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RadCat 2.0 User Guide

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ABSTRACT

This document provides a detailed discussion and a guide for the use of the RadCat 2.0 Graphical User Interface input file generator for the RADTRAN 5.5 code. The differences between RadCat 2.0 and RadCat 1.0 can be attributed to the differences between RADTRAN 5 and RADTRAN 5.5 as well as clarification for some of the input parameters.

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1. WELCOME TO RADTRAN / RADCAT

RADTRAN is the nationally accepted standard 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 (USNRC, 1977), the first environmental impact statement on transportation of radioactive materials. RADTRAN and its associated software have undergone a number of improvements and advances consistent with improvements in computer technology.

2. DOWNLOADING AND CHECKING FOR THE LATEST VERSION

The RADCAT/RADTRAN package may be downloaded from
http://www.evolutionnext.com/radcat.

- On the web page, click on click here and fill out the application.
- When you are approved, you will be notified by email.
- When you are approved, you can click on Download RadCat. You will be asked for your username. Your username 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 ; scroll to the green box at the upper right of the screen, and click on the yellow bar labeled "Get It Now."
- Download the Windows online installation. (You may want to download and read the instructions, but it isn't absolutely necessary.)
- Install the Java Runtime Environment (JRE) on your PC. 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 fire wall 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.
- Once JRE is installed, you can go back to Download RadCat on the Main Menu and download RADCAT. You will be asked to integrate it to the desktop environment, which is suggested. When you launch RADCAT (the application), you may get a notice that says there is no certificate of authenticity; launch the application anyway. The process for applying for the certificate may not be complete.
- Once you have installed JRE, you can launch RADCAT either from JRE or from the RADCAT icon. If you want to download the latest version, go back to http://www.evolutionnext.com/radcat , click on Download RadCat, click on Launch the Application, and the latest version will be downloaded. You may get a notice that says there is no certificate of authenticity; launch the application anyway. The process for applying for the certificate may not be complete.

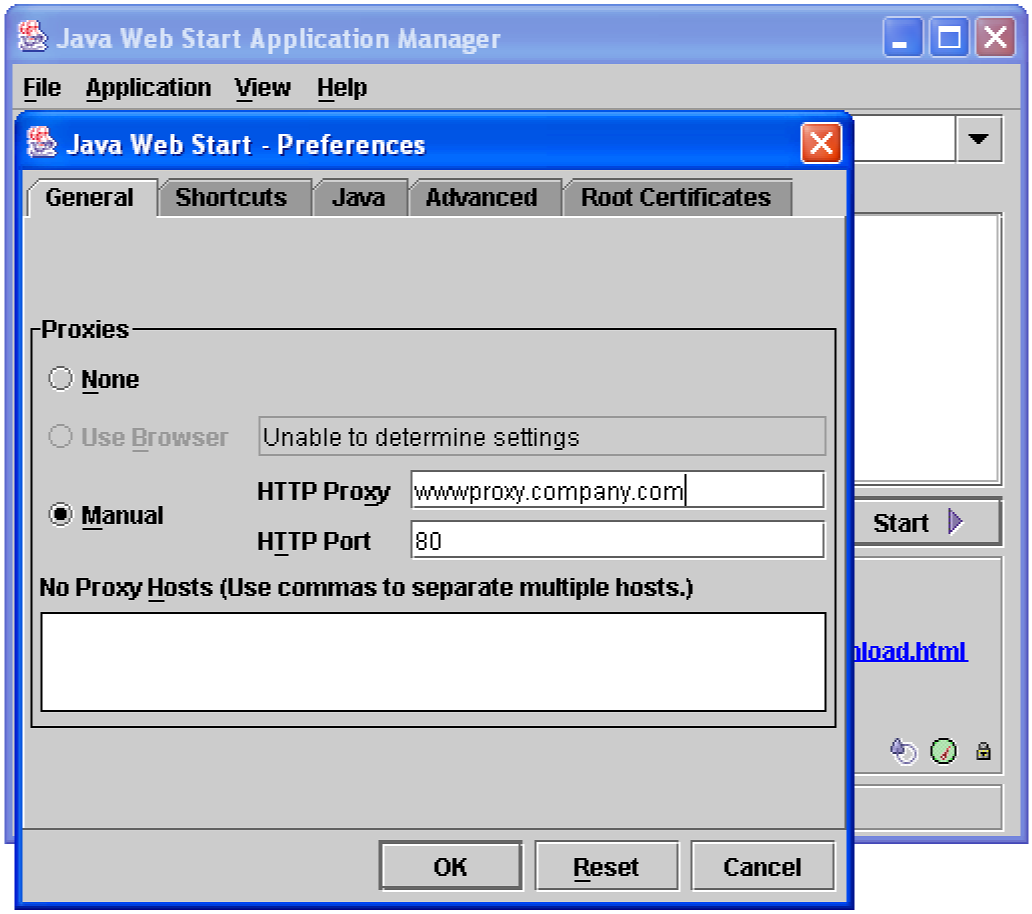


Figure 1: Proxy and Port Settings

When you download RADCAT, you will be prompted to save the icon on your desktop. A Java Web Start icon can also be placed on your desktop. RADCAT/RADTRAN can be opened at any time from the desktop icon.

IMPORTANT: Because of minor changes within the formatting and the addition of features it is suggested that RADCAT 2.0 be opened using Java Web Start and this will automatically update your version of RADCAT. Users will still be notified via email of any major changes or additions to RADCAT.

3. RUNNING RADTRAN WITH RADCAT

To run an existing input file with RADCAT, by following 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 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.

Please note that a file using more than one transportation mode (e.g., both truck and rail in a single file) will not run under RADCAT. RADCAT will only run one mode at a time.

3.1 IMPORTING OLD RADTRAN 5 FILES

RADCAT 2.0 has the ability to import old RADTRAN 5 input files and convert them to be ran as RADTRAN 5.5 files. This feature can be selected from the **File** pull-down menu by clicking on the **Import** icon. This can be seen in Figure 2. You must ensure that your input files are listed as a "**.in5**" file in order for RADCAT to properly convert it.

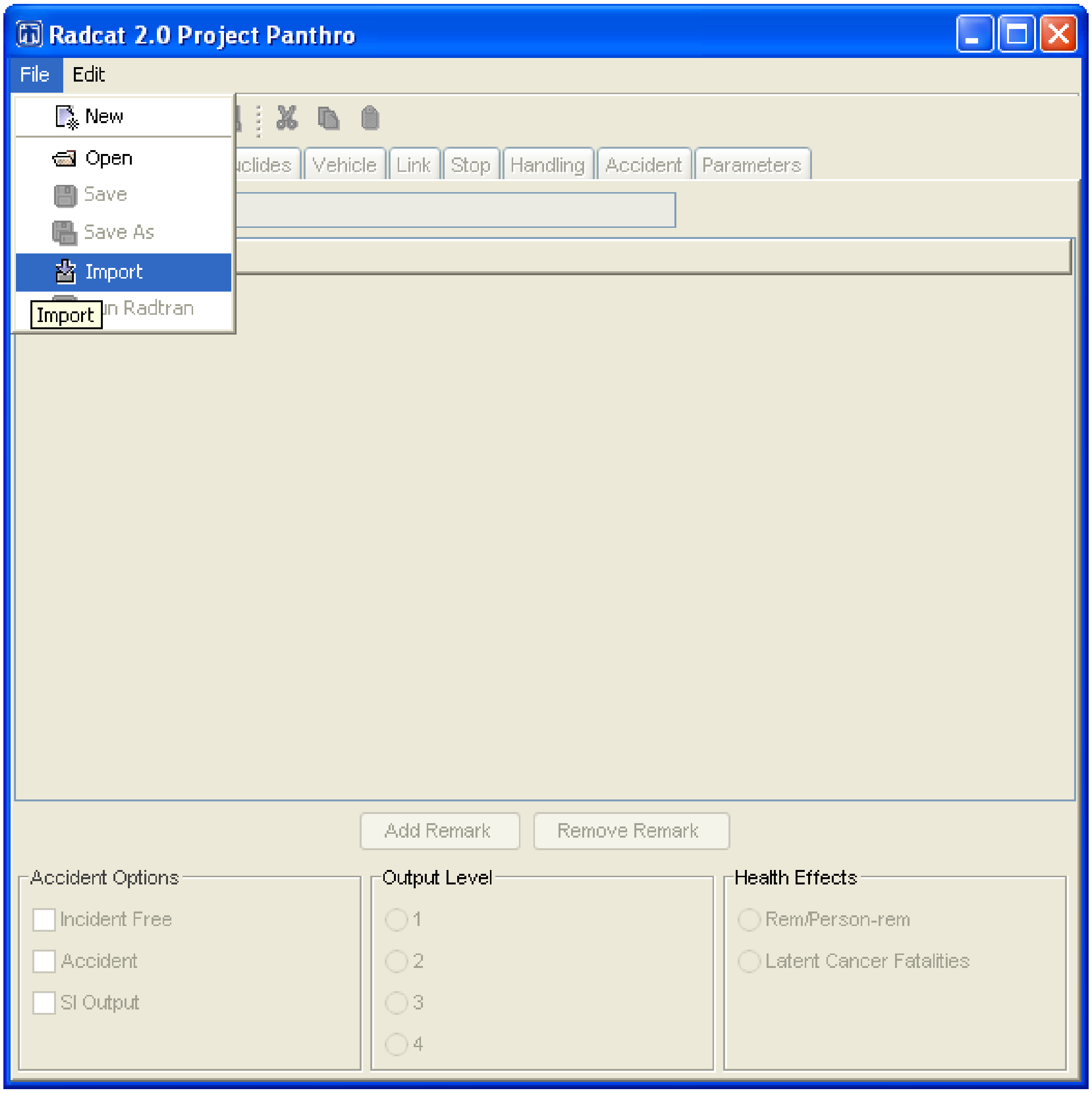


Figure 2: File Pull-down Menu

4. SAVING AN INPUT FILE

An input file may be saved at any time by clicking on the **Save** icon (the floppy disk). The **Save As** window will open and the user can save the file in the normal Windows manner. Your file will be saved as a **".rml"** file. You do not need to add this extension to your filename when saving it.

5. GENERATING AN INPUT FILE WITH RADCAT

If you do not wish to use RADCAT 2.0 to create a RADTRAN 5.5 file, you may use the reference sheet provided in Appendix A of this user guide to assist in creating a text input file. However, in order for RADTRAN 5.5 to properly execute your text input it must be saved as a "**.in5**" file and use the import feature in RADCAT 2.0 and use the **Run RADTRAN** icon.

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 3. A selection of a transportation mode (highway, rail, or barge) must be made before a new file can be created. A file cannot be created with more than one mode. The mode is selected from the pull-down menu.

If a current file is already open selecting the **New** icon will open another Java window from which you will be able to select another transportation mode from the **Mode Selection** dialog box. This will not reset any of prior files information to the default values.

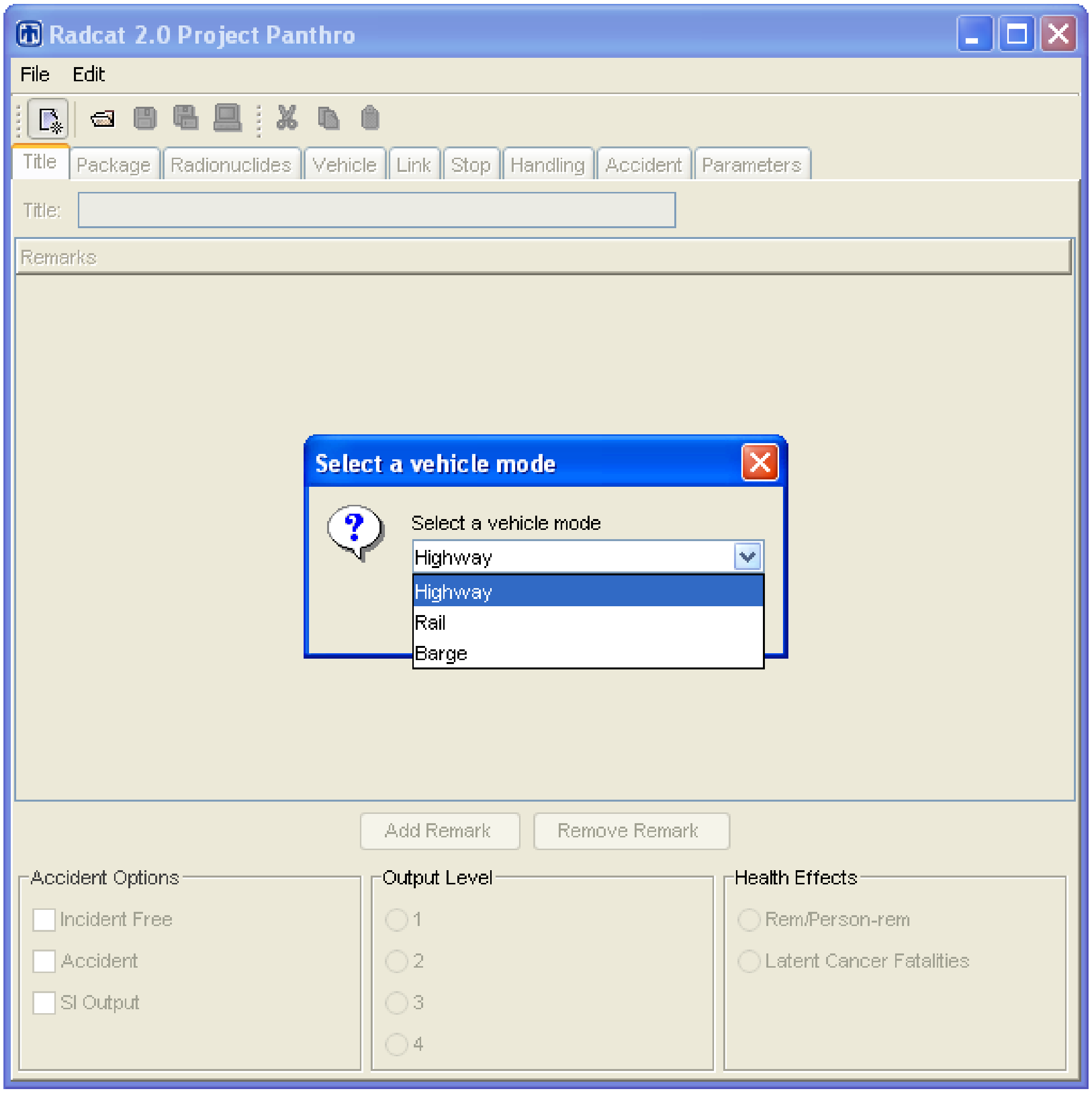


Figure 3: Mode Selection

Title

There is no default title in the **Title** box, and you may type any name for your file in the **Title** box. Your file <u>must</u> have a title. The **Title** box can be seen in Figure 4.

Remarks

The **Remarks** screen is for you to annotate your file; e.g., give a brief description of the problem, 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 added for each line. Click on **Add Remark** to append additional remarks. **Remarks** can be seen in Figure 4.

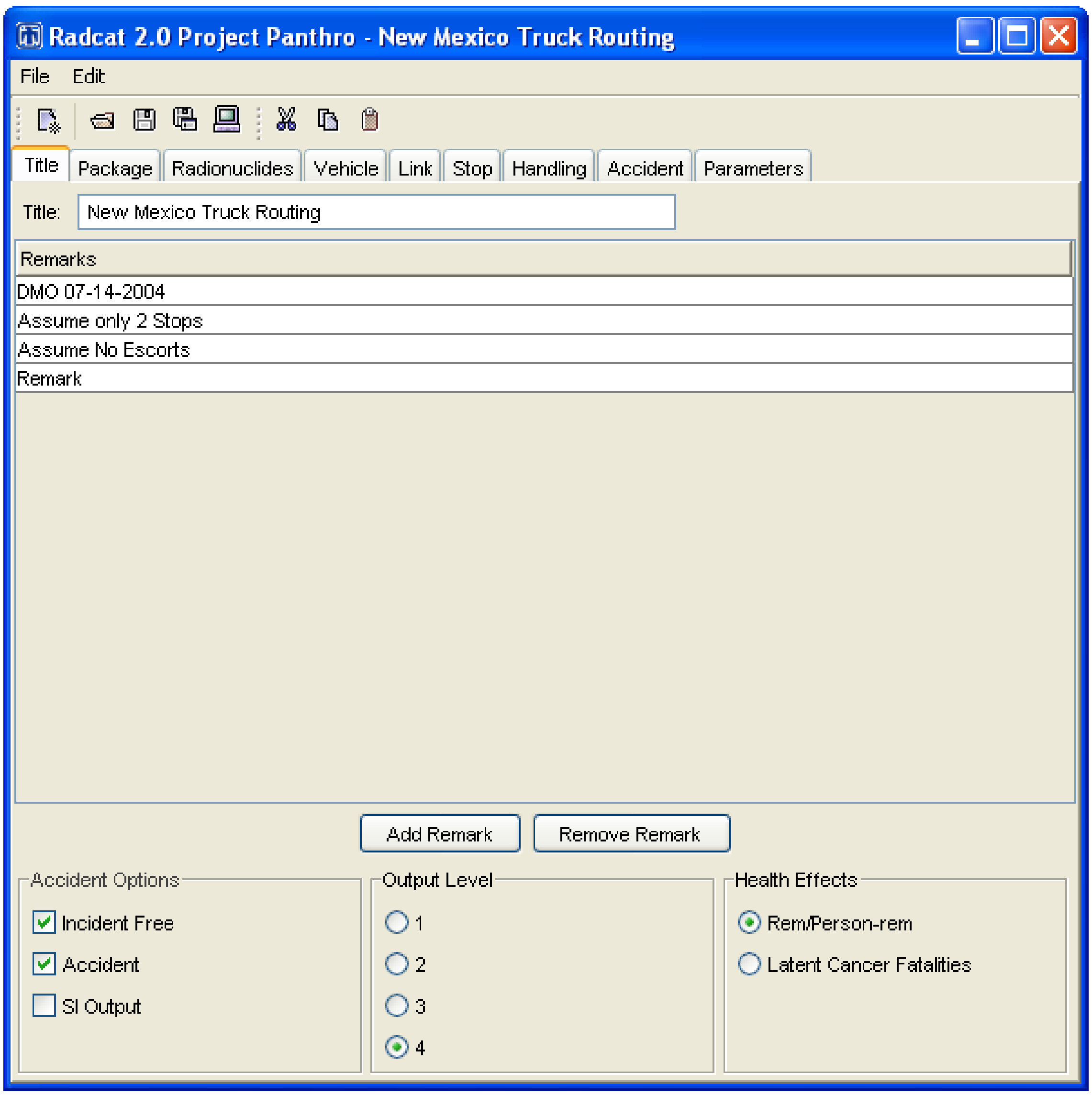


Figure 4: Title Tab

Accident Options

Checking the **Incident Free** box will result in analysis of routine, incident-free transportation only. Checking the **Accident** box will result in analysis of transportation accidents only. Checking both, the **Incident Free** and **Accident,** boxes results in a full analysis of the incident-free and accident routines. Checking the **SI Output** will cause the output results to be in Standard International (SI) units. These options can be seen in Figure 4.

Output Level

Four options are available for controlling output size:

1. Short output form. The input echo, incident-free, and accident and non-radiological risk tables printed. Size of output file is approximately 10 pages.
2. Output for #1 plus input tables, early effects values, ground contamination tables, intermediate tables, and total expected population dose tables. Size of output file is approximately 28 pages.
3. Output for #2 plus consequence tables. Size of output file is approximately 31 pages.
4. Full output. Output for #3 plus sensitivity analysis. Size of output file is approximately 33 pages.

This option can be seen in Figure 4.

Health Effects

The health effects may be either as individual and collective doses or as latent cancer fatalities. The individual dose and collective dose outputs may be in historical units – rem and person-rem, as appropriate – or Standard International (SI) units – sievert (Sv) and person-sievert (person-Sv).

Some useful conversion factors are:

1 Sv = 100 rem
1 millisievert (mSv) = 100 mrem
1 gray (Gy) = 100 rad
(rem)*(5×10^{-4}) = latent cancer fatality probability (LCF) for the public
(rem)*(4×10^{-4}) = occupational latent cancer fatality probability (LCF)
1 becquerel (Bq) = one disintegration per second, the units of Bq are sec^{-1}
1 curie (Ci) = 3.7×10^{10} Bq

5.1 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 order in which the tabs are opened will not make any difference. This can be seen in Figure 5.

Name

Give your package a name in the left-hand column. You can delete "PACKAGE_1" and substitute any name that you like. 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. This can be seen in Figure 5.

List all the packages that you will want for this run on this tab. You cannot add packages on other tabs, nor can you delete them from other tabs.

Long Dimension

Enter the largest dimension of the package in meters, e.g. length of a cylinder if larger than the diameter. (In the RADTRAN Technical Manual, for historical reasons, this dimension is called the "critical dimension", although it is not critical in the usual sense of the word.)

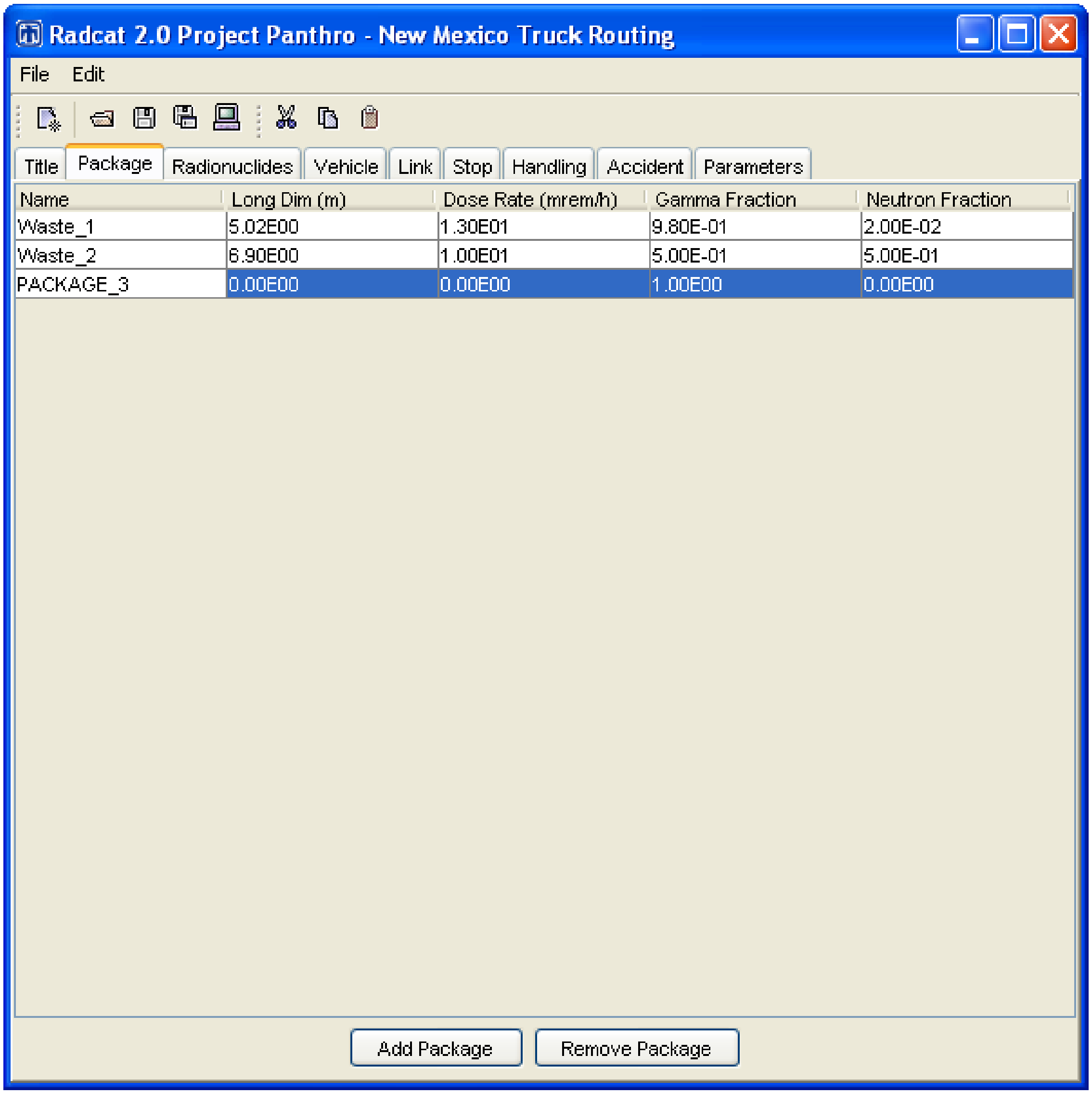


Figure 5: Package Tab

Dose Rate

Enter the external dose rate, at one meter from the package surface, in units of mrem/hr. Note that 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 13 mrem/hr at one meter from the package surface for a “critical dimension” of about 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, 13 mrem/hr, as the external dose rate, recognizing that this value is conservative. This can be seen in Figure 5.

RADTRAN has a flag on the **Parameter** tab, “Imposed regulatory limit on vehicle external dose,” that imposes a regulatory constraint on the shipment. Selecting **YES** will cause RADTRAN to internally adjust the dose rate 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 users prefer to lift this regulatory constraint (by selecting **NO)** so they always know exactly what they are modeling.

Remember that 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.

Gamma and Neutron Fractions

When you enter a value into either of these cells, RADCAT will automatically adjust the other cell so that the two add to one. This can be seen in Figure 5.

5.2 RADIONUCLIDES

When making a new input file, or adding or deleting a vehicle in an existing file, select the **Radionuclides** tab next after the **Package** tab. When editing an existing file without adding or deleting a package, the order in which the tabs are opened will not make any difference. This can be seen in Figure 6.

