

SANDIA REPORT

SAND2013-8095

Unlimited Release

Printed September 2013

RADTRAN 6/RadCat 6 User Guide

Ruth F. Weiner, Daniel Hinojosa, Terence J. Heames,
Cathy Ottinger Farnum, Elena A. Kalinina

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.



Sandia National Laboratories

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represent that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof, or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-Mail: reports@adonis.osti.gov
Online ordering: <http://www.osti.gov/bridge>

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Rd.
Springfield, VA 22161

Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-Mail: orders@ntis.fedworld.gov
Online order: <http://www.ntis.gov/help/ordermethods.asp?loc=7-4-0#online>



SAND2013-8095
Unlimited Release
Printed September 2013

RADTRAN 6/RadCat 6 User Guide

Ruth F. Weiner, Daniel Hinojosa, Terence J. Heames,
Cathy Ottinger Farnum, Elena A. Kalinina
Transportation and Environmental Safety Department
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-0718

ABSTRACT

This document provides a detailed discussion and a guide for the use of the RadCat 6.0 Graphical User Interface input file generator for the RADTRAN code, Version 6. RadCat 6.0 integrates the newest analysis capabilities of RADTRAN 6.0, including an economic model, updated loss-of-lead shielding model, a new ingestion dose model, and unit conversion. As of this writing, the RADTRAN version in use is RADTRAN 6.02.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the management support of the Offices of Environmental Management and Nuclear Energy of the U. S. Department of Energy. We owe particular thanks to Michael Wangler, Corinne Macaluso, and Jeff Williams of the U. S. Department of Energy.

The authors would also like to acknowledge the management support of Shawn P. Burns, Jeffrey J. Danneels, David R. Miller, and Ken B. Sorenson at Sandia National Laboratories. In addition, the following individuals contributed significantly to earlier versions of this document:

Matthew L. Dennis
Michelle K. Marincel
G. Scott Mills
Douglas M. Osborn
Brandon M. O'Donnell
David Orcutt
Janelle J. Penisten
Danielle A. Worthy

Finally, this User Guide is incalculably indebted to Sieglinde Neuhauser, who first made RADTRAN available to the radioactive materials transportation community.

TABLE OF CONTENTS

1. WELCOME TO RADTRAN/RADCAT	11
2. ORGANIZATION OF THIS USER GUIDE	11
3. DOWNLOADING AND CHECKING FOR THE LATEST VERSION.....	11
4. RUNNING RADTRAN WITH RADCAT	13
4.1 Importing RADTRAN 5 Files	13
4.2 Saving An Input File.....	14
4.3 Generating An Input File With RadCat	15
4.3.1 New	15
4.3.2 Preferences (Unit Conversion).....	16
4.3.3 Entering Data	17
4.3.4 Title	17
4.3.5 Remarks	17
4.3.6 Incident-Free and Accident Options	18
4.3.7 Output Level	18
4.3.8 Health Effects.....	19
4.3.9 Ingestion Dose Model	19
5. PACKAGE.....	19
5.1 Name.....	20
5.2 Long Dimension.....	20
5.3 Dose Rate	20
5.4 Gamma and Neutron Fractions	21
6. RADIONUCLIDES	21
6.1 Adding Radionuclides from the Internal Library	22
6.2. Adding User-Defined Radionuclides.....	23
7. VEHICLE	24
7.1 Vehicle Name.....	25
7.2 Number of Shipments	25
7.3 Vehicle Size	25
7.4 Vehicle Dose Rate.....	25
7.5 Gamma and Neutron Fractions	26
7.6 Crew Size	27
7.7 Crew Distance.....	27

7.8 Crew Shielding Factor	27
7.9 Crew View	27
7.10 Exclusive Use.....	28
8. LINK	28
8.1 Link Name	30
8.2 Vehicle	31
8.3 Length	31
8.4 Speed.....	31
8.5 Population Density.....	32
8.6 Vehicle Density.....	33
8.7 Persons per Vehicle (Vehicle Occupancy)	34
8.8 Accident Rate (How RADTRAN Analyzes Accidents)	34
8.9 Fatalities per Accident	34
8.10 Population Zone	35
8.11 Road Type.....	36
8.12 Farm Fraction and State	36
9.STOPS	37
9.1 Name	37
9.2 Vehicle	37
9.3 Minimum and Maximum Distances and People or People/km ²	37
9.4 Shielding Factor	39
9.5 Time	39
10. HANDLING	39
11.ACCIDENTS	41
11.1 Conditional Probabilities (Severity Fractions).....	42
11.2 Deposition Velocity	44
11.3 Release Fraction.....	45
11.4 Aerosol Fraction.....	46
11.5 Respirable Fraction	48
11.6 Isopleth P	49
11.7 Weather.....	50
11.7.1 The Average Option.....	51
11.7.2 The Pasquill Option	52
11.7.3 The User-Defined Option	53
12.PARAMETERS.....	56
13.LOSS OF LEAD SHIELDING (LOS)	65

13.1 LOS probability	65
13.2 Loss Of Shielding Event	67
14.ECONOMIC MODEL	69
15.RADTRAN OUTPUT	70
16.SAVING, RUNNING RADTRAN, EXITING	75
17.REFERENCES	77
APPENDIX A. A SPECIAL CASE	81
APPENDIX B. VARIABLE NAMES IN RADTRAN	83
APPENDIX C. DOSE CONVERSION FACTORS.....	91
APPENDIX D. HIGHWAY VEHICLE DENSITIES	102
APPENDIX E. RADTRAN OUTPUT	113

TABLES

Table 1 Historic and SI units and conversions.....	16
Table 2. State truck speed limits (National Motorists Association, 2012)* .	32
Table 4. Severity and release fractions for rail-transported, uncanistered PWR spent fuel (adapted from NRC, 2013) .	43
Table 5. Severity and release fractions for truck-transported PWR spent fuel (adapted from DOE, 2002b) .	43
Table 6: Pasquill Wind Speeds for Each Stability Class	52
Table 7. Sample conditional probabilities and LOS fractions (adapted from NRC (2013, Table E-2)	66
Table B-1. Flag chart and default values	83
Table B-2: Definitions for Input to the RISKIND Dispersion Model	89
Table B-2: Economic Model Default Values.....	90
Table D-1: Historical Values Used for Traffic Density in RADTRAN Calculations	102
Table D-2: United States Divided into 10 EPA Regions.....	105
Table D-3: State-by-State Traffic Densities Divided into Population Density Zones— Interstate Highways	106
Table D-4: State-by-State Traffic Densities Divided into Population Density Zones—U.S. Highways	107
Table D-5: Average Regional Traffic Densities Divided into Population Density Zones— Interstate Highways	109
Table D-6: Average Regional Traffic Densities Divided into Population Density Zones— U.S. Highways	110
Table D-7: National Average Traffic Densities Divided into Population Density Zones— Interstate Highways	111
Table D-8: National Average Traffic Densities Divided into Population Density Zones— U.S. Highways	111

FIGURES

Figure 1: Proxy and Port Settings	12
Figure 2. File pull-down menu.....	14
Figure 3. Saving a file.....	15
Figure 4: Mode selection	16
Figure 5. Unit Conversion.....	17
Figure 6: Title tab showing output options.	18
Figure 7: Package tab.....	21
Figure 8: Radionuclides tab.	22
Figure 9: Radionuclides tab with user defined radionuclides window	23
Figure 10. Vehicle tab.....	26
Figure 11: Vehicle tab continued.....	28
Figure 12. A possible truck route from Idaho Falls, ID to Albuquerque, NM.	29
Figure 13: Interstate Truck Route.	30
Figure 14: Link tab.....	33
Figure 14a: Link tab -- continued	36
Figure 15. Truck Stop Model.....	39
Figure 16: Stop Tab	40
Figure 17: Handling Tab.....	41
Figure 18. Truck Event Tree (from Mills, et al., 2006)	42
Figure 19: Accident/probability tab	44
Figure 20: Accident/deposition velocity tab	45
Figure 21: Accident/release tab	46
Figure 22: Accident/aerosol tab	47
Figure 23: Accident/respirable tab.....	48
Figure 24: Accident/isopleth P tab.....	50
Figure 25. Accident/weather tab with user-defined dispersion option	51
Figure 26. Accident/weather tab with national average weather option.....	52
Figure 27. Accident/weather tab with Pasquill option.....	53
Figure 28: Accident/weather tab with user-defined option.....	55
Figure 29: Parameters tab for highway mode	58
Figure 30: Parameters Tab with Rail Mode.....	63
Figure 31: Parameters tab with barge mode	65
Figure 32. Loss of lead shielding tab, probability	67
Figure 33. Loss of lead shielding tab, LOS event.....	69
Figure 34. Economic model default values.....	70
Figure 35. Run RADTRAN	71
Figure 36. End of RADTRAN Output.....	72
Figure 37. Accident output.	73
Figure 38. Graphical output.	74
Figure 39. Graphical output property changes.....	75
Figure 41: Saving a RadCat Input File	76
Figure A-1. Diagram for the on-link dose on a highway that parallels a rail route	81

ACRONYM LIST

CFR	Code of Federal Regulations
DCF	Dose conversion factor
DOE	[U.S.] Department of Energy
DOT	[U.S.] Department of Transportation
EPA	[U.S.] Environmental Protection Agency
GIS	Geographic Information System
GUI	Graphical user interface
ICRP	International Commission on Radiation Protection
ISCORS	Interagency Standing Committee on Radiation Safety
JRE	Java Runtime Environment
LCF	Latent cancer fatalities
LOS	Loss of shielding
MEI	Maximally exposed individual
NRC	[U.S.] Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PC	Personal computer
SI	Standard International [units]
SNL	Sandia National Laboratories

1. WELCOME TO RADTRAN/RADCAT

RADTRAN is an internationally accepted program and code for calculating the risks of transporting radioactive materials. The first versions of the program, RADTRAN I and II, were developed for NUREG-0170 (NRC, 1977), the first environmental statement on transportation of radioactive materials. RADTRAN and its associated software have undergone a number of improvements and advances consistent with improvements in both available data and computer technology.

RadCat is a Graphical User Interface (GUI) which generates an input file for RADTRAN. The version of RADTRAN currently bundled with RadCat 6 is RADTRAN 6.

2. ORGANIZATION OF THIS USER GUIDE

This User Guide provides step by step instructions for creating an input file using RadCat. The topics in the Table of Contents reflect the tabs and screen names for the RadCat screens. Some details and sample input data are discussed in the appendices at the end. A very brief explanation is presented with each topic. For an in-depth discussion of the technical details of the program, anyone using RADTRAN is advised to consult the appropriate bibliographic references or (when it becomes available) the forthcoming technical Appendix.

3. DOWNLOADING AND CHECKING FOR THE LATEST VERSION

The RADTRAN/RadCat package may be downloaded from:
<https://radtran.sandia.gov/radcat>.

On the web page, click on [click here](#) and fill out the application. You will be notified by email when you are approved. When you are approved, you can click on [Download RadCat](#). You will be asked for your username, which is the email address you listed in the application.

When you sign in, you must download the Java Runtime Environment if it is not already on your computer. To do this, go to <http://www.java.com> and click on [Java Software Download](#). Download the Windows online installation. (You may want to download and read the instructions, but it isn't absolutely necessary.) The download installs the Java Runtime Environment (JRE) on your PC. The most recent version of the Runtime Environment will download to your computer. If you are on a network, you may get a message indicating that you can't install. If this happens, you will need help from your network administrator to install it, or to give you access through a firewall. If you have a firewall (like ZoneAlarm) on the computer you are using, turn it off before installing the JRE. To gain access through a network firewall you'll need the proxy access and port number as shown in Figure 1. The proxy and port settings can be obtained from your network administrator (the port is usually Port 80).

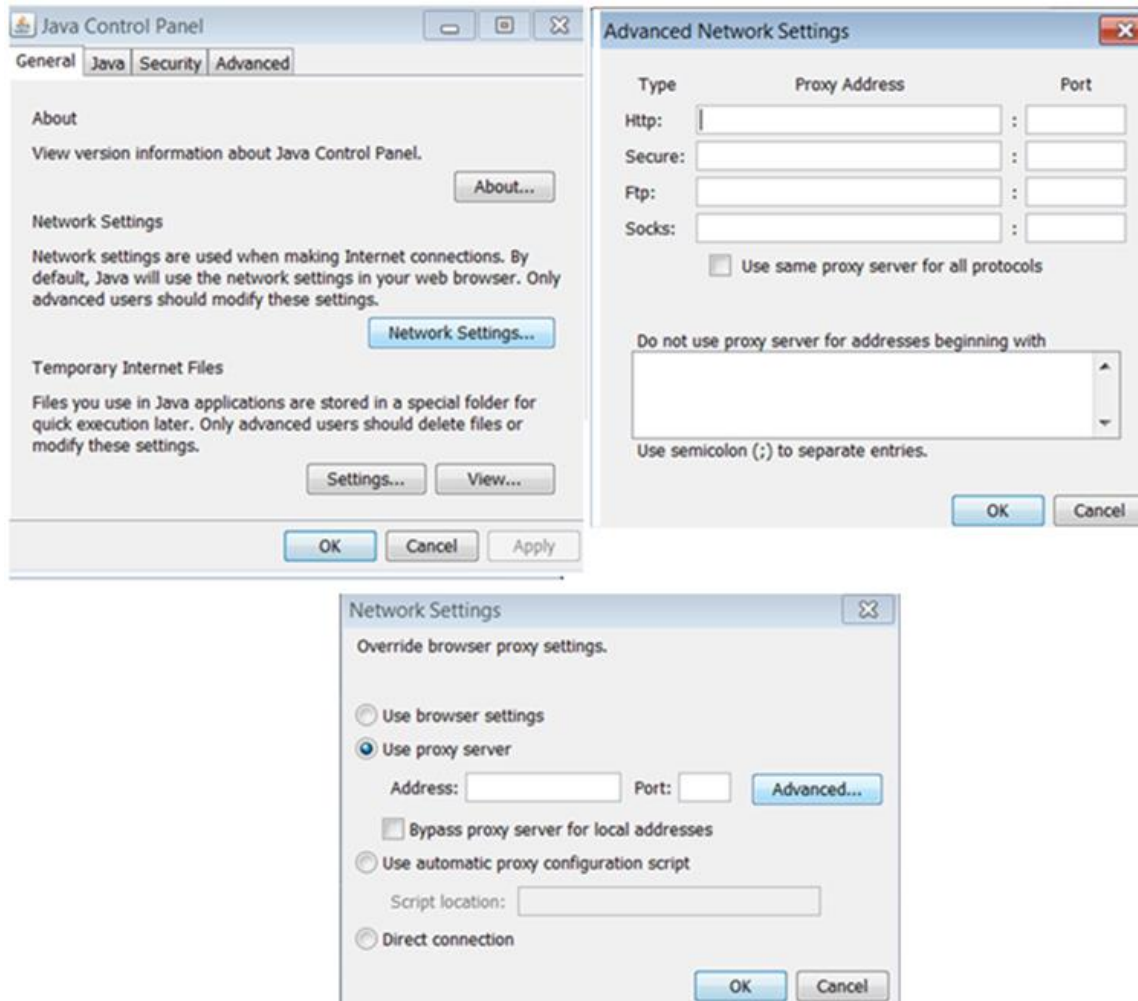


Figure 1: Proxy and Port Settings

Once JRE is installed, you can go back to [Download RadCat](#) on the Main Menu and click on [Launch the application](#) to download RadCat. When you launch RadCat (the application), you may get a notice that says there is no certificate of authenticity or that there is a risk in running the program; launch the application anyway. The process for applying for the certificate may not be complete. If you wish to put the Java Runtime Environment icon on your desktop, go to C:\Program Files\Java, open the *bin* folder, find the coffee cup javacpl.exe icon, and copy the icon or create a shortcut to your desktop. To access RadCat from the Java Control Panel, click on “View” in the Temporary Internet Files section of the General tab.

Once you have installed JRE, you can launch RadCat either from the Java cache or from the RadCat icon. JRE maintains a cache of recent RadCat downloads with the associated date of download. To view the cache or start RadCat from the cache, go to C:\Program Files\Java\, open the bin folder, and click on the coffee cup javacpl.exe icon. The Java Control Panel dialog box will open. Click on “View” in the Temporary Internet Files

section of the General tab and the Java Cache Viewer will open and show your cached RadCats. If you have difficulty downloading, try emptying your cache. If you want to download the latest version, go back to <https://radtran.sandia.gov/radcat> and click on Download RadCat. You may see more than one version of RadCat. The latest version is RadCat 6. RadCat 3 does not include all of the most recent features, but does include the basic RadCat. RadCat 2.3 is bundled with an obsolete version of RADTRAN and should not be used. Click on Launch the application, and the latest version will be downloaded.

When RADTRAN/RadCat is downloaded, the RADTRAN 6 executable is downloaded to c:/users/your computer username/radcat along with the text files used by RADTRAN.

RADTRAN 6.02 will expire automatically two years after download. If the RADTRAN that you have downloaded expires, simply reapply and you will be given a different password and can download again. Earlier versions of RADTRAN do not contain the latest enhancements and will gradually become obsolete, even though you can continue to use them.

4. RUNNING RADTRAN WITH RADCAT

RadCat will only **open** “*.rml” files. If you are using a “*.in5” or “.input” file, **import** the file instead of opening it (see Section 4.1). Please note that a file using more than one transportation mode (e.g., both truck and rail in a single file) will not open in RadCat. RadCat will only open files that have only one transportation mode and can run only one mode at a time. RadCat 6 will open files created with RadCat 3.0, but these files do not include all of the features in RadCat 6.

To open an existing input file with RadCat and run it, follow these steps:

1. Open RadCat.
2. In RadCat, choose the file to be run, either by using the **File** pull-down menu or by clicking on the **Open** icon. This can be seen in Figure 2. The directory will appear and you may choose the file to be run. When the file has been selected, the title of the file will appear in the **Title** space.
3. Click on the **Run RADTRAN** icon (the icon showing a computer monitor). The output file will appear and can be saved.

Versions of RADTRAN 6 earlier than RADTRAN 6.02 will open in RadCat 6 but will not provide access to the alternate ingestion dose model INGEST.

4.1 Importing RADTRAN 5 Files

RadCat has the ability to import RADTRAN 5 input files and convert them to be run by RADTRAN 6.0 or later versions. This feature can be selected from the **File** pull-down

menu by clicking on the **Import** icon. You must ensure that your input files are listed as a “*.in5,” “*.dat,” or “.input” file for RadCat to import and convert it properly.

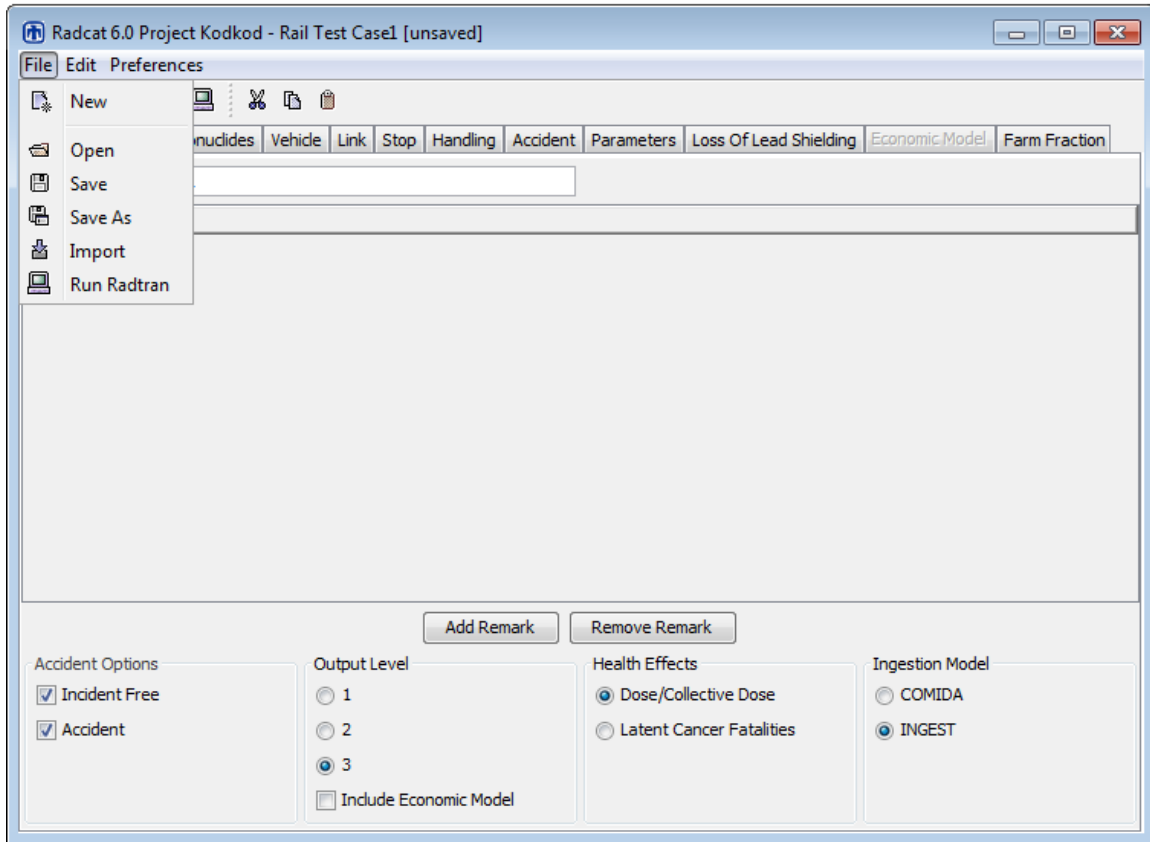


Figure 2: File pull-down menu.

4.2 Saving An Input File

An input file may be saved at any time by clicking on the **Save** icon (the floppy disk icon). The **Save As** window will open and you can save the file in the normal Windows manner. Your file should be saved as a “*filename.rml*” file, and you will need to add the “*.rml” extension to your filename when saving it. RADTRAN will run the file even if it isn’t saved. Save often.

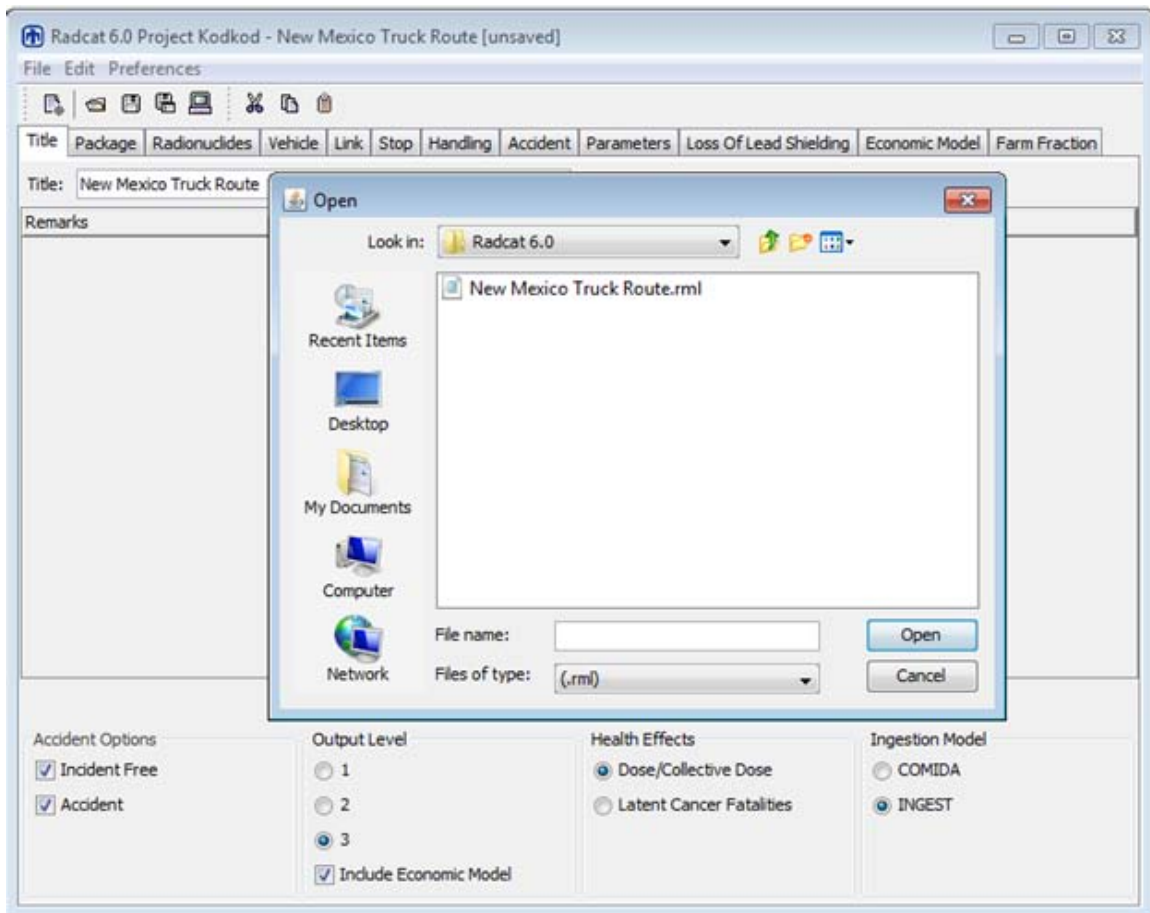


Figure 3: Saving a file

4.3 Generating An Input File With RadCat

4.3.1 New

When the **New** icon is selected to create a new file, the **Mode Selection** dialog box appears. An example of the **Mode Selection** dialog box can be seen in Figure 4. Selection of a transportation mode (highway, rail, or barge) must be made before a new file can be created. A file cannot be created in RadCat with more than one mode. The mode is selected from the pull-down menu.

If a file is already open, selecting the **New** icon will open a second Java window from which you will be able to select another transportation mode from the **Mode Selection** dialog box. This will not change or otherwise affect any of the information in the first open file.

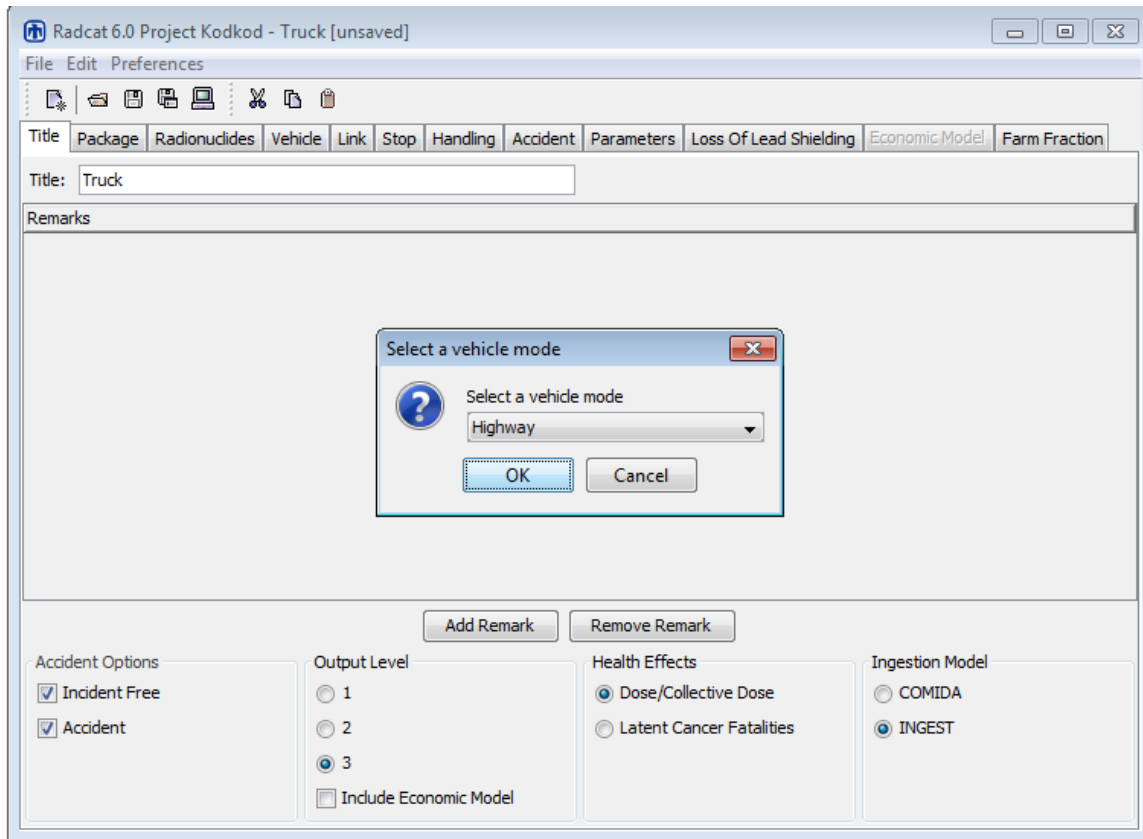


Figure 4: Vehicle Mode selection

4.3.2 Preferences (Unit Conversion)

RadCat automatically defaults to historical units, i.e. rems and curies. However, due to increased international use and the need for unit flexibility, RadCat 6 will accept for input either historical (rem, curie) or international (SI, sievert, becquerel) units, and will output either, at your discretion. If you wish to change units, you can do so only for an active file.

In the **Preferences** heading on the main toolbar, you can select **Convert Units**. This will display a dialog box that will instruct you to select **Convert to SI Mode and Change the Existing Values** or **Convert to SI mode without changing the Existing Values** (Figure 5). The first option automatically converts any historical numerical value in RadCat. The latter is meant to allow for changing unit headings in the event you accidentally enter values in SI units. Once in SI mode, you can convert back to historical units by again selecting the **Preferences, Convert Units**. Table 1 show the input and output units for the two systems:

Table 1 Historic and SI units and conversions.

Parameter	Historic Units	SI Units
Source strength	curies (Ci)	becquerel (Bq)

Conversion	1 Ci = 3.7×10^{10} Bq	1 Bq = 2.7×10^{-11} Ci*
Transferred energy	rad	gray (Gy)
Conversion	1 rad = 0.01Gy	1 Gy = 100 rad
Dose	rem	sievert (Sv)
Conversion	1 rem = 0.01Sv	1 Sv = 100 rem
Collective dose	person-rem	person-Sv

- 1 Bq = one disintegration per second

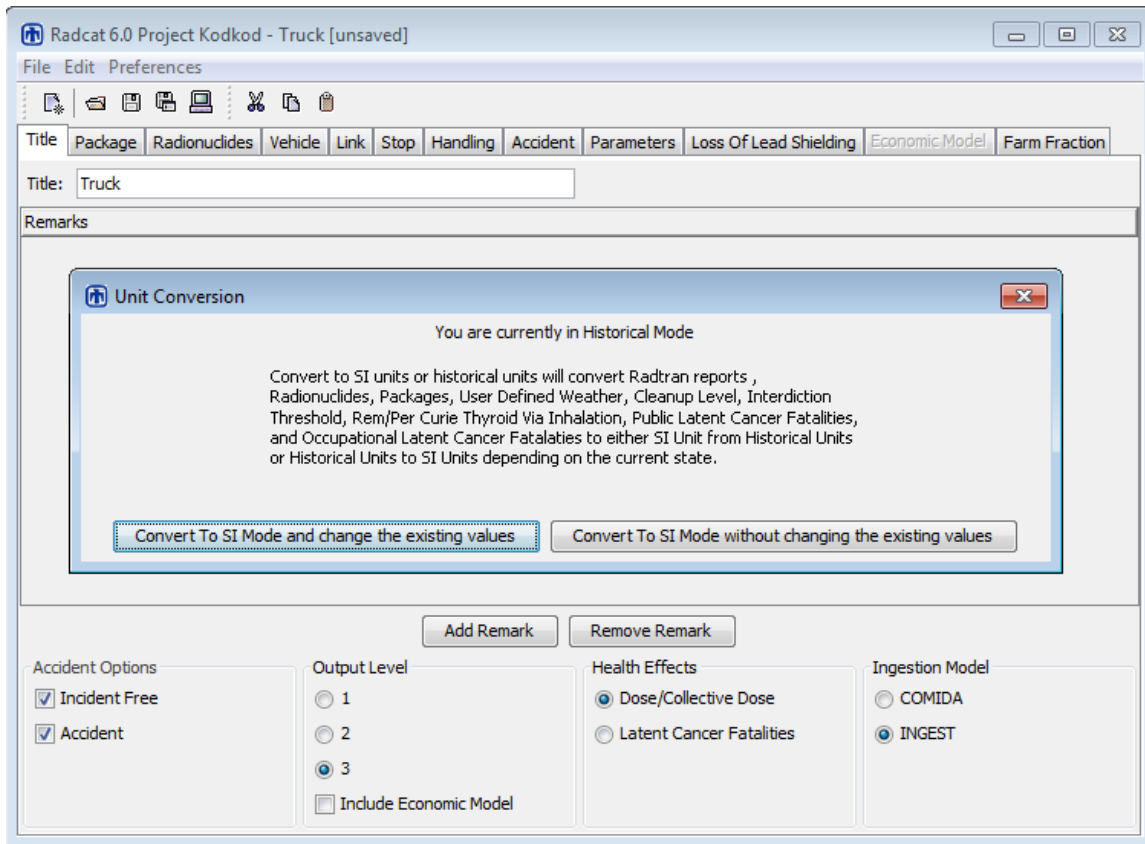


Figure 5: Unit Conversion

4.3.3 Entering Data

Whenever an entry is made on a RadCat tab, you must hit ENTER (depress the ENTER key).

4.3.4 Title

You may type any name for your file in the **Title** box and hit “ENTER” to give your file a title. Your file must have a title. The **Title** box can be seen in Figure 4.

4.3.5 Remarks

The **Remarks** screen is for you to annotate your file; e.g., give a brief description of the scenario, the sources of your input parameters, etc. When you click on **Add Remark** a line appears in the remarks screen. The word “REMARK” is on this line. You can delete it and enter your own remark. You must hit “ENTER” for your remarks to be added for each line. Click on **Add Remark** to append additional remarks. **Remarks** can be seen in Figure 6.

4.3.6 Incident-Free and Accident Options

Checking the **Incident Free** box will result in analysis of routine, incident-free transportation. Checking the **Accident** box will result in analysis of transportation accidents. Even if you only wish to have accident output, you must enter non-zero data on the **Package**, **Vehicle**, and **Link**, and **Stop** tabs. Checking both the **Incident Free** and **Accident**, boxes results in a full analysis of incident-free transportation and transportation accidents. These options can be seen in Figure 6.

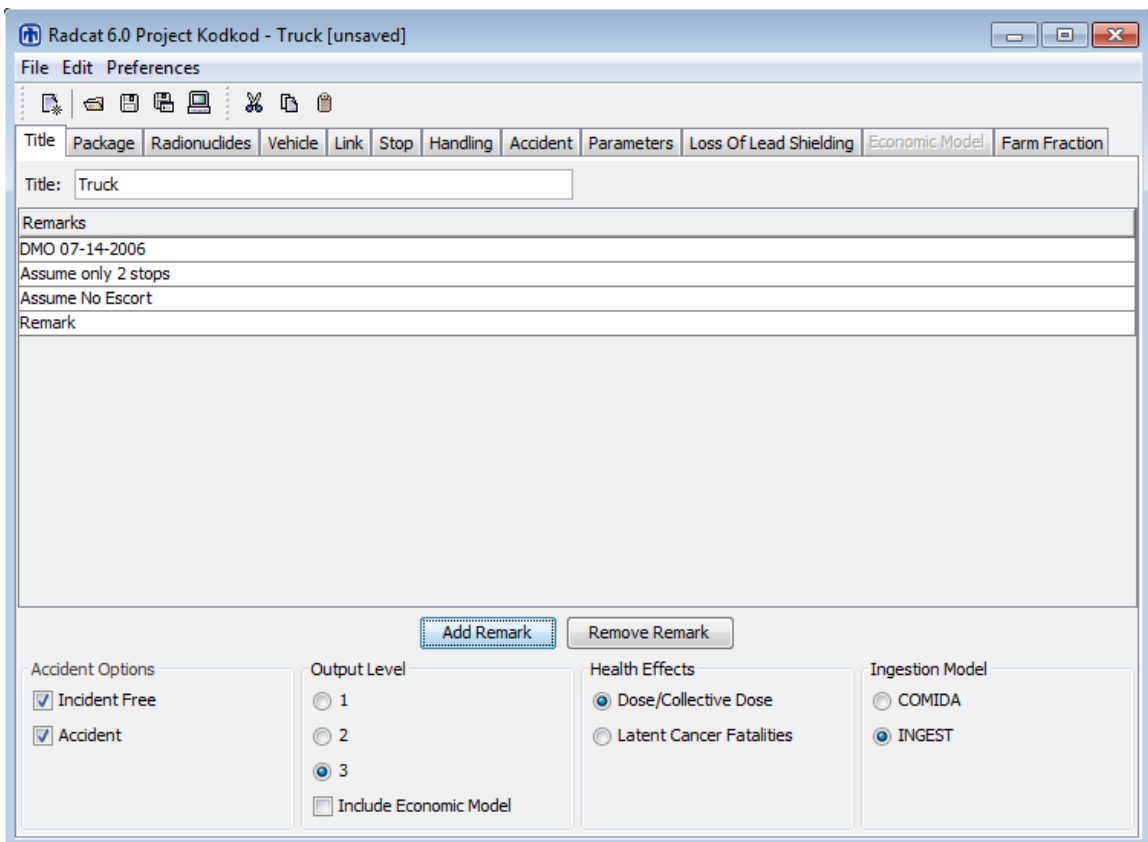


Figure 6: Title tab showing Incident Free and Accident options and outputlevel.

4.3.7 Output Level

Three options are available for controlling output size:

Short output. The input echo, incident-free, and accident and non-radiological risk tables are printed. The output file is approximately 10 pages long.

Intermediate Output. Short output plus input tables, early effects values, ground contamination tables, intermediate tables, and total expected population dose tables are printed. The output file is approximately 28 pages long.

Full Output. Intermediate output plus consequence tables and sensitivity analysis. The output file is approximately 33 pages long. This option can be seen in Figure 6. If you are importing an older file which used the four-level output, your output level will be adjusted automatically to match the new three-level output structure.

A checkbox for the **Economic Model** is included on the **Title** tab. When unchecked (as shown in Figure 6), the Economic Model Tab remains grayed out, and results from the Economic Model will not be included in the RADTRAN output. However, if the box is checked, the Economic Model Tab will become functional, allowing for default value editing and inclusion in the RADTRAN output.

4.3.8 Health Effects

Health effects may be reported in the output either as individual and collective doses or as latent cancer fatalities (LCF). RADTRAN can calculate the risk of latent cancer fatalities (LCF) by multiplying the dose by a linear conversion factor; the default factor in RADTRAN, is 6×10^{-2} LCF/Sv (6×10^{-4} LCF/rem) (DOE 2002a, ISCORS 2002). The validity of this linear conversion for small individual or average doses has been called into question (Tubiana and Aurengo, 2005; Raabe, 2011, Gonzalez, et al., 2013) and it is included only because it has been used extensively. Reporting results in units of dose rather than LCF¹ is encouraged.

4.3.9 Ingestion Dose Model

RADTRAN calculates ingestion dose by two different models, COMIDA and INGEST. COMIDA (Abbott and Rood, 1993) and the new model, INGEST (Weiner and Heames, 2013). INGEST uses state specific food transfer factors. Select the ingestion dose model you wish to use. If you select **INGEST**, be aware that it only works with **User-Defined Weather** (Section 11 – Accidents) and will not work with either of the other **Weather** options. COMIDA works with all **Weather** options.

5. PACKAGE

When making a new input file or adding or deleting a package in an existing file, select the **Package** tab. When editing an existing file without adding or deleting a package, the

¹ Use of a linear conversion factor has been the subject of skepticism for some time. The papers by Tubiana and Aurengo and Gonzalez et al. present a summaries and reviews of peer-reviewed molecular biologic and epidemiologic studies that support this skeptical view.

order in which the tabs are opened will not make any difference. This can be seen in Figure 6.

5.1 Name

Give your package a name in the left-hand column. You may delete “PACKAGE_1” and substitute any name that you like. A package name must be a continuous text string and may not contain any spaces.

If you wish to transport more than one package, click the **Add Package** bar and add as many packages as you wish. You can give your added packages any names that you want to give them. You will be adding packages to vehicles in a later tab. The package tab can be seen in Figure 7. RadCat 6 includes some spreadsheet functionality; cells can be copied to a new location using the copy and paste icons at the top of the GUI, the pull-down “Edit” menu, or CTRL+C and CTRL+V. A line can be copied to another line, but cannot be copied where no line exists. Lines can be added or deleted only with the buttons at the bottom of the tab.

List all the packages that you will want for this run on this tab. You can add or delete packages only on this tab; you cannot add them or delete them from other tabs.

5.2 Long Dimension

Enter the largest dimension of the package in meters, e.g. length of a cylinder if larger than the diameter. In RADTRAN literature, for historical reasons, this dimension is called the “critical dimension,” although it is not critical in the sense of nuclear criticality.

5.3 Dose Rate

Enter the external dose rate at one meter from the package surface, in units of mrem/hr or Sv/hr. External dose rate can often be obtained by measurement or from the cask Safety Analysis Report (SAR), or can be estimated by calculating package shielding. The regulations of 10 CFR Part 71 specify that the external dose rate *at two meters* from the package surface should not exceed 10 mrem/hour. This is equivalent to about 14 mrem/hr at one meter from the package surface for a “critical dimension” of about 5 meters. The package parameters, including dose rate, are shown in Figure 7.

The **Parameters** tab (Section 12) includes a flag that reads “Imposed regulatory limit on vehicle external dose.” When the flag is on, a regulatory constraint is imposed on the shipment. Selecting **YES** will cause RADTRAN to adjust the package length and dose rate internally so that the external dose rate at two meters does not exceed 10 mrem/hr, and thus may be modeling a different dose rate than the one you entered. If the regulatory constraint is in place, RADTRAN will print a message noting this in the output. If you want to lift this regulatory constraint, select **NO**. Some analysts prefer to lift this regulatory constraint (by selecting **NO**) so they always know exactly what they are modeling.

RADTRAN models the external dose rate as a virtual source at the center of the package. The distance between the source and the receptor must take this into account. The dose rate at one meter from the surface may be calculated from the dose rate at two meters using RADTRAN, remembering to take into account the distance between the cask surface (the actual radiation source) and the center of the cask (location of the virtual source).

5.4 Gamma and Neutron Fractions

When you enter a value into either of these cells, RadCat will automatically adjust the other cell so that the sum is equal to one. This can be seen in Figure 7.

Name	Long Dim (m)	Dose Rate (mrem/h)	Gamma Fraction	Neutron Fraction
Waste_1	5.02E00	1.30E01	9.80E-01	2.00E-02
Waste_2	6.90E00	1.00E01	5.00E-01	5.00E-01
Waste_3	0.00E00	0.00E00	1.00E00	0.00E00

Figure 7: Package tab

6. RADIONUCLIDES

Select the **Radionuclides** tab next after the **Package** tab (Figure 8). When editing an existing file without adding or deleting a package, the order in which the tabs are opened will not make any difference.

At the top of the **Radionuclides** tab is a pull-down menu of the packages you have created. Select the package whose inventory you wish to specify.

6.1 Adding Radionuclides from the Internal Library

The window just below the package pull-down menu lists all of the radionuclides in the internal RADTRAN library. Radionuclides from the internal library may be added to your package by clicking on the **Add Library Radionuclide** arrow. The radioisotope name will then appear on the right-hand screen. Name the **Physical/Chemical Group** to which the radionuclide belongs. You may use any name you like, but the name can have no more than eight alpha-numeric characters and cannot contain any spaces. Remember that the release behavior in the event of an accident depends on the physical/chemical group (gas, particle, volatile substance, etc.). RADTRAN will accept up to 15 different physical chemical groups. Once you have added a **Physical/Chemical Group** name to your first radionuclide, the **Physical/Chemical Group** entry will become a pull-down menu that reflects your additions, so that you can select existing physical/chemical groups for other entries without re-typing the name each time. Physical/chemical groups must be entered at this tab; they cannot be entered on any other tab (Figure 8). Enter the number of curies of the radionuclide in the **Curies** column.

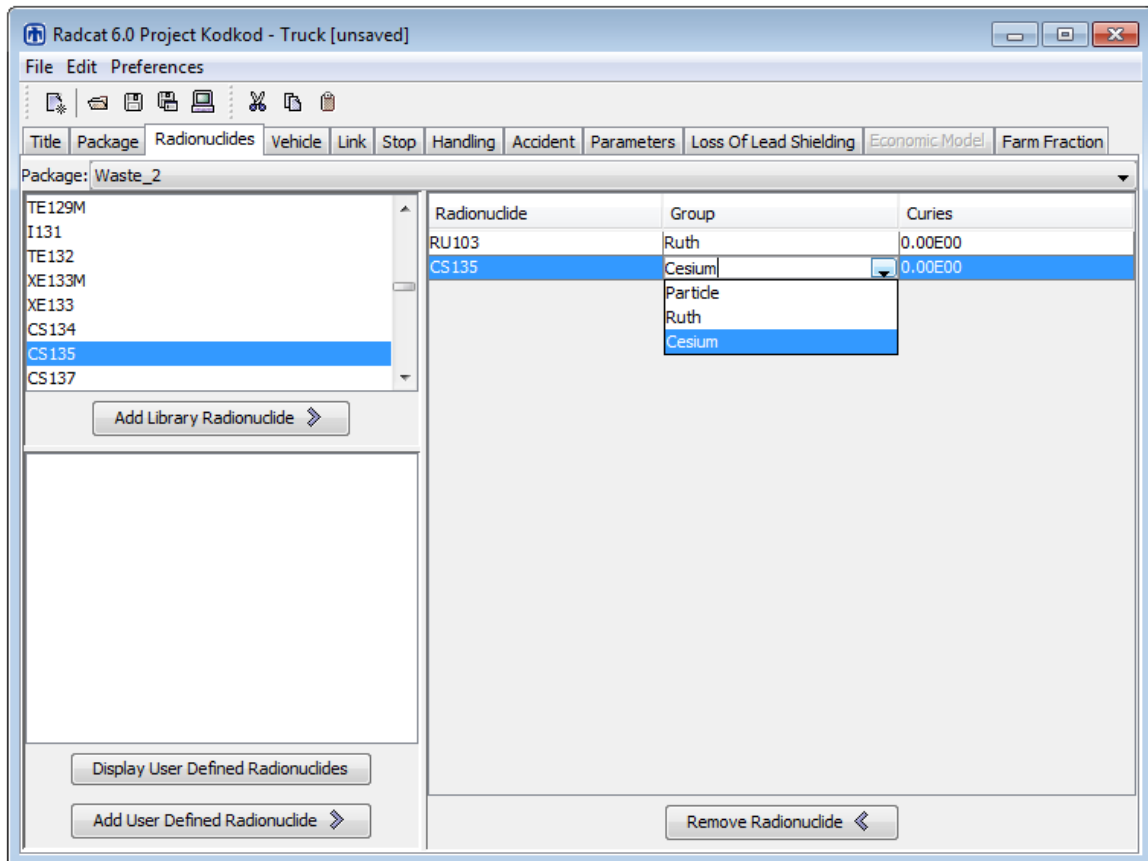


Figure 8: Radionuclides tab.

