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NUREG/CR-XXXX

MELCOR Accident Consequence Code System (MACCS)

User's Guide and Reference Manual

Draft Report

Office of Nuclear Regulatory Research

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Manuscript Completed: TBD
Date Published: TBD

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ABSTRACT

The MACCS User's Guide is intended to assist analysts in understanding the MACCS/WinMACCS model and to a lesser degree provide information regarding the code. The historical reference to the consequence code has been MACCS or MACCS2, which was related to the version number. The purpose of this document is to update the User's Guide to reflect the model as it is presented in MACCS Version 3.10.0. This User's Guide provides a brief description of the model history, explains to a user how to set up and execute a problem, and informs the user of the definition of various input parameters and any constraints placed on those parameters.

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TABLE OF CONTENTS

LIST OF FIGURES

Figure Page

LIST OF TABLES

EXECUTIVE SUMMARY

The purpose of this document is to provide a reference document for MACCS, which is used for calculating health and economic consequences from a release of radioactive materials into the atmosphere. The program has been widely distributed and used throughout the Department of Energy (DOE) and by the Nuclear Regulatory Commission (NRC) as well as other organizations, including international regulators and industry. The historical reference to the consequence code has been MACCS or MACCS2. The number 2 has now been dropped in favor of a single version number, which is 3.10.0 at the time of this writing.

In 2001, the NRC initiated an effort to create a Window's based interface and framework for performing the consequence analysis. This manual describes the functions of both WinMACCS and MACCS together. For simplicity, the combined functions of MACCS and WinMACCS are often referred to as MACCS. However, WinMACCS and MACCS are separate codes and it is often useful to distinguish the functions of the two codes. This User's Guide is based on version 3.10.0 of both MACCS and WinMACCS.

ACKNOWLEDGEMENTS

Contributions to this User's Guide and Reference Manual were received from NRC and Sandia National Laboratories (SNL) project managers, technical experts, and code authors dedicated to the production of a valuable resource for the MACCS user community. Instructions and guidance included herein were developed over many years and include advancements in the code that provide user's the ability to develop complex consequence modeling scenarios. The NRC Project Manager, Jonathan Barr, provided the leadership to ensure this project met the objectives of the program. Numerous NRC and Sandia staff provided insights supporting development of the document. Katherine McFadden, Lee Eubanks, and Rick Haaker have contributed to the WinMACCS and MACCS codes for many years and were instrumental in the creation of this comprehensive User's Guide and Reference Manual.

ACRONYMS AND ABBREVIATIONS

BEIR	Biological Effects of Ionizing Radiation
CPI	Consumer Price Index
DOE	U.S. Department of Energy
DDREF	Dose and Dose Rate Effectiveness Factor
EAL	Emergency Action Level
EP	Emergency Preparedness
EPA	U.S. Environmental Protection Agency
EPZ	Emergency Planning Zone
ER	Emergency Response
ESPMUL	Evacuation Speed Multiplier
ETE	Evacuation Time Estimate
FGR	Federal Guidance Report
GE	General Emergency
GUI	Graphical User Interface
HPS	Health Physics Society
ICRP	International Commission on Radiation Protection
ISLOCA	Interfacing Systems Loss of Coolant Accident
LCF	Latent Cancer Fatality
LET	Linear Energy Transfer
LHS	Latin Hypercube Sampling
LNT	Linear No Threshold
LOCA	Loss of Coolant Accident
LTSBO	Long Term Station Blackout
MACCS	MELCOR Accident Consequence Code System
ORNL	Oak Ridge National Laboratory
ORO	Offsite Response Organization
PAG	Protective Action Guide
PAR	Protective Action Recommendation
PRA	Probabilistic Risk Assessment
PRC	Peer Review Committee
RCIC	Reactor Core Isolation Cooling system
ROP	Reactor Oversight Program
SAE	Site Area Emergency
SAMA	Severe Accident Mitigation Alternatives
SAMG	Severe Accident Management Guidelines
SecPop	Sector Population and Economic Estimator
SNL	Sandia National Laboratories
SOARCA	State-Of-the-Art Reactor Consequence Analyses project
STSBO	Short Term Station Blackout
TISGTR	Thermally Induced Steam Generator Tube Rupture
TSC	Technical Support Center
USBGR	U.S. Background

1. INTRODUCTION

The historical reference to the consequence code has been MACCS or MACCS2, which was related to the version number. In 2001, the NRC initiated an effort to create a Window's based interface and framework for performing the consequence analysis. This manual describes the functions of both WinMACCS and MACCS together. For simplicity, the combined functions of MACCS and WinMACCS are often referred to as MACCS. However, WinMACCS and MACCS are separate codes and it is often useful to distinguish the functions of the two codes.

MACCS is the NRC code used to estimate the offsite consequences of potential severe accidents at nuclear power plants (NPPs). The code is used to perform probabilistic health and economic consequence assessment of hypothetical releases of radioactive material. Atmospheric dispersion and transport, wet and dry deposition, probabilistic treatment of meteorology, environmental transfer, countermeasure strategies, dosimetry, health effects, and economic impacts are addressed in the code.

The lineage of development of accident consequence codes for the NRC is described as follows:

CRAC was used in the landmark Reactor Safety Study (WASH-1400) to estimate consequences of a set of hypothetical accidents. WASH-1400 was published in 1975 but a CRAC users' manual was never published.

CRAC2 was published in 1983 (Ritchie et al., 1984) and was most notably used to support Technical Guidance for Siting Criteria Development (Aldrich et al., 1982)

MACCS was published in 1990 (H-N Jow, et al., 1990) and was used to perform the consequence analyses for the landmark PRA study documented in NUREG-1150 (NRC, 1989)

MACCS2 was published in 1997 (Chanin and Young, 1997). The work to create MACCS2 was sponsored by the U.S. Department of Energy (DOE) and was focused on generalizing MACCS to be used for nonreactor applications.

WinMACCS was first released to the public in March of 2008 as Version 3.4.0. Version 3.10.0 is the sixth release version to be published. WinMACCS has been used for a large number of important studies, including the SOARCA study (NRC, 2012, N. Bixler et al., 2013, and Sandia National Laboratories, 2013), the SOARCA uncertainty study for Peach Bottom (Sandia National Laboratories, draft published in 2015), and Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor (Barto et al., draft published in 2013).

1.1 MACCS History

MACCS2.1.12 was released in April of 1997 as a batch process code. In September 2001 version 1.13 was released to allow execution under newer operating systems and to fix several bugs in the previous version. Since 2001 a new version of MACCS has been released approximately every two years. New versions offered enhancements as well as addressed bugs. The current version of MACCS is 3.10.0. A detailed chronicle of changes made to MACCS is distributed as along with MACCS in a document titled, "History of MACCS."

1.2 WinMACCS Overview

In 2001, the NRC initiated an effort to create a Windows-based interface and framework for performing consequence analyses. WinMACCS is developed for Windows operating systems. This effort was intended to address the following needs:

- Simplify and make the effort required to create or modify input files more intuitive;
- Reduce the likelihood of user errors in performing consequence analyses;
- Enable the user to simply and conveniently account for uncertainties in input data; and
- Displace the original batch framework with a Windows-based framework.

The result of this development effort was the WinMACCS code. WinMACCS is currently integrated with versions of MACCS, COMIDA2, and LHS (Latin Hypercube Sampling) to perform all of the required functionality. The original MACCS2 batch framework is preserved; MACCS can still be run in stand-alone fashion apart from the WinMACCS interface. However, there are significant advantages for migrating to the WinMACCS framework for running consequence calculations.

1.3 MACCS Framework

1.3.1 Software used to Develop WinMACCS

Components used to develop the WinMACCS software are described in the Reference Guide provided in Chapter 4.

1.3.2 WinMACCS Components

The components of WinMACCS are shown in Figure 1-1. WinMACCS allows one or more calculations to be run on a computer. The user can modify model input variables and model settings and save them in the project database. The user can initiate a WinMACCS deterministic simulation or a set of simulations to evaluate uncertainty from input parameters represented by probability distributions to reflect degree of belief. To do the latter, WinMACCS uses a code called LHS (Latin Hypercube Sampling) to generate vectors of sampled input variables to create a set of equally probable realizations. LHS, can use either of two sampling algorithms: simple random sampling (SRS) or Latin Hypercube Sampling, which is a type of stratified sampling. WinMACCS can also run three other codes: COMIDA2 to evaluate parameters affecting the food ingestion pathway, PopMod to change the number of sectors in a site file, and CombineSource to combine source terms for multiple units and/or spent fuel pools. These codes act as preprocessors for MACCS.

WinMACCS can run LHS to generate values of the uncertain variables and builds the MACCS input files for each simulation. It runs MACCS multiple times, once for each realization. Multiple simulations can also be created using the cyclical file option. In this case, MACCS input can be modified using a set of input files that effectively act as change cards. One application of this feature is to run successive MACCS simulations using multiple source terms from MELCOR simulations. The interface utility, MelMACCS, can be used to create the input files containing the source-term data. This feature is called cyclical because it can be combined with sampling of uncertain input data and the input files are cycled if there are more simulations than input files. The user may view, export, and aggregate results of MACCS simulations in various formats, such as text, Microsoft Excel, JPEG, BMP, XML, and HTML.

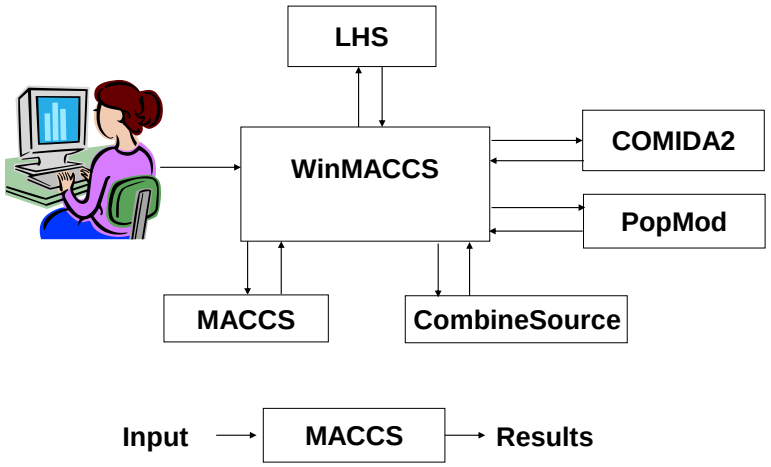


Figure 1-1 WinMACCS components

PopMod is required with site files generated with versions of SecPop prior to 4.0 to support MACCS grids with more than 16 compass sectors. The work of PopMod is primarily interpolation and reformatting. No new information is added to the site data file that is created.

Data files managed by WinMACCS include a set of auxiliary files, such as a site file, a meteorological file, one or more COMIDA2 binary file(s), and one or more DCF file(s). Input files are created by WinMACCS using the model and input settings stored in an underlying database. This input files can include Atmos*n*.inp, Early*n*.inp, Chronc*n*.inp, Comida*n*.inp, and Lhs.inp input files. Here, *n* is 1 or more and denotes the simulation number. Multiple simulations are performed when evaluating uncertainty and/or using the cyclical file option discussed in this document. Output files are created by MACCS and its preprocessors (e.g., LHS and COMIDA2). A set of MACCS output files, Model*n*.out and Model*n*.bin, are normally created for each simulation. Other files may or may not be created, depending on settings chosen by the user.

An Access database file is created from a database template file, Initialize2000.mdb, when a new project is created. The project database is modified using the Microsoft DAO 3.6 library. The database contains the following information:

- Default input values and model settings,
- Input values and model settings specified by user,
- Input variable descriptions and limits,
- Information to construct input forms,
- Information to construct input files,
- LHS results, and
- MACCS results read from binary files.

1.3.3 WinMACCS Project File Structure

A project folder contains the following files and subfolders:

A database file (e.g., myProject\myProject.mxd). This file is an Access 2010 database file. In addition to its settings, this file contains the parameter values used to build the MACCS input files when a simulation is run.

Three subdirectories as follows:

- myProject\Data\ contains user specified data files, such as the site file, the meteorological file, and the dose conversion factor file.
- myProject\Input\ contains input files created by WinMACCS each time the user requests a MACCS simulation.
- myProject\Output\ contains output files from MACCS and other executables run by WinMACCS.

To move the location of the project, the user can simply move (or drag and drop) the folder myProject\, including its files and subdirectories, to a new location.

1.3.4 Parameters Tab

The parameters are organized in a tree structure to facilitate access. The highest level of the tree structure is called a main category, the second level is called a category, the third level is called a subcategory, fourth level is called a form and under a form are one or more parameters. In some cases there is an additional level called a sub subcategory that falls directly below a *subcategory*. The example in Figure 1-2, shows the main categories: *GENERAL, ATMOS, EARLY, CHRONC, DOSE COEFFICIENTS*, and *COMIDA2*. *GENERAL* contains categories named *Properties*, *File Specifications*, and *Output Options*. More information under each of the categories can be viewed if the + is clicked to display more detail. The convention used in this document is that italicized words are names or labels that appear in the WinMACCS interface.

Within the *ATMOS* main category, the *Radionuclide* category has been completed, as indicated by the solid orange diamond next to the category name. The orange color of the symbol indicates that there is at least one form in this category that is optional.

Within the *ATMOS* main category, the *Deposition* category detail is shown. The X-ed red octagon indicates that there is missing or inconsistent information in this category. The *Wet/Dry Depos Flags* and *Wet Deposition* forms have been completed consistently, as indicated by the solid green octagons. The *Dry Deposition* form needs attention, as indicated by the X-ed red octagon next to the form name. This form contains two variables: *NPSGRP* and *VDEPOS*. If the form name or the variables are double-clicked, the corresponding parameter modification form is opened.

It is important to note that the symbols do not indicate whether input values are correct or incorrect; they only indicate whether they are consistent and within acceptable bounds imposed by WinMACCS. The user is responsible for entering and performing adequate quality assurance/control to verify that correct (or at least intended) values of input parameters are entered in the interface.

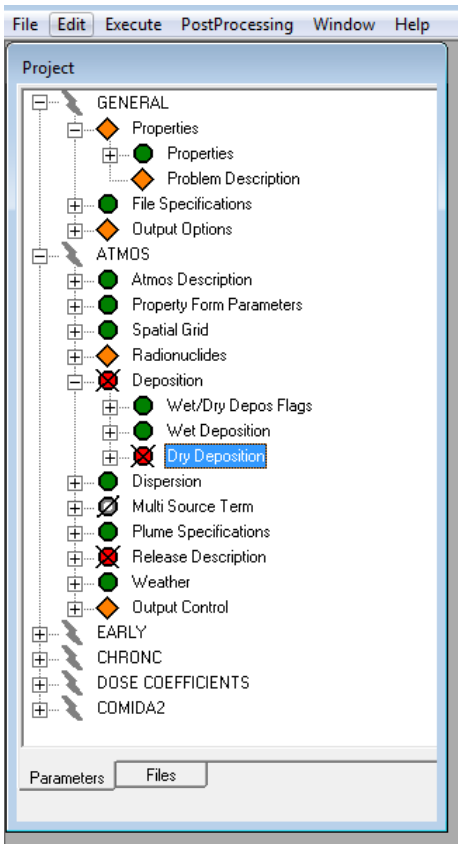


Figure 1-2 Parameters tab under the Project window

Each entry in the tree shown in Figure 1-2 has a related icon. This icon reflects the state of the object. The objects and icons are as follows:

Input associated with a main category is represented by a lightning bolt icon.

GENERAL, *ATMOS*, *EARLY*, *CHRONC*, DOSE COEFFICIENTS and *COMIDA2* are the major categories. The *GENERAL* category contains the links to the model settings (for example, the weather sampling method) and the links to the auxiliary files to be used in a simulation. There are a number of categories within each module. These categories contain forms that are used to specify input parameters. An example of a category is *Plume Specifications*.

Icons next to category names define the form states as follows:

An X-ed red octagon or X-ed orange diamond indicates that the user needs to

complete or correct this form before running MACCS.

A solid green octagon indicates that the user has correctly completed this form and that the data defined on this form are needed to perform a calculation.

A solid orange diamond indicates that the user has completed this optional form. The data defined on all forms with an orange diamond are used to perform a calculation.

 An empty orange diamond indicates that the user has not completed this optional form.

 A solid X-ed orange diamond indicates that this optional form needs attention before running MACCS. This can be done by opening, clearing the form, and clicking *OK or by correcting it*, in which case the data on this form will be conveyed to the appropriate MACCS input file.

 A solid gray octagon with a diagonal line indicates that the user has completed this form, but the data are not needed under the current model choices.

 An empty gray octagon with a diagonal line indicates that the user has not completed this form, but it is not required and can be ignored.

 A black circle indicates a parameter that is contained on a form. The parameter names are listed to facilitate navigation of WinMACCS and are given the same names as the MACCS input variables. Double-clicking on a parameter object causes the related form to open with the focus at the selected parameter value.

Double-clicking on a form or on a variable name associated with a form causes that form to open for editing.

The *Properties* form found under the *GENERAL* main category and under the *Properties* category allows the user to modify model choices to be used in a subsequent MACCS calculation(s). Data entry on this form can modify the status of the categories and forms as indicated by the icons listed above. The user should generally start a new project or modify an existing project by making appropriate model choices under the *Properties* form. This defines the status of the categories and forms shown under the *Project Parameters* tab.

1.3.5 Files Tab

There are three file categories on the *Files* tab: *Data*, *Input,* and *Output*. The Data file category contains several file-type variables. Beneath the file-type variables are links to the files currently used or defined in the project. Each of the file categories corresponds to folders stored in the project folder.

The structure emulates the folder structure displayed when the project is viewed in Windows Explorer as shown in Figure 1-3 with differences noted below in the detailed description of each of the three file categories.

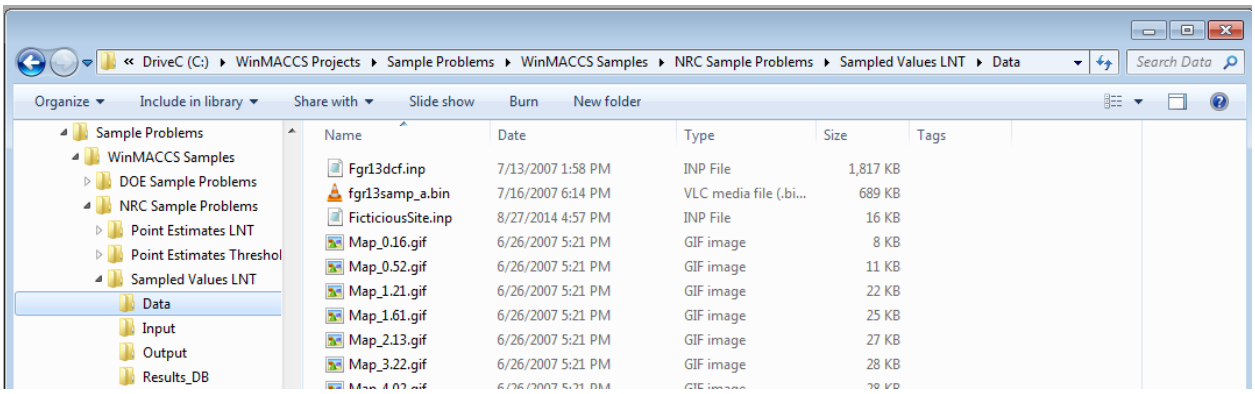


Figure 1-3 Data folder as seen from Windows Explorer

1.3.5.1 Data Files

This file category called *Data* contains data files specified by the user under the *General*/*File Specifications* category on the *Parameters* tab of the *Project* window. Double-clicking on a file link opens the selected file in Notepad for editing. This allows the user to modify the file and save it. The modified file is used when MACCS is run. Files in the Data folder, as shown in Figure 1-3, other than those in *File Specifications,* are not shown in under the *Data* files category.

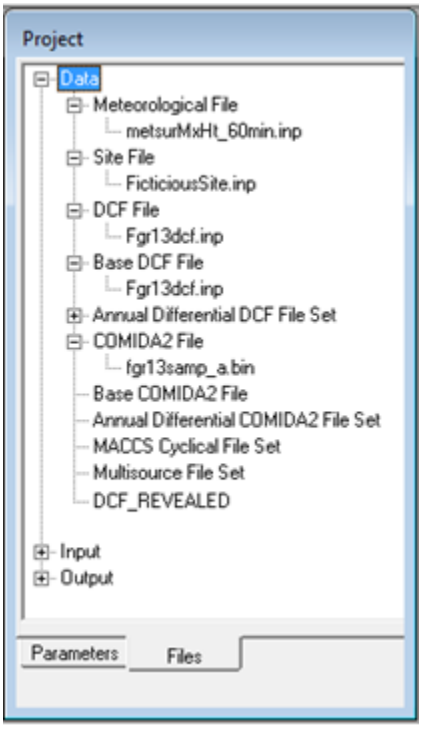


Figure 1-4 Project data folder

Not all of the files shown in Figure 1-4, are necessarily used when MACCS is run. Which files are used depends on the models that have been selected on the *Properties* form. For example, if *Early Consequences* is not selected under the *Scope* tab on the *Properties* form, the DCF file

is not needed for the simulation. This is indicated by the icon displayed next to *Dose Conversion Factor File* under the *File Specifications* category.

The file links displayed in Figure 1-4 can be modified by double-clicking on the form or variable name under the *GENERAL*/*File Specifications* category, as shown in Figure 1-5.

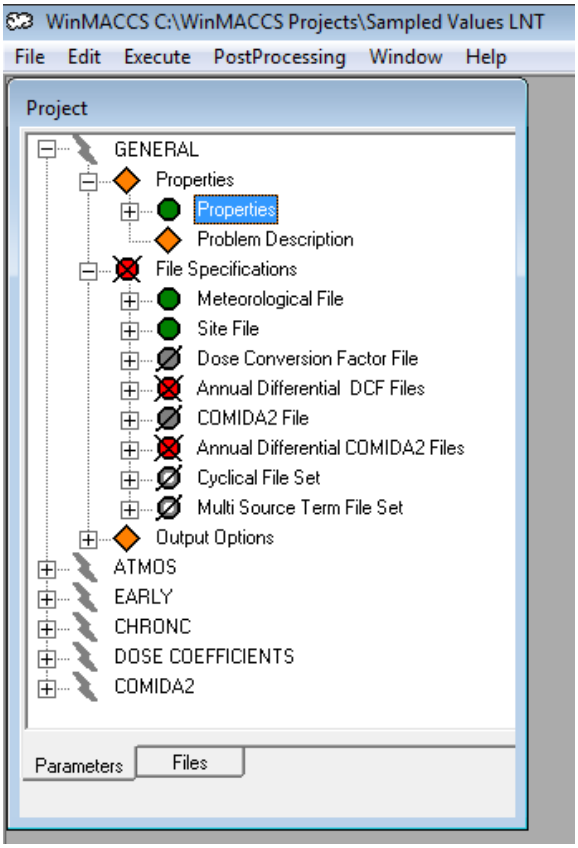


Figure 1-5 File specifications

Model settings that determine which data files are needed for a calculation are controlled with the *Project Properties* form shown in Figure 1-6.

Map files that are displayed behind a spatial grid also need to be placed in the Data folder. These files need to be in Graphics Interchange Format (.gif). The .gif files are created for the spatial grid entered by the user in WinMACCS by a stand-alone executable called MapGen (Section 1.3.2). MapGen reads an interface file containing information about the spatial grid written by WinMACCS and creates a set of map files from this interface file. (Using this capability currently requires the user to have Microsoft MapPoint installed on their computer.) While the map files need to be saved in the Data folder, they are not shown in the *Files* tab in the *Project* form. Some forms use these maps as background to help the user determined evacuation model settings. These forms are present in each of the *EARLY/Emergency Cohort* categories (e.g., *EARLY/Emergency Cohort One*).

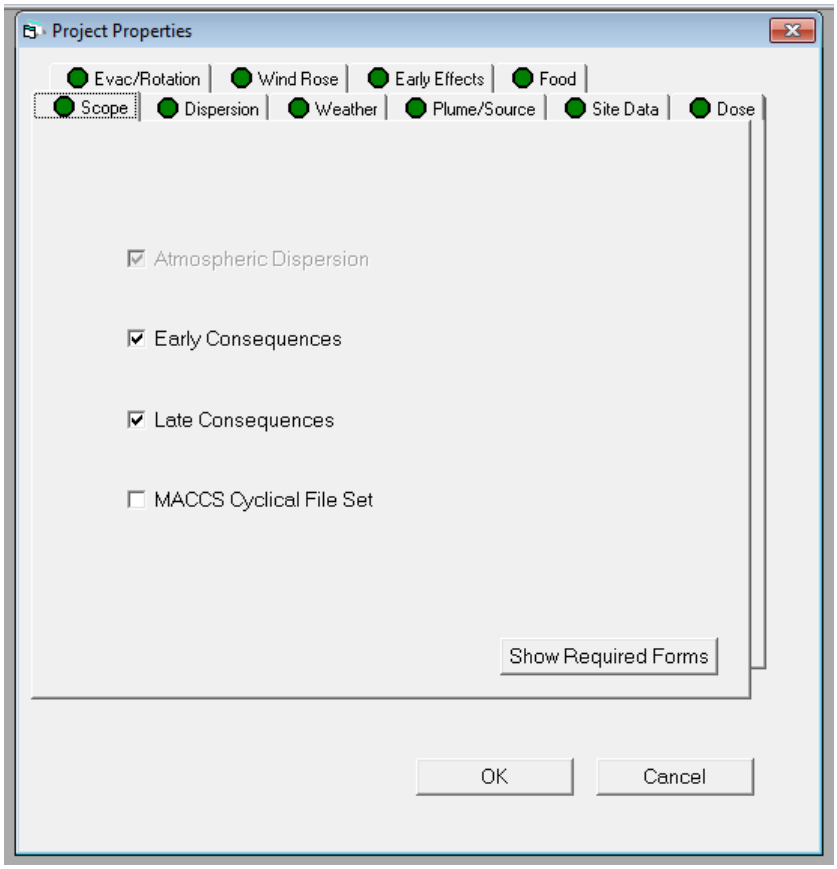


Figure 1-6 Project properties form

1.3.5.2 Input Files

This category contains input files as shown in Figure 1-7 that are normally created by MACCS before running a MACCS simulation. If the main menu option, *Execute→Refresh Template Input Files before Running* is not checked, the template files atmosTemplate.txt, earlyTemplate.txt, chroncTemplate.txt, and comidaTemplate.txt are not recreated from the settings within WinMACCS before running a simulation. This feature allows the user to edit these files and run a simulation using the edited files. This feature was created to allow users to modify the template files manually during the implementation of new features not yet supported by WinMACCS. It is unusual to uncheck this menu option, but it could be useful in exceptional situations when the WinMACCS template file does not satisfy the user's needs. When any project is opened, regardless of the previous state of this menu option, this option is checked.

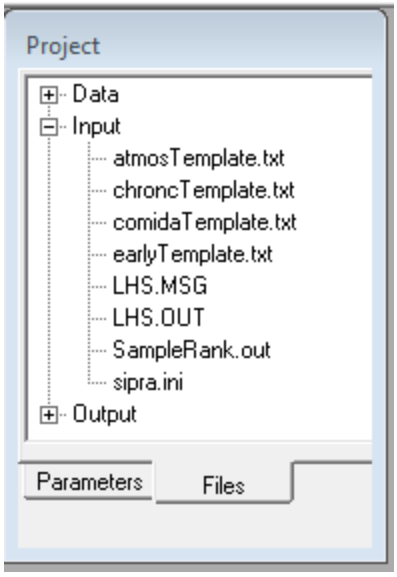


Figure 1-7 Input files

All files in Project\Input\ are shown in the *Project* window. Selecting main menu option *File→Refresh File View* causes the hard drive to be queried and refreshes the set of files shown in the *Project* window.

***WARNING*: The Input folder is not a good place to store any files that the user wants to keep! The Data (Project\Data\) and root directories (Project\) are safe places to store files because they are never deleted by MACCS. The user can also create additional directories for archiving files under the Project\ folder.**

The following example reflects a run with a scope of *Atmospheric Dispersion, Early Consequences*, *Late Consequences*, and *COMIDA2*. In this example, some variables are sampled, the template files are created and two simulations are requested.

Table 1-1 Files created in the input folder by WinMACCS during execution.

Name of file	Conditions when file Is created	Description
atmosTemplate.txt		File atmosTemplate.txt is used to create input files Atmos1.inp and Atmos2.inp. This file is used by WinMACCS
earlyTemplate.txt	*EARLY* module is selected under the *Scope* tab in the *Properties* form.	File earlyTemplate.txt is used to create input files Early1.inp and Early2.inp. This file is used by WinMACCS.
chroncTemplate.txt	*CHRONC* module is selected under the *Scope* tab in the *Properties* form.	File chroncTemplate.txt file is used to create input files Chronc1.inp and Chronc2.inp. This file is used by WinMACCS.

Name of file	Conditions when file Is created	Description
Atmos1.inp Early1.inp Chronc1.inp Atmos2.inp Early2.inp Chronc2.inp	Input files are created consistently with the model scope. For example, when the user has only specified *Atmospheric Dispersion* and *Early Consequences* on the *Scope* tab in the *Properties* form, Atmos1.inp, Atmos2.inp, Early1.inp, and Early2.inp are created using atmosTemplate.txt and earlyTemplate.txt. Chronc*n*.inp is not created. This example is for Late Consequences selected so that the Chronc files are created.	Files are created using the template files in conjunction with data from LHS.out relevant to each simulation. If any of the variables are uncertain, this information is encoded in the relevant template file. The actual values used in simulation *n* correspond to realization *n* in the LHS.out file. These files are used by MACCS.
LHS.inp	Created whenever uncertain variables are defined.	This file contains input to LHS that indicates the number of observations, probability distributions, variable names, and correlations between sampled parameters.
Sipra.ini	Created whenever uncertain variables are defined.	This file contains LHS settings and is copied from Program Files\WinMACCS folder into the \Project\Input\ folder. It is read by LHS.
LHS.out LHS.msg	Created whenever uncertain variables are defined.	These files are created by LHS. LHS.msg is a detailed output file describing the run. LHS.out is used to create the input files by WinMACCS for MACCS.
comidaTemplate.txt	Created when the *Late Consequences* option is selected on the *Scope* tab in the *Properties* form and the *Create COMIDA2 File* option is selected on the *Food* tab in the *Properties* form.	This file is similar to the other template files. It is used with LHS.out to create the three input files required by COMIDA2, namely Comida*n*.inp, Comida*n*.par, and Comida*n*.var, where *n* is the simulation number.

Name of file	Conditions when file Is created	Description
Comida1.inp Comida2.inp	Created when the *Late Consequences* option is selected on the *Scope* tab in the *Properties* form and the *Create COMIDA2 File* option is selected on the *Food* tab in the *Properties* form.	This is a pair of one of three input files required by COMIDA2.
Comida1.var Comida2.var	Created when the *Late Consequences* option is selected on the *Scope* tab in the *Properties* form and the *Create COMIDA2 File* option is selected on the *Food* tab in the *Properties* form.	This is a pair of one of three input files required by COMDIA2. It contains radionuclide data.
Comida1.par Comida2.par	Created when the *Late Consequences* option is selected on the *Scope* tab in the *Properties* form and the *Create COMIDA2 File* option is selected on the *Food* tab in the *Properties* form.	This is a pair of one of three input files required by COMDIA2. It contains food-pathway data.

When the *Execute→Refresh Template Input Files before Running* from the main menu is checked (the default setting):

- All of the files in the Project\Input folder are deleted when Run is clicked on the Run formRun_Form.

When the *Execute→Refresh Template Input Files before Running* from the main menu is unchecked:

- All of the files in the Project\Input folder are deleted except for the files atmosTemplate.txt, earlyTemplate.txt, chroncTemplate.txt, and comidaInpTemplate.txt when Run is clicked on the Run form.

- The option allows the template files to be manually edited before running MACCS. While this option would not normally be selected by a user, it could be helpful if there were new models in MACCS that are not yet supported by WinMACCS.

If the user has checked the box labeled *Delete Atmos, Early, Chronc and COMIDA2 Input Files* on the *Advanced Execution Parameters* form, the input files that aren't used as templates are deleted when the calculation is finished. In the example above, this means that Atmos1.inp, Atmos2.inp, Early1.inp, Early2.inp, Chronc1.inp, Chronc2.inp, LHS.inp, Comida1.inp,

Comida2.inp, Comida1.par, Comida2.par, Comida1.var and Comida2.var are deleted. Normally, this box is checked. The user would have this box unchecked if the MACCS input files were needed for some other process.

1.3.5.3 Output Files

This category contains output files created by MACCS and COMIDA2.

The entries under the file category *Output* are file names found in the user's project folder Project\Output\ excluding the binary MACCS result files, which end with a .bin extension. They are created when *Run* is selected. Select main menu option *File→Refresh File View* to query the hard drive and refresh the file list.

The Output folder is a convenient place to store files because they are listed in the file view of the project as shown in Figure 1-8.

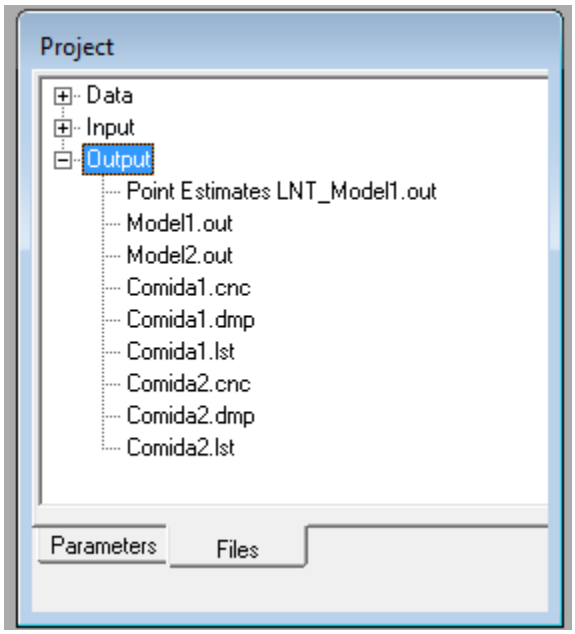


Figure 1-8 Output files

***WARNING*: Do not name any files in the output folder Model*n*.out, Model*n*.bin, Comida*n*.cnc, Comida*n*.dmp, or Comida*n*.lst. These files are deleted from the Ouput folder each time a simulation is run. Likewise, never put any files in the Project\Input\ folder. These are all deleted each time a simulation is run.**

Double-clicking on a file opens it in Notepad. The following example shows a simulation with a scope including *Atmospheric Dispersion*, *Early Consequences,* and *Late Consequences*. Comida2 is run to create the .bin files used for *Late Consequences*. In the example shown in Table 1-2, two simulations are requested.

Table 1-2 Output files created by MACCS and COMIDA2.

Name of file	Description
Model1.out Model2.out	These are the text output files created by MACCS corresponding to each of the LHS samples.
Model1.bin Model2.bin	These are the binary result files created by MACCS corresponding to each of the LHS samples. These files are not shown on the Project\Output\ screen.
Comida1.lst Comida2.lst Comida1.cnc Comida2.cnc Comida1.dmp Comida2.dmp	These are output created by COMIDA2 for each of the LHS samples.

If the user has checked the box labeled *Delete MACCS and COMIDA2 Output Files* on the *Advanced Execution Parameters* form, the text output files are deleted after each simulation. Normally, this box is unchecked as shown in Figure 1-9. The user would have this box checked if it was not necessary to view the output results. Results that are written to the binary file would still be available in the form of plots, summary.out and custom available reporting options. This is important if there are many simulations and it is important to conserve space on the hard drive.

Similarly, if the user has checked the box labeled *Delete MACCS and COMIDA2 Binary Result Files* the binary result files are deleted after the reports have been created. See 4.5.2 for more information. Normally, this box is unchecked as shown in Figure 1-9. WinMACCS imports the binary results into the project file (the .mxd file) after the simulations are complete. Having this box checked causes these files to be deleted after the data are imported into WinMACCS. This may be important for conserving space on the hard drive.

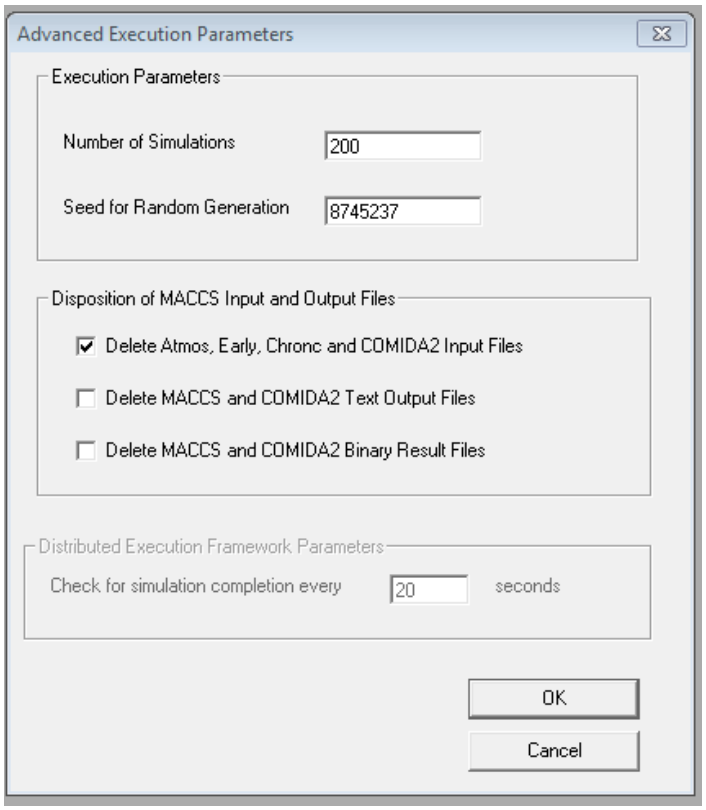


Figure 1-9 Advanced Execution Parameters

1.3.6 Results Window

The *Results* window is found at the bottom of the application window. The *Results* window communicates progress, e.g., during MACCS execution.

Text shown in Figure 1-10 can be selected and copied to the Windows clipboard by using the copy and paste functions available when right clicking the mouse. Alternatively, the user can use the control-C option to copy text from this window. Normally, this would not be necessary. However, it may be useful if an error occurs and it is necessary to save or share the messages with another analyst.

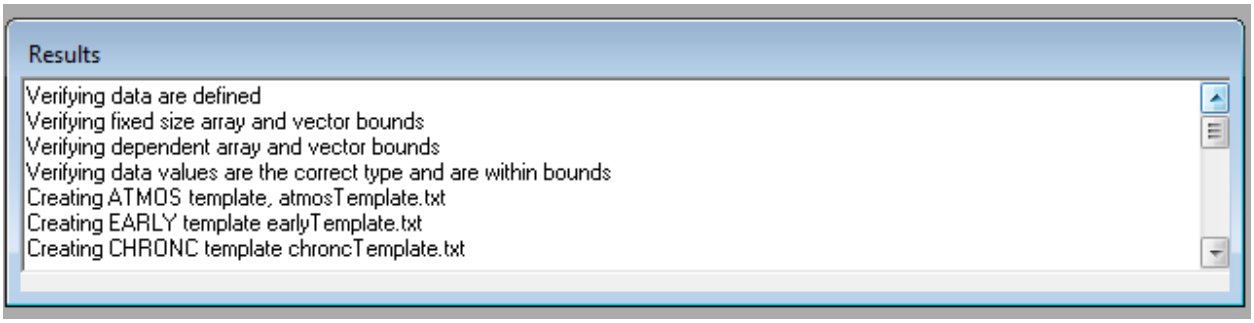


Figure 1-10 Sample results window

1.4 Main Menu Options

Figure 1-11 shows the main menu options listed at the top of the MACCS application.

Figure 1-11 Main menu

The main menu contains the following drop-down menus:

- *File* allows projects to be managed and MACCS files to be imported, along with several other functions.
- *Edit* manages some screens, enables distributions for uncertain input parameters to be correlated, enables editing of some parameters, and allows the user to open all windows containing a specified parameter.
- *Execute* allows the user to run calculations and to control choices related to those calculations.
- *PostProcessing* controls the post-processing options, both graphical and tabular.
- Window manages screens within WinMACCS.
- *Help* provides information on the version of WinMACCS that is installed on the user's computer.

Chapter 2 describes each of these menu items in more detail.

2. GETTING STARTED

2.1 Overview of User Interface

When a project is opened using the *File→Open Project* command or a new project is created using the *File→New Project* command, *Project* and *Results* screens are also opened, as illustrated in Figure 2-1. The *Project* window is used to modify parameter values and view related project files.

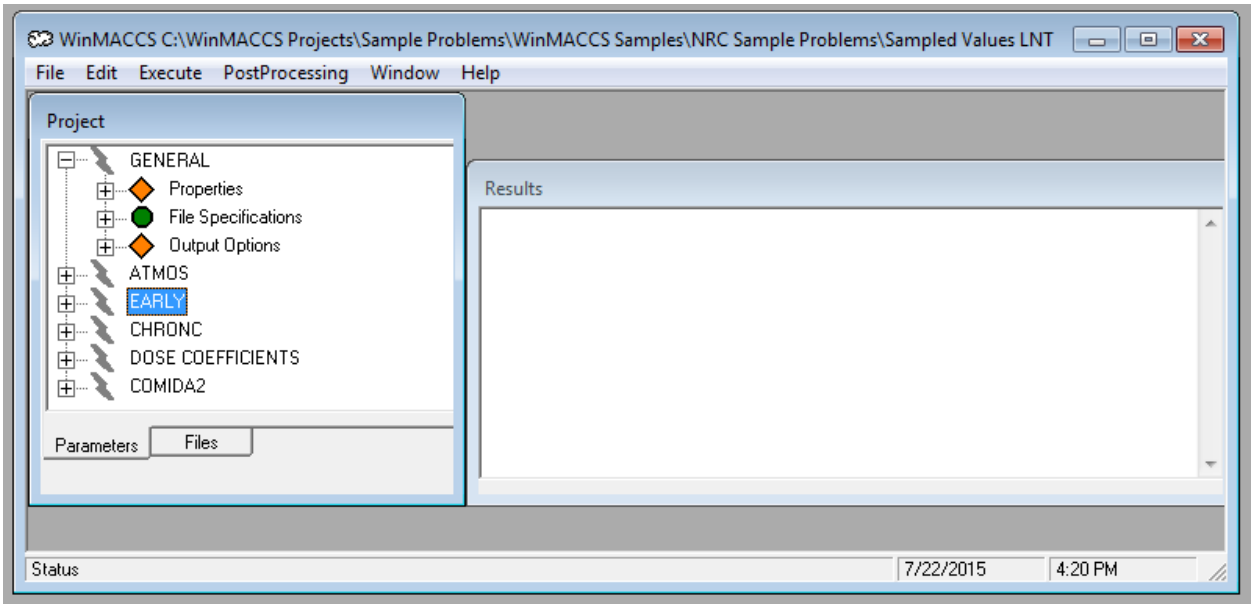


Figure 2-1 Project and results windows

The caption at the top of the window indicates the file name and location of the project. In the example shown in Figure 2-1, the file C:\WinMACCS Samples\Tutorials\sample 1 is displayed.

The main menu options are *File*, *Edit*, *Execute*, *PostProcessing*, *Window*, and *Help*.
The *Project* window contains two tabs, the *Parameters* tab and the *Files* tab.

- The *Parameters* tab contains a list of forms that are used to select model options, modify input parameters, and create file links.

- The *Files* tab contains links to active files in the project folder displayed at the top of the window.

The *Results* window displays the progress of a user initiated action, such as importing a file or running a simulation.

A legend automatically opens with a project, as shown in Figure 2-2. The legend defines the meaning of the icons shown next to the form names and categories in the *Parameters* tab of the *Project* window.

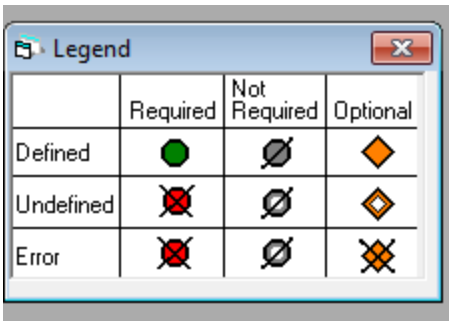


Figure 2-2 Legend

The information displayed under the *Parameters* tab is organized as follows:

- The top display level is called a main category, which include GENERAL, ATMOS, EARLY, CHRONC, DOSE COEFFIENTS, and COMIDA2. The icon used for main categories looks like a lightning bolt and they can contain categories, subcategories, and forms, as defined below.

- The next level of organization below a main category is a category. For example, Radionuclides is a category under ATMOS. Several types of icons are used to represent categories, depending on whether they are required, not required, optional, defined, undefined, or have an error state. The icons corresponding to each possibility are displayed in the Legend window shown in Figure 2-2.

- The next level below a category is either a subcategory. For example, Emergency Cohort 2 is a subcategory under Additional Emergency Cohorts, which is a category under EARLY.

- The next level of organization below a subcategory is a form. The icons for forms are identical to those for categories and subcategories. For example, Basic Parameters is a form under Additional Emergency Cohorts.

- Each form contains one or more parameters. Parameters are denoted by black dots.

In some cases, forms are directly under categories or even main categories because the intermediate levels are not required.

2.2 Modifying a Parameter Value

A parameter can be modified by opening the form containing the parameter. This is illustrated in Figure 2-3 for the parameters associated with wet deposition.

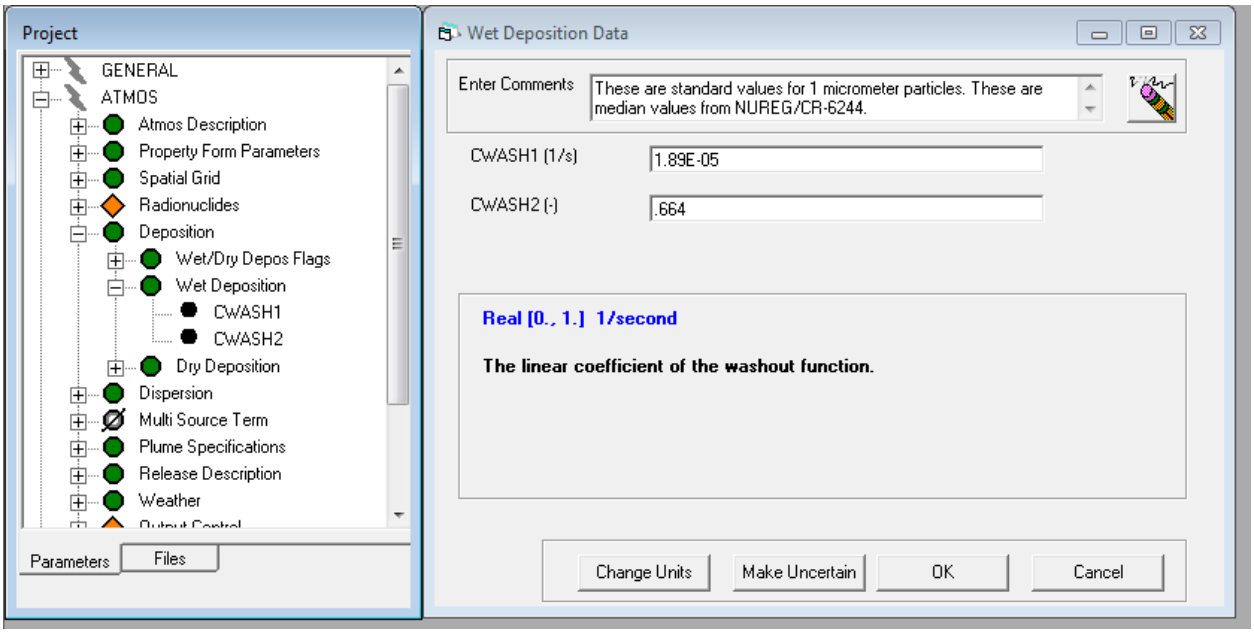


Figure 2-3 Modifying a parameter on a form

Parameter values are changed by replacing the value on the form and clicking the *OK* button. The *Make Uncertain* button allows a probability distribution to be assigned to an uncertain variable for sampling in an uncertainty analysis. Clicking *OK* saves all changes and closes the form; Clicking *Cancel* retains the previous values and closes the form. Clicking the pencil eraser button on the top right clears the form of all values and comments.

The user is not allowed to save values by clicking *OK* unless all values have been defined and are within the bounds specified on the form. For example, the limits on CWASH1 in Figure 2-3 are from 0.0 to 1.0, inclusive of the end points. Resetting a form to the default state is accomplished by closing the form, right clicking on the form name, and selecting *Reset to Default*.

2.3 Specifying and Viewing Files

MACCS may require auxiliary files depending on the selections made in *Project Properties*. For example, if one of the file-sampling options was selected on the *Weather* tab of *Project Properties*, the user must provide a meteorological data file.

Under the *GENERAL/File Specifications* category, icons displayed next to the names indicate which files are required. Figure 2-4 shows an example in which the *Meteorological File* and *Dose Conversion Factor File* are required. The dose conversion factor file has been defined previously, as is indicated by the solid green octagon, but the user has not yet defined a meteorological data file, as is indicated by the red, X-ed octagon. The undefined status for this file is addressed by opening this form, clicking the *Browse* button, and selecting the desired file. The selected file is copied to the project's data folder, *ProjectName/Data,* where *ProjectName* is the name of the project. This copy is used for subsequent MACCS calculations.

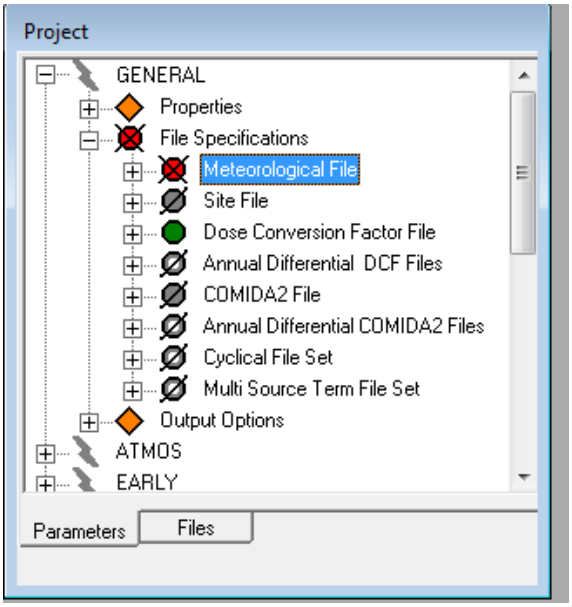


Figure 2-4 File specifications

Selecting a site file works the same way as selecting a meteorological data file. The *Site File* form contains extra functionality to allow the creation of a more finely gridded site file from an existing, more coarsely gridded one. This function is described in a subsequent chapter.

The *Annual Differential DCF Files*, *Annual Differential COMIDA2 Files,* and *Cyclical File Set* are organized to allow selection of a set of files. Copies of the files are used for a calculation, and these copies are placed in the *ProjectName/Data* folder.

Once a file has been selected, it can be viewed and edited via the *Files* tab. The *Data*, *Input,* and *Output* categories on the *File* tab correspond to files stored in the project folders named Data\, Input\, and Output\. Any of these files can be viewed and edited in Notepad by double clicking on the file name. The files in the Input\ and Output\ folders are automatically generated when a simulation is run.

2.4 Filling out a Map Form

Some forms in the interface display a polar grid. These are used to specify evacuation directions if the network evacuation model is enabled or speed multipliers if the speed multiplier option is enabled on the *Project Properties* form, *Evac/Rotation* tab, or to specify what population group is designated to that grid element.

Detailed instructions are provided in Chapter 4. The following notes, however, can help the user get started with these forms:

- Evacuation directions are initially set to be radially outward and the speed multiplier is set to one. The evacuation direction in each grid element is shown as an arrow. The speed multiplier is identified by an integer.

- Speed multipliers are modified on the forms named Radial Evacuation Speed and Network Evacuation Speed, depending on which model is selected on the *Properties* form. Evacuation directions are modified on the form named *Network Evacuation*

Direction. There is one of these forms for each cohort. Both speeds and directions are shown on all of these forms, but only one of them can be changed from that form.

- Speed multipliers are added by clicking on the button *Modify Multipliers*.

- There are several ways to change evacuation directions on this screen. The simplest is to click on one of the grid elements, which causes the arrow to rotate clockwise to the next direction. Directions can also be changed on the *Network Evacuation Direction* form by selecting multiple radii and/or sectors, and applying a direction to the selected portion of the map. The direction is selected by clicking on an entry in the table labeled *Direction;* the multiple radii and sectors are selected from the lists labeled *Radius* and *Sector.* Clicking the *Assign* button applies the direction to the selected area(s). Multiple radii and sectors can be selected by holding down either the shift or the control key for contiguous or noncontiguous selections, respectively. Similar options are available on the *Radial Evacuation Speed* and *Network Evacuation Speed* forms.

- The *SaveMap* button saves a copy of the evacuation map with the grid background as either a jpeg or Windows bit map file. This allows maps to be easily imported into other applications and documents.

- The sliders labeled Inner Ring Shown and Outer Ring Shown allow the user to zoom in and out and to eliminate detail at the center of the map.

- In WinMACCS versions 3.9.0 and newer, the maps forms can be resized by grabbing the corner/edge of the map and dragging it to the desired size.

2.5 Running a Simulation

Select *Execute→Run Models* from the main menu.

The MACCS modules to be used, *Atmospheric Dispersion, Early Consequences, and Late Consequences*, can be selected or deselected from the *Scope* tab. The *Create COMIDA2 File* setting can be chosen from the *Food* tab.

Clicking the *Run Simulation* button initiates a simulation. If there are any input inconsistencies detected by winMACCS, forms open automatically to allow values to be corrected. However, not all input inconsistencies are caught at this stage. Some input problems are detected when MACCS is run. Errors generated at this step are described into the *Results* window.

The simulation progress can be observed in the command-prompt window (Results Window) from which MACCS is initiated. The window is minimized by default, but can be opened by the user.

When the simulation has completed, the command window closes and a message conveying successful completion is written to the *Results* window. At this point, results can be viewed as follows:

- Double-clicking on Output/Model1.out found under the *Files* tab of the *Project* window to open the results file in Notepad.

- Select Post Processing/Graphical Result/Results Over All Weather Trials to view a CCDF over weather trials.

- If sampling was used (variables were set to be uncertain and multiple realizations were run), the option *Post Processing/Create Custom Report* can be used to combine results. The quantiles reported can be modified on the form *GENERAL/Reporting Options.*

- If sampling was used, the option *Post Processing/Graphical Result/Statistical Summary Results* can be used to display the distributions of the results.

2.6 Running MACCS from a command line

A MACCS run can be generated by using command line parameters. The following parameters can be specified on the MACCS.exe command line in any order.

-a ATMOS input file and path

-e EARLY input file and path

-c CHRONC input file and path

-m meteorological data file and path

-s site file and path

-o output file and path. The prefix portion of the output file name is also used to name the binary output file. For example, if the output file is named model1.out, the binary file created by MACCS is named model1.bin.

-i file containing names of MACCS input files. This is the path and name of a file containing the ATMOS, EARLY, CHRONC, meteorological, site and output file names and paths, one file name per line in that order. If any of these files have been specified on the command line using the -a, -e, -c, -m, -s, or -o parameter, this file is not used for any of the file names. If this -i option is not used and the files are not specified on the command line, the file names are expected to be in a file named MACCS.tmp located in the same folder as MACCS.exe. If a file is not needed for a calculation, the line must contain a dummy name or blank field defined by two consecutive double quotes.

The following example shows the contents of a sample MACCS.tmp file. Only the Atmos model is to be executed. The EARLY, CHRONC, and site files are not needed and file names do not need to be specified. A meteorological data file, Metsur.inp, is to be used. MACCS creates the output files Model1.out and Model1.bin.

```
C:\WinMACCSSamp\inb\Input\Atmos1.inp
""
""
C:\WinMACCSSamp\inb\Data\Metsur.inp
""
C:\WinMACCSSamp\inb\Output\Model1.out
```

-p is a prefix used in naming the status files. If this isn't specified, the status files are named MaxStat.log and FortErr.log by default. If it is specified, the names of the two status files are prefixed with the string following this flag. For example,

"MACCS.exe -p MyRun" would create status files MyRunMaxStat.log and MyRunFortErr.log. These files are placed in the same folder as the output file specified with the -o parameter. If the -i option was used to specify the file names (instead of the -a, -e, -c, -m, -s and -o parameters), the status files are placed in the same folder as the output file specified using the -i option. If neither of these options were used, the status files are placed in the same folder as the MACCS executable file, MACCS.exe.

The status file, MaxStat.log, contains a single line with the string 'OK' if the MACCS execution was successful. If the execution was not successful, this file contains a line with the string 'NO'. If MACCS detected an error and exited, the line containing the string 'NO' is followed by a MACCS generated error message.

The FORTRAN error file, FortErr.log, is created only if MACCS aborts abnormally. It contains trace-back information and system level error messages. If this file exists before MACCS crashes, the error messages are appended to the end of the file rather than overwriting the previous contents.

When at least one of the command line parameters, -a, -e, -c, -m, -s, or -o, is present, the MACCS.tmp file is not used to define the names and paths of the required files. In this case all of the files used by MACCS must be specified on the command line.

The following example shows a case in which all files are specified on the command line.

```
C:\Program Files\WinMACCS> MACCS.exe  -a C:\inb\Input\Atmos1.inp -m
C:\inb\Data\Metsur.inp -o C:\inb\Output\Model1.out
```

The following example shows a case in which a file is used to specify the names of MACCS files. The file specifying the names is Maccs.tmp. Error files are named inbMaxStat.log and inbFortErr.log. These files are placed in the folder C:\inb\.

```
C:\ Program Files\WinMACCS> MACCS.exe -i C:\inb\Maccs.tmp –p inb
```

3. USERS GUIDE

All WinMACCS model choices and parameters are specified through the *Parameters* tab on the *Project* window. The main categories are *GENERAL*, *ATMOS*, *EARLY*, *CHRONC*, *DOSE COEFFICIENTS*, and *COMIDA2*.

3.1 GENERAL Main Categories

The *GENERAL* main category consists of *Properties, File Specifications,* and *Reporting Options*.

The hierarchical structure in WinMACCS can be expanded or contracted by clicking on the + or – next to items on the parameters tab, respectively. For example, clicking on the + to the right of the *GENERAL* main category reveals three categories that belong to this main category. Clicking on the + to the left of the Properties category expands it, revealing the two forms that it contains. Finally, clicking on the + to the left of the *Properties* form reveals the set of parameters that it contains.

3.1.1 Properties

The *Properties* form is opened by double-clicking on *General/Properties/Properties* from the *Parameters* tab in the *Project* window, as illustrated in Figure 3-1.

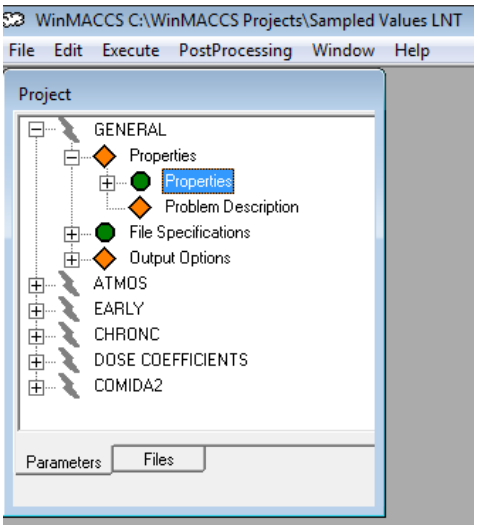


Figure 3-1 Accessing *Properties* form

A window opens that shows the scope of the calculation and related model settings, as shown in Figure 3-2. Depending on the selections made, input parameters may be or may not be required. Details describing the available models are included in the User's Guide portion of this document.

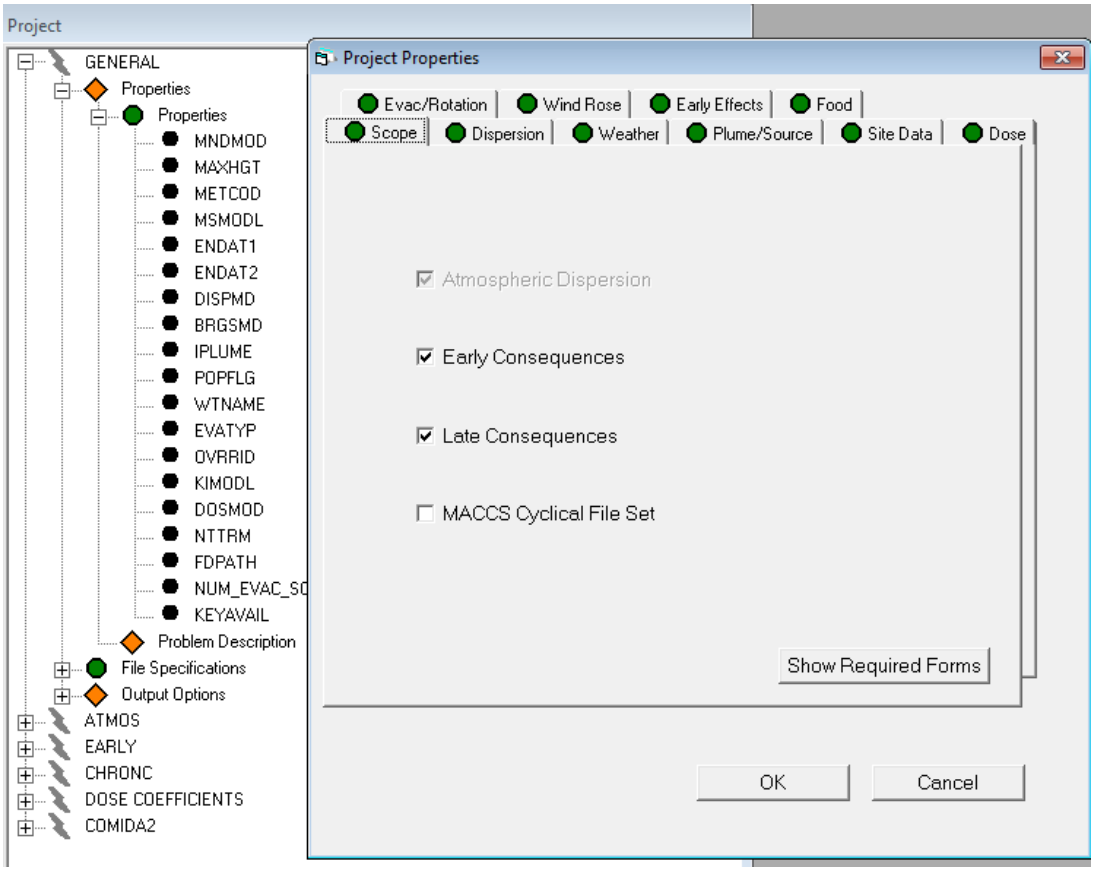


Figure 3-2 *Project Properties* Form

The following describes how modifying the scope of the calculation affects the forms that are required.

1. Creating a new project by selecting *File→New* from the main menu causes *Project Properties* to open after the new project is created with default settings. Notice that *Atmospheric Dispersion* (corresponding to the ATMOS Main Category in the Parameters tab) is always selected and cannot be modified, as indicated by the light gray color of this item. *Early Consequences* (corresponding to the EARLY Main Category) and *Late Consequences* (corresponding to the CHRONC Main Category) are not checked by default.
2. Clicking on the plus sign next to the *ATMOS*, *EARLY,* and *CHRONC* main categories on the *Parameters* tab causes additional subcategories to become visible, as illustrated in Figure 3-3. All of the categories under *EARLY* and *CHRONC* are empty grey circles with a single slash. This means that the parameters on these forms are not defined but are not required in order to run a simulation given the model choices on the *Properties* form.
3. Clicking the check box next to the *Early Consequences* label and clicking the button labeled *Show Required Forms* shows that some categories in the *EARLY* main category now require attention. These categories have icons consisting of an X-ed red octagon. If the *OK* button is clicked in *Properties*, the scope of the calculation changes to include early health effects.
4. Repeating the process by adding *Late Consequences* to the scope causes an additional group of categories to require attention.

5. Each of the selected main categories (ATMOS, EARLY, CHRONC) contains a form called *Property Form Parameters*. Next to each of these names is a solid green icon, indicating that this form requires no attention. Opening these by double-clicking on the word *Property Form Parameters* under each of the main categories allows a user to see the variable values that are defined on the *Project Properties* form.

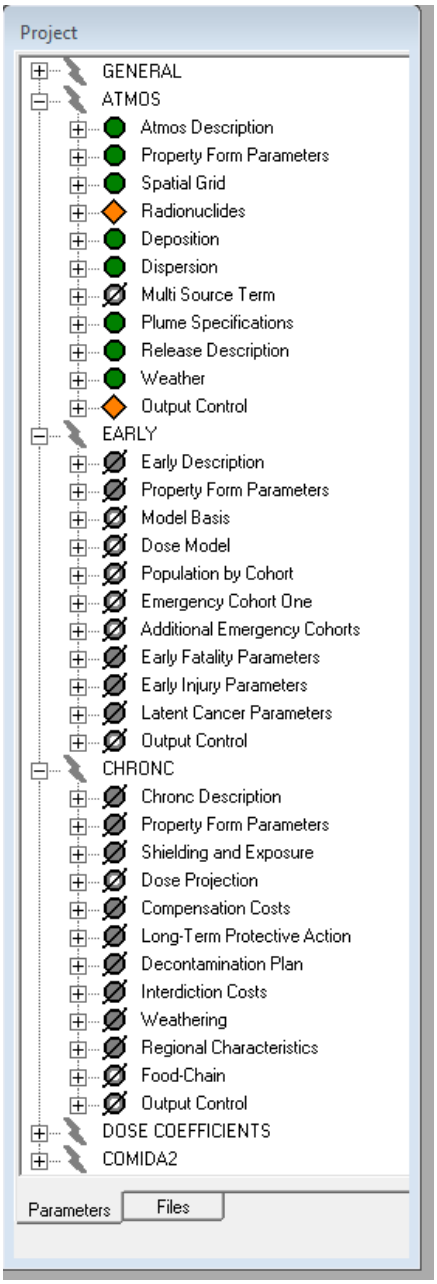


Figure 3-3 Form icons

Figure 3-4 shows the form for EARLY. The values on these forms correspond to model settings in *Project Properties*. These values can be modified by changing settings in *Project Properties (under the GENERAL* main category) but cannot be changed from the *Property Form Parameters* form, as indicated by the light gray backgrounds.

The settings on the other *Project Properties* tabs function in a similar way.

When the *Show Required Forms* is clicked on the *Project Properties* form, WinMACCS modifies the icons next to each category to indicate the ones that would be required if the change is selected by clicking *OK*.

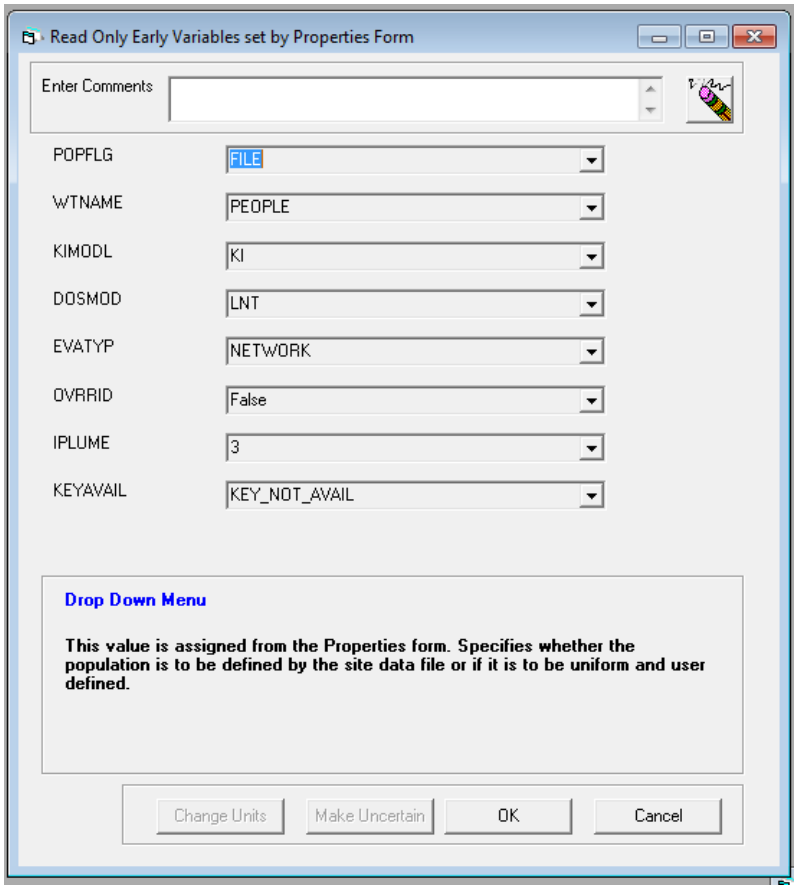


Figure 3-4 Read-only variables on property form under the *EARLY* main category

Scope Tab

MACCS uses variables ENDAT1 and ENDAT2 to determine whether the simulation should run ATMOS; ATMOS and EARLY; or ATMOS, EARLY, and CHRONC. The *Scope* tab in Figure 3-5 determines the value of these variables. ENDAT1 is set to False if the EARLY model is to be run. ENDAT2 is set to False if the CHRONC model is to be run. The option to invoke the *MACCS Cyclical File Set* does not correspond to any MACCS parameters; this option is handled within the WinMACCS interface.

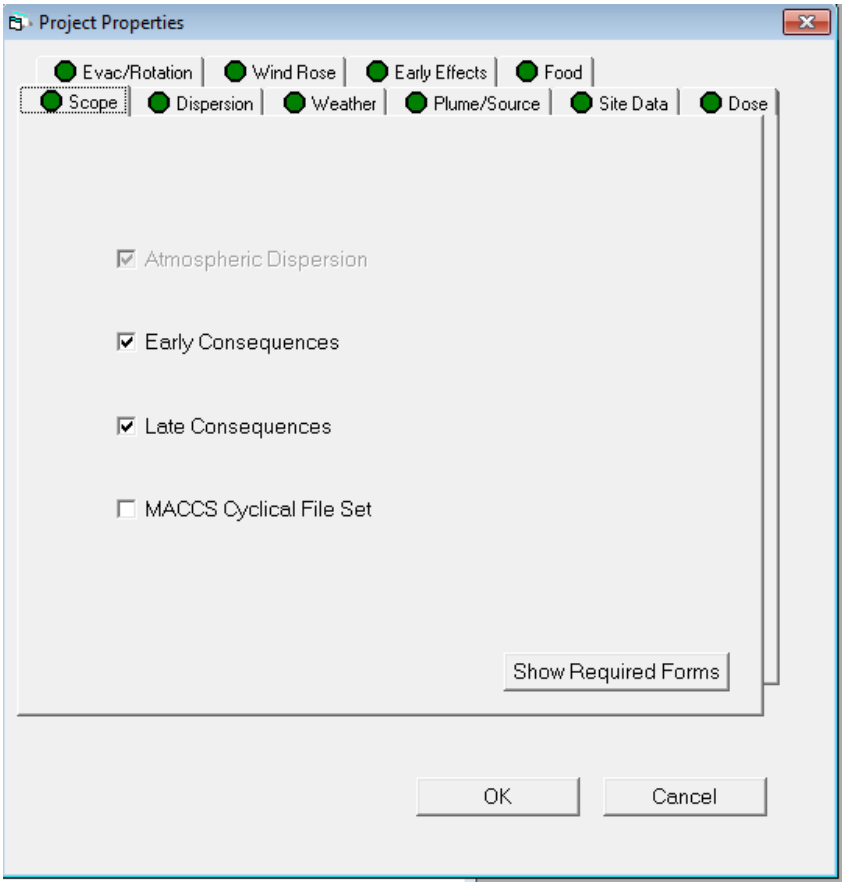


Figure 3-5 Scope Tab on the *Project Properties* Form

The *Atmospheric Dispersion* (ATMOS) box is always checked.

Checking the *Early Consequences* Module (EARLY) box means:

- A dose conversion factor file needs to be assigned under the File Specifications category on the Parameters tab of the Project window.
- Entries on other tabs, namely *Site Data, Dose, Evac/Rotation, Wind Rose*, and *Early Effects* determine which other EARLY input variables are required.

Checking the *Late Consequences m*odule (CHRONC) means:

- *Early Consequences* are automatically checked. The CHRONC module cannot be run without the EARLY module.
- Entries on the *Food* tab determine which additional CHRONC input variables are required.

Checking the *MACCS Cyclical File Set* means:

- A cyclical file set needs to be assigned under the *File Specifications* category on the *Parameters* tab of the *Project* window. The function of this model choice is described in a subsequent section.
- *OK* saves changes made under any tab and closes the form. *Show Required Forms* shows how changes affect the form states on the *Parameters* tab window and the tab states in *Project Properties* without saving the changes.
- *Cancel* closes the form without saving any changes.

***Dispersion* Tab**

The contents of the *Dispersion* tab are shown in Figure 3-6. The user must either select power law functions or lookup tables to define the dispersion parameters.

Selecting the *Power Law Functions* means:

- Power law function parameters are required. They must be defined in the *Dispersion Function* form found in the *ATMOS/Dispersion* category in the *Parameters* tab.
- WinMACCS sets NUM_DIST to be zero when building input images for MACCS.

Selecting *Lookup Tables* means:

- Lookup table parameters are required. These must be defined in the *Dispersion Table* form found in the *ATMOS/Dispersion* category in the *Parameters* tab.
- WinMACCS sets NUM_DIST to be the value defined on the *Dispersion Table* form when building input images for MACCS.

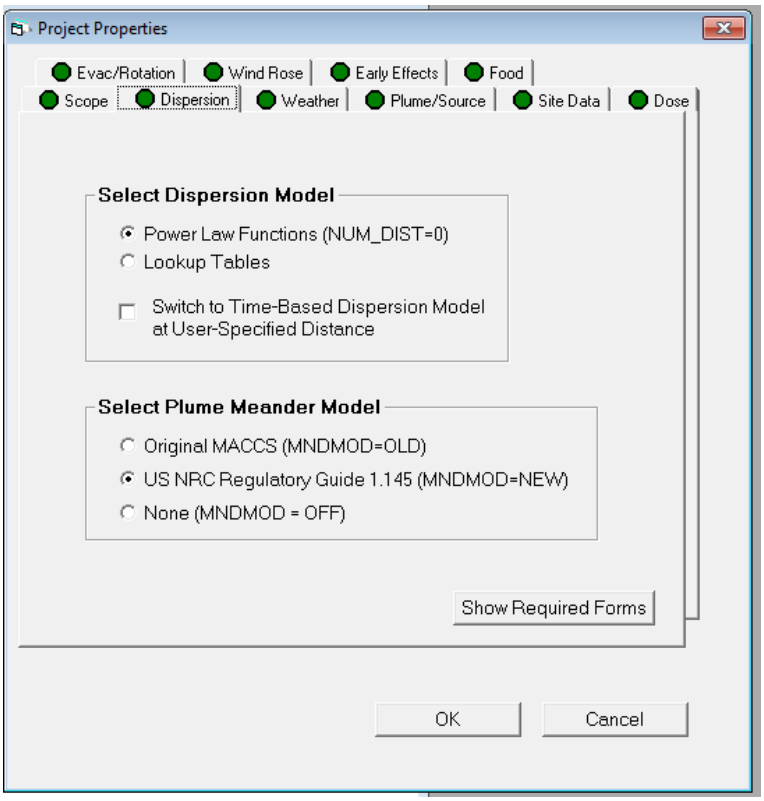


Figure 3-6 Dispersion tab on the *Project Properties* form

Switch to Time-Based Dispersion Model at User-Specified Distance:

- If checked, WinMACCS sets the variable DISPMD to the value LRTIME. Parameters on the *Long-Range Time Based Parameters* form found in the *ATMOS/Dispersion* category in the *Parameters* tab are required. Dispersion parameters are functions of time rather than distance beyond a user-specified distance.
- If not checked, DISPMD is set to the value LRDIST. The value LRDIST causes MACCS to use the original model in which dispersion parameters are functions of distance.

There are three choices for the plume meander model. MACCS uses a variable, MNDMOD, to determine which plume meander model to use. The corresponding value of MNDMOD is shown parenthetically on the right of each entry.

Selecting *Original MACCS* means:

- The plume meander model is the original one in MACCS 1.12. This model accounts for the effect of the duration of release.
- The ATMOS/Plume Specifications/Original Meander form is required.

Selecting *US NRC Regulatory Guide 1.145* means:

- The Regulatory Guide 1.145 plume meander model is used. This model assumes one-hour duration plume segments. It accounts for the effects of stability class and wind speed on plume meander. It should not be used when plume segment durations are substantially different than one hour, especially when they are less than one hour, because this violates the assumptions of the model.
- Parameters on the form ATMOS/Plume Specifications/US NRC Reg. Guide 1.145 Meander are required.

Selecting *None* means:

- There are no required parameters.
- The plume meander model is turned off.

Weather Tab

The contents of the *Weather* tab are shown in Figure 3-7.

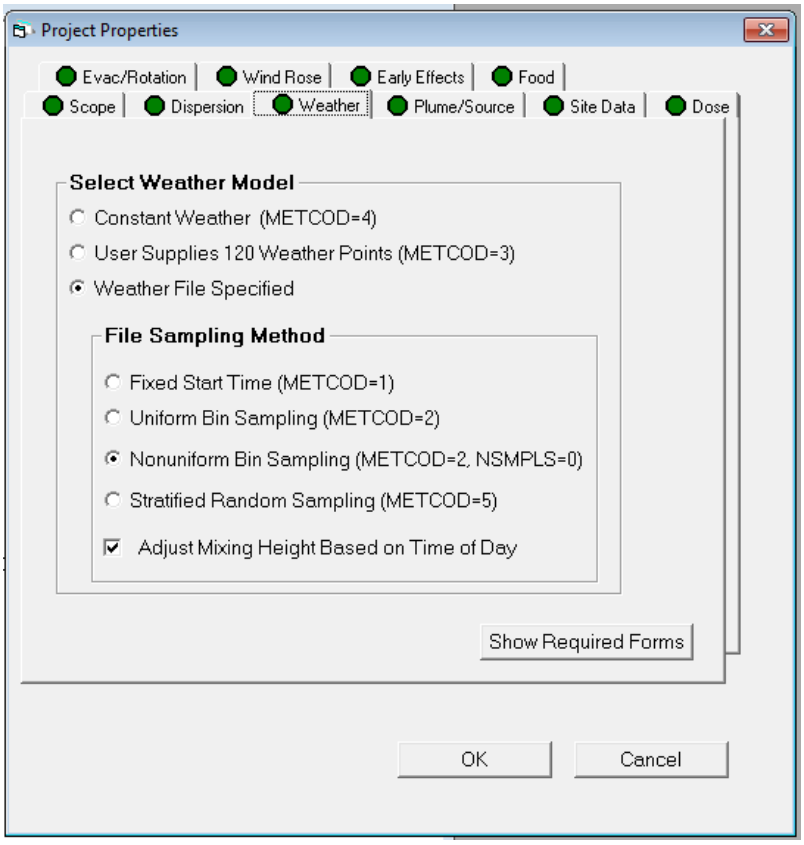


Figure 3-7 *Weather* tab on the *Project Properties* form

MACCS uses a variable, METCOD, to specify which weather sampling option to use. The corresponding value of METCOD is shown on the right of each entry.

Constant Weather means inputs on the following *ATMOS*/*Weather* category forms on the *Parameters* tab are required:

- Constant or Boundary Conditions
- Fixed Start Time Data

User Supplies 120 Weather Points means that the following inputs found on the *ATMOS*/*Weather* category on the *Parameters* tab are required:

- Constant or Boundary Conditions
- Fixed Start Time Data
- User-Supplied Weather
- Boundary Limit

The fixed start time is required for these options to determine the time the accident occurs during the growing season in connection with food ingestion modeling. These inputs are required even if food ingestion is not being treated, but can be set to dummy values.

The other weather sampling options require specifying a meteorological data file. The meteorological data file supports 15-minute, 30-minute, and one-hour intervals. Only the traditional hourly weather data are supported with the *User Supplies 120 Weather Points (METCOD=3)* option.

If *Weather File Specified* is selected, a meteorological data file is required and needs to be assigned under the *File Specifications* category. Also, a sampling method must be chosen. The input data requirements for the weather sampling options are described in the subsequent paragraphs.

Fixed Start Time means that the following *ATMOS/Weather* category forms under the *Parameters* tab inputs are required:

- Constant or Boundary Conditions
- Fixed Start Time Data
- Boundary Limit

Uniform Bin Sampling means the following *ATMOS*/*Weather* category forms under the *Parameters* tab are required:

- Constant or Boundary Conditions
- Samples per Bin
- Seed
- Boundary Limit
- Rain Distances
- Rain Intensities

Nonuniform Bin Sampling means the following *ATMOS*/*Weather* category forms under the *Parameters* tab are required:

- Constant or Boundary Conditions
- Seed
- Boundary Limit
- Bins
- Rain Distances
- Rain Intensities

Stratified Random Sampling means the following *ATMOS*/*Weather* category forms under the *Parameters* tab are required:

- Constant or Boundary Conditions
- Samples per Day
- Seed
- Boundary Limit

If the *Weather File Specified* is selected, an optional, mixing-height model can be chosen. MACCS uses a variable, MAXHGT, to determine which mixing height model to use.

Adjust Mixing Height Based on Time of Day means:

- WinMACCS sets the variable MAXHGT to the value DAY_AND_NIGHT.
- Parameters in *Site Location* found on the *ATMOS/Weather* category are required.
- Both daytime and nighttime values of the mixing heights in the meteorological data file are used.
- If not checked, MAXHGT is set to the value DAY_ONLY. This causes MACCS to use the model in MACCS 1.12, which uses only the maximum seasonal values that normally correspond to daytime values.

***Plume/Source* Tab**

The contents of the *Plume/Source* tab are shown in Figure 3-8.

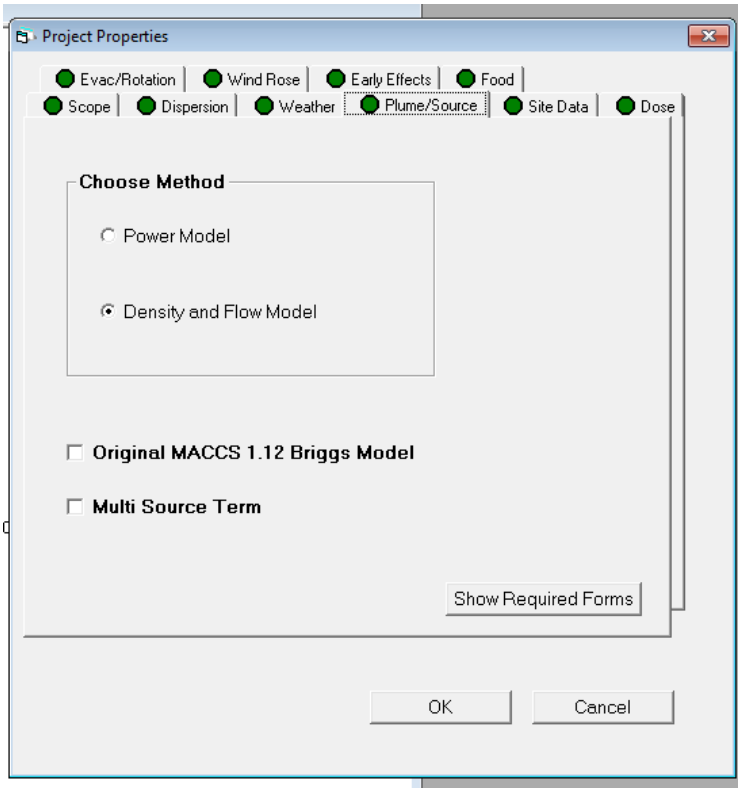


Figure 3-8 *Plume/Source* Tab on the *Project Properties* form

Choosing *Power Model* means:

- The original MACCS model is used.

- Heat rate input for each plume segment must be specified in *ATMOS*/*Release Description/Heat*.

Choosing *Density and Flow Model* means:

- Mass flow rate and mass density are required for each plume segment. These are defined in *ATMOS*/*Release Description/Density and Flow*.

Choosing Original MACCS 1.12 Briggs Model means:

- WinMACCS sets the variable BRGSMD to the value ORIGINAL. The original Briggs model is used to simulate plume rise. The default and recommended model is the improved one.
- If not checked, BRGSMD is set to the value IMPROVED. This causes MACCS to use the improved plume rise model.

Choosing *Multi Source Term* means:

- MACCS allows the user to use multiple source term definitions, possibly from different .ptf files, to define the overall source term for an accident.
- The user specifies these files under *File Specifications* and needs to fill out additional forms in the *ATMOS* main category.

Site Data **Tab**

The contents of the *Site Data* tab are shown in Figure 3-9. This tab is required if *Early Consequences* are selected on the *Scope* tab. MACCS uses a variable, POPFLG, to define the source of the site data.

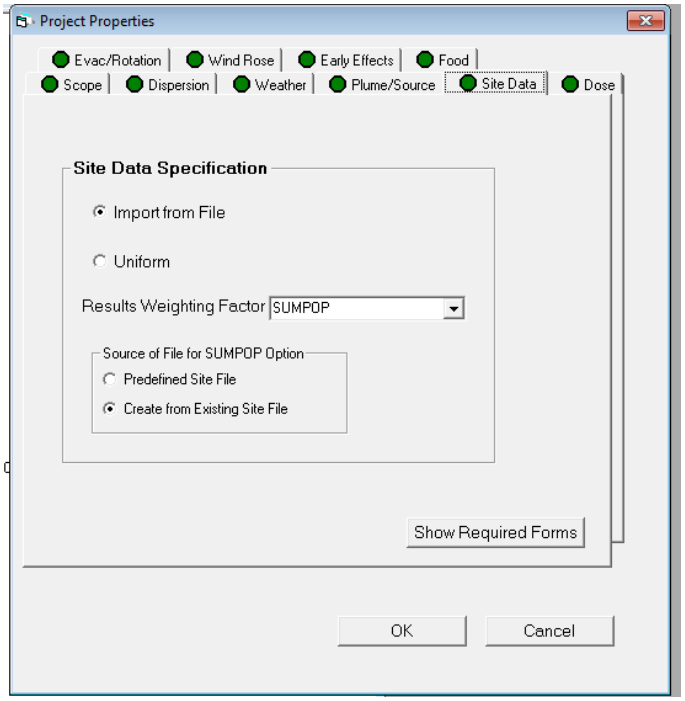


Figure 3-9 *Site Data* tab on the *Project Properties* form

Choosing *Import from File* means:

- A site file is required and needs to be chosen under the *File Specifications* category under the *Parameters* tab. This file can be created by a preprocessor, e.g., SecPop, to generate a file containing census and economic data for the chosen site. A sample site

file, FicticiousSite.inp, is included in the WinMACCS installation. WinMACCS allows the user to increase the angular resolution of a site file, and this feature has been integrated into the site file specification form.

- WinMACCS sets the variable POPFLG to the value FILE.

Choosing *Uniform* means:

- Population density data are required and are specified in *Population Data* form found under the *EARLY*/*Model Basis* category.
- MACCS sets the variable POPFLG to the value UNIFORM.
- The SUMPOP option is unavailable under Results Weighting Factor.

  Results Weighting Factor determines the way multiple-cohort results are combined. Except when SUMPOP is selected, the weighting factor used for each of the cohorts is assigned by the variable WTFRAC found under the *EARLY*/*Emergency Cohort N*/*Basic Parameters* forms, where *N* is the cohort number.

- If *SUMPOP* is selected, the site file must include a separate population distribution for each evacuation scenario. This option enables cohorts to be defined in a very general fashion.
- If *TIME* is selected, the weighting factor under each *Basic Parameters* form refers to fraction of time.
- If *PEOPLE* is selected, the weighting factor under each *Basic Parameters* form refers to fraction of people.

MACCS uses a variable, WTNAME, to determine the cohort weighting method. This is set to SUMPOP, TIME, or PEOPLE, depending on the choice on this form.

If *Import from File* is chosen and the *Results Weighting Factor* is set to be equal to *SUMPOP,* the user must specify the source of the site file by choosing one of two options as follows.

Choosing *Predefined Site File* means:

- The user is required to link an existing site file to the project using the *Site File* form in the *GENERAL/File Specifications* category on the *Parameters* tab. This site file should have a POPULATIONn section defined for each evacuation cohort or MACCS will fail. The n a number corresponding to the cohort number.

Choosing *Create from Existing Site File* means:

- The user is required to link an existing site file to the project using the *Site File* form in the *GENERAL/File Specifications* category on the *Parameters* tab. The number of POPULATION sections in this file is not relevant. In other words, a site file previously created with or without the SUMPOP option is acceptable. Most commonly, the site file is created using SecPop.
- Additional forms in the EARLY category *Population by Cohort* is required.

After a site file is linked, the total population can be viewed on the *Population from Site File* form found in the EARLY/Model Basis category within the *Parameters* tab.

Dose **Tab**

Choices under the *Dose* tab must be made if the *Early Consequences* option is selected under the *Scope* tab. The contents of the *Dose* tab are shown in Figure 3-10.

MACCS supports Federal Guidance Reports (FGRs) 11 and 12 dose coefficient files created by a preprocessor program, FGRDCF, files created from Federal Guidance Report 13, and dose conversion files created by DOSFAC2. DOSFAC2 bases its dose conversion factors on DOE/EH-0070 (1988). Changing the type of dose conversion factor file has the effect of changing the allowed organ types on a number of forms and the user is required to modify these forms.

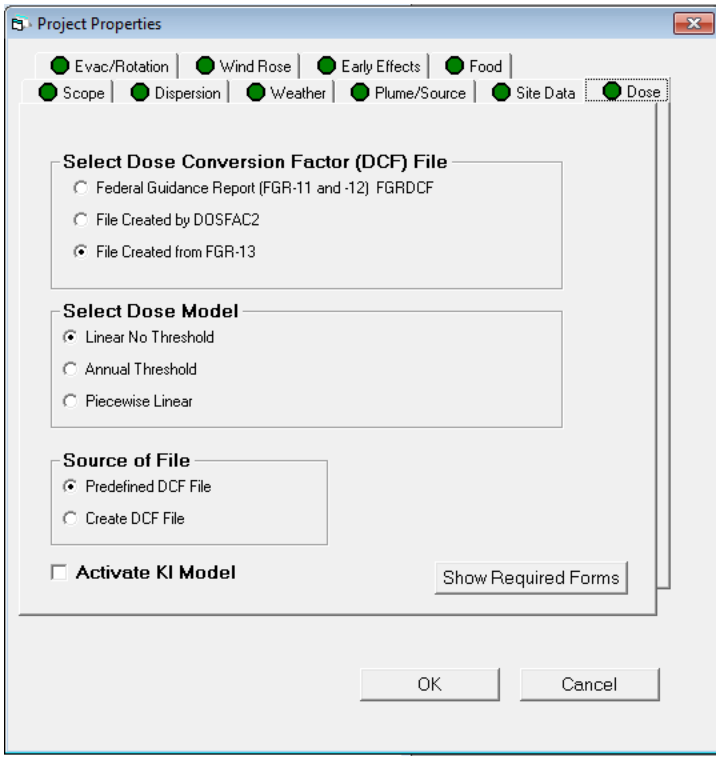


Figure 3-10 *Dose* tab on the *Project Properties* form

Choosing *Federal Guidance Report (FGR-11 and -12) Dose Conversion Factor File (FGRDCF)* means:

- Early injury and early fatality results are not available. These selections, *Early Fatality Effects* and *Early Injury Effects*, are grayed out on the *Early Effects* tab of the *Project Properties* form.
- Data on the related forms, Early Fatality Parameters and Early Injury Parameters, are not used.
- Outputs requested on the *Early Fatality Radius* form in the *Early/Output Control* category are not available.
- The *Annual Threshold* and *Piecewise Linear* dose-response models are not available on the *Dose* tab. Only the *Linear No Threshold* dose-response model is available.

Choosing *File Created by DOSFAC2* means:

- If the *Late Consequences* option is selected on the *Scope* tab, the *Annual Threshold* and *Piecewise Linear* dose-response models are available.
- The form *Organs of Risk DOSFAC2* is required.

Choosing *File Created from FGR-13* means:

- If the *Late Consequences* option is selected on the *Scope* tab, the *Annual Threshold* and *Piecewise Linear* dose models are available.

- The form *Organs of Risk FGR-13* is required.

The user has three dose-response models to choose from. MACCS uses a variable, DOSMOD, to specify which dose-response model is to be used.

Choosing *Linear No Threshold* means:

- The linear no-threshold dose-response model (the only option in earlier versions of MACCS) is used to calculate latent health effects. (MACCS continues to support a linear-quadratic dose response model under this option, although it has fallen into disuse.)
- DOSMOD is set to LNT

Choosing *Annual Threshold* means:

- The *EARLY/Dose Model/Annual Threshold* form is required.
- The *EARLY/Dose Model/Lifetime Threshold* is optional.
- DOSMOD is set to AT.

Choosing *Piecewise Linear* means:

- The EARLY/Dose Model/Piecewise Linear form is required.
- DOSMOD is set to PL.

Choosing either *Annual Threshold* or *Piecewise Linear* means:

- If the Activate KI Model box is checked, the EARLY/Emergency Cohort N/KI Ingestion Threshold or Piecewise form must be filled out instead of the EARLY/Emergency Cohort N/KI Ingestion Linear No Threshold form. In this case, only the values 0 or 1 are valid for POPFRAC on the KI Ingestion form.
- On the *Food* tab the options *User supplies COMIDA2 file* or *No Food Model* must be chosen.
- Files must be specified under the GENERAL/File Specifications/Annual Differential DCF Files and, if the COMIDA2 food option is selected, GENERAL/File Specifications/Annual Differential COMIDA2 Files forms.

MACCS uses a variable named KIMODL to determine whether the KI model is to be used. If the check box *Activate KI Model* is checked, this variable is set to *KI.* Otherwise, this variable is set to *NOKI.*

Choosing *Predefined DCF File* means:

- The user is required to link an existing DCF file to the project using the *Dose Conversion Factor File* in the *GENERAL/File Specifications* category on the *Parameters* tab.
- If the user has chosen *Predefined COMIDA2 File* on the *Food* tab, the COMIDA2 file chosen must have been created using the same DCF file that is specified.

Choosing *Create DCF File* means:

- The user is required to link an existing DCF file to the project using the *Dose Conversion Factor File* in the *GENERAL/File Specifications* category on the *Parameters* tab. This file will be used to extract the list of available radionuclides. The default DCF values will be the values defined in this file.
- The COMIDA2 Food Model is unavailable, even though it appears to be enabled in the WinMACCS interface.
- After the DCF file is linked to the project, the user can select radionuclides and define both deterministic and uncertain DCF values using forms in the category DOSE COEFFICIENTS within the *Parameters* tab.

Evac/Rotation Tab

Information under this tab is required when the *Early Consequences* module is selected. The *Evac/Rotation* tab is broken up into three main areas: problem model, number of cohorts, and model activation, as shown in Figure 3-11. First, the user must choose the type of evacuation to use. The choices are *Radial, Network*, and *None*. Choosing *Radial* causes evacuees to move radially outward from each grid element to the next. *Network* evacuation models evacuation from a grid element to any of the four adjacent grid elements. Finally, *None* specifies that no evacuation occurs.

The next action is to specify whether the *Speed Multiplier Model* and/or *Keyhole Evacuation Model* is active. Finally, the user specifies the number of cohorts represented in the problem. WinMACCS supports up to 20 cohorts. All scenarios correspond to EARLY change sets in the MACCS input files. MACCS uses a variable, EVATYP, to determine the evacuation model for each cohort. The choices for the evacuation model are is automatically designated once you choose one of the three options, *Radial*, *Network* or *None*. The selection in the *Problem Model* box applies to all cohorts.

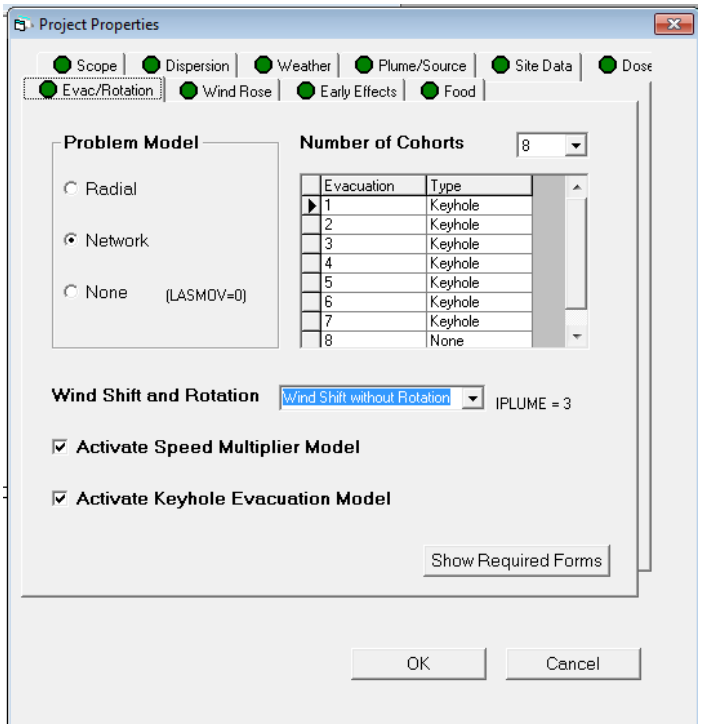


Figure 3-11 *Evac/Rotation* Tab on the *Project Properties* form

Choosing *None* under *Problem Model* means:

- The only option for the evacuation type field for all evacuation cohorts is *None.*
- The *Activate Speed Multiplier Model* check box cannot be activated on this form.
- The *Activate Keyhole Evacuation Model* check box cannot be activated on this form.

Choosing *Radial* means:

- The options for the evacuation *Type* field for all evacuation cohorts are *None* and *Circular. Keyhole* is available if the *Activate Keyhole Evacuation Model* check box is checked.

- The options for the evacuation type for all evacuation cohorts must be entered. The first Cohort must be assigned the type *Circular* or *Keyhole* to allow *Circular* or *Keyhole* to be assigned for subsequent cohorts.

Choosing *Network* means:

- The options for the evacuation *Type* field for all evacuation cohorts are *None* and *Circular. Keyhole* is available if the *Activate Keyhole Evacuation Model* check box is checked.
- The options for the evacuation type for all evacuation cohorts must be entered. The first Cohort must be assigned the type *Circular* or *Keyhole* to allow *Circular* or *Keyhole* to be assigned for subsequent cohorts.
- The field Wind Shift and Rotation must be set to *Wind Shift without Rotation*.

Choosing *Activate Speed Multiplier Model* Means:

- If the *Network* evacuation option has been selected, the evacuation speed can be adjusted by grid element on the *Network Evacuation Speed* form.
- If the *Radial* evacuation option has been selected, the evacuation speed can be adjusted by grid element on the *Radial Evacuation Speed* form.

The user must choose the method for plume segment modeling. MACCS uses a variable, IPLUME, to specify the option that is used. The corresponding value of IPLUME is shown to the right of the drop-down box, as shown in Figure 3-11.

Choosing *No Wind Shift with Rotation* means:

- All subsequent plume segments travel in the same direction as the initial plume segment.
- When weather bin sampling is selected, a set of results is constructed for each weather trial by considering that the wind might have blown toward each compass direction. This is equivalent to rotating the results for the weather trial around the compass, one compass sector at a time. This process creates an expanded set of results for each weather trial. The total number of results generated by this process is the number of compass sectors times the number of weather trials. Probabilities for each of the rotated results are calculated by using the wind rose for the corresponding weather bin or using a user-defined wind rose, depending on the wind rose option selected by the user (see below).

Choosing *Wind Shift with Rotation* means:

- Each plume segment moves in the direction that the wind is blowing at the time of its release. Thus, each plume segment is allowed to travel in its own direction.
- When weather bin sampling is selected, each weather pattern is rotated around the compass, creating a set of results equal to the number of compass sectors times the number of weather trials. The probability of each result is calculated using the wind rose for the weather bin or the user defined values for the wind rose, depending on the wind rose option selected by the user (see below). The wind-rose probability is assigned based on the direction taken by the first plume segment.

Wind Shift with Rotation is based on the assumption that specific weather patterns (i.e., time dependence of wind directions) can occur in all wind directions and that the likelihood only depends on the wind rose probability of the initial wind direction. For example, the conditional probability of the second plume segment traveling southeast given that the first segment traveled east is the same as same as the conditional probability of the second plume segment traveling northwest given that the first segment traveled west. This option has been used in past

analyses, such as NUREG-1150, where only a few plume segments were used to represent the source term. More recent analyses commonly use more than a few plume segments to represent the source term. However, the more plume segments that are used in an analysis, the less likely this assumption is to be valid. As a result, this option should be avoided when more than a few plume segments are used.

Choosing *Wind Shift without Rotation* means:

- Each plume segment moves in the direction that the wind is blowing at the time of its release. Thus, each plume segment is allowed to travel in its own direction.
- Only the set of wind directions indicated in the meteorological file is used; no wind rotation is performed. Thus, only a single result is generated per weather trial.

Wind Shift without Rotation produces the most realistic results and is recommended for most analyses when more than a single plume segment is used. The drawback is that more weather trials may be required to achieve adequate weather statistics than are required using *Wind Shift with Rotation*.

When more than one cohort is specified, the user must enter the evacuation *Type* for each cohort by filling in the grid, as illustrated in Figure 3-12.

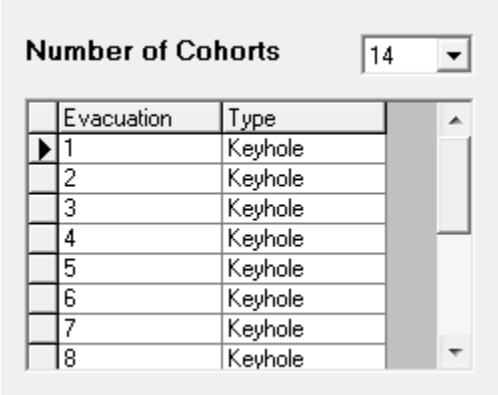


Figure 3-12 Specifying cohort evacuation types

***Wind Rose* Tab**

This *Wind Rose* tab in Figure 3-13 is required if the *Early Consequences* module is selected.

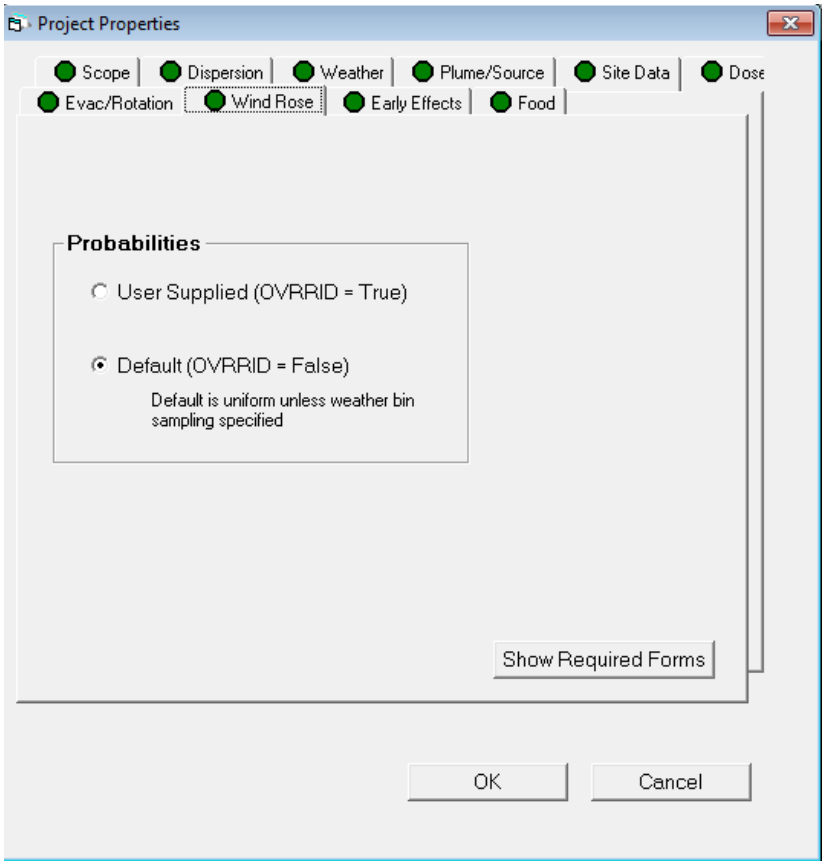


Figure 3-13 *Wind Rose* tab on the *Project Properties* form

The corresponding value of the MACCS variable OVRRID is shown to the right of each entry.

Choosing *User Supplied* means:

- Wind rose probabilities are required. These are defined on the *Wind Rose Probabilities* form found on the *EARLY/Model Basis* in the *Parameters* tab.
- User defined wind rose probabilities are used in place of values taken from the weather file.

Choosing *Default* means:

- Wind rose probabilities for each weather sampling bin constructed from the meteorological data file are used if one of the bin sampling options is selected.
- Wind rose data are only used by MACCS when one of the *Wind Rotation* options and one of the weather binning options are selected.

***Early Effects* Tab**

This *Early Effects* tab shown in Figure 3-14 is required if the *Early Consequences* module is selected.

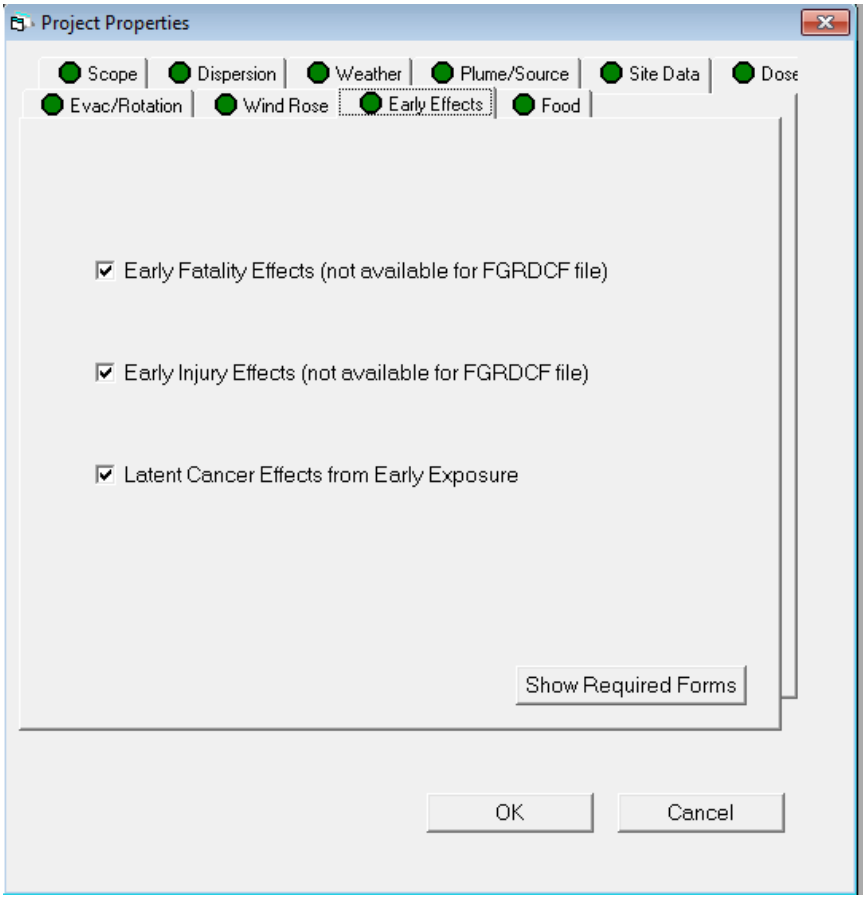


Figure 3-14 Early effects on the *Project Properties* form

This form allows the user to select the health effects to be calculated. If an FGRDCF dose conversion factor file is specified, early fatality and injury results are not available.

Checking the box next to *Early Fatality Effects* means:

- Early fatality parameters must be defined on the *Early Fatality Parameters* form.
- The fatalities defined can be included in the output requests on the *Health-Effect Cases* form (type 1), *Early Fatality Radius* form (type 2), *Average Individual Risk* form (type 4), *Centerline Risk* form (type 7), and *Population-Weighted Risk* form (type 8). Early fatality results are unavailable when this box is not checked.
- The user must choose a dose conversion factor file type that supports early health effects.

Checking the box next to *Early Injury Effects* means:

- Early injury parameters must be defined on the *Early Injury Parameters* form.
- The injuries defined can be included in the output requests on the *Health-Effect Cases* form (type 1), *Average Individual Risk* form (type 4), *Centerline Risk* form (type 7) and *Population-Weighted Risk* form (type 8). Early injury results are unavailable when this box is not checked.
- The user must choose a dose conversion factor file type that supports early health effects.

Checking the box next to *Latent Cancer Effects from Early Exposure* means:

- Latent cancer parameters must be defined on the forms found under the *Latent Cancer Parameters* category, namely those on the *Latent Cancer Parameters* and *Latent Cancer Thresholds* forms.
- The latent cancer results can be included in the output requests on the *Health-Effect Cases* form (type 1), *Average Individual Risk* form (type 4), *Centerline Risk* form (type 7) and *Population-Weighted Risk* form (type 8). Latent cancer results are unavailable when this box is not checked.

***Food* Tab**

The *Food* tab in Figure 3-15 is required when *Long-Term Consequences* was selected on the *Scope* tab.

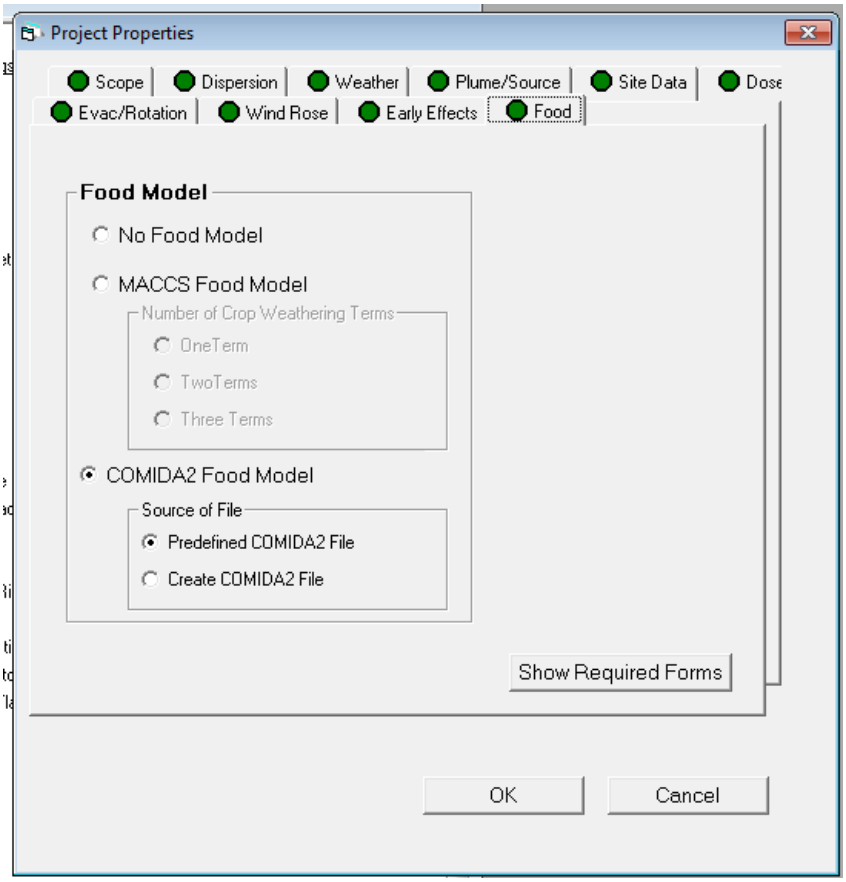


Figure 3-15 *Food* tab on the *Project Properties* form

MACCS uses a variable, FDPATH, to determine which food model to use.

Checking the radio button next to *No Food Model* means:

- FDPATH is set to OFF.
- No food-chain doses are calculated.
- Economic consequences are disabled.

Checking the radio button next to *MACCS Food Model* means:

- The original MACCS food-chain model is used.
- The *Annual Threshold* and *Piecewise Linear* dose-response models are not available.

- FDPATH is set to OLD.
- MACCS uses variable NTTRM to indicate the number of crop weathering terms used when the MACCS food model is used. The value of NTTRM is chosen on this tab.
- A set of forms under *CHRONC/Food-Chain* are required.

Predefined COMIDA2 File:
- The COMIDA2 food chain model is used.
- The *Annual Threshold* and *Piecewise Linear* dose-response models are available on the *Dose* tab. If either of these models is chosen, a set of binary files created by the preprocessor COMIDA2 and the corresponding dose conversion factor files used to create those binary COMIDA2 files must be linked to the project.
- If the *Linear No Threshold* (LNT) dose-response model is chosen on the *Dose* tab, a single COMIDA2 binary file must be linked to the project. The dose conversion factor file must be the same one used to create the COMIDA2 binary file.
- FDPATH is set to NEW.

Create COMIDA2 File:
- The *Annual Threshold* and *Piecewise Linear* dose-response models are not available, even though they appear to be available in the WinMACCS interface.
- One or more COMIDA2 binary files are created when a simulation is run, depending on whether the run is deterministic or uncertain. Values are specified under the *COMIDA2* main category on the *Parameters* tab.

3.1.2 Problem Description Form

WinMACCS provides a number of options for documenting a project by adding comments and other description fields. One of the options is to enter a general project description on the *General/Properties/Problem Description* form.

Comments entered anywhere within WinMACCS are echoed in the MACCS input files. MACCS echoes the comments in the input files to the output file, so comments are traceable throughout the calculation process.

