OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

2. ☒ Analysis — Check all that apply

Type of Analysis	☐ Engineering	
	☒ Performance Assessment	
	☒ Scientific	
Intended Use of Analysis	☐ Input to Calculation	
	☒ Input to another Analysis or Model	
	☒ Input to Technical Document	
	☒ Input to other Technical Products	
Describe use:		

3. ☒ Model — Check all that apply

Type of Model	☒ Conceptual Model	☐ Abstraction Model
	☒ Mathematical Model	☐ System Model
	☐ Process Model	
Intended Use of Model	☐ Input to Calculation	
	☒ Input to another Model or Analysis	
	☒ Input to Technical Document	
	☒ Input to other Technical Products	
Describe use:		

4. Title:

Disruptive Event Biosphere Dose Conversion Factor Analysis

5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-MGR-MD-000003 REV 01

6. Total Attachments:

5

7. Attachment Numbers - No. of Pages in Each:

I - 10, II - 24, III - 6, IV - 12, V - 6

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8.	Originator	Maryla A. Wasiolek	SIGNATURE ON FILE	12/2800
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12. Remarks:

2. Analysis or Model Title:

Disruptive Event Biosphere Dose Conversion Factor Analysis

3. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-MGR-MD-000003 REV 01

4. Revision/Change No.	5. Description of Revision/Change
Revision 0	Initial issue
Revision 1	Revision to incorporate the revised exposure scenarios, re-developed input parameters, especially those related to mass loading (concentration of suspended particulates in air), add pathway and limited uncertainty analyses; append the list of radionuclides to include those important for up to 1 million years after the potential repository closure; remove bounding case, and add biosphere model validation (moved from ANL-MGR-MD-000011 REV 00). Entire AMR has been revised because changes were extensive. This revision supersedes REV 00.

EXECUTIVE SUMMARY

The purpose of this report was to document the process leading to, and the results of, development of radionuclide-, exposure scenario-, and ash thickness-specific Biosphere Dose Conversion Factors (BDCFs) for the postulated postclosure extrusive igneous event (volcanic eruption) at Yucca Mountain. BDCF calculations were done for seventeen radionuclides. The selection of radionuclides included those that may be significant dose contributors during the compliance period of up to 10,000 years, as well as radionuclides of importance for up to 1 million years postclosure. The approach documented in this report takes into account human exposure during three different phases at the time of, and after, volcanic eruption. Calculations of disruptive event BDCFs used the GENII-S computer code in a series of probabilistic realizations to propagate the uncertainties of input parameters into the output. The pathway analysis included consideration of different exposure pathway's contribution to the BDCFs.

BDCFs for volcanic eruption, when combined with the concentration of radioactivity deposited by eruption on the soil surface, allow calculation of potential radiation doses to the receptor of interest. Calculation of radioactivity deposition is outside the scope of this report and so is the transport of contaminated ash from the volcano to the location of the receptor. The integration of the biosphere modeling results (BDCFs) with the outcomes of the other component models is accomplished in the Total System Performance Assessment (TSPA), in which doses are calculated to the receptor of interest from radionuclides postulated to be released to the environment from the potential repository at Yucca Mountain.

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ACRONYMS AND ABBREVIATIONS

Acronyms

AMAD	Activity Median Aerodynamic Diameter
AMCG	Average Member of the Critical Group
AMR	Analysis Model Report
BDCF	Biosphere Dose Conversion Factor
CNWRA	Center for Nuclear Waste Regulatory Analyses
CEDE	Committed Effective Dose Equivalent
CRWMS M&O	Civilian Radioactive Waste Management System Management and Operating Contractor
DCF	Dose Conversion Factor
DF	Dose Factors
DOE	U.S. Department of Energy
DTN	Data Tracking Number
EDE	Effective Dose Equivalent
EPA	U.S. Environmental Protection Agency
FEP	Feature, Event, and Process
GENII-S	Hanford Environmental Dosimetry System (Generation II or GENII – Sensitivity and Uncertainty Analysis Shell)
KTI	Key Technical Issue
LHS	Latin Hypercube Sampling
MC	Monte Carlo (Sampling)
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
PA	Performance Assessment
PDF	Probability Distribution Function
SR	Site Recommendation
STD	Standard Deviation
TDMS	Technical Data Management System
TEDE	Total Effective Dose Equivalent
TSPA	Total System Performance Assessment

ACRONYMS AND ABBREVIATIONS (Continued)

TSPAI	Total System Performance Assessment and Integration
TSPA-SR	Total System Performance Assessment for the SR
YMP	Yucca Mountain Site Characterization Project

Abbreviations

Ac	Actinium
Am	Americium
At	Astatine
Ba	Barium
Bq	becquerel
Bi	Bismuth
cm	centimeter
Ci	curie
Cs	Cesium
d	day
Eq.	equation
Fr	Francium
hr	hour
in	inch
kg	kilogram
m	meter
mm	millimeter
mo	month
Np	Neptunium
Pa	Protactinium
pCi	picocurie
Pb	Lead
Po	Polonium
Pu	Plutonium
Ra	Radium
Rn	Radon

ACRONYMS AND ABBREVIATIONS (Continued)

rem	unit of dose
Sr	Strontium
Sv	Sievert
Th	Thorium
Tl	Thallium
U	Uranium
Y	Yttrium
yr	year

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1. PURPOSE

The biosphere model is one of the component process models of the Total System Performance Assessment (TSPA) model. The biosphere model considers the movement of radionuclides in the reference biosphere and human exposure to these radionuclides. The outcome of biosphere model consists of radionuclide-specific biosphere dose conversion factors (BDCFs). BDCFs are included, together with other parameters, in the input for the TSPA code, which allows dose assessment from the postulated radionuclide releases from the potential repository.

The objective of biosphere modeling is to evaluate human exposure to radionuclides present in environmental media, such as water, soil, air, and food. Such exposures may be internal or external in origin. Internal exposure pathways considered in the biosphere model include ingestion and inhalation of radionuclides. The external exposure pathway considered external irradiation from contaminated soil. BDCFs for the disruptive event quantify internal and external exposure to the receptor of interest resulting from radioactive ash deposited on the soil surface. The integration of the biosphere modeling results for the disruptive event and other models of the TSPA system is shown in Figure 1. The figure shows the diagram of the component models contributing to the TSPA.

The evolution of the approach to the biosphere modeling for disruptive events is an iterative process. The previous revision of this Analysis Model Report (AMR) (CRWMS M&O 2000a) developed a set of BDCFs for disruptive events that concerned environmental conditions following volcanic eruption that are different from what is currently considered. Subsequent to the previous revision of this AMR a calculation report was produced (CRWMS M&O 2000b) in accordance with AP-3.12Q, *Calculations*, in which three exposure scenarios based on three phases during and after volcanic eruption and two thicknesses of contaminated volcanic ash were taken into account. Also, the list of radionuclides of interest was extended to include radionuclides important for up to 1 million years to support the National Environmental Policy Act process. BDCFs generated in such a way were used as input to the TSPA-Site Recommendation (SR) (CRWMS M&O 2000c). This revision will be used in the TSPA-SR Rev 1, which will support the Site Recommendation Report. The current analysis supersedes the preceding one; it also includes the consideration of the 10-year-average conditions of mass loading, as well as the pathway and limited uncertainty analyses. Furthermore, the bounding case considered in the previous AMR has been removed.

Disruptive processes and events important to the total system performance of the potential repository include volcanism, seismic events and inadvertent human intrusion. Volcanic (igneous) events are classified as either extrusive or intrusive type. Extrusive igneous events are postulated to result in a direct deposition of contaminated volcanic ash on the ground, while intrusive events are postulated to lead to the groundwater contamination with radionuclides released from the potential repository. Biosphere modeling of disruptive events resulting in radionuclide release into the groundwater uses the same radionuclide transport and uptake elements of the model as those considered for the nominal performance. BDCFs for all cases that share groundwater contamination scenario are being developed in the *Nominal Performance BDCF Analysis* (ANL-MGR-MD-000009 REV 01). BDCFs developed in this report apply to the direct release of radionuclides from the potential repository as a result of extrusive igneous activity.

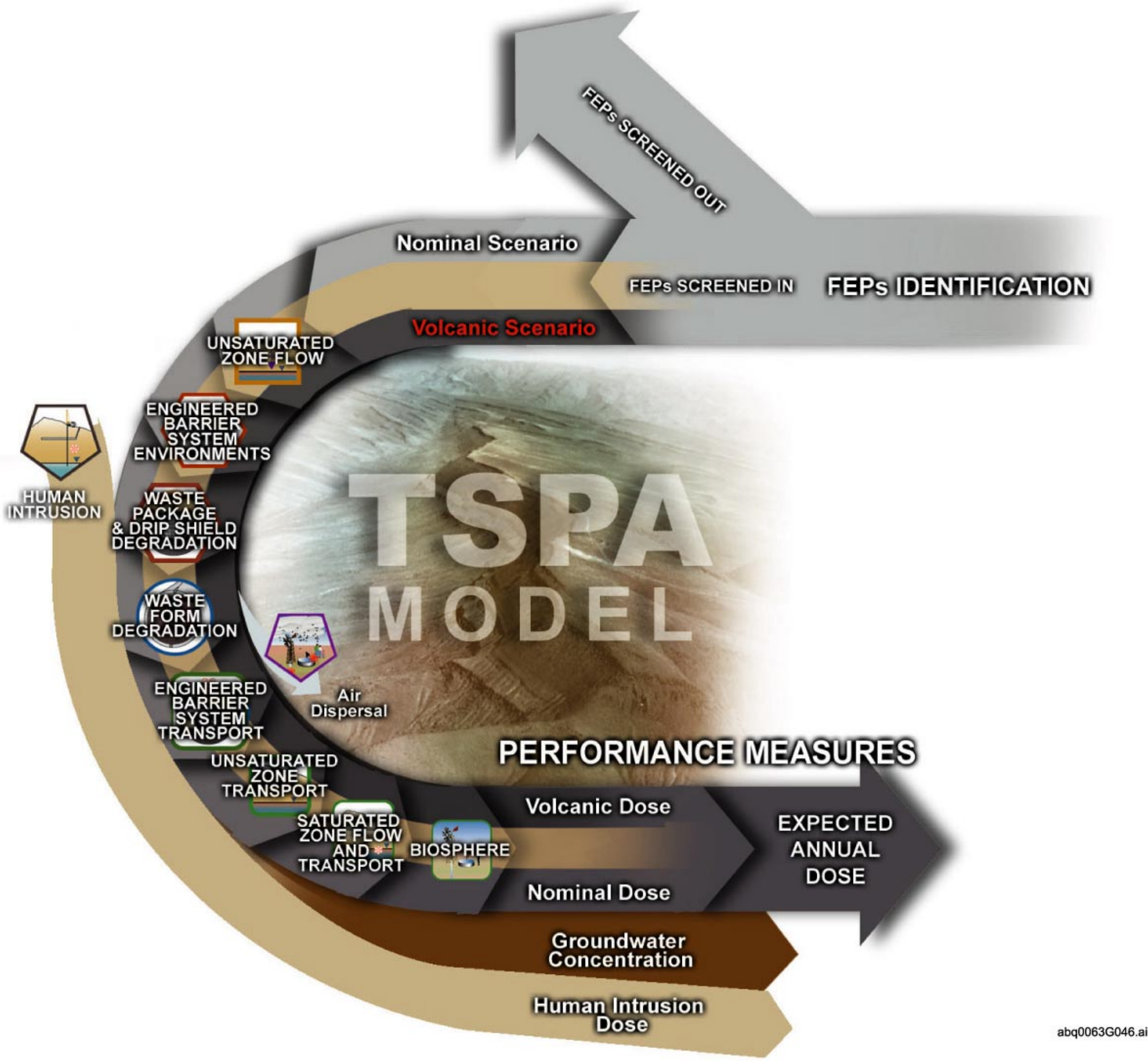


Figure 1. Summary of the Total System Performance Assessment-Site Recommendation Scenarios, Models and Analyses

Table 1 contains the summary of `the scenarios and the corresponding radionuclides of interest considered in biosphere modeling. BDCFs for radionuclides important for the igneous intrusive scenario were not specifically developed. However, the BDCFs for groundwater release can be used for this purpose within the limits of applicability of the dose conversion factors for chronic exposure used in the BDCF development.

Table 1. Summary of Scenarios and Radionuclides of Interest

Radionuclide	Groundwater Release (ANL-MGR-MD-000009 REV 01)				Direct Release (This AMR)	
	Nominal Performance Scenario		Human Intrusion Scenario		Extrusive Volcanic Event Scenario	
	10,000 yr.	1,000,000 yr.	10,000 yr.	1,000,000 yr.	10,000 yr.	1,000,000 yr.
^{14}C	×		×			
^{90}Sr			×		×	
^{63}Ni			×			
^{99}Tc	×		×			
^{129}I	×		×			
^{137}Cs			×		×	
^{210}Pb		×		×		×
^{226}Ra		×		×		×
^{227}Ac	×		×		×	
^{229}Th	×		×		×	
^{230}Th		×		×		×
^{231}Pa		×		×	×	
^{232}U	×		×		×	
^{233}U	×		×		×	
^{234}U	×		×		×	
^{236}U	×		×			
^{238}U	×		×			
^{237}Np	×		×			
^{238}Pu	×		×		×	
^{239}Pu	×		×		×	
^{240}Pu	×		×		×	
^{242}Pu		×		×		×
^{241}Am	×		×		×	
^{243}Am	×		×		×	

The scope of analysis encompasses development of BDCFs for an average member of the critical group for the:

- Seventeen radionuclides of interest for direct release, as indicated in the 'Direct Release' (last two) columns of Table 1.
- Three exposure scenarios corresponding to three phases during and following volcanic eruption: eruption phase, transition phase and steady-state phase.
- Two thicknesses of volcanic ash deposition on the ground: 1 cm and 15 cm.
- Two types of mass loading value: annual average and 10-year average.

Activities described in this report were conducted in accordance with the *Technical Work Plan for Biosphere Modeling And Expert Support* (CRWMS M&O 2000d). The analysis was conducted in accordance with the Office of Civilian Radioactive Waste Management (OCRWM) procedure AP-3.10Q, *Analyses and Models*.

2. QUALITY ASSURANCE

The activities documented in this AMR were evaluated in accordance with AP-2.21Q*, Quality Determinations and Planning for Scientific, Engineering, and Regulatory Compliance Activities,* and were determined to be quality affecting and subject to the requirements of the U.S. Department of Energy (DOE) OCRWM Quality Assurance Requirements and Description (QARD) (DOE 2000). This evaluation is documented in the Technical Work Plan (CRWMS M&O 2000d). Consequently, the modeling or analysis activities documented in this AMR have been conducted in accordance with the Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) quality assurance program, using approved procedures.

The primary implementing procedure for this work is OCRWM procedure AP-3.10Q, Analyses and Models. To perform this work, several other procedures are invoked by AP-3.10Q. These include the following:

- AP-2.14Q, *Review of Technical Products*
- AP-2.21Q, *Quality Determinations and Planning for Scientific, Engineering, and Regulatory Compliance Activities*
- AP-3.4Q, *Level 3 Change Control*
- AP-3.14Q, *Transmittal of Input*
- AP-3.15Q, *Managing Technical Product Inputs*
- AP-3.17Q, *Impact Reviews*
- AP-6.1Q, *Controlled Documents*
- AP-17.1Q, *Record Source Responsibilities for Inclusionary Records*
- AP-SI.1Q, *Software Management*
- AP-SIII.2Q, *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data*
- AP-SIII.3Q*, Submittal and Incorporation of Data to the Technical Data Management System*
- AP-SIII.4Q, *Development, Review, Online Placement, and Maintenance of Individual Reference Information Base Data Items*
- AP-SV.1Q, *Control of the Electronic Management of Data*.

Personnel performing work on this analysis were trained and qualified according to OCRWM procedures AP-2.1Q, *Indoctrination and Training of Personnel*, and AP-2.2Q, *Establishment* *and Verification of Required Education and Experience of Personnel*. Preparation of this analysis did not require the classification of items in accordance with CRWMS M&O procedure QAP-2-3, *Classification of Permanent Items*. This analysis is not a field activity. Therefore, a *Determination of Importance Evaluation* in accordance with CRWMS M&O procedure NLP-2-0, *Determination of Importance Evaluations,* was not required.

Evaluation of electronic data management process control was performed and documented (CRWMS M&O 2000d) in accordance with AP-SV.1Q, *Control of the Electronic Management of Data* and was accomplished in accordance with the controls specified in the Technical Work Plan (CRWSM M&O 2000d). The control process ensuring accuracy and completeness as well as security of data included the following. Access to the data contained on the personal computers used to perform this work was controlled (password protected). The data were stored on the network drive, which was periodically backed up and updated daily, as appropriate.

The development of BDCF did not depend on electronic data transfer for the model input. Upon completion of model runs, the files generated by the computer code were transferred to the Modeling Warehouse Database of the Technical Data Management System. To accomplish this transfer, the files were compressed, using the WinZip utility to maintain data security and integrity. The list of the transferred files, including filename, file size, and date the file was generated is included in Attachment IV.

3. COMPUTER SOFTWARE AND MODEL USAGE

The computer code GENII-S V1.4.8.5 was used to calculate BDCFs for extrusive volcanic activity (Sandia National Laboratories 1998). GENII-S is a computer program used to calculate statistical and deterministic values of radiation doses to humans from exposure to radionuclides in the environment. GENII-S is acquired software, which was qualified for use on the Yucca Mountain Project (CRWMS M&O 1998a). Justification for the selection of this software to perform calculation of radionuclide transport in the biosphere and uptake by a human receptor is documented in a letter from M.W. Harris to W.R. Dixon (Harris 1997).

The GENII-S computer code consists of an executable program and auxiliary files, all of which are maintained under Configuration Management (CM) (CSCI: 30034 V1.4.8.5). The software was obtained from CM; it is appropriate for this application; and was used within the range of validation in accordance with AP-SI.1Q, *Software Management*, as described in the software qualification report (CRWMS M&O 1998a). The analysis was performed using Gateway 2000 Personal Computers, CPU# 111161 and 111163 located in Building 3, Summerlin, in cubicles number 327D, and 327C, respectively.

The biosphere model used by GENII-S was validated in accordance with AP-3.10Q (see Attachment II for details) and was used within the range of validation. The documentation, inputs, and outputs for the biosphere model for the extrusive volcanic event has been placed within the Model Warehouse component of the Technical Data Management System (TDMS), DTN MO0010MWDPBD03.007, *Biosphere Dose Conversion Factors for Disruptive Event*.

BDCF pathway contributions (see table and figures in Section 6.7) were developed using Microsoft Excel version 97 SR-2. To accomplish this, portions of GENII-S output files were copied into the spreadsheet. Determination of pathway contributions to BDCFs was done using the *Pathway Contribution* software routine described in Attachment V of this report in accordance with AP-SI.1Q, *Software Management*.

4. INPUTS

4.1 DATA AND PARAMETERS

Input parameters were developed in a series of analyses and model reports (AMRs) and a calculation, which are listed in Table 2. The data sets used in this calculation of the volcanic eruption BDCFs are listed in Table 2. Selection of the values, ranges, and distributions of input parameters as well as justification of the applicability of the selected data to the specific exposure scenarios considered for the proposed Yucca Mountain repository is described in the corresponding AMRs, which are also listed in Table 2 together with the corresponding data tracking numbers (DTNs). Some input parameters were developed in this analysis and are documented in this report. Input parameters developed in this report include selected ingestion pathway parameters (see Attachment III for details) and selected dose coefficients (see Section 6.5.2.2).

Input parameters listed as items 1 through 7 in Table 2 were developed specifically for the purpose of GENII-S analyses and are, therefore, appropriate for the use in this model. The values of dose conversion factors and dose coefficients (DCF) (i.e., factors used to convert exposure to radionuclides to dose) apply to chronic low-level intakes and exposure conditions and are inappropriate for acute, high-level intakes and exposures. Therefore the BDCFs developed using such DCFs can not be applied to acute, high-level exposures to radionuclides.

4.2 CRITERIA

Total System Performance Assessment and Integration (TSPAI) U.S. Nuclear Regulatory Commission (NRC) Key Technical Issue (KTI) (NRC 2000) includes subissues and the related technical acceptance criteria that are applicable to this work scope because the biosphere model is one of the TSPA component models. The TSPAI subissues include:

- Subissue 1, System Description and Demonstration of Multiple Barriers
- Subissue 2, Scenario Analysis
- Subissue 3, Model Abstraction
- Subissue 4, Demonstration of the Overall Performance Objective.

The acceptance criteria associated with these subissues that are applicable to the development of BDCFs are relevant to several concepts which are addressed throughout this document. They include the following:

- The pedigree of data is clearly identified
- Input parameter development and basis for their selection is described
- Documents and reports are clear and consistent
- Data and model uncertainty is discussed
- Alternative modeling approaches are presented.

Table 2. Input Data

No.	Data Tracking Number/Data Title Document Identifier/Document Title	Parameters/Comments
1	MO0010SPAPET07.004 Environmental Transport Parameters <u>Source of the DTN</u> ANL-MGR-MD-000007 REV 00/ICN 1, *Environmental Transport Parameters Analysis* (CRWMS M&O 2000f)	Deposition velocity Crop resuspension factor Crop biomass Depth of surface soil Surface and deep soil density Fraction of roots in surface soil Fraction of roots in deep soil Soil ingestion rate Weathering half-life Translocation factor Animal feed and water consumption rate Dry-to-wet ratio
2	MO0010SPAPTC08.005, Transfer Coefficients <u>Source of the DTN</u> ANL-MGR-MD-000008 REV 00/ICN 2, *Transfer Coefficient Analysis,* (CRWMS M&O 2000g)	Soil-to-plant transfer coefficients Soil-to-plant transfer scaling factor Animal feed-to-animal transfer coefficients Animal feed-to-animal transfer scaling factor Bioaccumulation factors
3	MO0010SPAAAM01.014, Input Parameter Values for External and Inhalation Radiation Exposure Analysis <u>Source of the DTN</u> ANL-MGR-MD-000001 REV 01, *Input Parameter Values for External and Inhalation Radiation Exposure Analysis* (CRWMS M&O 2000h)	Mass loading Inhalation exposure time Chronic breathing rate Soil exposure time Home irrigation rate Duration of home irrigation
4	MO0002RIB00068.000, Ingestion Exposure Parameter Values <u>Source of the DTN</u> ANL-MGR-MD-000006 REV 00, *Identification of Ingestion Exposure Parameters* (CRWMS M&O 2000i)	Irrigation water source Drinking water treatment Crop interception fraction Water contaminated fraction Irrigation water contamination fraction Aquatic food consideration Holdup time Storage time Dietary fraction Selected parameters from this data set (irrigation time, irrigation rate, food yield, grow time) were re-developed as documented in Attachment III of this report.

Table 2. Input Data (Continued)

No.	Data Tracking Number/Data Title Document Identifier/Document Title	Comments
5	MO0007SPADMM05.002, Distributions, Mean, Minimum and Maximum Consumption Levels of Locally Produced Food by Type and Tap Water for the Amargosa Valley Receptor of Interest <u>Source of the DTN</u> CAL-MGR-MD-000005 REV 00, *Calculation: Values and Consumption Rates of Locally Produced Food and Tap Water for the Receptor of Interest* (CRWMS M&O 2000j)	Consumption rates for locally produced food and tap water
6	MO9912RIB00066.000, Parameter Values for Internal and External Dose Conversion Factors <u>Source of the DTN</u> ANL-MGR-MD-000002 REV 00, *Dose Conversion Factor Analysis: Evaluation of GENII-S Dose Assessment Methods* (CRWMS M&O 1999)	Dose coefficients for exposure to soil contaminated to a depth of 15 cm (external dose conversion factors) External dose conversion factors for additional radionuclides and for the soil contaminated to a depth of 1 cm have been developed in addition to coefficients included in this data set, as described in Section 6.4.2 of this document.
7	MO0004RIB00085.000, Soil and Radionuclide Removal by Erosion and Leaching <u>Source of the DTN</u> ANL-NBS-MD-000009 REV 00, *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* (CRWMS M&O 2000k)	Removal rates by leaching (leaching coefficients)
8	MO9912SPASUB02.001 Dose Coefficients for Air Submersion and Exposure to Contaminated Soil	The source of the data is Federal Guidance Report No. 12 (Eckerman and Ryman 1993).
9	MO0007SPAEDC20.002 Exposure-to-Dose Conversion Factors for Inhalation and Ingestion of Radionuclides	The source of the data is Federal Guidance Report No. 11 (Eckerman et al. 1988).

4.3 CODES AND STANDARDS

At present, the regulatory framework for a potential repository at Yucca Mountain is evolving and the final applicable rules have not been released yet. Until the final rules become available, DOE has issued interim guidance (Dyer 1999) pending issuance of the NRC regulations. The interim guidance, which is based on the proposed rule 10 CFR 63 (64 FR 8640), *Disposal of High-level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada,* has been taken into consideration for the development of the BDCFs for volcanic eruption. Of particular relevance to this analysis are: (1) Section 114 of the guidance which details requirements for performance assessment, including treatment of features, events, and processes (FEPs) with regard to their inclusion or exclusion from the model, and (2) Section 115 of the guidance which specifies required characteristics of the reference biosphere and critical group.

In parallel to the NRC rulemaking efforts, U.S. Environmental Protection Agency (EPA) is presently developing *Environmental Radiation Protection Standards for Yucca Mountain, Nevada* (64 FR 46976). Another proposed rule applicable to the potential repository at Yucca Mountain is the proposed rule 10 CFR 963 (64 FR 67054), which outlines the Yucca Mountain site suitability guidelines.

5. ASSUMPTIONS

It was assumed that the volcanic eruption can be represented by three phases: eruption phase which continues through the duration of the event, the transition phase characterized by increased dustiness caused by resuspension of volcanic ash, and the steady-state phase characterized by the return of particulate concentration in air to the pre-eruption level. It was also assumed that the range of ash deposit thicknesses can be represented by two discrete values: 1 cm and 15 cm. The values of mass loading as well as the fraction of roots in upper and deep soil described in this section are phase- and ash thickness-specific.

5.1 THICKNESS OF ASH DEPOSIT

The thickness of the ash layer that could be deposited 20 km from the potential repository is uncertain (CRWMS M&O 2000c, Section 3.10.5.1). The TSPA-SR modeling of the consequences of an extrusive volcanic event was carried out for two wind conditions. One set of ash thickness results at 20 km was obtained assuming that the wind always blows directly south, toward the critical group. The other set of results included a sampling of wind directions, so that wind blows away from the critical group for a significant number of realizations. The maximum thickness of the calculated ash layer at 20 km turned out to be relatively insensitive to the wind direction (CRWMS M&O 2000c, Figure 3.10-14). The median calculated thickness (and all other thicknesses below the upper bound) at any one specified location are strongly sensitive to wind direction.

The median eruptive event produces an ash layer less than 1 cm thick, 20 km downwind. The minimum ash layer calculated for the midpoint of the plume at 20 km is less than 0.1 mm, corresponding to a relatively small eruption that produces only a dusting of ash at that distance. The maximum ash layer is 36 cm, corresponding to a large eruption that produces a major ash fall covering a large area. Under variable wind conditions, the minimum predicted ash depth was less than 1×10^{-8} cm. About 80 percent of predicted depths were less than 0.1 cm, and an additional 15 percent were 0.1 to 1 cm in thickness. With southerly winds, the minimum depth was less than 10^{-2} cm and the maximum was 36 cm. About 20-25 percent of predicted depths were less than 0.1 cm, 40 percent were 01 to 1 cm, 30-35 percent were 1 to 10 cm, and 5 percent were greater than 10 cm (CRWMS M&O 2000c, Section 3.10.5.1).

Considering the wide range of ash thicknesses, transition phase BDCFs were developed for two different thicknesses of ash: 1 cm, representing the more likely conditions, and 15 cm, representing thicker ash deposits. The thicker ash layer was chosen to be 15 cm because this thickness corresponds to the depth of plant growing zone (CRWMS M&O 2000f), which is one of the input parameters in the GENII-S. Greater thicknesses have no effect on the calculation outcome because it is assumed that plant roots do not extend past 15 cm in depth. It was assumed that the contaminated ash layer was not mixed into the soil for the entire duration of the transition phase, but rather it remained on the soil surface. Such assumption maximized human exposure be inhalation. BDCFs for the steady-state phase use the 15-cm thickness of the ash or soil layer. This assumption was used in Section 6.5.3.

5.2 DOSE CONVERSION FACTORS FOR LARGE PARTICLES

The predicted distribution of the average size of ash particles resulting from a volcanic eruption at Yucca Mountain is log-triangular with a minimum of 10 µm, a mode of 100 µm, and a maximum of 1,000 µm (CRWMS M&O 2000l, Section 6.5.1). Thus, only a small fraction of particles (the smallest predicted average ash sizes have a very low probability of occurrence) would be available for resuspension. This distribution was based in part on measurements of particles size distributions from Cerro Negro eruption, which was a violent strombolian eruption, the type predicted at Yucca Mountain (CRWMS M&O 2000l, Section 6.5.1).

Dose conversion factors for inhalation of suspended particles depend on particle size represented by activity median aerodynamic diameter (AMAD). Although the particle size for resuspended material can range over several orders of magnitude, GENII-S code can accommodate only one set of coefficients converting radionuclide intake by inhalation to doses. Most commonly used dose conversion factors for inhalation apply to particulates whose diameter is distributed lognormally with an AMAD of 1 µm. Such conversion factors are also built into GENII-S. Applicability of these coefficients for a wider size range of particles that could become resuspended in the air was evaluated as described below.

Values of organ committed dose equivalent per unit intake and committed effective dose equivalent per unit intake given in most reports that use methods recommended by the International Commission on Radiological Protection (ICRP) in its Publication 30 (ICRP 1979, Eckerman et al. 1988) are for particles with an AMAD of 1 µm. However, it is possible to estimate the organ committed dose equivalent for an aerosol of AMAD other than 1 µm. The method is described in ICRP Publication 30 (ICRP-30) (ICRP 1979, Equation 5.8). The formula that is used to calculate the committed dose equivalent in an organ T for particles of a given AMAD, H_T (*AMAD*), as a fraction of the committed dose equivalent in this organ for 1 µm particles, H_T (1 µm), is as follows:

$$\frac{H_T(AMAD)}{H_T(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_P\frac{D_P(AMAD)}{D_P(1\ \mu m)} \quad \text{(Eq. 1)}$$

where:

f_{N-P}	–	fraction of the committed dose equivalent in the reference tissue resulting from deposition in the naso-pharyngeal region of the respiratory tract
D_{N-P} *(AMAD)*	–	deposition probability in the naso-pharyngeal region of the respiratory tract for a given AMAD
D_{N-P} *(1 µm)*	–	deposition probability in the naso-pharyngeal region of the respiratory tract for a given AMAD (from ICRP 1979, Figure 5.1)
F_{T-B}	–	fraction of the committed dose equivalent in the reference tissue resulting from deposition in the tracheo-bronchial region of the respiratory tract

$D_{T\text{-}B}\,(AMAD)$	–	deposition probability in the tracheo-bronchial region of the respiratory tract for a given AMAD
$D_{T\text{-}B}\,(1\ \mu m)$	–	deposition probability in the tracheo-bronchial region of the respiratory tract for a given AMAD (from ICRP 1979, Figure 5.1)
f_P	–	fraction of the committed dose equivalent in the reference tissue resulting from deposition in the pulmonary region of the respiratory tract
$D_P\,(AMAD)$	–	deposition probability in the pulmonary region of the respiratory tract for a given AMAD
$D_P\,(1\ \mu m)$	–	deposition probability in the pulmonary region of the respiratory tract for a given AMAD (from ICRP 1979, Figure 5.1)

The weighted committed dose equivalent in an organ per intake of unit activity for particles (here 1 Bq) of a given AMAD, $w_T\ H_{T,1}(AMAD)$, can then be calculated by multiplying the ratio obtained using Equation 1 by the weighted committed dose equivalent in this organ per intake of unit activity for 1 μm particles.

$$w_T\ H_{T,1}(AMAD) = \frac{H_T(AMAD)}{H_T(1\ \mu m)}\ w_T\ H_{T,1}(1\ \mu m)$$

(Eq. 2)

where:

w_T	–	organ or tissue weighting factor

The weighted committed dose equivalent in this organ per intake of unit activity for 1 μm particles can be found in ICRP-30 (ICRP 1978, ICRP 1981a, ICRP 1982). The committed effective dose equivalent can then be calculated by summing up the organ weighted committed dose equivalents. Their sum is the effective (weighted) dose equivalent for a given AMAD per intake of unit activity by inhalation. This quantity can be compared to the corresponding dose conversion factor (DCF) for 1 μm particles by producing a following ratio of these two quantities:

$$Ratio = \frac{\sum_T w_T\ H_{T,1}(AMAD)}{\sum_T w_T\ H_{T,1}(1\ \mu m)}$$

(Eq. 3)

The ratio identified in Equation 3 is a measure of how closely the DCFs for 1μm particles represent DCFs for other particle sizes, with the value of 1 meaning that the respective DCFs are equal. Such ratios were calculated for a range of particle sizes within the applicability limits of the ICRP-30 respiratory tract model. The results of comparison are summarized in Table 3.

Table 3. Comparison of Inhalation DCFs between 1- μm Particles and Other Selected Particle Sizes

Radionuclide	DCF Ratio (DCF for a Given Size Particles to DCF for 1-μm Particles)[a]						
	0.2 μm	0.5 μm	1 μm	2 μm	5 μm	10 μm	20 μm
^{90}Sr	1.2	1.0	1.0	1.1	1.2	1.3	1.3
^{137}Cs	1.0	1.0	1.0	1.1	1.4	1.6	1.6
^{210}Pb	1.2	1.0	1.0	1.1	1.2	1.3	1.2
^{226}Ra	1.9	1.4	1.0	0.7	0.5	0.3	0.2
^{227}Ac	1.2	1.1	1.0	1.0	1.1	1.1	0.9
^{229}Th	1.2	1.1	1.0	1.0	1.1	1.1	0.9
^{230}Th	1.2	1.1	1.0	1.0	1.1	1.1	0.9
^{231}Pa	1.2	1.1	1.0	1.0	1.1	1.1	0.9
^{232}U	2.0	1.4	1.0	0.7	0.4	0.2	0.1
^{233}U	2.0	1.4	1.0	0.7	0.4	0.2	0.1
^{234}U	2.0	1.4	1.0	0.7	0.4	0.2	0.1
^{238}Pu	1.2	1.1	1.0	1.0	1.1	1.1	0.9
^{239}Pu	1.2	1.1	1.0	1.0	1.1	1.1	0.9
^{240}Pu	1.2	1.1	1.0	1.0	1.1	1.1	0.9
^{242}Pu	1.2	1.1	1.0	1.0	1.1	1.1	0.9
^{241}Am	1.2	1.1	1.0	1.0	1.1	1.1	0.9
^{243}Am	1.2	1.1	1.0	1.0	1.1	1.1	0.9

[a] Developed from Equation 3

It was concluded that DCFs for particles with AMAD of 1 μm represent well the DCFs for the particle sizes expected to be deposited on the ground following volcanic eruption. Considering that the expected distribution contain significant fraction of large particles, application of DCFs for 1μm particles will lead, in most cases, to overestimates of the resulting doses. Conversion of radionuclide intake by inhalation to dose using conversion factors for 1-μm particles is performed by the GENII-S code. This assumption allows application of GENII-S DCFs for inhalation to the whole range of ash particle sizes. This assumption is used in Section 6.5.

5.3 ROOTS IN UPPER AND DEEP SOIL

For thin ash deposits (1 cm and less), the fraction of roots in the upper soil was assumed to be $1/15^{th}$ of the root length of 15 cm, for consistency with the assumption that for the transition phase volcanic ash remains on the soil surface for the entire crop growing season. The assumption of an undisturbed layer of ash continuously present on the soil surface maximizes the inhalation of resuspended particles, and the ingestion from particle deposition on the plant surfaces without reducing root uptake value. (Although only $1/15^{th}$ of the root participates in the uptake, radionuclide concentration in soil is 15 times higher than that for the 15-cm surface soil layer.) For the remaining phase/ash-thickness combinations, fraction of roots in upper soil was assumed to be equal to 1.0 (CRWMS M&O 2000f). Fraction of roots in deep soil complements the fraction of roots in upper soil (their sum is equal to one). This assumption was used in Tables 9 and 10.

5.4 MASS LOADING FOR 1-CM LAYER OF ASH

A conservative assumption was made that for calculations based on annual average mass loading for the transition phase and 1-cm ash layer, the values of mass loading developed for deep ash depths (MO0010SPAAAM01.014), with the maximum of 3.00×10^{-3} g/m^3 apply. This assumption is reasonable considering that only a very thin layer of ash will be available for resuspension. Therefore, for the intermediate and thick ash layers, mass loading will be independent of the thickness of ash. This assumption is used in Table 9.

5.5 MEAT CONSUMPTION

A conservative assumption was made that the GENII-S beef consumption category included both beef and pork, and that the animal food-to-animal product transfer coefficients for beef could be applied to pork. This assumption allows including all types of locally produced meat using a single GENII-S food type category related to meat consumption. This assumption is used in Section 6.5.3.

5.6 PARAMETER DEPENDENCE

Parameters represented by their probability distribution functions included in this analysis are assumed to vary independently (except for plant-to-soil and animal food-to-animal product transfer factors). Therefore, for this analysis the covariance among parameters was not included in the biosphere model. In general, the effect of neglecting covariances is to estimate slightly wider confidence intervals on BDCFs. In other words, ignoring positive correlations amongst input parameters, the uncertainty in the BDCFs will be underestimated. This assumption is used for entering GENII-S input (Section 6.5.3).

6. ANALYSIS/MODEL

This chapter describes development of radionuclide- and exposure scenario-specific BDCFs. The context of analysis is presented in terms of selection of radionuclides of interest (Section 6.1), definition of the human receptor (Section 6.2) and the conditions of the receptor's exposure to radiation (Section 6.3). Development of dose factors for the eruption phase is described in Section 6.4. Application of the biosphere model, including the modeling inputs and outcomes, to calculate BDCFs for the current and the evolved climates are discussed in Section 6.5. Pathway analysis is discussed in Section 6.6, while Section 6.7 presents the results of limited uncertainty analysis. The last section of this chapter (Section 6.8) addresses alternative models. Validation of the biosphere model used in this analysis is discussed in Attachment II of this report.

Radionuclide-specific BDCFs developed in this analysis are expressed in terms of total effective dose equivalent (TEDE) (10 CFR 20) for the average member of the critical group resulting from an annual internal and external exposure to radionuclides in the environmental media, from unit of surface activity concentration deposited on the ground with contaminated volcanic ash. Exposure pathways included in the BDCFs are specific to the exposure scenario under consideration. In general, they include ingestion, inhalation, and external exposure (see Section 6.3 for the description of exposure scenario and pathways). The BDCFs were calculated in a probabilistic analysis by producing multiple realizations of the model outcome from multiple sampling results of the model input parameters. The present analysis is analogous to the ones conducted previously to develop disruptive event BDCFs (CRWMS M&O 2000a, CRWMS M&O 2000b) and is appropriate for generation of input for the TSPA model.