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

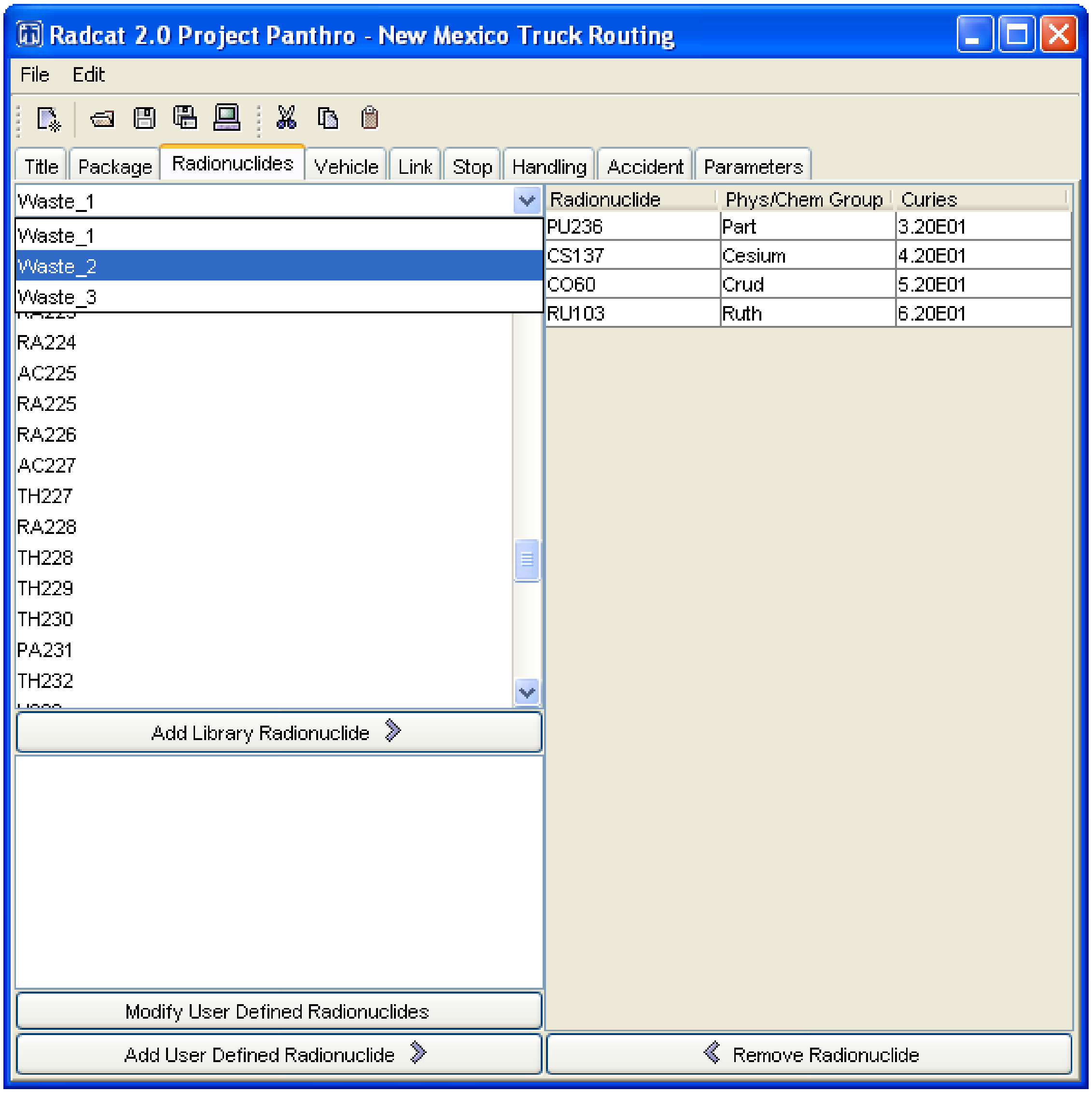


Figure 6: Radionuclides Tab with Package pull-down menu

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. 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. Physical/chemical groups must be entered at this screen; they cannot be entered on any other screen. This can be seen in Figure 7.

Enter the number of curies of the radionuclide in the **Curies** column.

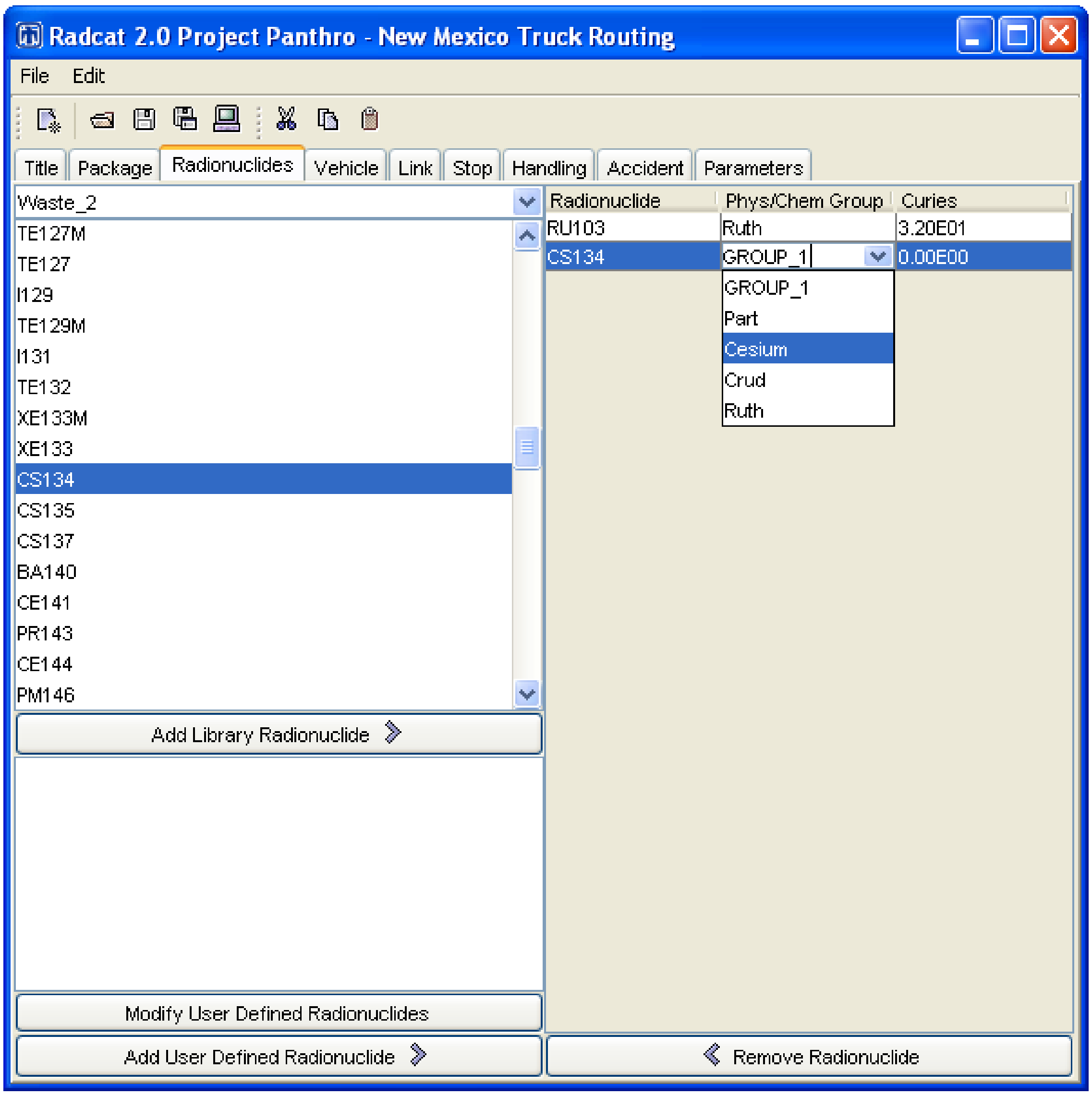


Figure 7: Radionuclides Tab with Physical / Chemical Group pull-down menu

Adding Radionuclides not in the Internal Library: 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 **Modify User Defined Radionuclides** bar. The **User Defined Radionuclides** screen will open. In this screen, 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), and it may be up to eight characters long. Ensure that there are no spaces in your radionuclide name. This can be seen in Figure 8.

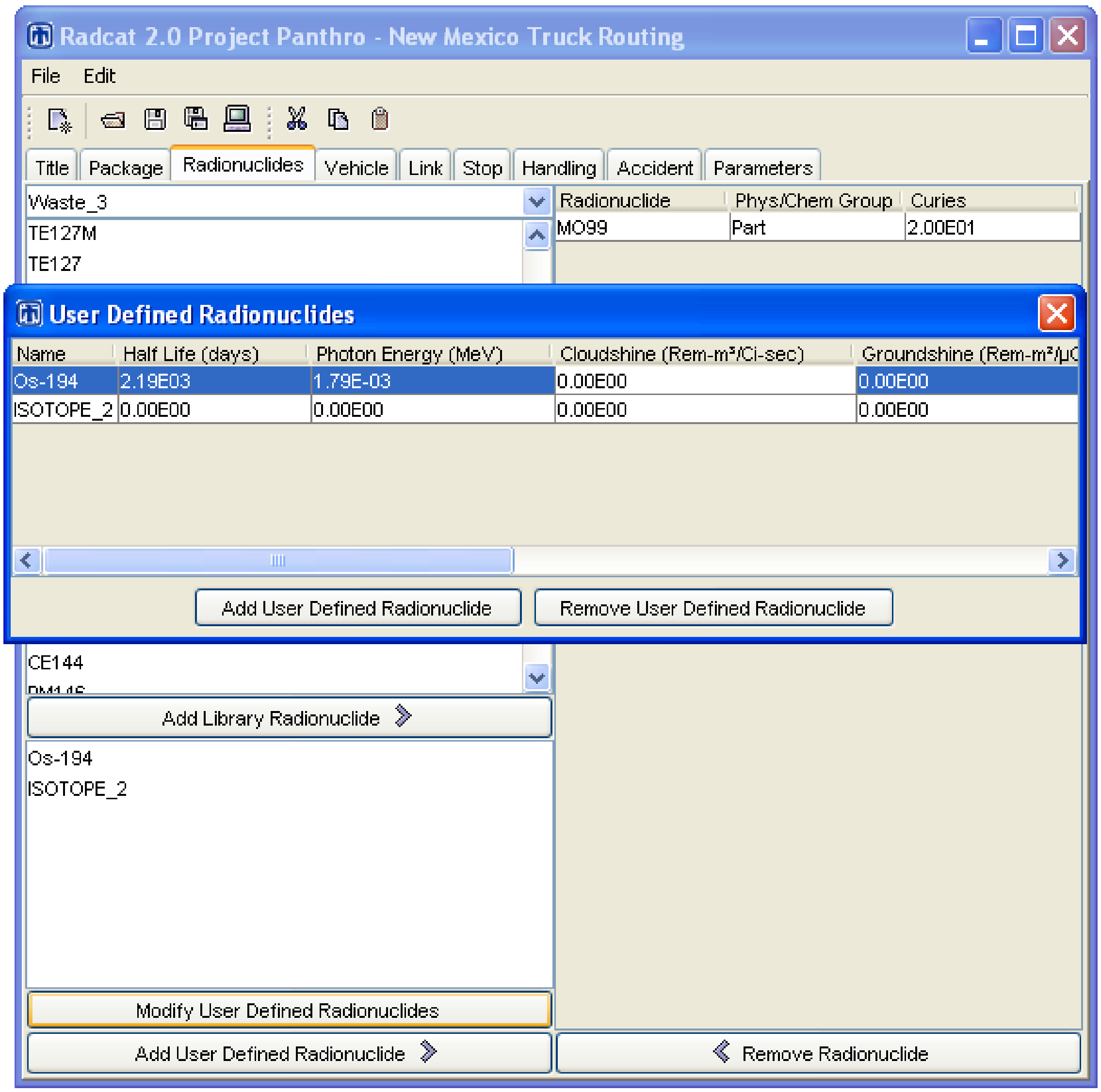


Figure 8: Radionuclides Tab with User Defined Radionuclides window

Half-lives may be found in the Chart of the Nuclides or the International Commission on Radiological Protection (ICRP) Publication 38, and dose conversion factors may be found in the Health Physics Handbook, Federal Guidance reports 12 and 13, ICRP Publication 72, and similar references. Enter values for **Half Life, Photon Energy,** and dose conversion factors for **Cloudshine, Groundshine, Inhalation Dose, Gonad Inhalation Dose, Lung Inhalation Dose, and Marrow Inhalation Dose.** 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. It is important to note that the **Inhalation** dose is entered as the **Effective Dose** in the **User Defined Isotope** window.

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., CO60 – CRUD, CO-60 – particulate) and include one or both as a **User Defined Isotope**.

Important Note: 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 5.5 only for radionuclides in the internal library and **NOT** for those radionuclides that are user-defined.

5.3 VEHICLE

Please note that the **vehicle** parameters (external dose rate, length, etc) determine the dose to residents along the route, to occupants of vehicles sharing the route, and to truck crew. The analogous **package** parameters determine doses to handlers. If there is only one package per vehicle, as for a spent fuel or UF_6 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 next after the **Radionuclides** tab. When 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 9.

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. To analyze more than one vehicle, click the **Add Vehicle** bar and add the desired number of vehicles. This can be seen in Figure 9. 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 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 9.

List all the desired vehicles on this tab. Vehicles cannot be added on other tabs, nor can they be deleted from other tabs.

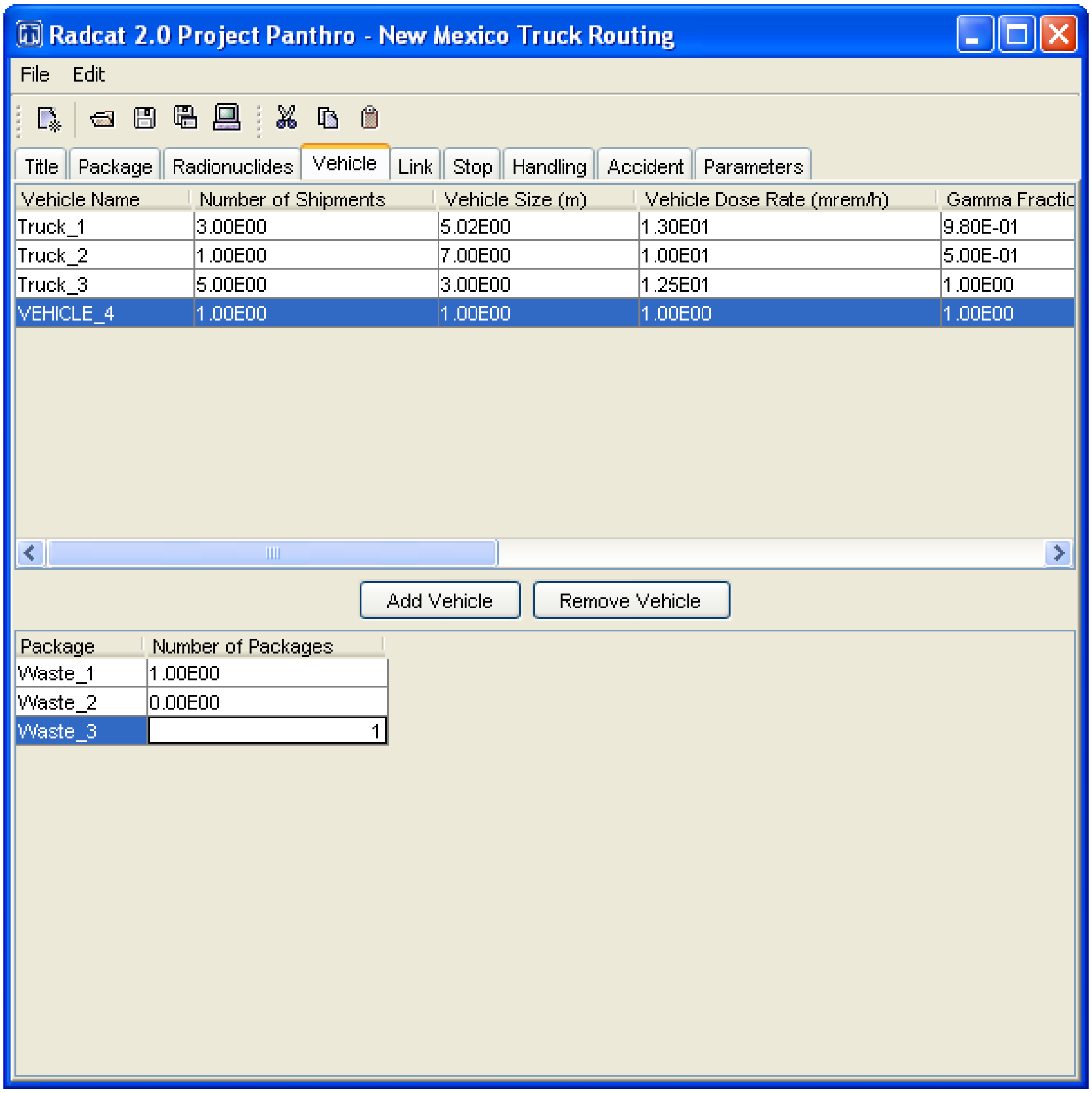


Figure 9: Vehicle Tab

Number of Shipments

Enter the number of shipments. This can be seen in Figure 9. Note that 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.

Vehicle Size

Enter the maximum 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 9.

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. Note that the regulations of 10 CFR Part 71 specify that the external dose rate *at two meters* from this edge should not exceed 10 mrem/hour. This is equivalent to 13 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, 13 mrem/hr, as the external dose rate, recognizing that this value is conservative. This can be seen in Figure 9.

RADTRAN has a flag on the **Parameter** tab, Section 5.8, "Imposed regulatory limit on vehicle external dose," that imposes a regulatory constraint on the shipment. Selecting **YES** will cause RADTRAN to internally adjust 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**.

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

Gamma and Neutron Fractions

A value into either of these cells, RADCAT will automatically adjust the other cell so that the two add up to one. This can be seen in Figure 9.

Crew Size

For highway for barge travel, enter the number of crew members that will be traveling on the vehicle. This can be seen in Figure 10. The crew on a train in transit is at least 150 meters from the radioactive cargo, and is shielded by intervening rail cars, so that the crew is considered to receive zero dose. Therefore, for rail mode, neither the default values nor any numbers you may enter will be read by RADTRAN.

Crew Distance

For highway and barge travel, enter the **Distance** in meters from the crew to the nearest surface of the cargo. This distance is usually between 3 and 7 meters for large trucks. This can be seen in Figure 10. The crew on a train in transit is at least 150 meters from the radioactive cargo and is shielded by intervening rail cars. The crew is considered to receive zero dose. Therefore, for rail mode, neither the default values nor any numbers you may enter will be read by RADTRAN.

"Crew" dose for rail shipments is the dose sustained by rail yard workers at stops along the route.

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

Crew Shielding Factor

For highway and barge travel, 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. The crew on a train in transit is at least 150 meters from the radioactive cargo and is shielded by intervening rail cars. The crew is considered to receive zero dose. Therefore, for rail mode, neither the default values nor any numbers you may enter will be read by RADTRAN.

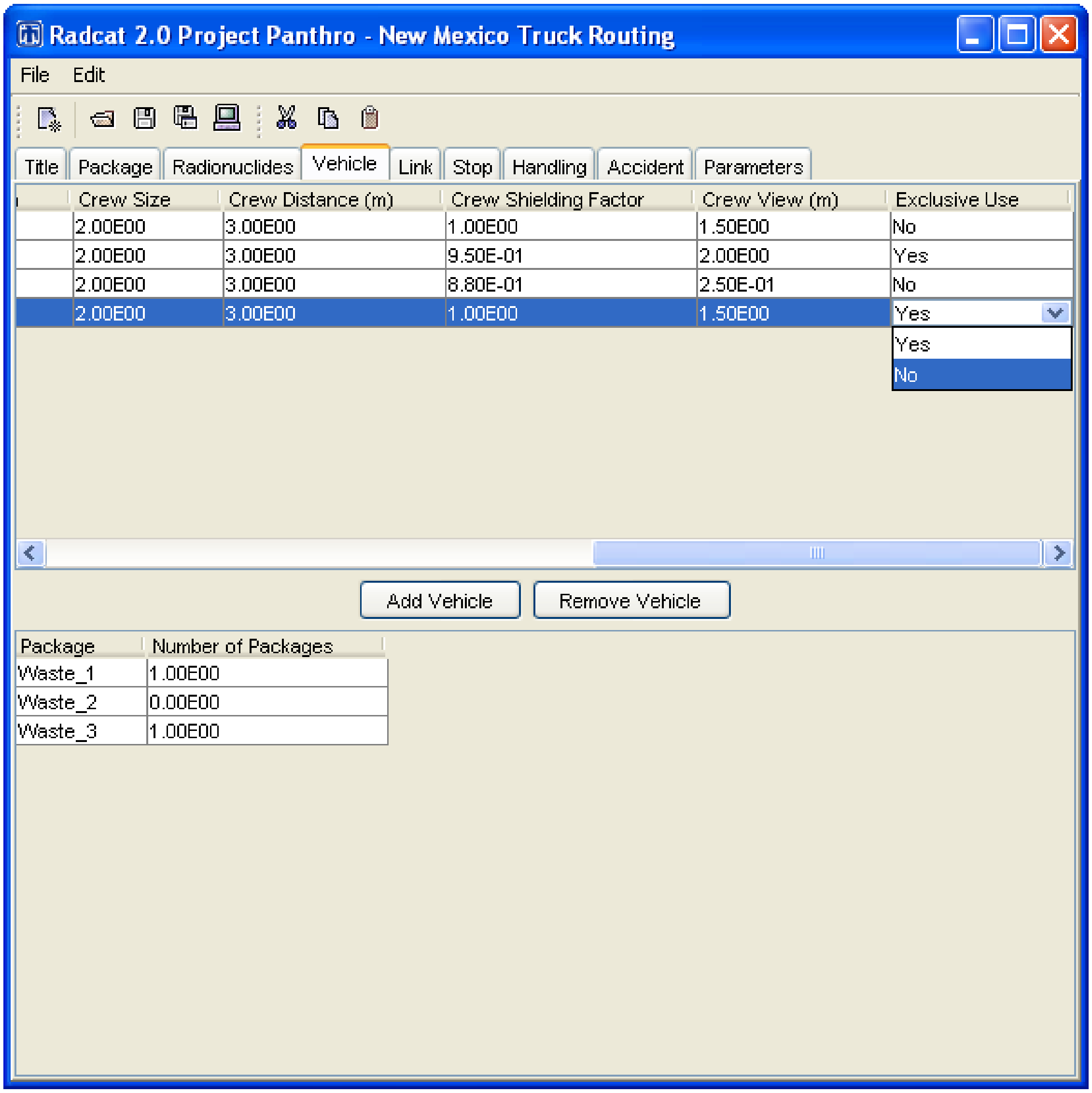


Figure 10: Vehicle Tab Continued

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. The crew on a train in transit is at least 150 meters from the radioactive cargo and is shielded by intervening rail cars. The crew is considered to receive zero dose. Therefore, for rail mode, neither the default values nor any numbers you may enter will be read by RADTRAN.

Exclusive Use

A pull-down menu allows the user to indicate whether the vehicle is exclusive use or not. This can be seen in Figure 10.

5.4 LINK

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. 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 13.

Note: The parameter values in this screen can be provided by a routing code or a geographic information system (GIS). The routing code WebTRAGIS is available from Oak Ridge National Laboratory at: [http://apps.ntp.doe.gov/tragis/tragis.htm.](http://apps.ntp.doe.gov/tragis/tragis.htm)

Figures 11 and 12 show examples of WebTRAGIS routes. Figure 11 is an example of a truck route across New Mexico, and Figure 12 is an example of a barge route in Florida.

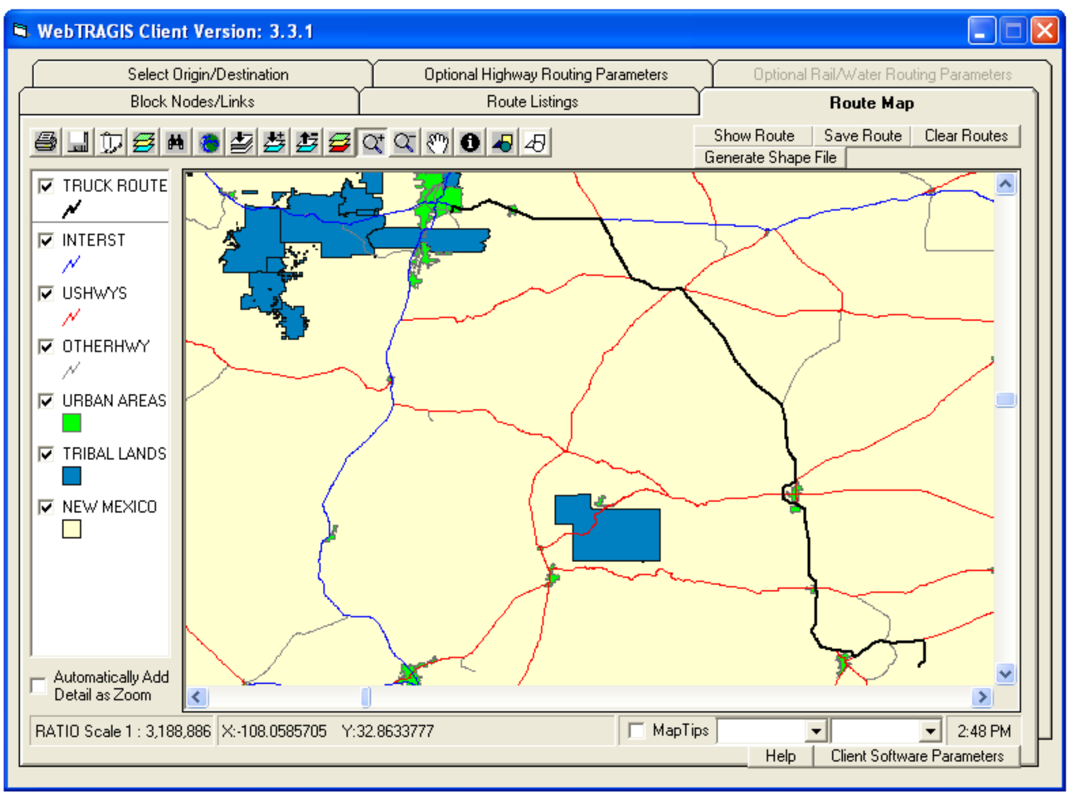


Figure 11: New Mexico Truck Route.

