PRELIMINARY DESCRIPTION OF ABSTRACTED MODELS FOR BIOSPHERE PATHWAYS AND DOSE IN THE TOTAL-SYSTEM PERFORMANCE ASSESSMENT (TPA) VERSION 5.1 BETA CODE

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PREVIOUS REPORTS IN SERIES

Number	Name	Date Issued
CNWRA 95–018	Initial Analysis of Selected Site-Specific Dose Assessment Parameters and Exposure Pathways Applicable to a Groundwater Release Scenario at Yucca Mountain	September 1995
CNWRA 97–009	Information and Analyses to Support Selections of Critical Groups and Reference Biospheres for Yucca Mountain Exposure Scenarios	August 1997
Letter Report	Total-system Performance Assessment (TPA) Version 4.0 Code: Module Descriptions and User's Guide	April 2002
CNWRA 2002–05, Revision 2	System-Level Performance Assessment of the Proposed Repository at Yucca Mountain	March 2004

ABSTRACT

The Total-system Performance Assessment (TPA) code was developed to independently evaluate uncertainties in risk-significant features, events, and processes related to the potential geologic repository for high-level waste at Yucca Mountain, Nevada. The code includes models to estimate release and transport of radioactive materials from the potential geologic repository to a receptor location defined in 10 CFR 63.312(a). Following calculations of radioactive material concentrations in groundwater or volcanic ash at the receptor location in the total-system model, additional models estimate the fate and transport of these contaminants at the receptor location considering the pathways applicable to site-specific dose assessment scenarios. Abstracted models are implemented in the code to gain fundamental insights into the influence of biosphere characteristics on dose estimates. This report describes the abstracted models of the biosphere and the implementation of dose calculations for a reasonably maximally exposed individual.

The abstracted biosphere models in the TPA code implement a flexible approach to executing a variety of pathway and dose calculations applicable to requirements established in 10 CFR Part 63 and characteristics of the region surrounding Yucca Mountain. This is accomplished by executing the TPA code module GENTPA Version 1.0 code, a pathway code based on the models in GENII Version 1.485 (Napier, et al., 1988) to compute receptor intakes and ground surface exposures per unit source concentration in the biosphere. Applying tabulated dosimetry coefficients from established compilations of dosimetry modeling results (International Commission on Radiological Protection, 2002, 1996; Environmental Protection Agency, 1993, 1988) and computed media concentrations from other TPA Version 5.1 Beta modules completes the dose calculations.

A variety of environmental exposure pathways are included in the model abstraction such as those resulting from pumping and agricultural use of water (or agricultural use of soil contaminated by deposition of airborne contaminants). The exposure conditions are consistent with present farming practices in the rural communities south of Yucca Mountain. Specific pathways include ingestion (contaminated drinking water, crops, animal products, and soil), inhalation of resuspended soil, and direct exposure to deposited radioactive materials.

The abstraction described in this report results from years of iterative performance assessment work conducted by the Center for Nuclear Waste Regulatory Analyses (CNWRA) and the U.S. Nuclear Regulatory Commission (NRC) staff. The approach has evolved incrementally over a number of years to address changes in applicable regulations, incorporate new technical information, and adapt to evolving risk insights and specific program needs. Following the previous documentation of the biosphere modeling capabilities in the code, specific enhancements that have been made include: (i) updating the GENTPA Version 1.0 code ground surface dose calculations to execute in a manner consistent with the implementation of the groundwater dose calculations, (ii) providing capabilities for exposure pathway-specific dose results, (iii) adding cumulative intermediate output files that provide output for each code realization, (iv) refining input parameter and data to enhance consistency and realism of calculations, (v) refining dosimetry coefficient selections for the igneous activity disruptive event dose calculations, and (vi) improving capabilities to conduct internal dose calculations using dose coefficient selections from either the International Commission on Radiological Protection or available federal guidance.

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QUALITY OF DATA, ANALYSES, AND CODE DEVELOPMENT

DATA: No CNWRA-generated data are contained in this report. Data from other sources are included with references to their source. The sources of these non-CNWRA data should be consulted to determine the level of quality assurance.

ANALYSES AND CODES: This report describes portions of the TPA Version 5.1 Beta code, including the GENTPA Version 1.0 code. The TPA Version 5.1 Beta code is being developed following the procedures in Geosciences and Engineering Division Technical Operating Procedure (TOP)–018, Development and Control of Scientific and Engineering Software.

1 INTRODUCTION

The U.S. Department of Energy (DOE) is preparing a license application for the potential geologic repository for high-level waste disposal at Yucca Mountain, Nevada. A performance assessment would be submitted as part of the license application for review by the U.S. Nuclear Regulatory Commission (NRC). NRC would conduct a risk-informed performance-based review, in which in-depth technical evaluations would focus on technical areas that are significant with respect to waste isolation. In preparation for a regulatory review of a potential DOE license application and its associated performance assessment, the Center for Nuclear Waste Regulatory Analyses (CNWRA) and NRC staff developed the Total-system Performance Assessment (TPA[1]) code to provide the capability to independently evaluate risk-significant features, events, and processes.

The TPA Version 5.1 Beta code executes calculations of radioactive material releases from engineered subsystems followed by transport through the geosphere and biosphere where estimates of radiation doses to an adult human receptor are calculated. The set of computations involving the fate and transport of radionuclides within the biosphere and the subsequent estimation of dose is the main topic of this report.

The abstraction described in this report results from years of iterative performance assessment work conducted by the NRC and CNWRA staffs. The approach has evolved incrementally over a number of years to address changes in applicable regulations, incorporate new technical information, and adapt to evolving risk-insights and specific program needs.

Initial pathway and dose assessment capabilities for performance assessment in the NRC high-level waste program were introduced in Phase 2 of the Iterative Performance Assessment effort (NRC, 1995). Additional biosphere modeling capabilities were explored further by CNWRA in 1995 (LaPlante, et al., 1995) and involved stochastic execution of the GENII-S software (Leigh, et al., 1993) to conduct auxiliary analyses involving dose calculations and sensitivity and uncertainty analyses for a limited set of radionuclides. These analyses were supported by literature reviews to select input parameters applicable to local conditions. A subsequent publication (LaPlante and Poor, 1997), expanded analyses to a larger suite of radionuclides, enhanced support for input parameters, and refined sensitivity analysis networks used to evaluate results. That effort resulted in tabulated sets of unit concentration-based dose conversion factors that were incorporated as lookup tables for implementing dose calculations in the TPA code. The aforementioned dose calculations and sensitivity analyses also provided useful early risk insights information for the biosphere calculations that focused efforts on refining important inputs and data. Biosphere pathway calculations were executed in this manner (outside of the TPA code) until Version 4.0 (Mohanty, et al., 2002) when the GENTPA Version 1.0 code, a modified version of the GENII Version 1.485 (Napier et al, 1988), was incorporated into the TPA code to execute pathway calculations during TPA code execution.

Following documentation of the biosphere modeling capabilities for TPA Version 4.0 code (Mohanty, et al., 2002) specific enhancements that have been made include: (i) adapting the GENTPA Version 1.0 code to ground surface dose calculations in a manner consistent with the

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[1]The Total-system Performance Assessment code is referenced frequently throughout this report. The abbreviation TPA will be used to refer to this code.

implementation of groundwater dose calculations, (ii) providing capabilities for exposure pathway-specific dose results, (iii) adding cumulative intermediate output files that provide output for each code realization, (iv) refining input parameter and data to enhance consistency and realism of calculations, (v) refining dosimetry coefficient selections for the igneous activity disruptive event dose calculations, and (vi) improving capabilities to conduct internal dose calculations using dose coefficient selections from either the International Commission on Radiological Protection or available federal guidance.

Details regarding the current biosphere pathway and dose calculation conceptual and mathematical models, implementation approach, inputs, and outputs are discussed in Chapter 2 of this report while Chapters 3 and 4 contain the summary and references, respectively. A table of the primary input parameters for the pathway and dose calculations is included in the Appendix.

The TPA Version 5.1 Beta code is being developed following Geosciences and Engineering Division Technical Operating Procedure (TOP)–018, Development and Control of Scientific and Engineering Software and is currently undergoing validation; therefore, parameters discussed in this report have not been validated and are subject to change.

2 BIOSPHERE PATHWAY AND DOSE CALCULATIONS IN THE TOTAL-SYSTEM PERFORMANCE ASSESSMENT CODE

Biosphere pathway and dose calculations in the TPA Version 5.1 Beta code convert groundwater or ground surface concentrations at the receptor location to annual pathway and radionuclide-specific doses. The approach multiplies ground surface or groundwater radionuclide concentrations (provided by other modules within the TPA Version 5.1 Beta code) by calculated pathway-specific biosphere dose conversion factors to generate all-pathway doses.

The pathway-specific biosphere dose conversion factors for internal doses (i.e., inhalation and ingestion) are computed within the TPA Version 5.1 Beta code as the product of pathway and radionuclide-specific human intakes (per unit media radionuclide concentration) calculated by the GENTPA software and tabulated intake-to-dose coefficients (hereafter dose coefficients) from available sources. Biosphere dose conversion factors for external doses are computed as the product of estimated exposure duration-weighted ground surface radionuclide concentrations (per unit ground surface concentration) computed by GENTPA and the appropriate tabulated external dose coefficients from available sources. The igneous disruptive event scenario inhalation dose calculations are computed by a separate model that is documented in another report.[2]

This chapter is divided into three sections to facilitate the description of the primary components of the pathway and dose calculations. The first section discusses the inputs passed to biosphere calculations from other TPA Version 5.1 Beta code modules; the second section describes conceptual and mathematical models for exposure pathways and dosimetry to provide the theoretical context for the modeling approach; and the third section provides practical implementation details regarding how the calculations are executed within the TPA Version 5.1 Beta code, including detailed descriptions of inputs, outputs, and supporting data files.

2.1 Inputs Supplied to the Dose Conversion Modules From Other Modules

Figure 2-1 shows the TPA Version 5.1 Beta code modules directly related to dose conversion for groundwater release and the igneous disruptive event release scenarios. The flow of information from one TPA Version 5.1 Beta code module to the next is denoted with arrows. In addition to information transferred from other modules, each module has specific local inputs. Local inputs in the TPA Version 5.1 Beta code can be input parameters (specified in a master input file for particular modules) or auxiliary files of input data.

For groundwater release scenario dose calculations, the module for saturated zone transport of radionuclides released to groundwater (SZFT[3]) provides the time series of annual radionuclide fluxes from the saturated zone at the receptor well location {18 km [11 mi] from the potential

[2]Benke, R., B. Hill, D. Hooper, and R. Nes. "Draft Description of Abstracted Models for Tephra Redistribution and Resuspension in the TPA Version 5.1 Beta Code." San Antonio, Texas: CNWRA. Unpublished Report (2006).

[3]The Saturated Zone Transport of Radionuclides Released to Groundwater module is referenced frequently throughout this report. The abbreviation SZFT will be used to refer to this module.

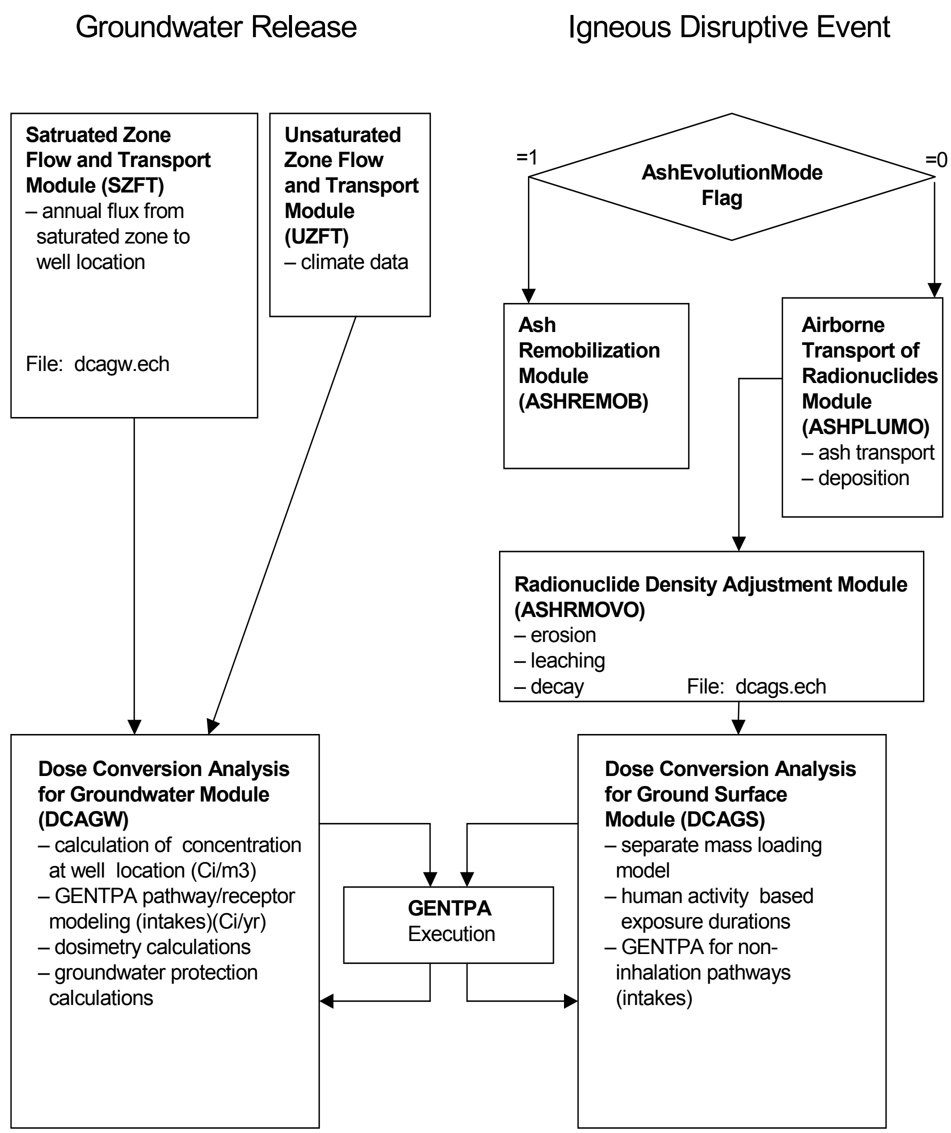

Figure 2-1. Modules Related to Pathway and Dose Calculations in the TPA Version 5.1 Beta Code

repository} in the *dcagw.ech* file. The dose conversion analysis for groundwater (DCAGW[4]) module converts the radionuclide fluxes to water concentrations by dispersing contaminants in the pumping volume defined in 10 CFR 63.312(c). The resulting concentrations are primary inputs to the groundwater release scenario dose calculations. Additional information on the climate state (mean annual precipitation and temperature) is also provided to DCAGW from the

[4]The Dose Conversion Analysis for Groundwater module is referenced frequently throughout this report. The abbreviation DCAGW will be used to refer to this module.

unsaturated zone flow and transport (UZFT[5]) module. This information is used by DCAGW in conjunction with the PluvialSwitchTime[yr] input parameter to evaluate whether pathway computations based on alternate (cooler, wetter) climate conditions will be used.

For the ground surface release scenario (i.e., igneous activity disruptive event), when ash evolution modeling is turned off (i.e., AshEvolutionMode flag = 0), the modeling component for airborne transport of radionuclides (ASHPLUMO[6]) passes time series of radionuclide areal densities deposited to the ground surface as input to the ASHRMOVO[7] module. ASHRMOVO adjusts the radionuclide densities for losses due to decay, erosion, and leaching and then passes ash blanket radionuclide concentrations (*dcags.ech* file) as input to pathway and dose calculations for ground surface exposure pathways in the dose conversion analysis for ground surface (DCAGS[8]) module. As with the aforementioned DCAGW computations, the GENTPA pathway code is executed for exposure pathways (other than inhalation) when DCAGS calculates pathway doses. When ash evolution modeling is turned on (i.e., AshEvolutionMode flag = 1), the TPA Version 5.1 Beta code computes only the inhalation pathway dose using a previously documented[9] model and does not execute GENTPA.