6.1 RADIONUCLIDES OF INTEREST

Seventeen radionuclides were identified as important for a direct release from an extrusive volcanic event. This includes thirteen radionuclides considered important out to 10,000 years (^{90}Sr, ^{137}Cs, ^{227}Ac, ^{229}Th. ^{231}Pa, ^{232}U, ^{233}U, ^{234}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, and ^{243}Am) and four additional radionuclides for the dose estimates out to one million years (^{210}Pb, ^{226}Ra, ^{230}Th, ^{242}Pu) (CRWMS M&O 2000m).

6.2 RECEPTOR OF INTEREST

Receptor of interest is defined as a hypothetical individual for whom the dose consequences of the postulated radionuclide release from the potential repository are assessed. For this analysis an average member of the critical group is a receptor of interest. The critical group is defined as the group of individuals reasonably expected to receive the greatest exposure to radioactive releases from the potential repository over time, considering the circumstances under which the analysis is carried out.

Critical group used in this analysis has been developed in CRWMS M&O (2000n). The report (CRWMS M&O 2000n) characterizes the critical group as a relatively homogeneously exposed group residing within a farming community. It is expected to receive the highest exposure for the exposure scenario under consideration (see Section 6.3 for the description of exposure scenario). It consists of full-time residents that are involved in agricultural activities for a significant part of a day; spend part of a day recreating outdoors; and consume locally grown food, some of which is grown in their own gardens. The average member of the critical group defined in such a manner is an individual who represents the exposure scenario based on the site-specific, but prudently conservative, exposure assumptions and parameter values within model calculations. The average member of the critical group is represented by mean values of behaviors and characteristics, which were derived from each individual exposure parameter's frequency distribution for the critical group. In terms of the biosphere model outcome, BDCFs for the average member of the critical group are represented by the mean value of the BDCF probability distribution for the critical group.

The proposed NRC rule requires that, "The behaviors and characteristics of the average member of the critical group shall be based on the mean value of the critical group's variability range" (Dyer 1999, Section 115 (b)(4) of the attachment). In the previous biosphere modeling effort (CRWMS M&O 2000a), for all exposure characteristics of the average member of the critical group, the mean fixed values were used, while the parameters associated with the environmental transport of radionuclides were allowed to be represented by probability distribution functions (see Sections 6.5.2 and 6.5.3 for the discussion of the model parameters). In the current analysis, exposure parameters (e.g., locally produced food consumption rates) for the critical group are represented by their probability distributions to include uncertainty in these important parameters in the overall uncertainty of the modeling outcome. However, the mean values of the parameters distributions were calculated such that they coincide with either the food consumption survey means, in the case of food consumption rates, or with the best estimates of the parameter value in the case of other parameters. By doing so, the mean values of the BDCF distributions are the same as the mean values of the BDCF distributions calculated using fixed mean values of exposure parameters. However, the latter BDCFs distributions are broader because they include variability in behavioral characteristics.

6.3 EXPOSURE SCENARIOS

The objective of biosphere modeling is to provide the numerical values of BDCFs, which represent expected annual doses to a human receptor of interest from radionuclides postulated to be released to the environment due to the volcanic eruption intersecting the repository (see Figure 2). BDCFs are calculated for a unit of activity concentration of contaminated volcanic ash deposited on the ground per unit surface area.

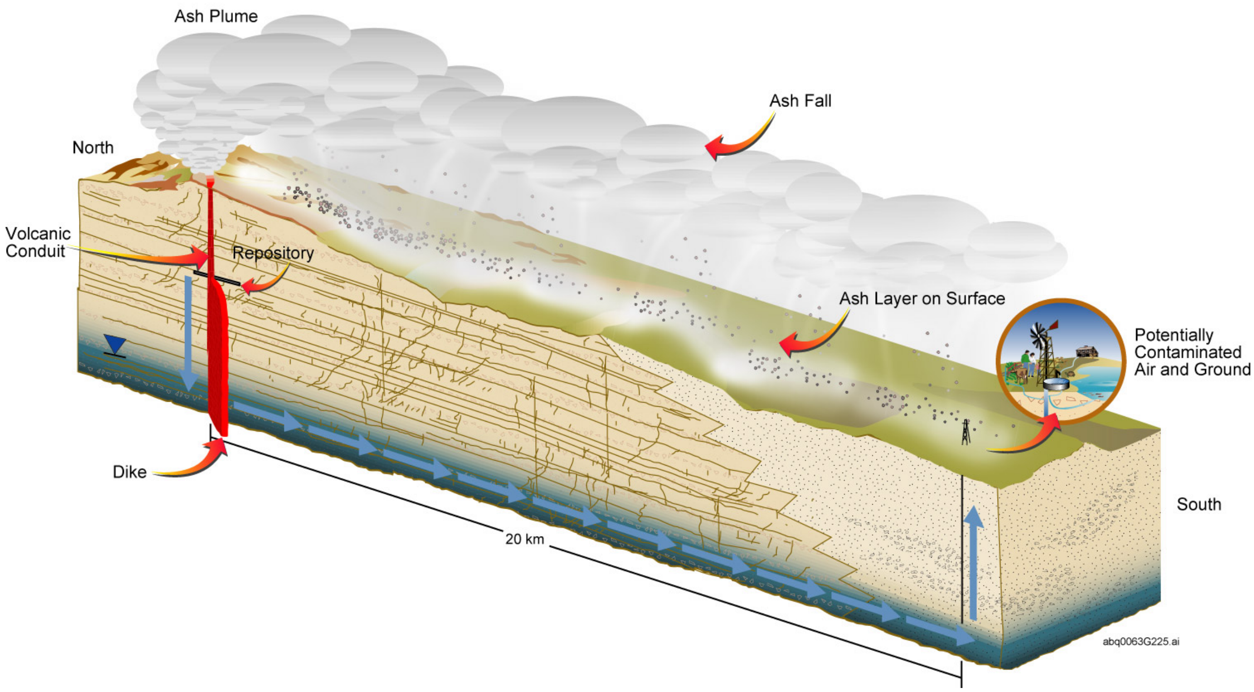


Figure 2. Representation of the Volcanic Eruption Intersecting the Repository

Exposure scenarios establish the circumstances of human exposure to radionuclides present in the biosphere. Specific aspects of exposure scenarios that are applicable to the Yucca Mountain region and to the type of receptor under consideration were first identified as features, events, and processes (FEPs).

6.3.1 Features, Events, and Processes

One of the requirements that the reference biosphere must meet is that FEPs that describe the reference biosphere shall be consistent with present knowledge of the conditions in the region surrounding the Yucca Mountain site (Dyer 1999, Section 115 (a)(1) of the attachment). The selection of applicable FEPs forms a basis of the definition of human exposure conditions. The selection should comprehensively address site-specific aspects of human exposure to radionuclides released to the environment from the potential repository. The list of FEPs potentially applicable to the Yucca Mountain Site Characterization Project has been constructed and described in detail (CRWMS M&O 2000o). The evaluation of the applicability of biosphere-related FEPs is being performed and the screening arguments for inclusion or exclusion of specific FEPs are being developed and documented (*Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*, ANL-MGR-MD-000011, REV 01). Table 4 lists FEPs that are considered in the biosphere model for the extrusive volcanic event and describes how and where a specific FEP is addressed within the current model.

BDCFs, developed for the average member of the critical group, account for transfer of radionuclides through the human food chain and for human dosimetry. The mechanisms of radionuclide transfer through the biosphere, called exposure pathways, were first identified and then modeled. These exposure pathways are described in the following section.

From the perspective of BDCF calculation for volcanic eruption, three different human exposure scenarios were specified for different phases during, and following, volcanic eruption: (1) eruption, (2) transition, and (3) steady-state. The eruption phase refers to the conditions during the volcanic eruption. Because of the expected high concentration of particulates in air during this phase, inhalation of airborne contaminated ash particles is the only primary pathway considered in calculation.

The transition phase is characterized by resuspension of volcanic ash deposited on the ground during the eruption phase. The contaminated ash is thus available for inhalation. Resuspended ash, if deposited on plant surfaces, may cause contamination on crops used for human consumption and animal feed. Contamination of crops may also occur through the root uptake of radioactivity in the soil. Contaminated animal feed results in contamination of animal products, such as milk, meat and eggs. It is postulated that contaminated ash is not mixed into the soil below the ash layer for the duration of the entire transition phase (see Section 5.1). This is a conservative approach that maximizes inhalation of resuspended particles, but does not affect other pathways, such as root uptake. Concentration of resuspended particles in air during the transition phase decreases exponentially, until it reaches pre-eruption conditions (CRWMS M&O 2000h). The process of reduction of initially high dust concentrations in air takes up to 10 years (CRWMS M&O 2000h). When the biosphere system returns to the pre-eruption dust levels, the third, steady-state, phase begins. This phase is characterized by the same levels of suspended particulates in the air as those used for the development of the nominal performance BDCFs. For the steady-state phase, radioactivity previously deposited on the ground from a volcanic eruption is assumed to be uniformly mixed into 15-cm layer of top soil, regardless of the initial thickness of ash deposit.

Table 4. Consideration of Features, Events, and Processes Considered Applicable to YMP within the Biosphere Model for Calculation of Nominal Performance Biosphere Dose Conversion Factors

FEP Name	YMP FEP Database Number	Reference/Comment
Soil type	2.3.02.01.00	The soil type FEP is considered for the selection of the values for the soil-to-plant transfer coefficient (values for sandy soils were selected, if available) controlling radionuclide transfer from soils to plants, as well as for the calculation of leaching factors, which quantify the fraction of radioactivity removed from the top soil layer by leaching, and development of soil-related parameters, such as soil density. (See Section 6.5.3 of this document for the specific use of these parameters within the model.) These parameters were developed and documented in the AMRs and are used as input to this analysis.
Soil and sediment transport	2.3.02.03.00	Removal of radionuclides from top layer of soil by the process of wind erosion (aeolian processes) is addressed within the biosphere model when considering long-term effects of agricultural land use. This process is not directly included in the calculation of the nominal performance BDCFs, but rather it is applied within the TSPA model to modify/adjust the contamination source term.
Precipitation	2.3.11.01.00	Precipitation (precipitation rate) is a parameter which is not used directly in the model, but rather it is used to derive the values of other input parameters that depend on the overall water balance, such as leaching rate, irrigation rates for various crops, as well as home irrigation rate. The usage of precipitation is addressed in the AMRs, which document development of input parameters for the biosphere model. (See Sections 6.5.2 and 6.5.3 of this document for the description of input and its sources).
Surface runoff and flooding	2.3.11.02.00	Evapotranspiration and infiltration are the factors in the water balance equation used to derive certain input parameters described above (see comment for FEP 2.3.11.01.00).
Biosphere characteristics	2.3.13.01.00	Biosphere characteristics such as climate, vegetation, fauna and flora are included in the model as the components of the reference biosphere. Specific relationships between these components form the foundation of the biosphere model used in this analysis and are shown in Figure 3 of this document.
Biosphere transport	2.3.13.02.00	See comment above, i.e., for FEP 2.3.13.01.00.
Human characteristics (physiology, metabolism)	2.4.01.00.00	Human characteristics, such as physiology and metabolism, are considered as elements of human dosimetry and they are inherent to dose conversion factors (conversion factors from radionuclide intake to dose). Alternative to the current selection of the dose conversion factors is discussed in Section 6.7 of this document. Also see Section 6.5.2 and 6.5.3 of this document for the additional description of dosimetric input.
Diet and fluid intake	2.4.03.00.00	Consumption rates of locally produced food and tap water for the critical group are included among the model input parameters which were developed in the input AMRs. See Section 6.5.3 of this document for the description of input and its sources.
Human lifestyle	2.4.04.01.00	Conditions of human exposure are based on the assumed lifestyle of the receptor of interest (farming community). This is apparent in the selection of specific values of exposure parameters (which, in addition to food and water consumption rates, include amount of time spent outdoors for work, recreation, and inhalation exposure time) specific to the critical group’s lifestyle. The human exposure parameters are described in the input AMR. (See Section 6.2 of this document for the discussion of human receptor and Sections 6.5.2 and 6.5.3 of this document for the description of input and its sources.)

Table 4. Consideration of Features, Events, and Processes Considered Applicable to YMP within the Biosphere Model for Calculation of Nominal Performance Biosphere Dose Conversion Factor (Continued)

FEP Name	YMP FEP Database Number	Reference/Comment
Dwellings	2.4.07.00.00	Type of dwellings and the habits of human receptor are addressed in the AMR, which develops the critical group. (See Section 6.2 of this document for the discussion of human receptor and Sections 6.5.2 and 6.5.3 of this document for the description of input and its sources.)
Agricultural land use and irrigation	2.4.09.01.00	Agricultural land use by the human receptor is addressed in the AMR that develops the critical group (see Section 6.2 of this document). Irrigation characteristics are included in biosphere model input. (See Section 6.2 of this document for the discussion of human receptor and Sections 6.5.2 and 6.5.3 of this document for the description of input and its sources.)
Animal farms and fisheries	2.4.09.02.00	Contamination of animal products is considered in the model. (See mathematical representation of the biosphere model in Attachment I of this document for the description of submodels addressing radionuclide transfer to animal products and fish.)
Drinking water, foodstuffs and drugs, contaminant concentrations in	3.3.01.00.00	Consumption rates of locally produced food and tap water for the critical group are included among the model input parameters which were developed in the input AMRs. (See Section 6.2 of this document for the discussion of human receptor and Sections 6.5.2 and 6.5.3 of this document for the description of input and its sources.)
Plant uptake	3.3.02.01.00	Contamination of crops is considered in the model by using steady-state transfer factors. (See mathematical representation of the biosphere model in Attachment I of this document for the description of submodels addressing radionuclide transfer to crops.)
Animal uptake	3.3.02.02.00	Contamination of animal products is considered in the model by using steady-state transfer factors. (See mathematical representation of the biosphere model in Attachment I of this document for the description of submodels addressing radionuclide transfer to animal products.)
Bioaccumulation	3.3.02.03.00	The process of accumulation of radioactive contaminants in food products is considered in the model. (See mathematical representation of the biosphere model in Attachment I of this document for the description of submodels addressing radionuclide transfer to crops, animal products and fish.)
Ingestion	3.3.04.01.00	Ingestion of locally produced food and tap water is included in the model as one of the exposure pathways. Consumption rates of locally produced food and tap water for the critical group are included among the model input parameters which were developed in the input AMRs. (See Sections 6.5.2 and 6.5.3 of this document for the description of input and its sources.)
Inhalation	3.3.04.02.00	Inhalation of resuspended particular matter is included in the model as one of the pathways. (See mathematical representation of the biosphere model in Attachment I of this document.) Parameters for the inhalation pathway are developed in the input AMR – see Sections 6.5.2 and 6.5.3 of this document for the description of input and its sources.
External exposure	3.3.04.03.00	External exposure pathway is included in the model. (See mathematical representation of the biosphere model in Attachment I of this document.) Parameters for the external exposure pathways are developed in the input AMR – see Sections 6.5.2 and 6.5.3 of this document for the description of input parameters and their sources.

Table 4. Consideration of Features, Events, and Processes Considered Applicable to YMP within the Biosphere Model for Calculation of Nominal Performance Biosphere Dose Conversion Factor (Continued)

FEP Name	YMP FEP Database Number	Reference/Comment
Radiation doses	3.3.05.01.00	Calculation of radiation doses is carried out by the human dosimetry component of the biosphere model. (See mathematical representation of the biosphere model in Attachment I of this document for the description of dosimetric component of the model.)

SOURCE: CRWMS M&O 2000o

6.3.2 Exposure Pathway Identification and Modeling

For the transition and steady-state phases, modeling of the movement of radionuclides through the food chain is accomplished by identifying specific routes, or pathways, taken by radionuclides through the biosphere from the source of contamination to a human receptor. Current regional land use and other local current conditions influence pathways that are considered significant. The analysis considered pathways that are typical for the current conditions for the critical group residing within a hypothetical farming community in the vicinity of Yucca Mountain. The farming critical group was selected because farming activities typically involve more exposure pathways than other human activities identified in the Yucca Mountain region (64 FR 8640, Section VI of the Supplementary Information). The exposure pathways included ingestion of contaminated crops and animal products, inhalation, and external exposure from contaminated soil. Specifically, the following exposure pathways were considered for the development of the BDCFs for an extrusive volcanic event:

- Consumption of locally produced leafy vegetables
- Consumption of other locally produced vegetables
- Consumption of locally produced fruit
- Consumption of locally produced grain
- Consumption of locally produced meat
- Consumption of locally produced poultry
- Consumption of locally produced milk
- Consumption of locally produced eggs
- Inadvertent soil ingestion
- Inhalation of resuspended particulate matter
- External exposure to contaminated soil.

Ingestion of contaminated drinking water and contaminated aquatic food, which were considered for the nominal performance of the potential repository, were not included in this analysis because of the assumption that groundwater was not contaminated.

Pathway modeling is accomplished using simple mathematical formulations reflecting transfer compartments in the environment. This approach to biosphere modeling was used to calculate BDCFs and it is shown schematically in Figure 3. Modeling of radionuclide transport through each compartment of the biosphere applied steady-state transfer factors, e.g., soil-to-plant and plant-to-animal product transfer coefficients. (See Attachment I for the numerical representation of the model, including the description of submodels and associated transfer parameters.)

The use of pathway analysis results in determination of the total exposure of the individual to radionuclides. The human dosimetry component of the biosphere model was then invoked to convert both internal exposure, through ingestion and inhalation, and external exposure from unit activity concentration in soil to TEDE for the human receptor resulting from an annual exposure to radionuclides.

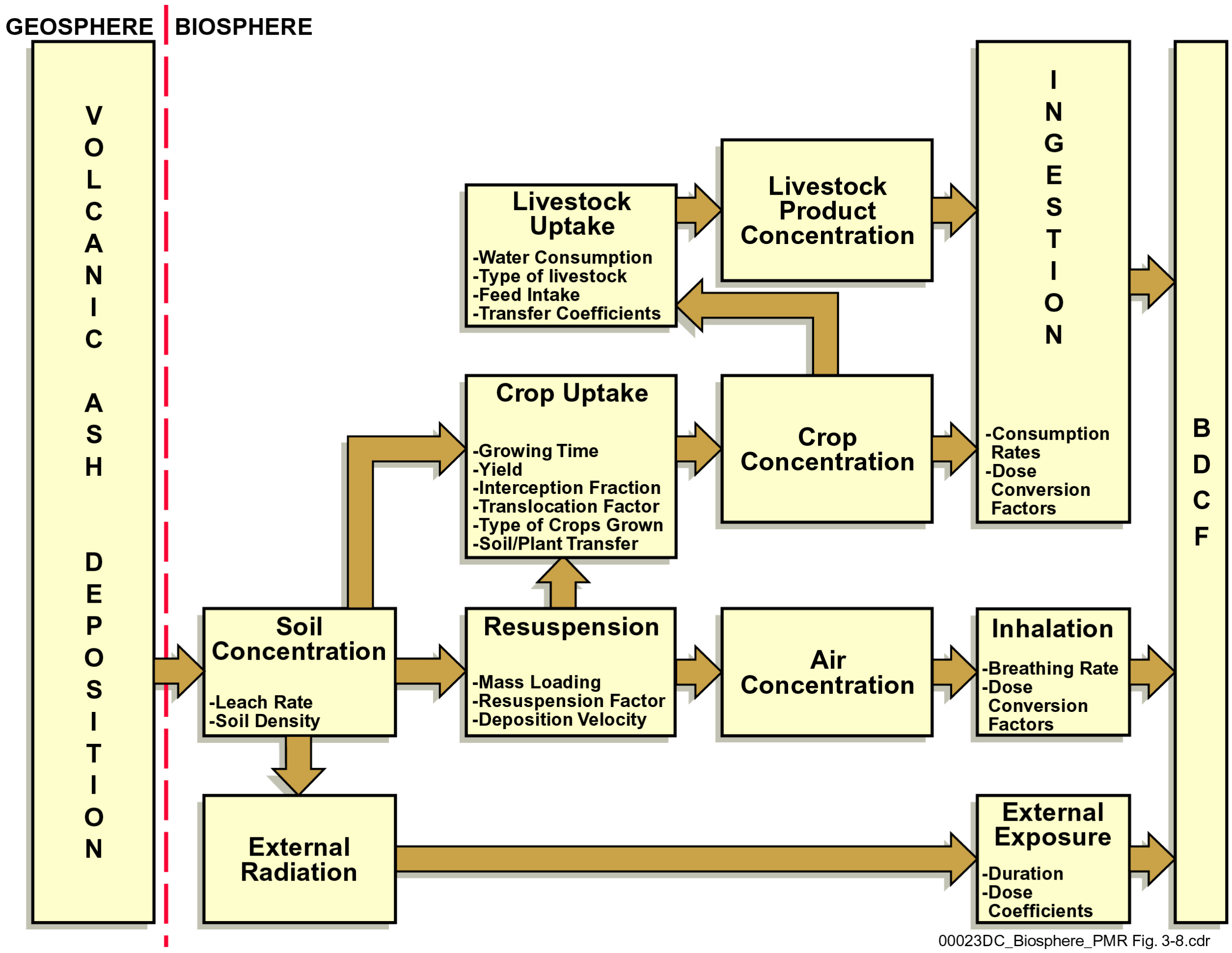


Figure 3. Block Diagram of Biosphere Conceptual Model for Extrusive Volcanic Event

6.4 DEVELOPMENT OF DOSE FACTORS FOR THE ERUPTION PHASE

For the eruption phase, dose factors (DFs) were developed, rather than BDCFs. DFs represent doses resulting from one-day intake of radionuclides by inhalation of air containing unit activity concentration of a radionuclide under consideration (1 pCi/m^3). The inhalation exposure time is equal to 6073.5 hours per year (CRWMS M&O 2000h) which results in an inhalation exposure factor of 0.693, calculated by dividing 6073.5 hours of inhalation exposure time per year by the total number of hours per year (8760 hours). Inhalation exposure time and, subsequently, inhalation exposure factor do not reflect actual time spent outdoors. Rather, they are scaling factors that include inhalation exposure both outdoors and indoors. DFs for the eruption were calculated using the following formula:

$$DF\left(\frac{rem\ m^3}{pCi\ d}\right) = 23\frac{m^3}{d} \times 0.693 \times DCF_{inh}\left(\frac{Sv}{Bq}\right) \times 0.037\frac{Bq}{pCi} \times 100\frac{rem}{Sv} \qquad \text{(Eq. 4)}$$

where:

$23\ \frac{m^3}{d}$ – breathing rate

DCF_{inh} – dose conversion factor for inhalation, $\frac{Sv}{Bq}$

$0.037\ \frac{Bq}{pCi}$ – conversion factor from picocuries to becquerels

$100\ \frac{rem}{Sv}$ – conversion factor from sieverts to rems.

DCFs for inhalation used in Equation 4 are listed in Table 5. Federal Guidance Report No. 11 (Eckerman et al. 1988) (MO0007SPAEDC20.002) was used as the source of DCFs. DFs are also listed in Table 5. When more than one DCF was given for a particular radionuclide, the most conservative DCF was used.

Table 5. Dose Conversion Factors and Dose Factors

Radionuclide	DCF for Inhalation[a] Sv/Bq	Dose Factors [b] rem/(pCi d)
^{90}Sr	6.47E-8	3.82E-06
^{137}Cs	8.63E-9	5.09E-07
^{210}Pb	3.67E-6	2.17E-04
^{226}Ra	2.32E-6	1.37E-04
^{227}Ac	1.81E-3	1.07E-01
^{229}Th	5.80E-4	3.42E-02
^{230}Th	8.80E-5	5.19E-03
^{231}Pa	3.47E-4	2.05E-02
^{232}U	1.78E-4	1.05E-02
^{233}U	3.66E-5	2.16E-03
^{234}U	3.58E-5	2.11E-03
^{238}Pu	1.06E-4	6.25E-03
^{239}Pu	1.16E-4	6.84E-03
^{240}Pu	1.16E-4	6.84E-03
^{242}Pu	1.11E-4	6.55E-03
^{241}Am	1.20E-4	7.08E-03
^{243}Am	1.19E-4	7.02E-03

NOTES: [a] Eckerman et al. 1988, Table 2.1
[b] Calculated using Equation 4

The use of DFs to calculate dose for the eruption phase is as follows:

$$Dose\left(\frac{rem}{d}\right) = S\left(\frac{g}{m^3}\right) \times C_{ash}\left(\frac{pCi}{g}\right) \times DF\left(\frac{rem\ m^3}{pCi\ d}\right) \qquad \text{(Eq. 5)}$$

where:

S – average daily mass concentration of particulates in air, $\frac{g}{m^3}$

C_{ash} – activity concentration of radionuclide in ash, $\frac{pCi}{g}$.

6.5 DEVELOPMENT OF BIOSPHERE DOSE CONVERSION FACTORS FOR THE TRANSITION AND THE STEADY-STATE PHASES

GENII-S, *A Code for Statistical and Deterministic Simulations of Radiation Doses to Humans from Radionuclides in the Environment* (Leigh et al. 1993) was chosen to support biosphere modeling for an extrusive igneous event (volcanic eruption). Using a comprehensive set of environmental pathway models, the code calculated the environmental transport of radionuclides following the initial deposition of contaminated ash on the soil surface. The code calculates radionuclide concentrations in air (from resuspension), soil, and various foodstuffs, which are combined with human intake and external exposure parameters and subsequently converted to internal and external radiation doses. A description of the environmental transport and uptake models implemented by the GENII-S code, which are important for biosphere modeling, is included in Attachment I.

Conversion of radionuclide intake by ingestion or inhalation is accomplished in GENII-S by application of dose conversion factors, which represent dose per unit activity intake by ingestion or by inhalation. Conversion factors depend on the chemical and physical form of the radionuclide. BDCFs for the extrusive igneous event were calculated using the set of the most conservative dose conversion factors which result in the highest doses for inhalation and ingestion.

BDCFs were developed, using probabilistic analysis, for five hypothetical ash thickness/mass loading conditions that could exist following volcanic eruption. The receptor of interest was an average member of the critical group. BDCFs were calculated in a series of GENII-S simulations for each of the 17 radionuclides (see Section 6.1). Each simulation resulted in 150 model realizations. (Model realization is one of the possible model outcomes obtained as a result of a single round of sampling of the model input parameters.) This section describes the details of probabilistic analysis, development of input parameters, as well as the specific modeling input values, and the summary of output for the five cases under consideration.

6.5.1 Probabilistic Analysis

To develop BDCFs, the probabilistic approach was taken which allows statistical sampling of parameter values described by their probability distribution functions (PDF). This method, called Monte Carlo analysis, provides a quantitative evaluation of uncertainty and its impacts on the modeling outcome represented by distributions of potential modeling results – BDCFs. When performing BDCF calculations, a large quantity of parameters is encountered. GENII-S has the capability of representing some of the model parameters by their PDFs. Parameter values were sampled using the Latin Hypercube Sampling (LHS) scheme. With LHS, the probability distribution is divided into intervals of equal probability. The code then samples a value for each interval, which results in a more even and consistent sampling compared with the conventional Monte Carlo random sampling scheme.

There are more than 100 input parameters used in the GENII-S model (see Table 6). Some of these parameters can be represented by a distribution while the others are fixed.

Table 6. GENII-S Parameters

Parameter	**Distribution**	
	GENII-S	**Biosphere Selection**
RADIONUCLIDE CONCENTRATION IN SOIL		
Depth of Surface Soil	Variable	Fixed
Surface Soil Density	Variable	Fixed
Deep Soil Density	Variable	Fixed
Prior Irrigation Duration	Fixed	Fixed
Home Irrigation Rate	Variable	Variable
Home Irrigation Duration	Variable	Fixed
Leaching Factors	Fixed	Fixed
Crop Yields	Variable	Variable
RADIONUCLIDE CONCENTRATION IN AIR		
Deposition Velocity	Variable	Fixed
Mass Loading	Variable	Variable
RADIONUCLIDE CONCENTRATION IN PLANTS FOR HUMAN AND ANIMAL CONSUMPTION		
Resuspension Factor	Variable	Variable
Growing Time	Variable	Variable
Fraction of Roots in Upper Soil	Variable	Fixed
Fraction of Roots in Deep Soil	Variable	Fixed
Irrigation Rates	Variable	Variable
Irrigation Times	Variable	Variable
Interception Fraction (irrigation)	Variable	Variable
Weathering Half-life	Fixed	Fixed
Translocation Factors	Fixed	Fixed
Soil-to-Plant Transfer Factors	Fixed	Fixed
Soil-to-Plant Transfer Scaling Factor	Variable	Variable
Crop Biomass	Fixed	Fixed
Dry-to-Wet Ratio	Fixed	Fixed
RADIONUCLIDE CONCENTRATION IN ANIMAL PRODUCTS		
Feed Storage Time	Variable	Fixed
Dietary Fraction	Variable	Fixed
Contaminated Water Fraction	Variable	Fixed
Animal Feed and Water Consumption Rates	Fixed	Fixed
Transfer Coefficients for Animal Products	Fixed	Fixed
Animal Product Transfer Scaling Factor	Variable	Variable
Bioaccumulation Factors for Fish	Fixed	Fixed
HUMAN EXPOSURE		
Drinking Water Holdup	Variable	Fixed
Water Consumption Rates	Variable	Variable
Crop/Animal Product Holdup	Variable	Fixed

Table 6. GENII-S Parameters (continued)

Parameter	Distribution	
	GENII-S	Biosphere Selection
Food Consumption Rates	Variable	Variable
Soil Ingestion Rate	Variable	Fixed
Inhalation Exposure Time	Variable	Variable
Chronic Breathing Rate	Fixed	Fixed
Soil Exposure Time	Variable	Variable
DOSIMETRIC PARAMETERS		
Human Dose Scaling Factor	Variable	Fixed
Dose Commitment Period	Fixed	Fixed
DCFs/DFs	Fixed	Fixed
Organ/Tissue Weighting Factors	Fixed	Fixed

NOTE: Shaded cells represent variables that are allowed in GENII-S to be represented by probability distribution functions, but were chosen as fixed values.

In general, parameters that could potentially be represented by a probability distribution function, but which were determined to have less influence on the final BDCF, were selected as fixed values (see shaded cells in Table 6). Such parameters include storage and holdup times (which are inconsequential for long-lived radionuclides), parameters related to properties of the soils (which were determined based on site-specific information), and parameters whose values were maximized for conservatism (e.g. home irrigation rate, fraction of contaminated water used for animal watering). Representing less important parameters as fixed values helped to alleviate the computational burden on the software and allowed increasing the maximum possible number of model realizations, thus improving statistical representation of the outcome. To obtain statistically valid results using LHS the minimum number of realizations has to be 1.33 times greater than the number of sampled parameters (LaPlante and Poor 1997, page 3-2). The number of sampled parameters was equal to 37 for the current analysis, which sets the minimum number of realization to about 50.

The code has a computational limitation on the combined total of the number of parameters represented by probability distributions and the number of realizations. That is, if more parameters are sampled from their probability distributions, the number of possible realizations decreases. The actual number of realizations that the code can process and produce output in a practical text format depends on the size of an output array and the number of variables that are sampled and calculated. The code calculates 27 dependent variables, which when combined with 37 independent variables gives 64 variables whose values are included in the output file (DTN: MO0010MWDPBD03.007). The maximum number of realizations can be determined by dividing 10,000 by the number of variables. In this case the number of variables was 64, so the maximum number of realizations was equal to 156. The number of realizations was therefore set at 150.

The statistical sampling technique described above produced a set of 150 single model realizations (BDCFs) from a set of sampled parameter values (inputs). The 150 model realizations were then statistically summarized and characterized to produce probability distributions of BDCFs that can be used in the TSPA model.

6.5.2 Development of Input Parameters

As noted before, GENII-S uses a large number of input parameters. These parameters can be classified into two main groups: (1) the parameters that influence, or are related to, radionuclide transport and accumulation in the biosphere, and (2) the parameters related to characteristics of the human receptor. Input parameters, whether characterized as fixed constants or uncertain parameters with associated probability distributions, have been developed for each of the model runs. When available, site-specific data were used to determine input parameter values. However, for many parameters, the only available data were not completely representative of the reference biosphere and the population being assessed. In those cases, developed parameter values reflect expert judgement regarding the degree to which each parameter is unknown. In this aspect, the resulting frequency distribution may be to some degree subjective and should not be considered to represent only natural variability. However, the selection of the parameter values was guided by the general assessment philosophy, which was to use generally conservative assumptions to ensure that the results are unlikely to underestimate the corresponding values of BDCFs for the considered radionuclide transport and uptake conditions and mechanisms.

A majority of the input parameters were developed in a series of analyses. The supporting documentation, including justification for the selection of parameter values, ranges, and distributions can be found in associated AMRs, as listed in Table 2. The remaining parameters are addressed below.

6.5.2.1 Ingestion Exposure Parameters

The previously developed set of ingestion exposure parameters (DTN: MO0002RIB00068.000) includes recommended values of thirteen parameters: water source, drinking water treatment, crop interception fraction, water contaminated fraction, irrigation water contamination fraction, irrigation time, irrigation rate, aquatic food consideration, food yield, grow time, holdup time, storage time, and dietary fraction. Some of these parameters were developed using inconsistent food type groupings. To correct for these inconsistencies, four of the parameters (growing time, irrigation time, irrigation rate, and yield) were re-developed as described in Attachment III. The summary of the results is presented in Table 7.

Table 7. Summary of Developed Ingestion Parameter Values for Amargosa Valley

Parameter	Distribution	Reasonable Estimate	Minimum Value	Maximum Value
Growing Time (d):				
Leafy vegetables	Uniform	57	45	68
Root vegetables	Uniform	84	70	98
Fruit	Uniform	136	88	184
Grain	Fixed	244	244	244
Fresh feed for beef	Triangular	47	46	135
Stored feed for poultry	Fixed	140	140	140
Fresh feed for milk	Triangular	47	46	135
Stored feed for eggs	Fixed	140	140	140
Irrigation Time (mo/yr):				
Leafy vegetables	Uniform	3.8	3.0	4.5
Root vegetables	Uniform	3.9	3.2	4.6
Fruit	Uniform	4.5	2.9	6.0
Grain	Fixed	8.0	8.0	8.0
Fresh feed for beef	Fixed	12	12	12
Stored feed for poultry	Fixed	4.6	4.6	4.6
Fresh feed for milk	Fixed	12	12	12
Stored feed for eggs	Fixed	4.6	4.6	4.6
Irrigation Rate (in/yr)				
Leafy vegetables	Uniform	36	28	43
Root vegetables	Uniform	50	47	52
Fruit	Uniform	38	30	45
Grain	Fixed	56	56	56
Fresh feed for beef	Fixed	95	95	95
Stored feed for poultry	Fixed	75	75	75
Fresh feed for milk	Fixed	95	95	95
Stored feed for eggs	Fixed	75	75	75
Crop Yield (kg/m2)				
Leafy vegetables	Uniform	4.6	4.4	4.8
Root vegetables	Uniform	7.0	4.1	9.8
Fruit	Uniform	2.0	1.6	2.3
Grain	Uniform	0.5	0.3	0.7
Fresh feed for beef	Uniform	1.1	1.0	1.2
Stored feed for poultry	Uniform	0.7	0.6	0.8
Fresh feed for milk	Uniform	1.1	1.0	1.2
Stored feed for eggs	Uniform	0.7	0.6	0.8

Source: Table III-1, Attachment III

6.5.2.2 Dose Coefficients

A previously developed set of dose coefficients (DCs) for a 15-cm layer of contaminated soil (MO9912RIB00066.000) was amended because it did not include radionuclides considered important for up to one million years. Also, an additional set of DCs was developed for the soil contaminated to a depth of 1 cm. This set was used in calculations of BDCFs for a thin layer of ash.

For most radionuclides, their progeny must be taken into account in BDCF calculations. Progeny should match those considered in GENII-S for a given radionuclide. Following computational methods of GENII-S, DCs for some radionuclides include contributions from their own chains of short-lived radionuclides. DCs were developed using the same method as that described previously (CRWMS M&O 1999), using accepted data from Federal Guidance Report No. 12 (FGR-12) (Eckerman and Ryman 1993) (MO9912SPASUB02.001) as the source of the data in Table 7. DCs in the FGR-12 are listed in units of Sv/s per Bq/m^3. GENII-S input has to be in Sv/y per Bq/m^3. DC were therefore converted to the units used in GENII-S input file by multiplying FGR-12 DCs by the conversion factor of 3.15×10^7 s/y. In addition, for three radionuclides (^{222}Rn, ^{225}Ac, and ^{223}Ra) contributions from their short-lived progeny were added to the DC of a parent, in a process described in CRWMS M&O (1999). DCs for radionuclides of interest and their progeny are summarized in Table 8.