3.1.3 File Specifications Category

Model settings that determine the types of files required are chosen on the *Project Properties* form. The set of files are shown as required under the *File Specifications* category. In the example shown in Figure 3-16, the meteorological, site, dose conversion factor, and COMIDA2 files are required, as indicated by the icons to the left of the forms.

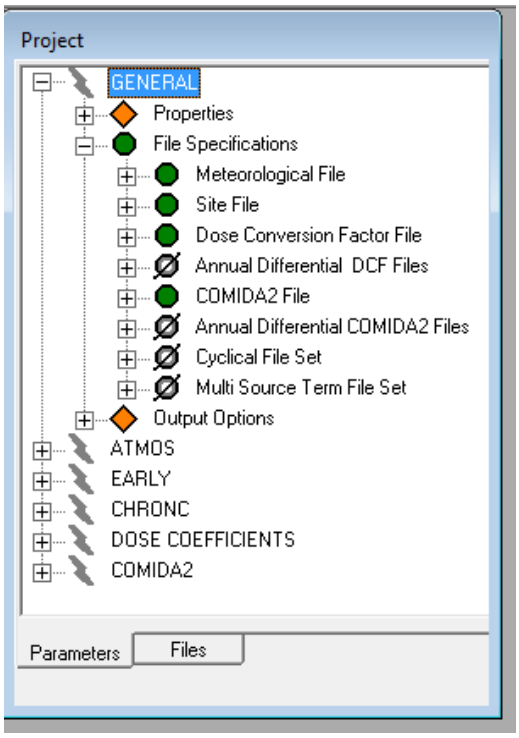


Figure 3-16 Specifying files

The following Table 3-1 describes the types of files that may be required, the conditions under which they are required, the tab within the *Properties* form that controls the requirement, and some sample files that are included with WinMACCS to illustrate the contents and format of the file. The interface uses icons just to the left of the form names to indicate which auxiliary files are required, depending on the project properties settings selected by the user.

Table 3-1 Auxiliary files used by WinMACCS.

Name of form	Related Project Properties tab	Conditions when form(s) is (are) required	Files from sample problems
Meteorological File	*Weather*	Radio button next to *Weather File Specified* is selected.	westernsite_04.inp metsurMxHt_60min.inp
Site File	*Scope* and *Site Data*	*EARLY Consequences* is selected on *Scope* tab. *Import from File* is selected on *Dose* tab.	FicticiousSite.inp
Dose Conversion Factor File	*Scope* and *Dose*	*EARLY Consequences* is selected on *Scope* tab. *Linear No Threshold* is selected on the *Dose* tab.	DosData20Organs.inp DOSD825.inp Fgr13dcf.inp Pu72.inp
Annual Differential DCF Files	*Scope, Dose,* and *Food*	*Late Consequences* is selected on *Scope* tab. *Annual Threshold* or *Piecewise Linear* dose model is selected on *Dose* tab. *Predefined DCF File* is selected on *Dose* tab. Either the *No Food Model* or the *Predefined COMIDA2 File* is selected on the *Food* tab.	dosdata20organs.inp dosdata20organs01.inp … dosdata20organs50.inp Fgr13dcf.inp Fgr13dcf01.inp … Fgr13dcf50.inp

Name of form	Related Project Properties tab	Conditions when form(s) is (are) required	Files from sample problems
COMIDA2 File	*Scope* and *Food*	*Late Consequences* is selected on *Scope* tab. *Linear No Threshold* is selected on the *Dose* tab. *Predefined COMIDA2 File* is selected on the *Food* tab. COMIDA2 file needs to have been created using the Dose Conversion Factor File specified.	samp_a20organs.inp samp_d.bin Fgr13samp_a.bin
Annual Differential COMIDA2 Files	*Scope*, *Dose*, and *Food*	*Late Consequences* is selected on *Scope* tab. *Annual Threshold* or *Piecewise Linear* dose model is selected on *Dose* tab. *Predefined DCF File* is selected on *Dose* tab. *Predefined COMIDA2 File* is selected on the *Food* tab.	samp_a20organs.inp samp_a20organs01.inp … samp_a20organs50.inp fgr13samp_a.bin fgr13samp_a01.bin … fgr13samp_a50.bin
Cyclical File Set	*Scope*	*MACCS Cyclical File Set* is selected.	Case 2, 1MW.txt Case 3, 5MW.txt Case 4, 10MW.txt Case 5, 1MW, Entr.+Wake.txt Case 6, 5MW, Entr.+Wake.txt Case 7, 10MW, Entr.+Wake.txt
Multi Source Term File Set	*Plume/Source*	*Multi Source Term* option is selected.	

***Meteorological File* Form**

A meteorological data file is required when the user selects *Weather File Specified* on the *Weather* tab. WinMACCS allows the user to select any file, but a file should be selected that conforms to the format described in the appendix, Meteorological File Format. The range of allowable wind directions in the meteorological file is determined by the value of the MACCS variable NUMCOR, the number of sectors in the spatial grid.

Variable Name	Definable	Type	Dimensions	Allowed Values
Meteorological File	Yes	Text File	None	Any file. File is not validated by WinMACCS.

***Site File* Form**

A site file is required when the user selects *EARLY CONSEQUENCES* on the *Scope* tab and selects the *Import From File* on the *Site Data* tab. NUMCOR is the number of sectors in the spatial grid. Site files created by older versions of SecPop or used in earlier versions of MACCS have 16 sectors in the spatial grid. Changing the value of NUMCOR is accomplished by clicking the button labeled *Create New.* The user can browse to an existing site file and create a new site file with a modified value of NUMCOR. The latest version of SecPop supports up to 64 sectors and should be used to create site files with more than 16 compass sectors.

The site file is a text file containing site specific information. This file is normally created using SecPop, but may be created by a different process as long as it has the required format. See section 4.4.8 for more information.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMCOR	Click *Create New…* to change value	Integer	None	16, 32, 48, and 64
Site File	Yes	Text File	None	Site data file. It is typically created by SecPop. It is partially validated by WinMACCS.

***Dose Conversion Factor File* Form**

A dose conversion factor (DCF) file is required when the user selects *Early Consequences* on the *Scope* tab and has selected *Linear No Threshold* on the *Dose* tab. A DCF File is an ASCII file containing dose conversion factors. DCF files are provided that were created using preprocessors *DOSFAC2* and *FGRDCF.* Files based on *FGR-13* are also provided with the WinMACCS installation.

Variable Name	Definable	Type	Dimensions	Allowed Values
DCF File	Yes	Text File	None	The format is defined in an appendix.

***Annual Differential DCF Files* Form**

A set of DCF files are required when the user selects *Late Consequences* on the *Scope* tab and has selected *Annual Threshold* or *Piecewise Linear* on the *Dose* tab. *Annual Differential DCF Files* are a set of fifty-one DCF files provided with the WinMACCS installation. These consist of a parent DCF file and a set of 50 annual DCF files, for which the 50-year dose commitment period is broken up into single years. Only the parent DCF file needs to be selected by the user; the set of annual files, with standardized nomenclature, are automatically included when the parent is selected. See section 4.4.5 for more information.

Variable Name	Definable	Type	Dimensions	Allowed Values
Annual Differential DCF File Set	Yes	Text Files	51	File sets are provided. WinMACCS does not validate the files.

***COMIDA2 File* Form**

This is required when the user selects *Late Consequences* on the *Scope* tab, selects *Linear No Threshold* on the *Dose* tab, and selects *User Supplies COMIDA2 File* on the *Food* tab. The COMIDA2 File is a binary file created by the COMIDA2 preprocessor. COMIDA2 requires a DCF file as part of its input. This DCF file must be the same as the DCF file specified in the section above.

Variable Name	Definable	Type	Dimensions	Allowed Values
COMIDA2 File	Yes	Binary File	None	Any file. It is not validated by WinMACCS.

***Annual Differential COMIDA2 Files* Form**
This is required if the user selects *Late Consequences* on the *Scope* tab, has selected *Annual Threshold* or *Piecewise Linear* on the *Dose* tab and has selected *User Supplies COMIDA2 File* on the *Food* tab. *Annual Differential COMIDA2 File Set* is a set of fifty-one COMIDA2 binary files provided with the WinMACCS installation.

Variable Name	Definable	Type	Dimensions	Allowed Values
Annual Differential COMIDA2 File Set	Yes	Binary Files	51	File set are provided. WinMACCS does not validate the files.

***Cyclical File Set* Form**
A set of cyclical files is required if the user selects *MACCS Cyclical File Set* on the *Scope* tab. A *MACCS Cyclical File Set* is a set of files in MACCS input format.

Variable Name	Definable	Type	Dimensions	Allowed Values
MACCS Cyclical File Set	Yes	Text File	>=1	MACCS input file format. Files are read by WinMACCS.

***Multi Source Term File Set* Form**
Using this option requires selecting *Multi Source Term* option on the *Properties* form, and selecting the multi-source term files created using MelMACCS or some other method. A software program, CombineSource, is integrated into WinMACCS and processes the set of multi-source term files specified and creates two output files. One output file, CombineSource.wmc, contains information that is directly imported into WinMACCS. The other file, CombineSource.out, contains information that is read by MACCS.

Variable Name	Definable	Type	Dimensions	Allowed Values
Multi Source Term File Set	Yes	Text Files	>=1	MelMACCS output file format

3.1.4 Output Options

***Reporting Options* Form**
Results are calculated by WinMACCS for each quantile level on this form. If variables have the Report option activated in the output request forms, results are automatically generated after model execution. The reported values are interpolated from the binned CCDF tables in the MACCS binary file. The quantile levels are also used when creating custom reports that combine results over simulations. See section 4.6.2.3 for more information.

Variable Name	Definable	Type	Dimensions	Allowed Values
Probabilities	Yes	Real	>= 1	0.0 to 1.0

***Output Units* Form**
Each time MACCS runs, an output file and a binary file is created containing results. The units used in this report and in the binary results can be modified for predetermined result types.

Variable Name	Definable	Type	Dimensions	Allowed Values
Activity Units	Yes	Character	None	{Bq, Ci}
Distance Units	Yes	Character	None	{km, mi}
Area Units	Yes	Character	None	{ha, km**2, mi**2}
Dose Units	Yes	Character	None	{rem, Sv}

3.2 ATMOS Input and Model Description

3.2.1 Overview of ATMOS

ATMOS performs all of the calculations pertaining to atmospheric transport, dispersion, and deposition, as well as the radioactive decay that occurs prior to release and while the material is in the atmosphere. (Following calculation of deposition or transport within the problem domain, radioactive decay and dose modeling are performed by the EARLY and CHRONC modules of MACCS.) The specification of the release characteristics designating a “source term” can consist of up to 500 plume segments. ATMOS models the transport of these plume segments considering time-varying meteorological conditions. Treatment of uncertain meteorological conditions, referred to as weather sampling, is supported using various sampling options. If weather sampling is used, results are reported as statistical summaries and optionally as binned cumulative distributions. This is done independently of uncertain variables designated in the WinMACCS interface.

The radioactive materials released are modeled as being dispersed while being transported by the prevailing wind. During transport, whether or not there is precipitation, deposition of particles onto the ground can be modeled. In addition to the air and ground concentrations, ATMOS determines plume arrival and departure times and plume dimensions.

ATMOS results are used by the EARLY and CHRONC modules. Therefore, at a minimum, a MACCS calculation must include the ATMOS module. In other words, calculations of early or latent health effects of a radioactive release are dependent on dispersion and deposition results provided by ATMOS.

MACCS allows multiple source terms to be specified in the ATMOS input using a method called change records. Change records allow the user to specify new values for previously defined source-term variables. When these are encountered, the code's calculations are rerun based on the new values for variables defined in the set of change records and new output is generated for each specified source term and emergency response scenario.

WinMACCS does not support this feature of ATMOS, although a similar feature in EARLY that allows the specification of multiple emergency response cohorts is supported. Results for multiple source term are treated by WinMACCS through multiple MACCS runs using the *MACCS Cyclical File Set* option found on the *Scope* tab.

A relatively new feature of MACCS is to treat releases from multiple units and/or spent fuel pools that occur in a sequential or overlapping fashion. These releases can have different isotopic inventories, different accident initiation and reactor shutdown times, and different release fractions. MACCS calculates the combined effects of the multiple releases.

3.2.2 Basic Parameters

***Atmos Description* Form**
Atmos Description contains one variable, which is a short description of the calculation. This description is printed in the output file. It is required input for all MACCS calculations.

Variable Name	Definable	Type	Dimensions	Allowed Values
ATNAM1	Yes	Character	None	1 to 80 characters

A more detailed description of the calculation can be entered on the *Problem Description* form under the *GENERAL/Properties* category.

***Property Form Parameters* Form**
Property Form Parameters verify how selections in the *Properties* form define some important variables that are required in the ATMOS input to MACCS. The variables are read-only and cannot be changed from this form.

ENDAT1 terminates the calculation after running ATMOS when set to True. Likewise, ENDAT2 terminates the calculation after running EARLY when set to True. ATMOS, EARLY, and CHRONC are run in sequence when both flags are set to False.

DISPMD is the crosswind dispersion model flag. The value is set to LRTIME for the long-range, time-based option, in which case dispersion is calculated as a function of time. The value is set to LRDIST for the long-range, distance-based option, in which dispersion is calculated as a function of downwind distance. The distance-based model is the original MACCS2 1.12 dispersion model.

MNDMOD defines the algorithm used to calculate plume meander. If set to OLD, the plume meander factor is a function of release duration only. If set to NEW, plume meander factor depends on wind speed and stability class, but not on the duration of release. This model is consistent with NUREG/CR-2260 and US NRC Regulatory Guide 1.145. If MNDMOD is chosen to be NEW, the plume segments should be approximately one hour in duration. OFF means no plume meander is treated.

METCOD determines what meteorological data are used and how weather sampling is performed. When the value is set to one, two, or five, a meteorological data file is needed to supply the meteorological data.

1. A value of one allows the user to choose a single starting point in the file, defined by a day and period of the day. A single weather trial is performed using this time as a starting point.
2. A value of two corresponds to weather-bin sampling from the meteorological data file.
3. A value of three is used for user-supplied hourly data for 120 hours.
4. A value of four is used for user-supplied, constant weather.
5. A value of five corresponds to stratified, random sampling from the meteorological data file.

MAXHGT determines whether only the daytime or both the daytime and nighttime mixing heights are to be used in the calculation. When DAY_AND_NIGHT is selected, the *Site Location* form is required. The required mixing heights are specified in the meteorological data file.

BRGSMD is the plume-rise model flag. IMPROVED is the recommended value. This recommendation is based on comparisons of several empirical models with results from the National Institute of Standards and Technology (NIST) ALOFT-FT code. ALOFT-FT solves the fundamental equations that govern the rise of hot gases into the atmosphere. ORIGINAL is the original MACCS 1.12 Briggs plume rise model. See 3.2.8.1 for more details.

MSMODL is the Multi Source Term model flag. When set to True, the Multi Source Term Files Set form is required, and MACCS will calculate the combined effects of the multiple releases defined in these files. When set to False, the source term is input in the WinMACCS interface.

Variable Name	Definable	Type	Dimensions	Allowed Values	Tab where defined on Properties form
ENDAT1	Read-Only	Logical	None	True, False	*Scope* tab
ENDAT2	Read-Only	Logical	None	True, False	*Scope* tab
DISPMD	Read-Only	Character	None	LRDIST, LRTIME	*Dispersion* tab
MNDMOD	Read-Only	Character	None	OLD, NEW, OFF	*Dispersion* tab
METCOD	Read-Only	Integer	None	1 to 5	*Weather* tab
MAXHGT	Read-Only	Character	None	DAY_ONLY, DAY_AND_NIGHT	*Weather* tab
BRGSMD	Read-Only	Character	None	ORIGINAL, IMPROVED	*Plume/Source* tab
MSMODL	Read-Only	Logical	None	True, False	*Plume/Source* tab

Spatial Grid **Form**

The region potentially affected by a release is represented by polar coordinates, (r,θ). The radius, *r*, represents distance from the release point, which is always at *r* = 0. The angle, θ, is the angle measured clockwise from north. The user must specify a set of radial endpoints, i.e., the outer radii for the grid elements. Up to 35 of these radii may be defined, extending out to a maximum distance of 9999 km. The number of angular divisions, or compass sectors, used to define the spatial grid are allowed to be 16, 32, 48, or 64. If the spatial grid is divided into 16 sectors, each sector is 22.5˚ wide. In all cases the sectors are equally spaced. The first sector is always centered on north.

NUMCOR is the number of sectors in the spatial grid. If a site file is used, it must be consistent with the number of sectors in the grid.

NUMRAD is the number of radial spatial intervals. The value of this parameter is automatically determined in WinMACCS by the number of entries in vector SPAEND. The number of radial intervals and the radial locations must be consistent with the site file, if one is used.

SPAEND defines the radial boundaries in the spatial grid. If a site data file is being used, these values are optionally updated when the site file is selected. This update ensures consistency between the site file and the MACCS input. The first radius must be at least 0.05 km. The minimum spacing between adjacent radii is 0.1 km.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMCOR	Yes	Integer	None	16, 32, 48, 64
NUMRAD	Linked	Integer	None	2 to 35
SPAEND	Yes	Real	NUMRAD	0.05 to 9999.0 Spacing ≥ 0.1 km

3.2.3 Radionuclides

This section defines the radionuclide classes and the radionuclides that are modeled. The radioactive decay data (half-life and decay chains) are provided to MACCS by the file INDEXR.DAT, which is from the Radiation Shielding Information Center as part of the FGR-DOSE/DLC-167 data package. This file is part of the WinMACCS installation.

3.2.3.1 Radionuclide Descriptions

Radionuclide names are case sensitive. Names of chemical elements follow the usual convention that the first letter is capitalized; second letters are lower case. The element names are followed by a hyphen and the atomic mass of the radionuclide to define the radionuclide name.

Each decay chain is limited to a maximum of six generations. Each decay chain is independent of the others. The MACCS output file lists the chains that are being used in the calculations.

Decay chains can be terminated in two ways. They are automatically terminated when the decay product is a stable isotope. In some cases, it is desirable to terminate a decay chain with a decay product that is not stable. This is commonly done when the decay product has a very long half-life or contributes very little to the overall dose. Terminating a decay chain in this way is done by adding the radionuclide to the pseudostable isotope list.

For example, Cs-135 is formed by beta-decay of Xe-135. It decays to Ba-135 from low-energy beta decay with a half-life of 2.3×10^6 years. Because of the long half-life and low energy beta produced by its decay, it has little effect on doses and is often included as a decay-chain terminator in MACCS calculations by including it as a pseudo-stable isotope.

In some older calculations, decay products were added implicitly by adding the dose conversion factors for the progeny to the parent and including the progeny in the list of pseudostable radionuclides. This simplification was done to reduce memory and CPU requirements. It works when the half-life for the progeny is much shorter than the one for the parent so that the progeny decays almost immediately once the parent decays. This practice somewhat disguises the set of radionuclides that are being treated in a problem and reduces flexibility. Since computer memory is at much less at a premium now than when MACCS was initially developed, this practice of implicitly including progeny in a calculation is now discouraged.

If an input error occurs because an unstable decay product is omitted, MACCS exits with an error message that lists the isotope or isotopes that are missing. The missing decay products must either be added to the radionuclide list or to the pseudostable isotope list. A radionuclide cannot be included on both lists. When one or more decay chain branches exist, the decay products in all of the active branches must be included in one of the two lists.

3.2.3.2 *Radionuclide*s Forms and Parameters

***Chemical Names* Form**

The *Chemical Names* form is required when *Multi Source Term* is not selected on the *Plume/Source* tab. Each radionuclide is assigned to a radionuclide class, which has an associated chemical name. Traditionally, the term radionuclide class has been used in MELCOR applications to identify a set of chemically similar elements that are assumed to behave identically within the radionuclide module of MELCOR. For example, all noble gases are generally assigned to the Xe class. In MACCS, the dry deposition characteristics and release fractions are assigned by radionuclide group, where group is equivalent to class. Thus, all

isotopes assigned to a radionuclide group are assumed to act similarly in terms of release fraction and deposition behavior. The user is required to assign a name for each radionuclide group, which is used as a label in the forms for RELFRC, DRYDEP, and WETDEP. The *Chemical Names* form is required for all WinMACCS calculations.

MAXGRP is the number of radionuclide groups. The value is linked to the number of entries in the vector GRPNAM.

GRPNAM is vector of character strings used to identify each of the radionuclide classes. This variable is used for labeling within WinMACCS and also appears as a comment in the ATMOS input file created by WinMACCS.

Variable Name	Definable	Type	Dimensions	Allowed Values
MAXGRP	Linked	Integer	None	1 to 150
GRPNAM	Yes	Character	MAXGRP	1 to 15 characters

***Radionuclides* Form**

The *Radionuclides* form is required when *Multi Source Term* is not selected on the *Plume/Source* tab.

The radionuclides form specifies the number of radionuclides treated in the WinMACCS calculation, the names of the radionuclides, the core inventory of each of the radionuclides, and the radionuclide group to which each one is assigned. The names of the radionuclides must correspond to those in the dose conversion factor (DCF) (ICRP now uses the term dose coefficient in place of dose conversion factor) file associated with the WinMACCS project. This form is required for all WinMACCS calculations.

Three types of DCF files are distributed with WinMACCS. The oldest of these was created by the program DOSFAC2. This file, named dosdata20organs.inp, contains 60 radionuclides. It includes DCFs for estimating acute and latent health effects. In addition to the 60 radionuclides, 11 decay products are implicitly included in this DCF file. This is done by summing the DCFs for the parent and progeny. This simplification was done to reduce CPU time and is appropriate when the progeny's half-life is very short compared with the parent's half-life. All implicit decay products must be included on the pseudostable isotope list.

The two other types of DCF files are based on FGR-11, -12, and -13. The DCFs for the external pathways are common to both and are from FGR-12. DCFs for the internal pathways are from FGR-11 in one case and from FGR-13 in the other case. Both of these files contain extensive lists of radionuclides (825); however, treatment of implicit progeny is different in the two files. The older file, based on FGR-11 and -12, includes a number of implicit progeny, e.g., Ba-137m is included with Cs-137. Thus, Ba-137m should not be treated directly using this file or it would be double counted. On the other hand, the newer DCF file based on FGR-12 and -13 does not include any implicit progeny, so both Cs-137 and Ba-137m must be explicitly included. This allows more flexibility in the treatment of decay products. For example, with the older DCF file, a calculation could include either Cs-137 or Ba-137m in the inventory. Including both would lead to double counting most of the Ba-137m dose. The newer DCF file allows either Cs-137, Ba-137m, or both to be included in the inventory. The newer file also includes DCFs for estimating both acute and latent health effects; the older file only includes DCFs for latent health effects.

NUMISO defines the number of radionuclides. It is linked to the number of entries in the NUCNAM vector.

NUCNAM is a vector of radionuclide names. Each radionuclide name must be in the decay-chain definition file, INDEXR.DAT, as well as the DCF file used in the calculation.

CORINV defines the inventory of each radionuclide in the facility at the time of reactor shutdown. The unit, Bq, or Becquerel, is equivalent to disintegrations/second. This inventory can be scaled by modifying variable CORSCA found on form *ATMOS/Release Description/Inventory Scale Factor*.

IGROUP identifies the radionuclide group to which the radionuclide is assigned. The radionuclides should be grouped according to their physical/chemical properties. All members of a radionuclide group have the same deposition characteristics and release fractions. The assignment into radionuclide groups or classes is often taken from MELCOR, especially if the source term was calculated using MELCOR.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMISO	Linked	Integer	None	1 to 150
NUCNAM	Yes	Character	NUMISO	3 to 8 characters
CORINV	Yes	Real	NUMISO	0 to 1×10^{25} Bq
IGROUP	Yes	Integer	NUMISO	1 to MAXGRP

***Pseudostable Radionuclides* Form**

The *Pseudostable Radionuclides* form is available when *Multi Source Term* is not selected on the *Plume/Source* tab. The *Pseudostable Radionuclides* form is optional, although it is almost always used in practice. This form specifies the name and number of pseudostable radionuclides, as described above.

NUMSTB is the number of pseudostable radionuclides. The value is determined by the number of entries in vector NAMSTB.

NAMSTB contains a set of decay-chain terminators. Each radionuclide must also be present in the decay-chain definition file, INDEXR.DAT. These entries and their decay products are excluded from dose calculations. Radionuclide names cannot appear in both NUCNAM and NAMSTB.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMSTB	Linked	Integer	None	1 to 150
NAMSTB	Yes	Character	NUMSTB	3 to 8 characters

3.2.4 Deposition

3.2.4.1 Deposition Model Description

The wet deposition model predicts how much material is deposited on the ground by rainfall. Wet deposition is treated as a function of both rain duration and rain intensity. The fraction of aerosols that remains suspended after wet deposition is calculated from the following equation (Brink and Vogt, 1981):

$$\exp\left(-C_1 \cdot t_r \cdot \left(\frac{I_r}{I_0}\right)^{C_2}\right)$$

(Equation 1)

Where

C_1 = linear washout coefficient, corresponding to MACCS input variable, CWASH1

t_r = duration or precipitation (s)

I_r = intensity of precipitation (mm/hr)

I_0 = unit rain intensity, 1 mm/hr

C_2 = exponential washout coefficient, corresponding to MACCS input variable, CWASH2

Dry deposition is modeled using the source depletion method. This method makes use of the simplifying assumption that deposition onto the ground does not significantly affect the air concentration near the ground. That is, removal by deposition is much slower than dispersion in the air. This assumption allows the plume to be treated as Gaussian when deposition occurs. This is generally an excellent assumption because turbulent advection is generally on the order of 0.5 m/s while deposition velocities are typically a few cm/s or less.

The concentration of monodisperse aerosols at a location on the ground is the product of the integrated ground-level air concentration there times the deposition velocity. In the general case, multiple aerosol sizes each with a different deposition velocity, the ground concentration is the sum over the set of aerosol sizes of the products of the time integrated air concentrations and the deposition velocities.

The material in each radionuclide group can be distributed among several particle-size groups (up to 20), with each radionuclide group having a different distribution of activity among the particle-size groups. The particle-size distribution of each radionuclide group is specified in the release description data. Because each particle size can deposit at a different rate, both the size distribution and the relative amounts of radionuclide groups can vary with downwind distance. For example, consider a release containing noble gases, which do not deposit (deposition velocity is zero) and iodine, which does deposit. As a result, the ratio of noble gases to iodine increases with downwind distance because iodine deposits while the noble gases do not. Further, consider that the iodine is represented by two aerosol bins, each with its own deposition velocity. The fraction in the bin that deposits faster is depleted more rapidly than the other bin as the plume travels downwind. Thus, both the chemical composition and size distribution of the plume change with time and distance.

3.2.4.2 Deposition Forms and Parameters

Wet/Dry Depos Flags

The Wet/Dry Depos Flags form is required. DRYDEP is defined for each of the radionuclide groups. This flag indicates whether the radionuclide group is subject to dry deposition. Setting the flag to False ensures that the deposition velocity is zero for this radionuclide class. WETDEP is also defined for each of the radionuclide groups. This flag indicates whether the radionuclide class is subject to wet deposition.

Variable Name	Definable	Type	Dimensions	Allowed Values
DRYDEP	Yes	Logical	MAXGRP	True, False
WETDEP	Yes	Logical	MAXGRP	True, False

The radionuclide group representing the noble gases, which do not form aerosols and are highly inert, is generally assigned deposition flags of False for both wet and dry deposition. Other radionuclide groups are generally assigned deposition flags of True for both wet and dry deposition.

Wet Deposition
CWASH1 is the linear coefficient in the washout function shown in Equation (1).

CWASH2 is the exponential coefficient in the washout function shown in Equation (1).

Variable Name	Definable	Type	Dimensions	Allowed Values
CWASH1	Yes	Real	None	0.0 to 1.0
CWASH2	Yes	Real	None	0.0 to 1.0

Dry Deposition
NPSGRP is the number of particle size groups, determined by the number of entries in vector VDEPOS.

VDEPOS is the set of dry deposition velocities corresponding to the set of particle size groups.

Variable Name	Definable	Type	Dimensions	Allowed Values
NPSGRP	Linked	Integer	None	1 to 20
VDEPOS	Yes	Real	NPSGRP	0.0 to 10.0 m/s

3.2.5 Dispersion

3.2.5.1 Dispersion Model Description

The Gaussian plume model of atmospheric dispersion uses spatially dependent dispersion parameters, σ_y and σ_z. These can be supplied in two different ways: as power-law functions or in the form of a lookup-table. The choice of which of the two models to use is made using the *Dispersion* tab on the *Properties* form.

***Dispersion Function* Parameters**
The MACCS power-law functions for σ_y and σ_z have the form:

$$\sigma_{yi} = a_i \cdot (x/x_0)^{b_i}$$
$$\sigma_{zi} = c_i \cdot (x/x_0)^{d_i} \qquad \text{(Equation 2)}$$

Where

σ_{yi} = lateral dispersion parameter for stability class, *i*, representing the standard deviation of a Gaussian distribution (m)

σ_{zi} = vertical dispersion parameter for stability class, *i*, representing the standard deviation of a Gaussian distribution (m)

x = downwind distance (m)

a_i, b_i = linear and exponential coefficients in the power-law expressions for crosswind dispersion. Subscript, *i*, represents stability class. Units are m and dimensionless, respectively.

c_i, d_i = linear and exponential coefficients in the power-law expressions for vertical dispersion. Subscript, *i*, represents stability class. Units are m and dimensionless, respectively.

x_0 = unit of length, 1 m

The user should ensure that the categorization scheme used to define the stability classes for the meteorology is consistent with the values of the dispersion coefficients.

Lookup-Table Parameters

The lookup-table option allows the user to define a lookup table in place of the power-law functions for σ_y and σ_z. This code option uses an interpolation algorithm that avoids the numerical instabilities observed with cubic spline fits. The calculational approach uses a Hermite cubic approach from Kahaner, Moler, and Nash (1989). This lookup-table algorithm can be used to implement alternative dispersion parameterizations or to use fits to site-specific tracer data.

This feature was implemented to allow the use of parameterizations other than simple power laws (*e.g.,* the Briggs formulas). Also, if tracer experiments are available for a site, it is possible to process such data into tables of horizontal and vertical standard deviations (σ_y and σ_z). A caution to the user is that the algorithms associated with the lookup tables do not allow for extrapolation, either to smaller values than the first entry or to larger values than the last entry in the table. If, for example, the initial value of one of the dispersion parameters is smaller than the first value in the table for a specific stability class, the initial value in the table is used. If a larger value of the dispersion parameter is needed than the final value in the table for a specific stability class, the dispersion parameter is held fixed until the stability class changes.

Time-Based Dispersion

A time-based dispersion model can be enabled, also from the Dispersion tab on the Properties form.

Hanna (2002) recommends that plume dispersion beyond 30 km be based on time, not on distance. This model allows the user to implement Hanna's recommendation. The basis for the recommended distance, 30 km, is that most measurements upon which dispersion tables are based have a limit of about 30 km. The time-based dispersion model is closer to the treatment used in some Gaussian puff codes. In the MACCS implementation, the user must select the downwind distance at which the code switches from distance-based dispersion to time-based dispersion. The user must also select a linear coefficient for the time-based dispersion model. Hanna recommends a value of 0.5 m/s. The virtual source concept is used to ensure that there

is no discontinuity in switching from distance-based to time-based dispersion. The following equation describes the new model:

$$\sigma_y = \begin{cases} a\left(\frac{x}{x_0}\right)^b & x < x_c \\ a_c t & x \geq x_c \end{cases} \qquad \text{(Equation 3)}$$

Where

σ_y = Value of crosswind dispersion (m)

a = Linear coefficient for distance-based, crosswind dispersion (m)

x = Downwind distance from the virtual source (m)

b = Exponential parameter for distance-based, crosswind dispersion (dimensionless)

x_c = Distance from the source (m) at which dispersion model switches from distance- to time-based (CYDIST in MACCS)

a_c = Linear coefficient for time-based, crosswind dispersion (m/s) (CYCOEF in MACCS)

t = Time since the plume was released from the virtual source (s)

When the time-based dispersion model is enabled, time-based dispersion is implemented at distances greater than or equal to x_c in Equation (3). However, distance-based dispersion is always applied within the first ring, regardless of the value of CYDIST. Either a power-law function, as illustrated in Equation (3) or a lookup table can be used to define the dependence of dispersion on downwind distance at distances less than CYDIST.

Gaussian Plume Equations

MACCS models plume dispersion during downwind transport using Gaussian plume models. Thus, the horizontal and vertical extent of plume segments is expressed in terms of the horizontal (σ_y) and vertical (σ_z) standard deviations of the normal concentration distributions that characterize a Gaussian plume. The Gaussian equations implemented in MACCS are derived assuming that turbulent velocities are negligible compared to the mean wind speed [Ka84]. Accordingly, MACCS assumes that the initial length of plume segments is unaffected by dispersion during downwind transport (i.e., plume segment lengths are constant once release of that plume segment is complete). Furthermore, MACCS assumes that concentration profiles have a sharp leading and trailing edge, i.e., the profile is a step function.

During downwind transport, atmospheric turbulence causes plume segments to expand in all directions with the rate of expansion increasing when atmospheric turbulence increases. Vertical expansion of the plume is increased by surface roughness and constrained by the ground and by the temperature structure of the atmosphere (location of inversion layers). Crosswind spreading of the plume along the y-direction is unconstrained. The effective crosswind dimensions of a plume segment are increased by lateral meander of the plume about its centerline trajectory. Because turbulent velocities are almost always very small compared to the mean wind speed that transports the bulk plume, expansion in the wind direction can be neglected [Tu70].

Because they are simple and computationally efficient, Gaussian plume models are commonly used to model atmospheric dispersion in reactor accident risk assessments (see for example the PRA Procedures Guide [US83]). Gaussian plume models assume that the diffusion of gas molecules and aerosol particles in the plume during its downwind transport can be modeled as a random walk that generates a normal distribution for air concentration in all directions. Because wind speed and temperature vary significantly with height near the ground, vertical and horizontal plume distributions differ significantly and must be calculated separately. Since the distribution in the wind direction does not appear in the Gaussian plume equations implemented in MACCS, only the vertical and crosswind distributions are actually calculated.

The size of a Gaussian plume in the vertical and crosswind directions is defined by the standard deviations (σ_y and σ_z) of the normal distributions of material concentrations in the vertical and crosswind directions. When not constrained by the ground or by inversion layers, the Gaussian plume equation has the following form [Tu70]:

$$\chi(x,y,z) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{z-h}{\sigma_z}\right)^2\right] \qquad \text{(Equation 4)}$$

Where

$\chi(x,y,z)$ =time-integrated air concentration (Bq·s/m^3) at the downwind location (x, y, z)

Q = released activity (Bq)

σ_y = lateral dispersion parameter representing the standard deviation of a Gaussian distribution (m)

σ_z = vertical dispersion parameter representing the standard deviation of a Gaussian distribution (m)

h = stabilized height of the plume centerline (m)

Once a plume has expanded sufficiently in the vertical dimension so that further vertical expansion is constrained by the ground and/or the capping inversion layer, Equation (4) is no longer applicable. To treat restricted growth in the vertical dimension, the ground and the inversion layer are treated as impenetrable, reflecting boundaries. Mathematically, reflection is accomplished by the addition of mirror image sources above the inversion layer and below the plane of the ground. This produces the following equation, which is used in MACCS to calculate

both the time-integrated, plume-centerline, air concentration, $\chi(x, y = 0, z = h)$, and time-integrated, ground-level, air concentration under the plume centerline, $\chi(x, y = 0, z = 0)$, from the time a plume segment is released until the vertical distribution of the segment becomes uniform between the ground and capping inversion layer (becomes well mixed in the vertical dimension):

$$\chi(x, y=0, z) = \frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\sum_{n=-\infty}^{\infty}\left\{\exp\left[-\frac{1}{2}\left(\frac{z-h+2nH}{\sigma_z}\right)^2\right]+\exp\left[-\frac{1}{2}\left(\frac{z+h+2nH}{\sigma_z}\right)^2\right]\right\}$$

(Equation 5)

Where

H = height (m) of the capping inversion layer, i.e., the height of the mixing layer

At each spatial interval along the plume's trajectory, MACCS tests for the occurrence of a uniform concentration distribution in the vertical direction (well-mixed plume between the ground and the capping inversion layer). Once a uniform vertical distribution is attained, Equation (5) reduces to the following equation:

$$\chi(x, y=0, z) = \frac{Q}{\sqrt{2\pi}\sigma_y u H}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

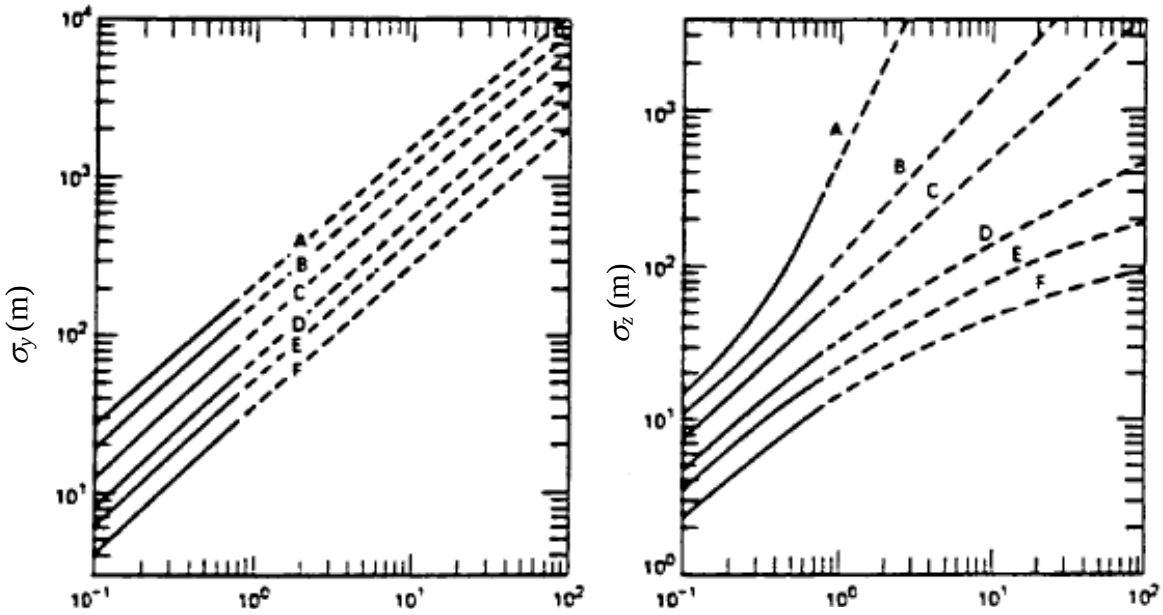
(Equation 6)

MACCS switches from Equation (5) to Equation (6) when $H/\sigma_z < 0.03$. This criterion approximately corresponds to the requirement that the results of the two equations agree within 1%. Because Equation (6) is independent of σ_z, this value is not calculated once the transition from Equation (5) to Equation (6) is made.

Dispersion Values

The rate at which materials disperse in the atmosphere depends strongly on atmospheric turbulence, which varies greatly with stability class. Therefore, the rate of expansion of a plume during downwind transport also varies with stability class.

The growth of plume dimensions during downwind transport to short distances (1 km) has been experimentally determined [Ha59] over flat terrain covered by prairie grass (surface roughness length z_0 = 3 cm) for short plumes (10 min release durations) released during stable, neutral, and unstable atmospheric conditions. Pasquill [Pa61] used this data to develop curves that depict the increase of plume dimensions (σ_y and σ_z values) with downwind distance for each of the six Pasquill-Gifford Stability Classes A through F. Although measurements had only been made to 1 km, Pasquill extrapolated the curves to 100 km. These curves, as later modified by Gifford [Gi75 and Gi76], are presented in Figure 3-17.



(b)

Figure 3-17 Dependence of σ_y and σ_z on distance for the six Pasquill-Gifford stability classes, A through F

Solid lines depict the range of the experimental data; dashed lines are extrapolations. Tadmor and Gur [Ta69] constructed power-law fits to the Pasquill-Gifford (P-G) curves. The coefficients are provided in Table 3-2.

Table 3-2 Tadmor and Gur coefficients for σ_y and σ_z for equation (2).

Stability Class		Constant*			
P-G	i	a_i	b_i	c_i	d_i
A	1	0.3658	0.9031	0.00025	2.125
B	2	0.2751	0.9031	0.0019	1.6021
C	3	0.2089	0.9031	0.2	0.8543
D	4	0.1474	0.9031	0.3	0.6532
E	5	0.1046	0.9031	0.4	0.6021
F	6	0.0722	0.9031	0.2	0.6020

*The values of these constants reflect correction of typographical errors identified by Dobbins [Do79].

As used in MACCS, the values of the dispersion parameters, σ_y and σ_z, in Equation (2) must change in a piecewise continuous fashion. Discontinuous changes in slope occur when stability class changes. Since stability class changes discretely, the source distance x in the dispersion parameter equation (Equation (2)) must be changed to some new value that causes dispersion parameter growth to be continuous. The new value of the source distance is called the "virtual source" distance and generally has a different value for σ_y and for σ_z. It is calculated as follows.

Let *i* be the stability class before the change in atmospheric conditions, *j* the stability class after the change, and x_{yi} and x_{zi} be the source distances under the old conditions (the downwind distances to the virtual source just before the stability class changes). Let x_{yj} and x_{zj} be the source distances under the new conditions (i.e., the new virtual source distances). To ensure continuity, σ_{yi} must be equal to σ_{yj} and σ_{zi} must be equal to σ_{zj}. Thus,

$$a_i\left(x_{y_i}\right)^{b_i} = \sigma_{y_i} = \sigma_{y_j} = a_j\left(x_{y_j}\right)^{b_j}$$
$$c_i\left(x_{z_i}\right)^{d_i} = \sigma_{z_i} = \sigma_{z_j} = c_j\left(x_{z_j}\right)^{d_j} \qquad \text{(Equation 7)}$$

These equations can be solved explicitly for the virtual source locations to produce the following result:

$$x_{y_j} = \left[\frac{1}{a_j} a_i\left(x_{y_i}\right)^{b_i}\right]^{\frac{1}{b_j}} = \left[\frac{\sigma_{y_i}}{a_j}\right]^{\frac{1}{b_j}}$$
$$x_{z_j} = \left[\frac{1}{c_j} c_i\left(x_{z_i}\right)^{d_i}\right]^{\frac{1}{d_j}} = \left[\frac{\sigma_{z_i}}{c_j}\right]^{\frac{1}{d_j}} \qquad \text{(Equation 8)}$$

This same approach can be used in conjunction with the lookup table option described above. This assumes that the inverse functional dependence for the lookup table can be evaluated, i.e., that given a dispersion value, a unique value of x can be determined. For the lookup table, the requirement of monotonically increasing values in the table ensures uniqueness. Performing the inverse function is done by interpolation in the same way as for the function itself.

Although new "virtual source" distances for σ_y and σ_z are calculated every time stability class changes, these distances are used only to calculate growth of σ_y and σ_z. Plume locations are always expressed relative to the release point that is the center point of the polar-coordinate computational grid.

For a given spatial element, the average values of σ_y and σ_z are used to calculate air and ground concentrations for the entire spatial element. The average values of σ_y and σ_z are the arithmetical means of the initial and final values of these two parameters as a plume segment traverses the spatial element.

Scaling Factors

MACCS allows the user to input a separate scaling factor for σ_y and σ_z. These scale factors can be used to account for phenomena that would tend to increase or decrease the plume dimensions. There are two such phenomena that are commonly included in plume modeling: plume broadening caused by meander (wind direction fluctuations) and increase in the vertical plume dimension caused by surface roughness. Separate options exist to account for plume meander, as described in a subsequent subsection, so the scale factor for σ_y is usually set to 1.0. However, MACCS does not contain a separate model to account for surface roughness, so most commonly the vertical scale factor is set to a value other than unity.

The Pasquill-Gifford curves depicted in Figure 3-17 are appropriate for transport over flat terrain covered by prairie grass (surface roughness length z_0 = 3 cm). But plume transport is usually over areas characterized by surface roughness lengths greater than 3 cm. Figure 3-18 presents

some approximate surface roughness lengths for different surfaces based on the values in [Le69, Br84, Ra84].

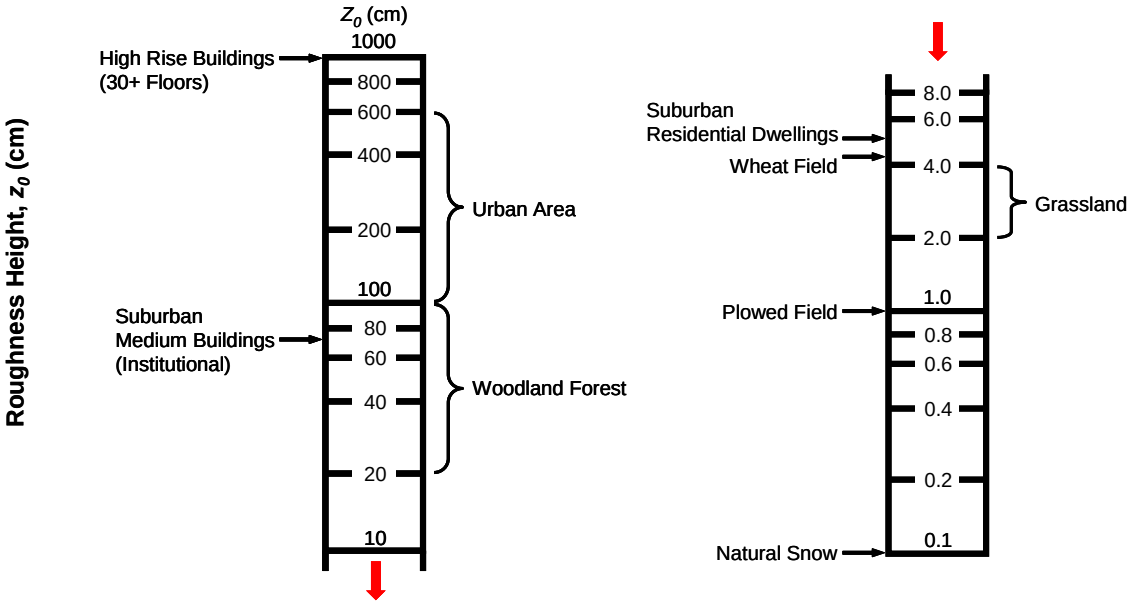


Figure 3-18 Approximate surface roughness lengths (z_0) for various surfaces

Figure 3-18 suggests that a roughness length greater than 3 cm, at least 5 cm and possibly as much as 1000 cm, is more likely typical of populated areas. Surface roughness principally affects vertical dispersion and thus σ_z values. The following formula [AMS77] can be used to correct Pasquill-Gifford values of $\sigma_{z,P-G}$, which are appropriate for $z_{0,P-G}$ = 3 cm, for the effects of smoother or rougher surfaces:

$$\sigma_{z,r} = \sigma_{z,P-G}\left[\frac{z_0}{z_{0,P-G}}\right]^{0.2} \qquad \text{(Equation 9)}$$

Where the subscript *P–G* refers to the Pasquill-Gifford formulation for dispersion parameters and subscript *r* refers to the scaled dispersion accounting for the actual surface roughness, z_0.

3.2.5.2 Dispersion Forms and Parameters

***Dispersion Function* Form**

The Dispersion Function form is required when the user selects *Power Law Functions* on the *Dispersion* tab. Values entered on this form correspond to the parameters used to calculate dispersion when using the six Pasquill–Gifford stability classes (classes A through F). The user must supply six values for each variable defined on this form, one value for each stability class in the order A through F.

CYSIGA is the linear coefficient of the expression for σ_y.

CYSIGB is the exponential coefficient of the expression for σ_y.

CZSIGA is the linear coefficient of the expression for σ_z.

CZSIGB is the exponential coefficient of the expression for σ_z.

Variable Name	Definable	Type	Dimensions	Allowed Values
CYSIGA	Yes	Real	6	1×10^{-6} to 10.0 m
CYSIGB	Yes	Real	6	1×10^{-6} to 10.0
CZSIGA	Yes	Real	6	1×10^{-6} 10.0 m
CZSIGB	Yes	Real	6	1×10^{-6} to 10.0

***Dispersion Table* Form**

The *Dispersion Table* form is required if the user selects *Lookup Tables* on the *Dispersion* tab. NUM_DIST is the number of distances in the lookup table and its value is determined by the number of rows entered in the grid containing the dispersion table. DISTANCE is the set of downwind distances corresponding to sigma-y and sigma-z data. These values must be monotonically increasing. SIGMA_Y and SIGMA_Z variables need to be provided on this form for each stability class, A, B, C, D, E, and F. Values must be monotonically increasing.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM_DIST	Linked	Integer	None	3 to 50
DISTANCE	Yes	Real	NUM_DIST	1.0 to 1×10^{8} m
SIGMA_Y_A	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Z_A	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Y_B	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Z_B	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Y_C	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Z_C	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Y_D	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Z_D	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Y_E	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Z_E	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Y_F	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m
SIGMA_Z_F	Yes	Real	NUM_DIST	1×10^{-6} to 1×10^{20} m

Scaling Factors

Scaling factors are required. MACCS allows linear scaling of σ_y and σ_z by means of the input parameters, YSCALE and ZSCALE. These scaling factors are used to multiply the values of σ_y and σ_z that have been defined for each of the six stability classes. YSCALE is the linear scaling factor that is applied to the formula for σ_y. This modifies all of the calculated σ_y values by a constant multiplicative factor for either the power-law or lookup-table options. ZSCALE is the linear scaling factor that is applied to the formula for σ_z. It is commonly used to account for surface roughness. This factor modifies all of the σ_z values by a constant multiplicative factor for either the power-law or lookup-table options. The value is normally set to 1.0.

Variable Name	Definable	Type	Dimensions	Allowed Values
YSCALE	Yes	Real	None	0.01 to 100.0
ZSCALE	Yes	Real	None	0.01 to 100.0

Long-Range Parameters
The *Long-Range Parameters* form is required if the user selects the option, *Switch to Time-Based Dispersion Model at User-Specified Distance*, on the *Dispersion* tab. CYDIST is the distance for switching from distance-based to time-based crosswind dispersion model. The distance-based dispersion model is always used within the first radial interval. The default value for this parameter is 30,000 m. CYCOEF is the linear coefficient for the time-based, crosswind dispersion model. The default value for this parameter is 0.5 m/s.Both of these default values are based on recommendation by Hanna (2002).

Variable Name	Definable	Type	Dimensions	Allowed Values
CYDIST	Yes	Real	None	0.0 to 1×10^{7} m
CYCOEF	Yes	Real	None	1×10^{-6} to 2.0 m/s

3.2.6 Multi Source Term Option

Variable Name	Definable	Type	Dimensions	Allowed Values
MAXGRP	No	Integer	None	0.0 to 1×10^{7} m
GRPNAM	No	Character	None	1×10^{-6} to 2.0 m/s

3.2.6.1 Multi Source Term Model Description

MelMACCS is the interface tool that allows MELCOR plot files to be post processed to create MACCS source term data that can be imported directly into WinMACCS using the *Import MACCS Input File* option discussed in Chapter 4. In the past, the process has only been able to address single-unit source terms. WinMACCS 3.10 now has the capability to merge a number of source terms to create a multi-unit source term. Furthermore, both MELCOR and MelMACCS have been modified to create multiple source terms from a single MELCOR plot file, provided this feature is activated in the MELCOR input. The new feature allows the user to create a source term file for each ring in the MELCOR analysis. This feature is especially designed for analyses of spent fuel pools, where each ring can represent a different age of spent fuel. This allows different ages of fuel to be assigned different isotopic inventories in performing the MACCS analysis. MelMACCS 2.0 and later allow the user to assign an inventory for a selected ring. One source term file is created for each ring processed by the user.

Source term files can be merged to create a multi-unit source term, as described subsequently in this section. Details of how to use MelMACCS are provided in Appendix A. Details of how to use WinMACCS to use the mult source term model is provided in 4.4.10

3.2.6.2 Multi Source Term Forms and Parameters

***Chemical Names* Form**
The values on this form were read from the multi-source term files and are not changeable.

Variable Name	Definable	Type	Dimensions	Allowed Values
MAXGRP	No	Integer	None	1 to 150
GRPNAM	No	Character	MAXGRP	1 to 15 characters

***Radionuclides* Form**
The values on this form were read from the multi-source term files and are not changeable.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMISO	No	Integer	None	1 to 150
NUCNAM	No	Character	NUMISO	3 to 8 characters
IGROUP	No	Integer	NUMISO	1 to MAXGRP

***Plume Segments* Form**
The values on this form were read from the multi source term files and are not changeable. Each row in the grid identifies a plume segment that was defined on one of the multi source term files.

Variable Name	Definable	Type	Dimensions	Allowed Values
TOTREL	No	Integer	None	2 to 500
MS_LABELS	No	Character	TOTREL	1 to 255 characters
IGROUP	No	Integer	NUMISO	1 to MAXGRP

***Time Offsets* Form**
A time offset can be associated with each of the multi source term files. This allows MACCS to adjust its calculation for the radioactive decay due to the time offsets.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM_SOURCES	No	Integer	None	2 to 500
Source Time Offset	Yes	Real	NUM_SOURCES	0 to 2.592×10^6 s (30 days)

3.2.7 Plume Specification

3.2.7.1 Plume Meander Model Descriptions

WinMACCS allows for three choices for plume meander model on the *Dispersion* tab. Namely, the original MACCS model, a model based on Reg Guide 1.145, and an option to turn off plume meander.

***Original MACCS* Plume Meander Option**
The original MACCS model accounted for the effect of meander during transport of a plume segment by using a meander factor. This factor, f_m, serves to broaden the plumes in the cross-wind dimension. It acts as a linear factor on σ_y, which affects the calculation of χ/Q. The expansion factor is defined as follows:

$$\begin{aligned} f_m &= 1 && \Delta t_{release} \le \Delta t_0 \\ f_m &= (\Delta t_{release}/\Delta t_0)^{F_1} \quad \text{if} && \Delta t_0 < \Delta t_{release} \le \Delta t_1 \\ f_m &= (\Delta t_{release}/\Delta t_0)^{F_2} && \Delta t_1 < \Delta t_{release} \le 10 \end{aligned} \qquad \text{(Equation 10)}$$

Where

$\Delta t_{release}$ = release duration for the plume segment (s)

Δt_0 = release duration for the P–G data (s), which was 600 s

Δt_1 = breakpoint in release duration (s), usually chosen to be 3600 s (the default value

F_1 = exponent for time dependence below the breakpoint (dimensionless), usually chosen to be 0.2 (the default value)

F_2 = exponent for time dependence above the breakpoint (dimensionless), usually chosen to be 0.25 (the default value)

The duration of each plume segment should be limited to 10 hr when using this meander model because the formula is not intended to be used above that value. If a plume segment exceeds 10 hr, a nonfatal warning is given in the output file and the expansion factor is calculated as though the plume duration were 10 hr.

Plume Meander Model Based on *US NRC Regulatory Guide 1.145*

MACCS now contains a plume meander model based on Regulatory Guide 1.145 and supporting document NUREG/CR-2260. The Regulatory Guide 1.145 plume meander model differs from the original model in MACCS in that it accounts for the effects of wind speed and stability class. On the other hand, the original model in MACCS accounts for the duration of the release; the new model is calibrated for 1-hour release durations. The plume meander model described below would lead to an over prediction of peak doses for release durations longer than 1 hour; it would under predict peak doses for release durations that are significantly shorter than 1 hour. Enforcement of this recommendation is left to the user; WinMACCS and MACCS do not restrict the duration of plume segments to be approximately 1 hour when this model is selected. The MACCS implementation of the Reg. Guide 1.145 plume meander model treats plume meander in a similar manner as an area source. The meander occurs in the first 800 m downwind, creating a broader plume at that distance. Beyond 800 m, the plume gradually approaches the size that it would have had if meander had not occurred, just like the effect of an area source.

The plume meander model described in Regulatory Guide 1.145 is described as follows:

$$\sigma_{ym} = f_m \cdot \sigma_y(x) \qquad \text{(Equation 11)}$$

Where

$\sigma_y(x)$ = lateral dispersion not accounting for plume meander (m)

f_m = meander factor (dimensionless)

σ_{ym} = lateral dispersion accounting for plume meander (m)

x = downwind distance measured from the source (m)

Lateral dispersion, σ_y, can be defined in terms of a power-law equation or as a look-up table. The meander factor is defined as follows:

$$f_m = m \cdot f(u) \qquad \text{(Equation 12)}$$

Where

m = 1 for stability classes A through C

2 for stability class D

3 for stability class E

4 for stability class F

$f(u)$ = a function of wind speed and is defined in Equation (13) below

u = wind speed (m/s)

$$f(u)=1$$
$$f(u)=\frac{1}{m}*\exp\left[\left(1-\frac{\ln(u)-\ln(2)}{\ln(6)-\ln(2)}\right)*\ln(m)\right] \quad \text{when} \quad \begin{matrix} u \le 2 \\ 2 < u \le 6 \\ 6 < u \end{matrix} \qquad \text{(Equation 13)}$$
$$f(u)=1/m$$

The above equations are valid for distances within 800 m of the source. Beyond 800 m downwind, Equation (11) is modified as follows:

$$\sigma_{ym}=(f_m-1)\cdot\sigma_y(800)+\sigma_y(x) \qquad \text{(Equation 14)}$$

The MACCS model is similar to the model described above except that it is more general and uses a different approach at distances greater than *D* (*D* = 800 m in Equation (14)). The equations used in MACCS are as follows:

$$f(u)=1$$
$$f(u)=\frac{1}{m}*\exp\left[\left(1-\frac{\ln(u)-\ln(u_1)}{\ln(u_2)-\ln(u_1)}\right)*\ln(m)\right] \quad \text{when} \quad \begin{matrix} u \le u_1 \\ u_1 < u \le u_2 \\ u_2 < u \end{matrix} \qquad \text{(Equation 15)}$$
$$f(u)=1/m$$

D is the location beyond which the plume meander factor is no longer used. At this distance, the location of the virtual source is adjusted to ensure continuity in the value of σ_{ym}. Just beyond MNDIST, the meander factor is set to unity and the effect of the plume meander is treated in just the same way as an area source, i.e., by using an appropriate value for the virtual source location.

The MACCS plume meander model matches the Reg. Guide 1.145 model when [MNDFAC(i)] = [1, 1, 1, 2, 3, 4], WINSP1 = 2 m/s, WINSP2 = 6 m/s, and MNDIST = 800 m. These are the default values.

3.2.7.2 Plume Forms and Parameters

***Original Meander* Form**

The *Original Meander* form is required when the user selects *Original MACCS (MNDMOD=OLD)* in the *Select Plume Meander Model* group on the *Dispersion* tab. TIMBAS is the release duration associated with the tests to determine dispersion coefficients. BRKPNT is the time breakpoint in the formula used to calculate the plume meander expansion factor. If the

release duration is less than or equal to this value, the first formula is used. If the release duration exceeds this value, the third expression is used in Equation (10). XPFAC1 is the exponential factor used to calculate the plume meander expansion factor for releases having durations that are less than or equal to BRKPNT. XPFAC2 is the exponential factor used in calculating the plume meander expansion factor for releases having durations that are greater than BRKPNT.

Variable Name	Definable	Type	Dimensions	Allowed Values
TIMBAS	Yes	Real	None	60.0 to 86400.0 s
BRKPNT	Yes	Real	None	60.0 to 86400.0 s
XPFAC1	Yes	Real	None	0.01 to 1.0
XPFAC2	Yes	Real	None	0.01 to 1.0

***US NRC Reg. Guide 1.145 Meander* Form**
This is required if the user selects *US NRC Regulatory Guide 1.145 (MNDMOD=NEW)* in the *Select Plume Meander Model* group on the *Dispersion* tab.

WINSP1 is the wind speed where the meander factor changes from a constant value to a linearly decreasing function of the wind speed. Meander factor decreases linearly from the value specified by MNDFAC(n) to one at WINSP2. The index n represents the atmospheric stability class.

WINSP2 is the wind speed where the meander factor reaches one for all stability classes. Meander factor decreases linearly from the value specified by MNDFAC(n) at WINSP1 to one at WINSP2. The index n represents the atmospheric stability class.

MNDIST is the downwind distance where the effect of meander begins to diminish. MNDIST is a breakpoint in the formulae for calculating sigma-y.

MNDFAC is the plume meander factor used to calculate sigma-y described in the NRC Regulatory Guide 1.145. MNDFAC(1) corresponds to atmospheric stability class A, MNDFAC(2) to stability class B, ..., and MNDFAC(6) to stability class F.

Variable Name	Definable	Type	Dimensions	Allowed Values
WINSP1	Yes	Real	None	0.0 to 20.0 m/s
WINSP2	Yes	Real	None	0.0 to 20.0 m/s
MNDIST	Yes	Real	None	0.0 to 10,000.0 m
MNDFAC	Yes	Real	6	1.0 to 10.0

Plume Rise Scale Factor
SCLCRW is a linear scaling factor on the critical wind speed used to determine whether buoyant plumes are trapped in the turbulent wake of the facility building complex. Parameter values less than unity make plume rise less likely to occur because plume liftoff occurs only when the ambient wind speed at the time of release is less than the calculated critical wind speed; values greater than unity make plume rise more likely to occur.

SCLADP is the linear scaling factor on the plume rise formula used to determine the amount of plume rise that occurs when the atmosphere is unstable or neutrally stable (stability classes A through D).

SCLEFP is the linear scaling factor on the plume rise formula used to determine the amount of plume rise that occurs when atmospheric conditions are stable (stability classes E and F).

Variable Name	Definable	Type	Dimensions	Allowed Values
SCLCRW	Yes	Real	None	0.001 to $1x10^6$
SCLADP	Yes	Real	None	0.01 to 100.0
SCLEFP	Yes	Real	None	0.01 to 100.0

3.2.8 Release Description

3.2.8.1 Release Model Description

Release Description

ATMOS can handle multiple plume segments in order to treat a source term that has a time-varying composition and release rate. The plume segments that describe a release can be separated with a time gap, can directly follow each other, or can overlap. Different release heights, heat contents, starting times, release durations, release fractions, and initial values for σ_y and σ_z can be assigned to each plume segment. Only one initial particle-size distribution can be assigned to each chemical group. Thus, the effective, initial, particle-size distribution can vary from one plume segment to another only as a function of the relative release fractions of the radionuclide classes. However, the aerosol size distribution of a plume segment changes with time (i.e., downwind location as the plume segment travels through the grid) when there are multiple particle sizes with different deposition velocities.

Initial Plume Dimensions

Mixing of the plume into the wake of a building from which a release occurs generally determines the initial crosswind dimensions of the plume. For the purpose of initializing plume dimensions, the common assumption is that the plume centerline is at ground level and in the middle of the downwind face of the building.

If plume concentrations at the sides and roofline of the building from which the release occurs are assumed to be 10% of plume centerline concentrations (building edges are 2.15 sigma from the plume centerline), initial values of the horizontal and vertical standard deviations of the Gaussian plume are given by

$$\sigma_y(x=0) = W_b / 4.3 = 0.23 W_b$$
$$\sigma_z(x=0) = H_b / 2.15 = 0.47 H_b \qquad \text{(Equation 16)}$$

Where

W_b = Width of the building from which release occurs (m)

H_b = Height of the building from which release occurs (m)

Choosing the height and, especially, the width of the building from which the release occurs is not always straightforward. In many cases, the reactor complex is comprised of a set of buildings, which may be connected or disconnected. The heights of the buildings in this complex may vary. Usually, the containment or reactor building is used to define the building height, but this may not be appropriate in all cases. Determining the width is more problematic because the complex is generally rectangular or irregular in shape. Thus, the apparent width depends on the direction of the wind. Fortunately, the effects of the initial size of the plume are quickly lost as the plume moves downwind of the plant. While the initial plume dimensions can have a significant effect on the maximum dose at the exclusion area boundary, they usually have little effect on the doses multiple kilometers from the plant.

Plume Rise Models

There are three basic components of the plume rise models in MACCS: (1) liftoff of buoyant plumes from a building wake, (2) plume rise under unstable and neutral atmospheric conditions (stability classes A to D), and (3) plume rise under stable conditions (stability classes E and F). Each of these components is described in this section.

When wind speeds are sufficiently high, a buoyant plume segment that is released into a building wake is unable to escape from the wake. In MACCS, escape of a buoyant plume segment from a building wake is governed by a liftoff criterion (Equation (17) below), which was originally proposed by Briggs [Br73] and validated by experiments performed at the Warren Spring Laboratory in Great Britain [Ha86]. The criterion states that plume rise occurs only when the wind speed upon release of the segment is less than a critical wind speed (u_c) that is calculated using the following formula:

$$u_c = \left[\frac{9.09F}{H_b}\right]^{\frac{1}{3}} \qquad \text{(Equation 17)}$$

Where

H_b = the height of the building from which the plume is escaping (m)

F = the buoyancy flux (m^4/s^3), which, under standard atmospheric conditions is

= $8.79 \cdot 10^{-6}\dot{Q}$

$\dot{Q}$ = the sensible heat release rate of the plume (W), i.e., the sensible heat content of the plume divided by its release duration. Sensible heat is measured relative to the ambient temperature.

This equation indicates that there is little or no possibility of plume liftoff when the sensible heat release rate is less than 10^5 W for a typical, 50-m high, reactor or containment building. Even when the rate of release of sensible heat is 1 MW, the plume only lifts off when wind speed is less than approximately 1.2 m/s.

Plume rise, when atmospheric conditions are neutral or unstable (stability classes A through D), is treated using the “two thirds” law for bent over plumes of Briggs [Ha82]:

$$\Delta h = \frac{1.6F^{\frac{1}{3}}x^{\frac{2}{3}}}{\bar{u}} \qquad \text{(Equation 18)}$$

Where

h = height of the plume centerline (m)

Δh = plume rise (m) measured from the initial release height

$\bar{u}$ = wind speed (m/s) averaged between the initial height and the current location (x, h)

Buoyant plume rise is terminated when any of the following conditions occur:

1. Δh reaches a final rise height, as defined below,
2. the height of the plume centerline reaches the mixing height (height of the capping inversion layer), or
3. one hour has elapsed since release of the plume segment began.

In the original MACCS plume rise model, the following equation recommended by Briggs [Br75] was used to determine the final rise height for stability classes A to D:

$$\Delta h = 300F / \bar{u}^3 \qquad \text{(Equation 19)}$$

In the currently recommended, improved MACCS plume rise model, a different formula is used, also based on the work of Briggs (Hanna, 1982):

$$\Delta h = \frac{38.7F^{0.60}}{\bar{u}} \quad \text{when} \quad F \geq 55$$
$$\Delta h = \frac{21.4F^{0.75}}{\bar{u}} \quad F < 55 \qquad \text{(Equation 20)}$$

In the original MACCS model, plume rise under stable atmospheric conditions (stability classes E and F) is calculated using the Briggs equation for the final rise (Δh) [Ha82]:

$$\Delta h = 2.6\left[\frac{F}{\bar{u}S}\right]^{\frac{1}{3}} \qquad \text{(Equation 21)}$$

In the improved MACCS model, plume rise under stable atmospheric conditions (stability classes E and F) is calculated using a slightly modified version of the above equation:

$$\Delta h = 2.4\left[\frac{F}{\bar{u}S}\right]^{\frac{1}{3}} \qquad \text{(Equation 22)}$$

In Equations (21) and (22), the stability parameter, *S*, is defined as follows:

S = stability parameter (s^{-2}) defined by the following equation

$$S = \frac{g}{T_a}\left[\frac{\partial T_a}{\partial z}\right] + \left[\frac{g}{c_p}\right] \qquad \text{(Equation 23)}$$

Where

g = acceleration due to gravity (m/s^2)

T_a = ambient temperature (K)

$\frac{\partial T_a}{\partial z}$ = ambient temperature lapse rate (K/m)

c_p = heat capacity of air at constant pressure (J/kg/K)

$\frac{g}{c_p}$ = dry adiabatic lapse rate (0.98 K/100 m)

Regulatory Guide 1.23 [US72] specifies ranges for temperature lapse rates $\left(\partial T_a / \partial z\right)$ for the six atmospheric stability classes A through F. The values of the stability parameter *S* used in MACCS were derived using midpoint values for these lapse-rate ranges. The lapse rate ranges specified for Stability Classes E and F are -0.5 K/100 m to 1.5 K/100 m and 1.5 K/100 m to 4.0 K/100 m. Thus, Class E has a lapse rate range midpoint of 0.5 K/100 m and Class F a midpoint of 2.75 K/100 m. Substitution of these midpoint values and the International Civil Aviation Organization standard atmosphere [We72] value of 288.16 K (15°C) into Equation (13) results in values of 5.04×10^{-4} s^{-2} and 1.27×10^{-3} s^{-2} for the stability parameter *S* for Stability Classes E and F, respectively.

Because near-surface wind speeds generally increase with altitude, Equations (21) and (22) both overestimate plume rise if surface wind speeds are used to calculate Δh. Since this could underestimate radiation exposures, for purposes of calculating plume rise, wind speeds aloft are estimated from surface wind speeds using the following equation [Ha82]:

$$u = u_0 \left(\frac{h}{h_r} \right)^p \qquad \text{(Equation 24)}$$

Where

u_0 = surface wind speed measured at the reference height, h_r (usually 10 m above ground level)

p = exponential coefficient (dimensionless), which depends on stability class and surface roughness. Values are provided in Table 3-3 below.

Table 3-3 Values of exponential coefficient, *p,* in equation (24) for six stability classes.

Stability class	A	B	C	D	E	F
Urban Surfaces	0.15	0.15	0.20	0.25	0.40	0.60
Rural Surfaces	0.07	0.07	0.10	0.15	0.35	0.55

For the purpose of calculating plume rise, the weather conditions that characterize the time period during which release of the plume segment begins are used to calculate the entire rise of the segment even when the rise extends into the next time period (e.g., a buoyant plume segment released at 1:30 PM would have its entire rise calculated using 1:00 PM weather).

In MACCS, plume rise is calculated in three steps. First, the surface wind speed u_0 and one of the Equations (19) through (22), as appropriate, are used to make a first-order estimate of the

final centerline height (h) of the plume segment after plume rise has taken place $\left(h = h_0 + \Delta h\right)$, where h_0 is the initial release height of the plume segment. Then the wind speed u at the height h is calculated using Equation (24). Finally, an average wind speed over this range is estimated by averaging u_0, the reference wind speed, and u, the wind speed at the first-order estimate of the final height of the plume centerline. This average value of u is used in one of Equations (19) through (22) to make a second-order estimate of the amount of plume rise, Δh, which is used to evaluate the final plume centerline height of the plume segment, h.

The individual numerical coefficients used by these models are fixed in the code with no provision for their convenient modification by the user. While it is not possible for the user to vary the individual coefficients used by the three components of the plume rise model, it is possible to modify their end results by specifying linear scaling factors, SCLCRW, SCLADP, and SCLEFP.

Two optional sets of inputs are available in MACCS to determine plume buoyancy. If the *Power Model* is selected on the *Plume/Source* tab, the plume buoyancy is calculated using the rate of release of sensible heat content in a plume ($\dot{Q}$ in the equations above). In some cases, it is simpler for the user to estimate the rate of mass release and the density of a plume segment rather than the rate of release of sensible heat. The second option, the *Density and Flow Model* allows these values to be specified in place of the rate of release of sensible heat. The required values, plume density and mass flow rate, are related to the buoyancy flux, *F,* by the following formula:

$$F = \frac{g}{\pi}\left(1 - \frac{\rho}{\rho_a}\right)\frac{\dot{m}}{\rho} \qquad \text{(Equation 25)}$$

Where

g = acceleration due to gravity (9.8 m/s)

ρ = mass density of the plume (kg/m^3)

ρ_a = mass density of surrounding air at ambient conditions (1.178 kg/m^3)

$\dot{m}$ = mass flow rate of the plume (kg/s)

Equation (25) can be used to account for release of gases that are lighter than air, such as hydrogen and steam, as well as releases at elevated temperatures. Generally, the presence of aerosols can be neglected when plume density and flow rate are calculated.

3.2.8.2 Release Description

***Release Info* Form**

The *Release Info* form allows the user to describe the source term and other ATMOS input parameters through MACCS parameter ATNAM2. This identifying information is printed in the output file.

OALARM is used as a reference time that provides user flexibility should it be desirable to shift the entire response timeline. It is important to note that response actions cannot occur before OALARM. The user should consider this when establishing this parameter. Traditionally it has been used to define the time at which the public is notified, which could either be aligned with

the declaration of site area emergency or general emergency. However, it's use is very flexible and there is no requirement to align it with either of these emergency levels. The user should be aware that whatever time is assigned to OALARM has implications for other delays discussed subsequently.

Variable Name	Definable	Type	Dimensions	Allowed Values
ATNAM2	Yes	Character	None	1 to 80 characters
OALARM	Yes	Real	None	0. to 2,592,000 s (30 d)

***Plume of Maximum Risk* Form**

The *Plume of Maximum Risk* form is required when *Multi Source Term* is not selected on the *Plume/Source* tab.

MAXRIS specifies which plume segment is to be considered risk dominant. The selection of this plume segment is usually based on its potential for causing early fatalities. Release of the risk-dominant plume begins at the start time of the selected weather sequence. The upper limit on this parameter, NUMREL, is defined below.

Variable Name	Definable	Type	Dimensions	Allowed Values
MAXRIS	Yes	Integer	None	1 to NUMREL

***Plume Parameters* Form**

The *Plume Parameters* form is required when *Multi Source Term* is not selected on the *Plume/Source* tab. It contains four parameters that define the timing of plume segments and the initial release height.

NUMREL defines the number of plume segments that are released. This value is determined by the number of rows in the grid containing values of PDELAY, PLHITE, REFTIM, and PLUDUR.

PDELAY specifies the start time of each plume segment from the time of reactor scram, which is usually the time of accident initiation. Sequential, overlapping, and gaps between plume segments are allowed.

PLHITE specifies the height above ground level at which each plume segment is released.

REFTIM specifies the representative location for each plume segment (e.g., 0.0 = leading edge, 0.5 = midpoint, 1.0 = trailing edge). This parameter allows the user to locate the contents of the plume in a bucket of material situated at some point along the plume segment. Radioactive decay, dry deposition, and dispersion are all calculated as if the entire contents of the plume segment were located at this point. The choice of this parameter has no impact on the wet deposition calculations since those are performed as if the entire contents of the plume are uniformly distributed along its length.

PLUDUR specifies the duration of each plume segment.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMREL	Linked	Integer	None	1 to 200
PDELAY	Yes	Real	NUMREL	0.0 to 2,592,000 s (30 d)
PLHITE	Yes	Real	NUMREL	1 to NUMREL
REFTIM	Yes	Real	NUMREL	0.0 to 1.0

Variable Name	Definable	Type	Dimensions	Allowed Values
PLUDUR	Yes	Real	NUMREL	60.0 to 86,400.0 s (1 min to 1 d)

***Particle Size Distribution* Form**

The *Particle Size Distribution* form is required when *Multi Source Term* is not selected on the *Plume/Source* tab. It defines the aerosol-size distribution for each chemical class in the analysis.

PSDIST defines the fraction of the released material allocated to each of the particle-size (deposition-velocity) groups. The initial particle-size distribution for a chemical group is the same for all plume segments. The deposition velocity (VDEPOS) is shown as the column header. There are NSPGRP, the number of particle size groups, columns and MAXGRP, the number of chemical groups, rows. The fractions across a row (over the set of size groups) must sum to approximately 1.0.

Variable Name	Definable	Type	Dimensions	Allowed Values
PSDIST	Yes	Real	MAXGRP by NSPGRP	0.0 to 1.0

***Inventory Scale Factor* Form**

The *Inventory Scale Factor* form is required when *Multi Source Term* is not selected on the *Plume/Source* tab. CORSCA, the only parameter on this form, is a linear scaling factor that can be used to adjust the inventory of all the radionuclides defined in the model. This factor is useful for modeling similar reactors with different power ratings.

It is preferable to obtain new sets of inventory values when studying reactors with different power ratings, fuel burnup levels, or fuel management histories, but this is not always practical. When facility-specific inventories are not available, a representative inventory may be obtained by linear scaling of the inventory of a similar reactor having a different thermal power level. The scale factor is usually chosen to be the ratio of the two reactors' thermal power levels.

The parameter CORSCA can also be used to convert the facility inventory from one set of units to another during the input processing phase in order to avoid the tedium of manually converting a set of data from one set of units to another. For example, to convert from curies to Becquerels, use a value of 3.7×10^{10} for CORSCA. However, a second way to accomplish this is by simply switching units using the *Change Units* button at the lower left corner of the form.

Variable Name	Definable	Type	Dimensions	Allowed Values
CORSCA	Yes	Real	None	2.7×10^{-10} to 1×10^{16}

***Daughter Ingrowth Flag* Form**

The *Daughter Ingrowth Flag* form is required when *Multi Source Term* is not selected on the *Plume/Source* tab. APLFRC, the only parameter on this form, specifies how release fractions are applied to decay products. PARENT indicates that decay products formed after reactor shutdown are released in the same fraction as their parent; PROGENY indicates decay products formed after reactor shutdown are released according to their own chemical class. PARENT is preferred when using MELCOR data because MELCOR does not account for radioactive decay and ingrowth.

Variable Name	Definable	Type	Dimensions	Allowed Values
APLFRC	Yes	Character	None	PARENT, PROGENY

***Release Fractions* Form**

The *Release Fractions* form is required when *Multi Source Term* is not selected on the *Plume/Source* tab. RELFRC defines the release fraction for each of the plume segments and for each chemical group. All radionuclides in a chemical group are released from the facility in the same fraction. Normally, the values of RELFRC summed over the set of plume segments should not exceed 1.0, but this requirement is not imposed by either WinMACCS or MACCS.

Variable Name	Definable	Type	Dimensions	Allowed Values
RELFRC	Yes	Real	NUMREL by MAXGRP	0.0 to 1.0

***Wake Effect Data* Form**

The *Wake Effect Data* form is required when *Multi Source Term* is not selected on the *Plume/Source* tab. BUILDH defines the height of the facility building or building complex. This value is used to evaluate whether a buoyant plume is entrained in the turbulent wake of the building based on Equation (17).

SIGYINIT defines the initial value of sigma-y for each plume segment released.

SIGZINIT defines the initial value of sigma-z for each plume segment released.

Variable Name	Definable	Type	Dimensions	Allowed Values
BUILDH	Yes	Real	NUMREL	0.1 to 1000.0 m
SIGYINIT	Yes	Real	NUMREL	0.1 to 1000.0 m
SIGZINIT	Yes	Real	NUMREL	0.1 to 1000.0 m

***Heat* Form**

The *Heat* form is required when the *Power Model* is selected on the *Plume Rise* tab and the *Multi Source Term* is not selected on the *Plume/Source* tab. The values are used to determine buoyant plume rise.

PLHEAT specifies the rate of release of sensible heat in each plume segment. This quantity is traditionally calculated based on the difference between the plume and ambient temperatures, the heat capacity of air, and the flow rate of the plume. This value is used to determine the amount of buoyant plume rise.

Variable Name	Definable	Type	Dimensions	Allowed Values
PLHEAT	Yes	Real	NUMREL	0.0 to 1×10^{10} W

***Density and Flow* Form**

The *Density and Flow* form is required if the *Density and Flow Model* is selected on the *Plume Rise* tab and the *Multi Source Term* is not selected on the *Plume/Source* tab. The values on this form are used to determine the amount of buoyant plume rise. This formulation is more general and sometimes more convenient than specifying rate of release of sensible heat.

PLMFLA is the average mass flow rate for a plume segment.

PLMDEN is the average gas density for a plume segment.

Variable Name	Definable	Type	Dimensions	Allowed Values
PLMFLA	Yes	Real	NUMREL	1×10^{-6} to 1×10^{32} kg/s
PLMDEN	Yes	Real	NUMREL	0.02 to 5.0 kg/m^3

3.2.9 Weather

3.2.9.1 Weather Model Description

There are five options available to the user for specifying the weather data that are used by ATMOS. MACCS can run either a single weather sequence or multiple weather sequences, as described in the following paragraphs.

When a single weather sequence is desired, there are three ways to specify the weather data. The user can (1) specify data for 120 hr, (2) specify a starting day and time period in the weather data file, or (3) specify constant weather conditions.

For the specified starting day and time period option, MACCS weather data from the meteorological data file beginning at the specified day and time. A file of weather data covering a period of 365 days (8760 hr) is required.

The two methods of weather sampling are (1) a modified version of the weather bin sampling method used in CRAC2 (Ritchie et al., 1984) and (2) a stratified, random sampling approach. The weather bin sampling method sorts weather sequences into categories and assigns a probability for each category, depending on the number of data points that fit into that category. The categories (i.e., bins) are defined by wind speed and stability class or by the occurrence of rain (intensity and distance). The rain bins depend on rain intensity as well as the downwind distance at which rain begins. The user is required to supply the parameters that define the rain bins as part of the ATMOS input file. The definitions of the weather bins that depend on stability class and wind speed are fixed in the code and are defined in the output file.

The stratified random sampling method allows the user to sample weather from each day of the year after division of each day into one, two, three or four equal time periods. Each weather sequence selected is considered to have the same probability of occurrence, that is, P = 1/(number of samples).

3.2.9.2 Mixing Height Option

Daytime and nighttime values for mixing height are specified for each of the four seasons in the meteorological data file. An option is available in MACCS to account for night-to-day transitions in mixing height. This is activated by checking the box *Adjust mixing height based on time of day* on the *Weather* tab. This option only applies when a meteorological file is used (i.e. METCOD = 1, 2, or 5).

If *Adjust mixing height based on time of day* is unchecked, only the daytime mixing heights are used. The meteorological file contains 2 sets of 4 values for mixing height at the end of the file. The first set is the morning mixing height values for each of the four seasons. The second set is afternoon mixing height values for each of the four seasons. Only the second set of values is used when this option is chosen. That is, the mixing height only depends on the season for which the calculation is performed.

If *Adjust mixing height based on time of day* is selected, mixing height is adjusted depending on time of day. This model uses both the morning and afternoon values. If the start time is between sunset and sunrise, the morning value for the appropriate season is used until the first hour after sunrise. At the first hour after sunrise and until the hour of sunset, the maximum mixing height is calculated by linearly interpolating between the morning value and the afternoon value for that season. Once the first sunset in the simulation is reached, the afternoon mixing height is used until the end of the weather trial. If the start time of the simulation is between the first hour after sunrise and the hour of sunset, the mixing height is calculated by interpolating between the morning value and the afternoon value for that season. Again, once the first sunset of the simulation is reached, the mixing height is fixed at the afternoon value. The mixing height is never allowed to decrease in the MACCS treatment because that would violate the second law of thermodynamics.

Calculations based on time of day require the user to supply the latitude and longitude of the accident site. This is done on the form labeled *Site Location*.

3.2.9.3 *Weather* Forms and Parameters

***Constant or Boundary Conditions* Form**

The *Constant or Boundary Conditions* form is required. This form allows the user to specify constant weather (METCOD = 4) or boundary weather conditions (METCOD = 1, 2, 3, or 5). Boundary weather is implemented when the radial interval greater than the value specified by LIMSPA is entered by a plume segment. Boundary weather allows the user to prescribe simple, constant weather conditions (in place of measured weather conditions taken from the meteorological data file) in the outer portion of the computational grid. This has traditionally been used to implement boundary rain, the purpose of which is to prevent the aerosols from escaping the grid. Using boundary rain tends to force a conservative result. A more realistic result can be obtained by setting LIMSPA = NUMRAD so that real weather data are used all the way to the edge of the grid.

BNDMXH is the mixing layer height that is used for the constant weather conditions (METCOD = 4). Mixing height is determined from other sources for all other values of METCOD.

IBDSTB is the stability class that is used for constant and boundary weather conditions. The integers 1 through 6 represent Pasquill-Gifford stability classes A through F, respectively.

BNDRAN is the rain rate that is used for the constant and boundary weather conditions.

BNDWND is the wind speed that is used for constant and boundary weather conditions.

Variable Name	Definable	Type	Dimensions	Allowed Values
BNDMXH	Yes	Real	None	100.0 to 10,000.0 m
IBDSTB	Yes	Integer	None	1 to 6
BNDRAN	Yes	Real	None	0 .0 to 99.0 mm/hr
BNDWND	Yes	Real	None	0.5 to 30.0 m/s

***Fixed Start Time Data* Form**

The *Fixed Start Time Data* form is required when *Constant Weather*, *User Supplies 120 Weather Points,* or *Fixed Start Time* is selected on the *Weather* tab. For the first two options, the start time is only used in conjunction with the COMIDA2 food-chain model. However, MACCS requires these input parameters even when the COMIDA2 food-chain model is not used.

ISTRDY is the day of the year when the weather sequence begins.

ISTRHR is the starting time period of the weather trial. A 24-hour day is divided into 15-, 30-, or 60-minute time periods in the meteorological file, depending on the value of PERIOD in the meteorological data file. These divisions correspond to 96 time periods per day, 48 time periods per day, and 24 time periods per day, respectively. MACCS enforces the following ranges of ISTRHR:

Allowed Range of ISTRHR	Data Interval	Third line of meteorological file
1 to 24	60 minutes	/PERIOD 60 (default)
1 to 48	30 minutes	/PERIOD 30
1 to 96	15 minutes	/PERIOD 15

Additionally, the food pathway calculations of the CHRONC module depend on the day the accident occurs when the COMIDA2 food-chain model is used. If the user has chosen the *Fixed Start Time* option, the values of ISTRDY and ISTRHR specify the starting day and time period in the weather file of the single weather trial that is performed.

Variable Name	Definable	Type	Dimensions	Allowed Values
ISTRDY	Yes	Integer	None	1 to 365
ISTRHR	Yes	Integer	None	1 to 96

***User-Supplied Weather* Form**

The *User-Supplied Weather* form is required when *User Supplies 120 Weather Points* is selected on the *Weather* tab. There must be one data record for each hour of weather in the sequence.

HRMXHT is the set of mixing layer heights that is used for a single weather trial. The user must supply 120 values, one per hour.

IHRSTB defines the list of stability classes that are used for a single weather trial. The integers 1 through 6 represent the Pasquill-Gifford stability classes A through F, respectively. The user must supply 120 values, one per hour.

HRRAIN defines the list of rain rates that are used for a single weather trial. The user must supply 120 values, one per hour.

HRWNDV defines the list of wind speeds that are used for a single weather trial. The user must supply 120 values, one per hour.

IHRDIR defines the list of wind directions that are used for a single trial. They are given as integers corresponding to each of the compass directions starting with north (1) and ending with the direction just to the west of north. The user must supply 120 values, one per hour.

Variable Name	Definable	Type	Dimensions	Allowed Values
HRMXHT	Yes	Real	120	100.0 to 10,000.0 m
IHRSTB	Yes	Integer	120	1 to 6
HRRAIN	Yes	Real	120	0.0 to 99.0 mm/hr
HRWNDV	Yes	Real	120	0.5 to 30.0 m/s
IHRDIR	Yes	Integer	120	1 to NUMCOR

Site Location **Form**

The *Site Location* form is required when *Adjust mixing height based on time of day* is selected on the *Weather* tab. The user must also specify the latitude and longitude of a site when map files need to be generated with MapGen, which allows maps to be displayed behind speed multiplier and network evacuation forms.

The latitude and longitude of a site can be found on a site file generated by SecPop as a comment line; however, this information must be entered manually because WinMACCS does not read this comment line from a site file.

LATITU_DEG, LATITU_MIN, and LATITU_SEC represent the degrees, minutes, and seconds of the latitude. These values are used to calculate the time of sunrise and sunset.

LATITU_DIREC indicates hemisphere, North or South.

LONGIT_DEG, LONGIT_MIN, and LONGIT_SEC represent the degrees, minutes, and seconds of the longitude.

LONGIT_DIREC indicates hemisphere, East or West.

Variable Name	Definable	Type	Dimensions	Allowed Values
LATITU_DEG	Yes	Real	None	0.0 to 90.0˚
LATITU_MIN	Yes	Real	None	0.0 to 60.0′
LATITU_SEC	Yes	Real	None	0.0 to 60.0″
LATITU_DIREC	Yes	Character	None	N, S
LONGIT_DEG	Yes	Real	None	0.0 to 360.0˚
LONGIT_MIN	Yes	Real	None	0.0 to 60.0′
LONGIT_SEC	Yes	Real	None	0.0 to 60.0″
LONGIT_DIREC	Yes	Character	None	E, W

Samples per Bin **Form**

Samples per Bin is required when *Uniform Bin Sampling (METCOD=2)* is selected on the *Weather* tab. The bins are defined to represent rain conditions at different distance intervals downwind from the accident site together with 16 bins for initial conditions organized by stability class and wind speed. The rain intensities and distance intervals that define the rain bins are chosen by the user. These values are specified on forms *Rain Distances* and *Rain Intensities.*

The total number of weather bins is determined by the number of rain intensities, NRINTN, and the number of rain distances, NRNINT, defined by NRNINT•(NRINTN+1)+16. The total number of bins can range from 28 to 40, depending on the number of rain distances and intensities supplied by the user. The 16 initial weather bins are fixed in MACCS according to the definitions given in

Table 3-4.

Table 3-4 Definition of the 16 standard weather bins in MACCS.

Bin number	Stability class	Wind speed
1	A/B	0 m/s < u ≤ 3 m/s
2	A/B	3 m/s < u
3	C/D	0 m/s < u ≤ 1 m/s
4	C/D	1 m/s < u ≤ 2 m/s
5	C/D	2 m/s < u ≤ 3 m/s
6	C/D	3 m/s < u ≤ 5 m/s
7	C/D	5 m/s < u ≤ 7 m/s
8	C/D	7 m/s < u
9	E	0 m/s < u ≤ 1 m/s
10	E	1 m/s < u ≤ 2 m/s
11	E	2 m/s < u ≤ 3 m/s
12	E	3 m/s < u
13	F	0 m/s < u ≤ 1 m/s
14	F	1 m/s < u ≤ 2 m/s
15	F	2 m/s < u ≤ 3 m/s
16	F	3 m/s < u

NSMPLS defines the number of weather sequences to be chosen from each of the individual bins. The more samples that are taken, the better the statistical representation of the results.

Range for NSMPLS (365 x number time periods per day)	Weather Data Time Interval	Third line of meteorological file
1 to 8760	60 minutes	/PERIOD 60
1 to 17520	30 minutes	/PERIOD 30
1 to 35040	15 minutes	/PERIOD 15

Variable Name	Definable	Type	Dimensions	Allowed Values
NSMPLS	Yes	Integer	None	0 to 35040

***Samples per Day* Form**

Samples per Day is required when *Stratified Random Sampling (METCOD=5)* is selected on the *Weather* tab.

NSMPLS defines the number of weather sequences to be chosen from each day of the year. MACCS enforces the following range:

Range for NSMPLS	Data Interval	Third line of meteorological file
1 to 24	60 minutes	/PERIOD 60
1 to 48	30 minutes	/PERIOD 30
1 to 96	15 minutes	/PERIOD 15

Although not enforced by MACCS or WinMACCS, NSMPLS should be set to be a factor of 24 when the meteorological data are hourly (i.e., 1, 2, 3, 4, 6, 8, or 24), a factor of 48 when there is one record of data for every 30 minutes, or a factor of 96 when there is one record of data for every 15 minutes. This is because the sampling algorithm begins by dividing each day up into NSPLS time intervals. One sample is selected from each time interval. For example, if NSPLS is 4 and hourly weather data are specified, each day is divided into 4 6-hr intervals. MACCS selects a single random starting time from each of these 4 intervals. Because the duration of each of the intervals is the same, each of the trials is equally probable. Selecting an integer that is not a factor causes some of the time intervals to be longer than others and leads to a bias in the sampling algorithm.

Variable Name	Definable	Type	Dimensions	Allowed Values
NSMPLS	Yes	Integer	None	1 to 96

Seed Form

Seed is required when *Stratified Random Sampling (METCOD=5)* is selected on the *Weather* tab.

IRSEED defines the seed of the random number generator. Changes to this value cause different weather trials to be selected.

Variable Name	Definable	Type	Dimensions	Allowed Values
IRSEED	Yes	Integer	None	0 to 255

***Boundary Limit* Form**

Boundary Limit is required when anything but *Constant Weather* (METCOD=4) is selected on the *Weather* tab.

LIMSPA is the limiting spatial interval for using recorded weather data. Spatial intervals greater than with this value use the boundary weather conditions specified on form *Constant or Boundary Conditions*. Boundary weather conditions are applied to all spatial intervals when a value of 0 is specified for this parameter.

Variable Name	Definable	Type	Dimensions	Allowed Values
LIMSPA	Yes	Integer	None	0 to NUMRAD

***Bins* Form**

The *Bins* form is required if *Nonuniform Bin Sampling (METCOD=2, NSMPLS=0)* is selected on the *Weather* tab. Sampling a subset of all the weather bins allows the effects of weather type to be examined. This is accomplished by setting INWGHT to zero for one or more of the bins. Another option for examining the importance of various weather bins is to set the RISCAT flag to True, as described below in the section on EARLY.

NSBINS defines the number of bins from which weather sequences are to be chosen. Its value is determined by the number of rows in the grid containing values of INDXBN and INWGHT. However, the user should ensure that the number of bins is consistent with the value of NRNINT•(NRINTN+1)+16.

INDXBN defines the list of bins from which weather sequences are to be selected when nonuniform bin sampling is chosen. Indices are reported in the MACCS output under METEOROLOGICAL BIN SUMMARY. MACCS requires that the range of values is $1 \leq$ value $\leq$ NSBINS. The total number of bins depends on the rain distances and intensities supplied by the user, as described above.

INWGHT defines the number of weather sequences to be selected from the each weather bin. If this number exceeds the number of sequences in the specified bin, the code selects all of the sequences in that bin. In order to find the index number for a rain bin, refer to the output titled METEOROLOGICAL BIN SUMMARY. MACCS requires that the sum of the values must be greater than or equal to one.

MACCS enforces the following range:

Range for INWGHT	Data Interval	Third line of meteorological file
1 to 8760	60 minutes	/PERIOD 60 (default)
1 to 17520	30 minutes	/PERIOD 30
1 to 35040	15 minutes	/PERIOD 15

Variable Name	Definable	Type	Dimensions	Allowed Values
NSBINS	Linked	Integer	None	1 to 40
INDXBN	Yes	Integer	NSBINS	1 to 40
INWGHT	Yes	Integer	NSBINS	0 to 35040

***Rain Distances* Form**

The *Rain Distances* form is required when either *Uniform Bin Sampling (METCOD=2)* or *Nonuniform Bin Sampling (METCOD=2, NSMPLS=0 to 35040)* is selected on the *Weather* tab.

NRNINT defines the number of rain distance intervals used for weather binning. The value is determined by the number of entries in vector RNDSTS.

RNDSTS defines the rain distance interval endpoints used for the weather binning. MACCS requires that each of these distances lie within 10% of one of the spatial interval endpoint distances, SPAEND, and that the user supply unique values in ascending order.

For example, if the user specifies 2, 4, 8, and 16 km, these values define the following four rain distance intervals:

1. 0 km $\leq$ distance of first rain occurrence $\leq$ 2 km
2. 2 km < distance of first rain occurrence $\leq$ 4 km
3. 4 km < distance of first rain occurrence $\leq$ 8 km
4. 8 km < distance of first rain occurrence $\leq$ 16 km.

Rain that occurs beyond 16 km in this example is not categorized as being in a rain bin. These time intervals are categorized under the 16 bins defined in

Table 3-4.

Variable Name	Definable	Type	Dimensions	Allowed Values
NRNINT	Linked	Integer	None	4 to 6
RNDSTS	Yes	Real	NRNINT	0.001 to 99.9 km

***Rain Intensities* Form**

The *Rain Intensities* form is required when either *Uniform Bin Sampling (METCOD=2)* or *Nonuniform Bin Sampling (METCOD=2, NSMPLS=0)* is selected on the *Weather* tab. The user must specify either two or three rain intensities that are used as breakpoints in the categorization of precipitation rate. For example, if the user specifies two rain intensity breakpoints of 1 and 4 mm/hr, the following three rain intensity intervals, where x is the rain intensity, are used:

1. 0 mm/hr < $x \leq$ 1 mm/hr
2. 1 mm/hr < $x \leq$ 4 mm/hr,
3. 4 mm/hr < x.

NRINTN defines the number of rain intensity breakpoints to be used for weather binning.

RNRATE defines the rain intensity breakpoints. MACCS requires that unique values are supplied in ascending order.

Variable Name	Definable	Type	Dimensions	Allowed Values
NRINTN	Linked	Integer	None	2 to 3
RNRATE	Yes	Real	NRINTN	0.001 to 100.0 mm/hr

3.2.10 Output Control

When requested by the user, the ATMOS module generates the complementary cumulative distribution function, CCDF, of ten atmospheric modeling parameters for user-specified distances and plume segments, as listed in

Table 3-5.

Air and ground concentrations are reported for the radionuclide specified for the variable NUCOUT. In addition to the results produced for the single specified radionuclide, the total radioactivity on the ground (from all radionuclides) is reported as well. Within a single run of the code, there is no provision in MACCS for generating CCDFs of air and ground concentrations for multiple individual radionuclides. When such output is needed, separate MACCS runs are required to produce results for each radionuclide.

Table 3-5 Results available from ATMOS in CCDF form.

Selected Radionuclide Centerline Air Concentration (Bq·s/m^3)
Selected Radionuclide Ground-Level Air Concentration (Bq·s/m^3)
Selected Radionuclide Centerline Ground Concentration (Bq/m^2)
Total Centerline Ground Concentration (Bq/m^2)
Ground-Level χ/Q Dispersion Factor (s/m^3) (Undepleted)
Selected Radionuclide Adjusted Source Strength, Q_a (Bq)
Plume σ_y, Crosswind Size (m)
Plume σ_z, Vertical Size (m)
Plume Centerline Height (m)
Plume Arrival Time at Centerpoint (s)

In the Gaussian plume equations, Q is commonly used to represent the amount released. When material decays or is deposited on the ground during transport, the effective source strength for downwind distances is reduced. This is treated in MACCS through the definition of an adjusted source strength, Q_a, which is reduced by deposition and radioactive decay that occur over each spatial interval. Note that all of the concentration results shown in this table account for plume depletion; however, the value for χ/Q does not. This quantity simply represents reduction in concentration due to dispersion.

3.2.10.1 Output Forms and Parameters

***Output Control* Form**

The *Output Control* form is required. The user has the option of printing tables of dispersion data for all of the trials that are performed. This information includes air and ground concentrations, σ_y and σ_z values, arrival time, and time overhead for each plume segment at each spatial interval. These data are written to the output file.

The following variables can be written to the output file using the variable IDEBUG.

Table 3-6 Additional ATMOS output information.

NUCNAM	name of the radionuclide for which results are being presented
DISTANCE	distance from the point of release to the center of the spatial interval (m)
GL AIRCON	centerline ground-level time-integrated air concentration from this plume segment averaged over the spatial interval (Bq·s/m^3)
GRNCON	centerline ground concentration after passage of this plume averaged over the spatial interval (Bq/m^2)
GL χ/Q	centerline ground-level χ/Q, the ratio of time-integrated air concentration (χ) to source strength (Q), averaged over the spatial interval (s/m^3). Values reported do not account for plume depletion by deposition or radioactive decay.
WETREM	fraction of material remaining in the plume segment after wet deposition over the spatial interval (dimensionless)
DRYREM	fraction of material remaining in the plume segment after dry deposition over the spatial interval (dimensionless)
REMINV	adjusted source strength of the plume upon entering each spatial interval after adjustment for losses in the previous intervals due to radioactive decay and wet and dry deposition (Bq)

PLSIGY	horizontal dispersion parameter, σ_y, averaged over the spatial interval (m)
WEATHER	indices to the first and last hours of the weather sequence used for determining atmospheric conditions during transport across each spatial interval
HTFCTR	ratio of the centerline ground-level air concentration (z=0) to the plume centerline air concentration (z=H), (dimensionless)
AVGHIT	average height (H) of the plume as it traversed the spatial interval (m)
TIMCEN	time after reactor shutdown at which the leading edge of the plume arrived at the centerpoint of the spatial interval (s)
TIMOVH	duration for which the plume was overhead at the centerpoint of the spatial interval (s)

IDEBUG specifies the quantity of debug output to be printed. For normal runs, IDEBUG should be set to 0 and no debug output is printed. If IDEBUG is set to 1 or 2, detailed results for atmospheric transport are generated for each weather trial and each plume segment. If IDEBUG is set to a value of 3 or more, the meteorological data used for each weather trial are also printed.

NUCOUT specifies which radionuclide is reported in the dispersion results. Debug results are only reported if IDEBUG is greater than zero. The specified radionuclide name must be in the previously defined list of radionuclides.

Variable Name	Definable	Type	Dimensions	Allowed Values
IDEBUG	Yes	Integer	None	-1 to 8
NUCOUT	Yes	Character	None	Must select a Radionuclide defined in vector NUCNAM.

Spatial Intervals for Output **Form**
The *Spatial Intervals for Output* form is optional.

NUM0 specifies the number of results. For each request, a set of ten results describing atmospheric transport and dispersion is reported. The value is determined by the number of rows in the grid containing values of vectors INDREL, INDRAD, and Report Options.

INDREL specifies the index of the plume segment for which results are to be reported.

INDRAD specifies the index of the radial grid element for which results are to be reported. The reported values are evaluated at the radial midpoint of the grid element by averaging the results at the grid boundaries.

When Report Options are set to CCDF or CCDF & REPORT, the complementary cumulative distribution function data are reported in the MACCS output file. When set to REPORT or CCDF & REPORT, WinMACCS automatically generates a report over all realizations based on the quantile values specified on the *Reporting Options* form.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM0	Linked	Integer	None	0 to 35
INDREL	Yes	Integer	None	1 to NUMREL
INDRAD	Yes	Integer	NUM0	1 to NUMRAD
Report Options	Yes	Character	NUM0	CCDF, NONE, REPORT, CCDF & REPORT

3.3 EARLY Input and Model Description

3.3.1 Overview of EARLY

The EARLY module models the time period immediately following a radioactive release. This period is commonly referred to as the emergency phase. It may extend up to 40 days after the arrival of the first plume segment at any downwind spatial interval. The subsequent intermediate and long-term phases are treated by CHRONC.

In the EARLY module the user may specify emergency response scenarios that include evacuation, sheltering, and dose-dependent relocation. The EARLY module has the capability to combine results from one to twenty different emergency response cohorts. The number of cohorts is specified on the *Evac/Rotation* tab found on the *GENERAL* main category under *Properties* in WinMACCS.

Results are output for each of the user-defined emergency response cohorts and for a weighted sum of the cohorts. Cohorts may be combined by assigning time fractions (frequencies of occurrence), population fractions (fraction of the population engaging in the specified behavior) to each cohort, or by a simple summation of the results for each emergency response cohort (when a unique population distribution is defined for each cohort). The weighting method is specified from the *Project/Site Data* tab.

CCDFs calculated for emergency response cohorts combined based on time fractions are a function of the probability for each meteorological trial/wind direction multiplied by the time fraction applied to the emergency response cohort. Emergency response cohorts combined using population fractions are a function of the consequence calculated for each meteorological trial/wind direction multiplied by the fraction of people assigned to the cohort. The approach selected (fraction of people or fraction of time) affects the shape of the CCDF but does not affect the mean results.

For results that are calculated by both EARLY and CHRONC, such as population dose and cancer cases, the consequence calculated by CHRONC is added to the value of the same consequence measure produced by EARLY in order to generate the overall combined results. Whenmore than one EARLY emergency response cohort is being run, these results are combined according to the weighting fractions supplied for each scenario variable WTFRAC. The weighted sum is combined with the CHRONC result to produce the overall result. MACCS models the entire population behaving the same in the CHRONC module, so only one CHRONC cohort exists. Whenever results are combined by the code, the output file list the overall combined results as well as results for each of the individual cohorts.

3.3.2 Dose Calculation

The calculation of radiation doses from early exposure considers five pathways: (1) direct external exposure to radioactive material in the plume (cloudshine), (2) exposure from inhalation

of radionuclides in the cloud (cloud inhalation), (3) exposure to radioactive material deposited on the ground (groundshine), (4) inhalation of resuspended material (resuspension inhalation), and (5) skin dose from material deposited on the skin.

Two kinds of doses are calculated: (1) acute doses used for calculating early fatalities and injuries and (2) lifetime committed dose used for calculating cancers resulting from the early exposure. The accumulation of radiation doses from early exposure is strongly dependent on the assumed emergency response, that is, evacuation, sheltering, and relocation. Cloudshine and cloud inhalation exposures are limited to the time of cloud passage. Groundshine and resuspension inhalation doses for early exposure are limited to the duration of the emergency phase.

In general, the dose equation for an early exposure pathway in a given spatial element is the product of the following quantities: radionuclide concentration, usage factor, duration of exposure, dose conversion factor, and shielding or protection factor. The quantities used in the dose equations depend on the exposure pathway. For example, for the cloud inhalation exposure pathway, these quantities are the ground-level air concentration within a spatial element, breathing rate, duration of inhalation, inhalation dose conversion factor, and inhalation protection factor.

The dose conversion factors for all exposure pathways are provided in the dose conversion factor files distributed with WinMACCS. However, the user can modify any of these factors by defining constant or uncertain values in WinMACCS.

Dose conversion factors are supplied in one of the following three ways:

- A single, predefined file. In this case, the linear no threshold model has been selected on the *Properties/Dose* tab. Files based on DOSFAC2, FGR-11 and -12, and FGR-13 are distributed with WinMACCS. The user selects this file from the WinMACCS *GENERAL* main category under *File Specifications/Dose Conversion Factor File*.

- A set of 51 predefined files, a base file and a file for each of the 50 years of dose commitment. In this case, the piecewise linear or annual threshold model has been selected. Files based on DOSFAC2 and FGR-13 are distributed. The user selects a base file, e.g., named FGR13DCF.INP, on the form found in the WinMACCS *GENERAL* main category under *File Specifications/Annual Differential DCF Files*.

- A single file or 51 files created by WinMACCS based on user input values. In this case, a predefined DCF file or files are used as the basis. The source of the DCF file is set to *Create DCF File* on the *Properties/Dose* tab. Values in the DCF file are modifiable for nuclides selected on the *DOSE COEFFICIENTS/Reveal Nuclides* form.

A MACCS user has some flexibility in the selection of a dose conversion factor file (DCF). Files based on (1) DOSFAC2, a pre-processer using data from DOE/EH-0070 and tissue weighting factors from ICRP-26 and -60; (2) files created using pre-processer utility FGRDCF based on Federal Guidance reports 11 and 12, and (3) files based on Federal Guidance Report 13 (FGR-13). The DCF set based on FGR-13 is the most complete and up to date and is currently recommended for most consequence analyses.

As a side note, the International Committee on Radiation Protection (ICRP) traditionally used the term dose conversion factors (DCFs) to refer to coefficients that convert activity levels for an exposure pathway to doses. The newer ICRP term is dose coefficients. In this document and in the WinMACCS interface, the two terms are used interchangeably.

The list of organs that can be used in a calculation depends on which DCF file is selected. WinMACCS forms show organ doses with an A- or an L- prefix. Organ doses beginning with A- (e.g., A-SKIN) are used for acute exposure doses in the EARLY module; organ names beginning with L- (for example L-THYROID) are used for lifetime, 50-year committed doses in both the EARLY and CHRONC modules. Internal doses from inhalation for the acute organ doses are calculated over a much shorter commitment period than doses for the lifetime organ doses. Because of the shorter commitment period, acute doses are less than or equal to lifetime doses for the same organ.

The DCF files do not use the A- or L- prefix for the organ names. They contain columns of data, some of which correspond to acute and some to lifetime doses. The dose conversion factor values, whether for acute or latent exposures, depend on the exposure pathway in the calculation.

Though SKIN is listed as an organ in the FGRDCF dose conversion factor file, the numbers for SKIN in the DCF are not used in the acute exposure calculation corresponding to A-SKIN. Dose to the skin is calculated directly in MACCS based on beta energy depositing in the skin from radionuclides that have deposited onto the skin. This is different than the long-term skin dose (L-SKIN), which is calculated using values from the FGRDCF file. To make this distinction clear, the lifetime organ dose is labeled L-SKIN(FGR). Lifetime skin doses are genrally unimportant in terms of estimating latent cancers and are not included in either of the other DCF files.

Organ choices shown on MACCS forms depend on the choice of dose conversion factor file type selected on the *Properties/Dose* tab. These choices are as shown in Table 3-7. Organs not included on this list, even though present in the DCF files, cannot currently be used in MACCS calculations. The list of organs that can be used is hardwired within the MACCS code.

Table 3-7 Organ doses defined in MACCS for each type of DCF file.

DCF based on FGR-13	DCF generated by DOSFAC2	DCF generated by FGRDCF
A-SKIN	A-SKIN	L-GONADS
A-RED MARR	A-RED MARR	L-BREAST
A-LUNGS	A-LUNGS	L-LUNGS
A-THYROID	A-THYROIDH	L-RED MARR
A-STOMACH	A-STOMACH	L-BONE SUR
A-LOWER LI	A-LOWER LI	L-THYROID
L-ICRP60ED	L-EDEWBODY	L-REMAINDER
L-RED MARR	L-RED MARR	L-EFFECTIVE
L-BONE SUR	L-BONE SUR	L-SKIN(FGR)
L-BREAST	L-BREAST	
L-LUNGS	L-LUNGS	
L-THYROID	L-THYROID	
L-LOWER LI	L-LOWER LI	
L-BLAD WAL	L-BLAD WAL	
L-LIVER	L-LIVER	
	L-THYROIDH	

When a COMIDA2-generated input file is used in a MACCS run, MACCS must use the same DCF file as the one used to generate the COMIDA2 file. The first two header records of the

DCF files used by MACCS and COMIDA2 are read and compared to ensure that the two sets of calculations used the same DCF file. This is important when predefined COMIDA2 files are used.

The duration of exposure depends on the exposure pathway and the emergency response at a spatial element and is calculated based on user-supplied data. The shielding factor is a dimensionless quantity used to reduce the radiation dose as a result of shielding protection provided by a given protective action for a given exposure pathway. Shielding factors for the various exposure pathways (cloudshine, inhalation, groundshine, and skin dose) and for three different groups of people (evacuees, people doing normal activity, and people taking shelter) are specified by the user.

The evacuation model incorporates two delay times that affect the timing of evacuation: one is a delay to shelter and the second is a delay to evacuate. Different shielding factors and breathing rates can be used while people continue normal activity, take shelter, or evacuate.

The EARLY calculation accumulates the radiation doses for an evacuating population by adding the doses they receive during normal activity, sheltering, and evacuation. This is done until the evacuees reach a user-defined distance where they are assumed to avoid further exposure.

Evacuees receive no additional emergency phase radiation doses after evacuation is complete. The CHRONC module allows the user to define dose projection criteria that determine whether evacuees return to their original locations during the intermediate and long-term phases. Additional radiation doses are calculated in the CHRONC module.

Before a population takes shelter, the members of the population are assumed to be carrying out normal activities. Shielding factors (cloudshine, groundshine, inhalation, and skin) for normal activity apply to them during this period of time. When the members take shelter, shielding factors for sheltering apply. After they begin to evacuate, shielding factors for evacuation apply. The user defines the durations of each of these activities; a null period is possible, e.g., no time period for sheltering.

The plume transport model assigns the plume a finite length calculated by using the assumed release duration and wind speed(s) during the release. The length of the plume segment is constant following the release (*i.e.,* the front and back of the plume travel at the prevailing wind speed), and the concentration of radioactive material is assumed to be uniform over the length of the segment. The radial position of evacuating persons, before or during evacuation, is compared with the positions of the front and back of the plume as a function of time to determine the period of exposure to airborne radionuclides.

3.3.3 Model Basis

3.3.3.1 Basic Model Description

Grid Subdivisions

The basic nodalization used in MACCS is defined above in the description of the spatial grid in the ATMOS section. In addition to this basic grid, a more refined grid, called the fine grid, is used in EARLY to calculate off-centerline doses. The fine grid is used both for calculation of acute and latent health effects.

Each one of the compass sectors is further subdivided into a number of fine grid divisions. The number of fine grid divisions is specified by the user and is allowed to be 3, 5, or 7.

The off-centerline correction factor of a fine spatial element for the cloudshine pathway is calculated in a different manner than correction factor for the other exposure pathways of the emergency phase. For the cloudshine pathway, the off-centerline correction factor within a fine spatial element is the finite cloud correction factor discussed below. This finite cloud correction factor takes into account both the total distance to the plume centerline and the size of the plume.

For cloud inhalation, groundshine, resuspension inhalation, and skin exposure pathways during the emergency phase, the Gaussian crosswind distribution is evaluated at the centerpoint of each fine grid. The outermost extent of the plume is the azimuthal location where the Gaussian distribution falls to one-tenth of its peak, i.e., the outermost fine grid that contains the point where the crosswind distance (measured around a circular arc) is ($2.15 \times \sigma_y$) from the plume centerline.

Weather Sampling and Wind Rose Probabilities

One of the basic options in MACCS that affects weather sampling is chosen under the Evac/Rotation tab. This choice defines the MACCS parameter, IPLUME. These options carry two independent concepts for weather sampling: wind shift and rotation.

Wind shift carries the idea of variations in wind direction. Wind shift only matters when a release is divided into multiple plume segments. The simplest Gaussian plume methods do not allow any variations in wind conditions. These methods treat the entire plume as following along a single direction. The MACCS implementation of the Gaussian plume model is more general. One of the generalizations is that plume segments are allowed to travel in different directions, depending on the directions indicated in the weather data that are being used. For example, suppose the wind blows toward the north in the first hour and to the east in the second hour. When two plume segments are modeled, each with release duration of one hour, the first plume segment travels north. The direction of the second plume segment depends on whether wind shift is included in the calculation or not. When it is, the second plume segment travels in the direction that the weather data indicate, to the east. When it is not, both plume segments must travel in the same direction, to the north.

