CAP88-PC Version 2.1 User Guide

Draft Revision 1

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1. INTRODUCTION

1.1   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 CAP-88 (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. CAP-88 is composed of modified versions of AIRDOS-EPA (Mo79) and DARTAB (ORNL5692). The original CAP-88 model is written in FORTRAN77 and has been compiled and run on an IBM 3090 under OS/VS2, using the IBM FORTRAN compiler, at the EPA National Computer Center in Research Triangle Park, NC.

1.2   Purpose

The original CAP88-PC software package, version 1.0, allows 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 provides 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 is 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). Other than modifications of the Windows user interface, Version 2.1 includes some additional changes compared to the DOS version and the previous Windows version, 2.0. The changes include the addition of decay chains for six radionuclides (Strontium, Zirconium, Ruthenium-103, Ruthenium-106, Cerium, and Plutonium), correction of a minor error in the Uranium decay chain, and correction of a typographical error in the concentration reports. Section 1.6 provides a summary of the changes incorporated into Version 2.1 relative to Version 2.0.

1.3   Model Summary

CAP-88 PC uses 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 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 produces results that agree with experimental data as well as any model, is fairly easy to work with, and is consistent with the random nature of turbulence.

There are a few differences between CAP88-PC and earlier versions of AIRDOS, PREPAR and DARTAB. In particular, population assessments are easier to perform in CAP88-PC. When performing 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, which the user may modify 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. When performing population dose assessments, CAP88-PC uses the distances in the population array to determine the sector midpoint distances where the code calculates concentrations. CAP88-PC only uses circular grids; square grids are not an option. When an individual assessment is run, the sector midpoint distances are input by the user on the Run Option tab form. Direct user input of radionuclide concentrations is not an option in CAP88-PC.

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.

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 on the Facility Data tab form. 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 is also modified to do 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. Assessments for Radon-222 now automatically include Working Level calculations when only a single source term of Rn-222 may be used in this option. Input of any additional radionuclides, even Rn-220, will cause CAP88-PC to omit working level calculations.

Organs and weighting factors are modified to follow the ICRP 26/30 Effective Dose Equivalent calculations, 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. 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.

Only 7 organs are valid for the Effective Dose Equivalent. Changing the organs and weights will invalidate the results. They are Gonads 25 percent, Breast 15 percent, R MAR 12 percent, Lungs 12 percent, Thyroid 3 percent, ENDOST 3 percent, and Remainder 30 percent.

1.4   Validation

The CAP88-PC programs represent one of the best available validated codes for the purpose of making comprehensive dose and risk assessments. The Gaussian plume model used in CAP88-PC to estimate dispersion of radionuclides in air is one of the most commonly used models in Government guidebooks. It produces results that agree with experimental data as well as any model, is fairly easy to work with, and is consistent with the random nature of turbulence.

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 predictions are within a factor of 2 of actual concentrations.

1.5   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 (buoyant or momentum) 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.

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 cannot be used for either short-term or high-level radionuclide intakes.

1.6   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 has been added to provide a text file output of errors encountered by the code. Most errors are now written to a file named 'YYYYMMDDErrorlog.txt', where the date code refers to the date when the error occurred. This file will be located in the CAP88-PC install directory
- Many updates to the directory structure, which provide 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 will 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 now located at the top of the window in accordance with Windows standard practice
- The data environment (the accompanying database) has been updated to Microsoft Access for greater compatibility with Windows
- The 'Open From File' option is provided 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 are now the default install directories for these files.
- The radionuclide entry method has been changed. Rather than enter data directly into the Nuclide Data tab, the user now selects either 'Add Nuclide', 'Edit Nuclide' or 'Delete Nuclide' from the buttons on the form. When 'Add Nuclide' or 'Edit Nuclide' are selected, a new data entry form containing all selectable data for the nuclide is presented.
- A new 'Save and Close' button is available 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 has been updated and tested with all Windows versions from 95(b) to XP. It will now check for some necessary Windows components, such as

DCOM and Windows Scripting, and will install these if needed. This has eliminated the requirement for a separate installation of the DCOM98 module.

2. GETTING STARTED

2.1. Installation of Version 2.1

The CAP88-PC Windows version 2.1 can be downloaded from the following EPA web site:
http://www.epa.gov/radiation/assessment/CAP88/index.html

