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MACCS User Guide – Version 5.0

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ABSTRACT

MACCS is used by the Nuclear Regulatory Commission (NRC) and various national and international organizations for probabilistic consequence analysis of nuclear power accidents. This user guide is intended to assist analysts in understanding the MACCS/MACCS-UI User Interface (UI) model and to provide information regarding the code. This user guide version describes MACCS Version 5.0, model history, explains 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. This report is part of a series of reports documenting MACCS. Other reports include the MACCS Theory Manual, MACCS Verification Report, Technical Bases for Consequence Analyses Using MACCS, as well as documentation for preprocessor codes including SecPop, MelMACCS, and COMIDA2.

ACKNOWLEDGEMENTS

The technical content for this User Guide highly leverages the content from previous MACCS User Guides, most recently the *MACCS User Guide - Version 4.2, Revision 1,* SAND2023-01315. Additional contributions to this User Guide were received from NRC and Sandia National Laboratories 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 users the ability to develop complex consequence modeling scenarios.

The following individuals, listed in alphabetical order, contributed to the updates for this version of the MACCS User Guide. Thank you for your contributions.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The purpose of this document is to provide a user guide and reference document for MACCS, which is used for calculating health and economic consequences from a release of radioactive materials into the atmosphere. The MACCS code suite has a diverse user base including the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of Energy (DOE), various research organizations, nuclear power plant applicants and licensees, as well as international regulators and technical support organizations.

In 2022, the NRC initiated an effort to replace the legacy WinMACCS user interface with a new interface and related backend code written in a modernized code language, known as MACCS-UI. This user guide describes the functions of both MACCS-UI and the MACCS executable together. For simplicity, the combined functions of the MACCS executable and MACCS-UI are often referred to as MACCS collectively. However, MACCS-UI and the MACCS executable are separate codes and it is often useful to distinguish the functions of the two codes when discussing specific features of the system. This User Guide applies to MACCS 4.2 and MACCS-UI 5.0.

ACRONYMS AND TERMS

Acronym/Term	Definition
AT	annual dose threshold
ATL	annual dose and lifetime threshold
ATMOS	atmospheric model
ATD	atmospheric transport and dispersion
CCDF	complimentary cumulative distribution function
CHRONC	chronic consequence model
COMIDA2	food chain model
CRAC	Calculations of Reactor Accident Consequences
DCF	dose conversion factor
DDREF	dose and dose rate effectiveness factor
DOE	U.S. Department of Energy
EARLY	early consequence model
EPA	U.S. Environmental Protection Agency
FGR	Federal Guidance Report
GDP	gross domestic product
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory model
ICRP	International Commission on Radiation Protection
LHS	Latin Hypercube Sampling
LNT	linear no threshold
LT	lifetime threshold
MACCS	MELCOR Accident Consequence Code System
MACCS-UI	MACCS user interface
NOAA	U.S. National Oceanic and Atmospheric Administration
NPPs	nuclear power plants
NRC	U.S. Nuclear Regulatory Commission
PL	piecewise linear
PRA	probabilistic risk assessment
RDEIM	Regional Disruption Economic Impact Model
SecPop	Sector Population and Economic Estimator
SOARCA	State-of-the-Art Reactor Consequence Analyses Project
Sandia	Sandia National Laboratories
SRS	simple random sampling
SQA	software quality assurance
TEDE	total effective dose equivalent

1. INTRODUCTION

MACCS is the NRC code used to estimate the offsite consequences of potential severe accidents at nuclear power plants. 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, protective action countermeasure strategies, dosimetry, health effects, and economic impacts are addressed in the code.

1.1. History

The historical reference to the consequence code has been MACCS or MACCS2, which was related to the version number for each code. In 2001, the NRC initiated efforts to create a Windows based user interface to augment the MACCS command line interface codes. This effort created greater ease of use in performing consequence analysis by enhancing user file management methods and easing user data input, helping reduce the likelihood of user errors.

Beginning in 2022, the NRC initiated an effort to modernize the Windows-based user interface and code framework using current industry standards for the code development efforts. This user guide describes the functions of both MACCS-UI and MACCS command line codes together. For simplicity, the combined functions of MACCS and MACCS-UI are often referred to as MACCS. However, MACCS and MACCS-UI are separate tools, and it is often useful to distinguish between their different functions.

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

- Calculations of Reactor Accident Consequences (CRAC) was used in the landmark Reactor Safety Study (WASH-1400) to estimate consequences from a set of hypothetical accidents. WASH-1400 was published in 1975 but a CRAC user manual does not appear to have been 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 probabilistic risk assessment (PRA) study documented in NUREG-1150 (NRC, 1989).
- MACCS2 1.12 was published in 1997 as a command line and batch-process code (Chanin and Young, 1997). In September 2001, version 1.13 was released to allow execution under newer operating systems and to fix several bugs in the previous version. The work to develop MACCS2 was sponsored by the DOE and was focused largely on generalizing MACCS to be used for nonreactor applications.
- Since 2001, a new version of MACCS has been released approximately every two years. New versions offered enhancements in addition to addressing bugs.
- WinMACCS was first released to the public in March of 2008 as Version 3.4.0. WinMACCS has been used for many important studies, including the State-of-the-Art Reactor Consequence Analyses (SOARCA) (Chang et al., 2012; Bixler et al., 2013, and Sandia National Laboratories, 2013), the SOARCA uncertainty analyses for Peach Bottom, Sequoyah, and Surry (Mattie et al., 2016; Sandia National Laboratories, 2019; Ross et al., 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., 2014).

- MACCS-UI was initially released in September of 2024 as Version 5.0**.** As a successor to WinMACCS, MACCS-UI was created to modernize the code and provide continued maintainability with improved interface useability. With previous software languages and tools at risk of deprecation and removal of vendor support, the entire code set was rewritten in modern programming languages. Other improvements were made to create a pathway to new technologies, as needed.

A detailed chronicle of changes made to MACCS is distributed along with MACCS and is entitled "History of MACCS." Parallel revisions to WinMACCS are similarly documented in the "History of WinMACCS". A "History of MACCS-UI" detailing changes from previous versions is also distributed along with MACCS.

1.2. Software Quality Assurance

Development of MACCS, MACCS-UI, and other supporting codes in the suite of MACCS software is controlled by a set of software quality assurance (SQA) requirements in compliance with NRC requirements. The details of the SQA plan are documented in MACCS Software Quality Assurance Plan, Version 1.7, which is available to MACCS users upon request. The elements of the SQA requirements include:

- QA training for the software developers, testers, and administrators;
- documentation of software requirements;
- documentation of software implementation;
- test plans;
- management of revision history and configuration control;
- test reports;
- bug tracking; and
- client tracking.

Bug tracking for MACCS version 4.0 and earlier used Melzilla, an implementation based on Bugzilla. Currently, as of this report's publication, bug tracking for newer versions of MACCS (later than 4.0) use FogBugz.

1.3. Overview

In 2020, the NRC initiated an effort to modernize the WinMACCS codebase to assure continuity of continue use in performing consequence analyses. Coding efforts started in 2023 to create the MACCS-UI code using modern software languages, tools, and software development concepts. The MACCS-UI code was fully tested and verified on Windows 11, the most recent release of the Windows OS system during the development period. This effort was intended to address the following needs.

- Modernize the software application to remove code and compiler deprecation and related cyber risks.
- Provide modern system architecture, code design, and code reuse capabilities.
- Reduce code maintenance by deploying modular design principles.
- Provide pathway for future MACCS improvements for use in cloud and web designed systems.

- Maintain the WinMACCS 4.2 functionality as well as backward compatibility with WinMACCS projects for ease of user migration to the MACCS-UI system.
- Maintain the WinMACCS user operation and file management concepts for ease of user migration to the MACCS-UI system.
- Remove window popup forms to reduce complexity in user operation of the system.
- Simplify and reduce the effort for completing input forms.
- Reduce the likelihood of user errors in performing consequence analyses.
- Replace the Visual Basic framework with an Electron-based framework.
- Replace the Microsoft Access database with code data structures and the related code operations.
- Improve the security and maintainability of the MACCS-UI codebase.

The result of this development effort was the MACCS-UI code. MACCS-UI is currently integrated with versions of MACCS, COMIDA2, and Latin Hypercube Sampling (LHS) to perform the required functionality provided in WinMACCS. Projects created in WinMACCS can be imported into MACCS-UI, and still be run. MACCS can still be run in stand-alone fashion apart from the MACCS-UI interface. However, there are significant advantages for using the MACCS-UI framework for running consequence calculations.

1.4. MACCS Framework

1.4.1. MACCS Suite Overview

The MACCS Code Suite is comprised of several separate tools. These are:

- MACCS, which calculates the plume dispersion as well as early and late consequences,
- MACCS-UI, which facilitates model selection, parameter input, and report generation. This supersedes the WinMACCS interface.
- AniMACCS, a separate utility for visualizing and animating MACCS output data over a geospatial map background.
- MelMACCS, a separate tool to interface with MELCOR. It creates MACCS source term input files from MELCOR plot files.
- SecPop, which calculates estimated population and economic data based on coordinates, using U.S. census data and economic databases.

1.4.2. Components

The components of MACCS-UI are shown in Figure 1-1. MACCS-UI allows one or more calculations to be run on a computer. The user can modify model input parameters and model settings and save them in the project database. The user can initiate a MACCS-UI 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, MACCS-UI uses a code called LHS to generate vectors of sampled input parameters to create a set of equally probable realizations. LHS can use either of two sampling algorithms: simple random sampling (SRS) or LHS, which is a type of stratified sampling. MACCS-UI can also run two other codes: COMIDA2 to evaluate parameters affecting the food ingestion pathway; and CombineSource to combine source terms for multiple units and/or spent fuel pools. These codes act as preprocessors for MACCS.

MACCS-UI can run LHS to generate values for the uncertain parameters and to build 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 accident progression 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.

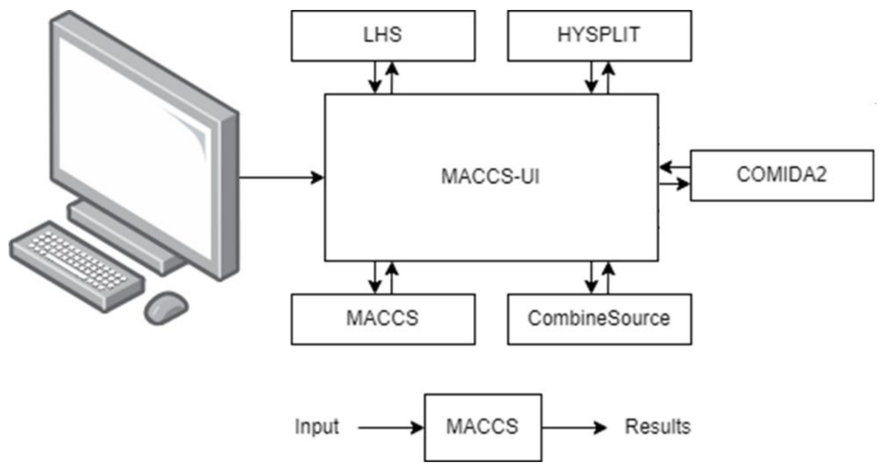

Figure 1-1. MACCS-UI components

SecPop is run before using MACCS-UI or MACCS and creates population distributions for grids with 16 and up to 64 compass sectors.

Data files managed by MACCS-UI 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 MACCS-UI using the model and input settings stored in an underlying database. These input files can include Atmos*n*.inp, Early*n*.inp, Chronc*n*.inp, Comida*n*.inp, and Lhs.inp. 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. Files are described further in Section 2.7.

2. GETTING STARTED

2.1. Overview of the User Interface

Instructions for MACCS-UI installation are located within the ReadMe file in the installation download folder. These instructions walk the user through running the installation executable and obtaining a product key. For MACCS-UI version 5.0, a product key is required and may be obtained by following the instructions in the ReadMe. If the key has expired, users may obtain a new key from the downloads site.

In this document, names or labels that appear in the MACCS-UI interface are italicized. For more in-depth information on some parts of this section, see Section 3.

When a project is opened, created, or imported from the *HOME* page, the *INPUT* page opens, as illustrated in Figure 2-1.

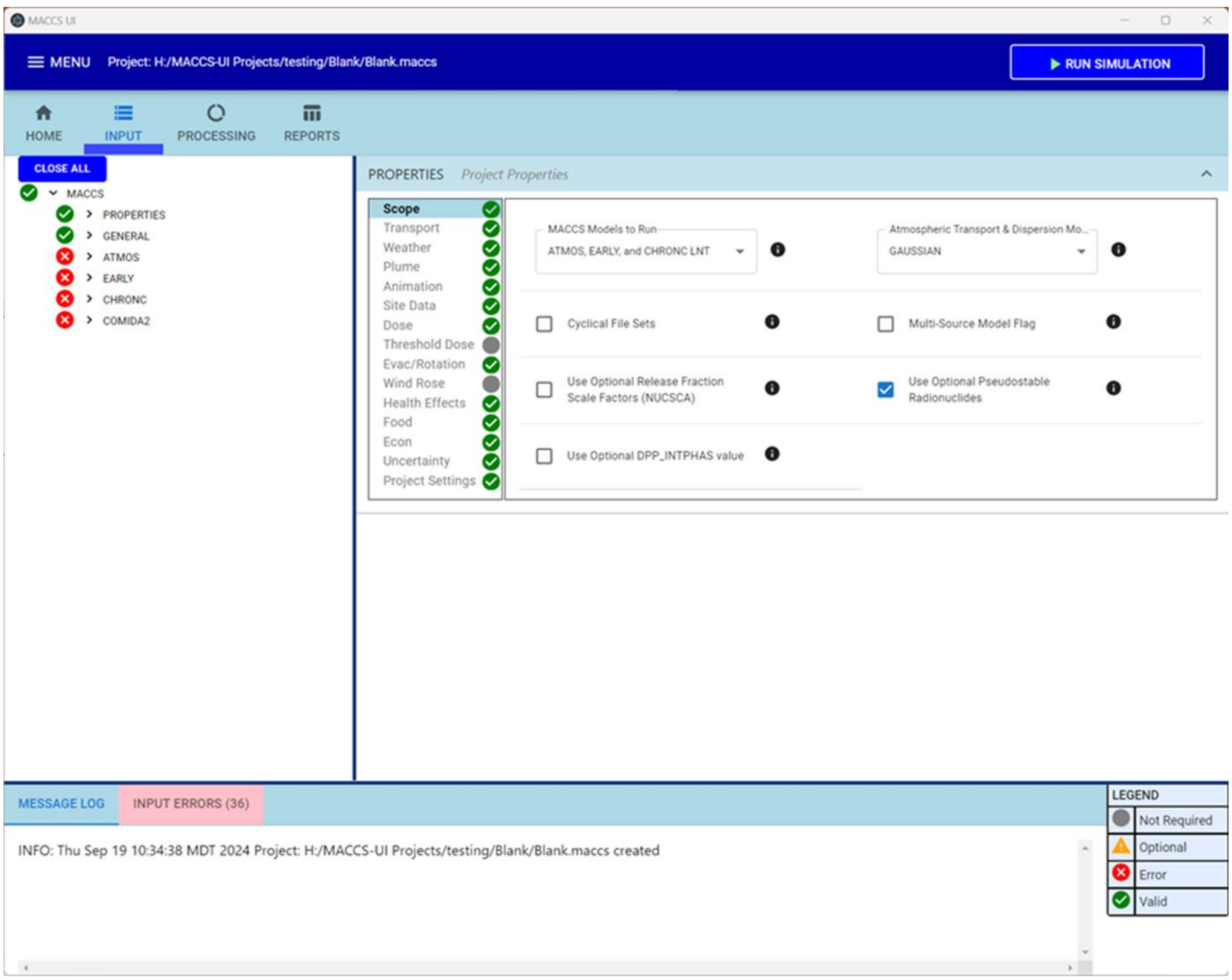

Figure 2-1. Sample *INPUT* page

The caption at the top of the window indicates the name and location of the project.

The parameters tree on the *INPUT* page contains a list of forms that are used to select model options, modify input parameters, and create file links. The meanings of the icons beside category and variable names are displayed in the legend, as shown in Figure 2-1. This legend automatically opens.

2.1.1. Main Menu

Different options for managing MACCS-UI projects are available in the *MENU* (see Figure 2-2 and Figure 2-3).

Figure 2-2. MACCS-UI *MENU* button

Figure 2-3. *MENU* options

- File
    - Open Project
    - Save Project
    - *Import MACCS Input File*, which allows users to import MACCS input files.
    - *Export MACCS Output as Text*, which allows users to export MACCS binary output as text.
- Edit
    - *Find Variable*, which allows the user to search forms by variable name.
- View
    - *Show Legend*, which enables or disables the legend.
- Tools
    - *Force Reload*, which can be used to force reload the application in case of errors.
- Help
    - *Read Me*, which opens ReadMe.pdf in the browser.
    - *MACCS Documentation*, which opens a folder in the installation directory containing documentation relevant to MACCS-UI.
    - *Check License*, which allows users to check if their license key is valid.
    - *About*, which provides current version and contact information for questions.

2.1.2. Navigation Bar

Different pages are accessible by the navigation bar (see Figure 2-4).

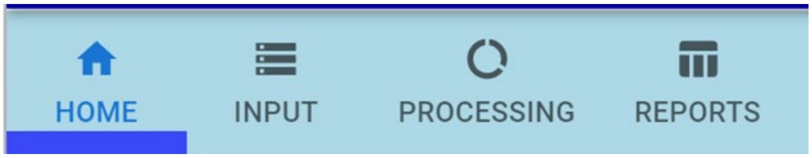

Figure 2-4. MACCS-UI navigation bar

- *HOME*, where users can open, create, or import projects.
- *INPUT*, where data are entered.
- *PROCESSING*, which shows the status of ran or running jobs.
- *REPORTS*, where reports can be created.

Options in this menu are different from those in WinMACCS main menu. Appendix C.1 contains a table of the MACCS equivalents of the different WinMACCS main menu options.

2.1.3. Parameters Tree

Like WinMACCS, parameters are organized in a tree structure, located on the *INPUT* page. The highest level is a main category; below that, a category; then a subcategory; and at the lowest level, a form, where data are entered.

Icons used in the tree next to category names define the underlying form states:


An X-ed red circle indicates that the user needs to complete or correct this form before running MACCS.


A checked green circle indicates that the user has completed this form and that data defined on this form are needed to perform a calculation. Forms marked with this include completed optional forms.


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


A gray circle indicates that this form is not required and will be ignored. Variables on this form will not be included in the calculation.

NOTE: These symbols do not indicate whether input values are correct or incorrect; they only indicate whether they are consistent and within acceptable bounds imposed by MACCS-UI. The user is responsible for entering and performing adequate quality assurance/control to verify that reasonable values of input parameters are entered in the interface.

The example in Figure 2-5, shows the main categories: *PROPERTIES, GENERAL, ATMOS, EARLY, CHRONC,* and *COMIDA2*. *GENERAL* contains categories named *File Specifications*, and *Output Options*. More information under each of the categories can be viewed by clicking the > symbols.

Within the *ATMOS* main category, the *Spatial Grid* category has been completed, as indicated by the green checked circle next to the category name.

The *Deposition* category is also shown. The X-ed red circle indicates that there is missing or inconsistent information in at least one this category's forms. The *Dry Deposition* form needs attention, as indicated by the X-ed red circle next to the form name. This form contains one variable: *VDEPOS*. If the form name or the parameter is clicked, the corresponding parameter modification form is opened.

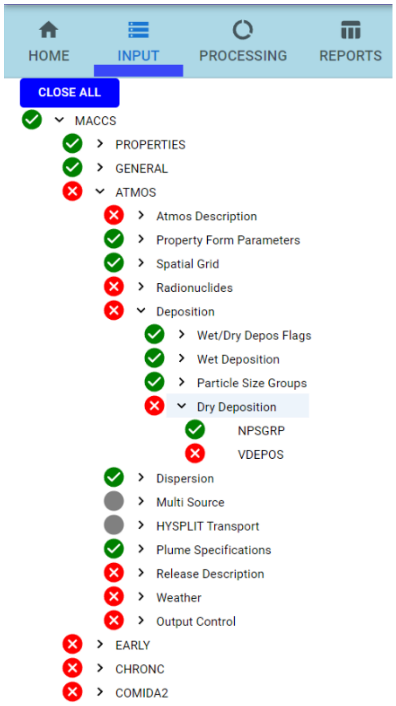

Figure 2-5. Parameters tree on the *INPUT* page

Each entry in the tree shown in Figure 2-5 has a related icon. This icon reflects the state of the object. *PROPERTIES, GENERAL*, *ATMOS*, *EARLY*, *CHRONC*, and *COMIDA2* are the main categories. The *PROPERTIES* and *GENERAL* categories control model settings (e.g., the weather sampling method) and the links to the auxiliary files to be used in a simulation. Data for those models are input in the *ATMOS*, *EARLY*, *CHRONC*, and *COMIDA2* categories.

Clicking on a form or parameter name associated with it causes that form to open for review or editing.

The *PROPERTIES* form 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. Generally, users should start or modify a project by first making appropriate model choices under the *PROPERTIES* forms. These forms affect which forms are needed in *ATMOS, EARLY, CHRONC,* and *COMIDA2* category forms.

2.1.4. Results Panel

The results panel is found at the bottom of the application window. It contains the *MESSAGE LOG* tab*,* which communicates progress; and the *INPUT ERRORS* tab, which displays input inconsistency errors. The *INPUT ERRORS* tab will be highlighted in green when no errors are present, and red when errors are present.

Results text, as shown in Figure 2-6, can be selected and copied to the 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. Error messages may be included in the text to describe an execution problem in need of resolution. For any questions regarding error messages, users are encouraged to contact maccs-questions@sandia.gov for user support.

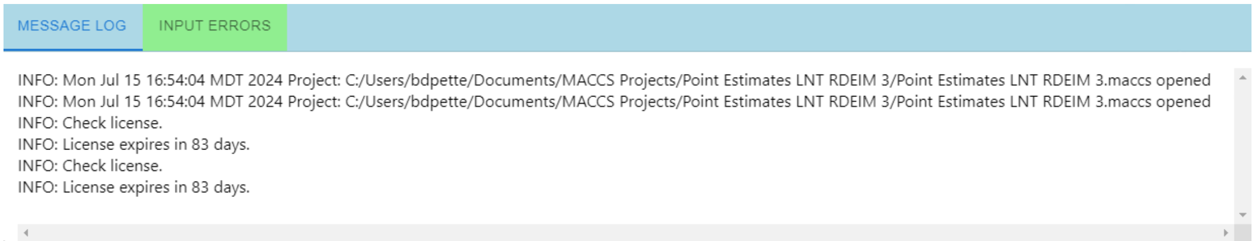

Figure 2-6. Sample results panel

2.2. Modifying Parameter Values

A parameter can be modified by opening the form containing the parameter. This is illustrated in Figure 2-7 for the parameters associated with wet deposition.

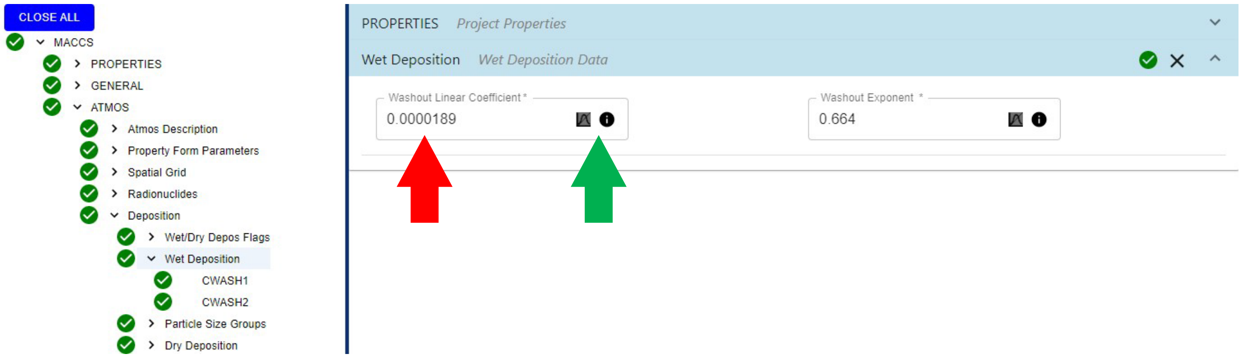

Figure 2-7. Modifying a parameter on a form

Parameter values are changed by replacing the value in their respective field (red arrow). The graph button inside the field (green arrow) allows a probability distribution to be assigned to an uncertain input parameter for sampling in an uncertainty analysis (see Section 3.3.3). The information icon shows additional information about the parameter, such as its limits. For example, the limits on *Washout Linear Coefficient* (CWASH1) in Figure 2-7 are from 0.0 to 1.0, inclusive of the end points.

If users would like to revert a form to its defaults, they should reference Appendix A for a table of default values.

2.3. Specifying Files

MACCS may require auxiliary files depending on the selections made in *PROPERTIES*. For example, if one of the file-sampling options was selected on the *Weather* tab of *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 2-8 shows an example in which the *Meteorological File*, and *Dose Conversion Factor File* (DCF) are required. Defining the 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.

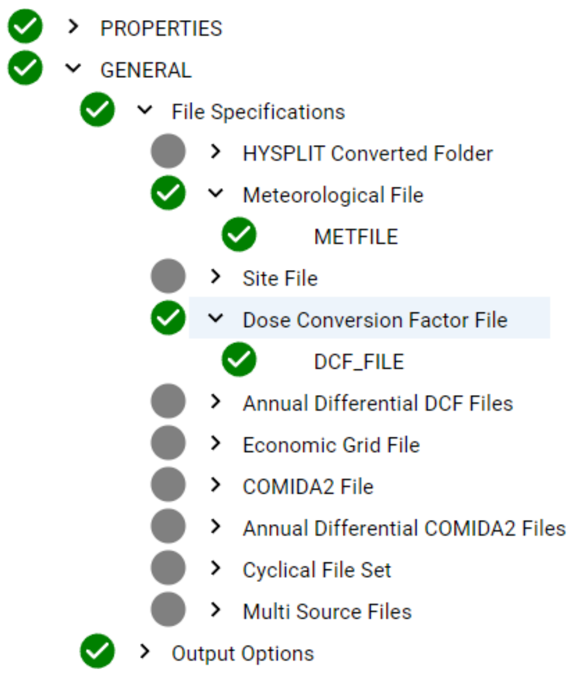

Figure 2-8. *File Specifications*

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 the calculation, and these copies are placed in the ProjectName\Data folder.

2.4. Filling Map Forms

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

Detailed instructions are provided in Section 4.3.7.2.11. 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 in *PROPERTIES*. 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 these forms, but only one of them can be changed from that form.
- Speed multipliers are activated by clicking on the *MODIFY MULTIPLIERS* button
- 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 the shift key for contiguous or noncontiguous selections, respectively. Similar options are available on the *Radial Evacuation Speed* and *Network Evacuation Speed* forms.

2.5. Running Simulations

A simulation can be started by clicking the *RUN SIMULATION* button in the top right corner.

If there are any input inconsistencies detected by MACCS-UI, the user will be warned and given the option to attempt to run the model or fix the issues. However, not all input inconsistencies are calculated at this stage. Some input problems are detected when MACCS is run. Errors generated at this step are described in the bottom results panel, *PROCESSING* tab.

Starting with MACCS version 4.0, parallel simulations on a local computer are now supported through *PROPERTIES/Project Settings* form. This feature takes advantage of the local system's processors to run multiple simulations concurrently. The number of simulations that can run in parallel is a parameter on the form. When one process completes on a processor, the next process starts.

Simulation progress can be observed in the *PROCESSING* tab from. When *RUN SIMULATION* is clicked, this tab is automatically switched to.

When the simulation has completed, a message conveying successful completion is written to the results panel. Its results can be viewed using the *REPORTS* tab.

2.6. Running MACCS from the 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. The file must have one file name per line, and they must be listed in the order above. If one of these files is not needed for a calculation, the line must contain a dummy name or blank field defined by two consecutive double quotes. 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.

The following example shows the contents of a sample MACCS.tmp file (Figure 2-9). Only the Atmos model is to be executed in this example. 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:\MACCSSamp\inb\Input\Atmos1.inp
""
""
C:\MACCSSamp\inb\Data\Metsur.inp
""
C:\MACCSSamp\inb\Output\Model1.out

Figure 2-9. *Example MACCS.tmp file contents*

-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 is not successful, this file contains a line with the string 'NO'. If MACCS detects an error and exits, the line containing the string 'NO' is followed by a MACCS generated error message.

The FORTRAN error file, FortErr.log, is created only when 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 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\maccs-ui> 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\maccs-ui> MACCS.exe -i C:\inb\Maccs.tmp –p inb

2.7. Project Files

Unlike WinMACCS, MACCS-UI does not include a *Files* tab. Instead, users should access input and output files by opening the project folder in the Windows Explorer or through their preferred text editor. Data file selections continue to be made in *GENERAL/File Specifications* forms.

A project folder contains the following files and subfolders.

- A MACCS project file (e.g., myProject\myProject.maccs), containing settings and the values used to build input files when a simulation is run. The path to this file is indicated at top of the MACCS-UI window.
- …\Data\ contains user specified data files, such as the site file, the meteorological file, and the dose conversion factor (DCF) file.
- …\Input\ contains input files created by MACCS-UI each time the user requests a MACCS simulation.
- …\Output\ contains output files from MACCS and other executables run by MACCS-UI.
- …\ResultsDB\ contains results from the MACCS model execution.

To change the location of the project, users can simply move (or drag and drop) the folder myProject\, including its files and subdirectories, to a new location. After this, the project will not show in the *Recent Projects* area until it is opened with the *OPEN PROJECT* button on the *HOME* page.

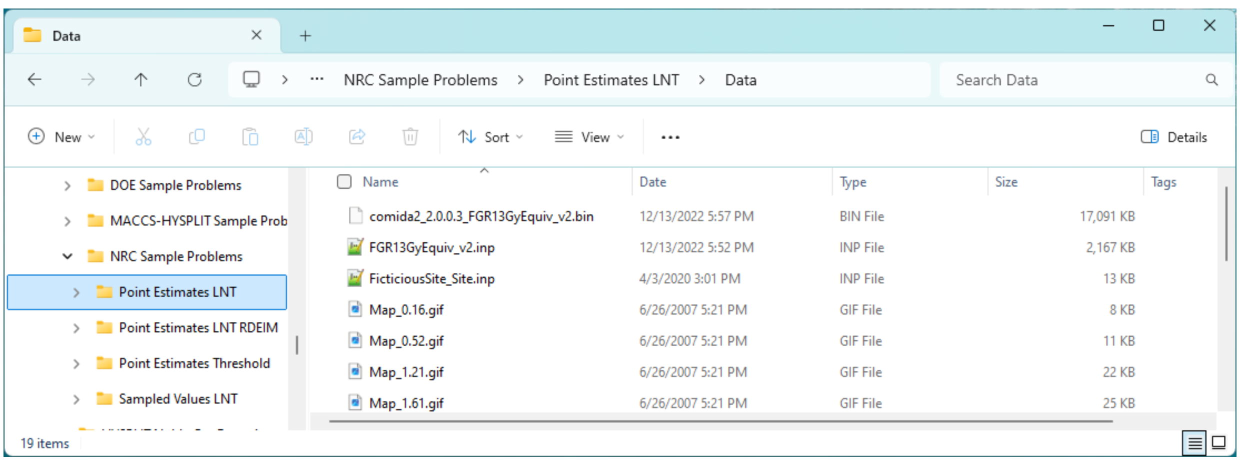

Figure 2-10. Data folder as seen from Windows Explorer

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3. REFERENCE GUIDE

3.1. Software Components

The MACCS suite is a set of interconnected software components. This section describes the main software components.

3.1.1. MACCS-UI

MACCS-UI is the graphical interface used to modify input parameters and model settings to support MACCS calculations. MACCS-UI creates input files, initiates the MACCS model, and post-processes MACCS results. It can also run several preprocessors that support a variety of functions described below.

3.1.2. MACCS

MACCS is the modeling engine and can be initiated from MACCS-UI or independently from the command line.

The following input files may be required, depending on modeling choices. These files are either created by MACCS-UI 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 lasts up to forty days from the beginning of release, and
- CHRONC input file containing parameters used to model 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 are printed to a file for each source term in the ATMOS input 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 at least one year.
- The site file is an optional file that defines population, land use, and economic parameters for each grid element.
- The 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 DCFs.

- MACCS-HYSPLIT files generated by a pre-processor, HyGridConvert. These files are relevant when using the HYSPLIT atmospheric transport model.
- Site specific economic data file generated by the pre-processor SecPop defines county population and area fractions per grid element. This file is used when using the RDEIM GDP based economic model.
- CombineSource.out is generated using the pre-processor CombineSource and is used by MACCS. This can be created from MACCS-UI. CombineSource uses data files generated by the pre-processor MelMACCS. This is used when running with the Multi Source model.

Several output files are created by MACCS (e.g., 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.

- Model*n*.out is a text file containing output from MACCS.
- Model*n*.bin is a binary file containing output from MACCS. This file can be viewed as text using the *MENU→File→Export MACCS Output as Text* option in the MACCS-UI main menu or can be used to create plots from within the MACCS-UI interface.
- FortErr.log is created when MACCS terminates abnormally.
- MaxStat.log contains the character string "OK" when MACCS terminates normally, "NO" when MACCS detects an error or when MACCS does not complete the simulation. This file contains an error message when termination is due to an error detected by MACCS.

3.1.3. Latin Hypercube Sampling

The executable file, lhs.exe, generates values of uncertain parameters using LHS. This program is initiated from MACCS-UI. The code, published by Sandia, is used to perform sampling from user-defined probability distributions that represent uncertain input parameters. LHS allows the uncertain distributions to be correlated.

The following required input files are transparent to the user when running LHS from within MACCS-UI:

- Lhs.inp is generated by MACCS-UI. 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 MACCS-UI and it is used to create MACCS and COMIDA2 input files and uncertain DCFs using the sampled values.
- Lhs.err is created when an error is detected during LHS execution.
- Lhs.msg contains details of LHS execution.

3.1.4. COMIDA2

The executable file, Comida2.exe, is a semi-dynamic food chain model that estimates annual concentrations in various food sources given a set of radionuclides and transfer coefficients for each crop type considered.

The following required input files are generated by MACCS-UI, with support for uncertainty:

- Comida2.inp, a parameter input file
- Comida2.var, a parameter input file
- Comida2.par, a parameter input file.
- A 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 text output file
- Comida2.lst, a text output file
- Comida2.cnc, a text output file

3.1.5. SecPop

The user can create site files supporting the number of compass directions required for their simulation using current versions of SecPop.

SecPop 4.0 uses Census 2010 data and supports up to 64 compass sectors. SecPop 4.4 uses Census 2020 data and supports up to 64 compass sectors. SecPop is separate from MACCS-UI. It can be downloaded from the MACCS website.

3.1.6. CombineSource

The executable file CombineSource.exe is integrated into MACCS-UI to support the multiple source model. The input files required are result files from MelMACCS, a separate software component used to extract source-term data from MELCOR (a reactor modeling product) results. Optionally, a user could create their own source files by replicating the format of a MelMACCS file.

3.1.7. Project Files

3.1.7.1. Project File Structure

A project folder contains the following files and subfolders.

- A MACCS project file (e.g., myProject\myProject.maccs), containing settings and the values used to build input files when a simulation is run. The path to this file is indicated at top of the MACCS-UI window.
- …\Data\ contains user specified data files, such as the site file, the meteorological file, and the dose conversion factor (DCF) file.
- …\Input\ contains input files created by MACCS-UI each time the user requests a MACCS simulation.
- …\Output\ contains output files from MACCS and other executables run by MACCS-UI.
- …\ResultsDB\ contains results from the MACCS model execution.

To change the location of the project, users can simply move (or drag and drop) the folder myProject\, including its files and subdirectories, to a new location. After this, the project will not show in the *Recent Projects* area until it is opened with the *OPEN PROJECT* button on the *HOME* page.

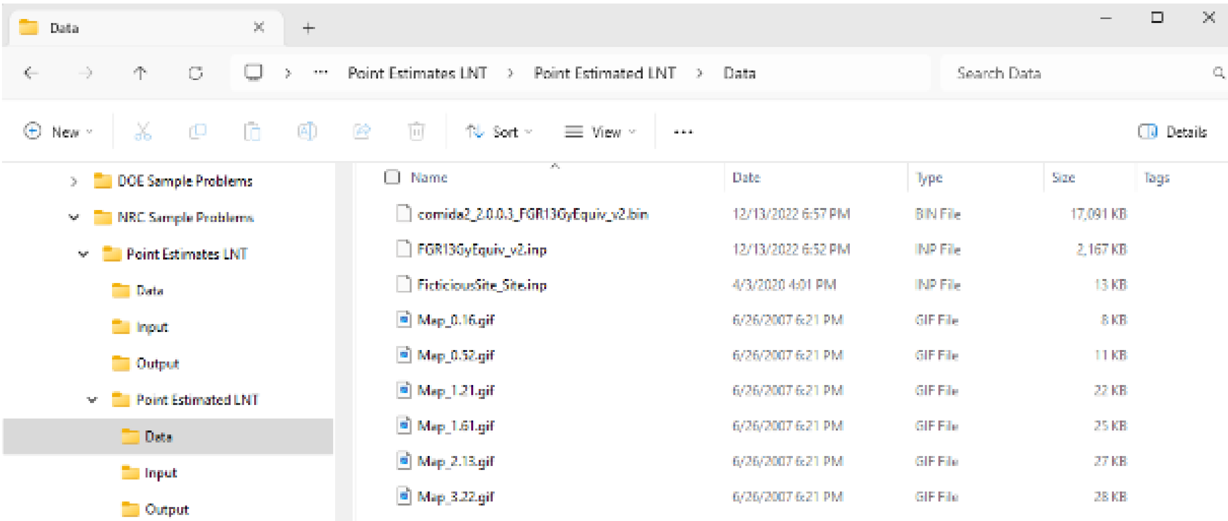


Figure 3-1. Data folder as seen from Windows Explorer

3.1.7.2. Data Files

The Data folder holds data files specified by the user under the *General/File Specifications* category on the *Parameters* tree. Users cannot modify these files through MACCS-UI. Instead, they should open the files in a text editor, such as Notepad. The files are used when MACCS is run. Not all files shown in the Data folder are shown in *File Specifications.*

Not all the files shown in Figure 3-1 are used when MACCS is run; this is dependent on selections in *PROPERTIES*. For example, if *EARLY* (Early Consequences) is enabled under the *Scope* tab in *PROPERTIES*, the DCF file is needed for the simulation, as indicated by the green checked circle displayed next to *Dose Conversion Factor File* under *File Specifications*. If *EARLY* (Early Consequences) is not enabled under the *Scope* tab in *PROPERTIES*, the DCF file is not needed for the simulation, as indicated by the grey circle displayed next to *Dose Conversion Factor File* under *File Specifications*.

The paths to data files can be modified by clicking on the *BROWSE* button on their respective form, under the *GENERAL/File Specifications* category, as shown in Figure 3-2.

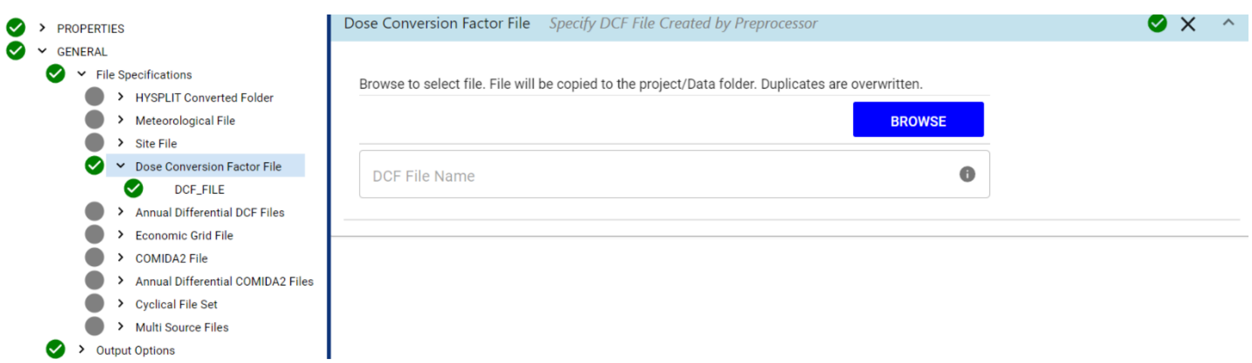


Figure 3-2. *File Specifications* category forms

Model settings that determine which data files are needed for a calculation are controlled with the *PROPERTIES* form (see Figure 3-3).

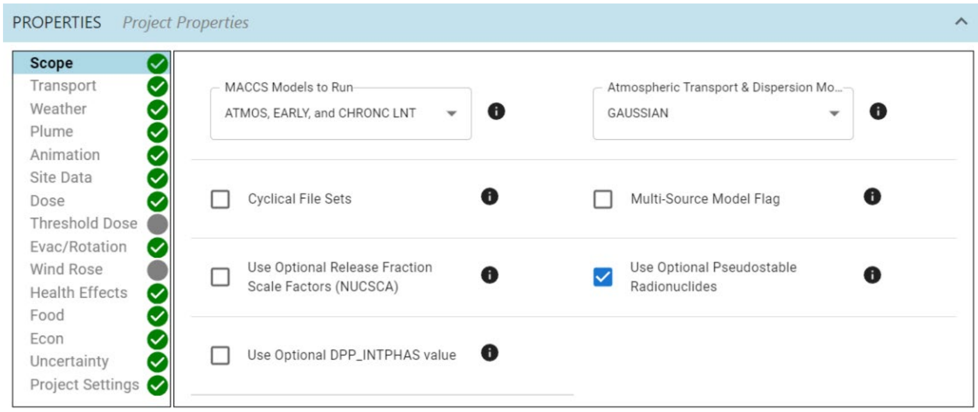


Figure 3-3. *PROPERTIES* form

If a user desires to include map files to use the network evacuation model, those files also need to be placed in the Data folder. These must be in Graphics Interchange Format (.gif) and correspond to the radial grid spacing defined for the problem (see Section 3.3.6).

Prior to MACCS 4.0, these files were created with the stand-alone executable MapGen. MapGen reads an interface file containing information about the spatial grid written by MACCS-UI and creates a set of map files using Microsoft MapPoint. MapPoint is no longer supported by Microsoft, so the maps would need to be generated with another method. These are used as a background layer to facilitate defining evacuation model settings, in *EARLY*/*Emergency Cohort* categories (e.g., *EARLY*/*Emergency Cohort One*).

3.1.7.3. Input Files

Users should modify input files by opening them through Notepad or their preferred text editor. They are contained in the project folder, which displayed at the top of the MACCS-UI window.

NOTE: The Input folder should not be used to store files that the user wants to keep! MACCS-UI deletes all files in this folder when MACCS is run. The Data folder (Project\Data\) and root directories (Project\) are safe places to store files because they are never deleted by MACCS-UI. The user can also create additional directories for archiving files under the Project\ folder.

The following table (Table 3-1) reflects a run with a scope of *ATMOS, EARLY*, *CHRONC*, and *COMIDA2*. In this example, some parameters are sampled, the template files are created, and two simulations are requested.

Table 3-1. Files created in the Input folder by MACCS-UI during execution

File name	Conditions when created	Description
atmosTemplate.txt	Always created when MACCS is run.	Used by MACCS-UI to create input files Atmos1.inp and Atmos2.inp.
earlyTemplate.txt	*EARLY* module is enabled under *PROPERTIES/Scope*.	Used by MACCS-UI to create input files Early1.inp and Early2.inp.
chroncTemplate.txt	CHRONC is enabled under *PROPERTIES/Scope.*	Used by MACCS-UI to create input files Chronc1.inp and Chronc2.inp.
Atmos1.inp Early1.inp Chronc1.inp Atmos2.inp Early2.inp Chronc2.inp	When either *ATMOS, EARLY, and CHRONC* option is selected in *PROPERTIES/Scope.*	Created consistently with the model scope, using template files and data from LHS.out, relevant to each simulation. If any of the parameters are uncertain, this information is encoded in the relevant template file. Actual values used in simulation *n* correspond to realization *n* in the LHS.out file. These files are used by MACCS.
LHS.inp	Uncertain parameters are defined.	Contains input to LHS indicating the number of observations, probability distributions, parameter names, and correlations between sampled parameters.
Sipra.ini	Uncertain parameters are defined.	Contains LHS settings and is copied from Program Files\MACCS-UI folder into the \Project\Input\ folder. It is read by LHS.
LHS.out LHS.msg	Uncertain parameters are defined.	Created by LHS. LHS.msg is a detailed output file describing the run. LHS.out is used to create the input files by MACCS-UI for MACCS.
comidaTemplate.txt	*CHRONC* model is enabled in *PROPERTIES/Scope* and the *File Created from User Input* option is selected in *PROPERTIES/Food*.	Similar to other template files, used with LHS.out to create the three sets of input files required by COMIDA2, namely Comida*n*.inp, Comida*n*.par, and Comida*n*.var, where *n* is the simulation number.
Comida1.inp Comida2.inp	*CHRONC* model is enabled in *PROPERTIES/Scope* and the *File Created from User Input* option is selected in *PROPERTIES/Food*.	This is a set of one of three input files required by COMIDA2.
Comida1.var Comida2.var	*CHRONC* model is enabled in *PROPERTIES/Scope* and the *File Created from User Input* option is selected in *PROPERTIES/Food*.	This is a set of one of three input files required by COMIDA2. The files contain radionuclide data.
Comida1.par Comida2.par	*CHRONC* model is enabled in *PROPERTIES/Scope* and the *File Created from User Input* option is selected in *PROPERTIES/Food*.	This is a set of one of three input files required by COMIDA2. The files contain food-pathway data.

3.1.7.4. Output Files

The Output\ folder contains output files created by MACCS and COMIDA2.

NOTE: Do not name any files in the output folder Modeln.out, Modeln.bin, Comidan.cnc, Comidan.dmp, or Comidan.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.

The following example shows a simulation with a scope including *ATMOS*, *EARLY,* and *CHRONC*. Comida2 is run to create the .bin files used for *CHRONC*. In the example shown in Table 3-2, two simulations are requested.

Table 3-2. Output files created by MACCS and COMIDA2

File name	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.

3.2. Selecting Models on the *PROPERTIES* form

The *PROPERTIES* form is always displayed at the top of the *INPUT* window but can be minimized.

Basic model options are chosen on the *PROPERTIES* form. Parameters affected by *PROPERTIES* can be viewed, but not modified, by opening the *Property Form Parameters* form contained in *ATMOS*, *EARLY*, and *CHRONC*.

Each tab in *PROPERTIES* has default selections. The user should ensure that the scope and specific model are aligned with the intent and purpose of creating and running the model.

Selections in *PROPERTIES* determine which parameter forms are required. For example, when CHRONC is not enabled on the *Scope* tab, parameters in the *CHRONC* category are not required. Consequently, all *CHRONC* parameters in the *Parameters* tree and tabs related to the *CHRONC* module in *PROPERTIES* have gray icons.

3.3. Modifying Parameters

Forms can opened in two ways to edit parameters:

- By clicking on the parameter or form name in the parameters tree; or,
- By selecting *MENU→Edit→Find Variable*, entering the variable name, and selecting the variable.

3.3.1. *Generic Forms*

There are generic forms, and custom forms, such as the forms to manage evacuation directions, evacuation speeds, and reports. This section describes generic forms.

The following are the main components of a parameter modification form as shown in Figure 3-4:

- Entry field: The portion of the form where values are entered. Editable parameters have dark text, while read-only parameters are grayed-out. The examples in Figure 3-4 are editable.
- Units dropdown: Some parameters can have their units changed, by clicking the blue unit text and selecting a different unit, near the red arrow. This menu is not present when units cannot be changed. See Section 3.3.2 for further discussion.
- Uncertainty: This button, at the green arrow, opens a menu used to associate a probability distribution with a variable, or disable uncertainty. Most parameters of type Real can be specified as uncertain. If this button is not present, uncertainty is not available for the variable.
- Information button: Hovering over this icon, near the blue arrow, shows a description of the parameter, its data type, limits, and units.

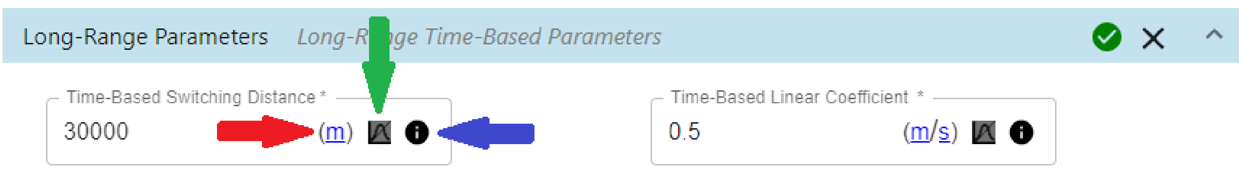
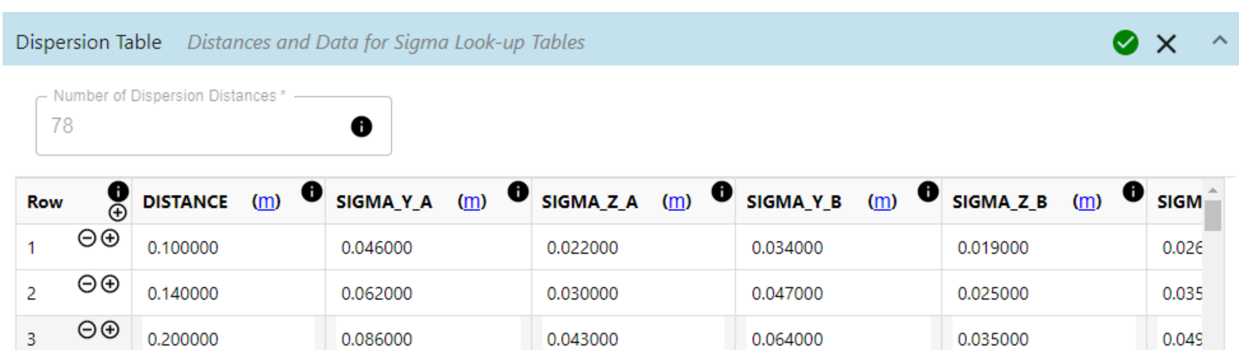


Figure 3-4. Components of a generic form

3.3.1.1. Modifying Tables Forms

Arrays and vectors are displayed in tables, as shown in Figure 3-5.



Dispersion Table *Distances and Data for Sigma Look-up Tables*

Number of Dispersion Distances *
78

Row	DISTANCE (m)	SIGMA_Y_A (m)	SIGMA_Z_A (m)	SIGMA_Y_B (m)	SIGMA_Z_B (m)	SIGM
1	0.100000	0.046000	0.022000	0.034000	0.019000	0.026
2	0.140000	0.062000	0.030000	0.047000	0.025000	0.035
3	0.200000	0.086000	0.043000	0.064000	0.035000	0.049

Figure 3-5. Example of a form with a table

- Like regular parameters, table columns have information buttons and may have unit buttons.
- Rows can be added or deleted in any position of the table with the + or – buttons on each row. Alternately, rows can be added to the bottom of the table with the + button at the top left of the table.

3.3.1.2. Supported Data Types

The following data dimensions are supported:

- Scalar data: single values that are associated with variables. A scalar can have various types, as listed below.
- Vector data: singly subscripted variables. Multiple vectors are sometimes displayed on the same grid when each of the vectors has the same number of rows.
- Array data: multiply subscripted variables. Only one array is 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: value is either *True* or *False*. Choices are selected from a pull-down menu.
- Characters: a character string. Size requirements are shown in blue letters below the data entry area.
- Dropdown 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: a file name 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 parameters are vector or array sizes calculated by MACCS-UI. For example, NUM_DIST is the length of the vectors DISTANCE, SIGMA_Y_A, etc. This parameter cannot be directly modified. When hovering the mouse over a linked parameter's information button, a description is displayed in the description area of the form. The value of the parameter is updated as the number of grid rows increases or decreases. Linked parameters are of type Integer but can only take on positive values. Parameter MAXGRP shown in Figure 3-6 is an example of a linked variable.

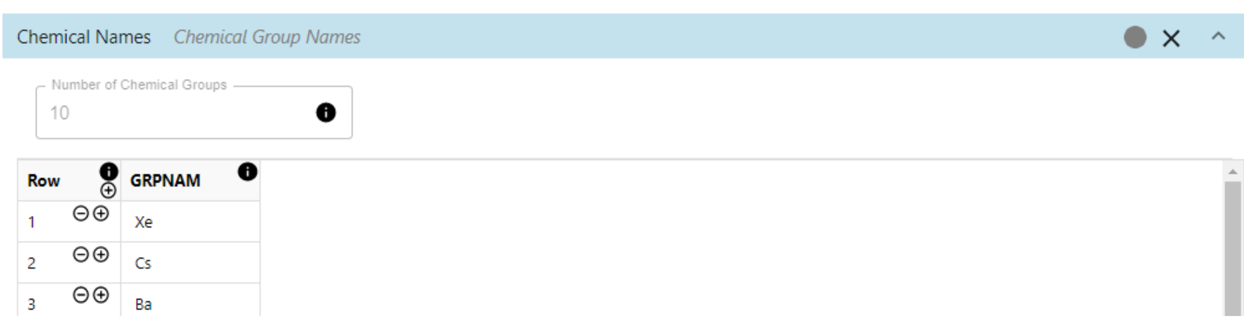


Figure 3-6. Example of a linked variable, MAXGRP

Grayed-out fields are read-only and cannot be changed on that form.

Examples of the data type and bounds that could be found in the description tooltip are:

- Real [.01, 100.]: A number between 0.01 and 100, inclusive, must be entered in the text field. This is displayed in Figure 3-7.

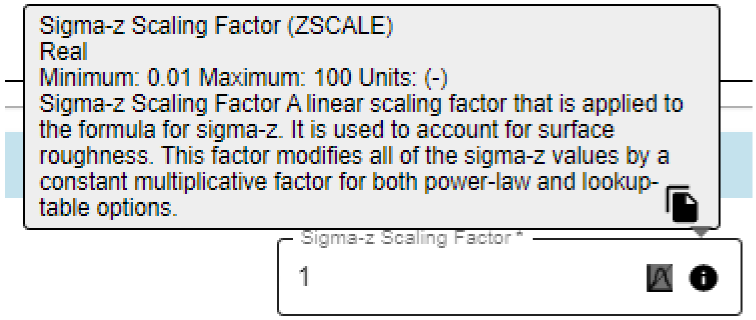


Figure 3-7. Description tooltip showing Real data type

- 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 3-8.

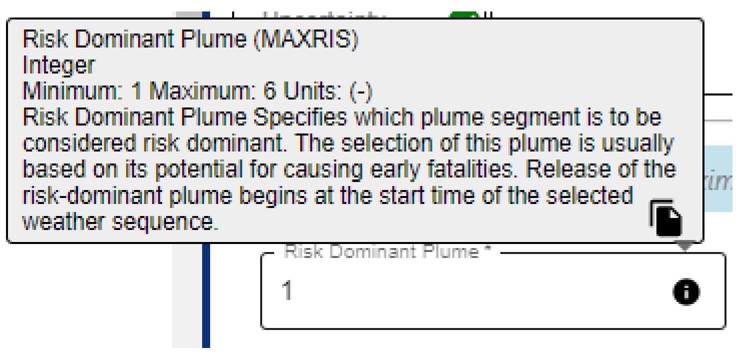


Figure 3-8. Description tooltip showing upper bound as another variable

- Character Minimum: 1 Maximum: 16: 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 3-9.

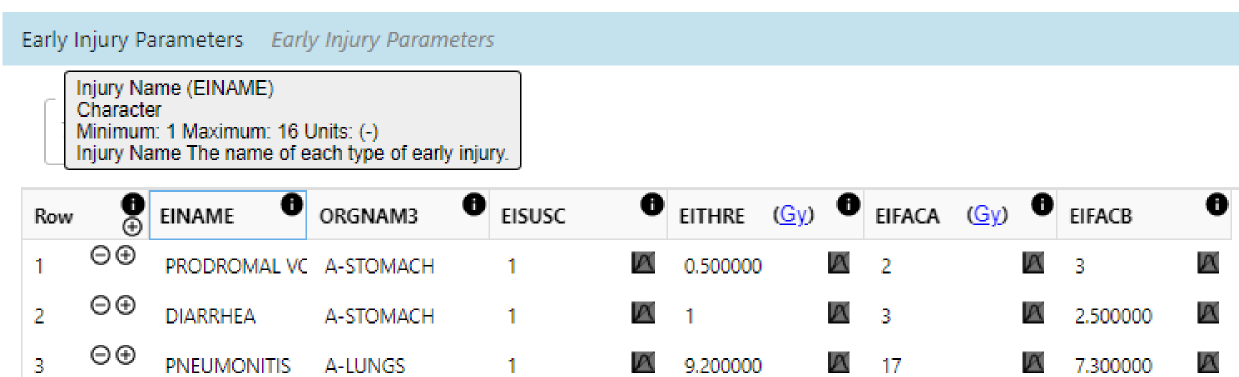


Figure 3-9. Character length limits

As shown in Figure 3-10, the number of MNDFAC rows is fixed at 6. Like other table forms with rows fixed in length, there are no + or – buttons.

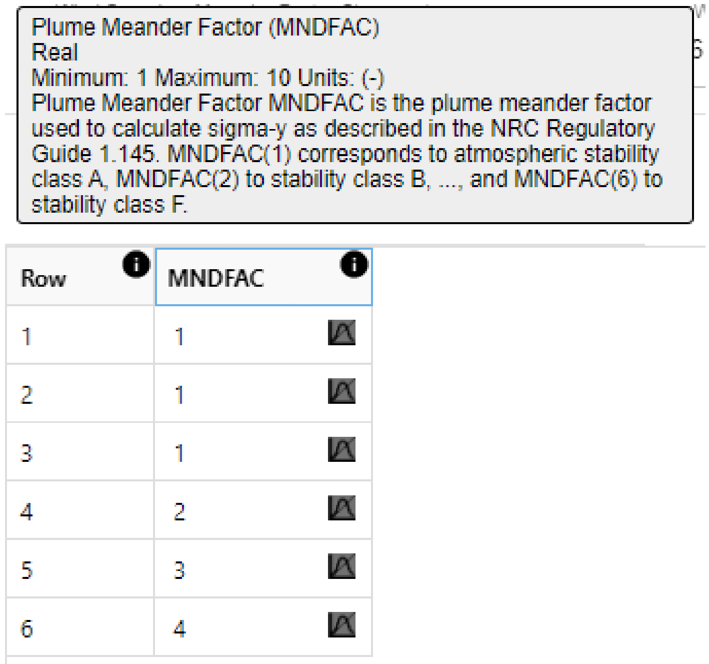


Figure 3-10. Grid with fixed number of rows

3.3.2. Changing Units

MACCS-UI allows the user to change units in two ways:

- On input forms; and
- For output forms used in MACCS reporting.

Unit changes are integrated into other MACCS-UI functions as follows:

- The function that imports MACCS input files into the user interface (*MENU→File→Import MACCS Input File*) converts values to user specified units on each form.
- Uncertain parameter 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 forms.
- Map forms (*Network Evacuation Direction, Network Evacuation Speed,* and *Populations Assigned*) show values and units labels (km, mi, etc.) in specified units.

3.3.2.1. Changing Units for Variables

The user can change input units for many parameters using the blue units button in input fields, as shown in Figure 3-11. Each dimensioned parameter in MACCS-UI is assigned to a unit family. The user can change input units and convert existing values to the new input units that belong to the family. Users can modify input units anywhere the unit button exists.

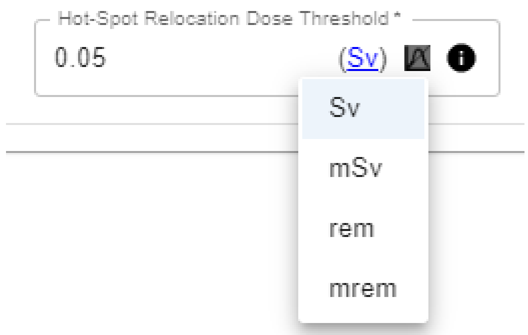


Figure 3-11. Changing a parameter's units

When building MACCS input files, input parameter values are converted to standard MACCS input parameter units, which are the same as the default units shown in Table 3-3. Thus, MACCS input files retain their default units and input unit conversion is handled by MACCS-UI.

Table 3-3. 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

3.3.2.2. Modify the output units for MACCS reporting

The form shown in Figure 3-12, *GENERAL/Output Units*, allows the user to request results to be reported in the optional units. This applies to both text and binary output files created by MACCS.

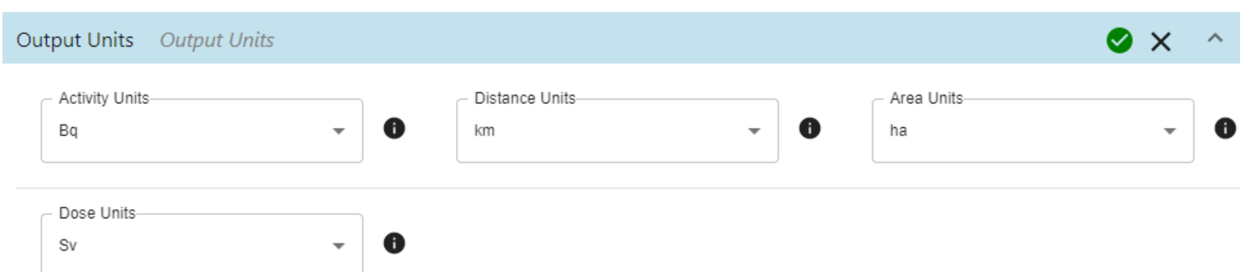


Figure 3-12. Specifying MACCS reporting units

3.3.3. Making a Parameter Value Uncertain

MACCS-UI allows input parameters to be made uncertain and enables sampling of uncertain variables. By default, this sampling is done using Latin Hypercube Sampling (LHS), though this can be changed to Simple Random Sampling (SRS) on the form *PROPERTIES/Uncertainty*.

The sampling allows the effect of an uncertain input value to be tested. Uncertain parameters 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.

Values can be made to be uncertain by first opening its form. This can be done by clicking on the parameter name in the parameters tree on the *INPUT* page or by using *MENU→Edit→Find Variable* to locate the form.

Once the form is opened, select the uncertainty button, which looks like a graph, as shown in Figure 3-13.

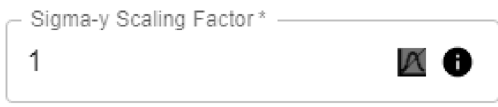


Figure 3-13. Example parameter field

An example uncertain parameter form is shown in Figure 3-14, which can be used to:

- Change parameters from constants to uncertain values described by probability distributions;
- Change parameters from distributions to constants; or
- Change the probability distribution associated with the variable.

MACCS-UI supports a wide range of distribution types, and each distribution type can accept a range of values for its parameters.

NOTE: It is possible to specify values for the distribution that lead to invalid parameter values, causing sampling to fail. The values that define the distribution should be chosen so that they do not cause the sampled input value to go out of range. (e.g., a negative value for a MACCS parameter that must be greater than zero).

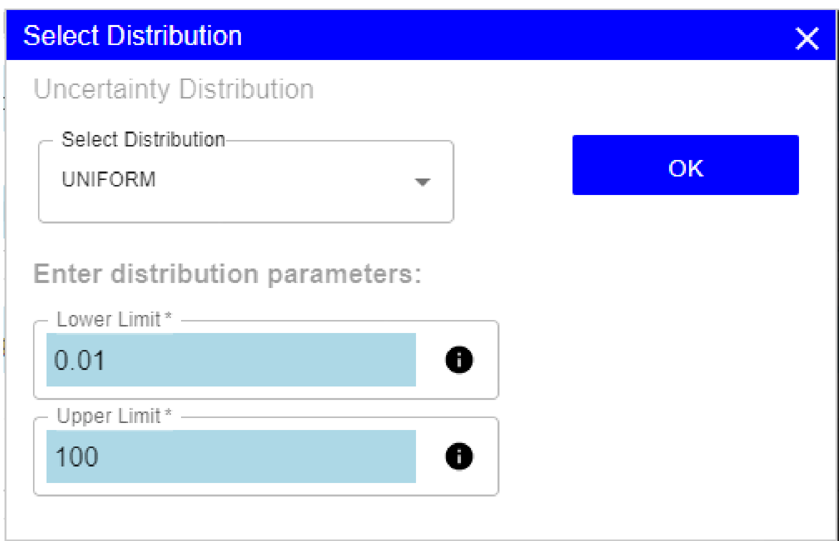


Figure 3-14. Assigning a probability distribution to a parameter

The value of an uncertain parameter can be modified as follows:

1. Selecting a distribution with the *Select Distribution* dropdown. Setting this to *NONE* means the variable is constant (or deterministic).
2. Entering the values that define the distribution in the input fields. The type of distribution determines the amount and type of information needed to define the value.

The *OK* button, as shown in Figure 3-14, can be clicked to save changes and close the window. To indicate the value is uncertain, the field is made blue and labeled *UNCERTAIN*, as shown in Figure 3-15.

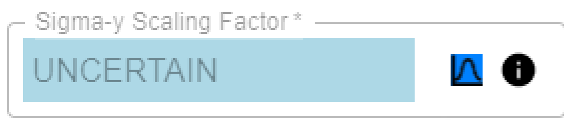


Figure 3-15. Uncertain parameter appearance

To view the set of parameters that were sampled after running MACCS, the user can open the LHS.inp file opening the project's …\Data folder in Windows Files Explorer, then clicking on LHS.inp. Values used in the MACCS simulation can be viewed in the LHS.out file. The option to use the correlate variables algorithms in LHS is not implemented in MACCS-UI. To use this option, it is recommended to update the LHS settings in a WinMACCS 4.2 case.

3.3.4. Annual Dose Conversion Factor and Annual COMIDA2 Files

When the Annual Threshold (AT) or Piecewise Linear (PL) dose-response models are chosen on the *Threshold Dose* tab in *PROPERTIES*, a set of fifty-one DCF files are needed by MACCS. Additionally, when either of these dose-response models is chosen and the *COMIDA2 Food Model* is chosen on the *Food* tab, a set of fifty-one COMIDA2 files are also needed by MACCS, each COMIDA2 file having been created with its associated DOSFAC2 file.

MACCS-UI is distributed with files sets to be used with the AT or PL dose-response models. The first set is based on DOE/EH-0070 (1988); the second and third set are 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 DCFs for each year of the 50-year commitment period. These file names are sequenced to enable the identification of the year number. For example, FGR13GyEquiv_v303.inp corresponds to the DCFs 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.

An annual differential DCF and COMIDA2 file set can be specified with the following steps:

1. Open the *GENERAL/File Specifications/Annual Differential DCF Files* form, as shown in Figure 3-16.
2. Click on the *BROWSE* button and select the base file. In the example shown in Figure 3-16, the name of the base file is FGR13GyEquiv_v3.inp. The name of the base file is displayed in the top box, with the corresponding folder name below it. MACCS-UI expects the additional files to be present in the folder.

3. Open the *GENERAL/File Specifications/Annual Differential COMIDA2 Files* form and repeat this process to define the COMIDA2 file set when needed.

MACCS-UI copies the base DCF file and the fifty auxiliary files to the project\Data folder.

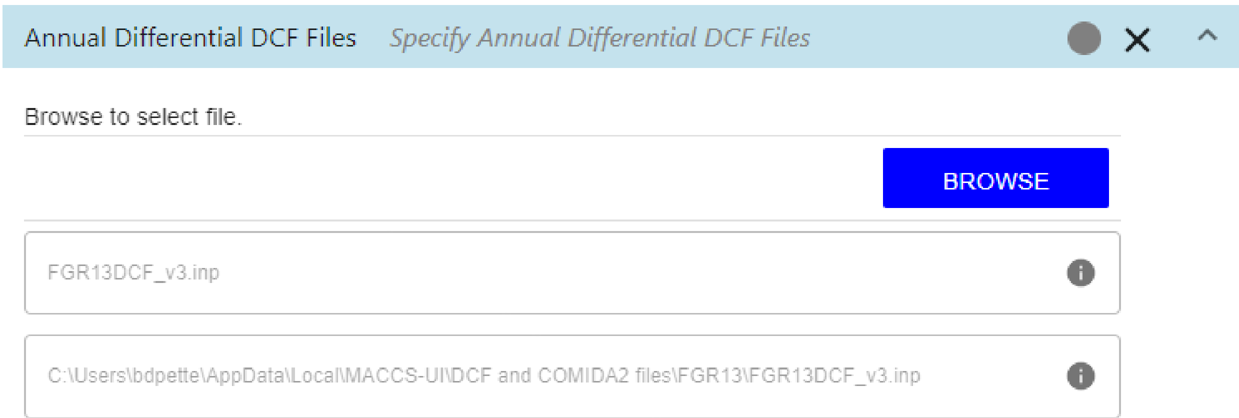


Figure 3-16. *Annual Differential DCF Files* form

3.3.5. *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 MACCS-UI 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 MACCS-UI. 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. MelMACCS is an interface tool that can be used to create MACCS-formatted files containing source term information extracted from a MELCOR plot file. These files can be specified as cyclical files, allowing a set of source terms for a plant to be run sequentially.

3.3.5.1. Specifying Cyclical MACCS Files

MACCS cyclical input files can be specified as follows:

1. Enabling the Cyclical File Sets model by checking *Cyclical File Sets* in *PROPERTIES/Scope*.
2. Specifying file locations in the *GENERAL/File Specifications/Cyclical File Set* form.
3. Clicking *SAVE* saves the file selection. The files are copied to the project …\Data\ folder.

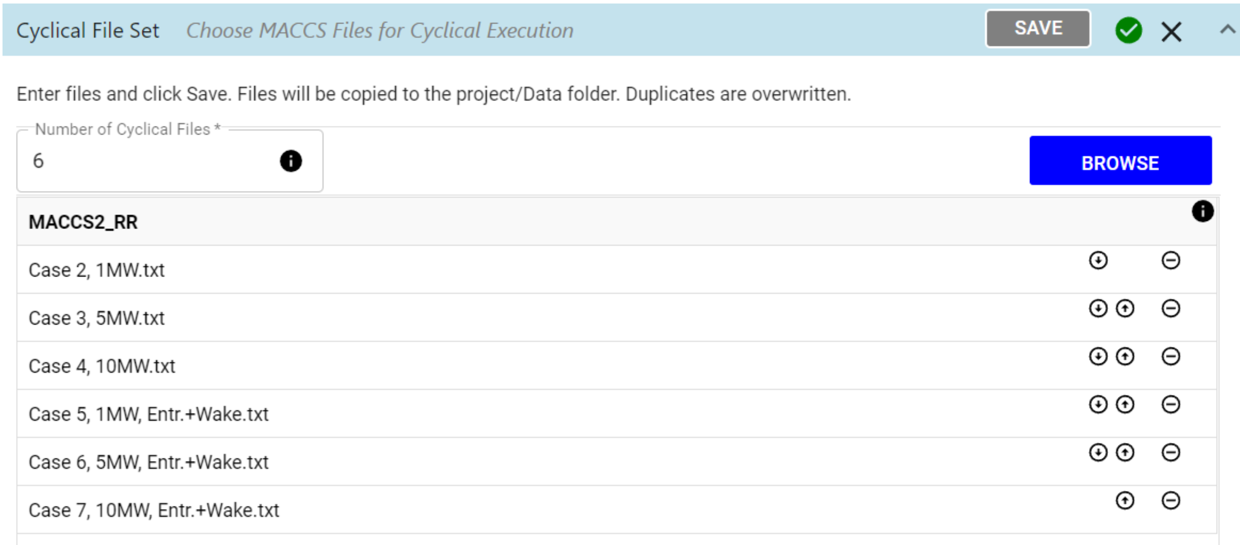


Figure 3-17. *Cyclical File Set* form

The order of processing the files by MACCS-UI can be changed by 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. Files can be removed from the cyclical set by selecting the subtract symbol to the right of the row.

The following input CARDs behave in the following way when imported from a MACCS formatted input file or used in a cyclical file.

M4NSMPLS: If METCOD = 5 (Stratified weather option) then the variable NSMPLS_DAY will be set. Otherwise, the variable NSMPLS_BIN will be set.

RDPLMMOD: No matter which value the card is set to (DENSITY or HEAT) the model is not changed. This is currently an error in this version of the code.

TYPE0NUMBER: If the Multi-Source option is OFF, then the variable NUM0 will be set. If the Multi-Source option is ON, then the NUM0_MS variable will be set.

TYPE0OUT: If the Multi-Source option is OFF, then the output request variables for the Non-Multi-Source option will be set. If the Multi-Source option is ON, then the Multi-Source output request variables will be set. The correct variables need to listed in the correct order for the Non-Multi-Source CARD or Multi-Source CARD in order to be read in correctly.

BIN_FILE and DCF_FILE file defining cards will have no effect to the current project. The COMIDA2 or DCF files can not be changed by using these CARDs when importing a MACCS input file or in a CYCLICAL file set file.

EZPOPFRC and EZEFFACY: If the dose model is set to LNT, the non-threshold model variables POPFRC and/or EFFACY will be set. If the dose model is set to any of the Threshold models then the threshold model variables POPFRC_TH and/or EFFACY_TH will be set.

3.3.5.2. Cyclical Execution with Uncertain Parameters

It is possible to perform calculations with a cyclical file set and to sample uncertain parameters 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 are 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 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 generates six sampled value sets and inserts these values into the MACCS input files as expected.

3.3.6. 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 in *PROPERTIES*, 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.

3.3.6.1. 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 in *PROPERTIES* with the following steps:

1. Clicking on the *Evac/Rotation* tab as shown in Figure 3-18 allows the user to select *Radial* or *Network* for the problem model.
2. The evacuation type needs to be defined for each of the cohorts.
3. When speeds vary within the evacuation grid elements for either the network or the radial evacuation models, check the box *Activate Speed Multiplier Option* (red arrow).

When the *Network* evacuation is selected, the *Network Evacuation Direction* form is required for cohort one. When the *Activate Speed Multiplier Option* is checked, either the *Radial Evacuation Speed* or the *Network Evacuation Speed* form is required for cohort one.

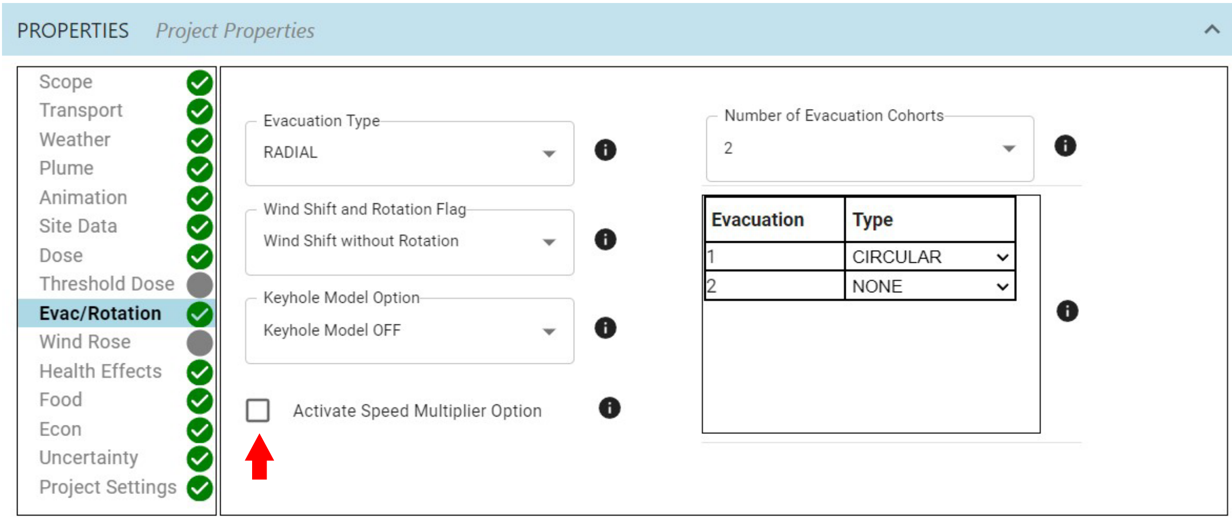


Figure 3-18. *Activate Speed Multiplier Option* on *Evac/Rotation* tab

The parameters SPAEND, as shown in Figure 3-19, and LASMOV, as shown in Figure 3-20, must be defined before the *Network Evacuation Direction* forms, *Radial Evacuation Speed* or the *Network Evacuation Speed* forms can be successfully opened. These two parameters 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.

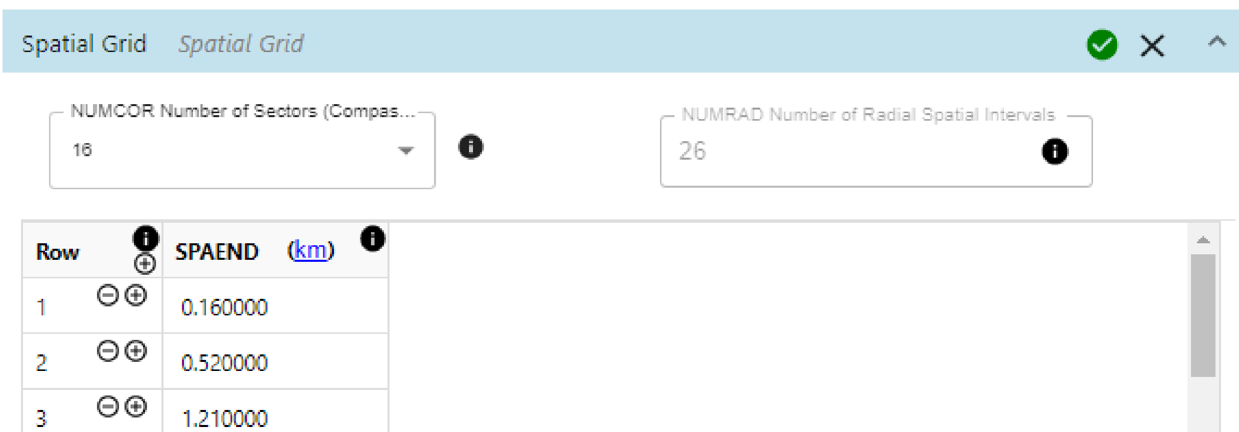


Figure 3-19. ATMOS radial grid, SPAEND

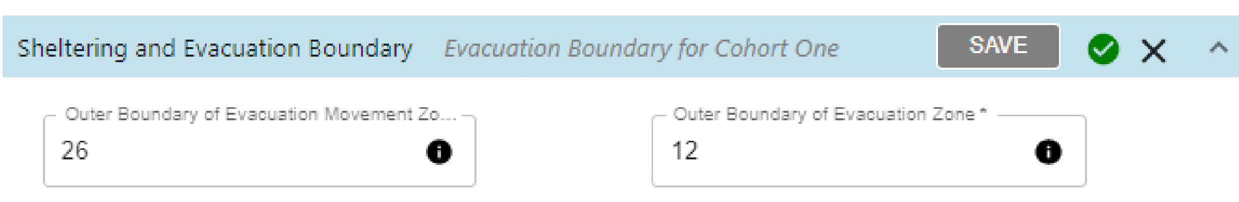


Figure 3-20. Evacuation boundary, LASMOV

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 parameters is different.

3.3.6.2. Population by Cohort

Populations are assigned to grid elements using a spatial grid form, *EARLY/Population by Cohort/Populations Assigned*. Note that populations are the locations of people, while cohorts describe their behavior.

To enable the specification of the population fraction by cohort, either SUMPOP option is chosen on the *Site Data* tab in *PROPERTIES* as shown in Figure 3-21.

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 *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.

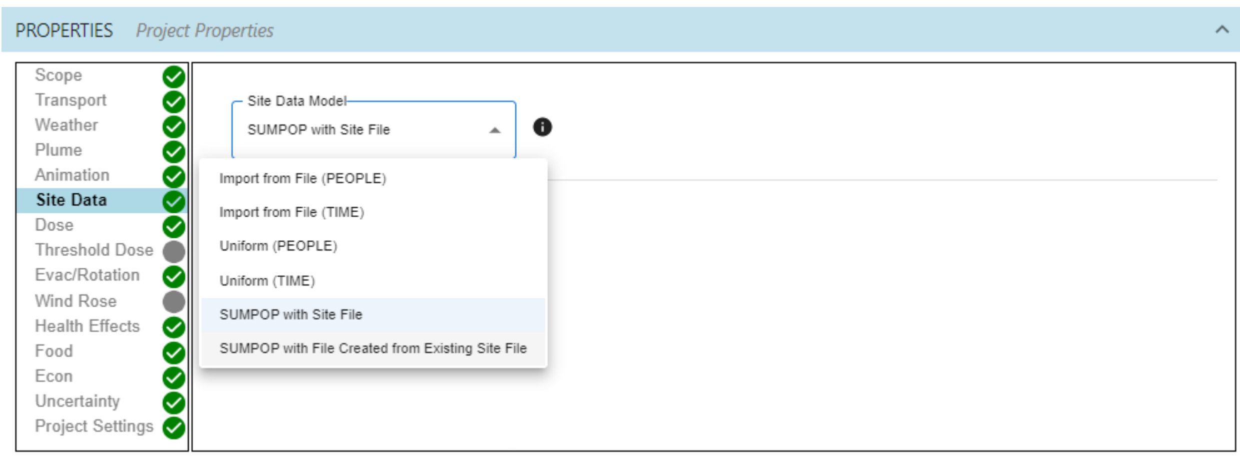


Figure 3-21. SUMPOP options in *PROPERTIES*

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 parameter contains the population array corresponding to the grid population in the existing site file. When the site file specified has multiple population arrays, *Population* is the array containing the sum of the population over all evacuation cohorts on the site file.

Though this parameter 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 3-22. It is not possible to change any values of the POPULATION on this form. To change the values, a new site file must be specified on the *Site File* form. This parameter is defined whenever the site file is updated.

Population from Site File *Population from Site File*

SPAEND (km)	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Sector 7
0.16	0	0	0	0	0	0	0
0.52	0	13	0	0	7	0	0
1.21	44	235	4	0	0	159	50

Figure 3-22. *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 are 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/Populations* allows the user to define the various population distributions. There can be up to ninety distributions defined. The example shown in Figure 3-23 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.