Rotation is a numerical convenience for squeezing more information out of a set of results without significantly increasing the amount of computer time required. Rotation uses wind-rose probabilities to expand a result for a single weather trial into a set of NUMCOR results, where NUMCOR is the number of compass directions treated in the calculation. For example, suppose MACCS performs a weather trial for which the initial wind direction is to the north. When rotation is not used, this is the only result that is computed. When rotation is used, NUMCOR results are constructed. These results are based on the probabilities that the wind might have blown in each of the compass directions, assuming that other weather conditions, e.g., stability class and wind speed, are the same. As a simple example, suppose the probability of the wind blowing in each compass direction is 1/N. For this case, MACCS constructs the consequences assuming that the initial wind direction were toward each of the compass sectors and assigns each result a probability of 1/N times the probability that the original weather trials would have had.

The assumption that the conditional probability of a weather trial occurring in any compass direction is the same as the wind rose probability for that direction is perfectly reasonable when only a single plume segment is modeled. The larger the number of plume segments modeled in a calculation, the more dubious this assumption becomes. That is because the inherent assumption is that the entire pattern of wind shifts that define a weather trial can occur in any direction around the compass, and that the likelihood is only determined by the wind-rose probability of the initial wind direction for that weather trial. Thus, for extended releases modeled

with a number of plume segments, modeling plume transport without rotation is the preferred approach.

There are three options allowed by MACCS, which are defined as follows:

- **No Wind Shift with Rotation.** In this case, all plume segments follow the same direction as each other. However, for each weather trial, results are constructed as though the wind had blown in each compass direction. The relative probability of the wind blowing in each direction is taken from wind rose data.

- **Wind Shift with Rotation.** In this case, all plume segments follow the direction indicated by the weather data. Generally, each plume segment can travel in a different direction than the other plume segments, depending on the weather data. Wind rose probabilities are used to construct N different results where the wind shift pattern is preserved for each of these results. For example, suppose that in the initial calculation, plume segment 1 travels toward compass sector 1 (north) and plume segment 2 travels toward compass sector 2. In the first rotation, plume segment 1 travels toward compass sector 2 and plume segment 2 travels toward compass sector 3. This pattern continues for each of the rotations, until all compass sectors are considered.

- **Wind Shift without Rotation.** In this case, wind shift is performed but not wind rotation. This is the only option that is allowed when the network evacuation model is selected. This is because the computational savings that can be achieved when evacuation patterns are the same in any direction around the compass disappear when they are not the same in any direction.

MACCS supports six choices for selection of one or more weather trials. Three of these are single weather-trial options; the remaining three are support random sampling from a set of annual data. These weather sampling options are described in this section. Specifically, the interaction between wind rose data and sampling option is described.

- **Constant Weather.** Conditions are specified on the *Constant or Boundary Conditions* form. However, the user is not allowed to specify wind direction. When wind rotation is not included, wind direction is always to the north. When wind rotation is included, wind directions are assumed to be distributed uniformly around the compass.

- **User Supplies 120 Weather Points.** Weather conditions are specified on the User Supplied Weather form. This form allows the user to specify hourly wind directions, which define the wind directions when wind rotation is not used. When wind rotation is used, the wind rose is uniform around the compass.

- **Fixed Start Time.** This option works exactly the same as the User Supplies 120 Weather Points option except that the weather data are extracted from the weather file, beginning with the hour and time period specified under the Fixed Start Time Data form.

- **Uniform Bin Sampling.** Weather data, including wind direction, are taken from the weather file. When wind rotation is performed, the default is that a separate wind rose is constructed within MACCS for each weather bin. Therefore, the wind rose varies from weather trial to weather trial, depending on which weather bin the trial is taken from. When OVRRID = True, the data on the *Wind Rose Probabilities* form are used for all weather trials.

- **Nonuniform Bin Sampling.** This option works exactly the same as Uniform Bin Sampling, except that the user defines the number of weather samples to be taken from each weather bin.

- **Stratified Random Sampling.** No weather binning is performed for this option. Instead, a user-specified number of weather trials are selected randomly from each weather day. Because weather bins are not created, MACCS does not assemble wind rose data. Thus, each weather trial is handled similarly as in the *User Supplies 120 Weather Points* option. When wind rotation is not used, wind directions are taken directly from the weather file. When wind rotation is used, the wind rose is uniform around the compass.

Relocation Model Description

Relocation is a post-accident protective measure designed to limit radiation exposure and is implemented in MACCS following plume arrival. The model provides four alternatives for relocation, including hot-spot relocation, normal relocation, relocation during the intermediate phase, and relocation during the long-term phase. During the emergency phase, relocation occurs at a user-specified time after plume arrival, conditional on a projected dose from cloudshine, groundshine, cloud inhalation, and resuspension inhalation that exceeds a user-specified limit.

MACCS includes the ability to simulate relocation of residents from elevated dose rate areas through the hotspot and normal relocation parameters. The user can specify a hotspot relocation criterion and a normal relocation criterion. For both relocation criteria, the user specifies a dose limit, the critical organ for the dose limit, and a relocation time. MACCS requires that the dose for hotspot relocation be greater than or equal to the dose for normal relocation and the delay time for hotspot relocation be less than or equal to the delay time for normal relocation. The concept is that the segment of the public that would receive larger doses would be relocated more urgently than those who would receive smaller doses.

For evaluating the need for relocation during the emergency phase, the dose commitment received from the sum of the following dose pathways is considered: cloudshine, inhalation of the cloud during plume passage, groundshine, and resuspension inhalation. These doses are assessed beginning with the arrival of the first plume segment for the dose-projection period. They are based on lifetime doses.

The relocating population is assumed to be in normal activity before relocation. The shielding factors for normal activity are used. Once they are relocated, no further dose is calculated for them in the EARLY module. Additional doses could be calculated in the CHRONC module. The criterion for determining whether or not they return to their original spatial element depends on dose projections for the intermediate and long-term phases evaluated in CHRONC. The dose projection criterion for the long-term phase is commonly referred to as the habitability criterion.

Emergency Phase Resuspension

The resuspension model in MACCS is as follows:

$$C = G \cdot RESCON \cdot 2^{-t/RESHAF} \qquad \text{(Equation 26)}$$

Where

C = Air concentration at ground level from resuspension (Bq/m^3)

G = Concentration on ground (Bq/m^2)

t = Time measured from the time of deposition (s)

RESCON is the initial value of the resuspension coefficient (m^{-1}) and RESHAF is the resuspension coefficient half-life (s).

Keyhole Model

The standard MACCS evacuation model assumes that the evacuation region is a circular area. With keyhole evacuation, the evacuation area is a keyhole shaped area with a circular area surrounding the nuclear site and an odd number of sectors projecting out to a larger radius, as illustrated in Figure 3-19. The region is defined by the radius of the inner, circular area, the number of sectors to evacuate beyond the circular area, and the outer radius of the evacuation area.

Initially, the keyhole is centered on the wind direction, as shown by the yellow and purple portion of the keyhole in Figure 3-19. The keyhole is expanded as the wind direction changes in subsequent hours, as illustrated by the green/orange portion of the keyhole.

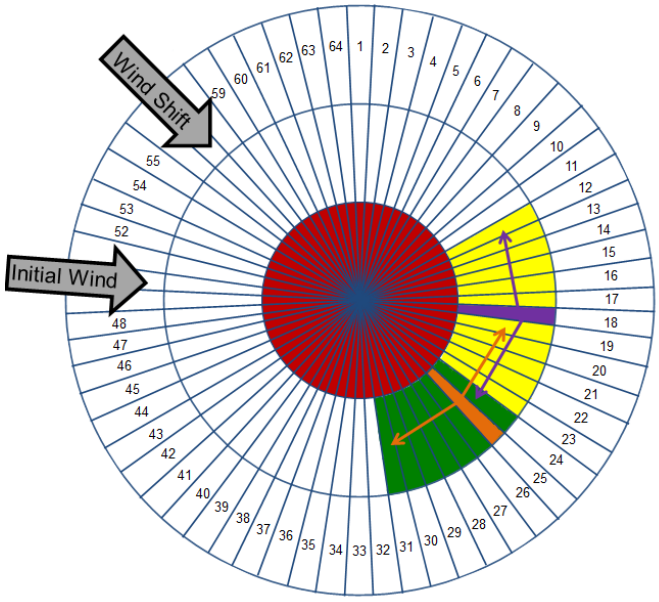


Figure 3-19 Illustration of a keyhole evacuation model

An additional model concept is to allow the keyhole to be expanded in advance of an actual wind shift to account for weather forecasting. This parameter in WinMACCS is defined as KEYFORCST. The user must specify the number of hours of weather forecasting to use in the model. When the number of hours is four, for example, the model considers the wind directions that will occur over the next four hours and expands the size of the keyhole accordingly.

When the check box titled *Activate Keyhole Evacuation Model* is checked, the forecast interval is required as shown in Figure 3-20. The same forecast interval is used for all evacuation cohorts that use keyhole evacuation. This parameter allows the keyhole to be expanded in advance of actual wind shifts to account for foreknowledge of weather. The model assumes that weather forecasting is perfectly known for the number of hours specified by this parameter. When no advance knowledge of weather is to be assumed in the model, the user enters 0.

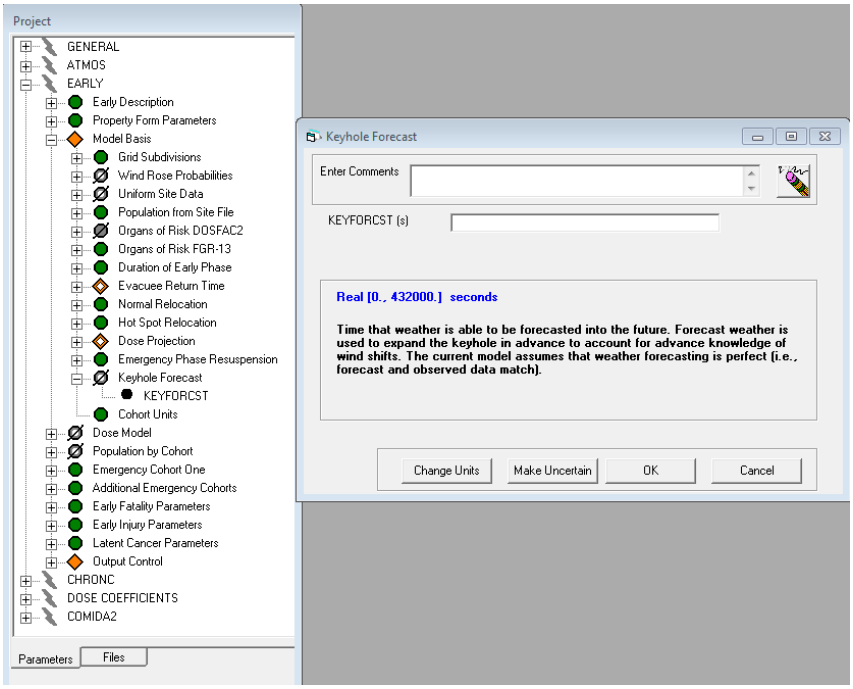


Figure 3-20 Form designating the number of hours of weather forecast data that are used to expand the keyhole

3.3.3.2 Basic Forms and Parameters

***Early Description* Form**

The *Early Description* form has one variable that contains a short description of the early model. This description is printed in the output file. This form is required when *Early Consequences* are selected on the *Properties/Scope* tab.

Variable Name	Definable	Type	Dimensions	Allowed Values
EANAM1	Yes	Character	None	1 to 80 characters

***Property Form Parameters* Form**

The *Property Form Parameters* form shows how selections under the *Properties* form define some important variables that are required in the EARLY input to MACCS. The variables on this form cannot be changed on this form; they are read only. Details about these parameters are provided in the following paragraphs.

POPFLG determines the source of population data. The value is set to FILE when the population is provided by a file either generated by the preprocessor, SecPop, or in a format consistent with SecPop files. POPFLG is set to UNIFORM when the population is to be treated as uniformly distributed.

WTNAM determines the method used for combining results from different cohorts when generating overall sums. The most commonly used values are PEOPLE or TIME. In these cases, the weighting factor for each cohort is determined by the value of variable WTFRAC. Results from CHRONC are included as a single, separate cohort, and are simply added to the weighted results from EARLY. When WTNAM is set to SUMPOP, the population for each cohort is present in the site file under headings POPULATION1, POPULATION2, etc. Such a site data file can be created by hand or using a relatively new feature of WinMACCS described below.

KIMODL determines whether consequence calculations consider potassium iodide (KI) ingestion. The value is set to KI when the effect of KI is to be included or to NOKI when they are not to be included in a calculation. When included, variables regarding the percentage of the population ingesting KI and its efficacy at reducing thyroid dose must be defined, as explained below.

DOSMOD determines which model is used for calculating dose. The choices are LNT (linear no threshold), AT (annual threshold), or PL (piecewise linear). The simplest and traditional choice is the LNT model, for which only one dose conversion factor (DCF) file is required. That file contains internal dose coefficients for a 50-year commitment period. Other choices require additional user input for threshold values and a set of 51 dose coefficient files. The additional 50 files break down the dose-commitment period of 50 years into annual periods.

EVATYP determines the evacuation model. The choices are NONE, RADIAL, or NETWORK. When RADIAL or NETWORK is chosen, further user input to define evacuation behavior is required. RADIAL models evacuation as being radially outward within each sector. NETWORK allows evacuees to travel from one grid element to any of the four adjacent grid elements.

OVRRID is a flag set to either True or False. This flag allows the user to override the default values used for wind rose probabilities. When either uniform or nonuniform weather bin sampling is selected, by default the wind rose probabilities are calculated from the weather file; when OVRRID is set to True, the default wind rose probabilities are replaced by user-specified values. When weather binning is not selected, equal probabilities (1/NUMCOR) are assumed for each compass direction regardless of the value of OVRRID. Setting OVRRID to True is sometimes done when a meteorological file is not available for the actual site being studied but wind rose data are available for the site. This option allows local wind rose characteristics to replace those contained in a meteorological data file. It assumes that other weather characteristics of the site are similar to those in the file. Wind rose data are only used when rotation is chosen (IPLUME = 1 or 2).

IPLUME defines two characteristics regarding plume transport. When set to 1, no wind shift is modeled; when set to 2 or 3, wind shift is modeled. No wind shift means that all plumes travel in the same direction; wind shift means that each plume segment can travel in its own direction. The second characteristic is rotation. When IPLUME is set to 1 or 2, rotation is used; when IPLUME is set to 3, no rotation is used in the model. These two concepts, wind shift and rotation, are discussed in detail below.

KEYAVAIL determines whether the keyhole evacuation model is an available choice for the cohort evacuation. When KEYAVAIL is equal to KEY_NOT_AVAIL the choices for the cohort evacuation are circular or none. When KEYAVAIL is equal to KEY_AVAIL the choices for the cohort evacuation are circular, none or keyhole.

Variable Name	Definable	Type	Dimensions	Allowed Values	Defined on Form
POPFLG	Read Only	Character	None	FILE, UNIFORM	*Site Data* tab on *Properties*
WTNAME	Read Only	Character	None	PEOPLE, TIME, SUMPOP	*Site Data* tab on *Properties*
KIMODL	Read Only	Character	None	KI, NOKI	*Dose* tab on *Properties*

Variable Name	Definable	Type	Dimensions	Allowed Values	Defined on Form
DOSMOD	Read Only	Character	None	LNT, AT, PL	*Dose* tab on *Properties*
EVATYP	Read Only	Character	None	RADIAL, NETWORK, NONE	*Evac/Rotation* tab on *Properties*
OVRRID	Read Only	Logical	None	True, False	*Wind Rose* tab on *Properties*
IPLUME	Read Only	Integer	None	1 to 3	*Evac/Rotation* tab on *Properties*
KEYAVAIL	Read Only	Character	None	KEY_AVAIL, KEY_NOT_AVAIL	*Evac/Rotation* tab on *Properties*

3.3.3.3 Basic Model Forms

Grid Subdivisions Form
The *Grid Subdivisions* form is required. NUMFIN is the number of fine-grid subdivisions used by the model. The fine grid is used to improve the resolution of doses in EARLY. This is especially important for non-linear dose responses such as early health effects. Each of the grid elements is subdivided into NUMFIN fine-grid elements in the azimuthal direction. NUMFIN is only used in the calculations performed by EARLY. Values in CHRONC are averaged over the fine grid.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMFIN	Yes	Character	None	3, 5, 7

Wind Rose Probabilities Form
The *Wind Rose Probabilities* form is required when the user selects *User Supplied* on the *Wind Rose* tab.

WINROS contains the probabilities of the wind blowing from the site toward each of the compass sectors. Values are listed clockwise on the wind rose starting from the value for north. When these values do not approximately sum to unity, the MACCS validation step fails when a simulation is run.

Variable Name	Definable	Type	Dimensions	Allowed Values
WINROS	Yes	Real	NUMCOR	0.0 to1.0

***Uniform Site Data* Form**
The *Uniform Site Data* form is required when the user selects *Uniform* on the *Site Data* tab of the *Properties* form. This information is required when a site data file is not used.

IBEGIN specifies the spatial interval beyond which the population begins. Inside of this region there are no people, usually representing the exclusion area.

POPDEN specifies the uniform population density of the region.

FRACLD specified the average fraction of the region that is land.

Variable Name	Definable	Type	Dimensions	Allowed Values
IBEGIN	Yes	Integer	None	1 to NUMRAD
POPDEN	Yes	Real	None	0 to 1,000,000 people/km^2
FRACLD	Yes	Real	None	1×10^{-6} to 1.0

***Population from Site File* Form**
The *Population from Site File* form is active when the user selects "*Import from File*" on the *Site Data* tab of the *Properties* Window. The *Population from Site File* form contains a table with column labels of sector number and rows labeled with values of SPAEND (radial distance). The table contains the total population in each grid element (not divided into cohorts).

***Organs of Risk DOSFAC2* Form**
The *Organs of Risk DOSFAC2* form is required when the user selects *File Created by DOSFAC2* on the *Dose* tab.

ORGNAM is the organ name with the appropriate prefix of A- or L-, where the prefix A- (e.g., A-LUNGS) indicates an acute dose and the prefix L- (e.g., L-LUNGS) indicates a lifetime (50-year commitment period) dose.

ORGFLG specifies whether the associated organ is to be included in the calculations. When the organ is not included in the calculations, health effects related to that organ cannot be calculated.

Variable Name	Definable	Type	Dimensions	Allowed Values
ORGNAM	No	Character	16	N/A
ORGFLG	Yes	Logical	16	True, False

***Organs of Risk FGR-13* Form**
The *Organs of Risk FGR-13* form is required when the user selects *File Created from FGR13* on the *Dose* tab.

ORGNAM and ORGFLG have the same meaning as in the *Organs of Risk DOSFAC2* form.

Variable Name	Definable	Type	Dimensions	Allowed Values
ORGNAM	No	Character	15	NA
ORGFLG	Yes	Logical	15	True, False

***Duration of Early Phase* Form**
The *Duration of Early Phase* form is required.

ENDEMP defines the duration of the emergency phase. Doses at each spatial interval end after ENDEMP seconds from the arrival of the first plume segment at that location. Normally, ENDEMP is chosen to be large enough so that all plume segments exit the problem domain. The allowed range corresponds to 1 to 40 days.

Variable Name	Definable	Type	Dimensions	Allowed Values
ENDEMP	Yes	Real	None	86,400 to 3,456,000 s

***Evacuee Return Time* Form**

The *Evacuee Return Time* is an optional form. When this is not defined, MACCS assumes the value of TIMRTN is the same as the value specified for ENDEMP.

TIMRTN is defines the elapsed time between the time of evacuation and return back to the home for an evacuee whose location on the grid is not affected by any contamination. In previous versions of MACCS, this value was assumed to be the duration of the emergency phase. TIMRTN allows the user to choose this time.

Variable Name	Definable	Type	Dimensions	Allowed Values
TIMRTN	Yes	Real	None	0 to ENDEMP

***Normal Relocation* Form**
The *Normal Relocation* is required.

TIMNRM defines the normal relocation action time after plume arrival. Normal relocation applies to individuals residing outside of the evacuation zone and nonevacuees within the evacuation zone (everyone who does not evacuate). Normal evacuation uses a dose projection criterion to determine the need to relocate. TIMNRM must be greater than or equal to TIMHOT and less than or equal to ENDEMP. The value of TIMNRM can account for the fact that the initial priority is on evacuating the public within the EPZ, for time needed to evaluate releases and project doses to the public, and for time needed for the public to receive notification and begin to relocate. Relocation is modeled as being instantaneous, so TIMNRM may also account for some portion of a realistic relocation time.

The normal relocation dose (DOSNRM), along with the critical organ and dose projection period, determines where relocation is required. When total projected dose commitment exceeds DOSNRM, people in an area are relocated at the normal relocation time TIMNRM. DOSNRM cannot exceed DOSHOT.

The dose used to evaluate normal relocation is the dose commitment projected for an individual who remains in place for the dose projection period (defined below) while engaging in normal activity. The dose pathways used to calculate the projected dose commitment are cloudshine, groundshine, direct inhalation, and resuspension inhalation. Any individuals relocated due to normal relocation are removed from the problem for the duration of the emergency phase and receive no additional dose during this phase.

Variable Name	Definable	Type	Dimensions	Allowed Values
TIMNRM	Yes	Real	None	0 to 3,456,000 s (40 d)
DOSNRM	Yes	Real	None	0 to 1×10^{10} Sv

***Hot Spot Relocation* Form**
The *Hot Spot Relocation* form is required when *EARLY* is selected on the *Scope* tab.

TIMHOT defines the hot-spot relocation action time after plume arrival. Hot-spot relocation occurs for individuals residing outside the evacuation zone and those within the evacuation zone who do not evacuate. Hot-spot relocation works similarly to normal relocation but is used to prioritize the population at higher risk. TIMHOT must be less than or equal to TIMNRM and less than or equal to ENDEMP. The same time elements described for defining TIMNRM also apply to TIMHOT.

The hotspot relocation dose (DOSHOT) is intended to trigger relocation beyond the evacuation area, although it also applies to non-evacuees who reside within the evacuation area. Areas identified for hotspot relocation would usually take priority once evacuation is completed or well along and would occur before normal relocation. When individuals are projected to exceed DOSHOT, those people are relocated at the hot-spot relocation time (TIMHOT).

The dose used to evaluate hotspot relocation is the dose commitment projected for an individual who remains in place for the dose projection period while engaging in normal activity. The dose pathways used to calculate the dose commitment are cloudshine, groundshine, direct inhalation, and resuspension inhalation. Any individuals relocated due to hot-spot relocation are removed from the problem for the duration of the emergency phase and receive no additional dose during this phase.

Variable Name	Definable	Type	Dimensions	Allowed Values
TIMHOT	Yes	Real	None	0 to 3,456,000 s (40 d)
DOSHOT	Yes	Real	None	0 to 1×10^{10} Sv

Dose Projection **Form**
The *Dose Projection* form is an optional form. When this is not defined MACCS assumes the value of DPPEMP is the same as the value specified for ENDEMP.

DPPEMP is the dose-projection period for the emergency phase. It defines the dose projection period used for normal and hot-spot relocation. A full definition of the dose projection criteria for normal and hot-spot relocation includes the dose level (DOSNRM or DOSHOT, respectively), the target organ (CRIORG, defined below), the dose projection period (DPPEMP), the commitment period for the dose (standard value of 50 years for internal doses), and the set of dose pathways that are included, which are cloudshine, groundshine, direct inhalation from the plume, and inhalation of resuspended aerosols. The dose projection period begins with plume arrival and ends after the time interval specified by DPPEMP. Older versions of MACCS used ENDEMP for the dose projection period.

Variable Name	Definable	Type	Dimensions	Allowed Values
DPPEMP	Yes	Real	None	0 to 1×10^{10} s

Emergency Phase Resuspension **Form**
The *Emergency Phase Resuspension* form is required.

RESCON is the linear factor for the emergency phase resuspension concentration factor.

RESHAF is the emergency phase resuspension concentration weathering half-life.

Variable Name	Definable	Type	Dimensions	Allowed Values
RESCON	Yes	Real	None	0 to 1 per m
RESHAF	Yes	Real	None	1 to 1×10^{10} s

Keyhole Forecast **Form**
The *Keyhole Forecast* form is required when *Activate Keyhole Evacuation Model* is checked on the *Evac/Rotation* tab.

KEYFORCST defines the advance time for which wind shifts can be reliably forecast by weather forecasters, e.g., the National Weather Service. The model expands the number of sectors included in a keyhole evacuation, as illustrated in Figure 3-19, KEYFORCST hours before a wind shift occurs. This model is currently implemented as if the forecasting were infallible, i.e., it uses wind shifts from the recorded meteorological data and these are correct 100% of the time. Real weather forecasting is less than 100% reliable, but that is not accounted for in the current model. To compensate for the assumption on reliability of forecasting, this value should normally be chosen to be a relatively small number of hours.

Variable Name	Definable	Type	Dimensions	Allowed Values
KEYFORCST	Yes	Real	None	0 to 432,000 s (5 d)

***Cohort Units* Form**

The *Cohort Units* form is required, but it contains a set of default values and the user is not required to reset these values.

The default units in MACCS are SI units. This form allows the user to change the units for a set of cohort variables for all of the cohorts. Units can be changed on this form for delays, phase durations, breathing rate, and evacuation speeds. To avoid confusion when entering input values, these units are required to be the same for all cohorts.

Variable Name	Allowed Units for variable
DLTSHL	(s), (min), (hr), (day), (yr)
DURBEG	(s), (min), (hr), (day), (yr)
DLTEVA	(s), (min), (hr), (day), (yr)
BRRATE	(m^3/s), (l/s), (l/day), (m^3/day), (m^3/yr)
DURMID	(s), (min), (hr), (day), (yr)
ESPEED	(m/s), (cm/s), (km/hr), (mi/hr), (in/hr), (mm/hr)

3.3.4 Dose-Response Models

3.3.4.1 Dose-Response Model Description

Three optional dose-response models are available to calculate latent-cancer injuries and fatalities. The three types of models are illustrated in Figure 3-21.

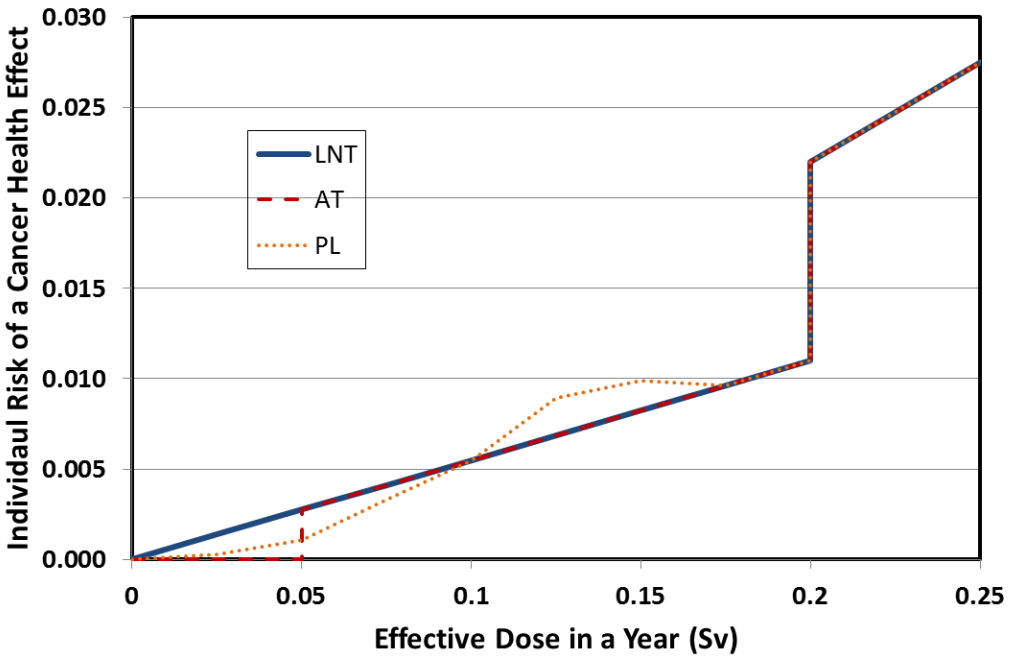


Figure 3-21 Three types of dose-response models for latent cancer health effects supported by MACCS

The first uses the standard, linear, no-threshold, hypothesis (LNT). This was the only model available in earlier versions of MACCS. In the linear, no-threshold model, the relationship between dose and health effects is proportional, even for infinitesimal doses. Even the LNT model is not a simple linear function as one might expect. The LNT dose-response function is discontinuous and has a change in slope at a dose equal to a threshold dose, as shown in Figure 3-21. In the MACCS model, for the purpose of evaluating latent health effects, doses are divided by a dose and dose-rate effectiveness factor (DDREFA) for dose levels below the threshold but not for doses above the threshold.

Figure 3-21 illustrates the simplified situation where all doses are delivered to an individual during the first year (internal doses from inhalation and ingestion have diminished to zero by the end of the first year). That means that equivalent organ doses are the same as effective dose. This assumption allows all three dose-response models to be compared on the same basis. Furthermore, the figure shows a typical dose response when radiation is assumed to be uniformly distributed over the body, although this assumption is not essential to the illustration. The figure shows typical values of 0.2 Sv for the threshold and a value of 2.0 for DDREFA. The solid curve in Figure 3-21 shows the individual risk of a cancer fatality using typical values for cancer induction and using the LNT dose-response model.

Effective dose is the term used by ICRP when the weighted sum of equivalent organ doses is calculated using ICRP-60 tissue weighting factors. An equivalent organ dose accounts for biological damage using a radiation weighting factor, which is generally unity for beta and gamma radiation and 20 for alpha radiation. Effective dose is the same in concept as the older term of total effective dose equivalent (TEDE). Technically, TEDE is based on older tissue weighting factors from ICRP-26. (The latest tissue weighting factors from ICRP are in ICRP-103, but these are not currently used in the MACCS dose coefficient files.)

The second option for dose-response model is called the annual threshold (AT) model. In this model, the user can specify a set of thresholds, one for each year of the calculation. The thresholds are specified in terms of effective dose. When the predicted effective dose falls below an annual threshold, there are no contributions to any latent cancer health effects; when the predicted effective dose exceeds the annual threshold, contributions to health consequences are calculated in the same way as with the LNT model. This dose response is illustrated in Figure 3-21 for the case that the annual threshold is 0.05 Sv (5 rem).

The third option for dose-response model is called the piecewise-linear (PL) model. In this model, the user can construct a series of line segments that define the functional dependence of health effects on dose. The line segments are required to form a continuous curve. The user defines a multiplicative factor that is applied to the LNT model as a function of annual dose. This model can be used to approximate a dose threshold, to create a sublinear dose-response model, or to create a supra-linear dose-response model. It cannot be used to construct a hormesis model because MACCS does not allow beneficial health effects from radiation exposure. Figure 3-21 illustrates a piecewise linear model that is sublinear below 0.1 Sv (10 rem) and supra-linear between 0.1 Sv and 0.175 Sv (17.5 rem). Above this 0.175 Sv, the piecewise linear model is identical to the LNT model.

For the general case where exposures occur over a number of years and internal dose pathways potentially deliver a dose over a 50-yr dose commitment period, the model is somewhat more complicated. For the two non-LNT models discussed above, annual doses are required for each year during the exposure and commitment periods. The models depend on the actual dose delivered to an individual during a one-year period, referred to as an annual dose. Annual doses account for external radiation received during the year and the first year of the commitment period for all internal radiation received during the year. They also account for the current year of the dose commitment for internal radiation received in all previous years. Once the annual doses are calculated for an individual, the latent cancer risk is the sum of the risks over the relevant set of years. In other words, the risk illustrated in Figure 3-21, which is for a single year, is summed over all the years for which doses are received by that individual.

Even when radiation is not distributed uniformly over the body, the effective dose is still used to determine whether an annual threshold is exceeded. When the threshold is exceeded, equivalent organ doses are used to estimate the contributions to cancer risks for each type of cancer. Total cancer risks are summations of the cancer types considered in the consequence analysis. In Figure 3-21, nonuniform radiation would potentially increase or decrease the cancer risks proportionally, depending on the radiosensitivity of the organs receiving larger and smaller doses.

The annual threshold model allows for an optional lifetime threshold, which is also based on effective dose. When the lifetime threshold is exceeded, the health effects are calculated to be identical to those for the LNT model. In that case, dose contributions to health effects are counted for all years, no matter how small the dose in a year.

3.3.4.2 Dose Model Forms and Parameters

***Annual Threshold* Form**
Annual Threshold is required when the user selects *Late Consequences* on the *Scope* tab and *Annual Threshold* on the *Dose* tab.

DTHNUM is number of annual dose threshold values. This value is determined from the number of entries for DTHANN.

DTHANN is a vector containing the annual dose threshold for latent cancer models. When calculated annual effective dose per person is below the specified threshold, all health consequences are zero for that year. The value specified for the last year is used for all subsequent years. When a single value is listed, it applies to every year in the exposure period. The first entry corresponds to year one, the second to year two, etc.

Variable Name	Definable	Type	Dimensions	Allowed Values
DTHNUM	Linked	Integer	None	1 to 398
DTHANN	Yes	Real	DTHNUM	0 to 1×10^{30} Sv/yr

***Lifetime Threshold* Form**
Lifetime Threshold is optional when the user selects *Annual Threshold* on the *Dose* tab.

DTHLIF is the lifetime dose restriction. When this dose is exceeded, all doses are used to estimate health effects the same as with the LNT model, regardless of annual threshold values.

Variable Name	Definable	Type	Dimensions	Allowed Values
DTHLIF	Yes	Real	DTHNUM	0 to 1×10^{30} Sv

***Piecewise Linear* Form**
The *Piecewise Linear* form is required when the user selects *Late Consequences* on the *Scope* tab and *Piecewise Linear* on the *Dose* tab.

PWLNUM is the number of piecewise dose values entered by user. Its value is determined by the number of values of PWLDOS and PWLFAC entered by the user.

PWLDOS is the effective dose associated with multiplier, PWLFAC. Linear interpolation is used to calculate a multiplicative factor for an annual effective dose between those supplied by the user. Health consequences are calculated for each annual effective dose using the multiplicative factor calculated from this model as a multiplier on the LNT model. The health effects are summed for all of the annual dose contributions, accounting for the number of exposure years and the commitment period for each exposure year, as described above. PWLDOS must be specified in ascending order.

PWLFAC is a multiplicative factor associated with PWLDOS. The last value in vector PWLFAC must be one. Above the last dose specified on this form, the LNT model is used.

Variable Name	Definable	Type	Dimensions	Allowed Values
PWLNUM	Linked	Integer	None	2 to 99
PWLDOS	Yes	Real	PWLNUM	1×10^{-10} to 1×10^{30} Sieverts/year
PWLFAC	Yes	Real	PWLNUM	0 to 1×10^{30}

3.3.5 Population by Cohort

The characteristics of each evacuation cohort are assigned in the Emergency Cohorts forms. The forms in this category allow assigning portions of the population to different evacuation cohorts for a given spatial grid element. First, populations are defined on the *Populations* forms, where a population consists of a fraction of each of the cohorts. Next, populations are assigned to spatial grid elements. This has the result of defining the population portion of each

evacuation cohort that belongs to that grid element. The total population per grid element is defined in the site data file. See Section 4.4.7.2 for more guidance.

***Populations* Form**
The *Populations* form is required when the user assigns SUMPOP to the *Results Weighting Factor* and selects *Create from Existing Site File* on the *Site Data* tab.

N_POP_DIST is the number of population distributions entered by the user.

POP_DIST defines the population distributions to be assigned to the evacuation grid. One distribution is entered per row. Each row should sum to one. Each column is associated with an evacuation cohort.

Variable Name	Definable	Type	Dimensions	Allowed Values
N_POP_DIST	Linked	Integer	None	1 to 90
POP_DIST	Yes	Real	N_POP_DIST by NUM_EVAC_SCEN	0 to 1.0

***Population Labels* Form**
The *Population Labels* form is required when the user assigns SUMPOP to the *Results Weighting Factor* and selects *Create from Existing Site File* on the *Site Data* tab.

DIST_SYMB is a single character that will be used to assigned a population to a grid element in the spatial grid form.

DIST_LABEL is a descriptive label associated with the population.

Variable Name	Definable	Type	Dimensions	Allowed Values
DIST_SYMB	Yes	Character	N_POP_DIST	1 character
DIST_LABEL	Yes	Real	N_POP_DIST	1 to 20 characters

***Populations Assigned* Form**
The *Populations Assigned* form is required when the user assigns SUMPOP to the *Results Weighting Factor* and selects *Create from Existing Site File* on the *Site Data* tab.

The spatial grid form allows the assignment of populations, identified by this symbol DIST_SYMB defined on the *Population Labels* form, to grid elements. After this form is saved, each *Population* form for every defined cohort will be updated defining the population associated with each cohort by spatial grid element. Before the MACCS simulation is run, a new site file is constructed based on each of the *Population* forms. This site file is created to be compatible with the MACCS SUMPOP option and specifies a separate section defining the population for each cohort.

POP_DIST is defined on the *Populations* form.

DIST_SYMB associates the population distribution with a symbol.

DIST_LABEL is a descriptive label associated with the population

COHORT_POP3D is an array defining the population assigned to each of the spatial grid elements.

COHORT_POP is the population array associated with cohort one. There are additional arrays associated with each of the cohorts.

Variable Name	Definable	Type	Dimensions	Allowed Values	Defined on Form
POP_DIST	No	Real	N_POP_DIST by NUM_EVAC_SCEN	0 to 1.0	Populations
DIST_SYMB	No	Character	N_POP_DIST	1 character	Population Labels
DIST_LABEL	No	Character	N_POP_DIST	1 to 20 characters	Population Labels
COHORT_POP3D	Yes	Character	NUMRAD by NUMCOR	1 character	Populations Assigned
COHORT_POP	Yes	Real	NUMRAD by NUMCOR	0 to 1×10^{9}	Populations Assigned

3.3.6 Emergency Response Cohorts

WinMACCS supports up to twenty emergency cohorts. The number of cohorts is defined on the *Evac/Rotation* tab. A number of cohort forms are defined in the *Emergency Cohort One* category. When there is more than one cohort, additional, identical, forms are defined in the *Additional Emergency Cohorts* category. The form names and parameters are the same in the interface. For example, a critical organ can be specified for each cohort on the *Critical Organ* form. There is an entry for this form for each of the cohorts. Each form must be filled out for the cohorts defined. However, data entry can be simplified by selecting *Edit/Auto Propagate Cohort Values* on the main menu as described in Section 4.2.2.

3.3.6.1 Emergency Cohort Model Description

For the purposes of accounting for dose and health effects, the dose received by an evacuee is attributed to the location in which the evacuee originates. Evacuees travel from the center of one grid element to the center of another in discreet steps. The transit time for an evacuee to move from one grid element to another is determined by several input values. Dose calculations are performed as though the evacuee is located at the center of one grid element for a period of time then suddenly moves to the center of the next grid element along the path of evacuation. The top-hat approximation for concentration is used to calculate doses for evacuees, as shown in Figure 3-22.

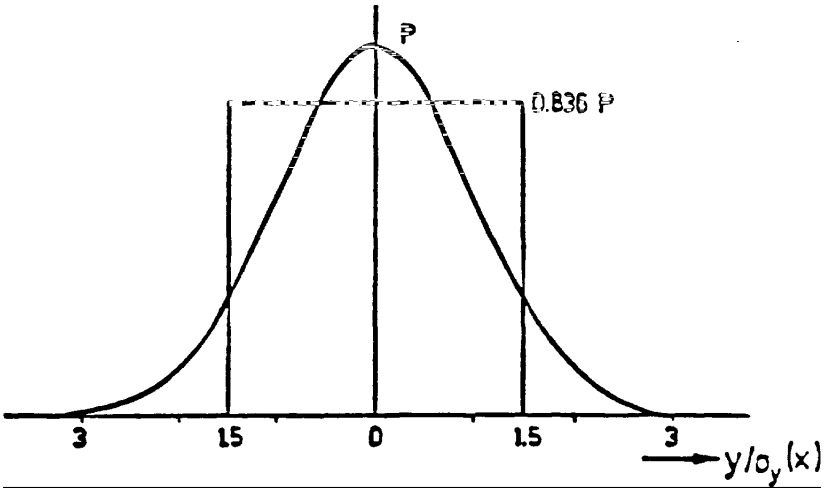


Figure 3-22 Top-Hat approximation for plume concentration used for evacuees

The starting point for all evacuees is the center of the element in which they begin. The transit time to arrive at the center of the next grid element depends on the choice of the parameter, TRAVELPOINT. When this parameter is equal to BOUNDARY, the evacuee is considered to be in the next grid element upon crossing the grid boundary; when equal to CENTERPOINT, the evacuee is considered to be in the next grid element upon arrival at the center of the destination grid element. The following formulae result for the case when TRAVELPOINT = BOUNDARY:

$T_{t,n} = (r_n - r_{n-1})/(2 \cdot V)$ when the evacuee moves radially and resides in the current grid element (Equation 27)

$T_{t,n} = (r_n - r_{n-1})/V$ when the evacuee moves radially and does not reside in the current grid element (Equation 28)

$T_{t,n} = \pi \cdot (r_n + r_{n-1})/(2 \cdot N_\theta \cdot V)$ when the evacuee moves around the compass and resides in the current grid element (Equation 29)

$T_{t,n} = \pi \cdot (r_n + r_{n-1})/(N_\theta \cdot V)$ when the evacuee moves around the compass and does not reside in the current grid element (Equation 30)

The following formulae result for the case when TRAVELPOINT = CENTERPOINT:

$T_{t,n} = (r_{n+1} - r_{n-1})/(2 \cdot V)$ when the evacuee moves radially outward (Equation 31)

$T_{t,n} = (r_n - r_{n-2})/(2 \cdot V)$ when the evacuee moves radially inward (Equation 32)

$T_{t,n} = \pi \cdot (r_n + r_{n-1})/(N_\theta \cdot V)$ when the evacuee moves around the compass (Equation 33)

Where

$T_{t,n}$ = transit time through the current grid element. For dose calculations, this value is used as the residence time at the center point of the element. The evacuee jumps instantaneously from the center point of one element to the next.

r_n = the outer radius of grid element n

V = the speed at which an evacuee moves through an element. This value is given by the equation $V = ESPEED \cdot ESPGRD$ when no precipitation is occurring and by $V = ESPEED \cdot ESPMUL \cdot ESPGRD$ when precipitation is occurring. ESPGRD corresponds to ESPGRD_RAD or ESPGRD_NET, depending on whether radial or network evacuation is selected, respectively. The values of ESPEED and ESPMUL depend on the phase of the evacuation period, as described below. The value of ESPGRD depends on the grid element through which the evacuee travels.

N_θ = number of compass sectors in the grid, i.e., 16, 32, 48, or 64.

The evacuee's location as a function of time is compared with the location of the head and tail of the plume. For periods of time when the evacuee is located within the plume, the doses from direct exposure pathways are accumulated, i.e., cloudshine and direct inhalation of the plume. Doses from groundshine and inhalation of resuspended aerosols are always accounted for when the evacuee is at a location where the ground is contaminated.

3.3.6.2 Emergency Cohort Forms and Parameters

Basic Parameters
Basic Parameters are required for each *Emergency Scenario* category.

EVAKEY determines the algorithm used in evacuation. CIRCULAR implies all sectors are subject to evacuation. KEYHOOLE limits the number to NSECTR sectors. NONE means that there is no evacuation. The evacuation type is defined under the *Project Properties/Evac Rotation* tab.

EANAM2 is a unique name that identifies the cohort being studied.

WTFRAC is a weight fraction to be applied to results from this emergency response cohort. This number is applied to either the fraction of people or the fraction of time, depending on whether the *Results Weighting Factor* is set to PEOPLE or TIME respectively on the *Site Data* tab. Population weight fractions are applied to results from this emergency response scenario. The value is used when combining results for the overall weighted sum over all evacuation scenarios. The meaning is dependent on the value of the *Results weighting factor* defined as follows:

- PEOPLE – WTFRAC represents the fraction of the population that belongs to this scenario.
- TIME – WTFRAC represents the fraction of the time or probability that this scenario is applicable. With this option, the entire population follows each scenario a fraction of the time.
- SUMPOP – in this case, the value of WTFRAC must be defined but isn't used by MACCS. Weighting information is taken from population distributions read from the site data file.

MACCS Requirement: The values of WTFRAC over all evacuation scenarios must add up to 1.0 within a tolerance of 0.001.

Variable Name	Definable	Type	Dimensions	Allowed Values
EVAKEY	No	Character	None	NONE, CIRCULAR, KEYHOLE
EANAM2	Yes	Character	None	1 to 80 characters
WTFRAC	Yes	Real	None	0.0 to 1.0

Phase Durations and Speeds

This form is required for *Emergency Cohort One* and any subsequent cohorts when the evacuation type is circular or keyhole.

The evacuation period is divided into three phases defined by DURBEG, DURMID, and the remainder of the emergency phase, as defined by ENDEMP-(DURBEG+DURMID). The purpose for the evacuation phases is to allow the option of having the evacuation speed parameters vary over time.

REFPNT defines the reference time point for actions in the evacuation and sheltering zone. The user may choose to have the reference time at ALARM (OALARM) or ARRIVAL which refers to the arrival time of the first plume. When using a keyhole evacuation, ALARM is the only legal choice for this variable.

TRAVELPOINT determines whether evacuees move from a spatial element when they cross the boundary between the two elements (BOUNDARY) or when they reach the center point of the destination element (CENTERPOINT).

DURBEG is the duration of the initial phase of evacuation. This phase starts when the cohort in the shelter and evacuation region begins to evacuate, which is defined by the minimum over all radial distances (i) of DLTSHL(i)+DLTEVA(i) after the time designated by REFPNT. The evacuation speed used during this phase is the initial value of ESPEED. Additionally, each cohort can be designated a DURBEG duration characteristic of that cohort.

DURMID defines the duration of the middle phase of the three phases of evacuation. The evacuation speed used during this phase is the middle value of ESPEED. The evacuation speed used during the final phase, which extends until evacuation is complete or until the end of the emergency phase, is the third value of ESPEED. Additionally, each cohort can be designated a DURMID duration characteristic of that cohort.

The initial evacuation phase begins when the first individual begins to travel out of the region. The durations of the initial and middle phases of the evacuation are defined by input variables DURBEG and DURMID. The late phase of the evacuation extends as long as necessary for all individuals to complete their travel or until the end of the emergency phase.

Vectors ESPEED and ESPMUL contain a set of values that correspond to each of the three evacuation phases.

ESPEED is the travel speed of the evacuees. Three values are required, one for each of the evacuation (travel) phases as follows: initial, middle and late. MACCS requires that all three values be the same when TRAVELPOINT is set to BOUNDARY.

ESPMUL is the multiplicative factor that affects ESPEED. This factor is applied during times of precipitation. Weather prior to release is assumed to be the same as at the beginning of release, which affects cases in which the evacuation begins before release. Precipitation data are from HRRAIN, BNDRAN, or the meteorological file, depending on the weather option. The

value of evacuation speed in an element is calculated with the following formula where ESPGRD is the speed multiplier (supplied in another form):

Evacuation Speed = ESPEED * ESPMUL * ESPGRD when precipitation is occurring
Evacuation Speed = ESPEED * ESPGRD when no precipitation is occurring

ESPEED is defined for each of the three sub-phases (initial, middle, and late) of the emergency phase, but are independent of grid elements. ESPGRD, a speed multiplier defined on the forms *Radial Evacuation Speed* or *Network Evacuation Speed*, is independent of the sub phase, but is defined for each grid element. When ESPGRD is not defined because *Activate Speed Multiplier Model* has not been selected on the *Project Properties/Evac Rotation* tab, a value of one is assumed.

Three values are required, one for each of the evacuation (travel) phases as follows: initial, middle, and late. MACCS requires that all three values must be the same when TRAVELPOINT is equal to BOUNDARY.

Variable Name	Definable	Type	Dimensions	Allowed Values
REFPNT	Yes	Character	None	ALARM, ARRIVAL
TRAVELPOINT	Yes	Character	None	BOUNDARY, CENTERPOINT
DURBEG	Yes	Real	None	0.0 to 86400.0 s
DURMID	Yes	Real	None	0.0 to 86400.0 s
ESPEED	Yes	Real	3	1.0×10^{-6} to 1.0×10^{6} m/s
ESPMUL	Yes	Real	3	0.0 to 1.0

Critical Organ
This form is required for *Emergency Cohort One* and any subsequent cohorts.

CRIORG is the critical organ for relocation decisions during the emergency phase. People remain in the grid element when the projected total committed dose to the critical organ is less than the values described relocation.

Variable Name	Definable	Type	Dimensions	Allowed Values
CRIORG	Yes	Character	None	Must select an Organ name. Choice will be depend on DCF file.

KI Ingestion Linear No Threshold
This form is required for *Emergency Cohort One* and any subsequent cohorts when the *Linear No Threshold* dose model and the *Activate KI Model* are selected on the *Dose* tab.

The KI ingestion model treats the reduction of uptake of radioiodine by the thyroid gland. The ingested KI saturates the thyroid gland so that the effect of inhaling iodine from a plume is diminished. The KI ingestion model allows the user to specify a population fraction that ingests KI and an efficacy factor. The efficacy factor defines the fractional dose reduction to the thyroid gland from inhaled radioiodine.

POPFRAC is the fraction of the population that ingests KI. A fractional portion of the population ingesting KI is allowed when the linear no threshold dose model is used.

EFFACY is a factor used to reduce the dose to the thyroid from inhalation of radioactive iodine. The dose is reduced by a factor of (1 - EFFAC) × POPFRAC.

Variable Name	Definable	Type	Dimensions	Allowed Values
POPFRAC	Yes	Real	None	0 to 1
EFFACY	Yes	Real	None	0 to 1

KI Ingestion Threshold or Piecewise

This form is required for *Emergency Cohort One* and any subsequent cohorts when the *Annual Threshold* or *Piecewise Linear* dose model and the *Activate KI Model* are selected on the *Dose* tab.

POPFRAC is the fraction of the population that ingests KI. When the piecewise linear or annual threshold dose model is used, either all of the population or none of the population ingest KI.

EFFACY is a factor used to reduce the dose to the thyroid from inhalation of radioactive iodine. The dose is reduced by a factor of (1 - EFFAC) when the population ingests KI.

Variable Name	Definable	Type	Dimensions	Allowed Values
POPFRAC	Yes	Real	None	0 or 1
EFFACY	Yes	Real	None	0 to 1

Sheltering and Evacuation Boundary

This form is required for *Emergency Cohort One* and any subsequent cohorts when the evacuation type is circular or keyhole. However, when the *Radial Evacuation Speed*, *Network Evacuation Direction* or the *Network Evacuation Speed* forms are used for any of the additional *Emergency Scenario* categories, this form must be completed first for that emergency scenario category.

LASMOV indicates the outer boundary at which evacuees are assumed to disappear from the early health effects model and receive no further dose. MACCS requires that the value be greater than or equal to NUMEVA.

NUMEVA defines the outer boundary of the sheltering and evacuation region (also known as the emergency planning zone). While LASMOV defines the outer boundary of the region that shelterees reside and evacuees traverse, NUMEVA defines the outer boundary of the sheltering and evacuation region, i.e., the emergency planning zone. MACCS requires that NUMEVA be no larger than LASMOV. For example, in a simple problem, the population within a 10 mile radius of the nuclear power plant is ordered to evacuate. We can assume that there will be a percentage of the population outside the 10 mile radius who will elect to evacuate on their own free-will. This is referred to as a shadow evacuation. Typically, a shadow evacuation is observed within a five miles radius of the declared evacuation zone. Even though we wouldn't assume population beyond 15 miles evacuates in this simple problem, we would want to model the population beyond that distance to quantify any dose they may receive. For this simple example, we could model the population out to 50 miles from the plant. So for this example, NUMEVA would equal 15 miles and LASMOV would be set at 50 miles.

Variable Name	Definable	Type	Dimensions	Allowed Values
LASMOV	Yes	Integer	None	1 to NUMRAD
NUMEVA	Yes	Integer	None	1 to NUMRAD

Shielding and Exposure
This form is required for *Emergency Scenario One* and is also required for each additional *Emergency Scenario* category.

This section defines the shielding factors for exposure to cloudshine, groundshine, inhalation and deposition onto skin for three types of activities: normal activity, evacuation, and sheltering. A breathing rate is also specified for each type of activity. When the evacuation type for scenario one is turned off, normal activity values are used.

The CHRONC module requires input for the inhalation protection factor (CHRONC variable LPROTIN), the breathing rate (CHRONC variable LBRRATE) and the ground shine (CHRONC variable LGSHFAC). A reasonable choice for these values would be the values used in EARLY for normal activity.

Each variable in the section must be defined for each of the three sub-phases (evacuation, normal, and sheltering) of the emergency phase.

CSFACT is the cloudshine shielding factor. This value is used as a multiplier on the value of cloudshine dose that would have been received when the person were standing outside. A value of 0 indicates complete shielding; a value of 1 indicates no shielding.

PROTIN is the inhalation protection factor. This value is used as a multiplier on the value of inhalation dose that would have been received if the person were standing outside. A value of 0 indicates complete protection from inhalation of radioactive materials; a value of 1 indicates no protection.

BRRATE is the breathing rate.

SKPFAC is the skin protection factor. This value is used as a multiplier on the value of skin dose that would have been received if the person were standing outside. A value of 0 indicates complete protection from aerosol deposition onto the skin; a value of 1 indicates no protection.

GSHFAC is the groundshine shielding factors. This value is used as a multiplier on the value of groundshine dose that would have been received if the person were standing outside and the ground were a perfectly flat surface. A value of 0 indicates complete shielding from groundshine; a value of 1 indicates no protection.

Variable Name	Definable	Type	Dimensions	Allowed Values
CSFACT	Yes	Real	3	0.0 to 1.0
PROTIN	Yes	Real	3	0.0 to 1.0
BRRATE	Yes	Real	3	0.0 to 1.0 m^3/s
SKPFAC	Yes	Real	3	0.0 to 1.0
GSHFAC	Yes	Real	3	0.0 to 1.0

Response Delays
This form is required for *Emergency Scenario One* and is also required for each additional *Emergency Scenario* category.

This form defines the delay from the time indicated by REFPNT until the beginning of sheltering and the delay from the beginning of sheltering until the beginning of evacuation.

DLTSHL defines the delay from the time represented by REFPNT to the start of sheltering. Normal activity shielding factors are used during this delay. Sheltering shielding factors are used following this delay. One number is supplied for each ring in the shelter/evacuate region.

DLTEVA defines the delay from the beginning of the sheltering period to the beginning of evacuation. Sheltering is assumed during this delay. Evacuation shielding factors are used following this delay. One number is supplied for each ring in the shelter/evacuate region.

Variable Name	Definable	Type	Dimensions	Allowed Values
DLTSHL	Yes	Real	NUMEVA	0 to 3.456 x 10^6 s or 40 days
DLTEVA	Yes	Real	NUMEVA	0 to 3.456 x 10^6 s or 40 days

Radial Evacuation Speed

This form is required for *Emergency Scenario One* when the *Problem Model* selected is *Radial* and *Activate Speed Multiplier Model* is selected on the *Project Properties/Evac Rotation* tab. This form is required for each additional *Emergency Scenario* category when evacuation type is circular or keyhole and *Activate Speed Multiplier Model* is selected.

ESPGRD_RAD defines the speed multiplier for each grid element where evacuation is allowed. This includes all grid elements from the center to the outer boundary of the evacuation movement, LASMOV, after which evacuation is no longer considered. A value of one indicates the speed is the same as the value of ESPEED. The ranks of these numbers are shown in the interface. See Section 4.4.7 for more information.

Variable Name	Definable	Type	Dimensions	Allowed Values
ESPGRD_RAD	Yes	Real	LASMOV by NUMCOR	0.001 to 1000.0

Network Evacuation Direction

This form is required for *Emergency Scenario One* when the *Problem Model* selected is *Network* is selected on the *Project Properties/Evac Rotation* tab. This form is required for each additional *Emergency Scenario* category when evacuation type is circular or keyhole.

ESPGRD_NET is a read-only variable on this form and is defined on the form *Network Evacuation Speed*. When this variable is undefined, a value of 1 is displayed for both the rank and the value of the speed multiplier.

IDIREC defines the evacuation direction. A value of one indicates an outward evacuation to the next grid element, two indicates clockwise evacuation, three indicates inward evacuation, and four indicates counter clockwise evacuation. These numbers are input in the interface as arrows that can be clicked on to change the evacuation direction.

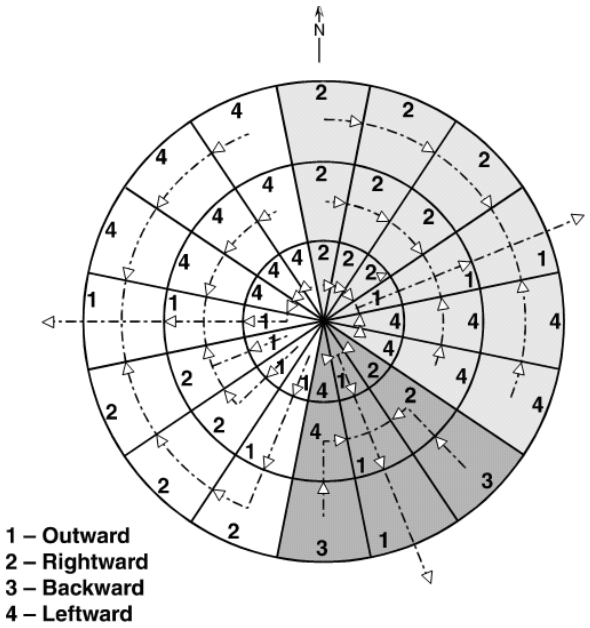


Figure 3-23 IDIREC Values in network evacuation grid

Variable Name	Definable	Type	Dimensions	Allowed Values	Defined on Form
ESPGRD_NET	No	Real	LASMOV by NUMCOR	0.001 to 1000.0	Network Evacuation Speed
IDIREC	Yes	Integer	LASMOV by NUMCOR	1 to 4	Network Evacuation Direction

Network Evacuation Speed

This form is required for *Emergency Scenario One* when the *Problem Model* selected is *Network* and *Activate Speed Multiplier Model* is selected on the *Project Properties/Evac Rotation* tab. This form is required for each additional *Emergency Scenario* category when the evacuation type is keyhole or circular and *Activate Speed Multiplier Model* is selected. This set of variables is useful for adjusting speeds for bottlenecks in the road network or for areas of freely flowing traffic compared with the base speeds of the cohort in the three phases.

ESPGRD_NET defines the speed multiplier for each grid element where evacuation is allowed. This includes all grid elements from the center to the outer boundary of the evacuation movement, LASMOV, after which evacuation is no longer considered. A value of one indicates the speed is the same as the value of ESPEED. The ranks of these numbers are shown in the interface. See Section 4.4.7 for more information.

IDIREC is a read-only variable on this form as is defined on the form *Network Evacuation Direction.* A value of one indicates an outward evacuation to the next grid element, two indicates clockwise evacuation, three indicates inward evacuation, and four indicates counter clockwise evacuation. These numbers are shown in the interface as arrows that display the direction of evacuation.

This data is indirectly input using the spatial grid as a background.

Variable Name	Definable	Type	Dimensions	Allowed Values	Defined on Form
ESPGRD_NET	Yes	Real	LASMOV by NUMCOR	0.001 to 1000.0	Network Evacuation Speed
IDIREC	No	Integer	LASMOV by NUMCOR	1 to 4	Network Evacuation Direction

Population

The *Population* form is relevant for each emegergency cohort category when the user assigns SUMPOP to the *Results Weighting Factor* and selects *Create from Existing Site File* on the *Site Data* tab. After the *Populations Assigned* form is completed, the *Population* form is updated. The values shown are the number of people assigned to each spatial grid element for the given cohort category.

COHORT_POP defines the number of people assocated with each spatial grid element in the given cohort.

Variable Name	Definable	Type	Dimensions	Allowed Values	Defined on Form
COHORT_POP	No	Real	NUMRAD by NUMCOR	0 to 1×10^{9}	Populations Assigned

Keyhole Definition

The *Keyhole Definition* form is required when the evacuation *Type* field is set to *Keyhole.*

NSECTR defines the number of sectors to be considered in the keyhole evacuation. This number should not exceed NUMCOR/2 – 1.

KEYDIS is the radius of the circular portion of the keyhole. The radius is the index into SPAEND. The outer radius of the evacuation region is defined by NUMEVA. Setting KEYDIS to zero eliminates the circular portion of the keyhole. Setting KEYDIS to NUMEVA eliminates the key portion of the keyhole.

Variable Name	Definable	Type	Dimensions	Allowed Values
NSECTR	Yes	Real	None	1, 3, 5, 7, …, 31
KEYDIS	Yes	Integer	None	0 to NUMEVA

3.3.7 Early Fatality and Injury Parameters

3.3.7.1 Fatality Model Description

The individual risk of prompt fatality is modeled in MACCS using a two-parameter Weibull function, termed a hazard function (Evans, Moeller, and Cooper, 1985). The hazard function is used to sum the cumulative risk from a number of potential types of damage as follows:

$$RISK = 1 - e^{-\sum_i H_i} \qquad \text{(Equation 34)}$$

Where

$$H = 0.693\left(\frac{DOSE}{EFFACA}\right)^{EFFACB}$$

DOSE = effective acute dose to the target organ (described later),

EFFACA = the alpha (LD_{50}) parameter in the hazard function (Evans, Moeller, and Cooper, 1985, p. II-8), and

EFFACB = the beta or exponential parameter in the hazard function that defines the steepness of the dose-response function.

In addition to the two Weibull parameters, a dose threshold is incorporated into the early fatality model. When the dose to any of the target organs is below the user-specified threshold (see EFFTHR below), the hazard function (*H*) for that organ is set to 0.

When radioactive material is inhaled and retained in the respiratory system, an individual may continue to receive a radiation dose for long periods of time after the material was inhaled. Depending on particle size and chemical form, clearance mechanisms may remove the material from the body or transport it from the respiratory system to other organs of the body. For this reason, reference to a radiation dose needs to include the time period of interest (commitment period). The concept of lifetime dose commitment is widely used in radiation protection (Eckerman, Wolbarst, and Richardson 1989), but is not appropriate for estimating acute health effects.

As applied in MACCS, lifetime dose refers to the dose received over the 50-year period following inhalation by a standard reference person who is 30 years old. This lifetime dose is used to determine the need for mitigative actions and to calculate cancers and population dose.

Implementation of the Evans, Moeller, and Cooper (1985) early health effects models requires a calculation method that takes account of dose protraction for radioactive material inhaled and retained in the respiratory system. MACCS applies dose reduction factors to protracted doses that contribute to early health effects. Dose reduction factors are derived from LD_{50} or D_{50} values that apply to a sequential set of time periods of fixed length. In addition, for the calculation of early fatalities and injuries in MACCS, a new measure of dose was defined in order to reduce the computational demands of the calculations. Throughout this document it is referred to as effective acute dose. This dose is different than the effective dose defined by ICRP.

The effective acute dose, D_e, is the dose which if it were delivered entirely in 1 day, would induce the same health effects as an actual dose delivered over many days. Thus,

$$H = \ln_2\left(\frac{D_e}{\alpha_1}\right)^{\beta} = \ln_2\left(\sum_t \frac{D_t}{\alpha_t}\right)^{\beta} \qquad \text{(Equation 35)}$$

Where

D_e = $C \cdot F_e$
D_t = $C \cdot F_t$
C = the amount of material inhaled from the plume,
F_e = the effective acute dose conversion factor,
F_t = the dose conversion factor for the actual dose, D_t, delivered in time period t.
α_t = the LD_{50} or D_{50} for time period t.

α_1 = the LD_{50} or D_{50} for time period of 1 day.

Substitution yields the following result:

$$F_e = \left(\sum_t \frac{\alpha_1}{\alpha_t} \right) F_t \ . \qquad \text{(Equation 36)}$$

Effective acute dose conversion factors are supplied only for the organs used for calculating the early health effects. The acute dose commitment period from inhaled and internally deposited radionuclides is from 1 week to 1 year, depending on the organ. The organs in the dose conversion factor file for which effective acute dose coefficients have not been assessed are assigned values of –1.0, which prevents their inadvertent use since any resulting doses would be negative.

	Time Period after Initial Exposure (Days)					
	0–1	**1–7**	**7–14**	**14–30**	**30–200**	**200–365**
	Effective Acute Dose Reduction Factors (α_1/α_t)					
RED MARR	1.0	0.5	0.5	0.25		
LUNGS	1.0	0.0625	0.0625	0.027	0.027	0.0109
THYROID	1.0	0.2	0.2	0.2		
STOMACH	1.0	0.37				
LOWER LI	1.0	0.43				
SMALL IN	1.0	0.43				

A MACCS DCF preprocessor, DOSFAC2, allows the user to modify the acute dose reduction factors. The dose reduction factors that are contained in the dose file supplied with WinMACCS (*i.e.*, α_1/α_t) applied in the effective acute dose calculations are shown in the table above.

For early fatalities (with supportive treatment) for bone marrow irradiation, Evans, Moellen, and Cooper (1985) show LD_{50} values of 4.5 Gy for the 0- to 1-day time period, 9 Gy for the 1- to 14-day time period, and 18 Gy for the 14- to 30-day time period. Instead of calculating three different red marrow doses and applying the three different values of LD_{50} to calculate risk, a single red marrow dose is calculated using the effective acute dose conversion factor, as described above. The result is equivalent to the one that would have been obtained if committed doses over all three time periods had been obtained and Equation (35) had been used directly.

So, according to the above table, effective acute red marrow dose is 100% of the first day's dose, 50% of the next 13 days' dose, and 25% of the subsequent 16 days' dose. This acute dose is used in the risk equation with the LD_{50} for the 0- to 1-day time period to obtain the hazard to bone marrow.

The dose protraction effect described here is used only for internal exposure from inhalation. Dose from the direct exposure pathways in EARLY (groundshine and cloudshine) are summed with no reduction factor even when the exposure lasted more than 1 day. In other words, external doses are treated as though they had occurred in a single day. The current implementation of the early health effects models does not distinguish among cloudshine, groundshine, and the 0- to 1-day inhalation dose commitment. They are considered in this model to be equally effective in causing damage. Finally, the radiation weighting factor used for

acute alpha radiation is 10 instead of the conventional value of 20 used for lifetime dose conversion factors.

The error introduced by attributing the entire direct exposure dose to the first day is small and is in the direction of overestimating the hazard function and resulting value of risk of an early fatality. In most cases, emergency plans should ensure that no individuals are permitted to remain on contaminated ground for much longer than one day when dose levels are high enough to pose a risk of early health effects.

Resuspension inhalation is another area where the importance of the pathway is overestimated somewhat. The inhalation dose from resuspended material is treated identically to the inhalation dose from direct inhalation of the plume. That is, it is treated as though all the resuspended material was inhaled during the first day of the exposure period.

Information in this section is used only to control the calculation of individual risk. Risks to be processed (*e.g.,* total cases of early fatality, average individual risk of early fatality, and centerline risk vs. distance of early fatality) are described in later sections of this document. In order for the code to produce early fatality results, the early fatality model must be activated.

3.3.7.2 Injury Model Description

The individual risk of each type of early injury is modeled in MACCS using an approach analogous to that used for early fatality risk (Evans, Moller and Cooper 1985). The early injury risk model differs from the early fatality model in that, instead of summing the damage from more than one organ, only a single organ is evaluated. The early injury risk function is as follows:

$$\text{RISK} = 1 - e^{-H} \qquad \text{(Equation 37)}$$

Where

$$H = 0.693\left(\frac{\text{DOSE}}{\text{EIFACA}}\right)^{\text{EIFACB}}$$

DOSE = effective acute dose (described in 3.3.7.1 Fatality Model Description) to the target organ,

EIFACA = the alpha (D_{50}) parameter in the hazard function (Evans, Moller and Cooper 1985, p. II-8), and

EIFACB = the beta or exponential parameter in the hazard function that defines the steepness of the dose-response function.

In addition to the two Weibull parameters, a dose threshold is incorporated into the early injury model. When the dose to any of the target organs is below the user-specified threshold (see EITHRE in the following discussion), the hazard function for this type of early injury is set to 0, which results in the risk being zero.

In addition to the values described above, the user must specify the fraction of the population that is susceptible to the injury, EISUSC. Information in this section is used only to control the calculation of individual risk. Risks to be processed (*e.g.,* total cases of a given injury, average individual risk of a given injury, and centerline risk vs. distance of a given injury) are described in

later sections. In order for the code to produce early injury results, the injuries must be activated.

3.3.7.3 Latent Cancer Model Description

The cancer risk model included in the first public release version of MACCS was based on a linear-quadratic risk model. In response to recommendations presented in an NRC-sponsored reassessment of cancer risk models published in 1991 and referred to as LMF-132 (Abrahamson *et al.* 1991), the cancer risk model was updated in MACCS version 1.5.11.1 (Chanin *et al*. 1993) to include linear, not-threshold dose-response function. The capability to exercise the linear-quadratic risk model was retained although it is not typically used at present for calculation of cancer induction risk.

Linear-Quadratic Dose-Response Model

The linear-quadratic dose-response model assumes that risk, *R*, increases linearly with increases in dose, *D*, at low doses and that risk increases quadratically with respect to dose at higher dose levels. The linear-quadratic dose-response function is of the form (International Commission on Radiological Protection 1991):

$$R(D) = D \cdot (a + \beta D). \qquad \text{(Equation 38)}$$

The implementation of the linear-quadratic dose-response model in MACCS 1.5 is based on the recommendations of NRC-sponsored work (Evans 1990) and is described as follows. In the period modeled by EARLY, a quadratic dose-response relationship is used when dose to the target organ is less than a user-specified limit (MACCS ACTHRE input parameter). The dose-response function used in this case has the form:

$$R(D) = DOSE \cdot CFRISK \cdot (DOSEFA + DOSE \cdot DOSEFB) \cdot ACSUSC \qquad \text{(Equation 39)}$$

Where

DOSE	=	50-year lifetime dose commitment to the target organ,
CFRISK	=	lifetime risk factor for cancer injury,
DOSEFA	=	the linear factor, α, of the dose dependence,
DOSEFB	=	the quadratic factor, β, of the dose dependence, and
ACSUSC	=	fraction of the population susceptible to the latent cancer.

When dose to the target organ is greater than the dose limit ACTHRE, the upper-bound linear dose-response relationship is used:

$$R(D) = DOSE \cdot CFRISK \cdot (DOSEFA + ACTHRE \cdot DOSEFB) \cdot ACSUSC \qquad \text{(Equation 40)}$$

The change from Equation (39) to (40) at the threshold value causes a discontinuity in the slope but not of the risk factor itself.

During the long-term phase modeled by CHRONC, it is assumed that exposure of the population is limited to low levels by mitigative actions and therefore the quadratic term of the risk equation is ignored. Cancer risk is calculated using only the linear term, $R(D) = \alpha D$, of the quadratic dose response function. Cancer risk from all pathways (groundshine, resuspension inhalation, and ingestion) is modeled with the linear dose-response function given below:

$$R(D) = DOSE \cdot CFRISK \cdot DOSEFA \cdot ACSUSC \qquad \text{(Equation 41)}$$

The meaning of DOSE and CFRISK depends on whether individual risk (groundshine and resuspension) or collective risk (also including ingestion and decontamination worker doses) is being calculated.

The quadratic form of the dose-response relationship is deactivated by assigning a 0 to the MACCS ACTHRE input parameter.

Dose and Dose-Rate Effectiveness Factor
In response to recommendations presented in LMF-132, the MACCS cancer risk model was updated in MACCS version 1.5.11.1 to include a dose and dose-rate effectiveness factor in the dose-response function as follows:

$$R(D) = \alpha \cdot \frac{D}{DDREF} \qquad D < 0.2 \text{ Gy or } 0.1 \text{ Gy per hour} \qquad \text{(Equation 42)}$$

$$R(D) = \alpha \cdot D \qquad D > 0.2 \text{ Gy or } 0.1 \text{ Gy per hour}$$

This function is shown as the LNT curve in Figure 3-21. DDREF is the dose and dose rate effectiveness factor. The LMF-132 report states that the DDREF is to be applied "when the total dose is less than 0.2 Gray, and for higher doses when the dose rate is less than 0.1 Gray per hour." This guidance for the application of the DDREF is identical to the recommendations provided in ICRP 60. The DDREF is given a value of 2 in LMF-132 for central estimates of most cancer types. In contrast, for central estimates of breast and thyroid cancers the DDREF is assigned a value of 1 in LMF-132.

The user defines the lifetime dose commitment, input parameter DDTHRE, to which the DDREF is applied to cancer risk calculations for emergency phase exposures. MACCS applies the DDREF to all of the dose calculations in the CHRONC module because exposures should always be less than 0.1 Gy per hour after the end of the emergency phase.

3.3.7.4 Injury and Fatality Forms and Parameters

***Early Fatality Parameters* Form**
The Early Fatality Parameters form is not needed when the dose conversion factor file FGRDCF is selected on the *Project Properties/Dose* tab or when *Early Fatality Effects* is not checked on the *Project Properties/Early Effects* tab. It is required when either of the other dose conversion factor file types is selected and *Early Fatality Effects* is checked.

NUMEFA is the number of early fatality effects to be included in the total risk of early fatality.

ORGNAM is an organ name. The possible values depend on the DCF file chosen. Possibilities are limited to supported acute organs (ones beginning with A-).

EFFACA is the Alpha factor (LD50) in the hazard function for the target organ.

EFFACB is the beta factor (shape parameter) in the hazard function for the target organ.

EFFTHR is the threshold dose below which the risk of a fatality is zero.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMEFA	Linked	Integer	None	1 to 5
ORGNAM	Yes	Character	NUMEFA	Acute Organ name from list in Table 3-7
EFFACA	Yes	Real	NUMEFA	1.0 to 100. Sv
EFFACB	Yes	Real	NUMEFA	1.0 to 100.0
EFFTHR	Yes	Real	NUMEFA	0.0 to 100.0 Sv

***Early Injury Parameters* Form**

The *Early Injury Parameters* form is not needed when the dose conversion factor file FGRDCF is selected on the *Project Properties/Dose* tab or when *Early Injury Effects* is not checked on the *Project Properties/Early Effects* tab. It is required when either of the other dose conversion factor file types is selected and *Early Injury Effects* is checked.

NUMEIN is the number of different types of early injuries that are to be calculated.

EINAME is the name of each type of early injury. This is a user defined label.

ORGNAM is an organ name. The possible values depend on the DCF file chosen. Possibilities are limited to acute organs.

EISUSC is the fraction of the population that is susceptible to early injury.

EITHRE is the threshold dose below which risk of the injury is zero.

EIFACA is the alpha factor (D50) in the hazard function for the injury.

EIFACB is the beta (shape) factor in the hazard function for the injury.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMEIN	Linked	Integer	None	1 to 10
EINAME	Yes	Character	NUMEIN	1 to 16 characters
ORGNAM	Yes	Character	NUMEIN	Acute Organ name from list in Table 3-7
EISUSC	Yes	Real	NUMEIN	0.0 to 1.0
EITHRE	Yes	Real	NUMEIN	0.0 to 1000.0 Sv
EIFACA	Yes	Real	NUMEIN	0.0 to 1000.0 Sv
EIFACB	Yes	Real	NUMEIN	0.0 to 100.0

***Latent Cancer Parameters* Form**

The *Latent Cancer Parameters* form is required when *Latent Cancer Effects* is checked on the *Project Properties/Early Effects* tab.

NUMACA is the number of different types of latent cancer effects that are to be calculated.

ACNAME is the name of each type of latent cancer effect. This is a user defined label.

ORGNAM is the name of the target organ for each type of latent cancer effect. The possible values offered depend on the DCF file. Possibilities are limited to supported latent organs.

ACSUSC is the fraction of the population that is susceptible to the latent cancer.

DOSFA defines the linear factor, alpha, of the dose dependence in the cancer risk model.

DOSFB defines the quadratic factor, beta, of dose dependence in the cancer risk model. It is used in EARLY, but not in CHRONC. When the dose to the organ is below ACTHRE, DOSEFB defines the quadratic term of the cancer dose-response function. The user should assign a value of zero to deactivate the quadratic portion of the linear-quadratic risk model.

CFRISK is the lifetime risk factor for cancer death. This parameter has units of risk/Sievert.

CIRISK is the lifetime risk factor for cancer incidence (injury). This parameter has units of risk/Sievert.

DDREFA is the dose-dependent reduction factor. When the lifetime dose commitment incurred during the EARLY exposure period is less than DDTHRE, the risk of cancer from irradiation of that organ is divided by DDREFA. Doses calculated in CHRONC are always divided by DDREFA.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMACA	Linked	Integer	None	1 to 10
ACNAME	Yes	Character	NUMACA	1 to 10 characters
ORGNAM	Yes	Character	NUMACA	Lifetime Organ name from list in Table 3-7
ACSUSC	Yes	Real	NUMACA	0.0 to 1.0
DOSEFA	Yes	Real	NUMACA	0.0 to 2.0
DOSEFB	Yes	Real	NUMACA	0.0 to 2.0
CFRISK	Yes	Real	NUMACA	0.0 to 1.0 per Sv
CIRISK	Yes	Real	NUMACA	0.0 to 1.0 per Sv
DDREFA	Yes	Real	NUMACA	1.0 to 10.0

Latent Cancer Thresholds **Form**

The *Latent Cancer Thresholds* form is required when *Latent Cancer Effects* is checked on the *Project Properties/Early Effects* tab.

ACTHRE is the lower dose limit for the linear dose-response relationship. For doses less than ACTHRE, a quadratic relationship is used. This parameter should be assigned a value of zero when the user wishes to deactivate the linear-quadratic risk model in favor of a linear relationship. This parameter might better be described as a breakpoint in the dose-response curve and its use is distinct from the model for a threshold in the dose-response function described in Section ?.

DDTHRE is the threshold dose for applying the dose-dependent reduction factor DDREFA. When the lifetime dose commitment incurred during the EARLY exposure period is less than DDTHRE, the risk of cancer from irradiation of that organ is reduced by a factor of DDREFA.

Variable Name	Definable	Type	Dimensions	Allowed Values
ACTHRE	Yes	Real	None	0.0 to 10.0 Sv
DDTHRE	Yes	Real	None	0.0 to 1.0 Sv

3.3.8 Output Control

3.3.8.1 Output Control Forms and Parameters

***Debug Options* Form**
IPRINT specifies the quantity of debug output that is desired. The higher the value, the more output is printed. Normal runs should use a value of zero.

Normally, centerline doses can be selected when IPLUME = 1 from the *Centerline Dose* form under *EARLY/Output Control*. An alternative method for evaluating centerline doses from EARLY is to set the output control variable, IPRINT, to a value greater than zero. When this is done, a listing of dose vs. distance for all the organs is included in the output. Since this is written for each weather trial, this option is normally used for single weather trial runs.

For various values of IPRINT, the output file contains some intermediate results. These are described below.

IPRINT ≥1: This option produces skin dose conversion factors, centerline doses for all organs (when IPLUME=1), Gaussian histogram and cloudshine correction factors, return code values (RETCOD).

IPRINT ≥2: This option produces final groundshine dose rate for each organ, each plume segment.

IPRINT ≥4: This option produces total acute dose for organs 2 and 3, early fatality, early injury, and cancer risk values for each spatial element.

IPRINT ≥8: This option produces acute dose to organs 2 and 3 after completion of subroutine RELZON, acute dose to organs 2 and 3 after completion of subroutine ESTAT.

When RISCAT is set to True and weather bin sampling is selected, the relative contribution of each of the weather-category bins to the mean consequence value is included in the MACCS output.

Variable Name	Definable	Type	Dimensions	Allowed Values
IPRINT	Yes	Integer	None	0 to 10
RISCAT	Yes	Logical	None	True, False

***Health-Effect Cases* Form**
The *Health Effect Cases* form is optional. Cancer results requested from this form are automatically produced by CHRONC so that the results can be combined in the output. In the results calculated by CHRONC, the cancer values include the following dose pathways: (1) groundshine to the residents, (2) inhalation of resuspended aerosols by the residents, (3) consumption of food and water produced in the region (not necessarily by the residents), and (4) groundshine exposure of workers required to decontaminate the region.

NUM1 specifies the number of results. The value is determined by the number of rows in the grid containing values of vectors *NAME, I1DIS1, I2DIS1,* and *Report Options*.

NAME indicates the type of result desired. Choices for this are presented by WinMACCS, and depend on the values of variable EINAME, which represents the types of early injuries, and ACNAME, which represents the types of latent cancers. Totals for early fatalities and cancer fatalities are always available.

I1DIS1 defines the inner spatial interval of the region of interest. The distance corresponds to the inner boundary of this ring.

I2DIS1 defines the outer spatial interval of the region of interest. The distance corresponds to the outer boundary of this ring. MACCS requires that the value must be greater than or equal to I1DIS1.

Report Options determine whether CCDF data are written to the MACCS output file and whether they are to be included in the WinMACCS summary report. WinMACCS reports can also be generated on demand and independently of the choice of Report Options.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM1	Linked	Integer	None	0 to 40
NAME	Yes	Character	NUM1	ERL FAT/TOTAL, ERL INJ/[EINAME], CAN FAT/[ACNAME], CAN FAT/TOTAL, CAN INJ/[ACNAME], CAN INJ/TOTAL
I1DIS1	Yes	Integer	NUM1	1 to NUMRAD
I2DIS1	Yes	Integer	NUM1	1 to NUMRAD
Report Options	Yes	Character	NUM1	CCDF, NONE, REPORT, CCDF & REPORT

***Early-Fatality Radius* Form**

The *Early-Fatality Radius* form is optional. This result type is unavailable when *Federal Guidance Report FGRDCF* is selected on *Dose* tab of the *Properties* form or when *Early Fatality Effects* is not selected under the *Early Effects* tab of the *Properties*.

NUM2 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors RISTHR and Report Options.

RISTHR defines the risk threshold used for calculating the fatality radius (reported in kilometers). It estimates the maximum distance at which a specified level of early fatality risk is exceeded. The user can obtain information about the size of the region in which early fatalities are predicted to occur by setting this variable to zero.

Report Options determine whether additional CCDF data are written to the MACCS output file, and whether the data are to be included in the WinMACCS summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM2	Linked	Integer	None	0 to 10
RISTHR	Yes	Real	NUM2	0.0 to 1.0
Report Options	Yes	Character	NUM2	CCDF, NONE, REPORT, CCDF & REPORT

***Population Exceeding Threshold* Form**

The *Population Exceeding Threshold* form is optional.

This output type provides an estimate of the number of people who receive acute or lifetime doses exceeding a user-definable level. This consequence measure is for doses calculated in the EARLY module. There is no analogous capability for doses estimated in CHRONC or for combined doses estimated in EARLY and CHRONC.

NUM3 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors NAME, DOSTH3 and Report Options.

NAME defines the name of the organ to which the dose threshold applies.

DOSTH3 defines the dose threshold that is used for counting the population.

Report Options determine whether CCDF data are written to the MACCS output file and whether they are to be included in the WinMACCS summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM3	Linked	Integer	None	0 to 10
NAME	Yes	Real	NUM3	Organ name from list in Table 3-7
DOSTH3	Yes	Real	NUM3	0.0 to 1000.0 Sievert
Report Options	Yes	Character	NUM3	CCDF, NONE, REPORT, CCDF & REPORT

***Average Individual Risk* Form**

The *Average Individual Risk* form is optional. Average individual risk is obtained by taking the sum of the risk values in all sectors at a given distance and dividing it by the number of sectors. The result is based on a phantom person residing in each grid element and does not depend on site data.

Cancer results are automatically produced by CHRONC so that the results can be combined in the MACCS output. When this result is produced by CHRONC, it is only a measure of the risk from the dose pathways of groundshine and inhalation or resuspended aerosols. The risk presented in this result does not include doses from ingestion of food and water by the region's population or doses to workers required to decontaminate the region.

NUM4 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors I1DIS4, NAME, and Report Options.

I1DIS4 specifies outer spatial boundary. For example, when I1DIS4 is two, the associated average risk is calculated from the center of the grid to the outer radius of SPAEND(2).

NAME indicates the type of result desired. Choices for this are presented by WinMACCS, and depend on the values of variable EINAME, which represents the types of early injuries, and ACNAME, which represents the types of latent cancers. Totals for early fatalities and cancer fatalities are always available.

Report Options determine whether CCDF data are written to the MACCS output file and whether they are to be included in the summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM4	Linked	Integer	None	0 to 20
I1DIS4	Yes	Integer	NUM4	1 to NUMRAD
NAME	Yes	Real	NUM4	ERL FAT/TOTAL, ERL INJ/[EINAME], CAN FAT/[ACNAME], CAN FAT/TOTAL, CAN INJ/[ACNAME]
Report Options	Yes	Character	NUM4	CCDF, NONE, REPORT, CCDF & REPORT

***Population Dose* Form**

The *Population Dose* form is optional. This form requests population dose to a given organ to be calculated. The user must supply the name of the target organ as well as the inner and outer spatial intervals of the region of interest. When only the EARLY module is run, this result reflects only the pathways considered by EARLY. When both EARLY and CHRONC are run, the population dose from all pathways is included in the calculation. The CHRONC pathways include (1) groundshine dose to the population, (2) inhalation of resuspended aerosols by the population, (3) food and water ingestion doses resulting from deposition within the region (not necessarily ingested by the population within the region), and (3) doses to workers decontaminating the region.

NUM5 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors NAME, I1DIS5, I2DIS5, and Report Options.

NAME is the name of the target organ for the dose calculation. The possible values offered depend on the DCF file chosen and include only lifetime doses.

I1DIS5 defines the inner spatial interval of the region of interest. The distance is the inner radius of the specified ring.

I2DIS5 defines the outer spatial interval of the region of interest. The distance is the outer radius of the specified ring. MACCS requires that its value must be greater than or equal to I1DIS5.

Report Options determine whether CCDF data are written to the MACCS output file and whether they are to be included in the summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM5	Linked	Integer	None	0 to 10
NAME	Yes	Character	NUM5	Organ name from list in Table 3-7.
I1DIS5	Yes	Integer	NUM5	1 to NUMRAD
I2DIS5	Yes	Integer	NUM5	1 to NUMRAD
Report Options	Yes	Character	NUM5	CCDF, NONE, REPORT, CCDF & REPORT

***Centerline Dose* Form**

The *Centerline Dose* form is optional. This form is available when *No Wind Shift with Rotation (IPLUME=1)* is selected on the *Evac/Rotation* tab on the *Properties* form. In this case, MACCS

saves the centerline dose between a range of distances for a set of dose pathways and for acute and lifetime doses.

The following pathways/dose types are supported:

Pathway	Description	Calculation
CLD	cloudshine dose	EARLY
GRD	groundshine dose	EARLY CHRONC
INH ACU	dose from inhalation of the passing plume	EARLY
INH LIF	dose from inhalation of the passing plume	EARLY
TOT ACU	total dose from all direct exposure pathways	EARLY CHRONC
TOT LIF	total dose from all direct exposure pathways	EARLY CHRONC
RES LIF	dose from inhalation of resuspended material after plume passage	EARLY CHRONC
RES ACU	dose from inhalation of resuspended material after plume passage	EARLY CHRONC

Depending on the exposure pathways and dose types requested, the results are calculated by EARLY and/or CHRONC. When both EARLY and CHRONC are being run, CHRONC automatically produces all of the results for the pathways it includes. When pathways 'GRD', 'RES LIF', or 'TOT LIF' are chosen, those results are automatically produced by CHRONC. The other pathway values are only produced by EARLY.

An alternative method to request centerline doses from EARLY is to set the output control variable, IPRINT, to a value greater than 0. When this is done, a listing of dose vs. distance for all organs are included in the output.

NUM6 specifies the number of results. Its value is determined by the number of rows in the grid containing vectors ORGNAM, PATHNM, I1DIS6, I2DIS6, and Report Options.

ORGNAM is the name of the target organ for the dose calculation. The possible values offered depend on the DCF file chosen.

PATHNM indicates the pathway/dose type to be used for the calculation. The pathway name is ignored when ‘A-SKIN’ is specified as the target organ because direct dry deposition is the only exposure pathway considered for skin.

I1DIS6 defines the inner spatial interval of the region of interest. The distance is the inner boundary of the specified ring.

I2DIS6 defines the outer spatial interval of the region of interest. The distance is the outer boundary of the specified ring. MACCS requires that the value must be greater than or equal to I1DIS6.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM6	Linked	Integer	None	0 to 10
ORGNAM	Yes	Character	NUM6	Organ name from list in Table 3-7
PATHNM	Yes	Character	NUM6	CLD, GRD, INH ACU, INH LIF, TOT ACU, TOT LIF, RES LIF, RES ACU
I1DIS6	Yes	Integer	NUM6	1 to NUMRAD
I2DIS6	Yes	Integer	NUM6	1 to NUMRAD
Report Options	Yes	Character	NUM6	CCDF, NONE, REPORT, CCDF & REPORT

***Centerline Risk* Form**

The *Centerline Risk* form is optional. This form is available when *No Wind Shift and Rotation* is set to *No Wind Shift with Rotation (IPLUME=1)* is selected on the *Evac/Rotation* tab on the *Properties* form.

Centerline risk is calculated for phantom individuals located directly under the path of the plume who are exposed to the Gaussian peak of the air and ground concentrations. The centerline risk at each distance in the region is treated as a separate result and MACCS generates a distribution of the consequence measure for each of the spatial intervals within the specified range.

Cancer results are automatically produced by CHRONC. The CHRONC values represent risk from groundshine and inhalation of resuspended aerosols. This risk does not include doses from ingestion of food and water or doses to workers decontaminating the area.

NUM7 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors NAME, I1DIS7, I2DIS7, and Report Options.

NAME indicates the type of health effect requested. Choices are presented by WinMACCS, and depend on the values of variable EINAME, the types of early injuries, and ACNAME, the types of latent cancers.

I1DIS7 defines the inner spatial interval of the region of interest. The distance is the inner boundary of this ring.

I2DIS7 defines the outer spatial interval of the region of interest. MACCS requires that the value must be greater than or equal to I1DIS7. The distance is the outer boundary of this ring.

Report Options determine whether CCDF data are written to the output file, and whether the data are to be included in the report generated after simulations are completed.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM7	Linked	Integer	None	0 to 10
NAME	Yes	Character	NUM7	ERL FAT/TOTAL, ERL INJ/[EINAME], CAN FAT/[ACNAME], CAN FAT/TOTAL, CAN INJ/[ACNAME], CAN INJ/TOTAL
I1DIS7	Yes	Integer	NUM7	1 to NUMRAD

Variable Name	Definable	Type	Dimensions	Allowed Values
I2DIS7	Yes	Integer	NUM7	1 to NUMRAD
Report Options	Yes	Character	NUM7	CCDF, NONE, REPORT, CCDF & REPORT

***Population Weighted Risk* Form**

The *Population Weighted Risk* form is optional. Population-weighted health effect risk is obtained by calculating the number of cases of a health effect within a region and dividing by the total population of that region. It takes account of the population distribution and the wind rose.

Cancer results are automatically produced by CHRONC. CHRONC risks include the exposure pathways of groundshine and inhalation of resuspended aerosols.

The population-weighted risk in CHRONC is calculated by estimating the number of cancer cases and dividing that value by the population of the region. The risk presented in this result does not include the societal pathways of (1) ingestion of contaminated food and water or (2) doses to workers decontaminating the area.

NUM8 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors NAME, I1DIS8, I2DIS8, and Report Options.

NAME indicates the type of health effect desired. Choices depend on the values of variable EINAME, the types of early injuries, and ACNAME, the types of latent cancers.

I1DIS8 defines the inner radius of the region of interest. The radius is the inner boundary of this ring.

I2DIS8 defines the outer boundary of the region of interest. The radius is the outer boundary of this ring. MACCS requires that the value must be greater than or equal to I1DIS8.

Report Options determine whether CCDF data are written to the output file and whether they are to be included in the MACCS report generated after simulations are completed.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM8	Linked	Integer	None	0 to 20
NAME	Yes	Character	NUM8	ERL FAT/TOTAL, ERL INJ/[EINAME], CAN FAT/[ACNAME], CAN FAT/TOTAL, CAN INJ/[ACNAME], CAN INJ/TOTAL
I1DIS8	Yes	Integer	NUM8	1 to NUMRAD
I2DIS8	Yes	Integer	NUM8	1 to NUMRAD
Report Options	Yes	Character	NUM8	CCDF, NONE, REPORT, CCDF & REPORT

***Peak Dose* Form**

The *Peak Dose* form is optional. Results are based on the dose at each distance for a range of distances, analogous to centerline dose results. Reporting of centerline doses is not an option when wind shift is considered because a centerline does not exist. Peak dose is more general

than centerline dose because it calculates the maximum dose around the compass for any option for plume transport. The implementation of this result differs from centerline dose in two ways: (1) there is no capability for reporting a breakdown of individual doses by pathway and (2) peak doses represent an average dose over the width of a fine grid and are not point values like centerline dose.

This result is produced for each emergency response cohort. The dose depends on the definition of that cohort in terms of evacuation and relocation. When the CHRONC module is exercised, this result is automatically produced by CHRONC as well. However, the peak dose is calculated on the fine grid level in EARLY but only on the course grid level in CHRONC.

The overall results represent the combination of doses calculated by EARLY and CHRONC. However, the overall results may be misleading because peak doses for the various cohorts may occur at different angular locations. Summation of these values may be meaningless when multiple plume segments travel in different directions (*i.e.,* when NUMREL is greater than 1 *and* IPLUME is equal to 2 or 3).

NUMA specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors NAME, I1DISA, I2DISA, and Report Options.

NAME is the name of the target organ for the dose calculation. The possible values offered depend on the choice of DCF file.

I1DISA defines the inner radius of the region of interest. The radius is the inner boundary of this ring.

I2DISA defines the outer radius of the region of interest. The radius is the outer boundary of this ring. MACCS requires that the value must be greater than or equal to I1DISA.

Report Options determine whether CCDF data are written to the output file and whether they are to be included in the summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMA	Linked	Integer	None	0 to 10
NAME	Yes	Character	NUMA	Organ name from list in Table 3-7
I1DISA	Yes	Integer	NUMA	1 to NUMRAD
I2DISA	Yes	Integer	NUMA	1 to NUMRAD
Report Options	Yes	Character	NUMA	CCDF, NONE, REPORT, CCDF & REPORT

***Peak Dose Polar* Form**

The *Peak Dose Polar* form is optional. In this output type, the peak dose is calculated for a user-specified (r,θ) location. Individual doses at locations other than directly under the plume(s) are reported with this option. There is no capability for reporting individual doses by dose pathway.

When CHRONC is used, these results are generated by CHRONC as well as by EARLY. The total dose is estimated for a representative individual assumed at a particular (r,θ) location on the spatial grid. The dose depends on the definition of that cohort in terms of evacuation and

relocation. Exposures resulting from the ingestion of contaminated food and water are not included in the dose.

The location for which this result is to be calculated is specified as a radial index (which can range from 1 to NUMRAD) and an angular index (which can range from 1 to 64). Following the convention used throughout MACCS, an angular index of 1 represents a compass sector centered to the north of the release point. Numbering of compass sectors increases in the clockwise direction from the north.

NUMB specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors NAME, IRAD_B, IANG_B, and Report Options.

NAME is the name of the target organ for the dose calculation. The possible values depend on the DCF file chosen.

IRAD_B defines the radial interval of the grid element for which this result is to be calculated.

IANG_B defines the angular index of the grid element for which this result is to be calculated.

Report Options determine whether CCDF data are written to the MACCS output file and whether they are to be included in the summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMB	Linked	Integer	None	0 to 32
NAME	Yes	Character	NUMB	Organ name from list in Table 3-7
IRAD_B	Yes	Integer	NUMB	1 to NUMRAD
IANG_B	Yes	Integer	NUMB	1 to NUMCOR
Report Options	Yes	Character	NUMB	CCDF, NONE, REPORT, CCDF & REPORT

***Land Area Exceeding Dose* Form**

The *Land Area Exceeding Dose* form is optional. The land area that exceeds a user-specified dose level to an organ is reported. Optionally, dose values for all grid elements for the selected organ are displayed.

NUMC specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors ORGNAM, ELEVDOSE, and PRINT_FLAG_C.

ORGNAM is the name of the target organ for the dose calculation. The possible values offered depend on the DCF file chosen.

ELEVDOSE is the threshold value for calculating land contamination areas. Land area that is contaminated above the threshold value is reported in the output.

PRINT_FLAG_C set to True means that the output includes results dose levels to the specified organ for each grid element. Otherwise, these results are suppressed.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMC	Linked	Integer	None	0 to 40
ORGNAM	Yes	Character	NUMC	Organ name from list in Table 3-7
ELEVDOSE	Yes	Real	NUMC	0.0 to 1×10^{12} Sv
PRINT_FLAG_C	Yes	Logical	NUMC	True, False

***Land Area Exceeding Concentration* Form**

The *Land Area Exceeding Concentration* form is optional. This output type provides the land area that exceeds a user-specified ground concentration for a specified radionuclide. Optionally, the user can also request ground concentrations and time-integrated, ground-level, air concentrations for every grid element.

NUMD specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors I1DISD, NUCLIDE, ELEVCONC, and PRINT_FLAG_D.

I1DISD is the outer spatial interval bounding the region of interest. The radius corresponds to the outer radius of the specified ring. The contaminated area in the calculation is from a radius of zero to the outer spatial interval.

NUCLIDE is the radionuclide of interest. The value must be an element of vector NUCNAM.

ELEVCONC is the threshold value for calculating the land contamination area. The land area that is contaminated above this threshold value is reported in the output.

PRINT_FLAG_D set to True means that the output includes ground and ground-level air concentrations for each grid element. Otherwise, this output is suppressed.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMD	Linked	Integer	None	0 to 40
I1DISD	Yes	Integer	NUMD	1 to NUMRAD
NUCLIDE	Yes	Character	NUMD	Must select a radionuclide from NUCNAM
ELEVCONC	Yes	Real	NUMD	0.0 to 1×10^{12} Bq/m^2
PRINT_FLAG_D	Yes	Logical	NUMD	True, False

***Population Movement* Form**

The model reports the fraction of each cohort and of the total population that has left the circular boundary corresponding to the I1DISE radial distance. The output reports the result at the time interval specified by TIMDIVE, but only when the fraction has changed since the previous time interval. For the case that the network evacuation model is used and some portion of the population exits the boundary then later returns into the circular region defined by the boundary, only the first crossing of the boundary is treated by the model.

NUME specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors I1DISE, TIMDIVE, and Report Options.

I1DISE specifies the radial index for which results are to be reported. The region considered is within the outer boundary of the specified radial grid element. The fraction of the population within this boundary crossing the boundary as a function of time is reported in the output.

TIMDIVE is the time interval for reporting.

Report Options determine whether CCDF data are written to the output file and whether they are to be included in the MACCS report generated after simulations are completed.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUME	Linked	Integer	None	0 to 35
I1DISE	Yes	Integer	NUME	1 to LASMOV
TIMDIVE	Yes	Integer	NUME	60 to 86400 s
Report Options	Yes	Character	NUME	CCDF, NONE, REPORT, CCDF & REPORT

3.4 CHRONC Input and Model description

3.4.1 Overview of CHRONC

The CHRONC module simulates the events that occur following the emergency phase time period modeled by EARLY. Various long-term protective actions can be taken during this period to limit radiation doses to acceptable levels.

CHRONC calculates the individual health effects that result from both external and internal dose pathways. CHRONC also calculates the economic costs of the long-term protective actions as well as the cost of the emergency response actions that were modeled in the EARLY module.

Three long-term exposure pathways are modeled to predict the long-term radiation exposures from accidental radiological releases: groundshine, resuspension inhalation, and ingestion of contaminated and drinking water. The models used in predicting the doses from these four pathways are described individually in the following sections. The dose from each of the long-term pathways is evaluated for each spatial element surrounding the accident site. For the intermediate phase, only the groundshine and resuspension inhalation exposure pathways are treated. The implicit assumption is that contaminated food and water would not be ingested during the intermediate phase.

MACCS incorporates two optional food ingestion models as follows:

- the food ingestion model from the original MACCS code, as used in NUREG-1150
- the COMIDA2 food ingestion model.

The MACCS food ingestion model is based on the principle that the long-term dose produced by any radionuclide to an organ via the food-ingestion pathway is the product of the ground concentration of the radionuclide, the integrated transfer factor for the radionuclide to human intake for the pathway, and the ingestion dose conversion factor.

There are a number of limitations in the MACCS food-ingestion model. A main drawback is that the integrated transfer factors for food pathway radionuclides not included in the MACCS sample problems must be derived externally. Calculation of the transfer factors is difficult and error prone. A second limitation of the MACCS food-ingestion model is that it is not capable of distinguishing the effects of contamination at different times during the growing season. This difference is substantial depending on whether deposition occurs directly onto standing crops or not.

By contrast, the COMIDA2 ingestion model is based on a preprocessor that can be exercised by the user, with consideration of site-specific data, when such data are available. Alternatively, the user can use a COMIDA2 file distributed with the code that provides typical values for the U.S. The COMIDA2 model considers a set of times during the growing season, so variations in food contamination over the growing season are automatically treated.

The radiation dose for the exposure pathways of the intermediate and long-term phases is calculated for each of the coarse spatial elements using the initial ground concentration under the plume centerline calculated by the ATMOS module. Similar to the early exposure pathways, MACCS uses centerline and off-centerline concentrations to estimate the initial ground concentration for any spatial element. By contrast with EARLY, which estimates deposition at the fine grid level, CHRONC only resolves deposition at the course grid level. For each dose pathway, the Gaussian distribution is averaged over the width of a compass sector to estimate a ground concentration for each grid element.

CHRONC incorporates calculations for two distinct periods of time, the intermediate phase and the long-term phase. These phases are described in the following subsections.

3.4.1.1 Intermediate Phase

The intermediate phase begins immediately after the emergency phase. The user can define the duration of the intermediate phase to be zero (i.e., no intermediate phase) or up to one year.

The only response considered during the intermediate phase is continued relocation for areas that are too heavily contaminated for the population to return. The criterion for relocation during the intermediated phase is based on a user-defined dose projection and dose level. The dose projection is defined in terms of an exposure period and a target organ. The user also specifies the maximum acceptable dose level. When the intermediate-phase dose criterion is satisfied, the residential population of a grid element is assumed to be present and subject to radiation exposure from groundshine and resuspension inhalation for the entire intermediate phase. When the criterion is exceeded, the population is assumed to be relocated to uncontaminated areas for the entire intermediate phase, with a corresponding per-capita economic cost defined by the user through the input variable POPCST.

3.4.1.2 Long-Term Phase

The long-term phase follows the intermediate phase, or directly follows the emergency phase when the duration of the intermediate phase is set to zero. A set of protective actions are implemented during the long-term phase, which are decontamination, interdiction, and condemnation of land that exceeds the habitability level set by the user.

Decisions on mitigative actions during the long-term phase are based on two sets of independent criteria as follows:

- Decisions are made relating to whether land at a specific location and time is suitable for human habitation. This criterion is often called the habitability criterion.
- Decisions are made relating to whether land at a specific location and time is suitable for agricultural production. This criterion is often called the farmability criterion.

3.4.1.3 Division Between Farm and Population

The long-term phase incorporates a fundamental distinction between the consequences associated with agricultural uses of land (denoted FARM-DEPENDENT in the code output), and habitation of land by humans (denoted POP.-DEPENDENT in the code output).

3.4.1.4 Habitability Decision Making

Habitability decision making determines whether land is immediately habitable, land is habitable after decontamination, land is habitable after a combination of decontamination and interdiction, or land is condemned.

The first step in the decision making regarding habitability is to determine whether, in the absence of any mitigative actions, the land in a grid element is suitable for habitation during the long-term exposure period. This is done by comparing the projected, lifetime, individual dose to the target organ (input variable CRTOCR) for the long-term dose projection period (input variable TMPACT) against the user-specified dose for long-term exposure (input variable DSCRLT). When the projected individual dose does not exceed DSCRLT, the land is considered immediately habitable, and no further tests regarding habitability are made. Residents are assumed to return to the grid element and no further costs are tallied.

When the land is not immediately habitable, a progressive series of actions are evaluated, beginning with decontamination for the various user-defined decontamination levels. The influence of decontamination is twofold:

- Doses are reduced by a dose reduction factor (DRF, input variable DSRFCT), which is a scaling factor by which the doses are reduced.
- Doses are also reduced by weathering and radioactive decay during the decontamination period.

The influence of these two factors is considered to be independent. That is, when the user specifies a DRF of 3, and a decontamination period of 1 year, the doses to habitants at the conclusion of decontamination are generally less than one-third of the doses before decontamination because decontamination, weathering, and radioactive decay all work to reduce subsequent doses.

The first level (smallest DRF) of decontamination is considered first. When this DRF plus weathering and decay is enough to meet the habitability criterion immediately after decontamination, this level of decontamination is performed and the population is assumed to return. When the first level of decontamination is not sufficient, higher levels of decontamination are considered. MACCS allows up to three levels.

When the highest level of decontamination is insufficient to restore habitability, MACCS evaluates whether performing this level of decontamination plus additional interdiction would restore habitability. MACCS allows up to 30 years of interdiction when it performs this calculation.

MACCS declares land to be condemned under two conditions:

- Habitability cannot be restored after decontaminating at the highest level plus additional interdiction.
- The total cost to restore habitability is greater than the cost to condemn the land.

Under either of these conditions, the land is condemned immediately at the beginning of the long-term phase; the model assumes that decontamination is not performed. The code calculates the corresponding long-term food and population doses to be zero for the condemned land and assesses an economic cost for condemnation of the property.

The effect of weathering and decay over the interdiction period is calculated with an interpolation technique that uses precalculated doses for predefined interdiction periods of 1, 5,

and 30 years. These three predefined interdiction periods all begin at the conclusion of the maximum-level decontamination effort, which is a user-specified duration that can extend up to 1 year. The time required for decontamination is considered to be part of the period of interdiction, so the total interdiction period can potentially extend to 31 years.

For the two separate land uses, farm and population, mitigative actions are chosen to yield the lowest-cost approach to satisfying the applicable criteria. For farms, the criteria define acceptable levels of foodstuff contamination; for populations, the criteria define acceptable levels of radiation exposures to individuals. The maximum duration of temporary farmland interdiction is 8 years; as previously discussed, the corresponding maximum duration for populated areas is 30 years. It is likely that neither of these limiting cases would be applied in practice because the cost of decontamination and interdiction would normally exceed the cost of condemnation before these time limits are reached.

3.4.1.5 Primacy of Habitability over Farmability Decisions

For both food-chain model options, farm production is allowed to occur only when the environmental contamination levels are sufficiently low enough to allow habitation. The implicit assumption is that people cannot work on land that is not habitable. When farmland is not habitable, it is treated exactly the same as described in the previous subsection on habitability decision making.

3.4.1.6 Farmability Decision Making

As described in the previous subsection, the decision on whether farmland can be used for agriculture is based first on evaluations of its suitability for human habitation. When farmland is immediately habitable or is restored to being habitable, it is next evaluated for farmability, which means that contamination levels of the agricultural products are low enough to be consumed. The criterion for farmability is specified through a set of maximum allowable food doses, which are input parameters DOSEMILK, DOSEOTHR, and DOSELONG. These parameters are discussed below.

Most often the farmability criterion is stricter than the habitability criterion, so it is not unusual that farmland is habitable but not farmable. Decontamination is only implemented in MACCS to restore habitability, not farmability. Land that is initially habitable but not farmable is either interdicted without decontamination or condemned.

3.4.2 Basic Parameters

3.4.2.1 Basic Forms and Parameters

***Chronc Description* Form**
The *Chronc Description* form contains one variable, which is a short description of the CHRONC model used in the calculation. This form is required.

Variable Name	Definable	Type	Dimensions	Allowed Values
CHNAME	Yes	Character	None	1 to 80 characters

***Property Form Parameters* Form**
This form allows the user to observe how the choices made on the *Properties* form define some important variables that are required in the CHRONC input. The variables on this form are

read-only and cannot be changed from this form. Details about the affect these parameters have on the model are provided in the subsections below.

FDPATH determines the food-chain model used. When this variable is set to OLD the food-chain model developed for MACCS is used. NEW means the COMIDA2 food-chain model is used. When this variable is set to OFF, no food-chain model is used.

NTTRM is the number of terms used in the growing crop retention model. This is only relevant when FDPATH is set to OLD.

Variable Name	Definable	Type	Dimensions	Allowed Values	Defined on Form
FDPATH	Read Only	Character	None	NEW, OFF, OLD	*Food* tab on *Properties* form
NTTRM	Read Only	Integer	None	1 to 3	*Number of Crop Weathering Terms* found on *Food* tab of the *Properties* form

3.4.3 Shielding and Exposure

3.4.3.1 Shielding and Exposure Model Description

Shielding and exposure factors are specified separately for EARLY and CHRONC, but serve the same purpose. These factors account for long-term behavior of the public and for the shielding offered by structures in which people dwell, work, and spend time.

Older versions of MACCS assumed that the long-term shielding and exposure factors in the intermediate and long-term phases are identical to those for normal activity during the emergency phase. This is still a reasonable assumption that is commonly used. However, there are some reasons why the factors could be different for these phases. The basic difference is in potential equilibration between the exterior and interior of buildings. The usual assumption in estimating these factors for the emergency phase is that the exterior is contaminated but the interior is clean. This may be a reasonable assumption for the short term, but may be less reasonable for the long term. Even for the short term, air exchange between the interior and exterior of a house or other building can cause some level of contamination to the interior. Filtered air exchange between the atmosphere and a control room is generally included when assessing doses to control-room workers for design-basis accidents. Similarly, ventilation systems in a home or other building would gradually introduce contaminants into the interior, which in turn would affect the shielding and exposure factors. After a long time, it is reasonable that the interior and exterior of a building would equilibrate. In other words, the contamination level of the interior of a building would be lower but proportional to the contamination level of the exterior of the building. By allowing a distinction between short-term and long-term shielding and exposure factors, MACCS can be used to evaluate possible time dependencies of these factors.

3.4.3.2 Shielding and Exposure Forms and Parameters

***Shielding and Exposure* Form**
The *Shielding and Exposure* form is required.

LPROTIN is the inhalation protection factor. A value of 0 indicates complete protection from inhalation of radioactive materials; a value of 1 indicates no protection and corresponds to a person standing outdoors with no protection from the surrounding atmosphere.

LBRRATE is the breathing rate. There is a range of breathing rates that can be assigned, which is based on level of activity and other factors. This value should reflect a long-term average that is consistent with the exposure period used for the long-term phase.

LGSHFAC is the groundshine shielding factor. This value is used as a multiplier on the value of groundshine dose that would have been received if the person were standing outside and the ground were a perfectly flat surface. A value of 0 indicates complete shielding from groundshine; a value of 1 indicates no protection. A typical surface roughness of the ground affords some shielding, which is typically taken to be 0.7.

Variable Name	Definable	Type	Dimensions	Allowed Values
LPROTIN	Yes	Real	None	0.0 to 1.0
LBRRATE	Yes	Real	None	0.0 to 1.0 m^3/s
LGSHFAC	Yes	Real	None	0.0 to 1.0

3.4.4 Dose Projection Model Description

Dose projection is used to determine the need for relocation during the intermediate phase and to determine habitability during the long-term phase. Dose projection is defined by an exposure period and a target or critical organ for the dose. It is used to estimate a dose that would occur if no protective action were taken. A criterion is defined to protect the population by ensuring that a dose projection is small enough; otherwise a protective action is taken to eliminate or reduce the projected dose.

The dose criterion for habitability is discussed in a subsequent subsection. The dose criterion for relocation during the intermediate phase is based on a dose projection period, DPP_INTERPHAS, and a target organ, CRTOCR. The criterion is that the projected dose is less than a user input dose defined by parameter DSCRTI. These parameters are discussed in this and subsequent subsections.

Dose Projection Form

The *Dose Projection* form is optional. It contains a single parameter that defines the exposure period for dose projection used in the relocation criterion for the intermediate.

DPP_INTERPHAS is the dose projection period for relocation during the intermediate phase.

Variable Name	Definable	Type	Dimensions	Allowed Values
DPP_INTERPHAS	Yes	Real	None	0.0 to 1×10^{10} s

3.4.5 Evacuation/Relocation Cost Model Description

The evacuation and relocation costs describe the expected compensation for people who are subject take these protective actions. Evacuation only occurs during the emergency phase. It is triggered by an emergency declaration at a nuclear plant or facility, e.g., declaration of a general emergency.

Relocation of individuals can occur during the emergency or intermediate phases. It can also occur during the long-term phase, but is commonly referred to as interdiction in that case.

In the presentation of economic cost results, the costs associated with the emergency phase (*i.e.,* for evacuation and short-term relocation) are reported separately from the costs associated with the intermediate phase (*i.e.,* for relocation) and the long-term phase (i.e., decontamination, interdiction, condemnation, loss of use, and permanent relocation costs).

3.4.5.1 Emergency Response Cost Forms and Parameters

***Compensation Costs* Form**
The *Compensation Costs* form is required.

EVACST defines the daily cost of compensation for evacuees and short-term relocatees who are removed from their homes during the emergency phase. MACCS does not impose any specific set of costs for this parameter; it is entirely up to the user to determine which costs should be included. The value usually includes food, housing, and transportation costs. It can optionally include lost income when this cost is not included in other cost inputs.