Follow steps 1-4 in section 2.2.1 if you have an existing installation of an earlier beta version of
CAP88-PC version 2.1. If you do not have an existing installation of CAP88-PC version 2.1 then
begin with step 5. CAP88-PC creates the following directory structure during a default installation:
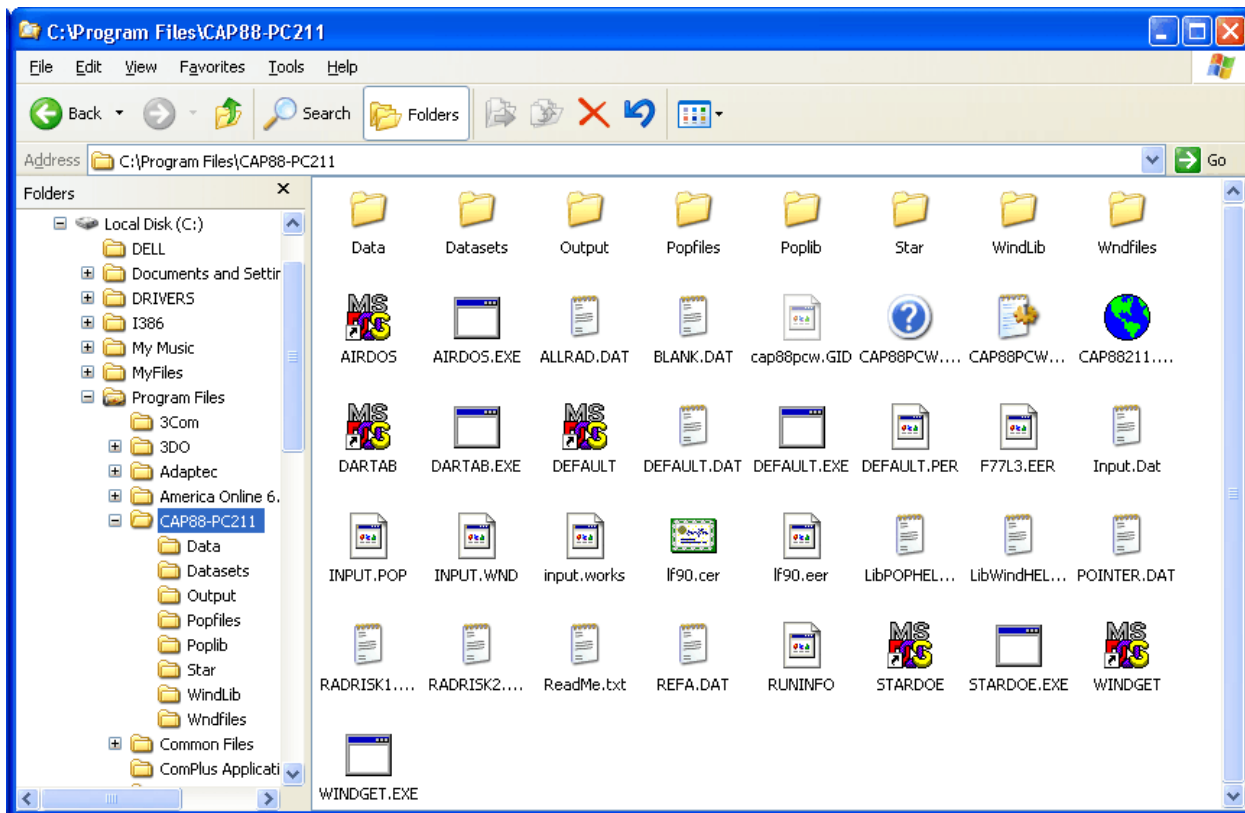
2.2   Installation Notes:

- CAP88-PC Version 2.1 will not install properly under Windows 95a, Linux, or Unix.
- If you are running Windows NT, 2000, or XP, we strongly recommend that you be logged
  on with administrative privileges to properly install CAP88-PC Version 2.1.
- We recommend that you disable all virus scanners prior to installation.
- The new installation program eliminates the need for a separate installation of DCOM98.
  Installation of DCOM98 and the Windows Scripting engine are included in the installation
  package. Installation of these Windows components may require rebooting the system
  during the installation process

- The procedure in Section 2.2.1 assumes you have an existing installation of an earlier beta version of CAP88-PC Version 2.1. If you do not have any existing installations begin at step 5.
- Steps 5 and 6 assume you are installing the software after downloading the CAP88-PC Version 2.1 archive. If you are installing from a CD then you may skip steps 5 and 6.

2.2.1 Installation Procedure

1. Save any user created input or output files that are in the 'Datasets' and 'Outputs' subdirectories of the previous install. Do not save the CAP88$ files as these are included in the install package.
2. Save any user generated wind or population files that are in the 'Popfiles' or 'Wndfiles' subdirectories of the previous install.
3. Uninstall any previous beta versions of CAP88-PC version 2.1.
4. Delete the directory structure from the previous install.
5. Create a temporary directory and download the .ZIP archive or self-extracting .EXE archive to the temporary directory.
6. Extract the files in the archive to the temporary directory. (Note - we recommend using a temporary directory as a location for the setup files rather than the directory where you intend to install CAP88-PC Version 2.1 to facilitate removal or archiving of the setup package following installation)
7. Run the SETUP.EXE program contained in the install package or on the CD. We recommend using the default installation directory for CAP88-PC Version 2.1. The install package will create the installation directory, and will also create a set of subdirectories underneath the installation directory. Please see section 2.1 (above) of this document for a description of the directory structure created by the CAP88-PC Version 2.1 installation routine.
8. As part of the installation, SETUP will install the Windows Scripting System and, for users running a WIN9x operating system, may install DCOM98 if it is not detected as already installed on your system.
9. Accept the Windows Scripting installation and the DCOM installation if they are requested by SETUP. If these are installed and you are running Windows 95b, 98, or ME, you may need to reboot during the CAP88-PC installation.
10. Copy any saved input files from step 1 into the new 'Datasets' subdirectory if you wish them to be readily available in the new version.
11. Copy any saved output files to the new 'Outputs' subdirectory if desired.
12. Copy any .WND or .POP saved during step 2 into the 'Windlib' or 'Poplib' subdirectories of the new CAP88-PC directory.
13. If you are running Windows 95b, 98, or ME, we recommend rebooting after the installation is completed. This may not be necessary under Windows 2000 or Windows XP.
14. Restart any virus scanner software that was disabled during installation of CAP88-PC.

