CAP88-PC Version 4.1

User Guide

Mr. Brian Littleton, EPA Project Manager
Office of Radiation and Indoor Air
1200 Pennsylvania Avenue, NW
Washington, DC 20460

By:
Trinity Engineering Associates, Inc.
25 W Fountain Ave.
Cincinnati, OH 45246-4308

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Introduction

Background

On October 31, 1989 the Environmental Protection Agency (EPA) issued final rules for radionuclide emissions to air under 40 CFR 61, National Emission Standards for Hazardous Air Pollutants (NESHAPS). Emission monitoring and compliance procedures for Department of Energy (DOE) facilities (40 CFR 61.93(a)) require the use of CAP-88 or AIRDOS-PC computer models, or other approved procedures, to calculate effective dose equivalents to members of the public.

The CAP88 (which stands for Clean Air Act Assessment Package - 1988) computer model is a set of computer programs, databases and associated utility programs for estimation of dose and risk from radionuclide emissions to air. EPA modified the ORNL mainframe program AIRDOS in 1979 to create AIRDOS-EPA (Mo79). The AIRDOS-EPA code was further modified to incorporate various dose and risk coefficients. AIRDOS-EPA (1982) used RADRISK (1980) database files for dose and risk coefficients. RADRISK calculated isotope dose and risk and stored them in binary card image format. The DARTAB (1981) code was developed to convert RADRISK files to the format used by AIRDOS-EPA. AIRDOS (1984) used doses from DARTAB rather than the doses calculated directly by AIRDOS.

To make compliance calculations easier for individuals without access to a mainframe computer, EPA developed the AIRDOS-PC program that was used from 1982 to 1986. AIRDOS-PC was succeeded by AIRDOS2 which was the predecessor of CAP88-PC. At the same time PC versions of RADRISK and DARTAB were developed. All were combined in CAP88-PC (1988).

Purpose and Version History

The original CAP88-PC software package, version 1.0, allowed users to perform full-featured dose and risk assessments in a DOS environment for the purpose of demonstrating compliance with 40 CFR 61.93(a). CAP88-PC provided the CAP-88 methodology for assessments of both collective populations and maximally-exposed individuals. The complete set of dose and risk factors used in CAP88 was provided. CAP88-PC differs from the dose assessment software AIRDOS-PC in that it estimates risk as well as dose, offers a wider selection of radionuclide and meteorological data, provides the capability for collective population assessments, and allows users greater freedom to alter values of environmental transport variables. CAP88-PC version 1.0 was approved for demonstrating compliance with 40 CFR 61.93(a) in February 1992.

CAP88-PC version 2.0 provided a framework for developing inputs to perform full-featured dose and risk assessments in a Windows environment for the purpose of demonstrating compliance with 40 CFR 61.93(a). The changes from version 2.0 to version 2.1 included the addition of more decay chains, improvements in the Windows code error handling, and a modified nuclide data input form.

CAP88-PC Version 3.0 marked a significant update to the version 2 system. Version 3 incorporated dose and risk factors from Federal Guidance Report 13 (FGR 13, EPA99) in place of the RADRISK data that was used in previous versions. The FGR 13 factors were

based on the methods in Publication 72 of the International Commission on Radiological Protection (ICRP72). In addition, the CAP88-PC database, user interface, and input/output files were modified to accommodate the FGR 13 data formats and nomenclature.

CAP88-PC Version 4 was a significant modification to version 3 intended to improve usability, increase stability, update the datasets, and provide a more maintainable code base and documentation set for the future. Version 4 adopted age-dependent dose and risk factors and introduced a new code architecture that conformed to updated coding standards and data formats. Version 4 also moved the database of isotopic data to eXtensible Markup Language (XML) format to enhance portability. Version 4.1 updates the dose/risk data to incorporate the DCFPAK 3.02 release of the FGR 13 information, and includes usability enhancements.

Model Summary

All versions of CAP88-PC use a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six emitting sources. The sources may be either elevated stacks, such as a smokestack, or uniform area sources, such as a pile of uranium mill tailings. Plume rise can be calculated assuming either a fixed, momentum, or buoyant-driven plume. Assessments are done for a circular grid of distances and directions for a radius of up to 80 kilometers (50 miles) around the facility. The Gaussian plume model is simple to use, has been widely tested, and has been shown to give reasonable predictions if a proper selection of model parameters is made (Faw99).

The mainframe version of CAP88 consisted of three independent programs; the atmospheric dispersion program AIRDOS, the dose calculation program DARTAB, and the input preparation program PREPAR. There are a few differences between all versions of CAP88-PC and the mainframe versions of AIRDOS, PREPAR and DARTAB. The PREPAR program has been eliminated and replaced by a graphical user interface in CAP88-PC versions 2 through 4.1. Population assessments are easier to perform in all versions of CAP88-PC. When performing population assessments, population arrays must always be supplied to the program as a file; for backward compatibility the population files still use the same format as those from the mainframe version of CAP88. Sample population files are supplied with CAP88-PC, which the user should modify to reflect their own population distributions. When performing population dose assessments, all versions of CAP88-PC use the distances in the population array to determine the sector midpoint distances where the code calculates concentrations. The AIRDOS dispersion module used in all versions of CAP88-PC only uses circular grids to define the assessment area, whereas square grids were available in the mainframe version. When an individual assessment is run in any version of CAP88-PC, the sector midpoint distances are input by the user and the sector boundary distances are calculated by CAP88-PC. Direct user input of radionuclide concentrations is not an option in any version of CAP88-PC.

All versions of CAP88-PC have the capability to vary Radon daughter equilibrium fractions; previously they were set to a constant fraction value of 0.7. The new method varies the equilibrium fractions depending on the distance from the source. Linear interpolation is used to determine the equilibrium fractions for distances that do not match the set distances given.

Agricultural arrays of milk cattle, beef cattle and agricultural crop area are generated automatically, requiring the user to supply only the State name or agricultural productivity values. When a population assessment is performed, the arrays are generated to match the

distances used in the population arrays supplied to the code, and use State-specific or user-supplied agricultural productivity values. The state name (standard two letter abbreviation) must be provided. Users are given the option to override the default agricultural productivity values by entering the data directly on the Agricultural Data tab form. If Alaska, Hawaii, or Washington, D.C. is selected, agricultural productivity values are set to zero and must be provided by the user.

CAP88-PC has been modified from the mainframe version to be capable of performing either "Radon-only" or "Non-Radon" runs in order to conform to the format of the 1988 Clean Air Act NESHAPS Rulemaking. "Radon-only" assessments are cases having Rn-222 as the only release isotope; including any other isotope in the release list cause CAP88-PC to consider the case as "Non-Radon". Cases that are "Radon-only" assessments perform calculations of Working Level and report Working Level in the output reports. Input of any other isotopes, including Radon-220, will cause CAP88-PC to omit calculations of Working Level. Synopsis reports are automatically customized based on whether the case is "Radon-only" or "Non-Radon". Version 4.1 has not changed the "Radon-only" methodology relative to previous versions.

The calculation of deposition velocity and the default scavenging coefficient is defined by current EPA policy. Deposition velocity is set to 3.5e-2 m/sec for Iodine, 1.8e-3 m/sec for Particulate, and 0.0 m/sec for Gas. The default scavenging coefficient is calculated as a function of annual precipitation, which is input on the Meteorological Data tab form. Version 4.1 has not modified these calculations, but the data formats introduced in Version 4.0 permit future updates to include element or isotope dependent deposition velocities.

Organs and weighting factors have been modified beginning with Version 3 to comport with the FGR 13 data supplied by Oak Rifge National Laboratory. In accordance with the FGR 13 dose model, the code now calculates dose for 25 internal organs, rather than the 23 organs in Version 3 and the 7 organs used in earlier versions. A "26th" organ is also calculated, which is the total effective dose equivalent; this was the 24th organ in version 3. The code now reports cancer risk for the 15 target cancer sites used in FGR 13. As was the case in previous versions, changing the organs and weights will invalidate the results. Version 4.1 adopted the radionuclide physical data, dose factors, risk factors and decay chain information provided by Oak Ridge National Laboratory in the DCFPAK Version 3.02 data release (Eck13). This data provides a more comprehensive set of dose and risk coefficients as compared to the DCFPAK 2.2 data used in Version 4.0. Version 4.1 retains the ability for the selection of age-dependent dose, risk, and ingestion data first introduced in CAP88-PC Version 4.0.

Food chain dose is calculated using the methodology of Regulatory Guide 1.109 published by the US Nuclear Regulatory Commission.

Validation and Testing

The various CAP88-PC programs represent one of the approved, validated codes for the purpose of making comprehensive dose and risk assessments verifying compliance with the radionuclide NESHAPS. The Gaussian plume model used in CAP88-PC to estimate dispersion of radionuclides in air is one of the more commonly used models in Government guidebooks. It produces results that agree with experimental data for long-term releases, is fairly easy to work with, and is consistent with the random nature of turbulence. CAP88-PC Version 4.1 has not modified the basic Gaussian plume algorithm used by the AIRDOS

module of CAP88-PC since Version 1. Comparison cases between versions 1, 2, 3 and 4 have shown no significant changes in the dispersion calculations.

The Office of Radiation and Indoor Air has made comparisons between the predictions of annual-average ground-level concentration to actual environmental measurements, and found very good agreement. In the paper "Comparison of AIRDOS-EPA Prediction of Ground-Level Airborne Radionuclide Concentrations to Measured Values" (Be86), environmental monitoring data at five Department of Energy (DOE) sites were compared to AIRDOS-EPA predictions. EPA concluded that, as often as not, AIRDOS-EPA dispersion predictions are within a factor of 2 of actual concentrations.

The results generated by Versions 4.0 and 4.1 have been verified by an extensive software testing program performed at both the module and program level. Formal software testing was performed by independent reviewers who were not involved in the development of the code. Software testing involved testing the user interface; verifying that that the results of the atmospheric model dispersion and environmental transport models were correct; verifying that the radioactive decay and decay product calculations were correct; verifying that the dose and risk calculations were correct; and testing that the migration tool was properly reformatting Version 3 datasets and ancillary files into Version 4.0 or 4.1 formats. The testing program has been documented in a testing report supplied to EPA. EPA then proceeded to perform its own independent quality testing program. This program consisted of development of a review plan, which after approval by EPA management, provided an independent review of the code, including identification of potential problems or issues with the functionality of the code. Corrective actions were then taken, and the results of the quality procedures, including independence of the reviewers, are available from EPA.

The software engineering and testing program used in the development of CAP88-PC Version 4.0 and 4.1 was implemented both to verify the code was producing the proper results and to upgrade the quality assurance status of the CAP88-PC program. Previous version of CAP88-PC were developed prior to the implementation of the more rigorous software quality requirements now being put in place by many organizations. In order to meet these more rigorous quality assurance requirements, the results from CAP88-PC Version 4.0 amd 4.1 were tested against not just black-box sample problems, but also hand calculations and spreadsheet models of the various calculations performed by the different code modules. The FORTRAN calculation modules of the code were developed using dual-confirmation coding, where all coding changes are performed by two individuals, one coding and one verifying the code as it is entered. As a result of using this method the FORTRAN subsystem in Version 4 has been subject to a line-by-line verification for over 90% of the active FORTRAN code. The sections not independently verified are contained in the DLSODE numerical solver libraries obtained from Lawrence Livermore National Laboratory (Ra93). Code configuration control and versioning was managed using the Visual SVN and GIT source control systems. Error tracking and resolution during the testing phase was managed in a dedicated Microsoft Sharepoint issue resolution list with versioning status and automatic notification of updates.

Limitations

Like all models, there are some limitations in the CAP88-PC system.

While up to six stack or area sources can be modeled, all the sources are modeled as if located at the same point; that is, stacks cannot be located in different areas of a facility. The same plume rise mechanism (fixed, buoyant, or momentum) is used for each source.

Also, area sources are treated as uniform. Variation in radionuclide concentrations due to complex terrain or local building wakes is not modeled.

Errors arising from these assumptions typicalle have a small effect for assessments where the distance to exposed individuals is large compared to the stack height, area or facility size. In general, the model has significant higher uncertainty for receptors that are within two stack heights of the release point.

Dose and risk estimates from CAP88-PC are applicable only to low-level chronic exposures, since the health effects and dosimetric data are based on low-level chronic intakes. CAP88-PC should not be used for either short-term or acute high-level radionuclide intakes.

Summary of Version 2.1 Changes from Version 2.0

Version 2.1.of CAP88-PC is an incremental change from Version 2.0, meaning that no significant modifications were introduced to the algorithms for calculating transport, uptake, dose, and risk. The changes have primarily been improvements to the Visual Basic code which performs the user interface and data collection functions. Some small changes were made to the FORTRAN calculation routines in order to accommodate variable input for humidity and to permit greater numbers of nuclides in a dataset. Additionally, the database files that are part of CAP88-PC's data management system have been updated to be more widely compatible with various versions of Windows. Some important modifications to the CAP88-PC code in Version 2.1 include:

- More extensive input field checking for valid values
- An error handling routine was added to provide a text file output of errors encountered by the code. Most errors are written to a file named "YYYYMMDDErrorlog.txt", where the date code refers to the date when the error occurred. This file is located in the CAP88-PC install directory
- Many updates to the directory structure, which provided more installation flexibility and better default initialization in the selection boxes for custom wind and population files.
- Added an absolute humidity entry on the Met Data tab for site specific calculation of tritium concentration in vegetables.
- Added a user selectable distance and sector (JLOC and ILOC) option for the individual assessment case. Setting these to non-zero values cause the code to provide results for the distance and sector indicated.
- Increased the number of radionuclides allowed in a run to 120 from 36
- Incorporated the Year 2000 patch needed by Version 2.0
- Eliminated all third-party functions and software packages that were in the Version 2.0 Visual Basic code
- Eliminated the dialog box that asked the user if they wanted to use MS-DOS mode
- Updated and shortened the initial splash screen
- The toolbar is located at the top of the window in accordance with Windows standard practice
- The data environment (the accompanying database) was updated to Microsoft Access for greater compatibility with Windows
- The "Open From File" option was added to allow the user to open input datasets that have not yet been included in the drop-down file list of available cases
- The default directory locations for the wind and population library were changed to be the default install directories for these files.

- The radionuclide entry method was changed. Rather than enter data directly into the Nuclide Data tab, the user selected either "Add Nuclide", "Edit Nuclide" or "Delete Nuclide" from the buttons on the form. When "Add Nuclide" or "Edit Nuclide" were selected, a new data entry form containing all selectable data for the nuclide was presented.
- A new "Save and Close" button was placed on the Nuclide Data tab of the input data form.

The user interface for Version 2.1 was built in Visual Basic 6.0, and the install package was made using InstallShield 7.2. The installer technology was updated and tested with all Windows versions from 95(b) to XP. It checked for some necessary Windows components, such as DCOM and Windows Scripting, and installed these if needed, eliminating the requirement for a separate installation of the DCOM98 module.

Summary of Version 3 Changes from Version 2.1

CAP88-PC Version 3 was a significant update to the previous version 2.1. Version 3 incorporated all the Version 2.1 updates listed in Section 1.6, along with the following additional modifications:

- Version 3 expanded the nuclide database to 825 nuclides, including all FGR 13 decay chains
- Version 3 internally calculated all the FGR-13 decay chains using a modified Bateman solution
- Version 3 was the first CAP88-PC code to perform calculation of the build-up factors on a case-specific basis for all isotopes in all chains
- Incorporation of the new FGR 13 dose and risk factors
- User-selectable analysis time period (default 100 years to maintain consistency with previous versions)
- User-selectable length of the decay chains were first included in Version 3
- User-selectable time step length for the calculation of build-up factors was first included in Version 3.
- Version 3 eliminated the calculation of Genetic Effects
- Dose factors were a function of radionuclide chemical form wherever that is included in the FGR 13 database
- Organ dose equivalent was calculated for 23 internal organs
- Cancer mortality risk is calculated for 15 cancer sites
- The radionuclide inhalation absorption "Class" terminology was replaced by the new "Type" nomenclature. The new types were F (fast), M (medium), and S (slow), and are analogous to the older classes D (day), W (week), and Y (year).
- All particulate sizes are 1.0 micron per the FGR 13 model data, except gases and vapor forms which are 0.
- Default values for all radionuclide inputs were included; these defaults corresponded to the recommended values from FGR 13 wherever a recommendation was available.
- The radionuclide transfer factors for all elements in the CAP88-PC database were updated to the values from the National Council on Radiation Protection and Measurement (NCRP) report number 123 (NCRP96).
- The nuclide input form was modified to allow selection of the nuclide absorption type and the nuclide chemical form wherever dose factors based on multiple values of these are included in the database
- Version 3 contained additional data for:
    - Age dependent dose factors

- Dose factors for additional pathways such as drinking water ingestion and external exposure from multiple depths of soil contamination.
- Dose factors for external exposure to infinite clouds
- Cancer morbidity risk factors in addition to mortality risk factors

CAP88-PC Version 3 continued to report data in the format and nomenclature used in previous versions. This was done to retain conformance of the model to the applicable regulation, 40 CFR Part 61 Subpart H. Accordingly, the dose factors used in version 3 for reporting dose to the maximum exposed individual and the populations were the values in FGR 13 for adults. The risk values reported by Version 3 and later were those for mortality, not morbidity. It is important to note that, because of the extensive data modifications, Version 3 did not allow the use of case input files created under earlier versions to be used as input for Version 3. Previous POP and WIND files were still useable.

Summary of Version 4 Changes from Version 3

CAP88-PC version 4 not only added significant features, but also redesigned the interface to give the user a more standard experience. The entire user interface module was re-written for Version 4 using VB.Net, the Microsoft .Net Framework version 4, and the Visual Studio 2010 development environment, in order to more comply with installation and security requirements in Windows 7 and Windows 8.

To conform to the Windows 7 security requirements, and to improve usability, the following significant changes were made:

- Version 4 could only be installed on Windows XP SP3 and later.
- Run Data is stored in the user's profile folders, rather than in the application's Program Files folder. This was required because Windows Vista and 7 security improvements restrict writing files to the Program Files folder.
- To improve management of runs, datasets are by default stored in their own folders, as subfolders of the Datasets folder.
- Reports (formerly "Output") are always stored in the same folder as the dataset.
- Population and Wind files can be stored with the dataset, or in the default Population/Wind folders. Storing them with the dataset enhances the configuration control for a case by eliminating file commingling, and improves sharing dataset info between organizations. A user can send a dataset, its population and wind files, and its reports to another user, who can open them confident that the right files for that case are being used.

Note that, like version 3, version 4 is not backward compatible. This is due to many factors, including the addition of age-specific data and the inclusion of many more nuclides than in previous versions. However, Version 4 introduced a dataset migration utility that upgrades many version 3 datasets to the version 4 format.

More improvements include:

Modeling

- Inclusion of all DCFPAK Version 2.2 nuclides. Nuclides in the database having external but not internal dose factors are now flagged to the user rather than

crashing the run. NOTE: the user must account for internal dose resulting from intake of these radionuclides using other methods, such as surrogates.
- Age-specific data is now returned for dose, risk, and inhalation/ingestion rate values.
- Nuclide Release Rates less than 1.000e-25 Ci/yr (e.g. "0") or greater than 7.92e+28 are no longer allowed.
- A FORTRAN numerical solver is now used to calculate decay-in-flight and ground build up concentrations for each sector. The time for decay in flight is calculated using the annual Pasquill category-averaged wind speed for each direction.
- Up to 500 radionuclides can be included in any case. The 500 limit includes both the nuclides released by the stacks and their progeny.
- Whole body and organ dose and risk factors are from DCFPAK Version 2.2. The data include six age groups; infant (100 days old), 1 year old, 5 years old, ten years old, fifteen years old, and adult.
- Age-specific inhalation and ingestion data developed by the U.S. Environmental Protection Agency has been included for the above age groups.
- The FORTRAN computational code has been consolidated into one module and variable names made consistent throughout the module. . Data transfer between the routines was streamlined by the use of Include statements for COMMON block variables.
- All nuclide-specific data are now stored in eXtensible Markup Language (XML) format.
- All significant floating-point calculations have been moved to the FORTRAN routines, greatly speeding up the code.
- The code uses the Intel FORTRAN Composer XE 11 compiler that permits many of the calculations to be vectorized and multi-threaded to take advantage of these capabilities in modern desktop processors.
- The bit-length of variables has been doubled, allowing much greater computational ranges for cases with large or small release rates.

User Interface

- A traditional document-style interface has been designed, similar to major applications with which users are already familiar. Users can more easily open, edit and save datasets, population and wind files using the Windows menus and familiar icons on the application bar.
- Dataset reports are now displayed in, and generated from, a Reports tab when the dataset is opened. The code is now executed using the Report generation button rather than a "Save and Close" button. The reports to be generated and viewed are selectable from the Reports tab. The "Save and Close" button from Version 3 has been removed.
- Multiple files (datasets, population files, wind files) can be open at once.
- When editing files, changes and errors are displayed in real time.
- Editing of nuclides is clearer and easier. In-grid editing is allowed, but note that fields are not recorded until the user clicks away from the field being edited. A Save performed without first clicking away from a filed being edited will result in that field's data not being saved.
- The application recognizes when a user is opening a version 3 file, and offers to create a version 4 copy of the file.
- The general layout, look, and feel of the user interface are similar to that in earlier versions of CAP88-PC in order to ease transition to CAP88-PC Version 4.

File Formats

- The dataset file format changed in Version 4 from Version 3 to accommodate the new requirements. The new dataset file format was documented both in the manual and the on-line help files.
- Population and Wind files previously had extended values such as State and Census stored in a Microsoft Access database. When migrating from version 3, this data--if available--is stored in the dataset file itself. Doing so removed the need for an external database, and allowed users to send their custom population/wind files with the extended values intact. These changes were documented in the file format description in the user manual and the on-line help files.
- Version 3 population and wind files could still be used in version 4 datasets. Extended values are only added to the pop/wind files if they are edited to add them.
- The use of additional applications, such as Microsoft Access, to manage data was eliminated in CAP88-PC Version 4. Radionuclide, agricultural, and other data previously held in the Microsoft Access database is now in a more portable and more easily accessible XML database.

Summary of Version 4.1 Changes from Version 4.0

Version 4.1 retains the major architectural, data handling, and user interface updates introduced in Version 4.0. Version 4.1 also implements a new Wix installer technology that enhances compatibility with Windows 10 and possible future Windows updates.

Specific changes from Version 4.0 visible to the user in Version 4.1 include:

User Interface

- Replaced the Print button on the Reports tab with one that opens the folder holding the report files;
- Modified some labels in hte user interface for clarity;
- Improved capabilities for migrating datasets from previous versions of CAP88-PC including automatic conversion of version 4.0 datasets to version 4.1.

Reports

- Modified some report headers for clarity;
- The Agricultural Data in the Synopsis report now prints the values used in the calculation, which may have been adjusted by CAP88-PC from the input values.

Data

- Updated the dose and risk coefficients from DCFPAK 2.2 to those in DCFPAK 3.02 provided by Oak Ridge;
- Dose and risk coefficient data was added for 151 more isotopes;
- Risk coefficient data was added for more isotopes and forms beyond the additional 151;
- Updated inhalation coefficients for radionuclides with special chemical forms such as Iodine.

Error Handling

CAP88-PC Versions 4.0 and 4.1 contain an internal error logging and tracking system. In the case of internal code errors, the code will write errors to a file in the Message Log folder located in the same folder set as the folder containing the datasets. Sending this file to the EPA representative will facilitate troubleshooting.

Installation

Download Location

CAP88-PC 4.1 can be downloaded from the following EPA web site:
http://www.epa.gov/radiation/assessment/CAP88/index.html

System Requirements

- Windows 7
- Windows 8 and 8.1
- Windows 10
- .NET Framework version 4 or later.
- CAP88-PC is written as a 32-bit x86 architecture application. The 32-bit version can be run under 64-bit versions of Microsoft Windows 7, 8, 8.1, and 10.
- Monitor resolutions of 1024x768 or higher

CAP88-PC 4.1 is not supported with Microsoft Windows operating system versions earlier than those listed above. However, version 3 data files can be migrated to a new version 4.1 installation.

Installation Procedure

CAP88-PC 4.1 can be installed side-by-side with CAP88-PC 3 but should not be with Version 4.0. Version 4.1 is an in-place upgrade of version 4.0, and will automatically update Version 4.0 dataset, population or wind files upon use, but does not automatically update Version 3 dataset, population, or wind files upon use. Updating Version 3 files to Version 4.1 is done using the Migration Utility that runs on first installation or on demand under the 'Tools' item on the main menu bar. In some cases, the Migration Utility will fail because of a bug in the Microsoft Access Database Engine installation needed to perform the direct V3-to-V4.1 data migration. Special instructions for overcoming this problem are provided below and in the Readme file that is part of the installation package. *It is strongly recommended that you upgrade your Version 3 installation to Version 4 using the Migration Utility, and then, after confirming success, uninstall Version 3.*

Procedure to Fix Migration Utility Failure Caused by Access Database Engine Install Bug

On most systems, to run the migration utility in Version 4.1, the system must first have the Access Database Engine installed. The V4.1 migration utility includes a button that will take the user to the Microsoft page from where the Access database Engine can be downloaded. Either (or both) 32/64-bit versions can be downloaded; the version you download and install should correspond to the Microsoft Office installation on the system.

During installation of the Access Database Engine you may encounter an error stating that the installation failed because there are 32-bit Office applications installed (if you are trying

to install the 64-bit engine) or that you have 64-bit Office applications installed (if you are trying to install the 32-bit engine). The source of this problem is that the Access Database Engine installer may have installed both the 32-bit and 64-bit versions of the Office Click-To-Run Extensibility Component.

To resolve this issue perform the following steps:

- Go to **Start > Run** (or Winkey + R) where the Winkey is the windows key on your keyboard
- Type **"installer"** (doing so opens the %windir%installer folder)
- Verify the folder settings are making all files visible
- Add the column "Subject" by a right-click on the column headers, click 'More", find "Subject" and add it
- NOTE: make the column "Subject" at least 400 pixels wide
- Sort on the "Subject" column and scroll down until you find the name mentioned in your error report, for example "Office 15 Click-to-Run Extensibility Component".
- NOTE: The 64-bit version is shown as such in the name, the 32-bit version name does not include the size
- **Right-click** the MSI to be removed and choose **uninstall**

After removing the version blocking installation of the Access Database Engine, rerun the migration utility.

General Installation Instructions

In general, it is recommended to uninstall previous CAP88-PC Version 4.0 and 4.1 installations prior to installing any updated version.

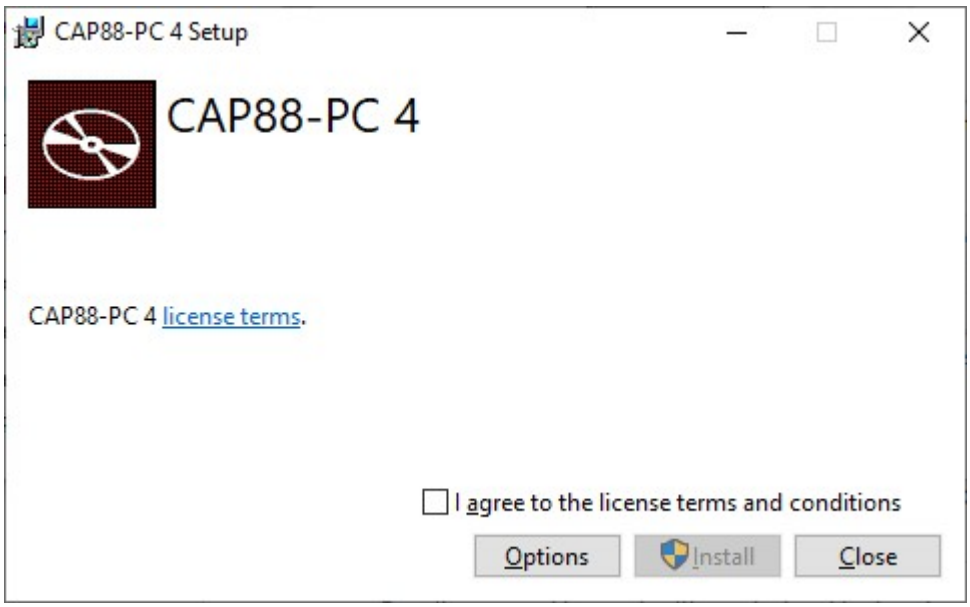
Download the installation file to a temporary folder, such as My Documents\Downloads\CAP88-PC 4.1. Unzip the file into a folder.

Before running the installation program, it is highly recommended to examine the README.txt file in the folder containing the unzipped installation program for information supporting the installation process. After checking the README.txt file, begin the installation process by double-clicking the executable file containing the program. It is recommended that the installing user have Administrator rights on the local machine

The installation checks if .NET Framework 4 is installed. If not, it attempts to download and install it. In some cases you may need to manually install it from the Microsoft web site.

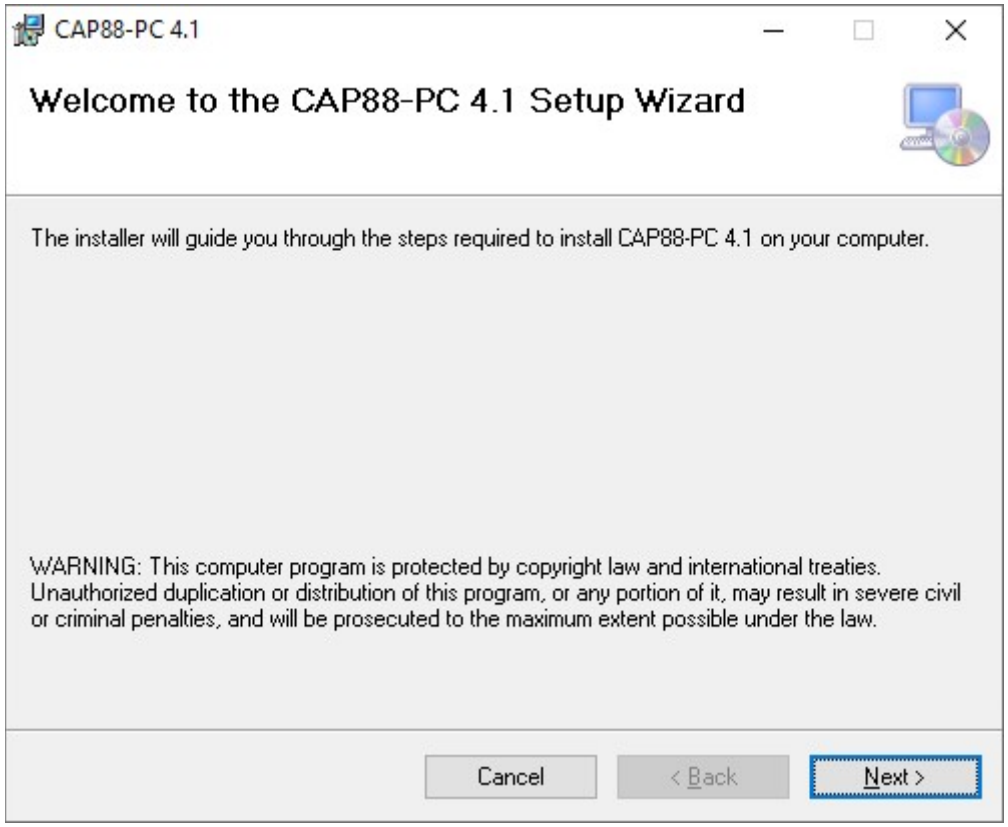
Initial Setup Screen

The initial setup screen is shown below. Check the box agreeing to the license terms to activate the Install button and proceed with the installation. The License Terms simply links to the EPA web site.