Table 8. Dose Coefficients for 1-cm and 15-cm Layer of Contaminated Soil for Radionuclides of Interest (shown in bold type) and Their Progeny

Radionuclide	Dose Coefficient for contaminated soil			
	1 cm		15 cm	
	Sv/s per Bq/m^3 [a]	Sv/y per Bq/m^3 [b]	Sv/s per Bq/m^3 [a]	Sv/y per Bq/m^3 [b]
^{90}Sr	1.31E-21	4.13E-14	3.72E-21	1.17E-13
^{90}Y	3.10E-20	9.77E-13	1.20E-19	3.78E-12
^{137}Cs + ^{137m}Ba	3.77E-18	1.12E-10	1.71E-17	5.39E-10
^{210}Pb	8.27E-21	2.61E-13	1.31E-20	4.13E-13
^{210}Bi	5.54E-21	1.75E-13	1.86E-20	5.86E-13
^{210}Po	5.32E-23	1.68E-15	2.45E-22	7.72E-15
^{226}Ra	4.15E-20	1.31E-12	1.65E-19	5.20E-12
^{222}Rn + progeny [c]	(2.54E-21)	3.40E-10	(1.14E-20)	1.58E-09
^{218}Po	(5.70E-23)		(2.63E-22)	
^{214}Pb	(1.57E-18)		(6.70E-18)	
^{214}Bi	(9.15E-18)		(4.36E-17)	
^{214}Po	(5.22E-22)		(2.40E-21)	
^{210}Pb [d]				
^{227}Ac	7.70E-22	2.43E-14	2.62E-21	8.26E-14
^{229}Th	5.09E-19	1.60E-11	1.70E-18	5.36E-11
^{225}Ra	4.24E-20	1.34E-12	5.90E-20	1.86E-12

Table 8. Dose Coefficients for 1-cm and 15-cm Layer of Contaminated Soil for Radionuclides of Interest (shown in bold type) and Their Progeny (Continued)

Radionuclide	Dose Coefficient for contaminated soil			
	1 cm		15 cm	
	Sv/s per Bq/m^3 [a]	Sv/y per Bq/m^3 [b]	Sv/s per Bq/m^3 [a]	Sv/y per Bq/m^3 [b]
^{225}Ac + progeny [c]	(9.56E-20)	4.44E-11	(3.34E-19)	1.93E-10
^{221}Fr	(1.93E-19)		(7.90E-19)	
^{217}At	(1.95E-21)		(8.61E-21)	
^{213}Bi	(8.52E-19)		(3.75E-18)	
^{213}Po at 97.84%	(0)		(0)	
^{209}Tl at 2.16%	(2.66E-19)		(1.25E-18)	
^{209}Pb	(1.40E-21)		(4.08E-21)	
^{230}Th	2.33E-21	7.34E-14	6.39E-21	2.02E-13
^{226}Ra [d]				
^{213}Pa	2.30E-19	7.25E-12	9.62E-19	3.03E-11
^{227}Th	6.49E-19	2.04E-11	2.65E-18	8.35E-11
^{223}Fr	3.10E-19	9.77E-12	1.01E-18	3.18E-11
^{223}Ra + progeny [c]	(8.10E-19)	5.70E-11	(3.10E-18)	2.36E-10
^{219}Rn	(3.56E-19)		(1.54E-18)	
^{215}Po	(1.13E-21)		(4.98E-21)	
^{211}Pb	(3.25E-19)		(1.46E-18)	
^{211}Bi	(2.96E-19)		(1.28E-18)	
^{207}Tl	(2.26E-20)		(9.48E-20)	
^{232}U	1.88E-21	5.92E-14	4.77E-21	1.50E-13
^{233}U	2.16E-21	6.80E-14	7.24E-21	2.28E-13
^{229}Th [d]				
^{234}U	1.01E-21	3.18E-14	2.14E-21	6.74E-14
^{238}Pu	6.34E-22	2.00E-14	8.07E-22	2.54E-14
^{234}U [d]				
^{239}Pu	5.61E-22	1.77E-14	1.52E-21	4.79E-14
^{240}Pu	6.20E-22	1.95E-14	7.84E-22	2.47E-14
^{236}U	6.53E-22	2.06E-14	1.14E-21	3.60E-14
^{242}Pu	5.23E-22	1.65E-14	6.85E-22	2.16E-14
^{241}Am	1.15E-19	3.62E-12	2.34E-19	7.37E-12
^{237}Np	1.38E-19	4.35E-12	4.16E-19	1.31E-11
^{243}Am	2.96E-19	9.32E-12	7.60E-19	2.39E-11
^{239}Np	1.02E-18	3.21E-11	3.90E-18	1.23E-10
^{239}Pu [d]				

NOTES:
[a] Eckerman and Ryman 1993
[b] (Sv/s per Bq/m^3) x (3.15 x 10^7 s/y) = Sv/yr per Bq/m^3
[c] Contribution from progeny listed below is added to the DC for this radionuclide
[d] The DCs for this radionuclide and its progeny, if applicable, have been listed earlier in this Table.

6.5.3 Modeling Input

GENII input consists of parameters included in input files and parameters entered using a menu-driven interface. The content of input files is shown, as images of the files, in Figures 4, 5, 6, and 7. Figure 4 shows the image of the DEFSR.IN file containing default parameter values and conversion factors for GENII-S simulations. (For some parameters, if the user does not enter a parameter value using a menu-driven interface, a value from the default file is assigned to this parameter. The file also contains unit conversion factors.) Parameters included in this file that were used in the calculation of BDCFs were developed in CRWMS M&O (2000f) (MO0010SPAPET07.004) except for the chronic breathing rate as documented in CRWMS M&O (2000h) (MO0010SPAAAM01.014). Parameters not used in the present analysis remained unchanged from the GENII-S original default value.

```
INVENTORY PARAMETERS-----------------------------------------------------------
0.037, 3.7E4, 3.7E7, 3.7E10, 1.0          NVU     Source input conversion
1.0, 0.15, 225.0                          SVU     Soil source conversion
ENVIRONMENTAL PARAMETERS-------------------------------------------------------
0.008                                     ABSHUM  Absolute humidity (kg/m3)
2                                         PRCNTI  Air dispersion conserv. flag
0.001                                     DPVRES  Deposition vel./resuspension
4.7E-10                                   LEAFRS  Leaf resuspension factor
2.0,2.0,3.0,0.8,0.8,0.8,1.0,0.8,1.0,1.5   BIOMAS  BIOMA2 Biomass (kg/m2)
0.259                                     DEPFR2  Interception frac./irrigate
15.0                                      SURCM   Depth of surface soil (cm)
225.0                                     SLDN    Surface soil density (kg/m2)
1.5E3                                     SSLDN   Soil density (kg/m3)
True                                      HARVST  Harvest removal considered?
50.0                                      SOLING  Soil ingested (mg/da)
14.0                                      WTIM    Weathering time (da)
1.0, 0.1, 0.1, 0.1                        TRANS   Translocation, plants
0.1, 0.1, 0.1, 0.1, 1.0, 1.0              TRANSA  Translocation, animal food
68.0, 0.12, 55.0, 0.12, 68.0, 55.0        CONSUM  Animal Consumption (kg/da)
50.0, 0.3, 60.0, 0.3                      DWATER  Animal drinking water (L/da)
0.0, 0.8, 1.0, 0.8                        FRACUT  Acute fresh forage by season
0.2, 0.3, 0.5, 1.0                        SHORWI  Shore width factors
0.02                                      INGWAT  Swim water ingested (L/hr)
25295.0                                   TCWS    H2O/sed. transfer (L/m2/yr)
0.4,  5.0, 4.0                            YELDBT  BIOT: Veg. prod. (kg/m2/yr)
9.41E-4, 2*7.48E-4                        TOTEXC  BIOT: Excavation (m2/m3-yr)
1.0, 0.81, 0.19, 0.02, 0.008, 0.002,      EXCAV   BIOT: Frac. soil brought to
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005,           surface from within the
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005            waste by animal excavation
266.2                                     RINH    Chronic breathing (cm3/sec)
330.0                                     RINHA   Acute breathing (cm3/sec)
10                                        NDIST   Number of distances
805.0, 2414.0, 4023.0, 5632.0, 7241.0,
12068.0, 24135.0, 40255.0, 56315.0,
72405.0                                   X       JF/chi/Q/pop grid dist. (m)
0.1, 0.25, 0.18, 0.91, 0.18, 0.91, 0.18,
0.91, 2*0.20                              DRYFAC, DRYFA2 dry/wet ratio
METABOLIC PARAMETERS-----------------------------------------------------------
0.5, 50.0, 500.0                                       XDIV
0.5,  0.5,  0.95, 0.05,  0.8, 0.0, 0.0,   0.2, 0.0,    ADJ
0.1,  0.9,  0.5,  0.5,  0.15, 0.4, 0.4,  0.05, 0.0,
0.01, 0.99, 0.01, 0.99, 0.05, 0.4, 0.4, 0.135, 0.015
DOSE PARAMETERS-----------------------------------------------------------------
0.25, 0.15, 0.12, 0.12, 0.03, 0.03, 5*0.06            WT   Weighting factors
2.0                                                   SI2I Semi-infinite/inf
================================================================================
```

Figure 4. The Image of the DEFSR.IN File (Default Parameter Values and Conversion Factors)

Food Transfer Factors for SR Runs (09/09/00)

Ele-men	Dep Vel m/sec	Leafy Veg	Root Veg	Fruit --	Grain --	Beef day/kg	Poulty day/kg	Milk day/L	Egg day/kg	Leaching Factor
AC	1.0E-3	3.5E-3	3.5E-4	3.5E-4	3.5E-4	2.5E-5	4.0E-3	2.0E-5	2.0E-3	1.5E-03
AM	1.0E-3	2.0E-3	4.7E-4	4.1E-4	9.0E-5	2.0E-5	6.0E-3	2.0E-6	4.0E-3	3.6E-04
BI	1.0E-3	3.5E-2	5.0E-3	5.0E-3	5.0E-3	4.0E-4	4.0E-2	5.0E-4	4.0E-2	6.8E-03
C	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	1.3E-01
CS	1.0E-3	1.3E-1	4.9E-2	2.2E-1	2.6E-2	5.0E-2	4.4E+0	8.0E-3	4.0E-1	2.4E-03
FR	1.0E-3	2.0E-2	2.0E-2	2.0E-2	1.0E-2	3.0E-2	4.4E+0	7.0E-3	4.9E-1	0.0E-10
I	1.0E-2	3.4E-3	5.0E-2	5.0E-2	5.0E-2	7.0E-3	1.8E-2	1.0E-2	3.0E+0	5.9E-01
NI	1.0E-3	1.8E-1	6.0E-2	6.0E-2	3.0E-2	5.0E-3	1.0E-3	2.0E-2	1.0E-1	1.7E-03
NP	1.0E-3	3.7E-2	1.7E-2	1.7E-2	2.7E-3	1.0E-3	4.0E-3	5.0E-6	2.0E-3	1.3E-01
PA	1.0E-3	2.5E-3	2.5E-4	2.5E-4	2.5E-4	1.0E-5	4.0E-3	5.0E-6	2.0E-3	1.2E-03
PB	1.0E-3	4.5E-2	9.0E-3	9.0E-3	4.7E-3	4.0E-4	4.0E-2	3.0E-4	8.0E-1	2.5E-03
PO	1.0E-3	2.5E-3	7.0E-3	4.0E-4	4.0E-4	4.0E-3	4.5E-1	3.4E-4	7.0E+0	4.5E-03
PU	1.0E-3	3.9E-4	2.0E-4	1.9E-4	2.6E-5	1.0E-5	4.0E-3	1.1E-6	8.0E-3	1.2E-03
RA	1.0E-3	8.0E-2	1.3E-2	6.1E-3	1.2E-3	9.0E-4	3.0E-2	1.3E-3	2.0E-5	1.4E-03
SR	1.0E-3	2.0E+0	1.2E+0	2.0E-1	2.0E-1	8.0E-3	3.5E-2	1.5E-3	3.0E-1	4.5E-02
TC	1.0E-3	4.0E+1	6.6E+0	1.5E+0	7.3E-1	1.0E-4	3.0E-2	9.9E-3	3.0E+0	2.8E+00
TH	1.0E-3	4.0E-3	3.0E-4	2.1E-4	3.4E-5	6.0E-6	4.0E-3	5.0E-6	2.0E-3	2.1E-04
U	1.0E-3	8.5E-3	1.4E-2	4.0E-3	1.3E-3	3.0E-4	1.2E+0	6.0E-4	1.0E+0	1.9E-02
Y	1.0E-3	1.5E-2	6.0E-3	6.0E-3	6.0E-3	1.0E-3	1.0E-2	2.0E-5	2.0E-3	4.0E-03

Figure 5. The Image of the FTRANSR.DAT File (Food Transfer Coefficients and Leaching Factors)

The image of the file containing food transfer factors for the elements under consideration, FTRANSR.DAT, developed in CRWMS M&O (2000g) (MO0010SPAPTC08.005) is shown in Figure 5. This file also contains leaching factors developed in a separate report (CRWMS M&O 2000k) (MO0004RIB00085.000). Figures 6 and 7 show the images of the files containing dose coefficients (for both the primary radionuclides and their decay products) for external exposure from soil contaminated to a depth of 15 cm (file name GRDFSR.DAT) and 1 cm (file name GRDF1SR.DAT), respectively. The dose coefficients for a 15-cm layer of soil were developed previously (CRWMS M&O 1999) (MO9912RIB00066.000). The remaining ones were developed in this analysis based on accepted data (MO9912SPASUB02.001) and are documented in this report (Section 6.5.2.2).

As noted previously, GENII-S input consists of input files and parameters entered using a menu-driven interface for the individual model runs. BDCFs for the transition phase were developed for two ash thicknesses, 1 cm and 15 cm, and for the two distributions of mass loading, a distribution of annual average values and a distribution of 10-year average values. All together four sets for the transition phase and one set for the steady-state phase BDCFs were developed.

Model input for the specific ash thickness/phase combinations consists of input files and menu-accessible input parameters, which are entered manually for individual runs. Some of these parameters are common to all the cases under consideration, while the other may be ash thickness- or phase-specific.

FGR12 air,water,soil(15 CM) DCFs (Sv/yr per Bq/n) (9 Sep 2000 MAW)

	Air	Water	Soil	Buried	Buried	Buried
	Submersion	Surface	15 cm	0.15 m	0.5 m	1.0m
n	m3	L	"m3"	m3	m3	m3
C 14	7.06E-12	0.00E+00	2.27E-15	0.00E+00	0.00E+00	0.00E+00
NI63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SR90	2.37E-10	0.00E+00	1.17E-13	0.00E+00	0.00E+00	0.00E+00
Y 90	5.99E-09	0.00E+00	3.78E-12	0.00E+00	0.00E+00	0.00E+00
TC99	5.11E-11	0.00E+00	2.11E-14	0.00E+00	0.00E+00	0.00E+00
I 129	1.20E-08	0.00E+00	2.19E-12	0.00E+00	0.00E+00	0.00E+00
CS137	9.08E-07	0.00E+00	5.39E-10	0.00E+00	0.00E+00	0.00E+00
TH230	5.49E-10	0.00E+00	2.02E-13	0.00E+00	0.00E+00	0.00E+00
RA226	9.93E-09	0.00E+00	5.20E-12	0.00E+00	0.00E+00	0.00E+00
RN222	2.79E-06	0.00E+00	1.59E-09	0.00E+00	0.00E+00	0.00E+00
PB210	1.78E-09	0.00E+00	4.13E-13	0.00E+00	0.00E+00	0.00E+00
BI210	1.04E-09	0.00E+00	5.87E-13	0.00E+00	0.00E+00	0.00E+00
PO210	1.31E-11	0.00E+00	7.73E-15	0.00E+00	0.00E+00	0.00E+00
U 232	4.48E-10	0.00E+00	1.50E-13	0.00E+00	0.00E+00	0.00E+00
TH232	2.75E-10	0.00E+00	8.76E-14	0.00E+00	0.00E+00	0.00E+00
RA228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AC228	1.51E-06	0.00E+00	8.69E-10	0.00E+00	0.00E+00	0.00E+00
TH228	2.90E-09	0.00E+00	1.32E-12	0.00E+00	0.00E+00	0.00E+00
RA224	1.55E-08	0.00E+00	8.62E-12	0.00E+00	0.00E+00	0.00E+00
PB212	2.17E-07	0.00E+00	1.14E-10	0.00E+00	0.00E+00	0.00E+00
BI212	2.30E-06	0.00E+00	1.27E-09	0.00E+00	0.00E+00	0.00E+00
PU242	1.26E-10	0.00E+00	2.16E-14	0.00E+00	0.00E+00	0.00E+00
NP238	8.57E-07	0.00E+00	4.98E-10	0.00E+00	0.00E+00	0.00E+00
U 234	2.41E-10	0.00E+00	6.75E-14	0.00E+00	0.00E+00	0.00E+00
U 236	1.58E-10	0.00E+00	3.60E-14	0.00E+00	0.00E+00	0.00E+00
PA231	5.42E-08	0.00E+00	3.03E-11	0.00E+00	0.00E+00	0.00E+00
AC227	1.84E-10	0.00E+00	8.26E-14	0.00E+00	0.00E+00	0.00E+00
TH227	1.54E-07	0.00E+00	8.36E-11	0.00E+00	0.00E+00	0.00E+00
FR223	7.22E-08	0.00E+00	3.19E-11	0.00E+00	0.00E+00	0.00E+00
RA223	4.30E-07	0.00E+00	2.36E-10	0.00E+00	0.00E+00	0.00E+00
NP237	3.25E-08	0.00E+00	1.31E-11	0.00E+00	0.00E+00	0.00E+00
PA233	2.95E-07	0.00E+00	1.63E-10	0.00E+00	0.00E+00	0.00E+00
U 233	5.14E-10	0.00E+00	2.28E-13	0.00E+00	0.00E+00	0.00E+00
TH229	1.21E-07	0.00E+00	5.36E-11	0.00E+00	0.00E+00	0.00E+00
RA225	8.80E-09	0.00E+00	1.86E-12	0.00E+00	0.00E+00	0.00E+00
AC225	3.40E-07	0.00E+00	1.94E-10	0.00E+00	0.00E+00	0.00E+00
U 238	1.08E-10	0.00E+00	1.74E-14	0.00E+00	0.00E+00	0.00E+00
TH234	3.33E-08	0.00E+00	1.73E-11	0.00E+00	0.00E+00	0.00E+00
PA234	2.95E-06	0.00E+00	1.70E-09	0.00E+00	0.00E+00	0.00E+00
PU238	1.54E-10	0.00E+00	2.54E-14	0.00E+00	0.00E+00	0.00E+00
PU240	1.50E-10	0.00E+00	2.47E-14	0.00E+00	0.00E+00	0.00E+00
AM241	2.58E-08	0.00E+00	7.38E-12	0.00E+00	0.00E+00	0.00E+00
PU237	6.36E-08	0.00E+00	2.72E-11	0.00E+00	0.00E+00	0.00E+00
AM243	6.87E-08	0.00E+00	2.40E-11	0.00E+00	0.00E+00	0.00E+00
NP239	2.43E-07	0.00E+00	1.23E-10	0.00E+00	0.00E+00	0.00E+00
PU239	1.34E-10	0.00E+00	4.79E-14	0.00E+00	0.00E+00	0.00E+00

Figure 6. Image of the GRDFSR.DAT File (Dose Coefficients for Soil Contaminated to 15 cm)

FGR12 air,water,soil(1 CM) DCFs (Sv/yr per Bq/n) (27 Sep 00 MAW)

n	Air Submersion m3	Water Surface L	Soil 1 cm "m3"	Buried 0.15 m m3	Buried 0.5 m m3	Buried 1.0m m3
C 14	7.06E-12	0.00E+00	1.35E-15	0.00E+00	0.00E+00	0.00E+00
NI63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SR90	2.37E-10	0.00E+00	4.13E-14	0.00E+00	0.00E+00	0.00E+00
Y 90	5.99E-09	0.00E+00	9.77E-13	0.00E+00	0.00E+00	0.00E+00
TC99	5.11E-11	0.00E+00	9.20E-15	0.00E+00	0.00E+00	0.00E+00
I 129	1.20E-08	0.00E+00	1.87E-12	0.00E+00	0.00E+00	0.00E+00
CS137	9.08E-07	0.00E+00	1.12E-10	0.00E+00	0.00E+00	0.00E+00
TH230	5.49E-10	0.00E+00	7.34E-14	0.00E+00	0.00E+00	0.00E+00
RA226	9.93E-09	0.00E+00	1.31E-12	0.00E+00	0.00E+00	0.00E+00
RN222	2.79E-06	0.00E+00	3.40E-10	0.00E+00	0.00E+00	0.00E+00
PB210	1.78E-09	0.00E+00	2.61E-13	0.00E+00	0.00E+00	0.00E+00
BI210	1.04E-09	0.00E+00	1.75E-13	0.00E+00	0.00E+00	0.00E+00
PO210	1.31E-11	0.00E+00	1.68E-15	0.00E+00	0.00E+00	0.00E+00
U 232	4.48E-10	0.00E+00	5.92E-14	0.00E+00	0.00E+00	0.00E+00
TH232	2.75E-10	0.00E+00	3.65E-14	0.00E+00	0.00E+00	0.00E+00
RA228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AC228	1.51E-06	0.00E+00	1.88E-10	0.00E+00	0.00E+00	0.00E+00
TH228	2.90E-09	0.00E+00	3.84E-13	0.00E+00	0.00E+00	0.00E+00
RA224	1.55E-08	0.00E+00	2.04E-12	0.00E+00	0.00E+00	0.00E+00
PB212	2.17E-07	0.00E+00	2.87E-11	0.00E+00	0.00E+00	0.00E+00
BI212	2.30E-06	0.00E+00	2.58E-10	0.00E+00	0.00E+00	0.00E+00
PU242	1.26E-10	0.00E+00	1.65E-14	0.00E+00	0.00E+00	0.00E+00
NP238	8.57E-07	0.00E+00	1.06E-10	0.00E+00	0.00E+00	0.00E+00
U 234	2.41E-10	0.00E+00	3.18E-14	0.00E+00	0.00E+00	0.00E+00
U 236	1.58E-10	0.00E+00	2.06E-14	0.00E+00	0.00E+00	0.00E+00
PA231	5.42E-08	0.00E+00	7.25E-12	0.00E+00	0.00E+00	0.00E+00
AC227	1.84E-10	0.00E+00	2.43E-14	0.00E+00	0.00E+00	0.00E+00
TH227	1.54E-07	0.00E+00	2.04E-11	0.00E+00	0.00E+00	0.00E+00
FR223	7.22E-08	0.00E+00	9.77E-12	0.00E+00	0.00E+00	0.00E+00
RA223	4.30E-07	0.00E+00	5.70E-11	0.00E+00	0.00E+00	0.00E+00
NP237	3.25E-08	0.00E+00	4.35E-12	0.00E+00	0.00E+00	0.00E+00
PA233	2.95E-07	0.00E+00	3.91E-11	0.00E+00	0.00E+00	0.00E+00
U 233	5.14E-10	0.00E+00	6.80E-14	0.00E+00	0.00E+00	0.00E+00
TH229	1.21E-07	0.00E+00	1.60E-11	0.00E+00	0.00E+00	0.00E+00
RA225	8.80E-09	0.00E+00	1.34E-12	0.00E+00	0.00E+00	0.00E+00
AC225	3.40E-07	0.00E+00	4.44E-11	0.00E+00	0.00E+00	0.00E+00
U 238	1.08E-10	0.00E+00	1.39E-14	0.00E+00	0.00E+00	0.00E+00
TH234	3.33E-08	0.00E+00	4.44E-12	0.00E+00	0.00E+00	0.00E+00
PA234	2.95E-06	0.00E+00	3.72E-10	0.00E+00	0.00E+00	0.00E+00
PU238	1.54E-10	0.00E+00	2.00E-14	0.00E+00	0.00E+00	0.00E+00
PU240	1.50E-10	0.00E+00	1.95E-14	0.00E+00	0.00E+00	0.00E+00
AM241	2.58E-08	0.00E+00	3.62E-12	0.00E+00	0.00E+00	0.00E+00
PU237	6.36E-08	0.00E+00	8.44E-12	0.00E+00	0.00E+00	0.00E+00
AM243	6.87E-08	0.00E+00	9.32E-12	0.00E+00	0.00E+00	0.00E+00
NP239	2.43E-07	0.00E+00	3.21E-11	0.00E+00	0.00E+00	0.00E+00
PU239	1.34E-10	0.00E+00	1.77E-14	0.00E+00	0.00E+00	0.00E+00

Figure 7. Image of the GRDF1SR.DAT File (Dose Coefficients for Soil Contaminated to 1 cm)

Two distributions of mass loading were considered for calculations of transition phase BDCFs. (Mass loading is a GENII-S parameter, which quantifies mass concentration of suspended particulates in air.) Detailed descriptions of these distributions are in CRWMS M&O (2000h). The first is a distribution of possible annual average values of mass loading following deposition of a deep ash layer at the location of the critical group. This distribution describes changes in average annual mass loading conditions during one 10-year transition period and is intended to bound uncertainties in mass loading due to variation in ash depth. The second is a distribution of transition-period (10-year) average values of mass loading that correspond to differences in predicted ash depth at the location of the critical group. This distribution is intended to account for uncertainties in mass loading due to variation over all predicted ash depths. Sampling of the BDCFs developed from this distribution should be performed such that this parameter is correlated with the amount of contaminated ash deposited on the ground at the location of the critical group.

Table 9 lists exposure scenarios considered in this calculation, the corresponding input files, and the ash thickness- and phase-specific input parameters. Table 10 contains an example of menu-driven input. The specific values apply to the transition phase, 1-cm ash deposit, and the annual average distribution of mass loading. Parameters listed in Table 10 other than those listed in Table 9 are the same for all of the remaining exposure scenarios. The values and selections shown in Table 10 are listed in the format that they are entered in GENII-S.

Table 9. Exposure Scenarios Considered in the Calculation, the Corresponding Input Files and the Ash Thickness-, and Phase-Specific Input Parameters

Exposure Scenario	Input Files	Parameter	Distribution Type	Minimum	Best Estimate	Maximum
Transition 1 cm of ash	defsr.in ftransr.dat grdf1sr.dat	Mass loading based on distribution of annual averages, g/m^3 [b]	Loguniform	1.05×10^{-4}	8.64×10^{-4}	3.00×10^{-3}
		Surface ash/soil density, g/m^2 [c]	Fixed		1.5×10^{4}	
		Crop resuspension factor, 1/m [c]	Loguniform	7.0×10^{-9}	5.76×10^{-8}	2.00×10^{-7}
		Fraction of root in upper soil [d]	Fixed		0.067	
		Fraction of root in deep soil [d]	Fixed		0.933	
Transition 15 cm of ash	defsr.in ftransr.dat grdfsr.dat	Mass loading based on distribution of annual averages, g/m^3 [a]	Loguniform	1.05×10^{-4}	8.64×10^{-4}	3.00×10^{-3}
		Surface ash/soil density, g/m^2 [c]	Fixed		2.25×10^{5}	
		Crop resuspension factor, 1/m [c]	Loguniform	4.67×10^{-10}	3.84×10^{-9}	1.33×10^{-8}
		Fraction of root in upper soil [d]	Fixed		1	
		Fraction of root in deep soil [d]	Fixed		0	
Transition 1 cm of ash	defsr.in ftransr.dat grdf1sr.dat	Mass loading based on distribution of 10-yr averages, g/m^3 [b]	Loguniform	1.05×10^{-4}	3.60×10^{-4}	8.64×10^{-4}
		Surface ash/soil density, g/m^2 [c]	Fixed		1.5×10^{4}	
		Crop resuspension factor, 1/m [c]	Loguniform	7.0×10^{-9}	2.40×10^{-8}	5.76×10^{-8}
		Fraction of root in upper soil [d]	Fixed		0.067	
		Fraction of root in deep soil [d]	Fixed		0.933	
Transition 15 cm of ash	defsr.in ftransr.dat grdfsr.dat	Mass loading based on distribution of 10-yr averages, g/m^3 [a]	Loguniform	1.05×10^{-4}	3.60×10^{-4}	8.64×10^{-4}
		Surface ash/soil density, g/m^2 [c]	Fixed		2.25×10^{5}	
		Crop resuspension factor, 1/m [c]	Loguniform	4.67×10^{-10}	1.60×10^{-9}	3.84×10^{-9}
		Fraction of root in upper soil [d]	Fixed		1	
		Fraction of root in deep soil [d]	Fixed		0	
Steady-state (15 cm of soil/ash mixture)	defsr.in ftransr.dat grdfsr.dat	Mass loading based on distribution of annual averages, g/m^3 [a]	Normal	3.8×10^{-5}	1.05×10^{-4}	1.73×10^{-4}
		Surface ash/soil density, g/m^2 [c]	Fixed		2.25×10^{5}	
		Crop resuspension factor, 1/m [c]	Normal	1.69×10^{-10}	4.67×10^{-10}	7.69×10^{-10}
		Fraction of root in upper soil [d]	Fixed		1	
		Fraction of root in deep soil [d]	Fixed		0	

SOURCES: [a] CRWMS M&O 2000h for 15-cm ash layer
[b] Section 5.4 of this report for 1-cm ash layer
[c] CRWMS M&O 2000f
[d] Section 5.3 of this report

Table 10. GENII-S Menu-Accessible Input Parameters for the Current Climate

Menu(s)	Option/ - Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
PRE-GENII							
Edit Flags and Options	Scenario Options						Near-field scenario
	- Near-Field Scenario	Y	NA [b]	NA	NA	NA	
	- Population Dose	N	NA	NA	NA	NA	
	- Acute Release	N	NA	NA	NA	NA	
	Transport Options						No radionuclide transport
	- Air Transport	N	NA	NA	NA	NA	
	- Surface Water Transport	N	NA	NA	NA	NA	
	- Biotic Transport	N	NA	NA	NA	NA	
	- Waste From Degradation	N	NA	NA	NA	NA	
	Exposure Pathway Options						Pathway selection
	- External Finite Plume	N	NA	NA	NA	NA	
	- External Infinite Plume	N	NA	NA	NA	NA	
	- External Ground Exposure	Y	NA	NA	NA	NA	
	- External Recreational Exposure	N	NA	NA	NA	NA	
	- Inhalation Uptake	Y	NA	NA	NA	NA	
	- Drinking Water Ingestion	N	NA	NA	NA	NA	
	- Aquatic Food Ingestion	N	NA	NA	NA	NA	
	- Terrestrial Food Ingestion	Y	NA	NA	NA	NA	
	- Animal Product Ingestion	Y	NA	NA	NA	NA	
	- Inadvertent Soil Ingestion	Y	NA	NA	NA	NA	
	Deterministic Output Options						Output selection
	- Both Committed and Cumulative	N	NA	NA	NA	NA	
	- EDE by Nuclide	N	NA	NA	NA	NA	
	- EDE by Pathway	N	NA	NA	NA	NA	
	Run Options						Unit selection, Run selection, Intake duration
	- Inventory Unit Index (1-5)	1, pCi	NA	NA	NA	NA	
	- Soil Inventory Unit Index (1-3)	1, per m^2	NA	NA	NA	NA	
	- Inventory Input Option (1-3)	2	NA	NA	NA	NA	
	- Det Run/Stat Run/Both (1/2/3)	2	NA	NA	NA	NA	
	- Nuclide Intake Duration, yr	1	NA	NA	NA	NA	
Select Nuclides	Radionuclide selection	Y/N	-	-	-	-	Section 6.1

Table 10. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/ - Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
PRE-GENII (continued)							
Select Statistical Output	- Statistical Committed Dose Summary	Y	NA	NA	NA	NA	Output Selection
	- Statistical Committed Nuclide Dose	N	NA	NA	NA	NA	
	- Statistical Committed Pathway Dose	N	NA	NA	NA	NA	
	- Statistical Committed Organ Dose	N	NA	NA	NA	NA	
	- Statistical Cumulative Pathway Dose	N	NA	NA	NA	NA	
	- Statistical Cumulative Organ Dose	N	NA	NA	NA	NA	
	- Statistical External Dose Summary	N	NA	NA	NA	NA	
MAIN EDITING MENU							
Titles And Run Controls	- Model Name		NA	NA	NA	NA	
	- Title (2 lines)		NA	NA	NA	NA	
	- Latin Hypercube (LHS) or Monte Carlo (MC) Sampling	LHS	NA	NA	NA	NA	
	- The Number of Trials (<=500)	150	NA	NA	NA	NA	
	- A Random Seed (0.0<=Seed<=1.0)	0.333	NA	NA	NA	NA	
Fixed Data Input Variable Distribution	**Population/Soil/Scenario Data**						
	- Total Population	1	NA	NA	NA	—	Not used
	- Population Scale Factor	NA	--	1	--	Fixed	Not used
	- Soil/Plant Transfer Scale Factor, (-)	NA	0.0275	--	36.4	Lognormal	Input #2
	- Animal Uptake Scale Factor, (-)	NA	0.117	--	8.51	Lognormal	Input #2
	- Human Dose Factor Scale Factor, (-)	NA	--	1	--	Fixed	Input #6
	- Dose Commitment Period, yr	NA	NA	50	NA	NA	
	- Surface Soil Depth, cm	NA	--	1	--	Fixed	Input #1
	- Surface Soil Density, kg/m^2	NA	--	15	--	Fixed	Input #1
	- Deep Soil Density, kg/m^3	NA	--	1500	--	Fixed	Input #1
	- Roots in Upper Soil, fraction	NA	--	0.067	--	Fixed	Input #1
	- Roots in Deep Soil, fraction	NA	--	0.933	--	Fixed	Input #1
	- Air Release Time Before Intake, yr	NA	NA	0	NA	NA	Not used
	- H2O Release Time Before Intake, yr	NA	NA	0	NA	NA	Not used
	Biotic Trans./Near Field Data Not used	—	—	—	—	—	—

Table 10. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/ - Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
Fixed Data Input Variable Distribution	**External/Inhalation Exposure (cont.)**						
	- Chronic Plume Exposure Time, hr	NA	--	0	--	Fixed	Not used
	- Acute Plume Exposure Time, hr/phr	NA	--	0	--	Fixed	Not used
	- Inhalation Exposure Time, hr/yr	NA	5793.5	6073.5	6353.5	Uniform	Input #3
	- Resuspension Model Flag (0-2)	1	NA	NA	NA	NA	Mass loading
	- Mass Loading, g/m^3	NA	1.05×10^{-4}	8.64×10^{-4}	3.00×10^{-3}	Loguniform	Input #3
	- Transit Time to Rec. Site, hr	NA	--	0	--	Fixed	|
	- Swimming Exposure Time, hr	NA	--	0	--	Fixed	|
	- Boating Exposure Time, hr	NA	--	0	--	Fixed	| Parameters
	- Shoreline Exposure Time, hr	NA	--	0	--	Fixed	| not used
	- Type of Shoreline Index (1-4)	0	NA	NA	NA	NA	|
	- H2O/Sediment Transfer1/m^2/yr	NA	--	0	--	Fixed	|
	- Soil Exposure Time, hr	NA	2827	3387	3947	Uniform	Input #3
	- Home Irrigation Flag (0/1 = N/Y)	0	NA	NA	NA	NA	Water not
	- Irrigation Water Index (1-2)	1	NA	NA	NA	NA	contaminated
	- Home Irrigation Rate, in/yr	NA	51	74	96	Uniform	Input #3
	- Home Irrigation Duration, mo/yr	NA	--	12	--	Fixed	Input #3
	Ingestion Exposure						
	- Food Production Option	0	NA	NA	NA	NA	Not used
	- Food-Weighted Chi/Q, kg-s/m^3	0	--	0	--	Fixed	Not used
	- Crop Resuspension Factor, 1/m	NA	7.00×10^{-9}	5.76×10^{-8}	2.00×10^{-7}	Loguniform	Input #1
	- Crop Deposition Velocity, m/s	NA	--	0.001	--	Fixed	Input #1
	- Crop Interception Fraction	NA	0.044	0.259	0.474	Normal	Input #4
	- Exported Food Dose (0/1 = N/Y)	0	NA	NA	NA	NA	Not used
	- Soil Ingestion Rate, mg/day	NA	--	50	--	Fixed	Input #1
	- Swim H2O Ingestion Rate, l/h	NA	--	0	--	Fixed	Not used
	- Population Ingesting Aquatic Food	0	NA	NA	NA	NA	Not used
	- Bioaccumulation Flag (0/1 = N/Y)	0	NA	NA	NA	NA	Not used
	- Population Drinking Contaminated Water	0	NA	NA	NA	NA	Whole population
	- Drink Water Source Index (0-3)	0	NA	NA	NA	NA	Groundwater
	- Drink Water Treated (0/1 = N/Y)	0	NA	NA	NA	NA	Input #4
	- Drink Water Holdup Time, days	NA	--	0	--	Fixed	Input #4
	- Drink Water Consumption, l/y	NA	0	752.85	1487.45	Fixed	Input #5

Table 10. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/ - Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
Array Data Input (cont.) Variable Distribution	**Aquatic Food Ingestion**						
	- Use (0/1 = F/T)						
	Fish	0	NA	NA	NA	NA	Water not cont.
	Mollusk	0	NA	NA	NA	NA	Input #5
	Crustacean	0	NA	NA	NA	NA	Input #5
	Plants	0	NA	NA	NA	NA	Input #5
	- Transit Time (hr)						
	Fish	NA	--	0	--	Fixed	|
	Mollusk	NA	--	0	--	Fixed	|
	Crustacean	NA	--	0	--	Fixed	|
	Plants	NA	--	0	--	Fixed	|
	- Production (kg/y)						|
	Fish	NA	--	0	--	Fixed	|
	Mollusk	NA	--	0	--	Fixed	|
	Crustacean	NA	--	0	--	Fixed	|
	Plants	NA	--	0	--	Fixed	| Parameters
	- Holdup (days)						| not used
	Fish	NA	--	0	--	Fixed	|
	Mollusk	NA	--	0	--	Fixed	|
	Crustacean	NA	--	0	--	Fixed	|
	Plants	NA	--	0	--	Fixed	|
	- Consumption (kg/yr)						
	Fish	NA	6.63E-8	0.47	8.79	Loguniform	Input #5
	Mollusk	NA	--	0	--		
	Crustacean	NA	--	0	--		
	Plants	NA	--	0	--		

Table 10. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/ - Parameter, Unit	Selection	Values Minimum	 Best Estimate	 Maximum	Distribution	Reference[a]/ Comments
Array Data Input (cont.) Variable Distribution	**Terrestrial Food Ingestion**						
	- Use (0/1 = F/T)						
	Leafy Vegetables	1	NA	NA	NA	NA	Input #5
	Root Vegetables	1	NA	NA	NA	NA	Input #5
	Fruit	1	NA	NA	NA	NA	Input #5
	Grain	1	NA	NA	NA	NA	Input #5
	- Growing Time, days						
	Leafy Vegetables	NA	45	57	68	Uniform	Attachment III
	Root Vegetables	NA	70	84	98	Uniform	Attachment III
	Fruit	NA	88	136	184	Uniform	Attachment III
	Grain	NA	--	244	--	Fixed	Attachment III
	- Water Source Flag (0-2)						
	Leafy Vegetables	0	NA	NA	NA	NA	|
	Root Vegetables	0	NA	NA	NA	NA	| Water not
	Fruit	0	NA	NA	NA	NA	| contaminated
	Grain	0	NA	NA	NA	NA	|
	- Irrigation Rate, in/yr						
	Leafy Vegetables	NA	28	36	43	Uniform	Attachment III
	Root Vegetables	NA	47	50	52	Uniform	Attachment III
	Fruit	NA	30	38	45	Uniform	Attachment III
	Grain	NA	--	56	--	Fixed	Attachment III
	- Irrigation Time, mo/yr						
	Leafy Vegetables	NA	3.0	3.8	4.9	Uniform	Attachment III
	Root Vegetables	NA	3.2	3.9	4.6	Uniform	Attachment III
	Fruit	NA	2.9	4.5	6.0	Uniform	Attachment III
	Grain	NA	--	8.0	--	Fixed	Attachment III
	- Crop Yield, kg/m^2						
	Leafy Vegetables	NA	4.4	4.6	4.8	Uniform	Attachment III
	Root Vegetables	NA	4.1	7.0	9.8	Uniform	Attachment III
	Fruit	NA	1.6	2.0	2.3	Uniform	Attachment III
	Grain	NA	0.3	0.5	0.7	Uniform	Attachment III

Table 10. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	<u>Option</u>/ - Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
Array Data Input (cont.) Variable Distribution	**Terrestrial Food Ingestion (cont.)**						
	- Production, kg/yr						
	Leafy Vegetables	NA	--	0	--	Fixed	
	Root Vegetables	NA	--	0	--	Fixed	Parameter
	Fruit	NA	--	0	--	Fixed	not used
	Grain	NA	--	0	--	Fixed	
	- Holdup, days						
	Leafy Vegetables	NA	--	1	--	Fixed	Input #4
	Root Vegetables	NA	--	14	--	Fixed	Input #4
	Fruit	NA	--	14	--	Fixed	Input #4
	Grain	NA	--	14	--	Fixed	Input #4
	- Consumption Rate, kg/yr						
	Leafy Vegetables	NA	1.16	15.14	59.68	Loguniform	Input #5
	Root Vegetables	NA	0.65	7.81	29.86	Loguniform	Input #5
	Fruit	NA	0.18	15.57	97.69	Loguniform	Input #5
	Grain	NA	8.79×10^{-11}	0.48	12.33	Loguniform	Input #5
	Animal Product Consumption						
	- Use (0/1 = F/T)						
	Beef	1	NA	NA	NA	NA	Input #5
	Poultry	1	NA	NA	NA	NA	Input #5
	Milk	1	NA	NA	NA	NA	Input #5
	Eggs	1	NA	NA	NA	NA	Input #5
	- Consumption Rate, kg/yr						
	Beef	NA	7.34×10^{-7}	2.93	53.11	Fixed	Input #5
	Poultry	NA	2.22×10^{-5}	0.80	10.50	Fixed	Input #5
	Milk	NA	2.91×10^{-9}	4.14	100.36	Fixed	Input #5
	Eggs	NA	0.23	6.68	33.34	Fixed	Input #5
	- Holdup, days						
	Beef	NA	--	20	--	Fixed	Input #4
	Poultry	NA	--	1	--	Fixed	Input #4
	Milk	NA	--	1	--	Fixed	Input #4
	Eggs	NA	--	1	--	Fixed	Input #4

Table 10. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/ - Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
Array Data Input (cont.) Variable Distribution	**Animal Product Consumption**						
	- Production, kg/yr						
	Beef	NA	--	0	--	Fixed	Parameter not used
	Poultry	NA	--	0	--	Fixed	
	Milk	NA	--	0	--	Fixed	
	Eggs	NA	--	0	--	Fixed	
	- Contaminated Water Fraction						
	Beef	NA	--	0	--	Fixed	Water not contaminated
	Poultry	NA	--	0	--	Fixed	
	Milk	NA	--	0	--	Fixed	
	Eggs	NA	--	0	--	Fixed	
	Animal Products (Stored Feed Data)						
	- Dietary Fraction						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	1	--	Fixed	Input #4
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	1	--	Fixed	Input #4
	- Growing Time, days						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	140	--	Fixed	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	140	--	Fixed	Attachment III
	- Water Source Flag						
	Beef	0	NA	NA	NA	NA	Input #4
	Poultry (corn)	1	NA	NA	NA	NA	Input #4
	Milk	0	NA	NA	NA	NA	Input #4
	Eggs (corn)	1	NA	NA	NA	NA	Input #4
	- Irrigation Rate, in/yr						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	75	--	Fixed	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	75	--	Fixed	Attachment III
	- Irrigation Time, mo/yr						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	4.6	--	Fixed	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	4.6	--	Fixed	Attachment III

Table 10. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/ - Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
Array Data Input (cont.) Variable Distribution	**Animal Products (Stored Feed Data) cont.**						
	- Feed Yield, kg/m^2						
	Beef	NA	-	0	--	Fixed	Input #4
	Poultry (corn)	NA	0.6	0.7	0.8	Uniform	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	0.6	0.7	0.8	Uniform	Attachment III
	- Storage, days						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	14	--	Fixed	Input #4
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	14	--	Fixed	Input #4
	Animal Products (Fresh Forage Data)						
	- Dietary Fraction						
	Beef (alfalfa)	NA	--	1	--	Fixed	Input #4
	Milk (alfalfa)	NA	--	1	--	Fixed	Input #4
	- Grow Time, days						
	Beef (alfalfa)	NA	46	47	135	Triangular	Attachment III
	Milk (alfalfa)	NA	46	47	135	Triangular	Attachment III
	- H2O Source Flag						
	Beef (alfalfa)	0	NA	NA	NA	NA	Groundwater
	Milk (alfalfa)	0	NA	NA	NA	NA	
	- Irrigation Rate, in/yr						
	Beef (alfalfa)	NA	--	95	--	Fixed	Attachment III
	Milk (alfalfa)	NA	--	95	--	Fixed	Attachment III
	- Irrigation Time, mo/yr						
	Beef (alfalfa)	NA	--	12	--	Fixed	Attachment III
	Milk (alfalfa)	NA	--	12	--	Fixed	Attachment III
	- Feed Yield, kg/m^2						
	Beef (alfalfa)	NA	1.0	1.1	1.2	Uniform	Attachment III
	Milk (alfalfa)	NA	1.0	1.1	1.2	Uniform	Attachment III
	- Storage, days						
	Beef (alfalfa)	NA	--	0	--	Fixed	Input #4
	Milk (alfalfa)	NA	--	0	--	Fixed	Input #4

Table 10. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/ - Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
Array Data Input (cont.) Variable Distribution	**Inventory – Basic Concentrations**						
	- Air, pCi/m^3	NA	--	0	--	Fixed	
	- Surface Soil, pCi/m^2	NA	--	1	--	Fixed	
	- Deep Soil, pCi/kg	NA	--	0	--	Fixed	
	- Ground Water, pCi/l	NA	--	0	--	Fixed	
	- Surface Water, pCi/l	NA	--	0	--	Fixed	

[a] Input numbers identified in Reference/Comment column refer to input numbers in Table 2.
[b] NA as an entry means that a given selection/option/value does not appear in GENII-S.