We recommend placing your previously saved wind and population files into the library subdirectories rather than the 'Wndfiles' or 'Popfiles' subdirectories, because the code will treat these initially as new files. The default open locations in CAP88-PC Version 2.1 for new wind or population files are the 'Windlib' and 'Poplib' subdirectories, not the 'Wndfiles' or "Popfiles' subdirectories, so this will make the files more readily accessible the first time you use them in the

new installation. The code will subsequently save these files in the 'Wndfiles' and 'Popfiles' subdirectories after you select them for a run and perform a save of the case.

2.3. Running Version 2.1

The installation package of CAP88-PC Version 2.1 ships with three pre-existing input files, named CAP88$.dat, NUKETEST.dat, and MODTEST.dat, along with their associated output files for those input datasets. The input file CAP88$.dat, along with its backup file CAP88$.bak, reside in the 'Datasets' subdirectory of the installation directory. Output files are still written into the 'Output' subdirectory in the same formats as under Version 2.0 and Version 2.1.

2.3.1 Initial Post-Installation Running of Version 2.1

When running Version 2.1 for the first time, no input datasets are included in the dropdown file selection list. In this instance, when selecting <File>, <Open Dataset>, the user will receive a message box stating "Nothing to Open!". The user has a choice to create a new dataset, or open an existing input dataset from a file. If the user selects to open an existing file, a listing of the available files that reside in the 'Datasets' subdirectory is provided in the directory navigation window. The user may select one of these, or may navigate to another directory and select an input file from there. Once the dataset is created either by manual entry or by opening an existing file, perform a save of the dataset. This dataset will then be included in the drop-down file list for opening and for executing the case.