6.2. Adding User-Defined Radionuclides

If the radionuclide you wish to add is not in the internal library, it may be added to your package. To do this, first click on the **Display User-Defined Radionuclides** bar. The **User Defined Radionuclides** screen will open. In this tab, you can click on the **Add User Defined Radionuclides** bar. You may then enter the name of the radionuclide in the left-hand cell (in place of ISOTOPE_1. The name can be up to eight characters long and may not contain any spaces. This can be seen in Figure 9.

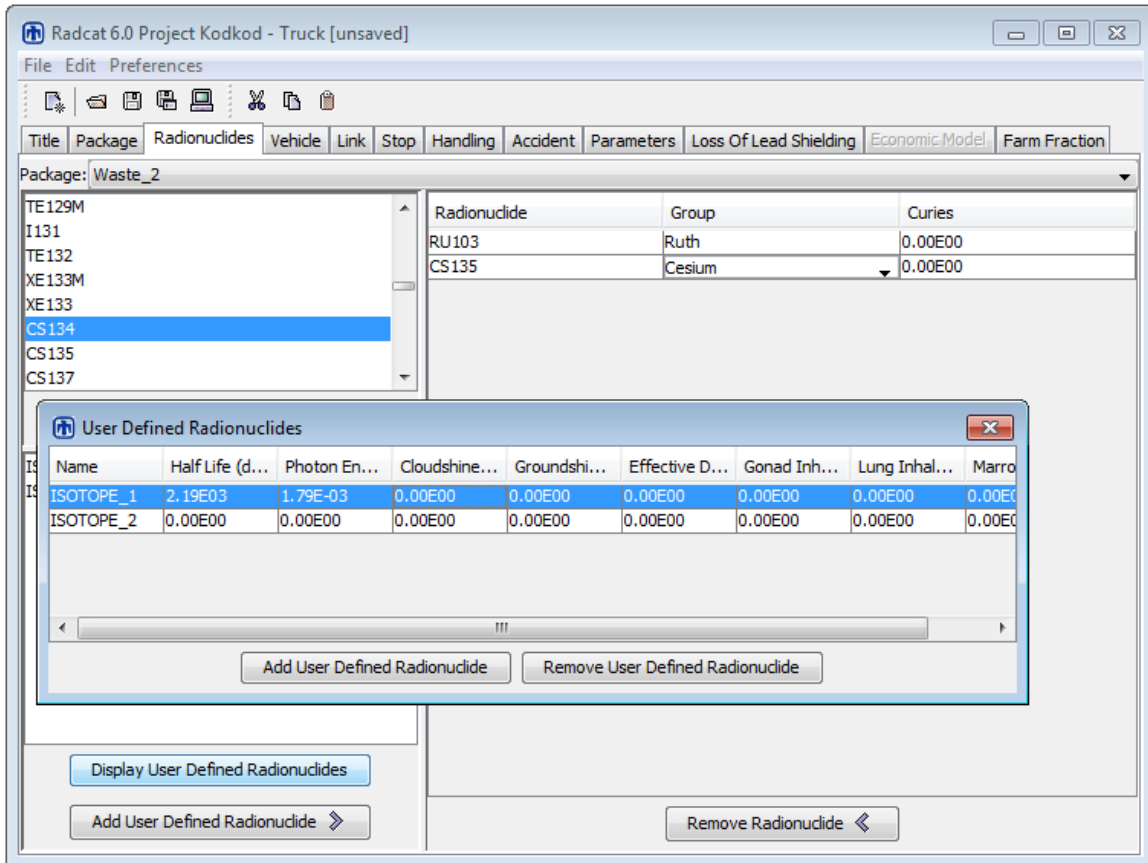


Figure 9: Radionuclides tab with user defined radionuclides window

Half-lives may be found in the Chart of the Nuclides (KAPL, 2003) or the International Commission on Radiological Protection (ICRP) Publication 38 (ICRP, 1983), and dose conversion factors may be found in the Health Physics Handbook (Shleien et al, 1996), Federal Guidance Report 12 (Eckerman and Ryman, 1993), ICRP Publication 72 (ICRP, 1996), and similar references. Dose conversion factors for radionuclides in the internal RADTRAN library are provided in Appendix B. Enter values for:

- Half-life in days,
- Photon Energy in MeV = Groundshine DCF/0.000304,
- Cloudshine Dose Conversion Factor (DCF) in rem-m³/Ci-sec or Sv-m³/Bq-sec,
- Groundshine DCF in rem-m²/μCi-day or Sv-m²/Bq-day ,

- Effective DCF in rem/Ci or Sv/Bq (called Inhalation Dose in the output),
- Gonad Inhalation DCF in rem/Ci or Sv/Bq,
- Lung Inhalation DCF in rem/Ci or Sv/Bq, and
- Marrow Inhalation DCF in rem/Ci or Sv/Bq.

Make sure you use the appropriate units. A value larger than zero for the half-life must be used for every user-defined radionuclide. RADTRAN will not run if there is a radionuclide with a half-life of zero or with a negative half-life.

If values for the **Cloudshine** dose conversion factor, the **Groundshine** dose conversion factor, and/or the **Inhalation** dose conversion factor are not entered, RADTRAN will run but will report zero for the appropriate doses. If values for the **Gonad Inhalation**, **Lung Inhalation**, and/or **Marrow Inhalation** dose conversion factors are not entered, there will be no effect on cloudshine, groundshine, inhalation, or resuspension collective doses, but specific gonad inhalation, etc., doses will not be reported.

When you have added a user-defined radionuclide, the name of that radionuclide appears on the lower part of the **Radionuclides** tab. Using the **Add User Defined Radionuclide** arrow under that screen, you add the user-defined radionuclide to your package, and indicate the physical/chemical group and number of curies as before. If you wish to include a radionuclide in more than one **Physical/Chemical Group** (e.g., Co-60 as both CRUD and particulate), give the radionuclide a different name for each **Physical/Chemical Group** (e.g., CO60CRUD, CO-60P) and include one or both as **User-Defined Isotope(s)**.

Inhalation, resuspension, groundshine, and cloudshine doses are calculated for all radionuclides: both those in the internal library and those that are user-defined. However, the ingestion dose is calculated by RADTRAN only for radionuclides in the internal library and not for those radionuclides that are user-defined.

7. VEHICLE

The **Vehicle** parameters (external dose rate, length, etc.) determine the dose to residents along the route and near stops, to occupants of vehicles sharing the route, to people sharing stops, to inspectors and to the vehicle crew. The analogous **Package** parameters determine doses to handlers. If there is only one package per vehicle, as for a spent fuel or UF₆ package, or if all the packages can be modeled as one, as for the TRUPACT-II (which is actually three cylinders standing adjacent to each other), the largest dimension, external dose rate, and gamma and neutron fraction should be the same for the vehicle and package.

When making a new input file or adding or deleting a vehicle in an existing file, select the **Vehicle** tab after the **Radionuclides** tab, because screens that come after the **Package** and **Radionuclides** screens require a vehicle name. When editing an existing file without adding or deleting a vehicle, the order in which the tabs are opened doesn't make any difference. This can be seen in Figure 10.

7.1 Vehicle Name

Provide a vehicle name in the left-hand column. The defaulted name may be substituted with any other name and additional vehicles can be given any name you wish to give them. A vehicle name must be a continuous text string and must not contain any spaces.

To analyze more than one vehicle, click the **Add Vehicle** bar and add the desired number of vehicles. This can be seen in Figure 10. Add packages to vehicles as follows:

1. Click on the vehicle to which the desired package is to be added.
2. Then click on the package to be added, and enter the number of those packages that are to be added to the vehicle.

Adding the package to the vehicle adds the radionuclide contents of the package to the analysis. The radionuclide content is important to the accident analysis, though not to the incident-free analysis. Different packages may be added to a vehicle. When selecting the vehicle, the number of each of the packages on that vehicle shows up in the **Number of Packages** column. If a package is not on a particular vehicle, the **Number of Packages** column will show a zero. This can be seen in Figure 10.

List all the desired vehicles on this tab. Vehicles cannot be added on other tabs, nor can they be deleted from other tabs. RADTRAN can handle as many as 20 vehicles in a single analysis.

7.2 Number of Shipments

Enter the number of shipments. This can be seen in Figure 10. RADTRAN calculates doses and dose risks for one shipment and multiplies that result by the number of shipments. The same result can be obtained, as many analysts prefer to do, by performing the RADTRAN analysis for one shipment and multiplying externally by the number of shipments.

7.3 Vehicle Size

Enter the largest dimension of the cargo section of the vehicle, or of the part of the vehicle holding the packages, in meters. This is the “critical dimension” of the vehicle in RADTRAN. This can be seen in Figure 10.

7.4 Vehicle Dose Rate

Enter the external dose rate at one meter from the edge of the cargo-carrying part of the vehicle, in units of mrem/hr or Sv/hr. The regulations of 10 CFR Part 71 specify that the external dose rate *at two meters* from this edge should not exceed 0.01 mSv/hour (10 mrem/hour). This is equivalent to 0.014 mSv/hr (14 mrem/hr) at one meter if the largest

dimension is approximately 5 meters. If the actual dose rate is not known, and one assumes that the shipper is abiding by regulations, one may use the regulatory maximum, 14 mrem/hr, as the external dose rate, recognizing that this value is conservative. This can be seen in Figure 10.

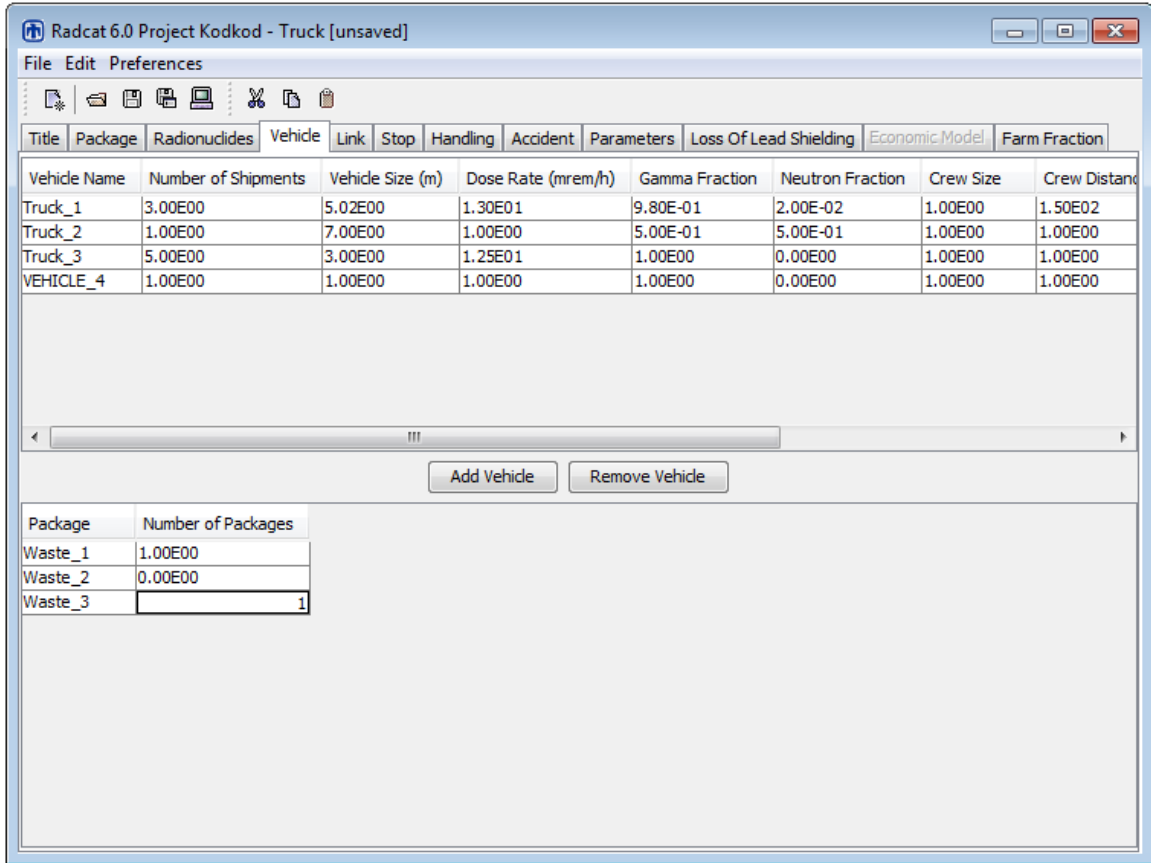


Figure 10: Vehicle tab

RADTRAN has a flag on the **Parameters** tab (Section 12), “Imposed regulatory limit on vehicle external dose,” that imposes a regulatory constraint on the shipment. As it was explained in Section 5.3 (Package tab), Selecting **YES** will cause RADTRAN to internally adjust the critical dimension and the dose rate so that the external dose rate at two meters does not exceed 10 mrem/hr, and thus may not use the dose rate you entered into the calculations. If you want to lift this regulatory constraint, select **NO**.

RADTRAN models the external dose rate as a virtual source at the center of the package. The distance between the source and the receptor must take this into account.

7.5 Gamma and Neutron Fractions

Enter a value into either of these cells; RadCat will automatically adjust the other cell so that the sum of both is equal to 1. This can be seen in Figure 10.

7.6 Crew Size

Enter the number of crew members traveling on the vehicle. This can be seen in Figure 11.

7.7 Crew Distance

For highway and barge travel, enter the **Distance** in meters from the crew to the nearest surface of the cargo in the **Crew Distance (m)** column. This distance is about 2 to 3 meters for large trailer rigs but may be much longer for heavy haul trucks. This can be seen in Figure 10. The crew on a train in transit is at least 150 m (several railcar lengths) from the radioactive cargo, and is shielded by intervening rail cars

Occupational dose for rail shipments includes the dose to the crew on the moving train and the dose sustained by rail yard workers at stops along the route. The dose to the train crew is usually small compared to the dose to railyard workers. The dose to railyard workers at classification stops is calculated internally by RADTRAN and the result is in the output, RADTRAN calculates and reports in-transit yard worker dose using the distance-dependent rail worker exposure factor per km (DDRWEF) listed on the **Parameters** tab (Section 12). The details on DDRWEF are provided in Section 12 under the **Minimum number of rail classification stops** subsection. Railyard worker dose can also (and preferably) be calculated from rail stops (Section 9) when the information on the number of classification stops and their duration is available.

A barge usually has a crew of 10. Enter the average distance of the crew from the cargo.

7.8 Crew Shielding Factor

Enter a factor between 0 and 1 for crew shielding. This factor is the fraction of ionizing radiation to which the crew is exposed (the inverse of the shielding fraction). This means that 1 = no shielding, and 0 = 100% shielding. This can be seen in Figure 10.

If RADTRAN is run with regulatory constraints (see the **Parameters** screen, Section 12) the maximum crew dose will automatically not be greater than 2 mrem (0.02 mSv) per hour. If RADTRAN is run without regulatory constraints, the crew shielding factor, if the crew distance from the package is 3 meters, is 0.38. This value was calculated using RADTRAN from the using the 2 mrem per hour standard

7.9 Crew View

The **Crew View** is the largest dimension, in meters, of the cargo that faces toward the crew. This is usually the diameter of a cylindrical cask or the diagonal end dimension of a rectangular container or array. This can be seen in Figure 10 in the **Crew View (m)** column.

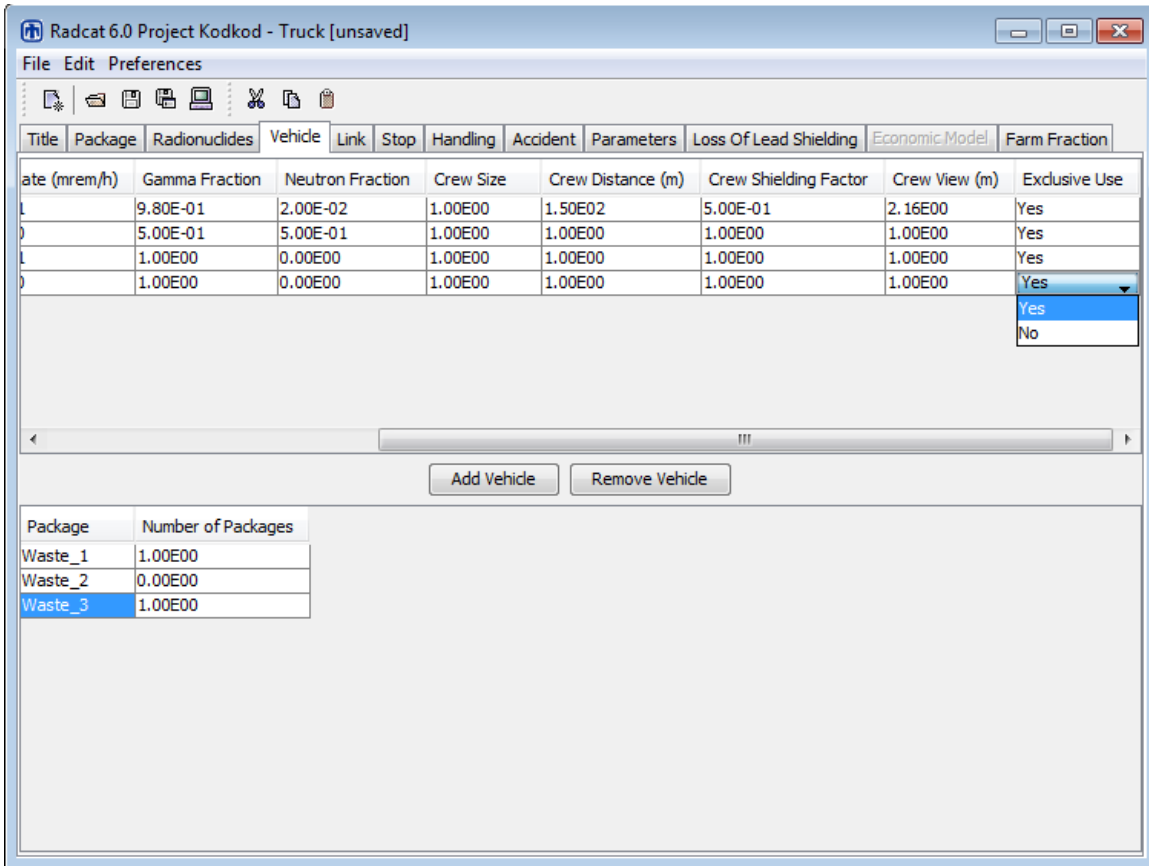


Figure 11: Vehicle tab continued

7.10 Exclusive Use

A pull-down menu allows you to indicate whether the vehicle is exclusive use or not. This can be seen in Figure 11 in the **Exclusive Use** column.

8. LINK

A “link” is a route segment. Links are designated as rural, suburban, and urban, based on population density (Johnsons and Michelhaugh, 2000). Each segment with a different population density can be designated as rural, suburban, or urban, as shown in Figure 12. The route shown in Figure 12 was produced using TRAGIS. The rural, suburban, urban designation affects the use of some default parameters as described in section 8.10.

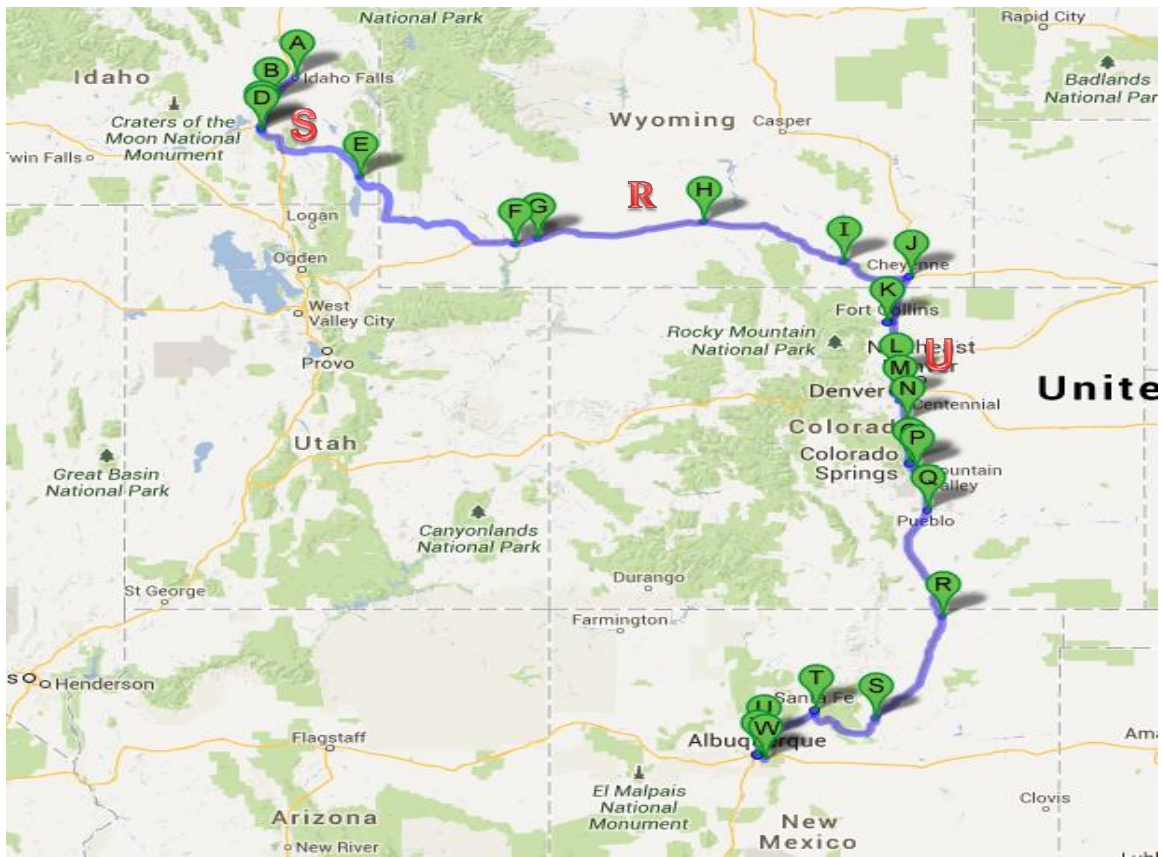


Figure 12: A possible truck route from Idaho Falls, ID to Albuquerque, NM (courtesy of ORNL). A rural segment (R), a suburban segment (S), and an urban segment (U) are indicated.

Routing codes like TRAGIS provide the population along the route. RADTRAN assumes a bandwidth (usually 800 meters) along each link and integrates the population density over this bandwidth for each link. RADTRAN adjusts internally for a band on both sides of the route. Links may be designated as rural, suburban, or urban according to the following population densities:

- rural: 0 to 139 persons/mi² (0 to 55 persons/km²)
- suburban: 139 to 3326 persons/mi² (55 to 1300 persons/km²)
- urban: more than 3326 persons/mi² (1300 persons/km²)

The population density classification is not automatic; i.e., any link can be designated as rural, suburban, or urban, independently of the population density.

Figure 13 is another example of a route using a different mapping system: Interstate 80 through Salt Lake City, UT. Urban, suburban, and rural segments are indicated in the figure.

I-80 Corridor Salt Lake City

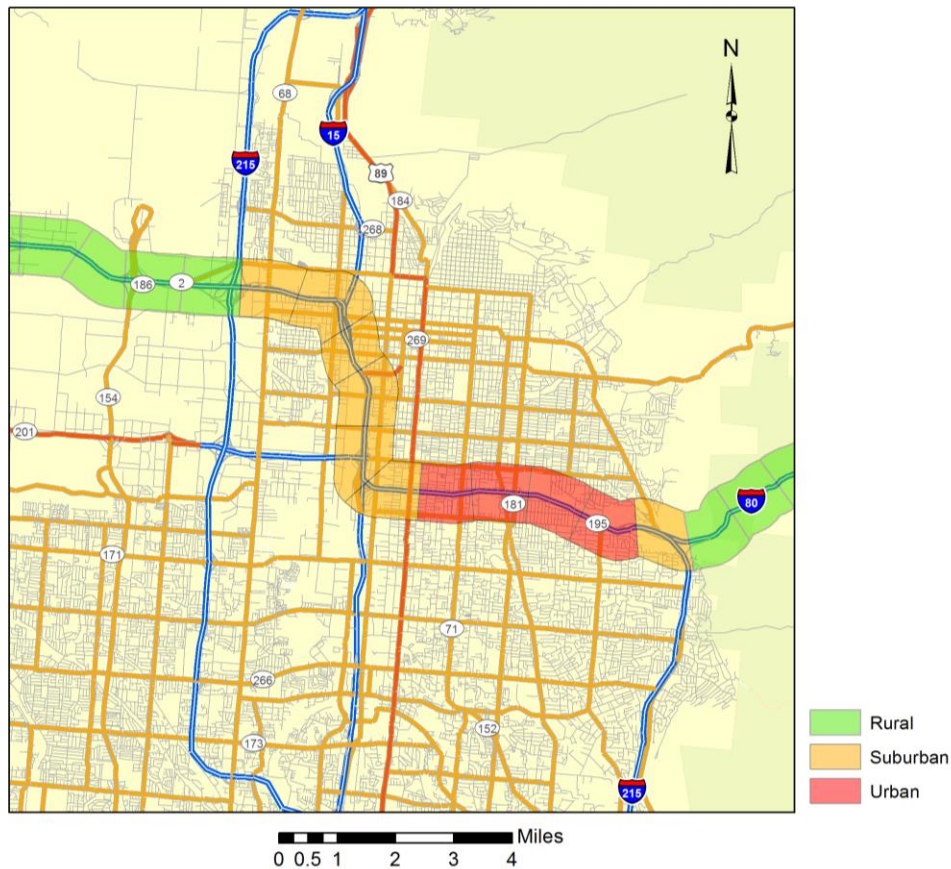


Figure 13: Interstate Truck Route generated by a SNL GIS.

When making a new input file or adding or deleting a vehicle in an existing file, select the **Link** tab next after the **Vehicle** tab since the vehicle name is required on the Link tab. If editing an existing file without adding or deleting a package, the order in which the tabs are opened doesn't make any difference. This can be seen in Figure 14.

8.1 Link Name

Give each link a name in the left-hand **Link Name** column. A link name must be a continuous text string and must not contain any spaces. Links do not need to be consecutive, but listing them the same order in which they occur along the route helps to visualize the route. Rush-hour periods can also be separate links to take into account different vehicle speeds and vehicle densities on these segments.

8.2 Vehicle

Available vehicle names are on a pull-down menu in the **Vehicle** column. Vehicle names cannot be added or deleted at this tab. This can be seen in Figure 14 in the Vehicle column.

8.3 Length

Enter the length of the route segment – the link – in kilometers, as obtained from a routing code like WebTRAGIS or from a GIS system or from a map. This can be seen in Figure 14 in the **Length (km)** column.

Useful conversion factors are:

1 km = 0.62137 mile

1 mile = 1.60934 km.

$1 \text{ person/mi}^2 = (1 \text{ person/mi}^2) * (1 \text{ mi}/1.608 \text{ km})^2 = 1 \text{ person}/2.59 \text{ km}^2$

8.4 Speed

Enter the average speed of each vehicle on each link, in km/hr. This can be seen in Figure 14 in the **Speed (km/h)** column. You may use any speeds you choose. Several options for speed are available:

- State highway speed limits as of 2012, in km/hour for various types of roads, are shown in Table 2. Suburban interstate highway speeds are usually the same as rural speeds.
- WebTRAGIS currently outputs the length and transit time for each link. The speed of the vehicle on the link can be calculated directly from this output.
- The state traffic reports available on www.bts.gov allow direct calculation of allowed maximum speed for each state transited.

Rail speed depends on the track class and type of cargo. Trains carrying hazardous materials, including radioactive materials, are often limited to 50 mph (80 km/hr) in rural areas and 40 mph (64 km/hr) in suburban and urban areas. When the slowing at curves is considered, the national average speed is approximately 35 kph. Rail speed on each link can also be calculated directly from WebTRAGIS data.,

Table 2. State truck speed limits (National Motorists Association, 2012)*.

Speed Limit (kilometers/hour)							
State	Interstate		Other	State	Interstate		Other
	Rural	Urban			Rural	Urban	
AL	113	105	105	NE	121	105	105
AZ	89	89	89	NV	121	105	113
AR	121	105	105	NH	105	105	89
CA	105	89	97	NJ	105	89	105
CO	89	89	89	NM	121	105	105
CT	121	105	105	NY	105	89	89
DE	105	89	105	NC	113	113	113
DC	89	89	105	ND	121	121	105
FL	113	89	105	OH	105	105	89
GA	113	105	113	OK	121	113	113
ID	105	105	105	OR	89	89	89
IL	105	89	89	PA	105	89	105
IN	105	89	97	RI	105	89	89
IA	113	89	105	SC	113	113	89
KS	121	121	121	SD	121	121	113
KY	105	105	105	TN	113	113	113
LA	113	113	113	TX	121	121	121
ME	105	105	105	UT	121	105	121
MD	105	105	105	VT	105	89	80
MA	105	105	105	VA	64	89	32
MI	105	105	105	WA	113	113	105
MN	113	105	105	WV	97	97	97
MS	113	113	113	WI	113	105	105
MO	113	97	105	WY	105	105	105
MT	105	105	105				

*Some states have different speed limits for night and day. In these cases, the lower of the speeds is the value in the table.

8.5 Population Density

RADTRAN requires population along a route to be entered in the appropriate column as a population density (persons/km²), which may be calculated for each link from WebTRAGIS. WebTRAGIS provides, for each route segment, the length of the segment the population, and the band width, and may in some cases provide the population density directly. Population density may also be calculated from the City/County data book, or some other GIS system or source. Population density is shown in Figure 14.

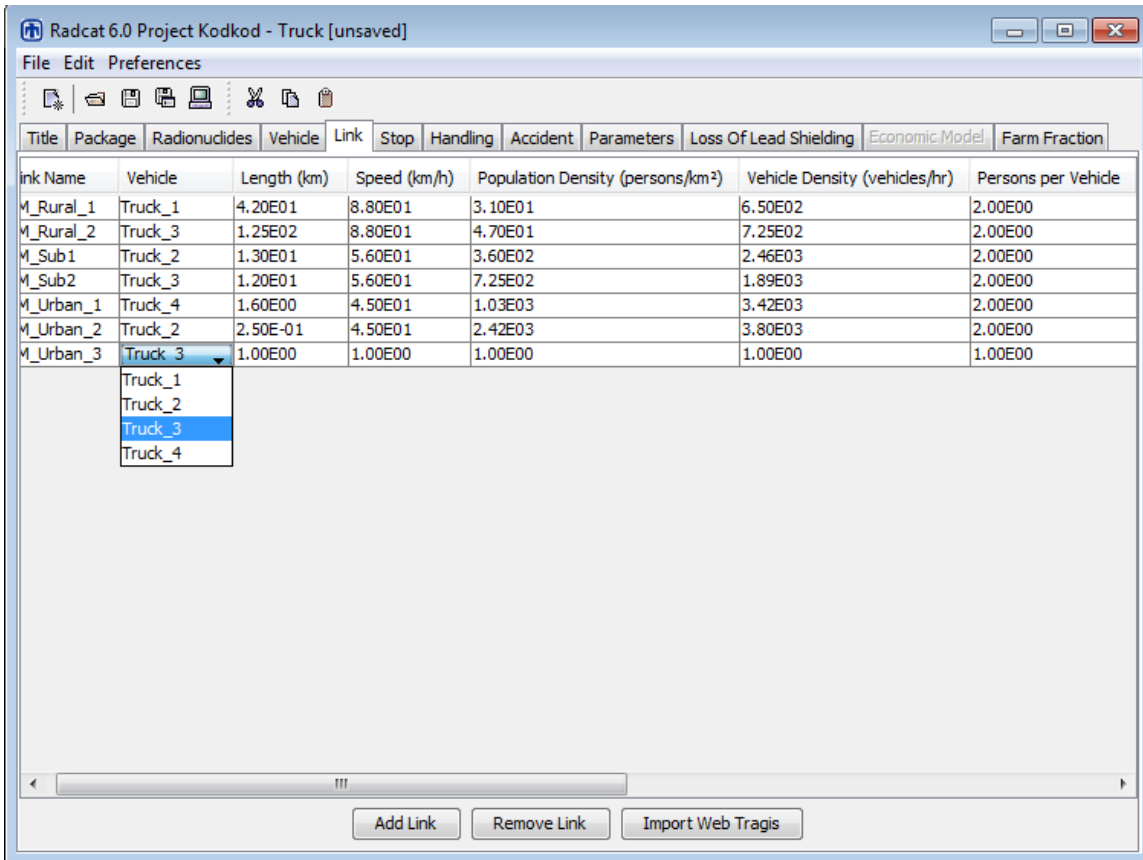


Figure 14: Link tab

8.6 Vehicle Density

Enter the vehicle density – the vehicles per hour sharing the route with the radioactive cargo. This can be seen in Figure 14 in the **Vehicle Density (vehicles/hr)** column. National average vehicle densities from 2003 to 2005 are (Appendix D):

Interstate Highways

- * rural: 1155 vehicles/hr
- * suburban: 2414 vehicles/hr
- * urban: 5490 vehicles/hr

U.S. Highways

- * rural: 287 vehicles/hr
- * suburban: 618 vehicles/hr
- * urban: 1711 vehicles/hr

The study from which these numbers are extracted is provided in Appendix D, which includes average regional vehicle densities from the ten Environmental Protection

Agency (EPA) regions and average vehicle densities from 21 states. More accurate vehicle densities can usually be obtained from state traffic counts.

Average rail densities, except for trains carrying passengers, are

Rail

- rural: 1 vehicle/hr
- suburban: 5 vehicles/hr
- urban: 5 vehicles/hr

8.7 Persons per Vehicle (Vehicle Occupancy)

Enter the average persons per vehicle for the route in the **Persons per Vehicle** column (Figure 14). For highway transportation, this is usually 1.5 or 2 persons per vehicle. For rail, since most rail transportation is freight, the number is usually 3 (the train crew). If passenger trains share the route, the average vehicle occupancy can be estimated.

The vehicle density and the vehicle occupancy are important parameters in determining the on-link incident-free dose from transportation of radioactive materials.

8.8 Accident Rate (How RADTRAN Analyzes Accidents)

RADTRAN analyzes only one accident, because only one accident would occur during a trip on any route. The accident analysis is based on the package and vehicle, because the package contains the radionuclides potentially released, and the location of the accident – the link – is identified by the vehicle. If the vehicle is in an accident, it goes no further than the accident location. However, the accident could occur on any segment of the route, so RADTRAN reports accident risks and consequences on every route segment (link). If you wish to model the accident on several links, but not on all links, enter accident rate in the “Accident Rate (accidents/veh-km)” only for the links on which you wish to model an accident. Enter zero in the “Accident Rate (accidents/veh-km)” column for those links on which you do not want an accident (don’t leave the cell empty: RADCAT hangs up if the cell is empty).

Enter the vehicle accident rate for each route segment in accidents per vehicle-km in the **Accident Rate (accidents/veh-km)** column (Figure 14a). Accident rates are usually reported by state and type of road or rail. A useful reference for accident rates is the Bureau of Transportation Statistics web site: <http://www.bts.gov>. Table 3 shows the data from that site.

8.9 Fatalities per Accident

Enter the number of fatalities per accident (Figure 14a). Fatality rates are usually reported by state and can be found at www.bts.gov. The fatalities per accident value is 0.00353, an approximately constant number in the U.S.

Table 3 Highway and rail accident rates ^a

State	Highway accidents/ vehicle km	Rail accidents/ railcar-km	State	Highway accidents/ vehicle km	Rail accidents/ railcar-km
AL	2.61E-06	2.27E-07	NE	1.96E-06	1.20E-07
AZ	1.7E-05	1.82E-07	NV	8.37E-06	1.80E-08
AK	2.07E-06	3.05E-07	NH	3.46E-06	7.82E-07
CA	3.98E-06	3.14E-07	NJ	5.19E-06	1.58E-07
CO	9.58E-07	2.53E-07	NM	4.78E-06	2.72E-07
CT	2.08E-06	9.61E-07	NY	1.21E-06	6.33E-08
DE	1.90E-06	3.36E-07	NC	4.78E-06	9.62E-08
DC	6.83E-06	4.42E-06	ND	1.15E-06	1.97E-07
FL	1.27E-05	1.81E-07	OH	1.63E-06	2.08E-07
GA	1.40E-06	1.74E-07	OM	7.61E-06	2.70E-07
ID	6.69E-06	3.39E-07	OR	1.22E-06	2.19E-07
IL	5.68E-06	1.89E-07	PA	2.45E-06	3.77E-07
IN	1.32E-06	2.15E-07	RI	2.18E-06	1.14E-07
IA	1.63E-06	2.03E-07	SC	1.59E-06	1.14E-07
KS	2.50E-06	2.01E-07	SD	5.36E-06	2.57E-07
KY	3.29E-06	3.16E-07	TN	3.00E-06	3.44E-07
LA	2.85E-06	7.60E-08	TX	1.11E-05	2.25E-07
ME	2.91E-06	4.27E-07	UT	2.04E-06	7.56E-08
MD	4.09E-06	1.97E-07	VT	1.16E-06	1.47E-07
MA	1.57E-06	1.03E-07	VA	2.67E-06	1.93E-07
MI	1.20E-06	1.39E-07	WA	6.91E-06	1.34E-07
MN	1.43E-06	1.84E-07	WV	1.55E-06	8.53E-08
MS	1.50E-06	1.73E-07	WI	1.79E-06	2.57E-07
MO	3.98E-06	1.05E-07	WY	5.21E-06	3.15E-07
MT	3.78E-06	3.24E-07	US	3.72E-06	1.82E-07

^aFrom BTS (2006), Table 1-23

8.10 Population Zone

A pull-down menu allows the designation of each link as rural, suburban, or urban. These designations affect certain RADTRAN calculations within the code. For example, rural, suburban, and urban areas have different shielding for residents, only a rural link can be associated with a non-zero farm fraction, urban links allow consideration of non-resident populations, urban links allow for a mixture of indoor and outdoor air, etc. Any link can be designated as rural, suburban, or urban regardless of the population density on the link, as discussed earlier.

Since about 1995, the following population density classification has been used in RADTRAN:

- rural: 0 to 139 persons/mi² (0 to 55 persons/km²)
- suburban: 139 to 3326 persons/mi² (55 to 1300 persons/km²)
- urban: more than 3326 persons/mi² (1300 persons/km²)

The **Population Zone** column is shown in Figure 14a.

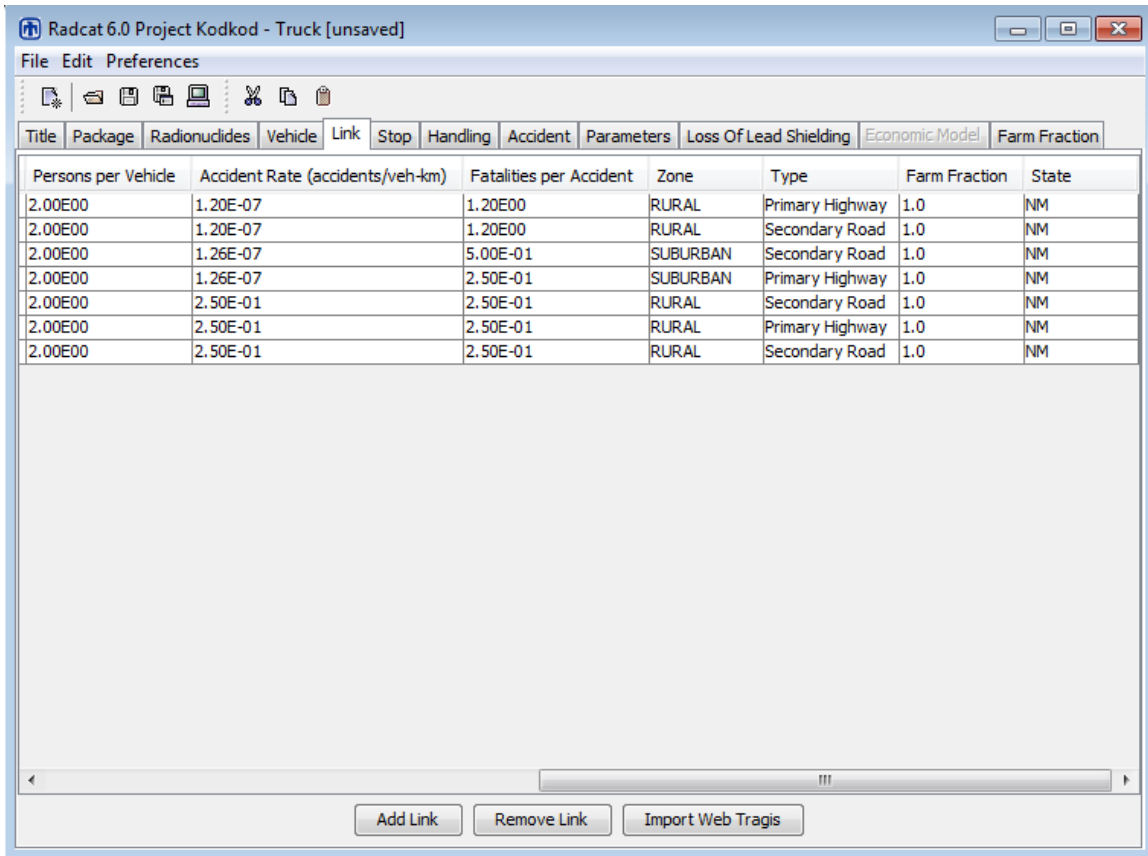


Figure 14a: Link tab -- continued

8.11 Road Type

A pull-down menu allows the designation of the road type as Interstate (Primary Highway) or Secondary Road for the Highway Mode (the **Type** column in Figure 14a). The designation “Other” is for rail and barge routes only. The RADTRAN code uses this designation.

8.12 Farm Fraction and State

There are two alternate methods that RADTRAN uses to calculate ingestion dose; COMIDA and INGEST. These are discussed in detail in the section on accidents, Section 11, but the input is on the LINKS tab. Input parameters for the two methods are different.

Farm Fraction is activated when COMIDA is selected (selection is made on the Title tab). It is the fraction of land along rural route segments that is farmland. COMIDA internally calculates, for each radionuclide that is released and dispersed, the activity that would be taken up by foodstuffs and then applies the fraction of the link along which the

uptake occurs. A farm fraction is only read by RADTRAN if it is on a rural route segment (if you wish to designate a farm fraction for a suburban or urban link, designate that link as rural). Farm fraction is shown in Figure 14a in the **Farm Fraction** column. The fraction of rural routes in agriculture is usually 0.4 or 0.5, but is at the user's discretion.

State is used if INGEST is selected on the Title tab). In order to calculate ingestion dose using INGEST, enter the two-letter state abbreviation in the **State** column (e.g.: MD, NY, IL) on the same line as the rural link of the state transited. This entry invokes agricultural parameters for the rural route segments in that particular state. If you wish to use INGEST on a suburban or urban link, designate that link as rural. This will affect the other parameters associated with this designation as described in Section 8.10.

9. STOPS

Select the **Stop** tab next after the **Link** tab. If editing an existing file without adding or deleting a package or vehicle, the order in which the tabs are opened will not make any difference. Figure 15 shows the **Stop** tab.

9.1 Name

Give each **Stop** a **Name** in the left-hand column. A stop name must be a continuous text string and must not include any spaces. Aggregation of all stops of a particular type (e.g., inspection stops, refueling stops) may be done if the parameters associated with these stops, except stop time, are the same. The total time for those stops is entered in the **Time** column. Each different receptor (e.g., other people at a refueling stop, residents near the stop, truck crew, an inspector) should be structured as a different stop. This difference can be seen in Figure 15. It is helpful to name the stop appropriately, e.g. inspector, resident, population sharing stop, etc.

9.2 Vehicle

Available vehicle names are on a pull-down menu in the Vehicle column. This can be seen in Figure 16 in the Vehicle column. Vehicle names cannot be added or deleted at this tab.

9.3 Minimum and Maximum Distances and People or People/km²

The columns labeled **Min(imum)** and **Max(imum) Distance** (Figure 16) refer to the shortest and longest distance, respectively, between the receptor and the radioactive cargo. Enter these distances for each receptor (each stop) The **Min(imum) Distance** cannot be less than 1.0 meter.

The **Min** and **Max** distances determine what should be entered into the **People or People/km²** column. When the **Min** and **Max** distances are equal (e.g., for an inspector who is 2 meters from the truck cargo) the number entered into the **People or People/km²**

column will be read as the number of people at that distance (1 in the case of the inspector). When the **Max** distance is larger than the **Min** distance (and it cannot be smaller), RADTRAN reads the number in the **People or People/km²** column as a population density (**People/km²**) in an annulus around the radioactive cargo, as shown in Figure 15.

Before being entered into RadCat, this population density must be calculated, since RADTRAN does not perform this calculation. For example, if there are 20 people around the cargo between one meter and 10 m, the population density in this annular ring may be calculated as follows:

Inner radius = 1 meter.

Outer radius = 10 meters.

$$\text{Area of annulus} = \pi * [(10)^2 - (1)^2] = 99\pi = 311\text{m}^2 = 3.11 \times 10^{-4} \text{ km}^2$$

$$\text{Population density in the annulus} = 20 / (3.11 \times 10^{-4}) = 6.43 \times 10^4 \text{ people/ km}^2$$

In RadCat, you would then enter 1 meter for the **Min(imum) Distance**, 10 meters for the **Max(imum) Distance**, and 6.43×10^4 for **People or People/km²**.

For areas surrounding the stop, for which the population density is given on the **Links** tab or is otherwise known, that population density may be entered directly into the **People or People/km²** of the stop model (Figure 15). The receptors in this case are the residents living in vicinity of the stop.

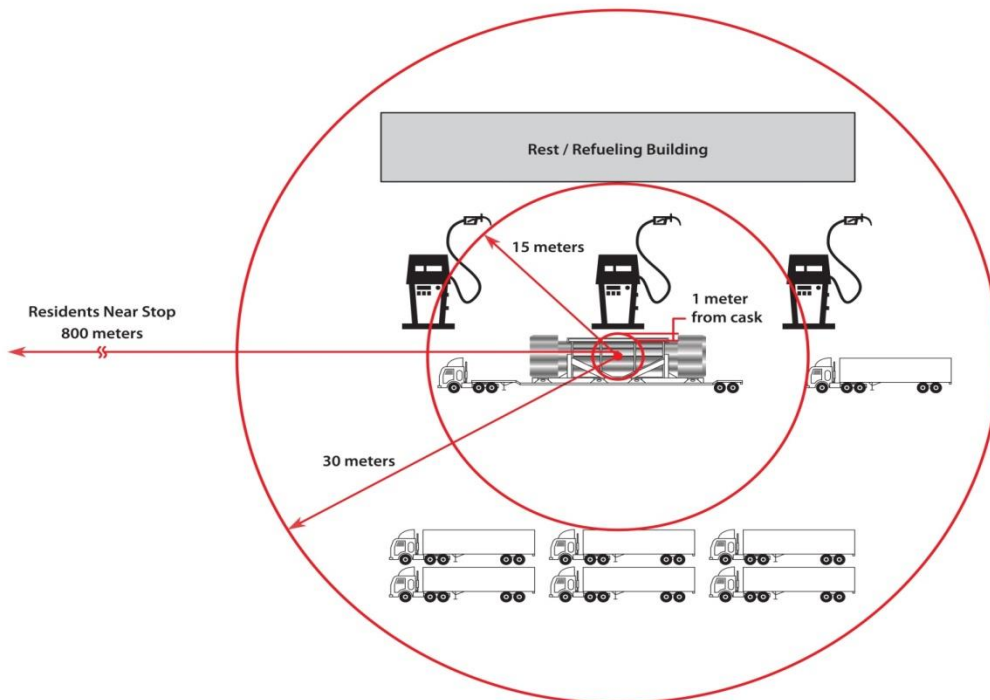


Figure 15: Truck Stop Model

9.4 Shielding Factor

The **Shielding Factor** is the fraction of ionizing radiation to which the receptors are exposed; that is, the inverse of the amount of shielding: 1 = no shielding and 0 = 100% shielding. Enter a number between 0 and 1 for the shielding factor for each stop. This can be seen in Figure 16 in the **Shielding Factor** column.