Populations *Population Distribution over Cohorts*

Number of Population Distributions *
3

Population #	COHORT 1	COHORT 2	COHORT 3	COHORT 4
Population 1	0.200000	0.800000	0	0
Population 2	0	0	0.999000	0.001000
Population 3	0.995000	0	0	0.005000

Figure 3-23. *Populations* form

To aid the user in assigning populations to spatial areas, the *EARLY/Population by Cohort /Population Labels* form, shown in Figure 3-24, allows a symbol and a label to be assigned to each of the population distributions. In this example, Population 2 is assigned to a spatial area that contains a school. 99.9% of the population in this area is in cohort 3, and .1% is in cohort 4. The fractional cohort for each of the populations must sum to one.

Population Labels *Population Distribution Labels*

Population #	DIST_SYMBOL	DIST_LABEL
Population 1	N	Special Needs
Population 2	S	Schools
Population 3	G	General Population

Figure 3-24. *Population Labels* form

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.

3.3.6.3. Radial Grid Parameters

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 map behind the polar grid. Evacuation directions are initially set to be radially outward, as shown in Figure 3-25, and the speed multipliers are set to one.

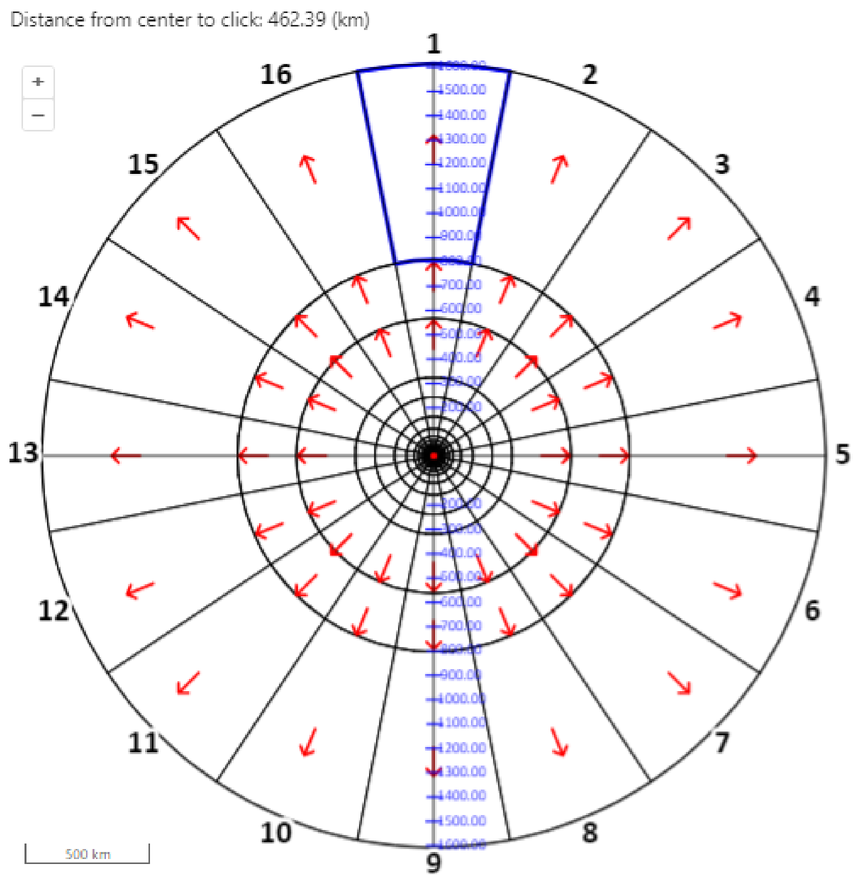


Figure 3-25. Initial state of evacuation grid

NOTE: When the spatial grid is modified, the set of road maps would need to be updated accordingly to be properly displayed.

To have a map projection displayed, the user must include map files in the Data folder. These must be in Graphics Interchange Format (.gif) and are named to correspond to the radial grid spacing defined for the problem. The map projection only works with distances of 0.16, 0.52, 1.21, 1.61, 2.13, 3.22, 4.02, 4.83, 5.63, 8.05, 11.27, 16.09, 20.92, 25.75, or 32.19 km. For example, with a spatial grid defined with radial distances of 0.16, 0.52, 1.21, 1.61, and 2.0 km, maps saved in .gif format, with the names Map_0.16.gif, Map_0.52.gif, Map_1.21.gif, and Map_1.61.gif would need to be present in the corresponding project's Data folder to then be displayed with the form. A file with the name Map_2.0.gif wouldn't be recognized. If some of the maps for some distances are not present or not in above distance list, MACCS-UI will keep the previously displayed map, but either zoomed in or out depending on the order of selections.

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.

3.3.6.3.1. Understanding the Map Overlay

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.

Arrows drawn on the grid elements indicate the evacuation direction as shown in Figure 3-26. There are four different directions supported by MACCS, outward, inward, counterclockwise, and clockwise. Each of these directions is shown in a different color.

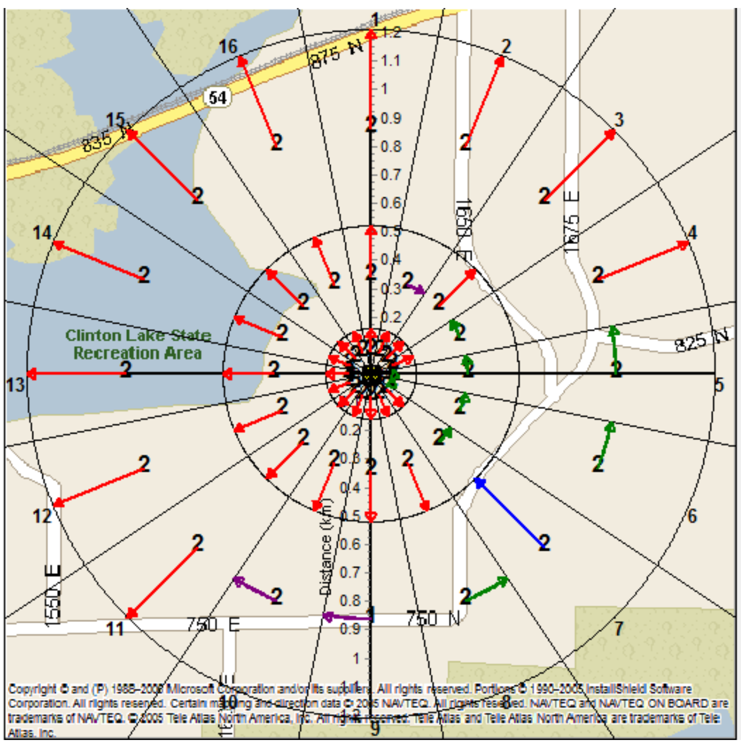


Figure 3-26. Evacuation grid

The symbols shown in column four labeled *Rank* as shown in Figure 3-27 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 the third column, *Speed Multiplier*. By showing ranks, the speed multipliers can be adjusted without requiring the user to adjust the settings on the polar grid.

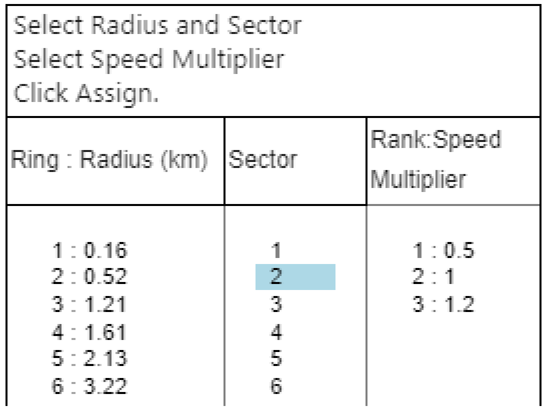


Figure 3-27. Radius, sector and multiplier

When the grid is clicked, the radial distance from the center of the grid to the click is shown on the top right portion of the form, as shown in Figure 3-28. 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 MACCS-UI corresponds to the scale of the polar coordinate system. From the viewpoint of MACCS-UI, the roadmap is simply a picture file.

Changes are saved every time *ASSIGN* is clicked.

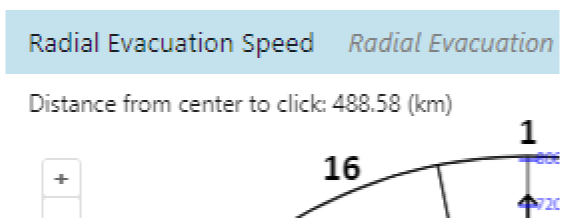


Figure 3-28. Radial click distance

3.3.6.3.2. Assigning Values to Radial Grid Forms

The same basic form used to assign speed multipliers to grid elements is also used to specify evacuation directions and population assignments. 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.

The same techniques are used to assign values to grid elements in the *Network Evacuation Direction*, *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.

3.3.6.3.2.1. Network Evacuation Direction Form

An example of a network evacuation direction form is shown in Figure 3-29.

The evacuation direction can be modified in two ways.

The first method is to click the grid element on the map. When clicked, grid element is highlighted and shows a list of directions. The clicked element is also highlighted in the Radius/Sector list. In the example shown in Figure 3-30, the grid element between 3.22 km and 4.02 km in the seventh sector is selected with a direction of Left current assigned. Sector 7 corresponds to SE in a grid that has been divided into 16 sectors. Changing the direction will change the displayed arrow in the grid. MACCS-UI will also check to ensure that a valid evacuation path has been defined. If the change is not valid, the paths affected by the change will highlight in red to help the user determine what to change to correct the issue.

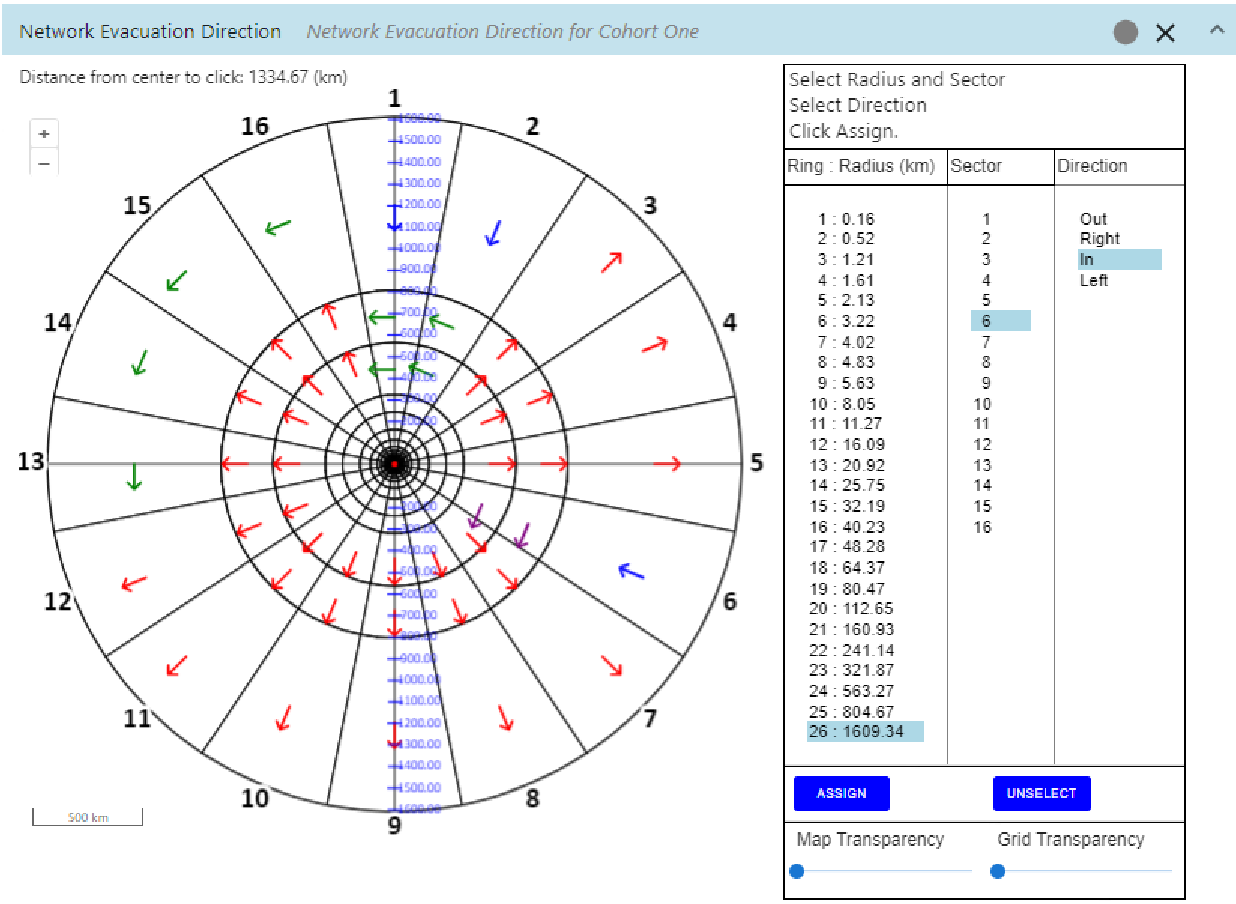


Figure 3-29. Network evacuation direction

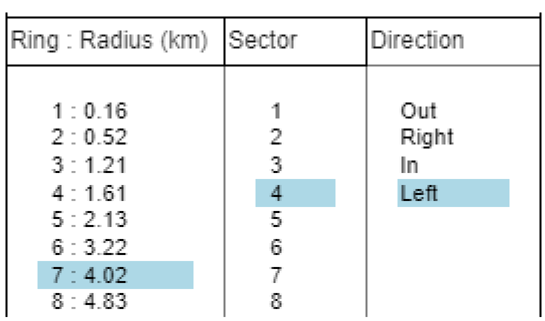


Figure 3-30. Radius and sector selected

The second method is to use the *ASSIGN* button.

Clicking the *UNSELECT* button clears the selection of the radius and sector.

Selecting a radius, all sectors, and a direction from the list and clicking the *ASSIGN* button changes the direction for all grid elements at the selected radius at the same time. Multiple radii can be selected by holding the shift key and the desired radii or selecting the first in the series and dragging the mouse down to highlight.

3.3.6.3.2.2. 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. When clicked, grid element is highlighted and shows a list of Speed Multipliers. The clicked element is also highlighted in the Radius/Sector list. The Speed Multipliers can then be changed for the element.

The second method is to use *ASSIGN* button. This method is the preferred way to change all the speed multipliers for a given radius or a given sector. To assign in bulk, first select the desired speed, then press shift while clicking the desired radii and sectors. Alternately, dragging from the top to the bottom of the desired ranges in each category will similarly select all options in the desired range.

In the example shown in Figure 3-31, 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.

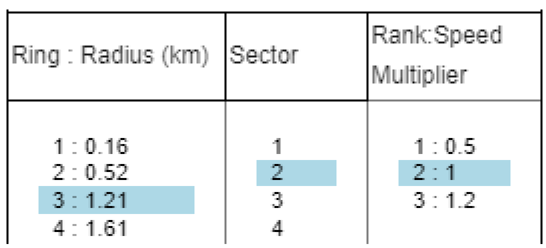


Figure 3-31. Select speed multiplier

3.3.6.3.2.3. Editing the Speed Multiplier List

A speed multiplier for each grid element is used to adjust the speeds assigned for 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 3-32.

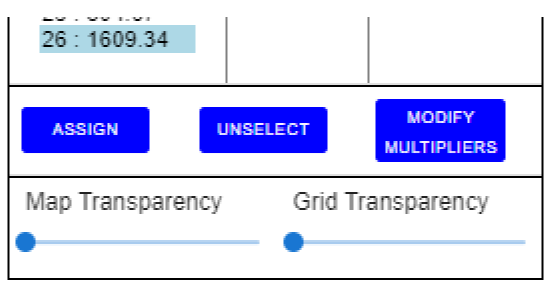


Figure 3-32. Modify multipliers

A dialog box like the one in Figure 3-33 opens.

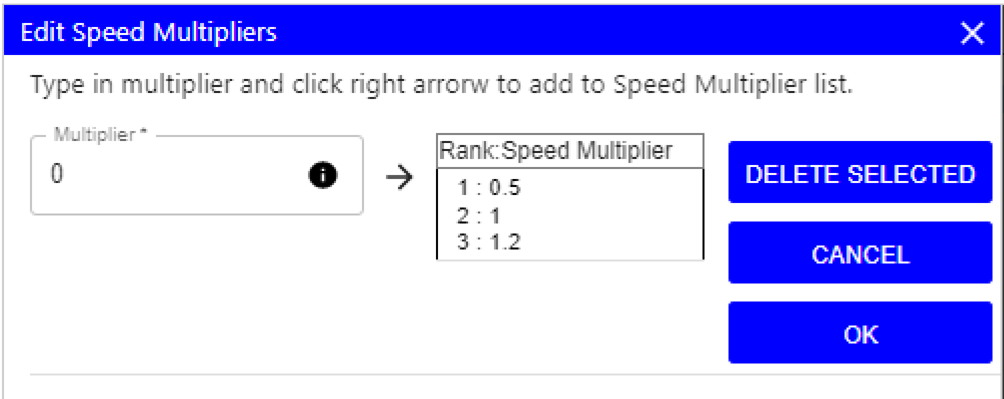


Figure 3-33. *Edit Speed Multipliers* dialog

Speed multipliers can be added to the list by entering a number in the text box followed by pressing the right arrow button on the form. When added, they are sorted into ascending order. Multiple entries of the same number are not allowed.

Multipliers can be deleted by selecting a multiplier from the *Rank: Speed Multiplier* list and clicking the *DELETE SELECTED* button.

Clicking *OK* preserves changes. Clicking *CANCEL* discards changes.

Ranks shown on the spatial grid may be modified 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 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 has initially rank one assigned to all the elements, which is now 0.5 instead of 1.0. The user is urged to use caution in assigning values to ensure the intent is met.

3.3.6.3.2.4. Assigning Values to the Populations Assigned Form

The *Populations Assigned* form is similar to the *Network Evacuation Direction* and *Network Evacuation Speed* forms used to assign populations to grid elements is shown in Figure 3-34. However, instead of assigning evacuation directions or evacuation speeds to the grid sectors, population distributions are assigned.

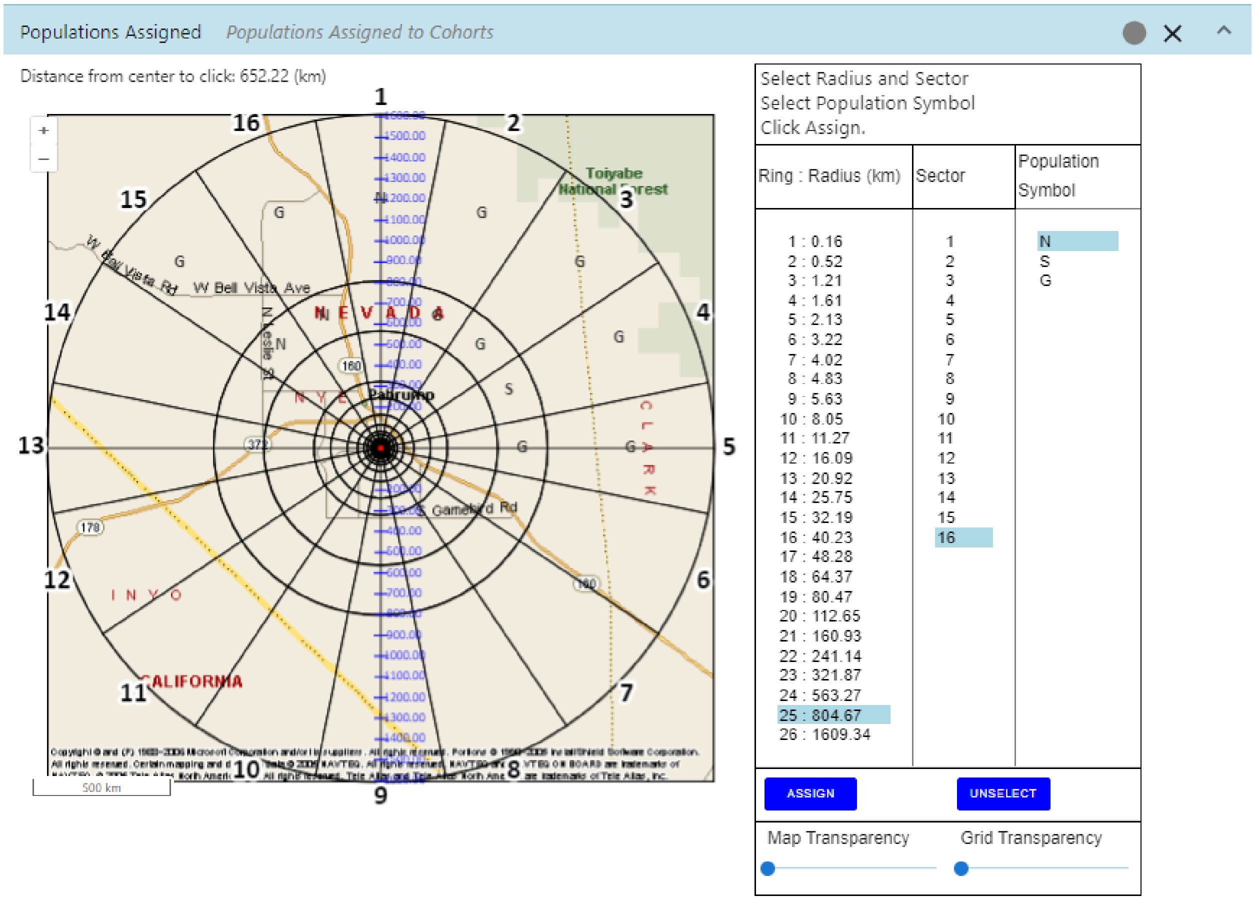


Figure 3-34. Selecting populations assigned to cohorts

On the right side of this window there is a list titled *Population*. In the example shown in Figure 3-34, 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 (604.67, 16) 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 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 *Ring : Radius*, selecting all sectors, and clicking the population in the list labeled *Population*, clicking the *ASSIGN* button. Similarly, a population can be assigned to all grid elements in each 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* and select all radii.

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 holding shift while clicking the top and bottom options in both *Ring : Radius* and *Sector* lists, then clicking *ASSIGN*. This can be followed by manually setting less-common populations by one of the other methods described.

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 MACCS-UI 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.

3.3.7. Multi Source

A group of MelMACCS files, possibly created from a combination of different MELCOR plot files and single files with multiple rings, can be run using the *Multi-Source Model Flag* option. This is done by opening a project in MACCS-UI and merging the source term files using the following steps:

1. The option is activated by selecting the *Multi-Source Model Flag* checkbox on the *Scope* tab in *PROPERTIES*, as shown in Figure 3-35.
2. Source term files are selected from the *GENERAL/File Specifications/Multi Source Files* form. From this form, the user can navigate to the folder containing the multi-source files created by MelMACCS.
3. Files can be selected by clicking the *BROWSE* button and double-clicking file names. The order that the files are processed can by changed clicking the up or down arrows, as shown in Figure 3-36. The order of the files affects some subsequent steps.
4. Save the selection with *SAVE* button, which is blue when unsaved changes are present.

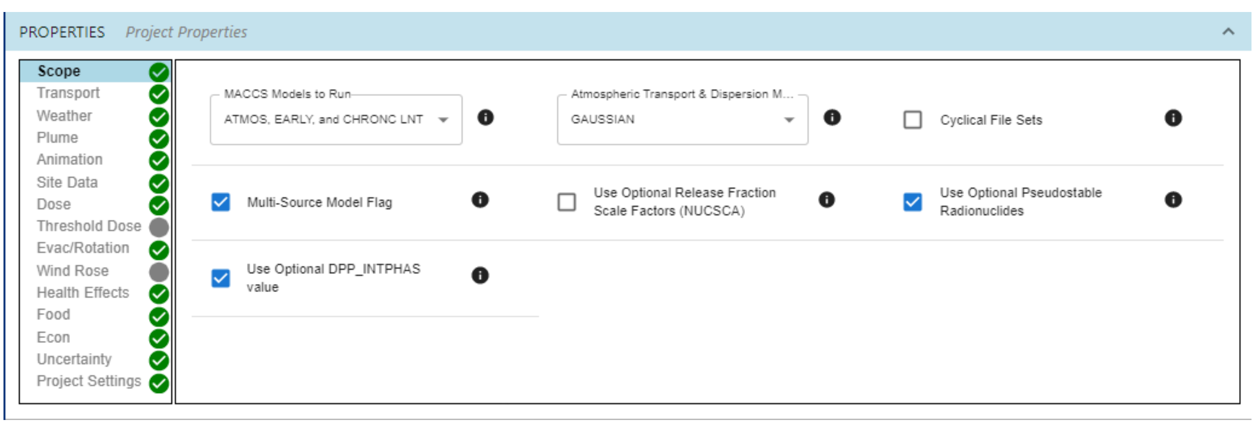


Figure 3-35. *Scope* tab with *Multi-Source Model Flag* selected

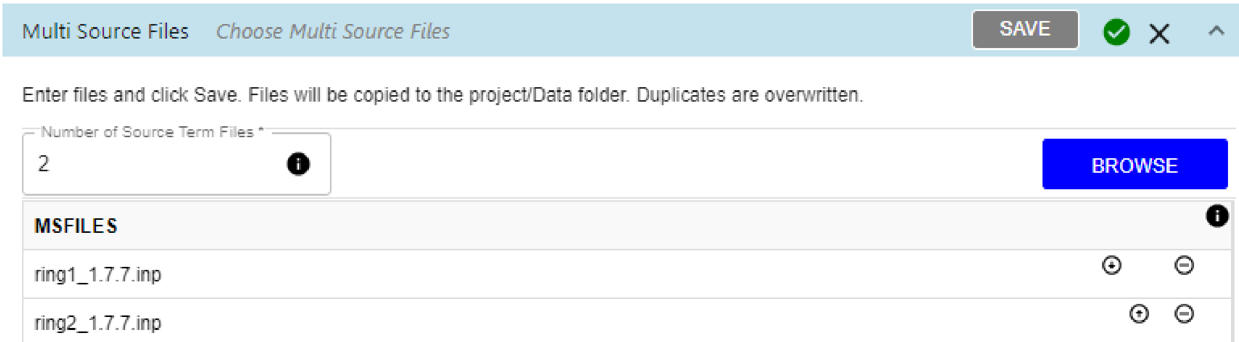


Figure 3-36. Specifying multi-unit source input files

The first four forms under the *Multi Source* category are required. Two are similar to ones required for a single-unit source term, namely *Chemical Names* and *Radionuclides*. The *Time Offsets* form allows the user to specify time offsets for each source term file, as illustrated in Figure 3-37.

The *Plume Segments* form shows the plume segments arranged chronologically and identifies which multi source 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 22 plume segments defined, 14 from the file ring1_1.7.7.inp and eight from the file ring2_.1.7.7.inp. The files used by MACCS-UI are copies of the original and are copied to the project's Input folder.

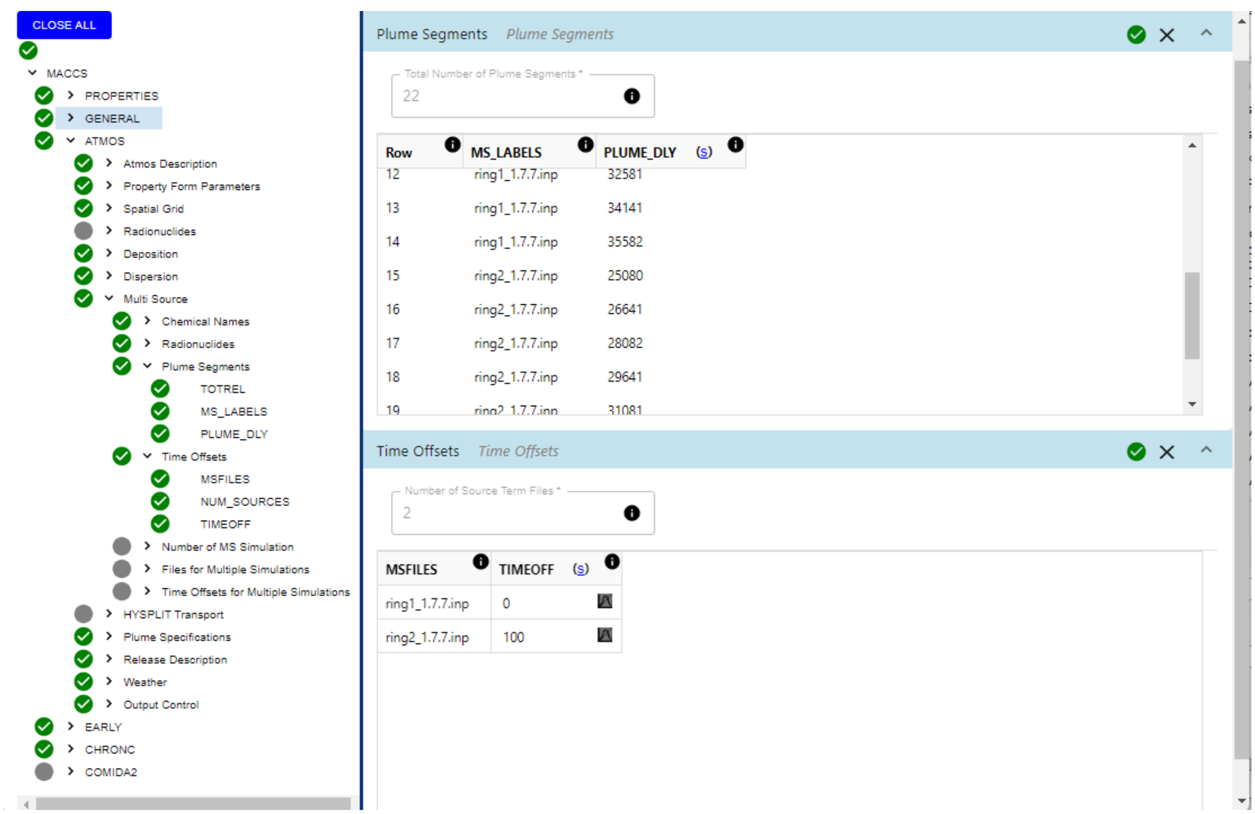


Figure 3-37. Forms for specifying multi-unit source

A form named *Plume and Spatial Intervals for MultiSource* is enabled under *ATMOS/Output Control* as well. This form has the same format name as *Plume and Spatial Intervals*, but is used for MultiSource analyses, as shown in Figure 3-38. However, the upper bound for the parameter INDREL, indicating the plume segment number, is the number of plumes segments in all of the multi-source files. The row number on the *Plume Segments* form shown in Figure 3-37 identifies value of INDREL for a specific plume segment.

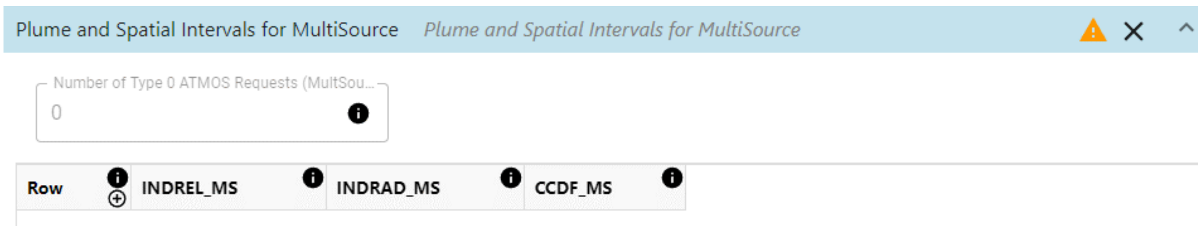


Figure 3-38. Specifying ATMOS output with the multi-unit source model

3.4. Running Simulations

Simulation progress can be observed in the *PROCESSING* tab from. When *RUN SIMULATION* is clicked, this tab is automatically switched to in the display.

When the simulation has completed, a message conveying successful completion is written to the results panel. Its results can be viewed using the *REPORTS* tab.

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 parameters 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 parameter 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 check the *Create Only Missing Input Files* option in the *Project Settings* tab in *PROPERTIES*. Otherwise, the modified file is overwritten before MACCS executes and the modification is lost.

3.5. 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 MACCS-UI as custom reports, custom plots or a text view of the binary file.

3.5.1. *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 opening the project \Output\ folder in Windows File Explorer and selecting the Modeln.out file of interest in the text editor.

Most MACCS results from a single simulation are probability distributions representing uncertain weather. For example, in Figure 3-39, 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 3-39.

	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 3-39. MACCS statistical summary results

A CCDF of output requests is created by MACCS when CCDF*x* (*x* being the type, i.e., A) is set to *CCDF* or *CCDF* & *REPORT* on the forms in ATMOS, EARLY, 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. For example, 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 MACCS-UI variable CCDF*x*. There are ten columns of numeric data which provide a statistical summary.

Table 3-4. Data in each summary report column

Column	Description
PROB NONZERO	Conditional probability of having a nonzero consequence estimate, conditional on the occurrence of the release under consideration.
MEAN	Average (expected) consequence over all weather trials, calculated by taking the sum of all the products [(consequence value) × (conditional probability of that value)] for each weather trial. Probabilities of the weather trials are not necessarily the same, so the conditional probabilities can be different for each weather trial.
50TH QUANTILE	Median of the estimated CCDF.
90TH QUANTILE	Based on the estimated CCDF. Value for which there is a 10% chance this consequence magnitude is exceeded.
95TH QUANTILE	Based on the estimated CCDF. Value for which there is a 5% chance this consequence magnitude is exceeded.
99TH QUANTILE	Based on the estimated CCDF. Value for which there is a 1% chance this consequence magnitude is exceeded.
99.5TH QUANTILE	Based on the estimated CCDF. Value for which there is a 0.5% chance this consequence magnitude is exceeded.
PEAK CONS	Largest consequence magnitude obtained from the set of weather trials that were examined.
PEAK PROB	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 parameters 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. MACCS-UI 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.

CCDFx (*x* being the type, i.e., A) 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*, MACCS-UI automatically generates a report over all realizations based on quantiles specified on the *CCDFx* form.

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.

3.5.2. Custom Reporting Options

Reports created from the MACCS binary result files are created using different methods as follows:

- Reports that combine the results over the MACCS simulations can be requested on the *Output Control* forms in the *ATMOS, EARLY,* and *CHRONC* categories. These requests result in 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 *Output Control* categories, even when report requests were not made on those forms.

Custom reports can only be created after the simulations are completed The *Auto-run reports after simulation* can be toggled on in the *REPORTS* page. When the project is rerun, then any defined reports would be automatically recalculated. The reports created include the Summary Report as well as any custom reports defined. These reports are placed in the project \Output folder.

The reports can be requested from the *REPORTS* page. The summary report can be created by selecting *Create Summary Report*. These post processing features only function when the MACCS binary files have not been deleted.

Custom reports are defined using the *+NEW REPORT* button. New custom reports must be defined after the MACCS simulations have completed because the list of results to place in the reports is not 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 by either using the *RUN* button for the report of interest or toggling the *Auto-run reports after simulation* option.

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 because previously created reports are not deleted unless the new file has the same name as the existing file.

3.5.2.1. Combining Results over Realizations

Reports that combine realizations contain the grand mean (i.e., the mean of the means for each realization) and the interpolated values based on the binned CCDF results for a user entered set of probabilities, or quantiles. The first step in defining these reports is to define the quantiles to use. When the probabilities are not defined, only the grand mean is reported.

Opening the form *GENERAL/Output Options/Reporting Options* allows quantiles to be entered. This is shown in Figure 3-40. When the MACCS simulations have already completed, a *Summary Report* cannot be created, but custom reports can be requested that combine the realizations.

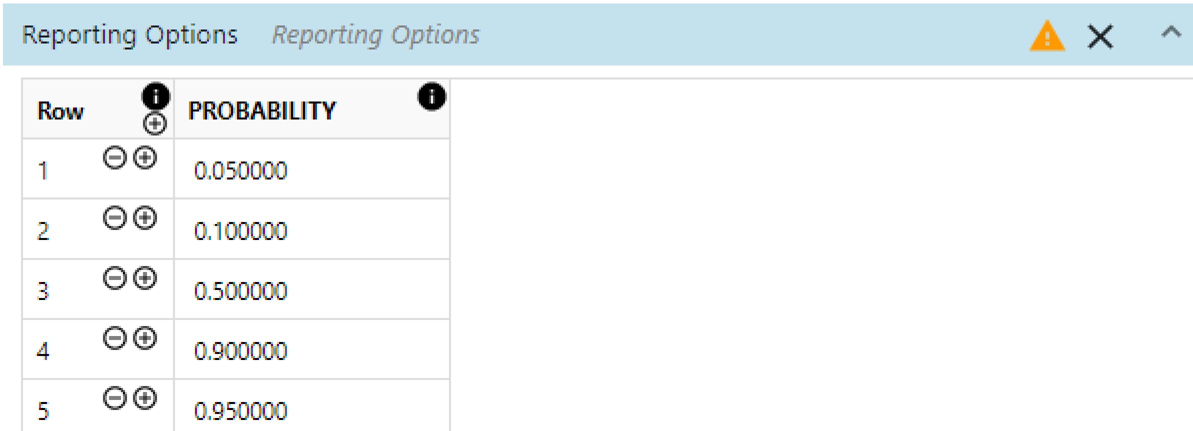


Figure 3-40. Specifying quantiles

3.5.2.2. Creating a Summary Report

A summary report based on MACCS outputs is created after MACCS simulations have completed. To include a result in the summary report, the CCDF flag should be set to *REPORT* or to *CCDF* & *REPORT* as shown in Figure 3-41. This report can also be recreated by clicking the *CREATE SUMMARY REPORT* button on the *REPORTS* page.

The categories *ATMOS/Output Control*, *EARLY/Output Control* and *CHRONC/Output Control* contain calculation requests. Most of the forms in these categories contain the CCDF option.

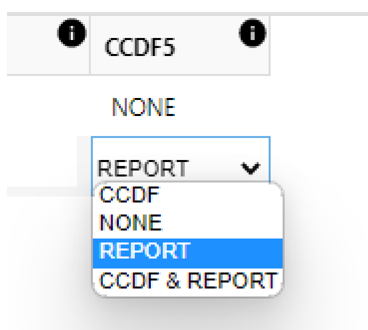


Figure 3-41. Summary report request

Summary reports can be requested as follows:

- Quantiles are defined as shown in Figure 3-40.
- 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.
- In the CCDF column, by choosing either *REPORT* or *CCDF* & *REPORT* causes MACCS-UI to include this result 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.
- This process can be repeated for all results to be included in the summary report. Clicking *OK* preserves the summary report requests.

- After running the MACCS simulations, the binary result files, Model1.bin and 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.

3.5.2.3. Creating a New Custom Report

This section describes how to create new combined realization and realization-based reports after MACCS simulations have completed.

After MACCS has run, the *REPORTS* page is available, where a new combined realization report can be created, shown in Figure 3-42. When the *Auto-run reports after simulation* toggle is enabled, all reports listed are automatically created after the MACCS simulations have completed.

This form lists the custom reports currently defined, as shown in Figure 3-42. There are three reports defined, with their types listed below their names. The first listed is a combined report, indicated by the *COMBINATION* label. The following two are realization-based reports, which are viewed by variable and by realization, similarly indicated by their labels.

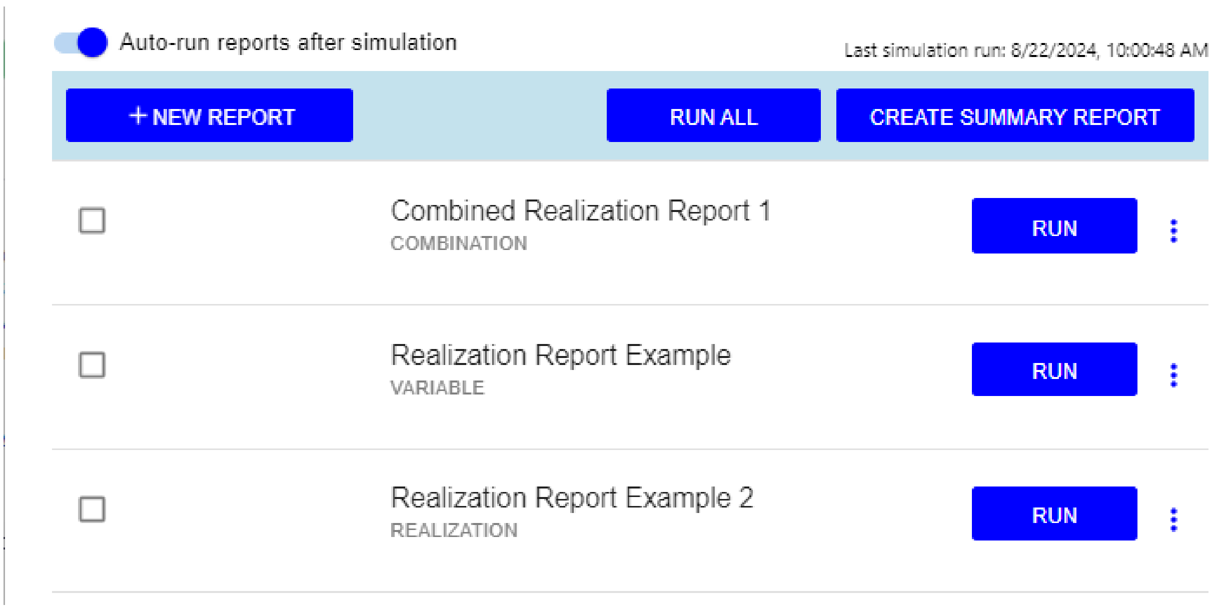


Figure 3-42. Example *REPORTS* page contents

The *Create Report* form, where reports are created or edited, lists each of the MACCS output requests, as shown in Figure 3-43.

The *Description* column identifies the form description as found in the parameters tree. For example, in Figure 3-43 the entries defining the report *Population Dose* were requested from the MACCS-UI form *EARLY/Output Control/Population Dose*. The *MACCS Input Card* column is a copy of the line written to the MACCS input file EARLY1.inp.

Combined realizations reports contain results similar to the Summary.txt report. MACCS-UI combines the CCDF data over all the MACCS binary result files and displays the grand mean and the interpolated quantile values.

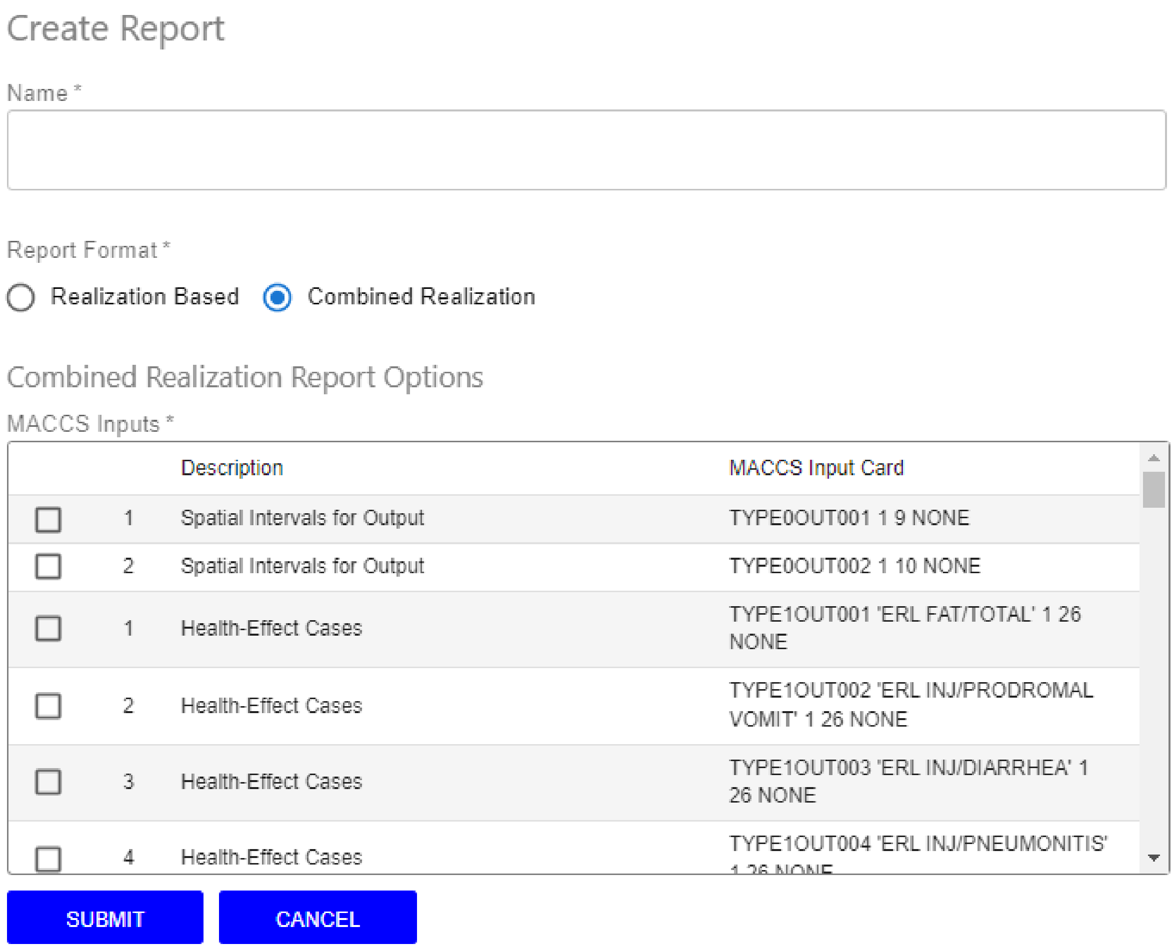


Figure 3-43. Defining a combined realization report

New combined realization reports can be defined as follows:

- Quantiles are defined as shown in Figure 3-40.
- The *REPORTS* page is opened as shown in Figure 3-42.
- A new definition can be made by selecting + *NEW REPORT* button.
- The user can enter report name in the *Name* field.
- The *Combined Realization* radio button can be selected in the *Report Format* field.
- The MACCS output requests are selected by clicking their respective check boxes.
- Clicking *SUBMIT* saves the new report definition.

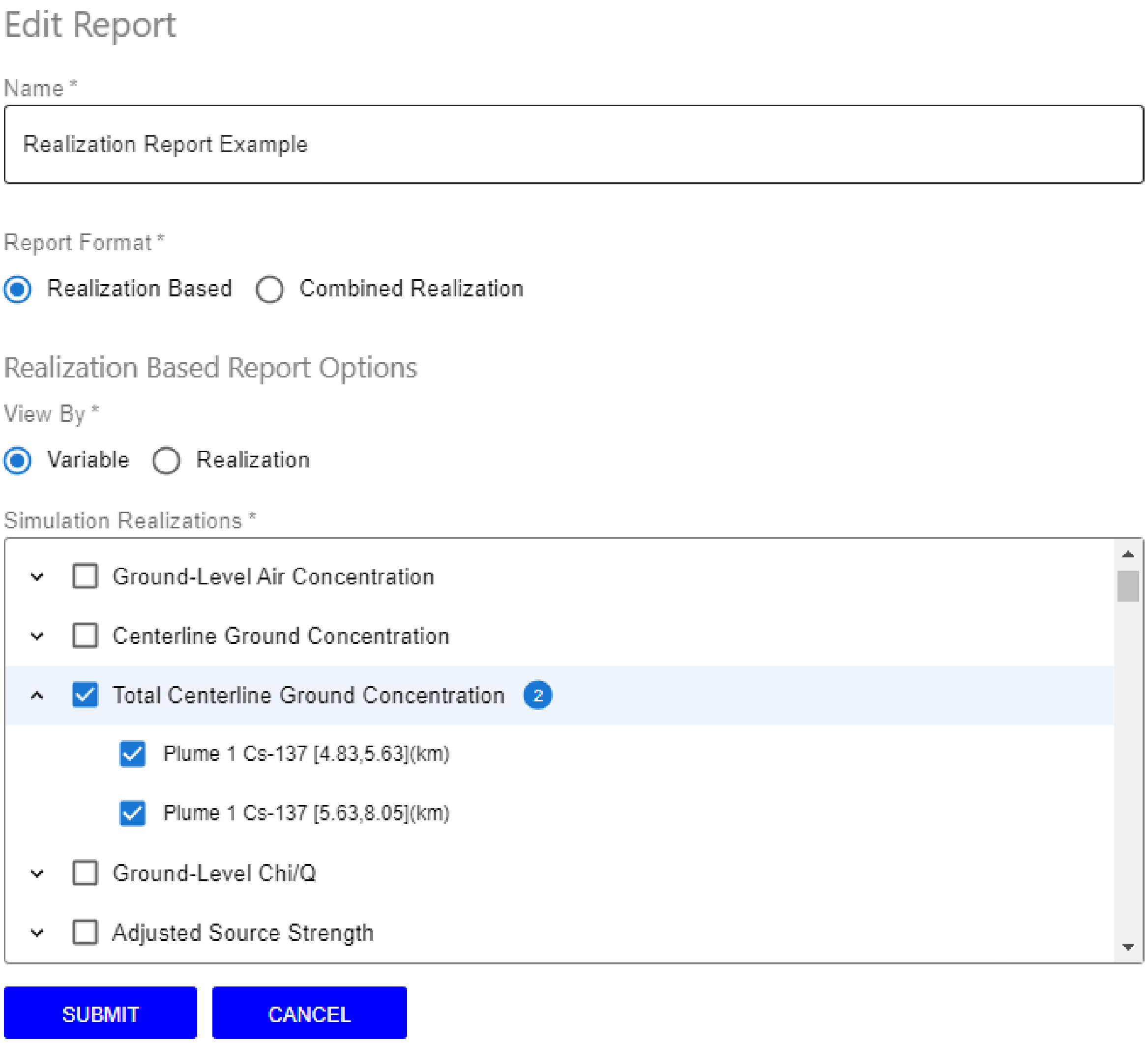


Figure 3-44. Defining a realization-based report

New realization-based reports can be defined as follows:

- The *Realization Based* radio button can be selected in the *Report Format* field.
- Selecting either the *Variable* or *Realization* radio buttons for the *View By* field.
    - When *Variable* is selected, the results are listed for a given trial when the report is created.
    - When *Realization* is selected the results for each trial are listed for a given result as shown in Figure 3-44.
- The MACCS output requests are selected by clicking their respective check boxes.
- Clicking *SUBMIT* saves the new report definition.

If the report has already been defined, the report can be opened in Notepad by clicking its *RUN* button or selecting its checkbox and selecting *RUN SELECTED*. They can also be opened through Windows File Explorer using a text editor.

Report definitions can be edited by clicking the menu on its right edge and selecting *Edit*. It can be deleted in the same menu by instead clicking the *Delete* option.