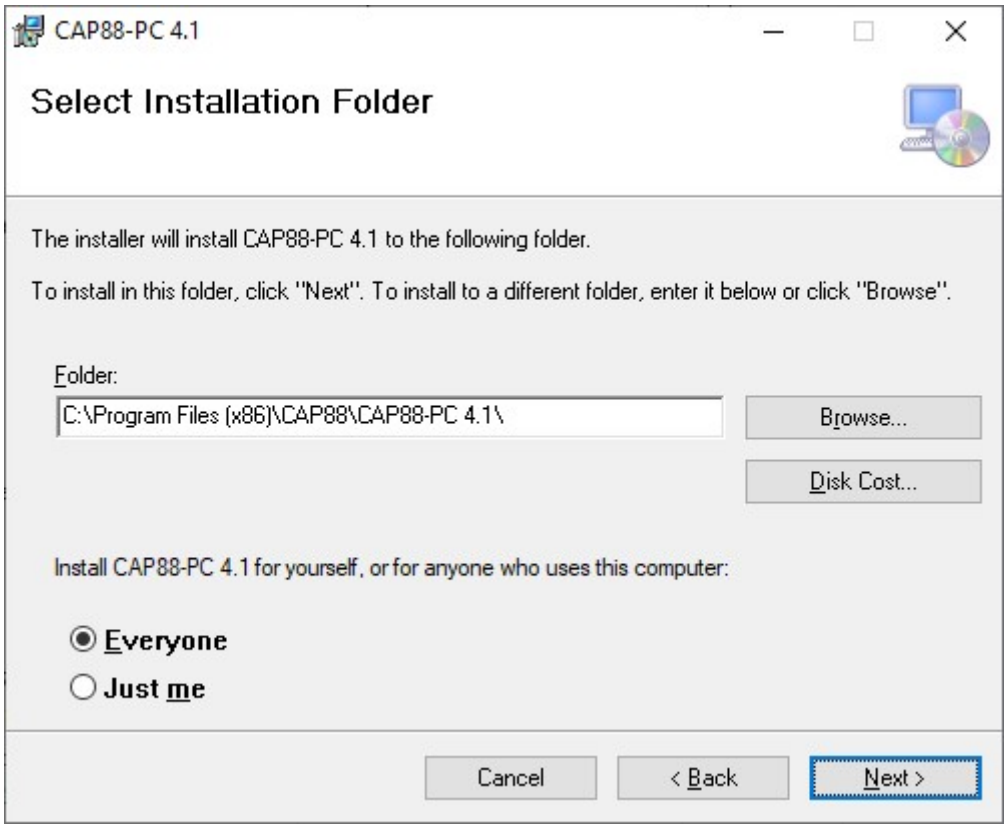


After clicking Install you will likely see a User Account Control screen asking if you will allow the program to install. Verify the publisher is either Trinity Engineering Associates or USEPA and then permit the installation by clicking Yes. You will then proceed through the installation.

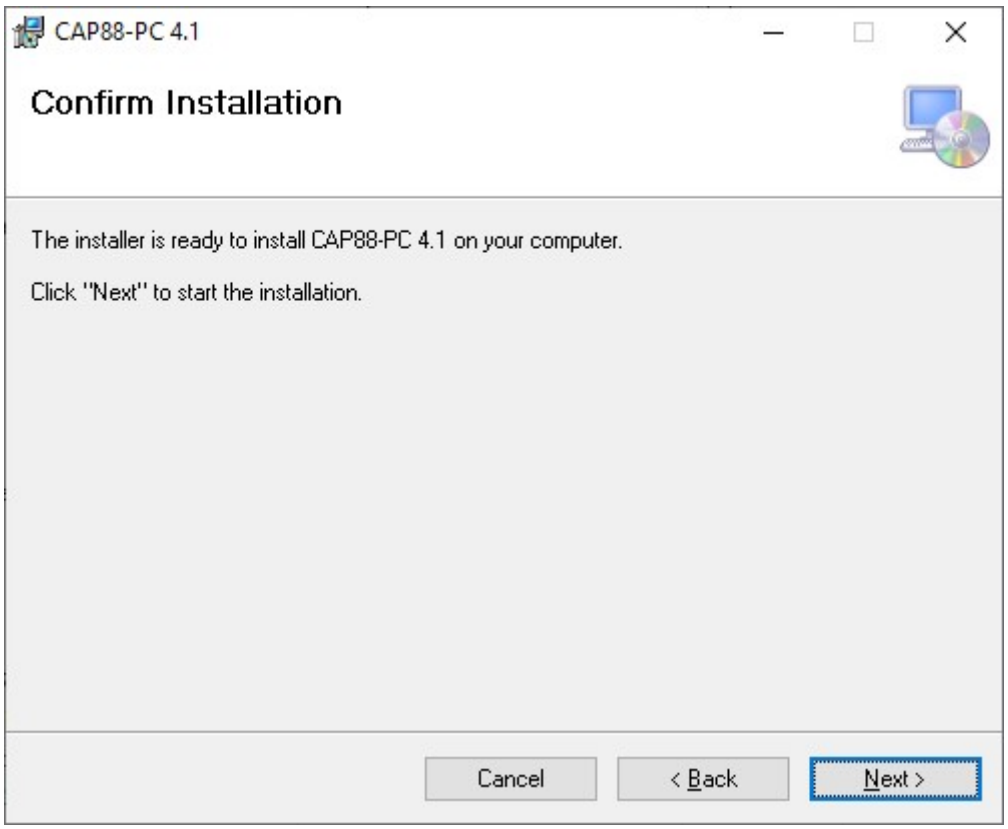
Click Next at the welcome window.



The following screen selects the location for the CAP88-PC Version 4.1 program files installation. This is not the location for the data files. Accepting the defaults is recommended. However, you can change the installation location and the user security. Please note that 64-bit versions of windows will default to "Program Files (x86)" instead of "Program Files". Click Next when ready.



Click Next to finish installation.



After the program files installation is complete, click Close to exit the installer. You can now run CAP88-PC Version 4.1 to complete the data installation and, if a first run after installation, will automatically launch the Migration Utility. The Migration Utility has two functions; to migrate existing Version 3 data to Version 4.0 or 4.1, and to install the initial set of program and user data. *The Migration Utility must be run after an initial installation in order to complete CAP88-PC setup.*

First Run

The first time you run CAP88-PC Version 4.0 or 4.1 after installation a message will appear noting that this is the First Run. Click OK to continue, which will open the Migration Utility. The utility will be preset to upgrade from version 3 to version 4. Even if version 3 is not installed, the migration folder must be run to populate the CAP88-PC V4.0 or V4.1 data environment. A message window will inform the user of this need.

Default Folders

The default folder layout for CAP88-PC datasets, program data, and FORTRAN execution files is shown below (this is for data files, not the program files already installed). This structure is the recommended configuration. The user may change the location of the folder set by specifying the location of the top-level folder (My Documents in the default setup) but the sub-folder structure will remain the same. Note that My Documents (or just Documents) is typically under the user's named folder in Windows, for example c:\users\username by default in Windows 7, 8, and 10. Your IT system policies may change the default location. After running the migration tool, it is also possible to change the settings through tools->options. The migration utility may also be run manually from the tools>options menu to migrate version 3 files or write the version 4.0 or 4.1 files into the destination folders selected in the migration utility dialog.

```
My Documents
|_CAP88-PC
  |_Datasets
  |_Fortran
  |_Message Log
  |_Population Files
  |_Wind Files
```

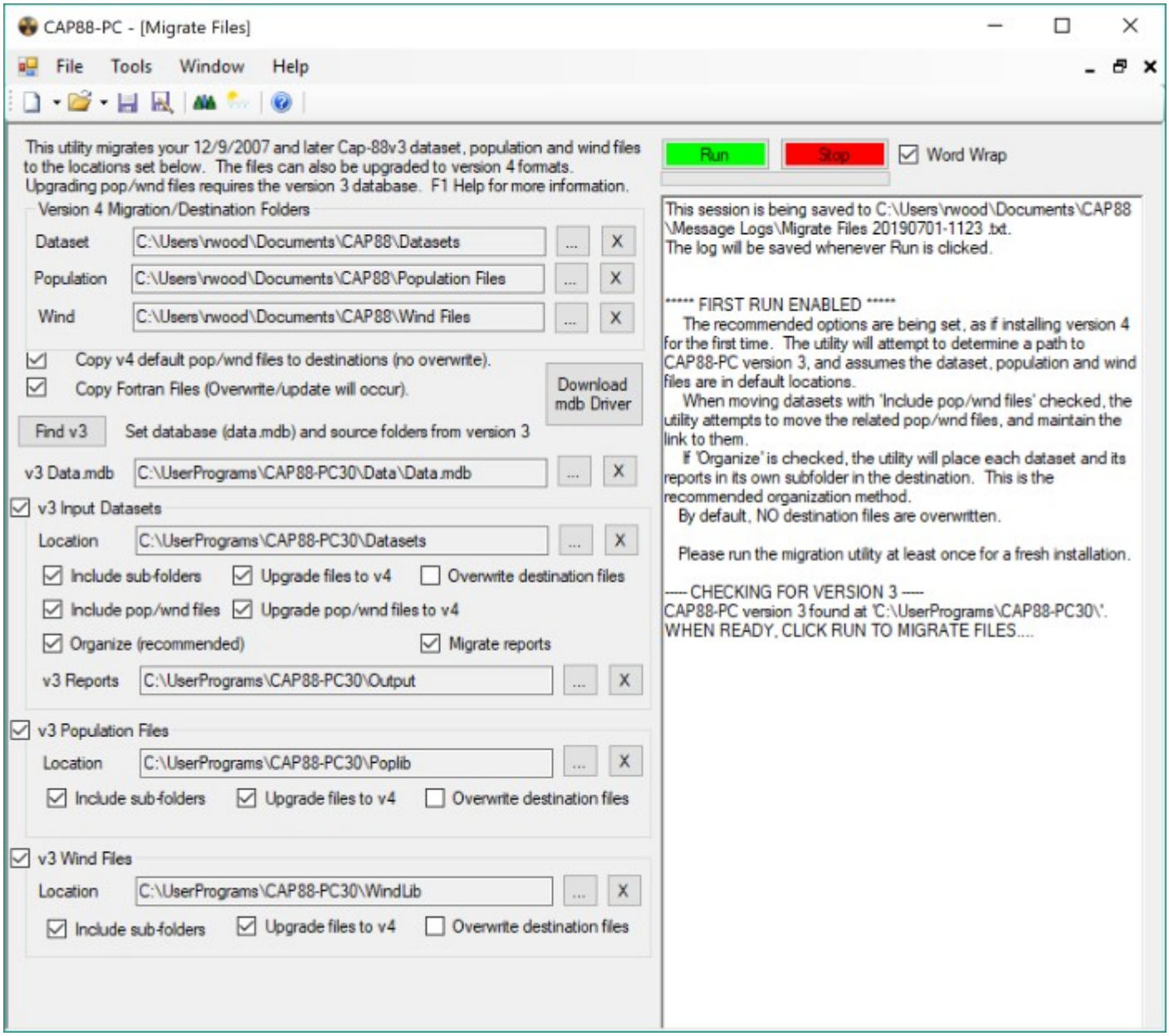
Uninstallation

In order to prevent inadvertent deletion of datasets and results, the Uninstall process will uninstall only those files that were installed in the CAP88-PC program files location. Any extracted or created Population and Wind Files, as well as any Datasets and Report Files, will not be deleted from the user's data location, nor from the program files location. These other files must be manually deleted from the installed data folder structure. Uninstall is best performed using the Add/Remove Programs option in the Windows Control Panel (called Programs and Features in Windows 7 or under Settings -> Apps in Windows 10).

To perform a complete reinstall, delete or rename any existing CAP88-PC data folders. Doing so will produce a first-time installation process when CAP88-PC V4.0 or V4.1 is re-installed. The user can also manually initiate the first-time install process from the Tools menu item by checking the "Is First Run" box under Tools->Options->Advanced.

Migration Utility

Tools > Migration Utility



The migration utility is used to move datasets, population, and wind files to new locations, and to upgrade their format from Version 3 to Version 4.0 or 4.1. It is typically used when CAP88-PC is first run. Note that only data files from the 12/9/2007 release of CAP88-PC Version 3 can be directly upgraded. If you have older datasets, try opening them in the 12/9/2007 version and save the dataset to put it in the proper format.

The conversion Results contains information on which files were successfully migrated. It also includes, for each dataset, whether it fails to comply with version 4.0 or 4.1 validation rules.

The utility will typically organize migrated files in the recommended way by creating the default or user-defined file system folders and populating the folders with the migrated data.

The Migration Utility also installs the standard datasets, population files, and wind files supplied as part ofthe CAP88-PC V4.1 release package. The user can select how these standard files get installed. By default, the standard data files supplied with the CAP88-PC installation system are not written into the data folders if a migrated file of the same name exists in the folder.

When first opened, the destination folders are set to match the folders selected in Tools->Options.

Version 4 Migration/Destination Folders

This section describes the process for selecting the migration utility input and output folder locations for the dialog box shown above. Using this dialog box the user can choose the location folders for the Version 4 Dataset files, the population files, and the wind files. The folders will initially be set to the values from the Tools->Options dialog, or the Cap-88 Version 4 installation folder located in the User's "My Documents" folder structure.

Dataset Destination Folder

The target folder where the Version 4.1 dataset files will be placed. Click the [...] button to select a folder using Windows Explorer. It is recommended to use the default locations under the user's Windows User account folder.

Population Destination Folder

The population file destination folder. Click the [...] button to select a folder using Windows Explorer.

Wind Destination Folder

The wind file destination folder. Click the [...] button to select a folder using Windows Explorer.

Find Version 3 Sources

Clicking this button causes the utility to attempt to locate the version 3 data files for migration. If not found, the user is prompted to specify the locations of the files to be migrated.

Version 3 Data.mdb

This is the Microsoft Access data file (commonly named Data.mdb) used in version 3 to store extended values for population and wind files. If available, it is used when upgrading those files.

Copy Default Files

If checked, the default population and wind files are copied from the installation location to the default folders.

Migrate v3 Datasets

If checked, the utility attempts to migrated datasets from the Dataset Source folder to the Dataset Destination folder, using the selected options.

Note that sample datasets from version 3 are not migrated. Instead, new versions have been created.

Location

This is the folder that contains the version 3 datasets. Click the [...] button to select a folder using Windows Explorer.

Include Dataset Sub-Folders

Check this box to include datasets in subfolders of the Dataset Source folder.

Upgrade Dataset Files

Check this box to upgrade datasets to version 4.1.

Overwrite Destination Dataset Files

Check this box to overwrite files in the Dataset Destination folder with files having matching names from the Dataset Source folder. NOTE: If the user wishes to retain files in the target folder that may be overwritten, then these files should be backed up by copying to another location or renamed prior to migration.

Include Dataset Population and Wind Files

Check this box to migrate population and wind files used by the dataset. When migrating pop/wind files:

1. The utility first checks if the user is also migrating population and wind files. If so, and the file was in a corresponding Pop or Wind Source folder, the new file is created in the proper Pop or Wind Destination folder.
2. If not migrating, or not found in the Pop/Wind Source folder, the utility checks if the source file is in the same path as Dataset Source and, if so, creates the new file in the same relative folder.
3. Finally, if neither of the above is true, the files are created in the same folder as the dataset.

Upgrade Dataset Population and Wind Files

If checked, the utility will attempt to find the pop/wnd file's extended values from the version 3 database, and write those values to the file. This option is disabled if the version 3 database hasn't been located.

Organize Dataset Files

If checked, dataset files are organized according to the defaults.

Migrate Reports

If checked, the utility attempts to find and copy the dataset's reports. It looks in the following locations, in order.

1. The V3 Output folder, which is the default location in version 3.
2. The Dataset Source folder.

Note: Reports are always copied to the same folder as the dataset.

V3 Reports

The location of the version 3 report (output) files.

Migrate V3 Population Files

If checked, the utility attempts to migrated population files from the Pop Source folder to the Pop Destination folder, using the selected options.

Location

The folder that contains the version 3 population files. Click the [...] button to select a folder.

Include Population Sub-Folders

Check this box to include population files in subfolders of the Pop Source folder.

Upgrade Population Files

Check the box to upgrade population files to version 4.1. The version 3 population files being migrated will need to be in the standard format produced by the version 3 population file editor in order to successfully migrate. Reading and parsing the files using the version 3 population file editor will verify the format. Additional notable format requirements: A space must follow the $ in the first column of row 1. Lines 4 through 43 are right justified decimal values in fields of width 10. The decimal point is the last character in the field and acts as a delimiter. The final 10 lines should hold zero values in the same format as lines 4 to 43. For more on the population file format please see Population File Format.

Overwrite Destination Population Files

Check this box to overwrite files in the Pop Destination folder with matching files from the Pop Source folder.

Migrate V3 Wind Files

If checked, the utility attempts to migrated wind files from the Wind Source folder to the Wind Destination folder, using the selected options.

Location

The folder that contains the V3 wind files. Click the [...] button to select a folder.

Include Wind Sub-Folders

Check this box to include wind files in subfolders of the Wind Source folder.

Upgrade Wind Files

Check this box to upgrade wind files to version 4.1.

Overwrite Destination Wind Files

Check this box to overwrite files in the Wind Destination folder with matching files from the Wind Source folder.

Run

Click this button to run the migration.

Migration to Version 4.1 of the old Access database files used in Version 3 requires updated versions of the Microsoft Access Database Engine. The Version 4.1 Migration Utility prompts the user at this step to determine if downloading and installing these updated drivers is necessary. If a previous Version 3 installation is not resident on the machine or if the user decides no migration of version 3 data is necessary and de-selects the V3 data migration option, then no V3-to-V4.1 migration will be performed. **Downloading and installing these drivers is not required, and not recommended, if no upgrade of Version 3 data is being performed as part of this V4.1 installation.**

Some versions of the Access Database Engine downloaded from Microsoft may fail to properly allow the Migration Utility to run. This is caused by a bug in the Access Database Engine installer whereby it installs both the 32-bit and 64-bit versions. Proper operation requires installation of only the version matching the installed version of Microsoft Office (32 or 64-bit). The procedure for resolving this problem is described in the Installation topic.

Stop

Click this button to stop a running migration.

Word Wrap

Check this box to wrap results text. Uncheck to show each message on its own line.

Results

This text box displays the results of the conversion. When a conversion is completed, the results are written to a file located in the Message Logs folder. The file is named Migrate Files [datetime].txt, where [datetime] is the date and time of the conversion in the ISO

standard format YYYYMMDD-HHMMSS. Below are examples from the beginning and end of a migration.

```
***** BEGIN MIGRATION *****
Migration Settings:
V3 Database:              C:\Program Files\CAP88-PC30\Data\Data.mdb
Migrade Datasets enabled.
Dataset Organize:         True
Dataset Output Folder:    C:\Program Files\CAP88-PC30\Output
Dataset Upgrade Files:    True
Dataset Upgrade Pop Wnd Files:True
Dataset Overwrite Files:  False
Dataset Include Pop Wind Files:True
Dataset Migrate Reports:  True
Dataset Include Sub Folders:  True
Dataset Destination:      C:\Users\charles\Documents\CAP88\Datasets
Dataset Source:           C:\Program Files\CAP88-PC30\Datasets
Migrate Population Files enabled.
Pop Include Sub Folders:  True
Pop Upgrade Files:        True
Pop Overwrite Files:      False
Pop Destination:          C:\Users\charles\Documents\CAP88\Population Files
Pop Source:               C:\Program Files\CAP88-PC30\Poplib
Migrate Wind File enabled.
Wind Include Sub Folders:  True
Wind Upgrade Files:       True
Wind Overwrite Files:     False
Wind Destination:         C:\Users\charles\Documents\CAP88\Wind Files
Wind Source:              C:\Program Files\CAP88-PC30\WindLib
Copy Default Files:       True


Migrating dataset CAP88Def.dat
Dataset written to C:\Users\charles\Documents\CAP88\Datasets\CAP88Def\CAP88Def.dat
ERR: Dataset's original pop file doesn't exist: C:\newsource\CAP88PC v2p1\PopFiles
\BATTELLE.POP
Searching for pop file in same folder as dataset.
ERR: Pop file doesn't exist.
ERR: Dataset's original wind file doesn't exist: C:\newsource\CAP88PC v2p1\WINDLIB\14821.WND
Searching wind pop file in same folder as dataset.
```

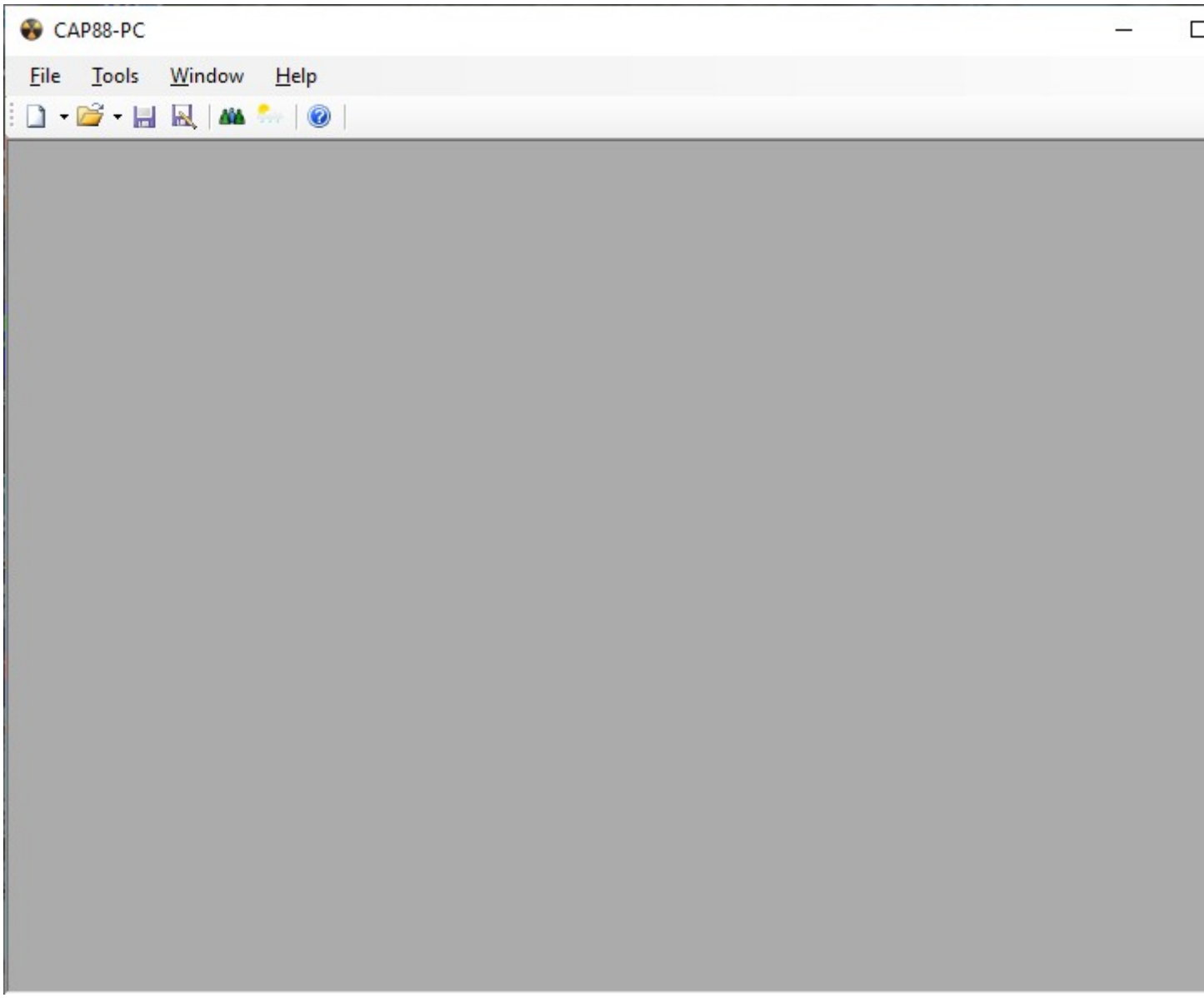
```
Migrating file: C:\Program Files\CAP88-PC30\WindLib\STL0603.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\STL0603.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\SUU0316.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\SUU0316.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\SWF0185.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\SWF0185.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\TLH0663.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\TLH0663.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\TOL0990.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\TOL0990.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\TOP0534.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\TOP0534.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\TPA0662.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\TPA0662.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\TPA0915.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\TPA0915.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\TRI1191.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\TRI1191.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\TVC0844.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\TVC0844.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\TYS1328.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\TYS1328.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\UCC1026.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\UCC1026.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\YIP1061.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\YIP1061.WND
Migrating file: C:\Program Files\CAP88-PC30\WindLib\YKM0484.WND
File created: C:\Users\charles\Documents\CAP88\Wind Files\YKM0484.WND

----------
Creating default population and wind files.  No files will be overwritten.
This can take a while.  Please wait.
Default population files created.
Default wind files created.
***** END MIGRATION*****
```

See Also Options
Dataset Folder Organization

Pop/Wind Search Order

Usage

Main Form



This is initial application view. It is a standard multi-document interface, with a menu and toolbar.

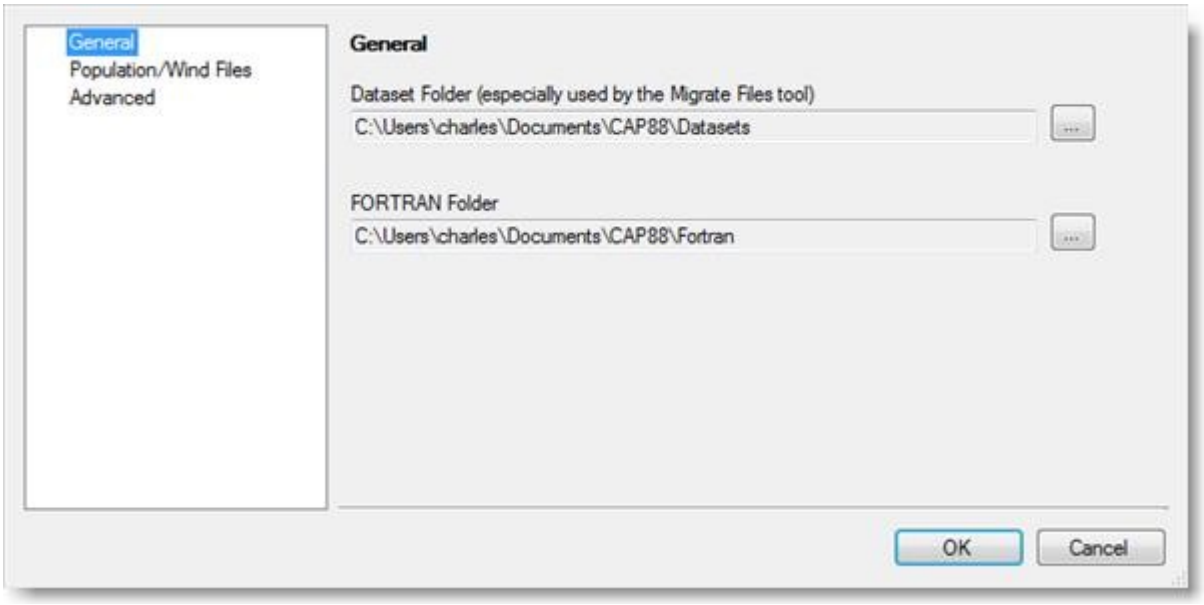
Important note: if you begin editing a field in a form, the change is not persisted until you click away from the field on the form itself. If the user clicks on a save button first, the in-process edit will revert to the previous value.

Errors: If an error occurs that you would like technical help on, please click here for further instructions

The menu bar contains a 'Tools' dropdown that allows access to many special functions including the ability manually run the Migration Utility, identify the location for installation folders and data folders, and view data on the population and wind files. More information on some of the funcitons within the 'Tools' menu bar selection are in

Options

Tools > Options



Dataset Folder Organization (Recommended)

Datasets are recommended to be put into their own folders. A dataset's reports are always stored in the same folder as the dataset. The corresponding population and wind files should be stored in the default Population and Wind folders.

```
Datasets
|_ModTest1
  |_ModTest1.dat
  |_ModTest1.SYN
  |_ModTest1.WEA
|ModTest2
  |_ModTest2.dat
  |_ModTest2.CHI
```

Population and Wind File Search Order

A dataset's population and wind files should be located in one of two places:

- In the same folder as the dataset file, OR
- In the default folder set in Options

The full path to these files is stored in the dataset. If a complete dataset (.dat, .pop, .wnd, and report files) needs to be opened on another machine, it's recommended that all related files be kept in one folder. If this is done, then CAP88-PC will find and use the correct files.

When opening a dataset that references population and wind files (and reports), the program searches for the files in this order:

1. Exact path match
2. In the same folder as the dataset
3. In the *user's* default folder defined in their Options.

General

Dataset Folder

This is the folder for dataset files. The image shows the locations following a default installation.

FORTRAN Folder

This folder contains the FORTRAN executable code. If the FORTRAN files are not seen in this folder, or if a patch to the FORTRAN is released, the FORTRAN can be replaced or updated using the Refresh Fortran button under Advanced. The FORTRAN code can also be run manually from the command line.