6.5.4 Modeling Output

The outcome of the BDCF statistical calculation consists of 150 results of individual model realizations for each radionuclide, for every volcanic scenario under consideration. These results are converted into the discrete cumulative probability distributions, which are used in the TSPA code together with other input parameters to evaluate doses following volcanic eruption. The TSPA dose assessment and, therefore, BDCFs are based on doses expressed in terms of TEDE, which is a sum of the committed effective dose equivalent and deep dose equivalent (10 CFR 20, Section 20.1003). TEDE may be expressed in terms of rems or millirems (thousandth parts of a rem). The summary of the BDCF calculations for the extrusive volcanic event is given in Tables 11 through 15. The tables include the mean, standard deviation, minimum, and the icosatile values (percentiles in increments of 5) for the BDCF cumulative probability distributions.

The results are given for the following cases:

- Transition phase, 1-cm ash layer, and annual average mass loading (Table 11)
- Transition phase, 1-cm ash layer, and 10-year average mass loading (Table 12)
- Transition phase, 15-cm ash layer, and annual average mass loading (Table 13)
- Transition phase, 15-cm ash layer, and 10-year average mass loading (Table 14)
- Steady-state phase (Table 15).

For most radionuclides BDCFs are different for the different exposure scenarios under consideration. The highest BDCFs are for the transition phase, 1-cm ash layer and the annual average mass loading. This set of BDCFs can be compared with the transition phase BDCFs for 15-cm ash layer and annual average mass loading. The reason for the difference is that for the 1-cm contaminated ash layer radionuclides are concentrated in the upper soil. Therefore the activity concentration in air from resuspended contaminated material is higher than that for the 15-cm layer of ash, where the same radioactivity is diluted in 15 times more material thus the resuspended particles would contain less radioactivity. This effect can be observed predominantly for those radionuclides whose BDCF contribution of the inhalation pathway is significant, such as isotopes of plutonium, thorium, uranium, and americium (see Section 6.6). For radionuclides whose BDCFs do not depend on the inhalation pathway, such as ^{90}Sr, the difference is less significant.

The two sets of transition phase BDCFs for 10-year average mass loading show a similar relationship as described above, i.e., the values for 1-cm ash layer are higher than those for the 15-cm ash layer for radionuclides with significant contribution from the inhalation pathway. Overall, BDCFs developed using 10-year average mass loading are lower than those developed using annual average mass loading. This is because annual average mass loading conditions include the high mass loading values characteristic of the initial period of the transition phase, when the concentration of particulates in air is high. BDCFs developed using annual average mass loading apply to the annual average condition for any time during the eruption phase. BDCFs developed using 10-year averages do not include extreme dustiness conditions because the mass loading values they use were integrated over the entire transition phase.

Table 11. BDCFs for Transition Phase, 1-cm Ash Layer, and Annual Average Mass Loading

	^{90}Sr	^{137}Cs	^{210}Pb	^{226}Ra	^{227}Ac	^{229}Th	^{230}Th	^{231}Pa	^{232}U	^{233}U	^{234}U	^{238}Pu	^{239}Pu	^{240}Pu	^{242}Pu	^{241}Am	^{243}Am
Mean	9.01E-09	1.86E-09	1.93E-08	5.86E-09	2.27E-06	7.20E-07	1.08E-07	4.50E-07	2.27E-07	4.58E-08	4.51E-08	1.36E-07	1.51E-07	1.51E-07	1.41E-07	1.54E-07	1.54E-07
STD	2.03E-08	2.43E-09	1.28E-08	3.92E-09	2.02E-06	6.42E-07	9.65E-08	3.89E-07	2.02E-07	4.06E-08	4.00E-08	1.18E-07	1.31E-07	1.31E-07	1.22E-07	1.33E-07	1.33E-07
Min.	2.30E-10	1.01E-09	7.73E-09	1.67E-09	3.00E-07	9.43E-08	1.42E-08	6.79E-08	3.06E-08	6.21E-09	6.11E-09	2.06E-08	2.28E-08	2.28E-08	2.12E-08	2.33E-08	2.33E-08
5%	5.58E-10	1.04E-09	7.96E-09	1.72E-09	3.18E-07	9.98E-08	1.50E-08	7.41E-08	3.17E-08	6.44E-09	6.34E-09	2.24E-08	2.48E-08	2.48E-08	2.31E-08	2.54E-08	2.53E-08
10%	6.33E-10	1.10E-09	8.91E-09	2.07E-09	3.73E-07	1.17E-07	1.76E-08	8.55E-08	3.72E-08	7.55E-09	7.43E-09	2.58E-08	2.86E-08	2.86E-08	2.67E-08	2.93E-08	2.93E-08
15%	7.79E-10	1.14E-09	9.96E-09	2.32E-09	4.41E-07	1.39E-07	2.09E-08	9.50E-08	4.40E-08	8.91E-09	8.77E-09	2.88E-08	3.19E-08	3.19E-08	2.97E-08	3.26E-08	3.25E-08
20%	1.15E-09	1.17E-09	1.07E-08	2.66E-09	5.33E-07	1.68E-07	2.52E-08	1.16E-07	5.35E-08	1.08E-08	1.07E-08	3.50E-08	3.88E-08	3.87E-08	3.61E-08	3.96E-08	3.96E-08
25%	1.31E-09	1.21E-09	1.13E-08	2.88E-09	6.25E-07	1.96E-07	2.94E-08	1.42E-07	6.22E-08	1.26E-08	1.24E-08	4.30E-08	4.77E-08	4.76E-08	4.44E-08	4.86E-08	4.86E-08
30%	1.86E-09	1.24E-09	1.20E-08	3.15E-09	7.57E-07	2.40E-07	3.60E-08	1.56E-07	7.56E-08	1.53E-08	1.50E-08	4.74E-08	5.25E-08	5.24E-08	4.89E-08	5.36E-08	5.35E-08
35%	2.12E-09	1.27E-09	1.27E-08	3.52E-09	9.00E-07	2.85E-07	4.27E-08	1.94E-07	9.12E-08	1.85E-08	1.82E-08	5.84E-08	6.47E-08	6.46E-08	6.03E-08	6.64E-08	6.63E-08
40%	2.50E-09	1.29E-09	1.31E-08	3.82E-09	1.03E-06	3.26E-07	4.90E-08	2.12E-07	1.03E-07	2.08E-08	2.05E-08	6.43E-08	7.12E-08	7.11E-08	6.64E-08	7.27E-08	7.26E-08
45%	2.77E-09	1.32E-09	1.44E-08	4.09E-09	1.25E-06	3.95E-07	5.92E-08	2.59E-07	1.25E-07	2.53E-08	2.49E-08	7.84E-08	8.70E-08	8.68E-08	8.10E-08	8.87E-08	8.85E-08
50%	3.03E-09	1.37E-09	1.54E-08	4.54E-09	1.50E-06	4.75E-07	7.13E-08	3.00E-07	1.50E-07	3.02E-08	2.98E-08	9.09E-08	1.01E-07	1.01E-07	9.39E-08	1.03E-07	1.03E-07
55%	3.47E-09	1.39E-09	1.66E-08	5.26E-09	1.76E-06	5.60E-07	8.41E-08	3.50E-07	1.76E-07	3.56E-08	3.50E-08	1.06E-07	1.18E-07	1.17E-07	1.10E-07	1.20E-07	1.20E-07
60%	4.74E-09	1.42E-09	1.82E-08	5.72E-09	2.12E-06	6.71E-07	1.01E-07	4.27E-07	2.11E-07	4.27E-08	4.20E-08	1.30E-07	1.44E-07	1.44E-07	1.34E-07	1.47E-07	1.46E-07
65%	5.65E-09	1.48E-09	1.91E-08	6.74E-09	2.57E-06	8.16E-07	1.23E-07	5.05E-07	2.57E-07	5.18E-08	5.10E-08	1.53E-07	1.70E-07	1.70E-07	1.58E-07	1.73E-07	1.73E-07
70%	6.60E-09	1.54E-09	2.09E-08	7.22E-09	3.02E-06	9.57E-07	1.44E-07	6.07E-07	3.02E-07	6.10E-08	6.00E-08	1.84E-07	2.04E-07	2.04E-07	1.90E-07	2.08E-07	2.08E-07
75%	7.96E-09	1.65E-09	2.25E-08	8.09E-09	3.71E-06	1.18E-06	1.77E-07	7.23E-07	3.71E-07	7.47E-08	7.36E-08	2.20E-07	2.43E-07	2.43E-07	2.27E-07	2.48E-07	2.48E-07
80%	1.10E-08	1.89E-09	2.49E-08	9.12E-09	4.25E-06	1.35E-06	2.03E-07	8.28E-07	4.24E-07	8.56E-08	8.42E-08	2.51E-07	2.79E-07	2.78E-07	2.60E-07	2.84E-07	2.83E-07
85%	1.44E-08	2.37E-09	2.97E-08	1.03E-08	5.18E-06	1.65E-06	2.48E-07	1.01E-06	5.18E-07	1.05E-07	1.03E-07	3.06E-07	3.39E-07	3.39E-07	3.16E-07	3.46E-07	3.45E-07
90%	2.68E-08	3.05E-09	3.90E-08	1.30E-08	6.19E-06	1.97E-06	2.96E-07	1.20E-06	6.19E-07	1.25E-07	1.23E-07	3.65E-07	4.05E-07	4.04E-07	3.77E-07	4.12E-07	4.11E-07
95%	7.70E-08	8.83E-09	6.04E-08	1.78E-08	7.40E-06	2.36E-06	3.54E-07	1.44E-06	7.40E-07	1.49E-07	1.47E-07	4.37E-07	4.84E-07	4.84E-07	4.51E-07	4.94E-07	4.92E-07
Max.	1.85E-07	2.79E-08	9.55E-08	2.31E-08	8.10E-06	2.57E-06	3.87E-07	1.59E-06	8.09E-07	1.63E-07	1.61E-07	4.81E-07	5.34E-07	5.33E-07	4.97E-07	5.44E-07	5.43E-07

Source: The values were taken from GENII-S runs (see Attachment IV).

Table 12. BDCFs for Transition Phase, 1-cm Ash Layer, and 10-year Average Mass Loading

	^{90}Sr	^{137}Cs	^{210}Pb	^{226}Ra	^{227}Ac	^{229}Th	^{230}Th	^{231}Pa	^{232}U	^{233}U	^{234}U	^{238}Pu	^{239}Pu	^{240}Pu	^{242}Pu	^{241}Am	^{243}Am
Mean	8.92E-09	1.82E-09	1.52E-08	4.01E-09	9.57E-07	3.03E-07	4.56E-08	1.95E-07	9.61E-08	1.94E-08	1.91E-08	5.92E-08	6.56E-08	6.55E-08	6.11E-08	6.70E-08	6.69E-08
STD	2.03E-08	2.39E-09	1.17E-08	3.13E-09	5.53E-07	1.76E-07	2.64E-08	1.06E-07	5.52E-08	1.11E-08	1.10E-08	3.23E-08	3.58E-08	3.58E-08	3.34E-08	3.65E-08	3.64E-08
Min.	2.24E-10	1.01E-09	7.53E-09	1.62E-09	3.00E-07	9.43E-08	1.41E-08	6.77E-08	3.02E-08	6.13E-09	6.03E-09	2.05E-08	2.27E-08	2.27E-08	2.12E-08	2.32E-08	2.32E-08
5%	4.21E-10	1.03E-09	7.80E-09	1.70E-09	3.08E-07	9.67E-08	1.45E-08	6.98E-08	3.07E-08	6.23E-09	6.13E-09	2.11E-08	2.34E-08	2.34E-08	2.18E-08	2.39E-08	2.39E-08
10%	5.79E-10	1.10E-09	8.28E-09	1.85E-09	3.37E-07	1.06E-07	1.59E-08	7.57E-08	3.36E-08	6.81E-09	6.70E-09	2.28E-08	2.53E-08	2.53E-08	2.36E-08	2.58E-08	2.58E-08
15%	7.24E-10	1.13E-09	8.90E-09	2.09E-09	3.80E-07	1.20E-07	1.80E-08	8.28E-08	3.80E-08	7.70E-09	7.57E-09	2.51E-08	2.78E-08	2.78E-08	2.59E-08	2.84E-08	2.84E-08
20%	1.14E-09	1.15E-09	9.26E-09	2.21E-09	4.28E-07	1.35E-07	2.03E-08	9.33E-08	4.30E-08	8.75E-09	8.61E-09	2.83E-08	3.14E-08	3.13E-08	2.92E-08	3.20E-08	3.20E-08
25%	1.27E-09	1.19E-09	9.84E-09	2.36E-09	4.68E-07	1.47E-07	2.21E-08	1.03E-07	4.68E-08	9.48E-09	9.33E-09	3.12E-08	3.46E-08	3.45E-08	3.22E-08	3.53E-08	3.52E-08
30%	1.72E-09	1.22E-09	1.00E-08	2.50E-09	5.15E-07	1.63E-07	2.44E-08	1.11E-07	5.20E-08	1.05E-08	1.04E-08	3.36E-08	3.73E-08	3.72E-08	3.47E-08	3.81E-08	3.80E-08
35%	2.07E-09	1.24E-09	1.03E-08	2.63E-09	5.85E-07	1.84E-07	2.77E-08	1.27E-07	6.11E-08	1.24E-08	1.22E-08	3.82E-08	4.24E-08	4.23E-08	3.95E-08	4.35E-08	4.34E-08
40%	2.44E-09	1.27E-09	1.09E-08	2.76E-09	6.43E-07	2.04E-07	3.06E-08	1.35E-07	6.49E-08	1.31E-08	1.29E-08	4.08E-08	4.53E-08	4.52E-08	4.22E-08	4.62E-08	4.62E-08
45%	2.70E-09	1.29E-09	1.11E-08	2.92E-09	6.96E-07	2.20E-07	3.30E-08	1.48E-07	7.02E-08	1.42E-08	1.40E-08	4.46E-08	4.95E-08	4.94E-08	4.61E-08	5.07E-08	5.06E-08
50%	2.91E-09	1.35E-09	1.13E-08	3.12E-09	8.23E-07	2.61E-07	3.92E-08	1.69E-07	8.26E-08	1.67E-08	1.64E-08	5.11E-08	5.67E-08	5.66E-08	5.28E-08	5.79E-08	5.78E-08
55%	3.40E-09	1.37E-09	1.18E-08	3.27E-09	8.90E-07	2.82E-07	4.24E-08	1.82E-07	8.91E-08	1.80E-08	1.77E-08	5.51E-08	6.11E-08	6.10E-08	5.69E-08	6.23E-08	6.22E-08
60%	4.62E-09	1.39E-09	1.29E-08	3.51E-09	1.02E-06	3.25E-07	4.88E-08	2.07E-07	1.02E-07	2.06E-08	2.03E-08	6.27E-08	6.95E-08	6.94E-08	6.48E-08	7.09E-08	7.08E-08
65%	5.61E-09	1.47E-09	1.36E-08	3.84E-09	1.16E-06	3.67E-07	5.52E-08	2.32E-07	1.16E-07	2.33E-08	2.30E-08	7.05E-08	7.82E-08	7.81E-08	7.29E-08	7.98E-08	7.96E-08
70%	6.41E-09	1.53E-09	1.47E-08	4.25E-09	1.24E-06	3.93E-07	5.90E-08	2.57E-07	1.24E-07	2.51E-08	2.47E-08	7.77E-08	8.62E-08	8.61E-08	8.03E-08	8.83E-08	8.81E-08
75%	7.96E-09	1.62E-09	1.61E-08	4.51E-09	1.43E-06	4.53E-07	6.80E-08	2.85E-07	1.43E-07	2.88E-08	2.83E-08	8.63E-08	9.57E-08	9.56E-08	8.92E-08	9.76E-08	9.74E-08
80%	1.10E-08	1.87E-09	1.83E-08	4.73E-09	1.56E-06	4.96E-07	7.44E-08	3.10E-07	1.56E-07	3.15E-08	3.10E-08	9.41E-08	1.04E-07	1.04E-07	9.72E-08	1.06E-07	1.06E-07
85%	1.44E-08	2.33E-09	2.09E-08	5.33E-09	1.76E-06	5.60E-07	8.41E-08	3.49E-07	1.76E-07	3.56E-08	3.50E-08	1.06E-07	1.17E-07	1.17E-07	1.09E-07	1.20E-07	1.20E-07
90%	2.64E-08	2.98E-09	2.82E-08	7.90E-09	1.96E-06	6.24E-07	9.37E-08	3.88E-07	1.96E-07	3.96E-08	3.90E-08	1.18E-07	1.31E-07	1.30E-07	1.22E-07	1.33E-07	1.33E-07
95%	7.70E-08	8.78E-09	5.73E-08	1.63E-08	2.17E-06	6.89E-07	1.03E-07	4.29E-07	2.17E-07	4.38E-08	4.31E-08	1.30E-07	1.44E-07	1.44E-07	1.35E-07	1.47E-07	1.47E-07
Max.	1.85E-07	2.75E-08	9.21E-08	2.17E-08	2.24E-06	7.12E-07	1.07E-07	4.47E-07	2.24E-07	4.52E-08	4.45E-08	1.36E-07	1.50E-07	1.50E-07	1.40E-07	1.53E-07	1.53E-07

Source: The values were taken from GENII-S runs (see Attachment IV).

Table 13. BDCFs for Transition Phase, 15-cm Ash Layer, and Annual Average Mass Loading

	^{90}Sr	^{137}Cs	^{210}Pb	^{226}Ra	^{227}Ac	^{229}Th	^{230}Th	^{231}Pa	^{232}U	^{233}U	^{234}U	^{238}Pu	^{239}Pu	^{240}Pu	^{242}Pu	^{241}Am	^{243}Am
Mean	8.71E-09	5.81E-09	6.71E-09	1.86E-09	1.52E-07	4.87E-08	7.24E-09	3.07E-08	1.57E-08	3.19E-09	3.13E-09	9.13E-09	1.01E-08	1.01E-08	9.43E-09	1.05E-08	1.06E-08
STD	2.02E-08	2.45E-09	1.13E-08	3.06E-09	1.34E-07	4.26E-08	6.40E-09	2.57E-08	1.33E-08	2.69E-09	2.65E-09	7.82E-09	8.67E-09	8.66E-09	8.08E-09	8.82E-09	8.80E-09
Min.	7.17E-11	4.33E-09	5.77E-10	1.85E-10	2.03E-08	6.86E-09	9.55E-10	4.94E-09	2.09E-09	4.25E-10	4.17E-10	1.40E-09	1.55E-09	1.55E-09	1.45E-09	1.67E-09	1.80E-09
5%	2.34E-10	4.52E-09	7.63E-10	2.51E-10	2.12E-08	7.12E-09	9.93E-10	5.33E-09	2.37E-09	4.83E-10	4.74E-10	1.49E-09	1.65E-09	1.65E-09	1.54E-09	1.77E-09	1.93E-09
10%	4.01E-10	4.57E-09	1.05E-09	2.95E-10	2.63E-08	8.67E-09	1.23E-09	6.17E-09	2.74E-09	5.62E-10	5.52E-10	1.73E-09	1.92E-09	1.91E-09	1.78E-09	2.09E-09	2.23E-09
15%	5.61E-10	4.70E-09	1.12E-09	3.80E-10	2.97E-08	9.77E-09	1.40E-09	7.25E-09	3.49E-09	7.12E-10	6.99E-10	1.93E-09	2.14E-09	2.14E-09	2.00E-09	2.48E-09	2.64E-09
20%	9.68E-10	4.77E-09	1.42E-09	4.82E-10	3.69E-08	1.21E-08	1.75E-09	8.45E-09	4.03E-09	8.19E-10	8.04E-10	2.43E-09	2.70E-09	2.69E-09	2.51E-09	2.86E-09	3.01E-09
25%	1.10E-09	4.88E-09	1.82E-09	5.25E-10	4.17E-08	1.35E-08	1.96E-09	1.01E-08	4.71E-09	9.65E-10	9.48E-10	2.87E-09	3.19E-09	3.18E-09	2.97E-09	3.43E-09	3.56E-09
30%	1.52E-09	5.05E-09	2.00E-09	5.54E-10	5.00E-08	1.63E-08	2.38E-09	1.11E-08	5.40E-09	1.10E-09	1.08E-09	3.19E-09	3.54E-09	3.54E-09	3.30E-09	3.77E-09	3.92E-09
35%	1.90E-09	5.17E-09	2.30E-09	6.57E-10	6.22E-08	2.01E-08	2.94E-09	1.37E-08	6.79E-09	1.40E-09	1.37E-09	3.95E-09	4.38E-09	4.37E-09	4.08E-09	4.72E-09	4.85E-09
40%	2.20E-09	5.25E-09	2.52E-09	7.36E-10	6.85E-08	2.22E-08	3.26E-09	1.45E-08	7.50E-09	1.53E-09	1.50E-09	4.26E-09	4.72E-09	4.72E-09	4.40E-09	4.93E-09	5.07E-09
45%	2.50E-09	5.35E-09	2.75E-09	7.66E-10	8.48E-08	2.73E-08	4.02E-09	1.82E-08	9.24E-09	1.88E-09	1.84E-09	5.34E-09	5.92E-09	5.91E-09	5.52E-09	6.22E-09	6.34E-09
50%	2.72E-09	5.49E-09	2.92E-09	8.64E-10	1.02E-07	3.30E-08	4.87E-09	2.09E-08	1.09E-08	2.21E-09	2.18E-09	6.20E-09	6.87E-09	6.86E-09	6.40E-09	7.15E-09	7.29E-09
55%	3.21E-09	5.57E-09	3.35E-09	9.30E-10	1.16E-07	3.73E-08	5.53E-09	2.37E-08	1.30E-08	2.63E-09	2.59E-09	7.10E-09	7.87E-09	7.86E-09	7.33E-09	8.10E-09	8.22E-09
60%	4.44E-09	5.69E-09	3.70E-09	1.11E-09	1.43E-07	4.58E-08	6.80E-09	2.87E-08	1.53E-08	3.10E-09	3.05E-09	8.56E-09	9.49E-09	9.47E-09	8.84E-09	1.00E-08	1.02E-08
65%	5.42E-09	5.80E-09	4.33E-09	1.30E-09	1.76E-07	5.63E-08	8.39E-09	3.48E-08	1.77E-08	3.58E-09	3.52E-09	1.05E-08	1.16E-08	1.16E-08	1.08E-08	1.19E-08	1.20E-08
70%	6.24E-09	5.87E-09	5.91E-09	1.59E-09	2.00E-07	6.39E-08	9.53E-09	4.00E-08	2.05E-08	4.17E-09	4.10E-09	1.20E-08	1.33E-08	1.33E-08	1.24E-08	1.37E-08	1.38E-08
75%	7.80E-09	6.00E-09	7.11E-09	1.73E-09	2.43E-07	7.76E-08	1.16E-08	4.77E-08	2.44E-08	4.93E-09	4.85E-09	1.44E-08	1.60E-08	1.59E-08	1.49E-08	1.64E-08	1.64E-08
80%	1.07E-08	6.12E-09	8.85E-09	2.37E-09	2.84E-07	9.06E-08	1.35E-08	5.57E-08	2.87E-08	5.81E-09	5.71E-09	1.68E-08	1.86E-08	1.86E-08	1.73E-08	1.91E-08	1.92E-08
85%	1.41E-08	6.56E-09	1.06E-08	2.88E-09	3.44E-07	1.10E-07	1.64E-08	6.76E-08	3.51E-08	7.09E-09	6.98E-09	2.04E-08	2.26E-08	2.26E-08	2.11E-08	2.32E-08	2.33E-08
90%	2.63E-08	7.04E-09	1.92E-08	5.99E-09	4.11E-07	1.31E-07	1.96E-08	8.02E-08	4.14E-08	8.36E-09	8.22E-09	2.42E-08	2.68E-08	2.68E-08	2.50E-08	2.75E-08	2.76E-08
95%	7.68E-08	1.33E-08	4.84E-08	1.49E-08	4.85E-07	1.55E-07	2.32E-08	9.53E-08	4.87E-08	9.83E-09	9.67E-09	2.86E-08	3.17E-08	3.17E-08	2.96E-08	3.26E-08	3.27E-08
Max.	1.83E-07	3.17E-08	8.23E-08	1.98E-08	5.20E-07	1.66E-07	2.48E-08	1.02E-07	5.20E-08	1.05E-08	1.03E-08	3.09E-08	3.43E-08	3.42E-08	3.19E-08	3.50E-08	3.51E-08

Source: The values were taken from GENII-S runs (see Attachment IV).

Table 14. BDCFs for Transition Phase, 15-cm Ash Layer, and 10-year Average Mass Loading

	^{90}Sr	^{137}Cs	^{210}Pb	^{226}Ra	^{227}Ac	^{229}Th	^{230}Th	^{231}Pa	^{232}U	^{233}U	^{234}U	^{238}Pu	^{239}Pu	^{240}Pu	^{242}Pu	^{241}Am	^{243}Am
Mean	8.70E-09	5.81E-09	6.44E-09	1.74E-09	6.44E-08	2.09E-08	3.06E-09	1.37E-08	6.97E-09	1.42E-09	1.40E-09	3.98E-09	4.41E-09	4.40E-09	4.11E-09	4.68E-09	4.83E-09
STD	2.02E-08	2.45E-09	1.13E-08	3.06E-09	3.66E-08	1.17E-08	1.75E-09	7.07E-09	3.81E-09	7.75E-10	7.63E-10	2.14E-09	2.37E-09	2.37E-09	2.21E-09	2.42E-09	2.42E-09
Min.	7.17E-11	4.33E-09	5.63E-10	1.80E-10	2.00E-08	6.76E-09	9.48E-10	4.81E-09	2.02E-09	4.12E-10	4.04E-10	1.37E-09	1.52E-09	1.51E-09	1.41E-09	1.62E-09	1.76E-09
5%	2.33E-10	4.52E-09	7.30E-10	2.17E-10	2.04E-08	6.91E-09	9.58E-10	5.02E-09	2.17E-09	4.43E-10	4.34E-10	1.40E-09	1.56E-09	1.55E-09	1.45E-09	1.70E-09	1.85E-09
10%	4.00E-10	4.57E-09	8.67E-10	2.71E-10	2.34E-08	7.83E-09	1.11E-09	5.48E-09	2.45E-09	4.99E-10	4.90E-10	1.58E-09	1.75E-09	1.75E-09	1.63E-09	1.86E-09	2.00E-09
15%	5.59E-10	4.69E-09	9.65E-10	3.02E-10	2.56E-08	8.58E-09	1.21E-09	6.27E-09	2.90E-09	5.92E-10	5.81E-10	1.69E-09	1.87E-09	1.87E-09	1.74E-09	2.12E-09	2.30E-09
20%	9.66E-10	4.77E-09	1.15E-09	3.33E-10	2.94E-08	9.83E-09	1.40E-09	6.77E-09	3.11E-09	6.40E-10	6.28E-10	1.92E-09	2.13E-09	2.13E-09	1.98E-09	2.30E-09	2.46E-09
25%	1.09E-09	4.87E-09	1.61E-09	4.08E-10	3.24E-08	1.04E-08	1.49E-09	7.74E-09	3.53E-09	7.37E-10	7.23E-10	2.10E-09	2.33E-09	2.32E-09	2.17E-09	2.55E-09	2.68E-09
30%	1.51E-09	5.05E-09	1.83E-09	4.83E-10	3.51E-08	1.16E-08	1.66E-09	8.23E-09	4.17E-09	8.46E-10	8.31E-10	2.26E-09	2.50E-09	2.50E-09	2.33E-09	2.79E-09	2.94E-09
35%	1.88E-09	5.17E-09	1.98E-09	5.26E-10	4.14E-08	1.36E-08	1.97E-09	9.20E-09	4.44E-09	9.07E-10	8.90E-10	2.62E-09	2.90E-09	2.90E-09	2.70E-09	3.14E-09	3.27E-09
40%	2.20E-09	5.25E-09	2.27E-09	5.97E-10	4.37E-08	1.44E-08	2.07E-09	1.00E-08	5.02E-09	1.03E-09	1.01E-09	2.77E-09	3.07E-09	3.06E-09	2.86E-09	3.29E-09	3.44E-09
45%	2.50E-09	5.34E-09	2.54E-09	6.94E-10	4.93E-08	1.59E-08	2.32E-09	1.07E-08	5.39E-09	1.12E-09	1.10E-09	3.09E-09	3.43E-09	3.42E-09	3.20E-09	3.64E-09	3.78E-09
50%	2.72E-09	5.49E-09	2.75E-09	7.41E-10	5.45E-08	1.78E-08	2.59E-09	1.18E-08	5.95E-09	1.21E-09	1.19E-09	3.42E-09	3.79E-09	3.78E-09	3.53E-09	4.04E-09	4.21E-09
55%	3.20E-09	5.57E-09	2.97E-09	8.21E-10	5.97E-08	1.94E-08	2.84E-09	1.30E-08	6.73E-09	1.36E-09	1.34E-09	3.71E-09	4.11E-09	4.10E-09	3.83E-09	4.51E-09	4.66E-09
60%	4.43E-09	5.69E-09	3.40E-09	8.96E-10	6.83E-08	2.17E-08	3.19E-09	1.47E-08	7.56E-09	1.53E-09	1.50E-09	4.19E-09	4.64E-09	4.64E-09	4.33E-09	5.03E-09	5.17E-09
65%	5.41E-09	5.79E-09	4.03E-09	1.14E-09	7.51E-08	2.43E-08	3.58E-09	1.65E-08	8.41E-09	1.72E-09	1.70E-09	4.59E-09	5.08E-09	5.08E-09	4.74E-09	5.62E-09	5.76E-09
70%	6.23E-09	5.87E-09	5.68E-09	1.40E-09	8.24E-08	2.66E-08	3.92E-09	1.72E-08	8.98E-09	1.82E-09	1.79E-09	5.02E-09	5.57E-09	5.56E-09	5.19E-09	6.14E-09	6.26E-09
75%	7.80E-09	6.00E-09	6.66E-09	1.61E-09	9.53E-08	3.06E-08	4.54E-09	1.93E-08	1.00E-08	2.04E-09	2.01E-09	5.78E-09	6.40E-09	6.39E-09	5.97E-09	6.61E-09	6.73E-09
80%	1.07E-08	6.12E-09	8.18E-09	2.13E-09	1.02E-07	3.30E-08	4.88E-09	2.08E-08	1.09E-08	2.20E-09	2.16E-09	6.19E-09	6.86E-09	6.85E-09	6.39E-09	7.11E-09	7.23E-09
85%	1.41E-08	6.56E-09	1.04E-08	2.86E-09	1.16E-07	3.73E-08	5.52E-09	2.37E-08	1.25E-08	2.52E-09	2.48E-09	6.97E-09	7.73E-09	7.72E-09	7.20E-09	8.08E-09	8.21E-09
90%	2.62E-08	7.04E-09	1.87E-08	5.85E-09	1.32E-07	4.23E-08	6.29E-09	2.70E-08	1.41E-08	2.87E-09	2.82E-09	7.83E-09	8.68E-09	8.66E-09	8.09E-09	9.24E-09	9.38E-09
95%	7.68E-08	1.33E-08	4.83E-08	1.49E-08	1.49E-07	4.78E-08	7.11E-09	2.97E-08	1.50E-08	3.06E-09	3.00E-09	8.92E-09	9.89E-09	9.88E-09	9.22E-09	1.02E-08	1.03E-08
Max.	1.83E-07	3.17E-08	8.23E-08	1.98E-08	1.50E-07	4.80E-08	7.13E-09	3.01E-08	1.52E-08	3.12E-09	3.06E-09	9.04E-09	1.00E-08	1.00E-08	9.34E-09	1.03E-08	1.05E-08

Source: The values were taken from GENII-S runs (see Attachment IV).

