	0.9	0.001	0.999	5.0E-06
Pb-210+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-8.11	0.9	0.001	0.999	3.0E-04
Pu-238	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-13.82	0.5	0.001	0.999	1.0E-06
Pu-239	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-13.82	0.5	0.001	0.999	1.0E-06
Pu-241+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-13.82	0.5	0.001	0.999	1.0E-06
Ra-226+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.91	0.5	0.001	0.999	1.0E-03
Sb-125	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-9.72	0.9	0.001	0.999	6.0E-05
Sr-90+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.21	0.5	0.001	0.999	2.0E-03
Tc-99	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-6.91	0.7	0.001	0.999	1.0E-03
Th-229+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-12.21	0.9	0.001	0.999	5.0E-06

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Th-230	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-12.21	0.9	0.001	0.999	5.0E-06
U-233	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-7.82	0.6	0.001	0.999	4.0E-04
U-234	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-7.82	0.6	0.001	0.999	4.0E-04
U-235+D	P	2	S	Truncated lognormal-n	NUREG/CR-6697, Att. C [2]	-7.82	0.6	0.001	0.999	4.0E-04
Bioaccumulation Factors for Fish ((pCi/kg)/(pCi/L))										
Ac-227+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	2.7	1.1			1.5E+01
Ag-108m	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	1.6	1.1			5.0E+00
Am-241	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.4	1.1			3.0E+01
Am-243+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.4	1.1			3.0E+01
C-14	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	10.8	1.1			4.9E+04
Cm-243	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.4	1.1			3.0E+01
Co-60	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	5.7	1.1			3.0E+02
Cs-134	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	7.6	0.7			2.0E+03
Cs-137+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	7.6	0.7			2.0E+03
Eu-152	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.9	1.1			4.9E+01
Eu-154	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.9	1.1			4.9E+01
Eu-155	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.9	1.1			4.9E+01
Fe-55	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	5.3	1.1			2.0E+02
Gd-152	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.2	1.1			2.5E+01
H-3	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	0	0.1			1.0E+00
Nb-94	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	5.7	1.1			3.0E+02
Ni-63	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	4.6	1.1			9.9E+01
Np-237+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.4	1.1			3.0E+01
Pa-231	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	2.3	1.1			1.0E+01
Pb-210+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	5.7	1.1			3.0E+02
Pu-238	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.4	1.1			3.0E+01
Pu-239	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.4	1.1			3.0E+01
Pu-241+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.4	1.1			3.0E+01
Ra-226+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3.9	1.1			4.9E+01

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Sb-125	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	4.6	1.1			9.9E+01
Sr-90+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	4.1	1.1			6.0E+01
Tc-99	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	3	1.1			2.0E+01
Th-229+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	4.6	1.1			9.9E+01
Th-230	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	4.6	1.1			9.9E+01
U-233	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	2.3	1.1			1.0E+01
U-234	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	2.3	1.1			1.0E+01
U-235+D	P	2	S	Lognormal-n	NUREG/CR-6697, Att. C [2]	2.3	1.1			1.0E+01
Bioaccumulation Factors for Crustacea/ Mollusks ((pCi/kg)/(pCi/L))										
Ac-227+D	P	3	D	1.00E+03	RESRAD Default	NR	NR	NR	NR	
Ag-108m	P	3	D	7.70E+02	RESRAD Default	NR	NR	NR	NR	
Am-241	P	3	D	1.00E+03	RESRAD Default	NR	NR	NR	NR	
Am-243+D	P	3	D	1.00E+03	RESRAD Default	NR	NR	NR	NR	
C-14	P	3	D	9.10E+03	RESRAD Default	NR	NR	NR	NR	
Cm-243	P	3	D	1.00E+03	RESRAD Default	NR	NR	NR	NR	
Co-60	P	3	D	2.00E+02	RESRAD Default	NR	NR	NR	NR	
Cs-134	P	3	D	1.00E+02	RESRAD Default	NR	NR	NR	NR	
Cs-137+D	P	3	D	1.00E+02	RESRAD Default	NR	NR	NR	NR	
Eu-152	P	3	D	1.00E+03	RESRAD Default	NR	NR	NR	NR	
Eu-154	P	3	D	1.00E+03	RESRAD Default	NR	NR	NR	NR	
Eu-155	P	3	D	1.00E+03	RESRAD Default	NR	NR	NR	NR	
Fe-55	P	3	D	3.20E+03	RESRAD Default	NR	NR	NR	NR	
Gd-152	P	3	D	1.00E+03	RESRAD Default	NR	NR	NR	NR	
H-3	P	3	D	1.00E+00	RESRAD Default	NR	NR	NR	NR	
Nb-94	P	3	D	1.00E+02	RESRAD Default	NR	NR	NR	NR	
Ni-63	P	3	D	1.00E+02	RESRAD Default	NR	NR	NR	NR	
Np-237+D	P	3	D	4.00E+02	RESRAD Default	NR	NR	NR	NR	
Pa-231	P	3	D	1.10E+02	RESRAD Default	NR	NR	NR	NR	
Pb-210+D	P	3	D	1.00E+02	RESRAD Default	NR	NR	NR	NR	
Pu-238	P	3	D	1.00E+02	RESRAD Default	NR	NR	NR	NR	
Pu-239	P	3	D	1.00E+02	RESRAD Default	NR	NR	NR	NR	

