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RISKIND Verification and Benchmark Comparisons

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RISKIND VERIFICATION AND BENCHMARK COMPARISONS

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ABSTRACT

This report presents verification calculations and benchmark comparisons for RISKIND, a computer code designed to estimate potential radiological consequences and health risks to individuals and the population from exposures associated with the transportation of spent nuclear fuel and other radioactive materials. Spreadsheet calculations were performed to verify the proper operation of the major options and calculational steps in RISKIND. The program is unique in that it combines a variety of well-established models into a comprehensive treatment for assessing risks from the transportation of radioactive materials. Benchmark comparisons with other validated codes that incorporate similar models were also performed. For instance, the external gamma and neutron dose rate curves for a shipping package estimated by RISKIND were compared with those estimated by using the MCNP and MicroShield 4 codes and NUREG-0170 methodology. Doses from external radiation from a passing shipment estimated by RISKIND were compared with those estimated by using the RADTRAN 4 code and NUREG-0170 methodology. Atmospheric dispersion of released material and dose estimates related to potential transportation accidents were compared with estimates from the GENII and CAP88-PC codes. Verification results have shown the program to be performing its intended function correctly. The benchmark results indicate that the predictions made by RISKIND are within acceptable limits when compared with predictions from similar existing models.

1 INTRODUCTION

The RISKIND computer code was developed at Argonne National Laboratory (ANL) under the auspices of the U.S. Department of Energy (DOE), Office of Civilian Radioactive Waste Management, to address public concerns with regard to the transportation of spent nuclear fuel (SNF) (Yuan et al. 1993). A revision to the RISKIND program (Yuan et al. 1995) added a number of new features, including the capability to assess the risks from transporting SNF and other radioactive materials. RISKIND is used to assess the risks to a nearby person or a group of people from the external radiation emanating from a shipping package of radioactive materials during routine, incident-free transport or from the possible release of radioactive material as the result of potential accidents. Its primary objective is to evaluate the risks to specific individuals and population subgroups by using local, site-specific input data. RISKIND provides answers to the "what if" situations postulated by those concerned about shipments passing through their area of interest.

To answer these types of questions by stakeholders, a modified version of the original program was used for a number of past environmental impact statements (EISs), including the *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE 1995), *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* (DOE 1996), and *Final Waste Management Programmatic Environmental Impact Statement* (DOE 1997). Proper operation of the code was independently documented (Maheras and Pippen 1995).

This acceptance of RISKIND by stakeholders has increased its use for transportation risk analysis in other areas. For example, the latest version of RISKIND (version 1.11) is also being applied at the state level for oversight of transportation activities (Deng et al. 1996; Baepler et al. 1996). It is therefore important to assure users that the program is performing properly.

The study discussed in this report had two objectives: (1) verify the proper operation of the code and (2) benchmark the code against previously accepted codes to show that the results are reasonable. We performed independent verification by using calculations external to the RISKIND code; Microsoft Excel (version 7) spreadsheets were used to verify all the major portions of the program discussed in this report. We conducted this verification on a step-by-step basis and used several test cases as templates, since all possible options could not be considered in a single analysis. The files used as input to and output from RISKIND (version 1.11) are provided in Appendix A. We introduced each test case for the verification as needed. The types of calculations we investigated are listed in Table 1.1. The calculations are presented as figures throughout this document. The equation numbers shown next to the calculations correspond with the numbers in the RISKIND manual (Yuan et al. 1995). In addition to verifying each major calculational step in the model, we benchmarked a set of results from the model against results from similar models in other programs, if available. Table 1.2 lists the benchmark comparisons made for this study.

The purpose of the benchmark cases was to help check the proper operation of the code and help validate the new code. In general, the various models incorporated in RISKIND are well established and needed little, if any, validation. The unique feature of RISKIND is that it combines these models into a comprehensive program for assessing risks from the transportation of SNF and other radioactive materials. The benchmark cases also helped provide a better understanding of the models incorporated in the code. A model's applicability and limitations become apparent when it is compared with known solutions or other estimates based on previously validated models (codes). The cases discussed in this report exercise the major options available in RISKIND.

TABLE 1.1 RISKIND Calculations Verified in This Study

Incident-free calculations

- Dose rate curve normalization
- Shape factor adjustment for package size
- Individual dose from a stationary shipment
- Individual dose from a passing shipment
- Population dose from a passing shipment

Accident calculations

- Accident response region determination
- Radionuclide screening
- Atmospheric dispersion
  - ◊ Effective wind speed and release height
  - ◊ Initial puff size and virtual distances
  - ◊ Buoyancy induced dispersion
  - ◊ Pasquill-Gifford and Briggs dispersion coefficients
  - ◊ Ground-level air concentrations
- Individual dose from short-term exposure
  - ◊ External dose from passing cloud
  - ◊ External dose from contaminated ground
  - ◊ Internal dose from inhalation during cloud passage
- Individual dose from long-term exposure
  - ◊ External dose from resuspended contamination
  - ◊ External dose from contaminated ground
  - ◊ Internal dose from inhalation of resuspended contamination
  - ◊ Internal dose from ingestion of contaminated food and water
- Individual fatality risk from acute health effects
- Individual risk from long-term health effects

TABLE 1.2 RISKIND Benchmark Comparisons Made in This Study

Type of Calculation	Parameter Being Benchmarked	Model Used for Comparison
Incident-free	Default gamma dose rate curve	MCNP, MicroShield, and NUREG-0170
	Default neutron dose rate curve	MCNP
	Shape factor correction	MicroShield
	Gamma and neutron doses from a passing shipment	NUREG-0170/RISKIND, RADTRAN 4
Accident	Ground-level air concentrations	GENII (Pasquill-Gifford coefficients) and CAP88-PC (Briggs coefficients)
	Short-term inhalation, cloudshine, and groundshine doses	GENII
	Ingestion doses	GENII
	Short-term inhalation and cloudshine doses	CAP88-PC

2 INCIDENT-FREE RISKS

Risks from the routine transport of radioactive material result from the external radiation emanating from the shipping package in the vicinity of the transport vehicle. The nature of the radiation can be gamma rays or neutrons that penetrate their package walls and escape to the outside. Alpha or beta particles do not contribute to such radiation since they are unable to penetrate container walls. Therefore, the magnitude of the risk involved depends on the (1) external dose rates of the shipping package from gamma rays and neutrons, (2) distance of any potential receptors from the package, and (3) amount of time spent near the package by a receptor.

The calculation of routine risks requires that the gamma and neutron dose rates be determined as a function of distance (dose rate curves). The model's default dose rate curves must then be scaled to match the dose rate input by the user for a receptor located 1 or 2 m from the source. Sections 2.1.1 and 2.1.2 compare the default dose rate curves in RISKIND with those of other models. However, RISKIND allows users to provide their own specific gamma and neutron dose rate curves as input.

Section 2.1.3 introduces a routine risk analysis, test case 1, and discusses how the scaling process is verified through sample spreadsheet calculations. The default dose rate curves in RISKIND are for an SNF uranium/water-shielded cask of specific dimensions that contains spent PWR fuel. An option is available to adjust the dose rates for different size casks by using a cylindrical surface source model. Section 2.1.4 shows spreadsheet calculations used to verify the proper operation of this model within the code.

2.1 EXTERNAL DOSE RATES

The external dose of radiation received by a receptor from a stationary shipment depends on the distance of separation between the receptor and radiation source and the magnitude of the source's radiation. The external gamma and neutron dose rate curves used by RISKIND were developed specifically for a spent fuel cask (Chen and Yuan 1988). The dose rates were obtained by using a three-dimensional (3-D) Monte Carlo method that considered air and ground scattering. The dose rate curves were then normalized to match the dose rate to a receptor located 1 or 2 m from the waste package of interest. Dose rates were determined for a cylindrical package 5.46 m long with a radius of 0.56 m (RISKIND default shipping cask dimensions).

2.1.1 Gamma Radiation

The default gamma dose rate curve supplied with RISKIND was compared with those estimated by the MicroShield 4™ (Negin and Worku 1992a,b), MCNP™ (Briesmeister 1993), and Nuclear Regulatory Commission (NRC 1977) models. Data from this comparison are shown in Table 2.1 and plotted in Figures 2.1 and 2.2. All gamma dose rates were normalized to

TABLE 2.1 Gamma Dose Rates (mrem/h) as a Function of Distance Estimated by MicroShield, MCNP, NUREG-0170, and RISKIND[a]

Distance (m)	RISKIND Default	MicroShield	MCNP	RISKIND Point Source	NUREG-0170
1	2.1E+01	2.2E+01	2.0E+01	3.9E+01	4.0E+01
2	1.0E+01	1.0E+01	1.0E+01	1.0E+01	1.0E+01
5	2.6E+00	2.5E+00	2.7E+00	1.7E+00	1.6E+00
7	1.5E+00	1.4E+00	1.5E+00	8.7E-01	8.1E-01
10	7.8E-01	7.2E-01	7.7E-01	4.3E-01	3.9E-01
15	3.6E-01	3.4E-01	3.5E-01	1.9E-01	1.7E-01
20	2.0E-01	1.9E-01	1.9E-01	1.0E-01	9.7E-02
30	8.8E-02	8.5E-02	8.6E-02	4.4E-02	4.2E-02
50	2.9E-02	3.1E-02	2.8E-02	1.4E-02	1.5E-02
70	1.3E-02	1.5E-02	1.3E-02	6.6E-03	7.1E-03
100	5.7E-03	7.0E-03	5.5E-03	2.8E-03	3.3E-03
150	2.0E-03	2.7E-03	1.8E-03	9.7E-04	1.3E-03
200	8.8E-04	1.3E-03	7.5E-04	4.2E-04	6.4E-04
300	2.3E-04	3.6E-04	1.5E-04	1.1E-04	2.2E-04
400	7.6E-05	1.2E-04	4.2E-05	3.7E-05	9.5E-05
500	2.8E-05	4.2E-05	1.1E-05	1.3E-05	4.6E-05
600	1.1E-05	1.5E-05	4.1E-06	5.3E-06	2.4E-05
700	4.5E-06	5.9E-06	1.1E-06	2.2E-06	1.3E-05
800	2.0E-06	2.3E-06	3.2E-07	9.4E-07	7.3E-06

[a] Normalized to 10 mrem/h at 2 m.

10 mrem/h at a distance of 2 m from the cask surface. The MicroShield and MCNP calculations assumed a shipping package having the same shape and size as those of the RISKIND default package (cylinder 5.46 m long with a 0.56-m radius). The dose rate curve described in NUREG-0170, the NRC (1977) report, is for a point source (rather than a cylindrical source) model. Therefore, a second RISKIND curve that used an approximation for a point source was generated for comparison; the cask length and radius were both set to 0.0001 m (a value of 0.001 m produces the same result).

MicroShield is an analytical point-source kernel model program for estimating gamma radiation shielding and exposure. Its validation and verification have been well-documented (Negin and Worku 1992a,b). For MicroShield, a cylindrical surface source model was used, and the same gamma energy spectrum (ranging from 0.3 to 2 MeV) that was used to generate the RISKIND curve was input (RSIC 1981). In general, approximately 98% of the gamma radiation from the surface of a spent fuel cask is within the 0.4-0.9 MeV range (Sandquist et al. 1985). MicroShield calculations take air attenuation and buildup into account, but the code does not address ground scattering. As can be seen in Figures 2.1 and 2.2, the agreement between the

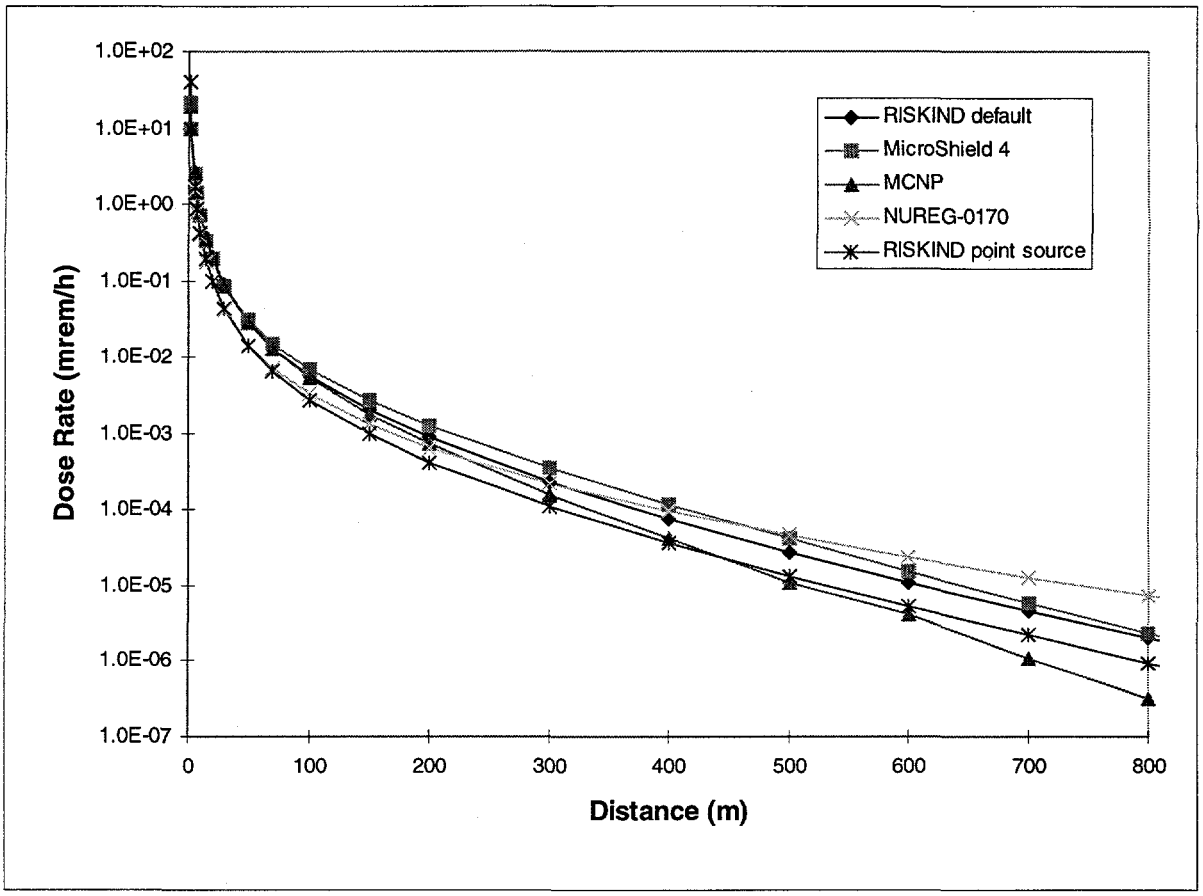


FIGURE 2.1 Comparison of RISKIND, MicroShield, MCNP, and NUREG-0170 Gamma Dose Rates

MicroShield and RISKIND results was quite good; the RISKIND curve stayed within 35% of the MicroShield results at the maximum deviation at distances of approximately 300 to 400 m.

MCNP is a general-purpose, Monte Carlo, photon and neutron transport code (Briesmeister 1993). It has been successfully benchmarked against experimental data for both photon (Whalen et al. 1991a) and neutron (Whalen et al. 1991b) transport. The MCNP calculations also used a cylindrical surface source having the same size and gamma spectrum as those used for the RISKIND and MicroShield calculations. Calculations took ground scattering (concrete) into account because ground scattering is considered in the default RISKIND dose rates. Figure 2.2 shows that the agreement between RISKIND and MCNP was excellent within the first 100 m. A difference of only about 5% or less in the dose rates was observed within this range. At further distances, where the inherent uncertainties in the Monte Carlo scattering calculations are magnified for both codes because of fewer photons, MCNP calculations resulted in slightly lower dose rates; the difference between MCNP and RISKIND reached a factor of about six at 800 m.

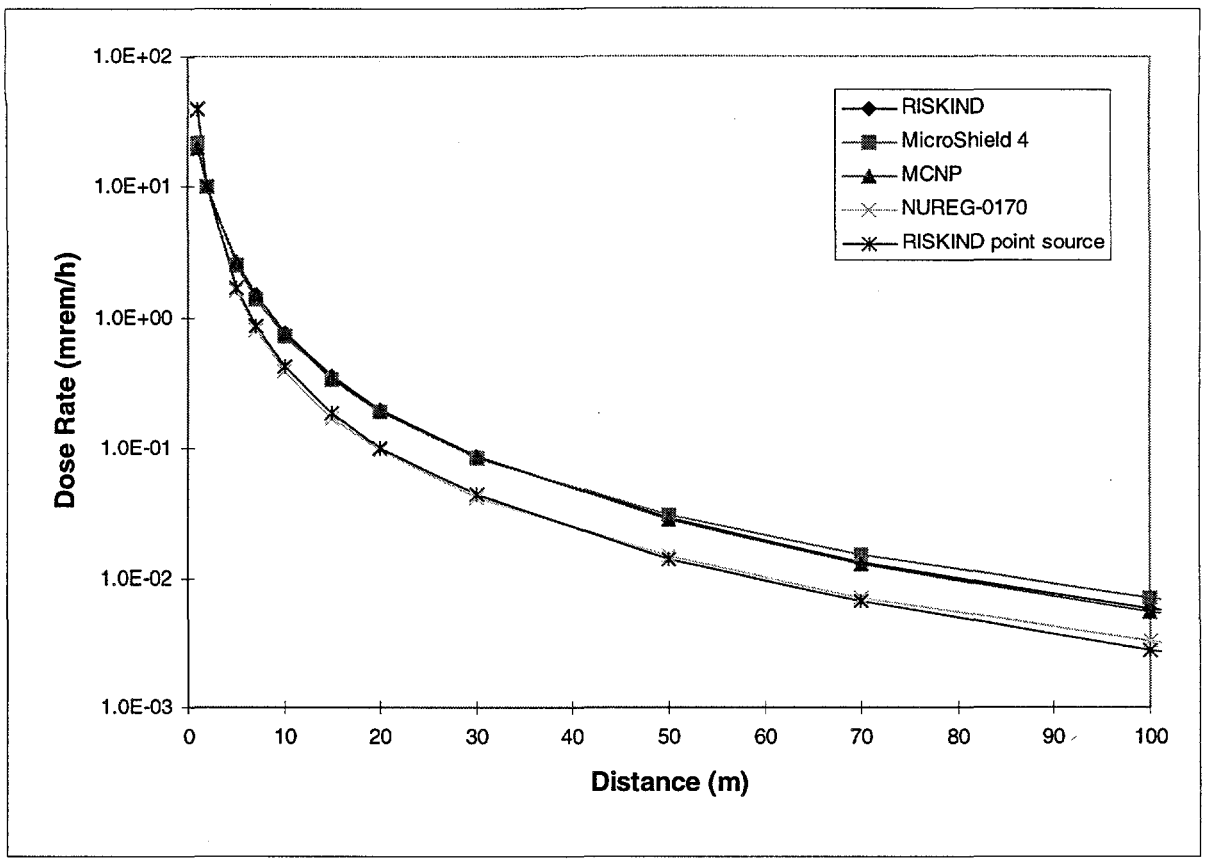


FIGURE 2.2 Comparison of RISKIND, MicroShield, MCNP, and NUREG-0170 Gamma Dose Rates When the Receptor Is Near the Source

Statistical errors for the RISKIND default curve were estimated to be less than 20% at distances less than 100 m and can be as high as about 50% at 800 m when generated by using the MORSE Monte Carlo transport code (Chen and Yuan 1988). For the MCNP calculations, the statistical errors were expected to be less than 2% at distances less than 100 m and were as high as about 20% at 800 m. At the far distances, the number of photons available for scattering decreases drastically, resulting in pronounced uncertainties. However, because of the good agreement at near distances and the sharp decrease in dose rates at far distances, the uncertainties were not expected to affect the overall consequences in any significant manner.

The NRC report, NUREG-0170, describes a point-source model that uses a gamma dose rate curve for analyzing risk associated with the transportation of radioactive materials. The dose rate incorporates air attenuation and buildup and is of the following form:

$$D(d) = \frac{K e^{-\mu d} B(d)}{d^2}, \tag{2.1}$$

where:

D(d) = dose rate at distance d (mrem/h);

d = distance from the source (ft);

μ = absorption coefficient for air (0.00118 ft^{-1});

B(d) = Berger buildup factor in air, B(d) = 0.0006 d + 1 (dimensionless); and

K = dose rate factor (mrem-ft^2/h).

Normalized to 10 mrem/h at 2 m, the value for K was taken to be 432 mrem-ft^2/h. Figures 2.1 and 2.2 compare this NRC model with a RISKIND point-source approximation. The agreement was excellent within the first 70 m; there was less than 5% difference at any point, despite a decrease in the dose rate of more than three orders of magnitude. Agreement between the two models diverged at distances beyond 100 m. The NUREG-0170 values became increasingly more conservative, differing from the RISKIND results by a factor of about eight at a distance of 800 m.

It can be seen from the model comparison in Figures 2.1 and 2.2 that the gamma dose rate curve for RISKIND is quite reasonable. RISKIND's default dose rate curve is in excellent agreement (within a difference of about 5%) with those of the other cylindrical surface models (MCNP and MicroShield) at near distances, where dose rates are highest. At further distances, RISKIND's default dose rate curve tends to stay within the limits defined by the MicroShield and MCNP results. Even when RISKIND is compared with the simple point-source model used in NUREG-0170, excellent agreement occurs at near distances and results diverge slightly at distances greater than about 100 m. At far distances, however, NUREG-0170 exhibits a conservative trend. For instance, at 800 m, NUREG-0170's estimated dose rate reaches a level eight times higher than RISKIND's.

2.1.2 Neutron Radiation

A comparison of RISKIND and MCNP neutron dose rates was made (Briesmeister 1993). RISKIND's and MCNP's estimated neutron dose rates as a function of distance are compared in Table 2.2 and plotted in Figures 2.3 and 2.4. All dose rates were normalized to 10 mrem/h at a distance of 2 m from the cask surface.

The same neutron energy spectrum (ranging from 0.1 to 15 MeV) that was used to generate the RISKIND default curve (RSIC 1981) was input to MCNP. The MCNP calculations also used the same size cylindrical surface source as that used for the RISKIND calculations (RSIC 1981). The MCNP calculations considered ground scattering (concrete), as do the RISKIND calculations. Figures 2.3 and 2.4 show good agreement (about 15% or less difference) between RISKIND and MCNP within the first 200 m and differences of 25% or less out to a distance of 600 m. Because both the RISKIND and MCNP results were based on Monte Carlo

TABLE 2.2 Neutron Dose Rates as a Function of Distance Estimated by MCNP and RISKIND[a]

Distance (m)	RISKIND (mrem/h)	MCNP (mrem/h)
2.0E+00	1.0E+01	1.0E+01
5.0E+00	2.7E+00	3.0E+00
7.0E+00	1.5E+00	1.7E+00
1.0E+01	7.7E-01	8.8E-01
1.5E+01	3.5E-01	4.1E-01
2.0E+01	2.0E-01	2.3E-01
3.0E+01	9.0E-02	1.1E-01
5.0E+01	3.1E-02	3.5E-02
7.0E+01	1.5E-02	1.7E-02
1.0E+02	6.4E-03	7.1E-03
1.5E+02	2.3E-03	2.3E-03
2.0E+02	1.1E-03	9.9E-04
3.0E+02	2.9E-04	3.9E-04
4.0E+02	9.1E-05	1.1E-04
5.0E+02	3.0E-05	3.4E-05
6.0E+02	9.6E-06	1.3E-05
7.0E+02	3.0E-06	4.5E-06
8.0E+02	9.4E-07	2.8E-06

[a] Normalized to 10 mrem/h at 2 m.

scattering calculations, the uncertainties increased with distance, resulting in greater differences in the dose rates at greater distances. At 800 m, MCNP values were higher than the RISKIND results by a factor of about three.

Similar to the gamma dose rate results discussed in Section 2.1.1, statistical errors for the RISKIND default curve are estimated to be less than 20% at distances less than 100 m and can be as high as approximately 50% at 800 m when generated by using the MORSE Monte Carlo transport code (Chen and Yuan 1988). For the MCNP calculations, the statistical errors were expected to be less than 2% at distances less than 100 m and were as high as approximately 20% at 800 m. At the far distances, the number of neutrons available for scattering decreases drastically, resulting in pronounced uncertainties. However, because of the good agreement at near distances and the sharp decrease in dose rates at far distances, the uncertainties were not expected to affect the overall consequences in any significant manner.

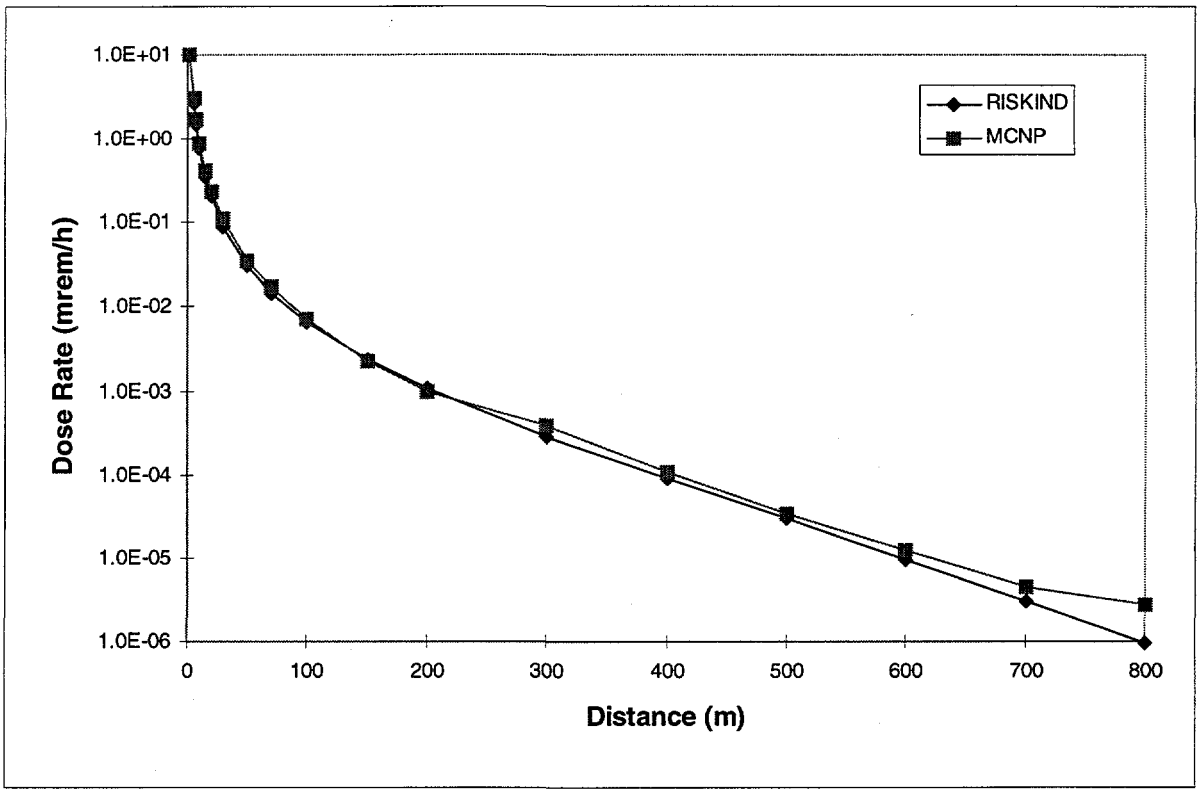


FIGURE 2.3 Comparison of RISKIND and MCNP Neutron Dose Rates

2.1.3 Dose Rate Curve Normalization

The calculations shown in this section and Sections 2.1.4 and 2.2 were performed to verify the proper operation of the RISKIND code in estimating the impacts to an individual from the routine transport of an SNF cask. The following input parameters defined the problem:

Distance of individual from SNF transport route: 30 m,

- Length of SNF cask: 4 m,
- Radius of SNF cask: 0.45 m,
- Dose rate at 1 m from cask surface: 11 mrem/h,
- Gamma radiation fraction of dose rate: 0.6,
- Neutron radiation fraction of dose rate: 0.4, and
- Speed of passing shipment: 24 km/h.

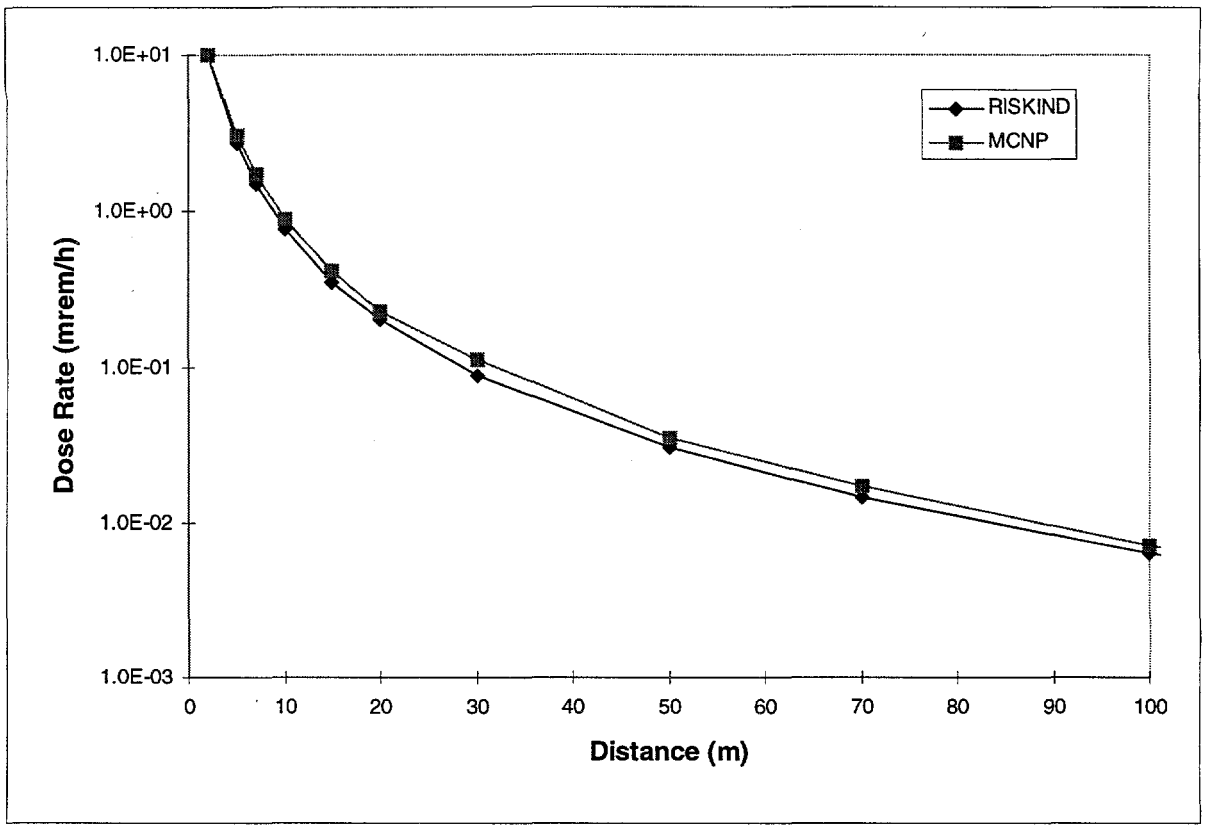


FIGURE 2.4 Comparison of RISKIND and MCNP Neutron Dose Rates When the Receptor Is Near the Source

This analysis is defined in the case 1 RISKIND input file, and the results are found in the case 1 output file, both of which are provided in Appendix A.

The first step in calculating impacts from external radiation was to normalize the dose rate curve to match the dose rate that was input for the problem. Figure 2.5 lists the calculations used to estimate the total dose rate at the receptor distance by normalizing the default dose rate curves for both gamma and neutron radiation. The shape factor correction calculated is shown in Section 2.1.4.

Normalization of the gamma and neutron dose rate curves consists of determining the first coefficient (A_{og} or A_{on}) in the equation for the appropriate curve. The empirical form of the equation used in RISKIND to model the dose rate curves makes this a simple calculation, in which the first coefficient is the logarithm of the measured dose rate at 1 m from the shipping package. The logarithms of the gamma and neutron dose rates are then calculated separately. Finally, the two results are combined to obtain the total dose rate at the receptor.

$$\underset{A_{0g}}{\boxed{0.820}} = \log\left(\underset{f_g}{\boxed{0.60}} * \underset{\substack{DR(1)\\(mrem/h)}}{\boxed{11}}\right) \qquad (2.4)$$

$$\underset{A_{0n}}{\boxed{0.643}} = \log\left[\left(1 - \underset{f_g}{\boxed{0.60}}\right) * \underset{\substack{DR(1)\\(mrem/h)}}{\boxed{11}}\right] \qquad (2.4)$$

$$\underset{\log[DR_g(30)]}{\boxed{-1.560}} = \underset{A_{0g}}{\boxed{0.820}} + \underset{A_{1g}}{\boxed{-0.86326}} * \left(\log \underset{r(m)}{\boxed{30}}\right) \qquad (2.2)$$

$$+ \underset{A_{2g}}{\boxed{-0.78497}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^2 + \underset{A_{3g}}{\boxed{0.36191}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^3$$

$$+ \underset{A_{4g}}{\boxed{-0.22023}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^4 + \underset{A_{5g}}{\boxed{0.09422}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^5$$

$$+ \underset{A_{6g}}{\boxed{-0.01546}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^6 + \underset{A_{7g}}{\boxed{-0.00075}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^7$$

$$\underset{\log[DR_n(30)]}{\boxed{-1.695}} = \underset{A_{0n}}{\boxed{0.643}} + \underset{A_{1n}}{\boxed{-0.97916}} * \left(\log \underset{r(m)}{\boxed{30}}\right) \qquad (2.2)$$

$$+ \underset{A_{2n}}{\boxed{0.85559}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^2 + \underset{A_{3n}}{\boxed{-3.77234}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^3$$

$$+ \underset{A_{4n}}{\boxed{4.27579}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^4 + \underset{A_{5n}}{\boxed{-2.36094}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^5$$

$$+ \underset{A_{6n}}{\boxed{0.65023}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^6 + \underset{A_{7n}}{\boxed{-0.07222}} * \left(\log \underset{r(m)}{\boxed{30}}\right)^7$$

$$\underset{\substack{DR_0(30\ m)\\(mrem/h)}}{\boxed{4.78E\text{-}02}} = 10^{\boxed{-1.560}\ \log[DR_g(30)]} + 10^{\boxed{-1.695}\ \log[DR_n(30)]}$$

FIGURE 2.5 Dose Rate Curve Normalization Calculations for Case 1

2.1.4 Shape Factor Correction

The dose rate at the receptor shown in Section 2.1.3 was calculated for a shipping package with the dimensions of the default cask. Figure 2.6 lists the additional calculations used to correct for the size of the shipping package specified by the user. As explained in Appendix B of the RISKIND manual, the correction to the dose rate at a given distance is the ratio of the true dose rate to the default cask dose rate. This ratio is determined by means of geometric

$$\underset{\substack{DR_1(30\ m)\\(rem/h)}}{\boxed{3.69E\text{-}05}} = \underset{\substack{DR_0(30\ m)\\(rem/h)}}{\boxed{4.78E\text{-}05}} * \underset{Q(30\ m)}{\boxed{0.772}} \qquad \textbf{(B.20)}$$

where:

$$\underset{Q(d)}{\boxed{0.772}} = \frac{(2 * \underset{R_0\ (m)}{\boxed{0.56}} + \underset{d\ (m)}{\boxed{30}}) * \underset{F(\psi_1,k_1)}{\boxed{6.66E\text{-}02}}) * (2 * \underset{R_1\ (m)}{\boxed{0.45}} + \underset{D\ (m)}{\boxed{1}}) * \underset{F(\psi_{0D},k_{0D})}{\boxed{1.51E+00}})}{(2 * \underset{R_1\ (m)}{\boxed{0.45}} + \underset{d\ (m)}{\boxed{30}}) * \underset{F(\psi_0,k_0)}{\boxed{9.08E\text{-}02}}) * (2 * \underset{R_0\ (m)}{\boxed{0.56}} + \underset{D\ (m)}{\boxed{1}}) * \underset{F(\psi_{1D},k_{1D})}{\boxed{1.30E+00}})} \qquad \textbf{(B.19)}$$

and

$$\underset{\psi_{0D}\ (rad)}{\boxed{1.22}} = \tan^{-1}(\underset{L_0\ (m)}{\boxed{5.46}} / (2 * \underset{D\ (m)}{\boxed{1}})) \qquad \textbf{(B.8)}$$

$$\underset{\psi_{1D}\ (rad)}{\boxed{1.11}} = \tan^{-1}(\underset{L_1\ (m)}{\boxed{4.00}} / (2 * \underset{D\ (m)}{\boxed{1}})) \qquad \textbf{(B.9)}$$

$$\underset{k_{0D}}{\boxed{0.882}} = \frac{2 * [(\underset{R_0\ (m)}{\boxed{0.56}} + \underset{D\ (m)}{\boxed{1}}) * \underset{R_0\ (m)}{\boxed{0.56}}]^{1/2}}{2 * \underset{R_0\ (m)}{\boxed{0.56}} + \underset{D\ (m)}{\boxed{1}}} \qquad \textbf{(B.10)}$$

$$\underset{k_{1D}}{\boxed{0.850}} = \frac{2 * [(\underset{R_1\ (m)}{\boxed{0.45}} + \underset{D\ (m)}{\boxed{1}}) * \underset{R_1\ (m)}{\boxed{0.45}}]^{1/2}}{2 * \underset{R_1\ (m)}{\boxed{0.45}} + \underset{D\ (m)}{\boxed{1}}} \qquad \textbf{(B.11)}$$

$$\underset{\psi_0\ (rad)}{\boxed{9.08E\text{-}02}} = \tan^{-1}(\underset{L_0\ (m)}{\boxed{5.46}} / (2 * \underset{d\ (m)}{\boxed{30}})) \qquad \textbf{(B.14)}$$

$$\underset{\psi_1\ (rad)}{\boxed{6.66E\text{-}02}} = \tan^{-1}(\underset{L_1\ (m)}{\boxed{4.00}} / (2 * \underset{d\ (m)}{\boxed{30}})) \qquad \textbf{(B.15)}$$

$$\underset{k_0}{\boxed{0.266}} = \frac{2 * [(\underset{R_0\ (m)}{\boxed{0.56}} + \underset{d\ (m)}{\boxed{30}}) * \underset{R_0\ (m)}{\boxed{0.56}}]^{1/2}}{2 * \underset{R_0\ (m)}{\boxed{0.56}} + \underset{d\ (m)}{\boxed{30}}} \qquad \textbf{(B.16)}$$

$$\underset{k_1}{\boxed{0.240}} = \frac{2 * [(\underset{R_1\ (m)}{\boxed{0.45}} + \underset{d\ (m)}{\boxed{30}}) * \underset{R_1\ (m)}{\boxed{0.45}}]^{1/2}}{2 * \underset{R_1\ (m)}{\boxed{0.45}} + \underset{d\ (m)}{\boxed{30}}} \qquad \textbf{(B.17)}$$

FIGURE 2.6 Dose Rate Shape Factor Calculations for Case 1

considerations and assumes that the nearest distance between the cask and the receptor is always measured from the midpoint of the cask.

In case 1, the exposure time for the stop dose to the individual receptor was set to 1 h. The calculated value of 3.7×10^{-5} rem (Appendix A, pg. A-6) was therefore the dose rate per hour that agreed with the final dose rate calculation in Figure 2.6.

In addition to this verification, the RISKIND shape factor correction was also benchmarked against MicroShield. The correction was the ratio of the dose received when the user input cask size is used to the dose received when the reference cask dimensions (RISKIND default values) are assumed. Table 2.3 presents these ratios for a receptor located 70 m from the shipping cask, as calculated by using RISKIND and MicroShield. As seen in Table 2.3, the results from the two codes were in good agreement; results were within a 7% difference when scaling down to a 3-m cask, and they were the same when scaling up to a 7-m cask.

2.2 EXTERNAL DOSE FROM A PASSING SPENT FUEL SHIPMENT

2.2.1 Individual Receptor

Case 1 modeled a shipment that passes by an individual at a speed of 24 km/h (15 miles per hour or mph) at a distance of 30 m. Gamma radiation was assumed to account for 60% of the dose, and neutron radiation was assumed to account for the remaining 40% of the dose at a distance of 1 m. The dose to that individual estimated by using RISKIND was thus 1.2×10^{-7} rem (Appendix A, pg. A-6).

At any one instant in time, the dose rate to an individual from a passing shipment can be estimated in the same way as the rate from a stationary shipment is estimated. At a fixed rate of

TABLE 2.3 Shape Factor Correction[a]

Cask Size Length × Radius (m)	Dose Ratio to Default Cask	
	RISKIND	MicroShield
3 × 0.3	0.74	0.69
5.46 × 0.56	1	1
7 × 0.7	1.2	1.2

[a] Gamma dose rates were normalized to 10 mrem/h at 2 m and compared at a distance of 70 m.

TABLE 2.4 Calculation of Dose to an Individual from a Passing Shipment

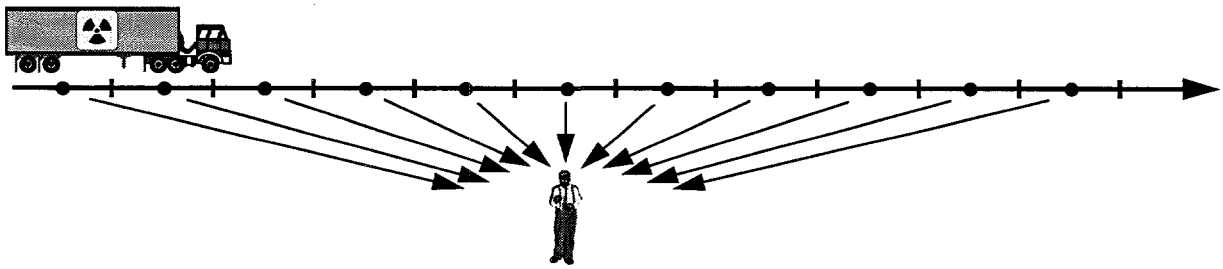
Segment Distance (m)	Number of Segments	Dose (rem)
100	21	1.77×10^{-7}
50	41	1.30×10^{-7}
25	81	1.23×10^{-7}
1	2001	1.23×10^{-7}

speed, the dose received while the shipment travels a short distance (a segment) can be approximated by the dose rate at the midpoint of the segment multiplied by the time taken to travel that distance (Figure 2.7). This approximation is similar to the numerical integration routine used by RISKIND to calculate the dose from a passing shipment. Table 2.4 summarizes the results when segment distances of 1, 25, 50, and 100 m were used. The estimated dose converged to the value of 1.2×10^{-7} rem calculated by RISKIND as the number of segments increased, indicating proper operation of the code.

For comparison, the RADTRAN 4 transportation risk assessment code (Neuhauser and Kanipe 1992) was used. In RADTRAN 4, the dose for a maximally exposed individual is calculated as part of the incident-free risks from a shipment. The maximally exposed individual is always assumed to be at the nearest distance of 30 m from the route, and the passing shipment is always assumed to travel at a speed of 24 km/h. This distance and speed were the same as those used above. The package dimension, dose rate at 1 m, and fraction of gamma and neutron radiation present were set to equal the values used above. The dose to the maximally exposed individual was estimated to be 3.79×10^{-7} rem. This result was approximately three times higher than the value of 1.2×10^{-7} rem calculated by RISKIND. The higher value calculated by RADTRAN 4 can be attributed primarily to the conservatism of the line source model it uses (Weiner and Neuhauser 1992), which is further demonstrated in the following section.

2.2.2 Population Receptor

Persons residing along the shipment route are exposed to low levels of external radiation as the shipment passes through populated areas (off-link population dose). In RISKIND, the collective population dose is estimated by integrating the dose received by one individual, as calculated above, over an area that is bounded by the nearest distance to the route,



Dose from passing shipment $= \sum_n D_i \times t_i$

n - number of segments
D_i - dose rate at midpoint of segment i (mrem/hr)
t_i - time within segment boundary = segment distance/speed

FIGURE 2.7 Method for Estimating the Dose from a Passing Shipment

furthest distance to the route, and distance traveled (Figure 2.8). The collective dose is calculated by using an average population density and includes one side of the route along the region of interest.

The routine risk to populations along the route from gamma radiation was estimated from two sources: a point source and a 3-m cask. A comparison was made of RISKIND when it uses its default gamma dose rate curve, RISKIND when it uses the NUREG–0170 curve as input, and RADTRAN 4. Although the areas of integration are fixed in RADTRAN 4, when the population zone and shielding factors are judiciously selected, population doses for specific distances from the transport route can be estimated for comparison. Table 2.5 presents the dose rate curve coefficients used in RISKIND to fit the NUREG-0170 dose rate curve for a point source. To approximate a point source in RISKIND, a value of 0.001 m was used for both cask length and radius; the calculated results were not affected if a value of 0.0001 m was used for these dimensions. In RADTRAN 4, a point source was approximated by using a value of 0.25 m for the package dimension, use of smaller values with the regulatory maximum dose rate of 10 mrem/h at 2 m caused the program to override the dose rate, because the dose rate at the package surface was estimated to exceed the regulatory maximum of 200 mrem/h.

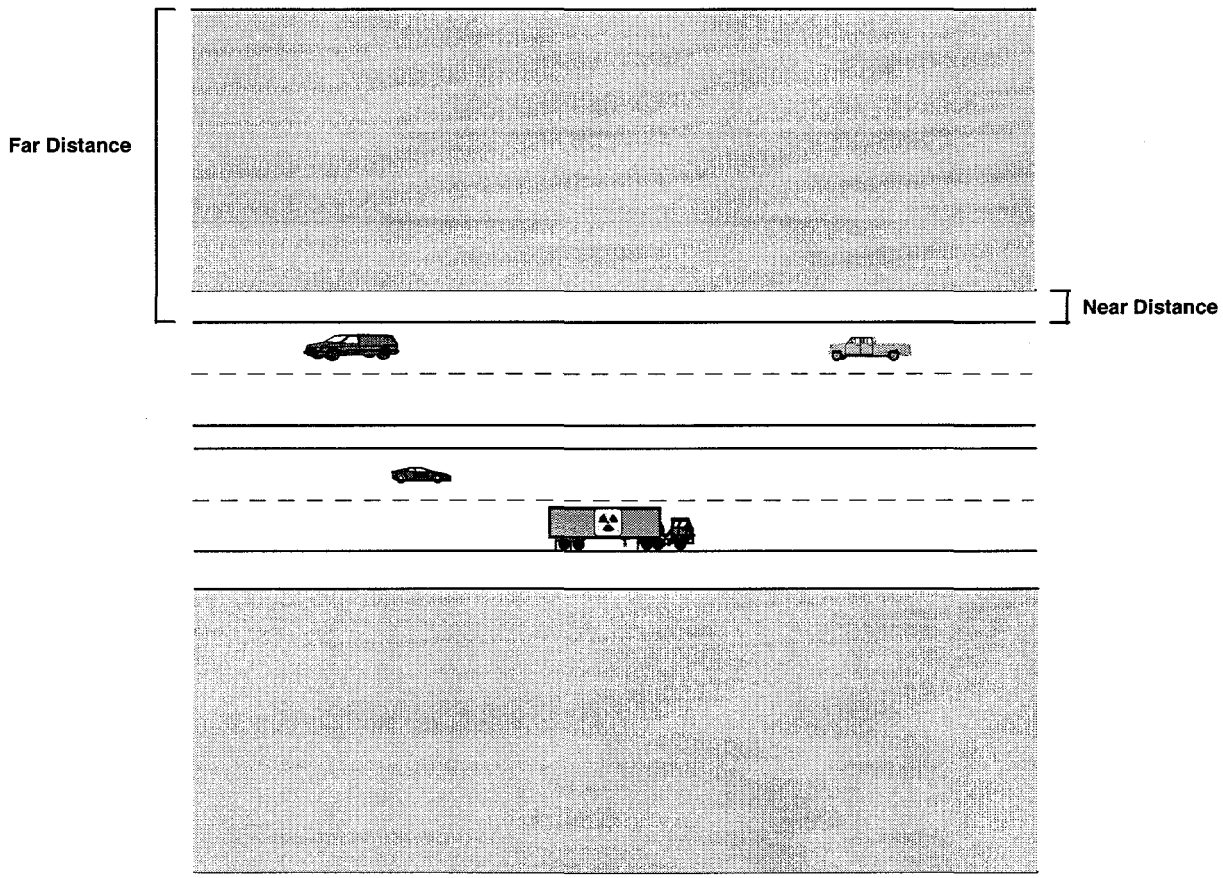


FIGURE 2.8 Area Used by RISKIND to Predict Incident-Free Off-Link Population Risks

TABLE 2.5 Gamma Dose Rate Curve Coefficients for Input into RISKIND to Fit the NUREG-0170 Dose Rate Curve[a]

Gamma Coefficient	Value	Gamma Coefficient	Value
A_{og}	1.60319	A_{4g}	0.134010
A_{1g}	-2.00868	A_{5g}	-0.0948845
A_{2g}	0.0369240	A_{6g}	0.0334039
A_{3g}	-0.103879	A_{7g}	-0.00496503

[a] Normalized to 10 mrem/h at 2 m for a point source.

The off-link population doses from a shipment with a gamma dose rate of 10 mrem/h at 2 m are shown in Table 2.6. The shipment was assumed to travel at 24 km/h through an area with a unit population density of 1 person/km^2. Relatively good agreement (approximately 40% difference in the worst case at 30-800 m) occurred among the three cases for the point source model. The RADTRAN 4 values increased with respect to those of the other two cases when the distances considered were increased. RADTRAN 4's increase can be attributed to its conservative assumptions, such as not taking credit for attenuation (Neuhauser and Kanipe 1995). For the cylindrical source (Table 2.6), the RISKIND default and RISKIND (NUREG-0170) cases were in relatively good agreement. Again, the conservative nature of RADTRAN 4's line source model produced results that were up to about four times higher than the RISKIND default values for the 30-m to 800-m region. Such differences are unavoidable because RADTRAN 4's line source model is generic in nature so it can accommodate a wide variety of packaging. On the other hand, the RISKIND values can also be made smaller or larger, depending on the cask's radius. For example, if the radius were increased to 1.5 m, the dose to the 30-m to 800-m region would almost double (1.60×10^{-8} person-rem/km).

Table 2.7 presents a comparison similar to that presented for the gamma radiation case. It compares the off-link population doses from a shipment with a neutron dose rate of 10 mrem/h at 2 m as estimated by RISKIND when it uses its default dose rate curve and RADTRAN 4. Good agreement (20% or less difference) was again obtained when a point-source configuration was used for both models. In this case, the RADTRAN 4 values always remained slightly lower than the RISKIND values. The RADTRAN 4 values did not become progressively larger relative to the RISKIND values with increasing distance, as they did for the gamma radiation case, because the neutron model in RADTRAN 4 accounts for attenuation (Neuhauser and Kanipe 1995). A comparison of the cylindrical source values again shows the conservative nature of the RADTRAN 4 line source approximation: the RADTRAN 4 value was about two times greater than the RISKIND value for the 30-m to 800-m zone.

TABLE 2.6 Comparison of RISKIND, NUREG-0170, and RADTRAN 4 Incident-Free Gamma Radiation Off-Link Population Dose (person rem/km)[a]

Near and Far Distance (m)	RISKIND	RISKIND (NUREG-0170)[b]	RADTRAN 4
Point source			
5-8	2.17×10^{-9}	2.01×10^{-9}	1.49×10^{-9}
27-30	4.15×10^{-10}	4.11×10^{-10}	3.33×10^{-10}
30-800	6.02×10^{-9}	8.28×10^{-9}	1.04×10^{-8}
5-800	1.49×10^{-8}	1.69×10^{-8}	1.60×10^{-8}
Cylindrical source[c]			
5-8	2.96×10^{-9}	2.96×10^{-9}	5.45×10^{-9}
27-30	6.00×10^{-10}	6.04×10^{-10}	1.22×10^{-9}
30-800	8.80×10^{-9}	1.22×10^{-8}	3.79×10^{-8}
5-800	2.14×10^{-8}	2.48×10^{-8}	5.85×10^{-8}

[a] Assumes a unit population density of 1 person/km^2 for comparison purposes. Doses are for a zone on one side of the transport route.

[b] NUREG-0170 dose rate curve used in RISKIND.

[c] Cylindrical source 3 m in length with a 0.3-m radius was assumed. A 3-m package dimension is used in RADTRAN.