See Also Dataset Reports
FORTRAN Executables

Population/Wind Files

Population Files Folder

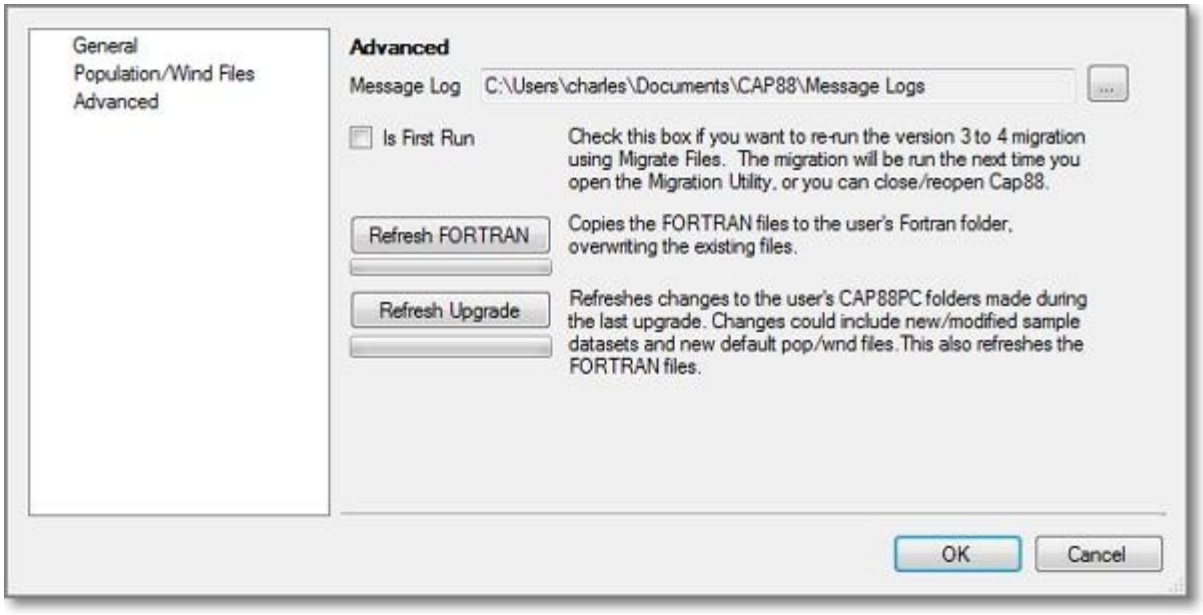
This folder contains the population files. Check "Include sub-folders" to include files in folders below the main folder.

Wind Files Folder

This folder contains the wind files. Check "Include sub-folders" to include files in folders below the main folder.

See Also Dataset Edit Population Tab
Dataset Edit Meteorological Tab
Population File List
Wind File List

Advanced



Message Log

This folder contains the error message log, and the First Run log. Error messages are in a text file named Cap88v4Log.txt. The log contains the latest messages, and older messages are deleted to make room for new ones. If you experience a problem, emailing a copy of this log to support personnel may help troubleshoot the problem.

Is First Run

If checked, the application will execute its "First Run" utility, which sets default folders and upgrades existing version 3 files. Only check this if you have backed up your files and are aware of the risk of data loss should unexpected interruption occur during the file upgrade process.

See Also Installation First Run

Refresh Fortran

Copies the FORTRAN files to the user's Fortran folder, overwriting the existing files.

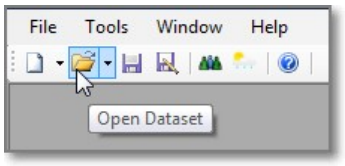
Refresh Upgrade

Refreshes changes to the user's CAP88PC folders made during the last upgrade. Changes could include new/modified sample datasets and new default pop/wnd files.This also refreshes the FORTRAN files.

Dataset

Dataset Open/New

File > Open > Dataset
File > New > Dataset



To open an existing dataset:

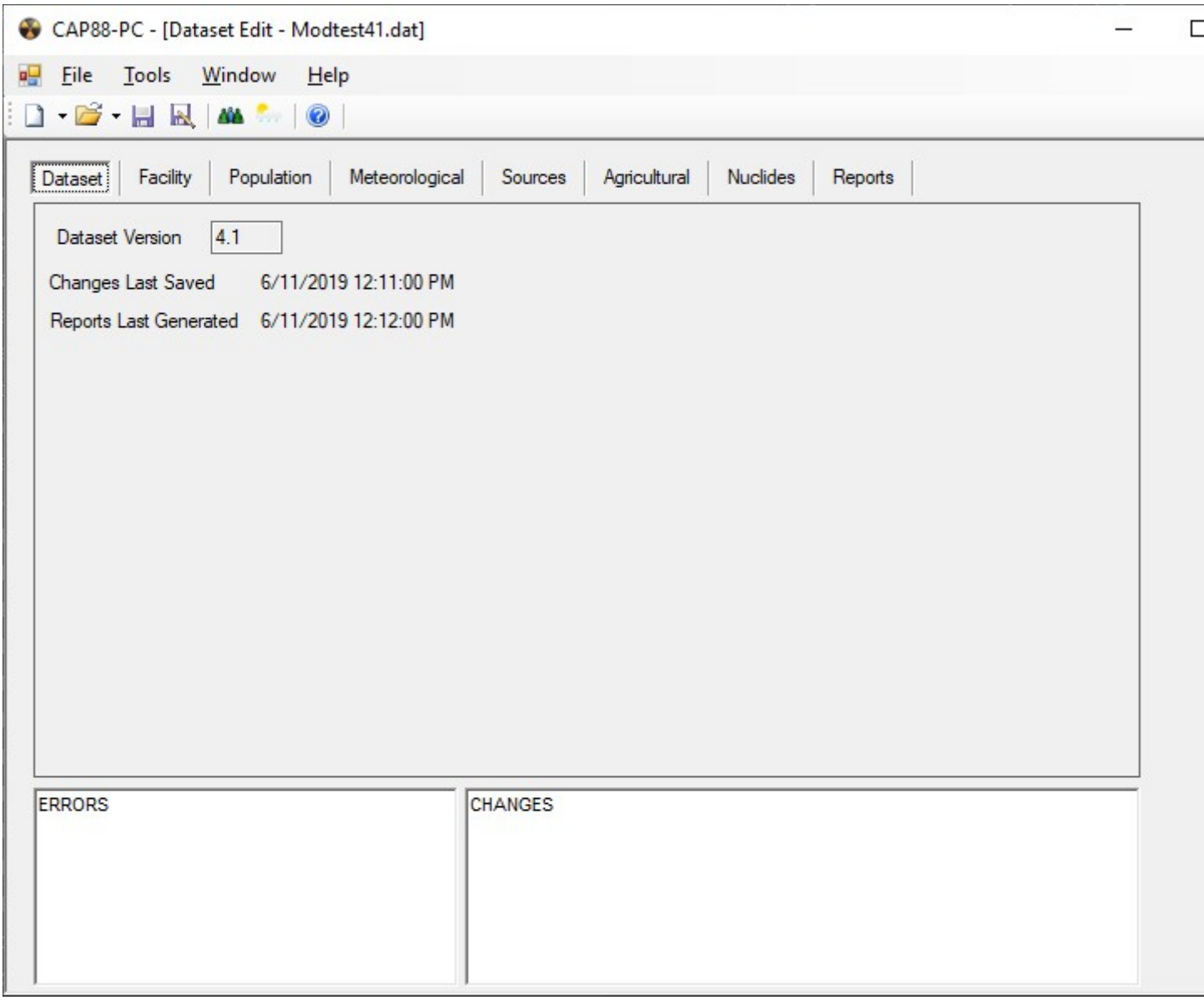
1. Choose Open > Dataset, OR
2. Click the toolbar's Open icon. The default action is to open a dataset.

To create a new dataset:

1. Choose File > New > New Dataset, OR
2. Click the toolbar's New icon. The default action is to create a new dataset.

Dataset Edit

File > Open > Dataset
File > New > Dataset



The dataset edit form is composed of multiple tabs. The Dataset tab, shown above, displays last save and report generation date times.

>NOTE: When entering or modifying data in a field within the CAP88-PC user interface, the data is not retained in the form until the user clicks away from the form field.

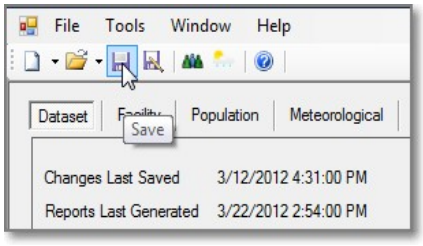
Changes Last Saved

The last date/time changes to the file were saved. The date/time doesn't update if the file is saved with no changes.

Reports Last Generated

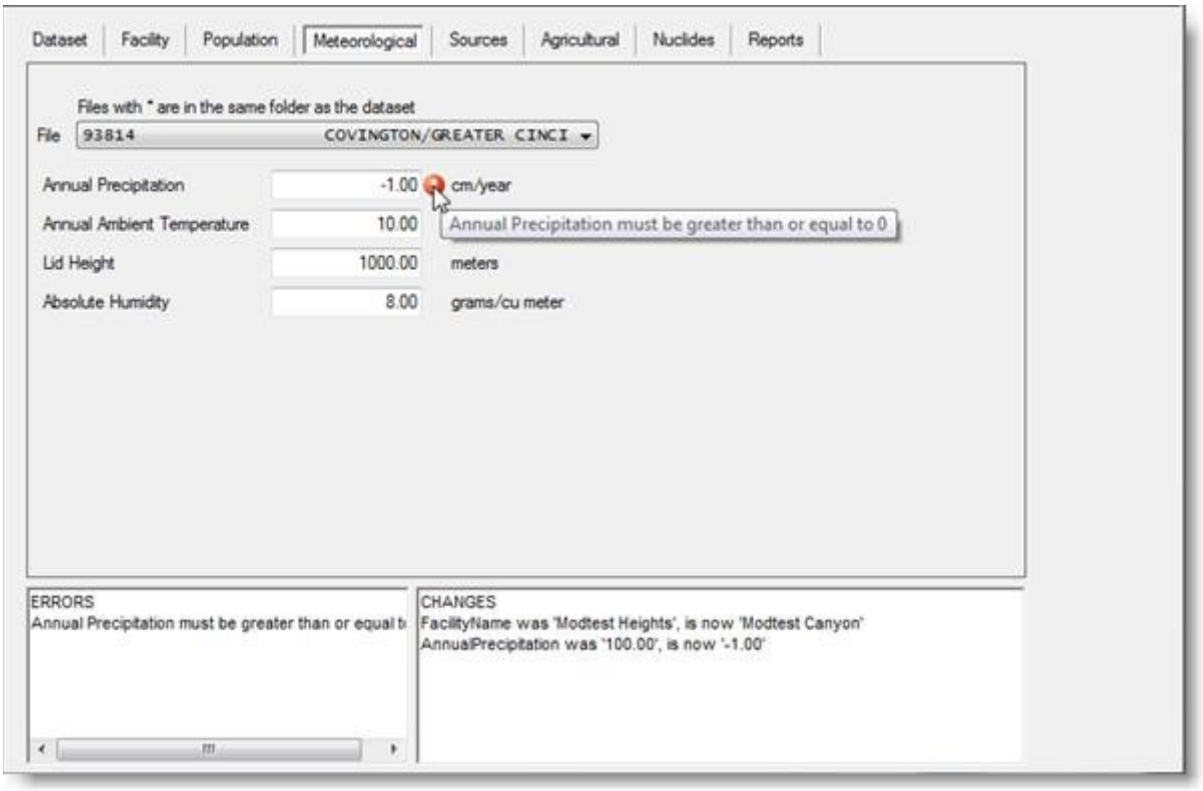
The last date/time reports were generated.

Dataset Save



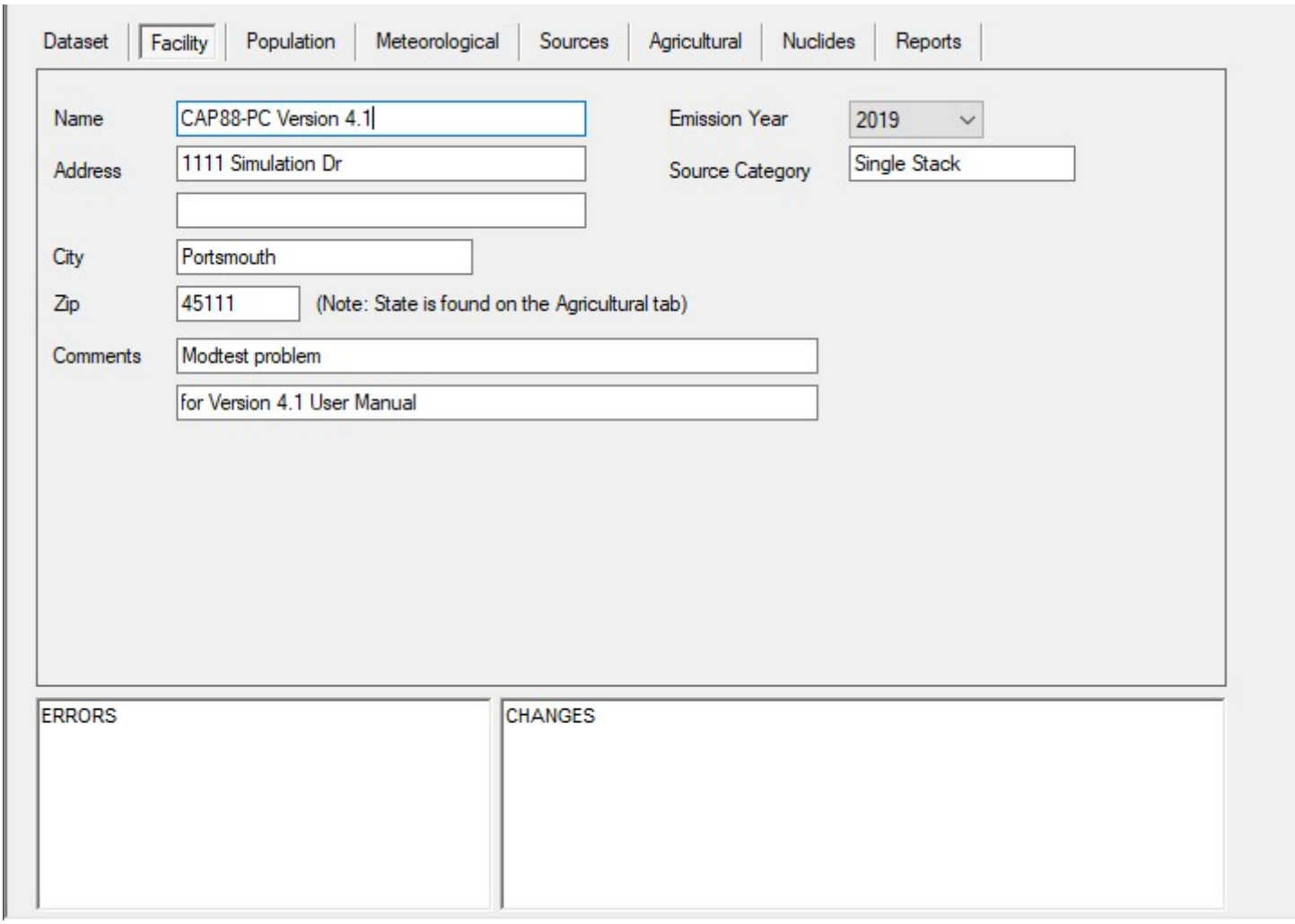
To save a dataset, click File > Save, File > Save As, or the toolbar Save button. After saving, the Dataset tab shows the last save datetime. This datetime only changes if the dataset, itself, had changes.

A file cannot be saved if it has errors. Errors are displayed in the ERRORS status box, and also next to the field(s) with errors, as shown below.



Important note: if you begin editing a field, the change is not recorded until you click away from the field on the form itself. If the user clicks on the save button first, the in-process edit will revert to the previous value.

Dataset Edit Facility Tab



The Facility tab is used to describe the facility and time period to be modeled.

Address Information

The fields available for entering address information are: Name, Address1, Address2, City and Zip.

Note: State is found on the Agricultural tab.

Comments

There are two lines available for short comments.

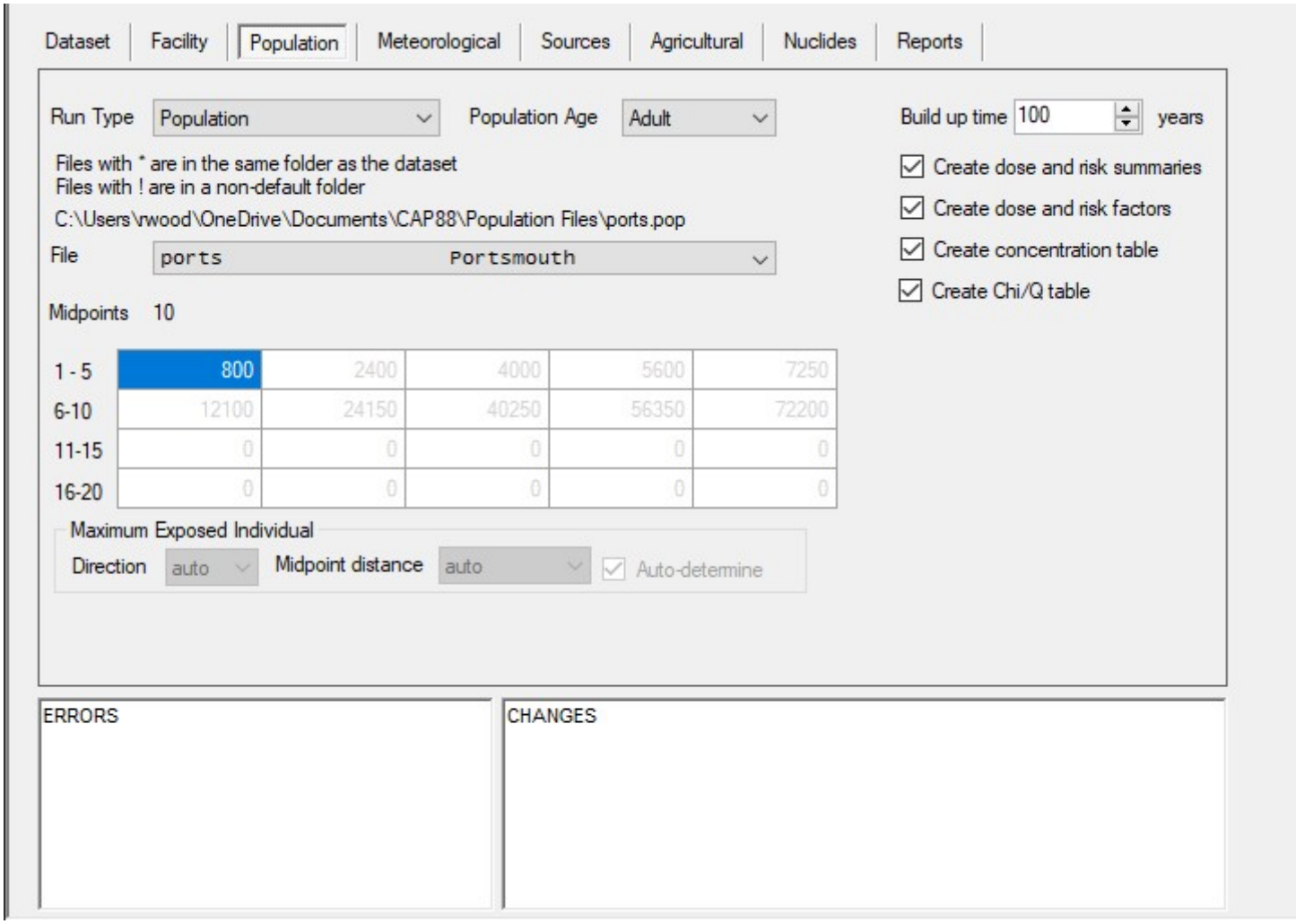
Emission Year

The year emissions were recorded.

Source Category

A text field used to store user-defined categories.

Dataset Edit Population Tab



The Population tab is used to describe the population to be assessed and select optional reports.

Run Type

A dataset either uses data from a population file by choosing "Population", or the user can manually enter population data by choosing "Individual".

Population Age

Selects the specific age for which dosage information is reported. Values are:

- Infant (100 days)
- One (year)
- Five (years)

- Ten (years)
- Fifteen (years)
- Adult (20+ years)

File

If Run Type is "Population", this drop down is displayed, and lists the available population files. If a file is in the same folder as the dataset, it's marked with an asterisk.

If a dataset is opened that has a reference to a file, but the file isn't found, the original path and file name will show in ERRORS. This may happen if a dataset is opened on a computer that's different from where it was created.

See Also Population and Wind File Search Order

Distances

Indicates the number of non-zero population distances in the Midpoints.

Midpoints

Displays the population mid point data derived from the population file, or entered by the user if "Individual" is selected. If "Population" is selected, these fields are read-only.

The distances entered must be contiguous and ascending, that is, no cells can be skipped and the midpoint distances must increase from left to right in each row.

A quick way to get a starting point for "Individual" mid points is to first set Run Type to "Population", choose a file with data approximating what is needed, then change Run Type to "Individual". The population files values will be retained, and can then be adjusted.

Maximum Exposed Individual

When Run Type is "Individual", the user can explicitly set the location of the maximum exposed individual in the population area. This is done by unchecking "Auto-determine", and selecting the Direction and Midpoint distance. If "Auto-determine" is checked, then CAP88-PC will calculate the maximum exposed individual.

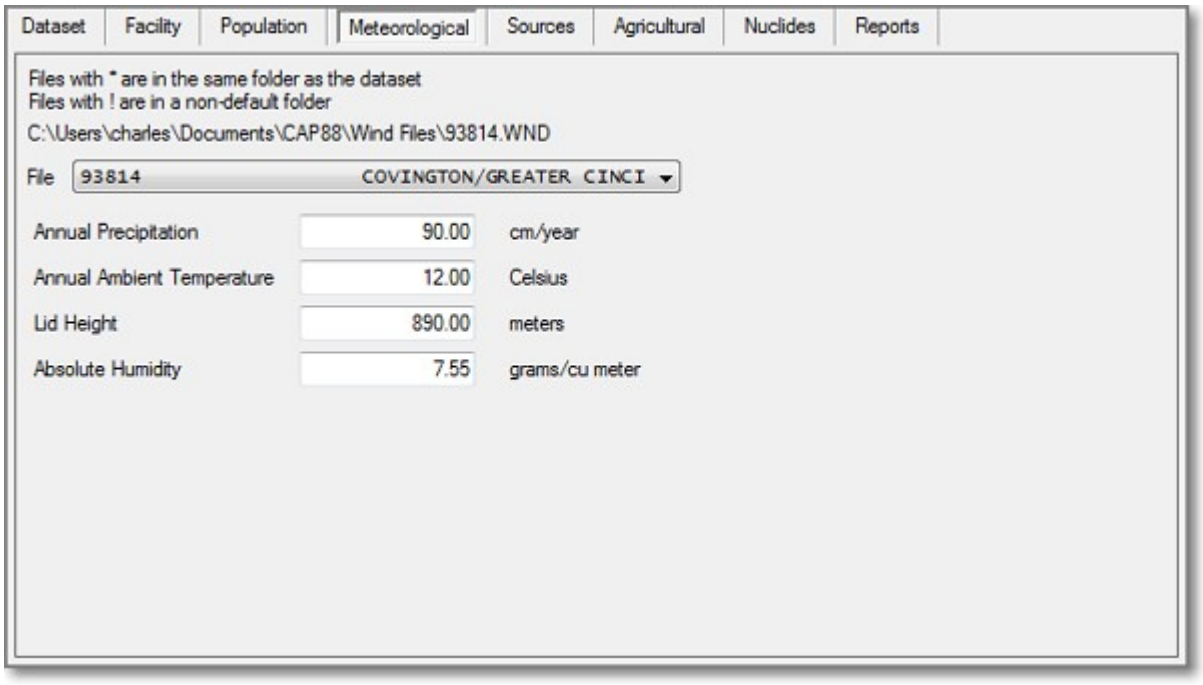
Build Up Time

The default value of 100 years is the value specified in the regulatory model for CAP88-PC assessment (the NUREG 1.109 approach). Using a value other than 100 years in this field will invalidate the run for compliance purposes. The option to change this field is provided only to permit future use of the code for modeling, and to allow users to use CAP88-PC as a means of generating decay sets for other purposes.

Report Selections

Check which reports should be generated in addition to the Synopsis, General and Weather reports.

Dataset Edit Meteorological Tab



File

This drop down displays the list of available wind files. If a file is in the same folder as the dataset, it's marked with an asterisk.

If a dataset is opened that has a reference to a file, but the file isn't found, the original path and file name will show in ERRORS. This may happen if a dataset is opened on a computer that's different from where it was created.

See Also Population and Wind File Search Order

Annual Precipitation

The average annual precipitation (in centimeters) at or near the site.

Annual Ambient Temperature

Average annual ambient temperature, in degrees Celsius, at or near the site.

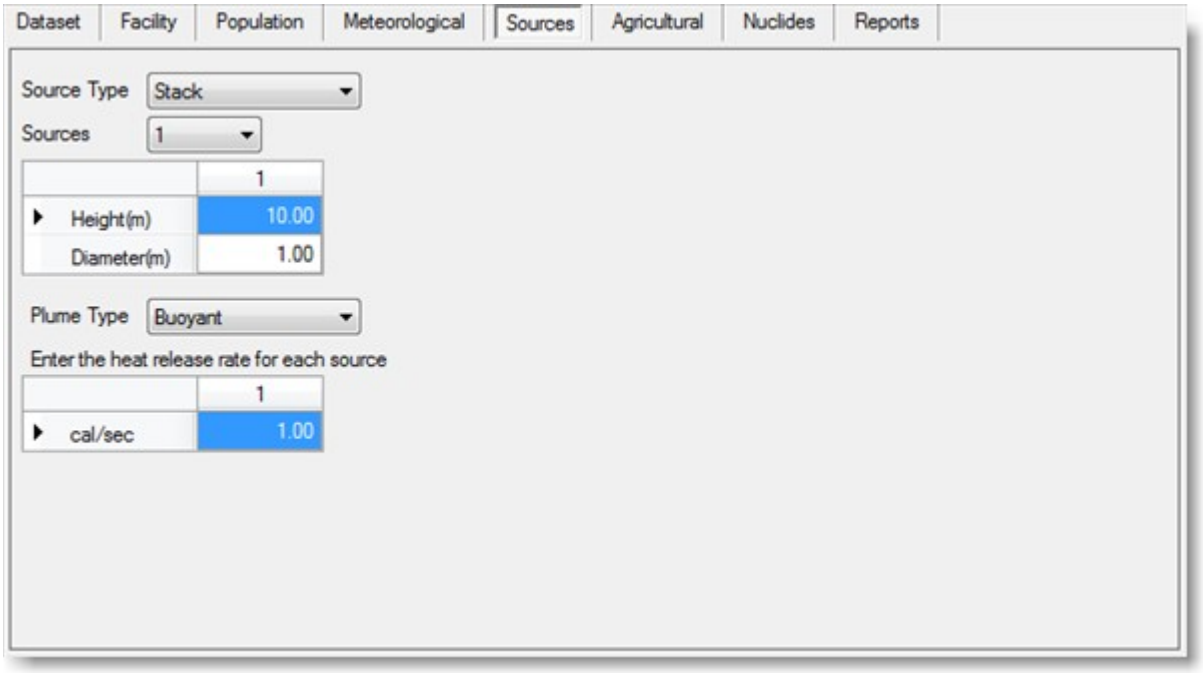
Lid Height

The height of the tropospheric mixing layer (in meters) at or near the site.

Absolute Humidity

The absolute humidity (in grams / cubic meter) at or near the site. Typical values are from 3 grams/cu m to 20 grams/cu m.

Dataset Edit Sources Tab



The Sources tab is used to identify the type of emitting source and the dimensions of each emitting source being assessed. Stack and Area Sources cannot be mixed in a single assessment. While up to six stack or area sources can be modeled, all the sources are modeled as if located at the same point. The same plume rise mechanism (Buoyant, Momentum, Fixed, or Zero) is used for each source. Also, area sources are treated as uniform. Variation in radionuclide concentrations due to complex terrain cannot be modeled. Errors arising from these assumptions will have a negligible effect for assessments where the distance to exposed individuals is large compared to the stack height, area, or facility size.

Source Type

The emitting sources must be identified as stacks (point) or area sources. While up to six stack or area sources can be modeled, all the sources are modeled as if located at the same point. The same plume rise mechanism (Buoyant, Momentum, Fixed, or Zero) is used for each source. Also, area sources are treated as uniform.

Sources

Up to six emitting sources (stacks or areas) may be modeled. The fields for Height, Diameter/Area, and Plume Rise Type (if Momentum or Buoyant) change as the number of

emitting sources change, so select the number of sources before entering any associated data.

Source Values

For each source, enter the Height (meters), and the Diameter (meters) or Area (meters squared).