2.3.2 Building an Example Data Set

1. Start the code by double-clicking on the desktop icon or by using the icons installed on the <Start>, <Programs>, <Cap88pc211> location on the Windows start menu. After the initial splash screen, you will be at the following screen:
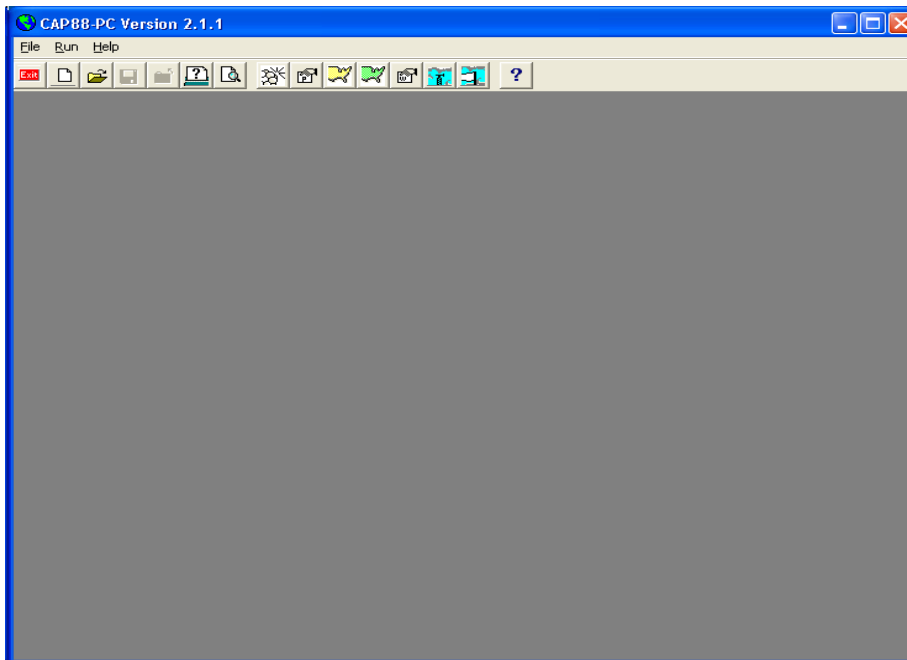
2. Select <File> from the menu bar, then <New Dataset> to begin creating a new CAP88-PC case. Enter the information for Dataset Name, Dataset Filename, and the two comment fields, and then click <OK>. Dataset Name must less than or equal to sixteen (**16**) characters, and Dataset Filename less than or equal to eight **(8)** characters. The comment fields are now optional; entries in each field must be less than fifty **(50)** characters.
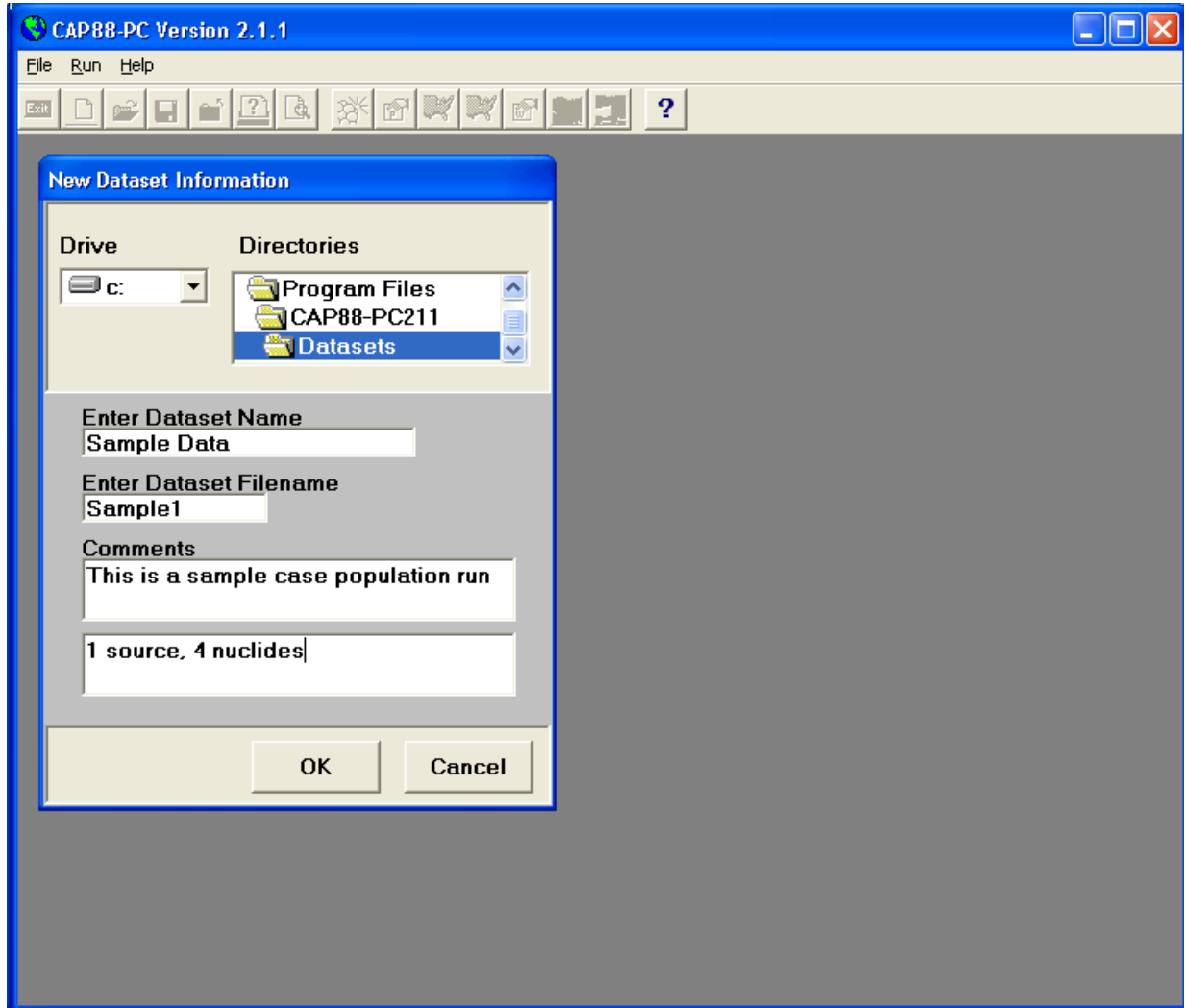