Table 15. BDCFs for Steady-State Phase

	^{90}Sr	^{137}Cs	^{210}Pb	^{226}Ra	^{227}Ac	^{229}Th	^{230}Th	^{231}Pa	^{232}U	^{233}U	^{234}U	^{238}Pu	^{239}Pu	^{240}Pu	^{242}Pu	^{241}Am	^{243}Am
Mean	8.70E-09	5.81E-09	6.30E-09	1.68E-09	2.03E-08	6.84E-09	9.53E-10	5.18E-09	2.56E-09	5.33E-10	5.23E-10	1.38E-09	1.53E-09	1.53E-09	1.42E-09	1.75E-09	1.90E-09
STD	2.02E-08	2.45E-09	1.13E-08	3.06E-09	4.05E-09	1.25E-09	1.88E-10	1.17E-09	1.35E-09	2.97E-10	2.91E-10	2.35E-10	2.60E-10	2.60E-10	2.43E-10	4.02E-10	4.02E-10
Min.	7.02E-11	4.33E-09	5.28E-10	1.67E-10	1.09E-08	3.86E-09	5.04E-10	3.15E-09	1.21E-09	2.49E-10	2.44E-10	8.40E-10	9.32E-10	9.31E-10	8.68E-10	1.07E-09	1.23E-09
5%	2.32E-10	4.52E-09	6.31E-10	1.88E-10	1.23E-08	4.35E-09	5.72E-10	3.49E-09	1.34E-09	2.75E-10	2.69E-10	9.36E-10	1.04E-09	1.04E-09	9.67E-10	1.18E-09	1.32E-09
10%	4.00E-10	4.57E-09	7.56E-10	2.25E-10	1.42E-08	4.90E-09	6.68E-10	3.78E-09	1.55E-09	3.18E-10	3.11E-10	1.03E-09	1.15E-09	1.14E-09	1.07E-09	1.26E-09	1.40E-09
15%	5.59E-10	4.69E-09	8.60E-10	2.49E-10	1.57E-08	5.38E-09	7.29E-10	4.12E-09	1.75E-09	3.59E-10	3.52E-10	1.10E-09	1.22E-09	1.21E-09	1.13E-09	1.39E-09	1.52E-09
20%	9.65E-10	4.77E-09	1.09E-09	2.75E-10	1.67E-08	5.66E-09	7.85E-10	4.25E-09	1.81E-09	3.72E-10	3.65E-10	1.17E-09	1.30E-09	1.29E-09	1.21E-09	1.43E-09	1.59E-09
25%	1.09E-09	4.87E-09	1.32E-09	3.60E-10	1.73E-08	5.90E-09	8.18E-10	4.47E-09	1.92E-09	3.95E-10	3.87E-10	1.20E-09	1.33E-09	1.33E-09	1.24E-09	1.52E-09	1.66E-09
30%	1.51E-09	5.04E-09	1.65E-09	4.14E-10	1.81E-08	6.12E-09	8.52E-10	4.59E-09	2.02E-09	4.15E-10	4.07E-10	1.25E-09	1.39E-09	1.39E-09	1.29E-09	1.54E-09	1.71E-09
35%	1.87E-09	5.17E-09	1.88E-09	4.61E-10	1.88E-08	6.40E-09	8.86E-10	4.69E-09	2.08E-09	4.30E-10	4.22E-10	1.28E-09	1.42E-09	1.42E-09	1.32E-09	1.60E-09	1.74E-09
40%	2.20E-09	5.25E-09	2.10E-09	5.16E-10	1.94E-08	6.54E-09	9.15E-10	4.81E-09	2.16E-09	4.42E-10	4.33E-10	1.32E-09	1.46E-09	1.46E-09	1.36E-09	1.63E-09	1.78E-09
45%	2.50E-09	5.34E-09	2.41E-09	6.12E-10	1.97E-08	6.64E-09	9.21E-10	4.90E-09	2.23E-09	4.54E-10	4.45E-10	1.34E-09	1.49E-09	1.48E-09	1.38E-09	1.66E-09	1.81E-09
50%	2.72E-09	5.49E-09	2.61E-09	6.93E-10	2.01E-08	6.78E-09	9.47E-10	5.04E-09	2.30E-09	4.70E-10	4.61E-10	1.37E-09	1.52E-09	1.52E-09	1.42E-09	1.70E-09	1.85E-09
55%	3.20E-09	5.56E-09	2.81E-09	7.73E-10	2.06E-08	6.96E-09	9.67E-10	5.21E-09	2.35E-09	4.85E-10	4.76E-10	1.40E-09	1.55E-09	1.55E-09	1.45E-09	1.77E-09	1.92E-09
60%	4.43E-09	5.68E-09	3.25E-09	8.16E-10	2.14E-08	7.17E-09	1.01E-09	5.29E-09	2.52E-09	5.20E-10	5.10E-10	1.44E-09	1.60E-09	1.60E-09	1.49E-09	1.79E-09	1.95E-09
65%	5.41E-09	5.76E-09	3.83E-09	1.05E-09	2.21E-08	7.35E-09	1.02E-09	5.44E-09	2.62E-09	5.41E-10	5.30E-10	1.48E-09	1.64E-09	1.64E-09	1.53E-09	1.83E-09	1.97E-09
70%	6.23E-09	5.87E-09	5.56E-09	1.28E-09	2.22E-08	7.52E-09	1.05E-09	5.56E-09	2.69E-09	5.56E-10	5.46E-10	1.51E-09	1.67E-09	1.67E-09	1.56E-09	1.88E-09	2.03E-09
75%	7.80E-09	6.00E-09	6.59E-09	1.53E-09	2.31E-08	7.74E-09	1.09E-09	5.67E-09	2.79E-09	5.78E-10	5.67E-10	1.55E-09	1.72E-09	1.72E-09	1.60E-09	1.91E-09	2.06E-09
80%	1.07E-08	6.12E-09	7.95E-09	2.09E-09	2.40E-08	7.99E-09	1.13E-09	5.97E-09	3.01E-09	6.25E-10	6.14E-10	1.59E-09	1.76E-09	1.76E-09	1.64E-09	2.02E-09	2.17E-09
85%	1.41E-08	6.56E-09	1.03E-08	2.71E-09	2.57E-08	8.42E-09	1.19E-09	6.25E-09	3.17E-09	6.63E-10	6.50E-10	1.68E-09	1.86E-09	1.86E-09	1.73E-09	2.10E-09	2.25E-09
90%	2.62E-08	7.04E-09	1.85E-08	5.73E-09	2.67E-08	8.94E-09	1.26E-09	6.88E-09	3.67E-09	7.67E-10	7.53E-10	1.73E-09	1.92E-09	1.92E-09	1.79E-09	2.25E-09	2.40E-09
95%	7.68E-08	1.33E-08	4.82E-08	1.49E-08	2.93E-08	9.39E-09	1.34E-09	8.77E-09	9.44E-09	2.05E-09	2.01E-09	1.95E-09	2.17E-09	2.16E-09	2.02E-09	3.00E-09	3.16E-09
Max.	1.83E-07	3.17E-08	8.22E-08	1.98E-08	3.02E-08	1.01E-08	1.43E-09	1.10E-08	1.24E-08	2.70E-09	2.65E-09	1.98E-09	2.20E-09	2.19E-09	2.04E-09	3.98E-09	4.15E-09

Source: The values were taken from GENII-S runs (see Attachment IV).

6.6 PATHWAY ANALYSIS

BDCF values include contributions from various radiological pathways through the biosphere, as described in Section 6.3.2. The evaluation of the degree to which different pathways contribute to BDCFs was the subject of an independent assessment presented in this section. To determine the contributions from different exposure pathways to the BDCF values, a single GENII-S deterministic assessment was performed for each radionuclide. Deterministic GENII-S runs were carried out simultaneously with the stochastic runs using input values listed in the column labeled "Best Estimate" of Tables 9 and 10. The software routine used to calculate pathway contributions has been developed and is documented in Attachment V of this report.

The results of pathway analysis are summarized in Tables 16 through 20 for the five exposure scenarios. For most radionuclides (except ^{90}Sr, ^{137}Cs, ^{210}Pb, and ^{226}Ra) inhalation of resuspended particulates is a dominant pathway for the transition phase, accounting for over 90 percent of the BDCFs. Inadvertent soil ingestion ranks second, contributing less than 7 percent to the BDCFs. Together, inhalation and inadvertent soil ingestion account for over 99 percent of most transition phase BDCF values for these radionuclides. Consumption of leafy vegetables is usually the third ranking pathway, but its contribution is usually less than one percent. Pathway contributions to the transition phase BDCFs for ^{90}Sr, ^{137}Cs, ^{210}Pb, and ^{226}Ra are different. Consumption of vegetables is a dominating pathway for ^{90}Sr, external exposure ranks first for ^{137}Cs, while for ^{210}Pb and ^{226}Ra pathway contributions are more evenly balanced among inhalation and crop consumption.

For the steady-state phase, inhalation is still a dominant pathway for most radionuclides other than ^{90}Sr, ^{137}Cs, ^{210}Pb, and ^{226}Ra. However, the percentage contribution to the BDCFs is less than that for the transition phase. Vegetable consumption pathways dominate for ^{90}Sr, ^{210}Pb, and ^{226}Ra, while the BDCF for ^{137}Cs is almost entirely due to external exposure.

Table 16. Percent Pathway Contribution to Volcanic Eruption Biosphere Dose Conversion Factors for Transition Phase, 1-cm Layer of Ash, and Annual Average Mass Loading

Nuclide	External Exposure	Inhalation	Leafy Vegetables	Other Vegetables	Fruit	Cereals	Meat	Poultry	Milk	Eggs	Soil Ingestion
^{90}Sr	0.0	1.6	42.1	31.9	7.9	1.3	9.3	0.0	1.8	0.6	3.5
^{137}Cs	74.4	0.7	3.9	1.5	9.1	0.2	5.2	0.2	0.9	0.1	3.9
^{210}Pb	0.0	27.9	21.0	3.7	5.5	0.5	0.2	0.0	0.2	0.7	40.3
^{226}Ra	0.3	54.5	16.3	2.8	2.3	0.1	0.4	0.0	0.6	0.0	22.6
^{227}Ac	0.0	99.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
^{229}Th	0.0	99.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
^{230}Th	0.0	99.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
^{231}Pa	0.0	96.2	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	2.8
^{232}U	0.0	98.9	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.7
^{233}U	0.0	98.8	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.8
^{234}U	0.0	98.8	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.8
^{238}Pu	0.0	96.1	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	2.9
^{239}Pu	0.0	96.1	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	2.9
^{240}Pu	0.0	96.1	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	2.9
^{242}Pu	0.0	96.2	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	2.9
^{241}Am	0.0	96.2	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	2.8
^{243}Am	0.1	96.1	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	2.8

NOTE: Pathway contributions were developed using the software routine described in Attachment V.

Table 17. Percent Pathway Contribution to Volcanic Eruption Biosphere Dose Conversion Factors for Transition Phase, 1-cm Layer of Ash, and 10-year Average Mass Loading

Nuclide	External Exposure	Inhalation	Leafy Vegetables	Other Vegetables	Fruit	Cereals	Meat	Poultry	Milk	Eggs	Soil Ingestion
^{90}Sr	0.0	0.7	42.5	32.3	7.9	1.2	9.4	0.0	1.9	0.6	3.6
^{137}Cs	76.1	0.3	3.3	1.5	9.3	0.2	4.3	0.2	0.8	0.1	4.0
^{210}Pb	0.0	15.6	19.5	4.1	5.7	0.5	0.2	0.0	0.2	0.7	53.4
^{226}Ra	0.4	35.9	20.2	3.9	2.8	0.1	0.5	0.0	0.7	0.0	35.4
^{227}Ac	0.0	98.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
^{229}Th	0.0	98.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
^{230}Th	0.0	98.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
^{231}Pa	0.0	92.4	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	6.6
^{232}U	0.0	97.8	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	1.6
^{233}U	0.0	97.6	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	1.8
^{234}U	0.0	97.5	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	1.8
^{238}Pu	0.0	92.6	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	6.5
^{239}Pu	0.0	92.5	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	6.5
^{240}Pu	0.0	92.5	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	6.6
^{242}Pu	0.0	92.5	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	6.5
^{241}Am	0.1	92.4	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	6.6
^{243}Am	0.1	92.3	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	6.5

NOTE: Pathway contributions were developed using the software routine described in Attachment V.

Table 18. Percent Pathway Contribution to Volcanic Eruption Biosphere Dose Conversion Factors for Transition Phase, 15-cm Layer of Ash, and Annual Average Mass Loading

Nuclide	External Exposure	Inhalation	Leafy Vegetables	Other Vegetables	Fruit	Cereals	Meat	Poultry	Milk	Eggs	Soil Ingestion
^{90}Sr	0.0	0.1	42.3	35.0	8.6	1.4	9.7	0.0	2.0	0.6	0.3
^{137}Cs	95.1	0.0	0.8	0.4	2.3	0.0	1.1	0.0	0.2	0.0	0.1
^{210}Pb	0.1	8.2	47.3	11.9	16.3	1.4	0.5	0.0	0.4	2.0	11.9
^{226}Ra	4.7	16.9	50.4	10.0	7.2	0.2	1.2	0.0	2.0	0.0	7.4
^{227}Ac	0.0	98.7	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.8
^{229}Th	1.1	97.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
^{230}Th	0.0	98.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
^{231}Pa	1.0	94.4	1.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	2.9
^{232}U	0.0	97.0	0.7	1.1	0.5	0.0	0.0	0.0	0.0	0.0	0.7
^{233}U	0.1	96.7	0.7	1.1	0.5	0.0	0.0	0.0	0.0	0.0	0.8
^{234}U	0.0	96.7	0.8	1.1	0.5	0.0	0.0	0.0	0.0	0.0	0.8
^{238}Pu	0.0	96.0	0.8	0.1	0.2	0.0	0.0	0.0	0.0	0.0	2.8
^{239}Pu	0.0	96.0	0.8	0.1	0.2	0.0	0.0	0.0	0.0	0.0	2.9
^{240}Pu	0.0	96.0	0.8	0.1	0.2	0.0	0.0	0.0	0.0	0.0	2.9
^{242}Pu	0.0	95.9	0.9	0.1	0.2	0.0	0.0	0.0	0.0	0.0	2.9
^{241}Am	0.7	94.7	1.2	0.2	0.3	0.0	0.0	0.0	0.0	0.0	2.9
^{243}Am	2.2	93.3	1.2	0.2	0.3	0.0	0.0	0.0	0.0	0.0	2.8

NOTE: Pathway contributions were developed using the software routine described in Attachment V.

Table 19. Percent Pathway Contribution to Volcanic Eruption Biosphere Dose Conversion Factors for Transition Phase, 15-cm Layer of Ash, and 10-year Average Mass Loading

Nuclide	External Exposure	Inhalation	Leafy Vegetables	Other Vegetables	Fruit	Cereals	Meat	Poultry	Milk	Eggs	Soil Ingestion
^{90}Sr	0.0	0.0	42.4	35.0	8.6	1.4	9.7	0.0	2.0	0.6	0.3
^{137}Cs	95.1	0.0	0.8	0.4	2.3	0.0	1.1	0.0	0.2	0.0	0.1
^{210}Pb	0.1	3.7	49.0	12.5	17.4	1.5	0.5	0.0	0.4	2.0	12.7
^{226}Ra	5.2	8.1	56.0	11.1	7.7	0.3	1.3	0.0	2.1	0.0	8.2
^{227}Ac	0.0	97.3	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.8
^{229}Th	2.5	95.4	0.6	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.4
^{230}Th	0.1	97.7	0.6	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.5
^{231}Pa	2.2	88.7	2.1	0.2	0.4	0.1	0.0	0.0	0.0	0.0	6.4
^{232}U	0.0	93.5	1.3	2.4	1.0	0.1	0.0	0.0	0.0	0.1	1.6
^{233}U	0.2	92.5	1.5	2.7	1.1	0.1	0.0	0.0	0.0	0.1	1.8
^{234}U	0.1	92.8	1.4	2.6	1.1	0.1	0.0	0.0	0.0	0.1	1.8
^{238}Pu	0.0	92.0	0.9	0.2	0.3	0.0	0.0	0.0	0.0	0.0	6.6
^{239}Pu	0.0	92.0	0.9	0.2	0.3	0.0	0.0	0.0	0.0	0.0	6.6
^{240}Pu	0.0	92.0	0.9	0.2	0.3	0.0	0.0	0.0	0.0	0.0	6.6
^{242}Pu	0.0	92.0	0.9	0.2	0.3	0.0	0.0	0.0	0.0	0.0	6.6
^{241}Am	1.6	89.3	1.8	0.4	0.5	0.0	0.0	0.0	0.0	0.0	6.5
^{243}Am	4.8	86.4	1.7	0.4	0.5	0.0	0.0	0.0	0.0	0.0	6.2

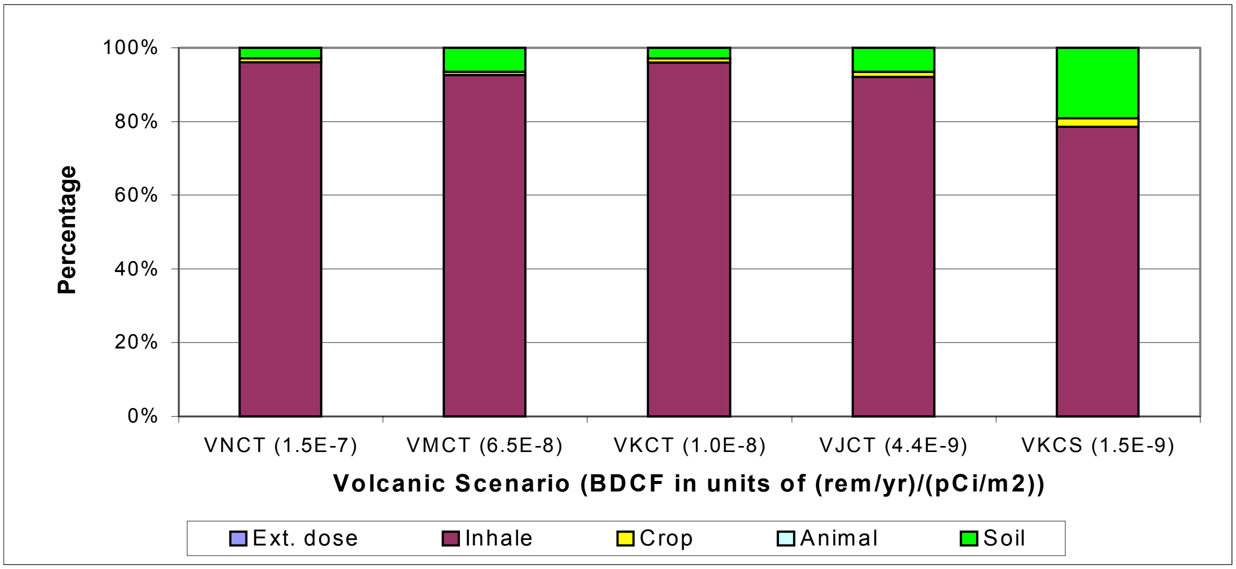
NOTE: Pathway contributions were developed using the software routine described in Attachment V.

Table 20. Percent Pathway Contribution to Volcanic Eruption Biosphere Dose Conversion Factors for Steady-State Phase

Nuclide	External Exposure	Inhalation	Leafy Vegetables	Other Vegetables	Fruit	Cereals	Meat	Poultry	Milk	Eggs	Soil Ingestion
^{90}Sr	0.0	0.0	42.4	35.0	8.6	1.4	9.7	0.0	2.0	0.6	0.3
^{137}Cs	95.1	0.0	0.8	0.4	2.3	0.0	1.1	0.0	0.2	0.0	0.1
^{210}Pb	0.1	1.1	50.4	12.8	17.9	1.5	0.5	0.0	0.4	2.1	13.1
^{226}Ra	5.6	2.5	58.9	11.9	8.3	0.3	1.4	0.0	2.3	0.0	8.8
^{227}Ac	0.0	91.8	1.9	0.2	0.3	0.1	0.0	0.0	0.0	0.0	5.7
^{229}Th	7.9	85.8	1.6	0.2	0.2	0.0	0.0	0.0	0.0	0.0	4.3
^{230}Th	0.2	92.9	1.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	4.9
^{231}Pa	5.9	71.0	4.1	0.5	0.8	0.1	0.0	0.0	0.0	0.0	17.6
^{232}U	0.1	81.0	3.6	7.1	2.9	0.2	0.0	0.0	0.1	0.3	4.8
^{233}U	0.5	79.2	3.9	7.6	3.2	0.2	0.0	0.0	0.1	0.3	5.1
^{234}U	0.1	79.8	3.7	7.6	3.1	0.2	0.0	0.0	0.1	0.3	5.1
^{238}Pu	0.0	78.1	1.3	0.5	0.6	0.0	0.0	0.0	0.0	0.0	19.4
^{239}Pu	0.0	78.5	1.2	0.5	0.6	0.0	0.0	0.0	0.0	0.0	19.1
^{240}Pu	0.0	78.5	1.2	0.5	0.6	0.0	0.0	0.0	0.0	0.0	19.1
^{242}Pu	0.0	78.5	1.2	0.5	0.6	0.0	0.0	0.0	0.0	0.0	19.2
^{241}Am	4.3	72.2	3.5	0.9	1.2	0.0	0.0	0.0	0.0	0.0	17.8
^{243}Am	12.7	66.0	3.2	0.9	1.1	0.0	0.0	0.0	0.0	0.0	16.1

NOTE: Pathway contributions were developed using the software routine described in Attachment V.

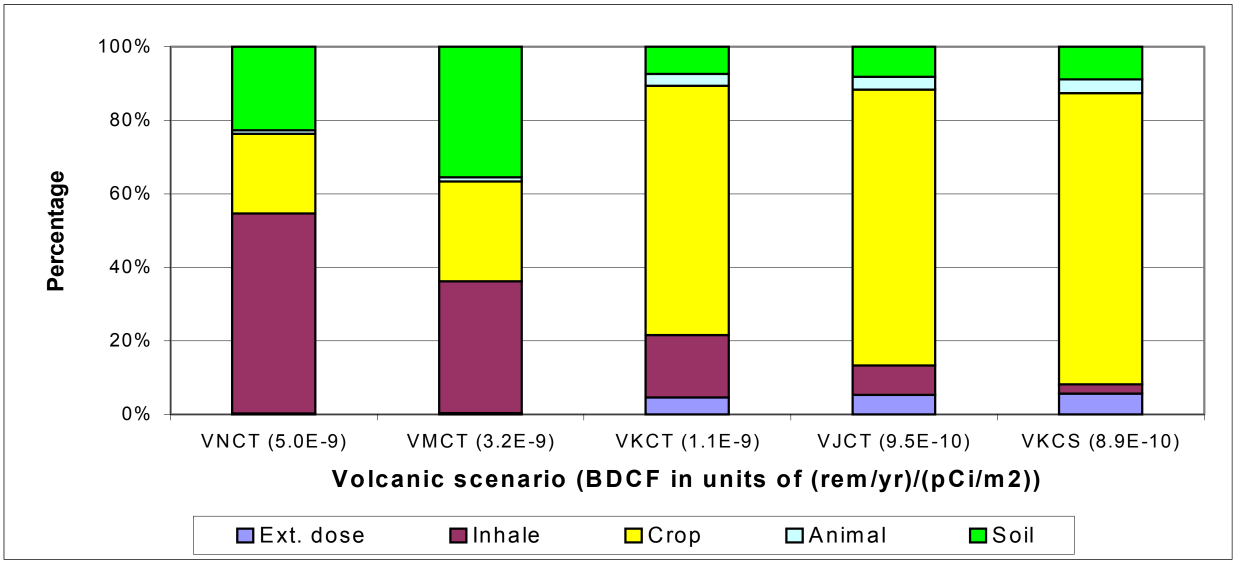
Pathway contributions to BDCFs are shown graphically in Figures 8 through 11 for the representative radionuclides. All five exposure scenarios (i.e., steady-state phase and four cases for the transition phase) are shown in each figure. Percentage pathway contributions for volcanic eruption BDCFs for ^{239}Pu are shown in Figure 8. ^{239}Pu is representative of the 13 radionuclides with inhalation as a dominant pathway which include isotopes of plutonium, thorium, uranium, and americium. For these radionuclides, contribution from the inhalation pathway is the greatest for the transition phase, 1-cm ash thickness, and annual average mass loading. Figures 9 through 11 show pathway contributions for other radionuclides: ^{226}Ra (Figure 9), ^{137}Cs (Figure 10), and ^{90}Sr (Figure 11).



NOTES:

VNCT –	Transition phase, 1-cm ash, 10 year average mass loading	Ext. dose	– External exposure
VMCT –	Transition phase, 1-cm ash, 10 year average mass loading	Inhale	– Inhalation
VKCT –	Transition phase, 15-cm ash, annual average mass loading	Crop	– Ingestion of crops
VJCT –	Transition phase, 15-cm ash, 10 year average mass loading	Animal	– Ing. of animal products
VKCS –	Steady-state, 15-cm ash, annual average mass loading	Soil	– Inadvertent soil ingestion

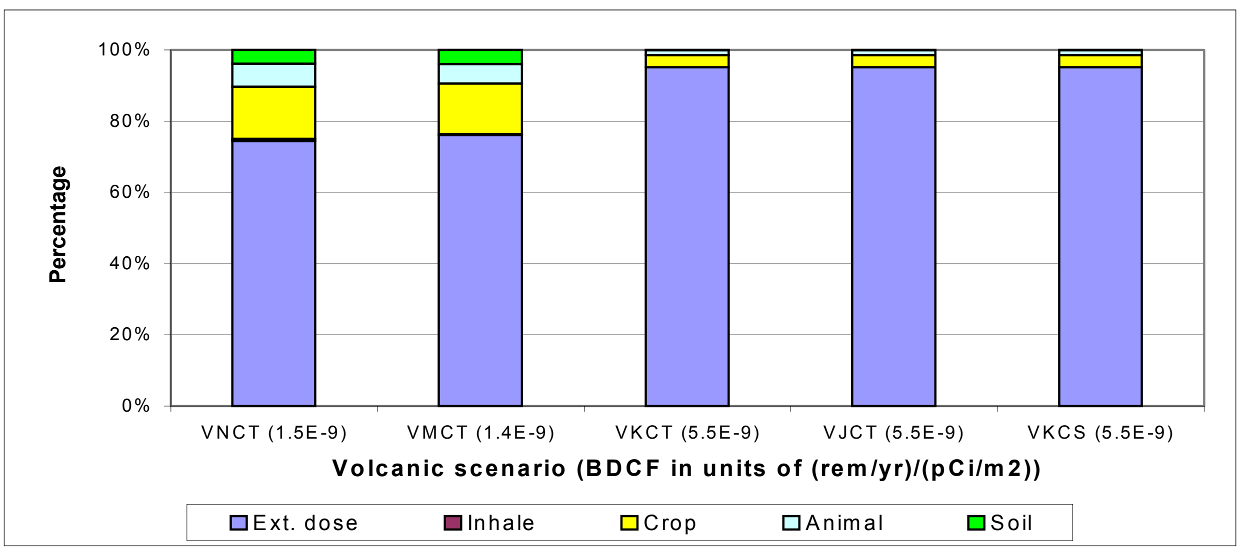
Figure 8. Percentage Pathway Contributions for Volcanic Eruption BDCFs for ^{239}Pu



NOTES:

VNCT –	Transition phase, 1-cm ash, 10 year average mass loading	Ext. dose	– External exposure
VMCT –	Transition phase, 1-cm ash, 10 year average mass loading	Inhale	– Inhalation
VKCT –	Transition phase, 15-cm ash, annual average mass loading	Crop	– Ingestion of crops
VJCT –	Transition phase, 15-cm ash, 10 year average mass loading	Animal	– Ing. of animal products
VKCS –	Steady-state, 15-cm ash, annual average mass loading	Soil	– Inadvertent soil ingestion

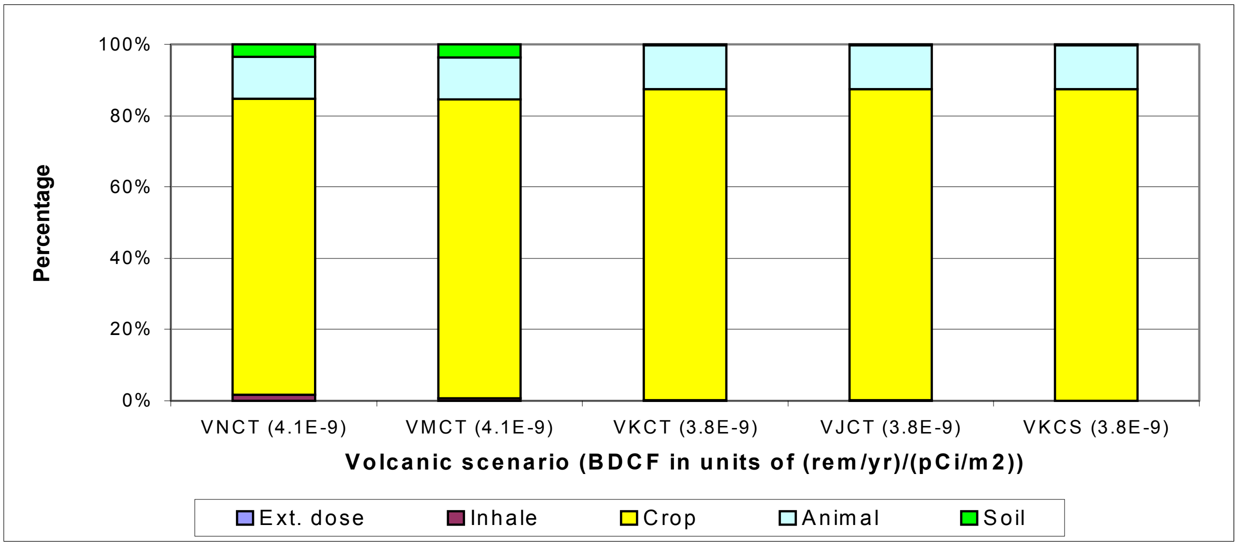
Figure 9. Percentage Pathway Contributions for Volcanic Eruption BDCFs for ^{226}Ra



NOTES:

VNCT –	Transition phase, 1-cm ash, 10 year average mass loading	Ext. dose	– External exposure
VMCT –	Transition phase, 1-cm ash, 10 year average mass loading	Inhale	– Inhalation
VKCT –	Transition phase, 15-cm ash, annual average mass loading	Crop	– Ingestion of crops
VJCT –	Transition phase, 15-cm ash, 10 year average mass loading	Animal	– Ing. of animal products
VKCS –	Steady-state, 15-cm ash, annual average mass loading	Soil	– Inadvertent soil ingestion

Figure 10. Percentage Pathway Contributions for Volcanic Eruption BDCFs for ^{137}Cs



NOTES:

VNCT –	Transition phase, 1-cm ash, 10 year average mass loading	Ext. dose	– External exposure
VMCT –	Transition phase, 1-cm ash, 10 year average mass loading	Inhale	– Inhalation
VKCT –	Transition phase, 15-cm ash, annual average mass loading	Crop	– Ingestion of crops
VJCT –	Transition phase, 15-cm ash, 10 year average mass loading	Animal	– Ing. of animal products
VKCS –	Steady-state, 15-cm ash, annual average mass loading	Soil	– Inadvertent soil ingestion

Figure 11. Percentage Pathway Contributions for Volcanic Eruption BDCFs for ^{90}Sr

6.7 UNCERTAINTY ANALYSIS

As with any modeling effort, uncertainty is inherent to the biosphere model. This means that the modeling results carry uncertainty resulting from both the uncertainties in the model itself as well as uncertainties in model parameters. Uncertainty analysis using probabilistic approach was used to assist in interpreting the results of BDCF calculation. The objective of the uncertainty analysis was to determine how the uncertainty in model parameters affects the model results.

6.7.1 Sources of Uncertainty

All assessments based on model calculations are inherently uncertain. This uncertainty arises from several factors, including: (1) the ability to adequately model the physical processes involved, (2) the degree to which exposure scenarios adequately represent individuals in the desired critical group, (3) the level of knowledge available to estimate appropriate values for parameters in the model, and (4) natural variability in various quantities used to estimate parameter values, and (5) the quality of data used in the model.

Uncertainty in the model refers to uncertainty regarding abstracting a real system (in this case the biosphere – its components and the radionuclide transport between the components of the biosphere, including humans) and its evolution into a form that can be mathematically modeled. It results from limitations in the ability to mathematically represent a complex system and its behavior. Model uncertainty, in the case of complex systems, may be difficult to quantify in a rigorous numerical fashion. However, it is usually possible to bound the effects of model uncertainties by making credible assumptions about the selection of likely processes and their conceptual representations. The compartment model selected to represent radionuclide behavior in the biosphere is an example of a bounding analysis. The submodels of such a system, which represent individual processes occurring in the biosphere, can be characterized as reasonably conservative, i.e., realistic, yet unlikely to underestimate their modeling outcome. Such conservative conceptual models are commonly used for demonstrating compliance with the regulatory standards.

Parameter uncertainty represents uncertainty in the data, parameters, and coefficients used in mathematical models and in the supporting computer codes, such as GENII-S in the case of biosphere modeling. Parameter uncertainty originates from a number of sources including insufficient information, or lack of site-specific information, to accurately determine values of parameters and coefficients used in the biosphere model. Another source of uncertainty is associated with the temporal and spatial heterogeneity of the biosphere system. However, lack of knowledge about an input parameter typically contributes more to the uncertainty of the parameter values than does the natural variability of that parameter. Contribution of parameter uncertainty to the overall uncertainty of the modeling outcome can be more readily quantified than model uncertainty. This analysis does not attempt to quantify the relative contribution of model uncertainty to the overall DCF uncertainty.

6.7.2 Parametric Analysis

When the BDCFs are plotted as a function of a specific parameter, the dependence on this parameter value can be shown. Inhalation is a dominant pathway for most of the radionuclides and it depends on input parameters such as mass loading and inhalation exposure time. When the results of individual model realizations (BDCFs) for ^{239}Pu are plotted as a function of mass loading (Figure 12) it can be seen that BDCFs vary almost linearly with mass loading. A similar plot for the inhalation exposure time (Figure 13) shows very weak correlation of BDCFs with this parameter.

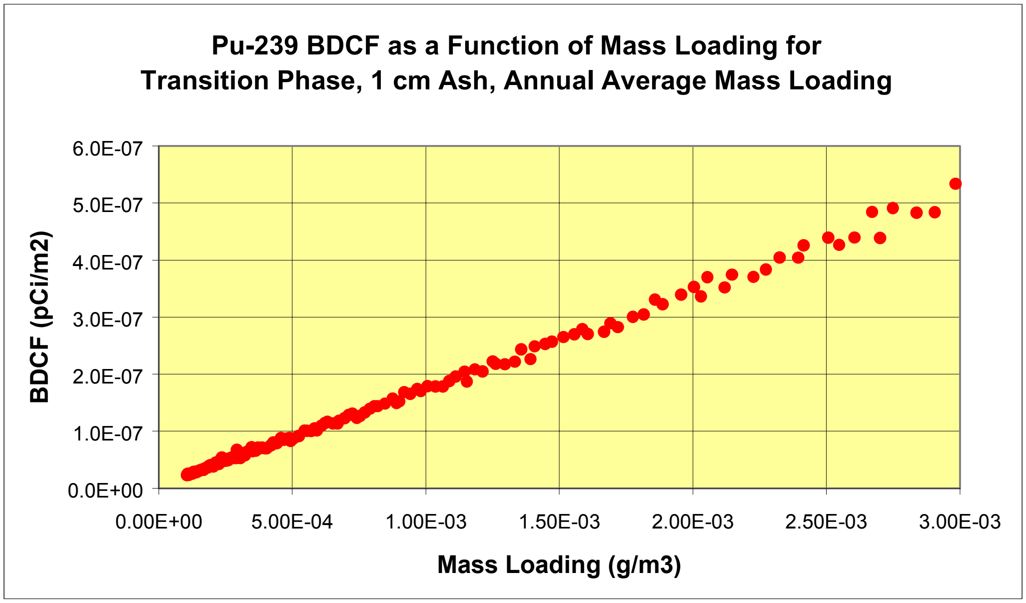


Figure 12. Dependence of BDCF for ^{239}Pu on Mass Loading for Transition Phase, 1-cm Ash Layer, and Annual Average Mass Loading

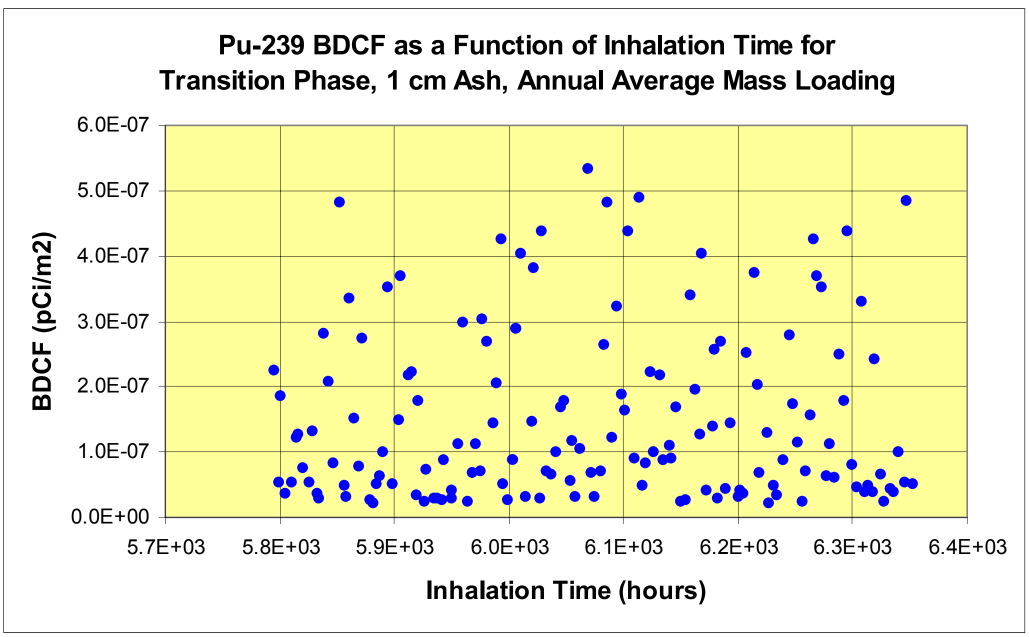


Figure 13. Dependence of BDCF for ^{239}Pu on Inhalation Time for Transition Phase, 1-cm Ash Layer, and Annual Average Mass Loading

6.7.3 Biosphere Dose Conversion Factor Uncertainty

As noted before, uncertainties are inherent in any modeling of a real system, such as the biosphere. These uncertainties include data uncertainty and model uncertainty. Data or parameter uncertainty is more readily quantified than model uncertainty.

The results of BDCF calculation consist of 150 outcomes of individual model simulation. These BDCF values can be represented as a probability distribution function. The shape of the probability distribution function, the range of values within the predetermined confidence limits, and the associated statistics characterize the spread of BDCF values generated by the model runs. Distribution of BDCF values are related to probability distribution of the key uncertain parameters. Representation of the parameter values by their probability distribution functions have their origin in either the uncertainty on the best estimate of the parameter's value or in the variability of the parameter in the sample. The examples of the latter include locally-produced food consumption rates which were obtained in the regional survey and thus represent variability of consumption rates in the surveyed population. On the other hand, soil-to-plant or animal food-to-animal product transfer scaling factors represent uncertainty in the best estimate of the parameter values.

6.8 ALTERNATIVE MODELS

The strategy governing conceptual description of the biosphere system is consistent with similar activities being pursued by the international scientific community. However, several issues were identified that are relevant to the model components and warrant consideration in this analysis.

6.8.1 Alternative Exposure Scenarios

BDCF development was carried out for a specific exposure scenario. An exposure scenario is defined as one possible combination of specified FEPs affecting the biosphere system that could lead to radiological consequences. There are several alternative exposure scenarios that could be considered for the current biosphere. The proposed rules and the guidance limit the assessment to the exposure scenario associated with an adult farming receptor group based on the behaviors and characteristics of Amargosa Valley residents. Other exposure scenarios that could be conceivable include the exposure conditions of a subsistence farmer receptor group, a residential receptor group, or a group consisting of non-adult receptors.

The non-adult receptor group is not considered appropriate for the analysis of long-term performance of the potential repository. Considering the time scale of the assessment, it could be assumed that radioactive contamination of the biosphere due to releases from the repository is likely to remain constant over periods that are considerably longer that the human life span. It is then reasonable to calculate the annual dose averaged over the lifetime of the individuals, which means that it is not necessary to calculate doses to different age groups. This average can be adequately represented by the annual dose to an adult (ICRP 2000).

6.8.2 Alternative Dosimetric Models

The current assessment uses dosimetric models based in the conceptual approach recommended by the ICRP in Publication 26 (ICRP 1977) and the dosimetric methods outlined in Publication 30 (ICRP 1979, ICRP 1980, ICRP 1981b). By using such a model the outcome of the biosphere model expressed in terms of TEDE is compatible with the format of the proposed performance standard (Dyer 1999, Section 113(b)) which uses the same methodology.

Since the publication of the ICRP recommendations and models in the late 1970s and early 1980s the Commission updated both its recommendations (ICRP 1991) as well as its dosimetric methods. Of particular significance is a set of publications concerning age-dependent doses to the members of the public from intakes of radionuclides. The summary document for this set, ICRP Publication 72 (ICRP 1996), provides a listing of dose coefficients (dose conversion factors) for inhalation and ingestion of radionuclides by age group.