Plume Type

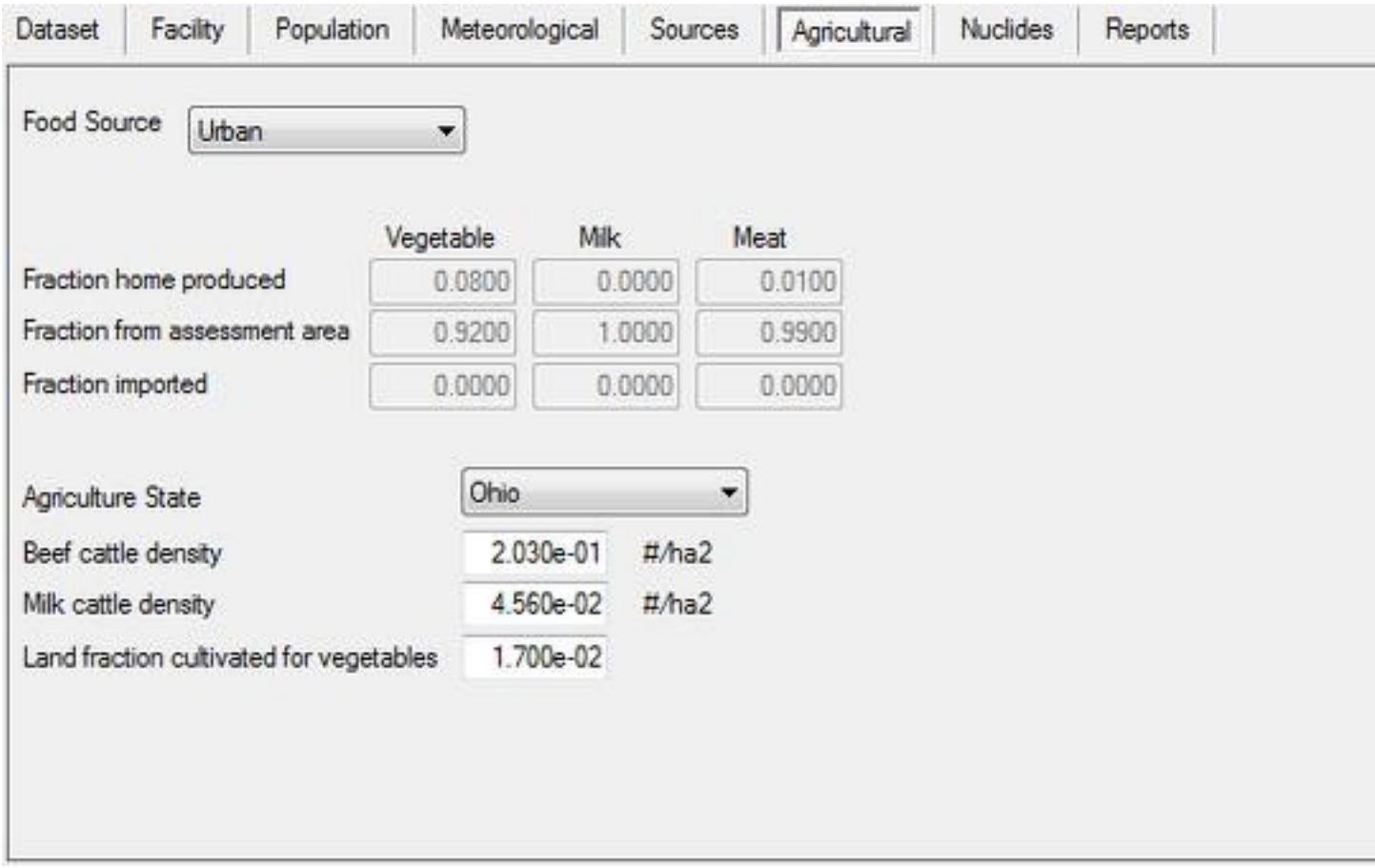
Select the Plume Rise Type for the dispersion modeling. The choices are Buoyant, Momentum, Fixed, and Zero. The same plume rise mechanism is used for each source.

Plume Type Values

Enter the plume rise values for each type.

- Buoyant: heat release rate in calories/sec
- Momentum: exit velocity in meters/sec
- Fixed: plume rise in meters for each Pasquill Category
- None: zero is entered for each Pasquill Category

Dataset Edit Agricultural Tab



The Agricultural tab is used to enter agricultural factors that will be applied to the dispersion data to estimate uptake of emitted radionuclides into the food chain.

Food Source

Selection of each EPA Food Source Scenario (Urban, Rural, Local, Regional, and Imported) will result in different fractions that describe the fraction of Vegetable, Milk, and Meat produced in the area, or imported to the area. The user may manually generate the food source scenario by selecting the Entered scenario.

Food Source Fractions

The food source fractions are not editable unless the Entered scenario is selected, in which case fractions must be entered by the user. The Entered fractions must total to 1.0 for each column. CAP88-PC may recalculate the input food source fractions should the productivity of the local or assessment area be insufficient to produce enough food to meet the population times the consumption rates. The input food source fractions are printed in the General report. The actual fractions used in the dose calculations are printed in the Synopsis report.

Agriculture State

Sample distributions of beef and milk cattle densities, and crop productivity, are provided by EPA for the assessment area using average agricultural productivity data for each of the fifty

states. Since data was not available for Alaska, Hawaii, and the District of Columbia, the user must supply relevant agricultural data for these areas.

Beef Cattle Density

The beef cattle density for the assessment area.

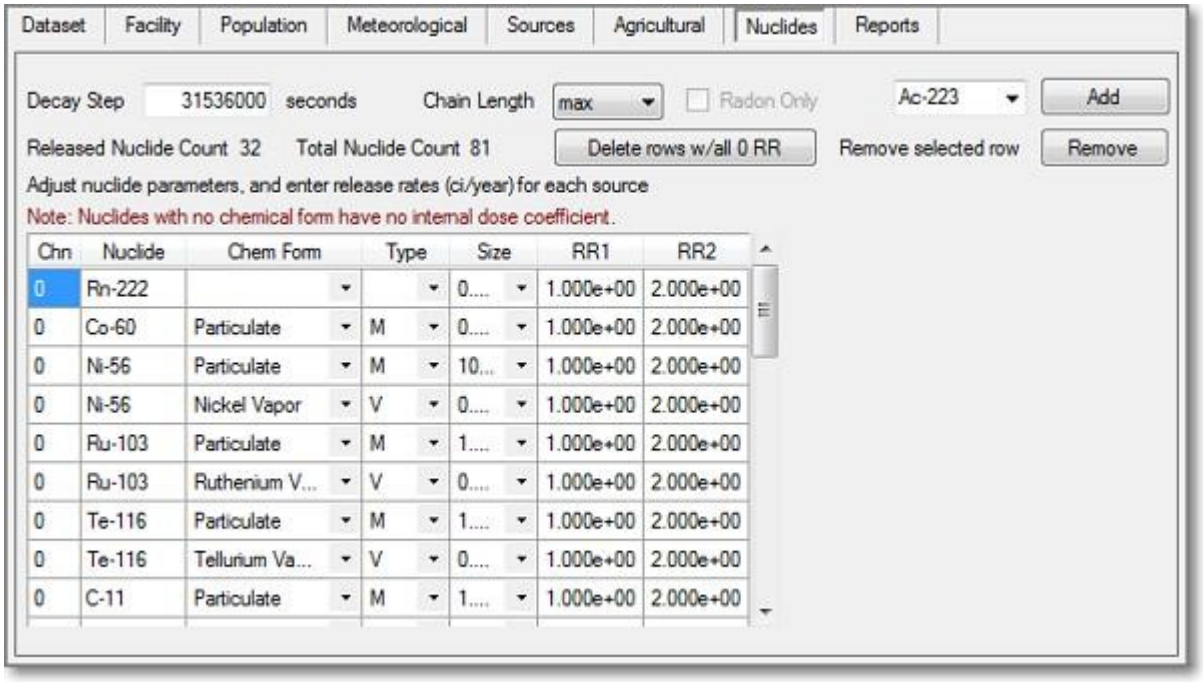
Milk Cattle Density

The milk cattle density for the assessment area.

Land Fraction Cultivated for Vegetables

The crop productivity for the assessment area.

Dataset Edit Nuclides Tab



The Nuclides tab is used to select and describe characteristics of the radionuclides emitted by each source.

Chain Length

Sets the maximum depth of the decayed chains used in the analysis. Setting to "max" uses the complete chains. Changing this setting updates the Decayed Chains value

Radon Only

This check box is only available if nuclide Rn-222 is the *only* nuclide in the list. Checking this box causes CAP88-PC to produce "Radon-Only" reports.

Released Nuclide Count

The number of nuclides in the list.

Total Nuclide Count

The sum of the complete decay chain for each nuclide in the list, to the depth specified in Chain Length. For example, if the Chain Length were "max", and the nuclides in the list were Fe-60, Co-60m and Co-60, the Decayed Chains count would be 6: Fe-60 has three nuclides in its chain, Co-60m has two, and Co-60 has one. Changing the Chain Length to 2 would reduce Decayed Chains to 5, because Fe-60 would only include its first two nuclides.

It is strongly recommended to use a Chain Length of 3 or higher.

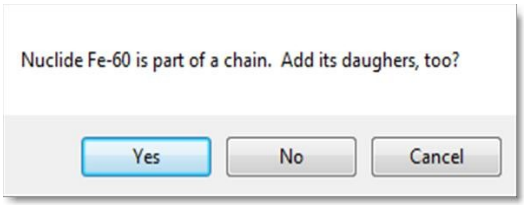
Note that the maximum number of nuclides allowed depends on their decay chains and the value selected for Chain Length. The maximum allowed Total Nuclide Count is 500.

Delete Rows w/All 0 RR

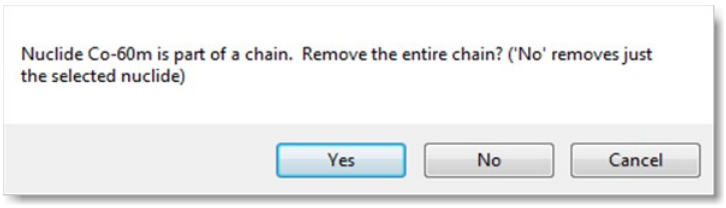
CAP88-PC requires a row to have at least one non-zero release rate. In some cases, a user may want to add only a few nuclides in a long chain. An easy way to accomplish this is to add the complete chain, enter the release rates for the desired nuclides, and then use "Delete Rows w/All 0 RR" to remove the undesired nuclides, i.e. the ones where all release rates are zero.

Add/Remove Nuclide

To add a nuclide, select it from the list and click the Add button. The user can type inside the text box to find a nuclide in the list. If the nuclide is part of a chain, the user is prompted whether to add the entire chain.



To remove a nuclide, place the cursor in its row and click the Remove button. If the nuclide is part of a chain, the user is prompted whether to remove the entire chain. *Note: If removing a chain, the entire chain is removed, even if the nuclide is not at the top of the chain.* When prompted to remove a chain, the user can choose to only remove the selected nuclide.



Nuclides

The user can directly edit the properties for each nuclide in the grid. The "Chn" (chain id) and "Nuclide" values are read-only. The editable properties are listed below. If a nuclide does not have internal (ingestion/inhalation) dose coefficients, Chemical Form and Type will be blank, and size will be zero.

See Decay Chains

Chem Form

The chemical form of the nuclide.

Type

The type of the nuclide's chemical form. If particulate, then this will be one of the FGR 13 types (F)ast, (M)edium or (S)low. If an inhalant, the type will be (G)as or (V)apor.

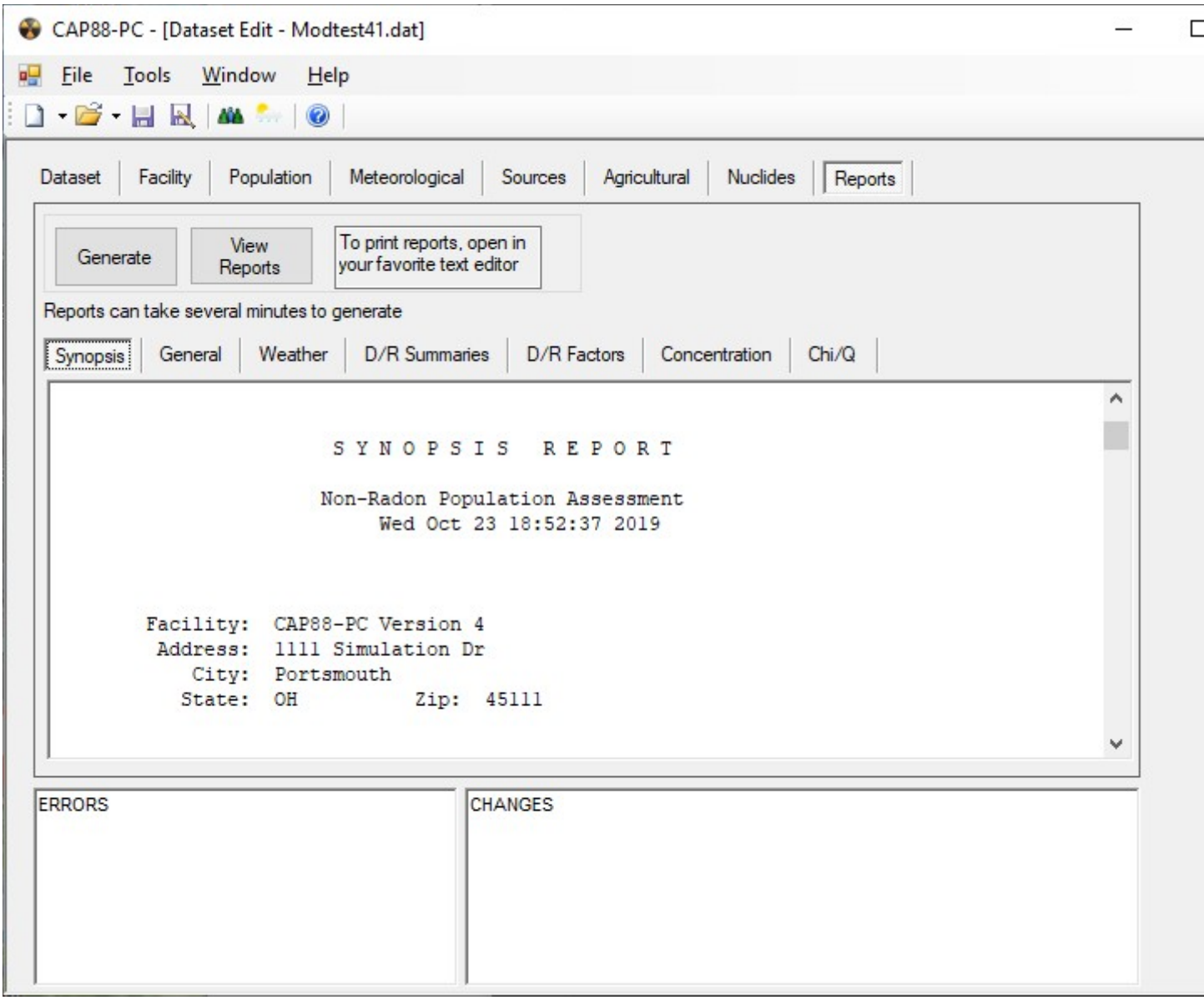
Size

If the chemical form is a particulate, the size can be any of the values 0.001, 0.003, 0.1, 0.3, 1, 3, 5, 10, 30, 50, 100. If the chemical form is not a particulate, the size will be zero.

Release Rate

The release rate in Ci/year, corresponding to the source column in the Sources Tab. A value must be at least 1.0e-25, but can't be greater than approximately 7.92e+28.

Dataset Edit Reports Tab



The Reports tab is used to generate the assessment reports. CAP88-PC will always create Synopsis, General and Weather reports. Which output reports to generate is selected in the Population Tab.

Select option "Current" to print the currently displayed report. Select option "Selected" to print one or more reports. Only checkboxes for available reports will be enabled.

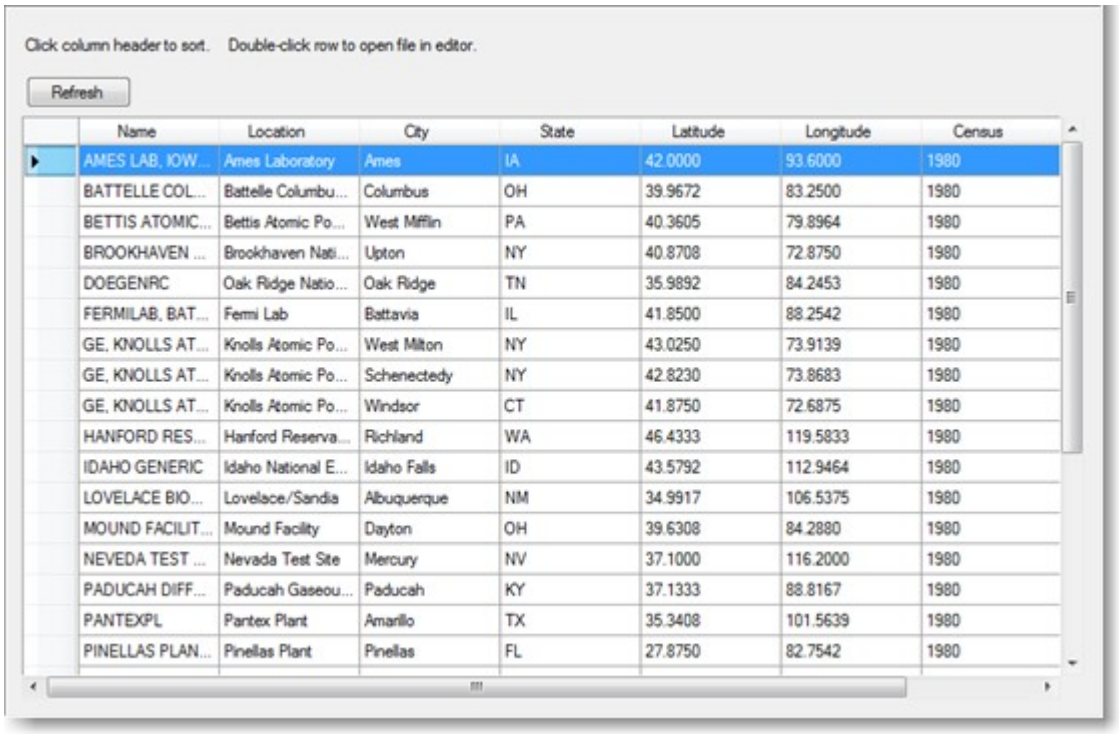
Version 4.1 has removed the ability to print reports directly from the application interface. Many printer drivers do not properly render the page feed in the report files, causing a print error. The recommended approach is now to open the report files in any program that can handle ASCII text files (most word processors and file editors) and print from that application. The report files can be accessed using the "View Reports" button.

Reports can only be generated if the dataset has no outstanding changes or errors. After generation, the Reports Last Generated datetime will be updated, and the dataset will be saved.

Population File

Population File List

Tools > Population File List



Name	Location	City	State	Latitude	Longitude	Census
AMES LAB, IOW...	Ames Laboratory	Ames	IA	42.0000	93.6000	1980
BATTELLE COL...	Battelle Columbu...	Columbus	OH	39.9672	83.2500	1980
BETTIS ATOMIC...	Bettis Atomic Po...	West Mifflin	PA	40.3605	79.8964	1980
BROOKHAVEN ...	Brookhaven Nati...	Upton	NY	40.8708	72.8750	1980
DOEGENRC	Oak Ridge Natio...	Oak Ridge	TN	35.9892	84.2453	1980
FERMILAB, BAT...	Fermi Lab	Battavia	IL	41.8500	88.2542	1980
GE, KNOLLS AT...	Knolls Atomic Po...	West Milton	NY	43.0250	73.9139	1980
GE, KNOLLS AT...	Knolls Atomic Po...	Schenectedy	NY	42.8230	73.8683	1980
GE, KNOLLS AT...	Knolls Atomic Po...	Windsor	CT	41.8750	72.6875	1980
HANFORD RES...	Hanford Reserva...	Richland	WA	46.4333	119.5833	1980
IDAHO GENERIC	Idaho National E...	Idaho Falls	ID	43.5792	112.9464	1980
LOVELACE BIO...	Lovelace/Sandia	Albuquerque	NM	34.9917	106.5375	1980
MOUND FACILIT...	Mound Facility	Dayton	OH	39.6308	84.2880	1980
NEVEDA TEST ...	Nevada Test Site	Mercury	NV	37.1000	116.2000	1980
PADUCAH DIFF...	Paducah Gaseou...	Paducah	KY	37.1333	88.8167	1980
PANTEXPL	Pantex Plant	Amarillo	TX	35.3408	101.5639	1980
PINELLAS PLAN...	Pinellas Plant	Pinellas	FL	27.8750	82.7542	1980

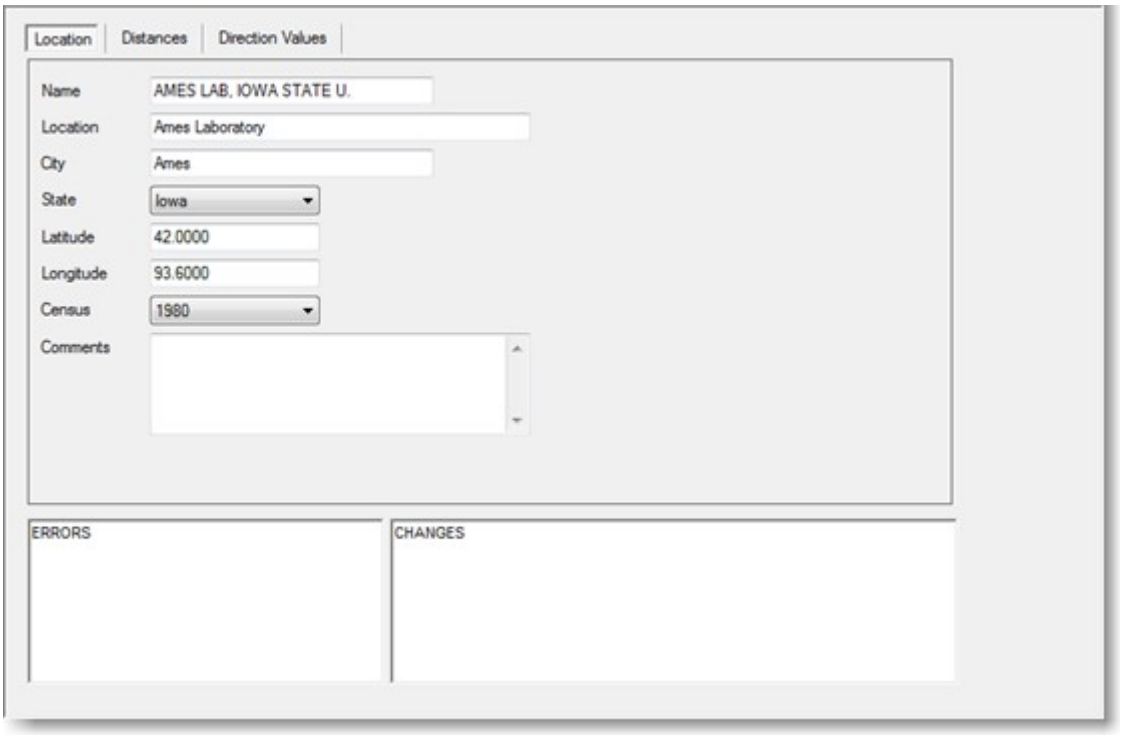
The Population File List displays the population files located in the folder location selected during installation in Options. The columns can be sorted both ascending and descending by clicking on column headings.

To edit a file, double click on its row.

See Also Population File Edit
Options
Population and Wind File Search Order

Population File Edit

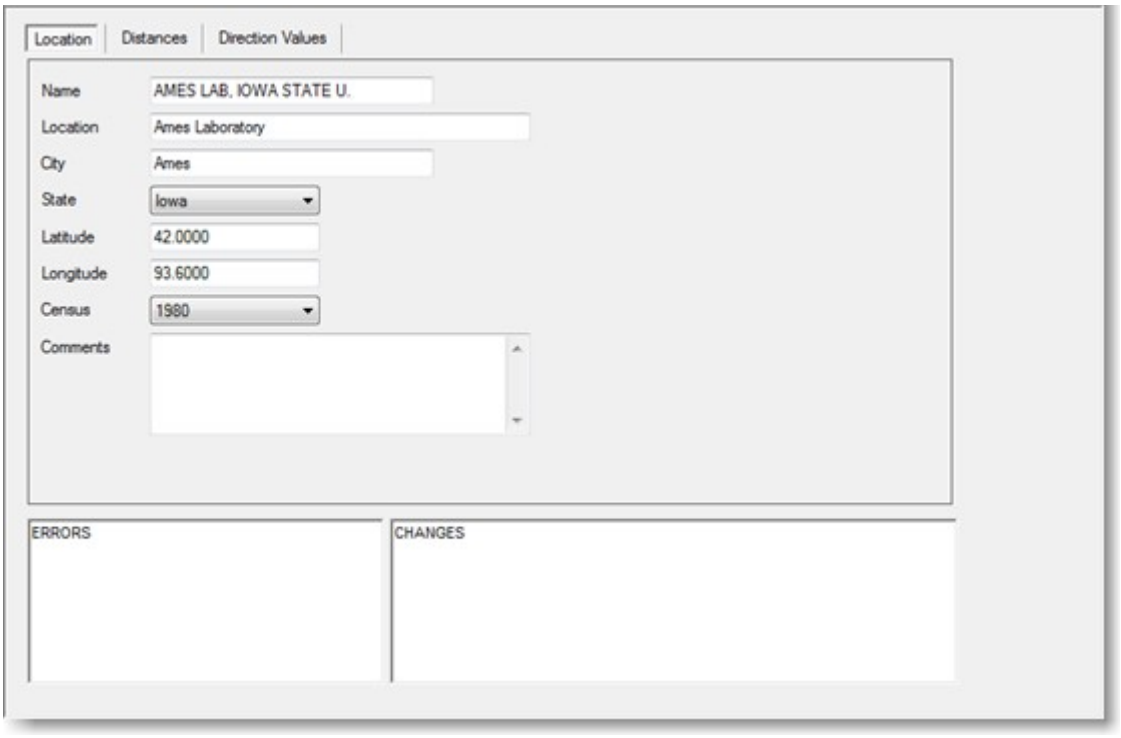
Access this function by drilling down the menus:
File > New > Population File
File > Open > Population File



Use this form to edit new or existing population files. Besides using the menu and toolbar, Population Files can also be opened from Population File List.

See Also Population File List
Population File Format

Population File Edit Location Tab



Name

The source of the population.

Location*

The specific location for the population.

City*

The population city.

State*

The population state.

Latitude

The latitude of the population location.

Longitude

The longitude of the population location.

Census*

The census year the population values were gathered.

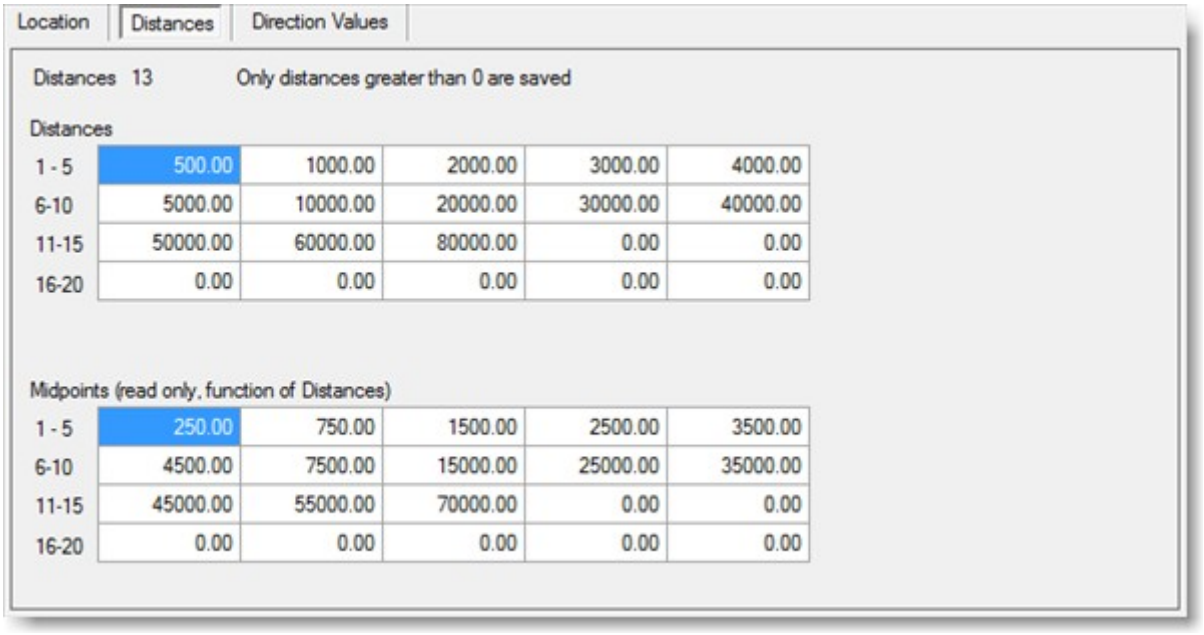
Comments*

Other comments about the file. Note that manual line breaks will be converted to spaces.

**Note: The population file contains both standard and "extended" data. Extended fields are only used and created by CAP88-PC, and are indicated with an asterisk.*

See Also Population File Format

Population File Edit Distances Tab



Use this tab to edit the distances used in the population file. CAP88-PC uses these values to generate Midpoints.

Midpoints

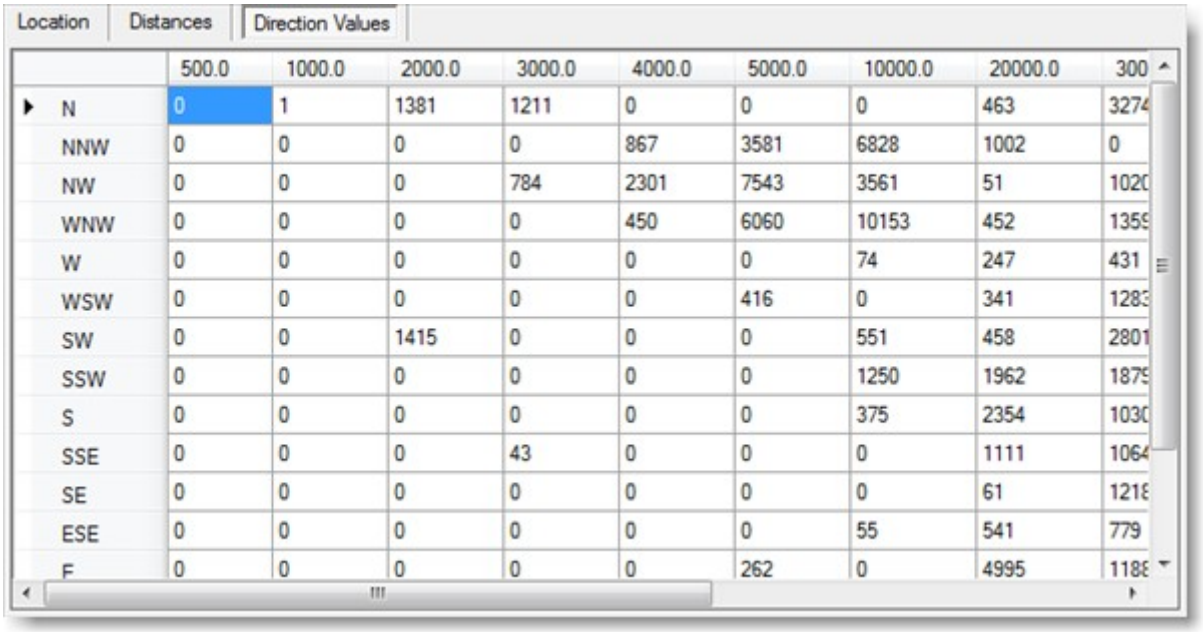
Population midpoints are calculated as follows:

1. Add the distance to its preceding distance (zero, if calculating midpoint 1)
2. Divide by 2

For example, Midpoint 1 = (Distance 1 plus zero)/2, i.e. 250 = (500 + 0)/2. Midpoint 5 = (Distance 5 + Distance 4)/2, i.e. 3500 = (4000 + 3000)/2.