RELCST defines the daily cost of compensation for individuals relocated from their homes during the intermediate phase of CHRONC. MACCS does not impose any specific set of costs for this parameter; it is entirely up to the user to determine which costs should be included. This value usually includes food, housing, and transportation costs. It can optionally include lost income and lost personal property when these are not included in other input parameters.

Variable Name	Definable	Type	Dimensions	Allowed Values
EVACST	Yes	Real	None	0 to 1000 $/person-da
RELCST	Yes	Real	None	0 to 1000 $/person-da
POPCST	Yes	Real	None	1×10^{-6} to 1×10^{6} $/person

3.4.6 Long-Term Protective Action Model Description

The long-term protective action parameters define the intermediate and long-term action time periods as well as the maximum doses that people are allowed to receive during these periods. The maximum allowable doses defined here are used to determine the need for relocation, decontamination, interdiction, and condemnation.

3.4.6.1 Long-Term Protective Action Forms and Parameters

***Long-Term Exposure Period* Form**
The *Long-Term Exposure Period* form is required.
DUR_INTPHAS is the duration of the intermediate-phase period. This period follows the emergency phase period, which is defined by EARLY variable ENDEMP. In the MACCS model, each phase is distinct and contiguous. The EPA definition allows for some overlap between the emergency and intermediate phases and of the intermediate and long-term phases (EPA, 2013). While this distinction should be recognized, it has little or no effect on the consequence results estimated by MACCS.

TMPACT is the long-term dose projection period corresponding to the long-term dose limit, DSCRLT. The dose projection is estimated at the beginning of the long-term phase for the target organ specified by CRTOCR to determine whether land is immediately habitable. The combination of these three parameters established the criterion commonly referred to as the habitability criterion. When habitability is not met at the beginning of the long-term phase, a set

of actions are evaluated to determine whether habitability can be restored at a later time, as described in section 3.4.1.

EXPTIM is the long-term exposure period. It begins when people return to their property. For example, when the code estimates that 5 years of interdiction are needed at a specific location to satisfy the habitability criterion and EXPTIM is 30 years, doses to the resident population is calculated for an exposure period that begins at the beginning of year 6 and ends at the end of year 35 of the long-term phase.

The accrual of doses from food and water ingestion is not affected by the user-specified value of EXPTIM. This accrual is not strictly associated with the population from which the contaminated food and water originate. The ingestion of contaminated food and water is estimated as a societal dose to an unspecified population. However, the ingestion dose is accounted for in the grid element from which the food and water originated in the output.

Variable Name	Definable	Type	Dimensions	Allowed Values
DUR_INTPHAS	Yes	Real	None	0 to 3.1536×10^{7} s
TMPACT	Yes	Real	None	0 to 1.0×10^{10} s
EXPTIM	Yes	Real	None	0 to 1.0×10^{10} s

***Long-Term Dose Criterion* Form**
The Long-Term Dose Criterion form is required.

DSCRTI is the maximum allowable dose commitment to the long-term critical organ (CRTOCR) over the intermediate-phase dose projection period (DPP_INTERPHAS). The exposure pathways considered in the dose projection are groundshine and resuspension inhalation. When the intermediate-phase dose criterion (DSCRTI) is exceeded within a grid element, the population there is relocated for the entire intermediate phase.

DSCRLT is the maximum allowable dose commitment to the long-term critical organ (CRTOCR) during the long-term dose-projection period (TMPACT). These three parameters establish the habitability criterion. The exposure pathways considered in the dose projection are groundshine and resuspension inhalation. When the long-term-phase dose criterion (DSCRLT) is exceeded within a grid element, the population there is relocated until the habitability criterion can be met. When it is not possible to reduce doses to this level in a cost-effective manner, the property is condemned and the resident population is permanently relocated. When this occurs, no doses are accrued during the long-term phase.

CRTOCR defines the critical organ that is used for both the intermediate and long-term phases.

Variable Name	Definable	Type	Dimensions	Allowed Values
DSCRTI	Yes	Real	None	0 to 1×10^{5} Sv
DSCRLT	Yes	Real	None	1×10^{-20} to 1×10^{5} Sv
CRTOCR	Yes	Character	None	Organ names from Table 3-7

3.4.7 Decontamination Plan

The decontamination plan data block defines the decontamination actions that may be taken during the long-term period to reduce doses to acceptable levels. Each decontamination level represents an alternative strategy that would reduce the projected long-term groundshine and resuspension doses by a factor called the *dose reduction factor*.

3.4.7.1 Decontamination Plan Model Description

The objective of decontamination is to reduce projected doses below the long-term dose criterion in a cost-effective manner. When the maximum decontamination level is insufficient to restore an area to immediate habitability, a period of temporary interdiction following the maximum decontamination level is considered in order to allow for dose reduction through radioactive decay and weathering. When the property cannot be made habitable within 30 years or when the cost of reclaiming the habitability of the property exceeds the cost of condemning it, the property is condemned and permanently withdrawn from use.

Decontamination cost is divided into two categories and these two types of cost are calculated separately. Farm-dependent decontamination cost represents the cost of farmland decontamination in a grid element. Farm-dependent decontamination cost is a function of the area of the grid element devoted to agriculture. Population-dependent decontamination represents the cost of non-farmland decontamination. Population-dependent decontamination cost is a function of the population residing in the grid element. The strategy of decontamination within a grid element is largely independent of the type of area being decontaminated, with the exception that farmland can be decontaminated to restore habitability but not to restore farmability, as explained above.

For a given decontamination level, the same decontamination time and effectiveness apply to both farmland and non-farmland, but the two costs are unique and are assigned independently for each type of decontamination. Owing to the requirement that the recovery of property must be cost-effective, it is possible, in a given element, that decontamination of non-farmland is performed and it is restored to use, but farmland is instead condemned.

Decontamination of a grid element serves to reduce the dose level in that element by the dose reduction factor associated with the decontamination effort being applied. Everything else being equal, a decontamination factor of 10 causes the integrated dose over any exposure period to be reduced by a factor of 10. Dose reduction factors are presented in Table 3-8.

Table 3-8 Decontamination factors.

Dose Reduction Factor	Percent of Dose Reduction
2	50%
3	66.7%
5	80%
10	90%
15	93.3%
20	95%
50	98%
100	99%

During the decontamination period, which is assumed to begin at the start of the long term phase, the population has been relocated from areas that are decontaminated.

While engaged in cleanup efforts, decontamination workers are assumed to wear respiratory protection devices. Therefore, they accumulate only groundshine doses. These doses contribute to the aggregate dose tabulated in the MACCS output.

Decontamination reduces direct exposure doses (both groundshine and resuspension) caused by contamination of land and buildings. Many decontamination processes reduce groundshine and resuspension doses by washing surface contamination down into the ground. These processes do not eliminate contamination from the area, but they do reduce doses to the population by adding shielding. Since these processes may not move contamination out of the root zone, the WASH-1400-based economic cost model of MACCS assumes that farmland decontamination reduces direct exposure doses to farmers without reducing uptake of radioactivity by root systems. Thus, decontamination of farmland does not reduce the ingestion doses produced by consumption of crops that are contaminated by root uptake. This is why decontamination is not considered for restoring farmability.

3.4.7.2 Decontamination Plan Forms and Parameters

***Number of Plan Levels* Form**
The *Number of Plan Levels* form is required.

LVLDEC is the number of decontamination levels that can be used. Each decontamination level represents an alternative strategy to reduce the projected long-term groundshine and resuspension inhalation doses.

Variable Name	Definable	Type	Dimensions	Allowed Values
LVLDEC	Yes	Integer	None	1 to 3

***Plan Definition* Form**
The *Plan Definition* form is required.

DLBCST is the labor cost of a decontamination worker.

TIMDEC defines the time required for completion of each level of decontamination. Decontamination begins at the end of the intermediate phase (TMIPND). The values must be monotonically increasing.

DSRFCT defines the effectiveness of the various decontamination levels in reducing dose. A dose reduction factor of 3 means that the resulting population dose at that location is reduced to one-third of what it would have been without decontamination. The values must be monotonically increasing.

TFWKF defines the fraction of the decontamination period (TIMDEC) that a farmland decontamination worker spends in the contaminated area for each level of decontamination.

TFWKNF defines the fraction of the decontamination period (TIMDEC) that a non-farmland decontamination worker spends in the contaminated area during the decontamination period for each level of decontamination.

Variable Name	Definable	Type	Dimensions	Allowed Values
DLBCST	Yes	Real	None	1.0 to 1×10^{6} $/person-yr
TIMDEC	Yes	Real	LVLDEC	1×10^{-6} to 3.15×10^{7} s (1 yr)
DSRFCT	Yes	Real	LVLDEC	1.01 to 100.0
TFWKF	Yes	Real	LVLDEC	0.0 to 1.0
TFWKNF	Yes	Real	LVLDEC	0.0 to 1.0

***Farmland Costs* Form**
The *Farmland Costs* form is required.

CDFRM defines the farmland decontamination costs for each level of decontamination. Values must be monotonically increasing.

FRFDL defines the fraction of the farmland decontamination cost that is due to labor for each level of decontamination.

Variable Name	Definable	Type	Dimensions	Allowed Values
CDFRM	Yes	Real	LVLDEC	1.0 to 1×10^{5} $/ha
FRFDL	Yes	Real	LVLDEC	0.0 to 1.0

***NonFarmland Costs* Form**
The *Non-farmland Costs* form is required.

CDNFRM defines the non-farmland decontamination costs of each level of decontamination. Values must be monotonically increasing.

FRNFDL defines the fraction of the non-farmland decontamination cost that is due to labor of each level of decontamination.

Variable Name	Definable	Type	Dimensions	Allowed Values
CDNFRM	Yes	Real	LVLDEC	1.0 to 1×10^{5} $/person
FRNFDL	Yes	Real	LVLDEC	0.0 to 1.0

3.4.8 Interdiction Costs

The interdiction plan cost data block defines the parameters needed to calculate the cost of interdiction. The data supplied here are combined with data in the site data file and the regional characteristics data in the course of the calculations.

3.4.8.1 Interdiction Cost Model Description

The model used in MACCS for assessing the cost of interdiction is based on the model described in WASH-1400, Appendix 6. It is currently used to calculate the economic cost of loss of use during both decontamination and temporary interdiction periods

3.4.8.2 Interdiction Cost Forms and Parameters

***Interdiction Costs* Form**
The *Interdiction Costs* form is required.

DPRATE defines the depreciation rate that applies to property improvements during a period of interdiction. This depreciation rate is intended to account for the loss of value of buildings and other structures resulting from a lack of habitation and maintenance.

DSRATE defines the expected rate of return from land, buildings, equipment, etc.

POPCST defines the per-capita, one-time relocation cost for temporary or permanent relocation of population and businesses in a region rendered uninhabitable during the long-term phase. This cost is assessed when any of the following actions are required: decontamination alone, decontamination followed by interdiction, or condemnation. This value can account for personal and corporate income losses for a transitional period and/or moving expenses.

Variable Name	Definable	Type	Dimensions	Allowed Values
DPRATE	Yes	Real	None	0.0 to 1.0 per yr
DSRATE	Yes	Real	None	0.0 to 1.0 per yr

3.4.9 Weathering

3.4.9.1 Weathering Model Description

The groundshine weathering relationship from Gale, Miller, and Fisher (1964) is described as follows:

$$GW(t) = GWCOEF(1) \bullet \exp[-\ln(2) \bullet t/TGWHLF(1)] + GWCOEF(2) \bullet \exp[-\ln(2) \bullet t/TGWHLF(2)] \quad \text{(Equation 43)}$$

Where

GW(*t*) represents the groundshine weathering at time *t*, given the weathering coefficients, GWCOEF, and the weathering half-lives, TGWHLF.

The resuspension weathering relationship is defined as:

$$RW(t) = RWCOEF(1) \bullet \exp[-\ln(2) \bullet t/TRWHLF(1)] + RWCOEF(2) \bullet \exp[-\ln(2) \bullet t/TRWHLF(2)] + RWCOEF(3) \bullet \exp[-\ln(2) \bullet t/TRWHLF(3)] \quad \text{(Equation 44)}$$

Where

RW(*t*) represents the resuspension weathering at time *t*, given the weathering coefficients, RWCOEF, and the weathering half-lives, TRWHLF.

The values are defined under the *Weathering* category in the WinMACCS interface.

3.4.9.2 Weathering Forms and Parameters

***Groundshine Weathering Terms* Form**
The *Groundshine Weathering Terms* form is required.

NGWTRM defines the number of terms in the groundshine weathering relationship.

Variable Name	Definable	Type	Dimensions	Allowed Values
NGWTRM	Yes	Integer	None	1 to 2

***Groundshine Weathering Coefficient* Form**
The *Groundshine Weathering Coefficient* form is required.

GWCOEF is the set of coefficients in the groundshine weathering equation.

TGWHLF is the set of half-lives in the groundshine weathering equation.

Variable Name	Definable	Type	Dimensions	Allowed Values
GWCOEF	Yes	Real	NGWTRM	1×10^{-20} to 1.0
TGWHLF	Yes	Real	NGWTRM	1×10^{-6} to 1×10^{12} s

***Resuspension Weathering Terms* Form**
The *Resuspension Weathering Terms* form is required.

NRWTRM defines the number of terms in the resuspension weathering relationship.

Variable Name	Definable	Type	Dimensions	Allowed Values
NRWTRM	Yes	Integer	None	1 to 3

***Resuspension Weathering Coefficient* Form**
Resuspension Weathering Coefficient is required.

RWCOEF is the set of resuspension weathering coefficients.

TRWHLF is the set of resuspension weathering half-lives.

Variable Name	Definable	Type	Dimensions	Allowed Values
RWCOEF	Yes	Real	NRWTRM	1×10^{-20} to 1.0 /m
TGWHLF	Yes	Real	NRWTRM	1×10^{-6} to 1×10^{12} s

3.4.10 Regional Characteristics

The regional characteristics data block defines the aggregate economic and agricultural characteristics of the area surrounding the accident site.

3.4.10.1 Regional Characteristics Model Description

When mitigative actions are needed to restore habitability or farmability, the regional characteristic values are used to evaluate the cost-effectiveness of those actions. For instance, when the average property values supplied here indicate that decontaminating a piece of land costs more than condemning it, the land is condemned.

In order to implement the rotation strategy when the user has chosen the option of *No Windshift with Rotation* (IPLUME=1) or *Windshift with Rotation* (IPLUME=2), the result of the cost-effectiveness test must the same in any direction. Thus, instead of using actual property

values from the site file, uniform values defined in the following section are used to make the decision on whether it is cost effective to decontaminate.

3.4.10.2 Regional Characteristic Forms and Parameters

***Farmland Wealth* Form**
The *Farmland Wealth* form is required.

VALWF defines the average value of farm wealth in the region. This value should include both publicly and privately owned grazing lands, farmland, farm buildings, and nonrecoverable farm machinery, as well as any publicly owned infrastructure serving the farm industry in the region. A corresponding value (VFRM) is calculated for each economic region by SecPop. The SecPop value is not averaged over the entire region, so it is able to represent variations in farmland wealth within a computation grid. When a site file is used in a calculation, the actual losses are estimated from the site file values (VFRM) rather than the input value (VALWF).

FRFIM defines the fraction of farm wealth in the region due to improvements. This value includes farm buildings and nonrecoverable machinery, as well as any infrastructure such as silos and irrigation, which are devoted exclusively to the support of farming.

Variable Name	Definable	Type	Dimensions	Allowed Values
VALWF	Yes	Real	None	1×10^{-6} to 1×10^{6} \$/ha
FRFIM	Yes	Real	None	0.0 to 1.0

***Non-farmland Wealth* Form**
The *Non-farmland Wealth* form is required.

VALWNF defines the value of the nonfarm wealth in the region. Nonfarm wealth includes all public and private property not associated with farming that would be unusable when the region was rendered either temporarily or permanently uninhabitable. This value should include the cost of land, buildings, infrastructure, and the cost of any nonrecoverable equipment or machinery. A corresponding value (VNFRM) is calculated for each economic region by SecPop. The SecPop value is not averaged over the entire region, so it is able to represent variations in non-farmland wealth within a computation grid. When a site file is used in a calculation, the actual losses are estimated from the site file values (VNFRM) rather than the input value (VALWNF).

FRNFIM defines the fraction of nonfarm wealth in the region due to improvements. This value includes buildings and infrastructure such as roads and utilities, as well as any nonrecoverable equipment or machinery.

Variable Name	Definable	Type	Dimensions	Allowed Values
VALWNF	Yes	Real	None	1×10^{-6} to 1×10^{6} \$/person
FRNFIM	Yes	Real	None	0.0 to 1.0

***Land Usage* Form**
Land Usage is required when *Uniform* is selected on the *Site Data* tab on the *Properties* form. When *Import from File* is selected on the *Site Data* tab, the values needed in the calculation are taken from the site data file.

FRCFRM defines the average fraction of land in the region devoted to farm production. The land area devoted to agriculture is calculated as follows:

$$\text{agricultural area} = \text{total area} \bullet \text{FRACLD} \bullet \text{FRCFRM} \qquad \text{(Equation 46)}$$

FRMPRD defines the value of the average annual farm production (gross sales) in the region.

DPFRCT defines the fraction of annual farm production (gross sales) in the region resulting from dairy production.

Variable Name	Definable	Type	Dimensions	Allowed Values
FRCFRM	Yes	Real	None	1×10^{-6} to 1.0
FRMPRD	Yes	Real	None	0 to 1×10^{5} $/ha
DPFRCT	Yes	Real	None	0.0 to 1.0

3.4.11 Food Chain

The user has a choice of using one of two food-chain models, or specifying that food-chain doses are not treated. These choices are made on the *Food* tab of the *Properties* form. When the user selects *No Food Model* on the *Food* tab, user input is not required in this section; otherwise input is required. When the *MACCS Food Model* is chosen on the *Food* tab, all input to the food-chain model is contained in this section. When the COMIDA2 food-chain model is used, MACCS uses a binary data file written by the preprocessing program, COMIDA2, which contains the results of the COMIDA2 food-chain modeling calculations.

When *User Supplies COMIDA2 File* is specified, the user must specify the COMIDA2 binary file to be used. The name of the files is specified on the *COMIDA2 File* form found under the *GENERAL/File Specifications* category. Additionally, the same DCF file used to create the user supplied COMIDA2 file must be specified as the DCF file specified in the *GENERAL/File Specifications/Dose Conversion Factor File* form.

When *Create COMIDA2 File* is specified, the user must complete the forms found in the main model category titled COMIDA2. In this case, when the model is executed, the COMIDA2 pre-processor is run first. This pre-processor uses the dose conversion factor file (DCF file) specified and creates a binary file to be used by MACCS. One purpose for using this option is that uncertainty in food-chain parameters can be included in MACCS calculations.

When one of the dose threshold models is used, either *Annual Threshold* or *Piecewise Linear*, creating the COMIDA2 binary file is not supported. Also, the MACCS food-chain model is not compatible with these choices. WinMACCS enforces these requirements.

3.4.11.1 Food-Chain Model Descriptions

Modeling of Agricultural Countermeasures

LASTACUM, a COMIDA2 input parameter, specifies the duration of the ingestion dose period. MACCS calculates the accumulated societal dose starting with the year that the land satisfies the human consumption criteria DOSEMILK and DOSEOTHR, with the exposure period ending in the LASTACUM year after the accident. The allowable range for the LASTACUM variable is from 1 to 50 years. The value of the LASTACUM variable is defined in the COMIDA2 user input file. It is communicated to MACCS as part of the header information on the .BIN file written by COMIDA2.

Consistent with the MACCS interdiction model, the maximum farmland interdiction period considered is 8 years. Land that cannot be returned to production after 8 years is condemned. MACCS condemns land that cannot be returned to production within LASTACUM years when the COMIDA2 model is used and the LASTACUM input variable is assigned a value less than 9.

To preserve the functionality of the MACCS food-chain model, agricultural countermeasures are always subordinate to the code's evaluation of habitability. That is, when land is uninhabitable because projected groundshine and resuspension doses exceed the long-term dose criterion DSCRLT, agricultural production at that location is not allowed.

Furthermore, when the resident population is never allowed to return, either because of a failure to meet the dose criterion, or because the costs to restore habitability exceed the value of the property, farmland is also assumed to be condemned, irrespective of the projected doses from food ingestion. When the farmland is condemned, none of the additional tests described below are performed. The costs associated with the condemnation of the farmland are based on the value of the property, input variable VALWF.

When the habitability dose criterion specified by the user is met, the following tests are performed by the code to determine the level of interdiction of agricultural production. The second year following the accident, year 2, is the first year for which the long-term ingestion dose criterion (DOSELONG) is evaluated. Milk and crop disposal during the year of the accident are triggered when the habitability criterion (DSCRLT) is exceeded in the year of the accident. When DSCRLT does not lead to the triggering of milk and nonmilk crop disposal, the individual criteria for the first year's milk (DOSEMILK) and the first year's nonmilk crops (DOSEOTHR) are examined separately to find whether either is exceeded. The disposal of milk and/or nonmilk crops is triggered when the projected ingestion dose for these two categories exceeds the DOSEMILK and/or DOSEOTHR criteria. The first-year dose criteria are evaluated using the consumption rates specified by the COMIDA2 input variable CONSUM_RATES.

Milk and crop disposal costs are calculated only for the year of the accident. Beginning in the second year after the accident, acceptability of food production is evaluated by comparing the projected individual dose with DOSELONG.

When the projected individual dose for the second year does not exceed the dose criterion DOSELONG, agricultural production for that year and all subsequent years is allowed. Implicit in the model is the assumption that the food doses resulting from successive years of production do not increase with time. Also, just as with the MACCS food-chain model, the long-term interdiction of farmland applies to *all* crop categories; there is no provision for long-term interdiction of a subset of the crops.

When the projected individual dose from the second year of agricultural production exceeds the dose criterion, the projected doses for up to eight successive annual periods are each examined in order to determine whether production can be resumed within the first 9 years after the accident.

When the projected doses in each of years 2 through 9 exceed DOSELONG, no further tests are performed and the farmland is condemned. When farmland is condemned, the associated cost is the market value of the farmland, VALWF, with dollar values reported on the output listing as FARM DEPENDENT CONDEMNATION COST.

When the projected doses for one of the years examined satisfy the long-term dose criterion, agricultural production is assumed to resume in that year. In that case, societal ingestion doses are assessed for the period ending with the LASTACUM year.

For example, when DOSELONG is satisfied in year 3, and LASTACUM has a value of 10, societal doses are accrued for the period denoted as years 3–10, an exposure period with a duration of 8 years. Since agricultural production was not allowed in the first and second years, economic costs for 2 years of interdiction are assessed for farmland. The model calculates the cost of temporary interdiction as the loss of return on investment of the land and improvements (see variables VALWF and FRFIM) and accounts for depreciation on the improvements (see input variables DSRATE and DPRATE).

First-Year Crop Disposal Cost

The economic cost of milk and/or nonmilk crop disposal during year 1 is modeled as the economic costs assessed for the loss of sales. The two crop disposal cost calculations, however, consistent with CRAC2, are treated differently, as follows.

When the disposal of the first year's milk production is triggered because the dose criterion DOSEMILK is exceeded, milk disposal costs are assessed as 0.25 of annual milk sales (see variables FRMPRD and DPFRCT). The rationale for the reduction in milk disposal costs by the application of the 0.25 adjustment factor was based on the assumption that cows would be taken off pasture and fed uncontaminated feed, allowing dairy production to resume after one-quarter of a year. In order to maintain consistency with the MACCS food-chain model, the application of the fixed 0.25 adjustment factor on milk disposal costs has also been implemented for the COMIDA2 food-chain model.

It is noted that the model implemented in MACCS for crop disposal costs, and the 0.25 factor for lost dairy sales, is not based on WASH-1400 because WASH-1400 did not account for crop disposal costs. CRAC2, in contrast to WASH-1400, *did* implement separate milk and nonmilk crop disposal costs, providing the technical basis for the MACCS model to assess such costs. CRAC2, however, in assessing the costs of milk and nonmilk crop disposal, assessed a milk disposal cost based on the full year's dairy sales, and not the 0.25 of dairy sales used in the MACCS cost model.

The technical basis for the 0.25 adjustment factor for milk disposal is not mentioned in the MACCS *Model Description*, but it was based on the assumption that dairy cows spend only a fraction of the year on pasture and obtain most of their food from stored feed.

Water Ingestion Model

When radioactive material is deposited on the ground, it is expected that some fraction of this material makes its way into drinking water consumed by humans (Helton, Muller, and Bayer, 1985). MACCS models this uptake into drinking water as two separate paths: (1) deposition of material directly onto freshwater bodies and (2) deposition of material onto land with subsequent wash off into freshwater bodies.

The water ingestion model assumes that the area surrounding the site is divided into two categories: water and land. The radioactive material deposited on a spatial element is initially apportioned between water and land according to the fraction of the region covered by land. For coastal sites, where both fresh water and ocean water need to be treated, it is recommended that the user create a site data file with more than one watershed. A site data file can define up to four watersheds. One or more of those watersheds (*e.g.,* ocean) can be defined to have a 0 uptake fraction.

The parameters described below are used to define the behavior of the single watershed that is used when a uniform population density has been specified. The user specifies which radionuclides are to be included with the water ingestion pathway.

Of the activity deposited directly onto water or transferred from land to water, the fraction represented by WINGF determines how much of that deposited activity is eventually consumed by humans. Once the activity is transferred to the water body, there is no adjustment to account for radioactive decay.

Of the activity that is initially deposited on land, some fraction makes its way through runoff into the freshwater supply over a relatively short time period after deposition. This fraction is specified by the value of WSHRTI. The remainder of the material deposited on land is assumed to be washed off to the freshwater supply at a constant fractional rate over the time from *t*=0 to *t*=infinity. The rate at which this subsequent wash off occurs is specified by the value of the rate constant WSHRTA.

The model uses the values of the two variables, WSHRTI and WSHRTA, and evaluates the integral of the wash off fraction in a way that takes account of radioactive decay of the material deposited on land surfaces. The model is described by Helton, Muller, and Bayer (1985). The evaluation of this integral produces a numerical value, *F*, that represents the fraction of activity falling on land that is eventually transferred to surface water bodies that supply drinking water.

With the value of *F*, the uptake fraction of activity deposited on land can be calculated, which is WINGF• *F*. The input variable WINGF is the ratio of the total amount of a radionuclide consumed via the drinking-water pathway (*i.e.,* by the entire population of the region surrounding the facility) and the amount entering potable surface-water bodies. Ideally, a value for WINGF should be derived from a model for radionuclide transport through the surface-water system of the surrounding region.

The models used to determine WINGF can vary in complexity from the very simple (*e.g.,* a single uniformly mixed cell) to the very complex (*e.g.,* three-dimensional fluid transport with temporal and spatial variability). The value of WINGF supplied with the sample problems was derived in a very simple manner.

MACCS Food Model

Ingestion Transfer Factors

When this model is selected, MACCS performs food and water ingestion calculations in the same manner as the original MACCS code used in NUREG-1150.

When radioactive material is deposited on land, some fraction of this material may make its way through the food chain and ultimately be consumed by man in the form of contaminated food or drinking water. The ingestion pathway is modeled in MACCS as a series of transfer processes that the material must undergo between the time of deposition and the consumption of the contaminated food products by humans; these processes decrease the amount of material passed on to the next step in the food chain.

To calculate the population dose resulting from the accumulated contamination of an area, it is necessary to know the efficiency of the entire food chain taken as a whole in transferring material from the ground to man. MACCS calculates the overall efficiency of the two ingestion pathways (food and water) by multiplication of all of the individual transfer factors which are described below, yielding an overall weighted sum representing the effectiveness of the pathway in transferring material from the ground to human consumption.

Removal of Radioactivity from Plant Surfaces by Weathering

When an accident occurs during the growing season, part of the radioactive material deposited on farmland is retained on plant surfaces and the remainder falls on the ground. Between the

time of deposition and the time of harvest, radioactive material can be lost from plant surfaces due to weathering, radioactive decay, translocation to interior portions of the plant, and the harvesting process.

The fraction of radioactive material that is removed from the air due to dry and wet deposition that ends up in edible portions of the harvested plant is referred to as the growing crop retention factor. Specifically, this factor is defined to be the ratio between the amount of a radionuclide present in the crop at harvest and the total amount of material initially deposited onto the land used for producing that crop.

For all crops except pasture, harvesting occurs at the end of the growing season. The harvesting of pasture differs from other crops in that it is a continuous process. In MACCS it is assumed that grazing takes exactly one growing season to harvest the year's entire production of the pasture crop. The numerical integration used in the pasture dose calculations is therefore different from that used for the other crop categories. The type of integration performed by the code is determined by the name given to the crop categories. Crop names beginning with PASTURE are treated differently from the rest.

For crops where the edible portion of the plant is exposed to the environment, weathering losses over the period from deposition to harvesting decreases the amount of radionuclides retained as a function of time. That is, the longer the time between deposition and harvesting, the lower the resultant dose.

Crops such as grains and legumes, which have the edible portions internal to the plant, may show the opposite behavior, with material being absorbed into the plant over time. Since this is a slow process and data on translocation rates are hard to obtain, the user should try to define an average retention factor appropriate for deposition onto crops that is independent of time during the growing season, and not use the weathering model for these types of crops. The situation is further complicated by the fact that available data suggest that total retention for grains is greatest when the deposition occurs near the middle of the growing season rather than at the end of it.

Both types of crops are modeled with a weathering equation that can have up to three exponential terms, each with a different weathering rate. For the types of crops not subject to weathering losses (that is, grains and legumes), a very long half-life can be specified for the weathering rate as a way of replacing the weathering function with a constant transfer fraction.
In MACCS the removal of radioactivity from plant surfaces by weathering is treated as a sum of terms that have the following form:

$$\text{CTCOEF} \cdot \exp(-\lambda \cdot t),$$

Where CTCOEF represents the fraction of material deposited on a cultivated field that is removed by weathering with a decay rate of $\lambda = 0.693 / \text{CTHALF}$.

CTCOEF equals the product of two quantities: the interception fraction and the availability fraction. The interception fraction is the fraction of material deposited onto a field that is intercepted by crop surfaces and the availability fraction is the fraction of material deposited onto crop surfaces that is weathered away with the half-life CTHALF.

When CTCOEF includes the effects of weathering, as suggested above, the exponential part of the weathering decay expression associated with this empirical value for CTCOEF is reduced to unity by setting CTHALF to the maximum allowable value, 3.15×10^{13} s (10^6 yr). Because translocation from the plant surface to interior portions influences the retention of radioactivity

for grains, legumes, and root crops, the weathering model can be modified provide a transfer factor that is nearly constant in time.

Since long-term uptake is treated separately from the growing-season portion of the model, this may cause the long-term uptake dose from grains and legumes to be double counted in the first growing season. However, since root uptake in a single season is typically small relative to the contamination resulting from direct deposition, the potential impact of such a double counting is unlikely to be significant.

The number of terms in the weathering equation is defined in on the *Food* tab. Up to three terms are supported.

Protective Action
In the unlikely event of an accident at a nuclear facility, an assessment of the accident's impact on agricultural production in the surrounding region can be performed with MACCS. Based on a projected dose to an individual consuming locally produced food products, the local authorities determine whether local agricultural products are safe to eat. When the food product is judged to be unsafe, two kinds of actions can be taken: disposal of current-year crops and long-term restriction of agricultural production in subsequent growing seasons.

The MACCS food-chain model divides agricultural activities into four components representing two sets of binary pairs:

- MILK DIRECT-DEPOSITION
- CROP DIRECT-DEPOSITION
- MILK ROOT-UPTAKE
- CROP ROOT-UPTAKE

This terminology is defined as follows. MILK refers to fresh milk and dairy products, such as cheese and butter. CROP refers to all other foodstuffs. DIRECT-DEPOSITION refers to doses that result when an accident occurs during the growing season and the doses are incurred in the single annual period following the accident. When an accident occurs outside of the growing season, the code does not evaluate the need for disposal of crops, and the corresponding doses from DIRECT-DEPOSITION are reported as zero. By contrast, ROOT-UPTAKE refers to food doses that result regardless of whether the accident occurs during the growing season, and these are calculated over an infinite time period. For accidents that occur during the growing season, first-year doses are from *both* direct-deposition and root-uptake in the MACCS food-chain model.

The stringency (degree of protection) for both types of mitigative actions is specified by the user through input parameters. All of these parameters are specified in terms of allowable ground concentration and are referred to as "action guides."

3.4.11.2 Food Chain Forms and Parameters

***Maximum Food Ingestion Dose* Form**
The *Maximum Food Ingestion Dose* form is required when the *COMIDA2 Food Model* is selected on the *Food* tab. When it is not acceptable to produce milk or crops, production is interdicted for up to LASTACUM–1 or 8 years, whichever is smaller, until farmability is restored. When the allowed years of interdiction are insufficient to restore farmability, farmland is condemned.

DOSEMILK, DOSEOTHR, and DOSELONG are vectors of size two. The first entry corresponds to a limit on effective dose, the second corresponds to a limit on thyroid dose. These parameters define the allowable individual food doses that determine farmability.

DOSEMILK is the maximum allowable food ingestion dose from milk products during the year of the accident. For dairy to be allowed in the first year after an accident, individual milk doses must be below this limit. In addition, second-year individual doses from milk products plus crops must not exceed DOSELONG. DOSEMILK is intended to fulfill a purpose similar to that served by the variable PSCMILK of the MACCS food-chain model.

DOSEOTHR is the maximum allowable food ingestion dose from non-milk crops during the year of the accident. For crops to be produced in the first year after an accident, individual doses from consumption of crops must be below this limit. In addition, second-year doses from milk plus crops must not exceed DOSELONG. This variable is intended to fulfill a purpose similar to that served by the variable PSCOTHR of the MACCS food-chain model.

DOSELONG is the maximum allowable "long-term" annual dose to an individual from ingestion of the combination of milk and non-milk crops. These parameter values are used for determining whether agricultural production is suitable for consumption in years subsequent to the year of the accident.

To use the COMIDA2 food-chain model in MACCS, the user must at a minimum select the lifetime (L-) organ flags to be true for two organs, effective and thyroid, for the EARLY variable ORGFLG.

Variable Name	Definable	Type	Dimensions	Allowed Values
DOSEMILK	Yes	Real	2	0.0 to 1×10^{10} Sv
DOSEOTHR	Yes	Real	2	0.0 to 1×10^{10} Sv
DOSELONG	Yes	Real	2	0.0 to 1×10^{10} Sv

***Radionuclides* Form**

The Radionuclides form is required when *MACCS Food Model* is selected on the *Food* tab. This model does not account for the food ingestion doses from decay products of the food pathway radionuclides defined in NAMIPI. For this reason, the MACCS food-chain model should only be used with DCF files created by DOSFAC because they include doses from short-lived decay products with their parents.

NFIISO defines the number of radionuclides for the food-ingestion pathway.

NAMIPI defines the set of radionuclides used in the food-pathway model. This list must include all of the radionuclides that are specified for the drinking water pathway, and they must appear in the same order as in NAMWPI.

Variable Name	Definable	Type	Dimensions	Allowed Values
NFIISO	Linked	Integer	None	1 to 10
NAMIPI	Yes	Character	NFIISO	Radionuclides defined in ATMOS variable NUCNAM

***Crop Ingestion* Form**

The *Crop Ingestion* form is required when the *MACCS Food Model* is selected on the *Food* tab.

NFICRP defines the number of crop categories that are used by the food-pathway model.

NAMCRP defines the name of a crop category used in the food-pathway model. MACCS distinguishes between two types of crops: those harvested at the end of the growing season, and those harvested continuously over the entire growing season. The first seven letters of the crop names supplied here are used to distinguish between these two types of crops. When a crop's name begins with 'PASTURE', it is harvested continuously; when it doesn't, it is harvested at the end of the growing season.

FRCTCH specifies the fraction of the edible portion of the harvested crop that is consumed by humans. The user must supply NFICRP values for this variable in column 2 of the data block.

FRCTCM specifies the fraction of the edible portion of the harvested crop that is consumed by milk-producing animals.

FRCTCB specifies the fraction of the edible portion of the harvested crop that is consumed by meat-producing animals.

Variable Name	Definable	Type	Dimensions	Allowed Values
NFICRP	Linked	Integer	None	1 to 10
NAMCRP	Yes	Character	NFICRP	6 to 20 characters
FRCTCH	Yes	Real	NFICRP	0.0 to 1.0
FRCTCM	Yes	Real	NFICRP	0.0 to 1.0
FRCTCB	Yes	Real	NFICRP	0.0 to 1.0

***Meat/Milk Ingestion* Form**

The *Meat/Milk Ingestion* form is required when the *MACCS Food Model* is selected on the *Food* tab.

DCYPMH is the transfer factor describing the processing losses and radioactive decay that occur between the production and the consumption of milk products. Specifically, it is the ratio of the amount of a radionuclide in milk products at the time of consumption to the amount in the milk at the time of its production (milking). The values are multiplied by the values of TFMLK to define the efficiency of the milk-to-man food pathway.

DCYPBH is the transfer factor describing the processing losses and radioactive decay that occur between the production and the consumption of meat products. It is the ratio of the amount of a radionuclide in meat products at the time of consumption to the amount of that radionuclide in the meat at the time of its production (slaughter). The values given here are multiplied by the values given for TFBF in order to define the efficiency of the meat-to-man pathway

TFMLK is the transfer factor describing how much of a radionuclide ingested by milk-producing animals ends up in milk products at the time of their production (milking). It is the ratio of the amount of a radionuclide in fresh milk to the amount of the radionuclide consumed by milk-producing animals. It accounts for biological transport within the animal as well as radioactive decay. The values are multiplied by the values of DCYPMH to define the efficiency of the milk-to-man food pathway.

TFBF is the transfer factor describing how much of the material ingested by meat-producing animals ends up in meat products at the time of their production. It is the ratio of the amount of a radionuclide in edible meat at the time of slaughter to the amount of the radionuclide that was

consumed by the meat-producing animals. It takes account of biological transport within the animals as well as radioactive decay. The values are multiplied by the values of DCYPBH to define the efficiency of the meat-to-man food pathway.

Variable Name	Definable	Type	Dimensions	Allowed Values
DCYPMH	Yes	Real	NFIISO	0.0 to 1.0
DCYPBH	Yes	Real	NFIISO	0.0 to 1.0
TFMLK	Yes	Real	NFIISO	0.0 to 1.0
TFBF	Yes	Real	NFIISO	0.0 to 1.0

***Soil to Edible Crops* Form**

The *Soil to Edible Crops* form is required when *MACCS Food Model* is selected on the *Food* tab.

TCROOT defines the transfer factor for long-term transfer of radionuclides from soil to edible crops. This is the ratio of the amount of a radionuclide taken up from soil into edible portions of a crop to the amount that was deposited onto the soil. The long-term transfer of radionuclides from soil to plants occurs principally by uptake (sorption) by plant root systems. Transfer to plant surfaces by rain splash and by deposition of materials resuspended from surface soil can also contribute to this pathway.

The values of TCROOT supplied in the data block should be calculated by integrating the overall uptake rate over the period from t=0 to infinity. In other words, TCROOT incorporates the total uptake over all time after the initial deposition. Since radionuclides are removed from the soil compartment not only by root uptake but also by radioactive decay, percolation, and irreversible chemical binding, all of these processes should be incorporated into the derivation of TCROOT.

The annual rate at which the material is made unavailable by these processes is specified by the input variable QROOT.

Variable Name	Definable	Type	Dimensions	Allowed Values
TCROOT	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

***Crop Radioactive Decay Loss* Form**

The *Crop Radioactive Decay Loss* form is required when *MACCS Food Model* is selected on the *Food* tab.

DCYPCH is the ratio of the amount of a radionuclide present in a crop at the time of consumption and the time of harvest, accounting for losses due to radioactive decay. The values are used to calculate ingestion doses arising from both direct deposition onto growing crops and the long-term uptake processes of subsequent growing seasons. It is only applied to crops that are directly consumed by humans (*e.g.,* grains, vegetables, and legumes). Values supplied for crops not consumed by humans have no impact on the calculations. The values are multiplied by the corresponding values of FPLSCH, which characterizes processing losses, to obtain the overall transfer factor for this part of the food chain. Values of DCYPCH must be specified for each crop category for all radionuclides treated by the food pathway model (*i.e.,* for all possible radionuclide/crop combinations).

Variable Name	Definable	Type	Dimensions	Allowed Values
DCYPCH	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

***Meat/Milk Radioactive Decay Loss* Form**
The *Meat/Milk Radioactive Decay Loss* form is required when *MACCS Food Model* is selected on the *Food* tab.

DCYPCM is the ratio of the amount of a radionuclide in the crop at the time of its consumption to the amount at the time of harvest. The data supplied here are used in calculating ingestion dose arising from both direct deposition onto growing crops and the long-term uptake processes of subsequent growing seasons. It is applied only to crops that are directly consumed by milk-producing animals (e.g., pasture and forage). Any values supplied for crops not consumed by milk-producing animals have no impact on the calculations.

For pasture crops, harvest and consumption are simultaneous and so DCYPCM should be set to 1.0 for the pasture crop categories. Values of DCYPCM must be specified for each crop category for all radionuclides treated by the food pathway model (i.e., for all possible radionuclide-crop combinations).

Variable Name	Definable	Type	Dimensions	Allowed Values
DCYPCM	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

***Crop Radioactive Retention* Form**
The *Crop Radioactive Retention* form is required when the *MACCS Food Model* is selected on the *Food* tab.

FPLSCH is the ratio of the amount of a radionuclide in the crop after it has been processed for human consumption to the amount before processing. The retention factor reflects the fraction of radioactive material in the edible portion of the plant that is retained after washing, peeling, or cooking. The values apply only to crops that are directly consumed by humans. Values specified for crops such as pasture have no impact on calculations.

Values of FPLSCH must be specified for each crop category for all radionuclides treated by the food pathway model (i.e., for all possible radionuclide-crop combinations). The values are multiplied with the corresponding values of DCYPCH in order to obtain the overall transfer factor for this part of the food chain.

Variable Name	Definable	Type	Dimensions	Allowed Values
FPLSCH	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

***Meat/Milk Radioactive Retention* Form**
The *Meat/Milk Radioactive Retention* form is required when *MACCS Food Model* is selected on the *Food* tab.

DCYPCB is the ratio of the amount of a radionuclide in the crop at the time of its consumption to the amount of that radionuclide in the crop at the time of harvest. This factor is only applied to

crops that are directly consumed by meat producing animals (e.g. pasture and forage). Values supplied for crops not consumed by meat-producing animals have no impact on the calculations.

Values of DCYPCB must be specified for each crop category for all radionuclides treated by the food pathway model (i.e., for all possible radionuclide-crop combinations).

Variable Name	Definable	Type	Dimensions	Allowed Values
DCYPCB	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

***Term One CTCOEF for Weathering* Form**
The *Term One CTCOEF for Weathering* form is required when *MACCS Food Model* is selected on the *Food* tab.

CTCOEF corresponds to the constant multiplier of the first term in the weathering equation as described in Subsection 3.4.11.1. This variable defines the product of the interception fraction and the availability fraction for each term in the weathering model for crops with exposed edible portions. For plants with edible portions internal to the plant, this defines the combined transfer fraction for interception, weathering, and translocation to seeds averaged over an entire growing season. Values of CTCOEF must be specified for each crop category and for all radionuclides treated by the food pathway model.

Variable Name	Definable	Type	Dimensions	Allowed Values
CTCOEF	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

***Term One CTHALF for Weathering* Form**
The *Term One CTHALF for Weathering* form is required when *MACCS Food Model* is selected on the *Food* tab.

CTHALF corresponds to the half-life value of the first term in the weathering equation, as described in Subsection 3.4.11.1. The values supplied for CTHALF must be properly paired with the corresponding values of CTCOEF defined in the previous form. Values of CTHALF must be specified for each crop category for all radionuclides treated by the food pathway model.

Variable Name	Definable	Type	Dimensions	Allowed Values
CTHALF	Yes	Real	NFIISO by NFICRP	1.0 to 3.15×10^{13} s

***Term Two CTCOEF for Weathering* Form**
The *Term Two CTCOEF for Weathering* form is required when *MACCS Food Model* is selected on the *Food* tab and the *Number of Crop Weathering Terms* is set to *Two Terms* or *Three Terms.*

CTCOEF corresponds to the constant multiplier of the second term in the weathering equation as described in Subsection 3.4.11.1. It defines the product of the interception fraction and the

availability fraction for each term in the weathering model for crops with exposed edible portions. For plants with edible portions internal to the plant, it defines the combined transfer fraction for interception, weathering, and translocation to seeds averaged over an entire growing season. Values of CTCOEF must be specified for each crop category and for all radionuclides treated by the food pathway model.

Variable Name	Definable	Type	Dimensions	Allowed Values
CTCOEF	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

***Term Two CTHALF for Weathering* Form**

The *Term Two CTHALF for Weathering* form is required when *MACCS Food Model* is selected on the *Food* tab and the *Number of Crop Weathering Terms* is set to *Two Terms* or *Three Terms.*

CTHALF corresponds to the half-life value of the second term in the weathering equation as described in Subsection 3.4.11.1. Values must be specified for each crop category for all radionuclides treated by the food pathway model.

Variable Name	Definable	Type	Dimensions	Allowed Values
CTHALF	Yes	Real	NFIISO by NFICRP	1.0 to 3.15×10^{13} s

***Term Three CTCOEF for Weathering* Form**

The *Term Three CTCOEF for Weathering* form is required when *MACCS Food Model* is selected on the *Food* tab and the *Number of Crop Weathering Terms* is set to *Three Terms.* In this case, variable NTTRM is set to three.

CTCOEF corresponds to the constant multiplier of the third term in the weathering equation as described in the section titled Removal of Radioactivity from Plant Surfaces by Weathering. This variable defines the product of the interception fraction and the availability fraction for each term in the weathering model for crops with exposed edible portions. For plants with edible portions internal to the plant, this defines the combined transfer fraction for interception, weathering, and translocation to seeds averaged over an entire growing season.

Values of CTCOEF must be specified for each crop category and for all radionuclides treated by the food pathway model.

Variable Name	Definable	Type	Dimensions	Allowed Values
CTCOEF	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

***Term Three CTHALF for Weather* Form**

The *Term Three CTHALF for Weathering* form is required when *MACCS Food Model* is selected on the *Food* tab and the *Number of Crop Weathering Terms* is set to *Three Terms.* In this case, variable NTTRM is set to three.

CTHALF corresponds to the half-life value of the third term in the weathering equation as described in the section titled Removal of Radioactivity from Plant Surfaces by Weathering. .

The values supplied for CTHALF must be properly paired with the corresponding values of CTCOEF defined in the previous form.

Values of CTHALF must be specified for each crop category for all radionuclides treated by the food pathway model.

Variable Name	Definable	Type	Dimensions	Allowed Values
CTHALF	Yes	Real	NFIISO by NFICRP	1.0 to 3.15×10^{13} s

***Crop Share and Growing Season* Form**
The *Crop Share and Growing Season* form is required when the *MACCS Food Model* is selected on the *Food* tab and the *Site Data Specification* is set to *Uniform* on the *Site Data* tab. Values are taken from the site file when *Import from File* is chosen on the *Site Data* tab.

TSGBEG defines the start of the growing season for the named crop category in terms of Julian day (January 1 is day 1).

TGSEND defines the end of the growing season for the named crop category in terms of Julian day.

FRCTFL defines the fraction of cultivated farmland that is used to grow the named crop category.

Variable Name	Definable	Type	Dimensions	Allowed Values
TGSBEG	Yes	Real	NFICRP	1.0 to 365.0 Jullian day
TGSEND	Yes	Real	NFICRP	1.0 to 365.0 Jullian day
FRCTFL	Yes	Real	NFICRP	0.0 to 1.0

Protective Action Form
The *Protective Action* form is required when *MACCS Food Model* is selected on the *Food* tab.

For an accident that occurs during the growing season, there are two types of actions that can occur: disposal of milk and its products and disposal of crops other than milk (nonmilk crops). All agricultural production is divided between these two categories. The action levels used for determining when these two actions are necessary are the input variables PSCMLK and PSCOTH, which are defined below.

When contamination levels are too high, agricultural production is restricted for one or more years after an accident. A single set of values for allowable ground concentration (variable GCMAXR) is used to make this determination. During the long-term interdiction period, either all crops (both milk and nonmilk) can be produced or no crops can be produced.

For accidents that occur outside of the growing season, MACCS, in all cases, evaluates only the long-term action level (GCMAXR). The growing season action levels, PSCMLK and PSCOTH, are not evaluated since crop disposal can only occur during the growing season. For accidents that occur during the growing season, however, both types of criteria (growing season and long-term) may be evaluated by the code. It is up to the user to determine whether these two

types of evaluation are performed either independently of each other (uncoupled) or in such a way that the exceedance of one type of criteria automatically forces the exceedance of the other criteria (coupled). The choice of these two options is defined by the user-specified input parameter, COUPLD.

When the two types of criteria are chosen to be evaluated independently, there are no interactions between the growing season pathway and the long-term pathway. The resulting doses and economic costs from these two components of the food model are calculated in a completely independent manner.

When the user chooses the option of a coupled evaluation, the following rules define the interactions between two types of actions. Whenever the long-term criteria (GCMAXR) are exceeded, the disposal of any growing crops (both milk and nonmilk) is automatically triggered. Alternatively, whenever both milk and nonmilk crop disposal are called for as a result of exceeding both the PSCMLK and PSCOTH criteria, the code automatically imposes at least 1 year of long-term farmland interdiction.

COUPLD defines whether the growing season and the long term action levels are evaluated in a coupled manner (True) or in a totally independent manner (False).

PSCMLK defines the growing season protective action level (i.e., maximum permissible surface concentration), for milk and milk products for the named radionuclide.

PSCOTH defines the growing season protective action level, maximum permissible surface concentration, for non-milk crops and their products for the named radionuclide.

The long-term uptake fractions for root uptake and soil ingestion by animals have been previously defined by variable TCROOT. These uptake fractions are integrated over all time, that is, from t=0 to t=infinity. MACCS allows the user to define a model for the temporary interdiction of the long-term uptake pathway when certain ground contamination levels are exceeded at the time of the accident. When this model is activated, and temporary interdiction of long-term uptake is needed, the period of temporary interdiction is the shortest number of whole years that allows the long-term criteria to be met. The longest allowed period of long-term interdiction is 8 years. When 8 years of weathering and radioactive decay are insufficient, the farmland is condemned and permanently removed from production.

GXMAXR defines the protective action level (i.e., maximum permissible surface concentration) for long-term crop production for the named radionuclide. This is the criteria to be met for each ingestion radionuclide.

QROOT defines the rate constant for the decrease in availability over the temporary interdiction period. This value accounts for radioactive decay, irreversible chemical binding to the soil, percolation downward into the soil and uptake into plants or ingestion by animals.

The value assigned to QROOT is used to determine how effective temporary interdiction of the long-term agricultural pathway is for reducing ingestion doses. For example, when the depletion rate is 0.5 per year (*i.e.,* 50%/annum), a year of temporary interdiction causes the integrated dose to be EXP(–0.5) of what it would be if there were no interdiction.

The MACCS food model input variables PSCMILK, PSCOTH, and GCMAXR are specified in terms of maximum allowable ground concentrations for each food radionuclide. The model sums the ratios of the actual to the maximum concentrations for the set of radionuclides. When this value is greater than 1.0, interdiction is imposed.

Variable Name	Definable	Type	Dimensions	Allowed Values
COUPLD	Yes	Logical	None	True, False
PSCMLK	Yes	Real	NFIISO	1×10^{-6} to 1×10^{20} Bq/m^2
PSCOTH	Yes	Real	NFIISO	1×10^{-6} to 1×10^{20} Bq/m^2
GXMAXR	Yes	Real	NFIISO	1×10^{-6} to 1×10^{35} Bq/m^2
QROOT	Yes	Real	NFIISO	0.0 to 1×10^{35} per year

***Water Ingestion Radionuclides* Form**

The *Water Ingestion Radionuclides* form is required when either *MACCS Food Model* or *COMIDA2 Food Model* is selected on the *Food* tab.

When *Import from File* is selected on the *Site Data* tab, the entries on this form must agree with the water ingestion radionuclides specified in the site data file.

NUMWPI defines the number of water ingestion radionuclides. Its value is determined by the number of rows in the grid containing values of NAMWPI.

NAMWPI defines the name of a radionuclide used in the drinking water pathway. The user must supply these nuclides in the same order that they were previously specified. Nuclide choices are from variable NAMIPI when the MACCS food-chain model is used. The choices must be consistent with radionuclides specified for COMIDA2 when that food-chain model is used.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUMWPI	Linked	Integer	None	1 to 10
NAMWPI	Yes	Character	NUMWPI	Must select a radionuclide defined in NAMIPI

***Water Washoff Fraction* Form**

The *Water Washoff Fraction* form is required when either the *MACCS Food Model* or *COMIDA2 Food Model* is selected on the *Food* tab.

When the *Site Data Specification* is set to *Import from File* on the *Site Data* tab, the entries on this form are not used. Instead, the corresponding values specified in the site data file are used.

For the purpose of calculating water ingestion doses, there is no provision for modeling the buildup of any radioactive daughter products that result from decay. There is no provision for accounting for the water ingestion dose resulting from radioactive daughter products of the water pathway radionuclides defined in NAMWPI.

WSHFRI defines the initial washoff fraction for the specified radionuclide. This is the fraction of material deposited on land that is easily washed off into the watershed drainage system immediately following the deposition of that radionuclide.

WSHRTA defines the annual washoff rate for the specified radionuclide. This is the rate at which material deposited on land is washed off into the watershed drainage system following the initial deposition.

Variable Name	Definable	Type	Dimensions	Allowed Values
WSHFRI	Yes	Real	NUMWPI	0.0 to 1.0
WSHRTA	Yes	Real	NUMWPI	0.0 to 1.0 per year

***Water Ingestion Factor* Form**
The *Water Ingestion Factor* form is required when the *MACCS Food Model* or *COMIDA2 Food Model* is selected on the *Food* tab and the *Site Data Specification* is set to *Uniform* on the *Site Data* tab.

WINGF defines the water ingestion factor for the radionuclide. This factor specifies the fraction of the radioactivity washed into the drainage system of the watershed that is ultimately consumed by humans.

Variable Name	Definable	Type	Dimensions	Allowed Values
WINGF	Yes	Real	NUMWPI	0.0 to 1.0

3.4.12 Output Control

3.4.12.1 Output Control Forms and Parameters

***Debug Flag* Form**
The *Debug Flag* form is required. This flag allows the user to print a detailed listing of values for intermediate variables used in CHRONC calculations. The output for this option is written to the output file. Most of the variables output are CHRONC internal FORTRAN variables. Thus, this output may be more useful to MACCS developers than to a user.

KSWTCH is used to print intermediate results on the output listing. This variable should be set to 0 for normal calculations. Because a nonzero value generates a large amount of output, it is preferable to use this option for single weather trial runs.

Variable Name	Definable	Type	Dimensions	Allowed Values
KSWTCH	Yes	Integer	None	0 or 1

***Population Dose Results* Form**
The *Population Dose Results* form is optional.

The CHRONC module calculates long-term population dose broken down by pathway for a list of organs defined in the EARLY input file. The option to examine this breakdown of long-term population doses for organs selected from the set of available organs is described in this section. This result type has no counterpart in the EARLY module. The EARLY module can produce just one consequence measure for population dose, which is total population dose for a specific organ.

No long-term population dose results for an organ are produced on the output listing unless the user requests it. Each request for the breakdown of the long-term population dose to an organ produces the block of either 12 or 15 dose results (depending on which food model is being used) identified below. All of the dose results are reported in person-Sv although the units are listed simply as Sieverts (Sv) in the output file. The following dose results are reported:

- TOTAL LONG-TERM PATHWAYS DOSE—total long-term population dose from groundshine and resuspension, from the consumption of contaminated food, from the ingestion of contaminated surface water, and from decontamination work.
- LONG-TERM DIRECT EXPOSURE PATHWAYS—total long-term population dose to resident population from groundshine and resuspension.
- TOTAL INGESTION PATHWAYS DOSE—total long-term population dose from the consumption of contaminated dairy products, contaminated nondairy products, and contaminated water.
- LONG-TERM GROUNDSHINE DOSE—total long-term population dose received by resident population from groundshine.
- LONG-TERM RESUSPENSION DOSE—total long-term population dose received by resident population from resuspension.
- POP.-DEPENDENT DECONTAMINATION DOSE—total long-term population dose received from groundshine by workers performing "population dependent" (nonfarm) decontamination (decontamination workers receive no inhalation dose).
- FARM-DEPENDENT DECONTAMINATION DOSE—total long-term population dose received from groundshine by workers performing "farm dependent" (farmland) decontamination (decontamination workers receive no inhalation dose).
- WATER INGESTION DOSE—total long-term population dose from ingestion of contaminated surface water.

When the MACCS food-chain model is used, the following food pathway results are reported:

- MILK GROWING SEASON DOSE—total long-term population dose resulting from consumption of milk and dairy products contaminated as a result of deposition onto crops during the growing season.
- CROP GROWING SEASON DOSE—total long-term population dose resulting from consumption of nonmilk food products contaminated as a result of deposition onto crops during the growing season.
- MILK LONG-TERM DOSE—total long-term population dose resulting from consumption of milk and dairy products contaminated by long-term uptake in the period following the accident.
- CROP LONG-TERM DOSE—total long-term population dose resulting from consumption of nondairy crops and their products contaminated by long-term uptake in the period following the accident.

When the COMIDA2 food-chain model is used, the following food pathway results are reported:

- INGESTION OF GRAINS—total long-term population dose resulting from consumption of grains by humans.
- INGESTION OF LEAF VEG—total long-term population dose resulting from consumption of leafy vegetables by humans.
- INGESTION OF ROOT CROPS—total long-term population dose resulting from consumption of root crops by humans.
- INGESTION OF FRUITS—total long-term population dose resulting from consumption of fruits by humans.
- INGESTION OF LEGUMES—total long-term population dose resulting from consumption of legumes by humans.
- INGESTION OF BEEF—total long-term population dose resulting from consumption of beef by humans.
- INGESTION OF MILK—total long-term population dose resulting from consumption of milk by humans.
- INGESTION OF POULTRY—total long-term population dose resulting from consumption of poultry by humans.

- INGESTION OF OTHER MEAT CROPS—total long-term population dose resulting from consumption of other meat crops by humans.

The region of interest, as specified earlier, is used to determine the size of the potentially contaminated area being evaluated. In the context of this consequence measure, the population dose within a region is the population dose that occurs as a result of activity deposited within the region. For groundshine and resuspension inhalation, the dose is received by the resident population, but for ingestion and doses to decontamination workers, the dose could be received by individuals who reside elsewhere.

NXUM9 specifies the number of results. Its value is determined by the number of rows in the grid containing vectors ORGNAM, IX1DS9, IX2DS9, and Report Options.

ORGNAM defines the name of the organ for which the long-term dose breakdown is to be reported. The possible values depend on the DCF file chosen.

IX1DS9 defines the inner spatial interval of the region of interest. The location is the inner radius of the specified ring.

IX2DS9 defines the outer spatial interval of the region of interest. The location is the outer radius of the specified ring. MACCS requires that the value must be greater than or equal to IX2DS9.

Report Options determine whether CCDF data are written to the MACCS output file and whether the data are to be included in the summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NXUM9	Linked	Integer	None	0 to 10
ORGNAM	Yes	Character	NXUM9	Must select a Long Term Organ name specified in EARLY
IX1DS9	Yes	Integer	NXUM9	1 to NUMRAD
IX2DS9	Yes	Integer	NXUM9	1 to NUMRAD
Report Options	Yes	Character	NXUM9	CCDF, NONE, REPORT, CCDF & REPORT

***Economic Cost Results* Form**

The Economic Cost Results form is optional. The CHRONC module calculates the economic costs of all the long-term protective actions as well as the cost of the emergency response actions that were modeled by EARLY.

No economic costs are printed unless the user specifically requests them. When Flag10 is set to true, each request for economic results produces the block of 13 economic results described below. All of the economic cost measures are reported in dollars.

- TOTAL ECONOMIC COSTS—the sum of population- and farm-dependent costs.
- POP.-DEPENDENT COSTS—the sum of population-dependent decontamination, interdiction, and condemnation costs.
- FARM-DEPENDENT COSTS—the sum of farm-dependent decontamination, interdiction, and condemnation costs as well as milk and crop disposal costs.
- POP.-DEPENDENT DECONTAMINATION COST—nonfarm property (*i.e.,* property associated with resident population) decontamination cost.

- FARM-DEPENDENT DECONTAMINATION COST—farm property decontamination cost.
- POP.-DEPENDENT INTERDICTION COST—depreciation and deterioration of nonfarm property during the period it cannot be used during both decontamination and interdiction plus the cost of population removal (see POPCST in Section 7.6).
- FARM-DEPENDENT INTERDICTION COST—depreciation and deterioration of farm property during the period it cannot be used during both decontamination and interdiction.
- POP.-DEPENDENT CONDEMNATION COST—compensation paid for permanent loss of nonfarm property plus the cost of population removal.
- FARM-DEPENDENT CONDEMNATION COST—compensation paid for permanent loss of farm property because it could not be returned to production within 8 years of the accident.
- EMERGENCY PHASE COSTS—per-diem costs to compensate people for being away from home due to evacuation and relocation during the emergency phase. When more than one emergency response scenario is being evaluated by the EARLY module, the presentation of evacuation and relocation cost is calculated on the basis of the scenario that was defined last in sequence on the EARLY input file.
- INTERMEDIATE PHASE COSTS—per-diem costs to compensate people for being away from home due to relocation for the duration of the intermediate phase when DSCRTI is exceeded.
- MILK DISPOSAL COSTS—compensation for lost milk sales during a quarter of a year when the first year's crops require disposal. This cost is incurred when the accident occurs during the growing season *and* any of the following conditions are found: the growing-season milk action guide is exceeded, or any decontamination actions are required, or (for MACCS food model only) when COUPLD=.TRUE. *and* any long-term interdiction is required.
- CROP DISPOSAL COSTS—compensation for lost nonmilk crop sales during a full year. This cost is incurred when the accident occurs during the growing season and any of the following conditions are found: the growing-season nonmilk action guide is exceeded, or any decontamination actions are required, or (for MACCS food model only) when COUPLD=.TRUE. *and* any long-term interdiction is required.

NXUM10 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors I1DS10, I2DS10 and Report Options.

I1DS10 defines the inner spatial interval of the region of interest. The location is the inner radius of the specified ring.

I2DS10 defines the outer spatial interval of the region of interest. The location is the outer radius of the specified ring. MACCS requires that the value must be greater than or equal to I2DS10.

FLAG10 equal to true extends the output to include an expanded breakdown of costs.

Report Options determine whether CCDF data are written to the MACCS output file, and whether the data are to be included in the WinMACCS summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NXUM10	Linked	Integer	None	0 to 10
I1DS10	Yes	Integer	NXUM10	1 to NUMRAD
I2DS10	Yes	Integer	NXUM10	1 to NUMRAD

Variable Name	Definable	Type	Dimensions	Allowed Values
FLAG10	Yes	Logical	NXUM10	True, False
Report Options	Yes	Character	NXUM10	CCDF, NONE, REPORT, CCDF & REPORT

***Action Distance Results* Form**

The Action Distance Results form is required when the *MACCS Food Model* or *COMIDA2 Food Model* is selected on the *Food* tab.

The long-term protective actions that result from the calculations of the CHRONC module depend on the data supplied by the user. Associated with the long-term actions of decontamination, interdiction, and crop disposal are the maximum distances to which these actions are implemented.

The option to print these long-term action distances is controlled by a flag specified by the user. When FLAG11 is set to true, MACCS produces the eight maximum action distance results that are described below. Each result is identified by the result name used on the output file along with a description of the result.

- FARM-DEPENDENT DECONTAMINATION DIST.—maximum distance at which farmland decontamination is required.
- POP.-DEPENDENT DECONTAMINATION DIST.—maximum distance at which non-farmland decontamination is required.
- FARM-DEPENDENT INTERDICTION DIST.—maximum distance at which farmland decontamination or interdiction is required.
- POP.-DEPENDENT INTERDICTION DIST.—maximum distance at which non-farmland decontamination or interdiction is required.
- FARM-DEPENDENT CONDEMNATION DIST.—maximum distance at which farmland condemnation is required.
- POP.-DEPENDENT CONDEMNATION DIST.—maximum distance at which non-farmland condemnation is required.
- MILK DISPOSAL DIST.—maximum distance at which the loss of 3 months of milk and dairy products sales is required.
- CROP DISPOSAL DIST.—maximum distance at which the loss of 1 year of nonmilk crop sales is required.

FLAG11 set to true indicates that the output file includes maximum action distance at which decontamination or interdiction is required for various categories or data.

Report Options determine whether CCDF data are written to the MACCS output file, and whether the data are to be included in the WinMACCS report generated after simulations are completed.

Variable Name	Definable	Type	Dimensions	Allowed Values
FLAG11	Yes	Logical	1	True, False
Report Options	Yes	Character	1	CCDF, NONE, REPORT, CCDF & REPORT

Impacted Area/Population Results Form

The Impacted Area/Population Results form is optional when MACCS Food Model or COMIDA2 Food Model is selected on the Food tab. Associated with the long-term actions of decontamination, interdiction, condemnation, and crop disposal are the farm areas and populations that are affected by these actions. The option to print these impacted area/population results are controlled by the user.

Each request for impacted farm-area/population results produces the block of eight results described below.

- FARM DECONTAMINATION (HECTARES)—area within which farmland decontamination was required.
- POP. DECONTAMINATION (INDIVIDUALS)—population of areas that required decontamination of nonfarm property.
- FARM INTERDICTION (HECTARES)—farmland area which required either decontamination or interdiction.
- POP. INTERDICTION (INDIVIDUALS)—population of areas that required either decontamination or interdiction of nonfarm property.
- FARM CONDEMNATION (HECTARES)—area within which farmland condemnation was required.
- POP. CONDEMNATION (INDIVIDUALS)—population of areas that required condemnation of nonfarm property.
- MILK DISPOSAL AREA (HECTARES)—affected area requiring the loss of milk and dairy products sales for 3 months.
- CROP DISPOSAL AREA (HECTARES)—affected area requiring the loss of nonmilk crop sales for a year.

NUM12 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors I1DS12, I2DS12, and Report Options.

I1DS12 defines the inner spatial interval of the region of interest. The location is the inner radius of the specified ring.

I2DS12 defines the outer spatial interval of the region of interest. The location is the outer radius of the specified ring. MACCS requires that the value must be greater than or equal to I1DS12.

Report Options determine whether CCDF data are written to the MACCS output file, and whether the data are to be included in the summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM12	Linked	Integer	None	0 to 10
I1DS12	Yes	Integer	NUM12	1 to NUMRAD
I2DS12	Yes	Integer	NUM12	1 to NUMRAD
Report Options	Yes	Character	NUM12	CCDF, NONE, REPORT, CCDF & REPORT

Individual Food Ingestion Dose Form

The *Individual Food Ingestion Dose* form is optional when the *COMIDA2 Food Model* is selected on the *Food* tab.

MACCS reports statistics on the maximum food ingestion dose calculated for each of the wind directions within a user-specified spatial interval for effective dose or thyroid dose. No other organs are available for this result.

The maximum dose is the dose calculated using the food consumption rates specified in the COMIDA2 input file for a representative individual. The projected doses in years 1 through 9 are examined in turn, and the maximum value found is used in generating this result.

NUM13 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors I1DS12, I2DS12, and Report Options.

IRAD13 defines the spatial interval of the region of interest. The location is the outer radius of the specified ring.

ORGN13 defines the organ to be used for each requested result.

Report Options determine whether CCDF data are written to the MACCS output file, and whether the data are to be included in the summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM13	Linked	Integer	None	0 to 20
IRAD13	Yes	Integer	NUM13	1 to NUMRAD
ORGN13	Yes	Character	NUM13	EFFECTIVE, THYROID
Report Options	Yes	Character	NUM13	CCDF, NONE, REPORT, CCDF & REPORT

***Impacted Population Results* Form**

The *Impacted Population Results* form is optional.

The results from this output type convey information about evacuees, relocatees, and impacted individuals for each phase. The output includes the following results:

- EVACUEES NOT AFFECTED BY PLUME—the number of evacuees whose property is not contaminated and can return during or immediately after the emergency phase
- EVACUEES AFFECTED BY PLUME—the number of evacuees whose property is affect is contaminated and may not be able to return immediately after the emergency phase
- NORMAL EMERGENCY PHASE RELOCATION—the number of relocatees who are affected by normal relocation during the emergency phase
- HOTSPOT EMERGENCY PHASE RELOCATION—the number of relocatees who are affected by hotspot relocation during the emergency phase
- INTERMEDIATE PHASE RELOCATION—the number of relocatees during the intermediate phase
- LEVEL 1 DECONTAMINATION RELOCATION—the number of people whose property requires the first level of decontamination during the long-term phase
- LEVEL 2 DECONTAMINATION RELOCATION—the number of people whose property requires the second level of decontamination during the long-term phase
- LEVEL 3 DECONTAMINATION RELOCATION—the number of people whose property requires the third level of decontamination during the long-term phase, but can return immediately after the decontamination is completed
- DECONTAMINATION+INTERDICTION RELOC—the number of people whose property requires the highest level of decontamination (depending on the number of levels specified in the input) plus additional interdiction following the decontamination

- CONDEMNATION RELOCATION—the number of people whose property is condemned

NUM14 specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors I1DS14, I2DS14, and Report Options.

I1DS14 defines the inner spatial interval of the region of interest. The location is the inner radius of the specified ring.

I2DS14 defines the outer spatial interval of the region of interest. The location is the outer radius of the specified ring. MACCS requires that the value must be greater than or equal to I1DS14.

Report Options determine whether CCDF data are written to the MACCS output file, and whether the data are to be included in the summary report.

Variable Name	Definable	Type	Dimensions	Allowed Values
NUM14	Linked	Integer	None	0 to 10
I1DS14	Yes	Integer	NUM14	1 to NUMRAD
I2DS12	Yes	Integer	NUM14	1 to NUMRAD
Report Options	Yes	Character	NUM14	CCDF, NONE, REPORT, CCDF & REPORT

4. WINMACCS REFERENCE GUIDE

4.1 Software Components

The MACCS suite is a set of interconnected software components. A description of the main software components follows.

4.1.1 WinMACCS

The WinMACCS user interface was created using Microsoft Visual Basic Pro 6.0 (Service Pack 5) and Microsoft Access 2010. WinMACCS is the graphical user interface used to modify input variables and model settings. WinMACCS creates input files, initiates the MACCS model and post processes MACCS results.

The following initialization files are used by WinMACCS:

- WinMACCS.ini contains initial settings. This file resides in the same folder as WinMACCS.exe. It is self-documenting, and can be edited in an ASCII editor such as Notepad.
- Initialize2000.mdb is a Microsoft database used to create a project file.

4.1.2 MACCS

The MACCS executable file was created using Intel Visual FORTRAN version 11.1. MACCS is the modeling engine and can be initiated from WinMACCS or independently from a command prompt window.

The following input files may be required, depending on modeling choices. These files are either created in MACCS or supplied by the user when MACCS is initiated via a command prompt window:

- ATMOS input file containing parameters pertaining to atmospheric transport, dispersion, deposition, and source term;
- EARLY input file containing parameters pertaining to the emergency phase, which is up to forty days from the beginning of release; and
- CHRONC input file containing parameters pertaining to the intermediate and long-term phases.

Additional files used by MACCS are as follows:

- Indexr.dat is an ASCII file containing decay-chain information. This file is included as part of the installation.
- MACCS2.ini. is an initialization file that contains two flags. When FileTempMem is set to true temporary files are used instead of dynamic memory. The default value for FileTempMem is false. When BinFileFlag is set to true, all dose values for all grid elements per cohort per weather trial per source term is printed to a file. The default value of BinFileFlag is false.
- MACCS.tmp is a text file containing the paths and names for the MACCS input files. The name of this file can be modified with a command line parameter.
- The meteorological file is an optional file that describes the weather conditions for one year.
- The site file is an optional file that describes the population, land use, and economic parameters.

- The dose conversion factor (DCF) file is an optional file used to calculate doses to a set of organs from radionuclide exposures corresponding to a set of exposure pathways.
- The COMIDA2 binary file, created by COMIDA2.exe, is an optional file used to define food-chain dose conversion factors.

A number of output files are created by MACCS; model1.out, model2.out, etc., where the number corresponds to the realization or calculation number. When the calculation is deterministic and the cyclical file option is not used, only model1.out is created.

- Modeln.out is a text file containing output from MACCS.
- Modeln.bin is a binary file containing output from MACCS. This file can be viewed as text using the File→Export Binary Results as Text option in the WinMACCS main menu or can be used to create plots from within the WinMACCS interface.
- FortErr.log is created when MACCS terminates abnormally.
- MaxStat.log contains the character string “OK” when MACCS terminates normally, “NO” when MACCS terminates abnormally or when MACCS does not complete the simulation. This file contains an error message when termination is due to an error detected by MACCS.

4.1.3 Latin Hypercube Sampling (LHS)

The executable file, Lhs.exe, generates values of uncertain variables using Latin Hypercube Sampling (LHS). This program is initiated from WinMACCS. The code, published by Sandia National Laboratories, is used to perform sampling from user-defined probability distributions that represent uncertain input parameters. LHS also allows uncertain distributions to be correlated.

The following required input files are transparent to the user when running LHS from within WinMACCS:

- Lhs.inp is generated by WinMACCS. This file contains the probability distribution types and values and the number of samples to generate.
- Sipra.inp contains software settings used by LHS.

The following output files are generated when using LHS:

- Lhs.out contains sampled values created by the LHS execution. This file is read by WinMACCS and it is used to create MACCS, COMIDA2 input files, and uncertain dose conversion factors, using the sampled values.
- Lhs.err iscreated when an error is detected during LHS execution.
- Lhs.msg contains details of LHS execution.

4.1.4 COMIDA2

The executable file, Comida2.exe, is a semi-dynamic food chain model that estimates annual concentrations in various food sources (dose-to-source ratios) given a set of radionuclides and transfer coefficients for each crop type considered.

The input files are generated by WinMACCS. Uncertainty is supported in this input. The following input files are required:

- Comida2.inp, a parameter input file.
- Comida2.var, a parameter input file.
- Comida2.par, a parameter input file.
- A dose conversion factor (DCF) file.

The following output files are generated by COMIDA2:

- Comida2.bin, a binary file that is used as input to MACCS.
- Comida2.dmp, a detailed output file.
- Comida2.lst, a detailed output file.
- Comida2.cnc, a detailed output file.

4.1.5 PopMod

PopMod was written to allow MACCS to support more than sixteen compass directions by reformatting a site data file created by SecPop. This function is no longer needed if the user can create site files supporting the number of compass directions required for their simulation.

PopMod reads a site file created by SecPop and creates a new population file containing more compass sectors. The work of PopMod is primarily interpolation and reformatting. No new information is added to the new site data file.

PopMod requires for input a site data file and the required number of angular sectors needed in the new file. The number of final sectors must be greater than the original site data file. PopMod generates a modified site data file.

Even though PopMod is still part of WinMACCS, it is not needed when SecPop 4.0 or later is used to create the site file. SecPop 4.0 uses Census 2010 data and supports up to 64 compass sectors.

4.1.6 CombineSource

The executable file, CombineSource.exe, is integrated into WinMACCS to support the multiple source term model. Input files required are result files referred to as source term files from MelMACCS, a separate software component used to extract source term data from MELCOR (a reactor modeling product) results.

4.1.7 Project Files

Data files managed by WinMACCS include a set of auxiliary files, such as the site file, the meteorological file, the COMIDA2 binary file(s), cyclical file(s), source term file(s) and the DCF file(s).

Input files are created by WinMACCS using the model and input settings. This set can include Atmos*n*.inp, Early*n*.inp, Chronc*n*.inp, Comida*n*.inp, and Lhs.inp input files.

Output files are created by MACCS and its preprocessors (e.g., LHS and COMIDA2). One or more sets of MACCS output files, Model*n*.out and Model*n*.bin, are normally created. Other files may or may not be created, depending on settings.

A project database, eg., project.mxd, is created from an Access 2010 database file, Initialize2000.mdb, by WinMACCS when a new project is created. The project database contains the following information:

- Input values specified by user,
- Default input values,
- Variable descriptions and limits,
- Information to construct input forms,
- Information to construct input files,

- LHS results, and
- MACCS results read from binary files

4.2 Main Menu Items

The main menu contains six drop down menus that allow the user to control WinMACCS projects and perform a number of useful functions. These are described in the following subsections for each of the menu items.

4.2.1 File Menu

The *File* menu shown in Figure 4-1 allows the user to do the following:

- Manage MACCS projects via the New Project, Open Project, Save Project, SaveAs Project, and Close Project commands.
- Refresh the view of the project files using *Refresh File View.*
- Import custom report definitions from another WinMACCS using utility *Import Custom Report Definitions.*
- View a MACCS binary output file in a text format using utility *Export Binary Results as Text.*

These commands are explained in more detail below.

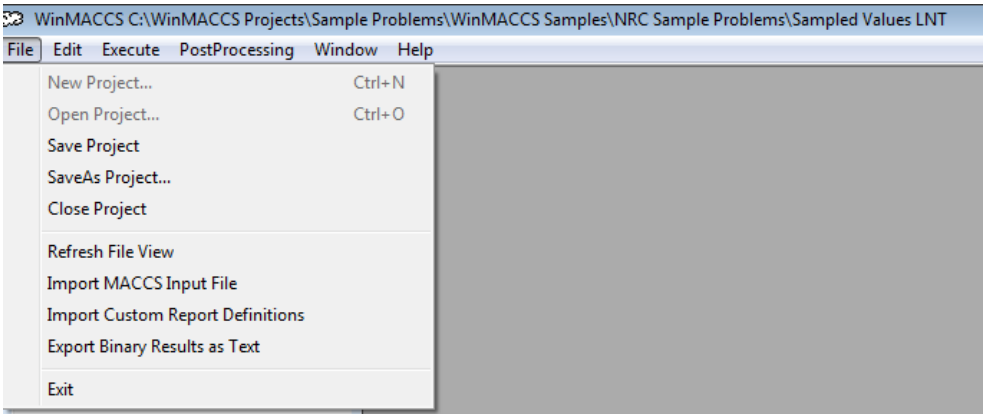


Figure 4-1 File menu

File→New Project

The command *File→New Project* is used to create a new WinMACCS project, as shown in Figure 4-2. The user is required to type a name for the project in the *Project Name* text box. This name is used as a folder name and as the prefix of the .mxd project file. The user is limited to enter only names that are legal names for windows folders and files. Optionally, the user can change the drive and parent folder for this new folder.

By default, the project location is on the drive where MACCS is installed. If the program was installed on the C:\ drive, the default project folder is C:\WinMACCS Projects\.

The user should click *OK* to close this window and complete the operation of creating a new project or click *Cancel* to close this window without creating a new project.

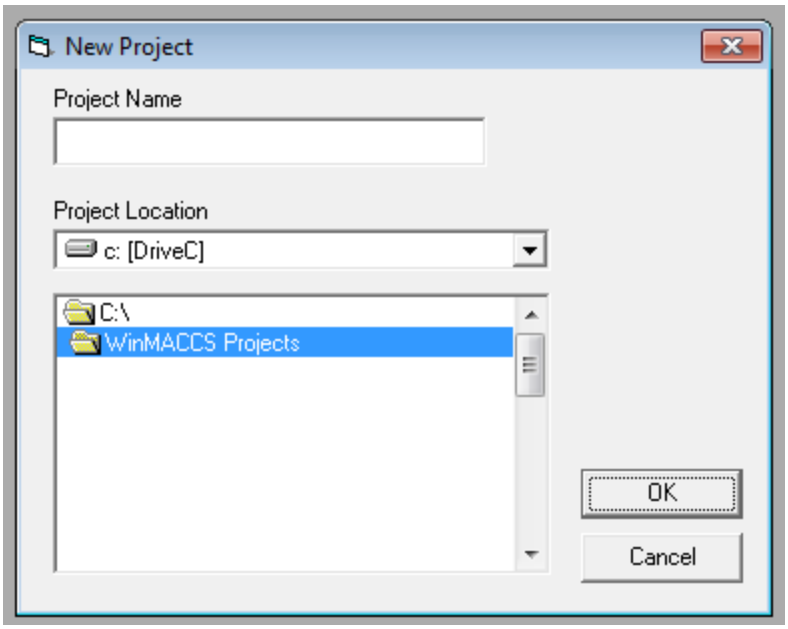


Figure 4-2 New project form

File→Open Project

The command *File→Open Project* opens an existing WinMACCS project. The user opens a project by selecting the .mxd file in the project root folder. When the project file was not created with the same WinMACCS version, a box similar to one shown in Figure 4-3 is displayed.

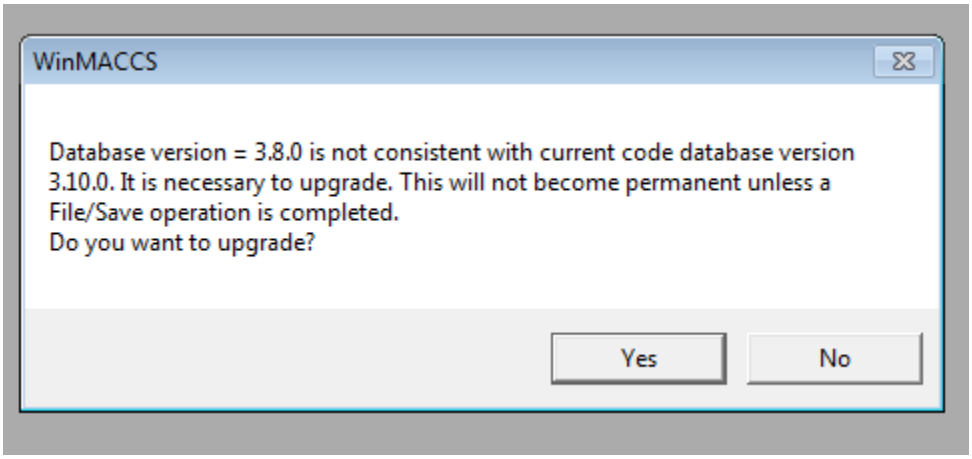


Figure 4-3 Database inconsistency

The database is upgraded to the current version of WinMACCS by clicking *Yes*. The original .mxd file is not modified unless the user selects *File→Save*. The user can also retain the old project version by selecting *File→SaveAs Project* to store the upgraded version under a different name.

File→Save Project

The command *File→Save Project* saves the changes made to the project variables and settings.

File→SaveAs Project

The command *File→SaveAs Project* creates a new WinMACCS project as shown in Figure 4-2 based on the current project settings. The folder structure and all files are copied to the new project.

File→Close Project

The command *File→Close Project* closes the current project. The current project must be closed before opening another project. The interface supports only one project at a time. However, multiple instances of WinMACCS can exist at the same time provided each instance corresponds to a different project folder.

File→Refresh File View

The command *File→Refresh File View* refreshes the data displayed on the project *Files* tab. This causes WinMACCS to update the files shown in the *Input* and *Output* entries on the project *Files* tab to be consistent with the files saved on the computer in the project Input/ and Output/ folders. This is done automatically when simulations are run. However, when a file is copied or deleted manually from the computer, the file view is inconsistent unless this command is selected.

File→Import MACCS Input File

This command *File→Refresh File View* prompts the user to select a MACCS input file such as an Atmos, Early or Chronc input file, e.g., Atmos1.inp. The file contents are read and data values are imported into WinMACCS variables in the currently opened project. If some of the WinMACCS variables were previously defined, the values read from the file are substituted in place of the old values.

The MACCS input file does not need to be complete. The MACCS input lines are read and the values overlaid onto the existing project. When a vector or array is present in the MACCS input file, all values associated with that vector or array are cleared before the new data are assigned to the project. Only the data relevant to the model settings shown in the *Project Properties* form are imported into the project.

The model settings may also be modified while importing a MACCS input file. For example, the MACCS input file modifies the weather sampling method when a METCOD card is included in the file. When the model settings are modified, data relevant to those modified settings are imported. Data not relevant to model settings are not imported.

File→Import Custom Report Definitions

The command *File→Import Custom Report Definitions* is used to import custom report definitions created in another WinMACCS projects into the current project. The WinMACCS project file is selected as shown in Figure 4-4. The new report definitions are accessible after the simulations have completed in the *Manage Reports* form described in sections 4.6.2.3 and 4.6.2.5. A new report definition is valid only when the results requested in the *Output Control* form that created that result is identical between the two projects.

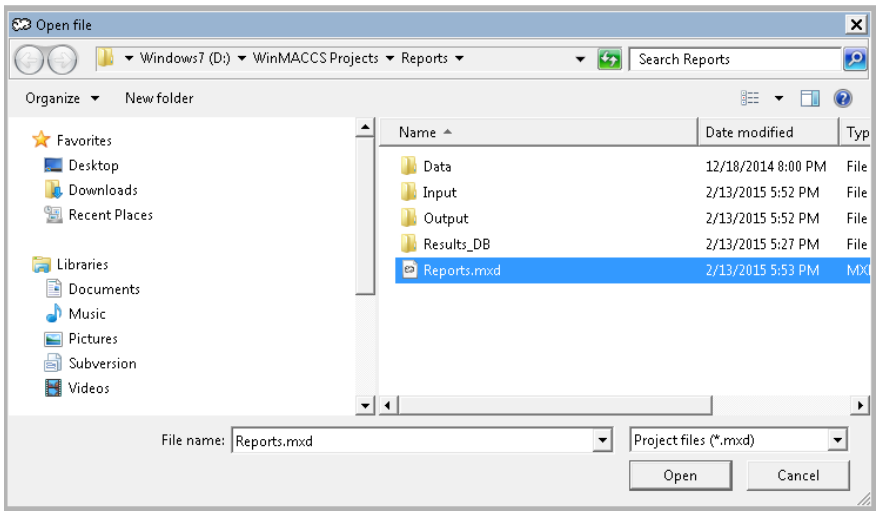


Figure 4-4 Import report definitions

File→Export Binary Results as Text

The command *File→Export Binary Results as Text* allows the user to open a MACCS binary output file in text format. These files are found in the Project\Output\ folder, one for each simulation, as shown in Figure 4-5. The binary output files are the same files that are used by the WinMACCS postprocessor to display MACCS results graphically.

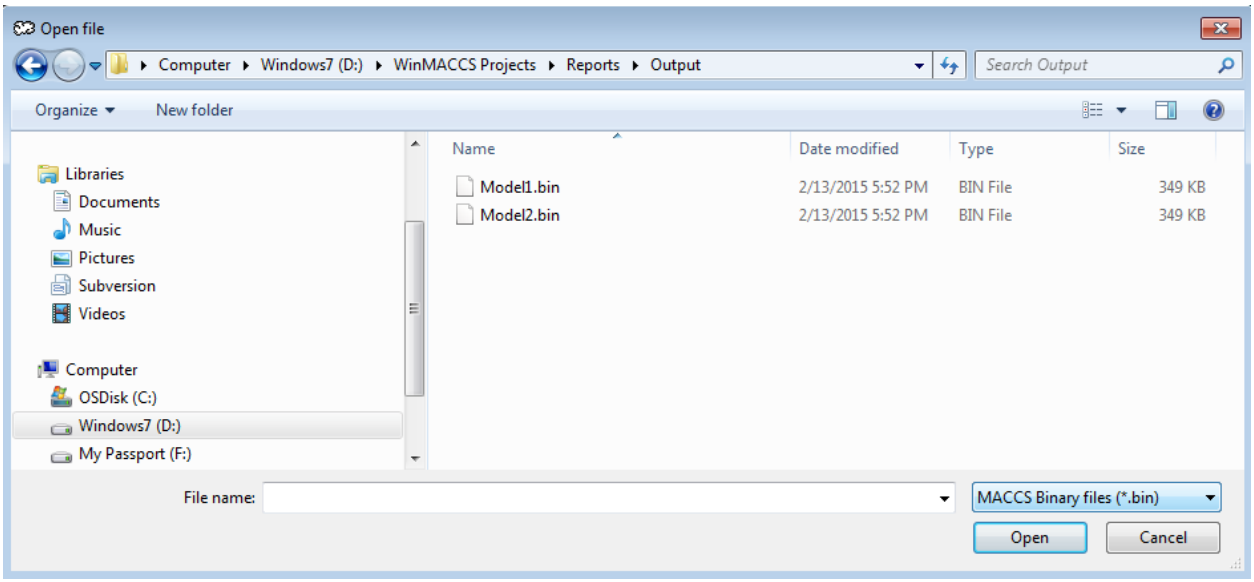


Figure 4-5 Export binary file as text

File→Exit

The command File→Exit closes the WinMACCS application. If the project has changed since the last time it was saved, a message box is displayed as shown in Figure 4-6.

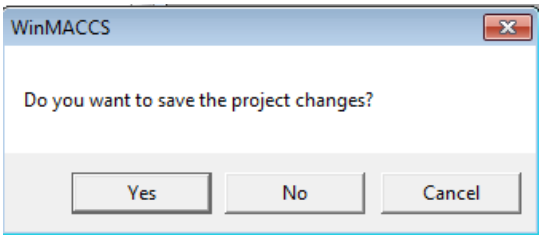


Figure 4-6 Message box to save project

4.2.2 Edit Menu

The *Edit* menu shown in Figure 4-7 allows the user to do the following:

- Show and hide the legend by checking or unchecking *Show Legend*. The legend shows the meaning of the icons associated with forms in the Project window.
- Modify data grids on parameter modification forms using commands from the submenu *Grid.*
- Correlate uncertain variables from the submenu *Correlate Uncertain Variables.*
- Modify form variables by selecting the form name and making a selection from the submenu *Modify Form Variables.*
- Open parameter modification forms by choosing the variable name using the command *Find Parameter Window.*
- Open the *Project Properties* window to modify basic modeling choices.

These commands are explained in more detail below.

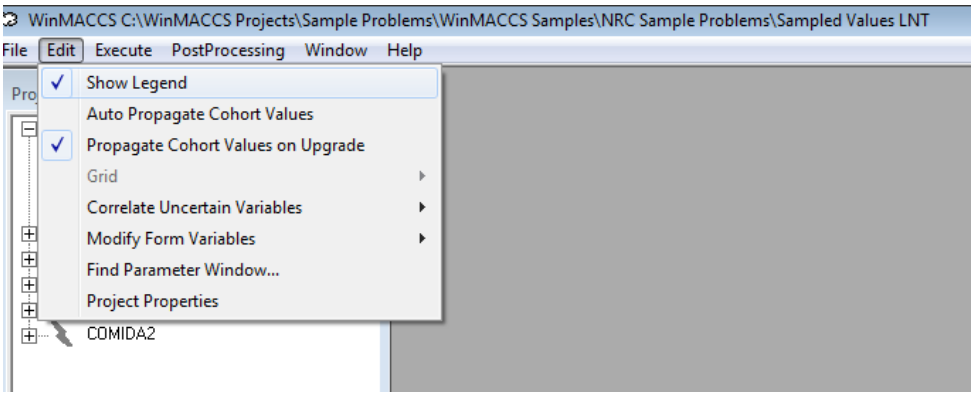


Figure 4-7 Edit menu

Edit→Show Legend

When the *Edit→Show Legend* checked command is checked, a window appears showing a legend, as shown in Figure 4-8. When the box is unchecked, the legend is hidden.

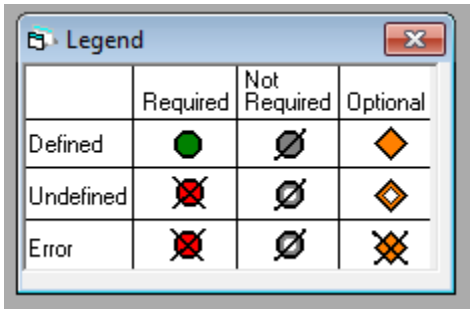


Figure 4-8 Legend

Edit→Auto Propagate Cohort Values

When the *Edit→Auto Propagate Cohort Values* command is checked, the values are propagated from one cohort form to other forms after the *OK* button is clicked on the parameter modification form. The propagation is applied to cohorts greater than the cohort saved. This option is set to off by default.

When this option is enabled and the values are saved on a cohort form, the same values are saved on other undefined cohort forms that have the same named variables for cohort numbers greater than the cohort number of the saved form. For example, when the variable *CRIORG* is updated on the *Critical Organ* form for cohort 3 and there are a total of 6 cohorts, CRIORG for cohorts 4, 5 and 6 is assigned the same value provided this variable is undefined for these cohorts.

When propagating values to other cohorts, when a form is encountered that is defined, the propagation stops and no more cohorts will receive the new value.

Stated in a more rigorous way, when form A (for example, Network Evacuation Speed) for cohort m is completed, propagation will start at form A for cohort m+1, m+2..., until a variable is found to be defined on form A for cohort n, n>m. At that point, the propagation ceases. No previously defined values are overwritten when using this option.

Edit→Propagate Cohort Values on Upgrade

The *Edit→Propagate Cohort Values on Upgrade* checked command was implemented to support backward compatibility with projects 3.6 and earlier. When this is checked, values are copied to undefined cohort forms when opening a project that was created earlier than the current WinMACCS version. By default this is checked (enabled). However, when this is unchecked and the project saved, the unchecked state will also be saved.

In earlier versions, the MACCS paradigm of change cards for cohort parameters was used within the user interface. Parameters for cohort one were required, but the corresponding value used for subsequent cohorts were assumed to be equal to the value used for the previous cohort unless explicitly changed.

All cohort forms are now required. This means that the values to define a cohort do not have default values but must be defined.

This option allows seamless opening of older projects in this version of WinMACCS.

Edit→Grid

The submenu *Edit→Grid* offers commands are available to manipulate grids in parameter modficiation forms. Some of the parameter modification forms contain a grid. Figure 4-9 shows

a grid found on the *ATMOS/Release Description/Release Fractions* form. The options available in the *Edit→Grid* submenu are enabled when the current parameter modification form contains a grid.

There are two types of grids within the parameter modification forms, vector and array grids. A grid showing an array represents a single variable containing both rows and columns. For example variable RELFRC is an array displayed in a grid, as shown in Figure 4-9. A grid containing vectors may display multiple variables on a single grid, one variable for each column. When a grid displays multiple vectors, each vector on the grid must have the same number of rows as shown in Figure 4-10.

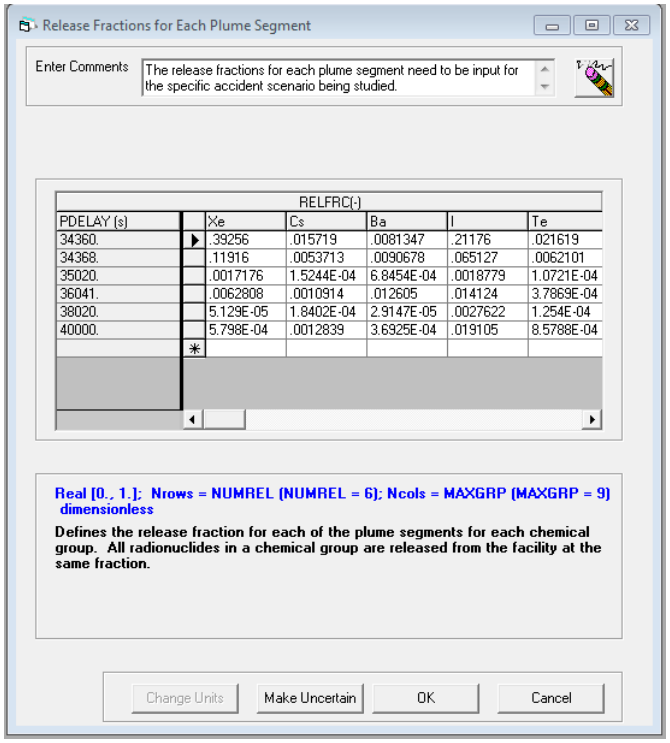


Figure 4-9 Grid showing an array of release fractions for each plume segment

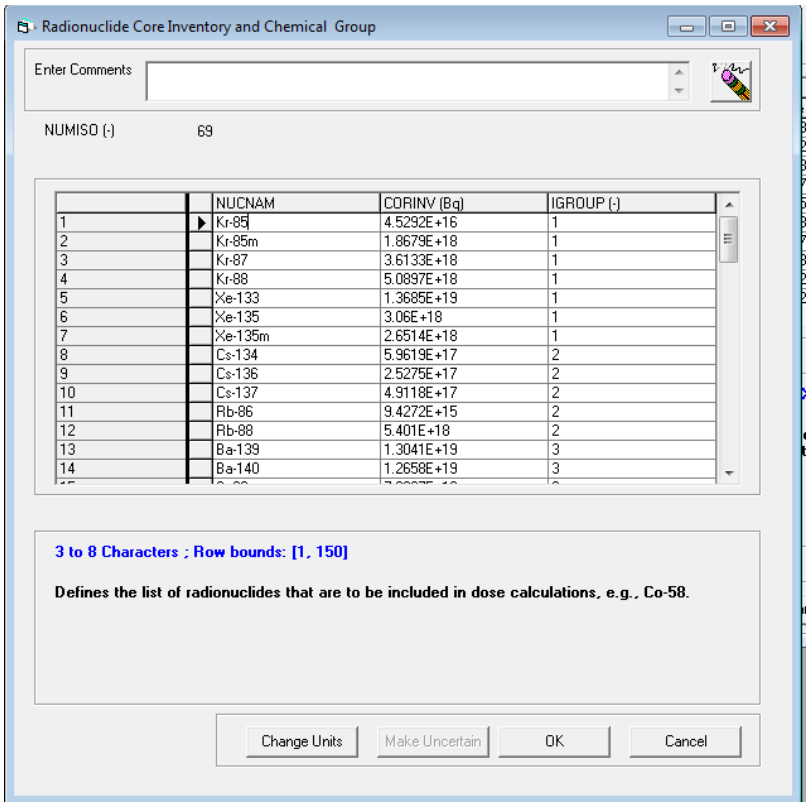


Figure 4-10 Grid showing multiple vectors NUCNAM, CORINV, and IGROUP

The array operations, *Edit→Grid→Insert Columns* and *Edit→Grid→Delete Columns*, are enabled when the grid contains an array but are disabled when it contains one or more vectors. When a parameter form contains either an array or vectors with a variable number of rows, the operations *Edit→Grid→Insert Rows* and *Edit→Grid→Delete Row Hint* are enabled. These functions are not enabled when the grid requires a fixed number of rows (e.g., vector variables CYSIGA, CYSIGB, CZSIGA and CZSIGB all require exactly six rows).

Edit→Grid→Insert Rows

The *Edit→Grid→Insert Rows* command is used to insert rows in a grid. A row on the grid must be selected before this operation can be completed. A row is selected by clicking on the small box between the row label and the data in the desired column. The row is highlighted as shown below in Figure 4-11.

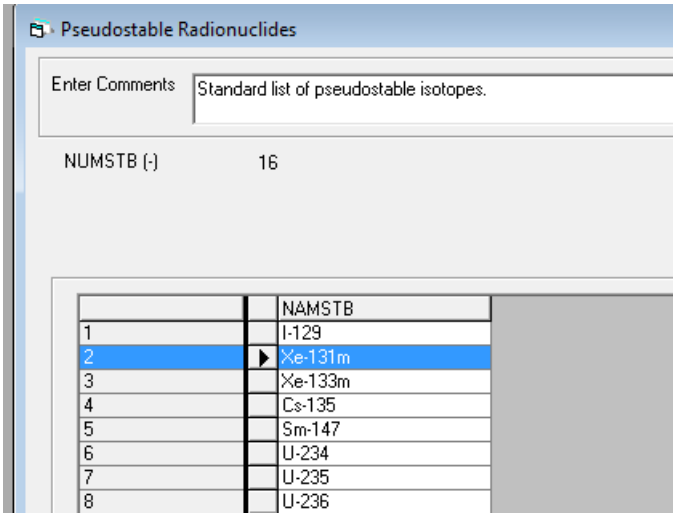


Figure 4-11 Grid showing a selected row

After the *Insert Rows* option is selected, the *Insert Row* form opens as shown in Figure 4-12. By clicking on the radio button *Before,* the new rows may be inserted before the current selected row. By clicking on the radio button *After,* the new rows may be inserted after the current selected row. The number of rows to insert is entered. Complete the form by clicking *OK* to insert the rows.

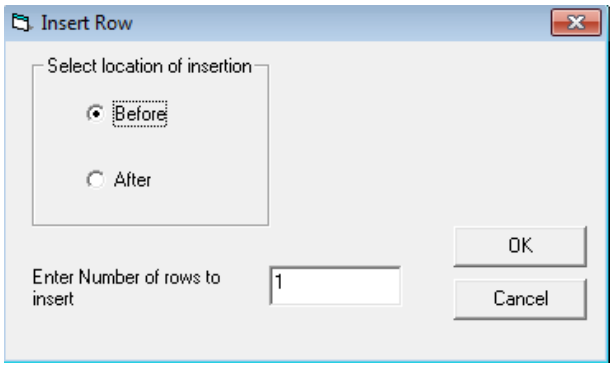


Figure 4-12 *Insert Row* form

The menu option to insert rows is not available when the number of rows on a form is fixed (e.g., the *ATMOS/Dispersion/Dispersion Function* form).

Edit→Grid→Delete Row Hint

The command *Edit→Grid→Delete Row Hint*, when selected, opens a message box as shown in Figure 4-13. This is an aid to give the novice user instructions on how to delete a row in the grid.

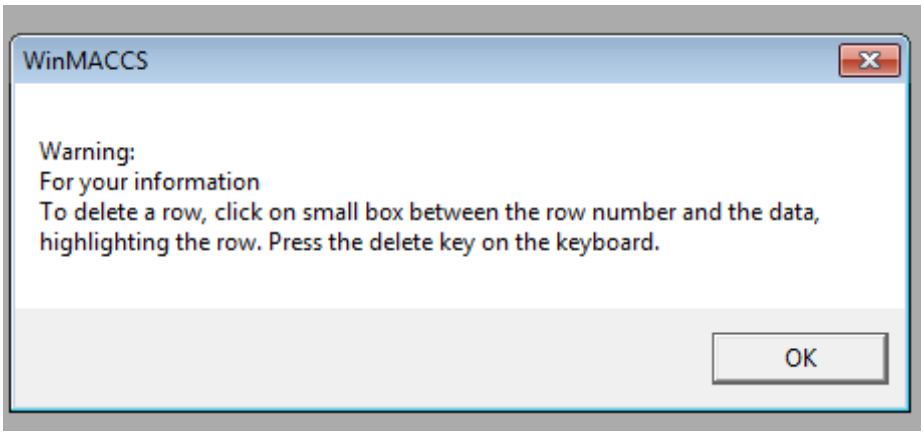
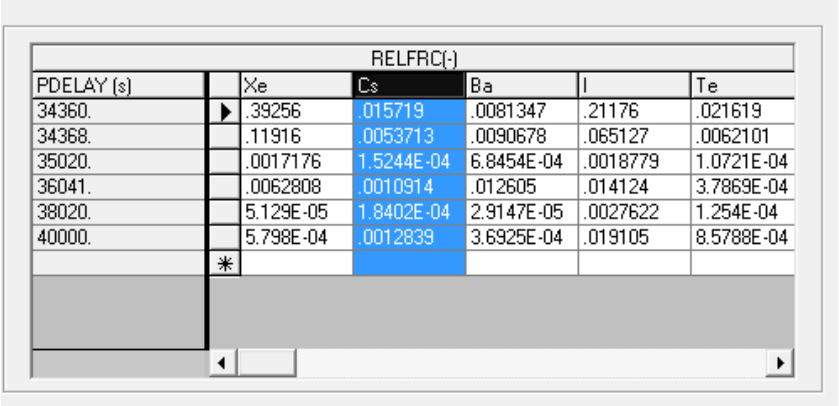


Figure 4-13 How to delete a grid row

Edit→Grid→Insert Columns

The command *Edit→Grid→Insert Columns* is used to insert columns in an array. A column of the array must first be selected by clicking the column header as shown in Figure 4-14.



RELFRC(-)

PDELAY (s)	Xe	Cs	Ba	I	Te
34360.	.39256	.015719	.0081347	.21176	.021619
34368.	.11916	.0053713	.0090678	.065127	.0062101
35020.	.0017176	1.5244E-04	6.8454E-04	.0018779	1.0721E-04
36041.	.0062808	.0010914	.012605	.014124	3.7869E-04
38020.	5.129E-05	1.8402E-04	2.9147E-05	.0027622	1.254E-04
40000.	5.798E-04	.0012839	3.6925E-04	.019105	8.5788E-04

Figure 4-14 Grid showing a selected column

After the *Insert Column* option is selected, the *Insert Column* form opens as shown in Figure 4-15. By clicking on the radio button *Before,* the new columns may be inserted before the current selected column. By clicking on the radio button *After,* the new column may be inserted after the current selected column. The number of column to insert is entered. Complete the form by clicking *OK* to insert the column.

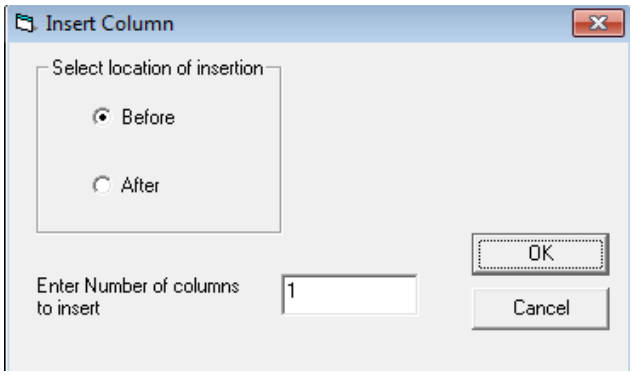


Figure 4-15 Insert Column form

The menu option to insert columns is not available when each column on a form represents a vector (e.g., the *ATMOS/Dispersion/Dispersion Table* form).

Edit→Grid→Delete Columns
The command *Edit→Grid→Delete Column* is used to delete the currently selected array column.

Edit→Grid→Copy to Clipboard
The command *Edit→Grid→Copy to Clipboard* is used to copy a portion of the grid data to the Windows clipboard.

Data can be copied to the Windows clipboard as follows:

1. A portion of the grid can be selected in WinMACCS by left clicking and holding button, dragging over the desired area, and then releasing the mouse button.

2. The selected data can be copied to the clipboard by typing the keyboard short-cut for copying (Ctrl+F), selecting *Edit→Grid→Copy to Clipboard,* or right clicking and selecting *Copy* from the popup menu.

Other methods described in section 4.4.1.1 are available for selecting portions of the grid to the clipboard.

The data can be easily pasted into another application, such as Microsoft Excel, with the keyboard shortcut (Ctrl+V). Note that the shortcut for copying from the grid is different than the standard Windows shortcut because these are distinct operations.

Edit→Grid→Paste from Clipboard
The command *Edit→Grid→Paste from Clipboard* is used to transfer a portion of the grid data from the Windows clipboard into a grid in a parameter modification form.

Before this can be done, clicking on a cell in the grid will define the position where the data will be pasted. Typing the keyboard short-cut for pasting (Ctrl+G), select *Edit→Grid→Paste from Clipboard*, or right clicking and selecting *Paste* will complete the paste operation. Note that the shortcut for pasting onto the grid is different than the standard Windows shortcut because these are distinct operations.

These operations work well for transferring data from a Microsoft Excel spreadsheet into the grid. When data are not being transferred from Excel, it is helpful to know WinMACCS expects a TAB character to separate cells and a new line (i.e., the Enter key) to separate rows.

Edit→ Correlate Uncertain Variables

The submenu *Edit→ Correlate Uncertain Variables* offers commands to correlate uncertain variables. Two options are offered, either to allow LHS to enforce rank correlations or to define a perfect rank order of variable values after LHS has run. Section **Error! Reference source not found.** can be referenced for more information.

Edit→ Correlate Uncertain Variables→ Linear Coefficients

The command Edit→ Correlate Uncertain Variables→ Linear Coefficients opens the Correlate Uncertain Variables form as shown in Figure 4-40. This option, only relevant when LHS is being used to sample a set of uncertain variables, allows the user to correlate uncertain variables. The correlation coefficient specifies the degree to which two uncertain variables are correlated. Section 4.4.3.1 can be referenced for more information.

Edit→ Correlate Uncertain Variables→ Enforce Rank Order

The command *Edit→ Correlate Uncertain Variables→ Enforce Rank Order* opens the Enforce Rank Order of Uncertain Variables form as shown in Figure 4-41.

After LHS has run and imposed correlations specified by the user, WinMACCS can reorder some of the variables to be consistent with the rank order of other variables. Section 4.4.3.2 can be referenced for more information.

Edit→Modify Form Variables

The submenu ***Edit→Modify Form Variables*** as shown in Figure 4-16 contains commands that can be used to define form variables without opening the forms. These menu items allow resetting forms to default values and applying the value of a cohort form, that is a form in the category *Emergency Cohort One* or *Additional Emergency Cohorts* to other forms in the *Additional Emergency Cohorts* category.

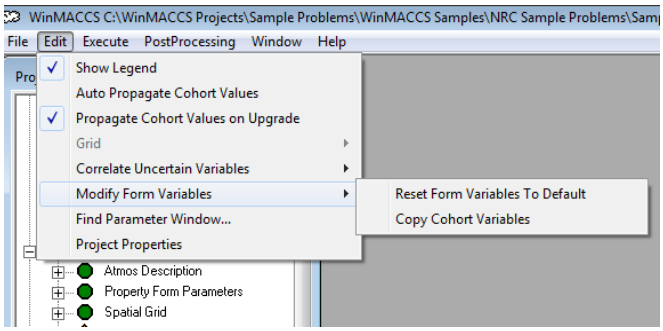


Figure 4-16 Submenu Modify Form Variables

Edit→Modify Form Variables→Reset Form Variables to Default

The command *Edit→Modify Form Variables→Reset Form Variables to Default* is used to conveniently replace all the data on a form with default values as shown in Figure 4-17.

Most forms in WinMACCS are undefined by default; in a few cases, there are specific values that are standard for a model. Thus, in most cases, selecting this menu option has the same effect of clearing the form.

The following operations will result a form to its default values:

- When the form is open, click anywhere on the form. This identifies it as the form of interest. Select the menu option, *Reset Form Variables to Default.* The values are set to

the WinMACCS default values. This is a convenient way to clear the data from a form. In some cases this resets variables to default values rather than clearing the values on the form. This may produce a different outcome than that of the erase button found on the parameter modification form. The Erase button clears all values from the form, but does not replace variables with their default values when default values exist.

- When the form is not open, an equivalent method for resetting form variables to their default is to click on the form name in the *Parameters* tab of the *Project* window. Select the menu option, *Reset Form Variables to Default.* Variables defined on the selected form are reset to their default values.
- To reset variables to their defaults, right click on the form name in the *Parameters* Tab, right click the mouse, and select *Reset to Default* from the popup menu.

Resetting form variables to default values does not affect read-only variables on the form. Read-only variables have gray backgrounds when viewed on parameter modification forms. They are defined on a different form.

This is the only way to remove data from required forms. Opening a required form, deleting the data, clicking the *OK* button is not allowed.

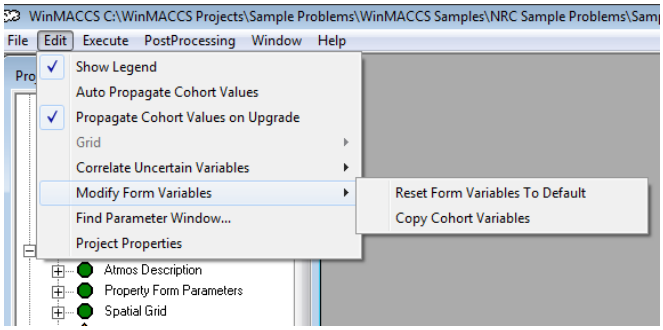


Figure 4-17 Reset form variables to default

Edit→Modify Form Variables→Copy Cohort Variables

The command *Edit→Modify Form Variables→Copy Cohort Variables* is used to copy form data from one of the cohort forms to other cohort forms. To use this function, a form must first be selected from the Parameters tab. A form opens similar to the one shown in Figure 4-43. Section 4.4.4 can be referenced for more information.

Edit→Find Parameter Window

The command *Edit→Find Parameter Window* opens the *Open Parameter Form* as shown in Figure 4-18 to assist in locating input variables within the user interface.

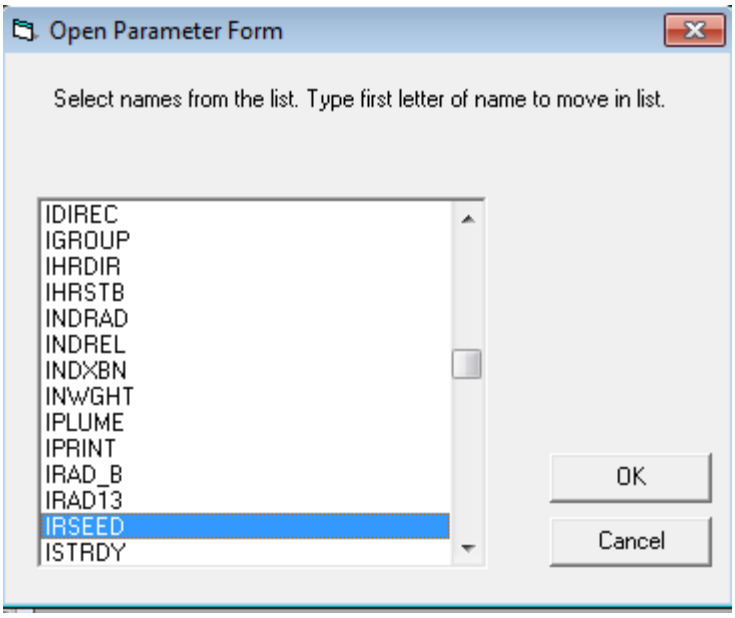


Figure 4-18 Open parameter form

The list of variables can be navigated by using:

- Pressing the up and down arrow keys on the keyboard.
- Typing a letter to position the list to parameters starting with that letter. For example, typing the letter m positions the list to the parameters starting with the letter M. Subsequent typing of that same letter moves the list position to the next variable starting with that letter.
- Moving the scroll bar on the form.