Table 3-1
Input Parameters for Sensitivity Analysis, Cellar Hole Concrete Debris
Resident Farmer/Intruder Scenario

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Pu-241+D	P	3	D	1.00E+02	RESRAD Default	NR	NR	NR	NR	
Ra-226+D	P	3	D	2.50E+02	RESRAD Default	NR	NR	NR	NR	
Sr-90+D	P	3	D	1.00E+02	RESRAD Default	NR	NR	NR	NR	
Sb-125	P	3	D	1.00E+01	RESRAD Default	NR	NR	NR	NR	
Tc-99	P	3	D	5.00E+00	RESRAD Default	NR	NR	NR	NR	
Th-229+D	P	3	D	5.00E+02	RESRAD Default	NR	NR	NR	NR	
Th-230	P	3	D	5.00E+02	RESRAD Default	NR	NR	NR	NR	
U-233	P	3	D	6.00E+01	RESRAD Default	NR	NR	NR	NR	
U-234	P	3	D	6.00E+01	RESRAD Default	NR	NR	NR	NR	
U-235+D	P	3	D	6.00E+01	RESRAD Default	NR	NR	NR	NR	
Graphics Parameters										
Number of points				32	RESRAD Default	NR	NR	NR	NR	
Spacing				log	RESRAD Default	NR	NR	NR	NR	
Time integration parameters										
Maximum number of points for dose				17	RESRAD Default	NR	NR	NR	NR	

Notes:

[a] P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
[b] 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter (see NUREG/CR-6697, Attachment B, Table 4.1)
[c] D = deterministic, S = stochastic
[d] Distributions Statistical Parameters:
Lognormal-n: 1= mean, 2 = standard deviation
Bounded lognormal-n: 1= mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Truncated lognormal-n: 1= mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Bounded normal: 1 = mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Beta: 1 = minimum, 2 = maximum, 3 = P-value, 4 = Q-value
Triangular: 1 = minimum, 2 = mode, 3 = maximum
Uniform: 1 = minimum, 2 = maximum

Additional Sensitivity Analysis Data:
Sampling technique = Latin Hypercube
Random Seed = 1000
Number of observations =2000

Number of repetitions = 1

Input Rank Correlation Coefficients:
Total porosity and Bulk density = - 0.99 (contaminated zone)
Evapotranspiration and Irrigation rate = 0.99
Distribution coefficient and Plant transfer factor = -0..99 (contaminated zone)

References:

1. Code of Federal Regulations, Title10, Section 20.1402, "Radiological Criteria for Unrestricted Use".
2. NUREG/CR-6697, "Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes", December 2000.
3. YA-REPT-01-003-03, "Basis for Selection of Concrete Kd Values,' August 2004.
4. Yu, C. et al., "Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil"; US Department of Energy – Argonne National Laboratory, April 1993.
5. Correspondence between J. Lynch and P. Littlefield, "RE. Concrete Debris,' August 4, 2004 (Attachment 1)
6. YA-REPT-00-008-03, "Evaluation of GeoTesting Express Soil Testing and Determination of Depth to Groundwater," December 2003
7. NUREG-1757. "Consolidated NMSS Decommissioning Guidance," Volume 2: Characterization, Survey and Determination of Radiological Criteria," September 2003.
8. YA-CALC-02-001-03, "RESRAD 6.21 Sensitivity Analysis for Resident Farmer Scenario – Soil," February 2004.
9. NUREG/CR-5512, Volume 3, "Residual Radioactive Contamination From Decommissioning: Parameter Analysis, Draft Report for Comment," October 1999.
10. Eckerman, K.F., et al., "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," EPA-520/1-88-020, Federal Guidance Report No. 11, U.S EPA, 1988.