2.2 Conceptual and Mathematical Models for Dose Conversion

The biosphere pathway and dose calculations in the TPA Version 5.1 Beta code include the characteristics of the physical environment surrounding Yucca Mountain and the characteristics of the hypothetical individual that could be exposed to releases from the potential repository (i.e., the receptor). Regulations in 10 CFR 63.312 define specific characteristics of the receptor (the reasonably maximally exposed individual), and 10 CFR 63.305 addresses the surrounding environment where the receptor lives (reference biosphere). When applied with additional information relevant to the Yucca Mountain region, these characteristics help define the exposure scenario for TPA Version 5.1 Beta code calculations. An exposure scenario describes the combinations of features and processes at the receptor location by which the receptor can be exposed to potential releases of contaminants. The exposure scenario modeled in the TPA Version 5.1 Beta code evaluates dose to an individual adult member of a rural residential community located 18 km [11 mi] south of the potential repository site in an arid or semi-arid climate zone. This scenario is consistent with the applicable characteristics of the Yucca Mountain region (LaPlante and Poor, 1997).

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[5]The Unsaturated Zone Flow and Transport module is referenced frequently throughout this report. The abbreviation UZFT will be used to refer to this module.

[6]The Airborne Transport of Radionuclides module is referenced frequently throughout this report. The abbreviation ASHPLUMO will be used to refer to this module.

[7]The Radionuclide Density Adjustment module is referenced frequently throughout this report. The abbreviation ASHRMOVO will be used to refer to this module.

[8]The Dose Conversion Analysis for Ground Surface module is referenced frequently throughout this report. The abbreviation DCAGS will be used to reference this module.

[9]Benke, R., B. Hill, D. Hooper, and R. Nes. "Draft Description of Abstracted Models for Tephra Redistribution and Resuspension in the TPA Version 5.1 Beta Code." San Antonio, Texas: CNWRA. Unpublished Report (2006).

The following sections provide descriptions of the conceptual and mathematical models used for biosphere pathway and dose calculations in the TPA Version 5.1 Beta code. To enhance the description of the calculations, a general overview of the approach is provided prior to describing the models in greater detail. The overview addresses the computation of dose at the system level, while the remaining sections on pathway and receptor models and dosimetry provide details of the process models.

2.2.1 Overview of Dose Conversion Calculations in the TPA Version 5.1 Beta Code

Dose conversion calculations in the TPA Version 5.1 Beta code are executed by the DCAGW and DCAGS modules. These modules execute biosphere calculations based on different source inputs (i.e., contaminated groundwater or contaminated ground surface); however, in the current version of the code, the calculations share many similarities and, therefore, are discussed together in the following sections of this chapter. Unique differences between calculations in DCAGW and DCAGS modeling components are mentioned where applicable.

As previously mentioned, the primary dose calculation approach in these modeling components multiplies time-dependent ground surface or groundwater radionuclide concentrations (provided by other modules within the TPA Version 5.1 Beta code) by pathway-specific biosphere dose conversion factors (i.e., calculated annual all-pathway individual dose per unit radionuclide concentration) to calculate all-pathway receptor doses. The pathway-specific biosphere dose conversion factors are the product of (i) calculated pathway-specific radionuclide human intakes (for internal exposures) or (ii) exposure time-weighted ground surface concentrations (for external exposures) and the appropriate dosimetry coefficients. Input selections provide the flexibility to select which dose coefficients are used (Section 2.2.3). The overall dose calculation is represented by the following set of equations applicable to a groundwater release and transport scenario. For transparency, units are presented as they exist in the code and data sources.

The annual inhalation dose for radionuclide *i* at timestep *t* is calculated as follows:

$$D_{inh,i}(t) = C_{gw,i}(t) \cdot E_{inh,i} \cdot I_i \cdot U_{conv} \tag{2-1}$$

where

$D_{inh,i}(t)$ — Time-dependent annual inhalation dose for the i^{th} radionuclide [rem/yr]

$C_{gw,i}(t)$ — Time-dependent activity of the i^{th} radionuclide per volume of pumped groundwater [Ci/m^3]

$E_{inh,i}$ — Total activity of the i^{th} radionuclide per unit groundwater concentration inhaled annually by the receptor; computed by the GENTPA model [mCi/yr per mCi/L in groundwater]

I_i — Inhalation does coefficient for the i^{th} radionuclide per unit intake [Sv/Bq] provided in the auxiliary data file, *gnewdf.dat*

U_{conv} — Unit conversions

The annual animal product ingestion dose for radionuclide *i* at timestep *t* is calculated as follows:

$$D_{ing,ani,i}(t) = C_{gw,i}(t) \cdot E_{ing,ani,i} \cdot G_i \cdot U_{conv} \tag{2-2}$$

where

$D_{ing,ani,i}(t)$ — Time-dependent annual animal product ingestion dose for the i^{th} radionuclide [rem/yr]

$C_{gw,i}(t)$ — Time-dependent activity of the i^{th} radionuclide per volume of pumped groundwater [Ci/m^3]

$E_{ing,ani,i}$ — Total activity of the i^{th} radionuclide per unit groundwater concentration ingested annually by the receptor for the animal product intake pathway [mCi/yr per mCi/L]; computed by the GENTPA model

G_i — Ingestion dose coefficient for the i^{th} radionuclide per unit intake [Sv/Bq] provided in the auxiliary data file, *gnewdf.dat*

U_{conv} — Unit conversions

The annual plant product ingestion dose for radionuclide *i* at timestep *t* is calculated as follows:

$$D_{ing,plt,i}(t) = C_{gw,i}(t) \cdot E_{ing,plt,i} \cdot G_i \cdot U_{conv} \tag{2-3}$$

where

$D_{ing,plt,i}(t)$ — Time-dependent annual plant product ingestion dose for the i^{th} radionuclide [rem/yr]

$C_{gw,i}(t)$ — Time-dependent activity of the i^{th} radionuclide per volume of pumped groundwater [Ci/m^3]

$E_{ing,plt,i}$ — Total activity of the i^{th} radionuclide per unit groundwater concentration ingested annually by the receptor for the plant product intake pathway [mCi/yr per mCi/L]; computed by the GENTPA model

G_i — Ingestion dose coefficient for the i^{th} radionuclide [Sv/Bq ingested] provided in the auxiliary date file, *gnewdf.dat*

U_{conv} — Unit conversions

The annual drinking water ingestion dose for radionuclide *i* at timestep *t* is calculated as follows:

$$D_{ing,dw,i}(t) = C_{gw,i}(t) \cdot E_{ing,dw,i} \cdot G_i \cdot U_{conv} \tag{2-4}$$

where

$D_{ing,dw,i}(t)$ — Time-dependent annual drinking water ingestion dose for the i^{th} radionuclide [rem/yr]

$C_{gw,i}(t)$ — Time-Dependent activity of the i^{th} radionuclide per volume of pumped groundwater [Ci/m^3]

$E_{ing,dw,i}$ — Total activity of the i^{th} radionuclide per unit groundwater concentration ingested annually by the receptor for the drinking water intake pathway [mCi/yr per mCi/L]; computed by the GENTPA model

G_i — Ingestion dose coefficient for the i^{th} radionuclide [Sv/Bq ingested] provided in the auxiliary data file; *gnewdf.dat*

U_{conv} — Unit conversions

The annual milk ingestion dose for radionuclide *i* at timestep *t* is calculated as follows:

$$D_{ing,mlk,i}(t) = C_{gw,i}(t) \cdot E_{ing,mlk,i} \cdot G_i \cdot U_{conv} \tag{2-5}$$

where

$D_{ing,mlk,i}(t)$ — Time-dependent annual milk ingestion dose for the i^{th} radionuclide [rem/yr]

$C_{gw,i}(t)$ — Time-dependent activity of the i^{th} radionuclide per volume of pumped groundwater [Ci/m^3]

$E_{ing,mlk,i}$ — Total activity of the i^{th} radionuclide per unit groundwater concentration ingested annually by the receptor for the milk intake pathway [mCi/yr per mCi/L]; computed by the GENTPA model

G_i — Ingestion dose coefficient for the i^{th} radionuclide [Sv/Bq ingested] provided in the auxiliary data file, *gnewdt.dat*

U_{conv} — Unit conversions

The annual external dose for radionuclide *i* at timestep *t* is calculated as follows:

$$D_{ext,i}(t) = C_{gw,i}(t) \cdot E_{ext,i} \cdot X_i \cdot U_{conv} \tag{2-6}$$

where

$D_{ext,i}(t)$ — Time-dependent annual external dose for the i^{th} radionuclide [rem/yr]

$C_{gw,i}(t)$ — Time-dependent activity of the i^{th} radionuclide per volume of pumped groundwater [Ci/m^3]

$E_{ext,i}$ — External exposure time-weighted ground surface concentration for radionuclide *i* at the receptor location [mCi–yr/m^2 per mCi/L]; computed by the GENTPA model

X_i — External dose coefficient per unit time-integrated exposure for the i^{th} radionuclide [Sv–m^2/Bq–yr] provided in the auxiliary data file, *ggrdf.dat*

U_{conv} — Unit conversions

The all-pathway annual dose is then calculated as the sum of the dose contributions from all radionuclides and exposure pathways.

$$D_{tot}(t) = D_{inh,i\,i}(t) + D_{ing,ani,i}(t) + D_{ing,plt,i}(t) + D_{ing,dw,i}(t) + D_{ing,mlk,i}(t) + D_{ext,i}(t) \tag{2-7}$$

Similar calculations are performed for the ground surface release scenario in the DCAGS module except the groundwater concentration term [$C_{gw,i}(t)$] is replaced by the ground surface concentration, the intake terms [E] are per unit soil concentration, and the inhalation pathway modeling is not computed by GENTPA Version 1.0 code.

The calculation of the human intake and ground surface concentration terms in Eqs. 2-1 through 2-6 involves execution of biosphere pathway models in the GENTPA Version 1.0 code. This code, and the models therein, are discussed in the following section.

2.2.2 Biosphere Pathway Models

Modeling fate and transport of radionuclides in the biosphere involves executing a series of models that partition contaminants from initial concentrations in water and ground surface (soil) to various human exposure pathways in the environment. The GENII Version 1.485 software (Napier, et al., 1988) includes pathway models that are generally consistent with the features and processes included in an exposure scenario applicable to the region surrounding Yucca Mountain. To address the biosphere pathway modeling needs of the TPA Version 5.1 Beta code, the pathway models in GENII Version 1.485 were recompiled to execute in the TPA Version 5.1 Beta code operating environment, and the resulting software was named GENTPA Version 1.0 code. GENTPA is based on and developed from the GENII Version 1.485 environmental pathway models. Detailed descriptions of models and algorithms can be found in the GENII Version 1.485 user manual (Napier, et al., 1988). The dosimetry modeling capabilities from GENII Version 1.485 are not used in GENTPA because more flexible dosimetry capabilities were developed for the TPA Version 5.1 Beta code (section 2.2.2). The following sections describe the pathway models used in GENTPA to compute the aforementioned human intakes for internal dose calculations and exposure-time-weighted surface concentrations for external dose calculations.

The exposure pathways modeled in the TPA Version 5.1 Beta code by GENTPA (including example inputs) are depicted in Figure 2-2. When groundwater is the source of contaminants entering the biosphere, the potential exposure pathways are assumed to be those resulting from pumping and agricultural use of water consistent with present farming practices in the rural communities south of Yucca Mountain. These pathways include ingestion (contaminated drinking water, crops, animal products, and soil), inhalation of resuspended soil, and direct exposure to deposited radioactive materials. When deposition of airborne contaminants to ground surface from an estimated igneous disruptive event release is the source of contaminants, the modeled exposure pathways are those shown in Figure 2-2 that result from soil concentration (i.e., no well water pathways). As previously mentioned, these pathways also

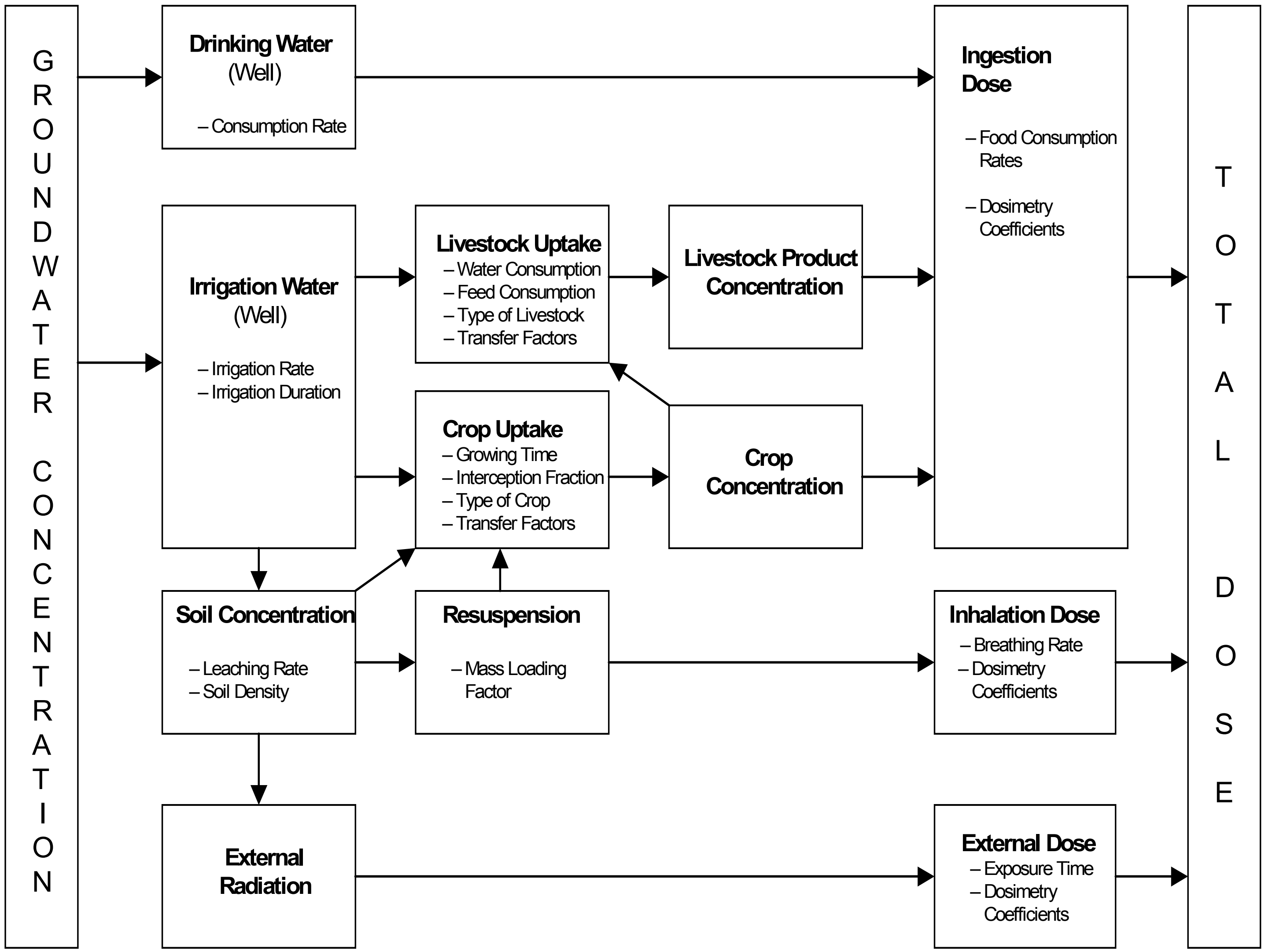

Figure 2-2. Biosphere Pathways in the GENTPA Version 1.0 Code

include ingestion (crops, animal products, soil) and direct exposure to deposited radioactive materials. Regional practices considered in the exposure scenarios include agricultural activities that produce food products for local consumption. Relevant food products include alfalfa (for beef and milk livestock feed), leafy and other vegetables, fruits, and grains for both human and livestock consumption; milk; beef; poultry; and eggs. Additional details of regional practices and characteristics have been previously documented by LaPlante and Poor (1997). Key features and processes included in the GENTPA Version 1.0 code models include radionuclide deposition to ground surface from irrigation; calculation of crop, feed, and livestock concentrations; and modeling of air concentrations from resuspended contamination. These process models are described in greater detail in the following paragraphs.

