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Benchmarking of Computer Codes and Approaches for Modeling Exposure Scenarios

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ABSTRACT

The U.S. Department of Energy Headquarters established a performance assessment task team (PATT) to integrate the activities of DOE sites that are preparing performance assessments for the disposal of newly generated low-level waste. The PATT chartered a subteam with the task of comparing computer codes and exposure scenarios used for dose calculations in performance assessments. This report documents the efforts of the subteam. Computer codes considered in the comparison include GENII, PATHRAE-EPA, MICROSHIELD, and ISOSHLD. Calculations were also conducted using spreadsheets to provide a comparison at the most fundamental level. Calculations and modeling approaches are compared for unit radionuclide concentrations in water and soil for the ingestion, inhalation, and external dose pathways. Over 30 tables comparing inputs and results are provided.

EXECUTIVE SUMMARY

The U.S. Department of Energy Headquarters (DOE-HQ) established a performance assessment task team (PATT) to integrate the activities of DOE sites that are preparing performance assessments for the disposal of newly generated low-level waste, as required by Chapter III of DOE Order 5820.2A (1). The PATT is comprised of representatives from each of the DOE sites that are actively disposing of low-level waste, representatives from DOE-HQ, and a liaison from the U.S. Nuclear Regulatory Commission. The PATT chartered a subteam with the task of comparing computer codes and exposure scenarios used for dose calculations in performance assessments. This report documents the activities of the subteam.

This report is divided into three sections: (a) comparison of inputs used to define exposure scenarios, (b) benchmark comparison of calculated doses per unit concentration of radionuclides in groundwater, and (c) benchmark comparison of calculated doses per unit concentration of radionuclides in soil. The first section is a discussion of differences in assumptions used to define the exposure scenarios at the different sites (e.g., dilution factors for waste mixed with soil, breathing parameters for inhalation pathway, and consumption parameters for ingestion pathway). The second and third sections use a standard set of inputs to demonstrate that similar results can be obtained using the two computer codes considered in the study as well as hand calculations. Differences in default inputs or models discovered during the comparison are discussed. The benchmark parameters were simply selected as a baseline for these comparisons and are not intended to be a recommended list. Each analyst should evaluate the applicability of input values for a specific site.

Results from the PATHRAE-EPA (Rogers and Hung 1987) and GENII (Napier et al. 1988) computer codes were compared for the ingestion, inhalation, and external exposure pathways for unit concentration in soil and water. Hand calculations were also conducted using a spreadsheet to compare with the computer code predictions. External exposure calculations were also compared with results from the Microshield (Grove Engineering 1987) and ISOSHLD (Engel et al. 1966) computer codes and results from Federal Guidance Report 12 (EPA 1993) for additional points of reference. Numerous tables with many combinations of the results are provided to allow detailed consideration of the reasons for differences. Input files used in the simulations are also provided in the appendices to aid with reproduction of the results. The comparisons provided feedback regarding inherent differences in the computer codes as well as minor errors in the codes or documentation.

In general, the computer codes compared very well for most of the pathways. Treatment of uptake of C-14 and H-3 was different in the two codes and warrants close attention when conducting calculations with PATHRAE-EPA and GENII. Treatment of stored feed consumed by cattle is also different in the two codes. This results in differences in predicted doses for a few radionuclides. The differences were generally 10% or less due to the assumptions related to stored feed. Some large differences in predicted doses were observed when the results using GENII average default inputs were compared with results using the benchmark parameters assumed for this analysis. (Note that no recommendation is implied for the benchmark values and that any inputs for an analysis should be determined based on site-specific considerations.) This reflects the potential for bias in default parameters for a computer code.

GENII showed the best agreement for external dose with Federal Guidance Report 12 (FGR 12) (EPA 1993) of the codes considered. The largest consistent differences were observed between PATHRAE-EPA and the other codes considered for the external dose pathway (although PATHRAE-EPA results are conservative). PATHRAE-EPA uses a fundamentally different approach to calculate external doses that yielded results significantly different from the other codes and FGR 12. Results in FGR 12 are the most up to date and should be considered a reasonable benchmark for other computer codes.

During the life of the activity, several changes were made to approaches used at different sites based on interim findings of the subteam. The changes affected scenario definition, selection of computer codes, and parameter values used for performance assessments. A number of subtle differences in the computer codes and default inputs were identified that need to be understood by potential users of the codes. These differences are discussed in the text. In general, this effort emphasized the importance of understanding the basis for the input data and the computer codes when conducting these calculations. Defensibility of results can be improved through this understanding.

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1. INTRODUCTION

The U.S. Department of Energy Headquarters (DOE-HQ) established a performance assessment task team (PATT) to integrate the activities of DOE sites that are preparing performance assessments for the disposal of newly generated low-level waste, as required by Chapter III of DOE Order 5820.2A (DOE 1988a). The PATT is comprised of representatives from each of the DOE sites that are actively disposing of low-level waste, representatives from DOE-HQ, and a liaison from the U.S. Nuclear Regulatory Commission (NRC). The PATT's charter is to recommend policy and provide guidance to DOE-HQ on technical issues that impact performance assessments. A goal for the team is to improve the consistency of approaches (where applicable) and interpretation of results across the DOE system. The PATT has met three or four times a year, and these meetings have led to improved communication between the sites on performance assessment issues and improved consistency of approaches where appropriate.

One of the first tasks undertaken by the PATT was to examine all aspects of a performance assessment to find areas in which consistency could be improved without impacting the credibility of the analyses. For example, groundwater modeling is strongly driven by site-specific considerations; therefore, efforts to standardize groundwater modeling would likely compromise the credibility of the calculations. Based on this evaluation, human intrusion scenarios and dose assessments (from contaminated soil or water to receptor) were judged the areas most likely to be amenable to some level of standardization.

The PATT established a subteam to evaluate the approaches and computer codes used to conduct these calculations at DOE sites. One goal of the subteam was to identify areas in which differences exist and provide recommendations for areas in which standardization may be appropriate. Subteam activities included performing a benchmark study of the results from GENII (Napier et al. 1988) and PATHRAE-EPA (Rogers and Hung 1987) computer codes and comparing assumed input values for selected parameters from scenarios used by DOE sites to address the inadvertent intrusion criteria of DOE Order 5820.2A. The benchmark comparisons address calculations of dose per unit concentration of radionuclides in soil and groundwater.

An important consideration during the comparison was to identify differences in default parameters assumed in the two computer codes. These comparisons had not been conducted previously and were considered essential to meet the goals of the subteam. The intent was not to critically review the codes, rather to objectively conduct the comparisons and report differences in approaches and assumptions. In this manner, users of the codes can be aware of inconsistencies in approaches or defaults.

This report documents the results of the work of the subteam. This work has been conducted in stages over a 2-to-3-year time frame. By necessity, the work has been discontinuous, which has been somewhat inefficient but has proved to be beneficial due to the ability to incorporate new information obtained during the off periods between each new set of calculations. Interaction with and contributions from analysts from several different DOE sites provided a broad range of experiences that contributed to the increased understanding obtained from the effort. The comparisons provided useful information regarding differences in the codes, default parameters in the codes, and differences in assumptions made at the DOE sites. The information in this report should be of use to anyone conducting calculations to determine receptor doses resulting from contaminated soils and groundwater, especially those using the PATHRAE and GENII computer codes.

This report is divided into three sections: (a) comparison of inputs used to define exposure scenarios, (b) benchmark comparison of calculated doses per unit concentration of radionuclides in groundwater, and (c) benchmark comparison of calculated doses per unit concentration of radionuclides in soil. The first section is a discussion of differences in assumptions used to define the exposure scenarios at the different sites (e.g., dilution factors for waste mixed with soil, breathing parameters for inhalation pathway, and consumption parameters for ingestion pathway). The second and third sections use a standard set of inputs to demonstrate that similar results can be obtained using the two computer codes considered in this study as well as hand calculations. Differences in default inputs or models discovered during the comparison are discussed. The benchmark parameters were simply selected as a baseline for these comparisons and are not intended to be a recommended list. Each analyst should evaluate the applicability of input values for a specific site.

2. COMPARISON OF ASSUMPTIONS USED AT DIFFERENT SITES

In the past, much of the performance assessment work at DOE sites was conducted with little or no communication between the analysts. Thus, the PATT subteam started by comparing general input parameters for human intrusion scenarios used at the different DOE sites and by the NRC. The comparison yielded a number of differences in approaches to solving a problem that on the surface appeared relatively well defined. Approaches for obtaining the dilution factor for waste mixed with soil are discussed first, followed by a discussion of the comparison of input parameters for exposure scenarios. The data in the tables in this section were obtained early in the project, and several sites have made changes to their approaches based on feedback from the subteam. Thus, a number of inputs will be different in the final performance assessments released by the sites.

2.1 Comparison of Site Approaches for Obtaining Soil Concentration

One objective of this effort was to compare input data and exposure scenarios used by the different sites. Comparison of significant parameters used to define the scenarios is provided in Table 2-1. Two scenarios are considered here: the post-drilling scenario and the post-excavation scenario. The post-drilling scenario assumes that a well is drilled through a disposal facility for drinking or irrigation water causing waste to be exhumed. Subsequently, the waste is mixed with surrounding clean soil on which crops are grown and cattle are raised. The dose received comes primarily from ingestion of crops, beef, and milk; inhalation of dust; and direct exposure to gamma radiation. The post-excavation scenario is identical except that waste is exhumed through excavation of a house basement to a depth that intersects the depth of burial. These scenarios were chosen because they often provide maximum dose estimates relative to other scenarios.

Table 2-1 lists the parameters and parameter values that are used to define waste loading in soil that controls estimated doses. In general, dose estimates increase linearly with increased waste loading in the soil. The primary parameter in Table 2-1 is the soil dilution fraction that represents the fraction of waste concentration in the soil relative to that initially present in the waste. Numbers used by all of the major DOE waste management sites and the NRC in preliminary analyses are shown.

The soil dilution factors agree well for the excavation scenario, although there were differences in the approaches used to derive the dilution factors. Almost three orders of magnitude spread is observed for the drilling scenario soil dilution value. Some of the differences can be attributed to site-specific considerations. (For example, the area of a lot used to calculate the volume of soil in Idaho can be expected to be larger than a lot in Oak Ridge because of population density.) However, the volume of soil also depends on the depth of mixing when the contaminated soil is distributed on the lot. This parameter is not shown, but PATHRAE uses a depth of 0.91 m, and GENII uses a depth of 0.15 m. Thus, the assumed mixing depth can result in a six-fold difference in the dilution factor.

The size of the well assumed to be drilled through the waste is another factor that is probably site-specific. Experience has shown that the best way to define the well size is to call a

Table 2-1. Soil dilution parameters for all exposure pathways.

Drilling and post-drilling parameters	Benchmark value	ORNL	Hanford	SRP	LANL	INEL and NTS	NRC
Soil dilution factor	1.9E-03	2.0E-02	9.3E-04	4.6E-05	7.9E-04	4.8E-05	NA
Waste volume (m^3)	7.0E-01	5.0E-01	3.5E-01	9.6E-02	6.3E-01	9.6E-02	NA
Volume of soil mixed with waste (m^3)	3.6E+02	3.0E+01	3.8E+02	2.0E+03	6.0E+02	2.0E+03	NA
Excavation and post-excavation parameters							
Soil dilution factor	1.0E-01	2.0E-01	2.0E-01	9.9E-02	1.1E-01	9.5E-02	1.3E-01
Waste volume (m^3)	2.0E+02	5.0E+00	7.5E+01	2.0E+02	8.8E+00	2.0E+02	2.3E+02
Volume of soil mixed with waste	3.6E+02	3.0E+01	3.8E+02	2.0E+03	8.0E+02	2.0E+03	6.8E+02

drilling contractor in the area and ask what size hole would be drilled to install a well near the site. The drilling technique can also have an impact on assumptions related to the intruder scenario. For example, in a region with soils as opposed to rock (e.g., basalt) between the surface and the aquifer, a driller will likely use drilling methods that would not penetrate a concrete vault. In this case, the drilling scenario can probably be excluded from consideration. However, at sites where a driller must penetrate through rock, a vault would not seem to be an obstacle.

2.2 Comparison of Pathway Parameters Used at Different Sites

Table 2-2 provides a similar comparison of key parameters for the three primary exposure pathways: inhalation, ingestion, and direct gamma. The significant parameters for inhalation include breathing rate, average dust loading, and dose conversion factors. The average yearly dust loading is calculated by summing the product of time and dust loading for each situation (outdoor or indoor gardening or both) and dividing by the total exposure time. These factors are all relatively consistent among sites. The table indicates that a variety of assumptions have been used to estimate dust loading, but the important factor is the average dust loading. Consequently, only an average dust loading value is used for the benchmark. It should be noted, however, that the ORNL parameters affecting inhalation, soil dilution, and average dust loading are the largest values assumed and result in a significantly larger dose estimate for ^{239}Pu compared to the other sites.

The significant parameters for ingestion are the types and amounts of food eaten, dose conversion factors, and the various uptake factors in the food chains. Values for consumption rates of contaminated foods are compared in Table 2-2. In general, the values are relatively similar, although different combinations of foods are considered by the different sites. The GENII code offers the capability to consider several types of foods, while PATHRAE allows less, and note that Oak Ridge simply assumes a composite total. Details regarding benchmark values for the other necessary parameters are provided in Section 3. Note that in the default data base for GENII, several uptake factors are entered in the FTRANS.DAT file as 9.9E-04. These values were used when no actual data were available. The user needs to seek out values for use in these cases.

Table 2-2. Specific parameter values for inhalation, ingestion, and direct gamma pathways.[a]

Inhalation pathway parameters	Benchmark value	ORNL	Hanford	SRP	LANL	INEL and NTS	NRC
Breathing rate (m^3/h)	9.7E-01	8.8E-01	9.7E-01	9.0E-01	1.2E+00	9.3E-01	9.3E-01
Exposure time	8.8E+03	4.5E+03	6.2E+03	2.2E+03	6.2E+03	8.7E+03	6.2E+03
Gardening time (h/year)	—	1.0E+02	1.0E+02	NA	NA	2.4E+01	1.0E+02
Gardening dust loading (g/m^3)	—	1.0E-03	1.0E-04	NA	NA	1.0E-03	5.7E-04
Outdoors time (h/year)	—	NA	1.7E+03	2.2E+03	1.8E+03	1.2E+03	1.7E+03
Outdoors dust loading (g/m^3)	—	NA	1.0E-05	1.0E-04	1.5E-04	7.0E-05	1.0E-04
Indoors time (h/year)	—	4.4E+03	4.4E+03	NA	4.4E+03	7.5E+03	4.4E+03
Indoors dust loading (g/m^3)	1.0E-04	1.0E-04	1.0E-05	NA	1.0E-04	5.0E-05	5.0E-05
Average yearly dust loading (g/m^3)	—	1.2E-04	1.0E-05	1.0E-04	1.1E-04	5.5E-05	7.3E-05
Ingestion pathway parameters							
Contaminated leafy vegetables consumed (kg/year)	5.0E+00	NA	3.8E+00	9.0E+00	NA	8.3E+00	NA
Other contaminated vegetables consumed (kg/year)	4.3E+01	NA	3.5E+01	8.8E+01	NA	4.7E+01	NA
Contaminated fruits consumed (kg/year)	NA	NA	1.6E+01	NA	NA	NA	NA
Contaminated cereals consumed (kg/year)	NA	NA	1.8E+01	NA	NA	NA	NA
Total contaminated vegetables consumed	4.8E+01	9.0E+01	7.3E+01	9.7E+01	9.5E+01	5.5E+01	4.8E+01
Contaminated water consumed (L/year)	?	7.3E+01	NA	?	?	4.7E+02	NA
Direct gamma pathway parameters							
Outdoors time (h/year)	—	1.0E+02	1.8E+03	8.8E+03	1.8E+03	2.5E+03	1.8E+03
Indoors time (h/year)	—	4.4E+03	4.4E+03	NA	4.4E+03	NA	4.4E+03
Shielding factor indoors	—	7.0E-01	3.3E-01	NA	?	NA	2.7E-01
Total weighted time (h/year)	8.8E+03	3.2E+03	3.3E+03	8.8E+03	?	2.5E+03	3.0E+03

a. These data are subject to change at each of the sites.

The significant parameters for direct gamma exposure are exposure time and external dose conversion factors. Exposure times were considered as strictly outdoors or a combination of outdoor and indoor time. When indoor time is used, a shielding factor is required to account for the shielding effect of the housing structure. To accommodate the different approaches, an average weighted time is assumed for the benchmark case.

2.3 Benchmark Input Parameters

Since the purpose is to simply benchmark results, an initial consideration was to use a value of 1 for most inputs. However, a number of input values were difficult to change in the two codes (especially for the ingestion pathway). For example, some inputs are hard-wired in PATHRAE, and GENII uses binary libraries for some inputs. This is an important consideration for specifying inputs. For this exercise, the subteam made a policy of not changing source code or protected (binary) libraries, if at all possible. Based on this consideration, some of the "unchangeable" inputs were set at the default values used in PATHRAE or GENII (as appropriate) for the benchmarks.

One example of "unchangeable" inputs was that PATHRAE has fixed values for the mixing depth and area of spreading for excavated wastes and requires waste concentrations as input, whereas GENII can simply use initial soil concentrations. Thus, the input waste concentrations for PATHRAE were scaled to force the initial soil concentration to be one (the value used in GENII). Another example was that the dose factors for GENII are stored in a binary library, whereas PATHRAE requires the user to input the dose factors. For the benchmarks, the dose conversion factors used in GENII were used as input for PATHRAE. Additional calculations were conducted with DOE dose factors (DOE 1988b) used as input to PATHRAE to compare the impacts of using different dose factors. Inhalation dose conversion factors for GENII and DOE are provided in Table 2-3. Note that the inhalation and ingestion dose factors include the contribution of short-lived radioactive progeny produced by decay of the long-lived parent in the body. In particular, Cs-137 includes Ba-137m; Ra-226 includes Rn-222, Pb-214, and Bi-214; U-238 includes Th-234, Pa-234m, and Pa-234; Np-237 includes Pa-233; and Pu-241 includes U-237.

A relatively consistent set of inputs for PATHRAE and GENII was generated based on the above constraints. The primary inputs were set to identical values. However, a number of secondary inputs are also included in the two codes. Complete consideration of these inputs would have required more time than was productive for this task. In general, the goal for the benchmarks was for the results to agree within 10%.

2.3.1 Inhalation

The inhalation pathway was straightforward. Cases were run with the benchmark parameters specified in Table 2-2 using GENII and DOE dose factors. For comparison purposes, predicted doses were compared using GENII with the benchmark parameters and the GENII defaults. Additional cases were also run with PATHRAE and GENII to compare with hand calculations. The hand calculations provided an exact comparison for the computer codes. The inhalation scenario used a dust loading rather than a resuspension factor. Input parameters needed for the scenario included soil concentration, average yearly dust loading, exposure time, breathing rate, and dose factor. Additional parameters that may be used include respirable fraction and fraction of dust from onsite. Inhalation dose factors are provided in Table 2-3. Note that the GENII dose factor for H-3 includes an increase of 50% to account for skin absorbtion. This 50% factor is not included in the DOE value.

2.3.2 Ingestion

Ingestion was more complicated than inhalation for a variety of reasons, including (a) different foods need to be considered (e.g., leafy vegetables, produce, and meat), (b) exposure results were from a sequence of transfer factors (e.g., soil to plant to human, and soil to plant to animal meat to human), and (c) transfer factors can be modeled using different assumptions (e.g., stored feed versus fresh forage, and composition of stored feed). Pathway selection that should be considered in the benchmarks is discussed below.

Table 2-3. Internal dose factors for inhalation, mrem/pCi.

Nuclide	Class	DOE[a]	GENII[b]	Difference[c] (%)
H-3	D	6.30E-08	9.03E-08[d]	43.3
C-14	D	2.10E-06	2.07E-06	-1.4
Co-60	Y	1.50E-04	2.01E-04	34.0
Ni-59	D	1.30E-06	1.28E-06	-1.5
Se-79	W	8.90E-06	9.54E-06	7.2
Sr-90	D	2.37E-04	2.12E-04	-10.5
Tc-99	W	7.50E-06	8.99E-06	19.9
I-129	D	1.80E-04	1.51E-04	-16.1
Cs-137	D	3.20E-05	3.00E-05	-6.2
Ra-226	W	7.90E-03	8.22E-03	4.1
U-238	Y	1.20E-01	1.18E-01	-1.7
Np-237	W	4.90E-01	6.36E-01	29.8
Pu-239	W	5.10E-01	4.34E-01	-14.9
Pu-241	W	1.00E-02	8.18E-03	-18.2
Am-241	W	5.20E-01	4.43E-01	-14.8

a. DOE values are from DOE (1988b).

b. GENII values are from the July 1993 recalculation of the GENII dose increment library (Rittmann 1993).

c. Negative percentages mean that the GENII value is smaller than the DOE value.

d. GENII H-3 inhalation dose factor is increased by 50% to account for skin absorbtion.

The comparison was complicated by the fact that the categories of food used by PATHRAE and GENII are different. PATHRAE considers only leafy vegetables and produce, while GENII considers leafy vegetables, root vegetables, grain, fruit, and eggs. To simplify the comparison, the values used for leafy vegetables and produce in PATHRAE were input into leafy vegetables and root vegetables in GENII. Comparisons of the meat and milk consumption pathways were more difficult because of differences in the codes. Inputs for this exposure route included soil concentrations, dry-to-wet ratios for plant uptake factors, plant uptake factors, delay times between harvest and consumption, consumption rates, meat and milk uptake factors, and dose factors. Tables 2-2, 2-4, 2-5, and 2-6 list benchmark inputs for the ingestion pathway.

Table 2-4. Benchmark values and GENII radioactive uptake factors and dose factors.

	FMC[a]		FF[b]		Bv[c]		Br[d]	
Nuclide	BENCH	GENII	BENCH	GENII	BENCH	GENII	BENCH	GENII
^{14}C	1.2E-2	0.0E+0	3.1E-2	0.0E+0	1.3E+0[e]	0.0E+0	1.3E+0[e]	0.0E+0
^{14A}C	1.2E-2	0.0E+0	3.1E-2	0.0E+0	1.3E+0[e]	0.0E+0	1.3E+0[e]	0.0E+0
^{60}Co	2.0E-3	1.0E-4	2.0E-2	2.0E-2	2.0E-2	1.0E-1	7.0E-3	4.0E-3
^{90}Sr	1.5E-3	1.3E-3	3.0E-4	8.0E-4	2.5E+0	2.0E+0	2.5E-1	2.0E-1
^{137}Cs	7.0E-3	7.0E-3	2.0E-2	3.0E-2	8.0E-2	2.0E-2	3.0E-2	1.0E-2
^{129}I	1.0E-2	1.2E-2	7.0E-3	2.0E-3	1.5E-1	4.0E-1	5.0E-2	4.0E-1
^{59}Ni	1.0E-3	1.0E-3	6.0E-3	6.0E-2	6.0E-2	1.0E-1	6.0E-2	5.0E-2
^{79}Se	4.0E-3	2.3E-2	1.5E-2	1.0E-0	2.5E-2	5.0E-1	2.5E-2	5.0E-2
^{99}Tc	1.0E-2	3.0E-4	8.5E-3	9.5E+0	9.5E+0	4.0E+1	1.5E+0	4.0E+1
^{3}H	1.0E-2	0.0E+0	1.2E-2	0.0E+0	4.8E+0	0.0E+0	4.8E+0	0.0E+0
^{3A}H	1.0E-2	0.0E+0	1.2E-2	0.0E+0	4.8E+0	0.0E+0	4.8E+0	0.0E+0
^{238}U	6.0E-4	6.0E-4	2.0E-4	2.0E-4	8.5E-3	4.0E-3	4.0E-3	2.0E-4
^{237}Np	5.0E-6	1.0E-5	5.5E-5	1.0E-3	1.0E-1	1.0E+0	1.0E-2	1.0E-1
^{239}Pu	1.0E-7	1.0E-7	5.0E-7	2.0E-6	4.5E-4	4.0E-4	4.5E-5	4.0E-5
^{241}Pu	1.0E-7	1.0E-7	5.0E-7	2.0E-6	4.5E-4	4.0E-4	4.5E-5	4.0E-5
^{241}Am	4.0E-7	3.0E-7	3.5E-6	2.0E-5	5.5E-3	2.0E-3	2.5E-4	2.0E-4
^{226}Ra	4.5E-4	2.0E-4	2.5E-4	9.0E-4	1.5E-2	1.0E-1	1.5E-3	1.0E-2

a. FMC - forage to milk transfer factor for cows (d/L).

b. FF - forage to beef transfer factor (d/kg).

c. Bv - soil to plant transfer factor for leafy vegetables (Bv values from PATHRAE were used for all results in Table 3-1.)

d. Br - soil to plant transfer factor for grain and other produce (Br values from PATHRAE were used for all results in Table 3-1).

e. Sheppard et al. (1991).