Multiple variables can be selected in the list by:

- Clicking more than one of the variable names on the list.
- By navigating through the list using the arrow keys, entries can be selected by pressing the space bar on the keyboard when the variable name is highlighted. Focus is indicated by a dotted rectangle boxing the variable name.

The windows associated with the selected variables can be opened by:

- Selecting OK.
- Pressing the Enter key on the keyboard.

In some cases, more than one form contains the same variable name. Sometimes the variables are separate entities, for example ORGNAM has a different usage on the *Early Fatality Effects* form and *Off Centerline Dose* form. All of the forms that contain the selected variable are opened.

Edit→Project Properties

The command *Edit→Project Properties* opens the *Properties* form. This form is used to modify the basic model choices. By selecting models using the *Properties* form, other variable values relevant to model selection that are used by MACCS are initialized. Sections 3.1.1 and 4.3 contains more information.

4.2.3 Execute Menu

The *Execute* menu as shown in Figure 4-19 allows the user to do the following:

- Allow complete control over the MACCS input files with respect to validation and creation before the MACCS simulations.
- Switch from Latin hypercube sampling to simple random sampling for creating a set of Monte Carlo realizations to estimate the effects of parameter uncertainty. Latin hypercube sampling is checked by default.
- Control when the binary result files are imported into WinMACCS and reports are created. This is checked when WinMACCS is started.
- Open the *Run Models* form to initiate a MACCS simulation.

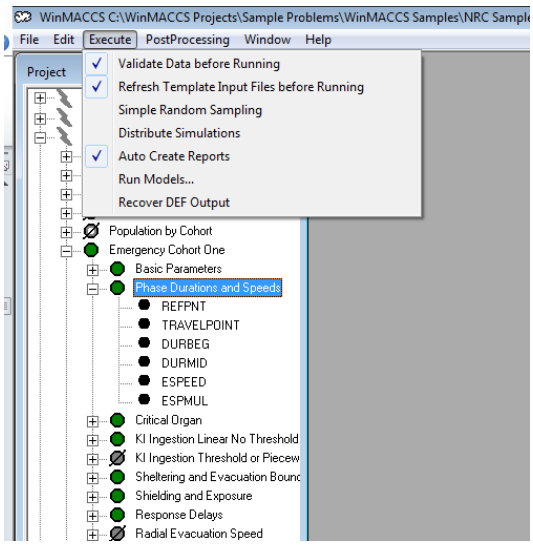


Figure 4-19 Execute menu

Execute→Validate Data before Running

The checked command *Execute→Validate Data before Running* has the following meaning:

- All data are tested for consistency before a simulation when checked.
- When unchecked, consistency testing is skipped. This may be desired if a minor modification was made and the user doesn't want to wait for the consistency check to be performed before executing MACCS.

Execute→Refresh Template Input files before Running

The checked command *Execute→Refresh Template Input files before Running* has the following meaning:

- When checked, the template files are deleted and recreated based on the variable values and settings stored in WinMACCS when *Run Simulation* is clicked.
- When unchecked, the template files are not recreated. This option is used to allow direct editing of the MACCS input files. In this case, the user can directly modify the file atmosTemplate.txt, earlyTemplate.txt, chroncTemplate.txt, and comidaTemplate.txt. The template files are than used by MACCS to create the actual MACCS input files. Links to these files can be found in the *Files* tab in the project window.

Changing variables in a template file does not modify variables in the database. The files used with MACCS, atmos1.inp, early1.inp, etc., are always recreated using the template files.

Execute→Simple Random Sampling

The checked command *Execute→Simple Random Sampling* has the following meaning:

- When checked, uncertain input parameter sampling uses a Monte Carlo method.
- When unchecked, a stratified sampling method known as Latin Hypercube Sampling (LHS) is used.

WinMACCS allows input parameter values to be made uncertain and enables sampling of the uncertain variables. Section 4.4.1.3 can be referenced for more information about uncertain variables.

Execute→Auto Create Reports

The checked command *Execute→Auto Create Reports* has the following meaning:

- When checked and reports have been requested, the binary files are imported into the project database and the requested report is created without additional action by the user following completion of an execution.
- When not checked, reports are not created after execution. The user has the option to create reports by selecting *PostProcessing→Create Custom Report* from the main menu. Reporting probabilities can also be modified after execution through the *General→Reporting Options* form.

Execute→Run Models…

The command Execute→Run Models… opens the form used to initiate simulations. This is used after the model data are defined to initiate a simulation. Section 4.5.1 can be referenced for more information.

4.2.4 The PostProcessing Menu

The *PostProcessing* menus as shown in Figure 4-20 and Figure 4-21 allow the user to do the following:

- Open various graphics windows using the Scalar Results, Statistical Summary Results, and Results over all Weather Trials options.
- Modify plot lables, save plots in various file formats, and select, unselect and delete series.
- Create custom reports using the *Create Custom Report* command for user defined probabilities.
- Create the summary report.

Post processing results are available after the simulations have completed. If the MACCS binary result files have not been imported into WinMACCS, requesting a plot or report will cause all binary files to be imported.

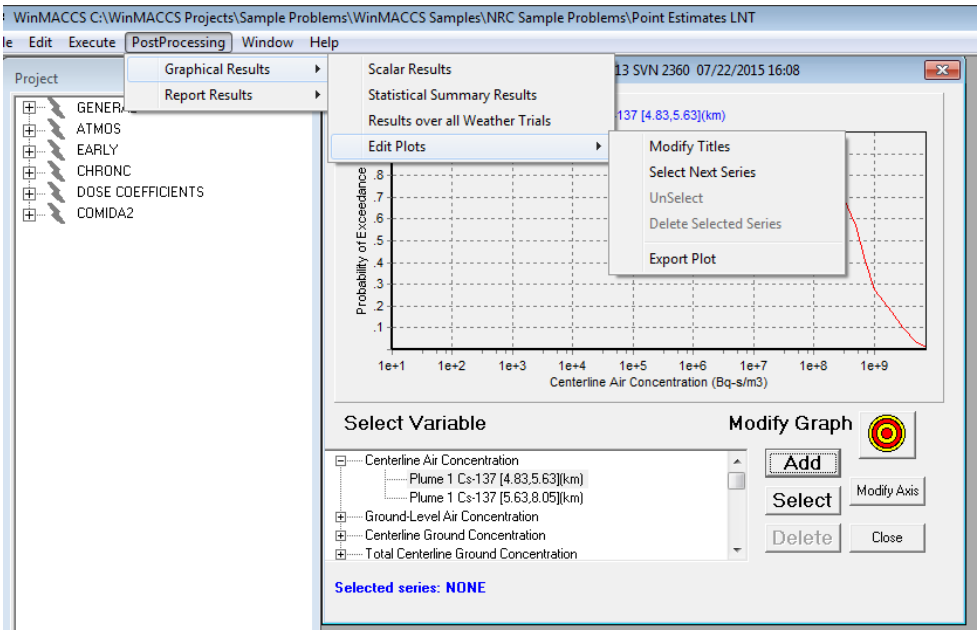


Figure 4-20 Postprocessing/Graphical Results menu

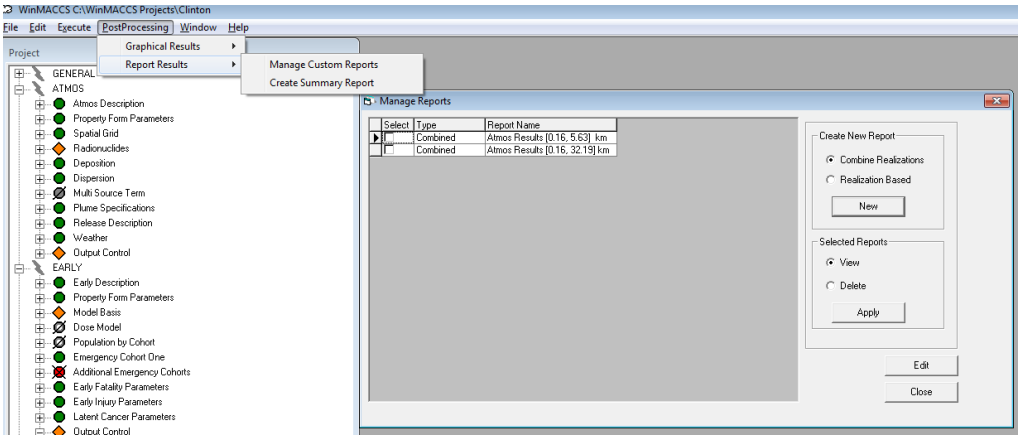


Figure 4-21 Postprocessing/Report Results menu

PostProcessing→Graphical Results→Scalar Results

The command *PostProcessing→Graphical Results→Scalar Results* is used to view plume releases by radionuclides as a CCDF as shown in Figure 4-22. Section 4.6.3.1 can be referenced for more information.

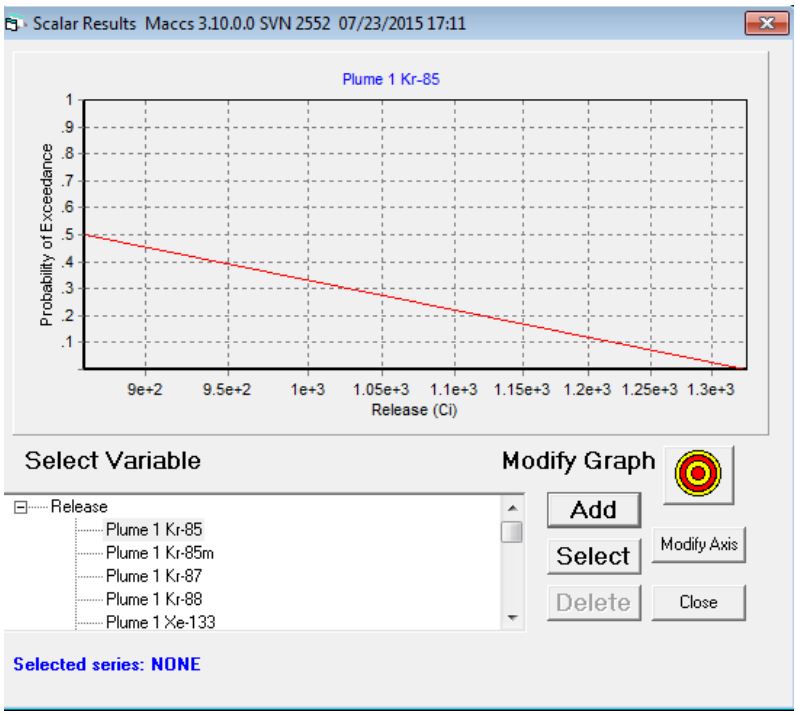


Figure 4-22 Plot of scalar results

PostProcessing→Graphical Results→Statistical Summary Results

The command *PostProcessing→Graphical Results→Statistical Summary Results* opens a graphics window to view statistical data MACCS has calculated for a set of realizations. The probability shown in the plot corresponds to the set of samples, cyclical files, or a combination of both. The implicit assumption is that the variations are equally probable. Section 4.6.3.2 can be referenced for more information.

PostProcessing→Graphical Results→Results over all Weather Trials

The command *PostProcessing→Graphical Results→Results over all Weather Trials* opens a graphical window to view the complementary cumulative distribution function reported on each individual simulation. The result is a series shown for each weather trial. The distribution shown corresponds to uncertainty in the weather for a hypothetical accident. Section 4.6.3.2 can be referenced for more information.

PostProcessing→Graphical Results→Edit Plots→Modify Titles

The command *PostProcessing→Graphical Results→Edit Plots→Modify Titles* is used to change the plot title and the axis labels. A description of all functions available for graphics forms is available in Section 4.6.3.4

.

PostProcessing→Graphical Results→Edit Plots →Select Next Series

The command *PostProcessing→Graphical Results→Edit Plots →Select Next Series* is used to select the next series drawn on the plot. This performs the same function as the *Select* button on the graphics screen. A description of all functions available for graphics forms is available in Section 4.6.3.4.

PostProcessing→Graphical Results→Edit Plots →UnSelect

The command *PostProcessing→Graphical Results→Edit Plots →UnSelect* is used to remove the selection of the current selected series drawn on the plot. It is possible to put the form in this same state by clicking the *Select* button repeatedly, though this is a tedious way to unselect

when there are many series drawn on the plot. A description of all functions available for graphics forms is available in Section 4.6.3.4.

PostProcessing→Graphical Results→Edit Plots →Delete Selected Series
The command *PostProcessing→Graphical Results→Edit Plots →Delete Selected Series* is used to remove the selected series from the plot. This can also be accomplished by clicking the *Delete* button on the graphics form. A description of all functions available for graphics forms is available in Section 4.6.3.4.

PostProcessing→Graphical Results→Edit Plots → Export Plot
The command *PostProcessing→Graphical Results→Edit Plots → Export Plot* is used to save the plot that the user has specified. A variety of formats, such as Excel (*.xls), Windows bitmap (*.bmp), Text (*.txt), JPEG (*.jpg), XML (*.xml), and HTML (*.html) are available. Two of these capture an image of the plot (.bmp and .jpg); the others capture the data that are plotted.

PostProcessing→ Report Results→Manage Custom Reports
The command *PostProcessing→ Report Results→Manage Custom Reports* is used to open the *Manage Reports* form. Sections 4.6.2.3 can be referenced for more information.

PostProcessing→ Report Results→Create Summary Report
The command *PostProcessing→ Report Results→Create Summary Reports* is used to create a custom report based on probabilities entered by the user on the *General→Output Options→Reporting Options* form and the selected output requests. Output requests are made on forms in the categories *Atmos→Output Control*, *Early→Output Control,* and *Chronc→Output Control*. Output will be available only for form entries where *Report Options* is set to *REPORT* or *CCDF & REPORT*. Section 4.6.2.2 can be referenced for more information.

4.2.5 The Window Menu

The *Window* menu as shown in Figure 4-23 allows the user to do the following:

- Cascade the parameter modification forms and the plot form windows by selecting the *Cascade* function.
- Change the focus to another window by selecting that window from the list shown under the *Cascade* function.

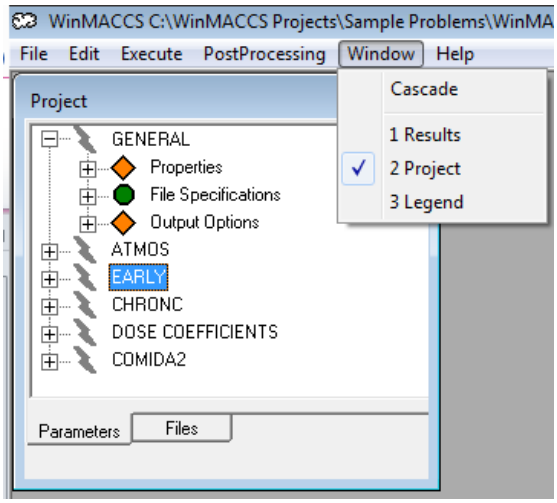


Figure 4-23 Window menu

4.2.6 The Help Menu

Selecting *About* on the *Help* menu, as shown in Figure 4-24 displays the version of WinMACCS being used.

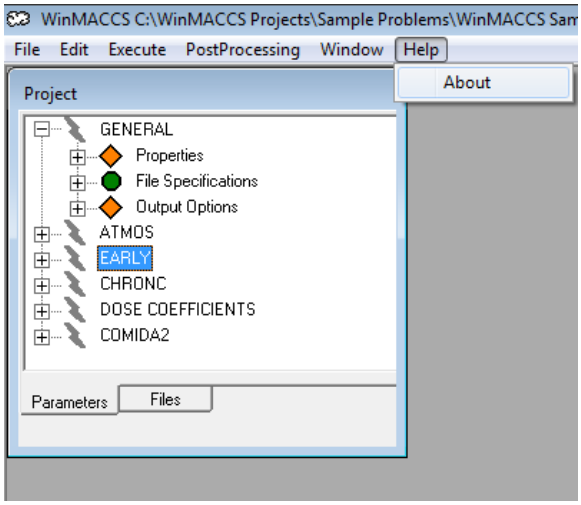


Figure 4-24 Help menu

4.3 Selecting Models on the Properties Form

The *Properties* form can be opened by selecting *Edit→Project Properties* from the main menu or by double-clicking on *General/Properties/Properties* from the *Parameters* tab in the *Project* window.

Basic model selections are made from the *Properties* form. By selecting models using the *Properties* form, other variable values relevant to model selection that are used by MACCS are initialized (e.g., METCOD). The variables affected by the *Properties* form can be viewed, but not modified, by opening the forms *ATMOS/Property Form Parameters, EARLY/Property Form Parameter* and *CHRONC/Property Form Parameters.*

The *Properties* form is automatically opened when a new project is created. Each tab of the *Properties* form has default selections. The user should ensure that the scope and intent of their problem is met through the designations on the *Properties* form.

The decisions the user makes at this point determine which parameter forms are required. For example, when the *Late Consequences* module is not selected on the *Properties*/*Scope* tab, variables in the *CHRONC* category are not required. Consequently, all *CHRONC* variables in the *Project* window *Parameters* tab have gray icons associated with them. Additionally, all tabs related to the *Late Consequences* module in the *Properties* form also have gray icons associated with them.

Each tab on the *Properties* form has at least one basic model associated with it. There is an icon next to the tab name. The meanings of the icons are as follows:

A solid green octagon means that a selection on this tab is required but has already been defined either by the user or by default. When any modifications are made to this form, the user must click *OK* to save them.

A solid gray octagon with a diagonal line means that the user has completed this tab, but the information is not used in a MACCS calculation given the basic modeling options the user has chosen.

An X-ed red octagon indicates that the model setting on this tab are not compatible with model settings on another tab.

Depending on the models selected, some of the radio buttons are disabled in the *Project Properties* form. For example, when *Constant Weather* is selected on the *Weather* tab, the group *File Sampling Method* is visible with the previous choices still showing on the form as shown in Figure 4-25. However these controls are not available for editing because they are not relevant to the current model choices.

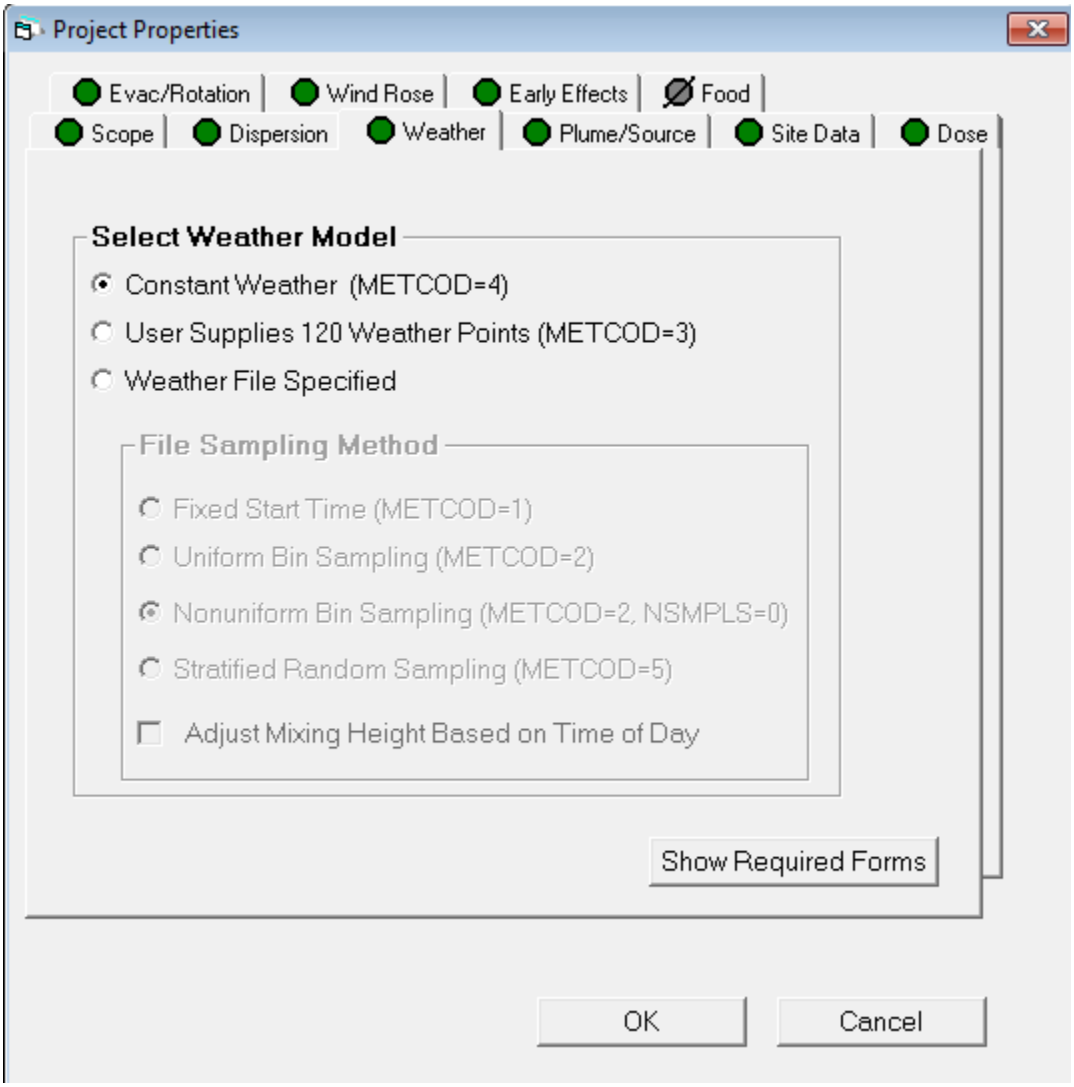


Figure 4-25 Disabled controls on Project Properties form

Clicking OK saves the changes.

Clicking *Cancel* or closing the window ignores the changes.

The *Show Required Forms* button shows which forms in the *Project* window are required when the models selected in the *Properties* form were saved. This does not save the current selection, but is a visual tool to help the user understand what input would be required when the selected options were saved.

In Figure 4-26, *Radial* was selected and *Show Required Forms* was clicked. When this was done, the *Radial Evacuation Speed* form link on the left changed from a gray octagon to an X-ed red octagon. This indicates that additional information is required for the *Radial Evacuation Speed* form and some form(s) in the *Additional Emergency Cohorts* category when *OK* is clicked and this problem model option is saved.

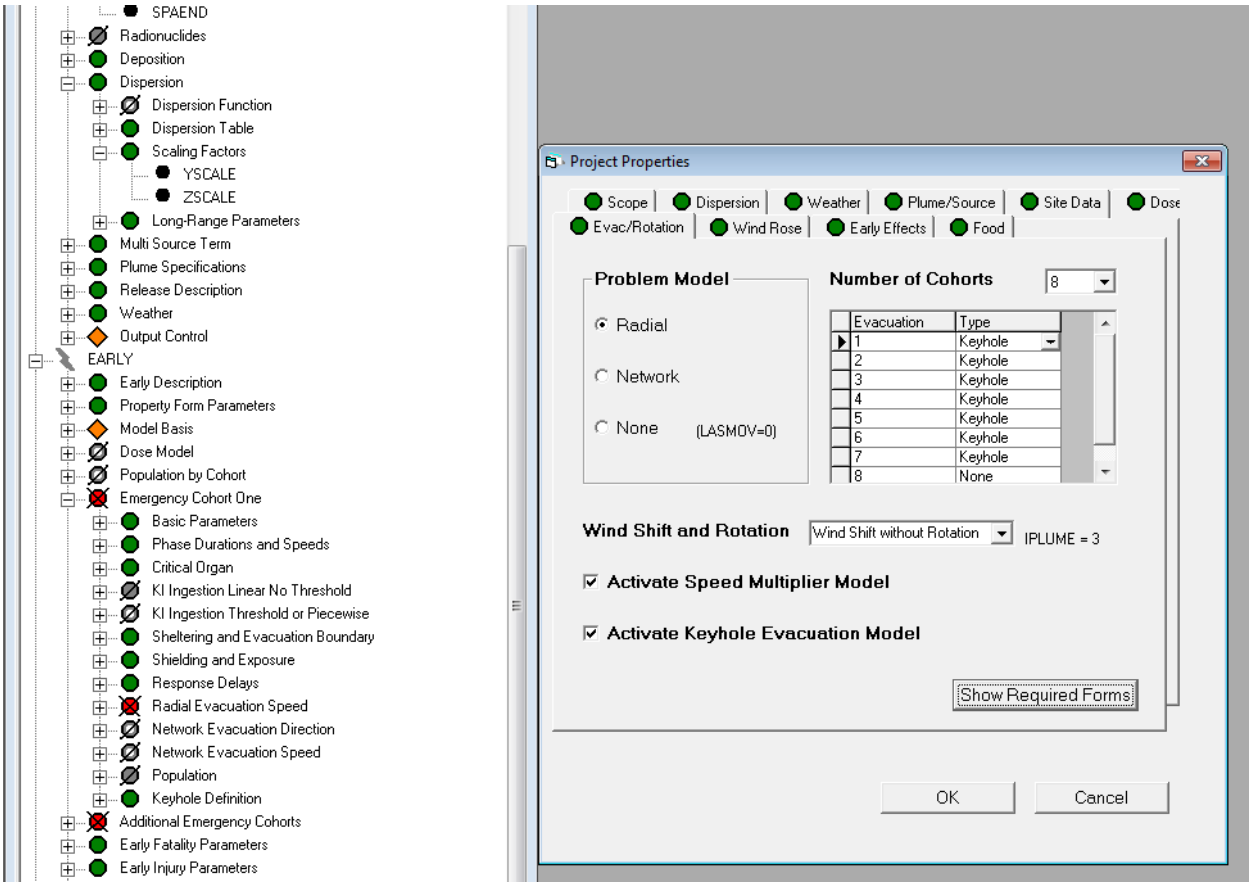


Figure 4-26 Relating model selection to forms

4.4 Modifying Parameters

A parameter modification form can be opened in one of two ways:

- By double-clicking on the variable name or the form containing the variable found on the *Parameters* tab in the *Project* window.
- By selecting the parameter name in the *Open Parameter Form* and click *OK*. The *Open Parameter Form* can be opened as shown in Figure 4-18 or by selecting *Edit→Find Parameter Window…* from the main menu. See section 4.2.2 for more information.

4.4.1 General Parameter Modification Forms

There are general parameter modification forms that have the same components, and custom parameter modification forms, such as the forms to manage evacuation directions, evacuation speeds, and reports. This section describes the general parameter modification forms.

The following are the main components of a parameter modification form as shown in Figure 4-27:

- Enter Comments: Optional comments are entered in this field. The expected usage is to enter comments related to the justification or derivation of parameter values.
-  Eraser Button: Clicking clears the values entered.
- Data entry area: This is the place where data values are entered.
- Description area: Describes the data type, limits and units of the variable that has focus on the form. Below this detail is a brief description of this variable.
- *Change Units*: This button is used to change parameter units. See section 4.4.2 for a further discussion.
- *Make Uncertain*: This button is used to associate a probability distribution with a variable. Most real-valued variables can be specified as uncertain. To change the value of a variable to uncertain, the user can either double-click on the text box or cell, or click *Make Uncertain*. This function is also used to change a variable from uncertain back to a constant.
- Clicking *OK* or *Cancel* closes the form*. OK* accepts the modifications*; Cancel* ignores them.

All of the data on the form must be entered before the user can save any of the data on the form. When a box is left blank, and *OK* is clicked, an error message pops up. This serves as a reminder to complete the form before clicking *OK* to save the data.

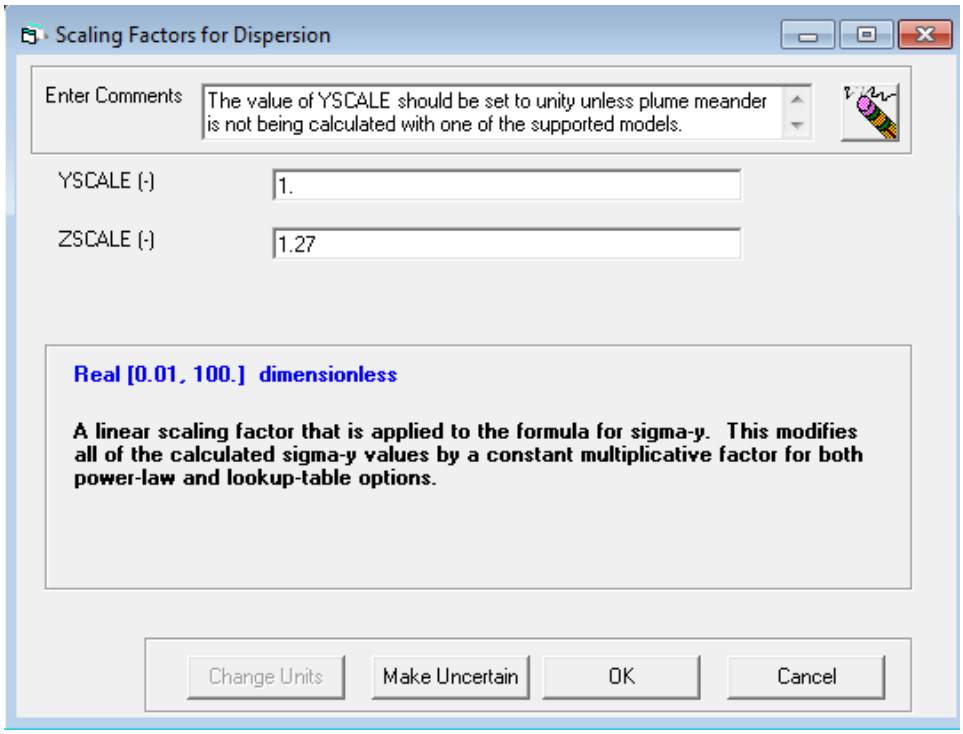
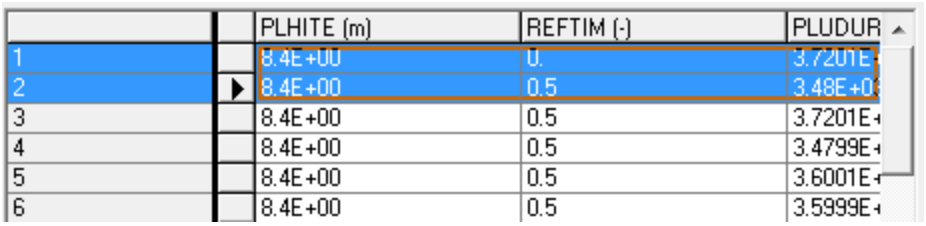


Figure 4-27 Parameter modification form

4.4.1.1 Modifying a Data Grid

Arrays and vectors are displayed in data grids. Data grids support the following operations:

- A row is selected by clicking on the small box between the row number and the data.
- A column is selected by clicking on the column heading.
- A row is deleted by pressing the Delete key on the keyboard after selecting the row.
- A change to a row can be undone by pressing the Esc key on the keyboard. As long as the pencil icon is shown on the left margin of a row, it is possible to click in a cell on that row and press the *ESC* key to undo changes.
- Clipboard functionality is provided. To use the copy feature in the grid, select the desired data from the grid with a mouse down, drag, mouse up motion. Figure 4-28 illustrates a selected area in the grid. To copy the data in this selected area to the Windows clipboard, select the *Edit→Grid→Copy to Clipboard* function from the main menu. Similarly, the *Edit→Grid→Paste from Clipboard* function can be used to replace a selected area in the grid with data on the Windows clipboard. This function can be used to transfer data from an Excel spreadsheet into WinMACCS.
- It is possible to select rows in a non-contiguous fashion by holding the control-key down while clicking on rows for selection. When pasting, it is possible to also select non-contiguous rows for pasting. In other words, not only can non-contiguous rows be selected for copying, but the effected rows for the past operation can also be selected.
- Columns can be selected, however these must be contiguous. When pasting, the area defining the paste is required to be contiguous.
- It is possible to select and paste a rectangular area by pressing the left mouse button down and dragging over the desired grid data.
- Copy and paste functions are supported with the keyboard shortcuts Cntl-F and Cntl-G respectively.



		PLHITE (m)	REFTIM (-)	PLUDUR
1		8.4E+00	0.	3.7201E
2	▶	8.4E+00	0.5	3.48E+0
3		8.4E+00	0.5	3.7201E
4		8.4E+00	0.5	3.4799E
5		8.4E+00	0.5	3.6001E
6		8.4E+00	0.5	3.5999E

Figure 4-28 Selecting grid data for copy and paste

When modifying a grid on a parameter form, it may be necessary to insert rows or columns. A row may be inserted by using the menu item *Edit→Grid→Insert Rows*. A column may be inserted by using the menu item *Edit→Grid→Insert Columns.*

4.4.1.2 Supported Data Types

The following data dimensions are supported:

- Scalar data: These are single values that are associated with variables. A scalar has various types, as listed below.
- Vector data: These are singly subscripted variables. Multiple vectors can be displayed on the same grid; however, each of these vectors must have the same number of rows.
- Array data: These are multiply subscripted variables (i.e., arrays). A single array can be displayed on a grid.

The following types are supported:

- Integer: A number with no decimal point. An integer can be positive, negative, or zero.
- Real: A number that has a decimal point.
- Logical: Represented by a pull down menu. Value is either *True* or *False*.
- Characters: A character string. Size requirements are shown in blue letters below the data entry area.
- Drop-Down Menu: Possible values are displayed as a pull down menu. Only a portion of the name needs to be typed. For example, on the ATMOS/Output Control/Spatial Intervals for Output form, typing a c for *CCDF* or an n for *NONE* and advancing to another field completes the data entry for the *CCDF* field.
- File: The name of a file is specified by clicking the browse button on the parameter modification form. The selected file is copied to the project\data\ folder.
- Linked Variables: The values of some variables are array sizes calculated by MACCS. For example, NUM_DIST is the size of the vectors DISTANCE, SIGMA_Y_A, etc. This variable cannot be directly modified. When a linked variable has focus, a description is displayed in the description area of the form. The value of the variable is updated as the number of grid rows increases or decreases. Linked variables are of type Integer, but can only take on positive values. Variable MAXGRP shown in Figure 4-29 is an example of a linked variable.

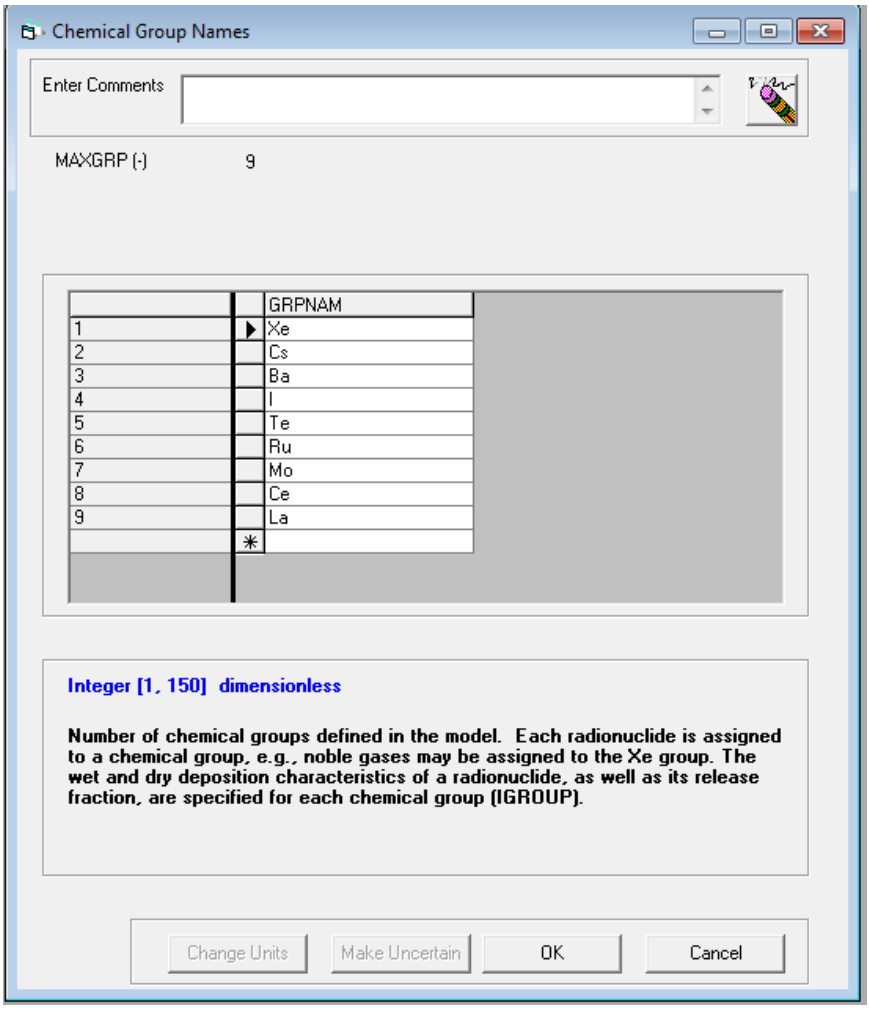


Figure 4-29 Example of a linked variable, MAXGRP

Note: A gray background in an input area indicates that the variable is read-only and cannot be changed in that form.

Examples of the data type and bounds that could be found in the description area are as follows:

- Real [.01, 100.]: A number between 0.01 and 100, inclusive, must be entered in the text field. This is displayed in Figure 4-30.

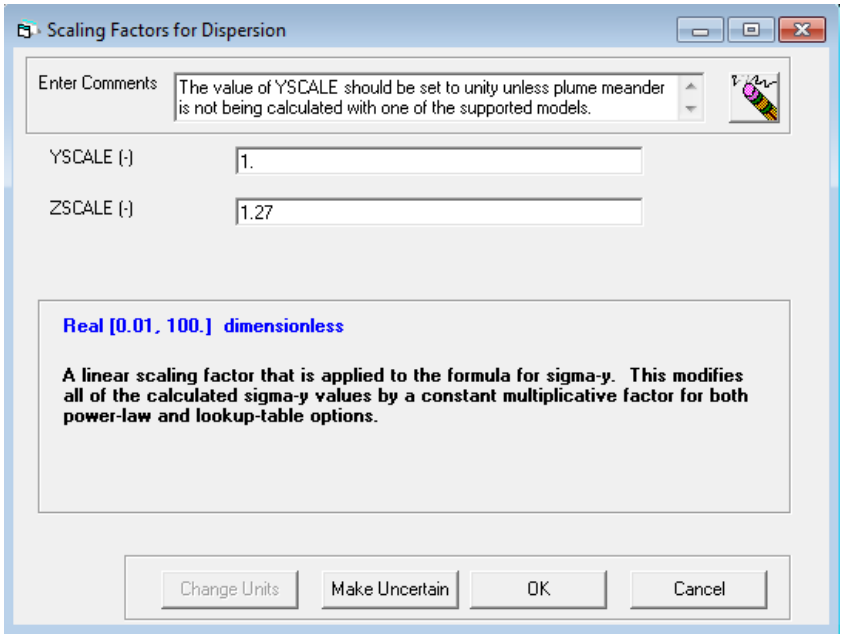


Figure 4-30 Real data type

- Integer [1, NUMREL], (NUMREL=10): An integer value from 1 to 10 must be entered in the text field. When the value of NUMREL, the number of plume segments, is modified and saved on another form, the bounds are changed to reflect the new value of NUMREL as shown in Figure 4-31.

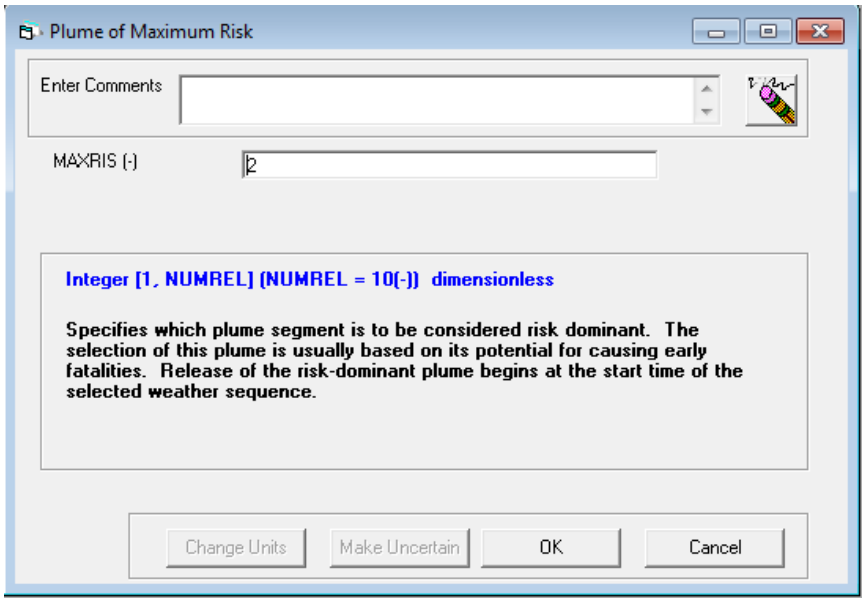


Figure 4-31 Variable upper bound is a variable

- 1 to 16 Characters: A character string that is at least one character and not more than 16 characters must be entered in the field as shown in Figure 4-32.
- Row Bounds: [1, 10]: The grid must have at least one row and not more than 10 rows as shown in Figure 4-32.

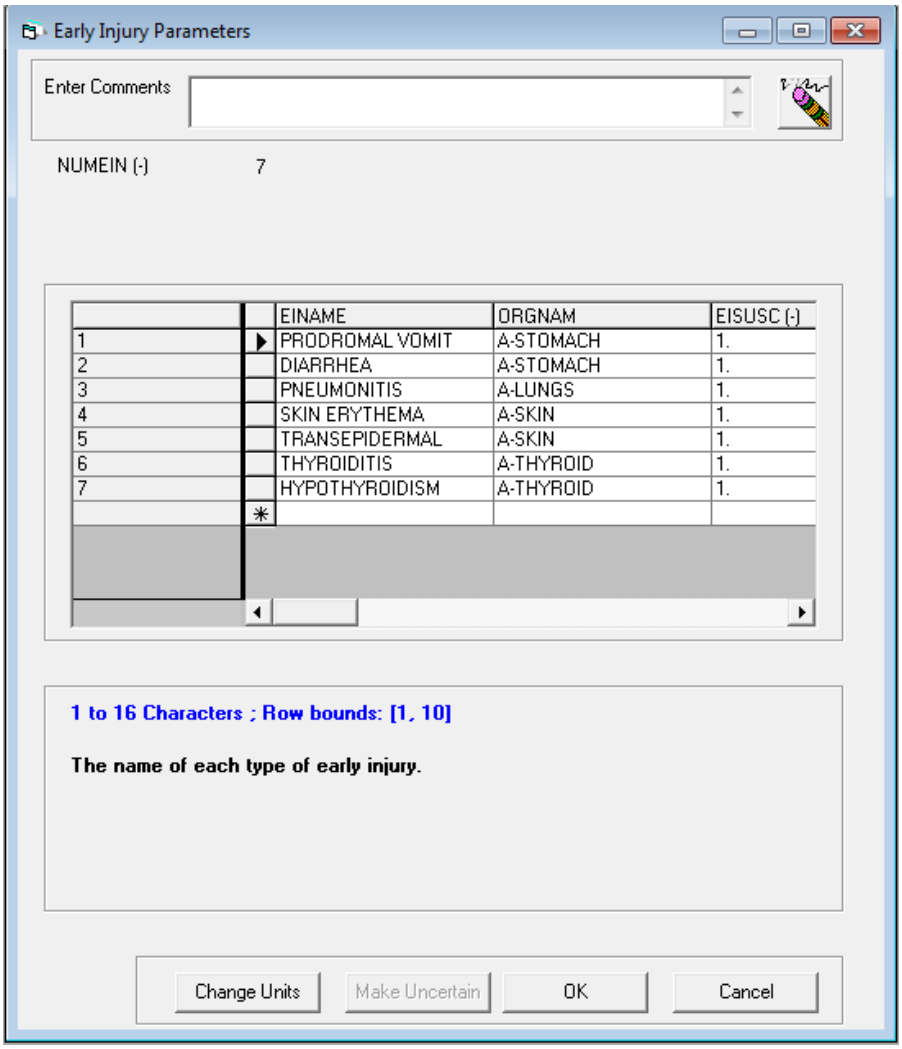


Figure 4-32 Character length limits

- Nrows = 6: The grid must have exactly 6 rows. This is shown in Figure 4-33.

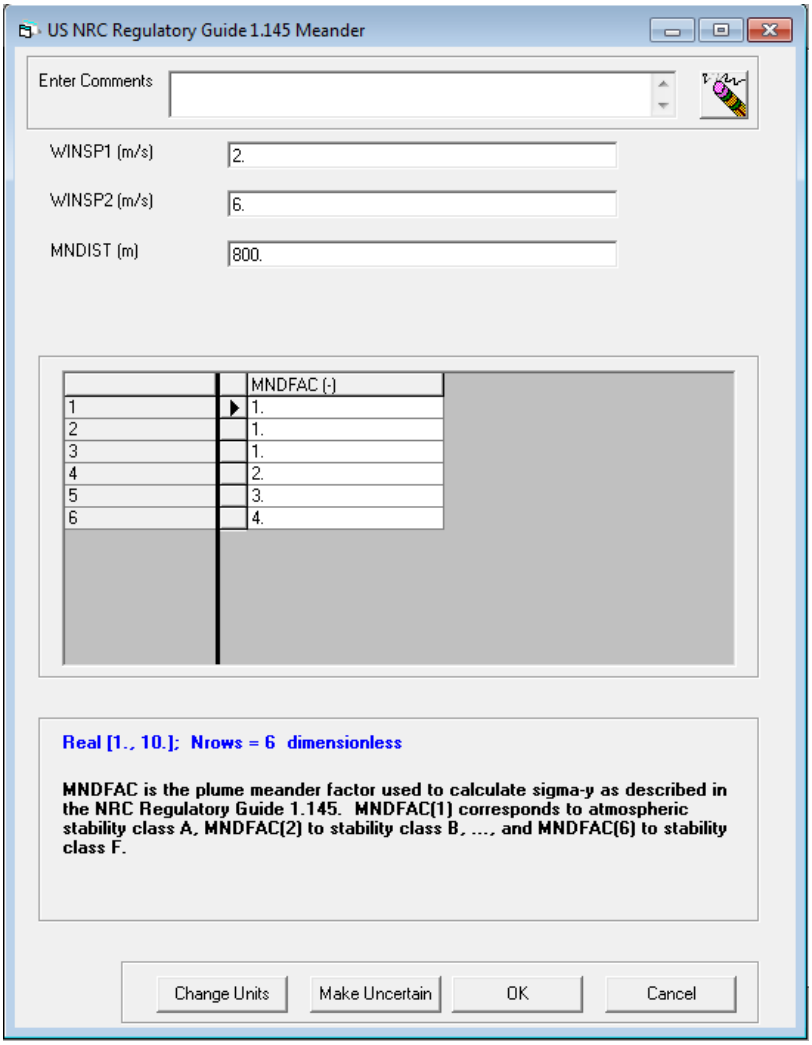


Figure 4-33 Grid with fixed number of rows

4.4.1.3 Making a Parameter Value Uncertain

WinMACCS allows input parameter values to be made uncertain and enables sampling of the uncertain variables. The sampling can be done using either a Monte Carlo method or a stratified method known as Latin Hypercube Sampling (LHS). The sampling method can be changed from the default of LHS to simple sampling by selecting the main menu entry *Execute→Simple Random Sampling.*

The sampling allows the effect of an uncertain input value to be explored. Uncertain variables must be assigned a distribution function from which samples are selected. The distribution function usually represents degree of belief over a range of values that are considered credible for that parameter.

A parameter value can be made to be uncertain by first opening the window associated with that parameter. This can be done by double-clicking on the variable name in the *Parameters* tab in the *Project* window or by using *Edit→Find Parameter Window* to locate the form.

The user can double-click on the parameter value or click on the parameter value and click on the *Make Uncertain* button. An example uncertain variable form is shown in Figure 4-34.

A form opens with the parameter name in the form title (or caption).

Use this form to:

- Change parameters from constants to uncertain values described by probability distributions.
- Change parameters from distributions to constants.
- Change the probability distribution associated with the variable.

Notice that the variable name is shown in the form caption. When an array or vector element is associated with a distribution, the index is also part of the name shown in the title bar. In Figure 4-34, BUILDH(3) in the caption portion of the form indicates that the third value of vector BUILDH is being considered for modification.

WinMACCS supports a wide range of distribution types, and each distribution type can accept a wide range of values for its parameters. It is possible to specify values for the distribution parameters that lead to invalid distributions, causing the LHS sampling to fail. The distribution parameter values entered should represent a reasonable distribution for the parameter. Furthermore, it is possible to define distributions that lead to values out of range of the parameter (e.g., a negative value for a MACCS parameter that must be greater than zero).

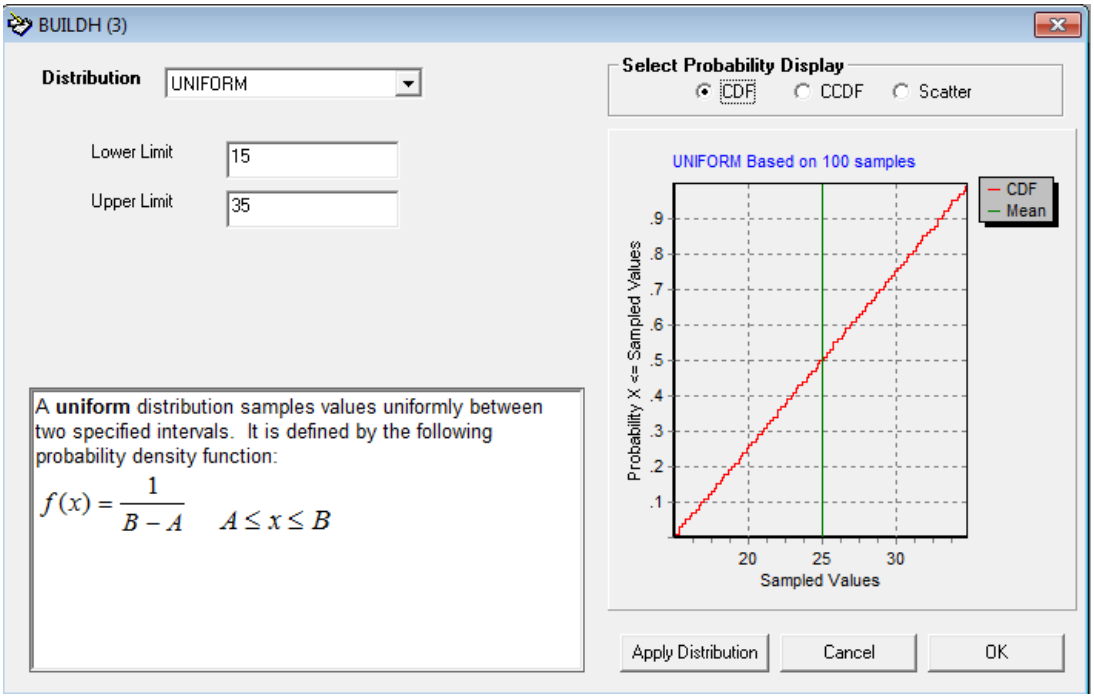


Figure 4-34 Assigning a probability distribution to a parameter

The value of an uncertain parameter can be modified as follows:

1. The user first must select the distribution from the *Distribution* pull down list. The parameter can be changed from a distribution to a constant (deterministic) value by setting the distribution to CONSTANT.

2. The user enters the values that define the distribution in the text boxes or tables. The type of distribution determines the amount and type of information needed to define the value. The values that define the distribution either consist of a list of (x, y) pairs (known as tabulated data), or a list of parameters (such as the mean and standard deviation of the normal distribution). An example is shown in Figure 4-35.

1. A representative sample of the current distribution entered can be viewed by clicking *Apply Distribution*. LHS starts, and one hundred samples are returned and displayed. The data can be viewed as a CDF, CCDF, or a Scatter plot. The mean of the distribution is shown in each view. The sampled values used when running the model may differ from those shown on this graph because the input to LHS with respect to the number of samples and the seed used may not be the same.

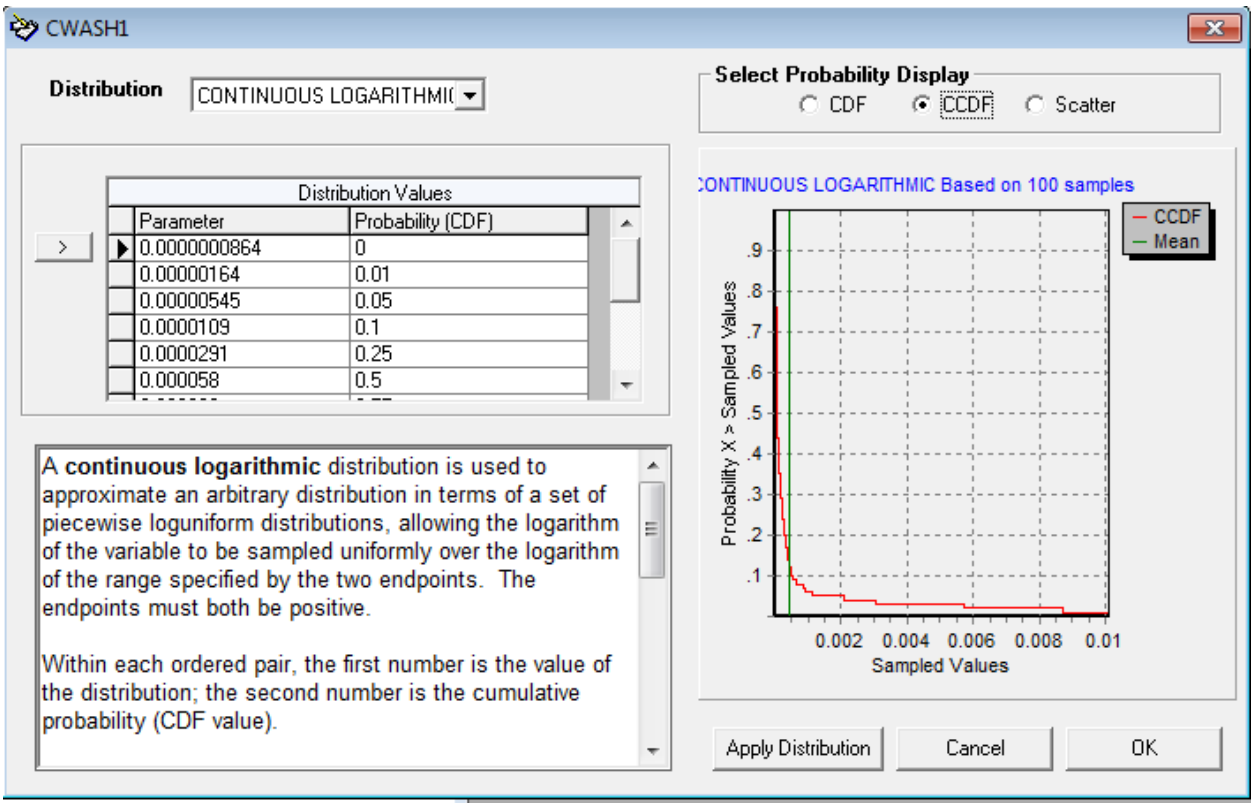


Figure 4-35 Tabulated uncertain parameters

3. A row of tabulated data can be deleted by selecting the row by clicking on the left margin of the row and pressing the Delete key on the keyboard.

4. By pressing the ESC key on the keyboard, typing can be undone. As long as the pencil icon is shown on the left margin of a row, it is possible to click in a cell on that row and press the ESC key to undo changes.

5. A row of data can be inserted by selecting an existing row and clicking the row insert button (>|).

6. By using the left or right arrow key on the keyboard, focus can be moved to an adjacent cell. The Enter key also advances the curser to the next cell.

7. When satisfied with the distribution specified the OK button can be clicked as shown in Figure 4-34 or Figure 4-35. This closes the window and saves any changes made to the parameter value. The value of the parameter in the parameter modification form is set to the character string "Uncertain" and has a different colored background than constant values on the form as shown in Figure 4-36.

	PDELAY (s)	PLHITE (m)	REFTIM (-)
	34360.	39.64	0.E+00
▶	34368.	4.04	UNCERTAIN
	35020.	39.64	.5

Figure 4-36 Uncertain variable in a parameter modification form

2. Changes can be discarded by selecting Cancel.

Another way to view the parameter values after running MACCS is to open the file LHS.inp by clicking the *Files* tab within the project, opening the *Input* category and double-clicking on the file name LHS.inp. The sampled values used in the MACCS simulation can be viewed by double-clicking on the file name LHS.out.

4.4.2 Changing Units

Within WinMACCS, it is possible to specify unit changes. There are three different types of unit changes, namely input units on a parameter modification form, input units used on forms defining the cohort parameters, and output units for MACCS reporting.

Unit changes are integrated into other WinMACCS functions as follows:

- The function that imports MACCS input files into the user interface (menu selection File/Import MACCS Input File) converts values to user specified units on each form.
- The reset to default function (right click on form name and select *Reset to Default*) respects units chosen by the user, and converts default values to units specified.
- Uncertain variable distributions must be changed by the user to be in the units specified on the form. In other words, when the units are changed on a form with an uncertain variable, the distribution is not automatically modified to be in the new units; the user is responsible to convert the distribution to the new units.
- Parameter bounds reflect the units selected on the parameter modification form.
- Map forms (evacuation direction, speed multiplier, and cohort population) show values and units labels (km, mi, etc.) in specified units.

4.4.2.1 Modify the Input Units for Non-Cohort Variables

The user is also allowed to change input units for many of the input forms by using the *Change Units* button on the parameter modification forms. Each dimensioned parameter in WinMACCS is assigned to a unit family. The user can change input units and also convert existing values to the new input units that belong to the family assigned.

Most parameter definition forms now include a *Change Units* button that allows unit changes, as shown in Figure 4-37. When there are no parameters on the form with units that can be changed, this button is grayed out. The *Change Units* button is always grayed out on the cohort specific forms since those units are changed on the *Cohort Units* form.

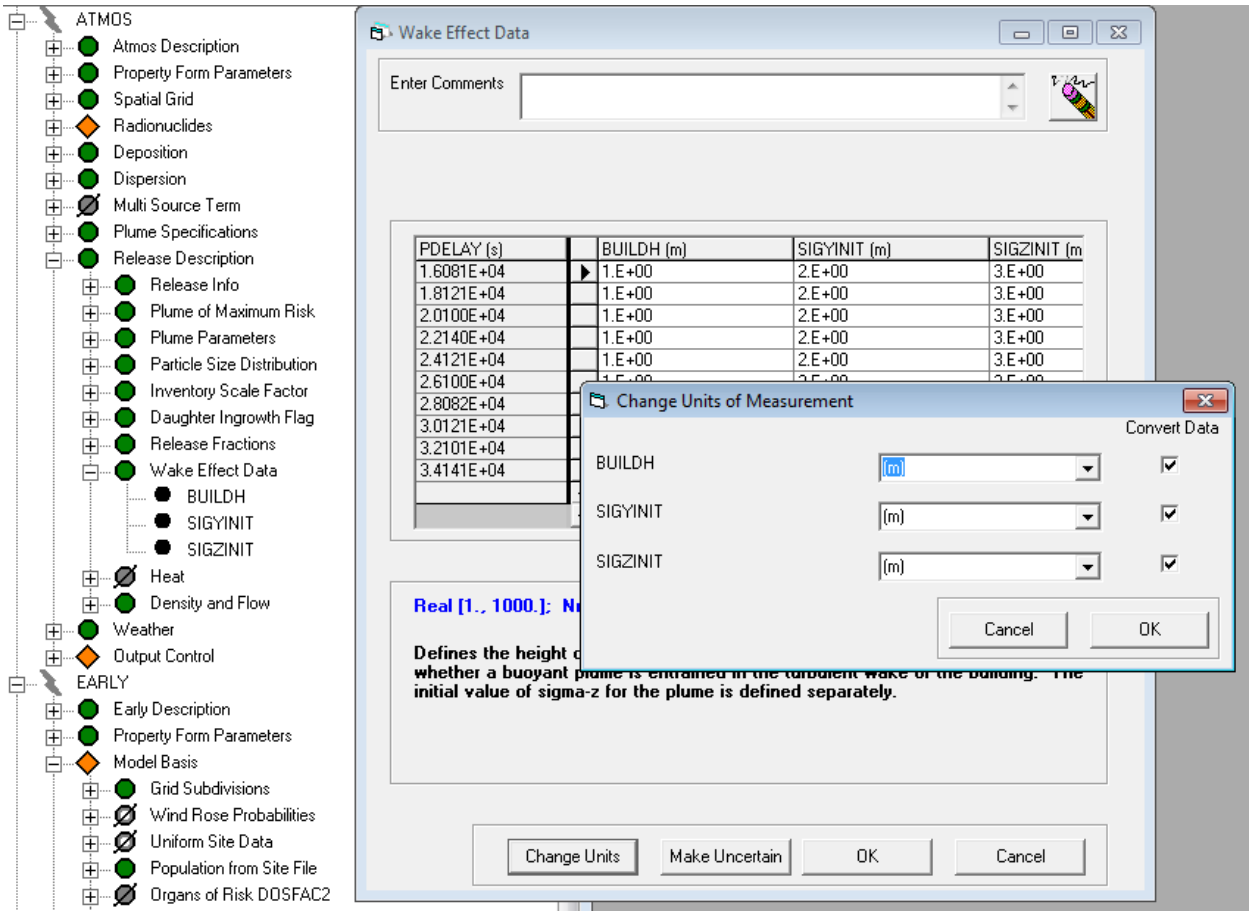


Figure 4-37 Changing units on a parameter form

When building the MACCS input files, input parameter values are modified to be consistent with MACCS input parameter units, which are consistent with the default units shown in Table 4-1. Thus, MACCS input files retain their default units and input unit conversion is handled by WinMACCS.

4.4.2.2 Modify the Input Units for Cohort Variables

To avoid confusion, units are not allowed to be different between the sets of cohorts. To enforce this requirement, there is one form used to specify units for all parameters associated with cohort definitions. This form is opened by clicking on the *EARLY/Model Basis/Cohort Units* entry as shown in Figure 4-38.

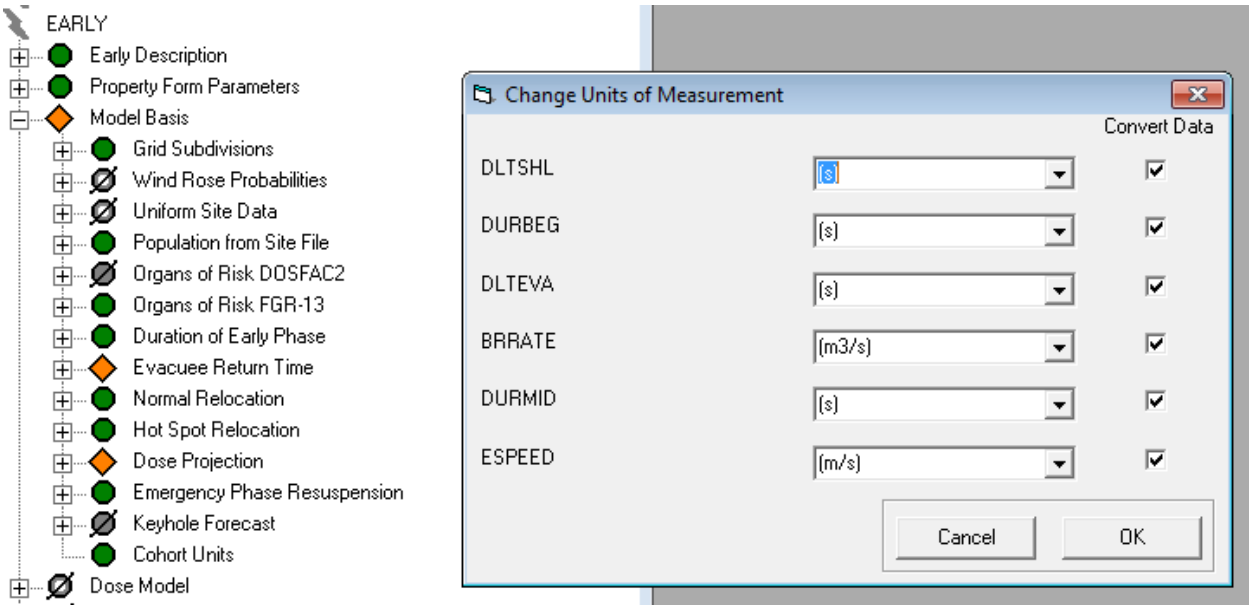


Figure 4-38 Assigning units for cohort parameters

4.4.2.3 Modify the Output Units for MACCS reporting

A form, shown in Figure 4-39, allows the user to request results be reported in optional units, shown in Table 4-1, in both the text and binary output files created by MACCS.

Table 4-1 Default and optional units for MACCS reporting.

Unit Family	Default Unit	Optional Units
Activity	Bq	Ci
Distance	km	mi
Area	ha	km^2, mi^2
Dose	Sv	rem

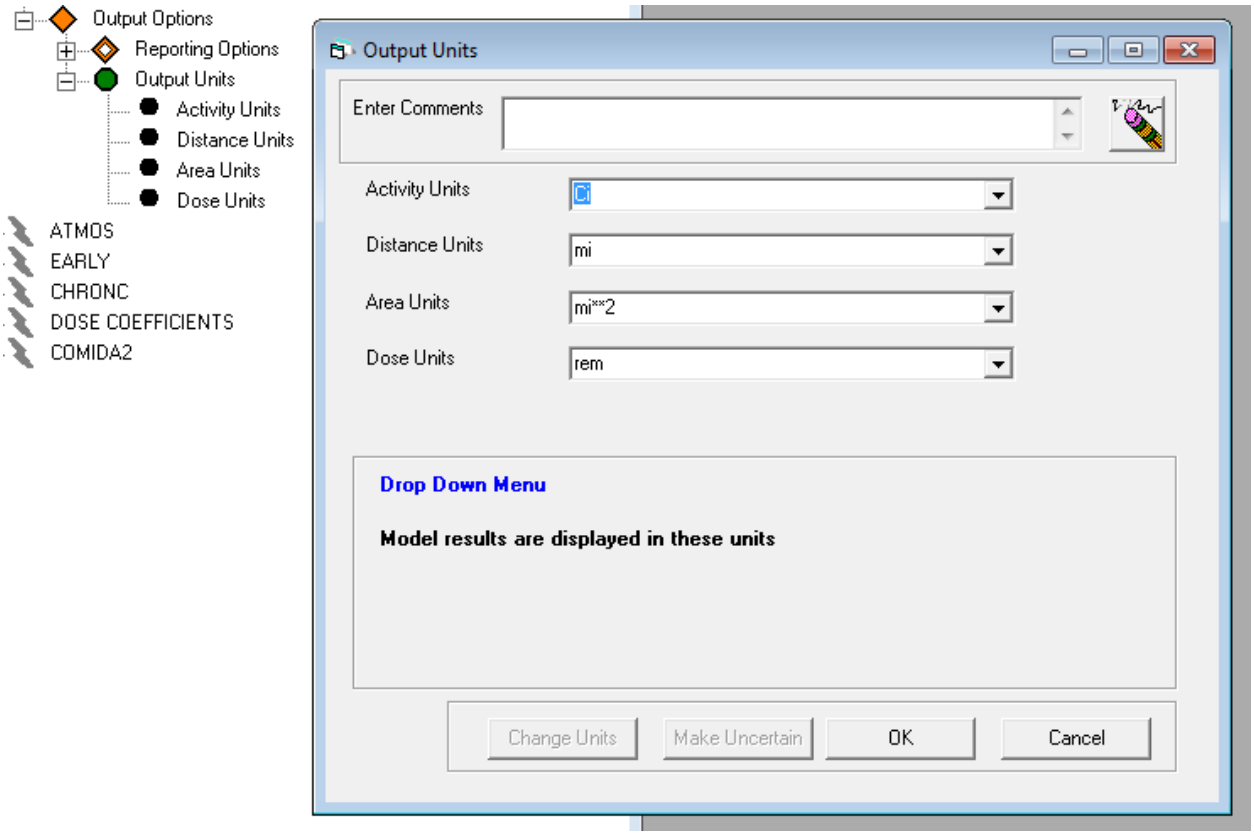


Figure 4-39 Specifying MACCS reporting units

4.4.3 Correlate Uncertain Parameters

In many cases, sets of uncertain input variables are correlated.

WinMACCS allows two methods for correlating uncertain input variables. The first uses rank correlation coefficients; the second method performs a direct rank reordering of one variable and is described in section 4.4.3.2.

To correlate variables that have been chosen to be uncertain, select *Edit→Correlate Uncertain Variables→Linear Coefficients* from the main menu. This opens the *Correlate Uncertain Variables* form, which lists each rank correlation that is currently defined and allows new correlations to be defined.

4.4.3.1 Correlation Using LHS

After LHS has run and imposed correlations specified by the user, WinMACCS can reorder some of the variables to be consistent with the rank order of other variables. This is a desirable feature when there is a need to impose a perfect correlation of 1 or -1 between two sets of variables. LHS does not support this feature.

The command Edit→ Correlate Uncertain Variables→ Linear Coefficients opens the Correlate Uncertain Variables form as shown in Figure 4-40.

Adding correlations in the table's insertion row (indicated by "*" at the beginning of the row) can be done by doing the following:

6. By clicking in the grid element in the *Parameter One* column, an uncertain parameter can be selected.
7. By clicking in the grid element in the *Parameter Two* column, the uncertain parameter to correlate with *Parameter One* can be selected.
8. The rank correlation coefficient between the two selected parameters in the column labeled *Correlation Coefficient* is done by typing a value in the third column.

Variables can be positively or negatively correlated by specifying a correlation coefficient within the range (-1.0, +1.0), where the value -1.0 and 1.0 is not allowed.

The correlations apply to the ranks of the parameter values rather than to the values themselves. Correlation coefficients must be greater than -1 and less than 1. These limits are enforced by WinMACCS.

When any two parameters are uncorrelated, they have an implied correlation coefficient of zero, which is the default. Implied correlation coefficients are not listed in the table. Correlations can be removed (i.e., set to zero) by selecting the grid row and pressing the delete key on the keyboard.

By using the arrow keys on the keyboard, focus moves from cell to cell in the grid.

Clicking *OK* preserves changes. Clicking *Cancel* discards changes.

WinMACCS creates a report titled SampleRank.out in the project Input/ folder that summarizes the correlations and the order and values of the uncertain variables used in the MACCS simulations.

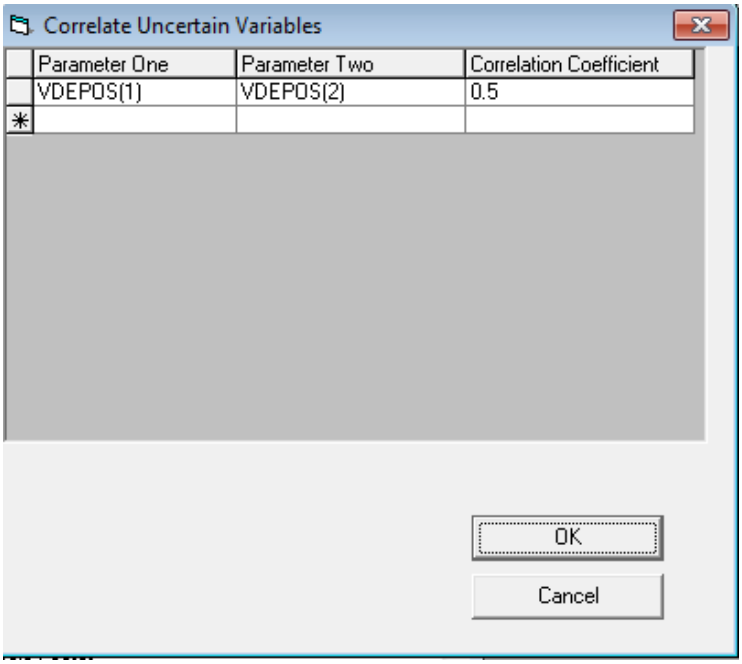


Figure 4-40 Correlate uncertain variables

There are some restrictions on the correlations that WinMACCS allows. For example, it doesn't make sense to rank correlate two variables, say A and B, with a coefficient, and impose a rank order of B with respect to the order of A. WinMACCS does not allow the same pair of variables to be rank correlated (as described in section 4.4.3.2) and also to be reordered.

It is possible to specify combinations of rank correlations that are not mutually consistent. Such inconsistencies are generally in the form of circular correlations. For example, two parameters "A" and "B" can be assigned a correlation coefficient of 0.99, parameters "B" and "C" can also be given a correlation coefficient of 0.99, but parameters "A" and "C" can be assigned a correlation of -0.99. Each correlation is valid by itself, but the three are logically incompatible. The parameter sampling may fail when circular correlations are inconsistently defined.

It is not possible to perfectly correlate two variables using this option. In this case, use the command *Edit→ Correlate Uncertain Variables→ Enforce Rank Order.*

4.4.3.2 Enforcing Rank Order

Selecting *Edit→ Correlate Uncertain Variables→ Enforce Rank Order* from the main menu allows ranking of variables that have been chosen to be uncertain. This opens the *Enforce Rank Order of Uncertain Variables* form as shown in Figure 4-41, which lists each rank correlation that is currently defined and allows new correlations to be defined.

Rank orders are specified as follows:

1. The uncertain varialbes are defined by opening the relevant parameter modification forms and associating the variables to be ranked with probability distributions by clicking on the *Make Uncertain* button, closing the forms, and saving the values.

2. The *Enforce Rank Order of Uncertain Variables* form is opened by selecting *Edit→Correlate Uncertain Variables→Enforce Rank Order*.

3. In the column labeled *Reorder Basis* the user selects the first uncertain variable. The order of this variable is not changed from the order of values returned from LHS.

4. In the column labeled *Reorder Parameter*, the user selects the uncertain variable whose order is to be changed.

5. In the column labeled *Rank Order* the user selects either *Inverse Order* to order the variable in the opposite order as the basis parameter, Reorder Basis, or *Same Order* to order the variable in the same relative order as the basis parameter.

6. As many entries as needed may be added to the table.

7. Clicking *OK* preserves changes. Clicking *Cancel* discards changes.

Rows can be deleted by selecting the grid row and pressing the delete key on the keyboard. The arrow keys are used to move from cell to cell in the table.

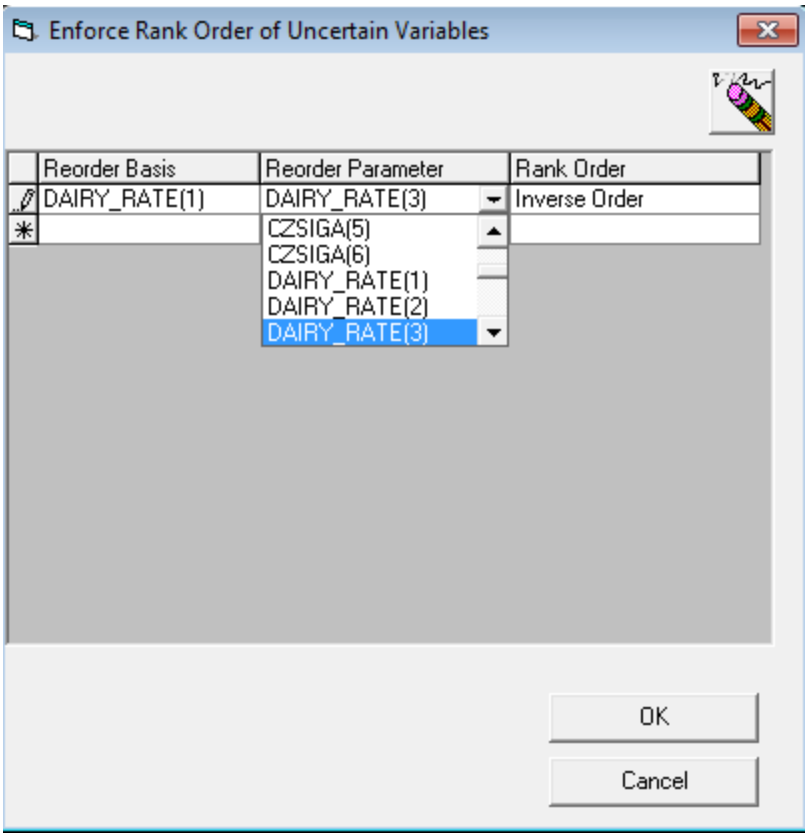


Figure 4-41 Enforce rank order form

In the example shown in Figure 4-42, a perfect positive correlation is imposed between ATMOS variables BUILDH(1) and SIGZINIT(1), and a perfect negative correlation is imposed between COMIDA2 variables DAIRY_RATE(1) and DAIRY_RATE(3).

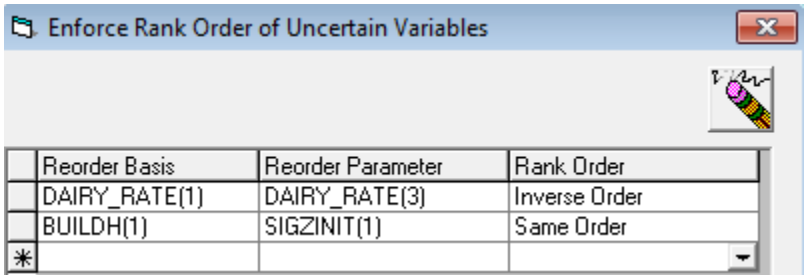


Figure 4-42 Enforce rank order example

This ordering request causes the values of DAIRY_RATE(3) and SIGZINIT(1) to be changed from the order returned by LHS. After execution, LHS.out can be opened by double clicking the entry LHS.out found on the *Files* Tab in the *Input* category. Sample values from LHS.out are shown in Table 4-2.

Table 4-2 Sampling example.

Trial	BUILDH(1)	DAIRY_RATE(1)	SIGZINIT(1)	DAIRY_RATE(3)
1	249.675	5.81245	295.12	9.16814
2	123.061	10.1165	281.956	10.3411

3	180.287	15.7363	338.324	12.1482
4	214.842	21.8037	267.811	13.5931
5	188.622	19.2878	312.628	5.65193

The actual order used in the sequence of MACCS simulations is in the file SampleRank.out, found in the project Input folder. In this example, the ranked order is shown in Table 4-3.

Table 4-3 Sampling ranked.

Sample	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Trial	BUILDH(1)		DAIRY_RATE(1)		SIGZINIT(1)		DAIRY_RATE(3)	
1	249.675	5	5.81245	1	338.324	5	13.5931	5
2	123.061	1	10.1165	2	267.811	1	12.1482	4
3	180.287	2	15.7363	3	281.956	2	10.3411	3
4	214.842	4	21.8037	5	312.628	4	5.65193	1
5	188.622	3	19.2878	4	295.12	3	9.16814	2

This table tells us which values are used in each MACCS simulation. For example, for trial number 3 (corresponding to the output file Model3.out), BUILDH(1) is set to 180.287 and SIGZINIT(1) is set to 281.956.

Notice that values of BUILDH(1) and DAIRY_RATE(1) are preserved from the order listed in the LHS output. However, values for SIGZINIT(1) and DAIRY_RATE(3) have been reordered so that the rank order for SIGZINIT(1) is the same as that of BUILDH(1), and the rank order of DAIRY_RATE(3) is the opposite of that for DAIRY_RATE(1).

WinMACCS creates a report titled SampleRank.out in the project Input/ folder that summarizes the correlations and the order and values of the uncertain variables used in the MACCS simulations.

With the introduction of spatial grid forms containing complex evacuation directions and speed multipliers, came a need to replicate the values to other cohorts. Cohort forms are forms that are in the *EARLY/Emergency Cohort One* and *EARLY/Additional Emergency Cohorts* categories. Copying form data from one cohort form to another cohort form can be accomplished by right clicking on the form within a cohort category and selecting the popup menu item Copy Cohort Variables or by using the main menu function *Edit→Modify Form Variables→Copy Cohort Variables*. See section 0 for more information.

4.4.4 Copy Values between Cohorts

With the introduction of spatial grid forms containing complex evacuation directions and speed multipliers, came a need to replicate the values to other cohorts. Cohort forms are forms that are in the *EARLY/Emergency Cohort One* and *EARLY/Additional Emergency Cohorts* categories. Copying form data from one cohort form to another cohort form can be accomplished by right clicking on the form within a cohort category and selecting the popup menu item Copy Cohort Variables or by using the main menu function *Edit→Modify Form Variables→Copy Cohort Variables*. A dialog box opens as shown in Figure 4-43.

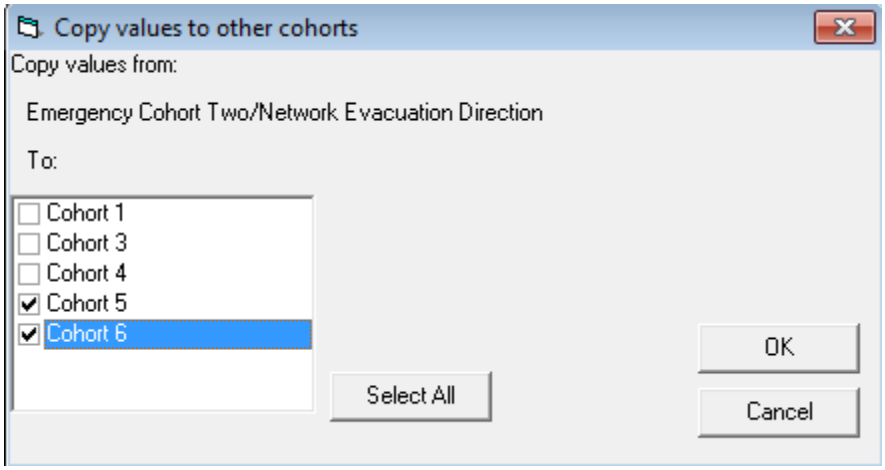


Figure 4-43 Copy values from one cohort form to other cohort forms

In the following example, the user wants to copy all of the values in the *Network Evacuation Direction* from cohort two to cohort five and cohort six.

3. The user first closes forms Emergency Cohort Two/Network Evacuation Direction, Emergency Cohort Two/Network Evacuation Direction and Emergency Cohort Two/Network Evacuation Direction.

4. The user clicks on the form name Network Evacuation Direction under the category Emergency Cohort Two, highlighting the form name as shown in Figure 4-44.

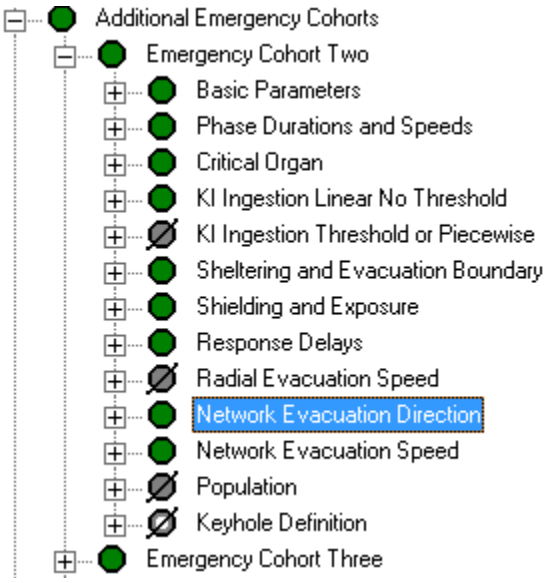


Figure 4-44 Select network evacuation direction form

5. The user right clicks on *Network Evacuation Direction* and selects the pop up menu item *Copy Cohort Variables*. Alternatively, *Edit→Modify Form Variables→Copy Cohort Variables* can be selected from the main menu as shown in Figure 4-43. Checking the boxes labeled *Cohort 5* and *Cohort 6* and clicking *OK* replicates the data for this form into the cohort 5 and cohort 6 forms.

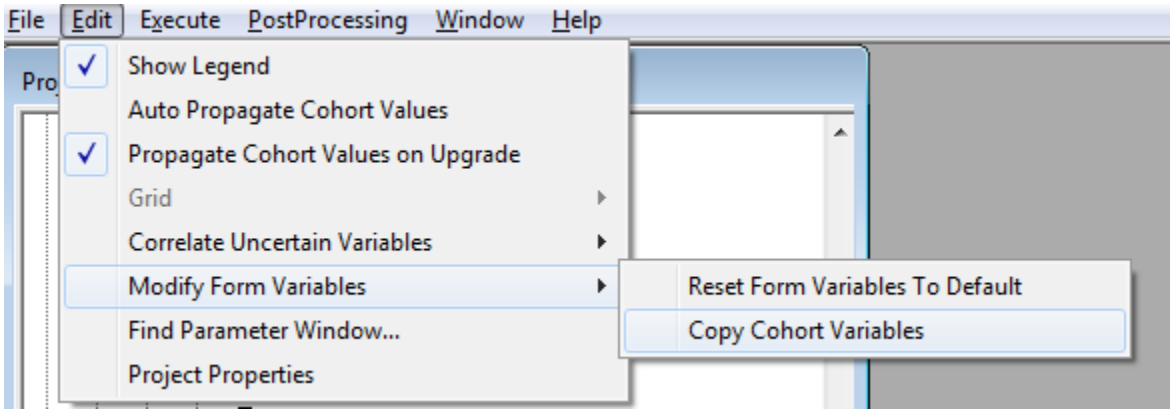


Figure 4-45 Copy form values between evacuation cohorts

6. When an empty form is selected as the form to copy from (or base form), no data are replaced on the forms selected for application.

7. When the base form is open and this option is used, the saved values of the variables are used in the copy. In other words, when the base form is opened and values are changed, when selecting *Edit->Modify Form Variables->Copy Cohort Variables* the values that are copied are the values saved the last time the form's *OK* button was clicked, not the new values just entered.

Comments on forms are not copied or propagated.

4.4.5 Annual Dose Conversion Factor and Annual COMIDA2 Files

When the Annual Threshold or Piecewise Linear dose models are chosen on the Dose tab of the Project Properties form, a set of fifty-one dose conversion factor (DCF) files are needed by MACCS. Additionally, when either of these dose models is chosen and the COMIDA2 Food Model is chosen on the Food tab, a set of fifty-one COMIDA2 files are needed by MACCS, each COMIDA2 file having been created with its associated DOSFAC2 file.

WinMACCS is distributed with files sets to be used with the annual threshold or piecewise linear dose models. The first set is based on DOE/EH-0070 (1988); the second is based on *EPA (2002) Federal Guidance Report No.13.*

The base DCF file is one that contains the conversion factors for a fifty year commitment period. The base COMIDA2 file is created using the base DCF file.

The annual, differential DCF files contain the dose conversion factors for each year of the 50-year commitment period. These file names are sequenced to enable the identification of the year number. For example, FGR13DCF03.inp corresponds to the dose conversion factors used to calculate the dose in year three for an exposure that occurred in year one. The annual COMIDA2 files are created using the corresponding annual DCF files.

The following example shows how an annual differential DCF and COMIDA2 file set can be specified:

1. Opening the *GENERAL/File Specifications/Annual Differential DCF Files* form allows the specification of the DCF files as shown in Figure 4-46.

2. Opening the folder where the DCF are files are located updates the column labeled *Click Base DCF File*. This is done by selecting the correct hard drive in the *Select Drive* pull down menu and locating the folder on the form. When WinMACCS is installed, a copy of the DCF and COMIDA2 files are put in the Program Files\WinMACCS folder.

3. Selecting the base DCF file in the box directly under the title *Click Base DCF File* results in the fields *Base DCF File* and *Expected Auxiliary Files* to be populated. In the example shown in Figure 4-46, the name of the base file is FGR13DCF.inp. The base file name is copied in the box labeled *Base DCF File.* Other file names are generated given this base file following the algorithm of appending the year number to the file name. WinMACCS expects these additional files to be present in the current folder.

4. *OK* can be clicked to save the changes. WinMACCS copies the base DCF file and the fifty auxiliary files to the project\Data folder. Click *Cancel* to close this form without saving any changes.

5. Open the *GENERAL/File Specifications/Annual Differential COMIDA2 Files* form and repeat this process to define the COMIDA2 file set when needed

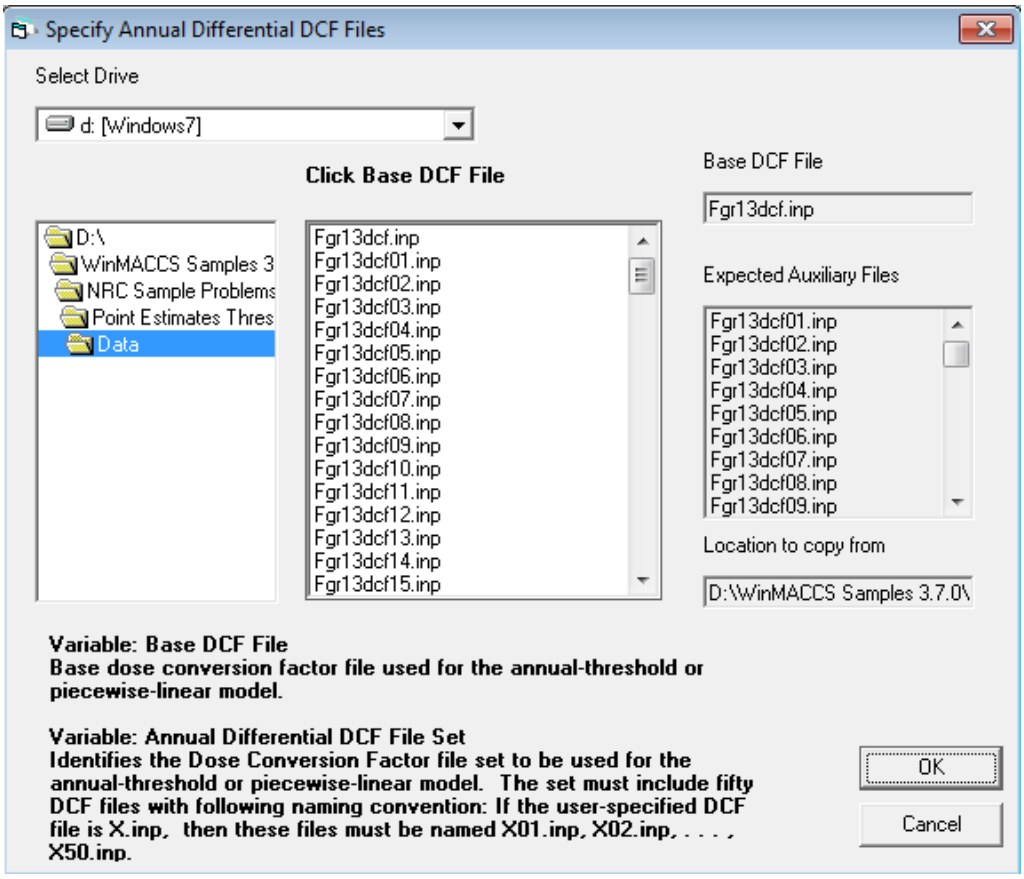


Figure 4-46 Threshold DCF files

4.4.6 Sequential MACCS Files

MACCS input can be changed using successive input files. A single MACCS simulation is run for each of the files specified.

The sequential, or cyclical, files must be formatted consistently as MACCS input files. However, the ATMOS, EARLY, CHRONC, and COMIDA2 input for a single simulation can be combined into a single file.

The parameter values specified in each of the cyclical files are used for a simulation. When a required parameter is not specified, the value of that parameter in the WinMACCS project is used.

Before executing a set of cyclical files, a complete problem description must be defined. Parameter values in the cyclical files override the parameters defined in WinMACCS. Thus, the cyclical files do not need to contain a complete problem description, but only the set of parameters to be modified.

An example of a cyclical file with a source term definition is a MelMACCS output file.

4.4.6.1 Specifying Cyclical MACCS Files

MACCS cyclical input files can be specified as follows:

1. The *MACCS Cyclical File Set* model can be selected by opening the *Properties* form, checking the box *MACCS Cyclical File Set* on the *Scope* tab, and clicking *OK*.

2. The *GENERAL/File Specifications/Cyclical File Set* form is opened, similar to the form shown in Figure 4-47.

3. The location of the MACCS cyclical files should be located by selecting the correct drive and folder.

4. Double-clicking on the MACCS cyclical file names will add them to the list on the right side of the window.

5. Clicking *OK* will save the file selection. The files are copied to the project Data\ folder. Clicking *Cancel* closes the window without copying any files.

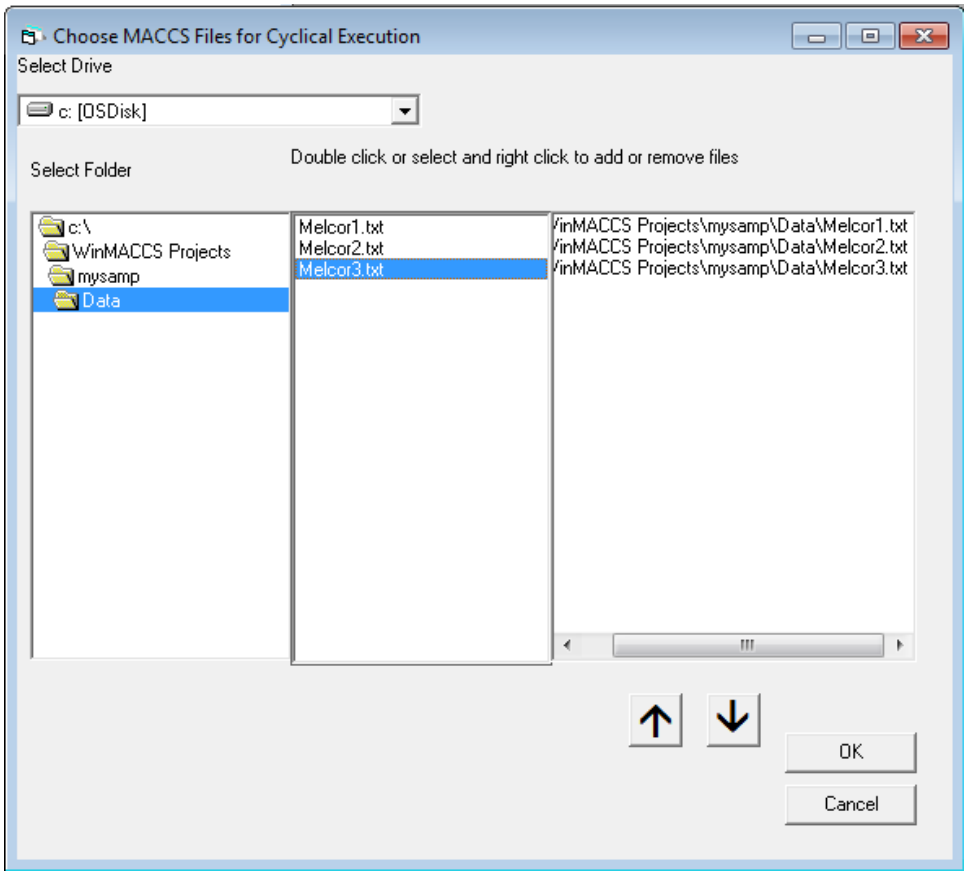


Figure 4-47 Choose input files for cyclical execution

A file can be removed from the cyclical set by selecting the file in the list on the right side of the form, as shown in Figure 4-47, and pressing the *Delete* key on the keyboard.

The order of processing the files by WinMACCS can be changed by selecting the file in the list of cyclical files and using the up and down arrow to change the order the selected file is listed. When MACCS executes, the files are used in the order they appear on this form.

An interface tool named MELMACCS can be used to create MACCS-formatted files that contain source term information extracted from a MELCOR plot file. These files can be specified as cyclical files. In this way, a set of source terms for a plant can be run sequentially.

4.4.6.2 Cyclical Execution with Uncertain Parameters

It is possible to perform calculations with a cyclical file set and to sample uncertain variables using LHS simultaneously. When this is done, the number of simulations should be set to a multiple of the number of cyclical files. The values from the cyclical files will be reused when the number of simulations is greater than the number of cyclical files.

For example, when six simulations are requested, but there are three cyclical files, simulation one and four will use the values from the first file, two and five the values from the second file and three and six the values from the last file. LHS will generate six sampled value sets and insert these values into the MACCS input files as expected.

4.4.7 Spatial Grid Forms

Spatial grid forms are applicable in the following situations:

- Evacuation directions are required when network evacuation is enabled.
- When the speed multiplier option has been activated on the *Properties* form, speed multipliers per grid element (i.e., for each direction and spatial distance) can be specified for either the radial or network evacuation models, depending on which option is selected.
- When population by cohort is specified, populations per grid element can be specified. This option is activated on the *Properties* form on the *Site Data* tab.

All spatial grid forms contain the following functions

- A copy of a map with the directions and speed multipliers as is shown in the spatial grid form can be created by clicking on the *Save Map* button as shown in Figure 4-57.
- The map shown behind the polar grid can be hidden by checking the *Hide Map* check box.
- Comments can be entered at the top of the form.
- The inner ring and outer ring controls allow zooming in and out.
- Multiple radii and sectors can be selected using the Windows shift-select and control-select functions. The selected grid elements can be assigned a common value.

4.4.7.1 Evacuation and Speed Multiplier Model

Radial and network evacuation and speed multiplier model parameters are defined using spatial grid forms.

These models can be enabled as follows:

1. By selecting *Edit→Project Properties* from the main menu, the *Project Properties* form can be opened.

2. Clicking on the *Evac/Rotation* tab as shown in Figure 4-48 allows the user to select *Radial* or *Network* for the problem model.

3. The evacuation type needs to be defined for each of the cohorts.

4. When speeds vary within the evacuation grid elements for either the network or the radial evacuation models, check the box *Activate Speed Multiplier Model*.

5. Clicking *OK* saves the settings, clicking *Cancel* cancels the settings.

When the *Network* evacuation is selected, the *Network Evacuation Direction* form is required for cohort one. When the *Activate Speed Multiplier Model* is checked, either the *Radial Evacuation Speed* or the *Network Evacuation Speed* form is required for cohort one.

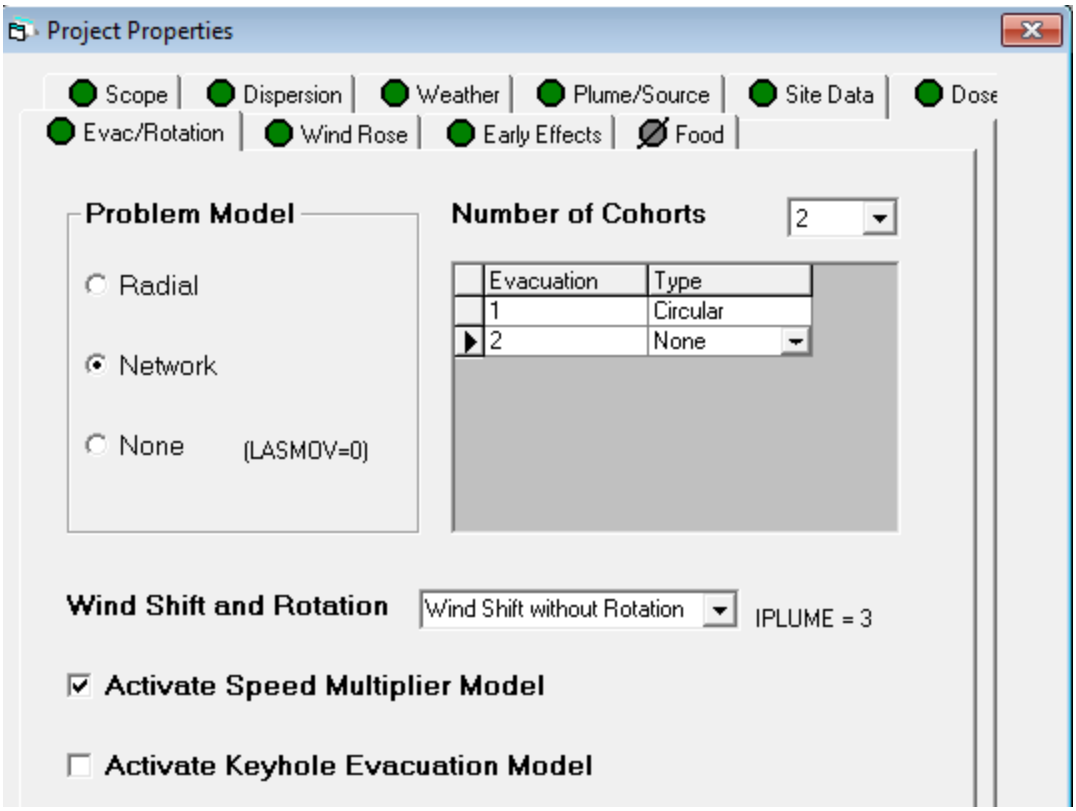


Figure 4-48 Activate speed multiplier model

The variables SPAEND, as shown in Figure 4-49, and LASMOV, as shown in Figure 4-50, must be defined before the *Network Evacuation Direction* forms, *Radial Evacuation Speed* or the *Network Evacuation Speed* forms can be successfully opened. These two variables are needed to define the evacuation grid. As a side effect, NUMEVA must also be defined because it is on the same form as LASMOV.

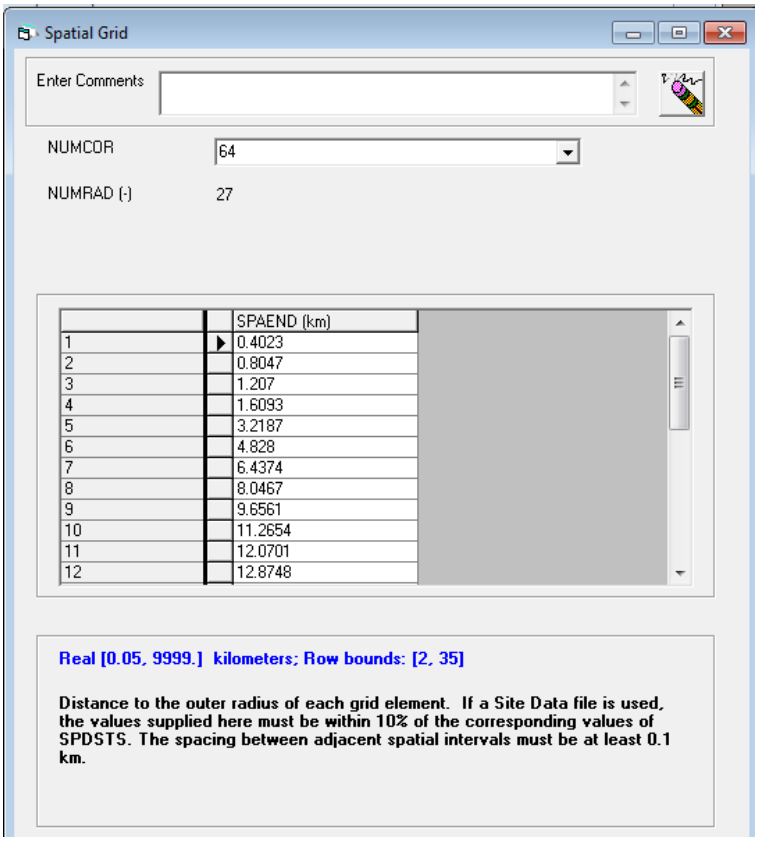


Figure 4-49 ATMOS radial grid, SPAEND

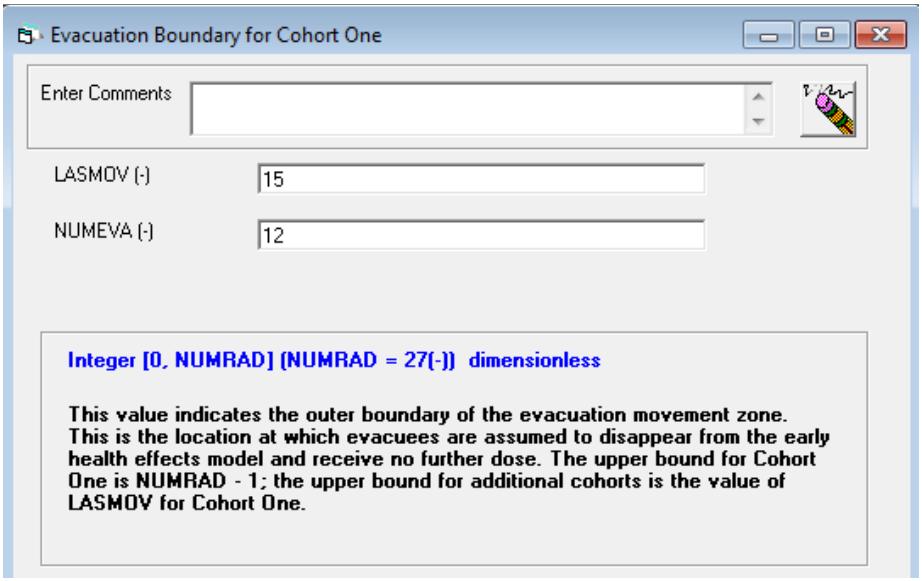


Figure 4-50 Evacuation boundary, LASMOV

The *Network Evacuation Direction* form and the *Evacuation Speed* form are similar. The navigation of the forms is the same; however, the navigation of the forms with respect to specifying the direction or speed variables is different.

4.4.7.2 Population by Cohort

Populations are assigned to grid elements using a spatial grid form, *EARLY/Population by Cohort/Populations Assigned*.

To enable the specification of the population fraction by cohort, the *Results Weighting Factor* is set to SUMPOP in the *Project Properties* form as shown in Figure 4-51. This form is opened by selecting *Edit/Project Properties* from the main menu.

Site data files that are not used with the SUMPOP option contain one array of population data, specifying the population for each grid element. When using SUMPOP, there is an array of population data for each cohort. The populations used per cohort are defined in forms found in the *Project Parameters* tab category *EARLY/Population by Cohort*. The SecPOP software is used to create the site data file, defining the populations to be consistent with Census data and the spatial grid.

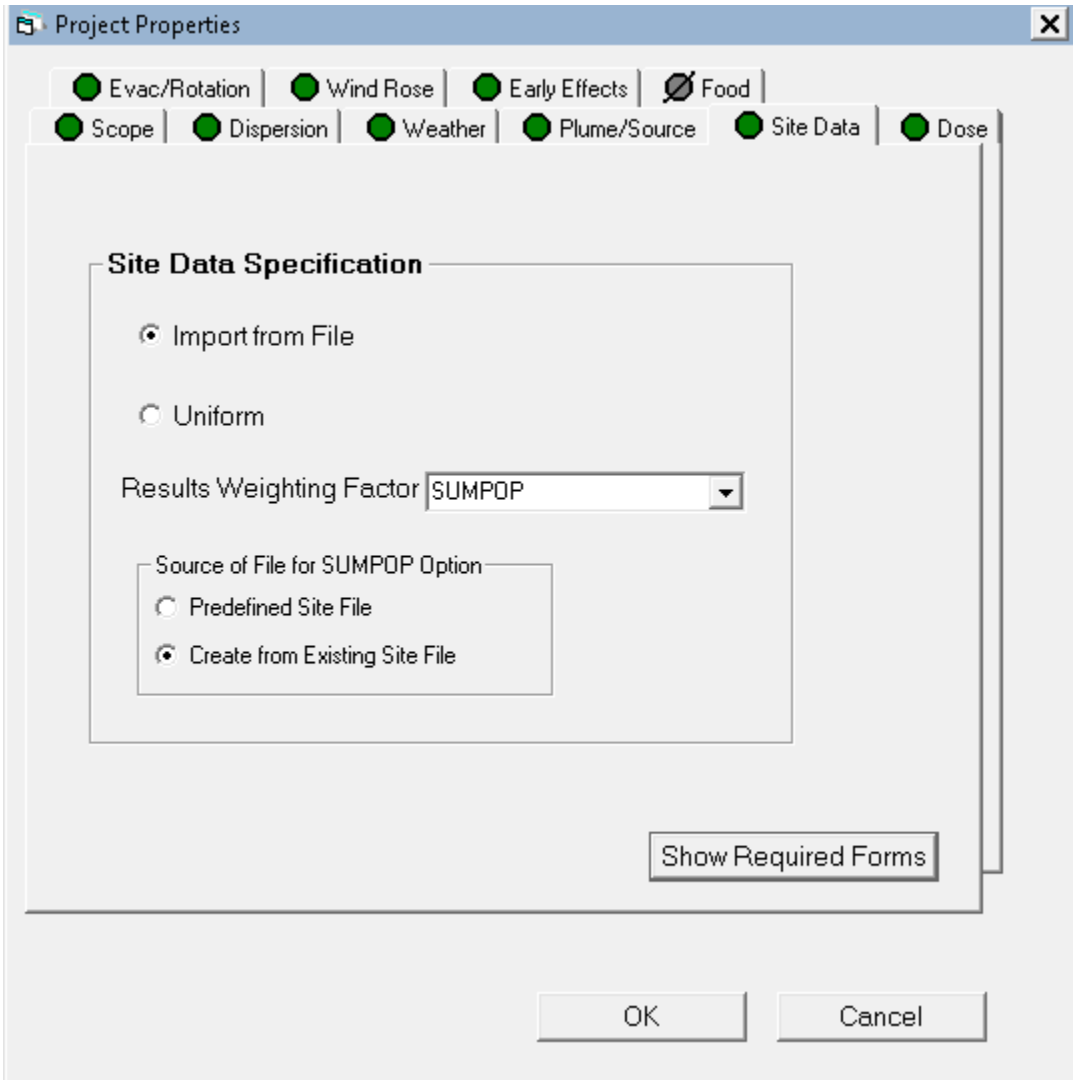


Figure 4-51 SUMPOP option on Project Properties form

An existing site file is specified to use as a basis for the new site file that supports the SUMPOP option. This site file can be one that has multiple cohorts defined (e.g., already supports SUMPOP), or it can be a site file with a single cohort defined.

A variable, *Population*, is defined when the site file is defined on the *General/File Specifications/Site File* form. This variable will contain the population array corresponding to the grid population in the existing site file. When the site file specified has multiple population arrays, variable *Population* is the array containing the sum of the population over all evacuation cohorts on the site file.

Though this variable is defined on the *Site File* form, the *EARLY/Model Basis/Population from Site File* form must be opened to view this array as shown in Figure 4-52. It is not possible to change any values of the variable *Population* on this form. To change the *Population* values, a new site file must be specified on the *Site File* form. This variable will be defined whenever the site file is updated.

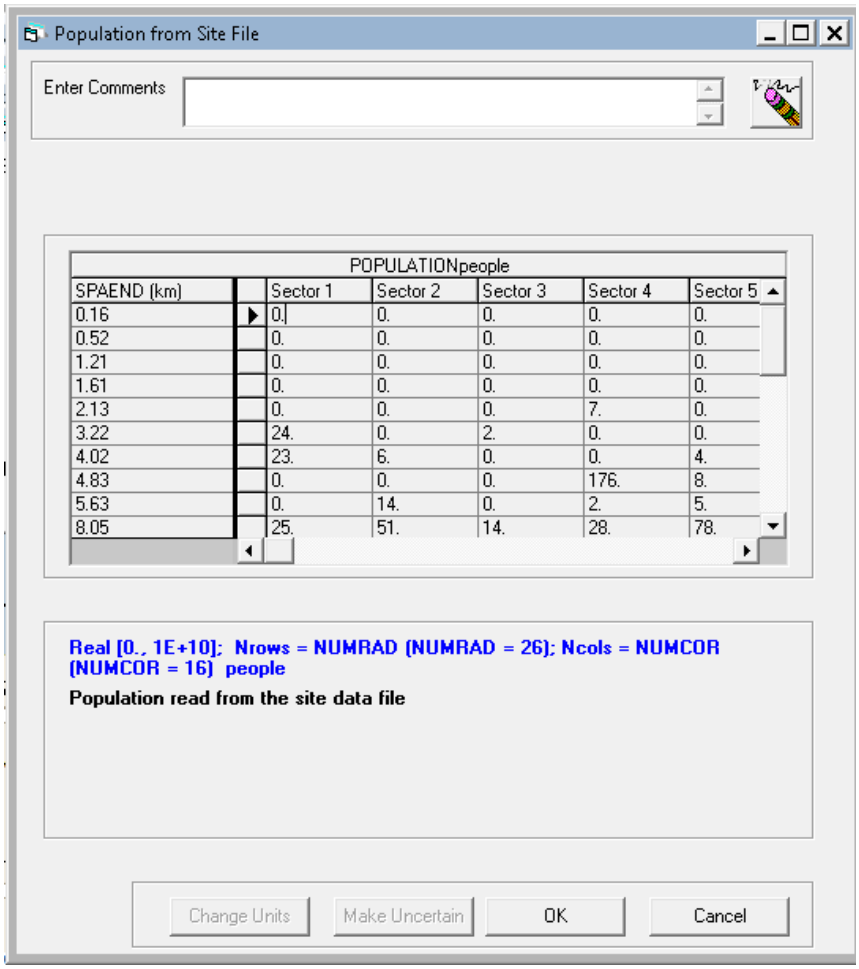


Figure 4-52 Population from Site File form

To support assigning portions of the population to different evacuation cohorts for a given spatial grid element, population distribution was introduced into the model. A population distribution is associated with a spatial grid element, and defines the portion of each evacuation cohort that belongs to that grid element. For example, when there were two cohorts defined, a

population distribution of (.6, .4) assigned to a spatial grid element would mean that 60% of the population exhibits cohort one evacuation behavior, and 40% belong to cohort two.