TABLE 2.7 Comparison of RISKIND and RADTRAN 4 Incident-Free Neutron Radiation Off-Link Population Dose (person-rem/km)[a]

Near and Far Distance (m)	RISKIND	RADTRAN 4
Point source		
5-8	2.16×10^{-9}	1.72×10^{-9}
27-30	4.32×10^{-10}	4.21×10^{-10}
30-800	6.76×10^{-9}	6.00×10^{-9}
5-800	1.58×10^{-8}	1.29×10^{-8}
Cylindrical source[b]		
5-8	2.95×10^{-9}	6.25×10^{-9}
27-30	6.26×10^{-10}	1.54×10^{-9}
30-800	9.89×10^{-9}	2.19×10^{-8}
5-800	2.26×10^{-8}	4.71×10^{-8}

[a] Assumes a unit population density of 1 person/km^2 for comparison purposes. Doses are for a zone on one side of the transport route.

[b] Cylindrical source 3 m in length with a 0.3-m radius was assumed. A 3-m package dimension is used in RADTRAN.

3 ACCIDENT RISKS

Risks from potential accidents are associated with the release and dispersal of radioactive material. Potential accident conditions can result in a release of radioactive material to the atmosphere, and nearby individuals can be exposed through a number of pathways. If contamination is released to the air, it is first dispersed through atmospheric transport and eventually deposited on the ground. The exposure pathways considered in RISKIND include inhalation of the passing plume immediately following the accident, inhalation of resuspended contamination in the time following the accident, external radiation from the passing plume and from ground contamination, and ingestion of contaminated water and foodstuffs.

Most of the major accident risk algorithms were exercised in test case 2. Case 2 involved the estimation of impacts to an individual who is 1 km downwind of a potential SNF accident site in a rural population zone. Accident conditions such as vehicle speed at the time of impact, cask orientation parameters, and fire considerations were input by the user so the program could determine the accident severity. The consequences from an accident in the calculated accident response region were determined on the basis of a given set of weather conditions. The consequences included consideration of the ingestion and water pathways. The calculations began with a determination of the accident response region that specified the fractions of the shipment inventory released (Section 3.1). Section 3.2 examines the radionuclide screening process to determine the major contributors to the impacts. Section 3.3 covers atmospheric dispersion, and the various exposure pathways are discussed in Section 3.4.

3.1 ACCIDENT RESPONSE REGION DETERMINATION

An accident's severity determines the potential amount of radioactive material that could be released in the accident. RISKIND permits users to directly input radionuclide inventories and release fractions for a given situation. When analyzing SNF shipments, the program has the added capability of estimating release amounts on the basis of potential accident conditions. It estimates the potential amount of radioactive material that could be released on the basis of the accident response region in which the potential accident is categorized. The work discussed in this section was designed to check that the RISKIND procedures for determining the accident response region for SNF shipments operate properly.

The accident response region determination in the RISKIND model is an implementation of the NRC modal study of SNF casks (LLNL 1987). The spectrum of accident severities — from high probability with no radioactive release to very low probability with some release — is covered by 20 regions. A region is selected on the basis of two criteria: (1) the mechanical load on the cask due to impact forces and (2) the thermal load imparted to the cask as a result of a potential fire. There are four regions of mechanical response and five regions of thermal response, yielding a total of 20 potential regions. Figure 3.1 shows the region matrix.

Legend:

(P_t) = Probability of occurrence assuming a truck accident occurs.
(P_r) = Probability of occurrence assuming a rail accident occurs.
The number in the upper right-hand corner of each cell represents RISKIND cask response region numbering.

Structural Response (maximum strain on inner shell, %)	T_1 (500)	T_2 (600)	T_3 (650)	T_4 (1050)	
S_3 (30)	4 R(4,1) (P_t)1.532×10^{-7} (P_r)1.786×10^{-9}	8 R(4,2) 3.926×10^{-14} 3.290×10^{-13}	12 R(4,3) 1.495×10^{-14} 2.137×10^{-13}	16 R(4,4) 7.681×10^{-16} 1.644×10^{-13}	20 R(4,5) $<1 \times 10^{-16}$ 3.459×10^{-14}
S_2 (2)	3 R(3,1) (P_t)1.7984×10^{-3} (P_r)5.545×10^{-4}	7 R(3,2) 1.574×10^{-7} 1.021×10^{-7}	11 R(3,3) 2.034×10^{-7} 6.634×10^{-8}	15 R(3,4) 1.076×10^{-7} 5.162×10^{-8}	19 R(3,5) 4.873×10^{-8} 5.296×10^{-8}
S_1 (0.2)	2 R(2,1) (P_t)3.8192×10^{-3} (P_r)2.7204×10^{-3}	6 R(2,2) 2.330×10^{-7} 5.011×10^{-7}	10 R(2,3) 3.008×10^{-7} 3.255×10^{-7}	14 R(2,4) 1.592×10^{-7} 2.531×10^{-7}	18 R(2,5) 7.201×10^{-8} 1.075×10^{-8}
	1 R(1,1) (P_t)0.994316 (P_r)0.993962	5 R(1,2) 1.687×10^{-5} 1.2275×10^{-3}	9 R(1,3) 2.362×10^{-5} 7.9511×10^{-4}	13 R(1,4) 1.525×10^{-5} 6.140×10^{-4}	17 R(1,5) 9.570×10^{-6} 1.249×10^{-4}

Thermal Response (lead midlayer thickness temperature, °F)

FIGURE 3.1 Matrix of Cask Response Regions and Probabilities of Occurrence for Combined Mechanical and Thermal Loads (Source: LLNL 1987)

3.1.1 Mechanical Loads

The mechanical response of the shipping cask to an impact is characterized by four input parameters:

1. Hardness of the object impacted (IHARD = 1-4, unyielding to very soft),

2. Velocity of the cask (VCASK = 0-150 mph [0-241 km/h]),

3. Cask impact angle (ALPHA = 0-90°), and

4. Cask orientation angle (BETA = 0-90°), see Figure 3.2.

In case 2, the input values were (Appendix A, pg. A-18) as follows: IHARD = 1, VCASK = 60 mph (97 km/h), ALPHA = 45°, and BETA = 45°. The mechanical response region is determined by calculating the impact velocity (impact velocity = VCASK × SIN(ALPHA)) and locating its relative position in Table 3.1. The hardness of the object impacted was unyielding for case 2 for truck transport, so the top line in Table 3.1 was used. Because an orientation angle of 45° was used, the impact velocity had to be less than 35 mph (0.2% strain) to be in mechanical response region 1, less than 49 mph (2% strain) to be in region 2, less than 113 mph (30% strain) to be in region 3, or greater than or equal to 113 mph to be in region 4. The impact velocity for case 2 was 42.4 mph:

$$\text{Impact velocity} = \text{VCASK} \times \text{SIN (ALPHA)}$$
$$42.4 \text{ mph} = 60 \text{ mph} \times \sin(45°) \qquad \text{(E.1 in Manual)} \tag{3.1}$$

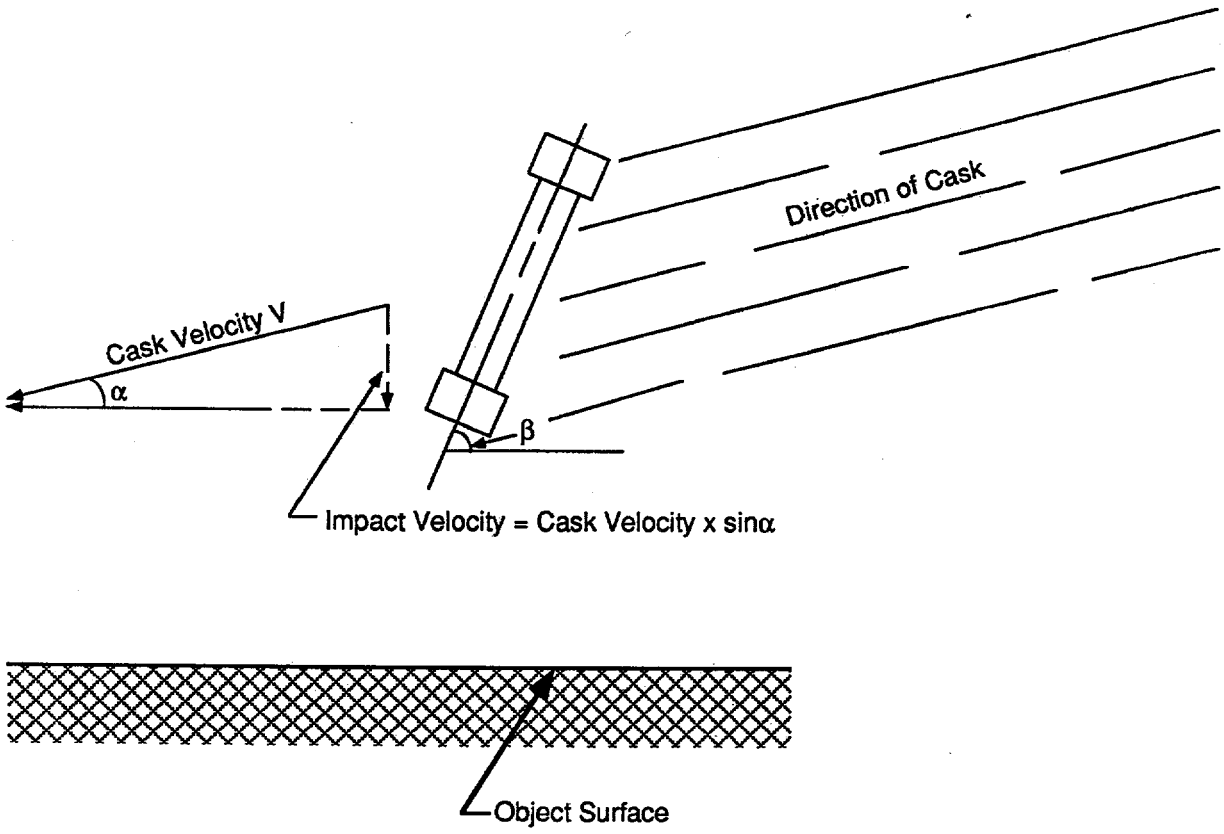


FIGURE 3.2 Three Impact Loading Parameters Considered in the Response Analysis for Impacts on Surfaces (Modified from LLNL 1987, Figure 2.1)

TABLE 3.1 Impact Velocities Required to Attain 0.2%, 2%, and 30% Strain Levels for Objects Impacted in Highway and Railway Accidents

	Impact Velocity (km/h) at Various Strain Levels and Orientation Angles[a]								
	0.2% Strain at Three Angles			2% Strain at Three Angles			30% Strain at Three Angles		
Accident Type/ Object Hardness	0°	45°	90°	0°	45°	90°	0°	45°	90°
Highway									
Unyielding	51.5 (32)	56.3 (35)	61.1 (38)	82.1 (51)	78.8 (49)	74.0 (46)	>241 (>150)	182 (113)	122 (76)
Median	51.5 (32)	56.3 (35)	61.1 (38)	82.1 (51)	78.8 (49)	74.0 (46)	241 (>150)	241 (>150)	241 (>150)
Soft	51.5 (32)	933 (58)	135 (84)	82.1 (51)	163 (101)	241 (>150)	241 (>150)	241 (>150)	241 (>150)
Very soft	67.6 (42)	>241 (>150)	61.1 (38)	94.9 (59)	241 (>150)	103 (64)	241 (>150)	241 (>150)	241 (>150)
Railway									
Unyielding	88.5 (55)	75.6 (47)	61.1 (38)	116 (72)	96.5(60)	77.2 (48)	241 (>150)	206 (128)	169 (105)
Median	88.5 (55)	75.6 (47)	61.1 (38)	116 (72)	96.5(60)	77.2 (48)	241 (>150)	206 (128)	169 (105)
Soft	88.5 (55)	75.6 (47)	64.4 (40)	116 (72)	111 (69)	105 (65)	241 (>150)	241 (>150)	241 (>150)
Very soft	88.5 (55)	>241 (>150)	61.1 (38)	116 (72)	241 (>150)	96.5 (60)	241 (>150)	241 (>150)	241 (>150)

[a] In the modal study (LLNL 1987), 150 mph (241 km/h) is defined as the maximum credible velocity. Numbers in parentheses indicate mph.

Source: LLNL (1987).

Because the calculated impact velocity was greater than 35 mph but less than 49 mph, the scenario fell into the second impact region. When the second impact region was combined with the estimated thermal response region of 3, as discussed in the following section, the scenario fell into RISKIND response region 10. This determination is reflected in the case 2 output file (Appendix A, pg. A-18).

It would not have been practical to check every possible combination of the four input parameters for this study. However, a spot check of a few well-chosen combinations was done to demonstrate the proper operation of most of the calculational steps. Variations in the cask velocity, impact angle, and orientation angle were investigated. Table 3.2 shows the response regions determined when only the cask velocity was changed. The effects from varying the impact angle at a cask velocity of 114 mph are shown in Table 3.3. Effects from varying the cask orientation angle (BETA) are shown in Table 3.4 for a cask velocity of 70 mph. When BETA equalled 45°, the estimated impact velocity was 49.5 mph. The impact velocity limit in Table 3.4 is the cutoff velocity between impact regions 2 and 3. This limit is obtained by interpolation when BETA is some value other than 0°, 45°, or 90°.

3.1.2 Thermal Loads

The thermal response region is determined on the basis of four discrete temperatures (response levels) of the midlayer of the cask's lead shield — 500, 600, 650, and 1,050°F — corresponding to five regions. The midlayer temperature is related to three input parameters:

1. Fire duration (DFIRE),
2. Flame temperature (TFLAME), and
3. Fire location (FLOC).

A 1,700°F engulfing fire was used as a reference point for estimates in the modal study. Results are extrapolated to other scenarios by using the following calculation:

$$d_F(t,l) = \delta(t)\, d_F(1700°F)\, \delta(l), \qquad \text{(E.2 in Manual)} \qquad (3.2)$$

where:

t = cask midlayer temperature (°F);

l = fire location (ft);

$d_F(t,l)$ = fire duration corresponding to cask midlayer temperature t and fire location l;

$\delta(t)$ = multiplication factor to adjust for flame temperature other than 1,700°F (Table 3.5);

TABLE 3.2 Response Region Determination with Variation in Cask Velocity

Cask Velocity (mph)	Impact Velocity (mph)	Impact Region	Fire Region	RISKIND Region
20	14.1	1	3	9
40	28.3	1	3	9
60	42.4	2	3	10
80	56.6	3	3	11
100	70.7	3	3	11
120	84.9	3	3	11
140	99.0	3	3	11

TABLE 3.3 Response Region Determination with Variation in Cask Impact Angle

Impact Angle, α (degrees)	Impact Velocity (mph)	Impact Region	Fire Region	RISKIND Region
0	0.0	1	3	9
15	29.5	1	3	9
30	57.0	3	3	11
45	80.6	3	3	11
60	98.7	3	3	11
75	110.1	3	3	11
90	114.0	4	3	12

TABLE 3.4 Response Region Determination with Variation in Cask Orientation Angle

Orientation Angle, β (degrees)	Impact Velocity Limit (mph)	Impact Region	Fire Region	RISKIND Region
0	51.0	2	3	10
15	50.3	2	3	10
30	49.7	2	3	10
45	49.0	3	3	11
60	48.0	3	3	11
75	47.0	3	3	11
90	46.0	3	3	11

TABLE 3.5 Heat Flux Factors for Flame Temperatures (engulfing fire)

Flame Temperature, t			Flame Temperature, t		
K	°F	δ(t)	K	°F	δ(t)
1,030	1,400	1.72	1,370	2,000	0.64
1,090	1,500	1.43	1,420	2,100	0.56
1,140	1,600	1.21	1,480	2,200	0.49
1,200	1,700	1.0	1,530	2,300	0.44
1,260	1,800	0.86	1,590	2,400	0.39
1,310	1,900	0.73			

Source: LLNL (1987).

$d_F(1700°F)$ = duration of 1,700°F fire (Table 3.6 has the fire durations necessary to reach the four response levels for both truck and rail casks); and

$\delta(l)$ = multiplication factor to adjust for cask distance away from fire location ($l = 0$ corresponds to an engulfing fire);

$$\delta(1) = 0.78 \exp(0.7732 + 0.06287\, l) \text{ for truck when } l \text{ is } >1.5 \text{ ft} \quad \text{(E.3 in Manual)} \tag{3.3}$$

$$\delta(1) = 0.78 \exp(0.62874 + 0.08471\, l) \text{ for rail when } l \text{ is } >4 \text{ ft} \quad \text{(E.4 in Manual)} \tag{3.4}$$

For case 2, DFIRE was 1.5 h, TFLAME was 1,850°F (1,283 K), and FLOC was 0 ft. The flame temperature multiplication factor, δ(t), which can be obtained by interpolating between the values for 1,800° and 1,900°F in Table 3.5, was a value of 0.81. Since an engulfing fire was present, the distance multiplication factor, δ(l), was 0. The fire duration adjusted for a 1,700°F flame temperature was:

$$d_F(t,l)/\delta(t) = 1.5 \text{ h}/0.81 = 1.9 \text{ h}. \tag{3.5}$$

This time fell between the time needed to result in midlayer temperatures of 600 and 650°F, the third thermal response region (Table 3.6). As discussed in the impact response section, the combined results of the impact response and thermal response placed the case 2 scenario in RISKIND response region 10, as noted in the case 2 output file (Appendix A, pg. A-18).

TABLE 3.6 Fire Duration Required to Reach the Four Levels of Lead Midlayer Thickness Temperatures for a 1,200 K (1,700°F) Engulfing Fire

Temperature		Duration (h)	
K	°F	Truck Cask	Rail Cask
530	500	1.1	1.2
590	600	1.4	1.8
616	650	2.1	2.7
839	1,050	3.3	5.1

Source: LLNL (1987).

3.2 RADIONUCLIDE SCREENING

Since an SNF shipment could contain more than 100 radionuclides, the number of potential radionuclides used in the risk calculations can be screened so that only those radionuclides responsible for the largest impacts are used. Radionuclides are screened with regard to their potential hazard via three pathways. Pathway I is short-term exposure from inhalation and air immersion during plume passage; pathway II is long-term external radiation exposure from contaminated ground; and pathway III is long-term internal exposure due to ingestion. A radionuclide is retained for calculations if its relative contribution to any of the three pathways is greater than the hazard limit set by the user, HZLM. Screening should not be used if there is a potential for acute effects, because the screening does not account for acute impacts. No screening is performed if HZLM is set to 0.

The relative importance of each radionuclide with regard to pathway I exposure can be written as:

$$FI(i) = \frac{DI(i)}{\sum_i DI(i)} = \frac{\sum_{j=1,2} Q(i)\, RS(i)\, DFI(i,j)}{\sum_i \sum_{j=1,2} Q(i)\, RS(i)\, DFI(i,j)} \qquad \text{(C.2, C.3 in Manual)} \qquad (3.6)$$

where:

Q(i) = source inventory for radionuclide i,

RS(i) = release fraction for radionuclide i, and

DFI(i, j) = dose conversion factor for radionuclide i for either inhalation or air immersion (j = 1 or 2).

The relative importance of each radionuclide with regard to pathway II exposure can be written as:

$$FII(i) = \frac{DII(i)}{\sum_i DII(i)} = \frac{Q(i)\,RS(i)\,V_d(i)\,TG(i)\,DFII(i)}{\sum_i Q(i)\,RS(i)\,V_d(i)\,TG(i)\,DFII(i)} \quad \text{(C.7, C.8 in Manual)} \quad (3.7)$$

where:

$V_d(i)$ = deposition velocity for radionuclide i;

$DFII(i)$ = dose conversion factor for radionuclide i for ground external exposure;

$TG(i) = \{1 - \exp[-\lambda_g(i)\,T]\} / \lambda_g(i)$ (C.6 in Manual); (3.8)

$\lambda_g(i)$ = $\lambda(i) + \lambda_w$, effective removal constant for radionuclide i (accounts for radioactive decay and weathering); and

T = total time period for ground external exposure.

The relative importance of each radionuclide with regard to pathway III exposure can be written as:

$$FIII(i) = \frac{DIII(i)}{\sum_i DIII(i)} = \frac{Q(i)\,RS(i)\,V_d(i)\,TG(i)\,DFIII(i)\,B_v(i)\,[F1(i)+F2(i)+F3(i)]}{\sum_i Q(i)\,RS(i)\,V_d(i)\,TG(i)\,DFIII(i)\,B_v(i)\,[F1(i)+F2(i)+F3(i)]}$$

(C.13, C.14 in Manual) (3.9)

where:

$B_v(i)$ = soil-to-vegetation transfer factor for radionuclide i;

$F1(i) = F_b(i)\,Q_a\,U_b / \rho$ (C.10 in Manual); (3.10)

$F2(i) = F_m(i)\,Q_a\,U_m / \rho$ (C.11 in Manual); (3.11)

$F3(i) = 0.5\,U_v / \rho$ (C.12 in Manual); (3.12)

$F_b(i)$ = meat transfer factor for radionuclide i;

$F_m(i)$ = milk transfer factor for radionuclide i;

Q_a = animal pasture grass ingestion rate for meat cattle and milk cows;

U_b, U_m, U_v = human food ingestion rate for meat, milk, and vegetables, respectively; and

ρ = vegetation yield density of pasture land or vegetable garden.

A set of example calculations for case 2 is given in Figure 3.3 for one of the more significant radionuclides, Cs-137. It was estimated to contribute to less than 10% of the acute dose, FI(Cs-137) = 0.069 but to more than 50% of the long-term ground exposure dose and 90% of the ingestion dose (FII = 0.58 and FIII = 0.945, respectively). These values are rough estimates only and do not represent the final contributions calculated by using the full methodology for each exposure pathway.

CS137

Pathway I, short-term exposure from inhalation and air immersion

8.76E-09	=	3.98E+04	x	2.00E-05	x	[1.10E-08	+	2.73E-14]				(C.1)
DI		Qi		RS(i)		DFI(i,1)		DFI(i,2)				
6.90E-02	=	8.76E-09	/	1.27E-07								(C.3)
FI		DI(i)		DIsum								

Pathway II, long-term exposure from contaminated ground exposure

3.69E-02	=	2.30E-02	+	1.39E-02								
$\lambda_g(i)$		$\lambda(i)$		λ_w								
2.28E+01	=	{ 1 - exp [-	3.69E-02	x	5.00E+01	] }	/	3.69E-02				(C.6)
TG(i)			$\lambda_g(i)$		T			$\lambda_g(i)$				
1.01E-17	=	3.98E+04	x	2.00E-05	x	1.00E-03	x	2.28E+01	x	5.54E-16		(C.4/C.5)
DII		Qi		RS(i)		$V_d(i)$		TG(i)		DFII(i)		
5.84E-01	=	1.01E-17	/	1.73E-17								(C.7)
FII		DII(i)		DIIsum								

Pathway III, long-term exposure from ingestion

8.00E-02	=	4.00E-03	x	5.00E+01	x	3.00E-01	/	7.50E-01				(C.10)
F1(i)		$F_b(i)$		Q_a		U_b		ρ				
6.80E-01	=	1.20E-02	x	5.00E+01	x	8.50E-01	/	7.50E-01				(C.11)
F2(i)		$F_m(i)$		Q_a		U_m		ρ				
1.93E-01	=	5.00E-01	x	7.70E-01	/	2.00E+00						(C.12)
F3(i)		DFACT		U_v		ρ						
2.75E-12	=	3.98E+04	x	2.00E-05	x	1.00E-03	x	2.28E+01	x	1.00E-02	x	
DIII		Qi		RS(i)		$V_d(i)$		TG(i)		$B_v(I)$		(C.9)
						[8.00E-02	+	6.80E-01	+	1.93E-01]	x	1.59E-08
						F1(i)		F2(i)		F3(i)		DFIII(i)
9.45E-01	=	2.75E-12	/	2.91E-12								(C.13)
FIII		DIII(i)		DIIIsum								

FIGURE 3.3 Radionuclide Screening Calculations for Cs-137

Table 3.7 provides the intermediate and final values for the relationships described above for case 2. It shows which radionuclides provide significant doses relative to the hazard limit of 0.005. Those radionuclides selected match those provided in the case 2 output file (Appendix A, pg. A-19).

3.3 ATMOSPHERIC DISPERSION

Once a radioactive material is released from its packaging after an accident, any aerosolized component may be dispersed by the prevailing weather conditions. The air concentrations lead directly to the inhalation and external radiation (cloudshine) exposure pathways covered in Section 3.4 and are intermediate values in the estimation of ground deposition. In turn, the calculated values for ground concentrations are required to estimate exposure to external radiation from the contaminated ground surface (groundshine) and resuspended inhalation, and they are used as input to the food and water ingestion pathways.

3.3.1 Initial Dispersion

RISKIND uses a simple Gaussian dispersion model that assumes a point source as the origin of a puff release. Since estimates of downwind concentrations depend on the size of the puff at a given location, adjustments are made to account for the initial size of the puff and to correct for this initial size at further locations downwind.

Following an accident, turbulent air flow around the packaging mixes the released material with the surrounding air. Therefore, the initial release of material from its packaging will result in a small puff whose cross section is roughly proportional to the size of the packaging, even if only a small breach is present. The size of the initial source is first estimated in the form of values for the initial horizontal and vertical dispersion coefficients, σ_{y0} and σ_{z0}, respectively.

Once the initial size of the puff is estimated, the Gaussian dispersion model is corrected for downwind concentration estimates by adding an additional length to the distance downwind from the source in the calculations. This additional virtual distance is the distance necessary for the puff to grow from a point source to its estimated initial size.

RISKIND provides an option to use one of two sets of dispersion coefficients in the Gaussian plume equations: the Pasquill-Gifford dispersion coefficients (Eimutis and Konicek 1972) or the Briggs dispersion coefficients (Briggs 1974). The Pasquill-Gifford dispersion coefficients are based on ground-level release data, and their use with elevated releases is discouraged. The Briggs dispersion coefficients are based on elevated releases. Briggs does not recommend their use for heights greater than 100 m.

TABLE 3.7 Radionuclide Screening Values for Case 2

Nuclide Name	Does it contribute?	Release Amount [Ci]	DI(i)	TG(i)	DII(i)	F1(i)	F2(i)	F3(i)	DIII(i)	FI(i)	FII(i)	FIII(i)
H-3	No	4.34E–05	7.51E–16	1.39E+01	0.00E+00	2.40 E–01	5.67E–01	1.93E–01	5.00 E–17	5.91 E–09	0.00E+00	1.72 E–05
Fe-55	No	2.14 E–05	1.55E–14	3.65E+00	0.00E+00	8.00E–01	6.80E–02	1.93E–01	8.97E–21	1.22E–07	0.00E+00	3.08E–09
Co-60	Yes	4.25E–01	2.51E–08	6.95E+00	6.94E–18	2.60E–01	5.67E–02	1.93E–01	1.03E–13	1.98E–01	4.02E–01	3.53E–02
Ni-63	No	3.76E–05	6.39E–14	3.11E+01	0.00E+00	1.06E–01	3.80E–01	1.93E–01	2.35E–18	5.03E–07	0.00E+00	8.07E–07
Kr-85	Yes	7.69E+01	7.92E–10	1.24E+01	0.00E+00	4.00E–01	1.13E+00	1.93E–01	0.00E+00	6.24E–03	0.00E+00	0.00E+00
Sr-90	Yes	5.54E–03	1.96E–09	2.24E+01	6.97E–22	1.20E–02	4.53E–02	1.93E–01	2.19E–14	1.54E–02	4.04E–05	7.51E–03
Y-90	No	5.54E–03	1.26E–11	1.05E–02	3.11E–25	9.20E–02	5.67E–04	1.93E–01	1.26E–19	9.95E–05	1.80E–08	4.32E–08
Ru-106	No	6.59E–04	8.56E–11	1.42E+00	1.98E–22	8.00E+00	5.67E–05	1.93E–01	3.18E–15	6.74E–04	1.15E–05	1.09E–03
Rh-106	No	6.59E–04	5.90E–13	1.37E–06	1.91E–28	3.00E–02	5.67E–01	1.93E–01	8.29E–21	4.64E–06	1.11E–11	2.85E–09
Sb-125	No	1.20E–04	4.51E–13	3.79E+00	1.97E–22	8.00E–02	8.50E–02	1.93E–01	1.76E–18	3.55E–06	1.14E–05	6.06E–07
Te-125m	No	2.94E–05	5.79E–14	2.27E–01	2.40E–25	1.54E+00	5.67E–02	1.93E–01	1.54E–17	4.56E–07	1.39E–08	5.28E–06
Cs-134	Yes	5.52E–02	6.90E–10	2.83E+00	2.37E–19	8.00E–02	6.80E–01	1.93E–01	2.94E–14	5.43E–03	1.37E–02	1.01E–02
Cs-137	Yes	7.96E–01	8.76E–09	2.28E+01	1.01E–17	8.00E–02	6.80E–01	1.93E–01	2.75E–12	6.90E–02	5.84E–01	9.45E–01
Ba-137m	No	7.52E–03	1.87E–11	7.14E–06	3.15E–26	6.40E–02	2.27E–02	1.93E–01	1.87E–22	1.47E–04	1.82E–09	6.41E–11
Ce-144	No	1.29E–05	1.30E–12	1.11E+00	8.32E–25	2.40E–02	3.40E–02	1.93E–01	5.10E–20	1.03E–05	4.82E–08	1.75E–08
Pr-144	No	1.29E–05	1.51E–16	4.76E–05	2.33E–29	9.40E–02	2.83E–04	1.93E–01	1.39E–26	1.19E–09	1.35E–12	4.76E–15
Pm-147	No	8.42E–04	8.93E–12	3.65E+00	1.05E–25	9.60E–02	2.83E–04	1.93E–01	6.28E–19	7.03E–05	6.06E–09	2.16E–07
Sm-151	No	3.62E–05	2.93E–13	3.06E+01	5.56E–27	1.00E–01	2.83E–04	1.93E–01	8.51E–20	2.31E–06	3.22E–10	2.92E–08
Eu-154	No	4.18E–04	3.23E–11	1.07E+01	5.26E–21	9.60E–02	2.83E–04	1.93E–01	8.30E–18	2.54E–04	3.05E–04	2.85E–06
Eu-155	No	1.54E–04	1.72E–12	6.50E+00	5.90E–23	9.60E–02	2.83E–04	1.93E–01	2.98E–19	1.36E–05	3.42E–06	1.02E–07
Pu-238	Yes	2.84E–04	3.01E–08	3.05E+01	7.24E–24	2.80E–04	1.13E–04	1.93E–01	3.61E–16	2.37E–01	4.20E–07	1.24E–04
Pu-239	Yes	3.30E–05	3.83E–09	3.60E+01	4.37E–25	2.80E–04	1.13E–04	1.93E–01	5.48E–17	3.01E–02	2.53E–08	1.88E–05
Pu-240	Yes	4.74E–05	5.50E–09	3.60E+01	1.37E–24	2.80E–04	1.13E–04	1.93E–01	7.86E–17	4.33E–02	7.93E–08	2.70E–05
Pu-241	Yes	7.76E–03	1.73E–08	1.54E+01	6.23E–25	2.80E–04	1.13E–04	1.93E–01	1.07E–16	1.36E–01	3.61E–08	3.67E–05
Am-241	Yes	1.73E–04	2.08E–08	3.48E+01	1.65E–22	4.00E–03	2.83E–04	1.93E–01	2.92E–16	1.64E–01	9.58E–06	1.00E–04
Cm-244	Yes	1.79E–04	1.20E–08	1.78E+01	2.80E–24	4.00E–03	2.83E–04	1.93E–01	8.56E–16	9.44E–02	1.63E–07	2.94E–04
Contributing totals			1.27E–07 (DIsum)		1.73E–17 (DIIsum)				2.91E–12 (DIIIsum)	**9.99E–01** inhale	**1.00E+00** ground	**9.98E–01** ingest

The Pasquill-Gifford dispersion coefficients were used in case 2. The estimated values for the initial dispersion coefficients and the virtual distances are presented in Figure 3.4 for the horizontal and vertical coefficients, respectively. Note that the Pasquill-Gifford coefficients used for determining the virtual distance for σ_{z0} are for an x that is less than 100 m, since the initial size of the plume is assumed to be smaller than it would be if the plume originated from a point source and traveled further than 100 m. If the Briggs coefficients were selected for case 2, the resulting virtual distances would be those shown in Figure 3.5.

initial value for σ_y

$$\underset{\sigma_{y0}\ (m)}{\boxed{0.441}} = (2 * \underset{HSIZE\ (m)}{\boxed{4.00}} * \underset{RSIZE\ (m)}{\boxed{0.45}})^{1/2} / 4.3 \qquad (3.37)$$

virtual distance for σ_y

$$\underset{x_{Yvirt}\ (m)}{\boxed{3.35}} = (\underset{\sigma_{y0}\ (m)}{\boxed{0.441}} / (0.000246 * \underset{\sigma_\theta^2}{\boxed{100}} + 0.00576 * \underset{\sigma_\theta}{\boxed{10}} + 0.066))^{1/0.9031} \qquad (3.39)$$

initial value for σ_z

$$\underset{\sigma_{z0}\ (m)}{\boxed{0.419}} = 2 * \underset{RSIZE\ (m)}{\boxed{0.45}} / 2.15 \qquad (3.38)$$

virtual distance for σ_z

$$\underset{x_{Zvirt}\ (m)}{\boxed{6.64}} = ((\underset{\sigma_{z0}\ (m)}{\boxed{0.419}} - \underset{c\ (m)}{\boxed{0.00}}) / \underset{a}{\boxed{0.079}})^{\boxed{1.14}\ 1/b} \qquad (3.40)$$

FIGURE 3.4 Initial Pasquill-Gifford Horizontal and Vertical Dispersion Parameter Estimates

virtual distance for σ_y

$$\underset{x_{Yvirt}\ (m)}{\boxed{5.52}} = \frac{\underset{\sigma_{y0}\ (m)}{\boxed{0.441}}}{\underset{a}{\boxed{0.08}} * (1 + \underset{b}{\boxed{0.0001}} * \underset{x_{Yvirt}\ (m)}{\boxed{5.52}})^{\boxed{-0.5}\ c}} \qquad (3.41)$$

virtual distance for σ_z

$$\underset{x_{Zvirt}\ (m)}{\boxed{7.01}} = \frac{\underset{\sigma_{z0}\ (m)}{\boxed{0.419}}}{\underset{a}{\boxed{0.06}} * (1 + \underset{b}{\boxed{0.0015}} * \underset{x_{Zvirt}\ (m)}{\boxed{7.01}})^{\boxed{-0.5}\ c}} \qquad (3.42)$$

FIGURE 3.5 Initial Briggs Horizontal and Vertical Virtual Distance Estimates

3.3.2 Effective Release Height

Another initial factor in addition to dispersion geometry that will affect downwind concentrations is the effective release height. The effective release height is the actual physical release height above the ground, adjusted for thermally induced plume rise and the terrain height of the receptor. The plume rise calculations depend on the effective wind speed, which depends, in turn, on the effective release height. This circular dependency requires iteration among the equations for effective release height, plume rise (Δh), and effective wind speed. The calculations for case 2 are presented in Figure 3.6. The resulting effective release height of 11.3 m agrees with the 11.2 m value found in the case 2 output file (Appendix A, pg. A-19).

3.3.3 Ground-Level Air Concentrations

To estimate the ground-level air concentrations at a given location from the release point, the effective dispersion coefficients must be calculated. Figure 3.7 presents the Pasquill-Gifford dispersion coefficients for case 2 calculated by using the results from Section 3.3.1 adjusted for buoyancy-induced dispersion. These data are in agreement with the case 2 program output (Appendix A, pg. A-19). The parallel calculations for Briggs dispersion coefficients are given in Figure 3.8.

As the plume migrates downwind, it is eventually restricted by an upper layer of stable air. This restriction results in reflection of the plume back toward the ground and eventually a homogenous vertical distribution. Figure 3.9 presents the calculations performed to estimate the time-integrated ground-level air concentration (C_a) of radionuclide *i* for a release of 1 Ci when the plume has not yet been restricted by a stable upper air layer. The value of 5.27×10^{-5} Ci-s/m^3 agrees with the χ/Q (Chi/Q; C_a/Q_{xi}) on page 10 of the case 2 output (Appendix A, pg. A-19) for gases that are assumed to not undergo plume depletion. Values of χ/Q for the other radionuclide types are slightly less than those for gases since they are assumed to undergo dry deposition. As a check, Figure 3.10 presents the ground-level air calculation when plume reflection occurs. This latter result of 2.15×10^{-7} Ci-s/m^3 can be obtained by using RISKIND if the case 2 input parameters for the receptor distance are changed from 1 to 10 km and the weather stability category is changed from D to B. The gas χ/Q value in the program output is 2.16×10^{-7} s/m^3. As an additional check, Figure 3.11 presents the ground-level air concentration calculations for the case 2 conditions, except the Briggs dispersion coefficients have been selected for input. The 4.43×10^{-5} Ci-s/m^3 end result agrees with the RISKIND output of 4.45×10^{-5} s/m^3 for the gas χ/Q if case 2 is run with the Briggs dispersion coefficients selected.

3.3.3.1 Comparison with GENII

The GENII computer code (Napier et al. 1988) uses a similar Gaussian plume model for accidental radioactive releases and is implemented with the Pasquill-Gifford dispersion coefficients. Plume centerline ($y = 0$) χ/Q values for a number of distances downwind were estimated by using RISKIND and GENII. Point source releases were modeled to compare codes, since the model in GENII assumes a point source configuration. The cask length was set to

Effective Release Height

$$\underset{H\ (m)}{\boxed{11.31}} = \underset{h\ (m)}{\boxed{1.00}} + \underset{\Delta h\ (m)}{\boxed{15.31}} - (1. - \underset{P_c}{\boxed{0.50}}) * [\min(\underset{h + \Delta h}{\boxed{16.31}}\ \underset{E_r - E_p}{\boxed{10.00}})\ (m)] \quad (3.2)$$

Plume Rise

Unstable/Neutral Conditons (A-D)

x <= 10 * stack height

$$\underset{\Delta h\ (m)}{\boxed{N/A}} = \frac{1.6}{\underset{U_H\ (m/s)}{\boxed{2.04}}} * [\underset{(m^4/cal\text{-}s^2)}{3.7 * 10^{-5}} * \underset{Q_h\ (cal/s)}{\boxed{2000000}} * \underset{x^2\ (m^2)}{\boxed{1000000}}]^{1/3} \quad (3.3)$$

x > 10 * stack height

$$\underset{\Delta h\ (m)}{\boxed{15.31}} = \frac{1.6}{\underset{U_H\ (m/s)}{\boxed{2.04}}} * [\underset{(m^4/cal\text{-}s^2)}{3.7 * 10^{-5}} * \underset{Q_h\ (cal/s)}{\boxed{2000000}} * 100 * \underset{h^2\ (m^2)}{\boxed{1.00}}]^{1/3} \quad (3.4)$$

Stable Conditions (E,F)

Still expanding [x <= 2.4*($U_H/s^{1/2}$) and U >= U_{test}]

$$\underset{\Delta h\ (m)}{\boxed{N/A}} = \frac{1.6}{\underset{U_H\ (m/s)}{\boxed{2.04}}} * [\underset{(m^4/cal\text{-}s^2)}{3.7 * 10^{-5}} * \underset{Q_h\ (cal/s)}{\boxed{2000000}} * \underset{x^2\ (m^2)}{\boxed{1000000}}]^{1/3} \quad (3.5)$$

Far limit [x > 2.4*($U_H/s^{1/2}$) and U >= U_{test}]

$$\underset{\Delta h\ (m)}{\boxed{N/A}} = 2.9 * \left[\frac{\underset{(m^4/cal\text{-}s^2)}{3.7 * 10^{-5}} * \underset{Q_h\ (cal/s)}{\boxed{2000000}}}{\underset{U_H\ (m/s)}{\boxed{2.04}} * \underset{s\ (s^{-2})}{\boxed{0.001192}}}\right]^{1/3} \quad (3.6)$$

Light wind, vertical rise (U < U_{test})

$$\underset{\Delta h\ (m)}{\boxed{N/A}} = 5.0 * \frac{[\underset{(m^4/cal\text{-}s^2)}{3.7 * 10^{-5}} * \underset{Q_h\ (cal/s)}{\boxed{2000000}}]^{1/4}}{[\underset{s\ (s^{-2})}{\boxed{0.001192}}]^{3/8}} \quad (3.7)$$

s: stability parameter [g/T * dθ/dz]

$$\underset{s\ (s^{-2})}{\boxed{0.001192}} = \frac{\underset{(m/s^2)}{9.80665}}{\underset{T_a(^oK)}{\boxed{288}}} * \underset{dT/dz + I\ (^oK/m)}{\boxed{0.035}} \quad (3.8)$$

wind speed cut-off

$$\underset{U_{test}}{\boxed{0.246528}}\ (m/s) = 0.195 * [\underset{(m^4/cal\text{-}s^2)}{3.7 * 10^{-5}} * \underset{Q_h\ (cal/s)}{\boxed{2000000}}]^{1/4} * [\underset{s\ (s^{-2})}{\boxed{0.001192}}]^{1/8} \quad (3.9)$$

Effective Wind Speed

If H <= 10 m

$$\underset{U_H\ (m/s)}{\boxed{N/A}} = \underset{U_a\ (m/s)}{\boxed{2.00}}$$

else

$$\underset{U_H\ (m/s)}{\boxed{2.04}} = \underset{U_a\ (m/s)}{\boxed{2.00}} * \left[\frac{\underset{H\ (m)}{\boxed{11.31}}}{\underset{z_a\ (m)}{\boxed{10.00}}}\right]^{\underset{p}{\boxed{0.15}}} \quad (3.10)$$

FIGURE 3.6 Effective Release Height Calculation in RISKIND

σ_y with virtual distance adjustment

$$\underset{\sigma_y'\ (m)}{\boxed{76.1}} = (0.000246 * \underset{\sigma_\theta^2}{\boxed{100}} + 0.00576 * \underset{\sigma_\theta}{\boxed{10}} + 0.066) * (\underset{x\ (m)}{\boxed{1000}} + \underset{x_{Yvirt}\ (m)}{\boxed{3.35}})^{0.9031} \quad (3.32)$$

σ_y adjusted for buoyancy-induced dispersion

$$\underset{\sigma_y\ (m)}{\boxed{76.2}} = (\underset{\sigma_y^2\ (m^2)}{\boxed{5.79E+03}} + (\underset{\Delta h\ (m)}{\boxed{15.31}} / 3.5)^2)^{1/2} \quad (3.46)$$

σ_z with virtual distance adjustment

$$\underset{\sigma_z'\ (m)}{\boxed{31.7}} = \underset{a}{\boxed{0.222}} * (\underset{x\ (m)}{\boxed{1000}} + \underset{x_{Zvirt}\ (m)}{\boxed{6.64}})^{\overset{b}{\boxed{0.725}}} + \underset{c\ (m)}{\boxed{-1.70}} \quad (3.33)$$

σ_z adjusted for buoyancy-induced dispersion

$$\underset{\sigma_z\ (m)}{\boxed{32.0}} = (\underset{\sigma_z^2\ (m^2)}{\boxed{1.00E+03}} + (\underset{\Delta h\ (m)}{\boxed{15.31}} / 3.5)^2)^{1/2} \quad (3.44)$$

FIGURE 3.7 Pasquill-Gifford Dispersion Coefficient Calculations

σ_y with virtual distance adjustment

$$\underset{\sigma_y'\ (m)}{\boxed{76.7}} = \underset{a}{\boxed{0.08}} * (\underset{x\ (m)}{\boxed{1000}} + \underset{x_{Yvirt}\ (m)}{\boxed{5.52}}) * (1 + \underset{b}{\boxed{0.0001}} * (\underset{x\ (m)}{\boxed{1000}} + \underset{x_{Yvirt}\ (m)}{\boxed{5.52}}))^{\overset{c}{\boxed{-0.5}}} \quad (3.34)$$

σ_y adjusted for buoyancy-induced dispersion

$$\underset{\sigma_y\ (m)}{\boxed{76.8}} = (\underset{\sigma_y^2\ (m^2)}{\boxed{5.88E+03}} + (\underset{\Delta h\ (m)}{\boxed{15.31}} / 3.5)^2)^{1/2} \quad (3.45)$$

σ_z with virtual distance adjustment

$$\underset{\sigma_z'\ (m)}{\boxed{38.1}} = \underset{a}{\boxed{0.06}} * (\underset{x\ (m)}{\boxed{1000}} + \underset{x_{Zvirt}\ (m)}{\boxed{7.01}}) * (1 + \underset{b}{\boxed{0.0015}} * (\underset{x\ (m)}{\boxed{1000}} + \underset{x_{Zvirt}\ (m)}{\boxed{7.01}}))^{\overset{c}{\boxed{-0.5}}} \quad (3.34)$$

σ_z adjusted for buoyancy-induced dispersion

$$\underset{\sigma_z\ (m)}{\boxed{38.4}} = (\underset{\sigma_z^2\ (m^2)}{\boxed{1.45E+03}} + (\underset{\Delta h\ (m)}{\boxed{15.31}} / 3.5)^2)^{1/2} \quad (3.43)$$

FIGURE 3.8 Briggs Dispersion Coefficient Calculations

0.01 m and the radius to 0.01 m in RISKIND. (The RISKIND results did not change if a value of 0.1 m was used instead for the cask dimensions.) The release height was fixed at 10 m, and average weather conditions were assumed. The Pasquill D stability category was used in conjunction with an average wind speed of 4 m/s.

As presented in Table 3.8, the time-integrated χ/Q air concentration values at ground-level for distances from 0.1 to 80 km were the same for the GENII results and for the RISKIND values when there was no plume depletion (inert gases). The GENII implementation is

Plume reflection not considered if

$$\sigma_z(x) <= \frac{\left(1 - \frac{11.31}{H\,(m)} / \frac{800}{L\,(m)}\right)^{1/2}}{1.2} * \frac{800}{L\,(m)} = \underset{\sigma_{z,no\text{-}mix}\,(m)}{661.9} \quad \text{[TRUE]} \qquad (3.16)$$

Then

$$\underset{\substack{C_a(i,x,y) \text{ if no mixing} \\ (Ci\text{-}s/m^3)}}{5.27E\text{-}05} = \frac{\frac{1}{Q_{xi}\,(Ci)}}{\pi * \frac{76.2}{\sigma_y\,(m)} * \frac{31.8}{\sigma_z\,(m)} * \frac{2.04}{U_H\,(m/s)}} * \exp\left[-\left(\frac{\frac{1.60E+03}{y^2\,(m^2)}}{2 * \frac{5.81E+03}{\sigma_y^2\,(m^2)}} + \frac{\frac{1.28E+02}{H^2\,(m^2)}}{\frac{1.01E+03}{\sigma_z^2\,(m^2)}}\right)\right] \qquad (3.14)$$

FIGURE 3.9 Ground-Level Air Concentration for Radionuclide *i* by Using Pasquill-Gifford Dispersion Coefficients without Plume Reflection

Plume reflection not considered if

$$\sigma_z(x) <= \frac{\left(1 - \frac{11.44}{H\,(m)} / \frac{800}{L\,(m)}\right)^{1/2}}{1.2} * \frac{800}{L\,(m)} = \underset{\sigma_{z,no\text{-}mix}\,(m)}{661.9} \quad \text{[FALSE]} \qquad (3.16)$$

Then

$$\underset{\substack{C_a(i,x,y) \text{ if no mixing} \\ (Ci\text{-}s/m^3)}}{1.01E\text{-}07} = \frac{\frac{1}{Q_{xi}\,(Ci)}}{\pi * \frac{1145.5}{\sigma_y\,(m)} * \frac{1358.8}{\sigma_z\,(m)} * \frac{2.02}{U_H\,(m/s)}} * \exp\left[-\left(\frac{\frac{1.60E+03}{y^2\,(m^2)}}{2 * \frac{1.31E+06}{\sigma_y^2\,(m^2)}} + \frac{\frac{1.31E+02}{H^2\,(m^2)}}{\frac{1.85E+06}{\sigma_z^2\,(m^2)}}\right)\right] \qquad (3.14)$$

Else a uniform distribution may be assumed if

$$0 <= \frac{11.44}{H\,(m)} / \frac{800}{L\,(m)} < 0.5 \quad \text{[TRUE]}$$

and

$$\sigma_z(x) >= \frac{800}{L\,(m)} * \left[-2.37 * \left(\frac{11.44}{H\,(m)} / \frac{800}{L\,(m)}\right)^2 + 0.489 * \left(\frac{11.44}{H\,(m)} / \frac{800}{L\,(m)}\right) + 0.756\right] = \underset{\sigma_{z,mix}\,(m)}{610.0} \quad \text{[TRUE]} \qquad (3.17)$$

OR

$$0.5 <= \frac{11.44}{H\,(m)} / \frac{800}{L\,(m)} < 1.0 \quad \text{[FALSE]}$$

and

$$\sigma_z(x) >= \frac{800}{L\,(m)} * \left[-2.37 * \left(\frac{11.44}{H\,(m)} / \frac{800}{L\,(m)}\right)^2 + 4.25 * \left(\frac{11.44}{H\,(m)} / \frac{800}{L\,(m)}\right) - 1.13\right] = \underset{\sigma_{z,mix}\,(m)}{-855.8} \quad \text{[TRUE]} \qquad (3.18)$$

Then

$$\underset{\substack{C_{a,mix}\,(Ci\text{-}s/m^3)}}{2.15E\text{-}07} = \frac{\frac{1}{Q_{xi}\,(Ci)}}{(2\pi)^{1/2} * \frac{1145.5}{\sigma_y\,(m)} * \frac{2.02}{U_H\,(m/s)} * \frac{800}{L\,(m)}} * \exp\left[-\left(\frac{\frac{1.60E+03}{y^2\,(m^2)}}{2 * \frac{1.31E+06}{\sigma_y^2\,(m^2)}}\right)\right] \qquad (3.15)$$

FIGURE 3.10 Ground-Level Air Concentration for Radionuclide *i* by Using Pasquill-Gifford Dispersion Coefficients with Plume Reflection

Plume reflection not considered if

$$\sigma_z(x) <= \frac{\left(1 - \frac{\boxed{11.31}}{H\,(m)} / \frac{\boxed{800}}{L\,(m)}\right)^{1/2}}{1.2} * \frac{\boxed{800}}{L\,(m)} = \frac{\boxed{661.9}}{\sigma_{z,no\text{-}mix}\,(m)} \text{ [TRUE]} \qquad (3.16)$$

Then

$$\frac{\boxed{4.43E\text{-}05}}{C_a(i,x,y) \text{ if no mixing } (Ci\text{-}s/m^3)} = \frac{\frac{\boxed{1}}{Q_{xi}\,(Ci)}}{\pi * \frac{\boxed{76.8}}{\sigma_y\,(m)} * \frac{\boxed{38.4}}{\sigma_z\,(m)} * \frac{\boxed{2.04}}{U_H\,(m/s)}} * \exp\left[-\left(\frac{\frac{\boxed{1.60E+03}}{y^2\,(m^2)}}{2 * \frac{\boxed{5.90E+03}}{\sigma_y^2\,(m^2)}} + \frac{\frac{\boxed{1.28E+02}}{H^2\,(m^2)}}{\frac{\boxed{1.47E+03}}{\sigma_z^2\,(m^2)}}\right)\right] \qquad (3.14)$$

FIGURE 3.11 Ground-Level Air Concentration for Radionuclide *i* by Using Briggs Dispersion Coefficients without Plume Reflection

TABLE 3.8 Comparison of RISKIND and GENII Air Concentration Calculations

	χ/Q (s/m^3)		
Distance (km)	GENII	RISKIND (gases)	RISKIND (particulates)
0.1	1.7E-04	1.66E-04	1.66E-04
0.2	2.7E-04	2.66E-04	2.63E-04
0.3	1.8E-04	1.82E-04	1.78E-04
0.4	1.3E-04	1.26E-04	1.22E-04
0.5	9.3E-05	9.20E-05	8.81E-05
0.6	7.1E-05	7.01E-05	6.66E-05
0.7	5.6E-05	5.54E-05	5.22E-05
0.8	4.5E-05	4.50E-05	4.21E-05
0.9	3.8E-05	3.74E-05	3.47E-05
1	3.2E-05	3.17E-05	2.92E-05
2.5	7.8E-06	7.73E-06	6.66E-06
5	2.8E-08	2.73E-06	2.20E-06
10	9.9E-07	9.83E-07	7.24E-07
20	3.6E-07	3.58E-07	2.33E-07
30	2.0E-07	1.99E-07	1.19E-07
40	1.3E-07	1.31E-07	7.37E-08
50	9.6E-08	9.51E-08	5.04E-08
60	7.4E-08	7.32E-08	3.69E-08
70	5.9E-08	5.86E-08	2.82E-08
80	4.9E-08	4.84E-08	2.23E-08

conservative, because it does not model plume depletion. The last column in Table 3.8 lists the ground-level χ/Q values when plume depletion from dry deposition was considered in RISKIND and the default deposition velocity of 0.01 m/s was used for everything except gases. Approximately 50% of the plume was depleted at a distance of 80 km.