Ground surface concentration calculations are dependent on the release scenario (i.e., groundwater or direct release from an igneous disruptive event). Radionuclide deposition to ground surface from irrigation is calculated in GENTPA Version 1.0 code from the annual irrigation rate and radionuclide concentration in groundwater. The irrigation rates are relevant to local conditions in the Amargosa Farms area of Nye County. Annual losses of contaminants from ground surface due to leaching and decay are considered when irrigation with contaminated groundwater is modeled. The leaching model involves applying a negative first order rate constant (i.e., the leaching factor) to the annual contaminant deposition to account for loss of contaminants to deeper soil layers away from plant roots (Napier, et al., 1988). The leaching factor is calculated by the TPA Version 5.1 Beta code based on a model described by Baes and Sharp (1981) using inputs provided in *tpa.inp* file. Inputs involve infiltrating water balance (i.e., rainfall and irrigation minus evapotranspiration) and element-dependent sorption capabilities (i.e., K_d) of the soil. The soil model is capable of modeling two soil strata (upper and lower) of specified thicknesses, with the fraction of roots in the upper layer specified as input (Napier, et al., 1988). Because crops have widely varying root depths, all roots for all crops are assumed to be in the upper contaminated layer of soil for TPA Version 5.1 Beta calculations. For the igneous release scenario, the annual ground surface concentration is passed from the ASHRMOVO module when the ash remobilization modeling option is turned off. GENTPA Version 1.0 code pathway calculations for a ground surface source (i.e., DCAGS module) do not include irrigation-based leaching of radionuclides from soil; however, this process is included in the calculation of ground surface radionuclide concentrations by the ASHRMOVO module.

Crop concentrations are computed based on processes such as direct deposition from irrigation water (groundwater scenario only), deposition of resuspended dust, and uptake of soil contaminants through roots. Deposition to crop surfaces from irrigation water is based on the annual irrigation rate, irrigation duration, and crop interception fraction inputs (i.e., LeafyVegetableIrrigationRateCB[in/yr], LeafyVegetableIrrigationTimeCB[mo/yr], and InterceptionFraction/Irrigate). Because the contaminant irrigation deposition model divides the annual amount of irrigation water by the specified irrigation duration period to compute an instantaneous deposition rate that is then applied to the growing period for specific crops, there is an inverse relationship between irrigation duration and crop contaminant deposition. Soil-to-plant transfer factors are selected from published values (International Atomic Energy Agency, 1994; Baes, et al., 1982) for crops applicable to local growing conditions (Mills, 1993). These factors are used to model root uptake to plants. Variation is propagated to sets of transfer factors for all radionuclides by sampling a single scale factor each realization (i.e., a single iteration of a stochastic calculation) of the TPA Version 5.1 Beta code. The PlantUptakeScaleFactor distribution is based on uncertainty factors provided for applicable crops in the source documentation (International Union of Radioecologists, 1989).

Radionuclide concentrations in livestock-based food products are calculated by quantifying the intake of contaminated feed and applying an animal transfer coefficient. The animal transfer coefficients are based on studies that measure radionuclide concentrations in livestock based on known intakes. These coefficients are provided in source data by element and livestock type. Values used in TPA Version 5.1 Beta are based on published values (Baes, et al., 1982; International Atomic Energy Agency, 1994). The animal transfer factors for all radionuclides are varied by sampling a single scale factor in a manner similar to the plant transfer factors. The AnimalUptakeScaleFactor distribution is based on the reported uncertainty information in the source documents (International Atomic Energy Agency, 1994; International Union of Radioecologists, 1989).

Air concentrations from resuspended contamination (irrigation deposition only) are calculated by applying a mass loading model. The model uses a constant mass loading factor representing the average mass of dust in the air at the receptor location. The concentration of contaminants in the airborne dust is assumed equal to the ground surface concentration in this model. Resuspension of contaminated dust is a highly variable and uncertain process that is influenced by a variety of factors including local wind speed, surface roughness, dust particle size and density, and moisture content of the soil (Eckart and Chen, 1993). A representative generic mass loading factor is used for resuspension of irrigation deposition (rather than a more refined or a sampled value) because the inhalation pathway is not a major contributor to the all-pathway groundwater release dose (NRC, 2005). For crop deposition of resuspended airborne contaminants, a resuspension factor derived from the generic mass loading factor used for resuspension of irrigation deposition is used (LaPlante and Poor, 1997). The mass loading models and applicable input parameters applied for ground surface inhalation dose calculations in DCAGS and ASHREMOB modeling components have been further analyzed and refined because of the importance of the inhalation pathway for the igneous disruptive event dose calculations (NRC, 2005). These models and inputs have been previously documented.[10] Additional details regarding the execution; input parameters and data files; and output from the DCAGW module, the DCAGS module, and GENTPA Version 1.0 code are included in Section 2.3.

2.2.3 Dosimetry Models

For the purpose of radiation protection, dosimetry calculations estimate annual human doses from radioactivity that is inhaled, ingested, or deposited on the ground surface. The modular construction of the GENII Version 1.485 software that is the basis for GENTPA Version 1.0 code allows implementation of more current dosimetry options in the TPA Version 5.1 Beta code than included in the original software.

The options in the TPA Version 5.1 Beta code include dosimetry methods recommended by the International Commission on Radiological Protection commonly used by both U.S. and international regulatory agencies for radiation protection. For decades, the International Commission on Radiological Protection has periodically updated and documented dosimetry models based on available scientific information and data (International Commission on Radiological Protection, 1996, 1979, 1977). Therefore, a variety of dosimetry models, data, and the resulting published sets of dose coefficients are available. Thus, differences in the dose

[10] Ibid.

coefficient selections provided in the TPA Version 5.1 Beta code reflect the state of the science when the recommendations were made. This section provides summary information pertaining to the dose coefficients that have been selected for use in the TPA Version 5.1 Beta dose calculations. Readers are referred to the source documents for additional detailed information and technical bases.

2.2.3.1 Internal Dosimetry Models

Calculation of internal human doses (i.e., doses from sources inside the body) in the TPA Version 5.1 Beta code is accomplished through the use of dose coefficients that convert the estimated unit human intakes of radioactivity in water, food, air, and soil (Ci/yr) to annual dose equivalents or effective doses. Separate, user selectable sets of dose coefficients are provided for inhaled and ingested radionuclides in the TPA Version 5.1 Beta code data file *gnewdf.dat.*

The dose coefficients used in the TPA Version 5.1 Beta code are derived from published results of internal dosimetry modeling. This modeling involves a biokinetic model that evaluates the partitioning of ingested or inhaled radioactive elements within the body (i.e., blood, organs, bone, and digestive tract) supported by available biokinetic data, and a dosimetric model that calculates dose to specific tissues. These primary components of dosimetry modeling (biokinetic model, biokinetic data, dosimetric model) have evolved over time and differentiate available methods that can be applied to convert human intakes of radioactive material to dose.

The dosimetry modeling that forms the basis for the default adult dose coefficients in the TPA Version 5.1 Beta code are described in International Commission on Radiological Protection Publication 72 (International Commission on Radiological Protection, 1996). This set of dose coefficients represents the most recent update of dosimetry recommendations by the International Commission on Radiological Protection. An alternate set of dose coefficients based on the models and data described in International Commission on Radiological Protection Publications 26 and 30 (International Commission on Radiological Protection, 1979, 1977) is also available for use in TPA Version 5.1 Beta dose calculations. These coefficients are published in Federal Guidance Report No. 11 (EPA, 1998).

Compared to dose coefficients in Federal Guidance Report No. 11 (EPA, 1988), Publication 72 (International Commission on Radiological Protection, 1996) inhalation dose coefficients for 31 elements are based on updated lung absorption data, a new human respiratory tract model, and a new biokinetic model to generate coefficient values for the three primary absorption categories (i.e., Fast, Moderate, Slow). Elements Np, Tc, I, Am, and Pu are included in this category. Inhalation dose coefficients for the remaining 60 elements are calculated by the International Commission on Radiological Protection by using the updated human respiratory tract model and older (International Commission on Radiological Protection Publication 30 based) biokinetic information regarding lung absorption and clearance (International Commission on Radiological Protection, 1996). For ingestion dose coefficients, the International Commission on Radiological Protection Publication 72 values for 31 elements are based on updated biokinetic information regarding fractional absorption into the gastrointestinal tract and no changes from Publication 30 for the remaining 60 elements (International Commission on Radiological Protection, 1996).

The ReceptorAge&Dosimetry flag in the *tpa.inp* file controls the age of the receptor and the selection of dosimetry coefficients tabulated in the *gnewdf.dat* file. Adult dosimetry is used based on the applicable regulations for Yucca Mountain in 10 CFR 63.312(e); however, the

TPA Version 5.1 Beta code is capable of executing calculations for other age groups (i.e., infant, toddler, preteen, teen, adult) provided the user changes the ReceptorAge&Dosimetry flag and supplies values for all applicable age-dependent biosphere input parameters (e.g., breathing rates, food consumption rates) in *tpa.inp*. The dose coefficients in *gnewdf.dat* for pre-adult age groups are selected from International Commission on Radiological Protection Publication 72 (International Commission on Radiological Protection, 1996).

Selection of inhalation dose coefficients from International Commission on Radiological Protection Publication 72 (International Commission on Radiological Protection, 1996) for inclusion in the *gnewdf.dat* file is based on consideration of options regarding airborne particle size distribution and the rate of absorption from the respiratory tract to body fluids. Selected coefficients are based on a lognormal particle size distribution (International Commission on Radiological Protection, 1995) with a particle activity mean aerodynamic diameter of 10 μm [0.0004 in] (International Commission on Radiological Protection, 2002). The 10 μm [0.0004 in] assumption is generally consistent with available measurements of resuspended volcanic ash particle sizes (Hill and Connor, 2000). Regarding the rate of absorption from the respiratory tract to body fluids, which is influenced by the expected chemical form of the inhaled material, International Commission on Radiological Protection Publication 72 provides coefficients by radionuclide for absorption classes including Very Fast, Fast, Moderate, and Slow. For key radionuclides (Am-241, Pu-239, Np-237, I-129, Tc-99) (NRC, 2005), values for inhalation dose coefficients were selected based on the assumed igneous scenario chemical form (i.e., oxidized)—a refinement based on the importance of the inhalation pathway in prior performance assessment calculations (NRC, 2005). The remaining inhalation dose coefficients were selected based on International Commission on Radiological Protection recommendations for absorption type (i.e., default recommendations for cases where no supporting chemical form data exist) (International Commission on Radiological Protection, 1996). For elements where no recommendations have been made (Cl, Y, Pd, Sn, Sm, Bi, Ac, and Pa), maximum values are used.

Selection of ingestion dose coefficients from International Commission on Radiological Protection Publication 72 for inclusion in the *gnewdf.dat* file is more straightforward. These coefficients are calculated using a single fractional absorption value (denoted f_1 in source documentation) for the gastrointestinal tract (International Commission on Radiological Protection, 1996). Thus, there are no options provided for selecting ingestion dose coefficients based on the chemical form of material.

Selection of dose coefficients for the *gnewdf.dat* file from Federal Guidance Report No. 11 (EPA, 1988), where options are provided (based on chemical form of inhaled or ingested material), are based on the maximum absorption classes. This is anticipated to be a conservative selection (i.e., no higher values available from the source document). This set of dose coefficients is commonly used in NRC regulatory programs and may also be useful for testing or evaluation purposes. The TPA Version 5.1 Beta code has the flexibility to read any values entered into the data file if calculations with alternative coefficients or updates are needed in the future.

2.2.3.2 External Dosimetry Models

Calculation of human dose from external exposure to photons and electrons emitted by radionuclides on a contaminated ground surface is based on dosimetry coefficients provided in Federal Guidance Report No. 12 (EPA, 1993). That report is intended to be a companion report to Federal Guidance Report No. 11 (EPA, 1988), which provides inhalation and ingestion dose coefficients. No analogous companion report was provided for the dose coefficients in International Commission on Radiological Protection Publication 72 (International Commission on Radiological Protection, 1996); therefore, Federal Guidance Report No. 12 is provided as the only option for external dosimetry modeling in the TPA Version 5.1 Beta code.

Because external doses arise from radioactive decay of isotopes outside of the body, the types of radiation of concern for external dose (i.e., photons and electrons) are those able to penetrate skin and tissues sufficiently to deposit ionizing radiation to radiosensitive organs and tissues(EPA, 1993). An idealized model that includes uniform infinite radionuclide ground surface concentration and simplified geometries is used for estimating dose to tissues. Because the external dose is dependent on time, the coefficients represent dose per unit time-integrated concentration on the ground surface (in Sv-m^2/Bq-yr).

2.3 Implementation of Dose Conversion Calculations in the TPA Version 5.1 Beta Code

The DCAGW and DCAGS modules process the appropriate inputs for all calculations, write input and data files for GENTPA Version 1.0 code calculations, run multiple executions of GENTPA Version 1.0 code per TPA Version 5.1 Beta code realization, convert the resulting intakes and surface concentrations to dose conversion factors, and then calculate dose by applying applicable dose coefficients and media concentrations. The multiple executions of GENTPA Version 1.0 code per TPA Version 5.1 Beta code realization are necessary to compute a series of human intakes and external exposure time-weighted ground surface concentrations for two separate climate states (current and pluvial), two receptor locations (compliance location and nearer to site), and two initial source media concentrations (groundwater and ground surface). The following sections provide additional execution details that can help users execute the code and understand and evaluate input and output.

2.3.1 Implementation Approach

GENTPA Version 1.0 code is a deterministic biosphere pathway code with input, output, and execution capabilities that allow modular incorporation into the TPA Version 5.1 Beta code. During code development, the generally large input parameter and data requirements necessitated preselection of a subset of influential input parameters for sampling or user modification. The remainder of input parameters and data are included as constants in supporting data files. These files can be modified using a text editor if these constants need to be changed or updated. Additional details of these input parameters and data are provided in the following sections. This section provides an overview of the biosphere pathway and dose calculation implementation approach in the TPA Version 5.1 Beta code.

As previously mentioned, GENTPA Version 1.0 code is based on the pathway models in the GENII Version 1.485 software (Napier, et al, 1988). GENII Version 1.485 consists of three executable programs that address specific functions that are necessary to complete the biosphere calculations. The ENVIN program handles the reading of the input files, the ENV program runs the environmental pathway and exposure models (i.e., human intake of radionuclide by pathway), and the DOSE program implements dosimetry computations. GENTPA Version 1.0 code consists of ENVIN and ENV programs that were recompiled to run in the operating systems used for the TPA Version 5.1 Beta code. The functions of DOSE are not used because similar computations are handled by the TPA Version 5.1 Beta code using the dose coefficients described in Section 2.2.3.

Details of the TPA Version 5.1 Beta code pathway dose calculation approach are provided in Figure 2-3. To execute GENTPA Version 1.0 code, the TPA Version 5.1 Beta code reads the appropriate input parameter values from the *tpa.inp* input file and writes these values to the applicable input or data files necessary for GENTPA Version 1.0 code execution. Because only a subset of input parameters used by GENTPA Version 1.0 code are written from *tpa.inp* to the GENTPA Version 1.0 code input files and other inputs are provided in fixed data files, additional input processing steps are necessary to generate a complete set of input files prior to execution. This is addressed by initially labeling GENTPA Version 1.0 code input and data files that accept inputs from *tpa.inp* with a unique *.def extension. These files contain a full set of default input values and upon execution, the TPA Version 5.1 Beta code overwrites parameter information for the subset of parameters included as input in *tpa.inp*. The overwritten **.def* file is then renamed with a **.inp* extension, which is used as an input file by GENTPA upon execution. Any values included in the GENTPA Version 1.0 code input files (**.def* or **.dat*) that are not listed in *tpa.inp* are effectively default constant values that are not changed during TPA Version 5.1 Beta code execution. Such inputs can only be changed by manually editing the file with a text editor prior to execution of the TPA Version 5.1 Beta code. Most of the input parameters for GENTPA Version 1.0 code are included in the text file *ggenii.def* (*ggeniis.def* for DCAGS); however, additional inputs of interest are included in *gdefault.def* (*gdefauls.def* for DCAGS) and the data file *gftrans.def* (*gftranss.def* for DCAGS runs). Details of all the files used for an execution of GENTPA Version 1.0 code are provided in Section 2.3.2.

Because there are multiple GENTPA Version 1.0 code executions for each TPA Version 5.1 Beta realization (i.e., source of contamination, climate state, receptor type/location), the append flag in *tpa.inp* (which provides selected input and output for each execution in **.cum* files) must be selected to generate all the input and output for each GENTPA Version 1.0 code execution in a single or multiple realization TPA Version 5.1 Beta code run. Therefore, users should be aware that, depending on the TPA Version 5.1 Beta input selections used, the **.inp* files may represent only the last set of input to GENTPA that was executed in a series of runs.