Dose conversion factors are a quintessence of dosimetric modeling, including metabolism of a specific radionuclide compound; possible deposition in various human organs and tissues; physical behavior, such as radioactive decay accompanied by the emission of ionizing radiation and production of radioactive progenies; irradiation of human organs and tissues by internally deposited radionuclides or radionuclides external to human body; and the contribution of the radiation effects in the irradiated organs and tissues to the overall radiation effect.

Dose conversion factors in ICRP Publication 30 and ICRP Publication 72 use different approach (e.g., they are based on different tissue weighting factors) and for some radionuclides DCFs may differ considerably between the two dosimetric systems. It needs to be noted, however, that comparing DCF values may be misleading in some cases because of the different bases for their calculation. In addition, application of ICRP-72 DCFs does not yield results compatible with the concept of ICRP-30-based TEDE, which is used in the proposed regulations to define performance objective for the repository.

7. CONCLUSIONS

The purpose of this analysis and model was to calculate BDCFs for an extrusive igneous event (volcanic eruption). BDCFs were developed for each of the 17 radionuclides of interest for the average member of the critical group (AMCG). BDCFs were calculated for the following radionuclides: ^{90}Sr, ^{137}Cs, ^{210}Pb, ^{226}Ra, ^{227}Ac, ^{229}Th, ^{230}Th, ^{231}Pa, ^{232}U, ^{233}U, ^{234}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{241}Am, and ^{243}Am. The following five cases were considered:

- Transition phase, 15-cm layer of ash, annual average mass loading
- Transition phase, 1-cm layer of ash, annual average mass loading
- Transition phase, 15-cm layer of ash, 10-year average mass loading
- Transition phase, 1-cm layer of ash, 10-year average mass loading
- Steady-state phase.

The term transition phase after volcanic eruption refers to the conditions of increased mass loading caused by resuspension of contaminated ash. Mass loading is a term used by the code, GENII-S, for mass concentration of suspended particulates in air. The steady-state phase after volcanic eruption represents conditions when the general dustiness in the area has returned to the pre-eruption levels.

BDCF development was accompanied by pathway, and limited uncertainty analyses. The resulting BDCFs are summarized in Tables 11 through 15 for the five combinations of exposure scenarios, ash thickness, and mass loading conditions as specified above. The complete set of model files can be found in the modeling database of the TDMS (DTN: MO0010MWDPBD03.007).

Pathway analysis showed that inhalation is the dominant pathway for most radionuclides except ^{90}Sr, ^{137}Cs, ^{210}Pb, and ^{226}Ra. Inadvertent soil ingestion was second. Together these two pathways account for about 99 percent of transition phase BDCFs for a 1-cm ash thickness, and over 95 percent for a 15-cm ash thickness. Pathway contribution to BDCFs for ^{90}Sr, ^{210}Pb, and ^{226}Ra is more diversified with a larger contribution from food consumption. External exposure to contaminated soil is the dominant pathway for ^{137}Cs.

The BDCFs developed in this AMR were obtained using current, updated inputs. If new input data become available, the BDCFs may be revised. The BDCF values presented in this report, as well as the conclusions from the pathway and uncertainty analyses, differ from those developed previously (CRWMS M&O 2000a) due to the differences in the input values.

Limitations, constrains, and restrictions on future use of BDCFs

BDCFs for volcanic eruption were developed for two ash thicknesses, 1 cm and 15 cm. BDCFs for the transition phase for 1-cm ash layer are the most conservative because the activity is assumed to be concentrated in the upper layer of soil and available for resuspension to a greater degree than in the case of the same activity diluted throughout the 15-cm layer of soil/ash. It is not recommended, however, that the transition phase BDCFs be used for the periods of time longer than 10 years. Steady-state BDCFs should be used for such conditions, i.e., for more than 10 years after volcanic eruption.

BDCFs developed for 15-cm ash thickness apply to ash layer deposits 15 cm in depth and greater, because radionuclides contained in ash beneath the roots are unavailable for plant uptake. The layers of ash below 15 cm do not participate in radionuclide uptake by plants or in the other pathways, which involve surface phenomena, therefore they do not contribute to BDCFs. Consequently, to use 15-cm BDCFs for ash deposits thicker than 15 cm, one should adjust the surface activity to the equivalent activity contained in the top 15 cm. For example, if ash deposit thickness is 30 cm and the surface activity deposition is 10 pCi/m^2, the activity contained in a top 15-cm ash layer corresponds to 5 pCi/m^2. Doses would then be calculated by using surface activity of 5 pCi/m^2 and the BDCFs developed for the 15-cm layer of ash. ^{137}Cs, which has a significant external radiation exposure pathway contribution in addition to the other pathways, should not be treated in the manner suggested above.

The values of dose conversion factors and dose coefficients (i.e., factors used to convert exposure to radionuclides to dose) used to develop BDCFs apply to chronic low-level intakes and exposure conditions and are inappropriate for acute, high-level intakes and exposures. Therefore, volcanic eruption BDCFs for all phases of volcanic eruption should not be used for other types of exposures than low-level chronic exposures.

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ATTACHMENT I

MATHEMATICAL MODELS USED BY GENII-S

ATTACHMENT I

MATHEMATICAL MODELS USED BY GENII-S

This attachment describes selected models used in the GENII-S computer code, which are important for the perspective of biosphere modeling for performance assessment. Some components of the models are omitted in order to maintain focus on the main model features. For example, the radioactive decay factor is not included in the equations presented in this section, while GENII-S considers the decay and in-growth of radionuclides during transport through environmental media.

I.1 ENVIRONMENTAL TRANSPORT OF RADIONUCLIDES

The exposure scenarios under consideration are discussed in Section 6.2. In the case of the groundwater contamination scenario, radionuclide migration in the biosphere, and the subsequent human exposure, which is initiated when contaminated water is used for domestic and agricultural needs. In the case of an extrusive igneous event, radionuclides become deposited with volcanic ash on the soil's surface following volcanic eruption. The subsequent use of contaminated land, combined with the natural processes, causes radionuclide migration through the environment. As a result, radionuclides become redistributed from the initial source of contamination (groundwater or volcanic ash) to other components of the biosphere, such as soil, air, plants, animals, and, eventually, humans.

I.1.1 Radionuclide Concentration in Soil

The soil model used in GENII-S is relatively simple. Although the code considers two soil strata: surface soil and deep soil, only contamination present in the surface soil layer is subject to resuspension and transfer to food products. The radionuclide concentration in the top layer of soil is governed by a conservation equation, where the rate of change in radionuclide concentration in a volume of soil is equal to the rate of activity addition (from either irrigation or ash fall) minus the rate of activity removal. GENII-S considers three mechanisms of potential radionuclide removal from the soil: radioactive decay, plant uptake, and leaching into the deeper soil layer where radioactivity becomes unavailable to plants. A fourth mechanism of potential radionuclide removal, not incorporated into the GENII-S computer code, is physical loss of soil (i.e., erosion by wind and water). This process is modeled outside of the GENII-S code.

Primary calculations of radionuclide concentration in soil in GENII-S are based on an irrigation period of one year. It is assumed that radioactivity is initially distributed throughout the upper soil layer, which is where all plant roots are assumed to be located. Radionuclide activity in soil per unit area, C_s, following irrigation with contaminated water is calculated using the following relationship (adapted from Napier et al. 1988, p. 4.57-4.58):

$$C_s = \frac{25.4\, C_w\, I}{\lambda_l}\left(1 - e^{-\lambda_l t}\right) \qquad \text{(Eq. I-1)}$$

where:

C_s	– radionuclide activity concentration in soil per unit area (Bq m^{-2})
C_w	– activity concentration of radionuclide in water (Bq L^{-1})
I	– irrigation rate (in y^{-1})
λ_l	– leaching rate (y^{-1})
t	– exposure time (equal to one year)
25.4 $L\ in^{-1}\ m^{-2}$	– unit conversion factor (number of liters in one inch of water applied over one m^2 of soil surface)

For irrigation periods longer than one year, GENII-S factors in removal of radionuclides from soil by harvest. Harvest removal calculations are based on radionuclide concentration in a plant and the plant's yield, and are carried out cyclically for the assumed duration of prior irrigation with the contaminated water.

I.1.2 Radionuclide Concentration in Air

The concentration of radionuclides in air, C_a, resulting from soil resuspension is calculated, from the definition of the resuspension factor, using the following equation (Napier et al. 1988, p. 4.63):

$$C_a = C_s \times M \qquad \text{(Eq. I-2)}$$

where:

C_a	– radionuclide concentration in air (Bq m^{-3})
M	– resuspension factor (m^{-1})

I.1.3 Radionuclide Concentration in Plants

Four categories of edible plants are considered in GENII-S: leafy vegetables, other (root) vegetables, fruit, and grain. There are two main mechanisms of radionuclide transfer to a plant: direct deposition on plant surfaces and the root uptake. Deposition on plant surfaces may result from irrigation with contaminated water and from resuspension of contaminated soil.

In order to evaluate radionuclide deposition onto leaf surfaces, the deposition rates for irrigation and soil resuspension have to be calculated separately. The leaf deposition rate from irrigation, DR_{ir}, is calculated as follows (adapted from Napier et al. 1988, p. 4.57):

$$DR_{ir} = \frac{25.4 \times 12\ C_w\ I}{ID} \qquad \text{(Eq. I-3)}$$

where:

DR_{ir}	– leaf deposition rate from irrigation (Bq m^{-2} y^{-1})
ID	– irrigation duration (months)
25.4 $l\ in^{-1}\ m^{-2}$	– unit conversion factor
12 $months\ y^{-1}$	– unit conversion factor

The leaf deposition rate from resuspension, DR_{rs}, is calculated as follows (adapted from Napier et al. 1988, p. 4.57):

$$DR_{rs} = 3.154 \times 10^7 \; C_a \; v_d \qquad \text{(Eq. I-4)}$$

where:

DR_{rs}	– leaf deposition rate from resuspension (Bq m^{-2} y^{-1})
v_d	– deposition velocity (m s^{-1})
3.154×10^7 $s\ y^{-1}$	– unit conversion factor

Activity concentration in a plant, following leaf deposition of airborne radionuclides, $C_{p,d}$, is calculated as follows (adapted from Napier et al. 1988, p. 4.67):

$$C_{p,d} = \frac{(DR_{ir}\ r_w + DR_{rs}\ r_a)T}{365\ \lambda_w\ B} \left(1 - e^{-\lambda_w t_g}\right) \qquad \text{(Eq. I-5)}$$

where:

$C_{p,d}$	– activity concentration in a plant (Bq kg^{-1})
λ_w	– weathering constant (d^{-1})
t_g	– growing time (days)
r_w	– irrigation interception fraction (dimensionless)
r_a	– air interception fraction (dimensionless)
T	– translocation factor (dimensionless)
365 d y^{-1}	– unit conversion factor

Translocation factor, T, descries the fraction of radionuclide transferred from plant surfaces to edible parts of the plant. Irrigation interception fraction, r_w, and the air interception fraction, r_a represent the fraction of initial deposition retained on the plant.

The air interception fraction, r_a, was calculated as follows (adopted from Napier et al. 1988, p. 4.69):

$$r_a = 1.0 - e^{-a\ B\ DW} \qquad \text{(Eq. I-6)}$$

where:

a	– empirical factor (m^2 kg$^{-1}_{\text{dry mass}}$)
B	– biomass (kg$_{\text{wet mass}}$ m^{-2})
DW	– plant dry-to-wet weight ratio (kg$_{\text{dry mass}}$ kg$^{-1}_{\text{wet mass}}$)

Empirical factor, a, is equal to 3.6 for root vegetables and fruit and 2.9 for leafy vegetables, grain and grasses (Napier et al. 1988, p. 4.69).

Activity concentration in a plant which results from radionuclide uptake by a plant root system, $C_{p,r}$, is calculated using the following equation (adapted from Napier et al. 1988, p. 4.67):

$$C_{p,r} = \frac{C_s}{\rho_s} F_{s \to p} \, DW \qquad \text{(Eq. I-7)}$$

where:

$C_{p,r}$	–	activity concentration in a plant from root uptake (Bq kg^{-1})
ρ_s	–	surface soil density (kg m^{-2})
$F_{s \to p}$	–	radionuclide soil-to-plant transfer factor (Bq $kg^{-1}_{\text{dry plant}}$ per Bq $kg^{-1}_{\text{dry soil}}$)

Total activity concentration in a plant, C_p, is the sum of deposition on plant surfaces and root uptake contributions (adapted from Napier et al. 1988, p. 4.68):

$$C_p = C_{p,d} + C_{p,r} \qquad \text{(Eq. I-8)}$$

where:

C_p	–	total activity concentration in a plant (Bq kg^{-1})

Activity concentration of Carbon-14 in plants was calculated using a different method (Napier et al. 1988, p. 4.86). It was assumed that the specific activity of Carbon-14 in an environmental medium, such as a plant, was the same as that of the contaminating medium. The fractional content of carbon in a plant was then used to compute the concentration of Carbon-14 in the food product under consideration. The following equation was used to determine Carbon-14 activity concentration in plants (Napier et al. 1988, p. 4.86):

$$C_p = \frac{25.4 \times 12 \; C_w \, I}{ID \; \lambda_l \; \rho_s} \times \frac{0.1}{0.01} \times FC_p \qquad \text{(Eq. I-9)}$$

where:

0.1	–	the assumed uptake of 10 percent of plant carbon from soil
0.01	–	the average fraction of soil that is carbon
FC_p	–	fraction of carbon in a plant

The assumption of uptake of 10 percent of plant carbon from the soil is conservative because plants acquire almost all of their carbon from the air (Napier et al. 1988, p. 4.86).

I.1.4 Radionuclide Concentration in Animal Products

Radionuclide transfer to animal products results from the ingestion of contaminated feed and contaminated water by the animal. Animal products considered include meat (beef and pork), milk, poultry, and eggs. Determination of radionuclide concentrations in animal products begins with the calculation of radionuclide concentrations in fresh forage and stored feed, C_f , using formulas similar to those described in Section I.1.3, but with parameter values characteristic of crops grown for animal consumption. Once the concentrations of radionuclides in fresh forage and stored feed were determined, the daily radionuclide intake by the animal is calculated which is then converted to the radionuclide concentration in animal product, C_{ap}, using the following formula (adapted from Napier et al. 1988, p. 4.70-4.72):

$$C_{ap} = \left(C_w \; CR_{a,w} + C_f \; CR_{a,f}\right) F_{ad \rightarrow ap} \qquad \text{(Eq. I-10)}$$

where:

C_{ap}	– radionuclide concentration in animal product (Bq kg^{-1} or Bq L^{-1})
$CR_{a,w}$	– animal consumption rate of water (L d^{-1})
C_f	– activity concentration in fresh forage or stored feed (Bq kg^{-1})
$CR_{a,f}$	– animal consumption rate of fresh forage or stored feed (kg d^{-1})
$F_{ad \rightarrow ap}$	– radionuclide transfer factor from animal diet to animal product (d kg^{-1} or d L^{-1})

The concentration of Carbon-14 in animal products is calculated using the following formula (Napier et al. 1988, p. 4.89):

$$C_{ap} = \frac{C_f \; CR_{a,f} + C_w \, CR_{a,w}}{FC_f \; CR_{a,f} + FC_w \, CR_{a,w}} \; FC_{ap} \qquad \text{(Eq. I-11)}$$

where:

FC_{ap}	– fraction of carbon in animal product
FC_f	– fraction of carbon in animal feed

I.1.5 Radionuclide Concentration in Aquatic Food

The concentration of radionuclides in fish, C_f, is calculated using the following formula:

$$C_f = C_w \; BF \qquad \text{(Eq. I-12)}$$

where:

BF	– bioaccumulation factor in fish (Bq kg^{-1} per Bq L^{-1})

I.2 DOSE ASSESSMENT

Radiation doses to humans may result from internal intake of radionuclides by inhalation or ingestion or from external exposure to radionuclides present in the environment. Dose assessment in GENII-S is carried out by considering radionuclide concentrations in environmental media, factoring in human exposure conditions, and performing the conversion of exposure to dose. For internal exposure, radionuclide activity intake is calculated by combining the radioactivity concentration in environmental media (e.g., food, soil, air, and water) with the amount of environmental medium taken into the body. Then, using dosimetric models, radionuclide intake is converted into dose. To assess exposure from external sources, GENII-S uses dose coefficients that convert radionuclide concentrations in environmental media to doses for the duration of exposure.

Dose calculations performed by GENII-S are based on methods developed in ICRP-30 (ICRP 1979, ICRP 1980, ICRP 1981b). The code calculates incremental organ dose equivalents for each year following an initial radionuclide intake. Committed dose equivalent (50-year organ dose following an intake) is then assembled from incremental dose equivalents to each organ over the commitment period. Committed effective dose equivalent is then calculated by producing a sum of the organ dose equivalents weighted by organ/tissue weighting factors.

Conceptually, calculation of doses from internally deposited radionuclides, D_{int}, can be considered as if the following relationship were used (adapted from Napier et al. 1988, pp. 4.63, 4.69, 4.72):

$$D_{\mathrm{int}} = IN \times DCF \qquad \text{(Eq. I-13)}$$

where:

D_{int}	–	dose from annual radionuclide intake (rem)
IN	–	annual radionuclide intake by inhalation or by ingestion (Bq)
DCF_{int}	–	dose conversion factor for internal radionuclide intake by inhalation or ingestion (Sv Bq^{-1})

Dose calculated as above is expressed in terms of committed effective dose equivalent (CEDE).

Annual intake, IN, is a product of activity concentration in a medium and the amount of this medium taken internally over one year. For annual intake with food, activity concentration in a food product is multiplied by the annual consumption rate for this food; for annual intake with water, activity concentration in water gets combined with the annual consumption rate of water; for inadvertent soil ingestion, activity concentration in soil is multiplied by the amount of soil ingested annually. To calculate intake by inhalation, the activity concentration in air is multiplied by the breathing rate and the amount of time a person is exposed to a given activity concentration in air.

GENII-S calculates the radiation doses from external exposures by considering radionuclide concentrations in soil or air and the duration of exposure to soil and air and combining them with dose coefficients to calculate radiation doses. For example, annual doses from external exposure, $D_{ext,}$ to radionuclides in soil were calculated using the following relationship (adapted from Napier et al. 1988, pp. 4.84):

$$D_{ext} = C_{s,v} \;\; T_{ext} \, DCF_{soil} \qquad \text{(Eq. I-14)}$$

where:

D_{ext}	–	annual dose from external exposure (Sv)
$C_{s,v}$	–	activity concentration in soil per unit volume (Bq m^{-3})
T_{ext}	–	duration of external exposure to contaminated soil (s)
DCF_{soil}	–	dose coefficient for exposure to soil contaminated to a depth of 15 cm from FGR 12 (Eckerman and Ryman 1993) (Sv s^{-1} per Bq m^{-3}).

Dose calculated as above is expressed in terms of effective dose equivalent (EDE).

Doses from exposure to internally deposited radionuclides are combined with doses from external irradiation to produce total all-pathway doses.

$$D_{tot} = D_{\text{int}} + D_{ext} \qquad \text{(Eq. I-15)}$$

where:

D_{tot}	–	total dose (Sv)

Total dose, calculated using Eq. I-15 is expressed in terms of total effective dose equivalent (TEDE). To convert the value of dose expressed in sieverts to rems, the value in sieverts should be multiplied by 100.

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ATTACHMENT II

BIOSPHERE MODEL VALIDATION

ATTACHMENT II

BIOSPHERE MODEL VALIDATION

II.1 INTRODUCTION

The biosphere system is the link between the geosphere system and the receptor and it is represented by the biosphere conceptual model. Typical scope of biosphere modeling includes the migration and accumulation of radionuclides in the biosphere and the evaluation of the potential radiological impacts on a human receptor. The specific case of the biosphere modeling for the potential repository at Yucca Mountain, described herein, differs from the conventional approach. The biosphere conceptual model in this case is limited to consideration of biosphere transport, and human intake and exposure, resulting from a unit of activity concentration present at the contamination source, which is volcanic ash. The model does not include evaluation of radiological impact or assessment of doses; it provides dose factors, called biosphere dose conversion factors (BDCFs), that enable such evaluations or assessments that are carried out in the TSPA model.

The biosphere system can be conceived as a set of specific biotic and abiotic components of the accessible environment and the relationships between these components. Typically, construction of the conceptual model of the biosphere is based on developing assumptions and hypotheses regarding these characteristics. This is followed by constructing a logical and comprehensive framework that combines those assumptions and hypotheses with relevant scientific understanding to enable calculations of radiological impact. The attention, therefore, is focused on the characteristics of the environment that are important from the perspective of contributing to BDCFs for exposure scenarios under consideration. The biosphere conceptual model constructed for the potential repository is representative of a reference biosphere system delineated by the proposed rules and the interim guidance (64 FR 46976, Section III.B.6; 64 FR 8640, 63.115; Dyer 1999, Section 115).

II.1.1 Description of Conceptual Model

The biosphere conceptual model for the region around Yucca Mountain consists of assumptions, simplifications, and idealizations that describe the essential aspects of the biosphere in the vicinity of Yucca Mountain. The model is used to evaluate the transport of radionuclides released from the source of contamination throughout the biosphere to the human receptor. The receptor of interest is discussed in Section II.1.2.1.

The biosphere conceptual model provides a mechanism for the evaluation of BDCFs from selected pathways to a defined receptor. The release scenario addressed here is a volcanic discharge through the repository leading to atmospheric dispersal of the contaminants into the accessible environment by an ash fall, thus contaminating the soil.

The biosphere conceptual model includes the following components: surface soil above the lower bounds of the plant root zone (including volcanic ash), surface water, the atmosphere, flora and fauna. In other words, the lowest boundary of the biosphere conceptual model is at the bottom of the plant root zone, and it includes all biological components that may be a part of a potential pathway of radionuclides to humans. The biosphere conceptual model does not include processes related to atmospheric transport and dispersion of airborne radionuclides. In the context of postclosure performance assessment, such processes are considered in relation to the atmospheric transport of contaminated ash from the erupting volcano to the receptor's location. This component is currently modeled within the disruptive event model (CRWMS M&O 2000p). The biosphere model does consider airborne radioactivity resulting from resuspension of contaminated ash/soil matrix. Therefore the contribution from inhalation of resuspended contaminated ash is included in the BDCFs presented in this document.

The primary function of the biosphere conceptual model is to support calculations of BDCFs. The BDCFs account for: (1) environmental transport of radionuclides by converting radionuclide concentrations at the source to concentrations in relevant biosphere media such as plants and animals; and (2) radionuclide uptake via, and external exposure to, environmental media and resulting dose factors. BDCFs are therefore functions of environmental transfer factors, exposure factors and dosimetric factors. Environmental transfer factors convert radionuclide concentrations in water to concentrations in a biosphere medium (e.g., plants, meat, milk, eggs). Exposure factors include parameters such as ingestion rate and exposure time (e.g., how much beef a receptor eats per year, how much time a receptor spends outdoors). Dosimetric factors convert internal and external exposures to radiation to doses. They account for the biological effectiveness of various types of radiation and the different sensitivities of various body tissues to radiation. Dosimetric factors are specific to each radionuclide and the mechanism by which they expose the receptor (e.g., direct radiation, ingestion, and inhalation).

The objective of the biosphere modeling effort is to determine the values of BDCFs for those radionuclides expected to enter the biosphere, considering all of the important exposure pathways. Radionuclide-specific BDCFs quantify radionuclide transport, intake and external exposure, and the resulting doses per unit of activity concentration at the source. They are calculated for a specific receptor of interest and they combine contributions from various exposure pathways, such as ingestion of food, inadvertent ingestion of soil, inhalation, and exposure to radionuclides external to the body.

BDCFs are multipliers, or factors, used in the TSPA model to convert a radionuclide concentration at the source of contamination into radiation dose that a human receptor would receive from exposure pathways under consideration. For the disruptive event scenario the doses are obtained by multiplying surface activity deposition of a radionuclide by the corresponding BDCF.

DCFs are expressed in terms of annual dose, i.e., TEDE or CEDE, per unit of activity concentration at the source of contamination. BDCFs are independent of the actual activity concentration in the layer of volcanic ash deposited on the soil surface. Details of calculations of contaminated ash deposition for extrusive igneous disruptive events are described in *Igneous Consequence Modeling for TSPA-SR* AMR (CRWMS M&O 2000q), which supports the *Disruptive Events PMR* (CRWMS M&O 2000r).

II.1.1.1 Model Development

The biosphere system at Yucca Mountain is represented by the reference biosphere. A starting point for biosphere conceptual model development is the requirement that "[f]eatures, events, and processes that describe the reference biosphere shall be consistent with present knowledge of the conditions in the region surrounding the Yucca Mountain site" (64 FR 8640, Section 63.115(a)(1), Dyer 1999, Section 115). To meet this requirement, any conceptual model of the biosphere around Yucca Mountain must be based on FEPs that are reflective of current conditions. A list of FEPs that have been identified as reflective of current conditions considered applicable to the conduct of performance assessment for Yucca Mountain has been developed. FEPs that are considered applicable to biosphere modeling are shown in Table II-1.

Table II-1. Features, Events, and Processes Applicable to Biosphere

FEP NAME	YMP FEP DATABASE NUMBER
Erosion/denudation	1.2.07.01.00
Deposition	1.2.07.02.00
Climate change, global	1.3.01.00.00
Wells	1.4.07.02.00
Soil type	2.3.02.01.00
Radionuclide accumulation in soils	2.3.02.02.00
Soil and sediment transport	2.3.02.03.00
Precipitation	2.3.11.01.00
Surface runoff and flooding	2.3.11.02.00
Biosphere characteristics	2.3.13.01.00
Biosphere transport	2.3.13.02.00
Human characteristics (physiology, metabolism)	2.4.01.00.00
Diet and fluid intake	2.4.03.00.00
Human lifestyle	2.4.04.01.00
Dwelling	2.4.07.00.00
Agricultural land use and irrigation	2.4.09.01.00
Animal farms and fisheries	2.4.09.02.00
Drinking water, foodstuffs and drugs, contaminant	3.3.01.00.00
Plant uptake	3.3.02.01.00
Animal uptake	3.3.02.02.00
Bioaccumulation	3.3.02.03.00
Ingestion	3.3.04.01.00
Inhalation	3.3.04.02.00
External exposure	3.3.04.03.00
Radiation doses	3.3.05.01.00

For the disruptive event scenario, volcanic ash deposition on the soil is the entry mechanism for the radionuclides released from the repository to the biosphere. It is assumed that the human receptor's water supply is extracted from a groundwater well that is similar to wells that currently exist. For the disruptive event scenario, an eruption would carry ash contaminated with radioactive material from the potential repository to the vicinity of the human receptor. Volcanic event modeling reported in the *Igneous Consequence Modeling for the TSPA-SR* (CRWMS M&O 2000q) has been used to identify the characteristics of volcanic eruption and the details of contaminated ash transport.

II.1.1.2 Conceptual Model of the Biosphere

As discussed in the previous sections, the attributes of the current biosphere model are based on a set of FEPs that conform to the proposed rules. These attributes, while sometimes appearing to be abstract, reflect the elements of a semi-arid environment in the Yucca Mountain vicinity and the possible processes leading to radionuclide transport in this environment. In the case of volcanic eruption intercepting the potential repository, contaminated volcanic ash may reach the hypothetical farming community in the biosphere.

For the disruptive events scenario, contamination becomes initially deposited on the ground. Small particles of soil contaminated by volcanic ash may become resuspended. Resuspended contamination may be deposited on the crops. A person may also inhale resuspended contamination. The contaminated ash/soil matrix is a source of external irradiation to a person from radionuclides emitting penetrating radiation, which are present in the ash/soil matrix. Figure 3 of this document presents an illustrative, but not comprehensive, block diagram of the biosphere conceptual model for the disruptive event scenario. The figure shows important mechanisms of radionuclide migration in the biosphere from the source of contamination to the human receptor for the primary pathways relevant to the exposure scenario under consideration.

The diagram for the extrusive igneous disruptive event scenario, where volcanic ash is the source of contamination, does not include components related to irrigation and drinking water consumption. Important parameters controlling radionuclide transport in the biosphere are also identified in the diagram.

Ingestion, inhalation and external exposure are the major exposure pathways included in the conceptual model of the biosphere. The ingestion pathway includes consumption of locally produced crops, consumption of meat and dairy products from livestock, and ingestion of contaminated soil. The biosphere conceptual model allows for the assumption that livestock and poultry are sustained with some quantity of locally grown feed (e.g., pasture and seasonally harvested alfalfa). Thus, these animals are exposed to the radionuclides by consuming the radionuclides present in, or on, the plant tissues. Alfalfa is the predominant crop produced by the Amargosa Valley community and alfalfa and forage grasses comprise a major proportion of Nye County agricultural land (CRWMS M&O 1998b). Another component of the ingestion pathway is the inadvertent ingestion of soil.

The primary inhalation pathway is through breathing of resuspended volcanic ash during outdoor activities such as farming and recreation. This pathway also includes expected inhalation of ash during the disruptive event. The factors that determine the degree of exposure through dust resuspension is the annual average concentration of suspended particles in air and the amount of time exposed annually to that concentration.

The external pathway occurs as a result of direct exposure to the radiation emitted by radioactive materials external to the body (e.g., those present in the soil or on the soil surface). Duration of exposures depends on the activity concentration in soil and the amount of time spent indoors and outdoors.

The magnitude of exposure from a number of pathways described above depends on the radionuclide concentration in soil. The dynamics of the radionuclide concentration in the top layer of soil are governed by a conservation equation where the rate of change in radionuclide concentration in a volume of soil is equal to the quantity flowing in (from the ash fall) minus the amount being removed. Mechanisms of potential radionuclide removal from the soil include radioactive decay, plant uptake, leaching into the deeper soil layer and physical loss of soil during crop harvesting. Continual land use with the attendant tilling may accelerate the erosion process.

II.1.2 Exposure Scenario

An exposure scenario establishes the circumstances of human exposure to radionuclides present in the biosphere. Each exposure scenario represents a different combination of FEPs and therefore has different exposure pathways.

The exposure scenario was defined in a two-step process. First, the geosphere-biosphere interface was defined. For the disruptive event scenario, the interface is from the volcanic ash deposition on the soil surface. Second, the conditions that would lead to radionuclide intake and external exposure were determined and the applicable exposure pathways were identified based on the site-specific environment and assumptions about the human receptor group. For all exposure scenarios, present-day practices by a farming community were considered, and commercial and industrial activities were excluded. Exclusion of activities other than farming was due to the fact that farming activities involve more exposure pathways than other known activities of the region.

II.1.2.1 Receptor of Interest

The receptor of interest is an average member of the critical group. The critical group is representative of individuals from the hypothetical farming community whose behavioral characteristics will result in the highest exposures among the individuals in the community. The average member of the critical group is an adult who lives year-round at this location, uses a well as the primary water source, and otherwise has habits (e.g., consumption of locally-produced foods) that are similar to those of the current population of the Amargosa Valley.

The routes taken by radionuclides through the biosphere from the source to a person are called exposure pathways. The analysis considered pathways that are typical for a hypothetical farming community. Farming activities usually involve more exposure pathways than other human activities in the Yucca Mountain region, including ingestion through consumption of crops and animal products; inhalation and direct exposure from surface contamination intensified by the significant outdoor activity of a farming lifestyle.

The following exposure pathways were considered for disruptive event scenario:

- Consumption of locally produced leafy vegetables
- Consumption of other (root) locally produced vegetables
- Consumption of locally produced fruit

- Consumption of locally produced grain
- Consumption of locally produced meat (beef and pork)
- Consumption of locally produced poultry
- Consumption of locally produced milk
- Consumption of locally produced eggs
- Inadvertent soil ingestion
- Inhalation of resuspended particulate matter
- External exposure to contaminated soil.

Pathways related to sediments and surface water were not considered because the current environment in the Yucca Mountain region lacks these features.

The contribution to a BDCF from a specific pathway depends on the amount of contamination the human receptor comes in contact with, either through intake or through external exposure. Radioactivity intake may occur through inhalation or ingestion. The magnitude of the BDCF contribution from ingestion depends on the activity concentration in consumed products and the rate of consumption of these products. The magnitude of inhalation contribution to the BDCF (e.g., from breathing resuspended ash/soil and dust during outdoor activities, such as gardening and recreation) is influenced by the amount of resuspended particulate matter in the air, breathing rate, as well as the amount of time a person is exposed to a given concentration of radioactivity in the air. BDCF component from the external exposure pathway results from exposure to radiation sources that are external to the body, such as the contaminated ash/soil matrix. For this pathway, the contribution depends on the amount of time a person is exposed to activity in the ash/soil.

II.1.2.2 Disruptive Event Scenario

The extrusive igneous disruptive event scenario provides the framework for evaluation of radiological consequences of volcanic eruption. The source of contamination for this scenario is the deposition of contaminated volcanic ash on the soil surface.

For calculation of BDCFs for the disruptive event scenario, the groundwater was considered to be uncontaminated because this factor is considered separately under the groundwater contamination scenario. Doses resulting from the combination of groundwater contamination and volcanic eruption can be calculated in the TSPA model by combining dose contributions from both scenarios.

Because the groundwater is considered to be uncontaminated, pathways resulting from groundwater contamination (e.g., consumption of water and consumption of fish) were excluded from the disruptive events scenario. Other pathways were the same as those considered for the groundwater contamination scenario.

II.2 BIOSPHERE MODEL VALIDATION

This attachment discusses the Biosphere Model Validation which was performed and originally presented in *Evaluation of the Applicability of Biosphere-related Features, Events, and Processes (FEP)* (CRWMS M&O 2000s). A model validation discussion will not be included in the revised document. An update to the model validation due to changes in input parameters is discussed in Section II.3.

II.2.1 YMP Biosphere Model Validation Activity

The validation activity documented here applies to all uses and applications of the YMP biosphere model, including the development of BDCFs. A BDCF is a multiplier used to convert a radionuclide concentration at the geosphere/biosphere interface into a dose that a human would receive from all pathways. BDCFs are expressed in units of annual dose per unit concentration in soil or water.

Application of the biosphere model to develop BDCFs is documented in two AMRs: the BDCFs for groundwater contamination (a non-disruptive event) were originally developed in *Non-Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000t), and BDCFs for an extursive igneous disruptive event (a disruptive event) were originally developed in *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000a). The biosphere model was also used to perform sensitivity analyses for groundwater BDCFs in *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* (CRWMS M&O 2000u), and for the disruptive event BDCFs in *Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* (CRWMS M&O 2000v). In addition, the model was used to support calculation of BDCF for an alternative receptor (CRWMS M&O 2000u).

II.2.2 Approach to Model Validation

AP-3.10Q, *Analyses and Models* identifies model validation as "…a process to determine and document the adequacy of the scientific bases (i.e., confidence) for a model and to demonstrate the model is appropriate and adequate for its intended use." Validation may be accomplished by different means and to different degrees, depending on the exact nature and complexity of the phenomenon, process or system being modeled. For a simple system, the actual outcome, as reflected in data from laboratory experiments, field experiments or observations of natural or man-made analogs, may be compared with the predictions of the model. If such data are not available to support validation of the model, AP-3.10Q, *Analyses and Models* suggests alternate approaches including:

- Peer review or review by international collaborations.
- Technical review through publication in open literature.
- Review of model calibration parameters for reasonableness or consistency in explanation of relevant data.
- Comparison of analysis results with results from alternative conceptual models.
- Calibration and corroboration within experimental data sets.
- Comparison of analysis results with data attained during Performance Confirmation studies.

For the conditions being predicted with the YMP biosphere model (future exposure of humans to radioactive materials that may be released from the repository) direct observation of an actual outcome may never be possible. Accordingly, validation of the biosphere conceptual model as implemented using the GENII-S computer software was conducted using a combination of the alternative approaches suggested by AP-3.10Q, *Analyses and Models*.

II.2.3 Validation Method

The YMP biosphere model is a synthesis of the biosphere conceptual model and a generic mathematical model and submodels that are executed by the GENII-S computer code. The conceptual model considered in this validation was that of a farming community, located approximately 20 km south of the potential repository. The general climatic conditions are those of an arid/semi-arid environment. The individuals living in this community have a lifestyle consistent with present day behaviors and obtain a portion of the food and water they consume from local sources. The objective of this validation effort was to enhance confidence that the YMP biosphere model has an adequate scientific basis and is appropriate and adequate for the basic biosphere concept and this intended use. A validation process was developed, with predetermined validation criteria, to provide a high degree of confidence that:

- The GENII-S code, as installed, is operating correctly and gives results consistent with the inputs.
- The BDCFs produced using GENII-S and the biosphere model are reasonable when compared with results of other calculations and conceptual models, and
- The YMP biosphere pathways were assessed and parameterized in a technically defensible manner.

A detailed presentation of the results of the validation method is provided in Section II.2.4.

II.2.3.1 Segment 1: Software Qualification

The GENII-S code qualification is one segment of the YMP biosphere model validation. As part of qualification process in the *Software Qualification Report (SQR) GENII-S 1.485* (CRWMS M&O 1998a) validation criteria were established for comparison of the GENII-S output with the results published in the software documentation or the results of hand calculations. Similar criterion are used to support model validation in this AMR.

Criterion 1.1: For test cases with numerical results, the GENII-S and expected (hand calculation or published) results agree within ±5 percent.

Criterion 1.2: For test cases with graphical output, actual and expected results agree (based on visual comparison).

Six validation test cases were executed as part of the software qualification discussed in the SQR (CRWMS M&O 1998a). Five were the sample cases (including both deterministic and stochastic versions) provided with the GENII-S software package. The sample case results published in *User's Guide for GENII-S: A Code for Statistical and Deterministic Simulations of*

Radiation Doses to Humans from Radionuclides in the Environment (Leigh et al. 1993) were used as the basis for comparison with results of the validation test runs. The sixth validation test case was an independent case specifically designed by the YMP staff to exercise all the pathways of interest. Hand calculations of the independent test case were done using the equations from the GENII-S mathematical model.

Each of the five sample test cases provided with the software was run in both stochastic and deterministic modes. The independent test case was run only in the deterministic mode. The results of each sample case were compared with the results published in Leigh et al. (1993). The results of the independent test case were compared with the hand-calculated doses.

For each of the six test cases, the numerical values produced by GENII-S fell within 5 percent of the published or hand-calculated value. It is concluded that validation criterion 1.1 was met.

For each test case, graphical outputs were consistent with the expected results. It is concluded that validation criterion 1.2 was met.

Meeting Criteria 1.1 and 1.2 demonstrates that the code was installed properly and is operating correctly.

II.2.3.2 Segment 2: Comparison of the YMP BDCF with Results of Other GENII-S Calculations and Conceptual Models

The YMP BDCFs produced using the YMP current biosphere model, as presented in *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000a), were compared and reconciled with results of other GENII-S calculations and conceptual models (LaPlante and Poor 1997 and CRWMS M&O 1998c). Most features of the alternative models selected for comparison are very similar to the YMP biosphere model. However, the alternative calculations reflect the professional judgement of different analysts regarding the GENII-S input settings and parameter values that best represent the YMP biosphere features. Thus, this segment corresponds to one of the alternative validation approaches specified in AP-3.10Q, *Analyses and Models*.