Table 3-2
Input Parameters for Sensitivity Analysis, H-3 Graded Concrete Debris
Resident Farmer/Intruder Scenario

Graded Concrete Debris (Basis for scenario is Reference 2)

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Median
Contaminated Zone										
Thickness of contaminated zone (m)	P	2	S	Uniform	Minimum equal depth of soil mixing layer (0.15m); maximum equal depth to water table (3.8m) [4]	0.15	3.8			1.975
Saturated Zone Hydrological Data										
Density of saturated zone (g/cm**3)	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - sand [3]	1.5105	0.159	1.019	2.002	1.5105
Saturated zone total porosity	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - sand [3]	0.43	0.06	0.2446	0.6154	0.43
Saturated zone effective porosity	P	1	S	Bounded Normal	NUREG 6697 dist for site soil type - sand [3]	0.383	0.0610	0.195	0.572	0.383
Saturated zone field capacity	P	3	D	0.05	Site-specific value calculated using Equation 4.4 from [2, 3]	NR	NR	NR	NR	0.05
Saturated zone hydraulic conductivity (m/yr)	P	1	S	Beta	NUREG 6697 dist for site soil type - sand [3]	110	5870	1.398	1.842	2506
Saturated zone b parameter	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - sand [3]	- 0.0253	0.216	0.501	1.90	0.975
Model: Nondispersion (ND)	P	3	D	ND	ND model for contaminated area > 1000 m2 [1, 2]					
Well pumping rate (m**/yr)	P	2	S	Uniform	Min, Max, median value based on site irrigation and area and calculated according to NUREG/CR-6697, Att. C section 3.10 method. [3]	957	1689	NR	NR	1323
Unsaturated Zone Hydrological Data										
Number of unsaturated zones	P	3	D	1	[3]					
Unsat. zone 1, thickness (m)	P	1	S	Uniform	Assumes 0.15 to 3.8 m contaminated zone thickness and 3.8 m depth to water table [3]	0.01	3.65			1.82
Unsat. zone 1, soil density (g/cm**3)	P	2	S	Bounded Normal	NUREG 6697 dist for site soil type - sand [3]	1.5105	0.159	1.019	2.002	1.5105
Unsat. zone 1, total porosity	P	2	S	Bounded Normal	NUREG 6697 dist for site soil type - sand [3]	0.43	0.06	0.2446	0.6154	0.43

Table 3-2
Input Parameters for Sensitivity Analysis, H-3 Graded Concrete Debris
Resident Farmer/Intruder Scenario

Graded Concrete Debris (Basis for scenario is Reference 2)										
Unsat. zone 1, effective porosity	P	2	S	Bounded Normal	NUREG 6697 dist for site soil type - sand [3]	0.383	0.0610	0.195	0.572	0.383
Unsat. zone 1, field capacity	P	3	D	0.05	Site-specific value calculated using Equation 4.4 [2, 3]	NR	NR	NR	NR	0.05
Unsat. zone 1, hydraulic conductivity (m/yr)	P	2	S	Beta	NUREG 6697 dist for site soil type - sand [3]	110	5870	1.398	1.842	2506
Unsat. zone 1, soil-specific b parameter	P	2	S	Bounded Log Normal n	NUREG 6697 dist for site soil type - sand [3]	- 0.0253	0.216	0.501	1.90	0.975

References:

1. ANL/EAD-4, "Users Manual for RESRAD Version 6.0," Yu, C. et al., July 2001.
2. YA-CALC-02-001-03, "RESRAD 6.21 Sensitivity Analysis for Resident Farmer Scenario – Soil," February 2004.
3. NUREG/CR-6697, "Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes", December 2000.
4. YA-REPT-00-008-03, "Evaluation of GeoTesting Express Soil Testing and Determination of Depth to Groundwater," December 2003.