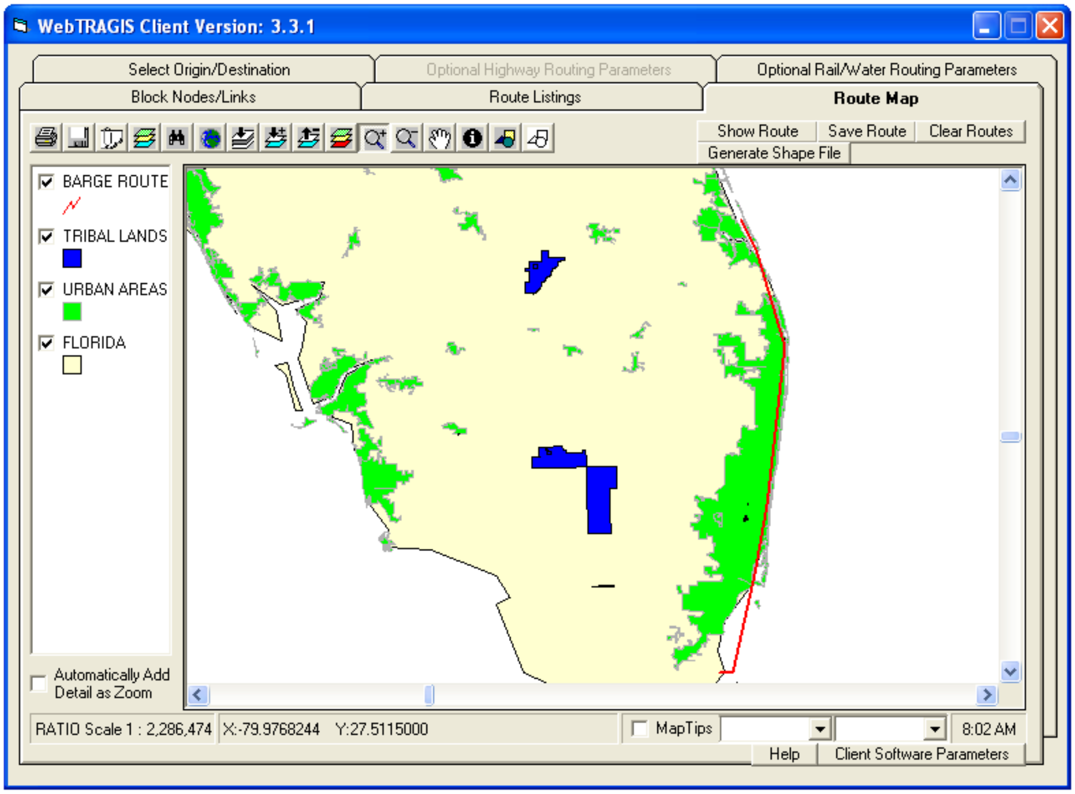


Figure 12: Florida Barge Route

Link Name

Give each route segment (**Link**) a name in the left-hand column. Links do not need to be consecutive. The user may divide the entire route into a rural link, which includes all rural segments, a suburban link, which includes all suburban segments, and an urban link, which includes all urban segments. Rush-hour periods can also be separate links. The designation of rural, suburban, or urban is defined by the resident population density along the route (see **Population Density**). This can be seen in Figure 13.

Vehicle

Available vehicle names are on a pull-down menu in the **Vehicle** column. Note that vehicle names cannot be added or deleted at this screen. This can be seen in Figure 13.

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 (TRAGIS is almost universally used). This can be seen in Figure 13.

A useful conversion factor is 1 km = 0.6217 mile.

Speed

Enter the average speed of each vehicle on each link, in km/hr. This can be seen in Figure 13. Based on speed limits, we have often used the following very conservative national average values in RADTRAN:

- Trucks on freeways, primary U. S. highways, or limited-access highways: 88 km/hr (55 mph). This includes trucks on interstate highways and bypasses through urban areas.

- Trucks on two-lane rural roads: 72 km/hr (45 mph)

- Trucks on urban or suburban two-lane roads: 40 km/hr (25 mph)

- Trucks on city streets: 24 km/hr (15 mph)

- Trucks in rush-hour traffic: one-half the non-rush hour speed on the particular road type

- Trains on rural route segments: 64 km/hr (40 mph)

- Trains on suburban route segments: 40 km/hr

- Trains on urban route segments: 24 km/hr

Population Density

Enter the population density in persons/km^2, as obtained from WebTRAGIS, the City/County data book, or some other GIS system or source. This can be seen in Figure 13. This population density is usually provided for a band one-half mile (800 meters) on either side of the route. Rural, suburban, and urban population densities are classified by WebTRAGIS according to the following scheme:

- rural: 0 to 139 persons/mi^2 (0 to 55 persons/km^2)
- suburban: 139 to 3326 persons/mi^2 (55 to 1300 persons/km^2)
- urban: more than 3326 persons/mi^2 (1300 persons/km^2)

The historic RADTRAN classifications are:

- rural: 0 to 66 persons/km^2
- suburban: 67 to 1670 persons/km^2)
- urban: more than 1670 persons/km^2)

National averages are approximately

- rural: 6 persons/km^2
- suburban: 720 persons/km^2
- urban: 3800 persons/km^2

Population density and vehicle speed are important parameters in determining the *off-link incident-free dose* from radioactive materials transportation. Population density is important in determining *accident dose risk.*

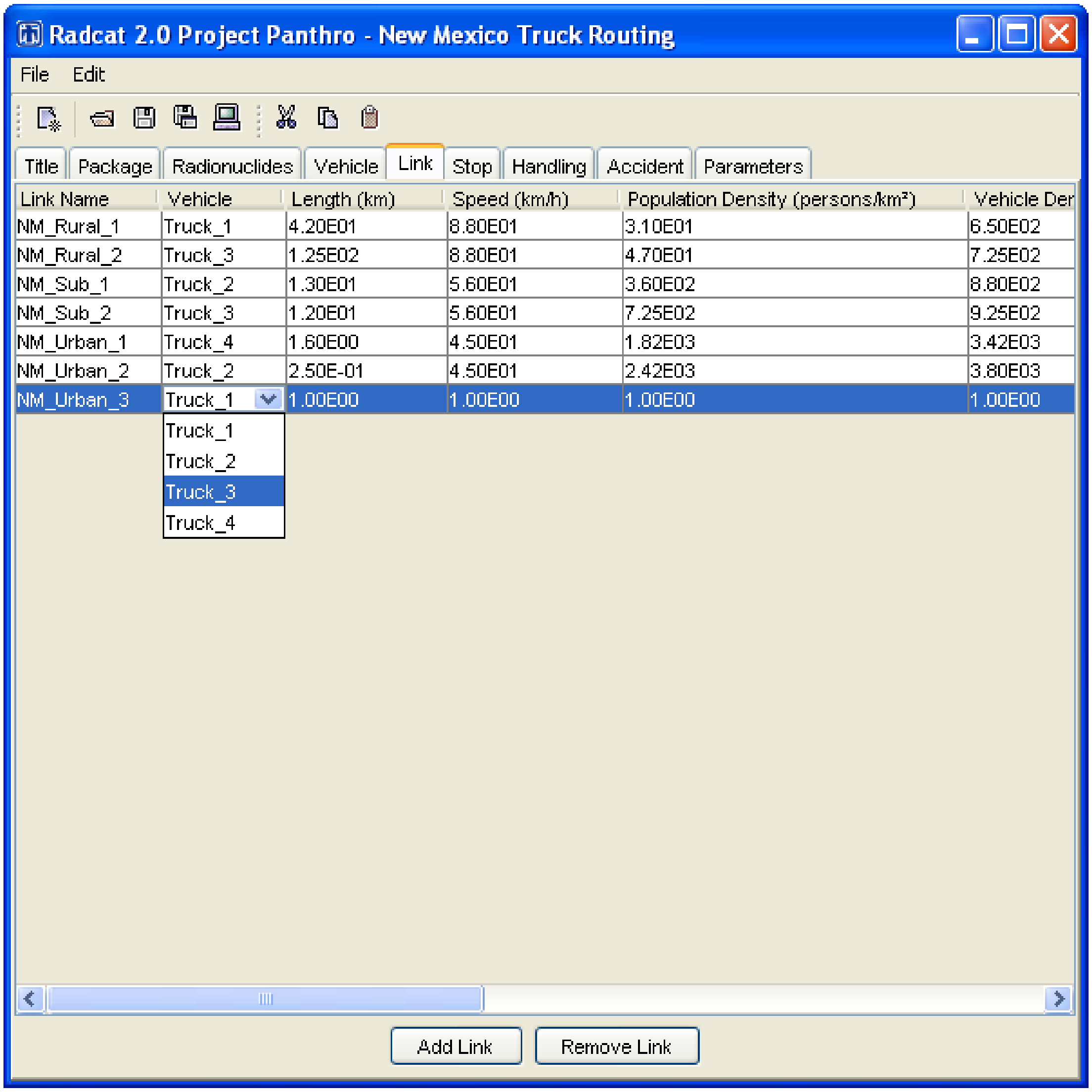


Figure 13: Link Tab

Vehicle Density

Enter the vehicle density – the vehicles that share the route with the radioactive cargo – in vehicles per hour. This can be seen in Figure 14. National average vehicle densities that have been used in RADTRAN are:

<u>Truck</u>

- rural: 460 vehicles/hr
- suburban: 780 vehicles/hr
- urban: 2800 vehicles/hr
- During rush hour the vehicle density may be assumed to double.

Rail

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

These vehicle densities, which have been used in RADTRAN since the mid-1980s, may underestimate current average traffic density on Interstate Highways, and may overestimate traffic density on other highways. Sandia National Laboratories is currently updating vehicle densities. Initial results of the update are:

Interstate Highways

- rural: 1130 vehicles/hr
- suburban: 2480 vehicles/hr
- urban: 5440 vehicles/hr

U.S. Highways

- rural: 280 vehicles/hr
- suburban: 610 vehicles/hr
- urban: 1640 vehicles/hr

These numbers will be revised when the vehicle density study is complete. More accurate vehicle densities can usually be obtained from state traffic counts.

Persons per Vehicle (Vehicle Occupancy)

Enter the average persons per vehicle for the route. This can be seen in 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.

Accident Rate

Enter the accident rate for each route segment in accidents per vehicle-km. This can be seen in Figure 14. Accident rates are usually reported by state and type of road or rail. Useful references for accident rates are:

- Saricks, C.L. and Tompkins, M.M. 1999. State-Level Accident Rates of Surface Freight Transportation: A Reexamination. ANL/ESD/TM-150. Argonne, Illinois: Argonne National Laboratory.

- The Bureau of Transportation Statistics web site: http://www.bts.gov

Zone

A pull-down menu allows the designation of each link as rural, suburban, or urban. These designations must be applied because they modify certain RADTRAN calculations within the code. This can be seen in Figure 14.

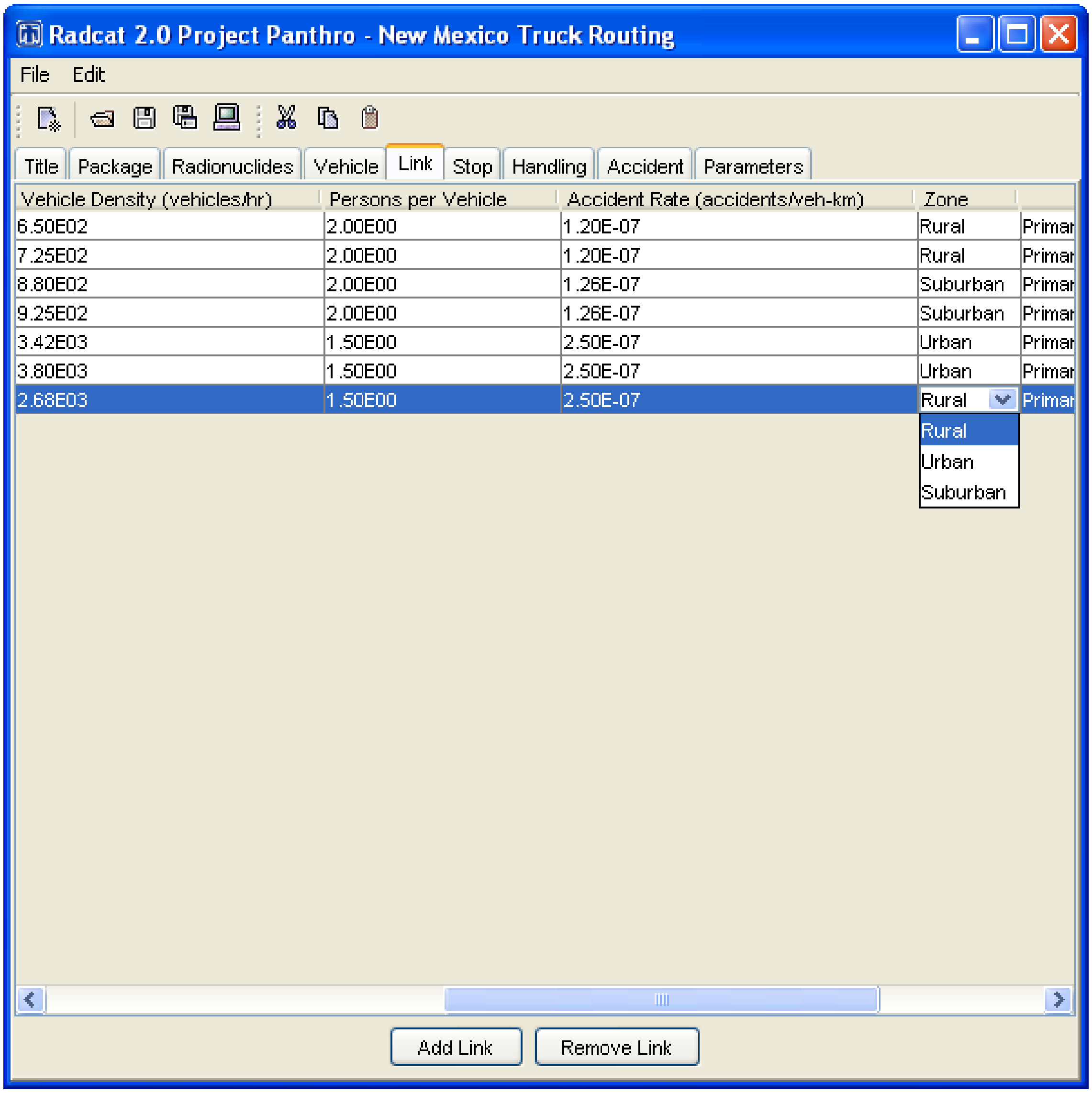


Figure 14: Link Tab Continued

Type

A pull-down menu allows the designation the road type as interstate or U. S. primary, secondary road, or "other." "Other" includes rail and barge routes. RADTRAN uses this designation to modify certain calculations within the code. This can be seen in Figure 15.

Farm Fraction

A fraction of land on rural route segments can be designated as farmland, and this fraction is then used in RADTRAN to calculate ingestion dose in the event of an accident. Farmland fractions should be set to zero on suburban or urban route segments. This can be seen in Figure 15.

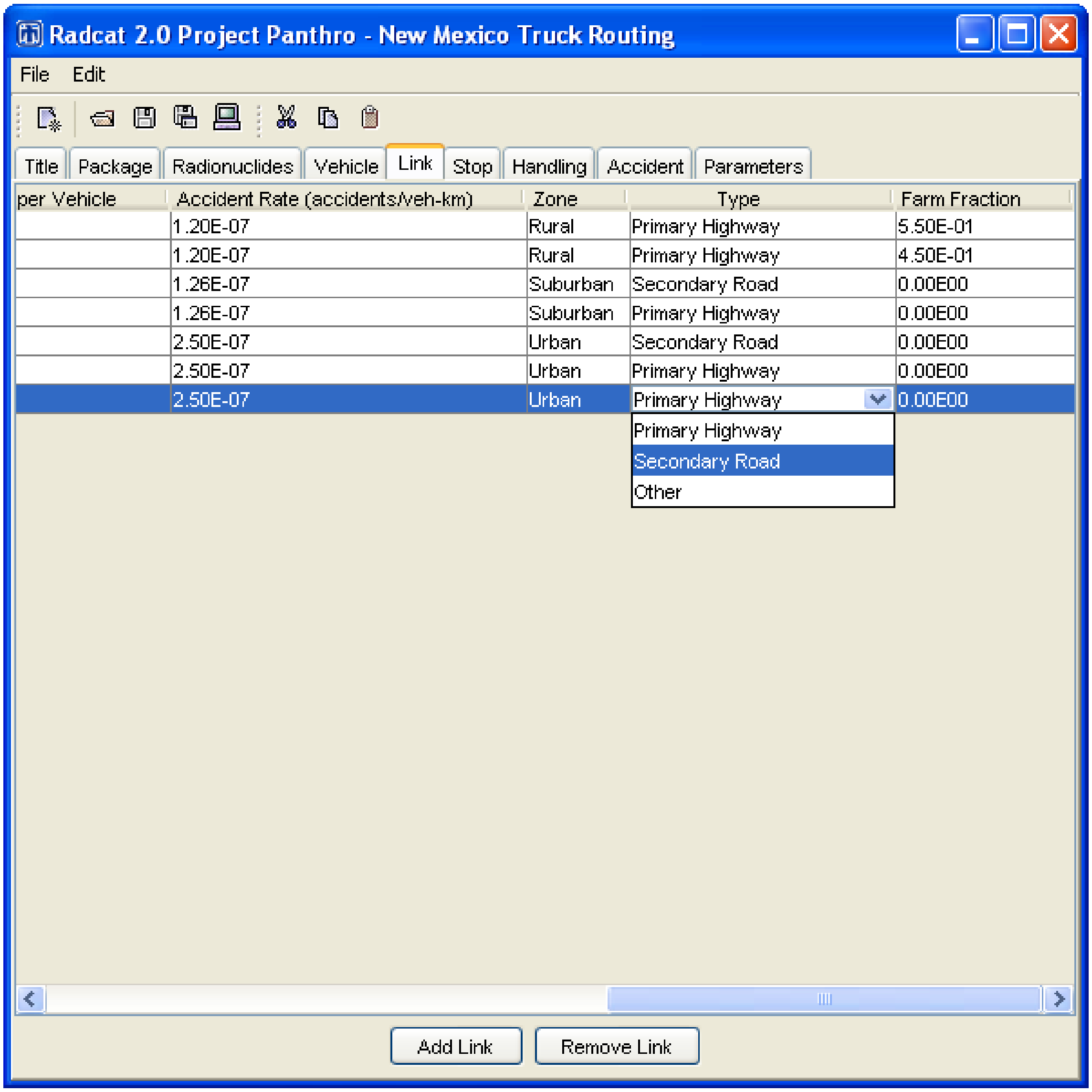


Figure 15: Link Tab with Type and Farm Fraction Cells

5.5 STOPS

When making a new input file or adding or deleting a vehicle in an existing file, select the **Stop** tab next after the **Link** tab. If editing an existing file without adding or deleting a package, the order in which the tabs are opened will not make any difference. Figure 16 shows the **Stop** tab.

Name

Give each **Stop** a **Name** in the left-hand column. Aggregation of all stops of a particular type (e.g., inspection stops, refueling stops) may be done and then enter the total time for those stops. Different types of populations (e.g., other people at a refueling stop, residents near the stop) may be structured as different stops. This difference can be seen in Figure 16.

Vehicle

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

Min Distance

Enter the shortest distance from the radioactive cargo to the receptor(s) whose dose from incident-free transportation will be calculated. This can be seen in Figure 16. The **Min(imum)** and **Max(imum) Distance** define the area around the radioactive cargo in which there are receptors at that particular stop.

Max Distance

Enter the longest distance from the radioactive cargo to the receptor(s) whose dose from incident-free transportation will be calculated. This can be seen in Figure 16. The **Min(imum)** and **Max(imum) Distance** define the area around the radioactive cargo in which there are receptors at that particular stop. The **Min(imum)** and **Max(imum) Distance** may be the same or may be different (see **People or People/km^2** below). The **Min(imum) Distance** can never be larger than the **Max(imum) Distance.**

People or People/km^2

This parameter defines the number of radiation receptors at each particular stop. If the **Min(imum)** and **Max(imum) Distance** are the same, RADTRAN reads the number in this column as the total number of people at that distance from the radioactive cargo; e.g., if there are 20 people all at 10 meters from the cargo, then enter 10 m for both **Min(imum) Distance** and **Max(imum) Distance**, and enter 20 for **People or People/Km^2.**

On the other hand, if the **Min(imum)** and **Max(imum) Distance** are different, RADTRAN reads the number in this column as a population density: persons/km^2, and this population density must be calculated off-line. For example, if there are 20 people around the cargo in an annular ring with a shortest distance to the cargo of 1 m. and a longest distance of 10 m., the population density in this annular ring may be calculated as follows:

Inner radius = 1 meter.
Outer radius = 10 meters.

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

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

Enter 1-meter for the **Min(imum) Distance,** 10 meters for the **Max(imum) Distance**, and then enter 6.43×10^4 for **People or People/km^2**.

RADTRAN reads total population when the **Min(imum)** and **Max(imum) Distance** are the same, and reads population density when the **Min(imum)** and **Max(imum) Distance** are different. This can be seen in Figure 16.

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. This means that 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.

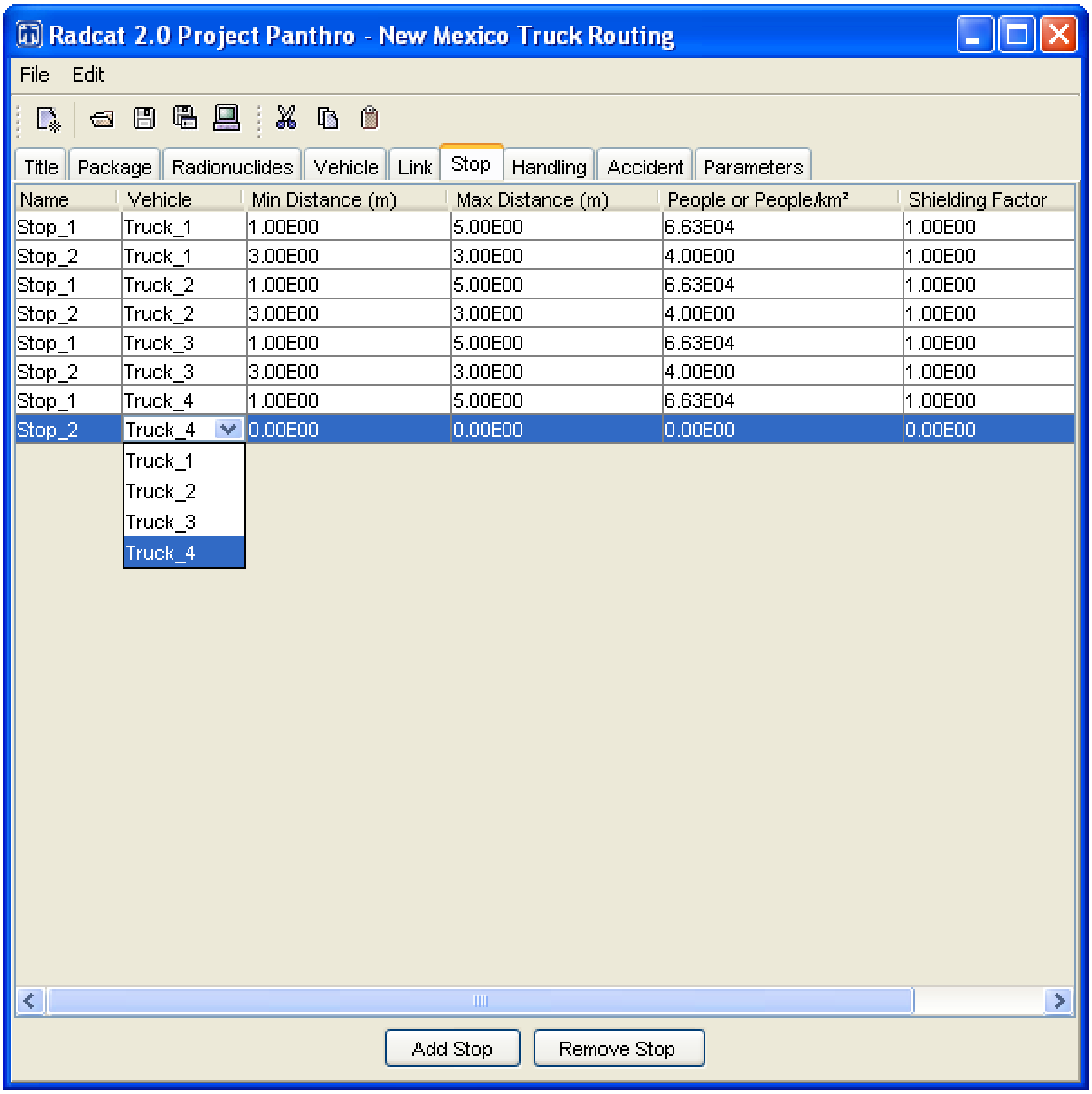


Figure 16: Stop Tab

Time

Enter the total time in hours for each type of stop. This is seen in Figure 17.

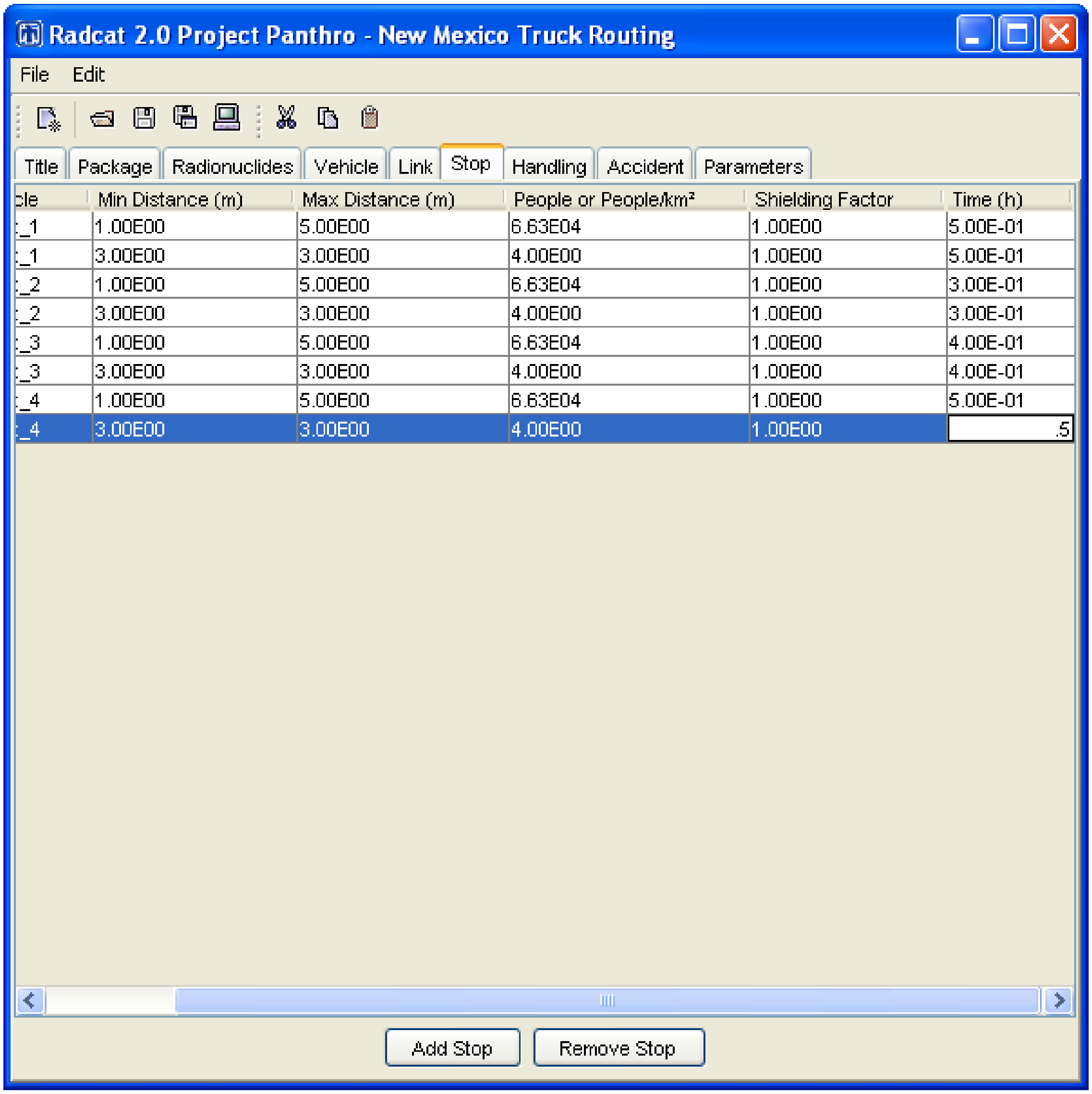


Figure 17: Stop Tab Continued

5.6 HANDLING

Handling refers to sustaining a potential dose from the cargo packages during storage, loading, and unloading, and similar activities. Doses to handlers may also be calculated using the **Stop** tab and parameters.