3.5.2.4. Interpretation of Combined 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 3-43.

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
```

Figure 3-45. Example Combined Realization Report Output

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 WTFRAC when the overall results are calculated for some of the results that are independent of the population such as Average Individual Risk, Peak Dose and Population Weighted Risk calculations.

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4. MAIN CATEGORIES

4.1. GENERAL

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

The parameters tree UI can be expanded or collapsed by clicking on the > or ˅ next to items on the parameters bar, respectively. For example, clicking on the > to the left of the *GENERAL* main category reveals the four categories that belong to this main category. Clicking on the > to the left of the *FILE SPECIFICATIONS* category expands it, revealing the eleven forms that it contains. Finally, clicking on the > to the left of *METEOROLOGICAL FILE* reveals the set of parameters that it contains. Clicking on the *CLOSE ALL* button will contract all open forms simultaneously (Figure 4-1).

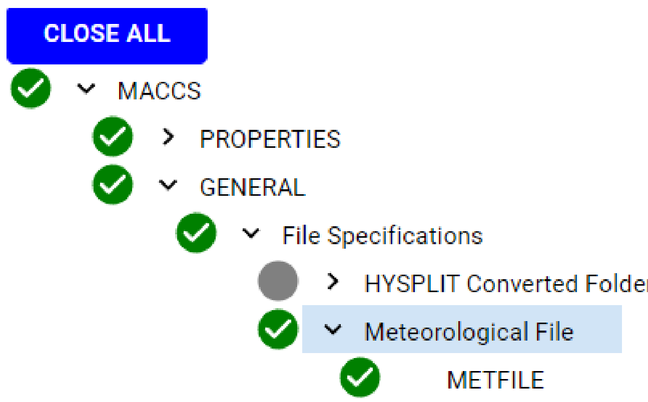


Figure 4-1. *GENERAL* category list partially expanded and *CLOSE ALL* button

4.1.1. PROPERTIES

The *PROPERTIES* form is opened by default when projects are opened or created. *PROPERTIES* controls the scope of the calculation and all the available model options, as shown in Figure 4-2. Depending on the selections made, input parameters may or may not be required. This section of the document provides a summary of the modeling choices. Sections 4 and 5 include detailed descriptions.

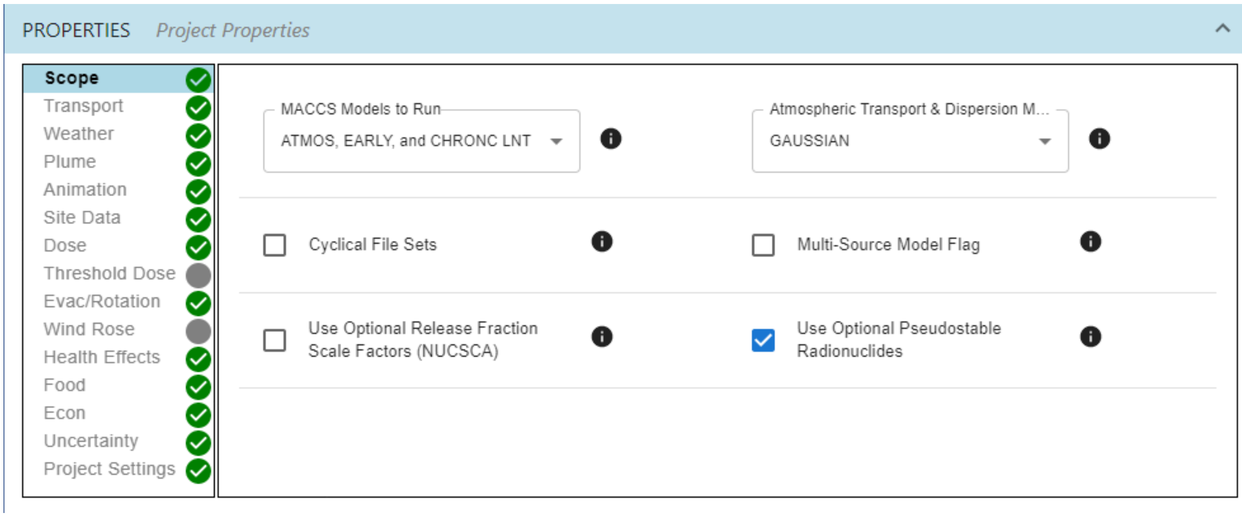


Figure 4-2. ***PROPERTIES*** **form**

The following provides an example of creating and updating a new project and how modifying the scope of the calculation affects the forms that are required.

- Creating a new project by selecting the *NEW PROJECT* button from the *HOME* page causes the *INPUT* page to open after the new project is created with default settings. Notice that the default model choice for *Atmospheric Transport & Dispersion* is the Gaussian model. EARLY (Early Consequences) and CHRONC (Late Consequences) are not enabled by default.
- Clicking on the expand arrow next to the ATMOS main category on the parameters tree causes forms to become visible, as illustrated in Figure 4-3. All the categories under EARLY and CHRONC are empty gray circles. This means that the parameters on these forms are not defined but are not required to run a simulation given the model choices in *PROPERTIES*.
- Enabling EARLY in the *MACCS Models to Run* dropdown will show that some categories in the EARLY main category now require attention. These categories have icons consisting of checked green circles and X-ed red circles. The scope of the calculation changes to include early consequences when it is selected.
- Repeating the process by adding CHRONC to the scope causes an additional group of categories to require attention.
- Each of the enabled main categories (ATMOS, EARLY, and CHRONC) contains a read-only form called *Property Form Parameters*. Opening these by clicking on the word *Property Form Parameters* under each of the main categories allows a user to see the parameter values that are defined in *PROPERTIES*.

Figure 4-4 shows the read-only *Property Form Parameters* form for EARLY. The values on these forms correspond to model settings in *Project Properties*. These values can only 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 grayed-out text.

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

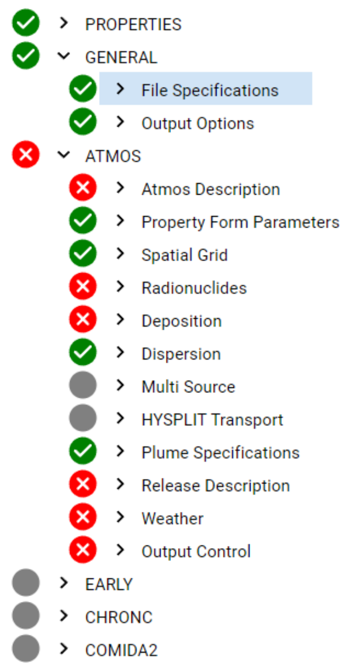


Figure 4-3. Form icons

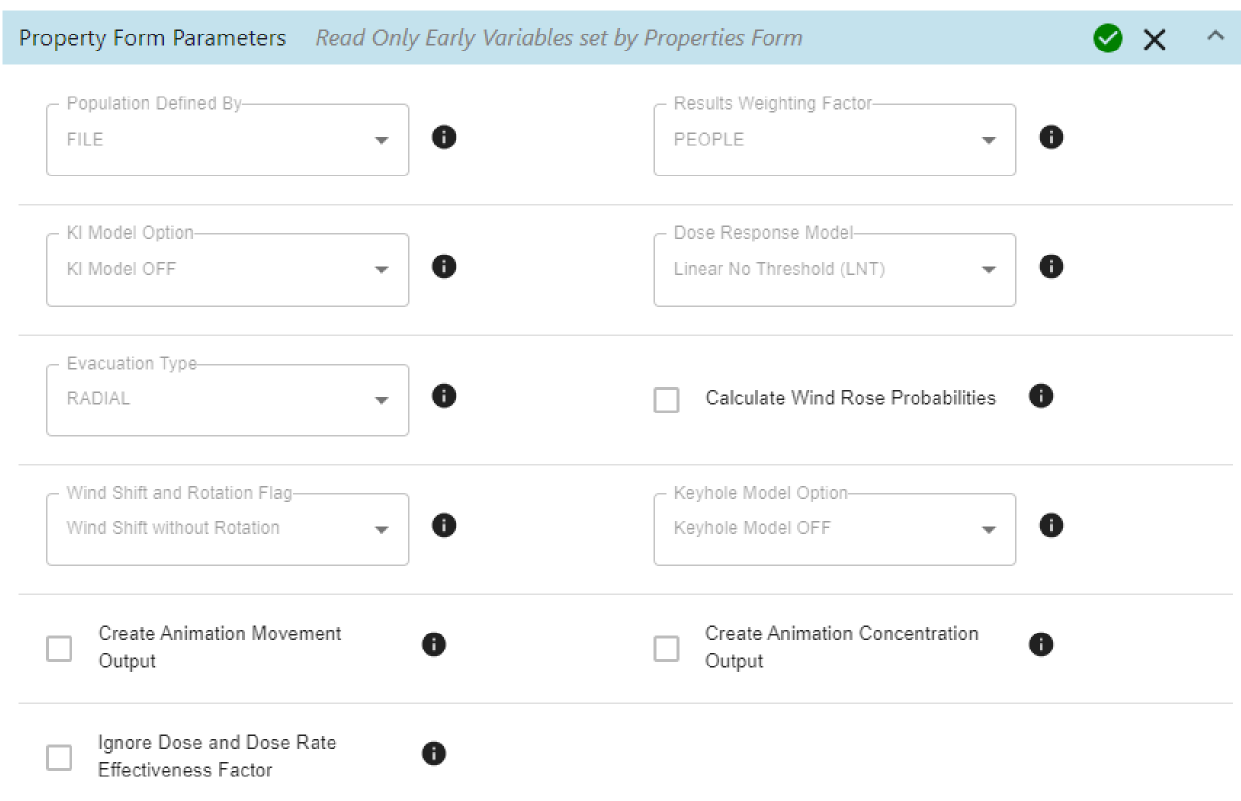


Figure 4-4. *EARLY* Read-only parameters in *Property Form Parameters*

4.1.1.1. Scope tab

The contents of the *Scope* tab are shown in Figure 3-5. The option to invoke the *Cyclical File Sets* does not correspond to any MACCS parameters; this option is handled within the MACCS-UI interface.

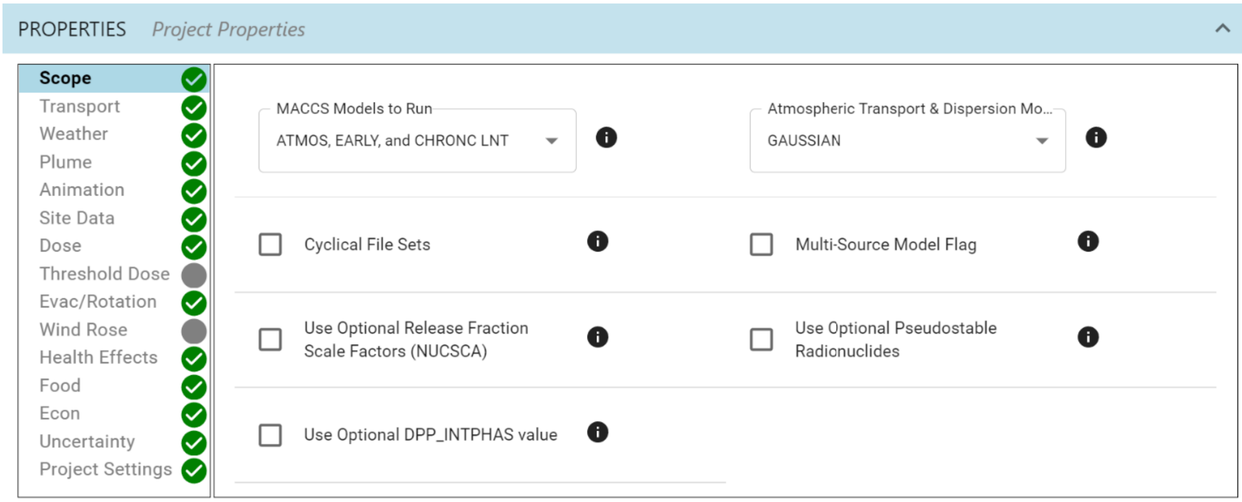


Figure 4-5. *Scope* tab in *PROPERTIES*

The *MACCS Models to Run* dropdown allows users to choose from a selection of additional models that may be run. ENDAT1 and ENDAT2, which correspond to EARLY and CHRONC, are set to false when their respective models are enabled.

WinMACCS users should notice that the option to select *Linear No Threshold* or *Threshold Model*, previously contained in the *Dose* tab has been moved to this form and incorporated into the selectable options in this dropdown.

Available options are:

- *ATMOS* only;
- ATMOS and EARLY;
- ATMOS, EARLY, and CHRONC LNT; or
- ATMOS, EARLY, and CHRONC Threshold.

Enabling EARLY (Early Consequences) means:

- A DCF file needs to be assigned under *GENERAL/File Specifications*.
- Entries on other tabs, namely *Site Data, Dose, Evac/Rotation,* and *Wind Rose* determine which other EARLY input parameters are required.

Enabling *CHRONC LNT* (Late Consequences, Linear No Threshold) means:

- EARLY must also be run. The CHRONC module cannot be run without the EARLY module.
- The *Threshold Dose* form is not required.
- The LNT dose-response model (the only option in early versions of MACCS) is used to calculate latent health effects.
- DOSMOD is set to LNT.

- *MACCS Food Model* on the *Food* tab is available.
- Checking *Ignore Dose and Dose Rate Effectiveness Factor* is not an option for this model.
- Checking *Dose/Linear Quadratic Dose Response* is an option for this model.
- Entries on the *Food* tab determine which additional CHRONC input parameters are required.

Enabling *CHRONC Threshold* (Late Consequences, with threshold model) means:

- EARLY must also be run. The CHRONC module cannot be run without the EARLY module.
- A dose threshold model must be selected in the *Dose Threshold* tab.
- DOSMOD is set to option selected in the *Dose Threshold* tab.
- *MACCS Food Model* on the *Food* tab is available.
- Checking *Ignore Dose and Dose Rate Effectiveness Factor* is an option for this model.
- Checking *Dose/Linear Quadratic Dose Response* is an option for this model.
- Entries on the *Food* tab determine which additional CHRONC input parameters are required.

The *Atmospheric Transport & Dispersion Model* dropdown provides two options for the atmospheric transport and dispersion model used by MACCS. Section 4.2.1 provides more description of these two options:

- The *Gaussian* option selects the standard Gaussian plume segment model.
- The *HYSPLIT* option selects the Hybrid Single-Particle Lagrangian Integrated Trajectory model.

Checking the *Cyclical File Sets* box means:

- A cyclical file set needs to be assigned under the *File Specifications* category on the *Parameters* bar. The function of this model choice is described in Section 3.3.5.

Checking *Multi Source Model Flag* means:

- MACCS allows the user to use multiple source term definition. The function of this model choice is described in Section 3.3.7.
- The user specifies these files under *File Specifications* and needs to fill out additional forms in the *ATMOS* main category.
- When selected, an optional selection to *Choose Files for each Simulation* becomes available, which allows the use of different MELCOR plot files for each simulation.

4.1.1.2. *Transport* tab

The contents of the *Transport* tab are shown in Figure 4-6.

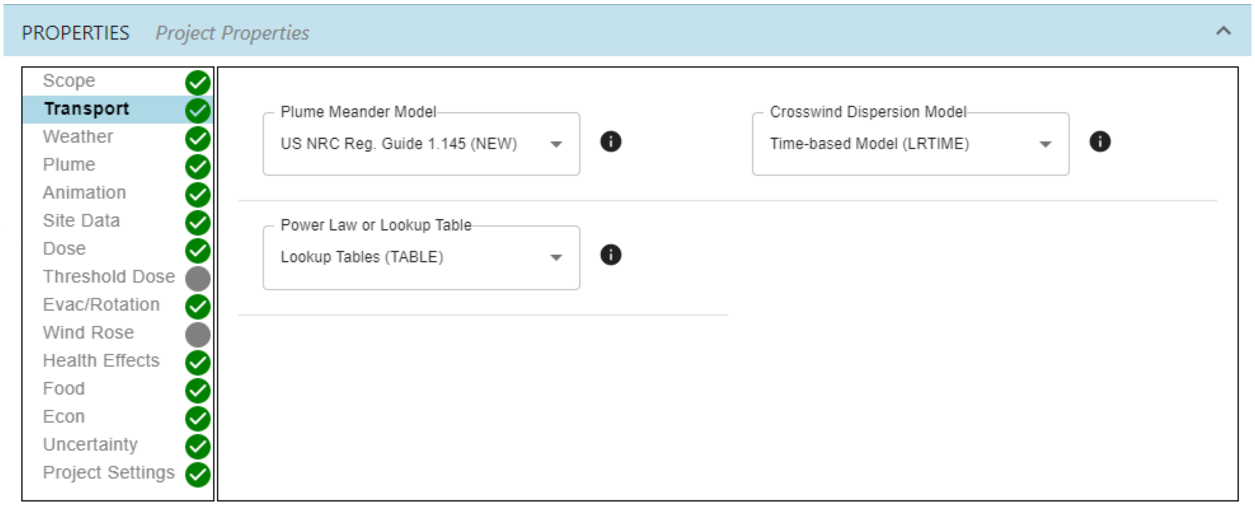


Figure 4-6. *Transport* tab in *PROPERTIES*

There are four choices for the plume meander model. These models are further discussed in Section 4.2.8.1. 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 item in the *Plume Meander Model* dropdown.

Selecting *Original MACCS (OLD)* means:

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

Selecting *U.S. NRC Reg. Guide 1.145 (NEW)* means:

- The Regulatory Guide 1.145 plume meander model is used, which 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.
- Depending on the options selected for plume source (on the Plume tab), the following ATMOS forms are required:
    - *Plume Specifications/US NRC Reg. Guide 1.145 Meander*
    - *Plume Specifications/US NRC Reg. Guide 1.145 Point Source Meander*
    - *Release Description/Building Height Data*
    - *Release Description/Additional Building Data*

Selecting *Ramsdell and Fosmire (RAF)* means:

- The Ramsdell and Fosmire plume meander model is used. This model includes enhanced dispersion near a building at low and high wind speeds.
- At low wind speeds, building wakes have a minimal effect and the major contributor to enhanced dispersion is plume meander. At high wind speeds, building wakes are the major contributor to enhanced dispersion.

- Parameters on the following ATMOS forms are required:
    - *Plume Specifications/Ramsdell and Fosmire Meander*
    - *Release Description/Building Height Data*
    - *Release Description/Additional Building Data*

Selecting *None (OFF)* means:

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

The crosswind dispersion model has two options:

- If *Time-based Model (LRTIME)* is selected, MACCS-UI sets the parameter DISPMD to the value LRTIME. Parameters on the *Long-Range Time-Based Parameters* form found in the *ATMOS/Dispersion* category in the *Parameters* tree are required. Dispersion parameters are functions of time rather than distance beyond a user-specified distance.
- If *Distance-based Model (LRDIST)* is selected, DISPMD is set to the value LRDIST. The value LRDIST causes MACCS to use the original model in which dispersion parameters are solely functions of distance.

The user must either first select either power law functions or lookup tables to define the dispersion parameters and whether to also use the time-based or distance-based dispersion model. Further information about the dispersion options is discussed in Section 4.2.5.

Selecting the *Power Law Functions (POWER)* means:

- Power law function parameters are required, on the *Dispersion Function* form found in the *ATMOS/Dispersion* category in the *Parameters* tree.
- MACCS-UI sets NUM_DIST to be zero in the ATMOS input for MACCS.

Selecting *Lookup Tables (TABLE)* means:

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

4.1.1.3. *Weather* tab

The contents of the *Weather* tab are shown in Figure 4-7.

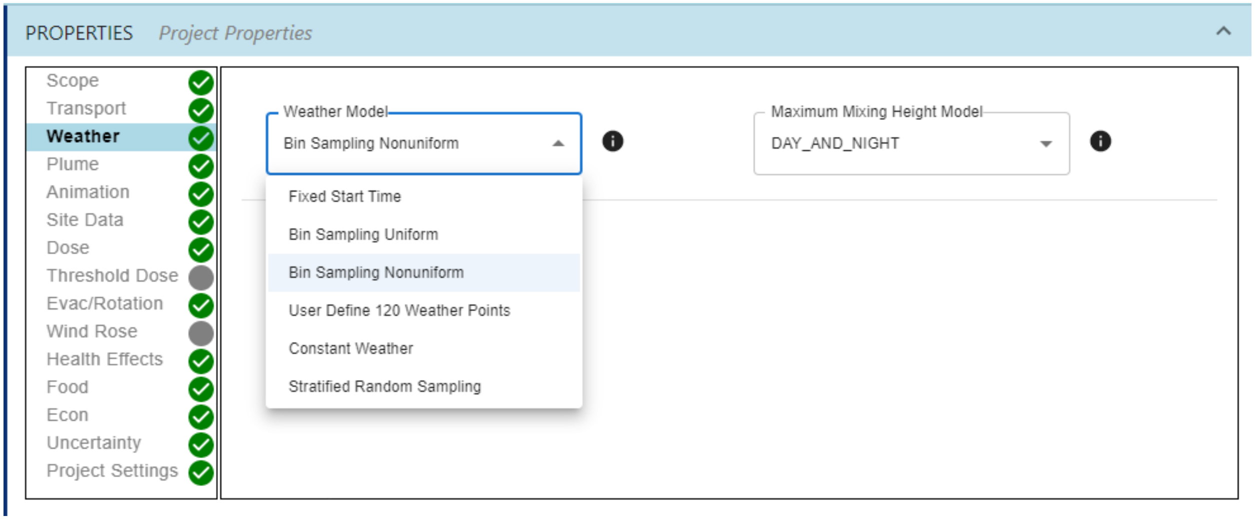


Figure 4-7. *Weather* tab in *PROPERTIES*

Selecting *Constant Weather* sets the value of METCOD to 4 and means that a single weather trial is evaluated and that inputs on the following *ATMOS/Weather* category forms on the *Parameters* bar are required:

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

Selecting *User Supplies 120 Weather Points* sets the value of METCOD to 3 and means that a single weather trial is evaluated and that the following inputs found on the *ATMOS/Weather* category are required:

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

Selecting *Fixed Start Time* sets the value of METCOD to 1 and means that the following *ATMOS/Weather* category forms are required:

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

Selecting *Uniform Bin Sampling* sets the value of METCOD to 2 and means the following *ATMOS/Weather* category forms are required:

- *Constant or Boundary Conditions*
- *Samples per Bin*
- *Seed*
- *Boundary Limit*

- *Rain Distances*
- *Rain Intensities*

Selecting *Nonuniform Bin Sampling* sets the value of METCOD to 2 and means the following *ATMOS/Weather* category forms are required:

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

Selecting *Stratified Random Sampling* sets the value of METCOD to 5 and means the following *ATMOS/Weather* category forms required:

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

The fixed start time is required for these options to determine the time of year the accident occurs, which is needed for food ingestion modeling. These inputs are required even if food ingestion is not being treated but they can be set to dummy values.

When *Fixed Start Time, Bin Sampling Uniform, Bin Sampling Nonuniform, or Stratified Weather Sampling* are selected, a meteorological data file is required and needs to be assigned under the *File Specifications* category. The meteorological data file allows 15-minute, 30-minute, and one-hour intervals. Only the traditional hourly weather data are supported with the *User Supplies 120 Weather Points* option described above. The input data requirements for the weather options are described in the subsequent paragraphs.

The *Maximum Mixing Height Model* dropdown is required, though it is unused when *Constant Weather* or *User Define 120 Points* is selected. This sets MACCS variable MAXHGT, which determines which mixing height model to use.

Selecting *DAY_AND_NIGHT* means:

- Parameters in *Site Location* found in *ATMOS/Weather* are required.
- Both daytime and nighttime values of the mixing heights in the meteorological data file are used.
- Selecting *DAY_ONLY* means:
- MACCS will use the model used in MACCS Version 1.12, which uses only the maximum seasonal values that normally correspond to daytime values.

4.1.1.4. *Plume* tab

The contents of the *Plume* tab are shown in Figure 4-8.

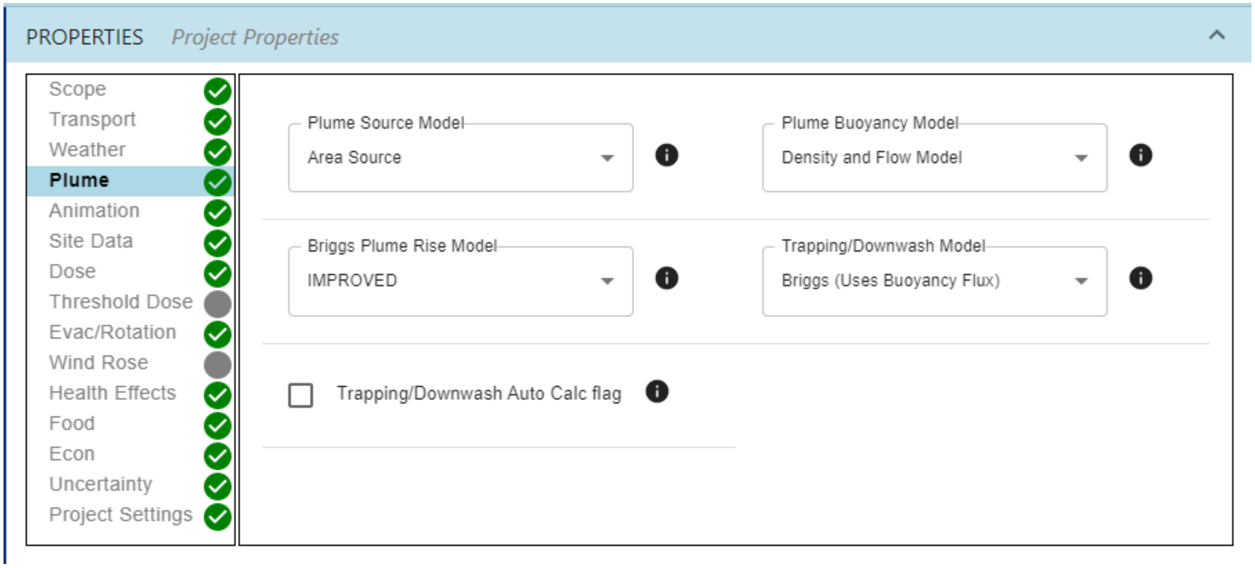


Figure 4-8. *Plume* tab in *PROPERTIES*

Beginning in MACCS 4.1, operations were added to the Plume tab, *Plume Source Model* dropdown, to allow selection of a point source, area source, or automatic area source calculation to enhance transparency in the plume source being modeled. The details of these three options are discussed in Section 4.2.9.

Choosing *Point Source* sets the value of SRCMOD to PNT and means:

- The initial area of the release is assumed to be from a single point, approximated by a release size of 0.1 m by 0.1 m.
- With the *US NRC Reg. Guide 1.145* plume meander model selected, the following ATMOS forms are required:
  - *Plume Specifications/US NRC Reg. Guide 1.145*
  - *Plume Specifications/US NRC Reg. Guide 1.145 Point Source Meander*
  - *Release Description/Building Height Data*
  - *Release Description/Additional Building Data*
- With the *Ramsdell and Fosmire* plume meander model selected, the following ATMOS forms are required:
  - *Plume Specifications/Ramsdell and Fosmire Meander*
  - *Release Description/Building Height Data*
  - *Release Description/Additional Building Data*
- With the *Original* plume meander model selected, the *Original Meander* form is required, found in *ATMOS/Plume Specification*.
- With the plume meander model set to *None*, no additional forms are required.

Choosing *Area Source* sets the value of SRCMOD to AREA and means:

- The initial area of the release is defined by the values in the *ATMOS/Release Description/Initial Area Source* form.
- With the *US NRC Reg. Guide 1.145* plume meander model selected, the following ATMOS forms are required:
  - *Plume Specifications/US NRC Reg. Guide 1.145*
  - *Plume Specifications/US NRC Reg. Guide 1.145 Point Source Meander*
  - *Release Description/Building Height Data*
  - *Release Description/Additional Building Data*
- With the *Ramsdell and Fosmire* plume meander model selected, the following ATMOS forms are required:
  - *Plume Specifications/Ramsdell and Fosmire Meander*
  - *Release Description/Building Height Data*
  - *Release Description/Additional Building Data*
- With the *Original* plume meander model selected, the *ATMOS/Plume Specification/Original Meander* form is also required.
- With the plume meander model set to *None*, no additional forms are required.

Choosing *Automatic Area Source Calculation* sets the value of SRCMOD to AUTO and means:

- The initial area of the release is calculated from the coefficients in:
  - the *Initial Area Source Coefficients* form;
  - the building parameters defined in *Release Description/Building Height Data*; and
  - *Release Description/Additional Building Data* forms; and
  - the wind direction at the time of the release.

There are two options listed under the *Plume Buoyancy Model* dropdown. These are detailed in Section 4.2.9.

Choosing *Power Model* sets the value of PLMMOD to HEAT and means:

- The original MACCS model is used.
- Values for rate of release of sensible heat for each plume segment must be specified in *ATMOS/Release Description/Heat*.

Choosing *Density and Flow Model* sets the value of PLMMOD to DENSITY and means:

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

There are two options available in the *Briggs Plume Rise Model* dropdown, which sets the parameter BRGSMD. The default and recommended model is *IMPROVED* (see Bixler et al., 2020, for more information).

- *ORIGINAL*. The original Briggs model is used to simulate plume rise.
- *IMPROVED*. This causes MACCS to use the improved plume rise model.

Additionally, MACCS 4.1 introduced two options for *Trapping/Downwash Model*. These are explained in Section 4.2.9.

Choosing *Briggs (Uses Building Parameters)* sets the value of TDWMOD to BRGBLD and means:

- The ability of the wake region induced by the building to trap or downwash the plume is calculated based on building parameters defined in forms *Building Height Data* and *Additional Building Data*, in *ATMOS/Release Description*.

Choosing *Briggs (Uses Buoyancy Flux)* sets the value of TDWMOD to BRGFLX and means:

- The ability of the wake region induced by the building to trap or downwash the plume is calculated based on the wind speed, buoyancy flux, and the building height defined in the B*uilding Height Data* form, in *ATMOS/Release Description*.

When either of the Briggs building parameters or Briggs buoyancy flux trapping and downwash models are selected, the plume centerline height to use after the plume has been influenced by the wake region needs to be specified. The calculations are discussed further in Section 4.2.9. This can be set manually or automatically calculated.

Leaving the *Trapping/Downwash Auto Calc flag* unchecked sets the value of TDWAUTO to FALSE and means:

- The plume centerline height to use after the plume has been influenced by the wake region is set manually by specifying the values on the *Trapped/Downwashed Plume Release Height* form.

Checking the *Trapping/Downwash Auto Calc flag* sets the value of TDWAUTO to TRUE and means:

- The plume centerline height to use after the plume has been influenced by the wake region is calculated based on building parameters defined in forms *Building Height Data* and *Additional Building Data*, in *ATMOS/Release Description*.

4.1.1.5. *Animation* tab

The contents of the *Animation* tab are shown in Figure 3-9. This tab allows the user to select the animation files to be created for use in AniMACCS and requires the *EARLY* module to be enabled for the choices to take effect.

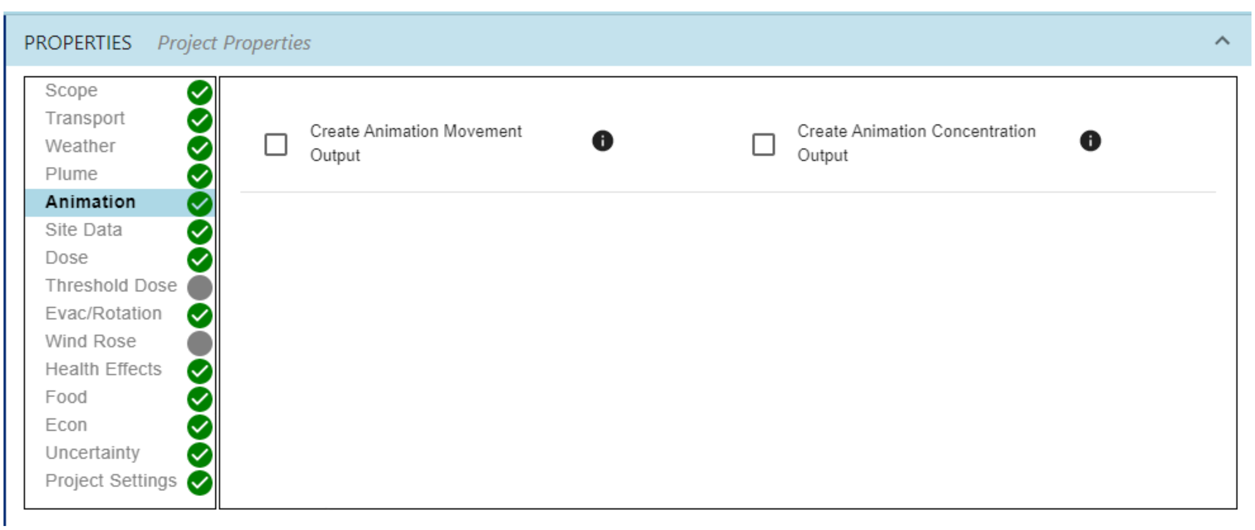


Figure 4-9. *Animation* tab in *PROPERTIES*

In the *Animation* tab there are two options available for generating output files that may be used in AniMACCS.

- *Create Plume Movement Output,* for animating the plume segment movement over time.
- *Create Ground and Air Concentration Output*, for animating the ground and air concentration of particular radionuclides over time.

4.1.1.6. *Site Data* tab

The contents of the *Site Data* tab are shown in Figure 3-10. This tab is required when EARLY is enabled on the *Scope* tab. The *Site Data Model* dropdown sets SITEDATA, which defines the source of the site data (POPFLG) and the population model used (WTNAME).

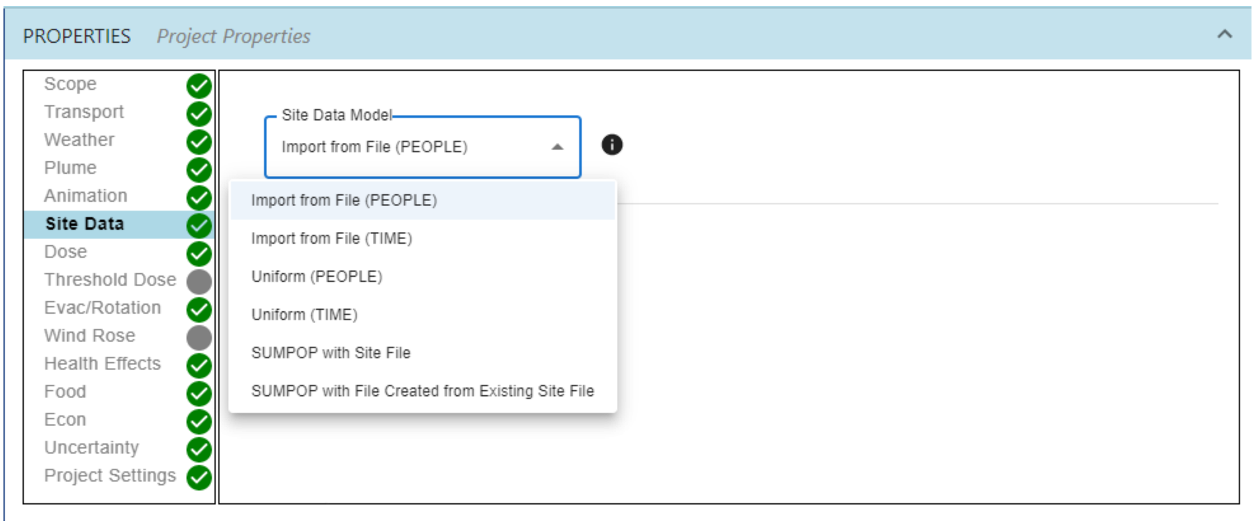


Figure 4-10. *Site Data* tab in *PROPERTIES*

The dropdown provides several combinations of options, shown in Figure 3-10.

Population definition (POPFLG) options:

- *Import from File*
  - MACCS-UI sets the POPFLG to FILE.
  - A site file is required in *GENERAL/File Specifications*.
  - The file can be created by a preprocessor, such as SecPop, to generate a file containing census and economic data for the chosen site. A sample site file, FicticiousSite.inp, is included in the MACCS-UI installation. MACCS-UI allows the user to increase the number of compass sectors in a site file, and this feature has been integrated into the site file specification form.
  - After a site file is linked, the total population can be viewed on the *Population from Site File* form in *EARLY/Model Basis*.
- *Uniform*
  - MACCS-UI sets the POPFLG to UNIFORM.
  - Population density data are required and are specified in the *Population Data* form found under the *EARLY/Model Basis* category.

The results weighting factor determines the way multiple-cohort results are combined. The weighting factor used for each of the cohorts is assigned by the parameter WTFRAC found under the *EARLY/Emergency Cohort* n/*Basic Parameters* forms, where n is the cohort number.

Results weighting factor (WTNAME) options:

- *PEOPLE*, where the weighting factor under each *EARLY/Emergency Cohort n/Basic Parameters* form refers to the fraction of people.
- *TIME*, where the weighting factor for each cohort refers to the fraction of time.
- *SUMPOP…*, which has two options for specifying the site file source.
    - The weighting factor for each cohort is not assigned by WTFRAC.
    - *…with Site File* option
        - The user is required to link an existing site file to the project using the *Site File* form in *GENERAL/File Specifications*.
        - The site file should have a POPULATIONn section defined for each evacuation cohort or MACCS will fail. The n in POPULATIONn is a number corresponding to the cohort number.
    - *…with File Created from Existing Site File* option
        - The user is required to link an existing site file to the project using the *Site File* form in *GENERAL/File Specifications*.
        - The number of POPULATION sections in the file is not relevant; a site file previously created with or without the SUMPOP option is acceptable. This site file is typically created with SecPop.
        - Additional forms in *EARLY/Population by Cohort* are required.

4.1.1.7. *Dose* tab

The contents of the *Dose* tab are shown in Figure 3-11. This tab is required when EARLY is enabled on the *Scope* tab. As of the initial release of MACCS-UI, options to select the dose response model have been moved to *Threshold Dose*. The choice of the Linear No Threshold (LNT) model was moved to the *Scope* tab, *MACCS Models to Run* dropdown. Beginning with MACCS-UI, two additional options were added to this tab, namely *Use Optional Dose Projection Time (DPPEMP)*, and *Use Optional Evacuee Return Time*.

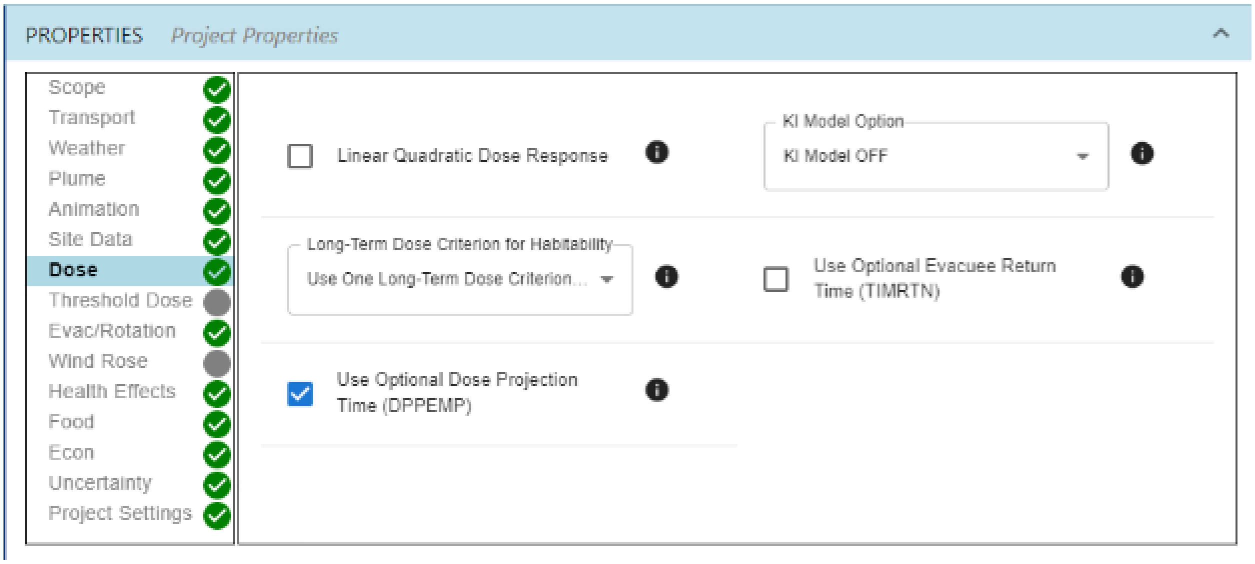


Figure 4-11. *Dose* tab in *PROPERTIES*

When the *Linear Quadratic Dose Response* is not enabled:

- In the high dose region, a linear relationship between dose and health effects will be used; and,
- In the low dose region, a linear relationship adjusted by the dose and dose rate effectiveness factor will be used.

Enabling the *Linear Quadratic Dose Response* flag means:

- In the high dose region, a linear relationship between dose and health effects will be used;
- In the low dose region, a quadratic relationship between dose and health effects will be used; and,
- The *EARLY/Latent Cancer Parameters/Latent Cancer Linear Quadratic* form is required.

The KI model can be enabled or disabled through the *KI Model Option* dropdown, which sets KIMODL to KI or NOKI respectively.

The user can select whether to use one long-term dose criterion or two long-term dose criteria for habitability (LONGTERM_DOSE_CRIT). This dose criterion is used to help determine if or when the affected land will be habitable.

4.1.1.8. *Threshold Dose* tab

The contents of the *Threshold Dose* tab are shown in Figure 4-12. There are four threshold dose-response models to choose from. Users should note that *the Linear No Threshold* option has been relocated to the *Scope* tab, under the *MACCS Models to Run* dropdown. MACCS uses a variable, DOSMOD, to specify which dose-response model is to be used.

All models on this tab have the option to enable *Ignore Dose and Dose Rate Effectiveness Factor*. Care should be taken in the selection of dose-response model in combination with the options on both the *Dose* and *Threshold Dose* tabs. The options are available to provide the user flexibility, not to indicate that it is recommended to use the combination of models and option. The dose-response model and options should be selected to reflect the intended analysis. The details of these models are discussed in Section 4.3.5.

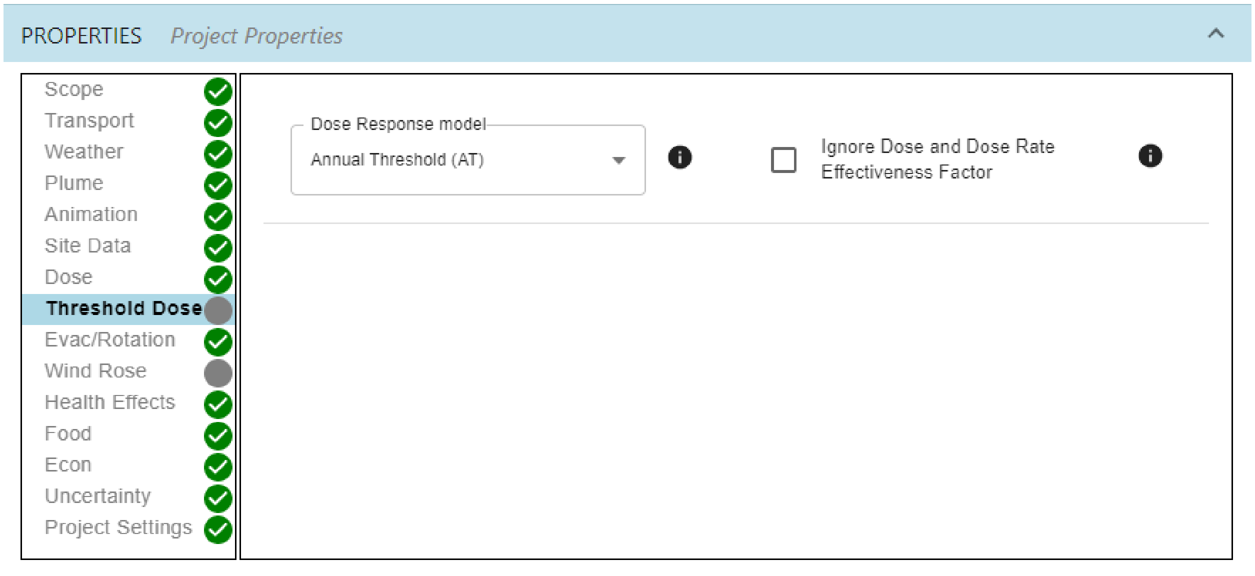


Figure 4-12 *Threshold Dose* tab in *PROPERTIES*

Choosing the *Ignore Dose and Dose Rate Effectiveness Factor* option means:

- Leaving this option unchecked means that *the Latent Cancer Parameters* form is required.
- Choosing this option means that the *Latent Cancer Parameters no DDREFA* form is required.

Choosing *Annual Threshold (AT)* means:

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

Choosing *Lifetime Threshold (LT)* means:

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

Choosing *Annual and Lifetime Threshold (ATL)* means:

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

Choosing *Piecewise Linear (PL)* means:

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

Choosing dose response models from this tab, rather than *LNT* under *Scope* means:

- When the dropdown option *Dose/KI Model ON* is selected, the *EARLY/Emergency Cohort n/KI Ingestion Threshold or Piecewise* form must be filled out instead of the *EARLY/Emergency Cohort n/KI Ingestion LNT* form.
- Only the values 0 or 1 are valid for POPFRAC on the *KI Ingestion* form.
- On the *Food* tab the options *COMIDA2 Food Model* or *No Food Model* must be chosen.
- Files must be specified under the *Annual Differential DCF Files* or *Annual Differential COMIDA2* form, dependent on the selected *Food Model Flag* on the *Food* tab.

4.1.1.9. *Evac/Rotation* tab

The contents of the *Evac/Rotation* tab are shown in Figure 4-13. Choices under this tab are required when the *EARLY* module is enabled.

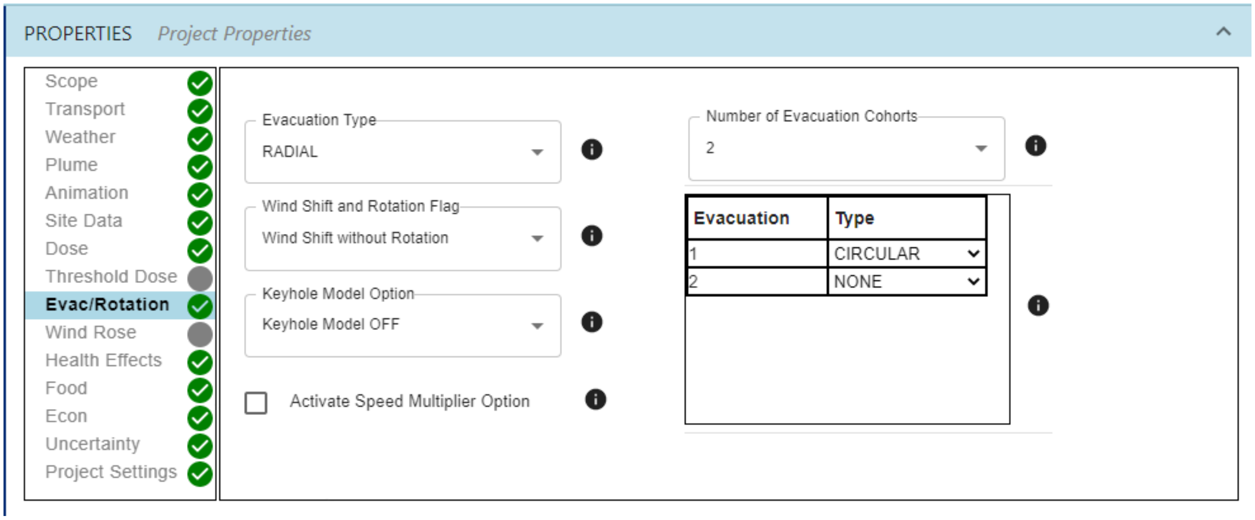


Figure 4-13. *Evac/Rotation* tab in *PROPERTIES*

First, the user must choose the type of evacuation to use. The choices are *Radial, Network*, and *None*. *Radial* evacuation 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. Selecting *None* means all cohorts are nonevacuating.

Choosing *Radial* as the *Evacuation Type* means:

- The options for the evacuation *Type* field for all evacuation cohorts are *None* and *Circular*. *Keyhole* is also available when the *Keyhole Model ON* dropdown option is selected.
- The options for the evacuation type for all evacuation cohorts must be entered. The MACCS executable requires that the first Cohort must be assigned the type *Circular* or *Keyhole* to allow *Circular* or *Keyhole* to be assigned for subsequent cohorts. MACCS-UI doesn't restrict the assignment, but the MACCS executable will produce an error if assigned in the incorrect order.

Choosing *Network* means:

- The options for the evacuation *Type* field for all evacuation cohorts are *None* and *Circular*. *Keyhole* is also available when the *Keyhole Model ON* option is selected in the dropdown.
- 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 *None* means:

- The evacuation type field for all evacuation cohorts is *None* regardless of the type specified in the *Type* field.

- The option *Keyhole Model ON* won't have an effect.
- The user must choose the method for plume segment modeling. MACCS uses the *Wind Shift and Rotation Flag*, IPLUME, to specify the option that is used.

Next, the user selects the wind shift and rotation flag.

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 with little additional processing time.
- 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).
- The wind-rose probability is assigned based on the direction taken by the first plume segment. This method may not create realistic results when more than one plume segment is modeled.

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 can 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. The wind-rose probability is assigned based on the direction taken by the first plume segment.

Wind Shift with Rotation assumes that specific weather patterns (i.e., time dependence of wind directions relative to the initial wind direction) are independent of the initial direction 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. 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 modeled.

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 can 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*. The user can evaluate the accuracy of weather statistics by comparing results for weather sampling options against the case of performing the maximum number of weather trials (e.g., 8760 weather trials when data are averaged over hourly periods) and using the *Wind Shift without Rotation* option.

The next action is to specify whether the *Speed Multiplier Model* and/or *Keyhole Evacuation Model* are active. Finally, the user specifies the number of cohorts represented in the problem. MACCS-UI 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 automatically designated based on the selected option, *Radial*, *Network* or *None* in the *Problem Model* box. The selected choice restricts the options for all cohorts that are defined.

Choosing *Activate Speed Multiplier Option* means:

- When the *Network* evacuation option has been selected, the evacuation speed can be adjusted by grid element on the *Network Evacuation Speed* form.
- When the *Radial* evacuation option has been selected, the evacuation speed can be adjusted by grid element on the *Radial Evacuation Speed* form.
- Wind Shift Without Rotation must be selected.

Choosing *Keyhold Model ON* in the *Keyhole Model Option* dropdown means:

- Keyhole evacuation methods become available for all cohorts.
- Wind Shift without Rotation must be selected.

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 4-14.

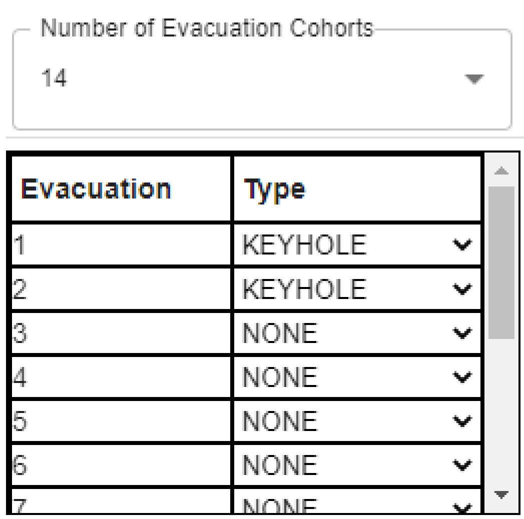


Figure 4-14. Specifying cohort evacuation types

4.1.1.10. ***Wind Rose* tab**

The *Wind Rose* tab shown in Figure 4-15 is required when the EARLY module is enabled.

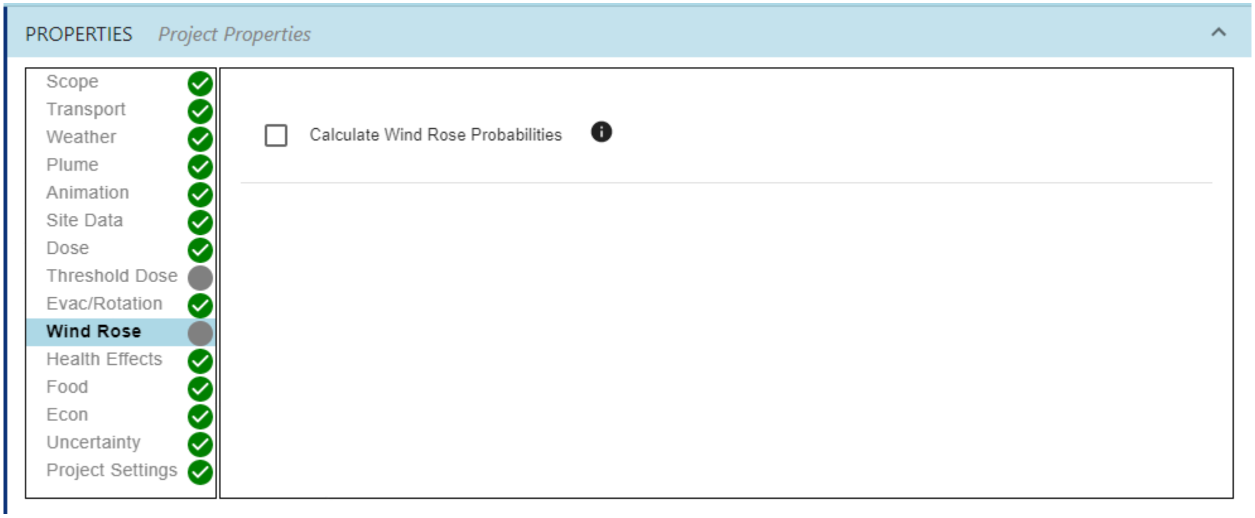


Figure 4-15. *Wind Rose* tab on the *PROPERTIES* form

The value of OVRRID corresponds to the *Calculate Wind Rose Probabilities* checkbox.

Checking means:

- Wind rose probabilities are required. These are defined on the *Wind Rose Probabilities* form found on the *EARLY/Model Basis*.
- User defined wind rose probabilities are used in place of values taken from the weather file when one of the *Wind Rotation* options and one of the weather binning options are selected.

Leaving unchecked 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.

User Supplied wind rose values are used for all weather bins, whereas the *Default* option constructs wind roses separately for each weather bin. As a result, the *User Supplied* option sacrifices some accuracy and is therefore only recommended when a weather file is only available for a nearby site, but wind rose data are available for the site to be analyzed.

4.1.1.11. ***Health Effects* tab**

The contents of the *Health Effects* tab are shown in Figure 4-16. This form allows for health effects to be calculated. If an FGRDCF DCF file is specified, early fatality and injury results are not available.

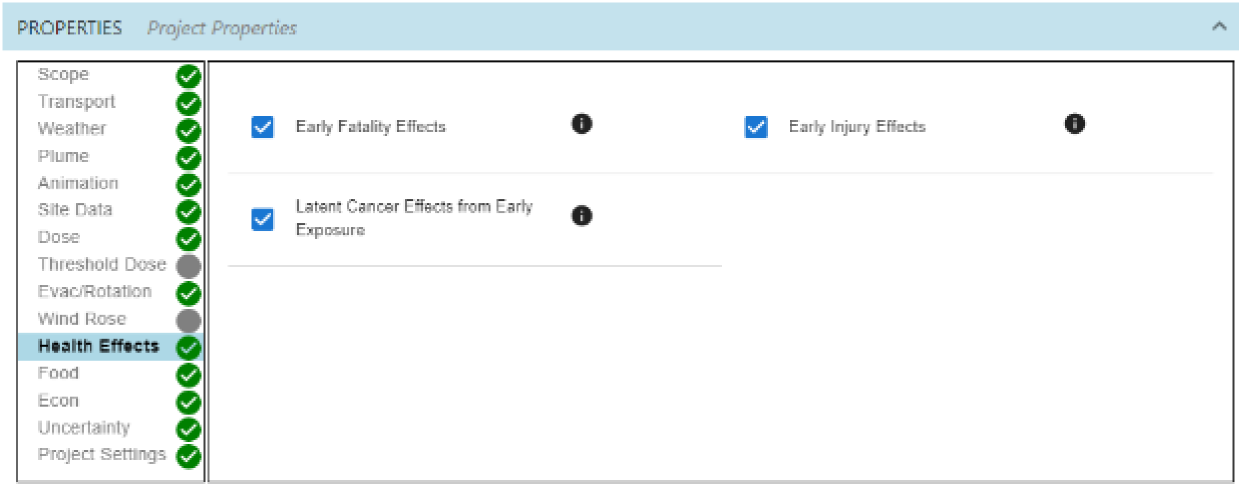


Figure 4-16. *Health Effects* tab in *PROPERTIES*

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

- At least one set of 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 coefficient file type that supports early health effects.

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

- At least one set of 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 DCF 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.

4.1.1.12. *Food* tab

The *Food* tab shown in Figure 4-17 is required when CHRONC is enabled on the *Scope* tab.

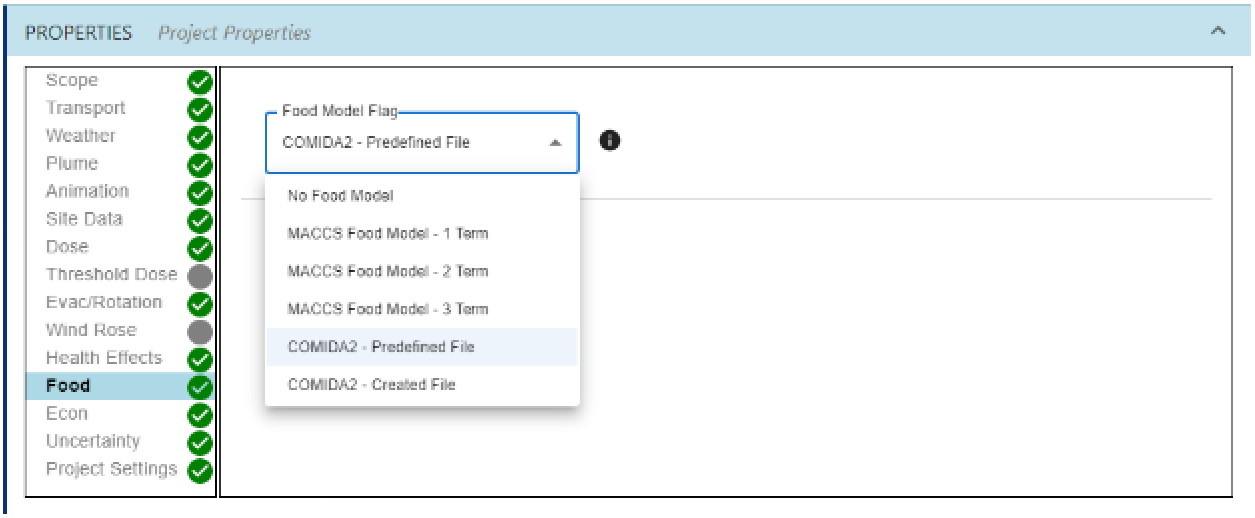


Figure 4-17. *Food* tab in *PROPERTIES*

MACCS uses a variable, FDPATH, to determine which food model to use. Options to set this can be selected in the *Food Model Flag* dropdown.

Selecting *No Food Model* means:

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

Selecting any number of terms of the *MACCS Food Model* option means:

- The original MACCS food-chain model is used.
- FDPATH is set to OLD.
- MACCS uses parameter 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.

The *MACCS Food Model* option is only available when *ATMOS, EARLY, and CHRONC LNT* is chosen on the *Scope* tab, even though they appear to be available in the MACCS-UI interface.

Selecting *COMIDA2 - Predefined File* means:

- The COMIDA2 food chain model is used.
- The *Annual Threshold* and *Piecewise Linear* dose-response models are available on the *Threshold Dose* tab. When either of these models is chosen, a set of binary files created by the preprocessor, COMIDA2, and the corresponding DCF files used to create those binary COMIDA2 files must be linked to the project.

- When the *LNT* dose-response model is chosen in *MACCS Models to Run* on the *Scope* tab, a single COMIDA2 binary file must be linked to the project. The DCF file must be the same one used to create the COMIDA2 binary file.
- FDPATH is set to NEW.

Selecting *COMIDA2 - Created File* means:

- The *Annual Threshold* and *Piecewise Linear* dose-response models are not available, even though they appear to be available in the MACCS-UI interface.
- One or more COMIDA2 binary files are created when a simulation is run, depending on whether there are uncertain parameters defined in the COMIDA2 inputs.
- Values must be specified on the forms under the *COMIDA2* main category.

4.1.1.13. *Econ* tab

The *Econ* tab is shown in Figure 4-18 and is required when *CHRONC LNT* or *CHRONC Threshold* are enabled in the *Scope* tab.

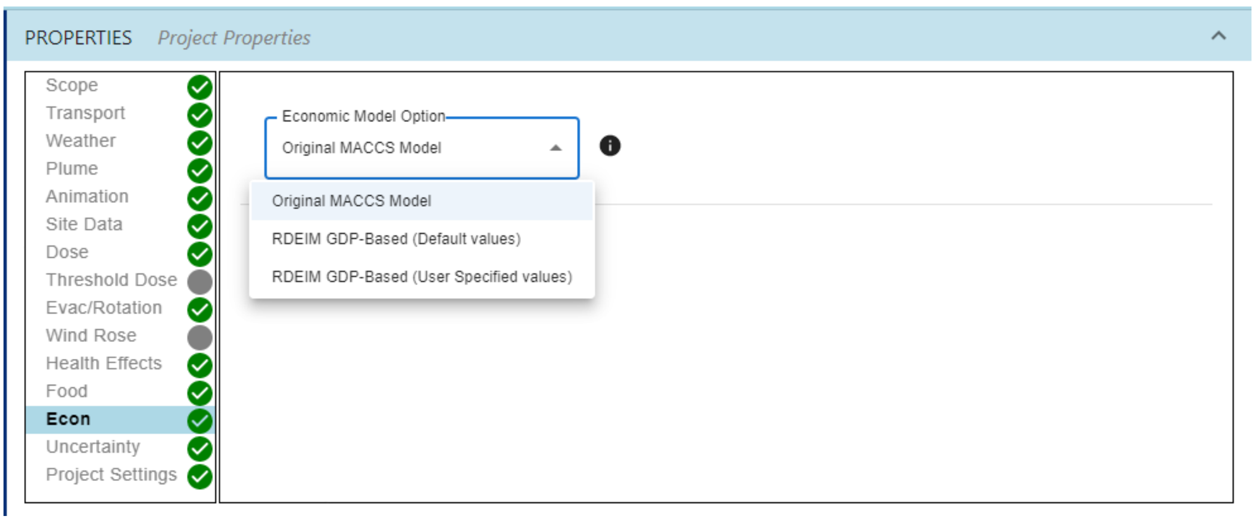


Figure 4-18. *Econ* tab in *PROPERTIES*

Selecting *Original MACCS Model* means the cost-based model in MACCS will calculate the economic losses.

Selecting *RDEIM GDP-Based (Default values)* means the new Gross Domestic Product (GDP) based economic model will be used to calculate economic losses with the default economic parameters. The forms *CHRONC/GDP Economic Parameters/Default GDP Economic Parameters* and *CHRONC/GDP Economic Parameters/Model Basis* are required.

Selecting *RDEIM GDP-Based (User Specified values)* means the new Gross Domestic Product (GDP) based economic model will be used to calculate economic losses with user specified economic parameters. The forms *CHRONC/GDP Economic Parameters/Model Basis* and *CHRONC/GDP Economic Parameters/GDP Economic Parameters* are required.

4.1.1.14. *Uncertainty* tab

The *Uncertainty* tab, shown in Figure 4-19 controls the number of MACCS runs to be executed and how uncertainty will be addressed. When there are uncertain parameters defined in the project, the *Number of Samples (Simulations)* entry determines the number of simulations that are to be used.

When MACCS cyclical files are used with uncertain parameters, enter the number of times you want MACCS to run. When uncertain parameters are not used, the Number of Simulations should be the same as the number of cyclical files; when uncertain parameters are used, the Number of Simulations should 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, MACCS-UI will run a number of simulations equal to 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 check box for *Simple Random Sampling* specifies if simple random sampling will be used instead of the default LHS sampling.

The value in the *Uncertainty Seed* is the random number seed used by the uncertainty sampling algorithm to create distribution samples of the parameters 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. It is recommended to choose values of about 1000 or greater.

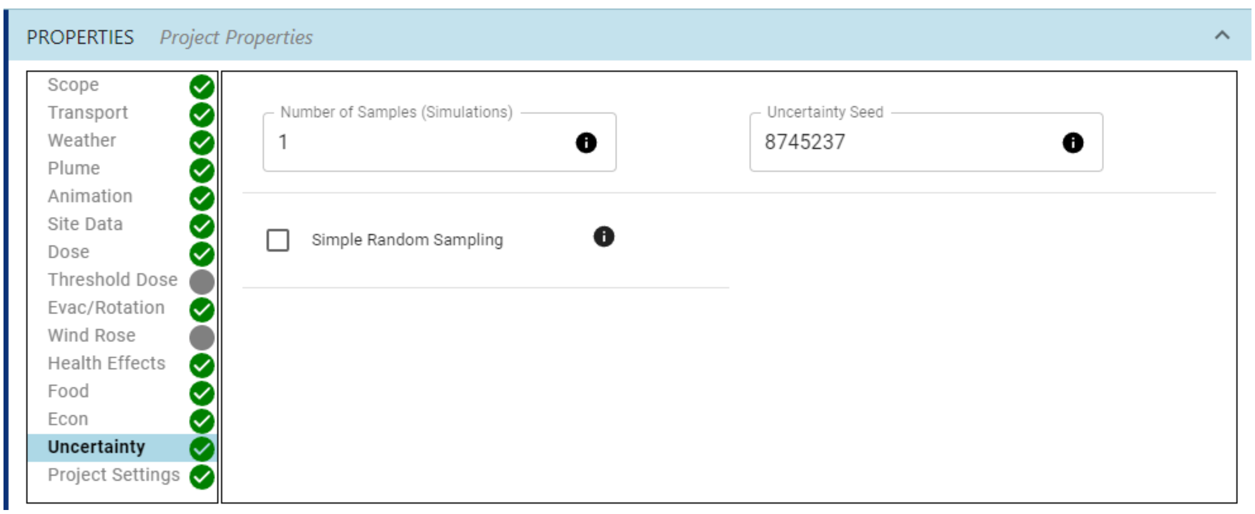


Figure 4-19. *Uncertainty* tab in PROPERTIES

4.1.1.15. *Project Settings* tab

The *Project Settings* tab controls how the project will be processed as shown in Figure 4-20. Parallel simulations can be enabled from this tab and are available when multiple simulations are run. Furthermore, parallel processing will only be used if the value of the *Processor Cores to Use* is greater than 1. MACCS-UI automatically detects the number of cores available, and the user can then select up to the total available. The option to only create missing input files means that all previously created required input files will be used without recreating them. This allows the user to manually edit an input file without having their changes being over written.

Figure 4-20. *Project Settings* tab in *PROPERTIES*

4.1.2. File Specifications

Model settings that determine the types of files required are chosen on the *PROPERTIES* form, while required files are shown under the *File Specifications* category. In the example shown in Figure 4-21, the meteorological, site, dose coefficient, and COMIDA2 files are required, as indicated by the icons to the left of the forms. Table 4-1 describes the types of and conditions requiring certain files, in addition to sample files included in MACCS-UI, with more details in the following sections.

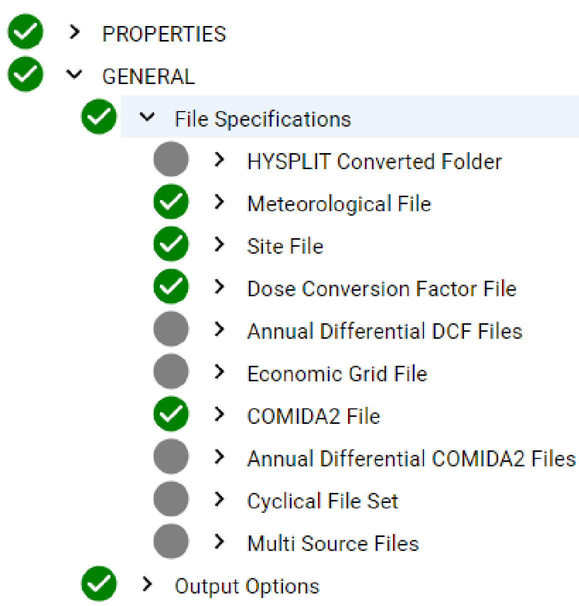


Figure 4-21. Specifying files

Table 4-1. Auxiliary files used by MACCS-UI

Form Name	*PROPERTIES* tab(s)	When Required	Supplied Files
License File	*N/A*	Required to use MACCS version 5.0	Supplied by Sandia after following ReadMe instructions
HYSPLIT Converted Folder	*Scope*	HYSPLIT is selected for the *Atmospheric Transport and Dispersion* model on the *Scope* tab	Due to the large file size, these are a special request on the MACCS download site.
Meteorological File	*Weather*	*Fixed Start Time, Bin Sampling Uniform, Bin Sampling Nonuniform, or Stratified Random Sampling* is selected.	FicticiousSite_dtdz.MET gdas0p5_dtdz.MET metsurMxHt_60min.inp westernsite_04.inp
Site File	*Scope and Site Data*	*EARLY* is selected on *Scope* tab. An *Import from File* option is selected on *Site Data* tab.	FicticiousSite.inp FicticiousSite_Site.inp
Dose Conversion Factor File	*Scope and Dose*	*ATMOS, EARLY, and CHRONC LNT* is selected on the *Scope* tab.	DOSD825_v2.inp dosdata21organs_v2.inp FGR13DCF_v2.inp FGR13GyEquiv_TEDE_v2.inp FGR13GyEquiv_v2.inp pu68_5_v2.inp pu72_v2.inp
Annual Differential DCF Files	*Scope, Dose, and Food*	*ATMOS, EARLY, and CHRONC Threshold* is selected on the *Scope* tab. Either the *No Food Model* or *COMIDA2 - Predefined File* is selected on the *Food tab.*	dosdata21organs_v2.inp dosdata21organs_v201.inp … dosdata21organs_v250.inp FGR13DCF_v2.inp FGR13DCF_v201.inp … FGR13DCF_v250.inp FGR13GyEquiv_v2.inp FGR13GyEquiv_v201.inp … FGR13GyEquiv_v250.inp
Economic Grid File	*Econ*	*RDEIM* is selected on the *Econ* tab.	SampleRDEIM.econ

Form Name	*PROPERTIES* tab(s)	When Required	Supplied Files
COMIDA2 File	*Scope and Food*	*ATMOS, EARLY, and CHRONC LNT* is selected on the *Scope* tab. *COMIDA2 - Predefined File* is selected on the *Food* tab.	comida2_2.0.0.3_DOSD825_v2.bin comida2_2.0.0.3_FGR13DCF_v2.bin comida2_2.0.0.3_FGR13GyEquiv_TEDE_v2.bin comida2_2.0.0.3_FGR13GyEquiv_v2.bin
Annual Differential COMIDA2 Files	*Scope, Dose, and Food*	*ATMOS, EARLY, and CHRONC Threshold* is selected on the *Scope* tab. *COMIDA2 - Predefined File* is selected on the *Food* tab.	comida2_2.0.0.3_DOSD825_v2.bin comida2_2.0.0.3_DOSD825_v201.bin … comida2_2.0.0.3_DOSD825_v250.bin comida2_2.0.0.3_FGR13GyEquiv_v2.bin comida2_2.0.0.3_FGR13GyEquiv_v201.bin … comida2_2.0.0.3_FGR13GyEquiv_v250.bin comida2_2.0.0.3_FGR13GyEquiv_v2.bin comida2_2.0.0.3_FGR13GyEquiv_v210.bin … comida2_2.0.0.3_FGR13GyEquiv_v250.bin
Cyclical File Set	*Scope*	*Cyclical File Sets* is enabled.	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 File Set	*Plume*	*Multi Source* option is selected.	None provided

4.1.2.1. HYSPLIT Converted Folder Form

MACCS-HYSPLIT files are required when the user selects *HYSPLIT* in *Atmospheric Transport & Dispersion Model* on the PROPERTIES/*Scope* tab. These are atmospheric transport files created by HyGridConvert and are linked to MACCS via the *HYSPLIT Converted Folder* form. Unlike other files, these files are not copied to the data folder.

4.1.2.2. Meteorological File Form

A meteorological data file is required when the user selects *Fixed Start Time, Bin Sampling Uniform, Bin Sampling Nonuniform,* or *Stratified Random Sampling* on the *Weather* tab. MACCS-UI allows the user to select any file, but a file should be selected that conforms to the format described in Appendix B.1. The range of allowable wind directions in the meteorological file is determined by the value of the MACCS parameter NUMCOR, the number of compass sectors in the spatial grid.

Table 4-2. *Meteorological File* form

Parameter	Definable	Type	Dimensions	Allowed Values
Meteorological File	Yes	Text File	None	Any file. File is not validated by MACCS-UI, but it should conform with the format described in Appendix B.1.

4.1.2.3. Site File Form

A site file is required when the user enables *EARLY* (Early Consequences) on the *Scope* tab and selects one of two *Import from File* or *SUMPOP* options on the *Site Data* tab.

NUMCOR is the number of compass 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. The latest version of SecPop supports up to 64 sectors and should be used to create site files with more than 16 compass sectors whenever possible.

The site file is a text file containing site specific information. This file is commonly created using SecPop but may be created by a different process as long as it has the required format. See Appendix B.2 for more information.

Table 4-3. *Site File* form

Parameter	Definable	Type	Dimensions	Allowed Values
NUMCOR	Yes Click File Created from Existing Site File to change value	Integer	None	16, 32, 48, and 64
Site File	Yes	Text File	None	Site data is partially validated by MACCS-UI, but the format required by MACCS is specified in Appendix B.2.

4.1.2.4. Dose Coefficient or Dose Conversion Factor File Form

The newer term used by International Commission on Radiation Protection (ICRP) is dose coefficient, but the older term, dose conversion factor or DCF, is generally used in MACCS-UI. A single DCF file is required when the user selects option *ATMOS, EARLY, and CHRONIC LNT* on the *Scope* tab. A DCF File is an ASCII file containing a set of DCFs. Multiple types of DCF files are provided with MACCS. The most recent of these is based on the CD supplement to FGR-13.

Table 4-4. *Dose Conversion Factor File* form

Parameter	Definable	Type	Dimensions	Allowed Values
DCF File	Yes	Text File	None	Files are provided. MACCS-UI does not validate the files, but the format required by MACCS is specified in Appendix B.3.

4.1.2.5. Annual Differential DCF Files Form

A set of DCF files are required when the user enables *CHRONC Threshold* on the *Scope* tab. *Annual Differential DCF Files* are a set of 51 DCF files provided with the MACCS-UI 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 Appendix B.3 for more information.

Table 4-5. *Annual Differential DCF Files* form

Parameter	Definable	Type	Dimensions	Allowed Values
Annual Differential DCF File Set	Yes	Text Files	51 files	File sets are provided. MACCS-UI does not validate the files, but the format required by MACCS is specified in Appendix B.3.

4.1.2.6. COMIDA2 File Form

This form is required when the user selects *ATMOS, EARLY, and CHRONC LNT* on the *Scope* tab and selects *COMIDA2 - Predefined 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, which must be the same as the one specified in the section above.

Table 4-6. *COMIDA2 File* form

Parameter	Definable	Type	Dimensions	Allowed Values
COMIDA2 File	Yes	Binary File	None	This file is not validated by MACCS-UI, but it is by MACCS.

4.1.2.7. Annual Differential COMIDA2 Files Form

This form is required when the user selects ATMOS, EARLY, and CHRONC Threshold on the Scope tab and selects COMIDA2 - Predefined File on the Food tab. Annual Differential COMIDA2 File Set is a set of 51 COMIDA2 binary files provided with the MACCS-UI installation.

Table 4-7. *Annual Differential COMIDA2 Files* form

Parameter	Definable	Type	Dimensions	Allowed Values
Annual Differential COMIDA2 File Set	Yes	Binary Files	51 files	File sets are provided. MACCS-UI does not validate the files, but they are validated by MACCS.

4.1.2.8. Cyclical File Set Form

A set of cyclical files is required when the user enables *Cyclical File Sets* on the *Scope* tab. A cyclical file set is a set of files in MACCS input format. The function of this file set is described in Section 3.3.5.

Table 4-8. ***Cyclical File Set*** **form**

Parameter	Definable	Type	Dimensions	Allowed Values
Cyclical File Sets	Yes	Text File	≥1 file	MACCS input file format. Files are read by MACCS-UI.

4.1.2.9. Multi Source File Set Form

Using this option requires selecting *Multi Source* option on the *PROPERTIES* form and selecting the multi-source term files created using MelMACCS (version 2.0.1 or later) or with some other method. A software program, CombineSource, is integrated into MACCS-UI 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 MACCS-UI. The other file, CombineSource.out, contains information that is read by MACCS.

Table 4-9. ***Multi Source File Set*** **form**

Parameter	Definable	Type	Dimensions	Allowed Values
Multi Source File Set	Yes	Text Files	≥1 file	MelMACCS output file format

4.1.3. Output Options

Model settings that determine the general output states are chosen on the *PROPERTIES* form, while required forms are shown under the *Output Options* category. An example is shown in Figure 4-22.

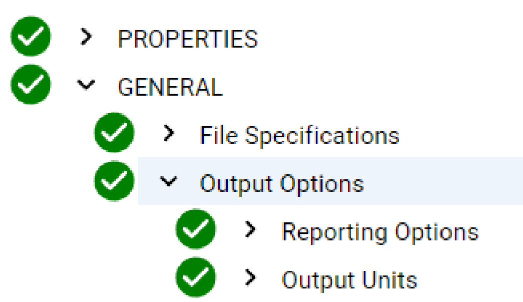


Figure 4-22. Output Options

4.1.3.1. Reporting Options Form

Results are calculated by MACCS-UI for each quantile level on this form. If results have the Report option activated in the output request forms, results are automatically generated after model execution. The reported values are determined from the MACCS binary file. The quantile levels are also used when creating custom reports that combine results over simulations. See Section 3.5.2.3 for more information.

Table 4-10. ***Reporting Options*** **form**

Parameter	Definable	Type	Dimensions	Allowed Values
Probabilities	Yes	Real	≥1 file	0.0 to 1.0

4.1.3.2. Output Units Form

Each time MACCS runs, an output file and a binary file is created containing the results. The units reported in the text and binary output files can be modified.

Table 4-11. *Output Units* form

Parameter	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}

4.2. ATMOS

4.2.1. Overview

ATMOS performs all the calculations pertaining to atmospheric transport, including dispersion and deposition, as well as the radioactive decay and ingrowth that occurs prior to release and while the material is in the atmosphere. (Following calculation of transport within the problem domain, radioactive decay and dose modeling are performed by the EARLY and CHRONC modules of MACCS.) Beginning with MACCS version 4.0, an optional Lagrangian particle tracking model (HYSPLIT) was added to MACCS, in addition to the Gaussian plume segment model traditionally used. An overview of both models is provided in this section.

4.2.1.1. Gaussian Plume Segment Model

The Gaussian plume segment model characterizes the plume dispersion during downwind transport using a Gaussian distribution. Thus, the crosswind and vertical extent of plume segments is expressed in terms of the crosswind (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 (Koa, 1984).

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 variable 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 a binned CCDF. This is done for an individual MACCS run and only reflects weather variability, not uncertainty in other input parameters.

The radioactive materials released are modeled as being dispersed while being advected by the prevailing wind. During transport, deposition of particles onto the ground from dry and wet processes can be modeled. In addition to the air and ground concentrations, ATMOS determines plume arrival time, plume departure time, and plume dimensions.

ATMOS results are used by the EARLY and CHRONC modules. At a minimum, a MACCS calculation must include the ATMOS module, as calculations of early or latent health effects of a radioactive release depend on its dispersion and deposition results.

MACCS allows multiple individual 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 variables. When these are encountered, the code's calculations are rerun based on the new values for parameters defined in the set of change records and new output is generated for each specified source term and emergency response scenario.

MACCS-UI does not support this feature of ATMOS, but a similar feature in EARLY that allows the specification of multiple emergency response cohorts is supported. Results for multiple source terms can be treated by MACCS-UI through multiple MACCS runs using the *Cyclical File Sets* 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 be associated with units having different isotopic inventories, different reactor shutdown times, and different release histories. MACCS can calculate the combined consequences of the multiple releases.

4.2.1.2. HYSPLIT Model

Starting with MACCS version 4.0 a new and more advanced atmospheric transport and dispersion (ATD) model has been enabled which uses HYSPLIT. This feature is partially supported in MACCS-UI, but the user must perform several steps before running to use this new feature. The user needs to separately download documentation and software to use this option. Additional details are in "Instructions and Sample Problems for Using the MACCS/HYSPLIT Capability" which is available on the MACCS website https://maccs.sandia.gov.

4.2.2. Basic Parameters

4.2.2.1. *ATMOS Description* Form

The *Atmos Description* form, as shown in Figure 4-23, contains two fields, *MACCS Calculation Name*, and *Sample Source Name*, corresponding to ATNAM1 and ATNAM2. ATNAM1 identifies the MACCS calculation and is printed in the output file. ATNAM2 identifies the name of the source term being studies. They are required input for all MACCS calculations. A more detailed description of the calculation can be entered on the *Problem Description* form under the *GENERAL/ PROPERTIES* category.

Table 4-12. *Atmos Description* form parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
ATNAM1	Yes	Character	None	1 to 80 characters
ATNAM2	Yes	Character	None	1 to 80 characters

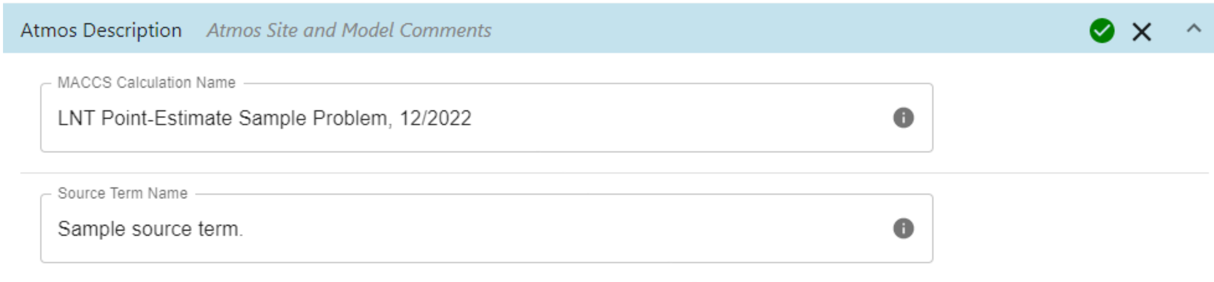


Figure 4-23. *Atmos Description* form

4.2.2.2. *Property Form Parameters* Form

All parameters are read-only and dimensionless.

Atmospheric Transport & Dispersion Model, ATDMODL, defines which model is selected; GAUSSIAN for the Gaussian plume segment model, and HYSPLIT for the Lagrangian particle tracking model.

Plume Meander Model, MNDMOD, can be set to:

- *Original MACCS Model (OLD)*: the plume meander factor is a function of release duration only.
- *US NRC Reg. Guide 1.145 (NEW):* plume meander factor depends on wind speed and stability class, but not on the duration of release. It is consistent with NUREG/CR-2260 and US NRC Regulatory Guide 1.145. When chosen, the plume segments should be approximately one hour in duration.
- *Ramsdell and Fosmire (RAF)*: which includes enhanced dispersion near a building at low and high wind speeds.
- *None (OFF)*: which does not model plume meander.

Weather Model Flag, METCOD, determines what meteorological data are used and how weather sampling is performed. When the value is set to 1, 2, or 5, a meteorological data file is needed to supply the data. Allowable settings are as follows:

1. Allows users to choose a single starting point in the file. This point is defined by a day and a period of that day. A single weather trial is performed using this time as a starting point.
2. Corresponds to weather-bin sampling from the meteorological data file.
3. Is used for user-supplied hourly data for 120 hours.
4. Is used for user-supplied, constant weather.
5. Corresponds to stratified, random sampling from the meteorological data file.

Maximum Mixing Height Model, 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 to estimate sunrise and sunset for each day of the year. The required mixing heights are specified in the meteorological data file.

Briggs Plume Rise Model, BRGSMD, selects whether the recommended *IMPROVED* or *ORIGINAL* model from MACCS 1.12 will be used. This recommendation for *IMPROVED* 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. See Section 4.2.9 for more details.

Multi-Source Model Flag, MSMODL, when true, requires forms under the *Multi Source* category. MACCS calculates the combined effects of the multiple releases defined in these files. Otherwise, the source term is specified directly in the MACCS-UI interface.

Plume Source Model, SRCMOD, specifies which plume source model to use. Available options are *Point Source*, *Area Source*, and *Automatic Area Source Calculation,* which correspond to values PNT, AREA, and AUTO, respectively. *Automatic Area Source Calculation* calculates the area source based on wind direction and building parameters.

Trapping/Downwind Model, TDWMOD, specifies which Briggs Trapping/Downwash model to use. *Briggs (Uses Building Parameters)* and *Briggs (Uses Buoyancy Flux)* correspond to values BRGBLD and BRGFLX.

Trapping/Downwash Auto Calc Flag, TDWAUTO, specifies if MACCS calculates the plume centerline height to use after the plume has been influenced by the wake region. When set to true, MACCS calculates this value based on the building parameters. When set to false, this value is set by the user.

Table 4-13. *Property Form Parameters* form inputs

Parameter	Description	Type	Allowed Values	*PROPERTIES* Tab
ENDAT1	Ends model after ATMOS is run when true	Logical	True, False	*Scope*
ENDAT2	Ends model after EARLY is run when true	Logical	True, False	*Scope*
DISPMD	Crosswind dispersion model	Character	LRDIST, LRTIME	*Transport*
MNDMOD	Plume meander model	Character	OLD, NEW, RAF, OFF	*Transport*
ATDMODL	Atmospheric transport and dispersion model	Character	GAUSSIAN, HYSPLIT	*Scope*
METCOD	Weather model flag	Integer	1 to 5	*Weather*
MAXHGT	Maximum mixing height model	Character	DAY_ONLY, DAY_AND_NIGHT	*Weather*
BRGSMD	Briggs plume rise model	Character	ORIGINAL, IMPROVED	*Plume*
MSMODL	Multi-source model flag	Logical	True, False	*Plume*
SRCMOD	Plume source model	Character	PNT, AREA, AUTO	*Plume*
TDWMOD	Trapping/downwind model	Character	BRGBLD, BRGFLX	*Plume*
TDWAUTO	Trapping/downwind automatic calculation flag	Logical	True, False	*Plume*

4.2.2.3. *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 measured clockwise from north.

Users must specify a set of radial endpoints (i.e., the outer radii for the grid elements), as shown in Figure 4-24. Up to 35 radii may be defined, extending out to a maximum distance of 9999 km. Users may define the spatial grid with 16, 32, 48, or 64 equally spaced angular divisions, or compass sectors, with the first centered on north.

NUMCOR Number of Sectors (Compass Directions) represents the number of the above-mentioned sectors. If a site file is used, it must be consistent with the number of sectors in the grid.

NUMRAD Number of Radial Spatial Intervals is set in MACCS-UI 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, ensuring consistency between the file and MACCS input. The first of these radii must be at least 0.05 km, and the minimum spacing between adjacent radii at 0.1 km.

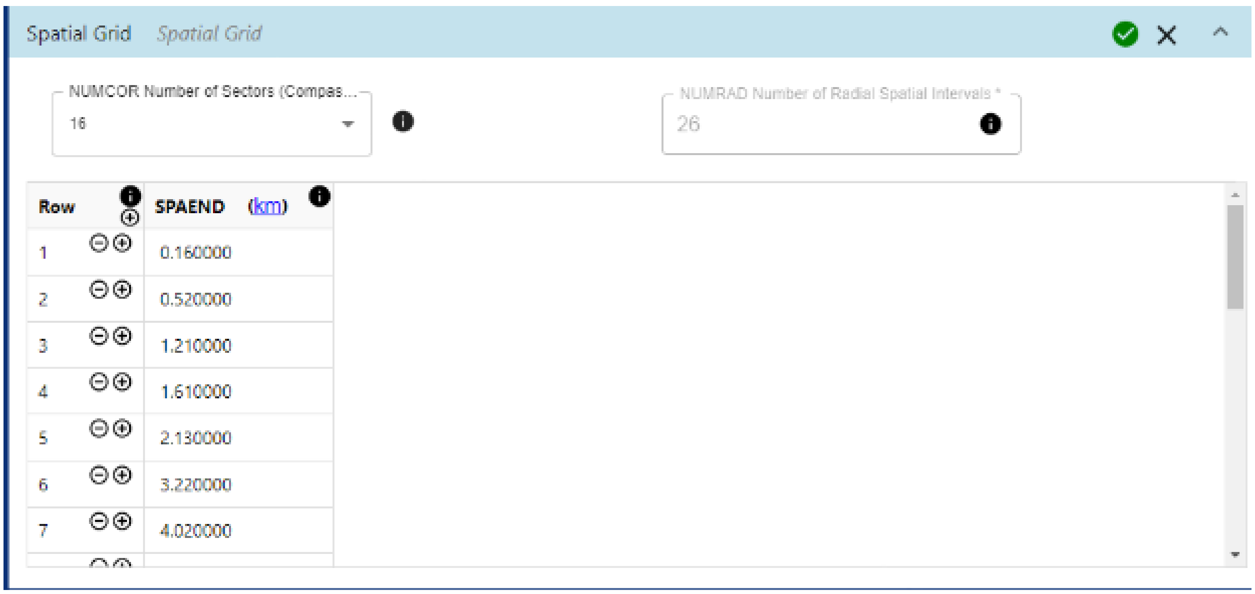


Figure 4-24. *Spatial Grid* form

Table 4-14. *Spatial Grid* form parameter inputs

Parameter	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

4.2.3. Radionuclides

This section defines the radionuclide classes (groups) 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 included with the MACCS-UI installation setup.

4.2.3.1. Radionuclide Descriptions

Radionuclide names are case sensitive. Names of chemical elements follow the usual convention that the first letter is capitalized, with the second letter lower case. Element names are followed by a hyphen and the atomic mass of the radionuclide to define the radionuclide name (i.e. Kr-85).

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 this 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 pseudostable isotope.

In some older calculations, decay products were added implicitly by adding the DCFs 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 of a premium now than when MACCS was initially developed, this practice of implicitly including progeny in a calculation is now discouraged. With the latest DCF file based on FGR-13, all progeny must be included in a calculation if their doses are to be included.

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 the active branches must be included in one of the two lists.

4.2.3.2. Forms

4.2.3.2.1. Chemical Names Form

The *Chemical Names* form is required when *Multi Source Model Flag* is not enabled on the *Scope* tab. Each radionuclide to be modeled is assigned to a chemical class. Traditionally, the term chemical class has been used in MELCOR applications to identify a set of chemically similar elements that are assumed to behave identically within the radionuclide package 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 chemical group, where group is commonly used instead of class. Thus, all isotopes assigned to a chemical group are assumed to act similarly in terms of release fraction and deposition behavior. Users must assign names to each chemical group, to be used as a label in the forms for RELFRC and DRYDEP.

Number of Chemical Groups, MAXGRP, is linked to the number of entries in the vector GRPNAM. GRPNAM is a vector of character strings used to identify each of the radionuclide classes. This parameter is used for labeling within MACCS-UI and appears in the ATMOS input file created by MACCS-UI.

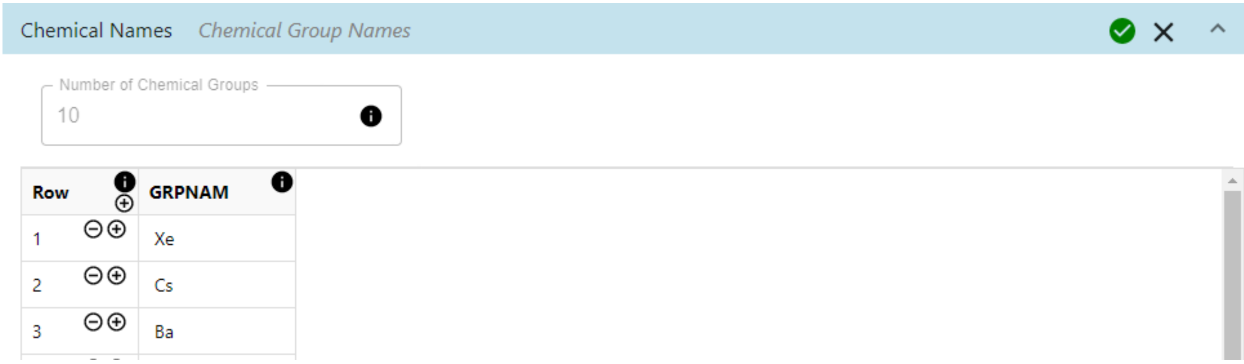


Figure 4-25. *Chemical Group Names* form

Table 4-15. *Chemical Names* form parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
MAXGRP	Linked	Integer	None	1 to 999
GRPNAM	Yes	Character	MAXGRP	1 to 15 characters

4.2.3.2.2. Radionuclides Form

The *Radionuclides* form is required when *Multi Source* is not selected on the *Scope* tab. The *Radionuclides* form specifies the number of radionuclides treated in the MACCS-UI calculation, the names of the radionuclides, the core inventory of each of the radionuclides, and the chemical group to which each one is assigned. The names of the radionuclides must correspond to those in the DCF file associated with the MACCS-UI project. (In their latest documents, ICRP uses "dose coefficients" in place of "dose conversion factors." These names are used interchangeably in this document.)

Three types of DCF files are distributed with MACCS. 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 when using this DCF file.

The two other types of DCF files are based on FGR-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-13. Both files contain extensive lists of radionuclides (825). The DCF file based on FGR-12 and -13 does not include any implicit progeny, so for example, both Cs-137 and Ba-137m must be explicitly included. This allows more flexibility in the treatment of decay products. The DCF file allows either Cs-137, Ba-137m, or both to be included in the inventory. The file also includes DCFs for estimating both acute and latent health effects.

The *Number of Radionuclides* box displays the value of NUMISO, which is linked to the number of table entries.

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 radionuclides 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 the parameter *Inventory Scale Factor,* CORSCA, found in the form *ATMOS/Release Description/Inventory Scale Factor.*

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

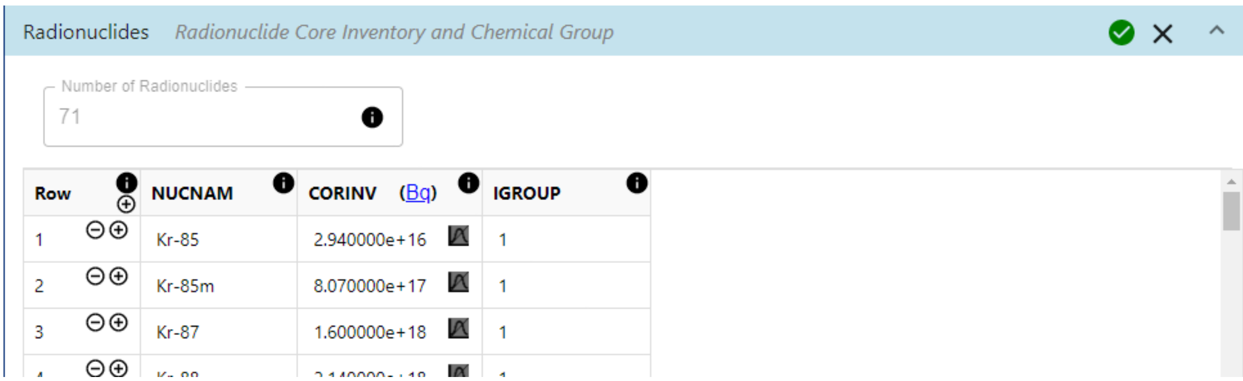


Figure 4-26. *Radionuclides* form

Table 4-16. *Radionuclides* form parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMISO	Linked	Integer	None	1 to 999
NUCNAM	Yes	Character	NUMISO	3 to 8 characters
CORINV	Yes	Real	NUMISO	0 to 10^{25} Bq
IGROUP	Yes	Integer	NUMISO	1 to MAXGRP

4.2.3.2.3. Pseudostable Radionuclides Form

The *Pseudostable Radionuclides* form specifies the name and number of pseudostable radionuclides, as described above.

Number of Pseudostable Radionuclides, NUMSTB, 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.

Figure 4-27. *Pseudostable Radionuclides* form

Table 4-17. *Pseudostable Radionuclides* form parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMSTB	Linked	Integer	None	1 to 999
NAMSTB	Yes	Character	NUMSTB	3 to 8 characters

4.2.4. Deposition

4.2.4.1. Model Description

The wet deposition model estimates how much material is deposited during episodes of precipitation. Wet deposition is treated as a function of both precipitation duration and intensity. The fraction of aerosols that remains suspended after wet deposition is calculated from the following equation (Brink and Vogt, 1981):

$$\frac{Q}{Q_0} = C_1 \cdot exp\left[-t_r \cdot \left(\frac{I_r}{I_0}\right)^{C_2}\right] \qquad \textbf{(4-1)}$$

Where

Q = Quantity of suspended aerosols after rain event (Bq)

Q_0 = Quantity of suspended aerosols before event (Bq)

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

t_r = duration of 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 (dimensionless)

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 assumed to be 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 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 chemical group can be distributed among several particle-size groups (up to 20), with each chemical group having a different distribution of activity among the particle-size groups. The particle-size distribution of each chemical 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 chemical 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 activity 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 a plume can change with time and distance.

4.2.4.2. Forms

4.2.4.2.1. Wet/Dry Depos Flags Form

The *Wet/Dry Depos Flags* form is required. DRYDEP is defined for each of the chemical groups. This flag indicates whether the chemical 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 chemical groups. This flag indicates whether the radionuclide class is subject to wet deposition.

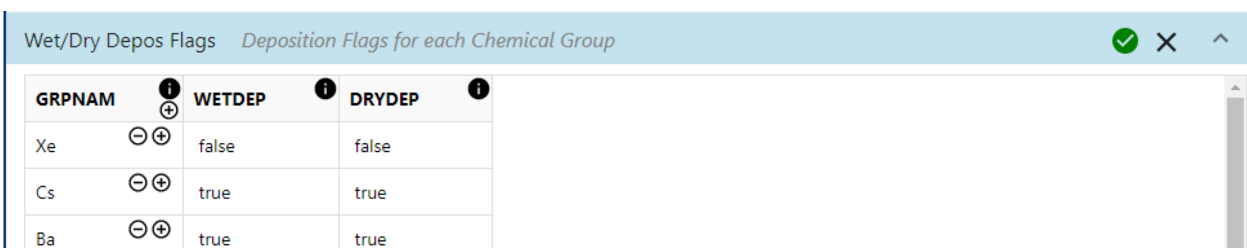


Figure 4-28. *Wet/Dry Depos Flags* form

Table 4-18. *Wet/Dry Depos Flags* form parameter inputs

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

The chemical 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 chemical groups are generally assigned deposition flags of True for both wet and dry deposition.

4.2.4.2.2. Wet Deposition Form

Washout Linear Coefficient, CWASH1; and *Washout Exponent,* CWASH2 (the exponential coefficient); are both used in the washout function shown in Equation (4-1).

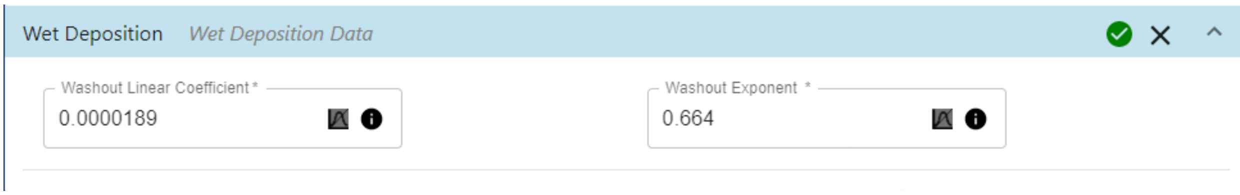


Figure 4-29. *Wet Deposition* form

Table 4-19. *Wet Deposition* form parameter inputs

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

4.2.4.2.3. Particle Size Groups Form

The *Number of Particle Size Groups,* NPSGRP, is determined by the number of entries in vector VDEPOS, contained on the *Dry Deposition* form.

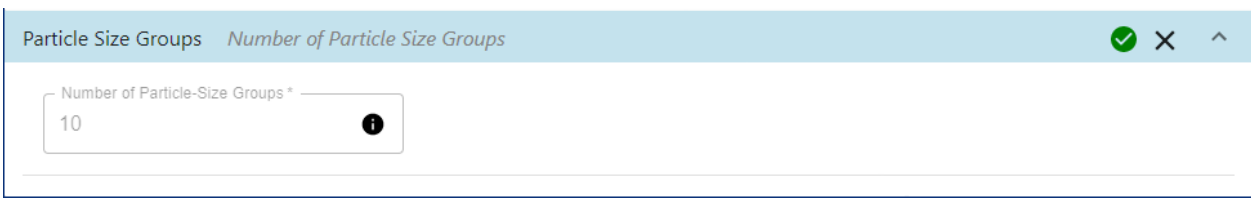


Figure 4-30. *Particle Size Groups* form

Table 4-20. *Particle Size Groups* form parameter input

Parameter	Definable	Type	Dimensions	Allowed Values
NPSGRP	Linked	Integer	None	1 to 20

4.2.4.2.4. Dry Deposition Form

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

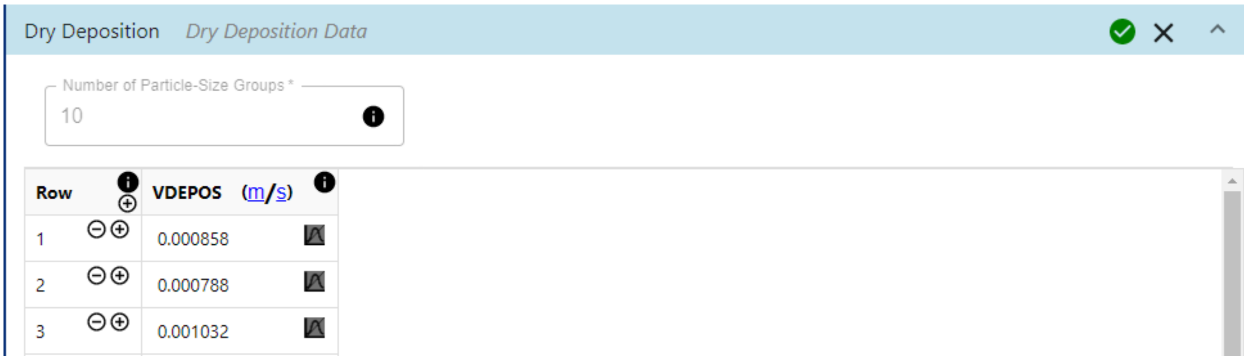


Figure 4-31. ***Dry Deposition*** **form**

Table 4-21. ***Dry Deposition*** **form parameter input**

Parameter	Definable	Type	Dimensions	Allowed Values
VDEPOS	Yes	Real	NPSGRP	0.0 to 10.0 m/s

4.2.5. Dispersion

4.2.5.1. Model Description

The Gaussian plume segment model of atmospheric dispersion optionally uses spatially dependent dispersion parameters, σ_y and σ_z. (A subsequent section describes an option to switch to time-based dispersion at a user-specified distance downwind of the source.) The dispersion parameters can be supplied in two different ways as functions of distance: as power-law functions or in the form of a lookup-table. The choice of which of the two models to use is made on the *Transport* tab in *PROPERTIES*.

4.2.5.1.1. Gaussian Plume Equations

MACCS models plume dispersion during downwind transport using a Gaussian plume segment model. Thus, the crosswind and vertical extent of plume segments is expressed in terms of the crosswind (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 (Koa, 1984). 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 in x at these locations).

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 (Turner, 1970).

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, NRC, 1983b). Gaussian plume models assume that the dispersion 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 crosswind plume distributions can 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 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 (Turner, 1970):

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

Where

$\chi(x,y,z)$	=	time-integrated air concentration (Bq·s/m^3) at downwind location (x, y, z)
Q	=	released activity (Bq)
u	=	mean wind speed (m/s)
σ_y	=	lateral or crosswind 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 (4-2) 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, Equation (4-3), which is used in MACCS to calculate both the time-integrated, plume-centerline, air concentration, χ (x, y = 0, z = h), and time-integrated, ground-level, air concentration under the plume centerline, χ (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):

$$\chi(x,y,z) = \frac{Q}{2\pi u \sigma_y \sigma_z} exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \sum_{n=-\infty}^{\infty} \left\{ exp\left[-\frac{1}{2}\left(\frac{z-h+2nH}{\sigma_z}\right)^2\right] + exp\left[-\frac{1}{2}\left(\frac{z+h+2nH}{\sigma_z}\right)^2\right]\right\} \quad \textbf{(4-3)}$$

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 (4-3) approximately reduces to the following equation:

$$\chi(x, y = 0, z) = \frac{Q}{\sqrt{2\pi}\sigma_y u H} exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \tag{4-4}$$

MACCS switches from Equation (4-5) to Equation (4-4) 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 (4-4) is independent of σ_z, this value is not calculated once the transition from Equation (4-3) to Equation (4-4) is made.

4.2.5.1.2. Dispersion Table

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 (Haugen, 1959) 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 (1961) used these 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 (1975, 1976), are presented in Figure 4-32.

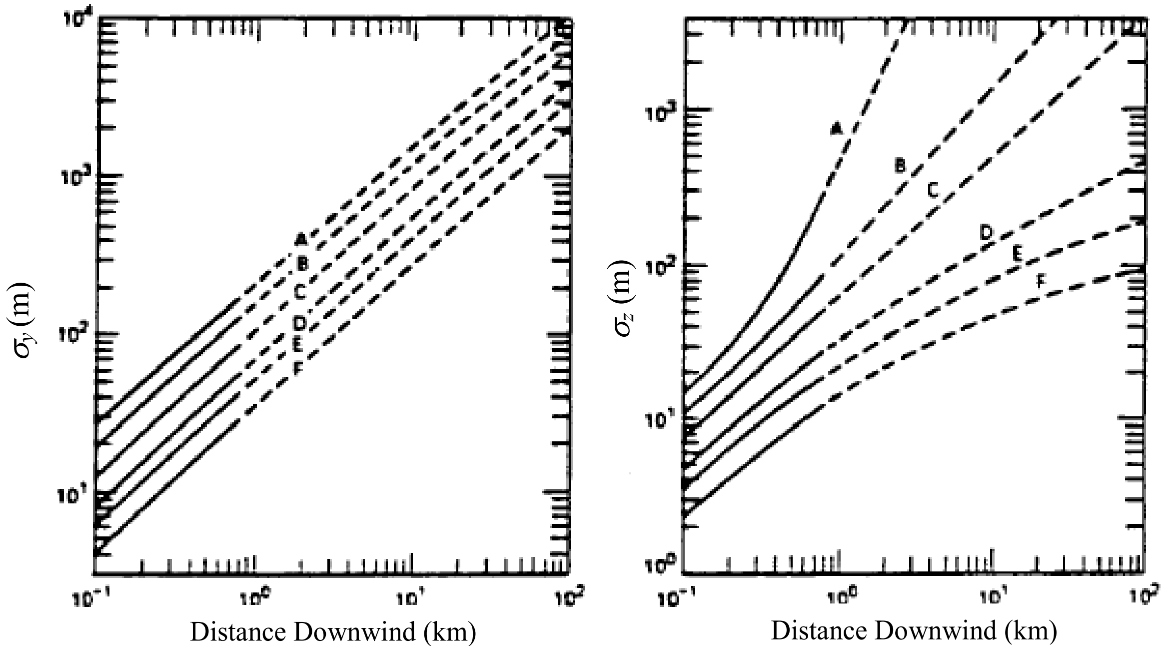


Figure 4-32. Dependence of σ_y and σ_z on distance for the six Pasquill-Gifford stability classes, A through F

Solid lines depict the range of the experimental data; dashed lines are extrapolations. Tadmor and Gur (1969) constructed power-law fits to the Pasquill-Gifford (P-G) curves. The coefficients are provided in Table 4-22. Technical guidance for selecting a parameterization to represent dispersion can be found in *Technical Bases for Consequence Analyses Using MACCS* (Bixler et al., 2020).