Table 3-3 - Sensitivity Analysis Summary, Percentile Values and Assignment of Conservative Values for Concrete Debris DCGL Determination

Nuclide R^2	Sensitive Parameter	PRCC	Distribution	Distribution Statistical Parameters				Mean	Percentile Values		Assigned Value
				1	2	3	4		25%	75%	
Ag-108m	External gamma shielding factor	1.0	Bounded Lognormal-n	-1.3	0.59	0.044	1	3.24E-01		3.98E-01	3.98E-01
R^2 = 1.0	Milk transfer factor for Ag	0.72	Truncated Lognormal -n	-5.12	0.7	0.001	0.999	7.64E-03		9.57E-03	9.57E-03
Am-241	Kd of Am in contaminated zone	-0.96	Loguniform	200	5000				4.47E02		
R^2 = 1.0	Weathering removal constant of all vegetation	-0.87	Triangular	5.1	18	84			2.15E01		
	Wet foliar interception fraction of leafy vegetables	0.60	Triangular	0.06	0.67	0.95		5.6E-01		7.00E-01	7.00E-01
	Wet weight crop yield of fruit, grain and non-leafy vege.	-0.56	Truncated Lognormal-n	0.56	0.48	0.001	0.999		1.27 E00		
	Plant transfer factor for Am	0.26	Loguniform	1.06E-05	3.31E-03			5.74E-04		7.86E-04	7.86E-04
	Fish transfer factor for Am	0.26	Lognormal-n	3.4	1.1			5.49E+01		6.29E01	6.29E01
C-14	Thickness of evasion layer of C-14 in soil	0.84	Triangular	0.2	0.3	0.6		3.67E-01		4.27E-01	4.27E-01
R^2 = 0.84	Fish transfer factor for C	0.67	Lognormal-n	10.8	1.1			8.98E04		1.03E05	1.03E05
Cm-243	Weathering removal constant of all vegetation	-0.81	Triangular	5.1	18	84			2.15E01		
R^2 = 0.99	Kd of Cm-243 in Contaminated Zone	-0.76	Uniform	200	1000				4.00E02		
	Wet foliar interception fraction of leafy vegetables	0.53	Triangular	0.06	0.67	0.95		5.6E-01		7.00E-01	7.00E-01
	Wet weight crop yield of fruit, grain and no-leafy vegetables	-0.48	Truncated Lognormal-n	0.56	0.48	0.001	0.999		1.27 E00		
	External gamma shielding factor	0.40	Bounded Lognormal-n	-1.3	0.59	0.044		3.24E-01		3.98E-01	3.98E-01
	Plant transfer factor for Cm	0.32	Uniform	1.87E-04	3.31E-03			1.75E-03		2.53E-03	2.53E-03
Co-60	External gamma shielding factor	1.0	Bounded Lognormal-n	-1.3	0.59	0.044	1	3.24E-01		3.98E-01	3.98E-01
R^2 = 1.0	Meat transfer factor for Co	0.66	Truncated Lognormal-n	-3.51	1.0	0.001	0.999	4.93E-02		5.85E-02	5.85E-02
Cs-134	External gamma shielding factor	0.88	Bounded Lognormal-n	-1.3	0.59	0.044	1	3.24E-01		3.98E-01	3.98E-01
R^2 = 0.91	Milk transfer factor for Cs	0.61	Truncated Lognormal-n	-4.61	0.5	0.001	0.999	1.13E-02		1.39E-02	1.39E-02
	Meat transfer factor for Cs	0.42	Truncated Lognormal-n	-3.00	0.4	0.001	0.999	5.39E-02		6.51E-02	6.51E-02
	Weathering removal constant of all vegetation	-0.29	Triangular	5.1	18	84			2.15E01		
Cs-137	External gamma shielding factor	0.81	Bounded Lognormal-n	-1.3	0.59	0.044	1	3.24E-01		3.98E-01	3.98E-01
R^2 = 0.94	Milk transfer factor for Cs	0.72	Truncated Lognormal-n	-4.61	0.5	0.001	0.999	1.13E-02		1.39E-02	1.39E-02
	Meat transfer factor for Cs	0.53	Truncated Lognormal-n	-3.00	0.4	0.001	0.999	5.39E-02		6.51E-02	6.51E-02
	Weathering removal constant of all vegetation	-0.37	Triangular	5.1	18	84			2.15E01		
	Fish transfer factor for Cs	0.30	Lognormal-n	7.6	0.7			2.55E03		3.20E03	3.20E03
	Plant transfer factor for Cs	0.28	Uniform	2.39E-03	7.83E-02			4.03E-02		5.93E-02	4.03E-02