Some input parameters for GENTPA Version 1.0 code are calculated from input or modified by input provided in *tpa.inp*. Soil leaching factors, for example, are computed based on a series of input parameters (i.e., rainfall, evapotranspiration, soil density, K_d) provided in *tpa.inp* and a leaching factor equation provided in the GENII 1.485 user manual (Baes, et al., 1981; Napier, et al., 1988). The resulting leaching factors are written to *gftrans.inp* GENTPA Version 1.0 code input file prior to execution of GENTPA. In another example, plant and animal transfer factor values included input data files *gftrans.def* and *gftranss.def* are read from the initial **.def* input files by TPA Version 5.1 Beta and weighted by the applicable sampled value of the PlantUptakeScaleFactor or AnimalUptakeScaleFactor input parameters from *tpa.inp*. The result is then written to the **.inp* data files (e.g, *gftrans.inp, gftranss.inp*). This scaling approach allows variation to be propagated to transfer factors that are input as fixed constants in the auxiliary data file.

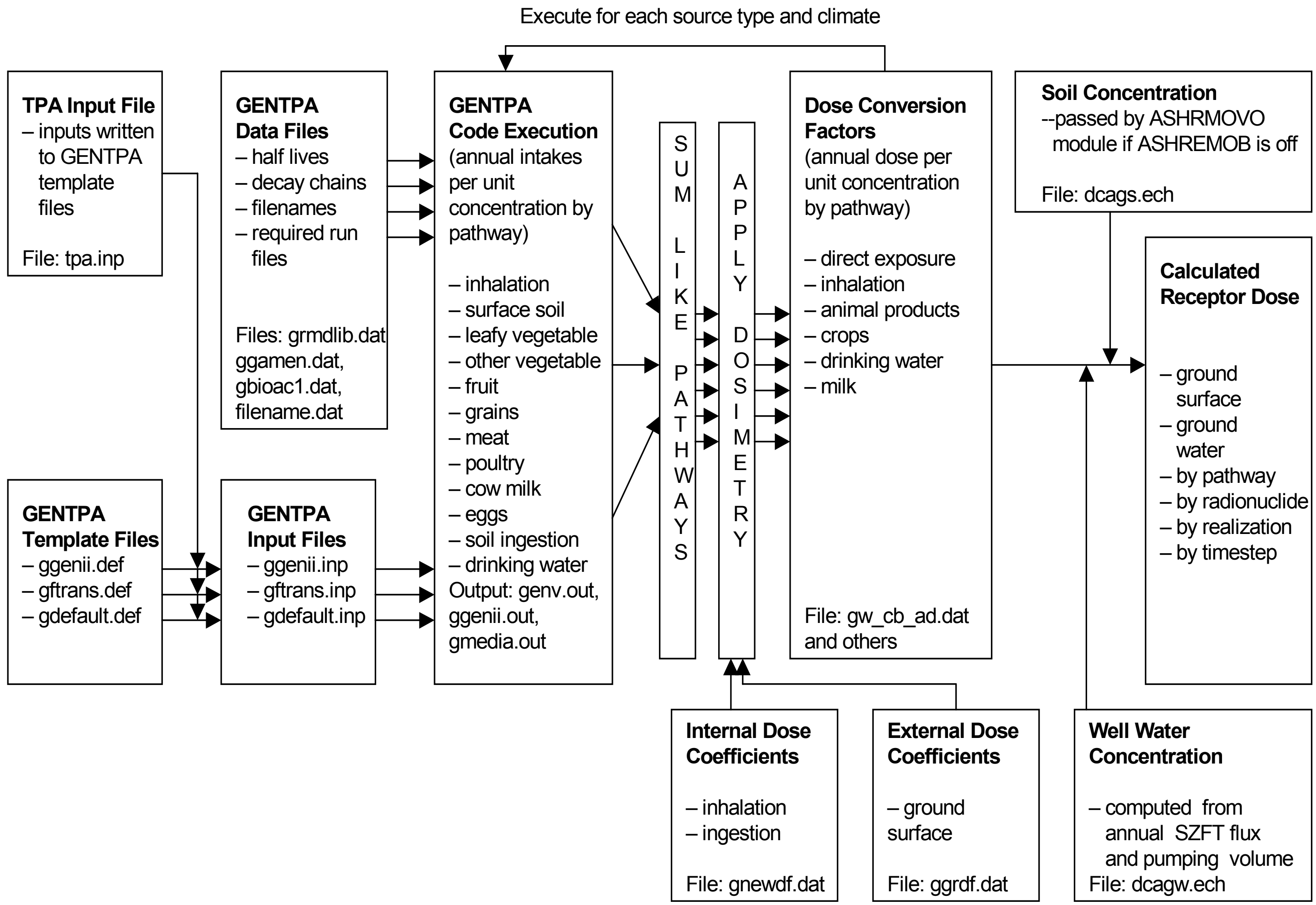

Figure 2-3. Implementation of Pathway and Dose Calculations in the TPA Version 5.1 Beta Code

Following execution of GENTPA Version 1.0 code, a series of intermediate output files are produced. The *genv.out* file is the primary output from GENTPA used by the TPA Version 5.1 Beta code. This file contains a list of the aforementioned pathway and radionuclide specific human intakes (in Ci/yr) per unit media concentration (i.e., groundwater, ground surface) for internal dose calculations and the exposure time weighted ground surface concentrations per unit concentration for external dose calculations. The *ggenii.out* file (*ggeniis.out* for DCAGS) provides a formatted and labeled input echo of the input parameters and supporting data files used for a single execution of GENTPA Version 1.0 code. This file can be useful for verifying the inputs used in any GENTPA run.

The TPA Version 5.1 Beta code multiplies the values in *genv.out* by the appropriate dose coefficients in *gnewdf.dat* to generate pathway and radionuclide specific unit (biosphere) dose conversion factors (e.g., rem/yr per Ci/m^3 in groundwater) provided in a series of intermediate output files for specific combinations of source, climate, and receptor (i.e., *gw_cb_ad.dat*, *gw_pb_ad.dat*, *gw_cb_ci.dat*, *gw_pb_ci.dat*, *gs_cb_ad.dat*, *gs_pb_ad.dat*, *gs_cb_ci.dat*, and *gs_pb_ci.dat*). These files can be used for verifying computations and other code testing. Once the dose conversion factor files are generated, the TPA Version 5.1 Beta code multiples them by ground surface or groundwater concentrations to compute the all-pathway doses reported in the total-system code output files (see Section 2.3.3). The following sections provide specific details of the input and output files included in the above implementation summary.

2.3.2 Input Parameters and Data

Input parameters and data required for GENTPA Version 1.0 code execution are described in this section. To enhance organization, these input parameters are grouped by primary inputs, secondary inputs (e.g., additional constants), and supporting data files.

2.3.2.1 Primary Input Parameters

A subset of input parameters for DCAGW, DCAGS, and GENTPA Version 1.0 code execution are included in the *tpa.inp* input file in sections labeled for these modules. Described here as primary input parameters for documentation purposes, these input parameters are a subset of the total number of input parameters used in the biosphere pathway computations. Some are sampled from distributions, and others are specified as constants. This subset of parameters was selected to include inputs either found to be important in initial stochastic biosphere calculations based on prior sensitivity analyses (LaPlante and Poor, 1997) of Yucca Mountain specific GENII-S runs (Leigh, et al., 1993) or inputs that required a user input capability (i.e., option to sample or modify). Because of the number of inputs, parameters are classified here according to the following categories: input flags/general, irrigation, soil leaching model, food transfer, animal feed, and receptor behavioral parameters (age-dependent). Additional details on these input parameters are provided in the Appendix.

Input flags and general inputs control important aspects of the biosphere calculations. These inputs are shown in Table 2-1. The ReceptorGroup flag controls the type of receptor and extent of biosphere pathways modeled. The farming community flag is the default selection for consistency with regulations in 10 CFR 63.305 and §63.312. The residential receptor group includes more limited pathways associated with residential living (i.e., drinking water and exposure to ground

Table 2-1. Input Flags for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code	
Input Parameter	**Description**
ReceptorGroup(1=Farming,2=Residential)	Flag for selection of receptor group. Impacts exposure pathways modeled.
DistanceToReceptorGroup[km]	Distance [km] of receptor group location from repository release location.
PluvialSwitchTime[yr]	Number of years from start of calculation when climate state switches from current climate to pluvial conditions.
Age&Dosimetry(1=Inf,2=Todl,3=PTeen, 4=Teen,5=Adlt,6=AdltFG11)	Flag for selection of receptor age group and dosimetry coefficients. Selections 1–5 dosimetry coefficients are from the International Commission on Radiological Protection (1996). Selection 6 dosimetry coefficients are from Federal Guidance Report No. 11 (EPA, 1988). Any changes to this flag requires changes to other related age-dependant input parameters (e.g., consumption rates).

surface from lawn/garden watering). The DistanceToReceptorGroup[km] input influences the location where the well water concentration is computed and is set to 18 km [11 mi] for consistency with 10 CFR 63.312(a). The Age&Dosimetry flag selects the age of the receptor and the dosimetry coefficients used in dose calculations (Section 2.2.3).

Options for dosimetry include International Commission on Radiological Protection Publication 72 (International Commission on Radiological Protection, 1996) and Federal Guidance Report No. 11 (EPA, 1988) (i.e., consistent with International Commission on Radiological Protection Publication 30). Age groups are categorized Infant, Toddler, Preteen, Teen, and Adult. Because International Commission on Radiological Protection Publication 72 contains age-dependent dosimetry coefficients, when pre-adult age groups are selected, this dosimetry approach is used. The numerical identifier for each age group is associated with related age-dependent receptor behavioral input parameters that are similarly labeled. The default selection for Age&Dosimetry is the International Commission on Radiological Protection Publication 72 dosimetry and adult age of receptor [for consistency with 10 CFR 63.312(e)]. As previously mentioned, any user executing age-dependent computations is required to specify, input, and justify the applicable age-dependent receptor behavioral input parameters.

A variety of irrigation input parameters are included in *tpa.inp*. Table 2-2 provides a list of these inputs. Irrigation is the initial mechanism that transfers contaminants from well water to terrestrial media. The YearsOfIrrigationPriorToIntakePeriod[yr] input parameter controls the number of years the GENTPA Version 1.0 code computes the ground surface concentration from the annual irrigation rate prior to the year the pathway calculations are executed. Conceptually, the model allows for prior farming and irrigation to buildup or leach (depending on element and soil conditions) contaminants in soil for the number of years specified prior to the calculation of the annual dose from all pathways. A period of 15 years is chosen as the default

Table 2-2. Primary Irrigation Parameters for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code	
Input Parameter	**Description**
InterceptionFraction/Irrigate	Fraction of contaminants in irrigation water intercepted and retained by crop canopy. Value is written to GENTPA Version 1.0 code input file *gdefault.inp*.
YearsOfIrrigationPriorToIntakePeriod[yr]	Years of annual irrigation of soil with contaminated water prior to the year pathway calculations are executed in GENTPA Version 1.0 code. Used to adjust soil concentrations for leaching, decay, or buildup prior to computing receptor intakes and dose.
LeafyVegetableIrrigationRatePB [in/yr]	Annual irrigation rate for leafy vegetables during the pluvial climate period.
OtherVegetableIrrigationRatePB[in/yr]	Annual irrigation rate for other vegetables during the pluvial climate period.
FruitIrrigationRatePB[in/yr]	Annual irrigation rate for fruit during the pluvial climate period.
GrainIrrigationRatePB[in/yr]	Annual irrigation rate for grain during the pluvial climate period.
HomeIrrigationRatePB[in/yr]	Annual residential irrigation rate (e.g., lawn watering) during the pluvial climate period.
PoultryFeedIrrigationRatePB[in/yr]	Annual irrigation rate for poultry feed during the pluvial climate period.
HenFeedIrrigationRatePB[in/yr]	Annual irrigation rate for hen feed during the pluvial climate period.
LeafyVegetableIrrigationTimePB[mo/yr]	Annual irrigation duration for leafy vegetables during the pluvial climate period.
OtherVegetableIrrigationTimePB[mo/yr]	Annual irrigation duration for other vegetables during the pluvial climate period.
FruitIrrigationTimePB[mo/yr]	Annual irrigation duration for fruit during the pluvial climate period.
GrainIrrigationTimePB[mo/yr]	Annual irrigation duration for grain during the pluvial climate period.
HomeIrrigationTimePB[mo/yr]	Annual residential irrigation duration during the pluvial climate period.

Table 2-2. Primary Irrigation Parameters for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)	
Input Parameter	**Description**
PoultryFeedIrrigationTimePB[mo/yr]	Annual irrigation duration for poultry feed during the pluvial climate period.
HenFeedIrrigationTimePB[mo/yr]	Annual irrigation duration for hen feed during the pluvial climate period.
LeafyVegetableIrrigationRateCB [in/yr]	Annual irrigation rate for leafy vegetables during current climate period.
OtherVegetableIrrigationRateCB[in/yr]	Annual irrigation rate for other vegetables during the current climate period.
FruitIrrigationRateCB[in/yr]	Annual irrigation rate for fruit during the current climate period.
GrainIrrigationRateCB[in/yr]	Annual irrigation rate for grain during the current climate period.
HomeIrrigationRateCB[in/yr]	Annual residential irrigation rate (e.g., lawn watering) during the current climate period.
PoultryFeedIrrigationRateCB[in/yr]	Annual irrigation rate for poultry feed during the current climate period.
HenFeedIrrigationRateCB[in/yr]	Annual irrigation rate for hen feed during the current climate period.
LeafyVegetableIrrigationTimeCB[mo/yr]	Annual irrigation duration for leafy vegetables during the current climate period.
OtherVegetableIrrigationTimeCB[mo/yr]	Annual irrigation duration for other vegetables during the current climate period.
FruitIrrigationTimeCB[mo/yr]	Annual irrigation duration for fruit during the current climate period.
GrainIrrigationTimeCB[mo/yr]	Annual irrigation duration for grain during the current climate period.
HomeIrrigationTimeCB[mo/yr]	Annual residential irrigation duration during the current climate period.
PoultryFeedIrrigationTimeCB[mo/yr]	Annual irrigation duration for poultry feed during the current climate period.
HenFeedIrrigationTimeCB[mo/yr]	Annual irrigation duration for hen feed during the current climate period.

Table 2-2. Primary Irrigation Parameters for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)	
Input Parameter	**Description**
BeefFreshForageIrrigationRatePB[in/yr]	Annual irrigation rate for beef cattle fresh forage crops (e.g., alfalfa) during the pluvial climate period.
MilkFreshForageIrrigationRatePB[in/yr]	Annual irrigation rate for milk cow fresh forage crops (e.g., alfalfa) during the pluvial climate period.
BeefFreshForageIrrigationTimePB[mo/yr]	Annual irrigation duration for beef cattle fresh forage crops (e.g., alfalfa) during the pluvial climate period.
MilkFreshForageIrrigationTimePB[mo/yr]	Annual irrigation duration for milk cow fresh forage crops (e.g., alfalfa) during the pluvial climate period.
BeefFreshForageIrrigationRateCB[in/yr]	Annual irrigation rate for beef cattle fresh forage crops (e.g., alfalfa) during the current climate period.
MilkFreshForageIrrigationRateCB[in/yr]	Annual irrigation rate for milk cow fresh forage crops (e.g., alfalfa) during the current climate period.
BeefFreshForageIrrigationTimeCB[mo/yr]	Annual irrigation duration for beef cattle fresh forage crops (e.g., alfalfa) during the current climate period.
MilkFreshForageIrrigationTimeCB[mo/yr]	Annual irrigation duration for milk cow fresh forage crops (e.g., alfalfa) during the current climate period.

based on the transient nature of farming in the Yucca Mountain region. Because various plants have different water requirements, a number of individual crop-specific irrigation rates and durations are included in *tpa.inp* (one set for each type of crop modeled by GENTPA Version 1.0 code). Sets of irrigation rates and durations are provided for current climate and a cooler and wetter future climate state (i.e., pluvial period). Crop types include leafy vegetables, other vegetables, fruit, and grain. Additional crops for animal feed include alfalfa for beef cattle and milk cows and grain for poultry birds and egg hens. Irrigation parameters are included in the input file for DCAGS related calculations; however, the information is not used in the ground surface source-based GENTPA calculations. All inputs listed in Table 2-2 are written to GENTPA Version 1.0 code input file *ggenii.inp*, except InterceptionFraction/Irrigate, which is written to *gdefault.inp*.