Opening the form *EARLY/Population by Cohort/Distributions* allows the user to define the various population distributions. There can be up to ninety distributions defined. The example shown in Figure 4-53 shows four cohorts that are differentiated by the delay to evacuate. To aid in envisioning this problem, consider cohort one to be associated with the general population behavior, cohort two the behavior of special needs people, cohort three the behavior of children in schools, and cohort four does not evacuate.

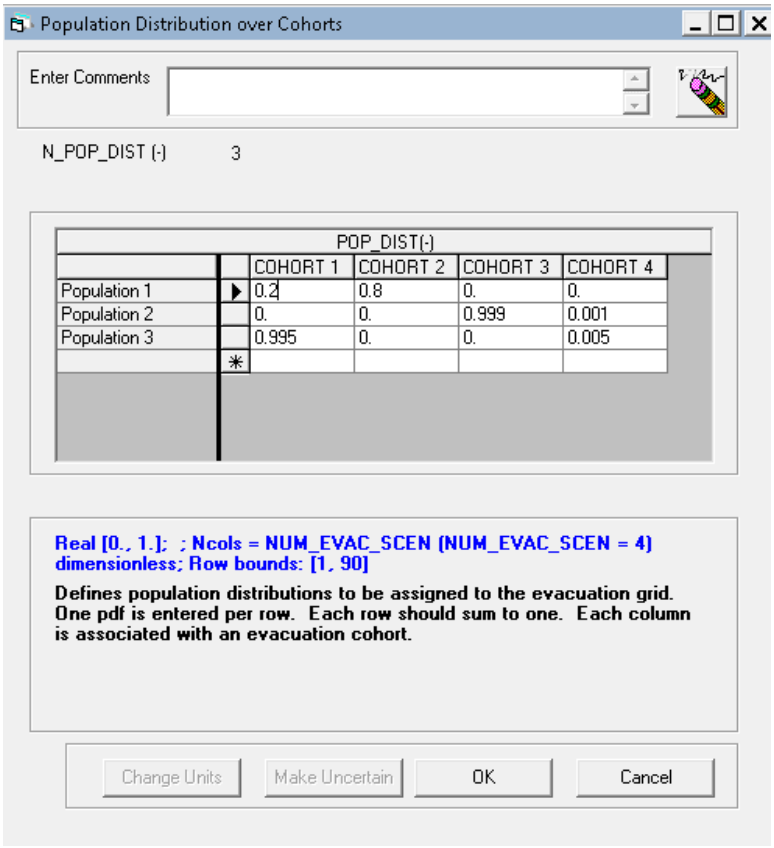


Figure 4-53 Population distributions over cohorts

To aid the user in assigning populations to spatial areas, the *EARLY/Population by Cohort /Population Labels* form as shown in Figure 4-54 allows a symbol and a label to be assigned to each of the population distributions. In this example, it is projected that Population 2 will be assigned to a spatial area that contains a school. The analyst has determined that 99.9% of the population in this area are in cohort 3, and .1% are in cohort 4. Notice that the fractional cohort sums for each of the populations defined add to one.

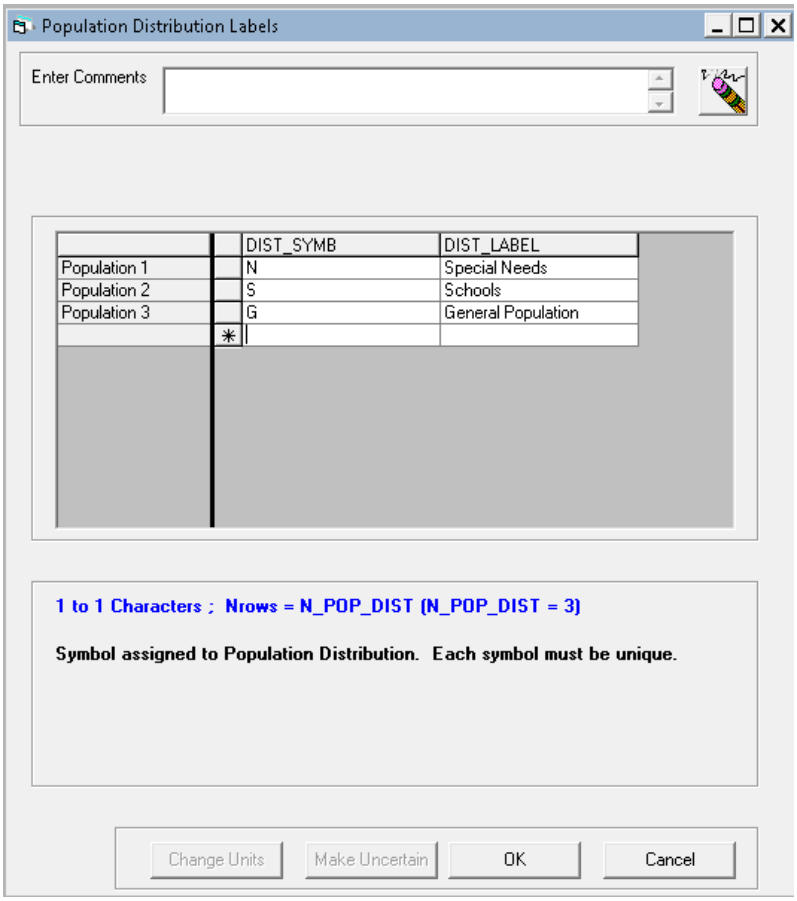


Figure 4-54 Population distribution labels

Lastly, a population distribution must be assigned to each spatial element. Open the form *EARLY/Population by Cohort/Populations Assigned* to assign distributions to grid elements.

4.4.7.3 Creating Road Maps

Radial distances vary from zero to the upper bound of SPAEND. Grid elements are numbered with 1 for north, 5 for east, etc., when the grid is divided into sixteen equal angles. Each value of SPAEND is represented as a concentric circle.

When a new project is created, the *Network Evacuation Direction* forms and the *Evacuation Speed* forms do not show a road map behind the polar grid. Evacuation directions are initially set to be radially outward, as shown in Figure 4-55, and the speed multiplier is set to one.

The number or letter drawn at the center of each of the grid elements indicates the associated speed multiplier rank. This is different than the value of the speed multiplier. If, for example, the speed multipliers are either .5 or 1.5, there are two possibilities for the multiplier rank, namely 1 corresponding to a speed multiplier of .5 and 2 corresponding to a speed multiplier of 1.5.

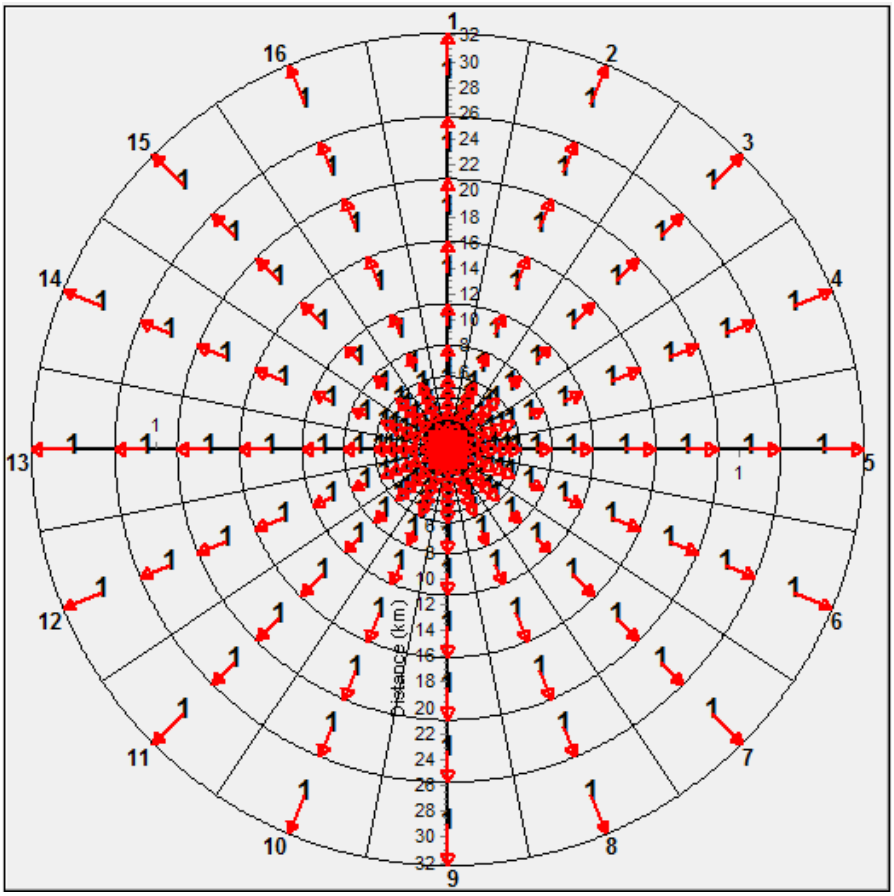


Figure 4-55 Initial state of evacuation grid

Road maps can be easily created to display behind the grid by using MapGen, a custom application that uses Microsoft MapPoint, by clicking the *Create Map File* button in any of the spatial grid forms in WinMACCS. When this is done, a file named *MapSummary.txt* is created and placed in the project *Input*\ folder.

The file, *MapSummary.txt* is subsequently read by MapGen to create the road maps. MapGen is implemented as a separate application because of licensing issues. No license outside of the NRC licensing requirements is required for MACCS. However, the map interface program, MapGen, requires that the Microsoft Map Point 2006 libraries be installed. Thus, to enable the use of maps in the MACCS, Microsoft Map Point 2006 must be purchased and installed.

***WARNING*: When the Spatial Grid is modified, a consistent set of road maps must be regenerated.**

Background map files can be created as follows:

1. Opening the form *ATMOS/Weather/Site Location* by double-clicking on this entry in the *Parameters* tab of the *Project* window allows the user to enter the latitude and longitude of the site. This form is shown in Figure 4-56. This form may not be flagged as a required data entry form for the MACCS models selected (i.e., the icon may have a slash through it), but to generate a set of road maps, it is necessary to enter the latitude and longitude of the site.

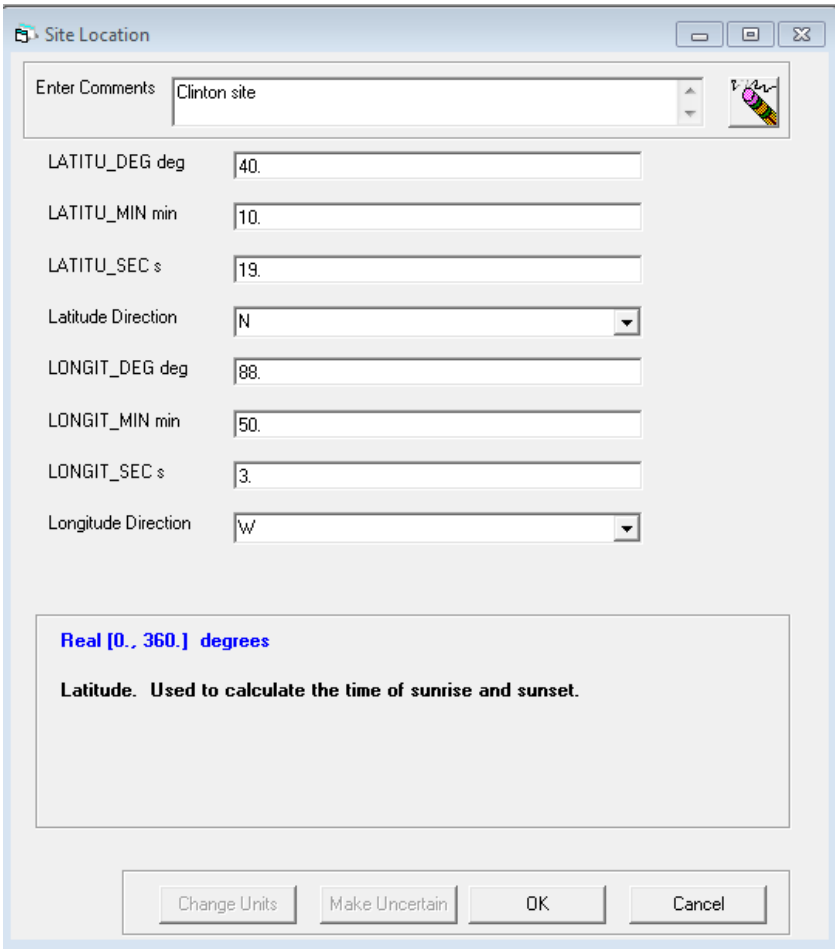


Figure 4-56 Enter latitude and longitude

2. In any form that shows the polar evacuation grid, selecting *Create Map File* as shown Figure 4-57 causes a file titled MapSummary.txt to be created and placed into the WinMACCS project Input folder.

Figure 4-57 Create map file

Within the Files Tab in the Project window, this file can be optionally viewed by double-clicking on the entry *Input/MapSummary.txt*.

A sample map interface file is as follows:

```
* File created using WinMaccs Version 3.10.0 SVN:2560 7/15/2015 4:52:15 PM
* Latitude and Longitude as a decimal
/LAT        40.17194
/LON        -88.83417
* File Name to create, Distance in km from lat,long to edge of square map
/DAT        Map_0.16.gif   0.1704918
```

```
/DAT    Map_0.52.gif   0.5540984
/DAT    Map_1.21.gif   1.289344
/DAT    Map_1.61.gif   1.715574
/DAT    Map_2.13.gif   2.269672
/DAT    Map_3.22.gif   3.431148
/DAT    Map_4.02.gif   4.283607
/DAT    Map_4.83.gif   5.146721
/DAT    Map_5.63.gif   5.99918
/DAT    Map_8.05.gif   8.577869
/DAT    Map_11.27.gif  12.00902
/DAT    Map_16.09.gif  17.14508
/DAT    Map_20.92.gif  22.2918
/DAT    Map_25.75.gif  27.43852
/DAT    Map_32.19.gif  34.30082
```

Notice each line of the file that starts with the character string "/DAT". Each /DAT lines directs MapGen to create a gif file.

Example:

```
/DAT    Map_0.16.gif   0.1704918
```

Two parameters are shown per input line. The first is the name of the image file that is created by MapGen, e.g., Map_0.16.gif. The second parameter is the distance in km from the center of the map to the edge of the map as displayed in the WinMACCS interface. This input line corresponds to the spatial grid element 0.16 km.

WinMACCS creates a line in the file for each value of SPAEND, the spatial grid distance. The value of SPAEND is built into the name of the GIF file. This ensures that an incorrect map is not shown behind the evacuation grid when the spatial grid entries are modified (SPAEND is changed in WinMACCS).

The second number is a measure in km from the center of the map to the outer edge calculated in WinMACCS to allow the map to fit to the edge of the form.

This process assumes that all maps are square.

1. MapGen can be started from the MapGen group found on the Windows Start Menu.

2. From the main MapGen menu as shown in Figure 4-58, selecting *File→Generate Gif from File* allows the user to select the file *MapSummary.txt* file created in the previous step as shown in Figure 4-59. Clicking on *Open* completes this form.

3. WinMACCS expects the map files to be located in the project Data folder. Choosing the Data folder for the gif file destination as shown in Figure 4-60 will enable WinMACCS to find the map files. Clicking *OK* causes the maps to be generated.

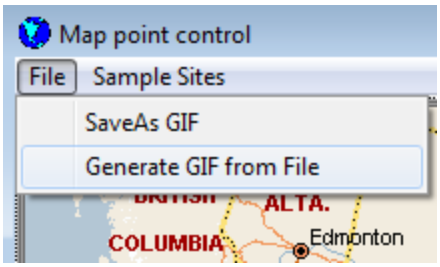


Figure 4-58 Generate road map files

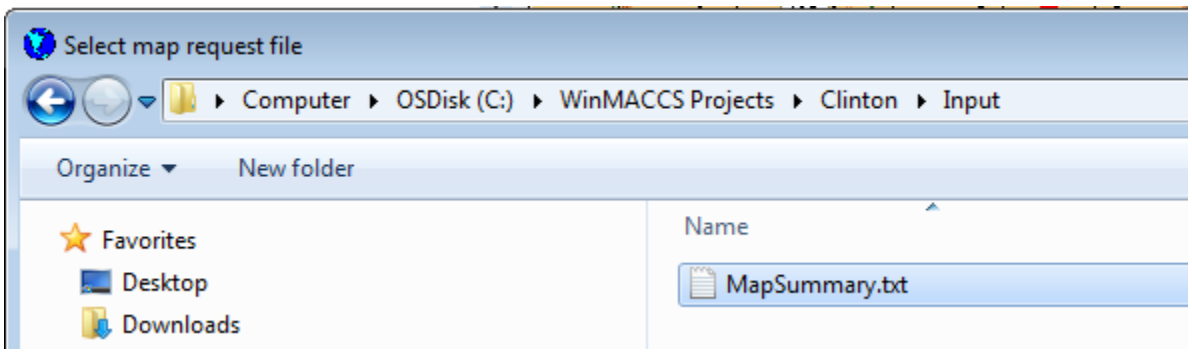


Figure 4-59 Open map summary.txt

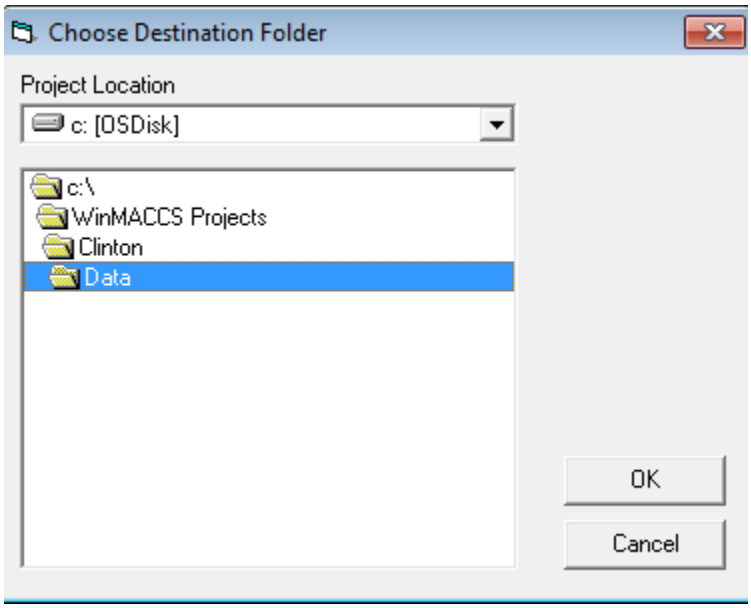


Figure 4-60 Complete creation of road maps

4. Opening a form that shows the polar evacuation grid, for example, *Radial Evacuation Speed,* the user can observe the map updating when changing the *Outer Ring Shown* slider as shown in Figure 4-66. The maps are displayed behind the spatial grid. When the maps do not display, verifying that the *Hide Map* check box is unchecked, that the map .gif files are in the project Data folder, and that the spatial grid values are in agreement with the names assigned to the map .gif files should fix the problem. For

example, Map_1609.34.gif corresponds to 1609.34 km. This is the map that is displayed when the outer ring in the polar grid is at 1609.34 km. This corresponds to an entry in array SPAEND.

The *Outer Ring Shown* slider must be clicked to refresh the background the first time the maps are created.

The roadmap can be displayed in MapGen by entering the latitude and longitude in decimal form and the distance from the center to the left edge as shown in Figure 4-61. These numbers can be read from the file MapSummary.txt as shown in the following example:

```
/LAT      40.17194
/LON      -88.83417
/DAT      Map_1.21.gif   1.289344
```

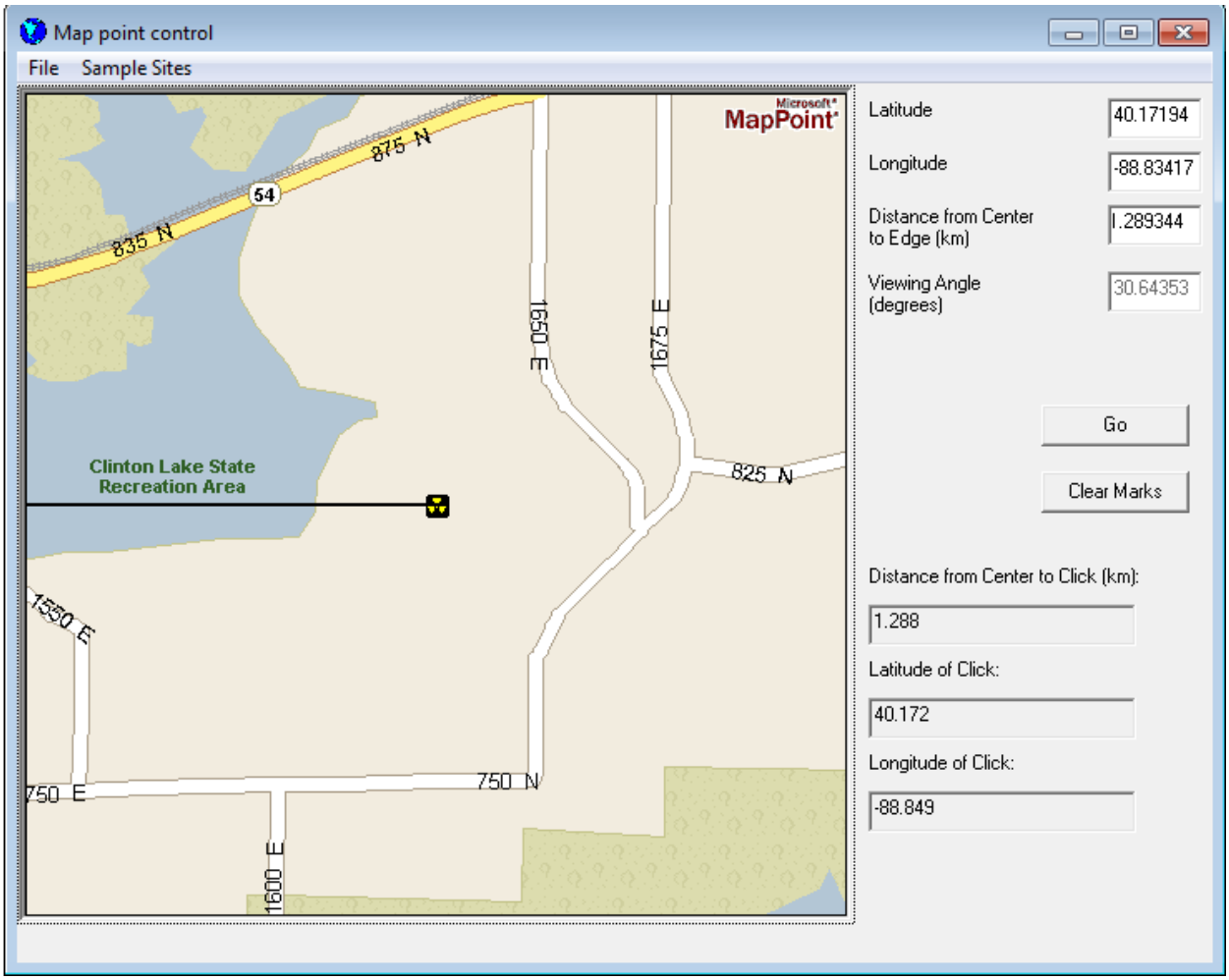


Figure 4-61 MapGen interface

The coordinates of each of the maps centers has a latitude of 40.17194 and a longitude of -88.83417. The line labeled /DAT instructs MapGen to create a map file named Map_1.21.gif, representing an outer radius of 1.21 km. This same line specifies that the distance from the center to the edge of the map is 1.289344 km.

Entering the latitude, longitude and the distance from the center to the edge in MapGen as shown in Figure 4-61 and clicking the button labeled *Go* generates the desired map manually. The actual distance from the center to the edge can be verified by clicking the edge of the map in MapGen. This is the shortest distance from the center to the edge as calculated by MapPoint, the underlying Microsoft map engine.

The MapPoint interface internally requires that a viewing altitude be specified. It was determined that the viewing angle of 30.64353 degrees creates consistent maps with the exception of very high altitudes. However, this does not appear to be a problem at distances less than 2000 km.

MapGen is designed to be consistent with MapPoint 2006. Future versions of MapPoint could use a different algorithm or viewing altitude formula, and so could produce unexpected results when used with MapGen.

4.4.7.4 Assigning Values to Grid Elements

The *Network Evacuation Direction* form is used as an example, shown in Figure 4-66. The same techniques used to assign values to grid elements in the *Network Evacuation Direction* form is used for the *Populations Assigned* and the *Radial* and *Network Evacuation Speed* forms. The only difference between these forms is the possible values the grid elements can have. In the example of the *Network Evacuation Direction* form, the values can be set to *In, Out, Right* or *Left.* In the case of the *Populations Assigned* and the *Radial* and *Network Evacuation Speed* forms, the values are set to user defined populations or user defined speed multipliers respectively.

Understanding the Spatial Grid

Spatial grids are used to enter speed multiplier data for radial and network evacuations, and evacuation directions in the case of the network evacuation option. An example of this form is shown in Figure 4-66.

Arrows drawn on the grid elements indicate the evacuation direction as shown in Figure 4-62. There are four different directions supported by MACCS, outward, inward, counter clockwise and clockwise. Each of these directions is shown in a different color.

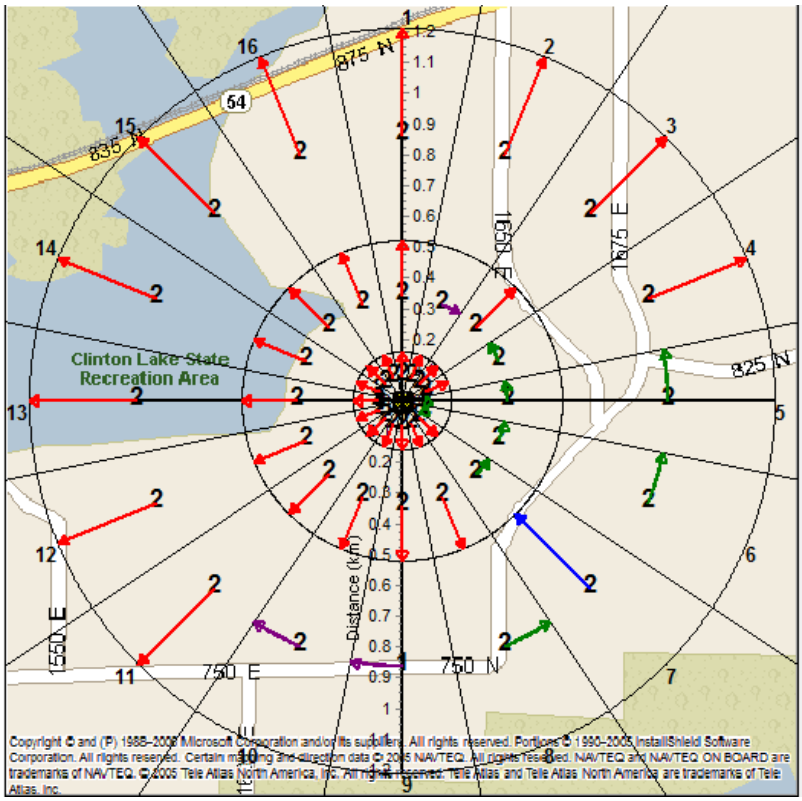


Figure 4-62 Evacuation grid

On the *Radial Evacuation Speed* form, all arrows are red and pointed outward as shown in Figure 4-55.

To the right of the map the inner and outer ring displayed on the polar grid are indicated as shown Figure 4-66. The integer value shown to the left of the sliders labeled *Inner Ring Shown* and *Outer Ring Shown* correspond to the first column labeled *Ring* as shown in Figure 4-63. In the example shown in Figure 4-64, the *Inner Ring Shown* is set to 2, corresponding to SPAEND(2) which is equal to 0.52. The *Outer Ring Shown* is set to 3, corresponding to SPAEND(3) which is equal to 1.21.

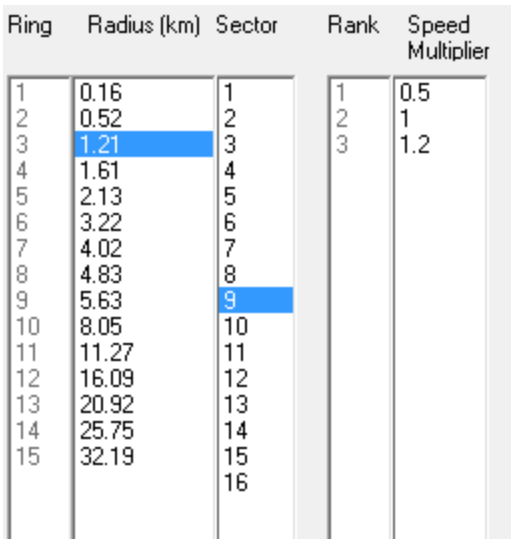


Figure 4-63 Radius, sector and multiplier

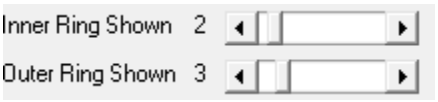


Figure 4-64 Inner ring and outer ring sliders

The symbols shown in column four labeled *Rank* as shown in Figure 4-63 indicate the speed multiplier rank. These values are different than the actual speed multiplier. In this example, the number 1 corresponds to a multiplier of 0.5, 2 to a multiplier of 1, and 3 to a multiplier of 1.2 as shown in column five, *Speed Multiplier*. By showing ranks, the speed multipliers can be adjusted without requiring the user to adjust the settings on the polar grid.

When the grid is clicked, the radial distance from the center of the grid to the click is shown on the bottom left portion of the form, as shown in Figure 4-65. This is useful for diagnostic reasons. Once a map is displayed behind the grid, the scale can be checked when there is a reason to believe that the polar scales and the map scales are inconsistent. The number shown in WinMACCS corresponds to the scale of the polar coordinate system. From the viewpoint of WinMACCS, the roadmap is simply a picture file.

Clicking *OK* preserves changes. Clicking *Cancel* discards changes.

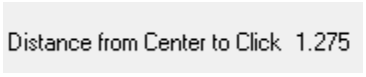


Figure 4-65 Radial click distance

Assigning Values to the Network Evacuation Direction Form

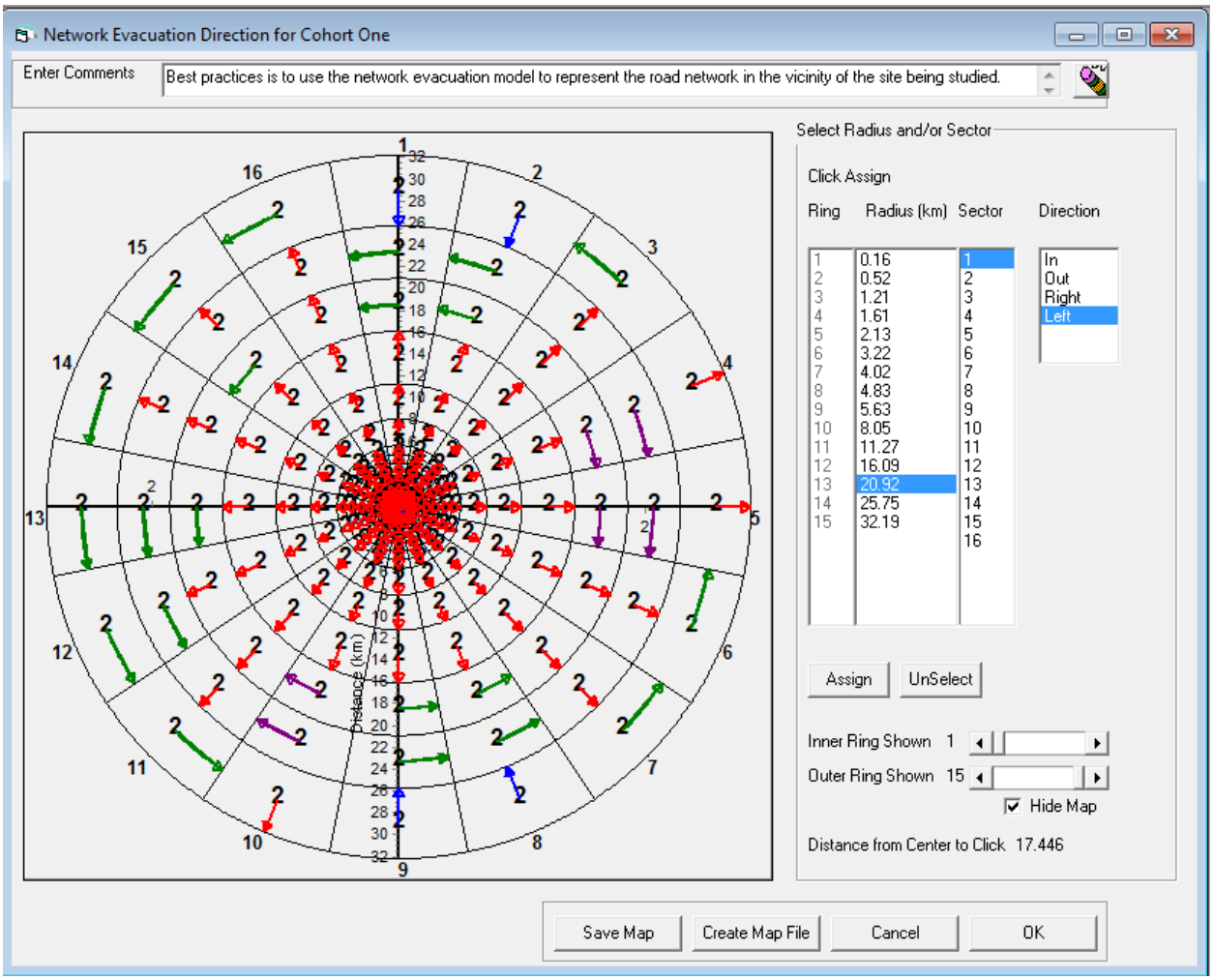


Figure 4-66 Network evacuation direction

The evacuation direction can be modified in two ways.

The first method is to click the grid element on the map. The direction changes for that grid element each time the area is clicked. The direction rotates ninety degrees clockwise each time the grid element is clicked.

When a grid element is clicked, the clicked element is selected in the Radius/Sector list. In the example shown in Figure 4-67, the grid element between 3.22 km and 4.02 km in the fourth sector is selected. Sector 4 corresponds to ENE in a grid that has been divided into 16 sectors.

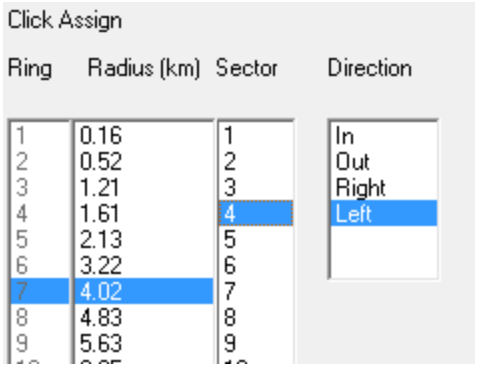


Figure 4-67 Radius and sector selected

The second method is to use the *Assign* button.

Clicking the *UnSelect* button clears the selection of the radius and sector.

Selecting a radius and a direction from the list and clicking the *Assign* button changes the direction for all grid elements at the selected radius.

Similarly, selecting a sector and a direction but no radius as shown in Figure 4-68 and clicking the *Assign* button changes the direction for all grid elements in the selected sector.

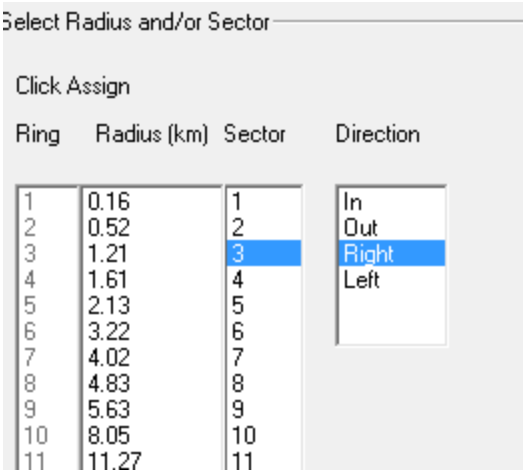


Figure 4-68 Select sector only

Assigning Values to the Radial or Network Speed Multiplier Form

The speed multiplier ranks can be modified in two ways.

The first method is to click the grid element on the map. The rank is incremented by one each time that grid element is clicked. For example, clicking a grid element with an initial rank of four results in a rank of five assigned when five or more ranks are defined; otherwise, the rank cycles from four back to one.

When a grid element is clicked, the clicked element is selected in the radius and sector lists.

The second method is to use *Assign* button. This method is the preferred way to change all of the speed multipliers for a given radius or a given sector. This can be done as follows:

1. Clicking the *UnSelect* button clears the selection of the radius and sector.

2. Selecting a radius and a direction from the list and clicking the *Assign* button changes the speed multiplier for all grid elements at the selected radius.

3. Selecting a sector and a direction but no radius and clicking the *Assign* button changes the speed multiplier for all grid elements in the selected sector.

4. Selecting a radius, a sector, and a speed multiplier rank and clicking *Assign* only changes the rank of the selected grid element.

In the example shown in Figure 4-69, the speed multiplier rank for the grid elements between 0.52 and 1.21 in sector two is changed to 2 when *Assign* is clicked.

Figure 4-69 Select speed multiplier

Assigning Values to the Populations Assigned Form

A graphical window similar to the *Network Evacuation Direction* and *Network Evacuation Speed* windows used to assign populations to grid elements is shown in Figure 4-70. However, instead of assigning evacuation directions or evacuation speeds to the grid sectors, population distributions are assigned.

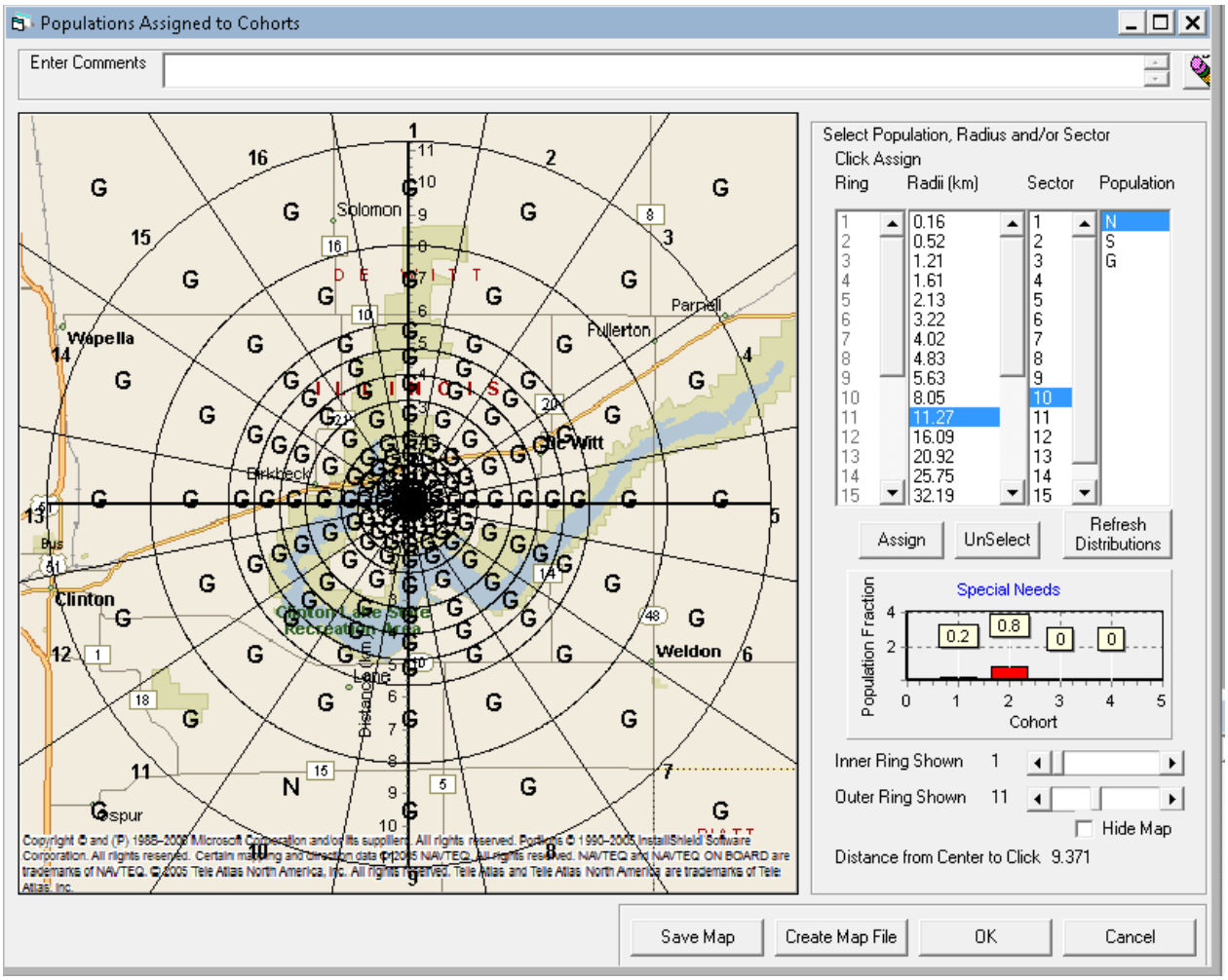


Figure 4-70 Selecting populations assigned to cohorts

On the right side of this window there is a list titled *Population.* In the example shown in

Figure 4-70, three symbols are listed, namely N, S and G. These symbols correspond to the distributions and distribution labels assigned on the forms *EARLY/Population by Cohort/Populations* and *EARLY/Population by Cohort /Population Labels.* A bar chart of the population distribution selected is shown below the radii, sector and population lists.

A population distribution can be assigned to a sector by clicking the distribution symbol, and clicking the sector on the map. For example, the sector (11.27, 10) is assigned the distribution N. This was accomplished by clicking on the N in the population list and clicking on the grid element on the map.

A population can be assigned to all of the grid elements in a radius by clicking the *UnSelect* button to remove the highlighted list elements, clicking the radius of interest in the list labeled *Radius*, clicking the population in the list labeled *Population*, and clicking the *Assign* button. Similarly, a population can be assigned to all grid elements in a given sector by following this same procedure, but instead of clicking on a radius, the user should click on the sector of interest in the list labeled *Sector*.

It can be convenient to predefine all grid elements to a population by clicking the *UnSelect* button, clicking a distribution in the *Population* list, and clicking the *Assign* button. This can be followed by manually setting less common populations by one of the other methods described. Clicking *OK* when completed will save the changes.

When the MACCS simulation has finished, the site file used in the simulation, Sumpop_site.inp, can be viewed. This file is found in the project Input folder. This site file, created by WinMACCS and used by MACCS, contains a population array for each of the evacuation cohorts.

The population for a grid element for a single evacuation cohort is calculated by considering the population fraction for that grid element. For the cohort of interest, the population fraction associated with the evacuation cohort is multiplied by the total population for that grid element. Recall the total population for each of the sectors can be viewed on the *EARLY/Model Basis/Population from Site File* form.

The population values per cohort can be viewed on the *EARLY/Emergency Cohort One/Population, EARLY/Additional Emergency Cohorts/Emergency Cohort Two (etc)/Population, …* forms. Fractional populations are supported.

4.4.7.5 Editing the Speed Multiplier List

The same basic form used to assign speed multipliers to grid elements is also used to specify evacuation directions and population assignments as shown in Figure 4-66. The *Modify Multipliers* button is not available on the *Network Evacuation Direction* forms but is available on the *Radial Evacuation Speed* and *Network Evacuation Speed* forms.

A speed multiplier for each grid element is used to adjust the speed multipliers assigned for each evacuation phase in variable ESPEED found on the *Evacuee Travel Speed* form for each emergency cohort. A value of one for the multiplier indicates that the speed in that grid element is the same as ESPEED.

The default value for the speed rank and the speed multiplier is one. Additional speed multipliers can be added by clicking the *Modify Multipliers* button in the *Radial Evacuation Speed* or the *Network Evacuation Speed* form as shown in Figure 4-71.

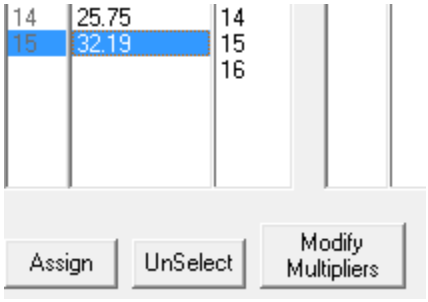


Figure 4-71 Modify multipliers

A dialog box similar to the one in Figure 4-72 opens.

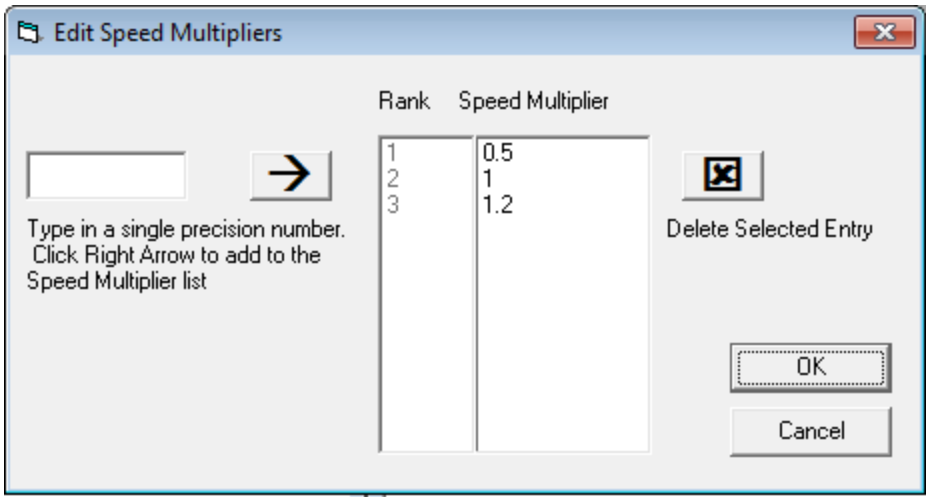


Figure 4-72 Edit speed multipliers

Speed multipliers can be added to the list by entering a number in the text box followed by pressing Enter on the keyboard or clicking the arrow button on the form.

Multipliers can be deleted by selecting a multiplier from the *Speed Multiplier* list and clicking the delete button as shown in Figure 4-73.

Figure 4-73 Delete speed multiplier button

Multipliers are automatically sorted in ascending order. Multiple entries of the same number are not allowed.

Clicking *OK* preserves changes. Clicking *Cancel* discards changes.

Ranks shown on the spatial grid may be modified by WinMACCS when the multipliers are modified. For example the default speed multiplier value is a single rank of one corresponded to a speed multiplier set to one. In this example, a multiplier of 0.5 is added using the *Edit Speed Multipliers* dialog box resulting in two multipliers, namely 0.5 and 1.0 with respective ranks one and two. After this dialog box is closed, the rank of one now corresponds to a speed multiplier of 0.5. The polar grid is updated to show the rank of two to correspond to a speed multiplier of one as shown in Figure 4-74.

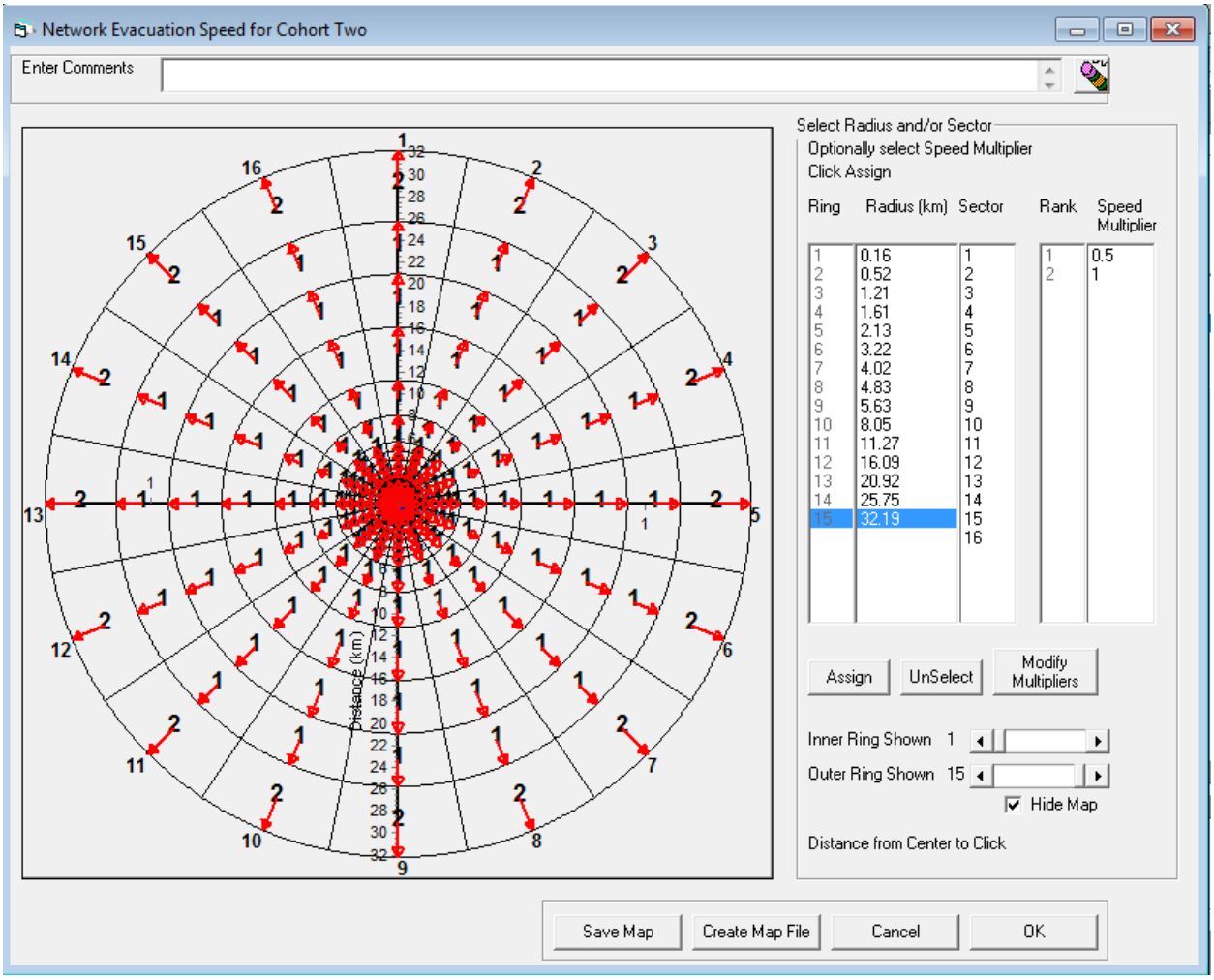


Figure 4-74 Speed multiplier ranks

Uncertain speed multipliers are not supported in WinMACCS.

Figure 4-75 Selecting a speed multiplier

4.4.8 Specifying a Site File

Files are generally specified in a general parameter modification form. However, the site file is specified in a custom form.

The site file is usually created using an external software source, such as SecPop. When SecPop 4.0 or later is used, it is possible to choose 16, 32, 48 or 64 compass directions (or

sectors). Older versions of SecPop such as SECPOP2000 support only 16 compass directions. For compatibility with MACCS models that require more compass directions, WinMACCS can create a site file that supports 32, 48 or 64 sectors from a site file that supports 16 sectors.

Double clicking on the *GENERAL/File Specifications/Site File* will open a form similar to the form shown in Figure 4-76.

A label titled *Angular Directions* shows the actual number of angular directions written to the site file shown in the text box labeled *Site File.*

Click *Browse* to choose a site file. After choosing a site file, the field *Angular Directions* is updated to reflect the number of sectors defined on the file.

NUMCOR, the number of sectors in the spatial grid, is shown as a pull down menu. It can't be modified in this form but can be modified in the *ATMOS/Spatial Grid* form.

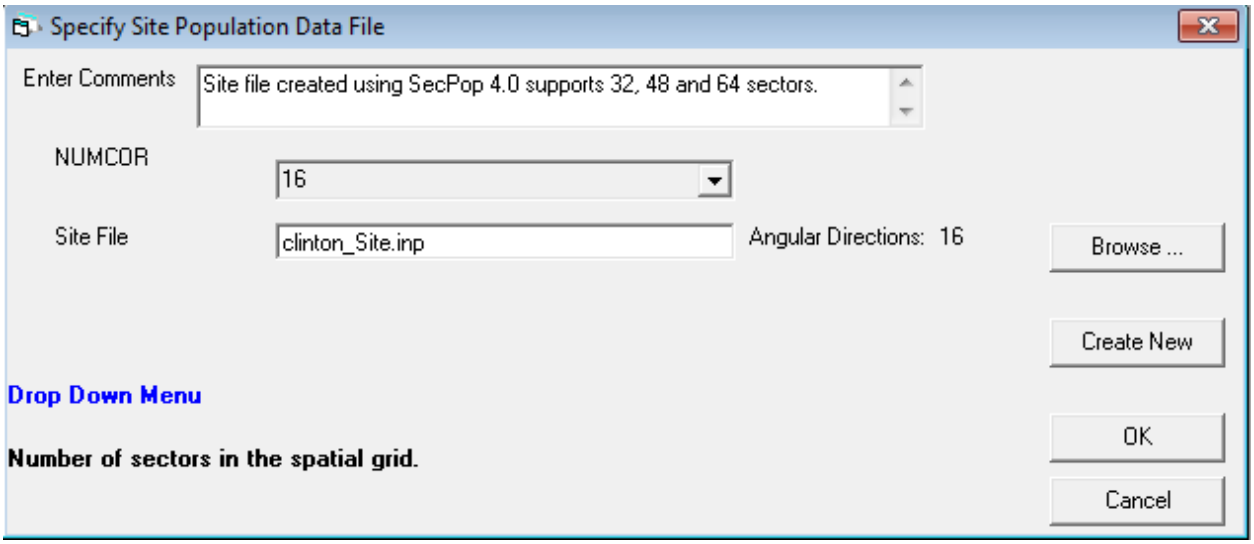


Figure 4-76 Specify site population file

Click *Create New* to create a new site file with more angular resolution. A dialog as shown in Figure 4-77 opens.

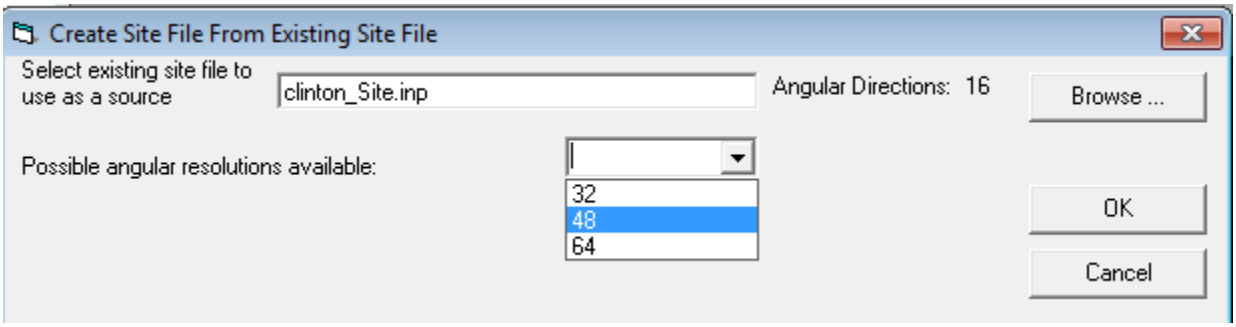


Figure 4-77 Create site file from existing site file

A new site file with more angular directions can be created from an existing site file as follows:

1. Clicking *Browse…* as shown in Figure 4-77, the user can choose a site file that has a smaller angular resolution than the file needed.

2. The angular resolution can be selected from the pull down menu labeled *Possible angular resolutions available*.

3. Clicking OK preserves changes and causes a new site file to be created. An external software program, PopMod, has been integrated into WinMACCS to create the new file. Clicking Cancel discards changes and the new file is not created.

4. The new file created is assigned a file name that contains the number of new angles appended to the file name. In our example, the source file is clinton_Site.inp. The new file created with 48 sectors is clinton_Site_48.inp. No new population data was added to the file. The existing population data was spread out into the new sectors.

5. Clicking OK preserves changes as shown in Figure 4-76. Clicking *Cancel* closes this form and discards changes.

4.4.9 User Specified Dose Conversion Factors (DCF) in WinMACCS

Normally, a single DCF file is used to specify the dose coefficients. These files have been created in the past using a process independent from WinMACCS, such as running the program DOSFAC2 to create this file, or using a dose conversion factor file supplied with the WinMACCS installation such as one based on FGR-13.

Default values for the dose conversion factors are determined by a predefined DCF file chosen within the WinMACCS user interface. After this file is specified, it is possible to replace DCF values by constants or probability distributions. This capability has been integrated into WinMACCS. This allows these values to be correlated against any other variables that have been assigned uncertain values, including other dose uncertain dose conversion factors.

The COMIDA2 food model is not currently integrated into the user specified dose conversion factor option.

4.4.9.1 Project Properties Settings

The *Project Properties* form can be opened by selecting *Edit/Project Properties* from the main menu.

The user specified DCF model can be defined on the *Properties* form as follows:

1. By selecting *Early Consequences* or *Late Consequences* on the *Scope* tab the user specified DCF model is available.

2. Selecting *Create DCF File* on the Dose tab chooses this model, as shown in Figure 4-78.

3. When Late Consequences is selected on the Scope tab, the user must select the Food model on the Food tab as shown in Figure 4-79. Either the *No Food* or the *MACCS Food Model* must be selected. The COMIDA2 Food Model is available for selection, but will not properly function with the *Create DCF File* selection.

4. Clicking *OK* preserves changes.

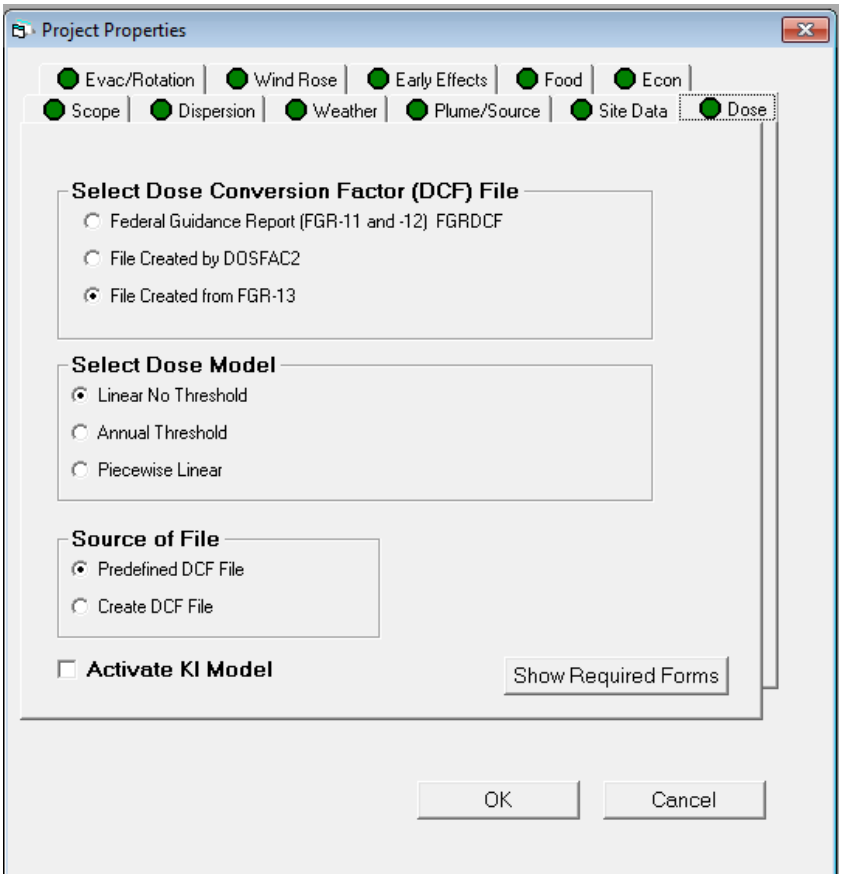


Figure 4-78 Project Properties Dose tab

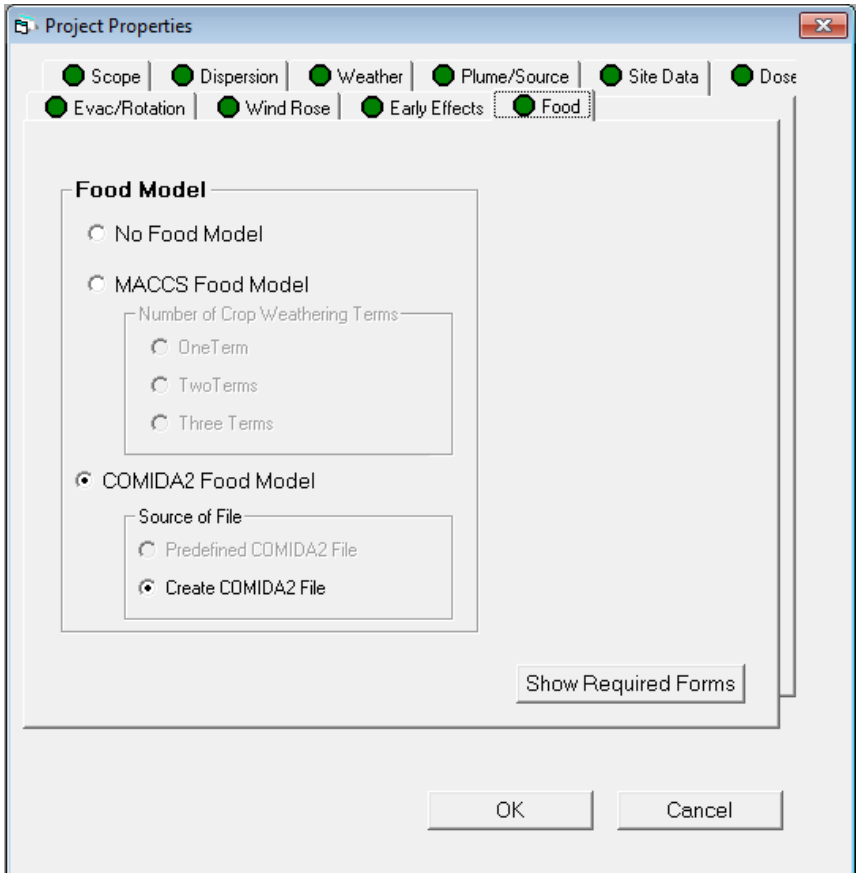


Figure 4-79 Project Properties Food tab

4.4.9.2 Specify a Basis DCF File

WinMACCS requires a preexisting DCF file to use for default values. This is specified on the same form used for specifying a predefined DCF file when not using the user specified option.

The DCF file can be specified by opening the form named *Dose Conversion Factor File* found on the *Parameters* tab of the main *Project* window in the *GENERAL/File Specifications* category as shown in Figure 4-80. Browse for the DCF file by clicking the *Browse* button. In the example shown, a DCF file that is distributed with WinMACCS based on Federal Guidance Report 13 has been selected.

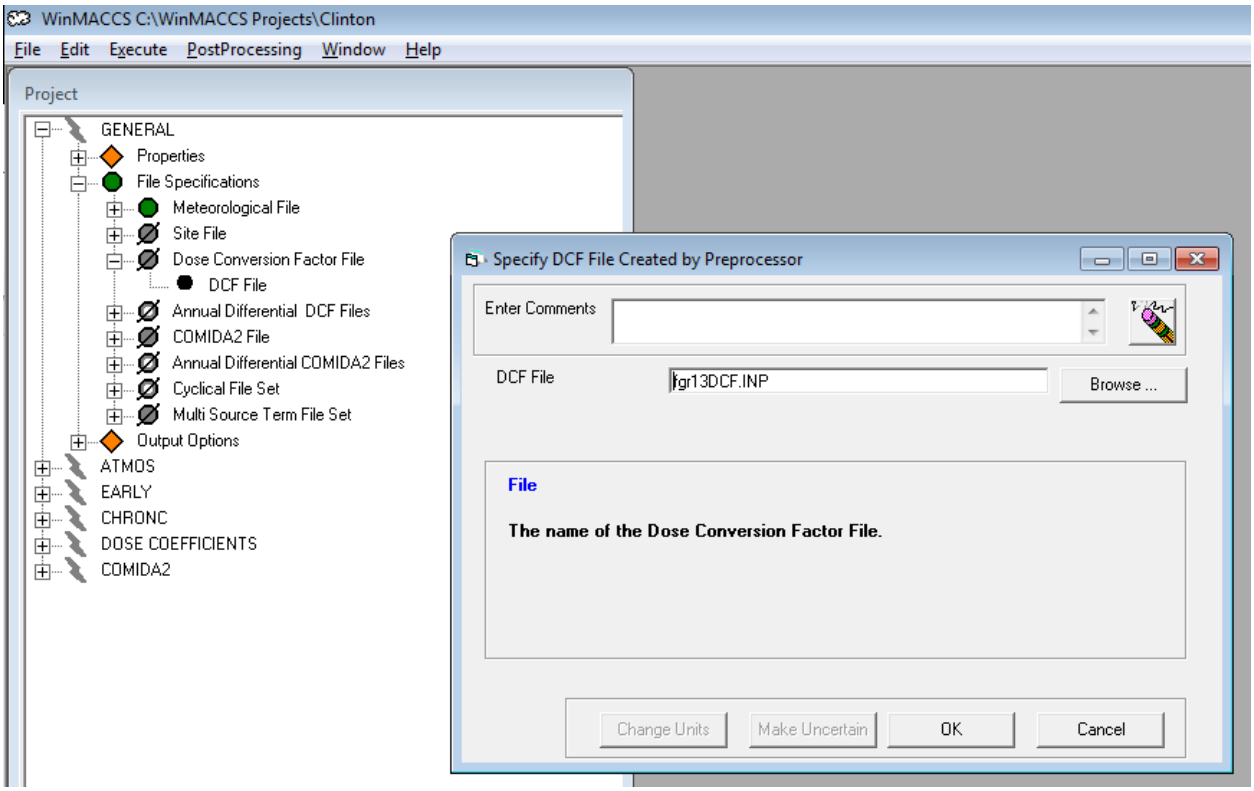


Figure 4-80 Identify location of the DCF file

4.4.9.3 ATMOS/Reveal Nuclides to modify DCF Values

The list of radionuclides to be considered in the MACCS simulation are specified on the *Radionuclides* form found on the *Parameters* tab in the *ATMOS/Radionuclides* category as shown in Figure 4-81. Modifying the DCF values of any of these radionuclides impacts subsequent actions by MACCS.

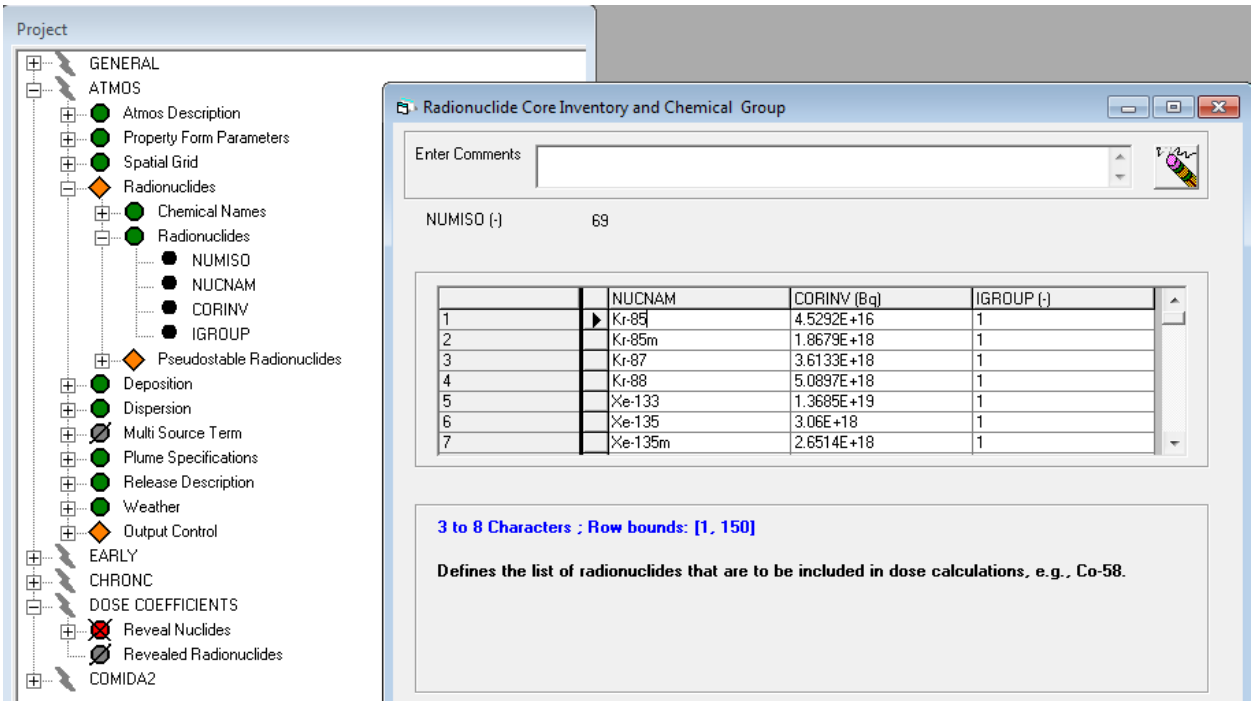


Figure 4-81 Radionuclides Used by MACCS

4.4.9.4 Specify Dose Coefficients to Change

Dose coefficients can be modified by opening the form *DOSE COEFFICIENTS/Reveal Nuclides* as shown in Figure 4-82. Notice that the DCF file previously specified, referred to as the base DCF file, is read and a list of nuclides is shown in the left hand portion of this form. These are the radionuclides in the DCF file. This DCF file name previously specified is saved in a variable named DCF_REVEALED.

Indicate the nuclides of interest by selecting the nuclides and clicking the arrow pointing to the right to move the selected nuclides from the *Hidden Nuclides* list to the *Revealed Nuclides* list. Double clicking on the radionuclide moves it from one list to the other list.

Nuclides can be moved back from the revealed list to the hidden list by selecting the nuclide on the revealed list and clicking the arrow pointing to the left.

Only nuclides whose DCF values need to be modified should be put on the list *Revealed Nuclides*. The original values in the DCF are used for the nuclides that are not revealed.

Shift click and Control click can be used to select multiple nuclides.

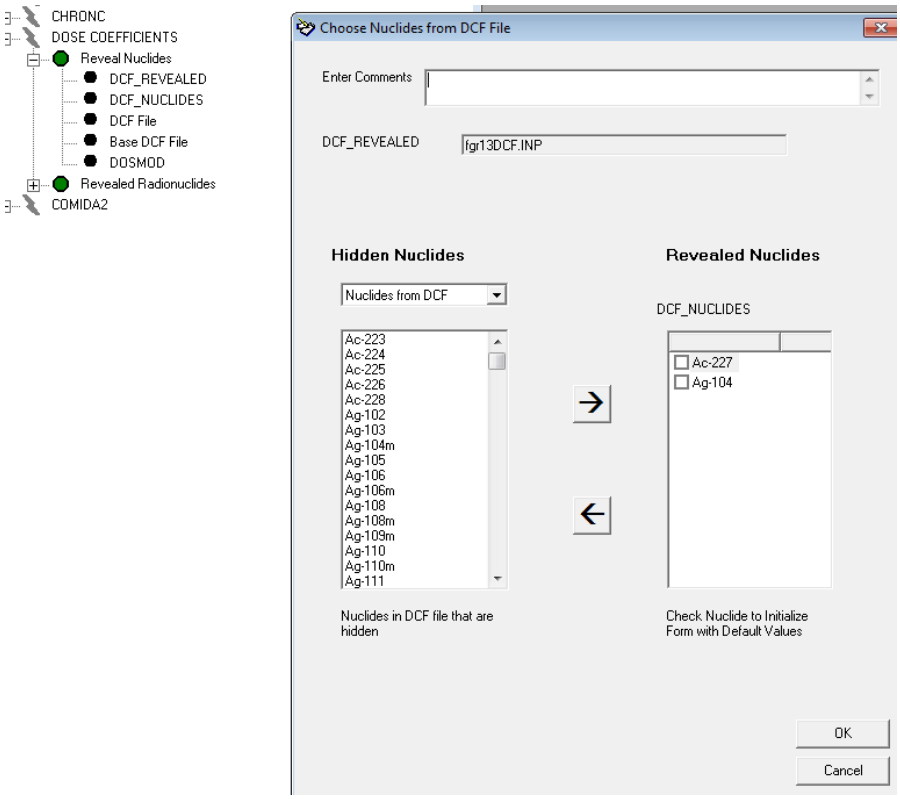


Figure 4-82 Choosing nuclides from DCF file

The check mark next to the nuclide name on the *Revealed Nuclides* list means that the forms for those nuclides will be populated with default values read from the basis DCF file.

By revealing nuclides, MACCS creates forms to allow modification of the dose conversion factors for those nuclides.

When these forms already exist, checking the nuclide name causes the current DCF values on these forms to be replaced with the default DCF values. When the user had replaced DCF values on some of these forms with their own distributions or with constant values, that information is overwritten with the default values.

Clicking *OK* preserves changes. This can take a long time the first time a radionuclide is exposed. Clicking *Cancel* discards changes.

4.4.9.5 Modifying the DCF Values

The first word in the base DCF file identifies the source of the data. MACCS expects this first word to be one of the following:

- FGR13DF
- FGRDCF
- DOSFAC2

The type of the base DCF file determines the forms to be built exposing the DCF values. This also determines the list of organs and pathways that are available.

In the following example the base file is of type FGR-13. In this case and in the case of a DOSFAC2 file, two forms are created for each exposed radionuclide as shown in

Figure 4-83. The Acute Inhalation pathway is relevant for a subset of organs, hence the related DCF values are placed on a separate form.

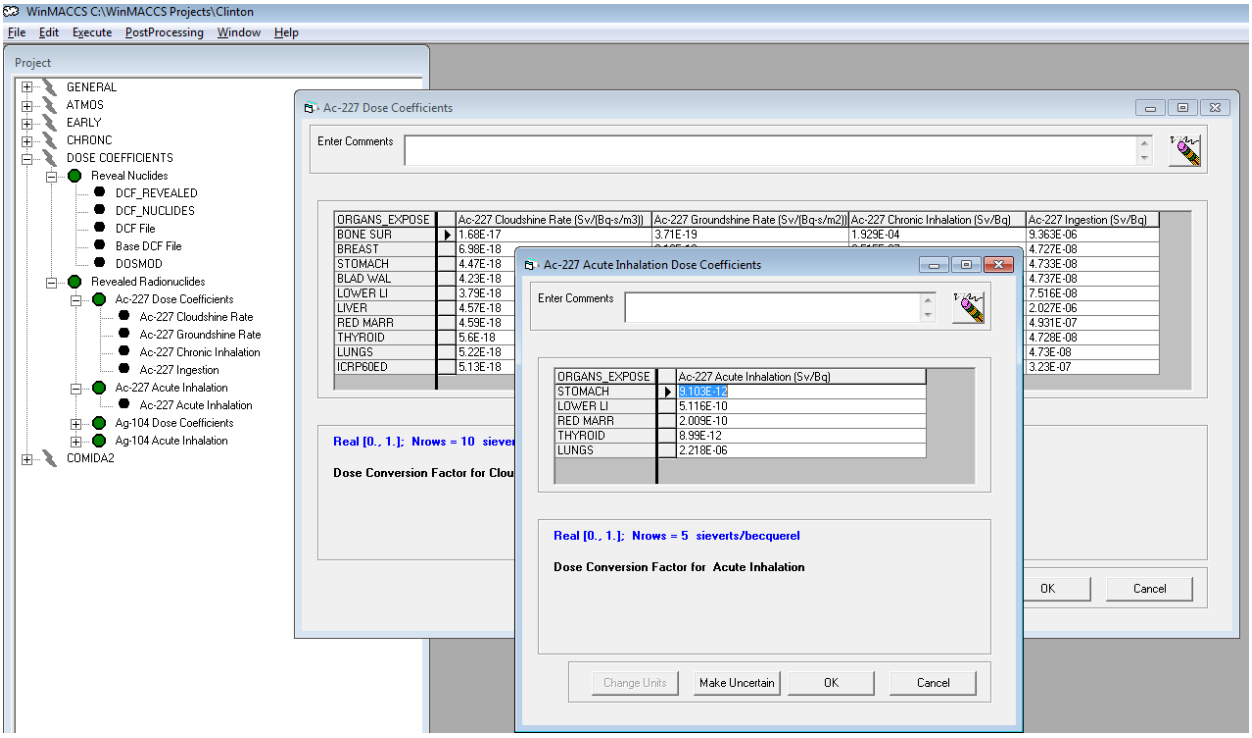


Figure 4-83 Dose Coefficient forms for FGR-13 file

In the example shown in Figure 4-84 the base file is of type DOSFAC2. Notice that the organ list is different than the organ list shown for the FGR-13 base file.

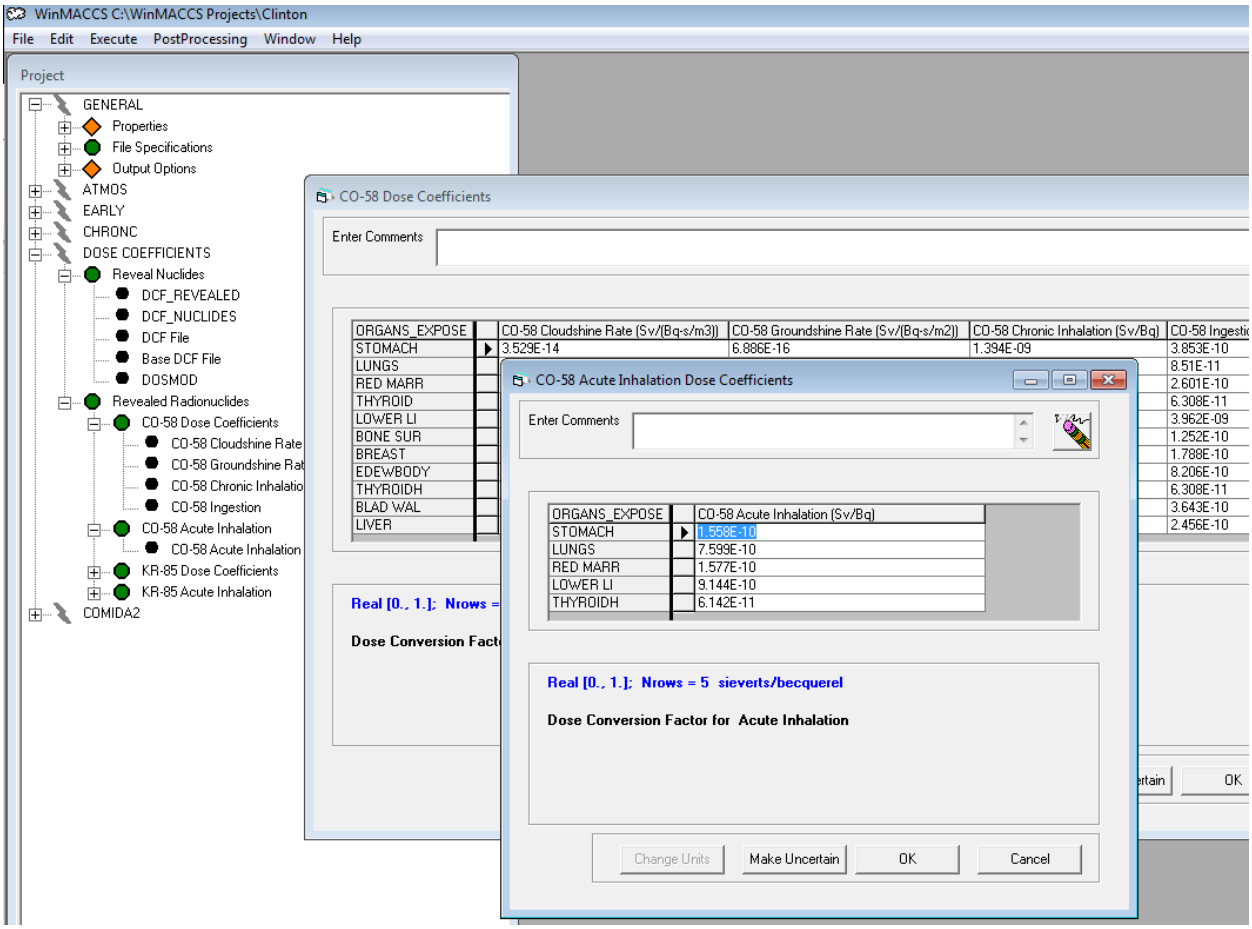


Figure 4-84 Dose Coefficient forms for DOSFAC2 DCF file

In the case of FGRDCF, there is one form per nuclide because acute health effects are not calculated when this DCF file is used as shown in Figure 4-85. The acute inhalation pathway is not relevant in this case.

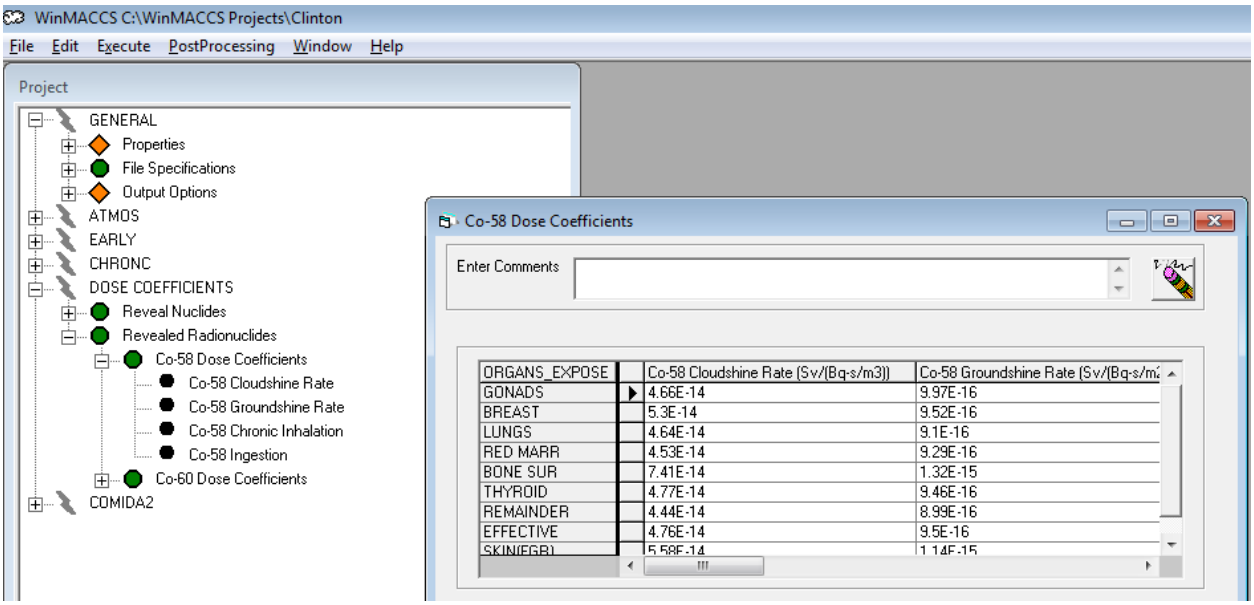


Figure 4-85 Dose Coefficient form for FGR 11-12 DCF file

DCF values can be modified by clicking on the grid cell and typing the new value. It is also possible to set any values to be uncertain by double clicking on the cell or by clicking in the cell and clicking the *Make Uncertain* button on the form. Clicking OK preserves changes. Clicking Cancel discards changes.

4.4.9.6 Running a Simulation

Select *Execute/Run Models* from the main menu to open the *Run Models* form. Notice that the *Create DCF File* check box is checked.

When a simulation is run in this mode, a DCF file is created for each LHS realization. The values are generated by LHS in the same LHS instance that generates all MACCS uncertain values.

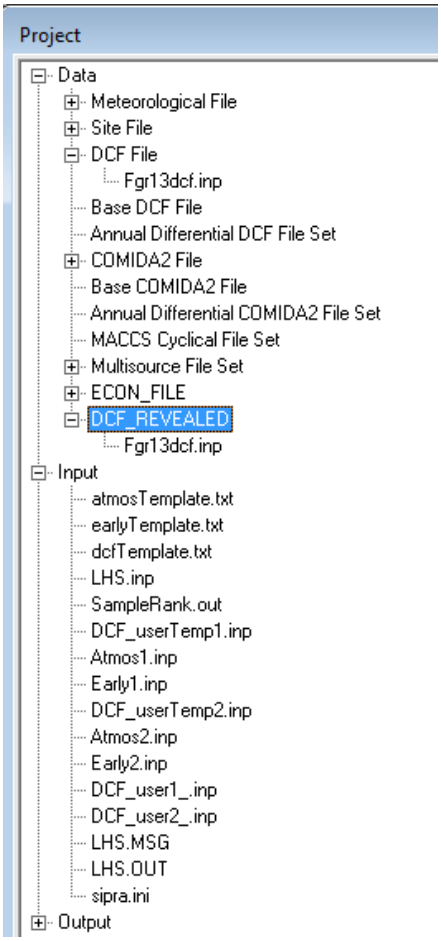


Figure 4-86 Files tab when creating DCF files

The *Files* tab in the WinMACCS *Project* window shown in Figure 4-86 shows a new entry in the Data category called *DCF_REVEALED*. This is the file that is used to define the *DOSE COEFFICIENTS* forms, the default values on those forms and the list of unexposed radionuclides. In this example, a file created by Fgr-13 was used, Fgr13dcf.inp.

The Input category lists files that are created by WinMACCS when running model simulations. The following files were created in an example with two simulations:

- Template file dcfTemplate.txt containing deterministic DCF values and place holders for LHS realizations were first created.
- Files DCF_userTemp1.inp and DCF_userTemp2.inp were created per realization. Uncertain values generated by LHS were inserted into these files. These files are in a MACCS standard input format, not in a DCF format.
- Files DCF_user1.inp and DCF_user2.inp are files in a standard DCF format. These files are used by MACCS, and contain the user specified dose conversion factors. There is one file per realization. These files were created from the files DCF_userTemp1.inp and DCF_userTemp2.inp.

4.4.9.7 Food Model available in WinMACCS with User Specified DCF

When the CHRONC module of WinMACCS is selected, there is an option allowing the use of a COMIDA2 food-chain file. It is required that the dose conversion file used in the EARLY module of MACCS be identical to the dose conversion file used to create the COMIDA2 food chain file.

The capabilities that create DCF files have not been integrated into the COMIDA2 food model. Either the food-chain model must be off or the older MACCS food-chain model used.

It is possible to create the dose conversion factor files and manually run each one through COMIDA2 by selecting the *Predefined DCF File Option*.

4.4.9.8 User Specified DCF file when using Annual DCF Files

When specifying the annual threshold or piecewise-linear dose model options, it is necessary to have the *Late Consequences* module on. Additionally, it is required that the *No Food Model* is also selected. Though the interface indicates that it is possible to use the *COMIDA2 Food Model*, this option is not functional.

It is also necessary, as in all threshold type calculations, to specify the basis annual threshold files as shown in Figure 4-46. These files are used to create the annual user specified threshold files.

In the following example, in the input folder, there are additional files created by WinMACCS.

When there are two realizations, there are two files created, DCF_TH_MULT1.inp and DCF_TH_MULT2.inp. These files are in a MACCS reconized DCF format. These files do not contain DCF values, but contain multipliers used to transform a predefined DCF file into a user based DCF file. These multipliers are applied to each of the predefined DCF threshold files to derive the user defined DCF threshold files. Values that are -1 indicate that the data are not used.

For example, the following is an excerpt from one of the multiplier files. For all DCF values used (values not equal to -1) the multiplier used is one. This means that the data will pass through with no changes. Columns correspond to pathways. Some values are set to –1 because MACCS does not consider these pathways.

```
Am-241
BONE SUR          1        -1        -1         1        -1         1         1
BREAST            1        -1        -1         1        -1         1         1
STOMACH           1        -1        -1         1         1         1         1
BLAD WAL          1        -1        -1         1        -1         1         1
LOWER LI          1        -1        -1         1         1         1         1
LIVER             1        -1        -1         1        -1         1         1
RED MARR          1        -1        -1         1         1         1         1
THYROID           1        -1        -1         1         1         1         1
LUNGS             1        -1        -1         1         1         1         1
ICRP60ED          1        -1        -1         1        -1         1         1
```

There is a multiplier file for every LHS realization.

In the following example, fgr13dcf.inp and its associated annual threshold files, fgr13dcfYY.inp, are shown, where YY is the year number (01, 02…50). Realization number 5 is shown in the following illustration.

- DCF_user5.inp is the DCF file associated with realization number five. LHS results for realization five have been inserted into this file.
- DCF_TH_MULT5.inp contains the multipliers calculated by calculating the ratio of the user defined value in the file DCF_user5.inp to the original value in FGR13dcf.inp. After this step has been completed, the 50 files used by the threshold model can be calculated by using this multiplier as a scale factor.

- DCF_user5_01.inp through DCF_user5_50.inp are the threshold files used for realization 5, derived by multiplying the DCF values in the predefined threshold DCF file, fgr13dcfYY.inp where YY is the year (01 through 50), with the multipliers for realization 5 in DCF_TH_MULT5.inp.

For example, to derive the file for realization number 5 for year 9, the multiplier file, DCF_TH_MULT5.inp is used with the data in the file Fgr13dcf09.inp to create a user defined input file DCF_user5_09.inp.

4.4.10 Multi Source Term

A group of MelMACCS files, possibly created from a combination of different MELCOR plot files and single files with multiple rings, can be run the *Multi Source Term* option. This is done by opening a project in WinMACCS and merging the source term files using the following steps:

1. The multi source term option is activated by clicking on the box labeled *Multi Source Term* on the *Plume/Source* tab, as shown in Figure 4-87. This setting needs to be saved by clicking *OK* in the *Project Properties* form.
2. Source term files are selected from the *GENERAL/File Specifications/Multi Source Term File Set* form. From this form, the user can navigate to the folder containing the multi source term files created by MelMaccs. Files can be selected by double clicking on the file names or by selecting or shift selecting, right clicking, and selecting Add Files from the pop-up menu. The order that the files are processed can by changed by selecting the file in the left most window pane, and clicking the up or down arrow below that pane to change the order, as shown in Figure 4-88. The order of the files affects some of the subsequent steps.

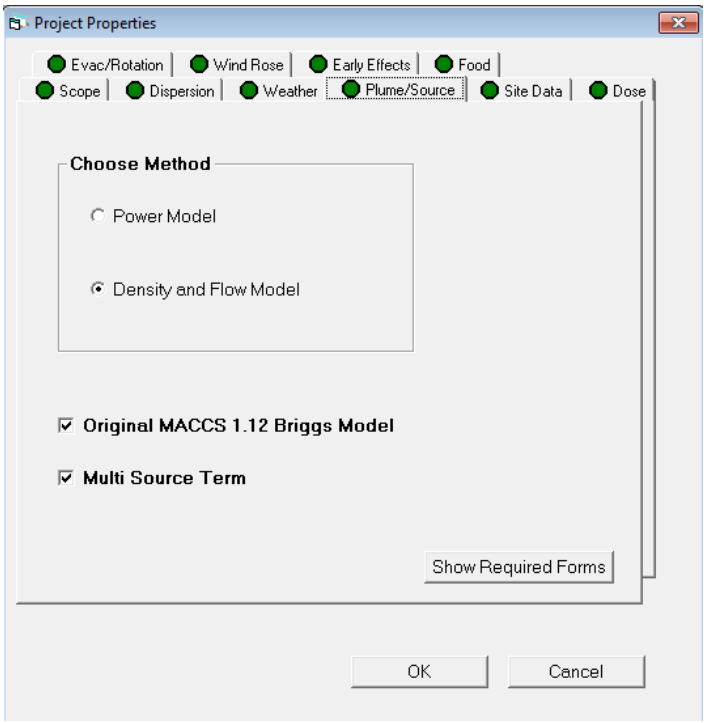


Figure 4-87 Selecting Multi Source Term option

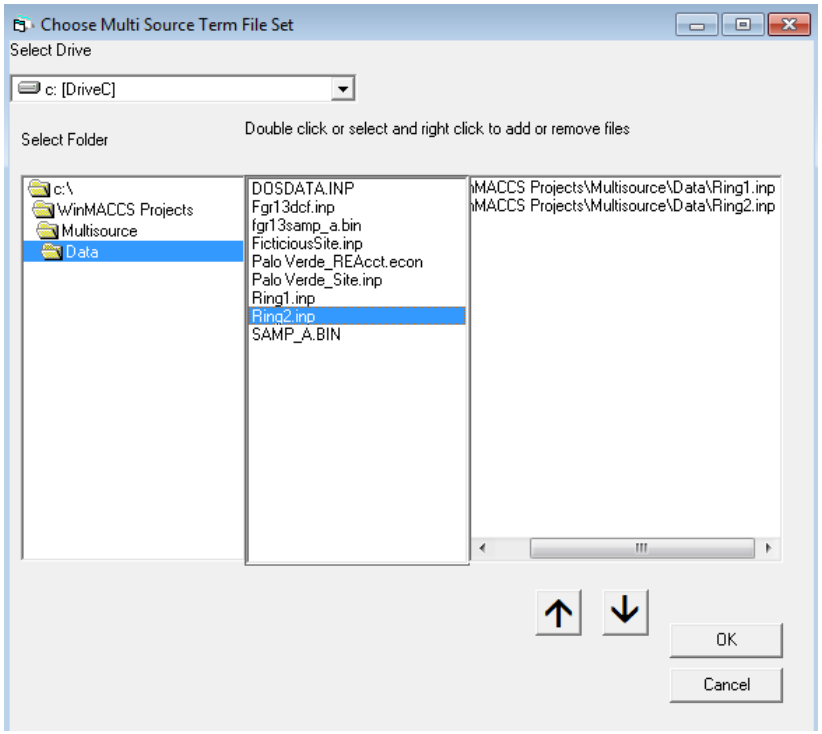


Figure 4-88 Specifying *Multi Source Term* input files

3. Forms under the category, Multi Source Term, are required. Two of the forms are the same or similar to the ones required for a single-unit source term, the *Chemical Names* and *Radionuclides* forms. The *Time Offsets* form allows the user to specify time offsets for each source term file, as illustrated in Figure 4-89. The *Plume Segments* form shows the plume segments arranged chronologically and identifies which multi source term file each plume segment is from. The plume delay values on this form account for the time offset values specified on the *Time Offsets* form. In the example shown, there are fifteen plume segments defined, ten from the file Ring1.inp and five from the file Ring2.inp. The files used by WinMACCS are copies of the original and are located in the Input folder of the project.

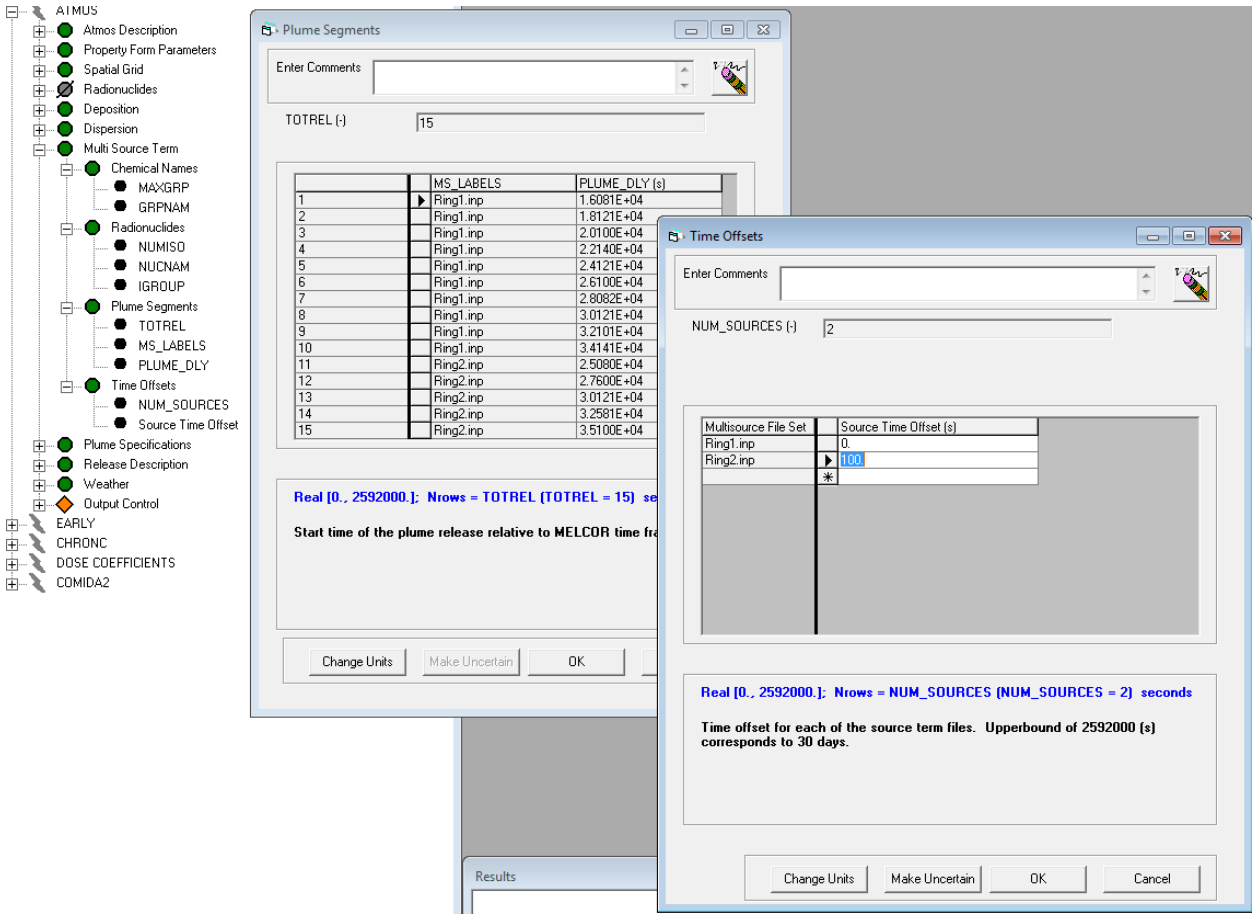


Figure 4-89 Forms for specifying a multi-unit source term

4. A special form named *Spatial Intervals for Output* can be found under the ATMOS/Output Control category. This form has the same name as another form, as shown in Figure 4-90. However, the upper bound for the variable INDREL, indicating the plume segment number, is the number of plumes segments in all of the multi source term files. The row number on the *Plume Segments* form shown in Figure 4-89 identifies value of INDREL for a specific plume segment.

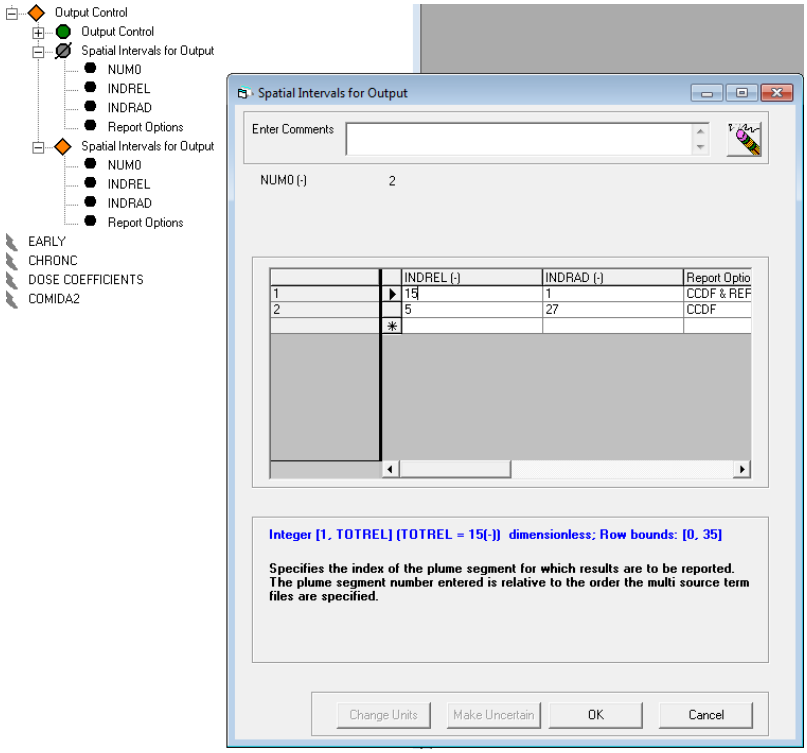


Figure 4-90 Specifying ATMOS output with the multi-unit source term model

5. Running a multi-unit source term calculation is performed from the Run Models form by selecting Execute/Run Models from the main menu, as shown in Figure 4-91. Notice that Create Multi Source Term File is checked. This means that Combine Source is to be run to recreate a file called CombineSource.out. This file is used by MACCS, and the file name is specified on an input card in the ATMOS input file.

6.

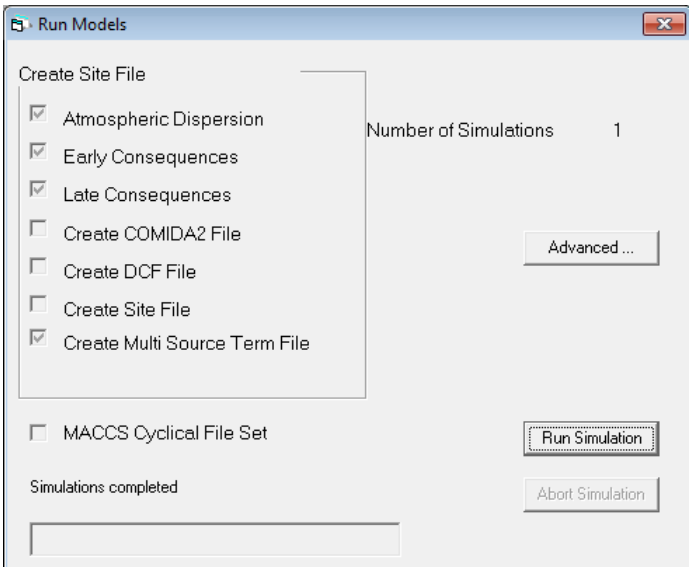


Figure 4-91 Running multi source term calculation with MACCS

4.5 Running Simulations

Model execution can be initiated by opening the *Run Models* form by selecting *Execute→Run Models…* from the main menu and clicking on *Run Simulation.*

This section describes the options available when running simulations.

4.5.1 Run Models Form

The following are the main components of the *Run Models* form as shown in Figure 4-92. The model settings are modified from the *Project Properties* form. The MACCS modules to be used, namely *Atmospheric Dispersion, Early Consequences, and Late Consequences*, are selected from the *Scope* tab of the *Project Properties* form. The *MACCS Cyclical File Set* is also selected from the *Scope* tab. The *Create COMIDA2 File* setting can be modified from the *Food* tab, *Create DCF File* from the *Dose* tab, *Create Site File* from the *Site/Data* tab, and the *Create Multi Source Term File* from the *Plume/Source* tab.

None of these settings can be modified directly from the *Run Models* form.

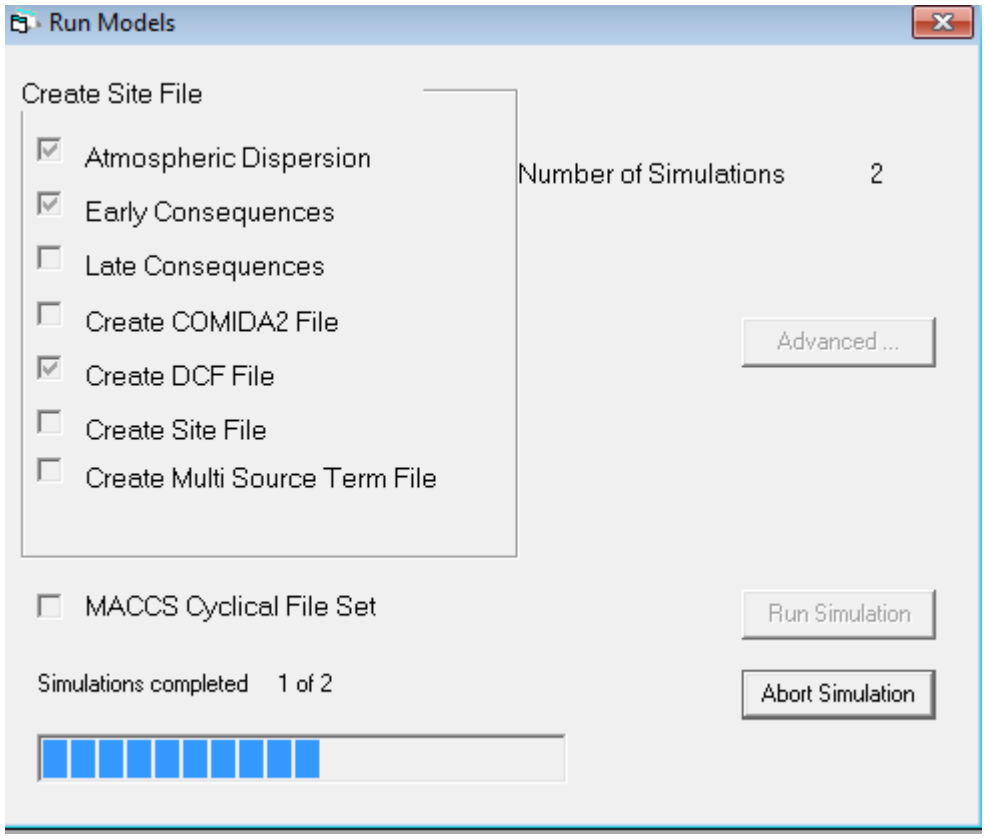


Figure 4-92 Run a simulation

The *Number of Simulations* is the number of cyclical and/or LHS samples to be run. However, MACCS attempts to prevent redundant simulations. For example, when no cyclical files or uncertain parameters are specified within MACCS, only a single simulation is performed. Likewise, when a set of cyclical files are specified but there are no uncertain parameters, MACCS performs the same number of simulations as cyclical files.

The *Number of Simulations* can be changed by selecting *Advanced* to open the *Advanced Execution Parameters* form. The seed used by the LHS random number generator can also be modified on this form.

Clicking *Run Simulation* initiates simulations. Progress is reported in the *Results* window.

The current simulation number (e.g., the MACCS run number) is displayed in the status bar found at the bottom of the *Run Models* form.

Selecting *Abort Simulation* aborts a MACCS run in progress.

4.5.2 Advanced Execution Parameters Form

Opening the *Run Models* window by selecting *Execute→Run Models* from the main menu allows the user to set advanced execution options. Clicking the button *Advanced* opens the *Advanced Execution Parameters* dialog as shown in Figure 4-93.

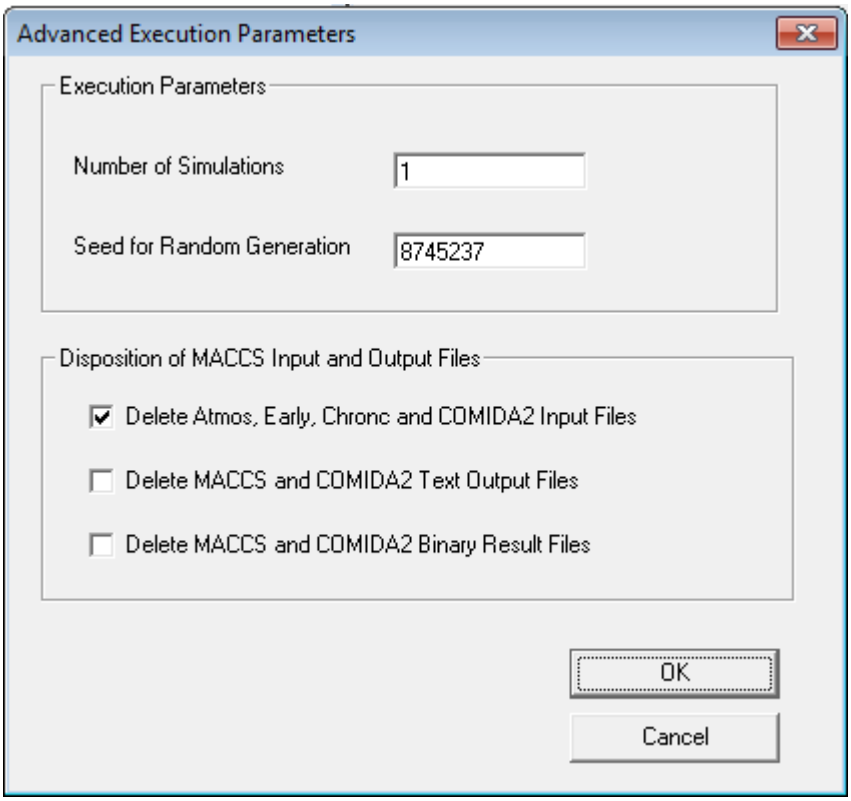


Figure 4-93 Advanced execution parameters form

The *Number of Simulations* text box is the number of times MACCS runs.

When there are uncertain parameters, set number of simulations to the number of LHS simulations that are to be used in the analysis. Changing this number changes the sampled values of the uncertain parameters used in the simulations.

When MACCS cyclical files are used with or without LHS, enter the number of times you want MACCS to run. When LHS is not used, the Number of Simulations should be the same as the number of cyclical files; when LHS is used, the Number of Simulations must be an integer

multiple of the number of cyclical files. When the value entered by the user is not a multiple of the number of cyclical files, WinMACCS resets this value to be the next larger integer that is a multiple of the number of cyclical files. Statistical results for the aggregated output assume that the conditions represented by the cyclical files are equally likely.

The value in the *Seed for Random Generation* text box is the random number seed used by LHS to create distribution samples of the variables the user has chosen to be represented by probability distributions. Changing this number changes the sampled values of the uncertain parameters used in the simulations. Powers of two should be avoided. The value of the seed must be between 1 and 2,147,483,647.

The section labeled *Disposition of MACCS Input and Output Files* gives the user the option of deleting various files that do not need to be referenced. These are useful options when there are many simulations. The files deleted are removed after MACCS has executed a single sample with the exception of the MACCS binary results files. The template files are always retained in the project Input folder.

When the *Delete Atmos, Early, Chronc and COMIDA2 Input Files* check box is checked, the MACCS input files are deleted after they have been used in a simulation. The template files (e.g., AtmosTemplate.txt) are not deleted. These files are located in the project /Input folder.

When the *Delete MACCS and COMIDA2 Text Output Files* check box is checked, the MACCS text output files and the COMIDA2 text output files are deleted after the simulations have all completed. These files are located in the project /Output folder.

When the *Delete MACCS and COMIDA2 Binary Result Files* check box is checked, the MACCS binary files are deleted after the reports are created. When no reports are requested and the *Execute→Auto Create Summary Report* checked command is off the MACCS binary results files are removed after each MACCS run and data is not available for post processing. In each other case, the binary data is imported into the project database and is available for post processing. Data for plots and additional reports are available through the database, even after the binary files are removed.

Clicking *OK* preserves changes. Clicking *Cancel* discards changes.

4.5.3 Template files

Template files are created by MACCS to facilitate the task of creating input files. These are named atmosTemplate.txt, earlyTemplate.txt, chroncTemplate.txt and comidaTemplate.txt. The positions where the values of uncertain variables are inserted are tagged within these files. The tags can be used to identify the uncertain variables. For example, notice the special characters around the number 309 in the following input line taken from a sample atmosTemplate.txt file.

WDCWASH1001 §309§

This line indicates that CWASH1 is uncertain. A sampled value from LHS is inserted into the space §309§ when the input file is created from the template file. The number 309 is an internal key used by MACCS to identify which variable to insert.

The Atmos1.inp, Early1.inp, Chronc1.inp and the three COMIDA2 input files are recreated from the template files when the user selects *Run Simulation*.

When the user desires to manually modify one or more input parameters within the MACCS template files, the user must first uncheck the main menu option *Execute→Refresh Template Input Files before Running*. Otherwise, the modified file is overwritten before MACCS executes and the modification is lost.

4.6 Model Results

Results are output from MACCS in text format, e.g. Model1.out, and in binary format, e.g., Model1.bin.

The binary results are available from WinMACCS as custom reports, custom plots or a text view of the binary file.

4.6.1 Text Results from MACCS

Text results from MACCS can be viewed in a text editor such as Notepad. These files can be opened directly by double clicking on the file name (e.g. Model1.out) found in the *Project/Files* tab.

Most MACCS results from a single simulation are probability distributions representing uncertain weather. For example, in Figure 4-94, the MACCS results for Center Air Concentration for Cs-137 for plume number one at 4.8 to 5.6 km is a probability distribution. MACCS reports statistics such as *Prob Non-Zero, Mean,* etc., calculated from this distribution. These statistics are listed as column headings in Figure 4-94.