Table 3-3 - Sensitivity Analysis Summary, Percentile Values and Assignment of Conservative Values for Concrete Debris DCGL Determination

Nuclide R^2	Sensitive Parameter	PRCC	Distribution	Distribution Statistical Parameters				Mean	Percentile Values		Assigned Value
				1	2	3	4		25%	75%	
Eu-152 $R^2 = 1.0$	External gamma shielding factor	1	Bounded Lognormal-n	-1.3	0.59	0.044	1	3.24E-01		3.98E-01	3.98E-01
Eu-154 $R^2 = 1.0$	External gamma shielding factor	1	Bounded Lognormal-n	-1.3	0.59	0.044	1	3.24E-01		3.98E-01	3.98E-01
Eu-155 $R^2 = 1.0$	External gamma shielding factor	1	Bounded Lognormal-n	-1.3	0.59	0.044	1	3.24E-01		3.98E-01	3.98E-01
Fe-55 $R^2 = 0.98$	Meat transfer factor for Fe	0.89	Truncated Lognormal-n	-3.51	0.4	0.001	0.999	3.23E-02		3.91E-02	3.91E-02
	Plant transfer factor for Fe	0.66	Uniform	2.44E-01	1.32E00			7.82E-01		1.05E00	1.05E00
	Weathering removal constant of all vegetation	-0.54	Triangular	5.1	18	84			2.15E01		
	Fish transfer factor for Fe	0.31	Lognormal-n	5.3	1.1			3.67E02		4.20E02	4.20E02
	Milk transfer factor for Fe	0.30	Truncated Lognormal-n	-8.11	0.7	0.001	0.999	3.84E-04		4.81E-04	4.81E-04
H-3 cellar hole $R^2 = 0.98$	Density of contaminated zone	0.62	Uniform	1.41	1.67			1.54E00		1.60E00	1.60E00
	Irrigation	-0.58	Uniform	0.252	0.618			4.35E-01	3.43E-01		3.43E-01
H-3 graded $R^2 = 0.97$	Depth of roots	-0.73	Uniform	0.3	3.8			2.05E00	1.17E00		1.17E00
	Thickness of contaminated zone	0.66	Uniform	0.15	3.8			1.98E00		2.89E00	2.89E00
Nb-94 $R^2 = 1.0$	External gamma shielding factor	1	Bounded Lognormal-n	-1.3	0.59	0.044	1	3.24E-01		3.98E-01	3.98E-01
Ni-63 $R^2 = 0.95$	Milk transfer factor for Ni	0.93	Truncated Lognormal-n	-3.91	0.7	0.001	0.999	2.56E-02		3.21E-02	3.21E-02
	Plant transfer factor for Ni	0.41	Uniform	2.76E-02	6.96E-01			3.62E-01		5.29E-01	5.29E-01
	Weathering removal constant of all vegetation	-0.31	Triangular	5.1	18	84			2.15E01		
Pu-238 $R^2 = 0.99$	Kd of Pu in contaminated zone	-0.83	Loguniform	500	5000				8.88E02		
	Weathering removal constant of all vegetation	-0.74	Triangular	5.1	18	84			2.15E01		
	Wet foliar interception fraction of leafy vegetables	0.41	Triangular	0.06	0.67	0.95		5.6E-01		7.00E-01	7.00E-01
	Wet weight crop yield of fruit, grain and non-leafy vege.	-0.36	Truncated Lognormal-n	0.56	0.48	0.001	0.999		1.27E00		
Pu-239 $R^2 = 1.0$	Kd of Pu in contaminated zone	-0.91	Loguniform	500	5000				8.88E02		
	Weathering removal constant of all vegetation	-0.87	Triangular	5.1	18	84			2.15E01		
	Wet foliar interception fraction of leafy vegetables	0.59	Triangular	0.06	0.67	0.95		5.6E-01		7.00E-01	7.00E-01
	Wet weight crop yield of fruit, grain and non-leafy vege	-0.55	Truncated Lognormal-n	0.56	0.48	0.001	0.999		1.27E00		
	Fish transfer factor for Pu	0.27	Lognormal-n	3.4	1.1			5.49E+01		6.29E01	6.29E01