See Also Population File Format

Population File Edit Direction Values Tab



	500.0	1000.0	2000.0	3000.0	4000.0	5000.0	10000.0	20000.0	300
N	0	1	1381	1211	0	0	0	463	3274
NNW	0	0	0	0	867	3581	6828	1002	0
NW	0	0	0	784	2301	7543	3561	51	1020
WNW	0	0	0	0	450	6060	10153	452	1359
W	0	0	0	0	0	0	74	247	431
WSW	0	0	0	0	0	416	0	341	1283
SW	0	0	1415	0	0	0	551	458	2801
SSW	0	0	0	0	0	0	1250	1962	1879
S	0	0	0	0	0	0	375	2354	1030
SSE	0	0	0	43	0	0	0	1111	1064
SE	0	0	0	0	0	0	0	61	1218
ESE	0	0	0	0	0	0	55	541	779
E	0	0	0	0	0	262	0	4995	1188

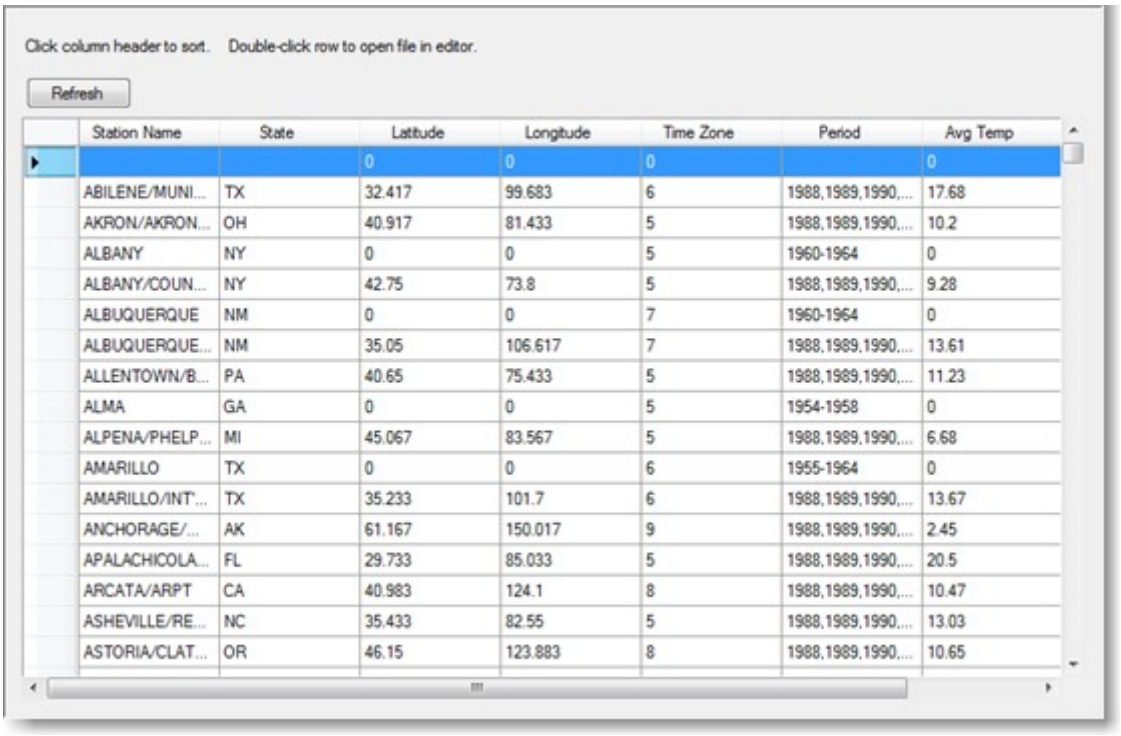
Use this tab to enter the populations at specific distances and directions. Each row is a direction, and each column is a distance specified in the Distances Tab.

See Also Population File Format

Wind File Wind

File List Tools >

Wind File List



Station Name	State	Latitude	Longitude	Time Zone	Period	Avg Temp
		0	0	0		0
ABILENE/MUNI...	TX	32.417	99.683	6	1988,1989,1990,...	17.68
AKRON/AKRON...	OH	40.917	81.433	5	1988,1989,1990,...	10.2
ALBANY	NY	0	0	5	1960-1964	0
ALBANY/COUN...	NY	42.75	73.8	5	1988,1989,1990,...	9.28
ALBUQUERQUE	NM	0	0	7	1960-1964	0
ALBUQUERQUE...	NM	35.05	106.617	7	1988,1989,1990,...	13.61
ALLENTOWN/B...	PA	40.65	75.433	5	1988,1989,1990,...	11.23
ALMA	GA	0	0	5	1954-1958	0
ALPENA/PHELP...	MI	45.067	83.567	5	1988,1989,1990,...	6.68
AMARILLO	TX	0	0	6	1955-1964	0
AMARILLO/INT'...	TX	35.233	101.7	6	1988,1989,1990,...	13.67
ANCHORAGE/...	AK	61.167	150.017	9	1988,1989,1990,...	2.45
APALACHICOLA...	FL	29.733	85.033	5	1988,1989,1990,...	20.5
ARCATA/ARPT	CA	40.983	124.1	8	1988,1989,1990,...	10.47
ASHEVILLE/RE...	NC	35.433	82.55	5	1988,1989,1990,...	13.03
ASTORIA/CLAT...	OR	46.15	123.883	8	1988,1989,1990,...	10.65

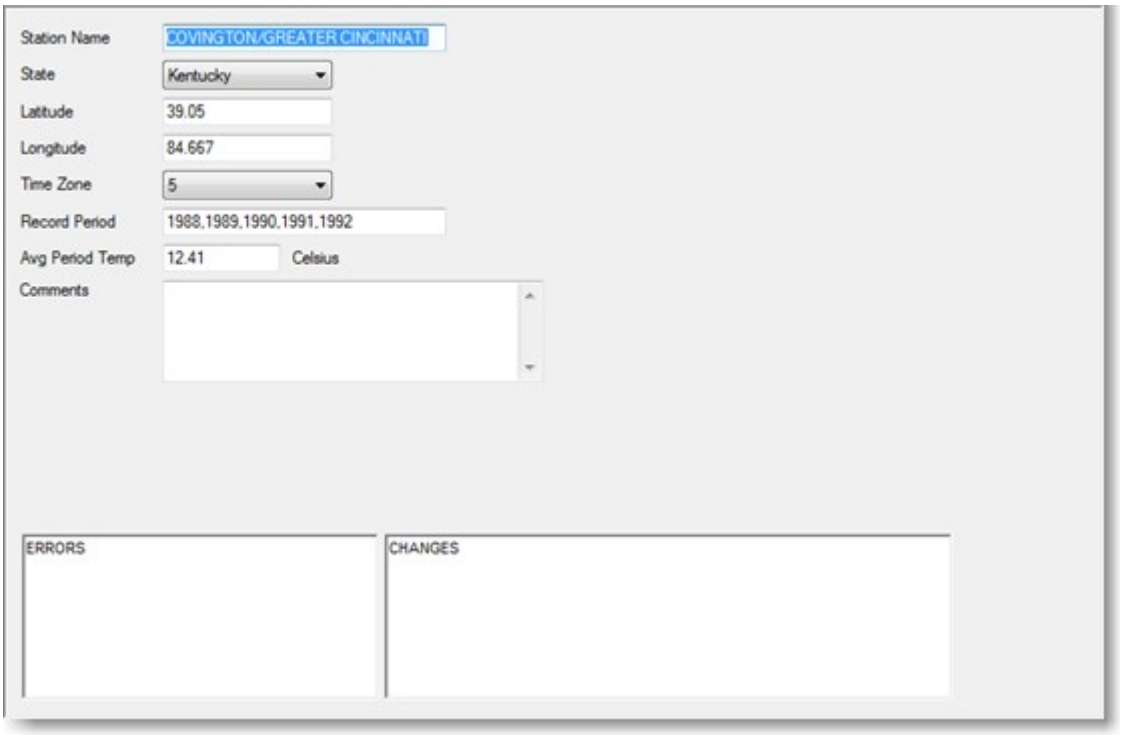
The Wind File List displays the wind files located in the default folder selected in Options. The columns can be sorted both ascending and descending by clicking on the column headings.

To edit a file, double click on its row.

See Also Wind File Edit
Options
Population and Wind File Search Order

Wind File Edit

File > Open > Wind File



Use this form to edit existing Wind files. Besides using the menu and toolbar, Wind Files can also be opened from Wind File List.

Note: Unlike Population Files, Wind files cannot be created manually using the CAP88-PC editor. They must be created using a separate text editor or by editing an existing file.

Note: The wind file contains both standard and "extended" data. Extended fields are only used and created by CAP88-PC. All fields below are extended fields.

Station Name

The name of the weather collection stations.

State

The station's state.

Latitude

The station's latitude.

Longitude

The station's longitude.

Time Zone

The station's time zone.

Record Period

The period reflected in the data file's values.

Avg. Period Temp

The average temperature for the Record Period, in degrees Celsius.

Comments

Other comments about the file. Note that manual line breaks will be converted to spaces.

See Also Wind File List
Wind File Format

Reference

Dataset File Format

Line and Col are both 1-based.

- Each property is on its own line in most cases.
- Decimal values are almost always scientific notation, 0.000e+00.
- Lines with multiple columns are logical groupings, such as Plume values.
- No wrapping of like columns, i.e. no 80-column limit.
- Column values are left-justified unless otherwise noted.
- Whenever possible, columns are length ten, or multiple of ten.

Field	Purpose	Line	Col	Len
Version	CAP88/file version major-minor, e.g. 4.1	1	1	var
Dataset FileNamePrefix	The dataset's file name without "dat", includes trailing "." Used when naming report files.	2	1	var
Last Change Date	date of last time Dataset info changed. Format: mmm d, yyyy hh:mm am/pm Jan 03, 2010 03:08 pm	3	1	var
Last Run Date	date of last time the Dataset had been executed, i.e. output files generated Format: mmm d, yyyy hh:mm am/pm	4	1	var
Facility				
Facility Name	Facility Name	5	1	var
Facility Address 1	Address 1	6	1	var
Facility Address 2	Address 2	7	1	var
Facility City	City	8	1	var
Facility Zip	Zip code	9	1	var
Source Category	The Source Category is for information only. No particular category is enforced at this time.	10	1	var
Emission Year	the year in which the radionuclide emissions occurred	11	1	4
Comment 1	Comment 1	12	1	var
Comment 2	Comment 2	13	1	var
Population				
Run Type	Individual=0 Population=1 Right justified	14	1	var
Population File	Population file path and name	15	1	var
Population Age	String value: Infant One Five Ten Fifteen Adult	16	1	var
Build Up Time	In days, Integer	17	1	var

Population Distance Count (NRADS)	Population file's NRADS value (number of distances) Integer	18	1	var
Max Exposed Direction (ILOC)	ILOC and JLOC are parameters used in DARTAB to specify the maximum exposed individual. They refer to indexes that determine the direction (ILOC) and distance (JLOC) to the individual. ILOC is 1 for North, 2 for North Northwest, 3 for Northwest, etc. up to 16 for North Northeast. JLOC is one for the first distance in the specified Midpoint Distances array, 2 for the second distance, etc. Set ILOC and JLOC to 0 to let DARTAB determine the distance and direction. Either both ILOC and JLOC must be set, or both must be 0.	19	1	var
Max Exposed Midpoint (JLOC)	The 1-based midpoint	20	1	var
MIDPOINTS For 1 to 20				
Midpoint1	Integer	21	1	10
Midpoint2	Integer	21	11	10
Midpoint3	Integer	21	21	10
...Midpoint20	Integer	21	191	10
Create organ dose summaries	True = T False = F	22	1	10
Create dose and risk factors	True = T False = F	22	11	10
Create concentration table	True = T False = F	22	21	10
Create Chi/Q table table	True = T False = F	22	31	10
Meteorological				
Wind File	Wind file path and name	23	1	var
Annual Precipitation	The average annual precipitation (in centimeters) at or near the site.	24	1	var
Annual Ambient Temperature	Average annual ambient temperature in degrees Celsius.	25	1	var
Lid Height	The height of the tropospheric mixing layer (in meters) at or near the site.	26	1	var
Absolute Humidity	The absolute humidity (in grams / cubic meter) at or near the site. This field must contain a positive non-zero value. Typical values are from 3 grams/cu m to 20 grams/cu m. The default is 8 grams/cu m.	27	1	var
Sources				

Source Type	Stack=0 Area=1	28	1	var
Sources Count	Up to six (6) emitting sources (stacks or areas) may be modeled.	29	1	var
SOURCE HEIGHTS For 1 to SourcesCount (x)				
SourceHeight1	Scientific	30	1	10
SourceHeight2	Scientific	30	11	10
...SourceHeightX	Scientific	30	etc	10
SOURCE DEPTHS (DIAMETER OR AREA) For 1 to SourcesCount (x) (Depth is "Diameter" if Type is Stack, or "Area" if Type is Area.)				
SourceDepth1	Scientific	31	1	10
SourceDepth2	Scientific	31	11	10
SourceDepthX	Scientific	31	etc	10
Plume Type	Buoyant=0 Momentum=1 Fixed=2 None=3	32	1	var
PLUME VALUES 1-7				
PlumeValue1	Scientific	33	1	10
PlumeValue2	Scientific	33	11	10
PlumeValue3	Scientific	33	21	10
PlumeValue4	Scientific	33	31	10
PlumeValue5	Scientific	33	41	10
PlumeValue6	Scientific	33	51	10
PlumeValue7	Scientific	33	61	10
Agricultural				
Food Source	Text: “Urban”, “Rural”, “Local”, “Regional”, “Imported”, “Entered” Notes: “entered” means the values were manually entered.	34	1	var
Vegetable fraction home produced	Format 0.00	35	1	10
Vegetable fraction from assessment area	Format 0.00	35	11	10
Vegetable Fraction imported	Format 0.00	35	21	10
Milk fraction home produced	Format 0.00	36	1	10
Milk fraction from assessment area	Format 0.00	36	11	10
Milk Fraction imported	Format 0.00	36	21	10
Meat fraction home produced	Format 0.00	37	1	10
Meat fraction from assessment area	Format 0.00	37	11	10
Meat Fraction imported	Format 0.00	37	21	10
Agriculture State	State. Abbreviation only	38	1	2
Beef cattle density	#/ha Format 0.000E-01	39	1	10
Milk cattle density	#/ha Format 0.000E-01	40	1	10
Vegetable cultivated land fraction	Format 0.000E-01	41	1	10
Nuclides				

DecayStep	Integer, number of seconds (not used in V4, kept for compatibility)	42	1	var
ChainLength	Integer 1 through 6, or 29 (max)	43	1	var
Radon Only Run	Allowed if Rn-222 is the only nuclide. True = T False = F	44	1	var
Nuclides Count	Integer	45	1	var
NUCLIDES For 1 to NuclideCount (x) (two nuclides shown)				
NUCLIDE1				
ChainId1	Integer, used to group nuclides	46	1	10
Name1	E.g. Rn-222	46	11	10
Form1	Chemical form, e.g. "Tritiated Water Vapor" or "B" (blank)	46	21	40
Type1	E.g. F, M, S, V, G, B (blank)	46	61	10
Size1	Decimal in format 000.0000, e.g. 0.0001, 10.0000, 300.0000	46	71	10
----RELEASE RATES Nuclide1, For 1 to SourceCount (y)				
RR1	Scientific	46	81	10
RR2	Scientific	46	91	10
RRy	Scientific	46	etc	10
Age-Dependent Usage Rates - Combined Genders (a single row of age-specific data)				
Total Vegetables	Integer	47	1	10
Total Diary	Integer	47	11	10
Total Milk	Integer	47	21	10
Total Meat	Integer	47	31	10
Drinking Water	Integer	47	41	10
Inhalation	Integer	47	51	10
Decay Chains				
Each user-selected nuclide has its complete chain written out. For the parent, the user's settings (chem form, type, size) are used for coefficients. For daughters, the nuclide's defaults are used. NOTE: If Radon Only = True, then only the parent nuclide is written, i.e. Rn-222.				
Dose Organs	The organ names that correspond to the dose coefficients. Each column left justified.	48	1-x	10
Risk Organs	The organ names that correspond to risk coefficients. Each column left justified.	49	1-x	10
For each user-selected nuclide (1 to NuclideCount)				
Chain Count	The number of nuclides in this nuclide's chain. If Radon Only, then this value is always 1.	50	1	var
For each nuclide in chain (parent and daughters) :				
NUCLIDE ATTRIBUTES	All numeric values are in Scientific			
Name	String	51	1	10

Default Chemical Form	Chemical form, e.g. "Tritiated Water Vapor" or "B" (blank)	51	11	40
Default Inhalation Type	E.g. F, M, S, V, G, B (blank)	51	51	10
Default Size	Decimal in format 000.0000, e.g. 0.0001, 10.0000, 300.0000	51	61	10
HalfLife	In Seconds	51	71	10
Deposition Velocity		51	81	10
Scavenging Coefficient		51	91	10
Surface Removal Rate Constant		51	101	10
Default Inhalation		51	111	10
GI Ingestion		51	121	10
BeefXfer		51	131	10
MilkXfer		51	141	10
VegetableXfer		51	151	10
ForageXfer		51	161	10
Branching Coefficients	Format Scientific. 1-dimensional 30-element array, which is the branching coefficient row for this daughter. Consider the whole chain as a two-dimensional array of 1 to 30 items, with nuclides down the left, and the same nuclides across the top. Each element in the array is the percentage decay from the parent. If no value, then zero is stored. For example: Sc-44m is the parent. It has one daugher, Sc-44. The branching coefficients for Sc-44m would be all zeros, because it's the parent: 0 0 0 0 0 ... The branching coefficients for Sc-44 would be: 9.880E-01 0 0 0 0 ... This indicates that Sc-44 decays 9.880e-01 % from nuclide 1, which is Sc-44m.	52	1-301	10
Dose Ingestion Coefficients	For each organ	53	1-x	10
Dose Inhalation Coefficients	For each organ	54	1-x	10
Dose Air Coefficients	For each organ	55	1-x	10
Dose Ground Coefficients	For each organ	56	1-x	10
Risk Ingestion Coefficients	For each organ	57	1-x	10
Risk Inhalation Coefficients	For each organ	58	1-x	10
Risk Air Coefficients	For each organ	59	1-x	10
Risk Ground Coefficients	For each organ	60	1-x	10

Quick Reference

Below is a simple, rough view of the dataset format.

```
Version
Dataset Filename
Last Change Datetime
Last Run Datetime
Facility Name
Address1
Address2
City Zip
Category
Emission Year
Comment1
Comment2
Run Type
Population Filename
Population Age
BuildUp Time
Distance Count
Max Exposed Direction
Max Exposed Midpoint
Midpoints
ReportSummary  ReportFactors  RepConcentrations ReportChiQ
Wind Filename
Annual Precipitation
Annual Temp Lid
Height Absolute
Humidity Source
Type
Source Count
Source Heights
Source Depths
Plume Type
Plume Values
Food Source
Veg fractions
Milk fractions
Meat fractions
Agri State
Beef Density
Milk Density
Veg Fraction
Decay Step
Chain Length
Radon Only
Nuclide Count
Nuclides
  (ChainId Name Form Type Size RR1-6)
  (ChainId Name Form Type Size RR1-6)
  etc.

[AGE-DEPENDENT USAGE RATES]
TotVeg TotDairy TotMilk TotMeat Water Inhalation

[DECAY CHAINS]
Dose organ list
Risk organ list
For each user-selected nuclide:
  Decay Chain Count
  For each nuclide in chain:
    (Line 1, nuclide info)
```

```
    Name, Chem Form, Type, Size, Half Life, Deposition Velocity, Scavenging
Coefficient,
    Surface Removal Rate Constant, Default Inhalation, GI Ingestion,
    BeefXfer, MilkXfer, VegetableXfer, ForageXfer

    (Line 2, branching coefficients)
    1x30 array, each element is the fraction decay from a parent nuclide

    Line 3: Dose Ingestion
    Line 4: Dose Inhalation
    Line 5: Dose Air
    Line 6: Dose Ground

    Line 7: Risk Ingestion
    Line 8: Risk Inhalation
    Line 9: Risk Air
    Line10: Risk Ground
```

Dataset Default File

Purpose Of Default Value

The DEFAULT.DAT file contains various types of default data for CAP88-PC. The file is divided into two segments. The first segment contains default values that can, with great caution, be changed by the user. The second segment contains permanent defaults which are values that must **never** be changed by the user since any changes would corrupt the assessments.

User Changeable Defaults

The defaults contained in the DEFAULT.DAT file for meteorological data, inhalation and ingestion rates, water use and agricultural productivity are the values approved by EPA to demonstrate compliance as required by 40 CFR 61.93(a).

CAUTION: Any modification to the DEFAULT.DAT file must be approved by EPA if the modified parameters are used to demonstrate compliance per 40 CFR 61.93(a), or any other NESHAP section which requires the use of CAP88 for regulatory purposes.

There may be users who, in rare instances, might need to change one or more of these values for a specific purpose. The user, however, should be fully aware that these values must only be changed when and if the user fully understands the full impact that the change(s) will have upon the assessments run with the user specified values.

CAUTION: If any of these values are changed without full knowledge of the impact of the change(s), the resulting assessments could be invalid for the intended purpose.

Permanent Defaults

The default values found in the second segment of the file contains defaults that must not be changed by the user. These values are contained in the DEFAULT.DAT file so that if directed by EPA, applicable defaults can be easily changed within this file and promptly

disseminated to all users. This will preclude the necessity of modifying program code and disseminating new executable programs.

Changeable Defaults

Variable Names and Descriptions

The following is a list of variable names whose values can be changed by the user. Also included are their units of measure, default values and a brief description. The variable names here will match the names you will see in the DEFAULT.DAT file. They are grouped in categories such as meteorological, agricultural, etc.

VARIABLE	UNITS	DEFAULT	DESCRIPTION
TG	$^oK/m$	.0728	Vertical temperature gradient for
		.1090	Pasquill categories E, F,
		.1455	and G (three element array)
DILFAC	cm	1.0	Depth of water for dilution for water immersion doses
USEFAC		0.0	Fraction of time spent swimming
ILOC		0	Direction index of the single location used for individual calculations
JLOC		0	Distance index of the single location used for individual calculations
PLOC		100.0	The percentile of the total risk to use in choosing the location for the exposure array used for the individual tables. When ILOC and JLOC are both 0, PLOC is used.
GSCFAC		0.5	A scaling factor used to correct ground surface dose factors for surface roughness
Default Rates			
BRTHRT	cm^3/hr	5.26E+03	Inhalation rate of man
DD1		0.5	Fraction of radioactivity retained on leafy vegetables and produce after washing
UF	kg/yr	84.0	Ingestion rate of meat by man
UL	kg/yr	7.79	Ingestion rate of leafy vegetables by man
UM	liter/yr	53.0	Ingestion rate of milk by man
UV	kg/yr	76.2	Ingestion rate of produce by man
Agricultural Defaults			
FSUBG		1.0	Fraction of produce ingested grown in garden of interest
FSUBL		1.0	Fraction of leafy vegetables grown in garden of interest
FSUBP		0.4	Fraction of year animals graze on pasture
FSUBS		0.43	Fraction of daily feed that is pasture grass when animal grazes on pasture
LAMW	hr^{-1}	2.9E-3	Removal rate constant for physical loss by weathering
MSUBB	kg	200.0	Muscle mass of animal at slaughter
P	kg/m^2	215.0	Effective surface density of soil, dry weight (assumes 15 cm plow layer)

VARIABLE	UNITS	DEFAULT	DESCRIPTION
QSUBF	kg/day	15.6	Consumption rate of contaminated feed or forage by an animal (dry weight)
R1		0.57	Fallout interception fraction-pasture
R2		0.2	Fallout interception fraction-vegetables
TAUBEF		3.81E-3	Fraction of animal herd slaughtered per day
TSUBE1	hr	720.0	Period of exposure during growing season--pasture grass
TSUBE2	hr	1440.0	Period of exposure during growing season--crops or leafy vegetables
TSUBF	day	2.0	Transport time: animal feed-milk-man
TSUBH1	hr	0.0	Time delay--ingestion of pasture grass by animals
TSUBH2	hr	2160.0	Time delay--ingestion of stored feed by animals
TSUBH3	hr	336.0	Time delay--ingestion of leafy vegetables by man
TSUBH4	hr	336.0	Time delay--ingestion of produce by man
TSUBS	day	20.0	Average time from slaughter of meat animal to consumption
VSUBM	liter/day	11.0	Milk production of cow
YSUBV1	kg/m^2	0.28	Agricultural productivity by unit area (grass-cow-milk-man pathway)
YSUBV2	kg/m^2	0.716	Agricultural productivity by unit area (produce or leafy vegetables ingested by man)
TSUBB	yr	100.0	Period of long-term buildup for activity in soil

Changing Default Values

The DEFAULT.DAT file is located in the CAP88PC directory of the drive you have chosen to load the system on. Go to this directory. Before you change anything in this file, you may want to make a copy of the original DEFAULT.DAT file giving it a different extension or save it on a floppy disk so that it can be easily retrieved.

Access DEFAULT.DAT (an ASCII file) using a word processor or a text editor. Find the variable name whose value you want to change and simply replace the default value with the value you want to use. The following are some conditions the user needs to be aware of.

- Additional digits can be included, exponential notation can be used in place of decimal numbers and decimal numbers can replace exponential notation. Integer values should remain integers.
- Do not delete any variables. The program will not abort but either zero or some unpredictable value will be used which will invalidate the assessment results.
- Do not move the variables around. They must remain in the original order and category. Each category begins with an Ampersand (&) followed by four or more descriptive characters. Each category ends with &END. The &END must follow the last variable in the category or be on a line by itself immediately following the last variable.
- The beginning of a category must be at the beginning of a line and there must be one or more spaces separating it from the first variable in the category.
- Do not change the order or delete any of the categories. If the order is changed or any category is eliminated the CAP88-PC system will abort and/or produce totally invalid assessment results.

- Additional lines can be added and variables moved from one line to another as long as the order of the variables does not change.
- There is no required number of spaces between variables but the variables must be separated by commas. A comma is not required between the last variable in a category and &END.
- Be sure not to eliminate the equal (=) sign between the variable and the value or values in the case of an array. The variable TG is a three element array; therefore, TG is followed by a single = sign which is then followed by three values separated by commas. TG(1) will contain .0728, TG(2) and TG(3) will contain the next two values respectively. If any or all of these values should ever be changed, be sure the values are entered in the correct order.
- Change only the variables listed in 10.2.1 (Variable Names and Descriptions). Do not alter in any way the variables and values in the categories that follow the &INPUT category.

Save the user altered file into DEFAULT.DAT after making sure that you have saved the original DEFAULT.DAT so that it will not be destroyed by your altered file. The new file is then ready to be used with the CAP88-PC System.

Restoring DEFAULT.DAT Values

When an assessment is executed The DEFAULT.DAT file is checked for changes. If changes have been made to defaults listed in Section 10.2.1, the changes will be printed to the screen as shown in the figure below.

```
              W A R N I N G !
The Following Default Values Have Been Changed,
DO NOT USE these changes unless you fully understand
the EFFECTS of these Changes:

These changes CANNOT BE USED to demonstrate compliance
per 40 CFR 61.93 unless specifically approved by EPA.

Inhalation Rate of Man
Changed From: 9.1670E+05
To:           8.5300E+05

Resetting of individual defaults cannot be done here.
CHANGE ALL DEFAULTS Back to their Original Values?

Y/N:
```

The changes shown will include the description, the original default value and the user specified value. After all changes have been printed to the screen, the user is given the opportunity to reset **all defaults** back to their original values with a response of Y or N. It is not possible to reset individual values at this point. Individual changes can only be made directly by accessing the DEFAULT.DAT file using a text editor or word processor as described in Section 10.2.2.

If the user elects to have all defaults reset, all defaults will be overwritten with the original defaults. The overwritten DEFAULT.DAT file will look a little different from the original file; however, the only actual difference will be the spacing of the variables. The variable names and values will be closer together using fewer lines.

Alternative DEFAULT.DAT Files

The user may want to create alternative default files with user specified values. Before initiating the CAP88-PC system the user would copy the default file they need for a given run into DEFAULT.DAT.

WARNING: CAP88-PC must have a DEFAULT.DAT file available in order for it to run.

It is not possible to alter any of the specified default values once CAP88-PC has been initiated except to reset all defaults to their original values. Therefore, when a user needs alternative default values it is the user's responsibility to assure that the appropriate alternative DEFAULT.DAT file is available when CAP88-PC is initiated.

When a DEFAULT.DAT file containing user altered default values is used, there will be a CAUTION message on the beginning page of the SYNOPSIS Report stating that defaults have been changed. The specific changes will be listed on the following page including the default description, the original default value, and the user specified value. This will alert the originators and anyone using the outputs that defaults have been changed and what changes have been made.

PERMANENT DEFAULTS

The DEFAULT.DAT file contains defaults that must not be changed by the user. All defaults beginning with &ORGAN through the end of the file must contain the original default values which can only be changed at the direction of EPA.

```
Permanent Defaults that MUST NOT BE ALTERED by the user
have been changed. They will be RESET to prevent CAP88-PC
from producing invalid results.
```

If any of the permanent defaults are changed, except at the direction of EPA, the CAP88-PC system will detect those changes and reset them to their original values. In this case, a message similar to the one shown above will be printed to the screen informing the user that these permanent defaults have been reset. If the user has changed default values defined as changeable by the user, the system will not reset those user changeable values except at the direction of the user.

Population File Format

Starting with CAP88-PC Version 4, extended data is included in the file. This data was previously stored in a separate database, preventing portability. All extended data is at the end of the file, after an "extended data" line. The format for the data is Setting=Value.