Table 2-5. Vegetation parameters.

Parameter type	Garden produce		Cattle feed	
	Leafy	Other	Fresh	Stored
Yield, kg/m^2	2.0	2.0	1.0	1.0
Dry-to-wet ratio	0.066	0.187	0.243	0.68
Growing period	60 d	60 d	30 d	30 d
Annual human consumption	20 kg	172 kg	—	—
Delay: harvest/consumption	1 d	60 d	0	90 d
Average cattle diet[a]	—	—	0.75	0.25
Fraction using Bv (PATHRAE)	—	—	1.00	0.622
Fraction using Br (PATHRAE)	—	—	0.0	0.378
Fraction using Bv (GENII)	—	—	1.00	0.0
Fraction using Br (GENII)	—	—	0.0	1.00

a. The cattle diet fractions for Bv and Br are part of the computer programs and cannot be changed by the normal user.

Table 2-6. Animal product parameters.

Parameter type	Milk	Beef
Daily water consumption	55 L	55 L
Daily fodder consumption	50 kg	50 kg
Annual human intakes	110 L	95 kg
Delay: cow feed to human	2 d	20 d

When assembling the input data for the comparison, an error was identified in the PATHRAE manual as a result of examining the hard-wired inputs. The manual indicates that a wet-weight soil-to-plant uptake factor should be used as input, when in reality it should be a dry weight. Dry-to-wet weight conversion factors are hard-wired into PATHRAE. For the benchmark, the hard-wired dry-to-wet weight conversion factors from PATHRAE were used as the inputs for the GENII runs. Another deficiency was that references for some of the default parameters in GENII were not clearly identified. Also, when conducting comparisons for intrusion scenarios without groundwater contributions, the user must ensure that leaching from the waste is turned off or set at the same value in the two codes. GENII also considers resuspension of radionuclides onto leaves by rain splash. For the purposes of this comparison, the variable controlling this parameter in GENII was set to zero.

The concentration ratios in Table 2-4 for plants and cattle are reproduced from ORNL-5785 and ORNL-5786 (Baes et al. 1984a, 1984b). Soil leaching is turned off by use of large retardation factors. The assumed irrigation rate is 36 in./yr (0.209 L/m^2/h). This is deposited during 6 months of the year. The fraction of contamination retained in the foliage is assumed to be 25% for all nuclides. The weathering removal half time is 14 days (0.00206 per hour). Weathering removal occurs only during the growing period for a plant type. For calculating radionuclide intakes, receptors are assumed to obtain 25% of the garden produce from contaminated sources. The rest is uncontaminated. All of the milk and beef is assumed to be supplied from contaminated sources. Receptors are assumed to drink 730 L of water annually.

3. INGESTION DOSES FROM CONTAMINATED WATER

GENII and PATHRAE were compared for ingestion pathways involving use of contaminated water. Fifteen radionuclides were considered with a variety of half-lives, dose factors, and uptake factors. The contaminated water could come from either a well or nearby surface water. All ingestion pathways were computed for this scenario. The pathways considered include ingestion of garden produce, meat and milk produced locally, and contaminated water. The intent is to compare the codes, but more importantly to understand why differences exist. Thus, the results are presented in a variety of forms, and reasons for significant differences are discussed.

3.1 Computer Code Results and Comparisons

GENII input was constructed to produce results similar to PATHRAE. In particular, (a) the leaching factors were all set to zero, (b) the resuspension factor used to compute rain splash was set to zero, (c) the harvest yields in GENII that are used to compute removal from the surface soil layer were set to 0.1 kg/yr, and (d) the dry-to-wet ratios that are hard-coded into PATHRAE were used in the GENII runs. GENII has an option that allows the user to specify the concentration in groundwater. This value was set to 1 μCi/L for all radionuclides considered. Sample input files are attached for reference in Appendix A.

The input to PATHRAE was constructed to create a groundwater concentration of 1 μCi/L (and calculate dose in terms of rem/yr), with little vertical leaching of contaminant from the surface layer of soil. This was accomplished by modifying the flow and transport parameters to yield the proper result for each radionuclide. Input files for the PATHRAE program are attached for reference in Appendix B. The PATHRAE internal dose factors are entered in the BRCDEF file. Since the GENII program has internal dose factors that are different from the DOE (1988b) values and cannot be changed, two BRCDEF files were used with PATHRAE. One uses DOE internal dose factors, and the other uses GENII internal dose factors. The internal ingestion dose factors are compared in Table 3-1. Most of the factors differ by 20% or less, except for Tc-99 and Np-237, which differ by 71.5% and 34.6%, respectively.

The predicted doses for GENII, PATHRAE with GENII dose factors, and PATHRAE with DOE dose factors are provided in Tables 3-2, 3-3, and 3-4, respectively. The differences in the predicted doses for GENII and PATHRAE are provided in Tables 3-5 and 3-6. The agreement was generally very good with predicted doses differing by 5% or less for most of the radionuclides when the GENII dose factors are used in PATHRAE. In general, the differences are larger when the DOE dose factors are used in PATHRAE, although most differ by 20% or less. Differences in excess of those listed above are discussed in the following paragraphs.

Note that two definitions are used for tritium (H-3) and carbon-14 (C-14). This was done because special models are used for these two radionuclides in the different codes. The "A" at the end of the second value (e.g., H-3A and C-14A) is used in PATHRAE input to ignore the special models for uptake of the two radionuclides. Thus, the results listed next to these identifiers indicate the prediction if uptake of H-3 and C-14 is treated like any other radionuclide.

Table 3-1. Comparison of internal dose factors for ingestion, mrem/pCi.

Nuclide	f1	DOE[a]	GENII[b]	Difference[c] (%)
H-3	1.00	6.30E-08	6.12E-08	-2.9
C-14	1.00	2.10E-06	2.07E-06	-1.4
Co-60	0.30	2.60E-05	2.65E-05	1.9
Ni-59	0.05	2.00E-07	2.05E-07	2.5
Se-79	0.80	8.30E-06	8.35E-06	0.6
Sr-90	0.30	1.40E-04	1.32E-04	-5.7
Tc-99	0.80	1.30E-06	2.23E-06	71.5
I-129	1.00	2.80E-04	2.50E-04	-10.7
Cs-137	1.00	5.00E-05	4.79E-05	-4.2
Ra-226	0.20	1.10E-03	9.56E-04	-13.1
U-238	0.05	2.43E-04	2.72E-04	11.9
Np-237	0.001	3.90E-03	5.25E-03	34.6
Pu-239	0.001	4.30E-03	3.57E-03	-17.0
Pu-241	0.001	8.60E-05	6.81E-05	-20.8
Am-241	0.001	4.50E-03	3.63E-03	-19.3

a. DOE values are from DOE (1988b).

b. GENII values are from the July 1993 recalculation of the GENII dose increment library (Rittmann 1993).

c. Negative percentages mean that the GENII value is smaller than the DOE value.

Table 3-2. Doses from GENII using benchmark parameters, rem/yr per μCi/L.

Nuclide	Vegetable	Milk	Beef	Water	Total
H-3[a]	1.9E-03	6.7E-03	5.4E-03	4.5E-02	5.9E-02
C-14[a]	3.8E+00	1.6E+00	4.8E+00	1.5E+00	1.2E+01
Co-60	2.9E+00	4.8E+00	4.0E+01	1.9E+01	6.7E+01
Ni-59	2.3E-02	1.8E-02	9.6E-02	1.5E-01	2.9E-01
Se-79	9.4E-01	3.0E+00	1.0E+01	6.1E+00	2.0E+01
Sr-90	1.6E+01	1.9E+01	3.4E+00	9.7E+01	1.3E+02
Tc-99	3.9E-01	2.9E+00	2.2E+00	1.6E+00	7.1E+00
I-129	2.8E+01	2.2E+02	1.4E+02	1.8E+02	5.7E+02
Cs-137	5.4E+00	3.0E+01	7.2E+01	3.5E+01	1.4E+02
Ra-226	1.1E+02	3.8E+01	1.8E+01	7.0E+02	8.6E+02
U-238	3.0E+01	1.4E+01	4.0E+00	2.0E+02	2.5E+02
Np-237	5.9E+02	2.4E+00	2.3E+01	3.8E+03	4.4E+03
Pu-239	4.0E+02	3.2E-02	1.4E-01	2.6E+03	3.0E+03
Pu-241	7.6E+00	6.2E-04	2.7E-03	5.0E+01	5.7E+01
Am-241	4.1E+02	1.3E-01	9.8E-01	2.7E+03	3.1E+03

a. This uses the specific activity models in GENII rather than the concentration ratios.

Table 3-3. Dose results from PATHRAE using benchmarks and GENII dose factor, rem/yr per µCi/L.

Nuclide	Vegetable	Milk	Beef	Water	Total
H-3	2.94E-03	7.07E-03	7.30E-03	4.47E-02	6.20E-02
H-3A[a]	1.63E-02	7.69E-02	7.94E-02	4.47E-02	2.17E-01
C-14	0.00E+00	1.50E-01	3.30E-01	1.50E+00	2.00E+00
C-14A[a]	3.23E-01	2.48E+00	5.53E+00	1.51E+00	9.85E+00
Co-60	2.92E+00	4.73E+00	4.06E+01	1.93E+01	6.76E+01
Ni-59	2.34E-02	1.85E-02	9.57E-02	1.50E-01	2.87E-01
Se-79	9.41E-01	3.00E+00	9.72E+00	6.10E+00	1.98E+01
Sr-90	1.62E+01	2.09E+01	3.61E+00	9.64E+01	1.37E+02
Tc-99	3.87E-01	3.41E+00	2.50E+00	1.63E+00	7.93E+00
I-129	2.84E+01	2.27E+02	1.37E+02	1.82E+02	5.75E+02
Cs-137	5.40E+00	3.02E+01	7.45E+01	3.50E+01	1.45E+02
Ra-226	1.07E+02	3.86E+01	1.85E+01	6.98E+02	8.62E+02
U-238	3.05E+01	1.46E+01	4.21E+00	1.99E+02	2.48E+02
Np-237	5.90E+02	2.37E+00	2.25E+01	3.83E+03	4.45E+03
Pu-239	3.99E+02	3.20E-02	1.38E-01	2.61E+03	3.01E+03
Pu-241	7.57E+00	6.09E-04	2.62E-03	4.97E+01	5.73E+01
Am-241	4.06E+02	1.30E-01	9.84E-01	2.65E+03	3.06E+03

a. This is a dummy name to allow use of the concentration ratios assumed for H-3 and C-14, rather than the special environmental transport model used by the code.

Table 3-4. Dose results from PATHRAE using benchmarks and DOE dose factor, rem/yr per µCi/L.

Nuclide	Vegetable	Milk	Beef	Water	Total
H-3	3.02E-03	7.27E-03	7.52E-03	4.60E-02	6.38E-02
H-3A	1.68E-02	7.91E-02	8.18E-02	4.60E-02	2.24E-01
C-14	0.00E+00	1.52E-01	3.40E-01	1.53E+00	2.02E+00
C-14A	3.28E-01	2.52E+00	5.61E+00	1.53E+00	9.99E+00
Co-60	2.87E+00	4.64E+00	3.99E+01	1.90E+01	6.63E+01
Ni-59	2.28E-02	1.80E-02	9.34E-02	1.46E-01	2.80E-01
Se-79	9.36E-01	2.98E+00	9.66E+00	6.06E+00	1.96E+01
Sr-90	1.72E+01	2.22E+01	3.83E+00	1.02E+02	1.45E+02
Tc-99	2.26E-01	1.99E+00	1.46E+00	9.49E-01	4.62E+00
I-129	3.18E+01	2.54E+02	1.53E+02	2.04E+02	6.44E+02
Cs-137	5.63E+00	3.15E+01	7.77E+01	3.65E+01	1.51E+02
Ra-226	1.23E+02	4.44E+01	2.13E+01	8.03E+02	9.92E+02
U-238	2.72E+01	1.31E+01	3.76E+00	1.77E+02	2.21E+02
Np-237	4.38E+02	1.76E+00	1.67E+01	2.85E+03	3.30E+03
Pu-239	4.81E+02	3.85E-02	1.66E-01	3.14E+03	3.62E+03
Pu-241	9.57E+00	7.69E-04	3.31E-03	6.28E+01	7.24E+01
Am-241	5.03E+02	1.61E-01	1.22E+00	3.28E+03	3.79E+03

Table 3-5. Dose differences: GENII versus PATHRAE (benchmarks and GENII dose factor).

Nuclide	Vegetable (%)	Milk (%)	Beef (%)	Water (%)	Total (%)
H-3	-35.4[a]	-5.2	-26.0	0.7	-4.8
H-3A	0.117[b]	0.087[b]	0.068[b]	0.7	0.272[b]
C-14	--[c]	10.7[b]	14.3[b]	-0.7	6.00[b]
C-14A	11.8[b]	-35.5	-13.2	-0.7	21.8
Co-60	-0.7	1.5	-1.5	-1.6	-0.9
Ni-59	-1.7	-2.7	0.3	0.0	1.0
Se-79	-0.1	0.0	2.9	0.0	1.0
Sr-90	-1.2	-9.1	-5.8	0.6	-5.1
Tc-99	0.8	-15.0	-12.0	-1.8	-10.5
I-129	-1.4	-3.1	2.2	-1.1	-0.9
Cs-137	0.0	-0.7	-3.4	0.0	-3.4
Ra-226	2.8	-1.6	-2.7	0.3	-0.2
U-238	-1.6	-4.1	-5.0	0.5	0.8
Np-237	0.0	1.3	2.2	-0.8	-1.1
Pu-239	0.3	0.0	1.4	-0.4	-0.3
Pu-241	0.4	1.8	3.1	0.6	-0.5
Am-241	1.0	0.0	-0.4	1.9	1.3

a. A negative percentage means that the GENII value was smaller than the PATHRAE value.

b. Ratio of doses: GENII/PATHRAE.

c. The PATHRAE dose was zero.

The comparison of GENII and PATHRAE for H-3 in Table 3-5 is within 5%. However, the difference for the vegetable pathway is greater than 35%. This illustrates that vegetables are not the major contributor to dose for H-3. This is identified in Tables 3-7 and 3-8, where vegetable consumption results in 3% and 5% of the total dose for H-3 in GENII and PATHRAE, respectively. However, the two codes differ by a factor of 6 for C-14 (i.e., the dose for GENII is predicted to be 600% greater than PATHRAE). In this case, vegetable uptake has more impact because vegetables account for 32% of the total dose in GENII as shown in Table 3-7.

Tc-99 demonstrates the only other difference greater than 5% between GENII and PATHRAE for these benchmark cases. The different doses are due to the hard-coded assumptions of the stored feed composition given to cattle. GENII assumes that stored feed is 100% grain, while PATHRAE assumes that stored feed is 37.8% grain and 62.2% other vegetation (translocation factor is 0.1, and Bv is used for root uptake). This makes a noticeable difference only for Tc-99, since it has the largest root uptake factors. The importance of the meat and milk pathways for Tc-99 is reflected in Tables 3-7 and 3-8. The meat and milk pathways account for over 70% of the total dose due to Tc-99 in both codes.

Table 3-6. Dose differences: GENII versus PATHRAE (benchmarks and DOE dose factor).

Nuclide	Vegetable (%)	Milk (%)	Beef (%)	Water (%)	Total (%)
H-3	-37.1[a]	-7.8	-28.2	-2.2	-7.5
H-3A	0.113[b]	0.085[b]	0.066[b]	-2.2	0.263[b]
C-14	-[c]	10.5[b]	14.1[b]	-2.0	5.94[b]
C-14A	11.6[b]	-36.5	-14.4	-2.0	20.1
Co-60	1.0	3.4	0.3	0.0	1.1
Ni-59	0.9	0.0	2.8	2.7	3.6
Se-79	0.4	0.7	3.5	0.7	2.0
Sr-90	-7.0	-14.4	-11.2	-4.9	-10.3
Tc-99	72.6	45.7	50.7	68.6	53.7
I-129	-11.9	-13.4	-8.5	-11.8	-11.5
Cs-137	-4.1	-4.8	-7.3	-4.1	-7.3
Ra-226	-10.6	-14.4	-15.5	-12.8	-13.3
U-238	10.3	6.9	6.4	13.0	13.1
Np-237	34.7	36.4	37.7	33.3	33.3
Pu-239	-16.8	-16.9	-15.7	-17.2	-17.1
Pu-241	-20.6	-19.4	-18.4	-20.4	-21.3
Am-241	-18.5	-19.3	-19.7	-17.7	-18.2

a. A negative percentage means that the GENII value was smaller than the PATHRAE value.

b. Ratio of doses: GENII/PATHRAE.

c. The PATHRAE dose was zero.

The small difference for U-238 is due to the treatment of the daughter activity. In PATHRAE, the daughter dose factors were added to the parent. It is assumed that they are in secular equilibrium with the parent in all environmental media. In GENII, the doses from the uptake of daughters are calculated separately from the parent. These doses are then added to give the final dose. In GENII, the daughter concentrations are allowed to depart from equilibrium due to different uptake amounts in environmental media. Since the concentration ratios for Th-234 are much smaller then those for U-238, there is less Th-234 in the produce, and the GENII doses are smaller. This results in a minor difference in doses, but was a difference in the codes deemed worth discussing.

When DOE dose factors are used, Tc-99 doses differed by 54%, which reflects the difference in stored feed discussed above and the difference in dose factors between DOE and GENII. This is identified in Table 3-6.

Table 3-7. Percentage of total dose by pathway for GENII using benchmarks.

Nuclide	Vegetable (%)	Milk (%)	Beef (%)	Water (%)
H-3	3.2	11.4	9.2	76.3
C-14	31.7	13.3	40.0	12.5
Co-60	4.3	7.2	59.7	28.4
Ni-59	7.9	6.2	33.1	51.7
Se-79	4.7	15.0	50.0	30.5
Sr-90	12.3	14.6	2.6	74.6
Tc-99	5.5	40.8	31.0	22.5
I-129	4.9	38.6	24.6	31.6
Cs-137	3.9	21.4	51.4	25.0
Ra-226	12.8	4.4	2.1	81.4
U-238	12.0	5.6	1.6	80.0
Np-237	13.4	0.055	0.52	86.4
Pu-239	13.3	0.0011	0.0047	86.7
Pu-241	13.3	0.0011	0.0047	87.7
Am-241	13.2	0.0042	0.032	87.1

Table 3-8. Percentage of total dose by pathway for PATHRAE using benchmarks.

Nuclide	Vegetable (%)	Milk (%)	Beef (%)	Water (%)
H-3	4.7	11.4	11.8	72.1
H-3A	7.5	35.4	36.6	20.6
C-14	0.0	7.5	16.8	75.5
C-14A	3.3	25.2	56.1	15.3
Co-60	4.3	7.0	60.0	28.6
Ni-59	8.2	6.4	33.3	52.3
Se-79	4.8	15.2	49.1	30.8
Sr-90	11.8	15.3	2.6	70.4
Tc-99	4.9	43.0	31.5	20.6
I-129	4.9	39.5	23.8	31.7
Cs-137	3.7	20.8	51.4	24.1
Ra-226	12.4	4.5	2.1	81.0
U-238	12.3	5.9	1.7	80.2
Np-237	13.3	0.053	0.51	86.1
Pu-239	13.3	0.0011	0.0046	86.7
Pu-241	13.2	0.0011	0.0046	86.7
Am-241	13.3	0.0042	0.032	86.6

3.2 Comparison Using GENII Default Parameters

GENII makes average default values available to the user for all parameters. These defaults are automatically inserted into the input files unless changed by the user. For comparison with the benchmark parameters used in the previous section, doses for the default average individual were computed. This comparison provides an indication of how much difference there can be in results just due to the assumed values used for inputs. Given the somewhat arbitrary nature of the benchmark parameters, the actual magnitude of the differences is not as critical as the fact that differences can be large.

For ingestion doses, there are many differences. An input file is attached for reference in Appendix A. Other default files (DEFAULT.IN and FTRANS.DAT) are described in Napier et al. (1988), the GENII document. A summary of differences between default and benchmark parameters is listed below.

1. GENII default has a different set of concentration ratios.

2. GENII default includes leaching from soil, which has an effect for H-3, C-14, Tc-99, and I-129.

3. GENII default has different (generally larger) consumption values:

   15 kg/y leafy
   140 kg/y other vegetables
   64 kg/y fruit
   72 kg/y grains
   70 kg/y beef
   230 L/y milk
   440 L/y (untreated) drinking water

4. Other environmental parameters, such as dry-to-wet ratios, growing periods, and crop yields also differ. See Appendix A for more information.

The predicted doses by pathway using the GENII average defaults are provided in Table 3-9. Table 3-10 is a comparison of the GENII results using the benchmark values from the previous section and the GENII average defaults. Only four of the radionuclides had differences less than 5%. In general, the differences in total dose were less than 20%, which indicates that the overall impact of using the GENII defaults is small in most cases. However, five radionuclides showed differences in excess of 40%. These radionuclides were Se-79, Sr-90, Tc-99, I-129, and Np-237. The most significant difference was a factor of 48 (i.e., the dose with GENII defaults was 48 times greater) for Se-79. This difference can be attributed to the assumptions for the beef pathway.

3.3 Comparison with Hand Calculations (Spreadsheet)

For comparison with the computer programs, a spreadsheet was developed, which carries out the calculations as conducted in either GENII or PATHRAE. The spreadsheet also served as a

Table 3-9. Doses from GENII using GENII default parameters, rem/yr per µCi/L.

Nuclide	Vegetable	Milk	Beef	Water	Total
H-3	1.2E-02	1.3E-02	4.0E-03	2.7E-02	5.7E-02
C-14	4.3E+00	4.3E+00	4.3E+00	9.1E-01	1.4E+01
Co-60	1.2E+01	4.8E-01	5.6E+01	1.2E+01	8.0E+01
Ni-59	9.1E-02	3.9E-02	4.7E-02	9.0E-02	2.7E-01
Se-79	4.5E+00	3.7E+01	9.2E+02	3.7E+00	9.6E+02
Sr-90	1.1E+02	3.5E+01	1.3E+01	5.8E+01	2.2E+02
Tc-99	1.4E+01	3.6E-01	5.4E-01	9.8E-01	1.6E+01
I-129	1.2E+02	5.7E+02	5.7E+01	1.1E+02	8.6E+02
Cs-137	2.1E+01	6.2E+01	1.6E+02	2.1E+01	2.6E+02
Ra-226	4.3E+02	3.5E+01	1.0E+02	4.2E+02	9.9E+02
U-238	1.2E+02	2.9E+01	8.8E+00	1.2E+02	2.7E+02
Np-237	3.3E+03	1.0E+01	6.3E+02	2.3E+03	6.3E+03
Pu-239	1.5E+03	6.4E-02	7.8E-01	1.6E+03	3.1E+03
Pu-241	2.9E+01	1.2E-03	1.9E-02	3.0E+01	5.9E+01
Am-241	1.5E+03	2.0E-01	8.0E+00	1.6E+03	3.1E+03

Table 3-10. Comparison of GENII results: default and benchmark.