Table 4-22. Tadmor and Gur coefficients for σ_y and σ_z for Equation (4-2)

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 (1979).

As used in MACCS, the values of the dispersion parameters, σ_y and σ_z, in Equation (4-2) 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 (4-2)) must be changed to some new value that causes dispersion parameter growth to be continuous. The value of the source distance, when it differs from the actual 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,

$$\begin{aligned} a_i\left(x_{y_i}\right)^{b_i} &= \sigma_{y_i} = \sigma_{y_j} = a_j\left(x_{y_j}\right)^{b_j} \\ c_i\left(x_{z_i}\right)^{d_i} &= \sigma_{z_i} = \sigma_{z_j} = c_j\left(x_{z_j}\right)^{d_j} \end{aligned} \tag{4-5}$$

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

$$\begin{aligned} x_{y_j} &= \left[\frac{1}{a_j} a_i\left(x_{y_i}\right)^{b_i}\right]^{\frac{1}{b_j}} = \left[\frac{\sigma_{y_i}}{a_j}\right]^{\frac{1}{b_j}} \\ x_{z_j} &= \left[\frac{1}{c_j} c_i\left(x_{z_i}\right)^{d_i}\right]^{\frac{1}{d_j}} = \left[\frac{\sigma_{z_i}}{c_j}\right]^{\frac{1}{d_j}} \end{aligned} \tag{4-6}$$

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.

4.2.5.1.3. 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 4-32 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 4-33 presents some approximate surface roughness lengths for different surfaces based on the values in (Lettau, 1969; Briggs, 1984; Randerson, 1984).

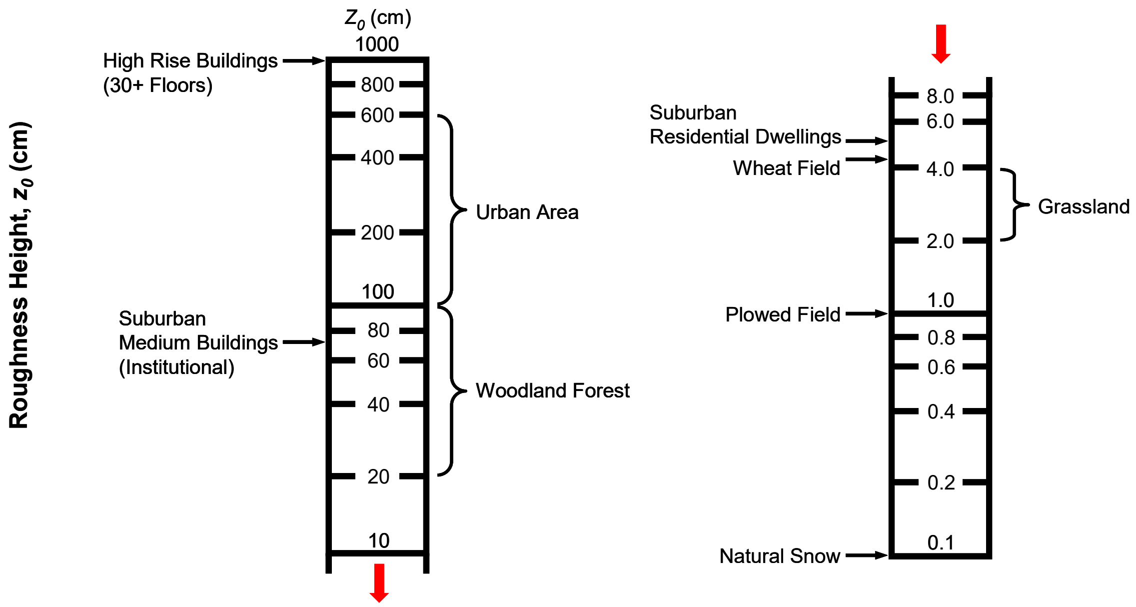


Figure 4-33. Approximate surface roughness lengths (z_0) for various surfaces (from Figure 7.3 in Whelan et al., 1987)

Figure 4-33 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 (AMS, 1977) 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:

$$\sigma_{z,r} = \sigma_{z,P-G} \left[\frac{z_0}{z_{0,P-G}} \right]^{0.2} \qquad \textbf{(4-7)}$$

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.

4.2.5.1.4. Dispersion Function Parameters

The MACCS power-law functions for σ_y and σ_z have the form:

$$\sigma_{yi} = a_i \cdot \left(\frac{x}{x_0}\right)^{b_i}$$
$$\sigma_{zi} = c_i \cdot \left(\frac{x}{x_0}\right)^{d_i} \quad \textbf{(4-8)}$$

Where

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

σ_{zi} = vertical dispersion parameter for stability class, *i*. This parameter is 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 for these coefficients 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 for these coefficients 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.

4.2.5.1.5. Lookup-Table Parameters

The lookup-table option allows the user to define a lookup table in place of power-law functions for s_y and s_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 may be possible to process the data into tables of horizontal and vertical standard deviations (s_y and s_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.

4.2.5.1.6. Time-Based Dispersion

A time-based dispersion model can be enabled as an option using the *Transport* tab in *PROPERTIES*.

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 nearly all 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, which is used as a default (see Bixler et al., 2020, for more information). 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 time-based model:

$$\sigma_y = \begin{cases} a\left(\frac{x}{x_0}\right)^b & x < x_c \\ a_c t & x \geq x_c \end{cases} \tag{4-9}$$

Where

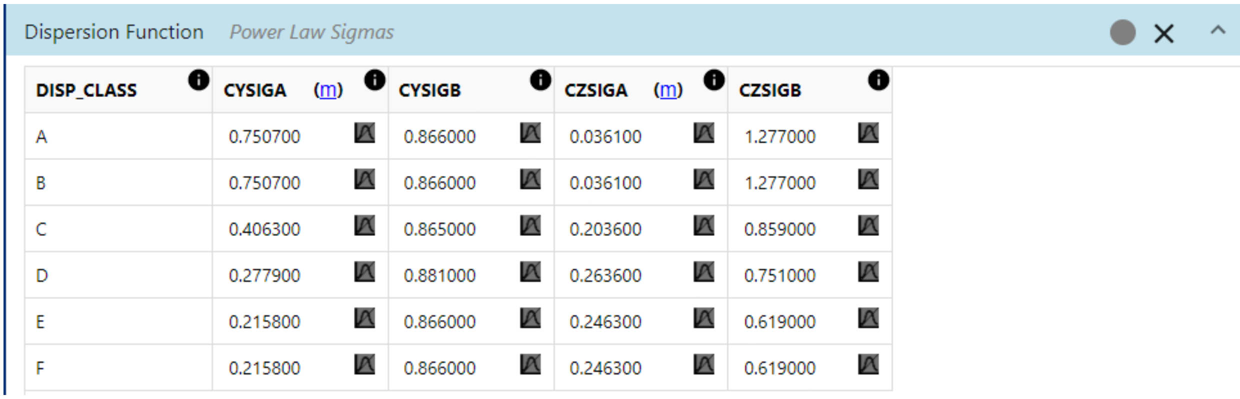
σ_y	=	Value of crosswind dispersion (m)
a	=	Linear coefficient for distance-based, crosswind dispersion (m). The subscript i is omitted but it is implied that the coefficient is for a specific stability class.
x	=	Downwind distance from the virtual source (m)
b	=	Exponential parameter for distance-based, crosswind dispersion (dimensionless). The subscript i is omitted but it is implied that the coefficient is for a specific stability class.
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 (4-3). 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 (4-3), or a lookup table can be used to define the dependence of dispersion on downwind distance at distances less than CYDIST.

4.2.5.2. Forms

4.2.5.2.1. Dispersion Function Form

The *Dispersion Function* form is required when the user selects *Power Law Functions (POWER)* on the *Transport 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 parameter defined on this form, one value for each stability class in the order A through F. All parameters are definable, of type Real.



Dispersion Function *Power Law Sigmas*

DISP_CLASS	CYSIGA (m)	CYSIGB	CZSIGA (m)	CZSIGB
A	0.750700	0.866000	0.036100	1.277000
B	0.750700	0.866000	0.036100	1.277000
C	0.406300	0.865000	0.203600	0.859000
D	0.277900	0.881000	0.263600	0.751000
E	0.215800	0.866000	0.246300	0.619000
F	0.215800	0.866000	0.246300	0.619000

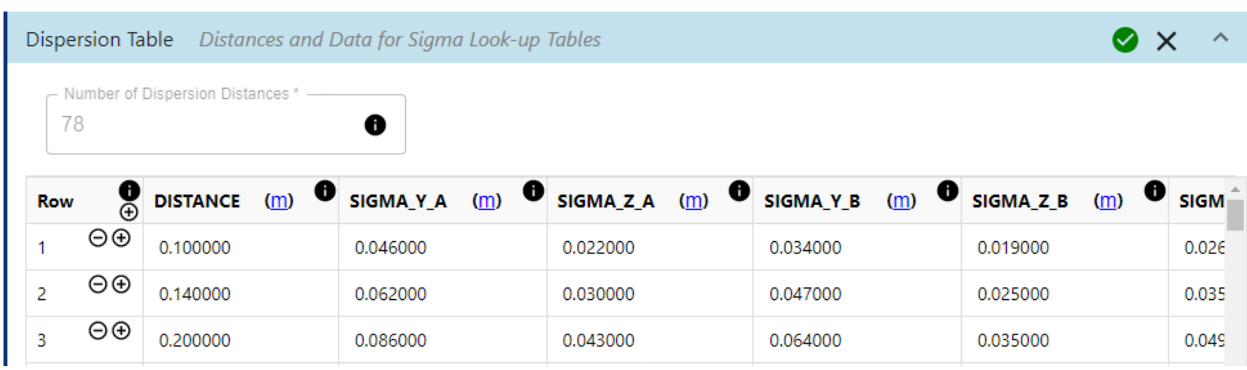
Figure 4-34. *Dispersion Function* form

Table 4-23. *Dispersion Function* parameter inputs

Parameter	Description	Allowed Values
CYSIGA	linear coefficient of the expression for σ_y.	1×10^{-6} to 10.0 m
CYSIGB	exponential coefficient of the expression for σ_y.	1×10^{-6} to 10.0
CZSIGA	linear coefficient of the expression for σ_z.	1×10^{-6} to 10.0 m
CZSIGB	exponential coefficient of the expression for σ_z.	1×10^{-6} to 10.0

4.2.5.2.2. Dispersion Table Form

The *Dispersion Table* form is required when the user selects *Lookup Tables (TABLE)* on the *Transport* tab. The *Number of Dispersion Distances* box displays NUM_DIST, which corresponds to the number of rows in the table. DISTANCE is the set of downwind distances corresponding to sigma-y and sigma-z values. Distances must be monotonically increasing. SIGMA_Y and SIGMA_Z values need to be provided on this form for each stability class, A, B, C, D, E, and F, and these values must be monotonically increasing.



Dispersion Table *Distances and Data for Sigma Look-up Tables*

Number of Dispersion Distances *
78

Row	DISTANCE (m)	SIGMA_Y_A (m)	SIGMA_Z_A (m)	SIGMA_Y_B (m)	SIGMA_Z_B (m)	SIGM
1	0.100000	0.046000	0.022000	0.034000	0.019000	0.026
2	0.140000	0.062000	0.030000	0.047000	0.025000	0.035
3	0.200000	0.086000	0.043000	0.064000	0.035000	0.049

Figure 4-35. *Dispersion Table* form

Table 4-24. *Dispersion Table* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM_DIST	Linked	Integer	None	3 to 99
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

4.2.5.2.3. Scaling Factors Form

MACCS allows linear scaling of σ_y and σ_z through this form. 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.

Sigma-y Scaling Factor, YSCALE; and *Sigma-z Scaling Factor*, ZSCALE; are applied to the formulas for σ_y and σ_z, respectively. Both modify all calculated values by a constant multiplicative factor for either the power-law or lookup-table options.

Sigma-y Scaling Factor is normally set to 1.0.

Sigma-z Scaling Factor is commonly used to account for surface roughness and typically set to a value greater than 1.0.

Figure 4-36. *Scaling Factors* form

Table 4-25. Scaling Factors parameter inputs

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

4.2.5.2.4. *Long-Range Time-Based Parameters Form*

The *Long-Range Time-Based Parameters* form is required when the user selects the *Time-Based Dispersion Model at User-Specified Distance*, on the *Transport* tab.

Time-Based Switching Distance, 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 (see Bixler et al., 2020, for more discussion).

Time-Based Linear Coefficient, *CYCOEF*, has a default value of 0.5 m/s. Both default values are based on a recommendation by Hanna (2002).

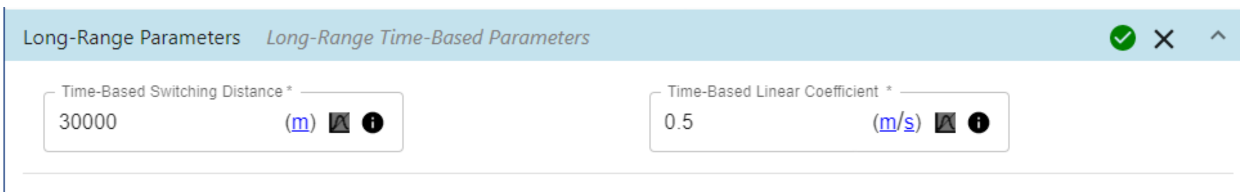


Figure 4-37. *Long-Range Time-Based Parameters* form

Table 4-26. Long Range Time-Based Parameters parameter inputs

Parameter	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

4.2.6. *Multi-Source Option*

4.2.6.1. 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 MACCS-UI using the *Import MACCS Input File* option. In the past, the process has only been able to address single-unit source terms. From WinMACCS 3.10 onward, there is the capability to merge several source terms to create a multi-unit source term.

Furthermore, 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. This feature allows the user to create a source term file for each ring in the MELCOR analysis. Multiple rings are generally used in MELCOR analyses to define annular portions of the reactor core in a polar coordinate system. Similarly, rings in the MELCOR analysis of a spent fuel pool are generally used to represent different regions of the fuel. This feature is especially advantageous for analyses of spent fuel pools, where each spent-fuel 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) is compatible with the multi-source model and allows 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 SAND2022-13278, the *MelMACCS 4.0.0 User Guide*. Details of how to use the multi-source model is provided in Section 3.

4.2.6.2. Forms

4.2.6.2.1. Chemical Names Form

The values on this form are read from the multi-source files and are not changeable.

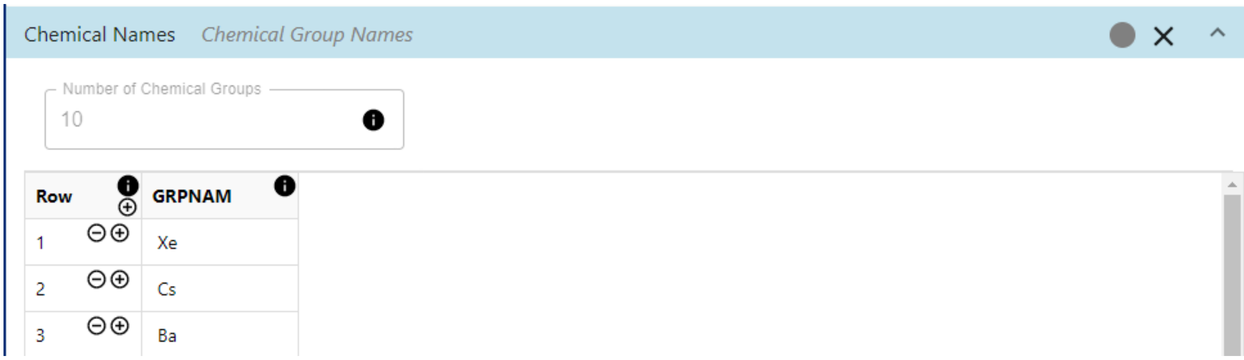


Figure 4-38. *Chemical Names* form

Table 4-27. *Chemical Names* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
MAXGRP	No	Integer	None	1 to 999
GRPNAM	No	Character	MAXGRP	1 to 15 characters

4.2.6.2.2. Radionuclides Form

The values on this form are read from the multi-source files and are not changeable.

Figure 4-39. *Radionuclides* form

Table 4-28. *Radionuclides* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMISO	No	Integer	None	1 to 999
NUCNAM	No	Character	NUMISO	3 to 8 characters
IGROUP	No	Integer	NUMISO	1 to MAXGRP

4.2.6.2.3. *Plume Segments Form*

The values on this form are read from the multi-source files and are not changeable. Each row in the grid identifies a plume segment that is defined on one of the multi-source files.

Figure 4-40. *Plume Segments* form

Table 4-29. *Plume Segments* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
TOTREL	No	Integer	None	2 to 9999
MS_LABELS	No	Character	TOTREL	1 to 255 characters
PLUME_DLY	No	Integer	TOTREL	0 to 2.592×10^6 s (30 days)

4.2.6.2.4. *Time Offsets Form*

A time offset can be associated with each of the multi-source files to account for different accident initiation times for each of the sources. Time offsets define the times associated with the inventories in each of the files. This information allows MACCS to adjust its calculation of radioactive decay for each unit or source.

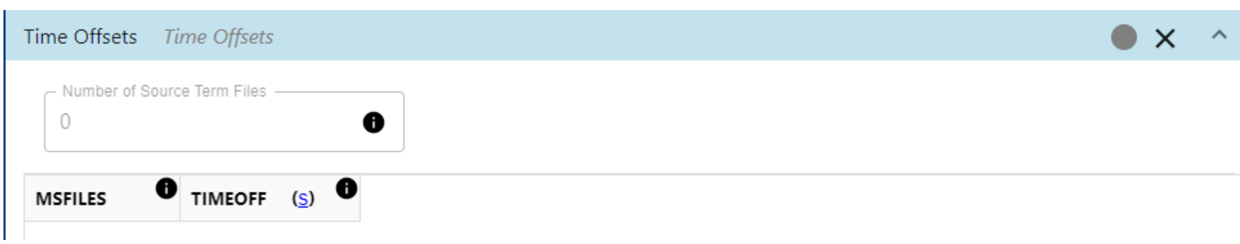


Figure 4-41. *Time Offsets* form

Table 4-30. *Time Offsets* parameter inputs

Parameter	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)

4.2.6.2.5. *Number of MS Simulation Form*

Multiple multi-source simulations may be run, where each simulation may use a different set of multi-source files. The number of simulations is specified on this form.

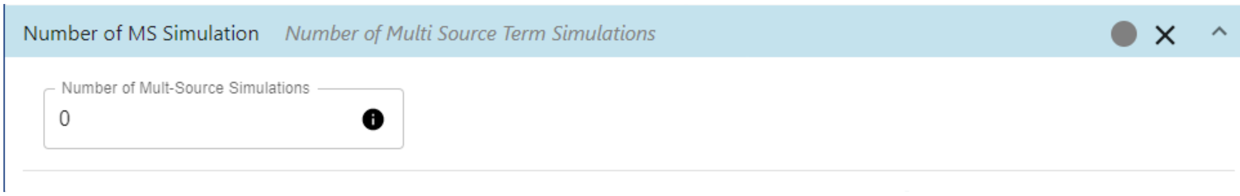


Figure 4-42. *Number of Multi-Source Term Simulations* form

Table 4-31. *Number of Multi-Source Term Simulations* form

Parameter	Definable	Type	Dimensions	Allowed Values
NUM_MS_SIM	Yes	Integer	None	1 to 1000

4.2.6.2.6. Files for Multiple Simulations Form

When multiple simulations are run, the user may select which source term files are used for each simulation.

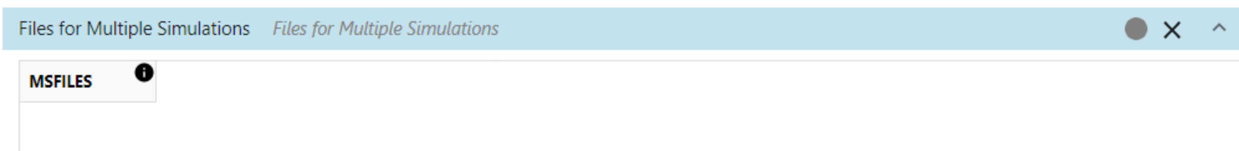


Figure 4-43. Files for Multiple Simulations form

Table 4-32. *Files for Multiple Simulations* form

Parameter	Definable	Type	Dimensions	Allowed Values
MSFILE_PER	Yes	Logical	NUM_SOURCES x NUM_MS_SIM	True, False

4.2.6.2.7. Time Offsets for Multiple Simulations Form

When multiple simulations are run, the user may specify time offsets between each source term file used in each simulation.

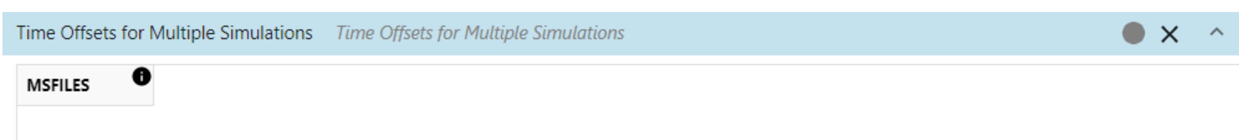


Figure 4-44. *Time Offsets for Multiple Simulations* form

Table 4-33. *Time Offsets for Multiple Simulations* form

Parameter	Definable	Type	Dimensions	Allowed Values
MSOFF_PER	Yes	Real	NUM_SOURCES x NUM_MS_SIM	0 to 2.592×10^6 s (30 days)

4.2.7. *HYSPLIT Transport*

4.2.7.1. Model Description

HYSPLIT is a Lagrangian particle tracking atmospheric transport and dispersion code developed by NOAA, which has been coupled to MACCS starting in version 4.0. The details of this model implementation are covered in *Instructions and Sample Problems for using the MACCS/HYSPLIT Capability*, which is provided to users upon request.

A high-level overview of the process is as follows:

- Meteorological files and the HYSPLIT executable plus supporting software are first downloaded. This process is detailed in a separate document organized as a tutorial, *Sample Problem for Generating HYSPLIT Files for MACCS*.
- MACCS-UI utilities are used to convert the HYSPLIT output files to files compatible with the spatial grid defined in the MACCS-UI project. Details are documented in a separate document, *Using the HYSPLIT Model with MACCS-UI*.
- Once these files are created outside of MACCS-UI, they are linked to the MACCS-UI project by completing the form *GENERAL/File Specifications/HYSPLIT Converted Folder*.

4.2.7.2. Forms

4.2.7.2.1. File Extensions and Lower Bounds Form

When running the HYSPLIT model, users may specify up to ten HYSPLIT file sets using the *File Extensions and Lower Bounds* Form. For HY_PREFIX, prefixes are specified by either the release height (Hxxx, where height = xxx*10m) or the power level (Pxxx, where power = xxx*.01MW). HY_LOWER corresponds to the minimum height or power level associated with that file set.

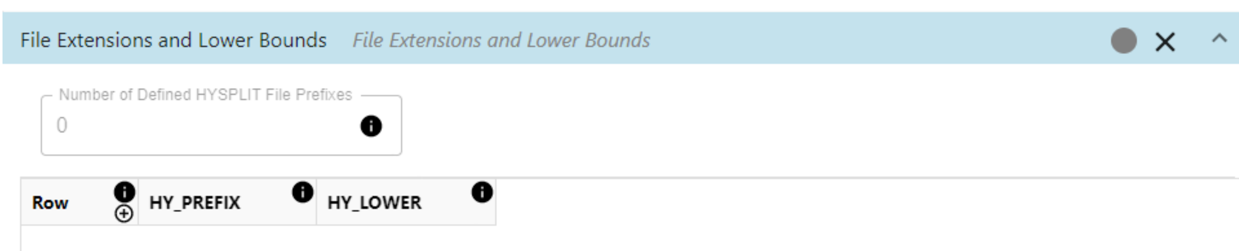


Figure 4-45. *File Extensions and Lower Bounds* form

Table 4-34. *File Extensions and Lower Bounds* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
HY_NUMPRE	Yes	Integer	None	1 to 10
HY_PREFIX	Yes	Character	HY_NUMPRE	Hxxx or Pxxx
HY_LOWER	Yes	Real	HY_NUMPRE	0 to 1x10^{5} m or MW

4.2.7.2.2. Fixed Start Time Form

The start time (date and hour) when the weather sequence begins is specified in the *HYSPLIT Fixed Start Time Data* Form. The starting date is specified by HY_FIXED in MM/DD/YYYY format, and the starting hour is specified by an integer, HY_HOUR, which can be 1 to 24.

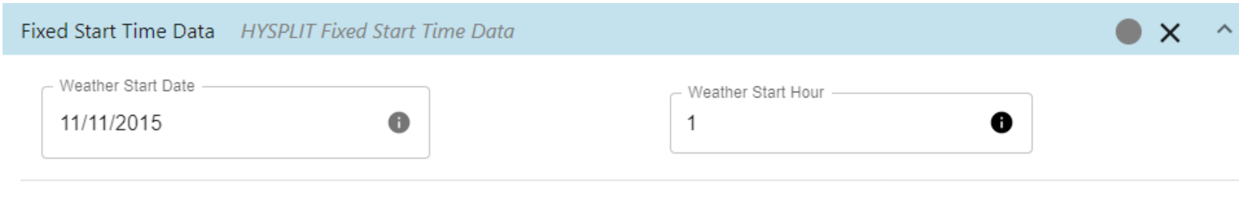


Figure 4-46. *Fixed Start Time Data* form

Table 4-35. *Fixed Start Time Data* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
HY_FIXED	Yes	Character	1	MM/DD/YYYY format
HY_HOUR	Yes	Integer	1	1 to 24 hrs

4.2.7.2.3. Transport Dates Form

The transport start and end dates are specified in the *HYSPLIT Transport Dates* Form. The starting date is specified by HY_START and the ending date is specified by HY_END. Both are in MM/DD/YYYY format.

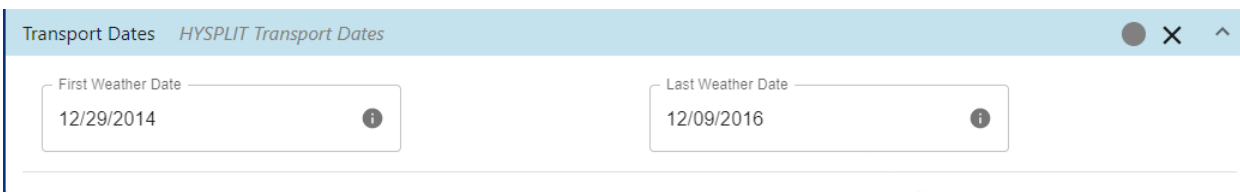


Figure 4-47. *Transport Dates* form

Table 4-36. *Transport Dates* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
HY_START	Yes	Character	None	MM/DD/YYYY format
HY_END	Yes	Character	None	MM/DD/YYYY format

4.2.7.2.4. Extended Time Form

Users may specify time before the start time and time after the end time. This extended time is specified in the *Extended Time* Form.

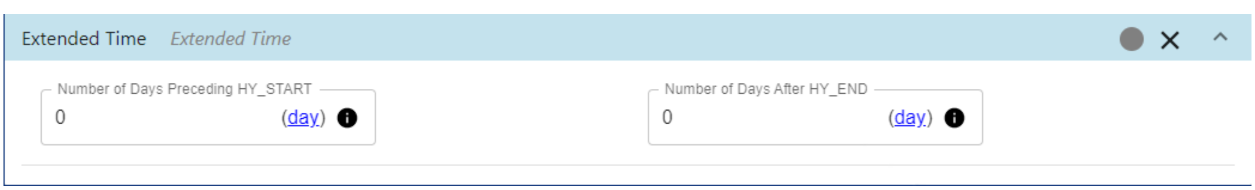


Figure 4-48. *Extended Time* form

Table 4-37. *Extended Time* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
HY_BEFORE	Yes	Integer	None	0 to 2 days

Parameter	Definable	Type	Dimensions	Allowed Values
HY_AFTER	Yes	Integer	None	0 to 40 days

4.2.8. Plume Specification

4.2.8.1. Plume Meander Model Descriptions

MACCS-UI allows four choices for plume meander model on the *Transport tab* shown in Figure 4-6. Namely, the original MACCS model, a model based on Reg Guide 1.145 (NRC, 1983a), the Ramsdell and Fosmire model, and an option to turn off plume meander. Plume meander accounts for the tendency of wind direction to vary over time. The amount of plume meander depends on wind speed, stability class, and the observation period. For the purposes of MACCS, observation period generally translates to the duration of release for a plume segment.

4.2.8.1.1. Original MACCS Plume Meander

The original MACCS model accounts 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:

$$
\begin{array}{lll}
f_m = 1 & & \Delta t_{release} \le \Delta t_0 \\
f_m = \left(\frac{\Delta t_{release}}{\Delta t_0}\right)^{F_1} & \text{if} & \Delta t_0 < \Delta t_{release} \le \Delta t_1 \\
f_m = \left(\frac{\Delta t_{release}}{\Delta t_0}\right)^{F_2} & & \Delta t_1 < \Delta t_{release} \le 10\ hours
\end{array}
\quad \textbf{(4-10)}
$$

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)

Bixler et al. (2020) provides more discussion on dispersion modeling and related recommendations. The duration of each plume segment should be limited to 10 hours when using this meander model because the formula is not intended to be used above that value. If a plume segment exceeds 10 hours (36,000 s), a nonfatal warning is given in the output file and the expansion factor is calculated as though the plume duration were 10 hours.

4.2.8.1.2. Plume Meander Model Based on U.S. Nuclear Regulatory Guide 1.145

MACCS now contains a plume meander model based on Regulatory Guide 1.145 (NRC, 1983a) 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. 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 significantly longer than 1 hour; it would under predict peak doses for release durations that are significantly shorter than 1 hour. Enforcement of this model restriction is left to the user; MACCS-UI 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 model described in Regulatory Guide 1.145 considers the effects of both building wake mixing and ambient plume meander and incorporates three principal equations. Prior to MACCS version 4.1, only the third equation from the Regulatory Guide 1.145 plume meander model was implemented. For MACCS 4.1, the Regulatory Guide 1.1.45 plume meander model was updated to enable the incorporation of the three principal equations and to include a vertical component for consistency with other models and is covered in detail in *Implementation of Additional Models into the MACCS Code for Nearfield Consequence Analysis* (SAND2021-6924).

Equations 1 and 2 in Regulatory Guide 1.145, are included to give credit for the turbulent mixing in the wake of buildings and structures in the crosswind direction. Equation 1 includes an additive term to the crosswind dispersion, while Equation 2 includes a multiplicative term. The crosswind meander factor is calculated with all three equations and the resulting values are compared. The crosswind meander factors calculated with Equations 1 and 2 are compared and the lower value of the two is selected. That value is compared with the value obtained using Equation 3 and the higher of these two is selected as the appropriate value for the crosswind meander factor. This procedure selects the more conservative (lower) value of the wake factors from Equations 1 and 2 based on local wakes and provides a mechanism to use their results if the determined factor is greater than the meander factor calculated by Equation 3. It is possible, based on building dimensions, wind speed and stability class, to use the factors calculated from all three equations at different distances in the same simulation.

The full three equation implementation of the Regulatory Guide 1.145 plume meander model is used in MACCS when the plume source model is set to point source (described in Section 4.2.9.1). Equations 1 and 2 in the Regulatory Guide 1.1.45 plume meander model account for the building wake. When an area source (described in Section 4.2.9.1) is used, to avoid double counting of the building wake effects, only the crosswind meander factor derived from the third equation from the Regulatory Guide 1.1.45 plume meander model is calculated and the factors from the first and second equations are set to one.

The MACCS implementation of the Regulatory Guide 1.145 plume meander model is described as follows:

$$\sigma_{ym}(x) = \max\left[min\left(f_{ym1}, f_{ym2}\right), f_{ym3}\right] \cdot \sigma_y(x) \quad \textbf{(4-11)}$$

$$\sigma_{zm}(x) = f_{zm} \cdot \sigma_z(x) \quad \textbf{(4-12)}$$

Where

$\sigma_y(x)$	=	the crosswind dispersion that is evaluated without meander (m)
$\sigma_{ym}(x)$	=	the crosswind dispersion accounting for plume meander (m)
$\sigma_z(x)$	=	the vertical dispersion that is evaluated without meander (m)

$\sigma_{zm}(x)$	= the vertical dispersion accounting for plume meander (m)
x	= the downwind distance measured from the source (m)
f_{ym1}	= the crosswind wake factor derived from Equation 1 in Regulatory Guide 1.145
f_{ym2}	= the crosswind wake factor derived from Equation 2 in Regulatory Guide 1.145
f_{ym3}	= the crosswind meander factor derived from Equation 3 in Regulatory Guide 1.145
f_{zm}	= the vertical meander factor

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

$$f_{ym1} = 1 + \frac{0.5 \cdot \mathrm{A}}{\pi \sigma_y(x) \sigma_z(x)} \tag{4-13}$$

$$f_{ym2} = 3 \tag{4-14}$$

$$f_{ym3} = m \cdot f(u) \tag{4-15}$$

Where

A	=	the cross-sectional area of the building (m^2)
m	=	1.0 for stability classes A through C
		2.0 for stability class D
		3.0 for stability class E
		4.0 for stability class F
f(u)	=	a function of wind speed and is defined in Equation (4-16) below
u	=	wind speed (m/s)

$$\begin{aligned} f(u) &= 1 \quad u \leq 2 \\ f(u) &= \frac{1}{m} * \exp\left[\left(1 - \frac{ln(u) - ln(2)}{ln(6) - ln(2)}\right) * ln(m)\right] \text{ when } 2 < u \leq 6 \\ f(u) &= \frac{1}{m} \quad 6 < u \end{aligned} \tag{4-16}$$

The values of 0.5 and 3 in Equations (4-13) and (4-14) are based on recommendations in NUREG/CR-2260 but can be changed by the MACCS user if desired as described below.

The vertical meander factor for the Regulatory Guide 1.145 plume meander model is modeled as follows:

$$f_{zm} = 1 \tag{4-17}$$

The above equations for crosswind dispersion are valid for distances within 800 m of the source. Beyond 800 m downwind, Equation (4-11) is modified as follows:

$$\sigma_{ym} = (f_m - 1) \cdot \sigma_y(800) + \sigma_y(x) \tag{4-18}$$

The MACCS model is like 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 (4-18)). The equations used in MACCS are as follows:

$$
\begin{aligned}
&f(u) = 1 && u \le u_1 \\
&f(u) = \frac{1}{m} * \exp\left[\left(1 - \frac{ln(u) - ln(u_1)}{ln(u_2) - ln(u_1)}\right) * ln(m)\right] && \text{when} \quad u_1 < u \le u_2 \\
&f(u) = \frac{1}{m} && u_2 < u
\end{aligned}
\tag{4-19}
$$

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} . Beyond MNDIST (the MACCS name corresponding to D), 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 closely 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, as discussed in Bixler et al. (2020).

4.2.8.1.3. Ramsdell and Fosmire Plume Meander

The Ramsdell and Fosmire plume meander model implementation in MACCS is covered in detail in the *Implementation of Additional Models into the MACCS Code for Nearfield Consequence Analysis* (SAND2021-6924).

This model includes enhanced dispersion near a building at low and high wind speeds. At low wind speeds, building wakes have a minimal effect and the major contributor to enhanced dispersion is plume meander. At high wind speeds, building wakes are the major contributor to enhanced dispersion.

The Ramsdell and Fosmire plume meander model replaces the standard form of the Gaussian dispersion parameters with a three-term equation, modeled as follows:

$$\Sigma(\mathrm{x}) = (\sigma_0(x)^2 + \Delta\sigma_1(x)^2 + \Delta\sigma_2(x)^2)^{\frac{1}{2}} \tag{4-20}$$

Where

σ_0	=	the standard function for Gaussian dispersion
$\Delta\sigma_1(x)$	=	the additional dispersion from low-wind-speed phenomena, primarily plume meander
$\Delta\sigma_2(x)$	=	the additional dispersion from high-wind-speed phenomena, primarily wake effects
$\Sigma(\mathrm{x})$	=	the combined dispersion parameter to be used in Gaussian plume equation
x	=	the downwind distance measured from the source

For implementation in MACCS, the above equation is rearranged to calculate a meander factor for use in the calculations.

$$\sigma_{\mathrm{ym}}(x) = f_{ymRF} \cdot \sigma_y(x) \tag{4-21}$$

$$\sigma_{zm}(x) = f_{zmRF} \cdot \sigma_z(x) \quad \text{(4-22)}$$

Where

$\sigma_y(x)$	=	the crosswind dispersion that is evaluation without meander
$\sigma_{ym}(x)$	=	the crosswind dispersion accounting for plume meander
$\sigma_z(x)$	=	the vertical dispersion that is evaluation without meander
$\sigma_{zm}(x)$	=	the vertical dispersion accounting for plume meander
f_{ymRF}	=	the crosswind meander factor
f_{zmRF}	=	the vertical meander factor

The crosswind (y) and vertical (z) meander factors are defined in the MACCS Ramsdell and Fosmire model as follows:

$$f_{ymRF} = \left(1 + \frac{\Delta\sigma_{y1}(x)^2 + \Delta\sigma_{y2}(x)^2}{\sigma_y(x)^2}\right)^{\frac{1}{2}} \quad \text{(4-23)}$$

$$f_{zmRF} = \left(1 + \frac{\Delta\sigma_{z1}(x)^2 + \Delta\sigma_{z2}(x)^2}{\sigma_z(x)^2}\right)^{\frac{1}{2}} \quad \text{(4-24)}$$

Where

$\Delta\sigma_{y1}(x)$ = the additional crosswind dispersion from low-wind-speed phenomena
$\Delta\sigma_{y2}(x)$ = the additional crosswind dispersion from high-wind-speed phenomena
$\Delta\sigma_{z1}(x)$ = the additional vertical dispersion from low-wind-speed phenomena
$\Delta\sigma_{z2}(x)$ = the additional vertical dispersion from high-wind-speed phenomena

4.2.8.2. Plume Forms and Parameters

4.2.8.2.1. Original Meander Form

The *Original Meander* form is required when *Original MACCS (OLD)* is selected on the *Transport tab*.

Time Adjustment Factor, TIMBAS, is the release duration associated with the Prairie Grass tests upon which the Pasquill-Gifford dispersion curves are based. *Breakpoint*, BRKPNT, is the time breakpoint in the formula used to calculate the plume meander expansion factor.

When the release duration is less than or equal to this value but greater than the *Time Adjustment Factor*, the second formula is used in Equation (4-10). When the release duration exceeds the value of the *Breakpoint*, the third expression is used in Equation (4-10).

Exponential Factor 1, XPFAC1, is used to calculate the plume meander expansion factor for releases with durations less than or equal to the *Breakpoint*. With values greater than *Breakpoint, Exponential Factor 2* is used.

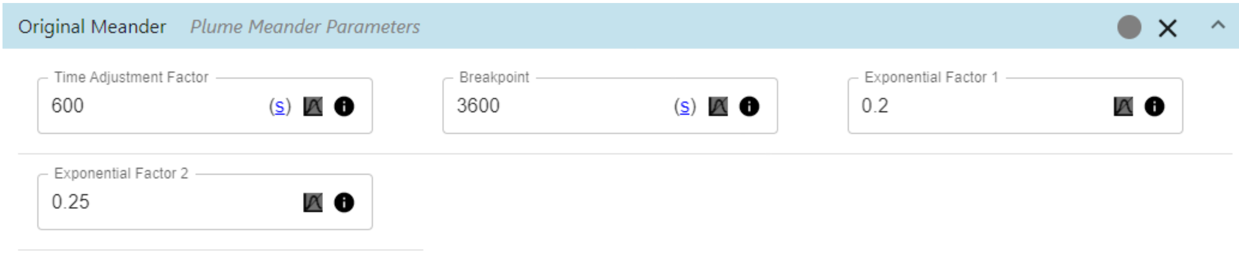


Figure 4-49. *Original Meander* form

Table 4-38. *Original Meander* parameter inputs

Parameter	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

4.2.8.2.2. US NRC Reg. Guide 1.145 Meander Form

The *U.S. NRC Reg. Guide Meander* form is required when *U.S. NRC Regulatory Guide 1.145 (NEW)* is selected on the *Transport* tab.

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

Wind Speed Where Meander Factor Reaches One, WINSP2, is the wind speed where the meander factor reaches one for all stability classes. Meander factor decreases log-linearly from the value specified by MNDFAC(n) at WINSP1 to one at WINSP2. The index n represents the atmospheric stability class.

Downward Distance, MNDIST, is the downwind distance where the effect of meander begins to diminish. MNDIST is a breakpoint in the formula 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.

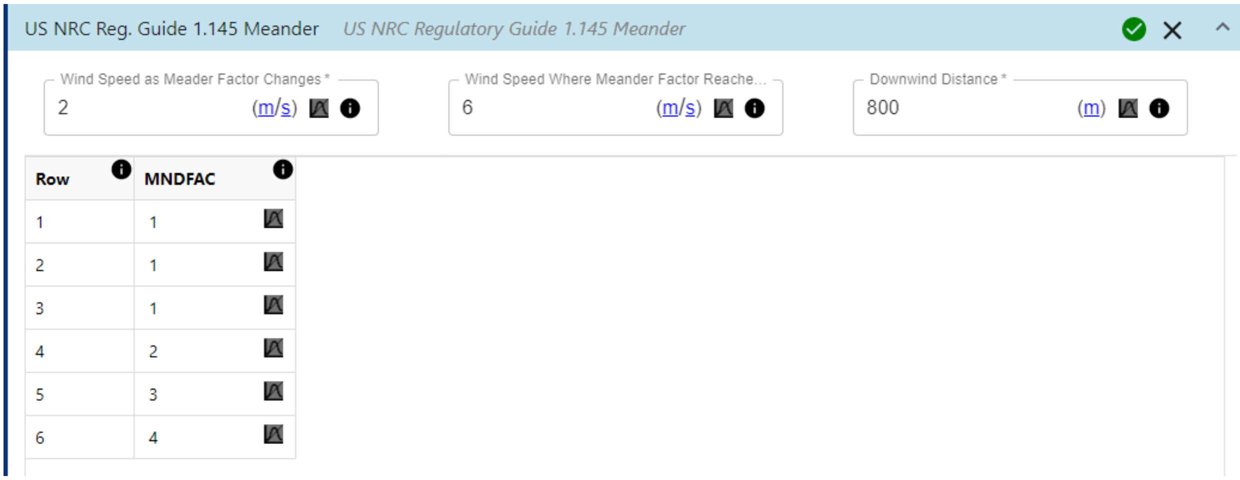


Figure 4-50. *U.S. NRC Reg. Guide 1.145 Meander* form

Table 4-39. U.S. NRC Regulatory Guide 1.145 Meander parameter inputs

Parameter	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

4.2.8.2.3. US NRC Reg. Guide 1.145 Point Source Meander Form

The *U.S. NRC Reg. Guide Point Source Meander* form is required when the user selects *U.S. NRC Regulatory Guide 1.145 (NEW)* in the *Plume Meander Model* dropdown on the *Transport* tab and *Point Source* in the *Plume Source Model* dropdown of the *Plume* tab.

Point Source Coefficient 1, PSMEQ1C; and *Point Source Coefficient 2*, PSMEQ2C; correspond to equations 1 and 2 of the Reg. Guide 1.145 meander model, respectively.

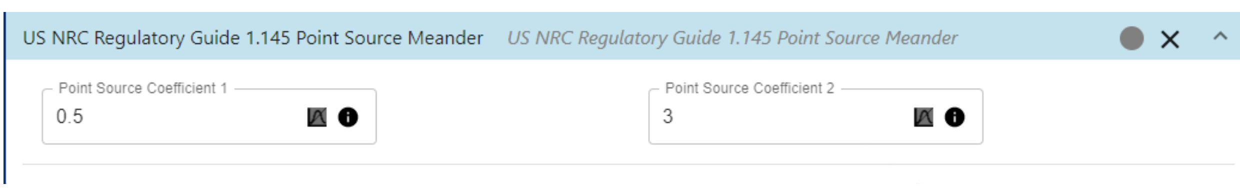


Figure 4-51. *U.S. NRC Reg. Guide 1.145 Point Source Meander* form

Table 4-40. *U.S. NRC Reg. Guide 1.145 Point Source Meander* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
PSMEQ1C	Yes	Real	None	0.0 to 10.0 1/m^2
PSMEQ2C	Yes	Real	None	0.0 to 10.0

4.2.8.2.4. Ramsdell and Fosmire Form

A new form was created under *Plume Specifications* for input of parameters for the Ramsdell and Fosmire (RAF) plume meander model. Recommended values are from *Implementation of Additional*

Models into the MACCS Code for Nearfield Consequence Analysis (Clayton, 2021). Recommended values are from *Implementation of Additional Models into the MACCS Code for Nearfield Consequence Analysis* (Clayton, 2021). All values are definable and of type Real.

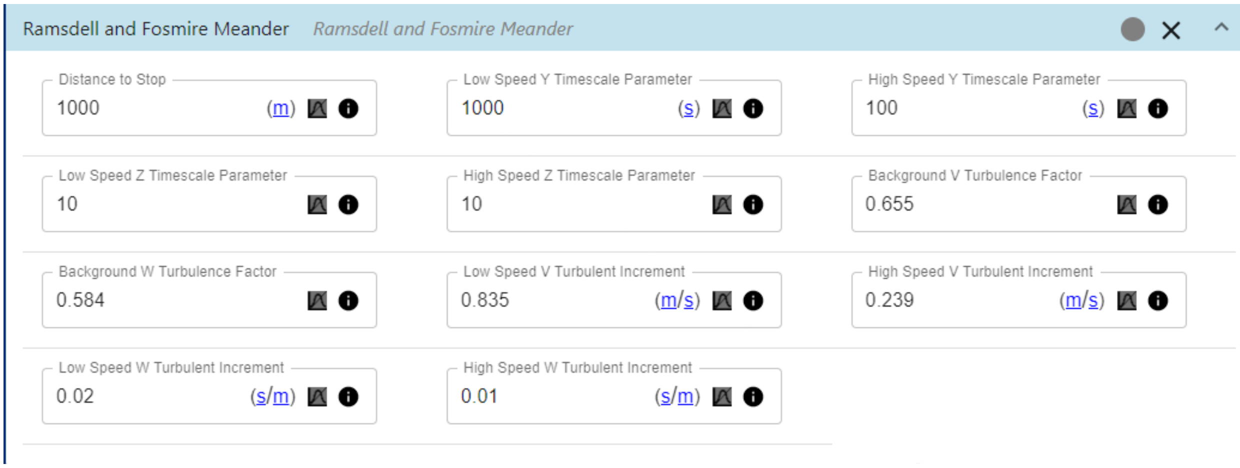


Figure 4-52. *Ramsdell and Fosmire Meander* form

Table 4-41. *Ramsdell and Fosmire* form inputs and recommended values

Parameter	Description	Recommended value	Allowed values
RAFDIST	Distance to stop	1000 m	1 to 2x10^6 m
TIMSCLY1	Low speed y timescale parameter	1000 s	1 to 1x10^4 s
TIMSCLZ1	Low speed z timescale parameter	100 s	1 to 1x10^4 s
TIMSCLY2	High speed y timescale coefficient	10	1 to 1x10^4
TIMSCLZ2	High speed z timescale coefficient	10	1 to 1x10^4
BKGTRBV	Background v turbulence	0.655	0.001 to 10
BKGTRBW	Background w turbulence	0.584	0.001 to 10
TRBINCV1	Low speed v turbulent increment	0.835 m/s	0.001 to 10 m/s
TRBINCW1	Low speed w turbulent increment	0.239 m/s	0.001 to 10 m/s
TRBINCV2	High speed v turbulent increment	0.02 s/m	0.001 to 10 s/m
TRBINCW2	High speed w turbulent increment	0.01 s/m	0.001 to 10 s/m

4.2.8.2.5. Plume Rise Scale Factor Form

Unstable/Neutral Class Scaling 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.

Critical Wind Speed Scaling Factor, 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).

Stable class Scaling Factor, 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).

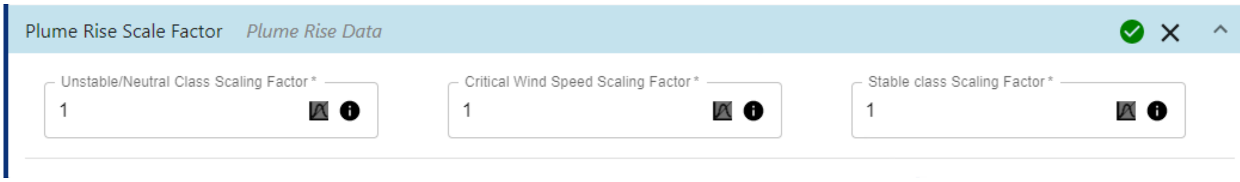


Figure 4-53. *Plume Rise Scale Factor* form

Table 4-42. *Plume Rise Scale Factor* parameter inputs

Parameter	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

4.2.9. Release Description

4.2.9.1. Model Description

ATMOS can handle multiple plume segments 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.

4.2.9.1.1. Initial Plume Dimensions

There are three models in MACCS for defining the initial plume dimensions:

- Point source
- Area source
- Automatic area source calculation

The point source model assumes the release is from a single point, approximated by a release size of 0.1 m by 0.1 m. This would represent a release from a location where there is no building wake, or the effects of the building wake are incorporated in the plume meander model (see Section 4.2.9.1.3).

The area source model allows the user to specify the initial plume dimensions. This can be used to represent a release from a location where there is a building wake, and the effects of the building wake are not incorporated in the plume meander model (see Section 4.2.9.1.3). Mixing of the plume into the wake of a building from which a release occurs generally determines the initial dimensions of the plume. For 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

$$\sigma_y(x=0) = \frac{W_b}{4.3} = 0.232W_b$$
$$\sigma_z(x=0) = \frac{H_b}{2.15} = 0.465H_b \quad \textbf{(4-25)}$$

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 footprint. Thus, the apparent width depends on the direction of the wind. Fortunately, the effect of the initial size of the plume is 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 doses multiple kilometers from the plant.

The automatic area source calculation model is like the area source model, but instead of specifying the initial plume dimensions, the initial plume dimensions are calculated based on the specified building parameters and wind direction. The vertical standard deviation of the Gaussian plume is calculated using Equation (4-25), the building height, and the 0.465 coefficient (entered by the user). The horizontal standard deviation of the Gaussian plume is calculated using Equation (4-25), the apparent building width and the 0.232 coefficient (entered by the user). The apparent building width is calculated assuming the building is rectangular in shape:

$$W_{ba} = W_b \text{ abs}(\cos(\theta_W)) + L_b \text{ abs}(\sin(\theta_W)) \quad \textbf{(4-26)}$$

Where

W_{ba}	=	Apparent width of the building from which release occurs (m)
L_b	=	Length of the building from which release occurs (m)
θ_W	=	Angle between the wind direction and the wall along the width of the building (radian) (e.g., if the wind is blowing directly towards the wall, the angle would be 90 degrees or p/2 radians)

4.2.9.1.2. Plume Rise Models

Plume Trapping an There are three basic components of the plume rise models in MACCS:

- liftoff of buoyant plumes from a building wake

- plume rise under unstable and neutral atmospheric conditions (stability classes A to D)
- plume rise under stable conditions (stability classes E and F)

Each of these components is described in this section.

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 Hanna et al. (1982):

$$\Delta h(x) = \frac{1.6F^{\frac{1}{3}}x^{\frac{2}{3}}}{\bar{u}} \tag{4-27}$$

Where

h	=	height of the plume centerline (m)
$\Delta h(x)$	=	plume rise (m) as a function of x measured from the initial release height
F	=	the buoyancy flux (m^4/s^3), which under standard atmospheric conditions is = $8.79 \cdot 10^{-6} Q$
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 ambient temperature
$\bar{u}$	=	wind speed (m/s) averaged between the initial release height and the final rise height (h)

Buoyant plume rise is terminated when $\Delta h(x)$ reaches a final rise height, Δh, as defined below;

- The height of the plume centerline reaches the mixing height (height of the capping inversion layer); or
- One hour has elapsed since release of the plume segment began.

In the original MACCS plume rise model, the following equation recommended by Briggs (1975) was used to determine the final rise height for stability classes A to D:

$$\Delta h = 300F/\bar{u}^3 \tag{4-28}$$

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

$$\begin{aligned} \Delta h &= \frac{38.7F^{0.60}}{\bar{u}} & & F \geq 55 \\ & & \text{when} & \\ \Delta h &= \frac{21.4F^{0.75}}{\bar{u}} & & F < 55 \end{aligned} \tag{4-29}$$

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) Hanna (1982):

$$\Delta h = 2.6\left[\frac{F}{\bar{u}S}\right]^{\frac{1}{3}} \tag{4-30}$$

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:

$$\Delta h = 2.4\left[\frac{F}{\bar{u}S}\right]^{\frac{1}{3}} \quad \textbf{(4-31)}$$

In Equations (4-30) and (4-31), the stability parameter, *S*, is defined as follows:

$$S = \frac{g}{T_a}\left[\frac{\partial T_a}{\partial z} + \frac{g}{c_p}\right] \quad \textbf{(4-32)}$$

Where

g = acceleration due to gravity (9.8 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 = 0.0098 K/m)

For E and F stability cases with small final rise height downwind distances, the plume is assumed to behave identically to the model for unstable condition.

When atmospheric conditions are stable (stability classes E or F), the final plume rise height, Δh_{final}, in the improved Briggs model depends on the downwind distance x_f when the plume reaches its final rise height, which in turn depends on the buoyancy flux *F*. The downwind distance x_f when the plume levels off is given by the following equation:

$$x_f = 119F^{0.4} \quad \text{if} \quad F \geq 55\, m^4/s^3$$
$$x_f = 49F^{0.625} \quad \text{if} \quad F < 55\, m^4/s^3 \quad \textbf{(4-33)}$$

If $x_f \leq 1.84\frac{\bar{u}}{\sqrt{S}}$, then MACCS assumes the plume behaves identically to the improved Briggs model for unstable conditions.

Regulatory Guide 1.23 (NRC, 1972) specifies ranges for temperature lapse rates $(\partial T_a/\partial z)$ 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 (West, 1972) value of 288.16 K (15°C) into Equation (4-16) 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 (4-28) through (4-31) 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 (Hanna, 1982):

$$u = u_0\left(\frac{h}{h_r}\right)^p \quad \textbf{(4-34)}$$

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 4-43.

Table 4-43. Values of exponential coefficient, *p*, in Equation (4-34) 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

To calculate plume rise, the weather conditions that characterize the time at which release of the plume segment begins are used to calculate the entire rise of the segment. In other words, transitions in stability class and wind speed are not considered for the purpose of plume rise (e.g., a buoyant plume segment released at 1:59 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 u0 and one of the Equations (4-28) through (4-31), 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 $(h = h_0 + \Delta h)$, where h0 is the initial release height of the plume segment. Then the wind speed u at the height h is calculated using Equation (4-34). Finally, an average wind speed over this range is estimated by averaging u0, 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 Equations (4-28) through (4-31) to make a second-order estimate of the amount of plume rise, Dh, 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 the end results by specifying linear scaling factors, SCLCRW, SCLADP, and SCLEFP.

Two optional sets of inputs are available in MACCS to determine plume buoyancy. When Power Model is selected on the Plume Buoyancy Model on the Plume tab (specified via the MACCS parameter PLMMOD), 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:

$$F = \frac{g}{\pi}\left(1 - \frac{\rho}{\rho_a}\right)\frac{\dot{m}}{\rho} \qquad \textbf{(4-35)}$$

Where

g = acceleration due to gravity (9.8 m/s^2)

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

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

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

Equation (4-35) 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.

4.2.9.1.3. Plume Trapping and Downwash Models

There are two plume trapping/downwash models available in MACCS. Both are based on the work of Briggs, with the first based on building parameters and the second based on buoyancy flux. When plume trapping occurs, MACCS disallows plume rise and instead assigns a post-wake-region centerline height to the plume segment. The plume trapping/downwash models do not affect plume spread. The nearfield models calculate plume spread according to the building wake and plume meander conditions regardless of whether plume rise occurs or not.

4.2.9.1.4. Briggs Building Parameters

In this model, a plume segment that is released near a building is influenced by the wake region. The wake region traps a plume segment when the release height is less than the building height plus 1.5 times x (where x is the smaller of the building height and the building dimension corresponding to the wind direction). When the release height is greater than that quantity, then the plume segment is assumed to be unaffected.

4.2.9.1.5. Briggs Buoyancy Flux

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 (4-36) below), which was originally proposed by Briggs (1973) and validated by experiments performed at the Warren Spring Laboratory in Great Britain (Hall and Waters, 1986). 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:

$$u_c = \left[\frac{9.09F}{H_b}\right]^{\frac{1}{3}} \tag{4-36}$$

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

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 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. Larger release rates of sensible heat, like 10 MW, produce lift off under a significant set of weather conditions for most sites.

4.2.9.1.6. *Post Wake Region Plume Centerline Height Options*

The *Automatic Trapped Plume Release Height Calculation* is an option in *PROPERTIES*. When it is not selected, the user manually sets the post wake region plume segment centerline height. When it is selected, MACCS calculates the post wake region plume segment centerline height using the following algorithm.

$$H_{Trap} = 2 * H_{Plume} - (H_b + 1.5 * x) \qquad \mathrm{H_b} < H_{Plume} < H_b + 1.5 * x\,,$$

$$H_{Trap} = H_{Plume} - 1.5 * x \qquad H_{Plume} < H_b \tag{4-37}$$

$$\text{If } H_{Trap} < 0.5 * x, \text{ then } H_{Trap} = 0$$

Where

$\mathrm{H_b}$	=	the height of the building from which the plume is escaping (m)
x	=	the smaller of the building height and the building dimension corresponding to the wind direction
H_{Plume}	=	the height above ground level at which each plume segment is released
H_{Trap}	=	the trapped plume centerline height

Prior to MACCS 4.1, the post wake region plume segment centerline height was assumed to always be the initial release height. If the user desires to mimic that behavior, the post wake region plume segment centerline height should be set to the initial release height of that plume segment.

4.2.9.2. Forms

4.2.9.2.1. *Plume of Maximum Risk Form*

The *Plume of Maximum Risk* form is required when *Multi Source Model Flag* is not selected on the *Scope* tab.

Plume of Maximum Risk, 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. Selecting a value is not always obvious, but the user should select a plume segment with relatively large release fractions that occurs early in the overall release timing. Release of the risk-dominant plume is aligned with the first hour of the selected weather sequence. The upper limit on this parameter, *Number of Plume Segments*, is defined below.

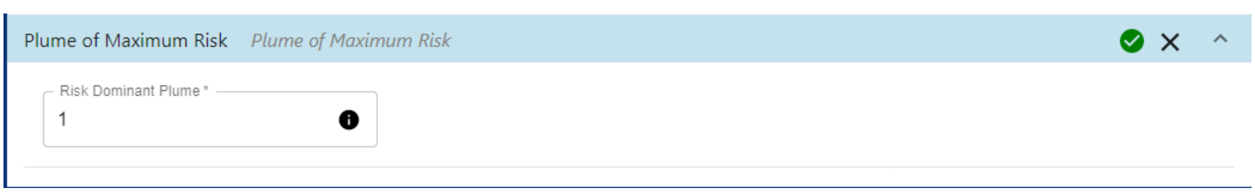


Figure 4-54. *Plume of Maximum Risk* form

Table 4-44. *Plume of Maximum Risk* parameter inputs

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

4.2.9.2.2. *Plume Parameters Form*

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

Number of Plume Segments, 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.

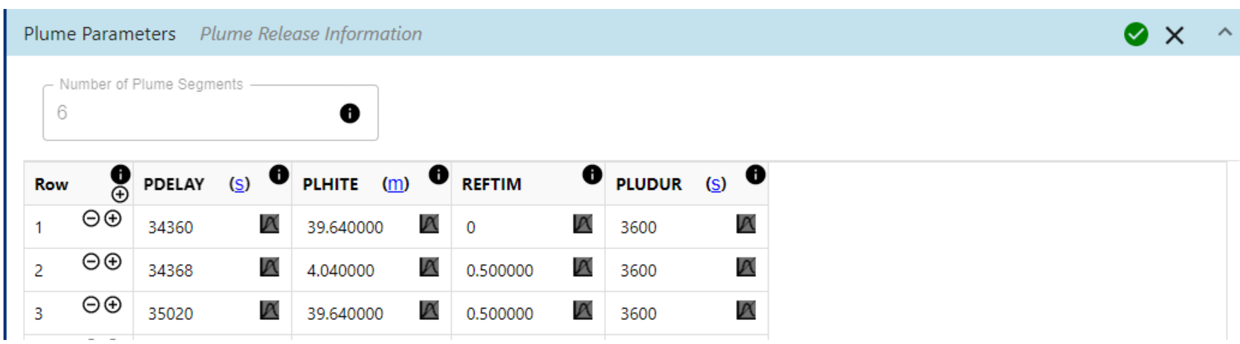


Figure 4-55. *Plume Parameters* form

Table 4-45. *Plume Parameters* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMREL	Linked	Integer	None	1 to 500
PDELAY	Yes	Real	NUMREL	0.0 to 2,592,000 s (30 d)
PLHITE	Yes	Real	NUMREL	0.0 to 1000.0
REFTIM	Yes	Real	NUMREL	0.0 to 1.0
PLUDUR	Yes	Real	NUMREL	60.0 to 86,400.0 s (1 min to 1 d)

4.2.9.2.3. *Trapped/Downwashed Plume Release Height Form*

The Trapped/Downwashed Plume Release Height Form is required when the Automatic Trapped Plume Release Height Calculation option is not selected, for all plume trapping/downwash models.

PHTRAP specifies the centerline height of each plume segment above ground level when the plume segment is caught in the building wake region.

Figure 4-56. *Trapped/Downwashed Plume Release Height* form

Table 4-46. *Trapped/Downwashed Plume Release Height* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
PHTRAP	Yes	Real	NUMREL	0.0 to 1000.0 m

4.2.9.2.4. Particle Size Distribution Form

The *Particle Size Distribution* form is required when *Multi Source Model Flag* is not selected on the *Plume* tab. It defines the aerosol-size distribution for each chemical group 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 columns (taken from the number of particle size groups in the *Dry Deposition* form) and MAXGRP rows (taken from the number of chemical groups in the *Chemical Names* form). The fractions across a row (over the set of size groups) must sum to approximately 1.0.

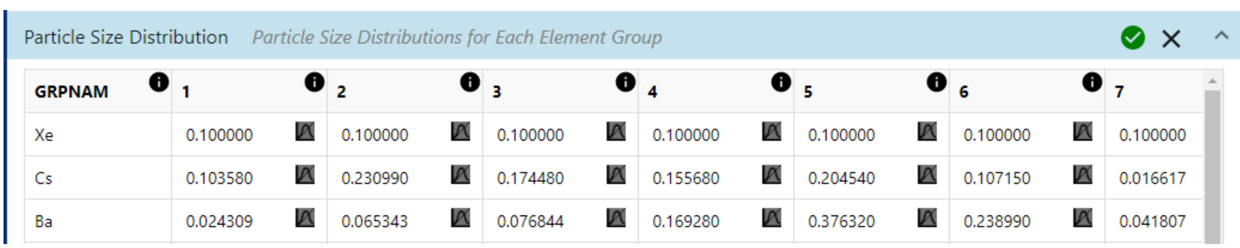


Figure 4-57. *Particle Size Distribution* form

Table 4-47. *Particle Size Distribution* parameter inputs

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

4.2.9.2.5. Inventory Scale Factor Form

The *Inventory Scale Factor* form is required when *Multi Source Model Flag* is not selected on the *Plume* tab. *Inventory Scaling Factor*, 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.

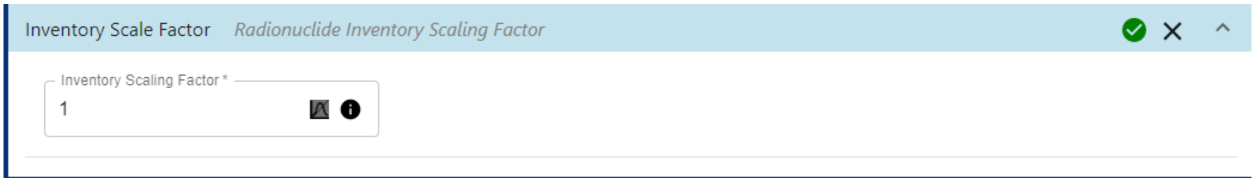


Figure 4-58. *Inventory Scale Factor* form

Table 4-48. *Inventory Scale Factor* parameter inputs

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

4.2.9.2.6. Daughter Ingrowth Flag Form

The *Daughter Ingrowth Flag* form is required when *Multi Source Model Flag* is not selected on the *Scope* tab. *Daughter Ingrowth Type*, 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 group. PARENT is preferred when using MELCOR data because MELCOR does not account for radioactive decay and ingrowth.

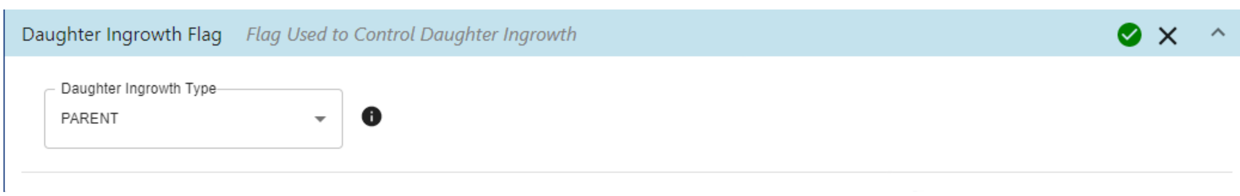


Figure 4-59. *Daughter Ingrowth* form

Table 4-49. *Daughter Ingrowth Flag* parameter inputs

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

4.2.9.2.7. Release Fractions Form

The *Release Fractions* form is required when *Multi Source Model Flag* is not selected on the *Scope* tab. RELFRC defines the release fraction for each of the plume segments and for each chemical group. Each row represents one of the plume segments declared on the *Plume Parameters* form. 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 MACCS-UI or MACCS.

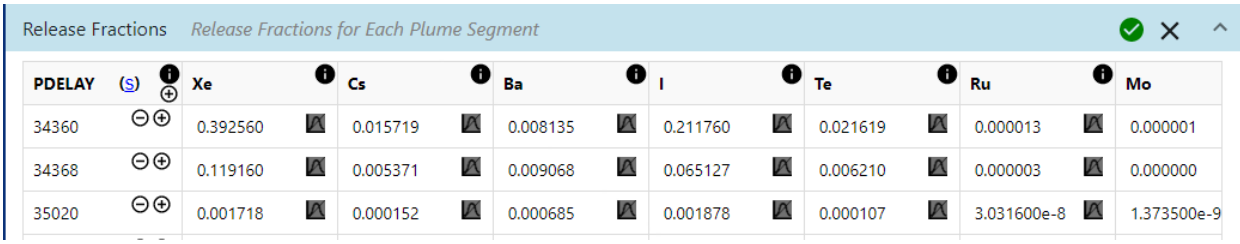


Figure 4-60. ***Release Fractions*** **form**

Table 4-50. *Release Fractions* parameter inputs

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

4.2.9.2.8. Scale Factors for Release Fractions Form

The *Scale Factors for Release Fractions* form is used to scale release fractions for each radionuclide defined in the model.

Number of Radionuclides, NUMISO, 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.

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

NUCSCA assigns a scaling factor to a particular radionuclide defined in the model. NUCSCA is similar to CORSCA, but instead of defining a scaling factor for the whole reactor, it is defined for each radionuclide individually.

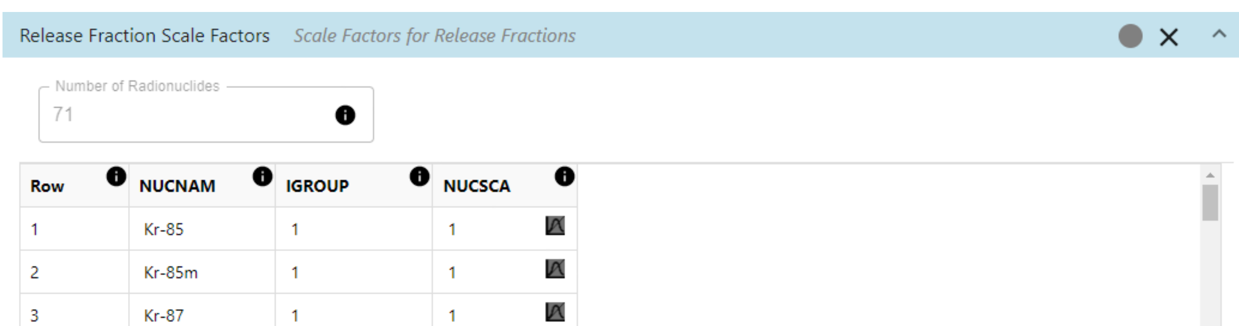


Figure 4-61. *Scale Factors for Release Fractions* form

Table 4-51. *Scale Factors for Release Fractions* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMISO	No	Integer	None	1 to 999
NUCNAM	No	Character	NUMISO	3 to 8 characters
IGROUP	No	Integer	NUMISO	1 to MAXGRP

Parameter	Definable	Type	Dimensions	Allowed Values
NUCSCA	Yes	Real	NUMISO	0 to 1

4.2.9.2.9. Heat Form

The *Heat* form is required when the *Power Model* is selected on the *Plume* tab and *Multi Source Model Flag* is not selected on the *Scope* 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.

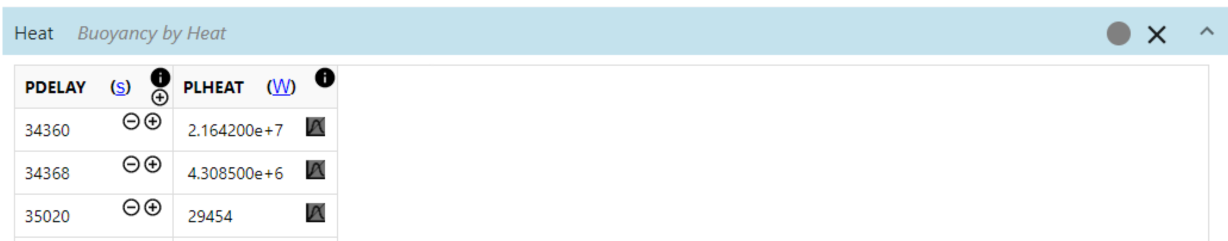


Figure 4-62. ***Buoyancy by Heat*** **form**

Table 4-52. ***Buoyancy by Heat Form*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
PLHEAT	Yes	Real	NUMREL	0.0 to 10^{10} W

4.2.9.2.10. Density and Flow Form

The *Density and Flow* form is required when the *Density and Flow Model* is selected on the *Plume* tab and the *Multi Source Model Flag* is not selected on the *Scope* 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, although these values are ultimately converted to buoyancy fluxes and those values are used in the same way as buoyancy fluxes derived from PLHEAT in calculating plume rise. This implies that one could derive values of PLHEAT that are exactly equivalent to the values from the density and flow model.

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

PLMDEN is the average gas density for a plume segment.

Figure 4-63. ***Density and Flow*** **form**

Table 4-53. ***Density and Flow*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
PLHEAT	Yes	Real	NUMREL	0.0 to 10^{10} W

4.2.9.2.11. Building Height Data Form

The *Building Height Data* form is required when *Multi Source Model Flag* is not selected on the *Scope* 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 (4-36).

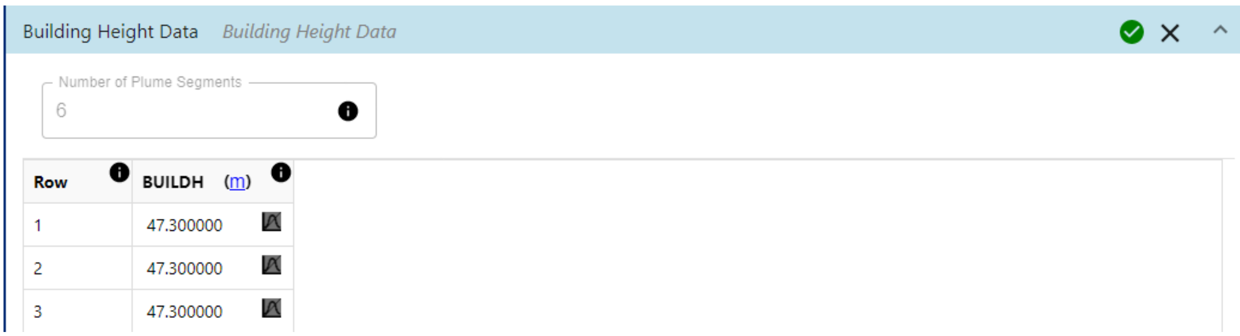


Figure 4-64. ***Building Height Data*** **form**

Table 4-54. ***Building Height Data*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
BUILDH	Yes	Real	NUMREL	0 to 1000.0 m

4.2.9.2.12. Additional Building Height Data Form

The *Additional Building Height Data* form is required when *Multi Source Model Flag* is not selected on the Scope tab.

BUILDA, BUILDW, and BUILDL define the angle relative to north, width, and length of the facility building or building complex, respectively.

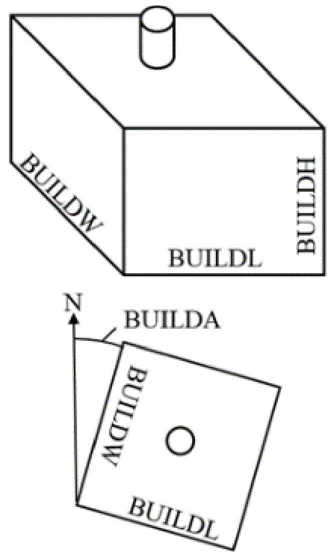


Figure 4-65. Visualization of variables in the *Additional Building Height Data* form

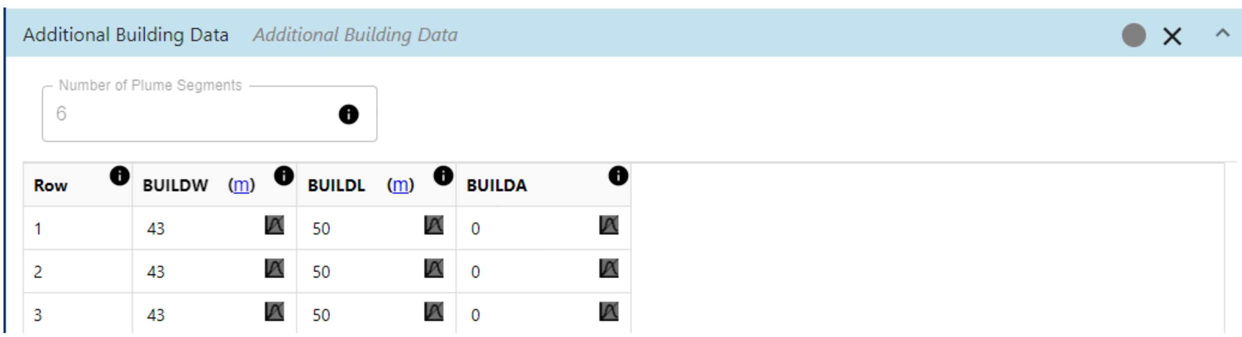


Figure 4-66. *Additional Building Height Data* form

Table 4-55. *Additional Building Height Data* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
BUILDW	Yes	Real	NUMREL	1 to 1000.0 m
BUILDL	Yes	Real	NUMREL	11 to 1000.0 m
BUILDA	Yes	Real	NUMREL	-180 to 180 degrees

4.2.9.2.13. Initial Area Source Form

The *Initial Area Source* form is required when *Multi Source Model Flag* is not selected on the Scope tab.

For each plume segment released, SIGYINIT and SIGZINIT define the initial values of sigma-y and sigma-z, respectively.

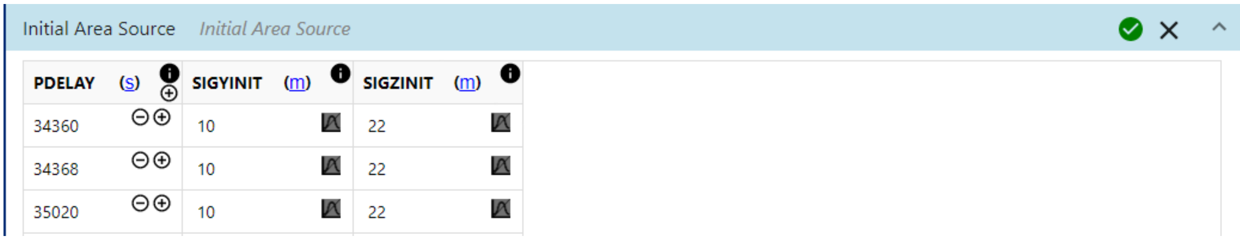


Figure 4-67. *Initial Area Source* form

Table 4-56. *Initial Area Source* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
SIGYINIT	Yes	Real	NUMREL	0.1 to 1000.0 m
SIGZINIT	Yes	Real	NUMREL	0.1 to 1000.0 m

4.2.9.2.14. Initial Area Source Coefficients Form

The *Initial Area Source Coefficients* form is required when *Multi Source Model Flag* is not selected on the Scope tab.

For each plume segment released, SIGYCOEF and SIGZCOEF define the coefficient for calculating the initial sigma-y and sigma-z, respectively.

Figure 4-68. *Initial Area Source Coefficients* form

Table 4-57. *Initial Area Source Coefficients* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
SIGYCOEF	Yes	Real	None	0.001 to 10.0
SIGZCOEF	Yes	Real	None	0.001 to 10

4.2.10. Weather

4.2.10.1. 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:

- specify data for 120 hr;
- specify a starting day and time period in the weather data file; or,
- specify constant weather conditions.

For the specified starting day and time period option, weather data are taken from the meteorological data file beginning at the specified day and time. A file of weather data covering a period of 365 days (8,760 hr) is required. The file can be defined to have 15 min, 30 min, or 1 hr time periods.

The two methods of weather sampling are:

- a modified version of the weather bin sampling method used in CRAC2 (Ritchie et al., 1984); and,
- a stratified, random sampling approach.

The weather bin sampling method sorts the 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 ranges of wind speeds paired with stability class or by the occurrence of rain. 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. For each day, a user-defined number of samples are selected randomly. Because of the way the samples are selected, each weather sequence has the same probability of occurrence, that is, P = 1/(number of samples).

4.2.10.2. Mixing Height Option

Daytime and nighttime values for mixing height are specified for each of the four seasons in the last line of the meteorological data file. There is also an option to specify the mixing height for each period in the meteorological data file instead of seasonal averages. An option is available in MACCS to account for night-to-day transitions in mixing height as DAY_AND_NIGHT on the Weather tab. This option only applies when a meteorological file is used (i.e. METCOD = 1, 2, or 5).

The meteorological file contains 2 sets of 4 values for mixing height at the end of the file when using the seasonal mixing height option. 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.

If DAY_ONLY is selected, only the afternoon mixing heights are used. That is, the mixing height only depends on the season for which the calculation is performed, not on time of day. When the mixing height is specified for each period instead of seasonal averages, the maximum value for each day is used when DAY_ONLY is selected. That is, the mixing height only depends on the day for which the calculation is performed, not on the time of day.

When 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 for seasonal values or the period specific values when the mixing height is specified for each period.

For seasonal values, when 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. 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*. Sunrise and sunset are calculated according to the site latitude. No adjustments are made to account for the east/west location of a site within a time zone or for switching to daylight savings time. Thus, the current version does not use the longitude value in the mixing height model.

4.2.10.3. Forms

4.2.10.3.1. 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 or simulated 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, one 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. A second reason to use boundary weather is that the mean time between precipitation events is on the order of 10 days, so precipitation is likely to occur during the transport of a plume through a MACCS grid when the grid is large (e.g., 1600 km). At longer distances, precipitation may not be correlated with precipitation at the origin of the MACCS grid. Boundary weather can be used to force precipitation to occur before plume segments exit the grid.

Boundary Mixing Height, BNDMXH, is the mixing layer height that is used for the constant weather conditions (METCOD = 4). Mixing height is determined separately for all other values of METCOD and this value is not used.

Boundary Stability Class, 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.

Boundary Rain Rate, BNDRAN; and *Boundary Wind Speed*, BNDWND; are used for constant and boundary weather conditions.

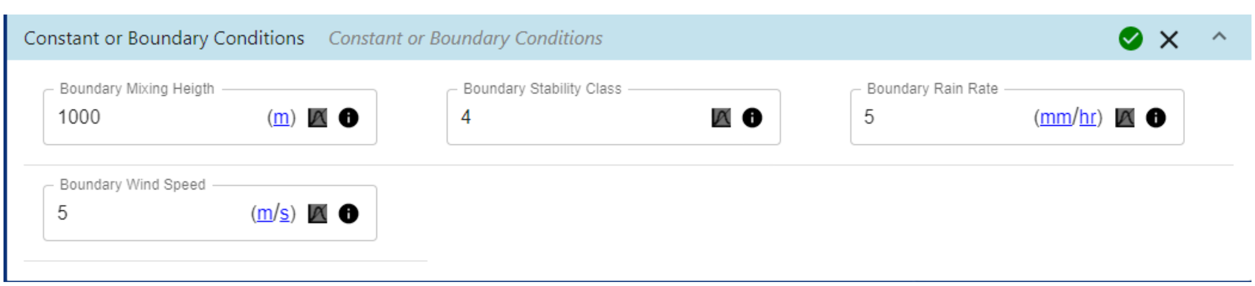


Figure 4-69. *Constant or Boundary Conditions* form

Table 4-58. Constant or Boundary Conditions Form Inputs

Parameter	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

4.2.10.3.2. 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. Shorter time periods for meteorological data are not supported on this form.

HRMXHT is the set of mixing layer heights that is used. The user can provide mixing heights in a general fashion in the input, but MACCS only allows HRMXHT to increase in the implementation of the Gaussian model to avoid unphysical plume behavior (i.e., to allow air concentration to increase at some downwind location). The user must supply 120 values, one per hour.

IHRSTB defines the list of stability classes that are used. 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. The user must supply 120 values, one per hour.

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

IHRDIR defines the list of wind directions that are used. 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.

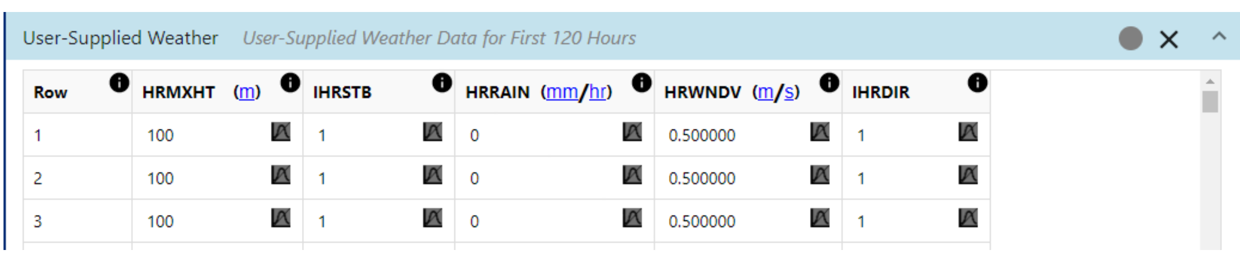


Figure 4-70. ***User-Supplied Weather*** form

Table 4-59. ***User-Supplied Weather*** parameter inputs

Parameter	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

4.2.10.3.3. *Site Location Form*

The *Site Location* form is required when DAY_AND_NIGHT is selected on the *Weather* tab. The user must also specify the latitude and longitude of a site. 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 MACCS-UI does not read this comment line from a site file. These values are used to calculate the time of sunrise and sunset.

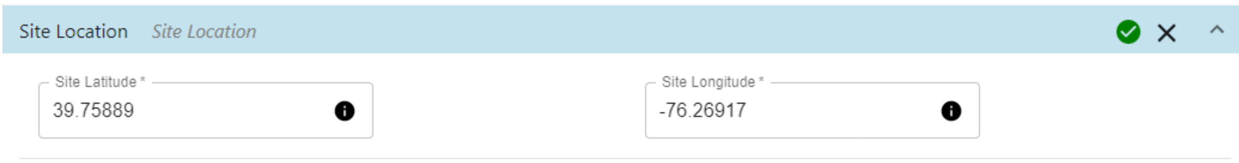


Figure 4-71. *Site Location* form

Table 4-60. *Site Location* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
Latitude (deg)	Yes	Real	None	-90.0 to 90.0
Longitude (deg)	Yes	Real	None	-180.0 to 180.0

4.2.10.3.4. *Samples per Bin Form*

The *Samples per Bin* form is required when *Bin Sampling Uniform* 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. These are set in the Rain Distances and Rain Intensities forms, respectively. The total number of weather bins is 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 4-61.

Table 4-61. 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

Number of Samples per Weather Bin, NSMPLS, defines the number of weather sequences to be chosen from each of the individual bins. The more samples that are taken, the better is the statistical representation of the results. The actual number of samples taken from a weather bin is the minimum of the number of time periods in the bin and the number of NSMPLS.

Table 4-62. Range of weather sequence samples

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 (default)
1 to 17520	30 minutes	/PERIOD 30
1 to 35040	15 minutes	/PERIOD 15

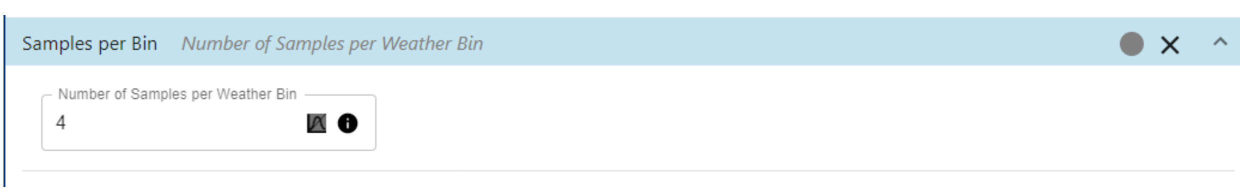


Figure 4-72. *Samples per Bin* form

Table 4-63. *Samples per Bin* parameter inputs

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

4.2.10.3.5. Samples per Day Form

Samples per Day is required when *Stratified Random Sampling* is selected on the *Weather* tab.

NSMPLS defines the number of weather sequences to be chosen from each day of the year. Table 4-64 contains the range of NSMPLS informed by MACCS.

Table 4-64. Range of weather sequences

Range for NSMPLS	Weather Data Time 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

Although not enforced by MACCS or MACCS-UI, NSMPLS should be set to be a factor of 24 when the meteorological data are hourly (i.e., 1, 2, 3, 4, 6, 8, 12, 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 randomly 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.

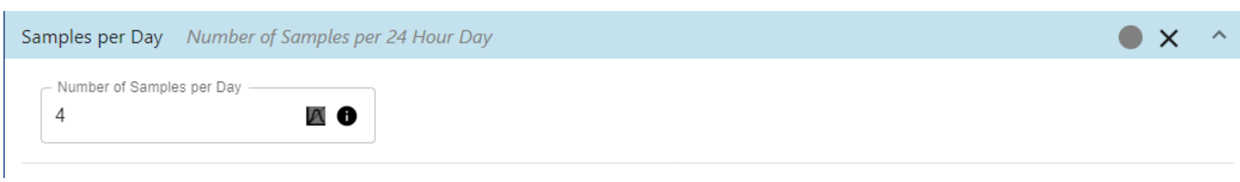


Figure 4-73. *Samples per Day* form

Table 4-65. *Samples per Day* parameter inputs

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

4.2.10.3.6. Seed Form

The *Seed* form is required when any of the sampling options (METCOD=2 or 5) is selected on the *Weather* tab. Changes to *Seed of the Random Number Generator*, IRSEED, cause different weather trials to be selected.

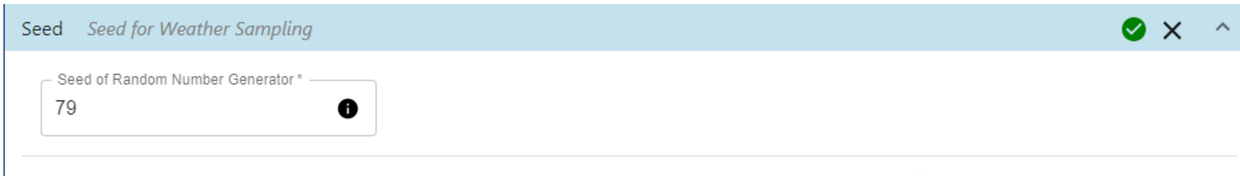


Figure 4-74. *Seed* form

Table 4-66. *Seed* parameter inputs

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

4.2.10.3.7. Boundary Limit Form

The *Boundary Limit* form is required when anything besides *Constant Weather* is selected on the *Weather* tab.

Last Spatial Interval to use *Recorded Weather*, 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. No boundary weather is employed when LIMSPA = NUMRAD.

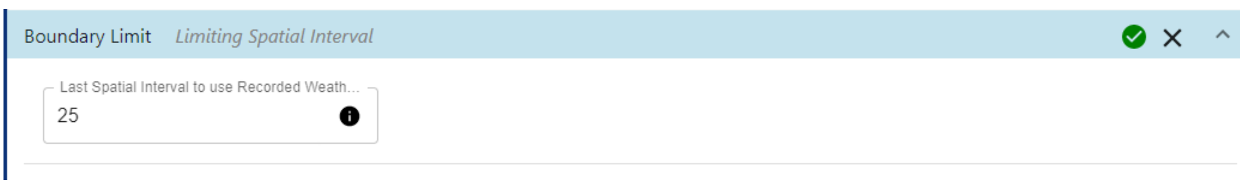


Figure 4-75. *Boundary Limit* Form

Table 4-67. *Boundary Limit* parameter inputs

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

4.2.10.3.8. Bins Form

The *Bins* form is required when *Bin Sampling Nonuniform* 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.

Number of Weather Bins, 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. MACCS-UI does not perform a consistency check on NSBINS, but MACCS does perform this check and issues an error message when it is inconsistent.

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 £ value £ 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 each weather bin. If this number exceeds the number of sequences in the specified bin, the code selects all the sequences in that bin. 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 of INWGHT must be greater than or equal to one. Table 4-68 contains the range of INWGHT enforced by MACCS.

Table 4-68. Ranges for INWGHT

Range for INWGHT	Weather Data Time 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

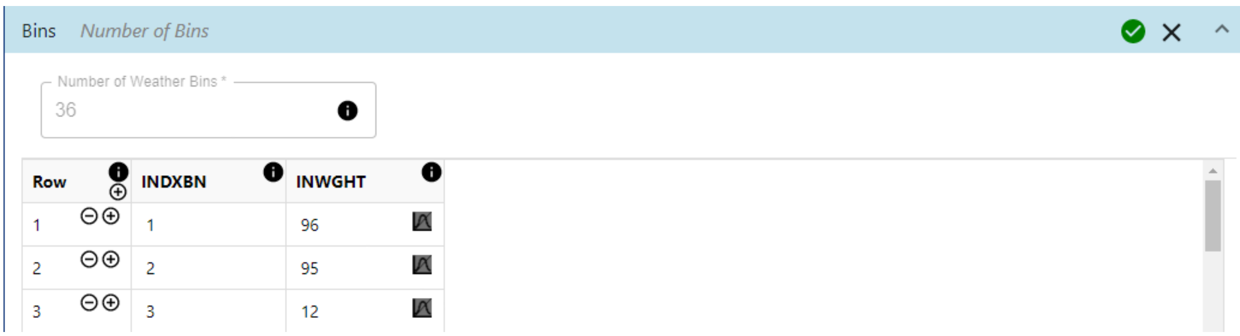


Figure 4-76. *Bins* form

Table 4-69. *Bins* form parameter inputs

Parameter	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

4.2.10.3.9. Rain Distances Form

The *Rain Distances* form is required when either *Bin Sampling Uniform* or *Bin Sampling Nonuniform* is selected on the *Weather* tab.

Number of Rain Distance Intervals, 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:

- 0 km < distance of first rain occurrence ≤ 2 km
- 2 km < distance of first rain occurrence ≤ 4 km
- 4 km < distance of first rain occurrence ≤ 8 km

- 8 km < distance of first rain occurrence ≤ 16 km.

Rain that occurs beyond 16 km in this example is not categorized as being in a rain bin. These weather sequences are categorized under the 16 bins defined in Table 4-61.

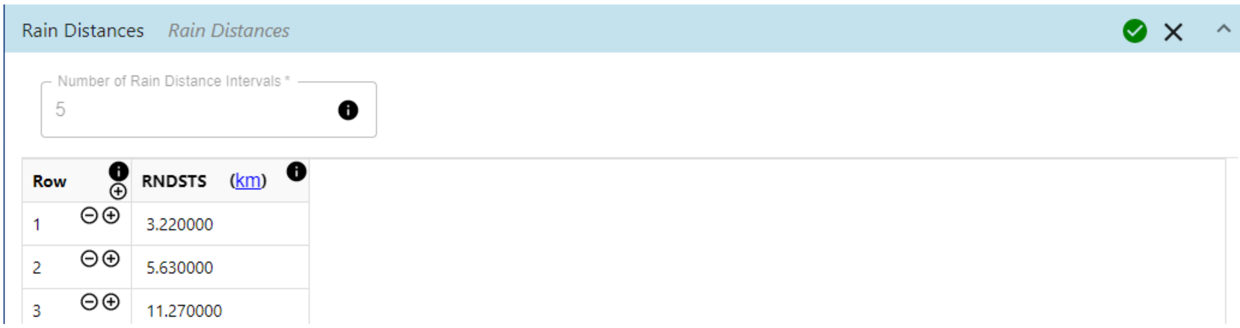


Figure 4-77. *Rain Distances* form

Table 4-70*. Rain Distances* parameter inputs

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

4.2.10.3.10. Rain Intensities Form

The *Rain Intensities* form is required when either *Bin Sampling Uniform* or *Bin Sampling Nonuniform* 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:

- 0 mm/hr < x ≤ 1 mm/hr
- 1 mm/hr < x ≤ 4 mm/hr,
- 4 mm/hr < x.

Number of Rain Intensity Breakpoints, NRINTN, defines the number of breakpoints to be used for weather binning.

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

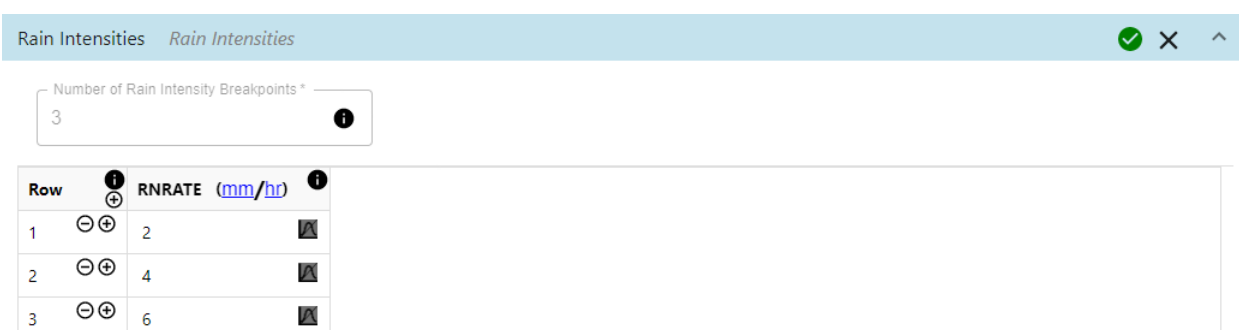


Figure 4-78. *Rain Intensities* form

Table 4-71. *Rain Intensities* parameter inputs

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

4.2.11. Output Control

When requested by the user, the ATMOS module generates outputs for ten atmospheric modeling results for user-specified distances and plume segments, as listed in Table 4-72. Air and ground concentrations are reported for the radionuclide specified by *Name of Debug Radionuclide*, NUCOUT. In addition, the total activity on the ground (from all radionuclides) is reported. Within a single run of the code, there is no provision for generating CCDFs of air and ground concentrations for multiple individual radionuclides. When such outputs are needed, separate MACCS runs are required to produce results for each radionuclide.

Table 4-72. Results available from ATMOS in statistical form

Available Result	Units
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 (Undepleted)	s/m^3
Selected Radionuclide Adjusted Source Strength, Q_a	Bq
Plume σ_y, Crosswind Dispersion Parameter	m
Plume σ_z, Vertical Dispersion Parameter	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 activity. When material decays or is deposited onto 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 plume trajectory up to the current location. Note that all the concentration results shown in this table account for plume depletion; however, the value for χ/Q does not. This quantity simply represents the normalized concentration (s/m^3) from dispersion at a downwind distance.

4.2.11.1. Forms

4.2.11.1.1. Output Control Form

The *Output Control* form is required. The user has the option of printing tables of dispersion data for all 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 parameters can be written to the output file using the parameter IDEBUG.

Table 4-73. Additional ATMOS output information

Parameter	Description	Units
NUCNAM	name of the radionuclide for which results are reported	-
DISTANCE	distance from the point of release to the center of the spatial interval (m)	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.	s/m^3
WETREM	fraction of material remaining in the plume segment after wet deposition along the plume trajectory up to the current location	-
DRYREM	fraction of material remaining in the plume segment after dry deposition along the plume trajectory up to the current location	-
REMINV	adjusted source strength of the plume accounting for losses over the plume trajectory from radioactive decay and wet and dry deposition	Bq
PLSIGY	crosswind dispersion parameter, σ_y, at the current location	m
PLSIGZ	vertical dispersion parameter, σ_z, at the current location	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),	-
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 current location	s
TIMOVH	duration for which the plume was overhead at the current location	s
MXMIXH	mixing height during plume passage through the current location	m

ATMOS Debug Level, IDEBUG specifies the quantity of debug output to be printed.

- For normal runs, this should be 0, with no debug output printed.

- If set to 1 or 2, detailed results for atmospheric transport are generated for each weather trial and each plume segment.
- If set to a 3 or greater, the meteorological data used for each weather trial are also printed.

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

Figure 4-79. ATMOS *Output Control* form

Table 4-74. ATMOS *Output Control* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
IDEBUG	Yes	Integer	None	-1 to 8
NUCOUT	Yes	Character	None	Must be a radionuclide defined in vector NUCNAM

4.2.11.1.2. Plume and Spatial Intervals for Output Form

There are three *Plume and Spatial Intervals for Output* forms. The first one is used if *Multi Source* is not selected in *PROPERTIES*. The second one is used if *Multi Source* is selected. A third *Spatial Intervals* form is available as well for HYSPLIT usage. The *Plume and Spatial Intervals for Output* form is optional.

Number of Type 0 ATMOS Requests, NUM0, is determined by the number of rows in the grid containing values of vectors INDREL, INDRAD, and CCDF. For each request, a set of ten results describing atmospheric transport and dispersion is reported.

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 CCDF, CCDF_MS, or CCDF_HY is 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*, MACCS-UI automatically generates a report over all realizations based on the quantile values specified on the *Reporting Options* form.

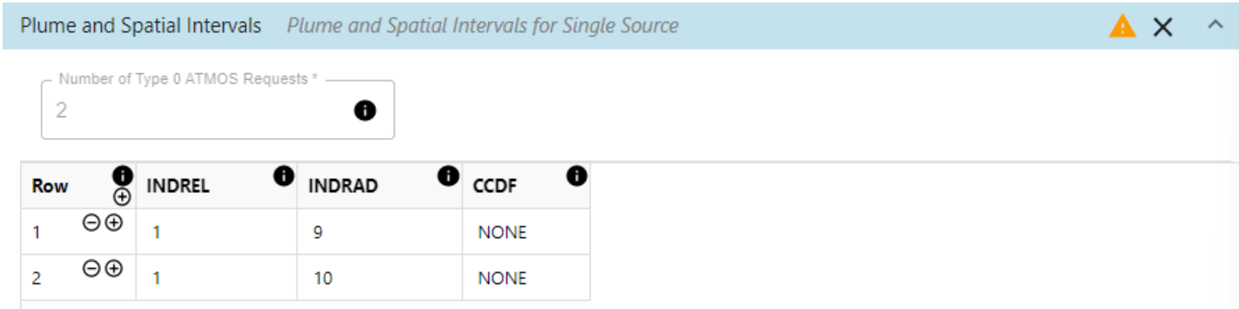


Figure 4-80. ***Plume and Spatial Intervals for Output*** **form**

Table 4-75. ***Plume and Spatial Intervals for Output*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
NUM0	Linked	Integer	None	0 to 999
INDREL	Yes	Integer	None	1 to NUMREL
INDRAD	Yes	Integer	NUM0	1 to NUMRAD
CCDF	Yes	Character	NUM0	CCDF, NONE, REPORT, CCDF & REPORT

4.3. EARLY

4.3.1. Overview

The EARLY module models the period starting with accident initiation. 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 in *PROPERTIES*.

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) to each cohort, 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 *PROPERTIES/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. This assumes that all the population behaves like each of the cohorts some fraction of the time. 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. This assumes that the population is divided into a set of responses, but those responses apply all of the time. The approach selected (fraction of people or fraction of time) affects the shape of the CCDF but does not affect the mean consequences.

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 to generate the overall combined results. When more than one EARLY emergency response cohort is being run, these results are combined according to the weighting fractions supplied for each scenario parameter WTFRAC. The weighted sum is combined with the CHRONC result to produce the overall result. MACCS models the entire population as behaving the same in the CHRONC module, so only one CHRONC cohort exists. Whenever multiple cohorts are defined, the output file lists the overall combined results as well as results for each of the individual cohorts.

4.3.2. Dose Calculation

The calculation of radiation doses from early exposure considers five pathways:

- direct external exposure to radiation from the plume (cloudshine)
- exposure from inhalation of radionuclides in the cloud (cloud inhalation)
- exposure to radioactive material deposited on the ground (groundshine)
- inhalation of resuspended material (resuspension inhalation)
- radionuclide deposition onto the skin (skin deposition)

Two kinds of doses are calculated:

- acute doses used for estimating occurrences of early fatalities and injuries
- lifetime doses used for estimating occurrences of cancers resulting from the early exposure