Users are encouraged to use site-specific population arrays with CAP88-PC. Users who have been operating the CAP88 mainframe software may download their population files for use on the CAP88-PC system. They must be in the same format as the following file. However, extended values are not required.

It is critical that all information be in the same exact locations with the "$" sign being in the first column of the first row of the file.

The population file name, latitude, and longitude on row 1 are information only for the purpose of verifying that the file desired is the file the user has selected.

NRADS is the number of distances within the population file. The value associated with NRADS must be in columns 68 and 69 of row 1 of the population file and the last digit must always found column 69 (right justified).

Distances begin in row 2 and all numbers are right justified. The number of distances found in the file will be the number specified by NRAD. The distances are edge points of each sector (the Midpoints used in by CAP88 are calculated by the program) and are entered in the population file in kilometers. The CAP88 programs will multiply each distance by 1000 before calculating the midpoints and using them in the assessment. For example, the first distance in the file, .62 kilometers, will become 620 meters and the midpoint calculated from that will be 310 meters. There can be up to 20 distances, but the typical number of distances is 13.

The population values are entered with distances across (columns) and directions down (rows); however, each row will not be a new direction. There will be 20 distances for each direction (regardless of the number of distances specified in the population file). The extra distances (usually 7) will simply contain zero. There will always be 8 population values per row with the first value ending at column 10 and each subsequent value ending at multiples of 10 with the last value per row ending in column 80. This means that for the direction N, the population values will be contained on the first, second and part of the third row of the distance-direction population values. The first population value for the next direction, NNW, will be contained in columns 41 through 50 of the third row and subsequent values for direction NNW will be contained on the remaining part of the third row, the fourth and part of the fifth row. There are 16 directions in counterclockwise order starting with North.

Sample Population File

The following is the population file Battelle.POP used in the CAP88Def41 sample assessment.

```
   $ BATTELLE COLUMBUS        LAT= 39.9672 LON= 83.2500 NSEC=16 NRADS=13
    0.5       1.0       2.0       3.0       4.0       5.0      10.0      20.0
   30.0      40.0      50.0      60.0      80.0
      0.        1.        0.        0.        0.        0.        0.     2705.
   2641.     3331.     3552.     5411.    55579.        0.        0.        0.
      0.        0.        0.        0.        0.        0.        0.        0.
      0.        0.        0.        0.     2333.    11675.     2212.     3061.
   7065.        0.        0.        0.        0.        0.        0.        0.
      0.        0.        0.        0.        0.        0.        0.     3071.
   1287.     2055.     1782.     5763.    24201.        0.        0.        0.
      0.        0.        0.        0.        0.        0.        0.        0.
      0.        0.        0.     1033.     3288.     1529.    13828.     2949.
   9707.        0.        0.        0.        0.        0.        0.        0.
      0.        0.        0.        0.        0.        0.      717.     1020.
   4615.     1333.    90022.    26249.    79387.        0.        0.        0.
      0.        0.        0.        0.        0.        0.        0.        0.
      0.        0.      797.     5611.     3905.        0.      861.    12543.
 176422.        0.        0.        0.        0.        0.        0.        0.
      0.        0.        0.        0.     2602.        0.      573.     1137.
    328.      710.     3812.     6853.    16705.        0.        0.        0.
      0.        0.        0.        0.        0.        0.        0.        0.
   2046.        0.      320.     1656.     1642.      976.     8788.    10199.
```

```
 11921.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
  2807.     2199.     2176.     2809.    14890.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.       55.     6325.     3726.      837.    11171.     1608.
 44798.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.     4477.     5592.
  8271.     6486.    11446.     3399.    10303.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.     4312.    55327.    36474.    18070.    12787.    22041.
 42086.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.     3282.    84555.
204255.   100483.    18087.     7393.    69779.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.      677.    50903.   177302.    47221.     4039.     9908.
 20086.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.      854.    20317.
 34864.     9203.     6955.     2119.    18770.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.     2458.     4158.     2559.    12434.    13663.     5086.
 17946.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
     0.        0.        0.        0.        0.        0.        0.        0.
extended data
Location=Battelle Columbus Laboratory
City=Columbus
State=OH
Census=1980
Comments=
```

Wind File Format

Starting with CAP88-PC Version 4, extended data is included in the file. This data was previously stored in a separate database, preventing portability. All extended data is at the end of the file, after an "extended data" line. The format for the data is Setting=Value.

Other than the extended data, the wind file format is not fully documented at this time. Known formatting is as follows:

Item	Description	Line	Col	Len
Magic Number	Indicates this is a wind file. The three characters are ASCII hexadecimal values 01, 02 and 03, with no spaces in between.	1	1	3

Sample Wind File

Below is the data found in file 03160.wnd. Note that the "magic number" on line one may not show any characters, depending on how you're viewing the documentation.

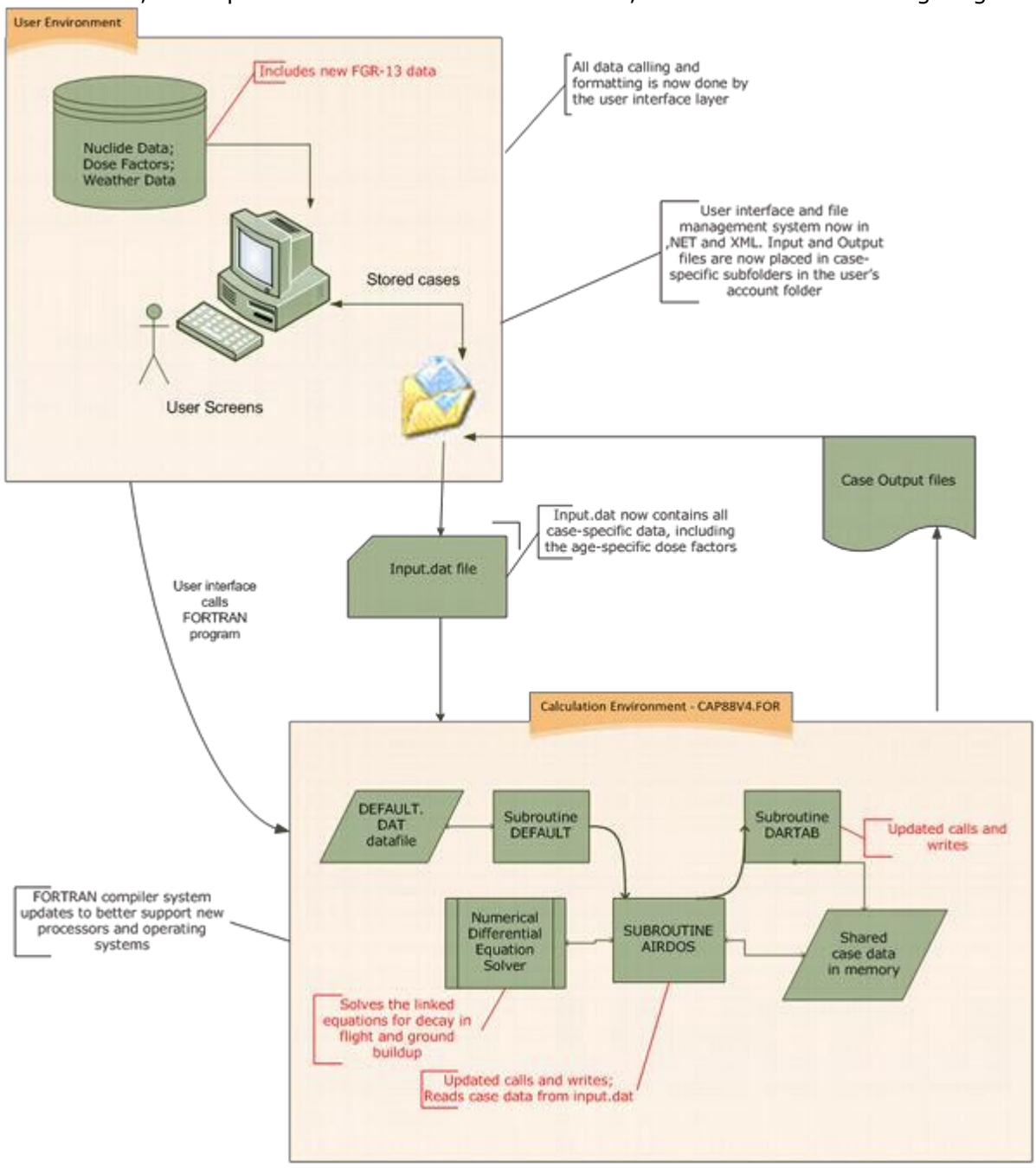
```
   4.27363
0.05900.01810.03940.07870.08100.06820.12380.09540.06090.02820.02530.02410.03750.06360.
10320.0936
 1.33 1.11 1.27 1.15 1.08 1.35 1.36 1.50 1.13 1.25 1.47 1.10 1.25 1.36 1.41 1.45
 1.47 1.33 1.25 1.38 1.25 1.39 1.33 1.50 1.45 1.24 1.34 1.23 1.51 1.71 1.85 1.62
 3.12 2.18 2.68 2.64 2.24 2.51 3.28 3.07 2.65 1.92 1.91 2.00 2.68 3.66 4.09 4.17
 6.07 3.43 4.29 4.77 4.19 4.69 6.02 5.91 4.68 3.68 3.25 3.42 3.87 5.17 6.15 6.89
 3.61 3.13 3.22 3.49 3.34 3.52 3.82 3.78 3.34 3.28 3.10 3.18 3.39 3.70 3.89 3.81
 1.26 1.24 1.26 1.39 1.38 1.38 1.40 1.43 1.34 1.35 1.14 1.17 1.28 1.36 1.37 1.20
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
 1.85 1.56 1.78 1.62 1.50 1.87 1.88 2.02 1.59 1.76 1.99 1.53 1.75 1.89 1.94 1.97
 2.32 2.16 2.04 2.30 2.00 2.22 2.05 2.47 2.27 1.97 2.08 1.91 2.33 2.67 2.80 2.59
 4.92 3.23 3.66 3.84 3.39 3.44 4.17 4.12 3.67 2.88 2.78 2.84 3.58 4.66 5.45 5.69
 7.10 4.59 5.22 5.56 5.30 5.76 6.61 6.68 6.01 5.20 4.81 4.64 5.00 5.99 6.97 7.68
 3.83 3.35 3.45 3.72 3.57 3.75 4.00 3.97 3.58 3.52 3.32 3.41 3.63 3.91 4.05 4.00
 1.77 1.74 1.76 1.91 1.90 1.90 1.93 1.96 1.87 1.87 1.60 1.65 1.79 1.88 1.89 1.68
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
    0.0147    0.0903    0.1610    0.4659    0.1289    0.1392    0.0000
    0.0177    0.1546    0.1866    0.2087    0.1160    0.3164    0.0000
    0.0041    0.0921    0.1707    0.3293    0.1347    0.2692    0.0000
    0.0048    0.0441    0.0980    0.3522    0.1750    0.3258    0.0000
    0.0064    0.0468    0.0757    0.2085    0.1890    0.4736    0.0000
    0.0072    0.0419    0.0629    0.2029    0.2365    0.4486    0.0000
    0.0021    0.0247    0.0604    0.4410    0.2253    0.2465    0.0000
    0.0024    0.0343    0.0926    0.4362    0.1943    0.2402    0.0000
    0.0076    0.0765    0.1248    0.2351    0.1912    0.3649    0.0000
    0.0149    0.1377    0.1360    0.2001    0.1512    0.3601    0.0000
    0.0269    0.1766    0.1797    0.1971    0.1342    0.2854    0.0000
    0.0295    0.2431    0.2003    0.1816    0.1222    0.2232    0.0000
    0.0181    0.2258    0.2490    0.2474    0.1017    0.1580    0.0000
    0.0157    0.1323    0.2612    0.3845    0.1053    0.1009    0.0000
    0.0069    0.0772    0.2351    0.5318    0.0916    0.0574    0.0000
    0.0051    0.0742    0.1790    0.6065    0.0828    0.0525    0.0000
extended data
StationName=DESERT ROCK
State=NV
Latitude=36.617
Longitude=116.017
TimeZone=8
RecordPeriod=1988,1989,1990,1991,1992
AveragePeriodTemperature=17.64
Comments=
```

Architecture and Mathematical Models

The purpose of this chapter is to present the code architecture, mathematical models, and equations used in CAP88-PC for environmental transport and estimation of dose and risk. In order to facilitate comparison of the programs with the theoretical model by interested users, the actual variable names used in the CAP88-PC FORTRAN code have been included in brackets, where applicable, following the explanation of the mathematical symbols used in the formulas.

Overall Code Architecture

The architecture of CAP88-PC was significantly modified in version 4.0 from Version 3. Many changes to the input dataset and output report file locations and file access methods were changed from version 3 in order to accommodate the stricter security policies built into the Windows Operating Systems after Windows XP Service Pack 3. The overall code architecture, with updates for version 4 in the callouts, is shown in the following diagram:



Version 4.1 has not midified the architectural changes introduced in Version 4.0.

Environmental Transport

CAP88-PC incorporates a modified version of the AIRDOS-EPA (Mo79) program to calculate environmental transport. Relevant portions of this document are reproduced here, as referenced.

Plume Rise

CAP88-PC calculates plume rise in the subroutine CONCEN using either Rupp's equation (Ru48) for momentum dominated plume rise, or Briggs' equations (Br69) for hot buoyant plumes (Mo79). CAP88-PC also accepts user-supplied values for plume rise for each Pasquill stability class. The plume rise, Δh, is added to the actual physical stack height, h [PH], to determine the effective stack height, H. The plume centerline is shifted from the physical height, h, to H as it moves downwind. The plume centerline remains at H unless gravitational settling of particulates produces a downward tilt, or until meteorological conditions change.

Rupp's equation for momentum dominated plumes is:

Equation 1

$$\Delta h = \frac{1.5\ vd}{\mu}$$

where:

Δh = plume rise [PR]
v = effluent stack gas velocity (m/sec) [VEL]
d = inside stack diameter (m) [DIA]
μ = wind velocity (m/sec) [U]

CAP88-PC models Briggs' buoyant plume rise for stability categories A, B, C, and D with:

Equation 2

$$\Delta h = \frac{1.6\ F^{1/3}\ x^{2/3}}{\mu}$$

where:

Δh = plume rise [PR]
F = $3.7 \times 10^{-5}\ Q_H$
Q_H = heat emission from stack gases (cal/sec) [QH]
x = downwind distance (m)
μ = wind speed (m/sec) [U]

This equation is valid until the downwind distance is approximately ten times the stack height, 10h, where the plume levels off. For downwind distances greater than 10h, the equation used is:

Equation 3

$$\Delta h = 1.6\ F^{1/3}\ (10h)^{2/3}$$

$$\frac{}{\mu}$$

Equation (2) is also used to a distance of $X = 2.4\,\mu S^{-1/2}$ for stable categories E, F, and G, beyond which the plume is assumed to level off. For higher values of x, the stability parameter, S, is used in the equation:

Equation 4

$$\Delta h = 2.9(F/\mu S)^{1/3}$$

in which:

Equation 5

$$S = (g/T_a)(dT_a/dz+\Gamma)$$

g = gravitational acceleration (m/sec^2)
T = air temperature (^{o} K) [TEMPERATURE]
dT_a/dz = vertical temperature gradient (^{o} K/m) [TG]
z = vertical distance above stack (m)
Γ = adiabatic lapse rate of atmosphere (0.0098^o K/m)

The value of the vertical temperature gradient, dT_a/dz, is positive for stable categories. In CAP88-PC, dT_a/dz values are:

7.280E-02 ^{o} K/m for Pasquill category E
1.090E-01 ^{o} K/m for Pasquill category F
1.455E-01 ^{o} K/m for Pasquill category G

The true-average wind speed for each Pasquill stability category is used in CAP88-PC to estimate plume rise, as it is greater than the reciprocal-averaged wind speed, and produces a smaller, more conservative plume rise. This procedure does not risk underestimating the significant contribution of relatively calm periods to downwind nuclide concentrations which could result from direct use of a plume rise calculated for each separate wind-speed category. This procedure avoids calculating an infinite plume rise when wind speed is zero (during calms), since both momentum and buoyancy plume rise equations contain wind speed in the denominator (Mo79).

CAP88-PC also accepts user-supplied plume rise values, for situations where actual measurements are available or the supplied equations are not appropriate. For example, plume rises of zero may be used to model local turbulence created by building wakes.

Plume Dispersion

Plume dispersion is modeled in the subroutine CONCEN with the Gaussian plume equation of Pasquill (Pa61, Mo79), as modified by Gifford:

Equation 6

$$X = \frac{Q}{2\,\pi\,\sigma_y\,\sigma_z\,\mu}\exp[-1/2(y/\sigma_y)^2]\{\exp[-1/2((z-H)/\sigma_z)^2]+\exp[-1/2((z+H)/\sigma_z)^2]\}$$

where:

X = concentration in air (chi) at x meters downwind, y meters crosswind, and z meters above ground (Ci/m^3) [ACON]
Q = Release rate from stack (Ci/sec) [REL]
μ = wind speed (m/sec) [U]
σ_y = horizontal dispersion coefficient (m)
σ_z = vertical dispersion coefficient (m)
H = effective stack height (m)
y = crosswind distance (m)
z = vertical distance (m)

The downwind distance x comes into Equation (6) through σ_y and σ_z, which are functions of x as well as the Pasquill atmospheric stability category applicable during emission from the stack. CAP88-PC converts X in Equation (6) and other plume dispersion equations from units of curies per cubic meter to units of picocuries per cubic centimeter.

Annual-average meteorological data sets usually include frequencies for several wind-speed categories for each wind direction and Pasquill atmospheric stability category. CAP88-PC uses reciprocal-averaged wind speeds in the atmospheric dispersion equations, which permit a single calculation for each wind-speed category. Equation (6) is applied to ground-level concentrations in air at the plume centerline by setting y and z to zero, which results in:

Equation 7

$$X = \frac{Q}{\pi \sigma_y \sigma_z \mu} \exp\left[-1/2(H/\sigma_z)^2\right]$$

The average ground-level concentration in air over a sector of 22.5° can be approximated by the expression:

Equation 8

$$X_{ave} = fX$$

where f is the integral of the exponential expression:

$$\exp\left[-1/2(y/\sigma_y)^2\right]$$

in Equation (6) from a value of y equals zero to infinity divided by y_s, the value of y at the edge of the 22.5° sector, which is the value of the downwind distance, x, multiplied by the tangent of half the sector angle. The expression is:

Equation 9

$$f = \frac{\int_0^{\infty} \exp\left[-\left(0.5/\sigma_y^2\right) y^2\right] dy}{y_s}$$

The definite integral in the numerator of Equation (9) is evaluated as

$$\sigma_y (\pi/2)^{1/2}$$

Since $y_s = x \tan (11.25^o)$,

Equation 10

$$f = \frac{6.300836\sigma_y}{x}$$

The equation for sector-averaged ground level concentration in air is therefore:

Equation 11

$$X = \frac{Q}{0.1587 \pi x \sigma_z \mu} \exp[-1/2(H/\sigma_z)^2]$$

This method of sector-averaging compresses the plume within the bounds of each of the sixteen 22.5° sectors for unstable Pasquill atmospheric stability categories in which horizontal dispersion is great enough to extend significantly beyond the sector edges. It is not a precise method, however, because the integration over the y-axis, which is perpendicular to the downwind direction, x, involves increasing values for x as y is increased from zero to infinity.

An average lid for the assessment area is provided as part of the input data. The lid is assumed not to affect the plume until x becomes equal to $2x_L$, where x_L is the value of x for which $\sigma_z = 0.47$ times the height of the lid (Tu69). For values of x greater than $2x_L$, vertical dispersion is restricted and radionuclide concentration in air is assumed to be uniform from ground to lid.

The average concentration between ground and lid, which is the ground-level concentration in air for values of x greater than $2x_L$, may be expressed by:

Equation 12

$$\chi_{ave} = \int_0^{\infty} \frac{\chi}{L} dz$$

where X is taken from Equation (6) and L is lid height. The value of H in Equation (6) may be set at zero since X_{ave} is not a function of the effective stack height.

The resulting simplified expression may be evaluated for constant x and y values (σ_y and σ_z held constant) by using a definite integral similar to that in Equation (10):

Equation 13

$$\chi_{ave} = \left(\frac{1}{L}\right)\int_0^{\infty}\left(\frac{Q}{\pi\sigma_y\sigma_z}\right)\exp\left(\frac{-z^2}{2\sigma_z^2}\right)\exp\left(\frac{-z^2}{2\sigma_y^2}\right)dz$$

The result is:

Equation 14

$$X_{ave} = \frac{Q}{2.5066\ \sigma_y\ L\ \mu} \exp(-y^2 / 2\sigma_y^2)$$

One obtains the sector-averaged concentration at ground level by replacing the exponential expression containing y by f in Equation (11):

Equation 15

$$X_{ave} = Q/(0.397825 \times L\ \mu)$$

It should be noted at this point that for values of the downwind distance greater than $2x_L$ dispersion, as expressed in Equation (16), no longer can be said to be represented by the Pasquill equation. The model is simply a uniform distribution with a rectangle of dimensions LID and 2x tan (11.25°).

Gravitational settling is handled by tilting the plume downward after it has leveled off at height H by subtracting V_g x/μ from H in the plume dispersion equations. For CAP88-PC V_g is set at the default value of zero and cannot be changed by the user.

Dry Deposition

Dry deposition is modeled in the subroutine CONCEN as being proportional to the ground-level concentration of the radionuclide (Mo79):

Equation 16

$$R_d = V_d X$$

where:

R_d = surface deposition rate (pCi/cm^2 -sec)
V_d = deposition velocity (cm/sec) [VD]
X = ground-level concentration (chi) in air (pCi/cm^3) [ACON]

Although V_d has units of velocity, it is only a proportionality constant and is usually higher than the actual, measured velocity of radionuclides falling to the ground. The proportionality constant must include deposition from fallout interception by foliage, which subsequently falls to the ground and so adds to ground deposition. Defaults for deposition velocity used by CAP88-PC are 3.5E-2 m/sec for Iodine, 1.8E-3 m/sec for particulates and zero for gases.

Precipitation Scavenging

The deposition rate from precipitation scavenging (Mo79), which occurs when rain or snow removes particles from the plume, is modeled in CONCEN with:

Equation 17

$$R_s = \Phi X_{ave} L$$

where:

R_s = surface deposition rate (pCi/cm^2 -sec)
Φ = scavenging coefficient (sec^{-1}) [SC]
X_{ave} = average concentration in plume up to lid height (pCi/cm^3)[ACON]
L = lid height (tropospheric mixing layer) (cm) [LID]

The scavenging coefficient, Φ (in sec^{-1}), is calculated in CAP88-PC by multiplying the rainfall rate, [RR] (in cm/yr), by 1E-7 yr/cm-sec.

Plume Depletion

Radionuclides are depleted from the plume by precipitation scavenging, dry deposition and radioactive decay. Depletion is accounted for by substituting a reduced release rate, Q^1 , for the original release rate Q for each downwind distance x (Sl68). The ratio of the reduced release rate to the original is the depletion fraction. The overall depletion fraction used in CAP88-PC is the product of the depletion fractions for precipitation scavenging, dry deposition and radioactive decay.

For precipitation scavenging the depletion fraction for each downwind distance (x) is:

Equation 18

$$\frac{Q^1}{Q} = e^{-\Phi t}$$

where:

Φ = scavenging coefficient (sec^{-1}) [SC]
t = time (sec) required for the plume to reach the downwind distance x

The depletion fraction for dry deposition is derived by using Equation (6) with z set to zero for ground-level concentrations, and subtracting the quantity (V_g x)/U from H for a tilted plume (Va68, Mo79):

Equation 19

$$\frac{Q^1}{Q} = \exp\left\{ -\left(\frac{2}{\pi}\right)^{\frac{1}{2}} \left(\frac{V_d}{\mu}\right) \int_0^x \frac{\exp\left[-\left(H - V_g x / \mu \right)^2 / 2\sigma_z^2 \right]}{\sigma_z} dx \right\}$$

where:

V_d = deposition velocity (m/sec) [VD]
μ = wind speed (m/sec) [U]

σ_z = vertical dispersion coefficient (m)
V_g = gravitational velocity (m/sec) [VG]
H = effective stack height (m)
x = downwind distance (m)

The integral expression must be evaluated numerically. Values for the vertical dispersion coefficient σ_z are expressed as functions of x in the form x^D/F where D and F are constants with different values for each Pasquill atmospheric stability category, to facilitate integrations over x.

Values for the depletion fraction for cases where V_g is zero are obtained from the subroutine QY in CAP-88. Subroutine QY obtains depletion fractions for the conditions V_d = 0.01 m/sec and μ = 1 m/sec for each Pasquill stability category from the data file REFA.DAT. This file contains values for release heights (meters) of:

1, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12.5, 15, 17.5, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, 200, 240, 260, 300 and 400.

and for downwind distances (meters) of:

35, 65, 100, 150, 200, 300, 400, 500, 650, 800, 1,000, 1,500, 2,000, 4,000, 7,000, 10,000, 25,000, 60,000, 90,000, and 200,000.

The stored depletion fractions were calculated numerically with a Simpson's rule routine. QY uses a linear interpolation to produce a fraction for the required downwind value, release height and Pasquill category for V_d = 0.01 m/sec and μ = 1 m/sec. The value is then converted to the appropriate value for the actual deposition velocity and wind speed by use of the equation:

Equation 20

$$(Q^1/Q)_2 = (Q^1/Q)_1^{\,100\,Vd/\mu}$$

in which subscript 2 refers to the desired value and subscript 1 refers to the value for V_d = 0.01 m/sec and μ = 1 m/sec.

For downwind distances greater than $2x_L$ where Equation 15 applies to the ground-level concentrations in air, the depletion is modeled with (Mo79):

Equation 21

$$\frac{Q^1_x}{Q^1_{2x_L}} = \exp\left[-V_d\left(x-2x_L\right)\Big/ L\mu\right]$$

Which shows the reduced release rates at distances x and $2x_L$, respectively.

The depletion fraction for radioactive decay is:

Equation 22

$$\frac{Q^1}{Q} = \exp\left(-\lambda_r t\right)$$

where:

λ_r = effective decay constant in plume [ANLAM]
t = time required for plume travel

The decay constant used is referred to as the "effective decay constant" since it is not the true radiological decay constant in all cases. For example, if a radionuclide is a short-lived decay product in equilibrium with a longer-lived parent, the effective decay constant would be equal to the true radiological decay constant of the parent.

The atmospheric dispersion equations use the reciprocal-averaged wind speed, but neither this value nor the true average wind speed can adequately be used to calculate reduced release rates to account for radiological decay and scavenging losses because averaging of exponential terms is required. CAP88-PC uses an approximate method of calculation for this purpose, which establishes three wind speeds (1 m/sec, the average wind speed, and 6 m/sec) to simulate the actual wind-speed spectrum for each specific wind direction and Pasquill category. The wind speeds 1 and 6 m/sec were chosen because they approximate the upper and lower bounds in most meteorological data sets.

If f_1, f_2 and f_3 are designated as the time fractions for the three wind speeds, then:

$f_1 + (\mu_a f_2) + 6f_3 = \mu,$
$f_1 + (f_2/\mu_a) + f_3/6 = 1/\mu_r$

and

$f_1 + f_2 + f_3 = 1$

where:

μ_a = Arithmetic-average wind speed [UDAV]
μ_r = Reciprocal-average wind speed [UDCAT]

Solving the three simultaneous equations yields:

$f_1 = 1 - f_2 - f_3$

$f_2 = \dfrac{(7/6) - (\mu_a/6) - (1/\mu_r)}{(7/6) - (\mu_a/6) - (1/\mu_a)}$

$f_3 = \dfrac{(\mu_a - 1)(1 - f_2)}{5}$

The depletion fraction to account for radioactive decay is then approximated by:

$$f_1 \exp(-\lambda_r x) + f_2 \exp[-\lambda_r (x/\mu_a)] + f_3 \exp[-\lambda_r (x/6)]$$

where:

λ_r = effective decay constant in plume (sec^{-1}) [ANLAM]
μ_a = Arithmetic-average wind speed [UDAV]

x = downwind distance (m)

For precipitation scavenging losses, the depletion fraction is:

$$f_1 \exp(-\Phi x) + f_2 \exp[-\Phi(x/\mu_a)] + f_3 \exp[-\Phi(x/6)]$$

where Φ is the scavenging coefficient (sec^{-1}).

The overall depletion fraction is calculated by multiplying the depletion fraction for dry deposition by the fraction for radioactive decay and precipitation scavenging.

Dispersion Coefficients

Horizontal and vertical dispersion coefficients (σ_y and σ_z) used for dispersion calculation in CONCEN and for depletion fraction determination in QY are taken from recommendations by G.A. Briggs of the Atmospheric Turbulence and Diffusion Laboratory at Oak Ridge, Tennessee (Mo79, Gi76). The coefficients are different functions of the downwind distance x for each Pasquill stability category for open-country conditions, as shown:

Pasquill category	**σ_y (m)**	**σ_z (m)**
A	$0.22 x (1+0.0001x)^{-1/2}$	$0.20 x$
B	$0.16 x (1+0.0001x)^{-1/2}$	$0.12 x$
C	$0.11 x (1+0.0001x)^{-1/2}$	$0.08 x (1+0.0002x)^{-1/2}$
D	$0.08 x (1+0.0001x)^{-1/2}$	$0.06 x (1+0.0015x)^{-1/2}$
E	$0.06 x (1+0.0001x)^{-1/2}$	$0.03 x (1+0.0003x)^{-1}$
F	$0.04 x (1+0.0001x)^{-1/2}$	$0.016 x (1+0.0003x)^{-1}$
G	calculated by subtracting half the difference between values for categories E and F from the value for category F.	

where:

x = downwind distance

CAP88-PC uses the functions in the form of

$$\sigma_y = x^A / C$$
$$\sigma_z = x^D / F$$

to facilitate integrations over x. Values for A, C, D, and F for each stability category and downwind distance are stored in a data statement.

Area Sources

Uniform area sources are modeled in CAP88-PC using a method described by Mills and Reeves, as modified by Christopher Nelson, EPA, and implemented by Culkowski and Patterson (Mo79). The method transforms the original area source into an annular segment with the same area. The transformation is dependent on the distance between the centroid of the area source and the receptor. At large distances (where the distance/diameter ratio is 2.5), the area source is modeled as a point source; at close distances it becomes a circular source centered at the receptor. A point source model is also used if the area source is 10 meters in diameter or less.