Nuclide	Vegetable (%)	Milk (%)	Beef (%)	Water (%)	Total (%)
H-3	6.32[b]	1.94[b]	-25.9	-40.0	-3.4
C-14	13.2	2.69[b]	-10.4	-39.3	16.7
Co-60	4.14[b]	0.100[b]	40.0	-36.8	19.4
Ni-59	3.96[b]	2.17[b]	0.490[b]	-40.0	-6.9
Se-79	4.79[b]	12.3[b]	92.0[b]	-39.3	48.0[b]
Sr-90	6.88[b]	1.84[b]	3.82[b]	-40.2	69.2
Tc-99	35.9[b]	0.124[b]	0.245[b]	-38.8	2.25[b]
I-129	4.29[b]	2.59[b]	0.407[b]	-38.9	50.9
Cs-137	3.89[b]	2.07[b]	2.22[b]	-40.0	1.86[b]
Ra-226	3.91[b]	-7.9	5.56[b]	-40.0	15.1
U-238	4.00[b]	2.07[b]	2.20[b]	-40.0	8.0
Np-237	5.59[b]	4.17[b]	27.4[b]	-39.5	43.2
Pu-239	3.75[b]	2.00[b]	5.57[b]	-38.5	3.3
Pu-241	3.82[b]	1.94[b]	7.04[b]	-40.0	3.5
Am-241	3.66[b]	53.8	8.16[b]	-40.7	0.0

a. Negative percentages mean that the default value was smaller than the benchmark value.

b. Ratio of default/benchmark doses.

verification tool to identify unique features of the programs that were not documented, and programming errors. Spreadsheet results are provided in Tables 3-11, 3-12, and 3-13. The results from the spreadsheet are compared in Table 3-14. The results from the spreadsheets are compared with the results from the computer codes in Tables 3-15, 3-16, and 3-17. Significant differences are discussed in the following paragraphs.

The results of the GENII and PATHRAE spreadsheet calculations in Table 3-14 are essentially identical except for H-3, C-14, and Tc-99. The differences in Tc-99 are due to the handling of stored feed described previously. An additional factor of one-half in C-14 doses appears in Table 3-15, which accounts for part of the difference observed in Table 3-14. This difference occurs due to a conflict between the GENII documentation and the code. The code introduces a factor of two by making the C-14 concentration in plants depend on the irrigation rate. Otherwise, the differences for H-3 and C-14 can be attributed to the modeling approaches used for uptake in the two codes as discussed in the previous section.

Excluding the factor of two for C-14 discussed above, the results for GENII and the spreadsheet are essentially identical with no differences greater than 5%. Likewise, Table 3-16 illustrates that the spreadsheet reproduces PATHRAE results within 5% for all radionuclides. However, there is a significant difference for the milk and meat pathways for Pu-241.

The Pu-241 dose in the spreadsheet is larger than in PATHRAE because the spreadsheet includes the ingrowth of Am-241. Not much Am-241 grows in during the year, but it adds to the dose because it has both larger dose factors and larger concentration ratios than Pu-241. PATHRAE allows the use of this decay chain, but this feature was not used. Note, however, that the total dose for Pu-241 was still in excellent agreement due to the insignificance of the meat and milk pathways for the total dose. Table 3-8 illustrates that the meat and milk pathways are insignificant contributors as a percentage of total dose in PATHRAE.

Table 3-11. Dose results from the spreadsheet using GENII methods and benchmarks, rem/yr per μCi/L.

Nuclide	Vegetable	Milk	Beef	Water	Total
H-3	1.9E-03	6.5E-03	5.5E-03	4.5E-02	5.9E-02
C-14	1.9E+00	8.1E-01	2.4E+00	1.5E+00	6.6E+00
Co-60	3.0E+00	4.7E+00	4.1E+01	1.9E+01	6.8E+01
Ni-59	2.3E-02	1.8E-02	9.5E-02	1.5E-01	2.9E-01
Se-79	9.4E-01	3.0E+00	9.7E+00	6.1E+00	2.0E+01
Sr-90	1.6E+01	2.0E+01	3.4E+00	9.6E+01	1.4E+02
Tc-99	3.9E-01	3.0E+00	2.2E+00	1.6E+00	7.2E+00
I-129	2.8E+01	2.2E+02	1.4E+02	1.8E+02	5.7E+02
Cs-137	5.4E+00	3.0E+01	7.4E+01	3.5E+01	1.4E+02
Ra-226	1.1E+02	3.9E+01	2.0E+01	7.0E+02	8.6E+02
U-238	3.0E+01	1.4E+01	4.2E+00	2.0E+02	2.5E+02
Np-237	5.9E+02	2.3E+00	2.2E+01	3.8E+03	4.4E+03
Pu-239	4.0E+02	3.2E-02	1.4E-01	2.6E+03	3.0E+03
Pu-241	7.6E+00	6.5E-04	3.0E-03	5.0E+01	5.7E+01
Am-241	4.0E+02	1.3E-01	9.8E-01	2.6E+03	3.1E+03

Table 3-12. Dose results from the spreadsheet using PATHRAE methods and GENII dose factor, rem/yr per μCi/L.

Nuclide	Vegetable	Milk	Beef	Water	Total
H-3	2.94E-03	7.07E-03	7.33E-03	4.47E-02	6.20E-02
H-3A	1.65E-02	7.67E-02	8.00E-02	4.47E-02	2.18E-01
C-14	0.00E+00	1.50E-01	3.35E-01	1.51E+00	2.00E+00
C-14A	3.22E-01	2.45E+00	5.52E+00	1.51E+00	8.93E+00
Co-60	2.96E+00	4.70E+00	4.10E+01	1.93E+01	6.80E+01
Ni-59	2.33E-02	1.83E-02	9.55E-02	1.50E-01	2.87E-01
Se-79	9.38E-01	2.97E+00	9.69E+00	6.10E+00	1.97E+01
Sr-90	1.62E+01	2.08E+01	3.61E+00	9.64E+01	1.37E+02
Tc-99	3.86E-01	3.39E+00	2.50E+00	1.63E+00	7.90E+00
I-129	2.83E+01	2.24E+02	1.37E+02	1.83E+02	5.72E+02
Cs-137	5.39E+00	2.99E+01	7.44E+01	3.50E+01	1.45E+02
Ra-226	1.07E+02	3.93E+01	1.97E+01	6.98E+02	8.64E+02
U-238	3.04E+01	1.45E+01	4.20E+00	1.99E+02	2.48E+02
Np-237	5.88E+02	2.34E+00	2.25E+01	3.83E+03	4.45E+03
Pu-239	3.98E+02	3.16E-02	1.38E-01	2.61E+03	3.00E+03
Pu-241	7.60E+00	6.51E-04	2.99E-03	4.97E+01	5.73E+01
Am-241	4.05E+02	1.29E-01	9.81E-01	2.65E+03	3.06E+03

Table 3-13. Dose results from the spreadsheet using PATHRAE methods and DOE dose factor, rem/yr per μCi/L.

Nuclide	Vegetable	Milk	Beef	Water	Total
H-3	3.02E-03	7.28E-03	7.54E-03	4.60E-02	6.38E-02
H-3A	1.70E-02	7.90E-02	8.24E-02	4.60E-02	2.24E-01
C-14	0.00E+00	1.52E-01	3.40E-01	1.53E+00	2.03E+00
C-14A	3.27E-01	2.49E+00	5.60E+00	1.53E+00	9.06E+00
Co-60	2.91E+00	4.61E+00	4.02E+01	1.90E+01	6.67E+01
Ni-59	2.27E-02	1.78E-02	9.32E-02	1.46E-01	2.80E-01
Se-79	9.33E-01	2.95E+00	9.64E+00	6.06E+00	1.96E+01
Sr-90	1.72E+01	2.20E+01	3.83E+00	1.02E+02	1.45E+02
Tc-99	2.25E-01	1.97E+00	1.46E+00	9.49E-01	4.61E+00
I-129	3.17E+01	2.51E+02	1.53E+02	2.04E+02	6.40E+02
Cs-137	5.63E+00	3.12E+01	7.77E+01	3.65E+01	1.51E+02
Ra-226	1.23E+02	4.50E+01	2.24E+01	8.03E+02	9.93E+02
U-238	2.71E+01	1.29E+01	3.76E+00	1.77E+02	2.21E+02
Np-237	4.37E+02	1.74E+00	1.67E+01	2.85E+03	3.30E+03
Pu-239	4.80E+02	3.81E-02	1.66E-01	3.14E+03	3.62E+03
Pu-241	9.59E+00	8.21E-04	3.77E-03	6.28E+01	7.24E+01
Am-241	5.02E+02	1.60E-01	1.22E+00	3.29E+03	3.79E+03

Table 3-14. Spreadsheet dose differences: GENII versus PATHRAE (benchmarks and GENII dose factor).

Nuclide	Vegetable (%)	Milk (%)	Beef (%)	Water (%)	Total (%)
H-3	-35.4[a]	-7.7	-25.5	0.0	-5.6
H-3A	0.120[b]	0.085[b]	0.068[b]	0.0	0.270[b]
C-14	–[c]	5.39[b]	7.15[b]	0.0	3.29[b]
C-14A	5.76[b]	0.330[b]	0.434[b]	0.0	-33.0
Co-60	0.0	-0.0	-0.0	0.0	-0.0
Ni-59	0.0	0.0	0.0	0.0	0.0
Se-79	0.0	0.0	0.0	0.0	0.0
Sr-90	0.0	-5.0	-5.0	0.0	-0.9
Tc-99	0.0	-12.4	-12.4	0.0	-9.3
I-129	0.0	-0.3	-0.3	0.0	-0.2
Cs-137	0.0	-0.1	-0.1	0.0	-0.1
Ra-226	0.0	-0.0	-0.0	0.0	-0.0
U-238	0.0	-0.0	-0.0	0.0	-0.0
Np-237	0.0	-0.2	-0.2	0.0	-0.0
Pu-239	0.0	-0.0	-0.0	0.0	-0.0
Pu-241	0.0	-0.0	-0.0	0.0	-0.0
Am-241	0.0	-0.0	-0.0	0.0	-0.0

a. A negative percentage means that the GENII value was smaller than the PATHRAE value.

b. Ratio of doses: GENII/PATHRAE.

c. The PATHRAE dose was zero.

Table 3-15. Dose differences: GENII versus spreadsheet (benchmark parameters).

Nuclide	Vegetable (%)	Milk (%)	Beef (%)	Water (%)	Total (%)
H-3	-0.1[a]	-2.6	1.0	-0.7	-0.8
C-14	0.488[b]	0.506[b]	0.499[b]	0.7	0.548[b]
Co-60	2.1	-2.1	2.4	1.8	1.5
Ni-59	1.2	1.4	-0.5	-0.2	-1.1
Se-79	-0.2	-1.2	-3.1	-0.1	-1.5
Sr-90	1.4	3.8	1.0	-0.7	4.4
Tc-99	-0.9	2.3	-0.4	1.7	1.0
I-129	1.2	1.6	-2.6	1.4	0.1
Cs-137	-0.1	-0.5	3.2	-0.1	3.2
Ra-226	-3.0	3.5	9.4	-0.3	0.4
U-238	1.3	3.3	5.1	-0.7	-1.0
Np-237	-0.3	-2.6	-2.6	0.9	1.0
Pu-239	-0.5	-1.2	-1.5	0.2	0.1
Pu-241	-0.1	5.0	10.8	-0.6	0.5
Am-241	-1.2	-1.0	0.1	-1.9	-1.4

a. A negative percentage means that the spreadsheet value was smaller than the GENII value.

b. Ratio of doses: spreadsheet/GENII.

Table 3-16. Dose differences: PATHRAE versus spreadsheet (benchmarks and GENII dose factor).

Nuclide	Vegetable (%)	Milk (%)	Beef (%)	Water (%)	Total (%)
H-3	-0.1[a]	-0.0	0.4	-0.1	0.0
H-3A	1.5	-0.3	0.8	-0.1	0.4
C-14	0.0	0.2	0.1	0.1	-0.2
C-14A	-0.2	-1.0	-0.1	0.1	-0.4
Co-60	1.4	-0.6	1.0	0.2	0.6
Ni-59	-0.5	-1.3	-0.2	-0.2	-0.1
Se-79	-0.3	-1.2	-0.3	-0.1	-0.5
Sr-90	0.2	-0.7	0.1	-0.0	-0.0
Tc-99	-0.1	-0.7	0.0	-0.1	-0.4
I-129	-0.2	-1.3	-0.2	0.3	-0.6
Cs-137	-0.1	-1.0	-0.1	-0.1	-0.2
Ra-226	-0.2	1.9	6.5	-0.0	0.2
U-238	-0.4	-0.9	-0.1	-0.2	-0.2
Np-237	-0.3	-1.1	-0.2	0.1	-0.1
Pu-239	-0.2	-1.2	-0.1	-0.1	-0.2
Pu-241	0.3	6.9	14.1	0.0	0.0
Am-241	-0.3	-1.0	-0.3	-0.0	-0.1

a. A negative percentage means that the spreadsheet value was smaller than the PATHRAE value.

Table 3-17. Dose differences: PATHRAE versus spreadsheet (benchmarks and DOE dose factor).

Nuclide	Vegetable (%)	Milk (%)	Beef (%)	Water (%)	Total (%)
H-3	0.1	0.1	0.3	-0.0[a]	0.0
H-3A	1.4	-0.2	0.7	-0.0	0.2
C-14	0.0	0.3	0.0	0.2	0.3
C-14A	-0.3	-1.2	-0.1	0.2	-0.4
Co-60	1.3	-0.6	0.8	-0.1	0.6
Ni-59	-0.4	-1.0	-0.3	0.0	-0.1
Se-79	-0.3	-1.1	-0.3	-0.0	-0.1
Sr-90	0.1	-0.8	0.1	0.2	0.2
Tc-99	-0.3	-0.8	-0.2	0.0	-0.3
I-129	-0.2	-1.2	0.1	0.2	-0.6
Cs-137	0.0	-1.0	-0.0	0.0	0.0
Ra-226	-0.2	1.3	5.1	0.0	0.1
U-238	-0.2	-1.3	-0.1	0.2	0.1
Np-237	-0.3	-1.1	-0.1	-0.1	0.1
Pu-239	-0.3	-1.1	0.0	-0.0	-0.0
Pu-241	0.2	6.8	13.8	-0.0	-0.0
Am-241	-0.2	-0.9	-0.3	0.2	-0.0

a. A negative percentage means that the spreadsheet value was smaller than the PATHRAE value.

4. DOSES FROM UNIT CONCENTRATION IN CONTAMINATED SOIL

The typical intruder scenario includes doses that result from garden activities on contaminated soil. Dose pathways include external dose from the soil, inhalation of resuspended dust, and ingestion of garden produce. This comparison addresses doses from a 1 Ci/m^3 concentration of each radionuclide in soil. Note that the inhalation and ingestion dose factors include the contribution of short-lived radioactive progeny produced by decay of the long-lived parent in the body. In particular, Cs-137 includes Ba-137m; Ra-226 includes Rn-222, Pb-214, and Bi-214; U-238 includes Th-234, Pa-234m, and Pa-234; Np-237 includes Pa-233; and Pu-241 includes U-237.

4.1 Computer Code Results and Comparisons

Doses from GENII and PATHRAE were calculated for the same 15 radionuclides as the water comparison. An initial soil concentration of 1 Ci/m^3 is assumed. The assumed soil density is 1.5 g/cm^3. The depth of the mixing zone in the soil is 15 cm. The results of the calculations are provided in Table 4-1. Results are provided for four cases: GENII with benchmarks, GENII with average defaults, PATHRAE with benchmarks and GENII dose factor, and PATHRAE with benchmarks and DOE dose factor. Differences between PATHRAE and GENII for the benchmark parameters are included in Table 4-2. Differences for GENII using the benchmark parameters and the GENII defaults are provided in Table 4-3.

Sample program inputs for GENII are included in Appendix A, while samples for PATHRAE are included in Appendix B. A special input parameter was used in the PATHRAE runs for inhalation dose to offset the dilution factor computed internally by this program. The parameter used was the width of the waste site. Instead of 100 m, it was adjusted to 88 m. This accounts for the different mixing depth used in PATHRAE.

The results in Table 4-2 illustrate that all inhalation and ingestion doses have differences less than 10% except for H-3, when the same dose factors are used. The large differences for external dose are discussed below. Table 4-3 illustrates that the inhalation doses are the same for the defaults and the benchmarks; however, large differences exist for the ingestion pathway, and a difference by a factor of three exists for the external pathway. For inhalation of resuspended dust, the GENII defaults are the same as the benchmark assumptions. For external exposure to contamination in the surface layer of soil, the exposure time was 2,920 hours per year, which is one-third of the benchmark assumption.

4.2 Comparison with Hand Calculations (Spreadsheet)

The spreadsheet results use the same input assumptions as the two codes for the cases tested. In addition, an effort was made to consider the effects of radioactive decay. Dose from external and inhalation is accumulated over a period of 1 year. Dose from ingestion of garden produce occurs after the contamination has been on the ground long enough to produce the first crop. The results for the spreadsheet calculations are provided in Table 4-4. Comparisons of GENII and PATHRAE with the respective spreadsheets are provided in Tables 4-5 and 4-6. The results are within 10% for all of the comparisons in the two tables.

Table 4-1. Code results for an initial soil contamination, rem per Ci/m^3.

GENII nuclide	Benchmark parameters			GENII default parameters		
	Inhale	Ingest	External	Inhale	Ingest	External
H-3	5.1E-05	0.0E+00	3.8E-08	5.1E-05	0.0E+00	1.3E-08
C-14	1.2E-03	0.0E+00	8.3E-03	1.2E-03	0.0E+00	2.8E-03
Co-60	1.1E-01	1.1E+00	8.7E+03	1.1E-01	8.5E+01	2.9E+03
Ni-59	7.3E-04	6.8E-02	1.5E-01	7.3E-04	7.4E-01	4.8E-02
Se-79	5.4E-03	1.1E+00	5.9E-03	5.4E-03	1.4E+02	2.0E-03
Sr-90	1.2E-01	2.4E+02	2.2E+01	1.2E-01	8.7E+03	7.4E+00
Tc-99	5.1E-03	2.3E+01	5.6E-02	5.1E-03	3.7E+03	1.9E-02
I-129	8.6E-02	7.6E+01	6.1E+00	8.6E-02	4.1E+03	2.0E+00
Cs-137	1.7E-02	8.5E+00	2.1E+03	1.7E-02	3.5E+01	6.9E+02
Ra-226	4.7E+00	1.1E+01	6.5E+03	4.7E+00	3.1E+03	2.2E+03
U-238	6.7E+01	6.4E+00	8.3E+01	6.7E+01	3.6E+01	2.8E+01
Np-237	3.6E+02	4.0E+02	8.1E+02	3.6E+02	1.7E+05	2.7E+02
Pu-239	2.5E+02	1.2E+00	1.5E-01	2.5E+02	6.1E+01	5.1E-02
Pu-241	4.7E+00	2.3E-02	8.5E-03	4.7E+00	1.2E+00	2.9E-03
Am-241	2.5E+02	9.1E+00	1.6E+01	2.5E+02	2.5E+02	5.2E+00

PATHRAE nuclide	Using GENII dose factor			Using DOE dose factor		
	Inhale	Ingest	External	Inhale	Ingest	External
H-3	5.0E-05	0.0E+00	0.0E+00	3.5E-05	0.0E+00	0.0E+00
H-3A	5.0E-05	1.6E+00	0.0E+00	3.5E-05	1.7E+00	0.0E+00
C-14	1.1E-03	0.0E+00	0.0E+00	1.2E-03	0.0E+00	0.0E+00
C-14A	1.1E-03	1.5E+01	0.0E+00	1.2E-03	1.5E+01	0.0E+00
Co-60	1.1E-01	1.1E+00	3.9E+04	8.3E-02	1.1E+00	3.9E+04
Ni-59	7.1E-04	6.9E-02	0.0E+00	7.2E-04	6.7E-02	0.0E+00
Se-79	5.3E-03	1.2E+00	0.0E+00	4.9E-03	1.2E+00	0.0E+00
Sr-90	1.2E-01	2.5E+02	0.0E+00	1.3E-01	2.6E+02	0.0E+00
Tc-99	5.0E-03	2.3E+01	0.0E+00	4.2E-03	1.3E+01	0.0E+00
I-129	8.4E-02	7.5E+01	6.1E+02	1.0E-01	8.4E+01	6.1E+02
Cs-137	1.7E-02	8.5E+00	1.1E+04	1.8E-02	8.9E+00	1.1E+04
Ra-226	4.6E+00	1.1E+01	3.2E+04	4.4E+00	1.2E+01	3.2E+04
U-238	6.5E+01	6.3E+00	1.3E+03	6.6E+01	5.7E+00	1.3E+03
Np-237	3.5E+02	4.0E+02	1.3E+04	2.7E+02	2.9E+02	1.3E+04
Pu-239	2.4E+02	1.2E+00	1.8E+01	2.8E+02	1.5E+00	1.8E+01
Pu-241	4.5E+00	2.3E-02	2.1E-01	5.5E+00	2.9E-02	2.1E-01
Am-241	2.5E+02	9.3E+00	1.1E+03	2.9E+02	1.1E+01	1.1E+03

Table 4-2. Dose differences: PATHRAE and GENII (benchmark parameters).

	Using GENII dose factor			Using DOE dose factor		
Nuclide	Inhale (%)	Ingest (%)	External	Inhale (%)	Ingest (%)	External
H-3	2.0	—	—	45.7	—	—
H-3A	2.0	—	—	45.7	—	—
C-14	9.1	—	—	0.0	—	—
C-14A	9.1	—	—	0.0	—	—
Co-60	0.0	0.0	0.223[a]	32.5	0.0	0.223[s]
Ni-59	2.8	-1.4[b]	—	1.4	1.5	—
Se-79	1.9	-8.3	—	10.2	-8.3	—
Sr-90	0.0	-4.0	—	-7.7	-7.7	—
Tc-99	2.0	0.0	—	21.4	1.77[a]	—
I-129	2.4	1.3	0.010[a]	-14.0	-9.5	0.010[a]
Cs-137	0.0	0.0	0.191[a]	-5.6	-4.5	0.191[a]
Ra-226	2.2	0.0	0.203[a]	6.8	-8.3	0.203[a]
U-238	3.1	1.6	0.064[a]	1.5	12.3	0.064[a]
Np-237	2.9	0.0	0.062[a]	33.3	37.9	0.062[a]
Pu-239	4.2	0.0	0.008[a]	-10.7	-20.0	0.008[a]
Pu-241	4.4	0.0	0.040[a]	-14.5	-20.7	0.040[a]
Am-241	0.0	-2.2	0.015[a]	-13.8	-17.3	0.015[a]

a. Ratio of GENII/PATHRAE.

b. A negative percentage means that the GENII value was smaller than the PATHRAE value.

There is a small difference between GENII and PATHRAE regarding how they consider radioactive decay for computing vegetation concentrations. PATHRAE only decays the soil contamination during the delay time between harvest and consumption. Since this is at most 60 days, there is essentially no decay for the half-lives we are using. GENII decays the soil contamination during both the growing period and the delay period. This adds only another 60 days, so there is essentially no difference in the dose results.

4.3 External Dose from PATHRAE

The method used by PATHRAE to calculate external dose from contaminated soil is designed to include the shielding provided by a soil cover over the waste. The amount of cover is variable because PATHRAE allows input soil cover thickness, and it may decrease with time due to a user-provided surface erosion rate. However, it was discovered that PATHRAE does not actually reduce the thickness of the soil cover when computing external dose rates.

Table 4-3. GENII differences: benchmark and default parameters.

Nuclide	Inhale	Ingest[a]	External[a]
H-3	0.0	—	0.342
C-14	0.0	—	0.337
Co-60	0.0	77.3	0.333
Ni-59	0.0	10.9	0.320
Se-79	0.0	127	0.339
Sr-90	0.0	36.3	0.336
Tc-99	0.0	161	0.339
I-129	0.0	53.9	0.328
Cs-137	0.0	4.12	0.329
Ra-226	0.0	282	0.338
U-238	0.0	5.63	0.337
Np-237	0.0	425	0.333
Pu-239	0.0	50.8	0.340
Pu-241	0.0	52.2	0.341
Am-241	0.0	27.5	0.325

a. Ratio of default to benchmark dose.