This validation segment helps assure that no significant deficiencies have been made in describing the YMP biosphere or in implementing the model using GENII-S. If the YMP BDCFs are shown to be consistent with results of other modeling efforts, additional confidence is gained in the appropriateness and adequacy of the YMP biosphere model and in the accuracy of its application. Selection of analyses for comparison was based on similarity of the pathways modeled and the documentation of the analysis inputs, both of which were necessary in order to compare and reconcile the results.

Validation Criterion 2.1 was established for comparison of the YMP BDCFs with results of other calculations and conceptual models.

> Criterion 2.1: For radionuclides in surface soil from volcanic ash, differences between the YMP BDCFs and the values inferred from other analyses can be explained by differences in the pathway assumptions and values of input parameters.

If values agree within about a factor of three, then they will be considered to be entirely consistent and no additional effort will be made to reconcile the differences. If the difference is greater than about a factor of three but less than a factor of ten, the values will be considered to be somewhat consistent, but no effort was made to explain the difference in terms of the values of the inputs used. If the difference is greater than a factor of ten, alternative calculations will be done to test the effect of different input parameter values and assumptions.

II.2.3.3 Segment 3: Independent Review of the Biosphere Model

The third segment of the validation process was an independent review of the model by a qualified technical expert. The review was conducted to enhance confidence that the model has adequate scientific basis and is appropriate and adequate for its intended use as described in Section II.2.3. Certain reviewer qualification criteria were deemed essential for the review to be credible, meaningful and constructive. Accordingly, it was determined that the independent reviewer must:

- Have had no prior involvement in the development of the YMP biosphere conceptual model.
- Be independent from the organization conducting the YMP biosphere modeling effort.
- Have broad experience in environmental dose assessment and biosphere model development.
- Possess detailed knowledge of the GENII-S code, its uses and limitations.

The following validation Criteria 3.1 – 3.4 were established for this independent review of the biosphere modeling effort.

Criterion 3.1: In the judgement of the independent reviewer, the pathways considered in the biosphere model and the manner in which they are applied is consistent with current environmental conditions in the Amargosa Valley and with the FEPs of interest.

Criterion 3.2: In the judgement of the independent reviewer, the logic and analysis methods used to select values for the GENII-S input parameters are reasonable.

Criterion 3.3: In the judgement of the independent reviewer, the references and data sources cited by the YMP analysts are current and defensible.

Criterion 3.4: In the judgement of the independent reviewer, the values and ranges of the GENII-S input parameters used to develop BDCF are reasonable for the environmental conditions implicit in the biosphere conceptual model.

II.2.4 Validation Results

II.2.4.1 Comparison of the YMP BDCFs with Results of Other GENII-S Calculations and Conceptual Models

DOE guidance (Dyer 1999) and the nature of the YMP physical environment limit the possible processes by which radionuclides from the potential repository may enter the biosphere and the pathways through which humans may be exposed. As a result of the DOE guidance (Dyer 1999), no alternative conceptual models were identified. Comparison of the YMP BDCF with results of other GENII-S calculations for similar pathways and radionuclides is intended to enhance confidence in the YMP biosphere model and the integrity of the BDCF calculation process.

As a basis for this comparison, alternative calculations involving the same dose pathways and some of the same radionuclides were identified. The first of these calculations is documented in *Information and Analyses to Support Selection of Critical Groups and Reference Biospheres for Yucca Mountain Exposure Scenarios* (LaPlante and Poor 1997), prepared for the U.S. Nuclear Regulatory Commission by the Center for Nuclear Waste Regulatory Analyses (CNWRA). The second set of calculations is documented in the TSPA-VA (CRWMS M&O 1998c). Although this second analysis was prepared within the CRWMS M&O, it represents a different set of biosphere calculations.

The criteria that apply to the validation segments address the overall consistency of the YMP BDCFs with results of other calculations. Substantial variation (for example, an order of magnitude or more) may be observed between different environmental dose calculation results that are fundamentally consistent in their conceptual treatment of an issue. When the same calculational tool is used and the values for the input variables are documented, the effects of different inputs can be taken into account and the differences reconciled.

Full and exact agreement between the YMP BDCFs as presented in CRWMS M&O (2000a), and the two other sets of calculations, reported in LaPlante and Poor (1997) and in CRWMS M&O (1998c) was not expected for all radionuclides. Whether or not the validation criteria were met was determined by the total weight of evidence presented by the alternative calculation results and not by any single BDCF comparison.

The following sections compare the BDCF values for the BDCF values for a disruptive event (CRWMS M&O 2000a) directly with the corresponding results of the alternative calculations. Values that agreed within about a factor of three were considered to be entirely consistent and no additional effort was made to reconcile the differences. If the difference was greater than about a factor of three but less than a factor of ten, the values were considered to be somewhat consistent, but no effort was made to explain the difference in terms of the values of the inputs used. If the difference was greater than a factor of ten, alternative calculations were done to test the effect of different input parameter values and assumptions.

II.2.4.2 Comparison of Disruptive Event BDCFs

Table II-2 presents the BDCF values for a disruptive event (CRWMS M&O 2000a, Table 7) which are identified in the table heading as YMP BDCF, the corresponding values from

CRWMS M&O (1998c), identified in the table heading as TSPA-VA, and the ratio of the two values, YMP BDCF:TSPA-VA ratio. The two sets of radionuclides considered in this table are those that may reach the biosphere, based on the referenced documents.

Table II-2. Comparison of YMP BDCFs with TSPA-VA BDCFs

Radionuclide	YMP BDCF[1,2]	TSPA/VA[1,3]	YMP BDCF:TSPA/VA
^{227}Ac	2.99E-09	8.49E-07	3.52E-03
^{241}Am	5.38E-10	2.14E-07	2.51E-03
^{243}Am	5.75E-10	2.14E-07	2.69E-03
^{137}Cs	1.81E-09	4	4
^{231}Pa	1.59E-09	7.42E-07	2.14E-03
^{238}Pu	3.62E-10	1.89E-07	1.92E-03
^{239}Pu	4.02E-10	2.10E-07	1.91E-03
^{240}Pu	4.01E-10	2.10E-07	1.91E-03
^{90}Sr	7.79E-09	4	4
^{229}Th	9.44E-10	2.17E-07	4.35E-03
^{232}U	8.07E-10	4	4
^{233}U	1.77E-10	1.78E-08	9.94E-03

1 All values in units of rem/y per pCi/m^2
2 CRWMS M&O 2000a
3 CRWMS M&O 1998c
4 BDCF Value for this radionuclide not included in TSPA-VA document (CRWMS M&O 1998c).

The ratios in Table II-2 show that the YMP BDCF values for a disruptive event (CRWMS M&O 2000a) are about 2 to 3 orders of magnitude lower than the TSPA-VA values (CRWMS M&O 1998c). A possible explanation for these differences can be found in the different input parameter values used in the two analyses.

First, the value of crop resuspension factor used in the TSPA-VA (CRWMS M&O 1998c) analysis (mean value 1E-5 m^{-1}) was several orders of magnitude greater than that used to generate the YMP BDCF (mean value of 8.3E-11 m^{-1}) (CRWMS M&O 2000a). The significance of this difference is that based on the BDCF sensitivity analysis results (CRWMS M&O 2000v), ingestion of crops contaminated by resuspended soil is an important dose pathway for most radionuclides of interest. Second, a value of 410 mg/d for inadvertent soil ingestion was used in the TSPA-VA analysis (CRWMS M&O 1998c) compared to the 50 mg/d value used in the YMP BDCF calculations (CRWMS M&O 2000a). The sensitivity analysis (CRWMS M&O 2000v) indicated that inadvertent soil ingestion accounts for a significant part (up to 77 percent) of the BDCF value for some radionuclides.

GENII-S calculations were performed to evaluate the effect of the crop resuspension factor and inadvertent soil ingestion values on BDCF. The calculations used the higher values for crop resuspension factor and soil ingestion rate, but replicated the BDCF "reasonable representation" (stochastic) cases from CRWMS M&O (2000a) in all other respects. Resuspension factor was represented as a lognormal distribution with minimum value of 5.89E-7, maximum of 1.70E-4 and mean of 1E-5 m^{-1}. Inadvertent soil ingestion was set at a fixed value of 410 mg/d. The calculation using the higher soil ingestion rate is designated Case 1 in Table II-3. Case 2 is the calculation using higher resuspension factor. Case 3 uses the higher values for both parameters. The results are presented in Table II-3, including the ratio of Case 3 to the TSPA-VA BDCF.

Table II-3. Comparison of TSPA BDCFs and Adjusted YMP BDCFs

Radionuclide	TSPA-VA[1,2]	Case 1[1,3,4] Adjusted BDCF	Case 2[1,3,5] Adjusted BDCF	Case 3[1,3,6] Adjusted BDCF	Ratio: Case 3 YMP BDCF: TSPA-VA
^{227}Ac	8.49E-07	1.13E-08	1.48E-06	1.49E-06	1.76
^{241}Am	2.14E-07	2.68E-09	3.80E-07	3.82E-07	1.79
^{243}Am	2.14E-07	2.71E-09	3.79E-07	3.81E-07	1.78
^{137}Cs	7	1.84E-09	1.47E-08	1.47E-08	7
^{231}Pa	7.42E-07	7.87E-09	1.12E-06	1.12E-06	1.51
^{238}Pu	1.89E-07	2.25E-09	3.35E-07	3.37E-07	1.78
^{239}Pu	2.10E-07	2.50E-09	3.73E-07	3.75E-07	1.79
^{240}Pu	2.10E-07	2.50E-09	3.72E-07	3.74E-07	1.78
^{90}Sr	7	7.86E-09	2.50E-08	2.51E-08	7
^{229}Th	2.17E-07	3.02E-09	3.86E-07	3.88E-07	1.79
^{232}U	7	1.58E-09	1.46E-07	1.47E-07	7
^{233}U	1.78E-08	3.48E-10	3.21E-08	3.23E-08	1.81

1 All values in units of rem/y per pCi/m^2
2 CRWMS M&O 1998c
3 DTN MO0012MWDDEB11.001
4 Case with inadvertent soil ingestion set at a fixed value of 410 mg/d
5 Case with resuspension factor represented as a lognormal distribution with minimum value of 5.89E-7, maximum of 1.70E-4 and mean of 1E-5 m^{-1}
6 Case with both resuspension factor and soil ingestion set at the higher values used in cases 1 and 2.
7 BDCF value for this radionuclide not included in TSPA-VA document (CRWMS M&O 1998c).

As seen from the ratios in Table II-3, the YMP BDCFs for all radionuclides except the plutonium isotopes were within a factor of two of those produced by the TSPA-VA calculation if the differences in crop resuspension factor and soil ingestion rate are considered. Nearly all the difference in the two sets of BDCF values can be attributed to the large difference in the crop resuspension factor values used in the calculations. Agreement of the adjusted BDCF values within a factor of two or less strongly supports the conclusion that the validation Criterion 2.1 was met.

Table II-4 presents the BDCF values for a disruptive event (CRWMS M&O 2000a) which are identified in the table heading as YMP BDCF, the corresponding values from LaPlante and Poor (1997), and the ratio of the two values, YMP: LaPlante and Poor ratio. The values in LaPlante and Poor (1997, Table 3-2) apply to the soil as the source of contamination for the nominal performance of the repository, rather than for the disruptive event. However, as described later in this section, human exposure conditions assumed in CRWMS M&O (2000a) resemble those of the nominal scenario. Therefore the comparison of the BDCF values from the previous revision of this report (CRWMS M&O 2000a) with the LaPlante and Poor (1997, Table 3-2) values is justified.

Table II-4. Comparison of YMP BDCFs with LaPlante and Poor BDCFs

Radionuclide	YMP BDCF[1,2]	LaPlante and Poor[1,3]	YMP BDCF: LaPlante and Poor
^{227}Ac	2.99E-09	2.7E-06	1.1E-03
^{241}Am	5.38E-10	7.0E-07	7.7E-04
^{243}Am	5.75E-10	7.0E-07	8.2E-04
^{137}Cs	1.81E-09	1.2E-07	1.5E-02
^{231}Pa	1.59E-09	2.1E-06	7.6E-04
^{238}Pu	3.62E-10	[4]	[4]
^{239}Pu	4.02E-10	1.0E-08	4.0E-02
^{240}Pu	4.01E-10	1.0E-08	4.0E-02
^{90}Sr	7.79E-09	7.3E-08	1.1E-01
^{229}Th	9.44E-10	7.3E-07	1.3E-03
^{232}U	8.07E-10	1.8E-08	4.5E-02
^{233}U	1.77E-10	5.8E-09	3.1E-02

1 All values in units of rem/y per pCi/m^2
2 CRWMS M&O 2000a
3 LaPlante and Poor 1997
4 BDCF Value for this radionuclide not included in LaPlante and Poor (1997).

Table II-4 shows that the YMP BDCFs are about 2 to 3 orders of magnitude less than the LaPlante and Poor values. By review of the inputs used for both analyses, it was noted that the crop resuspension factor distribution used in the LaPlante and Poor analysis (mean value of 1E-5 m^{-1}, minimum of 1.66E-6 m^{-1} and maximum of 6.03E-5 m^{-1}) was similar to that used in the TSPA-VA analysis (mean value of 1E-5, a minimum of 5.89E-7 and a maximum of 1.70E-4 m^{-1}), about five orders of magnitude greater than was used in the YMP BDCF calculation. Using the results of the "adjusted BDCF" case 2 from Table II-3 for comparison, the differences between the two sets of calculations are presented in Table II-5.

The ratios presented in Table II-5 indicate that the YMP BDCFs for all radionuclides except the plutonium isotopes are within a factor of about eight of those produced by LaPlante and Poor (1997) if the difference in the crop resuspension factor is considered. The fact that the adjusted YMP BDCF values for both plutonium isotopes are higher than the LaPlante and Poor (1997) values by about a factor of 40 is attributable to the selection of a different dose conversion factors set than that used to calculate the YMP BDCFs. The analysis presented in CRWMS M&O (2000a) used more conservative values of DCFs for the plutonium isotopes than were used for the LaPlante and Poor BDCFs. Agreement of the adjusted BDCF values within a factor of three for six of the radionuclides and within an order of magnitude for three more radionuclides supports the conclusion that validation Criterion 2.1 was met.

Table II-5. Comparison of Adjusted YMP BDCFs with LaPlante and Poor BDCFs

Radionuclide	Adjusted YMP BDCF[1,2]	LaPlante and Poor[1,3]	Ratio: Adjusted YMP BDCF /LaPlante and Poor
^{227}Ac	1.48E-06	2.7E-06	0.55
^{241}Am	3.80E-07	7.0E-07	0.54
^{243}Am	3.79E-07	7.0E-07	0.54
^{137}Cs	1.47E-08	1.2E-07	0.12
^{231}Pa	1.12E-06	2.1E-06	0.53
^{238}Pu	3.35E-07	4	4
^{239}Pu	3.73E-07	1.0E-08	37
^{240}Pu	3.72E-07	1.0E-08	37
^{90}Sr	2.50E-08	7.3E-08	0.34
^{229}Th	3.86E-07	7.3E-07	0.53
^{232}U	1.46E-07	1.8E-08	8.1
^{233}U	3.21E-08	5.8E-09	5.5

1 All values in units of rem/y per pCi/m2
2 DTN MO0012MEDDEB11.001, Case with resuspension factor represented as a lognormal distribution with minimum value of 5.89E-7, maximum of 1.70E-4 and mean of 1E-5 m^{-1}
3 LaPlante and Poor 1997
4 BDCF Value for this radionuclide not included in LaPlante and Poor (1997).

The three models presented in this section (CRWMS M&O 1998c, CRWMS M&O 2000a, and LaPlante and Poor 1997), produce different outcomes (BDCFs) because of the differences in the input parameter values. Of particular importance are parameters with large influence on the disruptive volcanic event BDCFs, such as the mass loading, crop resuspension factor, and inadvertent soil ingestion rate.

The values of mass loading and crop resuspension factor used in CRWMS M&O (2000a) are relatively low because they represented human exposure conditions following a volcanic eruption event of the magnitude predicted in the TSPA-VA effort. The eruption event assumed most probable in TSPA-VA was expected to result in a very thin ash deposition, 0.008 cm on the average, at the location 20 km south from the potential repository (Burck 1999). Given this thin ash deposit, the values of mass loading and the crop resuspension factor were assumed to be the same as those used for the nominal performance scenario. Selection of input parameter values corresponding to a thin ash deposit resulted in relatively low values for the YMP BDCFs (CRWMS M&O 2000a).

In contrast, the value of crop resuspension factor used in LaPlante and Poor (1997, Table B-1) is very high (1E-5 1/m), especially since this value is being applied to the nominal performance scenario. (The crop resuspension factor is used to calculate contaminant deposition on plant surfaces.) Considering the value of soil density of 225 kg/m^2 and the surface soil depth of 15 cm used in LaPlante and Poor (1997, Table B-1), the value of mass loading can be derived by multiplying the crop resuspension factor by the soil density. The result is equal to 2250 $\mu g/m^3$. The actual mass loading value used in that report is 50 $\mu g/m^3$. Therefore the parameters of mass loading and the crop resuspension factor are in conflict with each other. The mass loading value obtained from the crop resuspension factor can be compared with the EPA National Ambient

Quality Standard for annual average concentration of PM_{10}, whose value is 50 $\mu g/m^3$ (40 CFR 50.7). (PM_{10} is a concentration of suspended particulates in air whose diameter is less than 10 μm.) The standard considers a 24-hour average of 600 $\mu g/m^3$ the significant harm level, the level at which serious and widespread health effects occur to the general population (EPA 1994, p. 13). PM_{10} contributes about 1/3 to the total value of mass loading (CRWMS M&O 2000h, Section 5.1.4). Therefore, the pathway BDCF from activity deposition on the plant surfaces is overestimated and that the lower crop resuspension values are more appropriate for the exposure scenario under consideration. The value of crop resuspension factor used by LaPlante and Poor to calculate revised dose conversion factors (LaPlante and Poor 1997, Table B-1) was almost five orders of magnitude lower (4.4 E-10 1/m).

BDCFs calculated in this report are based on the volcanic eruption scenario developed in the TSPA-SR (CRWMS M&O 2000c). Many input parameters have been revised since the previous iterations (CRWMS M&O 1998c, CRWMS M&O 2000a). Specifically, the mass loading and the crop resuspension factor values were modified to correspond to the human exposure conditions that could be expected following a volcanic eruption event, as modeled in the TSPA-SR. This evolution of the volcanic eruption exposure scenario and justification of the important parameters selection is presented in Section II.3, which discusses the model validation update.

II.2.4.3 Independent Review of the Biosphere Model

The independent reviewer selected was Mr. Bruce Napier of Pacific Northwest National Laboratory, principal architect of the GENII computer code. Mr. Napier is a nationally known expert in environmental dose assessment. In addition to developing GENII and collaborating in the creation of GENII-S, he has directed or participated in several other major environmental dose modeling efforts. He is currently in the process of completing the next generation of stochastic environmental exposure, dose, and risk computer codes for radionuclides for the U.S. Environmental Protection Agency (EPA). His experience and qualifications include:

- Technical Integrator and Chief Scientist for the Hanford Environmental Dose Reconstruction project.
- Principal investigator on the U. S./Russia Joint Coordinating Committee on Radiation Effects Research Projects on reconstruction of dose to the public around the Russian Mayak (Chelyabinsk-65) nuclear materials production site in Siberia.
- U. S. Chair of the U. S./Belarus and U. S./Ukraine Bi-National Advisory Committees on Chernobyl Studies for the U. S. National Cancer Institute.
- Consultant to the International Atomic Energy Agency (IAEA) and a participant in the IAEA's Cooperative Research Program on Biosphere Modeling and Assessment (BIOMASS).
- Member of EPA Science Advisory Board.

- Member of National Council on Radiation Protection and Measurements (NCRP) Scientific Committee 64 on Radionuclides in the Environment, Task Group 7 on Contaminated Soil as a Source of Radioactive Exposure.

The review was conducted by Mr. Napier in February-March of 2000 (Napier 2000) using the most recent final and draft documents that describe the characteristics of the YMP biosphere and the associated receptor of interest. Those references and his findings with regard to the adequacy of the model are documented in a letter report (Napier 2000). Based on the information provided to him, he stated that, with minor exceptions:

- *The critical group consists of a farming community with members consuming locally-produced food as a substantial part of their diet. This combination is reasonable, appropriate for the surroundings, and justifiable. The pathways considered in the biosphere model and the manner in which they are applied is consistent with current environmental conditions in the Amargosa Valley and with the FEP of interest.* Criterion 3.1 was judged to be met.

- *The logic and analysis methods used to select values for the GENII-S input parameters for the resident farmer scenario are sound.* Criterion 3.2 was judged to be met.

- *The references and data sources cited by the YMP analysts are current and credible. The parameters selected are well-described and traceable.* Criterion 3.3 was judged to be met.

- *The approach to selecting values and ranges for the input parameters is sound. The documentation is complete and relatively easily followed. The values and ranges of the GENII-S input parameters used to develop BDCF are reasonable for the environmental conditions implicit in the biosphere conceptual model.* Criterion 3.4 was judged to be met.

Mr. Napier concluded that "…the conceptual model of the biosphere, as laid out in the documents reviewed, is reasonable and in keeping with both the draft regulatory requirements and the actual physical setting. The biosphere conceptual model is clear, appropriate, and well documented. The mean or central values of the BDCF estimated are reasonable and appropriate." In addition to the above conclusion, Mr. Napier offered a number of suggestions and insights regarding stochastic environmental dose modeling and specific biosphere model parameters (Napier 2000).

The results of the independent review indicate that the model is appropriate and adequate for the intended use.

II.3 BIOSPHERE MODEL VALIDATION UPDATE

As shown in previous sections, the biosphere model was validated. However with the revision of the related AMRs, the validation needs to be revisited to ensure that the validation is still valid. AP-3.10Q, *Analyses and Models,* does not provide any direction as to when a validated model is no longer valid. To ensure that the validation is still sufficient, the revised YMP BDCFs were compared with the results of other modeling efforts to ensure that the criterion 2.1 is still being satisfied.

II.3.1 Software Qualification

The GENII-S code was qualified and has not been changed, so the original qualification is still valid. The original criteria 1.1 and 1.2 are still being met.

II.3.2 Comparison of the Revised YMP BDCFs with Other Modeling Efforts

Tables II-6 through II-8 present the BDCF values for disruptive event, from Table 11 (transition phase, 1-cm ash thickness, and annual average mass loading) and Table 15 (steady-state phase) of this document, which are identified in the table heading as Revised YMP BDCF. The BDCF sets selected for this comparison represent two opposite ends of the BDCF value range, with the transition phase, 1-cm ash, and annual average mass loading BDCFs being the highest; and the steady state phase BDCFs being the lowest of the five sets developed. These two BDCF sets for volcanic eruption are compared with the results of the three previously developed BDCF sets identified in Section II.2.4.2, i.e., the TSPA-VA set (CRWMS M&O 1998c), LaPlante and Poor set (La Plante and Poor 1997), and the YMP BDCF set (CRWMS M&O 2000a), in Tables II-6 through II-8, respectively.

Table II-6. Comparison of Revised YMP BDCFs with TSPA-VA BDCFs

Radionuclide	Revised YMP BDCF[1,3]	Revised YMP BDCF[1,4]	TSPA-VA[1]	Revised YMP[3] BDCF:TSPA-VA	Revised YMP[4] BDCF:TSPA-VA
^{227}Ac	2.03E-08	2.27E-06	8.49E-07	2.39E-02	2.67E+00
^{241}Am	1.75E-09	1.54E-07	2.14E-07	8.20E-03	7.20E-01
^{243}Am	1.09E-09	1.54E-07	2.14E-07	5.1E-03	7.20E-01
^{137}Cs	5.81E-09	1.86E-09	2	2	2
^{231}Pa	5.18E-09	4.50E-07	7.42E-07	6.98E-03	6.06E-01
^{238}Pu	1.38E-09	1.36E-07	1.89E-07	7.30E-03	7.20E-01
^{239}Pu	1.53E-09	1.51E-07	2.10E-07	7.29E-03	7.19E-01
^{240}Pu	1.53E-09	1.51E-07	2.10E-07	7.29E-03	7.19E-01
^{90}Sr	8.70E-09	9.01E-09	2	2	2
^{229}Th	6.84E-09	7.20E-07	2.17E-07	3.15E-02	3.32E-00
^{232}U	2.56E-09	2.27E-07	2	2	2
^{233}U	5.33E-10	4.58E-08	1.78E-08	2.99E-02	2.57E-00

1 All values in units of rem/y per pCi/m^2
2 BDCF Value for this radionuclide not included in TSPA-VA document (CRWMS M&O 1998c).
3 Table 15 of this document for the steady-state phase
4 Table 11 of this document for the transition phase, 1-cm ash and annual average mass loading

Table II-7. Comparison of Revised YMP BDCFs with LaPlante and Poor

Radionuclide	Revised YMP BDCF[1,3]	Revised YMP BDCF[1,4]	LaPlante and Poor[1]	Revised YMP[3] BDCF:LaPlante and Poor	Revised YMP[4] BDCF:LaPlante and Poor
^{227}Ac	2.03E-08	2.27E-06	2.7E-06	7.5E-03	8.4E-01
^{241}Am	1.75E-09	1.54E-07	7.0E-07	2.5E-03	2.2E-01
^{243}Am	1.09E-09	1.54E-07	7.0E-07	1.6E-03	2.2E-01
^{137}Cs	5.81E-09	1.86E-09	1.2E-07	4.8E-02	1.6E-02
^{231}Pa	5.18E-09	4.50E-07	2.1E-06	2.5E-03	2.1E-01
^{238}Pu	1.38E-09	1.36E-07	[2]	[2]	[2]
^{239}Pu	1.53E-09	1.51E-07	1.0E-08	1.5E-01	1.5E+01
^{240}Pu	1.53E-09	1.51E-07	1.0E-08	1.5E-01	1.5E+01
^{90}Sr	8.70E-09	9.01E-09	7.3E-08	1.2E-01	1.2E-01
^{229}Th	6.84E-09	7.20E-07	7.3E-07	9.4E-03	9.9E-01
^{232}U	2.56E-09	2.27E-07	1.8E-08	1.4E-01	1.3E+01
^{233}U	5.33E-10	4.58E-08	5.8E-09	9.2E-02	7.9E+00

1 All values in units of rem/y per pCi/m^2
2 BDCF Value for this radionuclide not included in LaPlante and Poor (1997).
3 Table 15 of this document for the steady-state phase
4 Table 11 of this document for the transition phase, 1-cm ash and annual average mass loading

Table II-8. Comparison of Revised YMP BDCFs with YMP BDCFs

Radionuclide	Revised YMP BDCF[1,3]	Revised YMP BDCF[1,4]	YMP BDCF[1]	Revised YMP[3] BDCF:YMP BDCF	Revised YMP[4] BDCF:YMP BDCF
^{227}Ac	2.03E-08	2.27E-06	2.99E-09	6.79E+00	7.59E+02
^{241}Am	1.75E-09	1.54E-07	5.38E-10	3.25E+00	2.86E+02
^{243}Am	1.09E-09	1.54E-07	5.75E-10	1.90E+00	2.68E+02
^{137}Cs	5.81E-09	1.86E-09	1.81E-09	3.21E+00	1.03E+00
^{231}Pa	5.18E-09	4.50E-07	1.59E-09	3.26E+00	2.83E+02
^{238}Pu	1.38E-09	1.36E-07	3.62E-10	3.81E+00	3.76E+02
^{239}Pu	1.53E-09	1.51E-07	4.02E-10	3.81E+00	3.76E+02
^{240}Pu	1.53E-09	1.51E-07	4.01E-10	3.82E+00	3.77E+02
^{90}Sr	8.70E-09	9.01E-09	7.79E-09	1.12E+00	1.16E+00
^{229}Th	6.84E-09	7.20E-07	9.44E-10	7.25E+00	7.63E+02
^{232}U	2.56E-09	2.27E-07	8.07E-10	3.17E+00	2.81E+02
^{233}U	5.33E-10	4.58E-08	1.77E-10	3.01E+00	2.59E+02

1 All values in units of rem/y per pCi/m^2
2 CRWMS M&O 2000a
3 Table 15 of this document for the steady-state phase
4 Table 11 of this document for the transition phase, 1-cm ash and annual average mass loading

The ratios in Table II-6 above show that the Revised YMP BDCF values for the steady state phase are about 2 to 3 orders of magnitude lower than the TSPA-VA values (CRWMS M&O 1998c). These ratio values compare favorably with the BDCFs for the transition phase, 1-cm ash thickness, and annual average mass loading (these ratios are within a factor of three except for the ^{229}Th, which is slightly over a factor of three). An explanation for these differences can be found in the different input parameter values used in the two analyses. Specifically, a very high value for crop resuspension factor and a relatively low value for mass loading were used in the TSPA-VA. In contrast, a high mass loading value and a relatively low crop resuspension factor were used to calculate the Revised YMP BDCFs for the transition phase. The agreement between the TSPA-VA BDCFs and the Revised YMP BDCF values is the result of the compensation between the effects these two important parameters have on the overall modeling outcome.

An analogous conclusion can be drawn from the comparison of the Revised YMP BDCF set and the LaPlante and Poor BDCF set (Table II-7 of this document). The latter also uses a high value for the crop resuspension factor and a relatively low value of mass loading, because it applies to the conditions of normal dustiness, as opposed to the conditions of elevated dustiness considered in this report. The specific values of these two parameters used by LaPlante and Poor are discussed in Section II.2.4.2 of this document.

One of the distributions of annual average mass loading used in this report to calculate BDCFs for the transition phase has a maximum value of 3000 $\mu g/m^3$ (CRWMS M&O 2000h). There is evidence of high levels of airborne concentrations, associated with short-term human activities, such as walking or driving, which were measured for the natural analogues of the modeled event. However, even following an event that resulted in a large contaminated ash deposition, the annual average values are expected to be significantly lower because people could not spend the majority of their outdoor time at such high particulate concentrations in air without developing serious health effects (see the discussion of EPA National Ambient Quality Standard in Section II.2.4.2 of this document). Therefore, the assumption that the annual average value of mass loading could be as high as 3000 $\mu g/m^3$ is extremely conservative. With time ash deposits will stabilize and less ash will be available for resuspension. In addition, agricultural activities will result in mixing of the ash deposit into the upper soil layer and the surface processes will tend to remove contaminated ash. This is reflected in the distributions of mass loading selected for this analysis (CRWMS M&O 2000h).

The comparison of the YMP BDCF set and the Revised YMP BDCF set (Table II-8) demonstrates the effect of the exposure scenario evolution on the values of the BDCFs. The exposure scenario on which the YMP BDCFs are based, used the assumption that the amount of contaminated ash deposited on the ground was insignificant, and, therefore, the overall concentration of airborne particulates were comparable to the nominal performance scenario. In the iterative scenario development process, this assumption was found to be no longer valid. Subsequently, a new set of model input parameters (including revised mass loading and crop resuspension factor values) has been developed. This set was used to develop the Revised YMP BDCFs. Therefore, the majority of the YMP BDCFs is over two orders of magnitude less than the corresponding Revised YMP BDCFs.

For the current model, the BDCF sets developed in this report, are reasonable and conservative. It needs to be noted that there is uncertainty associated with the biosphere modeling results. The efforts presented in this report are an attempt to bound this uncertainty by selecting more conservative parameter values that are appropriate for the current scenario. A more representative analysis could ultimately include the temporal evolution of the ash deposit and more precise definition of human activities, which could result in changes of mass loading distribution.

Conclusion: Comparison of the Revised YMP BDCF values for a disruptive event from this analysis with the previously developed BDCF values (CRWMS M&O 1998c, LaPlante and Poor 1997, and CRWMS M&O 2000a) supports the finding that validation Criterion 2.1 is met. The high values of the Revised YMP BDCFs for the transition phase reflect conservative nature of mass loading used in this analysis. Meeting this validation criterion demonstrates the continued appropriateness and adequacy of the model for its intended use.

II.3.4 Independent Reviewer

The independent reviewer, Bruce Napier, concluded that all criteria, 3-1 through 3-4, had been met in the original model validation. For the validation update the independent reviewer was not contacted since primarily only the input parameters had changed and the comparison of the revised BDCF with the both the TSPA-VA (CRWMS M&O 1998c) and LaPlante and Poor (1997) are good as shown in Table II-6. The other items included in the independent review have had minimum changes. In addition, the data being used for generating the BDCFs is qualified data.

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ATTACHMENT III

INGESTION EXPOSURE PARAMETERS

ATTACHMENT III

INGESTION EXPOSURE PARAMETERS

The data set (RIB item) *Ingestion Exposure Parameter Values* (MO0002RIB00068.000) contains values for thirteen ingestion exposure pathway parameters including: irrigation water source, drinking water treatment, crop interception fraction, water contaminated fraction, irrigation water contamination fraction, irrigation time, irrigation rate, aquatic food consideration, food yield, grow time, holdup time, storage time, dietary fraction. These parameters which were developed for the current climate conditions for the Yucca Mountain (Amargosa Valley) are necessary to calculate radionuclide-specific BDCFs.

Several inconsistencies were found in the AMR *Identification of Ingestion Exposure Parameters* REV 00 (CRWMS M&O 2000i) which was used to develop RIB item MO0002RIB00068.000. They are as follows:

1. The food groupings were incorrect (CRWMS M&O 2000i, Table 2). Crops such as tomatoes, cucumbers and corn were categorized as leafy vegetables, which is inconsistent with the 1997 Biosphere Food Consumption Survey (DOE 1997) and other references, such as Till and Meyer (1983, p. 5-50).

2. Corn for grain was treated similarly to sweet corn, which has a shorter growing time (CRWMS M&O 2000i, Table 1).

3. Two harvests each year for corn were considered, with planting dates conflicting with growing dates (CRWMS M&O 2000i, Table 1).

4. Some crop yields were developed using different crop types than those used to develop other parameters. For example, irrigation rate for fresh feed was based on alfalfa, while crop yield for fresh feed was based on alfalfa and other hays.

5. Only one-harvest yield was considered for some vegetables, which can be harvested twice (CRWMS M&O 2000i, Table 1 and Table 6).

To conduct BDCF analysis, the current data set had to be corrected for the above inconsistencies.

III.1 SELECTION OF INPUT DATA SET

To correct the inconsistencies listed above new values for growing time, irrigation time, irrigation rate and crop yield were developed based on the data listed in CRWMS M&O (2000i, Table 2). These data, as shown in Table III-1 below, include growing time, irrigation rate, annual crop evapotranspiration, precipitation and annual irrigation rate for the crop of interest. Crops, such as tomatoes, cucumbers, peppers, snap beans, and peas, previously categorized as leafy vegetables, were not used in this analysis. Corn data were also corrected by using one harvest per year. Growing time of 140 days for grain corn was selected for warm desert climate as suggested by Doorenbos and Pruitt (1977, p.42). The four growing stage periods (number of days needed for crop development) for corn were 25/40/45/30. Planting time was kept at the same date as that for spring corn used in the AMR. Irrigation rate was then calculated using the methods provided in Tables 3 through 5 of the AMR (CRWMS M&O 2000i). The new data for grain corn are also listed in Table III-1.

The value of the crop yield for a specific crop was used in the calculation only if the same crop was also considered for growing time, irrigation time and irrigation rate. Most of the crop yields were adopted from the previous work (CRWMS M&O 2000i, Table 6), but their values were doubled for two-harvest crops (spinach, lettuce, and carrots) to become annual crop yields. Other crop yields were taken from the same report (CRWMS M&O 2000i, Section 6.7). Since fresh feed was determined to be the only feed for beef cattle and milk cows (CRWMS M&O 2000i, Section 6.11), alfalfa was selected as a representative crop, and other hay was not included. All crop yields are shown in Table III-1.

Table III-1. Summary of Selected Ingestion Exposure Parameters

Crop	Crop Type	Growing Time (d)	Irrigation Time (mo/yr)	Annual ET (in/yr)	Precipi-ta tion (in/yr)	Annual Irrigation (in/yr)	Annual Crop Yield [1] (kg/m^2)
Spinach	Leafy vegetable	45	3.0	22.9	0.8	28	4.4
Lettuce	Leafy vegetable	68	4.5	38.5	1.2	43	4.8
Carrots	Root vegetable	70	4.6	46.7	1.1	52	7.8-9.8
Potatoes	Root vegetable	98	3.2	42.1	0.7	47	4.1
Melons	Fruit	88	2.9	39.8	0.4	45	1.9
Grapes	Fruit	184	6.0	N/A	N/A	30	1.6-2.3
Wheat	Grain	244	8.0	53.3	3.4	56	0.3-0.7
Corn	Stored feed for poultry and eggs	140	4.6	70.1	0.8	75	0.6-0.8
Alfalfa	Fresh feed for beef and milk	46-135	12	92.7	4.0	95	1.0-1.2

Source: CRWMS M&O 2000i

Note: [1] The values for spinach, lettuce, and carrots yields were doubled because of the double harvest.

III.2 DEVELOPMENT OF INGESTION EXPOSURE PARAMETERS

Based on data listed in Table III-1, the four ingestion exposure parameters for eight crop categories were developed as listed in Table III-2. Due to limited data available, if there were two values available for one parameter within the same crop type, a uniform distribution was assumed between the minimum and maximum values. Otherwise, a fixed value was used for the parameter. The only exception was growing time for forage. The same distribution and values were used as the ones developed previously (CRWMS M&O 2000i, Section 6.8).