9.5 Time

Enter the total time in hours for each stop (Figure 16).

10 HANDLING

Handling refers to a potential package dose sustained by a handler during storage, loading, and unloading, and similar activities. The handling dose was related to the package rather than the vehicle in an early version of RADTRAN. The handler dose is calculated the same way as for a stop in which the minimum and maximum distances are the same. Modeling handling as a stop using the **Stop** tab allows more flexibility and is more accurate. The input parameters **Name**, **Vehicle**, **Time**, and **Shielding** are the same as those parameters would be in the **Stop** model. **Distance** is the average distance of handlers from the source, and the **Number of Handlers** is the number of people at that distance. Figure 17 shows the **Handler** tab.

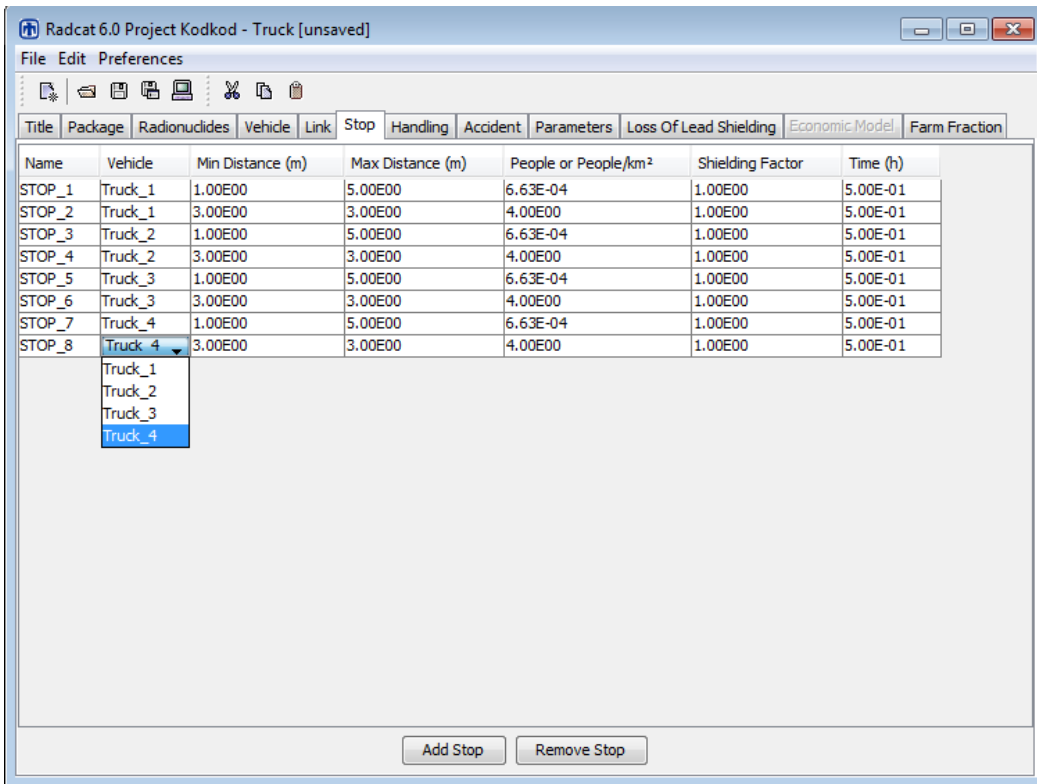


Figure 16: Stop Tab

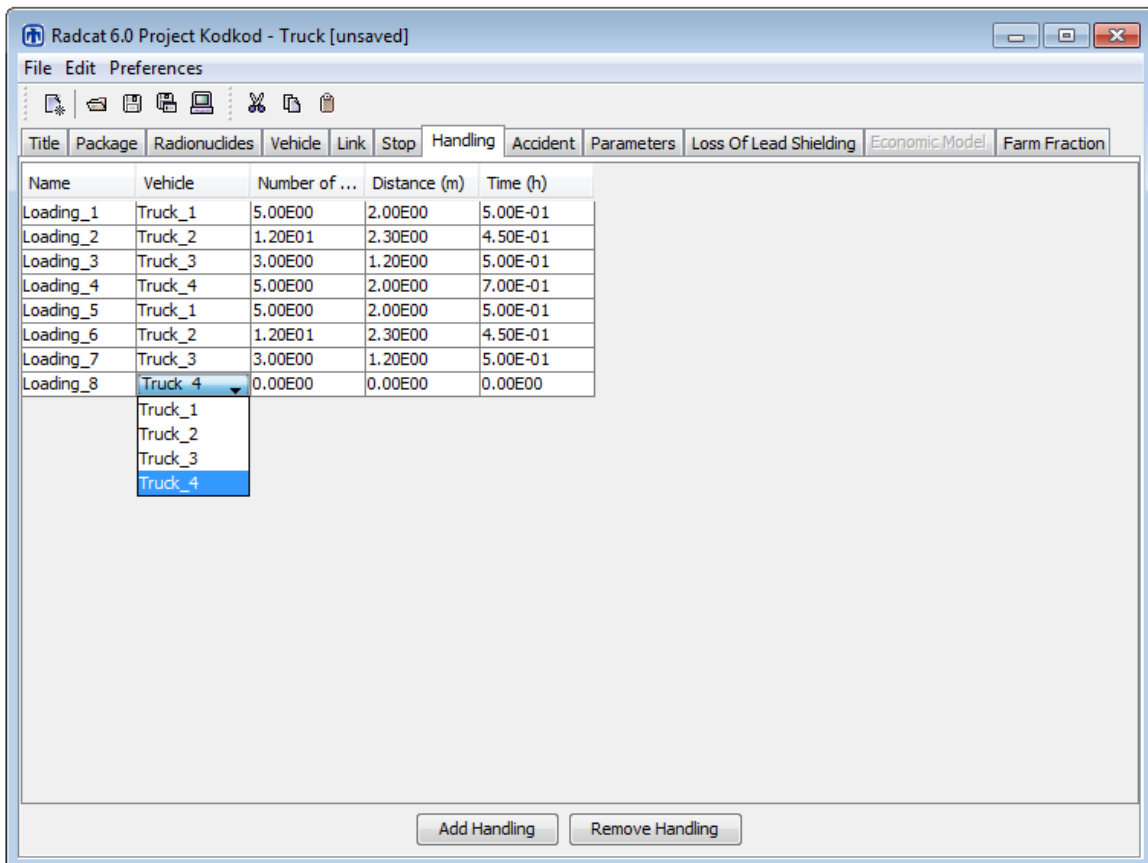


Figure17: Handling Tab

11. ACCIDENTS

The following types of accidents are modeled in RADTRAN

- accidents in which the radioactive cargo is not damaged or affected
 - minor traffic accidents (e.g., fender-benders, flat tires) that result in minor damage to the vehicle—usually called “incidents”²
 - accidents that damage the vehicle or trailer enough that the vehicle cannot move from the scene of the accident under its own power, but which do not result in damage to the cargo
 - accidents that involve a death or injury, but no damage to the cargo
- accidents in which the radioactive cargo is affected
 - accidents in which there is a release of radioactive material
 - accidents that result in loss of gamma shielding but no release of radioactive material

Accidents in which the radioactive cargo is not damaged or affected

These accident are modeled as **Stops** (Section 9, above). The stop time can be estimated by you; for very large casks it is often estimated as ten hours.

Accidents in which the cargo is affected and radioactive material may be released.

The accident analysis requires a radionuclide inventory to have been entered at the **Radionuclides** tab for each package, and accident rates and population densities at the **Link** tab. If no radionuclides have been put in the **Package** tab of the input file, or if the **Package** with the radionuclides has not been put on the **Vehicle** involved in the accident, RADTRAN will run but the accident outputs will be zeros. When the **Accident** tab is opened, the following tabs appear:

- Probability
- Deposition Velocity
- Release
- Aerosol
- Respirable
- Isopleth P
- Weather

² In U.S. Department of Transportation parlance, an “accident” is an event that results in a death, an injury, or enough damage to a vehicle that it cannot move under its own power. All other non-routine transportation events are termed “incidents.” This document uses the term “accident” for both accidents and incidents.

11.1 Conditional Probabilities (Severity Fractions)

The **Probability** tab allows you to specify the conditional probability of an accident of a particular severity, given that an accident happens. Earlier versions of RADTRAN referred to conditional probabilities as “severity fractions”. The probability tab is shown in Figure 19.

The **Index** is a numbering system for conditional probabilities and enumerates them (note that the **Index** begins with zero). The conditional probabilities should include the all possible accidents; references that may be used for Type B packages are NRC, 2013 and DOE, 2002. The most likely accidents are those in which there is neither a release of radioactive material nor loss of gamma shielding.

Conditional probabilities are often based on event trees, like the one shown in Figure 18 (Mills, et al., 2006).

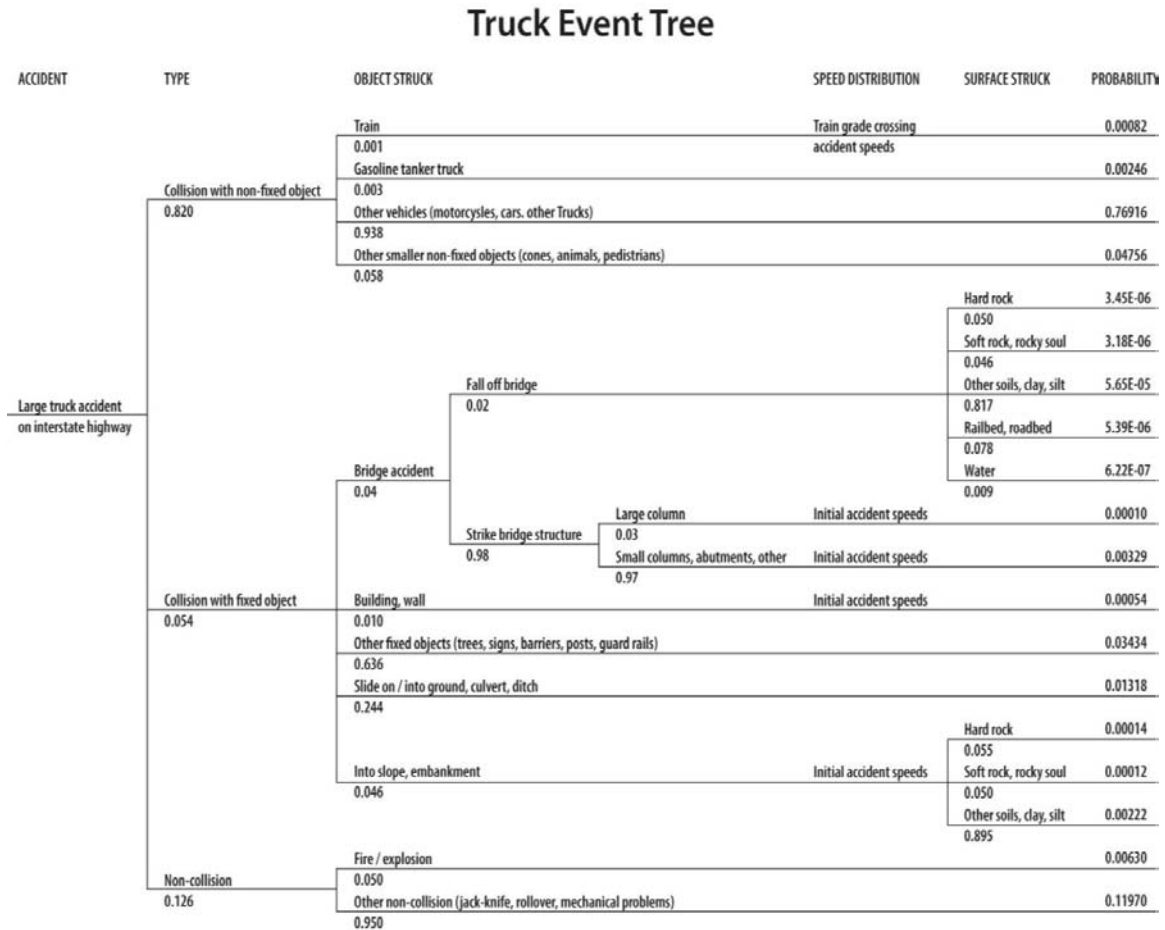


Figure 18: Truck Event Tree (from Mills, et al., 2006)

Event trees are obtained from studies of accidents as described most recently in NRC, 2013, Appendix E, and in Sprung, J.L., et al. (2000 DOE (U.S. Department of Energy), 2002b, and Fischer, L.E., et al. 1987. Tables 4 and 5, adapted from NRC, 2013 and DOE (2002b), respectively, show the relationship between the index, severity fractions (conditional probabilities) and release fractions. The reader is encouraged to consult the source documents for these tables to learn how they were arrived at.

Table 4. Severity and release fractions for rail-transported, uncanistered PWR spent fuel (adapted from NRC, 2013) .

Index	Conditional Probability	Gas	Volatiles	Particulates	CRUD
0	0.99993	0	0	0	0
1	5.96E-12	0.80	0.50	0.70	0.001
2	3.57E-11	0.80	0.50	0.70	0.001
3	1.79E-11	0.80	0.50	0.70	0.001
4	1.79E-11	0.80	0.50	0.70	0.001
5	3.4E-10	0.80	0.50	0.70	0.001
6	3.4E-10	0.80	0.50	0.70	0.001
7	1.13E-10	0.80	0.64	0.45	0.001

Table 5. Severity and release fractions for uncanistered truck-transported PWR spent fuel (adapted from DOE, 2002b) .

Index	Conditional Probability	Gas	Volatiles	Particulates	CRUD
0	0.99993	0	0	0	0
1	6.06E-05	0.136	4.09E-09	1.02E-07	1.36E-03
2	5.86E-06	0.839	1.68E-05	6.71E-08	2.52E-03
3	4.95E-07	0.449	1.35E-08	3.37E-07	1.83E-03
4	7.49E-08	0.835	3.60E-05	3.77E-06	3.16E-03
5	3.00E-10	0.84	2.40E-05	5.01E-06	3.17E-03

Conditional probabilities should add to 1.00, though this is sometimes difficult to see with very small probability fractions. RadCat does not force addition to 1.00. Enter the conditional probabilities in the right-hand column. Conditional probabilities may only be added and deleted on this tab. This can be seen in Figure19.

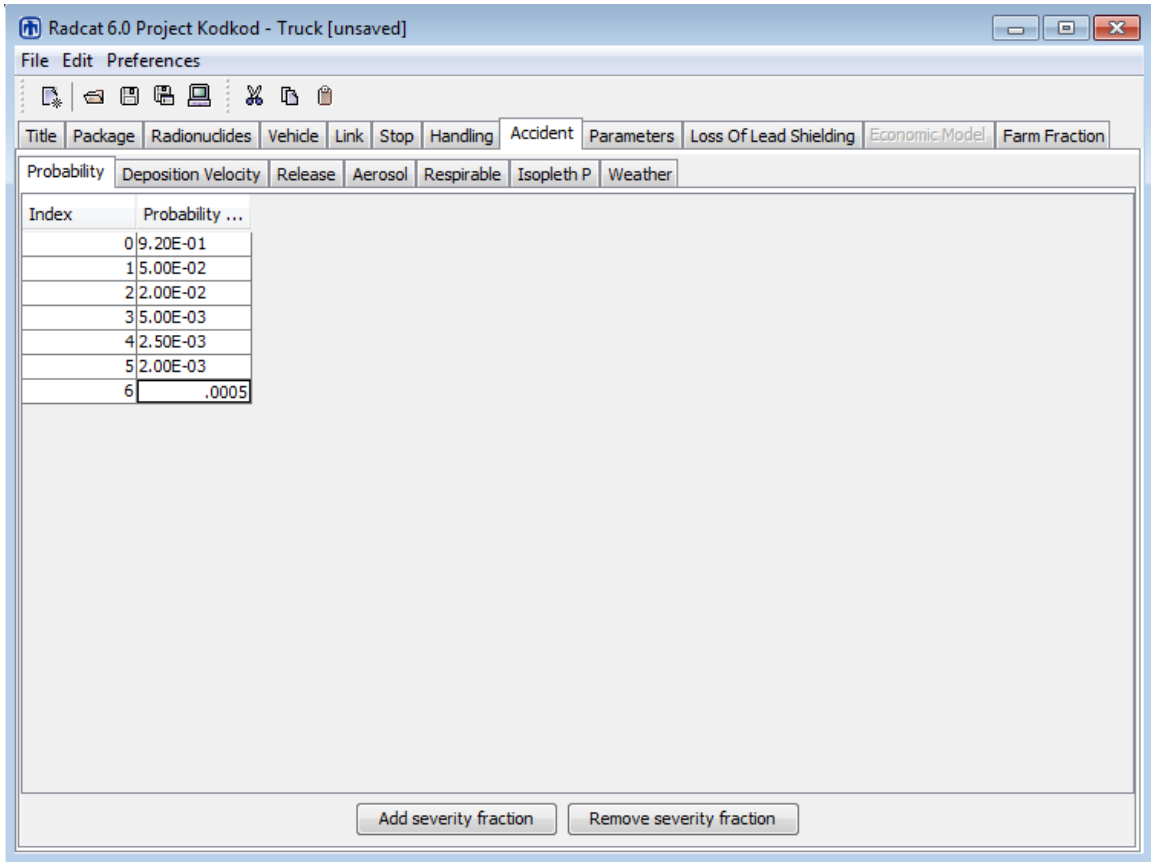


Figure19: Accident/probability tab

11.2 Deposition Velocity

Deposition Velocity (Figure 20) depends on the size, density, and shape of the radionuclides that are released into the environment as a result of the accident. The **Group** column on the left has a pull-down menu of the physical chemical groups entered at the **Radionuclides** tab. Enter a **Deposition Velocity** in meters/sec for each **Group**. Gases do not deposit and thus have a **Deposition Velocity** = 0. A **Deposition Velocity** of 0.01 m/sec is often used as being generally representative of the aerodynamic diameter of aerosol particles that can be dispersed over long distances. The **Deposition Velocity** should be small enough that the material is deposited in at least two isopleths. If the **Deposition Velocity** is too large RADTRAN will abort reading the input file at that point.. It is recommended that the **Deposition Velocity** be no larger than 0.1 m/sec for proper results. **Groups** may not be added or deleted at this tab.

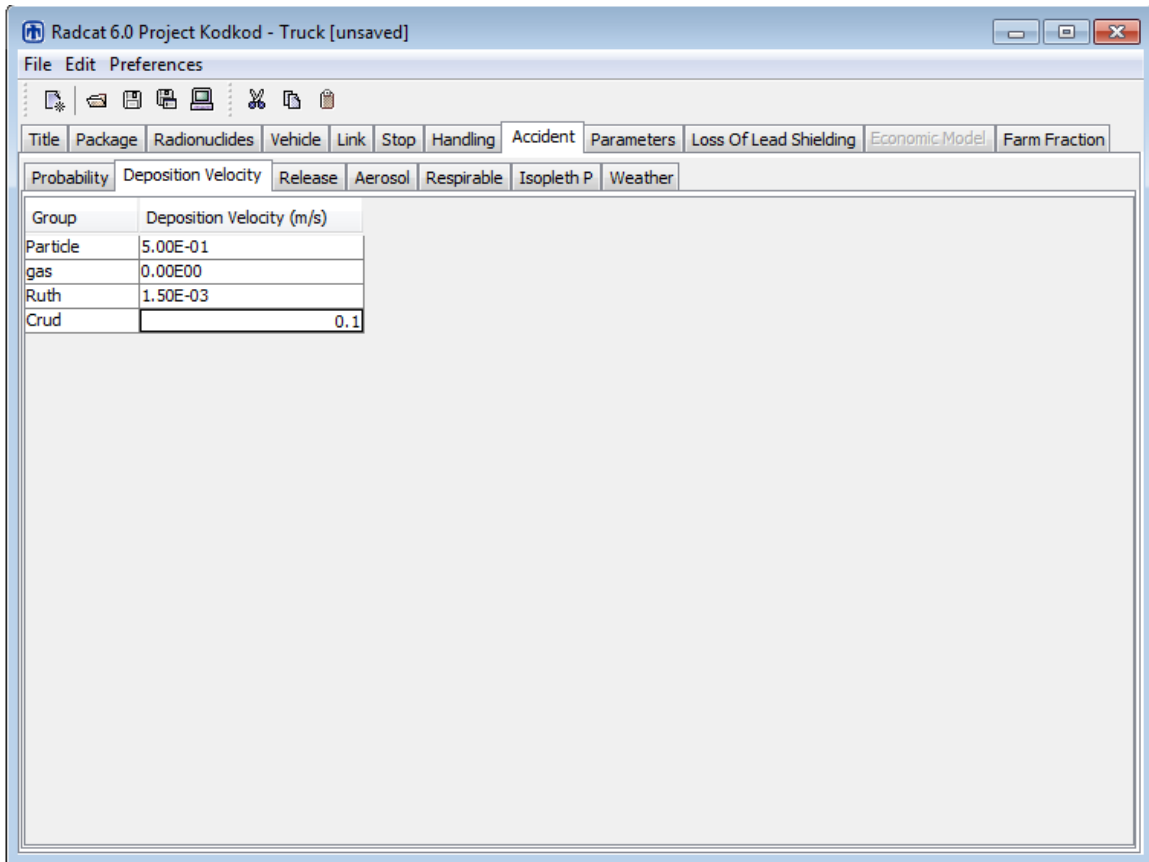


Figure 20: Accident/deposition velocity tab

11.3 Release Fraction

Release Fraction, the fraction of each radionuclide in the cargo that could be released in an accident, depends on the physical and chemical behavior of the radionuclides and on the severity of the accident. These are shown in Tables 4 and 5.

The pull-down menu at the top allows selection of the physical/chemical **Group**. Groups may not be added or deleted at this tab. Select a physical/chemical **Group** from the pull-down menu. This can be seen in Figure 21.

The left-hand column shows the **Index** number which is associated with each conditional probability. Enter a **Release Fraction** for each **Index** and each **Group**. Indices may not be added or deleted at this tab.

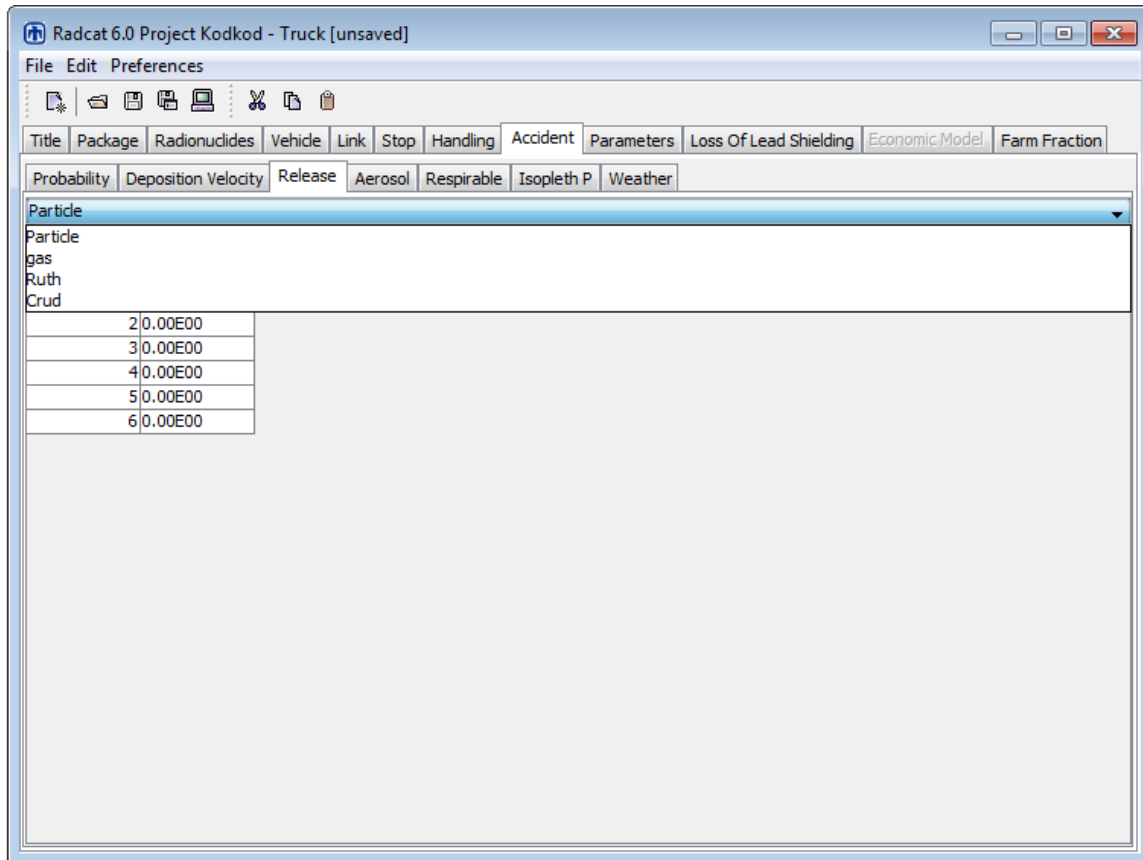


Figure 21: Accident/release tab

11.4 Aerosol Fraction

The **Aerosol Fraction**, the fraction of each **Release Fraction** that would be aerosolized in an accident, depends on the physical behavior of the radionuclides and on the severity of the accident. The pull-down menu at the top allows selection of the physical/chemical **Group**. Groups may not be added or deleted at this tab. Select a physical/chemical **Group** from the pull-down menu seen in Figure 22.

The left-hand column shows the **Index** number which is associated with each conditional probability. Enter an **Aerosol Fraction** for each **Index** and each **Group**. In most accidents involving Type B casks or containers, only very small particles are released; in such cases, the **Aerosol Fraction** = 1. Indices may not be added or deleted at this tab.

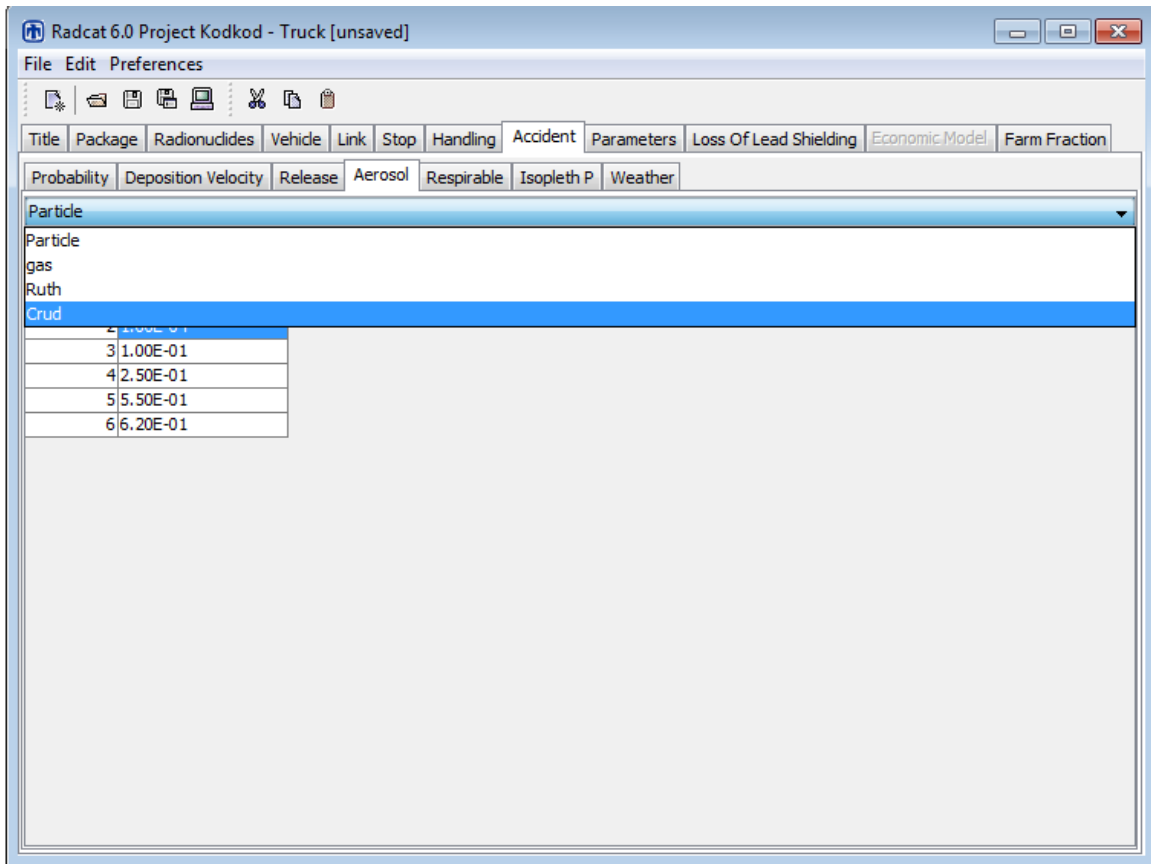


Figure 22: Accident/aerosol tab

11.5 Respirable Fraction

The **Respirable Fraction**, the fraction of each **Aerosol Fraction** that consists of particles or droplets small enough to enter the lung alveoli (usually considered to be less than 10 microns in diameter)³, depends on the physical and chemical behavior of the radionuclides and on the severity of the accident. The pull-down menu at the top allows selection of the physical/chemical **Group**. Groups may not be added or deleted at this tab. Select a physical/chemical **Group** from the pull-down menu seen in Figure 23.

The left-hand column shows the **Index** number which is associated with each conditional probability. Enter a **Respirable Fraction** for each **Index** and each **Group**. The **Respirable Fraction** is usually between 0.02 and 0.05. Indices may not be added or deleted at this tab.

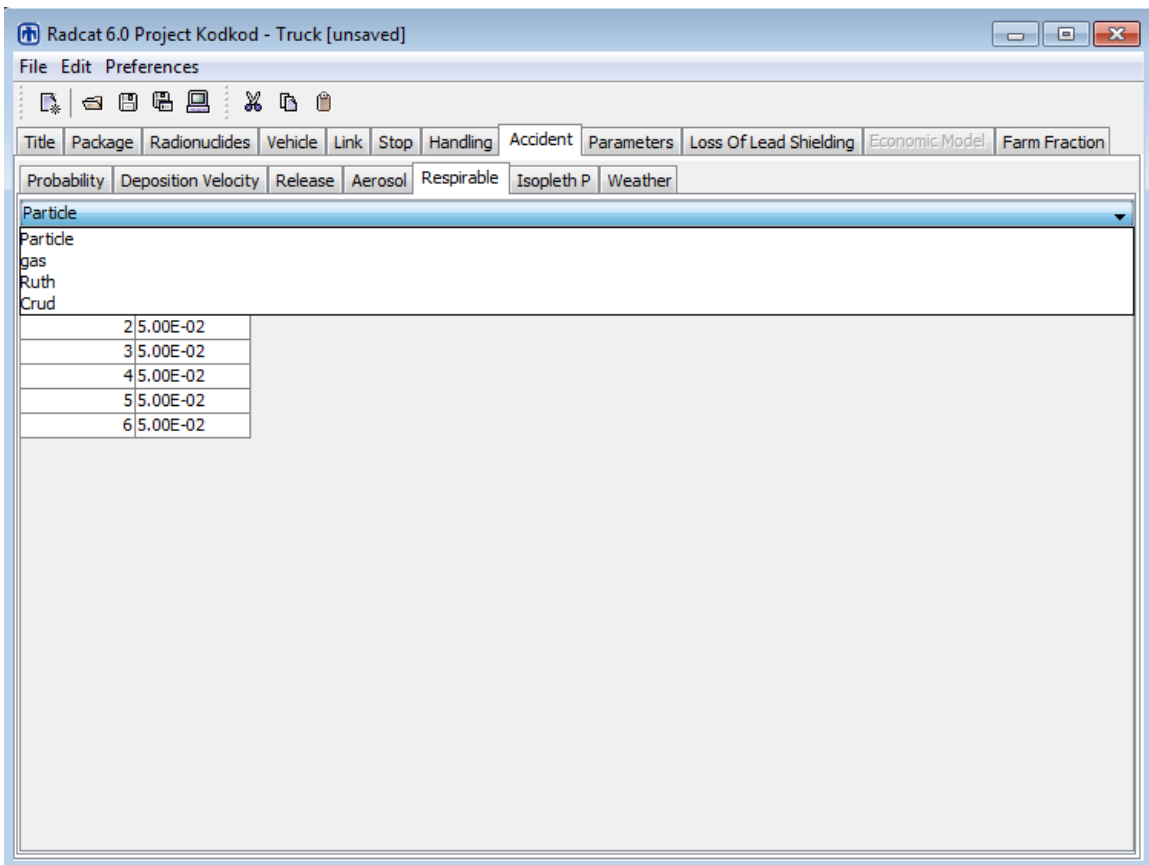


Figure 23: Accident/respirable tab

³ The inhalation dose conversion factors used in RADTRAN, which are from ICRP 72, include contributions from larger particles in the nasopharyngeal system

11.6 Isopleth P

RADTRAN provides two alternative methods of identifying the population that could experience the fallout from an accidental release of radioactive material. The default method takes the population density in the 800-meter band on either side of the transportation route, from the **Links** tab, and applies it to the footprint of the entire plume, encompassing all selected isopleths. The alternate method allows a different population density to be associated with (and entered for) each isopleth; the population densities must be obtained offline from a GIS system or some other population map. The **Isopleth P** tab provides you with a choice between the default and the alternate method. Open the **Isopleth P** tab before you open the **Weather** tab. The two buttons at the top of the tab provide the choice between the default population density (the density in the 800-meter band) and user-supplied population densities. This can be seen in Figure 24. User-supplied population densities in **Isopleth P** may only be used with the **Average** option on the **Weather** tab. If **Specify your own population densities** is selected, a population density must be added for each isopleth area by adding or removing population densities with the “Add Isopleth P” or “Remove Isopleth P” buttons respectively. If **Use the default population densities** is selected, you can choose any of the options listed in the **Weather** tab, and the population densities listed in the **Link** tab will be used for the isopleth areas. Isopleth areas may not be added or deleted at this tab. As RADTRAN is currently configured, the user-supplied population densities option in Isopleth P can be used only with National Average weather (**Average Option** in the **Weather** tab).

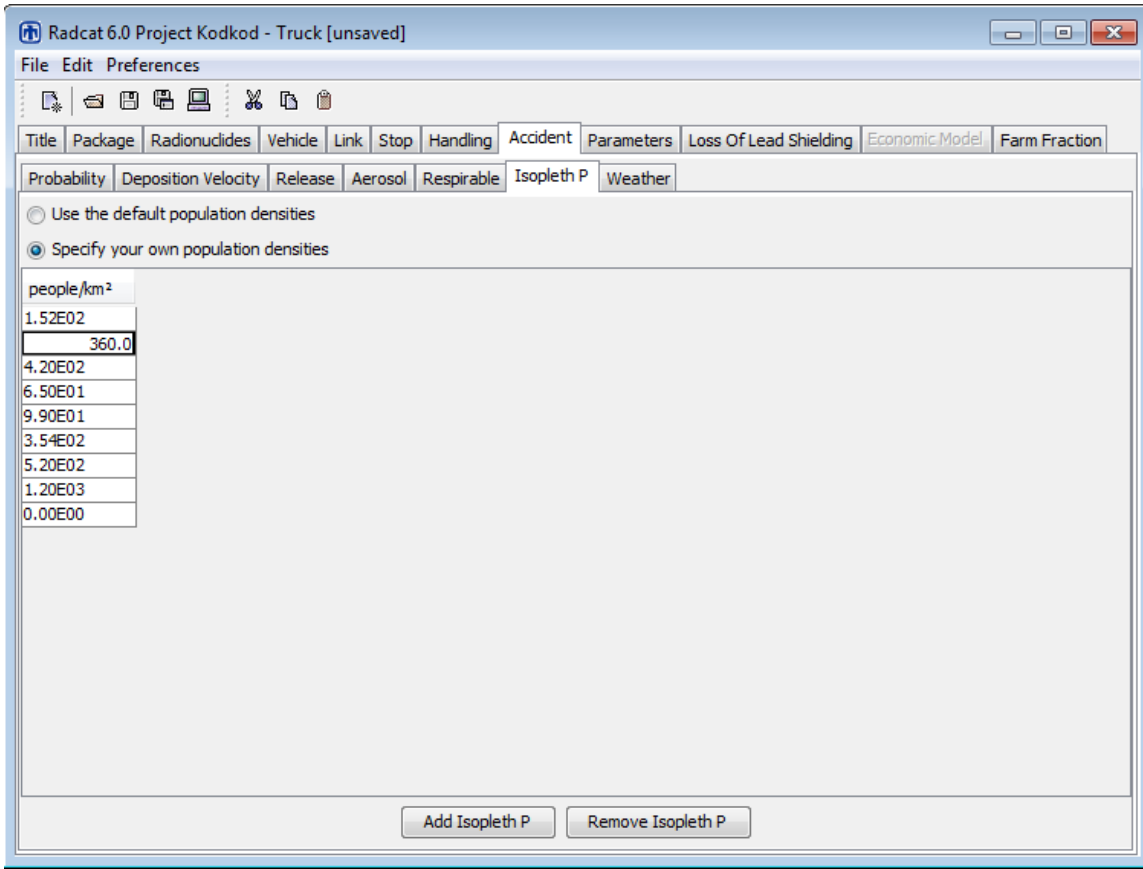


Figure 24: Accident/isopleth P tab

11.7 Weather

Open the **Weather** tab after you open the **Isopleth P** tab. If **Specify your own population densities** is selected on the **Isopleth P** tab, you must select the **Average Weather** tab and the same number of dispersion areas as **Isopleth P** population densities. The number of dispersion areas may be added or removed using the bars at the bottom of the tab. This can be seen in Figure 25. If desired, **Isopleth Areas**, maximum **Centerline Distances** for each area, and corresponding **Time Integrated Concentrations** may be calculated externally using any Gaussian dispersion program, and can be entered manually into the table on this tab. You cannot add or delete population densities in this tab.

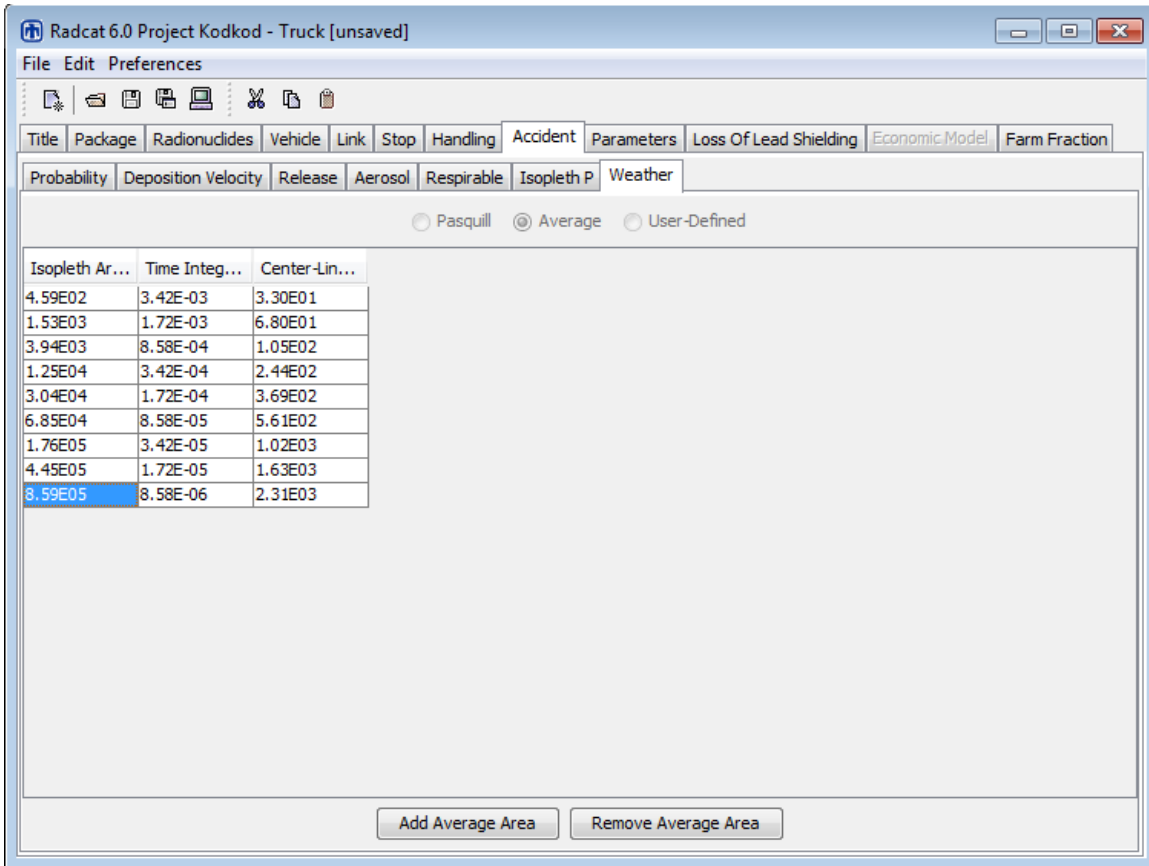


Figure 25: Accident/weather tab with user-defined dispersion option

11.7.1 The Average Option

Choosing the **Average** option selects a set of **Isopleth areas**, maximum **Centerline Distances** for each area, and corresponding **Time Integrated Concentration** (dilution, or Chi/Q, factors) based on U. S. national average meteorology (NRC, 1977) and wind speed (Figure 26). Areas may be added to or withdrawn using the bars at the bottom of the tab. RADTRAN cannot handle more than 18 isopleth areas. This option cannot be used if INGEST ingestion dose model is selected (the selection is made on the **Title** tab).

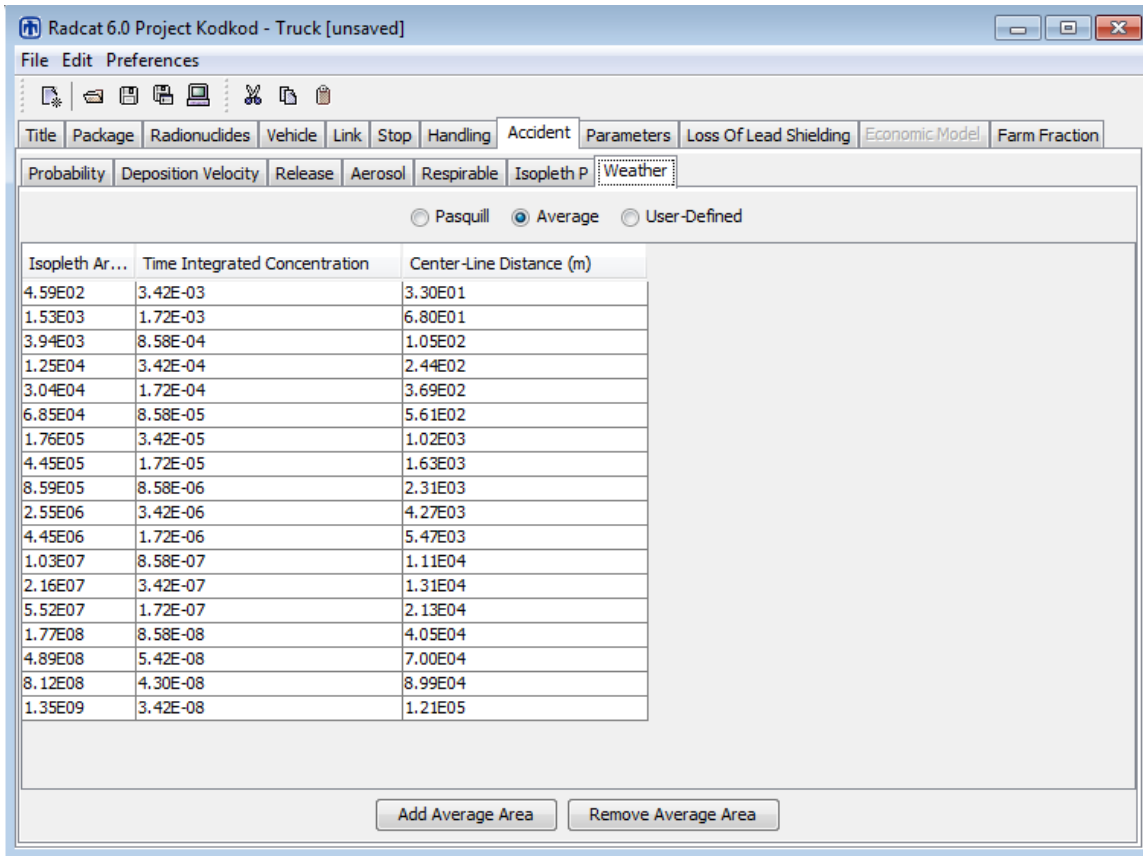


Figure 26: Accident/weather tab with national average weather option

11.7.2 The Pasquill Option

Choosing the **Pasquill** option opens a tab listing the six meteorological **Pasquill Stability Classes** in the left-hand column and allows you to enter the fraction of occurrence of each **Stability Class** in the **Fraction** column as seen in Figure 27. These fractions must total exactly 1 or RADTRAN will not execute in this option, each **Stability Class** has an associated fixed wind speed, as shown in Table 6. This option cannot be used if INGEST ingestion dose model is selected (the selection is made on the **Title** tab).