The benchmark case has zero cover. For this case, the formula used by PATHRAE (Equation 2-15 in Rogers and Hung 1987) is paraphrased below as

$$\text{Dose rate} = Cs \cdot [1 + 1.3293/Eg + B \cdot \text{Exp}(-\mu \cdot D)] \cdot DFG \cdot (8{,}760 \text{ hr/yr})/\mu$$

where

Dose rate	=	external dose rate, rem/yr
Cs	=	soil concentration, pCi/m^3
Eg	=	energy of the average photon emitted, Mev
B	=	dose buildup factor in soil, $B = 1 + (\mu \cdot D)^{1.5}/Eg$
μ	=	photon attenuation coefficient in soil, per meter
D	=	soil depth, meters
DFG	=	infinite plane dose conversion factor, mrem/hr per pCi/m^2.

Table 4-4. Spreadsheet results for soil contamination, rem per Ci/m3.

GENII nuclide	Benchmark parameters		
	Inhale	Ingest	External
H-3	5.1E-05	0.0E+00	3.8E-08
C-14	1.2E-03	0.0E+00	8.2E-03
Co-60	1.1E-01	1.1E+00	8.7E+03
Ni-59	7.3E-04	6.9E-02	1.4E-01
Se-79	5.4E-03	1.2E+00	5.9E-03
Sr-90	1.2E-01	2.5E+02	2.2E+01
Tc-99	5.1E-03	2.3E+01	5.5E-02
I-129	8.6E-02	7.5E+01	6.1E+00
Cs-137	1.7E-02	8.5E+00	2.1E+03
Ra-226	4.7E+00	1.1E+01	6.5E+03
U-238	6.7E+01	6.3E+00	8.3E+01
Np-237	3.6E+02	4.0E+02	8.1E+02
Pu-239	2.5E+02	1.2E+00	1.5E-01
Pu-241	4.7E+00	2.4E-02	8.9E-03
Am-241	2.5E+02	9.3E+00	1.6E+01

PATHRAE nuclide	Using GENII dose factor			Using DOE dose factor		
	Inhale	Ingest	External	Inhale	Ingest	External
H-3	5.1E-05	0.0E+00	0.0E+00	3.5E-05	0.0E+00	0.0E+00
H-3A	5.1E-05	1.6E+00	0.0E+00	3.5E-05	1.7E+00	0.0E+00
C-14	1.2E-03	0.0E+00	0.0E+00	1.2E-03	0.0E+00	0.0E+00
C-14A	1.2E-03	1.5E+01	0.0E+00	1.2E-03	1.5E+01	0.0E+00
Co-60	1.1E-01	1.1E+00	3.9E+04	8.4E-02	1.1E+00	3.9E+04
Ni-59	7.3E-04	6.9E-02	0.0E+00	7.3E-04	6.7E-02	0.0E+00
Se-79	5.4E-03	1.2E+00	0.0E+00	5.0E-03	1.2E+00	0.0E+00
Sr-90	1.2E-01	2.5E+02	0.0E+00	1.3E-01	2.6E+02	0.0E+00
Tc-99	5.1E-03	2.3E+01	0.0E+00	4.2E-03	1.3E+01	0.0E+00
I-129	8.6E-02	7.5E+01	6.1E+02	1.0E-01	8.4E+01	6.1E+02
Cs-137	1.7E-02	8.5E+00	1.1E+04	1.8E-02	8.9E+00	1.1E+04
Ra-226	4.7E+00	1.1E+01	3.2E+04	4.4E+00	1.2E+01	3.2E+04
U-238	6.7E+01	6.3E+00	1.3E+03	6.7E+01	5.7E+00	1.3E+03
Np-237	3.6E+02	4.0E+02	1.3E+04	2.7E+02	2.9E+02	1.3E+04
Pu-239	2.5E+02	1.2E+00	1.8E+01	2.9E+02	1.5E+00	1.8E+01
Pu-241	4.7E+00	2.4E-02	2.1E-01	5.6E+00	3.0E-02	2.1E-01
Am-241	2.5E+02	9.3E+00	1.1E+03	2.9E+02	1.1E+01	1.1E+03

Table 4-5. Dose differences: GENII versus spreadsheet.

GENII nuclide	Benchmark parameters Inhale (%)	Ingest (%)	External (%)
H-3	0.6	—	1.3
C-14	-2.0[a]	—	-0.6
Co-60	3.8	1.0	-0.1
Ni-59	-0.4	0.9	-3.3
Se-79	0.3	5.9	-0.3
Sr-90	0.3	4.0	1.3
Tc-99	0.1	-1.8	-0.9
I-129	-0.3	-1.0	0.1
Cs-137	0.2	0.5	-0.8
Ra-226	-0.6	-1.1	-0.4
U-238	0.0	-0.9	0.1
Np-237	0.3	-0.8	-0.1
Pu-239	-1.4	1.2	2.1
Pu-241	-0.9	4.3	4.9
Am-241	0.7	2.1	-1.7

a. A negative percentage means that the spreadsheet dose was smaller than the GENII dose.

This formula does not include the physics of the problem (i.e., not based on calculational methods for a volume source distributed in surface soil). The formula appears to be fit to data over a limited range of photon energies, but outside that range, significant errors are introduced. The results of external dose calculations for PATHRAE and GENII are provided in Table 4-7. There are significant differences for all radionuclides considered.

Shown in Table 4-7 are the values used in the current benchmark cases and the dose results predicted by the above formula if the soil concentration is 1 Ci/m^3. The values for average photon energy come from *Table of Radioactive Isotopes* (Browne and Firestone 1986). The attenuation coefficients come from concrete with a density of 1.5 g/cm^3 as reported in ANSI/ANS-6.4.3-1991, Table 1a. The DFG values were obtained from DOE/EH-0070 (DOE 1988c.)

Note that the values for Eg include the contribution of radioactive progeny (see Table 4-8). In particular, Cs-137 includes Ba-137m; Ra-226 includes Rn-222, Pb-214, and Bi-214; U-238 includes Th-234, Pa-234m, and Pa-234; Np-237 includes Pa-233; and Pu-241 includes U-237. Note also that the values for attenuation coefficient are based on the value for Eg. The values for DFG for PATHRAE are for an infinite plane source. PATHRAE then adjusts these for the finite soil thickness.

Table 4-6. Dose differences: PATHRAE versus spreadsheet.

PATHRAE nuclide	Using GENII dose factor			Using DOE dose factor		
	Inhale	Ingest	External	Inhale	Ingest	External
H-3	2.6	—	—	0.9	—	—
H-3A	2.6	2.5	—	0.9	-0.7[a]	—
C-14	6.9	—	—	-1.9	—	—
C-14A	6.9	-0.7	—	-1.9	0.7	—
Co-60	3.8	1.0	0.1	1.3	-0.9	0.1
Ni-59	2.4	-0.5	—	1.2	-0.1	—
Se-79	2.2	-2.9	—	1.8	-3.5	—
Sr-90	0.3	-0.2	—	2.3	1.8	—
Tc-99	2.1	-1.8	—	0.1	1.3	—
I-129	2.1	0.3	-0.6	0.9	0.3	-0.6
Cs-137	0.2	0.5	2.9	-0.4	0.2	2.9
Ra-226	1.5	-1.1	-0.4	0.6	4.2	-0.4
U-238	3.1	0.6	2.9	1.9	-0.6	2.9
Np-237	3.2	-0.8	-2.6	1.7	1.7	-2.6
Pu-239	2.7	1.2	-2.3	2.1	-2.5	-2.3
Pu-241	3.5	4.3	1.7	2.1	4.3	1.7
Am-241	0.7	-0.1	-2.0	0.5	4.5	-2.0

a. A negative percentage means that the spreadsheet dose was smaller than the PATHRAE dose.

Table 4-7. External dose parameters and annual doses for PATHRAE and GENII. (Soil Concentration is 1 Ci/m^3. Contamination thickness is 0.15 m.)

Nuclide	μ	Eg	DFG[a]	PATHRAE rem/yr	GENII DRF[b]	GENII rem/yr
Co-60	8.5	1.25	2.59E-08	3.90E+04	2.35E-09	8.70E+03
I-129	158	0.031	2.51E-10	6.06E+02	2.35E-09	6.11E+00
Cs-137	12	0.613	6.59E-09	1.13E+04	5.63E-10	2.08E+03
Ra-226	11.2	0.709	1.92E-08	3.19E+04	1.75E-09	6.49E+03
U-238	31.3	0.077	2.80E-10	1.34E+03	2.24E-11	8.31E+01
Np-237	24.5	0.109	3.06E-09	1.27E+04	2.19E-10	8.09E+02
Pu-239	24.3	0.111	4.31E-12	1.76E+01	4.14E-14	1.53E-01
Pu-241	30.4	0.079	4.50E-14	2.14E-01	2.22E-15	8.23E-03
Am-241	103	0.037	3.41E-10	1.08E+03	4.24E-12	1.57E+01

a. Units are mrem/hour per pCi/m^2 (infinite plane with zero thickness).

b. Units are Sieverts/year per Becquerel/m^3 in the top 15 cm of soil.

Table 4-8. Nuclides with short-lived progeny.[a]

Nuclide	Progeny included in calculations
Sr-90	Y-90
Cs-137	Ba-137m (0.946)
Ra-226	Rn-222, Po-218, Pb-214, Bi-214, Po-214
U-238	Th-234, Pa-234m, Pa-234 (0.0016)
Np-237	Pa-233
Pu-241	U-237 (2.45E-05)

a. Branching ratios different from 1 are shown.

4.4 External Dose from GENII

The method used by GENII is a point-kernel integration using attenuation coefficients and buildup factors from ISOSHLD. The method in GENII applies directly to volume sources distributed in surface soil. The external dose factor (EXTDF) generator program, which generated the dose factors for GENII, converts the exposure rates to dose equivalent. The computed dose rate factors for specific geometries is stored in a data file (GRDF.DAT) read by GENII. The formula used by GENII to compute the external dose is the following:

$$\text{Dose rate} = \text{Cs} \cdot \text{DRF} \cdot (3.7 \times 10^{12} \text{ rem/Sv} \cdot \text{Bq/Ci})$$

where

Dose rate	=	external dose rate, rem/yr
Cs	=	soil concentration, Ci/m^3
DRF	=	dose rate factor generated by EXTDF, Sv/yr per Bq/m^3.

Note that the GENII DRF values include the contribution of the same short-lived radioactive progeny mentioned earlier. Note also that the GENII DRF values include the contribution from bremsstrahlung radiation for sources such as Sr-90. Finally, Table 4-7 ignores radioactive decay and the ingrowth of long-lived progeny. Hence the dose results for GENII are slightly larger than is shown for the spreadsheet results in Table 4-4. The results for the GENII calculations referred to in this section are included in Table 4-7.

4.5 External Dose Using Microshield and ISOSHLD-PC

Previously, GENII and PATHRAE were compared. Additional comparisons were also conducted using MICROSHIELD (Version 3.12 by Grove Engineering) and ISOSHLD-PC (Version 1.6) and results were published in FGR 12 (EPA 1993). Results from all of the approaches are compared in Section 4.6.

For the MICROSHIELD and ISOSHLD calculations, the assumed configuration was a 15-cm thickness of soil that was infinite in extent. The exposure rates were computed at a height of 1 m above this layer. The assumed air density was 1.22 kg/m^3. Two soil densities were used: 1.5 kg/L and 1.6 kg/L. The soil was modelled as concrete for calculation of photon attenuation and buildup.

Short-lived progeny nuclides were included in the calculation of exposure rates as specified in Table 4-8. Branching ratios which differed from 1 are also included in the table. In MICROSHIELD, these progeny were allowed to accumulate by using a decay time of 1 year.

Tables 4-9 and 4-10 show the exposure rates computed by MICROSHIELD and ISOSHLD. The conversion from exposure (R) to dose equivalent (rem) has not been carried out in these tables due to the variety of methods for this conversion and its energy dependence.

Table 4-9. External dose results from MICROSHIELD.

	R/h per μCi/cm^3		R/y per μCi/m^3	
Nuclide	1.5 g/cm^3	1.6 g/cm^3	1.5 g/cm^3	1.6 g/cm^3
H-3	0	0	0	0
C-14	0	0	0	0
Co-60	1.700E+00	1.629E+00	1.49E-02	1.43E-02
Ni-59	0	0	0	0
Se-79	0	0	0	0
Sr-90	0	0	0	0
Tc-99	0	0	0	0
I-129	0	0	0	0
Cs-137	4.486E-01	4.284E-01	3.93E-03	3.76E-03
Ra-226	1.212E+00	1.160E+00	1.06E-02	1.02E-02
U-238	1.020E-02	9.760E-03	8.94E-05	8.56E-05
Np-237	1.240E-01	1.177E-01	1.09E-03	1.03E-03
Pu-239	2.067E-05	1.948E-05	1.81E-07	1.71E-07
Pu-241	1.153E-06	1.090E-06	1.01E-08	9.55E-09
Am-241	3.596E-08	3.414E-08	3.15E-10	2.99E-10

Table 4-10. External dose results from ISOSHLD.

Nuclide	R/h per µCi/cm³		R/y per µCi/m³	
	1.5 g/cm³	1.6 g/cm³	1.5 g/cm³	1.6 g/cm³
H-3	0	0	0	0
C-14	4.325E-06	4.055E-06	3.79E-08	3.55E-08
Co-60	1.612E+00	1.543E+00	1.41E-02	1.35E-02
Ni-59	0	0	0	0
Se-79	3.343E-06	3.134E-06	2.93E-08	2.75E-08
Sr-90	4.659E-03	4.417E-03	4.08E-05	3.87E-05
Tc-99	2.008E-05	1.884E-05	1.76E-07	1.65E-07
I-129	4.475E-03	4.195E-03	3.92E-05	3.68E-05
Cs-137	4.382E-01	4.177E-01	3.84E-03	3.66E-03
Ra-226	1.171E+00	1.120E+00	1.03E-02	9.82E-03
U-238	1.533E-02	1.458E-02	1.34E-04	1.28E-04
Np-237	1.666E-01	1.582E-01	1.46E-03	1.39E-03
Pu-239	8.366E-05	7.870E-05	7.33E-07	6.90E-07
Pu-241	2.416E-06	2.279E-06	2.12E-08	2.00E-08
Am-241	4.867E-03	4.563E-03	4.27E-05	4.00E-05

The first two columns of numbers show the code output in R/h for an input concentration of 1 µCi/cm³. These are then converted by hand to the units chosen for this comparison, R/y per µCi/m³. The conversion factor used is 8.766E-03 hr· m³/yr· cm³. The density has little effect. Decreasing the density increased the exposure rate by only 6% at most.

4.6 Comparison of Computer Code Results and FGR 12 Results

Dose rates from GENII and PATHRAE were provided in Table 4-7. The conversion factors for changing exposure to dose equivalent in GENII are provided in Table 4-11. The doses in Table 4-7 had to be scaled down for the lower soil concentration being assumed. Values from FGR 12 are also shown. These values were also converted to the comparison units using the factor 1.1676E+14 rem· sec· Bq per Sv· year· Ci. External dose results for revised GENII and PATHRAE calculations and from FGR 12 are provided in Table 4-12. The FGR 12 values should be considered the best currently available, since a considerably more sophisticated photon transport model was employed in their derivation.

The assumed soil densities in the calculations are slightly different. GENII assumes a density of 1.5 kg/L, and the PATHRAE calculations were done using the same density. Meanwhile, FGR 12 assumes a density of 1.6 kg/L. From the previous calculations, it is apparent that this density difference has little effect.

Table 4-11. Conversion from exposure to dose equivalent in GENII.

Photon energies (MeV)			Conversion factors	
Midpoint	Low	High	rem/R	R/rem
0.015	0.01	0.02	0.0424	23.58
0.025	0.02	0.03	0.131	7.63
0.035	0.03	0.04	0.267	3.75
0.045	0.04	0.05	0.41	2.44
0.055	0.05	0.06	0.507	1.97
0.065	0.06	0.07	0.55	1.82
0.075	0.07	0.08	0.59	1.69
0.085	0.08	0.09	0.62	1.61
0.095	0.09	0.1	0.65	1.54
0.15	0.1	0.2	0.67	1.49
0.25	0.2	0.3	0.66	1.52
0.35	0.3	0.4	0.65	1.54
0.475	0.4	0.55	0.65	1.54
0.65	0.55	0.75	0.66	1.52
0.825	0.75	0.9	0.67	1.49
1	0.9	1.1	0.68	1.47
1.225	1.1	1.35	0.7	1.43
1.475	1.35	1.6	0.72	1.39
1.7	1.6	1.8	0.74	1.35
1.9	1.8	2	0.76	1.32
2.1	2	2.2	0.765	1.31
2.3	2.2	2.4	0.77	1.30
2.5	2.4	2.6	0.775	1.29
2.7	2.6	2.8	0.777	1.29
3	2.8	3.2	0.78	1.28

Comparisons between GENII, ISOSHLD, and MICROSHIELD are shown in Table 4-13. The first two columns of numbers show the ratios of ISOSHLD to MICROSHIELD exposure rates. The last two columns show the ratios of ISOSHLD and MICROSHIELD with GENII.

The principal differences between ISOSHLD and MICROSHIELD are the inclusion of bremsstrahlung radiation in ISOSHLD and the lower photon energies allowed in ISOSHLD. The first difference shows up as nonzero values for most of the beta emitters. Tritium is a very low energy photon emitter, while Ni-59 decays by electron capture, and thus emits almost nothing. The second difference shows up as a really large exposure rate ratio between ISOSHLD and MICROSHIELD for Am-241. MICROSHIELD ignores the photons less than 0.1 MeV, which is most of the source for Am-241.

Table 4-12. External dose results from GENII, PATHRAE and FGR 12.

Nuclide	GENII (rem/y per μCi/m³) 1.5 g/cm³	PATHRAE (rem/y per μCi/m³) 1.5 g/cm³	FGR 12 (rem/y per μCi/m³) 1.6 g/cm³	FGR 12 Sv/s per Bq/m³ 1.6 g/cm³
H-3	3.8E-14	0	0	0
C-14	8.3E-09	0	8.41E-09	7.20E-23
Co-60	8.7E-03	3.9E-02	8.47E-03	7.25E-17
Ni-59	1.5E-07	0	0	0
Se-79	5.9E-09	0	1.16E-08	9.96E-23
Sr-90	2.2E-05	0	1.44E-05	1.24E-19
Tc-99	5.6E-08	0	7.82E-08	6.70E-22
I-129	6.1E-06	6.1E-04	8.09E-06	6.93E-20
Cs-137	2.1E-03	1.1E-02	1.93E-03	1.65E-17
Ra-226	6.5E-03	3.2E-02	5.89E-03	5.05E-17
U-238	8.3E-05	1.3E-03	7.42E-05	6.36E-19
Np-237	8.1E-04	1.3E-02	6.51E-04	5.58E-18
Pu-239	1.5E-07	1.8E-05	1.77E-07	1.52E-21
Pu-241	8.5E-09	2.1E-07	1.16E-08	9.96E-23
Am-241	1.6E-05	1.1E-03	2.73E-05	2.34E-19

Table 4-13. Comparisons between MICROSHIELD, ISOSHLD, and GENII.

Nuclide	ISOSHLD/MICROSHIELD 1.5 g/cm³	ISOSHLD/MICROSHIELD 1.6 g/cm³	ISO/GENII 1.5 g/cm³	MICRO/GENII 1.5 g/cm³
H-3	—	—	—	—
C-14	—	—	4.57	—
Co-60	0.95	0.95	1.62	1.71
Ni-59	—	—	—	—
Se-79	—	—	4.97	—
Sr-90	—	—	1.86	—
Tc-99	—	—	3.14	—
I-129	—	—	6.43	—
Cs-137	0.98	0.98	1.83	1.87
Ra-226	0.97	0.97	1.58	1.63
U-238	1.50	1.49	1.62	1.08
Np-237	1.34	1.34	1.80	1.34
Pu-239	4.05	4.04	4.89	1.21
Pu-241	2.10	2.09	2.49	1.19
Am-241	1.4E-05	1.3E-05	2.67	2.0E-05

The differences between ISOSHLD and GENII are mostly due to ISOSHLD results being in units of exposure rate (R/y), while GENII results are in units of dose equivalent rate (rem/y). The energy groups and the corresponding conversion factors used by the GENII EXTDF are shown in Table 4-11. Low-energy photons produce the greatest difference between exposure and dose equivalent. Values for nuclides with well-defined photon energies agree fairly well. For example, the ISOSHLD/GENII ratio for Cs-137 is 1.83, while the conversion factor ratio is 1.52.

Table 4-14 shows ratios between FGR 12 and each of the other models. The agreement with GENII is remarkable, in view of the substantial differences in the photon transport methods followed. This illustrates that GENII provides the best approximation of the approach used in FGR 12. The results for MICROSHIELD are also relatively close. There are more significant differences in the ISOSHLD results, and PATHRAE provided the worst match of the codes considered. It should be noted that the ISOSHLD and PATHRAE codes both overestimate the doses and, thus, could be considered conservative. Some differences between the codes are due to the fact that MICROSHIELD and ISOSHLD calculate exposure, which is converted to dose equivalent, while GENII, PATHRAE, and FGR 12 calculate dose equivalent. These comparisons provide an indication of the radionuclides that are modeled well by the different codes as well as radionuclides that are not modeled as well.

Table 4-14. Ratios with FGR 12.

Nuclide	MSHIELD	ISOSHLD	GENII	PATHRAE
H-3	—	—	—	—
C-14	—	4.23	0.99	—
Co-60	1.69	1.60	1.03	4.6
Ni-59	—	—	—	—
Se-79	—	2.36	0.51	—
Sr-90	—	2.68	1.52	—
Tc-99	—	2.11	0.72	—
I-129	—	4.54	0.75	75.4
Cs-137	1.95	1.90	1.09	5.7
Ra-226	1.73	1.67	1.10	5.4
U-238	1.15	1.72	1.12	17.5
Np-237	1.58	2.13	1.24	20.0
Pu-239	0.96	3.89	0.85	101.4
Pu-241	0.82	1.72	0.73	18.1
Am-241	0.0	1.46	0.59	40.3

5. CONCLUSIONS

Computer codes and approaches for modeling doses due to exposure to water, soil, and foods contaminated with radionuclides were compared. The comparison addressed the ingestion, inhalation, and external exposure pathways for a number of radionuclides common to performance assessments of low-level waste disposal facilities. The purpose of the comparison was to identify similarities and differences between the codes and input data as well as develop a better understanding of the models included in the codes. The intent was not to recommend specific parameters or approaches. Rather, the intent was to make potential users aware of differences and the potential impacts of the differences on modeling results. A primary conclusion of this effort is the need for users to understand the computer code and models and the inputs used in some detail. Such understanding will result in more defensible analyses.

GENII and PATHRAE were compared for all of the pathways, and additional comparisons with MICROSHIELD, ISOSHLD, and FGR 12 were conducted for the external exposure pathway. Spreadsheet calculations were also conducted for comparison with GENII and PATHRAE results. The spreadsheet calculations provided the opportunity to identify any subtle differences between the codes and as an error check. One of the baseline parameters that has an impact on all results is the dose factor for ingestion. PATHRAE was compared with GENII using the GENII binary dose factor files and the DOE dose factor from DOE (1988b). This comparison allowed differences simply due to use of different dose factor libraries. Additional comparisons were conducted using the GENII average default values. Effects of changes in input parameters are identified through this comparison.

5.1 Comparison for Unit Concentration in Groundwater

GENII and PATHRAE results were compared for ingestion of vegetables, milk, meat, and water contaminated by 15 radionuclides. Attempts were made to make the inputs for the two codes as consistent as possible. The results for total dose were very similar for most of the radionuclides considered. Differences in total dose of slightly more than 10% were identified for Tc-99 due to the way stored feed is treated in the two codes. Stored feed affects the calculations for the milk and meat pathways, which are more significant for Tc-99 than other radionuclides. The largest differences for the two codes related to treatment of uptake of H-3 and C-14. The two codes use different models for uptake of these two radionuclides. Users should exercise caution when interpreting results for C-14 and H-3.

The comparison between GENII using the benchmark values and GENII using built in average defaults was good for most of the radionuclides considered. Most of the differences in total dose were less than 20%. In general, the water pathway was uniformly different due to the different consumption rate assumed in the GENII defaults. The largest difference occurred for Se-79, where the total dose was 48 times greater using the GENII defaults. Tc-99 differed by a factor of two, and Sr-90, Cs-137, and Np-237 differed by 40% or more.