The accumulation of radiation doses from early exposure is strongly dependent on the assumed emergency response (i.e., evacuation, sheltering, and relocation). Cloudshine and cloud inhalation exposures are limited to the time of cloud passage. Groundshine and resuspension inhalation doses from early exposure (emergency phase) are limited to the duration of the emergency phase.

In general, the dose equation for an early exposure pathway in each spatial element is the product of the following quantities: radionuclide concentration, usage factor, duration of exposure, DCF, 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 DCF, and inhalation protection factor.

The DCFs for all exposure pathways are provided in the DCF files distributed with MACCS-UI. However, the user can modify any of these factors by defining constant or uncertain values in MACCS-UI.

DCFs are selected to be used with MACCS in one of the following ways:

- **A single, predefined file.** In this case, the LNT model is selected in *MACCS Models to Run* on the *PROPERTIES/Scope* tab. Files based on DOSFAC2, FGR-11 and -12, and FGR-13 are distributed with MACCS-UI. The user selects a file from the *GENERAL/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 PL or AT model is selected. Files of this type based on DOSFAC2 and FGR-13 are distributed with MACCS. The user selects a base file, e.g.,

FGR13GyEquiv_v2.INP, on the form found in the MACCS-UI *GENERAL* main category under *File Specifications/Annual Differential DCF Files*.

Users have flexibility in the selection of a DCF file. These can be based on:

- DOSFAC2, a pre-processer using data from DOE/EH-0070 and tissue weighting factors from ICRP-26 and ICRP-60;
- FRG-11 and FRG-12; and
- the FGR-13 CD supplement.
- The DCF set based on FGR-13 is the most complete and current and is recommended for most consequence analyses.

NOTE: ICRP traditionally used the term 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 MACCS-UI 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, with MACCS 4.0 and later supporting all organs in specified DCF files. MACCS-UI 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 lifetime, 50-year doses that are used in both the EARLY and CHRONC modules.
- Acute internal doses from inhalation are calculated over a much shorter commitment period than lifetime doses. Because of the shorter commitment period, acute doses are less than or equal to lifetime doses for the same organ. The method used to construct the acute doses accounts for dose protraction by weighting internal doses received after the first day less heavily than doses received during the first day.

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 doses, some to lifetime doses, and some are used for both. The DCFs for acute or lifetime exposures depend on exposure pathway.

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 *COMIDA2 - Predefined 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 from shielding protection provided by a given protective action for a given exposure pathway. The user specifies shielding factors for the various exposure pathways (cloudshine, inhalation, groundshine, and skin deposition) and for three different groups of people (evacuees, people continuing normal activity, and people taking shelter).

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 can return to their residences during the emergency phase, depending on user inputs, only when no additional radiation exposure would be received.

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 shelters, the members of the population are assumed to be carrying out normal activities. Shielding factors (cloudshine, groundshine, inhalation, and skin deposition) for normal activity apply to them during this period. 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 duration for sheltering).

The plume transport model assigns the plume a finite length calculated by using the assigned release duration and wind speed(s) during the release. The length of a 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 a 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.

4.3.3. Model Basis

4.3.3.1. Basic Model Description

4.3.3.1.1. 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 early and latent health effects during the early (i.e., emergency) phase.

Each one of the compass sectors is further subdivided into several fine grid divisions. The number of fine grid divisions is specified by the user and can 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 the correction factors for the other exposure pathways during 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 factor considers both the total distance to the plume centerline and the size of the plume. It accounts for the geometrical view factor between the plume and the receptor.

For cloud inhalation, groundshine, resuspension inhalation, and skin deposition 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 taken to be 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.

4.3.3.1.2. 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 capture 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, at a single speed, with a single stability class. The MACCS implementation of the Gaussian plume model is much more general. One of the generalizations is that plume segments can 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 toward 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 wind shift is not included, both plume segments 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 computational 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, given that other weather conditions (e.g., stability class and wind speed, are within the same bin (weather binning is described previously)). As a simple example, suppose the probability of the wind blowing in each compass direction is 1/NUMCOR. For this case, MACCS constructs the consequences assuming the initial wind direction was toward each of the compass sectors and assigns each result a probability of 1/NUMCOR times the probability of the original weather trial selected from one of the weather bins. The rotation option is only available when the weather bin option for constructing a set of weather trials. The wind rose probability for each result is the value for the wind direction and the weather bin (i.e., a wind rose is calculated for each weather bin and used for weather trials belonging to that bin).

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. Even when two plume segments are treated, the underlying assumption becomes somewhat questionable. The larger the number of plume segments modeled in a calculation, the more dubious this assumption becomes. This is because the underlying assumption is that the entire pattern of wind shifts that define a weather trial can be rotated in any direction around the compass, and that the likelihood only depends on the wind-rose probability of the initial wind direction for that weather trial. Thus, for extended releases modeled with more than a few plume segments, modeling plume transport without rotation is the preferred option.

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 the first plume segment. 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 compass direction is taken from wind rose data, usually constructed from the weather file. Optionally, the user can specify a wind rose in the input.

- **Wind Shift with Rotation.** In this case, all plume segments follow the direction indicated by the weather data when the plume segment begins to be released. Depending on the weather data, each plume segment can travel in a different direction than the other plume segments. 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 possible compass direction.
- **Wind Shift without Rotation.** In this case, wind shift is performed but wind rotation is not. This is the only option that is allowed when the network evacuation model is selected or either the speed multiplier or keyhole evacuation model is activated. This is because the symmetry assumptions required for rotation to be valid are violated with these options. This is the preferred option when multiple plume segments are treated.

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

- **Fixed Start Time.** This option works the same as the User Supplies 120 Weather Points option except that the weather data are extracted from the weather file, beginning with the day and time period specified under the *Fixed Start Time Data* form. When weather data are read from the weather file, however, 1200 hours of data are extracted rather than only 120 hours to represent temporal weather variations.
- **Bin Sampling Uniform.** 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, regardless of which weather bin they are taken from. 1200 hours of data are extracted from the weather file to represent temporal weather variations for each weather trial.
- **Bin Sampling Nonuniform.** This option works the same as Uniform Bin Sampling, except that the user defines the number of weather trials to be sampled from each weather bin. 1200 hours of data are extracted from the weather file to represent temporal weather variations for each weather trial.
- **User Define 120 Weather Points.** Weather conditions are specified on the *User-Supplied Weather* form. This form allows the user to specify hourly wind directions. When wind rotation is used, the wind rose is assumed to be uniform around the compass. When wind shift is used, the direction taken by each plume segment is defined by the user-specified wind direction at the time it is released.
- **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. Wind shift has no affect since wind directions are constant for each weather trial.

- **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 and, 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 assumed to be uniform around the compass. 1200 hours of data are extracted from the weather file to represent temporal weather variations for each weather trial.

4.3.3.1.3. 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 during the emergency phase, normal relocation during the emergency phase, 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 areas of elevated dose rate 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, a dose projection period, 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. However, the two criteria can be collapsed into a single criterion by specifying all the parameters to be the same for the two relocation types.

To evaluate the need for relocation during the emergency phase, the dose received from the sum of the following dose pathways is considered: skin deposition, cloudshine, inhalation of the cloud during plume passage, groundshine, and inhalation of resuspended contamination. These doses are assessed beginning with the arrival of the first plume segment for the dose-projection period. They are based on lifetime doses. MACCS also has the option of evaluating the need for relocation during the emergency phase while considering only the groundshine and inhalation of resuspended contamination pathways.

The relocating population is assumed to be in normal activity before relocation. Thus, the shielding factors for normal activity are used. Once the population is relocated, no further dose is calculated for them during the emergency phase. Additional doses could be calculated in the CHRONC module for the intermediate and long-term phases. The criterion for determining whether they return to their original spatial element depends on dose projections. The dose projection criterion used for relocation during the long-term phase is commonly referred to as the habitability criterion.

4.3.3.1.4. Emergency Phase Resuspension

The emergency phase resuspension model in MACCS is the following:

$$C = G \cdot RESCON \cdot 2^{-t/RESHAF} \tag{4-38}$$

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), which accounts for weathering.

4.3.3.1.5. 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 (i.e., a circular area surrounding the site and an odd number of consecutive sectors projecting out to a larger radius), as illustrated in Figure 4-81. 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 portions of the keyhole in Figure 4-81. The keyhole is expanded as the wind direction changes in subsequent hours, as illustrated by the green and orange portions of the keyhole. The purple and orange sectors are in the downwind directions before and after the wind shift, respectively.

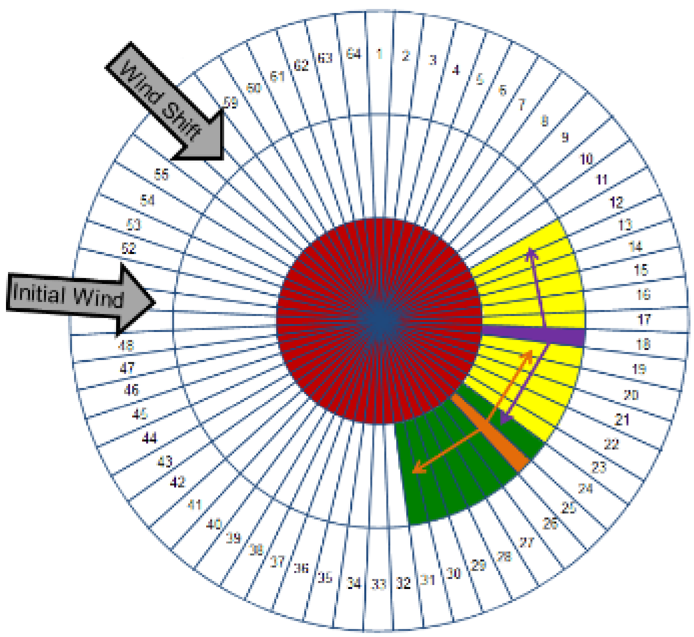


Figure 4-81. Illustration of the MACCS keyhole evacuation model

An additional concept employed with the keyhole model is to allow the keyhole to be expanded in advance of an actual wind shift to account for weather forecasting. The user must specify the duration, in hours, of weather forecasting to use in the model in *Weather Forecasted Time*, or KEYFORCST. When set to four hours, for example, the model considers the wind directions that occur over the next four hours and expands the size of the keyhole accordingly.

Users should consider that the MACCS implementation inherently assumes that wind shifts are forecasted with 100% accuracy for KEYFORCST hours.

4.3.4. *Model Basis Forms*

4.3.4.1. Early Description Form

The *Early Description* form has a single parameter for giving a brief description of the early model, which is printed in the output file. This form is required when the *ATMOS and EARLY* option is selected on the *PROPERTIES/Scope* tab.

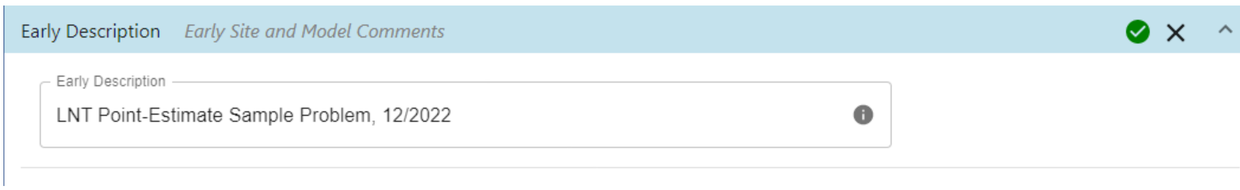


Figure 4-82. *Early Description* form

Table 4-76. *Early Description* parameter inputs

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

4.3.4.2. Property Form Parameters Form

The *Property Form Parameters* form shows how selections under *PROPERTIES* define some important parameters that are required in the EARLY input to MACCS. The parameters cannot be changed from this form; they are read only.

Population Defined By, 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 separately; or
- UNIFORM, when the population is to be treated as uniformly distributed on the grid.

Results Weighting Factor, WTNAME, determines the method used for combining results from different cohorts when generating overall results.

- When PEOPLE or TIME is selected, the weighting factor for each cohort is determined by the value of WTFRAC. Results from CHRONC are included as a single, separate cohort, and are simply added to the weighted results from EARLY.
- When set to SUMPOP, the population for each cohort is present in the site file under headings POPULATION1, POPULATION2, etc., for each cohort. Such a site data file can be created by hand. When used, the values of WTFRAC are not needed to combine results from the EARLY cohorts.

KI Model Option, 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 it is not to be included in a calculation. When included parameters 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:

- Linear No Threshold (LNT),
- Annual Threshold (AT),
- piecewise linear (PL),
- Life Time Threshold (LT), or
- Annual and Life Time Threshold (ATL).
- The simplest and traditional choice is the LNT model, for which only one DCF file is required. This 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.

Evacuation Type, 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.

Calculate Wind Rose Probabilities, OVRRID, allows the user to override the default values used for wind rose probabilities.

- When either uniform or nonuniform weather bin sampling is selected, the wind rose probabilities are usually calculated from the weather file; when OVRRID is checked, or 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.
- OVRRID can be set to True when a meteorological file is not available for the actual site being studied but wind rose data are available for the site. This allows local wind rose characteristics to replace those contained in a meteorological data file. It assumes that other weather characteristics of the site are like those in the file.
- Wind rose data are only needed when either rotation option is chosen; otherwise, wind directions are taken directly from the weather file and wind rose probabilities are not used.

Wind Shift and Rotation Flag, IPLUME, defines two characteristics regarding plume transport. The value IPLUME is set to corresponds the following MACCS-UI selections:

- *No Wind Shift with Rotation*, where all plume segments travel in the same direction.
- *Wind Shift with Rotation*, which uses wind direction at the time of release for each plume, with rotation.
- *Wind Shift without Rotation*, which uses wind direction at the time of release for each plume, without rotation used.

These two concepts, wind shift and rotation, are discussed in more detail above.

Keyhole Model Option, KEYAVAIL, determines whether the keyhole evacuation model can be chosen for evacuation. When KEYAVAIL is:

- *Keyhole Model OFF*, equal to KEY_NOT_AVAIL, the choices for the cohort evacuation are circular or none.

- *Keyhole Model ON*, equal to KEY_AVAIL, the choices for the cohort evacuation are circular, none, or keyhole. The only choice for IPLUME is 3, *Wind Shift without Rotation*.

Create Animation Movement Output, ANIM_MOVE, when set to true, or checked, will cause MACCS to create a plume movement file. This file can be used by the AniMACCS postprocessor to view the plume movement as a function of time. This option is available when *Wind Shift and Rotation Flag* is set to *Wind Shift Without Rotation,* and not available when using the HYSPLIT model.

Create Animation Concentration Output, ANIM_CONC, when set to true, or checked, will cause MACCS to create a ground and air concentration file which can be used by the AniMACCS postprocessor to view the concentrations as a function of time. This option is available when *Wind Shift and Rotation Flag* is set to *Wind Shift Without Rotation.*

Ignore Dose and Dose Rate Effectiveness Factor, IDDREF, when set to true, or checked:

- Ignores DDREFA;
- Enables the *Latent Cancer Parameters no DDREF* form; and
- Writes 1.0 to all DDREFA values in the output file.

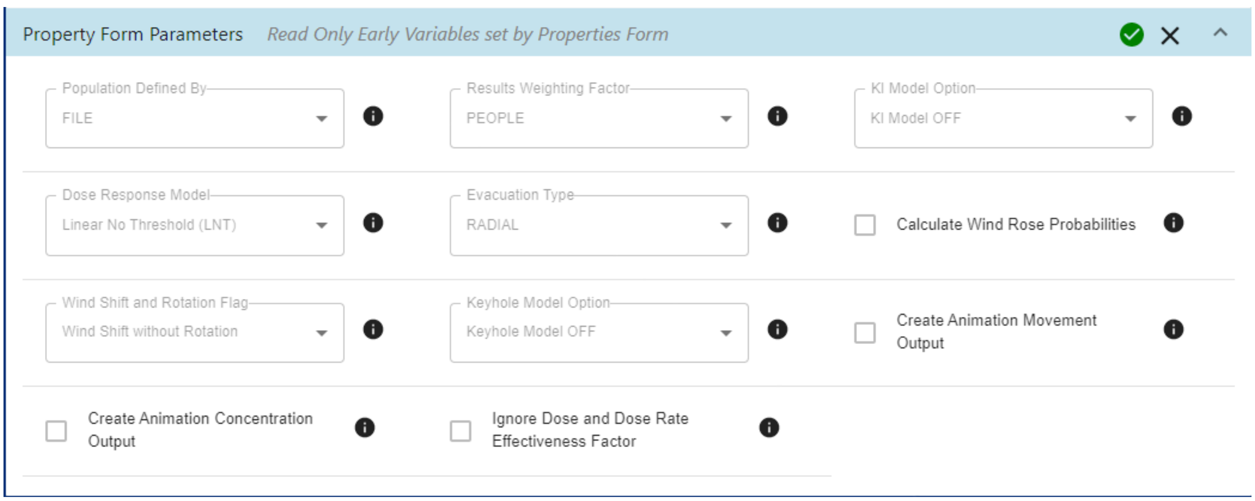


Figure 4-83. *Property Form Parameters* form

Table 4-77. ***Property Form Parameters*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values	*PROPERTIES* Tab
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*
DOSMOD	Read Only	Character	None	LNT, AT, PL, LT, ATL	*Dose* or *Scope* 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*
ANIM_MOVE	Read Only	Logical	None	True, False	*Animation* tab on *PROPERTIES*
ANIM_CONC	Read Only	Logical	None	True, False	*Animation* tab on *PROPERTIES*
IDDREF	Read Only	Logical	None	True, False	*Threshold Dose* tab on *PROPERTIES*

4.3.4.3. Grid Subdivisions Form

The *Grid Subdivisions* form is required. *Number of Fine-Grid Subdivisions*, NUMFIN, 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 used in the calculations performed by EARLY to improve resolution for consequences that behave nonlinearly with dose, e.g., early health effects. Values in CHRONC are averaged over the fine grid at the coarse grid level because the consequences evaluated for the intermediate and long-term phases behave relatively linearly with dose.

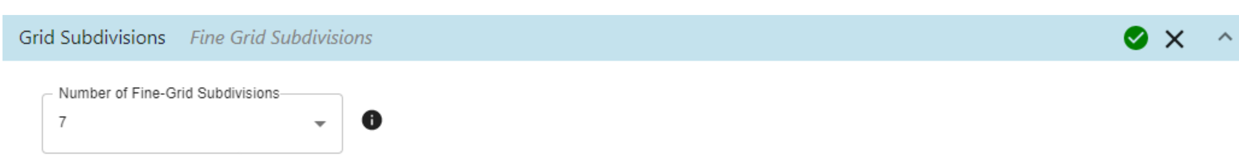


Figure 4-84. ***Grid Subdivisions*** **form**

Table 4-78. ***Grid Subdivisions*** **parameter inputs**

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

4.3.4.4. Wind Rose Probabilities Form

The *Wind Rose Probabilities* form is required when the user selects *Calculate Wind Rose Probabilities* 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 starting with the value for north. When these values do not approximately sum to unity, MACCS validation fails and generates an error message.

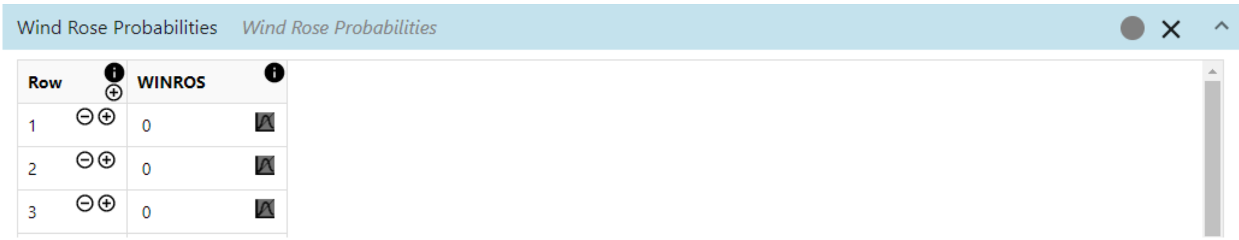


Figure 4-85. *Wind Rose Probabilities* form

Table 4-79. *Wind Rose Probabilities* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
WINROS	Yes	Real	NUMCOR	0.0 to 1.0

4.3.4.5. Uniform Site Data Form

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

Spatial Interval Where Population Begins sets the value of IBEGIN. Inside the radius corresponding to IBEGIN, the assumption is that there is no population. This can be used to represent the exclusion area.

Unform Population Density sets the value of POPDEN.

Land Fraction, or FRACLD, specifies the average fraction of the region that is land.

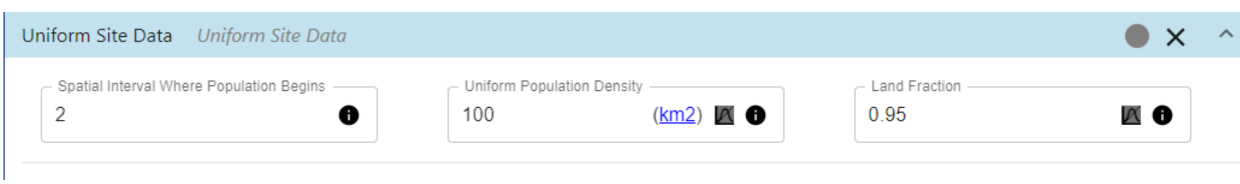


Figure 4-86. *Uniform Site Data* form

Table 4-80. *Uniform Site Data* parameter inputs

Parameter	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

4.3.4.6. 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 *PROPERTIES*. The *Population from Site File* form contains a table with columns for the set of compass sectors and rows labeled with values of SPAEND (radial distance). The table contains the total population in each grid element read from the site file.

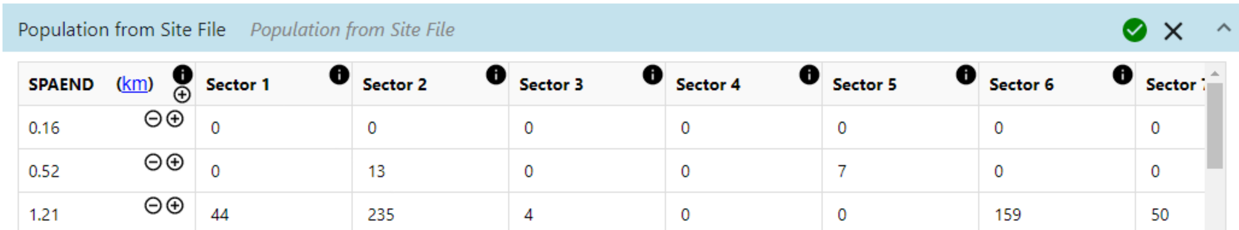


Figure 4-87. *Population from Site File* form

4.3.4.7. Organs of Risk Form

The *Organs of Risk* form is required when the user selects EARLY to run on the *Scope* tab. This form allows all organs in the specified DCF file to be selected for health effects calculations. Organs predefined in the DCF file are prepopulated in the left column. Users may select organs to be included in calculations by placing them in the right column using the arrows. Once the DCF file is defined, organs on this form can be selected.

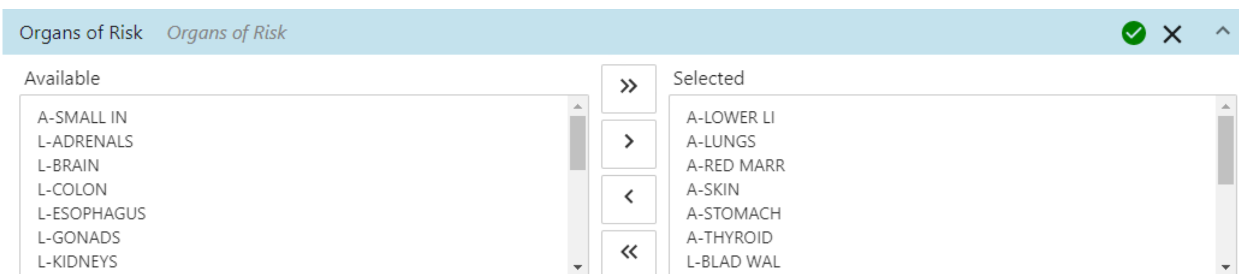


Figure 4-88. *Organs of Risk* form

4.3.4.8. Thyroid Organs Form

The *Thyroid Organs* form is required when the user selects *KI Model ON* on the *Dose* tab, *KI Model Option* dropdown. Both the effective organ and up to three organs affected by the KI model can be selected for the KI model.

Effective Organ, KI_EFF, defines the effective organ affected by the ingestion of KI.

Number of Organs Effected by KI Model, NUMKIORG, defines the number of thyroid organs affected by the ingestion of KI.

KINAME provides a dropdown menu to select the organ names affected by the KI model.

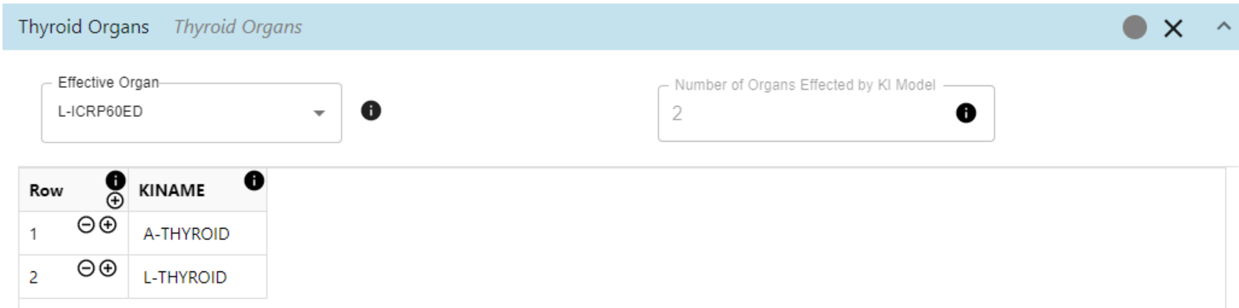


Figure 4-89. *Thyroid Organs* form

Table 4-81. *Thyroid Organs* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
KI_EFF	Yes	Character	None	Based on DCF File
NUMKIORG	Yes	Integer	None	1 to 3
KINAME	Yes	Character	NUMKIORG	Based on DCF File

4.3.4.9. Duration of Early Phase Form

The Duration of Early Phase form is required, containing a single parameter, *Duration of Emergency Phase*, ENDEMP. Calculation of doses in each grid element start with the arrival of the first plume segment at that location and continue for the period defined by ENDEMP. This period should normally be chosen to be large enough so that all plume segments have time to exit the problem domain. The allowed range is 1 to 40 days.

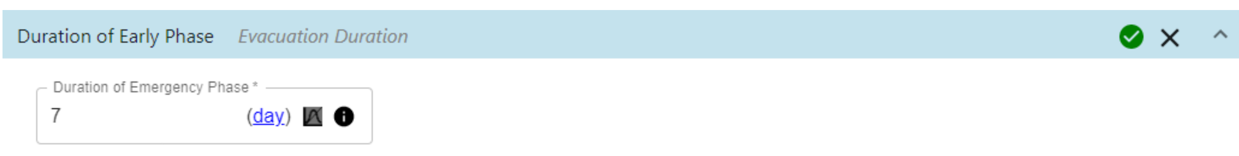


Figure 4-90. *Duration of Early Phase* form

Table 4-82. *Duration of Early Phase* parameter inputs

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

4.3.4.10. Evacuee Return Time Form

The *Evacuee Return Time* is required when *Use Optional Evacuee Return Time (TIMRTN)* is enabled on the *PROPERTIES/Dose* tab. When not enabled, MACCS assumes the value of TIMRTN is the same as the value specified for ENDEMP.

Evacuee Return Time, TIMRTN, defines the elapsed time between the time of evacuation and return 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. This value only affects the time used to evaluate economic losses.

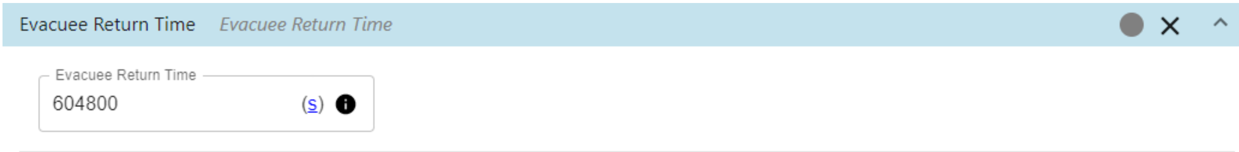


Figure 4-91. ***Evacuee Return Time*** **form**

Table 4-83. ***Evacuee Return Time*** **parameter inputs**

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

4.3.4.11. Normal Relocation Form

The *Normal Relocation* form is required.

Normal Relocation Action Time, TIMNRM, defines the normal relocation action time measured from plume arrival. Normal relocation applies to everyone who does not evacuate; it does not apply to evacuees. Normal relocation is based on 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 may be to evacuate the public within the emergency planning zone, 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 Threshold*, DOSNRM, along with the critical organ and dose projection period, determines where relocation is required. When the total projected dose exceeds DOSNRM, people in an area are relocated at the normal relocation time, TIMNRM. DOSNRM cannot exceed DOSHOT, which is described below.

The dose used to evaluate normal relocation is the dose projected for an individual who remains in place for the dose projection period (defined in 4.3.4.14) 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 receive no additional dose during the emergency phase.

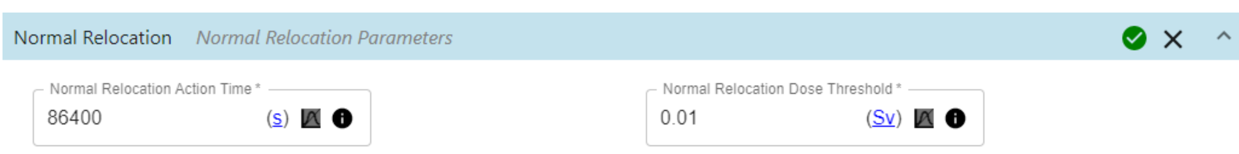


Figure 4-92. ***Normal Relocation*** **form**

Table 4-84. ***Normal Relocation*** **parameter inputs**

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

4.3.4.12. Hotspot Relocation Form

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

Hot-Spot Relocation Action Time, TIMHOT, defines the hot-spot relocation action time after plume arrival. Hot-spot relocation applies to everyone who does not evacuate; it does not apply to evacuees. Hot-spot relocation works similarly to normal relocation but is used to prioritize relocation of 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 *Normal Relocation Dose Threshold*, DOSHOT, is intended to trigger relocation beyond the evacuation area, although it also applies to nonevacuees who reside within the evacuation area. Areas identified for hotspot relocation usually take priority once evacuation is completed or well along and occur before normal relocation. When dose projections for individuals exceed DOSHOT, they are relocated at TIMHOT.

The dose used to evaluate hotspot relocation is the dose 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 projected dose commitment are cloudshine, groundshine, direct inhalation, and resuspension inhalation. Any individuals relocated due to hot-spot relocation receive no additional dose during the emergency phase.

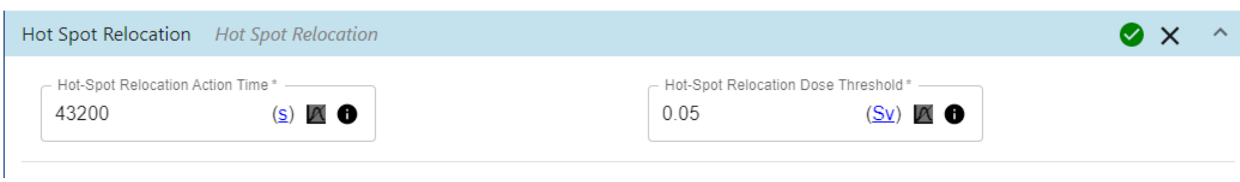


Figure 4-93. *Hot Spot Relocation* form

Table 4-85. *Hot Spot Relocation* parameter inputs

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

4.3.4.13. Dose Projection Form

The *Dose Projection* form is required when Use Optional Dose Projection Time (DPPEMP) is enabled on the *PROPERTIES/Dose* tab.

When it is not used, MACCS assumes the value of *Dose Projection Period*, DPPEMP, is the same as the value specified for ENDEMP.

Dose Projection Period, 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:

- Dose level (DOSNRM and DOSHOT);
- *Critical Organ*, CRIORG (defined below);
- Dose Projection Period, DPPEMP;
- 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, including shielding and exposure parameters for each pathway.
- 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.

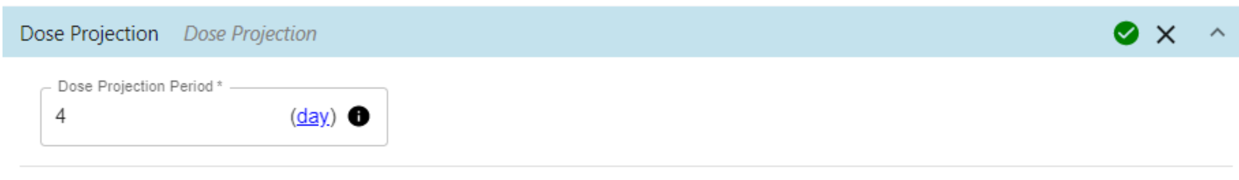


Figure 4-94. *Dose Projection* form

Table 4-86. *Dose Projection* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DPPEMP	Yes	Real	None	0 to ENDEMP

4.3.4.14. Dose Projection Period Form

The Dose Projection Period Form is a required form, containing only the Relocation Dose Projection Model Flag, RELMOD.

This determines which Early relocation dose projection period model to be used. Selecting:

- ORIGL, the original MACCS model, will use a 0.0 start time for the dose projected period and beginning relocation at ENDEMP + relocation delay (TIMNRM or TIMHOT).
- TOTAL will use the total dose model with start time equal to every plume arrival time and relocation beginning at OALARM + relocation delay.
- AVOID will use the avoidable dose model where the projected doses are calculated using only ground pathways.
- The dose projection project period starts at every plume exit time plus the relocation delay, TIMNRM or TIMHOT. Two projected doses will be calculated, one for normal relocation and another for hotspot relocation.

Figure 4-95. *Dose Projection Period* form

Table 4-87. *Dose Projection Period* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
RELMOD	No	Character	None	ORIGL, TOTAL, AVOID

4.3.4.15. Emergency Phase Resuspension Form

The *Emergency Phase Resuspension* form is required, and contains two parameters, *Initial Resuspension Concentration Factor*, RESCON; and *Resuspension Weathering Half-Life*, RESHAF. Resuspension can be excluded from a calculation by setting RESCON to be zero.

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

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

Figure 4-96. *Emergency Phase Resuspension* form

Table 4-88. *Emergency Phase Resuspension* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
RESCON	Yes	Real	None	0 to 1 m^{-1}
RESHAF	Yes	Real	None	1 to 10^{10} s

4.3.4.16. Keyhole Forecast Form

The *Keyhole Forecast* form is required when *Keyhole Model ON* is selected on the *Evac/Rotation* tab. It contains a single parameter, *Weather Forecasted Time*, KEYFORCST, which 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 4-97, KEYFORCST hours before a wind shift occurs.

This model assumes that the forecasting is perfect, using real weather shifts from recorded meteorological data. As real weather forecasting is imperfect, to compensate for this assumption, this value should normally be chosen to be a relatively small number of hours.

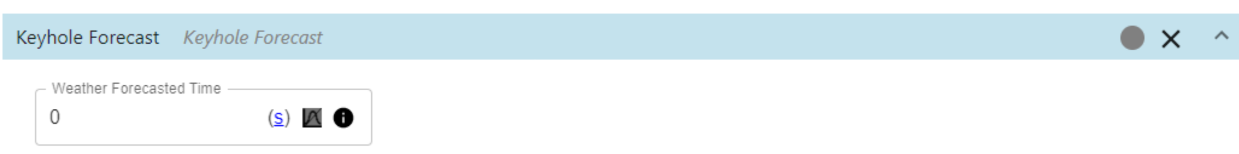


Figure 4-97. *Keyhole Forecast* form

Table 4-89. *Keyhole Forecast* parameter inputs

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

4.3.4.17. Skin Pathways Form

The Skin Pathway Parameters form is required.

Skin Dose Deposition Velocity, SKINDV, is the deposition velocity of radioactive particulate onto skin, a user-defined term. *Time of Radionuclide Residence on Skin* corresponds to WASHTM.

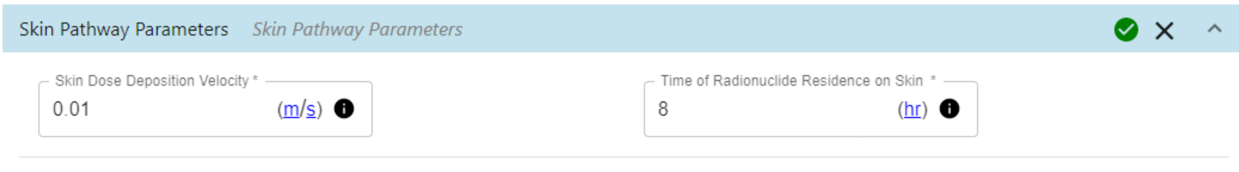


Figure 4-98. *Skin Pathway Parameters* form

Table 4-90. *Skin Pathway Parameters* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
SKINDV	Yes	Real	None	0 to 0.1 m/s
WASHTM	Yes	Real	None	0 to 604,800 s

4.3.5. Dose-Response Models

4.3.5.1. Model Description

Optional dose-response models are available to evaluate stochastic risk effects. These calculate risk due to latent cancer injuries and fatalities. These models fall into two categories – non-threshold dose response models and other computational models.

Non-threshold dose response models are:

- The linear no-threshold (LNT) model;
- The piecewise-linear (PL) model; and
- The LNT model with the linear quadratic model option.

These assume that any radiation exposure carries some risk of latent cancer and are based on the lifetime dose.

Models that fall in the second group, threshold models, are:

- The annual dose threshold (AT) model;
- The lifetime threshold (LT) model; and
- The combined annual dose and lifetime threshold (ATL).

These include a threshold below which it is assumed that radiation exposure below a specified dose level (on an annual or lifetime basis) carries no risk of latent cancer.

Four types of dose response models are illustrated in Figure 4-99.

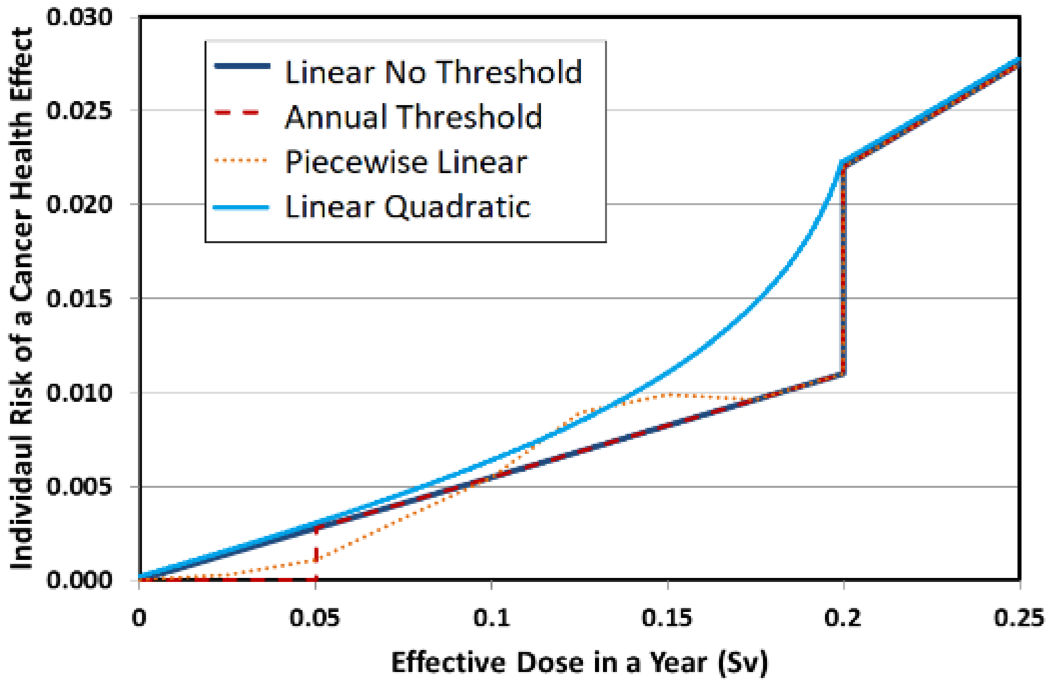


Figure 4-99. Four types of dose-response models for latent cancer health effects supported by MACCS

The first dose response model uses the standard, LNT hypothesis. This was the only model available in earlier versions of MACCS. In the linear, no-threshold model, the relationship between dose and risk of health effects is linear in the low-dose range, even for infinitesimal doses. Note that the LNT dose-response model implemented in MACCS includes a discontinuity and has a change in slope at a threshold dose, as shown in Figure 4-99. In the MACCS model, to calculate the risk of latent health effects, doses values are divided by a dose and dose-rate effectiveness factor (DDREF) for dose levels below the threshold but not for doses above the threshold. MACCS uses the standard implementation of the LNT model in which internal doses over an exposure period are calculated as 50-year doses and it combines internal and external doses to estimate a total organ dose, including the effective pseudo-organ. This total organ dose is compared with the dose threshold to determine whether to divide by DDREF. Doses incurred after the emergency phase are assumed to stay below the threshold dose, so they are always divided by DDREF to calculate risk.

Figure 4-99 illustrates the simplified situation where all doses are delivered to an individual during the first year (i.e., internal doses from inhalation and ingestion have diminished to zero by the end of the first year). This allows these four dose-response models – linear quadratic, LNT, annual dose threshold, and piecewise linear, 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. For example, effective dose could be replaced by equivalent dose to a specific organ and latent cancer health effects could represent just the cancers associated with that organ. The figure shows typical values of 0.2 Sv for the threshold dose and a value of 2.0 for DDREFA. The solid curve in Figure 4-99 shows the individual risk of a cancer fatality using typical values for cancer induction and the LNT dose-response model.

Effective dose is a central feature of radiation protection – it is a calculated dose value that takes into account the sum of all of the stochastic effects of the dose sustained on the body. Equivalent dose is calculated per individual organ and takes into account the actual biological damage sustained by using a radiation weighting factor. Generally, this would be unity for beta and gamma radiation and 20 for alpha radiation. Two options for calculating effective dose are available within MACCS – one following the ICRP 30+ model, the total effective dose equivalent (TEDE) and one following ICRP 60+ model, the effective dose (ICRP60ED). These models use different tissue weighting factors. There is a more current set of tissue weighting factors published in ICRP 103, but these are not currently provided with MACCS.

Rather than a standalone model, the linear-quadratic model is an option that when selected, modifies the linear response of dose response model, and adds a quadratic dependence. MACCS allows the linear-quadratic functionality to be applied to all the dose-response models. Care should be taken to ensure the options selected represent the intent of the analysis. For the dose response illustrated in Figure 4-99, the parameters were set to eliminate the discontinuity seen in the LNT model. A discontinuity may still be present with the linear-quadratic model depending on how the parameters are set in the analysis. If a threshold model is selected, the thresholds in these models will still be applicable and the linear-quadratic parameters will modify the dose response above the threshold value.

Another option for dose-response model is the Annual Threshold (AT), model. In this model, the user can specify one or more annual thresholds, up to one for each year of the exposure period. The annual thresholds are specified in terms of the organ dose. When the predicted organ dose is below the specified annual dose threshold, there are no contributions to any latent cancer health effects for that year; when the predicted organ dose exceeds the dose threshold, contributions to health consequences are calculated in the same way as with the LNT model. Contributions to health effects are summed over all exposure years. This dose response model is illustrated in Figure 4-99 for the case that the AT is 0.05 Sv (5 rem). To compare with the threshold, internal doses are calculated as annual doses rather than as a single 50-year committed dose. The process for doing this in MACCS is described a few paragraphs below.

For the Life Time (LT) model, the organ dose is calculated each year of the exposure period. If the sum of the annual doses is below the lifetime threshold, there are no contributions to health consequences. If the sum of the annual doses is above the lifetime threshold, the contributions to health consequences are calculated in the same way as with the LNT model.

The combined Annual and Life Time threshold model – ATL, is based on the capability of the previous two models. Whenever the life-time threshold or the annual threshold is exceeded, the organ dose contributes to health effect. When the life-time threshold is exceeded, dose contributions to health effects are counted for all years, no matter how small the dose was in a year. If the sum of the annual doses is below the lifetime threshold, then only the annual doses above the annual thresholds are used for calculating contributions to health effects.

The Piecewise-Linear (PL) model is an additional option for the dose-response model in MACCS. In this model, the user can construct a series of line segments that define the functional dependence of health effects on annual dose, as illustrated in Figure 4-99. The line segments are required to form a continuous curve. To define the PL function, the user defines a multiplicative factor that is applied to the LNT model. This model can be used to approximate a dose threshold (by setting the factor to zero), 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 (negative risk) from radiation exposure. Figure 4-99 illustrates a PL 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 0.175 Sv, the PL model is identical to the LNT model in this illustration.

For the general case where exposures occur over many years and internal dose pathways potentially deliver a dose over the 50-yr dose commitment period, the model is somewhat more complicated than it is for the LNT model. For the models discussed above, PL, AT, LT and ATL, annual doses are estimated 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 exposures during the year. They also account for the current year of dose commitment for internal exposures 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 4-99, which is for a single year, is summed over all the years for which doses are received by that individual. Years in which the annual doses are below the dose threshold are assumed not to contribute to latent health effects in the AT model. Similarly, annual doses contribute based on the PL factor using the PL model.

4.3.5.2. Forms

4.3.5.2.1. Lifetime Threshold Form

Annual Threshold is required when the user selects *CHRONC Threshold* on the *Scope* tab and *Annual Threshold* or *Annual and Life Time Threshold* on the *Threshold Dose* tab of *PROPERTIES*.

Number of Annual Dose Threshold Values, DTHNUM, is determined by the number of entries for DTHANN.

DTHANN is a vector containing the annual dose threshold for latent cancer models, with each row corresponding to a year. When calculated annual dose per person is below the specified threshold for a year, all latent health consequences are calculated to be 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 of the exposure period.

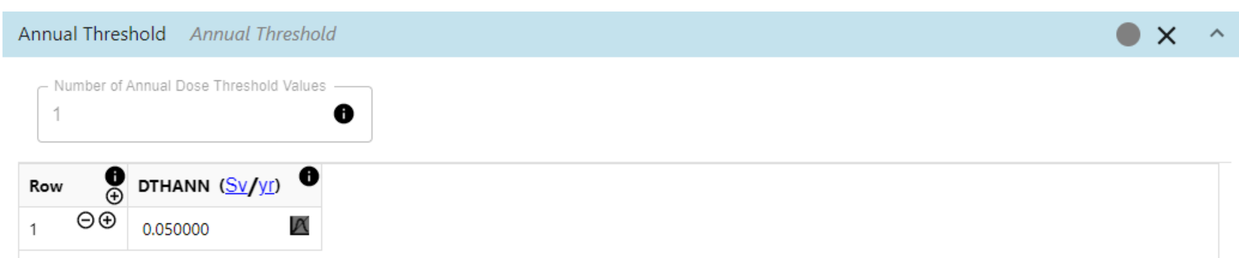


Figure 4-100. *Annual Threshold* form

Table 4-91. *Annual Threshold* parameter inputs

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

4.3.5.2.2. Lifetime Threshold Form

The *Lifetime Threshold* form is required when the user selects *CHRONC Threshold* on the *Scope* tab and either *Life Time Threshold* or *Annual and Life Time Threshold* on the *Threshold Dose* tab of the *PROPERTIES* form.

When *Lifetime Dose Restriction*, DTHLIF, is exceeded, all doses are used to estimate health effects the same as with the LNT model, regardless of *Annual Threshold* form values.

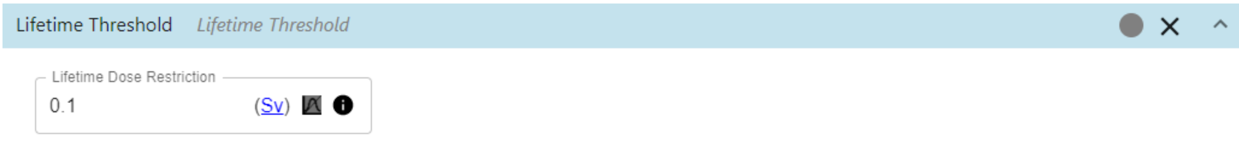


Figure 4-101. *Lifetime Threshold* form

Table 4-92. *Lifetime Threshold* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DTHLIF	Yes	Real	DTHNUM	0 to 10^{30} Sv

4.3.5.2.3. *Piecewise Linear Form*

The *Piecewise Linear* form is required when the user selects *CHRONC Threshold* on the *Scope* tab and *Piecewise Linear* on the *Threshold Dose* tab of the *PROPERTIES* form.

Number of Piecewise Dose Values, PWLNUM, is determined by the number of values of PWLDOS and PWLFAC entered.

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

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.

Figure 4-102. *Piecewise Linear* form

Table 4-93. *Piecewise Linear* parameter inputs

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

4.3.6. Population by Cohort

The characteristics of each evacuation cohort are assigned on *Emergency Cohorts* forms. The forms in the Population by Cohort category enable assigning portions of the population to different evacuation cohorts for each spatial grid element. Each cohort should represent a segment of the population that displays a distinct evacuation behavior (e.g., the general populace vs. people with special needs). First, populations are defined on the *Populations* forms, where a population is defined by a set of cohort fractions. Next, populations are assigned to spatial grid elements. This defines the population fraction 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 3.3.6.2 for more guidance.

4.3.6.1. Forms

4.3.6.1.1. Populations Form

The *Populations* form is required when the user assigns *SUMPOP with File Created from Existing Site File* on the *Site Data* tab.

Number of Population Distributions, N_POP_DIST, is linked to the number of entered distributions.

The cohort columns correspond to POP_DIST, which defines the population distributions to be assigned to the grid. One distribution is entered per row. The cohort fractions on each row should sum to one. Each column of the grid is associated with a cohort.

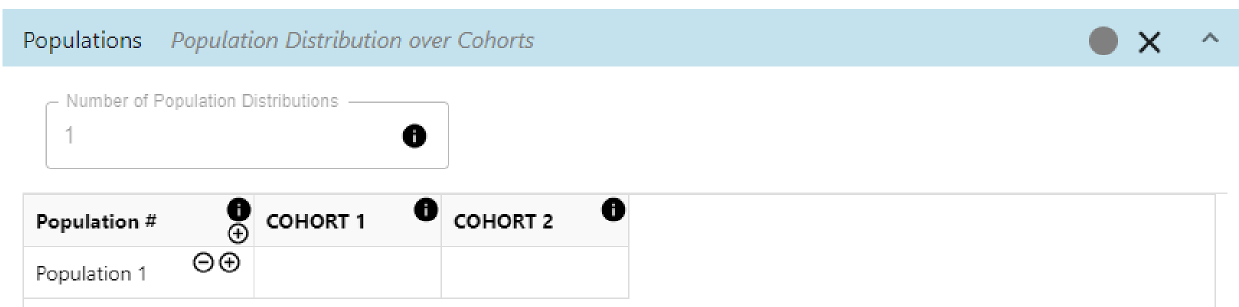


Figure 4-103. *Populations* form

Table 4-94. *Populations* parameter inputs

Parameter	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

4.3.6.1.2. Population Labels Form

The *Population Labels* form is required when *SUMPOP with File Created from Existing Site File* is selected on the *Site Data* tab.

DIST_SYMB is a single character used to assign a population to a grid element in the spatial grid form.

DIST_LABEL is a descriptive label associated with the population.

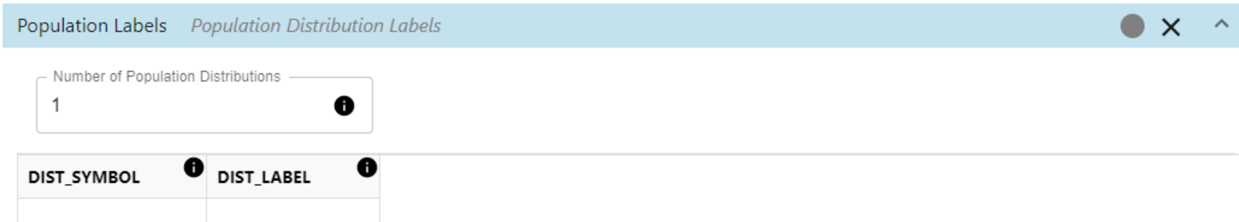


Figure 4-104. *Population Labels* form

Table 4-95. *Population Labels* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DIST_SYMB	Yes	Character	N_POP_DIST	1 character
DIST_LABEL	Yes	Character	N_POP_DIST	1 to 20 characters

4.3.6.1.3. Populations Assigned Form

The *Populations Assigned* form is required when *SUMPOP with File Created from Existing Site File* is selected on the *Site Data* tab.

The *Populations Assigned* form allows the user to assign populations, identified by the symbol, DIST_SYMB, defined on the *Population Labels* form, to grid elements. Any time a population is assigned, each *Population* form for each cohort in the calculation is updated to show the population by grid element. Before the MACCS simulation is run, a new site file is constructed with the populations shown on the *Populations* forms for each cohort. The site file is created to be compatible with the MACCS SUMPOP option and includes a section defining the population for each cohort.

POP_DIST is defined on the *Populations* form.

DIST_SYMB associates a population distribution with a symbol.

DIST_LABEL is a descriptive label associated with a 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 a cohort.

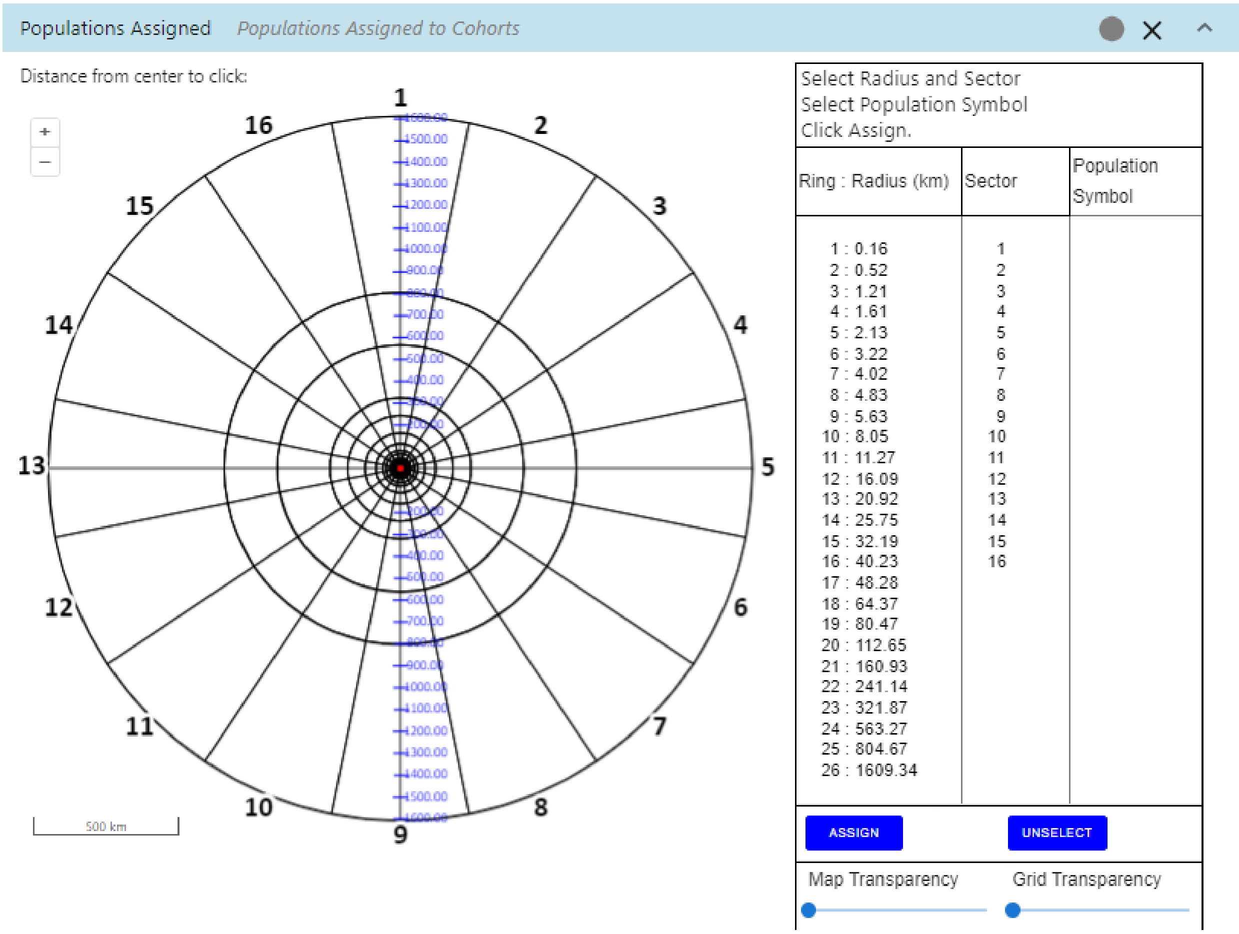


Figure 4-105. *Populations Assigned* form

Table 4-96. *Populations Assigned* parameter inputs

Parameter	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

4.3.7. Emergency Response Cohorts

MACCS-UI supports up to twenty emergency cohorts, which is defined on the *Evac/Rotation* tab. Several cohort forms must be defined under the *Emergency Cohort One* category. For additional cohorts, identical, forms must be defined under the *Additional Emergency Cohorts* category. For example, a critical organ can be specified for each cohort on the *Critical Organ* form.

4.3.7.1. 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 discrete 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 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. The top hat approximates the Gaussian profile as a constant concentration over a width of $3 \cdot \sigma_y$, as shown in Figure 4-106.

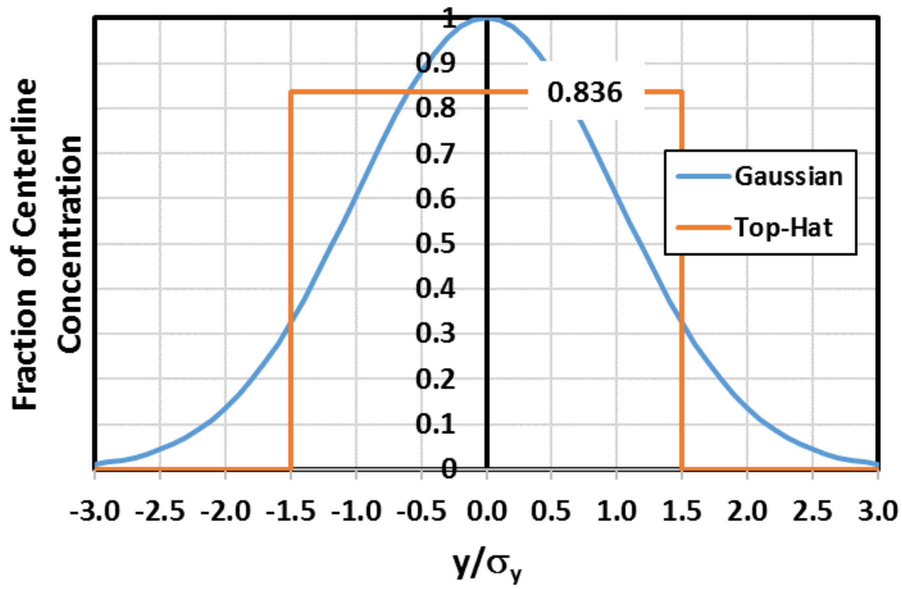


Figure 4-106. Top-hat approximation for plume concentration used for evacuees

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 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 are used in the case when TRAVELPOINT = BOUNDARY:

- when the evacuee moves radially and resides in the current grid element

$$T_{t,n} = (r_n - r_{n-1})/(2 \cdot V) \tag{4-39}$$

- when the evacuee moves radially and does not reside in the current grid element

$$T_{t,n} = (r_n - r_{n-1})/V \tag{4-40}$$

- when the evacuee moves around the compass and resides in the current grid element

$$T_{t,n} = \pi \cdot (r_n + r_{n-1})/(2 \cdot N_\theta \cdot V) \tag{4-41}$$

- when the evacuee moves around the compass and does not reside in the current grid element

$$T_{t,n} = \pi \cdot (r_n + r_{n-1})/(N_\theta \cdot V) \tag{4-42}$$

The following formulae are used in the case when TRAVELPOINT = CENTERPOINT:

- when the evacuee moves radially outward

$$T_{t,n} = (r_{n+1} - r_{n-1})/(2 \cdot V) \tag{4-43}$$

- when the evacuee moves radially inward

$$T_{t,n} = (r_n - r_{n-2})/(2 \cdot V) \tag{4-44}$$

- when the evacuee moves around the compass

$$T_{t,n} = \pi \cdot (r_n + r_{n-1})/(N_\theta \cdot V) \tag{4-45}$$

Where

$T_{t,n}$ = transit time to move from the current to the next 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×ESPGRD when no precipitation is occurring and by V = ESPEED×ESPGRD×ESPMUL 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, direct inhalation of the plume, and skin deposition). Doses from groundshine are always accounted for when the evacuee is at a location where the ground is contaminated. Resuspension inhalation is only considered once the plume segment has exited the grid element.

4.3.7.2. Forms

4.3.7.2.1. Basic Parameters Form

Basic Parameters are required for each *Emergency Cohort* category.

Evacuation Type, EVAKEY, determines the algorithms used:

- CIRCULAR implies all sectors are subject to evacuation.
- KEYHOLE limits the number to NSECTR sectors beyond an inner circular region.

- NONE means that there is no evacuation.

The evacuation type is defined for each cohort under the *PROPERTIES/Evac Rotation* tab. *Cohort Description*, EANAM2, is a name identifying each cohort.

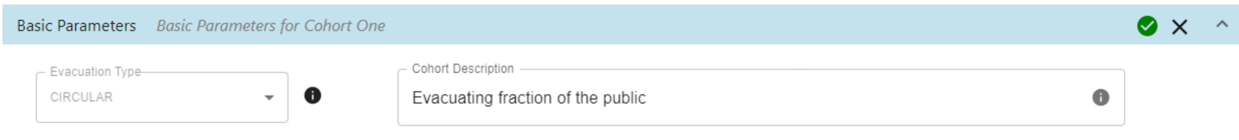


Figure 4-107. *Basic Parameters* form

Table 4-97. *Basic Parameters* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
EVAKEY	No	Character	None	NONE, CIRCULAR, KEYHOLE
EANAM2	Yes	Character	None	1 to 80 characters

4.3.7.2.2. Cohort Fraction

WTFRAC is a weight fraction to be applied to results from each emergency response cohort. The value is used when combining results for the overall weighted sum over all evacuation cohorts. The meaning depends on the selection on the *Site Data Model* tab in *PROPERTIES*.

- PEOPLE represents the fraction of the population that belongs to this cohort. With this option, a fraction of the population follows each cohort definition all the time.
- TIME represents the fraction of the time or probability that this cohort is applicable. With this option, the entire population follows each cohort definition a fraction of the time.
- SUMPOP – WTFRAC must be defined but isn't used by MACCS. Instead, weighting information is based on population distributions read from the site data file.

MACCS requires that the sum of values of WTFRAC over all evacuation scenarios must add up to 1.0 within a tolerance of 0.001. MACCS-UI does not enforce this requirement.

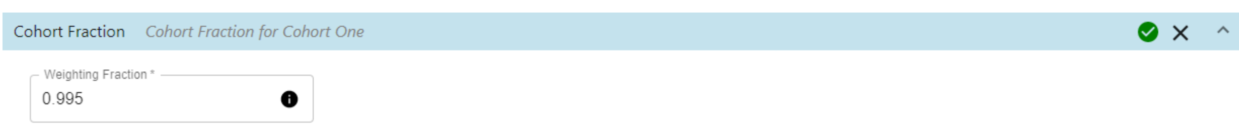


Figure 4-108. *Cohort Fraction* form

Table 4-98. *Cohort Fraction* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
WTFRAC	Yes	Real	None	0.0 to 1.0

4.3.7.2.3. Phase Durations and Speeds Form

This form is required for *Emergency Cohort One* and any subsequent cohorts when the evacuation type is circular or keyhole.

The evacuation phase is divided into three subphases defined by DURBEG, DURMID, and the remainder of the emergency phase. The purpose for the evacuation subphases is to allow evacuation speed parameters to vary over time.

Reference Time, REFPNT, is the time point for actions in the evacuation and sheltering zone. The user may choose to have the reference time be:

- Alarm time (ALARM), which is established by the value of OALARM; or
- The first plume arrival (ARRIVAL) at each grid element.
- With keyhole evacuation, ALARM is the only legal choice for this variable.

Evacuees Travel Flag, 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).

Beginning of the Middle Phase, DURBEG, is the duration of the initial subphase 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.

Duration of the Middle Phase, DURMID, defines the duration of the middle subphase of evacuation. The evacuation speed used during this subphase is the middle value of ESPEED. The evacuation speed used during the final subphase, which extends until evacuation is complete or until the end of the emergency phase, is the third value of ESPEED.

The evacuation phase begins when the first individual begins to travel out of the region. The durations of the initial and middle subphases of evacuation are defined by input parameters DURBEG and DURMID. The late phase of evacuation extends until all individuals complete their travel or until the end of the emergency phase, whichever is sooner. Normally, all evacuation should be complete by 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) subphases: initial, middle and late. MACCS requires that all three values be the same when TRAVELPOINT is set to BOUNDARY. They can be different when TRAVELPOINT is set to CENTERPOINT.

ESPMUL is a multiplicative factor that affects ESPEED during adverse weather, i.e., when precipitation is occurring. The occurrence of precipitation is determined 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 formulae, where ESPGRD is the grid-level speed multiplier ESPGRD_NET or ESPGRD_RAD (supplied on another form):

Evacuation Speed = ESPEED × ESPGRD × ESPMUL when precipitation is occurring

Evacuation Speed = ESPEED × ESPGRD when no precipitation is occurring

ESPEED is defined for each of the three subphases (initial, middle, and late) of evacuation, but is independent of grid elements. ESPGRD, a speed multiplier defined on the forms *Radial Evacuation Speed* or *Network Evacuation Speed*, is independent of subphase, but is defined for each grid element. When ESPGRD is not defined because *Activate Speed Multiplier Option* has not been selected on the *PROPERTIES/Evac Rotation* tab, a value of one is assumed.

Three values of ESPEED 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.

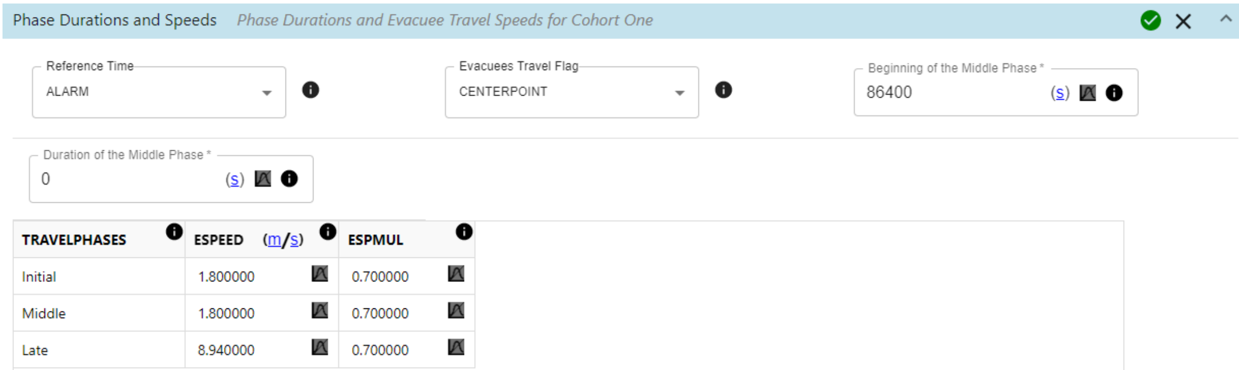


Figure 4-109. *Phase Duration and Speeds* form

Table 4-99. *Phase Duration and Speeds* parameter inputs

Parameter	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	10^{-6} to10^{6} m/s
ESPMUL	Yes	Real	3	0.0 to 1.0

4.3.7.2.4. Critical Organ Form

This form is required for *Emergency Cohort One* and any additional cohorts.

Critical Organ Name, CRIORG, is the critical organ for relocation decisions during the emergency phase. People remain in the grid element when the projected total dose to the critical organ is less than the values that trigger relocation.

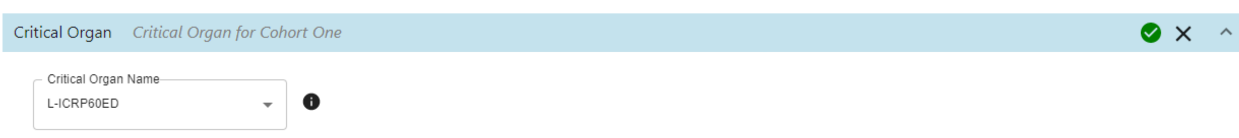


Figure 4-110. *Critical Organ* form

Table 4-100. *Critical Organ* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CRIORG	Yes	Character	None	Must select an Organ name. Choice depends on DCF file.

4.3.7.2.5. *KI Ingestion Linear No Threshold Form*

This form is required for *Emergency Cohort One* and any subsequent cohorts when *LNT* is selected on the *Scope* tab and *KI Model ON* are selected on the *Dose* tab of *PROPERTIES*.

The KI ingestion model accounts for potential reduction in uptake of inhaled radioiodine by the thyroid gland. The ingested KI saturates the thyroid gland so that the effect of inhaling iodine from a plume can be significantly diminished. The KI ingestion model allows the user to specify a population fraction that ingests KI and an associated efficacy factor. The efficacy factor defines the fractional dose reduction to the thyroid gland from inhaled radioiodine. The efficacy factor depends on the relative timing between KI ingestion and exposure to radioiodine.

Fraction of Population that Ingests KI is POPFRAC. A fraction of the population ingesting KI is allowed when the LNT dose-response model is used; it must be 0 or 1 when a non-LNT option is chosen, as described below.

KI Efficacy Factor, EFFACY, is a factor used to reduce the dose to the thyroid from inhalation of radioiodine. The dose to a population is modified by a factor of (1 - EFFAC) × POPFRAC.

Figure 4-111. *KI Ingestion Linear No Threshold* form

Table 4-101. *KI Ingestion Linear No Threshold* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
POPFRAC	Yes	Real	None	0 to 1
EFFACY	Yes	Real	None	0 to 1

4.3.7.2.6. *KI Ingestion Threshold or Piecewise Form*

This form is required for *Emergency Cohort One* and any subsequent cohorts when *Threshold* is selected on the *Scope* tab and *KI Model ON* are selected on the *Dose* tab of *PROPERTIES*.

Fraction of Population that Ingests KI is POPFRAC. When any threshold dose response model is enabled, either all or none of the population ingest KI. A cohort can be split into two cohorts, one that takes KI and one that does not to accommodate this restriction.

KI Efficacy Factor, EFFACY, is a factor used to reduce the dose to the thyroid from inhalation of radioactive iodine. The dose to a population is modified by a factor of (1 - EFFACY) when the population ingests KI.

Figure 4-112. *KI Ingestion Threshold or Piecewise* form

Table 4-102. *KI Ingestion Threshold or Piecewise* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
POPFRAC	Yes	Real	None	0 to 1
EFFACY	Yes	Real	None	0 to 1

4.3.7.2.7. Sheltering and Evacuation Boundary Form

This form is required for Emergency Cohort One and any additional cohorts when the evacuation type is circular or keyhole. When the Radial Evacuation Speed, Network Evacuation Direction, or the Network Evacuation Speed forms are used for any of the additional Emergency Cohort categories, this form must be completed first to define distances on those forms.

Outer Boundary of Evacuation Movement Zone, LASMOV, is where 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 and less than or equal to NUMRAD. The upper bound for Cohort One is NUMRAD; the upper bound for additional cohorts is the value of LASMOV for Cohort One.

Outer Boundary of Evacuation Zone, NUMEVA, defines the outer boundary of the sheltering and evacuation region (often the same as the emergency planning zone). MACCS requires that NUMEVA be no larger than LASMOV. The upper bound for Cohort One is LASMOV; the upper bound for additional cohorts is the value of NUMEVA for Cohort One.

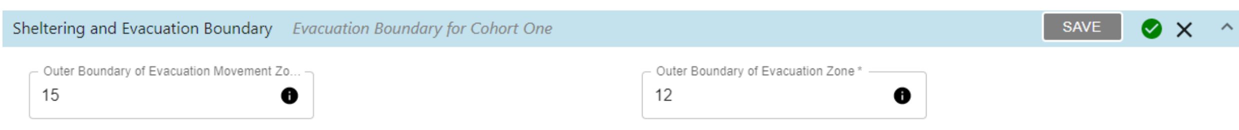


Figure 4-113. *Sheltering and Evacuation Boundary* form

Table 4-103. *Sheltering and Evacuation Boundary* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMEVA	Yes	Integer	None	1 to NUMRAD
LASMOV	Yes	Integer	None	0 to NUMRAD (required to be >= NUMEVA)

4.3.7.2.8. Shielding and Exposure Form

This form is required for *Emergency Scenario One* and 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. Normal activity values are used throughout the emergency phase for nonevacuating cohorts.

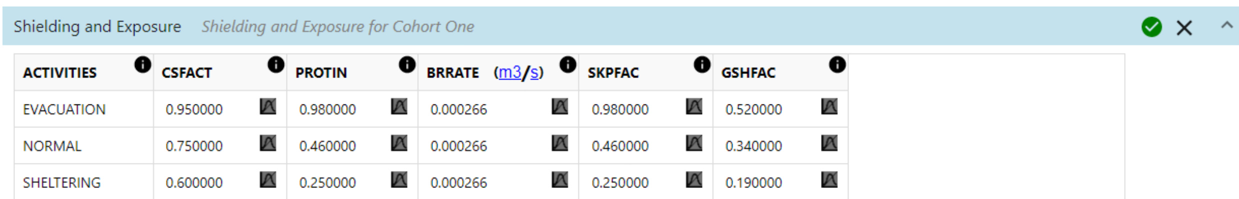
CSFACT is cloudshine shielding factor. This value is used as a multiplier on the value of cloudshine dose that would have been received if the person were standing outside in an unshielded location. A value of 0 indicates complete shielding; a value of 1 indicates no shielding.

PROTIN is 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 average breathing rate for the specified cohort and activity.

SKPFAC is skin protection factor. This value is used as a multiplier on the value of the dose that would have been received from skin deposition 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 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 in an unshielded location and the ground were a perfectly flat surface. A value of 0 indicates complete shielding from groundshine; a value of 1 indicates no protection.


Shielding and Exposure Shielding and Exposure for Cohort One

ACTIVITIES	CSFACT	PROTIN	BRRATE (m3/s)	SKPFAC	GSHFAC
EVACUATION	0.950000	0.980000	0.000266	0.980000	0.520000
NORMAL	0.750000	0.460000	0.000266	0.460000	0.340000
SHELTERING	0.600000	0.250000	0.000266	0.250000	0.190000

Figure 4-114. *Shielding and Exposure* form

Table 4-104. *Shielding and Exposure* parameter inputs

Parameter	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

4.3.7.2.9. Notification Delay Form

Starting with MACCS version 4.0, notification delays can be set for each individual cohort, which is done via the *Notification Delay* Form for each cohort.

Notification Delay, OALARM, is the parameter that specifies the notification delay and is defined as the elapsed time between accident initiation to notification of the public to take protective actions. OALARM represents declaration of a site emergency, a general emergency, or some other notification time used to trigger emergency response. OALARM does not need to be specified when evacuation is off.

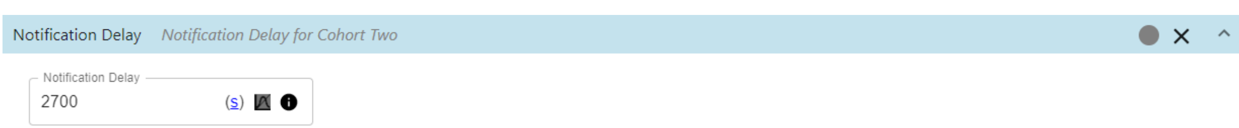


Figure 4-115. *Notification Delay* form

Table 4-105. ***Notification Delay*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
OALARM	Yes	Real	None	0.0 to 2.592 x 10^6 sec

4.3.7.2.10. Response Delays Form

This form is required for *Emergency Scenario One* and for each additional *Emergency Cohort* 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 value of DLTSHL must be supplied for each ring in the sheltering/evacuation 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 value must be supplied for each ring in the sheltering/evacuation region.

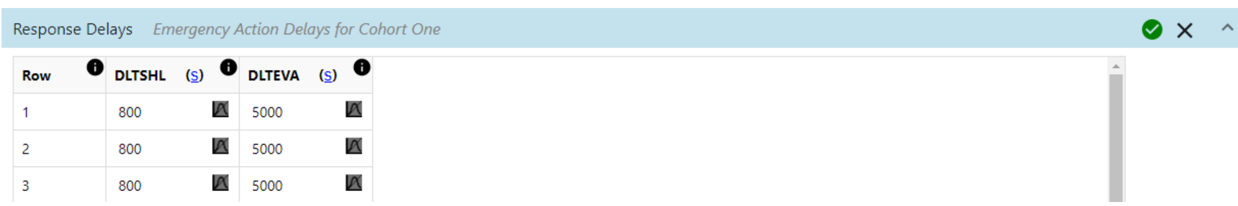


Figure 4-116. *Emergency Actions Delays* form

Table 4-106. *Emergency Actions Delays* parameter inputs

Parameter	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

4.3.7.2.11. Radial Evacuation Speed Form

This form is required for *Emergency Cohort One* when the *Problem Model* is *Radial* and *Activate Speed Multiplier Option* is selected on the *PROPERTIES/Evac Rotation* tab. This form is required for each additional *Emergency Cohort* category when evacuation type is circular or keyhole and *Activate Speed Multiplier Option* is selected.

ESPGRD_RAD defines the speed multiplier for each grid element where evacuation is treated. This includes all grid elements from the center to the outer boundary of evacuation movement, defined by LASMOV. 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 3.3.6 for more information.

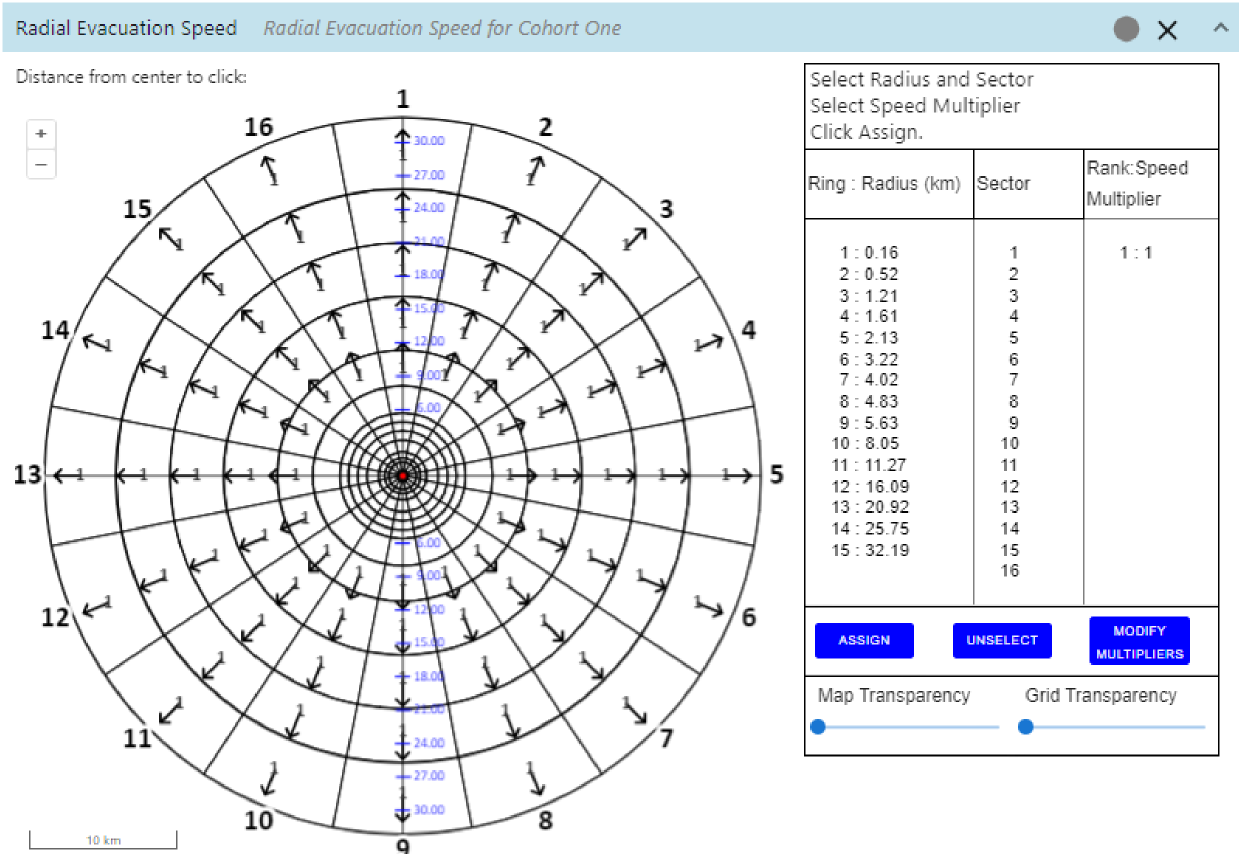


Figure 4-117. *Radial Evacuation Speed* form

Table 4-107. *Radial Evacuation Speed* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
ESPGRD_RAD	Yes	Real	LASMOV by NUMCOR	0.001 to 1000.0

4.3.7.2.12. Network Evacuation Direction Form

This form is required for *Emergency Scenario One* when the *Problem Model* is chosen to be *Network* on the *PROPERTIES/Evac Rotation* tab. This form is required for each additional *Emergency Cohort* category when evacuation type is circular or keyhole.

ESPGRD_NET is a read-only parameter on this form and is defined on the form *Network Evacuation Speed*. When this parameter is undefined, a value of 1 is used 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 counterclockwise evacuation. These numbers are input as arrows that can be clicked to change the evacuation direction.

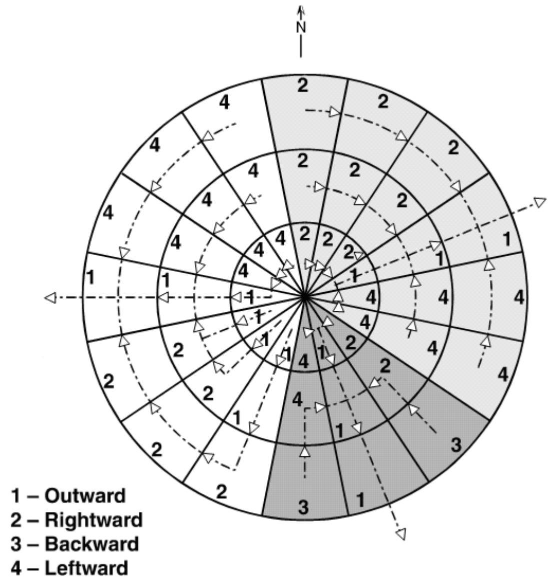


Figure 4-118. IDIREC values in network evacuation grid

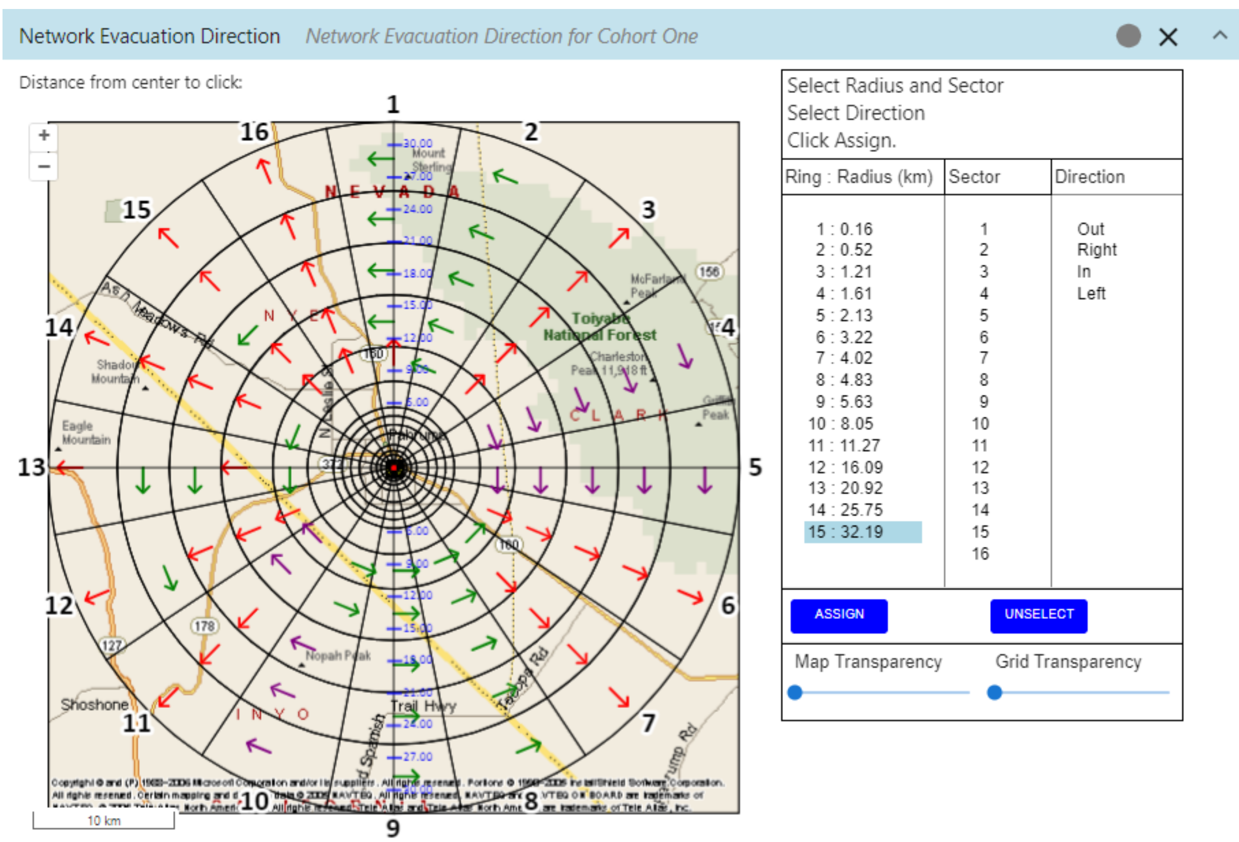


Figure 4-119. ***Network Evacuation Direction*** **form**

Table 4-108. *Network Evacuation Direction* parameter inputs

Parameter	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

4.3.7.2.13. Network Evacuation Speed Form

This form is required for *Emergency Cohort One* when the *Problem Model* is *Network* and *Activate Speed Multiplier Option* is selected on the *PROPERTIES/Evac Rotation* tab. This form is required for each additional *Emergency Cohort* category for which the evacuation type is keyhole or circular. This set of parameters is useful for adjusting speeds to account for bottlenecks in the road network or for areas of freely flowing traffic.

ESPGRD_NET defines the speed multiplier for each grid element where evacuation is treated. This includes all grid elements from the center to the outer boundary of the evacuation movement, defined by LASMOV. 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 3.3.6 for more information.

IDIREC is a read-only parameter on this form and 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 counterclockwise evacuation. These numbers are shown in the interface.

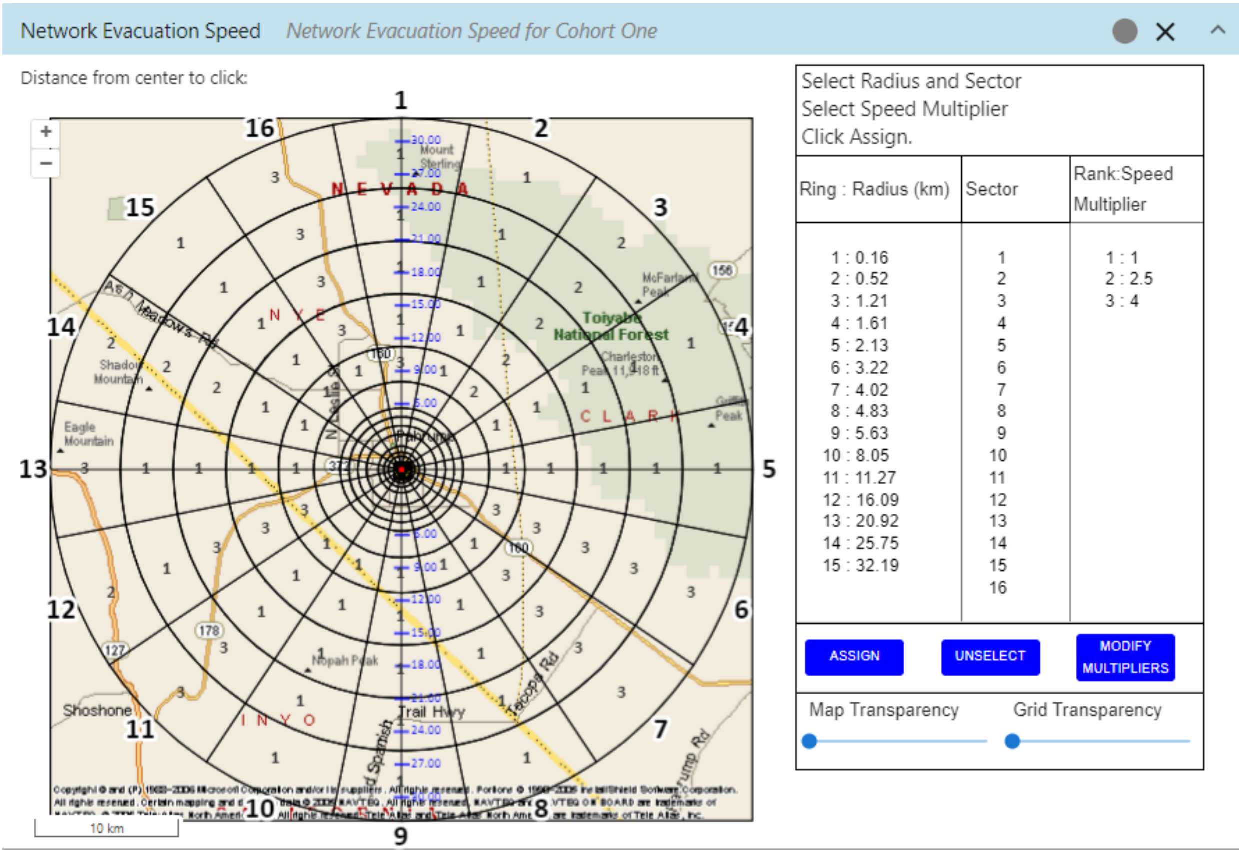


Figure 4-120. *Network Evacuation Speed* form

Table 4-109. *Network Evacuation Speed* parameter inputs

Parameter	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

4.3.7.2.14. Population Form

The *Population* form is relevant for each emergency cohort when the user chooses *SUMPOP with File Created from Existing Site File* on the *Site Data* tab. When the *Populations Assigned* form is completed or modified, the *Population* form is updated. The values shown are the number of people assigned to each spatial grid element for the given cohort.

COHORT_POP defines the number of people associated with each spatial grid element for a cohort.

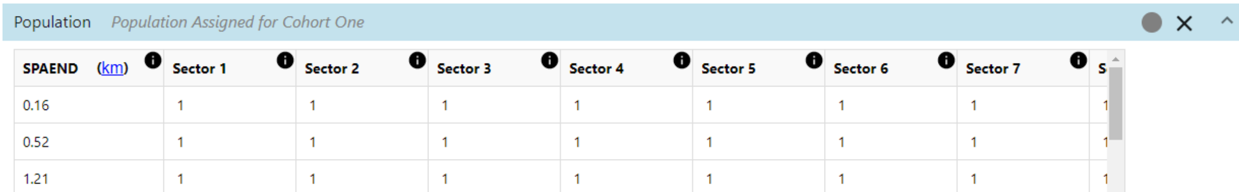


Figure 4-121. *Population* form

Table 4-110. *Population* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values	Defined on Form
COHORT_POP	No	Real	NUMRAD by NUMCOR	0 to 10^9	Populations Assigned

4.3.7.2.15. Keyhole Definition Form

The *Keyhole Definition* form is required when Keyhole Model ON is selected on the Evac/Rotation tab in *PROPERTIES*.

Number of Sectors in Keyhole, NSECTR, defines the number of sectors to be considered in keyhole evacuation. This number should not exceed NUMCOR/2 – 1. If it does, the evacuation model defaults to a circular one.

Distance of Circular Portion Keyhole, KEYDIS, is the radius of the circular portion of the keyhole. KEYDIS is the index of a radius in 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.

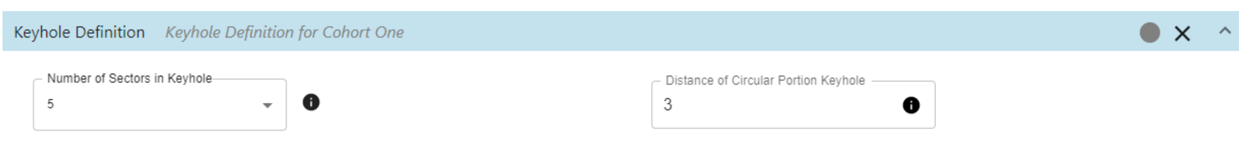


Figure 4-122. *Keyhole Definition* form

Table 4-111. *Keyhole Definition* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NSECTR	Yes	Integer	None	1, 3, 5, 7, …, 31
KEYDIS	Yes	Integer	None	0 to NUMEVA

4.3.8. Early Fatality and Injury Parameters

4.3.8.1. Fatality Model Description

The individual risk of early 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 several potential types of damage as follows:

$$RISK = 1 - e^{-\sum_i H_i} \quad \textbf{(4-46)}$$

$$H_i = 0.693 \left(\frac{DOSE_i}{EFFACA_i}\right)^{EFFACB_i} \quad \textbf{(4-47)}$$

Where

$DOSE_i$	=	acute dose to organ i (described later),
$EFFACA_i$	=	the alpha (LD_{50}) parameter in the hazard function (Evans, Moeller, and Cooper, 1985, p. II-8) for organ i, and
$EFFACB_i$	=	the beta or exponential parameter in the hazard function that defines the steepness of the dose-response function for organ i.

In addition to the two Weibull parameters, a dose threshold is incorporated into the early fatality model. When the dose to any organ is below the user-specified threshold (see EFFTHR below), the hazard function (H_i) 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 extended 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. Acute radiation doses represent doses delivered to an organ over a relatively brief 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 a 50-year commitment period following inhalation by a standard reference person who is 30 years old. Lifetime doses are used to determine the need for mitigative actions and to estimate cancers occurrences and population doses.

Implementation of the Evans, Moeller, and Cooper (1985) early health effects model requires a calculation method that takes account of dose protraction for radioactive material inhaled and retained in the respiratory system. The assumption is that the exposure occurs on the first day, but that dose is received by an organ over a period of time. 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 to reduce the computational demands of the calculations. This dose is termed the acute dose.

The acute dose, D_{ac}, is the dose, which if it were delivered entirely in one day, would induce the same health effects as an actual dose delivered over many days. Thus,

$$H = log_2 \left(\frac{D_{ac}}{\alpha_1}\right)^{\beta} = log_2 \left(\sum_t \frac{D_t}{\alpha_t}\right)^{\beta} \quad \textbf{(4-48)}$$

Where

D_{ac}	=	$C \cdot F_e$
D_t	=	$C \cdot F_t$
C	=	the amount of material inhaled from the plume,
F_{ac}	=	the acute DCF,

F_t = the DCF for the actual dose, D_t, delivered over time t.

a_t = the LD_{50} or D_{50} delivered over time t.

a_1 = the LD_{50} or D_{50} delivered over 1 day.

Substitution yields the following result:

$$F_e = \sum_t \left(\frac{\alpha_1}{\alpha_t} F_t\right) \quad \textbf{(4-49)}$$

Acute DCFs are supplied only for the organs used for calculating early health effects. The acute dose commitment period from inhaled and internally deposited radionuclides is from one week to one year, depending on the organ. The organs in the DCF file for which 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. Thus, a value of -1.0 found in the DCF file will not display a warning message. However, negative numbers other than -1.0 in the DCF file will trigger a warning message output to the text output file. The dose reduction factors (*i.e.*, α_1/α_t) that underly the acute values in the dose coefficient files supplied with MACCS-UI are shown in the table below. The values in this table are taken from Evans, Moeller, and Cooper (1985) and are also documented in H-N Jow et al. (1990).

Table 4-112. Acute dose reduction factors used to construct acute dose coefficients for inhalation in MACCS DCF files

	Period after initial exposure (days)					
	0–1	1–7	7–14	14–30	30–200	200–365
Organ Name	Acute Dose Reduction Factors (α_1/α_t) (Dimensionless)					
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				

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 period, 9 Gy for the 1- to 14-day period, and 18 Gy for the 14- to 30-day 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 acute DCF, as described above. The result is the same as the one that would have been obtained if doses over all three periods had been obtained and Equation (4-48) had been used directly.