Table 6: Pasquill Wind Speeds for Each Stability Class

Stability Class	Wind Speed (m/sec)
A	1
B	2
C	3
D	4
E	2.5
F/G	1

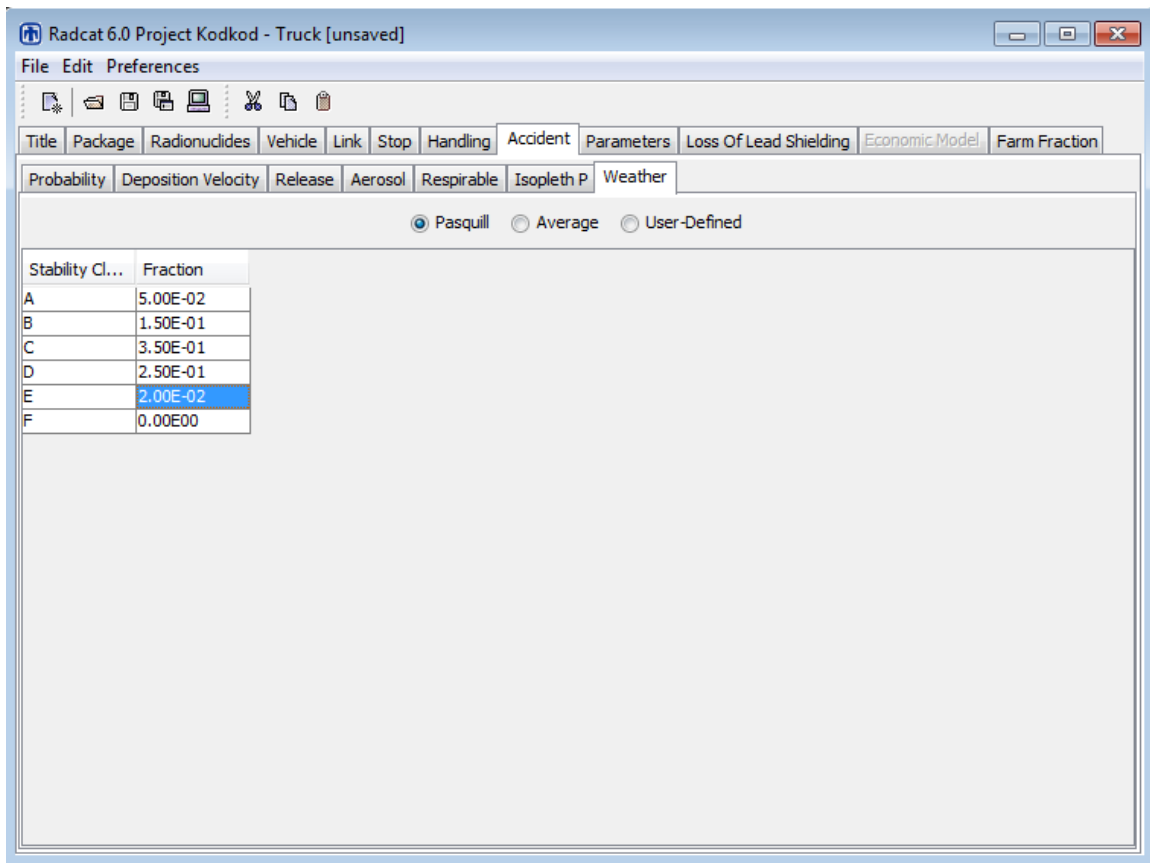


Figure 27: Accident/weather tab with Pasquill option

11.7.3 The User-Defined Option

The User-Defined option allows modeling of higher temperature and elevated releases, rainout, and the application of user-defined wind speeds. Choosing the User-Defined option opens a tab listing the input parameters listed below and shown in Figure 28. You can only use this option for one specific type of cask, release location, and wind stability class. Use of the INGEST ingestion dose model requires the User-Defined weather option.

Release Height (m) – This parameter allows you to specify the release height for an atmospheric dispersion. “Effective release height” is generally the elevation at which the plume begins to move downwind.

1. **Heat Release (calories/sec)** – This parameter allows you to incorporate thermally-induced buoyancy and momentum that will affect the effective release height.
2. **Cask Length (m)** – This cask length should be the same as the largest cask dimension indicated on the **Package** tab.

3. **Cask Radius (m)** – This cask radius should be the same as indicated on the **Package** tab.
4. **Wind Speed at Anemometer (m/sec)** – This parameter will allow you to specify the wind speed at an anemometer reading site.
5. **Anemometer Height (m)** – This parameter will allow you to correlate the anemometer wind speed with the wind speed at the effective release height, usually 10 meters.
6. **Ambient Temperature (degrees Kelvin, °K)** – This parameter adjusts the plume rise accordingly to adiabatic and potential temperature lapse rates. $293\text{ °K} = 20\text{ °C} = 68\text{ °F}$; $273\text{ °K} = 0\text{ °C} = 32\text{ °F}$
7. **Atmospheric Mixing Height (m)** – This parameter will allow you to define the height to which the atmosphere is uniformly mixed, which is the *de facto* height to which the plume will rise. The mixing height can be determined analytically by finding the height above the ground of the intersection of the ambient temperature profile with the dry adiabatic lapse rate. If there is no temperature inversion, the mixing height can be infinite, but is often entered as a kilometer (1000 meters) or more.
8. **Rainfall Rate** – This parameter will allow you to incorporate wet deposition into the dispersion model. It is recommended that this parameter be used for light and medium rainfall (a few millimeters per hour) since this model does not incorporate the surface runoff or washout which is experienced with heavy rainfall. The Solar and Meteorological Surface Observation Network has the following definitions for rainfall rates:
 - Light Drizzle: Up to 0.25 mm/hr
 - Medium Drizzle: 0.25 to 0.51 mm/hr
 - Heavy Drizzle: Greater than 0.51 mm/hr

 - Light Rainfall: Up to 2.5 mm/hr
 - Medium Rainfall: 2.5 to 7.6 mm/hr
 - Heavy Rainfall: Greater than 7.6 mm/hr

The website <http://precip.fsl.noaa.gov/beta/precip7.html> can provide hourly rain data from the National Oceanic and Atmospheric Administration (NOAA) Forecast System Laboratory:

9. **Dispersion Model** – This parameter allows a choice between the Pasquill-Gifford dispersion coefficients and the Briggs dispersion coefficients. The former is suitable for rural areas and the latter, for urban areas (Turner, 1967).

10. **Stability Category** – This parameter will allow you to determine which Pasquill stability class (A-F) will be used. In general, classes A, B, and C are consistent with increasing wind speed and unstable atmospheric conditions, class D is neutral (the ambient lapse rate is the same as the adiabatic lapse rate) and consistent with wind speeds about 4 to 5 m/sec, and classes E and F are consistent with very light winds, poor dispersion, and temperature inversions. Any text on air pollution can provide a complete discussion of Pasquill stability class. References that may be consulted are Turner (1967), Randerson (1984) and Wark, et al (1998).

11. **Release Location** – This parameter allows you to designate whether the release will be in a rural or suburban/urban location. This option provides different dispersion results, but at present RADTRAN models only one accident. If some links on a route are rural and some, urbanorsuburban, two different RADTRAN analyses can be conducted. Both the COMIDA and INGEST ingestion dose models apply only to rural links.

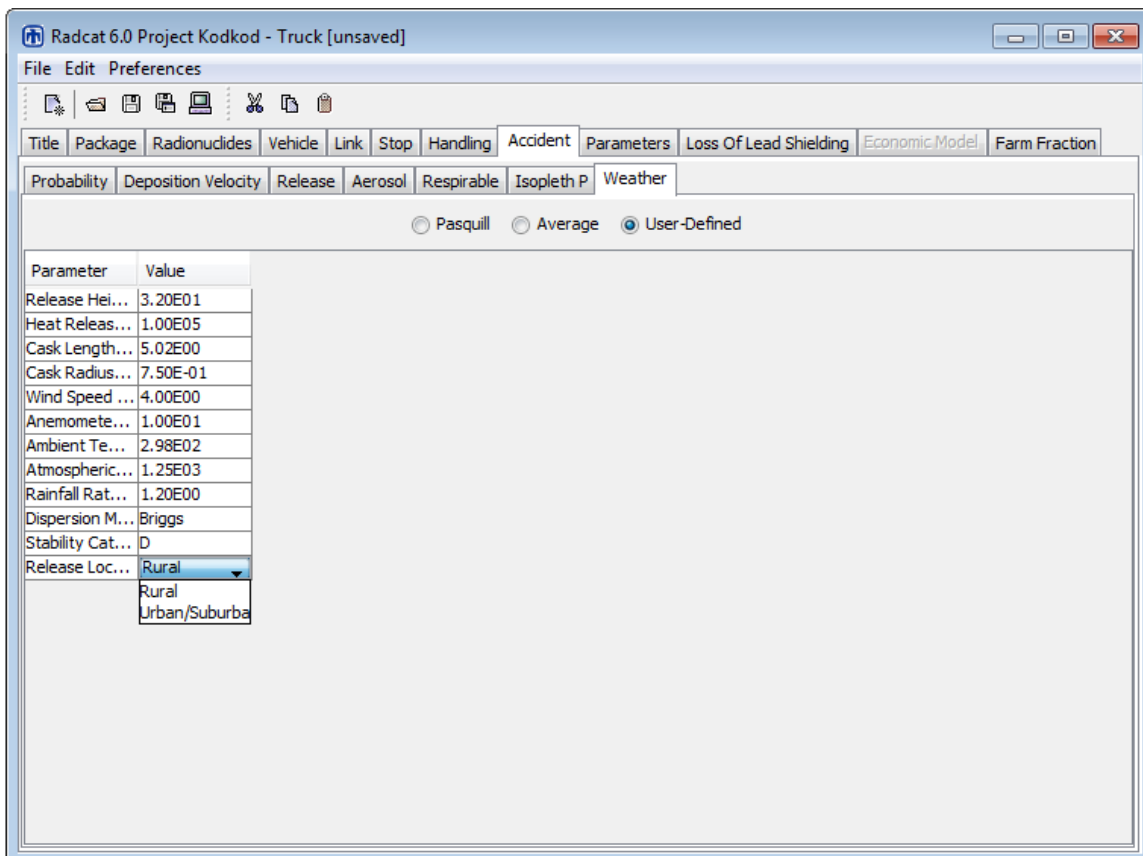


Figure 28: Accident/weather tab with user-defined option

12. PARAMETERS

Figures 29, 30, and 31 lists values that have historically been used in RADTRAN for a variety of parameters. They are referred to as “default” values but are not true defaults, because any or all of them can be overwritten. These parameter values are presented for the RADTRAN user’s convenience. Figure 29 shows the **Parameters** tab for highway routes, Figure 30 shows the **Parameters** tab for rail routes and Figure 31 shows the **Parameters** tab for barge routes.

Shielding factor for residences

The shielding factor is the fraction of ionizing radiation to which residents along the route are exposed in their homes or other buildings. It is the inverse of the shielding fraction; i.e., a shielding factor of 1 indicates no shielding, and a shielding factor of zero indicates 100% shielding. The shielding factor is different for rural, suburban, and urban zones because building materials differ. Figures 29, 30, and 31 show the default values for shielding factors: 1.0 (i.e., no shielding) for rural buildings, 0.87 for suburban buildings, and 0.018 for urban buildings. You can substitute any number for these values.

Fraction of outside air in urban buildings

This is the fraction of aerosol particles in the outside air which may be entrained in building ventilation systems (i.e., the fraction of particles of an external aerosol that remain in aerosol form after passing through a ventilation system) to which people in urban structures are exposed. The fraction of outside air in urban buildings is used to calculate the inhalation dose to that population. The default value of 0.05 represents a conservative average across a series of building types, including residential, office, and industrial structures (Engelmann, 1990) and is possibly outdated.

Fraction of population occupying the sidewalk

This parameter applies only to sidewalks on an urban link (a city street) that abuts the streets on which the vehicle travels, and specifies the fraction of population that is not inside buildings. The default value of 0.48 is for the latter model, and is taken from Finley et al. (1980). This value is suitable for large cities and conservative for smaller cities. This parameter and the **Fraction of urban population inside buildings** automatically add to 1.00.

Fraction of urban population inside buildings

This parameter describes either the fraction of the population that is indoors or the fraction of the area that is occupied by buildings, depending on the type of population model being used. The default value of 0.52 is for the latter model, and is taken from Finley et al. (1980).

Ratio of pedestrians/km² to residential population/km²

This ratio is used to calculate the exposure of unshielded persons on sidewalks in urban areas. This parameter applies only to sidewalks that line the transportation route on an urban link. The ratio can also serve as a surrogate for the ratio of non-resident (e.g., tourist) urban population to resident urban population since the U. S. Census, the source of population densities used in RADTRAN, includes only resident population. The default value is 6.0, which is based on empirical data from New York City (Finley et al., 1980).

Minimum small package dimension for handling

This parameter specifies the package size threshold, which determines the calculation of handler dose in RADTRAN. If a package is designated as “small,” i.e., smaller than the default threshold, the dose to the handler is calculated as originating in a uniform source. If package dimensions exceed the threshold, handler dose is calculated as described in Section 10. The default value is 0.5 m (Javitz, 1985)

Distance from shipment for maximum exposure

This parameter is used to calculate the maximum individual “in-transit” off-link dose. It is the minimum distance, in meters, perpendicular to the route, from the shipment centerline to an individual standing beside the route right-of-way while a shipment passes. The default value is 30 meters (NRC, 1977).

Vehicle speed for maximum exposure

This parameter is also used to calculate the maximum individual “in-transit” dose. It is the minimum speed of a shipment in km/hr. The default value is 24 km/hr (15 mph) (NRC, 1977), which is probably conservative. The appropriate table on the Bureau of Transportation Statistics web site (www.bts.gov) should be consulted for more realistic values for this parameter.

Parameter	Value
Shielding factor for rural residents	1.00E00
Shielding factor for suburban residents	8.70E-01
Shielding factor for urban residents	1.80E-02
Fraction of outside air in urban buildings	5.00E-02
Fraction of urban population occupying the sidewalk	4.80E-01
Fraction of urban population inside buildings	5.20E-01
Ratio of pedestrians/km ² to residential population/km ²	6.00E00
Minimum small package dimension for handling (m)	5.00E-01
Distance from shipment for maximum exposure (m)	3.00E01
Vehicle speed for maximum exposure (km/hr)	2.40E01
Imposed regulatory limit on vehicle external dose	Yes
Average breathing rate (m ³ /sec)	3.30E-04
Cleanup Level (microcuries/m ²)	2.00E-01
Interdiction Threshold(Ci/mCi)	4.00E01
Evacuation time for groundshine (days)	1.00E00
Survey interval for groundshine (days)	1.00E01
Occupational latent cancer fatalities per person-rem	6.00E-04
Public latent cancer fatalities per person-rem	6.00E-04
Campaign (year)	8.33E-02
Iodine	I131
Rem per curie thyroid via inhalation (Rem/Ci)	1.27E06
Distance of freeway vehicle carrying radioactive cargo to pedestrians (m)	3.00E01
Distance of freeway vehicle carrying radioactive cargo to right-of-way edge (m)	3.00E01
Distance of freeway vehicle carrying radioactive cargo to maximum exposure distance (m)	8.00E02
Distance of vehicle on secondary road carrying radioactive cargo to pedestrians (m)	2.70E01
Distance of vehicle on secondary road carrying radioactive cargo to right-of-way edge (m)	3.00E01
Distance of vehicle on secondary road carrying radioactive cargo to maximum exposure distance (m)	8.00E02
Distance of vehicle on city street carrying radioactive cargo to pedestrians (m)	5.00E00
Distance of vehicle on city street carrying radioactive cargo to right-of-way edge (m)	8.00E00
Distance of vehicle on city street carrying radioactive cargo to maximum exposure distance (m)	8.00E02
Perpendicular distance to freeway vehicle going in opposite direction (m)	1.50E01
Perpendicular distance to non-freeway vehicle going in opposite direction (m)	3.00E00
Perpendicular distance to city vehicle going in opposite direction (m)	3.00E00
Perpendicular distance to all vehicles going in same direction (m)	4.00E00

Figure 29: Parameters tab for highway mode

Imposed regulatory limit

The default setting is “YES” which causes a series of regulatory checks to be performed. If any circumstances are identified that violate the regulatory requirements (e.g., package dose rate exceeds regulatory maximum), then the appropriate parameter values are reset to the regulatory maximum (the critical package dimension may be adjusted as well) and the calculation continues. A message informing you is printed in the output. You may adjust the setting to “NO” which will bypass the regulatory check subroutine, and ensure that the package dose rate and package critical dimension used in RADTRAN calculations are those that you intended to use.

Average breathing rate

This parameter is used to calculate inhalation doses. The default is $3.30 \times 10^{-4} \text{ m}^3/\text{sec}$. This breathing rate is taken from the Reference Man (70-kg adult male at light work

derived from Shleien et al, 1996; Table 12.6). The value in the cited table, 20 liters/minute, has been converted to m³/sec.

Cleanup level

This parameter is the desired concentration, in microcuries/m² or mSv/m², to which a contaminated surface should be cleaned. The parameter is the total allowed activity of all deposited radionuclides. The default value is the EPA guidance of 0.2 μCi/m² (EPA, 1977).

Interdiction threshold

This parameter specifies the threshold value for interdiction of contaminated land. The default value is 40, i.e., a value 40 times greater than the **Cleanup Level** (NRC (1977)).

Evacuation time for groundshine

This is the evacuation time in days following a dispersal accident. The default value is 1.0 day (24 hours). Mills et al. (1995) analyzed 66 verified HazMat accidents in which evacuations were carried out and found that the mean evacuation time was approximately one hour. The resuspension model also uses this parameter as the time that the receptor is exposed to resuspended material. This time is an input to the calculation of the resuspension dose. If you wish to use a time for exposure to resuspended material different from the groundshine exposure time, you can run RADTRAN separately with a different groundshine exposure time.

Survey interval for groundshine

This parameter is the time (in days) required to survey contaminated land following a dispersal accident. None of the residents of the area are exposed to the released radioactive material during the survey interval. The default value for the survey interval is 10 days (NRC, 1977).

Occupational latent cancer fatalities per person-rem

This parameter specifies the occupational Latent Cancer Fatality (LCF) conversion factor for worker exposure; units are LCF per rem. The default value for workers is 6.0E-04 LCF/rem (0.06 LCF/Sv) and is consistent with the recommendations from the Interagency Steering Committee on Radiation Standards (DOE 2002a, ISCORS 2002). The uncertainties surrounding the use of the linear non-threshold theory to calculate potential LCF are discussed in the section below.

Public latent cancer fatalities per person-rem

This parameter specifies the non-occupational LCF conversion factor for public exposure; units are LCF per rem. The default value is 6.0E-04 LCF/rem (0.06 LCF/Sv) (ISCORS 2002).

No empirical evidence exists to support the default value. The joint report of the French Academies of Science and Medicine, cited in Tubiana and Aurengo (2005) states:

Epidemiological studies have clearly shown that the carcinogenic risks of low doses (< 100 mSv) are very small, if any.... [Radiobiological] data show that the use of a linear no-threshold relationship is not justified for assessing by extrapolation the risk of low doses...since this extrapolation relies on the concept of a constant carcinogenic effect per unit dose, which is inconsistent with radiobiological data. [100 mSv = 10,000 mrem = 10 rem]

Moreover, Gonzalez, et al (2013), in an extensive discussion of the misapplication of the linear non-threshold theory of radiation damage to predict “latent cancer fatalities,” state

In some low dose radiation exposure situations, particularly after accidents, nominal risk coefficients have been improperly used to ascribe hypothetical future deaths. Speculative, unproven, undetectable and ‘phantom’ numbers are obtained by multiplying the nominal risk coefficients by an estimate of the collective dose received by a huge number of individuals theoretically incurring very tiny doses that are hypothesized from radioactive substances released into the environment....(Gonzalez, et al, 2013, Section 2.2, p. 508)

The conversion to LCF is, however, commonly used and is therefore included as an option in RADTRAN output. Analysts are encouraged to report results in dose units and not in LCF.

Campaign

This is the duration of the shipping campaign in years, and is used to calculate the total number of off-link persons exposed, using the Census Bureau algorithm for the average length of residence in the U.S. The default value is 0.0833 years, an average month in an average year or 1/12th of a year. Although the total number of exposed persons is calculated, neither the time that each person is exposed nor the exposure time for the total group is calculated.

Rem per curie thyroid via inhalation

This is the one-year committed effective dose equivalent (CEDE) in rem per curie to the thyroid from inhalation of iodine isotopes to estimate early-mortality risk. The default values are 1.27×10^6 for Iodine-131, 5.77×10^6 for Iodine-129, and 9.25×10^5 for Iodine-125. Currently only I-131 is called out in the input file.

The following parameters apply to traffic on highways.

Distance of freeway vehicle carrying radioactive cargo to pedestrians
Distance of freeway vehicle carrying radioactive cargo to right-of-way edge
Distance of freeway vehicle carrying radioactive cargo to maximum exposure distance

These are the distances between a vehicle that is transporting radioactive material on a limited access highway (a freeway) or U.U. primary highway and, respectively, pedestrians on the sidewalk along the route, residents along the route at the edge of the right-of-way, and the outer boundary of band along the route occupied by the residents. The default value for the right of way edge is 30 meters and for the outer boundary, it is usually 800 meters. The distance to a sidewalk (valid only for urban areas) is 27 meters, allowing for a 3-meter sidewalk (NRC, 1977). These distances are for truck travel and are shown in Figure 29.

Distance of non-freeway vehicle carrying radioactive cargo to pedestrians
Distance of non-freeway vehicle carrying radioactive cargo to right-of-way edge
Distance of non-freeway vehicle carrying radioactive cargo to maximum exposure distance

These are the distances between a vehicle that is transporting radioactive material on a secondary road and, respectively, pedestrians on the sidewalk along the route, residents along the route at the edge of the right-of-way, and the outer boundary of band along the route occupied by the residents. The default value for the right of way edge is 30 meters and for the outer boundary, it is usually 800 meters. The distance to a sidewalk (valid only for urban areas) is 27 meters, allowing for a 3-meter sidewalk (NRC, 1977). These distances are for truck travel and are shown in Figure 29.

Distance of city street vehicle carrying radioactive cargo to pedestrians
Distance of city street vehicle carrying radioactive cargo to right-of-way edge
Distance of city street vehicle carrying radioactive cargo to maximum exposure distance

These are the distances between a vehicle that is transporting radioactive material on a city street and, respectively, pedestrians on the sidewalk along the route, residents along the route at the edge of the right-of-way, and the outer boundary of band along the route occupied by the residents. The default value for the right of way edge is 8 meters and for the outer boundary, it is usually 800 meters. The distance to a sidewalk is 5 meters, allowing for a 3-meter sidewalk (NRC, 1977). Although Type B and most Type A casks would not be transported on city streets, radiopharmaceuticals, blood irradiators, and research materials are transported in cities. These distances are shown in Figure 29.

Perpendicular distance to freeway vehicle going in the opposite direction

The default value is 15 meters (Madsen et al., 1986, pp. 36-37). This parameter specifies the average perpendicular distance (i.e. a distance measured along a line at right angles to the line of travel of the radioactive materials shipment) between the radioactive

materials shipment and lanes of traffic traveling in the opposite direction, in meters. The value is based on a configuration of four lanes with an average lane width of 5 meters, with the radioactive materials shipment in the outside lane, oncoming traffic in the corresponding outside lane, and passing vehicles in the inner lanes.

Perpendicular distance to non-freeway vehicle going in the opposite direction
Perpendicular distance to city vehicle going in the opposite direction

The default value is 3 meters (Madsen et al. 1986 p. 36-37), based on a road configuration of two lanes with an average lane width of 3 meters, in the most typical traffic configuration.

Perpendicular distance of all vehicles going in the same direction

The default value is 4 meters (Madsen et al., 1986). This value is based on the median value for all interstate and secondary-road lane widths.

The following parameters apply to rail transportation.

Minimum number of rail classification stops

This applies to rail mode only and specifies the minimum number of railcar classifications per trip. The default value is 2 since there are at least two inspections per trip – one at the beginning and one at the end of each trip (Wooden 1986). The collective dose to railyard workers at a 30-hour classification stop has been integrated into RADTRAN, and is multiplied by this number to give the dose to yard workers at classification stops. The dose is the weighted sum of the doses for railyard worker groups, and is calculated primarily with a line-source model, though a point-source model is used when appropriate. For general freight, dose is calculated with the modifying factors b_1 through b_7 , which have units of person-hr/km and are derived from Wooden (1987) as described in Appendix B of Neuhauser, et al (2000) (Figure 30).

Although there are always classification stops at the origin and terminus of a trip, the residential population around the stop may differ. In this case it may, for clarity, be better to use one classification stop.

Parameter	Value
Shielding factor for rural residents	1.00E00
Shielding factor for suburban residents	8.70E-01
Shielding factor for urban residents	1.80E-02
Fraction of outside air in urban buildings	5.00E-02
Fraction of urban population occupying the sidewalk	4.80E-01
Fraction of urban population inside buildings	5.20E-01
Ratio of pedestrians/km ² to residential population/km ²	6.00E00
Minimum small package dimension for handling (m)	5.00E-01
Distance from shipment for maximum exposure (m)	3.00E01
Vehicle speed for maximum exposure (km/hr)	2.40E01
Imposed regulatory limit on vehicle external dose	Yes
Average breathing rate (m ³ /sec)	3.30E-04
Cleanup Level (microcuries/m ²)	2.00E-01
Interdiction Threshold(Ci/mCi)	4.00E01
Evacuation time for groundshine (days)	1.00E00
Survey interval for groundshine (days)	1.00E01
Occupational latent cancer fatalities per person-rem	6.00E-04
Public latent cancer fatalities per person-rem	6.00E-04
Campaign (year)	8.33E-02
Iodine	I129
Rem per curie thyroid via inhalation (Rem/Ci)	1.27E06
Minimum number of rail classification stops	2.00E00
Distance dependent rail worker exposure factor (inspections/km)	1.80E-03
Dedicated trains	No
Distance of rail vehicle carrying radioactive cargo to pedestrians (m)	3.00E01
Distance of rail vehicle carrying radioactive cargo to right-of-way edge (m)	3.00E01
Distance of rail vehicle carrying radioactive cargo to maximum exposure distance (m)	8.00E02
Perpendicular distance to rail vehicle vehicle going in opposite direction (m)	3.00E00

Figure 30: Parameters Tab with Rail Mode

Distance dependent rail worker exposure factor

In the event that the actual data on rail stops along a route is not available, this factor can be used to calculate the railyard worker dose at stops along the route. Ostmeyer (1986) estimated an average of 0.0018 inspections/km. The 30-hour collective railyard worker dose is multiplied by this number and by the total shipment distance in kilometers to give the in-transit railyard worker dose.

Dedicated Trains

If a shipment is by general freight or key trains, this switch should read **NO**; if by dedicated rail, **YES**. The default setting is **NO**. This can be seen in Figure 30. The main difference between the two options is the exposure of rail workers in rail yards. For dedicated rail, worker dose is calculated with factors b_8 through b_{11} of Appendix B of Neuhauser, et al (2000).

Distance of rail car carrying radioactive cargo to pedestrians

Distance of rail car carrying radioactive cargo to right-of-way edge

These two distances are the same, since there is no pedestrian walkway or sidewalk along a rail route. The default value is 30 meters (NRC, 1977). This parameter is the minimum perpendicular distance over which the off-link dose calculation will be integrated. no sidewalk available.

Distance of rail car carrying radioactive cargo to maximum exposure distance

The default value is 800 meters (NRC, 1977). This parameter is the maximum perpendicular distance over which the off-link dose calculations will be integrated.

Perpendicular distance to rail car vehicle going in the opposite direction

The default value is 3 meters (Madsen et al. (1986 p. 36-37). This parameter specifies the perpendicular distance between the radioactive materials shipment and other traffic lanes, in meters and is based on a minimum clearance between passing trains on double rail segments.

Distance of waterway barge carrying radioactive cargo to pedestrians

Distance of waterway barge carrying radioactive cargo to right-of-way edge

These two distances are the same, since there is no pedestrian walkway or sidewalk along a barge route. The default value is 200 meters (NRC, 1977). This parameter the minimum perpendicular distance over which the off-link dose calculation will be integrated. This can be seen in Figure 31.

Distance of waterway barge carrying radioactive cargo to maximum exposure distance

The default value is 1 km (NRC, 1977). This parameter is the maximum perpendicular distance over which the off-link dose calculations will be integrated

Parameter	Value
Shielding factor for rural residents	1.00E00
Shielding factor for suburban residents	8.70E-01
Shielding factor for urban residents	1.80E-02
Fraction of outside air in urban buildings	5.00E-02
Fraction of urban population occupying the sidewalk	4.80E-01
Fraction of urban population inside buildings	5.20E-01
Ratio of pedestrians/km ² to residential population/km ²	6.00E00
Minimum small package dimension for handling (m)	5.00E-01
Distance from shipment for maximum exposure (m)	2.00E02
Vehicle speed for maximum exposure (km/hr)	2.40E01
Imposed regulatory limit on vehicle external dose	Yes
Average breathing rate (m ³ /sec)	3.30E-04
Cleanup Level (microcuries/m ²)	2.00E-01
Interdiction Threshold(Ci/mCi)	4.00E01
Evacuation time for groundshine (days)	1.00E00
Survey interval for groundshine (days)	1.00E01
Occupational latent cancer fatalities per person-rem	6.00E-04
Public latent cancer fatalities per person-rem	6.00E-04
Campaign (year)	8.33E-02
Iodine	I125
Rem per curie thyroid via inhalation (Rem/Ci)	9.25E05
Distance of waterway barge carrying radioactive cargo to pedestrians (m)	2.00E02
Distance of waterway barge carrying radioactive cargo to water's edge (m)	2.00E02
Distance of waterway barge carrying radioactive cargo to maximum exposure distance (m)	8.00E02

Figure 31: Parameters tab with barge mode

13. LOSS OF LEAD SHIELDING (LOS)

Loss of Lead Shielding is modeled in a manner analogous to the modeling of an accident. The radiation dose from a loss of lead gamma shielding is calculated by RADTRAN using a multiplier of the external radiation dose from the shielded cask (O'Donnell, et al, 2004). The conditional probability of a particular loss of shielding is the probability, given an accident, that a particular fraction of lead shielding will be lost. The dose from that particular shielding loss is calculated using the RADTRAN Stop model (Section 9).

13.1 LOS probability

The **Probability** tab allows you to specify the conditional probability of an accident of a particular severity, given that an accident happens (just as with an accident involving a release). The probability tab is shown in Figure 32.

The **Index** is a numbering system for conditional probabilities and simply enumerates them (note that the **Index** begins with zero). One conditional probability (usually the zeroth) should represent an accident in which there is no loss of lead gamma shielding.

Conditional probabilities for LOS events may be obtained from studies of accidents as described in Sprung, et al (2000), DOE (2002b), NRC (2013), and similar references. Table 7 (from NRC 2013, Table V-2) shows some typical conditional probabilities and slump fractions for a Type B spent fuel cask. These are different from the parameter values shown in Figure 32.

Table 7. Sample conditional probabilities and LOS fractions (adapted from NRC (2013, Table V-2))

Index	Conditional probability of LOS	Maximum lead slump (mm)	Slump Fraction
0	0.9999	0.0	0.0
1	1.9E-06	0.09	0.017
2	4.3E-07	0.37	3.7E-03
3	3.4E-10	20.9	1.3E-03
4	1.8E-11	15.5	0.063
5	3.8E-6	1.65	0.023
6	8.6E-7	25.1	5.1E-03
7	6.8E-10	114.5	3.4E-04
8	3.6E-11	310.5	3.2E-03
9	6.3E-7	6.43	4.3E-03
10	1.4E-7	18.3	2.8E-04
11	1.1E-10	83.2	1.8E-05

Slump fraction

RADTRAN can only model removal (loss) of gamma shielding, and therefore uses removal as a surrogate for thinning or other distortions of the gamma shield. The **Slump Fraction** is the fractional portion of the lead gamma shielding that is removed during an LOS event. Each index and probability fraction will have an associated slump fraction as shown in Table 7 and Figure 32.

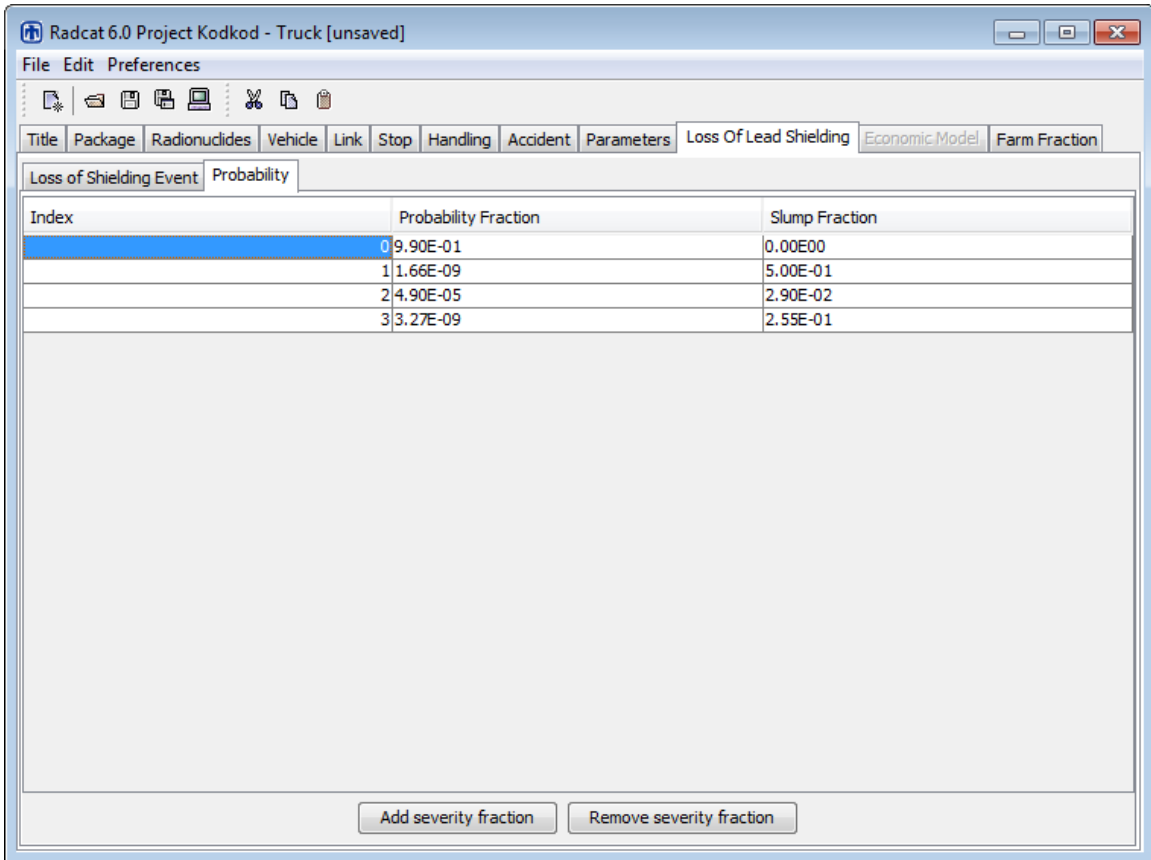


Figure 32. Loss of lead shielding tab, probability

13.2 Loss of Shielding Event

The input for a loss of shielding event is structured in part like the input for a stop, like the input for an accident that does not involve a release.

Name

Give each **Loss of shielding event** a **Name** in the left-hand column. An event name must be a continuous text string and must not include any spaces. Different dose receptors (e.g., public near the event, emergency first responders) and different population densities can be structured as different events.

Vehicle

Available vehicle names are on a pull-down menu in the **Vehicle** column, as shown in Figure 33 in the **Vehicle** column. Vehicle names cannot be added or deleted at this tab.

Minimum distance

Enter the shortest distance at the LOS event from the radioactive cargo to the receptor(s) whose dose will be calculated. The **Min(imum) distance** cannot be less than 1.0 meters and must be less than or equal to the **Max(imum) distance**.

Maximum distance

Enter the longest distance at the LOS event from the radioactive cargo to the receptor(s) whose dose will be calculated. The **Max(imum) Distance** must be greater than or equal to the **Min(imum) distance**.

People

This parameter defines the number of radiation receptors at each particular LOS Event as seen in Figure 33. If the **Min(imum)** and **Max(imum) distance** are the same, RADTRAN will report the dose for the given number of receptors at that distance. If the **Min(imum)** and **Max(imum) distance** are different, the number in the “People” column will be read as a population density, usually the population density along the route. The **Min(imum)** and **Max(imum) distance** will usually be 30 and 800 meters, respectively.

Shielding factor

The **Shielding factor** is the fraction of ionizing radiation to which the receptors are exposed; that is, the inverse of the amount of shielding. Thus 1 = no shielding and 0 = 100% shielding. Enter a number between 0 and 1 for the shielding factor for each stop. This can be seen in Figure 33 in the **Shielding Factor** column.

Time

Enter the total time in hours for each LOS event. The total time represents the duration of potential radiation exposure, and can be indicative of an emergency services first responder or the public awaiting evacuation. This is seen in Figure 33 in the **Time (h)** column.

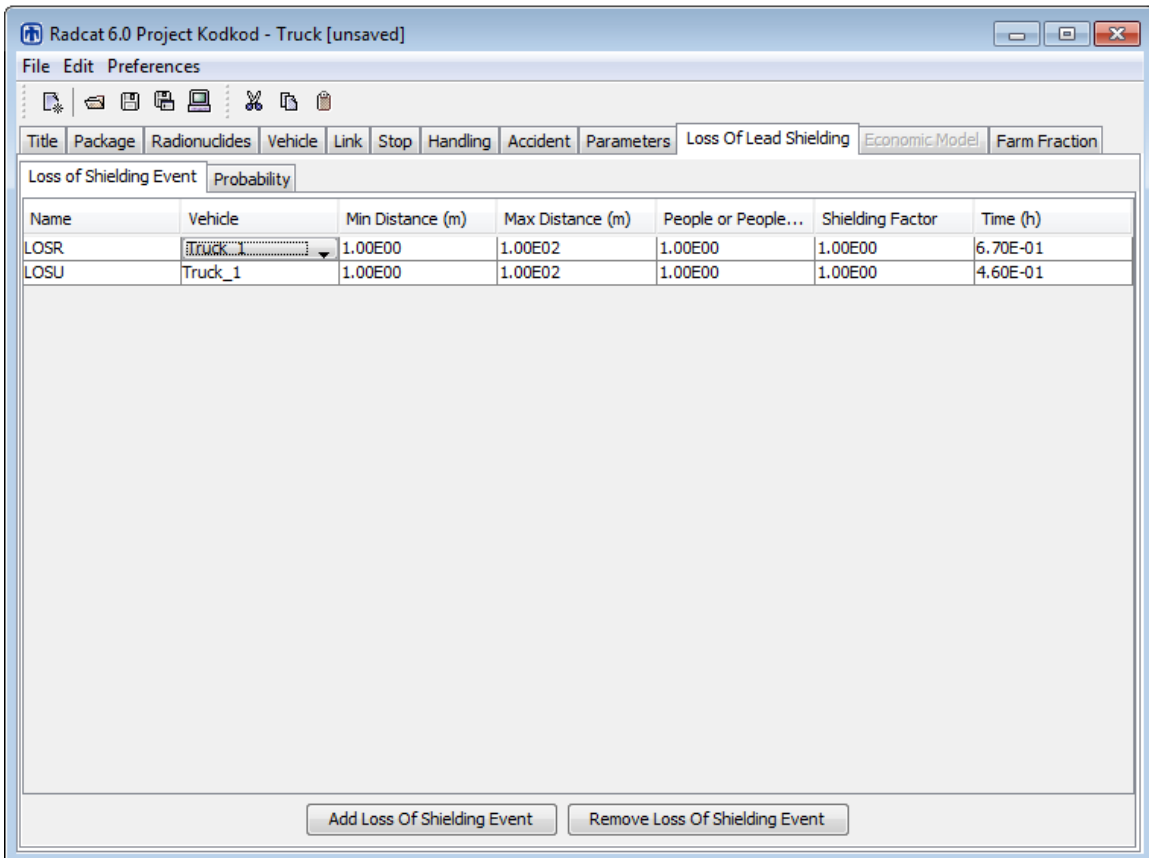


Figure 33: Loss of lead shielding tab, LOS event

14. ECONOMIC MODEL

An accidental release and dispersal of radioactive material during transportation could require evacuation of the population and decontamination of the affected area. The economic model in RADTRAN 6 estimates the cost of evacuation and decontamination.

A checkbox for the **Economic Model** is included on the **Title** tab. When unchecked, the **Economic Model** tab remains grayed out, and results from the **Economic Model** will not be included in the RADTRAN 6.0 output. However, if the box is checked, the Economic Model Tab will become functional. Figure 34 lists default values for the Economic Model, which can be overwritten. A listing of economic model parameter names, descriptions, average values and units can be found in Appendix B. Derivation of the economic model parameters is discussed in Osborn, et al (2007).

The screenshot shows the 'Economic Model' tab in the Radcat 6.0 software. The window title is 'Radcat 6.0 Project Kodkod - Truck [unsaved]'. The menu bar includes 'File', 'Edit', and 'Preferences'. The toolbar contains icons for file operations and editing. The 'Economic Model' tab is active, displaying a table of parameters and their default values. The 'Urban residential land use fraction' row is highlighted in blue.

Parameter	Value
Footprint of commercial buildings	3.37E02
Footprint of industrial buildings	6.62E03
Footprint of residential buildings	1.18E02
Area of commercial lots	9.30E02
Area of industrial lots	9.70E03
Area of residential lots	2.23E02
External dose rate per drum of resin	5.00E00
External dose rate for 1 Ci of Co-60 resin drum	2.70E02
Annual crop profit	1.30E-02
Cost of washing contaminated area	3.23E01
Rural evacuation cost	7.88E00
Suburban evacuation cost	1.36E01
Urban evacuation cost	1.36E01
Rural commercial land use fraction	1.00E-02
Suburban commercial land use fraction	1.40E-01
Urban commercial land use fraction	3.70E-01
Rural industrial land use fraction	1.00E-02
Suburban industrial land use fraction	9.00E-02
Urban industrial land use fraction	1.10E-01
Rural residential land use fraction	3.00E-02
Suburban residential land use fraction	2.80E-01
Urban residential land use fraction	2.40E-01
Rural soil land use fraction	9.50E-01
Suburban soil land use fraction	4.10E-01
Urban soil land use fraction	9.00E-02
Fraction of building surfaces contaminated	4.49E-01
Rural soil land use fraction for crops	2.00E-01
Rural soil land use fraction for livestock	2.80E-01
Average commercial building outside height	1.64E01
Average industrial building outside height	6.05E00
Average residential building outside height	5.32E00
Rural road density	5.97E-04
Suburban road density	8.11E-04
urban road density	8.06E-02
Resin density	1.28E00
Road width	8.84E00
Cost of soil removal	1.00E01
Contaminated soil depth	3.00E-02
Bi-annual profit from livestock	2.50E-02
Volume of waste container	2.17E-01

Figure 34: Economic model default values

15. RADTRAN OUTPUT

Once all the necessary input data has been entered to run RADTRAN, click on the Run RADTRAN icon, as shown in Figure 35. Once RADTRAN has run, a new Java window will open. If RADTRAN has run properly, SUCCESSFUL COMPLETION will be shown at the bottom of the Java window as shown in Figure 36.

8

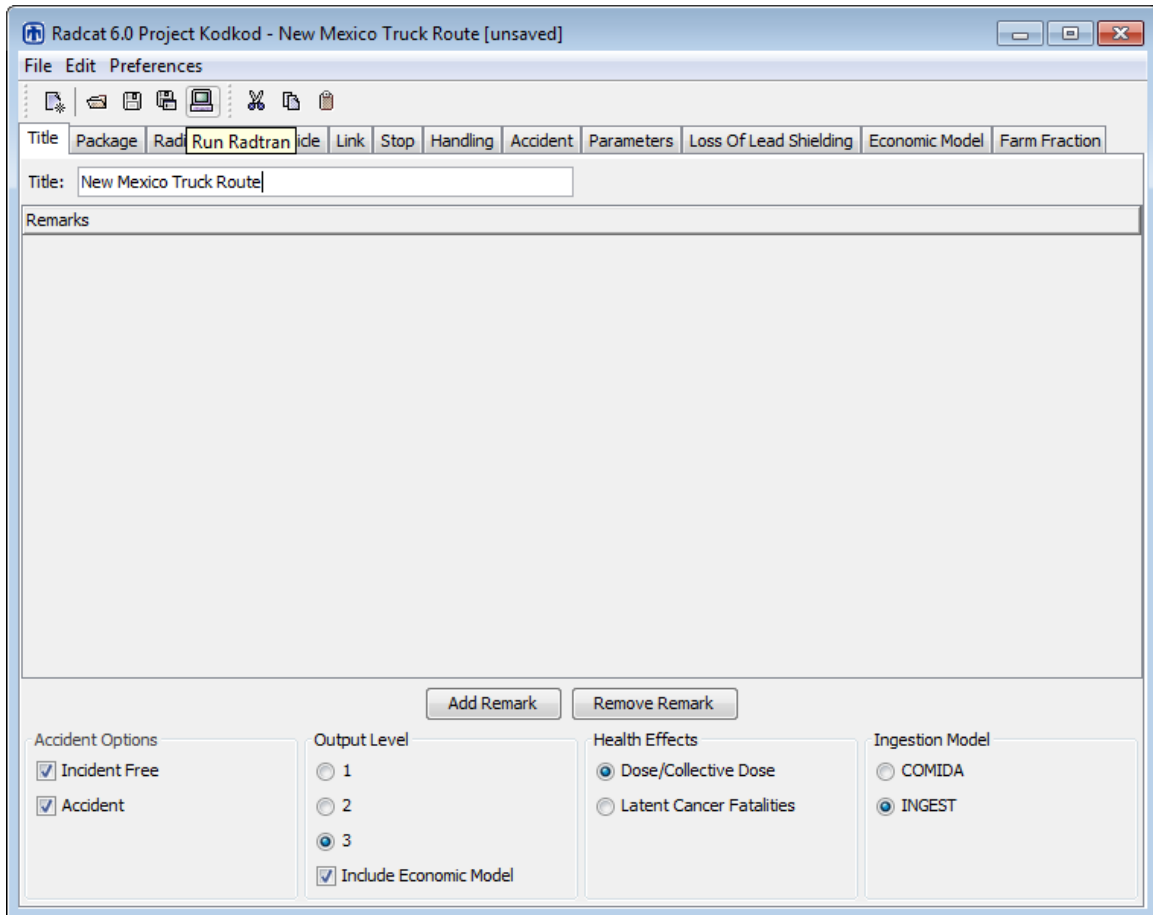


Figure 35: Run RADTRAN

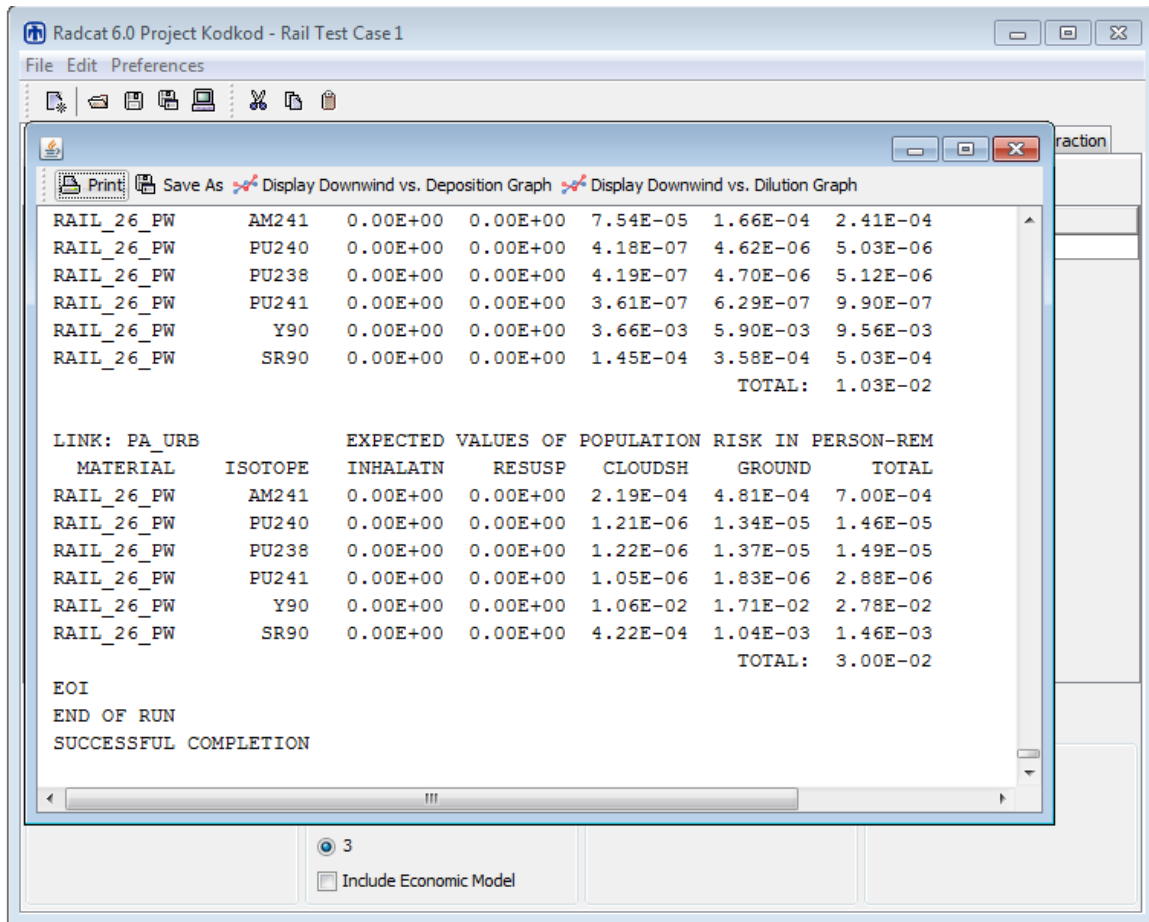


Figure 36: End of RADTRAN Output

The output is a text file that can be saved in text form. It can also be saved as, or imported into, an EXCEL spreadsheet so that you can work with the numbers in the output. An annotated copy of the RADTRAN output is provided in Appendix E.