3.3.3.2 Comparison with CAP88-PC

The CAP88-PC computer code (EPA 1992) is used to show compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPS) air monitoring requirements (*Code of Federal Regulations*, Title 40, Part 61, Subpart H). This code uses the Briggs dispersion coefficients (Briggs 1974) for open country (rural area) in a Gaussian plume model similar to that used in RISKIND. CAP88-PC estimates exposures from chronic releases, but the Gaussian dispersion equation used to estimate ground-level air concentrations for these chronic exposures is identical in form to that for acute exposures. (For more information, compare equations 3.116 [continuous] and 3.158 [puff] in Slade [1968].) The main exception is in the definitions and dimensions of the source terms (constant release rate for continuous exposure; one-time total release for puff) and the air concentrations (constant instantaneous air concentration for continuous exposure; integrated over time for puff). The exposures in CAP88-PC are therefore given in dose per unit time rather than as a single (acute) dose.

The comparison between RISKIND and CAP88-PC used point sources at a release height of 20 m with average weather conditions of Pasquill stability category D in conjunction with an average wind speed of 4.37 m/s (the average wind speed of the third wind speed category in STAR files as used by CAP88-PC). The first two columns in Table 3.9 present the ground-level air χ/Q values as calculated by the two programs. The values from RISKIND are more than twice the values from CAPP88-PC primarily because CAP88-PC uses a modified form of the Gaussian plume equation that produces a sector-averaged value at the plume centerline (y = 0). Plume reflection is not an issue in this problem, so the RISKIND value is evaluated by using the following calculation:

$$\overline{C}_a(i,x,y) = \frac{Q_{xi}}{\pi\sigma_y\sigma_z u_H}\left[\exp-\left(\frac{y^2}{2\sigma_y^2}+\frac{H^2}{2\sigma_z^2}\right)\right] \quad \text{(3.14 in Manual)} \qquad (3.13)$$

When y = 0, this equation reduces to one that provides the basis for the CAP88-PC sector-average derivation:

$$\overline{C}_a(i,x,y) = \frac{Q_{xi}}{\pi\sigma_y\sigma_z u_H}\left[\exp-\left(\frac{H^2}{2\sigma_z^2}\right)\right] \qquad (3.14)$$

The inclusion of sector averaging results in the final form of the equation that is used in CAP88-PC when the atmospheric lid height has not been reached (EPA 1992):

TABLE 3.9 Comparison of RISKIND and CAP88-PC Air Concentration Calculations

	χ/Q (gases) (s/m³)			
Distance (km)	RISKIND	CAP88-PC	CAP88-PC without Sector Averaging	RISKIND/ CAP88-PC
0.1	2.79E-06	1.06E-06	2.11E-06	1.32
0.2	7.19E-05	2.70E-05	5.41E-05	1.33
0.3	8.42E-05	3.70E-05	7.45E-05	1.13
0.4	7.01E-05	3.36E-05	6.79E-05	1.03
0.5	5.57E-05	2.78E-05	5.66E-05	0.98
0.6	4.46E-05	2.27E-05	4.64E-05	0.96
0.7	3.63E-05	1.87E-05	3.83E-05	0.95
0.8	3.02E-05	1.55E-05	3.20E-05	0.94
0.9	2.55E-05	1.31E-05	2.71E-05	0.94
1	2.19E-05	1.11E-05	2.31E-05	0.95
2.5	5.67E-06	2.70E-06	5.98E-06	0.95
5	2.13E-06	9.45E-07	2.30E-06	0.93
10	8.50E-07	3.35E-07	9.41E-07	0.90
20	3.64E-07	1.17E-07	4.02E-07	0.91
30	2.28E-07	6.32E-08	2.51E-07	0.91
40	1.65E-07	4.08E-08	1.81E-07	0.91
50	1.29E-07	2.90E-08	1.41E-07	0.91
60	1.06E-07	2.20E-08	1.15E-07	0.92
70	9.00E-08	1.74E-08	9.75E-08	0.92
80	7.81E-08	1.42E-08	8.44E-08	0.93

$$\chi = \frac{Q}{0.15871\pi x \sigma_z u_H}\left[\exp - \left(\frac{H^2}{2\sigma_z^2}\right)\right] \quad \text{(Equation 12 in EPA 1992)} \qquad (3.15)$$

where $\chi = C_a(i,x,y)$ and $Q = Q_{xi}$. To provide a fair comparison between RISKIND and CAP88-PC, the value for the original form of the Gaussian equation can be obtained by multiplying the CAP88-PC result (Equation 3.15) by 0.15871 * x / σ_y (to obtain Equation 3.14, the RISKIND result), where x is the distance from the release point to the receptor and σ_y is the horizontal dispersion coefficient in the Briggs form for D weather stability in a rural area:

$$\sigma_y = \frac{0.08x}{\sqrt{1+0.0001x}} \quad \text{(specific case of Equation 3.34 in the Manual)} \qquad (3.16)$$

The third column in Table 3.9 provides the modified CAP88-PC results, and the fourth column provides the ratio of the RISKIND and modified CAP88-PC results for comparison. Disagreement is greater than 10% at distances less than 0.5 km because of CAP88-PC's use of modified Briggs coefficients:

$$\sigma_y = \frac{x^A}{C} \tag{3.17}$$

and

$$\sigma_z = \frac{x^D}{F} \tag{3.18}$$

rather than the form of Equation 3.16 as originally proposed by Briggs (1974). For example, at 200 m, the χ/Q value estimated by CAP88-PC was 2.7×10^{-5} s/m^3. This calculation used a σ_z value of 9.57 m, obtained by using D = 0.8061 and F = 7.48 in Equation 3.18. If CAP88-PC had used:

$$\sigma_z = \frac{0.06x}{\sqrt{1+0.0015x}} \tag{3.19}$$

as did RISKIND, σ_z would have been 10.52, and χ/Q would have been 3.58×10^{-5} s/m^3. Removing the sector averaging from this value (multiplying by 0.15871 * x/σ_y, as discussed above) would have yielded the 7.19×10^{-5} s/m^3 result given by RISKIND for a receptor at 200 m (Table 3.9).

3.4 EXPOSURE PATHWAYS

The air concentrations calculated in Section 3.3 lead directly to the inhalation and cloudshine exposure pathways and are intermediate values in the estimation of ground deposition. The calculated ground concentrations are required, in turn, to estimate exposure from groundshine and resuspended inhalation and are used as input to the food and water ingestion pathways.

3.4.1 Short-Term Exposure

During passage of a radioactive cloud following an accident, individuals downwind from the accident may be exposed to external radiation from the radioactive material in the cloud, internal radiation from inhalation of the radioactive material in the cloud, and external radiation from radioactive material deposited on the ground. The calculated doses resulting from short-term exposure to the passing radioactive cloud are shown in Table 3.10. Figure 3.12 presents the individual calculations for exposure to Cs-137. The estimated ground concentration for calculating the groundshine dose is obtained by multiplying the air concentration calculated in Section 3.3.3 by the radionuclide deposition velocity (Equation 3.19 in the Manual). A comparison between Table 3.10 and page 11 of the case 2 output file (Appendix A, page A-20) shows proper operation of the code in calculating the total short-term (acute) doses received from cloudshine, groundshine, and inhalation.

TABLE 3.10 Calculated Doses from Short-Term Exposure (rem)

	External		
Radionuclide	Cloudshine	Groundshine	Internal Inhalation
Kr-85	1.61E-06	0.00E+00	3.93E-05
Co-60	8.11E-06	4.84E-06	1.07E-03
Sr-90	1.66E-10	1.51E-10	8.36E-05
Cs-134	6.32E-07	4.07E-07	2.94E-05
Cs-137	3.29E-06	2.14E-06	3.73E-04
Pu-238	2.09E-13	1.15E-12	1.28E-03
Pu-239	2.12E-14	5.87E-14	1.63E-04
Pu-240	3.40E-14	1.84E-13	2.34E-04
Pu-241	2.58E-13	1.96E-13	7.39E-04
Am-241	2.14E-11	2.30E-11	8.86E-04
Cm-244	1.33E-13	7.62E-13	5.12E-04
Total	1.36E-05	7.38E-06	5.41E-03

Cloudshine

3.29E-06	=	7.95E-01	*	4.55E-05	*	2.73E-14	*	0.9	*	3.7×10^{12} rem-Bq/Sv-Ci	**(3.47)**
D_{AirST} (rem)		Q_x (Ci)		χ/Q (sec/m^3)		DCF_{Air}(Cs-137) (Sv-m^3/Bq-s)		SF_{AirST}			

Groundshine

2.14E-06	=	7.95E-01	*	4.55E-07	*	5.54E-16	*	2	*	0.4	*	**(3.48)**
D_{GndST} (rem)		Q_x (Ci)		χ/Q_{gnd} (m^{-2})		DCF_{Gnd}(Cs-137) (Sv-m^2/Bq-s)		T_{Ext} (hr)		SF_{GndST}	1.332×10^{16} rem-Bq-s/Sv-Ci-h	

Inhalation

3.73E-04	=	7.95E-01	*	4.55E-05	*	1.10E-08	*	8000	*	1.0	*	**(3.50)**
D_{InhST}(rem)		Q_x (Ci)		χ/Q (sec/m^3)		DCF_{Inh}(Cs-137)		BR (m^3/yr)		SF_{InhST}	1.172×10^5 rem-Bq-yr/Sv-Ci-s	

FIGURE 3.12 Dose Calculations for Short-Term Exposure to Cs-137

3.4.2 Long–Term Exposure

For the long-term period following an accident, individuals may be exposed to external radiation from the radionuclides remaining on the ground, internal radiation from inhalation of resuspended radionuclides, external radiation from resuspended radionuclides, and ingestion of contaminated food and water. Data on time-integrated contaminant ground concentrations and resuspended air concentrations are needed to estimate these long-term exposure doses. The calculations for Cs-137 concentrations are presented in Figure 3.13. The values for the other radionuclides are given in Table 3.11.

Individual dose calculations for long-term groundshine, cloudshine, and inhalation exposure to Cs-137 are shown in Figure 3.14 for case 2. Table 3.12 presents the results for the other radionuclides and the cumulative totals. The total individual long-term exposure doses given in Table 3.12 agree with those calculated by RISKIND for case 2, as shown on page 11 of the output file (Appendix A, pg. A-20).

RISKIND estimates ingestion doses in two parts. The first part, if selected by the user, consists of doses calculated for the first year following an accident. Estimated doses for this first year are generally higher than they are for following years, because direct deposition from the passing radioactive cloud results in higher radionuclide concentrations in vegetation eaten by humans and animals. For individual doses, first-year doses are calculated by assuming a 365-day supply of contaminated food. For the second part of the ingestion calculations, plant contamination is dominated by the root uptake pathway. Ingestion doses are calculated for human consumption of vegetables, meat, and milk.

TABLE 3.11 Time-Integrated Ground and Resuspended Air Concentrations for Use in Long-Term Exposure Calculations

Radionuclide	Ground ($Ci\text{-}s/m^2$)	Air ($Ci\text{-}s/m^3$)
Kr-85	0.00E+00	0.00E+00
Co-60	4.24E+01	1.18E-05
Sr-90	1.79E+00	1.58E-07
Cs-134	2.24E+00	1.47E-06
Cs-137	2.61E+02	2.26E-05
Pu-238	1.24E-01	8.11E-09
Pu-239	1.71E-02	9.50E-10
Pu-240	2.44E-02	1.36E-09
Pu-241	1.72E+00	2.19E-07
Am-241	8.65E-02	4.98E-09
Cm-244	4.59E-02	5.07E-09

TABLE 3.12 Calculated Individual Doses (rem) from Long-Term Exposure to External Radiation from Ground Contamination and to External and Internal Radiation from Resuspended Air Contamination

	Resuspended Air		Ground
Radionuclide	Internal Inhalation	External	External
Kr-85	0.00E+00	0.00E+00	0.00E+00
Co-60	4.89E-04	3.02E-06	1.29E-01
Sr-90	3.92E-05	6.33E-11	1.30E-05
Cs-134	1.29E-05	2.25E-07	4.41E-03
Cs-137	1.75E-04	1.26E-06	1.87E-01
Pu-238	6.05E-04	8.04E-14	1.34E-07
Pu-239	7.75E-05	8.20E-15	8.12E-09
Pu-240	1.11E-04	1.32E-14	2.54E-08
Pu-241	3.44E-04	9.78E-14	1.16E-08
Am-241	4.20E-04	8.28E-12	3.07E-06
Cm-244	2.39E-04	5.07E-14	5.21E-08
Total	2.51E-03	4.50E-06	3.20E-01

Time-Integrated Ground Concentration

$$\underset{\substack{C_g(i,x,y,T)\\(Ci\text{-}s/m^2)}}{\boxed{2.61E{+}02}} = \underset{Q_x\ (Ci)}{\boxed{7.95E{-}01}} * \underset{\chi/Q_{gnd}\ (m^{-2})}{\boxed{4.55E{-}07}} * \left(\frac{1 - \exp\{-(\underset{\lambda(i)\ (1/yr)}{\boxed{2.30E{-}02}} + \underset{\lambda_g\ (1/yr)}{\boxed{0.01386}}) * \underset{T\ (yr)}{\boxed{50.00}}\}]}{\underset{\lambda(i)\ (1/yr)}{\boxed{2.30E{-}02}} + \underset{\lambda_g\ (1/yr)}{\boxed{0.01386}}} \right) * 3.156 \times 10^7\ s/yr \qquad (3.52)$$

Time-Integrated Resuspended Air Concentration

$$\underset{T_a\ (yr)}{\boxed{1.82}} = -1 / \underset{\lambda_r\ (1/yr)}{\boxed{5.06}} * \ln(\underset{FE\ (1/m)}{\boxed{1.00E{-}09}} / \underset{FI\ (1/m)}{\boxed{1.00E{-}05}}) \qquad (3.55)$$

$$\underset{\substack{C_g(i,x,y,T_a)\\(Ci\text{-}s/m^2)}}{\boxed{2.01E{+}01}} = \underset{Q_x\ (Ci)}{\boxed{7.95E{-}01}} * \underset{\chi/Q_{gnd}\ (m^{-2})}{\boxed{4.55E{-}07}} * \left(\frac{1 - \exp\{-(\underset{\lambda(i)\ (1/yr)}{\boxed{2.30E{-}02}} + \underset{\lambda_g\ (1/yr)}{\boxed{0.01386}}) * \underset{T_a\ (yr)}{\boxed{1.82}}\}}{\underset{\lambda(i)\ (1/yr)}{\boxed{2.30E{-}02}} + \underset{\lambda_g\ (1/yr)}{\boxed{0.01386}}} \right) * 3.156 \times 10^7\ s/yr \qquad (3.52)$$

for $T > T_a$

$$\underset{\substack{C_r(i,x,y,T)\\(Ci\text{-}s/m^3)}}{\boxed{2.26E{-}05}} = \underset{FI\ (1/m)}{\boxed{1.00E{-}05}} * \underset{Q_x\ (Ci)}{\boxed{7.95E{-}01}} * \underset{\chi/Q_{gnd}\ (m^{-2})}{\boxed{4.55E{-}07}} * \left(\frac{[1 - \exp\{-(\underset{\lambda(i)\ (1/yr)}{\boxed{2.30E{-}02}} + \underset{\lambda_g\ (1/yr)}{\boxed{0.01386}} + \underset{\lambda_r\ (1/yr)}{\boxed{5.06}}) * \underset{T\ (yr)}{\boxed{50}}\}]}{\underset{\lambda(i)\ (1/yr)}{\boxed{2.30E{-}02}} + \underset{\lambda_g\ (1/yr)}{\boxed{0.01386}} + \underset{\lambda_r\ (1/yr)}{\boxed{5.06}}} \right)$$

$$* 3.156 \times 10^7\ s/yr + \underset{FE\ (1/m)}{\boxed{1.00E{-}09}} * (\underset{\substack{C_g(i,x,y,T)\\(Ci\text{-}s/m^2)}}{\boxed{2.61E{+}02}} - \underset{\substack{C_g(i,x,y,T_a)\\(Ci\text{-}s/m^2)}}{\boxed{2.01E{+}01}}) \qquad (3.57)$$

FIGURE 3.13 Time-Integrated Ground and Resuspended Air Concentration Calculations for Long-Term Exposure to Cs-137

Cloudshine from Resuspended Contamination

$$\underset{SF_{AirLT}}{\boxed{0.55}} = \underset{OF_{out}}{\boxed{0.25}} + \underset{OF_{in}}{\boxed{0.5}} * \underset{SF_{kAir}}{\boxed{0.6}} \qquad (3.69)$$

$$\underset{D_{AirLT}\ (rem)}{\boxed{1.26E{-}06}} = \underset{SF_{AirLT}}{\boxed{0.55}} * \underset{\substack{C_r(i,x,y,T)\\(Ci\text{-}s/m^3)}}{\boxed{2.26E{-}05}} * \underset{\substack{DCF_{Air}(Cs\text{-}137)\\(Sv\text{-}m^3/Bq\text{-}s)}}{\boxed{2.73E{-}14}} * 3.7 \times 10^{12}\ rem\text{-}Bq/Sv\text{-}Ci \qquad (3.68)$$

Groundshine

$$\underset{SF_{GndLT}}{\boxed{0.35}} = \underset{OF_{out}}{\boxed{0.25}} + \underset{OF_{in}}{\boxed{0.5}} * \underset{SF_{kGnd}}{\boxed{0.2}} \qquad (3.71)$$

$$\underset{D_{GndLT}\ (rem)}{\boxed{1.87E{-}01}} = \underset{SF_{GndLT}}{\boxed{0.35}} * \underset{\substack{C_g(i,x,y,T)\\(Ci\text{-}s/m^2)}}{\boxed{2.61E{+}02}} * \underset{\substack{DCF_{Gnd}(Cs\text{-}137)\\(Sv\text{-}m^2/Bq\text{-}s)}}{\boxed{5.54E{-}16}} * 3.7 \times 10^{12}\ rem\text{-}Bq/Sv\text{-}Ci \qquad (3.70)$$

Inhalation from Resuspended Contamnation

$$\underset{SF_{InhLT}}{\boxed{0.75}} = \underset{OF_{out}}{\boxed{0.25}} + \underset{OF_{in}}{\boxed{0.5}} * \underset{SF_{kInh}}{\boxed{1}} \qquad (3.73)$$

$$\underset{D_{InhLT}\ (rem)}{\boxed{1.75E{-}04}} = \underset{SF_{InhLT}}{\boxed{0.75}} * \underset{\substack{C_r(i,x,y,T)\\(Ci\text{-}s/m^3)}}{\boxed{2.26E{-}05}} * \underset{\substack{DCF_{Inh}(Cs\text{-}137)\\(Sv/Bq)}}{\boxed{1.10E{-}08}} * \underset{BR\ (m^3/yr)}{\boxed{8000}} * 1.172 \times 10^5\ rem\text{-}Bq\text{-}yr/Sv\text{-}Ci\text{-}s \qquad (3.72)$$

FIGURE 3.14 Groundshine, Cloudshine, and Inhalation Dose Calculations for Long-Term Exposure to Cs-137

Individual dose calculations for first-year and long-term exposure to Cs-137 resulting from vegetable ingestion are shown in Figure 3.15 for case 2. Table 3.13 presents the results for radionuclide concentrations found in vegetables meant for animal and human consumption and in meat and milk meant for human consumption that are to be used to calculate first-year and long-term exposures. Table 3.14 presents the radionuclide doses and the cumulative totals for consumption of vegetables, meat, and milk. Cs-137 concentrations in vegetation meant for animal consumption are calculated in Figure 3.16. Individual dose calculations for first-year and long-term exposure to Cs-137 from meat and milk ingestion are presented in Figures 3.17 and 3.18, respectively. The total dose values presented in Table 3.14 agree with the doses calculated by RISKIND, shown on page 11 of the case 2 output file (Appendix A, pg. A-20).

The case 2 input problem also specified the calculation to estimate exposure to contaminated drinking water. Radionuclide concentrations in contaminated water and individual doses from consuming this water are presented in Table 3.15. Figure 3.19 shows the calculations necessary to estimate the dose received from Cs-137 in the drinking water. The dose from drinking water exposure calculated here agrees with that given on page 11 of the case 2 RISKIND output file (Appendix A, pg. A-20).

3.4.3 GENII Dose Comparison

A hypothetical release of Cs-137 (1 Ci) was modeled by RISKIND and GENII to compare their estimated doses to an individual 1 km downwind. A point source at a release height of 10 m, Pasquill stability category D weather conditions, and a wind speed of 4 m/s were assumed. The receptor was assumed to be exposed without shielding to the passing radioactive cloud immediately following the release. A Cs-137 deposition velocity of 0.001 m/s was used for determining the contaminated ground concentration. Long-term exposure to groundshine (unshielded for 0.5 yr) and ingestion (1 yr) were compared. The output file for each program is listed in Appendix B, Section B.1.1. As shown in Section 3.3.1, RISKIND and GENII calculate the same ground-level air concentrations for the same release conditions. Therefore the exposure calculations used to compare dose estimates started with the same air concentrations at the receptor location.

The results of the dose comparison are shown in Table 3.16. Differences were generally within one order of magnitude. Except for the ingestion exposure pathway, as shown in the last three columns of Table 3.16, these differences can be ascribed to the different dose conversion factors used by the two programs rather than any differences in methodology. To determine ingestion exposure, human ingestion rates for vegetables, meat, and milk were set to the RISKIND defaults in GENII, and agricultural productivity was matched between the two models as closely as possible.

The differences in the ingestion doses, approximately an order of magnitude at most, are not unreasonable considering the differences in the models. The ingestion doses of 0.155 rem from RISKIND and 0.21 rem from GENII following contamination of crops at the end of the growing season are in relatively good agreement. However, there is an order-of-magnitude

$$\underset{\lambda_{Ve}\ (1/d)}{\boxed{4.96E\text{-}02}} = \underset{\lambda_{Vw}\ (1/d)}{\boxed{0.0495}} + \underset{\lambda(i)\ (1/yr)}{\boxed{2.30E\text{-}02}} * 1\ yr / 365\ d$$

effective decay constant accounts for weathering and radioactive decay

Initial Deposition (1st year ingestion dose)

$$\underset{C_{Vdep}(Cs\text{-}137)\ (Ci/kg)}{\boxed{8.18E\text{-}09}} = \frac{\underset{Q_x\ (Ci)}{\boxed{0.795}} * \underset{\chi/Q\ (s/m^3)}{\boxed{4.55E\text{-}05}} * \underset{V_d\ (m/s)}{\boxed{0.01}} * \underset{F_r}{\boxed{0.2}} * \underset{E_{vh}}{\boxed{1}} * \exp\left(-\underset{\lambda_{Ve}\ (1/d)}{\boxed{4.96E\text{-}02}} * \underset{T_{vh}\ (d)}{\boxed{30}}\right)}{\underset{Y_{vh}\ (kg/m^2)}{\boxed{2}}} \quad (3.58)$$

also 1st term in 3.60

$$\underset{D_{VegST}\ (rem)}{\boxed{6.76E\text{-}02}} = \underset{DF}{\boxed{0.5}} * \underset{U_v\ (kg/d)}{\boxed{0.77}} * \underset{CF_V}{\boxed{1}} * \underset{C_{Vdep}(Cs\text{-}137)\ (Ci/kg)}{\boxed{8.18E\text{-}09}} * \underset{DCF_{Ing}(Cs\text{-}137)\ (Sv/Bq)}{\boxed{1.59E\text{-}08}} * 365\ d * 3.7 \times 10^{12}\ rem\text{-}Bq/Sv\text{-}Ci \quad (3.74)$$

Long-Term

$$\underset{C_{Vlt}(Cs\text{-}137)\ (Ci\text{-}s/kg)}{\boxed{4.83E\text{-}02}} = \frac{\underset{C_g(i,x,y,T)\ (Ci\text{-}s/m^2)}{\boxed{2.61E+02}} * \underset{B_v(i)}{\boxed{0.01}}}{\underset{\rho\ (kg/m^2)}{\boxed{240}}} + \underset{C_r(i,x,y,T)\ (Ci\text{-}s/m^3)}{\boxed{2.26E\text{-}05}} * \frac{\underset{V_d\ (m/s)}{\boxed{0.01}} * \underset{F_r}{\boxed{0.2}} * \underset{E_{vh}}{\boxed{1}} * \left[1 - \exp\left(-\underset{\lambda_{Ve}\ (1/d)}{\boxed{4.96E\text{-}02}} * \underset{t_{vh}\ (d)}{\boxed{60}}\right)\right]}{\underset{Y_{vh}\ (kg/m^2)}{\boxed{2}} * \underset{\lambda_{Ve}\ (1/d)}{\boxed{4.96E\text{-}02}} * 1\ d/\ 86400\ s}$$

last 2 terms in (3.60)

$$\underset{D_{vegLT}\ (rem)}{\boxed{1.27E\text{-}02}} = \underset{DF}{\boxed{0.5}} * \underset{U_v\ (kg/d)}{\boxed{0.77}} * \underset{CF_V}{\boxed{1}} * \underset{C_{Vlt}(Cs\text{-}137)\ (Ci\text{-}s/kg)}{\boxed{4.83E\text{-}02}} * \underset{DCF_{Ing}(Cs\text{-}137)\ (Sv/Bq)}{\boxed{1.59E\text{-}08}} * 3.7 \times 10^{12}\ rem\text{-}Bq/Sv\text{-}Ci \quad (3.74)$$

FIGURE 3.15 Vegetable Ingestion Dose Calculations for Exposure to Cs-137

TABLE 3.13 Calculated Radionuclide Concentrations in Vegetables, Meat, and Milk

	Animal Consumption		Human Consumption					
	Vegetable		Vegetable		Meat		Milk	
Radionuclide	First Year (Ci/kg)	Long Term (Ci-s/kg)	First Year (Ci/kg)	Long Term (Ci-s/kg)	First Year (Ci/kg)	Long Term (Ci-s/kg)	First Year (Ci/kg)	Long Term (Ci-s/kg)
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-60	2.44E-08	4.38E-02	4.33E-09	2.10E-02	1.59E-08	2.85E-02	1.22E-09	2.19E-03
Sr-90	3.20E-10	6.95E-04	5.71E-11	3.88E-04	9.61E-12	2.08E-05	1.28E-11	2.78E-05
Cs-134	3.14E-09	5.31E-03	5.53E-10	2.48E-03	6.29E-10	1.06E-03	1.89E-09	3.19E-03
Cs-137	4.59E-08	9.23E-02	8.18E-09	4.83E-02	9.17E-09	1.85E-02	2.75E-08	5.54E-02
Pu-238	1.63E-11	2.93E-05	2.91E-12	1.36E-05	1.14E-14	2.05E-08	1.63E-15	2.93E-09
Pu-239	1.91E-12	3.44E-06	3.40E-13	1.59E-06	1.33E-15	2.41E-09	1.91E-16	3.44E-10
Pu-240	2.73E-12	4.93E-06	4.87E-13	2.28E-06	1.91E-15	3.45E-09	2.73E-16	4.93E-10
Pu-241	4.48E-10	7.90E-04	7.98E-11	3.64E-04	3.13E-13	5.53E-07	4.48E-14	7.90E-08
Am-241	9.99E-12	1.80E-05	1.78E-12	8.33E-06	9.99E-14	1.80E-07	2.50E-15	4.50E-09
Cm-244	1.03E-11	1.87E-05	1.84E-12	8.86E-06	1.03E-13	1.87E-07	2.58E-15	4.68E-09

TABLE 3.14 Calculated Individual Doses (rem) from Ingestion of Vegetables, Meat, and Milk

	Vegetable		Meat		Milk	
Radionuclide	First Year	Long Term	First Year	Long Term	First Year	Long Term
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-60	1.64E-02	2.52E-03	4.68E-02	2.66E-03	1.02E-02	5.81E-04
Sr-90	1.23E-03	2.65E-04	1.61E-04	1.11E-05	6.09E-04	4.19E-05
Cs-134	5.70E-03	8.10E-04	5.05E-03	2.70E-04	4.29E-02	2.30E-03
Cs-137	6.76E-02	1.27E-02	5.91E-02	3.77E-03	5.03E-01	3.20E-02
Pu-238	1.31E-03	1.93E-04	4.01E-06	2.28E-07	1.62E-06	9.23E-08
Pu-239	1.69E-04	2.51E-05	5.17E-07	2.96E-08	2.09E-07	1.20E-08
Pu-240	2.42E-04	3.59E-05	7.41E-07	4.24E-08	3.00E-07	1.71E-08
Pu-241	7.68E-04	1.11E-04	2.35E-06	1.31E-07	9.52E-07	5.32E-08
Am-241	9.13E-04	1.35E-04	3.98E-05	2.28E-06	2.82E-06	1.61E-07
Cm-244	5.21E-04	7.96E-05	2.28E-05	1.31E-06	1.62E-06	9.28E-08
Total	9.49E-02	1.68E-02	1.11E-01	6.72E-03	5.56E-01	3.50E-02

disparity between the models (4.96×10^{-4} rem for RISKIND and 3.4×10^{-5} rem for GENII) when direct deposition on crops does not occur and root uptake is the main route for crop contamination. Although the programs use different food transfer factors, the main difference occurs because of GENII's estimate for contaminated ground concentration. GENII redistributes the deposited radionuclide(s) within a top surface layer (0.15 m is the default used here) to account for weathering and leaching of the deposited contamination to subsurface soil levels, lowering soil concentrations and thereby lowering dose estimates. This approach is also reflected in the groundshine dose conversion factor used by GENII, as seen in Table 3.16; RISKIND uses a more conservative value.

A hypothetical SNF accident could release a number of radionuclides simultaneously. Such a potential release was also modeled by RISKIND and GENII; the same exposure parameters as those used above for the 1-Ci Cs-137 release were used. The program output files are listed in Appendix B, Section B.1.2. The results are presented in Table 3.17. The general trends in the relative doses were the same as those observed for the Cs-137 release.

3.4.4 CAP88-PC Dose Comparison

A hypothetical release of Cs-137 (1 Ci) was modeled by RISKIND and CAP88-PC to compare their estimated doses to an individual. As discussed in Section 3.3.3.2, RISKIND's downwind air concentrations from an acute release (time-integrated, Ci-s/m^3) and CAP88-PC's chronic release (instantaneous, Ci/m^3) are the same except for the unit of time. Thus, inhalation and cloudshine exposure to a 1-Ci puff release (RISKIND) should be the same as a 1-year exposure to a 1-Ci/yr release (CAP88-PC) when the χ/Q value is the same for the two programs. However, the two programs' groundshine and ingestion doses are not comparable because of the time-dependence of the calculations.

Initial Deposition

$$\underset{\substack{C_{Vdep}(Cs\text{-}137)\\(Ci/kg)}}{\boxed{4.59E\text{-}08}} = \frac{\underset{Q_x\ (Ci)}{\boxed{0.795}} * \underset{\chi/Q\ (s/m^3)}{\boxed{4.55E\text{-}05}} * \underset{V_d\ (m/s)}{\boxed{0.01}} * \underset{F_r}{\boxed{0.2}} * \underset{E_{va}}{\boxed{1}} * \exp\left(-\underset{\lambda_{Ve}\ (1/d)}{\boxed{4.96E\text{-}02}} * \underset{T_{va}\ (d)}{\boxed{15}}\right)}{\underset{Y_{va}\ (kg/m^2)}{\boxed{0.75}}} \quad \textbf{(3.58)}$$

also 1st term in 3.60

Long-Term

$$\underset{\substack{C_{Vlt}(Cs\text{-}137)\\(Ci\text{-}s/kg)}}{\boxed{9.23E\text{-}02}} = \frac{\underset{C_g(i,x,y,T)\ (Ci\text{-}s/m^2)}{\boxed{2.61E+02}} * \underset{B_v(i)}{\boxed{0.01}}}{\underset{\rho\ (kg/m^2)}{\boxed{240}}} + \underset{\substack{C_r(i,x,y,T)\\(Ci\text{-}s/m^3)}}{\boxed{2.26E\text{-}05}} * \frac{\underset{V_d\ (m/s)}{\boxed{0.01}} * \underset{F_r}{\boxed{0.2}} * \underset{E_{va}}{\boxed{1}} * \left[1 - \exp\left(-\underset{\lambda_{Ve}\ (1/d)}{\boxed{4.96E\text{-}02}} * \underset{t_{va}\ (d)}{\boxed{30}}\right)\right]}{\underset{Y_{va}\ (kg/m^2)}{\boxed{0.75}} * \underset{\lambda_{Ve}\ (1/d)}{\boxed{4.96E\text{-}02}} * 1\ d/\ 86400\ s}$$

last 2 terms in (3.60)

FIGURE 3.16 Initial and Long-Term Cs-137 Concentrations in Vegetation for Animal Consumption

Initial Deposition (1st year ingestion dose)

9.17E-09	=	4.59E-08	*	50	*	4.00E-03									(3.61)
$C_{bI}(i,T)$ (Ci/kg)		C_{Vdep}(Cs-137) (Ci/kg)		Q_a (kg/d)		$F_b(i)$(d/kg)									
5.91E-02	=	0.3	*	1	*	9.17E-09	*	1.59E-08	*	365 d	*	86,400 s/d	*	4.282×10^7 rem-Bq-d/Sv-Ci-s	(3.75)
$D_{MeatST}(i)$ (rem)		U_b (kg/d)		CF_b		$C_{bI}(i,T)$ (Ci/kg)		DCF_{Ing}(Cs-137) (Sv/Bq)							

Long-Term

1.85E-02	=	9.23E-02	*	50	*	4.00E-03									(3.61)
$C_{bLT}(i,T)$ (Ci-s/kg)		C_{Vlt}(Cs-137) (Ci/kg)		Q_a (kg/d)		$F_b(i)$(d/kg)									
3.77E-03	=	0.3	*	1	*	1.85E-02	*	1.59E-08	*	4.282×10^7 rem-Bq-d/Sv-Ci-s					(3.75)
$D_{MeatLT}(i)$ (rem)		U_b (kg/d)		CF_b		$C_{bLT}(i,T)$ (Ci-s/kg)		DCF_{Ing}(Cs-137) (Sv/Bq)							

FIGURE 3.17 Meat Ingestion Dose Calculations for Exposure to Cs-137

Initial Deposition (1st year ingestion dose)

2.75E-08	=	4.59E-08	*	50	*	1.20E-02									(3.62)
$C_{ml}(i,T)$ (Ci/kg)		C_{Vdep}(Cs-137) (Ci/kg)		Q_a (kg/d)		$F_m(i)$(d/kg)									
5.02E-01	=	0.85	*	1	*	2.75E-08	*	1.59E-08	*	365 d	*	86,400 s/d	*	4.282×10^7 rem-Bq-d/Sv-Ci-s	(3.76)
$D_{MilkST}(i)$ (rem)		U_m (kg/d)		CF_m		$C_{ml}(i,T)$ (Ci/kg)		DCF_{Ing}(Cs-137) (Sv/Bq)							

Long-Term

5.54E-02	=	9.23E-02	*	50	*	1.20E-02									(3.62)
$C_{mLT}(i,T)$ (Ci-s/kg)		C_{Vlt}(Cs-137) (Ci-s/kg)		Q_a (kg/d)		$F_m(i)$(d/kg)									
3.20E-02	=	0.85	*	1	*	5.54E-02	*	1.59E-08	*	4.282×10^7 rem-Bq-d/Sv-Ci-s					(3.76)
$D_{MilkLT}(i)$ (rem)		U_m (kg/d)		CF_m		$C_{ml}(i,T)$ (Ci/kg)		DCF_{Ing}(Cs-137) (Sv/Bq)							

FIGURE 3.18 Milk Ingestion Dose Calculations for Exposure to Cs-137

TABLE 3.15 Contaminated Drinking Water Radionuclide Concentrations and Doses from Individual Consumption

Radionuclide	Concentration (Ci-yr/m^3)	Dose (rem)
Kr-85	0.00E+00	0.00E+00
Co-60	4.73E-08	4.66E-04
Sr-90	6.82E-10	3.82E-05
Cs-134	5.19E-09	1.39E-04
Cs-137	9.78E-08	2.10E-03
Pu-238	3.53E-11	4.13E-05
Pu-239	4.15E-12	5.36E-06
Pu-240	5.95E-12	7.69E-06
Pu-241	9.33E-10	2.33E-05
Am-241	2.17E-11	2.89E-05
Cm-244	2.17E-11	1.60E-05
Total		2.87E-03

$$\underset{F_w(x,y)}{\boxed{8.30E\text{-}01}} = \frac{(2\pi)^{1/2} * \underset{\sigma_y(x)\ (m)}{\boxed{76.15}}}{\underset{W_c(x,y)\ (m)}{\boxed{230}}} \tag{3.65}$$

$$\underset{\substack{C_w(i,x,y,T) \\ (Ci\text{-}yr/m^3)}}{\boxed{9.78E\text{-}08}} = \frac{\underset{Q_x\ (Ci)}{\boxed{7.95E\text{-}01}} * \underset{\chi/Q_g\ (1/m^2)}{\boxed{4.55E\text{-}07}} * \underset{F_a(x,y)}{\boxed{8.30E\text{-}01}} * [1 - \underset{E_w}{\boxed{0}}] * [1 - \exp\{-(\underset{\lambda(i)\ (1/yr)}{\boxed{2.30E\text{-}02}} + \underset{\lambda_W(x,y)\ (1/yr)}{\boxed{1}}) * \underset{T\ (yr)}{\boxed{50}}\}]}{\underset{W_d(x,y)\ (m)}{\boxed{3}} * (\underset{\lambda(i)\ (1/yr)}{\boxed{2.30E\text{-}02}} + \underset{\lambda_W(x,y)\ (1/yr)}{\boxed{1}})} \tag{3.67}$$

$$\underset{D_{Water}\ (rem)}{\boxed{2.10E\text{-}03}} = \underset{U_w\ (L/d)}{\boxed{1}} * \underset{CF_w}{\boxed{1}} * \underset{\substack{C_w(i,x,y,T) \\ (Ci\text{-}yr/m^3)}}{\boxed{9.78E\text{-}08}} * \underset{\substack{DCF_{Ing}(Cs\text{-}137) \\ (Sv/Bq)}}{\boxed{1.59E\text{-}08}} * 1.351 \times 10^{12}\ rem\text{-}Bq\text{-}d\text{-}m^3/Sv\text{-}Ci\text{-}yr\text{-}L \tag{3.77}$$

FIGURE 3.19 Water Consumption Dose Calculations for Exposure to Cs-137

TABLE 3.16 Comparison of RISKIND and GENII Dose Calculations for a 1-Ci Cs-137 Release

Pathway	Dose (rem)		Dose Ratio	Dose Conversion Factor		Factor Ratio
	RISKIND	GENII	RISKIND/ GENII	RISKIND[a]	GENII[b]	RISKIND/ GENII
Inhalation from plume passage[c]	3.21×10^{-4}	2.4×10^{-4}	1.3	1.1×10^{-8} Sv/Bq	7.9×10^{-9} to 9.1×10^{-9} Sv/Bq	~ 1.2
Cloudshine from plume passage[c]	3.14×10^{-6}	3.6×10^{-6}	0.87	2.73×10^{-14} Sv/s/Bq/m^3	3.12×10^{-14} Sv/s/Bq/m^3	0.875
Groundshine[d]	9.87×10^{-4}	2.2×10^{-4}	4.49	5.54×10^{-16} Sv/s/Bq/m^2	1.19×10^{-16} Sv/s/Bq/m^2	4.66
Ingestion[e]	4.96×10^{-4} to 0.155	3.4×10^{-5} to 0.21	15 to 0.74	1.59×10^{-8} Sv/Bq	1.3×10^{-8} to 1.4×10^{-8} Sv/Bq	~ 1.2

[a] RISKIND DCFs are from Eckerman et al. (1988) and Eckerman and Ryman (1993).

[b] The internal doses from inhalation and ingestion are estimated in GENII by using weighted organ doses, in which each internal organ has its own dose conversion factor.

[c] Inhalation and cloudshine doses are from exposure to passage of the radioactive cloud immediately following an accident.

[d] Groundshine doses are for exposure without shielding to external radiation from contaminated ground for 0.5 yr.

[e] Ingestion doses from RISKIND do not include initial contamination of the crops and do include direct deposition from the radioactive cloud following an accident, respectively. The GENII ingestion doses are from the "winter" and "autumn" portion of the output; these are comparable to the RISKIND doses, since "winter" assumes no direct deposition on crops (none are assumed to be growing at the time of the accident), and "autumn" assumes the accident occurs at the end of the growing season.

Note that 1 Ci of Ba-137m (the short-lived progeny radionuclide of Cs-137 assumed to be in secular equilibrium with Cs-137) was also released in the CAP88-PC calculations. The dose conversion factors for Cs-137 in RISKIND (and GENII) account for the Ba-137m, whereas those in CAP88-PC do not. For the calculations, a point source at a release height of 20 m, Pasquill stability category D weather conditions, and a wind speed of 4.373 m/s were used. The receptor was assumed to be exposed without shielding to the passing radioactive cloud immediately following the release. For dose comparison purposes, the receptor distances from the release point were different for each program in order to start the exposure calculations with the same χ/Q value at the receptor locations. The output for each program is listed in Appendix B, Section B.2.1.

The results of the inhalation and cloudshine dose comparisons are shown in Table 3.18. Differences can be directly attributed to differences in the dose conversion factors used by the two programs. The Cs-137 inhalation dose conversion factor is orders of magnitude larger than the Ba-137m factor, while the reverse situation is true for the cloudshine dose conversion factors. Therefore, the Cs-137 inhalation and Ba-137m cloudshine dose conversion factors are shown for CAP88-PC in Table 3.18.

TABLE 3.17 Comparison of RISKIND and GENII Individual Dose Calculations for a Hypothetical Spent Fuel Transportation Accident

Pathway	Dose (rem)		Dose Ratio of RISKIND to GENII
	RISKIND	GENII	
Inhalation from plume passage[a]	3.68×10^{-3}	3.6×10^{-3}	1.0
Cloudshine from plume passage[a]	9.15×10^{-6}	1.0×10^{-5}	0.92
Groundshine[b]	2.60×10^{-3}	5.8×10^{-4}	4.5
Ingestion[c]	4.98×10^{-4} to 0.155	5.6×10^{-5} to 0.22	8.9 to 0.70

[a] Inhalation and cloudshine doses are from exposure to passage of the radioactive cloud immediately following an accident.

[b] Groundshine doses are for exposure without shielding to external radiation from contaminated ground for 0.5 yr.

[c] Ingestion doses from RISKIND do not include initial contamination of the crops and do include direct deposition from the radioactive cloud following an accident, respectively. The GENII ingestion doses are from the "winter" and "autumn" portion of the output; these are comparable to the RISKIND doses, since "winter" assumes no direct deposition on crops (none are assumed to be growing at the time of the accident), and "autumn" assumes the accident occurs at the end of the growing season.

A hypothetical SNF accident could release a number of radionuclides simultaneously. Such a potential release was also modeled by RISKIND and CAP88-PC; the same exposure parameters as those used above for the 1-Ci Cs-137 release were used. The program output files are listed in Appendix B, Section B.2.2. The results are presented in Table 3.19. The general trends in the relative doses were the same as those for the Cs-137 release; RISKIND was more conservative for both inhalation and cloudshine exposures.

TABLE 3.18 Comparison of RISKIND and CAP88-PC Doses Calculated for a 1-Ci Cs-137 Release

Pathway	Dose (rem) RISKIND	Dose (rem) CAP88-PC	Dose Ratio of RISKIND to CAP88-PC
Inhalation from plume passage[a]	3.84×10^{-4}	2.92×10^{-4}	1.32
Cloudshine from plume passage[a,b,c]	3.74×10^{-6}	2.61×10^{-6}	$1.43 \times 0.733 = 1.05$
Pathway	**Dose Conversion Factor RISKIND**	**Dose Conversion Factor CAP88-PC**	**Factor Ratio of RISKIND to CAP88-PC**
Inhalation from plume passage[a]	1.10×10^{-8} Sv/Bq	8.38×10^{-9} Sv/Bq	1.31
Cloudshine from plume passage[a,b,c]	2.73×10^{-14} Sv/s / Bq/m^3	2.60×10^{-14} Sv/s / Bq/m^3	1.05

[a] For inhalation and cloudshine doses, the time-integrated air concentrations for exposure to a 1-Ci puff release used in RISKIND are equivalent to a 1-yr exposure to the 1-Ci/yr release used in CAP88-PC.

[b] The factor of 0.733 in the dose ratio accounts for the difference between the Cs-137 and Ba-137m concentrations at the receptor location calculated by CAP88-PC. CAP88-PC calculates radionuclide decay during plume travel.

[c] The CAP88-PC cloudshine dose conversion factor is for Ba-137m, the short-lived progeny radionuclide of Cs-137.

TABLE 3.19 Comparison of RISKIND and CAP88-PC Individual Doses Calculated for a Hypothetical Spent Fuel Transportation Accident

Pathway	Dose (rem) RISKIND	Dose (rem) CAP88-PC	Dose Ratio of RISKIND to CAP88-PC
Inhalation from plume passage[a]	4.39×10^{-3}	3.99×10^{-3}	1.10
Cloudshine from plume passage[a]	1.09×10^{-5}	9.02×10^{-6}	1.21

[a] For inhalation and cloudshine doses, the time-integrated air concentrations for exposure to a 1-Ci puff release used in RISKIND are equivalent to a 1-yr exposure to the 1-Ci/yr release used in CAP88-PC.

4 HEALTH EFFECTS

RISKIND calculates potential early health effects from acute, short-term exposure to high dose rates received from a hypothetical severe accident, as well as potential latent health effects from short- and long-term exposures to low dose rates received during routine transport or from potential accident events.

4.1 EARLY EFFECTS

When using RISKIND, radionuclide screening (Section 3.2) should be turned off (HAZLM = 0) to assess early health effects properly, since early effects are not considered in the screening process.

Calculations of early effects were performed to verify the RISKIND results for case 3. Case 3 involved a receptor 25 m downwind from a spent fuel rail accident with a severity in response region 4 (Figure 3.1), one of the most severe accident regions. The scenario assumptions were a 1-m release height, no fire, and unfavorable weather conditions (stability = F, wind speed = 1 m/s), which do little to disperse the released and aerosolized material. Such a release might occur if a rail cask were traveling at a speed of more than about 170 km/h (105 mph) into an unyielding surface (LLNL 1987).

The early effects model is based on the NRC health effects study (Evans et al. 1985; Abrahamson et al. 1989, 1991). Fatalities are estimated on the basis of the responses of the bone marrow, gastrointestinal (GI) tract, and lungs to high dose rates. The acute dose received is considered in two parts, brief and protracted. The brief dose consists of the inhalation dose received within the first 24 h of a release and external radiation received from the passing radioactive cloud, the radionuclide-contaminated ground surface, or loss of cask shielding. The protracted dose consists of the exposure from inhaled radionuclides for periods up to one year, depending on the target organ, following an accident.

4.1.1 External Exposure

The calculation of external exposure to the bone marrow, GI tract, and the lungs is a straightforward modification of the calculations performed in Section 3.4.1 for whole body exposure. Equations 3.47 and 3.48 in the RISKIND manual for external radiation exposure from radionuclides in the passing radioactive cloud and deposited on the ground, respectively, are modified slightly by replacing the whole body dose conversion factors (DCFs) with organ-specific DCFs (Eckerman and Ryman 1993). In addition, the radiation trauma (physical damage) induced by the high dose rates is measured in terms of absorbed dose (units of Gy) rather than the effective dose equivalent (units of Sv or rem, 1 Sv = 100 rem) applied in Section 3. Figures 4.1, 4.2, and 4.3 provide the calculations of early effects from doses of Cs-137 to the bone marrow, GI tract, and lungs, respectively. For Cs-137, the absorbed inhalation dose is the same as the effective dose equivalent (1 Gy is equivalent to 1 Sv since the quality factor for

Acute Dose to Bone Marrow from:

Cloudshine

0.142	=	1.61E+03	*	1.02E-01	*	2.59E-14	*	0.9	*	3.7×10^{10} Bq/Ci	**(3.47)** modified
D_B (bone) (Gy)*		Q_x (Ci)		χ/Q (s/m^3)		DCF_{Air}(Cs-137) (Sv-m^3/Bq-s)		SF_{AirST}			
7.08E-02	=	0.142	/	2.00							
DR_B (bone) (Gy/h)		D_B (bone) (Gy)		T_{Ext} (h)							

Groundshine

9.43E-02	=	1.61E+03	*	1.02E-03	*	5.39E-16	*	2	*	0.4	*	modified **(3.48)**
D_B (bone) (Gy)*		Q_x (Ci)		χ/Q_{gnd} (m^{-2})		DCF_{Gnd}(Cs-137) (Sv-m^2/Bq-s)		T_{Ext} (h)		SF_{GndST}	1.332×10^{14} Bq-s/Ci-h	
4.72E-02	=	9.43E-02	/	2.00								
DR_B (bone) (Gy/h)		D_B (bone) (Gy)		T_{Ext} (h)								

Inhalation

Inhalation (1st year dose)

1.17E+01	=	1.61E+03	*	1.02E-01	*	7.57E-09	*	8000	*	1.0	*	modified **(3.50)**
D_{InhST}(Gy)*		Q_x (Ci)		χ/Q (s/m^3)		DCF_{Inh}(Cs-137) Sv/Bq		BR (m^3/yr)		SF_{InhST}	1.172×10^3 Bq-yr/Ci-s	

FIGURE 4.1 Short-Term External Dose and First-Year Inhalation Dose to the Bone Marrow from Cs-137

Acute Dose to Gastrointestinal Tract from:

Cloudshine

1.36E-01	=	1.61E+03	*	1.02E-01	*	2.48E-14	*	0.9	*	3.7×10^{10} Bq/Ci	**(3.47)** modified
D_B (GI) (Gy)*		Q_x (Ci)		χ/Q (s/m^3)		DCF_{Air}(Cs-137) (Sv-m^3/Bq-s)		SF_{AirST}			
6.78E-02	=	0.136	/	2.00							
DR_B (GI) (Gy/h)		D_B (GI) (Gy)		T_{Ext} (h)							

Groundshine

8.63E-02	=	1.61E+03	*	1.02E-03	*	4.93E-16	*	2	*	0.4	*	modified **(3.48)**
D_B (GI) (Gy)*		Q_x (Ci)		χ/Q_{gnd} (m^{-2})		DCF_{Gnd}(Cs-137) (Sv-m^2/Bq-s)		T_{Ext} (h)		SF_{GndST}		1.332×10^{14} Bq-s/Ci-h
4.31E-02	=	8.63E-02	/	2.00								
DR_B (GI) (Gy/h)		D_B (GI) (Gy)		T_{Ext} (h)								

Inhalation

Inhalation (1st year dose)

1.25E+01	=	1.61E+03	*	1.02E-01	*	8.11E-09	*	8000	*	1.0	*	modified **(3.50)**
D_{InhST}(Gy)*		Q_x (Ci)		χ/Q (s/m^3)		DCF_{Inh}(Cs-137) Sv/Bq		BR (m^3/yr)		SF_{InhST}		1.172×10^3 Bq-yr/Ci-s

FIGURE 4.2 Short-Term External Dose and First-Year Inhalation Dose to the Gastrointestinal Tract from Cs-137

Acute Dose to Lung from:

Cloudshine

0.145	=	1.61E+03	*	1.02E-01	*	2.65E-14	*	0.9	*	3.7×10^{10} Bq/Ci	**(3.47)** modified
D_B (lung) (Gy)*		Q_x (Ci)		χ/Q (s/m^3)		DCF_{Air}(Cs-137) (Sv-m^3/Bq-s)		SF_{AirST}			
7.25E-02	=	0.145	/	2.00							
DR_B (lung) (Gy/h)		D_B (lung) (Gy)		T_{Ext} (h)							

Groundshine

9.27E-02	=	1.61E+03	*	1.02E-03	*	5.30E-16	*	2	*	0.4	*	modified **(3.48)**
D_B (lung) (Gy)*		Q_x (Ci)		χ/Q_{gnd} (m^{-2})		DCF_{Gnd}(Cs-137) (Sv-m^2/Bq-s)		T_{Ext} (h)		SF_{GndST}		1.332×10^{14} Bq-s/Ci-h
4.64E-02	=	9.27E-02	/	2.00								
DR_B (lung) (Gy/h)		D_B (lung) (Gy)		T_{Ext} (h)								

Inhalation

Inhalation (1st year dose)

1.25E+01	=	1.61E+03	*	1.02E-01	*	8.11E-09	*	8000	*	1.0	*	modified **(3.50)**
D_{InhST}(Gy)*		Q_x (Ci)		χ/Q (s/m^3)		DCF_{Inh}(Cs-137) Sv/Bq		BR (m^3/yr)		SF_{InhST}		1.172×10^3 Bq-yr/Ci-s

FIGURE 4.3 Short-Term External Dose and First-Year Inhalation Dose to the Lungs from Cs-137

CS-137 is 1). The calculated dose rates to each organ are also shown because this information is needed when estimating the lethality hazard. Tables 4.1 and 4.2 provide the calculated doses and dose rates, respectively, for the other radionuclides.