In the MACCS model, exposure via the inhalation pathway is assumed to occur on the first day, and this exposure results in committed doses for each of the periods listed in the table. To illustrate use of the above table, acute red marrow dose from inhaling a contaminant is 100% of the first day's committed dose, 50% of the next 13 days' committed dose, plus 25% of the subsequent 16 days' committed dose. The acute dose from inhalation is added to doses from external sources to get a total acute dose. The external exposures are also assumed to occur in the first day, so they are applied with a dose reduction factor of one. The total acute dose is used in the risk equation with the LD_{50} for the 0- to 1-day period to evaluate the hazard function for bone marrow.

The current implementation of the early health effect models does not distinguish between cloudshine, groundshine, and the 0- to 1-day inhalation dose commitment. These pathways 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 DCFs, which corresponds to the fact that the endpoint of the damage for early and latent health effects is different (i.e., the former corresponds to cell death and the latter to chromosome damage).

The error introduced by attributing the entire direct exposure dose to the first day is usually 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 in a contaminated area for much longer than one day when dose levels are high enough to pose a risk of early health effects.

This section describes the MACCS models used to estimate early health effect cases and individual risks. Results to be processed (*e.g.,* total cases of early fatalities, average individual risk of early fatalities, and centerline risk vs. distance of early fatalities) are described in later sections of this document. To produce early fatality results, the early fatality model must be activated in *PROPERTIES*.

4.3.8.2. Injury Model Description

The individual risk of each type of early injury is modeled in MACCS using an approach analogous to the one 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 at a time. The early injury risk function is as follows:

$$RISK = 1 - e^{-\sum_i H_i} \quad \textbf{(4-50)}$$

$$H_i = 0.693 \left(\frac{DOSE_i}{EIFACA_i}\right)^{EIFACB_i} \quad \textbf{(4-51)}$$

Where

$DOSE_i$	=	acute dose to organ I (described later),
$EIFACA_i$	=	the alpha (D_{50}) parameter in the hazard function (Evans, Moller and Cooper 1985, p. II-8) for a one-day dose to organ i, and
$EIFACB_i$	=	the beta or exponential parameter in the hazard function that defines the steepness of the dose-response function for organ i.

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. Results to be processed (*e.g.,* total cases of a given injury, average individual risk, and centerline risk vs. distance of a given injury) are described in later sections. To produce early injury results, early injuries must be activated in *PROPERTIES*.

4.3.8.3. Forms

4.3.8.3.1. Early Fatality Parameters Form

The *Early Fatality Parameters* form is not used when the DCF file FGRDCF is selected on the *PROPERTIES/Dose* tab or when *Early Fatality Effects* is not checked on the *Health Effects* tab. It is required when either of the other DCF file types is selected and *Early Fatality Effects* is checked.

Number of Defined Early Fatality Effects, 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.

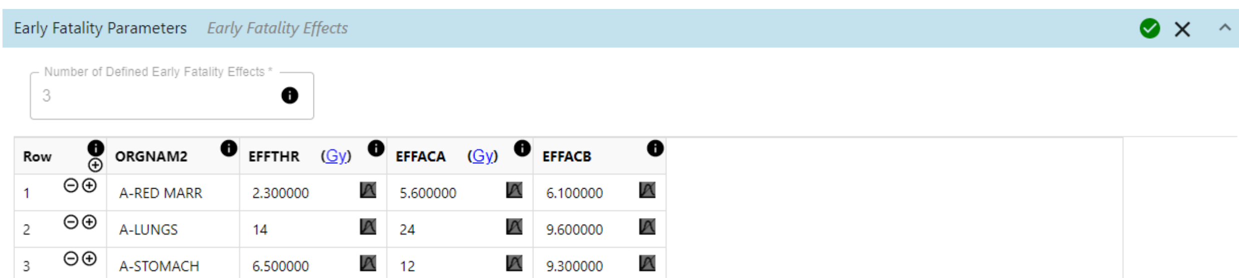


Figure 4-123. *Early Fatality Parameters* form

Table 4-113. *Early Fatality Parameters* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMEFA	Linked	Integer	None	1 to 10
ORGNAM	Yes	Character	NUMEFA	Acute Organ name from DCF File
EFFACA	Yes	Real	NUMEFA	1.0 to 100. Gy
EFFACB	Yes	Real	NUMEFA	1.0 to 100.
EFFTHR	Yes	Real	NUMEFA	0.0 to 100. Gy

4.3.8.3.2. Early Injury Parameters Form

The *Early Fatality Parameters* form is not used when the DCF file FGRDCF is selected on the *PROPERTIES/Dose* tab or when *Early Fatality Effects* is not checked on the *Health Effects* tab. It is required when either of the other DCF file types is selected and *Early Fatality Effects* is checked.

Number of Defined Early Injuries is NUMEIN.

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 organs with acute dose coefficients (ones beginning with A-).

EISUSC is the fraction of the population that is susceptible to the type of 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.

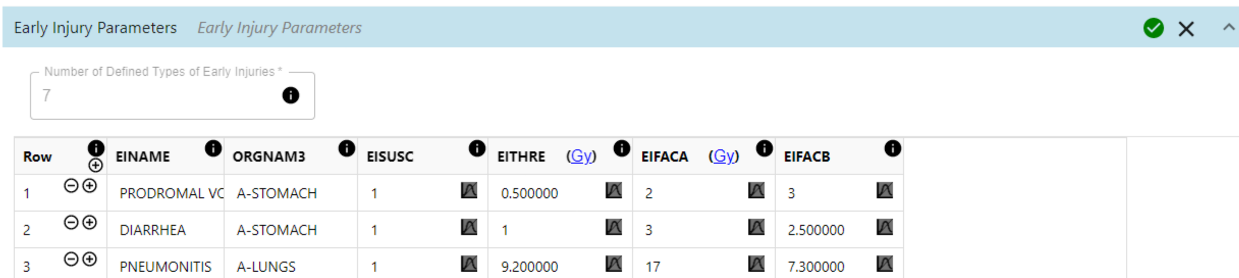


Figure 4-124. *Early Injury Parameters* form

Table 4-114. *Early Injury Parameters* parameter inputs

Parameter	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 DCF File
EISUSC	Yes	Real	NUMEIN	0.0 to 1.0
EITHRE	Yes	Real	NUMEIN	0.0 to 1000.0 Gy
EIFACA	Yes	Real	NUMEIN	0.0 to 1000.0 Gy
EIFACB	Yes	Real	NUMEIN	0.0 to 100.0

4.3.9. Latent Cancer Parameters

4.3.9.1. 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 a linear, no-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.

4.3.9.1.1. 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 has the form (ICRP, 1991):

$$R(D) = D \cdot (\alpha + \beta D) \quad \textbf{(4-52)}$$

The implementation of the linear-quadratic dose-response model in MACCS 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:

$$R(DOSE) = DOSE \times CFRISK \times (DOSEFA + DOSE \times DOSEFB) \times ACSUSC \quad \textbf{(4-53)}$$

Where

$DOSE$	=	50-year lifetime dose commitment to the target organ,
$CFRISK$	=	lifetime risk factor for cancer injury,
$DOSEFA$	=	the linear factor, a, of the dose dependence,
$DOSEFB$	=	the quadratic factor, b, 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:

$$R(D) = DOSE \times CFRISK \times (DOSEFA + ACTHRE \times DOSEFB) \times ACSUSC \quad \textbf{(4-54)}$$

The change from Equation (4-53) to Equation (4-54) 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:

$$R(D)= DOSE \times CFRISK \times DOSEFA \times ACSUSC \quad \textbf{(4-55)}$$

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 zero to the ACTHRE input parameter.

4.3.9.1.2. 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:

$$R(D) = \alpha \cdot \frac{D}{DDREF} \qquad D < 0.2 \text{ Gy or } 0.1 \text{ Gy per hour}$$

$$R(D) = \alpha \cdot D \qquad D > 0.2 \text{ Gy or } 0.1 \text{ Gy per hour} \quad \textbf{(4-56)}$$

This function is shown as the LNT curve in . 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; for central estimates of breast and thyroid cancers, DDREF is assigned a value of 1 in LMF-132. In current modeling with FGR-13 dose coefficient files, DDREF is generally chosen to be 2 for all organs but breast, which is assigned a value of 1.

The user defines the lifetime dose commitment, input parameter DDTHRE, below which the DDREFA is applied to cancer risk calculations for emergency-phase exposures. MACCS applies DDREFA to all the dose calculations in the CHRONC module because doses should always be less than 0.2 Gy after the end of the emergency phase.

4.3.9.1.3. Latent Cancer Parameters Form

The *Latent Cancer Parameters* form is required when *Latent Cancer Effects from Early Exposure* is checked on the *PROPERTIES/Health Effects* tab. There are two versions of this form, one with and one without DDREFA. The first form called *Latent Cancer Parameters* is used when the user wishes to specify a value for the DDREFA variable.

The second form called *Latent Cancer Parameters no DDREFA* is used when the user does not wish to use a DDREFA value. This option can only be used with the Threshold model dose calculations and is turned on by selecting the check box labeled *Ignore Dose and Dose Rate Effectiveness Factor* which is found on the *Threshold Dose* tab in *PROPERTIES*. The use of DDREF is only applicable for an LNT dose response. This is because DDREF and dose thresholds represent alternative approaches to modeling low dose response. However, MACCS still allows analysts to use a dose threshold model and DDREF at the same time. Using both is a method to conduct sensitivity calculations of the LNT results. In this manner, the dose threshold acts as a truncation of the LNT health effects, which can allow the analyst to bin latent cancer results into different dose bins. Therefore, when using DDREF and a dose threshold, it is more precise to consider the latent cancer estimates as representing a portion of the total LNT results.

Number of Latent Cancer Effects is NUMACA.

Threshold Dose, DDTHRE, is the threshold dose for applying the dose and dose-rate effectiveness 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 dividing by DDREFA.

ACNAME is the name of each type of latent cancer.

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 (ones beginning with L-).

ACSUSC is the fraction of the population that is susceptible to the latent cancer.

CFRISK is the lifetime risk factor for a cancer fatality. This parameter has units of risk/Sievert.

CIRISK is the lifetime risk factor for a cancer incidence (injury). This parameter has units of risk/Sievert.

DDREFA is the dose and dose-rate effectiveness factor. When the lifetime dose commitment to an organ during the EARLY exposure period is less than DDTHRE, the risk of cancer for that organ is divided by DDREFA. Doses calculated in CHRONC are always divided by DDREFA because the doses are assumed to be below DDTHRE.

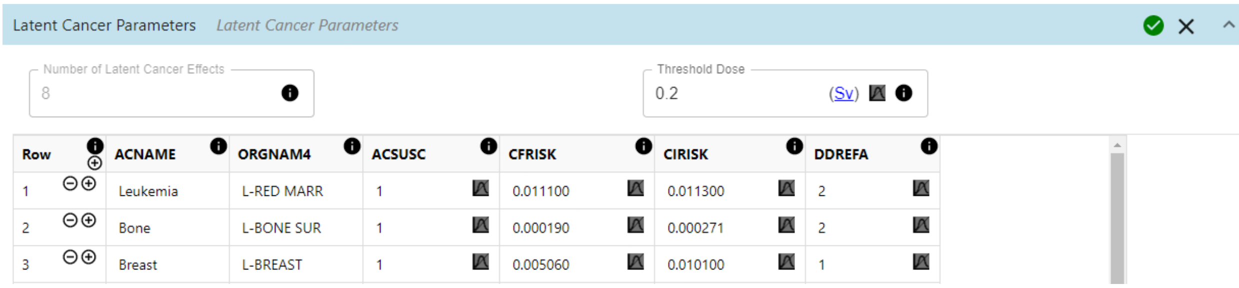


Figure 4-125. *Latent Cancer Parameters* form

Table 4-115. *Latent Cancer Parameters* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMACA	Linked	Integer	None	1 to 30
DDTHRE	Yes	Real	None	0 to 1 Sv
ACNAME	Yes	Character	NUMACA	1 to 10 characters
ORGNAM	Yes	Character	NUMACA	Lifetime Organ name from DCF File
ACSUSC	Yes	Real	NUMACA	0.0 to 1.0
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

4.3.9.1.4. Latent Cancer Linear Quadratic Form

The *Latent Cancer Linear Quadratic* Form is required when *Linear Quadratic Dose Response* is checked on the *PROPERTIES/Dose* tab, and *Latent Cancer Effects from Early Exposure* is checked on the *Health Effects* tab.

When *Linear Quadratic Dose Response* is not checked, ACTHRE, DOSEFA, and DOSEFB are automatically set to 0., 1., and 0., respectively, for each organ in the EARLY input file.

ACTHRE is the dose limit for the linear-quadratic 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 4.3.5.

DOSEFA defines the linear factor, alpha, of the dose dependence in the cancer risk model.

DOSEFB defines the quadratic factor, beta, of dose dependence in the cancer risk model. It is used in EARLY, but not in CHRONC. The quadratic factor is used when dose to an organ is below ACTHRE. The user should assign a value of zero to deactivate the quadratic portion of the linear-quadratic risk model.

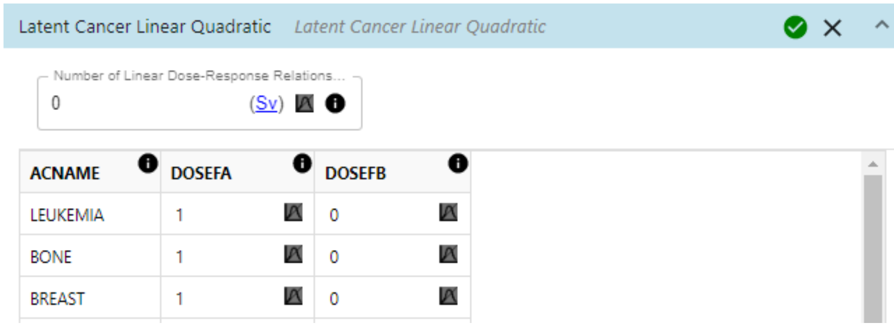


Figure 4-126. *Latent Cancer Linear Quadratic* form

Table 4-116. *Latent Cancer Linear Quadratic* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
ACTHRE	Yes	Real	None	0.0 to 10.0 Sv
DOSEFA	Yes	Real	NUMACA	0.0 to 2.0
DOSEFB	Yes	Real	NUMACA	0.0 to 2.0

4.3.10. Output Control

4.3.10.1. Debug Options Form

IPRINT specifies the quantity of debug output that is desired. The higher the value, the more output that is printed. Normal runs should use a value of zero.

Normally, centerline doses can be selected from the *Centerline Dose* form under *EARLY/Output Control* when *No Wind Shift with Rotation* is selected on the *Evac/Rotation* tab in *PROPERTIES*. 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.

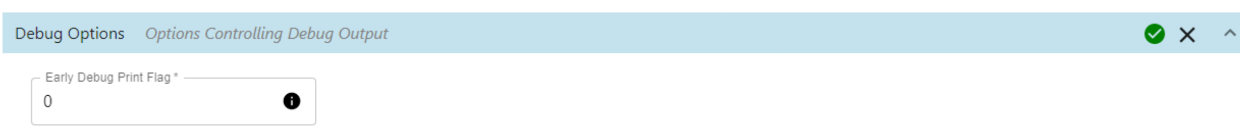


Figure 4-127. *Debug Options* form

For various values of IPRINT, the output file contains some intermediate results. These are described below.

Table 4-117. Results produced by values of IPRINT

IPRINT Value	Output Produced
≥1	• Skin DCFs • Centerline doses for all organs (when IPLUME=1) • Gaussian histogram and cloudshine correction factors • Return code values (RETCOD)
≥2	Final groundshine dose rate for each organ and each plume segment.
≥4	Acute dose for organs 2 and 3, early fatality, early injury, and cancer risk values for each spatial element.
≥8	Acute dose to organs 2 and 3 after completion of subroutines RELZON and ESTAT.

Table 4-118. *Debug Options* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
IPRINT	Yes	Integer	None	0 to 10

4.3.10.2. 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 results include the following dose pathways:

- Groundshine to the residents
- Inhalation of resuspended aerosols by the residents
- Consumption of food and water produced in the region (not necessarily by the residents)
- Groundshine exposure to workers required to decontaminate the area

Number of Health-Effect Cases Results Requested, NUM1, is determined by the number of rows in the grid containing values of vectors *NAME, I1DIS1, I2DIS1,* and *CCDF1*.

NAME indicates the type of result desired. Choices for this are presented by MACCS-UI, and depend on the values of parameter 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 also 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.

CCDF1 determines whether CCDF data are written to the MACCS output file and whether the results are to be included in the MACCS-UI summary report. MACCS-UI reports can also be generated on demand and independently of the choice of Report Options.

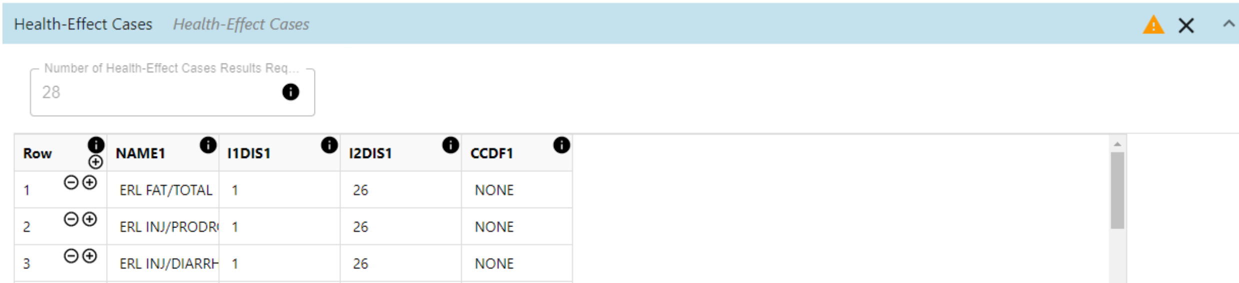


Figure 4-128. *Health-Effect Cases* form

Table 4-119. *Health-Effect Cases* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM1	Linked	Integer	None	0 to 999
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 (MACCS requires I2DIS2 ≥ I1DIS1)
CCDF1	Yes	Character	NUM1	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.2.1. Early-Fatality Radius Form

The *Early-Fatality Radius* form is optional. This result type is unavailable when *Early Fatality Effects* is not selected under the *Health Effects* tab.

Number of Early-Fatality Radius Results Requested, NUM2, is determined by the number of rows in the grid containing values of vectors RISTHR and CCDF2.

RISTHR defines the risk threshold used for calculating the fatality radius. 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 may possibly occur by setting this parameter to zero.

CCDF2 determines whether additional CCDF data are written to the MACCS output file and whether the results are to be included in the MACCS-UI summary report.

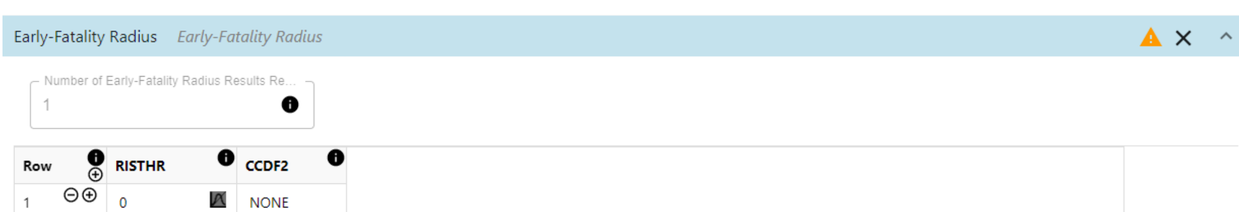


Figure 4-129. *Early-Fatality Radius* form

Table 4-120. *Early-Fatality Radius* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM2	Linked	Integer	None	0 to 999
RISTHR	Yes	Real	NUM2	0.0 to 1.0
CCDF2	Yes	Character	NUM2	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.3. 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.

Number of Population Exceeding Threshold Results Requested, NUM3, specifies the number of results. Its value is determined by the number of rows in the grid containing values of vectors NAME3, DOSTH3 and CCDF3.

NAME3 defines the name of the organ to which the dose threshold applies.

DOSTH3 defines the dose threshold that is used for counting the population.

CCDF3 determine whether CCDF data are written to the MACCS output file and whether they are included in the MACCS-UI summary report.

Figure 4-130. *Population Exceeding Threshold* form

Table 4-121. *Population Exceeding Threshold* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM3	Linked	Integer	None	0 to 999
NAME	Yes	Real	NUM3	Organ name from DCF File
DOSTH3	Yes	Real	NUM3	0.0 to 1000.0 Gy or Sv
CCDF3	Yes	Character	NUM3	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.4. 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 (i.e., population distribution).

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 of resuspended aerosols. The risk presented in this result does not include doses from ingestion of food and water by the population or doses to workers required to decontaminate the region. The reason these doses are excluded is that they cannot necessarily be attributed to the same population that resides in the area being evaluated.

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 CCDF4.

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 value of SPAEND(2).

NAME indicates the type of result desired. Choices are contained in a dropdown menu and depend on the values of parameter EINAME, which are the types of early injuries, and ACNAME, which are the types of latent cancers. Totals for early fatalities and cancer fatalities are also available.

CCDF4 determines whether CCDF data are written to the MACCS output file and whether they are included in the summary report.

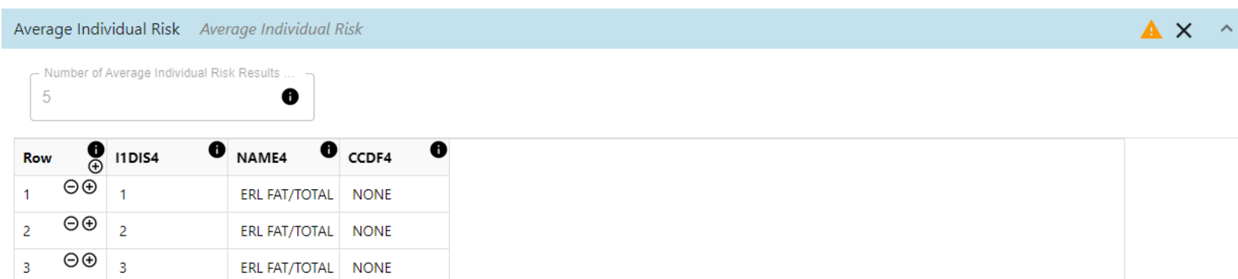


Figure 4-131. *Average Individual Risk* form

Table 4-122. *Average Individual Risk* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM4	Linked	Integer	None	0 to 999
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]
CCDF4	Yes	Character	NUM4	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.5. Population Dose Form

The *Population Dose* form is optional. This form requests that population dose to a given organ be reported. 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. In the results calculated by CHRONC, the cancer results include the following dose pathways:

- Groundshine to the residents
- Inhalation of resuspended aerosols by the residents
- Consumption of food and water produced in the region (not necessarily by the residents)
- Groundshine exposure to workers required to decontaminate the area

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.

CCDF5 determines whether CCDF data are written to the MACCS output file and whether they are included in the summary report.

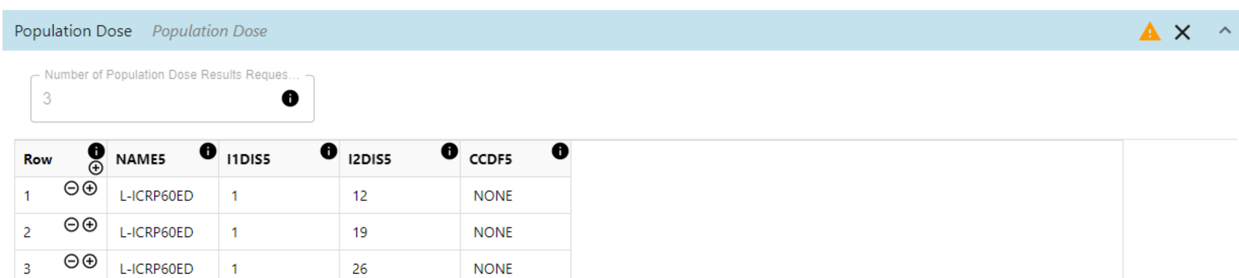


Figure 4-132. *Population Dose* form

Table 4-123. *Population Dose* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM5	Linked	Integer	None	0 to 999
NAME	Yes	Character	NUM5	Organ name from DCF File
I1DIS5	Yes	Integer	NUM5	1 to NUMRAD
I2DIS5	Yes	Integer	NUM5	1 to NUMRAD (MACCS requires I2DIS5 ≥ I1DIS5)
CCDF5	Yes	Character	NUM5	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.5.1. Centerline Dose Form

The *Centerline Dose* form is optional. This form is available when *No Wind Shift with Rotation* is selected on the *Evac/Rotation* tab on the *PROPERTIES* form. In this case, MACCS reports the centerline dose between a range of distances for a set of dose pathways and for acute and lifetime doses.

Table 4-124. Supported pathways/dose types

Pathway	Description	Calculation
CLD	cloudshine dose	EARLY
GRD	groundshine dose	EARLY, CHRONC
INH ACU	acute dose from inhalation of the passing plume	EARLY
INH LIF	lifetime dose from inhalation of the passing plume	EARLY, CHRONC
TOT ACU	total acute dose from all direct exposure pathways	EARLY
TOT LIF	total lifetime dose from all direct exposure pathways	EARLY, CHRONC
RES ACU	acute dose from inhalation of resuspended material after plume passage	EARLY
RES LIF	lifetime 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 the results for the pathways it includes. When pathways 'GRD', 'INH LIF', '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 or risk are included in the output.

NUM6 specifies the number of centerline dose results to be reported. 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

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.

CCDF6 determines whether CCDF data are written to the MACCS output file and whether they are included in the summary report.

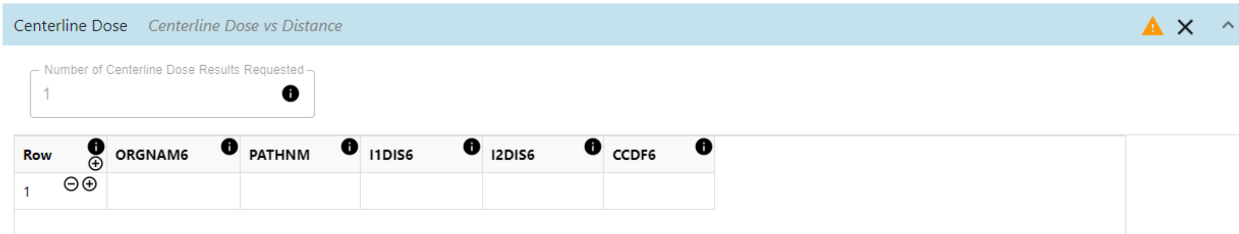


Figure 4-133. *Centerline Dose* form

Table 4-125. *Centerline Dose* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM6	Linked	Integer	None	0 to 999
ORGNAM	Yes	Character	NUM6	Organ name from DCF File
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 (MACCS requires I2DIS6 ≥ I1DIS6)
CCDF6	Yes	Character	NUM6	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.5.2. Centerline Risk Form

The *Centerline Risk* form is optional. This form is available when Wind Shift and Rotation is set to No Wind Shift with Rotation on the *Evac/Rotation tab* on the *PROPERTIES* form.

Centerline risk is calculated for phantom individuals located directly under the plume centerline who are exposed to 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 listed in a dropdown menu and depend on the values of parameter 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.

CCDF7 determines whether CCDF data are written to the output file and whether the data are included in the report generated after simulations are completed.

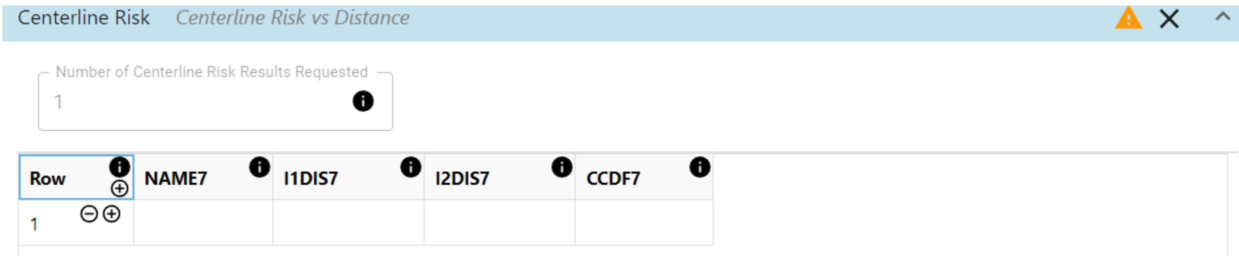


Figure 4-134. *Centerline Risk* form

Table 4-126. *Centerline Risk* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM7	Linked	Integer	None	0 to 999
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
I2DIS7	Yes	Integer	NUM7	1 to NUMRAD (MACCS requires I2DIS7 ≥ I1DIS7)
CCDF7	Yes	Character	NUM7	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.5.3. 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 accounts for the population distribution.

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 ingestion of contaminated food and water or 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 CCDF8.

NAME indicates the type of health effect desired. Choices depend on the values of parameter 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.

CCDF8 determines whether CCDF data are written to the output file and whether they are included in the MACCS report generated after simulations are completed.

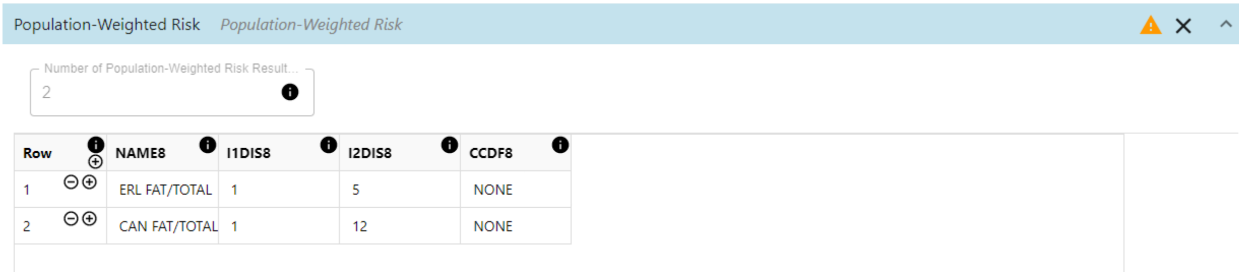


Figure 4-135. *Population Weighted Risk* form

Table 4-127. *Population Weighted Risk* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM8	Linked	Integer	None	0 to 999
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 (MACCS requires I2DIS8 ≥ I1DIS8)
CCDF8	Yes	Character	NUM8	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.6. 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 when multiple plume segments each travel in their own direction. Peak dose is more general than centerline dose because it calculates the maximum dose around the compass for any of the plume transport options. The implementation of this result differs from centerline dose in two ways:

- There is no option to report a breakdown of individual doses by pathway
- Peak dose represents an average dose over the width of a fine grid and is not a point value like centerline dose.

Peak doses are produced for each emergency response cohort. The doses depend 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 coarse 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 questionable when multiple plume segments travel in different directions (*i.e.,* when NUMREL is greater than 1 and either *Wind Shift* option is selected).

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 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.

CCDFA determines whether CCDF data are written to the output file and whether they are included in the summary report.

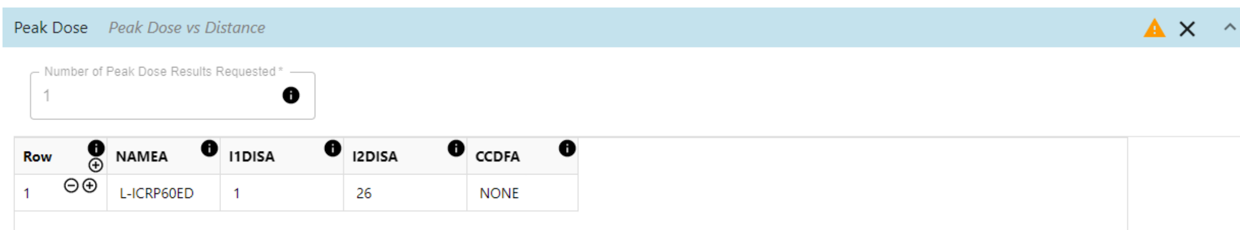


Figure 4-136. *Peak Dose* form

Table 4-128. *Peak Dose* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMA	Linked	Integer	None	0 to 999
NAME	Yes	Character	NUMA	Organ name from DCF File
I1DISA	Yes	Integer	NUMA	1 to NUMRAD
I2DISA	Yes	Integer	NUMA	1 to NUMRAD (MACCS requires I2DISA ≥ I1DISA)
CCDFA	Yes	Character	NUMA	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.7. 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) grid location. Individual doses at locations other than directly under the plume(s) are reported with this option. There is no option to report 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 to be at a (r,θ) grid location. 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 because this in an individual dose and ingestion dose is not attributed to a specific individual.

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 NUMCOR). 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 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 calculated.

IANG_B defines the angular index of the grid element for which this result is calculated.

CCDFB determines whether CCDF data are written to the MACCS output file and whether they are included in the summary report.

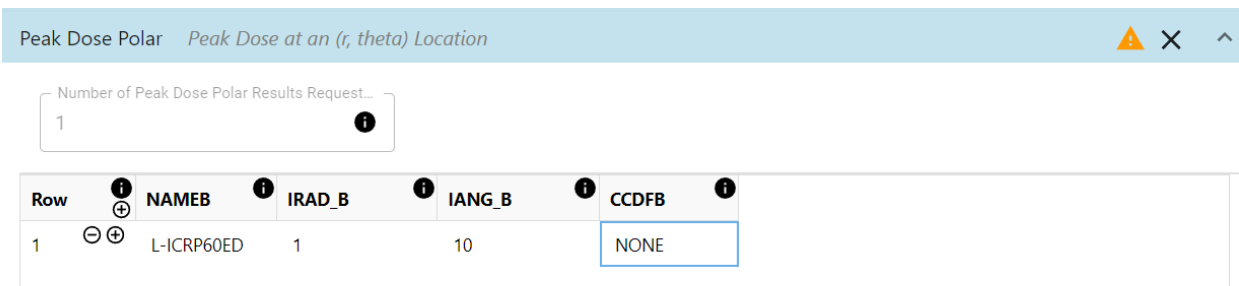


Figure 4-137. *Peak Dose Polar* form

Table 4-129. *Peak Dose Polar* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMB	Linked	Integer	None	0 to 999
NAME	Yes	Character	NUMB	Organ name from DCF File
IRAD_B	Yes	Integer	NUMB	1 to NUMRAD
IANG_B	Yes	Integer	NUMB	1 to NUMCOR
CCDFB	Yes	Character	NUMB	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.8. 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 and selected organ can be 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 depend on the DCF file chosen.

ELEVDOSE is the threshold dose value for calculating land contamination areas. Land area that is contaminated above the threshold dose level is reported in the output. The dose level is calculated a representative individual in a grid element who evacuates or relocates according to the parameters defining a cohort. Results are provided for each cohort.

PRINT_FLAG_C set to True means that the output includes dose levels to the specified organ for each grid element. Otherwise, these results are suppressed.

CCDFC determines whether CCDF data are written to the MACCS output file and whether they are included in the summary report.

Figure 4-138. *Land Area Exceeding Dose* form

Table 4-130. *Land Area Exceeding Dose* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMC	Linked	Integer	None	0 to 999
ORGNAM	Yes	Character	NUMC	Organ name from DCF File
ELEVDOSE	Yes	Real	NUMC	0.0 to 10^{12} Sv
PRINT_FLAG_C	Yes	Logical	NUMC	True, False
CCDFC	Yes	Character	NUMC	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.9. 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 request ground concentrations and time-integrated, ground-level, air concentrations be reported 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 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.

CCDFD determines whether CCDF data are written to the MACCS output file and whether they are included in the summary report.

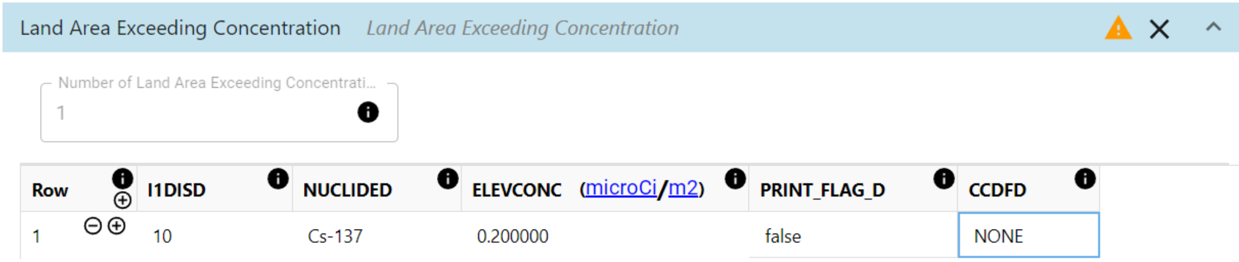


Figure 4-139. *Land Area Exceeding Concentration* form

Table 4-131. *Land Area Exceeding Concentration* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMD	Linked	Integer	None	0 to 999
I1DISD	Yes	Integer	NUMD	1 to NUMRAD
NUCLIDE	Yes	Character	NUMD	Must select a radionuclide from NUCNAM
ELEVCONC	Yes	Real	NUMD	0.0 to 10^{12} Bq/m^2
PRINT_FLAG_D	Yes	Logical	NUMD	True, False
CCDFD	Yes	Character	NUMD	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.10. 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 if 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 considered 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 is defined by the outer boundary of the specified radial grid element. The fraction of the population within this boundary exiting the region as a function of time is reported in the output.

TIMDIVE is the time interval for reporting.

CCDFE determines whether CCDF data are written to the output file and whether they are included in the summary report.

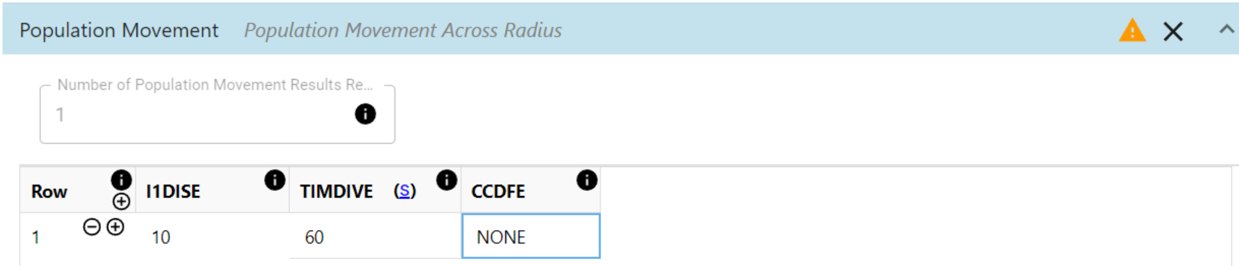


Figure 4-140. *Population Movement* form

Table 4-132. *Population Movement* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUME	Linked	Integer	None	0 to 999
I1DISE	Yes	Integer	NUME	1 to LASMOV
TIMDIVE	Yes	Integer	NUME	60 to 86400 s
CCDFE	Yes	Character	NUME	CCDF, NONE, REPORT, CCDF & REPORT

4.3.10.11. Animation Radionuclides Form

Currently, there are two types of animation files that can be selected to be created. If the option *Create Animation Concentration Output* is selected on the *Animation* tab, then the *Animation Radionuclides for Concentration File* form under *Output Control* must be filled out with the list of radionuclides that the user wants to be include in the animation file.

NUM_NUC_ANIM defines the number of radionuclides to be included in the animation concentration file.

NUC_ANIM defines the radionuclides to be included in the animation concentration file.

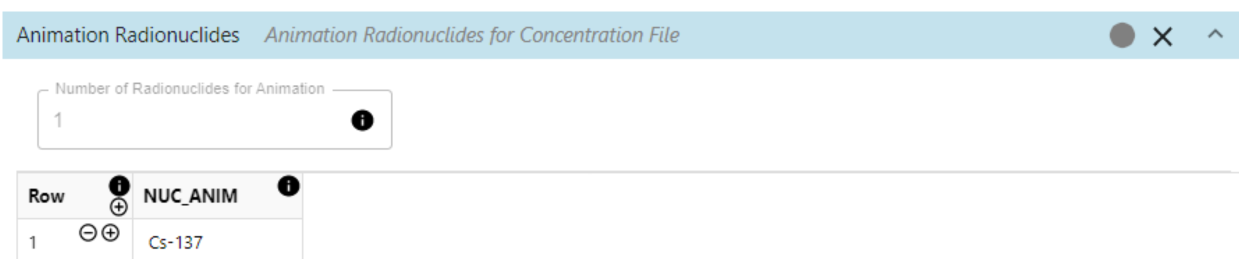


Figure 4-141. *Animation Radionuclides* form

Table 4-133. *Animation Radionuclides* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM_NUC_ANIM	Linked	Integer	None	1 to 10
NUC_ANIM	Yes	Character	NUM_NUC_ANIM	From DCF file

4.3.10.12. Projective Peak Dose Form

MACCS 4.1 introduced a new *Projective Peak Dose* output control form to project a peak dose over a fixed exposure window. This may be of interest to project doses for comparison to emergency response guidelines for evacuation. Each dose will be calculated running from the time a plume arrives at a grid element to the end of the given time period. Then the maximum of the sum of the different plume releases will be set as the peak dose.

NUMF defines the number of results of this type being requested.

NAME defines the name of the organ for the dose measure.

DURATION defines the time duration for the moving projective peak dose time window.

CCDFF indicates which outputs will be displayed: NONE, CCDF, REPORT, and CCDF & REPORT.

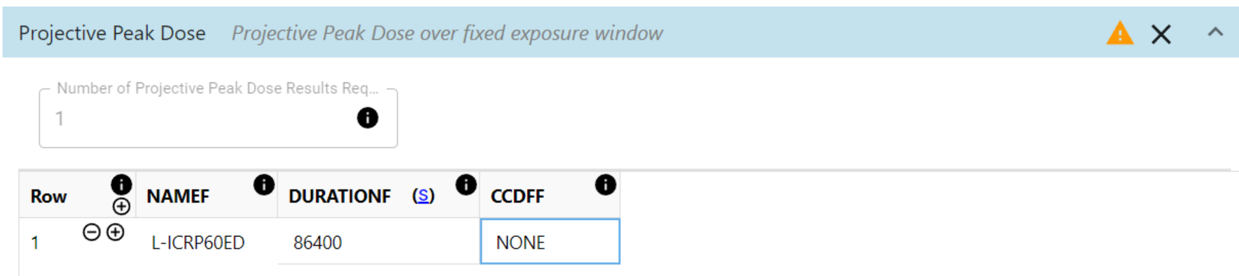


Figure 4-142. *Projective Peak Dose* form

Table 4-134. *Projective Peak Dose* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMF	No	Integer	None	0 to 999
NAMEF	Yes	Logical	NUMF	Based on DCF file
DURATION	Yes	Real	NUMF	0 to 1 x 10^{10} s
CCDFF	Yes	Character	NUMF	NONE, CCDF, REPORT, CCDF & REPORT

4.4. CHRONC

4.4.1. Overview

The CHRONC module simulates the events that occur following the emergency phase 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 radiation exposures from accidental radiological releases: groundshine, resuspension inhalation, and ingestion of contaminated food and water. The models used to predict the doses from these three 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.

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. Like 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. 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.

4.4.1.1. 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 thirty years, but it is usually modeled as 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, which is that the projected dose is less than the maximum acceptable dose, 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 and per-diem economic cost (RELCST).

4.4.1.2. 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 criteria set by the user.

Decisions on mitigative actions during the long-term phase are based on three independent sets of safety criteria as follows:

- Decisions are made relating to whether land at a specific location and time is suitable for human habitation. These criteria are often called the habitability criteria.
- Decisions are made relating to whether land at a specific location and time is suitable for agricultural production. These criteria are often called the farmability criteria.
- Decisions are made relating to whether land at a specific location and time requires decontamination and whether people can permanently return. This criterion is often called the cleanup criterion.

In addition to these three sets of safety criteria, MACCS also considers cost effectiveness of decontamination. If it is not cost effective to decontaminate (plus additional interdiction when required to reach habitability), then land is condemned.

4.4.1.3. Decontamination, Reoccupation, and Condemnation Decision-Making

Decontamination decision making determines whether land requires decontamination. It also determines whether people can return after decontamination, people can return after a combination of decontamination and additional interdiction, or land is condemned. In MACCS version 4.1 and earlier, these decisions were determined using the habitability criterion. With MACCS 4.2, these decisions are determined using a new criterion known as the cleanup criterion. The following new independent cleanup criterion variables have been added: DECCRLT defines the long-term phase cleanup dose criterion for decontamination and DECDPP defines the long-term phase dose projection period for decontamination.

The ability to specify a cleanup criterion that is separate from the habitability criterion provides additional flexibility in decontamination decision making. The cleanup criterion determines the area subject to decontamination, and it applies to both habitable and interdiction areas. When the cleanup criterion is less than the habitability criteria, decontamination can occur in lightly contaminated, habitable areas. In areas that exceed the habitability criteria, the cleanup criterion also acts as a return criterion that determines if and when people will permanently reoccupy an area.

Decontamination remedies apply to any farmland and non-farmland area that exceeds the cleanup criterion when the property is not otherwise condemned. When the land exceeds the cleanup criterion, a progressive series of actions are evaluated, beginning with decontamination using the various user-defined decontamination levels. The dose reduction during decontamination is twofold:

- Doses are reduced by a dose reduction factor (DRF, input parameter 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.

These two factors are independent. That is, when the user specifies a DRF of 2 and a decontamination period of one year, the doses to the population after decontamination are generally less than half of the doses before decontamination because decontamination, weathering, and radioactive decay all work to reduce subsequent doses.

When doses exceed the cleanup criterion, the first level (smallest DRF) of decontamination is considered first. When this DRF plus weathering and decay is enough to meet the cleanup criterion immediately after decontamination, this level of decontamination is performed. When the first level of decontamination is not sufficient, higher levels of decontamination are considered. MACCS allows up to three levels.

For interdicted areas, the population is assumed to return after decontamination and doses no longer exceed the cleanup criterion. When the highest level of decontamination is insufficient to reduce doses below the cleanup criterion, MACCS evaluates whether performing this level of decontamination plus additional interdiction would restore the property. MACCS allows up to 30 years of interdiction when it performs this calculation. If the cleanup level in interdicted areas cannot be reached, MACCS declares the land to be condemned.

For habitable areas, the highest level of decontamination is the last action MACCS considers. If the highest level of decontamination is insufficient to reach the cleanup level by the end of decontamination, MACCS simply applies the highest level and allows the dose to exceed the cleanup level. When additional time after decontamination is considered, the land will eventually reach the cleanup level. MACCS does not consider interdiction of habitable areas and condemnation of habitable areas will not occur if the cleanup level cannot be reached in a given timeframe.

For interdicted areas that require the maximum decontamination level plus additional interdiction time for dose reduction, the effect of weathering and decay over the interdiction period is calculated with an interpolation technique that uses 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 30 years. So, the three dose projections are calculated at starting times of 1, 5, and 30 years after the maximum level of decontamination would be complete.

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. However, decontamination plus additional interdiction is usually not cost effective when the required interdiction period is significantly less than 30 years.

In MACCS 4.2, the decontamination cost-effectiveness decision process remains in effect and has been expanded to include decontamination decisions in habitable areas. If the total cost to decontaminate is greater than the cost to condemn the land, MACCS declares land to be condemned. Although condemnation of a habitable area is possible, it is less likely than in interdicted areas since the cost of decontamination in habitable areas is just cleanup and not cleanup + interdiction.

When a decision to condemn land is reached, it occurs immediately at the beginning of the long-term phase; the model assumes that decontamination is not performed, and that the population never returns. Thus, MACCS calculates the corresponding long-term food and population doses to be zero for the condemned land and assesses an economic cost for condemnation. If condemnation does not occur, MACCS assumes the population fully returns when interdiction is lifted. At this time, the economic costs cease to accumulate and long-term doses after return are tallied.

4.4.1.4. Farmability Decision-Making

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 can be decontaminated to allow humans to return to the farmland, it is next evaluated for farmability, which means that contamination levels of the agricultural products are low enough to be consumed. When using the COMIDA2 food-chain model, 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.

The farmability criteria can be stricter than the cleanup criterion, so it is possible that farmland is not subject to decontamination but still not farmable. Decontamination in MACCS reduces resuspension inhalation and groundshine doses; it does not reduce food ingestion doses and therefore does not restore farmland that is interdicted due to exceedance of farmability criteria. Farmland that does not require decontamination but is not farmable is either interdicted without decontamination or condemned.

4.4.2. Basic Parameters

4.4.2.1. Chronc Description Form

The *Chronc Description* form contains one variable, a brief description of the CHRONC model used in the calculation. This form is required.

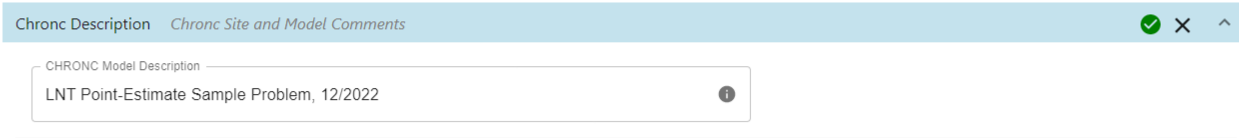


Figure 4-143. *Chronc Description* form

Table 4-135. *Chronc Description* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CHNAME	Yes	Character	None	1 to 80 characters

4.4.2.2. Property Form Parameters Form

This form allows the user to observe how the choices made on the *PROPERTIES* form define some important parameters that are required in the CHRONC input. The parameters on this form are read-only and cannot be changed from this form. Details about the effect of these parameters are provided in the subsections below.

Food Model Flag, FDPATH, determines the food-chain model used. It can be set to:

- OLD, to use the MACCS 1.5 food chain model;
- NEW, to use the COMIDA2 food chain model; or,
- OFF, to not use a food chain model.

Number of Terms in Growing Crop Retention Model, NTTRM, is the number of terms used in the growing crop retention model. This parameter is only relevant when FDPATH is set to OLD.

Economic model flag, ECON_MODL, defines which economic model is used for the economic consequence calculation. Original uses the original MACCS cost-based model, and RDEIM uses the new GDP-based economic model.

Number of dose projection criterion used, LTDPMOD, determines the number of dose projection criterion used. Selecting:

- ONE means that only one dose projection period, corresponding with DSCRLT1, TMPACT1, and LTDPDL1.
- TWO means two dose projection periods are used, the first with DSCRLT1, TMPACT1, and LTDPDL1 and the second with DSCRLT2, TMPACT2, and LTDPDL2.

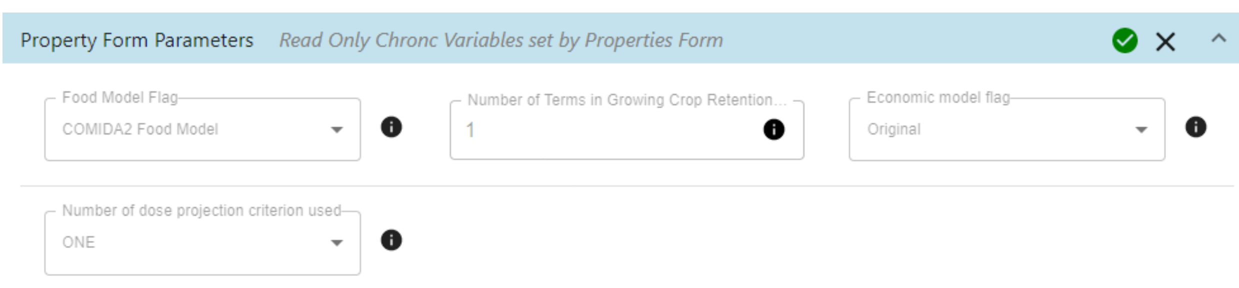


Figure 4-144. *Property Form Parameters* form

All parameters are read-only and dimensionless.

Table 4-136. ***Property Form Parameters*** **parameter inputs**

Parameter	Description	Type	Allowed Values	Defined on *PROPERTIES* Tab
FDPATH	Food Model Flag	Character	NEW, OFF, OLD	*Food* tab
NTTRM	Number of Crop Weathering Terms	Integer	1 to 3	*Food* tab
ECON_MODL	Economic Model Option	Character	Original, RDEIM	*Econ* tab
LTDPMOD	Long-term dose criterion for habitability	Character	ONE, TWO	*Dose tab*

4.4.3. *Shielding and Exposure*

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 and is commonly used. However, there are some reasons why the factors could be different for these phases. The main reason is potential equilibration of contamination levels between the exterior and interior of buildings after an extended period. The usual assumption in estimating these factors for the emergency phase is that the exterior is contaminated but the interior is relatively 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 building can cause some level of contamination on 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 possible 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 longer-term influences on these factors.

4.4.3.1. *Shielding and Exposure Form*

The *Shielding and Exposure* form is required.

Inhalation Protection Factor, LPROTIN, can be set to:

- 0, to indicates complete protection from inhalation of radioactive materials; or,
- 1, indicating no protection, corresponding to a person standing outdoors with no protection from the surrounding atmosphere.

Breathing Rate, LBRRATE, is the long-term breathing rate. There is a range of breathing rates that can be assigned 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.

Groundshine Shielding Factor, LGSHFAC, 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. Other shielding from houses and building would be expected to reduce this factor below 0.7.

Figure 4-145. *Shielding and Exposure* form

Table 4-137. *Shielding and Exposure* parameter Inputs

Parameter	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

4.4.4. Dose Projection

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 critical organ for the dose. It is used to estimate a dose that would occur if no protective action were taken. The purpose is to protect the population by ensuring that the projected dose 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 defined by DPP_INTPHAS, 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.

4.4.4.1. Dose Projection Form

The *Dose Projection* form is required when *Use Optional DPP_INTPHAS value* is enabled in *PROPERTIES/Scope* tab.

It contains a single parameter that defines the exposure period for dose projection used in the relocation criterion for the intermediate phase.

DPP_INTPHAS is the dose projection period for relocation during the intermediate phase.

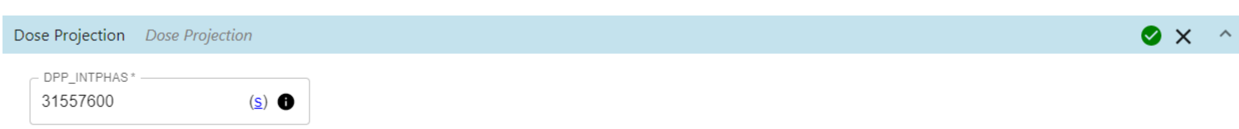


Figure 4-146. *Dose Projection* form

Table 4-138. ***Dose Projection*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
DPP_INTPHAS	Yes	Real	None	0.0 to 10^{10} s

4.4.5. *Evacuation and Relocation Cost*

The evacuation and relocation costs describe the expected compensation for people who 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).

4.4.5.1. Compensation Costs Form

The *Compensation Costs* form is required.

Some of the compensation parameters are for actions taken during the emergency phase. Nonetheless, these parameters are CHRONC inputs because the costs of these actions are only tallied when CHRONC is run.

Emergency Evacuation Cost, EVACST, is 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.

Immediate Relocation Cost, RELCST, is 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.

Long-Term Relocation Cost, POPCST, defines the per-capita, one-time relocation cost for temporary or permanent relocation of population and businesses in a region that is interdicted 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.

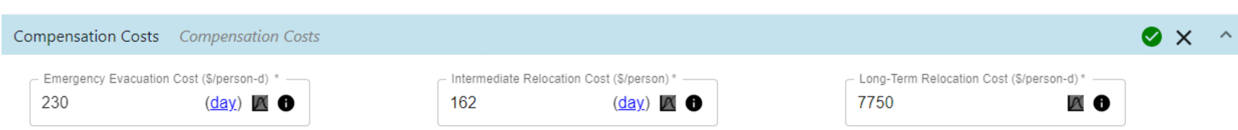


Figure 4-147. *Compensation Costs* form

Table 4-139. ***Compensation Costs*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
EVACST	Yes	Real	None	0 to 1000 $/person-day
RELCST	Yes	Real	None	0 to 1000 $/person-day
POPCST	Yes	Real	None	10^{-6} to 10^{6} $/person

4.4.6. Long-Term Protective Action

The long-term protective action parameters define the intermediate and long term action time periods as well as the maximum doses that people can receive during these periods. The maximum allowable doses defined here are used to determine the need for relocation, decontamination, interdiction, and condemnation.

4.4.6.1. Long-Term Exposure Period Form

The *Long-Term Exposure Period* form is required.

Intermediate-phase duration, DUR_INTPHAS, is the duration of the intermediate phase. This phase follows the emergency phase. In the MACCS model, each phase is distinct and contiguous. The U.S. Environmental Protection Agency (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.

Long-term exposure period, EXPTIM, 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, dose 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 originate.

Cleanup projected dose period, DECDPP, is the projected dose period used for cleanup.

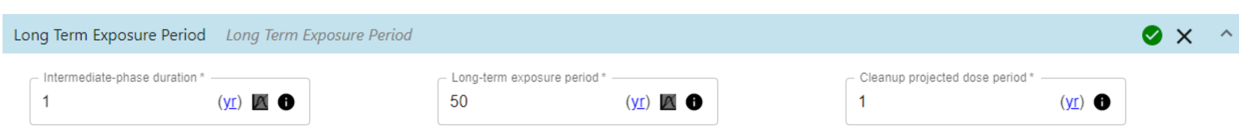


Figure 4-148. ***Long-Term Exposure Period*** **form**

Table 4-140. ***Long-Term Exposure Period*** **parameter input**

Parameter	Definable	Type	Dimensions	Allowed Values
DUR_INTPHAS	Yes	Real	None	0 to 9.46×10^{8} s (30 yrs)
EXPTIM	Yes	Real	None	0 to 10^{10} s
DECDPP	Yes	Real	None	0 to 10^{10} s

4.4.6.2. Long-Term Dose Criterion Form

The *Long-Term Dose Criterion* form is required.

Intermediate Dose Criterion, DSCRTI, is the maximum allowable dose to the long-term critical organ (CRTOCR) over the intermediate-phase dose projection period (DPP_INTPHAS). 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.

Long-term Critical Organ Name, CRTOCR, defines the critical organ that is used for both the intermediate and long-term phases.

Cleanup dose criterion, DECCRLT, is used in decontamination and interdiction. The cleanup criterion determines if a grid element is subject to decontamination, and it applies to both habitable and interdicted grid elements. When the cleanup criterion is less than the habitability criteria, decontamination can occur in lightly contaminated, habitable grid elements. In grid elements that exceed the habitability criteria, the cleanup criterion also acts as a return criterion that determines when (or if) people will permanently reoccupy the area.

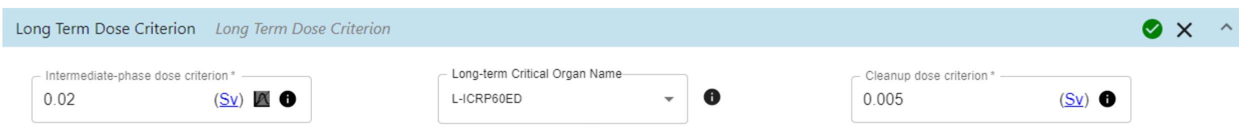


Figure 4-149. *Long-Term Dose Criterion* form

Table 4-141. *Long-Term Dose Criterion* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DSCRTI	Yes	Real	None	0 to 10^5 Sv
CRTOCR	Yes	Character	None	Organ names from DCF File
DECCRLT	Yes	Real	None	10^{-20} to 10^5 Sv

4.4.6.3. First and Second Long-Term Dose Criterion Forms

The *First Long-Term Dose Criterion* form is required. A *Second Long-Term Dose Criterion* form is also available and required when *Use Two Long-Term Dose Criterion for Habitability* is selected on the *Dose* tab of the *PROPERTIES* form.

The *long-term habitability projected dose criterion*, DSCRLT1 and DSCRLT2, are the maximum allowable direct-exposure dose commitment to the long-term critical organ (CRTOCR) during long-term habitability projected dose periods (TMPACT1, TMPACT2). The direct exposure pathways considered in this evaluation are groundshine and resuspension inhalation.

The *long-term habitability projected dose periods*, TMPACT1 and TMPACT2, correspond to the long-term dose limit, DSCRLT1 and DSCRLT2, respectively. The dose projection is performed 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 establishes 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 the property can be restored later, as described in Section 4.4.7.

The *long-term habitability projected dose delays* correspond to LTDPDL1 and LTDPDL2.

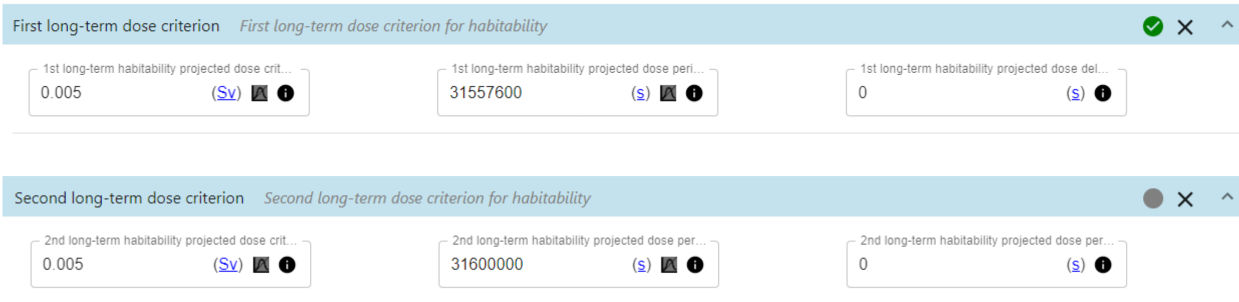


Figure 4-150. *First* and *Second Long-Term Dose Criterion* Forms

Table 4-142. *First* and *Second Long-Term Dose Criterion* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DSCRLT1 or DSCRLT2	Yes	Real	None	10^{-20} to 10^{5} Sv
TMPACT1 or TMPACT2	Yes	Real	None	0 to 10^{10} s
LTDPDL1 or LTDPDL2	Yes	Real	None	0 to EXPTIM s

4.4.7. 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, DRF.

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 independent of the type of area being decontaminated. However, because decontamination in MACCS does not reduce farm food contamination, decontamination does not restore use of farmland that is projected to produce excessive foodstuff contamination.

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 that non-farmland is decontaminated and restored to use but farmland is instead condemned within the same grid element.

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 of what it would have been without decontamination. Dose reduction factors are presented in Table 4-143.

Table 4-143. Decontamination factors

Dose Reduction Factor	Percent of Dose Reduction
2	50%
3	66.7%
5	80%
10	90%
15	93.3%
20	95%

During the decontamination period, which is assumed to begin at the start of the long-term phase, the population is 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 population dose tabulated in the MACCS output.

Decontamination reduces direct exposure doses (both groundshine and resuspension) caused by contamination of land and buildings. Some 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. Therefore, decontamination is not considered for restoring farmability. Nonetheless, contamination levels from produce, meat, and dairy products drops significantly in the second year because edible surfaces can be contaminated by direct deposition only in the first year of the accident.

4.4.7.1. Number of Plan Levels Form

The *Number of Plan Levels* form is required.

Number of Decontamination Levels, LVLDEC, is the number of levels that can be used. Each decontamination level represents an alternative strategy to reduce the projected long-term groundshine and resuspension inhalation doses.

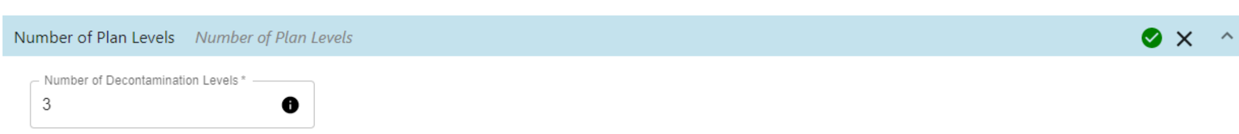


Figure 4-151. *Number of Plan Levels* form

Table 4-144. *Number of Plan Levels* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
LVLDEC	Yes	Integer	None	1 to 3

4.4.7.2. Plan Definition Form

The *Plan Definition* form is required.

Decontamination Labor Cost, 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 when there is more than one decontamination plan.

DSRFCT defines the effectiveness of the various decontamination levels for 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 when there is more than one plan.

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.

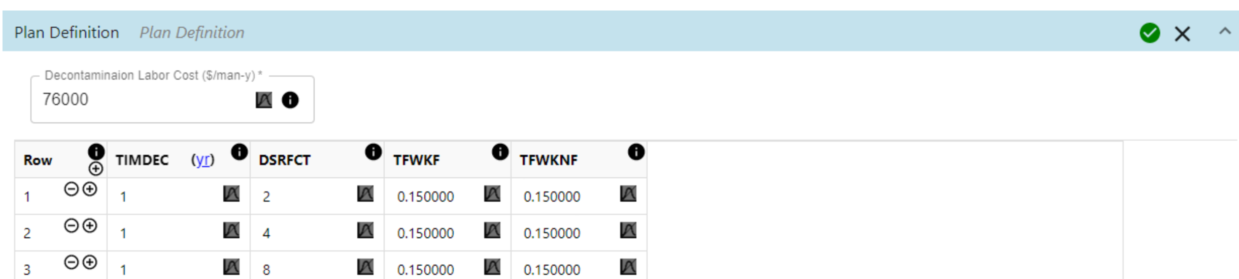


Figure 4-152. *Plan Definition* form

Table 4-145. *Plan Definition* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DLBCST	Yes	Real	None	1.0 to 10^6 $/person-yr
TIMDEC	Yes	Real	LVLDEC	10^{-6} to 9.46×10^8 s (30 yrs)
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

4.4.7.3. Farmland Costs Form

The *Farmland Costs* form is required when CHRONC is enabled.

CDFRM defines the farmland decontamination costs for each level of decontamination. Values must be monotonically increasing when more than one plan is defined.

FRFDL defines the fraction of the farmland decontamination cost that is due to labor for each level of decontamination.

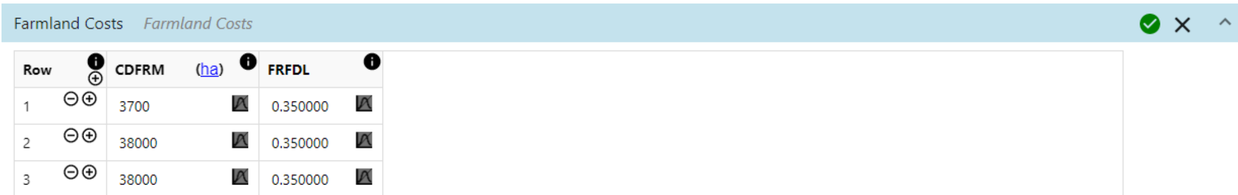


Figure 4-153. *Farmland Costs* form

Table 4-146. *Farmland Costs* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CDFRM	Yes	Real	LVLDEC	1.0 to 10^6 \$/ha
FRFDL	Yes	Real	LVLDEC	0.0 to 1.0

4.4.7.4. NonFarmland Costs Form

The *NonFarmland Costs* form is required when CHRONC is enabled.

CDNFRM defines the non-farmland decontamination costs for each level of decontamination. Values must be monotonically increasing when more than one plan is defined.

FRNFDL defines the fraction of the non-farmland decontamination cost that is due to labor for each level of decontamination.

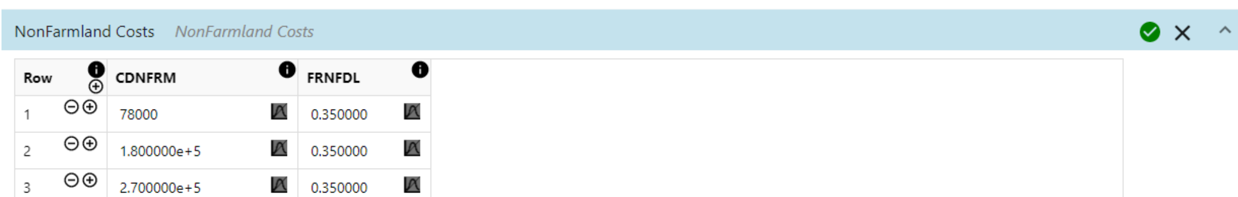


Figure 4-154. *NonFarmland Costs* form

Table 4-147. *NonFarmland Costs* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CDNFRM	Yes	Real	LVLDEC	1.0 to 10^6 \$/person
FRNFDL	Yes	Real	LVLDEC	0.0 to 1.0

4.4.8. Interdiction Costs

The interdiction plan cost data block defines the parameters needed to calculate the cost of interdiction. The values supplied here are combined with values in the site data file (if one is used) and the regional characteristics data to estimate losses.

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 from depreciation and loss of use during both decontamination and temporary interdiction periods.

4.4.8.1. Interdiction Costs Form

The *Interdiction Costs* form is required when CHRONC is enabled.

Depreciation Rate, DPRATE, defines the 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 improvements resulting from a lack of habitation and maintenance. Depreciation losses are compounded continuously.

Expected Rate of Return, DSRATE, defines the expected rate of return from land, buildings, equipment, etc. It also used for discounting losses that occur in future years. Losses are compounded continuously.

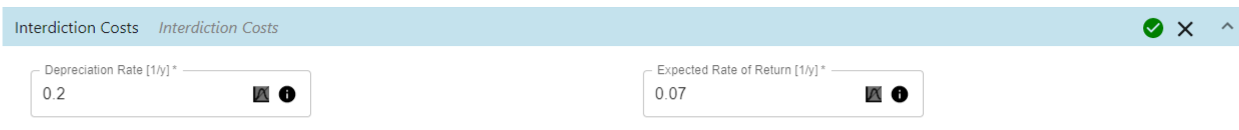


Figure 4-155. *Interdiction Costs* form

Table 4-148. *Interdiction Costs* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DPRATE	Yes	Real	None	0.0 to 1.0 yr^{-1}
DSRATE	Yes	Real	None	0.0 to 1.0 yr^{-1}

4.4.9. GDP Economic Parameters

RDEIM (Regional Disruption Economic Impact Model) is an economic model that estimates the impact on direct, indirect, and induced GDP, for a disrupted geographic area. Indirect GDP losses are calculated using national RIMS II (Regional Input-Output Modeling System) multipliers. In addition to GDP losses, the RDEIM model also captures other losses for property damage and expenditures in a similar way to the cost-based economic valuation model.

The result of the RDEIM GDP model is direct, indirect, and induced GDP losses for each industry in the grid and recovery values associated with each type of loss. This is accomplished by aggregating the RDEIM county-level results to a grid-level result that accounts for full and partial counties affected by an accident.

RDEIM uses state-of-practice input-output (I-O) economics to develop estimates of economic impact due to business disruption resulting from an atmospheric radioactive release. The modeling process considers multiple types of GDP impacts in its estimations: direct losses are losses to the affected region in which the business disruption occurs; indirect losses are to the remainder of the US economy, ie: disruption to the supply chain; and induced losses correspond to the lost spending power from the income of impacted workers. These categories are described more precisely below:

- Direct impacts result from a loss of final demand of a product or service due to the supplier firm of that product or service being in the affected region.
- Indirect impacts result from the lack of demand for goods/services within the directly affected area. These can be thought of as supplier firms outside the directly affected region that are no longer supplying those persons/companies/areas within the affected region. This excludes any geographic areas that are contained within the disrupted region. Previous

versions of MACCS combined the indirect impacts and the recovery impacts and displayed this as a single value in the indirect cost category. MACCS 5.0 now separates recovery values from indirect costs and displays both values separately in the output.

- Induced impacts result from the spending by workers whose incomes were affected/interrupted by the disruption. This loss applies to both the directly and indirectly affected regions.

Direct impacts occur in a known geographic area, unlike indirect impacts, which may occur throughout the nation. Additionally, suppliers may exist within the actual affected area, introducing an opportunity for double counting these suppliers as both direct (based on geographic location) and indirect (based on who the supplier supplies) impact contributions. Additional complexity is introduced in the induced impacts where workers lost wages cannot be wholly attributed to lost economic stimulus (sales) within the affected region. Those workers may spend none, some, or all their income in the affected region with the remainder being spent outside of that region.

RDEIM estimates these losses for both the regional and national economies. Additionally, independent recovery schedules for local and national markets are permitted, under the premise that the national recovery timeframe is always shorter than that of the regional economic recovery.

Two spatial regions are naturally defined for RDEIM. *Intra-* is defined as the area affected directly by contamination to the extent that the land is labeled as currently unusable. This area may change over time due to remediation efforts and natural processes that diminish dose rates. All intraregional losses are treated as direct. The second region, *extra-*, includes the locations where indirect impacts occur and encompasses the contiguous United States less the *intraregional* area. Indirect and induced losses occur within the extraregional area. Together, the intra- and extra-regional losses sum to the national value, wherein national refers to the 48 contiguous states.

Multipliers are used to estimate national GDP losses and recovery values. Two types of multipliers are used: Type I and Type II. The multipliers are based on Industry-by-Industry Total Requirement (TRII) tables. For Type I, the TRII tables without households is used. For Type II, households are included. These multipliers are adjusted to be valid for regional and national data for each industry. Direct losses are estimated by calculating the number of affected workers per industry and multiplying by the value added by each worker in that industry. Total direct losses are estimated by summing losses for all industries and over the affected set of grid elements. Direct plus indirect losses/recovery values are calculated using the sum of the products of losses/recovery by industry and the Type I multipliers. Indirect losses/recovery values are estimated by taking the difference between direct + indirect and direct losses/recovery values. Induced losses are estimated from the difference between the losses using Type II and Type I multipliers.

The results of RDEIM aim to provide the user with a comprehensive view of the economic effect following a disruption. This is done by including most of the previous economic model's cost-based valuations with the GDP losses. Economic losses for evacuation/relocation, long-term relocation, decontamination costs, depreciation on property improvements, condemned property, and disposal of contaminated crop and dairy products are calculated the same way in both the cost- and GDP-based models. GDP losses replace expected return on investment in the original, cost-based model.

Input-Output (I-O) modeling uses a framework of inputs and outputs for different types of industries and areas of the economic sector. An output from one industry may serve as input for a different industry. Using this modeling system, a national economic network can be established, and it is possible to measure the far-reaching economic effects suffered by the loss of a single industry or region.

The process for determining losses (or loss of value additions) involves comparing a baseline GDP scenario and a disruption scenario. Direct GDP is the GDP produced in a region if it were open for business (the baseline case). Direct GDP loss assumes the area is shut down for a period specified in the disruption scenario, as calculated by MACCS, and considers GDP of the affected area to be lost.

MACCS uses a set of weather trials to obtain a distribution of impact results for various weather events. These results are analyzed producing standard statistical outputs, such as mean, median, and 90th percentile economic losses.

MACCS uses a grid structure. Grid elements may contain 1 or more partial or full counties. MACCS determines if the grid element should be condemned due to radiological contamination and if/when the element recovers. The area is also modeled in terms of industry, where all industries within a grid element are assumed to be non-operable for some (MACCS calculated) period (not longer than the user-defined "Maximum Duration of Local Economic Impact" parameter).

Data are available for the number of workers in each industry for each county in the continental U.S. Since grid elements are not necessarily full counties, the value for a partial county is found by multiplying the number of employees within the entire county by the fraction of land area or fraction of the population affected for each industry and summing the results. For industries that are based on land (e.g., farming), the fraction of affected land area is used to determine the fraction of a county within a grid element. Conversely, for industries where labor is the primary factor (e.g., manufacturing), the fraction of the county population affected is used to determine the fraction of an industry within a grid element. A table of industries and how partial counties are apportioned is shown below:

Table 4-149. Method for apportioning county in a grid element for each industry treated by RDEIM

Industry	By Area	By Population
Agriculture, forestry, fishing, and hunting	X	
Mining	X	
Utilities	X	
Construction		X
Wholesale trade		X
Retail trade		X
Transportation & Warehousing	X	
Information		X
Finance & Insurance		X
Manufacturing		X
Real estate & rental leasing		X
Professional, scientific, and technical services		X
Management of companies & Enterprises	X	
Administrative & Waste management services	X	
Educational services		X
Health care & Social assistance		X

Industry	By Area	By Population
Arts, entertainment & recreation		X
Accommodations & food services		X
Other services, except government		X
Federal government		X
State & local government		X

For each industry that exists in a grid element, a value added to GDP by each worker per year is used to estimate the direct impact of affected workers. Multipliers are used to address Type I and Type II impacts. Disruptions for each grid element are summed to provide GDP losses.

A significantly more detailed discussion of the RDEIM model can be found in Outkin et. al., 2020, and Outkin et. al., 2022.

4.4.9.1. Default GDP Economic Parameters Form

This form contains the default values that are used when default economic values are selected in *PROPERTIES*. These values may be updated when the RDEIM is updated, but current values are shown in the table below.

Default Social discount rate, ECON_DEF_DRT, is the default rate over the economic impact duration as a fraction.

Default (GDP) growth rate, ECON_DEF_GRT, is the default gross domestic product (GDP) growth rate over the economic impact duration as a fraction.

Default Accident year, ECON_DEF_AYR, is the year that an accident is assumed to occur. The default is that the accident year is the same as the RDEIM year, which is currently 2011.

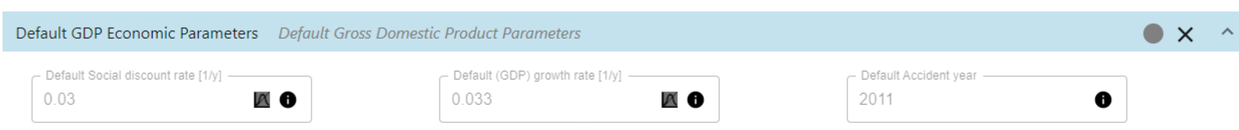


Figure 4-156. *Default Gross Domestic Product Parameters* form

Table 4-150. *Default Gross Domestic Product Parameters* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
ECON_DEF_DRT	No	Real	None	0 to 0.1
ECON_DEF_GRT	No	Real	None	0 to 0.1
ECON_DEF_AYR	No	Integer	None	1980 to 2050

4.4.9.2. Model Basis Form

This form is required when RDEIM is selected in the *Econ* tab in *PROPERTIES*.

If creating COMIDA2 input files, *Duration of Regional Disruption*, ECON_RGDR, must be less than the COMIDA2 variable LASTACUM.

Duration of National Disruption, ECON_NTDR, must not exceed ECON_RGDR.

Land Condemnation Factor, ECON_MULT, multiplies the value of the land in the inequality that determines whether decontamination is cost beneficial.

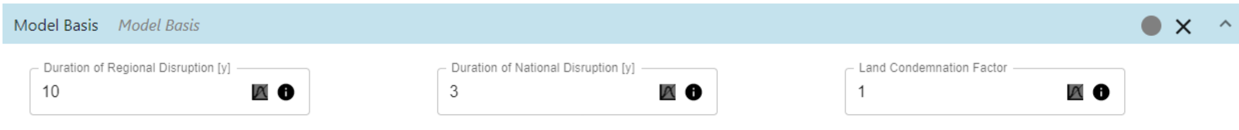


Figure 4-157. *Model Basis* form

Table 4-151. *Model Basis* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
ECON_RGDR	Yes	Integer	None	1 to 30 years
ECON_NTDR	Yes	Integer	None	1 to 10 years
ECON_MULT	Yes	Real	None	0.0 to 1000.0

4.4.9.3. GDP Economic Parameters Form

This form is used when the *RDEIM GDP-Based (User Specified values)* is selected in *PROPERTIES* under the *Econ* tab.

User Social discount rate, ECON_DRT, is the annual rate over the economic impact duration specified as a fraction.

User (GDP) growth rate, ECON_GRT, is the annual gross domestic product (GDP) growth rate over the economic impact duration specified as a fraction.

User Accident year, ECON_AYR, is the year the accident occurred. GDP values are adjusted to be consistent with the accident year using the GDP growth rate. RDEIM economic data is adjusted based on this year.

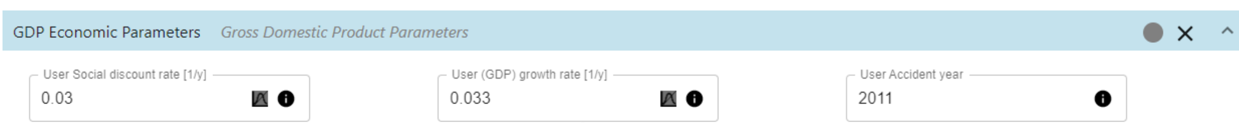


Figure 4-158. *GDP Economic Parameters* form

Table 4-152. *GDP Economic Parameters* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
ECON_DRT	Yes	Real	None	0.0 to 0.1 per year
ECON_GRT	Yes	Real	None	0.0 to 0.1 per year
ECON_AYR	Yes	Integer	None	1980 to 2050

4.4.10. Weathering

The groundshine weathering relationship from Gale, Miller, and Fisher (1964) is described as follows:

$$GW(t) = GWCOEF(1) \cdot \exp[-\ln(2) \cdot t/TGWHLF(1)] + GWCOEF(2) \cdot \exp[-\ln(2) \cdot t/TGWHLF(2)] \quad \text{(4-57)}$$

Where

GW(*t*) represents groundshine weathering factor at time *t*, given the weathering coefficients, GWCOEF(i), and the weathering half-lives, TGWHLF(i).

The resuspension weathering relationship is defined as:

$$RW(t) = RWCOEF(1) \cdot \exp[-\ln(2) \cdot t/TRWHLF(1)] + RWCOEF(2) \cdot \exp[-\ln(2) \cdot t/TRWHLF(2)] \; RWCOEF(3) \cdot \exp[-\ln(2) \cdot t/TRWHLF(3)] \quad \text{(4-58)}$$

Where

RW(*t*) represents the resuspension weathering at time *t*, given the weathering coefficients, RWCOEF(i), and the weathering half-lives, TRWHLF(i).

The values are defined under the *Weathering* category in the MACCS-UI interface.

4.4.10.1. Groundshine Weathering Terms Form

The *Groundshine Weathering Terms* form is required when CHRONC is enabled and contains a single parameter, *Number of Groundshine Relationships*, NGWTRM.

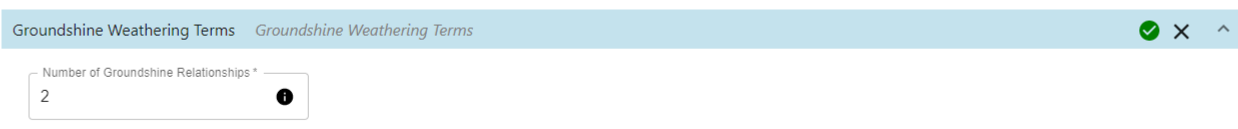


Figure 4-159. *Groundshine Weathering Terms* form

Table 4-153. *Groundshine Weathering Terms* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NGWTRM	Yes	Integer	None	1 or 2

4.4.10.2. Groundshine Weathering Coef Form

The *Groundshine Weathering Coef* form is required when CHRONC is enabled.

GWCOEF is the set of linear coefficients in the groundshine weathering equation; and TGWHLF, the set of half-lives in the groundshine weathering equation.

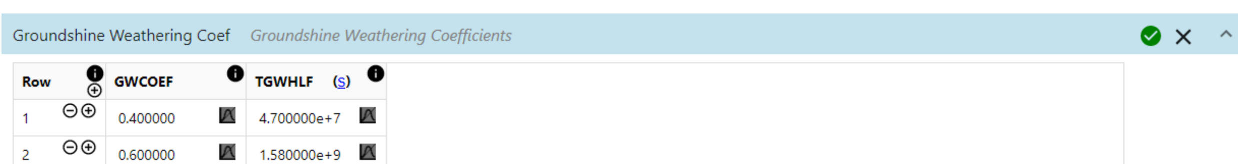


Figure 4-160. *Groundshine Weathering Coef* form

Table 4-154. ***Groundshine Weathering Coef*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
GWCOEF	Yes	Real	NGWTRM	10^{-20} to 1.0
TGWHLF	Yes	Real	NGWTRM	10^{-6} to 10^{12} s

4.4.10.3. Resuspension Weathering Terms Form

The *Resuspension Weathering Terms* form is required when CHRONC is enabled and contains a single parameter, *Number of Resuspension Relationships*, NRWTRM.

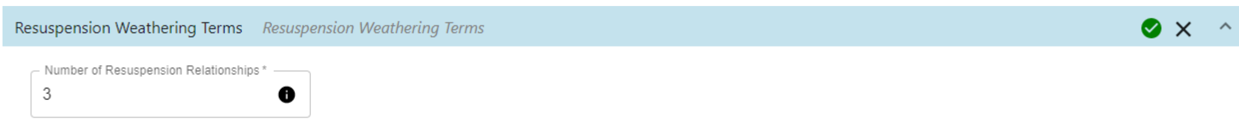


Figure 4-161. *Resuspension Weathering Terms* parameter form

Table 4-155. *Resuspension Weathering Terms* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NRWTRM	Yes	Integer	None	1 to 3

4.4.10.4. Resuspension Weathering Coef Form

The *Resuspension Weathering Coefficient* form is required when CHRONC is enabled and contains RWCOEF, the set of linear coefficients in the resuspension weathering equation; and TRWHLF, the set of resuspension weathering half-lives.

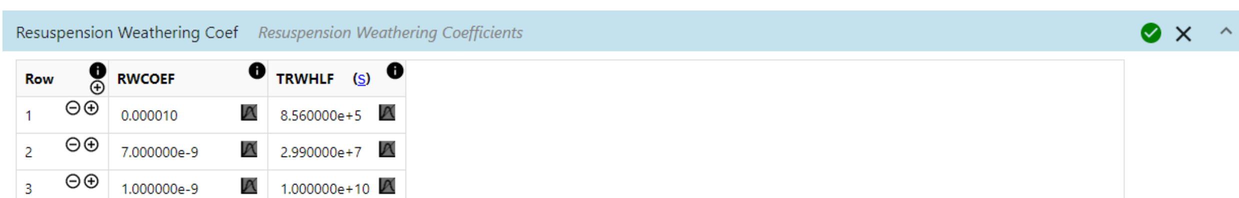


Figure 4-162. *Resuspension Weathering Coef* form

Table 4-156. *Resuspension Weathering Coef* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
RWCOEF	Yes	Real	NRWTRM	10^{-20} to 1.0 m^{-1}
TGWHLF	Yes	Real	NRWTRM	10^{-6} to 10^{12} s

4.4.11. Regional Characteristics