Spreadsheet comparisons with the two codes were nearly identical for all radionuclides and pathways. The only significant difference was for C-14 in GENII (a factor of two). This difference resulted from the dependence of C-14 uptake on the irrigation rate, which not identified in the manual.

5.2 Comparison for Unit Concentration in Soil

Ingestion and inhalation pathways compared well for GENII and PATHRAE. The only significant difference was ingestion of H-3, which results from different models for uptake. The external pathway did not compare well. External exposure is discussed separately in the following section. Comparisons between GENII and GENII average defaults were excellent except for the ingestion pathway, where significant differences occurred for a number of radionuclides. This illustrates the potential for rather large differences based on the choice of somewhat arbitrary input values. The comparison of spreadsheet calculations with the two codes yielded excellent agreement.

5.3 Comparison of External Exposure Calculations

Five approaches were compared for the external exposure pathway. The GENII, PATHRAE, MICROSHIELD, and ISOSHLD codes and the results from FGR 12 were considered. FGR 12 is presumed to provide the most accurate model for the comparison. GENII resulted in the best agreement with FGR 12. GENII provided the best comparison with the worst case still within a factor of two of the FGR 12 results. MICROSHIELD also agreed well with FGR 12 except for Am-241 and lower energy emitters. ISOSHLD and PATHRAE did not agree as well. PATHRAE provided the worst comparison with all radionuclides, varying by a factor of five or more from the FGR 12 results.

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Appendix A

GENII Input Files

Appendix A

GENII Input Files

GENII Input File for the Irrigator Dose Calculations

```
######################### Program GENII Input File ############  8 Jul 88 ####
Title: All Ingestion Pathways - Irrigation
      \ALL.IN                              Created on 11-04-1992 at 17:39
OPTIONS========================= Default ===================================
T    Near-field scenario?      (Far-field)    NEAR-FIELD: narrowly-focused
F    Population dose?         (Individual)                release, single site
F    Acute release?             (Chronic)     FAR-FIELD:  wide-scale release,
     Average Individual data set used                     multiple sites
                              Complete                                Complete
TRANSPORT OPTIONS============ Section   EXPOSURE PATHWAY OPTIONS===== Section
F  Air Transport                  1     F  Finite plume, external       5
F  Surface Water Transport        2     F  Infinite plume, external     5
F  Biotic Transport (near-field) 3,4    F  Ground, external             5
F  Waste Form Degradation (near) 3,4    F  Recreation, external         5
                                        F  Inhalation uptake            5,6
REPORT OPTIONS======================    T  Drinking water ingestion     7,8
T  Report AEDE only                     F  Aquatic foods ingestion      7,8
F  Report by radionuclide               T  Terrestrial foods ingestion  7,9
T  Report by exposure pathway           T  Animal product ingestion     7,10
F  Debug report on screen               F  Inadvertent soil ingestion

INVENTORY ##################################################################

 2   Inventory input activity units: (1-pCi  2-uCi  3-mCi  4-Ci  5-Bq)
 0   Surface soil source units (1- m2  2- m3  3- kg)
     Equilibrium question goes here

     --------|----Release Terms------|----------Basic Concentrations---------|
     Use when| transport selected    | near-field scenario, optionally       |
     --------|-----------------------|---------------------------------------|
     Release |        Surface Buried |        Surface Deep    Ground  Surface|
     Radio-  |Air     Water   Waste  |Air     Soil    Soil    Water   Water  |
     nuclide |/yr     /yr     /m3    |/m3     /unit   /m3     /L      /L     |
     --------|------- ------- -------|------- ------- ------- ------- -------|
     H 3                                                      1.0E+00

     --------|----Derived Concentrations-----|
     Use when|   measured values are known   |
     --------|-------------------------------|
     Release |Terres. Animal  Drink   Aquatic|
     Radio-  |Plant   Product Water   Food   |
     nuclide |/kg     /kg     /L      /kg    |
     --------|------- ------- ------- -------|

TIME #######################################################################

1    Intake ends after (yr)
50   Dose calc. ends after (yr)
0    Release ends after (yr)
0    No. of years of air deposition prior to the intake period
0    No. of years of irrigation water deposition prior to the intake period
```

```
FAR-FIELD SCENARIOS (IF POPULATION DOSE) ####################################

0          Definition option: 1-Use population grid in file POP.IN
0                             2-Use total entered on this line

NEAR-FIELD SCENARIOS ########################################################

           Prior to the beginning of the intake period: (yr)
0            When was the inventory disposed?  (Package degradation starts)
0            When was LOIC?  (Biotic transport starts)
1.0        Fraction of roots in upper soil (top 15 cm)
0          Fraction of roots in deep soil
0.0        Manual redistribution: deep soil/surface soil dilution factor
1250       Source area for external dose modification factor (m2)

TRANSPORT ###################################################################

           ====AIR TRANSPORT====================================SECTION 1=====

                  0-Calculate PM              |0          Release type (0-3)
 1         Option: 1-Use chi/Q or PM value    |F          Stack release (T/F)
                  2-Select MI dist & dir      |0          Stack height (m)
                  3-Specify MI dist & dir     |0          Stack flow (m3/sec)
0          Chi/Q or PM value                  |0          Stack radius (m)
0          MI sector index (1=S)              |0          Effluent temp. (C)
0          MI distance from release point (m)|0          Building x-section (m2)
T          Use jf data, (T/F) else chi/Q grid|0          Building height (m)

           ====SURFACE WATER TRANSPORT==========================SECTION 2=====

0          Mixing ratio model: 0-use value, 1-river, 2-lake
0          Mixing ratio, dimensionless
0          Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0          Transit time to irrigation withdrawl location (hr)
           If mixing ratio model > 0:
0            Rate of effluent discharge to receiving water body (m3/s)
0            Longshore distance from release point to usage location (m)
0            Offshore distance to the water intake (m)
0            Average water depth in surface water body (m)
0            Average river width (m), MIXFLG=1 only
0            Depth of effluent discharge point to surface water (m), lake only

           ====WASTE FORM AVAILABILITY==========================SECTION 3=====

0          Waste form/package half life, (yr)
0          Waste thickness, (m)
0          Depth of soil overburden, m

           ====BIOTIC TRANSPORT OF BURIED SOURCE================SECTION 4=====

T          Consider during inventory decay/buildup period (T/F)?
T          Consider during intake period (T/F)?   | 1-Arid non agricultural
0          Pre-Intake site condition..............| 2-Humid non agricultural
                                                  | 3-Agricultural
```

```
EXPOSURE #######################################################################

         ====EXTERNAL EXPOSURE================================SECTION 5=====

         Exposure time:                 |  Residential irrigation:
0          Plume (hr)                   | T       Consider: (T/F)
0          Soil contamination (hr)      | 1       Source: 1-ground water
0          Swimming (hr)                |                 2-surface water
0          Boating (hr)                 | 40.0    Application rate (in/yr)
0          Shoreline activities (hr)    | 6.0     Duration (mo/yr)
0        Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
0        Transit time for release to reach aquatic recreation (hr)
0        Average fraction of time submersed in acute cloud (hr/person hr)

         ====INHALATION======================================SECTION 6=====

0        Hours of exposure to contamination per year
0        0-No resus-  1-Use Mass Loading          2-Use Anspaugh model
0          pension      Mass loading factor (g/m3)  Top soil available (cm)

         ====INGESTION POPULATION============================SECTION 7=====

0        Atmospheric production definition (select option):
0          0-Use food-weighted chi/Q, (food-sec/m3), enter value on this line
           1-Use population-weighted chi/Q
           2-Use uniform production
           3-Use chi/Q and production grids (PRODUCTION will be overridden)
0        Population ingesting aquatic foods, 0 defaults to total (person)
0        Population ingesting drinking water, 0 defaults to total (person)
F        Consider dose from food exported out of region (default=F)

         Note below: S* or Source: 0-none, 1-ground water, 2-surface water
                                   3-Derived concentration entered above

         ==== AQUATIC FOODS / DRINKING WATER INGESTION=========SECTION 8====

F        Salt water? (default is fresh)

         USE        TRAN-  PROD-    -CONSUMPTION- |
         ?   FOOD   SIT    UCTION   HOLDUP  RATE  |
         T/F TYPE   hr     kg/yr    da      kg/yr |      DRINKING WATER
         --- ------ -----  -------  ------  ----- |------------------------
         F   FISH    0.00  0.0E+00   0.00    0.0  | 1     Source (see above)
         F   MOLLUS  0.00  0.0E+00   0.00    0.0  | F     Treatment? T/F
         F   CRUSTA  0.00  0.0E+00   0.00    0.0  | 1.0   Holdup/transit(da)
         F   PLANTS  0.00  0.0E+00   0.00    0.0  | 730.0 Consumption (L/yr)

         ====TERRESTRIAL FOOD INGESTION======================SECTION 9=====

         USE        GROW   --IRRIGATION--          PROD-    --CONSUMPTION--
         ?   FOOD   TIME   S RATE   TIME    YIELD  UCTION   HOLDUP   RATE
         T/F TYPE   da     * in/yr  mo/yr   kg/m2  kg/yr    da       kg/yr
         --- ------ -----  - -----  -----   -----  -------  ------   ------
         T   LEAF V 60.00  1  36.0   6.0     0.1   0.0E+00    1.0      5.0
         F   ROOT V 60.00  1   0.0   6.0     0.1   0.0E+00   60.0      0.0
         F   FRUIT  60.00  1   0.0   6.0     0.1   0.0E+00   60.0      0.0
         T   GRAIN  60.00  1  36.0   6.0     0.1   0.0E+00   60.0     43.0
```

====ANIMAL PRODUCTION CONSUMPTION===================SECTION 10====

USE ? T/F	FOOD TYPE	---HUMAN---- CONSUMPTION RATE kg/yr	HOLDUP da	TOTAL PROD-UCTION kg/yr	DRINK WATER CONTAM FRACT.	DIET FRAC-TION	GROW TIME da	S *	-IRRIGATION-- RATE in/yr	TIME mo/yr	YIELD kg/m3	STOR-AGE da
						-------------STORED FEED						
T	BEEF	95.0	20.0	0.00	1.00	0.25	30.0	1	36.0	6.00	0.10	90.0
F	POULTR	0.0	0.0	0.00	1.00	1.00	30.0	1	0.0	6.00	0.10	0.0
T	MILK	110.0	2.0	0.00	1.00	0.25	30.0	1	36.0	6.00	0.10	90.0
F	EGG	0.0	0.0	0.00	1.00	1.00	30.0	1	0.0	6.00	0.10	0.0
						-------------FRESH FORAGE------------						
	BEEF					0.75	30.0	1	36.0	6.00	0.10	0.0
	MILK					0.75	30.0	1	36.0	6.00	0.10	0.0

##

GENII Input File for the Intruder Dose Calculations

```
######################### Program GENII Input File ############  8 Jul 88 ####
Title: Intruder:  Inhale, Veggie, & External (50 yr Dose)
      \INTRUDE.IN                                Created on 09-03-1993 at 11:36
OPTIONS========================= Default ====================================
T    Near-field scenario?       (Far-field)    NEAR-FIELD: narrowly-focused
F    Population dose?          (Individual)                release, single site
F    Acute release?              (Chronic)     FAR-FIELD:  wide-scale release,
     Average Individual data set used                      multiple sites
                               Complete                                Complete
TRANSPORT OPTIONS============ Section    EXPOSURE PATHWAY OPTIONS===== Section
F  Air Transport                  1      F  Finite plume, external       5
F  Surface Water Transport        2      F  Infinite plume, external     5
F  Biotic Transport (near-field)  3,4    T  Ground, external             5
F  Waste Form Degradation (near)  3,4    F  Recreation, external         5
                                         T  Inhalation uptake            5,6
REPORT OPTIONS======================     F  Drinking water ingestion     7,8
T  Report AEDE only                      F  Aquatic foods ingestion      7,8
F  Report by radionuclide                T  Terrestrial foods ingestion  7,9
F  Report by exposure pathway            F  Animal product ingestion     7,10
F  Debug report on screen                F  Inadvertent soil ingestion

INVENTORY ####################################################################

 4   Inventory input activity units: (1-pCi  2-uCi  3-mCi  4-Ci  5-Bq)
 2   Surface soil source units (1- m2  2- m3  3- kg)
     Equilibrium question goes here

     --------|----Release Terms------|----------Basic Concentrations---------|
     Use when| transport selected    |  near-field scenario, optionally      |
     --------|-----------------------|---------------------------------------|
     Release |        Surface Buried |        Surface Deep    Ground  Surface|
     Radio-  |Air     Water   Waste  |Air     Soil    Soil    Water   Water  |
     nuclide |/yr     /yr     /m3    |/m3     /unit   /m3     /L      /L     |
     --------|------- ------- -------|------- ------- ------- ------- -------|
     CS137                                      1.0

     --------|----Derived Concentrations-----|
     Use when|  measured values are known    |
     --------|-------------------------------|
     Release |Terres. Animal  Drink   Aquatic|
     Radio-  |Plant   Product Water   Food   |
     nuclide |/kg     /kg     /L      /kg    |
     --------|------- ------- ------- -------|

TIME #########################################################################

1    Intake ends after (yr)
50   Dose calc. ends after (yr)
0    Release ends after (yr)
0    No. of years of air deposition prior to the intake period
0    No. of years of irrigation water deposition prior to the intake period

FAR-FIELD SCENARIOS (IF POPULATION DOSE) #####################################

0          Definition option: 1-Use population grid in file POP.IN
0                             2-Use total entered on this line
```

```
NEAR-FIELD SCENARIOS ##########################################################

          Prior to the beginning of the intake period: (yr)
0           When was the inventory disposed?  (Package degradation starts)
0           When was LOIC?  (Biotic transport starts)
1.0       Fraction of roots in upper soil (top 15 cm)
0         Fraction of roots in deep soil
0.0       Manual redistribution: deep soil/surface soil dilution factor
1250      Source area for external dose modification factor (m2)

TRANSPORT #####################################################################

          ====AIR TRANSPORT===================================SECTION 1=====

                  0-Calculate PM            |0        Release type (0-3)
 1        Option: 1-Use chi/Q or PM value   |F        Stack release (T/F)
                  2-Select MI dist & dir    |0        Stack height (m)
                  3-Specify MI dist & dir   |0        Stack flow (m3/sec)
0         Chi/Q or PM value                 |0        Stack radius (m)
0         MI sector index (1=S)             |0        Effluent temp. (C)
0         MI distance from release point (m)|0        Building x-section (m2)
T         Use jf data, (T/F) else chi/Q grid|0        Building height (m)

          ====SURFACE WATER TRANSPORT=========================SECTION 2=====

0         Mixing ratio model: 0-use value, 1-river, 2-lake
0         Mixing ratio, dimensionless
0         Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0         Transit time to irrigation withdrawl location (hr)
          If mixing ratio model > 0:
0           Rate of effluent discharge to receiving water body (m3/s)
0           Longshore distance from release point to usage location (m)
0           Offshore distance to the water intake (m)
0           Average water depth in surface water body (m)
0           Average river width (m), MIXFLG=1 only
0           Depth of effluent discharge point to surface water (m), lake only

          ====WASTE FORM AVAILABILITY=========================SECTION 3=====

0         Waste form/package half life, (yr)
0         Waste thickness, (m)
0         Depth of soil overburden, m

          ====BIOTIC TRANSPORT OF BURIED SOURCE================SECTION 4=====

T         Consider during inventory decay/buildup period (T/F)?
T         Consider during intake period (T/F)?  | 1-Arid non agricultural
0         Pre-Intake site condition.............| 2-Humid non agricultural
                                                | 3-Agricultural

EXPOSURE ######################################################################

          ====EXTERNAL EXPOSURE===============================SECTION 5=====
          Exposure time:                 |  Residential irrigation:
0           Plume (hr)                   | T        Consider: (T/F)
8766.0      Soil contamination (hr)      | 0        Source: 1-ground water
0           Swimming (hr)                |                  2-surface water
0           Boating (hr)                 | 0        Application rate (in/yr)
0           Shoreline activities (hr)    | 0        Duration (mo/yr)
0         Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
0         Transit time for release to reach aquatic recreation (hr)
0         Average fraction of time submersed in acute cloud (hr/person hr)
```

====INHALATION=====================================SECTION 6=====

8766.0	Hours of exposure to contamination per year
1	0-No resus- 1-Use Mass Loading 2-Use Anspaugh model
0.0001	pension Mass loading factor (g/m3) Top soil available (cm)

====INGESTION POPULATION===========================SECTION 7=====

0	Atmospheric production definition (select option):
0	0-Use food-weighted chi/Q, (food-sec/m3), enter value on this line
	1-Use population-weighted chi/Q
	2-Use uniform production
	3-Use chi/Q and production grids (PRODUCTION will be overridden)
0	Population ingesting aquatic foods, 0 defaults to total (person)
0	Population ingesting drinking water, 0 defaults to total (person)
F	Consider dose from food exported out of region (default=F)

Note below: S* or Source: 0-none, 1-ground water, 2-surface water
3-Derived concentration entered above

==== AQUATIC FOODS / DRINKING WATER INGESTION=========SECTION 8====

F Salt water? (default is fresh)

USE ? T/F	FOOD TYPE	TRAN-SIT hr	PROD-UCTION kg/yr	-CONSUMPTION- HOLDUP da	RATE kg/yr	DRINKING WATER	
F	FISH	0.00	0.0E+00	0.00	0.0	0	Source (see above)
F	MOLLUS	0.00	0.0E+00	0.00	0.0	T	Treatment? T/F
F	CRUSTA	0.00	0.0E+00	0.00	0.0	0	Holdup/transit(da)
F	PLANTS	0.00	0.0E+00	0.00	0.0	0	Consumption (L/yr)

====TERRESTRIAL FOOD INGESTION=====================SECTION 9=====

USE ? T/F	FOOD TYPE	GROW TIME da	--IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m2	PROD-UCTION kg/yr	--CONSUMPTION-- HOLDUP da	RATE kg/yr
T	LEAF V	60.00	0	0.0	0.0	0.1	0.0E+00	1.0	5.0
T	ROOT V	60.00	0	0.0	0.0	0.1	0.0E+00	60.0	43.0
F	FRUIT	60.00	0	0.0	0.0	0.1	0.0E+00	60.0	43.0
F	GRAIN	60.00	0	0.0	0.0	0.1	0.0E+00	60.0	43.0

====ANIMAL PRODUCTION CONSUMPTION==================SECTION 10====

USE ? T/F	FOOD TYPE	---HUMAN---- CONSUMPTION RATE kg/yr	HOLDUP da	TOTAL PROD-UCTION kg/yr	DRINK WATER CONTAM FRACT.	-------------STORED FEED------------- DIET FRAC-TION	GROW TIME da	-IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m3	STOR-AGE da
T	BEEF	95.0	20.0	0.00	0.00	0.25	30.0	0	0.0	0.00	0.10	90.0
F	POULTR	0.0	0.0	0.00	0.00	1.00	0.0	0	0.0	0.00	0.10	0.0
T	MILK	110.0	2.0	0.00	0.00	0.25	30.0	0	0.0	0.00	0.10	90.0
F	EGG	0.0	0.0	0.00	0.00	1.00	0.0	0	0.0	0.00	0.10	0.0
						-------------FRESH FORAGE------------						
	BEEF					0.75	30.0	0	0.0	0.00	0.10	0.0
	MILK					0.75	30.0	0	0.0	0.00	0.10	0.0

##

GENII Parameter File (DEFAULT.IN) with Benchmark Values

```
Benchmark Default Parameter Values (3 Sep 1993)

INVENTORY PARAMETERS---------------------------------------------------------
0.037, 3.7E4, 3.7E7, 3.7E10, 1.0             NVU     Source input conversion
1.0, 0.15, 224.0                             SVU     Soil source conversion

ENVIRONMENTAL PARAMETERS-----------------------------------------------------
0.008                                        ABSHUM  Absolute humidity (kg/m3)
2                                            PRCNTI  Air dispersion conserv. flag
0.001                                        DPVRES  Deposition vel./resuspension
0.0                                        * LEAFRS  Leaf resuspension factor
4*2.0, 6*1.0                               * BIOMAS  BIOMA2 Biomass (kg/m2)
0.25                                         DEPFR2  Interception frac./irrigate
15.0                                         SURCM   Depth of surface soil (cm)
224.0                                        SLDN    Surface soil density (kg/m2)
1.5E3                                        SSLDN   Soil density (kg/m3)
True                                         HARVST  Harvest removal considered?
410.0                                        SOLING  Soil ingested (mg/da)
14.0                                         WTIM    Weathering time (da)
1.0, 0.1, 0.1, 0.1                           TRANS   Translocation, plants
0.1, 0.1, 0.1, 0.1, 1.0, 1.0                 TRANSA  Translocation, animal food
50.0, 0.12, 50.0, 0.12, 50.0, 50.0         * CONSUM  Animal Consumption (kg/da)
55.0, 0.3, 55.0, 0.3                       * DWATER  Animal drinking water (L/da)
0.0, 0.8, 1.0, 0.8                           FRACUT  Acute fresh forage by season
0.2, 0.3, 0.5, 1.0                           SHORWI  Shore width factors
0.02                                         INGWAT  Swim water ingested (L/hr)
25295.0                                      TCWS    H2O/sed. transfer (L/m2/yr)
0.4,  5.0, 4.0                               YELDBT  BIOT: Veg. prod. (kg/m2/yr)
9.41E-4, 2*7.48E-4                           TOTEXC  BIOT: Excavation (m2/m3-yr)
1.0, 0.81, 0.19, 0.02, 0.008, 0.002,         EXCAV   BIOT: Frac. soil brought to
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005,              surface from within the
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005               waste by animal excavation
270.0                                        RINH    Chronic breathing (cm3/sec)
330.0                                        RINHA   Acute breathing (cm3/sec)
10                                           NDIST   Number of distances
805.0, 2414.0, 4023.0, 5632.0, 7241.0,
12068.0, 24135.0, 40255.0, 56315.0,
72405.0                                      X       JF/chi/Q/pop grid dist. (m)
0.066, 3*0.187, 4*0.68, 2*0.243            * DRYFAC, DRYFA2 dry/wet ratio

METABOLIC PARAMETERS---------------------------------------------------------
0.5, 50.0, 500.0                                         XDIV
0.5,  0.5,  0.95, 0.05,  0.8, 0.0, 0.0,  0.2, 0.0,       ADJ
0.1,  0.9,  0.5,  0.5,  0.15, 0.4, 0.4, 0.05, 0.0,
0.01, 0.99, 0.01, 0.99, 0.05, 0.4, 0.4, 0.135, 0.015

DOSE PARAMETERS--------------------------------------------------------------
0.25, 0.15, 0.12, 0.12, 0.03, 0.03, 5*0.06               WT   Weighting factors
2.0                                                      SI2I Semi-infinite/inf
=============================================================================
```