Table 3-3 - Sensitivity Analysis Summary, Percentile Values and Assignment of Conservative Values for Concrete Debris DCGL Determination

Nuclide R^2	Sensitive Parameter	PRCC	Distribution	Distribution Statistical Parameters				Mean	Percentile Values		Assigned Value
				1	2	3	4		25%	75%	
Pu-241 $R^2 = 1.0$	Kd of Am241 in contaminated zone	-0.95	Loguniform	200	5000				4.47E02		
	Weathering removal constant of all vegetation	-0.85	Triangular	5.1	18	84			2.15E01		
	Wet foliar interception fraction of leafy vegetables	0.56	Triangular	0.06	0.67	0.95		5.6E-01		7.00E-01	7.00E-01
	Wet weight crop yield of fruit, grain and non-leafy vege	-0.51	Truncated Lognormal-n	0.56	0.48	0.001	0.999		1.27E00		
Sb-125 $R^2 = 1.0$	External gamma shielding factor	1	Bounded Lognormal-n	-1.3	0.59	0.044	1	3.24E-01		3.98E-01	3.98E-01
Sr-90 $R^2 = 0.91$	Milk transfer factor	0.91	Truncated Lognormal-n	-6.21	0.5	0.001	0.999	2.28E-03		2.81E-03	2.81E-03
	Weathering removal constant of all vegetation	-0.76	Triangular	5.1	18	84			2.15E01		
	Meat transfer factor for Sr	0.74	Truncated Lognormal-n	-4.61	0.4	0.001	0.999	1.08E-02		1.3E-02	1.3E-02
Tc-99 $R^2 = 0.99$	Milk transfer factor for Tc	0.84	Truncated Lognormal-n	-6.91	0.7	0.001	0.999	1.28E-03		1.60E-03	1.60E-03
	Plant transfer factor for Tc	0.79	Uniform	1.85E-01	1.73E00			9.60E-01		1.34E00	1.34E00
	Weathering removal constant of all vegetation	-0.48	Triangular	5.1	18	84			2.15E01		

- Source of percentile values is RESRAD ".MCO" files.

Loguniform mean calculated using NUREG/CR-6697, Attachment C, Appendix A
Mean = b -a / (lnb – lna)
a = min
b = max

Triangular mean calculated using NUREG/CR-6697, Attachment C, Appendix A
Mean = (a + b + c) / 3
a = min
b = most likely
c = max

Lognormal mean calculated using the following:
$\mu = \exp([2m+s^2] / 2)$
Where the mean = m and std dev = s, both of the underlying normal distribution

Attachment 4

Table 4-1 - DCGL for Concrete Debris and % Dose from Exposure Pathways
And
Table 4-2 – Equilibrium Groundwater Concentrations