The principle of reciprocity is used to calculate the effective chi/Q. The problem is equivalent to interchanging source and receptor and calculating the mean chi/Q from a point source to one or more sector segments according to the angular width of the transformed source. The mean value of chi/Q for each sector segment is estimated by calculating chi/Q at the distance which would provide the exact value of the mean if the variation in chi/Q were proportional to $r^{-1.5}$ for distances from the point source to location within the sector segment. The chi/Q for the entire transformed source is the sum of the chi/Q values for each sector weighted by the portion of the total annular source contained in that sector.

Carbon-14 and Tritium

Special consideration is given to the radionuclides hydrogen-3 (tritium), carbon-14, and radon-222. The specific activity of tritium in air is calculated based on the input absolute humidity, which has a default value of 8 g/m3. The specific activity of atmospheric carbon-14 is calculated for a carbon dioxide concentration of 330 ppm by volume. Concentrations of these nuclides in vegetation are calculated on the assumption that the water and carbon content in vegetation are from the atmosphere and have the same specific activity as in the atmosphere. Drinking water is assumed to have one percent (1%) the concentration of air moisture. The ingestion dose includes a contribution from this assumed tritium concentration when tritium is included as one of the modeled nuclides in the case. The new dose factors in CAP88-PC Version 4 include many chemical forms for these special isotopes that were not available in previous versions (see the radionuclide list table for chemical forms). The user should examine which of the chemical forms is most applicable to their model case and select accordingly.

Rn-222 Working Levels

The radon decay product concentration (in working level units) is estimated using an equilibrium fraction that varies as a function of travel time, assuming a wind speed of 3.5 meters/second, with a final equilibrium fraction of 0.7.

Equilibrium fractions for radon decay products are calculated as a function of downwind distance, starting at 0.267 at 150 meters and reaching a final equilibrium fraction of 0.698 at 19,551 meters. Equilibrium fractions for specific distances are calculated by linear interpolation, using this table:

Distance (meters)	**Equilibirum Fraction**
150	.267
200	.273
250	.276
300	.278
400	.284

500	.289
600	.293
800	.302
1000	.311
1500	.331
2000	.349
2500	.366
3000	.382
4000	.414
5000	.443
6000	.471
8000	.522
10000	.566
15000	.650
19551	.698

Sector Air Concentrations

Air concentrations in each sector are calculated using the CAP88-PC Version 4 numerical solver to solve the serial radioactive decay equations for chains up to 30 isotopes in length at each sector. The equations solved include chain branching coefficients as defined by the chain decay data contained in the Oak Ridge National Laboratory DCFPAK Version 2.2. The initial values in the chain are the dispersed release rates for the isotopes specified in the release list. The dispersed concentrations of the released isotopes as calculated by the Gaussian Plume equations are used as the time zero concentration for each sector. Decay chain isotopic air concentrations for each sector are calculated using the Pasquill category averaged travel times and the midpoint distance for the sector to generate the decay time. The isotopic air concentrations generated for each sector form the list of source isotopes for the ground deposition rates used in the sector ground surface concentration calculation.

Sector Ground Surface Concentrations

Ground surface and soil concentrations are calculated for those nuclides subject to deposition due to dry deposition and precipitation scavenging. The deposition accumulation time, [TSUBB], is user selectable. The default value of 100 years is the value required to be used for NESHAPS compliance runs. This value determines the length of time that isotopes accumulate in the soil based upon continuous deposition, decay, and removal. The isotopic profile in the soil at the end of the buildup period is the one used as input to the dose and risk calculations.

Ingrowth from a parent radionuclide is calculated using a numerical solution to the coupled set of differential equations describing radionuclide ingrowth in the presence of a constant deposition rate and a constant removal rate of 2 percent per year. The deposition rate for each isotope is calculated from the air concentration of that isotope in the sector of interest times the scavenging rate for each isotope in the air. Ingrowth and decay are calculated using the decay chain data from the Oak Ridge National Laboratory DCFPAK Version 2.2 package. All chain decays include branching. Sectors are assumed to have a zero ground surface concentration at time zero.

Ingrowth of progeny chains up to 30 isotopes in length can be solved by the CAP88-PC Version 4 solver code. The solver code implemented in CAP88-PC Version 4 is the DLSODE

package from Lawrence Livermore National Lab. DLSODE solves the initial-value problem for stiff or nonstiff systems of first-order Ordinary Differential Equations, dy/dt = f(t,y).

Dose and Risk Estimates

CAP88-PC uses a database of dose and risk factors provided in Federal Guidance Report 13 (EPA99) for estimating dose and risk as implemented in the DCFPAK Version 2.2 model. Relevant portions of these documents are reproduced here, as referenced.

Dose and risk conversion factors include the effective dose equivalent calculated according to the methods in ICRP Publication Number 72 (ICRP72). CAP88-PC Version 4 now implements the FGR 13 age-dependent dose and risk factors, where previous version of CAP88-PC only used adult dose and risk factors. The risk factors used are those for lifetime fatal cancer risk (mortality) per FGR 13. Dose and risk factors for the pathways of ingestion and inhalation intake, ground level air immersion and ground surface irradiation are used in order to remain consistent with versions 1, 2, and 3 of CAP88-PC. Factors are further broken down by particle size [SIZE], clearance category [FMSTYPE], chemical form [CHEMFORM], and gut-to-blood [GI_ING and GI_INH] transfer factors. These factors are stored in a series of data files for use by the program. The CAP88-PC Version 4 UI reads the dose and risk factor data for each organ or compartment and builds the appropriate factor using the methodology in the DFCPAK Version 2.2 model.

For assessments where Rn-222 decay products are not considered, estimates of dose and risk are made by combining the inhalation and ingestion intake rates, air and ground surface concentrations with the appropriate dose and risk conversion factors. CAP88-PC lists the dose and risk to the maximum individual and the collective population. CAP88-PC calculates dose to the 25 internal organs modeled in DCFPAK Version 2.2, in addition to a 26th "organ", the 50 year effective dose equivalent. Risks are estimated for the 15 cancer sites modeled in DCFPAK Version 2.2. Doses and risks can be further tabulated as a function of radionuclide, pathway, location and organ.

For assessments of Rn-222 decay products, CAP88-PC calculates working levels, not concentrations of specific radionuclides. A working level [WLEVEL] is defined as any combination of short-lived radon decay products in 1 liter of air that will result in the ultimate emission of 1.3 x 105 MeV of alpha particle energy. CAP88-PC calculates risk, but not dose, from the working level calculations. Risk to the maximum individual and the collective population are tabulated. The radon methods have not been modified in CAP88-pC Version 4 from those of previous versions.

For each assessment, CAP88-PC tabulates the frequency distribution of risk, that is, the number of people at various levels of risk (lifetime risk). The risk categories are divided into powers of ten, from 1 in ten to one in a million. The number of health effects is also tabulated for each risk category.

Air Immersion

Individual dose is calculated for air immersion with the general equation:

$$\frac{E_{ij}(k)\ DF_{ijl}}{P(k)}\ K_i$$

where:

$E_{ij}(k)$ = exposure rate, person-pCi/cm^3 [EXPP]
DF_{ijl} = Dose rate factor, mrem/nCi-yr/m^3 [DOSE]
$P(k)$ = number of exposed people [POP]
K_j = 0.001 nCi/pCi x 1,000,000 cm^3/m^3 (proportionality factor) [FAC]

Risk is calculated similarly, by substituting the risk conversion factor, RF_{ijl} [RISK], for DF_{ijl} [DOSE]. The risk conversion factor is in units of risk/nCi-yr/m^3 .

Surface Exposure

Individual dose is calculated for ground surface exposure with the general equation:

$$\frac{E_{ij}(k)\ DF_{ijl}}{P(k)}\ K_i$$

where:

$E_{ij}(k)$ = exposure rate, person-pCi/cm^3 [EXPP]
DF_{ijl} = Dose rate factor, mrem/nCi-yr/m^3 [DOSE]
$P(k)$ = number of exposed people [POP]
K_j = 0.001 nCi/pCi x 10,000 cm^3/m^3 (proportionality factor) [FAC]

Risk is calculated by substituting the risk conversion factor, RF_{ijl} [RISK], for DF_{ijl} [DOSE]. The risk conversion factor is in units of risk/nCi-yr/m^2 .

Ingestion and Inhalation

Individual dose is calculated for the ingestion and inhalation exposure pathway with the general equation:

$$\frac{E_{ij}(k)\ DF_{ijl}}{P(k)}\ K_i$$

where:

$E_{ij}(k)$ = exposure rate, person-pCi/cm^3 [EXPP]
DF_{ijl} = Dose rate factor, mrem/nCi-yr/m^3 [DOSE]
$P(k)$ = number of exposed people [POP]
K_j = 0.001 nCi/pCi x 1,000,000 cm^3/m^3 (proportionality factor) [FAC]

Risk is calculated by substituting the risk conversion factor, RISK (risk/nCi), for DOSE.

Maximally-Exposed Individual

Doses for the maximally-exposed individual in population runs are estimated by CAP88-PC for the location, or sector-segment in the radial assessment grid, of highest risk where at least one individual actually resides. The effective dose equivalent for the maximally-

exposed individual is tabulated in mrem/yr for a 50 year exposure. Risk is estimated as total lifetime riske.

Collective Population

Collective population dose and risk are found by summing, for all sector segments, the intake and exposure rates multiplied by the appropriate dose or risk conversion factors (ORNL5692). Collective population dose is reported by person-Rem/yr (not millirem), and collective risk is reported in deaths/yr. Note that collective risk is reported as annual risk, while maximally-exposed individual risk is reported as lifetime risk.

State Agricultural Productivies

The following values are Beef Cattle Densities, Milk Cattle Densities, and Vegetable Crop Food Fractions by state.

State	Beef	Milk	Vegetable
Alabama	1.52E-001	7.02E-003	4.16E-003
Alaska	0.00E+000	0.00E+000	0.00E+000
Arkansas	1.27E-001	5.90E-003	1.46E-003
Arizona	3.73E-002	2.80E-003	2.90E-003
California	8.81E-002	2.85E-002	1.18E-002
Colorado	1.13E-001	3.50E-003	1.39E-002
Connecticut	3.60E-002	2.50E-003	7.93E-003
Wash. D.C.	0.00E+000	0.00E+000	0.00E+000
Delaware	6.48E-002	2.72E-002	5.85E-002
Florida	1.28E-001	1.37E-002	6.92E-003
Georgia	1.43E-001	8.63E-003	2.17E-003
Hawaii	0.00E+000	0.00E+000	0.00E+000
Idaho	7.19E-002	8.56E-003	7.15E-002
Illinois	3.33E-001	2.16E-002	2.80E-002
Indiana	3.34E-001	2.80E-002	2.72E-002
Iowa	7.40E-001	3.14E-002	2.43E-002
Kansas	2.90E-001	8.00E-003	5.97E-002
Kentucky	2.65E-001	2.57E-002	3.98E-003
Louisiana	1.08E-001	9.62E-003	4.35E-002
Maine	7.65E-003	8.07E-003	5.97E-002
Maryland	1.09E-001	6.11E-002	1.11E-002
Massachusetts	2.90E-002	3.13E-002	4.96E-003
Michigan	7.90E-002	3.51E-002	1.70E-002
Minnesota	1.85E+000	4.88E-002	3.05E-002
Mississippi	1.75E-001	8.70E-003	1.07E-003
Missouri	3.43E-001	1.89E-002	8.14E-003
Montana	7.29E-002	9.27E-004	8.78E-003
Nebraska	3.50E-001	8.78E-003	2.39E-002
Nevada	1.84E-002	5.65E-004	8.92E-003
New Hampshire	1.40E-002	1.58E-002	6.69E-002
New Jersey	4.25E-002	3.29E-002	1.82E-002
New Mexico	4.13E-002	1.14E-003	1.38E-003
New York	5.83E-002	8.56E-002	1.88E-002

North Carolina	1.02E-001	1.26E-002	6.32E-003
North Dakota	1.18E-001	6.25E-003	6.29E-002
Ohio	2.03E-001	4.56E-002	1.70E-002
Oklahoma	2.68E-001	7.13E-003	2.800E-02
Oregon	4.56E-002	4.53E-003	1.590E-02
Pennsylvania	9.63E-002	6.46E-002	1.320E-02
Rhode Island	2.50E-002	2.30E-002	4.540E-02
South Carolina	8.87E-002	7.02E-003	1.84E-003
South Dakota	2.32E-001	8.85E-003	1.20E-002
Tennessee	2.11E-001	2.00E-003	2.72E-003
Texas	1.90E-001	5.30E-003	5.77E-003
Utah	2.84E-002	4.46E-003	1.83E-003
Vermont	4.71E-002	8.88E-002	1.08E-003
Virginia	1.31E-001	1.84E-002	8.700E-03
Washington	5.62E-002	1.500E-02	5.200E-02
West Virginia	6.23E-002	6.00E-003	1.160E-03
Wisconsin	1.81E-001	1.43E-001	1.789E-02
Wyoming	5.12E-002	5.79E-004	1.590E-03

Differences From Mainframe Versions of AIRDOS-EPA/DARTAB

There are differences between CAP88-PC and earlier versions of AIRDOS, PREPAR and DARTAB. CAP88-PC is optimized for doing population assessments. Population arrays must always be supplied to the program as a file, using the same format as the mainframe version of CAP88. Sample population files are supplied with CAP88-PC, the user may modify the supplied files to reflect their own population distributions. Population files for the mainframe version of CAP88 may be downloaded in ASCII format and used with CAP88-PC. CAP88-PC is programmed to use the distances in the population array to determine the distances used to calculate concentrations, to eliminate human error. CAP88-PC only uses circular grids; square grids are not an option. Direct user input of concentrations is also not an option. Agricultural arrays are generated automatically, as a function of state-specific productivity data, requiring the user to supply only the State abbreviation or agricultural productivity values.

Note that input files generated with previous versions of CAP88-PC, or the mainframe version, will not run unaltered in the current CAP88-PC version.

CAP88-PC is also modified to perform either "Radon-only" or "Non-Radon" runs, to conform to the format of the 1988 Clean Air Act NESHAPS Rulemaking. "Radon-only" assessments, which only have Rn-222 in the source term, automatically include working level calculations; any other source term ignores working levels. Synopsis reports customized to both formats are automatically generated.

Organs and weighting factors are modified to follow the ICRP-72 Effective Dose Equivalent calculation, which eliminates flexibility on specifying organs and weighting factors. The calculation of deposition velocity and the default scavenging coefficient is also modified to incorporate current EPA policy.

Incorporation of FGR-13 Dose and Risk Factors

CAP88-PC Version 4.1 incorporates the dose and risk factors from Federal Guidance Report 13 (FGR-13), as received from Oak Ridge National Laboratory via the DCFPAK Version 3.0 software package. Using the DCFPAK 3.0 dataset has increased the supported number of isotopes to 1252 from 825 in version 3 and 256 in version 2. It is important to note that the 1252 isotope number is those with external dose coefficients. The number of isotopes having internal dose coefficients in Version 4.1 is 888. Version 4.1 flags isotopes in the input that have external but not internal dose coefficients.

Dose and risk coefficents are provided for external ground surface exposure, external immersion, internal ingestion, and internal inhalation. Internal dose and risk coefficients are provided for six age groups, infant (100 days), 1 year old, 5 year old, 10 year old, 15 year old, and adult.

Organs and Weighting Factors

The FGR 13 model as implemented in CAP88-PC Version 4.1 includes wieght factors and committed equivalent dose coefficents for 25 organs. The DCFPAK 3.02 data also include a '26th organ', the effective dose. CAP88-PC Version 4.1 uses the 25 organ data to calculate organ committed equivalent dose and the 26th organ data to calculate total effective dose. The list of organs contained in Version 4.1 is:

Adrenals	UB_Wall	Bone_Sur	Brain
Breasts	St_Wall	SI_Wall	ULI_Wall
LLI_Wall	Kidneys	Liver	Muscle
Ovaries	Pancreas	R_Marrow	Skin
Spleen	Testes	Thymus	Thyroid
GB_Wall	Ht_Wall	Uterus	ET_Reg
Lung_66	Effecti		

UB = Urinary Bladder

St = Stomach

SI = Small Intestine

ULI = Upper Large Intestine

LLI = Lower large Intestine

R_Marrow = Red Bone Marrow

GB = Gall Bladder

Ht = Heart

ET = Extra-thoracic

Changing the organ list or the weighting factors will invalidate the results.

Cancer Risk Sites

The FGR 13 data in CAP88PC Version 4 includes cancer morbidity and mortality risk factors for 14 cancer induction sites, with the total risk listed as the 15th site. CAP88PC Version 4.1 only outputs results for cancer mortality risk, not cancer morbidity risk. This is done to retain consistency with previous versions of the CAP88 model. The cancer sites included in CAP88PC Version 4.1 are:

Esophagus	Stomach	Colon	Liver	Lung
Bone	Skin	Breast	Ovaries	Bladder
Kidneys	Thyroid	Leukemia	Residual	Total

As with the organ data, changing the cancer site information will invalidate the results.

Build-up Factors Calculated for the Specific Case

Starting with Version 3, CAP88-PC eliminated the old build-up factor methodology using pre-calculated factors for a limited number of decay chains. The greatly expanded isotope list contained in the FGR-13 data did not support the use of the old pre-calculated build-up factors. The solution method in Version 3 included a number of approximations to speed up the build-up calculation. Version 4 greatly improved the buildup and decay calculations by implementing solution that calculates the decay and ground surface concentrations as a function of time by solving the ingrowth + deposition equations using a numerical solver.

Selectable Progeny Chain Length

CAP88-PC version 4.1 permits the user to select the length of the progeny chain for which dose and risk will be calculated. Versions of CAP88-PC before Version 3 limited the decay chain to a maximum of five isotopes. The selectable chain length permits analyses to include up to the entire decay chain modeled in FGR-13. The default length is all isotopes.

NCRP-123 Elemental Transfer Factors

The plant and food chain transfer factors for each element are the factors found in Publication 123 of the National Council on Radiation Protection. The old transfer factors used through version 2.1 did not include all the elements that are in the FGR-13 dataset.

Population Arrays

Population arrays must be entered only as a file. In the 1985 CAAC version of AIRDOSEPA/DARTAB, population arrays could be entered as instream data in PREPAR. Population files for the mainframe version of CAP88 may be downloaded in ASCII format and used with CAP88-PC. Sample population files are supplied with CAP88-PC, the user may modify the supplied files to reflect their own population distributions. The distances at the top of the population file are used by CAP88-PC to determine the distances used in the assessment. This was programmed to eliminate errors caused by mismatching the distances used to calculate concentrations with the distances used to generate the population array. Distances used for calculating concentrations are now automatically set in CAP88-PC so as to calculate concentrations for the midpoint of each sector.

Distances

In population assessments, distances for calculating concentrations (IDIST) are calculated automatically as a function of the distances in the population array file. CAP88-PC is written to only allow user assignments of IDIST for individual assessments.

Agricultural Arrays

Arrays of milk cattle, beef cattle and agricultural crop area are automatically generated by the CAP88-PC; the user is not required to supply the arrays. The arrays are generated to match the distances used in the population arrays supplied to the code, and use State-specific agricultural productivity values. The state name (standard two letter abbreviation) must be provided to the variable STATE. Users are given the option to override the default agricultural productivity values.

Radon-222 Assessments

Assessments for Radon-222 automatically include Working Level calculations. When the only radionuclide entered is Rn-222, CAP88-PC assumes the run is a 'Radon Only' run; in this case the code generates total effective dose and mortality risk resulting from the Working Level calculations and omits the organ calculations. If Rn-222 is included as part of a case that has multiple radioisotopes in the release source, then organ dose and risk calculations are performed for the nuclides in the list, and the Working Level calculations of total effective dose and mortality risk are also performed and reported. Working Level calculations are only omitted if Rn-222 is not included in the isotope list.

Square Grids

Option 2 in earlier versions of AIRDOS-EPA allowed users to choose either a square (0) or circular grid (1). Since CAP88-PC requires a circular grid for population assessments, this option is not available.

Scavenging Coefficient

The subroutine SETSC (from PREPAR) is no longer used. The default scavenging coefficient (SC) is now calculated as a function of rainfall rate (RR). The formula used is: SC = RR * 1E-7. Users are given the option of overriding the default value but doing so will invalidate the use of the case for any NESHAPS compliance demonstration.

Direct Input of Concentrations

In all versions of CAP88-PC the user may not supply concentrations as input. The subroutine DIRECT contained in the mainframe version has been removed.

Deposition Velocity

The mainframe subroutine SETVD is no longer used to calculate deposition velocity (VD). In all version of CAP88-PC VD is set as follows:

Class	VD (m/sec)
Iodine	3.5e-2
Particulate	1.8e-3

Gas	0

Unlike previous versions of CAP88-PC, CAP88-PC since Version 4 has the ability to use isotope-specific deposition velocities. This data has not yet been implemented.

Equilibrium Fractions

CAP88-PC has the capability to vary equilibrium fractions; previously they were set to a constant of 0.7. The new method varies the equilibrium fractions depending on the distance from the source. Linear interpolation is used to determine the equilibrium fractions for distances that do not match the set distances given. The equation is as follows:

EFY = EFX + ((EFZ - EFX) * ((Y - X) / (Z - X)))

Where you have X < Y < Z

X and Z are the set distances given and Y is the user given distance (between X and Z). The new method finds the equilibrium fraction for EFX, and EFZ is the value returned by the subroutine SET_EQUIL_FRACTIONS corresponding to the set distances.

DOSMIC Subroutine

DOSMIC was modified to print only Working Levels. Working Levels are only output for RN-222. Checks are performed before DOSMIC is called to determine if Working Levels are needed.

Water Arrays

Arrays of water areas are not used in CAP88-PC

NOMA fix

CAP88-PC uses a slightly different approach in calculating NOMA, following discovery of a potential error in the 1985 CAAC version of AIRDOS-EPA. In the earlier version, this error caused multiple point sources to be treated as an area source if the nuclides emitted from each stack had identical characteristics. This may cause some differences with previous assessments.

Wind Frequencies

The GETWND routine has been modified to accept wind speeds greater than 10 m/sec. Earlier versions would only accept wind speeds less than 10 m/sec, and there was a problem with some facilities, which had high wind speeds, generating overflow errors in the wind speed arrays. In order to accommodate higher wind speeds, and remain compatible with existing wind data sets, precision limits force the calculations to truncate the last digit in the wind speed data. This may cause a slight variation in the determination of PERD, the wind frequency for each direction, caused by roundup error. This may cause a variation in concentrations as compared with earlier versions of PREPAR and AIRDOS.

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Credits

Nuclear icon royalty free by http://www.woothemes.com/ via http://www.mricons.com/icon/20/128/danger-nuclear-icon

Appendices

STAR File Format

This is a **ST**ability **AR**ay (**STAR**) file. It shows the frequencies of occurrence that the wind is blowing **FROM**a particular direction, at a particular stability, at a particular speed. GETWIND converts the star array to a WIND file which shows wind blowing **TOWARD** (not **FROM**) particular directions. The frequencies are in x.xxxxx format, unspaced. The format is:

Layout

Column	Value
1	Blank
2-4	Wind Direction
5	Blank
6	Stability Category
7	Blank
8	Start of Wind Speed Categories (knots)
8-14	Wind Speeds 1-3 (knots)
15-21	Wind Speeds 4-6 (knots)
22-28	Wind Speeds 7-10 (knots)
29-35	Wind Speeds 11-16 (knots)
36-42	Wind Speeds 17-21 (knots)
43-49	Wind Speeds > 21 (knots)

Sample

This is the included 94823.str file.

```
   N A 0.000000.000000.000000.000000.000000.00000
 NNE A 0.000000.000000.000000.000000.000000.00000
  NE A 0.000000.000000.000000.000000.000000.00000
 ENE A 0.000000.000000.000000.000000.000000.00000
   E A 0.000000.000000.000000.000000.000000.00000
 ESE A 0.000000.000000.000000.000000.000000.00000
  SE A 0.000000.000000.000000.000000.000000.00000
 SSE A 0.000000.000000.000000.000000.000000.00000
   S A 0.000000.000000.000000.000000.000000.00000
 SSW A 0.000000.000000.000000.000000.000000.00000
  SW A 0.000000.000000.000000.000000.000000.00000
 WSW A 0.000000.000000.000000.000000.000000.00000
   W A 0.000000.000000.000000.000000.000000.00000
 WNW A 0.000000.000000.000000.000000.000000.00000
  NW A 0.000000.000000.000000.000000.000000.00000
 NNW A 0.000000.000000.000000.000000.000000.00000
   N B 0.000000.000000.000000.000000.000000.00000
 NNE B 0.000000.000000.000000.000000.000000.00000
  NE B 0.000000.000000.000000.000000.000000.00000
 ENE B 0.000000.000000.000000.000000.000000.00000
   E B 0.000000.016670.000000.000000.000000.00000
 ESE B 0.000000.000000.000000.000000.000000.00000
  SE B 0.000000.008330.008330.000000.000000.00000
 SSE B 0.000000.000000.000000.000000.000000.00000
   S B 0.000000.000000.000000.000000.000000.00000
 SSW B 0.000000.000000.000000.000000.000000.00000
  SW B 0.000000.000000.000000.000000.000000.00000
```

```
WSW B 0.000000.000000.000000.000000.000000.00000
  W B 0.000000.000000.000000.000000.000000.00000
WNW B 0.000000.000000.000000.000000.000000.00000
 NW B 0.000000.000000.000000.000000.000000.00000
NNW B 0.000000.000000.000000.000000.000000.00000
  N C 0.000000.000000.000000.000000.000000.00000
NNE C 0.000000.000000.000000.000000.000000.00000
 NE C 0.000000.008330.000000.000000.000000.00000
ENE C 0.000000.008330.008330.000000.000000.00000
  E C 0.000000.041670.058330.000000.000000.00000
ESE C 0.000000.000000.000000.000000.000000.00000
 SE C 0.008330.000000.016670.000000.000000.00000
SSE C 0.008330.000000.000000.000000.000000.00000
  S C 0.000000.000000.000000.000000.000000.00000
SSW C 0.008330.000000.000000.000000.000000.00000
 SW C 0.000000.000000.000000.000000.000000.00000
WSW C 0.000000.016670.000000.000000.000000.00000
  W C 0.000000.008330.008330.000000.000000.00000
WNW C 0.008330.008330.000000.000000.000000.00000
 NW C 0.000000.008330.000000.000000.000000.00000
NNW C 0.000000.008330.000000.000000.000000.00000
  N D 0.000000.000000.000000.000000.000000.00000
NNE D 0.000000.000000.000000.000000.000000.00000
 NE D 0.000000.000000.000000.000000.000000.00000
ENE D 0.000000.000000.008330.000000.000000.00000
  E D 0.000000.050000.075000.000000.000000.00000
ESE D 0.000000.008330.000000.000000.000000.00000
 SE D 0.025000.000000.033330.000000.000000.00000
SSE D 0.016670.000000.000000.000000.000000.00000
  S D 0.000000.000000.000000.000000.000000.00000
SSW D 0.000000.000000.000000.000000.000000.00000
 SW D 0.000000.000000.000000.000000.000000.00000
WSW D 0.000000.000000.000000.000000.000000.00000
  W D 0.008330.025000.016670.000000.000000.00000
WNW D 0.000000.016670.025000.000000.000000.00000
 NW D 0.000000.008330.008330.000000.000000.00000
NNW D 0.000000.008330.000000.000000.000000.00000
  N E 0.000000.000000.000000.000000.000000.00000
NNE E 0.000000.000000.000000.000000.000000.00000
 NE E 0.000000.000000.000000.000000.000000.00000
ENE E 0.000000.000000.000000.000000.000000.00000
  E E 0.000000.041670.000000.000000.000000.00000
ESE E 0.008330.000000.000000.000000.000000.00000
 SE E 0.025000.000000.000000.000000.000000.00000
SSE E 0.050000.000000.000000.000000.000000.00000
  S E 0.000000.000000.000000.000000.000000.00000
SSW E 0.000000.000000.000000.000000.000000.00000
 SW E 0.008330.000000.000000.000000.000000.00000
WSW E 0.000000.000000.000000.000000.000000.00000
  W E 0.008330.016670.000000.000000.000000.00000
WNW E 0.000000.000000.000000.000000.000000.00000
 NW E 0.000000.008330.008330.000000.000000.00000
NNW E 0.000000.000000.000000.000000.000000.00000
  N F 0.000000.000000.000000.000000.000000.00000
NNE F 0.000000.000000.000000.000000.000000.00000
 NE F 0.000000.000000.000000.000000.000000.00000
ENE F 0.000000.000000.000000.000000.000000.00000
  E F 0.000000.008330.000000.000000.000000.00000
ESE F 0.008330.008330.000000.000000.000000.00000
 SE F 0.008330.000000.000000.000000.000000.00000
SSE F 0.008330.000000.000000.000000.000000.00000
  S F 0.033330.000000.000000.000000.000000.00000
SSW F 0.025000.008330.000000.000000.000000.00000
```

```
 SW F 0.033330.000000.000000.000000.000000.00000
WSW F 0.041670.008330.000000.000000.000000.00000
  W F 0.016670.000000.000000.000000.000000.00000
WNW F 0.008330.008330.000000.000000.000000.00000
 NW F 0.000000.000000.000000.000000.000000.00000
NNW F 0.000000.000000.000000.000000.000000.00000
```

Weather Data Library

ALABAMA

Abbreviation	City	State	Year/Month Range
HSV0544	Huntsville	AL	60/1-64/12

ARIZONA

Abbreviation	City	State	Year/Month Range
INW0314	Winslow	AZ	49/1-54/12
PNX0309	Phoenix	AZ	55/1-64/12

ARKANSAS

Abbreviation	City	State	Year/Month Range
LIT0516	Little Rock	AR	55/1-64/12
LIT0165	Little Rock	AR	72/2-73/2

CALIFORNIA

Abbreviation	City	State	Year/Month Range
BUR1051	Burbank	CA	60/1-64/12
LAX0304	Los Angeles	CA	64/5-69/4
LGB1052	Long Beach	CA	60/1-64/12
NZY0380	San Diego	CA	67/1-71/12
OAK0319	Oakland	CA	60/1-64/12
SAC0320	Sacramento	CA	66/1-70/12
SBA0313	Santa Barbara	CA	60/1-64/12
SNA1467	Santa Ana	CA	72/1-76/12
SUU0316	Fairfield/Travis	CA	60/1-64/12