When making a new input file or adding or deleting a vehicle in an existing file, select the **Handling** tab after the **Vehicle** 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 18.

Name

Give each group of **Handlers** a **Name** in the left-hand column. This can be seen in Figure 18.

Vehicle

Available vehicle names are on a pull-down menu in the **Vehicle** column. This can be seen in Figure 18. Note that vehicle names cannot be added or deleted at this tab.

Number of Handlers

Enter the number of people in each group of handlers. This can be seen in Figure 18.

Distance

Enter the average distance from the radioactive cargo to the handler group whose dose from incident-free transportation that will be calculated. This can be seen in Figure 18.

Time

Enter the total time in hours that each group of handlers is handling the cargo. This can be seen in Figure 18.

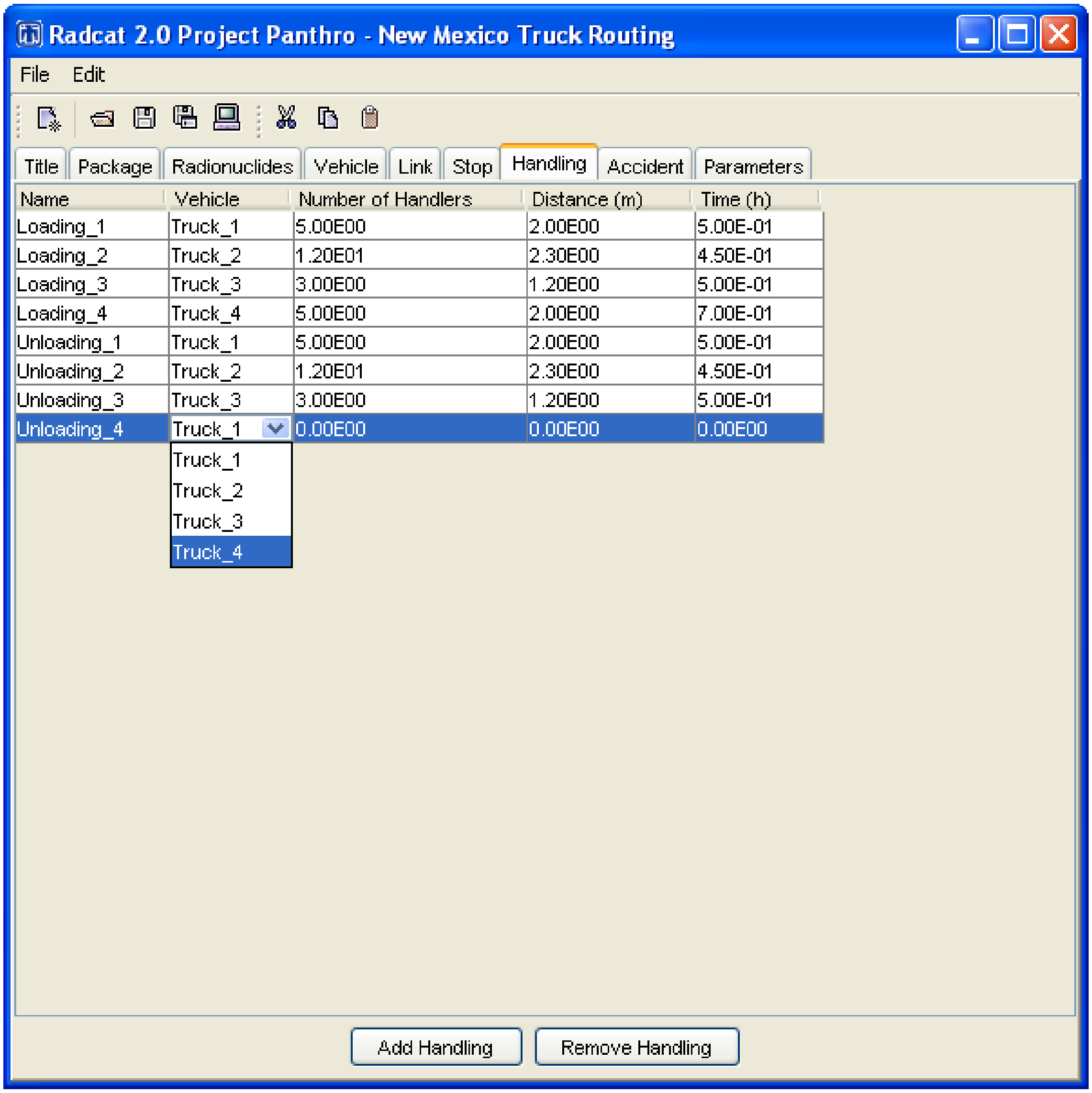


Figure 18: Handling Tab

5.7 ACCIDENT

The accident analysis requires that a radionuclide inventory that was entered at the **Radionuclides** tab, and accident rates and population densities at the **Link** tab. If no radionuclides have been put in the input file, RADTRAN will run but the accident outputs will be zeros.

When the **Accident** screen is opened, seven tabs appear:

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

5.7.1 CONDITIONAL PROBABILITIES (SEVERITY FRACTIONS)

Probability is the conditional probability of an accident of a particular severity, given that an accident happens. Severity of an accident – how damaging the accident is – is a function of the transportation mode. This can be seen in Figure 19.

Probability Fraction and Index

On the **Probability** tab, you can enter indices and probability fractions. The **Probability Fraction** is the conditional probability of an accident of a particular severity (previously referred to in RADTRAN as "severity fraction"). The **Index** is a numbering system for **Probability Fractions** and simply enumerates them. Note that the **Index** begins with zero. One **Probability Fraction** (usually the zeroth) should represent an accident in which there is neither a release of radioactive material nor loss of gamma shielding. The probability of this type of accident is usually more than 90%. This can be seen in Figure 19. **Probability Fractions** may be obtained from studies of accidents as described in the following references:

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.

DOE (U.S. Department of Energy), 2002, "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, Office of Civilian Radioactive Waste Management. Appendix J.

Probability Fractions should add to 1.0, though this is sometimes difficult to see with very small probability fractions. RADCAT does not force addition to 1.0. Enter the **Probability Fractions** in the right-hand column. Indices may only be added and deleted on this screen. This can be seen in Figure 19.

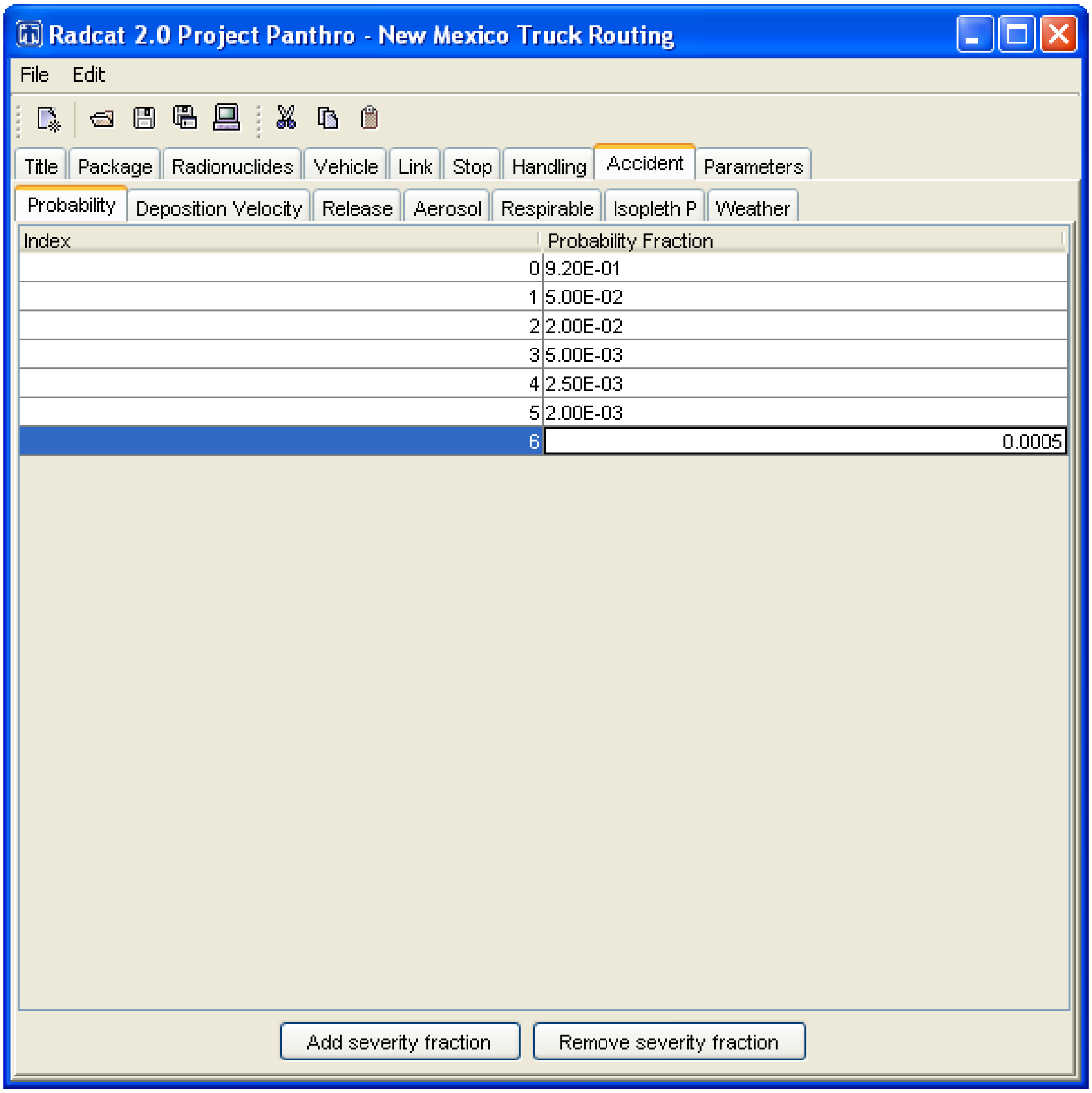


Figure 19: Accident / Probability Tab

5.7.2 DEPOSITION VELOCITY

Deposition Velocity 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 aerosol particles that can be dispersed over long distances. The **Deposition Velocity** should be small enough that the material is deposited in at least 2 isopleths. If the **Deposition Velocity** is too large RADTRAN will not finish the calculations. 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 screen. This can be seen in Figure 20.

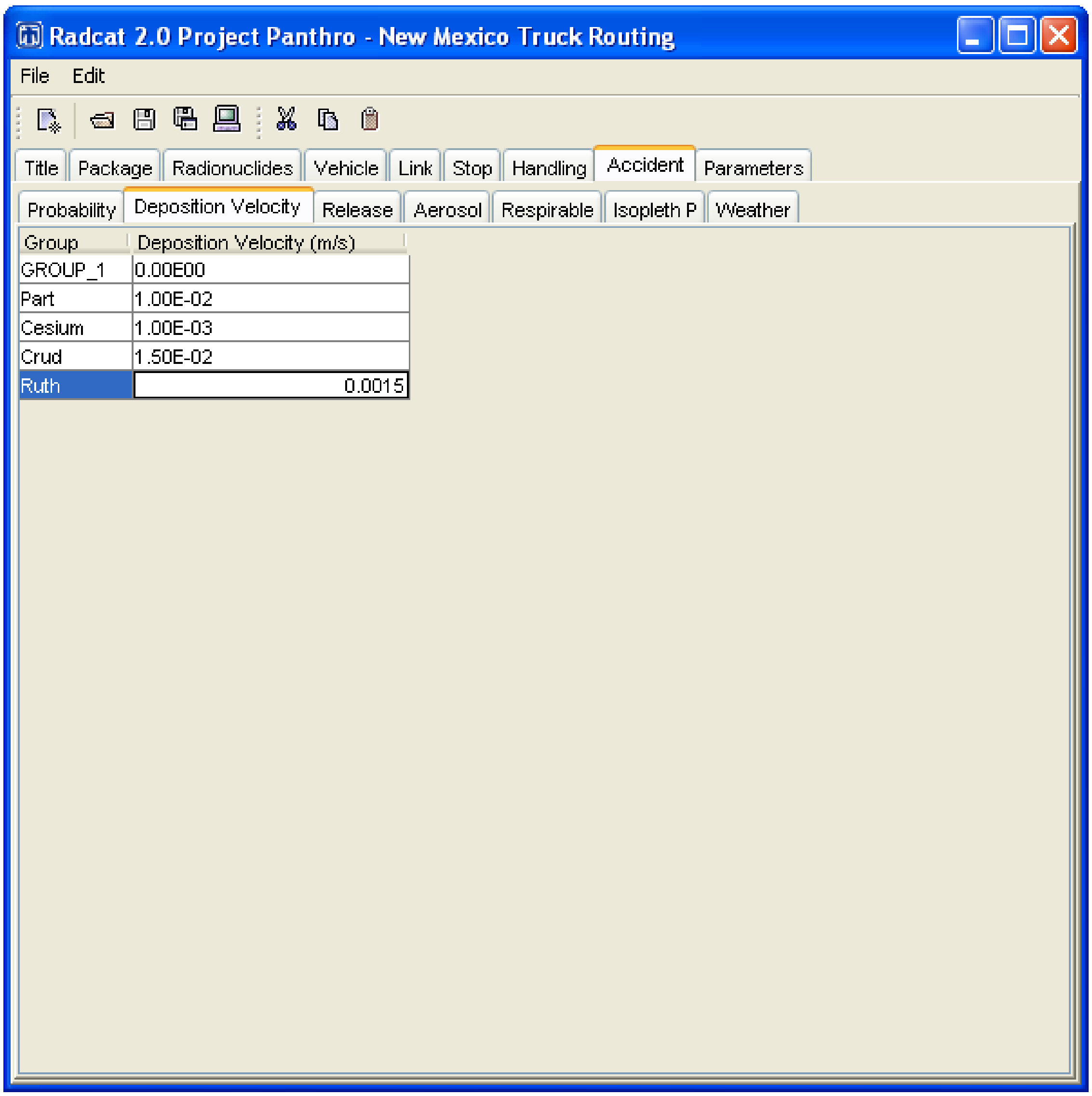


Figure 20: Accident / Deposition Velocity Tab

5.7.3 RELEASE FRACTION

Release Fraction, the fraction of each radionuclide in the cargo that could be released 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. This can be seen in Figure 21.

The left-hand column shows the **Index** number for each **Probability Fraction.** Enter a **Release Fraction** for each **Index** and each **Group.** Indices may not be added or deleted at this screen.

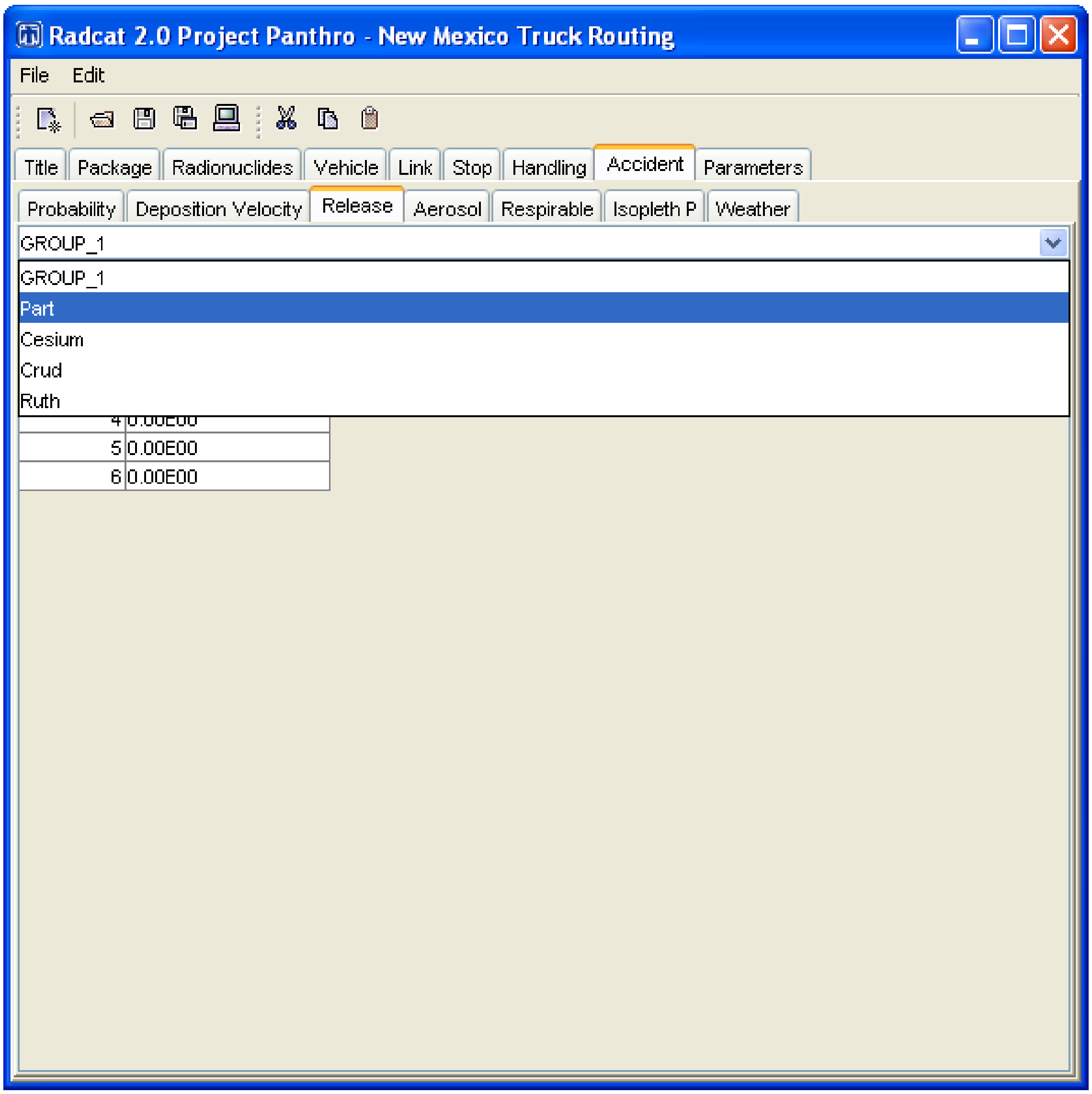


Figure 21: Accident / Release Tab

5.7.4 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. This can be seen in Figure 22.

The left-hand column shows the **Index** number for each **Probability Fraction.** 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 screen.

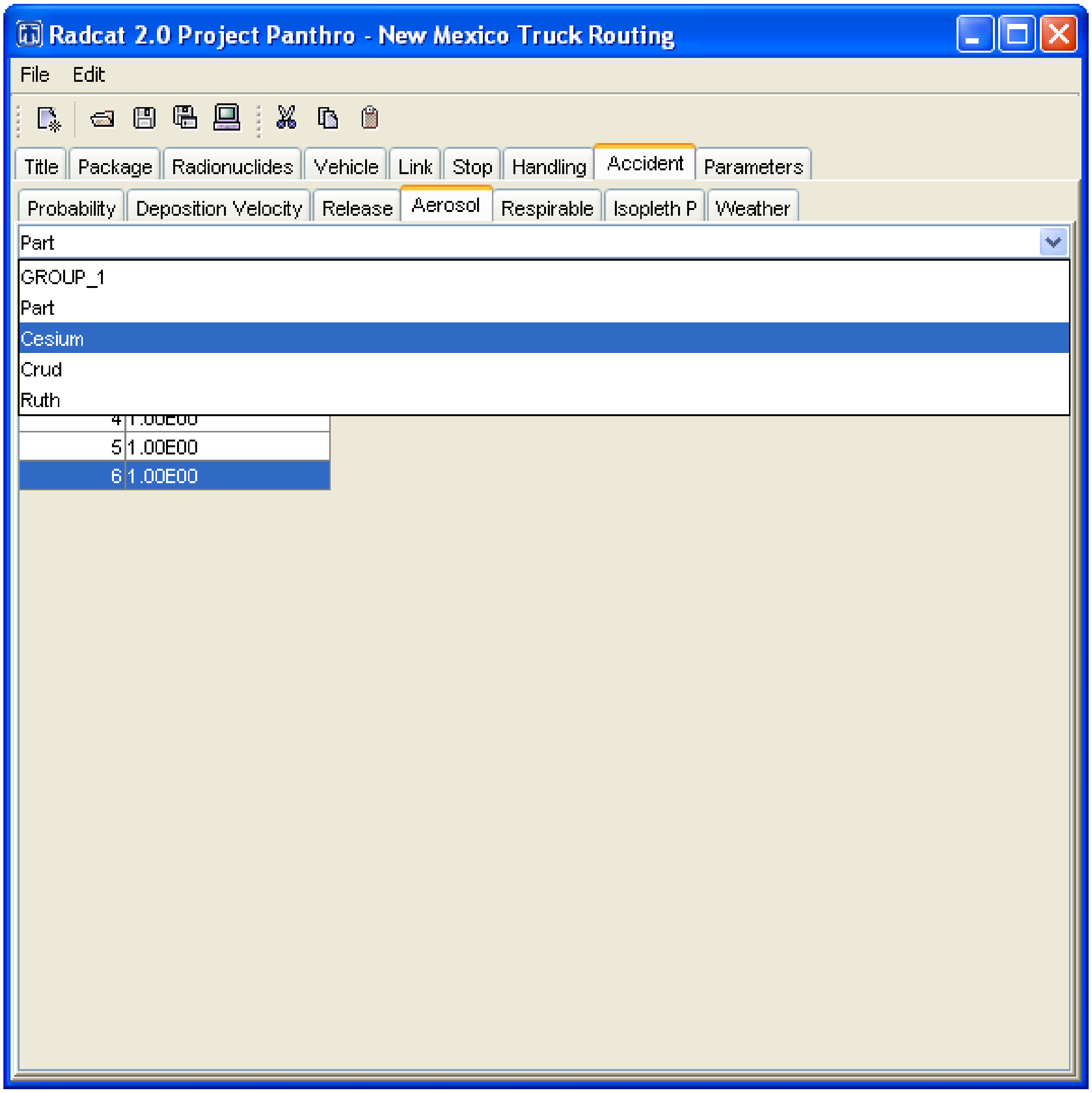


Figure 22: Accident / Aerosol Tab

5.7.5 RESPIRABLE FRACTION

The **Respirable Fraction,** the fraction of each **Aerosol Fraction** that consists of particles or droplets less than 10 microns in diameter, 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. This can be seen in Figure 23.

The left-hand column shows the **Index** number for each **Probability Fraction.** Enter a **Respirable Fraction** for each **Index** and each **Group.** The **Respirable Fraction** is often between 0.05 and 0.1, but may be as much as 1.0. Indices may not be added or deleted at this screen.

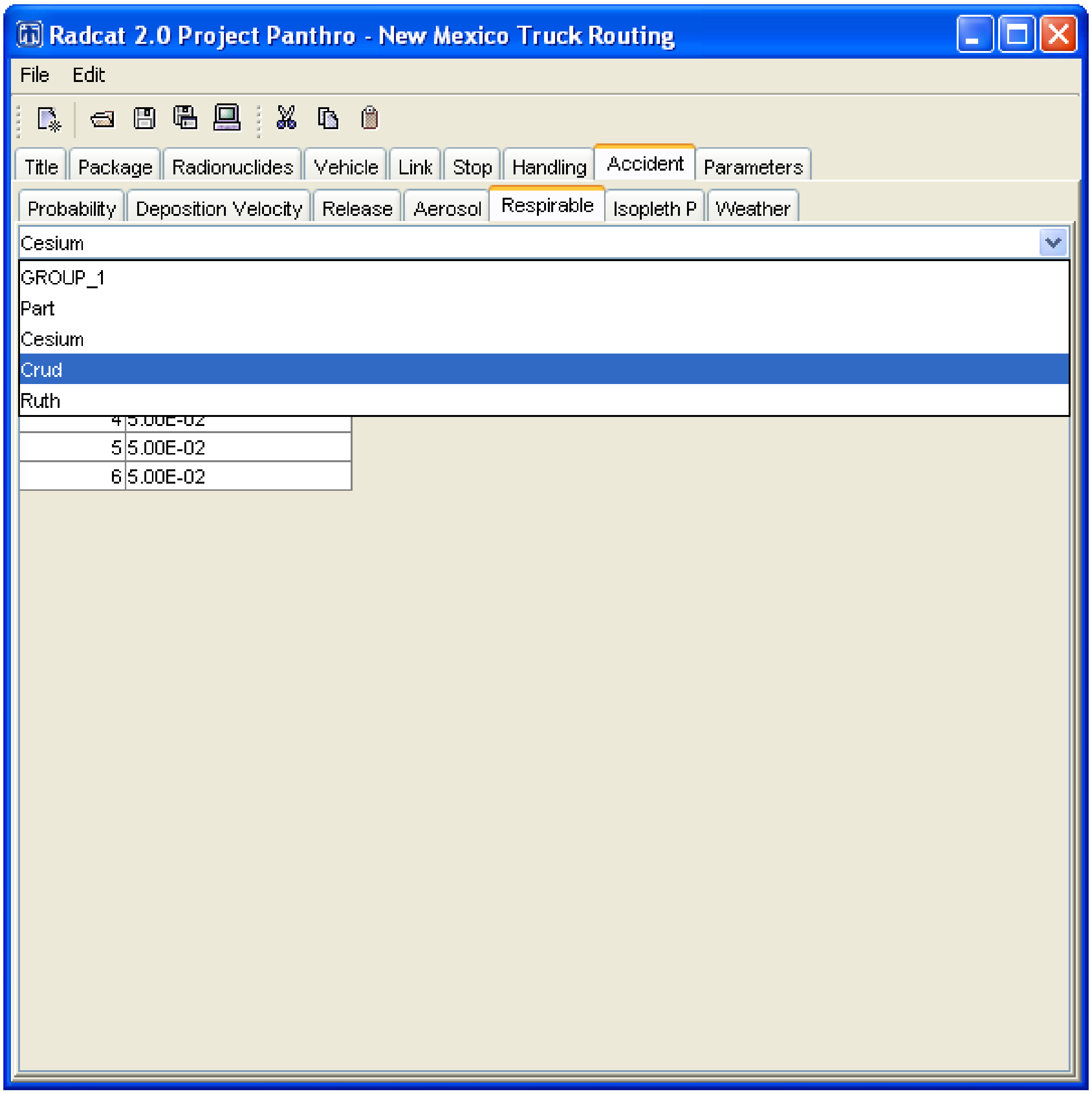


Figure 23: Accident / Respirable Tab

5.7.6 ISOPLETH P

RADTRAN provides two alternate methods of identifying the population that could receive a radiation dose 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 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 alternative.