4.1.2 Inhalation Exposure

Estimation of brief and protracted doses from inhalation exposure is more difficult because internal DCFs are unavailable for the target organs for the time periods of interest. To estimate the appropriate DCFs, RISKIND multiplies the 1-yr DCFs from Dunning (1986) by the ratio of retention functions for the organ under consideration (the retention function for the time period of interest divided by that for a 1-yr period). Figure 4.4 presents the 1-yr Cs-137 retention function, and Figure 4.5 presents the subsequent calculations of inhalation doses and dose rates to bone marrow from exposure to Cs-137. The calculations for the GI tract and lungs, respectively, are given in Figures 4.6 and 4.7. Tables 4.1 and 4.2 present the brief inhalation doses and dose rates, respectively, for the other radionuclides. The protracted inhalation doses and dose rates for the other radionuclides are presented in Table 4.3. The total protracted inhalation doses and dose rates agreed with the RISKIND calculations shown on page 9 of the case 3 output (Appendix A, pg. A-34).

4.1.3 Lethality Risk

In RISKIND, the lethality risk is the probability of fatality from a radiation dose received immediately following a potential accident. A hazard function approach that follows the methodology in Evans et al. (1985) and Abrahamson et al. (1989) is used. A hazard function was calculated for each of the three major organs considered: bone marrow, GI tract, and lungs, as presented in Figures 4.8, 4.9, and 4.10, respectively. For each organ, the total brief dose received and the brief dose rate from inhalation, cloudshine, and groundshine were first calculated from the individual exposure pathway totals found in Tables 4.1 and 4.2. The total brief doses and dose rates estimated in Figures 4.8 to 4.10 agreed with those presented on page 9 of the case 3 output (Appendix A, pg. A-34).

The hazards were then calculated on the basis of median lethal dose estimates. The hazards calculated in Figures 4.8, 4.9, and 4.10 agreed with the RISKIND output (Appendix A, pg. A-34), although there was a little more deviation between these verification calculations and the RISKIND output resulting from round-off errors because of the rather sharp fatality threshold estimates used (the exponential rise) in the acute effects model. The deviations were still less than 5%: 0.308 versus 0.299 for bone marrow, 1.02×10^4 versus 1.07×10^4 for the lungs, and 883 versus 844 for the GI tract.

The calculations for the lethality risk from each organ and the combined risk are shown in Figure 4.11. Again, the calculated risks for each organ were in relatively good agreement with the RISKIND output values for "Acute Risk" (Appendix A, pg. A-34).

TABLE 4.1 Brief Doses (Gy) to the Bone Marrow, Gastrointestinal Tract, and Lungs

	Bone Marrow			Gastrointestinal Tract			Lungs		
Radionuclide	Inhalation	Ext. Gnd.	Ext. Cloud	Inhalation	Ext. Gnd.	Ext. Cloud	Inhalation	Ext. Gnd.	Ext. Cloud
H-3	0.00E+00	0.00E+00	0.00E+00	1.28E-06	0.00E+00	0.00E+00	1.35E-06	0.00E+00	0.00E+00
Fe-55	1.45E-08	0.00E+00	0.00E+00	4.87E-06	5.71E-10	9.30E-11	1.51E-07	0.00E+00	0.00E+00
Co-60	1.42E-02	5.09E-02	8.36E-02	1.09E+00	4.22E-02	7.54E-02	1.30E-01	4.93E-02	8.42E-02
Ni-63	1.52E-10	0.00E+00	0.00E+00	2.09E-08	0.00E+00	0.00E+00	1.46E-09	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	1.13E-02	0.00E+00	0.00E+00	9.91E-03	0.00E+00	0.00E+00	1.18E-02
Sr-90	1.37E-04	5.50E-06	6.05E-06	1.64E-01	0.00E+00	0.00E+00	3.71E-02	5.74E-06	6.62E-06
Y-90	5.55E-05	5.27E-06	5.83E-06	1.24E-01	0.00E+00	0.00E+00	3.93E-02	5.48E-06	6.37E-06
Ru-106	1.66E-05	2.71E-05	4.01E-05	3.88E-02	2.37E-05	3.69E-05	5.41E-03	2.67E-05	4.15E-05
Rh-106	2.99E-04	2.71E-05	4.01E-05	1.32E-03	2.37E-05	3.69E-05	2.99E-04	2.67E-05	4.15E-05
Sb-125	5.03E-10	1.15E-05	1.67E-05	7.72E-07	1.08E-05	1.61E-05	5.88E-07	1.14E-05	1.73E-05
Te-125m	1.93E-10	9.50E-08	4.03E-08	1.39E-07	1.23E-07	8.88E-08	2.80E-08	1.23E-07	4.83E-08
Cs-134	1.47E-02	1.99E-02	3.03E-02	1.44E+00	1.81E-02	2.88E-02	1.28E+00	1.97E-02	3.10E-02
Cs-137	1.27E-01	9.43E-02	1.42E-01	1.19E+01	8.63E-02	1.36E-01	1.25E+01	9.27E-02	1.45E-01
Ba-137m	3.97E-04	9.42E-04	1.41E-03	0.00E+00	8.62E-04	1.35E-03	3.97E-04	9.25E-04	1.45E-03
Ce-144	8.67E-08	1.14E-07	1.71E-07	5.83E-04	3.92E-08	5.17E-08	8.00E-05	1.16E-07	1.79E-07
Pr-144	3.62E-10	7.84E-08	1.26E-07	4.07E-10	5.44E-08	1.02E-07	1.78E-06	7.73E-08	1.28E-07
Pm-147	6.08E-07	2.83E-09	2.12E-09	2.07E-03	5.30E-10	7.37E-10	2.72E-04	3.35E-09	2.59E-09
Sm-151	7.87E-10	1.15E-11	2.93E-12	6.03E-08	3.70E-11	1.01E-11	4.49E-09	8.39E-12	1.85E-12
Eu-154	6.83E-08	1.24E-04	1.96E-04	8.25E-06	1.10E-04	1.85E-04	7.89E-07	1.22E-04	2.00E-04
Eu-155	4.16E-09	1.94E-06	2.38E-06	5.49E-07	2.49E-06	3.11E-06	5.04E-08	2.19E-06	2.85E-06
Pu-238	3.16E-05	1.70E-08	4.59E-09	1.09E-03	6.42E-08	1.03E-08	1.40E-02	6.88E-09	2.89E-09
Pu-239	2.18E-06	7.90E-10	5.54E-10	7.53E-05	2.15E-09	7.26E-10	1.02E-03	5.23E-10	5.50E-10
Pu-240	3.41E-06	1.96E-09	5.40E-10	1.18E-04	7.30E-09	1.20E-09	1.59E-03	8.12E-10	3.54E-10
Pu-241	1.35E-05	7.63E-09	9.99E-09	2.16E-03	0.00E+00	0.00E+00	4.80E-03	7.96E-09	1.14E-08
Am-241	2.18E-04	6.98E-07	6.76E-07	5.18E-04	1.05E-06	1.04E-06	1.05E-02	8.30E-07	8.75E-07
Cm-244	4.79E-04	1.72E-08	3.85E-09	1.15E-03	5.99E-08	9.41E-09	2.26E-02	7.59E-09	1.86E-09
Cd-113m	7.57E-08	9.87E-11	8.68E-11	1.89E-08	0.00E+00	0.00E+00	1.39E-09	1.13E-10	1.03E-10
Totals	1.58E-01	1.66E-01	2.68E-01	1.48E+01	1.48E-01	2.51E-01	1.40E+01	1.63E-01	2.74E-01

TABLE 4.2 Brief Dose Rates (Gy/h) to the Bone Marrow, Gastrointestinal Tract, and Lungs

	Bone Marrow			Gastrointestinal Tract			Lungs		
Radionuclide	Inhalation	Ext. Gnd.	Ext. Cloud	Inhalation	Ext. Gnd.	Ext. Cloud	Inhalation	Ext. Gnd.	Ext. Cloud
H-3	0.00E+00	0.00E+00	0.00E+00	5.35E-08	0.00E+00	0.00E+00	7.78E-08	0.00E+00	0.00E+00
Fe-55	6.04E-10	0.00E+00	0.00E+00	2.03E-07	2.86E-10	4.65E-11	6.30E-09	0.00E+00	0.00E+00
Co-60	5.93E-04	2.54E-02	4.18E-02	4.53E-02	2.11E-02	3.77E-02	5.40E-03	2.47E-02	4.21E-02
Ni-63	6.35E-12	0.00E+00	0.00E+00	8.69E-10	0.00E+00	0.00E+00	6.10E-11	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	5.63E-03	0.00E+00	0.00E+00	4.95E-03	0.00E+00	0.00E+00	5.89E-03
Sr-90	5.71E-06	2.75E-06	3.02E-06	6.85E-03	0.00E+00	0.00E+00	1.55E-03	2.87E-06	3.31E-06
Y-90	2.31E-06	2.63E-06	2.92E-06	5.16E-03	0.00E+00	0.00E+00	1.64E-03	2.74E-06	3.19E-06
Ru-106	6.92E-07	1.35E-05	2.01E-05	1.62E-03	1.18E-05	1.85E-05	2.25E-04	1.33E-05	2.08E-05
Rh-106	2.49E-02	1.35E-05	2.01E-05	1.10E-01	1.18E-05	1.85E-05	2.49E-02	1.33E-05	2.08E-05
Sb-125	2.10E-11	5.74E-06	8.33E-06	3.22E-08	5.38E-06	8.07E-06	2.45E-08	5.72E-06	8.64E-06
Te-125m	8.06E-12	4.75E-08	2.02E-08	5.78E-09	6.17E-08	4.44E-08	1.16E-09	6.14E-08	2.42E-08
Cs-134	6.14E-04	9.97E-03	1.51E-02	5.99E-02	9.03E-03	1.44E-02	7.40E-02	9.84E-03	1.55E-02
Cs-137	5.29E-03	4.72E-02	7.08E-02	4.97E-01	4.31E-02	6.78E-02	7.21E-01	4.64E-02	7.25E-02
Ba-137m	6.34E-03	4.71E-04	7.05E-04	0.00E+00	4.31E-04	6.74E-04	6.34E-03	4.63E-04	7.23E-04
Ce-144	3.61E-09	5.68E-08	8.53E-08	2.43E-05	1.96E-08	2.59E-08	3.33E-06	5.81E-08	8.97E-08
Pr-144	8.67E-10	3.92E-08	6.29E-08	9.76E-10	2.72E-08	5.09E-08	4.27E-06	3.86E-08	6.39E-08
Pm-147	2.53E-08	1.42E-09	1.06E-09	8.63E-05	2.65E-10	3.69E-10	1.13E-05	1.67E-09	1.30E-09
Sm-151	3.28E-11	5.77E-12	1.47E-12	2.51E-09	1.85E-11	5.07E-12	1.87E-10	4.19E-12	9.25E-13
Eu-154	2.85E-09	6.20E-05	9.81E-05	3.44E-07	5.51E-05	9.26E-05	3.29E-08	6.10E-05	1.00E-04
Eu-155	1.73E-10	9.68E-07	1.19E-06	2.29E-08	1.24E-06	1.55E-06	2.10E-09	1.10E-06	1.43E-06
Pu-238	1.32E-06	8.48E-09	2.29E-09	4.54E-05	3.21E-08	5.15E-09	5.82E-04	3.44E-09	1.45E-09
Pu-239	9.07E-08	3.95E-10	2.77E-10	3.14E-06	1.08E-09	3.63E-10	4.24E-05	2.61E-10	2.75E-10
Pu-240	1.42E-07	9.78E-10	2.70E-10	4.91E-06	3.65E-09	6.00E-10	6.64E-05	4.06E-10	1.77E-10
Pu-241	5.62E-07	3.82E-09	4.99E-09	9.01E-05	0.00E+00	0.00E+00	2.00E-04	3.98E-09	5.68E-09
Am-241	9.08E-06	3.49E-07	3.38E-07	2.16E-05	5.23E-07	5.19E-07	4.36E-04	4.15E-07	4.37E-07
Cm-244	2.00E-05	8.60E-09	1.92E-09	4.78E-05	2.99E-08	4.70E-09	9.43E-04	3.80E-09	9.32E-10
Cd-113m	3.15E-09	4.93E-11	4.34E-11	7.85E-10	0.00E+00	0.00E+00	5.80E-11	5.63E-11	5.14E-11
Totals	3.78E-02	8.31E-02	1.34E-01	7.26E-01	7.38E-02	1.26E-01	8.38E-01	8.14E-02	1.37E-01

$$\underset{t_2\,(d)}{\boxed{159}} = \mathrm{MIN}\left(365\ d,\ 1\ /\ \underset{\lambda_m(i,j,2)\ (1/d)}{\boxed{6.30E\text{-}03}}\right) \qquad (4.7)$$

$$\underset{\lambda_b(i,1,2)\ (1/d)}{\boxed{0.347}} = 0.693\ /\ \underset{T_b(i,1,2)\ (d)}{\boxed{2}} \qquad \text{pg. 78}$$

$$\underset{\lambda_b(i,2,2)\ (1/d)}{\boxed{6.30E\text{-}03}} = 0.693\ /\ \underset{T_b(i,2,2)\ (d)}{\boxed{110}} \qquad \text{pg. 78}$$

$$\underset{R(i,2,t_2)}{\boxed{90.20729}} = \frac{\underset{a(i,1,2)}{\boxed{0.1}} * [1 - \exp\{-(\underset{\lambda_b(i,1,2)\ (1/d)}{\boxed{0.347}} + \underset{\lambda(i)\ (1/yr)}{\boxed{2.30E\text{-}02}} * \underset{(yr/d)}{1/365.25}) * \underset{t_2\ (d)}{\boxed{159}}\}]}{\underset{\lambda_b(i,1,2)\ (1/d)}{\boxed{0.347}} + \underset{\lambda(i)\ (1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)} + \frac{\underset{a(i,2,2)}{\boxed{0.9}} * [1 - \exp\{-(\underset{\lambda_b(i,2,2)\ (1/d)}{\boxed{6.30E\text{-}03}} + \underset{\lambda(i)\ (1/yr)}{\boxed{2.30E\text{-}02}} * \underset{(yr/d)}{1/365.25}) * \underset{t_2\ (d)}{\boxed{159}}\}]}{\underset{\lambda_b(i,2,2)\ (1/d)}{\boxed{6.30E\text{-}03}} + \underset{\lambda(i)\ (1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)} \qquad (4.3)$$

FIGURE 4.4 One-Year Retention Function Calculation for Cs-137 in Bone Marrow

4.2 Latent Effects

Latent effects may occur following cumulative short-term and long-term routine and accidental exposures to radiation. Three latent health effects are considered in RISKIND: (1) nonfatal cancer occurrence, (2) fatal cancer occurrence, and (3) genetic effects manifested in the exposed individual's descendants. These effects are calculated in RISKIND by using dose to risk conversion factors recommended by the ICRP (ICRP 1991).

The estimated latent health effects are presented in Table 4.4 for the individuals exposed in cases 1 and 2. Case 1 involved risks to a member of the public with the associated DCFs as shown in the output file (Appendix A, page A-5). This individual received a routine passing dose of 1.2×10^{-7} rem. Multiplying this dose by the appropriate DCF resulted in the estimated risks shown in Table 4.4, which match the respective values shown in the output file (Appendix A, pg. A-6) within round-off errors. Case 2 involved risks to a worker exposed as the result of an accident, and the associated DCFs are shown in the output file (Appendix A, pg. A-11). Multiplying the 1.15-rem dose received by the appropriate DCF results in the estimated risks shown in Table 4.4, which matched the respective values shown in the output file (Appendix A, pg. A-20).

For Brief Exposures

$$\underset{t_1\,(d)}{\boxed{1}} = \mathrm{MIN}\left(1\,d,\ 1 / \underset{\lambda_m(i,j,2)\,(1/d)}{\boxed{6.30E\text{-}03}}\right) \qquad (4.8)$$

$$\underset{R(i,2,t_1)}{\boxed{0.981651}} = \frac{\underset{a(i,1,2)}{\boxed{0.1}} * [1 - \exp\{-(\underset{\lambda_b(i,1,2)\,(1/d)}{\boxed{0.347}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)) * \underset{t_1\,(d)}{\boxed{1}}\}]}{\underset{\lambda_b(i,1,2)\,(1/d)}{\boxed{0.347}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)} + \frac{\underset{a(i,2,2)}{\boxed{0.9}} * [1 - \exp\{-(\underset{\lambda_b(i,2,2)\,(1/d)}{\boxed{6.30E\text{-}03}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)) * \underset{t_1\,(d)}{\boxed{1}}\}]}{\underset{\lambda_b(i,2,2)\,(1/d)}{\boxed{6.30E\text{-}03}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)} \qquad (4.3)$$

$$\underset{\substack{D_B\,(bone)\\(Gy)}}{\boxed{1.27E\text{-}01}} = \underset{D_{InhST}(Gy)}{\boxed{1.17E+01}} * \left(\underset{R(i,2,t_1)}{\boxed{0.981651}} / \underset{R(i,2,t_2)}{\boxed{90.20729}}\right) \qquad (4.5)$$

$$\underset{\substack{DR_B\,(bone)\\(Gy/h)}}{\boxed{5.28E\text{-}03}} = \underset{\substack{D_B\,(bone)\\(Gy)}}{\boxed{1.27E\text{-}01}} / \underset{t_1\,(d)}{\boxed{1}} / 24\ h/d \qquad (4.6)\ \text{modified}$$

For Protracted Exposures

$$\underset{t_1\,(d)}{\boxed{30}} = \mathrm{MIN}\left(30\,d,\ 1 / \underset{\lambda_m(i,j,2)\,(1/d)}{\boxed{6.30E\text{-}03}}\right) \qquad (4.9)$$

$$\underset{R(i,2,t_1)}{\boxed{24.9}} = \frac{\underset{a(i,1,2)}{\boxed{0.1}} * [1 - \exp\{-(\underset{\lambda_b(i,1,2)\,(1/d)}{\boxed{0.347}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)) * \underset{t_1\,(d)}{\boxed{30}}\}]}{\underset{\lambda_b(i,1,2)\,(1/d)}{\boxed{0.347}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)} + \frac{\underset{a(i,2,2)}{\boxed{0.9}} * [1 - \exp\{-(\underset{\lambda_b(i,2,2)\,(1/d)}{\boxed{6.30E\text{-}03}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)) * \underset{t_1\,(d)}{\boxed{30}}\}]}{\underset{\lambda_b(i,2,2)\,(1/d)}{\boxed{6.30E\text{-}03}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)} \qquad (4.3)$$

$$\underset{\substack{D_P\,(bone)\\(Gy)}}{\boxed{3.21}} = \underset{D_{InhST}(Gy)}{\boxed{11.7}} * \left(\underset{R(i,2,t_1)}{\boxed{24.9}} / \underset{R(i,2,t_2)}{\boxed{90.2}}\right) \qquad (4.5)$$

$$\underset{\substack{DR_P\,(bone)\\(Gy/h)}}{\boxed{4.46E\text{-}03}} = \underset{\substack{D_P\,(bone)\\(Gy)}}{\boxed{3.21E+00}} / \underset{t_1\,(d)}{\boxed{30}} / 24\ h/d \qquad (4.6)\ \text{modified}$$

FIGURE 4.5 Inhalation Dose Calculations for the Early Effects from the Exposure of Bone Marrow to Cs-137

$$\underset{t_2\,(d)}{\boxed{1.08}} = \text{MIN}\left(365\,d,\ 1 / \underset{\lambda_m(i,1,3)\,(1/d)}{\boxed{0.924}}\right) \qquad (4.7)$$

$$\underset{\lambda_b(i,1,3)\,(1/d)}{\boxed{0.924}} = 0.693 / \underset{T_b(i,1,3)\,(d)}{\boxed{0.75}} \qquad \text{pg. 78}$$

$$\underset{R(i,3,t_2)}{\boxed{0.684}} = \frac{\underset{a(i,1,3)}{\boxed{1}} * [1 - \exp\{-(\underset{\lambda_b(i,1,3)\,(1/d)}{\boxed{0.924}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * \underset{(yr/d)}{1/365.25}) * \underset{t_2\,(d)}{\boxed{1.08}}\}]}{\underset{\lambda_b(i,1,3)\,(1/d)}{\boxed{0.924}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)} \qquad (4.3)$$

For Brief Exposures

$$\underset{t_1\,(d)}{\boxed{1.00}} = \text{MIN}\left(1\,d,\ 1 / \underset{\lambda_m(i,1,3)\,(1/d)}{\boxed{0.924}}\right) \qquad (4.8)$$

$$\underset{R(i,3,t_1)}{\boxed{0.653}} = \frac{\underset{a(i,1,3)}{\boxed{1}} * [1 - \exp\{-(\underset{\lambda_b(i,1,3)\,(1/d)}{\boxed{0.924}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * \underset{(yr/d)}{1/365.25}) * \underset{t_1\,(d)}{\boxed{1.00}}\}]}{\underset{\lambda_b(i,1,3)\,(1/d)}{\boxed{0.924}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)} \qquad (4.3)$$

$$\underset{\substack{D_B\,(GI)\\(Gy)}}{\boxed{11.9}} = \underset{D_{InhST}(Gy)}{\boxed{12.5}} * \left(\underset{R(i,3,t_1)}{\boxed{0.653}} / \underset{R(i,3,t_2)}{\boxed{0.684}}\right) \qquad (4.5)$$

$$\underset{\substack{DR_B\,(GI)\\(Gy/h)}}{\boxed{4.96E\text{-}01}} = \underset{\substack{D_B\,(GI)\\(Gy)}}{\boxed{11.9}} / \underset{t_1\,(d)}{\boxed{1.00}} / 24\ h/d \qquad (4.6)\ \text{modified}$$

For Protracted Exposures

$$\underset{t_1\,(d)}{\boxed{1.08}} = \text{MIN}\left(7\,d,\ 1 / \underset{\lambda_m(i,1,3)\,(1/d)}{\boxed{0.924}}\right) \qquad (4.9)$$

$$\underset{R(i,3,t_1)}{\boxed{0.684}} = \frac{\underset{a(i,1,3)}{\boxed{1}} * [1 - \exp\{-(\underset{\lambda_b(i,1,3)\,(1/d)}{\boxed{0.924}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * \underset{(yr/d)}{1/365.25}) * \underset{t_1\,(d)}{\boxed{1.08}}\}]}{\underset{\lambda_b(i,1,3)\,(1/d)}{\boxed{0.924}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\ (yr/d)} \qquad (4.3)$$

$$\underset{\substack{D_P\,(GI)\\(Gy)}}{\boxed{12.5}} = \underset{D_{InhST}(Gy)}{\boxed{12.5}} * \left(\underset{R(i,3,t_1)}{\boxed{0.684}} / \underset{R(i,3,t_2)}{\boxed{0.684}}\right) \qquad (4.5)$$

$$\underset{\substack{DR_P\,(GI)\\(Gy/h)}}{\boxed{4.81E\text{-}01}} = \underset{\substack{D_P\,(GI)\\(Gy)}}{\boxed{12.5}} / \underset{t_1\,(d)}{\boxed{1.08}} / 24\ h/d \qquad (4.6)\ \text{modified}$$

FIGURE 4.6 Inhalation Dose Calculations for the Early Effects from the Exposure of the Gastrointestinal Tract to Cs-137

$$\underset{t_2\,(d)}{\boxed{0.721}} = \text{MIN}\left(365\,d,\ 1 \,/\, \underset{\lambda_m(i,1,1)\,(1/d)}{\boxed{1.39}}\right) \qquad (4.7)$$

$$\underset{\lambda_b(i,1,1)\,(1/d)}{\boxed{1.39}} = 0.693 \,/\, \underset{T_b(i,1,1)\,(d)}{\boxed{0.5}} \qquad \text{pg. 78}$$

$$\underset{R(i,1,t_2)}{\boxed{0.456}} = \frac{\underset{a(i,1,1)}{\boxed{1}} * \left[1 - \exp\left\{-\left(\underset{\lambda_b(i,1,1)\,(1/d)}{\boxed{1.39}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\,(yr/d)\right) * \underset{t_2\,(d)}{\boxed{0.721}}\right\}\right]}{\underset{\lambda_b(i,1,1)\,(1/d)}{\boxed{1.39}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\,(yr/d)} \qquad (4.3)$$

For Brief Exposures

$$\underset{t_1\,(d)}{\boxed{0.721}} = \text{MIN}\left(1\,d,\ 1 \,/\, \underset{\lambda_m(i,1,1)\,(1/d)}{\boxed{1.39}}\right) \qquad (4.8)$$

$$\underset{R(i,1,t_1)}{\boxed{0.456}} = \frac{\underset{a(i,1,1)}{\boxed{1}} * \left[1 - \exp\left\{-\left(\underset{\lambda_b(i,1,1)\,(1/d)}{\boxed{1.39}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\,(yr/d)\right) * \underset{t_1\,(d)}{\boxed{0.721}}\right\}\right]}{\underset{\lambda_b(i,1,1)\,(1/d)}{\boxed{1.39}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\,(yr/d)} \qquad (4.3)$$

$$\underset{\substack{D_B\,(lung)\\(Gy)}}{\boxed{12.5}} = \underset{D_{InhST}(Gy)}{\boxed{12.5}} * \left(\underset{R(i,1,t_1)}{\boxed{0.456}} \,/\, \underset{R(i,1,t_2)}{\boxed{0.456}}\right) \qquad (4.5)$$

$$\underset{\substack{DR_B\,(lung)\\(Gy/h)}}{\boxed{7.21E\text{-}01}} = \underset{\substack{D_B\,(lung)\\(Gy)}}{\boxed{12.5}} \,/\, \underset{t_1\,(d)}{\boxed{0.721}} \,/\, 24\,h/d \qquad (4.6)\ \text{modified}$$

For Protracted Exposures

$$\underset{t_1\,(d)}{\boxed{0.721}} = \text{MIN}\left(365\,d,\ 1 \,/\, \underset{\lambda_m(i,1,1)\,(1/d)}{\boxed{1.39}}\right) \qquad (4.9)$$

$$\underset{R(i,1,t_1)}{\boxed{0.456}} = \frac{\underset{a(i,1,1)}{\boxed{1}} * \left[1 - \exp\left\{-\left(\underset{\lambda_b(i,1,1)\,(1/d)}{\boxed{1.39}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\,(yr/d)\right) * \underset{t_1\,(d)}{\boxed{0.721}}\right\}\right]}{\underset{\lambda_b(i,1,1)\,(1/d)}{\boxed{1.39}} + \underset{\lambda(i)\,(1/yr)}{\boxed{2.30E\text{-}02}} * 1/365.25\,(yr/d)} \qquad (4.3)$$

$$\underset{\substack{D_P\,(lung)\\(Gy)}}{\boxed{12.5}} = \underset{D_{InhST}(Gy)}{\boxed{12.5}} * \left(\underset{R(i,1,t_1)}{\boxed{0.456}} \,/\, \underset{R(i,1,t_2)}{\boxed{0.456}}\right) \qquad (4.5)$$

$$\underset{\substack{DR_P\,(lung)\\(Gy/h)}}{\boxed{7.21E\text{-}01}} = \underset{\substack{D_P\,(lung)\\(Gy)}}{\boxed{12.5}} \,/\, \underset{t_1\,(d)}{\boxed{0.721}} \,/\, 24\,h/d \qquad (4.6)\ \text{modified}$$

FIGURE 4.7 Inhalation Dose Calculations for the Early Effects from the Exposure of the Lungs to Cs-137

TABLE 4.3 Protracted Inhalation Doses and Dose Rates from the Exposure of Bone Marrow, Gastrointestinal Tract, and Lungs to Radionuclides

	Bone Marrow		Gastrointestinal Tract		Lungs	
Radionuclide	Dose (Gy)	Dose Rate (Gy)	Dose (Gy)	Dose Rate (Gy)	Dose (Gy)	Dose Rate (Gy)
H-3	0.00E+00	0.00E+00	1.35E-06	5.19E-08	1.35E-06	7.78E-08
Fe-55	4.28E-07	5.94E-10	5.11E-06	1.97E-07	4.68E-06	2.70E-09
Co-60	2.35E-01	3.27E-04	1.14E+00	4.38E-02	2.37E+01	2.71E-03
Ni-63	4.53E-09	6.30E-12	2.19E-08	8.42E-10	2.83E-07	3.24E-11
Kr-85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	1.48E-03	2.06E-06	1.72E-01	6.64E-03	7.13E+00	8.14E-04
Y-90	1.53E-04	1.66E-06	1.29E-01	4.96E-03	9.32E-02	1.01E-03
Ru-106	3.01E-04	4.18E-07	4.06E-02	1.56E-03	7.83E-01	8.93E-05
Rh-106	2.99E-04	2.49E-02	1.32E-03	1.10E-01	2.99E-04	2.49E-02
Sb-125	4.33E-09	6.01E-12	8.09E-07	3.11E-08	1.82E-05	1.05E-08
Te-125m	3.14E-09	4.53E-12	1.45E-07	5.59E-09	6.41E-07	3.70E-10
Cs-134	3.69E-01	5.13E-04	1.51E+00	5.80E-02	1.28E+00	7.40E-02
Cs-137	3.21E+00	4.46E-03	1.25E+01	4.81E-01	1.25E+01	7.21E-01
Ba-137m	3.97E-04	6.34E-03	0.00E+00	0.00E+00	3.97E-04	6.34E-03
Ce-144	2.50E-06	3.48E-09	6.11E-04	2.35E-05	1.07E-02	1.22E-06
Pr-144	3.62E-10	8.67E-10	4.07E-10	9.76E-10	1.78E-06	4.27E-06
Pm-147	1.80E-05	2.50E-08	2.17E-03	8.35E-05	4.70E-02	5.37E-06
Sm-151	2.35E-08	3.27E-11	6.32E-08	2.43E-09	8.70E-07	9.93E-11
Eu-154	2.04E-06	2.83E-09	8.65E-06	3.33E-07	1.48E-04	1.69E-08
Eu-155	1.24E-07	1.72E-10	5.75E-07	2.21E-08	9.19E-06	1.05E-09
Pu-238	9.48E-04	1.32E-06	1.14E-03	4.40E-05	2.70E+00	3.09E-04
Pu-239	6.53E-05	9.07E-08	7.89E-05	3.04E-06	1.98E-01	2.26E-05
Pu-240	1.02E-04	1.42E-07	1.24E-04	4.76E-06	3.09E-01	3.53E-05
Pu-241	4.04E-04	5.61E-07	2.27E-03	8.72E-05	9.13E-01	1.04E-04
Am-241	6.53E-03	9.08E-06	5.43E-04	2.09E-05	3.31E-01	1.91E-04
Cm-244	1.43E-02	1.99E-05	1.20E-03	4.63E-05	7.13E-01	4.12E-04
Cd-113m	1.98E-07	2.28E-09	1.98E-08	7.61E-10	2.64E-07	3.01E-11
Totals	3.84E+00	3.66E-02	1.55E+01	7.06E-01	5.07E+01	8.32E-01

Brief Exposure

0.592	=	0.158	+	0.166	+	0.268
D_B(bone) (Gy)		$D_{B,Inh}$(bone) (Gy)		$D_{B,Gnd}$(bone) (Gy)		$D_{B,Cld}$(bone) (Gy)

0.255	=	3.78E-02	+	8.31E-02	+	1.34E-01
DR_B(bone) (Gy/h)		$DR_{B,Inh}$(bone) (Gy/h)		$DR_{B,Gnd}$(bone) (Gy/h)		$DR_{B,Cld}$(bone) (Gy/h)

High dose rate section, if dose rate >= 0.06 Gy/hr [True]

0.191	=	0.592	/	3.1	**(4.11)**
X_B(bone)		D_B(bone) (Gy)		$D_{50,B}$ (Gy)	

Protracted Exposure

0.874	=	3.84	/	4.4	**(4.11)**
X_P(bone)		D_P(bone) (Gy)		$D_{50,P}$ (Gy)	

Bone Marrow Hazard

Threshold effect, if X_B(bone) < 0.5, X_B(bone) = 0
Threshold effect, if X_P(bone) < 0.5, X_P(bone) = 0

$$\underset{X(bone)}{\boxed{0.874}} = \frac{\underset{X_B(bone)}{\boxed{0}} + \underset{X_P(bone)}{\boxed{0.874}}}{\underset{\text{treatment factor}}{\boxed{1}}} \qquad \textbf{(4.15)} \text{ modified}$$

$$\underset{H_A(bone)}{\boxed{0.308}} = \ln(2) * \underset{X(bone)}{\boxed{0.874}}^{\overset{6}{\boxed{v}}} \qquad \textbf{(4.10)}$$

FIGURE 4.8 Lethality Hazard Calculations for Bone Marrow

Brief Exposure

15.2	=	14.8	+	1.48E-01	+	0.251
$D_B(GI)$ (Gy)		$D_{B,Inh}(GI)$ (Gy)		$D_{B,Gnd}(GI)$ (Gy)		$D_{B,Cld}(GI)$ (Gy)

0.925	=	0.726	+	7.38E-02	+	1.26E-01
$DR_B(GI)$ (Gy/h)		$DR_{B,Inh}(GI)$ (Gy/h)		$DR_{B,Gnd}(GI)$ (Gy/h)		$DR_{B,Cld}(GI)$ (Gy/h)

High dose rate section, if dose rate >= 0.06 Gy/hr [True]

1.012	=	15.2	/	15	(4.11)
$X_B(GI)$		$D_B(GI)$ (Gy)		$D_{50,B}$ (Gy)	

Protracted Exposure

1.032	=	15.5	/	15	(4.11)
$X_P(GI)$		$D_P(GI)$ (Gy)		$D_{50,P}$ (Gy)	

Gastrointestinal Tract Hazard

Threshold effect, if $X_B(GI) < 0.5$, $X_B(GI) = 0$
Threshold effect, if $X_P(GI) < 0.5$, $X_P(GI) = 0$

$$\underset{X(GI)}{\boxed{2.04}} = \frac{\underset{X_B(GI)}{\boxed{1.012}} + \underset{X_P(GI)}{\boxed{1.032}}}{\underset{\text{treatment factor}}{\boxed{1}}} \qquad \textbf{(4.15)} \text{ modified}$$

$$\underset{H_A(GI)}{\boxed{883}} = \ln(2) * \underset{X(GI)}{\boxed{2.04}}^{\overset{\boxed{10}}{v}} \qquad \textbf{(4.10)}$$

FIGURE 4.9 Lethality Hazard Calculations for the Gastrointestinal Tract

Brief Exposure

14.5	=	14.0	+	0.163	+	0.274
D_B(lung) (Gy)		$D_{B,Inh}$(lung) (Gy)		$D_{B,Gnd}$(lung) (Gy)		$D_{B,Cld}$(lung) (Gy)

1.056	=	0.838	+	8.14E-01	+	1.37E-01
DR_B(lung) (Gy/h)		$DR_{B,Inh}$(lung) (Gy/h)		$DR_{B,Gnd}$(lung) (Gy/h)		$DR_{B,Cld}$(lung) (Gy/h)

High dose rate section, if dose rate >= 0.06 Gy/hr [True]

0.965	=	14.5	/	15	**(4.11)**
X_B(lung)		D_B(lung) (Gy)		$D_{50,B}$ (Gy)	

Protracted Exposure

1.268	=	50.7	/	40	**(4.11)**
X_P(lung)		D_P(lung) (Gy)		$D_{50,P}$ (Gy)	

Lung Hazard

Threshold effect, if X_B(lung) < 0.5, X_B(lung) = 0
Threshold effect, if X_P(lung) < 0.5, X_P(lung) = 0

$$\underset{X(lung)}{\boxed{2.233}} = \frac{\underset{X_B(lung)}{\boxed{0.965054}} + \underset{X_P(lung)}{\boxed{1.268}}}{\underset{\text{treatment factor}}{\boxed{1}}} \qquad \textbf{(4.15)} \text{ modified}$$

$$\underset{H_A(lung)}{\boxed{1.07E+04}} = \ln(2) * \underset{X(lung)}{\boxed{2.233}}^{\overset{\boxed{12}}{v}} \qquad \textbf{(4.10)}$$

FIGURE 4.10 Lethality Hazard Calculations for the Lungs

$$\underset{\text{Lethality Risk (bone)}}{\boxed{0.265}} = 1 - \exp\left[-\underset{H_A(\text{bone})}{\boxed{0.308}}\right] \qquad \textbf{(4.12)}$$

$$\underset{\text{Lethality Risk (lung)}}{\boxed{1}} = 1 - \exp\left[-\underset{H_A(\text{lung})}{\boxed{1.07E{+}04}}\right] \qquad \textbf{(4.12)}$$

$$\underset{\text{Lethality Risk (GI)}}{\boxed{1}} = 1 - \exp\left[-\underset{H_A(\text{GI})}{\boxed{883}}\right] \qquad \textbf{(4.12)}$$

(4.13)

$$\underset{\text{Lethality Risk}}{\boxed{1}} = 1 - \exp\left[-\left(\underset{H_A(\text{bone})}{\boxed{0.308}} + \underset{H_A(\text{lung})}{\boxed{1.07E{+}04}} + \underset{H_A(\text{GI})}{\boxed{883}}\right)\right]$$

FIGURE 4.11 Lethality Risk Calculations for Case 3

TABLE 4.4 Latent Health Risks for an Individual

	Case 1 Dose of 1.2×10^{-7} rem		Case 2 Dose of 1.15 rem	
Latent Health Effect	DCF[a]	Risk[b]	DCF[a]	Risk[b]
Nonfatal cancer	1.0×10^{-4}	1.2×10^{-11}	8.0×10^{-5}	9.2×10^{-5}
Fatal cancer	5.0×10^{-4}	6.0×10^{-11}	4.0×10^{-4}	4.6×10^{-4}
Genetic effects	1.3×10^{-4}	1.6×10^{-11}	8.0×10^{-5}	9.2×10^{-5}

[a] Source: ICRP (1991).

[b] Lifetime risk of experiencing nonfatal or fatal cancer or risk of genetic effects occurring in descendants.

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APPENDIX A:

TEST CASES

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APPENDIX A: TEST CASES

A.1 Case 1: Routine Risk to Individual

A.1.1 Case 1 Input File

```
&INDATA
 VERSION = '1.11R'
 TITLE = 'Case 1, Routine Risk to Individual',
 ACTA =          1            ,
 METFREQ =       1            ,
 PPVH =         -1            ,
 TRAF_DEN =     -1            ,
 PAG =           27           ,
 QA =            50           ,
 STATEN = '',
 HS =            1            ,
 HZLM =          .01          ,
 IACDT =         0            ,
 IACFOD =        1            ,
 IBOUND =        2            ,
 IMOD =          1            ,
 IRDTY =         3            ,
 IRUTIN =        1            ,
 ICONSQ =        1            ,
 NISOPL =        10           ,
 IACOEF =        0            ,
 ISPENT =        1            ,
 ITREAT =        1            ,
 ISTATE =        49           ,
 IZONE =         2            ,
 WDTHMED =      -1            ,
 NUMLANES =     -1            ,
 OUTFIL ='output\case1.out',
 EFF_SURF_DEN =                240          ,
 PHALF =         50           ,
 RSALF =         .137         ,
 UF =  3*1,
 SEXT =  40*1,
 IDISPMOD =      1            ,
 SPEED =         24           ,
 SHIPDIST =      1            ,
 BRTPOP =        8000         ,
 SUFI =          .00001       ,
 SUFF =          .000000001   ,
 TD2M =          0            ,
 TIDX =          11           ,
 TIOFF =         0            ,
 VDEP =          .001         ,
 VDEPNUC =  3*.001, .01 , 0 ,
 YEVD =          50           ,
 BURNUP =        35000        ,
 CACTD =         1            ,
 CAREA =         39           ,
 FRAD =  .6 , .4 ,
 HSIZE =         4            ,
 RSIZE =         .45          ,
 RTYPE ='PWR',
 TFUEL =         10           ,
 TYPCSK ='Modal Truck',
 UMT =           .46          ,
 IADD =          1            ,
 POPTYPE =       1            ,
 DECAY_WEATHER =               .0495        ,
```

```
 F_RETAIN =     .2            ,
 F_EDBL_COW =  1              ,
 F_EDBL_HUM =  1              ,
 T_HARVEST_COW =              15            ,
 T_HARVEST_HUM =              30            ,
 YIELD_COW =   .7             ,
 YIELD_HUM =   2              ,
 T_GROW_COW =  30             ,
 T_GROW_HUM =  60             ,
 IDFOOD =  0 , 19*1,
 IDPG =  1 , 5 , 3*1, 5*5, 6*1, 2*5, 16*1, 2*5, 6*1, 3*2, 7*1, 4 , 5 , 3 , 30*1, 5 ,
14*1, 10*0,
 IRTP =  20*1,
 ISHLT =  0 , 19*1,
 LSHLT =  20*0,
 INDTYPE =  20*1,
 WSHLT =  1 , 4*0,
 SHLDVAL =  1 , 2*0,
 IWATER =  1 , 19*0,
 OCUPF =  20*.5, 20*.25,
 POPW =  20*1,
 TEXT =  20*2,
 TSTP =  20*1,
 BRTIND =  20*8000,
 DISTSTOP =  .03 , 19*1,
 DISTPASS =  .03 , 19*1,
 WBDYD =  20*2,
 WBDYW =  20*50,
 WEXCG =  20*1,
 XRECEP =  .03 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1
, 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 ,
2*0, 1 , 2*0, 1 , 2*0,
 XNAME =     ' Individual 1 ',
    19*'',

 NUTYPE =    'Particulate',
   'Ru',
   'Cs',
   'I',
   'Gas',

 ANH =          10            ,
 TABK =         288           ,
 IYOURW =       1             ,
 DMIX =         800           ,
 ITYPE =        4             ,
 RAIN =         0             ,
 WSM =          4             ,
 AMIX =         300           ,
 PMIX =         2400          ,
 DFREQ =  36*.0278,
 WS =  .67 , 2.46 , 4.47 , 6.93 , 9.61 , 12.52 ,
 DFACT =        .5            ,
 PFIN =  5*1,
 TREATM =       0             ,
 XIN =  .3 , .85 , .77 , 2*1,
 IYOURS =       2             ,
 VCASK =        65.57         ,
 ALPHA =        90            ,
 BETA =         90            ,
 IHARD =        1             ,
 TFLAME =       1199.67       ,
 DFIRE =        5             ,
 FLOCA =        0             ,
 DSTP =  2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 ,
50 , 2 , 50 ,
 FARM =        -1             ,
```

```
 GMEAT =      -1            ,
 GMILK =      -1            ,
 GVEGE =      -1            ,
 HSTP =  10*1,
 HTEXP =       2            ,
 IPFOD =       1            ,
 IPWATR =      0            ,
 NSTP =  10*1,
 NSTY =        0            ,
 POPD =        2            ,
 PSTP =  10*50,
 RDWTH =      -1            ,
 RFIE =        0            ,
 XING =  .26 , .33 , .28 , 2*0,
 XPZ =  .05 , 80 ,
 NSV =         20           ,
 FRELS =  3*.000002, .00002 , 3*.000002, .00002 , 3*.000002, .00002 , 3*.000002,
5*.00002, 3*.000027, .00027 , 3*.000027, .00027 , 3*.000027, .00027 , 3*.000048,
5*.00048, 3*.0002, .002 , 3*.0002, .002 , 3*.0002, .002 , 3*.0002, 5*.002, 3*.0025,
.043 , 3*.0025, .043 , 3*.0025, .043 , 3*.0043, 5*.043, 3*.33, .63 , 3*.33, .63 ,
3*.33, .63 , 3*.39, 5*.63,
 FDISP =  0 , 19*1, 0 , 19*1, 0 , 19*1, 0 , 19*1, 0 , 19*1,
 FSEV =  .994316 , .00382 , .0017984 , .0000001532 , .00001687 , .000000233 ,
.0000001574 , 3.926E-14 , .00002362 , .0000003008 , .0000002034 , 1.495E-14 ,
.00001525 , .0000001592 , .0000001076 , 7.681E-16 , .00000957 , .00000007201 ,
.00000004873 , 1E-16 , .993962 , .0027204 , .0005545 , .000000001786 , .0012275 ,
.0000005011 , .0000001021 , .000000000000329 , .00079511 , .0000003255 , .00000006634
, 2.137E-13 , .000614 , .0000002531 , .00000005162 , 1.644E-13 , .0001249 ,
.00000001075 , .00000005296 , 3.459E-14 , 20*.0000000001,
 FAILS =  .03 , .1 , 2*1, .03 , .1 , 2*1, .03 , .1 , 10*1,
 FSPAL =  0 , 3*1, .15 , 3*1, .15 , 3*1, .15 , 3*1, .15 , 3*1,
 FRCRUD =  20*1,
 HEATF =  4*500, 16*2000000,
&END
```

A.1.2 Case 1 Output File

```
================= RISKIND Program Output, Version 1.11     ========= Page:   1
 Title       : Case 1, Routine Risk to Individual
 Date/Time   : 11/27/95 13:57
 Input  File : c:\riskind\input\case1.inp
 Output File : output\case1.out
==============================================================================



==============================================================================
========================== RISKIND Computer Program ==========================
==============================================================================



 Problem Description
____________________________________________

               Individual Receptors

               Routine Calculations



     Note: * next to input description signifies
           a data dependent default value
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   2
 Title       : Case 1, Routine Risk to Individual
 Date/Time   : 11/27/95 13:57
 Input  File : c:\riskind\input\case1.inp
 Output File : output\case1.out
==============================   Routine Problem   ==============================

================================================================================
=================== RISKIND Routine Individual Problem Input ===================
================================================================================
```

Shipment Parameters

Transport Mode [IMOD]:	Truck	
Population Zone [IZONE]:	Suburban	
Dose at 1 m [TIDX]:	11.00	mrem/hr
Measurement Offset [TIOFF]:	0.00	m
Gamma Fraction [FRAD(1)]:	0.60	
Neutron Fraction [FRAD(2)]:	0.40	
Cask Length [HSIZE]:	4.00	m
Cask Radius [RSIZE]:	0.45	m
Traveling speed [SPEED]:	24.00	km/hr
Individual type [INDTYPE]:	Public	
Risk Conversion Factors		
Non-Fatal Cancers/rem:	1.0E-04	
Fatal Cancers/rem:	5.0E-04	
Genetic Effects/rem:	1.3E-04	

#	Individual Name	Stop Distance [DISTSTOP] [km]	Stop Time [TSTP] [hr]	Passing Distance [DISTPASS] [km]
1	Individual 1	3.0E-02	1.00	3.0E-02

```
================= RISKIND Program Output, Version 1.11     ========= Page:   3
 Title       : Case 1, Routine Risk to Individual
 Date/Time   : 11/27/95 13:57
 Input  File : c:\riskind\input\case1.inp
 Output File : output\case1.out
==============================   Routine Problem   ==============================

==============================================================================
================== RISKIND Routine Individual Problem Results ==================
==============================================================================
```

#	Individual Name	Dose (rem)	Expected Non-Fatal Cancers	Expected Cancer Fatalities	Expected Genetic Effects
		========== Stop ==========			
1	Individual 1	3.7E-05	3.7E-09	1.8E-08	4.8E-09

#	Individual Name	Dose (rem)	Expected Non-Fatal Cancers	Expected Cancer Fatalities	Expected Genetic Effects
		========== Passing ==========			
1	Individual 1	1.2E-07	1.2E-11	6.1E-11	1.6E-11

A.2 Case 2: Accident Risk to Individual

A.2.1 Case 2 Input File

```
&INDATA
 VERSION = '1.11R'
 TITLE = 'Case 2, Accident Risk to Individual',
 ACTA =          1            ,
 METFREQ =       1            ,
 PPVH =         -1            ,
 TRAF_DEN =     -1            ,
 PAG =           27           ,
 QA =            50           ,
 STATEN = '',
 HS =            1            ,
 HZLM =          .005         ,
 IACDT =         1            ,
 IACFOD =        1            ,
 IBOUND =        2            ,
 IMOD =          1            ,
 IRDTY =         3            ,
 IRUTIN =        0            ,
 ICONSQ =        1            ,
 NISOPL =        10           ,
 IACOEF =        0            ,
 ISPENT =        1            ,
 ITREAT =        1            ,
 ISTATE =        49           ,
 IZONE =         1            ,
 WDTHMED =      -1            ,
 NUMLANES =     -1            ,
 OUTFIL ='output\case2.out',
 EFF_SURF_DEN =                240          ,
 PHALF =         50           ,
 RSALF =         .137         ,
 UF =  3*1,
 SEXT =  40*1,
 IDISPMOD =      1            ,
 SPEED =         24           ,
 SHIPDIST =      1            ,
 BRTPOP =        8000         ,
 SUFI =          .00001       ,
 SUFF =          .000000001   ,
 TD2M =          1E-34        ,
 TIDX =          11           ,
 TIOFF =         0            ,
 VDEP =          .01          ,
 VDEPNUC =  4*.01, 0 ,
 YEVD =          50           ,
 BURNUP =        35000        ,
 CACTD =         4            ,
 CAREA =         39           ,
 FRAD =  .6 , .4 ,
 HSIZE =         4            ,
 RSIZE =         .45          ,
 RTYPE ='PWR',
 TFUEL =         10           ,
 TYPCSK ='Modal Truck',
 UMT =           .46          ,
 IADD =          1            ,
 POPTYPE =       0            ,
 DECAY_WEATHER =               .0495        ,
 F_RETAIN =      .2           ,
```

```
 F_EDBL_COW =  1            ,
 F_EDBL_HUM =  1            ,
 T_HARVEST_COW =             15          ,
 T_HARVEST_HUM =             30          ,
 YIELD_COW =   .75          ,
 YIELD_HUM =   2            ,
 T_GROW_COW =  30           ,
 T_GROW_HUM =  60           ,
 IDFOOD =  20*1,
 IDPG =  1 , 5 , 3*1, 5*5, 6*1, 2*5, 16*1, 2*5, 6*1, 3*2, 7*1, 4 , 5 , 3 , 30*1, 5 ,
14*1, 10*0,
 IRTP =  20*1,
 ISHLT =  20*1,
 LSHLT =  2 , 19*0,
 INDTYPE =  20*0,
 WSHLT =  1 , 4*0,
 SHLDVAL =  1 , 2*0,
 IWATER =  1 , 19*0,
 OCUPF =  20*.5, 20*.25,
 POPW =  20*1,
 TEXT =  20*2,
 TSTP =  20*1,
 BRTIND =  20*8000,
 DISTSTOP =  .5 , 19*.001,
 DISTPASS =  .3 , 19*.001,
 WBDYD =  3 , 19*2,
 WBDYW =  230 , 19*50,
 WEXCG =  20*1,
 XRECEP =  1 , .04 , 10 , 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 ,
2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0,
1 , 2*0, 1 , 2*0, 1 , 2*0,
 XNAME =     ' Individual 1 ',
    19*'',

 NUTYPE =    'Particulate',
   'Ruthenium',
   'Cesium',
   'Iodine',
   'Inert Gas',

 ANH =          10          ,
 TABK =         288         ,
 IYOURW =       1           ,
 DMIX =         800         ,
 ITYPE =        4           ,
 RAIN =         0           ,
 WSM =          2           ,
 AMIX =         300         ,
 PMIX =         2400        ,
 DFREQ =  36*.0278,
 WS =  .67 , 2.46 , 4.47 , 6.93 , 9.61 , 12.52 ,
 DFACT =        .5          ,
 PFIN =  5*1,
 TREATM =       0           ,
 XIN =  .3 , .85 , .77 , 2*1,
 IYOURS =      -1           ,
 VCASK =        97          ,
 ALPHA =        45          ,
 BETA =         45          ,
 IHARD =        1           ,
 TFLAME =       1283        ,
 DFIRE =        1.5         ,
 FLOCA =        0           ,
 DSTP =  2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 ,
50 , 2 , 50 ,
 FARM =        -1           ,
 GMEAT =       -1           ,
```

```
 GMILK =      -1            ,
 GVEGE =      -1            ,
 HSTP =  10*1,
 HTEXP =       2            ,
 IPFOD =       1            ,
 IPWATR =      0            ,
 NSTP =  10*1,
 NSTY =        0            ,
 POPD =        600          ,
 PSTP =  10*50,
 RDWTH =      -1            ,
 RFIE =        0            ,
 XING =  .26 , .33 , .28 , 2*0,
 XPZ =  .2 , .4 ,
 NSV =         20           ,
 FRELS =  3*.000002, .00002 , 3*.000002, .00002 , 3*.000002, .00002 , 3*.000002,
5*.00002, 3*.000027, .00027 , 3*.000027, .00027 , 3*.000027, .00027 , 3*.000048,
5*.00048, 3*.0002, .002 , 3*.0002, .002 , 3*.0002, .002 , 3*.0002, 5*.002, 3*.0025,
.043 , 3*.0025, .043 , 3*.0025, .043 , 3*.0043, 5*.043, 3*.33, .63 , 3*.33, .63 ,
3*.33, .63 , 3*.39, 5*.63,
 FDISP =  0 , 19*1, 0 , 19*1, 0 , 19*1, 0 , 19*1, 0 , 19*1,
 FSEV =  .994316 , .00382 , .0017984 , .0000001532 , .00001687 , .000000233 ,
.0000001574 , 3.926E-14 , .00002362 , .000000301 , .0000002034 , 1.495E-14 , .00001525
, .0000001592 , .0000001076 , 7.681E-16 , .00000957 , .00000007201 , .00000004873 ,
1E-16 , .993962 , .0027204 , .0005545 , .000000001786 , .0012275 , .0000005011 ,
.0000001021 , .000000000000329 , .00079511 , .0000003255 , .00000006634 , 2.137E-13 ,
.000614 , .0000002531 , .00000005162 , 1.644E-13 , .0001249 , .00000001075 ,
.00000005296 , 3.459E-14 , 20*.0000000001,
 FAILS =  .03 , .1 , 2*1, .03 , .1 , 2*1, .03 , .1 , 10*1,
 FSPAL =  0 , 3*1, .15 , 3*1, .15 , 3*1, .15 , 3*1, .15 , 3*1,
 FRCRUD =  20*1,
 HEATF =  4*500, 16*2000000,
&END
```