3. The next screen is the initial tab of the main form used to provide dataset information to CAP88-PC. The form consists of six tabs; each tab provides fields of related data. The user fills in these fields to build the dataset for the case being analyzed. This particular tab, shown here, is used to provide descriptive information regarding the facility being modeled. Providing the sample case data to this <Facility Data> tab results in the following screen.
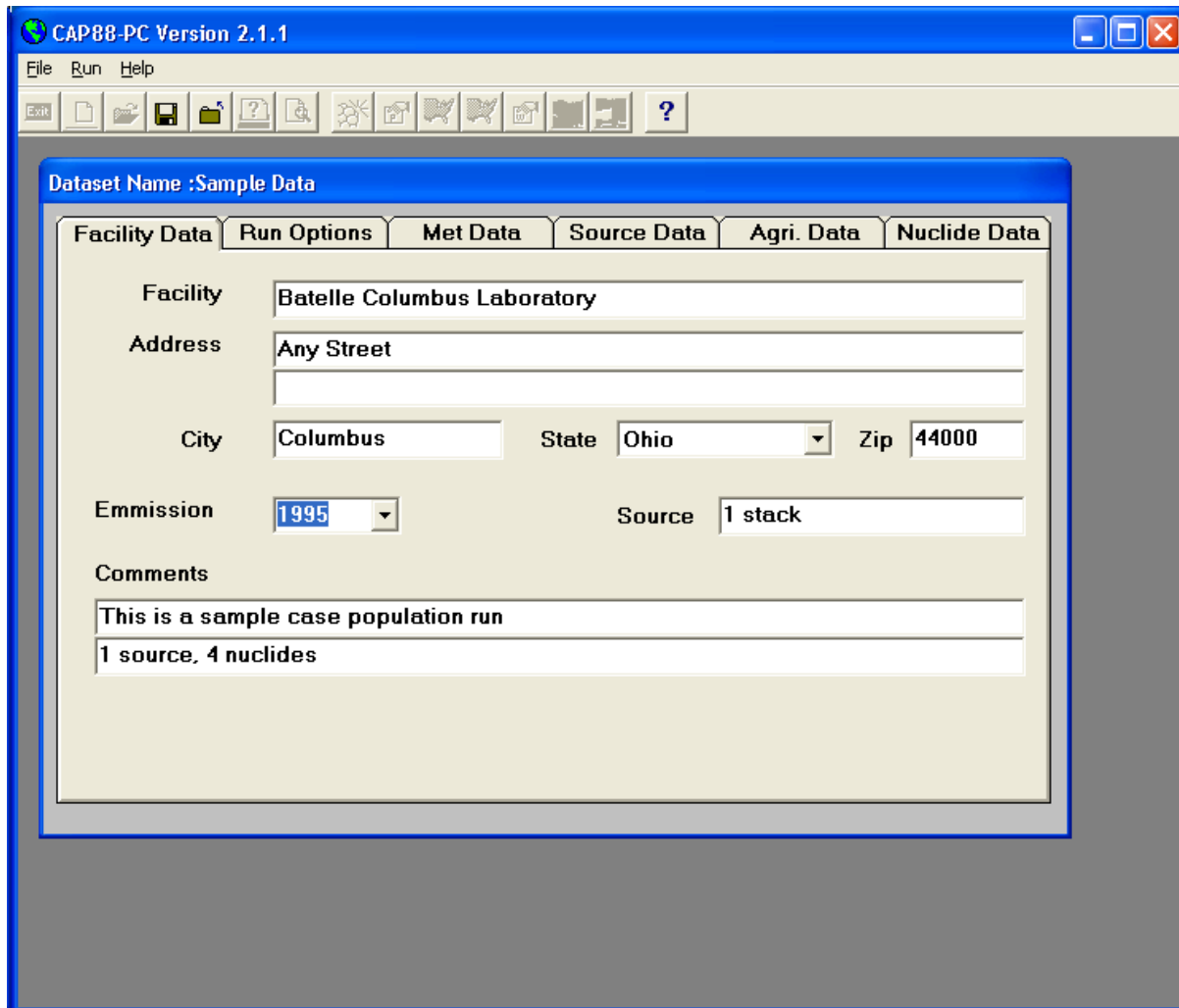
4. Select the <Run Options> tab, which will display the fields for selecting the type of run for this dataset (population or individual), for selecting the population file, and for selecting the type of output files for the run. For this sample dataset, select the data as shown in the figure below. Note that when the radio button for Population File Directory