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 densities. This can be seen in Figure 24. Thus 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, the user 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. Note that isopleth areas may not be added or deleted at this screen.

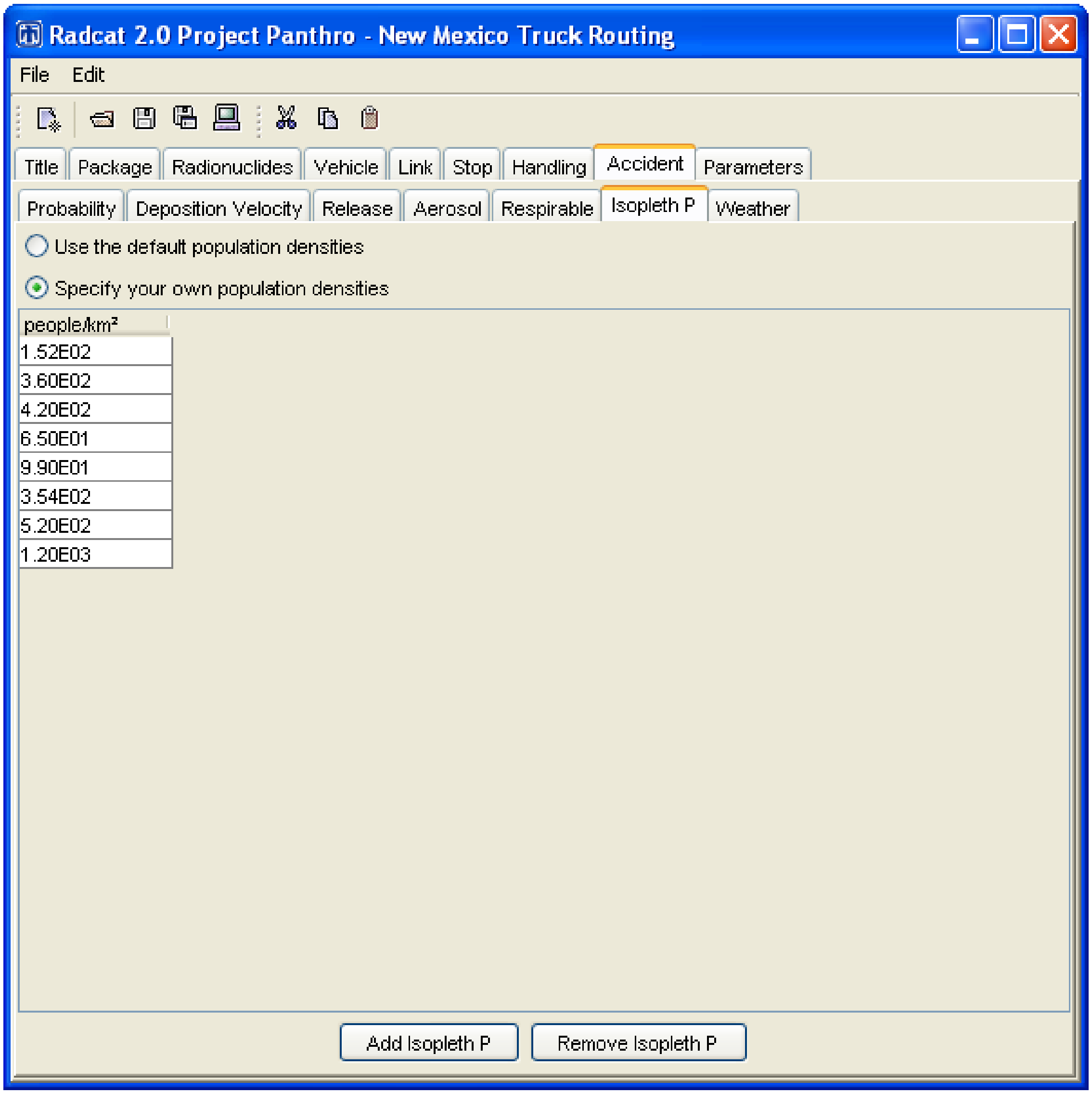


Figure 24: Accident / Isopleth P Tab

5.7.7 WEATHER

Open the **Weather** tab after you open the **Isopleth P** tab. If **Specify your own population densities** is selected, you must select the same number of dispersion areas as Isopleth P population densities in the **Isopleth P** tab. The number of dispersion areas may be added or removed using the bars at the bottom of the screen. This can be seen in Figure 25. **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 screen. Note that you cannot add or delete population densities in this tab.

Open the **Weather** tab after you open the **Isopleth P** tab.

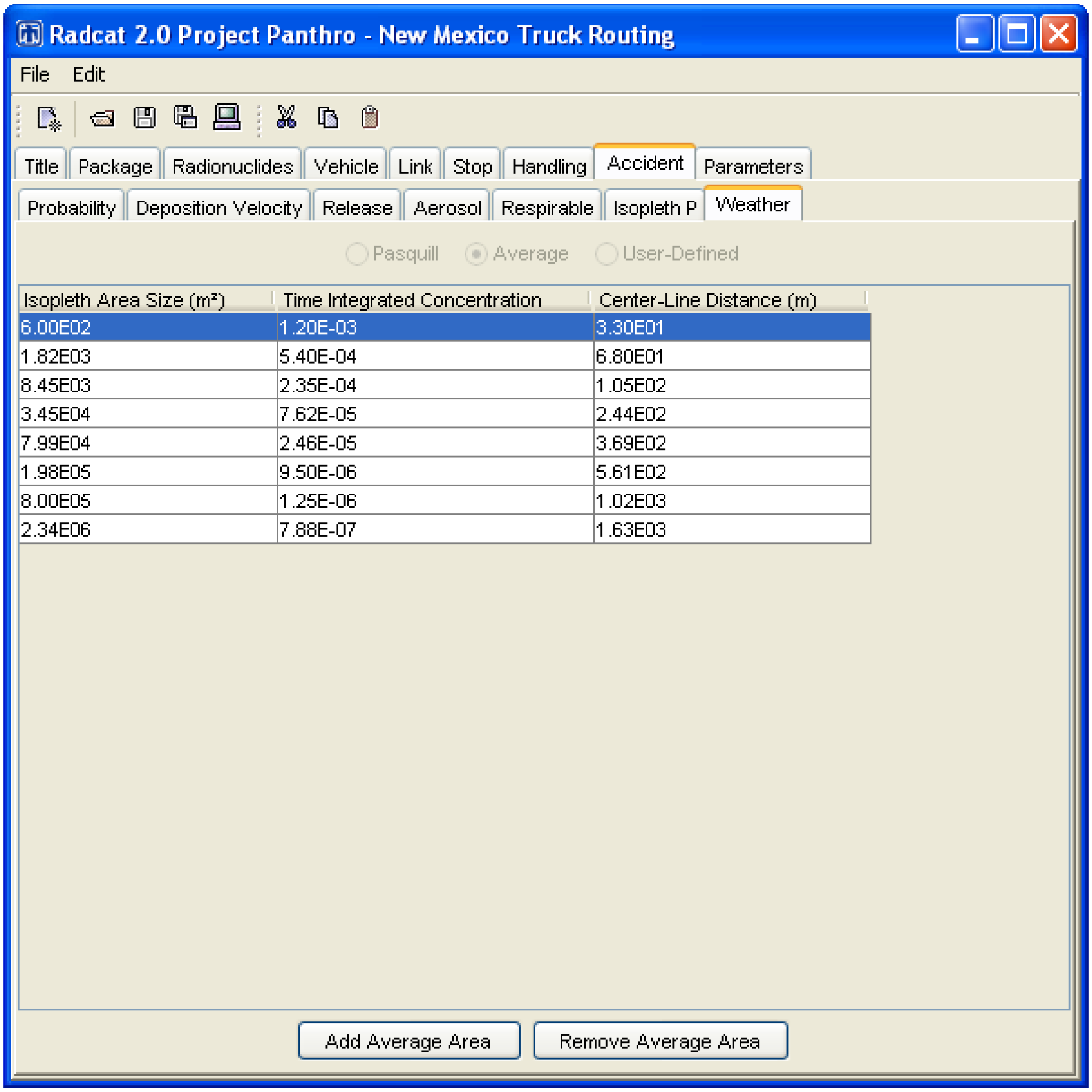


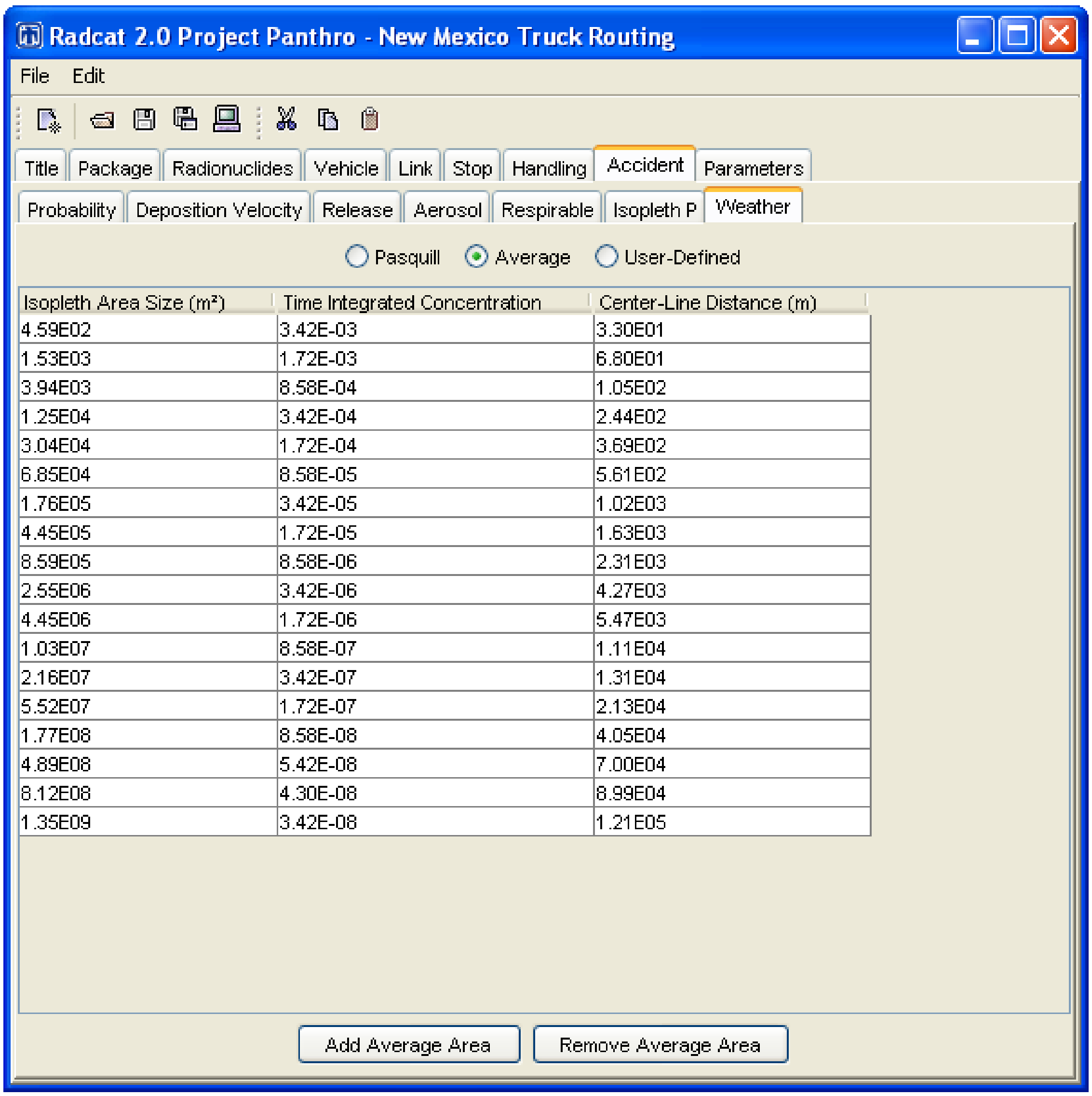
Figure 25: Accident / Weather Tab with User-Defined Dispersion Option

5.7.7.1 Weather and Use the default population densities

If **Use the default population densities** is selected in the **Isopleth P** tab, any of the three potions shown in Figure 26: **Average, Pasquill,** or **User-Defined** may be selected.

5.7.7.1.1 The Average Option

Choosing the **Average** option selects a set of **Isopleth Areas**, maximum **Centerline Distances** for each area, and corresponding **Time Integrated Concentrations** (dilution, or Chi/Q, factors) based on U. S. national average meteorology and wind speed. This can be seen in Figure 26. The number of areas may be added to or withdrawn using the bars at the bottom of the screen.



Isopleth Area Size (m²)	Time Integrated Concentration	Center-Line Distance (m)
4.59E02	3.42E-03	3.30E01
1.53E03	1.72E-03	6.80E01
3.94E03	8.58E-04	1.05E02
1.25E04	3.42E-04	2.44E02
3.04E04	1.72E-04	3.69E02
6.85E04	8.58E-05	5.61E02
1.76E05	3.42E-05	1.02E03
4.45E05	1.72E-05	1.63E03
8.59E05	8.58E-06	2.31E03
2.55E06	3.42E-06	4.27E03
4.45E06	1.72E-06	5.47E03
1.03E07	8.58E-07	1.11E04
2.16E07	3.42E-07	1.31E04
5.52E07	1.72E-07	2.13E04
1.77E08	8.58E-08	4.05E04
4.89E08	5.42E-08	7.00E04
8.12E08	4.30E-08	8.99E04
1.35E09	3.42E-08	1.21E05

Figure 26: Accident / Weather Tab with National Average Weather Option

5.7.7.1.2 The Pasquill Option

Choosing the **Pasquill** option opens a screen listing the six Pasquill **Stability Classes** in the left-hand column and allowing the user to enter the fraction of occurrence of each **Stability Class** in the **Fraction** column; these fractions must sum to 1.0 else RADTRAN will not execute. This can be seen in Figure 27. Note that in this option, wind speeds are constant for each **Stability Class,** as shown in Table 1.

Table 1: Pasquill Wind Speeds for Stability Class

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

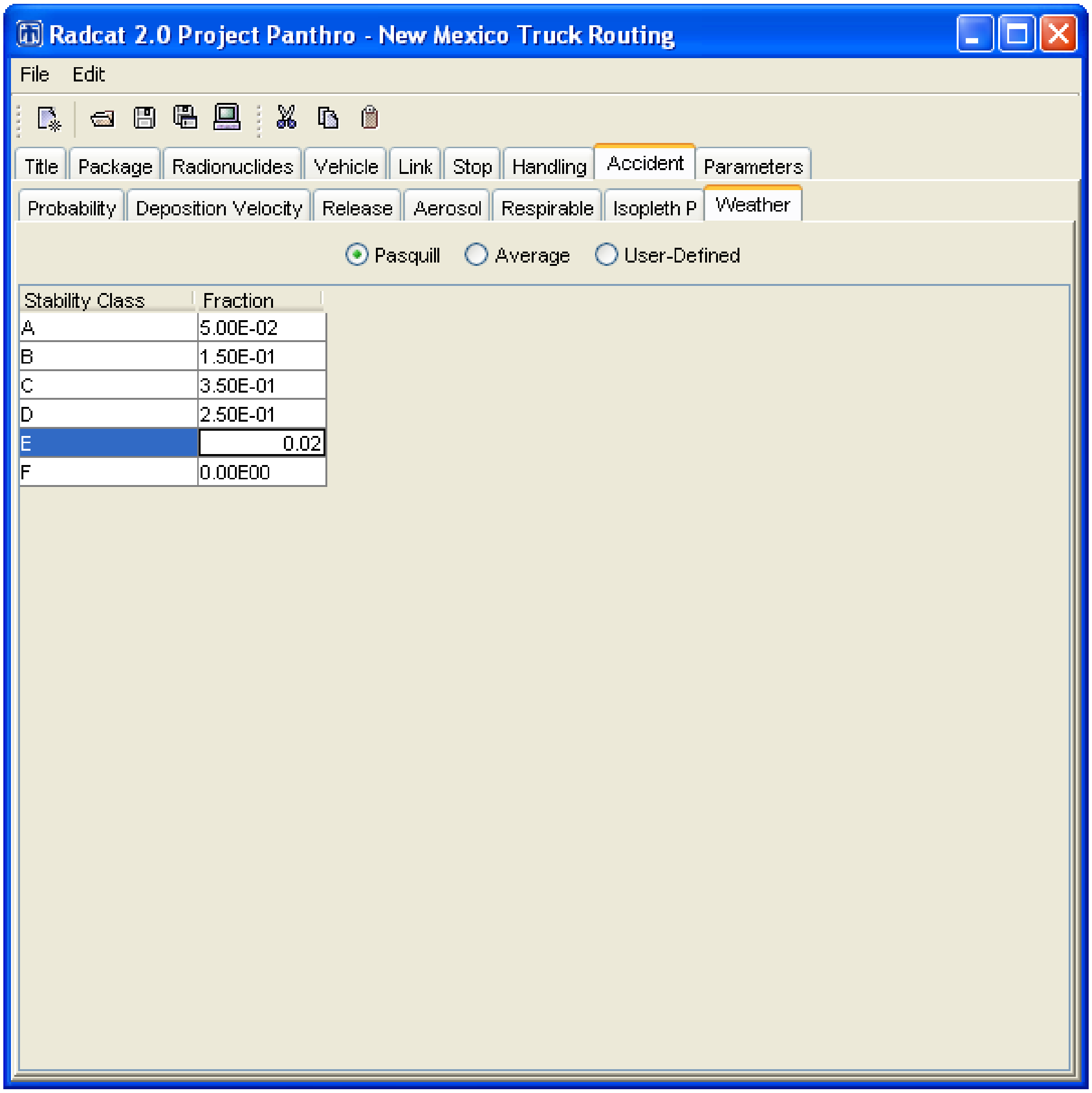


Figure 27: Accident / Weather Tab with Pasquill Option

5.7.7.1.3 The User-Defined Option

Choosing the **User-Defined** option opens a screen listing the following input parameters and can be seen in Figure 28. Note that the user can only use this option for one specific type of cask, release location, and wind stability class.

1. **Release Height** – This parameter allows the user to specify the physical release height for an atmospheric dispersion.

2. **Heat Release** – This parameter allows the user to incorporate the amount of thermally-induced plume rise that will affect the effective release height.

3. **Cask Length** – This parameter will allow the user to define the length of a cylindrical cask.

4. **Cask Radius** – This parameter will allow the user to define the radius of a cylindrical cask.

5. **Wind Speed at Anemometer** – This parameter will allow the user to specify the wind speed at an anemometer reading site.

6. **Anemometer Height** – This parameter will allow the user to incorporate the anemometer wind speed with the wind speed at the effective release height

7. **Ambient Temperature** – This parameter will allow the user to adjust the plume rise accordingly to adiabatic and potential temperature lapse rates.

8. **Atmospheric Mixing Height** – This parameter will allow the user to define the height at which the plume will mix within other atmospheric conditions.

9. **Rainfall Rate** – This parameter will allow the user to incorporate wet deposition by rain or snowfall 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 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 following website can provide hourly rain data from the National Oceanic and Atmospheric Administration (NOAA) Forecast System Laboratory:

    http://precip.fsl.noaa.gov/hourly_precip.html

10. **Dispersion Model** – This parameter will allow the user to choose between the Pasquill dispersion model, or the Briggs dispersion model. The former is suitable for ground-level releases and the latter is better for elevated releases.

11. **Stability Category** – This parameter will allow the user to determine which wind stability class (A-F) will be used.

12. **Release Location** – This parameter allows the user to define which type of terrain will be used for the dispersion model (rural or suburban/urban).
    Note: Since this option provides different dispersion results, it should be used for Links that are either suburban/urban, or rural only. If a combination of Links that are urban, suburban, and rural need to be investigated, it is suggested that two different RADTRAN 5.5 runs are conducted so as to properly reflect the dispersion models.

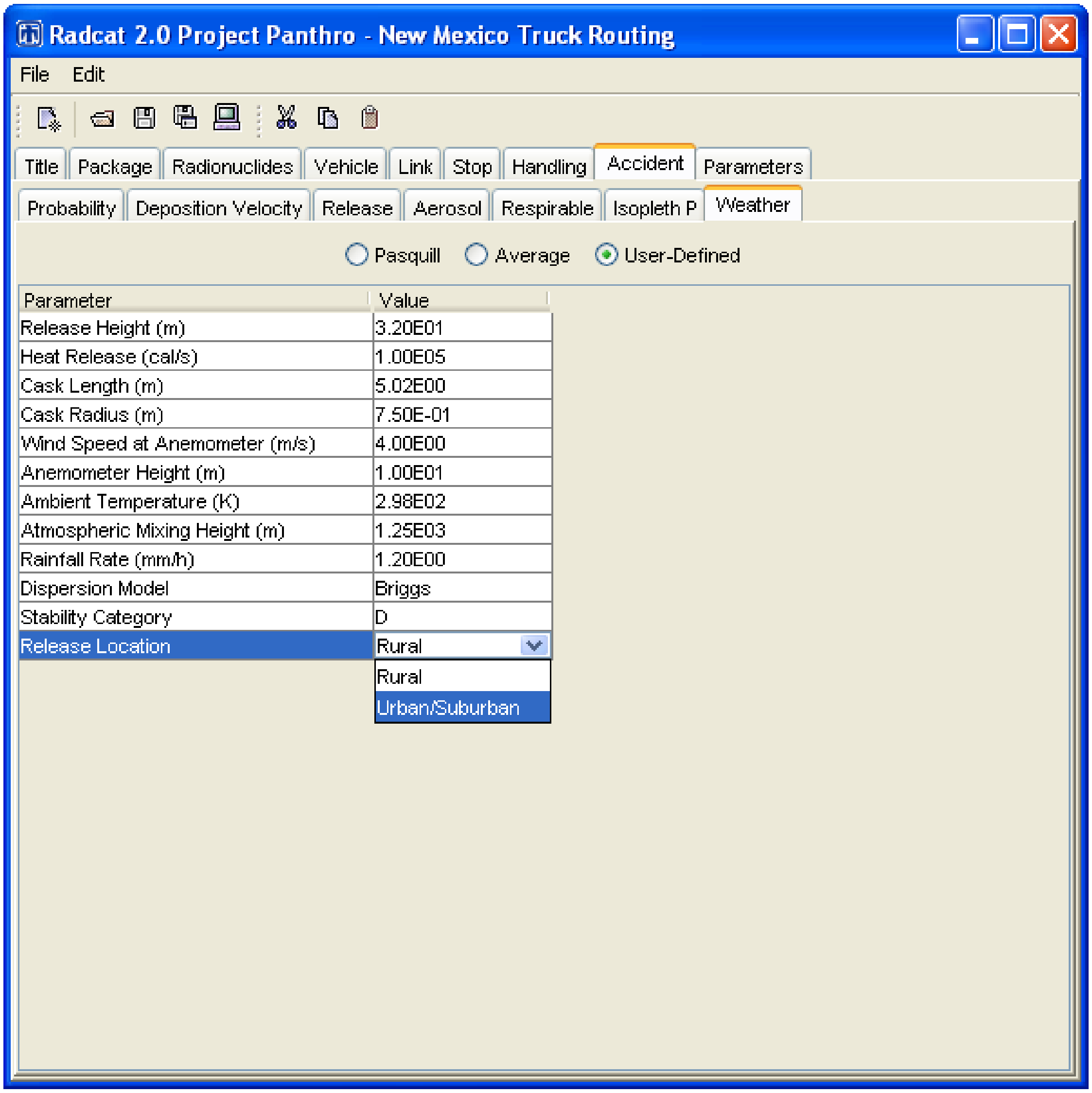


Figure 28: Accident / Weather Tab with User-Defined Option

5.8 PARAMETERS

This screen lists values that have historically been used in RADTRAN for a variety of parameters. Any of these values can be overwritten by the user. Figures 29 and 30 show the **Parameters** tab for highway routes, Figure 31 shows the **Parameters** tab for rail routes, and Figure 32 shows the **Parameters** tab for barge routes.

Shielding factor for residences

The shielding factor is inverse of the shielding fractions; i.e., a shielding factor of 1 indicates no shielding, and a shielding factor of zero indicates 100% shielding. The shielding factor is the fraction of ionizing radiation to which rural residents are exposed to in their homes or other buildings in this zone. This can be seen in Figures 29, 31, and 32. The standard (default) value is 1.0 (i.e., no shielding) for rural buildings, 0.87 for suburban buildings, and 0.018 for urban buildings.

Fraction of outside air in urban buildings

This fraction represents 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 to. The fraction of outside air in urban buildings is used to calculate the inhalation and resuspension dose to that population. The standard (default) value of 0.05 represents a conservative average across a series of building types, including residential, office, and industrial structures (Engelmann, 1990). This value is about five times 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. This can be seen in Figures 29, 31, and 32.

Fraction of population occupying the sidewalk

This parameter is the Urban Sidewalk Fraction; it specifies the fraction of population that is outdoors or the fraction of population that occupies sidewalks, depending on the type of population model being used. The standard (default) pre-assigned value of 0.1 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 can be seen in Figures 29, 31, and 32.

Fraction of urban population inside buildings

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 standard (default) value is

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 City and is somewhat conservative for smaller cities. This can be seen in Figures 29, 31, and 32.