	PROB		QUANTILES					PEAK	PEAK	PEAK
	NON-ZERO	MEAN	50TH	90TH	95TH	99TH	99.5TH	CONS	PROB	TRIAL
Source Term 1: Plume 1, at 4.8-5.6 km										
Cs-137 Center Air Conc. (Ci-s/m3)	0.9994	9.79E-03	6.41E-03	2.50E-02	3.17E-02	4.26E-02	4.83E-02	5.53E-02	2.08E-03	152
Cs-137 Ground Air Conc. (Ci-s/m3)	0.9994	1.07E-02	6.74E-03	2.81E-02	3.75E-02	5.33E-02	5.62E-02	5.99E-02	2.08E-03	152
Cs-137 Center Ground Conc. (Ci/m2)	0.9994	8.72E-05	6.16E-05	2.27E-04	2.92E-04	3.53E-04	3.80E-04	4.17E-04	2.08E-03	152
Total Center Ground Conc. (Ci/m2)	0.9997	2.91E-02	2.04E-02	7.75E-02	1.01E-01	1.26E-01	****	1.35E-01	6.09E-03	127
Ground-Level Dilution, X/Q (s/m3)	0.9997	5.99E-06	3.13E-06	1.55E-05	2.32E-05	3.30E-05	3.50E-05	3.77E-05	2.08E-03	242
Cs-137 Adjusted Source, Q (Ci)	0.9994	2.05E+03	2.03E+03	2.19E+03	2.26E+03	2.43E+03	2.52E+03	2.62E+03	2.17E-03	58
Plume Sigma-y (m)	0.9997	4.38E+02	3.49E+02	7.23E+02	7.46E+02	8.03E+02	8.29E+02	8.35E+02	4.25E-03	76
Plume Sigma-z (m)	0.9997	5.47E+03	1.05E+02	2.14E+04	2.29E+04	****	****	2.63E+04	1.31E-02	36
Plume Height (m)	0.9997	3.27E+01	3.28E+01	4.05E+01	4.44E+01	5.82E+01	****	6.61E+01	5.62E-03	230
Plume Arrival Time (s)	0.9997	1.90E+04	1.35E+04	2.15E+04	2.31E+04	****	****	2.65E+04	1.34E-02	63

Figure 4-94 MACCS statistical summary results

The *Statistical Summary Results* form described in section 4.6.3.3 allows the user to display a graphical view of the CCDF for each of the entries in Figure 4-94(e.g., the mean value of Center Air Concentration for Cs-137 for plume number one at 4.8 to 5.6 km) over all realizations. In other words, a plot created with this option displays a probability distribution (CCDF) of one of the statistics above calculated over the set of LHS samples.

A binned CCDF of output requests is created by MACCS when the Report Option is set to CCDF or CCDF & REPORT on the forms in the ATMOS/Output Control, EARLY/Output Control and CHRONC/Output Control categories.

Parameters set under the EARLY and CHRONC *Output Control* categories of the interface determine the consequences calculated by MACCS. MACCS can calculate a variety of different consequence measures to portray the impact of a facility accident on the surrounding region. The user has control over the results that are produced. By choosing appropriate values in *Output Control*, the user can ensure that the code produces only desired results. This affords a great deal of flexibility but it also requires that the user anticipate the results that are needed.

When any are omitted, the user needs to correct the parameter choices and rerun the calculation.

In this regard, a result can only be produced when the model needed for its calculation has been previously defined in the appropriate section. When any results pertaining to health effects are requested, risk factors for that model must have been supplied on forms *Early Fatality Parameters, Early Injury Parameters,* and *Latent Cancer Parameters.*

EARLY can produce many different types of results. Some of these types of results are also calculated by CHRONC, but some are not. For instance, both EARLY and CHRONC calculate cancer cases and population dose, but only EARLY calculates early fatalities, and only CHRONC calculates economic costs. When the user requests EARLY to produce a result that is also produced by CHRONC, the code automatically calculates results for both EARLY and CHRONC.

Summary statistics with respect to each requested result are reported independently of the value of the WinMACCS variable, *Report Options*. There are ten columns of numeric data which provide a statistical summary, as follows:

- PROB NON-ZERO is the conditional probability of having a nonzero consequence estimate, conditional on the occurrence of the release under consideration.
- MEAN is the average (expected) consequence over all weather trials. This is calculated by taking the sum of all the products [(consequence value) $\times$ (conditional probability of that value)] for each weather trial. The probability of the weather trials are not necessarily the same, so the conditional probabilities can be different for each weather trial.
- 50TH QUANTILE is the median of the estimated complimentary cumulative distribution function (CCDF).
- 90TH QUANTILE is based on the estimated CCDF. It is the value for which there is a 10% chance this consequence magnitude is exceeded.
- 95TH QUANTILE is based on the estimated CCDF. It is the value for which there is a 5% chance this consequence magnitude is exceeded.
- 99TH QUANTILE is based on the estimated CCDF. It is the value for which there is a 1% chance this consequence magnitude is exceeded.
- 99.5TH QUANTILE is based on the estimated CCDF. It is the value for which there is a 0.5% chance this consequence magnitude is exceeded.
- PEAK CONS is the largest consequence magnitude obtained from the set of weather trials that were examined.
- PEAK PROB is the conditional probability associated with the largest consequence magnitude.
- PEAK TRIAL refers to the weather trial for which the largest consequence occurred. By referring to the ATMOS portion of the output file, the user can determine the start time (day and time period) of this weather sequence.

A CCDF is an estimate of the distribution of consequence magnitudes. The variability of consequence values in a single MACCS simulation is due solely to the uncertainty of the weather conditions existing at the time of the accident. A MACCS output file is created for each simulation when any input variables are chosen to be uncertain. In this case, the user chooses the number of realizations to capture the uncertainty in the input variables. MACCS produces one CCDF per realization. WinMACCS can quantify the overall uncertainty in results by assembling the set of CCDFs into a single CCDF that accounts for both weather and input uncertainty.

CCDFs can be viewed as spider plots (one CCDF curve per simulation) from within the WinMACCS interface using *Post Processing/Graphical Results/Results over all Weather Trials* under the main menu selection. Additionally, statistical results (such as the mean result over all weather trials) can be viewed using *Post Processing/Report Results/Create Summary Report* under the main menu.

Report Options appears on most of the output request forms. When set to *CCDF* or *CCDF & REPORT*, CCDF data are reported in the MACCS output file. When set to *REPORT* or *CCDF & REPORT*, WinMACCS automatically generates a report over all realizations based on quantiles specified on the *Reporting Options* form.

When the user did not select *Report Options* to be *CCDF* or *CCDF & REPORT* when requesting the calculation in the WinMACCS input forms, it is still possible to retrieve those data from WinMACCS. Though the CCDF data are not written to the output file, when the user requests a report based on the desired data using the custom report form, *Post Processing/Create Custom Report*, CCDF data are read into WinMACCS from the binary output file and are available in the *Post Processing/Graphical Results* forms. The user should be aware that the method used to estimate quantile levels in WinMACCS differs from the one used in MACCS, so quantile values for a single realization produced by WinMACCS will differ slightly from those produced by MACCS.

When a consequence measure was calculated by both EARLY and CHRONC, the output lists results separately for EARLY and CHRONC. The weighted sum or average of all consequence results is presented at the beginning of the output file in a section labeled OVERALL RESULTS... Following the overall results, those from each of the cohorts are presented. The total number of cohorts listed is one greater than the number of emergency response cohorts created in EARLY. The final cohort in the output represents CHRONC.

4.6.2 Custom Reporting Options

Reports created from the MACCS binary result files are created using different methods as follows:

- Report requests that combine the results over the MACCS simulations can be requested on the forms in the *ATMOS/Output Control*, *EARLY/Output Control* and *CHRONC/Output Control* categories. These requests result in a report referred to as a *Summary Report.*
- Reports that combine the results over the MACCS simulations can also be created using the custom report features. Data is available from every calculation request made from ATMOS/Output Control, EARLY/Output Control and CHRONC/Output Control categories, even when report requests were not made on those forms. These can be created using the *Combine Realizations* option on the *Manage Reports* form as described in section 4.6.2.3.
- Reports that display results without combining data over the MACCS simulations are created using the *Realization Based* option on the *Manage Reports* form as described in section 4.6.2.54.6.2.3.

Reports are created automatically after the simulations are completed provided the main menu item *Execute→Auto Create Reports* is checked. The reports created include the *Summary Report* and all of the custom reports defined. These reports are placed in the project \Output folder, and are also available within WinMACCS on the *Project/Files* tab.

When the menu item *Execute→Auto Create Reports* was not checked before the simulations began, the reports can still be requested from the *Manage Reports* form described in section 4.6.2.3 and section 4.6.2.5. The summary report can be created by selecting *PostProcessing→Report Results→Create Summary Report.* These post processing features only function when the MACCS binary files have not been deleted.

Custom reports are defined using the menu item *PostProcessing→Report Results→Manage Custom Reports.* New custom reports must be defined after the MACCS simulations have completed because the list of variables to place on the reports is not be available before the run has been finished. After the custom reports have been set up, it is possible to recreate them for each subsequent run.

When the output requests to MACCS (see the forms in *Output Control*) are modified to exclude some output requests that were used to define the custom reports, those custom reports are not created. The user should be careful not to confuse reports from previous runs with current runs since old created reports are not deleted unless the new file has the same name as the existing file.

It is possible to import custom report definitions from other projects using the menu item *File→Import Custom Report Definitions* as description in section 4.2.1.

4.6.2.1 Combining Results over Realizations

The first step in defining the reports that combine data over realizations is to define the probabilities, or quantiles, to use. When the probabilities are not defined, only the grand mean (e.g., the mean over all realizations) is reported. These reports that combine realizations contain the grand mean and the interpolated values based on the binned CCDF results for a user entered quantile.

Opening the form *GENERAL/Output Options/Reporting Options* allows quantiles to be entered. This is shown in Figure 4-95. When the MACCS simulations have already completed, a *Summary Report* cannot be created, but custom reports can be requested that combine the realizations.

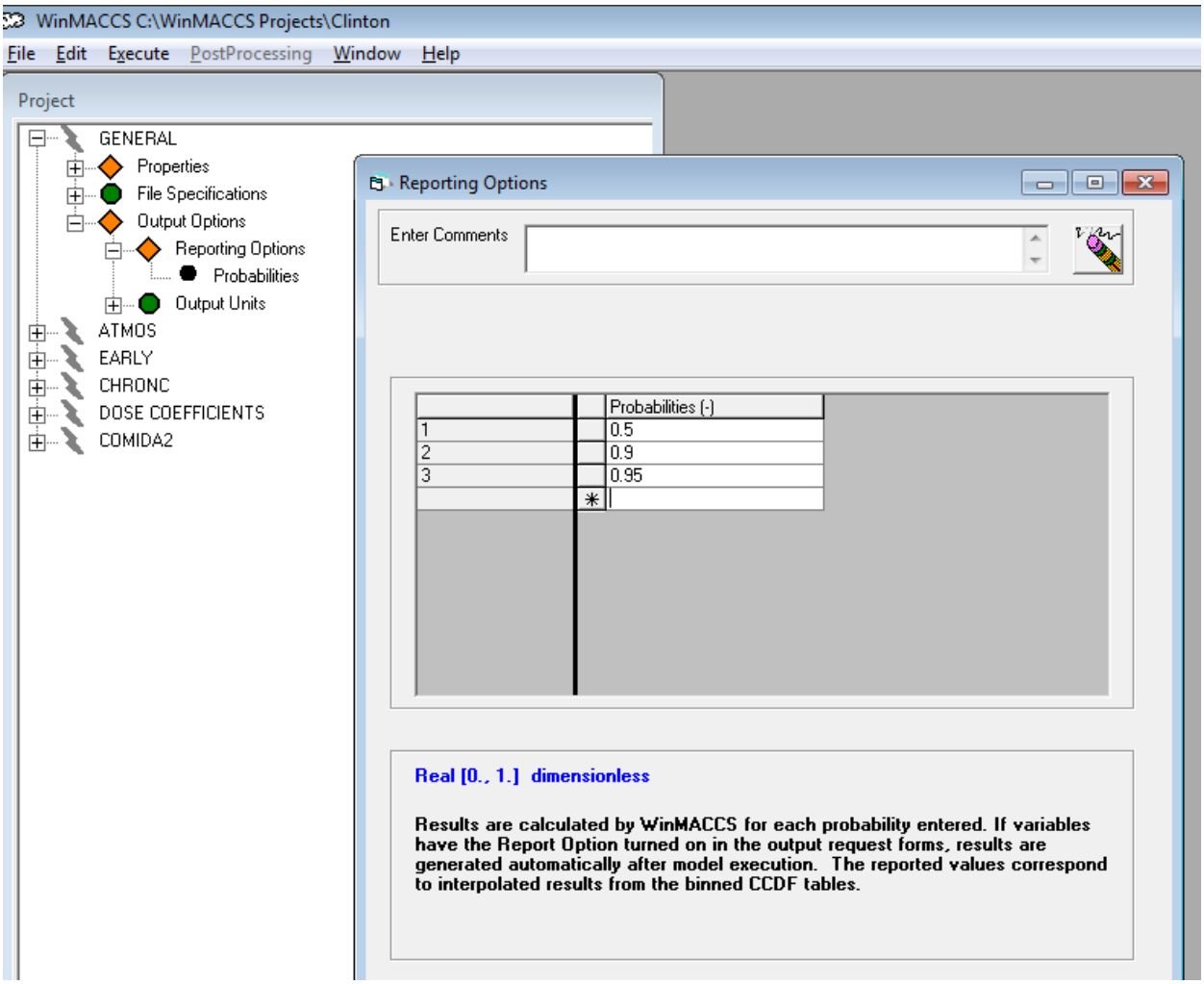


Figure 4-95 Specifying quantiles

4.6.2.2 Creating a Summary Report

A summary report based on MACCS output variables is created after MACCS simulations have completed. To include a variable in the summary report, the *Report Options* flag should be set to *REPORT* or to *CCDF & REPORT* as shown in Figure 4-96.

The summary report is created after MACCS simulations have completed provided the *Execute→Auto Create Summary Report* menu item is checked. This report can also be created by selecting *PostProcessing→Report Results→Create Summary Report.*

The categories *ATMOS/Output Control*, *EARLY/Output Control* and *CHRONC/Output Control* contain calculation requests. Most of the forms in these categories contain the *Report Options* flag.

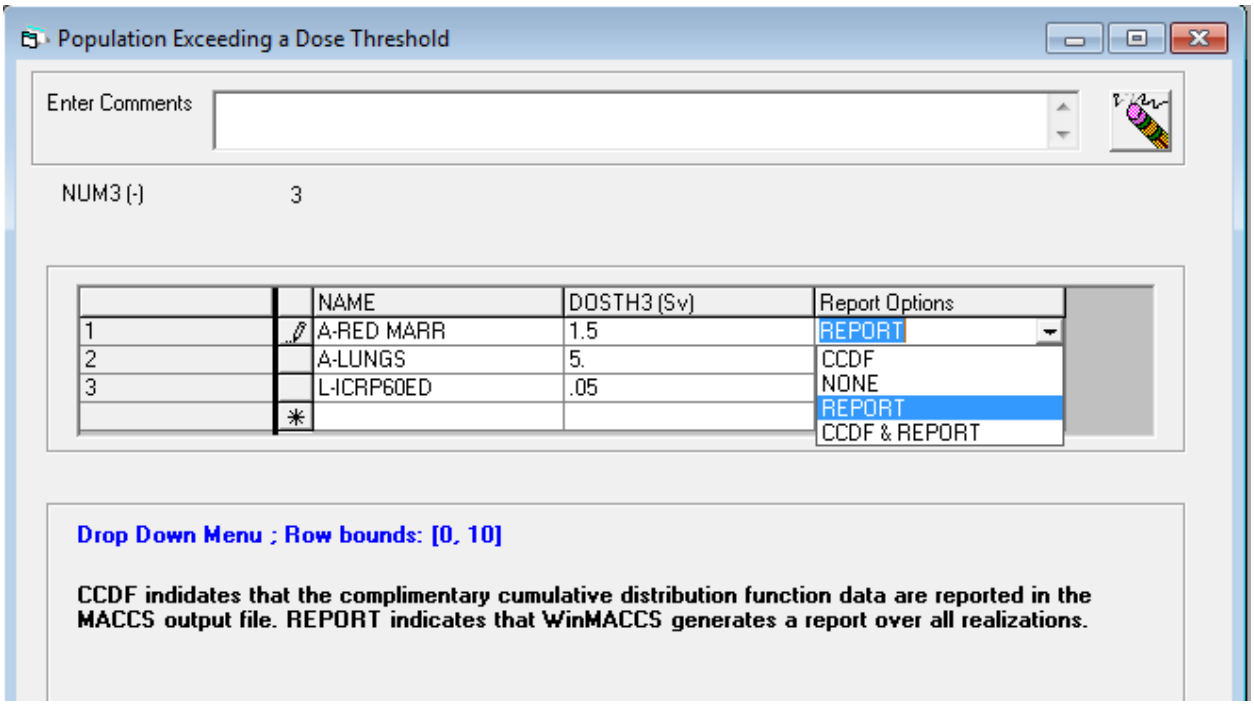


Figure 4-96 Summary report request

Summary reports can be requested as follows:

1. Quantiles are defined as shown in Figure 4-95.

2. The outputs of interest are selected by first opening an output request form. This is a form that is in one of the *Output Control* categories.

3. In the *Report Options* column, by choosing either *REPORT* or *CCDF & REPORT* causes WinMACCS to include this variable in the report after all MACCS simulations are completed. When the CCDF & REPORT is chosen, the additional binned data for each cohort is printed in each of the MACCS output files associated with the simulation.

4. This process can be repeated for all variables to be included in the summary report. Clicking *OK* preserves the summary report requests.

5. After running the MACCS simulations, the binary result files, Model1.bin, Model2.bin, …, are imported into the database. The report, summary.txt, is automatically created based on the user input, and placed in the project output folder. Double clicking on Output/Summary.txt found on the *Files* tab of the *Project* window will open the report.

4.6.2.3 Creating a Report that Combines Realizations

This section describes how to create new combine realization reports after MACCS simulations have completed.

After MACCS has run, the *PostProcessing* menu is available. The custom report generator can be opened by selecting *PostProcessing→Report Results→Manage Custom Reports* as shown in Figure 4-97 .

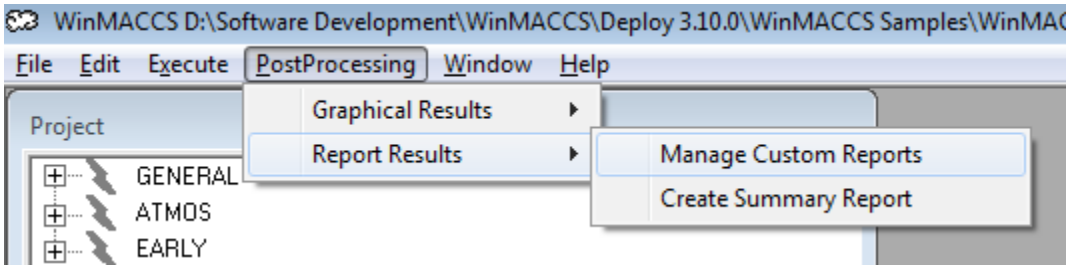


Figure 4-97 Opening the Manage Reports form

This form lists the custom reports currently defined as shown in the example shown in

Figure 4-98. In this example there are two reports defined. The column labeled *Type* identify the report format as *Combined.* This means that these are reports based on combining realizations. All reports listed in the *Manage Reports* form are automatically created after the MACCS simulations have completed provided the menu item *Execute→Auto Create Reports* is checked.

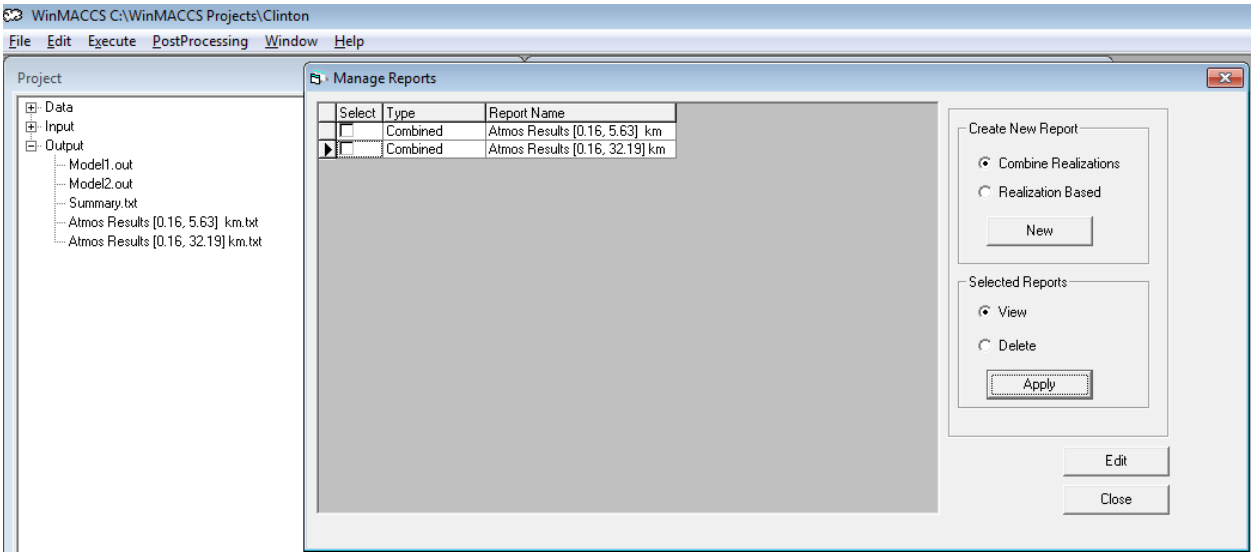


Figure 4-98 Reports based on combining realizations

The *Custom Combined Report* form as shown in Figure 4-99 lists each of the MACCS output requests. This form is opened when a new *Combine Realizations* report is created, or when an existed *Combine Realizations* report is edited.

The column labeled *Report Description* identifies the form description as found in the *Project/Parameters* tab. For example, in Figure 4-99 the entries defining the report *Population Dose* were requested from the WinMACCS form *EARLY/Output Control/Population Dose.* The column labeled MACCS Input Card is a copy of the line written to the MACCS input file EARLY1.inp.

The *Combine Realizations* report contains results similar to the Summary.txt report. WinMACCS combines the CCDF data over all of the MACCS binary result files and displays the grand mean and the interpolated quantile values.

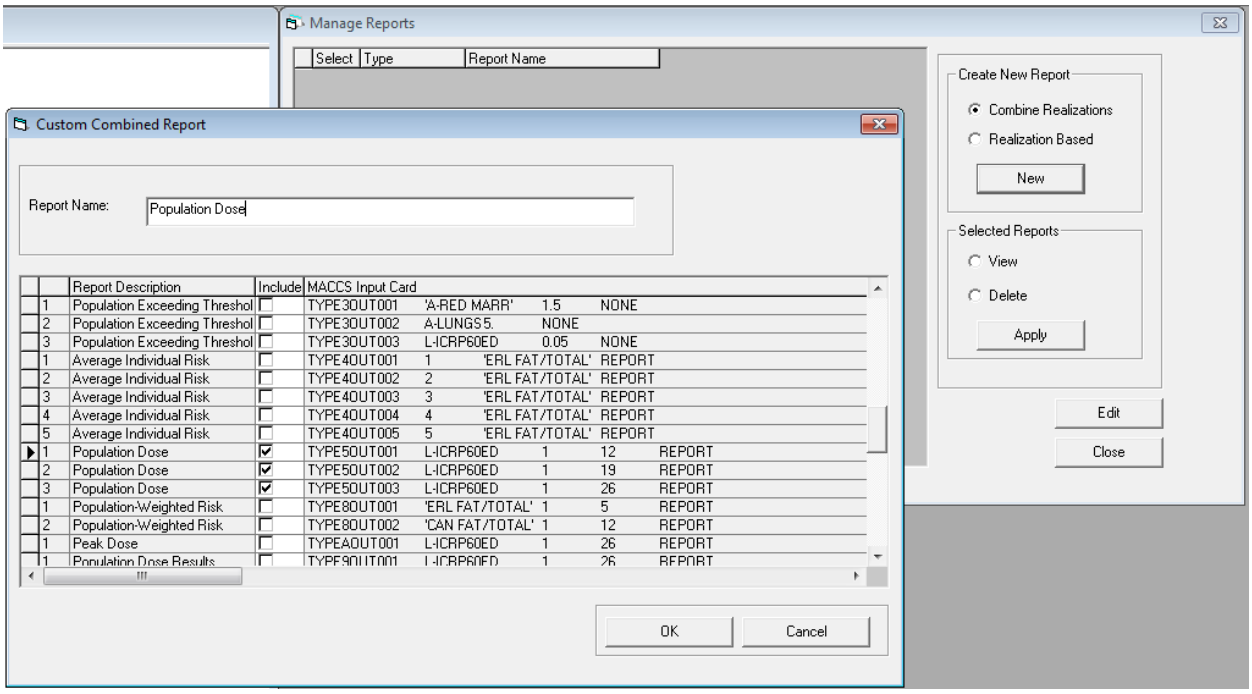


Figure 4-99 Defining a Combine Realizations report

New combine realization reports can be defined as follows:

1. Quantiles are defined as shown in Figure 4-95.

2. The Manage Reports form is opened by selecting *PostProcessing→Report Results→Manage Custom Reports* as shown in Figure 4-99.

3. A new definition can be defined by first selecting the radio button *Combine Realizations* and clicking on the button *New*.

4. The user can enter report name in the field labeled *Report Name*.

5. The MACCS output requests are selected by clicking check boxes in the *Include* column.

6. Clicking *OK* to saves the new report definition.

If the report has already been defined, the report can be opened by checking the box in the column labeled *Select.* Selecting the radio button labeled *View* in the group *Selected Reports* and clicking the *Apply* button will create and open the report.

A defined report can be edited by checking the box in the column labeled *Select* and clicking the *Edit* button.

A defined report can be deleted by checking the box in the column labeled *Select*, selecting the radio button labeled *Delete* in the group *Selected Reports* and clicking the *Apply* button.

4.6.2.4 Interpretation of Combining Realization Reports

The report format used for summary reports is the same format that is used when creating a custom report when the combine realization is option is used as shown in Figure 4-99.

These reports consist of the grand mean and an estimate for the probability of exceedance for the probabilities requested on the *General/Reporting Options* form based on the binned cumulative probability distributions calculated by MACCS.

If all of the CCDF values are identical, there is no variance in the parameter values. In this case it is not possible to calculate a meaningful value for the probability of exceedance and the report contains the text “Unable to transform CCDF No differences in probability values in CCDF”.

In the following example, the report request was made on the form *Early/Output Control/Health-Effect Cases.* The statistics from each of the LHS trials are combined.

```
**************************************************************************
Request 1  Health-Effect Cases
MACCS Image:TYPE1OUT009        'CAN FAT/TOTAL'     1        26       REPORT
**************************************************************************

Evacuation CHRONC CAN FAT/TOTAL [0.,1609.34](km)
                              Probability of Exceedance
                               Grand Mean     0.5             0.9             0.95
Health-Effect Cases (none)  2.732E+03     9.231E+02     1.006E+02     5.008E+01

Evacuation Evac #  1 CAN FAT/TOTAL [0.,1609.34](km)
                              Probability of Exceedance
                               Grand Mean     0.5             0.9             0.95
Health-Effect Cases (none)  4.094E+02     1.017E+02     5.141E+00     1.856E+00

Evacuation Evac #  2 CAN FAT/TOTAL [0.,1609.34](km)
                              Probability of Exceedance
                               Grand Mean     0.5             0.9             0.95
Health-Effect Cases (none)  3.637E+00     1.83E+00      3.321E-01     2.049E-01

Evacuation Overall CAN FAT/TOTAL [0.,1609.34](km)
                              Probability of Exceedance
                               Grand Mean     0.5             0.9             0.95
Health-Effect Cases (none)  3.145E+03     1.273E+03     1.35E+02      7.178E+01
```

The first entry, CHRONC, reports the cancer fatalities due late consequences. The next two entries, Evac # 1 and Evac # 2 report the cancer fatalities due to early consequences for cohort 1 and cohort 2 respectively. The early and late consequences are combined in the entry labeled Evacuation Overall.

Interpreting the results for the overall health effects, we are 90 percent certain that the number of total fatalities exceeds 135. The mean number of fatalities over all LHS realizations is 3145. This is precisely the sum of the mean cancer fatalities due to the late and early consequences.

Cohort results are combined using the weighting factors stored in variable *WTFRAC* when the overall results are calculated for some of the variables that are independent of the population such as Average Individual Risk, Peak Dose and Population Weighted Risk calculations.

4.6.2.5 Creating a Report Based on Individual Realizations

This section describes how to create reports that show results for individual realizations after MACCS simulations have completed.

After MACCS has run, the *PostProcessing* menu is available. The custom report generator is opened by selecting *PostProcessing→Report Results→Manage Custom Reports*.

This form lists the custom reports currently defined. In the example shown in Figure 4-100 the column labeled *Type* indicates the report format. For reports based on individual realizations, the *Type* is either *byVariable* or *byTrial* depending on whether the *By Variable* or the *By Realization* radio button was selected on the *Custom Realization Based Report* form as shown in Figure 4-101. See section 4.6.2.3 for creating reports where the *Type* is *Combined.*

All reports listed are automatically created after the MACCS simulations have completed provided the menu item *Execute→Auto Create Reports* is checked.

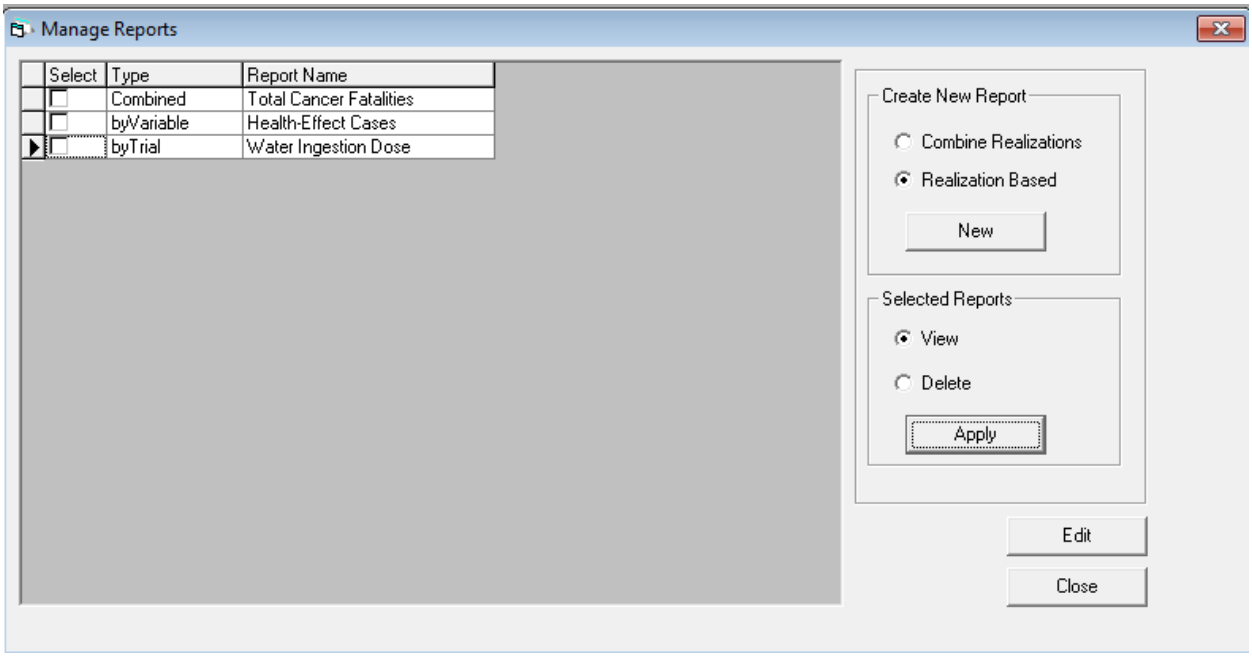


Figure 4-100 Reports based on each realization

The *Custom Realization Based Report* form as shown in Figure 4-101 is organized as a list of available results read from the MACCS binary results file. Each available variable for reporting is listed. A list is opened by clicking the plus sign where more specific results can be selected. In the example, there are two results available for Total Centerline Ground Concentration. Items in the list, called qualifiers, can be individually selected or selected as a group by clicking on the box preceding the variable name.

This form is opened when a new *Realization Based* report is created, or when an existed *Realization Based* report is edited.

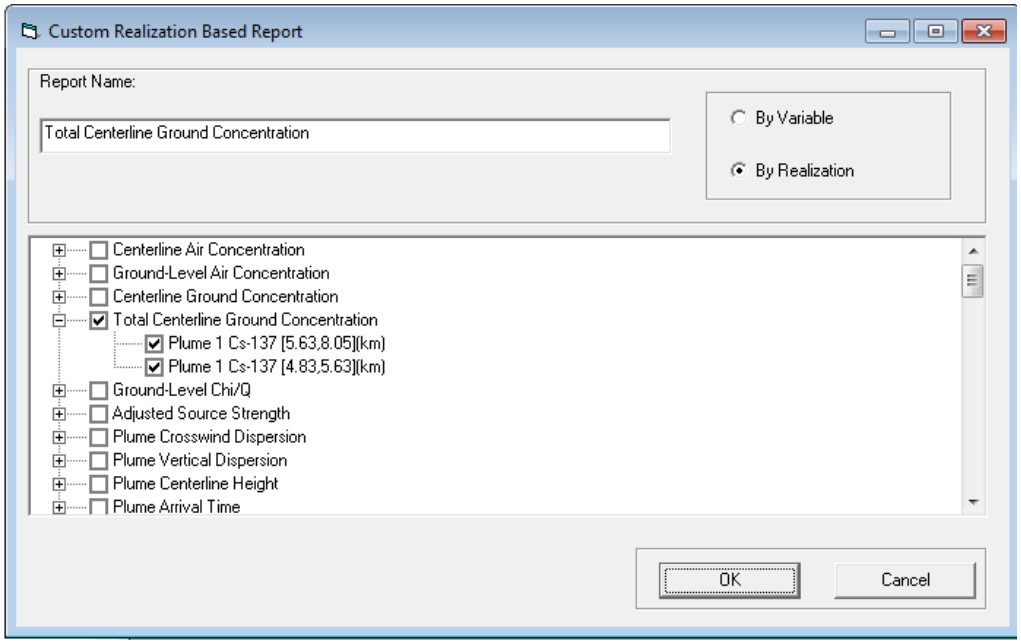


Figure 4-101 Defining a Realization Based report

New realization based reports can be defined as follows:

1. The Manage Reports form can be opened by selecting PostProcessing→Report Results→Manage Custom Reports from the main menu.

2. Selecting the radio button *Realization Based* and clicking the button *New* opens the *Custom Realization Based Report* form as shown in Figure 4-101.

3. A report name must be entered in the field labeled *Report Name*.

4. Variables can be selected by clicking on the empty boxes in front of the variable names. Individual items can be selected from the qualifier lists by clicking the + in front of the variable name and clicking the empty boxes in front of the qualifiers.

5. Selecting either the radio button *By Variable* or *By Realization* will complete the report definition. When *By Variable* is selected the results for each variable are listed for a given trial when the report is created. When *By Realization* is selected the results for each trial are listed for a given variable as shown in Figure 4-97.

6. Clicking *OK* saves the report definition.

When the report has already been defined the report can be opened by checking the box in the column labeled *Select.* Select the radio button labeled *View* in the group *Selected Reports.* Click the *Apply* button. The report is created and opened.

A defined report can be edited by checking the box in the column labeled *Select* and clicking the *Edit* button.

A defined report can be deleted by checking the box in the column labeled *Select,* selecting the radio button labeled *Delete* in the group *Selected Reports* and clicking the *Apply* button.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Report based on Project D:\Software Development\WinMACCS\Deploy 3.10.0\WinMACCS Samples\WinMACCS Samples\NRC Sample Problems\Sampled Values LNT\Sampled Values LNT.mxd												
2	WinMACCS Version 3.10.0 SVN:2560												
3	Report based on MACCS Version 3.10.0.0 SVN 2560												
4	First binary file date/time stamp 03/27/2015 16:40												
5	7/15/2015 18:28												
6													
7	Health-Effect Cases (none) Evacuation Evac # 2 ERL FAT/TOTAL [0.,1609.34](km)												
8		Probability Non-zero	Mean	5th Quantile	10th Quantile	50th Quantile	90th Quantile	95th Quantile	99th Quantile	99.5th Quantile	Peak Concentration	Peak Probability	Peak Trial
9	Realization 1	2.09E-01	2.01E-04	0.00E+00	0.00E+00	0.00E+00	4.16E-04	1.14E-03	3.16E-03	3.63E-03	9.99E-02	1.81E-04	2.26E+02
10	Realization 2	1.12E-01	3.01E-02	0.00E+00	0.00E+00	0.00E+00	5.28E-03	1.92E-01	7.43E-01	8.41E-01	1.56E+00	3.90E-04	2.64E+02
11	Realization 3	2.08E-01	1.30E-02	0.00E+00	0.00E+00	0.00E+00	8.27E-03	6.52E-02	3.56E-01	4.85E-01	5.61E-01	2.28E-03	4.19E+02
12	Realization 4	3.01E-02	1.83E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.93E-03	5.65E-03	1.80E-01	1.81E-04	1.30E+02
13	Realization 5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14	Realization 6	1.81E-04	2.31E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-03	1.81E-04	2.26E+02
15	Realization 7	5.05E-01	6.47E-03	0.00E+00	0.00E+00	1.47E-07	7.74E-03	5.07E-02	1.15E-01	1.36E-01	5.77E-01	1.62E-04	5.95E+02
16	Realization 8	1.47E-01	1.86E-03	0.00E+00	0.00E+00	0.00E+00	1.63E-06	2.92E-05	4.24E-02	1.10E-01	1.31E+00	1.81E-04	2.26E+02

Figure 4-102 Report of type *By Realization* opened in Excel

4.6.3 Custom Plotting Options

Graphical output can be displayed after completing a MACCS run by selecting an entry from the main menu *Post Processing→Graphical Results.* The following results are available:

- Scalar results are displayed by selecting *PostProcessing→Graphical Results→Scalar Results* from the main menu.
- Statistical summary results are displayed by selecting *PostProcessing→Graphical Results→Statistical Summary Results* from the main menu.
- Probability distribution results representing weather uncertainty are displayed by selecting *Post Processing→Graphical Results→Results over all Weather Trials* from the main menu.

When a plot request is made after a simulation (e.g., one of the menu entries such as *PostProcessing→Graphics→ Results over all Weather Trials*) is selected, the MACCS binary result files (e.g., Model1.bin and Model2.bin*)* are imported into the project database when they were not already imported to support automatic or custom reports. This progress can be observed in the *Results* window as shown in Figure 4-103.

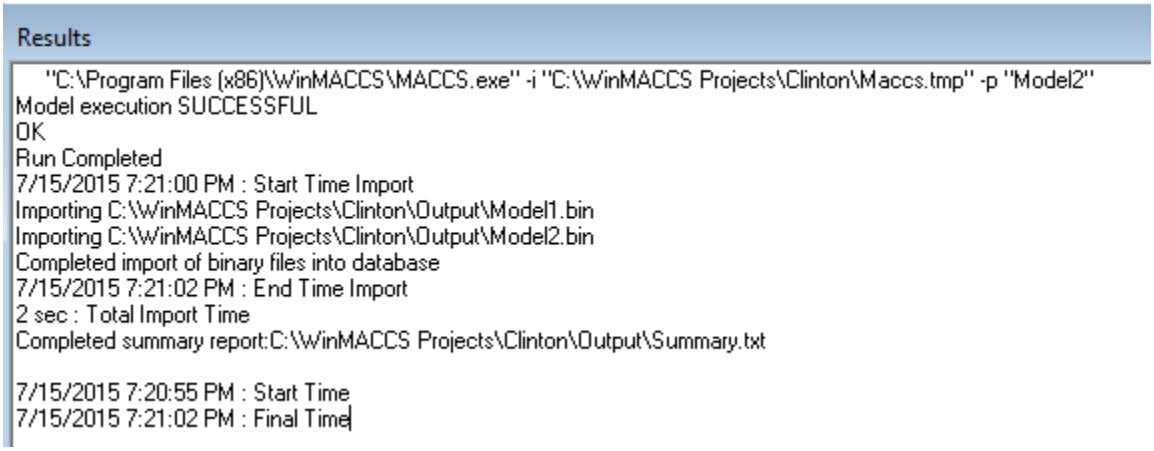


Figure 4-103 Results window after processing binary files

After the binary result files have been processed into the project database, the result information is available for quick access without repeating the import process.

4.6.3.1 Scalar Results

Graphical results are displayed after completing a MACCS run by selecting an entry from the main menu item *PostProcessing→Graphical Results→Scalar Results* as shown in Figure 4-104. This graph was made by selecting the entry under release, *Plume 1 Kr-85*, clicking *Add* and clicking *Select* to show the data points. In this example, the release duration was made uncertain.

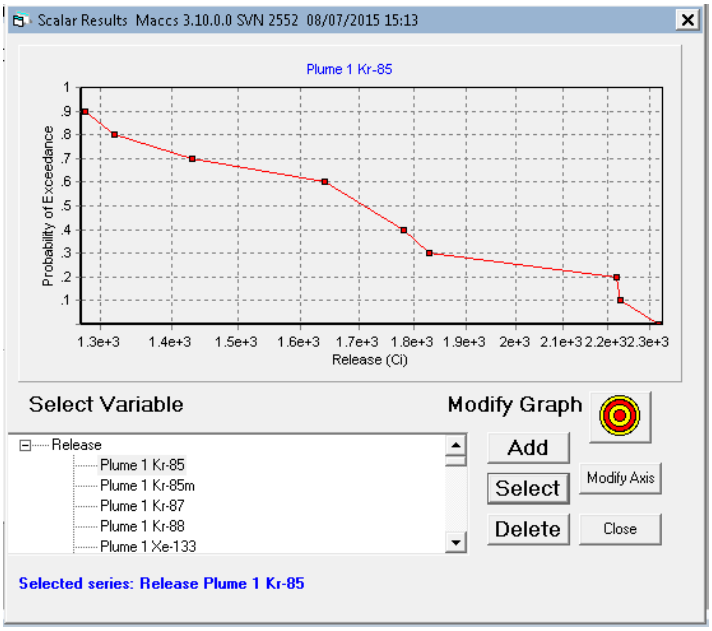


Figure 4-104 *Scalar Results* plot

4.6.3.2 Results Displayed as a Complementary Cumulative Distribution Function (CCDF)

Graphical results are displayed after completing a MACCS run by selecting an entry from the main menu *PostProcessing→Graphical Results→Results over all Weather Trials* from the main menu as shown in Figure 4-105. This graph was made by selecting the entry under *Ground Level Air Concentration*, *Plume 1 Cs-137(25.75, 32.19] km*, and clicking *Add.* In this example, uniform bin sampling from the weather file was used.

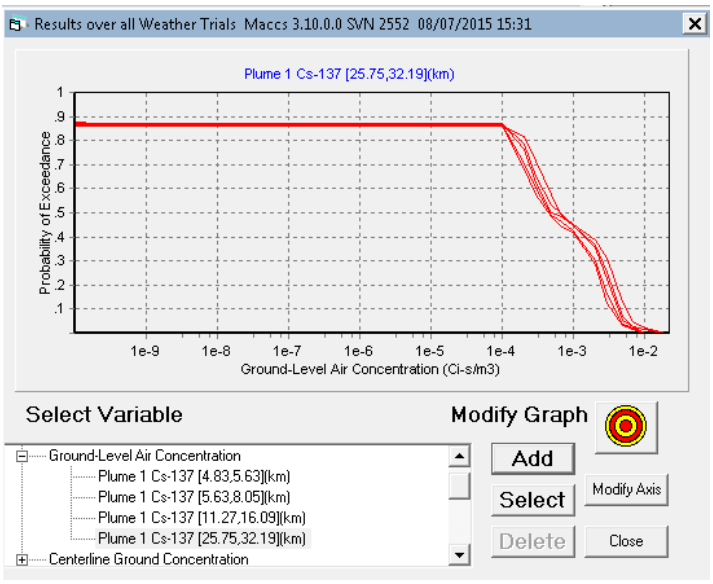


Figure 4-105 *Results over all Weather Trials* plot

Early and Chronc MACCS results from a single execution are often CCDF's or statistics representing uncertainty of the weather during a hypothetical accident. This window displays the CCDF distributions for each MACCS calculation. For example, when five MACCS simulations were run using LHS, there would be five CCDF curves for each result.

Even when not requested by the user, all CCDF results are written to the binary results files *(e.g.,* Model1.bin). In the example shown in Figure 4-106, even though CCDF results for plume one (INDREL) at grid element ten (INDRAD) are not reported in the Model1.txt results files, they are saved in the binary-result files and are available in the plots and reports.

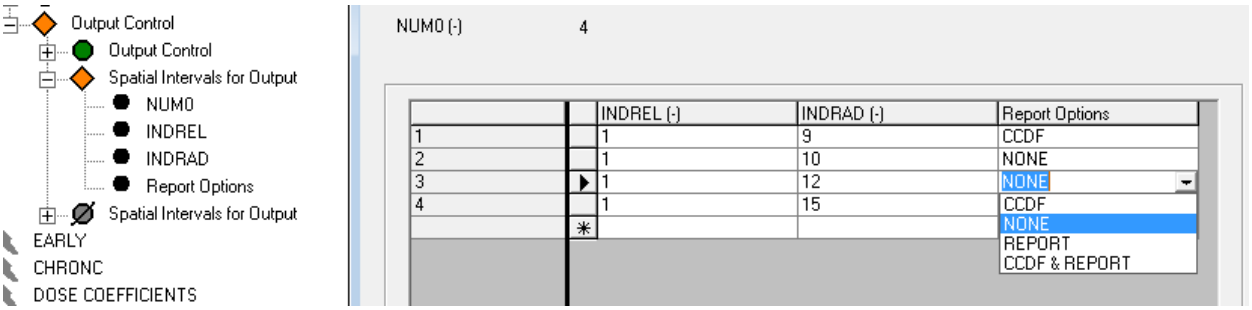


Figure 4-106 Requesting CCDF results in WinMACCS

4.6.3.3 Statistical Summary Results

Graphical results can be displayed after completing a MACCS run by selecting an entry from the main menu *PostProcessing→Graphical Results→Statistical Summary Results* from the main menu as shown in Figure 4-110. This graph was made by selecting the entry under *Ground-Level Air Concentration*, *Plume 1 Cs-137[4.83, 5.63] km*, and clicking *Add.* The mean of the means (over all realizations) is shown on the plot as a vertical green line. The plot is the distribution of the means.

4.6.3.4 Navigation of the Plot window

Multiple plot windows can be opened after simulations have completed as shown in Figure 4-107.

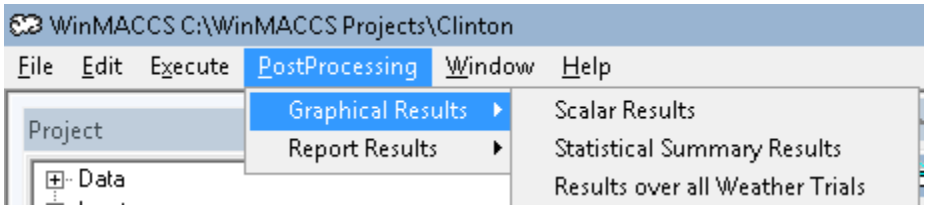


Figure 4-107 Plot windows available

The caption of each plot window contains the MACCS version used in the simulation. The date and time correspond to a date/time stamp written on the first binary output files (e.g., model1.bin) as shown in Figure 4-108.

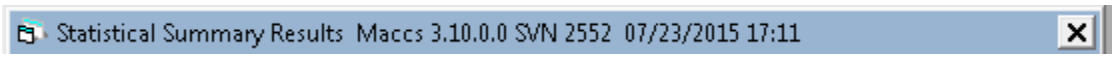


Figure 4-108 Plot window caption

A series can be added to a *Statistical Summary Reports* window by selecting the variable to plot from the *Select Variable* list as shown in Figure 4-109, selecting the desired statistic in the *Statistic* list and clicking *Add* to add it to the existing graph.

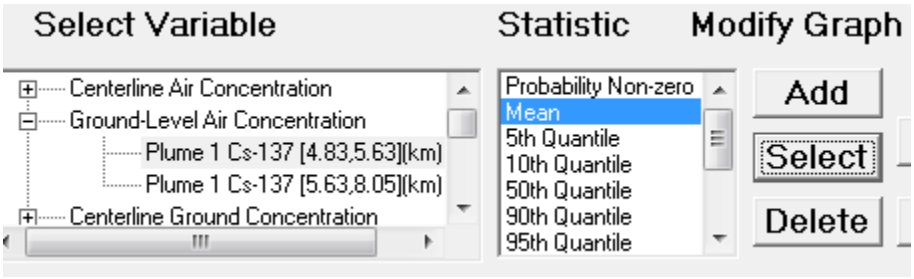


Figure 4-109 Add a Series to a Statistical Summary Reports Window

When the *Mean* is added, notice that the grand mean (average of all means over all simulations) is calculated and displayed on the graph as a vertical line.

A series can be selected by doing any of the following operations:

- Clicking the *Select* button.
- Selecting Select Next Series from the PostProcessing→Graphical Results→Edit Plots menu.
- Clicking on the series on the plot.
- Pressing the Enter key on the keyboard.

After a series is selected the following is true:

- The individual points are marked.
- The details, including the qualifier, indicating the series selected are shown in blue at the bottom of the window.
- The Select Variable list and the Statistic list are selected to entries consistent with the selected series.
- The series is also selected in the legend.
- When the bulls-eye button is pushed in, the data values of the selected series are shown on the plot.

Series are selected in the order they were added. Only one series can be selected at a time.

When the last series added is the selected series and the *Select* is clicked, no series is selected. This feature allows the user to cycle through all the series, unselect all plots, and start the selection again with successive mouse clicks on the *Select* button.

In Figure 4-110, the *Ground-Level Air Concentration for Plume 1, Cs-137* at a spatial distance of 4.83 to 5.63 km for the mean statistic is choosen. Notice that this information is displayed in blue at the bottom of the window. Also notice that the *Grand Mean* is displayed on the plot as a vertical line.

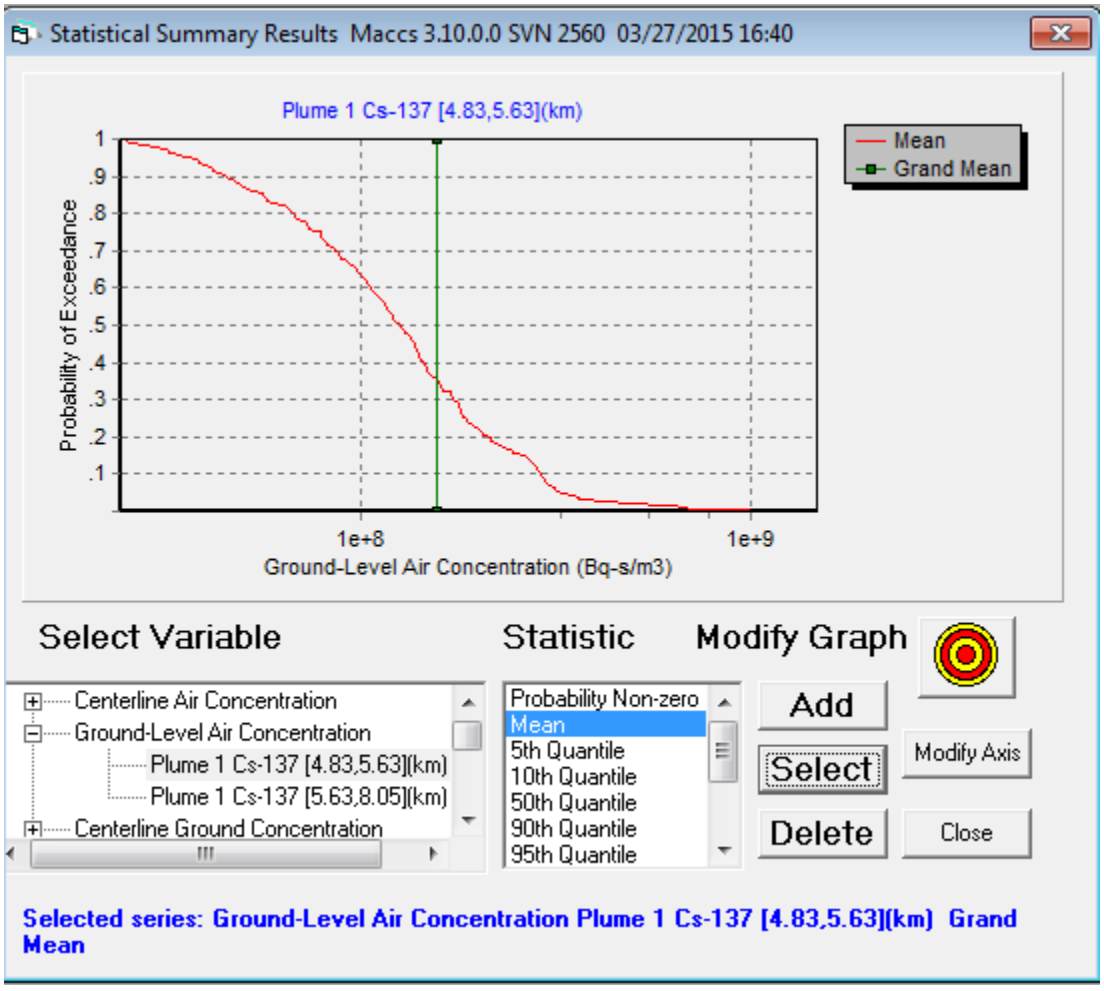


Figure 4-110 *Statistical Summary Results* plot

A series can be deleted by selecting the plot by clicking *Select* until the desired plot is selected, clicking *Delete*. After the series has been selected, it can also be deleted by selecting *Delete Selected Series* from the *PostProcessing→Graphical Results→Edit Plots* menu.

The axis labels or title of a graph can be modified by selecting the *Modify Titles* entry from the *PostProcessing→Graphical Results→Edit Plots* menu. The *Modify Titles* form opens as shown in Figure 4-111. This allows the user to modify the plot and axis titles. Notice that by default the main plot title and the X axis title corresponds to the first plot placed on the graph. Clicking *OK* saves the settings. Clicking *Cancel* discards the changes.

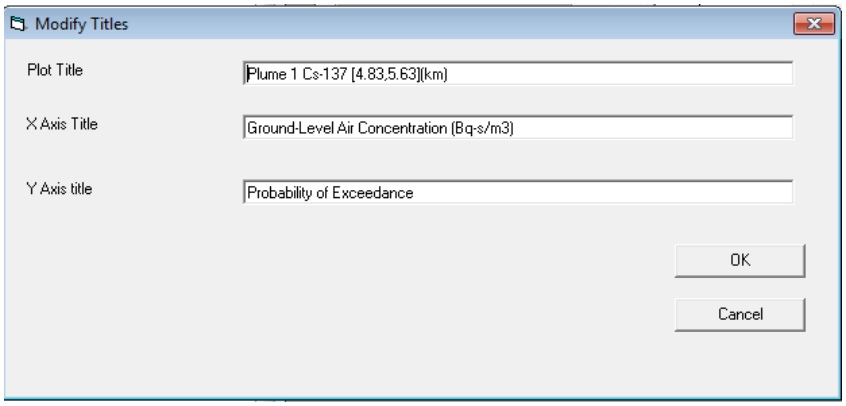


Figure 4-111 Modify plot titles

To zoom in the graphics window hold the left mouse down in the top right corner of the desired area. Drag a rectangle by moving the mouse down and to the right. Release the mouse.

To unzoom, or restore the graphics window to its original scale hold the left mouse down anywhere in the plot. Drag a rectangle by moving up and to the left. Release the mouse.

To show the values in the series select the bulls-eye toggle. When this toggle is pushed in, as shown in Figure 4-112, the associated data points in the selected series are overlayed as coordinate pairs. To view some of the values, it may be necessary to use the zoom feature.

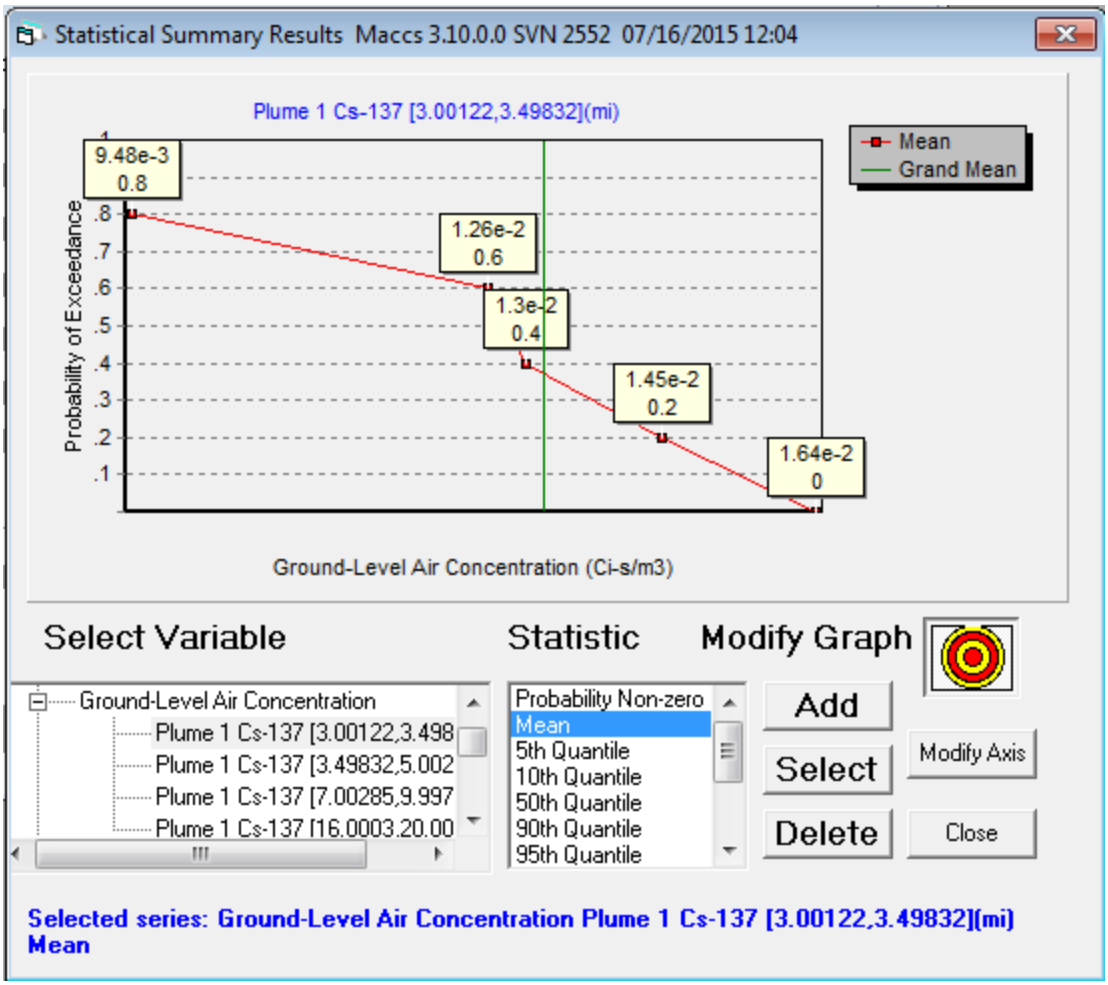


Figure 4-112 Data values as text displayed in a plot window

To modify the plot axis click *Modify Axis* to open the *Modify Axis Bounds* form as shown in Figure 4-113. This allows the user to change the axis limits or switch to a log scale.

The *X* or *Y* axis can be rescaled by:

- Selecting the X or Y toggles. By default, the X axis is selected.
- Selecting the scale of the toggled axis by selecting either *Linear* or *Log*.
- Setting the bounds of the toggled axis to *Automatic* or *Manual*.
- Deciding whether the axis limits are to be determined by WinMACCS by selecting *Automatic* or entered by the user by selecting *Manual*.
- Manually entering the axis limits if the selection was *Manual* in the text boxes labeled *Minimum* and *Maximum*.
- Clicking OK preserves changes. Clicking Cancel discards changes.

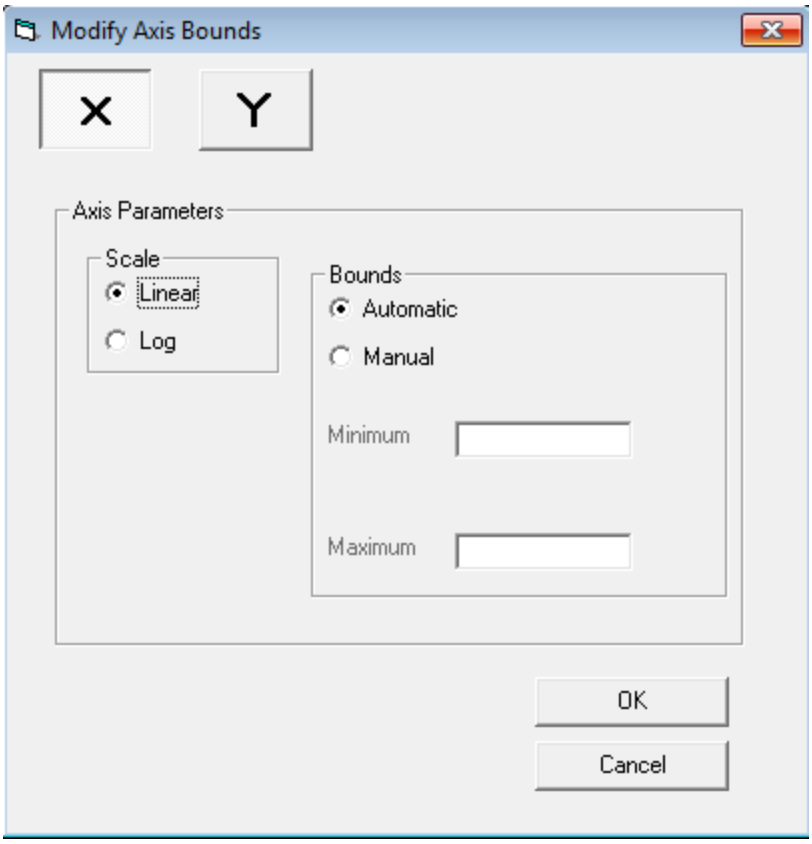


Figure 4-113 Modify axis bounds

The plots can be exported by selecting *Export Plot* from the *PostProcessing→Graphical Results→Edit Plots* menu. A *SaveAs* dialog is opened as shown in Figure 4-114. The following file types are supported:

- Windows bit map (.bmp): A graphical format that integrates into other Microsoft documents such as Microsoft Word, Excel, or WordPad. Files can be edited in Microsoft Paint.
- Jpeg (.jpg): Viewable as a graphic in a web browser or photo editing software. Requires less memory than a .bmp file.
- Text files (.txt): ASCII text that is viewable in a text editor such as Notepad, WordPad, or Microsoft Word.
- XML and HTML: Viewable in a web browser such as Internet Explorer. This file can also be edited in Microsoft Word.
- Excel file (.xls): A document that can be opened with Microsoft Excel. Allows the user to do further data analysis in the graphical and functionally rich environment of Excel.

The result file is saved in the Project\Output folder unless the path is modified in the *Save As* form. Saved files are shown in the *Files* tab of the *Project* window as shown in Figure 4-115. Double-clicking on the exported file in the *Project* window causes the associated application to open that file for viewing.

The file names shown in the *Files* tab of the Project window are updated by selecting *File→Refresh File View* from the main window.

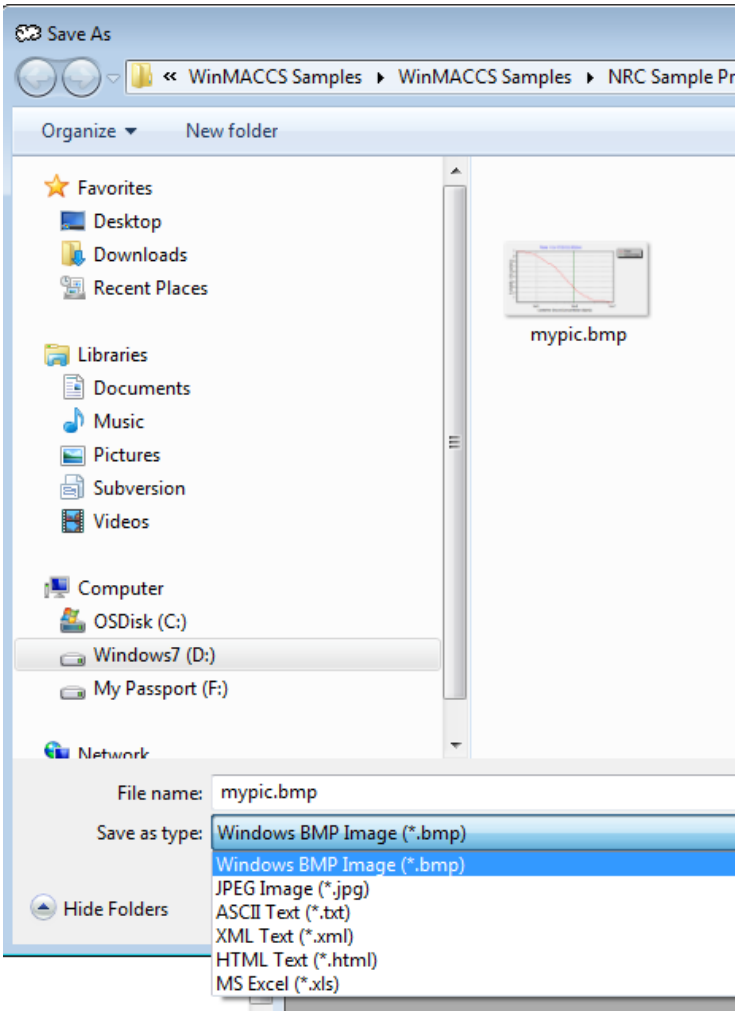


Figure 4-114 Exporting plots

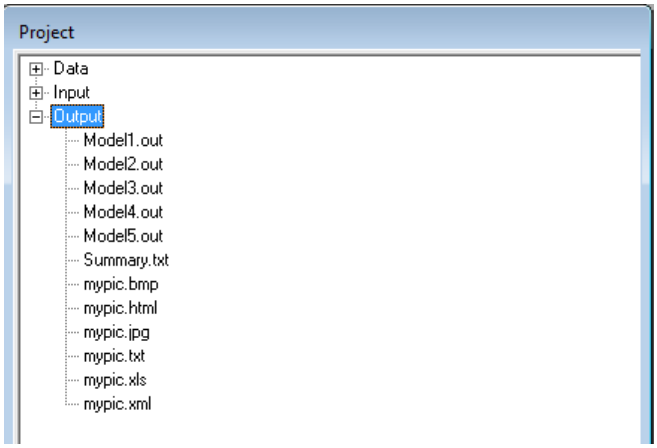


Figure 4-115 Exported plots in *Files* tab of project window

5. TUTORIALS

The following tutorials demonstrate how to modify an existing WinMACCS project and how to convert a legacy MACCS project into a WinMACCS project. Following the tutorials are some guidelines for constructing a new project from scratch, i.e., without the benefit of an existing project.

Tutorial One should be tried by all new users. Tutorial Two will be primarily useful if it is necessary to convert MACCS input files into a WinMACCS project file.

Tutorial One demonstrates how to:

- Open the existing sample project, Point Estimates LNT.
- Save this as a project, sample 1.
- Modify models.
- Run a simulation.
- Modify a deterministic parameter and compare results.
- Change from two to one evacuation scenarios.
- Create uncertain parameters.
- Run an uncertainty calculation.
- View and export results.

Tutorial Two demonstrates how to:

- Import MACCS input files to create a sample WinMACCS project.
- Connect the meteorological file, site data file, dose conversion factor file and COMIDA2 file with the imported project.
- Understand how the import process is reported in the WinMACCS Results window.
- Understand that some modifications to the input are required to run MACCS. In particular, it is necessary to enter chemical group names in ATMOS (variable GRPNAM).

5.1 Tutorial One

What follows is a description of running six samples using sample problem "Point Estimates LNT" as a basis.

Table 5-1 Open WinMACCS project.

User Action	WinMACCS response
Double-click on the WinMACCS icon on the desktop or select *WinMACCS* from the WinMACCS group within the Windows *Start* Menu.	WinMACCS starts and displays menus on the top of the screen. *File* and *Help* are accessible.
Choose File→Open Project. Change directory to C:\WinMACCS Samples\NRC Sample Problems	WinMACCS shows available sample project folders.
Double-click on the *Point Estimates LNT* folder.	Folder opens and shows the project file Point Estimates LNT.mxd.
Double-click on Point Estimates LNT.mxd.	WinMACCS loads the project. All projects will have four directories, \Input, \Data, \Results_DB and \Output. WinMACCS will display a message and will create the missing folder(s) if any of these folders are missing. WinMACCS displays two tabs on the bottom of the *Project* window: *Parameters* and *Files*. Above the tab, WinMACCS displays a list containing the following headings: *GENERAL, ATMOS, EARLY, CHRONC, DOSE COEFFICIENTS* and *COMIDA2.*
Select *File→Save As Project* from the main menu. Change to the directory in the root drive called *WinMACCS Projects*. Type Sample 1 in the Project Name field. Click *OK.*	A new copy of the sample project, Sample 1, is created in the default WinMACCS project directory, WinMACCS Projects. The path shown in the caption of the main WinMACCS window is as follows: C:\WinMACCS Projects\Sample 1
Click on the *Files* tab in the *Project* window.	Above the tab, WinMACCS displays a list containing the following headings: *Data, Input,* and *Output*.

Table 5-2 Viewing parameters.

User action	WinMACCS response
Click on the *Parameters* tab in the *Project* window.	Each + button, when clicked, displays sub-lists until the lowest level is reached. At the lowest levels, black bullets appear next to the names of variables. For example, *METCOD* is one of the variables under *ATMOS/Property Form Parameters*.
Open the *ATMOS* or *EARLY* heading by clicking on the + button. Peruse the different lists by clicking on the + buttons.	 A solid green octagon indicates that all of the variables under that entry are required and have been properly defined.
	 A solid orange diamond indicates that all of the optional variables under that entry have been properly defined.
	 An empty orange diamond indicates that all of the optional variables have not been defined.
	 An X-ed red octagon indicates that must be defined or corrected before proceeding with a MACCS simulation.
	 A X-ed orange diamond indicates that there is an error on this optional form.
	 A solid gray octagon with a diagonal line indicates that the variables are not used in a MACCS simulation because they are not needed under the current choices. This symbol also indicates that all of the variables have been defined.
	 An empty gray octagon with a diagonal line indicates that the variables are not used in a MACCS simulation because they are not needed under the current choices. This symbol also indicates that not all of the variables have been defined.
Choose ATMOS/Property Form Parameters. Double-click on the word METCOD.	The *Property Form Parameters* form opens. At the bottom of the form, the variable type "Integer" and range of values "[1,5]" is shown, as well as a description of the METCOD variable. Values on this form cannot be modified as indicated by the grey background; the values indicate choices made on *GENERAL/Properties/Properties* form.

User action	WinMACCS response
Click inside the other variable boxes in the *Property Form Parameters* window.	Notice that the variable type, range, and description change for each variable.
Close the property form by clicking *OK* or *Cancel*.	Property Form Parameters form closes.
Open the *ATMOS/Deposition* category by clicking on the + button.	Notice that this entry on the *Parameters* tab contains a list of several forms, namely *Wet/Dry Depos Flags*, *Wet Deposition*, and *Dry Deposition*. The category, *Deposition,* contains many forms. The icon next to a category name summarizes the state of those forms.  A solid green octagon means the information under that category is required and has been properly specified. This also means that there are no optional variables in this category. No more user attention is required.
Click on the *ATMOS/Radionuclides* category	Notice that the Pseudostable Radionuclides form is optional.  An orange diamond, empty or solid, indicates that there is at least one optional form in this category.
	 A crossed red octagon means that there are forms in this category containing variables that must be defined or corrected before proceeding with a MACCS simulation.
	 A crossed orange diamond means that there are optional forms in this category that need to be corrected before proceeding with a MACCS simulation.
Click on the *COMIDA2/Model Basis* category	Notice that none of these forms are used in a simulation. This is consistent with the current model settings on the *GENERAL/Properties/Properties* form.  All forms in this category have a grey symbol; hence the category symbol is grey. No user attention is required.

Table 5-3 Changing the main model to early only.

User action	WinMACCS response
Click on the + sign next to *General.* Click the + sign next to *Properties.* Double-click on the solid green octagon next to *Properties.*	The *Project Properties* window opens with tabs showing different model options. The model definition state is displayed in color at each of the tab headings. A solid green octagon indicates that the data have been defined; if there were an empty red octagon on this form, it would indicate that the data were not defined or the data were inconsistent with other choices.
Click on the check box next to the heading *Early Consequences.*	Both check boxes *Early Consequences* (EARLY) and *Late Consequences* (CHRONC) are unchecked. If *Early Consequences* is unchecked, it is not possible to run the *Late Consequences* model. The choice means that only *Atmospheric Dispersion* (ATMOS) will be considered in the simulation.
Click on the tab labeled *Dispersion*	Notice that the *Properties* form is the location where modeling choices are made. When the *Dispersion* tab is clicked the symbols next to the heading prefixes are updated to reflect that Atmospheric Dispersion will be the only main module considered. Only tabs relevant to the ATMOS module, namely *Scope, Dispersion, Weather, and Plume/Source,* have a solid green octagon next to them in this example. The rest of the headings are prefixed with a solid gray octagon containing a diagonal line, indicating the model selections are valid but are not needed.
Click on the *Scope* tab.	Notice that all of the labels within the *Parameters* tab in the *Project* window under the *EARLY* heading continue to have green and orange icons associated with them, even though the *Early Consequences* check box is unchecked.
Click the Show Required Forms button.	The EARLY module is temporarily deactivated. Notice that the symbols within the *Parameters* tab in the *Project* window in the *EARLY* category now have grey octagons associated with them.
Click on the check box next to the heading *Early Consequences*. Click the *OK* button to save the model settings.	By clicking *OK*, the simulation will have ATMOS and EARLY results. The *Project Properties* window closes.

Table 5-4 Run a simulation.

User action	WinMACCS response
Choose *Execute→Run Models…* on the top menu.	The *Run Models* window opens.
Click the button labeled *Advanced…*	The Advanced Execution Parameters window opens.
Uncheck the check box labeled Delete Atmos, Early, Chronc and COMIDA2 input files. Click *OK*	All check boxes should be unchecked. This will insure that all intermediate files will not be deleted.
Click Run Simulation. A message box will be displayed as follows: "Do you want to save the project changes?" Click "Yes" or type the Enter key to save the project changes.	Before running a simulation, the user is prompted to save the changes made to modeling parameters.
A minimized command window will be created. Bring the command window to the foreground to see the progress of the MACCS simulation.	WinMACCS executes the run and shows the steps in the process in the *Results* window at the bottom of the screen (e.g., *"Verifying data are defined*"). Trials listed in the command window refer to calculating results for each weather trial. After the simulation has completed, notice one of the messages written in the Results window is "*Model execution SUCCESSFUL*," indicating that the simulation was successful. If an error had occurred, an error condition would have been reported in the *Results* window.
Close *Run Models* box by clicking on the  .	

Table 5-5 Viewing simulation results.

User action	WinMACCS response
Click on the *Files* tab on the bottom of the *Project* window.	Above the tab, WinMACCS shows a list containing the following headings: *Data, Input,* and *Output*.
Click the + next to *Input.*	Notice that four files have been created as follows: atmosTemplate.txt, earlyTemplate.txt, Atmos1.inp, Early1.inp Atmos1.inp and Early1.inp contain model input parameters to MACCS. The file atmosTemplate.txt is identical to Atmos1.inp because there are no uncertain parameters specified in this project. Similarly, earlyTemplate.txt and Early1.inp are identical. The template files contain placeholders for uncertain values when these are specified.
Double-click on the Atmos1.inp file in the *Input* category.	Atmos1.inp will open up in Notepad. Notice that the creation date of the input file and version of WinMACCS is reported on the first line.
Close Atmos1.inp by clicking on the 	The text editor closes.
Click on the + next to the *Output* category.	Notice that one file is listed as follows: When the model was run, MACCS results were written to Model1.out. File Model1.bin is also present and contains binary results. This is not shown in the WinMACCS interface, but is read by WinMACCS. The information read is saved in the /Results_DB folder and will be used to create custom reports and plots upon request.
Double-click on Model1.out.	Notepad starts and Model1.out opens. Notice that the creation date of the output file and version of MACCS is reported on the first line.

User action	WinMACCS response
Search for the second occurrence of the label *AVERAGE INDIVIDUAL RISK*. Select the row titled *ERL FAT/TOTAL 0.2-0.5 km*. (The early fatality risk considering all radionuclides to the average individual at a spatial range of .2 to .5 km.)	The second number in the row (mean risk) should be 6.20E-06, reflecting a weighted combination of evacuating and non-evacuating cohorts. Values can also be located reflecting evacuation risk for scenario one (0.0) and non-evacuation risk for scenario two (1.24E-03).
Close Model1.out by clicking on the  .	The text editor closes.

Table 5-6 Sample effect of changing a single input parameter.

User action	WinMACCS response
Click on the *Parameters* tab in the *Project* window. Find ATMOS/Release Description/Inventory Scale Factor. Double-click on CORSCA.	Radionuclide Inventory Scaling Factor window opens.
Modify the value of *CORSCA* from 1.0 to 2.0. Click *OK*.	Radionuclide Inventory Scaling Factor window closes.
Choose *Execute→Run Models* on the top menu. Click Run Simulation. Wait until the simulation has completed.	WinMACCS executes run with the changed input. In the Results window the text "*Model execution SUCCESSFUL*," is displayed indicating that the simulations were successful.
Open the file Model1.out found in the Output category. Search for the second occurrence of the label *AVERAGE INDIVIDUAL RISK*. Select the row titled *ERL FAT/TOTAL 0.2-0.5 km.*	The mean of *AVERAGE INDIVIDUAL RISK ERL FAT/TOTAL 0.2-0.5* km from all causes should be larger than before (i.e., 6.50E-05 as compared with 6.20E-06).
Close Model1.out.	The text editor closes.

Table 5-7 Changing parameters from deterministic to uncertain.

User action	WinMACCS response
Click on the *Parameters* tab. Open the category *EARLY/Additional Emergency Cohorts* by clicking on the +. Select *Edit→Project Properties* from the main window. Click the *Evac/Rotation* tab Change the *Number of Cohorts* from 2 to 1. Click *OK*	*EARLY/Additional Emergency Cohorts* graphic is now grey. This means that there is only one evacuation scenario to be considered.
Open the parameter modification form that contains the variable WTFRAC by selecting *Edit→Find Parameter Window…* From the main menu. Scroll down to *WTFRAC* using the scroll bar. Click on *WTFRAC*. Click *OK* Change the value of variable WTFRAC to 1. Click *OK*.	Variable WTNAM has the value PEOPLE. This means that the population fraction, WTFRAC, is considered for each cohort (defined on the *Edit→Project Properties, Site Data* tab). The previous run had two evacuation cohorts. The value of WTFRAC associated with cohort 1, 0.995, meant that 99.5% of the people would evacuate according to the parameters specific to cohort one. The value of WTFRAC associated with scenario 2, no evacuation, was set to 0.005 (defined on the *EARLY/Additional Emergency Cohorts/Emergency Cohort Two/Basic Parameters* form). Because all values of WTFRAC must sum to one, WTFRAC needed to be set to 1.
Using the *Edit→Find Parameter Window* open the form associated with variable ESPEED.	Variable ESPEED is displayed in a grid. There are three rows shown corresponding to the Initial, Middle and Late evacuation phases for cohort one. Notice that the tree displayed on the *Parameters* tab is expanded and the variables on the form, *Phase Durations and Evacuee Travel Speeds for Cohort One*, are listed in the Project window in the category *EARLY/Emergency Cohort One/Phase Durations and Speeds*

User action	WinMACCS response
Double click the text box associated with ESPEED in row number one or click that text box and click the *Make Uncertain* button.	A dialog will open with a caption as follows: *ESPEED(1)* . A pull-down menu of distribution types next to the label *Distribution* is shown with *Constant* indicated. Note: to change a distribution from uncertain to deterministic, open the distribution window and change the distribution to *Constant.* It is not possible to type in a constant in a box on a parameter modification form that has been set to be uncertain.
Click on the down arrow and select *Uniform.* Enter 0.9 in the text box labeled *Lower Limit*. Enter 3.6 in the text box labeled *Upper Limit*. Click *OK*	The uncertain value has been associated with variable ESPEED(1). The background of the text box associated with ESPEED(1) is shaded and contains the text *UNCERTAIN.*
Set ESPEED(2) and ESPEED(3) to a Uniform distribution using the same parameters used for ESPEED(1). Click OK in the Phase Durations and Evacuee Travel Speeds for Cohort One window.	Only when *OK* is clicked in the main parameter modification form (e.g., *Evacuee Travel Speed for Scenario One)* will the uncertain values be saved.
Set variable SCLADP to a UNIFORM distribution where the Lower Limit is 0.5 and the Upper Limit is 1.5.	The background of the text for variable SCLADP on the form *Plume Rise Data* is shaded and contains the text *Uncertain*.
Choose *File→SaveAs Project*. Change directory to WinMACCS Projects Specify "*sample 1 uncertain"* for the Project name.	WinMACCS creates a new project, *sample 1 uncertain.*
Choose *Execute→Run Models* Click on the button *Advanced…* Type 3 in the box labeled *Number of Simulations* Click the *OK* button	Number of samples (or number of MACCS simulations) is now three.

User action	WinMACCS response
Click the *Run Simulation* button Click *Yes* when prompted to save the project	MACCS will run three times, creating three results files, model1.out, model2.out and model3.out.
Click on the *Files* tab on the bottom of the *Project* window.	Above the tab, WinMACCS shows a list containing the following headings: *Data, Input,* and *Output*.
Click the + next to *Input.*	WinMACCS created MACCS input files *Atmos1.inp, Early1.inp, Atmos2.inp, Early2.inp, Atmos3.inp, Early3.inp,* one set of files for each realization from LHS using the data in LHS.out.
Double-click on the input file for Latin Hypercube Sampling, LHS.inp.	LHS.inp, a file created by WinMACCS, contains a summary of uncertain variables and their distributions. The Latin Hypercube Sampling program, LHS, is run with input as reported in this file: ESPEED(1) UNIFORM 0.9 3.6 ESPEED(2) UNIFORM 0.9 3.6 ESPEED(3) UNIFORM 0.9 3.6 SCLADP UNIFORM 0.5 1.5
Open the file in the Input folder created by Latin Hypercube Sampling, LHS.out.	A list of mean values for each variable and the sampled values are shown.
Close LHS.inp and LHS.out	The text editors close.
Click on the + next to *Output.*	Model1.out, Model2.out and Model3.out are displayed.

User action	WinMACCS response
Choose *PostProcessing→Report Results→Manage Custom Reports* Click on the radio button labeled *Combine Realizations.* Click on the button *New.* Click on the column labeled *Include* for the first two entries labeled *Spatial Intervals for Output*. Click on the column labeled *Include* for all of the entries where the *Report Description* column is labeled *Population Dose*. There are three entries. Enter report name Atmos Summary and Population Dose. Click *OK* to close the *Custom Combined Report* form.	Define a new custom report. A copy of the MACCS output requests created by WinMACCS are shown in the grid. These entries are found in the MACCS input files.
Click the *Select* check box to choose the report Atmos Summary and Population Dose. Select the radio button labeled *View.* Click the *Apply* button.	Report defined in the previous step is created and opened in the Notepad text editor.
In the report, scroll down to *Request 3 Population Dose*	Notice that the columns labeled *Probability of Exceedence* are based on quantiles specified on the form *GENERAL/Output Options/Reporting Options* found on the *Parameters* tab. The reported data is based on binned CCDF tables. Variation of values for any given LHS simulation is due to weather sampling. These CCDF tables can be viewed in the MACCS output when the Report Option variable is set to CCDF or CCDF & REPORT for the Output Control form of interest (e.g., *EARLY/Ouput Control/Population Dose*). Notice the following message is displayed for request 3: Unable to transform CCDF No differences in probability values in CCDF. This is because the population dose was zero from 0 to 16.09 km and did not change for the set of weather trials.

User action	WinMACCS response
In the report, scroll down to the entry labeled *Request 4 Population Dose.*	The Population Dose corresponding to combining the LHS realizations is shown as follows: Evacuation Evac # 1 L-ICRP60ED [0.E+00,80.47](km) Grand Mean Population Dose (Sv) 1.36E+03 Note: The custom reports can be used to report overall statistics when multiple realizations are being calculated with sampled variables. However, it can also be used to conveniently calculate additional quantile information using the binned CCDF results from MACCS.
Close report.	The text editor closes. The report, Atmos Summary and Population Dose.txt, can also be opened by double clicking on this named entry *Output* category found on the Files tab. Note: It is possible to summarize the output without combining the data from the realizations. When creating a new report, select the radio button labeled *Realization Based* on the *Manage Reports* form instead of the *Combine Realizations* button.
Double-click on *General/Output Options/Reporting Options* on the *Parameters* tab to open the *Reporting Options* form.	A form labeled *Reporting Options* opens.
Clear all old entries by clicking the erasor icon. Enter the following quantiles: 0.01, 0.25, 0.50, 0.75, 0.99 Click OK.	Note: Rows can be deleted in a grid by selecting the row and pressing the Delete key on the keyboard. New rows can be added to the grid by clicking on the text in a row and selecting *Edit →Grid →Insert Rows* A new row can be added to the bottom of the grid by typing in the text area of the last row.

User action	WinMACCS response
Create a new summary report by selecting *PostProcessing→Report Results→Manage Custom Reports*. Click the *Select* check box to choose the report Atmos Summary and Population Dose. Select the radio button labeled *View.* Click the *Apply* button.	Data corresponding to user chosen quantiles are calculated by interpolating values from the binned CCDF's that MACCS calculates.

Table 5-8 Viewing results as plots.

User action	WinMACCS response
Choose *PostProcessing→Graphical Results→Results over all Weather Trials*.	A *Results Over All Weather Trials* window opens with the version of MACCS used in the simulation displayed in the Window caption.
Click the + next to *Centerline Ground Concentration* Click on *Plume 1 CS-137[5.63, 8.05] (km)* Click on *Add*.	Result is placed on chart. There is a single plot corresponding to each of the three simulations.
Click *Modify Axis*.	The *Modify Axis Bounds* window opens with options for *X*- and *Y*-axis and their bounds. In addition, the user may choose a linear or a logarithmic scale for *X* and *Y*. The minimum and maximum values must be specified for the logarithmic scale; the linear scale can either be automatically set or manually set by the user.
Click *Cancel* in the *Modify Axis Bounds* window.	The *Modify Axis Bounds* window closes.
Select *PostProcessing→Graphical Results→Edit Plots→Modify Titles*. Close the *Modify Titles* window by clicking the *Cancel* button.	The plot title and axis labels can be modified.
Click the *Select* button on the plot window three times.	The data points representing the complementary cumulative distribution function (CCDF) are shown. Notice that the sample numbers, LHS1, LHS2 and finally LHS3 are shown. The bottom of the plot window displays details describing the selected plot series in blue lettering.
Click the *Select* button again.	The plot is now in an unselected state. Notice that the bottom of the plot window displays the words "Selected Series: NONE."
Click the *Bulls-eye* button. 	The plotted values are now displayed as text. Click and drag to draw a rectangle from upper left corner to lower right to zoom in on the plot. Click and drag from lower right to upper left to un-zoom.

User action	WinMACCS response
Click the *Bulls-eye* button again.	The text values are no longer displayed.
Select *PostProcessing→Graphical Results→Edit Plots→Export Plot*.	A *Save As* window appears. Notice the different file formats available, including JPEG image, MS Excel, and ASCII text.
Enter "MyData" in the text box labeled *File Name*. Select Windows BMP Image (*.bmp) in the Save as Type pull-down menu. Type the name of the file, MyData. Do not type an extension.	WinMACCS saves the data as a .bmp file called *MyData.bmp* into the \WinMACCS Projects\sample 1 uncertain\Output directory. This file can be opened in MS Paint.
Double-click on file MyData.bmp in the *Output* directory found under the *Files* tab in WinMACCS.	The .bmp file opens in the associated application, usually MS Paint.

5.2 Tutorial Two

What follows is a description of how to import a MACCS input set into WinMACCS. This is necessary when there are MACCS input files that have been used outside of the WinMACCS environment.

Table 5-9 Create a new project based on a MACCS input set.

User action	WinMACCS response
Double-click on the WinMACCS icon on the desktop or select *WinMACCS* from the WinMACCS group from the Windows *Start* Menu.	WinMACCS starts and displays pull-down menus on the top of the screen. *File* and *Help* are accessible.
Choose *File→Open Project* Open file Point Estimates LNT.mxd found in directory C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT	Sample project *Point Estimates LNT* is opened. Path is displayed in caption of main window C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT
Choose *Execute→Run Models* From the main menu	The run models window is open
Click the button labeled *Advanced…*	The Advanced Execution Parameters window opens.
Uncheck the check box labeled *Delete Atmos, Early, Chronc and COMIDA2 input files*. Click *OK*	All check boxes should be unchecked. This will insure that all intermediate files will not be deleted. The MACCS input files were created in the previous exercise, but were deleted because the box labeled *Delete Atmos, Early, Chronc and COMIDA2 input files* was checked.
Click *Run Simulation*. Click *No* when asked when you want to save the project changes	WinMACCS creates input files every time the *Run Simulation* button is checked. A simulation is run.
Choose *File→Close Project* When prompted *Do you want to save the project changes?* click *No*	Sample problem will be closed. MACCS input files will be used in this exercise. The following MACCS input files have been created. These files are in the project directory. Maccs.tmp \Input\Atmos1.inp \Input\Early1.inp \Input\Chronc1.inp

User action	WinMACCS response
Open an ASCII text editor such as Windows Notepad. Open the file *C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT\Maccs.tmp* in the editor.	Some of the files used by the MACCS simulation are listed. This file is read by MACCS. The full path is referenced, but only the file name are indicated below. These are as follows: Line 1: ATMOS input file Atmos1.inp Line2: EARLY input file Early1.inp Line 3: CHRONC input file Chronc1.inp Line 4: Meteorological data file, metsurMxHt_60min.inp Line 5: Site data file FicticiousSite.inp Line 5: Output data file, specified name of results file written by MACCS Model1.out The file Early1.inp contains the name of the DCF file on line labeled DCF_FILE001 as follows: Data\Fgr13dcf.inp Chronc1.inp contains the name of the COMIDA2 binary file on line labeled BIN_FILE001 Data\fgr13samp_a.bin
Close the ASCII text editor.	The text editor closes.
Choose *File→New Project*. Navigate to the folder *WinMACCS Projects*. Enter the name *Sample 2* in the *Project Name* field. Click *OK*.	A new project is created. The *Project Properties* form is opened. This form is used to select the appropriate models for the simulation. Notice that only the ATMOS model is checked. This is the default setting for new projects.
Click the *Cancel* button in the form titled *Project Properties.*	It is not necessary to select models when importing MACCS input files such as Atmos1.inp. WinMACCS will define the radio buttons and check boxes in the Project Properties form dependent on the values in the imported files

Table 5-10 Import Atmos1.inp, Early1.inp and Chronc1.inp.

User action	WinMACCS response
On the *Parameters* tab of the *Project* window, click the plus sign, +, to the left of the headings GENERAL, ATMOS, EARLY and CHRONC.	Notice the crossed red octagons next to categories of data in the GENERAL and ATMOS categories indicating that data are required but are not yet defined. Notice the filled in green octagon next to the heading *Property Form Parameters*. These are variables that are defined and can be changed only by using the *Project Properties* form. These are set to default model settings. Notice the slashed grey octagons in the EARLY and CHRONC categories. These data are not required because *Early Consequences* and *Late Consequences* have not been checked on the *Project Properties* form.
Select File→Import MACCS Input File from the main menu. Select the ATMOS input file titled Atmos1.inp in the directory *C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT\Input* Click Open.	The file Atmos1.inp is read by WinMACCS. The data in this file is loaded into the interface. The progress of processing this file can be seen in the WinMACCS *Results* window. The ATMOS crossed red octagons have turned into solid green octagons, indicating that the data on these forms are now defined. The EARLY model is now on. This is because a variable, ENDAT1, in the file Atmos1.inp, was set to .FALSE. indicating that the EARLY model should be executed.
Observe stage one of the import process. Expand the *Results* window by moving the mouse to the Title bar on that window. When the mouse pointer turns to a double sided arrow, hold the left mouse button down while dragging towards the main window caption. Release the mouse button to resize the window. Models are normally turned on or off in WinMACCS using the *Project Properties* form. This is done automatically when reading in a MACCS file.	The first line shown in the Results window indicates the name of the file that is being imported is as follows: *Importing MACCS input file C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT\Input\Atmos1.inp* The next line shows that the file is being read to determine which models are turned on in WinMACCS. *Processing input lines that define models* The next set of lines report which lines of Atmos1.inp are used to determine the model settings.

User action	WinMACCS response
The models that are set in WinMACCS can be viewed or changed on the Properties form that can be opened by selecting *Edit→Project Properties* from the main menu. Open the form Project Properties Click on the *Dispersion* tab	This tutorial will not go through all the logic used to define WinMACCS model settings from the MACCS input files. However, dispersion is offered as a single example to increase understanding of this process. Some project property settings defined on the *Project Properties* form are translated into variable values. These variable values can be observed by opening the forms ATMOS/Property Form Parameters EARLY/Property Form Parameters CHRONC/Property Form Parameters Notice that the dispersion model is set to *Lookup Tables* in the Project Properties form. When the MACCS variable NUM_DIST is equal to zero in the imported file, the dispersion model is set to *Power Law Functions (NUM_DIST=0)* Often, there is a direct correspondence between a model setting and the value of a MACCS imported variable (e.g., NUM_DIST). In these cases, the value of the MACCS input variable will be part of the model label shown on the *Project Properties* form.
Open the file Atmos1.inp in an ASCII text editor such as Notepad. Search for the character string NUM_DIST001 Notice that the value is set to 50	Recall, the MACCS input file Atmos1.inp can be found in the following folder: *C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT\Input* The input lines that are used to define the models are shown in the *Results* window, e.g., *Saving MACCS Data for input line: NUM_DIST* Setting this value to a nonzero quantity indicates that the source of the dispersion data is the form *ATMOS/Dispersion/Dispersion Table.*

User action	WinMACCS response
Observe stage two of the import process. The variables relevant to the updated model settings are extracted from the file. Lines are processed until a period in column one is encountered. This is considered the end of the data to be imported in stage two.	In the second stage, only the data relevant to the current model settings are extracted. The file is read for the second time. Example output in the *Results* window from the second pass is: *Processing input lines for file section 1* *Saving MACCS Data for input line: RIATNAM1*
Observe stage three of the import process. In the last step in the import process, WinMACCS looks for multiple cohort data. When other cohorts (I.e., change card sets) are present, they will be separated by a period in column one. EARLY model input sets created by WinMACCS may contain up to twenty cohorts to support multiple evacuation scenarios.	There was no additional scenario data present. Example output from stage three is as follows: *Processing input lines for file section 2* *No data to import for file section 2* *WARNING - Check the Properties form for model settings.* *When importing older MACCS input files, some models are not specified.* This concludes the import of the ATMOS input file.
Repeat the import process, and import the file Early1.inp and Chronc1.inp.	Notice that two evacuation cohorts were defined in the Early1.inp file. WinMACCS properly processes this and sets the variables accordingly.

Table 5-11 Define additional forms.

User action	WinMACCS response
Click on the *Parameters* tab of the *Project* Window. Click on the plus sign, +, next to the label GENERAL	Notice that the File Specification category has an associated icon as follows:  This indicates that attention is needed.
Click the plus sign, +, to the left of the heading *GENERAL\Properties*. Double click on the form name *Problem Description*. Enter some text in the box Click *OK.*	Notice that the form *Problem Description* is an optional form, as indicated by the diamond shaped icon:  After the file is defined, the diamond becomes filled. The text entered will become comments in the MACCS input files.
Click the plus sign, +, to the left of the heading *GENERAL\File Specifications*. Double click on the form name *Meteorological File*.	Notice that all file specifications for the project are listed in the category *File Specifications.* The form titled *Specify Meteorological File* is opened.
Click on the button labeled *Browse*. Locate file titled metsurMxHt_60min.inp A copy of this file is in *C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT\Data* Click *OK.*	A copy of this file will be made and placed in the current projects \Data directory. Recall that the name of this file was referenced in the file Maccs.tmp
Define the site file by double clicking on the form name *GENERAL/File Specifications/Site File*. Click on the *Browse* button to find the file FicticiousSite.inp in the directory *C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT\Data* Click *OK*.	Notice that the number of angular directions shown in 16. WinMACCS opens and reads FicticiousSite.inp to determine this. When the user needs to change the number of angular directions on the evacuation grid on an existing site file, the *Create New* button can be used to create a new site file based on the older site file. It is preferable to create a new site file using the program SecPOP. A copy of this file will be made and placed in the current projects /Data directory.

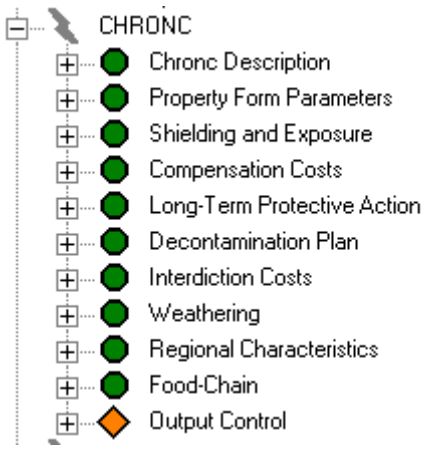
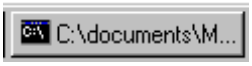
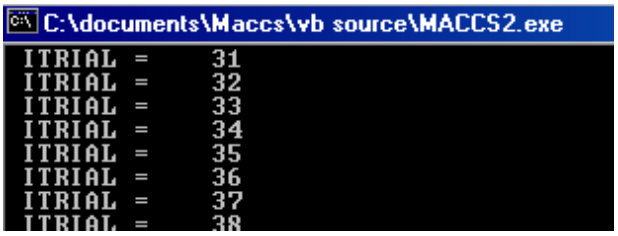
User action	WinMACCS response
Answer *Yes* to the following questions shown in the message box: *Do you want to update the spatial grid to be consistent with the site file?*	This updates the values of variable SPAEND. SPAEND and the site file should be consistent. NUMCOR will be updated to be consistent with the number of angular directions specified on the site file independent of the answer given in the message box. Recall that the name of this file was referenced in the file Maccs.tmp
Open the form *Dose Conversion Factor File*. Specify the file Fgr13dcf.inp in the directory *C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT\Data* Click *OK*.	A copy of this file will be made and placed in the current projects /Data directory. The name of this file can be found in the file Early1.inp on the line containing the keyword DCF_FILE001. The data files can be opened by clicking on the *Files* tab of the *Project* window, clicking on the + next to the word *Data,* clicking on the variable of interest (e.g., Site File), and double clicking on the file name.
Open the form *COMIDA2 File*. Specify the file `fgr13samp_a.bin` in the directory *C:\WinMACCS Samples\NRC Sample Problems\Point Estimates LNT\Data* Click *OK*.	A copy of this file will be made and placed in the current projects /Data directory. The name of this file can be found in the file Chronc1.inp on the line containing the keyword: `BIN_FILE001` MACCS requires that this binary file was created using the specified DCF file (in this example Fgr13dcf.inp) using the COMIDA2 preprocessor.
Click the plus sign, +, to the left of the heading CHRONC.	Notice there are no errors. Interface should appear as follows: 

Table 5-12 Execute new project.

User action	MACCS response
Select *Execute→Run Models* from the main menu. Click on the *Run Simulation* button on the *Run Models* form. Click on the entry on the task bar: 	The progress is displayed in the command prompt window.  Successful execution can be verified by observing that the *Results* window contains the following: *Running model as follows:* *"C:\Program Files\WinMaccs\MACCS.exe" -i "C:\WinMACCS Projects\Sample 2\Maccs.tmp" -p "Model1"* *Model execution SUCCESSFUL* *OK* *Run Completed*

The following are a few guidelines for creating a new project from scratch:

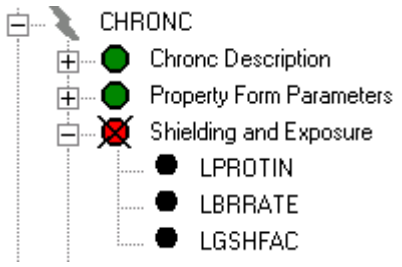
- When a new project is created by selecting *File→New Project* from the main menu, the WinMACCS *Properties* form is opened. The settings on this form should be reviewed and changed as needed. After this has been reviewed, click *OK* to save the settings. These settings determine which subsequent forms are required, not required, and are optional.
- Starting at the top of the *Parameters* tab, fill in the required forms in order. There are six main models listed, namely GENERAL, ATMOS, EARLY, CHRONC, DOSE COEFFICIENTS and COMIDA2. Each contains many forms, however only the data in the required forms will be used. A form is not required when the icon to the left of the form name is a grey octagon with diagonal line. Forms with orange diamond shaped icons are optional. The *Project Properties* form can be modified at will. It is not required that the forms be filled out in order, but it may be helpful because information on some forms is required before other forms can be completed. Filling out the forms in order avoids any conflicts.
- When the X-ed red octagons have been converted to solid green octagons, select *Execute→Run Models* from the main menu. Click on *Run Simulation* to run. Look in the *Results* window to verify that the execution was successful. The output files from the execution can be opened by double clicking on the file names on the *Files* tab.

- It may be easier to debug the input when only the ATMOS model is enabled the first time MACCS is executed. After ATMOS is running successfully, change the main model to include EARLY on the *Properties* form. When needed, continue with CHRONC and COMIDA2 as each set of model input is debugged.

The following are a few guidelines for importing a project from MACCS input files:

- When importing MACCS input files, the improved Briggs model will always be used unless *Original MACCS 1.12 Briggs Model* is manually checked on the *Plume Rise* tab of the *Project Properties* form. To compare results to MACCS 1.12, it is necessary for the plume rise model to be consistent.
- ATMOS input for MACCS 1.12 supported multiple source terms using change card sets. This is not supported in WinMACCS for ATMOS. Any additional change card sets in an imported card set will be considered to be related to additional evacuation cohorts only. However, multiple source terms can be modeled by using the MACCS Cyclical File Set feature found on the *Scope* tab of the *Project Properties* form. Multiple Source terms can also be modeled by selecting the *Multi Source Term* check box on the *Plume/Source* tab. This process requires input files in a format compatible with MelMACCS version 1.7.3 (or greater) output files.
- When importing an ATMOS input deck created using MACCS 1.12, it will be necessary to manually define the chemical group names, GRPNAM.
- Before importing an EARLY input file, when the DCF file used is not based on Federal Guidance Report FGR-13, it is necessary to manually specify this on the *Dose* tab of the *Project Properties* form. For example, when the DCF file was created by the preprocessor DOSFAC2, the form EARLY/Model Basis/Organs of Risk DOSFAC2 is required. Similarly, the form EARLY/Model Basis/Organs of Risk FGR-13 is required when the DCF file was created from FGR-13 data. Neither form is required when the DCF file is of type FGRDCF (based on FGR-11 and FGR-12).
- When importing an EARLY input file, the number of evacuation cohorts are not decreased from the number specified on the Project Properties tab. However, the number may be increased when more cohorts are specified than is defined on the Project Properties tab. This can be manually changed by using the *Evac/Rotation* tab of the *Project Properties* form. This is by design because of considerations with respect to the MACCS Cyclical File Set option that uses the same import algorithms.
- When importing a CHRONC input deck created using MACCS 1.12, the CHRONC/*Shielding and Exposure* form is not defined. A reasonable value to use is the value used for the *Shielding and Exposure* variables defined for Normal behavior in Early as shown in Table 5-13..

Table 5-13 Defining CHRONC shielding and exposure.

User action	WinMACCS response
Click on the + next to the headings GENERAL, EARLY and CHRONC when these headings are not already open. Double click on the form name *Shielding and Exposure* in CHRONC. 	Notice that the CHRONC variables LPROTIN, LBRRATE and LGSHFAC are not defined. These are new variables that do not have images in the imported file.
Open the form EARLY/Emergency Scenario One/ Shielding and Exposure Enter the related data in the row labeled *Normal* into the *CHRONC/Shielding and Exposure* form.	Adding these CHRONC variables ensures that consistent values are independent of the EARLY evacuation scenarios. Before this modification, MACCS used the values used during the last EARLY evacuation scenario for the CHRONC calculation. It was not clear to the user which values were used, so these variables were added to CHRONC.

6. SITE FILE FORMAT

6.1 Format Overview

In the site file, the user specifies the population distribution and land use information for the region surrounding the site. Contained in the site file are the geometry data used for the site (spatial intervals), population distribution, fraction of the area that is land, watershed data for the liquid pathways model, information on agricultural land use and growing seasons, and regional economic information. An example of a site file is provided in NUREG/CR-4691, Volume 1, Appendix D.2.

The user specifies on the *Site Data* tab on *Properties* form whether a Site Data file is to be used. When a Site Data file is not being used, the population density applied in the EARLY and CHRONC modules are specified on the *EARLY/Model Basis/Population Data* form.

The site file used in MACCS is a fixed formatted file. The data must appear exactly as described below and in exactly the same order.

The use of fixed format requires that the user exercise special attention to line up the data items in their proper fields. Any numeric items specified in exponential format (*e.g.,* 1.E-) must be right-justified in the field because trailing blanks are processed as zeros. To prevent errors due to right justification of data, it is recommended that a decimal point is used, and the exponential portion of the field is indicated using the letter E as in 1.E-6. When this recommendation is followed, the number to the right of the FORTRAN format descriptor (e.g., the 2 in F8.2 or E8.2) is ignored and only the field length is considered (e.g., the 8 in F8.2).

The FORTRAN fixed field input rules for an edit descriptor Fw.d or Ew.d are as follows. The input field consists of an optional sign, followed by a string of digits optionally containing a decimal point. When the decimal point is omitted, the rightmost d digits of the string are interpreted as the fractional part of the value represented. This is why it is critical not to omit the decimal point. The basic form may be followed by an exponent of one of the following forms:

1. Signed integer constant (e.g., 1.-6 means 1.E-6)

2. E followed by zero or more blanks followed by an optionally signed integer constant.

It is recommended that SECPOP be used to construct the site data file. When it is necessary to edit this file, or create a site file from scratch, it is recommended that the user exercise care in constructing the file. It is very important that all items appear in their proper fields and that all numeric values lie within the range of acceptable values. Failure to conform to these requirements may lead to the generation of spurious results. This is because the validation performed on the site data is only partially complete in MACCS.

The first two records of the site data file contain identification information. This header information is printed on the output listing.

When using SECPOP to create the site file, quality assurance information is written to the first two lines to include the version identification of SECPOP and parameter settings used to create the site data file. For example, the first two lines in the sample site file distributed with WinMACCS are as follows:

SECPOP Version: 4.3.0 SVN:2242 FileType: MACCS_Site Project: "Fictitious" Census: "C:\Program Files (x86)\SecPop\Census\Census2010.bin" County: "C:\Program Files (x86)\SecPop\Census\County2012.dat"

Lat: 36d11'35" Long: 115d58'55" Latitude: 36.193058 Longitude: 115.98194 Population_multiplier: 1.0 Economic_multiplier: 1.0 Run_Time: 2016/02/04_12:28:56

Following the descriptive text fields, there are six data records that specify the amount of data that is being supplied on the file. The values defined on these data records must be consistent with values defined in WinMACCS. The data are input as integers in FORTRAN (I4) format. The integers must be right justified in the four character long input field.

Some of the variables defined in the site file must agree with variables defined in WinMACCS. However, when the variable is not required by WinMACCS, agreement is not required. For example, when the CHRONC model is not selected, variables such as NFICRP, NUMWPI are not required to be defined in WinMACCS. When the MACCS Food Model is not selected, the CROP variable will not be defined in WinMACCS. However, variables listed in Table 6-1 are required to be defined in the site file even though they may not be used in calculations.

Table 6-1 Basic site file parameters.

Line in site file	Columns	FORTRAN format	Variable name	*Allowed values*	*Description*	Example line from FicticiousSite.inp
3	1 to 4	I4	NUMRAD	2 to 35 Must agree with WinMACCS variable NUMRAD	Number of radial spatial intervals.	26 SPATIAL INTERVALS
4	1 to 4	I4	NUMCOR	16, 32, 48 or 64 Must agree with WinMACCS variable NUMCOR.	Number of sectors in the spatial grid.	16 WIND DIRECTIONS
5	1 to 4	I4	NFICRP	1 to 10 Must agree with WinMACCS variable NFICRP	Number of crop categories that will be used by the food pathway model	7 CROP CATEGORIES
6	1 to 4	I4	NUMWPI	1 to 10 Must agree with WinMACCS variable NUMWPI	Number of radionuclides in drinking water pathway	4 WATER ISOTOPES
7	1 to 4	I4	NUMWPA	1 to 4	Number of water pathways	1 WATERSHEDS
8	1 to 4	I4	NECRGN	1 to 99	Number of economic regions	97 ECONOMIC REGIONS

SecPop2000 only supports NUMCOR equal to 16. SecPop 4.0 and later allow the values of NUMCOR to be 16, 32, 48 or 64. However, once a site file is created, WinMACCS can create a new site file based on this site file that supports NUMCOR equal to 32, 48 or 64. This feature can be accessed on the WinMACCS form GENERAL/File Specifications/Site File. This is necessary to allow the WinMACCS user a finer grid resolution. When not using a site data file, WinMACCS assumes one watershed. Water ingestion data for each radionuclide considered in the water pathway is defined in the WinMACCS variable WINGF for one watershed only. Only

by using the site data file can more water pathways be specified. In this case, MACCS will use the ingestion factor read from the site file. The format for input of the ingestion data is described below. SecPOPenters constants for these values with the intention that this data would be edited further.

Eight blocks of site data follow the introductory block described in Table 6-2. Each of these data blocks as summarized in Table 6-2 is introduced by a separator line that identifies the block of the data to follow. The first line of data block must be the separator for that block. Data block separators start in column 2 and are right justified.

Table 6-2 Site file data blocks.

Data block in site file	Columns	FORTRAN format	First line of data block	*Description of data block*
1	2 to 23	A22	SPATIAL DISTANCES	Defines the distance to the outer radii of each grid element
2	2 to 23	A22	POPULATION	Defines the population of each grid sector
3	2 to 23	A22	LAND FRACTION	Defines the fraction of land of each grid sector
4	2 to 23	A22	REGION INDEX	Defines the economic region for each grid sector.
5	2 to 23	A22	WATERSHED INDEX	Defines the appropriate watershed to use for each grid sector
6	2 to 23	A22	CROP SEASON AND SHARE	Defines variables associated with crops
7	2 to 23	A22	WATERSHED DEFINITION	Defines water ingestion data for each watershed
8	2 to 23	A22	REGIONAL ECONOMIC DATA	Economic data for each economic region defined

6.2 Spatial Distances Data Block

The spatial distance data define the spatial grid for which the population and land use data are specified. The data define the distance in kilometers to the endpoints of the spatial intervals. The areas between the spatial interval endpoints within each of the 16, 32, 48 or 64 direction sectors are referred to as spatial elements. This grid definition must agree with the grid defined in the ATMOS input variable SPAEND.MACCS reads the spatial intervals distances in the site file and compares the values to SPAEND. If MACCS is run without the WinMACCS interface, an error of 10% is allowed, however only the values in the ATMOS variable SPAEND values are used in the calculations. For larger discrepancies in the geometry data, the error flag will be set and execution will terminate upon completion of the Site Data file input processing. WinMACCS sets the values of SPAEND to be identical with the values in the Site Data file when the Site

Data file is specified, so it is not possible to to have any difference between the spatial distances data block and SPAEND.

The first line of the spatial distance data block contains the 22-character separator beginning with SPATIAL DISTANCES in column 2. Next, the endpoint distances in kilometers are specified, eight values per line, using the format described below. As many lines as are needed to define the spatial distances are used. The minimum spacing between adjacent spatial intervals is 0.1 km.

A maximum of eight interval endpoints may be input per line within ten column intervals. The first interval endpoint would be input in columns 1–10, the second interval endpoint would be input in columns 11–20, etc. The data must be right justified in the ten columns allotted to that data point. The data are input as real numbers.

Variable Name	*Dimensions*	*FORTRAN Format*	*Allowed Values*	*Description*
SPAEND	NUMRAD	8E10.2	0.05 to 9999.0 km	Radial spatial intervals

6.3 Population Data Block

The population data for each element in the spatial grid is defined here. The first line of the data block contains the 22-character separator beginning with POPULATION in column 2. Next, the number of people in each element is given for the first sector. (The first sector is assumed to be centered on north.) The population data are specified, eight values per line, using the format described below. As many lines as needed to cover all the spatial elements in the sector are used. Proceeding in a clockwise rotation, the population data for the second (NNE when there are 16 sectors) and subsequent sectors follow. Data for all directions (sectors) must be provided. Data for each sector begin on a new line.

The population data are input as a real number. Fractional values are supported. The population data for up to eight spatial elements may be defined per line and the data are input per ten column intervals; *i.e.*, the population in the first element would be input in columns 1–10, the population in the second element would be input in columns 11–20, etc. The data must be right justified in the ten columns allotted to that data point. The data are input as real numbers supporting whole numbers.

Variable Name	*Dimensions*	*FORTRAN Format*	*Allowed Values*	*Description*
POPDAT	NUMRAD by NUMCOR	8E10.0	0.0 to 10^9	Number of people living in sector

MACCS combines evacuation scenarios using one of three different algorithms specified by a variable WTNAM. This variable can be set to PEOPLE, TIME or SUMPOP. This variable is defined on the *Site Data* tab in WinMACCS.

When WTNAM is set to PEOPLE, EARLY variable specified per cohort, WTFRAC, represents the fraction of the population that belongs to the cohort. When WTNAM is set to TIME, the EARLY variable WTFRAC represents the fraction of the time or probability that this evacuation scenario is applicable. With this option, the entire population follows each evacuation scenario a

fraction of the time. When the variable WTNAM is set to SUMPOP, population data for each evacuation scenario are defined in the site data file as follows.

When WTNAM is set to TIME or PEOPLE the population data block is delimited with the header record POPULATION beginning at column 2, followed by the population data.