The regional characteristics data block defines the average economic and agricultural characteristics of the area surrounding the accident site.

When doses exceed the cleanup criterion, the regional characteristic values are used to evaluate whether decontamination or condemnation is more cost effective. 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.

To implement the rotation strategy when the user has chosen either wind shift option on the *Evac/Rotation* tab in *PROPERTIES*, the result of the cost-effectiveness test must be 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. When no site file is supplied by the user, land values are assumed to be uniform over the grid and so the regional characteristic values are also used to calculate economic losses.

4.4.11.1. Property Improvements *Form*

Fraction of Nonfarm Improvements Wealth, FRNFIM, defines the fraction of non-farm 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.

Fraction of Farm Improvements Wealth, 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 that exclusively support farming.

Figure 4-163. *Property Improvements* form

Table 4-157. *Property Improvements* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
FRNFIM	Yes	Real	None	0.0 to 1.0
FRFIM	Yes	Real	None	0.0 to 1.0

4.4.11.2. Property Values Form

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 while the region is interdicted. 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 the 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).

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 the 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).

Figure 4-164. ***Property Values*** **form**

Table 4-158. ***Property Values*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
VALWNF	Yes	Real	None	10^{-6} to 10^{6} \$/person
VALWF	Yes	Real	None	10^{-6} to 10^{6} \$/ha

4.4.11.2.1. Land Usage Form

Land Usage is required when *Uniform* is selected on the *Site Data* tab 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.

Average Land Fraction of Farm Production, FRCFRM, defines the average fraction of land in the region devoted to agriculture. The land area devoted to agriculture is calculated as follows:

$$\text{agricultural area} = \text{total area} \bullet \text{FRACLD} \bullet \text{FRCFRM} \quad \textbf{(4-59)}$$

Average Annual Farm Sales, FRMPRD, defines the value of the average annual farm production (gross sales) in the region.

Fraction of Farm Sales Resulting from Dairy, DPFRCT, defines the fraction of annual farm production (gross sales) in the region resulting from dairy production.

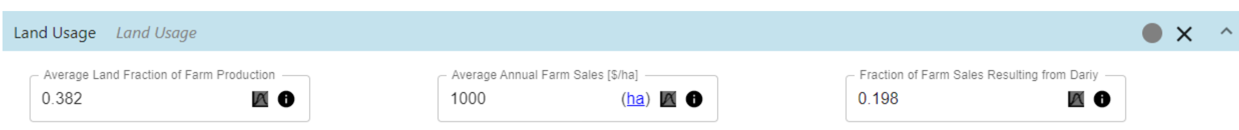


Figure 4-165. ***Land Usage*** **Form**

Table 4-159. ***Land Usage*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
FRCFRM	Yes	Real	None	10^{-6} to 1.0
FRMPRD	Yes	Real	None	0 to 10^{5} \$/ha
DPFRCT	Yes	Real	None	0.0 to 1.0

4.4.12. Food Chain

MACCS incorporates three optional food-ingestion models:

- the food-ingestion model from the original MACCS code, as used in NUREG-1150
- the COMIDA2 food ingestion model
- no 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 DCF.

There are several 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 is that it is not capable of distinguishing the effects of contamination at different times during the growing season. The 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 user has a choice of using one of two food-chain models or specifying that food-chain doses should not be 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, some input is required. When the *MACCS Food Model* is chosen on the *Food* tab, all the inputs to the food-chain model are contained in this section. When the COMIDA2 food-chain model is used, MACCS uses a binary data file created by the preprocessing program, COMIDA2, that contains the results of the COMIDA2 food-chain modeling calculations.

When *COMIDA2 - Predefined 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 on the *GENERAL/File Specifications/ Dose Conversion Factor File* form.

When *COMIDA2 - Created 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 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 COMIDA2 binary files is not supported. Also, the MACCS food-chain model is not compatible with these choices.

4.4.12.1. Food-Chain Model Descriptions

4.4.12.1.1. Modeling of Agricultural Countermeasures

LASTACUM, a COMIDA2 input parameter, specifies the maximum duration of the ingestion dose period. MACCS calculates the accumulated societal dose starting with the year that the land satisfies the human consumption criteria specified by DOSEMILK, DOSEOTHR, and DOSELONG, with the exposure period ending in the LASTACUM year after the accident. The allowable range for the LASTACUM parameter is from 1 to 50 years. The value of the LASTACUM parameter 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 eight years. Land that cannot be returned to production after eight 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 parameter 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 interdicted 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 of decontamination 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.

Milk and crop disposal during the year of the accident are triggered when the habitability criterion (DSCRLT#) is exceeded. Milk and crop disposal costs are calculated only for the year of the accident. When DSCRLT# does not lead to milk and nonmilk crop disposal, the maximum dose levels for the first year's milk production (DOSEMILK) and the first year's nonmilk crops (DOSEOTHR) are examined separately to find whether either is exceeded. The first-year dose criteria are evaluated using the consumption rates specified by the COMIDA2 input parameter CONSUM_RATES. Crop or milk disposal is triggered when the corresponding dose level is exceeded. Beginning with the second year following the accident, year 2, the long-term ingestion dose criterion (based on DOSELONG) is evaluated. The disposal of milk and/or nonmilk crops is triggered when the projected ingestion dose for food and milk combined exceeds DOSELONG.

When the projected individual dose for a year does not exceed the dose level 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 to determine whether production can be resumed within the first nine years after the accident.

When the projected doses in each of years two through nine 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 satisfies the long-term dose criterion, agricultural production is assumed to resume in that year. Societal ingestion doses are assessed for the period ending with the LASTACUM year.

For example, when DOSELONG is satisfied in year three, and LASTACUM has a value of 9, societal doses are accrued for the period denoted as years three to nine. Since agricultural production was not allowed in the first and second years, economic costs for two years of interdiction are assessed for farmland. The model calculates the cost of temporary interdiction as the loss of return on investment on the land and improvements (see parameters VALWF and FRFIM) and accounts for depreciation on the improvements.

4.4.12.1.2. First-Year Crop Disposal Cost

The economic cost of milk and/or nonmilk crop disposal during year one is modeled based on 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 parameters FRMPRD and DPFRCT). The 0.25 adjustment factor assumes that cows would be taken off pasture and fed uncontaminated feed, allowing dairy production to resume after one-quarter of a year. To maintain consistency with the MACCS food-chain model, the application of the fixed 0.25 adjustment factor on milk disposal costs is also 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.

4.4.12.1.3. 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 that is consumed by humans (Helton, Muller, and Bayer, 1985). MACCS models this uptake into drinking water as two separate paths: deposition of contaminants directly onto freshwater bodies and deposition of contaminants 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, the user can manually edit the site data file to account for 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 no uptake fraction.

The parameters described below are used to define the behavior of the single watershed; however, the discussion is easily extended to multiple watersheds where the parameter values depend on grid element. 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 brief period following 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 parameter 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. See Bixler et al. (2020) for a more extensive discussion of the water ingestion parameters, including WINGF.

4.4.12.1.4. MACCS Food-Chain Model

When the MACCS food-chain 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 humans 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 for transferring material from the ground to man. MACCS calculates the overall efficiency of two ingestion sources (food and water) by multiplying all the individual transfer factors, yielding an overall weighted sum representing the effectiveness of the pathway in transferring contaminants from the ground to human consumption.

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 assumed to be continuous. 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 activity of radionuclides retained as a function of time. That is, the longer the time between deposition and harvesting, the lower the resulting 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:

$$\text{CTCOEF} \times \exp(-\lambda t),$$

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 remains after weathering, 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 to 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.

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 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. These parameters are specified in terms of allowable ground concentration and are referred to as "action guides."

4.4.12.2. Forms

4.4.12.2.1. 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.

Name of COMIDA2 effective organ, CM2EFF, selects the effective organ name to be used with the COMIDA2 food model.

Name of COMIDA2 thyroid organ, CM2THY, selects the lifetime thyroid organ name to be used with the COMIDA2 food model.

DOSEMILK, DOSEOTHR, and DOSELONG are vectors of size two. The first entry corresponds to a limit on 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 like that served by the parameter 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 parameter is intended to fulfill a purpose like that served by the parameter 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 after the year of the accident.

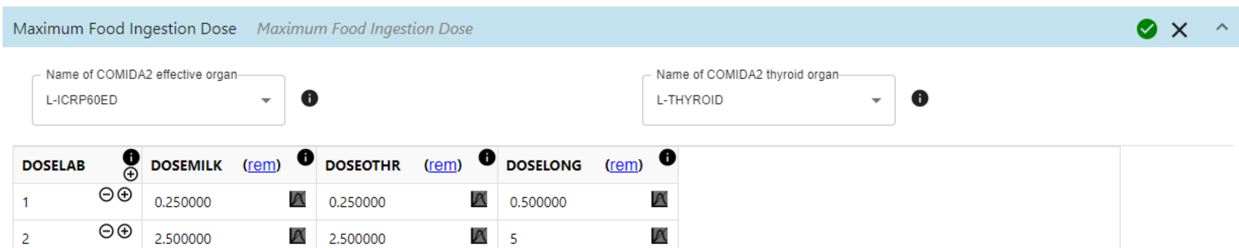


Figure 4-166. *Maximum Food Ingestion Dose* form

Table 4-160. *Maximum Food Ingestion Dose* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CM2EFF	Yes	Character	None	Based on DCF File
CM2THY	Yes	Character	None	Based on DCF File
DOSEMILK	Yes	Real	2	0.0 to 10^{10} Sv
DOSEOTHR	Yes	Real	2	0.0 to 10^{10} Sv
DOSELONG	Yes	Real	2	0.0 to 10^{10} Sv

4.4.12.2.2. 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 when radioactive decay occurs before consumption. Dose coefficients implicitly account for decay products of a parent radionuclide when the decay occurs after consumption.

Number of food pathway radionuclides, 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 the radionuclides that are specified for the drinking water pathway, and they must appear in the same order as in NAMWPI.

Figure 4-167. *Radionuclides* form

Table 4-161. *Radionuclides* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NFIISO	Linked	Integer	None	1 to 10
NAMIPI	Yes	Character	NFIISO	Radionuclides defined in ATMOS parameter NUCNAM

4.4.12.2.3. Crop Ingestion Form

The *Crop Ingestion* form is required when the *MACCS Food Model* is selected on the *Food* tab.

Number of crop categories, 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 parameter 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.

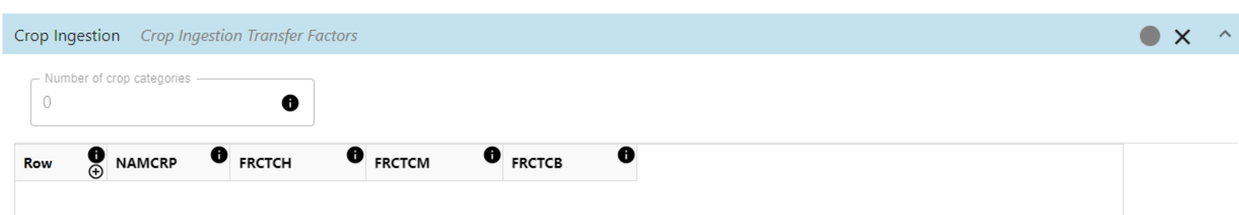


Figure 4-168. *Crop Ingestion* form

Table 4-162. *Crop Ingestion* parameter inputs

Parameter	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

4.4.12.2.4. 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 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-human food pathway.

TFBF is the transfer factor describing how much of the material ingested by meat-producing animals is 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.

Figure 4-169. *Meat/Milk Ingestion* form

Table 4-163. *Meat/Milk Ingestion* parameter inputs

Parameter	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

4.4.12.2.5. *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 up 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 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, 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 parameter QROOT.

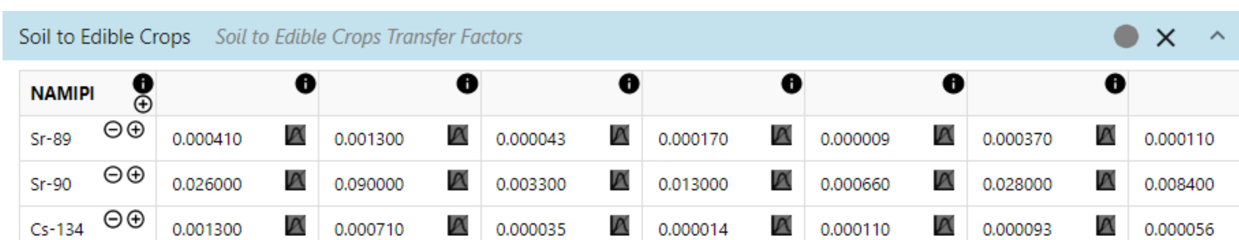


Figure 4-170. *Soil to Edible Crops* form

Table 4-164. *Soil to Edible Crops* parameters inputs

Parameter	Definable	Type	Dimensions	Allowed Values
TCROOT	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

4.4.12.2.6. *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).

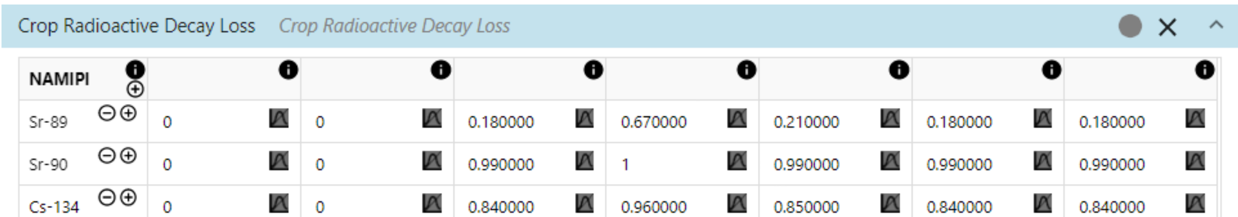


Figure 4-171. *Crop Radioactive Decay Loss* form

Table 4-165. *Crop Radioactive Decay Loss* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DCYPCH	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

4.4.12.2.7. 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 values are used to calculate 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).

Figure 4-172. *Meat/Milk Radioactive Decay Loss* form

Table 4-166. Meat/Milk Radioactive Decay Loss parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DCYPCM	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

4.4.12.2.8. 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 to obtain the overall transfer factor for this part of the food chain.

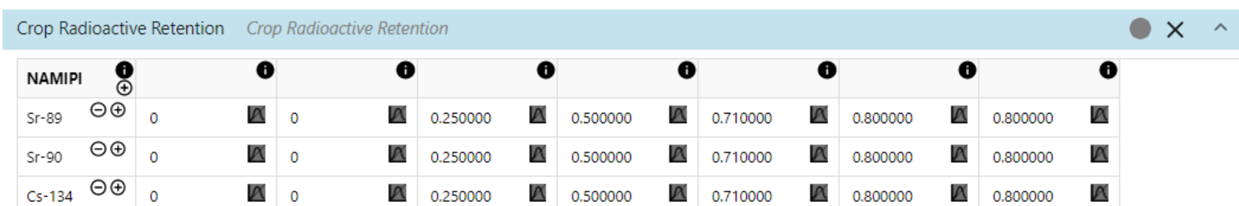


Figure 4-173. *Crop Radioactive Retention* form

Table 4-167. *Crop Radioactive Retention* parameter inputs

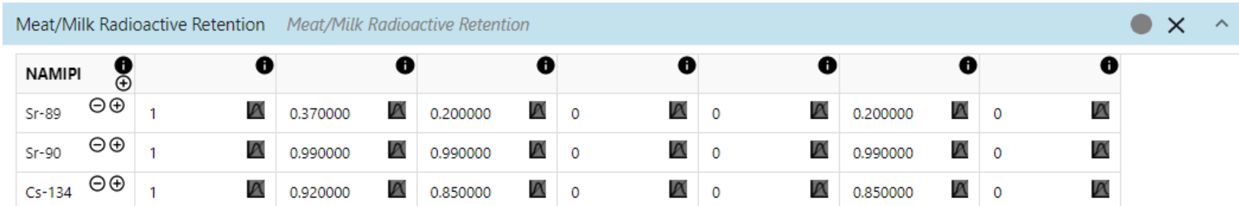
Parameter	Definable	Type	Dimensions	Allowed Values
FPLSCH	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

4.4.12.2.9. 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).



Meat/Milk Radioactive Retention *Meat/Milk Radioactive Retention*

NAMIPI							
Sr-89	1	0.370000	0.200000	0	0	0.200000	0
Sr-90	1	0.990000	0.990000	0	0	0.990000	0
Cs-134	1	0.920000	0.850000	0	0	0.850000	0

Figure 4-174. *Meat/Milk Radioactive Retention* form

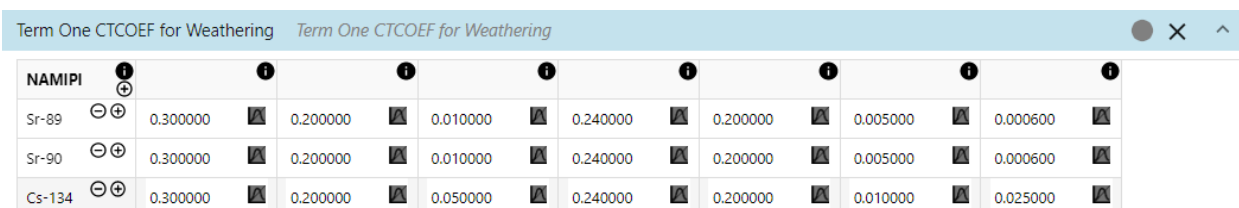
Table 4-168. *Meat/Milk Radioactive Retention* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
DCYPCB	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

4.4.12.2.10. 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 4.4.12.1. This parameter 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 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.



Term One CTCOEF for Weathering *Term One CTCOEF for Weathering*

NAMIPI							
Sr-89	0.300000	0.200000	0.010000	0.240000	0.200000	0.005000	0.000600
Sr-90	0.300000	0.200000	0.010000	0.240000	0.200000	0.005000	0.000600
Cs-134	0.300000	0.200000	0.050000	0.240000	0.200000	0.010000	0.025000

Figure 4-175. *Term One CTCOEF for Weathering* form

Table 4-169. *Term One CTCOEF for Weathering* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CTCOEF	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

4.4.12.2.11. 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 4.4.12.1. 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.

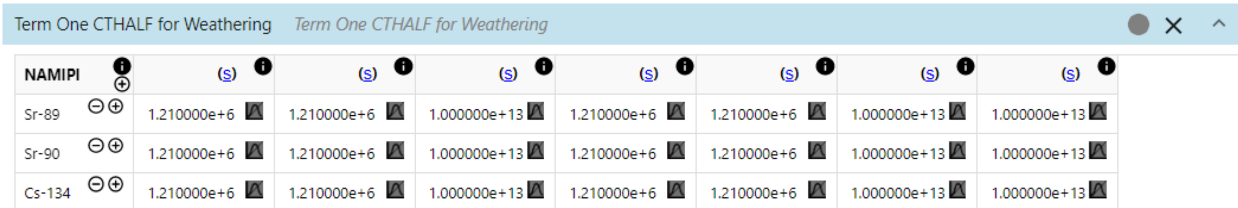


Figure 4-176. *Term One CTHALF for Weathering* form

Table 4-170. *Term One CTHALF for Weathering* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CTHALF	Yes	Real	NFIISO by NFICRP	1 to 3.15×10^{13} s

4.4.12.2.12. 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 4.4.12.1. 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.

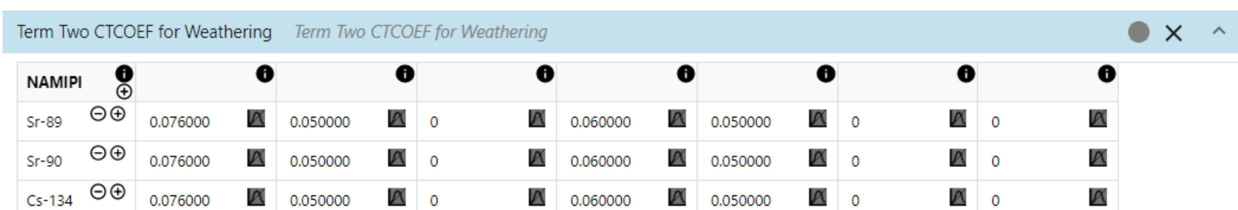


Figure 4-177. *Term Two CTCOEF for Weathering* form

Table 4-171. *Term Two CTCOEF for Weathering* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CTCOEF	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

4.4.12.2.13. 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 4.4.12.1. Values must be specified for each crop category for all radionuclides treated by the food pathway model.

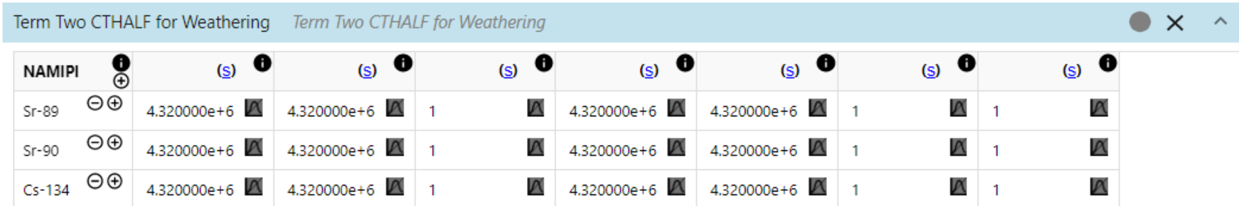


Figure 4-178. *Term Two CTHALF for Weathering* form

Table 4-172. *Term Two CTHALF for Weathering* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CTHALF	Yes	Real	NFIISO by NFICRP	1.0 to 3.15×10^{13} s

4.4.12.2.14. 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, parameter NTTRM is set to three.

CTCOEF corresponds to the constant multiplier of the third term in the weathering equation, as described in Subsection 4.4.12.1. This parameter 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 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.

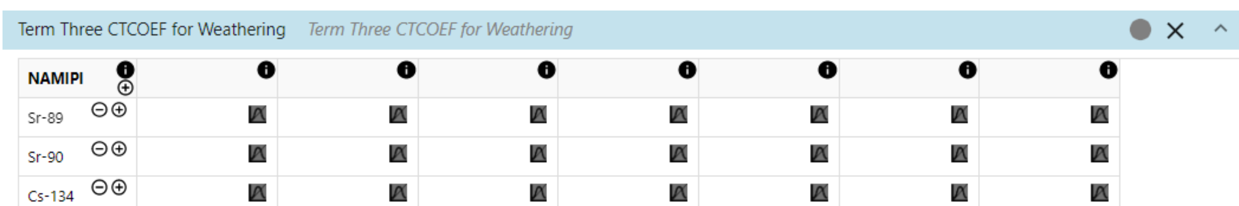


Figure 4-179. *Term Three CTCOEF for Weathering* form

Table 4-173. *Term Three CTCOEF Weathering* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
CTCOEF	Yes	Real	NFIISO by NFICRP	0.0 to 1.0

4.4.12.2.15. Term Three CTHALF for Weathering 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, parameter NTTRM is set to three.

CTHALF corresponds to the half-life value of the third term in the weathering equation, as described in Subsection 4.4.12.1. 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.

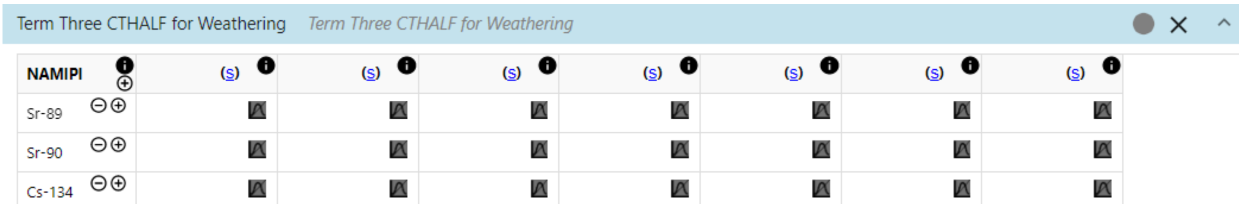


Figure 4-180. ***Term Three CTHALF for Weathering*** **form**

Table 4-174. ***Term Three CTHALF for Weathering*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
CTHALF	Yes	Real	NFIISO by NFICRP	1.0 to 3.15×10^{13} s

4.4.12.2.16. 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 the Julian day (January 1 is day 1; December 31 is day 365 for a non-leap year).

TGSEND defines the end of the growing season for the named crop category in terms of the Julian day.

FRCTFL defines the fraction of cultivated farmland that is used to grow the named crop category.

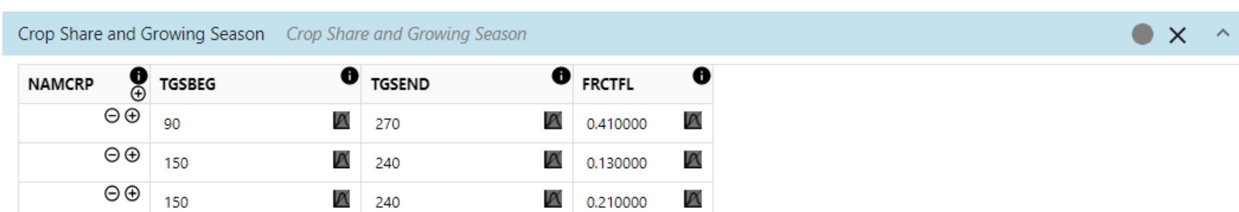


Figure 4-181. ***Crop Share and Growing Season*** **form**

Table 4-175. ***Crop Share and Growing Season*** **parameter inputs**

Parameter	Definable	Type	Dimensions	Allowed Values
TGSBEG	Yes	Real	NFICRP	1.0 to 365.0 Julian day
TGSEND	Yes	Real	NFICRP	1.0 to 365.0 Julian day
FRCTFL	Yes	Real	NFICRP	0.0 to 1.0

4.4.12.2.17. 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 parameters 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 (parameter 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 the growing season, MACCS, 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 evaluations 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 because of exceeding both the PSCMLK and PSCOTH criteria, the code automatically imposes at least one 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 parameter 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, 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 parameters 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.

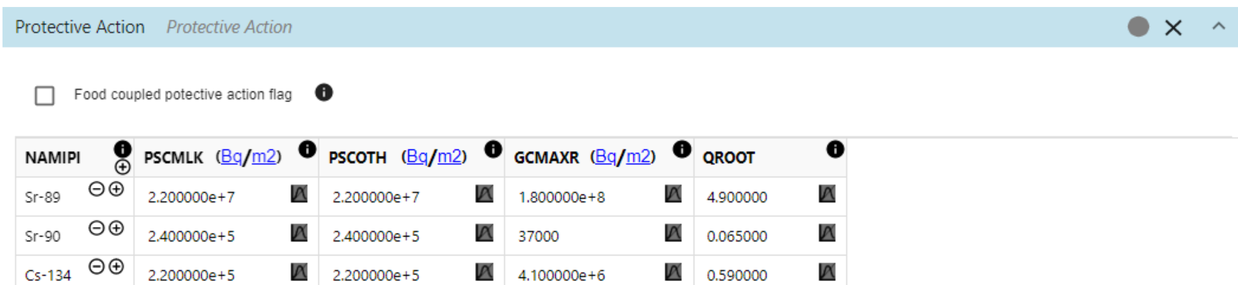


Figure 4-182. *Protective Action* form

Table 4-176. *Protective Action* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
COUPLD	Yes	Logical	None	True, False
PSCMLK	Yes	Real	NFIISO	10^{-6} to 10^{20} Bq/m^2
PSCOTH	Yes	Real	NFIISO	10^{-6} to 10^{20} Bq/m^2
GXMAXR	Yes	Real	NFIISO	10^{-6} to 10^{35} Bq/m^2
QROOT	Yes	Real	NFIISO	0.0 to 10^{35} yr^{-1}

4.4.12.2.18. 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.

Number of Water Ingestion Radionuclides, NUMWPI, is 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 specified in the relevant food-chain model, either MACCS or COMIDA2. Nuclide choices are from parameter NAMIPI when the MACCS food-chain model is used. The choices must be consistent with radionuclides specified by parameter PARENTS when the COMIDA2 food-chain model is used.

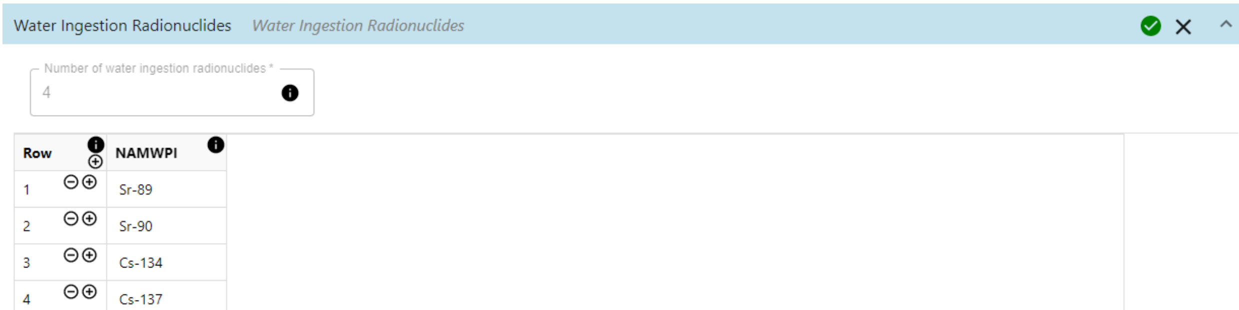


Figure 4-183. *Water Ingestion Radionuclides* form

Table 4-177. *Water Ingestion Radionuclides* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUMWPI	Linked	Integer	None	1 to 10
NAMWPI	Yes	Character	NUMWPI	Must select a radionuclide defined in NAMIPI

4.4.12.2.19. 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.

The water-ingestion model does not account for the decay of parents or the buildup of decay products from radioactive decay that occurs between deposition and ingestion.

WSHFRI defines the initial wash-off fraction for the specified radionuclide. This is the fraction of material deposited on land that is easily washed off into the watershed drainage system shortly after the deposition of that radionuclide.

WSHRTA defines the annual wash-off rate for the specified radionuclide. This is the annual rate at which material deposited on land is washed off into the watershed drainage system following the initial deposition.

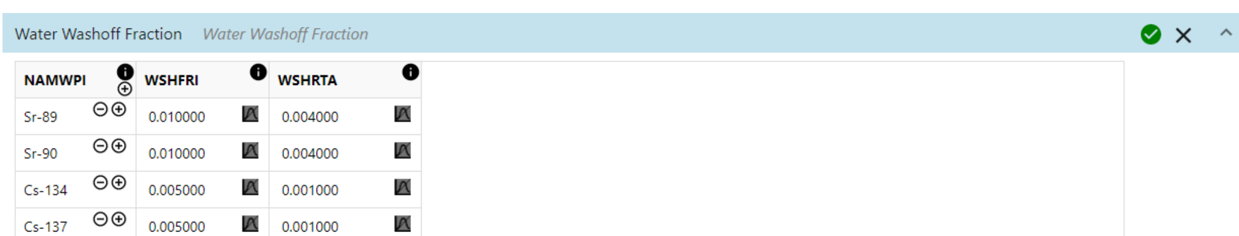


Figure 4-184. *Water Washoff Fraction* form

Table 4-178. *Water Washoff Fraction* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
WSHFRI	Yes	Real	NUMWPI	0.0 to 1.0
WSHRTA	Yes	Real	NUMWPI	0.0 to 1.0 yr^{-1}

4.4.12.2.20. 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. The values are taken from the site file when one is used.

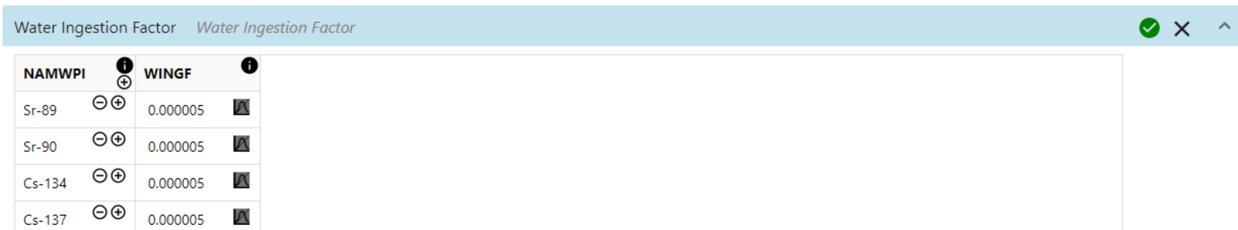


Figure 4-185. *Water Ingestion Factor* form

Table 4-179. *Water Ingestion Factor* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
WINGF	Yes	Real	NUMWPI	0.0 to 1.0

4.4.13. Output Control

4.4.13.1. Debug Flag Form

The *Debug Flag* form is required. This flag allows the user to print a detailed listing of values for intermediate parameters used in CHRONC calculations. The results for this option are written to the output file. Most of the parameters are CHRONC internal 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 parameter should be set to 0 for normal calculations. Because setting this parameter to 1 generates a large amount of output, it is usually preferable to use this option for single weather trial runs.

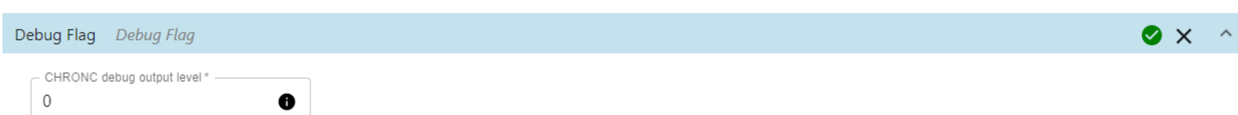


Figure 4-186. *Debug Flag* form

Table 4-180. *Debug Flag* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
KSWTCH	Yes	Integer	None	0 or 1

4.4.13.2. 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. This result type has no counterpart in the EARLY module. The EARLY module does not allow for population dose to be broken down by exposure pathway.

No long-term population dose results for an organ are produced in the output listing unless the user requests it. Each request for the breakdown of long-term population dose to an organ produces a block of either 12 or 15 dose results (depending on which food-chain model is being used), as identified below. All the dose results are reported in person-Sv by default, 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 inhalation of resuspended aerosols.
- 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 inhalation of resuspended aerosols.
- POP-DEPENDENT DECONTAMINATION DOSE—total long-term population dose received by groundshine to 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 because 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 because 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 during the entire 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 during the entire 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 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 because 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 IX1DS9.

CCDF9 determines whether CCDF data are written to the MACCS output file and whether the data are included in the summary report.

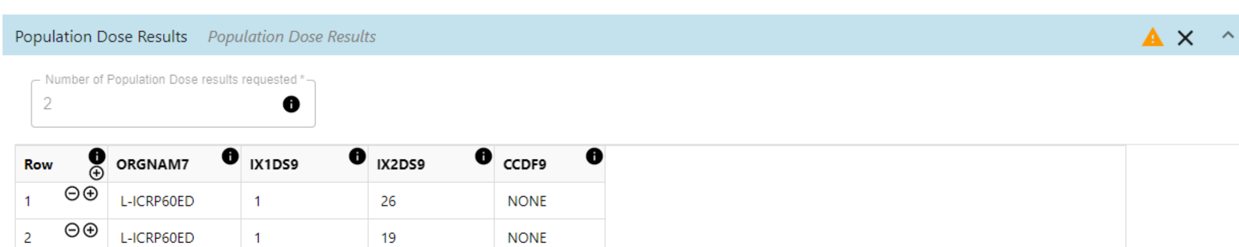


Figure 4-187. *Population Dose Results* form

Table 4-181. *Population Dose Results* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NXUM9	Linked	Integer	None	0 to 999
ORGNAM	Yes	Character	NXUM9	Long Term Organ name specified in EARLY
IX1DS9	Yes	Integer	NXUM9	1 to NUMRAD
IX2DS9	Yes	Integer	NXUM9	1 to NUMRAD
CCDF9	Yes	Character	NXUM9	CCDF, NONE, REPORT, CCDF & REPORT

4.4.13.3. 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 and the original MACCS cost-based economic model is selected, each request for economic results produces the block of 20 economic results described below. All the economic cost measures are reported in dollars.

- TOTAL ECONOMIC COSTS—sum of population- and farm-dependent costs
- POP-DEPENDENT COSTS—sum of population-dependent decontamination, loss of use, depreciation, and condemnation costs
- FARM-DEPENDENT COSTS—sum of farm-dependent decontamination, loss of use, depreciation, and condemnation costs as well as milk and crop disposal costs
- POP-DEPENDENT INTERDICTION DECON. COST – decontamination costs of nonfarm property (i.e., property associated with resident population) for relocation areas
- FARM-DEPENDENT INTERDICTION DECON. COST – decontamination costs of farm property for relocation areas
- POP-DEPENDENT HABITABLE DECON. COST – decontamination cost for nonfarm habitable areas
- FARM-DEPENDENT HABITABLE DECON. COST – decontamination cost for farm habitable areas
- POP-DEPENDENT LOSS OF USE COST – loss of use of nonfarm property during both periods of decontamination and interdiction
- FARM-DEPENDENT LOSS OF USE COST – loss of use of farm property during both periods of decontamination and interdiction
- POP-DEPENDENT DEPRECIATION LOSSES – depreciation of nonfarm property during both decontamination and extended interdiction plus a one-time cost to relocate the population
- FARM-DEPENDENT DEPRECIATION LOSSES – depreciation and loss of use of farm property during both periods of decontamination and interdiction

- POP-COST-EFFECTIVE CONDEMN. COST – compensation paid for permanent loss of nonfarm property since it is more cost effective to condemn then to decontaminate (price for decontamination is higher than cost to condemn)
- FARM-COST-EFFECTIVE CONDEMN. COST – compensation paid for permanent loss of farm property since it is more cost effective to condemn then to decontaminate (price for decontamination is higher than cost to condemn)
- POP-REGULAR CONDEMN. COST – compensation paid for permanent loss of nonfarm property because full decontamination is not sufficient to restore the property
- FARM-REGULAR CONDEMN. COST – compensation paid for permanent loss of farm property because it was not returned to production within 8 years of the accident since full decontamination is not sufficient to restore the property
- EMERGENCY RELOCATION COST – per diem costs to compensate people for being away from home due to relocation during the emergency phase
- INTERMEDIATE RELOCATION COST – per diem costs to compensate people for being away from home due to relocation during the intermediate phase
- LONG-TERM RELOCATION COST – costs to compensate people for being away from home due to relocation during the long-term phase
- 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 occur: 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.

When Flag10 is set to true and the RDEIM economic model is selected, each request for economic results produces the block of the last 17 economic results described above, with the the first three entries replaced by the list below. All the economic cost measures are reported in dollars. Before these outputs, a list of the individual industries included in the calculation is given.

- TOTAL LOSSES—total losses
- TOTAL NATIONAL GDP LOSSES—total of national GDP losses
- ALL GROSS DIRECT GDP LOSSES—sum of all industries' direct GDP losses
- Individual Industry GROSS DIRECT GDP LOSSES—direct GDP losses for each industry
- ALL NET NATIONAL GDP LOSSES—sum of all industries' net national GDP losses
- Individual Industry NET NATIONAL GDP LOSSES—net national GDP losses for each industry
- ALL NET DIRECT GDP LOSSES—sum of all industries' net direct GDP losses
- Individual Industry NET DIRECT GDP LOSSES—net direct GDP losses for each industry
- ALL NET INDIRECT GDP LOSSES—sum of all industries' net indirect GDP losses

- Individual Industry NET INDIRECT GDP LOSSES—net indirect GDP losses for each industry
- ALL NET INDUCED GDP LOSSES—sum of all industries' net induced GDP losses
- Individual Industry NET INDUCED GDP LOSSES—net induced GDP losses for each industry
- ALL NATIONAL GDP RECOVERY — sum of all industries' national GDP recovery
- Individual Industry NATIONAL GDP RECOVERY—national GDP recovery for each industry
- ALL DIRECT GDP RECOVERY —sum of all industries' national direct GDP recovery
- Individual Industry DIRECT GDP RECOVERY—national direct GDP recovery for each industry
- ALL INDIRECT GDP RECOVERY—sum of all industries' national indirect GDP recovery
- Individual Industry INDIRECT GDP RECOVERY—national indirect GDP recovery for each industry
- ALL INDUCED GDP RECOVERY—sum of all industries' national direct GDP recovery
- Individual Industry INDUCED GDP RECOVERY—national induced GDP recovery for each industry
- DIRECT GDP Losses per year—sum of all industries' direct GDP losses per year
- National GDP Losses per year—sum of all industries' national GPD losses per year

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 boundary is the inner radius of the specified ring.

I2DS10 defines the outer spatial interval of the region of interest. The boundary is the outer radius of the specified ring. MACCS requires that the value must be greater than or equal to I1DS10.

FLAG10 equal to true extends the output to include an expanded breakdown of costs.

CCDF10 determines whether CCDF results are written to the MACCS output file, and whether the results are to be included in the MACCS-UI summary report.

Figure 4-188. *Economic Cost Results* form

Table 4-182. *Economic Cost Results* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NXUM10	Linked	Integer	None	0 to 999
I1DS10	Yes	Integer	NXUM10	1 to NUMRAD
I2DS10	Yes	Integer	NXUM10	1 to NUMRAD
FLAG10	Yes	Logical	NXUM10	True, False
CCDF10	Yes	Character	NXUM10	CCDF, NONE, REPORT, CCDF & REPORT

4.4.13.4. 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 12 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 INTERDICT DECON. DIST. – distance to which farmland decontamination is required for relocation areas
- POP-DEPENDENT INTERDICT DECON. DIST. – distance to which nonfarmland decontamination is required for relocation areas
- FARM-DEPENDENT HABITABLE DECON. DIST. – distance to which farmland decontamination is required for habitable areas
- POP-DEPENDENT HABITABLE DECON. DIST. – distance to which nonfarmland decontamination is required for habitable areas
- FARM-DEPENDENT INTERDICTION DIST.—distance to which farmland interdiction is required.
- POP-DEPENDENT INTERDICTION DIST.—distance to which non-farmland interdiction is required.
- FARM-COST-EFFECTIVE CONDEMN. DIST. – distance to which farmland condemnation is required when it is more cost effective to condemn then to decontaminate (price for decontamination is higher than cost to condemn)
- POP-COST-EFFECTIVE CONDEMN. DIST. – distance to which nonfarmland condemnation is required when it is more cost effective to condemn then to decontaminate (price for decontamination is higher than cost to condemn)
- FARM-REGULAR CONDEMN. DIST. – distance to which farmland condemnation is required when full decontamination is not sufficient to restore the property
- POP-REGULAR CONDEMN. DIST. – distance to which nonfarmland condemnation is required when full decontamination is not sufficient to restore the property

- MILK DISPOSAL DIST.— distance to which milk disposal is required.
- CROP DISPOSAL DIST.— distance to which crop disposal is required.

FLAG11 set to true indicates that the output file includes maximum action distances.

The value chosen for CCDF11 determines whether CCDF values are written to the MACCS output file and whether they are included in the MACCS-UI report generated after simulations are complete.

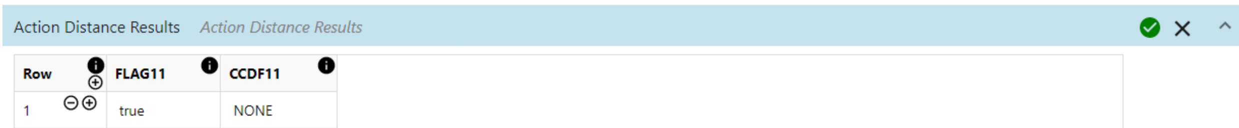


Figure 4-189. *Action Distance Results* form

Table 4-183. *Action Distance Results* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
FLAG11	Yes	Logical	1	True, False
CCDF11	Yes	Character	1	CCDF, NONE, REPORT, CCDF & REPORT

4.4.13.5. 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 areas and populations that are affected by these actions. The option to print these impacted area/population results is controlled by the user.

Each request for impacted farm-area/population results produces the block of 17 results described as follows:

- FARM-INTERDICTION DECON. (ha) – farmland area that requires decontamination for relocation
- POP-INTERDICTION DECON. (INDIVIDUALS) – population of relocation areas that require decontamination
- POP-INTERDICTION DECON. AREA (ha) – land area of nonfarm property that requires decontamination for relocation
- FARM-HABITABLE DECON. (ha) – farmland area that requires decontamination for habitability
- POP-HABITABLE DECON. (INDIVIDUALS) – population of habitable areas that require decontamination
- POP-HABITABLE DECON. AREA (ha) – land area of nonfarm property that requires decontamination for habitability
- FARM INTERDICTION (ha)—farmland area that requires interdiction
- POP. INTERDICTION (INDIVIDUALS)—population of areas that require interdiction
- POP. INTERDICTION AREA (ha)— area of nonfarm property requiring interdiction

- FARM-COST-EFF. CONDEMN. (ha) – farmland area that requires condemnation for areas where it is more cost effective to condemn then to decontaminate (price for decontamination is higher than cost to condemn)
- POP-COST-EFF. CONDEMN. (INDIVIDUALS) – population of areas that require condemnation for areas where it is more cost effective to condemn then to decontaminate (price for decontamination is higher than cost to condemn)
- POP-COST-EFF. CONDEMN. AREA (ha) – nonfarmland area that requires condemnation for areas where it is more cost effective to condemn then to decontaminate (price for decontamination is higher than cost to condemn)
- FARM-REGULAR CONDEMN. (ha) – farmland area that requires condemnation when full decontamination is not sufficient to restore the property
- POP-REGULAR CONDEMN. (INDIVIDUALS) – population of areas that require condemnation when full decontamination is not sufficient to restore the property
- POP-REGULAR CONDEMN. AREA (ha) – nonfarmland area that requires condemnation when full decontamination is not sufficient to restore the property
- MILK DISPOSAL AREA (ha)—area requiring milk disposal
- CROP DISPOSAL AREA (ha)—area requiring crop disposal

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.

CCDF12 determines whether CCDF values are written to the MACCS output file, and whether they are to be included in the summary report.

Figure 4-190. *Impacted Area/Population Results* form

Table 4-184. *Impacted Area/Population Results* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM12	Linked	Integer	None	0 to 999
I1DS12	Yes	Integer	NUM12	1 to NUMRAD
I2DS12	Yes	Integer	NUM12	1 to NUMRAD
CCDF12	Yes	Character	NUM12	CCDF, NONE, REPORT, CCDF & REPORT

4.4.13.6. 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 within a user-specified spatial interval for the total 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. The inner radius is taken to be zero.

ORGN13 defines the organ to be used for each requested result.

CCDF13 determines determine whether CCDF values are written to the MACCS output file, and whether they are included in the summary report.

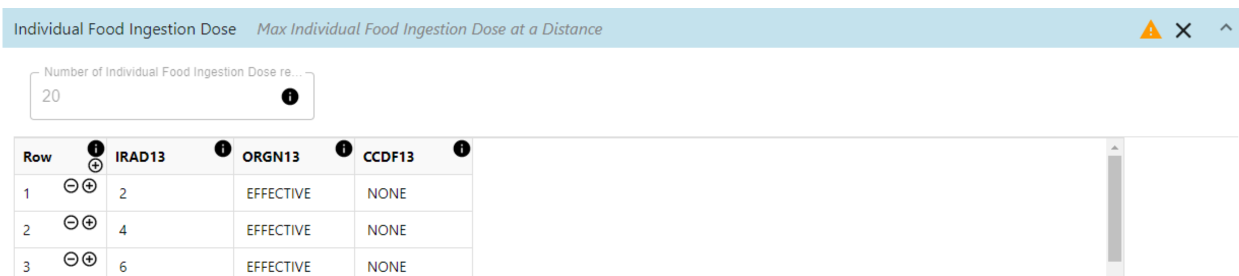


Figure 4-191. *Individual Food Ingestion Dose* form

Table 4-185. *Individual Food Ingestion Dose* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM13	Linked	Integer	None	0 to 999
IRAD13	Yes	Integer	NUM13	1 to NUMRAD
ORGN13	Yes	Character	NUM13	EFFECTIVE, THYROID
CCDF13	Yes	Character	NUM13	CCDF, NONE, REPORT, CCDF & REPORT

4.4.13.7. 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 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
- COST-EFF. CONDEMNATION RELOCATION—the number of people whose property is condemned because it is more cost effective to condemn then to decontaminate (price for decontamination is higher than cost to condemn)
- REGULAR CONDEMNATION RELOCATION—the number of people whose property is condemned because full decontamination is not sufficient to restore the property

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.

CCDF14 determines whether CCDF values are written to the MACCS output file, and whether they are to be included in the summary report.

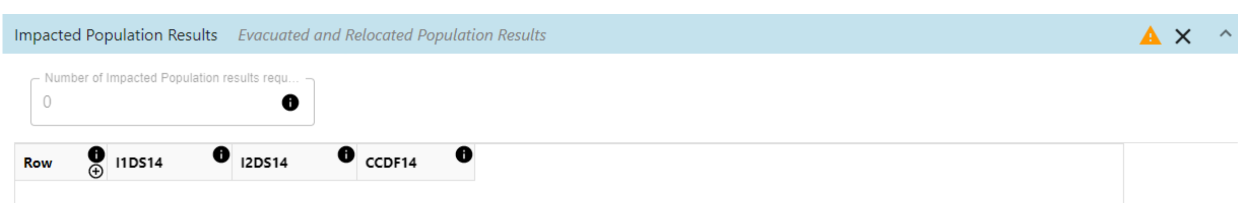


Figure 4-192. *Impacted Population Results* form

Table 4-186. *Impacted Population Results* parameter inputs

Parameter	Definable	Type	Dimensions	Allowed Values
NUM14	Linked	Integer	None	0 to 999
I1DS14	Yes	Integer	NUM14	1 to NUMRAD
I2DS12	Yes	Integer	NUM14	1 to NUMRAD
CCDF14	Yes	Character	NUM14	CCDF, NONE, REPORT, CCDF & REPORT

5. TUTORIALS

5.1.1. Creating a New Project

A new project can be created in MACCS from the *HOME* page. The *HOME* is opened when MACCS-UI is launched, or users can select the page after working on an existing project.

6. Launch MACCS-UI. This can be done through the Windows Start Menu, the taskbar, or a shortcut. Once open, you will be presented with the *HOME* page (red arrow), shown in Figure 5-1.
7. Click the *NEW PROJECT* button in the *Actions* panel (green arrow).
8. A window will open, where a project name can be entered. This will be the name of the project file and folder.
9. Click *BROWSE* to select where the project folder should be saved. Once selected, the location of the project will be displayed. Click *OK* when finished.
10. The *INPUT* page will open, where parameters for the new project can be entered.

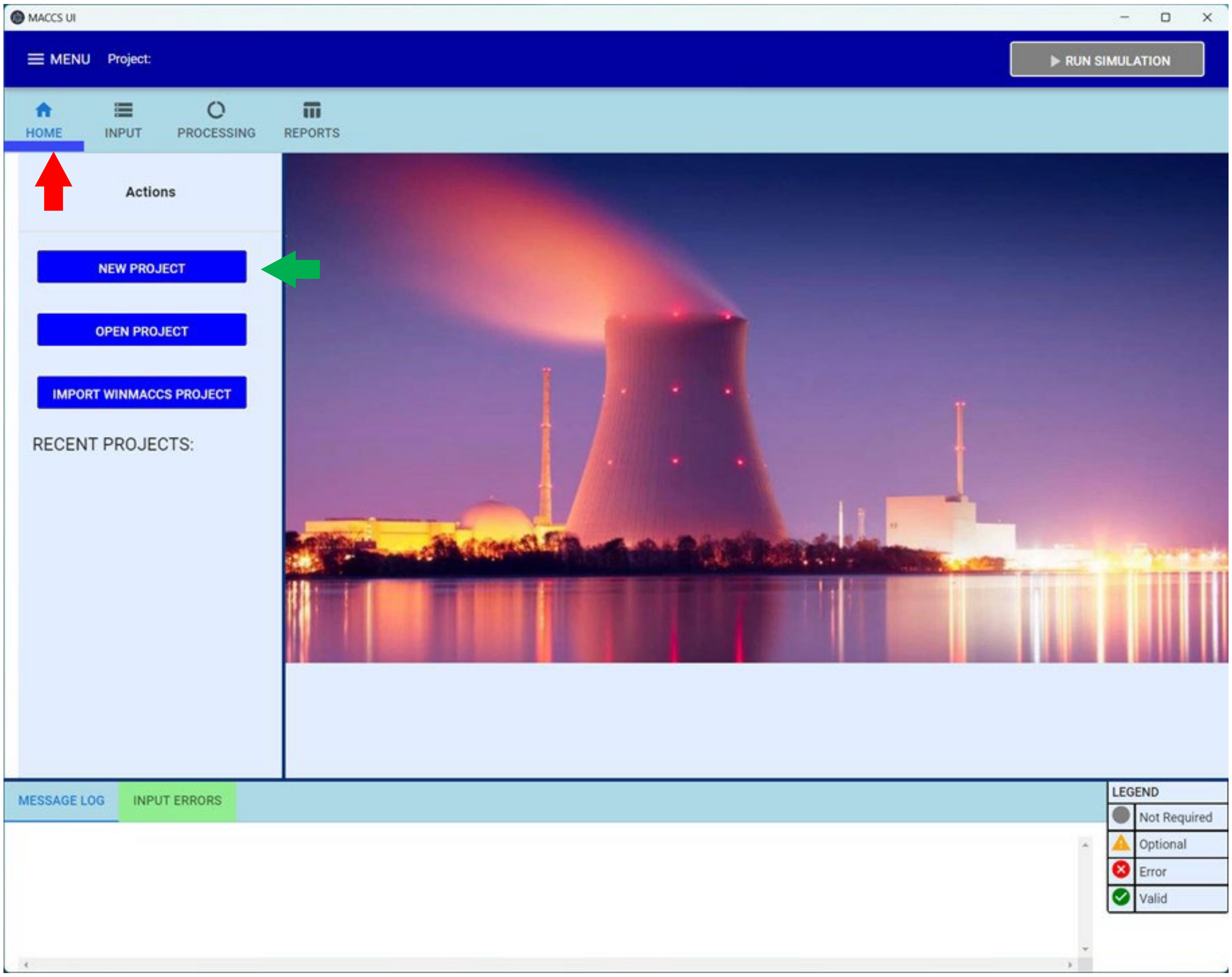


Figure 5-1. *NEW PROJECT* button on the *HOME* page

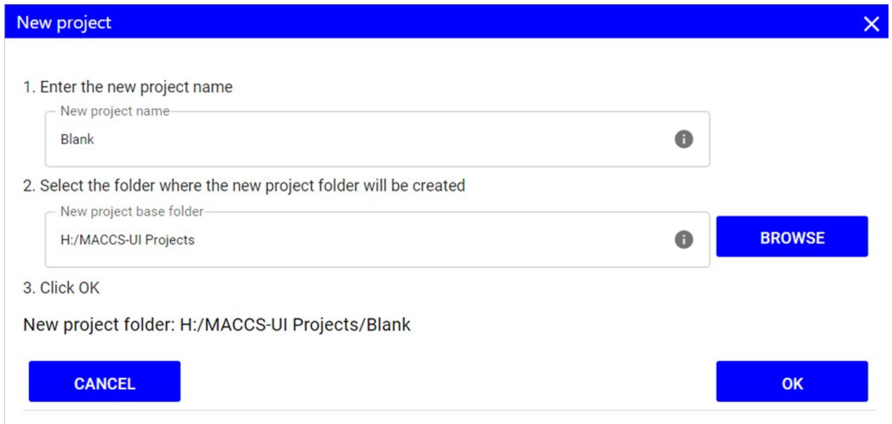


Figure 5-2. *New Project* dialog

5.1.2. Importing a WinMACCS Project

Projects previously used in WinMACCS can be imported into MACCS-UI and converted to the .maccs format.

1. Launch MACCS-UI. This can be done through the Windows Start Menu, the taskbar, or a shortcut. Once open, you will be presented with the *HOME* page (red arrow), shown in Figure 5-3.
2. Click on the *IMPORT PROJECT* button in the *Actions* panel (green arrow).
3. A window will open, where a project name can be entered. This can be the same or different from the original project. This will be the name of the project file and folder.
4. Click the *BROWSE* button beside the *New project base folder* field to select where the new project folder should be saved.
5. Click *BROWSE* button beside the *WinMACCS project to import* field to select which WinMACCS project should be imported. Once selected, the location of the imported project will be displayed. Click *OK* when finished.
6. The *INPUT* page will open, where parameters for the imported project can be modified.

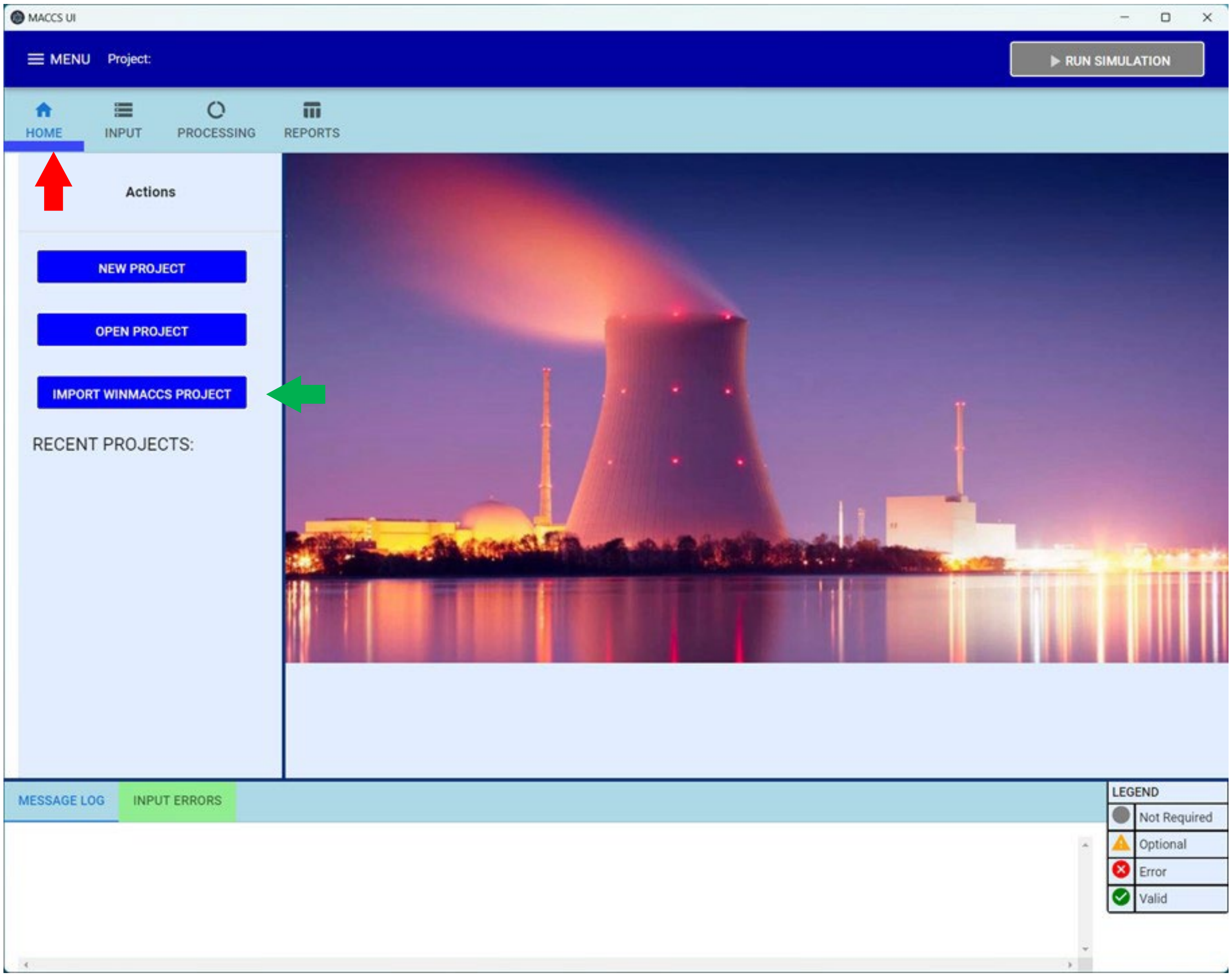


Figure 5-3. ***IMPORT PROJECT*** **button on** ***HOME*** **page**

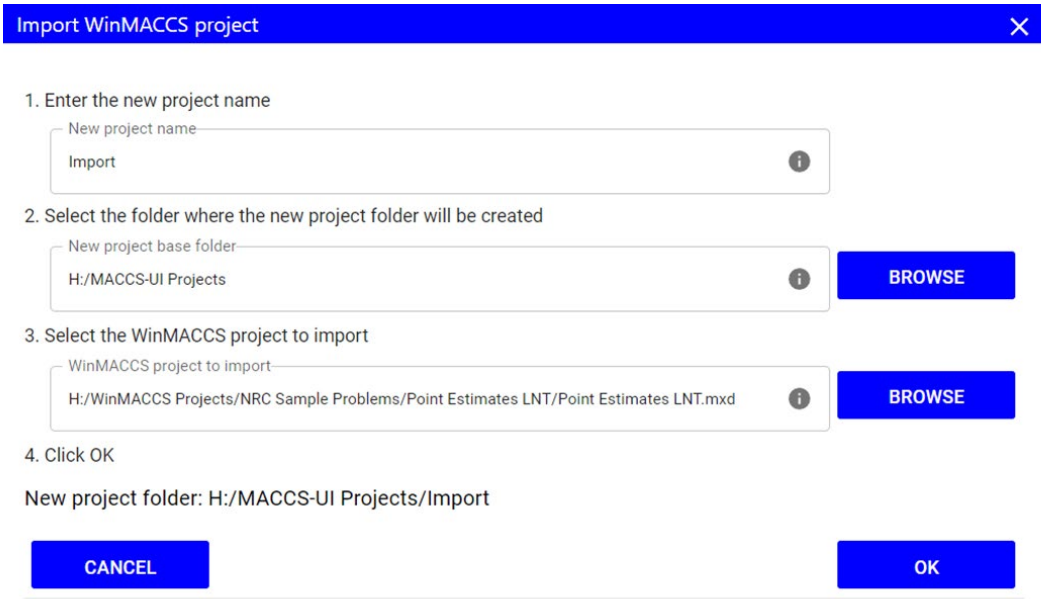


Figure 5-4. ***Import*** **WinMACCS** ***project*** **dialog**

5.1.3. *Selecting a License File*

To use MACCS-UI, a valid license file is required. This can be obtained from the same site MACCS-UI was downloaded.

1. Download and extract the Product.key file.
2. Copy the file.
3. Navigate to …\executables\maccs\, contained in the MACCS-UI installation folder. By default, this is %localappdata%\MACCS-UI\executables\maccs\.
4. Paste the Product.key file, ensuring that it has the name Product.key. If there is an older Product.key file within the same folder, replace it with the newly downloaded one.
5. Confirm valid license file by launcing MACCS-UI and selecting *Check License* from *MENU\Help* (red arrow).

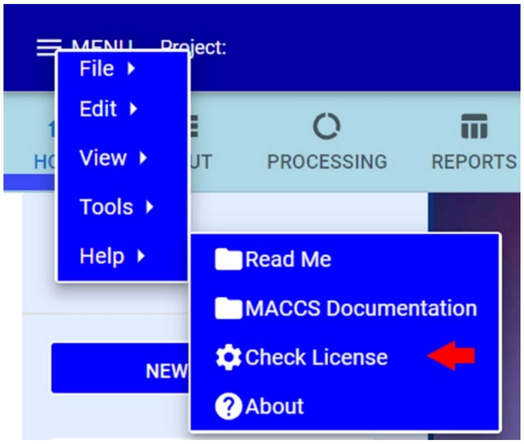


Figure 5-5. *Check License* Dialog

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APPENDIX A. DEFAULT PARAMETER VALUES

The ability to define default parameter values was incorporated into MACCS-UI. In the case that users need to access these default parameters, this appendix is included.

A.1. General

Table A-1. General category default parameters

Category	Variable	Value	Description
File Specifications	NUMCYC	0	Number of Cyclical Files
License	LICENSE_PATH	\executables\maccs\Product.key	License File Path
Output Control	ACTIVITY_UNITS	Bq	Activity Units
Output Control	AREA_UNITS	ha	Area Units
Output Control	DIST_UNITS	km	Distance Units
Output Control	DOSE_UNITS	Sv	Dose Units
Output Control	PROBABILITY	[.05,.1,.5,.9,.95]	Report Option Probabilities to be Reported
Properties	NUMEVAC	1	Number of Evacuation Cohorts

A.2. ATMOS

Table A-2. Constants/Property Form Parameters default values

Variable	Value	Description
ATDMODL	GAUSSIAN	Atmospheric Transport & Dispersion Model
BRGSMD	IMPROVED	Briggs Plume Rise Model
DISPMD	LRTIME	Crosswind Dispersion Model
ENDAT1	FALSE	EARLY Phase Flag
ENDAT2	FALSE	CHRONC Phase Flag
MAXHGT	DAY_AND_NIGHT	Maximum Mixing Height Model
METCOD	4	Weather Model Flag
MNDMOD	NEW	Plume Meander Model Flag
MSMODL	FALSE	Multi-Source Model Flag
SRCMOD	PNT	Plume Source Model
TDWAUTO	FALSE	Trapping/Downwash Auto Calc flag
TDWMOD	BRGFLX	Trapping/Downwash Model

Table A-3. Deposition default values

Variable	Value	Description
CWASH1	1.89E-05	Washout Linear Coefficient
CWASH2	0.664	Washout Exponent

Table A-4. Dispersion default values

Variable	Value	Description
CYSIGA	[0.7507, 0.7507, 0.4063, 0.2779, 0.2158, 0.2158]	Sigma-y Power-Law Linear Term
CYSIGB	[0.866, 0.866, 0.865, 0.881, 0.866, 0.866]	Sigma-y Power-Law Exponential Term
CZSIGA	[0.0361, 0.0361, 0.2036, 0.2636, 0.2463, 0.2463]	Sigma-z Power-Law Linear Term
CZSIGB	[1.277, 1.277, 0.859, 0.751, 0.619, 0.619]	Sigma-z Power-Law Exponential Term
DISTANCE	[0.1,0.14,0.2,0.3,0.4,0.6,0.8,1,1.4,2,3,4,6,8,10,14,20,30,40,60,80,100,140,200,300,400,600,800,1000,1400,2000,3000,4000,6000,8000,10000,14000,20000,30000,40000,60000,80000,1.00E+05,1.40E+05,2.00E+05,3.00E+05,4.00E+05,6.00E+05,8.00E+05,1.00E+06,1.40E+06,2.00E+06,3.00E+06,4.00E+06,6.00E+06,8.00E+06,1.00E+07,1.40E+07,2.00E+07,3.00E+07,4.00E+07,6.00E+07,8.00E+07,1.00E+08,1.40E+08,2.00E+08,3.00E+08,4.00E+08,6.00E+08,8.00E+08,1.00E+09,1.40E+09,2.00E+09,3.00E+09,4.00E+09,6.00E+09,8.00E+09,1.00E+10]	Downwind Dispersion Distance
NUM_DIST	78	Number of Dispersion Distances
SIGMA_Y_A	[4.60E-02,6.20E-02,8.60E-02,1.23E-01,1.60E-01,2.31E-01,2.99E-01,3.66E-01,4.96E-01,6.84E-01,9.87E-01,1.28E+00,1.84E+00,2.39E+00,2.93E+00,3.97E+00,5.47E+00,7.89E+00,1.02E+01,1.48E+01,1.91E+01,2.34E+01,3.17E+01,4.38E+01,6.31E+01,8.19E+01,1.18E+02,1.53E+02,1.87E+02,2.54E+02,3.50E+02,5.05E+02,6.55E+02,9.45E+02,1.22E+03,1.50E+03,2.03E+03,2.80E+03,4.04E+03,5.24E+03,7.56E+03,9.80E+03,1.20E+04,1.62E+04,2.24E+04,3.23E+04,4.19E+04,6.05E+04,7.84E+04,9.59E+04,1.30E+05,1.79E+05,2.59E+05,3.35E+05,4.84E+05,6.27E+05,7.67E+05,1.04E+06,1.43E+06,2.07E+06,2.68E+06,3.87E+06,5.02E+06,6.14E+06,8.32E+06,1.15E+07,1.66E+07,2.15E+07,3.10E+07,4.01E+07,4.91E+07,6.65E+07,9.18E+07,1.32E+08,1.72E+08,2.48E+08,3.21E+08,3.93E+08]	Sigma-y Value for Stability Class A

Variable	Value	Description
SIGMA_Y_B	[3.40E-02,4.70E-02,6.40E-02,9.30E-02,1.20E-01,1.73E-01,2.25E-01,2.75E-01,3.73E-01,5.14E-01,7.42E-01,9.62E-01,1.39E+00,1.80E+00,2.20E+00,2.98E+00,4.12E+00,5.94E+00,7.70E+00,1.11E+01,1.44E+01,1.76E+01,2.39E+01,3.29E+01,4.75E+01,6.16E+01,8.88E+01,1.15E+02,1.41E+02,1.91E+02,2.63E+02,3.80E+02,4.93E+02,7.10E+02,9.21E+02,1.13E+03,1.53E+03,2.11E+03,3.04E+03,3.94E+03,5.68E+03,7.37E+03,9.02E+03,1.22E+04,1.69E+04,2.43E+04,3.15E+04,4.55E+04,5.90E+04,7.21E+04,9.77E+04,1.35E+05,1.95E+05,2.52E+05,3.64E+05,4.72E+05,5.77E+05,7.82E+05,1.08E+06,1.56E+06,2.02E+06,2.91E+06,3.77E+06,4.62E+06,6.26E+06,8.63E+06,1.25E+07,1.61E+07,2.33E+07,3.02E+07,3.69E+07,5.00E+07,6.91E+07,9.96E+07,1.29E+08,1.86E+08,2.42E+08,2.95E+08]	Sigma-y Value for Stability Class B
SIGMA_Y_C	[2.60E-02,3.50E-02,4.90E-02,7.00E-02,9.10E-02,1.32E-01,1.71E-01,2.09E-01,2.83E-01,3.91E-01,5.63E-01,7.31E-01,1.05E+00,1.37E+00,1.67E+00,2.26E+00,3.13E+00,4.51E+00,5.84E+00,8.43E+00,1.09E+01,1.34E+01,1.81E+01,2.50E+01,3.61E+01,4.68E+01,6.74E+01,8.74E+01,1.07E+02,1.45E+02,2.00E+02,2.88E+02,3.74E+02,5.39E+02,7.00E+02,8.56E+02,1.16E+03,1.60E+03,2.31E+03,2.99E+03,4.32E+03,5.60E+03,6.85E+03,9.28E+03,1.28E+04,1.85E+04,2.39E+04,3.45E+04,4.48E+04,5.48E+04,7.42E+04,1.02E+05,1.48E+05,1.92E+05,2.76E+05,3.58E+05,4.38E+05,5.94E+05,8.19E+05,1.18E+06,1.53E+06,2.21E+06,2.87E+06,3.51E+06,4.75E+06,6.56E+06,9.45E+06,1.23E+07,1.77E+07,2.29E+07,2.80E+07,3.80E+07,5.24E+07,7.56E+07,9.81E+07,1.41E+08,1.83E+08,2.24E+08]	Sigma-y Value for Stability Class C
SIGMA_Y_D	[1.80E-02,2.50E-02,3.40E-02,5.00E-02,6.40E-02,9.30E-02,1.20E-01,1.47E-01,1.99E-01,2.75E-01,3.97E-01,5.14E-01,7.42E-01,9.62E-01,1.18E+00,1.59E+00,2.20E+00,3.17E+00,4.12E+00,5.94E+00,7.70E+00,9.41E+00,1.28E+01,1.76E+01,2.54E+01,3.29E+01,4.75E+01,6.16E+01,7.53E+01,1.02E+02,1.41E+02,2.03E+02,2.63E+02,3.80E+02,4.93E+02,6.03E+02,8.17E+02,1.13E+03,1.63E+03,2.11E+03,3.04E+03,3.94E+03,4.82E+03,6.53E+03,9.02E+03,1.30E+04,1.69E+04,2.43E+04,3.15E+04,3.86E+04,5.23E+04,7.21E+04,1.04E+05,1.35E+05,1.95E+05,2.52E+05,3.09E+05,4.18E+05,5.77E+05,8.32E+05,1.08E+06,1.56E+06,2.02E+06,2.47E+06,3.34E+06,4.62E+06,6.66E+06,8.63E+06,1.24E+07,1.61E+07,1.97E+07,2.68E+07,3.69E+07,5.33E+07,6.91E+07,9.96E+07,1.29E+08,1.58E+08]	Sigma-y Value for Stability Class D

Variable	Value	Description
SIGMA_Y_E	[1.30E-02,1.80E-02,2.40E-02,3.50E-02,4.60E-02,6.60E-02,8.60E-02,1.05E-01,1.42E-01,1.96E-01,2.82E-01,3.66E-01,5.28E-01,6.84E-01,8.37E-01,1.13E+00,1.56E+00,2.26E+00,2.93E+00,4.22E+00,5.47E+00,6.69E+00,9.07E+00,1.25E+01,1.81E+01,2.34E+01,3.38E+01,4.38E+01,5.36E+01,7.26E+01,1.00E+02,1.44E+02,1.87E+02,2.70E+02,3.50E+02,4.28E+02,5.81E+02,8.01E+02,1.16E+03,1.50E+03,2.16E+03,2.80E+03,3.43E+03,4.65E+03,6.41E+03,9.25E+03,1.20E+04,1.73E+04,2.24E+04,2.74E+04,3.72E+04,5.13E+04,7.40E+04,9.59E+04,1.38E+05,1.79E+05,2.19E+05,2.97E+05,4.10E+05,5.92E+05,7.67E+05,1.11E+06,1.43E+06,1.76E+06,2.38E+06,3.28E+06,4.73E+06,6.14E+06,8.85E+06,1.15E+07,1.40E+07,1.90E+07,2.63E+07,3.79E+07,4.91E+07,7.08E+07,9.18E+07,1.12E+08]	Sigma-y Value for Stability Class E
SIGMA_Y_F	[9.00E-03,1.20E-02,1.70E-02,2.40E-02,3.20E-02,4.60E-02,5.90E-02,7.20E-02,9.78E-02,1.35E-01,1.95E-01,2.52E-01,3.64E-01,4.72E-01,5.78E-01,7.83E-01,1.08E+00,1.56E+00,2.02E+00,2.91E+00,3.78E+00,4.62E+00,6.26E+00,8.64E+00,1.25E+01,1.62E+01,2.33E+01,3.02E+01,3.70E+01,5.01E+01,6.91E+01,9.97E+01,1.29E+02,1.86E+02,2.42E+02,2.96E+02,4.01E+02,5.53E+02,7.98E+02,1.03E+03,1.49E+03,1.93E+03,2.37E+03,3.21E+03,4.42E+03,6.38E+03,8.27E+03,1.19E+04,1.55E+04,1.89E+04,2.57E+04,3.54E+04,5.11E+04,6.62E+04,9.55E+04,1.24E+05,1.51E+05,2.05E+05,2.83E+05,4.08E+05,5.30E+05,7.64E+05,9.90E+05,1.21E+06,1.64E+06,2.27E+06,3.27E+06,4.24E+06,6.11E+06,7.92E+06,9.69E+06,1.31E+07,1.81E+07,2.61E+07,3.39E+07,4.89E+07,6.34E+07,7.75E+07]	Sigma-y Value for Stability Class F
SIGMA_Z_A	[0.022,0.03,0.043,0.062,0.081,0.119,0.156,0.192,0.263,0.367,0.537,0.703,1.03,1.34,1.66,2.27,3.17,4.63,6.06,8.86,11.6,14.3,18.9,28.6,51.7,83.4,172,294,448,920,1950,4580,8360,19600,35700,57000,1.15E+05,2.44E+05,5.69E+05,1.04E+06,2.43E+06,4.44E+06,7.08E+06,1.43E+07,3.02E+07,7.07E+07,1.29E+08,3.02E+08,5.51E+08,8.79E+08,1.78E+09,3.75E+09,8.78E+09,1.60E+10,3.75E+10,6.84E+10,1.09E+11,2.21E+11,4.66E+11,1.09E+12,1.99E+12,4.65E+12,8.50E+12,1.36E+13,2.74E+13,5.79E+13,1.35E+14,2.47E+14,5.78E+14,1.06E+15,1.68E+15,3.41E+15,7.19E+15,1.68E+16,3.07E+16,7.17E+16,1.31E+17,2.09E+17]	Sigma-z Value for Stability Class A
SIGMA_Z_B	[0.019,0.025,0.035,0.051,0.067,0.097,0.127,0.156,0.213,0.296,0.43,0.56,0.814,1.06,1.3,1.78,2.47,3.59,4.68,6.8,8.87,10.9,14.5,20.1,30.1,40.6,62.8,86,110,159,234,364,498,776,1060,1360,1.96E+03,2.91E+03,4.53E+03,6.22E+03,9.70E+03,1.33E+04,1.70E+04,2.46E+04,3.64E+04,5.68E+04,7.79E+04,1.22E+05,1.67E+05,2.13E+05,3.08E+05,4.56E+05,7.12E+05,9.76E+05,1.52E+06,2.09E+06,2.67E+06,3.86E+06,5.71E+06,8.92E+06,1.22E+07,1.91E+07,2.62E+07,3.34E+07,4.84E+07,7.16E+07,1.12E+08,1.53E+08,2.39E+08,3.28E+08,4.19E+08,6.06E+08,8.97E+08,1.40E+09,1.92E+09,3.00E+09,4.11E+09,5.25E+09]	Sigma-z Value for Stability Class B

Variable	Value	Description
SIGMA_Z_C	[0.014,0.02,0.027,0.039,0.051,0.073,0.095,0.116,0.157,0.217,0.314,0.407,0.587,0.762,0.932,1.26,1.75,2.52,3.27,4.72,6.12,7.49,10.2,14.1,20.4,26.5,38.4,49.9,61.1,83,115,166,216,313,406,498,6.76E+02,9.36E+02,1.35E+03,1.76E+03,2.55E+03,3.31E+03,4.06E+03,5.51E+03,7.63E+03,1.10E+04,1.43E+04,2.07E+04,2.70E+04,3.30E+04,4.49E+04,6.21E+04,8.99E+04,1.17E+05,1.69E+05,2.20E+05,2.69E+05,3.66E+05,5.06E+05,7.32E+05,9.52E+05,1.38E+06,1.79E+06,2.19E+06,2.98E+06,4.12E+06,5.97E+06,7.75E+06,1.12E+07,1.46E+07,1.79E+07,2.43E+07,3.36E+07,4.86E+07,6.32E+07,9.14E+07,1.19E+08,1.46E+08]	Sigma-z Value for Stability Class C
SIGMA_Z_D	[0.01,0.014,0.019,0.027,0.035,0.05,0.065,0.079,0.106,0.145,0.208,0.268,0.383,0.493,0.601,0.808,1.11,1.58,2.04,2.91,3.75,4.57,6.29,8.64,12.2,15.4,21.2,26.6,31.5,39.9,50.6,65.4,78,99.2,117,133,1.61E+02,1.96E+02,2.44E+02,2.86E+02,3.55E+02,4.14E+02,4.66E+02,5.57E+02,6.72E+02,8.31E+02,9.67E+02,1.19E+03,1.39E+03,1.56E+03,1.86E+03,2.23E+03,2.76E+03,3.20E+03,3.95E+03,4.58E+03,5.14E+03,6.12E+03,7.36E+03,9.08E+03,1.05E+04,1.30E+04,1.51E+04,1.69E+04,2.01E+04,2.42E+04,2.98E+04,3.46E+04,4.26E+04,4.95E+04,5.55E+04,6.60E+04,7.94E+04,9.78E+04,1.13E+05,1.40E+05,1.62E+05,1.82E+05]	Sigma-z Value for Stability Class D
SIGMA_Z_E	[0.008,0.011,0.016,0.022,0.028,0.04,0.052,0.063,0.0845,0.115,0.164,0.211,0.3,0.385,0.468,0.628,0.856,1.22,1.57,2.23,2.86,3.48,4.72,6.36,8.79,11,14.8,18.3,21.5,27.3,34.4,43.4,50.5,61.6,70.3,77.7,8.98E+01,1.04E+02,1.22E+02,1.36E+02,1.59E+02,1.77E+02,1.91E+02,2.16E+02,2.45E+02,2.81E+02,3.10E+02,3.55E+02,3.91E+02,4.21E+02,4.70E+02,5.28E+02,6.02E+02,6.60E+02,7.52E+02,8.24E+02,8.84E+02,9.84E+02,1.10E+03,1.25E+03,1.37E+03,1.55E+03,1.70E+03,1.82E+03,2.02E+03,2.26E+03,2.56E+03,2.80E+03,3.17E+03,3.46E+03,3.71E+03,4.11E+03,4.59E+03,5.20E+03,5.68E+03,6.43E+03,7.02E+03,7.52E+03]	Sigma-z Value for Stability Class E
SIGMA_Z_F	[0.008,0.011,0.014,0.02,0.025,0.035,0.044,0.053,0.0697,0.0932,0.13,0.164,0.228,0.288,0.345,0.454,0.607,0.845,1.07,1.48,1.88,2.25,2.98,3.99,5.51,6.89,9.43,11.7,13.9,17.9,22.3,27.7,31.7,37.8,42.4,46.1,5.20E+01,5.87E+01,6.68E+01,7.30E+01,8.22E+01,8.91E+01,9.48E+01,1.04E+02,1.14E+02,1.26E+02,1.35E+02,1.49E+02,1.60E+02,1.68E+02,1.82E+02,1.97E+02,2.16E+02,2.30E+02,2.51E+02,2.67E+02,2.80E+02,3.00E+02,3.24E+02,3.52E+02,3.73E+02,4.05E+02,4.29E+02,4.49E+02,4.80E+02,5.15E+02,5.57E+02,5.89E+02,6.38E+02,6.74E+02,7.04E+02,7.51E+02,8.04E+02,8.68E+02,9.17E+02,9.90E+02,1.05E+03,1.09E+03]	Sigma-z Value for Stability Class F

Variable	Value	Description
CYCOEF	0.5	Time-Based Linear Coefficient
CYDIST	30000	Time-Based Switching Distance
YSCALE	1	Sigma-y Scaling Factor
ZSCALE	1	Sigma-z Scaling Factor

Table A-5. Plume Specifications/Original Meander default values

Variable	Value	Description
BRKPNT	3600	Breakpoint
TIMBAS	600	Time Adjustment Factor
XPFAC1	0.2	Exponential Factor 1
XPFAC2	0.25	Exponential Factor 2

Table A-6. Plume Specification/Ramsdell and Fosmire default values

Variable	Value	Description
BKGTRBV	0.655	Background V Turbulence Factor
BKGTRBW	0.584	Background W Turbulence Factor
RAFDIST	1000	Distance to Stop
TIMSCLY1	1000	Low Speed Y Timescale Parameter
TIMSCLY2	10	Low Speed Z Timescale Parameter
TIMSCLZ1	100	High Speed Y Timescale Parameter
TIMSCLZ2	10	High Speed Z Timescale Parameter
TRBINCV1	0.835	Low Speed V Turbulent Increment
TRBINCW1	0.239	Low Speed W Turbulent Increment
TRBINCV2	0.02	High Speed V Turbulent Increment
TRBINCW2	0.01	High Speed W Turbulent Increment

Table A-7. Plume Specification/US NRC Reg Guide 1.145 Meander default values

Variable	Value	Description
MNDFAC	[1,1,1,2,3,4]	Plume Meander Factor
MNDIST	800	Downwind Distance
WINSP1	2	Wind Speed as Meander Factor Changes
WINSP2	6	Wind Speed Where Meander Factor Reaches One

Table A-8. Plume Specification/US NRC Reg Guide 1.145 Point Source Meander default values

Variable	Value	Description
PSMEQ1C	0.5	Point Source Coefficient 1
PSMEQ2C	3	Point Source Coefficient 2

Table A-9. Radial Grid/Spatial Grid default values

Variable	Value	Description
NUMCOR	16	NUMCOR Number of Sectors (Compass Directions)
NUMRAD	1	NUMRAD Number of Radial Spatial Intervals
SPAEND	1	Distance to Outer Radius

Table A-10. Release Description default values

Variable	Value	Description
APLFRC	PARENT	Daughter Ingrowth Type
SIGYCOEF	0.23	Sigma y Area Source Coeffiecent
SIGZCOEF	0.47	Sigma z Area Source Coefficient

Table A-11. Weather default values

Variable	Value	Description
IRSEED	79	Seed of Random Number Generator

A.3. EARLY

Table A-12. Constants/Property Form Parameters default values

Variable	Value	Description
ANIM_CONC	FALSE	Create Animation Concentration Output
ANIM_MOVE	FALSE	Create Animation Movement Output
EVATYP	NONE	Evacuation Type
IDDREF	FALSE	Ignore DDREFA Values
IPLUME	3	Wind Shift and Rotation Flag
KEYAVAIL	KEY_NOT_AVAIL	Keyhole Evacation Available
KIMODL	NOKI	KI Model Flag
OVRRID	FALSE	Calculate Wind Rose Probabilities
POPFLG	UNIFORM	Population Defined By
WTNAME	PEOPLE	Results Weighting Factor

Table A-13. Dose Model default values

Variable	Value	Description
DTHANN	0.05	Annual Dose Threshold Value
DTHNUM	1	Number of Annual Dose Threshold Values
DTHLIF	0.1	Lifetime Dose Restriction

Table A-14. Emergency Cohort One default values

Variable	Value	Description
WTFRAC	1	Weighting Fraction
ESPGRD_NET	[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]	Speed Modifier
IDIREC	[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]	Evacuation Direction
DURBEG	0	Beginning of the Middle Phase
DURMID	0	Duration of the Middle Phase
ESPEED	[1.8, 1.8, 8.94]	Travel Speed
ESPMUL	[0.7, 0.7, 0.7]	Travel Speed Multiplier Factor
COHORT_POP	[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]	Number of People that Evacuate per Grid
ESPGRD_RAD	[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]	Radial Evacuation Speed Multiplier per Grid
BRRATE	[2.66e-4, 2.66e-4, 2.66e-4]	Breathing Rate

Variable	Value	Description
CSFACT	[0.95, 0.75, 0.6]	Cloudshine Shielding Factor
GSHFAC	[0.52, 0.34, 0.19]	Groundshine Shielding Factor
PROTIN	[0.98, 0.46, 0.25]	Inhalation Protection Factor
SKPFAC	[0.98, 0.46, 0.25]	Skin Protection Factor

Table A-15. Emergency Cohort Two through Twenty default values

Variable	Value	Description
ESPGRD_NET	[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]	Speed Modifier
IDIREC	[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]	Evacuation Direction
DURBEG	0	Beginning of the Middle Phase
DURMID	0	Duration of the Middle Phase
ESPEED	[1.8, 1.8, 8.94]	Travel Speed
ESPMUL	[0.7, 0.7, 0.7]	Travel Speed Multiplier Factor
COHORT_POP	[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]	Number of People that Evacuate per Grid
ESPGRD_RAD	[1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]	Radial Evacuation Speed Multiplier per Grid
BRRATE	[2.66e-4, 2.66e-4, 2.66e-4]	Breathing Rate
CSFACT	[0.95, 0.75, 0.6]	Cloudshine Shielding Factor
GSHFAC	[0.52, 0.34, 0.19]	Groundshine Shielding Factor
PROTIN	[0.98, 0.46, 0.25]	Inhalation Protection Factor
SKPFAC	[0.98, 0.46, 0.25]	Skin Protection Factor

A.4. CHRONC

Table A-16. Property Form Parameters default values

Variable	Value	Description
ECON_MODL	Original	Economic model flag
FDPATH	OFF	Food model flag
LTDPMOD	ONE	Number of dose projection criterion used
NTTRM	3	Number of Terms in Growing Crop Retention Model

Table A-17. GDP Economic Parameters/Default GDP Economic Parameters default values

Variable	Value	Description
ECON_DEF_AYR	2011	Default Accident year
ECON_DEF_DRT	0.03	Default Social discount rate [1/y]
ECON_DEF_GRT	0.033	Default (GDP) growth rate [1/y]

Table A-18. Interdiction Plan Cost default values

Variable	Value	Description
DPRATE	0.2	Depreciation Rate [1/y]
DSRATE	0.07	Expected Rate of Return [1/y]

Table A-19. Long-Term Protective Action default values

Variable	Value	Description
DSCRLT1	0.005	1st long-term habitability projected dose criterion
LTDPDL1	0	1st long-term habitability projected dose delay
TMPACT1	3.16E+07	1st long-term habitability projected dose period
CRTOCR	L-ICRP60ED	Long-term Critical Organ Name
DECCRLT	0.005	Cleanup dose criterion
DSCRTI	0.02	Intermediate-phase dose criterion
DECDPP	3.16E+07	Cleanup projected dose period
DUR_INTPHAS	3.16E+07	Intermediate-phase duration
EXPTIM	1.58E+09	Long-term exposure period
DSCRLT2	0.005	2nd long-term habitability projected dose criterion
TMPACT2	3.16E+07	2nd long-term habitability projected dose period

Table A-20. Shielding and Exposure default values

Variable	Value	Description
LBRRATE	2.66E-04	Breathing Rate
LGSHFAC	0.34	Groundshine Shielding Factor
LPROTIN	0.46	Inhalation Protection Factor

Table A-21. Weathering default values

Variable	Value	Description
GWCOEF	[0.4, 0.6]	Groundshine Weathering Coefficient
TGWHLF	[4.7e7, 1.58e9]	Groundshine Weathering Half-Lives
NGWTRM	2	Number of Groundshine Relationships
RWCOEF	[1.0e-5, 7.0e-9, 1.0e-9]	Resuspension Coefficient
TRWHLF	[8.56e5, 2.99e7, 1.0e10]	Resuspension Half-Lives
NRWTRM	3	Number of Resuspension Relationships

A.5. COMIDA2

Table A-22. Animal Parameters default values

Variable	Value	Description
BEEF_RATE	[1,1,1,1,1]	Beef cattle daily feed rates
DAIRY_RATE	[1,1,1,1,1]	Dairy cattle daily feed rates
OTHER_RATE	[1,1,1,1,1]	Other animal daily feed rates
POULTRY_RATE	[1,1,1]	Meat poultry feed rate

Table A-23. Base Radionuclide Data default values

Variable	Value	Description
NNUCLIDES	1	Number of radionuclides
NUCLIDES	[Sr-89]	Radionuclide name
THALF	[50.5]	Half-lives of parent radionuclide
NPARENTS	1	Number of Parent radionuclides
PARENTS	[Sr-89]	Radionuclide name

Table A-24. Crop Data default values

Variable	Value	Description
HOLDUPTM	[0,0,0,0,0]	Holdup Time
PROCLOSS	[0.25,0.8,0.8,065,075,09,1.0,0.9,1.0]	Reduction Factor

Table A-25. Concentration Ratio default values

Variable	Value	Description
CR_FRUIT	[.005]	Fruit Concentration Ratio
CR_GRAIN	[.005]	Grain Concentration Ratio
CR_HAY	[.005]	Hay Concentration Ratio
CR_LEAFY	[.005]	Leafy Vegetable Concentration Ratio
CR_LEGUME	[.005]	Concentration Ratio
CR_PASTURE	[.005]	Pasture Concentration Ratio
CR_ROOT	[.005]	Root Concentration Ratio

Table A-26. Model Basis default values

Variable	Value	Description
ACCDATES	[1,61,121,151,181,201,241,271,301]	Accident Dates
LASTACUM	10	Ingestion Dose Duration
NUMDATES	9	Number of Accident Dates

Table A-27. Soil Parameters default values

Variable	Value	Description
PSR	1400	Root Soil Density
PSS	2000	Surface Soil Density
XR	0.25	Root Zone Thickness
XS	0.001	Surface Soil Thickness
ZKP	0.0198	Percolation Rate
ZKR	0.00173	Resuspension Rate
ZKRS	8.60E-04	Rain Splash Rate

Table A-28. Time Parameters default values

Variable	Value	Description
TT	65	Tillage Date
TEC	290	Harvest Date
TSC	75	Begin Growth Date
TSH	120	Growing Season Date
TEL	300	Livestock End Date
TINTM	71	Days from Fallout
TSL	111	Livestock Grazing Date
TSP	110	Pasture Growing Date

Table A-29. Transfer Coefficients default values

Variable	Value	Description
TC_BEEF	[.02]	Beef Transfer Coefficient
TC_MILK	[.02]	Milk Transfer Coefficient
TC_OTHER	[.02]	Other Products Transfer Coefficient
TC_POULTRY	[.02]	Poultry Transfer Coefficient

Table A-30. Transfer Coefficients default values

Variable	Value	Description
ZKAB_FRUIT	[.02]	Fruit Foliar Absorption Rate
ZKAB_GRAIN	[.02]	Grain Foliar Absorption Rate
ZKAB_HAY	[.02]	Hay Foliar Absorption Rate
ZKAB_LEAFY	[.02]	Leafy Foliar Absorption Rate
ZKAB_LEGUME	[.02]	Legume Foliar Absorption Rate
ZKAB_PASTURE	[.02]	Pasture Foliar Absorption Rate
ZKAB_ROOT	[.02]	Root Foliar Absorption Rate

Table A-31. Vegetation Parameters default values

Variable	Value	Description
ALPHA	[2,2,2,2,2,2,2]	ALPHA
BIC	[.15,.15,.15,.15,.15]	BIC
BIH	0.07	BIH
BIP	0.08	BIP
BMAXC	[.7,.7,.7,.7,.7]	BMAXC
BMAXH	0.629	BMAXH
BMAXP	0.3	BMAXP
BSTAND	[.7,.7,.7,.7,.7]	BSTAND
ZKW	0.057	ZKW
ZSEN	0.12	ZSEN
TVC	[.1,1,.1,.1,.1]	TVC
ZKGC	[.12,.12,.12,.12,.12]	ZKGC
ZKGH	0.27	ZKGH
ZKGP	0.035	ZKGP
NCUT	3	NCUT
TCUT	[170,230,290]	TCUT

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APPENDIX B. FILE FORMATS

B.1. Meteorological File

B.1.1. Overview

When running MACCS-UI, a weather model is selected using the *Weather* tab when it is needed. When one of the file sampling methods is chosen, a meteorological file is required. It is also required when modeling a weather sequence starting with a day and time period from the weather file.

Data must be provided for a 365-day year. The file consists of either fifteen-minute, thirty-minute, or hourly averages. Each line of the file contains the Julian day of the year, the time period of the day, wind direction, wind speed, atmospheric stability class, and precipitation rate. Most commonly, the data are taken from a weather station at the site or from a nearby weather station.

The meteorological data file is a formatted text file. The first two lines of contain identification information. Up to 80 characters may be used on each line. This header information is printed on the output listing.

Table B-1. Meteorological data identification information

Line	FORTRAN Format	Allowed Values	Description
1 and 2	A80	N/A	File identifying information. Should contain quality assurance information.

The default recording interval for the weather data is an hour. When 30-minute or 15-minute averaging times are used, the next line is required. When this line is omitted in the meteorological file, a period of 60 minutes is assumed.

Table B-2. Meteorological data interval information

Columns	FORTRAN Format	Allowed Values	Description
1 to 7	A7	/PERIOD	Keyword that identifies parameter
9-10	I2	60, 30 or 15	Time-averaging period for values in the file

The possible values for the parameter WINDIR depend on the MACCS-UI parameter NUMCOR. MACCS-UI and MACCS allow NUMCOR to be 16, 32, 48, or 64. The value should be consistent with NUMCOR in MACCS-UI and in the site data file when a site data file is used. It is up to the user to select or create a meteorological file that is consistent with the value of NUMCOR used in MACCS. If the meteorological file is based on fewer sectors than NUMCOR, no error message is created, but the results reported by MACCS are not calculated correctly. If the meteorological file contains values for WINDIR that exceed the value of NUMCOR, MACCS stops with a fatal error.

NUMCOR can be optionally defined using a line following the /PERIOD line or following the last comment line if the /PERIOD line is missing.

Table B-3. NUMCOR allowable values

Columns	FORTRAN Format	Allowed Values	Description
1 to 7	A7	/NUMCOR	Keyword that identifies parameter
9-10	I2	16, 32, 48 or 64	Number of compass directions. The parameter WINDIR must be a positive number less than or equal to this value.

The default option for specifying mixing height is to use seasonal averages for morning and afternoon at the bottom of the file. Another option available is to specify the mixing height for each period in the file by adding the /MIXHGT option to the file. When this line is omitted in the meteorological file, seasonal averages are assumed to be located at the bottom of the file as discussed below.

Table B-4. Mixing height specification type

Columns	FORTRAN Format	Allowed Values	Description
1 to 7	A7	/MIXHGT	Keyword that identifies mixing height specified for each period in the meteorological file

The default option for time in the meteorological file is that the hours of each day represent local time. Another option available is to specify the time in the file relative to UTC time by adding the /MIXHGT option to the file. When this line is omitted in the meteorological file, seasonal averages are assumed to be located at the bottom of the file as discussed below.

Table B-5. File time zone type

Columns	FORTRAN Format	Allowed Values	Description
1 to 7	A7	/UTCTIM	Keyword that identifies that the time of day in the file does not correlate to local time and should be adjusted based on the time zone.
9-10	I2	-23 to 23	Difference from time zone in the file and local zone time.

This is followed by a line for each recorded period. There are 8760 lines when the period is 1 hr; there are 17520 lines when the time period is 30 min; there are 35040 lines when the period is 15 min.

Table B-6. Weather period data

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 96	Interval of the day. Should not exceed 24 when period is 60 min; 48 when period is 30 min; 96 when period is 15 min.
9 to 10	I2	WINDIR	1 to NUMCOR	Direction of wind. 1 is north and the number increases in the clockwise direction.
11 to 13	I3	WINDSPD	1 to 300*	Units are 0.1 m/s.
14	I1	ISTAB	1 to 7**	Stability category. Value corresponds to Pasquill stability class A through G.
15 to 17	I3	RNMM	-1 to 999***	Rain rate in units of 0.01 in/hr.
18 to 80	F10.0	MIXH	100 to 10,000	Optional mixing height per period in units of m.

* Values less than 5 are automatically changed to 5 (0.5 m/s). Values greater than 300 result in an error.

** 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 interprets these values to be 0.

Following these lines of input is a line with eight values of mixing layer height. The units for these values are 100 m. Two values of mixing height are supplied for each of the four seasons of the year. The first four of these values correspond to morning (average daily minimum) mixing heights and the final four values correspond to afternoon (average daily maximum) mixing heights. If the option for period specific mixing heights is enabled, this line of seasonal mixing heights is not read in by MACCS and should be deleted.

The FORTRAN format for these values is F10.0. This means that the input field is ten characters long and should be right justified when no decimal point is included (i.e., any blanks to the right of the number within the field of 10 characters are interpreted as zeros). To reduce the possibility of an error, it is recommended that a decimal point be used. Engineering format can also be used (e.g., 1.4E1). A real number within the allowed range of 1 to 100 (100 m to 10,000 m) is allowed.

Table B-7. Seasonal mixing height data

Columns	FORTRAN Format	Variable	Allowed Values	Description
1 to 10	F10.0	HEIGHT(1,1)	1 to 100	Morning winter mixing height. Units are 100 m.
11 to 20	F10.0	HEIGHT(2,1)	1 to 100	Morning spring mixing height. Units are 100 m.
21 to 30	F10.0	HEIGHT(3,1)	1 to 100	Morning summer mixing height. Units are 100 m.
31 to 40	F10.0	HEIGHT(4,1)	1 to 100	Morning autumn mixing height. Units are 100 m.
41 to 50	F10.0	HEIGHT(1,2)	1 to 100	Afternoon winter mixing height. Units are 100 m.
51 to 60	F10.0	HEIGHT(2,2)	1 to 100	Afternoon spring mixing height. Units are 100 m.
61 to 70	F10.0	HEIGHT(3,2)	1 to 100	Afternoon summer mixing height. Units are 100 m.
71 to 80	F10.0	HEIGHT(4,2)	1 to 100	Afternoon autumn mixing height. Units are 100 m.

B.1.2. Sample Meteorological Data

Two sample sets of records from the meteorological data file are provided, which show the first and last ten records of the files. NUMCOR is assumed to be 16. 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 category 4 (D), and precipitation rate of 0.07 in/hr (1.8 mm/hr) during the hour. The winter, spring, summer, and autumn mixing heights for neutral and unstable conditions (record 8763) are all 1200 m. In the second set, the period specific mixing heights are shown, and no seasonal values are present.

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.  1.2E1     12     12     12     12
```