GENII Food Transfer Factor Library File (FTRANS.DAT) with Benchmark Values

Food Transfer Factors, ORNL-5785, No Leaching (2/12/93 PDR) by symbol

Ele-ment	Dep Spd m/sec	Soil-to-Plant Conc Ratios Leafy	Root	Fruit	Grain	Beef day/kg	Poultry day/kg	Milk day/L	Egg day/kg	Leach Factr
AC	0.001	0.0035	0.00035	0.00035	0.00035	2.5E-05	0.004	2E-05	0.002	0.0
AG	0.001	0.4	0.1	0.1	0.1	0.003	0	0.02	0	0.0
AL	0.001	0.004	0.00065	0.00065	0.00065	0.0015	0	0.0002	0	0.0
AM	0.001	0.0055	0.00025	0.00025	0.00025	3.5E-06	0.0002	4E-07	0.009	0.0
AR	0	0	0	0	0	0	0	0	0	0.0
AS	0.001	0.04	0.006	0.006	0.006	0.002	0.83	6E-05	0	0.0
AT	0.001	1	0.15	0.15	0.15	0.01	0	0.01	0	0.0
AU	0.001	0.4	0.1	0.1	0.1	0.008	0	5.5E-06	0	0.0
B	0.001	4	2	2	2	0.0008	0	0.0015	0	0.0
BA	0.001	0.15	0.015	0.015	0.015	0.00015	0.00081	0.00035	1.5	0.0
BE	0.001	0.01	0.0015	0.0015	0.0015	0.001	0.4	9E-07	0.02	0.0
BI	0.001	0.035	0.005	0.005	0.005	0.0004	0	0.0005	0	0.0
BK	0.001	0.0055	0.00025	0.00025	0.00025	3.5E-06	0.0002	4E-07	0.009	0.0
BR	0.01	1.5	1.5	1.5	1.5	0.025	0.004	0.02	1.6	0.0
C	0	0	0	0	0	0	0	0	0	0.0
CA	0.001	3.5	0.35	0.35	0.35	0.0007	0.044	0.01	0.44	0.0
CD	0.001	0.55	0.15	0.15	0.15	0.00055	0.84	0.001	0.1	0.0
CE	0.001	0.01	0.004	0.004	0.004	0.00075	0.01	2E-05	0.005	0.0
CF	0.001	0.00085	1.5E-05	1.5E-05	1.5E-05	3.5E-06	0.004	2E-05	0.002	0.0
CL	0.001	70	70	70	70	0.08	0.03	0.015	0	0.0
CM	0.001	0.00085	1.5E-05	1.5E-05	1.5E-05	3.5E-06	0.004	2E-05	0.002	0.0
CO	0.001	0.02	0.007	0.007	0.007	0.02	0.5	0.002	0.1	0.0
CR	0.001	0.0075	0.0045	0.0045	0.0045	0.0055	0	0.0015	0	0.0
CS	0.001	0.08	0.03	0.03	0.03	0.02	4.4	0.007	0.49	0.0
CU	0.001	0.4	0.25	0.25	0.25	0.01	0.51	0.0015	0.49	0.0
DY	0.001	0.01	0.004	0.004	0.004	0.0055	0	2E-05	0	0.0
ER	0.001	0.01	0.004	0.004	0.004	0.004	0	2E-05	0	0.0
EU	0.001	0.01	0.004	0.004	0.004	0.005	0.004	2E-05	0.007	0.0
F	0.01	0.06	0.006	0.006	0.006	0.15	0	0.001	0	0.0
FE	0.001	0.004	0.001	0.001	0.001	0.02	1.5	0.00025	1.3	0.0
FR	0.001	0.03	0.008	0.008	0.008	0.0025	0	0.02	0	0.0
GA	0.001	0.004	0.0004	0.0004	0.0004	0.0005	0	5E-05	0	0.0
GD	0.001	0.01	0.004	0.004	0.004	0.0035	0	2E-05	0	0.0
GE	0.001	0.4	0.08	0.08	0.08	0.7	0	0.07	0	0.0
H	0	0	0	0	0	0	0	0	0	0.0
HF	0.001	0.0035	0.00085	0.00085	0.00085	0.001	0	5E-06	0	0.0
HG	0.001	0.9	0.2	0.2	0.2	0.25	0.011	0.00045	0	0.0
HO	0.001	0.01	0.004	0.004	0.004	0.0045	0.004	2E-05	0.007	0.0
I	0.01	0.15	0.05	0.05	0.05	0.007	0.018	0.01	2.8	0.0
IN	0.001	0.004	0.0004	0.0004	0.0004	0.008	0	0.0001	0	0.0
IR	0.001	0.055	0.015	0.015	0.015	0.0015	0	2E-06	0	0.0
K	0.001	1	0.55	0.55	0.55	0.02	0	0.007	0	0.0
KR	0	0	0	0	0	0	0	0	0	0.0
LA	0.001	0.01	0.004	0.004	0.004	0.0003	0.1	2E-05	0.009	0.0
LI	0.001	0.025	0.004	0.004	0.004	0.01	0	0.02	0	0.0
LU	0.001	0.01	0.004	0.004	0.004	0.0045	0	2E-05	0	0.0
MG	0.001	1	0.55	0.55	0.55	0.005	0	0.004	1.6	0.0

GENII Food Transfer Factor Library File -- Continued (column header repeated)

Ele-	Dep Spd	Soil-to-Plant Conc Ratios				Beef	Poultry	Milk	Egg	Leach
ment	m/sec	Leafy	Root	Fruit	Grain	day/kg	day/kg	day/L	day/kg	Factr
MN	0.001	0.25	0.05	0.05	0.05	0.0004	0.05	0.00035	0.065	0.0
MO	0.001	0.25	0.06	0.06	0.06	0.006	0.19	0.0015	0.78	0.0
N	0.001	30	30	30	30	0.075	0	0.025	0	0.0
NA	0.001	0.075	0.055	0.055	0.055	0.055	0.01	0.035	0.2	0.0
NB	0.001	0.02	0.005	0.005	0.005	0.25	0.00031	0.02	0.0013	0.0
ND	0.001	0.01	0.004	0.004	0.004	0.0003	0.004	2E-05	0.0002	0.0
NE	0	0	0	0	0	0	0	0	0	0.0
NI	0.001	0.06	0.06	0.06	0.06	0.006	0.001	0.001	0.1	0.0
NP	0.001	0.1	0.01	0.01	0.01	5.5E-05	0.004	5E-06	0.002	0.0
OS	0.001	0.015	0.0035	0.0035	0.0035	0.4	0	0.005	0	0.0
P	0.001	3.5	3.5	3.5	3.5	0.055	0.19	0.015	10	0.0
PA	0.001	0.0025	0.00025	0.00025	0.00025	1E-05	0.004	5E-06	0.002	0.0
PB	0.001	0.045	0.009	0.009	0.009	0.0003	0	0.00025	0	0.0
PD	0.001	0.15	0.04	0.04	0.04	0.004	0.0003	0.01	0.004	0.0
PM	0.001	0.01	0.004	0.004	0.004	0.005	0.002	2E-05	0.02	0.0
PO	0.001	0.0025	0.0004	0.0004	0.0004	0.0003	0	0.00035	0	0.0
PR	0.001	0.01	0.004	0.004	0.004	0.0003	0.03	2E-05	0.005	0.0
PT	0.001	0.095	0.025	0.025	0.025	0.004	0	0.005	0	0.0
PU	0.001	0.00045	4.5E-05	4.5E-05	4.5E-05	5E-07	0.00015	1E-07	0.008	0.0
RA	0.001	0.015	0.0015	0.0015	0.0015	0.00025	0	0.00045	2E-05	0.0
RB	0.001	0.15	0.07	0.07	0.07	0.015	2	0.01	3	0.0
RE	0.001	1.5	0.35	0.35	0.35	0.008	0	0.0015	0	0.0
RH	0.001	0.15	0.04	0.04	0.04	0.002	0.0003	0.01	0.004	0.0
RN	0	0	0	0	0	0	0	0	0	0.0
RU	0.001	0.075	0.02	0.02	0.02	0.002	0.007	6E-07	0.006	0.0
S	0.001	1.5	1.5	1.5	1.5	0.1	0	0.015	0	0.0
SB	0.001	0.2	0.03	0.03	0.03	0.001	0.006	0.0001	0.07	0.0
SC	0.001	0.006	0.001	0.001	0.001	0.015	0.004	5E-06	0	0.0
SE	0.001	0.025	0.025	0.025	0.025	0.015	8.5	0.004	9.3	0.0
SI	0.001	0.35	0.07	0.07	0.07	4E-05	0	2E-05	0	0.0
SM	0.001	0.01	0.004	0.004	0.004	0.005	0.004	2E-05	0.007	0.0
SN	0.001	0.03	0.006	0.006	0.006	0.08	0	0.001	0	0.0
SR	0.001	2.5	0.25	0.25	0.25	0.0003	0.035	0.0015	0.3	0.0
TA	0.001	0.01	0.0025	0.0025	0.0025	0.0006	0	3E-06	0	0.0
TB	0.001	0.01	0.004	0.004	0.004	0.0045	0.004	2E-05	0.007	0.0
TC	0.001	9.5	1.5	1.5	1.5	0.0085	0.03	0.01	3	0.0
TE	0.001	0.025	0.004	0.004	0.004	0.015	0.085	0.0002	5.2	0.0
TH	0.001	0.00025	8.5E-05	8.5E-05	8.5E-05	6E-06	0.004	5E-06	0.002	0.0
TI	0.001	0.0055	0.003	0.003	0.003	0.03	0	0.01	0	0.0
TL	0.001	0.004	0.0004	0.0004	0.0004	0.04	0	0.002	0	0.0
TM	0.001	0.01	0.004	0.004	0.004	0.0045	0	2E-05	0	0.0
U	0.001	0.0085	0.004	0.004	0.004	0.0002	1.2	0.0006	0.99	0.0
V	0.001	0.0055	0.003	0.003	0.003	0.0025	0	2E-05	0	0.0
W	0.001	0.045	0.01	0.01	0.01	0.045	0	0.0003	0	0.0
XE	0	0	0	0	0	0	0	0	0	0.0
Y	0.001	0.015	0.006	0.006	0.006	0.0003	0.01	2E-05	0.002	0.0
YB	0.001	0.01	0.004	0.004	0.004	0.004	0	2E-05	0	0.0
ZN	0.001	1.5	0.9	0.9	0.9	0.1	6.5	0.01	2.6	0.0
ZR	0.001	0.002	0.0005	0.0005	0.0005	0.0055	6.4E-05	3E-05	0.00019	0.0

GENII Input File with Default Parameters for an Average Individual

```
######################### Program GENII Input File ############  8 Jul 88 ####
Title: All Ingestion Pathways - Irrigation
     \ALL-D.IN                                   Created on 11-02-1993 at 10:03
OPTIONS========================= Default ===================================
T    Near-field scenario?      (Far-field)    NEAR-FIELD: narrowly-focused
F    Population dose?         (Individual)                release, single site
F    Acute release?              (Chronic)    FAR-FIELD:  wide-scale release,
     Average Individual data set used                     multiple sites
                                Complete                              Complete
TRANSPORT OPTIONS============ Section    EXPOSURE PATHWAY OPTIONS===== Section
F  Air Transport                  1      F  Finite plume, external       5
F  Surface Water Transport        2      F  Infinite plume, external     5
F  Biotic Transport (near-field) 3,4     F  Ground, external             5
F  Waste Form Degradation (near) 3,4     F  Recreation, external         5
                                         F  Inhalation uptake            5,6
REPORT OPTIONS=======================    T  Drinking water ingestion     7,8
T  Report AEDE only                      F  Aquatic foods ingestion      7,8
F  Report by radionuclide                T  Terrestrial foods ingestion  7,9
F  Report by exposure pathway            T  Animal product ingestion     7,10
F  Debug report on screen                F  Inadvertent soil ingestion

INVENTORY ####################################################################

 2   Inventory input activity units: (1-pCi  2-uCi  3-mCi  4-Ci  5-Bq)
 0   Surface soil source units (1- m2  2- m3  3- kg)
     Equilibrium question goes here

     --------|----Release Terms------|----------Basic Concentrations---------|
     Use when|  transport selected   |  near-field scenario, optionally      |
     --------|-----------------------|---------------------------------------|
     Release |        Surface Buried |        Surface Deep    Ground  Surface|
     Radio-  |Air     Water   Waste  |Air     Soil    Soil    Water   Water  |
     nuclide |/yr     /yr     /m3    |/m3     /unit   /m3     /L      /L     |
     --------|------- ------- -------|------- ------- ------- ------- -------|
     TC99                                                    1.0E+00

     --------|----Derived Concentrations-----|
     Use when|  measured values are known    |
     --------|-------------------------------|
     Release |Terres. Animal  Drink   Aquatic|
     Radio-  |Plant   Product Water   Food   |
     nuclide |/kg     /kg     /L      /kg    |
     --------|------- ------- ------- -------|

TIME #########################################################################

1    Intake ends after (yr)
50   Dose calc. ends after (yr)
0    Release ends after (yr)
0    No. of years of air deposition prior to the intake period
0    No. of years of irrigation water deposition prior to the intake period

FAR-FIELD SCENARIOS (IF POPULATION DOSE) #####################################

0          Definition option: 1-Use population grid in file POP.IN
0                             2-Use total entered on this line
```

```
NEAR-FIELD SCENARIOS ##########################################################

          Prior to the beginning of the intake period: (yr)
0           When was the inventory disposed?  (Package degradation starts)
0           When was LOIC?  (Biotic transport starts)
1.0       Fraction of roots in upper soil (top 15 cm)
0         Fraction of roots in deep soil
0.0       Manual redistribution: deep soil/surface soil dilution factor
1250      Source area for external dose modification factor (m2)

TRANSPORT #####################################################################

          ====AIR TRANSPORT===================================SECTION 1=====

                  0-Calculate PM            |0        Release type (0-3)
 1        Option: 1-Use chi/Q or PM value   |F        Stack release (T/F)
                  2-Select MI dist & dir    |0        Stack height (m)
                  3-Specify MI dist & dir   |0        Stack flow (m3/sec)
0         Chi/Q or PM value                 |0        Stack radius (m)
0         MI sector index (1=S)             |0        Effluent temp. (C)
0         MI distance from release point (m)|0        Building x-section (m2)
T         Use jf data, (T/F) else chi/Q grid|0        Building height (m)

          ====SURFACE WATER TRANSPORT=========================SECTION 2=====

0         Mixing ratio model: 0-use value, 1-river, 2-lake
0         Mixing ratio, dimensionless
0         Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0         Transit time to irrigation withdrawl location (hr)
          If mixing ratio model > 0:
0           Rate of effluent discharge to receiving water body (m3/s)
0           Longshore distance from release point to usage location (m)
0           Offshore distance to the water intake (m)
0           Average water depth in surface water body (m)
0           Average river width (m), MIXFLG=1 only
0           Depth of effluent discharge point to surface water (m), lake only

          ====WASTE FORM AVAILABILITY=========================SECTION 3=====

0         Waste form/package half life, (yr)
0         Waste thickness, (m)
0         Depth of soil overburden, m

          ====BIOTIC TRANSPORT OF BURIED SOURCE===============SECTION 4=====

T         Consider during inventory decay/buildup period (T/F)?
T         Consider during intake period (T/F)?  | 1-Arid non agricultural
0         Pre-Intake site condition.............| 2-Humid non agricultural
                                                | 3-Agricultural

EXPOSURE ######################################################################

          ====EXTERNAL EXPOSURE===============================SECTION 5=====
          Exposure time:                 |  Residential irrigation:
0           Plume (hr)                   | T        Consider: (T/F)
2920.0      Soil contamination (hr)      | 1        Source: 1-ground water
0           Swimming (hr)                |                  2-surface water
0           Boating (hr)                 | 40.0     Application rate (in/yr)
0           Shoreline activities (hr)    | 6.0      Duration (mo/yr)
0         Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
0         Transit time for release to reach aquatic recreation (hr)
0         Average fraction of time submersed in acute cloud (hr/person hr)
```

```
          ====INHALATION=====================================SECTION 6=====

8766.0    Hours of exposure to contamination per year
0         0-No resus-  1-Use Mass Loading          2-Use Anspaugh model
0           pension      Mass loading factor (g/m3)   Top soil available (cm)

          ====INGESTION POPULATION==========================SECTION 7=====

0         Atmospheric production definition (select option):
0           0-Use food-weighted chi/Q, (food-sec/m3), enter value on this line
            1-Use population-weighted chi/Q
            2-Use uniform production
            3-Use chi/Q and production grids (PRODUCTION will be overridden)
0         Population ingesting aquatic foods, 0 defaults to total (person)
0         Population ingesting drinking water, 0 defaults to total (person)
F         Consider dose from food exported out of region (default=F)

          Note below: S* or Source: 0-none, 1-ground water, 2-surface water
                                    3-Derived concentration entered above

          ==== AQUATIC FOODS / DRINKING WATER INGESTION=========SECTION 8====

F         Salt water? (default is fresh)

          USE        TRAN-  PROD-    -CONSUMPTION- |
          ?   FOOD   SIT    UCTION   HOLDUP   RATE |
          T/F TYPE   hr     kg/yr    da      kg/yr |      DRINKING WATER
          --- ------ -----  -------  ------  ----- |-------------------------
          F   FISH    0.00  0.0E+00   0.00     0.0 | 1      Source (see above)
          F   MOLLUS  0.00  0.0E+00   0.00     0.0 | F      Treatment? T/F
          F   CRUSTA  0.00  0.0E+00   0.00     0.0 | 1.0    Holdup/transit(da)
          F   PLANTS  0.00  0.0E+00   0.00     0.0 | 440.0  Consumption (L/yr)

          ====TERRESTRIAL FOOD INGESTION======================SECTION 9=====

          USE         GROW   --IRRIGATION--          PROD-     --CONSUMPTION--
          ?   FOOD    TIME   S RATE   TIME    YIELD  UCTION    HOLDUP   RATE
          T/F TYPE    da     * in/yr  mo/yr   kg/m2  kg/yr     da       kg/yr
          --- ------  -----  - -----  -----   -----  -------   ------   ------
          T   LEAF V  90.00  1  35.0   6.0     1.5   0.0E+00    14.0     15.0
          T   ROOT V  90.00  1  40.0   6.0     4.0   0.0E+00    14.0    140.0
          T   FRUIT   90.00  1  35.0   6.0     2.0   0.0E+00    14.0     64.0
          T   GRAIN   90.00  1   0.0   0.0     0.8   0.0E+00   180.0     72.0

          ====ANIMAL PRODUCTION CONSUMPTION==================SECTION 10====

                ---HUMAN---- TOTAL  DRINK   -------------STORED FEED--------------
USE             CONSUMPTION  PROD-  WATER   DIET  GROW  -IRRIGATION--        STOR-
?   FOOD        RATE  HOLDUP UCTION CONTAM  FRAC- TIME  S RATE  TIME   YIELD  AGE
T/F TYPE        kg/yr  da    kg/yr  FRACT.  TION  da    * in/yr mo/yr  kg/m3  da
--- ------      ------ ----- ------ ------- ----  ----  - ----- -----  -----  -----
T   BEEF         70.0  34.0   0.00    1.00  0.25  90.0  1  35.0  6.00   0.80  180.0
F   POULTR        8.5  34.0   0.00    1.00  1.00  90.0  1   0.0  0.00   0.80  180.0
T   MILK        230.0   4.0   0.00    1.00  0.25  45.0  1  47.0  6.00   2.00  100.0
F   EGG          20.0  18.0   0.00    1.00  1.00  90.0  1   0.0  0.00   0.80  180.0
                                            -------------FRESH FORAGE------------
    BEEF                                    0.75  45.0  1  47.0  6.00   2.00  100.0
    MILK                                    0.75  30.0  1  47.0  6.00   1.50    0.0

##########################################################################
```

GENII Parameter File (DEFAULT.IN) with GENII Default Values

```
GENII Default Parameter Values (28-Mar-90 RAP)

INVENTORY PARAMETERS------------------------------------------------------------
0.037, 3.7E4, 3.7E7, 3.7E10, 1.0          NVU     Source input conversion
1.0, 0.15, 224.0                          SVU     Soil source conversion

ENVIRONMENTAL PARAMETERS--------------------------------------------------------
0.008                                     ABSHUM  Absolute humidity (kg/m3)
2                                         PRCNTI  Air dispersion conserv. flag
0.001                                     DPVRES  Deposition vel./resuspension
1.0E-9                                    LEAFRS  Leaf resuspension factor
2.0,2.0,3.0,0.8,0.8,0.8,1.0,0.8,1.0,1.5   BIOMAS  BIOMA2 Biomass (kg/m2)
0.25                                      DEPFR2  Interception frac./irrigate
15.0                                      SURCM   Depth of surface soil (cm)
224.0                                     SLDN    Surface soil density (kg/m2)
1.5E3                                     SSLDN   Soil density (kg/m3)
True                                      HARVST  Harvest removal considered?
410.0                                     SOLING  Soil ingested (mg/da)
14.0                                      WTIM    Weathering time (da)
1.0, 0.1, 0.1, 0.1                        TRANS   Translocation, plants
0.1, 0.1, 0.1, 0.1, 1.0, 1.0              TRANSA  Translocation, animal food
68.0, 0.12, 55.0, 0.12, 68.0, 55.0        CONSUM  Animal Consumption (kg/da)
50.0, 0.3, 60., 0.3                       DWATER  Animal drinking water (L/da)
0.0, 0.8, 1.0, 0.8                        FRACUT  Acute fresh forage by season
0.2, 0.3, 0.5, 1.0                        SHORWI  Shore width factors
0.02                                      INGWAT  Swim water ingested (L/hr)
25295.0                                   TCWS    H2O/sed. transfer (L/m2/yr)
0.4,  5.0, 4.0                            YELDBT  BIOT: Veg. prod. (kg/m2/yr)
9.41E-4, 2*7.48E-4                        TOTEXC  BIOT: Excavation (m2/m3-yr)
1.0, 0.81, 0.19, 0.02, 0.008, 0.002,      EXCAV   BIOT: Frac. soil brought to
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005,           surface from within the
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005            waste by animal excavation
270.0                                     RINH    Chronic breathing (cm3/sec)
330.0                                     RINHA   Acute breathing (cm3/sec)
10                                        NDIST   Number of distances
805.0, 2414.0, 4023.0, 5632.0, 7241.0,
12068.0, 24135.0, 40255.0, 56315.0,
72405.0                                   X       JF/chi/Q/pop grid dist. (m)
0.1, 0.25, 6*0.18, 2*0.2                  DRYFAC, DRYFA2 dry/wet ratio

METABOLIC PARAMETERS------------------------------------------------------------
0.5, 50.0, 500.0                                         XDIV
0.5,  0.5,  0.95, 0.05,  0.8, 0.0, 0.0,   0.2, 0.0,     ADJ
0.1,  0.9,  0.5,  0.5,  0.15, 0.4, 0.4,  0.05, 0.0,
0.01, 0.99, 0.01, 0.99, 0.05, 0.4, 0.4, 0.135, 0.015

DOSE PARAMETERS-----------------------------------------------------------------
0.25, 0.15, 0.12, 0.12, 0.03, 0.03, 5*0.06             WT   Weighting factors
2.0                                                    SI2I Semi-infinite/inf
================================================================================
```

GENII Food Transfer Factor Library File (FTRANS.DAT) with Default Values

PNL Food Transfer Factor Library (by Z, with Fr&Os 7/19/93 PDR)