The soil leaching model in GENTPA Version 1.0 code requires a first order leaching rate constant as the key input parameter. The leaching rate is computed by TPA Version 5.1 Beta using the input parameters in *tpa.inp* that are listed in Table 2-3. Because the soil leaching applies to soils at the receptor location, the parameter values used in the leaching calculation

Table 2-3. Soil Leaching Input Parameters for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code	
Input Parameter	**Description**
DepthOfSurfaceSoil[cm]	Depth of surface layer of soil used for crop farming.
AnnualPrecipitation[m/yr]	Annual precipitation rate at the receptor location.
AnnualIrrigation[m/yr]	Annual irrigation rate at the receptor location.
SoilBulkDensity[g/cm^3]	Bulk density of surface layer of soil used for crop farming.
SoilVolumetricWaterContent[ml/cm^3]	Volume of water per volume of soil for surface layer of soil used for crop farming.
TotalAnnualEvapotranspiration[m/yr]	Annual volume of water evaporated from a square meter of surface soil.
KD_Soil_Cm[cm^3/g] KD_Soil_Pu[cm^3/g] KD_Soil_U[cm^3/g] KD_Soil_Am[cm^3/g] KD_Soil_Np[cm^3/g] KD_Soil_Th[cm^3/g] KD_Soil_Ra[cm^3/g] KD_Soil_Pb[cm^3/g] KD_Soil_Cs[cm^3/g] KD_Soil_I[cm^3/g] KD_Soil_Tc[cm^3/g] KD_Soil_Ni[cm^3/g] KD_Soil_Cl[cm^3/g] KD_Soil_C[cm^3/g] KD_Soil_Se[cm^3/g] KD_Soil_Nb[cm^3/g]	Distribution coefficients (i.e., solid to liquid partition coefficients) by radionuclide for farming soils.

are selected to be representative of that location. Some of the parameters such as rainfall and evapotranspiration can differ from similar TPA Version 5.1 Beta input parameters that are representative of conditions at Yucca Mountain. All inputs listed in Table 2-3 are used to calculate leaching factors that are written to the GENTPA Version 1.0 code data file *gftrans.inp*.

Two input parameters directly related to the food transfer model are included in *tpa.inp*. These inputs are shown in Table 2-4. The PlantUptakeScaleFactor and AnimalUptakeScaleFactor are inputs that provide the capability to propagate variability and uncertainty to the mean plant and animal uptake factors provided in the data files *gftrans.def* and *gftranss.def*. This general approach to sampling transfer factors as a group is implemented to preserve code efficiency due to the large number of individual transfer factors included in the data files. For each TPA Version 5.1 Beta code realization, an individual scale factor is sampled from the distribution and is then multiplied by the values in gftrans.def (or *gftranss.def*), and the result is saved to the *gftrans.inp* file (or *gftranss.inp*) prior to GENTPA Version 1.0 code execution.

Table 2-4. Plant and Animal Uptake Input Parameters for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code

Input Parameter	Description
PlantUptakeScaleFactor	Scale factor used for weighting mean plant transfer factors in *gftrans.def* and *gftranss.def* files prior to writing values to *gftrans.inp* and *gftranss.inp* for use in GENTPA Version 1.0 code. When sampled from a distribution the scale factor provides a means to propagate variation in this constant input data.
AnimalUptakeScaleFactor	Scale factor used for weighting mean animal transfer factors in *gftrans.def* and *gftranss.def* files prior to writing values to *gftrans.inp* and *gftranss.inp* for use in GENTPA Version 1.0 code. When sampled from a distribution the scale factor provides a means to propagate variation in this constant input data.

Inputs related to growing animal feed for livestock are also included in *tpa.inp*. Table 2-5 provides a list of animal feed and livestock inputs. Growing times for feed are used to compute the amount of irrigation intercepted by edible portions of these crops. Forage diet fractions for both beef cattle and milk cows represent the proportion of the animals diet that is consumed as fresh forage. Inputs listed in Table 2-5 are written to GENTPA Version 1.0 code input files *ggenii.inp* and *ggeniis.inp* prior to GENTPA Version 1.0 code execution.

Table 2-5. Livestock and Feed Input Parameters for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code

Input Parameter	Description
PoultryFeedGrowTime[day]	Duration of growing period for poultry livestock feed (e.g., grain).
HenFeedGrowTime[day]	Duration of growing period for egg-laying hen feed (e.g., grain).
BeefFreshForageDietFraction	Fraction of beef cattle diet that is fresh forage.
MilkFreshForageDietFraction	Fraction of milk cow diet that is fresh forage.
BeefFreshForageGrowTime[day]	Duration of growing period for beef cattle fresh forage crop (alfalfa).
MilkFreshForageGrowTime[day]	Duration of growing period for milk cow fresh forage crop (alfalfa).

Receptor characteristics parameters in *tpa.inp* (see Table 2-6) include consumption rates for the various food products (water, leafy vegetables, other vegetables, fruit, grain, beef, milk, egg) as well as inadvertent soil ingestion. Other inputs included in this group are the inhalation rate and exposure times for contaminated ground surface and resuspended contaminants. Values for these parameters are affected by receptor age; however, only adult inputs are provided based on the requirements of 10 CFR 63.312 specifying adult dosimetry. Parameters are numbered by age group, consistent with the aforementioned Age&Dosimetry flag. As previously mentioned, if the receptor age is changed, the user must provide age-dependent values for these input parameters. Inputs listed in Table 2-6 are written to GENTPA Version 1.0 code input files *ggenii.inp* and *ggeniis.inp*.

Table 2-6. Receptor Characteristics Input Parameters for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code

Input Parameter	Description
DrinkingWaterConsumptionRate5[L/yr]	Annual drinking water consumption rate for receptor Age&Dosimetry flag selection 5.
LeafyVegetableConsumptionRate5[kg/yr]	Annual leafy vegetable consumption rate for receptor Age&Dosimetry flag selection 5.
OtherVegetableConsumptionRate5[kg/yr]	Annual other vegetable consumption rate for receptor Age&Dosimetry flag selection 5.
FruitConsumptionRate5[kg/yr]	Annual fruit consumption rate for receptor Age&Dosimetry flag selection 5.
GrainConsumptionRate5[kg/yr]	Annual grain consumption rate for receptor Age&Dosimetry flag selection 5.
BeefConsumptionRate5[kg/yr]	Annual beef consumption rate for receptor Age&Dosimetry flag selection 5.
PoultryConsumptionRate5[kg/yr]	Annual poultry consumption rate for receptor Age&Dosimetry flag selection 5.
MilkConsumptionRate5[kg/yr]	Annual milk consumption rate for receptor Age&Dosimetry flag selection 5.
EggConsumptionRate5[kg/yr]	Annual egg consumption rate for receptor Age&Dosimetry flag selection 5.
InhalationExposureTime5[hr]	Annual effective exposure time for DCAGW* inhalation dose calculation. Accounts for both indoor and outdoor exposures.
InhalationRate5[cm^3/s]	Breathing rate for receptor Age&Dosimetry flag selection 5.
SoilContaminationExposureTime5[hr]	Annual time receptor spends outdoors exposed to contaminated ground surface for receptor Age&Dosimetry flag selection 5.
*Dose Conversion Analysis for Groundwater	

2.3.2.2 Secondary Input Parameters in GENTPA Version 1.0 Code Files

The input parameters not included in *tpa.inp* that are treated as constants are included in input data files *ggenii.def*, *ggeniis.def*, *gdefault.def*, and *gdefauls.def*. Because these inputs in the **.def* files are not overwritten by any values from *tpa.inp*, the values will be copied directly to **.inp* files without modification prior to GENTPA Version 1.0 code execution. While users are not expected to change these inputs, these parameters can be updated or modified by editing the **.def* files manually prior to executing the code. Any such modifications to the approved inputs should be executed with care to ensure any modified files are not mixed with original TPA Version 5.1 Beta code files compromising the verified data set. Tables 2-7 and 2-8 provide lists of the key secondary inputs and the files that contain them. Some parameter entries in Table 2-7 apply to groups of inputs (e.g., by crop type) to limit repetition. All inputs listed in Table 2-7 are included in GENTPA Version 1.0 code input files *ggenii.def* and *ggeniis.def*. Inputs listed in Table 2-8 are included in files *gdefault.def* and *gdefauls.def*.

Table 2-7. Secondary Constant Input Parameters in the GENTPA Version 1.0 Code Input Files *ggenii.def* and *ggeniis.def*

Input Parameter	Description
Fraction of Roots in Upper Soil	Fraction of roots in the surface layer of soil (i.e., the layer used for atmospheric and irrigation deposition and root uptake).
Fraction of Roots in Deep Soil	Fraction of roots in deep soil layer (e.g., this soil layer only becomes contaminated by buried waste in the model and is not applicable to the TPA Version 5.1 Beta exposure scenarios).
Mass Loading Factor [g/m^3]	Mass of resuspended ground surface dust per volume of air applicable to average annual receptor exposure conditions.
Growing Times [d] (by crop)	Duration of growing period for various crops (see consumption rates in Table 2-6) and livestock feed including beef cattle and milk cow fresh forage and stored feed for poultry and egg laying hens.
Crop Yields [kg/m^2] (by crop)	Mass (wet weight) of biomass per surface area by crop type for various food and livestock feed crops.
Holdup Times [d] (by food type)	Number of days a harvested crop or livestock product is delayed (e.g., processing, storage) prior to human consumption.

Table 2-7. Secondary Constant Input Parameters in the GENTPA Version 1.0 Code Input Files *ggenii.def* and *ggeniis.def* (continued)	
Input Parameter	**Description**
Livestock Drinking Water Contaminated Fraction (by food type)	Fraction of livestock drinking water consumption from contaminated source (see growing times).
Livestock Dietary Fractions (by food type and feed type)	Fraction of livestock diet that is either stored feed or fresh forage by food type (see growing times).
Livestock Feed Storage Times [d] (by food type)	Number of days a harvested feed product is stored prior to use.

Table 2-8. Secondary Constant Input Parameters in the GENTPA Version 1.0 Code Input Files *gdefault.def* and *gdefauls.def*	
Input Parameter	**Description**
Deposition Velocity for Resuspension [m/s]	Rate resuspended dust deposits to crop surface.
Leaf Resuspension Factor [m^{-1}]	Resuspension factor for ground surface dust resuspension and deposition to crop surface.
Biomass [kg/m^2] (by crop)	Mass (wet weight) of standing biomass per area for crops.
Depth of Surface Soil [cm]	Depth of surface layer of soil used for crop farming.
Surface Soil Density [kg/m^3]	Bulk density of surface layer of soil used for crop farming.
Harvest Removal Flag	Flag for whether soil model accounts for annual removal of contaminants from soil equal to the amount transferred to harvested crops.
Soil Ingestion Rate [mg/day]	Daily consumption rate for inadvertent soil ingestion.
Crop Deposition Weathering Time [day]	Removal constant for deposited contamination on plant surfaces to be removed by weathering.

Table 2-8. Secondary Constant Input Parameters in the GENTPA Version 1.0 Code Input Files *gdefault.def* and *gdefauls.def* (continued)	
Input Parameter	**Description**
Plant Translocation Factor (by crop)	Fraction of contaminants on external surface of plant that transfer to into edible portions.
Livestock Feed Translocation Factor (by feed type)	Fraction of contaminants on external surface of feed crops that transfer to into edible portions.
Livestock Feed Consumption Rates [kg/day] (by feed type)	Mass (wet weight) of feed consumed by livestock per day. Values for beef cattle stored feed, poultry fowl stored feed, milk cow stored feed, egg hen stored feed, beef cattle fresh forage, milk cow fresh forage.
Livestock Drinking Water Consumption Rate [L/day] (by livestock)	Livestock water consumption rates for beef cattle, poultry fowl, milk cow, and egg laying hen.
Plant Dry to Wet Ratio	Ratio of plant dry weight to wet weight. Used to convert wet weight based input parameter to dry weight for use in pathway calculations (e.g., transfer factors are based on dry weight).

2.3.2.3 GENTPA Version 1.0 Code Supporting Data Files

A number of data files support the execution of GENTPA Version 1.0 code in the TPA Version 5.1 Beta code. Table 2-9 provides a list of the applicable files and description of the type of data or information included in each.

Table 2-9. GENTPA Version 1.0 Code Supporting Data Files	
Filename	**Description of Data**
gftrans.def, gftranss.def	Element-specific soil to plant and feed to animal uptake factors (International Atomic Energy Agency, 1994); and soil leaching factors (computed by the TPA Version 5.1 Beta code during execution from inputs in *tpa.inp*).
gnewdf.dat	Age-dependent dose coefficients for ingestion and inhalation from Publication 72 (International Commission on Radiological Protection, 2002; 1996) and adult dose coefficients from Federal Guidance Report No. 11 (EPA, 1988).

Table 2-9. GENTPA Version 1.0 Code Supporting Data Files (continued)	
Filename	**Description of Data**
ggrdf.dat	External dose coefficients (only ground surface coefficients are used) from Federal Guidance Report No. 12 (EPA, 1993).
grmblib.dat	GENTPA radionuclide library including half lives and decay chain information. This is the default data file from GENII Version 1.485 (Napier, et al., 1988) with no modification except as noted in the file header.
ggamen.dat	Gamma energies for plume calculations (data is not used in calculations, but file is required for code execution).
gbioac1.dat	Bioaccumulation data (data not used in calculations, but file is required for code execution).

2.3.3 Output

The DCAGW and DCAGS modules compute all pathway radionuclide doses for the groundwater release and the igneous eruption scenarios at every simulation timestep. Output files vary depending on the TPA Version 5.1 Beta code run options selected. For example, GENTPA Version 1.0 code-related output files will not be produced for igneous disruptive event dose calculations if AshEvolutionMode is set to 1, which runs ASHREMOB rather than DCAGS (Figure 2-1). The output tables below include primary TPA Version 5.1 Beta code output as well as intermediate output files. Intermediate output may be useful for checking results and evaluation or testing specific segments of the computations.

Primary output from DCAGW includes *totdose.res* and *totdose_c.res*, which include time histories of all-pathway, all-radionuclide dose by realization and water pumping volumes used for groundwater well concentration calculations. Comparable output from DCAGS includes the *airpkdos.res* and *arpkds_c.res* files that provide all-pathway direct release total peak dose, peak dose time, and peak radionuclide doses at the time of peak dose by realization.
When the append option is selected in the *tpa.inp* file (Select Append Files flag set to all), additional intermediate outputs are created. Because doses are calculated by radionclide, timestep, realization, and exposure pathway and there are numerous intermediate steps in the dose calculations, various compilations of output are provided. For example, the annual radionuclide-specific saturated zone fluxes and areal radionuclide activity concentrations on the ground surface for all times are provided in *the dcagw.ech and dcags.ech* files, respectively. The time history of doses for all radionuclides are available in the *dcagw.rlt and dcags.rlt* files.

Tables 2-10 and 2-11 present the output files applicable to pathway and dose calculations in DCAGW and DCAGS, respectively.

Table 2-10. Description of Output File Contents for DCAGW* Module	
Output File	**Contents**
totdose.res	Time history of all-pathway, all radionuclide dose by realization including the dilution volume used to calculate well water concentration by realization.
totdose_c.res	Time history of all-pathway, all radionuclide dose by realization for the compliance period including the dilution volume used to calculate well water concentration by realization.
rgwna.tpa	Time history of groundwater all-pathway dose by radionuclide, averaged among all realizations.
rgwnapani.tpa	Time history of groundwater livestock food product (e.g., beef, poultry, egg) pathway dose by radionuclide, averaged among all realizations.
rgwnapdw.tpa	Time history of groundwater drinking water dose by radionuclide, averaged among all realizations.
rgwnapext.tpa	Time history of groundwater external pathway dose by radionuclide, averaged among all realizations.
rgwnapinh.tpa	Time history of groundwater inhalation dose by radionuclide, averaged among all realizations.
rgwnapmlk.tpa	Time history of groundwater milk pathway dose by radionuclide, averaged among all realizations.
rgwnappla.tpa	Time history of groundwater crop ingestion pathway dose by radionuclide, averaged among all realizations.
rgwnr.tpa	Time history of groundwater dose by radionuclide for all realizations.
rgwsa.tpa	Time history of groundwater dose summed for all radionuclides and averaged among all realizations.
rgwsr.tpa	Time history of groundwater dose for all realizations summed by radionuclide.
rgwgssa.tpa	Time history of groundwater and direct release dose summed for all radionuclides and averaged for all realizations.
ggenii.out *ggenii.cum*	GENTPA run output showing input echo for last execution including data files read and input parameters read from *ggenii.inp* file (**.cum* file is compilation of this output for all realizations).
gmedia.out	Intermediate output from GENTPA with media specific concentrations in the biosphere.
genv.out *genv.cum*	Radionuclide-specific human intakes and exposure time weighted soil concentrations calculated by GENTPA pathway modeling for a single execution or all executions.