Ratio of pedestrians/km^2 to residential population/km^2

This ratio is used to calculate the density of unshielded persons on sidewalks and elsewhere in urban areas by indexing it to the population density of the surrounding area. This ratio can also serve as the ratio of non-resident (e.g., tourist) urban population to resident urban population, since the U. S. Census includes only resident population. The standard (default) value is 6.0, which is based on empirical data from New York City (Finley et al., 1980). This can be seen in Figures 29, 31, and 32.

Minimum small package dimension for handling

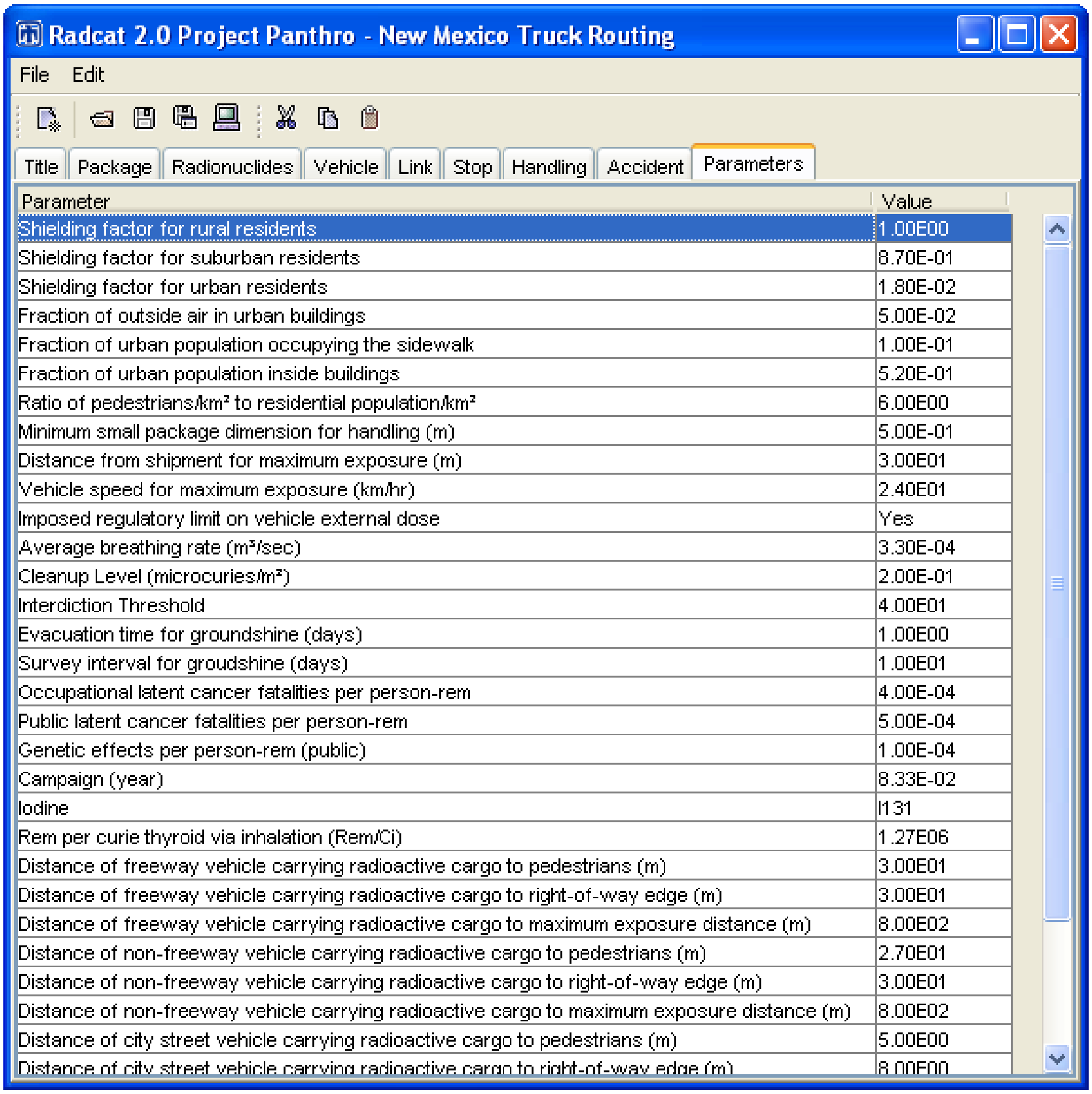
This parameter specifies the first Package Size Threshold. In RADTRAN, This parameter determines the calculation of handler dose. If a package is designated as "small," i.e., smaller than the standard (default) threshold, the dose to the handler is calculated as originating in a uniform source. If package dimensions exceed the threshold, handler dose is calculated as directly proportional to exposure time and inversely proportional to the square of the distance from package to handler. The value is standard (default) 0.5 (Javitz, 1985). This can be seen in Figures 29, 31, and 32.

Distance from shipment for maximum exposure

This parameter is used to calculate the maximum individual "in-transit" off-link dose to a member of the public. It represents the minimum perpendicular 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 standard (default) value is 30.0 meters (NRC, 1977). This can be seen in Figures 29, 31, and 32.

Vehicle speed for maximum exposure

This parameter is used to calculate the maximum individual "in-transit" dose. It represents the minimum velocity, in km/hr, of a shipment. The standard (default) value is 24.0 km/hr (15 mph) (NRC, 1977). This can be seen in Figures 29, 31, and 32.



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	1.00E-01
Fraction of urban population inside buildings	5.20E-01
Ratio of pedestrians/km² to residential population/km²	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 (m³/sec)	3.30E-04
Cleanup Level (microcuries/m²)	2.00E-01
Interdiction Threshold	4.00E01
Evacuation time for groundshine (days)	1.00E00
Survey interval for groudshine (days)	1.00E01
Occupational latent cancer fatalities per person-rem	4.00E-04
Public latent cancer fatalities per person-rem	5.00E-04
Genetic effects per person-rem (public)	1.00E-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 non-freeway vehicle carrying radioactive cargo to pedestrians (m)	2.70E01
Distance of non-freeway vehicle carrying radioactive cargo to right-of-way edge (m)	3.00E01
Distance of non-freeway vehicle carrying radioactive cargo to maximum exposure distance (m)	8.00E02
Distance of city street vehicle carrying radioactive cargo to pedestrians (m)	5.00E00
Distance of city street vehicle carrying radioactive cargo to right-of-way edge (m)	8.00E00

Figure 29: Parameters Tab with Highway Mode

Imposed regulatory limit on vehicle external dose

The standard (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 and the calculation continues. A message informing the analyst is printed in the output. The analyst 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 the analyst has INPUT. This can be seen in Figures 29, 31, and 32.

Average breathing rate

This parameter represents breathing rate and is used for calculation of inhalation doses. The standard (default) is 3.30E-04 m^3/sec. This breathing rate is taken from the Reference Man (70-kg adult male at light work derived from Shleien 1992; Table 12.6). The value in the cited table has been converted from liters per hour to m^3/sec. This can be seen in Figures 29, 31, and 32.

Cleanup Level

This parameter is the desired concentration, in microcuries/m^2, to which a contaminated surface should be cleaned. The parameter is the sum of deposited activity over all radionuclides of a multi-radionuclide material. The standard (default) value is the EPA guidance of 0.2 uCi/m^2 (EPA, 1977). This can be seen in Figures 29, 31, and 32. In order to estimate ground contamination accurately, this value may be changed to some number much larger than the default value (e.g., 100 uCi/m^2).

Interdiction Threshold

This parameter specifies the threshold value for interdiction of contaminated land. The standard (default) value is 40, i.e., a value 40 times greater than the **Cleanup Level**, and it was taken from NUREG-0170 (NRC, 1977). This can be seen in Figures 29, 31, and 32. RADTRAN does not calculate ground deposition or groundshine doses if the interdiction value is exceeded. Therefore, in order to estimate ground contamination accurately, this value may be changed to some number much higher than the default value (e.g., 10,000).

Evacuation time for groundshine

This parameter specifies evacuation time in days following a dispersal accident. The standard (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. This can be seen in Figures 29, 31, and 32.

Survey interval for groundshine

This parameter is used to specify the time (in days) required to survey contaminated land following a dispersal accident. The standard (default) value is 10 days (NRC, 1977). This can be seen in Figures 29, 31, and 32.

Occupational latent cancer fatalities per person-REM

This parameter specifies the occupational Latent Cancer Fatality (LCF) conversion factor for worker exposure; units are LCF's per REM. The standard (default) value for workers is 4.0E-04 LCF/REM. This value, bases on the linear non-threshold theory of radiation carcinogenesis, is consistent with the recommendations of BEIR V (NRC/NAS, 1990) and ICRP 60 (ICRP, 1991). Another value that may be used for workers is 5.0E-04 LCF/REM and is consistent with the recommendations from the Interagency Steering Committee on Radiation Standards (DOE 2002). The dose-response relationship is assumed to be a linear with no threshold in order to agree with current regulations. This can be seen in Figures 29, 31, and 32.

Public latent cancer fatalities per person-REM

This parameter specifies the non-occupational Latent Cancer Fatality (LCF) conversion factor for public exposure; units are LCF's per REM. The standard (default) value for the public is 5.0E-04 LCF/REM. This value, based on the linear non-threshold theory of radiation carcinogenesis, is consistent with the recommendations of BEIR V (NRC/NAS, 1990) and ICRP 60 (ICRP, 1991). Another value for the public that may also be used is 6.0E-04 and is consistent wit the recommendations from the Interagency Steering Committee on Radiation Standards (DOE 2002). The dose-response relationship is assumed to be a linear with no threshold in order to agree with current regulations. This can be seen in Figures 29, 31, and 32.

Genetic effects per person-REM (public)

This parameter specifies the Genetic Effects Conversion Factor (GECF). The standard (default) value is 1.0E-04 genetic effects/REM. This value is consistent with the recommendations of BEIR V (NRC/NAS, 1990) and ICRP 60 (ICRP, 1991). This can be seen in Figures 29, 31, and 32.

Campaign

This parameter specifies the duration of the shipping campaign in years. The standard (default) value is 0.0833 years, an average month in an average year or $1/12^{th}$ of a year. This value calculates the total number of off-link persons exposed, using the Census Bureau algorithm for the average length of residence in the U.S. This result may be used to perform external calculations of the average off-link individual dose for the entire campaign. This can be seen in Figures 29, 31, and 32.

REM per curie thyroid via inhalation

This parameter is used to specify one-year Committed Effective Dose Equivalent (CEDE) in 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 the 50-year CEDE was used to approximate the one-year dose. One-year committed doses to the thyroid have been calculated directly from 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 radioiodines. The information has been included in this parameter instead. The standard (default) values are 1.27E+06 for Iodine-131, 5.77E+06 for Iodine-129, and 9.25E+05 for Iodine-125. This can be seen in Figures 29, 31, and 32.

Distance of freeway vehicle carrying radioactive cargo to pedestrians

The standard (default) value is 30 meters and is taken from NUREG-0170(NRC, 1977). This parameter is the minimum pedestrian-walkway width, for instances in which does to pedestrians beside the link is calculated. This parameter is the minimum perpendicular distance over which the off-link dose calculation will be integrated. This can be seen in Figure 29. A freeway is any limited-access divided highway.

Distance of freeway vehicle carrying radioactive cargo to right-of-way edge

The standard (default) value is 30 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum pedestrian-walkway width. This parameter is set equal to **Distance of freeway car carrying radioactive cargo to pedestrians**. This means that the sidewalk width is zero and thus there is no sidewalk available. This can be seen in Figure 29. A freeway is any limited-access divided highway.

Distance of freeway vehicle carrying radioactive cargo to maximum exposure distance

The standard (default) value is 800 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum perpendicular distance over which the off-link dose calculations will be integrated. This can be seen in Figure 29. A freeway is any limited-access divided highway.

Distance of non-freeway vehicle carrying radioactive cargo to pedestrians

The standard (default) value is 27 meters and is taken from NUREG-0170(NRC, 1977). This parameter is the minimum pedestrian-walkway width, for instances in which doses to pedestrians beside the link is calculated. This parameter is the minimum perpendicular distance over which the off-link dose calculation will be integrated. This can be seen in Figure 29. A non-freeway is any non-limited-access highway that is not a city street.

Distance of non-freeway vehicle carrying radioactive cargo to right-of-way edge

The standard (default) value is 30 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum pedestrian-walkway width. This parameter is set 3 meters greater than to **Distance of non-freeway vehicle carrying radioactive cargo to pedestrians**. This means that the sidewalk width is 3 meters and will thus allow for an off-link dose to be calculated to unshielded persons (pedestrians, bicyclists, ect.) where they may reasonably be expected to be found. This can be seen in Figure 29. A non-freeway is any non-limited-access highway that is not a city street.

Distance of non-freeway vehicle carrying radioactive cargo to maximum exposure distance

The standard (default) value is 800 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum perpendicular distance over which the off-link dose calculations will be integrated. This can be seen in Figure 29. A non-freeway is any non-limited-access highway that is not a city street.

Distance of city street vehicle carrying radioactive cargo to pedestrians

The standard (default) value is 5 meters and is taken from NUREG-0170(NRC, 1977). This parameter is the minimum pedestrian-walkway width, for instances in which does to pedestrians beside the link is calculated. This parameter is the minimum perpendicular distance over which the off-link dose calculation will be integrated. This can be seen in Figure 30. A city street is any city street.

Distance of city street vehicle carrying radioactive cargo to right-of-way edge

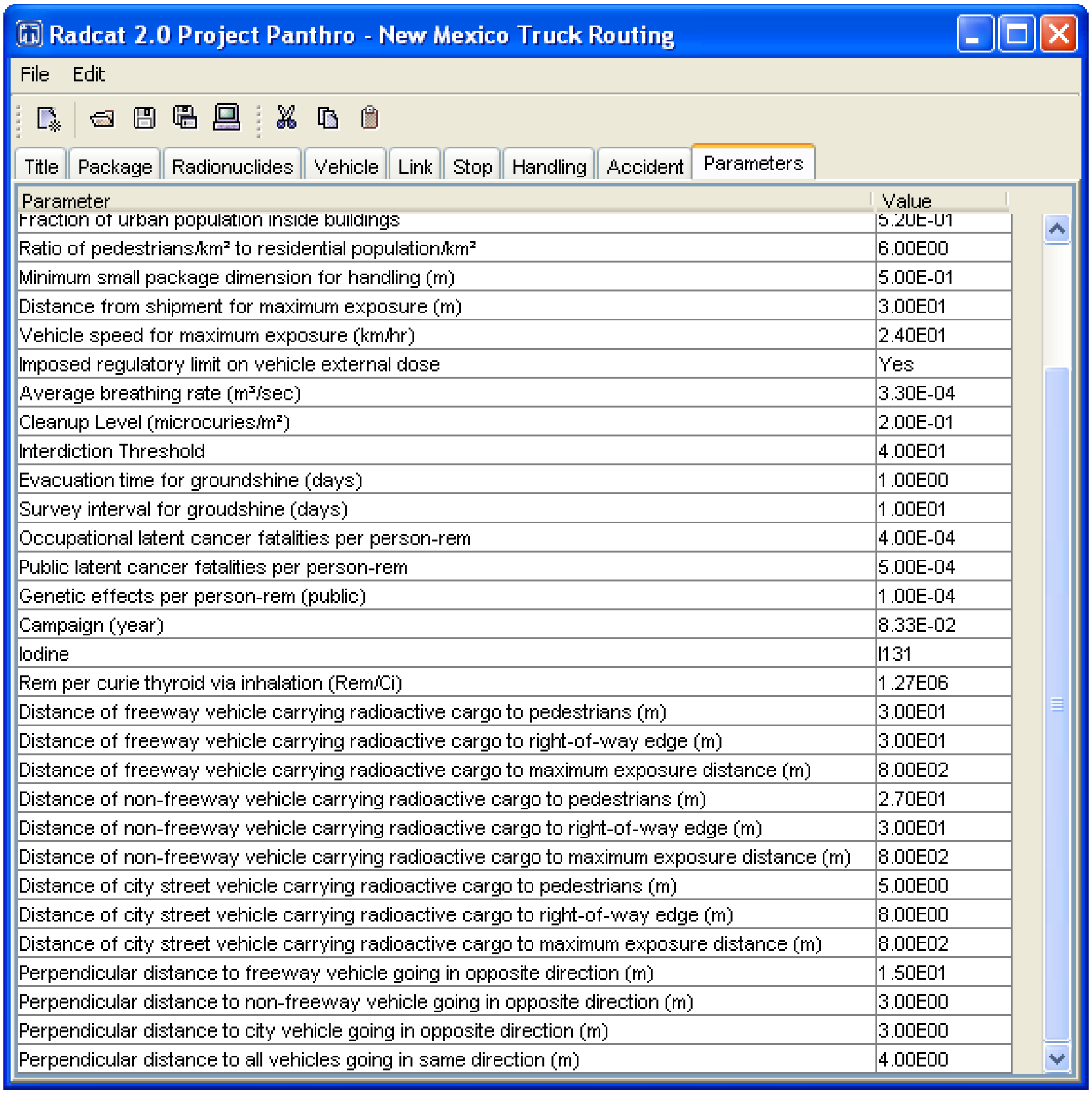
The standard (default) value is 8 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum pedestrian-walkway width. This parameter is set 3 meters greater than to **Distance of city street car carrying radioactive cargo to pedestrians**. This means that the sidewalk width is 3 meters and will thus allow for an off-link dose to be calculated to unshielded persons (pedestrians, bicyclists, ect.) where they may reasonably be expected to be found. This can be seen in Figure 30. A city street is any city street.

Distance of city street vehicle carrying radioactive cargo to maximum exposure distance

The standard (default) value is 800 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum perpendicular distance over which the off-link dose calculations will be integrated. This can be seen in Figures 30. A city street is any city street.

Perpendicular distance to freeway vehicle going in the opposite direction

The standard (default) value is 15 meters and is taken from Madsen et al. (1986 p. 36-37). This can be seen in Figure 30. This parameter specifies the perpendicular distance (i.e. a distance measured along a ling at right angles to the line of travel of the RAM shipment) between the RAM shipment and other traffic lanes, in meters. This is an average perpendicular distance between the shipment centerline and the centerline of oncoming traffic lanes. This value is based on a minimal Interstate configuration of four lanes with an average lane width of 5 meters, in the most typical traffic configuration. The latter refers to the RAM shipment being in the outside lane, oncoming traffic in the corresponding outside lane, and passing vehicles in the inner lanes. A freeway is any limited-access divided highway.



Radcat 2.0 Project Panthro - New Mexico Truck Routing

File Edit

Title | Package | Radionuclides | Vehicle | Link | Stop | Handling | Accident | Parameters

Parameter	Value
Fraction of urban population inside buildings	5.20E-01
Ratio of pedestrians/km² to residential population/km²	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 (m³/sec)	3.30E-04
Cleanup Level (microcuries/m²)	2.00E-01
Interdiction Threshold	4.00E01
Evacuation time for groundshine (days)	1.00E00
Survey interval for groudshine (days)	1.00E01
Occupational latent cancer fatalities per person-rem	4.00E-04
Public latent cancer fatalities per person-rem	5.00E-04
Genetic effects per person-rem (public)	1.00E-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 non-freeway vehicle carrying radioactive cargo to pedestrians (m)	2.70E01
Distance of non-freeway vehicle carrying radioactive cargo to right-of-way edge (m)	3.00E01
Distance of non-freeway vehicle carrying radioactive cargo to maximum exposure distance (m)	8.00E02
Distance of city street vehicle carrying radioactive cargo to pedestrians (m)	5.00E00
Distance of city street vehicle carrying radioactive cargo to right-of-way edge (m)	8.00E00
Distance of city street vehicle 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 30: Parameters Tab with Highway Mode Continued

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

The standard (default) value is 3 meters and is taken from Madsen et al. (1986 p. 36-37). This can be seen in Figure 30. This parameter specifies the perpendicular distance (i.e. a distance measured along a line at right angles to the line of travel of the RAM shipment) between the RAM shipment and other traffic lanes, in meters. This is an average perpendicular distance between the shipment centerline and the centerline of oncoming traffic lanes. This value is based on a minimal road configuration of two lanes with an average lane width of 3 meters, in the most typical traffic configuration. A non-freeway is any non-limited-access highway that is not a city street.

Perpendicular distance to city vehicle going in the opposite direction

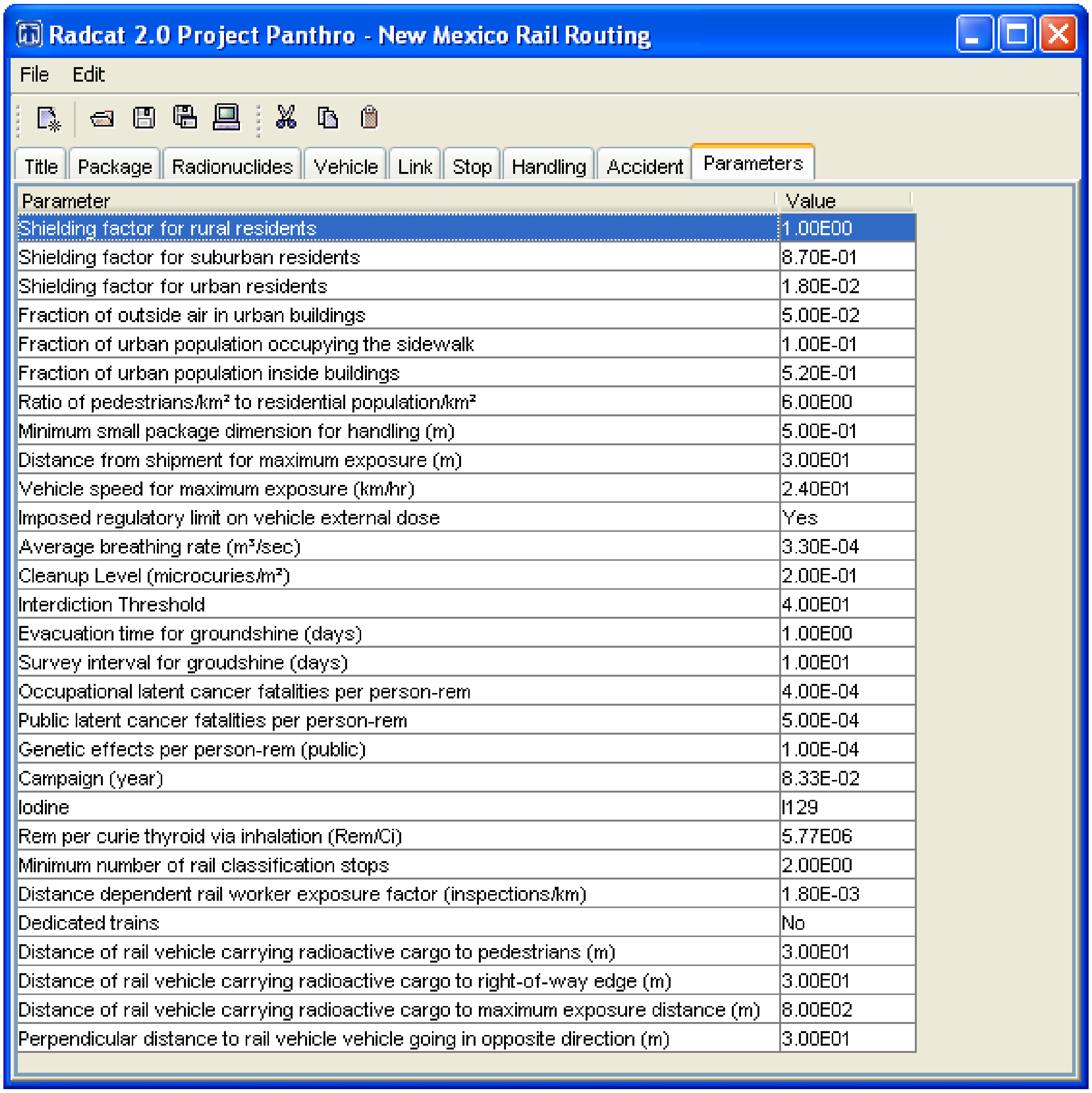
The standard (default) value is 3 meters and is taken from Madsen et al. (1986 p. 36-37). This can be seen in Figure 30. This parameter specifies the perpendicular distance (i.e. a distance measured along a line at right angles to the line of travel of the RAM shipment) between the RAM shipment and other traffic lanes, in meters. This is an average perpendicular distance between the shipment centerline and the centerline of oncoming traffic lanes. This value is based on a minimal road configuration of two lanes with an average lane width of 3 meters, in the most typical traffic configuration. A city street is any city street.

Perpendicular distance of all vehicles going in the same direction

The standard (default) value is 4 meters and is taken from Madsen et al. (1986). This can be seen in Figure 30. This parameter specifies the perpendicular distance (i.e. a distance measured along a line at right angles to the line of travel of the RAM shipment) between the RAM shipment and other traffic lanes, in meters. This is an average perpendicular distance between the shipment centerline and the centerline of adjacent passing vehicles. This value is based on the median value for all Interstate and secondary-road lane widths.

Minimum number of rail classification stops

This applies to rail mode only and specifies the minimum number of railcar classifications per trip. The standard (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). When the origin of a rail shipment is very different from its destination, it may be useful to change the value to 1. 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 these workers at classification stops. The dose is the weighted sum of the doses for all close-proximity 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 the RADTRAN 5 Technical Manual (Neuhauser, et al, 2000). This can be seen in Figure 31.



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	1.00E-01
Fraction of urban population inside buildings	5.20E-01
Ratio of pedestrians/km² to residential population/km²	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 (m³/sec)	3.30E-04
Cleanup Level (microcuries/m²)	2.00E-01
Interdiction Threshold	4.00E01
Evacuation time for groundshine (days)	1.00E00
Survey interval for groudshine (days)	1.00E01
Occupational latent cancer fatalities per person-rem	4.00E-04
Public latent cancer fatalities per person-rem	5.00E-04
Genetic effects per person-rem (public)	1.00E-04
Campaign (year)	8.33E-02
Iodine	I129
Rem per curie thyroid via inhalation (Rem/Ci)	5.77E06
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)	3.00E01

Figure 31: Parameters Tab with Rail Mode

Distance dependant rail worker exposure factor per km

This parameter applies to rail mode only. It is used to calculate the component of rail-worker dose that depends on distance traveled (e.g., exposure related to stops between the shipment origin and destination). The standard (default) value of 0.0018 inspections/km is taken from Ostmeyer (1986). 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. This can be seen in Figure 31.