COLORADO

Abbreviation	City	State	Year/Month Range
DEN0618	Denver	CO	60/1-64/12
DEN0952	Denver	CO	70/1-74/12
EEE1420	Eagle Co.	CO	76/1-76/12
GJT0476	Grand Junction	CO	60/1-64/12
PUB0564	Pueblo	CO	66/1-70/12

CONN

Abbreviation	City	State	Year/Month Range
BDL1262	Hartford	CT	55/1-64/12
BDR0558	Bridgeport	CT	65/1-69/12
NHZ0180	Brunswick	CT	60/1-69/12

DELAWARE

Abbreviation	City	State	Year/Month Range
ILG1058	Wilmington	DE	60/1-64/12

DISTRICT OF COLUMBIA

Abbreviation	City	State	Year/Month Range
DCA1047	Washington	DC	68/1-73/12

FLORIDA

Abbreviation	City	State	Year/Month Range
MIA0979	Miami	FL	70/1-74/12
PBI0054	West Palm Beach	FL	70/1-70/12
TLH0663	Tallahassee	FL	60/1-64/12
TPA0662	Tampa	FL	60/1-64/12
TPA0915	Tampa	FL	69/1-73/12
MCO0838	Orlando	FL	74/1-74/12

GEORGIA

Abbreviation	City	State	Year/Month Range
AGS1018	Augusta	GA	70/1-74/12
AMB0771	Alma	GA	54/1-58/12
CSG0767	Columbus	GA	69/1-73/12

IDAHO

Abbreviation	City	State	Year/Month Range
BOI0653	Boise	ID	60/1-64/12
MLP1448	Mullan Pass	ID	50/1-54/12
PIH0359	Pocatello	ID	58/1-62/12

ILLINOIS

Abbreviation	City	State	Year/Month Range
MDW0675	Chicago/Midway	IL	73/1-73/12
MLI0269	Moline/Quad City	IL	67/1-71/12
ORD0452	Chicago/OHare	IL	65/1-69/12
PIA0716	Peoria	IL	65/1-69/12
RAN0234	Rantoul/Chanute AFB	IL	63/1-67/12
SPI0415	Springfield	IL	67/1-71/12

INDIANA

Abbreviation	City	State	Year/Month Range
EVV0406	Evansville	IN	60/1-64/12
FWA1156	Ft. Wayne	IN	60/1-64/12
IND1080	Indianapolis	IN	55/1-74/12
SBN0257	South Bend	IN	67/1-71/12

IOWA

Abbreviation	City	State	Year/Month Range
ALO0729	Waterloo	IA	60/1-64/12
DSM0753	Des Moines	IA	72/1-72/12

KANSAS

Abbreviation	City	State	Year/Month Range
FLV0561	Ft Leavenworth	KS	62/1-70/12
MKC1323	Kansas City	KS	67/1-71/12
TOP0534	Topeka	KS	63/1-72/12

KENTUCKY

Abbreviation	City	State	Year/Month Range
CVG0403	Covington	KY	58/1-62/12
CVG1916	Covington	KY	70/1-74/12
PAH0479	Paducah	KY	60/1-64/12

LOUISIANA

Abbreviation	City	State	Year/Month Range
BTR0169	Baton Rouge	LA	72/1-72/12
BTR0166	Baton Rouge	LA	55/1-64/12
NBG1379	New Orleans	LA	67/1-71/12

MARYLAND

Abbreviation	City	State	Year/Month Range
BAL1059	Baltimore	MD	69/1-73/12
FME1207	Ft Meade	MD	60/1-64/12
NHK1306	Patuxent River	MD	75/1-75/12

MASS

Abbreviation	City	State	Year/Month Range
BED0181	Bedford	MA	63/1-67/12
BOS0211	Boston/Logan	MA	67/1-71/12
CEF0182	Chicopee Falls	MA	60/1-64/12
NZW1144	So. Weymouth	MA	70/1-74/12

MICHIGAN

Abbreviation	City	State	Year/Month Range
BTL1460	Battle Creek	MI	50/1-54/12
TVC0844	Traverse City	MI	74/1-74/12
MKG0251	Muskegon County	MI	67/1-71/12
YIP1061	Detroit	MI	63/10-68/9

MINNESOTA

Abbreviation	City	State	Year/Month Range
MSP0267	Minneapolis/St. Pl	MN	67/1-71/12

MISSOURI

Abbreviation	City	State	Year/Month Range
COU0170	Columbia	MO	64/1-68/12
STL0603	St. Louis	MO	60/1-64/12

MISSISSIPPI

Abbreviation	City	State	Year/Month Range

BIX0538	Biloxi	MS	60/1-64/12
CGM0670	Columbus	MS	66/1-70/12
SGF0178	Springfield	MS	66/1-70/12
JAN1169	Jackson	MS	55/1-64/12

MONTANA

Abbreviation	City	State	Year/Month Range
BIL0331	Billings	MT	67/1-71/12
BTM0357	Butte	MT	56/1-60/12

NEBRASKA

Abbreviation	City	State	Year/Month Range
LNK1142	Lincoln	NE	59/1-63/12
OMA0991	Omaha/Eppley	NB	55/1-64/12

NEVADA

Abbreviation	City	State	Year/Month Range
UCC1026	Yucca Flats	NV	61/12-64/11

NEW JERSEY

Abbreviation	City	State	Year/Month Range
NEL0505	Lakehurst	NJ	68/1-72/12

NEW MEXICO

Abbreviation	City	State	Year/Month Range
ABQ0282	Albuquerque	NM	60/1-64/12
CNM1741	Carlsbad	NM	50/1-54/12
FMN0285	Farmington	NM	63/5-68/4
GNT1246	Grants	NM	54/1-54/12
SAF1184	Santa Fe	NM	50/1-54/12

NEW YORK

Abbreviation	City	State	Year/Month Range
ALB0523	Albany	NY	60/1-64/12
BUF0741	Buffalo	NY	73/1-73/12
HPN0429	White Plain	NY	49/1-53/12
IAG0905	Niagra Falls	NY	55/1-59/12
LEA0189	New York/LaGuardia	NY	65/1-70/12
LEA0435	NY/Ft Totte	NY	65/1-69/12
ROC0598	Rochester	NY	55/1-64/12
SWF0185	Newburgh	NY	65/1-69/12

NORTH CAROLINA

Abbreviation	City	State	Year/Month Range
CLT0682	Charlotte	NC	69/1-73/12
FBG0075	Ft Bragg	NC	66/1-70/12
HAT0392	Cape Hatteras	NC	66/1-70/12
INT0531	Winston Salem	NC	60/1-64/12
NKT0106	Cherry Pt	NC	67/1-71/12

ILM0104	Wilmington	NC	66/1-70/12
RDU0083	Raleigh	NC	66/1-70/12

NORTH DAKOTA

Abbreviation	City	State	Year/Month Range
DIK0509	Dickinson	ND	60/1-64/12

OHIO

Abbreviation	City	State	Year/Month Range
CLE1140	Cleveland	OH	70/1-74/12
CMH0243	Columbus	OH	60/1-64/12
DAY0404	Dayton	OH	65/1-69/12
DAY1502	Dayton	OH	76/1-76/12
IBG0745	Perry	OH	49/1-49/12
TOL0990	Toledo	OH	60/1-64/12

OREGON

Abbreviation	City	State	Year/Month Range
PDX0364	Portland	OR	67/1-71/12

PENNSYLVANIA

Abbreviation	City	State	Year/Month Range
AVP0499	Wilkes-Barre	PA	60/1-64/12
ERI0610	Erie	PA	64/1-73/12
HAR0631	Harrisburg	PA	64/1-64/12
RDG0184	Reading	PA	49/1-49/12

RHODE ISLAND

Abbreviation	City	State	Year/Month Range
PVD0560	Providence	RI	68/1-72/12

SOUTH CAROLINA

Abbreviation	City	State	Year/Month Range
CAE1371	Columbia	SC	56/1-75/12
FLO0600	Florence/Gilbert	SC	60/1-64/12
GSP0528	Greenville/Sparta	SC	68/1-72/12
MYR1027	Myrtle Beach	SC	66/1-70/12

SOUTH DAKOTA

Abbreviation	City	State	Year/Month Range
RAP0336	Rapid City	SD	67/1-71/12

TENNESSEE

Abbreviation	City	State	Year/Month Range
BNA0149	Nashville	TN	66/1-70/12
CHA0711	Chattanooga	TN	68/1-73/12
MEM0143	Memphis	TN	67/1-71/12
TRI1191	Bristol	TN	74/1-74/12
TYS1328	Knoxville	TN	55/1-64/12

TEXAS

Abbreviation	City	State	Year/Month Range
AMA0621	Amarillo	TX	55/1-64/12
CRP1459	Corpus Christi	TX	73/7-77/6
SAT0064	San Antonio	TX	60/1-64/12

UTAH

Abbreviation	City	State	Year/Month Range
HV40302	Hanksville	UT	49/1-54/12
SLC1411	Salt Lake City	UT	72/1-76/12

VIRGINIA

Abbreviation	City	State	Year/Month Range
IAD0398	Wash/Dulles	VA	66/1-70/12
GVE0824	Gordonsville	VA	56/1-60/12
ROA0526	Roanoke	VA	68/1-72/12

WASHINGTON

Abbreviation	City	State	Year/Month Range
GEG0360	Spokane	WA	67/1-71/12
MWH0486	Moses Lake	WA	61/1-65/12
YKM0484	Yakima	WA	50/1-54/12

WEST VIRGINIA

Abbreviation	City	State	Year/Month Range
CRW0655	Charleston	WV	68/1-73/12
HTS0019	Huntington	WV	67/1-71/12

WISCONSIN

Abbreviation	City	State	Year/Month Range
EAU0715	Eau Claire	WI	69/1-73/12
ERB0776	Green Bay	WI	64/1-73/12

WYOMING

Abbreviation	City	State	Year/Month Range
CPR0335	Casper	WY	67/1-71/12
LND1100	Lander	WY	70/1-74/12
RWL1261	Rawlins	WY	55/1-64/12
RKS1588	Rocky Springs	WY	71/1-75/12

Radionuclide List

This is the list of nuclides used by CAP88-PC Version 4.1 from the DCFPAK V3.02 data.

Count: 1252

Special Ingestion and Inhalation Chemical Forms in CAP88 Version 4.1

Element	Special Ingestion Chemical Forms	Special Inhalation Chemical Forms (including gases and vapors)
Hydrogen	Tritiated Water (HTO) Organically Bound Tritium	Tritiated Water (HTO) Elemental Tritium (HT) Organically Bound Tritium
Carbon		Carbon Monoxide (CO) Carbon Dioxide (CO2)
Sulfur		Sulfur Dioxide (SO2) Carbon Disulfide (CS2)
Nickel		Nickel Vapor
Ruthenium		Ruthenium Vapor
Tellurium		Tellurium Vapor
Iodine		Iodine Vapor Methyl Iodide (CH3I)
Mercury	Inorganic Methyl Organic	Inorganic Mercury Vapor Organic
Polonium	Organic Inorganic	

Nuclides in CAP88 Version 4.1

Element	Internal & External Dose Conversion Factors	External Dose Conversion Factors Only
Hydrogen	H-3	
Helium		
Lithium		
Beryllium	Be-7, Be-10	
Boron		
Carbon	C-11, C-14	C-10
Nitrogen		N-13, N-16
Oxygen		O-14, O-15, O-19
Fluorine	F-18	F-17
Neon		Ne-19, Ne-24
Sodium	Na-22, Na-24	
Magnesium	Mg-28	Mg-27
Aluminum	Al-26	Al-28, Al-29
Silicon	Si-31, Si-32	
Phosphorus	P-32, P-33	P-30
Sulfur	S-35, S-38	S-37
Chlorine	Cl-34m, Cl-36, Cl-38, Cl-39	Cl-34, Cl-40
Argon		Ar-37, Ar-39, Ar-41, Ar-42, Ar-43, Ar-44
Potassium	K-40, K-42, K-43, K-44, K-45	K-38, K-46
Calcium	Ca-41, Ca-45, Ca-47	Ca-49
Scandium	Sc-43, Sc-44, Sc-44m, Sc-46, Sc-47, Sc-48, Sc-49	Sc-42m, Sc-50
Titanium	Ti-44, Ti-45	Ti-51, Ti-52
Vanadium	V-47, V-48, V-49, V-50	V-52, V-53
Chromium	Cr-48, Cr-49, Cr-51	Cr-55, Cr-56
Manganese	Mn-51, Mn-52, Mn-52m, Mn-53, Mn-54, Mn-56	Mn-50m, Mn-57, Mn-58m
Iron	Fe-52, Fe-55, Fe-59, Fe-60	Fe-53, Fe-53m, Fe-61, Fe-62
Cobalt	Co-55, Co-56, Co-57, Co-58, Co-58m, Co-60, Co-60m, Co-61, Co-62m	Co-54m, Co-62
Nickel	Ni-56, Ni-57, Ni-59, Ni-63, Ni-65, Ni-66	
Copper	Cu-60, Cu-61, Cu-64, Cu-67	Cu-57, Cu-59, Cu-62, Cu-66, Cu-69
Zinc	Zn-62, Zn-63, Zn-65, Zn-69, Zn-69m, Zn-71m, Zn-72	Zn-60, Zn-61, Zn-71
Gallium	Ga-65, Ga-66, Ga-67, Ga-68, Ga-70, Ga-72, Ga-73	Ga-64, Ga-74
Germanium	Ge-66, Ge-67, Ge-68, Ge-69, Ge-71, Ge-75, Ge-77, Ge-78	
Arsenic	As-69, As-70, As-71, As-72, As-73, As-74, As-76, As-77, As-78	As-68, As-79
Selenium	Se-70, Se-72, Se-73, Se-73m, Se-75, Se-79, Se-81, Se-81m, Se-83	Se-71, Se-77m, Se-79m, Se-83m, Se-84

Element	Internal & External Dose Conversion Factors	External Dose Conversion Factors Only
Bromine	Br-74, Br-74m, Br-75, Br-76, Br-77, Br-80, Br-80m, Br-82, Br-83, Br-84	Br-72, Br-73, Br-76m, Br-77m, Br-78, Br-82m, Br-84m, Br-85
Krypton		Kr-74, Kr-75, Kr-76, Kr-77, Kr-79, Kr-81, Kr-81m, Kr-83m, Kr-85, Kr-85m, Kr-87, Kr-88, Kr-89
Rubidium	Rb-78, Rb-79, Rb-81, Rb-81m, Rb-82m, Rb-83, Rb-84, Rb-84m, Rb-86, Rb-87, Rb-88, Rb-89	Rb-77, Rb-78m, Rb-80, Rb-82, Rb-86m, Rb-90, Rb-90m
Strontium	Sr-80, Sr-81, Sr-82, Sr-83, Sr-85, Sr-85m, Sr-87m, Sr-89, Sr-90, Sr-91, Sr-92	Sr-79, Sr-93, Sr-94
Yttrium	Y-84m, Y-85, Y-85m, Y-86, Y-86m, Y-87, Y-87m, Y-88, Y-90, Y-90m, Y-91, Y-91m, Y-92, Y-93, Y-94, Y-95	Y-81, Y-83, Y-83m, Y-89m
Zirconium	Zr-86, Zr-87, Zr-88, Zr-89, Zr-93, Zr-95, Zr-97	Zr-85, Zr-89m
Niobium	Nb-88, Nb-89, Nb-89m, Nb-90, Nb-91, Nb-91m, Nb-92, Nb-92m, Nb-93m, Nb-94, Nb-95, Nb-95m, Nb-96, Nb-97, Nb-98m	Nb-87, Nb-88m, Nb-94m, Nb-99, Nb-99m
Molybdenum	Mo-90, Mo-91, Mo-93, Mo-93m, Mo-99, Mo-101, Mo-102	Mo-89, Mo-91m
Technetium	Tc-93, Tc-93m, Tc-94, Tc-94m, Tc-95, Tc-95m, Tc-96, Tc-96m, Tc-97, Tc-97m, Tc-98, Tc-99, Tc-99m, Tc-101, Tc-104	Tc-91, Tc-91m, Tc-92, Tc-102, Tc-102m, Tc-105
Ruthenium	Ru-94, Ru-95, Ru-97, Ru-103, Ru-105, Ru-106	Ru-92, Ru-107, Ru-108
Rhodium	Rh-97, Rh-97m, Rh-99, Rh-99m, Rh-100, Rh-101, Rh-101m, Rh-102, Rh-102m, Rh-103m, Rh-105, Rh-106m, Rh-107	Rh-94, Rh-95, Rh-95m, Rh-96, Rh-96m, Rh-98, Rh-100m, Rh-104, Rh-104m, Rh-106, Rh-108, Rh-109
Palladium	Pd-98, Pd-99, Pd-100, Pd-101, Pd-103, Pd-107, Pd-109, Pd-111, Pd-112	Pd-96, Pd-97, Pd-109m, Pd-114
Silver	Ag-101, Ag-102, Ag-103, Ag-104, Ag-104m, Ag-105, Ag-106, Ag-106m, Ag-108m, Ag-110m, Ag-111, Ag-112, Ag-113, Ag-115	Ag-99, Ag-100m, Ag-102m, Ag-105m, Ag-108, Ag-109m, Ag-110, Ag-111m, Ag-113m, Ag-114, Ag-116, Ag-117
Cadmium	Cd-104, Cd-105, Cd-107, Cd-109, Cd-111m, Cd-113, Cd-113m, Cd-115, Cd-115m, Cd-117, Cd-117m, Cd-118	Cd-101, Cd-102, Cd-103, Cd-119, Cd-119m
Indium	In-107, In-108, In-108m, In-109, In-110, In-110m, In-111, In-112, In-112m, In-113m, In-114m, In-115, In-115m, In-116m, In-117, In-117m, In-119m	In-103, In-105, In-106, In-106m, In-109m, In-111m, In-114, In-118, In-118m, In-119, In-121, In-121m
Tin	Sn-108, Sn-109, Sn-110, Sn-111, Sn-113, Sn-113m, Sn-117m, Sn-119m, Sn-121, Sn-121m, Sn-123, Sn-123m, Sn-125, Sn-126, Sn-127, Sn-128	Sn-106, Sn-125m, Sn-127m, Sn-129, Sn-130, Sn-130m
Antimony	Sb-115, Sb-116, Sb-116m, Sb-117, Sb-118m, Sb-119, Sb-120, Sb-120m, Sb-122, Sb-124, Sb-124n, Sb-125, Sb-126,	Sb-111, Sb-113, Sb-114, Sb-118, Sb-122m, Sb-124m, Sb-130m, Sb-133

Element	Internal & External Dose Conversion Factors	External Dose Conversion Factors Only
	Sb-126m, Sb-127, Sb-128, Sb-128m, Sb-129, Sb-130, Sb-131	
Tellurium	Te-114, Te-116, Te-117, Te-118, Te-119, Te-119m, Te-121, Te-121m, Te-123, Te-123m, Te-125m, Te-127, Te-127m, Te-129, Te-129m, Te-131, Te-131m, Te-132, Te-133, Te-133m, Te-134	Te-113, Te-115, Te-115m
Iodine	I-118, I-119, I-120, I-120m, I-121, I-123, I-124, I-125, I-126, I-128, I-129, I-130, I-131, I-132, I-132m, I-133, I-134, I-135	I-118m, I-122, I-130m, I-134m
Xenon		Xe-120, Xe-121, Xe-122, Xe-123, Xe-125, Xe-127, Xe-127m, Xe-129m, Xe-131m, Xe-133, Xe-133m, Xe-135, Xe-135m, Xe-137, Xe-138
Cesium	Cs-125, Cs-127, Cs-129, Cs-130, Cs-131, Cs-132, Cs-134, Cs-134m, Cs-135, Cs-135m, Cs-136, Cs-137, Cs-138	Cs-121, Cs-121m, Cs-123, Cs-124, Cs-126, Cs-128, Cs-130m, Cs-138m, Cs-139, Cs-140
Barium	Ba-124, Ba-126, Ba-127, Ba-128, Ba-129, Ba-129m, Ba-131, Ba-131m, Ba-133, Ba-133m, Ba-135m, Ba-139, Ba-140, Ba-141, Ba-142	Ba-137m
Lanthanum	La-129, La-131, La-132, La-132m, La-133, La-135, La-137, La-138, La-140, La-141, La-142, La-143	La-128, La-130, La-134, La-136
Cerium	Ce-130, Ce-131, Ce-132, Ce-133, Ce-133m, Ce-134, Ce-135, Ce-137, Ce-137m, Ce-139, Ce-141, Ce-143, Ce-144	Ce-145
Praseodymium	Pr-134, Pr-134m, Pr-135, Pr-136, Pr-137, Pr-138m, Pr-139, Pr-142, Pr-142m, Pr-143, Pr-144, Pr-145, Pr-146, Pr-147	Pr-138, Pr-140, Pr-144m, Pr-148, Pr-148m
Neodymium	Nd-135, Nd-136, Nd-137, Nd-138, Nd-139, Nd-139m, Nd-140, Nd-141, Nd-144, Nd-147, Nd-149, Nd-151, Nd-152	Nd-134, Nd-141m
Promethium	Pm-141, Pm-143, Pm-144, Pm-145, Pm-146, Pm-147, Pm-148, Pm-148m, Pm-149, Pm-150, Pm-151	Pm-136, Pm-137m, Pm-139, Pm-140, Pm-140m, Pm-142, Pm-152, Pm-152m, Pm-153, Pm-154, Pm-154m
Samarium	Sm-140, Sm-141, Sm-141m, Sm-142, Sm-145, Sm-146, Sm-147, Sm-148, Sm-151, Sm-153, Sm-155, Sm-156	Sm-139, Sm-143, Sm-143m, Sm-157
Europium	Eu-145, Eu-146, Eu-147, Eu-148, Eu-149, Eu-150, Eu-150m, Eu-152, Eu-152m, Eu-152n, Eu-154, Eu-154m, Eu-155, Eu-156, Eu-157, Eu-158, Eu-159	Eu-142, Eu-142m, Eu-143, Eu-144
Gadolinium	Gd-145, Gd-146, Gd-147, Gd-148, Gd-149, Gd-150, Gd-151, Gd-152, Gd-153, Gd-159	Gd-142, Gd-143m, Gd-144, Gd-145m, Gd-162
Terbium	Tb-147, Tb-148, Tb-149, Tb-150, Tb-151, Tb-152, Tb-153, Tb-154, Tb-155, Tb-156, Tb-156m, Tb-156n, Tb-157, Tb-158, Tb-160, Tb-161, Tb-163	Tb-146, Tb-147m, Tb-148m, Tb-149m, Tb-150m, Tb-151m, Tb-152m, Tb-162, Tb-164, Tb-165

Element	Internal & External Dose Conversion Factors	External Dose Conversion Factors Only
Dysprosium	Dy-151, Dy-152, Dy-153, Dy-154, Dy-155, Dy-157, Dy-159, Dy-165, Dy-166	Dy-148, Dy-149, Dy-150, Dy-165m, Dy-167, Dy-168
Holmium	Ho-154, Ho-155, Ho-156, Ho-157, Ho-159, Ho-160, Ho-161, Ho-162, Ho-162m, Ho-163, Ho-164, Ho-164m, Ho-166, Ho-166m, Ho-167	Ho-150, Ho-153, Ho-153m, Ho-154m, Ho-168, Ho-168m, Ho-170
Erbium	Er-156, Er-159, Er-161, Er-163, Er-165, Er-169, Er-171, Er-172	Er-154, Er-167m, Er-173
Thulium	Tm-161, Tm-162, Tm-163, Tm-165, Tm-166, Tm-167, Tm-168, Tm-170, Tm-171, Tm-172, Tm-173, Tm-175	Tm-164, Tm-174, Tm-176
Ytterbium	Yb-162, Yb-163, Yb-164, Yb-166, Yb-167, Yb-169, Yb-175, Yb-177, Yb-178	Yb-165, Yb-179
Lutetium	Lu-165, Lu-167, Lu-169, Lu-170, Lu-171, Lu-172, Lu-173, Lu-174, Lu-174m, Lu-176, Lu-176m, Lu-177, Lu-177m, Lu-178, Lu-178m, Lu-179	Lu-169m, Lu-171m, Lu-172m, Lu-180, Lu-181
Hafnium	Hf-170, Hf-172, Hf-173, Hf-174, Hf-175, Hf-177m, Hf-178m, Hf-179m, Hf-180m, Hf-181, Hf-182, Hf-182m, Hf-183, Hf-184	Hf-167, Hf-169
Tantalum	Ta-172, Ta-173, Ta-174, Ta-175, Ta-176, Ta-177, Ta-178m, Ta-179, Ta-180, Ta-182, Ta-182m, Ta-183, Ta-184, Ta-185, Ta-186	Ta-170, Ta-178
Tungsten	W-177, W-178, W-179, W-181, W-185, W-187, W-188, W-190	W-179m, W-185m
Rhenium	Re-178, Re-179, Re-181, Re-182, Re-182m, Re-183, Re-184, Re-184m, Re-186, Re-186m, Re-187, Re-188, Re-188m, Re-189, Re-190m	Re-180, Re-190
Osmium	Os-180, Os-181, Os-182, Os-183, Os-183m, Os-185, Os-186, Os-189m, Os-191, Os-191m, Os-193, Os-194, Os-196	Os-190m
Iridium	Ir-182, Ir-183, Ir-184, Ir-185, Ir-186, Ir-186m, Ir-187, Ir-188, Ir-189, Ir-190, Ir-190m, Ir-190n, Ir-192, Ir-192n, Ir-193m, Ir-194, Ir-194m, Ir-195, Ir-195m, Ir-196m	Ir-180, Ir-191m, Ir-192m, Ir-196
Platinum	Pt-184, Pt-186, Pt-187, Pt-188, Pt-189, Pt-190, Pt-191, Pt-193, Pt-193m, Pt-195m, Pt-197, Pt-197m, Pt-199, Pt-200, Pt-202	
Gold	Au-186, Au-190, Au-191, Au-192, Au-193, Au-194, Au-195, Au-196, Au-196m, Au-198, Au-198m, Au-199, Au-200, Au-200m, Au-201	Au-187, Au-193m, Au-195m, Au-202
Mercury	Hg-190, Hg-191m, Hg-192, Hg-193, Hg-193m, Hg-194, Hg-195, Hg-195m, Hg-197, Hg-197m, Hg-199m, Hg-203	Hg-205, Hg-206, Hg-207
Thallium	Tl-194, Tl-194m, Tl-195, Tl-196, Tl-197, Tl-198, Tl-198m, Tl-199, Tl-200, Tl-201, Tl-202, Tl-204	Tl-190, Tl-190m, Tl-206, Tl-206m, Tl-207, Tl-208, Tl-209, Tl-210

Element	Internal & External Dose Conversion Factors	External Dose Conversion Factors Only
Lead	Pb-194, Pb-195m, Pb-196, Pb-197m, Pb-198, Pb-199, Pb-200, Pb-201, Pb-202, Pb-202m, Pb-203, Pb-204m, Pb-205, Pb-209, Pb-210, Pb-211, Pb-212, Pb-214	Pb-197, Pb-201m
Bismuth	Bi-200, Bi-201, Bi-202, Bi-203, Bi-204, Bi-205, Bi-206, Bi-207, Bi-208, Bi-210, Bi-210m, Bi-212, Bi-213, Bi-214	Bi-197, Bi-211, Bi-212n, Bi-215, Bi-216
Polonium	Po-203, Po-204, Po-205, Po-206, Po-207, Po-208, Po-209, Po-210	Po-211, Po-212, Po-212m, Po-213, Po-214, Po-215, Po-216, Po-218
Astatine	At-205, At-206, At-207, At-208, At-209, At-210, At-211	At-204, At-215, At-216, At-217, At-218, At-219, At-220
Radon		Rn-207, Rn-209, Rn-210, Rn-211, Rn-212, Rn-215, Rn-216, Rn-217, Rn-218, Rn-219, Rn-220, Rn-222, Rn-223
Francium	Fr-212, Fr-222, Fr-223	Fr-219, Fr-220, Fr-221, Fr-224, Fr-227
Radium	Ra-223, Ra-224, Ra-225, Ra-226, Ra-227, Ra-228, Ra-230	Ra-219, Ra-220, Ra-221, Ra-222
Actinium	Ac-224, Ac-225, Ac-226, Ac-227, Ac-228	Ac-223, Ac-230, Ac-231, Ac-232, Ac-233
Thorium	Th-226, Th-227, Th-228, Th-229, Th-230, Th-231, Th-232, Th-233, Th-234, Th-236	Th-223, Th-224, Th-235
Protactinium	Pa-227, Pa-228, Pa-229, Pa-230, Pa-231, Pa-232, Pa-233, Pa-234, Pa-235	Pa-234m, Pa-236, Pa-237
Uranium	U-230, U-231, U-232, U-233, U-234, U-235, U-235m, U-236, U-237, U-238, U-239, U-240, U-242	U-227, U-228
Neptunium	Np-232, Np-233, Np-234, Np-235, Np-236, Np-236m, Np-237, Np-238, Np-239, Np-240, Np-241	Np-240m, Np-242, Np-242m
Plutonium	Pu-232, Pu-234, Pu-235, Pu-236, Pu-237, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Pu-243, Pu-244, Pu-245, Pu-246	
Americium	Am-237, Am-238, Am-239, Am-240, Am-241, Am-242, Am-242m, Am-243, Am-244, Am-244m, Am-245, Am-246, Am-246m, Am-247	
Curium	Cm-238, Cm-239, Cm-240, Cm-241, Cm-242, Cm-243, Cm-244, Cm-245, Cm-246, Cm-247, Cm-248, Cm-249, Cm-250, Cm-251	
Berkelium	Bk-245, Bk-246, Bk-247, Bk-248m, Bk-249, Bk-250, Bk-251	
Californium	Cf-244, Cf-246, Cf-247, Cf-248, Cf-249, Cf-250, Cf-251, Cf-252, Cf-253, Cf-254, Cf-255	
Einsteinium	Es-249, Es-250, Es-250m, Es-251, Es-253, Es-254, Es-254m, Es-255, Es-256	
Fermium	Fm-251, Fm-252, Fm-253, Fm-254, Fm-255, Fm-256, Fm-257	