Table 2-10. Description of Output File Contents for DCAGW* Module (continued)	
Output File	**Contents**
dcagw.ech	Input to DCAGW * including annual saturated zone groundwater flux by radionuclide and timestep.
dcagw.rlt	Time series of all-pathway dose by radionuclide and realization.
gw_cb_ad.dat *gw_pb_ad.dat* *gw_cb_ci.dat* *gw_pb_ci.dat*	Intermediate output of annual dose to the receptor by exposure pathway and radionuclide per unit concentration in receptor well water (e.g., biosphere dose conversion factors). Separate files are produced by climate state and receptor type.
dcfgw.cum	Compilation of all groundwater biosphere dose conversion factor output files (e.g., *gw_cb_ad.dat*) for all realizations.
*Dose Conversion Analysis for Groundwater	

Table 2-11. Description of Output File Contents Related to the DCAGS* Module	
Output File	**Contents**
airpkdos.res	All-pathway direct release total peak dose, peak dose time, and peak radionuclide doses at the time of peak dose by realization.
arpkds_c.res	All-pathway direct release total peak dose, peak dose time, and peak radionuclide doses at the time of peak dose by realization for the compliance period.
rgsna.tpa	Time history of soil and ash all-pathway dose by radionuclide, averaged among all realizations.
rgsnr.tpa	Time history of soil and ash all-pathway dose by radionuclide for all realizations.
rgssa.tpa	Time history of soil and ash all-pathway dose summed for all radionuclides and averaged among all realizations.
rgssr.tpa	Time history of soil and ash all-pathway dose for all realizations summed by radionuclide.
ggeniis.out	GENTPA run output showing input echo for last execution including data files read and input parameters read from *ggenii.inp* file.
gmedia.out	Intermediate output from GENTPA with media specific concentrations in the biosphere.
genv.out, *genv.cum*	Radionuclide-specific human intakes and exposure time weighted soil concentrations calculated by GENTPA pathway modeling for a single execution or all executions.
dcags.ech	Input to DCAGS* including areal radionuclide activity concentrations on the ground surface by radionuclide and timestep.

Table 2-11. Description of Output File Contents Related to the DCAGS* Module (continued)	
Output File	**Contents**
dcags.rlt	Time series of ground surface all pathway dose by radionuclide and by realization.
gs_cb_ad.dat *gs_pb_ad.dat* *gs_cb_ci.dat* *gs_pb_ci.dat*	Intermediate output of annual dose to the receptor by exposure pathway and radionuclide per unit concentration in ground surface soil and ash at the receptor location (e.g., biosphere dose conversion factors). A separate file is produced by climate state and receptor type.
dcfgs.cum	Compilation of all ground surface biosphere dose conversion factor output files (e.g., *gs_cb_ad.dat*) for all realizations.
*Dose Conversion for Ground Surface	

2.3.4 Assumptions

The biosphere pathway and dose models as implemented in the TPA Version 5.1 Beta code include specific assumptions that users should be familiar with prior to running the code and interpreting results. The following section summarizes the key assumptions associated with the pathway and dose calculations in the TPA Version 5.1 Beta code. This list includes assumptions applicable to models and input parameter selections.

- Consumption of crops in GENTPA Version 1.0 code pathway calculations does not account for washing fruits and vegetables prior to consumption.

- Soil concentration calculations in GENTPA Version 1.0 code are based on annual irrigation rate and annual loss from leaching. These calculations are not influenced by the growing period or irrigation time input parameters.

- Input parameters associated with receptor behavioral characteristics are constants based on mean values, consistent with the requirements in 10 CFR 63.312(b). Food consumption rates for the receptor are based on a survey of Amargosa Valley residents (CRWMS M&O, 2000). The survey provides the best available information on local food consumption practices. The consumption rates are representative of average consumption practices of the population group that eats locally produced food.

- Fifteen years of prior irrigation are assumed to occur prior to computing the dose calculation. This is considered reasonable based on the transient nature of farming in the Yucca Mountain region. Sorption characteristics of the soil and radionuclides in the groundwater determine the degree to which buildup or washout occurs during the 15 years of prior irrigation.

- Leaching from soil represents a loss route for contaminants in the biosphere. Secondary pathways beyond the deep soil layer are not accounted for in the GENTPA Version 1.0 code pathway models.

- Modeling plant uptake using a general model involving groups of crops requires a method to be applied to derive representative plant transfer factors from available crop-specific information. For this modeling, representative crops were considered, and mean or expected values of the applicable plant uptake factors were chosen. Because the GENTPA Version 1.0 model applies the leafy vegetable plant transfer factor to fresh forage (beef, milk), a plant transfer factor that was representative for both hay and leafy vegetable crops was selected.

- The default dosimetry coefficients are based on Publication 72 (International Commission on Radiological Protection, 1996). For the ingestion intake pathway, no choices are offered in the source documents. Published International Commission on Radiological Protection values for inhalation are based on a 10 μm [0.0004 in] mean aerodynamic diameter (International Commission on Radiological Protection, 2002). For key radionuclides (Am-241, Pu-239, Np-237, I-129, Tc-99), values for dose coefficients were selected based on assumed igneous scenario chemical form conditions (i.e., oxidation). This was done to refine the selection due to the importance of the inhalation pathway in TPA Version 5.1 Beta dose calculations (NRC, 2005). The remainder of inhalation dose coefficients from Publication 72 are consistent with the default recommendations or maximum values where no recommendations were made. If the option to use Federal Guidance Report No. 11 (EPA, 1988) coefficients is selected using the Age&Dosimetry flag in *tpa.inp*, then maximum reported values are used for both ingestion and inhalation dose coefficients.

- For human dosimetry modeling, the receptor group is assumed to be an adult based on requirements in 10 CFR 63.312(e).

- Inhalation (DCAGW only) and external exposure times are based on information provided by LaPlante and Poor, (1997). For the farming community receptor group, 4,800 hr/yr is assumed to be spent inside the residence, 1,800 hr/yr outside of residence, and 40 hr/week offsite. A 50 percent indoor exposure factor (NRC, 1994) is applied to indoor exposure time (i.e., the dwelling structure reduces indoor inhalation exposure to 50 percent of outdoor exposure) to derive a single effective exposure time (4,200 hr/yr) to meet the input requirements of GENTPA Version 1.0 code.

- Resuspension of contaminated soil in GENTPA Version 1.0 code applies to crop deposition, inhalation (DCAGW only), and external dose modeling. A mass loading model is applicable to a homogeneously mixed layer of contamination in the soil; therefore, a reasonable mass loading factor from applicable literature is used (Kennedy and Strenge, 1992). For crop deposition, the GENTPA Version 1.0 code uses a resuspension model with the selected mass loading factor that was converted to a resuspension factor using an equation in the GENII Version 1.485 user manual (Napier, et al., 1988). The mass loading and resuspension models are abstractions of complex and varying processes.

- DCAGW and DCAGS use ground surface external dose coefficients directly from Federal Guidance Report No. 12 (EPA, 1993). The original GENII Version 1.485 code divides the dose coefficients read from the *grdf.dat* file by 0.15 m [0.49 ft] (the depth of the contaminated soil layer) for use with volume-based external dose coefficients (Napier, et al., 1988). The external dose coefficients in Federal Guidance Report No. 12

(EPA, 1993) used in the TPA Version 5.1 Beta code are area-based (i.e., ground surface). Therefore, the 0.15-m [0.49-ft] value was removed from the calculations as part of the GENTPA Version 1.0 code development. This was the only change made to GENII Version 1.485 algorithms for the development of GENTPA Version 1.0 code.

- Doses calculated by DCAGW and DCAGS modules are annual doses to an individual receptor, consistent with the requirements in 10 CFR 63.311.

3 SUMMARY

In preparation for a regulatory review of a potential U.S. Department of Energy license application and its associated performance assessment, the Nuclear Regulatory Commission (NRC) and Center for Nuclear Waste Regulatory Analyses (CNWRA) staff are developing the TPA Version 5.1 Beta code to provide the capability to independently evaluate risk-significant features, events, and processes. The specific set of computations involving fate and transport of radionuclides within the biosphere and estimation of dose are conducted by various TPA Version 5.1 Beta modules depending on user input selections. Modules that are the primary topic of this report include DCAGW and DCAGS.

Both DCAGW and DCAGS implement a flexible approach to executing various pathway and dose calculations applicable to requirements in 10 CFR Part 63 and characteristics of the Yucca Mountain region. This is accomplished by executing GENTPA Version 1.0 code, a separate pathway code based on the models and code in GENII Version 1.485 (Napier, et al., 1988), to compute receptor intakes and ground surface exposures per unit source concentration in the biosphere. Applying tabulated dosimetry coefficients from established compilations (International Commission on Radiological Protection, 2002, 2996; EPA, 1993, 1988) and computed media concentrations from other TPA Version 5.1 Beta modules completes the dose calculations.

The approach includes contributions to dose from a variety of environmental exposure pathways, including those resulting from pumping and agricultural use of water (or agricultural use of soil contaminated by deposition of airborne contaminants), consistent with present farming practices in the rural communities south of Yucca Mountain. Such pathways include ingestion (contaminated drinking water, crops, animal products, and soil), inhalation of resuspended soil, and direct exposure to deposited radioactive materials.

The abstraction described in this report results from years of iterative performance assessment work conducted by NRC and CNWRA staff. The approach has evolved incrementally over a number of years to address changes in applicable regulations, incorporate new technical information, and adapt to evolving risk insights and specific program needs. Following the previous documentation of the biosphere modeling capabilities in the code, specific enhancements have been made to expand and integrate GENTPA Version 1.0 code calculations, refine input parameters and data, expand output capabilities, and provide greater flexibility to select available dosimetry options.

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APPENDIX

REFERENCE DATA SET

REFERENCE DATA SHEET

This appendix provides information about the input parameters for the TPA Version 5.1 Beta code in a format that is consistent with the TPA Version 4.0 code user guide (Mohanty, et al., 2002, Appendix). The parameters listed in this reference data sheet are applicable primary inputs for the pathway and dose modeling applicable to groundwater and ground surface release scenarios for the potential repository at Yucca Mountain previously described in this report. These input parameters are consistent with the applicable inputs in the *tpa.inp* input file. The TPA Version 5.1 Beta code is being developed following Geosciences and Engineering Division Technical Operating Procedure (TOP)–018, Development and Control of Scientific and Engineering Software and is currently undergoing validation; therefore, parameters listed in this reference data sheet have not yet been validated and are subject to change.

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
DCAGW*	ReceptorGroup (1=Farming, 2=Residential)	Receptor Group (1 = Member of Farming Community, 2 = Residential)	constant	1	Farming community consistent with 10 CFR 63.312(b) requirements	N/A
DCAGW	DistanceToReceptor Group[km]**	Distance to receptor group [km]	constant	18	18 km consistent with 10 CFR 63.312(a) requirements	N/A
DCAGW	PluvialSwitchTime[yr]	Time to switch from nonpluvial (current) biosphere climate conditions to pluvial (cooler and wetter)	constant	2000	Available information and analyses on climate change is summarized in Forester (2000). This analysis suggests a transition to the Glacial Transition Climate after 2,000 years. This value is consistent with updated information that the TPA† code uses to calculate mean annual precipitation and temperature values for each timestep.	N/A
GENTPA	Age&Dosimetry (1=inf,2=todl, 3=pteen,4=teen, 5=Adlt,6=AdltFG11)	Flag to select dosimetry standard	constant	5	Allows selection of either the existing Federal Guidance Report No. 11 dosimetry approach (value=6) or the newer ICRP 72 approach (value=5) for all TPA dose calculations in DCAGW and DCAGS‡.	N/A
GENTPA	InterceptionFraction/ Irrigate	Irrigation interception fraction	triangular	0.06, 0.4, 0.8	Based on review of the literature summary by Anspaugh (1987). The lower bound is 0.06 and the upper bound was reduced from 1.0 in the reference to 0.8 to limit excessive conservatism. The mode of the distribution is the recommended value of 0.4.	*gdefault.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
GENTPA	DepthOfSurfaceSoil [cm]††	Depth of surface soil [cm]	constant	15	Default value from Napier, et al. (1988). Parameter represents plow depth that is used in the model to differentiate between two soil layers (surface and deep). The surface layer is contaminated and the deep layer is clean. TPA implementation assumes all roots are in surface soil layer.	*gdefault.in; gdefauls.inp*
GENTPA	YearsOfIrrigationPriorToIntakePeriod[yr]	Years of irrigation water deposition prior to the intake period [yr]	constant	15	Assumption based on transient nature of farming in Amargosa Valley (insights gained from visiting with local residents). DOE§ has concluded that the irrigation time significantly impacts soil buildup for elements such as Am, Cs, Ni, Pa, Pu, Ra, Sr, Th, and U (CRWMS M&O, 2000a), but not the key contributors to dose for the groundwater irrigation-based exposure scenario (i.e., Tc-99, I-129, Np-237). Thus uncertainty in the parameter is not expected to be significant for the basecase results. For the igneous scenario, there is no irrigation buildup of radionuclides and the radionuclides that dominate that scenario dose are not prone to leaching so any “washout” effect from irrigation would be small.	*ggenii.inp*