is selected, the file selection control is a drop down list of the population files that have been extracted into CAP88-PC's data environment. If the Custom Population File button is selected, then the file selection control allows selecting a population file by navigating to any file location. The initial default directory for the Custom Population File selection is the POPLIB subdirectory of the CAP88-PC Version 2.1 installation directory.
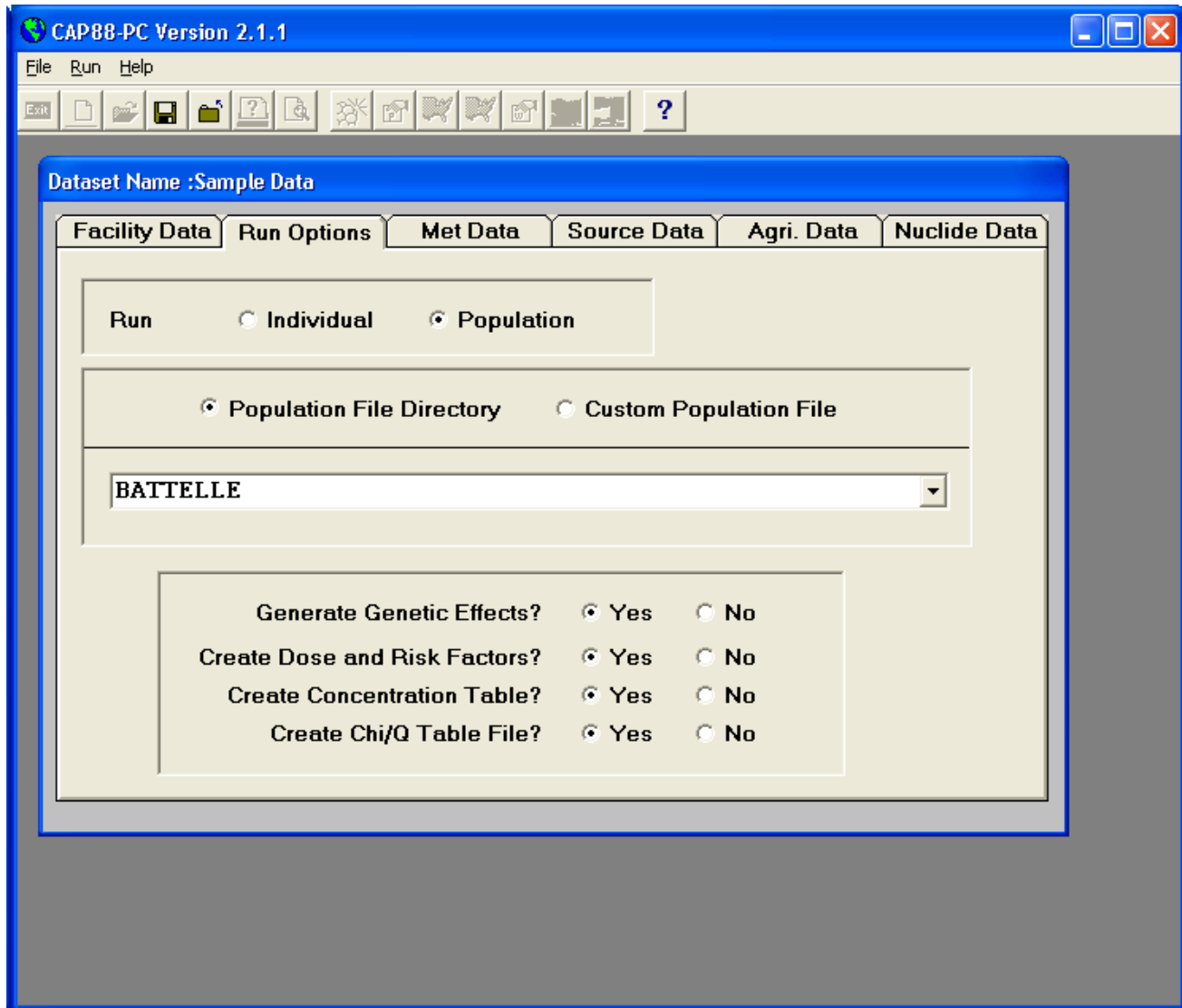
5. Select the <Met Data> tab to display the fields for describing the meteorological data required by CAP88-PC Version 2.1. One change to this tab from version 2.0 is the addition of the Absolute Humidity field, which has a default value of 8 grams water per cubic meter of air. The tab should initially appear similar to the following figure:

CAP88-PC Version 2.1.1

File Run Help

Dataset Name :Sample Data

Facility Data | Run Options | Met Data | Source Data | Agri. Data | Nuclide Data

● Wind File Directory   ○ Custom Wind File

03813 | MACON/LEWIS B WILSON | 1988,1989,19 ▼

Annual Precipitation: 100.   (cm/year)

Annual Ambient: 10   (Celsius)

Height of Lid: 1000   (meters)

Absolute Humidity: 8.   (grams/cu meter)
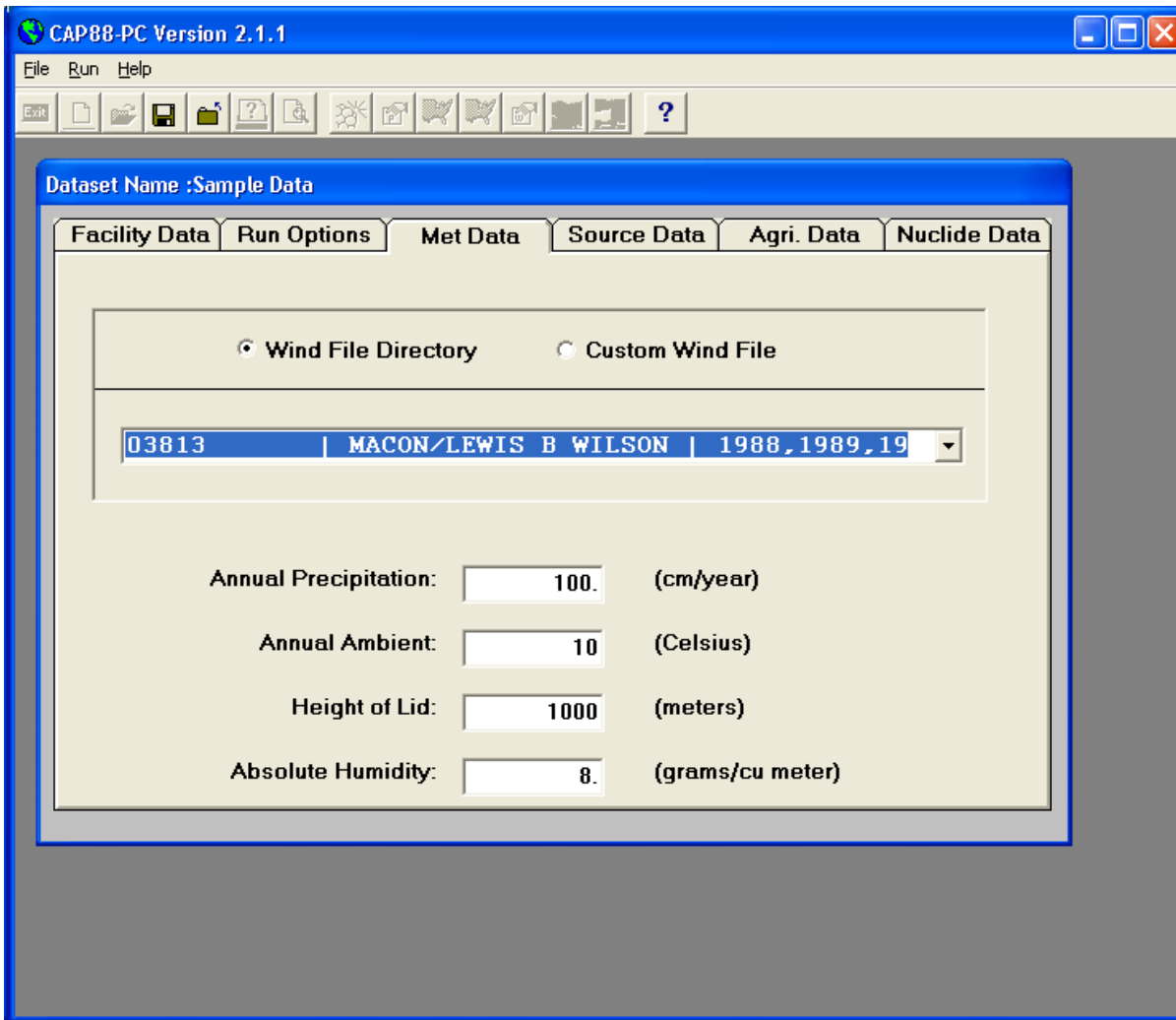
For this sample dataset, do not use the Wind File Directory button, since no wind file applicable to Columbus Ohio has been extracted into the CAP88-PC data environment. Select the Custom Wind File button to change the file selection control to one that will permit selecting a wind file from a separate directory. The tab should now display as follows:
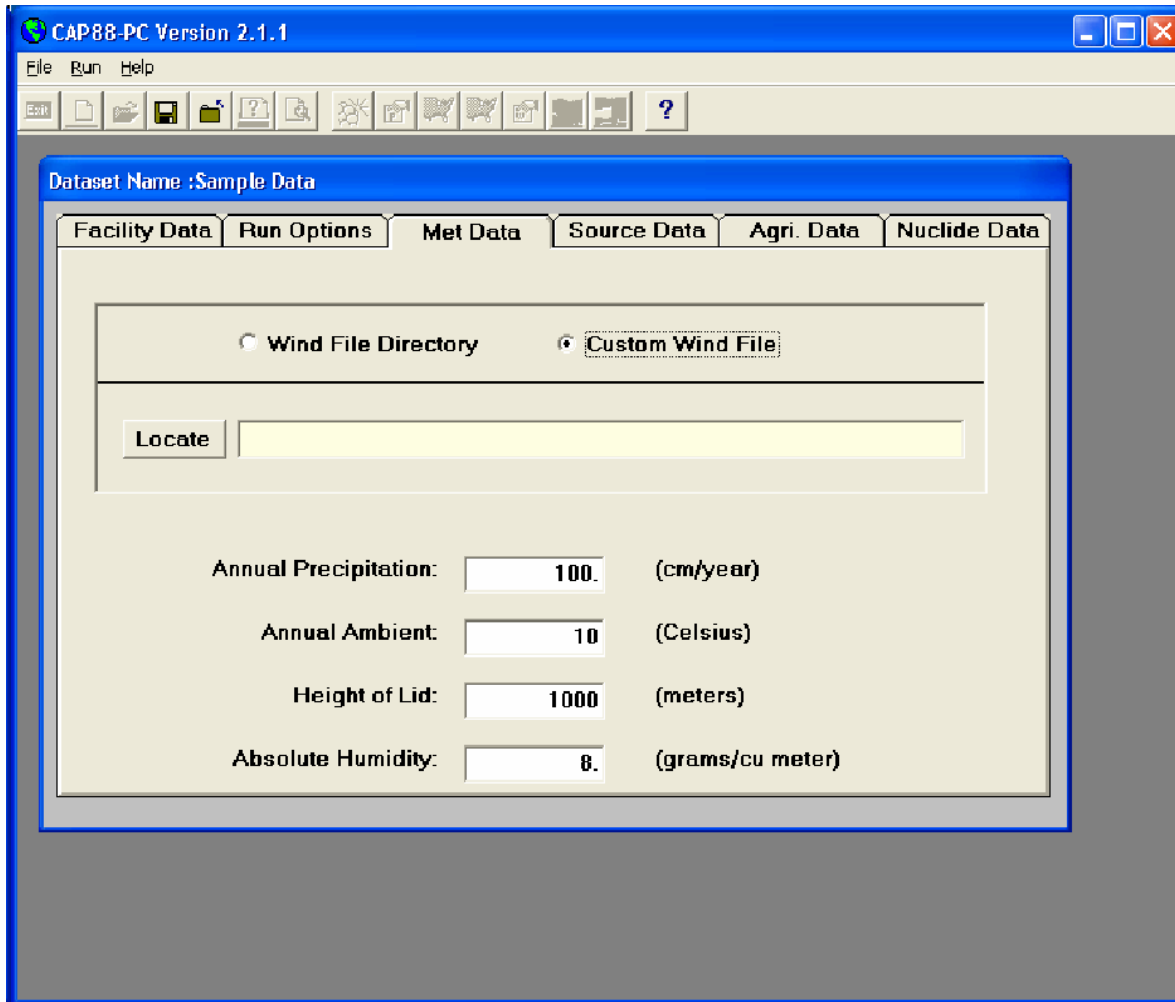