The incident-free output is self-explanatory. “No release” accidents are modeled as stops, and are part of the incident-free stop output.

The output for an accident involving a release of radioactive material lists accident dose risks for each link, as shown in Figure 37. The links on which there is no accident (these are the links for which the user specified zero accident rate) show zero for all accident risks for that link. In versions of RADTRAN before RADTRAN 6.02, the total rural, suburban and urban accident risks were listed. These totals are meaningless and should be ignored, since only one accident will occur on each route.

On the bar at the top of the output screen is an icon titled “Display Downwind vs. Deposition Graph” as shown in Figure 38. These graphical displays plot the downwind distance vs. deposition and the downwind distance vs. dilution for National Average and User-defined weather only; results using the Pasquill option cannot be displayed as

graphs. Figure 38 shows an example of a graphical output. The graphical outputs are made with every successful RADTRAN run.

When RADTRAN is run, the output appears immediately on the screen, and may be printed and/or saved. The file that appears on the screen starts with an echo of the input file. The beginning of the output file is clearly marked. The file in Figure 37 can be saved as a text file, an excel file, or a Word document. It can be saved to any folder on the computer or LAN. An incomplete output file indicates some error in the input file that caused RADTRAN to abort. The error message that appears at the end of the output file in these cases is usually self-explanatory.

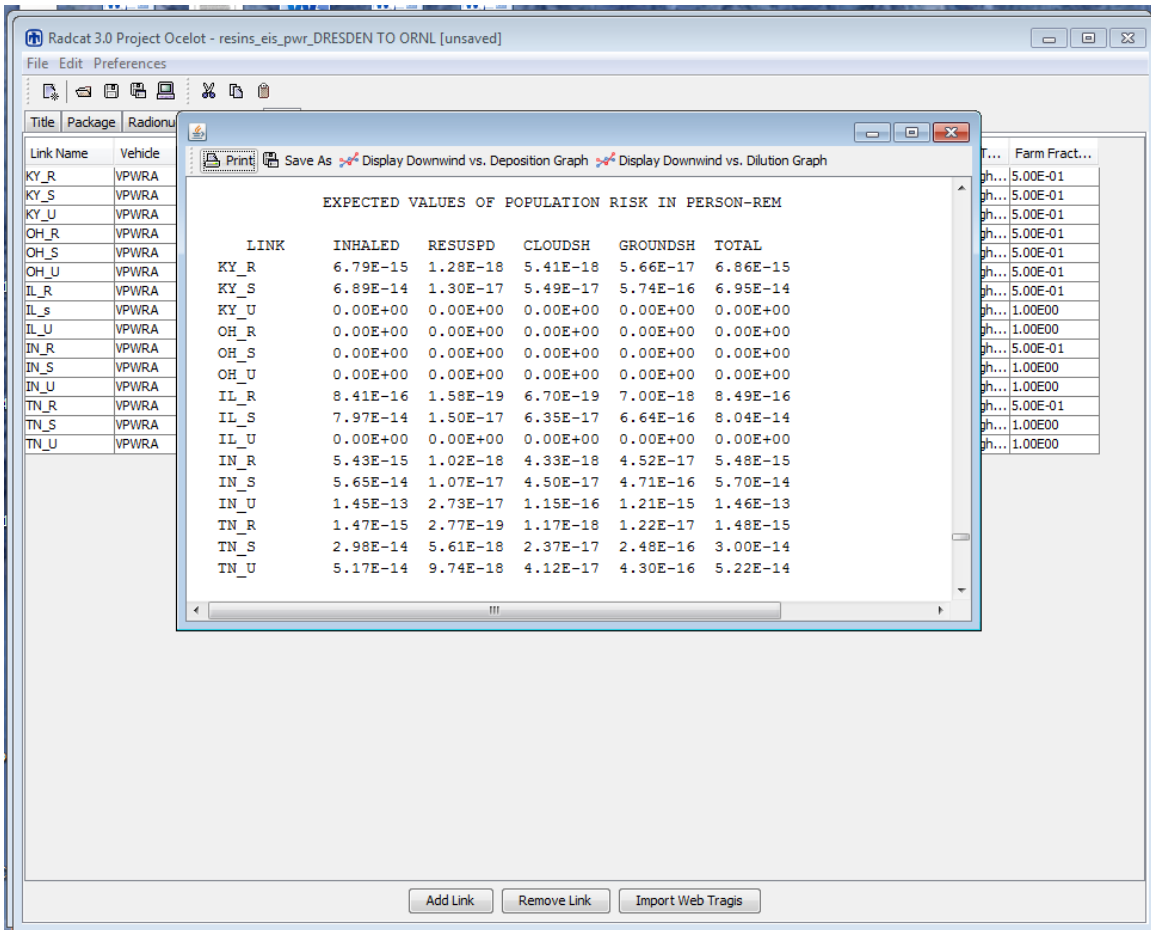


Figure 37: Accident output.

Figure 38 shows the accident output graphically. Changes can be made in the appearance of the output and graphical outputs can be saved. Left click over the graph window and select “Properties” or “Save as”, as shown in Figure 38. The graphical outputs can be saved as PNG Image Files. The properties that can be changed are:

- Title

- y-axis Name
- y-axis Range
- x-axis Name
- x-axis Range
- Background color

The legend and line colors cannot be changed. An example of these changes can be seen in Figure 40.

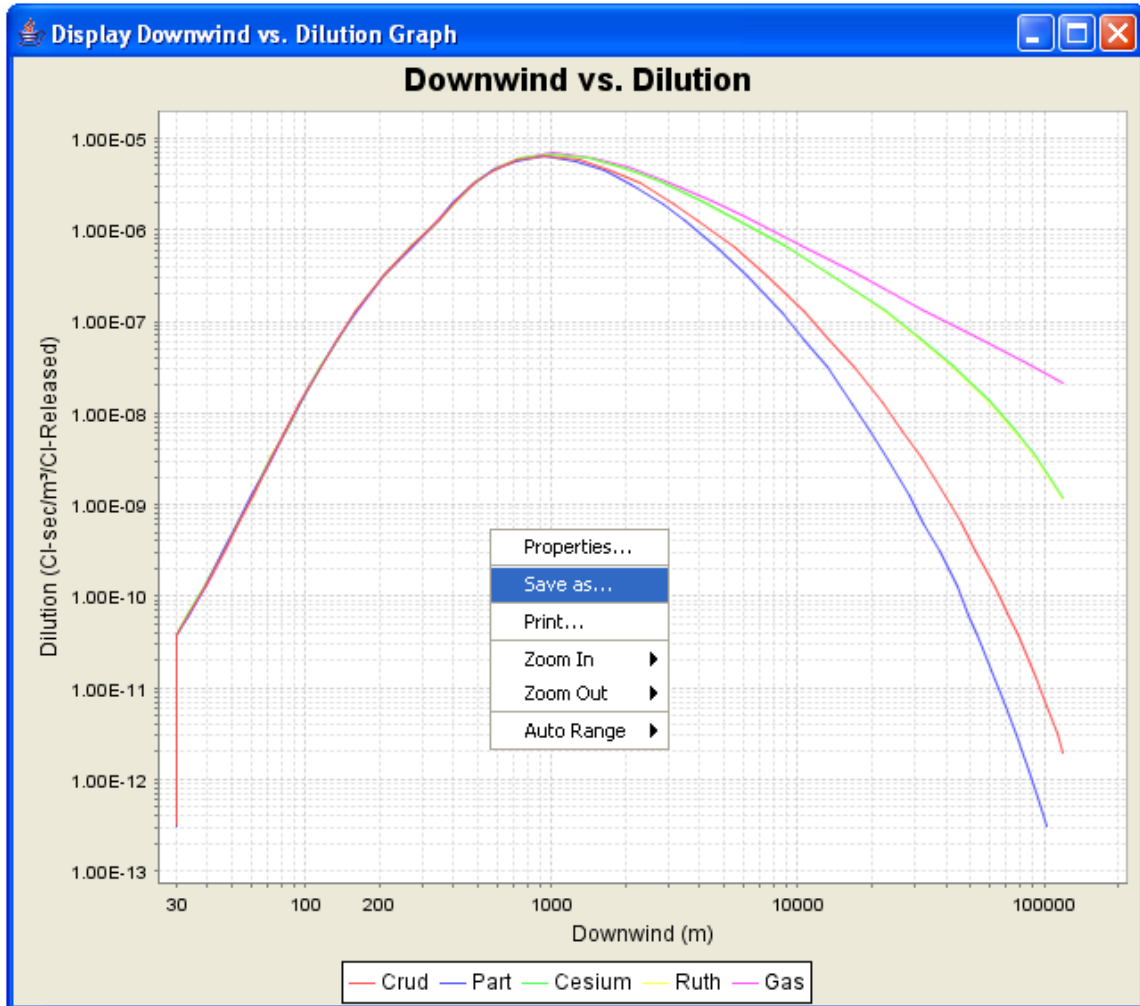


Figure 38: Graphical output.

An example of these changes can be seen in Figure 39.

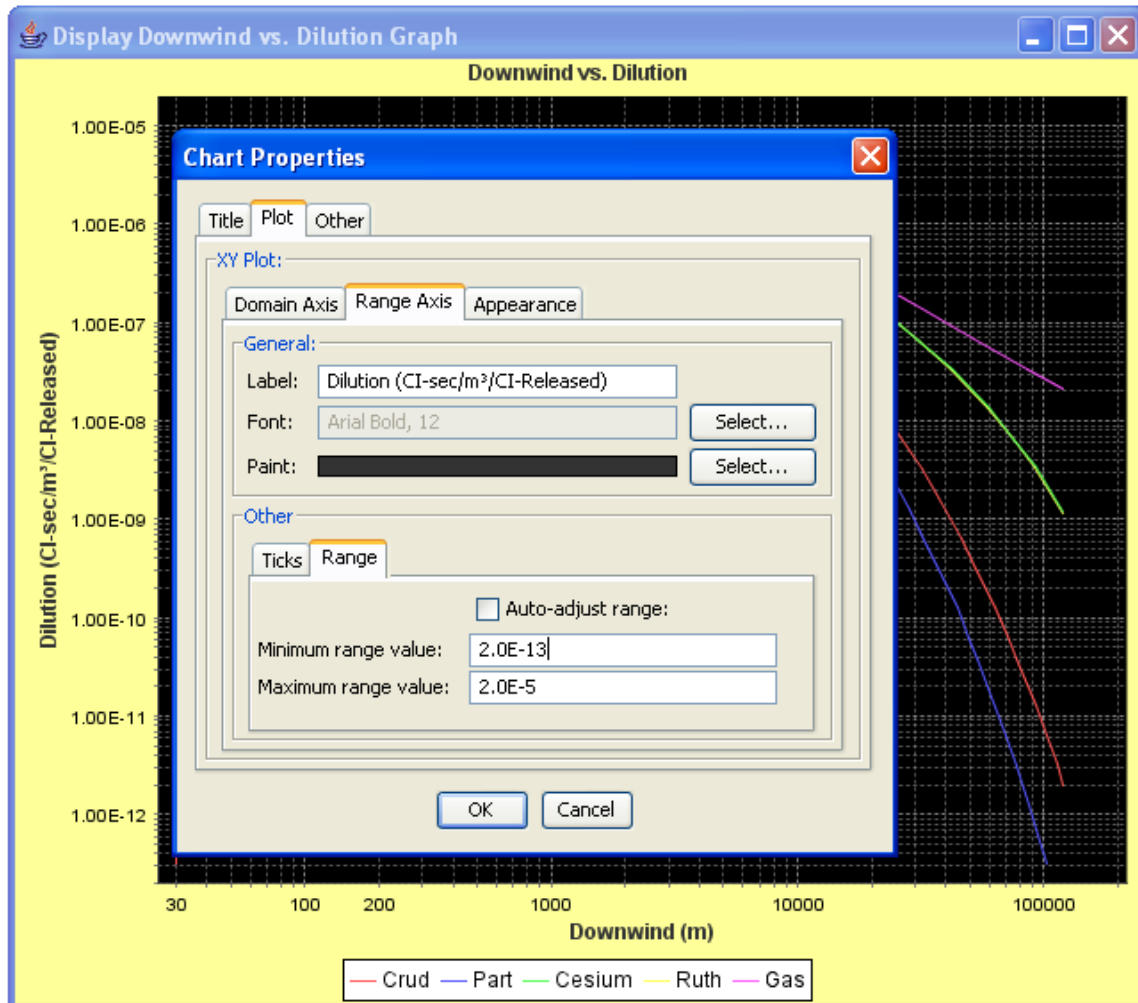


Figure 39: Graphical output property changes

16. SAVING, RUNNING RADTRAN, EXITING

The input file can be saved with either the **Save** or the **Save As** icon. Your input file should be saved as a **“.rml”** file. You will need to add this extension to your filename when saving it, because RadCat does not automatically add the **“.rml”** extension when saving the file. The file may be run in RADTRAN by clicking on the **Run RADTRAN** icon (the computer icon). RADTRAN can be run without saving

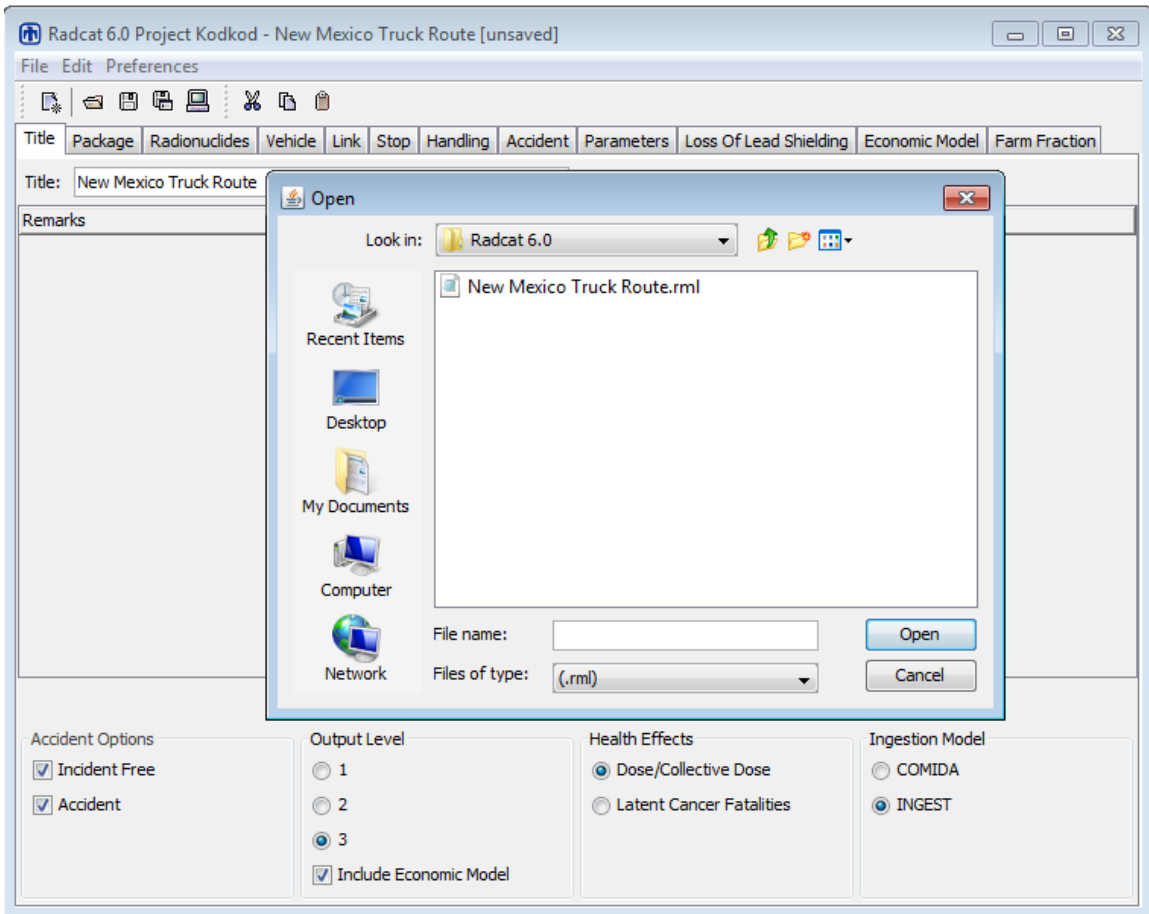


Figure 40: Saving a RadCat Input File

Exit from RADTRAN/RadCat by clicking on the “x” in the upper right-hand corner of the screen, as with any file.

17. REFERENCES

Abbot, M. L. and A. S. Rood, 1994, "COMIDA: A Radionuclide Food Chain Model for Acute Fallout Deposition," *Health Physics* 66(1), p. 17-29.

BTS (U.S. Department of Transportation, Bureau of Transportation Statistics), 2005

DOE (U.S. Department of Energy), 2002b, "Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada," DOE/EIS-0250F, Washington, D.C.: U.S. Department of Energy. Appendix J and Transportation Health and Safety Calculation/Analysis Documentation, CAL-HSS-ND-000003, Section 5.3.2.

Eckerman, K.F. and Ryman, J.C. 1993. "External Exposure to Radionuclides in Air, Water, and Soil, Exposure-to-Dose Coefficients for General Application, Based on the 1987 Federal Radiation Protection Guidance." EPA 402-R-93-081. Federal Guidance Report No. 12. Washington, D.C.: U.S. Environmental Protection Agency, Office of Radiation and Indoor Air.

Finley, N. et al., 1980, "Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment," NUREG/CR-0743, Nuclear Regulatory Commission, Washington DC.

Finley, N., J.D. McClure, and P.C. Reardon, 1988, "An Analysis of the Risks and Consequences of Accidents Involving Shipments of Multiple Type A Radioactive Material Packages," SAND88-1915, Sandia National Laboratories, Albuquerque, NM.

Fischer, L.E., et al. 1987. Shipping Container Response to Severe Highway and Railway Accident Conditions. NUREG/CR-4829. Two volumes. Washington, D.C.: U.S. Nuclear Regulatory Commission.

Gonzalez, A.J., Akashi, M., Boice, Jr., J.D., Chino, M., Homma, T., Ishigure, N., Kai, M., Kuzumi, S., Lee, J-K., Menzel, H.G., Niwa, O., Sakai, K., Weiss, W., Yamashita, S., Yonekura, Y., 2013. "Radiological protection issues arising during and after the Fukushima nuclear reactor accident," *J. Radiol. Prot.* v. 33, pp. 497-571.

ICRP (International Commission on Radiological Protection), 1983, "Radionuclide Transformations" Publication 38, *Annals of the ICRP*, Volume 11, Pergamon Press, Oxford, England.

ICRP (International Commission on Radiological Protection), 1991, "Recommendations of the International Commission on Radiological Protection," Publication 60, *Annals of the ICRP*, Volume 21, No. 1-3, Pergamon Press, Oxford, England.

ICRP (International Commission on Radiological Protection) 1996. "Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of

Ingestion and Inhalation Dose Coefficients.” Volume 26, No. 1 of Annals of the ICRP. Smith, H., ed.. ICRP Publication 72. New York, New York: Pergamon Press.

ICRP (International Commission on Radiological Protection), 2004 *Committee 1 Task Group Report (Draft)* “Low-dose Extrapolation of Radiation-Related Cancer Risk “

ISCORS (Interagency Steering Committee on Radiation Safety). 2002. “Estimating Radiation Risk fro Total effective Dose Equivalent (TEDE)” ISCORS Technical Report #1, USDOE Office of environmental Policy and Guidance, Washington, DC.

Javitz, H.S. et al., 1985, “Transport of Radioactive Material in the United States: Results of a Survey to Determine the Magnitude of Characteristics of Domestic, Unclassified Shipments of Radioactive Materials,” SAND84-7174, Sandia National Laboratories, Albuquerque, NM.

Johnson, P.E. and Michelhaugh, R.D. 2000. Transportation Routing Analysis Geographic Information System (WebTRAGIS) User's Manual. ORNL/TM-2000/86. Oak Ridge, Tennessee:

Knolls Atomic Power Laboratory (KAPL). 2003. “Chart of the Nuclides and Isotopes, 16th edition ,” <http://www.chartofthenuclides.com/>

Madsen, M.M., et al., 1986, “RADTRAN III,” SAND84-0036, Sandia National Laboratories, Albuquerque, NM.

Mills, G.S., K.S. Neuhauser, and J.D. Smith, 1995, “Evacuation Time Based on General Accident History,” Proceedings of the 11th International Conference on the Packaging and Transportation of Radioactive materials (PATRAM’95), Volume II, p. 716, Las Vegas, NV.

Mills, G.S., Sprung, J.L., and Osborn, D.M., 2006. “Tractor/Trailer Accident Statistics,” SAND2006-7723, Sandia National Laboratories, Albuquerque, NM.

Neuhauser, K.S., F.L. Kanipe, and R.F. Weiner, 2000, “RADTRAN 5 Technical Manual,” SAND2000-1256, Sandia National Laboratories, Albuquerque, NM.

NAS/NRC (National Academy of Science/National Research Council) Committee on the Biological Effects of Ionizing Radiations, 2005, “Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2,” National Academy of Sciences, National Academy Press, Washington, DC.

National Motorists Association. 2013 <http://www.motorists.org/speed-limits/state-chart>

NRC (Nuclear Regulatory Commission), 1977, “Final Environmental Statement on the Transportation of Radioactive Materials by Air and other Modes,” NUREG-0170, Nuclear Regulatory Commission, Washington DC.

- NRC (Nuclear Regulatory Commission), 2013, “Spent Fuel Transportation Risk Assessment” NUREG-2125, Nuclear Regulatory Commission, Washington DC.
- O’Donnell, B., Kearfott, K., James, S., and Weiner, R.F., “Calculating External Dose Increase from Partial Loss of Lead Shielding in a Spent Fuel Cask,” Institute for Nuclear Materials Management’s Annual Meeting, Orlando, FL, 2004.
- Osborn, D.M., et al. 2007, “An Economic Model for RADTRAN,” SAND2007-7120, Sandia National Laboratories, Albuquerque, NM.
- Ostmeyer, R.M., 1986, “A Revised Rail-Stop Exposure Model for Incident-Free Transport of Nuclear Waste,” SAND85-1722, Sandia National Laboratories, Albuquerque, NM.
- Raabe, O. 2011. “Toward Improved Ionizing Radiation Safety Standards” *Health Physics* v.101, pp. 84-93.
- Randerson, Darryl (editor) . 1984. *Atmospheric Science and Power Production* Office of Scientific and Technical Information, U. S. Department of Energy, Washington, DC.
- Shleien, B., Slaback, L.A., Birky, B.K. 1996. *Handbook of Health Physics and Radiological Health* Third Edition, Williams and Wilkins, Baltimore, MD.
- Sprung, J.L., et al. 2000, “Reexamination of Spent Fuel Shipment Risk Estimates,” NUREG/CR-6672, Washington, D.C.: U.S. Nuclear Regulatory Commission. Chapter 7, pp. 7-73 to 7-76.
- Taylor, J.M. and S.L. Daniel, 1982, “RADTRAN II: Revised Computer Code to Analyze Transportation of Radioactive Material,” SAND80-1943, Sandia National Laboratories, Albuquerque, NM.
- Tubiana, M. and A. Aurengo, 2005, “Dose-effect relationship and estimation of the carcinogenic effects of low doses of ionizing radiation: the Joint Report of the Académie des Sciences (Paris) and of the Académie Nationale de Médecine” *Int. J. Low Radiation, Vol. 2, pp. 1-19*
- Turner, D. Bruce, 1967 (reprinted 1994), “Workbook of Atmospheric Dispersion Estimates,” CRC Press, Boca Raton, FL.
- Yuan, Y.C., S.Y. Chen, B.M. Biwer, and D. J. LePoire, 1995, “RISKIND – A Computer Program for Calculating Radiological Consequences and Health Risks from Transportation of Spent Nuclear Fuel,” ANL/EAD-1, Argonne National Laboratory, Argonne, IL.
- Wark, K, Warner, C. E., Davis, W. T. 1998. *Air Pollution: Its Origin and Control*, Addison-Wesley-Longman, Menlo Park, CA

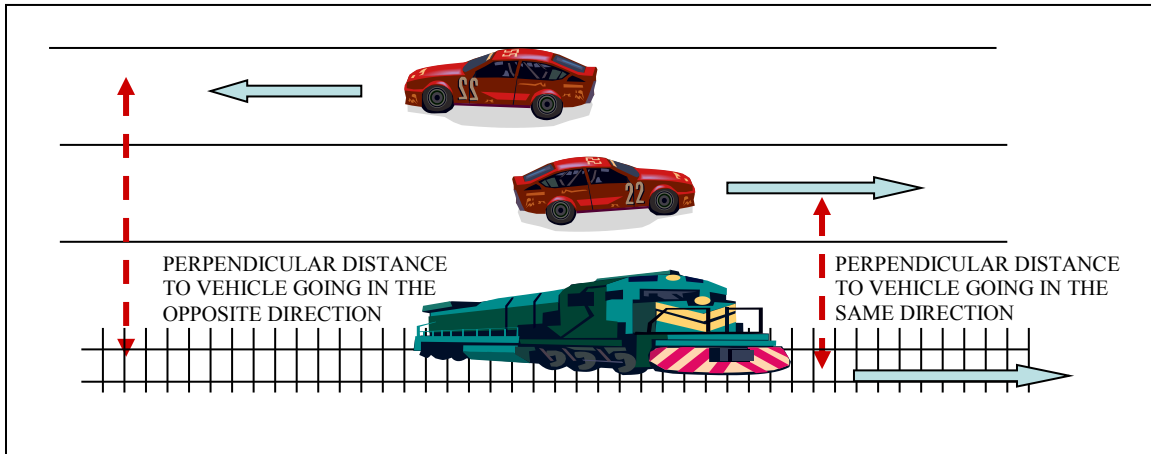
Wooden, D.G., 1986, "Railroad Transportation of Spent Nuclear Fuel," SAND86-7083, Sandia National Laboratories, Albuquerque, NM.

APPENDIX A. A SPECIAL CASE

The parameter ADJACENT specifies the average perpendicular distance (at right angles to the line of travel) between the radioactive materials shipment centerline and the center of other traffic lanes, in meters.

There are times when rail shipments will travel on a route parallel to an adjacent highway. In such a case, occupants of vehicles on the highway going both in the same direction as the rail shipment, as well as in the opposite direction, may receive an external dose from the rail shipment. Although you will be in Rail Mode for your calculation, you may wish to use **Highway Mode** to determine the incident-free dose to the occupants of vehicles on the parallel highway.

Figure 20 is a diagram of the situation you are modeling.



FigureA-1. Diagram for the on-link dose on a highway that parallels a rail route

Structure your supplemental **Highway Mode** calculation as follows:

- Create a new RadCat **Highway** file. This file will include some parameters from your rail (or barge) file and some that you will create for this file.
- You cannot just import the **Rail** (or **Barge**) file. Create a new package and vehicle that are the same as your rail package and vehicle: use the rail
 - package size,
 - package dose rate,
 - package gamma and neutron fractions,
 - add at least one radionuclide. It does not figure in the calculation, but RADTRAN hangs up without it.
 - vehicle size,
 - vehicle dose rate,
 - vehicle gamma and neutron fractions.
- What you put for crew parameters is up to you – they do not enter into this calculation.

- Make a link for each segment for which the train (or barge) parallels the highway. On the LINKS tab, the Vehicle Speed will be the relative speed of the train and the vehicles on the highway because you are calculating only the on-link dose.
- “Vehicle Density” is the vehicle density -- vehicles **per hour** -- on the highway
- “Persons per Vehicle” is the average occupancy of the vehicles on the highway,
- “Type” will be the type of highway you are considering: primary highway or secondary road.
- The parameters on the **Parameter** tab that affect your calculation are:
 - Perpendicular distance to freeway vehicle going in opposite direction (m)
 - Perpendicular distance to non-freeway vehicle going in opposite direction (m)
 - Perpendicular distance to city vehicle going in opposite direction (m)
 - Perpendicular distance to all vehicles going in the same direction (m)
 The default values for these parameters are 15m, 3m, 3m, and 4m, respectively , and refer to the lane widths and distances between lane centers. RADTRAN will call the first parameter if your LINK is designated as “primary highway,” the second and third if your LINK is designated as “secondary road.”
- Estimate the distance, in meters, between the center of the highway lane closest to the train (or barge) and change the “perpendicular distance to all vehicles going in the same direction (m)” from its default of 4-meters to the value you have estimated.
- Add the distance between your highway lanes to that estimate, and substitute that sum for the default values for the other three “perpendicular distance...” parameters.

The only output result that should be taken from this modified Highway Mode is the **ONLINK** population dose for each link. This dose is taken from the **Incident-Free**

APPENDIX B. VARIABLE NAMES IN RADTRAN

Table B-1. Flag chart and default values

Flag Name	Flag Description	Default Value
IACC	Setting this flag to 2 directs the code to work through all exposure pathways associated with atmospheric dispersal of package contents during an accident. The alternative value of IACC = 1 denotes non-dispersal and is no longer used in RADTRAN	2
ITRAIN	This flag, used only for rail mode, denotes whether shipment is by general freight (ITRAIN = 1) or by dedicated rail (ITRAIN = 2).	1
IUOPT	This flag is used to select a building shielding option. For the STANDARD value, persons in rural buildings are not shielded (100% exposure), persons in suburban dwellings are 87% exposed, and persons in urban dwellings are 1.8% exposed. Setting the IUOPT flag to 1 is equivalent to full shielding (everyone indoors is fully shielded and receives no dose). Setting the IUOPT flag to 3 is equivalent to no shielding.	2
REGCHECK	Setting this flag to 1 causes a series of regulatory checks to be performed. If any circumstances are identified that violate the regulatory requirements, then the appropriate parameter values are reset to the regulatory maximum and the calculation continues. REGCHECK = 0 bypasses the regulatory-check subroutine.	1
BDF	The Building Dose Factor describes the entrainment of aerosol particles in ventilation systems (i.e., the fraction of particles of an external aerosol that remain in aerosol form after passing through a ventilation system). The BDF is used to modify inhalation doses to persons in urban structures. The default value of 0.05 is about five times higher than the value for high-rise buildings with air-conditioning systems used by Finley et al., (1980) for New York City, which has been used in RADTRAN in the past.	0.05

BRATE	This factor represents breathing rate and is used for calculation of inhalation doses. The breathing rate (BRATE = 3.30E-04 m ³ /sec) of the Reference Man (70-kg adult male at light work) derived from Shleien, et al 1996; Table 12.6) has been used as the default value. The value in the cited table has been converted from liters per hour to m ³ /sec.	3.30E-04
CULVL	This factor describes Clean-Up Level, which is the required level to which contaminated surfaces must be cleaned up. The default value is the EPA guideline of 0.2 μCi/m ² (EPA, 1977). This value applies to the sum of deposited activity over all radionuclides of a multi-radionuclide material. Analysts who can justify use of more realistic values are urged to do so.	0.2
EVACUATION	This parameter specifies evacuation time in days following a dispersal accident, where this includes time to respond to the accident and carry out a course of action. The default value is 24 h (1 day). Mills et al. (1995) analyzed 66 verified hazmat accidents in which evacuations were carried out and found that the mean evacuation time was approximately 1 hour. Even when response time is added, a 24-hour (1-day) value for this variable is conservative. This parameter defined the time of exposure to groundshine and to resuspended material.	1.0
INTERDICT	This parameter specifies the threshold value for interdiction of contaminated land. The default value is 40, i.e., a value 40 times greater than CULVL, and it was taken from NUREG-0170 (NRC, 1977).	40
LCFCON	This parameter specifies the Latent Cancer Fatality (LCF) Conversion Factors; units are LCFs per rem. The default values are 5.0E-04 LCF/rem for the general public and 4.0E-04 LCF/rem for workers. They have been adjusted for low-dose and low-dose-rate decrease in effects with a DRRF (Dose and Dose Rate Reduction Factor) of 2. These values are consistent with the recommendations of BEIR VII (NRC/NAS, 2005) and ICRP 60 (ICRP, 1991). The dose-response relationship is assumed to be linear with no threshold in order to agree with current regulations. However, the majority of available data indicate that the actual dose-response relationship at very low doses is likely to be considerably less and, as noted in BEIR VII, is not incompatible with zero (NRC/NAS, 2005). Thus, cancer risk estimates obtained from RADTRAN 5 will be generally conservative.	6.0E-04
LOS	The parameter was used to analyze loss-of-shielding accidents. It is no longer used in RADTRAN analyses.	

RADIST	This parameter is used to specify an array of Radial Distances, which are used to define annular areas for dose-calculation purposes when the IACC Flag is set to 1. It is no longer used in RADTRAN.	
RPCTHYROID	This parameter is used to specify 1-year CEDE (rem per curie) to the thyroid from inhalation of radionuclides of iodine for estimation of early-mortality risk. Radioiodine mainly travels to and irradiates a single organ, the thyroid. In previous releases of RADTRAN, however, the 50-year CEDE was used to approximate the 1-year dose. One-year committed doses to the thyroid have been calculated directly for RADTRAN 5. This new parameter was not included in the internal radionuclide database, since it would have meant adding a new column containing zeros for all radionuclides but the radioiodines. The information has been included under the RPCTHYROID keyword instead. The default values are 1.27E+06 for iodine-131, 5.77E+06 for iodine-129, and 9.25E+05 for iodine-125.	1.27E+06 for I-131 5.77E+06 for I-129 9.25E+05 for I-125
SURVEY	This parameter is used to specify the time (in days) required to survey contaminated land following a dispersal accident. The amount of deposited material removed by radioactive decay is calculated beginning with time of initial deposition. The longer a deposited material remains on the ground, the more is removed by decay and spread by forces such as wind and rain. The actual elapsed time between accident occurrence and completion of a survey is impossible to determine in advance, but is likely to be prolonged because of governmental and regulatory complexities. The default value is set to an unrealistically brief, but radiologically conservative, 10 days (NRC, 1977).	10
TIMENDE	This parameter specifies the time, in days, required to effect evacuation following a non-dispersal accident. It is no longer used in RADTRAN.	
UBF	This parameter is the Urban Building Fraction; it describes either the fraction of the population that is indoors or the fraction of the area that is occupied by buildings, depending on the type of population model being used. The default value of 0.52 is for the latter model, and is taken from Finley et al. (1980). The value is most accurate for large cities such as New York and is somewhat conservative for smaller cities.	0.52
USWF	This parameter is the Urban Sidewalk Fraction; it specifies the fraction of the population that is out of doors or the fraction of the population that occupies sidewalks, depending on the type of population model being used. The default pre-assigned value of 0.1 is for the latter model, and is taken from Finley et al. (1980). As with the UBF, this value is suitable for large cities and is conservative for smaller cities.	0.1

ADJACENT	See DISTON	
CAMPAIGN	This keyword specifies the duration of the shipping campaign in years. The value calculated with CAMPAIGN is the total number of off-link persons exposed. This result may be used to perform external calculations of annual off-link dose. Annual dose values may be compared with total dose in multi-year shipping campaigns and are useful for assessing regulatory compliance with standards based on annual doses. The default value is 0.0833 years. This is an average month in an average year, or 1/12 th of a year.	0.0833
DDRWEF	This keyword applies to rail mode only and specifies the Distance Dependent Rail Worker Exposure Factor. This factor is used to calculate the component of rail-worker dose that depends on distance traveled (e.g., exposure related to engine changes, crew shift-changes, etc., while en route). The default value of 0.0018 inspections/km is taken from Ostmeyer (1986).	0.0018
DISTOFF	This keyword specifies a set of three distances, in meters, used in off-link dose calculations for highway, rail, and barge modes. The three distances are: (1) the minimum perpendicular distance over which the off-link dose calculation will be integrated; (2) the minimum pedestrian-walkway width, for instances in which dose to pedestrians beside the link is calculated (see RPD for discussion of pedestrian density); and (3) the maximum perpendicular distance over which the off-link dose calculation will be integrated. DISTOFF must be followed one or more keywords that specify values for various link types. The default values, which are supplied for each link type, are from NUREG-0170 (NRC, 1977). The link types and values for each are:	
	FREEWAY Any limited-access divided highway. [30, 30, 800]	30, 30, 800
	SECONDARY Any non-limited-access highway that is not a city street (27, 30, 800)	27, 30, 800
	STREET Any city street. [5, 8, 800]	5,8,800
	RAIL Any rail right-of-way in the U.S. [30, 30, 800]	30, 30, 800
	WATER Any vessel. [200,200,800]	200, 200, 1000
DISTON	FREEWAY Any limited-access, divided highway [15.0 m];	15
	SECONDARY Any non-limited access highway [3 m];STREET Any city street [3 m];	3 for secondary roads 3 for city streets

	RAIL Any rail right-of-way [3 m].	3
	An additional parameter for highway mode only is ADJACENT It represents the minimum perpendicular distance between shipment centerline and centerline of adjacent passing vehicles [4 m].	4
FMINCL	This keyword is applied to rail mode only and specifies the minimum number of railcar classifications or inspections per one-way trip. The default value is 2 since there are always at least two inspections per one-way trip - one at the beginning and one at the end of each trip (Wooden, 1986).	2
FNOATT	This parameter is applied to passenger-air mode only and specifies the Number of Flight Attendants. The default value is 4 (NRC, 1977).	4
FREEWAY	See DISTOFF and DISTON	
MITDDIST	This parameter is used to calculate the maximum individual “in-transit” dose to a member of the public; it represents the minimum perpendicular distance, in meters, from the shipment centerline to an individual standing beside the road or railroad while a shipment passes. The default value is 30.0 m (NRC, 1977).	30
MITDVEL	This parameter is used to calculate the maximum individual “in-transit” dose; it represents the minimum velocity, in km/hr, of a shipment. The default value is 24.0 km/hr (15 mph) (NRC, 1977).	24
RAIL	See DISTOFF and DISTON	
RPD	This parameter is the Ratio of Pedestrian Density. It is used to calculate the density of unshielded persons on sidewalks and elsewhere in urban areas when the IUOPT Flag is not equal to 3 by indexing it to the population density of the surrounding area. RPD is also used in the calculation of accident consequences. The default is 6.0, which is based on empirical data from New York City (Finley, 1980). It means that the pedestrian density is six times the residential population density. This figure is likely to be conservative for most other urban areas, but similar data are seldom collected in other cities.	6.0

RR	This parameter specifies the Rural Shielding Factor. The default value is 1.0 (i.e., no shielding). Although even wood-frame construction provides some shielding, the Rural Shielding Factor is set to 1.0 to conservatively account for the fact that rural economies involve a relatively large fraction of outdoor employment (farming, ranching, etc.). RR is used in incident-free dose and in dose-risk calculation for non-dispersal accidents.	1.0
RS	This parameter specifies the Suburban Shielding Factor. The default value is 0.87, which represents a residential structure of wood-frame construction (Taylor and Daniel, 1982, p.12). RS is used in incident-free dose and in dose-risk calculations for non-dispersal accidents.	0.87
RU	This parameter specifies the Urban Shielding Factor. The default value is 0.018, which represents an urban commercial building constructed of concrete block (Taylor and Daniel, 1982, p.12). RU is used in incident-free dose and in dose-risk calculations for non-dispersal accidents.	0.018
SMALLPKG	This parameter specifies the first Package Size Threshold. This parameter is used to determine the handling method that will be used for a package, which, in turn, is used in the calculation of handler dose. If a package is designated as “small” then an empirical algorithm for handling dose is used; if package dimensions exceed the threshold then another method is used. The default value for SMALLPKG is 0.5 m (Javitz, 1985). Although it is highly unlikely that this value will need to be altered, you has the option to do so.	0.5

Mode	Mode Number	Conveyance Types Associated with Mode
HIGHWAY	1	Any truck; usually a tractor-trailer(also called a “semi” or a combination truck)
RAILWAY	2	One or more railcars in a single train
WATERWAY	3	Any vessel; usually barge

Table B-2: Definitions for Input to the RISKIND Dispersion Model

USE_RADTRAN:	0 use RISKIND center line distances – preferred 1 use RADTRAN distances (only if REL_HT < 3 meters)
REL_HT:	Release Height (m)
HEAT_REL:	Heat Release (cal/sec)
SRC_WIDTH:	Source Width or Cask Length (m)
SRC_HT:	Source Height or Cask Radius (m)
WS:	Wind Speed (m/sec)
ANEM_HT:	Anemometer Height (m)
AMB_T:	Ambient Temperature (K)
HT_MIX:	Atmospheric Mixing Height (m)
Pasquill/Briggs:	1 use the Pasquill-Gifford dispersion model with coefficients 2 use the Briggs dispersion model with coefficients
Stability:	Pasquill Stability Category A=1 through F=6
Rural – or – Suburban/Urban	1 use the rural terrain coefficients 2 use the suburban/urban terrain coefficients

Table B-2: Economic Model Default Values

Parameter Name	Description	Average Value	Units
AF_C	Footprint of commercial buildings	337	m ²
AF_I	Footprint of industrial buildings	6620	m ²
AF_R	Footprint of residential buildings	118	m ²
ALOT_C	Area of commercial lots	930	m ²
ALOT_I	Area of industrial lots	9700	m ²
ALOT_R	Area of residential lots	223	m ²
BARL_DR_LM	External dose rate per barrel of resin	5.0	mrem/hour
CO_BARL_DR	External dose rate per 1 Ci of Co-60	269.7	mrem/hour
CROP_PROFT	Annual crop profit	0.01303	\$/m ²
C_WASH	Cost of washing contaminated area	32.29	\$/m ²
EVAC_CST_R	Rural evacuation cost	7.88	\$/person-km ²
EVAC_CST_S	Suburban evacuation cost	13.61	\$/person-km ²
EVAC_CST_U	Urban evacuation cost	13.61	\$/person-km ²
F_CR	Rural commercial land use fraction	0.01	
F_CS	Suburban commercial land use fraction	0.14	
F_CU	Urban commercial land use fraction	0.37	
F_IR	Rural industrial land use fraction	0.01	
F_IS	Suburban industrial land use fraction	0.09	
F_IU	Urban industrial land use fraction	0.11	
F_RR	Rural residential land use fraction	0.03	
F_RS	Suburban residential land use fraction	0.28	
F_RU	Urban residential land use fraction	0.24	
F_SR	Rural soil land use fraction	0.95	
F_SS	Suburban soil land use fraction	0.41	
F_SU	Urban soil land use fraction	0.09	
FBC	Fraction of building surfaces contaminated	0.449	
FR_C	Rural soil land use fraction for crops	0.20	
FR_L	Rural soil land use fraction for livestock	0.28	
OH_C	Average commercial building outside height	16.40	m
OH_I	Average industrial building outside height	6.05	m
OH_R	Average residential building outside height	5.32	m
RHO_RD_R	Rural road density	5.97E-04	m of road/m ² of land
RHO_RD_S	Suburban road density	8.11E-04	m of road/m ² of land
RHO_RD_U	urban road density	8.06E-02	m of road/m ² of land
RHO_RESIN	Resin density	1.28	g/cm ³
ROAD_W	Road width	8.84	m
SOIL_COST	Cost of soil removal	10	\$/m ³
SOIL_DPTH	Contaminated soil depth	0.03	m
STCK_PROFIT	Bi-annual profit from livestock	0.02499	\$/m ²
VOL_BARREL	Volume of waste container	0.2167	m ³

APPENDIX C. DOSE CONVERSION FACTORS

Correspondence for the radionuclide arrays:

1. Half-Life (days). Source: ICRP 38 (as reported in Federal Guidance Report (FGR) 13)
2. Photon Energy (MeV). Source: ICRP 72 (this value is not used in RADTRAN 5.5)
3. Cloud/Immersion Dose Factor ($\text{rem}\cdot\text{m}^3/\text{Ci}\cdot\text{sec}$). Source: FGR 12 (multiply by 3.7×10^{12} to convert from SI units to historical units)
4. Groundshine Dose Factor ($\text{rem}\cdot\text{m}^2/\mu\text{Ci}\cdot\text{day}$). Source: FGR 12 (multiply by 3.197×10^{11} to convert from SI units to historical units)
5. 50-year Effective Inhalation Dose Factor (rem/Ci). Source: ICRP 72 – 50-year Effective Inhalation Dose Type M to adult obtained from ICRP-DOSE CD v. 2.0.1 (multiply by 3.7×10^{12} to convert from SI units to historical units)
6. 50-year Gonad Inhalation Dose Factor (rem/Ci). Source: ICRP 72 – 50-year Testes Inhalation Dose Type M to adult obtained from ICRP-DOSE CD v. 2.0.1 (multiply by 3.7×10^{12} to convert from SI units to historical units)
7. 1-year Lung Inhalation Dose Factor (rem/Ci). Source: ICRP 72 – 1-year Lung Inhalation Dose Type M to adult obtained from ICRP-DOSE CD v. 2.0.1 (multiply by 3.7×10^{12} to convert from SI units to historical units)
8. 1-year Marrow Inhalation Dose Factor (rem/Ci). Source: ICRP 72 – 1-year Red Marrow Inhalation Dose Type M to adult obtained from ICRP-DOSE CD v. 2.0.1 (multiply by 3.7×10^{12} to convert from SI units to historical units)
9. Nuclide Name for Ingestion Data. Source: COMIDA2 – Names must match RT5INGEST.BIN
10. A1 Activity Limit Values (Ci). Source: 10CFR71 Appendix A – Revised 1/1/2004
11. A2 Activity Limit Values (Ci). Source: 10CFR71 Appendix A – Revised 1/1/2004

The inhalation dose conversion factors use a 1.0-micron AMAD particle as a conservative value. ICRP-66 uses a distribution from 1 to 5 microns and the occupational respirable size is 5.0-microns. The upper limit for truly respirable particles is 10.0-microns.

ICRP 72 gives dose commitments to adult members of the public at age 20 that are assumed to live another 50 yrs.