When the SUMPOP option is selected, the header lines for each population data block are POPULATION1, POPULATION2, and POPULATION3, corresponding to the respective emergency cohorts, all beginning in column 2. MACCS reports an error when the number of population data blocks does not equal the number of emergency response cohorts defined in the EARLY input file.

6.4 Land Fraction Data Block

The fraction of each spatial element that is land (as opposed to lakes, oceans, *etc.*) must be defined. The first line of the data block contains the 22-character separator beginning with LAND FRACTION in column 2. Next, the fraction of area that is land in each radial spatial interval of the first sector is given. All values must be between 0 and 1. A value of 0 means the grid element has no land, a value of 1 means the element is all land. The land fraction data are specified, 16 values per line, with the format described below. As many lines as needed to define all the spatial intervals in the sector are used. The land fraction data for the second and subsequent sectors follow in a clockwise rotation. Data for all direction sectors must be provided. The data for each sector begin on a new line.

The land fraction data are read as a real number and land fractions are input every five columns. The data must be right justified in the five columns allotted to that data point.

Variable Name	*Dimensions*	*FORTRAN Format*	*Allowed Values*	*Description*
FRCLND	NUMRAD by NUMCOR	816F5.2	0.0 to 1.0	Fraction of sector that is land

6.5 Region Index Data Block

In this data block the user assigns a user-defined economic region to each of the spatial intervals. The economic regions are defined in the regional economic data block. The regional economic data block defines the economic data for each economic region. Data for each sector must be provided. The data for each sector begins on a new line.

The first line in the Region Index data block contains the 22-character separator beginning with REGION INDEX in column 2. The next line contains two-digit integers associating a region index with each of the spatial elements in the first sector limiting the region numbers to 99 possible regions. For example, a region index of 09 means that economic data for region number nine will be used for the spatial element. Though the FORTRAN format, 40I2, supports up to forty values per line, the number of values considered on each line will be NUMRAD. As many lines as needed to cover each sector are used, a new line for each sector in a clockwise rotation. For example, when the spatial grid has been divided into 16 sectors, there are a total of 16 lines of data.

The data must be right justified in the two columns allotted to that data point. The data are input as integer, supporting digits only with no decimal component.

Variable Name	*Dimensions*	*FORTRAN Format*	*Allowed Values*	*Description*
INDREG	NUMRAD by NUMCOR	40I2	1 to NECRGN	Economic region associated with sector

6.6 Watershed Index Data Block

Each of the spatial intervals in the grid must be associated with one of the watershed classes. The watershed identification data block begins with the 22-character separator beginning with WATERSHED INDEX in column 2. The next line contains two-digit integers associating a watershed type with each of the spatial elements in the first sector. Data for all sectors must be provided. The data for each sector begins on a new line.

The next line contains two-digit integers associating a watershed index with each of the spatial elements in the first sector. The next line contains two-digit integers associating a watershed index with each of the spatial elements in the first sector. The watershed index data are specified. For example, a watershed index of 1 means that the water ingestion factor for watershed type 1 will be used for all material deposited on that spatial element. A watershed index of 2 means that the water ingestion factor for watershed type 2 will be used for all material deposited on that spatial element. Though the FORTRAN format, 40I2, supports up to forty values per line, the number of values considered on each line is NUMRAD. As many lines as needed to cover each sector are used, a new line for each sector in a clockwise rotation. For example, when the spatial grid has been divided into 16 sectors, there is a total of 16 lines of data.

Variable Name	*Dimensions*	*FORTRAN Format*	*Allowed Values*	*Description*
INDWTR	NUMRAD by NUMCOR	40I2	1 to NUMWPA	Watershed index associated with sector

6.7 Crop and Season Share Data Block

The length of the growing season and the average fraction of the farmland area at the site devoted to each crop type must be specified. These fractions need not sum to exactly 1, but their sum should not exceed a value of 1. When these values sum to a value less than 1, that sum indicates the fraction of farmland in production in an average year (some fraction of farmland may be fallow). Data must be given for each of the crop categories.

This information is used only when *MACCS Food Model* is specified on the *Food* tab in WinMACCS. This data will not be used when the *MACCS Food Model* is not used, but it still will be required.

When *MACCS Food Model* is specified on the *Food* tab in WinMACCS, the crop names must agree with the variable NAMCRP. The data block begins with the separator CROP SEASON AND SHARE in column 2. This is followed by NFICRP lines of data.

Variable Name	*Columns*	*FORTRAN Format*	*Allowed Values*	*Description*
I	1 to 4	I4	1 to NFICRP	Crop Index, line number starting at 1
CROP	6 to 25	A20	When the MACCS Food Model is selected in WinMACCS, must match with a value in vector NAMCRP	Name of crop group.
GBEG	26 to 30	F5.0	1 to GEND	Day of the year the growing season begins
GEND	31 to 35	F5.0	GBEG to 365	Day of the year the growing season ends
FRCLCP	36 to 45	F10.0	0.0 to 1.0	Fraction of the site-averaged farmland devoted to this Crop

6.8 Watershed Definition Data Block

The data block begins with the 22-character separator beginning with WATERSHED DEFINITION in column 2. For each of the radionuclides considered in the liquid pathways model, a single line is supplied. Exactly NUMWPA ingestion factors are supplied on each line. Values supplied will override values of WinMACCS variable WINGF when defined. MACCS supports up to 10 radionuclides in the liquid pathway model.

Variable Name	*Columns*	*FORTRAN Format*	*Allowed Values*	*Description*
I	1 to 4	I4	1 to NWPISO	Radionuclide Index, line number starting at 1
NMISO	6 to 13	A8	Should match with WinMACCS variable NAMIPI when defined. Otherwise, should be match with a value in vector NUCNAM.	Radionuclide name
WTRINF(1)	36 to 45	E10.1	0.0 to 1.0	Ingestion Factor for Watershed Class 1
WTRINF(2)	46 to 55	E10.1	0.0 to 1.0	Ingestion Factor for Watershed Class 2
WTRINF(3)	56 to 65	E10.1	0.0 to 1.0	Ingestion Factor for Watershed Class 3
WTRINF(4)	66 to 75	E10.1	0.0 to 1.0	Ingestion Factor for Watershed Class 4

6.9 Regional Economic Data Block

Economic data must be specified for each of the economic regions. The data block begins with the separator REGIONAL ECONOMIC DATA in column 2. An economic region is typically identified with an existing county, a state, or country to provide an indication of the source of the data or the type of geographical area it is intended to represent. The economic regions defined in this section are identified with spatial elements in the Region Index data block. There is a line for each one of the economic regions.

Variable Name	*Columns*	*FORTRAN Format*	*Allowed Values*	*Description*
I	1 to 4	I4	1 to NECRGN	Region index, line number starting at 1
NMRGN	6 to 15	A10		Name of region
FRMFRC	21 to 25	F5.3	0.0 to 1.0	Fraction of land devoted to farming
DPF	26 to 30	F5.3	0.0 to 1.0	fraction of farm sales resulting from dairy
ASFP	31 to 40	F10.1	0.0 to 10^9 dollars/hectare	Total annual farm sales for the region
VFRM	41 to 50	F10.1	0.0 to 10^9 dollars/hectare	Farmland property value for the region
VNFRM	51 to 60	F10.1	0.0 to 10^9 dollars/person	Non-farmland property value for the region

6.10 Sample Site Data File

SECPOP Version: 4.3.0 SVN:2242 FileType: MACCS_Site Project: "Fictitious" Census: "C:\Program Files (x86)\SecPop\Census\Census2010.bin" County: "C:\Program Files (x86)\SecPop\Census\County2012.dat"
Lat: 36d11'35" Long: 115d58'55" Latitude: 36.193058 Longitude: 115.98194 Population_multiplier: 1.0 Economic_multiplier: 1.0 Run_Time: 2016/02/04_12:28:56
26 SPATIAL INTERVALS
16 WIND DIRECTIONS
7 CROP CATEGORIES
4 WATER PATHWAY ISOTOPES
1 WATERSHEDS
98 ECONOMIC REGIONS
SPATIAL DISTANCES KILOMETERS
0.1600 0.5200 1.2100 1.6100 2.1300 3.2200 4.0200 4.8300
5.6300 8.0500 11.2700 16.0900 20.9200 25.7500 32.1900 40.2300
48.2800 64.3700 80.4700 112.6500 160.9300 241.1400 321.8700 563.2700
804.6700 1609.3400
POPULATION
0. 0. 44. 3. 9. 198. 0. 12.
29. 43. 96. 536. 25. 0. 0. 1.
0. 0. 0. 0. 0. 94. 203. 48711.
153798. 2143468.
0. 13. 235. 61. 0. 8. 35. 5.
0. 5. 0. 0. 0. 0. 5. 0.
2. 746. 0. 0. 1193. 136. 678. 18438.

949973. 929596.
0. 0. 4. 0. 17. 16. 0. 0.
0. 0. 0. 0. 0. 0. 10. 82.
0. 5237. 0. 0. 3. 3741. 9992. 129062.
1669744. 676429.
0. 0. 0. 15. 5. 42. 0. 0.
148. 0. 0. 0. 0. 0. 212. 220.
292. 18068. 8387. 0. 8549. 109552. 93470. 18927.
284016. 5256346.
0. 7. 0. 57. 73. 327. 0. 0.
0. 0. 0. 0. 0. 0. 3. 0.
152. 254610. 848885. 365223. 255. 1224. 500. 68862.
358505. 2331523.
0. 0. 159. 42. 31. 198. 171. 167.
0. 97. 5. 11. 0. 0. 0. 0.
107. 22919. 211576. 177910. 465. 58248. 2876. 355158.
147099. 2542701.
0. 0. 50. 15. 72. 298. 288. 303.
16. 1266. 1273. 10. 0. 0. 0. 0.
609. 1677. 169. 354. 935. 97790. 54566. 4173727.
1169129. 20674.
0. 29. 46. 79. 66. 283. 148. 130.
154. 605. 1963. 316. 2. 10. 45. 0.
0. 48. 5. 42. 46. 65. 29179. 203628.
106. 0.
0. 0. 7. 33. 333. 266. 329. 627.
340. 1449. 218. 311. 0. 16. 4. 0.
0. 0. 0. 743. 25. 63475. 412494. 199515.
0. 0.
0. 0. 0. 24. 5. 215. 284. 66.
25. 144. 0. 0. 0. 0. 6. 0.
137. 0. 0. 0. 10691. 287689. 3724726. 4275018.
0. 0.
0. 36. 0. 0. 81. 305. 283. 196.
46. 0. 0. 0. 0. 5. 0. 31.
13. 0. 0. 0. 11. 147077. 6849804. 5136399.
0. 0.
0. 0. 83. 175. 123. 425. 193. 304.
323. 494. 79. 0. 0. 0. 0. 0.
0. 0. 0. 0. 2024. 65914. 648666. 647997.
0. 0.
0. 0. 155. 131. 42. 352. 392. 307.
214. 343. 1846. 74. 0. 0. 0. 3.
0. 0. 0. 16. 56. 688. 581198. 1608661.
652. 0.
0. 0. 0. 71. 114. 436. 616. 240.
461. 1494. 1536. 42. 9. 0. 0. 0.
89. 0. 344. 101. 3. 4595. 31218. 6807141.
4594572. 2463.
0. 0. 38. 98. 471. 92. 345. 362.
320. 1130. 1871. 957. 126. 0. 13. 0.
30. 1058. 270. 1002. 28. 330. 1578. 863619.
660171. 795687.

0. 0. 5. 60. 80. 18. 67. 33.
37. 500. 1571. 1242. 14. 0. 0. 100.
7. 0. 0. 0. 4. 2720. 1712. 37428.
15288. 9114675.
LAND FRACTION
0.00 0.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.99
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1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.98 0.99 0.99
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1.00 1.00 1.00 1.00 0.98 0.99 1.00 0.87 0.00 0.00
0.00 0.00 1.00 1.00 1.00 0.99 1.00 1.00 1.00 1.00 1.00 1.00 0.00 0.00 1.00 0.99
1.00 1.00 0.99 1.00 1.00 0.99 1.00 0.94 0.40 0.00
0.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 0.99 1.00 0.99 1.00 1.00 0.98 0.98 0.88 0.69
0.00 0.00 1.00 1.00 0.99 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
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0.00 0.00 1.00 0.98 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.98 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.98 0.95
REGION INDEX
1 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 5 4 6 7 8 910828298
1 4 4 4 4 4 4 4 4 4 3 3 3 311121313141516171883839 8
1 3 4 4 4 4 4 4 4 3 4 4191313131313131320212223848498
1 4 4 4 4 4 4 3 3 4 4241313 3131313131313252627858598
1 4 4 4 4 4 4 3 3 3 4 3 3 3 313131313131328293086869 8
1 4 4 4 4 4 4 4 4 3 4 4 4131313131313131331323387879 8
1 3 4 4 4 4 4 4 4 4 4 4 4341313131335363738394088889 8
1 4 4 4 4 4 4 4 4 4 4 4 4 4414243444546474747474889 89 3
1 3 4 4 4 4 4 4 4 4 4 4495050505051474747475253 90 3 3
1 3 4 4 4 4 4 4 4 4 4 350 3 3505054554747474756 91 3 3
1 4 4 4 4 4 4 4 4 4 35750 35050505058474747596092 3 3
1 3 4 4 4 4 4 4 4 4 46162 3 350505050506364656693 3 3
1 3 4 4 4 4 4 4 4 4 4 467 3 3505050505050506869 9494 3
1 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4707172505050737495 9598
1 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 47576777879969698

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1 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 48081979798
 WATERSHED INDEX
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 CROP SEASON AND SHARE
   1 PASTURE              90. 270.  0.4100
   2 STORED FORAGE        150. 240.  0.1300
   3 GRAINS               150. 240.  0.2100
   4 GRN LEAFY VEGETABLES 150. 240.  0.0020
   5 OTHER FOOD CROPS     150. 240.  0.0040
   6 LEGUMES AND SEEDS    150. 240.  0.1500
   7 ROOTS AND TUBERS     150. 240.  0.0030
 WATERSHED DEFINITION -- INITIAL AND ANNUAL WASHOFF AND INGESTION
FACTORS
   1 Sr-89                     5.00E-06      0.0
   2 Sr-90                     5.00E-06      0.0
   3 Cs-134                    5.00E-06      0.0
   4 Cs-137                    5.00E-06      0.0
 REGIONAL ECONOMIC DATA
   1 EXCLUSION       .000 .000       .0       .0       .0
   2 EMPTY02         .000 .000       .0       .0       .0
   3 EMPTY03         .000 .000       .0       .0       .0
   4 Nye04           .006 .000    2675.0   5531.0  325945.0
   5 MIX_CNTY05      .006 .000    2635.1    5745.5       .0
   6 MIX_CNTY06      .005 .000    2589.3    5791.5       .0
   7 MIX_CNTY07      .004 .000    2075.2    4290.7       .0
   8 MIX_CNTY08      .003 .000    1497.8    3096.9       .0
   9 MIX_CNTY09      .004 .000    2099.9    4341.8  278872.3
  10 MIX_CNTY10      .005 .000    2511.3    5331.2  325945.0
  11 MIX_CNTY11      .003 .000    1080.0   14111.0  359500.0
  12 MIX_CNTY12      .005 .000    2150.7    8351.3       .0
  13 Clark13         .003 .000    1080.0   14111.0  359500.0
  14 MIX_CNTY14      .003 .000    1079.9   14110.3       .0
  15 MIX_CNTY15      .000 .000       2.7      35.0       .0
  16 Lincoln16       .000 .000       .0       .0  261817.0
  17 MIX_CNTY17      .001 .000     617.0    1275.7  261817.0
  18 MIX_CNTY18      .002 .001     486.8    1620.2  368899.1
  19 MIX_CNTY19      .004 .000    1681.0   10878.0       .0
  20 MIX_CNTY20      .003 .000    1017.4   13293.0       .0
```

21	MIX_CNTY21	.000	.000	34.2	447.5	261817.0
22	MIX_CNTY22	.014	.005	32.5	1235.3	262068.2
23	MIX_CNTY23	.172	.133	1195.1	4544.1	254878.7
24	MIX_CNTY24	.003	.000	1080.0	14111.0	.0
25	MIX_CNTY25	.002	.000	831.6	10865.9	359500.0
26	MIX_CNTY26	.094	.006	217.8	40749.5	291911.2
27	MIX_CNTY27	.131	.037	192.5	37899.7	270410.3
28	MIX_CNTY28	.059	.000	679.8	39357.5	330392.3
29	MIX_CNTY29	.128	.000	190.1	70249.3	261836.0
30	MIX_CNTY30	.376	.000	27.0	309321.1	334469.2
31	MIX_CNTY31	.104	.000	356.6	59747.0	272337.5
32	Mohave32	.146	.000	60.0	78456.0	261836.0
33	MIX_CNTY33	.241	.000	79.6	155479.9	287032.1
34	MIX_CNTY34	.004	.000	1448.4	12129.4	.0
35	MIX_CNTY35	.004	.051	2397.4	15520.1	359002.3
36	MIX_CNTY36	.004	.108	3908.4	17345.3	359500.0
37	MIX_CNTY37	.004	.179	5776.0	19480.8	354342.9
38	MIX_CNTY38	.014	.249	7537.0	26199.0	358495.8
39	MIX_CNTY39	.095	.214	6035.3	61683.1	271843.2
40	MIX_CNTY40	.093	.054	1542.5	51014.8	269887.5
41	MIX_CNTY41	.007	.000	2615.5	5468.3	325945.0
42	MIX_CNTY42	.025	.000	1504.1	4919.9	374168.5
43	MIX_CNTY43	.038	.000	445.0	5605.8	418105.5
44	MIX_CNTY44	.048	.000	201.4	3532.4	.0
45	MIX_CNTY45	.039	.180	5128.1	11304.4	.0
46	MIX_CNTY46	.007	.659	18361.4	33720.8	307340.0
47	San_Bern47	.006	.669	18636.0	34186.0	307340.0
48	MIX_CNTY48	.054	.174	7152.4	21712.8	310148.9
49	MIX_CNTY49	.023	.000	1673.8	4475.6	325945.0
50	Inyo50	.051	.000	146.0	2865.0	422392.0
51	MIX_CNTY51	.046	.075	2224.9	6386.5	.0
52	MIX_CNTY52	.006	.666	18571.0	34139.4	307340.3
53	MIX_CNTY53	.085	.133	7674.7	27115.0	311830.5
54	MIX_CNTY54	.042	.135	3873.5	9179.2	422392.0
55	MIX_CNTY55	.036	.222	6286.0	13265.8	.0
56	MIX_CNTY56	.061	.274	10340.4	31195.3	342463.5
57	MIX_CNTY57	.018	.000	2004.4	4824.1	.0
58	MIX_CNTY58	.048	.036	1148.5	4563.2	.0
59	MIX_CNTY59	.121	.468	13731.4	28287.7	310216.5
60	MIX_CNTY60	.057	.045	6120.4	31832.6	443771.9
61	MIX_CNTY61	.006	.000	2647.9	5502.4	325945.0
62	MIX_CNTY62	.050	.000	199.0	2920.9	.0
63	MIX_CNTY63	.035	.240	6793.3	14125.2	.0
64	MIX_CNTY64	.029	.453	12671.0	24123.4	312914.7
65	MIX_CNTY65	.413	.157	5060.7	13126.1	336839.9
66	MIX_CNTY66	.424	.115	4527.7	13533.2	337157.7
67	MIX_CNTY67	.024	.000	1637.8	4437.6	365045.1
68	MIX_CNTY68	.269	.277	5042.5	13256.6	376652.8
69	MIX_CNTY69	.417	.392	7587.6	18887.0	311376.9
70	MIX_CNTY70	.009	.000	2478.8	5324.2	.0
71	MIX_CNTY71	.049	.000	229.4	2952.9	327028.7
72	MIX_CNTY72	.049	.000	228.0	2951.4	.0
73	MIX_CNTY73	.094	.044	1067.0	4921.6	422392.0

74	MIX_CNTY74	.343	.070	5391.2	17111.6	394223.3
75	MIX_CNTY75	.006	.000	2674.4	5530.4	325945.0
76	MIX_CNTY76	.007	.000	2602.8	5454.9	325945.0
77	MIX_CNTY77	.018	.000	1903.3	4775.2	332834.1
78	MIX_CNTY78	.024	.000	802.5	4269.0	447628.5
79	MIX_CNTY79	.015	.000	584.1	4300.2	408604.4
80	MIX_CNTY80	.007	.000	2469.8	5429.5	339779.0
81	MIX_CNTY81	.006	.000	2338.6	5144.8	325945.0
82	MIX_CNTY82	.183	.126	916.5	3266.3	358653.5
83	MIX_CNTY83	.240	.114	794.5	4224.6	333545.4
84	MIX_CNTY84	.207	.091	571.4	4251.9	358974.7
85	MIX_CNTY85	.162	.008	260.7	13629.7	341927.2
86	MIX_CNTY86	.500	.010	34.1	183740.1	303938.2
87	MIX_CNTY87	.334	.012	167.6	145198.8	299802.0
88	MIX_CNTY88	.152	.149	1830.4	35440.3	364356.0
89	MIX_CNTY89	.070	.006	7822.9	10749.2	259639.5
90	MIX_CNTY90	.140	.019	8597.2	31095.0	330385.6
91	MIX_CNTY91	.086	.038	7810.2	45764.2	494904.5
92	MIX_CNTY92	.159	.000	8860.2	35902.6	453981.2
93	MIX_CNTY93	.458	.022	4370.8	18134.3	456231.0
94	MIX_CNTY94	.576	.076	5302.3	15582.4	400578.5
95	MIX_CNTY95	.472	.094	3086.1	18982.9	528965.4
96	MIX_CNTY96	.175	.023	676.9	8584.3	405306.7
97	MIX_CNTY97	.125	.046	533.9	3165.3	400316.2
98	MIX_CNTY98	.601	.039	626.9	4428.2	412895.8

7. METEOROLOGICAL FILE FORMAT

7.1 Format Overview

When running WinMACCS, a weather model is selected using the *Weather* tab. When one of the file sampling method models is picked, a meteorological file needs to be supplied.

WinMACCS supports data in this file. Data may be recorded for one year. The file consists of up to ten years of either fifteen-minute, thirty-minute or hourly averages of the wind direction, wind speed, atmospheric stability, and precipitation rate. Each line of the file will have a wind direction, wind speed, atmospheric stability, and accumulated precipitation. Generally, the data are taken from either the facility site or from a nearby weather station.

The meteorological data file used is a formatted text file.

The first two records contain identification information. Up to 80 characters may be used on each line. This header information is printed on the output listing.

Line in Met file	***FORTRAN Format***	***Allowed Values***	***Description***
1	A80		File identifying information. Should contain quality assurance information.
2	A80		Continuation of file identifying information.

The default recording interval for the weather data are every hour. When 30 minutes or 15 minutes information is used, the next line is required. When this line is omitted in the meteorological file, a value of 60 minutes is assumed.

Columns	***FORTRAN Format***	***Allowed Values***	***Description***
1 to 7	A7	/PERIOD	Keyword that identifies line
9-10	I2	60, 30 or 15	Number of minutes between each recorded value on the file

This is followed by a line for each time recorded. There will be 8760 lines of information when the time period is set to 60 minutes. When the time period is 30, there are 17520 lines of weather data in the file; when the time period is 15, there are 35040 lines of weather data in the file.

The possible values for the variable WINDIR will depend on the WinMACCS variable NUMCOR. WinMACCS and MACCS allow NUMCOR to be 16, 32, 48 or 64. This needs to be consistent with NUMCOR written on the site data file when used in the calculation. In other words, when the site data file value for NUMCOR is 16, the possible values for variable WINDIR is 1 to 16, and the value of NUMCOR used in WinMACCS should be set to 16. It is up to the user to select or create a meteorological file that is consistent with the value of NUMCOR used in MACCS. When this is not done, there will be no error messages, but the results reported from MACCS will be wrong.

Columns	FORTRAN Format	*Variable*	*Allowed Values*	*Description*
2 to 4	I3	ISTRDY	1 to 365	Julian day of the year
6 to 7	I2	ISTRHR	1 to 24	Hour of the day
9 to 10	I2	WINDIR	1 to NUMCOR	Direction of wind, where 1 is north, proceed clockwise to NNW
11 to 13	I3	WINDSPD	1 to 300*	10ths of a meter per second
14	I1	ISTAB	1 to 7**	Stability Category, corresponds to Pasquill stability class A through G
15 to 17	I3	RNMM	-1 to 999***	Rain rate in hundredths of an inch per hour

* Values between 1 and 4 are automatically changed to 5 (0.5 m/s).
** A value of 7 is automatically changed to 6 by the code.
*** Some meteorological data files use –1 to indicate a trace of precipitation during the hour. MACCS assumes these values to be 0.

Following this is a table of eight values of mixing layer height. Two values of mixing height are supplied for each of the four seasons of the year. The first of these two values corresponds to the morning mixing height and the second to the afternoon height.

The FORTRAN edit descriptor for this data is F10.0. This means that the input field is ten characters long and right justified. To prevent errors due to right justification of data, it is recommended that a decimal point is used. When desired, an exponential portion of the field is indicated using the letter E as in 1.4E4. Any real number within the allowed values (including fractional values for meters) is allowed.

Columns	FORTRAN Format	*Variable*	*Allowed Values*	*Description*
1 to 10	F10.0	HEIGHT(1,1)	1 to 100 hundreds of meters	Morning-winter mixing height
11 to 20	F10.0	HEIGHT(2,1)	1 to 100 hundreds of meters	Morning-spring mixing height
21 to 30	F10.0	HEIGHT(3,1)	1 to 100 hundreds of meters	Morning-summer mixing height
31 to 40	F10.0	HEIGHT(4,1)	1 to 100 hundreds of meters	Morning-autumn mixing height
41 to 50	F10.0	HEIGHT(1,2)	1 to 100 hundreds of meters	Afternoon-winter mixing height
51 to 60	F10.0	HEIGHT(2,2)	1 to 100 hundreds of meters	Afternoon-spring mixing height
61 to 70	F10.0	HEIGHT(3,2)	1 to 100 hundreds of meters	Afternoon-summer mixing height
71 to 80	F10.0	HEIGHT(4,2)	1 to 100 hundreds of meters	Afternoon-autumn mixing height

7.2 Sample Meteorological Data File

A sample set of records from the meteorological data file is provided, which shows the first and last ten records of the file. NUMCOR is assumed to be 16. In this example, the weather conditions for day one, hour one (record number three) are: wind direction—blowing toward the SE, wind speed of 2.6 m/s, stability 4 (category D), and accumulated precipitation of 0.07 inches (1.8 mm) in the hour. The winter, spring, summer, and autumn mixing heights for neutral and unstable conditions (record 8763) are all 1200 m.

```
U.S. NATIONAL WEATHER SERVICE METEOROLOGICAL DATA FILE
Sample Input for the MACCS Documentation
 1   1  70264  7
 1   2  60624  7
 1   3  80414  2
 1   4  80364 -1
 1   5  90314  0
 1   6 110464  0
 1   7 110264 -1
 1   8 110414 -1
 .
 .
 .
365 16 120154  4
365 17 110154  4
```

```
365 18 130214  4
365 19 130154  3
365 20 130104  2
365 21 130154  2
365 22 140104  2
365 23 130104  2
365 24 140104  2
    12.    12.    12.    12.    12     12     12     12
```

8. DOSE CONVERSION FACTOR FILE

8.1 Introduction

WinMACCS is supplied with a set of 51 “adult” dose factor files which are based on the CD supplement to Federal Guidance Report 13 (EPA 2002). Data for 825 isotopes are provided. This dose factor file set supports WinMACCS calculations using the linear no threshold, annual threshold, and piecewise linear dose-response models for latent cancer health effects and the acute health effects model.

These dose factors use ICRP publication 60 (ICRP 1991) tissue weighting and the respiratory tract model defined in ICRP-publication 66 (ICRP 1994). Federal Guidance Report 13 dose factors are generally similar to those published in ICRP publication 72 (1996), but they incorporate modifications to ICRP publication 72 assumptions that were agreed to by the U. S. Environmental Protection Agency and the ORNL Center for Biokinetic and Dosimetric Research. Minor differences between Federal Guidance Report 13 and ICRP publication 72 dose coefficients are largely attributable to differences in:

1. Assumptions of shared kinetics in some decay chains
2. Systemic biokinetic models for some elements, and
3. Gastrointestinal tract absorption-to-blood fractions, f1.

8.2 Lung Clearance Behavior

With few exceptions, the absorption types are consistent with those used in the current dose factor files. The dose factor files do not show an absorption type for certain isotopes when either there was no choice of clearance type in Federal Guidance Report 13, or the choice was superfluous because the inhalation dose coefficients were zero.

8.3 Gastrointestinal Tract Uptake Fraction, f1

Federal Guidance Report 13 assigned *f1* values for uptake of elements from the digestive tract via the ingestion pathway based on the chemical form expected to be encountered in the environment, and these values were not necessarily consistent with the *f1* values used in the computation of inhalation dose coefficients. There were choices of *f1* to be made for only four elements: hydrogen, sulfur, mercury, and polonium. The ingestion dose coefficient for tritium was based on tritiated water (HTO). Sulfur, mercury, and polonium isotopes were assigned ingestion dose coefficient based on the form and f1 that gave the highest dose.

8.4 Particle Size Distribution

Inhalation dose coefficients for micron sized particles depend on the activity median aerodynamic diameter (AMAD). The Federal Guidance Report 13 inhalation dose factors are based on an AMAD of 1 μm.

8.5 Organs Included in Data Set

The following organs and tissues are included in the Federal Guidance Report 13 dose factor files.

Organs with annual and 50-year equivalent dose commitment coefficients	Organs with acute dose commitment coefficients
Adrenals	
Urinary Bladder Wall	
Bone Surface	
Brain	
Breasts	
Stomach Wall	Stomach Wall
Small Intestine Wall	Small Intestine Wall
Upper Large Intestine Wall (ULI)	
Lower Large Intestine Wall (LLI)	Lower Large Intestine Wall
Kidneys	
Liver	
Esophagus	
Muscle	
Ovaries	
Pancreas	
Red Marrow	Red Marrow
Skin	
Spleen	
Testes	
Thymus	
Thyroid	Thyroid
Uterus	
Lungs	Lungs
Colon	
Gonads	
Remainder	
Effective	

8.6 Annual and 50-year Equivalent Dose Commitment Factors

The annual and 50-year dose commitment factors are intended for stochastic health effect (cancer and heritable effect) estimation, so they include a radiation weighting factor of 20 for the high linear energy transfer (LET) contributions to these dose coefficients.

8.7 Calculating Annual and 50-Year Dose Commitment Factors for "Composite Organs"

Dose factors for composite organs were calculated from dose factors for the underlying tissues or organs as follows:

1. The esophagus was assigned the corresponding inhalation dose coefficients and ingestion dose coefficients of the thymus.
2. Inhalation and ingestion dose coefficients for the colon were calculated as a weighted sum of the dose coefficients for upper large intestine (57%) and lower large intestine (43%)
3. The inhalation and ingestion dose coefficients for the lung (thoracic portion of respiratory tract) and ET_{Reg} (the extra-thoracic region of the respiratory tract) were calculated using

equations on page 35 of ICRP publication 66. The lung coefficient is the weighted sum of the coefficients for the several respiratory tract tissues.

4. The dose coefficients for remainder were calculated using equations on ICRP publication 71 (ICRP 1995) page 27.
5. The dose coefficients for gonads were the larger of the dose coefficients for testes and ovaries.
6. The dose coefficients for effective were computed from the individual organ dose coefficients using the ICRP 60 tissue weighting method.

8.8 Acute Inhalation Dose Factors

Reliable data on relative biological effectiveness, RBE, of high LET radiation at causing acute health effects were not available; so the acute inhalation dose factors were based on an RBE of 10 for consistency with DOSFAC2 dose factor files.

Next, the resulting acute dose coefficients DCF[i, at, org, cp] were weighted by acute dose protraction factors, WTFRAC[cp,org], and summed to obtain adjusted acute dose coefficients, DCF[i, at, org]. Here, i represents an isotope, at represents absorption type (equivalent to lung clearance class), org represents an organ, and cp represents a commitment period. The values of WTFRAC[cp, org] that were used are given in the DOSFAC2 Users Manual (Young and Chanin, 1997).

8.9 Designating Pseudo-Stable Isotopes When Using Federal Guidance Report 13 Dose Factor Files

In contrast to DOSFAC2 and FGRDCF dose factor files, Federal Guidance Report 13 dose factors make no assumptions about the degree of equilibrium within decay chains for radioactive materials in the environment or for intakes of radioactive materials from the environment. Consequently, one must be mindful about specifying both parent and the corresponding progeny that are released or form as decay products in the environment via the WinMACCS “Radionuclide Core Inventory and Chemical Group” window. For long decay chains, such as uranium-238, the sixth member of the chain (thorium-230 for example) must be identified as pseudo-stable. When the pseudo-stable isotope conventions commonly observed for DOSFAC2 or FGRDCF dose factor files are used with Federal Guidance Report 13 dose factor files, doses and health effects may be significantly underestimated. For example, Ba-137m must be listed as a pseudostable isotope when using a DOSFAC2 dose factor file because it’s dose is included implicitly with Cs-137. With the FGR-13 dose factor file, including Ba-137m as a pseudostable isotope could lead to a significant under-prediction of overall dose.

8.10 Known Issues

The FGR-13 dose factor files have inherited the following issues from the CD Supplement to FGR-13:

1. The ingestion and inhalation dose coefficients for four alpha-emitting rare-earth isotopes (Sm-146, Sm-147, Gd-148, and Gd-152) are incorrect.
2. The ingestion and inhalation dose coefficients for four isotopes having significant spontaneous fission decay modes (Cm-248, Cm-250, Cf-252, and Cf-254) are listed as zero.

9. CYCLICAL FILE FORMAT

It is possible to run successive MACCS simulations without using LHS. Model values can be varied using successive MACCS input files. This feature is enabled in WinMACCS through the Project Properties form setting on the Scope tab. The files are selected and copied into the WinMACCS project after the user completes the form *GENERAL/File Specifications/Cyclical File Set*.

When the user clicks the Run button to begin a simulation, WinMACCS reads a cyclical file, and imports the values temporarily into the project using the algorithm identical to the *File→Import MACCS Input File* option on the main menu. WinMACCS creates the MACCS template input files. The template input files are identical to the MACCS input files when LHS is not incorporated into the simulation.

The format required for the cyclical input files is identical to the input format required for MACCS with the following exceptions:

1. ATMOS, EARLY, CHRONC and COMIDA2 model input are grouped together in a single cyclical input file. When MACCS was run directly, input for these models is placed in separate files.
2. The period in column one is used to separate EARLY evacuation scenarios. The first evacuation scenario occurs before the first period in column one. On the other hand, MACCS supports a period in column one in the ATMOS input to separate different source terms, a period in column one in the EARLY input to separate different evacuation scenarios, and a period at the end of each input file to indicate the end of the file.
3. It is not necessary to end the file with a period in column one.
4. MACCS has evolved since 1.13.1, and though cyclical file input is backward compatible, new model options and hence new input has been added.

The MACCS file format is not documented in detail here. However, note the following rules:

1. An asterisk (*) in column one signifies a comment
2. Multiple values on an input line can be separated by any amount of white space, including TAB characters
3. An input line begins with a prefix. Depending on the input line, this is followed by a two or three digit sequence number, or no sequence number. The value(s) of the variable(s) follow separated by white space. The situation will be obvious when viewing a MACCS input file. For example, the following line is a valid MACCS input file line with a three digit sequence number and the prefix “RDPDELAY”

```
RDPDELAY001        3700.
```

Cyclical input files can be created in a number of ways as follows:

1. Modify a MACCS file to reflect the changes desired. As a starting point, use a file created by WinMACCS such as Atmos1.inp, Early1.inp, etc.
2. Include only relevant changes between the simulations in a cyclical input file. As a starting point, edit a file created by WinMACCS, removing data that will not be changed between cyclical runs.
3. Use a file created by MelMACCS when the basis of the cyclical input file is a varying source term created by the MELCOR modeling code.

The easiest way to determine the proper format of a cyclical input card is to run a simulation with the MACCS Cyclical File Set option in the Project Properties form, Scope tab, set to OFF. Open the MACCS input file (Atmos1.inp, Early1.inp, Chronc1.inp or Comida1.inp) in the project Input folder , and copy the relevant lines into the cyclical input file.

For example, to find the variable PDELAY in the MACCS input file, as referenced in the WinMACCS interface, search for the string PDELAY in the Atmos1.txt file. This will be found in a comment immediately preceding the MACCS input lines responsible for setting the value of PDELAY in MACCS to as shown in the following excerpt from atmosTemplate.txt:

```
* PDELAY, time of release for each plume from xxxx (sec)
RDPDELAY001     3700.
RDPDELAY002     10000.
```

These lines can be copied into a new cyclical input file created in Notepad. Do not create the cyclical input file in a word processor such as Word.

1. The order of the lines is not important, however include all lines relevant to a variable. In the above example, when the second line is omitted, PDELAY is set to be a vector of length one.
2. Blank lines are allowed.
3. Sections are separated by a line containing a period in column one.
4. Each emergency evacuation scenario is in a separate section.

The following is a sample cyclical file. Notice that there are ATMOS, EARLY and CHRONC variables in the first section. The second section, separated from the first section with a period in column one, contains EARLY emergency scenario two input.

```
* CWASH1, Washout Coefficient Number One, Linear Factor
WDCWASH1001     9.7x10-5

* WTFRAC - weighting fraction applied to EARLYemergency response scenario one
EZWTFRAC001     .90

* EXPTIM - long term exposure period, CHRONC variable
CHEXPTIM001     9.7x108
.
* WTFRAC - weighting fraction applied to EARLY emergency response scenario two
EZWTFRAC001     .1
```

10. MACCS BINARY FILE FORMAT

10.1 Binary File Overview

With the WinMACCS development, it became necessary to create a file for easy communication of results between the MACCS modeling engine and the WinMACCS interface. All that existed at the point of MACCS 1.12 was an ASCII formatted output file. The information on this file did not have sufficient structure to serve as a generic output file. It was believed to be an unreasonable constraint to require the MACCS ASCII output file to always comply with a format that WinMACCS could automatically process. In a development environment, output files often change formats. It was decided that there would be a separate file created by MACCS that would provide a better interface between MACCS and WinMACCS with the design criteria discussed below.

The binary file created by MACCS is a separate file that serves as the interface between MACCS and WinMACCS. The real and integer representations of the results are consistent with the values used by MACCS reflecting the accuracy of the calculated results without the round off caused by formatted write statements used to create the readable MACCS output files.

If the MACCS developer adds new variables to the file in a later version of MACCS, WinMACCS does not have to be modified to display the new data.

The binary file supports multivariate data. For example, Centerline Ground Concentration is associated with the plume number, a radionuclide and a position on the spatial grid.

10.2 Mulitvariate Support

MACCS data are multivariate data. Each variable written to the binary file is associated a set of qualifiers. Qualifier can have one of three data types, character, 4-byte integer and 4-byte real. The qualifier “MACCS2_Input” is not an additional dimension to the variable, but is used internally by WinMACCS to identify the source of the variable request. The qualifier units are determined by the MACCS input.

New qualifiers can be defined without impacting the file processing in WinMACCS. A list of possible qualifiers and the possible units supported is shown in Table 10-1.

Table 10-1 Qualifiers associated with variables.

Qualifier	Units	Data type	Example value
Nuclide	none	character	Co-60
Ldistance	km, mi	real	5.3
Rdistance	km, mi	real	6.5
Distance	km, mi	real	6.6
Plume	none	integer	3
Evacuation	none	integer	1
Health Effect	none	character	ERL INJ/PRODROMAL VOMIT
Exceeds Risk	none	real	5.6
Organ	none	character	A-LUNGS

Qualifier	Units	Data type	Example value
Exceeds Dose	Sv, rem	real	5.2
Source Term	none	integer	1
Angle	none	character	ENE
Pathway	none	character	GRD
Elevation Dose	Sv, rem	real	10.
Elevation Concentrat	Bq/m^2, Ci/m^2	real	4.2
MACCS2_Input	none	not applicable	TYPE1OUT001 'ERL FAT/TOTAL' 1 26 NONE
Time	S	real	60

10.3 Data available on the binary file

The available variables are determined by the input to MACCS. Output requests to MACCS are organized by an output type and details regarding the output request. For example, the following EARLY input card results in a type1 output request of the total early fatalities between spatial intervals 1 to 26.

TYPE1OUT001 'ERL FAT/TOTAL' 1 26 NONE

The number of variables associated with this particular calculation request is one, namely Health Effects.

What follows in is a description of the results written to the binary file. Results written depend on the output requests made in WinMACCS, however the output requests determine the results that MACCS calculate. Some results are available in different units depending on the ATMOS input, however the results are available in only of the units listed for any run.

The data available for each of the variables are statistics as shown in Table 10-2 and the CCDF of the data stored in a binned form consistent with the MACCS output file.

Table 10-2 Statistics written to the binary file.

StatID	StatLab
1	Probability Non-zero
2	Mean
3	50th Quantile
4	90th Quantile
5	95th Quantile
6	99th Quantile
7	99.5th Quantile
8	Peak Concentration
9	Peak Probability
10	Peak Trial

The possible variables are shown in Table 10-3.

Table 10-3 Binary file results records.

VarLab	Comments	Qualifiers	Units
Release	This output is always included. There are entries for each isotope (1 to NUMISO), for each plume release, and for each ATMOS change set (or source term)	Source Term Plume Nuclide	Bq, Ci
Centerline Air Concentration	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	Bq-s/m^3, Ci-s/m^3
Ground-Level Air Concentration	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	Bq-s/m^3, Ci-s/m^3
Centerline Ground Concentration	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	Bq/m^2, Ci/m^2
Total Centerline Ground Concentration	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	Bq/m^2, Ci/m^2
Ground-Level Chi/Q	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	s/m^3
Adjusted Source Strength	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	Bq, Ci

VarLab	Comments	Qualifiers	Units
Plume Crosswind Dispersion	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	m
Plume Vertical Dispersion	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	m
Plume Centerline Height	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	m
Plume Arrival Time	Type 0 output	Source Term Plume Nuclide Ldistance Rdistance MACCS_Input	s
Health-Effect Cases	Type 1 output	Source Term Evacuation Health Effect Ldistance Rdistance MACCS_Input	none
Health Effects LNT Adjusted Population Dose	Type 1 output Note: This output is only printed when the Threshold or Piecewise model is used	Source Term Evacuation Health Effect Ldistance Rdistance Organ MACCS_Input	Sv, rem
Health Effects Used Adjusted Population Dose	Type1 output Note: This output is only printed when the Threshold or Piecewise model is used	Source Term Evacuation Health Effect Ldistance Rdistance Organ MACCS_Input	Sv, rem
Early Fatality Radius	Type 2 output	Source Term Evacuation Exceeds Risk MACCS_Input	km, mi

VarLab	Comments	Qualifiers	Units
Population Exceeding Threshold	Type 3 output	Source Term Evacuation Organ Exceeds Dose MACCS_Input	none
Average Individual Risk	Type 4 output	Source Term Evacuation Health Effect Ldistance Rdistance MACCS_Input	none
Population Dose	Type 5 output	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	Sv, rem
Centerline Dose	Type 6 output	Source Term Evacuation Organ Pathway Ldistance Rdistance MACCS_Input	Sv, rem
Centerline Risk	Type 7 output	Source Term Evacuation Health Effect Ldistance Rdistance MACCS_Input	none
Population-Weighted Risk	Type 8 output	Source Term Evacuation Health Effect Ldistance Rdistance MACCS_Input	none
Peak dose	Type A output	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	Sv, rem
Peak dose Polar	Type B results	Source Term Evacuation Organ Ldistance Rdistance Angle MACCS_Input	Sv, rem

VarLab	Comments	Qualifiers	Units
Dose by Grid Element	Type C results	Source Term Evacuation Organ Angle Ldistance Rdistance MACCS_Input	Sv, rem
Area that Exceeds Dose Threshold	Type C results	Source Term Evacuation Elevation Dose Organ Ldistance Rdistance MACCS_Input	Ha, km^2, mi^2
Ground Concentration by Grid Element ****here***	Type D output	Source Term Evacuation Nuclide Angle Ldistance Rdistance MACCS_Input	Bq/m^2
Early Ground Conc Area That Exceeds Threshold	Type D output	Source Term Evacuation Elevation Concentration Nuclide Ldistance Rdistance MACCS_Input	Ha
Early Air Concentration	Type D output	Source Term Evacuation Nuclide Angle Ldistance Rdistance MACCS_Input	$Bq\text{-}s/m^3$
Tot Long-Term Pathways Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Tot Long-Term Direct Exposure Pathways	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv

VarLab	Comments	Qualifiers	Units
Tot Ingestion Pathways Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Long-Term Groundshine Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Long-Term Resuspension Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Population Dependent Decontamination Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Farm Dependent Decontamination Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Water Ingestion Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Milk Growing Season Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Crop Growing Season Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv

VarLab	Comments	Qualifiers	Units
Milk Long-Term Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Crop Long-Term Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Ingestion of Grains	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Ingestion of Leafy Vegetables	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Ingestion of Root Crops	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Ingestion of Fruits	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Ingestion of Legumes	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Ingestion of Beef	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv

VarLab	Comments	Qualifiers	Units
Ingestion of Milk	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Ingestion of Poultry	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Ingestion of Other Meat Crops	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Total Economic Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Pop Dependent Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Farm Dependent Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Pop Dependent Decontamination Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Farm Dependent Decontamination Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Pop Dependent Interdiction Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$

VarLab	Comments	Qualifiers	Units
Farm Dependent Interdiction Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Pop Dependent Condemnation Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Farm Dependent Condemnation Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Emergency Phase Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Intermediate Phase Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Milk Disposal Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Crop Disposal Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Farm Dependent Decontamination Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Pop Dependent Decontamination Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Farm Dependent Interdiction Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Pop Dependent Interdiction Distance	Type 11 results	Source Term Evacuation MACCS_Input	km

VarLab	Comments	Qualifiers	Units
Farm Dependent Condemnation Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Pop Dependent Condemnation Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Milk Disposal Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Crop Disposal Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Farm Decontamination	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Pop Decontamination	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	individuals
Pop Decontamination Area	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Farm Interdiction	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Pop Interdiction	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	individuals
Pop Interdiction Area	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Farm Condemnation	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha

VarLab	Comments	Qualifiers	Units
Pop Condemnation	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	individuals
Pop Condemnation Area	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Milk Disposal Area	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Crop Disposal Area	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Maximum Annual Food Dose	Type 13 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	Sv

11. MAPGEN

This section provides directions on how to use MapGen to create road maps in a .gif format at specific latitudes, longitudes and distances. These maps can be generated in two different ways.

1. Directing MapGen to read a file created in WinMACCS. This file, MapSummary.txt. can be generated by clicking the Create Map File button in any of the WinMACCS map forms such as the Network Evacuation Direction form.
2. Manually entering information into MapGen consisting of latitude, longitude and distance information.

This application was developed for Sandia National Laboratories by Sigma Software LLC to be used starting with WinMACCS version 3.2. The maps generated are used in the WinMACCS network evacuation path forms.

This software uses the Microsoft Map Point 2006 libraries. It is required that Microsoft Map Point 2006 be purchased and installed for this software to be functional. Export restrictions do not allow the Map Point North America maps to be used in India, Morocco, Pakistan, China, Hong Kong SAR, Maucau SAR, Turkey or Taiwan.

We recommend that all maps be checked against another reliable source for quality assurance purposes. The Microsoft Map Point 2006 license states the following: "Do not expect the software to provide or depict exact distances, directions or geographic features." Though we have not experienced any problems with the maps, and we interpret this to be stated for the protection of Microsoft, it does remind us that roads are dynamic by nature and computer maps can be subject to map database and software errors.

11.1 Installation of MapGen

Install Microsoft Map Point 2006. When a trial version of available, it will work with MapGen, but only for a limited time. Our trial version worked for 60 days.

Run Setup.exe from the folder of the MapGen 1.0 found on the WinMACCS installation CD.

After you install MapGen the following is added to the MapGen group. These can be accessed from the Start menu. The entries are as follows:

1. readme.txt contains installation instructions, current issues and contact information.
2. Users Guide contains instructions and tutorials.
3. MapGen is the custom windows software used to create maps for use in WinMACCS.

11.2 Uninstallation of MapGen

1. *Open the Windows* Control Panel found in the Settings category on the Windows *Start* menu.
2. Double click on the *Add/Remove* programs entry.
3. Select the entry *MapGen*.
4. Click on *Remove*.

11.3 Tutorial One: How to Create a Map as a GIF file

11.3.1 Step One: Start the MapGen program.

Navigation to a location is by latitude and longitude as expressed as a decimal.

Enter -22.906 for the latitude, -43.195 for the longitude and 100 km for the distance in the text boxes on the form.

Click the Go button.

The map generated should look like the map shown in Figure 11-1.

When the Go button was clicked, a radioactive symbol was placed on the map showing the latitude and longitude requested.

Figure 11-1 MapGen interface

11.3.2 Step Two: Load a sample site and save a gif file

From the main menu, select Sample Sites/Duane Arnold.
The parameters of the Duane Arnold site are loaded into the map form.

From the main menu, select File/SaveAs Gif

A window is opened allowing you to select a preexisting folder for the gif file.

Select a folder and click OK
A file named image_map.gif is created.

11.4 Tutorial Two: Exploring Mouse Clicks on the Map

11.4.1 Step One: Load Rio de Janeiro

Type the latitude, longitude and distance as shown in Figure 11-1*, namely ---22.906, -43.195 and 100.*

Click the Go button.
The distance from the center point (latitude/longitude point) to the far right or left edge of the map in this example is 100 km. This is not exact because the width of the map is an even 500 pixels. Because of this these distances are close, but differ by a single pixel.

11.4.2 Step Two: Measure the distance from the center to the edge of the map

Click on the right edge of the map until the line drawn from the center of the map to the edge is perfectly straight.
Notice that the distance shown is 99.565 km

Click on the left edge of the map until the line drawn is perfectly straight
Notice that this distance shown is 100.377. Observe that the right edge is slightly different than the left edge. Notice that neither is exactly 100 km. This is because the number of pixels used to display the map is a counting number. However, when used in WinMACCS, we will be assuming that the maps are square and of the measurement requested (100 km in this example). This error is less than one percent of the expected (maximum percent error in this example is .435%), and was deemed acceptable.

11.4.3 Step Three: Measure a long distance from the center to the edge

Enter 3500 for distance. Click on Go. Click on right edge of map.
Distance shown is the shortest flight distance (straight line distance). Notice that it is curved because of the distortion of the map. The error between the expected and the actual distance has now increased to around 80%.

The distance entered by the user was translated to an altitude by MapGen before the map was requested from Map Point. A viewing angle is shown in the interface (30.64353 km). This value was empirically determined to minimize the distance error. However, for large distances, Map Point changes the map view from a flat view to a distorted view in order to view the globe (because the curvature of the earth). The correlation between the actual distance to the edge and the distance requested is not valid for large distances. However, for shorter distances (say 2000 km), the map view is consistent with our calculations of the viewing angle.

You can trust the distance displayed in the box labeled ‘Distance from Center to Click’. The lesson learned is that before exporting maps created manually; check the distances you request against the true distance measured by clicking the mouse on the edge. When distance lines shown are curved lines, the MapGen method of determining map dimensions has failed.

11.4.4 Step Four: Clear distance marks from the map

Enter 50 for distance.
Click Go.
Click on right edge of map.
Click 'Clear Marks'.
Click Go.

Notice that the line drawn from center to edge has been erased.

11.5 Tutorial Three: Creating a set of maps to be used by WinMACCS

11.5.1 Step One: Create a file, MapSummary.txt

Open a WinMACCS sample problem such as Sampled Values LNT.
Sample problem is opened.

Open form Network Evacuation Direction for Scenario One.
A form containing a polar grid is opened.

Click on the button titled Create Map File as shown in Figure 11-2*.*
An information box is displayed.

Read and click OK.
A file called MapSummary.txt was created and placed in the WinMACCS project Input folder.

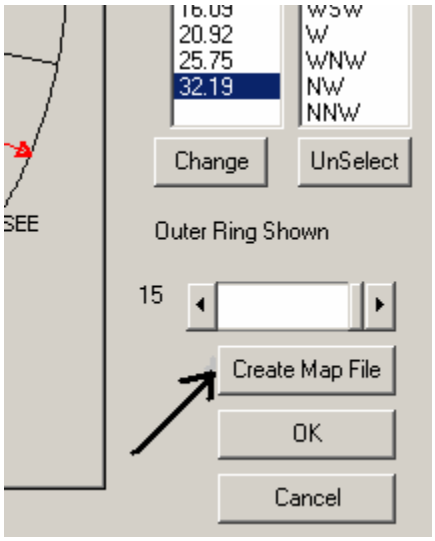

Figure 11-2 Create map interface file

11.5.2 Step Two: Generate maps using MapGen and map interface file, MapSummary.txt

Select File/Generate Gif from File from the main menu as shown in Figure 11-3*.*

Figure 11-3 Generate maps from map interface file

Locate and select the MapSummary.txt file created in the previous step.

Click the Open button.

Choose your project Data folder for the gif file destination as demonstrated Figure 11-4.

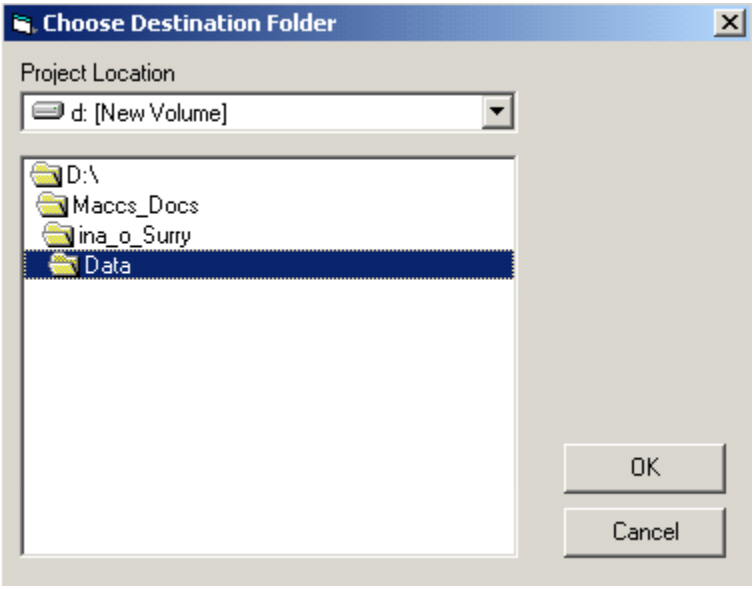

Figure 11-4 Select folder for map files

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APPENDIX A MELMACCS VERSION 2.0 USER'S GUIDE

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TABLE OF CONTENTS

TABLE OF FIGURES

Figure Page

Appendix A: MelMACCS Version 2.0 User's Guide

A.1 Introduction

This document provides directions on how to use MelMACCS in both interactive and batch modes to create a MACCS source-term file from a MELCOR plot file. The standard method of processing a MelMACCS output in MACCS is to use the WinMACCS interface (Bixler et al., 2015) either using the import file option or the cyclical file set option, which can be used to process multiple MelMACCS output files. Section A.6 describes the requirements for creating the MACCS input files directly without using the WinMACCS interface.

Not all MELCOR plot files have the information that MelMACCS needs. The release paths must be defined in the MELCOR input cards to create MACCS-specific data in the plot file. A description of the cards needed for MELCOR is included in this document.

MelMACCS comes with a set of default core inventories that can be used without modification. However, it is preferable that the user define his/her inventories specific to the reactor that is being evaluated. Information on how create an inventory file is provided in the MelMACCS Models Document that is provided with MelMACCS.

Section A.2 of this document describes how to use MelMACCS in interactive mode. Section A.3 describes the MelMACCS data files. Section A.4 defines the format of a project file. Section A.5 describes how to run MelMACCS in batch mode. Section A.6 describes how to use a MelMACCS source term file without using the WinMACCS interface. Finally, Section A.7 describes the inputs required to run MELCOR so that the plot file is compatible with MelMACCS.

A.2 MELMACCS in Interactive Mode

MelMACCS is started by selecting the MelMACCS symbol from the Windows Start Menu, as shown in Figure A-1. This application leads the user one window at a time through the process of creating a MELCOR/MACCS interface file, also referred to as a MelMACCS output file or a MACCS source-term file.

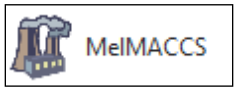


Figure A-1 MelMACCS Symbol

A.2.1 Selecting the MELCOR Plot File

The first form that opens when the user starts MelMACCS contains the text "Welcome to the MELCOR to MACCS wizard." The *Select File* button is clicked to choose a MELCOR plot file, see Figure A-2. The user chooses the MELCOR plot file and clicks *Open*. The MELCOR plot file commonly has a .ptf extension. The user clicks *Next* > to continue.

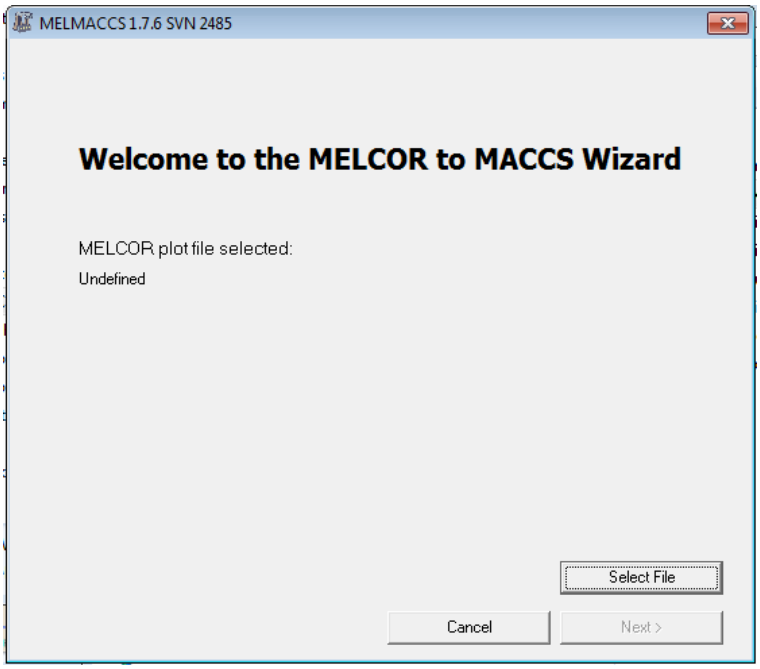


Figure A-2 MelMACCS "Welcome" Window

A.2.2 Reading the MELCOR plot file

The next form contains the text "Reading data from plot file…" After this form is opened, MelMACCS starts to read the plot file. When this step has completed, the last time read from the MELCOR plot file is displayed next to the text labeled *Problem Time*, Figure A-3. The user clicks the *Next >* button to proceed to the next form. Optionally, the *Create Text File* button can be clicked to create an ASCII file containing a summary of the MELCOR data that are relevant to MACCS.

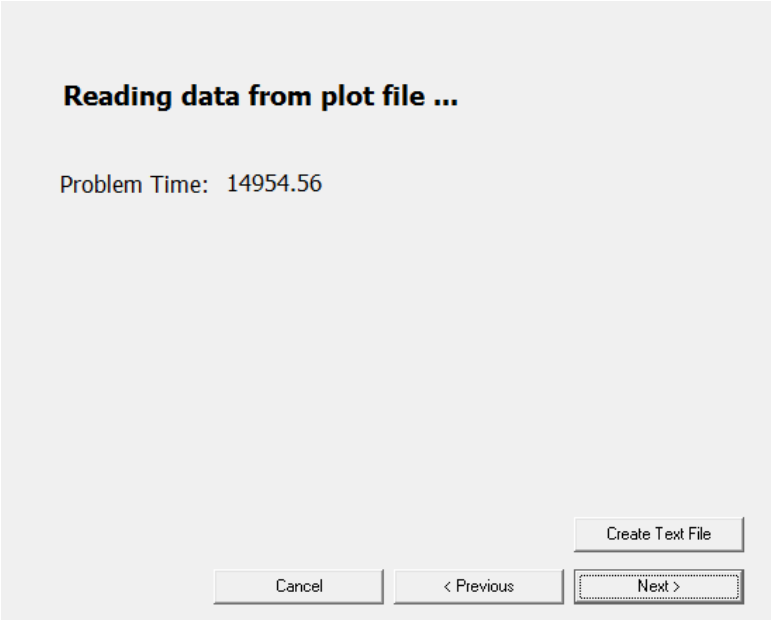


Figure A-3 MelMACCS Window 3: Problem Time

A.2.3 Entering the Reference Time and Height

The default value of the MelMACCS variable labeled *Reference time,* Figure A-4*,* corresponds to a MELCOR input variable indicating the reactor scram time. Typically, MELCOR input is set up so that reactor scram occurs at time zero, but this need not be the case. When either this value is missing from the plot file or when the value on the plot file is less than the time of the first data block written to the plot file, the value is set to zero. The primary significance of this parameter is to control the start of radionuclide decay in the MACCS calculation.

This time is also used to adjust the time of plume releases saved in the MelMACCS output file. For example, when the value of the time of accident initiation is input to be 100 s and the user selects a plume segment that starts at MELCOR time 300 s in a *Release Path* form, the starting time for the plume written to the MACCS Input file is 300 -100 = 200 s.

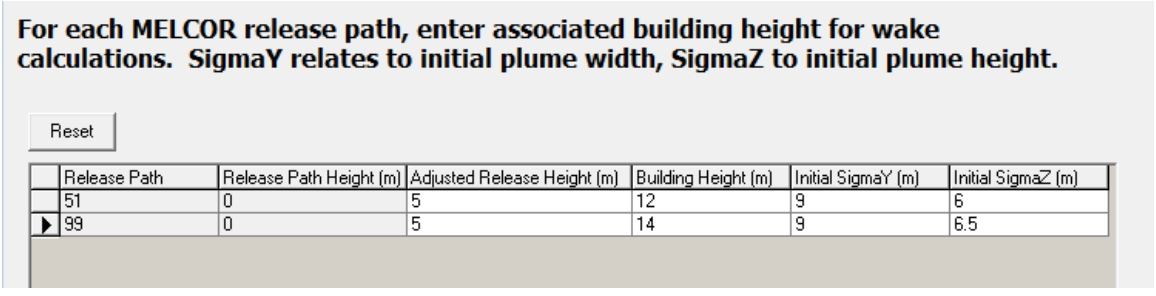
The text box labeled *MELCOR height associated with ground level (m)* (Figure A-4) is the ground height in the MELCOR reference frame. This value is used to adjust the height of plume segments saved in the MelMACCS output file. For example, when MELCOR records a release path height of -10 m and this corresponds to a height of 30 m above ground, this variable should be set to –40. This value is used to calculate the MACCS variable PLHITE by subtracting it from the height for the release path in the MELCOR reference frame.

Figure A-4 Setting up MelMACCS run: Reference Time and GRD Level height

The user clicks *Next* > to continue.

A.2.4 Entering the Release Path Geometry

The grid shown on Figure A-5 contains the release path identification number, the release path height, and the adjusted release height based on subtracting the user entered value labeled "*MELCOR height associated with ground level"* from the release path height read from the MELCOR plot file. All of this information comes directly from the MELCOR plot file except the value used to adjust the release height.



	Release Path	Release Path Height (m)	Adjusted Release Height (m)	Building Height (m)	Initial SigmaY (m)	Initial SigmaZ (m)
	51	0	5	12	9	6
▶	99	0	5	14	9	6.5

Figure A-5 Release path geometry

The value of the adjusted release height is user editable. For each plume segment, MACCS requires a value of building height to evaluate whether a buoyant plume is entrained in the building wake. Initial plume dimensions, SigmaY and SigmaZ, are also needed by MACCS. These values represent the standard deviation of the Gaussian plume in the cross-wind and vertical dimensions, respectively. The MACCS User's Guide recommends values as follows:

SigmaY = W/4.3 = 0.23 x W
SigmaZ = H/2.15 = 0.47 x H

Here, W is the building width and H is the building height. These values are not always trivial to select since most buildings are rectangular or have even more complex footprints and have multiple roof heights. In reality, the best choice for the building dimensions often depends on wind direction, but single, representative values are required by MACCS. Fortunately, these values only influence the plume concentrations at relatively short distances and generally have modest influence at distances of several kilometers downwind.

Clicking the button labeled *Reset* removes all the values entered by the user and replaces the Adjusted Release Height with the default values.

When a row in the grid is defined, clicking the button labeled *Auto Fill* copies the row to vacant entries in subsequent rows until a completed row is encountered. The row is copied is the last defined row.

The user clicks *Next* > to continue.

A.2.5 Specifying the Deposition Velocity Algorithm

Figure A-6 allows the user to select the method of calculating MACCS variable VDEPOS. There are two model choices. The first is based on gravitational settling. The default model is based on a correlation of expert elicitation data (Bixler et al., 2013).

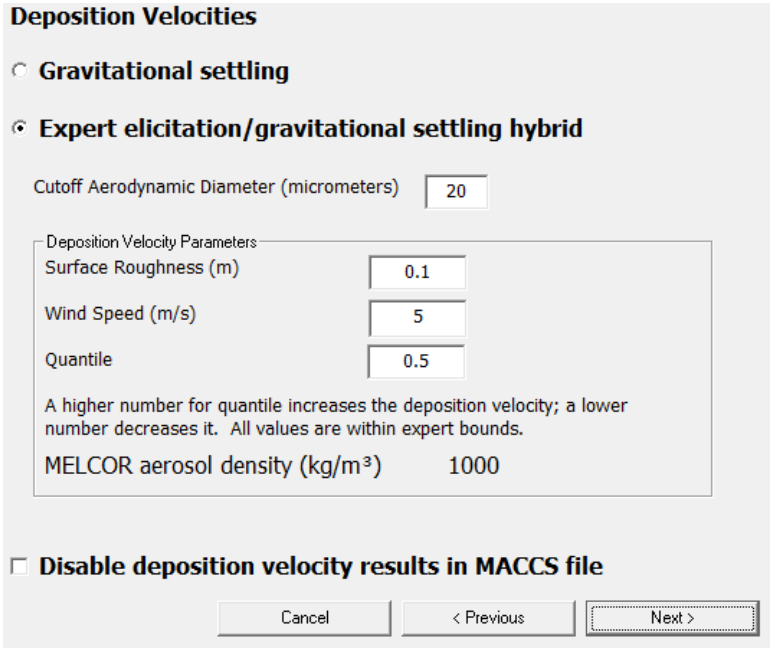


Figure A-6 Selecting deposition velocity algorithm

When the expert elicitation option is chosen, additional inputs are required as follows:

- *Cutoff Aerodynamic Diameter*: This is the point at which the deposition velocity calculation is switched from the expert elicitation correlation to gravitational settling. The default and recommended value is 20 μm. An exception to this rule is made when the gravitational settling result for a particle diameter is less than the value calculated using the expert elicitation correlation for the cutoff diameter, in which case the velocity calculated for the cutoff diameter using the expert correlation is used.

- *Surface Roughness*: This is a measure of the terrain roughness. By default this is set to 0.1 m. This value is allowed to range from 0.01 m to 1.0 m. A value of 0.03 m represents grasslands; a value of 0.1 m to 0.8 m represents suburban terrain; a value of 0.2 m to 1.0 m represents forested land.

- *Wind Speed*: The default wind speed is 5 m/s. The range of values are 0.5 to 10 m/s.

- *Quantile*: This is a measure of degree of belief in deposition velocity, as expressed by a group of experts. A value of 0 represents the smallest value that the experts thought to be possible; a value of 0.5 represents the best guess; a value of 1 represents the highest value that the experts thought to be possible. This value is 0.5 by default.

Two of these parameters, wind speed and surface roughness, must be specified as representative values over the grid and for all weather trials. Surface roughness often varies over the grid and wind speed varies from hour to hour and weather trial to weather trial. As a result, the user needs to choose a reasonable, representative value in light of the expected variability at a site.

The *MELCOR Aerosol Density* is read from the MELCOR plot file. When this value is not included on the plot file, the number 1000 kg/m^3 is used as a default.

When the check box titled *"Disable deposition velocity results in MACCS file"* is checked, the deposition velocity is calculated, but when the MACCS input images are written to the MelMACCS output file as comments. Thus, both WinMACCS and MACCS ignore these cards and deposition velocities must be specified separately. This option is useful for uncertainty analyses for which deposition velocity is treated as an uncertain input.

For example, the input image containing the deposition velocity is disabled in the following line because it starts with the * character:
*DDVDEPOS001 8.7563E-04

When the check box is not selected, the input image containing the deposition velocity is enabled, as shown in the line below:
DDVDEPOS001 8.7563E-04

The user clicks *Next* > to continue.

A.2.6 Entering the Mass Threshold Fractions

Figure A-7 allows the user to filter out release paths and plume segments that are insignificant. There are two threshold values that can be entered to allow this filtering as follows:

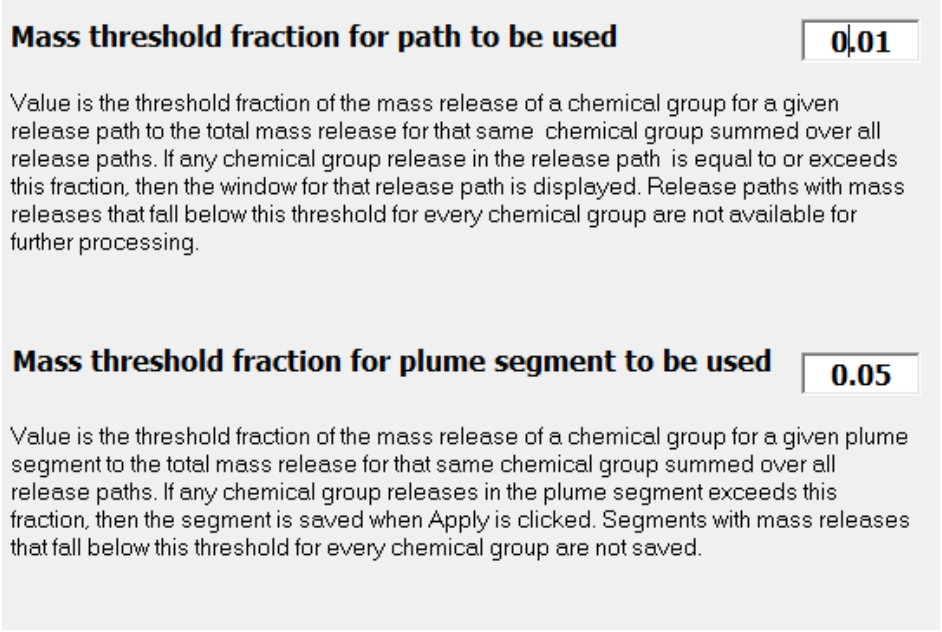


Figure A-7 Mass threshold fraction

When zero is entered for *Mass threshold fraction for path to be used,* every *Release Path* form is active. Otherwise, only forms with a release fraction exceeding or equal to the threshold are active. Inactive forms do not appear on the screen.

When zero is entered for *Mass threshold fraction for plume segment to be used* and the *Apply* button is clicked in the *Release Path* form, every plume segment has an entry in the form showing the plume segment parameters. When a positive value is entered, each release fraction for each chemical group of a plume segment is tested against the threshold value. When a plume segment has at least one release fraction for a chemical group that is greater than or equal to the threshold, it is applied to the form showing the plume segment parameters. The user clicks *Next* > to continue.

A.2.7 Entering the Options That Affect the Core Inventory

Figure A-8 allows the user to specify the set of chemical groups to be included, the core inventory, and the ring (when the MELCOR plot file contains release data for more than one ring).

All available chemical groups found on the MELCOR plot file that are not specifically excluded are shown on this form, see Figure A-9. The user can eliminate chemical groups from this form by editing the MelMACCS.usr file in the section labeled /EXCLUDE-GROUPS. Groups listed in this section do not appear in the MelMACCS user interface.

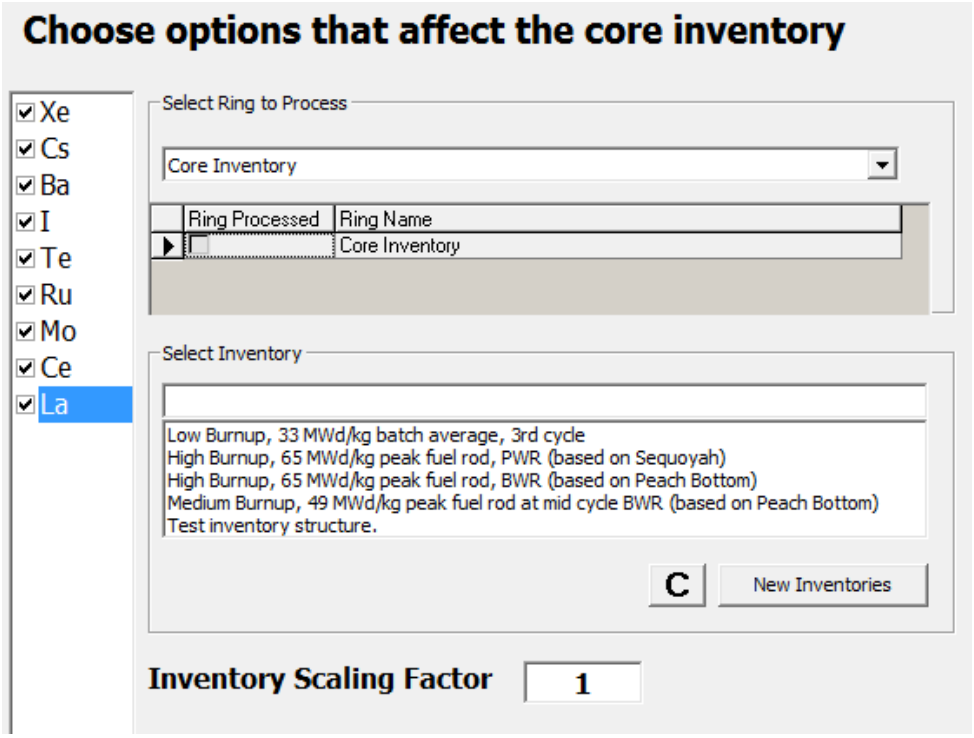


Figure A-8 Core inventory

Example from the MelMACCS.usr file. In this example, chemical group B is excluded from the MelMACCS interface.

```
/EXCLUDE-GROUPS
B
/END
```

Select the chemical groups that are to be included in the MACCS analysis using the check boxes. By default, all chemical groups are included and the user must deselect groups to be excluded.

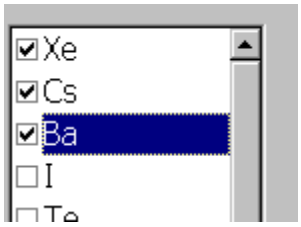


Figure A-9 Specifying core inventory

Next, select the inventory that is closest to the inventory modeled by MELCOR. A description field is shown in the user interface to describe each inventory. Ideally, the same ORIGEN calculation is used to define the MELCOR inputs and to create an inventory for MelMACCS. This is done by creating one of more inventory files, as discussed in Section 6 and also in the MelMACCS Models Manual.

The inventory list in Figure A-10 shows the core inventories read from the MelMACCS.inv file found in the installation folder and additional inventory files created by the user. User-defined

inventory files must be located in the MelMACCS_Docs\Inventories folder in the Windows user area. Under Windows 7, the inventory folder is C:\Users\username\MelMACCS_Docs\Inventories. All inventory types defined in these files are displayed in the user interface and can be selected, as shown below:

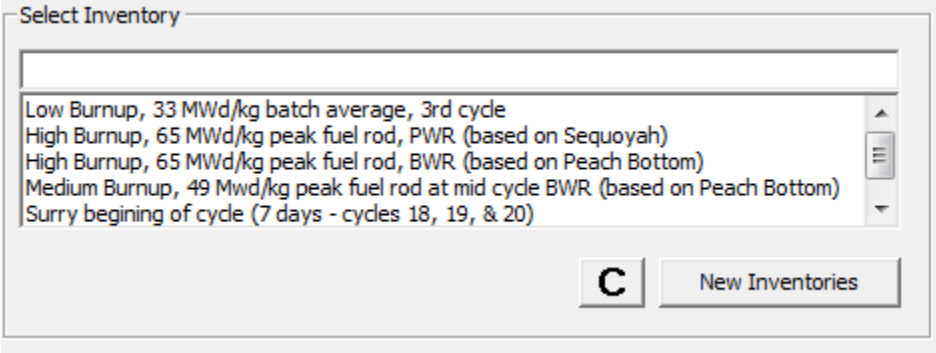


Figure A-10 Core inventory lists

New inventory files can be added by clicking the button labeled *New Inventories.* When a new inventory file is added, a copy of that file is placed in the MelMACCS_Docs\Inventories folder. The next time MelMACCS starts, the new inventory file is automatically loaded.

Inventories can be prevented from loading into MelMACCS by removing the inventory file from the MelMACCS_Docs\Inventories folder.

All inventories can be removed from the current MelMACCS run by selecting the button labeled *C*. This does not change the files that will be loaded the next time MelMACCS is run.

MELCOR is commonly run with multiple rings, but in most cases a single release fraction is recorded in the plot file for all of the rings. However, MELCOR can be run in a mode that records release fractions on the plot file for each ring. This is especially useful for spent fuel pools, where different rings can represent fuel of different ages. MelMACCS processes multi-ring release fractions when they are present on the MELCOR plot file. When this is done, each ring has a set of initial masses and released masses on the plot file. The same set of chemical groups is common for all rings. Because the rings may represent fuel of different ages, each ring may be associated with a different inventory. When the MELCOR plot file only contains a single ring, the selection has already been made and the user does not need to do anything further.

The user may select the ring in Figure A-11 to consider in any order.

Figure A-11 Selection of ring(s)

After the plots associated with a ring have been displayed in the *Release Path* windows, the *Ring Processed* check box is checked the next time this window is displayed. The ring can be reevaluated. This check box is only a visual guide to help the user keep track of which rings have already been evaluated.

The default value of the inventory scaling factor is 1.0, which is usually the desired value, but this value can be changed and defines the value of the MACCS parameter, CORSCA. This parameter is useful when the MELCOR calculation has been done for a reactor that is similar, but different in size and power rating, than the reactor that is to be evaluated with MACCS.

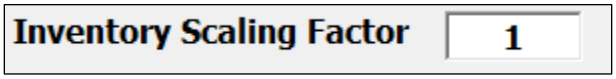


Figure A-12 Inventory scaling factor

The user clicks *Next >* to continue.

A.2.8 Creating the MelMACCS output File

A form with the text *Select plume segments and click "Apply…",* referred to as the *master form*, Figure A-13**,** is opened along with supporting *Release Path* forms, Figure A-15, where each window corresponds to a MELCOR release path written to the plot file. Each release path is displayed provided that the mass release threshold requirements are met, Figure A-14. After defining plume segments from the release path windows, as described in this section, the MelMACCS output file is created.

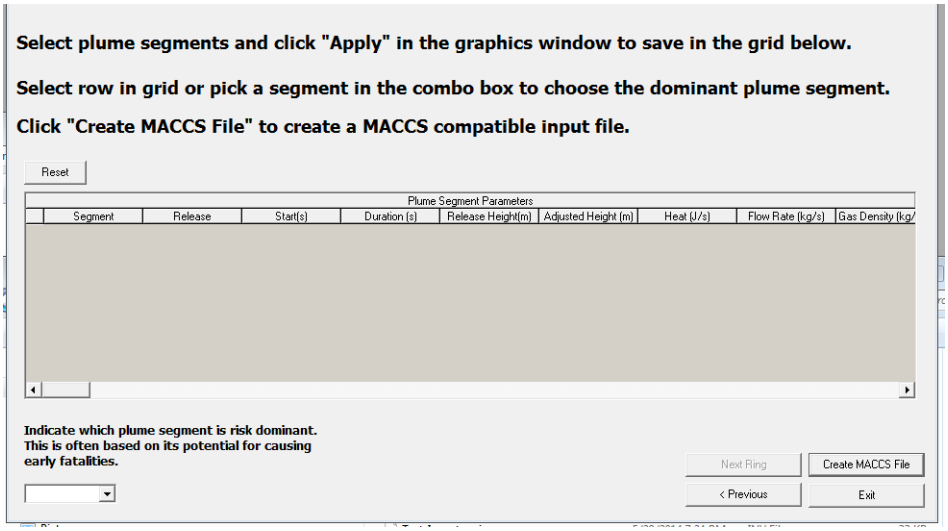


Figure A-13 Master form (empty)

Plume segments can be selected from the *Release Path* windows, and applied to the *master form* in the manner described below. When these segments are applied in the *master form* from the *Release Path* windows, the data are summarized in the table titled *Plume Segment Parameters.*

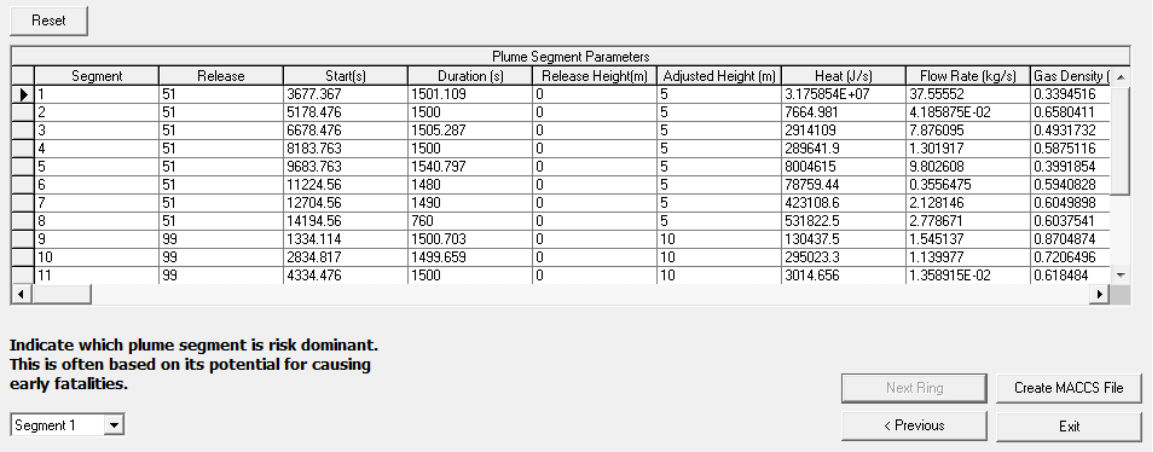


Figure A-14 Master form (filled)

For the user to create a MelMACCS output file:

- The user records times in the *Recorded Times* window of the *MELCOR Release Path* forms, Figure A-15. These times define the beginning and end of the plume segments associated with this release path.
- The user clicks the *Apply* button in a *Release Path* form to apply the times record in the plot to the *master form*.
- The user indicates in the pull down menu with the title *"Indicate which plume segment is risk dominant…"* the risk dominant plume segment. This can also be chosen by selecting the row containing that segment. Typically, the plume segment with the highest heat release and/or fastest flow rate is chosen as the risk dominant segment.
- After all release paths have been considered, the user clicks the *Create MACCS File* button to create the MELMACCS output file.
- To start over again, the user can click the *Reset* button in the *master form* to clear all plume segments from the grid.
- Clicking the *Next Ring* button returns to the form containing options that define the core inventory.

When the header area on any given column heading of the table is clicked on the *master form*, the data in the table are reordered. The order is toggled between ascending and descending order each time the heading is clicked. However, the values in the MelMACCS output file is always created in ascending order of plume release time (the column labeled *Start (s)* in the table).

Clicking the *Exit* button closes MelMACCS.

A.2.9 Navigating a release path form

The following options are available on a release path form:

- A dashed, vertical line tracks the mouse movement as the mouse moves across a plot. The time corresponding to the location of the mouse is displayed adjacent to the label *Current Time.* Clicking on the plot records a time in the *Recorded Times* window. A series of n recorded times, t_1, t_2…t_n corresponds to plume segments $[t_1,t_2]$, $[t_2,t_3]$, …, $[t_{n-1},t_n]$.

- A time can also be recorded by typing a value in the text box labeled *Current Time* and pressing the *Enter* key on the keyboard. Clipboard functionality is also supported in this text box.

- To select an entry in the *Recorded Times* list, the user can click on the entry in the list. This value is copied to the clipboard using Ctrl-C. This function allows easy duplication of recorded of times between *Release Path* forms.

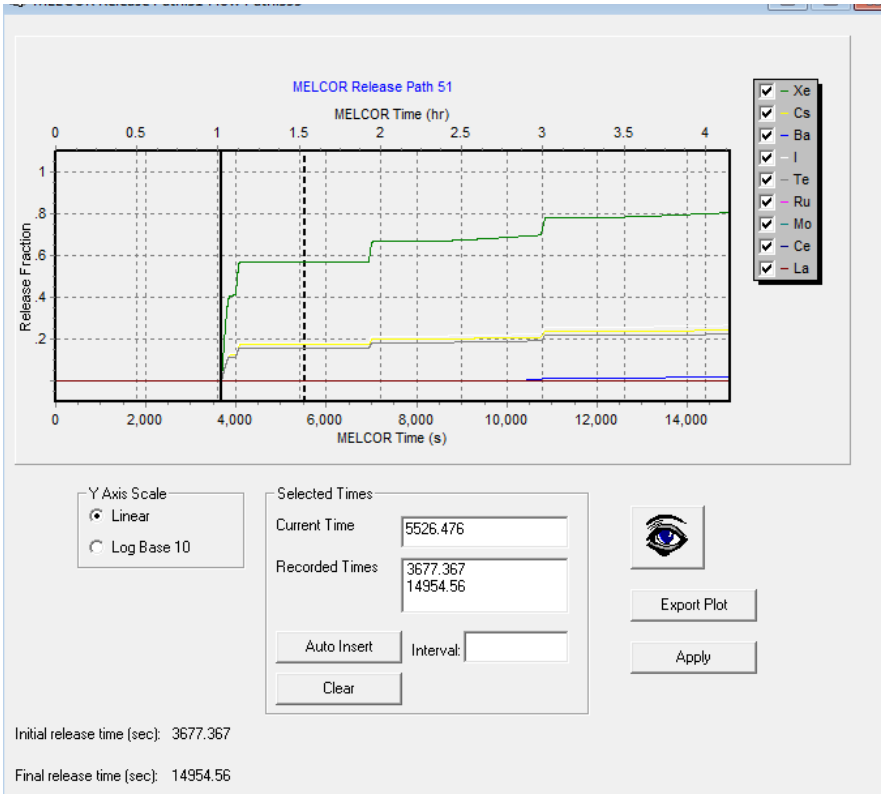


Figure A-15 Release path form

In Figure A-15, times 3677.367 and 14954.56 seconds are recorded. The mouse pointer is positioned over 5526.476, but the user has not recorded this time by clicking the left mouse button.

- A single selected time can be deleted by clicking the time in the list labeled *Recorded Times* and pressing the *Delete* key on the keyboard, see .

All user recorded times are deleted when the user clicks the button *Clear.* The time of the first and last mass released is retained.

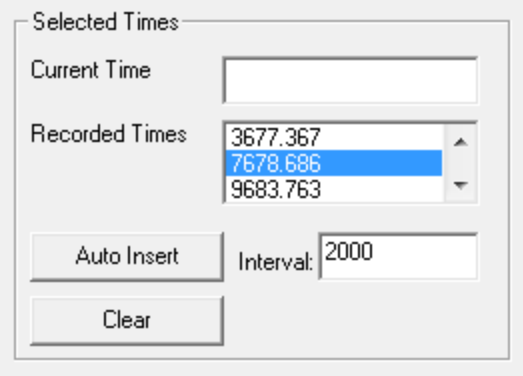


Figure A-16 Deleting plume segment time

Time 7678.686 is selected. Remove by pressing the Delete key.

- A sequence of times is inserted by typing in a time interval in the *Interval* box and clicking the *Auto Insert* button. To use this feature, at least two times must be recorded. Insertion is between the first and last recorded times at the interval indicated. The last interval is usually shorter than the selected time interval.

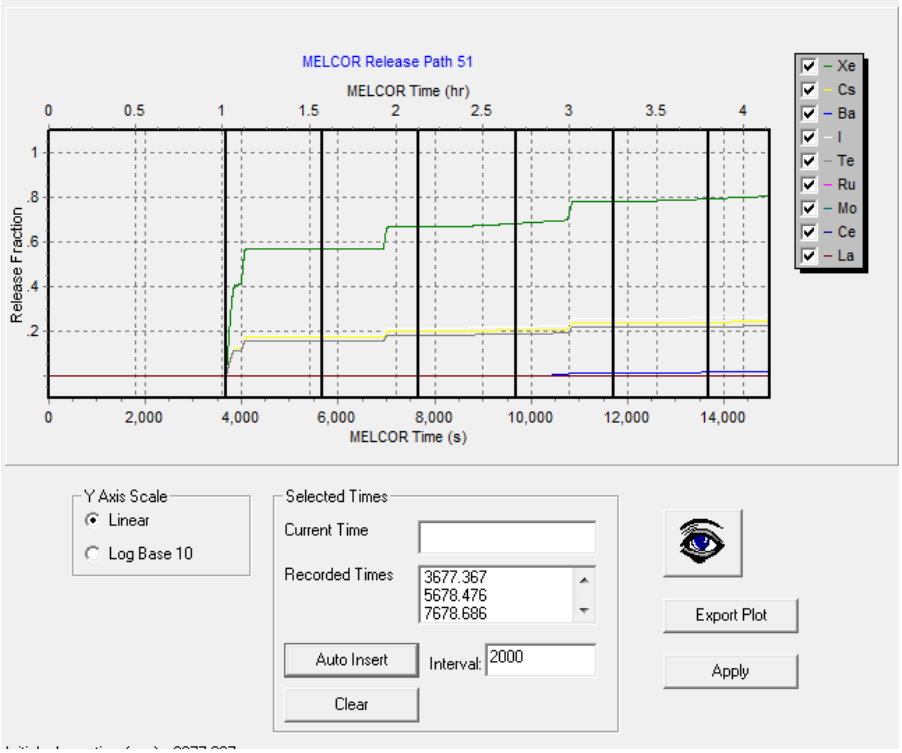


Figure A-17 Release path form automatic time intervals

In the illustration, auto Insert is used to insert lines at intervals of 2000 s.

- Toggle the zoom mode by clicking on the zoom button. This prevents recorded times from being selected.

When zoom mode is on, the graph can be magnified by drawing a box from top left to bottom right by a drag and release motion using the left mouse button. To return to the original graph magnification, repeat this process, but move the mouse from bottom right to top left.

Times can be recorded while the graph is magnified provided the zoom mode is off.

Zoom Off *Zoom On*

Figure A-18 Zoom on/off

- Y-axis scale can be changed from linear to log by choosing the appropriate radio button in the group labeled *Y Axis Scale.*

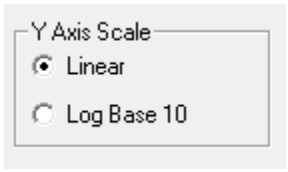


Figure A-19 Changing scale on release form

- The plot can be exported in various formats by clicking *Export Plot* button. The formats include graphics formats, such as Windows bmp (bitmap) and jpeg, and text formats such as ASCII, HTML, and XML. All MELCOR data used in MELMACCS calculations can also be exported as text by clicking the *Create Text File* button on the form that contains the text "Reading data from plot file…".. The *Export Plot* option only exports the data shown in the plot window.

- The *Apply* button on the Release Form can be clicked to apply the recorded times to the *master form*. When this button is clicked, previously applied plume segments associated with the current release path are replaced.

The time preceding the first nonzero flow greater than or equal to the reference time and the time corresponding to the last nonzero flow are automatically recorded for the user, although these can be manually deleted. These times mark the logical beginning and end of a set of plume segments for this release path.

The time corresponding to the first nonzero flow is recorded on the bottom left of the graphics window adjacent to the label *Initial release time (sec)* and similarly for the *Final release time (sec).*

The plot legend in Figure A-15 shows the chemical groups chosen in the form *"Choose options that affect the core inventory"*. The legend entries can be unchecked in the legend, which causes the corresponding release fraction curve to become invisible in the plot. This option is used to help identify the data series in the plot. This option does not modify the chemical group information saved in the MelMACCS output file. When one or more chemical groups are to be removed from consideration in the MelMACCS output file, the user must navigate back to form

titled "*Choose options that affect the core inventory"* by clicking the <*Previous* button on the *master form.*

A.3 MelMACCS Data File Format

A project file is defined in an easily editable format. A general format is used for all data files read by MelMaccs. This includes the user defined inventory files (.inv), the user project files (.mel), the user settings file, MelMACCS.usr, and the MelMACCS data files, MelMACCS.ini and MelMACCS.inv.

With the exception of the MELCOR plot file, the format of data files read by MelMACCS all follow the same language rules. This format supports editing in an ASCII text editor, such as Microsoft Notepad. Microsoft Word and Microsoft Word Pad can add extra invisible formatting characters that are not compatible with MelMACCS, so these editors should not be used to modify these files. Additionally, new lines in the MelMACCS data files are indicated by the Windows standard carriage return (ASCII 13) and line feed (ASCII 10) characters. Because UNIX files have only the line feed character, files created on a UNIX box are not compatible with MelMACCS.

The following components are found in a MelMACCS data file:

- A comment is indicated by an asterisk, "*", in column one. Comments can occur anywhere in the file.
- Comments following data in a data line are not supported. Place all comments on their own line beginning with an asterisk in column one.
- A keyword starts with a slash, "/", in column one, followed by a keyword followed by value(s) associated with that keyword. The number of values required depends on the keyword.
- Values are separated on data or keyword lines using spaces or tabs.
- A data block begins with a keyword line. This is followed by a series of data lines. The end of the data block is indicated by the following character sequence starting in column one, "/END".
- Some keyword lines are not associated with a data block.
- Blank lines are permitted in the file. Blank lines can occur anywhere.
- When a value is a string containing spaces, it must be enclosed by the double quote characters (" ").
- White space can be any number of spaces, tabs or otherwise unreadable characters. More precisely, characters with an ASCII code less than or equal to 32 are considered white space.

The following is an example of a keyword taken from a MelMACCS.usr file. The keyword is "DEFAULT-DIR". The value is enclosed in double quotes because it contains a space.

```
/DEFAULT-DIR "C:\MelMACCS Results"
```

The following is an example of a data block from the file MelMACCS.ini. The keyword is "COMPOUND-GROUPS". The data block contains four lines of data.

```
/COMPOUND-GROUPS
CSI   I   0.488444
CSI   Cs  0.511556
CSM   Cs  0.73478922
CSM   Mo  0.26521078
```

/END

A.4 Format of a Project File

A project file is used to define settings of a MelMACCS project. When a keyword or data block is not defined in a project file, a default value is used when the keyword or data block is optional. However, some keywords and data blocks are required.

The keywords in a MelMACCS project file are not case sensitive.

A.4.1 Chemical groups

List of chemical groups to be considered, matching the entries in the MELCOR plot file.

This is an optional data block.

Keyword	Default	Example
Chemical_Groups	All available chemical groups are selected	/Chemical_Groups Xe Cs Ba /End

A.4.2 Ring number

Ring number associated with the MELCOR plot file. When there is only one ring or the ring referenced is out of range, the value is set to 1.

The value following the keyword is as follows:

- Ring number, integer

This is an optional variable.

Keyword	Default	Example
Ring	1	/Ring 2

A.4.3 Inventory scale factor

The inventory scale factor defines the value to write to output file for MACCS variable CORSCA.

The value following the keyword is as follows:

- Scale factor, positive real

This is an optional variable.

Keyword	Default	Example
Inventory_Scale	1.0	/Inventory_Scale 1.2

A.4.4 Reactor type

Value indicates which inventory to use when calculating the core inventory. The value of the Reactor_Type must be an inventory defined in the file MelMACCS.inv or in an inventory file found in the MelMACCS_Docs\Inventories folder in the user area are loaded into the user interface when MelMACCS starts. Under Windows 7, the inventory folder is C:\Users\username\MelMACCS_Docs\Inventories.

The value following the keyword is as follows:

- Inventory identifier, inventories provided in the MelMACCS.inv file or another user loaded inventory file. LOW, HIGH_PWR, HIGH_BWR and MEDIUM_BWR are provided in MelMACCS.inv.

This is a required variable.

Keyword	Default	Example
Reactor_Type	None.	/Reactor_Type HIGH_PWR

A.4.5 Reference time

This is used to adjust the plume release time, PDELAY. The reference time is subtracted from the start time of each plume segment to calculate the time written to the MelMACCS output file.

The value following the keyword is as follows:

- Time (sec), real, not to exceed the last time on the plot file

This is an optional variable.

Keyword	Default	Example
ATime	0	/ATime 100.0

A.4.6 Ground height relative to MELCOR

This is used to adjust the MELCOR height associated with each release path considered. The value is used to define the MELCOR height associated with ground level, i.e., the height of the ground (grade) in the MELCOR reference frame. See section A.2.3 for more information about how this variable is used.

The value following the keyword is as follows:

- Height (meters), real, range [-1000.,1000.]

This is an optional variable.

Keyword	Default	Example
Ground_Height	0.	/Ground_Height 5.0

A.4.7 Building Height, Sigma Y and Sigma Z

This data block has an associated data line for every path defined on the MELCOR plot file. See section A.2.4 for more information about how these variables are used.

The lines in the data block contain the following:

- MELCOR release path, integer

- Building Height (meters), real, range [1.,1000.]
- Initial SigmaY (meters), real, range [0.1,1000]
- Initial SigmaZ (meters), real, range [0.1,1000]

This is a required data block. There must be an entry for every path on the MELCOR plot file.

Keyword	Default	Example
Path	None	/ Path 51 10.0 0.2 0.3 99 4.0 0.5 0.6 101 7.0 0.8 0.9 /End

A.4.8 Adjusted Release Height

This keyword allows the adjusted release height to be set for each release path. The automatic adjustment for all paths using the value entered for /Ground_Height is ignored for paths listed in this data block.

The lines in the data block contain the following:
- MELCOR release path, integer
- Release height (meters), real, suggested range [0.,1000.]

Not all paths are required to be listed.

This is an optional data block.

Keyword	Default	Example
Adjusted_Release_Height	Height of Release Path minus Ground _Height	/Adjusted_Release_Height 51 0.0 99 10.0 /End

A.4.9 Deposition Velocity

This indicates the method used to estimate deposition velocity. See section A.2.5 for more information about how this variable is used.

Possible values are EXPERT and GRAVITY.

This is an optional variable.

Keyword	Default	Example
Deposition_Velocity	EXPERT	/Deposition_Velocity EXPERT /Deposition_Velocity GRAVITY

A.4.10 Aerodynamic Cutoff Diameter

The aerodynamic particle size above which the gravitational settling method is used to calculate the deposition velocity is defined on this line. This variable is used only when the deposition

velocity method is set to EXPERT. See section A.2.5 for more information about how this variable is used.

The value following the keyword is as follows:

- Cutoff diameter (μ meters), real, positive number, range (0,25]

This is an optional variable.

Keyword	Default	Example
Cutoff_Diameter	20 μ meters	/Cutoff_Diameter 25.0

A.4.11 Surface Roughness

A representative value of surface roughness is entered on this line. This variable is used only when the deposition velocity method is set to EXPERT. See section A.2.5 for more information about how this variable is used.

The value following the keyword is as follows:

- Surface roughness (meters), real, range [0.01,1.]

This is an optional variable.

Keyword	Default	Example
Surface	0.1 (m)	/Surface 0.2

A.4.12 Wind speed

The wind speed is entered on this line. This variable is used only when the deposition velocity method is set to EXPERT. See section A.2.5 for more information about how this variable is used.

The value following the keyword is as follows:

- Windspeed (meters/second), real, range [0.5,10.]

This is an optional variable.

Keyword	Default	Example
Wind_Speed	5.0 (m/s)	/ Wind_Speed 4.0

A.4.13 Quantile

The quantile level determines the expert coefficients to use. This variable is used only when the deposition velocity method is set to EXPERT. See section A.2.5 for more information about how this variable is used.

The value following the keyword is as follows:

- Quantile, real, range [0.,1.]

This is an optional variable.

Keyword	Default	Example

Quantile	.5	/Quantile 0.76

A.4.14 Output Format of Deposition Velocity

This value determines whether the deposition velocity values are written to the MelMACCS output file as comments. The value is set to True when the WinMACCS user wants to override the deposition velocities with other values entered in WinMACCS.

This is an optional variable.

Keyword	Default	Example
Disable_Deposition_Velocity	False	/Disable_Deposition_Velocity True

A.4.15 Release Path Threshold

This variable is used to eliminate paths that have an insignificant release. See section A.2.6 for more information about how this variable is used.

The value following the keyword is as follows:

- Release path threshold, real, range [0.,1.]

This is an optional variable.

Keyword	Default	Example
ReleasePathThreshold	0	/ ReleasePathThreshold 0.001

A.4.16 Plume Release Threshold

This variable is used to eliminate plume segments that have an insignificant release. See section A.2.6 for more information about how this variable is used.

The value following the keyword is as follows:

- Plume release threshold, real, range [0.,1.]

This is an optional variable.

Keyword	Default	Example
ReleaseThreshold	0	/ ReleaseThreshold 0.0001

A.4.17 Default Path Boundary

The time boundaries for each path can be determined based on the first and last mass released, or can be based on specific user entered times. When running MelMACCS in interface mode, the boundaries are initially determined by the first and last mass released.

This keyword allows the user to override the boundary values with constants. These boundaries are used for every path. See section A.4.18 to override the boundary determination for specific paths.

Possible values associated with the boundary assignment are as follows:

- AutoBoth: MelMACCS determines the upper and lower bound based on the first and last mass released. No further parameters are needed.
- AutoBeginOnly: MelMACCS determines the lower bound. The upper bound needs to be supplied.
- AutoEndOnly: MelMACCS determines the upper bound. The lower bound needs to be supplied.
- AutoNone: Both the lower and the upper bounds need to be supplied.

This is an optional variable.

Keyword	Default	Examples
Default_Plume_Boundaries	AutoBoth	Default_Plume_Boundaries AutoBoth /Default_Plume_Boundaries AutoBeginOnly 12000. /Default_Plume_Boundaries AutoEndOnly 4000. /Default_Plume_Boundaries AutoNone 4000. 12000.

A.4.18 Path Boundaries

The determination of the plume boundaries may be specified per path. This takes precedence over the default method for determining the boundaries. See section A.4.17 for a description of the possible default methods.

The first value on a line is the MELCOR release path. The values following the release path are identical to the values following the Default_Plume_Boundary keyword described in section A.4.17.

This is an optional data block. When path boundaries are not defined for a path the default boundaries are used.

Keyword	Default	Examples
Plume_Boundaries	Value of Default_Plume_Boundaries	/Plume_Boundaries 51 AutoNone 4000. 13000. 99 AutoBeginOnly 13000. /End /Plume_Boundaries 99 AutoEndOnly 4000. /End

A.4.19 Default Plume Segment Interval

A time interval can be specified to define plume segments for all release paths. The insertion of this time interval occurs between the path boundaries for every release path that has not been eliminated because of mass threshold limits as defined in section A.4.15. This operation is similar to the Auto Insert function in the user interface; however, it is applied to all release paths.

See section A.4.20 to specify the release interval by path.

This line causes plume segments to be defined for each path at the interval specified. When the user wants to define plume segments for a limited number of paths, this line should not be used. However, the time interval for a specific release path overrides this time interval, as described in the following subsection.

The value following the keyword is as follows:

- Time interval for insertion in seconds, real

When this line is not present, there is no default interval insertion. In this case, all insertions are specified by path as described in section A.4.20 or by specifying each release point manually in section A.4.21.

This is an optional variable.

Keyword	Default	Example
DefaultAutoInsert	none	/DefaultAutoInsert 1500.0

A.4.20 Plume Segment Interval

A time interval can be specified to determine plume segments. The insertion of this time interval occurs between the path boundaries for the path specified. This operation is similar to the Auto Insert function in the user interface.

This line causes the default insertion interval for the specified path defined using the /DefaultAutoInsert line to be replaced.

The values following the keyword are as follows:

- MELCOR release path, integer
- Time interval for insertion in seconds, real

Not all paths are required to be listed.

This is an optional variable. There can be multiple entries of this line.

Keyword	Default	Examples
AutoInsert	Time interval defined on the DefaultAutoInsert line is applied to all paths	/AutoInsert 51 1000.0 /AutoInsert 99 2000.0

A.4.21 Manual Plume Segment Definition

Time points can also be specified for individual release paths. This can be used in place of the /AutoInsert or /DefaultAutoInsert lines, but when auto insertion is defined for a path and specific release times using the /ManualInsert data block are defined for that same path, all times are applied.

This data block can be repeated for multiple release paths.

The value following the keyword is as follows:

- MELCOR release path, integer

The lines in the data block contain the following:

- Time (seconds), real

This is an optional variable.

Keyword	Default	Examples
ManualInsert	none	/ManualInsert 99 1515. 4000. 10000. 25000. /End

A.4.22 Plume Segment of Maximum Risk

This line identifies which plume segment is considered to have the maximum risk in the MACCS calculation. This value defines the MACCS parameter MAXRIS. For the MACCS calculation the plume segments are ordered by start time of release, independent of the release path. MaxRisk identifies the plume segment ordered by start of the release.

The values following the keyword are as follows:

- Plume release number identifying interval, integer

This is an optional variable.

Keyword	Default	Examples
MaxRisk	1	/MaxRisk 14

A.5 Running MELMACCS in Batch Mode

MelMACCS can be run from a command prompt window (cmd.exe) or from a batch file (.bat file). The parameter values are read from a MelMACCS project file (.mel extension). A sample project file, sampleProject.mel, based on the sample plot file demo.ptf, is provided with MelMACCS. The format of this file is described in section A.4.

The format of a command is as follows:

MelMACCS.exe projectfile [-i melcorplotfile] [-o maccsfile][-r]

The order of the optional parameters as indicated by the brackets is not important.

The following is an example of a line to run MelMACCS in batch mode:

MelMACCS.exe sampleProject.mel -i "D:\Demo.ptf" -o MACCSInterface.inp -r

There are three files specified. When full paths are not specified, it is assumed that the files are in the users default folder. File paths and names should be delimited by quotes when there are embedded spaces in the file names.

When any of the optional arguments are specified, the project file, in this example sampleProject.mel, must be specified.

The meanings of the arguments are as follows:

- MelMACCS project file: This must be the first argument. This file has a special format containing all information that would normally be entered in the user interface via mouse clicks and keyboarding. All values specified in the project file are loaded into the interface.

  The interface opens with the preloaded values when the -r option is not used. In this case, the values specified in the project file are viewed in the user interface.

  When the –r option is used and an error occurs, the message is appended to the log file, AutoRun.log, located in the same folder as the MelMACCS project file.

  A MelMACCS project file can be debugged by omitting the -r option, which allows the user to review the settings.

- MELCOR plot file: The plot file is specified with the optional entry, “-i melcorplotfile”. The plot file normally ends with a .ptf extension. This must be defined when the -r option is used. When missing, a visual dialog box displays an error message as follows in Figure A-20:

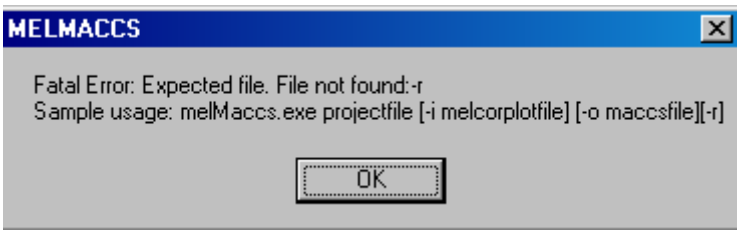


Figure A-20 Error message

- MelMACCS output file: The output file is specified in the optional entry, “-o maccsname”. This entry defines the MACCS interface file that MelMACCS creates. When not specified, the file is called MACCS.inp and is placed in the users default folder.

- Run in background: Using the “-r” option indicates that MelMACCS is to be run without any user input.

  When the –r option is not used, a dialog box pops up explaining any errors, such as data validation errors. This allows the user to adjust values in the interface. When the –r option is used, any error other than an informative message in MelMACCS causes the batch mode to abort. Messages are appended to the AutoRun.log file found in the same folder as the MelMACCS project file. In this case, the user should open this file to view the error message.

When using the -r option, any plume segment deemed illegal is not applied. This does not cause an error, but a message is written to the log file. Illegal plume segments are those with time durations greater than 86400 s, segments or paths not meeting the threshold criteria, and segments with zero flow or zero gas density. The user can force these segments to be written to the MelMACCS output file only when running in user interface mode. Additionally, plume segments are not created when there is no mass released.

A.6 Creating a Complete MACCS Input File

The MelMACCS output file created contains MACCS input cards that define the source term. This is not a complete MACCS ATMOS input file. To create a complete input file, the source-term file created by MelMACCS must be merged with another MACCS ATMOS input file.

One technique that can be used to incorporate the source-term information into an existing MACCS input file is to copy the contents of the MelMACCS output file and paste it at the end of an existing ATMOS input file, provided the file does not include multiple source terms. This works because MACCS uses the last data values encountered in the input file. The user needs to be cautious when there are fewer values for a given MACCS variable in the MELMACCS interface file than are in the exiting MACCS input deck. For example, when the number of plume segments, chemical groups, radionuclides, pseudostable radionuclides, or particle size groups is less than the original set in the MACCS ATMOS file, errors may be generated or the calculation may not produce correct results.

To merge a MelMACCS output file with an existing MACCS ATMOS input file

- Open the MelMACCS output file in Notepad or another ASCII text editor. Select the contents of this file and copy to the windows clipboard (using the Copy function from the Edit menu).

- Open an existing MACCS ATMOS input file in a text editor. Paste the contents of the clipboard into an ATMOS file immediately preceding the first line consisting of a "." in column one. The amended file is a valid ATMOS file that can be run using MACCS.

A new input variable, GRPNAM, is included in the MACCS cards, one vector entry for each chemical group. This is required by WinMaccs, but at this time MACCS does not recognize this card and ignores it. When the output from MELMACCS is imported into WinMaccs, these cards should not be removed.

A.7 Creating a MELCOR Plot File with MACCS Information

There are two major versions of MELCOR available, 1.8.6 and 2.1. Input for 2.1 differs from 1.8.6. Directions are included in the MELCOR user's guide. The following excerpts have been copied and edited for this document.

A.7.1 Directions for MELCOR version 1.8.6:

When using 1.8.6 RG, created on November 20, 2002, or later, the following input cards should be included in the MELGEN input.

MACCSnn - MACCS Release Path Definition

1 <= nn <= 99 is the release path assigned by the MELCOR user.

This input card contains one parameter as follows:

(1) MCCSFP - MCCSFP is the number of the flow path; the sign is the sign of flow corresponding to "release".

(type = integer, default = none, units = none)

This record allows identification of flow paths that serve as “release” paths for the consequences code, MACCS. For these paths, and these paths only, fluid and radionuclide transport data are written to the plot file.

Example: This example is consistent with DEMO(rhonom=2500, the sample MELCOR input file released with MelMACCS.

MACCS51 399

MACCS99 398

A.8 Directions for MELCOR Version 2.1:

The MELCOR version must be 2.1.1461 or later. Previous versions of 2.1 MELCOR create plot files that are not compatible with MelMACCS.

FL_MACCS – MACCS Release Paths Definition

This record allows identification of flow paths that serve as release paths for the consequences code MACCS. For these paths, and these paths only, data about fluid and radionuclide transport through the path are written to the plot file. The record can also be used simply to force such data to be written to the plot file for other applications. However, all MACCS flow paths in a MELCOR plot file are evaluated by MelMACCS, so only the ones relevant to MACCS calculations should be defined when the plot file is to be processed with MelMACCS.

MACCSN - The number of MACCS release paths.
(type = integer, default = 0, units = dimensionless)

The following data are input as a table with length MACCSN. Variables are input in the order listed below.

Variable	Description
NFL	Table row index.
	(type = integer, default = none, units = none)
MACCSNAME	MACCS release path name (type = character*16, default = none, units = none)
MACCSNUMBER	MACCS release path (type = integer, default = none, units = none)
FPNAME	Flow path name (type = character*16, default = none, units = none)
DIRFL	Direction of flow corresponding to release. FROM TO (type = character*4, default = none, units = none)

MELCOR allows the flow path name to be any character string. However, MelMACCS requires this to be converted to an integer. This means that it is necessary to use an integer in the field FPNAME.

The field MACCSNAME is not currently used by MelMACCS.

When comparing the input format, a positive flow release path in 1.8.6 input corresponds to the keyword FROM, a negative number corresponds to the keyword TO.

Example corresponding to the same problem as referenced above in describing the sample input for 1.8.6:

FL_MACCS 2
1 'Release 51' 51 '399' FROM
2 'Release 99' 99 '398' FROM

A.8.1 Adding New Chemical Groups:

All chemical groups written to the MELCOR plot file are considered for processing. However, for a new chemical group to be accepted by MelMACCS, the MelMACCS.ini file needs to be edited. Each chemical group is associated with a set of elements. The association corresponding to the MelMACCS.ini file is in a section labeled /CHEM-TO-ISO. This is necessary to calculate the core inventory by isotope.

Chemical groups are removed from consideration by MelMACCS by modifying the section titled /EXCLUDE-GROUPS in the MelMACCS.usr file found in the Windows user's folder. Under Windows 7, this folder is C:\Users\username\MelMACCS_Docs, where username is the user's login name.

New compound groups such as CsI can be added by editing the MelMACCS.ini file. See the MelMACCS Models Document for more information.

A.9 REFERENCES

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Chanin, D., M. L. Young, J. Randall, and K. Jamali, "Code Manual for MACCS: Volume 1, User's Guide," **NUREG/CR-6613**, SAND97-0594, US Nuclear Regulatory Commission, Washington, DC, 1998.

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