Dedicated Trains

This is only used for rail mode. It denotes whether the shipment is by general freight or key trains (**NO**) or by dedicated rail (**YES**). The standard (default) setting is **NO**. This can be seen in Figure 31. The main difference between the two options is the exposures of rail workers in rail yards. For dedicated rail, worker dose is calculated with factors b_8 through b_{11} of Appendix B of the RADTRAN 5 Technical Manual (Neuhauser, et al, 2000).

Distance of rail car carrying radioactive cargo to pedestrians

The standard (default) value is 30 meters and is taken from NUREG-0170(NRC, 1977). This parameter is the minimum perpendicular distance over which the off-link dose calculation will be integrated. This parameter is the minimum pedestrian-walkway width, for instances in which does to pedestrians beside the link is calculated. This can be seen in Figure 31. A rail route is any rail right-of-way in the U.S.

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

The standard (default) value is 30 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum pedestrian-walkway width. This parameter is set equal to **Distance of rail car carrying radioactive cargo to pedestrians**. This means that the sidewalk width is zero and thus there is no sidewalk available. This can be seen in Figure 31. A route is any rail right-of-way in the U.S.

Distance of rail car carrying radioactive cargo to maximum exposure distance

The standard (default) value is 800 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum perpendicular distance over which the off-link dose calculations will be integrated. This can be seen in Figure 31. A rail route is any rail right-of-way in the U.S.

Perpendicular distance to rail car vehicle going in the opposite direction

The standard (default) value is 3 meters and is taken from Madsen et al. (1986 p. 36-37). This can be seen in Figure 31. This parameter specifies the perpendicular distance (i.e. a distance measured along a line at right angles to the line of travel of the RAM shipment) between the RAM shipment and other traffic lanes, in meters. This is an average perpendicular distance between the shipment centerline and the centerline of oncoming traffic lanes. This value is based on a minimum clearance between passing trains on double rail segments. A rail route is any rail right-of-way in the U.S.

Distance of waterway barge carrying radioactive cargo to pedestrians

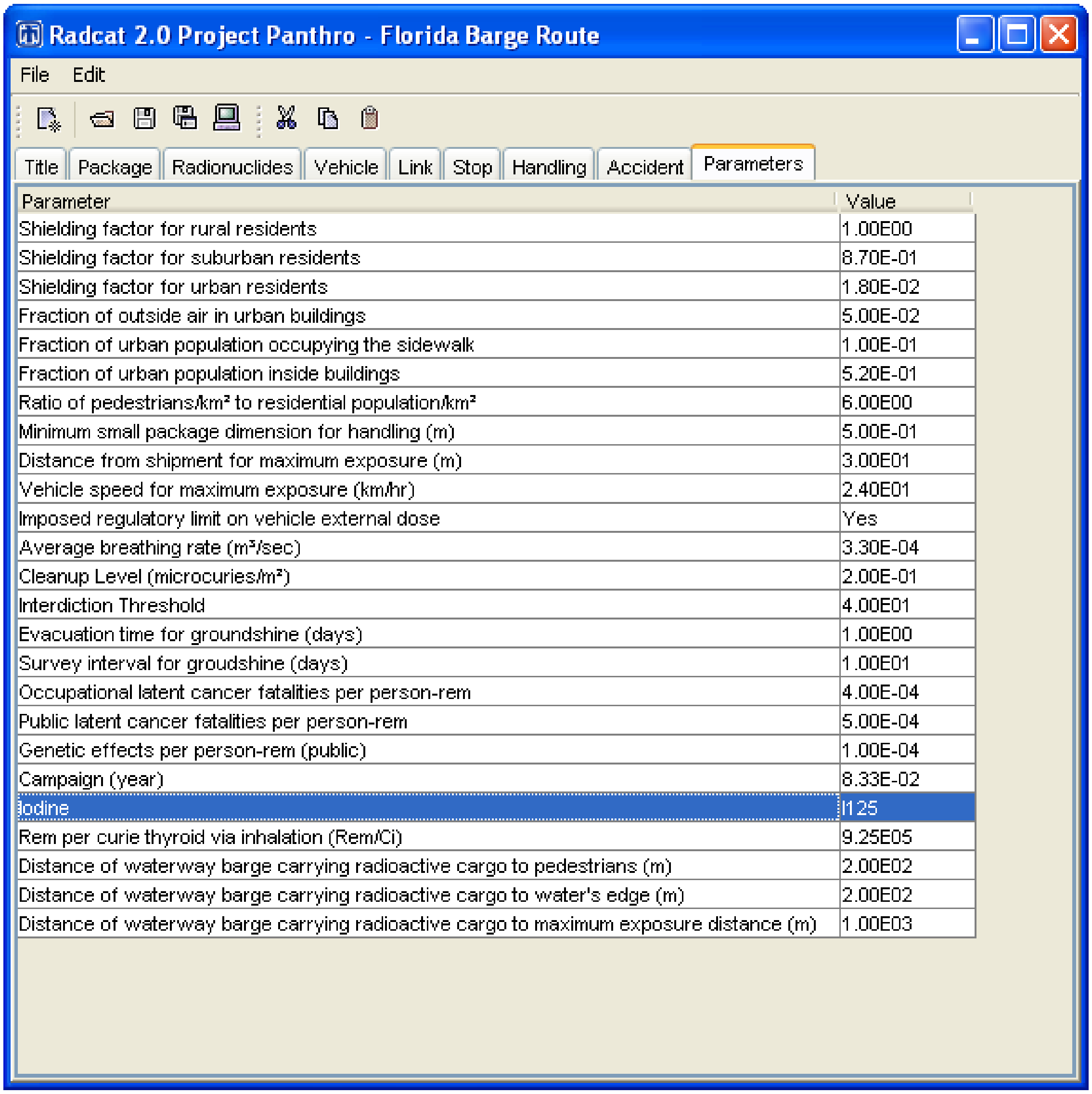
The standard (default) value is 200 meters and is taken from NUREG-0170(NRC, 1977). This parameter is the minimum pedestrian-walkway width, for instances in which does to pedestrians beside the link is calculated. This parameter is the minimum perpendicular distance over which the off-link dose calculation will be integrated. This can be seen in Figure 32.

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

The standard (default) value is 200 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum pedestrian-walkway width. This parameter is set equal to **Distance of waterway barge carrying radioactive cargo to pedestrians**. This means that the sidewalk width is zero and thus there is no sidewalk available. This can be seen in Figure 32.

Distance of waterway barge carrying radioactive cargo to maximum exposure distance

The standard (default) value is 1000 meters and is taken from NUREG-0170 (NRC, 1977). This parameter is the maximum perpendicular distance over which the off-link dose calculations will be integrated. This can be seen in Figure 32.



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	1.00E-01
Fraction of urban population inside buildings	5.20E-01
Ratio of pedestrians/km² to residential population/km²	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 (m³/sec)	3.30E-04
Cleanup Level (microcuries/m²)	2.00E-01
Interdiction Threshold	4.00E01
Evacuation time for groundshine (days)	1.00E00
Survey interval for groudshine (days)	1.00E01
Occupational latent cancer fatalities per person-rem	4.00E-04
Public latent cancer fatalities per person-rem	5.00E-04
Genetic effects per person-rem (public)	1.00E-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)	1.00E03

Figure 32: Parameters Tab with Barge Mode

6. SAVING, RUNNING RADTRAN, EXITING

The input file can be saved with either the **Save** or the **Save As** icon. Your file will be saved as a **".rml"** file. You do not need to add this extension to your filename when saving it. This can be seen in Figure 33. The file may be run in RADTRAN by clicking on the **Run RADTRAN** icon (the computer icon). If the file is not saved a prompt will appear to save the file before running it. If the file has already been saved, the prompt will not appear.

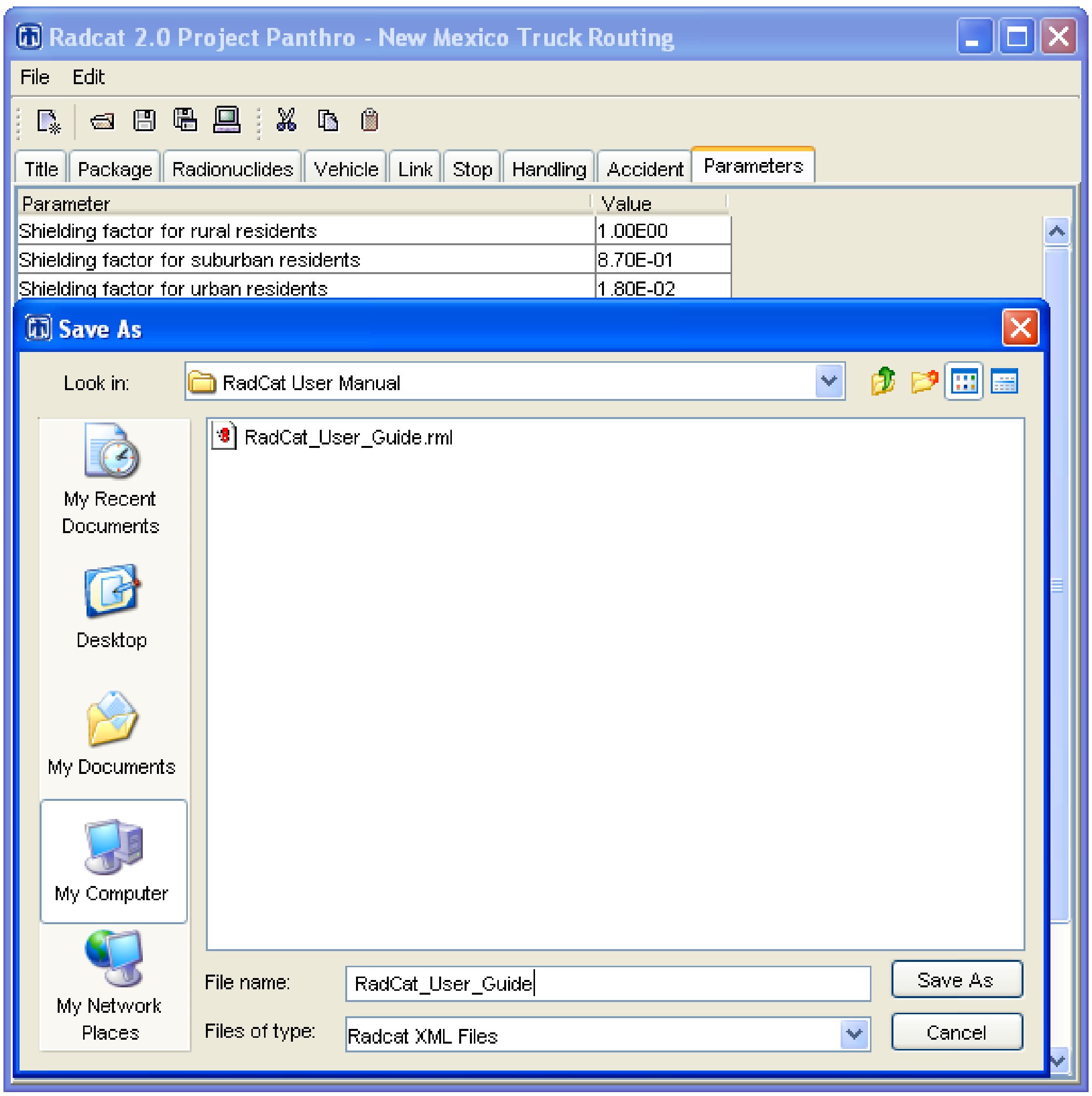


Figure 33: Saving a RADCAT 2.0 input file

When RADTRAN is run, the output appears immediately on the screen, and may be printed and/or saved. This output file can be saved as a text file (*filename*.txt), an excel file (*filename*.xls), or a word document (*filename*.doc). 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. This is rare when the input file is created using RadCat. The error message that appears at the end of the output file in these cases is usually self-explanatory.

Exit from RADTRAN/RADCAT by clicking on the "x" in the upper right-hand corner as seen in Figure 34.

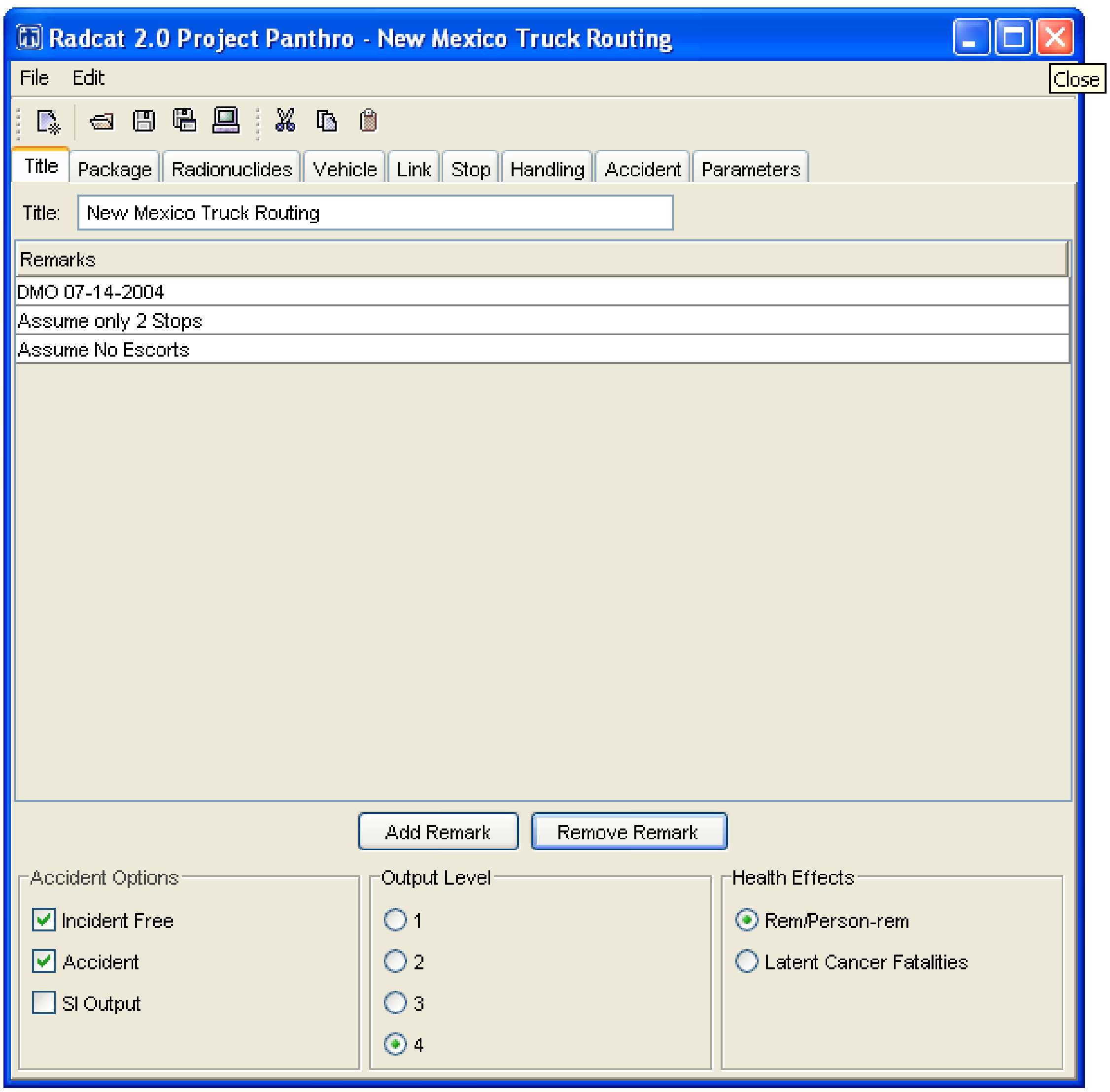


Figure 34: Closing RADTRAN / RADCAT

7.0 REFERENCES

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APPENDIX A: RADTRAN 5 REFERENCE SHEET

Creating RADTRAN 5.5 Files with a Text Editor

Key:
[Brackets] indicate an optional statement
{Braces} indicate a required value
ALL CAPS indicates a keyword that must be entered

TITLE **{alphanumeric title}**
INPUT **{STANDARD (Default values) or ZERO}**
[OUTPUT] **{BQ_SV for SI Units}**
FORM **{UNIT for population dose or NONUNIT for health effects}**
DIMEN **{# of severity categories} {# of nondispersal accident radii} {# of dispersal areas}**
PARM **{0 no plotting/1 plotting} {1 incident free/2 accident/3 both} {1/2/3/4 level of output} {0 User-supplied time-integrated concentration isopleths and areas/1 Pasquill stability fractions/2 User-defined metrological conditions}**
SEVERITY
  NPOP = **{1 rural}**
    NMODE = **{transport mode (see Mode Chart in Table 1)}**
      {Severity Fraction 1} {Severity Fraction 2} {Severity Fraction 3...}
  NPOP = **{2 suburban}**
    NMODE = **{transport mode (see Mode Chart in Table 1)}**
      {Severity Fraction 1} {Severity Fraction 2} {Severity Fraction 3...}
  NPOP = **{3 urban}**
    NMODE = **{transport mode (see Mode Chart in Table 1)}**
      {Severity Fraction 1} {Severity Fraction 2} {Severity Fraction 3...}

RELEASE
  GROUP=**{group name}**
    RFRAC
      {Release Fraction 1} {Release Fraction 2} {Release Fraction 3...}
    AERSOL
      {Aerosol Fraction 1} {Aerosol Fraction 2} {Aerosol Fraction 3...}
    RESP
      {Respirable Fraction 1} {Respirable Fraction 2} {Respirable Fraction 3...}
    LOS
      {Loss of Shielding Fraction 1} {Loss of Shielding Fraction 2...}
    DEPVEL
      Deposition Velocity of Group (m/s)
  [GROUP=...]

  [ISOPLETHP]
    {Population density of isopleth 1} {Population density of isopleth 2...}
  [AREADA]
    {Area of Isopleth 1 (m^2)} {Area of Isopleth 2...}
  [DFLEV]
    {Dilution Factor for Isopleth 1} {Dilution Factor for Isopleth 2...}
  [CLINE]
    {Center-Line Distance for Isopleth 1 (m)} {Center-Line Distance for Isopleth 2...}

  [PSPROB]
    {Pasquill Category A Fraction} {Pasquill Category B Fraction...}

[RISKIND] **(See Definitions for Input to the RISKIND Dispersion Model)**
&& USE_RADTRAN, REL_HT, HEAT_REL, SRC_WDTH, SRC_HT
0 10.0 100000 3.45 2.87
&& WS, ANEM_HT, AMB_T, HT_MIX, RAIN_RT
4.0 10.0 298.0 5000 0.0
&& (Pasquill-1, Briggs-2), Stability (A=1 through F=6)
1 4
&& (Rural-1, Urban/Suburban-2)
2

[DEFINE] **{Radionuclide Name}**
{Half-life (days)} {Photon Energy (MeV/disintegration)} {Cloudshine dose factor (rem-m^3/Ci-second)} {Groundshine dose factor (rem-m^3/μCi-day)} {50-yr committed effective dose equivalent for inhalation (rem/Ci inhaled)} {50-yr committed effective gonad dose for inhalation (rem/Ci inhaled)} {1-yr lung dose for inhalation (rem/Ci inhaled)} {1-yr marrow dose for inhalation (rem/Ci inhaled)}
{Name for COMIDA Ingestion Data (or NONE)}
[DEFINE] **{Radionuclide Name...}**

PACKAGE **{alphanumeric identifier} {dose rate at 1m (mrem/hr)} {gamma fraction} {neutron fraction} {package dimension (m)}**
{Radionuclide Name} {Package Inventory (Ci)} {Group Name}
[**{Radionuclide Name} {Package Inventory (Ci)} {Group Name...}**]
END

VEHICLE **{minus sign if shipment is exclusive} {transportation mode number (see mode chart)} {identifier} {dose rate at one meter from vehicle (mrem/hr)} {gamma fraction} {neutron fraction} {vehicle length (m)} {number of shipments} {number of crew members} {distance of crew from package (m)} {crew shielding factor} {crew view dimension (m)}**
{package identifier} {number of packages per shipment}
[**{package identifier} {number of packages per shipment...}**]

[FLAGS]
{see Flag Chart in Table 2}
[MODSTD]
{see MODSTD Standard Values List}
EOF

LINK **{link identifier} {vehicle name} {segment length (km)} {velocity (kph)} {vehicle occupancy} {population density (persons/km^2)} {vehicle density} {accident rate (acc/km)} {R rural/S suburban/U urban} {1 interstate/2 non-interstate/3 other} {farm fraction}**
[LINK] **{link identifier...}**

STOP **{stop identifier} {vehicle name} {population density (annular) or number of persons (radial)} {minimum annular radius} {maximum annular radius (or same as minimum for radial)} {shielding fraction} {stop time (hr)}**
[STOP] **{stop identifier...}**

HANDLING **{handling identifier} {vehicle name} {number of handlers} {average handler distance} {handling time per package (hr)}**
[HANDLING] **{handling identifier...}**

EOF
EOI

Table 1: Mode Chart

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 2 – Flag Chart

Flag Name	Flag Description	STANDARD (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 used to examine particular scenarios such as loss-of-shielding or accidents involving non-dispersible package contents	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 buildings are exposed at reduced rates and the reduction in dose rate is a function of the shielding factors RR, RS, and RU. 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 (being indoors provides no protection and is the same as being outdoors).	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. The analyst may set REGCHECK = 0, which bypasses the regulatory-check subroutine.	1

MODSTD STANDARD (Default) VALUES LIST

MODSTD Name	Description	STANDARD (Default) Value
BDF	This is the Building Dose Factor. This 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 standard (default) value of 0.05 represents a conservative average across a series of building types, including residential, office, and industrial structures (Engelmann, 1990). This value 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 1992; Table 12.6) has been used as the standard (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 standard (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. Although never officially adopted by the EPA or superseded by another standard, this value has become a *de facto* standard (Chanin and Murfin, 1996). This is a controversial issue at present, and 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 standard (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. [For non-dispersal accident evacuation, see TIMENDE.]	1.0

MODSTD Name	Description	STANDARD (Default) Value
GECON	This parameter specifies the Genetic Effects Conversion Factor. The standard (default) value is 1.0E-04 genetic effects/rem. This value is consistent with the recommendations of BEIR V (NRC/NAS, 1990) and ICRP 60 (ICRP, 1991). Estimates based on the only genetic effects (untoward pregnancy outcome and F_1 mortality) to have been documented in the atomic-bomb survivors have extremely high statistical and model uncertainties. Animal data, which is more reliable, consistently yield lower estimates. As noted in BEIR V, the recommended value is "probably …too high rather than too low" (NRC/NAS, 1990, p. 77).	1.00E-04
INTERDICT	This parameter specifies the threshold value for interdiction of contaminated land. The standard (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 standard (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 DDRRF (Dose and Dose Rate Reduction Factor) of 2. These values are consistent with the recommendations of BEIR V (NRC/NAS, 1990) 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 V, is not incompatible with zero (NRC/NAS, 1990, p. 181). Thus, cancer risk estimates obtained from RADTRAN 5 will be generally conservative.	5.0E-04 for the public 4.04E-04 for workers
LOS	The parameter is used to analyze loss-of-shielding accidents. It represents the fractional degradation of package shielding for each severity category in the analysis. Values may be any number between zero and 1.0.	
NE	This parameter is the neutron emission factor; it may be used to model neutron emissions following a loss-of-shielding accident. For commonly encountered radionuclides that spontaneously emit neutrons (curium-242, curium-244, and californium-242), the NE values are already available in the radionuclide library. All other radionuclides have no assigned NE factor. The NE keyword is applied only when the analyst wishes to assign a new value to an existing radionuclide or to a new material. The analyst must enter NE followed by the radionuclide name in standard format (or exactly as entered under keyword DEFINE) and the emission factor value in neutrons/s-Ci. The analyst must repeat the process (i.e., type NE followed by radionuclide name and NE factor value) for each radionuclide desired.	

MODSTD Name	<u>Description</u>	STANDARD (Default) Value
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.	
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 standard (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 standard (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. Three values are entered, one for each population-density zone (rural, suburban, and urban, in that order). TIMENDE represents the time required to move potentially exposed members of the public to safe distances beyond the areas specified by the RADIST keyword. The three STANDARD values are 0.67, 0.67, and 0.42 hours (Mills et al., 1995) [for dispersal accident evacuation, see EVACUATION]	0.67 for rural 0.67 for suburban 0.42 for urban
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 standard (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

MODSTD Name	Description	STANDARD (Default) Value
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 standard (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 standard (default) value is 0.0833 years. This is an average month in an average year, or 1/12th 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 standard (default) value of 0.0018 inspections/km is taken from Ostmeyer (1986).	0.0018

MODSTD Name	Description	STANDARD (Default) Value
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 standard (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
	Note: that the values are the same for FREEWAY and RAIL. Setting the first two values equal to each other is equivalent to a sidewalk width of zero and means there are no sidewalks or similar close-in areas where unshielded persons (pedestrians, bicyclists, etc.) may reasonably be expected to be found. For STREET, the sidewalk is modeled as being 3 m wide (Finley et al. 1980). The values for WATER conservatively model a narrow navigable waterway (e.g., Houston Ship Channel) and are taken from NUREG-0170 (NRC, 1977). The WATER values are the ones most likely to require modification by the analyst since other bodies of water that might be modeled have ship-to-shore distances that greatly exceed 200 m and even 800 m.	

MODSTD Name	Description	STANDARD (Default) Value
DISTON	This keyword specifies a perpendicular distance (i.e., a distance measured along a line at right angles to the line of travel of the RAM shipment) between the RAM shipment and other traffic lanes, in meters. For three link types, DISTON represents the *average* perpendicular distance between the shipment *centerline* and the *centerline* of oncoming traffic lanes(s). In the passing-vehicle case, DISTON represents the distance between the shipment *centerline* and the *centerline* of adjacent passing vehicles (HIGHWAY mode only). DISTON must be followed by a second keyword that specifies the link type. The standard (default) values in parentheses in the following list are taken from Madsen et al. (1986, p. 36-37).	
	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
	Note: The FREEWAY value is based on the Madsen et al. (1986) model of a minimal Interstate configuration of 4 lanes with an average lane width of 5 m, in the most typical traffic configuration. The latter refers to the RAM shipment being in the outside lane, oncoming traffic in the corresponding outside lane, and passing vehicles in the inner lanes. The SECONDARY and STREET values are smaller because these roadways are modeled as being only 2 lanes wide with an average lane width of 3 m. The RAIL value is based on the minimum clearance between passing trains on double rail segments. The ADJACENT value represents the median value for all Interstate and secondary-road lane widths.	