Ele- ment	Dep Vel m/sec	Leafy Veg	Root Veg	Fruit --	Grain --	Beef day/kg	Poultry day/kg	Milk day/L	Egg day/kg	Leaching Factor
H	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
BE	1.0E-3	8.0E-3	8.0E-3	8.0E-3	3.3E-3	8.0E-4	4.0E-1	2.0E-6	2.0E-2	1.9E-4
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
N	1.0E-3	7.5	7.5	7.5	7.5	9.9E-4	9.9E-4	1.1E-2	9.9E-4	0.8
F	1.0E-2	2.0E-2	2.0E-2	2.0E-2	2.0E-2	2.0E-2	9.9E-4	7.0E-3	9.9E-4	0.8
NA	1.0E-3	10.0	10.0	10.0	10.0	8.0E-2	1.0E-2	2.0E-2	2.0E-1	0.5
MG	1.0E-3	9.9E-4	9.9E-4	9.9E-4	9.9E-4	1.8E-2	9.9E-4	9.9E-4	1.6	1.9E-4
SI	1.0E-3	3.5E-1	3.5E-1	3.5E-1	3.5E-1	4.0E-5	9.9E-4	2.0E-5	9.9E-4	8.8E-3
P	1.0E-3	4.0	4.0	4.0	4.0	5.0E-2	1.9E-1	1.5E-2	10.0	0.8
S	1.0E-3	2.0	2.0	2.0	2.0	2.0E-1	9.9E-4	1.5E-2	9.9E-4	3.4E-2
CL	1.0E-3	50.0	50.0	50.0	1.0	3.0E-2	3.0E-2	2.0E-2	9.9E-4	0.8
AR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
K	1.0E-3	3.0	3.0	3.0	3.0	1.8E-2	9.9E-4	7.0E-3	9.9E-4	0.5
CA	1.0E-3	2.0	2.0	2.0	2.0	1.6E-3	4.4E-2	8.0E-3	4.4E-1	1.9E-4
SC	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-2	6.0E-3	4.0E-3	2.5E-6	9.9E-4	2.7E-4
CR	1.0E-3	4.0E-2	4.0E-2	4.0E-2	4.0E-3	9.0E-3	9.9E-4	1.0E-5	9.9E-4	4.7E-3
MN	1.0E-3	7.0E-1	7.0E-1	7.0E-1	2.0E-1	5.0E-4	5.0E-2	3.0E-4	6.5E-2	1.1E-2
FE	1.0E-3	2.0E-2	2.0E-2	2.0E-2	5.0E-3	2.0E-2	1.5	5.0E-5	1.3	1.8E-2
CO	1.0E-3	1.0E-1	1.0E-1	1.0E-1	4.0E-3	2.0E-2	5.0E-1	1.0E-4	1.0E-1	3.0E-2
NI	1.0E-3	1.0E-1	1.0E-1	1.0E-1	5.0E-2	2.0E-3	1.0E-3	1.0E-3	1.0E-1	4.6E-3
CU	1.0E-3	5.0E-1	5.0E-1	5.0E-1	5.0E-2	9.0E-3	5.1E-1	2.0E-3	4.9E-1	2.9E-3
ZN	1.0E-3	2.0	2.0	2.0	2.0	1.0E-1	6.5	1.0E-2	2.6	2.8E-4
GA	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-3	3.0E-4	9.9E-4	1.0E-5	9.9E-4	1.8E-4
AS	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-2	1.5E-3	8.3E-1	8.0E-5	9.9E-4	1.3E-3
SE	1.0E-3	5.0E-1	5.0E-1	5.0E-1	5.0E-2	1.0	8.5	2.3E-2	9.3	1.7E-2
BR	1.0E-2	7.6E-1	7.6E-1	7.6E-1	7.6E-1	2.0E-2	4.0E-3	2.0E-2	1.6	0.11
KR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
RB	1.0E-3	3.0E-1	3.0E-1	3.0E-1	3.0E-1	1.0E-2	2.0	1.0E-2	3.0	4.4E-3
SR	1.0E-3	2.0	2.0	2.0	2.0E-1	8.0E-4	3.5E-2	1.3E-3	3.0E-1	2.7E-3
Y	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-3	1.0E-3	1.0E-2	5.0E-6	2.0E-3	5.0E-4
ZR	1.0E-3	4.0E-2	4.0E-2	4.0E-2	4.0E-2	1.2E-6	6.4E-5	5.5E-7	1.9E-4	5.3E-4
NB	1.0E-3	4.0E-2	4.0E-2	4.0E-2	8.0E-3	2.6E-7	3.1E-4	4.1E-7	1.3E-3	2.7E-3
MO	1.0E-3	1.0	1.0	1.0	1.0E-1	1.2E-3	1.9E-1	1.7E-3	7.8E-1	0.8
TC	1.0E-3	40.0	40.0	40.0	40.0	9.9E-4	3.0E-2	3.0E-4	3.0	0.8
RU	1.0E-3	2.0E-1	2.0E-1	2.0E-1	2.0E-1	2.0E-3	7.0E-3	6.0E-7	6.0E-3	7.6E-4
RH	1.0E-3	50.0	50.0	50.0	5.0	1.0E-3	3.0E-4	5.0E-3	4.0E-3	4.4E-3
PD	1.0E-3	3.0E-1	3.0E-1	3.0E-1	5.0E-2	1.0E-3	3.0E-4	5.0E-3	4.0E-3	4.6E-3
AG	1.0E-3	6.0E-1	6.0E-1	6.0E-1	6.0E-2	2.0E-3	9.9E-4	2.5E-2	9.9E-4	0.27
CD	1.0E-3	2.0	2.0	2.0	6.0E-1	4.0E-4	8.4E-1	1.2E-4	1.0E-1	6.3E-4
IN	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-3	4.0E-3	9.9E-4	2.0E-4	9.9E-4	1.8E-4
SN	1.0E-3	1.0E-1	1.0E-1	1.0E-1	1.0E-2	1.0E-2	9.9E-4	1.0E-3	9.9E-4	2.7E-3
SB	1.0E-3	5.0E-2	5.0E-2	5.0E-2	5.0E-2	1.0E-3	6.0E-3	7.5E-4	7.0E-2	4.2E-2
TE	1.0E-3	5.0	5.0	5.0	5.0E-1	7.0E-3	8.5E-2	4.5E-4	5.2	0.8
I	1.0E-2	4.0E-1	4.0E-1	4.0E-1	4.0E-1	2.0E-3	1.8E-2	1.2E-2	2.8	0.8
XE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8

GENII Food Transfer Factor Library File -- Continued (column header repeated)

Ele- ment	Dep Vel m/sec	Leafy Veg	Root Veg	Fruit --	Grain --	Beef day/kg	Poultry day/kg	Milk day/L	Egg day/kg	Leaching Factor
CS	1.0E-3	2.0E-2	2.0E-2	2.0E-2	1.0E-2	3.0E-2	4.4	7.0E-3	4.9E-1	1.1E-3
BA	1.0E-3	4.0E-2	4.0E-2	4.0E-2	4.0E-3	5.0E-4	8.1E-4	4.8E-4	1.5	9.5E-5
LA	1.0E-3	1.0E-2	1.0E-2	1.0E-2	3.0E-4	5.0E-3	1.0E-1	2.5E-6	9.0E-3	4.1E-4
CE	1.0E-3	4.0E-2	4.0E-2	4.0E-2	4.0E-3	2.0E-3	1.0E-2	4.0E-5	5.0E-3	5.0E-4
PR	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-3	5.0E-3	3.0E-2	2.5E-6	5.0E-3	5.0E-4
ND	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-3	5.0E-3	4.0E-3	2.0E-5	2.0E-4	4.1E-4
PM	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-3	5.0E-3	2.0E-3	2.5E-6	2.0E-2	5.0E-4
SM	1.0E-3	1.0E-2	1.0E-2	1.0E-2	2.0E-3	5.0E-3	4.0E-3	2.0E-5	7.0E-3	4.1E-4
EU	1.0E-3	1.0E-2	1.0E-2	1.0E-2	2.0E-3	6.0E-3	4.0E-3	2.0E-5	7.0E-3	5.0E-4
GD	1.0E-3	5.0E-2	5.0E-2	5.0E-2	5.0E-3	2.0E-3	9.9E-4	6.0E-5	9.9E-4	4.1E-4
TB	1.0E-3	2.6E-3	2.6E-3	2.6E-3	2.6E-3	5.0E-3	4.0E-3	2.5E-6	7.0E-3	4.1E-4
DY	1.0E-3	9.9E-4	9.9E-4	9.9E-4	9.9E-4	5.3E-3	9.9E-4	5.0E-6	9.9E-4	4.1E-4
HO	1.0E-3	1.0E-2	2.0E-2	1.0E-2	2.7E-3	5.0E-3	4.0E-3	2.5E-6	7.0E-3	4.1E-4
ER	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-2	4.0E-3	9.9E-4	2.0E-5	9.9E-4	4.1E-4
HF	1.0E-3	1.0E-2	1.0E-2	1.0E-2	2.0E-3	4.0E-4	9.9E-4	2.0E-5	9.9E-4	1.8E-4
TA	1.0E-3	9.9E-4	9.9E-4	9.9E-4	9.9E-4	9.9E-4	9.9E-4	3.0E-6	9.9E-4	4.1E-4
W	1.0E-3	3.0	3.0	3.0	3.0E-1	3.7E-2	9.9E-4	3.0E-4	9.9E-4	1.8E-3
RE	1.0E-3	9.9E-4	9.9E-4	9.9E-4	9.9E-4	9.9E-4	9.9E-4	1.0E-3	9.9E-4	3.3E-2
OS	1.0E-3	0.015	0.0035	0.0035	0.0035	0.4	0.1	0.005	0.09	1.8E-3
IR	1.0E-3	1.0E-1	1.0E-1	1.0E-1	4.0E-3	2.0E-3	9.9E-4	2.0E-6	9.9E-4	1.8E-3
AU	1.0E-3	4.0E-1	4.0E-1	4.0E-1	4.0E-2	5.0E-3	9.9E-4	1.0E-5	9.9E-4	1.1E-2
HG	1.0E-3	1.0	1.0	1.0	1.0E-1	1.0E-1	1.1E-2	4.0E-4	9.9E-4	4.6E-4
TL	1.0E-3	9.9E-4	9.9E-4	9.9E-4	9.9E-4	9.9E-4	9.9E-4	2.0E-3	9.9E-4	0.5
PB	1.0E-3	1.0E-1	1.0E-1	1.0E-1	1.0E-2	4.0E-4	9.9E-4	3.0E-5	9.9E-4	4.5E-4
BI	1.0E-3	6.0E-1	6.0E-1	6.0E-1	6.0E-1	1.7E-2	9.9E-4	5.0E-4	9.9E-4	2.7E-5
PO	1.0E-3	1.0E-2	1.0E-2	1.0E-2	1.0E-3	4.5E-3	9.9E-4	1.2E-4	9.9E-4	2.7E-5
RN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
FR	1.0E-3	2.0E-2	2.0E-2	2.0E-2	1.0E-2	3.0E-2	4.4	7.0E-3	4.9E-1	1.1E-3
RA	1.0E-3	1.0E-1	1.0E-1	1.0E-1	1.0E-2	9.0E-4	9.9E-4	2.0E-4	2.0E-5	5.9E-4
AC	1.0E-3	1.0E-2	1.0E-2	3.0E-3	3.0E-4	4.0E-4	4.0E-3	2.0E-5	2.0E-3	1.3E-3
TH	1.0E-3	4.0E-3	4.0E-3	4.0E-3	4.0E-4	5.0E-3	4.0E-3	2.5E-6	2.0E-3	5.3E-4
PA	1.0E-3	5.0E-2	5.0E-2	5.0E-2	2.0E-2	5.0E-3	4.0E-3	2.5E-6	2.0E-3	1.3E-3
U	1.0E-3	4.0E-3	4.0E-3	4.0E-3	2.0E-4	2.0E-4	1.2	6.0E-4	9.9E-1	1.3E-3
NP	1.0E-3	1.0	1.0	1.0	1.0E-1	1.0E-3	4.0E-3	1.0E-5	2.0E-3	3.3E-3
PU	1.0E-3	4.0E-4	4.0E-4	4.0E-4	4.0E-5	2.0E-6	1.5E-4	1.0E-7	8.0E-3	1.3E-3
AM	1.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-4	2.0E-5	2.0E-4	3.0E-7	9.0E-3	1.3E-3
CM	1.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-4	5.0E-3	4.0E-3	3.0E-7	2.0E-3	1.3E-4
CF	1.0E-3	2.5E-3	2.5E-3	2.5E-3	2.5E-3	5.0E-3	4.0E-3	7.5E-7	2.0E-3	4.1E-4

Appendix B

PATHRAE Input Files

Appendix B

PATHRAE Input Files

PATHRAE Input Files for Irrigator Dose Calculations

ABCDEF.DAT

```
 Performance Assessment Task Team Test Case (G-W Concentration 1 pCi/cm^3-ALL)
 17   0   1
  2   2
  0.0D+00   1.0D+02   1.0D+02   1.0D+00   1.0D+00   1.0D+00   0.0D+00
  1.6D+03   1.0D-01   0.0D+00   0.0D+00   7.0D-01   1.0D-01   1.0D+00   1.0D+00
 20   2   0   1   1
  0.0D+00   1.0D+01  1.00D+05   1.0D+00   0.0D+00   1.5D+03   2.5D-01   1.0D+00
  1.5D-01   1.0D+00
 1.00D-07  8.52D+03   1.0D+00   0.0D+00   1.0D+00
  2.4D+02  5.56D-04   3.0D-01   2.0D-02   3.0D-04   2.0D+01   1.0D-02
        4   3.0D+00   1.0D+00   1.1D+04   1.0D-07   1.0D-02  0.0D+00   0.0D+00
  0.0D+00   0.0D+00
  0   0   0   0   0   0   0
  1   0   0   1
```

BRCDCF.DAT (GENII dose factor)

```
   17   0.0D+00   0.0D+00
          1   1.0D+00
    1  H-3            6.12E-08  9.03E-08   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    2  H-3A           6.12E-08  9.03E-08   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    3  C-14           2.07E-06  2.07E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    4  C-14A          2.07E-06  2.07E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    5  Co-60          2.65E-05  2.01E-04  2.59D-08  0.0  0.0  0.0  0.0  0.0  0.0
    6  Ni-59          2.05E-07  1.28E-06   0.0D-00  0.0  0.0  0.0  0.0  0.0  0.0
    7  Se-79          8.35E-06  9.54E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    8  Sr-90          1.32E-04  2.12E-04   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    9  Tc-99          2.23E-06  8.99E-06   0.0D-00  0.0  0.0  0.0  0.0  0.0  0.0
   10  I-129          2.50E-04  1.51E-04  2.51D-10  0.0  0.0  0.0  0.0  0.0  0.0
   11  Cs-137         4.79E-05  3.00E-05  6.59D-09  0.0  0.0  0.0  0.0  0.0  0.0
   12  Ra-226         9.56E-04  8.22E-03  1.92D-08  0.0  0.0  0.0  0.0  0.0  0.0
   13  U-238          2.72E-04  1.18E-01  2.80D-10  0.0  0.0  0.0  0.0  0.0  0.0
   14  Np-237         5.25E-03  6.36E-01  3.06D-09  0.0  0.0  0.0  0.0  0.0  0.0
   15  Pu-239         3.57E-03  4.34E-01  4.31D-12  0.0  0.0  0.0  0.0  0.0  0.0
   16  Pu-241         6.81E-05  8.18E-03  4.50D-14  0.0  0.0  0.0  0.0  0.0  0.0
   17  Am-241         3.63E-03  4.43E-01  3.41D-10  0.0  0.0  0.0  0.0  0.0  0.0
```

INVNTRY.DAT

```
    1     12.28  2.311D-02   0.0D+01   0.0D+00   4.8D+00   0.0       0.0   H-3
    2     12.28  2.311D-02   0.0D+01   0.0D+00   4.8D+00   0.0       0.0   H-3A
    3   5730.0    2.00D-02   0.0D+01   0.0D+00   1.3D+00   0.0       0.0   C-14
    4   5730.0    2.00D-02   0.0D+01   0.0D+00   1.3D+00   0.0       0.0   C-14A
    5      5.271 2.774D-02  8.50D+00  1.25D+00   2.0D-02   0.0       0.0   Co-60
    6    7.5D+04  2.00D-02   0.0D+01   0.0D+00   6.0D-02   0.0       0.0   Ni-59
    7    6.5D+04  2.00D-02   0.0D+01   0.0D+00   2.5D-02   0.0       0.0   Se-79
    8     28.6   2.132D-02   0.0D+00   0.0D+00   2.5D+00   0.0       0.0   Sr-90
    9   2.13D+05  2.00D-02   0.0D+00   0.0D+00   9.5D+00   0.0       0.0   Tc-99
   10   1.57D+07  2.00D-02  1.58D+02  3.10D-02   1.5D-01   0.0       0.0   I-129
   11     30.17   2.125D-02  1.20D+01  6.13D-01   8.0D-02   0.0       0.0   Cs-137
   12   1600.0   2.002D-02  1.12D+01  7.09D-01   1.5D-02   0.0       0.0   Ra-226
   13 4.468D+09   2.00D-02  3.13D+01  7.70D-02   8.5D-03   0.0       0.0   U-238
   14   2.14D+06  2.00D-02  2.45D+01  1.09D-01   1.0D-01   0.0       0.0   Np-237
   15 2.413D+04   2.00D-02  2.43D+01  1.11D-01   4.5D-04   0.0       0.0   Pu-239
   16     14.4   2.264D-02  3.04D+01  7.90D-02   4.5D-04   0.0       0.0   Pu-241
   17    432.2   2.009D-02  1.03D+02  3.70D-02   5.5D-03   0.0       0.0   Am-241
```

RQSITE.DAT

```
 1.000D+00   1.0D+01   0.2D+00   1.0D-02  1.000D+01 5.000E+00   1.0D-04   1.0D+00
  0.0D+00   0.0D+00
    1       5.000D-01  0.0D-00   1.0D+02   H-3
    2       5.000D-01  0.0D-00   1.0D+02   H-3A
    3       5.000D-01  0.0D-00   1.0D+02   C-14
    4       5.000D-01  0.0D-00   1.0D+02   C-14A
    5       5.000D-01  0.0D-00   1.0D+02   Co-60
    6       5.000D-01  0.0D-00   1.0D+02   Ni-59
    7       5.000D-01  0.0D-00   1.0D+02   Se-79
    8       5.000D-01  0.0D-00   1.0D+02   Sr-90
    9       5.000D-01  0.0D-00   1.0D+02   Tc-99
   10       5.000D-01  0.0D-00   1.0D+02   I-129
   11       5.000D-01  0.0D-00   1.0D+02   Cs-137
   12       5.000D-01  0.0D-00   1.0D+02   Ra-226
   13       5.000D-01  0.0D-00   1.0D+02   U-238
   14       5.000D-01  0.0D-00   1.0D+02   Np-237
   15       5.000D-01  0.0D-00   1.0D+02   Pu-239
   16       5.000D-01  0.0D-00   1.0D+02   Pu-241
   17       5.000D-01  0.0D-00   1.0D+02   Am-241
```

UPTAKE.DAT

```
   1.0D-03   2.0D-01   1.5D+00
   1.0D+00   2.0D+00  2.06D-03  7.20D+02  1.44D+03
   0.0D+00  2.16D+03   2.4D+01 1.440D+03   7.5D-01   1.0D+00
   5.0D+01   0.0D+00   4.8D+01   4.8D+02   4.8D+01
   1.0      2.09D-01   5.5D+01   0.0D+00   5.5D+01
   5.0D+00   4.3D+01   1.1D+02   0.0D+00   9.5D+01   7.3D+02   0.0D+00
H-3          2.5D-01   4.8D+00   1.0D-02    0.0      1.2D-02   9.0D-01
H-3A         2.5D-01   4.8D+00   1.0D-02   0.0D+00   1.2D-02   9.0D-01
C-14         2.5D-01   1.3D+00   1.2D-02   0.0D+00   3.1D-02   4.6D+03
C-14A        2.5D-01   1.3D+00   1.2D-02   0.0D+00   3.1D-02   4.6D+03
Co-60        2.5D-01   7.0D-03   2.0D-03   0.0D+00   2.0D-02   1.0D+02
Ni-59        2.5D-01   6.0D-02   1.0D-03   0.0D+00   6.0D-03   1.0D+02
Se-79        2.5D-01   2.5D-02   4.0D-03   0.0D+00   1.5D-02   1.7D+02
Sr-90        2.5D-01   2.5D-01   1.5D-03   0.0D+00   3.0D-04   3.0D+01
Tc-99        2.5D-01   1.5D+00   1.0D-02   0.0D+00   8.5D-03   1.5D+01
I-129        2.5D-01   5.0D-02   1.0D-02   0.0D+00   7.0D-03   1.5D+01
Cs-137       2.5D-01   3.0D-02   7.0D-03   0.0D+00   2.0D-02   2.0D+03
Ra-226       2.5D-01   1.5D-03   4.5D-04   0.0D+00   2.5D-04   1.0D+02
U-238        2.5D-01   4.0D-03   6.0D-04   0.0D+00   2.0D-04   2.0D+00
Np-237       2.5D-01   1.0D-02   5.0D-06   0.0D+00   5.5D-05   1.0D+01
Pu-239       2.5D-01   4.5D-05   1.0D-07   0.0D+00   5.0D-07   3.5D+00
Pu-241       2.5D-01   4.5D-05   1.0D-07   0.0D+00   5.0D-07   1.0D+02
Am-241       2.5D-01   2.5D-04   4.0D-07   0.0D+00   3.5D-06   1.0D+02
```

ABCDEF.DAT

```
1 Ci/m3 - Vegetation Only
 17   0   1
  5   0
  0.0D+00   1.0D+02   1.0D+02   1.0D+00   1.0D+00   1.0D+00   0.0D+00
  1.6D+03   1.0D-01   0.0D+00   0.0D+00   7.0D-01   1.0D-01   1.0D+00   1.0D+00
 20   2   0   1   1
  0.0D+00   1.0D+01  1.00D+05   1.0D+00   0.0D+00   1.5D+03   2.5D-01   1.0D+00
  1.5D-01   1.0D+00
 1.00D-07  8.52D+03   1.0D+00   0.0D+00   1.0D+00
  2.4D+02  5.56D-04   3.0D-01   2.0D-02   3.0D-04   2.0D+01   1.0D-02
        4   3.0D+00   1.0D+00   1.1D+04   1.0D-07   1.0D-02  0.0D+00   0.0D+00
  0.0D+00   0.0D+00
  0   0   0   0   0   0   0
  1   0   0   0
```

BRCDCF.DAT (GENII dose factor)

```
   17    0.0D+00    0.0D+00
          1    0.0D+00
    1  H-3            6.12E-08  9.03E-08   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    2  H-3A           6.12E-08  9.03E-08   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    3  C-14           2.07E-06  2.07E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    4  C-14A          2.07E-06  2.07E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    5  Co-60          2.65E-05  2.01E-04  2.59D-08  0.0  0.0  0.0  0.0  0.0  0.0
    6  Ni-59          2.05E-07  1.28E-06   0.0D-00  0.0  0.0  0.0  0.0  0.0  0.0
    7  Se-79          8.35E-06  9.54E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    8  Sr-90          1.32E-04  2.12E-04   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    9  Tc-99          2.23E-06  8.99E-06   0.0D-00  0.0  0.0  0.0  0.0  0.0  0.0
   10  I-129          2.50E-04  1.51E-04  2.51D-10  0.0  0.0  0.0  0.0  0.0  0.0
   11  Cs-137         4.79E-05  3.00E-05  6.59D-09  0.0  0.0  0.0  0.0  0.0  0.0
   12  Ra-226         9.56E-04  8.22E-03  1.92D-08  0.0  0.0  0.0  0.0  0.0  0.0
   13  U-238          2.72E-04  1.18E-01  2.80D-10  0.0  0.0  0.0  0.0  0.0  0.0
   14  Np-237         5.25E-03  6.36E-01  3.06D-09  0.0  0.0  0.0  0.0  0.0  0.0
   15  Pu-239         3.57E-03  4.34E-01  4.31D-12  0.0  0.0  0.0  0.0  0.0  0.0
   16  Pu-241         6.81E-05  8.18E-03  4.50D-14  0.0  0.0  0.0  0.0  0.0  0.0
   17  Am-241         3.63E-03  4.43E-01  3.41D-10  0.0  0.0  0.0  0.0  0.0  0.0
```

INVNTRY.DAT

```
    1      12.28   1.00D+02   0.0D+01   0.0D+00   4.8D+00   0.0       0.0   H-3
    2      12.28   1.00D+02   0.0D+01   0.0D+00   4.8D+00   0.0       0.0   H-3A
    3     5730.0   1.00D+02   0.0D+01   0.0D+00   1.3D+00   0.0       0.0   C-14
    4     5730.0   1.00D+02   0.0D+01   0.0D+00   1.3D+00   0.0       0.0   C-14A
    5      5.271   1.00D+02  8.50D+00  1.25D+00   2.0D-02   0.0       0.0   Co-60
    6    7.5D+04   1.00D+02   0.0D+01   0.0D+00   6.0D-02   0.0       0.0   Ni-59
    7    6.5D+04   1.00D+02   0.0D+01   0.0D+00   2.5D-02   0.0       0.0   Se-79
    8       28.6   1.00D+02   0.0D+00   0.0D+00   2.5D+00   0.0       0.0   Sr-90
    9   2.13D+05   1.00D+02   0.0D+00   0.0D+00   9.5D+00   0.0       0.0   Tc-99
   10   1.57D+07   1.00D+02  1.58D+02  3.10D-02   1.5D-01   0.0       0.0   I-129
   11      30.17   1.00D+02  1.20D+01  6.13D-01   8.0D-02   0.0       0.0   Cs-137
   12     1600.0   1.00D+02  1.12D+01  7.09D-01   1.5D-02   0.0       0.0   Ra-226
   13 4.468D+09    1.00D+02  3.13D+01  7.70D-02   8.5D-03   0.0       0.0   U-238
   14   2.14D+06   1.00D+02  2.45D+01  1.09D-01   1.0D-01   0.0       0.0   Np-237
   15 2.413D+04    1.00D+02  2.43D+01  1.11D-01   4.5D-04   0.0       0.0   Pu-239
   16       14.4   1.00D+02  3.04D+01  7.90D-02   4.5D-04   0.0       0.0   Pu-241
   17      432.2   1.00D+02  1.03D+02  3.70D-02   5.5D-03   0.0       0.0   Am-241
```