Table III-2. Summary of Developed Ingestion Parameter Values for Amargosa Valley

Parameter	Distribution	Reasonable Estimate	Minimum Value	Maximum Value
Growing Time (d):				
Leafy vegetables	Uniform	57	45	68
Root vegetables	Uniform	84	70	98
Fruit	Uniform	136	88	184
Grain	Fixed	244	244	244
Fresh feed for beef	Triangular	47	46	135
Stored feed for poultry	Fixed	140	140	140
Fresh feed for milk	Triangular	47	46	135
Stored feed for eggs	Fixed	140	140	140
Irrigation Time (mo/yr):				
Leafy vegetables	Uniform	3.8	3.0	4.5
Root vegetables	Uniform	3.9	3.2	4.6
Fruit	Uniform	4.5	2.9	6.0
Grain	Fixed	8.0	8.0	8.0
Fresh feed for beef	Fixed	12	12	12
Stored feed for poultry	Fixed	4.6	4.6	4.6
Fresh feed for milk	Fixed	12	12	12
Stored feed for eggs	Fixed	4.6	4.6	4.6
Irrigation Rate (in/yr)				
Leafy vegetables	Uniform	36	28	43
Root vegetables	Uniform	50	47	52
Fruit	Uniform	38	30	45
Grain	Fixed	56	56	56
Fresh feed for beef	Fixed	95	95	95
Stored feed for poultry	Fixed	75	75	75
Fresh feed for milk	Fixed	95	95	95
Stored feed for eggs	Fixed	75	75	75
Crop Yield (kg/m^2)				
Leafy vegetables	Uniform	4.6	4.4	4.8
Root vegetables	Uniform	7.0	4.1	9.8
Fruit	Uniform	2.0	1.6	2.3
Grain	Uniform	0.5	0.3	0.7
Fresh feed for beef	Uniform	1.1	1.0	1.2
Stored feed for poultry	Uniform	0.7	0.6	0.8
Fresh feed for milk	Uniform	1.1	1.0	1.2
Stored feed for eggs	Uniform	0.7	0.6	0.8

Source: Table III-1

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ATTACHMENT IV

FILES GENERATED IN MODEL RUNS

ATTACHMENT IV

FILES GENERATED IN MODEL RUNS

Input and output for the biosphere model used in this analysis is included in DTN: MO0010MWDPBD03.007. The following file name notation was used:

File name: ABCDEFGH.*

A	V	– volcanic scenario
B	J	– thick ash (15 cm), 10-year average mass loading for volcanic scenario
	K	– thick ash, annual mass loading for volcanic scenario
	M	– thin ash (1-cm layer), 10-yr-average mass loading for volcanic scenario
	N	– thin ash (1 cm), annual average mass loading for volcanic scenario
C	C	– Average Member of the Critical Group
D	T	– transition period for volcanic case
	S	– stable condition for volcanic case

EFGH notation for radionuclide

e.g., CX14 for C-14
I129 for I-129
PU21 for Pu-241

* file extension (.inp and .flg are extensions for input files, while .out, .vec and .pti are extensions for output files)

IV.1 GENII-S FILES FOR THE TRANSITION PHASE, 1-CM ASH THICKNESS, AND ANNUAL AVERAGE MASS LOADING

```
VNCTAC27 FLG          712  09-27-00  1:50p
VNCTAC27 INP       14,966  09-27-00  1:55p
VNCTAC27 OUT       16,345  09-27-00  1:55p
VNCTAC27 PTI        8,242  09-27-00  1:55p
VNCTAC27 VEC       54,252  09-27-00  1:55p
VNCTAM21 FLG          712  09-27-00  2:18p
VNCTAM21 INP       14,966  09-27-00  2:19p
VNCTAM21 OUT       16,457  09-27-00  2:19p
VNCTAM21 PTI        8,242  09-27-00  2:19p
VNCTAM21 VEC       54,252  09-27-00  2:19p
VNCTAM23 FLG          712  09-27-00  2:20p
VNCTAM23 INP       14,966  09-27-00  2:20p
VNCTAM23 OUT       16,272  09-27-00  2:20p
VNCTAM23 PTI        8,242  09-27-00  2:20p
VNCTAM23 VEC       54,252  09-27-00  2:20p
VNCTCS17 FLG          712  09-27-00  2:38p
VNCTCS17 INP       14,966  09-27-00  2:38p
VNCTCS17 OUT       14,804  09-27-00  2:00p
```

VNCTCS17	PTI	8,242	09-27-00	2:00p
VNCTCS17	VEC	54,252	09-27-00	2:00p
VNCTPA21	FLG	712	09-27-00	2:09p
VNCTPA21	INP	14,966	09-27-00	2:09p
VNCTPA21	OUT	16,530	09-27-00	2:09p
VNCTPA21	PTI	8,242	09-27-00	2:09p
VNCTPA21	VEC	54,252	09-27-00	2:09p
VNCTPB20	FLG	712	09-27-00	2:40p
VNCTPB20	INP	14,966	09-27-00	2:40p
VNCTPB20	OUT	16,496	09-27-00	2:02p
VNCTPB20	PTI	8,242	09-27-00	2:02p
VNCTPB20	VEC	54,252	09-27-00	2:02p
VNCTPU20	FLG	712	09-27-00	2:16p
VNCTPU20	INP	14,966	09-27-00	2:16p
VNCTPU20	OUT	16,311	09-27-00	2:17p
VNCTPU20	PTI	8,242	09-27-00	2:17p
VNCTPU20	VEC	54,252	09-27-00	2:17p
VNCTPU22	FLG	712	09-27-00	2:17p
VNCTPU22	INP	14,966	09-27-00	2:17p
VNCTPU22	OUT	16,345	09-27-00	2:18p
VNCTPU22	PTI	8,242	09-27-00	2:18p
VNCTPU22	VEC	54,252	09-27-00	2:18p
VNCTPU28	FLG	712	09-27-00	2:14p
VNCTPU28	INP	14,966	09-27-00	2:14p
VNCTPU28	OUT	16,311	09-27-00	2:15p
VNCTPU28	PTI	8,242	09-27-00	2:15p
VNCTPU28	VEC	54,252	09-27-00	2:15p
VNCTPU29	FLG	712	09-27-00	2:15p
VNCTPU29	INP	14,966	09-27-00	2:15p
VNCTPU29	OUT	14,974	09-27-00	2:16p
VNCTPU29	PTI	8,242	09-27-00	2:16p
VNCTPU29	VEC	54,252	09-27-00	2:16p
VNCTRA26	FLG	712	09-27-00	2:04p
VNCTRA26	INP	14,966	09-27-00	2:04p
VNCTRA26	OUT	16,701	09-27-00	2:05p
VNCTRA26	PTI	8,242	09-27-00	2:05p
VNCTRA26	VEC	54,252	09-27-00	2:05p
VNCTSR90	FLG	711	09-27-00	2:30p
VNCTSR90	INP	14,966	09-27-00	2:30p
VNCTSR90	OUT	16,199	09-27-00	1:58p
VNCTSR90	PTI	8,242	09-27-00	1:58p
VNCTSR90	VEC	54,252	09-27-00	1:58p
VNCTTH20	FLG	712	09-27-00	2:07p
VNCTTH20	INP	14,966	09-27-00	2:08p
VNCTTH20	OUT	16,774	09-27-00	2:08p
VNCTTH20	PTI	8,242	09-27-00	2:08p
VNCTTH20	VEC	54,252	09-27-00	2:08p
VNCTTH29	FLG	712	09-27-00	2:05p
VNCTTH29	INP	14,966	09-27-00	2:06p
VNCTTH29	OUT	16,272	09-27-00	2:06p
VNCTTH29	PTI	8,242	09-27-00	2:06p
VNCTTH29	VEC	54,252	09-27-00	2:06p
VNCTU232	FLG	712	09-27-00	2:10p
VNCTU232	INP	14,966	09-27-00	2:10p
VNCTU232	OUT	16,749	09-27-00	2:11p
VNCTU232	PTI	8,242	09-27-00	2:11p
VNCTU232	VEC	54,252	09-27-00	2:11p

VNCTU233	FLG	712	09-27-00	2:11p
VNCTU233	INP	14,966	09-27-00	2:11p
VNCTU233	OUT	16,457	09-27-00	2:12p
VNCTU233	PTI	8,242	09-27-00	2:12p
VNCTU233	VEC	54,252	09-27-00	2:12p
VNCTU234	FLG	712	09-27-00	2:12p
VNCTU234	INP	14,966	09-27-00	2:12p
VNCTU234	OUT	14,974	09-27-00	2:13p
VNCTU234	PTI	8,242	09-27-00	2:13p
VNCTU234	VEC	54,252	09-27-00	2:13p

IV.2 GENII-S FILES FOR THE TRANSITION PHASE, 1-CM ASH THICKNESS, AND 10-YEAR AVERAGE MASS LOADING

VMCTAC27	FLG	712	10-10-00	10:07a
VMCTAC27	INP	14,967	10-10-00	10:08a
VMCTAC27	OUT	16,345	10-10-00	10:09a
VMCTAC27	PTI	8,242	10-10-00	10:09a
VMCTAC27	VEC	54,252	10-10-00	10:09a
VMCTAM21	FLG	712	10-10-00	10:10a
VMCTAM21	INP	14,967	10-10-00	10:10a
VMCTAM21	OUT	16,457	10-10-00	10:11a
VMCTAM21	PTI	8,242	10-10-00	10:11a
VMCTAM21	VEC	54,252	10-10-00	10:11a
VMCTAM23	FLG	712	10-10-00	10:11a
VMCTAM23	INP	14,967	10-10-00	10:12a
VMCTAM23	OUT	16,272	10-10-00	10:12a
VMCTAM23	PTI	8,242	10-10-00	10:12a
VMCTAM23	VEC	54,252	10-10-00	10:12a
VMCTCS17	FLG	712	10-10-00	10:12a
VMCTCS17	INP	14,967	10-10-00	10:13a
VMCTCS17	OUT	14,804	10-10-00	10:13a
VMCTCS17	PTI	8,242	10-10-00	10:13a
VMCTCS17	VEC	54,252	10-10-00	10:13a
VMCTPA21	FLG	712	10-10-00	10:14a
VMCTPA21	INP	14,967	10-10-00	10:15a
VMCTPA21	OUT	16,530	10-10-00	10:15a
VMCTPA21	PTI	8,242	10-10-00	10:15a
VMCTPA21	VEC	54,252	10-10-00	10:15a
VMCTPB20	FLG	712	10-10-00	10:34a
VMCTPB20	INP	14,967	10-10-00	10:34a
VMCTPB20	OUT	16,496	10-10-00	10:35a
VMCTPB20	PTI	8,242	10-10-00	10:35a
VMCTPB20	VEC	54,252	10-10-00	10:35a
VMCTPU20	FLG	712	10-10-00	10:36a
VMCTPU20	INP	14,967	10-10-00	10:37a
VMCTPU20	OUT	16,311	10-10-00	10:37a
VMCTPU20	PTI	8,242	10-10-00	10:37a
VMCTPU20	VEC	54,252	10-10-00	10:37a
VMCTPU22	FLG	712	10-10-00	10:38a
VMCTPU22	INP	14,967	10-10-00	10:38a
VMCTPU22	OUT	16,345	10-10-00	10:39a
VMCTPU22	PTI	8,242	10-10-00	10:39a
VMCTPU22	VEC	54,252	10-10-00	10:39a
VMCTPU28	FLG	712	10-10-00	10:40a
VMCTPU28	INP	14,967	10-10-00	10:40a

VMCTPU28	OUT	16,311	10-10-00	10:40a
VMCTPU28	PTI	8,242	10-10-00	10:40a
VMCTPU28	VEC	54,252	10-10-00	10:40a
VMCTPU29	FLG	712	10-10-00	10:41a
VMCTPU29	INP	14,967	10-10-00	10:41a
VMCTPU29	OUT	14,974	10-10-00	10:42a
VMCTPU29	PTI	8,242	10-10-00	10:42a
VMCTPU29	VEC	54,252	10-10-00	10:42a
VMCTRA26	FLG	712	10-10-00	10:43a
VMCTRA26	INP	14,967	10-10-00	10:43a
VMCTRA26	OUT	16,701	10-10-00	10:43a
VMCTRA26	PTI	8,242	10-10-00	10:43a
VMCTRA26	VEC	54,252	10-10-00	10:43a
VMCTSR90	FLG	711	10-10-00	10:44a
VMCTSR90	INP	14,967	10-10-00	10:44a
VMCTSR90	OUT	16,199	10-10-00	10:45a
VMCTSR90	PTI	8,242	10-10-00	10:45a
VMCTSR90	VEC	54,252	10-10-00	10:45a
VMCTTH20	FLG	712	10-10-00	10:45a
VMCTTH20	INP	14,967	10-10-00	10:46a
VMCTTH20	OUT	16,774	10-10-00	10:46a
VMCTTH20	PTI	8,242	10-10-00	10:46a
VMCTTH20	VEC	54,252	10-10-00	10:46a
VMCTTH29	FLG	712	10-10-00	10:47a
VMCTTH29	INP	14,967	10-10-00	10:47a
VMCTTH29	OUT	16,272	10-10-00	10:48a
VMCTTH29	PTI	8,242	10-10-00	10:48a
VMCTTH29	VEC	54,252	10-10-00	10:48a
VMCTU232	FLG	712	10-10-00	10:48a
VMCTU232	INP	14,967	10-10-00	10:49a
VMCTU232	OUT	16,749	10-10-00	10:49a
VMCTU232	PTI	8,242	10-10-00	10:49a
VMCTU232	VEC	54,252	10-10-00	10:49a
VMCTU233	FLG	712	10-10-00	10:50a
VMCTU233	INP	14,967	10-10-00	10:50a
VMCTU233	OUT	16,457	10-10-00	10:50a
VMCTU233	PTI	8,242	10-10-00	10:50a
VMCTU233	VEC	54,252	10-10-00	10:50a
VMCTU234	FLG	712	10-10-00	10:51a
VMCTU234	INP	14,967	10-10-00	10:51a
VMCTU234	OUT	14,974	10-10-00	10:52a
VMCTU234	PTI	8,242	10-10-00	10:52a
VMCTU234	VEC	54,252	10-10-00	10:52a

IV.3 GENII-S FILES FOR THE TRANSITION PHASE, 15-CM ASH THICKNESS, AND ANNUAL AVERAGE MASS LOADING

VKCTAC27	FLG	712	09-27-00	5:42p
VKCTAC27	INP	14,966	09-27-00	5:42p
VKCTAC27	OUT	16,345	09-27-00	5:12p
VKCTAC27	PTI	8,242	09-27-00	5:12p
VKCTAC27	VEC	54,252	09-27-00	5:12p
VKCTAM21	FLG	712	09-27-00	5:30p
VKCTAM21	INP	14,966	09-27-00	5:30p
VKCTAM21	OUT	16,457	09-27-00	5:30p
VKCTAM21	PTI	8,242	09-27-00	5:30p

VKCTAM21	VEC	54,252	09-27-00	5:30p
VKCTAM23	FLG	712	09-27-00	5:31p
VKCTAM23	INP	14,966	09-27-00	5:31p
VKCTAM23	OUT	16,272	09-27-00	5:31p
VKCTAM23	PTI	8,242	09-27-00	5:31p
VKCTAM23	VEC	54,252	09-27-00	5:31p
VKCTCS17	FLG	712	09-27-00	5:16p
VKCTCS17	INP	14,966	09-27-00	5:16p
VKCTCS17	OUT	14,804	09-27-00	5:16p
VKCTCS17	PTI	8,242	09-27-00	5:16p
VKCTCS17	VEC	54,252	09-27-00	5:16p
VKCTPA21	FLG	712	09-27-00	5:21p
VKCTPA21	INP	14,966	09-27-00	5:21p
VKCTPA21	OUT	16,530	09-27-00	5:22p
VKCTPA21	PTI	8,242	09-27-00	5:22p
VKCTPA21	VEC	54,252	09-27-00	5:22p
VKCTPB20	FLG	712	09-27-00	5:17p
VKCTPB20	INP	14,966	09-27-00	5:17p
VKCTPB20	OUT	16,496	09-27-00	5:17p
VKCTPB20	PTI	8,242	09-27-00	5:17p
VKCTPB20	VEC	54,252	09-27-00	5:17p
VKCTPU20	FLG	712	09-27-00	5:28p
VKCTPU20	INP	14,966	09-27-00	5:28p
VKCTPU20	OUT	16,311	09-27-00	5:28p
VKCTPU20	PTI	8,242	09-27-00	5:28p
VKCTPU20	VEC	54,252	09-27-00	5:28p
VKCTPU22	FLG	712	09-27-00	5:29p
VKCTPU22	INP	14,966	09-27-00	5:29p
VKCTPU22	OUT	16,345	09-27-00	5:29p
VKCTPU22	PTI	8,242	09-27-00	5:29p
VKCTPU22	VEC	54,252	09-27-00	5:29p
VKCTPU28	FLG	712	09-27-00	5:26p
VKCTPU28	INP	14,966	09-27-00	5:26p
VKCTPU28	OUT	16,311	09-27-00	5:27p
VKCTPU28	PTI	8,242	09-27-00	5:27p
VKCTPU28	VEC	54,252	09-27-00	5:27p
VKCTPU29	FLG	712	09-27-00	5:27p
VKCTPU29	INP	14,966	09-27-00	5:27p
VKCTPU29	OUT	14,974	09-27-00	5:28p
VKCTPU29	PTI	8,242	09-27-00	5:28p
VKCTPU29	VEC	54,252	09-27-00	5:28p
VKCTRA26	FLG	712	09-27-00	5:18p
VKCTRA26	INP	14,966	09-27-00	5:18p
VKCTRA26	OUT	16,701	09-27-00	5:18p
VKCTRA26	PTI	8,242	09-27-00	5:18p
VKCTRA26	VEC	54,252	09-27-00	5:18p
VKCTSR90	FLG	711	09-27-00	5:15p
VKCTSR90	INP	14,966	09-27-00	5:15p
VKCTSR90	OUT	16,199	09-27-00	5:15p
VKCTSR90	PTI	8,242	09-27-00	5:15p
VKCTSR90	VEC	54,252	09-27-00	5:15p
VKCTTH20	FLG	712	09-27-00	5:20p
VKCTTH20	INP	14,966	09-27-00	5:20p
VKCTTH20	OUT	16,774	09-27-00	5:21p
VKCTTH20	PTI	8,242	09-27-00	5:21p
VKCTTH20	VEC	54,252	09-27-00	5:21p
VKCTTH29	FLG	712	09-27-00	5:19p

VKCTTH29	INP	14,966	09-27-00	5:19p
VKCTTH29	OUT	16,272	09-27-00	5:19p
VKCTTH29	PTI	8,242	09-27-00	5:19p
VKCTTH29	VEC	54,252	09-27-00	5:19p
VKCTU232	FLG	712	09-27-00	5:22p
VKCTU232	INP	14,966	09-27-00	5:22p
VKCTU232	OUT	16,749	09-27-00	5:23p
VKCTU232	PTI	8,242	09-27-00	5:23p
VKCTU232	VEC	54,252	09-27-00	5:23p
VKCTU233	FLG	712	09-27-00	5:23p
VKCTU233	INP	14,966	09-27-00	5:23p
VKCTU233	OUT	16,457	09-27-00	5:24p
VKCTU233	PTI	8,242	09-27-00	5:24p
VKCTU233	VEC	54,252	09-27-00	5:24p
VKCTU234	FLG	712	09-27-00	5:24p
VKCTU234	INP	14,966	09-27-00	5:24p
VKCTU234	OUT	14,974	09-27-00	5:24p
VKCTU234	PTI	8,242	09-27-00	5:24p
VKCTU234	VEC	54,252	09-27-00	5:24p

IV.4 GENII-S FILES FOR THE TRANSITION PHASE, 15-CM ASH THICKNESS, AND 10-YEAR AVERAGE MASS LOADING

VJCTAC27	FLG	712	10-10-00	9:10a
VJCTAC27	INP	14,967	10-10-00	9:10a
VJCTAC27	OUT	16,345	10-10-00	9:11a
VJCTAC27	PTI	8,242	10-10-00	9:11a
VJCTAC27	VEC	54,252	10-10-00	9:11a
VJCTAM21	FLG	712	10-10-00	9:14a
VJCTAM21	INP	14,967	10-10-00	9:14a
VJCTAM21	OUT	16,457	10-10-00	9:15a
VJCTAM21	PTI	8,242	10-10-00	9:15a
VJCTAM21	VEC	54,252	10-10-00	9:15a
VJCTAM23	FLG	712	10-10-00	9:16a
VJCTAM23	INP	14,967	10-10-00	9:17a
VJCTAM23	OUT	16,272	10-10-00	9:17a
VJCTAM23	PTI	8,242	10-10-00	9:17a
VJCTAM23	VEC	54,252	10-10-00	9:17a
VJCTCS17	FLG	712	10-10-00	9:18a
VJCTCS17	INP	14,967	10-10-00	9:19a
VJCTCS17	OUT	14,804	10-10-00	9:19a
VJCTCS17	PTI	8,242	10-10-00	9:19a
VJCTCS17	VEC	54,252	10-10-00	9:19a
VJCTPA21	FLG	712	10-10-00	9:20a
VJCTPA21	INP	14,967	10-10-00	9:21a
VJCTPA21	OUT	16,530	10-10-00	9:21a
VJCTPA21	PTI	8,242	10-10-00	9:21a
VJCTPA21	VEC	54,252	10-10-00	9:21a
VJCTPB20	FLG	712	10-10-00	9:22a
VJCTPB20	INP	14,967	10-10-00	9:23a
VJCTPB20	OUT	16,496	10-10-00	9:23a
VJCTPB20	PTI	8,242	10-10-00	9:23a
VJCTPB20	VEC	54,252	10-10-00	9:23a
VJCTPU20	FLG	712	10-10-00	9:32a
VJCTPU20	INP	14,967	10-10-00	9:33a
VJCTPU20	OUT	16,311	10-10-00	9:33a

VJCTPU20	PTI	8,242	10-10-00	9:33a
VJCTPU20	VEC	54,252	10-10-00	9:33a
VJCTPU22	FLG	712	10-10-00	9:34a
VJCTPU22	INP	14,967	10-10-00	9:34a
VJCTPU22	OUT	16,345	10-10-00	9:34a
VJCTPU22	PTI	8,242	10-10-00	9:34a
VJCTPU22	VEC	54,252	10-10-00	9:34a
VJCTPU28	FLG	712	10-10-00	9:35a
VJCTPU28	INP	14,967	10-10-00	9:36a
VJCTPU28	OUT	16,311	10-10-00	9:36a
VJCTPU28	PTI	8,242	10-10-00	9:36a
VJCTPU28	VEC	54,252	10-10-00	9:36a
VJCTPU29	FLG	712	10-10-00	9:37a
VJCTPU29	INP	14,967	10-10-00	9:37a
VJCTPU29	OUT	14,974	10-10-00	9:37a
VJCTPU29	PTI	8,242	10-10-00	9:37a
VJCTPU29	VEC	54,252	10-10-00	9:37a
VJCTRA26	FLG	712	10-10-00	9:38a
VJCTRA26	INP	14,967	10-10-00	9:39a
VJCTRA26	OUT	16,701	10-10-00	9:39a
VJCTRA26	PTI	8,242	10-10-00	9:39a
VJCTRA26	VEC	54,252	10-10-00	9:39a
VJCTSR90	FLG	711	10-10-00	9:59a
VJCTSR90	INP	14,967	10-10-00	9:59a
VJCTSR90	OUT	16,199	10-10-00	9:41a
VJCTSR90	PTI	8,242	10-10-00	9:41a
VJCTSR90	VEC	54,252	10-10-00	9:41a
VJCTTH20	FLG	712	10-10-00	9:42a
VJCTTH20	INP	14,967	10-10-00	9:43a
VJCTTH20	OUT	16,774	10-10-00	9:43a
VJCTTH20	PTI	8,242	10-10-00	9:43a
VJCTTH20	VEC	54,252	10-10-00	9:43a
VJCTTH29	FLG	712	10-10-00	9:44a
VJCTTH29	INP	14,967	10-10-00	9:44a
VJCTTH29	OUT	16,272	10-10-00	9:45a
VJCTTH29	PTI	8,242	10-10-00	9:45a
VJCTTH29	VEC	54,252	10-10-00	9:45a
VJCTU232	FLG	712	10-10-00	9:45a
VJCTU232	INP	14,967	10-10-00	9:46a
VJCTU232	OUT	16,749	10-10-00	9:46a
VJCTU232	PTI	8,242	10-10-00	9:46a
VJCTU232	VEC	54,252	10-10-00	9:46a
VJCTU233	FLG	712	10-10-00	9:47a
VJCTU233	INP	14,967	10-10-00	9:47a
VJCTU233	OUT	16,457	10-10-00	9:48a
VJCTU233	PTI	8,242	10-10-00	9:48a
VJCTU233	VEC	54,252	10-10-00	9:48a
VJCTU234	FLG	712	10-10-00	9:48a
VJCTU234	INP	14,967	10-10-00	9:49a
VJCTU234	OUT	14,974	10-10-00	9:49a
VJCTU234	PTI	8,242	10-10-00	9:49a
VJCTU234	VEC	54,252	10-10-00	9:49a

IV.5 GENII-S FILES FOR THE STEADY-STATE PHASE

VKCSAC27	FLG	712	09-28-00	12:55p

VKCSAC27	INP	14,968	09-28-00	12:59p
VKCSAC27	OUT	16,345	09-28-00	12:59p
VKCSAC27	PTI	8,242	09-28-00	12:59p
VKCSAC27	VEC	54,252	09-28-00	12:59p
VKCSAM21	FLG	712	09-28-00	1:21p
VKCSAM21	INP	14,968	09-28-00	1:21p
VKCSAM21	OUT	16,457	09-28-00	1:21p
VKCSAM21	PTI	8,242	09-28-00	1:21p
VKCSAM21	VEC	54,252	09-28-00	1:21p
VKCSAM23	FLG	712	09-28-00	1:22p
VKCSAM23	INP	14,968	09-28-00	1:22p
VKCSAM23	OUT	16,272	09-28-00	1:22p
VKCSAM23	PTI	8,242	09-28-00	1:22p
VKCSAM23	VEC	54,252	09-28-00	1:22p
VKCSCS17	FLG	712	09-28-00	1:05p
VKCSCS17	INP	14,968	09-28-00	1:05p
VKCSCS17	OUT	14,804	09-28-00	1:06p
VKCSCS17	PTI	8,242	09-28-00	1:06p
VKCSCS17	VEC	54,252	09-28-00	1:06p
VKCSPA21	FLG	712	09-28-00	1:10p
VKCSPA21	INP	14,968	09-28-00	1:11p
VKCSPA21	OUT	16,530	09-28-00	1:11p
VKCSPA21	PTI	8,242	09-28-00	1:11p
VKCSPA21	VEC	54,252	09-28-00	1:11p
VKCSPB20	FLG	712	09-28-00	1:06p
VKCSPB20	INP	14,968	09-28-00	1:06p
VKCSPB20	OUT	16,496	09-28-00	1:07p
VKCSPB20	PTI	8,242	09-28-00	1:07p
VKCSPB20	VEC	54,252	09-28-00	1:07p
VKCSPU20	FLG	712	09-28-00	1:18p
VKCSPU20	INP	14,968	09-28-00	1:19p
VKCSPU20	OUT	16,311	09-28-00	1:19p
VKCSPU20	PTI	8,242	09-28-00	1:19p
VKCSPU20	VEC	54,252	09-28-00	1:19p
VKCSPU22	FLG	712	09-28-00	1:19p
VKCSPU22	INP	14,968	09-28-00	1:20p
VKCSPU22	OUT	16,345	09-28-00	1:20p
VKCSPU22	PTI	8,242	09-28-00	1:20p
VKCSPU22	VEC	54,252	09-28-00	1:20p
VKCSPU28	FLG	712	09-28-00	1:16p
VKCSPU28	INP	14,968	09-28-00	1:16p
VKCSPU28	OUT	16,311	09-28-00	1:17p
VKCSPU28	PTI	8,242	09-28-00	1:17p
VKCSPU28	VEC	54,252	09-28-00	1:17p
VKCSPU29	FLG	712	09-28-00	1:18p
VKCSPU29	INP	14,968	09-28-00	1:18p
VKCSPU29	OUT	14,974	09-28-00	1:18p
VKCSPU29	PTI	8,242	09-28-00	1:18p
VKCSPU29	VEC	54,252	09-28-00	1:18p
VKCSRA26	FLG	712	09-28-00	1:07p
VKCSRA26	INP	14,968	09-28-00	1:07p
VKCSRA26	OUT	16,701	09-28-00	1:08p
VKCSRA26	PTI	8,242	09-28-00	1:08p
VKCSRA26	VEC	54,252	09-28-00	1:08p
VKCSSR90	FLG	711	09-28-00	1:04p
VKCSSR90	INP	14,968	09-28-00	1:04p
VKCSSR90	OUT	16,199	09-28-00	1:05p

VKCSSR90	PTI	8,242	09-28-00	1:05p
VKCSSR90	VEC	54,252	09-28-00	1:05p
VKCSTH20	FLG	712	09-28-00	1:09p
VKCSTH20	INP	14,968	09-28-00	1:10p
VKCSTH20	OUT	16,774	09-28-00	1:10p
VKCSTH20	PTI	8,242	09-28-00	1:10p
VKCSTH20	VEC	54,252	09-28-00	1:10p
VKCSTH29	FLG	712	09-28-00	1:08p
VKCSTH29	INP	14,968	09-28-00	1:09p
VKCSTH29	OUT	16,272	09-28-00	1:09p
VKCSTH29	PTI	8,242	09-28-00	1:09p
VKCSTH29	VEC	54,252	09-28-00	1:09p
VKCSU232	FLG	712	09-28-00	1:12p
VKCSU232	INP	14,968	09-28-00	1:13p
VKCSU232	OUT	16,749	09-28-00	1:13p
VKCSU232	PTI	8,242	09-28-00	1:13p
VKCSU232	VEC	54,252	09-28-00	1:13p
VKCSU233	FLG	712	09-28-00	1:13p
VKCSU233	INP	14,968	09-28-00	1:14p
VKCSU233	OUT	16,457	09-28-00	1:14p
VKCSU233	PTI	8,242	09-28-00	1:14p
VKCSU233	VEC	54,252	09-28-00	1:14p
VKCSU234	FLG	712	09-28-00	1:15p
VKCSU234	INP	14,968	09-28-00	1:15p
VKCSU234	OUT	14,974	09-28-00	1:15p
VKCSU234	PTI	8,242	09-28-00	1:15p
VKCSU234	VEC	54,252	09-28-00	1:15p

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ATTACHMENT V

DETERMINATION OF PATHWAY CONTRIBUTION

ATTACHMENT V

DETERMINATION OF PATHWAY CONTRIBUTION

A software routine, built into a Microsoft Excel version 97 SR-2 spreadsheet, was used to automate the determination of contribution to the BDCF by each pathway.

Software routine: *Pathway Contribution* REV 0

Set-up and Operation of Software Routine:

An example of the application is provided to assist the user in understanding the organization and function of the routine used to determine the contribution to the BDCF by each pathway. A representation of the spreadsheet for Plutonium-239, transition phase, 1-cm ash thickness, and annual average mass loading follows. The spreadsheet has been divided into three areas (i.e., A, B and C) for ease of explanation.

All data imported from the GENII-S output files is obtained by blocking and copying the desired data and then pasting it into the appropriate section of the spreadsheet. Inserting the data into the spreadsheet is accomplished by using the "Paste" command and the "Text to columns" submenu item under "Data" from the tool bar to arrange the data into individual cells.

Area "A" is a table imported directly from the GENII-S output file which shows the contributions to the annual committed effective dose equivalent from internal exposure by inhalation and ingestion and the external exposure. GENII-S calculates internal doses by multiplying the committed dose equivalent to each organ times the weighting factor for that organ, then summing the weighted organ dose equivalents. The sum of the internal dose (committed effective dose equivalent) from annual intake and the external dose (effective dose equivalent) from annual exposure yields the annual total effective dose equivalent.

The upper portion of area "B" is a table imported directly from the GENII-S output file. This table contains the committed dose equivalent to each organ from each individual pathway. The totals at the bottom of the organ columns are the same as the values shown in the committed dose equivalent column from the table shown in area "A". In order to determine the contribution by pathway to the annual total effective dose equivalent it is necessary to calculate the weighted dose equivalent to each organ from each pathway. This is done by multiplying the values in the upper table by each organ's weighting factor. The results are contained in the table in the lower portion of area "B". The total contribution for each pathway is obtained by summing the weighted organ committed dose equivalents. The results are found in the lower right corner of area "B" under the column titled "Total".

In area "C" the total percentage contributions to the BDCF are presented. The percentage contributions from each pathway were calculated by dividing the pathway contribution by the annual total effective dose equivalent and multiplying the result by 100.

Confirmation of Correct Operation:

The individual calculations have been spot checked with hand calculations to ensure that correct results are being produced. Also, as a spot check for each use of the routine, the total from the lower right hand corner of area “B” is compared to the “Internal Effective Dose Equivalent” value from the bottom of area “A”. These values should be almost the same.

VNCT BDCF: Pu-239

A

Organ	Committed Dose Equiv.	Weighting Factors	Weighted Dose Equiv.		Check
Gonads	3.80E-08	2.50E-01	9.50E-09	Gonads	9.62E-09
Breast	1.20E-12	1.50E-01	1.80E-13	Breast	1.72E-13
R marrow	2.10E-07	1.20E-01	2.60E-08	R	2.62E-08
Lung	2.10E-08	1.20E-01	2.50E-09	Lung	2.52E-09
Thyroid	1.20E-12	3.00E-02	3.50E-14	Thyroid	3.43E-14
Bone Sur	2.80E-06	3.00E-02	8.30E-08	Bone	8.12E-08
Liver	4.80E-07	6.00E-02	2.90E-08	Liver	2.87E-08
LL Int.	3.50E-10	6.00E-02	2.10E-11	LL	2.12E-11
UL Int.	1.10E-10	6.00E-02	6.80E-12	UL	6.75E-12
S Int.	2.10E-11	6.00E-02	1.20E-12	S	1.23E-12
Stomach	9.00E-12	6.00E-02	5.40E-13	Stom.	5.33E-13
Internal Effective Dose Equivalent			1.50E-07		1.48E-07
External Dose			1.70E-13		
Annual Effective Dose Equiv.			1.50E-07		

B Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes	Ovaries	Muscle	Thyroid	Liver
Inhale	2.10E-08	1.80E-12	2.90E-12	1.20E-11	3.40E-11	2.60E-06	2.10E-07	3.70E-08	3.60E-08	1.10E-12	1.10E-12	4.60E-07
Leaf Veg	9.20E-15	1.40E-12	3.60E-12	2.00E-11	6.30E-11	2.10E-08	1.60E-09	2.90E-10	2.90E-10	9.20E-15	8.90E-15	3.70E-09
Oth. Veg	9.80E-16	1.50E-13	3.80E-13	2.10E-12	6.70E-12	2.30E-09	1.80E-10	3.10E-11	3.10E-11	9.80E-16	9.40E-16	4.00E-10
Fruit	1.40E-15	2.10E-13	5.20E-13	3.00E-12	9.20E-12	3.10E-09	2.40E-10	4.30E-11	4.30E-11	1.40E-15	1.30E-15	5.50E-10
Cereals	1.60E-16	2.40E-14	6.00E-14	3.40E-13	1.10E-12	3.60E-10	2.80E-11	5.00E-12	5.00E-12	1.60E-16	1.50E-16	6.30E-11
Meat	2.30E-18	3.60E-16	9.00E-16	5.10E-15	1.60E-14	5.40E-12	4.20E-13	7.50E-14	7.40E-14	2.30E-18	2.20E-18	9.40E-13
Poultry	1.20E-19	1.90E-17	4.80E-17	2.70E-16	8.40E-16	2.90E-13	2.20E-14	4.00E-15	3.90E-15	1.20E-19	1.20E-19	5.00E-14
Cow Milk	2.60E-19	4.00E-17	9.90E-17	5.60E-16	1.70E-15	5.90E-13	4.60E-14	8.20E-15	8.20E-15	2.60E-19	2.50E-19	1.00E-13
Eggs	2.10E-18	3.20E-16	8.00E-16	4.50E-15	1.40E-14	4.80E-12	3.70E-13	6.60E-14	6.60E-14	2.10E-18	2.00E-18	8.40E-13
Soil Ing	3.50E-14	5.30E-12	1.30E-11	7.50E-11	2.40E-10	8.00E-08	6.20E-09	1.10E-09	1.10E-09	3.50E-14	3.30E-14	1.40E-08
Total	2.10E-08	9.00E-12	2.10E-11	1.10E-10	3.50E-10	2.80E-06	2.10E-07	3.80E-08	3.80E-08	1.20E-12	1.20E-12	4.80E-07
Weighting Factor	1.20E-01	6.00E-02	6.00E-02	6.00E-02	6.00E-02	3.00E-02	1.20E-01	2.50E-01		1.50E-01	3.00E-02	6.00E-02

CEDE

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes	Ovaries	Muscle	Thyroid	Liver	Total
Inhale	2.52E-09	1.08E-13	1.74E-13	7.20E-13	2.04E-12	7.80E-08	2.52E-08	9.25E-09	0.00E+00	1.65E-13	3.30E-14	2.76E-08	1.43E-07
Leaf Veg	1.10E-15	8.40E-14	2.16E-13	1.20E-12	3.78E-12	6.30E-10	1.92E-10	7.25E-11	0.00E+00	1.38E-15	2.67E-16	2.22E-10	1.12E-09
Oth. Veg	1.18E-16	9.00E-15	2.28E-14	1.26E-13	4.02E-13	6.90E-11	2.16E-11	7.75E-12	0.00E+00	1.47E-16	2.82E-17	2.40E-11	1.23E-10
Fruit	1.68E-16	1.26E-14	3.12E-14	1.80E-13	5.52E-13	9.30E-11	2.88E-11	1.08E-11	0.00E+00	2.10E-16	3.90E-17	3.30E-11	1.66E-10
Cereals	1.92E-17	1.44E-15	3.60E-15	2.04E-14	6.60E-14	1.08E-11	3.36E-12	1.25E-12	0.00E+00	2.40E-17	4.50E-18	3.78E-12	1.93E-11
Meat	2.76E-19	2.16E-17	5.40E-17	3.06E-16	9.60E-16	1.62E-13	5.04E-14	1.88E-14	0.00E+00	3.45E-19	6.60E-20	5.64E-14	2.89E-13
Poultry	1.44E-20	1.14E-18	2.88E-18	1.62E-17	5.04E-17	8.70E-15	2.64E-15	1.00E-15	0.00E+00	1.80E-20	3.60E-21	3.00E-15	1.54E-14
Cow Milk	3.12E-20	2.40E-18	5.94E-18	3.36E-17	1.02E-16	1.77E-14	5.52E-15	2.05E-15	0.00E+00	3.90E-20	7.50E-21	6.00E-15	3.14E-14
Eggs	2.52E-19	1.92E-17	4.80E-17	2.70E-16	8.40E-16	1.44E-13	4.44E-14	1.65E-14	0.00E+00	3.15E-19	6.00E-20	5.04E-14	2.56E-13
Soil Ing.	4.20E-15	3.18E-13	7.80E-13	4.50E-12	1.44E-11	2.40E-09	7.44E-10	2.75E-10	0.00E+00	5.25E-15	9.90E-16	8.40E-10	4.28E-09
Total	2.52E-09	5.40E-13	1.26E-12	6.60E-12	2.10E-11	8.40E-08	2.52E-08	9.50E-09	0.00E+00	1.80E-13	3.60E-14	2.88E-08	1.50E-07

C

pathway	rem/yr	mrem/yr	%
Inhale	1.43E-07	1.43E-04	96.1%
Leaf Veg	1.12E-09	1.12E-06	0.8%
Oth. Veg	1.23E-10	1.23E-07	0.1%
Fruit	1.66E-10	1.66E-07	0.1%
Cereals	1.93E-11	1.93E-08	0.0%
Meat	2.89E-13	2.89E-10	0.0%
Poultry	1.54E-14	1.54E-11	0.0%
Cow Milk	3.14E-14	3.14E-11	0.0%
Eggs	2.56E-13	2.56E-10	0.0%
Soil Ing	4.28E-09	4.28E-06	2.9%
Ext. dose	1.70E-13	1.70E-10	0.0%
Total	1.48E-07	1.48E-04	100%

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