A.2.2 Case 2 Output File

```
================= RISKIND Program Output, Version 1.11     ========= Page:   1
 Title       : Case 2, Accident Risk to Individual
 Date/Time   : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
==============================================================================
```

```
==============================================================================
========================== RISKIND Computer Program ==========================
==============================================================================
```

```
 Problem Description
 ___________________________________________

               Individual Receptors

               Accident Calculations
                  User Defined Accident
                  Single Weather Analysis

                  Acute Exposure
                     Plume Inhalation
                     Plume Immersion
                     Early Ground Exposure
                     Exposure to Cask
                  Long Term Exposure
                     Ground Exposure
                     Resuspension Inhalation
                     Resuspension Cloud
                     Ingestion
                        Initially contaminated Food
                        Long Term Food Contamination
                        Water ingestion


     Note: * next to input description signifies
           a data dependent default value
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   2
 Title       : Case 2, Accident Risk to Individual
 Date/Time   : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
============================  Input Parameters  ============================
```

```
==============================================================================
================== RISKIND Accident Individual Problem Input ================
==============================================================================
```

Individual Accident Parameters

```
                                  State:  US
                        Population Zone: Rural
      Long-Term Exposure Duration [YEVD]: 5.00E+01      yr

         Average Breathing Rate [BRTIND]: 8.00E+03   m3/yr
               Individual type [INDTYPE]:  Worker
           Risk Conversion Factors
                   Non-Fatal Cancers/rem: 8.0E-05
                       Fatal Cancers/rem: 4.0E-04
                     Genetic Effects/rem: 8.0E-05
```

Individual Name [XNAME]	======= Location ======= Down Wind [km]	Cross Wind [km] [XRECEP]	Elevation [m]	Acute Exposure Time [hr] [TEXT]	Long Term Exposure [IRTP]	Food Ingestion [IDFOOD]
Individual 1	1.00E+00	4.00E-02	1.00E+01	2.00E+00	Yes	Yes

Individual Name	Shielding Type Short	Long	Long-Term In	Out	====== Shielding Factors ==== Acute: Inh	Cld	Ext	Long-Term: Inh	Cld	Ext
Individual 1	Frame Ho	Brick Ho	0.50	0.25	1.00	0.90	0.40	0.75	0.55	0.35

Ingestion Parameters

Food Type	Individual Consumption Rate [kg/d] [XIN]	Contaminated Fraction [PFIN]
Meat	3.00E-01	1.00E+00
Milk	8.50E-01	1.00E+00
Vegetable	7.70E-01	1.00E+00
Water	1.00E+00	1.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   3
 Title       : Case 2, Accident Risk to Individual
 Date/Time   : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
============================  Input Parameters  ============================

 Meteorological Parameters
_____________________________________________

            Dry deposition rates [VDEPNUC]
                          Particulates   : 1.00E-02      m/s
                          Ruthenium      : 1.00E-02      m/s
                          Cesium         : 1.00E-02      m/s
                          Iodine         : 1.00E-02      m/s
                          Gases          : 0.00E+00      m/s
                    Rain fall rate [RAIN]: 0.00E+00     mm/h
                  Anemometer height [ANH]:    10.00        m
               Ambient Temperature [TABK]:   288.00        K
                     Mixing height [DMIX]:   800.00        m
                 Wind at anemometer [WSM]:     2.00      m/s
           Pasquill stability cat. [ITYPE]:       D



 Shipment Parameters
_____________________________________________

                Transportation Mode [IMOD]:    Truck
                        Dose at 1 m [TIDX]:    11.00  mrem/hr
                Measurement Offset [TIOFF]:     0.00        m
                  Gamma Fraction [FRAD(1)]:     0.60
                Neutron Fraction [FRAD(2)]:     0.40
                       Cask Length [HSIZE]:     4.00        m
                       Cask Radius [RSIZE]:     0.45        m
                   Amount of Uranium [UMT]:     0.46      MTU
                      Reactor Type [RTYPE]:      PWR
                   Reactor Burnup [BURNUP]: 3.50E+04     MWD
                 Fuel Cooling Time [TFUEL]:    10.00       yr
        Total Surface Area of Cask [CAREA]:    39.00       m2
     Crud Surface Activity Density [CACTD]:     4.00  uCi/cm2
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   4
 Title        : Case 2, Accident Risk to Individual
 Date/Time    : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
============================  Input Parameters  ============================
```

Long-Term Environmental Parameters

Removal half-life from soil [PHALF]:	50.00	yr
Initial resuspension factor [SUFI]:	1.00E-05	1/m
Final Resuspension factor [SUFF]:	1.00E-09	1/m
Resus. factor decay halflife [RSALF]:	1.37E-01	yr

Water Pathway Parameters

Water Treatment Cleanup [TREATM]: 0.00

Individual [XNAME]	Water Bodies Depth [m] [WBDYD]	Water Body Width [m] [WBDYW]	Exhange Rate [1/yr] [WEXCG]
Individual 1	3.00E+00	2.30E+02	1.00E+00

Food Production Parameters

Food decontamination factor [DFACT]:	0.50	
Cow's ingestion rate of grass [QA]:	50.00	kg/d
Yield of pasture grass [YIELD_COW]:	7.50E-01	kg/m2
Yield of edible vegetation [YIELD_HUM]:	2.00E+00	kg/m2
Time to first harvest		
Pasture grass [T_HARVEST_COW]:	15.00	days
Vegetation [T_HARVEST_HUM]:	30.00	days
Pasture grass grow time [T_GROW_COW]:	30.00	days
Vegetation grow time [T_GROW_HUM]:	60.00	days
Deposition retention fraction [F_RETAIN]:	0.20	
Edible vegetation fraction [F_EDBL_HUM]:	1.00	
Edible pasture fraction [F_EDBL_COW]:	1.00	
Weathering decay const. [DECAY_WEATHER]:	4.95E-02	1/day
Effective Surface Density [EFF_SURF_DEN]:	240.00	kg/m2

```
================= RISKIND Program Output, Version 1.11     ========= Page:   5
 Title        : Case 2, Accident Risk to Individual
 Date/Time    : 04/29/97 09:52
 Input  File  : c:\riskind\input\case2.inp
 Output File  : output\case2.out
============================  Input Parameters  ============================
```

Nuclide Parameters

Nuclide Inventory and DCFs

Nuclide Name	Inventory Amount [Ci]	======= Dose Conversion Factors ====== Inhalation [Sv/Bq]	Ingestion [Sv/Bq]	Cloud [Sv/s] [Bq/m3]	Ground [Sv/s] [Bq/m2]	Nucl. Class	Decay Const. [1/yr]
H 3	2.17E+02	1.73E-11	1.73E-11	0.00E+00	0.00E+00	Particul	5.60E-02
FE 55	1.07E+02	7.26E-10	1.64E-10	0.00E+00	0.00E+00	Particul	2.60E-01
CO 60	1.10E+03	5.91E-08	7.28E-09	1.26E-13	2.35E-15	Particul	1.30E-01
NI 63	1.88E+02	1.70E-09	1.56E-10	0.00E+00	0.00E+00	Particul	6.90E-03
KR 85	2.33E+03	1.03E-11	1.03E-11	1.19E-16	2.64E-18	Inert Ga	6.50E-02
SR 90	2.77E+04	3.53E-07	4.14E-08	1.97E-16	5.61E-18	Particul	2.40E-02
Y 90	2.77E+04	2.28E-09	2.91E-09	1.90E-16	5.33E-18	Particul	9.50E+01
RU106	2.44E+02	1.30E-07	8.30E-09	1.04E-14	2.12E-16	Rutheniu	6.90E-01
RH106	2.44E+02	8.95E-10	8.95E-10	1.04E-14	2.12E-16	Rutheniu	7.30E+05
SB125	6.01E+02	3.75E-09	9.85E-10	2.02E-14	4.33E-16	Particul	2.50E-01
TE125M	1.47E+02	1.97E-09	9.92E-10	4.53E-16	3.61E-17	Particul	4.40E+00
CS134	2.76E+03	1.25E-08	1.98E-08	7.56E-14	1.52E-15	Cesium	3.40E-01
CS137	3.98E+04	1.10E-08	1.59E-08	2.73E-14	5.54E-16	Cesium	2.30E-02
BA137M	3.76E+04	2.49E-09	2.49E-09	2.88E-14	5.86E-16	Particul	1.40E+05
CE144	6.45E+01	1.01E-07	5.71E-09	2.80E-15	5.83E-17	Particul	8.90E-01
PR144	6.45E+01	1.17E-11	3.15E-11	1.94E-15	3.79E-17	Particul	2.10E+04
PM147	4.21E+03	1.06E-08	2.83E-10	6.92E-19	3.40E-20	Particul	2.60E-01
SM151	1.81E+02	8.10E-09	1.05E-10	3.61E-20	5.02E-21	Particul	7.70E-03
EU154	2.09E+03	7.73E-08	2.58E-09	6.14E-14	1.18E-15	Particul	7.90E-02
EU155	7.69E+02	1.12E-08	4.13E-10	2.49E-15	5.90E-17	Particul	1.40E-01
PU238	1.42E+03	1.06E-04	8.65E-07	4.87E-18	8.37E-19	Particul	7.90E-03
PU239	1.65E+02	1.16E-04	9.56E-07	4.24E-18	3.67E-19	Particul	2.90E-05
PU240	2.37E+02	1.16E-04	9.56E-07	4.75E-18	8.02E-19	Particul	1.10E-04
PU241	3.88E+04	2.23E-06	1.85E-08	2.19E-19	5.20E-21	Particul	4.80E-02
AM241	8.66E+02	1.20E-04	9.84E-07	8.18E-16	2.74E-17	Particul	1.60E-03
CM244	8.95E+02	6.70E-05	5.45E-07	4.91E-18	8.78E-19	Particul	3.80E-02

```
================= RISKIND Program Output, Version 1.11     ========= Page:   6
 Title        : Case 2, Accident Risk to Individual
 Date/Time    : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
============================  Input Parameters  ============================
```

Nuclide Food Transfer Parameters

Nuclide Name	Soil-to-Plant [unitless]	Grass-to-Meat [day/kg]	Grass-to-Milk [day/L]
H 3	4.80E+00	1.20E-02	1.00E-02
FE 55	6.60E-04	4.00E-02	1.20E-03
CO 60	9.40E-03	1.30E-02	1.00E-03
NI 63	1.90E-02	5.30E-03	6.70E-03
KR 85	3.00E+00	2.00E-02	2.00E-02
SR 90	1.70E-02	6.00E-04	8.00E-04
Y 90	2.60E-03	4.60E-03	1.00E-05
RU106	5.00E-02	4.00E-01	1.00E-06
RH106	1.30E+01	1.50E-03	1.00E-02
SB125	1.10E-02	4.00E-03	1.50E-03
TE125M	1.30E+00	7.70E-02	1.00E-03
CS134	1.00E-02	4.00E-03	1.20E-02
CS137	1.00E-02	4.00E-03	1.20E-02
BA137M	5.00E-03	3.20E-03	4.00E-04
CE144	2.50E-03	1.20E-03	6.00E-04
PR144	2.50E-03	4.70E-03	5.00E-06
PM147	2.50E-03	4.80E-03	5.00E-06
SM151	2.50E-03	5.00E-03	5.00E-06
EU154	2.50E-03	4.80E-03	5.00E-06
EU155	2.50E-03	4.80E-03	5.00E-06
PU238	2.50E-04	1.40E-05	2.00E-06
PU239	2.50E-04	1.40E-05	2.00E-06
PU240	2.50E-04	1.40E-05	2.00E-06
PU241	2.50E-04	1.40E-05	2.00E-06
AM241	2.50E-04	2.00E-04	5.00E-06
CM244	2.50E-03	2.00E-04	5.00E-06

```
================= RISKIND Program Output, Version 1.11     ========= Page:   7
 Title       : Case 2, Accident Risk to Individual
 Date/Time   : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
============================  Input Parameters  ============================
```

Nuclide Health Effects Parameters

Nuclide Name	Solubility Class	Acute Organ Dose Conversion Factors =========Inhalation======== [Sv/Bq] Marrow	Lung	Intestine	========Ground========== [Sv/s//Bq/m2] Marrow	Lung	Intestine
H 3	D	1.62E-11	1.62E-11	1.62E-11	0.00E+00	0.00E+00	0.00E+00
FE 55	W	1.65E-10	1.76E-10	1.92E-10	0.00E+00	0.00E+00	1.89E-19
CO 60	Y	6.22E-09	1.24E-07	5.95E-09	2.34E-15	2.27E-15	1.94E-15
NI 63	Y	1.05E-12	5.95E-12	4.59E-13	0.00E+00	0.00E+00	0.00E+00
KR 85	D	0.00E+00	0.00E+00	0.00E+00	2.43E-18	2.45E-18	1.97E-18
SR 90	Y	1.08E-09	7.03E-07	1.70E-08	4.77E-18	4.98E-18	0.00E+00
Y 90	Y	1.51E-11	9.19E-09	1.27E-08	4.57E-18	4.76E-18	0.00E+00
RU106	Y	1.05E-09	6.76E-07	3.51E-08	2.06E-16	2.03E-16	1.80E-16
RH106	Y	2.58E-10	2.58E-10	1.14E-09	2.06E-16	2.03E-16	1.80E-16
SB125	W	2.41E-14	7.30E-11	3.24E-12	4.05E-16	4.03E-16	3.79E-16
TE125M	W	5.14E-14	1.05E-11	2.38E-12	1.37E-17	1.77E-17	1.78E-17
CS134	D	1.08E-08	1.08E-08	1.27E-08	1.48E-15	1.46E-15	1.34E-15
CS137	D	7.57E-09	8.11E-09	8.11E-09	5.39E-16	5.30E-16	4.93E-16
BA137M	D	2.73E-11	2.73E-11	0.00E+00	5.70E-16	5.60E-16	5.22E-16
CE144	Y	1.08E-09	5.68E-07	3.24E-08	5.31E-17	5.43E-17	1.83E-17
PR144	Y	1.92E-14	9.46E-11	2.16E-14	3.66E-17	3.61E-17	2.54E-17
PM147	Y	1.41E-10	3.51E-08	1.62E-09	1.86E-20	2.20E-20	3.48E-21
SM151	Y	3.78E-12	1.19E-11	8.65E-13	1.39E-21	1.01E-21	4.45E-21
EU154	Y	2.46E-11	1.57E-10	9.19E-12	1.16E-15	1.14E-15	1.03E-15
EU155	Y	3.78E-12	2.54E-11	1.59E-12	4.71E-17	5.34E-17	6.05E-17
PU238	Y	2.97E-07	7.03E-05	2.97E-08	1.94E-19	7.87E-20	7.35E-19
PU239	Y	2.70E-07	6.76E-05	2.70E-08	1.19E-19	7.87E-20	3.24E-19
PU240	Y	2.70E-07	6.76E-05	2.70E-08	1.88E-19	7.81E-20	7.02E-19
PU241	Y	2.97E-10	5.68E-08	1.41E-10	4.18E-21	4.36E-21	0.00E+00
AM241	W	4.32E-06	1.81E-05	2.97E-08	1.68E-17	2.00E-17	2.52E-17
CM244	W	4.59E-06	1.92E-05	3.24E-08	2.04E-19	9.00E-20	7.10E-19

```
================= RISKIND Program Output, Version 1.11     ========= Page:   8
 Title       : Case 2, Accident Risk to Individual
 Date/Time   : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
============================  Input Parameters  ============================
```

Nuclide Health Effects Parameters

Name	Acute Organ Dose Conversion Factors =========Cloudshine======== [Sv/s//Bq/m3] Marrow	Lung	Intestine
H 3	0.00E+00	0.00E+00	0.00E+00
FE 55	0.00E+00	0.00E+00	9.85E-19
CO 60	1.23E-13	1.24E-13	1.11E-13
NI 63	0.00E+00	0.00E+00	0.00E+00
KR 85	1.09E-16	1.14E-16	9.59E-17
SR 90	1.68E-16	1.84E-16	0.00E+00
Y 90	1.62E-16	1.77E-16	0.00E+00
RU106	9.76E-15	1.01E-14	8.99E-15
RH106	9.76E-15	1.01E-14	8.99E-15
SB125	1.88E-14	1.95E-14	1.82E-14
TE125M	1.86E-16	2.23E-16	4.10E-16
CS134	7.19E-14	7.37E-14	6.84E-14
CS137	2.59E-14	2.65E-14	2.48E-14
BA137M	2.73E-14	2.80E-14	2.61E-14
CE144	2.55E-15	2.68E-15	7.73E-16
PR144	1.88E-15	1.91E-15	1.52E-15
PM147	4.46E-19	5.45E-19	1.55E-19
SM151	1.13E-20	7.13E-21	3.91E-20
EU154	5.87E-14	5.99E-14	5.54E-14
EU155	1.85E-15	2.22E-15	2.42E-15
PU238	1.68E-18	1.06E-18	3.77E-18
PU239	2.67E-18	2.65E-18	3.50E-18
PU240	1.66E-18	1.09E-18	3.69E-18
PU241	1.75E-19	1.99E-19	0.00E+00
AM241	5.21E-16	6.74E-16	8.00E-16
CM244	1.46E-18	7.07E-19	3.57E-18

```
================= RISKIND Program Output, Version 1.11     ========= Page:   9
 Title       : Case 2, Accident Risk to Individual
 Date/Time   : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
===============  Input Parameters  - Accident Response Region: 10===============
```

Accident Parameters

Physical Release Height [HS]:	1.00	m
Dispersion Model Coefficients [IDISPMOD]:	Pasquill-Gifford	
Accident Analysis Type:	Consequence	

Accident Response Region Determined By

Accident Cask Velocity [VCASK]:	97.00	km/h
Cask Impact Angle [ALPHA]:	45.00	Degrees
Cask Orientation Angle [BETA]:	45.00	Degrees
Impact Object Hardness [IHARD]:	1.00	
Flame Temperature [TFLAME]:	1.28E+03	K
Fire Duration [DFIRE]:	1.50	hr
Fire Location [FLOCA]:	0.00	m

Accident Response Region Parameters

Response Region [IYOURS]:	10	
Region Conditional Probability [FSEV]:	3.01E-07	
Heat Flux [HEATF]:	2.00E+06	cal/s
Loss of Cask Shielding Factor [SEXT]		
Gamma:	1.00	
Neutron:	1.00	
Failure Rate [FAILS]:	1.00E-01	
Crud Spallation Rate [FSPAL]:	1.00E+00	
Crud Release Rate [FRCRUD]:	1.00E+00	

Nuclide Class [NUTYPE]	Conditional Release Fraction [FRELS]	Dispersion Fraction [FDISP]	Released and Dispersed Fraction (FRELS*FAILS*FDISP)
Particulate	2.00E-06	1.00E+00	2.00E-07
Ruthenium	2.70E-05	1.00E+00	2.70E-06
Cesium	2.00E-04	1.00E+00	2.00E-05
Iodine	2.50E-03	1.00E+00	2.50E-04
Inert Gas	3.30E-01	1.00E+00	3.30E-02

```
================= RISKIND Program Output, Version 1.11     ========= Page:  10
 Title       : Case 2, Accident Risk to Individual
 Date/Time   : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
=============== Intermediate Calcs - Accident Response Region: 10===============
```

Nuclide Release

Nuclide Name	Release Amount [Ci]	Hazard Index Inhalation	Hazard Index Ingestion	Hazard Index Ground
CO 60	4.25E-01	1.99E-01	4.26E-02	4.03E-01
KR 85	7.70E+01	6.52E-03	0.00E+00	0.00E+00
SR 90	5.55E-03	1.54E-02	1.27E-02	4.05E-05
CS134	5.52E-02	5.55E-03	9.98E-03	1.37E-02
CS137	7.95E-01	6.94E-02	9.33E-01	5.83E-01
PU238	2.83E-04	2.36E-01	2.43E-04	4.19E-07
PU239	3.30E-05	3.01E-02	3.71E-05	2.53E-08
PU240	4.73E-05	4.31E-02	5.30E-05	7.92E-08
PU241	7.77E-03	1.36E-01	7.23E-05	3.61E-08
AM241	1.73E-04	1.63E-01	1.95E-04	9.59E-06
CM244	1.79E-04	9.42E-02	5.71E-04	1.62E-07
Total	7.83E+01	9.99E-01	9.99E-01	1.00E+00

Puff Calculations

Individual Name	Plume Parameters: Effective Release Height [m]	Dispersion Sigma (Horizontal) [m]	Dispersion Sigma (Vertical) [m]
Individual 1	1.12E+01	7.62E+01	3.18E+01

Individual Name	Chi/Q Air [s/m3]	Chi/Q Ground [1/m2]	Depletion Fraction	Wet/Dry Ratio
Individual 1				
Particulates	4.55E-05	4.55E-07	1.38E-01	0.00E+00
Ruthenium	4.55E-05	4.55E-07	1.38E-01	0.00E+00
Cesium	4.55E-05	4.55E-07	1.38E-01	0.00E+00
Iodine	4.55E-05	4.55E-07	1.38E-01	0.00E+00
Gases	5.28E-05	0.00E+00	0.00E+00	0.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:  11
 Title       : Case 2, Accident Risk to Individual
 Date/Time   : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
===============      Results       - Accident Response Region: 10===============

================================================================================
===============          Accident Dose to :  Individual 1        ===============
================================================================================
```

Individual Summary Results Per Accident		
Committed Effective Dose Equivalent	1.15E+00	rem
Expected Genetic Effects	9.23E-05	
Expected Non-fatal Cancers	9.23E-05	
Expected Cancer Fatalities	4.62E-04	
Acute Risk (Expected fatalities)	0.00E+00	

Pathway	Doses(rem)			
Acute	5.44E-03			
Cask		8.69E-11		
Ground Shine		7.40E-06		
Inhalation		5.42E-03		
Cloud Shine		1.37E-05		
Long-Term	1.15E+00			
Ground Shine		3.21E-01		
Inhalation		2.52E-03		
Cloud Shine		4.51E-06		
Ingestion		8.25E-01		
Initial Year			7.64E-01	
Vegetable				9.51E-02
Meat				1.11E-01
Milk				5.57E-01
Long-Term			6.15E-02	
Vegetable				1.69E-02
Meat				6.73E-03
Milk				3.50E-02
Water				2.87E-03

	Organ Exposure			
Exposure Parameter	Marrow	Lung	Intestine	Gonads
Long-Term Dose [rem]	1.12E+00	1.07E+00	1.10E+00	7.81E+01
Brief Dose [Gy]	2.49E-07	3.35E-06	4.17E-06	
Brief Exposure Time [d]	1.00E+00	1.00E+00	1.00E+00	
Brief Dose Rate [Gy/hr]	1.04E-07	2.82E-07	2.57E-07	
Prolonged Dose [Gy]	1.01E-06	2.81E-05	4.18E-06	
Prolong Exposure Time [d]	3.00E+01	3.65E+02	7.00E+00	
Prolong Dose Rate [Gy/hr]	1.40E-09	1.77E-07	1.61E-07	
Hazard	0.00E+00	0.00E+00	0.00E+00	
Acute Risk [Expected fatalities]	0.00E+00	0.00E+00	0.00E+00	

```
================= RISKIND Program Output, Version 1.11     ========= Page:  12
 Title       : Case 2, Accident Risk to Individual
 Date/Time   : 04/29/97 09:52
 Input  File : c:\riskind\input\case2.inp
 Output File : output\case2.out
==============================      Results      ==============================

==============================================================================
========================== Accident Risk to Individuals ======================
==============================================================================
```

Individual Accident Dose Summary Results
Consequences

	Acute		Total			
	Dose [rem]	Risk [Fatality]	Dose [rem]	Expected Non-Fatal Cancer Incidence	Expected Cancer Fatalities	Expected Genetic Effects
Individual 1	5.44E-03	0.00E+00	1.15E+00	9.23E-05	4.62E-04	9.23E-05

A.3 Case 3: Acute Health Effects

A.3.1 Case 3 Input File

```
&INDATA
 VERSION = '1.11R'
 TITLE = 'Case 3, Acute Healt Effects',
 ACTA =        1            ,
 METFREQ =     1            ,
 PPVH =       -1            ,
 TRAF_DEN =   -1            ,
 PAG =         27           ,
 QA =          50           ,
 STATEN = '',
 HS =          1            ,
 HZLM =        0            ,
 IACDT =       1            ,
 IACFOD =      1            ,
 IBOUND =      2            ,
 IMOD =        2            ,
 IRDTY =       2            ,
 IRUTIN =      0            ,
 ICONSQ =      1            ,
 NISOPL =      10           ,
 IACOEF =      0            ,
 ISPENT =      1            ,
 ITREAT =      1            ,
 ISTATE =      49           ,
 IZONE =       1            ,
 WDTHMED =    -1            ,
 NUMLANES =   -1            ,
 OUTFIL ='output\case3.out',
 EFF_SURF_DEN =              240          ,
 PHALF =       50           ,
 RSALF =       .137         ,
 UF =  3*1,
 SEXT =  40*1,
 IDISPMOD =    1            ,
 SPEED =       24           ,
 SHIPDIST =    1            ,
 BRTPOP =      8000         ,
 SUFI =        .00001       ,
 SUFF =        .000000001   ,
 TD2M =        0            ,
 TIDX =        11           ,
 TIOFF =       0            ,
 VDEP =        .01          ,
 VDEPNUC =  4*.01, 0 ,
 YEVD =        50           ,
 BURNUP =      35000        ,
 CACTD =      -1            ,
 CAREA =      -1            ,
 FRAD =  .6 , .4 ,
 HSIZE =       4            ,
 RSIZE =       .45          ,
 RTYPE ='BWR',
 TFUEL =       10           ,
 TYPCSK ='Modal Rail',
 UMT =        -1            ,
 IADD =        1            ,
 POPTYPE =     1            ,
 DECAY_WEATHER =             .0495        ,
```

```
 F_RETAIN =     .2            ,
 F_EDBL_COW =  1              ,
 F_EDBL_HUM =  1              ,
 T_HARVEST_COW =              15            ,
 T_HARVEST_HUM =              30            ,
 YIELD_COW =   .75            ,
 YIELD_HUM =   2              ,
 T_GROW_COW =  30             ,
 T_GROW_HUM =  60             ,
 IDFOOD =  20*1,
 IDPG =  1 , 5 , 3*1, 5*5, 6*1, 2*5, 16*1, 2*5, 6*1, 3*2, 7*1, 4 , 5 , 3 , 30*1, 5 ,
14*1, 10*0,
 IRTP =  0 , 19*1,
 ISHLT =  20*1,
 LSHLT =  20*0,
 INDTYPE =  20*1,
 WSHLT =  1 , 4*0,
 SHLDVAL =  1 , 2*0,
 IWATER =  1 , 19*0,
 OCUPF =  20*.5, 20*.25,
 POPW =  20*1,
 TEXT =  20*2,
 TSTP =  20*1,
 BRTIND =  20*8000,
 DISTSTOP =  20*.001,
 DISTPASS =  20*.001,
 WBDYD =  3 , 19*2,
 WBDYW =  230 , 19*50,
 WEXCG =  20*1,
 XRECEP =  .025 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0,
1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 , 2*0, 1 ,
2*0, 1 , 2*0, 1 , 2*0,
 XNAME =    ' Individual 1 ',
    19*'',

 NUTYPE =    'Particulate',
   'Ru',
   'Cs',
   'I',
   'Gas',

 ANH =         10           ,
 TABK =        288          ,
 IYOURW =      1            ,
 DMIX =        1000         ,
 ITYPE =       6            ,
 RAIN =        0            ,
 WSM =         1            ,
 AMIX =        300          ,
 PMIX =        2400         ,
 DFREQ =  36*.0278,
 WS =  .67 , 2.46 , 4.47 , 6.93 , 9.61 , 12.52 ,
 DFACT =       .5           ,
 PFIN =  5*1,
 TREATM =      .15          ,
 XIN =  .3 , .85 , .77 , 2*1,
 IYOURS =      4            ,
 VCASK =       106.56       ,
 ALPHA =       90           ,
 BETA =        90           ,
 IHARD =       1            ,
 TFLAME =      1005.22      ,
 DFIRE =       .75          ,
 FLOCA =       0            ,
 DSTP =  2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 , 50 , 2 ,
50 , 2 , 50 ,
 FARM =       -1            ,
```

```
 GMEAT =      -1            ,
 GMILK =      -1            ,
 GVEGE =      -1            ,
 HSTP =  10*1,
 HTEXP =       2            ,
 IPFOD =       1            ,
 IPWATR =      1            ,
 NSTP =  10*1,
 NSTY =        0            ,
 POPD =        600          ,
 PSTP =  10*50,
 RDWTH =      -1            ,
 RFIE =        0            ,
 XING =  .26 , .33 , .28 , 2*0,
 XPZ =  .005 , .6 ,
 NSV =         20           ,
 FRELS =  3*.000002, .00002 , 3*.000002, .00002 , 3*.000002, .00002 , 3*.000002,
5*.00002, 3*.000027, .00027 , 3*.000027, .00027 , 3*.000027, .00027 , 3*.000048,
5*.00048, 3*.0002, .002 , 3*.0002, .002 , 3*.0002, .002 , 3*.0002, 5*.002, 3*.0025,
.043 , 3*.0025, .043 , 3*.0025, .043 , 3*.0043, 5*.043, 3*.33, .63 , 3*.33, .63 ,
3*.33, .63 , 3*.39, 5*.63,
 FDISP =  0 , 19*1, 0 , 19*1, 0 , 19*1, 0 , 19*1, 0 , 19*1,
 FSEV =  .994316 , .00382 , .0017984 , .0000001532 , .00001687 , .000000233 ,
.0000001574 , 3.926E-14 , .00002362 , .000000301 , .0000002034 , 1.495E-14 , .00001525
, .0000001592 , .0000001076 , 7.681E-16 , .00000957 , .00000007201 , .00000004873 ,
1E-16 , .993962 , .0027204 , .0005545 , .00000000179 , .0012275 , .0000005011 ,
.0000001021 , .000000000000329 , .00079511 , .0000003255 , .00000006634 , 2.137E-13 ,
.000614 , .0000002531 , .00000005162 , 1.644E-13 , .0001249 , .00000001075 ,
.00000005296 , 3.46E-14 , 20*.0000000001,
 FAILS =  .03 , .1 , 2*1, .03 , .1 , 2*1, .03 , .1 , 10*1,
 FSPAL =  0 , 3*1, .15 , 3*1, .15 , 3*1, .15 , 3*1, .15 , 3*1,
 FRCRUD =  20*1,
 HEATF =  3*500, 0 , 16*2000000,
&END
```

A.3.2 Case 3 Output File

```
================= RISKIND Program Output, Version 1.11     ========= Page:   1
 Title       : Case 3, Acute Healt Effects
 Date/Time   : 04/29/97 10:25
 Input  File : c:\riskind\input\case3.inp
 Output File : output\case3.out
==============================================================================



==============================================================================
========================== RISKIND Computer Program ==========================
==============================================================================



 Problem Description
_____________________________________________

              Individual Receptors

              Accident Calculations
                 Single Accident Analysis
                 Single Weather Analysis

                 Acute Exposure
                    Plume Inhalation
                    Plume Immersion
                    Early Ground Exposure
                    Exposure to Cask



     Note: * next to input description signifies
           a data dependent default value
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   2
 Title       : Case 3, Acute Healt Effects
 Date/Time   : 04/29/97 10:25
 Input  File : c:\riskind\input\case3.inp
 Output File : output\case3.out
============================  Input Parameters  ============================


==========================================================================
=================== RISKIND Accident Individual Problem Input ==================
==========================================================================
```

Individual Accident Parameters

State: US
Population Zone: Rural

Average Breathing Rate [BRTIND]: 8.00E+03 m3/yr
Individual type [INDTYPE]: Public
Risk Conversion Factors
Non-Fatal Cancers/rem: 1.0E-04
Fatal Cancers/rem: 5.0E-04
Genetic Effects/rem: 1.3E-04

Individual Name [XNAME]	======= Location ======= Down Wind [km]	Cross Wind [km] [XRECEP]	Elevation [m]	Acute Exposure Time [hr] [TEXT]	Long Term Exposure [IRTP]	Food Ingestion [IDFOOD]
Individual 1	2.50E-02	0.00E+00	0.00E+00	2.00E+00	Non	No

Individual Name	Shielding Type Short	Long	Long-Term In	Out	====== Shielding Factors ==== Acute: Inh	Cld	Ext	Long-Term: Inh	Cld	Ext
Individual 1	Frame Ho	None	0.50	0.25	1.00	0.90	0.40	0.75	0.75	0.75

```
================= RISKIND Program Output, Version 1.11     ========= Page:   3
 Title       : Case 3, Acute Healt Effects
 Date/Time   : 04/29/97 10:25
 Input  File : c:\riskind\input\case3.inp
 Output File : output\case3.out
============================  Input Parameters  ============================

 Meteorological Parameters
 ____________________________________________

            Dry deposition rates [VDEPNUC]
                          Particulates   : 1.00E-02      m/s
                          Ruthenium      : 1.00E-02      m/s
                          Cesium         : 1.00E-02      m/s
                          Iodine         : 1.00E-02      m/s
                          Gases          : 0.00E+00      m/s
                    Rain fall rate [RAIN]: 0.00E+00     mm/h
                  Anemometer height [ANH]:    10.00        m
               Ambient Temperature [TABK]:   288.00        K
                     Mixing height [DMIX]:  1000.00        m
                 Wind at anemometer [WSM]:     1.00      m/s
           Pasquill stability cat. [ITYPE]:       F



 Shipment Parameters
 ____________________________________________

                Transportation Mode [IMOD]:    Rail
                        Dose at 1 m [TIDX]:    11.00  mrem/hr
                Measurement Offset [TIOFF]:     0.00        m
                  Gamma Fraction [FRAD(1)]:     0.60
                Neutron Fraction [FRAD(2)]:     0.40
                       Cask Length [HSIZE]:     4.00        m
                       Cask Radius [RSIZE]:     0.45        m
                  Amount of Uranium [UMT]*:     8.89      MTU
                      Reactor Type [RTYPE]:      BWR
                   Reactor Burnup [BURNUP]: 3.50E+04     MWD
                 Fuel Cooling Time [TFUEL]:    10.00       yr
       Total Surface Area of Cask [CAREA]*:   209.50       m2
    Crud Surface Activity Density [CACTD]*:   350.00  uCi/cm2
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   4
 Title       : Case 3, Acute Healt Effects
 Date/Time   : 04/29/97 10:25
 Input  File : c:\riskind\input\case3.inp
 Output File : output\case3.out
============================  Input Parameters  ============================
```

Nuclide Parameters

Nuclide Inventory and DCFs

Nuclide Name	Inventory Amount [Ci]	======= Dose Conversion Factors ====== Inhalation [Sv/Bq]	Ingestion [Sv/Bq]	Cloud [Sv/s] [Bq/m3]	Ground [Sv/s] [Bq/m2]	Nucl. Class	Decay Const. [1/yr]
H 3	4.35E+03	1.73E-11	1.73E-11	0.00E+00	0.00E+00	Particul	5.60E-02
FE 55	1.39E+03	7.26E-10	1.64E-10	0.00E+00	0.00E+00	Particul	2.60E-01
CO 60	1.74E+04	5.91E-08	7.28E-09	1.26E-13	2.35E-15	Particul	1.30E-01
NI 63	2.49E+03	1.70E-09	1.56E-10	0.00E+00	0.00E+00	Particul	6.90E-03
KR 85	4.39E+04	1.03E-11	1.03E-11	1.19E-16	2.64E-18	Gas	6.50E-02
SR 90	5.31E+05	3.53E-07	4.14E-08	1.97E-16	5.61E-18	Particul	2.40E-02
Y 90	5.31E+05	2.28E-09	2.91E-09	1.90E-16	5.33E-18	Particul	9.50E+01
RU106	4.49E+03	1.30E-07	8.30E-09	1.04E-14	2.12E-16	Ru	6.90E-01
RH106	4.49E+03	8.95E-10	8.95E-10	1.04E-14	2.12E-16	Ru	7.30E+05
SB125	1.31E+04	3.75E-09	9.85E-10	2.02E-14	4.33E-16	Particul	2.50E-01
TE125M	3.19E+03	1.97E-09	9.92E-10	4.53E-16	3.61E-17	Particul	4.40E+00
CS134	6.19E+04	1.25E-08	1.98E-08	7.56E-14	1.52E-15	Cs	3.40E-01
CS137	8.03E+05	1.10E-08	1.59E-08	2.73E-14	5.54E-16	Cs	2.30E-02
BA137M	7.60E+05	2.49E-09	2.49E-09	2.88E-14	5.86E-16	Particul	1.40E+05
CE144	9.83E+02	1.01E-07	5.71E-09	2.80E-15	5.83E-17	Particul	8.90E-01
PR144	9.83E+02	1.17E-11	3.15E-11	1.94E-15	3.79E-17	Particul	2.10E+04
PM147	6.99E+04	1.06E-08	2.83E-10	6.92E-19	3.40E-20	Particul	2.60E-01
SM151	3.82E+03	8.10E-09	1.05E-10	3.61E-20	5.02E-21	Particul	7.70E-03
EU154	4.92E+04	7.73E-08	2.58E-09	6.14E-14	1.18E-15	Particul	7.90E-02
EU155	1.89E+04	1.12E-08	4.13E-10	2.49E-15	5.90E-17	Particul	1.40E-01
PU238	4.02E+04	1.06E-04	8.65E-07	4.87E-18	8.37E-19	Particul	7.90E-03
PU239	3.06E+03	1.16E-04	9.56E-07	4.24E-18	3.67E-19	Particul	2.90E-05
PU240	4.79E+03	1.16E-04	9.56E-07	4.75E-18	8.02E-19	Particul	1.10E-04
PU241	8.39E+05	2.23E-06	1.85E-08	2.19E-19	5.20E-21	Particul	4.80E-02
AM241	1.91E+04	1.20E-04	9.84E-07	8.18E-16	2.74E-17	Particul	1.60E-03
CM244	3.88E+04	6.70E-05	5.45E-07	4.91E-18	8.78E-19	Particul	3.80E-02
CD113M	2.55E+02	4.13E-07	4.35E-08	6.93E-18	2.63E-19	Particul	5.10E-02

```
================= RISKIND Program Output, Version 1.11     ========= Page:   5
 Title       : Case 3, Acute Healt Effects
 Date/Time   : 04/29/97 10:25
 Input  File : c:\riskind\input\case3.inp
 Output File : output\case3.out
============================  Input Parameters  ============================
```

Nuclide Health Effects Parameters

Nuclide Name	Solubility Class	Acute Organ Dose Conversion Factors =========Inhalation======== [Sv/Bq] Marrow	Lung	Intestine	=======Ground========== [Sv/s//Bq/m2] Marrow	Lung	Intestine
H 3	D	1.62E-11	1.62E-11	1.62E-11	0.00E+00	0.00E+00	0.00E+00
FE 55	W	1.65E-10	1.76E-10	1.92E-10	0.00E+00	0.00E+00	1.89E-19
CO 60	Y	6.22E-09	1.24E-07	5.95E-09	2.34E-15	2.27E-15	1.94E-15
NI 63	Y	1.05E-12	5.95E-12	4.59E-13	0.00E+00	0.00E+00	0.00E+00
KR 85	D	0.00E+00	0.00E+00	0.00E+00	2.43E-18	2.45E-18	1.97E-18
SR 90	Y	1.08E-09	7.03E-07	1.70E-08	4.77E-18	4.98E-18	0.00E+00
Y 90	Y	1.51E-11	9.19E-09	1.27E-08	4.57E-18	4.76E-18	0.00E+00
RU106	Y	1.05E-09	6.76E-07	3.51E-08	2.06E-16	2.03E-16	1.80E-16
RH106	Y	2.58E-10	2.58E-10	1.14E-09	2.06E-16	2.03E-16	1.80E-16
SB125	W	2.41E-14	7.30E-11	3.24E-12	4.05E-16	4.03E-16	3.79E-16
TE125M	W	5.14E-14	1.05E-11	2.38E-12	1.37E-17	1.77E-17	1.78E-17
CS134	D	1.08E-08	1.08E-08	1.27E-08	1.48E-15	1.46E-15	1.34E-15
CS137	D	7.57E-09	8.11E-09	8.11E-09	5.39E-16	5.30E-16	4.93E-16
BA137M	D	2.73E-11	2.73E-11	0.00E+00	5.70E-16	5.60E-16	5.22E-16
CE144	Y	1.08E-09	5.68E-07	3.24E-08	5.31E-17	5.43E-17	1.83E-17
PR144	Y	1.92E-14	9.46E-11	2.16E-14	3.66E-17	3.61E-17	2.54E-17
PM147	Y	1.41E-10	3.51E-08	1.62E-09	1.86E-20	2.20E-20	3.48E-21
SM151	Y	3.78E-12	1.19E-11	8.65E-13	1.39E-21	1.01E-21	4.45E-21
EU154	Y	2.46E-11	1.57E-10	9.19E-12	1.16E-15	1.14E-15	1.03E-15
EU155	Y	3.78E-12	2.54E-11	1.59E-12	4.71E-17	5.34E-17	6.05E-17
PU238	Y	2.97E-07	7.03E-05	2.97E-08	1.94E-19	7.87E-20	7.35E-19
PU239	Y	2.70E-07	6.76E-05	2.70E-08	1.19E-19	7.87E-20	3.24E-19
PU240	Y	2.70E-07	6.76E-05	2.70E-08	1.88E-19	7.81E-20	7.02E-19
PU241	Y	2.97E-10	5.68E-08	1.41E-10	4.18E-21	4.36E-21	0.00E+00
AM241	W	4.32E-06	1.81E-05	2.97E-08	1.68E-17	2.00E-17	2.52E-17
CM244	W	4.59E-06	1.92E-05	3.24E-08	2.04E-19	9.00E-20	7.10E-19
CD113M	Y	4.05E-11	5.41E-11	4.05E-12	1.78E-19	2.03E-19	0.00E+00

```
================= RISKIND Program Output, Version 1.11      ========= Page:   6
 Title       : Case 3, Acute Healt Effects
 Date/Time   : 04/29/97 10:25
 Input  File : c:\riskind\input\case3.inp
 Output File : output\case3.out
============================  Input Parameters  ============================
```

Nuclide Health Effects Parameters

Name	Acute Organ Dose Conversion Factors =========Cloudshine======== [Sv/s//Bq/m3] Marrow	Lung	Intestine
H 3	0.00E+00	0.00E+00	0.00E+00
FE 55	0.00E+00	0.00E+00	9.85E-19
CO 60	1.23E-13	1.24E-13	1.11E-13
NI 63	0.00E+00	0.00E+00	0.00E+00
KR 85	1.09E-16	1.14E-16	9.59E-17
SR 90	1.68E-16	1.84E-16	0.00E+00
Y 90	1.62E-16	1.77E-16	0.00E+00
RU106	9.76E-15	1.01E-14	8.99E-15
RH106	9.76E-15	1.01E-14	8.99E-15
SB125	1.88E-14	1.95E-14	1.82E-14
TE125M	1.86E-16	2.23E-16	4.10E-16
CS134	7.19E-14	7.37E-14	6.84E-14
CS137	2.59E-14	2.65E-14	2.48E-14
BA137M	2.73E-14	2.80E-14	2.61E-14
CE144	2.55E-15	2.68E-15	7.73E-16
PR144	1.88E-15	1.91E-15	1.52E-15
PM147	4.46E-19	5.45E-19	1.55E-19
SM151	1.13E-20	7.13E-21	3.91E-20
EU154	5.87E-14	5.99E-14	5.54E-14
EU155	1.85E-15	2.22E-15	2.42E-15
PU238	1.68E-18	1.06E-18	3.77E-18
PU239	2.67E-18	2.65E-18	3.50E-18
PU240	1.66E-18	1.09E-18	3.69E-18
PU241	1.75E-19	1.99E-19	0.00E+00
AM241	5.21E-16	6.74E-16	8.00E-16
CM244	1.46E-18	7.07E-19	3.57E-18
CD113M	5.01E-18	5.93E-18	0.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   7
 Title       : Case 3, Acute Healt Effects
 Date/Time   : 04/29/97 10:25
 Input  File : c:\riskind\input\case3.inp
 Output File : output\case3.out
===============  Input Parameters  - Accident Response Region:  4===============

 Accident Parameters
 ____________________________________________

              Physical Release Height [HS]:     1.00        m
   Dispersion Model Coefficients [IDISPMOD]: Pasquill-Gifford
                    Accident Analysis Type: Consequence


 Accident Response Region Parameters
 ____________________________________________
                  Response Region [IYOURS]:        4
      Region Conditional Probability [FSEV]: 1.79E-09
                         Heat Flux [HEATF]: 0.00E+00   cal/s
       Loss of Cask Shielding Factor [SEXT]
                                     Gamma:     1.00
                                   Neutron:     1.00
                      Failure Rate [FAILS]: 1.00E+00
              Crud Spallation Rate [FSPAL]: 1.00E+00
                Crud Release Rate [FRCRUD]: 1.00E+00
```

Nuclide Class [NUTYPE]	Conditional Release Fraction [FRELS]	Dispersion Fraction [FDISP]	Released and Dispersed Fraction (FRELS*FAILS*FDISP)
Particulate	2.00E-05	1.00E+00	2.00E-05
Ru	2.70E-04	1.00E+00	2.70E-04
Cs	2.00E-03	1.00E+00	2.00E-03
I	4.30E-02	1.00E+00	4.30E-02
Gas	6.30E-01	1.00E+00	6.30E-01

```
================= RISKIND Program Output, Version 1.11      ========= Page:   8
 Title        : Case 3, Acute Healt Effects
 Date/Time    : 04/29/97 10:25
 Input  File  : c:\riskind\input\case3.inp
 Output File  : output\case3.out
=============== Intermediate Calcs - Accident Response Region:  4===============
```

==========
========== Nuclide Release ==========
==========

Nuclide Name	Release Amount [Ci]	Hazard Index Inhalation	Hazard Index Ingestion	Hazard Index Ground
H 3	8.69E-02	5.48E-09	1.71E-05	0.00E+00
FE 55	2.78E-02	7.35E-08	1.97E-09	0.00E+00
CO 60	2.00E+02	4.35E-02	1.02E-02	1.35E-01
NI 63	4.98E-02	3.09E-07	5.95E-07	0.00E+00
KR 85	2.77E+04	1.09E-03	0.00E+00	0.00E+00
SR 90	1.06E+01	1.37E-02	1.24E-02	5.54E-05
Y 90	1.06E+01	8.83E-05	6.65E-08	2.47E-08
RU106	1.21E+00	5.74E-04	7.89E-04	1.51E-05
RH106	1.21E+00	4.13E-06	2.78E-09	1.46E-11
SB125	2.61E-01	3.65E-06	9.44E-07	1.78E-05
TE125M	6.38E-02	4.58E-07	5.10E-06	2.16E-08
CS134	1.24E+02	5.77E-03	1.14E-02	2.20E-02
CS137	1.61E+03	6.50E-02	9.63E-01	8.42E-01
BA137M	1.52E+01	1.44E-04	1.05E-10	2.64E-09
CE144	1.97E-02	7.24E-06	2.30E-08	5.25E-08
PR144	1.97E-02	1.39E-09	5.81E-15	1.47E-12
PM147	1.40E+00	5.40E-05	2.85E-07	7.19E-09
SM151	7.64E-02	2.25E-06	4.88E-08	4.86E-10
EU154	9.84E-01	2.78E-04	5.35E-06	5.13E-04
EU155	3.78E-01	1.54E-05	2.00E-07	6.00E-06
PU238	8.04E-01	3.11E-01	3.53E-04	8.50E-07
PU239	6.11E-02	2.58E-02	3.51E-05	3.35E-08
PU240	9.57E-02	4.05E-02	5.48E-05	1.14E-07
PU241	1.68E+01	1.36E-01	7.98E-05	5.58E-08
AM241	3.82E-01	1.67E-01	2.20E-04	1.51E-05
CM244	7.76E-01	1.89E-01	1.27E-03	5.03E-07
CD113M	5.10E-03	7.67E-06	6.78E-05	8.23E-10
Total	2.97E+04	1.00E+00	1.00E+00	1.00E+00

==========
========== Puff Calculations ==========
==========

Individual Name	Plume Parameters: Effective Release Height [m]	Dispersion Sigma (Horizontal) [m]	Dispersion Sigma (Vertical) [m]
Individual 1	1.00E+00	1.72E+00	1.02E+00

Individual Name	===== Chi/Q ====== Air [s/m3]	Ground [1/m2]	Depletion Fraction	Wet/Dry Ratio
Individual 1				
Particulates	1.02E-01	1.02E-03	9.12E-02	0.00E+00
Ruthenium	1.02E-01	1.02E-03	9.12E-02	0.00E+00
Cesium	1.02E-01	1.02E-03	9.12E-02	0.00E+00
Iodine	1.02E-01	1.02E-03	9.12E-02	0.00E+00
Gases	1.12E-01	0.00E+00	0.00E+00	0.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   9
 Title       : Case 3, Acute Healt Effects
 Date/Time   : 04/29/97 10:25
 Input  File : c:\riskind\input\case3.inp
 Output File : output\case3.out
===============      Results       - Accident Response Region:  4===============

==============================================================================
===============          Accident Dose to :  Individual 1        ===============
==============================================================================
```

Individual Summary Results Per Accident		
Committed Effective Dose Equivalent	2.62E+04	rem
Expected Genetic Effects	6.81E+00	
Expected Non-fatal Cancers	5.24E+00	
Expected Cancer Fatalities	1.00E+00	
Acute Risk (Expected fatalities)	1.00E+00	

Pathway	Doses(rem)			
Acute	2.62E+04			
Cask		4.31E-05		
Ground Shine		1.69E+01		
Inhalation		2.62E+04		
Cloud Shine		2.80E+01		
Long-Term	0.00E+00			
Ground Shine		0.00E+00		
Inhalation		0.00E+00		
Cloud Shine		0.00E+00		
Ingestion		0.00E+00		
Initial Year			0.00E+00	
Vegetable				0.00E+00
Meat				0.00E+00
Milk				0.00E+00
Long-Term			0.00E+00	
Vegetable				0.00E+00
Meat				0.00E+00
Milk				0.00E+00
Water				0.00E+00

	Organ Exposure			
Exposure Parameter	Marrow	Lung	Intestine	Gonads
Long-Term Dose [rem]	3.51E+04	1.54E+04	1.78E+03	2.85E+03
Brief Dose [Gy]	5.90E-01	1.44E+01	1.51E+01	
Brief Exposure Time [d]	1.00E+00	1.00E+00	1.00E+00	
Brief Dose Rate [Gy/hr]	2.54E-01	1.05E+00	9.21E-01	
Prolonged Dose [Gy]	3.83E+00	5.06E+01	1.54E+01	
Prolong Exposure Time [d]	3.00E+01	3.65E+02	7.00E+00	
Prolong Dose Rate [Gy/hr]	3.65E-02	8.28E-01	7.03E-01	
Hazard	2.99E-01	1.02E+04	8.44E+02	
Acute Risk [Expected fatalities]	2.59E-01	1.00E+00	1.00E+00	

```
================= RISKIND Program Output, Version 1.11     ========= Page:  10
 Title       : Case 3, Acute Healt Effects
 Date/Time   : 04/29/97 10:25
 Input  File : c:\riskind\input\case3.inp
 Output File : output\case3.out
==============================      Results       ==============================

===============================================================================
========================= Accident Risk to Individuals =========================
===============================================================================
```