RQSITE.DAT

```
  1.00D+00    1.0D+01    0.2D+00    1.0D-02   1.00D+01 5.000E+00    1.0D-04    1.0D+00
   0.0D+00    0.0D+00
       1     5.000D-01   0.0D-00    1.0D+02     H-3
       2     5.000D-01   0.0D-00    1.0D+02     H-3A
       3     5.000D-01   0.0D-00    1.0D+02     C-14
       4     5.000D-01   0.0D-00    1.0D+02     C-14A
       5     5.000D-01   0.0D-00    1.0D+02     Co-60
       6     5.000D-01   0.0D-00    1.0D+02     Ni-59
       7     5.000D-01   0.0D-00    1.0D+02     Se-79
       8     5.000D-01   0.0D-00    1.0D+02     Sr-90
       9     5.000D-01   0.0D-00    1.0D+02     Tc-99
      10     5.000D-01   0.0D-00    1.0D+02     I-129
      11     5.000D-01   0.0D-00    1.0D+02     Cs-137
      12     5.000D-01   0.0D-00    1.0D+02     Ra-226
      13     5.000D-01   0.0D-00    1.0D+02     U-238
      14     5.000D-01   0.0D-00    1.0D+02     Np-237
      15     5.000D-01   0.0D-00    1.0D+02     Pu-239
      16     5.000D-01   0.0D-00    1.0D+02     Pu-241
      17     5.000D-01   0.0D-00    1.0D+02     Am-241
```

UPTAKE.DAT

```
   1.0D-03    2.0D-01    1.5D+00
   1.0D+00    2.0D+00  2.06D-03  7.20D+02  1.44D+03
   0.0D+00   2.16D+03   2.4D+01 1.440D+03   7.5D-01    1.0D+00
   5.0D+01    0.0D+00   4.8D+01   4.8D+02   4.8D+01
   1.0       2.09D-01   5.5D+01   0.0D+00   5.5D+01
   2.0D+01   1.72D+02   0.0D+00   0.0D+00   0.0D+00    0.0D+00    0.0D+00
H-3           2.5D-01   4.8D+00   1.0D-02    0.0       1.2D-02    9.0D-01
H-3A          2.5D-01   4.8D+00   1.0D-02   0.0D+00    1.2D-02    9.0D-01
C-14          2.5D-01   1.3D+00   1.2D-02   0.0D+00    3.1D-02    4.6D+03
C-14A         2.5D-01   1.3D+00   1.2D-02   0.0D+00    3.1D-02    4.6D+03
Co-60         2.5D-01   7.0D-03   2.0D-03   0.0D+00    2.0D-02    1.0D+02
Ni-59         2.5D-01   6.0D-02   1.0D-03   0.0D+00    6.0D-03    1.0D+02
Se-79         2.5D-01   2.5D-02   4.0D-03   0.0D+00    1.5D-02    1.7D+02
Sr-90         2.5D-01   2.5D-01   1.5D-03   0.0D+00    3.0D-04    3.0D+01
Tc-99         2.5D-01   1.5D+00   1.0D-02   0.0D+00    8.5D-03    1.5D+01
I-129         2.5D-01   5.0D-02   1.0D-02   0.0D+00    7.0D-03    1.5D+01
Cs-137        2.5D-01   3.0D-02   7.0D-03   0.0D+00    2.0D-02    2.0D+03
Ra-226        2.5D-01   1.5D-03   4.5D-04   0.0D+00    2.5D-04    1.0D+02
U-238         2.5D-01   4.0D-03   6.0D-04   0.0D+00    2.0D-04    2.0D+00
Np-237        2.5D-01   1.0D-02   5.0D-06   0.0D+00    5.5D-05    1.0D+01
Pu-239        2.5D-01   4.5D-05   1.0D-07   0.0D+00    5.0D-07    3.5D+00
Pu-241        2.5D-01   4.5D-05   1.0D-07   0.0D+00    5.0D-07    1.0D+02
Am-241        2.5D-01   2.5D-04   4.0D-07   0.0D+00    3.5D-06    1.0D+02
```

ABCDEF.DAT
```
1 Ci/m3 - Inhalation Only
  17   0   1
   8   0
   0.0D+00   1.0D+02   8.8D+01   1.0D+00   1.0D+00   1.0D+00   0.0D+00
   1.6D+03   1.0D-01   0.0D+00   0.0D+00   7.0D-01   1.0D-01   1.0D+00   1.0D+00
  20   0   0   1   1
   0.0D+00   1.5D-01  1.50D+03   1.0D+00   0.0D+00   1.5D+03   2.5D-01   1.0D+00
   1.5D-01   1.0D+00
  1.00D-07  8.52D+03   1.0D+00   0.0D+00   1.0D+00
   2.4D+02  5.56D-04   3.0D-01   2.0D-02   3.0D-04   2.0D+01   1.0D-02
         4   3.0D+00   1.0D+00   1.1D+04   1.0D-07   1.0D-02  0.0D+00   0.0D+00
   0.0D+00   0.0D+00
   0   0   0   0   0   0   0
   1   0   0   0
```

BRCDCF.DAT (DOE dose factor)
```
   17   0.0D+00   0.0D+00
         1   0.0D+00
    1  H-3             6.30E-08  6.30E-08   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    2  H-3A            6.30E-08  6.30E-08   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    3  C-14            2.10E-06  2.10E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    4  C-14A           2.10E-06  2.10E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    5  Co-60           2.60E-05  1.50E-04  2.59D-08  0.0  0.0  0.0  0.0  0.0  0.0
    6  Ni-59           2.00E-07  1.30E-06   0.0D-00  0.0  0.0  0.0  0.0  0.0  0.0
    7  Se-79           8.30E-06  8.90E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    8  Sr-90           1.40E-04  2.37E-04   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    9  Tc-99           1.30E-06  7.50E-06   0.0D-00  0.0  0.0  0.0  0.0  0.0  0.0
   10  I-129           2.80E-04  1.80E-04  2.51D-10  0.0  0.0  0.0  0.0  0.0  0.0
   11  Cs-137          5.00E-05  3.20E-05  6.59D-09  0.0  0.0  0.0  0.0  0.0  0.0
   12  Ra-226          1.10E-03  7.90E-03  1.92D-08  0.0  0.0  0.0  0.0  0.0  0.0
   13  U-238           2.43E-04  1.20E-01  2.80D-10  0.0  0.0  0.0  0.0  0.0  0.0
   14  Np-237          3.90E-03  4.90E-01  3.06D-09  0.0  0.0  0.0  0.0  0.0  0.0
   15  Pu-239          4.30E-03  5.10E-01  4.31D-12  0.0  0.0  0.0  0.0  0.0  0.0
   16  Pu-241          8.60E-05  1.00E-02  4.50D-14  0.0  0.0  0.0  0.0  0.0  0.0
   17  Am-241          4.50E-03  5.20E-01  3.41D-10  0.0  0.0  0.0  0.0  0.0  0.0
```

INVNTRY.DAT
```
    1     12.28   1.50D+00   0.0D+01   0.0D+00   4.8D+00   0.0       0.0    H-3
    2     12.28   1.50D+00   0.0D+01   0.0D+00   4.8D+00   0.0       0.0    H-3A
    3    5730.0   1.50D+00   0.0D+01   0.0D+00   1.3D+00   0.0       0.0    C-14
    4    5730.0   1.50D+00   0.0D+01   0.0D+00   1.3D+00   0.0       0.0    C-14A
    5     5.271   1.50D+00  8.50D+00  1.25D+00   2.0D-02   0.0       0.0    Co-60
    6    7.5D+04  1.50D+00   0.0D+01   0.0D+00   6.0D-02   0.0       0.0    Ni-59
    7    6.5D+04  1.50D+00   0.0D+01   0.0D+00   2.5D-02   0.0       0.0    Se-79
    8      28.6   1.50D+00   0.0D+00   0.0D+00   2.5D+00   0.0       0.0    Sr-90
    9   2.13D+05  1.50D+00   0.0D+00   0.0D+00   9.5D+00   0.0       0.0    Tc-99
   10   1.57D+07  1.50D+00  1.58D+02  3.10D-02   1.5D-01   0.0       0.0    I-129
   11     30.17   1.50D+00  1.20D+01  6.13D-01   8.0D-02   0.0       0.0    Cs-137
   12   1600.0    1.50D+00  1.12D+01  7.09D-01   1.5D-02   0.0       0.0    Ra-226
   13 4.468D+09   1.50D+00  3.13D+01  7.70D-02   8.5D-03   0.0       0.0    U-238
   14   2.14D+06  1.50D+00  2.45D+01  1.09D-01   1.0D-01   0.0       0.0    Np-237
   15 2.413D+04   1.50D+00  2.43D+01  1.11D-01   4.5D-04   0.0       0.0    Pu-239
   16     14.4    1.50D+00  3.04D+01  7.90D-02   4.5D-04   0.0       0.0    Pu-241
   17    432.2    1.50D+00  1.03D+02  3.70D-02   5.5D-03   0.0       0.0    Am-241
```

RQSITE.DAT

1.00D+00	1.0D+01	0.2D+00	1.0D-02	1.00D+01	5.000E+00	1.0D-04	1.0D+00
0.0D+00	0.0D+00						
1	5.00D-01	0.0D-00	1.0D+02	H-3			
2	5.00D-01	0.0D-00	1.0D+02	H-3A			
3	5.00D-01	0.0D-00	1.0D+02	C-14			
4	5.00D-01	0.0D-00	1.0D+02	C-14A			
5	5.00D-01	0.0D-00	1.0D+02	Co-60			
6	5.00D-01	0.0D-00	1.0D+02	Ni-59			
7	5.00D-01	0.0D-00	1.0D+02	Se-79			
8	5.00D-01	0.0D-00	1.0D+02	Sr-90			
9	5.00D-01	0.0D-00	1.0D+02	Tc-99			
10	5.00D-01	0.0D-00	1.0D+02	I-129			
11	5.00D-01	0.0D-00	1.0D+02	Cs-137			
12	5.00D-01	0.0D-00	1.0D+02	Ra-226			
13	5.00D-01	0.0D-00	1.0D+02	U-238			
14	5.00D-01	0.0D-00	1.0D+02	Np-237			
15	5.00D-01	0.0D-00	1.0D+02	Pu-239			
16	5.00D-01	0.0D-00	1.0D+02	Pu-241			
17	5.00D-01	0.0D-00	1.0D+02	Am-241			

UPTAKE.DAT

	1.0D-03	2.0D-01	1.5D+00				
	1.0D+00	2.0D+00	2.06D-03	7.20D+02	1.44D+03		
	0.0D+00	2.16D+03	2.4D+01	1.440D+03	7.5D-01	1.0D+00	
	5.0D+01	0.0D+00	4.8D+01	4.8D+02	4.8D+01		
	1.0	2.09D-01	5.5D+01	0.0D+00	5.5D+01		
	0.0D+00	0.00D+00	0.0D+00	0.0D+00	0.0D+00	0.0D+00	0.0D+00
H-3		2.5D-01	4.8D+00	1.0D-02	0.0	1.2D-02	9.0D-01
H-3A		2.5D-01	4.8D+00	1.0D-02	0.0D+00	1.2D-02	9.0D-01
C-14		2.5D-01	1.3D+00	1.2D-02	0.0D+00	3.1D-02	4.6D+03
C-14A		2.5D-01	1.3D+00	1.2D-02	0.0D+00	3.1D-02	4.6D+03
Co-60		2.5D-01	7.0D-03	2.0D-03	0.0D+00	2.0D-02	1.0D+02
Ni-59		2.5D-01	6.0D-02	1.0D-03	0.0D+00	6.0D-03	1.0D+02
Se-79		2.5D-01	2.5D-02	4.0D-03	0.0D+00	1.5D-02	1.7D+02
Sr-90		2.5D-01	2.5D-01	1.5D-03	0.0D+00	3.0D-04	3.0D+01
Tc-99		2.5D-01	1.5D+00	1.0D-02	0.0D+00	8.5D-03	1.5D+01
I-129		2.5D-01	5.0D-02	1.0D-02	0.0D+00	7.0D-03	1.5D+01
Cs-137		2.5D-01	3.0D-02	7.0D-03	0.0D+00	2.0D-02	2.0D+03
Ra-226		2.5D-01	1.5D-03	4.5D-04	0.0D+00	2.5D-04	1.0D+02
U-238		2.5D-01	4.0D-03	6.0D-04	0.0D+00	2.0D-04	2.0D+00
Np-237		2.5D-01	1.0D-02	5.0D-06	0.0D+00	5.5D-05	1.0D+01
Pu-239		2.5D-01	4.5D-05	1.0D-07	0.0D+00	5.0D-07	3.5D+00
Pu-241		2.5D-01	4.5D-05	1.0D-07	0.0D+00	5.0D-07	1.0D+02
Am-241		2.5D-01	2.5D-04	4.0D-07	0.0D+00	3.5D-06	1.0D+02

PATHRAE Input Files for Intruder (External Pathway) Dose Calculations

ABCDEF.DAT

```
1 Ci/m3 - External Only
  17   0   1
   7   0
   0.0D+00   1.0D+02   1.0D+02   1.0D+00   1.0D+00   1.0D+00   0.0D+00
   1.6D+03   1.0D-01   0.0D+00   0.0D+00   7.0D-01   1.0D-01   1.0D+00   1.0D+00
  20   0   0   1   1
   0.0D+00   1.5D-01  1.50D+03   1.0D+00   0.0D+00   1.5D+03   2.5D-01   1.0D+00
   1.5D-01   1.0D+00
  1.00D-07  8.52D+03   1.0D+00   0.0D+00   1.0D+00
   2.4D+02  5.56D-04   3.0D-01   2.0D-02   3.0D-04   2.0D+01   1.0D-02
         4   3.0D+00   1.0D+00   1.1D+04   1.0D-07   1.0D-02  0.0D+00   0.0D+00
   0.0D+00   0.0D+00
   0   0   0   0   0   0   0
   1   0   0   0
```

BRCDCF.DAT (DOE dose factor)

```
   17    0.0D+00    0.0D+00
          1   0.0D+00
    1  H-3          6.30E-08  6.30E-08   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    2  H-3A         6.30E-08  6.30E-08   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    3  C-14         2.10E-06  2.10E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    4  C-14A        2.10E-06  2.10E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    5  Co-60        2.60E-05  1.50E-04  2.59D-08  0.0  0.0  0.0  0.0  0.0  0.0
    6  Ni-59        2.00E-07  1.30E-06   0.0D-00  0.0  0.0  0.0  0.0  0.0  0.0
    7  Se-79        8.30E-06  8.90E-06   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    8  Sr-90        1.40E-04  2.37E-04   0.0D+00  0.0  0.0  0.0  0.0  0.0  0.0
    9  Tc-99        1.30E-06  7.50E-06   0.0D-00  0.0  0.0  0.0  0.0  0.0  0.0
   10  I-129        2.80E-04  1.80E-04  2.51D-10  0.0  0.0  0.0  0.0  0.0  0.0
   11  Cs-137       5.00E-05  3.20E-05  6.59D-09  0.0  0.0  0.0  0.0  0.0  0.0
   12  Ra-226       1.10E-03  7.90E-03  1.92D-08  0.0  0.0  0.0  0.0  0.0  0.0
   13  U-238        2.43E-04  1.20E-01  2.80D-10  0.0  0.0  0.0  0.0  0.0  0.0
   14  Np-237       3.90E-03  4.90E-01  3.06D-09  0.0  0.0  0.0  0.0  0.0  0.0
   15  Pu-239       4.30E-03  5.10E-01  4.31D-12  0.0  0.0  0.0  0.0  0.0  0.0
   16  Pu-241       8.60E-05  1.00E-02  4.50D-14  0.0  0.0  0.0  0.0  0.0  0.0
   17  Am-241       4.50E-03  5.20E-01  3.41D-10  0.0  0.0  0.0  0.0  0.0  0.0
```

INVNTRY.DAT

```
    1    12.28   1.50D+00   0.0D+01   0.0D+00   4.8D+00   0.0      0.0   H-3
    2    12.28   1.50D+00   0.0D+01   0.0D+00   4.8D+00   0.0      0.0   H-3A
    3   5730.0   1.50D+00   0.0D+01   0.0D+00   1.3D+00   0.0      0.0   C-14
    4   5730.0   1.50D+00   0.0D+01   0.0D+00   1.3D+00   0.0      0.0   C-14A
    5    5.271   1.50D+00  8.50D+00  1.25D+00   2.0D-02   0.0      0.0   Co-60
    6   7.5D+04  1.50D+00   0.0D+01   0.0D+00   6.0D-02   0.0      0.0   Ni-59
    7   6.5D+04  1.50D+00   0.0D+01   0.0D+00   2.5D-02   0.0      0.0   Se-79
    8     28.6   1.50D+00   0.0D+00   0.0D+00   2.5D+00   0.0      0.0   Sr-90
    9  2.13D+05  1.50D+00   0.0D+00   0.0D+00   9.5D+00   0.0      0.0   Tc-99
   10  1.57D+07  1.50D+00  1.58D+02  3.10D-02   1.5D-01   0.0      0.0   I-129
   11    30.17   1.50D+00  1.20D+01  6.13D-01   8.0D-02   0.0      0.0   Cs-137
   12   1600.0   1.50D+00  1.12D+01  7.09D-01   1.5D-02   0.0      0.0   Ra-226
   13 4.468D+09  1.50D+00  3.13D+01  7.70D-02   8.5D-03   0.0      0.0   U-238
   14  2.14D+06  1.50D+00  2.45D+01  1.09D-01   1.0D-01   0.0      0.0   Np-237
   15 2.413D+04  1.50D+00  2.43D+01  1.11D-01   4.5D-04   0.0      0.0   Pu-239
   16     14.4   1.50D+00  3.04D+01  7.90D-02   4.5D-04   0.0      0.0   Pu-241
   17    432.2   1.50D+00  1.03D+02  3.70D-02   5.5D-03   0.0      0.0   Am-241
```

RQSITE.DAT

1.000D+00	1.0D+01	0.2D+00	1.0D-02	1.000D+01	5.000E+00	1.0D-04	1.0D+00
0.0D+00	0.0D+00						
1	5.000D-01	0.0D-00	1.0D+02	H-3			
2	5.000D-01	0.0D-00	1.0D+02	H-3A			
3	5.000D-01	0.0D-00	1.0D+02	C-14			
4	5.000D-01	0.0D-00	1.0D+02	C-14A			
5	5.000D-01	0.0D-00	1.0D+02	Co-60			
6	5.000D-01	0.0D-00	1.0D+02	Ni-59			
7	5.000D-01	0.0D-00	1.0D+02	Se-79			
8	5.000D-01	0.0D-00	1.0D+02	Sr-90			
9	5.000D-01	0.0D-00	1.0D+02	Tc-99			
10	5.000D-01	0.0D-00	1.0D+02	I-129			
11	5.000D-01	0.0D-00	1.0D+02	Cs-137			
12	5.000D-01	0.0D-00	1.0D+02	Ra-226			
13	5.000D-01	0.0D-00	1.0D+02	U-238			
14	5.000D-01	0.0D-00	1.0D+02	Np-237			
15	5.000D-01	0.0D-00	1.0D+02	Pu-239			
16	5.000D-01	0.0D-00	1.0D+02	Pu-241			
17	5.000D-01	0.0D-00	1.0D+02	Am-241			

UPTAKE.DAT

1.0D-03	2.0D-01	1.5D+00				
1.0D+00	2.0D+00	2.06D-03	7.20D+02	1.44D+03		
0.0D+00	2.16D+03	2.4D+01	1.440D+03	7.5D-01	1.0D+00	
5.0D+01	0.0D+00	4.8D+01	4.8D+02	4.8D+01		
1.0	2.09D-01	5.5D+01	0.0D+00	5.5D+01		
0.0D+00	0.000D+00	0.0D+00	0.0D+00	0.0D+00	0.0D+00	0.0D+00
H-3	2.5D-01	4.8D+00	1.0D-02	0.0	1.2D-02	9.0D-01
H-3A	2.5D-01	4.8D+00	1.0D-02	0.0D+00	1.2D-02	9.0D-01
C-14	2.5D-01	1.3D+00	1.2D-02	0.0D+00	3.1D-02	4.6D+03
C-14A	2.5D-01	1.3D+00	1.2D-02	0.0D+00	3.1D-02	4.6D+03
Co-60	2.5D-01	7.0D-03	2.0D-03	0.0D+00	2.0D-02	1.0D+02
Ni-59	2.5D-01	6.0D-02	1.0D-03	0.0D+00	6.0D-03	1.0D+02
Se-79	2.5D-01	2.5D-02	4.0D-03	0.0D+00	1.5D-02	1.7D+02
Sr-90	2.5D-01	2.5D-01	1.5D-03	0.0D+00	3.0D-04	3.0D+01
Tc-99	2.5D-01	1.5D+00	1.0D-02	0.0D+00	8.5D-03	1.5D+01
I-129	2.5D-01	5.0D-02	1.0D-02	0.0D+00	7.0D-03	1.5D+01
Cs-137	2.5D-01	3.0D-02	7.0D-03	0.0D+00	2.0D-02	2.0D+03
Ra-226	2.5D-01	1.5D-03	4.5D-04	0.0D+00	2.5D-04	1.0D+02
U-238	2.5D-01	4.0D-03	6.0D-04	0.0D+00	2.0D-04	2.0D+00
Np-237	2.5D-01	1.0D-02	5.0D-06	0.0D+00	5.5D-05	1.0D+01
Pu-239	2.5D-01	4.5D-05	1.0D-07	0.0D+00	5.0D-07	3.5D+00
Pu-241	2.5D-01	4.5D-05	1.0D-07	0.0D+00	5.0D-07	1.0D+02
Am-241	2.5D-01	2.5D-04	4.0D-07	0.0D+00	3.5D-06	1.0D+02

Appendix C

ISOSHLD Input File

Appendix C

ISOSHLD Input File

ISOSHLD Input File:

```
0        2 Infinite Slab 15 cm Thick, R/hr per µCi/cm3, 1.5 g/cm3
C-14
 &Input  Next=1,  IGeom= 5,  ANGl= 90,  T= 15,99,  X= 115,
  NShld= 2,  JBuf= 1,  IConc= 1,  Weight(451)= 1  &
  soil  16   1.5
1  air   3          0.00122
Co-60
 &Input Next= 2, Weight(451)= 0, Weight(472)= 1  &
Se-79
 &Input Weight(472)= 0, Weight(27)= 1  &
Sr-90 & Y-90
 &Input Weight(27)= 0, Weight(82)= 1, Weight(84)= 1  &
Tc-99
 &Input Weight(82)= 0, Weight(84)= 0, Weight(141)= 1  &
I-129
 &Input Weight(141)= 0, Weight(290)= 1  &
Cs-137
 &Input Weight(290)= 0, Weight(335)= 1, Weight(336)= 1  &
Ra-226
 &Input Weight(335)= 0, Weight(336)= 0,
  Weight(485)= 1, Weight(514)= 1, Weight(510)= 1, Weight(511)= 1 &
U-238
 &Input
 Weight(485)= 0, Weight(514)= 0, Weight(510)= 0, Weight(511)= 0,
 Weight(526)= 1, Weight(530)= 1, Weight(533)= 1, Weight(441)= 0.0016 &
Np-237
 &Input  Weight(502)= 1, Weight(490)= 1,
 Weight(526)= 0, Weight(530)= 0, Weight(533)= 0, Weight(441)= 0 &
Pu-239
 &Input  Weight(502)= 0, Weight(490)= 0, Weight(493)= 1  &
Pu-241
 &Input  Weight(493)= 0, Weight(495)= 1, Weight(491)= 2.45E-05  &
Am-241
 &Input  Weight(495)= 0, Weight(491)= 0, Weight(496)= 1,
 Weight(502)= 3.24E-07, Weight(490)= 2.89E-07  &
This is the End of the Soil Cases !!
 &Input Next= 6  &
```