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
GENTPA	LeafyVegetable IrrigationRatePB [in/yr]‡‡	Leafy vegetable irrigation rate for pluvial biosphere [in/yr]	triangular	14.3, 19.5, 25.7	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods. The climate adjustment done by CNWRA‖, documented by LaPlante and Poor (1997) for pluvial biosphere dose conversion factors, is applied to the irrigation rate data from Bechtel SAIC Company, LLC, 2003. The CNWRA climate adjustment to the irrigation rate estimates is based on differences in irrigation rates for the Yucca Mountain region and a location in Idaho that exhibits temperature and rainfall characteristics similar to estimated future Yucca Mountain region climate change conditions (semi-arid).	*ggenii.inp*
GENTPA	OtherVegetable IrrigationRatePB [in/yr]	Other vegetable irrigation rate for pluvial biosphere [in/yr]	triangular	11.1, 24.1, 42.0	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
					established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods. The climate adjustment done by CNWRA, documented by LaPlante and Poor (1997) for pluvial biosphere dose conversion factors, is applied to the irrigation rate data from Bechtel SAIC Company, LLC (2003). The CNWRA climate adjustment to the irrigation rate estimates is based on differences in irrigation rates for the Yucca Mountain region and a location in Idaho that exhibits temperature and rainfall characteristics similar to estimated future Yucca Mountain region climate change conditions (semi-arid).	
GENTPA	FruitIrrigationRatePB [in/yr]	Fruit irrigation rate for pluvial biosphere [in/yr]	triangular	27.4, 39.4, 50.9	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods. The climate adjustment done by CNWRA, documented by LaPlante and Poor (1997) for pluvial biosphere	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
					dose conversion factors, is applied to the irrigation rate data from Bechtel SAIC Company, LLC (2003). The CNWRA climate adjustment to the irrigation rate estimates is based on differences in irrigation rates for the Yucca Mountain region and a location in Idaho that exhibits temperature and rainfall characteristics similar to estimated future Yucca Mountain region climate change conditions (semi-arid).	
GENTPA	GrainIrrigationRatePB[in/yr]	Grain irrigation rate for pluvial biosphere [in/yr]	triangular	15.9, 21.1, 26.3	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods. The climate adjustment done by CNWRA, documented by LaPlante and Poor (1997) for pluvial biosphere dose conversion factors, is applied to the irrigation rate data from Bechtel SAIC Company, LLC, 2003. The CNWRA climate adjustment to the irrigation rate estimates is based on differences in irrigation rates for the Yucca Mountain region	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					and a location in Idaho that exhibits temperature and rainfall characteristics similar to estimated future Yucca Mountain region climate change conditions (semi-arid).	
GENTPA	HomeIrrigationRatePB[in/yr]	Residential irrigation rate for pluvial biosphere [in/yr]	constant	45	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods. The climate adjustment done by CNWRA, documented by LaPlante and Poor (1997) for pluvial biosphere dose conversion factors, is applied to the irrigation rate data from Bechtel SAIC Company, LLC (2003). The CNWRA climate adjustment to the irrigation rate estimates is based on differences in irrigation rates for the Yucca Mountain region and a location in Idaho that exhibits temperature and rainfall characteristics similar to estimated future Yucca Mountain region climate change conditions (semi-arid).	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
GENTPA	PoultryFeedIrrigation RatePB[in/yr]	Poultry feed irrigation rate for pluvial biosphere [in/yr]	triangular	15.9, 21.1, 26.3	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods. The climate adjustment done by CNWRA, documented by LaPlante and Poor (1997) for pluvial biosphere dose conversion factors, is applied to the irrigation rate data from Bechtel SAIC Company, LLC (2003). The CNWRA climate adjustment to the irrigation rate estimates is based on differences in irrigation rates for the Yucca Mountain region and a location in Idaho that exhibits temperature and rainfall characteristics similar to estimated future Yucca Mountain region climate change conditions (semi-arid).	*ggenii.inp*
GENTPA	HenFeedIrrigation RatePB[in/yr]	Egg-laying hen feed irrigation rate for pluvial biosphere [in/yr]	triangular	15.9, 21.1, 26.3	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					that incorporate data on local climate, soil, crops, and irrigation methods. The climate adjustment done by CNWRA, documented by LaPlante and Poor (1997) for pluvial biosphere dose conversion factors, is applied to the irrigation rate data from Bechtel SAIC Company, LLC (2003). The CNWRA climate adjustment to the irrigation rate estimates is based on differences in irrigation rates for the Yucca Mountain region and a location in Idaho that exhibits temperature and rainfall characteristics similar to estimated future Yucca Mountain region climate change conditions (semi-arid).	
GENTPA	LeafyVegetable IrrigationTimePB [mo/yr]	Leafy vegetable irrigation time for pluvial biosphere [mo/yr]	uniform	3.0, 7.0	Crops that are grown in Amargosa Valley were selected from a list produced by the local agricultural extension office (Mills, 1993). The list also contained information on the duration of the growing season for various crops. Selected crop growing times were then obtained from a gardening book (Chambers and Mays, 1994), and the irrigation duration was calculated based on the number of plantings per year that was possible given the estimated pluvial temperature profile in LaPlante and Poor (1997).	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
GENTPA	OtherVegetable IrrigationTimePB [mo/yr]	Other vegetable irrigation time for pluvial biosphere [mo/yr]	uniform	2.0, 7.0	Crops that are grown in Amargosa Valley were selected from a list produced by the local agricultural extension office (Mills, 1993). The list also contained information on the duration of the growing season for various crops. Selected crop growing times were then obtained from a gardening book (Chambers and Mays, 1994), and the irrigation duration was calculated based on the number of plantings per year that was possible given the estimated pluvial temperature profile in LaPlante and Poor (1997).	*ggenii.inp*
GENTPA	FruitIrrigationTimePB [mo/yr]	Fruit irrigation rate for pluvial biosphere [in/yr]	uniform	2.0, 6.0	Crops that are grown in Amargosa Valley were selected from a list produced by the local agricultural extension office (Mills, 1993). The list also contained information on the duration of the growing season for various crops. Selected crop growing times were then obtained from a gardening book (Chambers and Mays, 1994), and the irrigation duration was calculated based on the number of plantings per year that was possible given the estimated pluvial temperature profile in LaPlante and Poor (1997).	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
GENTPA	GrainIrrigationTime PB[mo/yr]	Grain irrigation time for pluvial biosphere [mo/yr]	uniform	3.0, 7.0	Crops that are grown in Amargosa Valley were selected from a list produced by the local agricultural extension office (Mills, 1993). The list also contained information on the duration of the growing season for various crops. Selected grain crop growing times were obtained English and Nakamura (1989), and the irrigation duration was calculated based on the number of plantings per year that was possible given the estimated pluvial temperature profile in LaPlante and Poor (1997) and a 1-month drying period prior to harvest.	*ggenii.inp*
GENTPA	HomeIrrigationTime PB[mo/yr]	Residential irrigation time for pluvial biosphere [mo/yr]	uniform	6.0, 12.0	Based on the assumption that the receptor cares for a lawn a minimum of 6 months (i.e., during the cooler months of the year) and a maximum for the entire year. This assumption was informed by a pamphlet provided by a local agricultural extension office (Mills, 1993) as discussed by LaPlante and Poor (1997).	*ggenii.inp*
GENTPA	PoultryFeedIrrigation TimePB[mo/yr]	Poultry feed irrigation time for pluvial biosphere [mo/yr]	uniform	3.0, 7.0	Same as for GrainIrrigationTimePB	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
GENTPA	HenFeedIrrigation TimePB[mo/yr]	Egg-laying hen feed irrigation time for pluvial biosphere [mo/yr]	uniform	3.0, 7.0	Same as for GrainIrrigationTimePB	*ggenii.inp*
GENTPA	LeafyVegetable IrrigationRateCB [in/yr]	Leafy vegetable irrigation rate for current biosphere [in/yr]	triangular	20.1, 27.4, 36.2	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods.	*ggenii.inp*
GENTPA	OtherVegetable IrrigationRateCB [in/yr]	Other vegetable irrigation rate for current biosphere [in/yr]	triangular	15.7, 34.0, 59.1	Irrigation rate data are tabulated in table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods.	*ggenii.inp*
GENTPA	FruitIrrigationRateCB [in/yr]	Fruit irrigation rate for current biosphere [in/yr]	triangular	38.6, 55.5, 71.7	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					climate, soil, crops, and irrigation methods.	
GENTPA	GrainIrrigationRate CB[in/yr]	Grain irrigation rate for current biosphere [in/yr]	triangular	22.4, 29.7, 37.0	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods.	*ggenii.inp*
GENTPA	HomeIrrigationRate CB[in/yr]	Residential irrigation rate for current biosphere [in/yr]	constant	63.4	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods.	*ggenii.inp*
GENTPA	PoultryFeedIrrigation RateCB[in/yr]	Poultry feed irrigation rate for current biosphere [in/yr]	triangular	22.4, 29.7, 37.0	Same as for GrainIrrigationRateCB[in/yr]	*ggenii.inp*
GENTPA	HenFeedIrrigation RateCB[in/yr]	Egg-laying hen feed irrigation rate for current biosphere [in/yr]	triangular	22.4, 29.7, 37.0	Same as for GrainIrrigationRateCB[in/yr]	*ggenii.inp*

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
GENTPA	LeafyVegetable IrrigationTimeCB [mo/yr]	Leafy vegetable irrigation time for current biosphere [mo/yr]	uniform	3.0, 8.0	Crops that are grown in Amargosa Valley were selected from a list produced by the local agricultural extension office (Mills, 1993). The list also contained information on the duration of the growing season for various crops. Selected crop growing times were then obtained from a gardening book (Chambers and Mays, 1994), and the irrigation duration was calculated based on the number of plantings per year that was possible per season.	*ggenii.inp*
GENTPA	OtherVegetable IrrigationTimeCB [mo/yr]	Other vegetable irrigation time for current biosphere [mo/yr]	uniform	2.0, 8.0	Crops that are grown in Amargosa Valley were selected from a list produced by the local agricultural extension office (Mills, 1993). The list also contained information on the duration of the growing season for various crops. Selected crop growing times were then obtained from a gardening book (Chambers and Mays, 1994), and the irrigation duration was calculated based on the number of plantings per year that was possible per season.	*ggenii.inp*
GENTPA	FruitIrrigationTimeCB [mo/yr]	Fruit irrigation time for current biosphere [mo/yr]	uniform	2.0, 3.0	Crops that are grown in Amargosa Valley were selected from a list produced by the local agricultural extension office (Mills, 1993). The list also	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					contained information on the duration of the growing season for various crops. Selected crop growing times were then obtained from a gardening book (Chambers and Mays, 1994), and the irrigation duration was calculated based on the number of plantings per year that was possible per season.	
GENTPA	GrainIrrigationTime CB[mo/yr]	Grain irrigation time for current biosphere [mo/yr]	uniform	6.0, 8.0	Crops that are grown in Amargosa Valley were selected from a list produced by the local agricultural extension office (Mills, 1993). The list also contained information on the duration of the growing season for various crops. Selected grain crop growing times were obtained English and Nakamura (1989), and the irrigation duration was calculated based on the number of plantings per year that was possible given the estimated pluvial temperature profile in LaPlante and Poor (1997) and a 1-month drying period prior to harvest.	*ggenii.inp*
GENTPA	HomeIrrigationTime CB[mo/yr]	Residential irrigation time for current biosphere [mo/yr]	uniform	6.0, 12.0	Based on the assumption that the receptor cares for a lawn a minimum of 6 months (i.e., during the cooler months of the year) and a maximum for the entire year. This assumption was informed by a pamphlet	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					provided by a local agricultural extension office (Mills, 1993) as discussed by LaPlante and Poor (1997).	
GENTPA	PoultryFeedIrrigation TimeCB[mo/yr]	Poultry feed irrigation time for current biosphere [mo/yr]	uniform	6.0, 8.0	Same as for GrainIrrigationTimeCB[mo/yr]	*ggenii.inp*
GENTPA	HenFeedIrrigation TimeCB[mo/yr]	Egg-laying hen feed irrigation time for current biosphere [mo/yr]	uniform	6.0, 8.0	Same as for GrainIrrigationTimeCB[mo/yr]	*ggenii.inp*
GENTPA	PoultryFeedGrow Time[day]	Poultry feed growing time [day]	uniform	60.0, 90.0	Value for wheat from English and Nakamura (1989)	*ggenii.inp; ggeniis.inp*
GENTPA	HenFeedGrowTime [day]	Egg-laying hen feed growing time [day]	uniform	60.0, 90.0	Value for wheat from English and Nakamura (1989)	*ggenii.inp; ggeniis.inp*
GENTPA	BeefFreshForageDie tFraction	Beef cattle fresh forage diet fraction	normal	0.12, 0.98	Values are from a Nevada test site pathways study by Breshears, et al. (1992) and are relevant to southern Nevada livestock husbandry.	*ggenii.inp; ggeniis.inp*
GENTPA	MilkFreshForageDiet Fraction	Dairy cattle fresh forage diet fraction	normal	0.12, 0.98	Values are from a Nevada test site pathways study by Breshears, et al. (1992) and are relevant to southern Nevada livestock husbandry.	*ggenii.inp; ggeniis.inp*
GENTPA	BeefFreshForage GrowTime[day]	Beef cattle fresh forage growing time [day]	uniform	30.0, 62.0	The values are derived from available information on alfalfa discussed by Stichler (1991) and Kennedy and Strenge (1992) as discussed by LaPlante and Poor (1997) .	*ggenii.inp; ggeniis.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
GENTPA	MilkFreshForage GrowTime[day]	Dairy cattle fresh forage growing time [day]	uniform	30.0, 62.0	The values for this parameter distribution were derived from available information on alfalfa discussed by Stichler (1991) and Kennedy and Strenge (1992) as discussed by LaPlante and Poor (1997) .	*ggenii.inp; ggeniis.inp*
GENTPA	BeefFreshForage IrrigationRatePB [in/yr]	Beef cattle fresh forage irrigation rate for pluvial biosphere [in/yr]	triangular	23.2, 36.8, 54.2	Forage is assumed to be alfalfa based on local conditions discussed by LaPlante and Poor (1997). Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulae that incorporate data on local climate, soil, crops, and irrigation methods. The climate adjustment done by CNWRA, documented by LaPlante and Poor (1997) for pluvial biosphere dose conversion factors, is applied to the irrigation rate data from Bechtel SAIC Company, LLC (2003). The CNWRA climate adjustment to the irrigation rate estimates is based on differences in irrigation rates for the Yucca Mountain region and a location in Idaho that exhibits temperature and rainfall characteristics similar to estimated future	*ggenii.inp; ggeniis.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
					Yucca Mountain region climate change conditions (semi-arid).	
GENTPA	MilkFreshForage IrrigationRatePB [in/yr]	Milk fresh forage irrigation rate for pluvial biosphere [in/yr]	triangular	23.2, 36.8, 54.2	Forage is assumed to be alfalfa based on local conditions discussed by LaPlante and Poor (1997). Irrigation rate data is tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods. The climate adjustment done by CNWRA, documented by LaPlante and Poor (1997) for pluvial biosphere dose conversion factors, is applied to the irrigation rate data from Bechtel SAIC Company, LLC (2003). The CNWRA climate adjustment to the irrigation rate estimates is based on differences in irrigation rates for the Yucca Mountain region and a location in Idaho that exhibits temperature and rainfall characteristics similar to estimated future Yucca Mountain region climate change conditions (semi-arid).	*ggenii.inp; ggeniis.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
GENTPA	BeefFreshForage IrrigationTimePB [mo/yr]	Beef cattle fresh forage irrigation time for pluvial biosphere [mo/yr]	uniform	3.0, 7.0	Based on expected climate change temperature conditions for pluvial period and forage information discussed by LaPlante and Poor (1997), 5 months of the year are expected to have temperatures intolerable for forage crops resulting in maximum growing season for forage of 7 months. Using the reported alfalfa growing times (see BeefFreshForageGrowTime) of 30 to 62 days (between cuttings) and 3 to 5 cuttings per season noted by LaPlante and Poor (1997), it is possible to irrigate for a minimum of 3 months for three cuttings and a maximum of 7 months for the entire growing season.	*ggenii.inp*
GENTPA	MilkFreshForage IrrigationTimePB [mo/yr]	Dairy cattle fresh forage irrigation time for pluvial biosphere [mo/yr]	uniform	3.0, 7.0	Based on expected climate change temperature conditions for pluvial period and forage information discussed by LaPlante and Poor (1997), 5 months of the year are expected to have temperatures intolerable for forage crops resulting in maximum growing season for forage of 7 months. Using the reported alfalfa growing times (see BeefFreshForageGrowTime) of 30 to 62 days (between cuttings) and 3 to 5 cuttings per	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					season noted in LaPlante and Poor (1997) it is possible to irrigate for a minimum of 3 months for three cuttings and a maximum of 7 months for the entire growing season.	
GENTPA	BeefFreshForage IrrigationRateCB [in/yr]	Beef cattle fresh forage irrigation rate for current biosphere [in/yr]	triangular	32.7, 51.8, 76.4	Forage is assumed to be alfalfa based on local conditions discussed by LaPlante and Poor (1997). Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods.	*ggenii.inp*
GENTPA	MilkFreshForage IrrigationRateCB [in/yr]	Dairy cattle fresh forage irrigation rate for current biosphere [in/yr]	triangular	32.7, 51.8, 76.4	Forage is assumed to be alfalfa based on local conditions discussed by LaPlante and Poor (1997). Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods.	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
GENTPA	BeefFreshForage IrrigationTimeCB [mo/yr]	Beef cattle fresh forage irrigation time for current biosphere [mo/yr]	uniform	3.0, 8.0	Based on current temperature conditions and forage information discussed by LaPlante and Poor (1997), 4 months of the year are expected to have temperatures intolerable for forage crops resulting in a maximum growing season for forage of 8 months. Using the reported alfalfa growing times (see BeefFreshForageGrowTime) of 30 to 62 days (between cuttings) and 3 to 5 cuttings per season noted by LaPlante and Poor (1997), it is possible to irrigate for a minimum of 3 months for three cuttings and maximum of 8 months for the entire growing season.	*ggenii.inp*
GENTPA	MilkFreshForageI rrigationTimeCB [mo/yr]	Dairy cattle fresh forage irrigation time for current biosphere [mo/yr]	uniform	3.0, 8.0	Based on current temperature conditions and forage information discussed by LaPlante and Poor (1997), 4 months of the year are expected to have temperatures intolerable for forage crops resulting in maximum growing season for forage of 8 months. Using the reported alfalfa growing times (see BeefFreshForageGrowTime) of 30 to 62 days (between cuttings) and 3 to 5 cuttings per	*ggenii.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					season noted by LaPlante and Poor (1997), it is possible to irrigate for a minimum of 3 months for three cuttings and maximum of 8 months for the entire growing season.	
GENTPA	DrinkingWater ConsumptionRate5 [L/yr]§§	Drinking water consumption rate for adult:ICRP72 [L/yr]	constant	730	Specified in NRC¶ regulation 10 CFR 63.312(d) that the reasonably maximally exposed individual drinks 2 liters of water per day. That value equals 730 liters per year.	*ggenii.inp; ggeniis.inp*
GENTPA	LeafyVegetable ConsumptionRate5 [kg/yr]‖‖	Leafy vegetable consumption rate for adult:ICRP72 [kg/yr]	constant	15	Mean annual consumption for residents of Amargosa Valley that consume local produce. This is the mean consumption rate of the adult population in Amargosa Valley that consumes locally produced food. Based on a DOE survey of local residents (CRWMS M&O, 2000b).	*ggenii.inp; ggeniis.inp*
GENTPA	OtherVegetable ConsumptionRate5 [kg/yr]	Other vegetable consumption rate for adult:ICRP72 [kg/yr]	constant	7.8	Mean annual consumption for residents of Amargosa Valley that consume local produce. This is the mean consumption rate of the adult population in Amargosa Valley that consumes locally produced food. Based on a DOE survey of local residents (CRWMS M&O, 2000b).	*ggenii.inp; ggeniis.inp*
GENTPA	FruitConsumption Rate5[kg/yr]	Fruit consumption rate for adult:ICRP72 [kg/yr]	constant	16	Mean annual consumption for residents of Amargosa Valley that consume local produce. This is the mean consumption	*ggenii.inp; ggeniis.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
					rate of the adult population in Amargosa Valley that consumes locally produced food. Based on a DOE survey of local residents (CRWMS M&O, 2000b).	
GENTPA	GrainConsumption Rate5[kg/yr]	Grain consumption rate for adult:ICRP72 [kg/yr]	constant	0.48	Mean annual consumption for residents of Amargosa Valley that consume local produce. This is the mean consumption rate of the adult population in Amargosa Valley that consumes locally produced food. Based on a DOE survey of local residents (CRWMS M&O, 2000b).	*ggenii.inp; ggeniis.inp*
GENTPA	BeefConsumption Rate5[kg/yr]	Beef consumption rate for adult:ICRP72 [kg/yr]	constant	2.9	Mean annual consumption for residents of Amargosa Valley that consume local produce. This is the mean consumption rate of the adult population in Amargosa Valley that consumes locally produced food. Based on a DOE survey of local residents (CRWMS M&O, 2000b).	*ggenii.inp; ggeniis.inp*
GENTPA	PoultryConsumption Rate5[kg/yr]	Poultry consumption rate for adult:ICRP72 [kg/yr]	constant	0.8	Mean annual consumption for residents of Amargosa Valley that consume local produce. This is the mean consumption rate of the adult population in Amargosa Valley that consumes locally produced food. Based on a DOE survey of local residents (CRWMS M&O, 2000b).	*ggenii.inp; ggeniis.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
GENTPA	MilkConsumption Rate5[kg/yr]	Milk consumption rate for adult:ICRP72 [kg/yr]	constant	4.1	Mean annual consumption for residents of Amargosa Valley that consume local produce. This is the mean consumption rate of the adult population in Amargosa Valley that consumes locally produced food. Based on a DOE survey of local residents (CRWMS M&O, 2000b).	*ggenii.inp; ggeniis.inp*
GENTPA	EggConsumption Rate5[kg/yr]	Egg consumption rate for adult:ICRP72 [kg/yr]	constant	6.7	Mean annual consumption for residents of Amargosa Valley that consume local produce. This is the mean consumption rate of the adult population in Amargosa Valley that consumes locally produced food. Based on a DOE survey of local residents (CRWMS M&O, 2000b).	*ggenii.inp; ggeniis.inp*
GENTPA	InhalationExposure Time5[hr]	Inhalation exposure time for adult:ICRP72 [hr/yr]	constant	4200	Based on information in Kennedy and Strenge (1992) as described by LaPlante and Poor (1997) including a 0.5 indoor exposure factor, 4,800 hr/yr indoors, 1,700 hr/yr outdoors, and 100 hr/yr gardening (i.e., 4,800*0.5+1,700+100=4,200). Forty hours per week are assumed to be spent outside of the area for employment.	*ggenii.inp*
GENTPA	InhalationRate5 [cm^3/s]¶¶	Inhalation rate for adult:ICRP72 [cm^3/s]	constant	270	Default chronic inhalation rate for GENII code (Napier, et al., 1988). Information and recommendations in the EPA#	*gdefault.dat*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					exposure factors handbook (EPA, 1997) suggests this value is above average for U.S. adults.	
GENTPA	SoilContamination ExposureTime5[hr]	Soil contamination exposure time adult:ICRP72 [hr/yr]	constant	1800	Based on outdoor exposure duration provided in Kennedy and Strenge (1993) as described by LaPlante and Poor (1997). Includes 1,700 hr/yr outdoors and 100 hr/yr gardening.	*ggenii.inp; ggeniis.inp*
GENTPA	PlantUptakeScale Factor	Plant uptake scaling factor used to scale plant transfer factors in *gftrans.dat*	lognormal	0.10, 9.8	The range for this parameter is the 0.1 to 99.9% interval using distribution statistics from International Union of Radioecologists (1989). For Yucca Mountain relevant crop types and elements, an uncertainty factor of four generally bounded the data (LaPlante and Poor, 1997). Assuming the data are lognormally distributed and the uncertainty factor used in the reference was for a 95 percent confidence interval the applicable geometric standard deviation is 2. Applying this geometric standard deviation to a 0.1 and 99.9 percentile interval using lognormal distribution statistics results in the range of 0.1 to 9.8. This scale factor is multiplied by the tabulated plant	*gftrans.def; gftrans.inp; gftranss.def; gftranss.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					uptake factors to induce variation in the fixed (tabulated) values.	
GENTPA	KD_Soil_Cm [cm^3/g]##	Soil K_d for Curium [cm^3/g]	user-supplied CDF	7666.0, 0.0 7785.4, 0.115 9604.6, 0.184 11849.0, 0.274 14617.9, 0.382 18033.7, 0.500 22247.8, 0.618 27446.7, 0.726 33860.4, 0.816 41772.8, 0.885 44260.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_Pu[cm^3/g]	Soil K_d for Plutonium [cm^3/g]	user-supplied CDF	316.0, 0.0 395.4, 0.115 742.5, 0.184 1394.1, 0.274 2617.6, 0.382 4914.8, 0.500 9228.0, 0.618 17326.6, 0.726 32532.7, 0.816 61083.7, 0.885 114691.4, 0.933 190000.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_U[cm^3/g]	Soil K_d for Uranium [cm^3/g]	user-supplied CDF	0.17, 0.0 0.27, 0.067 0.71, 0.115 1.86, 0.184 4.85, 0.274 12.7, 0.382 33.1, 0.500	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
				86.5, 0.618 225.9, 0.726 589.9, 0.816 1540.7, 0.885 4023.9, 0.933 6000.0, 1.0		
GENTPA	AnimalUptakeScale Factor	Animal uptake scaling factor used to scale animal transfer factors in *gftrans.dat*	lognormal	0.10, 9.8	Information quantifying uncertainty in animal uptake factors equivalent to that available for plants was not provided in the source documentation, but the scale factor distribution applied to plant uptake (based on a geometric standard deviation of 2) generally encompassed the variation reported for the animal uptake factors in International Atomic Energy Agency, (1994). (see basis for PlantUptakeScaleFactor).	*gftrans.def; gftrans.inp; gftranss.def; gftranss.inp*
GENTPA	KD_Soil_Am[cm^3/g]	Soil K_d for Americium [cm^3/g]	user-supplied CDF	100.0, 0.0 192.5, 0.184 419.9, 0.274 916.0, 0.382 1998.2, 0.500 4359.0, 0.618 9509.1, 0.726 20743.7, 0.816 45251.9, 0.885 98715.8, 0.933 215345.7, 0.964 300000.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
GENTPA	KD_Soil_Np[cm^3/g]	Soil K_d for Neptunium [cm^3/g]	user-supplied CDF	1.30, 0.0 1.92, 0.067 3.19, 0.115 5.31, 0.184 8.85, 0.274 14.7, 0.382 24.5, 0.500 40.9, 0.618 68.0, 0.726 113.3, 0.816 188.7, 0.885 314.2, 0.933 400.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_Ra[cm^3/g]	Soil K_d for Radium [cm^3/g]	user-supplied CDF	1262.0, 0.0 2230.5, 0.184 5653.3, 0.274 14328.4, 0.382 36315.5, 0.500 92042.0, 0.618 233281.2, 0.726 530000.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_Pb[cm^3/g]	Soil K_d for Lead [cm^3/g]	user-supplied CDF	800.0, 0.0 955.0, 0.274218 7.8, 0.382 5011.9, 0.500 11481.5, 0.618 26302.7, 0.726 60256.0, 0.816 100000.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_Cs[cm^3/g]	Soil K_d for Cesium [cm^3/g]	user-supplied CDF	1000.0, 0.0 1380.2, 0.184 2038.6, 0.274 3010.9, 0.382	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user	*gftrans.inp; gftranss.inp* (leaching factor)