MODSTD Name	Description	STANDARD (Default) Value
FMINCL	This keyword is applied to rail mode only and specifies the minimum number of railcar classifications or inspections per one-way trip. The standard (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 standard (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 standard (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 standard (default) value is 24.0 km/hr (15 mph) (NRC, 1977).	24
RAIL	See DISTOFF and DISTON	

MODSTD Name	<u>Description</u>	STANDARD (Default) Value
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 standard (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 standard (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 standard (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 standard (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

MODSTD Name	Description	STANDARD (Default) Value
SECONDARY	See DISTOFF and DISTON	
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 standard (default) value for SMALLPKG is 0.5 m (Javitz, 1985). Although it is highly unlikely that this value will need to be altered, the analyst has the option to do so.	0.5
STREET	See DISTOFF and DISTON	

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_WDTH:	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

APPENDIX B: DOSE CONVERSION FACTORS

Correspondence for the radionuclide arrays:

1. Half-Life (days). Source: ICRP 38 (as reported in Federal Guidance Report (FGR) 12)

2. Photon Energy (MeV). Source: ICRP 38 (this value is not used in RADTRAN 5.5)

3. Cloud/Immersion Dose Factor (rem-m^3/Ci-sec). Source: FGR 12 (multiply by $3.7x10^{12}$ to convert)

4. Groundshine Dose Factor (rem-m^2/μCi-day). Source: FGR 12 (multiply by $3.197x10^{11}$ to convert)

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 $3.7x10^{12}$ to convert)

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 $3.7x10^{12}$ to convert)

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 $3.7x10^{12}$ to convert)

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 $3.7x10^{12}$ to convert)

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

Note the following:

Inhalation values are based on 1.0-micron AMAD particle except for the following radionuclides:

- Kr-85, Xe-133M, and Xe-133 are gases.
- H-3(WTR) which is tritiated water.
- H-3(GAS) which is elemental hydrogen vapor.
- C-14(ORG) which is organic gases and vapors.
- C-14(GAS) which is carbon dioxide.

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 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-m^3/Ci-sec)	Groundshine (rem-m^2/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-m^3/Ci-sec)	Groundshine (rem-m^2/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	1.01E-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-m^3/Ci-sec)	Groundshine (rem-m^2/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-m^3/Ci-sec)	Groundshine (rem-m^2/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 C: COMIDA DATABASE

Due to the amount of information that is in the COMIDA database, this appendix will only provide the ingestion information for one radionuclide. If the entire database is needed please contact one of the following persons at Sandia National Laboratories:

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The ingestion doses used by RADTRAN are taken from the COMIDA2 ingestion code and summed over all crop types. The summed values are then averaged over the dates and divided by the initial ground concentration of 1.00×10^{12} Bq/m^2.

The backyard farmer dose is used to calculate a maximum individual dose with the assumption that a family of 5 is on a totally self-reliant subsistence farm of 5×10^4 square meters (1 person per 1×10^4 square meters).

The individual backyard farmer dose is in units of (Sv/m^2) and the societal dose is in units of (person-Sv/m^2). The following tables list values taken directly from the COMIDA2 ingestion file for Na-22 radionuclide:

Julian	Na-22	Effective Backyard Farmer Dose Values							
Date	CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
1	2.60E-01	3.10E-01	3.10E-01	4.50E-01	2.80E-01	1.30E+03	1.50E+03	3.30E-01	8.30E+00
61	4.70E-01	5.60E-01	5.60E-01	8.30E-01	5.10E-01	2.80E+03	3.40E+03	3.40E-01	8.30E+00
121	3.90E+02	4.20E+02	5.30E+02	7.80E+02	4.50E+02	1.00E+04	1.20E+04	1.70E+00	4.10E+01
151	4.80E+02	5.10E+02	6.30E+02	9.20E+02	5.30E+02	1.10E+04	1.30E+04	2.00E+00	4.90E+01
181	5.40E+02	6.10E+02	7.10E+02	1.00E+03	6.00E+02	1.00E+04	1.20E+04	2.30E+00	5.70E+01
201	5.80E+02	6.90E+02	7.70E+02	1.10E+03	6.50E+02	1.10E+04	1.30E+04	2.60E+00	6.30E+01
241	6.60E+02	1.10E+03	8.60E+02	1.30E+03	7.30E+02	1.00E+04	1.30E+04	3.90E+00	9.70E+01
271	7.20E+02	3.00E+03	9.50E+02	1.40E+03	8.00E+02	1.30E+04	1.60E+04	1.00E+01	2.50E+02
301	3.70E-02	4.40E-02	4.40E-02	6.40E-02	4.00E-02	7.90E+02	9.40E+02	3.30E-01	8.20E+00

Julian Date	Na-22 CROP 1	CROP 2	CROP 3	CROP 4	Thyroid Backyard Farmer Dose Values CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
1	2.10E-01	2.50E-01	2.50E-01	3.60E-01	2.30E-01	1.00E+03	1.20E+03	2.70E-01	6.70E+00
61	3.80E-01	4.60E-01	4.50E-01	6.70E-01	4.10E-01	2.30E+03	2.70E+03	2.70E-01	6.70E+00
121	3.10E+02	3.40E+02	4.30E+02	6.30E+02	3.60E+02	8.30E+03	9.90E+03	1.30E+00	3.30E+01
151	3.90E+02	4.10E+02	5.10E+02	7.40E+02	4.30E+02	9.00E+03	1.10E+04	1.60E+00	4.00E+01
181	4.40E+02	4.90E+02	5.70E+02	8.40E+02	4.90E+02	8.40E+03	1.00E+04	1.90E+00	4.60E+01
201	4.70E+02	5.60E+02	6.20E+02	9.10E+02	5.20E+02	8.80E+03	1.10E+04	2.10E+00	5.10E+01
241	5.30E+02	9.00E+02	7.00E+02	1.00E+03	5.90E+02	8.40E+03	1.00E+04	3.20E+00	7.80E+01
271	5.80E+02	2.40E+03	7.60E+02	1.10E+03	6.50E+02	1.10E+04	1.30E+04	8.10E+00	2.00E+02
301	3.00E-02	3.50E-02	3.50E-02	5.10E-02	3.20E-02	6.40E+02	7.60E+02	2.70E-01	6.60E+00

Julian Date	Na-22 CROP 1	CROP 2	CROP 3	CROP 4	Gonad Societal Dose Values CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
1	3.80E-04	4.50E-04	4.50E-04	6.60E-04	4.10E-04	1.20E-01	1.40E-01	3.20E-05	7.80E-04
61	4.00E-04	4.80E-04	4.70E-04	7.00E-04	4.30E-04	2.60E-01	3.20E-01	3.20E-05	7.80E-04
121	6.20E-02	6.80E-02	8.40E-02	1.20E-01	7.10E-02	9.90E-01	1.20E+00	2.40E-04	6.00E-03
151	6.70E-02	7.20E-02	8.80E-02	1.30E-01	7.40E-02	1.10E+00	1.30E+00	2.60E-04	6.50E-03
181	6.80E-02	7.60E-02	8.90E-02	1.30E-01	7.50E-02	9.90E-01	1.20E+00	2.80E-04	6.80E-03
201	6.80E-02	8.10E-02	8.90E-02	1.30E-01	7.60E-02	1.00E+00	1.30E+00	2.90E-04	7.20E-03
241	6.80E-02	1.20E-01	8.90E-02	1.30E-01	7.60E-02	9.80E-01	1.20E+00	4.00E-04	9.90E-03
271	6.90E-02	2.80E-01	9.00E-02	1.30E-01	7.70E-02	1.20E+00	1.50E+00	9.50E-04	2.30E-02
301	3.60E-04	4.30E-04	4.30E-04	6.30E-04	3.90E-04	7.30E-02	8.80E-02	3.10E-05	7.80E-04

Julian Date	Na-22 CROP 1	CROP 2	CROP 3	CROP 4	Breast Societal Dose Values CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
1	3.50E-04	4.20E-04	4.10E-04	6.10E-04	3.80E-04	1.10E-01	1.30E-01	2.90E-05	7.10E-04
61	3.70E-04	4.40E-04	4.40E-04	6.40E-04	4.00E-04	2.40E-01	2.90E-01	2.90E-05	7.20E-04
121	5.70E-02	6.20E-02	7.80E-02	1.10E-01	6.60E-02	9.10E-01	1.10E+00	2.20E-04	5.50E-03
151	6.10E-02	6.60E-02	8.00E-02	1.20E-01	6.80E-02	1.00E+00	1.20E+00	2.40E-04	5.90E-03
181	6.20E-02	7.00E-02	8.20E-02	1.20E-01	6.90E-02	9.10E-01	1.10E+00	2.50E-04	6.20E-03
201	6.30E-02	7.40E-02	8.20E-02	1.20E-01	6.90E-02	9.60E-01	1.20E+00	2.70E-04	6.60E-03
241	6.30E-02	1.10E-01	8.20E-02	1.20E-01	7.00E-02	9.00E-01	1.10E+00	3.70E-04	9.10E-03
271	6.30E-02	2.60E-01	8.30E-02	1.20E-01	7.00E-02	1.10E+00	1.40E+00	8.70E-04	2.20E-02
301	3.30E-04	3.90E-04	3.90E-04	5.80E-04	3.60E-04	6.70E-02	8.10E-02	2.90E-05	7.10E-04

Julian Date	Na-22 CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
					Lungs Societal Dose Values				
1	3.40E-04	4.00E-04	4.00E-04	5.90E-04	3.70E-04	1.10E-01	1.30E-01	2.80E-05	7.00E-04
61	3.60E-04	4.20E-04	4.20E-04	6.20E-04	3.90E-04	2.40E-01	2.80E-01	2.80E-05	7.00E-04
121	5.60E-02	6.00E-02	7.50E-02	1.10E-01	6.40E-02	8.90E-01	1.10E+00	2.20E-04	5.30E-03
151	6.00E-02	6.40E-02	7.80E-02	1.10E-01	6.60E-02	1.00E+00	1.20E+00	2.30E-04	5.80E-03
181	6.10E-02	6.80E-02	7.90E-02	1.20E-01	6.70E-02	8.90E-01	1.10E+00	2.50E-04	6.10E-03
201	6.10E-02	7.20E-02	8.00E-02	1.20E-01	6.80E-02	9.40E-01	1.10E+00	2.60E-04	6.40E-03
241	6.10E-02	1.00E-01	8.00E-02	1.20E-01	6.80E-02	8.80E-01	1.00E+00	3.60E-04	8.80E-03
271	6.20E-02	2.50E-01	8.00E-02	1.20E-01	6.80E-02	1.10E+00	1.30E+00	8.50E-04	2.10E-02
301	3.20E-04	3.80E-04	3.80E-04	5.60E-04	3.50E-04	6.50E-02	7.80E-02	2.80E-05	6.90E-04

Julian Date	Na-22 CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
					Red Marrow Societal Dose Values				
1	5.80E-04	6.90E-04	6.90E-04	1.00E-03	6.30E-04	1.80E-01	2.20E-01	4.80E-05	1.20E-03
61	6.10E-04	7.30E-04	7.30E-04	1.10E-03	6.60E-04	4.00E-01	4.80E-01	4.80E-05	1.20E-03
121	9.50E-02	1.00E-01	1.30E-01	1.90E-01	1.10E-01	1.50E+00	1.80E+00	3.70E-04	9.10E-03
151	1.00E-01	1.10E-01	1.30E-01	2.00E-01	1.10E-01	1.70E+00	2.00E+00	4.00E-04	9.90E-03
181	1.00E-01	1.20E-01	1.40E-01	2.00E-01	1.10E-01	1.50E+00	1.80E+00	4.20E-04	1.00E-02
201	1.00E-01	1.20E-01	1.40E-01	2.00E-01	1.20E-01	1.60E+00	1.90E+00	4.40E-04	1.10E-02
241	1.00E-01	1.80E-01	1.40E-01	2.00E-01	1.20E-01	1.50E+00	1.80E+00	6.10E-04	1.50E-02
271	1.10E-01	4.30E-01	1.40E-01	2.00E-01	1.20E-01	1.90E+00	2.30E+00	1.50E-03	3.60E-02
301	5.50E-04	6.50E-04	6.50E-04	9.60E-04	5.90E-04	1.10E-01	1.30E-01	4.80E-05	1.20E-03

Julian Date	Na-22 CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
					Bone Surface Societal Dose Values				
1	7.50E-04	8.90E-04	8.90E-04	1.30E-03	8.10E-04	2.30E-01	2.80E-01	6.20E-05	1.50E-03
61	7.90E-04	9.40E-04	9.40E-04	1.40E-03	8.50E-04	5.20E-01	6.20E-01	6.20E-05	1.50E-03
121	1.20E-01	1.30E-01	1.70E-01	2.40E-01	1.40E-01	2.00E+00	2.30E+00	4.80E-04	1.20E-02
151	1.30E-01	1.40E-01	1.70E-01	2.50E-01	1.50E-01	2.20E+00	2.60E+00	5.20E-04	1.30E-02
181	1.30E-01	1.50E-01	1.80E-01	2.60E-01	1.50E-01	2.00E+00	2.30E+00	5.40E-04	1.30E-02
201	1.30E-01	1.60E-01	1.80E-01	2.60E-01	1.50E-01	2.10E+00	2.50E+00	5.70E-04	1.40E-02
241	1.30E-01	2.30E-01	1.80E-01	2.60E-01	1.50E-01	1.90E+00	2.30E+00	7.90E-04	1.90E-02
271	1.40E-01	5.60E-01	1.80E-01	2.60E-01	1.50E-01	2.40E+00	2.90E+00	1.90E-03	4.60E-02
301	7.10E-04	8.40E-04	8.40E-04	1.20E-03	7.70E-04	1.40E-01	1.70E-01	6.20E-05	1.50E-03

Julian	Na-22				Thyroid Societal Doe Values				
Date	CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
1	3.40E-04	4.00E-04	4.00E-04	5.90E-04	3.70E-04	1.10E-01	1.30E-01	2.80E-05	6.90E-04
61	3.60E-04	4.20E-04	4.20E-04	6.20E-04	3.80E-04	2.40E-01	2.80E-01	2.80E-05	6.90E-04
121	5.50E-02	6.00E-02	7.50E-02	1.10E-01	6.40E-02	8.80E-01	1.10E+00	2.20E-04	5.30E-03
151	5.90E-02	6.40E-02	7.80E-02	1.10E-01	6.60E-02	1.00E+00	1.20E+00	2.30E-04	5.80E-03
181	6.00E-02	6.80E-02	7.90E-02	1.20E-01	6.70E-02	8.80E-01	1.10E+00	2.50E-04	6.10E-03
201	6.10E-02	7.20E-02	7.90E-02	1.20E-01	6.70E-02	9.30E-01	1.10E+00	2.60E-04	6.40E-03
241	6.10E-02	1.00E-01	7.90E-02	1.20E-01	6.70E-02	8.70E-01	1.00E+00	3.60E-04	8.80E-03
271	6.10E-02	2.50E-01	8.00E-02	1.20E-01	6.80E-02	1.10E+00	1.30E+00	8.50E-04	2.10E-02
301	3.20E-04	3.80E-04	3.80E-04	5.60E-04	3.50E-04	6.50E-02	7.80E-02	2.80E-05	6.90E-04

Julian	Na-22				Remainder Societal Dose Values				
Date	CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
1	4.30E-04	5.10E-04	5.10E-04	7.50E-04	4.70E-04	1.30E-01	1.60E-01	3.60E-05	8.80E-04
61	4.50E-04	5.40E-04	5.40E-04	7.90E-04	4.90E-04	3.00E-01	3.60E-01	3.60E-05	8.80E-04
121	7.00E-02	7.70E-02	9.60E-02	1.40E-01	8.10E-02	1.10E+00	1.30E+00	2.70E-04	6.80E-03
151	7.60E-02	8.10E-02	9.90E-02	1.50E-01	8.40E-02	1.30E+00	1.50E+00	3.00E-04	7.30E-03
181	7.70E-02	8.60E-02	1.00E-01	1.50E-01	8.50E-02	1.10E+00	1.30E+00	3.10E-04	7.70E-03
201	7.70E-02	9.20E-02	1.00E-01	1.50E-01	8.60E-02	1.20E+00	1.40E+00	3.30E-04	8.10E-03
241	7.70E-02	1.30E-01	1.00E-01	1.50E-01	8.60E-02	1.10E+00	1.30E+00	4.50E-04	1.10E-02
271	7.80E-02	3.20E-01	1.00E-01	1.50E-01	8.70E-02	1.40E+00	1.70E+00	1.10E-03	2.70E-02
301	4.10E-04	4.80E-04	4.80E-04	7.10E-04	4.40E-04	8.30E-02	9.90E-02	3.60E-05	8.80E-04

Julian	Na-22				Effective Societal Dose Values				
Date	CROP 1	CROP 2	CROP 3	CROP 4	CROP 5	CROP 6	CROP 7	CROP 8	CROP 9
1	4.20E-04	5.00E-04	5.00E-04	7.30E-04	4.50E-04	1.30E-01	1.60E-01	3.50E-05	8.60E-04
61	4.40E-04	5.20E-04	5.20E-04	7.70E-04	4.80E-04	2.90E-01	3.50E-01	3.50E-05	8.60E-04
121	6.90E-02	7.50E-02	9.30E-02	1.40E-01	7.90E-02	1.10E+00	1.30E+00	2.70E-04	6.60E-03
151	7.40E-02	7.90E-02	9.70E-02	1.40E-01	8.20E-02	1.20E+00	1.50E+00	2.90E-04	7.10E-03
181	7.50E-02	8.40E-02	9.80E-02	1.40E-01	8.30E-02	1.10E+00	1.30E+00	3.00E-04	7.50E-03
201	7.50E-02	8.90E-02	9.90E-02	1.40E-01	8.30E-02	1.20E+00	1.40E+00	3.20E-04	7.90E-03
241	7.50E-02	1.30E-01	9.90E-02	1.40E-01	8.40E-02	1.10E+00	1.30E+00	4.40E-04	1.10E-02
271	7.60E-02	3.10E-01	9.90E-02	1.50E-01	8.40E-02	1.40E+00	1.60E+00	1.00E-03	2.60E-02
301	4.00E-04	4.70E-04	4.70E-04	6.90E-04	4.30E-04	8.10E-02	9.70E-02	3.50E-05	8.60E-04

Backyard Farmer Dose Example Calculation

An example of how to use the backyard farmer dose value charts is done with the following parameters:

Radionuclide:	Na-22
Number of Curies:	1.00 (Ci)
Release Fraction:	0.012
Aerosolized Fraction:	1.00
Deposition Velocity:	0.01 (m/sec)
Number of Packages:	1
Dispersion:	National Average Weather – 18 Isopleths

The following equation is used to determine the backyard farmer dose:

$$D = \frac{average\left[\sum_{i=1}^{9} \mathrm{Crop}_i\right]}{\mathrm{IG}} \cdot \mathrm{CF} \cdot \mathrm{GC}$$

where:

D = The backyard farmer dose (Rem)
Crop_i = The crop dose value for the i^{th} crop (Sv/m^2)
IG = Initial ground concentration (Bq/m^2)
CF = Conversion factor (3.7×10^6 Rem-Bq/Sv-μCi)
GC = Ground contamination prior to clean-up (μCi)

Then for the example listed above:

Average crop dose value for the effective dose	= 19,972 Sv/m^2
Average crop dose value for the thyroid dose	= 16,396 Sv/m^2
Initial ground concentration	= 1.00×10^{12} Bq/m^2
Ground contamination prior to clean-up	= 0.41 μCi

- Severity Class 6
- 33 meters centerline downwind

The results are then the following for the backyard farmer dose:

	Hand Calculation	RADTRAN 5.5	Error
Effective:	3.03×10^{-2} Rem	3.07×10^{-2} Rem	-1.3%
Thyroid:	2.49×10^{-2} Rem	2.47×10^{-2} Rem	0.7%

Societal Ingestion Dose Example Calculation
With No Rainfall

An example of how to calculate the societal ingestion dose is done using the following input parameters:

Radionuclide:	Na-22
Number of Curies:	1.00 (Ci)
Probability of an Accident:	0.1
Release Fraction:	0.01
Aerosolized Fraction:	1.00
Accident Rate:	1.00 (accidents/km)
Distance Traveled:	1.00 (km)
Farm Fraction:	1.00
Deposition Velocity:	0.01 (m/sec)
Number of Shipments:	1
Number of Packages:	1
Rainfall:	0.00 mm/hr
Dispersion:	National Average Weather – 18 Isopleths

The following equation is used to determine the societal ingestion dose:

$$D = \frac{average\left[\sum_{k=1}^{9} \mathrm{Crop}_k\right]}{\mathrm{IG}} \cdot \mathrm{CF} \cdot \mathrm{FF} \cdot \mathrm{AR} \cdot \mathrm{NS} \cdot \mathrm{NP} \cdot \mathrm{DT} \cdot \sum_{a=1}^{z}\sum_{j=1}^{m}\sum_{i=1}^{n} \mathrm{AF}_a \cdot \mathrm{PA}_a \cdot \mathrm{RF}_a \cdot \mathrm{NC}_j \cdot \mathrm{CQ}_i \cdot \left(\mathrm{AD}_i - \mathrm{AD}_{(i-1)}\right) \cdot \mathrm{DV}$$

where:

D	= The societal ingestion dose (Person-Rem)
$Crop_k$	= The crop dose value for the k^{th} crop (Person-Sv/m^2)
IG	= Initial ground concentration (Bq/m^2)
CF	= Conversion factor (3.7×10^{12} Rem-Bq/Sv-Ci)
FF	= Farm Fraction
AR	= Accident rate (accident/km)
NS	= Number of shipments
NP	= Number of packages
DT	= Distance traveled (km)
AF_a	= Aerosolized fraction of the a^{th} severity category
PA_a	= Probability of an accident for the a^{th} severity category
RF_a	= Release fraction of the a^{th} severity category
NC_j	= Number of curies for the j^{th} radionuclide (Ci)
CQ_i	= The Chi/Q with deposition value for the i^{th} isopleth (s/m^3)
AD_i	= Area of the i^{th} isopleth (m^2)
$AD_{(i-1)}$	= Area of the $(i-1)^{th}$ isopleth (m^2)
DV	= Deposition velocity (m/s)

This equation is only valid for scenarios in which there is no rainfall. For meteorological conditions which rainfall is present, there is another equation that must be used in order to determine the societal ingestion dose since the peak deposited concentration is not in the same isopleth as the peak air concentration.

This equation also assumes that only one physical/chemical group is used. If more than one physical/chemical group is used then using this equation and summing the results for each group will result in the societal ingestion dose.

Then for the example listed above:

Average crop dose value for the effective dose	= 2.203 Sv/m^2
Average crop dose value for the lung dose	= 1.779 Sv/m^2
Initial ground concentration	= 1.00 x 10^{12} Bq/m^2

The results are then the following for the societal ingestion dose:

	Hand Calculation	RADTRAN 5.5	Error
Effective:	4.67 x 10^{-3} Person-Rem	4.60 x 10^{-3} Person-Rem	1.4%
Lung:	3.77 x 10^{-3} Person-Rem	3.72 x 10^{-3} Person-Rem	1.3%

Societal Ingestion Dose Example Calculation
With Rainfall

An example of how to calculate the societal ingestion dose is done using the following input parameters:

Radionuclide:	Na-22
Number of Curies:	1.00 (Ci)
Probability of an Accident:	0.1
Release Fraction:	0.01
Aerosolized Fraction:	1.00
Accident Rate:	1.00 (accidents/km)
Distance Traveled:	1.00 (km)
Farm Fraction:	1.00
Deposition Velocity:	0.01 (m/sec)
Number of Shipments:	1
Number of Packages:	1
Dispersion:	User Defined Model – 17 Isopleths
Release Height:	10.0 (meters)
Rainfall:	1.00 (mm/h)
Heat Release:	100,000 (cal/sec)
Cask Length:	3.45 (meters)
Cask Radius:	2.87 (meters)
Wind Speed:	4.00 (m/sec)
Anemometer Height:	10.0 (meters)
Ambient Temperature:	270.0 (K)
Atmospheric Mixing Height:	5,000 (meters)
Briggs:	Used the Briggs dispersion model with coefficients
Stability:	D
Rural:	Used the rural terrain coefficients

The following equation is used to determine the societal ingestion dose:

$$D = \frac{average\left[\sum_{k=1}^{9} \mathrm{Crop}_k\right]}{\mathrm{IG}} \cdot \mathrm{CF} \cdot \mathrm{FF} \cdot \mathrm{AR} \cdot \mathrm{NS} \cdot \mathrm{NP} \cdot \mathrm{DT} \cdot \sum_{a=1}^{z} \sum_{j=1}^{m} \sum_{i=1}^{n} \mathrm{AF}_a \cdot \mathrm{PA}_a \cdot \mathrm{RF}_a \cdot \mathrm{NC}_j \cdot \mathrm{CQ}_i \cdot \left(\mathrm{AD}_i - \mathrm{AD}_{(i-1)}\right)$$

where:

D	= The societal ingestion dose (Person-Rem)
$Crop_k$	= The crop dose value for the k^{th} crop (Person-Sv/m^2)
IG	= Initial ground concentration (Bq/m^2)
CF	= Conversion factor (3.7 x 10^{12} Rem-Bq/Sv-Ci)
FF	= Farm Fraction
AR	= Accident rate (accident/km)
NS	= Number of shipments
NP	= Number of packages
DT	= Distance traveled (km)
AF_a	= Aerosolized fraction of the a^{th} severity category
PA_a	= Probability of an accident for the a^{th} severity category
RF_a	= Release fraction of the a^{th} severity category
NC_j	= Number of curies for the j^{th} radionuclide (Ci)
CQ_i	= The Chi/Q deposited for the i^{th} isopleth (1/m^2)
AD_i	= Area of the i^{th} isopleth (m^2)
$AD_{(i-1)}$	= Area of the $(i-1)^{th}$ isopleth (m^2)

This equation is only valid for scenarios in which there is rainfall. For meteorological conditions which no rainfall is present, there is another equation that must be used in order to determine the societal ingestion dose since the peak deposited concentration is in the same isopleth as the peak air concentration.

This equation also assumes that only one physical/chemical group is used. If more than one physical/chemical group is used then using this equation and summing the results for each group will result in the societal ingestion dose.

Then for the example listed above:

Average crop dose value for the effective dose	= 2.203 Sv/m^2
Average crop dose value for the lung dose	= 1.779 Sv/m^2
Initial ground concentration	= 1.00 x 10^{12} Bq/m^2

The results are then the following for the societal ingestion dose:

	Hand Calculation	RADTRAN 5.5	Error
Effective:	5.42 x 10^{-3} Person-Rem	5.47 x 10^{-3} Person-Rem	0.9%
Lung:	4.38 x 10^{-3} Person-Rem	4.43 x 10^{-3} Person-Rem	1.1%