Table 4-1 – DCGL for Concrete Debris and % Dose from Exposure Pathways

Nuclide	DCGL for Concrete Debris (pCi/gm)	Time to Maximum Dose (yr)	Dose Fraction from Water-Independent Pathways (%)					Dose Fraction from Water-Dependent Pathways (%)					
			Ground	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk
H-3 cellar hole	100	0	0.0	0.05	1.74	0.03	0.18	0.0	85.13	0.00	12.13	0.10	0.64
H-3 graded	300	0	0.0	0.57	42.55	7.02	47.95	0.0	0.65	0.02	0.92	0.03	0.28
C-14	7.6	0	0.0	0.01	51.50	22.15	21.01	0.0	0.16	4.64	0.34	0.10	0.09
Fe-55	150	0	0.0	0.0	46.39	24.42	2.48	0.0	11.89	1.85	4.09	8.15	0.71
Co-60	4.5	0	97.02	0.0	0.15	0.99	0.14	0.01	0.73	0.06	0.13	0.62	0.14
Ni-63	110	0	0.0	0.0	17.74	1.21	63.82	0.0	3.21	0.09	0.97	0.028	12.67
Sr-90	0.8	0	0.02	0.0	40.85	7.23	12.83	0.01	20.51	0.37	6.42	4.66	7.11
Nb-94	7.4	0	99.57	0.0	0.04	0.0	0.0	0.0	0.30	0.03	0.05	0.0	0.0
Tc-99	64	0.23	0.01	0.0	67.83	0.09	12.06	0.01	12.71	0.07	4.65	0.02	2.55
Ag-108m	7.4	0	99.70	0.0	0.0	0.01	0.25	0.0	0.02	0.0	0.0	0.0	0.01
Sb-125	33	0	99.82	0.0	0.0	0.01	0.0	0.01	0.12	0.0	0.02	0.0	0.0
Cs-134	5.0	0	54.85	0.0	6.53	8.20	11.99	0.02	3.90	2.22	1.06	4.45	6.71
Cs-137	7.1	0	33.63	0.0	11.16	12.59	19.40	0.02	4.66	4.16	1.25	5.24	7.88
Eu-152	10	0	99.82	0.0	0.01	0.02	0.0	0.0	0.12	0.0	0.02	0.0	0.0
Eu-154	9.6	0	99.76	0.0	0.01	0.02	0.0	0.0	0.16	0.0	0.03	0.0	0.0
Eu-155	400	0	98.46	0.0	0.06	0.15	0.02	0.03	1.04	0.03	0.18	0.03	0.01
Pu-238	10	0.12	0.0	0.25	1.60	0.46	0.02	1.97	71.14	0.68	23.74	0.12	0.01
Pu-239	9.3	0.28	0.0	0.25	1.59	0.45	0.02	1.96	70.68	1.32	23.59	0.12	0.01
Pu-241	150	65	0.05	0.39	3.29	0.07	0.03	3.08	68.67	0.03	22.85	0.11	0.01
Am-241	4.3	0.12	0.23	0.12	6.97	0.11	0.02	0.94	67.14	1.99	22.41	0.06	0.02
Cm-243	4.9	0.10	4.20	0.09	17.13	0.04	0.02	0.72	57.42	1.18	19.18	0.02	0.01

Table 4-2 – Comparison of Well Water Concentrations and Equilibrium Ground Water Concentrations at One Year

Nuclide	Well Water Concentration (pCi/L)	Equilibrium Ground Water Concentration (pCi/L)
H-3 cellar hole	1143	218.78
C-14	1.34	1.17
Fe-55	61.38	60.65
Co-60	3.11	3.11
Ni-63	27.88	27.77
Sr-90	92.09	90.80
Nb-94	3.16	3.16
Tc-99	73.51	72.71
Ag-108m	0.15	0.15
Sb-125	0.50	0.50
Cs-134	5.21	5.21
Cs-137	7.13	7.12
Eu-152	0.95	0.95
Eu-154	0.92	0.92
Eu-155	0.87	0.87
Pu-238	1.12	1.12
Pu-239	1.13	1.13
Pu-241	0.60	0.60
Am-241	2.23	2.23
Cm-243	2.44	2.44

Attachment 5

YA_CALC-00-002-04 CD Contents

Selected portions of the concrete debris RESRAD output files are located on the accompanying CD. The intended use of these pages is to verify the deterministic and probabilistic input values, the sensitivity analysis results, deterministic dose and subsequent DCGL and the well water concentrations.

CD Name: YA-CALC-00-002-04

File: 1. deterministic summary.rep pages

Included pages are in alphabetical order by nuclide:

- Table of Contents
- Deterministic Parameter Values
- Contaminated Zone and Total Dose Summary @ Tmax and the Total Dose Summary if Tmax @ t =0

2..probabilistic mcsummar.rep pages

Included pages are in alphabetical order by nuclide:

- Part VI, Uncertainty Analysis
- Probabilistic Input
- Page Coef 1, Coefficients for Peak of the Mean Dose

3.. concent.rpt pages

Included pages are in alphabetical order by nuclide:

- Page 3, Concentration of Radionuclide in Environmental Media