This example shows the file period specific mixing height option enabled.

U.S. NATIONAL WEATHER SERVICE METEOROLOGICAL DATA FILE

Sample Input for the MACCS Documentation

/MIXHGT

```
 1   1 70264 7 100.
 1   2 60624 7 100.
 1   3 80414 2 100.
 1   4 80364 -1 100.
 1   5 90314 0 107.
 1   6 110464 0 138.
 1   7 110264 -1 233.
 1   8 110414 -1 329.
 .
 .
 .
 365 15 110124 0 247.
 365 16 120154 4 176.
 365 17 110154 4 137.
 365 18 130214 4 100.
 365 19 130154 3 100.
 365 20 130104 2 100.
 365 21 130154 2 100.
 365 22 140104 2 100.
 365 23 130104 2 1.e2
 365 24 140104 2 100.
```

B.2. Site File

B.2.1. Overview

A site file contains the population distribution and land use information for the region surrounding the site subject to user inputs. It contains the radial and azimuthal intervals used to define the grid, the population within each grid element, the 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.

Site files for sites within the continental US are usually created by SecPop. Users should consult NUREG/CR-6525, Rev. 2 (Weber et al., 2019), for details on using SecPop. The latest version, SecPop 4.3.1, produces four types of result files as follows:

- A file ending with _REAcct.econ that is required when using the RDEIM economic model.
- A file ending with _REAcct_Extended.tsv that is in tab-separated format, contains information like the previous file, and is convenient for examining in a spreadsheet. This file is not currently used by MACCS.
- A file ending with _Site.inp that is the standard site file required by MACCS.
- A file ending with _Site_Extended.tsv that is in tab-separated format, contains information like the previous file but treats each grid element as its own economic region, and is convenient for examining in a spreadsheet. This file is not currently used by MACCS.

On the *Site Data* tab of *PROPERTIES*, the user specifies whether a site data file is to be used. When it is not used, the population density applied in the EARLY and CHRONC modules are specified on the *EARLY/Model Basis/Population Data* form. Beyond a user-specified radius representing the exclusion area boundary, this density is applied uniformly over the grid.

The site file used in MACCS is a fixed-format file. The data must appear exactly as described below and in the same order.

The file is fixed format, which requires care to align the values into their proper fields. Any numeric items specified in exponential format (e.g., 1.E-6) must be right justified in the field because trailing blanks are processed as zeros. To prevent errors due to right justification, it is recommended that a decimal point be 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. The basic form may be followed by an exponent of one of the following forms:

- Signed integer constant (e.g., 1.-6 means 1.E-6)
- E followed by zero or more blanks followed by an optionally signed integer exponent.

Users are cautioned that site files use a fixed format. Site files are formatted correctly by SecPop, but there are some reasons for the user to manually edit the site file (e.g., to add a transient population or to modify the watershed information). Sites outside the continental US must be constructed manually or with other software. Failure to conform to the formatting requirements for a site file may lead to incorrect results in a MACCS calculation.

When using SecPop to create a site file, quality assurance information is written to the first two lines that includes 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 MACCS-UI 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 records that specify the amount of data that are contained in 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 input field.

Some of the parameters defined in the site file must agree with parameters defined in WinMACCS. However, when the parameter is not required by WinMACCS, agreement is not required. For example, when the CHRONC model is not selected, parameters such as NFICRP, NUMWPI are not required to be defined in WinMACCS. When the *MACCS Food Model* is not selected, the CROP parameters are not used by WinMACCS. The parameters listed in Table B-8 are required to be defined in the site file even though they may not be used by MACCS to perform calculations.

Table B-8. Basic site file parameters

Line	Columns	FORTRAN Format	MACCS Parameter 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 intervals.	26 SPATIAL INTERVALS
4	1 to 4	I4	NUMCOR	16, 32, 48, or 64 Must agree with WinMACCS parameter NUMCOR.	Number of sectors in the spatial grid.	16 WIND DIRECTIONS
5	1 to 4	I4	NFICRP	1 to 10 Must agree with WinMACCS parameter NFICRP	Number of crop categories that are to be used by the food pathway model	7 CROP CATEGORIES

Line	Columns	FORTRAN Format	MACCS Parameter Name	Allowed Values	Description	Example line from FicticiousSite.inp
6	1 to 4	I4	NUMWPI	1 to 10 Must agree with WinMACCS parameter NUMWPI	Number of radionuclides in drinking water pathway	4 WATER ISOTOPES
7	1 to 4	I4	NUMWPA	1 to 4	Number of watersheds	1 WATERSHED
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. MACCS-UI can create a new site file that supports NUMCOR equal to 32, 48 or 64 based on an existing site file. This feature can be accessed on the MACCS-UI form *GENERAL/File Specifications/Site File*. This is useful when MACCS-UI uses a finer grid resolution than the original site file. When not using a site data file, MACCS-UI assumes one watershed. Water ingestion data for each radionuclide considered in the water pathway are defined in the MACCS-UI parameter WINGF for one watershed only. Only by using the site data file can more water pathways be specified. In this case, MACCS uses the ingestion factor read from the site file. The format for input of the ingestion data is described below. SecPop enters constants for these values with the intention that they can be edited by the user if needed.

Eight blocks of site data follow the introductory block described in Table B-9. Each of these data blocks are summarized in Table B-9 and are introduced by a separator line that identifies the block of the data to follow. Data block separators start in column 2 and are right justified.

Table B-9. Site file data blocks

Data Block	Columns	FORTRAN Format	First Line	Description
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 parameters associated with crops

Data Block	Columns	FORTRAN Format	First Line	Description
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

B.2.2. Spatial Distances Data Block

The spatial distances data define the spatial grid for which the population and some other data are specified. The data define the distances 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 grid elements. This grid definition must agree with the grid defined by the ATMOS input parameter SPAEND. MACCS reads the spatial intervals distances in the site file and compares the values with SPAEND. MACCS allows a relative error of 10%, but only the ATMOS values for SPAEND are used in calculations. For larger discrepancies in the geometry data, an error flag is set and execution terminates upon completion of the site data file input processing. MACCS-UI sets the values of SPAEND to be identical with the values in the site data file, so it is not possible to have any difference between the spatial distances data block in the site file 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, up to eight values per line, using the format described below, using as many lines as needed. The minimum spacing between adjacent spatial intervals is 0.1 km.

The first interval endpoint is in columns 1–10, the second interval endpoint is in columns 11–20, etc. The values must be right justified within the ten columns allotted. The values are input as real numbers.

Table B-10. Spatial distances data

Parameter Name	Dimensions	FORTRAN Format	Allowed Values	Description
SPAEND	NUMRAD	8E10.2	0.05 to 9999.0 km	Radial spatial intervals

B.2.3. 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, which is centered on north. The sector number increases in the clockwise direction.

The population data are input as real numbers; fractional values are supported. The population data for up to eight grid elements may be defined per line and the data are input in ten column intervals; i.e., the population of the first element is in columns 1–10, the population in the second element is in columns 11–20, etc. The data must be right justified in the ten columns allotted to that value.

Table B-11. Population data

Parameter Name	Dimensions	FORTRAN Format	Allowed Values	Description
POPDAT	NUMRAD by NUMCOR	8E10.0	0.0 to 109	Number of people living in grid element

MACCS combines evacuation scenarios using one of three different algorithms specified by a parameter WTNAM. This parameter can be set to PEOPLE, TIME or SUMPOP. This parameter is defined on the *Site Data* tab in MACCS-UI under *PROPERTIES*.

When WTNAM is set to PEOPLE, the EARLY variable, WTFRAC, specified per cohort, represents the fraction of the population that belongs to the cohort. When WTNAM is set to TIME, the EARLY parameter WTFRAC represents the fraction of time (i.e., probability) that this evacuation scenario is applicable. With this option, the entire population follows an evacuation scenario a fraction of the time. When the parameter WTNAM is set to SUMPOP, population data for each evacuation scenario are defined in the site data file as described below.

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 corresponding emergency-phase cohorts, all beginning in column 2. MACCS reports an error when the number of population data blocks does not equal the number of emergency-phase cohorts defined in the EARLY input file.

B.2.4. Land Fraction Data Block

The fraction of each spatial element that is land (as opposed to lakes, oceans, etc.) is defined for each grid element. The first line of the data block contains a 22-character separator beginning in column 2, the character string LAND FRACTION. 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, using 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 clockwise order. The values for each sector begin on a new line.

The land fraction data are read as real numbers and land fractions values each occupy five columns. The values must be right justified in the five columns allotted.

Table B-12. Land fraction data

Parameter Name	Dimensions	FORTRAN Format	Allowed Values	Description
FRCLND	NUMRAD by NUMCOR	16F5.2	0.0 to 1.0	Fraction of sector that is land

B.2.5. Watershed Index Data Block

Each of the spatial intervals in the grid must be associated with one of the watershed indices. The watershed identification data block begins with a 22-character separator beginning in column 2 containing the character string WATERSHED INDEX. The next line contains two digit integers associating a watershed type for each of the grid elements in the first sector. Data for all sectors must be provided. The data for each sector begins on a new line.

A watershed index of 1 means that the water ingestion factor for watershed type 1 is used for all deposition in that grid element. A watershed index of 2 means that the water ingestion factor for watershed type 2 is used for all deposition in that spatial element. Though the FORTRAN format, 40I2, supports up to forty values per line, the number of values on each line should be NUMRAD. The number of lines in this data block is the number of compass sectors, a new line for each sector ordered in a clockwise fashion starting from north.

Table B-13. Watershed index data

Parameter Name	Dimensions	FORTRAN Format	Allowed Values	Description
INDWTR	NUMRAD by NUMCOR	40I2	1 to NUMWPA	Watershed index associated with sector

B.2.6. 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 exactly to 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). Values must be specified for each of crop type.

This information is used only when *MACCS Food Model* is specified on the *Food* tab in MACCS-UI; it is not used when the *MACCS Food Model* is not used, but the values are required, nonetheless.

When *MACCS Food Model* is specified on the *Food* tab in MACCS-UI, the crop names must agree with the parameter NAMCRP. The data block begins with the separator CROP SEASON AND SHARE in column 2. This is followed by NFICRP lines of data.

Table B-14. Crop and season share data block

Parameter Name	Dimensions	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, 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

B.2.7. Watershed Definition Data Block

The data block begins with a 22-character separator beginning in column 2 containing the character string WATERSHED DEFINITION. 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 override values of MACCS-UI parameter WINGF when defined. MACCS supports up to 10 radionuclides in the liquid pathway model.

Table B-15. Watershed definition data

Parameter Name	Dimensions	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 MACCS-UI parameter NAMIPI when defined. Otherwise, should match a value in vector NUCNAM.	Radionuclide name
WTRINF(1)	36 to 45	E10.1	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	to 1.0	Ingestion Factor for Watershed Class 3
WTRINF(4)	66 to 75	E10.1	to 1.0	Ingestion Factor for Watershed Class 4

B.2.8. 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 the name of a county, 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.

Table B-16. Regional economic data

Parameter Name	Dimensions	FORTRAN Format	Allowed Values	Description
I	1 to 4	I4	1 to NECRGN	Region index, starting with 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 from dairy
ASFP	31 to 40	F10.1	0.0 to 10^9 $/hectare	Total annual farm sales
VFRM	41 to 50	F10.1	0.0 to 10^9 $/hectare	Farmland property value
VNFRM	51 to 60	F10.1	0.0 to 10^9 $/person	Non-farmland property value

B.2.9. Sample Site Data File

This is an example site file for a fictitious site located in Pahrump, Nevada, USA. It includes 16 compass sectors, 26 spatial intervals, uses one watershed, and has 98 economic regions. It uses the 2010 Census for population and 2012 economic data. Multipliers for population and economic values are both set to unity. Crop season and watershed definition are defaults from SecPop and must be edited manually if they need to be modified.

```
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
0.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.00 0.00 0.00 0.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.92 0.99
0.00 0.00 1.00 1.00 1.00 1.00 1.00 1.00 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 0.98 0.99 0.99
0.00 1.00 1.00 1.00 1.00 1.00 0.00 0.00 1.00 0.98 0.93 1.00 1.00 0.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.98 1.00 0.99
0.00 0.99 1.00 1.00 1.00 1.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00 1.00 1.00
1.00 1.00 1.00 0.94 0.85 0.99 1.00 1.00 1.00 1.00
0.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 0.98 0.99 1.00 1.00 1.00 1.00
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 0.98 0.99 0.99 1.00 1.00 1.00
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 1.00 0.00
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
1.00 1.00 1.00 1.00 1.00 1.00 0.94 0.96 0.00 0.00
0.00 0.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.00 1.00 0.00 0.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.80 0.00 0.00
0.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.00 1.00 1.00 0.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.62 0.00 0.00
0.00 0.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.00 0.00 1.00 1.00
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
1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.96 0.98 0.94
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 3 4 419131313131313131320212223848498
1 4 4 4 4 4 3 3 4 4241313 313131313131313252627858598
1 4 4 4 4 4 3 3 3 4 3 3 3 313131313131313282930868698
1 4 4 4 4 4 4 4 3 4 4 41313131313131313133131323387879 8
1 3 4 4 4 4 4 4 4 4 4 434131313133536373839408888898
1 4 4 4 4 4 4 4 4 4 4 441424344454647474747488989 3
1 3 4 4 4 4 4 4 4 4 449505050505147474747525390 3 3
1 3 4 4 4 4 4 4 4 4 350 3 350505455474747475691 3 3
1 4 4 4 4 4 4 4 4 35750 35050505058474747596092 3 3
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1 3 4 4 4 4 4 4 4 46162 3 350505050506364656693 3 3
1 3 4 4 4 4 4 4 4 4 467 3 3505050505050505068699494 3
1 4 4 4 4 4 4 4 4 4 4 4 4 4 470717250505073749595 98
1 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 47576777879969698
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
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 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

B.3. Dose Conversion Factor File

B.3.1. Introduction

MACCS-UI is supplied with a set of 51 "adult" dose coefficient files which are based on the CD supplement to FGR-13 (EPA 2002). Data for 825 isotopes are provided. This dose factor file set supports MACCS-UI calculations using the LNT, AT, PL, LT, and ATL dose-response models for latent cancer health effects and the acute health effects model.

In SAND2023-10896, it was identified that the inhalation dose coefficient for tritium in the FGR-13 dose coefficient files supplied with MACCS is consistent with tritium in the form of tritiated water vapor (HTO). However, the inhalation dose coefficient was not adjusted to account for the absorption of tritium through the skin during immersion in airborne tritium (Pinson and Langham 1957). Therefore, the most recent FGR-13 DCF file discussed here and supplied with MACCS includes this adjustment and increases the tritium inhalation dose coefficient by 50% (IAEA 2004). The annual dose conversion factor files were adjusted accordingly as well.

These dose factors use ICRP Publication 60 (ICRP 1991) tissue weighting, and the respiratory tract model defined in ICRP Publication 66 (ICRP 1994). FGR-13 dose coefficients 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 EPA and the Oak Ridge National Laboratory Center for Biokinetic and Dosimetric Research. The differences between FGR-13 and ICRP 72 dose coefficients are largely attributable to differences in:

- Assumptions of shared kinetics in some decay chains
- Systemic biokinetic models for some elements, and
- Gastrointestinal tract absorption-to-blood fractions, f1.

B.3.2. Lung Clearance Behavior

With few exceptions, the absorption types are consistent with those in ICRP 72. The dose coefficient files do not indicate an absorption type for certain isotopes when either there was no choice of clearance type in FGR-13, or the choice was superfluous because the inhalation dose coefficients were zero.

B.3.3. 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 in FGR-13. 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 coefficients based on the form and f1 that gave the highest dose.

B.3.4. Particle Size Distribution

Inhalation dose coefficients for micron sized particles depend on the activity median aerodynamic diameter (AMAD). The FGR-13 inhalation dose factors are based on an activity mean aerodynamic diameter (AMAD) of 1 μm.

B.3.5. Organs Included in the Data Set

The following organs and tissues are included in the FGR-13 dose coefficient files.

Table B-17. Organs and tissues included in data set

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	

B.3.6. 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 contributions to these dose coefficients. The annual files contain the contribution to dose in a specific year from an exposure during the first year.

B.3.7. 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:

- The **esophagus** was assigned the corresponding inhalation dose coefficients and ingestion dose coefficients of the **thymus**.
- 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%).
- The inhalation and ingestion dose coefficients for the **lung** (thoracic portion of respiratory tract) and $\mathbf{ET_{Reg}}$ (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.
- The dose coefficients for **remainder** were calculated using equations in ICRP publication 71 (ICRP 1995) page 27.
- The dose coefficients for **gonads** were the larger of the dose coefficients for testes and ovaries.
- The dose coefficients for **effective** were computed from the individual organ dose coefficients using the ICRP 60 tissue weighting method.

B.3.8. Acute Inhalation Dose Factors

Reliable data on relative biological effectiveness, **RBE**, of high linear energy transfer radiation at causing acute health effects were not located; so, the acute inhalation dose factors were based on an RBE of 10 for consistency with DOSFAC2 DCF 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).

B.3.9. Designating Pseudo-Stable Isotopes When Using Federal Guidance Report 13 Dose Coefficient Files

In contrast to DOSFAC2 and FGRDCF dose coefficients, Federal Guidance Report 13 dose coefficients do not implicitly account for doses from a decay product in the dose coefficients of the parent. 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 MACCS-UI "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 its 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.

B.3.10. Known Issues

The FGR-13 dose coefficient files have inherited the following issues from the CD Supplement to FGR-13:

- The ingestion and inhalation dose coefficients for four alpha-emitting rare-earth isotopes (Sm-146, Sm-147, Gd-148, and Gd-152) are incorrect.
- 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.

B.4. Cyclical File

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 MACCS-UI through *PROPERTIES* setting on the Scope tab. The files are selected and copied into the MACCS-UI project after the user completes the form *GENERAL/File Specifications/Cyclical File Set*.

When the user clicks the Run button to begin a simulation, MACCS-UI 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. MACCS-UI creates the MACCS template input files. The template input files are identical to the MACCS input files when sampling is not used for the simulation.

The format required for the cyclical input files is identical to the input format required for MACCS with the following exceptions:

- ATMOS, EARLY, CHRONC and COMIDA2 model input can be grouped together in a single cyclical input file. When MACCS is run directly, input for these models must be in separate files.
- A period in column one is used solely to separate EARLY evacuation scenarios. The first evacuation scenario occurs before the first period in column one. MACCS also supports using a period in column one to separate different source terms in the ATMOS input, but this is not supported in MACCS-UI. Instead, MACCS-UI uses the cyclical file capability to support multiple source terms.
- MACCS has evolved since 1.13.1, and though cyclical file input is backward compatible, new model options and hence new input values have been added. Thus, older files may not be entirely compatible with newer versions of MACCS-UI and MACCS.

The MACCS file format is not documented in detail here. However, note the following rules:

- An asterisk (*) in column one signifies a comment.
- Multiple values on an input line can be separated by any amount of white space, including TAB characters.

- An input line begins with a prefix. Depending on the input line, this is followed by a two- or three-digit sequence number or by no sequence number. The value(s) of the variable(s) follow separated by white space. 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 any of the following ways:

- Modify a MACCS file to reflect the changes desired. As a starting point, use a file created by MACCS-UI such as Atmos1.inp, Early1.inp, etc.
- Include only relevant changes between the simulations in a cyclical input file. As a starting point, edit a file created by MACCS-UI, removing data that are not changed between cyclical runs.
- 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 *Cyclical File Sets* option in *PROPERTIES*, *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 parameter PDELAY in the MACCS input file, as referenced in the MACCS-UI interface, search for the string PDELAY in the Atmos1.txt file. This is first found in a comment immediately preceding the MACCS input lines responsible for setting the value of PDELAY, 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 or other basic text processor.

- The order of the lines is not important.
- 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.
- Blank lines are allowed.
- Cohort definitions are separated by a line containing a period in column one.

The following is a sample cyclical file. Notice that there are ATMOS, EARLY and CHRONC parameters in the first section. The second section, separated from the first section with a period in column one, contains values to define the second EARLY emergency cohort.

* CWASH1, Washout Coefficient Number One, Linear Factor

WDCWASH1001 $9.7x10^{-5}$

* WTFRAC - weighting fraction applied to EARLY emergency response cohort one

EZWTFRAC001 .90

* EXPTIM - long term exposure period, CHRONC variable

CHEXPTIM001 $9.7x10^8$

* WTFRAC - weighting fraction applied to EARLY emergency response cohort two

EZWTFRAC001   .1

B.5. MACCS Binary File

B.5.1. Overview

With the development of MACCS-UI, it became desirable to create a file to facilitate communication of results from the MACCS modeling engine to MACCS-UI. The standard text output file created by MACCS is not an ideal basis for this communication. As a result, a structured, binary output file was created. Results in this file contain the full numerical precision of the MACCS calculations. When additional parameters are added to the file, MACCS-UI does not have to be modified to display the new data.

The binary file supports multidimensional data. For example, Centerline Ground Concentration is associated with the plume number, a radionuclide, and a position on the spatial grid.

B.5.2. Multidimensional Data

Many of the MACCS data are multidimensional. Each result written to the binary file is associated with 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 MACCS-UI to identify the input line associated with the result. The qualifier units for many of the results are specified in the MACCS input.

New qualifiers can be defined without modifications to MACCS-UI. A list of the current qualifiers and the optional units are shown in B-18.

Table B-18. 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
Exceeds Dose	Sv, rem	real	5.2
Source Term	none	integer	1
Angle	none	character	ENE
Pathway	none	character	GRD

Qualifier	Units	Data Type	Example Value
Elevation Dose	Sv, rem	real	10.
Elevation Concentration	Bq/m^2, Ci/m^2	real	4.2
MACCS2_Input	none	n/a	TYPE1OUT001 ‘ERL FAT/TOTAL' 1 26 NONE
Time	S	real	60
Industry Type	none	character	3 : Agriculture, forestry,
GDP loss for Year #	none	Integer	1

B.5.3. Data in the Binary File

The results in the binary file are defined by 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 results associated with this request is one, namely the number of total early fatality health effects.

The following describes the format of the binary file. Some results are available in units that depend on the ATMOS input.

The data for each of the results are the statistics shown in Table B-19 and the CCDF of the data stored in a binned form, the same as in the MACCS output file.

Table B-19. 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 types of results are shown in Table B-20.

Table B-20. 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 *ATMOS, EARLY, and CHRONC LNT* is selected on the *PROPERTIES/Scope* tab.	Source Term Evacuation Health Effect Ldistance Rdistance Organ MACCS_Input	Sv, rem
Health Effects Used Adjusted Population Dose	Type 1 output Note: This output is only printed when *ATMOS, EARLY, and CHRONC Threshold* is selected on the *PROPERTIES/Scope* tab.	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	Type D output	Source Term Evacuation Nuclide Angle Ldistance Rdistance MACCS_Input	Bq/m^2
Area That Exceeds Concentration Threshold	Type D output	Source Term Evacuation Elevation Concentration Nuclide Ldistance Rdistance MACCS_Input	Ha
Air Concentration by Grid Element	Type D output	Source Term Evacuation Nuclide Angle Ldistance Rdistance MACCS_Input	$Bq\text{-}s/m^3$
Population Movement	Type E output	Source Term Evacuation Distance Time MACCS2_Input	Fraction of Cohort
Tot Long-Term Pathways Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv

VarLab	Comments	Qualifiers	Units
Tot Long-Term Direct Exposure Pathways	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
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 Interdict Decontamination Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Population Hapitable Decontamination Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Farm Interdict Decontamination Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv
Farm Habitable Decontamination Dose	Type 9 results	Source Term Evacuation Organ Ldistance Rdistance MACCS_Input	person-Sv

VarLab	Comments	Qualifiers	Units
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
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

VarLab	Comments	Qualifiers	Units
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
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	$

VarLab	Comments	Qualifiers	Units
Farm Dependent Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Pop Dependent Interdiction Decontamination Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Farm Dependent Interdiction Decontamination Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Pop Dependent Habitable Decontamination Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Farm Dependent Habitable 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	$
Farm Dependent Interdiction Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Pop Cost-Effective Condemnation Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Farm Cost-Effective Dependent Condemnation Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$

VarLab	Comments	Qualifiers	Units
Pop Regular Condemnation Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Farm Regular 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	$
National GDP Losses for Year	Type 10 results	Source Term Evacuation Ldistance Rdistance GDP loss for Year # MACCS_Input	$
Direct GDP Losses for Year	Type 10 results	Source Term Evacuation Ldistance Rdistance GDP loss for Year # MACCS_Input	$
Total Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$

VarLab	Comments	Qualifiers	Units
Total National GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
All Gross Direct GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Gross Direct Industry GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
All Net National GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
Net National Industry GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
All Net Direct GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
Net Direct Industry GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
All Net Indirect GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$

VarLab	Comments	Qualifiers	Units
Net Indirect Industry GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
All Net Induced GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	$
Net Induced Industry GDP Losses	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
All National GDP Recovery	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
National Industry GDP Recovery	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
All Direct GDP Recovery	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
Direct Industry GDP Recovery	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
All Indirect GDP Recovery	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$

VarLab	Comments	Qualifiers	Units
Indirect Industry GDP Recovery	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
All Induced GDP Recovery	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
Induced Industry GDP Recovery	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
Farm Dependent Loss Of Use Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
Pop Dependent Depreciation Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
Farm Dependent Depreciation Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
Long-Term Phase Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$
Pop Dependent Loss Of Use Costs	Type 10 results	Source Term Evacuation Ldistance Rdistance Industry Type MACCS_Input	$

VarLab	Comments	Qualifiers	Units
Farm Dependent Interdiction Decontamination Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Pop Dependent Interdiction Decontamination Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Farm Dependent Habitable Decontamination Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Pop Dependent Habitable 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
Farm Dependent Cost-Effective Condemnation Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Pop Dependent Cost-Effective Condemnation Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Farm Dependent Regular Condemnation Distance	Type 11 results	Source Term Evacuation MACCS_Input	km
Pop Dependent Regular 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 Interdicted Decontamination	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Pop Interdicted Decontamination	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	individuals

VarLab	Comments	Qualifiers	Units
Pop Interdicted Decontamination Area	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Farm Habitable Decontamination	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Pop Habitable Decontamination	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Pop Habitable 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 Cost-Effective Condemnation	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Pop Cost- Effective Condemnation	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	individuals

VarLab	Comments	Qualifiers	Units
Pop Cost-Effective Condemnation Area	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Farm Regular Condemnation	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Pop Regular Condemnation	Type 12 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	ha
Pop Regular 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
Emergency Phase Reloc No Plume Affect	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	none
Emergency Phase Reloc Plume Affected	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None

VarLab	Comments	Qualifiers	Units
Normal Emergency Phase Relocation	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None
Hotspot Emergency Phase Relocation	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None
Intermediate Phase Relocation	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None
Level 1 Decontamination Relocation	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None
Level 2 Decontamination Relocation	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None
Level 3 Decontamination Relocation	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None
Decontamination+Interdiction Relocation	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None
Cost-Effective Condemnation Relocation	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None
Regular Condemnation Relocation	Type 14 results	Source Term Evacuation Ldistance Rdistance MACCS_Input	None

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APPENDIX C. INFORMATION FOR USERS FAMILIAR WITH WINMACCS

C.1. Relocated Menu Actions

Many WinMACCS main menu actions are not included in MACCS-UI, as they were not necessary, implemented differently, or not completed by the end date. Table C-1 describes equivalents of the previous menu options.

Table C-1. MACCS-UI equivalents of WinMACCS 4.2 main menu actions

WinMACCS Menu Action	MACCS-UI Equivalent
Files	
New Project	*HOME* page→*Actions*→*NEW PROJECT*
Open Project	*HOME* page→*Actions*→*OPEN PROJECT*, or *MENU*→*File*→*Open Project*
Save Project	*MENU*→*File*→*Save Project*
SaveAs Project	Not implemented.
Close Project	Not implemented. Projects do not need to be closed before opening a new one.
Refresh File View	Not implemented.
Import MACCS Input File	*MENU*→*File*→*Import MACCS Input File*
Import Custom Report Definitions	Not implemented.
Import Parameters from Special Export	Not implemented.
Export Binary Results as Text	*MENU*→*File*→*Export MACCS Output As Text*
Edit	
Show Legend	*MENU*→*View*→*Show Legend*
Auto Propagate Cohort Values	Not implemented.
Propagate Cohort Values on Upgrade	Not implemented.
Grid	Not implemented.
Correlate Uncertain Variables	Not implemented.
Modify Form Variables	Forms can be modified by simply clicking on the form or variable name in the parameters tree.
Find or Export Parameters	*MENU*→*Edit*→*Find Variable*
Project Properties	The *PROPERTIES* form is always displayed at the top of the *INPUT* page.
PreProcessing	
Create MACCS-HYSPLIT files	Use HyGridConvert, an external program.
Execute	
Validate Data Before Running	Automatically handled in MACCS-UI.
Simple Random Sampling	*Simple Random Sampling* checkbox in *PROPERTIES/Uncertainty*

WinMACCS Menu Action	MACCS-UI Equivalent
Parallel Simulations	*Parallel Simulations* checkbox in *PROPERTIES/Project Settings.*
Auto Create Reports	*REPORTS* tab→*Auto-run reports after simulation* toggle
Run Models	*RUN SIMULATIONS* button in top right corner.
Advanced Execution Parameters accessed through *Run Models→Advanced*	Settings in *PROPERTIES/Project Settings*.
PostProcessing	
Graphical Results	Not implemented.
Graphical Results→Scalar Results	Not implemented.
Graphical Results→ Statistical Summary Results	Not implemented.
Graphical Results→ Results over all Weather Trials	Not implemented.
Graphical Results→Edit Plots	Not implemented.
Report Results	Run one or a selection of reports on the *REPORTS* tab.
Report Results→ Manage Custom Reports	*REPORTS* tab.
Report Results→ Create Summary Report	*REPORTS* tab→*CREATE SUMMARY REPORT*
Window	
Cascade	Not used.
Numbered windows	Not used.
Help	
MACCS Documentation	*MENU→Help→MACCS Documentation*
About	*MENU→Help→About*

C.2. File Management

Files are managed differently between WinMACCS and MACCS-UI. In contrast to WinMACCS, most file management in MACCS-UI is done through the Windows File Explorer. However, the *File Specifications* category in *GENERAL* is retained.

C.2.1. Accessing Input, Output, and Data Files

The *Files* tab is no longer used. In its place, users should open the Windows File Explorer and navigate to the project's folder, displayed at the top of the window. The example folder, …\Import Example\… is created when a new project is created or imported. An example of the path is shown in the red box in Figure C-1.

Figure C-1. Example project path

The folder at this path is shown below in Figure C-2. These are the Data, Input, and Output files that would previously be accessed through the *Files* tab. An in-depth description of the file structure is in Section 3.1.7.

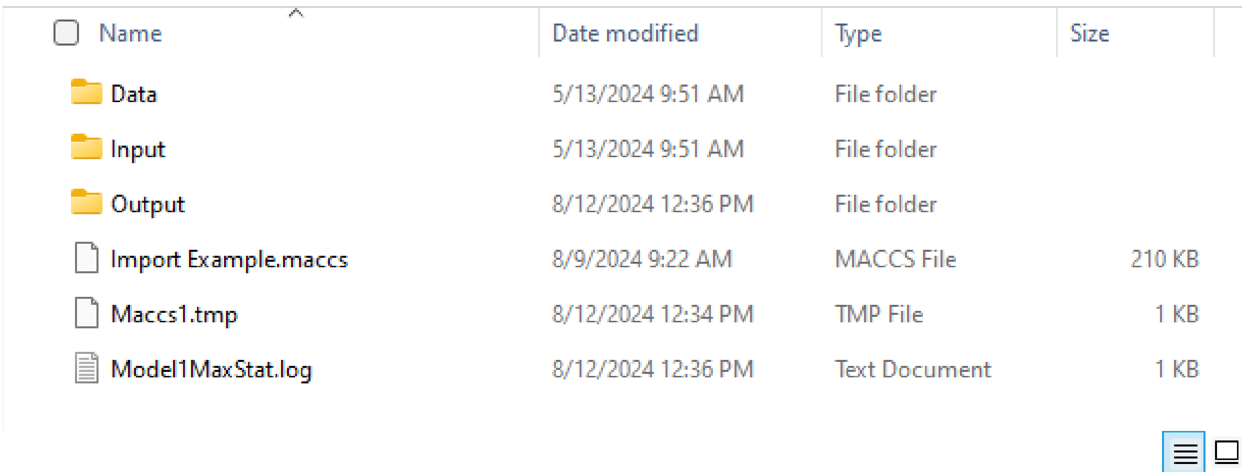

Figure C-2. Example view of project folder

C.3. WinMACCS Features Not Implemented in MACCS-UI

Some features available in WinMACCS are not yet implemented in MACCS-UI. Below is a table of these, with available workarounds listed. See Table C-1 for WinMACCS actions and MACCS-UI equivalents.

Table C-2. Additional workarounds for WinMACCS features not yet implemented in MACCS-UI.

Feature	Work-Around
Some uncertainty distributions cannot be defined in MACCS-UI	These distributions can still be used in MACCS-UI, but must be defined in WinMACCS.
Files tab is not present	Use Windows File Explorer to view and edit files.
Resetting a form	Delete values in form by hand and use the defaults provided in Appendix A.
Copy values between cohorts	Use cut and paste for each form.
Create MACCS-HYSPLIT files	Use HyGridConvert, an external program or WinMACCS to set up files.

Additional workarounds and changes are discussed in the Release Notes provided with MACCS-UI.

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