Individual Accident Dose Summary Results
Consequences

	Acute		Total			
	Dose [rem]	Risk [Fatality]	Dose [rem]	Expected Non-Fatal Cancer Incidence	Expected Cancer Fatalities	Expected Genetic Effects
Individual 1	2.62E+04	1.00E+00	2.62E+04	5.24E+00	1.00E+00	6.81E+00

APPENDIX B:

DOSE COMPARISON CASES

CONTENTS

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B.1.1 Cs-137 Release (1 Ci) B-1
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APPENDIX B: DOSE COMPARISON CASES

B.1 Comparison with GENII

B.1.1 Cs-137 Release (1 Ci)

B.1.1.1 RISKIND Output for Cs-137 Release

```
================= RISKIND Program Output, Version 1.11     ========= Page:   1
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
==============================================================================




==============================================================================
========================== RISKIND Computer Program ==========================
==============================================================================



 Problem Description
 ___________________________________________

               Individual Receptors

               Accident Calculations
                  User Defined Accident
                  Single Weather Analysis

                  Acute Exposure
                     Plume Inhalation
                     Plume Immersion
                     Early Ground Exposure
                     Exposure to Cask
                  Long Term Exposure
                     Ground Exposure
                     Resuspension Inhalation
                     Resuspension Cloud
                     Ingestion
                        Initially contaminated Food
                        Long Term Food Contamination



     Note: * next to input description signifies
           a data dependent default value
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   2
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
============================  Input Parameters  ============================
```

```
==============================================================================
================== RISKIND Accident Individual Problem Input ==================
==============================================================================
```

Individual Accident Parameters

```
                                  State:  US
                        Population Zone: Rural
      Long-Term Exposure Duration [YEVD]: 1.00E+00      yr

         Average Breathing Rate [BRTIND]: 8.00E+03   m3/yr
               Individual type [INDTYPE]:  Public
           Risk Conversion Factors
                   Non-Fatal Cancers/rem: 1.0E-04
                       Fatal Cancers/rem: 5.0E-04
                     Genetic Effects/rem: 1.3E-04
```

Individual Name [XNAME]	======= Location ======= Down Wind [km]	Cross Wind [km] [XRECEP]	Elevation [m]	Acute Exposure Time [hr] [TEXT]	Long Term Exposure [IRTP]	Food Ingestion [IDFOOD]
Individual 1	1.00E+00	0.00E+00	0.00E+00	2.00E+00	Yes	Yes

Individual Name	Shielding Type Short	Long	Long-Term In	Out	====== Shielding Factors ==== Acute: Inh	Cld	Ext	Long-Term: Inh	Cld	Ext
Individual 1	None	None	0.00	0.50	1.00	1.00	1.00	0.50	0.50	0.50

Ingestion Parameters

Food Type	Individual Consumption Rate [kg/d] [XIN]	Contaminated Fraction [PFIN]
Meat	3.00E-01	1.00E+00
Milk	8.50E-01	1.00E+00
Vegetable	1.60E+00	1.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   3
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
============================  Input Parameters  ============================

 Meteorological Parameters
_____________________________________________

            Dry deposition rates [VDEPNUC]
                          Particulates   : 1.00E-03      m/s
                          Ruthenium      : 1.00E-03      m/s
                          Cesium         : 1.00E-03      m/s
                          Iodine         : 1.00E-02      m/s
                          Gases          : 0.00E+00      m/s
                   Rain fall rate [RAIN]: 0.00E+00     mm/h
                Anemometer height [ANH]:    10.00        m
             Ambient Temperature [TABK]:   283.00        K
                   Mixing height [DMIX]:  1000.00        m
              Wind at anemometer [WSM]:     4.00      m/s
          Pasquill stability cat. [ITYPE]:       D
   Weather condition probability [METFREQ]: 1.00E+00



 Shipment Parameters
_____________________________________________

             Transportation Mode [IMOD]:    Truck
                     Dose at 2 m [TD2M]:    10.00  mrem/hr
             Measurement Offset [TIOFF]:     0.00        m
               Gamma Fraction [FRAD(1)]:     0.60
             Neutron Fraction [FRAD(2)]:     0.40
                    Cask Length [HSIZE]:     5.46        m
                    Cask Radius [RSIZE]:     0.56        m
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   4
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
============================  Input Parameters  ============================


 Long-Term Environmental Parameters
_____________________________________________

        Removal half-life from soil [PHALF]:    50.00        yr
         Initial resuspension factor [SUFI]: 1.00E-05       1/m
           Final Resuspension factor [SUFF]: 1.00E-09       1/m
       Resus. factor decay halflife [RSALF]: 1.37E-01        yr


 Food Production Parameters
_____________________________________________

        Food decontamination factor [DFACT]:     0.50
         Cow's ingestion rate of grass [QA]:    50.00      kg/d
         Yield of pasture grass [YIELD_COW]: 7.00E-01     kg/m2
     Yield of edible vegetation [YIELD_HUM]: 2.00E+00     kg/m2
              Time to first harvest
              Pasture grass [T_HARVEST_COW]:     1.00      days
                 Vegetation [T_HARVEST_HUM]:     1.00      days
       Pasture grass grow time [T_GROW_COW]:    30.00      days
          Vegetation grow time [T_GROW_HUM]:    60.00      days
   Deposition retention fraction [F_RETAIN]:     0.20
    Edible vegetation fraction [F_EDBL_HUM]:     1.00
       Edible pasture fraction [F_EDBL_COW]:     1.00
    Weathering decay const. [DECAY_WEATHER]: 4.95E-02     1/day
   Effective Surface Density [EFF_SURF_DEN]:   240.00     kg/m2
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   5
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
============================  Input Parameters  ============================
```

Nuclide Parameters

Nuclide Inventory and DCFs

Nuclide Name	Inventory Amount [Ci]	Dose Conversion Factors: Inhalation [Sv/Bq]	Ingestion [Sv/Bq]	Cloud [Sv/s] [Bq/m3]	Ground [Sv/s] [Bq/m2]	Nucl. Class	Decay Const. [1/yr]
CS137	1.00E+00	1.10E-08	1.59E-08	2.73E-14	5.54E-16	Cs	2.30E-02

Nuclide Food Transfer Parameters

Nuclide Name	Soil-to-Plant [unitless]	Grass-to-Meat [day/kg]	Grass-to-Milk [day/L]
CS137	1.00E-02	4.00E-03	1.20E-02

Nuclide Health Effects Parameters

Nuclide Name	Solubility Class	Acute Organ Dose Conversion Factors: Inhalation [Sv/Bq] Marrow	Lung	Intestine	Ground [Sv/s//Bq/m2] Marrow	Lung	Intestine
CS137	D	7.57E-09	8.11E-09	8.11E-09	5.39E-16	5.30E-16	4.93E-16

```
================= RISKIND Program Output, Version 1.11     ========= Page:   6
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
==============================  Input Parameters  ==============================
```

Nuclide Health Effects Parameters

Name	Acute Organ Dose Conversion Factors =========Cloudshine======== [Sv/s//Bq/m3] Marrow	Lung	Intestine
CS137	2.59E-14	2.65E-14	2.48E-14

```
================= RISKIND Program Output, Version 1.11     ========= Page:   7
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
===============  Input Parameters  - Accident Response Region:  6===============

 Accident Parameters
 ____________________________________________

              Physical Release Height [HS]:    10.00        m
   Dispersion Model Coefficients [IDISPMOD]: Pasquill-Gifford
                    Accident Analysis Type:     Risk
                      Accident Rate [ACTA]: 1.00E+00    1/km


 Accident Response Region Determined By
 ____________________________________________
            Accident Cask Velocity [VCASK]:    65.00     km/h
                 Cask Impact Angle [ALPHA]:    90.00  Degrees
             Cask Orientation Angle [BETA]:    90.00  Degrees
            Impact Object Hardness [IHARD]:     1.00
                Flame Temperature [TFLAME]: 1.35E+03       K
                     Fire Duration [DFIRE]:     0.75       hr
                     Fire Location [FLOCA]:     0.00        m


 Accident Response Region Parameters
 ____________________________________________
                  Response Region [IYOURS]:        6
      Region Conditional Probability [FSEV]: 2.33E-07
                         Heat Flux [HEATF]: 0.00E+00   cal/s
       Loss of Cask Shielding Factor [SEXT]
                                    Gamma:     1.00
                                  Neutron:     1.00
                      Failure Rate [FAILS]: 1.00E+00
              Crud Spallation Rate [FSPAL]: 0.00E+00
                Crud Release Rate [FRCRUD]: 1.00E+00
```

Nuclide Class [NUTYPE]	Conditional Release Fraction [FRELS]	Dispersion Fraction [FDISP]	Released and Dispersed Fraction (FRELS*FAILS*FDISP)
Particulate	2.00E-06	1.00E+00	2.00E-06
Ru	2.70E-05	1.00E+00	2.70E-05
Cs	1.00E+00	1.00E+00	1.00E+00
I	2.50E-03	1.00E+00	2.50E-03
Gas	3.30E-01	1.00E+00	3.30E-01

```
================= RISKIND Program Output, Version 1.11     ========= Page:   8
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
=============== Intermediate Calcs - Accident Response Region:  6===============

==============================================================================
================================ Nuclide Release ==============================
==============================================================================
```

Nuclide Name	Release Amount [Ci]	Hazard Index Inhalation	Hazard Index Ingestion	Hazard Index Ground
CS137	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Total	1.00E+00	1.00E+00	1.00E+00	1.00E+00

```
==============================================================================
================================ Puff Calculations ============================
==============================================================================
```

Individual Name	Plume Parameters: Effective Release Height [m]	Dispersion Sigma (Horizontal) [m]	Dispersion Sigma (Vertical) [m]
Individual 1	1.00E+01	7.62E+01	3.17E+01

Individual Name	Chi/Q: Air [s/m3]	Chi/Q: Ground [1/m2]	Depletion Fraction	Wet/Dry Ratio
Individual 1				
Particulates	3.11E-05	3.11E-08	7.94E-03	0.00E+00
Ruthenium	3.11E-05	3.11E-08	7.94E-03	0.00E+00
Cesium	3.11E-05	3.11E-08	7.94E-03	0.00E+00
Iodine	2.89E-05	2.89E-07	7.67E-02	0.00E+00
Gases	3.14E-05	0.00E+00	0.00E+00	0.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   9
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
===============      Results       - Accident Response Region:  6===============

================================================================================
===============          Accident Dose to :  Individual 1        ===============
================================================================================
```

Individual Summary Results Per Accident		
Committed Effective Dose Equivalent Risk	1.56E-01	rem
Expected Genetic Effects	2.03E-05	
Expected Non-fatal Cancers	1.56E-05	
Expected Cancer Fatalities	7.81E-05	
Acute Risk (Expected fatalities)	0.00E+00	

Pathway		Doses(rem)		
Acute	3.25E-04			
Cask		5.37E-10		
Ground Shine		4.59E-07		
Inhalation		3.21E-04		
Cloud Shine		3.14E-06		
Long-Term	1.56E-01			
Ground Shine		9.87E-04		
Inhalation		9.88E-06		
Cloud Shine		9.67E-08		
Ingestion		1.55E-01		
Initial Year			1.54E-01	
Vegetable				5.09E-02
Meat				1.09E-02
Milk				9.27E-02
Long-Term			4.96E-04	
Vegetable				1.94E-04
Meat				3.18E-05
Milk				2.70E-04
Water				0.00E+00

	Organ Exposure			
Exposure Parameter	Marrow	Lung	Intestine	Gonads
Long-Term Dose [rem]	1.53E-01	1.48E-01	1.41E-01	7.61E+00
Brief Dose [Gy]	5.83E-08	2.40E-06	2.29E-06	
Brief Exposure Time [d]	1.00E+00	1.00E+00	1.00E+00	
Brief Dose Rate [Gy/hr]	1.81E-08	1.54E-07	1.10E-07	
Prolonged Dose [Gy]	6.09E-07	2.37E-06	2.37E-06	
Prolong Exposure Time [d]	3.00E+01	3.65E+02	7.00E+00	
Prolong Dose Rate [Gy/hr]	8.45E-10	1.37E-07	9.11E-08	
Hazard	0.00E+00	0.00E+00	0.00E+00	
Acute Risk [Expected fatalities]	0.00E+00	0.00E+00	0.00E+00	

```
================= RISKIND Program Output, Version 1.11     ========= Page:  10
 Title       : Dose comparison with GENII, 1 Ci Cs Release
 Date/Time   : 05/12/97 08:15
 Input  File : c:\riskind\input\dose_cs.inp
 Output File : output\dose_cs.out
==============================      Results       ==============================

==============================================================================
========================= Accident Risk to Individuals =========================
==============================================================================
```

Individual Accident Dose Summary Results
Dose Risks reported on a per km basis

	Acute		Total			
	Dose [rem]	Risk [Fatality]	Dose [rem]	Expected Non-Fatal Cancer Incidence	Expected Cancer Fatalities	Expected Genetic Effects
Individual 1	7.56E-11	0.00E+00	3.64E-08	3.64E-12	1.82E-11	4.73E-12

B.1.1.2 GENII Output for Cs-137 Release

```
Default value changed from   8.0E-01 to   1.0E+00 for parameter  FRACUT(n)
Default value changed from   2.7E+02 to   2.5E+02 for parameter       RINH
Default value changed from   3.3E+02 to   2.5E+02 for parameter      RINHA

--------------------------------------------------------------------------------
                        GENII  Dose Calculation Program
                           (Version 1.485 3-Dec-90)

Case title:   Dose comparison with RISKIND, 1 Ci Cs release

Executed on:  05/08/97 at 09:37:31                                  Page A.  1
--------------------------------------------------------------------------------

          This is a far-field (wide-scale release, multiple site) scenario.
          Release is acute
          Individual dose

          THE FOLLOWING TRANSPORT MODES ARE CONSIDERED
               Air

          THE FOLLOWING EXPOSURE PATHS ARE CONSIDERED:
               Infinite plume, external
               Ground, external
               Inhalation uptake
               Terrestrial foods ingestion
               Animal product ingestion

          THE FOLLOWING TIMES ARE USED:
               Intake ends after (yr):                  1.0
               Dose calculations ends after (yr):      50.0

========== FILENAMES AND TITLES OF FILES/LIBRARIES USED ========================

Input file name: dose_cs.in
GENII Default Parameter Values w/ some RISKIND defaults (5/08/97 bb)
Radionuclide Master Library   (11/28/90 RAP)
Food Transfer Factor Library - (RAP  29-Aug-88) (UPDATED LEACHING FA
External Dose Factors for GENII in person Sv/yr per Bq/n (8-May-90 R
Internal Dose Increments, Worst Case Solubilities, 12/3/90 PDR
4.0 m/s avg. wind speed, 100% persistence towards S, class D, 6/6/94 bb

================================================================================

          -------- ----Release Terms------
          Release          Surface Buried
          Radio-   Air     Water   Source
          nuclide   Ci/yr   Ci/yr   Ci/m3
          -------- ------- ------- -------
          CS137    1.0E+00 0.0E+00 0.0E+00

========== AIR TRANSPORT ========================================================
          Joint frequency data input.
1.0E+03   Maximum individual distance from release point (m)
1.0E+00   Maximum individual sector index (Wind Toward S  )
1.0E+01   Effective stack height (m)

========== EXTERNAL EXPOSURE ====================================================
 1.0E+00  Fraction of time spent in cloud
 4.4E+03  Hours of exposure to ground contamination

========== INHALATION ===========================================================
          Resuspension not considered
```

========== INGESTION POPULATION ==========
1 Atmospheric production definition: 1 - Use population-weighted chi/Q

========== TERRESTRIAL FOOD INGESTION ==========

FOOD TYPE	GROW TIME d	--IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m2	PROD-UCTION kg/yr	--CONSUMPTION-- HOLDUP d	RATE kg/yr
Leaf Veg	60.0	0	0.0	0.0	2.0		0.0	1.9E+02

========== ANIMAL FOOD INGESTION ==========

FOOD TYPE	---HUMAN---- CONSUMPTION RATE kg/yr	HOLDUP d	TOTAL PROD-UCTION kg/yr	DRINK WATER CONTAM FRACT.	----------STORED FEED---------- DIET FRAC-TION	GROW TIME d	-IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m3	STOR-AGE d
Meat	9.5E+01	0.0		0.00		90.00	0	0.0	0.0	0.80	
Cow Milk	1.1E+02	0.0		0.00		45.00	0	0.0	0.0	2.00	
					----------FRESH FORAGE----------						
Meat						30.00	0	0.0	0.0	0.70	
Cow Milk						30.00	0	0.0	0.0	0.70	

==========

Input prepared by: _____ Date: _____

Input checked by: _____ Date: _____

==========

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:31 Page A. 2

	Probability	E/Q (sec/m3)	DOQ (m2)	Travel Time (sec)	Population-Weighted E/Q (person-sec/m3)
Sector index: 1					
Distance: 1000.0					
	0.5000	3.2E-05	3.2E-07	250.	
	0.5000	3.2E-05	3.2E-07	250.	
	0.5000	3.2E-05	3.2E-07	250.	
	0.5000	3.2E-05	3.2E-07	250.	
	0.0000	0.0E+00	0.0E+00	0.	

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:35 Page B. 1

3.2E-05 Individual E/Q

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Winter: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:37 Page C. 1

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	3.0E-04	2.5E-01	7.6E-05
Breast	2.7E-04	1.5E-01	4.1E-05
R Marrow	2.9E-04	1.2E-01	3.4E-05
Lung	3.0E-04	1.2E-01	3.6E-05
Thyroid	2.7E-04	3.0E-02	8.1E-06
Bone Sur	2.8E-04	3.0E-02	8.3E-06
S Int.	3.1E-04	6.0E-02	1.9E-05
LL Int.	3.1E-04	6.0E-02	1.9E-05
UL Int.	3.1E-04	6.0E-02	1.8E-05
Stomach	3.0E-04	6.0E-02	1.8E-05

Internal Effective Dose Equivalent	2.8E-04
External Dose	2.3E-04
Annual Effective Dose Equivalent	5.0E-04

Controlling Organ:	S Int.
Controlling Pathway:	Inh
Controlling Radionuclide:	CS137
Total Inhalation EDE:	2.4E-04
Total Ingestion EDE:	3.4E-05

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Winter: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:37 Page C. 2

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

	Dose Commitment Year 1	2	3	...			
Internal Intake Year: 3			0.0E+00	...			
			+				
2		0.0E+00	0.0E+00	...			Internal Effective Dose Equivalent
		+	+				
1	2.5E-04 +	2.4E-05 +	2.4E-06 +	...	=	2.8E-04	
	||	||	||				
Internal Annual Dose	2.5E-04 +	2.4E-05 +	2.4E-06 +	...	=	2.8E-04	Cumulative Internal Dose
	+	+	+			+	
External Annual Dose	2.3E-04	0.0E+00	0.0E+00	...		2.3E-04	
	||	||	||			||	
Annual Dose	4.8E-04 +	2.4E-05 +	2.4E-06 +	...	=	5.0E-04	Cumulative Dose
						4.8E-04	Maximum Annual Dose Occurred In Year 1

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Winter: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:37 Page C. 3

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	2.7E-04	2.6E-04	2.7E-04	2.7E-04	2.7E-04	2.4E-04	2.5E-04	2.7E-04
Leaf Veg	2.6E-06	2.8E-06	2.8E-06	2.8E-06	2.8E-06	2.6E-06	2.6E-06	2.8E-06
Meat	2.6E-05	2.9E-05	2.9E-05	2.9E-05	2.9E-05	2.6E-05	2.7E-05	2.9E-05
Cow Milk	5.9E-06	6.4E-06	6.4E-06	6.4E-06	6.4E-06	5.9E-06	5.9E-06	6.4E-06
Total	3.0E-04	3.0E-04	3.1E-04	3.1E-04	3.1E-04	2.8E-04	2.9E-04	3.0E-04

Pathway	Ovaries	Muscle	Thyroid
Inhale	2.5E-04	2.4E-04	2.4E-04
Leaf Veg	2.6E-06	2.4E-06	2.4E-06
Meat	2.6E-05	2.4E-05	2.4E-05
Cow Milk	5.9E-06	5.4E-06	5.4E-06
Total	2.8E-04	2.7E-04	2.7E-04

External Dose by Exposure Pathway

Pathway	
Plume	3.6E-06
Sur Soil	2.2E-04
Total	2.3E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Spring: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:38 Page C. 4

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	1.2E-02	2.5E-01	2.9E-03
Breast	1.0E-02	1.5E-01	1.5E-03
R Marrow	1.1E-02	1.2E-01	1.3E-03
Lung	1.1E-02	1.2E-01	1.3E-03
Thyroid	1.0E-02	3.0E-02	3.0E-04
Bone Sur	1.1E-02	3.0E-02	3.3E-04
S Int.	1.2E-02	6.0E-02	7.1E-04
LL Int.	1.2E-02	6.0E-02	7.1E-04
UL Int.	1.2E-02	6.0E-02	7.1E-04
Stomach	1.2E-02	6.0E-02	7.1E-04
Internal Effective Dose Equivalent			1.1E-02
External Dose			2.3E-04
Annual Effective Dose Equivalent			1.1E-02

Controlling Organ:	S Int.
Controlling Pathway:	Ing
Controlling Radionuclide:	CS137
Total Inhalation EDE:	2.4E-04
Total Ingestion EDE:	1.0E-02

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Spring: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:38 Page C. 5

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

	Dose Commitment Year 1	2	3	...			
Internal Intake Year: 3			0.0E+00	...			
			+				
2		0.0E+00	0.0E+00	...			Internal Effective Dose Equivalent
		+	+				
1	9.5E-03 +	9.1E-04 +	9.0E-05 +	...	=	1.1E-02	
	||	||	||				
Internal Annual Dose	9.5E-03 +	9.1E-04 +	9.0E-05 +	...	=	1.1E-02	Cumulative Internal Dose
	+	+	+			+	
External Annual Dose	2.3E-04	0.0E+00	0.0E+00	...		2.3E-04	
	||	||	||			||	
Annual Dose	9.8E-03 +	9.1E-04 +	9.0E-05 +	...	=	1.1E-02	Cumulative Dose
						9.8E-03	Maximum Annual Dose Occurred In Year 1

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Spring: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:38 Page C. 6

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	2.7E-04	2.6E-04	2.7E-04	2.7E-04	2.7E-04	2.4E-04	2.5E-04	2.7E-04
Leaf Veg	3.6E-03	3.9E-03	3.9E-03	3.9E-03	3.9E-03	3.6E-03	3.6E-03	3.9E-03
Meat	5.9E-03	6.4E-03	6.4E-03	6.4E-03	6.4E-03	5.9E-03	5.9E-03	6.4E-03
Cow Milk	1.1E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03	1.1E-03	1.1E-03	1.2E-03
Total	1.1E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.1E-02	1.1E-02	1.2E-02

Pathway	Ovaries	Muscle	Thyroid
Inhale	2.5E-04	2.4E-04	2.4E-04
Leaf Veg	3.6E-03	3.3E-03	3.3E-03
Meat	5.9E-03	5.4E-03	5.4E-03
Cow Milk	1.1E-03	1.0E-03	1.0E-03
Total	1.1E-02	1.0E-02	1.0E-02

External Dose by Exposure Pathway

Pathway	
Plume	3.6E-06
Sur Soil	2.2E-04
Total	2.3E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Summer: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:38 Page C. 7

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	1.4E-02	2.5E-01	3.4E-03
Breast	1.2E-02	1.5E-01	1.8E-03
R Marrow	1.3E-02	1.2E-01	1.5E-03
Lung	1.3E-02	1.2E-01	1.5E-03
Thyroid	1.2E-02	3.0E-02	3.5E-04
Bone Sur	1.3E-02	3.0E-02	3.8E-04
S Int.	1.4E-02	6.0E-02	8.3E-04
LL Int.	1.4E-02	6.0E-02	8.3E-04
UL Int.	1.4E-02	6.0E-02	8.3E-04
Stomach	1.4E-02	6.0E-02	8.2E-04
Internal Effective Dose Equivalent			1.2E-02
External Dose			2.3E-04
Annual Effective Dose Equivalent			1.2E-02

Controlling Organ:	S Int.
Controlling Pathway:	Ing
Controlling Radionuclide:	CS137
Total Inhalation EDE:	2.4E-04
Total Ingestion EDE:	1.2E-02

```
-----------------------------------------------------------------------------
                        GENII  Dose Calculation Program
                           (Version 1.485 3-Dec-90)

Case title:   Summer: Dose comparison with RISKIND, 1 Ci Cs release

Executed on:  05/08/97 at 09:37:38                                Page C.  8
-----------------------------------------------------------------------------

Acute release
Uptake/exposure period:                                              1.0
Dose commitment period:                                             50.0
Dose units:                                                      Rem



              Dose Commitment Year
                   1         2         3    ...
             ____________________________________
Internal   : |
Intake     : |
Year:      3 |                     0.0E+00   ...
             |                        +
           2 |           0.0E+00   0.0E+00   ...                 Internal
             |              +         +                         Effective
           1 | 1.1E-02 + 1.1E-03 + 1.0E-04 + ...  =  1.2E-02   Dose
                                                                Equivalent
                ||        ||        ||
Internal                                                        Cumulative
Annual        1.1E-02 + 1.1E-03 + 1.0E-04 + ...  =  1.2E-02   Internal
Dose                                                            Dose
                 +         +         +                 +
External
Annual        2.3E-04   0.0E+00   0.0E+00   ...     2.3E-04
Dose
                ||        ||        ||                 ||
Annual                                                          Cumulative
Dose          1.1E-02 + 1.1E-03 + 1.0E-04 + ...  =  1.2E-02   Dose

                                                                Maximum
                                                     1.1E-02    Annual
                                                                Dose Occurred
                                                                In Year  1
_____________________________________________________________________________
```

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Summer: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:38 Page C. 9

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	2.7E-04	2.6E-04	2.7E-04	2.7E-04	2.7E-04	2.4E-04	2.5E-04	2.7E-04
Leaf Veg	3.6E-03	3.9E-03	3.9E-03	3.9E-03	3.9E-03	3.6E-03	3.6E-03	3.9E-03
Meat	7.3E-03	7.9E-03	8.0E-03	8.0E-03	8.0E-03	7.3E-03	7.4E-03	7.9E-03
Cow Milk	1.4E-03	1.5E-03	1.5E-03	1.5E-03	1.5E-03	1.4E-03	1.4E-03	1.5E-03
Total	1.3E-02	1.4E-02	1.4E-02	1.4E-02	1.4E-02	1.3E-02	1.3E-02	1.4E-02

Pathway	Ovaries	Muscle	Thyroid
Inhale	2.5E-04	2.4E-04	2.4E-04
Leaf Veg	3.6E-03	3.3E-03	3.3E-03
Meat	7.3E-03	6.8E-03	6.8E-03
Cow Milk	1.4E-03	1.3E-03	1.3E-03
Total	1.3E-02	1.2E-02	1.2E-02

External Dose by Exposure Pathway

Pathway	
Plume	3.6E-06
Sur Soil	2.2E-04
Total	2.3E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Autumn: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:39 Page C. 10

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	2.4E-01	2.5E-01	6.0E-02
Breast	2.0E-01	1.5E-01	3.1E-02
R Marrow	2.2E-01	1.2E-01	2.7E-02
Lung	2.2E-01	1.2E-01	2.7E-02
Thyroid	2.0E-01	3.0E-02	6.1E-03
Bone Sur	2.2E-01	3.0E-02	6.6E-03
S Int.	2.4E-01	6.0E-02	1.4E-02
LL Int.	2.4E-01	6.0E-02	1.4E-02
UL Int.	2.4E-01	6.0E-02	1.4E-02
Stomach	2.4E-01	6.0E-02	1.4E-02
Internal Effective Dose Equivalent			2.1E-01
External Dose			2.3E-04
Annual Effective Dose Equivalent			2.1E-01

Controlling Organ:	S Int.
Controlling Pathway:	Ing
Controlling Radionuclide:	CS137
Total Inhalation EDE:	2.4E-04
Total Ingestion EDE:	2.1E-01

```
-----------------------------------------------------------------------------
                        GENII  Dose Calculation Program
                           (Version 1.485 3-Dec-90)

Case title:   Autumn: Dose comparison with RISKIND, 1 Ci Cs release

Executed on:  05/08/97 at 09:37:39                                Page C. 11
-----------------------------------------------------------------------------

Acute release
Uptake/exposure period:                                              1.0
Dose commitment period:                                             50.0
Dose units:                                                      Rem



             Dose Commitment Year
                  1         2         3    ...
            ____________________________________
Internal  : |
Intake    : |
Year:     3 |                     0.0E+00   ...
            |                        +
          2 |           0.0E+00   0.0E+00   ...                 Internal
            |              +        +                          Effective
          1 | 1.9E-01 + 1.9E-02 + 1.8E-03 + ...  =  2.1E-01   Dose
                                                               Equivalent
                ||        ||        ||
Internal                                                       Cumulative
Annual        1.9E-01 + 1.9E-02 + 1.8E-03 + ...  =  2.1E-01   Internal
Dose                                                           Dose
                 +         +         +                 +
External
Annual        2.3E-04   0.0E+00   0.0E+00   ...     2.3E-04
Dose
                ||        ||        ||                 ||
Annual                                                         Cumulative
Dose          1.9E-01 + 1.9E-02 + 1.8E-03 + ...  =  2.1E-01   Dose

                                                               Maximum
                                                     1.9E-01   Annual
                                                               Dose Occurred
                                                               In Year  1
_____________________________________________________________________________
```

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Autumn: Dose comparison with RISKIND, 1 Ci Cs release

Executed on: 05/08/97 at 09:37:39 Page C. 12

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	2.7E-04	2.6E-04	2.7E-04	2.7E-04	2.7E-04	2.4E-04	2.5E-04	2.7E-04
Leaf Veg	6.4E-02	6.9E-02	6.9E-02	6.9E-02	6.9E-02	6.4E-02	6.4E-02	6.9E-02
Meat	1.3E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01	1.3E-01	1.3E-01	1.4E-01
Cow Milk	2.5E-02	2.8E-02	2.8E-02	2.8E-02	2.8E-02	2.5E-02	2.6E-02	2.8E-02
Total	2.2E-01	2.4E-01	2.4E-01	2.4E-01	2.4E-01	2.2E-01	2.2E-01	2.4E-01

Pathway	Ovaries	Muscle	Thyroid
Inhale	2.5E-04	2.4E-04	2.4E-04
Leaf Veg	6.4E-02	5.9E-02	5.9E-02
Meat	1.3E-01	1.2E-01	1.2E-01
Cow Milk	2.5E-02	2.3E-02	2.3E-02
Total	2.2E-01	2.0E-01	2.0E-01

External Dose by Exposure Pathway

Pathway	
Plume	3.6E-06
Sur Soil	2.2E-04
Total	2.3E-04

B.1.2 Spent Fuel Accident

B.1.2.1 RISKIND Output for Spent Fuel Accident

```
================= RISKIND Program Output, Version 1.11     ========= Page:   1
 Title       : Dose comparison with GENII
 Date/Time   : 05/09/97 17:45
 Input  File : c:\riskind\input\dos_gen.inp
 Output File : output\dos_gen.out
==============================================================================




==============================================================================
============================ RISKIND Computer Program ==========================
==============================================================================



 Problem Description
_____________________________________________

               Individual Receptors

               Accident Calculations
                  User Defined Accident
                  Single Weather Analysis

                  Acute Exposure
                     Plume Inhalation
                     Plume Immersion
                     Early Ground Exposure
                     Exposure to Cask
                  Long Term Exposure
                     Ground Exposure
                     Resuspension Inhalation
                     Resuspension Cloud
                     Ingestion
                        Initially contaminated Food
                        Long Term Food Contamination



     Note: * next to input description signifies
           a data dependent default value
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   2
 Title       : Dose comparison with GENII
 Date/Time   : 05/09/97 17:45
 Input  File : c:\riskind\input\dos_gen.inp
 Output File : output\dos_gen.out
============================  Input Parameters  ============================
```

```
==============================================================================
================== RISKIND Accident Individual Problem Input ==================
==============================================================================
```

Individual Accident Parameters

```
                                  State:  US
                        Population Zone: Rural
      Long-Term Exposure Duration [YEVD]: 1.00E+00      yr

         Average Breathing Rate [BRTIND]: 8.00E+03   m3/yr
               Individual type [INDTYPE]:  Public
           Risk Conversion Factors
                   Non-Fatal Cancers/rem: 1.0E-04
                       Fatal Cancers/rem: 5.0E-04
                     Genetic Effects/rem: 1.3E-04
```

Individual Name [XNAME]	======= Location ======= Down Wind [km]	Cross Wind [km] [XRECEP]	Elevation [m]	Acute Exposure Time [hr] [TEXT]	Long Term Exposure [IRTP]	Food Ingestion [IDFOOD]
Individual 1	1.00E+00	0.00E+00	0.00E+00	2.00E+00	Yes	Yes

Individual Name	Shielding Type Short	Long	Long-Term In	Out	====== Shielding Factors ==== Acute: Inh	Cld	Ext	Long-Term: Inh	Cld	Ext
Individual 1	None	None	0.00	0.50	1.00	1.00	1.00	0.50	0.50	0.50

Ingestion Parameters

Food Type	Individual Consumption Rate [kg/d] [XIN]	Contaminated Fraction [PFIN]
Meat	3.00E-01	1.00E+00
Milk	8.50E-01	1.00E+00
Vegetable	1.60E+00	1.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   3
 Title       : Dose comparison with GENII
 Date/Time   : 05/09/97 17:45
 Input  File : c:\riskind\input\dos_gen.inp
 Output File : output\dos_gen.out
============================  Input Parameters  ============================

 Meteorological Parameters
 ____________________________________________

            Dry deposition rates [VDEPNUC]
                          Particulates   : 1.00E-03      m/s
                          Ruthenium      : 1.00E-03      m/s
                          Cesium         : 1.00E-03      m/s
                          Iodine         : 1.00E-02      m/s
                          Gases          : 0.00E+00      m/s
                    Rain fall rate [RAIN]: 0.00E+00     mm/h
                  Anemometer height [ANH]:    10.00        m
               Ambient Temperature [TABK]:   283.00        K
                     Mixing height [DMIX]:  1000.00        m
                 Wind at anemometer [WSM]:     4.00      m/s
           Pasquill stability cat. [ITYPE]:       D
   Weather condition probability [METFREQ]: 1.00E+00



 Shipment Parameters
 ____________________________________________

                Transportation Mode [IMOD]:    Truck
                        Dose at 2 m [TD2M]:    10.00  mrem/hr
                Measurement Offset [TIOFF]:     0.00        m
                  Gamma Fraction [FRAD(1)]:     0.60
                Neutron Fraction [FRAD(2)]:     0.40
                       Cask Length [HSIZE]:     5.46        m
                       Cask Radius [RSIZE]:     0.56        m
                  Amount of Uranium [UMT]*:     0.46      MTU
                      Reactor Type [RTYPE]:      PWR
                   Reactor Burnup [BURNUP]: 3.50E+04     MWD
                 Fuel Cooling Time [TFUEL]:    10.00       yr
       Total Surface Area of Cask [CAREA]*:    39.00       m2
    Crud Surface Activity Density [CACTD]*:     4.00  uCi/cm2
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   4
 Title        : Dose comparison with GENII
 Date/Time    : 05/09/97 17:45
 Input  File  : c:\riskind\input\dos_gen.inp
 Output File  : output\dos_gen.out
============================  Input Parameters  ============================
```

Long-Term Environmental Parameters

Removal half-life from soil [PHALF]:	50.00	yr
Initial resuspension factor [SUFI]:	1.00E-05	1/m
Final Resuspension factor [SUFF]:	1.00E-09	1/m
Resus. factor decay halflife [RSALF]:	1.37E-01	yr

Food Production Parameters

Food decontamination factor [DFACT]:	0.50	
Cow's ingestion rate of grass [QA]:	50.00	kg/d
Yield of pasture grass [YIELD_COW]:	7.00E-01	kg/m2
Yield of edible vegetation [YIELD_HUM]:	2.00E+00	kg/m2
Time to first harvest		
Pasture grass [T_HARVEST_COW]:	1.00	days
Vegetation [T_HARVEST_HUM]:	1.00	days
Pasture grass grow time [T_GROW_COW]:	30.00	days
Vegetation grow time [T_GROW_HUM]:	60.00	days
Deposition retention fraction [F_RETAIN]:	0.20	
Edible vegetation fraction [F_EDBL_HUM]:	1.00	
Edible pasture fraction [F_EDBL_COW]:	1.00	
Weathering decay const. [DECAY_WEATHER]:	4.95E-02	1/day
Effective Surface Density [EFF_SURF_DEN]:	240.00	kg/m2

```
================= RISKIND Program Output, Version 1.11     ========= Page:   5
 Title        : Dose comparison with GENII
 Date/Time    : 05/09/97 17:45
 Input  File : c:\riskind\input\dos_gen.inp
 Output File : output\dos_gen.out
============================  Input Parameters  ============================
```

Nuclide Parameters

Nuclide Inventory and DCFs

Nuclide Name	Inventory Amount [Ci]	======= Dose Conversion Factors ====== Inhalation [Sv/Bq]	Ingestion [Sv/Bq]	Cloud [Sv/s] [Bq/m3]	Ground [Sv/s] [Bq/m2]	Nucl. Class	Decay Const. [1/yr]
H 3	2.17E+02	1.73E-11	1.73E-11	0.00E+00	0.00E+00	Particul	5.60E-02
FE 55	1.07E+02	7.26E-10	1.64E-10	0.00E+00	0.00E+00	Particul	2.60E-01
CO 60	1.10E+03	5.91E-08	7.28E-09	1.26E-13	2.35E-15	Particul	1.30E-01
NI 63	1.88E+02	1.70E-09	1.56E-10	0.00E+00	0.00E+00	Particul	6.90E-03
KR 85	2.33E+03	1.03E-11	1.03E-11	1.19E-16	2.64E-18	Gas	6.50E-02
SR 90	2.77E+04	3.53E-07	4.14E-08	1.97E-16	5.61E-18	Particul	2.40E-02
Y 90	2.77E+04	2.28E-09	2.91E-09	1.90E-16	5.33E-18	Particul	9.50E+01
RU106	2.44E+02	1.30E-07	8.30E-09	1.04E-14	2.12E-16	Ru	6.90E-01
RH106	2.44E+02	8.95E-10	8.95E-10	1.04E-14	2.12E-16	Ru	7.30E+05
SB125	6.01E+02	3.75E-09	9.85E-10	2.02E-14	4.33E-16	Particul	2.50E-01
TE125M	1.47E+02	1.97E-09	9.92E-10	4.53E-16	3.61E-17	Particul	4.40E+00
CS134	2.76E+03	1.25E-08	1.98E-08	7.56E-14	1.52E-15	Cs	3.40E-01
CS137	3.98E+04	1.10E-08	1.59E-08	2.73E-14	5.54E-16	Cs	2.30E-02
BA137M	3.76E+04	2.49E-09	2.49E-09	2.88E-14	5.86E-16	Particul	1.40E+05
CE144	6.45E+01	1.01E-07	5.71E-09	2.80E-15	5.83E-17	Particul	8.90E-01
PR144	6.45E+01	1.17E-11	3.15E-11	1.94E-15	3.79E-17	Particul	2.10E+04
PM147	4.21E+03	1.06E-08	2.83E-10	6.92E-19	3.40E-20	Particul	2.60E-01
SM151	1.81E+02	8.10E-09	1.05E-10	3.61E-20	5.02E-21	Particul	7.70E-03
EU154	2.09E+03	7.73E-08	2.58E-09	6.14E-14	1.18E-15	Particul	7.90E-02
EU155	7.69E+02	1.12E-08	4.13E-10	2.49E-15	5.90E-17	Particul	1.40E-01
PU238	1.42E+03	1.06E-04	8.65E-07	4.87E-18	8.37E-19	Particul	7.90E-03
PU239	1.65E+02	1.16E-04	9.56E-07	4.24E-18	3.67E-19	Particul	2.90E-05
PU240	2.37E+02	1.16E-04	9.56E-07	4.75E-18	8.02E-19	Particul	1.10E-04
PU241	3.88E+04	2.23E-06	1.85E-08	2.19E-19	5.20E-21	Particul	4.80E-02
AM241	8.66E+02	1.20E-04	9.84E-07	8.18E-16	2.74E-17	Particul	1.60E-03
CM244	8.95E+02	6.70E-05	5.45E-07	4.91E-18	8.78E-19	Particul	3.80E-02

```
================= RISKIND Program Output, Version 1.11     ========= Page:   6
 Title        : Dose comparison with GENII
 Date/Time    : 05/09/97 17:45
 Input  File  : c:\riskind\input\dos_gen.inp
 Output File  : output\dos_gen.out
============================  Input Parameters  ============================
```

Nuclide Food Transfer Parameters

Nuclide Name	Soil-to-Plant [unitless]	Grass-to-Meat [day/kg]	Grass-to-Milk [day/L]
H 3	4.80E+00	1.20E-02	1.00E-02
FE 55	6.60E-04	4.00E-02	1.20E-03
CO 60	9.40E-03	1.30E-02	1.00E-03
NI 63	1.90E-02	5.30E-03	6.70E-03
KR 85	3.00E+00	2.00E-02	2.00E-02
SR 90	1.70E-02	6.00E-04	8.00E-04
Y 90	2.60E-03	4.60E-03	1.00E-05
RU106	5.00E-02	4.00E-01	1.00E-06
RH106	1.30E+01	1.50E-03	1.00E-02
SB125	1.10E-02	4.00E-03	1.50E-03
TE125M	1.30E+00	7.70E-02	1.00E-03
CS134	1.00E-02	4.00E-03	1.20E-02
CS137	1.00E-02	4.00E-03	1.20E-02
BA137M	5.00E-03	3.20E-03	4.00E-04
CE144	2.50E-03	1.20E-03	6.00E-04
PR144	2.50E-03	4.70E-03	5.00E-06
PM147	2.50E-03	4.80E-03	5.00E-06
SM151	2.50E-03	5.00E-03	5.00E-06
EU154	2.50E-03	4.80E-03	5.00E-06
EU155	2.50E-03	4.80E-03	5.00E-06
PU238	2.50E-04	1.40E-05	2.00E-06
PU239	2.50E-04	1.40E-05	2.00E-06
PU240	2.50E-04	1.40E-05	2.00E-06
PU241	2.50E-04	1.40E-05	2.00E-06
AM241	2.50E-04	2.00E-04	5.00E-06
CM244	2.50E-03	2.00E-04	5.00E-06

```
================= RISKIND Program Output, Version 1.11     ========= Page:   7
 Title       : Dose comparison with GENII
 Date/Time   : 05/09/97 17:45
 Input  File : c:\riskind\input\dos_gen.inp
 Output File : output\dos_gen.out
============================  Input Parameters  ==============================
```

Nuclide Health Effects Parameters

Nuclide Name	Solubility Class	Acute Organ Dose Conversion Factors =========Inhalation======== [Sv/Bq] Marrow	Lung	Intestine	=======Ground========== [Sv/s//Bq/m2] Marrow	Lung	Intestine
H 3	D	1.62E-11	1.62E-11	1.62E-11	0.00E+00	0.00E+00	0.00E+00
FE 55	W	1.65E-10	1.76E-10	1.92E-10	0.00E+00	0.00E+00	1.89E-19
CO 60	Y	6.22E-09	1.24E-07	5.95E-09	2.34E-15	2.27E-15	1.94E-15
NI 63	Y	1.05E-12	5.95E-12	4.59E-13	0.00E+00	0.00E+00	0.00E+00
KR 85	D	0.00E+00	0.00E+00	0.00E+00	2.43E-18	2.45E-18	1.97E-18
SR 90	Y	1.08E-09	7.03E-07	1.70E-08	4.77E-18	4.98E-18	0.00E+00
Y 90	Y	1.51E-11	9.19E-09	1.27E-08	4.57E-18	4.76E-18	0.00E+00
RU106	Y	1.05E-09	6.76E-07	3.51E-08	2.06E-16	2.03E-16	1.80E-16
RH106	Y	2.58E-10	2.58E-10	1.14E-09	2.06E-16	2.03E-16	1.80E-16
SB125	W	2.41E-14	7.30E-11	3.24E-12	4.05E-16	4.03E-16	3.79E-16
TE125M	W	5.14E-14	1.05E-11	2.38E-12	1.37E-17	1.77E-17	1.78E-17
CS134	D	1.08E-08	1.08E-08	1.27E-08	1.48E-15	1.46E-15	1.34E-15
CS137	D	7.57E-09	8.11E-09	8.11E-09	5.39E-16	5.30E-16	4.93E-16
BA137M	D	2.73E-11	2.73E-11	0.00E+00	5.70E-16	5.60E-16	5.22E-16
CE144	Y	1.08E-09	5.68E-07	3.24E-08	5.31E-17	5.43E-17	1.83E-17
PR144	Y	1.92E-14	9.46E-11	2.16E-14	3.66E-17	3.61E-17	2.54E-17
PM147	Y	1.41E-10	3.51E-08	1.62E-09	1.86E-20	2.20E-20	3.48E-21
SM151	Y	3.78E-12	1.19E-11	8.65E-13	1.39E-21	1.01E-21	4.45E-21
EU154	Y	2.46E-11	1.57E-10	9.19E-12	1.16E-15	1.14E-15	1.03E-15
EU155	Y	3.78E-12	2.54E-11	1.59E-12	4.71E-17	5.34E-17	6.05E-17
PU238	Y	2.97E-07	7.03E-05	2.97E-08	1.94E-19	7.87E-20	7.35E-19
PU239	Y	2.70E-07	6.76E-05	2.70E-08	1.19E-19	7.87E-20	3.24E-19
PU240	Y	2.70E-07	6.76E-05	2.70E-08	1.88E-19	7.81E-20	7.02E-19
PU241	Y	2.97E-10	5.68E-08	1.41E-10	4.18E-21	4.36E-21	0.00E+00
AM241	W	4.32E-06	1.81E-05	2.97E-08	1.68E-17	2.00E-17	2.52E-17
CM244	W	4.59E-06	1.92E-05	3.24E-08	2.04E-19	9.00E-20	7.10E-19

```
================= RISKIND Program Output, Version 1.11     ========= Page:   8
 Title       : Dose comparison with GENII
 Date/Time   : 05/09/97 17:45
 Input  File : c:\riskind\input\dos_gen.inp
 Output File : output\dos_gen.out
=================================== Input Parameters ==============================
```

Nuclide Health Effects Parameters

Name	Acute Organ Dose Conversion Factors =========Cloudshine======== [Sv/s//Bq/m3] Marrow	Lung	Intestine
H 3	0.00E+00	0.00E+00	0.00E+00
FE 55	0.00E+00	0.00E+00	9.85E-19
CO 60	1.23E-13	1.24E-13	1.11E-13
NI 63	0.00E+00	0.00E+00	0.00E+00
KR 85	1.09E-16	1.14E-16	9.59E-17
SR 90	1.68E-16	1.84E-16	0.00E+00
Y 90	1.62E-16	1.77E-16	0.00E+00
RU106	9.76E-15	1.01E-14	8.99E-15
RH106	9.76E-15	1.01E-14	8.99E-15
SB125	1.88E-14	1.95E-14	1.82E-14
TE125M	1.86E-16	2.23E-16	4.10E-16
CS134	7.19E-14	7.37E-14	6.84E-14
CS137	2.59E-14	2.65E-14	2.48E-14
BA137M	2.73E-14	2.80E-14	2.61E-14
CE144	2.55E-15	2.68E-15	7.73E-16
PR144	1.88E-15	1.91E-15	1.52E-15
PM147	4.46E-19	5.45E-19	1.55E-19
SM151	1.13E-20	7.13E-21	3.91E-20
EU154	5.87E-14	5.99E-14	5.54E-14
EU155	1.85E-15	2.22E-15	2.42E-15
PU238	1.68E-18	1.06E-18	3.77E-18
PU239	2.67E-18	2.65E-18	3.50E-18
PU240	1.66E-18	1.09E-18	3.69E-18
PU241	1.75E-19	1.99E-19	0.00E+00
AM241	5.21E-16	6.74E-16	8.00E-16
CM244	1.46E-18	7.07E-19	3.57E-18

```
================= RISKIND Program Output, Version 1.11     ========= Page:   9
 Title        : Dose comparison with GENII
 Date/Time    : 05/09/97 17:45
 Input  File  : c:\riskind\input\dos_gen.inp
 Output File  : output\dos_gen.out
===============  Input Parameters  - Accident Response Region:  6===============

 Accident Parameters
 ____________________________________________

              Physical Release Height [HS]:    10.00        m
   Dispersion Model Coefficients [IDISPMOD]: Pasquill-Gifford
                    Accident Analysis Type:     Risk
                      Accident Rate [ACTA]: 1.00E+00    1/km


 Accident Response Region Determined By
 ____________________________________________
            Accident Cask Velocity [VCASK]:    65.00     km/h
                 Cask Impact Angle [ALPHA]:    90.00  Degrees
             Cask Orientation Angle [BETA]:    90.00  Degrees
            Impact Object Hardness [IHARD]:     1.00
                Flame Temperature [TFLAME]: 1.35E+03       K
                     Fire Duration [DFIRE]:     0.75       hr
                     Fire Location [FLOCA]:     0.00        m


 Accident Response Region Parameters
 ____________________________________________
                  Response Region [IYOURS]:        6
      Region Conditional Probability [FSEV]: 2.33E-07
                         Heat Flux [HEATF]: 0.00E+00   cal/s
       Loss of Cask Shielding Factor [SEXT]
                                    Gamma:     1.00
                                  Neutron:     1.00
                      Failure Rate [FAILS]: 1.00E-01
              Crud Spallation Rate [FSPAL]: 1.00E+00
                Crud Release Rate [FRCRUD]: 1.00E+00
```

Nuclide Class [NUTYPE]	Conditional Release Fraction [FRELS]	Dispersion Fraction [FDISP]	Released and Dispersed Fraction (FRELS*FAILS*FDISP)
Particulate	2.00E-06	1.00E+00	2.00E-07
Ru	2.70E-05	1.00E+00	2.70E-06
Cs	2.00E-04	1.00E+00	2.00E-05
I	2.50E-03	1.00E+00	2.50E-04
Gas	3.30E-01	1.00E+00	3.30E-02

```
================= RISKIND Program Output, Version 1.11     ========= Page:  10
 Title        : Dose comparison with GENII
 Date/Time    : 05/09/97 17:45
 Input  File  : c:\riskind\input\dos_gen.inp
 Output File  : output\dos_gen.out
=============== Intermediate Calcs - Accident Response Region:  6===============
```

Nuclide Release

Nuclide Name	Release Amount [Ci]	Hazard Index Inhalation	Hazard Index Ingestion	Hazard Index Ground
CO 60	4.25E-01	1.99E-01	1.30E-01	6.49E-01
SR 90	5.55E-03	1.54E-02	1.50E-02	2.13E-05
CS134	5.52E-02	5.55E-03	5.85E-02	4.92E-02
CS137	7.95E-01	6.94E-02	7.88E-01	3.01E-01
PU238	2.83E-04	2.36E-01	2.25E-04	1.63E-07
PU239	3.30E-05	3.01E-02	2.91E-05	8.39E-09
PU240	4.73E-05	4.31E-02	4.17E-05	2.63E-08
PU241	7.77E-03	1.36E-01	1.29E-04	2.73E-08
AM241	1.73E-04	1.63E-01	1.57E-04	3.28E-06
CM244	1.79E-04	9.42E-02	8.85E-04	1.07E-07
Total	1.29E+00	9.92E-01	9.94E-01	1.00E+00

Puff Calculations

Individual Name	Plume Parameters: Effective Release Height [m]	Dispersion Sigma (Horizontal) [m]	Dispersion Sigma (Vertical) [m]
Individual 1	1.00E+01	7.62E+01	3.17E+01

Individual Name	Chi/Q Air [s/m3]	Chi/Q Ground [1/m2]	Depletion Fraction	Wet/Dry Ratio
Individual 1				
Particulates	3.11E-05	3.11E-08	7.94E-03	0.00E+00
Ruthenium	3.11E-05	3.11E-08	7.94E-03	0.00E+00
Cesium	3.11E-05	3.11E-08	7.94E-03	0.00E+00
Iodine	2.89E-05	2.89E-07	7.67E-02	0.00E+00
Gases	3.14E-05	0.00E+00	0.00E+00	0.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:  11
 Title        : Dose comparison with GENII
 Date/Time    : 05/09/97 17:45
 Input  File  : c:\riskind\input\dos_gen.inp
 Output File  : output\dos_gen.out
===============      Results       - Accident Response Region:  6===============

==============================================================================
===============          Accident Dose to :  Individual 1        ===============
==============================================================================
```