All dose conversion factors (DCFs) and photon energies are calculated for each individual radionuclide with the exception of the following radionuclides which have their progenies included:

- Mo-99 includes the weighted contribution from the short half-life of its Tc-99m daughter.
- Ru-103 includes the weighted contribution from its short half-life Rh-103m daughter.
- Ru-106 includes the weighted contribution from the short half-life of its Rh-106 daughter. Inhalation DCFs were determined with Ru-106 only. There is no information for Rh-106.
- Cs-137 includes the weighted contribution from the short half-life of its Ba-137m daughter. Inhalation DCFs were determined with Cs-137 only. There is no information for Ba-137m.
- Ce-144 includes the weighted contributions from the short half-lives of its Pr-144 and Pr-144m daughters. Inhalation DCFs were determined with Ce-144 and Pr-144. There is no information for Pr-144m.

Nuclide Name	Half Life (days)	Photon Energy (MeV)	Cloudshine (rem-m³/Ci-sec)	Groundshine (rem-m²/μCi-day)	Effective Inhalation (rem/Ci)
H-3 (WTR)	4.51E+03	0.00E+00	1.22E-06	0.00E+00	6.66E+01
H-3 (GAS)	4.51E+03	0.00E+00	1.22E-06	0.00E+00	6.66E-03
Be-10	5.84E+08	0.00E+00	4.14E-05	1.32E-07	3.55E+04
C-14 (ORG)	2.09E+06	0.00E+00	8.29E-07	5.15E-09	2.15E+03
C-14 (GAS)	2.09E+06	0.00E+00	8.29E-07	5.15E-09	2.29E+01
Na-22	9.49E+02	2.19E+00	4.00E-01	6.71E-04	4.81E+03
P-32	1.43E+01	0.00E+00	3.66E-04	9.30E-07	1.26E+04
S-35	8.74E+01	0.00E+00	8.99E-07	5.37E-09	5.18E+03
Cl-36	1.10E+08	1.55E-04	8.25E-05	2.15E-07	2.70E+04
Ca-41	5.11E+07	4.19E-04	0.00E+00	0.00E+00	3.52E+02
Ca-45	1.63E+02	4.35E-08	3.19E-06	1.47E-08	9.99E+03
Sc-46	8.38E+01	2.01E+00	3.69E-01	6.17E-04	2.52E+04
Cr-51	2.77E+01	3.26E-02	5.59E-03	9.85E-06	1.18E+02
Mn-54	3.13E+02	8.35E-01	1.51E-01	2.60E-04	5.55E+03
Fe-55	9.86E+02	1.69E-03	0.00E+00	0.00E+00	1.41E+03
Co-57	2.71E+02	1.25E-01	2.08E-02	3.68E-05	2.04E+03
Co-58	7.08E+01	9.75E-01	1.76E-01	3.04E-04	5.92E+03
Fe-59	4.45E+01	1.19E+00	2.21E-01	3.58E-04	1.37E+04
Ni-59	2.74E+07	2.41E-03	0.00E+00	0.00E+00	4.81E+02
Co-60	1.92E+03	2.50E+00	4.66E-01	7.51E-04	3.70E+04
Ni-63	3.50E+04	0.00E+00	0.00E+00	0.00E+00	1.78E+03
Zn-65	2.44E+02	5.84E-01	1.07E-01	1.77E-04	5.92E+03
Ga-67	3.26E+00	1.58E-01	2.66E-02	4.76E-05	8.88E+02
Kr-85	3.91E+03	2.21E-03	4.40E-04	8.44E-07	0.00E+00
Rb-86	1.87E+01	9.45E-02	1.78E-02	2.98E-05	3.44E+03
Rb-87	1.72E+13	0.00E+00	6.73E-06	2.81E-08	1.85E+03
Sr-89	5.05E+01	8.45E-05	2.86E-04	7.26E-07	2.26E+04
Sr-90	1.06E+04	0.00E+00	2.79E-05	9.08E-08	1.33E+05
Y-90	2.67E+00	1.69E-06	7.03E-04	1.70E-06	5.18E+03
Y-91	5.85E+01	3.61E-03	9.62E-04	1.84E-06	2.63E+04
Zr-93	5.58E+08	0.00E+00	0.00E+00	0.00E+00	3.70E+04
Zr-95	6.40E+01	7.39E-01	1.33E-01	2.31E-04	1.78E+04
Nb-94	7.41E+06	1.57E+00	2.85E-01	4.89E-04	4.07E+04
Nb-95m	3.61E+00	6.83E-02	1.08E-02	2.00E-05	2.92E+03
Nb-95	3.52E+01	7.66E-01	1.38E-01	2.39E-04	5.55E+03
Mo-99	2.75E+00	2.60E-01	4.60E-02	8.09E-05	3.36E+03

Nuclide Name	Gonad Inhalation (rem-Ci)	Lung Inhalation (rem/Ci)	Marrow Inhalation (rem-Ci)	COMIDA Name	A1 Limit (Ci)	A2 Limit (Ci)
H-3 (WTR)	6.66E+01	6.66E+01	6.66E+01	NONE	1080	1080
H-3 (GAS)	6.66E-03	6.66E-03	6.66E-03	NONE	1080	1080
Be-10	1.78E+03	2.00E+05	5.92E+03	Be-10	541	13.5
C-14 (ORG)	2.15E+03	2.15E+03	2.11E+03	NONE	1080	54.1
C-14 (GAS)	2.29E+01	2.29E+01	2.29E+01	NONE	1080	54.1
Na-22	3.00E+03	3.29E+03	5.55E+03	Na-22	13.5	13.5
P-32	6.29E+02	8.88E+04	7.77E+03	P-32	8.11	8.11
S-35	2.85E+01	4.44E+04	2.74E+01	S-35	1080	54.1
Cl-36	9.99E+02	2.04E+05	9.62E+02	Cl-36	541	13.5
Ca-41	3.48E+00	5.18E+02	1.96E+02	Ca-41	1080	1080
Ca-45	4.44E+01	7.77E+04	2.66E+03	Ca-45	1080	24.3
Sc-46	3.26E+02	1.63E+05	5.92E+03	Sc-46	13.5	13.5
Cr-51	1.18E+01	5.18E+02	4.81E+01	Cr-51	811	811
Mn-54	5.55E+02	2.22E+04	4.07E+03	Mn-54	27	27
Fe-55	3.52E+02	1.11E+03	6.66E+02	Fe-55	1080	1080
Co-57	1.85E+02	1.18E+04	4.81E+02	Co-57	216	216
Co-58	4.44E+02	3.29E+04	2.07E+03	Co-58	27	27
Fe-59	1.37E+03	8.51E+04	4.81E+03	Fe-59	21.6	21.6
Ni-59	2.89E+02	1.33E+03	4.07E+01	Ni-59	1080	1080
Co-60	7.03E+03	1.78E+05	1.07E+04	Co-60	10.8	10.8
Ni-63	7.03E+02	8.14E+03	1.04E+02	Ni-63	1080	811
Zn-65	2.29E+03	1.78E+04	4.07E+03	Zn-65	54.1	54.1
Ga-67	1.41E+01	5.92E+03	6.29E+01	Ga-67	162	162
Kr-85	0.00E+00	0.00E+00	0.00E+00	NONE	541	270
Rb-86	2.74E+03	2.81E+03	5.18E+03	Rb-86	8.11	8.11
Rb-87	1.44E+03	1.52E+03	2.85E+03	Rb-87	100000	100000
Sr-89	1.70E+02	1.67E+05	4.07E+03	Sr-89	16.2	13.5
Sr-90	1.04E+03	7.03E+05	4.07E+04	Sr-90	5.41	2.7
Y-90	1.33E+01	2.59E+04	3.70E+02	Y-90	5.41	5.41
Y-91	2.22E+02	1.85E+05	1.07E+04	Y-91	8.11	8.11
Zr-93	8.51E+00	9.99E+03	2.15E+03	Zr-93	1080	5.41
Zr-95	5.92E+02	1.15E+05	8.51E+03	Zr-95	27	24.3
Nb-94	4.44E+03	2.07E+05	1.26E+04	Nb-94	16.2	16.2
Nb-95m	3.03E+01	2.00E+04	2.37E+02	Nb-95m	27	24.3
Nb-95	2.22E+02	3.52E+04	1.52E+03	Nb-95	27	27
Mo-99	5.66E+01	1.99E+04	1.72E+02	Mo-99	16.2	13.5

Nuclide Name	Half Life (days)	Photon Energy (MeV)	Cloudshine (rem-m³/Ci-sec)	Groundshine (rem-m²/μCi-day)	Effective Inhalation (rem/Ci)
Tc-99	7.77E+07	0.00E+00	5.99E-06	2.49E-08	1.48E+04
Rh-102	1.06E+03	2.13E+00	3.85E-01	6.65E-04	2.55E+04
Ru-103	3.93E+01	4.70E-01	8.33E-02	1.48E-04	8.89E+03
Ru-106	3.68E+02	2.01E-01	3.85E-02	6.78E-05	1.04E+05
Pd-107	2.37E+09	0.00E+00	0.00E+00	0.00E+00	3.15E+02
Cd-109	4.64E+02	2.64E-02	1.09E-03	7.19E-06	2.44E+04
Ag-111	7.45E+00	2.63E-02	4.77E-03	8.54E-06	5.55E+03
In-111	2.83E+00	4.05E-01	6.88E-02	1.25E-04	8.51E+02
Cd-113m	4.96E+03	0.00E+00	2.57E-05	8.41E-08	1.92E+05
Sn-113	1.15E+02	2.28E-02	1.41E-03	6.81E-06	9.99E+03
In-114m	4.95E+01	9.42E-02	1.55E-02	2.93E-05	2.26E+04
Cd-115m	4.46E+01	2.19E-02	4.33E-03	7.48E-06	3.63E+03
Sn-119m	2.93E+02	1.15E-02	3.74E-04	3.32E-06	8.14E+03
Sn-121m	2.01E+04	4.94E-03	2.23E-04	1.56E-06	1.67E+04
Sn-123	1.29E+02	6.88E-03	1.49E-03	2.68E-06	3.00E+04
Te-123m	1.20E+02	1.48E-01	2.41E-02	4.57E-05	1.48E+04
Sb-124	6.02E+01	1.80E+00	3.39E-01	5.47E-04	2.37E+04
I-125	6.01E+01	4.20E-02	1.93E-03	1.37E-05	5.18E+03
Te-125m	5.80E+01	3.55E-02	1.68E-03	1.15E-05	1.26E+04
Sb-125	1.01E+03	4.30E-01	7.47E-02	1.36E-04	1.78E+04
Sn-125	9.64E+00	3.11E-01	5.85E-02	9.62E-05	1.15E+04
Sb-126	1.24E+01	2.83E+00	5.07E-01	8.89E-04	1.04E+04
Sn-126	3.65E+07	5.65E-02	7.81E-03	1.75E-05	1.04E+05
Sb-127	3.85E+00	6.85E-01	1.23E-01	2.16E-04	6.29E+03
Te-127m	1.09E+02	1.12E-02	5.44E-04	3.61E-06	2.74E+04
Te-127	3.90E-01	4.86E-03	8.95E-04	1.66E-06	4.81E+02
I-129	5.73E+09	2.46E-02	1.41E-03	8.25E-06	5.55E+04
Te-129m	3.36E+01	3.75E-02	5.74E-03	1.21E-05	2.44E+04
I-131	8.04E+00	3.80E-01	6.73E-02	1.20E-04	8.88E+03
Te-132	3.26E+00	2.33E-01	3.81E-02	7.29E-05	7.40E+03
Xe-133m	2.19E+00	4.07E-02	5.07E-03	1.30E-05	0.00E+00
Xe-133	5.25E+00	4.60E-02	5.77E-03	1.47E-05	0.00E+00
Cs-134	7.52E+02	1.55E+00	2.80E-01	4.86E-04	3.37E+04
Cs-135	8.40E+08	0.00E+00	2.09E-06	1.06E-08	1.15E+04
Cs-137	1.10E+04	5.69E-02	1.07E-01	1.77E-04	3.59E+04
Ba-140	1.27E+01	1.82E-01	3.17E-02	5.75E-05	1.89E+04

Nuclide Name	Gonad Inhalation (rem-Ci)	Lung Inhalation (rem/Ci)	Marrow Inhalation (rem-Ci)	COMIDA Name	A1 Limit (Ci)	A2 Limit (Ci)
Tc-99	3.40E+01	1.15E+05	3.15E+01	Tc-99	1080	24.3
Rh-102	9.62E+03	7.40E+04	1.11E+04	Rh-102	13.5	13.5
Ru-103	3.07E+02	6.67E+04	9.25E+02	Ru-103	54.1	24.3
Ru-106	9.62E+03	7.03E+05	6.29E+03	Ru-106	5.41	5.41
Pd-107	7.03E-01	1.96E+03	3.59E+00	Pd-107	100000	100000
Cd-109	1.89E+03	1.04E+05	7.03E+02	Cd-109	1080	27
Ag-111	5.18E+01	3.70E+04	6.66E+01	Ag-111	16.2	13.5
In-111	3.07E+01	3.55E+03	1.74E+02	In-111	54.1	54.1
Cd-113m	2.74E+04	1.63E+05	1.59E+03	Cd-113m	541	2.43
Sn-113	2.55E+02	7.03E+04	1.70E+03	Sn-113	108	108
In-114m	1.18E+03	1.15E+05	3.37E+04	In-114m	8.11	8.11
Cd-115m	4.44E+01	2.15E+04	1.18E+02	Cd-115m	8.11	8.11
Sn-119m	1.33E+02	5.92E+04	7.03E+02	Sn-119m	1080	1080
Sn-121m	5.18E+02	1.22E+05	1.55E+03	Sn-121m	1080	24.3
Sn-123	4.07E+02	2.26E+05	2.78E+03	Sn-123	16.2	13.5
Te-123m	1.26E+02	1.11E+05	3.37E+03	Te-123m	189	189
Sb-124	5.18E+02	1.63E+05	4.44E+03	Sb-124	16.2	13.5
I-125	7.77E+00	5.92E+03	6.29E+01	I-125	541	54.1
Te-125m	4.44E+01	9.62E+04	1.52E+03	Te-125m	811	243
Sb-125	7.77E+02	1.17E+05	3.15E+03	Sb-125	54.1	24.3
Sn-125	8.88E+01	7.40E+04	1.22E+03	Sn-125	5.41	5.41
Sb-126	3.66E+02	6.29E+04	2.37E+03	Sb-126	10.8	10.8
Sn-126	9.25E+03	6.29E+05	2.41E+04	Sn-126	8.11	8.11
Sb-127	7.40E+01	4.07E+04	4.44E+02	Sb-127	541	13.5
Te-127m	1.30E+02	2.07E+05	7.40E+03	Te-127m	541	13.5
Te-127	2.70E+00	2.78E+03	6.29E+00	NONE	541	13.5
I-129	5.18E+01	6.66E+04	1.26E+02	I-129	10000	100000
Te-129m	1.70E+02	1.78E+05	4.44E+03	Te-129m	16.2	13.5
I-131	3.44E+01	3.55E+04	2.07E+02	I-131	81.1	13.5
Te-132	2.52E+02	3.70E+04	8.14E+02	Te-132	10.8	10.8
Xe-133m	0.00E+00	0.00E+00	0.00E+00	NONE	16.2	13.5
Xe-133	0.00E+00	0.00E+00	0.00E+00	NONE	541	541
Cs-134	7.40E+03	1.78E+05	1.15E+04	Cs-134	16.2	13.5
Cs-135	8.51E+02	8.51E+04	6.66E+02	Cs-135	1080	24.3
Cs-137	5.55E+03	2.18E+05	6.29E+03	Cs-137	54.1	13.5
Ba-140	1.89E+02	1.30E+05	2.37E+03	Ba-140	10.8	10.8

Nuclide Name	Half Life (days)	Photon Energy (MeV)	Cloudshine (rem-m³/Ci-sec)	Groundshine (rem-m²/μCi-day)	Effective Inhalation (rem/Ci)
Ce-141	3.25E+01	7.61E-02	1.27E-02	2.36E-05	1.18E+04
Pr-143	1.36E+01	8.90E-09	7.77E-05	2.24E-07	8.14E+03
Ce-144	2.84E+02	5.27E-02	1.04E-02	1.88E-05	1.33E+05
Pm-146	2.02E+03	7.53E-01	1.33E-01	2.37E-04	7.77E+04
Nd-147	1.10E+01	1.40E-01	2.29E-02	4.44E-05	7.77E+03
Pm-147	9.58E+02	4.37E-06	2.56E-06	1.09E-08	1.85E+04
Sm-147	3.87E+13	0.00E+00	0.00E+00	0.00E+00	3.55E+07
Pm-148m	4.13E+01	1.99E+00	3.58E-01	6.27E-04	1.89E+04
Sm-151	3.29E+04	1.34E-05	1.34E-07	1.61E-09	1.48E+04
Eu-152	4.87E+03	1.14E+00	2.09E-01	3.52E-04	1.55E+05
Gd-153	2.42E+02	1.05E-01	1.37E-02	3.39E-05	7.77E+03
Eu-154	3.21E+03	1.22E+00	2.27E-01	3.80E-04	1.96E+05
Eu-155	1.81E+03	6.05E-02	9.21E-03	1.89E-05	2.55E+04
Eu-156	1.52E+01	1.31E+00	2.50E-01	3.93E-04	1.26E+04
Tb-160	7.23E+01	1.12E+00	2.05E-01	3.45E-04	2.59E+04
Ho-166m	4.38E+05	1.74E+00	3.13E-01	5.43E-04	4.44E+05
Tm-170	1.29E+02	5.46E-03	8.25E-04	1.89E-06	2.59E+04
Hf-175	7.00E+01	3.68E-01	6.25E-02	1.16E-04	4.44E+03
Hf-181	4.24E+01	5.55E-01	9.69E-02	1.75E-04	1.85E+04
W-181	1.21E+02	4.04E-02	5.18E-03	1.26E-05	2.81E+04
Ta-182	1.15E+02	1.29E+00	2.37E-01	3.93E-04	2.81E+04
W-185	7.51E+01	5.67E-05	1.99E-05	5.88E-08	4.44E+02
W-188	6.94E+01	1.90E-03	3.34E-04	6.14E-07	2.11E+03
Ir-192	7.40E+01	8.11E-01	1.45E-01	2.57E-04	1.92E+04
Tl-202	1.22E+01	4.67E-01	8.07E-02	1.47E-04	7.03E+02
Tl-204	1.38E+03	1.13E-03	2.07E-04	4.73E-07	1.44E+03
Bi-210	5.01E+00	0.00E+00	1.22E-04	3.36E-07	3.44E+05
Pb-210	8.14E+03	4.81E-03	2.09E-04	7.93E-07	4.07E+06
Po-210	1.38E+02	8.50E-06	1.54E-06	2.65E-09	1.22E+07
Pb-212	4.43E-01	1.48E-01	2.54E-02	4.57E-05	6.25E+05
Ra-223	1.14E+01	1.33E-01	2.25E-02	4.09E-05	2.74E+07
Ra-224	3.66E+00	9.89E-03	1.74E-03	3.06E-06	1.11E+07
Ac-225	1.00E+01	1.79E-02	2.67E-03	5.05E-06	2.74E+07
Ra-225	1.48E+01	1.37E-02	1.03E-03	4.25E-06	2.33E+07
Ra-226	5.84E+05	6.74E-03	1.17E-03	2.06E-06	1.30E+07
Ac-227	7.95E+03	2.31E-04	2.15E-05	5.02E-08	8.14E+08

Nuclide Name	Gonad Inhalation (rem-Ci)	Lung Inhalation (rem/Ci)	Marrow Inhalation (rem-Ci)	COMIDA Name	A1 Limit (Ci)	A2 Limit (Ci)
Ce-141	7.77E+01	8.88E+04	1.07E+03	Ce-141	270	13.5
Pr-143	2.78E+00	5.55E+04	4.44E+02	Pr-143	108	13.5
Ce-144	6.29E+03	6.66E+05	5.18E+04	Ce-144	5.41	5.41
Pm-146	6.29E+03	9.99E+04	1.92E+04	Pm-146	5	0.5
Nd-147	1.70E+01	5.55E+04	7.03E+02	Nd-147	108	13.5
Pm-147	1.48E+00	7.03E+04	4.81E+03	Pm-147	1080	24.3
Sm-147	1.18E+03	1.70E+07	4.07E+06	Sm-147	100000	100000
Pm-148m	4.81E+02	1.15E+05	7.40E+03	Pm-148m	13.5	13.5
Sm-151	5.18E-01	1.11E+04	1.81E+03	Sm-151	1080	108
Eu-152	1.37E+04	1.44E+05	2.59E+05	Eu-152	24.3	24.3
Gd-153	8.51E+01	4.07E+04	3.44E+03	Gd-153	270	135
Eu-154	1.22E+04	2.92E+05	3.70E+04	Eu-154	21.6	13.5
Eu-155	3.11E+02	6.66E+04	5.55E+03	Eu-155	541	54.1
Eu-156	1.59E+02	8.14E+04	2.33E+03	Eu-156	16.2	13.5
Tb-160	4.44E+02	1.67E+05	1.04E+04	Tb-160	24.3	13.5
Ho-166m	3.59E+04	2.07E+05	3.55E+04	Ho-166m	16.2	8.11
Tm-170	3.22E+02	1.78E+05	1.70E+04	Tm-170	108	13.5
Hf-175	1.70E+02	2.52E+04	2.59E+03	Hf-175	81.1	81.1
Hf-181	2.04E+02	1.37E+05	4.07E+03	Hf-181	54.1	24.3
W-181	1.18E+03	1.96E+05	5.18E+03	W-181	811	811
Ta-182	1.18E+03	1.96E+05	5.18E+03	Ta-182	21.6	13.5
W-185	9.25E+00	7.77E+01	1.63E+02	W-185	1080	24.3
W-188	2.96E+01	9.62E+01	1.07E+03	W-188	5.41	5.41
Ir-192	8.51E+02	1.33E+05	2.55E+03	Ir-192	27	13.5
Tl-202	3.70E+02	4.07E+02	4.44E+02	Tl-202	54.1	54.1
Tl-204	8.51E+02	9.25E+02	8.51E+02	Tl-204	108	13.5
Bi-210	1.74E+02	2.85E+06	1.70E+02	Bi-210	16.2	13.5
Pb-210	2.41E+05	1.81E+07	1.22E+06	Pb-210	16.2	0.243
Po-210	1.81E+05	9.62E+07	1.67E+06	Po-210	1080	0.541
Pb-212	1.92E+03	5.18E+06	6.29E+03	Pb-212	8.11	8.11
Ra-223	1.22E+04	2.29E+08	2.78E+05	Ra-223	16.2	0.811
Ra-224	9.25E+03	9.25E+07	1.48E+05	Ra-224	8.11	1.62
Ac-225	1.33E+05	2.26E+08	9.25E+05	Ac-225	16.2	0.27
Ra-225	5.55E+04	1.92E+08	7.40E+05	Ra-225	16.2	0.541
Ra-226	8.88E+04	9.99E+07	3.70E+05	Ra-226	8.11	0.541
Ac-227	2.89E+08	3.66E+08	5.55E+07	Ac-227	1080	0.000541

Nuclide Name	Half Life (days)	Photon Energy (MeV)	Cloudshine (rem-m³/Ci-sec)	Groundshine (rem-m²/μCi-day)	Effective Inhalation (rem/Ci)
Th-227	1.87E+01	1.06E-01	1.81E-02	3.32E-05	3.15E+07
Ra-228	2.10E+03	4.14E-09	0.00E+00	0.00E+00	9.62E+06
Th-228	6.98E+02	3.30E-03	3.40E-04	7.51E-07	1.18E+08
Th-229	2.68E+06	9.54E-02	1.42E-02	2.73E-05	4.07E+08
Th-230	2.81E+07	1.55E-03	6.44E-05	2.40E-07	1.59E+08
Pa-231	1.20E+07	4.76E-02	6.36E-03	1.30E-05	5.18E+08
Th-232	5.13E+12	1.33E-03	3.23E-05	1.76E-07	1.67E+08
U-232	2.63E+04	2.19E-03	5.25E-05	3.23E-07	2.89E+07
Pa-233	2.70E+01	2.03E-01	3.46E-02	6.23E-05	1.22E+04
U-233	5.79E+07	1.31E-03	6.03E-05	2.29E-07	1.33E+07
Th-234	2.41E+01	9.34E-03	1.25E-03	2.66E-06	2.44E+04
U-234	8.92E+07	1.73E-03	2.82E-05	2.39E-07	1.30E+07
Np-235	3.96E+02	7.09E-03	1.89E-04	1.17E-06	1.55E+03
U-235	2.57E+11	1.54E-01	2.66E-02	4.73E-05	1.15E+07
Np-236a	4.20E+07	1.36E-01	1.98E-02	3.84E-05	1.18E+07
Pu-236	1.04E+03	2.09E-03	2.35E-05	3.14E-07	7.40E+07
U-236	8.55E+09	1.57E-03	1.85E-05	2.08E-07	1.18E+07
Np-237	7.82E+08	3.43E-02	3.81E-03	9.17E-06	8.51E+07
Pu-237	4.53E+01	5.23E-02	7.47E-03	1.49E-05	1.30E+03
U-237	6.75E+00	1.42E-01	2.21E-02	4.25E-05	6.29E+03
Np-238	2.12E+00	5.50E-01	1.01E-01	1.69E-04	7.77E+03
Pu-238	3.20E+04	1.81E-03	1.81E-05	2.68E-07	1.70E+08
U-238	1.63E+12	1.36E-03	1.26E-05	1.76E-07	1.07E+07
Np-239	2.36E+00	1.72E-01	2.85E-02	5.21E-05	3.44E+03
Pu-239	8.78E+06	7.96E-04	1.57E-05	1.17E-07	1.85E+08
Pu-240	2.39E+06	1.73E-03	1.76E-05	2.57E-07	1.85E+08
Am-241	1.58E+05	3.24E-02	3.03E-03	8.79E-06	1.55E+08
Pu-241	5.26E+03	2.54E-06	2.68E-07	6.17E-10	3.33E+06
Am-242m	5.55E+04	5.11E-03	1.17E-04	9.65E-07	1.37E+08
Cm-242	1.63E+02	1.83E-03	2.11E-05	3.06E-07	1.92E+07
Pu-242	1.37E+08	1.44E-03	1.48E-05	2.13E-07	1.78E+08
Am-243	2.69E+06	5.59E-02	8.07E-03	1.71E-05	1.52E+08
Cm-243	1.04E+04	1.34E-01	2.18E-02	4.00E-05	1.15E+08
Cm-244	6.61E+03	1.70E-03	1.82E-05	2.81E-07	9.99E+07
Pu-244	3.01E+10	1.22E-03	1.10E-05	1.78E-07	1.74E+08
Cm-245	3.10E+06	9.55E-03	1.47E-02	2.78E-05	1.55E+08

Nuclide Name	Gonad Inhalation (rem-Ci)	Lung Inhalation (rem/Ci)	Marrow Inhalation (rem-Ci)	COMIDA Name	A1 Limit (Ci)	A2 Limit (Ci)
Th-227	1.04E+05	2.59E+08	1.22E+06	Th-227	243	0.27
Ra-228	1.85E+06	2.92E+07	1.92E+06	Ra-228	16.2	1.08
Th-228	1.30E+07	6.66E+08	3.29E+07	Th-228	8.11	0.0108
Th-229	1.22E+08	4.44E+08	2.78E+07	Th-229	8.11	0.000811
Th-230	7.03E+07	2.60E+05	1.41E+07	Th-230	54.1	0.00541
Pa-231	1.52E+04	1.07E+08	9.25E+06	Pa-231	16.2	0.00162
Th-232	7.77E+07	7.40E+07	1.18E+07	Th-232	100000	100000
U-232	4.81E+06	1.44E+08	2.29E+06	U-232	81.1	0.00811
Pa-233	3.40E+01	9.25E+04	1.37E+03	Pa-233	135	24.3
U-233	5.18E+05	9.99E+07	3.18E+05	U-233	270	0.027
Th-234	5.92E+02	1.70E+05	7.03E+03	Th-234	5.41	5.41
U-234	5.18E+05	9.62E+07	3.15E+05	U-234	270	0.027
Np-235	4.07E+02	5.92E+03	1.04E+03	Np-235	1080	1080
U-235	4.81E+05	8.51E+07	2.92E+05	U-235	100000	100000
Np-236a	8.88E+06	5.92E+05	1.67E+05	Np-236a	189	0.027
Pu-236	2.37E+07	1.33E+08	1.26E+07	Pu-236	189	0.0189
U-236	4.81E+05	8.88E+07	2.96E+05	U-236	270	0.027
Np-237	5.18E+07	9.99E+07	1.04E+07	Np-237	54.1	0.00541
Pu-237	6.29E+01	8.51E+03	4.81E+02	Pu-237	541	541
U-237	1.44E+01	4.44E+04	1.33E+02	U-237	5	0.5
Np-238	3.44E+03	1.96E+04	9.99E+02	Np-238	5	0.5
Pu-238	7.03E+07	1.26E+08	1.37E+07	Pu-238	54.1	0.00541
U-238	4.44E+05	8.14E+07	2.92E+05	U-238	100000	100000
Np-239	3.70E+01	2.33E+04	1.30E+02	Np-239	162	13.5
Pu-239	7.77E+07	1.11E+08	1.30E+07	Pu-239	54.1	0.00541
Pu-240	7.77E+07	1.11E+08	1.30E+07	Pu-240	54.1	0.00541
Am-241	1.22E+08	1.22E+08	8.14E+06	Am-241	54.1	0.00541
Pu-241	1.55E+06	2.85E+04	1.33E+04	Pu-241	1080	0.27
Am-242m	1.18E+08	1.96E+07	4.07E+06	Am-242m	54.1	0.00541
Cm-242	1.78E+06	1.30E+08	4.07E+06	Cm-242	1080	0.27
Pu-242	7.40E+07	1.04E+08	1.22E+07	Pu-242	54.1	0.00541
Am-243	1.22E+08	1.15E+08	7.77E+06	Am-243	54.1	0.00541
Cm-243	8.51E+07	1.37E+08	8.51E+06	Cm-243	81.1	0.00811
Cm-244	6.66E+07	1.37E+08	8.51E+06	Cm-244	108	0.0108
Pu-244	7.40E+07	9.62E+07	1.22E+07	Pu-244	8.11	0.00541
Cm-245	1.26E+08	1.18E+08	8.14E+06	Cm-245	54.1	0.00541

Nuclide Name	Half Life (days)	Photon Energy (MeV)	Cloudshine (rem-m³/Ci-sec)	Groundshine (rem-m²/μCi-day)	Effective Inhalation (rem/Ci)
Cm-246	1.73E+06	1.51E-03	1.65E-05	2.51E-07	1.55E+08
Cm-247	5.69E+09	3.14E-01	5.55E-02	9.91E-05	1.44E+08
Cm-248	1.24E+08	1.16E-03	1.25E-05	1.92E-07	5.55E+08
Cf-252	9.63E+02	1.20E-03	1.87E-05	2.31E-07	7.40E+07

Nuclide Name	Gonad Inhalation (rem-Ci)	Lung Inhalation (rem/Ci)	Marrow Inhalation (rem-Ci)	COMIDA Name	A1 Limit (Ci)	A2 Limit (Ci)
Cm-246	1.22E+08	1.18E+08	8.14E+06	Cm-246	54.1	0.00541
Cm-247	1.15E+08	1.04E+08	7.40E+06	Cm-247	54.1	0.00541
Cm-248	4.44E+08	2.33E+08	3.00E+07	Cm-248	1.08	0.00135
Cf-252	1.48E+07	1.92E+08	2.81E+07	Cf-252	2.7	0.027

APPENDIX D. HIGHWAY VEHICLE DENSITIES

David Orcutt and G. Scott Mills
Sandia National Laboratories

History

While the data contained in this report can be utilized to provide traffic density figures for any application where such values would be appropriate, they were gathered to aid users of RADTRAN. Historically, standard inputs for the vehicle densities on highways in the United States were the values shown in Table 1 below. The population density zone divisions are those employed by the routing software TRAGIS, which was developed by Oak Ridge National Laboratories (Johnson and Michelhaugh, 2000), and provide the mileage of each route that falls within each of these three zones. A 1975 traffic study (NRC, 1977) resulted in the traffic density values shown in the Table D-1; these values have been used in the RADTRAN program since 1977. Recognition that traffic densities have changed during the past 30 years warranted reinvestigation of those traffic density figures, resulting in this report.

Table D-1: Historical Values Used for Traffic Density in RADTRAN Calculations

Population Density Zone	Traffic Density
0 persons/km ² – 54 persons/km ² : <i>Rural</i>	470 vehicles/hr
54 persons/km ² – 1284 persons/km ² : <i>Suburban</i>	780 vehicles/hr
1284 persons/km ² and up: <i>Urban</i>	2800 vehicles/hr

Approach

The present study was conducted by combining state traffic data (which provided average traffic counts) and U.S. Census 2000 data (which allowed the geographic correlation of the traffic counts with the three familiar population density zones). This process also allowed the division of traffic counts into those for two highway categories: U.S. highways and interstate highways. An additional benefit of this approach is that it provides the ability to define traffic densities for each state individually, or to combine the values for several states along a shipment route to determine an average traffic density along that route.

2000 U.S. Census Data

The U. S. Census (<http://www.census.gov>) divides the entire population of the country by state, subdivides it by county, further subdivides it into tracts, and finally includes individual census blocks as its smallest subdivision. The size of census blocks is roughly of inverse proportion to the number of inhabitants in each block; therefore, census blocks in less populated areas of the United States, such as the Mojave Desert, will often be several thousand times larger than census blocks in the middle of Manhattan where population is abundant. Within each census block the ethnicities, ages, and other identifying characteristics of inhabitants are compiled. A digital version of this census data for the 2000 Census was imported into the software program ArcView GIS, the geographic information system used in this analysis. Also used in the GIS program was a digital map of all of the U.S. and Interstate highways in the continental U.S.

The GIS program was configured to divide each highway into 1.6-kilometer-long pieces, and to calculate the number of persons within each 1.6-km-by-1.6-km square centered on the highway. Each of these numbers was compared to the limits of the three population density zones, and assigned a corresponding letter (“R” for rural zones, “S” for suburban zones, and “U” for urban zones).

Traffic Count Data

Most states, through their local departments of transportation, compile annual reports containing average traffic counts for their U.S., interstate, and state highways. The only highways considered for this analysis were U.S. and interstate highways, because these are the highways most frequented by radioactive material shipments. These counts are typically carried out using one of two types of equipment: a permanent collector, which is permanently located at the counting site, or a temporary counter, which can be moved frequently among several locations; most use optical or pressure sensing technology to obtain counts of passing vehicles.

This raw data is refined to obtain Average Annual Daily Traffic Counts (AADTs) for each considered public road. In the case of permanent counters, a yearly count total is simply divided by the number of days in the counting year to produce this value; for temporary counters, however, the process is more complicated. Because this type of counter is only present at the count location for a few hours or days during the count year, the raw count data that they produce are extrapolated using a variety of weighting algorithms, the contents of which are outside the scope of this report. The AADT for each considered road is then integrated into an annual report. This analysis used reports from the most recent count year, 2003.

While most states have a system in place similar to the one described above, some states do not currently have such a count report. These states have necessarily been unable to provide data for this traffic study and will not be included in this report. This is discussed in more detail in the next bolded section.

Data Synthesis

Once each highway is divided into rural, suburban, and urban portions via the GIS program, the traffic count data is similarly divided into 1.6-km-long portions and the average traffic density is calculated for each section. Every portion of the traffic data is then matched up with its corresponding population density zone designation. Finally, the traffic densities of all of the sections of the road that fall into each designation are averaged; thus, traffic densities divided into population density categories are calculated for each highway. These are compiled for each state, and then all of the traffic densities for each highway type within the state are distance averaged using Equation D-1. This is done to determine an average state-wide value for each highway type and population density zone.

$$TD_{i,j} = \frac{\sum_{k=1}^N TD_{i,j,k} \cdot L_{i,j,k}}{\sum_{k=1}^N L_{i,j,k}} \quad \text{Equation D-1}$$

Where:

- TD_{i,j} ≡ State-Wide Average Traffic Density for the Current i,j Set
- i ≡ Highway Type (U.S. or Interstate)
- j ≡ Population Density Zone (Rural, Suburban, or Urban)
- k ≡ Highway Index
- N ≡ Number of Highways in the Current i,j Set
- TD_{i,j,k} ≡ Average Traffic Density for the Current i,j,k Set
- L_{i,j,k} ≡ Length for the Current i,j,k Set

This process was completed for each state included in the analysis, and the results are included in this report. Also included are the average traffic density values for each highway type divided into ten U.S. Environmental Protection Agency (EPA) regions, shown in Table 2. Finally, the data is also combined into a national average.

Limitations of Study

The U.S. Census only counts people where they reside; therefore, the data does not take into account the day-time influx of population into commercial and industrial centers. Also, only states whose traffic count data were readily available were considered for reporting. States that do not have the capability of developing or maintaining electronic traffic counts were automatically discounted, in addition to Hawaii and Alaska, which were considered to be relatively free of radiological shipments. In all, 21 states were included in this analysis; these states are shown in dark gray in Figure D-1. The figure also shows, in light gray, states whose data are available, but for which an analysis was not completed.

Table D-2: United States Divided into 10 EPA Regions

Region	States Included in Region
1	Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, Vermont
2	New Jersey, New York
3	Delaware, Maryland, Pennsylvania, Virginia, West Virginia
4	Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee
5	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin
6	Arkansas, Louisiana, New Mexico, Oklahoma, Texas
7	Iowa, Kansas, Missouri, Nebraska
8	Colorado, Montana, North Dakota, South Dakota, Utah
9	Arizona, California, Nevada
10	Idaho, Oregon, Washington

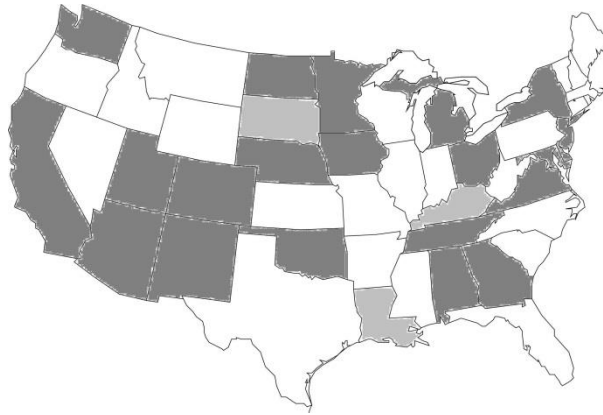


Figure D-1: States currently considered in this report (dark gray), and states whose data are available, but for which an analysis was not completed (light gray)

State-by-State Average Traffic Densities

Tables D-3 and D-4 on the following two pages list a state-by-state summary of the vehicle densities in each of the three population density zones. Each traffic density is compared to the historical values from Table D-1, and the total length of all of the sections of highway with each zone designation is given as the final column under each zone type.

Table D-3: State-by-State Traffic Densities Divided into Population Density Zones—Interstate Highways

Interstate Highways									
	Rural Zone			Suburban Zone			Urban Zone		
State	Traffic Density (vehicles/hr)	Departure from Historic Value (470 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (780 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (2800 vehicles/hr)	Length (km)
Alabama	1161	1477%	813	2138	174%	541	3784	35%	90
Arizona	825	76%	1401	2144	175%	288	4208	50%	145
California	1924	309%	1660	4509	478%	589	7914	183%	1205
Colorado	1248	166%	1036	2342	200%	338	4051	45%	127
Delaware	7187	1429%	3	3651	368%	19	3350	20%	34
Georgia	1537	227%	956	3286	321%	730	7340	162%	208
Iowa	992	111%	956	1588	104%	171	2157	-23%	80
Maryland	1953	315%	159	3656	369%	294	6100	118%	230
Michigan	1219	159%	827	2309	196%	792	4648	66%	360
Minnesota	738	57%	895	2296	194%	383	4376	56%	196
Nebraska	833	77%	677	1685	116%	50	3075	10%	40
New Jersey	2609	455%	105	3322	326%	277	4527	62%	225
New Mexico	654	39%	1195	1208	55%	349	3347	20%	58
New York	835	78%	927	1818	133%	1236	4002	43%	508
North Dakota	293	-38%	793	575	-26%	95	1063	-62%	29
Ohio	1824	288%	637	2655	240%	1002	4241	51%	476
Oklahoma	1175	150%	1046	1786	129%	352	2778	-1%	88
Tennessee	1570	234%	780	2735	251%	674	4121	47%	130
Utah	731	56%	1113	1958	151%	256	3940	41%	142
Vermont	439	-7%	259	726	-7%	230	2129	-24%	5
Washington	1123	139%	616	2670	242%	362	5624	101	206

Table D-4: State-by-State Traffic Densities Divided into Population Density Zones—U.S. Highways

U.S Highways									
	Rural Zone			Suburban Zone			Urban Zone		
State	Traffic Density (vehicles/hr)	Departure from Historic Value (470 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (780 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (2800 vehicles/hr)	Length (km)
Alabama	313	-33%	2888	607	-22%	2650	1077	-62%	230
Arizona	169	-64%	2296	364	-53%	348	2718	-3%	109
California	628	34%	1401	2231	186%	483	5771	106%	455
Colorado	320	-32%	4953	665	-15%	1250	1069	-62%	389
Delaware	800	70%	69	1134	45%	217	1712	-39%	63
Georgia*									
Iowa	280	-40%	3627	306	-61%	1073	481	-83%	262
Maryland	915	95%	302	1156	48%	365	1634	-42%	161
Michigan	471	0%	1911	786	1%	1268	1771	-37%	237
Minnesota	249	-47%	3768	523	-33%	1393	1323	-53%	296
Nebraska	161	-66%	4827	289	-63%	1014	857	-69%	177
New Jersey	916	95%	124	948	21%	656	1521	-46%	478
New Mexico	175	-63%	4693	450	-42%	759	563	-80%	93
New York	290	-38%	829	453	-42%	1022	887	-68%	296
North Dakota	129	-73%	2233	182	-77%	348	666	-76%	21
Ohio	363	-23%	2225	551	-29%	2029	816	-71%	774
Oklahoma	279	-41%	3911	354	-55%	1234	716	-74%	132
Tennessee*									
Utah	386	-18%	1585	509	-35%	328	1147	-59%	135
Vermont	288	-39%	467	377	-52%	451	422	-85%	66
Washington	322	-31%	1883	482	-38%	763	718	-74%	140

* These states only provided interstate highway data; U.S. highway data was not available.

Average Regional Traffic Densities

Tables D-5 and D-6 were constructed by taking existing data for all of the states within each region and distance-averaging them into the three familiar zone types. It is important to note that these values should be seen only as an approximation of the final traffic density values for each region; in Region 6, for example, Texas will eventually play a major role in defining the traffic densities of the region.

National Average Traffic Densities

Tables D-7 and D-8 display the results obtained when the state-wide data are distance-averaged over the entire country. These are the results that directly compare with the historical values found in Table D-1.

Table D-5: Average Regional Traffic Densities Divided into Population Density Zones—Interstate Highways

Interstate Highways									
Region	Rural Zone			Suburban Zone			Urban Zone		
	Traffic Density (vehicles/hr)	Departure from Historic Value (470 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (780 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (2800 vehicles/hr)	Length (km)
1	439	-7%	259	726	-7%	230	2129	-24%	5
2	1015	116%	1031	2094	168%	1512	4163	49%	734
3	2056	338%	163	3655	369%	314	5748	105%	264
4	1427	204%	2549	2776	256%	1945	5611	100%	428
5	1200	155%	2359	2466	216%	2177	4408	57%	1033
6	897	91%	2241	1498	92%	702	3003	7%	146
7	926	97%	1633	1610	106%	220	2463	-12%	121
8	795	69%	2943	1956	151%	689	3708	32%	298
9	1421	202%	3062	3732	379%	877	7517	168%	1350
10	1123	139%	616	2670	242%	362	5624	101%	206

Table D-6: Average Regional Traffic Densities Divided into Population Density Zones—U.S. Highways

U.S. Highways									
	Rural Zone			Suburban Zone			Urban Zone		
Region	Traffic Density (vehicles/hr)	Departure from Historic Value (470 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (780 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (2800 vehicles/hr)	Length (km)
1	288	-39%	467	377	-52%	451	422	-85%	66
2	371	-21%	953	647	-17%	1678	1278	-54%	774
3	894	90%	372	1148	47%	582	1656	-41%	224
4	313	-34%	2888	607	-22%	2650	1077	-62%	230
5	335	-29%	7905	606	-22%	4690	1104	-61%	1307
6	222	-53%	8605	391	-50%	1994	653	-77%	225
7	212	-55%	8454	298	-62%	2087	632	-77%	439
8	283	-40%	8771	551	-29%	1926	1072	-62%	545
9	343	-27%	3697	1449	86%	830	5180	85%	565
10	322	-31%	1883	482	-38%	763	718	-74%	140

Table D-7: National Average Traffic Densities Divided into Population Density Zones—Interstate Highways

Interstate Highways								
Rural Zone			Suburban Zone			Urban Zone		
Traffic Density (vehicles/hr)	Departure from Historic Value (470 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (780 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (2800 vehicles/hr)	Length (km)
1119	138%	16856	2463	26%	9028	5385	93%	4584

Table D-8: National Average Traffic Densities Divided into Population Density Zones—U.S. Highways

U.S. Highways								
Rural Zone			Suburban Zone			Urban Zone		
Traffic Density (vehicles/hr)	Departure from Historic Value (470 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (780 vehicles/hr)	Length (km)	Traffic Density (vehicles/hr)	Departure from Historic Value (2800 vehicles/hr)	Length (km)
283	-40%	43993	590	-24%	28400	1575	-44%	4515

Results

This study reveals the importance of distinguishing between road types, which is captured in Figure D-2. The figure displays the departure of each traffic density in Tables D-7 and D-8 from the historical values found in Table D-1 (NRC, 1977). While traffic density on U.S. highways shows a decrease from the historically used values, interstate highways show a dramatic increase over those values.

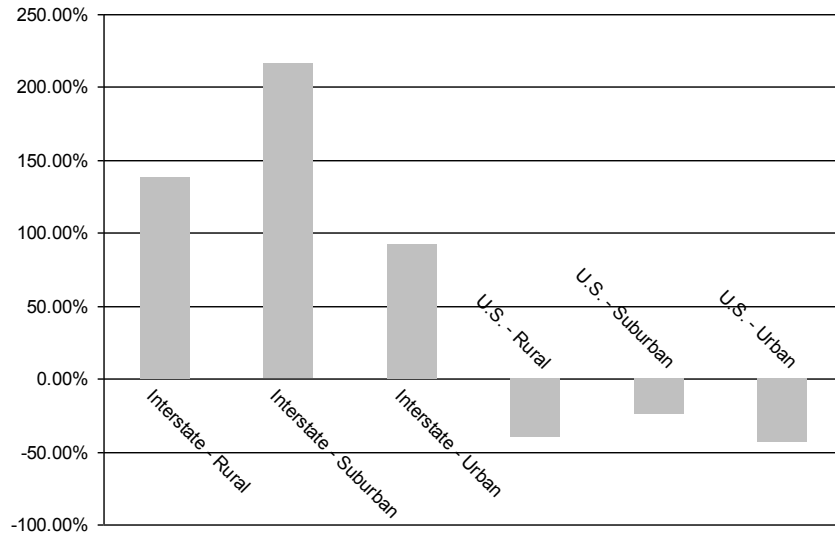


Figure D-2: Departure of National Average Traffic Densities from Historical Values

APPENDIX E. RADTRAN OUTPUT

```
RRRR AAA DDDD TTTTT RRRR AAA N N 6 000 000
R RA A D D T R RA ANNN 6 0 0 0 0
R RA A D D T R RA ANNN 6 0 0 0 0
RRRR A A D D T RRRR A ANNN 6666 0 0 0 0
RR AAAAA D D T RR AAAAA N N 6 6 0 0 0 0
R RA A D D T R RA AN N 6 6 0 0 0 0
R RA A DDDD T R RA AN N 6 6 6 * 0 0 0 000
```

RADTRAN 6.00 September 28, 2007

Copyright 2007 Sandia Corporation

RADTRAN 6.02 February 01, 2013

INPUT ECHO

RADTRAN 6 July 2008

&& DEFAULT PARAMETERS IN TABLE 1 APPENDIX B **The text following the ampersands are remarks (Fig. 3)**

&& NEUTRAL STABILITY AND WORST CASE

&& 45GWD FUEL

&& TI=14 MREM@1 M.