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
				4447.1, 0.500 6568.2, 0.618 9701.2, 0.726 14328.4, 0.816 21162.8, 0.885 31257.0, 0.933 46166.1, 0.964 61287.0, 1.0	supplied piecewise distributions that simulate truncated log normal distributions.	
GENTPA	KD_Soil_Th[cm^3/g]	Soil K_d for Thorium [cm^3/g]	user-supplied CDF	1700.0, 0.0 2981.0, 0.500 5597.1, 0.618 10509.1, 0.726 19732.1, 0.816 37049.1, 0.885 69563.8, 0.933 130613.8, 0.964 170000.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_I[cm^3/g]	Soil K_d for Iodine [cm^3/g]	user-supplied CDF	0.1, 0.0 0.12, 0.036 0.22, 0.067 0.41, 0.115 0.74, 0.184 1.35, 0.274 2.46, 0.382 4.48, 0.500 8.17, 0.618 14.88, 0.726 27.11, 0.816 43.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_Tc[cm^3/g]	Soil K_d for Technetium [cm^3/g]	user-supplied CDF	0.01, 0.0 0.016, 0.115 0.027, 0.184 0.046, 0.274	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user	*gftrans.inp; gftranss.inp* (leaching factor)

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
				0.079, 0.382 0.135, 0.500 0.232, 0.618 0.399, 0.726 0.684, 0.816 1.174, 0.885 2.014, 0.933 3.456, 0.964 5.930, 0.982 10.176, 0.992 16.0, 1.0	supplied piecewise distributions that simulate truncated log normal distributions.	
GENTPA	KD_Soil_Ni[cm^3/g]	Soil K_d for Nickel [cm^3/g]	user-supplied CDF	60.0, 0.0 100.0, 0.036 141.3, 0.067 199.5, 0.115 281.8, 0.184 398.1, 0.274 562.3, 0.382 794.3, 0.500 1122.0, 0.618 1584.9, 0.726 2238.7, 0.816 3162.3, 0.885 4466.8, 0.933 6309.6, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_Cl[cm^3/g]	Soil K_d for Chlorine [cm^3/g]	user-supplied CDF	0.0, 0.0 0.010, 0.018 0.014, 0.036 0.019, 0.067 0.027, 0.115 0.037, 0.184 0.052, 0.274 0.072, 0.382	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
				0.100, 0.500 0.139, 0.618 0.194, 0.726 0.270, 0.816 0.375, 0.885 0.4, 1.0		
GENTPA	KD_Soil_C[cm^3/g]	Soil K_d for Carbon [cm^3/g]	user-supplied CDF	1.12, 0.0 1.42, 0.067 2.36, 0.115 3.94, 0.184 6.6, 0.274 10.9, 0.382 18.2, 0.500 30.3, 0.618 50.4, 0.726 83.9, 0.816 139.8, 0.885 232.8, 0.933 299.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_Se[cm^3/g]	Soil K_d for Selenium [cm^3/g]	user-supplied CDF	36.0, 0.0 38.1, 0.184 42.9, 0.274 48.4, 0.382 54.6, 0.500 61.6, 0.618 69.4, 0.726 78.3, 0.816 88.2, 0.885 99.5, 0.933 100.0, 1.0	Per Software Change Report 552, log normal distributions using data from Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	KD_Soil_Nb[cm^3/g]	Soil K_d for Niobium [cm^3/g]	user-supplied CDF	33.0, 0.0 42.5, 0.067	Per Software Change Report 552, log normal distributions using data from	*gftrans.inp; gftranss.inp*

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)						
Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
				70.8, 0.115 117.9, 0.184 196.4, 0.274 327.0, 0.382 544.6, 0.500 906.9, 0.618 1510.2, 0.726 2514.9, 0.816 4188.1, 0.885 6974.4, 0.933 8500.0, 1.0	Sheppard and Thibault (1990) have been replaced by user supplied piecewise distributions that simulate truncated log normal distributions.	(leaching factor)
GENTPA	AnnualPrecipitation [m/yr]***	Annual precipitation rate [m/yr]	constant	0.102	Annual precipitation in Amargosa Valley determined from data reported in the Bechtel SAIC Company, LLC (2003) Table 4.1-2.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	AnnualIrrigation[m/yr]	Annual irrigation rate [m/yr]	constant	1.05	Irrigation rate data are tabulated in Table 6.5-2 of Bechtel SAIC Company, LLC (2003) showing irrigation rates for various crops applicable to the Yucca Mountain region. These rates were calculated using established agricultural formulas that incorporate data on local climate, soil, crops, and irrigation methods. For TPA code use, these crop-specific rates were used to derive representative values for crop categories consistent with the model inputs. The crop category-specific rates were averaged to derive the	*gftrans.inp; gftranss.inp* (leaching factor)

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	**Parameter Name**	**Description**	**Distribution Type**	**Parameter Value(s)**	**Remarks**	**GENTPA Data File**
					annual irrigation rate listed here (1.05 m/yr).	
GENTPA	SoilBulkDensity [g/cm^3]	Soil bulk density [g/cm^3]	constant	1.5	Based on LaPlante and Poor (1997).	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	SoilVolumetricWater Content	Soil volumetric water content [ml/cm^3]†††	constant	0.35	Data from Tanner (1991) for soils similar to Amargosa Valley farming soils.	*gftrans.inp; gftranss.inp* (leaching factor)
GENTPA	TotalAnnual Evapotranspiration [m/yr]	Total annual evapotranspiration [m/yr]	constant	1.07	Using data in Bechtel SAIC Company, LLC (2003), the average irrigation rate for all crop groups (see description of the Annual Irrigation rate of 1.05 m/yr) and the annual precipitation in Amargosa Valley from data reported in the Bechtel SAIC Company, LLC (2003) Table 4.1-2 (0.102 m/yr) were summed and the mean overwatering rate for all crops reported in Table 6.9-1 (0.079 m/yr) was subtracted from this sum to estimate the evapotranspiration (because precipitation + irrigation -- evapotranspiration = overwatering). The resulting evapotranspiration is 1.07 m/yr. This value was checked against U.S. Geological Survey estimates of deep percolation for	*gftrans.inp; gftranss.inp* (leaching factor)

Table 1. Reference Date Sheet for Pathway and Dose Calculations in the TPA Version 5.1 Beta Code (continued)

Input Block in *Tpa.inp*	Parameter Name	Description	Distribution Type	Parameter Value(s)	Remarks	GENTPA Data File
					farming locations in Amargosa Valley (U.S. Geological Survey, 2003) for additional confidence. U.S. Geological Survey concludes that 8 to 16 percent of irrigation water becomes deep percolation. Applying the low estimate to the average irrigation rate used to calculate evapotranspiration (1.05 m/yr × 0.08) results in a deep percolation estimate of 0.084 m/yr. This value compares with the aforementioned 0.079 value for overwatering reported by Bechtel SAIC Company, LLC (2003).	

*Dose Conversion Analysis for Groundwater
†Total-system Performance Assessment
‡Dose Conversion for Ground Surface
§U.S. Department of Energy
‖Center for Nuclear Waste Regulatory Analyses
¶U.S. Nuclear Regulatory Commission
#U.S. Environmental Protection Agency
**1 km = 1,000m or 0.621 mi
††1 cm = 0.01 m or 0.304 in
‡‡1 in = 0.0254 m
§§1 L = 0.001 m^3 or 0.264 gal
‖‖1 kg = 2.20 lb
¶¶1 cm^3 = 1.0E−6 m^3 or 0.0610 in^3
##1 g = 0.001 kg or 2.20E−3 lb
***1 m = 1.094 yd
†††1 ml = 1.0E−m^3 or 0.0610 in^3

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