Individual Summary Results Per Accident

Committed Effective Dose Equivalent Risk	1.62E-01	rem
Expected Genetic Effects	2.10E-05	
Expected Non-fatal Cancers	1.62E-05	
Expected Cancer Fatalities	8.09E-05	
Acute Risk (Expected fatalities)	0.00E+00	

Pathway		Doses(rem)		
Acute	3.69E-03			
Cask		5.37E-10		
Ground Shine		1.26E-06		
Inhalation		3.68E-03		
Cloud Shine		9.15E-06		
Long-Term	1.58E-01			
Ground Shine		2.60E-03		
Inhalation		1.13E-04		
Cloud Shine		2.77E-07		
Ingestion		1.55E-01		
Initial Year			1.55E-01	
Vegetable				5.70E-02
Meat				1.64E-02
Milk				8.17E-02
Long-Term			4.98E-04	
Vegetable				2.15E-04
Meat				4.70E-05
Milk				2.37E-04
Water				0.00E+00

	Organ Exposure			
Exposure Parameter	Marrow	Lung	Intestine	Gonads
Long-Term Dose [rem]	1.59E-01	1.47E-01	1.60E-01	1.60E+01
Brief Dose [Gy]	1.31E-07	2.25E-06	2.81E-06	
Brief Exposure Time [d]	1.00E+00	1.00E+00	1.00E+00	
Brief Dose Rate [Gy/hr]	5.17E-08	1.74E-07	1.59E-07	
Prolonged Dose [Gy]	6.89E-07	1.92E-05	2.85E-06	
Prolong Exposure Time [d]	3.00E+01	3.65E+02	7.00E+00	
Prolong Dose Rate [Gy/hr]	9.57E-10	1.21E-07	1.10E-07	
Hazard	0.00E+00	0.00E+00	0.00E+00	
Acute Risk [Expected fatalities]	0.00E+00	0.00E+00	0.00E+00	

```
================= RISKIND Program Output, Version 1.11     ========= Page:  12
 Title        : Dose comparison with GENII
 Date/Time    : 05/09/97 17:45
 Input  File  : c:\riskind\input\dos_gen.inp
 Output File  : output\dos_gen.out
==============================      Results      ==============================

==============================================================================
========================= Accident Risk to Individuals =========================
==============================================================================
```

Individual Accident Dose Summary Results
Dose Risks reported on a per km basis

	Acute		Total			
	Dose [rem]	Risk [Fatality]	Dose [rem]	Expected Non-Fatal Cancer Incidence	Expected Cancer Fatalities	Expected Genetic Effects
Individual 1	8.59E-10	0.00E+00	3.77E-08	3.77E-12	1.89E-11	4.90E-12

B.1.2.2 GENII Output for Spent Fuel Accident

```
Default value changed from   8.0E-01 to   1.0E+00 for parameter  FRACUT(n)
 Default value changed from   2.7E+02 to   2.5E+02 for parameter       RINH
 Default value changed from   3.3E+02 to   2.5E+02 for parameter      RINHA

 ---------------------------------------------------------------------------
                        GENII  Dose Calculation Program
                           (Version 1.485 3-Dec-90)

 Case title:   Dose comparison with RISKIND

 Executed on:  05/08/97 at 09:17:47                                Page A.  1
 ---------------------------------------------------------------------------

           This is a far-field (wide-scale release, multiple site) scenario.
           Release is acute
           Individual dose

           THE FOLLOWING TRANSPORT MODES ARE CONSIDERED
                Air

           THE FOLLOWING EXPOSURE PATHS ARE CONSIDERED:
                Infinite plume, external
                Ground, external
                Inhalation uptake
                Terrestrial foods ingestion
                Animal product ingestion

           THE FOLLOWING TIMES ARE USED:
                Intake ends after (yr):                 1.0
                Dose calculations ends after (yr):     50.0

========== FILENAMES AND TITLES OF FILES/LIBRARIES USED ========================

 Input file name: dose_rkd.in
 GENII Default Parameter Values w/ some RISKIND defaults (5/08/97 bb)
 Radionuclide Master Library   (11/28/90 RAP)
 Food Transfer Factor Library - (RAP  29-Aug-88) (UPDATED LEACHING FA
 External Dose Factors for GENII in person Sv/yr per Bq/n (8-May-90 R
 Internal Dose Increments, Worst Case Solubilities, 12/3/90 PDR
 4.0 m/s avg. wind speed, 100% persistence towards S, class D, 6/6/94 bb

===============================================================================

           -------- ----Release Terms------
           Release          Surface Buried
           Radio-   Air     Water   Source
           nuclide   Ci/yr   Ci/yr   Ci/m3
           -------- ------- ------- -------
           CO60     4.3E-01 0.0E+00 0.0E+00
           SR90     5.6E-03 0.0E+00 0.0E+00
           CS134    5.5E-02 0.0E+00 0.0E+00
           CS137    8.0E-01 0.0E+00 0.0E+00
           PU238    2.8E-04 0.0E+00 0.0E+00
           PU239    3.3E-05 0.0E+00 0.0E+00
           PU240    4.7E-05 0.0E+00 0.0E+00
           PU241    7.8E-03 0.0E+00 0.0E+00
           AM241    1.7E-04 0.0E+00 0.0E+00
           CM244    1.8E-04 0.0E+00 0.0E+00

========== AIR TRANSPORT ========================================================
           Joint frequency data input.
1.0E+03    Maximum individual distance from release point (m)
1.0E+00    Maximum individual sector index (Wind Toward S  )
```

1.0E+01 Effective stack height (m)

========== EXTERNAL EXPOSURE ==========
1.0E+00 Fraction of time spent in cloud
4.4E+03 Hours of exposure to ground contamination

========== INHALATION ==========
Resuspension not considered

========== INGESTION POPULATION ==========
1 Atmospheric production definition: 1 - Use population-weighted chi/Q

========== TERRESTRIAL FOOD INGESTION ==========

FOOD TYPE	GROW TIME d	--IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m2	PROD-UCTION kg/yr	--CONSUMPTION-- HOLDUP d	RATE kg/yr
Leaf Veg	60.0	0	0.0	0.0	2.0		0.0	1.9E+02

========== ANIMAL FOOD INGESTION ==========

FOOD TYPE	---HUMAN---- CONSUMPTION RATE kg/yr	HOLDUP d	TOTAL PROD-UCTION kg/yr	DRINK WATER CONTAM FRACT.	----------STORED FEED---------- DIET FRAC-TION	GROW TIME d	-IRRIGATION-- S *	RATE in/yr	TIME mo/yr	YIELD kg/m3	STOR-AGE d
Meat	9.5E+01	0.0		0.00		90.00	0	0.0	0.0	0.80	
Cow Milk	1.1E+02	0.0		0.00		45.00	0	0.0	0.0	2.00	
					----------FRESH FORAGE----------						
Meat						30.00	0	0.0	0.0	0.70	
Cow Milk						30.00	0	0.0	0.0	0.70	

==========

Input prepared by: _____ Date: _____

Input checked by: _____ Date: _____

==========

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:17:47 Page A. 2

	Probability	E/Q (sec/m3)	DOQ (m2)	Travel Time (sec)	Population-Weighted E/Q (person-sec/m3)
Sector index: 1					
Distance: 1000.0					
	0.5000	3.2E-05	3.2E-07	250.	
	0.5000	3.2E-05	3.2E-07	250.	
	0.5000	3.2E-05	3.2E-07	250.	
	0.5000	3.2E-05	3.2E-07	250.	
	0.0000	0.0E+00	0.0E+00	0.	

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:17:51 Page B. 1

3.2E-05 Individual E/Q

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Winter: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:03 Page C. 1

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	1.0E-03	2.5E-01	2.5E-04
Breast	4.8E-04	1.5E-01	7.1E-05
R Marrow	4.5E-03	1.2E-01	5.4E-04
Lung	5.3E-03	1.2E-01	6.3E-04
Thyroid	4.5E-04	3.0E-02	1.4E-05
Bone Sur	5.0E-02	3.0E-02	1.5E-03
Liver	9.2E-03	6.0E-02	5.5E-04
Stomach	6.3E-04	6.0E-02	3.8E-05
LL Int.	4.2E-04	6.0E-02	2.5E-05
UL Int.	4.2E-04	6.0E-02	2.5E-05
S Int.	3.9E-04	6.0E-02	2.3E-05
Internal Effective Dose Equivalent			3.7E-03
External Dose			5.9E-04
Annual Effective Dose Equivalent			4.2E-03

Controlling Organ:	Bone Sur
Controlling Pathway:	Inh
Controlling Radionuclide:	CO60
Total Inhalation EDE:	3.6E-03
Total Ingestion EDE:	5.6E-05

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Winter: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:03 Page C. 2

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

	Dose Commitment Year 1	2	3	...			
Internal Intake Year: 3			0.0E+00	...			
			+				
2		0.0E+00	0.0E+00	...			Internal Effective Dose Equivalent
		+	+				
1	6.1E-04 +	2.5E-04 +	1.8E-04 +	...	=	3.7E-03	
	||	||	||				
Internal Annual Dose	6.1E-04 +	2.5E-04 +	1.8E-04 +	...	=	3.7E-03	Cumulative Internal Dose
	+	+	+			+	
External Annual Dose	5.9E-04	0.0E+00	0.0E+00	...		5.9E-04	
	||	||	||			||	
Annual Dose	1.2E-03 +	2.5E-04 +	1.8E-04 +	...	=	4.3E-03	Cumulative Dose
						1.2E-03	Maximum Annual Dose Occurred In Year 1

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Winter: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:03 Page C. 3

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	5.2E-03	5.8E-04	3.3E-04	3.6E-04	3.4E-04	5.0E-02	4.4E-03	9.4E-04
Leaf Veg	4.0E-06	4.7E-06	5.8E-06	7.9E-06	1.3E-05	4.6E-05	2.3E-05	4.4E-06
Meat	3.5E-05	3.9E-05	4.6E-05	5.0E-05	6.1E-05	4.6E-05	4.2E-05	3.9E-05
Cow Milk	5.0E-06	5.4E-06	5.5E-06	5.7E-06	6.4E-06	2.2E-05	1.2E-05	5.4E-06
Total	5.3E-03	6.3E-04	3.9E-04	4.2E-04	4.2E-04	5.0E-02	4.5E-03	9.9E-04

Pathway	Ovaries	Muscle	Thyroid	Liver
Inhale	9.5E-04	4.3E-04	4.1E-04	9.2E-03
Leaf Veg	4.9E-06	4.0E-06	3.8E-06	4.8E-06
Meat	4.1E-05	3.4E-05	3.3E-05	3.3E-05
Cow Milk	5.0E-06	4.6E-06	4.6E-06	1.5E-07
Total	1.0E-03	4.8E-04	4.5E-04	9.2E-03

External Dose by Exposure Pathway

Pathway	
Plume	1.0E-05
Sur Soil	5.8E-04
Total	5.9E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Winter: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:03 Page C. 4

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Radionuclide

Radionuclide	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
CO 60	4.6E-03	3.7E-04	1.1E-04	1.5E-04	1.4E-04	1.9E-04	2.3E-04	3.2E-05
SR 90	2.7E-07	1.4E-07	1.9E-07	9.4E-07	3.8E-06	1.8E-04	7.9E-05	8.8E-08
Y 90	1.2E-09	1.6E-07	3.7E-07	1.9E-06	4.6E-06	6.0E-11	5.8E-11	1.9E-12
CS 134	2.1E-05	2.2E-05	2.6E-05	2.4E-05	2.6E-05	2.0E-05	2.2E-05	2.4E-05
CS 137	2.4E-04	2.4E-04	2.5E-04	2.5E-04	2.5E-04	2.2E-04	2.3E-04	2.4E-04
PU 238	1.5E-04	1.4E-08	2.2E-08	8.5E-08	2.6E-07	1.6E-02	1.3E-03	2.3E-04
CM 244	1.1E-04	9.4E-09	1.6E-08	6.1E-08	1.7E-07	6.5E-03	5.3E-04	8.6E-05
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	2.3E-05	2.1E-09	3.4E-09	1.4E-08	3.9E-08	3.0E-03	2.4E-04	4.2E-05
PU 241	1.7E-06	7.7E-10	1.9E-09	1.1E-08	3.3E-08	9.8E-03	7.7E-04	1.5E-04
AM 241	9.4E-05	8.8E-09	1.4E-08	5.7E-08	1.6E-07	1.1E-02	8.9E-04	1.6E-04
PU 239	1.6E-05	1.5E-09	2.4E-09	9.7E-09	2.8E-08	2.2E-03	1.7E-04	3.0E-05
Total	5.3E-03	6.3E-04	3.9E-04	4.2E-04	4.2E-04	5.0E-02	4.5E-03	9.9E-04

Radionuclide	Ovaries	Muscle	Thyroid	Liver
CO 60	7.7E-05	2.4E-04	2.1E-04	4.7E-04
SR 90	8.8E-08	8.7E-08	8.8E-08	0.0E+00
Y 90	2.2E-12	1.9E-12	1.9E-12	5.7E-11
CS 134	2.0E-05	2.0E-05	2.0E-05	0.0E+00
CS 137	2.2E-04	2.2E-04	2.2E-04	0.0E+00
PU 238	2.2E-04	8.2E-09	8.2E-09	3.0E-03
CM 244	8.7E-05	5.6E-09	5.6E-09	1.3E-03
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	4.2E-05	1.3E-09	1.3E-09	5.3E-04
PU 241	1.5E-04	6.3E-11	5.4E-11	1.5E-03
AM 241	1.6E-04	5.2E-09	5.1E-09	2.0E-03
PU 239	3.0E-05	9.0E-10	9.0E-10	3.8E-04
Total	1.0E-03	4.8E-04	4.5E-04	9.2E-03

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Winter: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:03 Page C. 5

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Radio-nuclide	Inhalation Effective Dose Equivalent	Ingestion Effective Dose Equivalent	External Dose	Internal Effective Dose Equivalent	Annual Effective Dose Equivalent
CO 60	7.0E-04	2.1E-05	3.8E-04	7.2E-04	1.1E-03
SR 90	9.1E-06	6.1E-06	2.4E-10	1.5E-05	1.5E-05
Y 90	3.0E-10	4.2E-07	1.3E-08	4.2E-07	4.3E-07
CS 134	1.9E-05	2.0E-06	3.0E-05	2.1E-05	5.1E-05
CS 137	2.0E-04	2.7E-05	1.8E-04	2.2E-04	4.1E-04
PU 238	9.0E-04	9.6E-10	2.3E-12	9.0E-04	9.0E-04
CM 244	3.7E-04	5.1E-09	1.2E-12	3.7E-04	3.7E-04
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	1.6E-04	1.8E-10	3.9E-13	1.6E-04	1.6E-04
PU 241	5.1E-04	5.4E-10	1.2E-16	5.1E-04	5.1E-04
AM 241	6.2E-04	3.5E-09	3.0E-10	6.2E-04	6.2E-04
PU 239	1.2E-04	1.3E-10	5.6E-13	1.2E-04	1.2E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Spring: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:04 Page C. 6

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	1.2E-02	2.5E-01	3.1E-03
Breast	1.0E-02	1.5E-01	1.5E-03
R Marrow	1.6E-02	1.2E-01	1.9E-03
Lung	1.6E-02	1.2E-01	1.9E-03
Thyroid	1.0E-02	3.0E-02	3.1E-04
Bone Sur	6.5E-02	3.0E-02	1.9E-03
LL Int.	1.4E-02	6.0E-02	8.4E-04
Liver	1.3E-02	6.0E-02	7.9E-04
UL Int.	1.3E-02	6.0E-02	7.8E-04
S Int.	1.3E-02	6.0E-02	7.6E-04
Stomach	1.2E-02	6.0E-02	7.2E-04
Internal Effective Dose Equivalent			1.5E-02
External Dose			5.9E-04
Annual Effective Dose Equivalent			1.5E-02

Controlling Organ:	Bone Sur
Controlling Pathway:	Ing
Controlling Radionuclide:	CS137
Total Inhalation EDE:	3.6E-03
Total Ingestion EDE:	1.1E-02

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Spring: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:04 Page C. 7

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

	Dose Commitment Year 1	2	3	...			
Internal Intake Year: 3			0.0E+00	...			
			+				
2		0.0E+00	0.0E+00	...			Internal Effective Dose Equivalent
		+	+				
1	9.7E-03 +	1.3E-03 +	4.4E-04 +	...	=	1.5E-02	
	||	||	||				
Internal Annual Dose	9.7E-03 +	1.3E-03 +	4.4E-04 +	...	=	1.5E-02	Cumulative Internal Dose
	+	+	+			+	
External Annual Dose	5.9E-04	0.0E+00	0.0E+00	...		5.9E-04	
	||	||	||			||	
Annual Dose	1.0E-02 +	1.3E-03 +	4.4E-04 +	...	=	1.5E-02	Cumulative Dose
						1.0E-02	Maximum Annual Dose Occurred In Year 1

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Spring: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:04 Page C. 8

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	5.2E-03	5.8E-04	3.3E-04	3.6E-04	3.4E-04	5.0E-02	4.4E-03	9.4E-04
Leaf Veg	3.7E-03	4.1E-03	4.5E-03	4.6E-03	5.2E-03	8.0E-03	4.4E-03	4.1E-03
Meat	5.7E-03	6.3E-03	6.7E-03	6.9E-03	7.4E-03	5.9E-03	6.0E-03	6.3E-03
Cow Milk	1.0E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03
Total	1.6E-02	1.2E-02	1.3E-02	1.3E-02	1.4E-02	6.5E-02	1.6E-02	1.2E-02

Pathway	Ovaries	Muscle	Thyroid	Liver
Inhale	9.5E-04	4.3E-04	4.1E-04	9.2E-03
Leaf Veg	4.0E-03	3.5E-03	3.5E-03	2.2E-03
Meat	6.0E-03	5.4E-03	5.4E-03	1.7E-03
Cow Milk	1.0E-03	9.4E-04	9.4E-04	6.7E-06
Total	1.2E-02	1.0E-02	1.0E-02	1.3E-02

External Dose by Exposure Pathway

Pathway	
Plume	1.0E-05
Sur Soil	5.8E-04
Total	5.9E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Spring: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:04 Page C. 9

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Radionuclide

Radionuclide	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
CO 60	5.8E-03	1.8E-03	2.1E-03	2.5E-03	3.4E-03	1.4E-03	1.6E-03	1.4E-03
SR 90	5.6E-07	8.2E-07	1.3E-06	7.8E-06	3.3E-05	7.9E-04	3.5E-04	3.8E-07
Y 90	1.2E-09	1.6E-06	3.9E-06	1.9E-05	4.8E-05	6.0E-10	5.8E-10	1.9E-11
CS 134	7.7E-04	8.7E-04	1.0E-03	9.2E-04	1.0E-03	7.7E-04	8.7E-04	9.2E-04
CS 137	8.7E-03	9.4E-03	9.5E-03	9.5E-03	9.5E-03	8.7E-03	8.8E-03	9.4E-03
PU 238	1.5E-04	1.1E-07	2.7E-07	1.6E-06	4.7E-06	1.8E-02	1.4E-03	2.4E-04
CM 244	1.1E-04	8.9E-08	2.3E-07	1.2E-06	3.8E-06	7.1E-03	5.7E-04	9.4E-05
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	2.3E-05	1.8E-08	4.2E-08	2.3E-07	7.4E-07	3.3E-03	2.5E-04	4.5E-05
PU 241	1.7E-06	1.3E-08	3.4E-08	2.0E-07	5.8E-07	1.1E-02	8.3E-04	1.6E-04
AM 241	9.4E-05	7.1E-08	1.7E-07	9.7E-07	3.0E-06	1.2E-02	9.6E-04	1.7E-04
PU 239	1.6E-05	1.2E-08	2.9E-08	1.6E-07	5.0E-07	2.3E-03	1.8E-04	3.2E-05
Total	1.6E-02	1.2E-02	1.3E-02	1.3E-02	1.4E-02	6.5E-02	1.6E-02	1.2E-02

Radionuclide	Ovaries	Muscle	Thyroid	Liver
CO 60	1.8E-03	1.5E-03	1.4E-03	3.6E-03
SR 90	3.8E-07	3.8E-07	3.8E-07	0.0E+00
Y 90	2.2E-11	1.9E-11	1.9E-11	5.7E-10
CS 134	7.7E-04	7.7E-04	7.7E-04	0.0E+00
CS 137	8.7E-03	8.1E-03	8.1E-03	0.0E+00
PU 238	2.4E-04	8.8E-09	8.8E-09	3.2E-03
CM 244	9.5E-05	6.1E-09	6.1E-09	1.4E-03
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	4.5E-05	1.4E-09	1.4E-09	5.7E-04
PU 241	1.6E-04	6.6E-11	5.5E-11	1.6E-03
AM 241	1.7E-04	5.8E-09	5.5E-09	2.2E-03
PU 239	3.2E-05	9.7E-10	9.7E-10	4.0E-04
Total	1.2E-02	1.0E-02	1.0E-02	1.3E-02

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Spring: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:04 Page C. 10

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Radio-nuclide	Inhalation Effective Dose Equivalent	Ingestion Effective Dose Equivalent	External Dose	Internal Effective Dose Equivalent	Annual Effective Dose Equivalent
CO 60	7.0E-04	1.8E-03	3.8E-04	2.5E-03	2.8E-03
SR 90	9.1E-06	5.9E-05	2.4E-10	6.9E-05	6.9E-05
Y 90	3.0E-10	4.3E-06	1.3E-08	4.3E-06	4.4E-06
CS 134	1.9E-05	8.0E-04	3.0E-05	8.2E-04	8.5E-04
CS 137	2.0E-04	8.2E-03	1.8E-04	8.4E-03	8.6E-03
PU 238	9.0E-04	6.7E-05	2.3E-12	9.7E-04	9.7E-04
CM 244	3.7E-04	3.3E-05	1.2E-12	4.0E-04	4.0E-04
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	1.6E-04	1.2E-05	3.9E-13	1.8E-04	1.8E-04
PU 241	5.1E-04	3.9E-05	1.2E-16	5.5E-04	5.5E-04
AM 241	6.2E-04	4.7E-05	3.0E-10	6.7E-04	6.7E-04
PU 239	1.2E-04	8.6E-06	5.6E-13	1.3E-04	1.3E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Summer: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:05 Page C. 11

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	1.4E-02	2.5E-01	3.6E-03
Breast	1.2E-02	1.5E-01	1.8E-03
R Marrow	1.8E-02	1.2E-01	2.1E-03
Lung	1.7E-02	1.2E-01	2.1E-03
Thyroid	1.2E-02	3.0E-02	3.5E-04
Bone Sur	6.6E-02	3.0E-02	2.0E-03
LL Int.	1.6E-02	6.0E-02	9.7E-04
UL Int.	1.5E-02	6.0E-02	8.9E-04
S Int.	1.5E-02	6.0E-02	8.7E-04
Stomach	1.4E-02	6.0E-02	8.3E-04
Liver	1.3E-02	6.0E-02	8.1E-04
Internal Effective Dose Equivalent			1.6E-02
External Dose			5.9E-04
Annual Effective Dose Equivalent			1.7E-02

Controlling Organ:	Bone Sur
Controlling Pathway:	Ing
Controlling Radionuclide:	CS137
Total Inhalation EDE:	3.6E-03
Total Ingestion EDE:	1.3E-02

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Summer: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:05 Page C. 12

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

	Dose Commitment Year 1	2	3	...			
Internal Intake Year: 3			0.0E+00	...			
			+				
2		0.0E+00	0.0E+00	...			Internal Effective Dose Equivalent
		+	+				
1	1.1E-02 +	1.5E-03 +	4.8E-04 +	...	=	1.6E-02	
	||	||	||				
Internal Annual Dose	1.1E-02 +	1.5E-03 +	4.8E-04 +	...	=	1.6E-02	Cumulative Internal Dose
	+	+	+			+	
External Annual Dose	5.9E-04	0.0E+00	0.0E+00	...		5.9E-04	
	||	||	||			||	
Annual Dose	1.2E-02 +	1.5E-03 +	4.8E-04 +	...	=	1.7E-02	Cumulative Dose
						1.2E-02	Maximum Annual Dose Occurred In Year 1

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Summer: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:05 Page C. 13

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	5.2E-03	5.8E-04	3.3E-04	3.6E-04	3.4E-04	5.0E-02	4.4E-03	9.4E-04
Leaf Veg	3.7E-03	4.1E-03	4.5E-03	4.6E-03	5.2E-03	8.0E-03	4.4E-03	4.1E-03
Meat	7.2E-03	7.8E-03	8.4E-03	8.6E-03	9.2E-03	7.4E-03	7.4E-03	7.9E-03
Cow Milk	1.2E-03	1.3E-03	1.4E-03	1.4E-03	1.4E-03	1.3E-03	1.3E-03	1.3E-03
Total	1.7E-02	1.4E-02	1.5E-02	1.5E-02	1.6E-02	6.6E-02	1.8E-02	1.4E-02

Pathway	Ovaries	Muscle	Thyroid	Liver
Inhale	9.5E-04	4.3E-04	4.1E-04	9.2E-03
Leaf Veg	4.0E-03	3.5E-03	3.5E-03	2.2E-03
Meat	7.5E-03	6.8E-03	6.7E-03	2.1E-03
Cow Milk	1.2E-03	1.1E-03	1.1E-03	8.6E-06
Total	1.4E-02	1.2E-02	1.2E-02	1.3E-02

External Dose by Exposure Pathway

Pathway	
Plume	1.0E-05
Sur Soil	5.8E-04
Total	5.9E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Summer: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:05 Page C. 14

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Radionuclide

Radionuclide	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
CO 60	5.9E-03	1.9E-03	2.4E-03	2.8E-03	3.8E-03	1.5E-03	1.8E-03	1.6E-03
SR 90	5.6E-07	8.3E-07	1.3E-06	7.9E-06	3.4E-05	8.0E-04	3.5E-04	3.9E-07
Y 90	1.2E-09	1.7E-06	3.9E-06	2.0E-05	4.8E-05	6.0E-10	5.9E-10	2.0E-11
CS 134	9.0E-04	1.0E-03	1.2E-03	1.1E-03	1.2E-03	8.9E-04	1.0E-03	1.1E-03
CS 137	1.0E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.0E-02	1.0E-02	1.1E-02
PU 238	1.5E-04	1.1E-07	2.7E-07	1.6E-06	4.7E-06	1.8E-02	1.4E-03	2.4E-04
CM 244	1.1E-04	9.4E-08	2.4E-07	1.3E-06	4.0E-06	7.1E-03	5.8E-04	9.4E-05
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	2.3E-05	1.8E-08	4.2E-08	2.3E-07	7.4E-07	3.3E-03	2.5E-04	4.5E-05
PU 241	1.7E-06	1.3E-08	3.4E-08	2.0E-07	5.8E-07	1.1E-02	8.3E-04	1.6E-04
AM 241	9.4E-05	7.1E-08	1.7E-07	9.7E-07	3.0E-06	1.2E-02	9.6E-04	1.7E-04
PU 239	1.6E-05	1.2E-08	2.9E-08	1.6E-07	5.0E-07	2.3E-03	1.8E-04	3.2E-05
Total	1.7E-02	1.4E-02	1.5E-02	1.5E-02	1.6E-02	6.6E-02	1.8E-02	1.4E-02

Radionuclide	Ovaries	Muscle	Thyroid	Liver
CO 60	2.1E-03	1.7E-03	1.5E-03	4.0E-03
SR 90	3.9E-07	3.8E-07	3.9E-07	0.0E+00
Y 90	2.3E-11	2.0E-11	2.0E-11	5.7E-10
CS 134	8.9E-04	8.9E-04	8.9E-04	0.0E+00
CS 137	1.0E-02	9.3E-03	9.3E-03	0.0E+00
PU 238	2.4E-04	8.8E-09	8.8E-09	3.2E-03
CM 244	9.5E-05	6.1E-09	6.1E-09	1.4E-03
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	4.5E-05	1.4E-09	1.4E-09	5.7E-04
PU 241	1.6E-04	6.6E-11	5.5E-11	1.6E-03
AM 241	1.7E-04	5.8E-09	5.5E-09	2.2E-03
PU 239	3.2E-05	9.7E-10	9.7E-10	4.0E-04
Total	1.4E-02	1.2E-02	1.2E-02	1.3E-02

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Summer: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:05 Page C. 15

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Radio-nuclide	Inhalation Effective Dose Equivalent	Ingestion Effective Dose Equivalent	External Dose	Internal Effective Dose Equivalent	Annual Effective Dose Equivalent
CO 60	7.0E-04	2.0E-03	3.8E-04	2.7E-03	3.1E-03
SR 90	9.1E-06	6.0E-05	2.4E-10	6.9E-05	6.9E-05
Y 90	3.0E-10	4.4E-06	1.3E-08	4.4E-06	4.4E-06
CS 134	1.9E-05	9.2E-04	3.0E-05	9.4E-04	9.7E-04
CS 137	2.0E-04	9.6E-03	1.8E-04	9.8E-03	1.0E-02
PU 238	9.0E-04	6.7E-05	2.3E-12	9.7E-04	9.7E-04
CM 244	3.7E-04	3.5E-05	1.2E-12	4.1E-04	4.1E-04
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	1.6E-04	1.2E-05	3.9E-13	1.8E-04	1.8E-04
PU 241	5.1E-04	3.9E-05	1.2E-16	5.5E-04	5.5E-04
AM 241	6.2E-04	4.7E-05	3.0E-10	6.7E-04	6.7E-04
PU 239	1.2E-04	8.6E-06	5.6E-13	1.3E-04	1.3E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Autumn: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:06 Page C. 16

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Organ	Committed Dose Equivalent	Weighting Factors	Weighted Dose Equivalent
Gonads	2.4E-01	2.5E-01	5.9E-02
Breast	2.0E-01	1.5E-01	3.0E-02
R Marrow	2.4E-01	1.2E-01	2.8E-02
Lung	2.2E-01	1.2E-01	2.6E-02
Thyroid	2.0E-01	3.0E-02	6.0E-03
Bone Sur	3.4E-01	3.0E-02	1.0E-02
LL Int.	2.8E-01	6.0E-02	1.7E-02
UL Int.	2.6E-01	6.0E-02	1.5E-02
S Int.	2.5E-01	6.0E-02	1.5E-02
Stomach	2.3E-01	6.0E-02	1.4E-02
Liver	8.2E-02	6.0E-02	4.9E-03
Internal Effective Dose Equivalent			2.3E-01
External Dose			5.9E-04
Annual Effective Dose Equivalent			2.3E-01

Controlling Organ:	Bone Sur
Controlling Pathway:	Ing
Controlling Radionuclide:	CS137
Total Inhalation EDE:	3.6E-03
Total Ingestion EDE:	2.2E-01

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                      GENII  Dose Calculation Program
                         (Version 1.485 3-Dec-90)

Case title:   Autumn: Dose comparison with RISKIND

Executed on:  05/08/97 at 09:18:06                                Page C. 17
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Acute release
Uptake/exposure period:                                              1.0
Dose commitment period:                                             50.0
Dose units:                                                      Rem


              Dose Commitment Year
                   1          2          3     ...
             ____________________________________
Internal   : |
Intake     : |
Year:      3 |                      0.0E+00    ...
             |                         +
           2 |            0.0E+00    0.0E+00    ...                Internal
             |               +          +                          Effective
           1 | 1.9E-01 + 2.2E-02 + 5.4E-03 + ...  =  2.3E-01      Dose
                                                                   Equivalent
                 ||         ||         ||
Internal                                                           Cumulative
Annual         1.9E-01 + 2.2E-02 + 5.4E-03 + ...  =  2.3E-01      Internal
Dose                                                               Dose
                  +          +          +                 +
External
Annual         5.9E-04    0.0E+00    0.0E+00    ...     5.9E-04
Dose
                 ||         ||         ||                  ||
Annual                                                             Cumulative
Dose           1.9E-01 + 2.2E-02 + 5.4E-03 + ...  =  2.3E-01      Dose

                                                                   Maximum
                                                        1.9E-01    Annual
                                                                   Dose Occurred
                                                                   In Year  1
_____________________________________________________________________________
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GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Autumn: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:06 Page C. 18

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Exposure Pathway

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
Inhale	5.2E-03	5.8E-04	3.3E-04	3.6E-04	3.4E-04	5.0E-02	4.4E-03	9.4E-04
Leaf Veg	6.8E-02	7.4E-02	8.1E-02	8.3E-02	9.2E-02	1.4E-01	8.0E-02	7.5E-02
Meat	1.2E-01	1.4E-01	1.5E-01	1.5E-01	1.6E-01	1.3E-01	1.3E-01	1.4E-01
Cow Milk	2.2E-02	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.2E-02	2.2E-02	2.4E-02
Total	2.2E-01	2.3E-01	2.5E-01	2.6E-01	2.8E-01	3.4E-01	2.4E-01	2.4E-01

Pathway	Ovaries	Muscle	Thyroid	Liver
Inhale	9.5E-04	4.3E-04	4.1E-04	9.2E-03
Leaf Veg	7.3E-02	6.4E-02	6.3E-02	3.8E-02
Meat	1.3E-01	1.2E-01	1.2E-01	3.6E-02
Cow Milk	2.2E-02	2.0E-02	2.0E-02	1.4E-04
Total	2.3E-01	2.0E-01	2.0E-01	8.2E-02

External Dose by Exposure Pathway

Pathway	
Plume	1.0E-05
Sur Soil	5.8E-04
Total	5.9E-04

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Autumn: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:06 Page C. 19

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Committed Dose Equivalent by Radionuclide

Radionuclide	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes
CO 60	2.8E-02	2.7E-02	3.9E-02	4.6E-02	6.4E-02	2.3E-02	2.7E-02	2.6E-02
SR 90	5.8E-06	1.3E-05	2.0E-05	1.3E-04	5.6E-04	1.2E-02	5.2E-03	5.6E-06
Y 90	1.6E-09	3.2E-05	7.5E-05	3.8E-04	9.2E-04	1.2E-08	1.1E-08	3.8E-10
CS 134	1.4E-02	1.6E-02	1.8E-02	1.6E-02	1.8E-02	1.4E-02	1.6E-02	1.6E-02
CS 137	1.8E-01	1.9E-01	1.9E-01	1.9E-01	1.9E-01	1.8E-01	1.8E-01	1.9E-01
PU 238	1.5E-04	1.8E-06	4.4E-06	2.6E-05	7.8E-05	3.8E-02	3.1E-03	5.3E-04
CM 244	1.1E-04	1.5E-06	4.2E-06	2.3E-05	7.0E-05	1.8E-02	1.5E-03	2.4E-04
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	2.3E-05	2.8E-07	7.0E-07	4.0E-06	1.3E-05	7.2E-03	5.6E-04	1.0E-04
PU 241	1.7E-06	2.2E-07	5.6E-07	3.3E-06	9.7E-06	2.3E-02	1.8E-03	3.4E-04
AM 241	9.4E-05	1.1E-06	2.8E-06	1.6E-05	5.0E-05	2.7E-02	2.1E-03	3.8E-04
PU 239	1.6E-05	2.0E-07	4.9E-07	2.8E-06	8.7E-06	5.1E-03	3.9E-04	7.0E-05
Total	2.2E-01	2.3E-01	2.5E-01	2.6E-01	2.8E-01	3.4E-01	2.4E-01	2.4E-01

Radionuclide	Ovaries	Muscle	Thyroid	Liver
CO 60	3.4E-02	2.4E-02	2.2E-02	6.1E-02
SR 90	5.6E-06	5.6E-06	5.6E-06	0.0E+00
Y 90	4.3E-10	3.8E-10	3.8E-10	1.1E-08
CS 134	1.4E-02	1.4E-02	1.4E-02	0.0E+00
CS 137	1.8E-01	1.6E-01	1.6E-01	0.0E+00
PU 238	5.2E-04	1.9E-08	1.9E-08	7.0E-03
CM 244	2.4E-04	1.6E-08	1.6E-08	3.6E-03
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	1.0E-04	3.0E-09	3.0E-09	1.3E-03
PU 241	3.4E-04	1.1E-10	8.0E-11	3.5E-03
AM 241	3.7E-04	1.6E-08	1.2E-08	4.8E-03
PU 239	7.0E-05	2.1E-09	2.1E-09	8.9E-04
Total	2.3E-01	2.0E-01	2.0E-01	8.2E-02

GENII Dose Calculation Program
(Version 1.485 3-Dec-90)

Case title: Autumn: Dose comparison with RISKIND

Executed on: 05/08/97 at 09:18:06 Page C. 20

Acute release
Uptake/exposure period: 1.0
Dose commitment period: 50.0
Dose units: Rem

Radio-nuclide	Inhalation Effective Dose Equivalent	Ingestion Effective Dose Equivalent	External Dose	Internal Effective Dose Equivalent	Annual Effective Dose Equivalent
CO 60	7.0E-04	3.4E-02	3.8E-04	3.4E-02	3.5E-02
SR 90	9.1E-06	1.0E-03	2.4E-10	1.0E-03	1.0E-03
Y 90	3.0E-10	8.4E-05	1.3E-08	8.4E-05	8.4E-05
CS 134	1.9E-05	1.5E-02	3.0E-05	1.5E-02	1.5E-02
CS 137	2.0E-04	1.7E-01	1.8E-04	1.7E-01	1.7E-01
PU 238	9.0E-04	1.2E-03	2.3E-12	2.1E-03	2.1E-03
CM 244	3.7E-04	6.4E-04	1.2E-12	1.0E-03	1.0E-03
PU 244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U 240	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
PU 240	1.6E-04	2.2E-04	3.9E-13	3.9E-04	3.9E-04
PU 241	5.1E-04	6.8E-04	1.2E-16	1.2E-03	1.2E-03
AM 241	6.2E-04	8.4E-04	3.0E-10	1.5E-03	1.5E-03
PU 239	1.2E-04	1.6E-04	5.6E-13	2.7E-04	2.7E-04

B.2 Comparison with CAP88-PC

B.2.1 Cs-137 Release (1 Ci)

B.2.1.1 RISKIND Output for Cs-137 Release

```
================= RISKIND Program Output, Version 1.11     ========= Page:   1
 Title       : CAP88-PC dose comparison, 1 Ci Cs-137 release
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\cs_cap88.inp
 Output File : output\cs_cap88.out
==============================================================================




==============================================================================
========================== RISKIND Computer Program ==========================
==============================================================================



 Problem Description
 ___________________________________________

               Individual Receptors

               Accident Calculations
                  Single Accident Analysis
                  Single Weather Analysis

                  Acute Exposure
                     Plume Inhalation
                     Plume Immersion
                     Early Ground Exposure
                     Exposure to Cask



     Note: * next to input description signifies
           a data dependent default value
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   2
 Title       : CAP88-PC dose comparison, 1 Ci Cs-137 release
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\cs_cap88.inp
 Output File : output\cs_cap88.out
============================  Input Parameters  ============================


==============================================================================
=================== RISKIND Accident Individual Problem Input ==================
==============================================================================
```

Individual Accident Parameters

State: ID
Population Zone: Rural

Average Breathing Rate [BRTIND]: 8.04E+03 m3/yr
Individual type [INDTYPE]: Public
Risk Conversion Factors
Non-Fatal Cancers/rem: 1.0E-04
Fatal Cancers/rem: 5.0E-04
Genetic Effects/rem: 1.3E-04

Individual Name [XNAME]	======= Location ======= Down Wind [km]	Cross Wind [km] [XRECEP]	Elevation [m]	Acute Exposure Time [hr] [TEXT]	Long Term Exposure [IRTP]	Food Ingestion [IDFOOD]
Receptor 1	1.50E-01	0.00E+00	0.00E+00	1.00E+00	Non	No

Individual Name	Shielding Type Short	Long	Long-Term In	Out	====== Shielding Factors ==== Acute: Inh	Cld	Ext	Long-Term: Inh	Cld	Ext
Receptor 1	None	None	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   3
 Title       : CAP88-PC dose comparison, 1 Ci Cs-137 release
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\cs_cap88.inp
 Output File : output\cs_cap88.out
============================  Input Parameters  ============================

 Meteorological Parameters
_____________________________________________

            Dry deposition rates [VDEPNUC]
                          Particulates   : 1.00E-02      m/s
                          Ruthenium      : 1.00E-02      m/s
                          Cesium         : 1.00E-02      m/s
                          Iodine         : 1.00E-02      m/s
                          Gases          : 0.00E+00      m/s
                    Rain fall rate [RAIN]: 0.00E+00     mm/h
                  Anemometer height [ANH]:    20.00        m
               Ambient Temperature [TABK]:   288.00        K
                     Mixing height [DMIX]:  1000.00        m
                 Wind at anemometer [WSM]:     4.37      m/s
           Pasquill stability cat. [ITYPE]:       D



 Shipment Parameters
_____________________________________________

                Transportation Mode [IMOD]:    Truck
                        Dose at 1 m [TIDX]:     3.48  mrem/hr
                Measurement Offset [TIOFF]:     0.00        m
                  Gamma Fraction [FRAD(1)]:     0.69
                Neutron Fraction [FRAD(2)]:     0.31
                       Cask Length [HSIZE]:     0.01        m
                       Cask Radius [RSIZE]:     0.01        m
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   4
 Title       : CAP88-PC dose comparison, 1 Ci Cs-137 release
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\cs_cap88.inp
 Output File : output\cs_cap88.out
============================  Input Parameters  ============================
```

Nuclide Parameters

Nuclide Inventory and DCFs

Nuclide Name	Inventory Amount [Ci]	======= Dose Conversion Factors ====== Inhalation [Sv/Bq]	Ingestion [Sv/Bq]	Cloud [Sv/s] [Bq/m3]	Ground [Sv/s] [Bq/m2]	Nucl. Class	Decay Const. [1/yr]
CS137	1.00E+00	1.10E-08	1.59E-08	2.73E-14	5.54E-16	Cs	2.30E-02

Nuclide Health Effects Parameters

Nuclide Name	Solubility Class	Acute Organ Dose Conversion Factors =========Inhalation======== [Sv/Bq] Marrow	Lung	Intestine	========Ground========== [Sv/s//Bq/m2] Marrow	Lung	Intestine
CS137	D	7.57E-09	8.11E-09	8.11E-09	5.39E-16	5.30E-16	4.93E-16

```
================= RISKIND Program Output, Version 1.11     ========= Page:   5
 Title        : CAP88-PC dose comparison, 1 Ci Cs-137 release
 Date/Time    : 05/13/97 14:18
 Input  File  : c:\riskind\input\cs_cap88.inp
 Output File  : output\cs_cap88.out
==============================  Input Parameters  ==============================
```

Nuclide Health Effects Parameters

Name	Acute Organ Dose Conversion Factors =========Cloudshine======== [Sv/s//Bq/m3] Marrow	Lung	Intestine
CS137	2.59E-14	2.65E-14	2.48E-14

```
================= RISKIND Program Output, Version 1.11     ========= Page:   6
 Title       : CAP88-PC dose comparison, 1 Ci Cs-137 release
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\cs_cap88.inp
 Output File : output\cs_cap88.out
===============  Input Parameters  - Accident Response Region:  1===============

 Accident Parameters
 ------------------------------------------

              Physical Release Height [HS]:    20.00        m
   Dispersion Model Coefficients [IDISPMOD]: Briggs
                    Accident Analysis Type: Consequence


 Accident Response Region Parameters
 ------------------------------------------
                   Response Region [IYOURS]:        1
          Response Regions Considered [NSV]:    20.00
      Region Conditional Probability [FSEV]: 1.00E+00
                       Heat Flux [HEATF]: 0.00E+00   cal/s
       Loss of Cask Shielding Factor [SEXT]
                                   Gamma:     2.00
                                 Neutron:     2.00
                    Failure Rate [FAILS]: 1.00E+00
              Crud Spallation Rate [FSPAL]: 0.00E+00
                Crud Release Rate [FRCRUD]: 1.00E+00
```

Nuclide Class [NUTYPE]	Conditional Release Fraction [FRELS]	Dispersion Fraction [FDISP]	Released and Dispersed Fraction (FRELS*FAILS*FDISP)
Particulate	1.00E+00	1.00E+00	1.00E+00
Ru	1.00E+00	1.00E+00	1.00E+00
Cs	1.00E+00	1.00E+00	1.00E+00
I	1.00E+00	1.00E+00	1.00E+00
Gas	1.00E+00	1.00E+00	1.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   7
 Title       : CAP88-PC dose comparison, 1 Ci Cs-137 release
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\cs_cap88.inp
 Output File : output\cs_cap88.out
=============== Intermediate Calcs - Accident Response Region:  1===============

==============================================================================
================================ Nuclide Release ==============================
==============================================================================
```

Nuclide Name	Release Amount [Ci]	Hazard Index Inhalation	Hazard Index Ingestion	Hazard Index Ground
CS137	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Total	1.00E+00	1.00E+00	1.00E+00	1.00E+00

```
==============================================================================
================================ Puff Calculations ============================
==============================================================================
```

Individual Name	Plume Parameters: Effective Release Height [m]	Dispersion Sigma (Horizontal) [m]	Dispersion Sigma (Vertical) [m]
Receptor 1	2.00E+01	1.19E+01	8.16E+00

Individual Name	Chi/Q: Air [s/m3]	Chi/Q: Ground [1/m2]	Depletion Fraction	Wet/Dry Ratio
Receptor 1				
Particulates	3.70E-05	3.70E-07	2.36E-04	0.00E+00
Ruthenium	3.70E-05	3.70E-07	2.36E-04	0.00E+00
Cesium	3.70E-05	3.70E-07	2.36E-04	0.00E+00
Iodine	3.70E-05	3.70E-07	2.36E-04	0.00E+00
Gases	3.70E-05	0.00E+00	0.00E+00	0.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   8
 Title       : CAP88-PC dose comparison, 1 Ci Cs-137 release
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\cs_cap88.inp
 Output File : output\cs_cap88.out
===============      Results       - Accident Response Region:  1===============

==============================================================================
===============          Accident Dose to :  Receptor 1          ===============
==============================================================================
```

Individual Summary Results Per Accident		
Committed Effective Dose Equivalent	3.90E-04	rem
Expected Genetic Effects	5.07E-08	
Expected Non-fatal Cancers	3.90E-08	
Expected Cancer Fatalities	1.95E-07	
Acute Risk (Expected fatalities)	0.00E+00	

Pathway	Doses(rem)			
Acute	3.90E-04			
Cask		1.91E-07		
Ground Shine		2.73E-06		
Inhalation		3.84E-04		
Cloud Shine		3.74E-06		
Long-Term	0.00E+00			
Ground Shine		0.00E+00		
Inhalation		0.00E+00		
Cloud Shine		0.00E+00		
Ingestion		0.00E+00		
Initial Year			0.00E+00	
Vegetable				0.00E+00
Meat				0.00E+00
Milk				0.00E+00
Long-Term			0.00E+00	
Vegetable				0.00E+00
Meat				0.00E+00
Milk				0.00E+00
Water				0.00E+00

	Organ Exposure			
Exposure Parameter	Marrow	Lung	Intestine	Gonads
Long-Term Dose [rem]	3.79E-04	3.97E-04	3.17E-04	5.04E-04
Brief Dose [Gy]	9.20E-08	2.89E-06	2.76E-06	
Brief Exposure Time [d]	1.00E+00	1.00E+00	1.00E+00	
Brief Dose Rate [Gy/hr]	6.45E-08	2.27E-07	1.72E-07	
Prolonged Dose [Gy]	7.29E-07	2.83E-06	2.83E-06	
Prolong Exposure Time [d]	3.00E+01	3.65E+02	7.00E+00	
Prolong Dose Rate [Gy/hr]	1.01E-09	1.63E-07	1.09E-07	
Hazard	0.00E+00	0.00E+00	0.00E+00	
Acute Risk [Expected fatalities]	0.00E+00	0.00E+00	0.00E+00	

```
================= RISKIND Program Output, Version 1.11     ========= Page:   9
 Title        : CAP88-PC dose comparison, 1 Ci Cs-137 release
 Date/Time    : 05/13/97 14:18
 Input  File  : c:\riskind\input\cs_cap88.inp
 Output File  : output\cs_cap88.out
==============================      Results       ==============================

==============================================================================
========================= Accident Risk to Individuals =========================
==============================================================================
```

Individual Accident Dose Summary Results
Consequences

	Acute		Total			
	Dose [rem]	Risk [Fatality]	Dose [rem]	Expected Non-Fatal Cancer Incidence	Expected Cancer Fatalities	Expected Genetic Effects
Receptor 1	3.90E-04	0.00E+00	3.90E-04	3.90E-08	1.95E-07	5.07E-08

B.2.1.2 CAP88-PC Output for Cs-137 Release

```
                    C A P 8 8 - P C

                      Version 1.00

          Clean Air Act Assessment Package - 1988


                S Y N O P S I S   R E P O R T

              Non-Radon Individual Assessment
                  May 13, 1997   2:08 pm


 Facility:  Riskind benchmark test, 20 m, 1 Ci Cs-137
  Address:
     City:
    State:  WA          Zip:


             Effective Dose Equivalent
                    (mrem/year)
             ____________________________

                     5.89E+01
             ____________________________


At This Location:    300 Meters South
 Source Category:
     Source Type:  Stack
   Emission Year:


 Comments:


    Dataset Name:  Riskind 20m, Cs
    Dataset Date:  May  5, 1997  10:10 am
       Wind File:  WNDFILES\D4FRMN.WND
```

MAXIMALLY EXPOSED INDIVIDUAL

Location Of The Individual: 300 Meters South
Lifetime Fatal Cancer Risk: 1.44E-03

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Dose Equivalent (mrem/y)
GONADS	6.64E+01
BREAST	6.29E+01
R MAR	5.36E+01
LUNGS	5.33E+01
THYROID	6.54E+01
ENDOST	5.44E+01
RMNDR	5.49E+01
EFFEC	5.89E+01

RADIONUCLIDE EMISSIONS DURING THE YEAR

Nuclide	Class	Size	Source #1 Ci/y	TOTAL Ci/y
CS-137	D	1.00	1.0E+00	1.0E+00
BA-137M	D	1.00	1.0E+00	1.0E+00

SITE INFORMATION

Temperature:	15 degrees C
Precipitation:	0 cm/y
Mixing Height:	1000 m

SOURCE INFORMATION

Source Number: 1

Stack Height (m): 20.00
Diameter (m): 0.00

Plume Rise Pasquill Cat:	A	B	C	D	E	F	G
Zero:	0.00	0.00	0.00	0.00	0.00	0.00	0.00

AGRICULTURAL DATA

	Vegetable	Milk	Meat
Fraction Home Produced:	1.000	1.000	1.000
Fraction From Assessment Area:	0.000	0.000	0.000
Fraction Imported:	0.000	0.000	0.000

Food Arrays were not generated for this run.
Default Values used.

DISTANCES USED FOR MAXIMUM INDIVIDUAL ASSESSMENT

100	200	300	400	500	600	700	800	900	1000
2500	5000	10000	20000	30000	40000	50000	60000	70000	80000

C A P 8 8 - P C

Version 1.00

Clean Air Act Assessment Package - 1988

D O S E A N D R I S K E Q U I V A L E N T S U M M A R I E S

Non-Radon Individual Assessment
May 13, 1997 2:08 pm

Facility: Riskind benchmark test, 20 m, 1 Ci Cs-137
Address:
City:
State: WA Zip:

Source Category:
Source Type: Stack
Emission Year:

Comments:

Dataset Name: Riskind 20m, Cs
Dataset Date: May 5, 1997 10:10 am
Wind File: WNDFILES\D4FRMN.WND

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Selected Individual (mrem/y)
GONADS	6.64E+01
BREAST	6.29E+01
R MAR	5.36E+01
LUNGS	5.33E+01
THYROID	6.54E+01
ENDOST	5.44E+01
RMNDR	5.49E+01
EFFEC	5.89E+01

PATHWAY EFFECTIVE DOSE EQUIVALENT SUMMARY

Pathway	Selected Individual (mrem/y)
INGESTION	1.33E+01
INHALATION	2.92E-01
AIR IMMERSION	2.61E-03
GROUND SURFACE	4.53E+01
INTERNAL	1.36E+01
EXTERNAL	4.53E+01
TOTAL	5.89E+01

NUCLIDE EFFECTIVE DOSE EQUIVALENT SUMMARY

Nuclide	Selected Individual (mrem/y)
CS-137	1.36E+01
BA-137M	4.53E+01
TOTAL	5.89E+01

CANCER RISK SUMMARY

Cancer	Selected Individual Total Lifetime Fatal Cancer Risk
LEUKEMIA	1.70E-04
BONE	9.63E-06
THYROID	2.97E-05
BREAST	2.46E-04
LUNG	2.64E-04
STOMACH	1.55E-04
BOWEL	7.39E-05
LIVER	1.80E-04
PANCREAS	1.10E-04
URINARY	6.79E-05
OTHER	1.35E-04
TOTAL	1.44E-03

PATHWAY RISK SUMMARY

Pathway	Selected Individual Total Lifetime Fatal Cancer Risk
INGESTION	3.48E-04
INHALATION	7.71E-06
AIR IMMERSION	6.25E-08
GROUND SURFACE	1.09E-03
INTERNAL	3.56E-04
EXTERNAL	1.09E-03
TOTAL	1.44E-03

NUCLIDE RISK SUMMARY

Nuclide	Selected Individual Total Lifetime Fatal Cancer Risk
CS-137	3.56E-04
BA-137M	1.09E-03
TOTAL	1.44E-03

May 13, 1997 2:08 pm

SUMMARY
Page 5

INDIVIDUAL EFFECTIVE DOSE EQUIVALENT RATE (mrem/y)
(All Radionuclides and Pathways)

	Distance (m)						
Direction	100	200	300	400	500	600	700
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	1.7E+00	4.3E+01	5.9E+01	5.3E+01	4.4E+01	3.6E+01	3.0E+01
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

	Distance (m)						
Direction	800	900	1000	2500	5000	10000	20000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	2.5E+01	2.1E+01	1.8E+01	4.2E+00	1.5E+00	5.1E-01	1.8E-01
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

INDIVIDUAL EFFECTIVE DOSE EQUIVALENT RATE (mrem/y)
(All Radionuclides and Pathways)

	Distance (m)					
Direction	30000	40000	50000	60000	70000	80000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	9.4E-02	6.0E-02	4.2E-02	3.1E-02	2.5E-02	2.0E-02
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

INDIVIDUAL LIFETIME RISK (deaths)
(All Radionuclides and Pathways)

	Distance (m)						
Direction	100	200	300	400	500	600	700
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	4.1E-05	1.1E-03	1.4E-03	1.3E-03	1.1E-03	8.8E-04	7.2E-04
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

	Distance (m)						
Direction	800	900	1000	2500	5000	10000	20000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	6.0E-04	5.1E-04	4.3E-04	1.0E-04	3.6E-05	1.3E-05	4.3E-06
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

INDIVIDUAL LIFETIME RISK (deaths)
(All Radionuclides and Pathways)

	Distance (m)					
Direction	30000	40000	50000	60000	70000	80000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	2.3E-06	1.5E-06	1.0E-06	7.7E-07	6.0E-07	4.9E-07
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

C A P 8 8 - P C

Version 1.00

Clean Air Act Assessment Package - 1988

C H I / Q T A B L E S

Non-Radon Individual Assessment
May 13, 1997 2:08 pm

Facility: Riskind benchmark test, 20 m, 1 Ci Cs-137
Address:
City:
State: WA Zip:

Source Category:
Source Type: Stack
Emission Year:

Comments:

Dataset Name: Riskind 20m, Cs
Dataset Date: May 5, 1997 10:10 am
Wind File: WNDFILES\D4FRMN.WND

May 13, 1997 2:08 pm

CHIQ
Page 1

GROUND-LEVEL CHI/Q VALUES FOR CS-137
CHI/Q TOWARD INDICATED DIRECTION (SEC/CUBIC METER)

	Distance (meters)						
Dir	100	200	300	400	500	600	700
N	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
W	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S	1.058E-06	2.699E-05	3.698E-05	3.349E-05	2.774E-05	2.264E-05	1.858E-05
SSE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ESE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
E	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ENE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

	Distance (meters)						
Dir	800	900	1000	2500	5000	10000	20000
N	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
W	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S	1.543E-05	1.297E-05	1.104E-05	2.655E-06	9.207E-07	3.222E-07	1.106E-07
SSE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ESE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
E	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ENE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

GROUND-LEVEL CHI/Q VALUES FOR CS-137
CHI/Q TOWARD INDICATED DIRECTION (SEC/CUBIC METER)

	Distance (meters)					
Dir	30000	40000	50000	60000	70000	80000
N	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
W	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S	5.878E-08	3.760E-08	2.646E-08	1.972E-08	1.549E-08	1.253E-08
SSE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ESE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
E	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ENE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

May 13, 1997 2:08 pm

CHIQ
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GROUND-LEVEL CHI/Q VALUES FOR BA-137M
CHI/Q TOWARD INDICATED DIRECTION (SEC/CUBIC METER)

	Distance (meters)						
Dir	100	200	300	400	500	600	700
N	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
W	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S	9.537E-07	2.194E-05	2.711E-05	2.214E-05	1.653E-05	1.217E-05	9.002E-06
SSE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ESE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
E	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ENE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

	Distance (meters)						
Dir	800	900	1000	2500	5000	10000	20000
N	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
W	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S	6.739E-06	5.110E-06	3.923E-06	1.996E-07	5.204E-09	1.029E-11	1.129E-16
SSE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ESE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
E	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ENE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

GROUND-LEVEL CHI/Q VALUES FOR BA-137M
CHI/Q TOWARD INDICATED DIRECTION (SEC/CUBIC METER)

	Distance (meters)					
Dir	30000	40000	50000	60000	70000	80000
N	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WNW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
W	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
WSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SSW	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
S	1.917E-21	3.920E-26	8.877E-31	2.357E-35	0.000E+00	0.000E+00
SSE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ESE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
E	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ENE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NNE	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

C A P 8 8 - P C

Version 1.00

Clean Air Act Assessment Package - 1988

D O S E A N D R I S K C O N V E R S I O N F A C T O R S

Non-Radon Individual Assessment
May 13, 1997 2:08 pm

Facility: Riskind benchmark test, 20 m, 1 Ci Cs-137
Address:
City:
State: WA Zip:

Source Category:
Source Type: Stack
Emission Year:

Comments:

Dataset Name: Riskind 20m, Cs
Dataset Date: May 5, 1997 10:10 am
Wind File: WNDFILES\D4FRMN.WND

DOSE AND RISK FACTOR UNITS

The units for each type of dose rate conversion factor are shown below, by pathway:

Pathway	Units
Ingestion	millirem/picoCurie
Inhalation	millirem/picoCurie
Immersion	millirem-cubic centimeter/microCurie-year
Surface	millirem-square centimeter/microCurie-year

Risks for internal exposures (inhalation and ingestion) are the lifetime risk of premature death in a birth cohort of 100,000 people for a 1 picoCurie/year intake rate, where the average lifetime is 70.7565 years. This is simplified to lifetime risk per 100,000 picoCuries.

The units for each type of risk conversion factor are shown below, by pathway:

Pathway	Units
Ingestion	lifetime risk/100,000 picoCuries
Inhalation	lifetime risk/100,000 picoCuries
Immersion	lifetime risk-cubic centimeter/100,000 picoCurie-years
Surface	lifetime risk-square centimeter/100,000 picoCurie-years

```
************************
*   NUCLIDE  CS-137    *
************************
```

DOSE RATE CONVERSION FACTORS

Organ	Ingestion	Inhalation	Air Immersion	Ground Surface
GONADS	4.404E-05	2.925E-05	0.000E+00	0.000E+00
BREAST	4.799E-05	3.190E-05	0.000E+00	0.000E+00
R MAR	4.365E-05	2.901E-05	0.000E+00	0.000E+00
LUNGS	4.438E-05	3.262E-05	0.000E+00	0.000E+00
THYROID	5.080E-05	3.378E-05	0.000E+00	0.000E+00
ENDOST	3.052E-05	2.029E-05	0.000E+00	0.000E+00
RMNDR	4.950E-05	3.291E-05	0.000E+00	0.000E+00
EFFEC	4.606E-05	3.099E-05	0.000E+00	0.000E+00

GENETIC EFFECT DOSE RATE CONVERSION FACTORS

TESTES	1.302E-03	8.650E-04	0.000E+00	0.000E+00
OVARIES	1.290E-03	8.550E-04	0.000E+00	0.000E+00
AVERAGE	1.296E-03	8.600E-04	0.000E+00	0.000E+00

RISK CONVERSION FACTORS

Cancer	Ingestion	Inhalation	Air Immersion	Ground Surface
LEUKEMIA	1.378E-05	9.158E-06	0.000E+00	0.000E+00
BONE	5.381E-07	3.578E-07	0.000E+00	0.000E+00
THYROID	2.301E-06	1.530E-06	0.000E+00	0.000E+00
BREAST	1.868E-05	1.242E-05	0.000E+00	0.000E+00
LUNG	2.187E-05	1.674E-05	0.000E+00	0.000E+00
STOMACH	1.153E-05	7.465E-06	0.000E+00	0.000E+00
BOWEL	4.723E-06	3.017E-06	0.000E+00	0.000E+00
LIVER	1.667E-05	1.109E-05	0.000E+00	0.000E+00
PANCREAS	1.079E-05	7.174E-06	0.000E+00	0.000E+00
URINARY	6.303E-06	4.188E-06	0.000E+00	0.000E+00
OTHER	1.320E-05	8.775E-06	0.000E+00	0.000E+00

GENETIC EFFECT RISK CONVERSION FACTORS

AVERAGE	3.370E-10	2.236E-10	0.000E+00	0.000E+00

****
* NUCLIDE BA-137M *
****

DOSE RATE CONVERSION FACTORS

Organ	Ingestion	Inhalation	Air Immersion	Ground Surface
GONADS	3.456E-10	5.090E-11	3.582E+09	7.141E+05
BREAST	3.743E-10	2.361E-10	3.260E+09	6.512E+05
R MAR	2.923E-10	2.177E-10	2.734E+09	5.439E+05
LUNGS	4.594E-10	7.201E-09	2.686E+09	5.365E+05
THYROID	4.051E-11	2.200E-10	3.367E+09	6.734E+05
ENDOST	1.608E-10	1.647E-10	3.034E+09	6.068E+05
RMNDR	7.704E-09	5.841E-10	2.702E+09	5.387E+05
EFFEC	2.550E-09	1.125E-09	3.038E+09	6.059E+05

GENETIC EFFECT DOSE RATE CONVERSION FACTORS

TESTES	7.174E-10	7.210E-10	1.074E+11	2.142E+07
OVARIES	1.037E-08	1.527E-09	7.304E+10	1.454E+07
AVERAGE	5.543E-09	1.124E-09	9.024E+10	1.798E+07

RISK CONVERSION FACTORS

Cancer	Ingestion	Inhalation	Air Immersion	Ground Surface
LEUKEMIA	9.259E-11	6.896E-11	8.660E+02	1.723E-01
BONE	2.847E-12	2.916E-12	5.370E+01	1.074E-02
THYROID	1.842E-12	1.001E-11	1.531E+02	3.063E-02
BREAST	1.466E-10	9.246E-11	1.277E+03	2.551E-01
LUNG	2.278E-10	2.678E-09	1.332E+03	2.660E-01
STOMACH	9.421E-09	3.193E-10	8.060E+02	1.612E-01
BOWEL	1.587E-10	1.215E-11	4.011E+02	8.010E-02
LIVER	1.845E-10	1.399E-10	8.794E+02	1.751E-01
PANCREAS	1.049E-09	1.267E-10	5.285E+02	1.050E-01
URINARY	1.079E-10	2.521E-11	3.301E+02	6.592E-02
OTHER	1.283E-09	1.550E-10	6.465E+02	1.284E-01

GENETIC EFFECT RISK CONVERSION FACTORS

AVERAGE	1.441E-15	2.922E-16	2.346E+04	4.675E+00

B.2.2 Spent Fuel Accident

B.2.2.1 RISKIND Output for Spent Fuel Accident

```
================= RISKIND Program Output, Version 1.11     ========= Page:   1
 Title       : CAP88-PC dose comparison
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\sf_cap88.inp
 Output File : output\sf_cap88.out
==============================================================================




==============================================================================
========================== RISKIND Computer Program ==========================
==============================================================================



 Problem Description
 ___________________________________________

               Individual Receptors

               Accident Calculations
                  Single Accident Analysis
                  Single Weather Analysis

                  Acute Exposure
                     Plume Inhalation
                     Plume Immersion
                     Early Ground Exposure
                     Exposure to Cask



     Note: * next to input description signifies
           a data dependent default value
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   2
 Title       : CAP88-PC dose comparison
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\sf_cap88.inp
 Output File : output\sf_cap88.out
============================  Input Parameters  ============================


==========================================================================
=================== RISKIND Accident Individual Problem Input ==================
==========================================================================
```

Individual Accident Parameters

State: US
Population Zone: Rural

Average Breathing Rate [BRTIND]: 8.04E+03 m3/yr
Individual type [INDTYPE]: Public
Risk Conversion Factors
Non-Fatal Cancers/rem: 1.0E-04
Fatal Cancers/rem: 5.0E-04
Genetic Effects/rem: 1.3E-04

Individual Name [XNAME]	======= Location ======= Down Wind [km]	Cross Wind [km] [XRECEP]	Elevation [m]	Acute Exposure Time [hr] [TEXT]	Long Term Exposure [IRTP]	Food Ingestion [IDFOOD]
Individual 1	1.50E-01	0.00E+00	0.00E+00	2.00E+00	Non	No

Individual Name	Shielding Type Short	Long	Long-Term In	Out	====== Shielding Factors ==== Acute: Inh	Cld	Ext	Long-Term: Inh	Cld	Ext
Individual 1	None	None	0.00	0.50	1.00	1.00	1.00	0.50	0.50	0.50

```
================= RISKIND Program Output, Version 1.11     ========= Page:   3
 Title       : CAP88-PC dose comparison
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\sf_cap88.inp
 Output File : output\sf_cap88.out
============================  Input Parameters  ============================

 Meteorological Parameters
_____________________________________________

            Dry deposition rates [VDEPNUC]
                          Particulates   : 1.00E-02      m/s
                          Ruthenium      : 1.00E-02      m/s
                          Cesium         : 1.00E-02      m/s
                          Iodine         : 1.00E-02      m/s
                          Gases          : 0.00E+00      m/s
                    Rain fall rate [RAIN]: 0.00E+00     mm/h
                  Anemometer height [ANH]:    20.00        m
               Ambient Temperature [TABK]:   288.00        K
                     Mixing height [DMIX]:  1000.00        m
                 Wind at anemometer [WSM]:     4.37      m/s
           Pasquill stability cat. [ITYPE]:       D



 Shipment Parameters
_____________________________________________

                Transportation Mode [IMOD]:    Truck
                        Dose at 1 m [TIDX]:     3.48  mrem/hr
                Measurement Offset [TIOFF]:     0.00        m
                  Gamma Fraction [FRAD(1)]:     0.60
                Neutron Fraction [FRAD(2)]:     0.40
                       Cask Length [HSIZE]:     0.01        m
                       Cask Radius [RSIZE]:     0.01        m
                  Amount of Uranium [UMT]*:     0.46      MTU
                      Reactor Type [RTYPE]:      PWR
                   Reactor Burnup [BURNUP]: 3.50E+04     MWD
                 Fuel Cooling Time [TFUEL]:    10.00       yr
       Total Surface Area of Cask [CAREA]*:    39.00       m2
    Crud Surface Activity Density [CACTD]*:     4.00  uCi/cm2
```

```
================= RISKIND Program Output, Version 1.11     ========= Page:   4
 Title        : CAP88-PC dose comparison
 Date/Time    : 05/13/97 14:18
 Input  File  : c:\riskind\input\sf_cap88.inp
 Output File  : output\sf_cap88.out
============================  Input Parameters  ============================
```

Nuclide Parameters

Nuclide Inventory and DCFs

Nuclide Name	Inventory Amount [Ci]	======= Dose Conversion Factors ====== Inhalation [Sv/Bq]	Ingestion [Sv/Bq]	Cloud [Sv/s] [Bq/m3]	Ground [Sv/s] [Bq/m2]	Nucl. Class	Decay Const. [1/yr]
H 3	2.17E+02	1.73E-11	1.73E-11	0.00E+00	0.00E+00	Particul	5.60E-02
FE 55	1.07E+02	7.26E-10	1.64E-10	0.00E+00	0.00E+00	Particul	2.60E-01
CO 60	1.10E+03	5.91E-08	7.28E-09	1.26E-13	2.35E-15	Particul	1.30E-01
NI 63	1.88E+02	1.70E-09	1.56E-10	0.00E+00	0.00E+00	Particul	6.90E-03
KR 85	2.33E+03	1.03E-11	1.03E-11	1.19E-16	2.64E-18	Gas	6.50E-02
SR 90	2.77E+04	3.53E-07	4.14E-08	1.97E-16	5.61E-18	Particul	2.40E-02
Y 90	2.77E+04	2.28E-09	2.91E-09	1.90E-16	5.33E-18	Particul	9.50E+01
RU106	2.44E+02	1.30E-07	8.30E-09	1.04E-14	2.12E-16	Ru	6.90E-01
RH106	2.44E+02	8.95E-10	8.95E-10	1.04E-14	2.12E-16	Ru	7.30E+05
SB125	6.01E+02	3.75E-09	9.85E-10	2.02E-14	4.33E-16	Particul	2.50E-01
TE125M	1.47E+02	1.97E-09	9.92E-10	4.53E-16	3.61E-17	Particul	4.40E+00
CS134	2.76E+03	1.25E-08	1.98E-08	7.56E-14	1.52E-15	Cs	3.40E-01
CS137	3.98E+04	1.10E-08	1.59E-08	2.73E-14	5.54E-16	Cs	2.30E-02
BA137M	3.76E+04	2.49E-09	2.49E-09	2.88E-14	5.86E-16	Particul	1.40E+05
CE144	6.45E+01	1.01E-07	5.71E-09	2.80E-15	5.83E-17	Particul	8.90E-01
PR144	6.45E+01	1.17E-11	3.15E-11	1.94E-15	3.79E-17	Particul	2.10E+04
PM147	4.21E+03	1.06E-08	2.83E-10	6.92E-19	3.40E-20	Particul	2.60E-01
SM151	1.81E+02	8.10E-09	1.05E-10	3.61E-20	5.02E-21	Particul	7.70E-03
EU154	2.09E+03	7.73E-08	2.58E-09	6.14E-14	1.18E-15	Particul	7.90E-02
EU155	7.69E+02	1.12E-08	4.13E-10	2.49E-15	5.90E-17	Particul	1.40E-01
PU238	1.42E+03	1.06E-04	8.65E-07	4.87E-18	8.37E-19	Particul	7.90E-03
PU239	1.65E+02	1.16E-04	9.56E-07	4.24E-18	3.67E-19	Particul	2.90E-05
PU240	2.37E+02	1.16E-04	9.56E-07	4.75E-18	8.02E-19	Particul	1.10E-04
PU241	3.88E+04	2.23E-06	1.85E-08	2.19E-19	5.20E-21	Particul	4.80E-02
AM241	8.66E+02	1.20E-04	9.84E-07	8.18E-16	2.74E-17	Particul	1.60E-03
CM244	8.95E+02	6.70E-05	5.45E-07	4.91E-18	8.78E-19	Particul	3.80E-02

```
================= RISKIND Program Output, Version 1.11     ========= Page:   5
 Title        : CAP88-PC dose comparison
 Date/Time    : 05/13/97 14:18
 Input  File  : c:\riskind\input\sf_cap88.inp
 Output File  : output\sf_cap88.out
============================  Input Parameters  ============================
```

Nuclide Health Effects Parameters

Nuclide Name	Solubility Class	Acute Organ Dose Conversion Factors =========Inhalation======== [Sv/Bq] Marrow	Lung	Intestine	========Ground========== [Sv/s//Bq/m2] Marrow	Lung	Intestine
H 3	D	1.62E-11	1.62E-11	1.62E-11	0.00E+00	0.00E+00	0.00E+00
FE 55	W	1.65E-10	1.76E-10	1.92E-10	0.00E+00	0.00E+00	1.89E-19
CO 60	Y	6.22E-09	1.24E-07	5.95E-09	2.34E-15	2.27E-15	1.94E-15
NI 63	Y	1.05E-12	5.95E-12	4.59E-13	0.00E+00	0.00E+00	0.00E+00
KR 85	D	0.00E+00	0.00E+00	0.00E+00	2.43E-18	2.45E-18	1.97E-18
SR 90	Y	1.08E-09	7.03E-07	1.70E-08	4.77E-18	4.98E-18	0.00E+00
Y 90	Y	1.51E-11	9.19E-09	1.27E-08	4.57E-18	4.76E-18	0.00E+00
RU106	Y	1.05E-09	6.76E-07	3.51E-08	2.06E-16	2.03E-16	1.80E-16
RH106	Y	2.58E-10	2.58E-10	1.14E-09	2.06E-16	2.03E-16	1.80E-16
SB125	W	2.41E-14	7.30E-11	3.24E-12	4.05E-16	4.03E-16	3.79E-16
TE125M	W	5.14E-14	1.05E-11	2.38E-12	1.37E-17	1.77E-17	1.78E-17
CS134	D	1.08E-08	1.08E-08	1.27E-08	1.48E-15	1.46E-15	1.34E-15
CS137	D	7.57E-09	8.11E-09	8.11E-09	5.39E-16	5.30E-16	4.93E-16
BA137M	D	2.73E-11	2.73E-11	0.00E+00	5.70E-16	5.60E-16	5.22E-16
CE144	Y	1.08E-09	5.68E-07	3.24E-08	5.31E-17	5.43E-17	1.83E-17
PR144	Y	1.92E-14	9.46E-11	2.16E-14	3.66E-17	3.61E-17	2.54E-17
PM147	Y	1.41E-10	3.51E-08	1.62E-09	1.86E-20	2.20E-20	3.48E-21
SM151	Y	3.78E-12	1.19E-11	8.65E-13	1.39E-21	1.01E-21	4.45E-21
EU154	Y	2.46E-11	1.57E-10	9.19E-12	1.16E-15	1.14E-15	1.03E-15
EU155	Y	3.78E-12	2.54E-11	1.59E-12	4.71E-17	5.34E-17	6.05E-17
PU238	Y	2.97E-07	7.03E-05	2.97E-08	1.94E-19	7.87E-20	7.35E-19
PU239	Y	2.70E-07	6.76E-05	2.70E-08	1.19E-19	7.87E-20	3.24E-19
PU240	Y	2.70E-07	6.76E-05	2.70E-08	1.88E-19	7.81E-20	7.02E-19
PU241	Y	2.97E-10	5.68E-08	1.41E-10	4.18E-21	4.36E-21	0.00E+00
AM241	W	4.32E-06	1.81E-05	2.97E-08	1.68E-17	2.00E-17	2.52E-17
CM244	W	4.59E-06	1.92E-05	3.24E-08	2.04E-19	9.00E-20	7.10E-19

```
================= RISKIND Program Output, Version 1.11     ========= Page:   6
 Title       : CAP88-PC dose comparison
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\sf_cap88.inp
 Output File : output\sf_cap88.out
============================  Input Parameters  ============================
```

Nuclide Health Effects Parameters

Name	Acute Organ Dose Conversion Factors =========Cloudshine======== [Sv/s//Bq/m3] Marrow	Lung	Intestine
H 3	0.00E+00	0.00E+00	0.00E+00
FE 55	0.00E+00	0.00E+00	9.85E-19
CO 60	1.23E-13	1.24E-13	1.11E-13
NI 63	0.00E+00	0.00E+00	0.00E+00
KR 85	1.09E-16	1.14E-16	9.59E-17
SR 90	1.68E-16	1.84E-16	0.00E+00
Y 90	1.62E-16	1.77E-16	0.00E+00
RU106	9.76E-15	1.01E-14	8.99E-15
RH106	9.76E-15	1.01E-14	8.99E-15
SB125	1.88E-14	1.95E-14	1.82E-14
TE125M	1.86E-16	2.23E-16	4.10E-16
CS134	7.19E-14	7.37E-14	6.84E-14
CS137	2.59E-14	2.65E-14	2.48E-14
BA137M	2.73E-14	2.80E-14	2.61E-14
CE144	2.55E-15	2.68E-15	7.73E-16
PR144	1.88E-15	1.91E-15	1.52E-15
PM147	4.46E-19	5.45E-19	1.55E-19
SM151	1.13E-20	7.13E-21	3.91E-20
EU154	5.87E-14	5.99E-14	5.54E-14
EU155	1.85E-15	2.22E-15	2.42E-15
PU238	1.68E-18	1.06E-18	3.77E-18
PU239	2.67E-18	2.65E-18	3.50E-18
PU240	1.66E-18	1.09E-18	3.69E-18
PU241	1.75E-19	1.99E-19	0.00E+00
AM241	5.21E-16	6.74E-16	8.00E-16
CM244	1.46E-18	7.07E-19	3.57E-18

```
================= RISKIND Program Output, Version 1.11     ========= Page:   7
 Title       : CAP88-PC dose comparison
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\sf_cap88.inp
 Output File : output\sf_cap88.out
===============  Input Parameters  - Accident Response Region:  6===============

 Accident Parameters
 ------------------------------------------

              Physical Release Height [HS]:    20.00        m
   Dispersion Model Coefficients [IDISPMOD]: Briggs
                    Accident Analysis Type: Consequence


 Accident Response Region Parameters
 ------------------------------------------
                   Response Region [IYOURS]:        6
      Region Conditional Probability [FSEV]: 2.33E-07
                         Heat Flux [HEATF]: 0.00E+00   cal/s
       Loss of Cask Shielding Factor [SEXT]
                                    Gamma:     1.00
                                  Neutron:     1.00
                     Failure Rate [FAILS]: 1.00E-01
               Crud Spallation Rate [FSPAL]: 1.00E+00
                 Crud Release Rate [FRCRUD]: 1.00E+00
```

Nuclide Class [NUTYPE]	Conditional Release Fraction [FRELS]	Dispersion Fraction [FDISP]	Released and Dispersed Fraction (FRELS*FAILS*FDISP)
Particulate	2.00E-06	1.00E+00	2.00E-07
Ru	2.70E-05	1.00E+00	2.70E-06
Cs	2.00E-04	1.00E+00	2.00E-05
I	2.50E-03	1.00E+00	2.50E-04
Gas	3.30E-01	1.00E+00	3.30E-02

```
================= RISKIND Program Output, Version 1.11     ========= Page:   8
 Title        : CAP88-PC dose comparison
 Date/Time    : 05/13/97 14:18
 Input  File : c:\riskind\input\sf_cap88.inp
 Output File : output\sf_cap88.out
=============== Intermediate Calcs - Accident Response Region:  6==============
```

==========
========== Nuclide Release ==========
==========

Nuclide Name	Release Amount [Ci]	Hazard Index Inhalation	Hazard Index Ingestion	Hazard Index Ground
CO 60	4.25E-01	1.99E-01	1.30E-01	6.49E-01
SR 90	5.55E-03	1.54E-02	1.50E-02	2.13E-05
CS134	5.52E-02	5.55E-03	5.85E-02	4.92E-02
CS137	7.95E-01	6.94E-02	7.88E-01	3.01E-01
PU238	2.83E-04	2.36E-01	2.25E-04	1.63E-07
PU239	3.30E-05	3.01E-02	2.91E-05	8.39E-09
PU240	4.73E-05	4.31E-02	4.17E-05	2.63E-08
PU241	7.77E-03	1.36E-01	1.29E-04	2.73E-08
AM241	1.73E-04	1.63E-01	1.57E-04	3.28E-06
CM244	1.79E-04	9.42E-02	8.85E-04	1.07E-07
Total	1.29E+00	9.92E-01	9.94E-01	1.00E+00

==========
========== Puff Calculations ==========
==========

Individual Name	Plume Parameters: Effective Release Height [m]	Dispersion Sigma (Horizontal) [m]	Dispersion Sigma (Vertical) [m]
Individual 1	2.00E+01	1.19E+01	8.16E+00

Individual Name	Chi/Q Air [s/m3]	Chi/Q Ground [1/m2]	Depletion Fraction	Wet/Dry Ratio
Individual 1				
Particulates	3.70E-05	3.70E-07	2.36E-04	0.00E+00
Ruthenium	3.70E-05	3.70E-07	2.36E-04	0.00E+00
Cesium	3.70E-05	3.70E-07	2.36E-04	0.00E+00
Iodine	3.70E-05	3.70E-07	2.36E-04	0.00E+00
Gases	3.70E-05	0.00E+00	0.00E+00	0.00E+00

```
================= RISKIND Program Output, Version 1.11     ========= Page:   9
 Title       : CAP88-PC dose comparison
 Date/Time   : 05/13/97 14:18
 Input  File : c:\riskind\input\sf_cap88.inp
 Output File : output\sf_cap88.out
===============      Results       - Accident Response Region:  6===============

==============================================================================
===============          Accident Dose to :  Individual 1        ===============
==============================================================================
```

Individual Summary Results Per Accident		
Committed Effective Dose Equivalent	4.42E-03	rem
Expected Genetic Effects	5.74E-07	
Expected Non-fatal Cancers	4.42E-07	
Expected Cancer Fatalities	2.21E-06	
Acute Risk (Expected fatalities)	0.00E+00	

Pathway		Doses(rem)		
Acute	4.42E-03			
Cask		1.95E-07		
Ground Shine		1.50E-05		
Inhalation		4.39E-03		
Cloud Shine		1.09E-05		
Long-Term	0.00E+00			
Ground Shine		0.00E+00		
Inhalation		0.00E+00		
Cloud Shine		0.00E+00		
Ingestion		0.00E+00		
Initial Year			0.00E+00	
Vegetable				0.00E+00
Meat				0.00E+00
Milk				0.00E+00
Long-Term			0.00E+00	
Vegetable				0.00E+00
Meat				0.00E+00
Milk				0.00E+00
Water				0.00E+00

	Organ Exposure			
Exposure Parameter	Marrow	Lung	Intestine	Gonads
Long-Term Dose [rem]	5.13E-03	6.49E-03	4.20E-04	6.65E-04
Brief Dose [Gy]	2.91E-07	2.82E-06	3.48E-06	
Brief Exposure Time [d]	1.00E+00	1.00E+00	1.00E+00	
Brief Dose Rate [Gy/hr]	1.29E-07	2.73E-07	2.48E-07	
Prolonged Dose [Gy]	8.25E-07	2.29E-05	3.41E-06	
Prolong Exposure Time [d]	3.00E+01	3.65E+02	7.00E+00	
Prolong Dose Rate [Gy/hr]	1.14E-09	1.44E-07	1.31E-07	
Hazard	0.00E+00	0.00E+00	0.00E+00	
Acute Risk [Expected fatalities]	0.00E+00	0.00E+00	0.00E+00	

```
================= RISKIND Program Output, Version 1.11     ========= Page:  10
 Title        : CAP88-PC dose comparison
 Date/Time    : 05/13/97 14:18
 Input  File  : c:\riskind\input\sf_cap88.inp
 Output File  : output\sf_cap88.out
==============================      Results       ==============================

==============================================================================
========================= Accident Risk to Individuals =========================
==============================================================================
```

Individual Accident Dose Summary Results
Consequences

	Acute		Total			
	Dose [rem]	Risk [Fatality]	Dose [rem]	Expected Non-Fatal Cancer Incidence	Expected Cancer Fatalities	Expected Genetic Effects
Individual 1	4.42E-03	0.00E+00	4.42E-03	4.42E-07	2.21E-06	5.74E-07

B.2.2.2 CAP88-PC Output for Spent Fuel Accident

C A P 8 8 - P C

Version 1.00

Clean Air Act Assessment Package - 1988

S Y N O P S I S R E P O R T

Non-Radon Individual Assessment
May 13, 1997 2:07 pm

Facility: Riskind benchmark test
Address:
City:
State: WA Zip:

Effective Dose Equivalent (mrem/year)
7.61E+01

At This Location: 300 Meters South
Source Category:
Source Type: Stack
Emission Year:

Comments:

Dataset Name: Riskind 20m
Dataset Date: May 12, 1997 9:46 am
Wind File: WNDFILES\D4FRMN.WND

MAXIMALLY EXPOSED INDIVIDUAL

Location Of The Individual: 300 Meters South
Lifetime Fatal Cancer Risk: 1.82E-03

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Dose Equivalent (mrem/y)
GONADS	8.20E+01
BREAST	7.63E+01
R MAR	7.00E+01
LUNGS	7.45E+01
THYROID	7.99E+01
ENDOST	1.13E+02
RMNDR	7.01E+01
EFFEC	7.61E+01

RADIONUCLIDE EMISSIONS DURING THE YEAR

Nuclide	Class	Size	Source #1 Ci/y	TOTAL Ci/y
CO-60	Y	1.00	4.3E-01	4.3E-01
SR-90	D	1.00	5.5E-03	5.5E-03
CS-134	D	1.00	5.5E-02	5.5E-02
CS-137	D	1.00	8.0E-01	8.0E-01
BA-137M	D	1.00	8.0E-01	8.0E-01
PU-238	Y	1.00	2.8E-04	2.8E-04
PU-239	Y	1.00	3.3E-05	3.3E-05
PU-240	Y	1.00	4.7E-05	4.7E-05
PU-241	Y	1.00	7.8E-03	7.8E-03
AM-241	W	1.00	1.7E-04	1.7E-04
CM-244	W	1.00	1.8E-04	1.8E-04

SITE INFORMATION

Temperature:	15 degrees C
Precipitation:	0 cm/y
Mixing Height:	1000 m

SOURCE INFORMATION

Source Number: 1

Stack Height (m): 20.00
Diameter (m): 0.00

Plume Rise Pasquill Cat:	A	B	C	D	E	F	G
Zero:	0.00	0.00	0.00	0.00	0.00	0.00	0.00

AGRICULTURAL DATA

	Vegetable	Milk	Meat
Fraction Home Produced:	1.000	1.000	1.000
Fraction From Assessment Area:	0.000	0.000	0.000
Fraction Imported:	0.000	0.000	0.000

Food Arrays were not generated for this run.
Default Values used.

DISTANCES USED FOR MAXIMUM INDIVIDUAL ASSESSMENT

100	200	300	400	500	600	700	800	900	1000
2500	5000	10000	20000	30000	40000	50000	60000	70000	80000

C A P 8 8 - P C

Version 1.00

Clean Air Act Assessment Package - 1988

D O S E A N D R I S K E Q U I V A L E N T S U M M A R I E S

Non-Radon Individual Assessment
May 13, 1997 2:07 pm

Facility: Riskind benchmark test
Address:
City:
State: WA Zip:

Source Category:
Source Type: Stack
Emission Year:

Comments:

Dataset Name: Riskind 20m
Dataset Date: May 12, 1997 9:46 am
Wind File: WNDFILES\D4FRMN.WND

May 13, 1997 2:07 pm

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Selected Individual (mrem/y)
GONADS	8.20E+01
BREAST	7.63E+01
R MAR	7.00E+01
LUNGS	7.45E+01
THYROID	7.99E+01
ENDOST	1.13E+02
RMNDR	7.01E+01
EFFEC	7.61E+01

PATHWAY EFFECTIVE DOSE EQUIVALENT SUMMARY

Pathway	Selected Individual (mrem/y)
INGESTION	1.41E+01
INHALATION	3.99E+00
AIR IMMERSION	9.02E-03
GROUND SURFACE	5.80E+01
INTERNAL	1.81E+01
EXTERNAL	5.80E+01
TOTAL	7.61E+01

NUCLIDE EFFECTIVE DOSE EQUIVALENT SUMMARY

Nuclide	Selected Individual (mrem/y)
CO-60	2.42E+01
SR-90	2.14E-01
CS-134	1.72E+00
CS-137	1.08E+01
BA-137M	3.60E+01
PU-238	9.23E-01
PU-239	1.16E-01
PU-240	1.66E-01
PU-241	4.28E-01
AM-241	9.39E-01
CM-244	5.13E-01
TOTAL	7.61E+01

CANCER RISK SUMMARY

Cancer	Selected Individual Total Lifetime Fatal Cancer Risk
LEUKEMIA	2.13E-04
BONE	1.40E-05
THYROID	3.63E-05
BREAST	2.98E-04
LUNG	3.58E-04
STOMACH	1.92E-04
BOWEL	9.43E-05
LIVER	2.33E-04
PANCREAS	1.35E-04
URINARY	8.28E-05
OTHER	1.65E-04
TOTAL	1.82E-03

PATHWAY RISK SUMMARY

Pathway	Selected Individual Total Lifetime Fatal Cancer Risk
INGESTION	3.65E-04
INHALATION	6.36E-05
AIR IMMERSION	2.17E-07
GROUND SURFACE	1.39E-03
INTERNAL	4.29E-04
EXTERNAL	1.39E-03
TOTAL	1.82E-03

NUCLIDE RISK SUMMARY

Nuclide	Selected Individual Total Lifetime Fatal Cancer Risk
CO-60	6.09E-04
SR-90	3.60E-06
CS-134	4.36E-05
CS-137	2.83E-04
BA-137M	8.63E-04
PU-238	7.85E-06
PU-239	9.08E-07
PU-240	1.30E-06
PU-241	1.63E-06
AM-241	4.79E-06
CM-244	3.31E-06
TOTAL	1.82E-03

INDIVIDUAL EFFECTIVE DOSE EQUIVALENT RATE (mrem/y)
(All Radionuclides and Pathways)

	Distance (m)						
Direction	100	200	300	400	500	600	700
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	2.2E+00	5.6E+01	7.6E+01	6.9E+01	5.7E+01	4.7E+01	3.8E+01
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

	Distance (m)						
Direction	800	900	1000	2500	5000	10000	20000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	3.2E+01	2.7E+01	2.3E+01	5.5E+00	1.9E+00	6.6E-01	2.3E-01
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

INDIVIDUAL EFFECTIVE DOSE EQUIVALENT RATE (mrem/y)
(All Radionuclides and Pathways)

	Distance (m)					
Direction	30000	40000	50000	60000	70000	80000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	1.2E-01	7.7E-02	5.4E-02	4.1E-02	3.2E-02	2.6E-02
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

INDIVIDUAL LIFETIME RISK (deaths)
(All Radionuclides and Pathways)

	Distance (m)						
Direction	100	200	300	400	500	600	700
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	5.2E-05	1.3E-03	1.8E-03	1.6E-03	1.4E-03	1.1E-03	9.2E-04
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

	Distance (m)						
Direction	800	900	1000	2500	5000	10000	20000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	7.6E-04	6.4E-04	5.4E-04	1.3E-04	4.5E-05	1.6E-05	5.4E-06
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

INDIVIDUAL LIFETIME RISK (deaths)
(All Radionuclides and Pathways)

	Distance (m)					
Direction	30000	40000	50000	60000	70000	80000
N	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WNW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
W	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
WSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SSW	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
S	2.9E-06	1.9E-06	1.3E-06	9.7E-07	7.6E-07	6.2E-07
SSE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
SE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ESE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
E	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
ENE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
NNE	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

APPENDIX C:

DEFINITIONS OF VARIABLES PRESENTED IN THE SPREADSHEET CALCULATIONS

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DEFINITIONS OF VARIABLES PRESENTED IN THE SPREADSHEET CALCULATIONS

Δh	Plume rise (m).
$\lambda(i)$	Radioactive decay constant for radionuclide i (1/yr).
$\lambda_b(i,j,k)$	Biological removal constant for radionuclide i in subcompartment j of organ k (1/d).
λ_g	Rate constant for environmental loss (1/yr).
$\lambda_m(i,j,k)$	Minimum decay constant (longest half-life) of radionuclide i from all subcompartments j from organ k (1/d); minimum value of $\lambda_b(i,j,k)$ over all j.
λ_r	Resuspension decay constant (1/yr).
λ_{Ve}	Effective decay constant, accounts for radioactive decay and weathering losses (1/d).
λ_{Vw}	Decay constant for weathering losses (1/d).
$\lambda_w(x,y)$	Water exchange rate for water body at location x,y (1/yr).
ρ	Effective surface density of the soil (kg/m^2).
σ_θ	Pasquill-Gifford dispersion parameter (unitless).
σ_y	Effective horizontal dispersion coefficient adjusted for initial puff size and buoyancy-induced dispersion (m).
σ'_y	Horizontal dispersion coefficient adjusted for initial puff size (m).
σ_{y0}	Initial value for the horizontal dispersion coefficient at the source location (m).
σ_z	Effective vertical dispersion coefficient adjusted for initial puff size and buoyancy-induced dispersion (m).
σ'_z	Vertical dispersion coefficient adjusted for initial puff size (m).
σ_{z0}	Initial value for the vertical dispersion coefficient at the source location (m).
Ψ	Angle subtended by the centerline and the edge of the cask, as viewed by the receptor (rad).
a	Briggs or Pasquill-Gifford dispersion parameter.
a(i,j,k)	Fraction of radionuclide i originally absorbed in subcompartment j of organ k (unitless).
A_{ig}	Fitted coefficients (i = 0 to 7) in the empirical formula for the shipping package gamma dose rate curve (unitless).
A_{in}	Fitted coefficients (i = 0 to 7) in the empirical formula for the shipping package neutron dose rate curve (unitless).

ALPHA	Cask impact angle. The impact angle is the angle between the cask velocity (the direction along which the cask is traveling) and the plane of the surface struck (degree).
b	Briggs or Pasquill-Gifford dispersion parameter.
$B_v(i)$	Soil-to-plant transfer factor for radionuclide i (unitless).
BR	Breathing rate for the receptor (m^3/yr).
c	Briggs or Pasquill-Gifford dispersion parameter.
$C_a(i,x,y)$	Time-integrated ground-level air concentration for radionuclide i (Ci-s/m^3).
$C_{bI}(i,T)$	Concentration in meat for radionuclide i from initial deposition on vegetation (Ci/kg).
$C_{bLT}(i,T)$	Time-integrated concentration in meat for radionuclide i, excluding from initial deposition on vegetation (Ci-s/kg).
$C_g(i,x,y,T)$	Time-integrated ground concentration of radionuclide i at receptor location x,y at time T following a release (Ci-s/m^2).
$C_{mI}(i,T)$	Concentration in milk for radionuclide i from initial deposition on vegetation (Ci/kg).
$C_{mLT}(i,T)$	Time-integrated concentration in milk for radionuclide i, excluding from initial deposition on vegetation (Ci-s/kg).
$C_r(i,x,y,T)$	Time-integrated resuspended air concentration of radionuclide i at receptor location x,y after time T following release (Ci-s/m^3).
$C_{Vdep}(i)$	Vegetation concentration of radionuclide i at location x,y from direct deposition from the passing plume (Ci/kg).
$C_{VIt}(i,x,y,T)$	Long-term time-integrated vegetation concentration of radionuclide i at receptor location x,y after time T following release, excluding direct deposition (Ci-s/kg).
$C_w(i,x,y,T)$	Time-integrated radionuclide i concentration in water body at location x,y at time T after puff passage (Ci-yr/m^3).
CF_b	Fraction of consumed meat that is contaminated (unitless).
CF_m	Fraction of consumed milk that is contaminated (unitless).
CF_v	Fraction of consumed vegetables that are contaminated (unitless).
CF_w	Fraction of consumed water that is contaminated (unitless).
d	Receptor distance from cask surface for shape factor correction (m).
D	Reference distance (1 or 2 m) for shape factor correction calculations (m).
$\frac{\partial T_a}{\partial z} + \ell$	Potential temperature lapse rate [0.002 and 0.035 for stability classes E and F respectively] (K/m).
D_{AirLT}	Dose to receptor from long-term external radiation exposure from resuspended contamination (rem).

D_{AirST}	External dose to receptor from air submersion during plume passage (rem).
$D_{50,B}(k)$	Median lethal dose , brief dose to organ k that produces the effect of interest in 50% of the population at risk (Gy).
$D_{50,P}(k)$	Median lethal dose, protracted dose to organ k that produces the effect of interest in 50% of the population at risk (Gy).
$D_B(i)$	Brief dose to organ i (i = bone, GI, or lung) (Gy).
D_{GndLT}	Dose to receptor from long-term external radiation exposure from ground contamination (rem).
D_{GndST}	Short-term external dose from ground-deposited contamination (rem).
D_{InhLT}	Dose to receptor from long-term inhalation of resuspended contamination (rem).
D_{InhST}	Short-term dose to receptor from inhalation during plume passage (rem).
$D_{MeatLT}(i)$	Long-term dose to receptor from ingestion of meat contaminated with radionuclide i, excluding that from initial deposition (rem).
$D_{MeatST}(i)$	Short-term dose to receptor from ingestion of meat contaminated with radionuclide i (rem).
$D_{MilkLT}(i)$	Long-term dose to receptor from ingestion of milk contaminated with radionuclide i, excluding that from initial deposition (rem).
$D_{MilkST}(i)$	Short-term dose to receptor from ingestion of milk contaminated with radionuclide i (rem).
$D_P(i)$	Protracted dose to organ i (i = bone, GI, or lung) (Gy).
D_{VegLT}	Long-term dose to receptor from ingestion of contaminated vegetables (rem).
D_{VegST}	Short-term dose to receptor from ingestion of contaminated vegetables (rem).
D_{Water}	Dose to receptor from ingestion of contaminated water (rem).
$DCF_{Air}(i)$	Dose conversion factor for air submersion for radionuclide i (Sv/Bq-s/m^3).
$DCF_{Gnd}(i)$	Dose conversion factor for external radiation from the ground for radionuclide i (Sv/Bq-s/m^2).
$DCF_{Ing}(i)$	Dose conversion factor for ingestion for radionuclide i (Sv/Bq).
$DCF_{Inh}(i)$	Dose conversion factor for inhalation for radionuclide i (Sv/Bq).
DF	Decontamination factor, that is, the fraction of contamination remaining on vegetation after food preparation at time of consumption (unitless).
$DR_B(i)$	Average brief dose rate to organ i (i = bone, GI, or lung) (Gy/h).
$DR_i(r)$	Dose rate (mrem/h) from gamma radiation (i = g), neutron radiation (i = n), or both (i = 0 for the reference cask [before shape factor correction], i = 1 after shape factor correction) at a distance r meters from the cask surface.
$DR_P(i)$	Average protracted dose rate to organ i (i = bone, GI, or lung) (Gy/h).

E_p	Release elevation, reference point for the release height (0 m).
E_r	Receptor elevation (m).
E_{Vk}	Fraction of foliar deposition reaching edible portions of vegetation type k (for human consumption, k = h, or pasture grass for animal consumption, k = a) (unitless)
E_w	Water treatment efficiency, fraction of contamination removed by water treatment facilities before use (0 = no contamination removed, 1 = all contamination removed) (unitless).
f_i	Fraction of total dose rate due to gamma (i = g) or neutron (i = n) radiation where $f_g + f_n = 1$.
$F(\Psi,k)$	$\int_0^{\Psi} (1 - k^2\sin^2\theta)^{-1/2} d\theta$, (rad).
$F_a(x,y)$	Fraction of the water body at location x,y covered by the passing puff, assumes puff travels full distance across the water body in the downwind direction (unitless), where $F_a(x,y) = \begin{cases} 1 \text{ , if } F_W(x,y) \geq 1 \\ F_W(x,y) \text{ , if } F_W(x,y) < 1 \end{cases}$
$F_b(i)$	Feed-to-meat transfer factor for radionuclide i (Ci/kg per Ci/d).
$F_m(i)$	Feed-to-milk transfer factor for radionuclide i (Ci/kg per Ci/d).
F_r	Fraction of deposition retained on the plant (unitless).
$F_w(x,y)$	When less than 1, fraction of the water body at location x,y covered by the passing puff, assumes puff travels full distance across the water body in the downwind direction (unitless).
FE	Final value of the resuspension factor (1/yr).
FI	Initial value of the resuspension factor for fresh deposits (1/m).
h	Physical release height (m).
H	Effective release height (m).
$H_A(k)$	Lethality hazard for organ k (unitless).
HSIZE	Length of user cask (m).
l	Normal adiabatic lapse rate of the atmosphere (0.0098 K/m).
L	Mixing layer height sometimes referred to as lid height (m).
L_0	Length of reference cask (m).
L_1	Length of user cask (m).
OF_{in}	Fraction of time spent indoors (unitless).

OF_{out}	Fraction of time spent outdoors (unitless).
p	Power for height ratio (unitless).
P_c	Plume-path coefficient (unitless).
Q(d)	Shape factor correction. Ratio of the external dose rates at a distance d meters from the surfaces of the new cask and the reference cask (unitless).
Q_a	Animal feed ingestion rate (kg/d).
Q_h	Heat flux from radionuclide release area (cal/s).
Q_{xi}	Depleted source strength of nuclide i at distance x (Ci).
r	Distance in meters from the cask surface; $r = r_0 + r_1$, where r_0 is the distance from the outer lateral surface of the vehicle and r_1 is the distance between the cask surface and the outer lateral surface of the vehicle.
R_0	Radius of reference cask (m).
R_1	Radius of user cask (m).
R(i,k,t)	Time-integrated retention of radionuclide i in organ k after time t (unitless).
RSIZE	Radius of user cask (m).
s	Stability parameter (s^{-2}).
SF_{AirLT}	Long-term shielding factor for air immersion, from 0 for full shielding to 1 for no shielding (unitless).
SF_{AirST}	Short-term shielding factor for air immersion, from 0 for full shielding to 1 for no shielding (unitless).
SF_{GndLT}	Long-term shielding factor for external ground radiation, from 0 for full shielding to 1 for no shielding (unitless).
SF_{GndST}	Short-term shielding factor for external ground radiation, from 0 for full shielding to 1 for no shielding (unitless).
SF_{InhLT}	Long-term shielding factor for resuspended contaminant inhalation, from 0 for full shielding to 1 for no shielding (unitless).
SF_{InhST}	Short-term shielding factor for inhalation, from 0 for full shielding to 1 for no shielding (unitless).
SF_{kAir}	Shielding factor afforded by shelter type k for air immersion (unitless).
SF_{kGnd}	Shielding factor afforded by shelter type k for external ground radiation (unitless).
SF_{kInh}	Shielding factor afforded by shelter type k for inhalation (unitless).
t_{Vk}	Time duration for growing season for vegetation type k (for human consumption, k = h, or pasture grass for animal consumption, k = a) (d).

t_1	Time since exposure; smaller of 1 d or the estimated half-life of a given radionuclide in the organ of interest for brief exposures, or the smaller of organ specific retention times or the estimated half-life of a given radionuclide in the organ of interest for protracted exposures (d).
t_2	Time since exposure, smaller of 365 d or estimated half-life of a given radionuclide in the organ of interest (d).
T	Time following accidental release (yr).
T_a	Ambient air temperature (K) in plume rise calculations.
T_a	For resuspension calculations, time required for the resuspension factor to decrease from its initial to final value (yr); $t = T_a$ when: $FE = FI \exp(-\lambda_r T_a)$
$T_b(i,j,k)$	Biological half-life of radionuclide i in subcompartment j of organ k (d).
T_{Ext}	Short-term exposure time for receptor after plume passage (h).
T_{Vk}	Time from accidental release to first harvest of vegetation type k (for human consumption, k = h, or pasture grass for animal consumption, k = a) (d).
U_a	Wind speed at measurement height (m/s).
U_b	Human consumption rate of meat (kg/d).
U_H	Average wind speed at the effective release height (m/s).
U_m	Human consumption rate of milk (kg/d).
U_V	Human consumption rate of vegetables (kg/d).
U_w	Human consumption rate of water (L/d).
V	Shape parameter for lethality risk calculations (unitless).
V_d	Deposition velocity (m/s).
VCASK	Speed of the cask at the time of impact (miles per hour or mph).
$W_c(x,y)$	Cross-wind width of the water body at location x,y (m).
$W_d(x,y)$	Effective mixing depth of the water body at location x,y (m).
x	Downwind receptor distance from the accident release point (m).
X(k)	Ratio of acute dose to organ k to the median lethal dose ($D_{50}(k)$) to organ k (unitless).
$X_B(k)$	Ratio of the brief acute dose to organ k to the brief median lethal dose ($D_{50,B}(k)$) to organ k (unitless).
$X_P(k)$	Ratio of the protracted acute dose to organ k to the median lethal dose ($D_{50,P}(k)$) to organ k (unitless).
x_{Yvirt}	Virtual distance from source location to virtual point source for σ_y calculation (m).
x_{Zvirt}	Virtual distance from source location to virtual point source for σ_z calculation (m).

y	Crosswind distance from the plume centerline (m).
Y_{Vk}	Yield density of vegetation type k (for human consumption, k = h, or pasture grass for animal consumption, k = a) (kg/m^2).
z	Vertical distance above the release point (m).
z_a	Height of anemometer for wind speed measurement (m).