&& INCLUDES NAC

&& LOS ALSO

&& REMARK

TITLE NACSTCCRUD_7_2011 **Title in Fig. 4**

INPUT STANDARD **This standard input includes many default values in RADTRAN. It is no longer used but is retained for RADTRAN TO RUN.**

STD: 0 18 && DIMEN=NSEV NAREAS

STD: 3 3 0 && PARM=IANA ISEN IPSQSB

STD: .TRUE. .FALSE. .FALSE. && FORM = UNIT, SI-OUTPUT, SI-INPUT

STD: 2.3E12 && NEVAL FOR CF252

STD: 9.25E5 5.77E6 1.27E6 && RPCTHY FOR I125, I129, I131

STD: 0.0 0.0 0.0 0.0 0.0 && TRANSFER GAMMA [COEF(1,0-4)]

STD: 7.42E-3 2.02E-2 6.17E-5 3.17E-8 0.0 && TRANSFER NEUTRON [COEF(2,0-4)]

STD: 30 24 && MITDDIST MITDVEL

STD: 1 2 .0018 && ITRAIN FMINCL DDRWEF

▪

OUTPUT CI_REM **Units are controlled by the “preference” choice (Fig. 5)**

FORM UNIT **Output is in dose units (“NON-UNIT” = LCF output) (Fig. 4)**

DIMEN 2 3 18 **2 conditional probabilities (Fig. 19), 3 LOS conditional probabilities (Fig. 32), 18 isopleths (Fig. 26)**

PARM 0 3 3 0 **0=economic model disabled (1= economic model enabled) (Fig. 4); 3=both incident-free and accident analyses (Fig. 4); 3=longest output (Fig. 4); 0 = national average weather (1=Pasquill classes; 2= user-defined)(Fig. 26)**

SEVERITY **“Severities” are conditional probabilities (Fig. 19)**

NPOP=1 **rural population density (Fig. 14)**

NMODE=1 **highway (2=rail; 3=waterway) (Fig. 3)**

0.00282 **conditional probability of release accident (Fig. 19)**

9.94E-4 **conditional probability of release accident (Fig. 19)**

NPOP=2 **suburban population density (Fig. 14)**

NMODE=1

0.00282

9.94E-4

NPOP=3 **urban population density (Fig. 14)**

NMODE=1
0.00282
9.94E-4

RELEASE accident release fractions listed by physical/chemical group (Fig. 21)

GROUP=CRUD

RFRAC release fractions (Fig. 21)

0.001 release fraction associated with conditional probability 0.00282

0.001 release fraction associated with conditional probability 9.94E-04

AERSOL aerosol fractions (Fig. 22)

1.0 aerosol fraction associated with release fraction 0.001 and conditional probability 0.00282

0.0 aerosol fraction associated with release fraction 0.0 and conditional probability 9.94E-04

RESP fraction of aerosol that is inhaled into the lung (Fig. 22)

0.01 respirable fraction associated with aerosol fraction 1.0, release fraction 0.001 and conditional probability 0.00282

0.01 respirable fraction associated with aerosol fraction 0.0, release fraction 0.001 and conditional probability 9.94E-04

DEPVEL 0.0323 deposition velocity of CRUD particles (Fig. 20)

LOS_SHIELD Loss of shielding (LOS) conditional probabilities (Fig. 32)

NPOP=1

ACIDNT_PRB accident probability (Fig. 32)

0.99 conditional probability of LOS accident 1 0.005 conditional probability of LOS accident 2 0.005

conditional probability of LOS accident 2

FRAC_LOST fraction lost (Fig. 33)

0.0 shielding fraction lost in LOS accident 1 0.1 shielding fraction lost in LOS accident 2 0.9

shielding fraction lost in LOS accident 3

NPOP=2

ACIDNT_PRB

0.99 0.005 0.005

FRAC_LOST

0.0 0.1 0.9

NPOP=3

ACIDNT_PRB

0.99 0.005 0.005

FRAC_LOST

0.0 0.1 0.9

PACKAGE (Fig.6) NACSTC package name 14.0 package external dose rate 0.77 gamma fraction 0.23 neutron fraction 4.9 package longest dimension

CO60 radionuclide in package (Figs 7,8) 225.42 curies of radionuclide CRUD physical/chemical group of radionuclide

END

VEHICLE -1 minus sign indicates exclusive use (Fig. 11) NACSTC vehicle name (Fig. 10) 1.400000E01

vehicle external dose rate (Fig. 10) 0.77 gamma fraction (Fig.11) 0.23 neutron fraction (Fig.11) 4.9

vehicle longest dimension (Fig. 10) 1.0 number of shipments (Fig. 10) 2.0 crew size (Fig. 11) 3.5 crew

distance (m) (Fig. 11) 0.38 crew shielding (Fig. 11) 2.5 crew view (vehicle short dimension) (Fig.11)

NACSTC 1.0 number of packages on vehicle (Fig. 11)

FLAGS

IACC 2 not used

IUOPT 2 default residential shielding factors: R: 0% shielding (factor =1); S:13% shielding (factor = 0.87); U: 98.8% shielding (factor = 0.012) (Fig. 29)

REGCHECK 0 no regulatory constraints (1= crew dose and external dose regulatory constraints imposed) (Fig. 29)

MODSTD list of default parameter values (Fig. 29)

DISTOFF FREEWAY 3.000000E01 3.000000E01 8.000000E02 shoulder, minimum, and maximum distances from moving vehicle on a freeway

DISTOFF SECONDARY 2.700000E01 3.000000E01 8.000000E02 shoulder, minimum, and maximum distances from moving vehicle on a freeway

DISTOFF STREET 5.000000E00 8.000000E00 8.000000E02 **pavement , minimum, and maximum distances from moving vehicle on a city street**
DISTON **perpendicular distances between vehicles on route (m)**
FREEWAY 1.500000E01
SECONDARY 3.000000E00
STREET 3.000000E00
ADJACENT 4.000000E00
BDF 5.000000E-02 **fraction of outside air in urban buildings**
BRATE 3.300000E-04 **breathing rate (m³/sec)**
CULVL 2.000000E-01 **cleanup level (μCi/m²)**
EVACUATION 1.000000E00 **evacuation time (days)**
GECON 1.000000E-04 **not used**
INTERDICT 4.000000E01 **interdiction level (multiplier on CULVL)**
LCFCON 6.000000E-04 **LCF/rem (public)** 6.000000E-04 **LCF/rem (occupational)**
SURVEY 1.000000E01 **survey interval (days)**
UBF 5.200000E-01 **fraction of urban population in buildings**
USWF 4.800000E-01 **fraction of urban population on the sidewalk**
CAMPAIGN 8.330000E-02 **length of shipping campaign (year)**
MITDDIST 3.000000E01 **distance from vehicle to MEI (m)**
MITDVEL 2.400000E01 **minimum speed of vehicle passing MEI (km/hr)**
RPD 6.000000E00 **ratio of pedestrians (on sidewalk along route) to urban residential population**
RR 1.000000E00 **rural shielding factor (0% shielding)**
RU 1.800000E-02 **urban shielding factor (98.8% shielding)**
RS 8.700000E-01 **suburban shielding factor (13% shielding)**
SMALLPKG 5.000000E-01 **minimum package dimension (m)**
RPCTHYROID I-131 **dose conversion factor**
EOF

LINK (Figs. 14 and 15) R link name NACSTC vehicle name 1.0 link length (km) 102 speed on link (km/hr) 795 vehicles/hour 1.0 persons/vehicle 17.0 population density (persons/km²) 2.89E-7 accidents/km 0.0363 fatalities/accident R population designator 1 primary highway (interstate) 0.5 fraction of land in agriculture
LINK S NACSTC 1.0 102 1956 1.0 300.0 2.89E-7 0.0363 S 1 0.0
LINK U NACSTC 1.0 85 3708 1.0 2400.0 2.89E-7 0.0363 U 1 0.0

STOP (Fig. 16) RURAL_1 stop name NACSTC vehicle name 10.0 minimum distance (m) 20.0 maximum distance (m) 17.0 exposed persons/km² 1.0 residential shielding 1.0 time at stop (hours)
STOP RURAL_2 NACSTC 10.0 50.0 17.0 1.0 1.0

LOS_STOP STOP_LOSS1 NACSTC 10.0 minimum distance (m) 20.0 maximum distance (m) 17.0 exposed persons/km² 1.0 residential shielding 1.0 time at stop (hours)
LOS_STOP STOP_LOSS2 NACSTC 10.0 50.0 17.0 1.0 1.0

EOF
END OF INPUT ECHO.I

Repeat of input file with some additions

NUMBER OF ACCIDENT SEVERITY CATEGORIES = 2
NUMBER OF LOSS OF SHIELDING PROBABILITIES = 3
These seven items are a repeat of PARM and DIMEN jn the input file,
NUMBER OF DEPOSITION AREAS (ISOPLETHS) = 18
INCIDENT FREE AND ACCIDENT ANALYSES INVOKED
DETAILED INPUT, FULL OUTPUT, SENSITIVITY ANALYSIS EDIT & POPULATION RISK BY LINK
& FULL ECONOMIC OUTPUT
USER SUPPLIED OR NATIONAL AVERAGE WEATHER DILUTION INPUT
HISTORICAL UNITS ON INPUT
HISTORICAL UNITS ON OUTPUT
DOSE UNITS ON OUTPUT

INGESTION FILE = RT6_Ingestion.BIN **From Title screen.**

PACKAGE AND MATERIAL CHARACTERISTICS INPUT DATA

DIMENSION EFFECTIVE K(0) FRACTION FRACTION DOSE RATE
MATERIAL (METERS) DIMENSION METERS SQ. GAMMA NEUTRON (mrem/hr)
NACSTC 4.900E+00 4.513E+00 1.060E+01 7.700E-01 2.300E-01 1.400E+01

K(0) IS DOSE RATE CONVERSION FACT

VEHICLE CHARACTERISTICS INPUT DATA

VEHICLE NAME NACSTC
MODE TYPE HIGHWAY
EXCLUSIVE USE YES
DOSE RATE (mrem/hr) 1.40E+01
FRACTION OF GAMMA FOR VEH 7.70E-01
FRACTION OF NEUTRON FOR V 2.30E-01
K(0) (SQ. METERS) 1.06E+01
VEHICLE SIZE (M) 4.90E+00
EFFECTIVE SIZE (M) 4.51E+00
NUMBER OF SHIPMENTS 1.00E+00
NUMBER OF CREW 2.00E+00
CREW DISTANCE (M) 3.50E+00
CREW DOSE ADJUSTMENT FACT 3.80E-01
CREW EXPOSER WIDTH (M) 2.50E+00
EFFECTIVE EXPOSER WIDTH 2.50E+00
K(0) (SQ M) CREW EXPOSURE 5.06E+00

VEHICLE MATERIAL NO.PACKAGES
NACSTC NACSTC 1.00E+00

TRANSFER

COEFFICIENTS: MU A(1) A(2) A(3) A(4)
GAMMA 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
NEUTRON 7.420E-03 2.020E-02 6.170E-05 3.170E-08 0.000E+00

The "transfer coefficients" are the coefficients of the Taylor expansion of the basic equation for dose from the spherical virtual source (Section 4(?)) to a receptor at some distance from the source.

The values below are from the Parameters screen,

DISTANCES (METERS) FREEWAY SECONDARY STREET RAIL WATER ADJACENT
OFFLINK:
MINIMUM DISTANCE 3.00E+01 2.70E+01 5.00E+00 3.00E+01 2.00E+02
SIDEWALK + MINIMUM 3.00E+01 3.00E+01 8.00E+00 3.00E+01 2.00E+02
MAXIMUM DISTANCE 8.00E+02 8.00E+02 8.00E+02 8.00E+02 1.00E+03
ONLINK:
OPPOSITE DIRECTION 1.50E+01 3.00E+00 3.00E+00 3.00E+00 4.00E+00
ADJACENT VEHICLE 4.00E+00

STOP RELATED INPUT DATA

STOP RURAL1 RURAL2
VEHICLE NACSTC NACSTC
PERSONS 1.70E+01 1.70E+01
MINIMUM DISTANCE(M) 1.00E+01 1.00E+01
MAXIMUM DISTANCE(M) 2.00E+01 5.00E+01
SHIELDING FACTOR 1.00E+00 1.00E+00

TIME (HR) 1.00E+00 1.00E+00

LINK RELATED INPUT DATA

LINK LINK_R LINK_S LINK_U
VEHICLE NACSTC NACSTC NACSTC
DISTANCE (KM) 1.00E+00 1.00E+00 1.00E+00
PERSONS PER VEHICLE 1.00E+00 1.00E+00 1.00E+00
SPEED (KM/HR) 1.02E+02 1.02E+02 8.50E+01
POPULATION DENSITY (#/KM^2) 1.70E+01 3.00E+02 2.40E+03
VEHICLE DENSITY (#/HR) 7.95E+02 1.96E+03 3.71E+03
ACCIDENT RATE/KM 2.89E-07 2.89E-07 2.89E-07
FATALITIES/ACCIDENT 3.63E-02 3.63E-02 3.63E-02
ZONE RURAL SUBURBAN URBAN
ROAD TYPE FREEWAY FREEWAY FREEWAY
FARMING FRACTION 5.00E-01 0.00E+00 0.00E+00

LOSS OF SHIELDING STOP RELATED INPUT DATA

LOSS SHIELDING STOPSTOP_LOSS1 STOP_LOSS2
VEHICLE NACSTC NACSTC
ZONE RURAL RURAL
NUMB PEOLPE EXPOSED 1.70E+01 1.70E+01
MINIMUM DISTANCE(M) 1.00E+01 1.00E+01
MAXIMUM DISTANCE(M) 2.00E+01 5.00E+01
SHIELDING FACTOR 1.00E+00 1.00E+00
EXPOSURE TIME (HR) 1.00E+00 1.00E+00

Chart of fractions of lead shielding lost v. conditional probability of loss.

RURAL SUBURBAN URBAN
FAIL FRAC PROB FAIL FRAC PROB FAIL FRAC PROB
0.00E+00 9.90E-01 0.00E+00 9.90E-01 0.00E+00 9.90E-01
1.00E-01 5.00E-03 1.00E-01 5.00E-03 1.00E-01 5.00E-03
9.00E-01 5.00E-03 9.00E-01 5.00E-03 9.00E-01 5.00E-03

ISOTOPE RELATED INPUT DATA

NUCLIDE CURIES WASTE RELEASE RESUSPENSION
PER PKG LIMIT GROUP FACTOR
NACSTC pkg name (Ci/M^3)

CO60 nuclide 2.25E+02 Ci/pkg 7.00E+02 LLW Class C limit – not used CRUD group 1.03E+00

The package name, radionuclide(s), physical/chemical group, and Ci/pkg are on the Radionuclides screen.

All nuclides for each package will be listed.

The dose conversion factors for all radionuclides loaded into packages, including the half-life in days are shown below (from the internal radionuclide library

NUCLIDE HALF GAMMA AIR IMMERISON (SHINE) DCF INGESTION NEUTRON
LIFE ENERGY CLOUD GROUND NUCLIDE EMISSION
NACSTC (Days) (MeV/nt) (rem-m^3/Ci-s)(rem-m^2/uCi-d) neu/sec/Ci
CO60 1.92E+03 2.50E+00 4.66E-01 7.51E-04 Co-60 0.00E+00

NUCLIDE INHALATION DOSE CONVERSION FACTORS

LUNG MARROW THYROID EFFECTIVE
NACSTC (REM/CI) (REM/CI) (REM/CI) (REM/CI)
CO60 1.78E+05 1.07E+04 0.00E+00 3.70E+04

RELEASE RELATED INPUT DATA

RELEASE FRACTIONS

GROUP SEVER: 1 SEVER: 2
CRUD 1.00E-03 1.00E-03

DEPOSITION VELOCITIES

GROUP M/SEC
CRUD 3.23E-02

ACCIDENT SEVERITY FRACTIONS
FOR HIGHWAY

ZONE SEVER: 1 SEVER: 2
RURAL 2.82E-03 9.94E-04
SUBURBAN 2.82E-03 9.94E-04
URBAN 2.82E-03 9.94E-04

AEROSOLIZED FRACTION OF RELEASED MATERIAL

GROUP SEVER: 1 SEVER: 2
CRUD 1.00E+00 0.00E+00

RESPIRABLE FRACTION OF AEROSOLS (BELOW 10 MICRONS AED)

GROUP SEVER: 1 SEVER: 2
CRUD 1.00E-02 1.00E-02

HEALTH RELATED INPUT DATA

These threshold values are taken from various literature sources. When RADTRAN is run, the appropriate RADTRAN output is compared with these values. If that output (e.g. the accident output for marrow dose) is larger than any of the listed values, an early morbidity and/or early mortality will be reported in the output.

EARLY MORBIDITY THRESHOLD VALUE FOR LUNG 5.000E+02 REM
EARLY MORBIDITY THRESHOLD VALUE FOR MARROW/WHOLE BODY 5.000E+01 REM
EARLY MORBIDITY THRESHOLD VALUE FOR THYROID 2.000E+02 REM

EARLY FATALITY PROBABILITIES (EF)

DOSE(REM) EF MARROW DOSE(REM) EF LUNG "EF" - effective

680.00	1.00000	1525.00	1.00000
670.00	0.99999	1500.00	0.99999
660.00	0.99998	1475.00	0.99997
650.00	0.99996	1450.00	0.99991
640.00	0.99992	1425.00	0.99974
630.00	0.99983	1400.00	0.99933
620.00	0.99967	1375.00	0.99840
610.00	0.99938	1350.00	0.99653
600.00	0.99889	1325.00	0.99306
590.00	0.99808	1300.00	0.98709
580.00	0.99679	1275.00	0.97755
570.00	0.99482	1250.00	0.96331
560.00	0.99192	1225.00	0.94326

550.00 0.98776 1200.00 0.91656
 540.00 0.98199 1175.00 0.88274
 530.00 0.97423 1150.00 0.84178
 520.00 0.96406 1125.00 0.79420
 510.00 0.95111 1100.00 0.74095
 500.00 0.93502 1075.00 0.68335
 490.00 0.91551 1050.00 0.62293
 480.00 0.89237 1025.00 0.56130
 470.00 0.86552 1000.00 0.50000
 460.00 0.83499 975.00 0.44042
 450.00 0.80096 950.00 0.38372
 440.00 0.76371 925.00 0.33077
 430.00 0.72363 900.00 0.28218
 420.00 0.68123 875.00 0.23830
 410.00 0.63706 850.00 0.19925
 400.00 0.59172 825.00 0.16498
 390.00 0.54583 800.00 0.13529
 380.00 0.50000 775.00 0.10988
 370.00 0.45481 750.00 0.08837
 360.00 0.41078 725.00 0.07038
 350.00 0.36838 700.00 0.05548
 340.00 0.32798 675.00 0.04329
 330.00 0.28990 650.00 0.03341
 320.00 0.25438 625.00 0.02549
 310.00 0.22155 600.00 0.01922
 300.00 0.19150 575.00 0.01430
 290.00 0.16425 550.00 0.01050
 280.00 0.13977 525.00 0.00759
 270.00 0.11797 500.00 0.00000
 260.00 0.09872
 250.00 0.08188
 240.00 0.06729
 230.00 0.05475
 220.00 0.04408
 210.00 0.03510
 200.00 0.02761
 190.00 0.02143
 180.00 0.01639
 170.00 0.01234
 160.00 0.00913
 150.00 0.00000

DISPERSAL ACCIDENT INPUT DATA

AREADA CENTER DILUTION

(M SQ) LINE(M) FACTOR*

4.590E+02 3.300E+01 3.420E-03
 1.530E+03 6.800E+01 1.720E-03
 3.940E+03 1.050E+02 8.580E-04
 1.250E+04 2.440E+02 3.420E-04
 3.040E+04 3.690E+02 1.720E-04
 6.850E+04 5.610E+02 8.580E-05
 1.760E+05 1.018E+03 3.420E-05
 4.450E+05 1.628E+03 1.720E-05
 8.590E+05 2.308E+03 8.580E-06
 2.550E+06 4.269E+03 3.420E-06
 4.450E+06 5.468E+03 1.720E-06
 1.030E+07 1.114E+04 8.580E-07
 2.160E+07 1.310E+04 3.420E-07
 5.520E+07 2.133E+04 1.720E-07
 1.770E+08 4.050E+04 8.580E-08

4.890E+08 6.999E+04 5.420E-08
8.120E+08 8.986E+04 4.300E-08
1.350E+09 1.209E+05 3.420E-08

* DILUTION FACTOR UNITS ARE (CI-SEC/M**3/CI-RELEASED)

OTHER DISPERSAL ACCIDENT INPUT PARAMETERS

BUILDING DOSE FACTOR (BDF) = 5.000E-02
CONTAMINATION CLEAN UP LEVEL(micro-CI/M^2)(CULVL) = 2.000E-01
BREATHING RATE (M**3/SEC) (BRATE) = 3.300E-04
INTERDICTION THRESHOLD (Ci/micro-Ci) (INTERDICT) = 4.000E+01
EVACUATION TIME (DAYS) (EVACUATION) = 1.000E+00
SURVEY INTERVAL (DAYS) (SURVEY) = 1.000E+01
CAMPAIGN LENGTH (YEARS) (TIMEYR) = 8.330E-02
FRACTION OF URBAN AREAS WITH BUILDINGS (UBF) = 5.200E-01
FRACTION OF URBAN AREAS WITH SIDEWALKS (USWF) = 4.800E-01
RATIO OF SIDEWALK PEDESTRIAN DENSITY (RPD) = 6.000E+00
MAXIMUM IN-TRANSIT DOSE DISTANCE (M) (DMDIST) = 3.000E+01
MAXIMUM IN-TRANSIT DOSE VELOCITY (KM/H) (DMVEL) = 2.400E+01
IACC VALUE: 1=NON-DISPERSAL, 2=DISPERSAL = 2
REGULATORY CHECK, 1=DO CHECKS, 0=NO CHECKS = 0
BUILDING SHIELDING OPTION (IUOPT) = 2
RURAL SHIELDING FACTOR = 1.000E+00
SUBURBAN SHIELDING FACTOR = 8.700E-01
URBAN SHIELDING FACTOR = 1.800E-02

INGESTION RELATED INPUT DATA

COMIDA INGESTION FILE USED: RT6_Ingestion.BIN

COMIDA FILE HEADER

COMIDA2 07/22/03 08:58:40 Ver. 1.11a, 1/28/96: avoiding use of UNIT 6 for HP

DOSE CONVERSION FILE USED IN COMIDA

FGRDCF 07/10/03 21:45:47 Version 1.10

Implicit daughter halfives (m) less than 90 and less than 0.100 of parent

BACKYARD FARMER INGESTION DOSE (REM/CI DEPOSITED)

PACKAGE NUCLIDE EFFECTIVE THYROID

NACSTC Co-60 1.328E+04 3.779E+03

SOCIETAL INGESTION DOSE (PERSON-REM/CI DEPOSITED)

NUCLIDE GONADS BREAST LUNGS RED MAR BONE SU THYROID REMAIND EFFECTI

Co-60 1.6E+00 5.7E-01 4.5E-01 6.8E-01 4.8E-01 4.1E-01 2.6E+00 1.4E+00

END OF INPUT EDIT

OOO U U TTTTT PPPP U U TTTTT
O OU U T P P U U T
O OU U T P P U U T
O OU U T PPPP U U T
O OU U T P U U T
O OU U T P U U T
OOO UUUUU T P UUUUU T

RADTRAN 6.00 September 28, 2007

Copyright 2007 Sandia Corporation

RUN DATE: [07-24-2013 AT 08:05] PAGE 15

NON-RADIOLOGICAL DATA (ACCIDENTS and FATALITIES)

HIGHWAY

NACSTC Calculated from LINKS input

LINK ACCIDENT RATE ACCIDENTS FATALITIES

LINK_R 2.89E-07 2.89E-07 1.05E-08

LINK_S 2.89E-07 2.89E-07 1.05E-08

LINK_U 2.89E-07 2.89E-07 1.05E-08

TOTALS: 8.67E-07 3.15E-08

REGULATORY CHECKS HAVE BEEN DISABLED

CALCULATIONAL INFORMATION

IN CALCULATING THE DEPLETION FOR THE FOLLOWING GROUPS,
THE CONCENTRATIONS IN THE LISTED AREA HAVE BECOME NEGATIVE.
THE CONTAMINATION AND CONCENTRATIONS IN THE LISTED AREA AND
LARGER HAVE BEEN SET TO ZERO.

GROUP CRUD AREA 15

FOR NACSTC AREAS WITH TOTAL CONTAMINATION RATIO GREATER THAN 40.0000
(THE AREAS MARKED WITH AN 'X' ARE INTERDICTED

AREA/SEVERITY P_c 1 P_c 2 SEVERITY, P_c = conditional probability

1	X	-
2	X	-
3	-	-
4	-	-
5	-	-
6	-	-
7	-	-
8	-	-
9	-	-
10	-	-
11	-	-
12	-	-
13	-	-
14	-	-
15	-	-
16	-	-
17	-	-
18	-	-

The areas marked with "x" are interdicted because the Ci/m² exceeds the cleanup standard (Parameters screen). This does not impact the dose calculation or any other calculation.

RELEASE FRACTIONS

GROUP SEVER: 1 SEVER: 2
CRUD 1.00E-03 1.00E-03

DEPOSITION VELOCITIES

GROUP M/SEC
CRUD 3.23E-02

DILUTION FACTORS

CHI VALUES AFTER DEPLETION (CI-SEC/M**3/CI-RELEASED)

DISTANCE CRUD

3.30E+01 3.42E-03
6.80E+01 1.72E-03
1.05E+02 7.85E-04
2.44E+02 2.82E-04
3.69E+02 1.19E-04
5.61E+02 5.05E-05
1.02E+03 1.69E-05
1.63E+03 6.74E-06
2.31E+03 2.57E-06
4.27E+03 8.34E-07
5.47E+03 2.82E-07
1.11E+04 1.15E-07
1.31E+04 3.43E-08
2.13E+04 1.33E-08
4.05E+04 4.65E-09
7.00E+04 0.00E+00
8.99E+04 0.00E+00
1.21E+05 0.00E+00

“CHI” (the Greek letter X) is concentration. The source of the downwind distance (left-hand column) is the Accident-Average Weather screen.

DEPOSITION FACTORS

CHI DEPOSITED (CI/M**2/CI-RELEASED)

DISTANCE CRUD **Distance is downwind distance in meters.**

3.30E+01 1.10E-04
6.80E+01 5.55E-05
1.05E+02 2.54E-05
2.44E+02 9.11E-06
3.69E+02 3.86E-06
5.61E+02 1.63E-06
1.02E+03 5.45E-07
1.63E+03 2.18E-07
2.31E+03 8.30E-08
4.27E+03 2.69E-08
5.47E+03 9.11E-09
1.11E+04 3.72E-09
1.31E+04 1.11E-09
2.13E+04 4.30E-10
4.05E+04 1.50E-10
7.00E+04 0.00E+00
8.99E+04 0.00E+00
1.21E+05 0.00E+00

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 1

AIR CONCENTRATION GROUND CONTAMINATION
 INHALATION ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
 PATHWAY BONE
 CNTR LINE LUNG MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)

3.30E+01	4.53E-04	1.91E-02	9.41E-05	7.71E-04	2.49E+01
6.80E+01	2.27E-04	9.58E-03	4.73E-05	3.87E-04	1.25E+01
1.05E+02	1.04E-04	4.38E-03	2.16E-05	1.77E-04	5.72E+00
2.44E+02	3.73E-05	1.57E-03	7.76E-06	6.36E-05	2.05E+00
3.69E+02	1.58E-05	6.66E-04	3.29E-06	2.69E-05	8.70E-01
5.61E+02	6.68E-06	2.81E-04	1.39E-06	1.14E-05	3.68E-01
1.02E+03	2.23E-06	9.41E-05	4.64E-07	3.80E-06	1.23E-01
1.63E+03	8.93E-07	3.76E-05	1.86E-07	1.52E-06	4.91E-02
2.31E+03	3.40E-07	1.43E-05	7.07E-08	5.79E-07	1.87E-02
4.27E+03	1.10E-07	4.65E-06	2.30E-08	1.88E-07	6.07E-03
5.47E+03	3.74E-08	1.57E-06	7.77E-09	6.36E-08	2.05E-03
1.11E+04	1.53E-08	6.42E-07	3.17E-09	2.60E-08	8.39E-04
1.31E+04	4.54E-09	1.91E-07	9.44E-10	7.73E-09	2.50E-04
2.13E+04	1.76E-09	7.42E-08	3.66E-10	3.00E-09	9.69E-05
4.05E+04	6.16E-10	2.59E-08	1.28E-10	1.05E-09	3.39E-05
7.00E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8.99E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.21E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Zeros occur when the calculated dose is negative

PASQUILL CATEGORY A
 VEHICLE NACSTC
 MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
 FROM EXPOSURE DURING EVACUATION
 SEVERITY= 1

INHALED SHINE BACKYARD FARMER
 CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID

3.30E+01	9.41E-05	1.36E-06	3.59E-04	1.87E-02	1.91E-02	3.31E-01	9.41E-02
6.80E+01	4.73E-05	3.42E-07	1.80E-04	9.38E-03	9.61E-03	1.66E-01	4.73E-02
1.05E+02	2.16E-05	7.15E-08	8.25E-05	4.29E-03	4.39E-03	7.59E-02	2.16E-02
2.44E+02	7.76E-06	9.23E-09	2.96E-05	1.54E-03	1.58E-03	2.73E-02	7.76E-03
3.69E+02	3.29E-06	1.65E-09	1.25E-05	6.52E-04	6.68E-04	1.16E-02	3.29E-03
5.61E+02	1.39E-06	2.95E-10	5.30E-06	2.76E-04	2.82E-04	4.88E-03	1.39E-03
1.02E+03	4.64E-07	3.30E-11	1.77E-06	9.22E-05	9.44E-05	1.63E-03	4.64E-04
1.63E+03	1.86E-07	5.27E-12	7.08E-07	3.68E-05	3.77E-05	6.52E-04	1.86E-04
2.31E+03	7.07E-08	7.66E-13	2.70E-07	1.40E-05	1.44E-05	2.49E-04	7.07E-05
4.27E+03	2.30E-08	8.07E-14	8.76E-08	4.56E-06	4.67E-06	8.07E-05	2.30E-05
5.47E+03	7.77E-09	9.23E-15	2.96E-08	1.54E-06	1.58E-06	2.73E-05	7.76E-06
1.11E+04	3.17E-09	1.54E-15	1.21E-08	6.29E-07	6.45E-07	1.11E-05	3.17E-06
1.31E+04	9.44E-10	1.36E-16	3.60E-09	1.87E-07	1.92E-07	3.32E-06	9.44E-07
2.13E+04	3.66E-10	2.05E-17	1.40E-09	7.27E-08	7.45E-08	1.29E-06	3.66E-07
4.05E+04	1.28E-10	2.51E-18	4.89E-10	2.54E-08	2.60E-08	4.50E-07	1.28E-07
7.00E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8.99E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.21E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

RUN DATE: [07-24-2013 AT 08:05] PAGE 21

NACSTD_SAMPLEREPEAT_01_03_14

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
 FROM EXPOSURE DURING EVACUATION
 SEVERITY= 2 **All zero because the aerosolized fraction for this conditional probability (severity) is zero.**

AIR CONCENTRATION GROUND CONTAMINATION
 INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
 CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)

3.30E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
----------	----------	----------	----------	----------	----------

6.80E+01 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.05E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.44E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
3.69E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
5.61E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.02E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.63E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.31E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
4.27E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
5.47E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.11E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.31E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.13E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
4.05E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
7.00E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
8.99E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.21E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00

PASQUILL CATEGORY A
VEHICLE NACSTC
MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 2

INHALED SHINE BACKYARD FARMER
CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
ALL VALUES WERE 0.0

INCIDENT-FREE SUMMARY
***** **

IN-TRANSIT POPULATION EXPOSURE IN PERSON-REM
From Link and Vehicle screens

CREW OFF LINK ON LINK **Off-link = residents along the route**
LINK_R 4.39E-05 4.65E-07 5.55E-06 **On-link = occupants of heicles sharing the route**
LINK_S 4.39E-05 7.13E-06 1.37E-05
LINK_U 5.27E-05 1.42E-06 3.76E-05

ZONE
RURAL 4.39E-05 4.65E-07 5.55E-06
SUBURB 4.39E-05 7.13E-06 1.37E-05
URBAN 5.27E-05 1.42E-06 3.76E-05

TOTALS: 1.40E-04 9.01E-06 5.68E-05

MAXIMUM INDIVIDUAL IN-TRANSIT DOSE from **incident-free transportation**
NACSTC 5.67E-07 REM

STOP EXPOSURE IN PERSON-REM

ANNULAR AREA RURAL1 1.14E-05
ANNULAR AREA RURAL2 2.71E-05

TOTAL: 3.86E-05

INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY
ESTIMATES THE PERSON-REM INFLUENCE OF A ONE PERCENT INCREASE IN THE PARAMETER

LINK PARAMETER	IMPORTANCE	CHANGE
LINK_R -----		
DISTANCE FROM PACKAGE TO CREW	-8.736E-07	-1.7502 %
VELOCITY	-5.547E-07	-1.1113 %
NUMBER OF SHIPMENTS	4.991E-07	1.0000 %
DISTANCE TRAVELED	4.991E-07	1.0000 %
DOSE RATE FOR VEHICLE (TI)	4.991E-07	1.0000 %
CREW DOSE ADJUSTMENT FACTOR	4.389E-07	0.8794 %
NUMBER OF CREW MEMBERS	4.389E-07	0.8794 %
NUMBER OF PEOPLE PER VEHICLE	5.554E-08	0.1113 %
TRAFFIC COUNT	5.554E-08	0.1113 %
SHIELDING FACTOR (RR,RS,RU)	4.645E-09	0.0093 %
POPULATION DENSITY	4.645E-09	0.0093 %

Same for all links.

INCIDENT-FREE IMPORTANCE ANALYSIS SUMMARY
ESTIMATES THE PERSON-REM INFLUENCE OF A ONE PERCENT INCREASE IN THE PARAMETER

STOP PARAMETER	IMPORTANCE	CHANGE
RURAL1 -----		
MAXIMUM DISTANCE AT STOP	-3.047E-07	-2.6667 %
STOP TIME	1.143E-07	1.0000 %
POPULATION/POPULATION DENSITY	1.143E-07	1.0000 %
NUMBER OF SHIPMENTS	1.143E-07	1.0000 %
DOSE RATE FOR VEHICLE	1.143E-07	1.0000 %
MINIMUM DISTANCE AT STOP	7.617E-08	0.6667 %

Same for all stops.

NUMBER OF EXPECTED ACCIDENTS

The products of the number of accidents on each link and the conditional probability (severity)

LINK SEVER: 1 SEVER: 2
LINK_R 8.15E-10 2.87E-10
LINK_S 8.15E-10 2.87E-10
LINK_U 8.15E-10 2.87E-10

NUMBER OF EARLY FATALITIES FROM INHALATION

ALL VALUES ARE 0.0

NUMBER OF EARLY MORBIDITY CASES FROM INHALATION

ALL VALUES ARE 0.0

MAXIMUM RISK FOR INDIVIDUAL IN NEAREST ISOPLETH (DOSE IN REM)
FROM INHALATION, CLOUDSHINE, AND GROUNDSHINE EXPOSURE DURING EVACUATION

LINK SEVER: 1 SEVER: 2
LINK_R 1.59E-11 0.00E+00
LINK_S 1.59E-11 0.00E+00
LINK_U 1.59E-11 0.00E+00

LOSS OF SHIELDING STOP = STOP_LOSS1 FOR LINK = LINK_R
AVERAGE RADIOLOGICAL DOSE (P_REM)

10.0 20.0
SLMP FRAC m TO CASK m TO CASK
0.00E+00 1.37E-02 3.43E-03

1.00E-01 4.34E-01 9.95E-02
9.00E-01 4.53E+01 1.04E+01

LOSS OF SHIELDING STOP = STOP_LOSS1 FOR LINK = LINK_S
AVERAGE RADIOLOGICAL DOSE (P_REM)

10.0 20.0
SLMP FRAC m TO CASK m TO CASK
0.00E+00 1.37E-02 3.43E-03
1.00E-01 4.34E-01 9.95E-02
9.00E-01 4.53E+01 1.04E+01

LOSS OF SHIELDING STOP = STOP_LOSS1 FOR LINK = LINK_U
AVERAGE RADIOLOGICAL DOSE (P_REM)

10.0 20.0
SLMP FRAC m TO CASK m TO CASK
0.00E+00 1.37E-02 3.43E-03
1.00E-01 4.34E-01 9.95E-02
9.00E-01 4.53E+01 1.04E+01

LOSS OF SHIELDING STOP = STOP_LOSS2 FOR LINK = LINK_R
AVERAGE RADIOLOGICAL DOSE (P_REM)

10.0 20.0 50.0
SLMP FRAC m TO CASK m TO CASK m TO CASK
0.00E+00 1.37E-02 3.43E-03 5.48E-04
1.00E-01 4.34E-01 9.95E-02 1.42E-02
9.00E-01 4.53E+01 1.04E+01 1.47E+00

LOSS OF SHIELDING STOP = STOP_LOSS2 FOR LINK = LINK_S
AVERAGE RADIOLOGICAL DOSE (P_REM)

10.0 20.0 50.0
SLMP FRAC m TO CASK m TO CASK m TO CASK
0.00E+00 1.37E-02 3.43E-03 5.48E-04
1.00E-01 4.34E-01 9.95E-02 1.42E-02
9.00E-01 4.53E+01 1.04E+01 1.47E+00

LOSS OF SHIELDING STOP = STOP_LOSS2 FOR LINK = LINK_U
AVERAGE RADIOLOGICAL DOSE (P_REM)

10.0 20.0 50.0
SLMP FRAC m TO CASK m TO CASK m TO CASK
0.00E+00 1.37E-02 3.43E-03 5.48E-04
1.00E-01 4.34E-01 9.95E-02 1.42E-02
9.00E-01 4.53E+01 1.04E+01 1.47E+00

LOSS OF SHIELDING STOP ON LINK = LINK_R
MAXIMUM RADIOLOGICAL DOSE (P_REM) AT 2 M FROM CASK
STOP STOP
SLMP FRACSTOP_LOSS1STOP_LOSS2
0.00E+00 1.46E-01 1.46E-01
1.00E-01 1.81E+02 1.81E+02
9.00E-01 1.15E+03 1.15E+03

LOSS OF SHIELDING STOP ON LINK = LINK_S
MAXIMUM RADIOLOGICAL DOSE (P_REM) AT 2 M FROM CASK
STOP STOP
SLMP FRACSTOP_LOSS1STOP_LOSS2
0.00E+00 1.46E-01 1.46E-01
1.00E-01 1.81E+02 1.81E+02
9.00E-01 1.15E+03 1.15E+03

LOSS OF SHIELDING STOP ON LINK = LINK_U
MAXIMUM RADIOLOGICAL DOSE (P_REM) AT 2 M FROM CASK
STOP STOP
SLMP FRACSTOP_LOSS1STOP_LOSS2
0.00E+00 1.46E-01 1.46E-01
1.00E-01 1.81E+02 1.81E+02
9.00E-01 1.15E+03 1.15E+03

EXPECTED VALUES OF POPULATION RISK IN PERSON-REM

LINK INHALED RESUSPD CLOUDSH GROUND SH TOTAL
LINK_R 1.15E-14 3.11E-16 4.40E-14 1.55E-12 1.61E-12
LINK_S 2.03E-13 5.49E-15 7.77E-13 2.74E-11 2.83E-11
LINK_U 4.73E-12 1.28E-13 1.81E-11 6.36E-10 6.59E-10

ZONE
RURAL 1.15E-14 3.11E-16 4.40E-14 1.55E-12 1.61E-12
SUBURB 2.03E-13 5.49E-15 7.77E-13 2.74E-11 2.83E-11
URBAN 4.73E-12 1.28E-13 1.81E-11 6.36E-10 6.59E-10

TOTALS: 4.95E-12 1.33E-13 1.89E-11 6.65E-10 6.89E-10

SOCIETAL INGESTION RISK - PERSON-REM

LINK GONADS EFFECTIVE
LINK_R 5.16E-11 4.48E-11

TOTAL 5.16E-11 4.48E-11

SOCIETAL INGESTION RISK BY ORGAN - PERSON-REM

LINK BREAST LUNGS RED MARR BONE SUR THYROID REMAINDER
LINK_R 1.78E-11 1.42E-11 2.13E-11 1.52E-11 1.27E-11 8.04E-11

TOTAL 1.78E-11 1.42E-11 2.13E-11 1.52E-11 1.27E-11 8.04E-11

EXPECTED RISK VALUES - OTHER

LINK EARLY EARLY
FATALITY MORBIDITY
LINK_R 0.00E+00 0.00E+00
LINK_S 0.00E+00 0.00E+00
LINK_U 0.00E+00 0.00E+00

TOTAL 0.00E+00 0.00E+00

LOSS OF SHIELDING RISK VALUES P_REM BY CASE

LOSS OF SHIELDING STOP STOP_LOSS1

DISTANCE 10.0 20.0
 LINK =LINK_R 2.42E-01 5.57E-02
 DISTANCE 10.0 20.0
 LINK =LINK_S 2.42E-01 5.57E-02
 DISTANCE 10.0 20.0
 LINK =LINK_U 2.42E-01 5.57E-02

LOSS OF SHIELDING STOP STOP_LOSS2

DISTANCE 10.0 20.0 50.0
 LINK =LINK_R 2.42E-01 5.57E-02 7.97E-03
 DISTANCE 10.0 20.0 50.0
 LINK =LINK_S 2.42E-01 5.57E-02 7.97E-03
 DISTANCE 10.0 20.0 50.0
 LINK =LINK_U 2.42E-01 5.57E-02 7.97E-03

LOSS OF SHIELDING TOTAL RISK VALUES

LINK =LINK_U
 DISTANCE FROM CASK (M) = 1.00 2.00 3.00 4.00 5.00 10.00
 RISK P_REM = 4.62E-06 2.08E-06 1.30E-06 9.32E-07 7.21E-07 1.40E-07

LINK =LINK_U
 DISTANCE FROM CASK (M) = 1.00 2.00 3.00 4.00 5.00 10.00
 RISK P_REM = 4.62E-06 2.08E-06 1.30E-06 9.32E-07 7.21E-07 1.40E-07

LINK =LINK_U
 DISTANCE FROM CASK (M) = 1.00 2.00 3.00 4.00 5.00 10.00
 RISK P_REM = 4.62E-06 2.08E-06 1.30E-06 9.32E-07 7.21E-07 1.40E-07

ACCIDENT RESULTS USING THE PASQUILL OPTION
Only results different from Average Weather are reported

METEOROLOGICAL INPUT DATA BASED ON PASQUILL CATEGORIES

 PROB. A PROB. B PROB. C PROB. D PROB. E PROB. F
 0.0000 0.1000 0.2000 0.5000 0.2000 0.0000

AREA (MSQ)	*PASQUILL CATEGORY					
	A	B	C	D	E	F
4.60E+02	6.00E-03	4.00E-03	4.00E-03	4.30E-03	9.60E-03	6.20E-02
1.50E+03	1.70E-03	1.30E-03	1.10E-03	1.30E-03	3.20E-03	1.80E-02
3.90E+03	8.40E-04	5.50E-04	5.70E-04	6.50E-04	1.60E-03	8.40E-03
1.30E+04	1.70E-04	1.30E-04	1.30E-04	1.80E-04	4.00E-04	2.00E-03
3.00E+04	7.80E-05	6.00E-05	6.70E-05	9.50E-05	2.10E-04	9.20E-04
6.90E+04	2.80E-05	2.70E-05	3.00E-05	4.30E-05	1.40E-04	4.40E-04
1.80E+05	8.00E-06	1.00E-05	1.00E-05	1.80E-05	4.40E-05	2.00E-04
4.50E+05	2.20E-06	3.50E-06	5.00E-06	8.50E-06	2.10E-05	1.00E-04
8.60E+05	9.00E-07	1.60E-06	2.80E-06	5.00E-06	1.20E-05	6.20E-05
2.60E+06	1.40E-07	4.10E-07	1.00E-06	1.90E-06	4.80E-06	2.60E-05
4.50E+06	7.00E-08	2.20E-07	6.00E-07	1.30E-06	3.60E-06	1.90E-05
1.70E+07	1.10E-08	5.00E-08	1.70E-07	4.00E-07	1.40E-06	8.40E-06
2.20E+07	7.76E-09	3.20E-08	1.30E-07	3.00E-07	1.20E-06	7.00E-06
5.50E+07	2.24E-09	1.10E-08	5.70E-08	1.50E-07	6.00E-07	4.00E-06
1.80E+08	4.50E-10	2.50E-09	1.70E-08	5.50E-08	2.80E-07	2.00E-06
5.00E+08	1.13E-10	7.24E-10	6.32E-09	2.41E-08	1.38E-07	1.09E-06
8.00E+08	5.96E-11	4.09E-10	4.01E-09	1.65E-08	9.97E-08	8.22E-07

1.40E+09 2.76E-11 2.08E-10 2.33E-09 1.05E-08 6.77E-08 5.89E-07

* DILUTION FACTOR UNITS ARE (CI-SEC/M**3/CI-RELEASED)

AREA (M SQ)	CENTER LINE DISTANCES (M)					
	A	B	C	D	E	F
4.60E+02	2.40E+01	3.00E+01	3.30E+01	3.60E+01	4.20E+01	2.50E+01
1.50E+03	4.50E+01	5.40E+01	6.80E+01	7.70E+01	8.40E+01	6.00E+01
3.90E+03	6.50E+01	8.50E+01	9.80E+01	1.18E+02	1.30E+02	1.04E+02
1.30E+04	1.48E+02	1.82E+02	2.23E+02	2.61E+02	3.12E+02	2.90E+02
3.00E+04	2.21E+02	2.74E+02	3.22E+02	3.87E+02	4.68E+02	5.05E+02
6.90E+04	3.74E+02	4.17E+02	5.03E+02	6.33E+02	6.05E+02	8.57E+02
1.80E+05	5.89E+02	7.04E+02	9.25E+02	1.08E+03	1.26E+03	1.51E+03
4.50E+05	8.99E+02	1.22E+03	1.36E+03	1.73E+03	2.00E+03	2.48E+03
8.60E+05	1.20E+03	1.85E+03	1.87E+03	2.40E+03	2.85E+03	3.49E+03
2.60E+06	2.22E+03	3.80E+03	3.31E+03	4.37E+03	5.09E+03	6.51E+03
4.50E+06	2.78E+03	5.27E+03	4.40E+03	5.53E+03	6.10E+03	8.16E+03
1.70E+07	5.11E+03	1.15E+04	8.85E+03	1.15E+04	1.19E+04	1.46E+04
2.20E+07	5.72E+03	1.46E+04	1.03E+04	1.37E+04	1.35E+04	1.67E+04
5.50E+07	8.65E+03	2.56E+04	1.62E+04	2.11E+04	2.37E+04	2.49E+04
1.80E+08	1.46E+04	5.59E+04	3.17E+04	3.92E+04	4.39E+04	4.09E+04
5.00E+08	2.31E+04	1.08E+05	5.50E+04	6.56E+04	7.70E+04	6.29E+04
8.00E+08	2.82E+04	1.45E+05	7.07E+04	8.12E+04	1.01E+05	7.76E+04
1.40E+09	3.62E+04	2.06E+05	9.61E+04	1.06E+05	1.38E+05	9.71E+04

BACKYARD FARMER INGESTION DOSE (REM/CI DEPOSITED)

PACKAGE NUCLIDE EFFECTIVE THYROID
NACSTC Co-60 1.328E+04 3.779E+03

SOCIETAL INGESTION DOSE (PERSON-REM/CI DEPOSITED)

NUCLIDE GONADS BREAST LUNGS RED MAR BONE SU THYROID REMAIND EFFECTI
Co-60 1.6E+00 5.7E-01 4.5E-01 6.8E-01 4.8E-01 4.1E-01 2.6E+00 1.4E+00

OOO U U TTTTT PPPP U U TTTTT
OOU U TP PU UT
OOU U TP PU UT
OOU U T PPPP U UT
OOU U TP U UT
OOU U TP U UT
OOO UUUUU TP UUUUU T

DEPOSITION VELOCITIES
GROUP M/SEC
CRUD 3.23E-02

DILUTION FACTORS FOR PASQUILL CATEGORY B
CHI VALUES AFTER DEPLETION (CI-SEC/M**3/CI-RELEASED)

DISTANCE CRUD
3.00E+01 4.00E-03
5.40E+01 1.30E-03
8.50E+01 5.07E-04
1.82E+02 1.12E-04
2.74E+02 4.73E-05
4.17E+02 2.02E-05
7.04E+02 7.11E-06

1.22E+03 2.34E-06
1.85E+03 1.01E-06
3.80E+03 2.51E-07
5.27E+03 1.28E-07
1.15E+04 2.86E-08
1.46E+04 1.75E-08
2.56E+04 5.99E-09
5.59E+04 1.33E-09
1.08E+05 3.78E-10
1.45E+05 2.11E-10
2.06E+05 1.06E-10

DEPOSITION FACTORS
CHI DEPOSITED (CI/M**2/CI-RELEASED)

DISTANCE CRUD
3.00E+01 1.29E-04
5.40E+01 4.19E-05
8.50E+01 1.64E-05
1.82E+02 3.61E-06
2.74E+02 1.53E-06
4.17E+02 6.54E-07
7.04E+02 2.30E-07
1.22E+03 7.55E-08
1.85E+03 3.27E-08
3.80E+03 8.10E-09
5.27E+03 4.15E-09
1.15E+04 9.24E-10
1.46E+04 5.66E-10
2.56E+04 1.93E-10
5.59E+04 4.31E-11
1.08E+05 1.22E-11
1.45E+05 6.80E-12
2.06E+05 3.44E-12

PASQUILL CATEGORY B
VEHICLE NACSTC

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 1

AIR CONCENTRATION GROUND CONTAMINATION
INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)

3.00E+01 5.30E-04 2.23E-02 1.10E-04 9.02E-04 2.91E+01
5.40E+01 1.72E-04 7.24E-03 3.57E-05 2.93E-04 9.45E+00
8.50E+01 6.72E-05 2.83E-03 1.40E-05 1.14E-04 3.69E+00
1.82E+02 1.48E-05 6.23E-04 3.07E-06 2.52E-05 8.13E-01
2.74E+02 6.27E-06 2.64E-04 1.30E-06 1.07E-05 3.45E-01
4.17E+02 2.68E-06 1.13E-04 5.57E-07 4.56E-06 1.47E-01
7.04E+02 9.41E-07 3.96E-05 1.96E-07 1.60E-06 5.17E-02
1.22E+03 3.09E-07 1.30E-05 6.43E-08 5.27E-07 1.70E-02
1.85E+03 1.34E-07 5.64E-06 2.78E-08 2.28E-07 7.36E-03
3.80E+03 3.32E-08 1.40E-06 6.90E-09 5.65E-08 1.83E-03
5.27E+03 1.70E-08 7.16E-07 3.53E-09 2.89E-08 9.35E-04
1.15E+04 3.79E-09 1.60E-07 7.88E-10 6.45E-09 2.08E-04
1.46E+04 2.32E-09 9.78E-08 4.83E-10 3.95E-09 1.28E-04
2.56E+04 7.93E-10 3.34E-08 1.65E-10 1.35E-09 4.36E-05
5.59E+04 1.77E-10 7.43E-09 3.67E-11 3.01E-10 9.71E-06
1.08E+05 5.00E-11 2.11E-09 1.04E-11 8.52E-11 2.75E-06
1.45E+05 2.79E-11 1.17E-09 5.79E-12 4.75E-11 1.53E-06

PASQUILL CATEGORY B
VEHICLE NACSTC
MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 1

INHALED SHINE BACKYARD FARMER
CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
3.00E+01 1.10E-04 1.98E-06 4.20E-04 2.18E-02 2.24E-02 3.87E-01 1.10E-01
5.40E+01 3.57E-05 2.09E-07 1.36E-04 7.09E-03 7.26E-03 1.26E-01 3.57E-02
8.50E+01 1.40E-05 3.19E-08 5.33E-05 2.77E-03 2.84E-03 4.91E-02 1.40E-02
1.82E+02 3.07E-06 1.54E-09 1.17E-05 6.10E-04 6.25E-04 1.08E-02 3.07E-03
2.74E+02 1.30E-06 2.77E-10 4.97E-06 2.59E-04 2.65E-04 4.58E-03 1.30E-03
4.17E+02 5.57E-07 5.07E-11 2.13E-06 1.11E-04 1.13E-04 1.96E-03 5.57E-04
7.04E+02 1.96E-07 6.25E-12 7.47E-07 3.88E-05 3.98E-05 6.87E-04 1.96E-04
1.22E+03 6.43E-08 6.76E-13 2.45E-07 1.28E-05 1.31E-05 2.26E-04 6.43E-05
1.85E+03 2.78E-08 1.27E-13 1.06E-07 5.52E-06 5.66E-06 9.78E-05 2.78E-05
3.80E+03 6.90E-09 7.79E-15 2.63E-08 1.37E-06 1.40E-06 2.43E-05 6.90E-06
5.27E+03 3.53E-09 2.04E-15 1.35E-08 7.01E-07 7.18E-07 1.24E-05 3.53E-06
1.15E+04 7.88E-10 1.01E-16 3.01E-09 1.56E-07 1.60E-07 2.77E-06 7.88E-07
1.46E+04 4.83E-10 3.81E-17 1.84E-09 9.58E-08 9.81E-08 1.70E-06 4.83E-07
2.56E+04 1.65E-10 4.44E-18 6.29E-10 3.27E-08 3.35E-08 5.79E-07 1.65E-07
5.59E+04 3.67E-11 2.20E-19 1.40E-10 7.28E-09 7.46E-09 1.29E-07 3.67E-08
1.08E+05 1.04E-11 1.77E-20 3.97E-11 2.06E-09 2.11E-09 3.66E-08 1.04E-08
1.45E+05 5.79E-12 5.49E-21 2.21E-11 1.15E-09 1.18E-09 2.04E-08 5.79E-09

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 2

AIR CONCENTRATION GROUND CONTAMINATION
INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)
3.00E+01 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
5.40E+01 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
8.50E+01 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.82E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.74E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
4.17E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
7.04E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.22E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.85E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
3.80E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
5.27E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.15E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.46E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.56E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
5.59E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.08E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.45E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00

PASQUILL CATEGORY B
VEHICLE NACSTC
MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 2

INHALED SHINE BACKYARD FARMER
CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
ALL VALUES WERE 0.0

DILUTION FACTORS FOR PASQUILL CATEGORY C

CHI VALUES AFTER DEPLETION (CI-SEC/M**3/CI-RELEASED)

DISTANCE CRUD
3.30E+01 4.00E-03
6.80E+01 1.10E-03
9.80E+01 5.29E-04
2.23E+02 1.13E-04
3.22E+02 5.34E-05
5.03E+02 2.27E-05
9.25E+02 7.11E-06
1.36E+03 3.33E-06
1.87E+03 1.74E-06
3.31E+03 5.91E-07
4.40E+03 3.20E-07
8.85E+03 8.63E-08
1.03E+04 5.73E-08
1.62E+04 2.45E-08
3.17E+04 6.62E-09
5.50E+04 2.14E-09
7.07E+04 1.20E-09
9.61E+04 6.61E-10

DEPOSITION FACTORS
CHI DEPOSITED (CI/M**2/CI-RELEASED)

DISTANCE CRUD
3.30E+01 1.29E-04
6.80E+01 3.55E-05
9.80E+01 1.71E-05
2.23E+02 3.65E-06
3.22E+02 1.72E-06
5.03E+02 7.32E-07
9.25E+02 2.30E-07
1.36E+03 1.07E-07
1.87E+03 5.64E-08
3.31E+03 1.91E-08
4.40E+03 1.04E-08
8.85E+03 2.79E-09
1.03E+04 1.85E-09
1.62E+04 7.91E-10
3.17E+04 2.14E-10
5.50E+04 6.90E-11
7.07E+04 3.88E-11
9.61E+04 2.14E-11

PASQUILL CATEGORY C
VEHICLE NACSTC

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 1

AIR CONCENTRATION GROUND CONTAMINATION
INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)
3.30E+01 5.30E-04 2.23E-02 1.10E-04 9.02E-04 2.91E+01
6.80E+01 1.45E-04 6.13E-03 3.02E-05 2.48E-04 8.00E+00
9.80E+01 7.01E-05 2.95E-03 1.46E-05 1.19E-04 3.85E+00
2.23E+02 1.50E-05 6.30E-04 3.11E-06 2.55E-05 8.23E-01
3.22E+02 7.07E-06 2.98E-04 1.47E-06 1.20E-05 3.89E-01
5.03E+02 3.00E-06 1.26E-04 6.23E-07 5.11E-06 1.65E-01
9.25E+02 9.42E-07 3.96E-05 1.96E-07 1.60E-06 5.18E-02
1.36E+03 4.41E-07 1.86E-05 9.16E-08 7.50E-07 2.42E-02

1.87E+03 2.31E-07 9.73E-06 4.80E-08 3.93E-07 1.27E-02
 3.31E+03 7.83E-08 3.30E-06 1.63E-08 1.33E-07 4.30E-03
 4.40E+03 4.24E-08 1.79E-06 8.82E-09 7.22E-08 2.33E-03
 8.85E+03 1.14E-08 4.81E-07 2.38E-09 1.95E-08 6.29E-04
 1.03E+04 7.59E-09 3.19E-07 1.58E-09 1.29E-08 4.17E-04
 1.62E+04 3.24E-09 1.36E-07 6.74E-10 5.52E-09 1.78E-04
 3.17E+04 8.77E-10 3.69E-08 1.82E-10 1.49E-09 4.82E-05
 5.50E+04 2.83E-10 1.19E-08 5.88E-11 4.82E-10 1.56E-05
 7.07E+04 1.59E-10 6.69E-09 3.30E-11 2.71E-10 8.74E-06
 9.61E+04 8.76E-11 3.69E-09 1.82E-11 1.49E-10 4.81E-06

PASQUILL CATEGORY C
 VEHICLE NACSTC
 MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
 FROM EXPOSURE DURING EVACUATION
 SEVERITY= 1

INHALED SHINE BACKYARD FARMER
 CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
 3.30E+01 1.10E-04 2.04E-06 4.20E-04 2.18E-02 2.24E-02 3.87E-01 1.10E-01
 6.80E+01 3.02E-05 1.54E-07 1.15E-04 6.00E-03 6.15E-03 1.06E-01 3.02E-02
 9.80E+01 1.46E-05 3.57E-08 5.56E-05 2.89E-03 2.96E-03 5.12E-02 1.46E-02
 2.23E+02 3.11E-06 1.63E-09 1.19E-05 6.17E-04 6.32E-04 1.09E-02 3.11E-03
 3.22E+02 1.47E-06 3.63E-10 5.61E-06 2.92E-04 2.99E-04 5.17E-03 1.47E-03
 5.03E+02 6.23E-07 6.53E-11 2.38E-06 1.24E-04 1.27E-04 2.19E-03 6.23E-04
 9.25E+02 1.96E-07 6.44E-12 7.47E-07 3.88E-05 3.98E-05 6.88E-04 1.96E-04
 1.36E+03 9.16E-08 1.41E-12 3.50E-07 1.82E-05 1.86E-05 3.22E-04 9.16E-05
 1.87E+03 4.80E-08 3.88E-13 1.83E-07 9.53E-06 9.76E-06 1.69E-04 4.80E-05
 3.31E+03 1.63E-08 4.45E-14 6.21E-08 3.23E-06 3.31E-06 5.72E-05 1.63E-05
 4.40E+03 8.82E-09 1.31E-14 3.37E-08 1.75E-06 1.79E-06 3.10E-05 8.82E-06
 8.85E+03 2.38E-09 9.49E-16 9.07E-09 4.72E-07 4.83E-07 8.35E-06 2.38E-06
 1.03E+04 1.58E-09 4.18E-16 6.02E-09 3.13E-07 3.21E-07 5.54E-06 1.58E-06
 1.62E+04 6.74E-10 7.63E-17 2.57E-09 1.34E-07 1.37E-07 2.37E-06 6.74E-07
 3.17E+04 1.82E-10 5.58E-18 6.96E-10 3.62E-08 3.70E-08 6.41E-07 1.82E-07
 5.50E+04 5.88E-11 5.82E-19 2.24E-10 1.17E-08 1.20E-08 2.07E-07 5.88E-08
 7.07E+04 3.30E-11 1.83E-19 1.26E-10 6.56E-09 6.71E-09 1.16E-07 3.30E-08
 9.61E+04 1.82E-11 5.57E-20 6.95E-11 3.61E-09 3.70E-09 6.40E-08 1.82E-08

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
 FROM EXPOSURE DURING EVACUATION
 SEVERITY= 2

AIR CONCENTRATION GROUND CONTAMINATION
 INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
 CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)
 3.30E+01 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 6.80E+01 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 9.80E+01 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 2.23E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 3.22E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 5.03E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 9.25E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 1.36E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 1.87E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 3.31E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 4.40E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 8.85E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 1.03E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 1.62E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 3.17E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 5.50E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 7.07E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 9.61E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00

PASQUILL CATEGORY C
VEHICLE NACSTC
MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 2

INHALED SHINE BACKYARD FARMER
CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
ALL VALUES WERE 0.0

DILUTION FACTORS FOR PASQUILL CATEGORY D
CHI VALUES AFTER DEPLETION (CI-SEC/M**3/CI-RELEASED)

DISTANCE CRUD
3.60E+01 4.30E-03
7.70E+01 1.30E-03
1.18E+02 5.98E-04
2.61E+02 1.53E-04
3.87E+02 7.24E-05
6.33E+02 3.03E-05
1.08E+03 1.16E-05
1.73E+03 4.91E-06
2.40E+03 2.56E-06
4.37E+03 8.85E-07
5.53E+03 4.96E-07
1.15E+04 1.36E-07
1.37E+04 7.07E-08
2.11E+04 3.30E-08
3.92E+04 9.27E-09
6.56E+04 2.36E-09
8.12E+04 8.21E-10
1.06E+05 3.81E-10

DEPOSITION FACTORS
CHI DEPOSITED (CI/M**2/CI-RELEASED)

DISTANCE CRUD
3.60E+01 1.39E-04
7.70E+01 4.19E-05
1.18E+02 1.93E-05
2.61E+02 4.95E-06
3.87E+02 2.34E-06
6.33E+02 9.79E-07
1.08E+03 3.75E-07
1.73E+03 1.59E-07
2.40E+03 8.28E-08
4.37E+03 2.86E-08
5.53E+03 1.60E-08
1.15E+04 4.40E-09
1.37E+04 2.28E-09
2.11E+04 1.07E-09
3.92E+04 2.99E-10
6.56E+04 7.63E-11
8.12E+04 2.65E-11
1.06E+05 1.23E-11

PASQUILL CATEGORY D
VEHICLE NACSTC

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION

SEVERITY= 1

AIR CONCENTRATION GROUND CONTAMINATION
INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)

3.60E+01	5.69E-04	2.40E-02	1.18E-04	9.69E-04	3.13E+01
7.70E+01	1.72E-04	7.24E-03	3.57E-05	2.93E-04	9.45E+00
1.18E+02	7.91E-05	3.33E-03	1.65E-05	1.35E-04	4.35E+00
2.61E+02	2.03E-05	8.54E-04	4.21E-06	3.45E-05	1.11E+00
3.87E+02	9.59E-06	4.04E-04	1.99E-06	1.63E-05	5.27E-01
6.33E+02	4.01E-06	1.69E-04	8.34E-07	6.83E-06	2.21E-01
1.08E+03	1.54E-06	6.48E-05	3.20E-07	2.62E-06	8.46E-02
1.73E+03	6.51E-07	2.74E-05	1.35E-07	1.11E-06	3.58E-02
2.40E+03	3.40E-07	1.43E-05	7.06E-08	5.78E-07	1.87E-02
4.37E+03	1.17E-07	4.93E-06	2.44E-08	2.00E-07	6.44E-03
5.53E+03	6.56E-08	2.76E-06	1.36E-08	1.12E-07	3.61E-03
1.15E+04	1.80E-08	7.59E-07	3.75E-09	3.07E-08	9.92E-04
1.37E+04	9.37E-09	3.94E-07	1.95E-09	1.59E-08	5.15E-04
2.11E+04	4.37E-09	1.84E-07	9.08E-10	7.44E-09	2.40E-04
3.92E+04	1.23E-09	5.17E-08	2.55E-10	2.09E-09	6.75E-05
6.56E+04	3.13E-10	1.32E-08	6.50E-11	5.33E-10	1.72E-05
8.12E+04	1.09E-10	4.58E-09	2.26E-11	1.85E-10	5.98E-06
1.06E+05	5.04E-11	2.12E-09	1.05E-11	8.59E-11	2.77E-06

PASQUILL CATEGORY D
VEHICLE NACSTC
MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 1

INHALED SHINE BACKYARD FARMER
CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID

3.60E+01	1.18E-04	2.12E-06	4.52E-04	2.35E-02	2.41E-02	4.16E-01	1.18E-01
7.70E+01	3.57E-05	1.93E-07	1.36E-04	7.09E-03	7.26E-03	1.26E-01	3.57E-02
1.18E+02	1.65E-05	4.10E-08	6.28E-05	3.26E-03	3.34E-03	5.78E-02	1.64E-02
2.61E+02	4.21E-06	2.69E-09	1.61E-05	8.36E-04	8.57E-04	1.48E-02	4.21E-03
3.87E+02	1.99E-06	6.02E-10	7.61E-06	3.96E-04	4.05E-04	7.01E-03	1.99E-03
6.33E+02	8.34E-07	1.05E-10	3.18E-06	1.65E-04	1.69E-04	2.93E-03	8.34E-04
1.08E+03	3.20E-07	1.55E-11	1.22E-06	6.35E-05	6.50E-05	1.12E-03	3.20E-04
1.73E+03	1.35E-07	2.77E-12	5.16E-07	2.68E-05	2.75E-05	4.75E-04	1.35E-04
2.40E+03	7.06E-08	7.54E-13	2.69E-07	1.40E-05	1.43E-05	2.48E-04	7.06E-05
4.37E+03	2.44E-08	8.98E-14	9.30E-08	4.83E-06	4.95E-06	8.56E-05	2.44E-05
5.53E+03	1.36E-08	2.82E-14	5.21E-08	2.71E-06	2.77E-06	4.79E-05	1.36E-05
1.15E+04	3.75E-09	2.13E-15	1.43E-08	7.44E-07	7.62E-07	1.32E-05	3.75E-06
1.37E+04	1.95E-09	5.74E-16	7.43E-09	3.86E-07	3.96E-07	6.84E-06	1.95E-06
2.11E+04	9.08E-10	1.25E-16	3.47E-09	1.80E-07	1.85E-07	3.19E-06	9.08E-07
3.92E+04	2.55E-10	9.85E-18	9.74E-10	5.06E-08	5.19E-08	8.97E-07	2.55E-07
6.56E+04	6.50E-11	6.40E-19	2.48E-10	1.29E-08	1.32E-08	2.29E-07	6.50E-08
8.12E+04	2.26E-11	7.73E-20	8.62E-11	4.48E-09	4.59E-09	7.94E-08	2.26E-08
1.06E+05	1.05E-11	1.66E-20	4.00E-11	2.08E-09	2.13E-09	3.68E-08	1.05E-08

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 2

AIR CONCENTRATION GROUND CONTAMINATION
INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)

3.60E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7.70E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.18E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.61E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.87E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

6.33E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 1.08E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 1.73E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 2.40E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 4.37E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 5.53E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 1.15E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 1.37E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 2.11E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 3.92E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 6.56E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 8.12E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
 1.06E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00

PASQUILL CATEGORY D
 VEHICLE NACSTC
 MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
 FROM EXPOSURE DURING EVACUATION
 SEVERITY= 2

INHALED SHINE BACKYARD FARMER
 CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
 ALL VALUES WERE 0.0

CALCULATIONAL INFORMATION FOR PASQUILL CATEGORY E

IN CALCULATING THE DEPLETION FOR THE FOLLOWING GROUPS,
 THE CONCENTRATIONS IN THE LISTED AREA HAVE BECOME NEGATIVE.
 THE CONTAMINATION AND CONCENTRATIONS IN THE LISTED AREA AND
 LARGER HAVE BEEN SET TO ZERO.

GROUP CRUD AREA 11

FOR NACSTC AREAS WITH TOTAL CONTAMINATION RATIO GREATER THAN 40.0000
 (THE AREAS MARKED WITH AN 'X' ARE INTERDICTED)

AREA/SEVERITY 1 2

1 X -
 2 X -
 3 X -
 4 --
 5 --
 6 --
 7 --
 8 --
 9 --
 10 --
 11 --
 12 --
 13 --
 14 --
 15 --
 16 --
 17 --
 18 --

DILUTION FACTORS FOR PASQUILL CATEGORY E
 CHI VALUES AFTER DEPLETION (CI-SEC/M**3/CI-RELEASED)

DISTANCE CRUD
 4.20E+01 9.60E-03

8.40E+01 3.20E-03
 1.30E+02 1.30E-03
 3.12E+02 2.62E-04
 4.68E+02 1.02E-04
 6.05E+02 5.52E-05
 1.26E+03 1.32E-05
 2.00E+03 4.27E-06
 2.85E+03 1.66E-06
 5.09E+03 4.93E-07
 6.10E+03 1.88E-07
 1.19E+04 0.00E+00
 1.35E+04 0.00E+00
 2.37E+04 0.00E+00
 4.39E+04 0.00E+00
 7.70E+04 0.00E+00
 1.01E+05 0.00E+00
 1.38E+05 0.00E+00

DEPOSITION FACTORS
 CHI DEPOSITED (CI/M**2/CI-RELEASED)

DISTANCE CRUD
 4.20E+01 3.10E-04
 8.40E+01 1.03E-04
 1.30E+02 4.20E-05
 3.12E+02 8.47E-06
 4.68E+02 3.28E-06
 6.05E+02 1.78E-06
 1.26E+03 4.26E-07
 2.00E+03 1.38E-07
 2.85E+03 5.35E-08
 5.09E+03 1.59E-08
 6.10E+03 6.06E-09
 1.19E+04 0.00E+00
 1.35E+04 0.00E+00
 2.37E+04 0.00E+00
 4.39E+04 0.00E+00
 7.70E+04 0.00E+00
 1.01E+05 0.00E+00
 1.38E+05 0.00E+00

PASQUILL CATEGORY E
 VEHICLE NACSTC

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
 FROM EXPOSURE DURING EVACUATION
 SEVERITY= 1

AIR CONCENTRATION GROUND CONTAMINATION
 INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
 CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)
 4.20E+01 1.27E-03 5.35E-02 2.64E-04 2.16E-03 6.99E+01
 8.40E+01 4.23E-04 1.78E-02 8.79E-05 7.20E-04 2.33E+01
 1.30E+02 1.72E-04 7.25E-03 3.58E-05 2.93E-04 9.47E+00
 3.12E+02 3.47E-05 1.46E-03 7.21E-06 5.91E-05 1.91E+00
 4.68E+02 1.35E-05 5.66E-04 2.80E-06 2.29E-05 7.40E-01
 6.05E+02 7.31E-06 3.08E-04 1.52E-06 1.24E-05 4.02E-01
 1.26E+03 1.75E-06 7.36E-05 3.63E-07 2.97E-06 9.61E-02
 2.00E+03 5.65E-07 2.38E-05 1.18E-07 9.62E-07 3.11E-02
 2.85E+03 2.19E-07 9.23E-06 4.56E-08 3.73E-07 1.21E-02
 5.09E+03 6.53E-08 2.75E-06 1.36E-08 1.11E-07 3.59E-03
 6.10E+03 2.48E-08 1.05E-06 5.16E-09 4.23E-08 1.37E-03
 1.19E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00

1.35E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.37E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
4.39E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
7.70E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.01E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.38E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00

PASQUILL CATEGORY E
VEHICLE NACSTC
MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 1

INHALED SHINE BACKYARD FARMER
CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
4.20E+01 2.64E-04 4.71E-06 1.01E-03 5.24E-02 5.37E-02 9.29E-01 2.64E-01
8.40E+01 8.79E-05 5.22E-07 3.36E-04 1.75E-02 1.79E-02 3.09E-01 8.79E-02
1.30E+02 3.58E-05 8.64E-08 1.37E-04 7.10E-03 7.28E-03 1.26E-01 3.58E-02
3.12E+02 7.21E-06 3.51E-09 2.75E-05 1.43E-03 1.47E-03 2.54E-02 7.21E-03
4.68E+02 2.80E-06 5.27E-10 1.07E-05 5.55E-04 5.68E-04 9.83E-03 2.80E-03
6.05E+02 1.52E-06 1.56E-10 5.80E-06 3.01E-04 3.09E-04 5.34E-03 1.52E-03
1.26E+03 3.63E-07 8.90E-12 1.39E-06 7.21E-05 7.38E-05 1.28E-03 3.63E-04
2.00E+03 1.18E-07 9.31E-13 4.48E-07 2.33E-05 2.39E-05 4.13E-04 1.17E-04
2.85E+03 4.56E-08 1.40E-13 1.74E-07 9.04E-06 9.26E-06 1.60E-04 4.55E-05
5.09E+03 1.36E-08 1.24E-14 5.18E-08 2.69E-06 2.76E-06 4.77E-05 1.36E-05
6.10E+03 5.16E-09 1.80E-15 1.97E-08 1.02E-06 1.05E-06 1.81E-05 5.16E-06
1.19E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.35E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.37E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
4.39E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
7.70E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.01E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.38E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 2

AIR CONCENTRATION GROUND CONTAMINATION
INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)
4.20E+01 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
8.40E+01 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.30E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
3.12E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
4.68E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
6.05E+02 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.26E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.00E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.85E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
5.09E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
6.10E+03 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.19E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.35E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
2.37E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
4.39E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
7.70E+04 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.01E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00
1.38E+05 0.00E+00 0.00E+00 0.00E+00 0.00E+00 0.00E+00

PASQUILL CATEGORY E
VEHICLE NACSTC
MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)

FROM EXPOSURE DURING EVACUATION
SEVERITY= 2

INHALED SHINE BACKYARD FARMER
CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
ALL VALUES WERE 0.0

MAXIMUM RISK FOR INDIVIDUAL IN NEAREST ISOPLETH (DOSE IN REM)
FROM INHALATION, CLOUDSHINE, AND GROUNDSHINE EXPOSURE DURING EVACUATION

LINK SEVER: 1 SEVER: 2
LINK_R 2.45E-11 0.00E+00
LINK_S 2.45E-11 0.00E+00
LINK_U 2.45E-11 0.00E+00

EXPECTED VALUES OF POPULATION RISK IN PERSON-REM

LINK INHALED RESUSPD CLOUDSH GROUND SH TOTAL
LINK_R 1.03E-14 2.79E-16 3.95E-14 1.41E-12 1.46E-12
LINK_S 1.83E-13 4.92E-15 6.97E-13 2.49E-11 2.58E-11
LINK_U 4.24E-12 1.14E-13 1.62E-11 5.78E-10 5.99E-10

ZONE

RURAL 1.03E-14 2.79E-16 3.95E-14 1.41E-12 1.46E-12
SUBURB 1.83E-13 4.92E-15 6.97E-13 2.49E-11 2.58E-11
URBAN 4.24E-12 1.14E-13 1.62E-11 5.78E-10 5.99E-10

TOTALS: 4.44E-12 1.20E-13 1.69E-11 6.04E-10 6.26E-10

SOCIETAL INGESTION RISK - PERSON-REM

LINK GONADS EFFECTIVE
LINK_R 5.17E-11 4.49E-11

TOTAL 5.17E-11 4.49E-11

SOCIETAL INGESTION RISK BY ORGAN - PERSON-REM

LINK BREAST LUNGS RED MARR BONE SUR THYROID REMAINDER
LINK_R 1.78E-11 1.42E-11 2.14E-11 1.52E-11 1.28E-11 8.06E-11

TOTAL 1.78E-11 1.42E-11 2.14E-11 1.52E-11 1.28E-11 8.06E-11

EXPECTED RISK VALUES - OTHER

LINK EARLY EARLY
FATALITY MORBIDITY
LINK_R 0.00E+00 0.00E+00
LINK_S 0.00E+00 0.00E+00
LINK_U 0.00E+00 0.00E+00

TOTAL 0.00E+00 0.00E+00

LINK: LINK_R EXPECTED VALUES OF POPULATION RISK IN PERSON-REM
MATERIAL ISOTOPE INHALATN RESUSP CLOUDSH GROUND TOTAL
NACSTC CO60 1.15E-14 3.11E-16 4.40E-14 1.55E-12 1.61E-12
TOTAL: 1.61E-12

LINK: LINK_S EXPECTED VALUES OF POPULATION RISK IN PERSON-REM
MATERIAL ISOTOPE INHALATN RESUSP CLOUDSH GROUND TOTAL

NACSTC CO60 2.03E-13 5.49E-15 7.77E-13 2.74E-11 2.83E-11
TOTAL: 2.83E-11

LINK: LINK_U EXPECTED VALUES OF POPULATION RISK IN PERSON-REM
MATERIAL ISOTOPE INHALATN RESUSP CLOUDSH GROUND TOTAL
NACSTC CO60 4.73E-12 1.28E-13 1.81E-11 6.36E-10 6.59E-10
TOTAL: 6.59E-10

EOI
END OF RUN
SUCCESSFUL COMPLETION

ACCIDENT RESULTS USING THE USER-DEFINED OPTION
Only results different from Average Weather are reported

DISPERSAL MODEL RELATED INPUT DATA

CENTER LINE DISTANCES FROM FRACTION OF PEAK:

0.9, 0.7, 0.5, 0.3, 0.2, 0.1,
0.05, 0.02, 0.01, 0.005, 0.002, 0.001,
5.0e-4, 2.0e-4, 1.0e-4, 5.0e-5, 2.0e-5, 1.0e-5,
5.0e-6, 2.0e-6, 1.0e-6, 5.0e-7, 2.0e-7, 1.0e-7

RELEASE HEIGHT (M) 0.00000E+00
HEAT FLUX (CAL/S) 0.00000E+00
SOURCE WIDTH (M) 1.25000E+00
SOURCE HEIGHT(M) 1.90000E+00
WIND SPEED (M/S) 4.00000E+00
ANEMOMETER HEIGHT (M) 1.00000E+01
AMBIENT TEMPERATURE (K) 2.93000E+02
ATMOSPHERIC MIXING HEIGHT (M) 1.00000E+03
RAINFALL RATE (MM/HR) 0.00000E+00

BRIGGS DISPERSION COEFFICIENTS USED
STABILITY CATEGORY D
RURAL POPULATION ZONE

OOO U U TTTTT PPPP U U TTTTT
OOU U TP PU UT
OOU U TP PU UT
OOU U T PPPP U UT
OOU U TP U UT
OOU U TP U UT
OOO UUUUU TP UUUUU T

AREA/SEVERITY 1 2

1 X-
2 X-
3 X-
4 X-
5 X-
6 X-
7 --
8 --
9 --
10 --
11 --
12 --
13 --
14 --
15 --
16 --

17 --
 18 --
 19 --
 20 --
 21 --
 22 --
 23 --
 24 --
 25 --

DEPOSITION VELOCITY = 0.32E-01 (M/SEC)

DILUTION FACTORS

AT DOWNWIND LOCATION = 2.0382E+01 (M)

MAXIMUM AIR CONCENTRATION = 1.1284E-02 (CI-SEC/M^3/CI-released)

AT DOWNWIND LOCATION = 2.0382E+01 (M)

MAXIMUM GROUND DEPOSITION = 3.6447E-04 (CI/M^2/CI-released)

DOWNWIND AREA DILUTION DILUTION DEPOSITED
 (M) (M^2) (CI-S/M^3/CI-rise) FRACTION (CI/M^2/CI-rise)

2.23E+01	3.41E+00	1.02E-02	9.00E-01	3.28E-04
2.74E+01	1.99E+01	7.90E-03	7.00E-01	2.55E-04
3.54E+01	6.14E+01	5.64E-03	5.00E-01	1.82E-04
5.04E+01	1.82E+02	3.39E-03	3.00E-01	1.09E-04
6.54E+01	3.51E+02	2.26E-03	2.00E-01	7.29E-05
9.93E+01	9.06E+02	1.13E-03	1.00E-01	3.64E-05
1.47E+02	2.09E+03	5.64E-04	5.00E-02	1.82E-05
2.44E+02	5.85E+03	2.26E-04	2.00E-02	7.29E-06
3.56E+02	1.24E+04	1.13E-04	1.00E-02	3.64E-06
5.20E+02	2.62E+04	5.64E-05	5.00E-03	1.82E-06
8.60E+02	7.02E+04	2.26E-05	2.00E-03	7.29E-07
1.27E+03	1.49E+05	1.13E-05	1.00E-03	3.64E-07
1.88E+03	3.20E+05	5.64E-06	5.00E-04	1.82E-07
3.20E+03	8.82E+05	2.26E-06	2.00E-04	7.29E-08
4.79E+03	1.91E+06	1.13E-06	1.00E-04	3.64E-08
7.21E+03	4.08E+06	5.64E-07	5.00E-05	1.82E-08
1.23E+04	1.10E+07	2.26E-07	2.00E-05	7.29E-09
1.83E+04	2.24E+07	1.13E-07	1.00E-05	3.64E-09
2.69E+04	4.47E+07	5.64E-08	5.00E-06	1.82E-09
4.29E+04	1.03E+08	2.26E-08	2.00E-06	7.29E-10
6.10E+04	1.87E+08	1.13E-08	1.00E-06	3.64E-10
8.31E+04	3.22E+08	5.64E-09	5.00E-07	1.82E-10
1.20E+05	6.09E+08	2.28E-09	2.02E-07	7.36E-11

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)

FROM EXPOSURE DURING EVACUATION

SEVERITY= 1

AIR CONCENTRATION GROUND CONTAMINATION

INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP

CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)

2.23E+01	1.34E-03	5.66E-02	2.80E-04	2.29E-03	7.39E+01
2.74E+01	1.05E-03	4.40E-02	2.17E-04	1.78E-03	5.75E+01
3.54E+01	7.47E-04	3.15E-02	1.55E-04	1.27E-03	4.11E+01
5.04E+01	4.48E-04	1.89E-02	9.32E-05	7.63E-04	2.46E+01
6.54E+01	2.99E-04	1.26E-02	6.21E-05	5.09E-04	1.64E+01
9.93E+01	1.49E-04	6.29E-03	3.11E-05	2.54E-04	8.22E+00
1.47E+02	7.47E-05	3.15E-03	1.55E-05	1.27E-04	4.11E+00
2.44E+02	2.99E-05	1.26E-03	6.21E-06	5.09E-05	1.64E+00
3.56E+02	1.49E-05	6.29E-04	3.11E-06	2.54E-05	8.22E-01
5.20E+02	7.47E-06	3.15E-04	1.55E-06	1.27E-05	4.11E-01
8.60E+02	2.99E-06	1.26E-04	6.21E-07	5.09E-06	1.64E-01
1.27E+03	1.49E-06	6.29E-05	3.11E-07	2.54E-06	8.22E-02

1.88E+03 7.47E-07 3.15E-05 1.55E-07 1.27E-06 4.11E-02
 3.20E+03 2.99E-07 1.26E-05 6.21E-08 5.09E-07 1.64E-02
 4.79E+03 1.49E-07 6.29E-06 3.11E-08 2.54E-07 8.22E-03
 7.21E+03 7.47E-08 3.15E-06 1.55E-08 1.27E-07 4.11E-03
 1.23E+04 2.99E-08 1.26E-06 6.21E-09 5.09E-08 1.64E-03
 1.83E+04 1.49E-08 6.29E-07 3.11E-09 2.54E-08 8.22E-04
 2.69E+04 7.47E-09 3.15E-07 1.55E-09 1.27E-08 4.11E-04
 4.29E+04 2.99E-09 1.26E-07 6.21E-10 5.09E-09 1.64E-04
 6.10E+04 1.49E-09 6.29E-08 3.11E-10 2.54E-09 8.22E-05
 8.31E+04 7.47E-10 3.15E-08 1.55E-10 1.27E-09 4.11E-05
 1.20E+05 3.02E-10 1.27E-08 6.27E-11 5.13E-10 1.66E-05

PASQUILL CATEGORY D
 VEHICLE NACSTC
 MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
 FROM EXPOSURE DURING EVACUATION
 SEVERITY= 1

INHALED SHINE BACKYARD FARMER
 CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
 2.23E+01 2.80E-04 2.43E-06 1.07E-03 5.55E-02 5.68E-02 9.82E-01 2.79E-01
 2.74E+01 2.17E-04 1.47E-06 8.30E-04 4.31E-02 4.42E-02 7.64E-01 2.17E-01
 3.54E+01 1.55E-04 7.51E-07 5.93E-04 3.08E-02 3.16E-02 5.46E-01 1.55E-01
 5.04E+01 9.32E-05 2.70E-07 3.56E-04 1.85E-02 1.89E-02 3.27E-01 9.31E-02
 6.54E+01 6.21E-05 1.20E-07 2.37E-04 1.23E-02 1.26E-02 2.18E-01 6.21E-02
 9.93E+01 3.11E-05 3.00E-08 1.19E-04 6.16E-03 6.31E-03 1.09E-01 3.10E-02
 1.47E+02 1.55E-05 7.51E-09 5.93E-05 3.08E-03 3.16E-03 5.46E-02 1.55E-02
 2.44E+02 6.21E-06 1.20E-09 2.37E-05 1.23E-03 1.26E-03 2.18E-02 6.21E-03
 3.56E+02 3.11E-06 3.00E-10 1.19E-05 6.16E-04 6.31E-04 1.09E-02 3.10E-03
 5.20E+02 1.55E-06 7.51E-11 5.93E-06 3.08E-04 3.16E-04 5.46E-03 1.55E-03
 8.60E+02 6.21E-07 1.20E-11 2.37E-06 1.23E-04 1.26E-04 2.18E-03 6.21E-04
 1.27E+03 3.11E-07 3.00E-12 1.19E-06 6.16E-05 6.31E-05 1.09E-03 3.10E-04
 1.88E+03 1.55E-07 7.51E-13 5.93E-07 3.08E-05 3.16E-05 5.46E-04 1.55E-04
 3.20E+03 6.21E-08 1.20E-13 2.37E-07 1.23E-05 1.26E-05 2.18E-04 6.21E-05
 4.79E+03 3.11E-08 3.00E-14 1.19E-07 6.16E-06 6.31E-06 1.09E-04 3.10E-05
 7.21E+03 1.55E-08 7.51E-15 5.93E-08 3.08E-06 3.16E-06 5.46E-05 1.55E-05
 1.23E+04 6.21E-09 1.20E-15 2.37E-08 1.23E-06 1.26E-06 2.18E-05 6.21E-06
 1.83E+04 3.11E-09 3.00E-16 1.19E-08 6.16E-07 6.31E-07 1.09E-05 3.10E-06
 2.69E+04 1.55E-09 7.51E-17 5.93E-09 3.08E-07 3.16E-07 5.46E-06 1.55E-06
 4.29E+04 6.21E-10 1.20E-17 2.37E-09 1.23E-07 1.26E-07 2.18E-06 6.21E-07
 6.10E+04 3.11E-10 3.00E-18 1.19E-09 6.16E-08 6.31E-08 1.09E-06 3.10E-07
 8.31E+04 1.55E-10 7.51E-19 5.93E-10 3.08E-08 3.16E-08 5.46E-07 1.55E-07
 1.20E+05 6.27E-11 1.22E-19 2.39E-10 1.24E-08 1.27E-08 2.20E-07 6.27E-08

NACSTD_SAMPLEREPEAT_01_03_14

MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 2

AIR CONCENTRATION GROUND CONTAMINATION
INHALATION PATHWAY ORGAN DOSE AFTER DEPOSITION BEFORE CLEANUP
CNTR LINE LUNG BONE MARROW THYROID (CI-S/M**3) (MICRO CI/M**2)

2.23E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.74E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.54E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5.04E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.54E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9.93E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.47E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.44E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.56E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5.20E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8.60E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.27E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.88E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.20E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.79E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7.21E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.23E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.83E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.69E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.29E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.10E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8.31E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.20E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

PASQUILL CATEGORY D
VEHICLE NACSTC
MAXIMUM INDIVIDUAL CONSEQUENCE (DOSE IN REM)
FROM EXPOSURE DURING EVACUATION
SEVERITY= 2

INHALED SHINE BACKYARD FARMER
CNTR LINE EFFECTIVE RESUSPEND CLOUD GROUND TOTAL EFFECTIVE THYROID
ALL VALUES WERE 0.

MAXIMUM RISK FOR INDIVIDUAL IN NEAREST ISOPLETH (DOSE IN REM)
FROM INHALATION, CLOUDSHINE, AND GROUNDSHINE EXPOSURE DURING EVACUATION

LINK SEVER: 1 SEVER: 2
LINK_R 4.72E-11 0.00E+00
LINK_S 4.72E-11 0.00E+00
LINK_U 4.72E-11 0.00E+00

EXPECTED VALUES OF POPULATION RISK IN PERSON-REM

LINK INHALED RESUSPD CLOUDSH GROUND SH TOTAL
LINK_R 1.08E-14 2.91E-16 4.12E-14 1.47E-12 1.52E-12
LINK_S 1.90E-13 5.14E-15 7.27E-13 2.59E-11 2.69E-11
LINK_U 4.43E-12 1.19E-13 1.69E-11 6.03E-10 6.24E-10

ZONE
RURAL 1.08E-14 2.91E-16 4.12E-14 1.47E-12 1.52E-12

SUBURB 1.90E-13 5.14E-15 7.27E-13 2.59E-11 2.69E-11
URBAN 4.43E-12 1.19E-13 1.69E-11 6.03E-10 6.24E-10

TOTALS: 4.63E-12 1.25E-13 1.77E-11 6.30E-10 6.53E-10

LINK GONADS EFFECTIVE
LINK_R 7.45E-11 6.46E-11

TOTAL 7.45E-11 6.46E-11

SOCIETAL INGESTION RISK BY ORGAN - PERSON-REM

LINK BREAST LUNGS RED MARR BONE SUR THYROID REMAINDER
LINK_R 2.57E-11 2.05E-11 3.08E-11 2.19E-11 1.84E-11 1.16E-10

TOTAL 2.57E-11 2.05E-11 3.08E-11 2.19E-11 1.84E-11 1.16E-10

EXPECTED RISK VALUES - OTHER

LINK EARLY EARLY
FATALITY MORBIDITY
LINK_R 0.00E+00 0.00E+00
LINK_S 0.00E+00 0.00E+00
LINK_U 0.00E+00 0.00E+00

TOTAL 0.00E+00 0.00E+00

LINK GONADS EFFECTIVE
LINK_R 7.45E-11 6.46E-11

TOTAL 7.45E-11 6.46E-11

SOCIETAL INGESTION RISK BY ORGAN - PERSON-REM

LINK BREAST LUNGS RED MARR BONE SUR THYROID REMAINDER
LINK_R 2.57E-11 2.05E-11 3.08E-11 2.19E-11 1.84E-11 1.16E-10

TOTAL 2.57E-11 2.05E-11 3.08E-11 2.19E-11 1.84E-11 1.16E-10

EXPECTED RISK VALUES - OTHER

LINK EARLY EARLY
FATALITY MORBIDITY
LINK_R 0.00E+00 0.00E+00
LINK_S 0.00E+00 0.00E+00
LINK_U 0.00E+00 0.00E+00

TOTAL 0.00E+00 0.00E+00

PASQUILL CATEGORY D
TOTAL EXPOSED POPULATION: ACCIDENT
(PERSONS UNDER PLUME FOOTPRINT FOR A SINGLE ACCIDENT)

LINK_R 1.59E+04 PERSONS
LINK_S 2.81E+05 PERSONS
LINK_U 2.25E+06 PERSONS

LINK: LINK_R EXPECTED VALUES OF POPULATION RISK IN PERSON-REM
MATERIAL ISOTOPE INHALATN RESUSP CLOUDSH GROUND TOTAL
NACSTC CO60 1.08E-14 2.91E-16 4.12E-14 1.47E-12 1.52E-12
TOTAL: 1.52E-12

LINK: LINK_S EXPECTED VALUES OF POPULATION RISK IN PERSON-REM
MATERIAL ISOTOPE INHALATN RESUSP CLOUDSH GROUND TOTAL
NACSTC CO60 1.90E-13 5.14E-15 7.27E-13 2.59E-11 2.69E-11
TOTAL: 2.69E-11

LINK: LINK_U EXPECTED VALUES OF POPULATION RISK IN PERSON-REM
MATERIAL ISOTOPE INHALATN RESUSP CLOUDSH GROUND TOTAL
NACSTC CO60 4.43E-12 1.19E-13 1.69E-11 6.03E-10 6.24E-10
TOTAL: 6.24E-10

EOI
END OF RUN
SUCCESSFUL COMPLETION

END OF OUTPUT

DISTRIBUTION

Sandia Internal:

6230, MS 0736	S. Pickering
6231, MS 0718	S. Burns
6231, MS 0718	M. Dennis
6231, MS 0718	R. Weiner
9536, MS 0899	Technical Library

External

Matthew Feldman, ORNL
John Wagner, ORNL