Click the <Locate> button to display a list of wind files stored in the Windlib subdirectory of the CAP88-PC Version 2.1 installation directory. Select the file named 14821.wnd, and the following sub-screen should result:
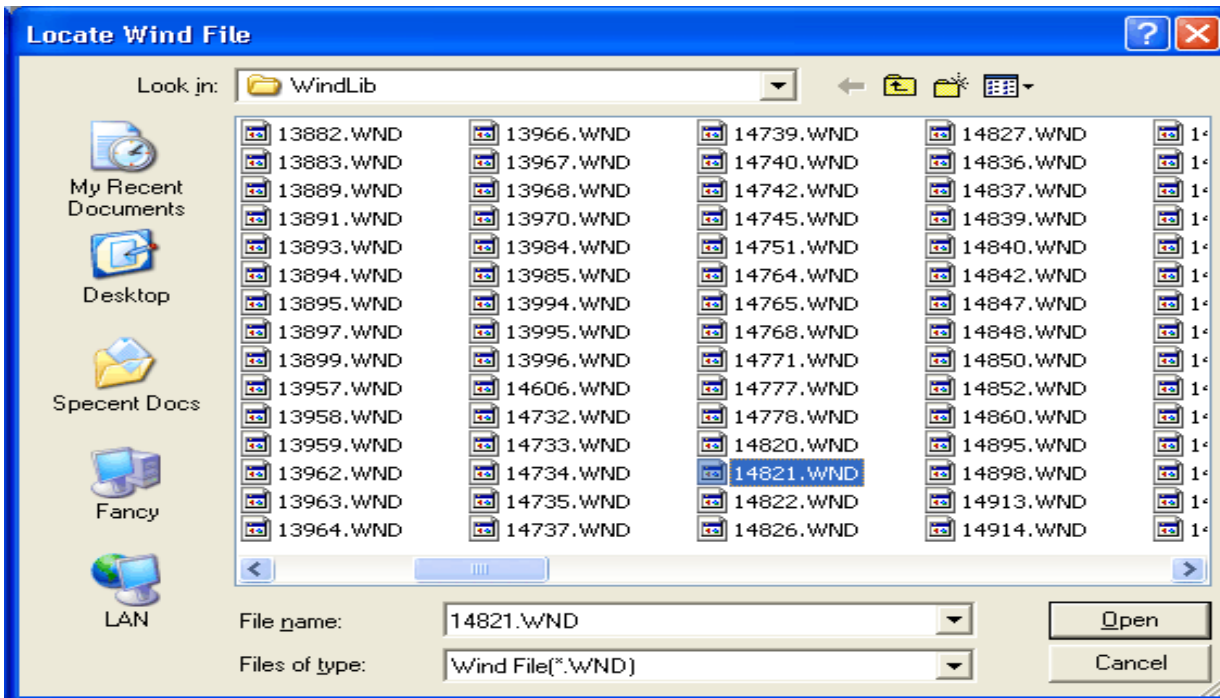
Click <Open>, and the file should be selected for use as the input wind file. The <Met Data> tab should now appear as follows:
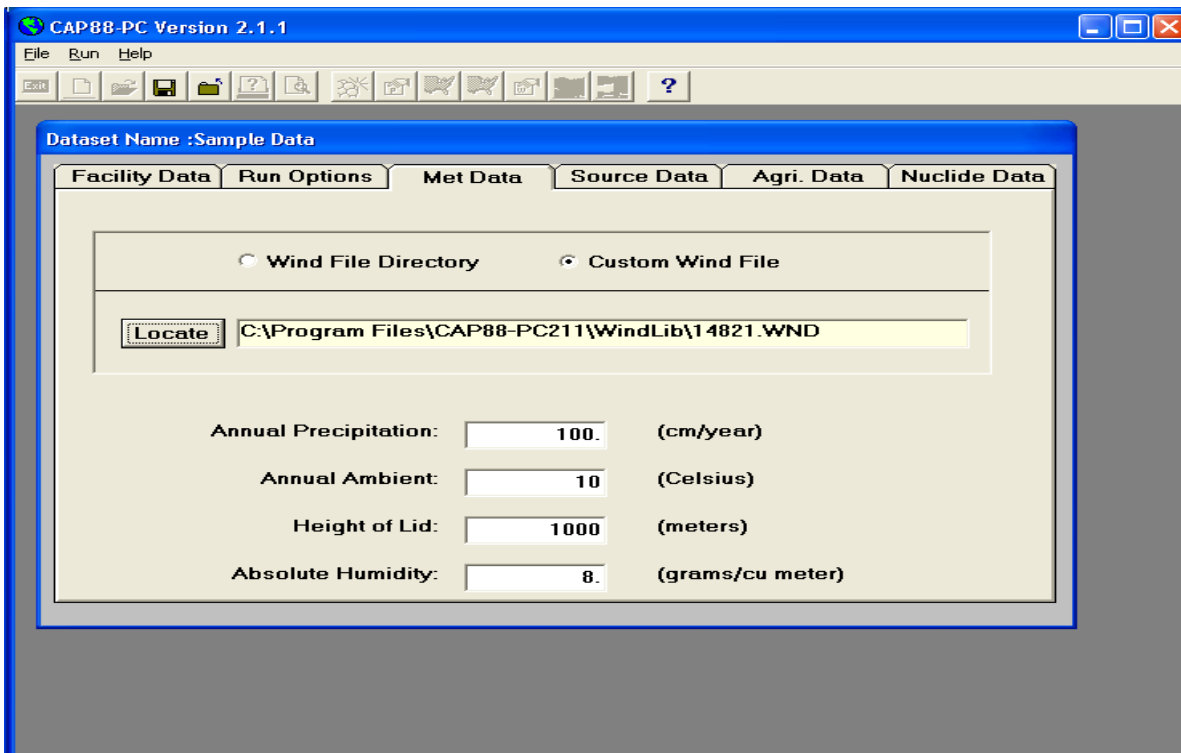
6. Select the <Source Data> tab to enable the fields that describe the physical parameters of the release. This sample dataset only uses a single stack release, but up to 6 sources can be selected. Note that although CAP88-PC allows up to 6 different sources, all sources must be of the same type (area or stack). Also, CAP88-PC models the sources as being co-located, i.e. they have the same physical center point. The displayed screen should be as follows after all data for the sample dataset have been entered:
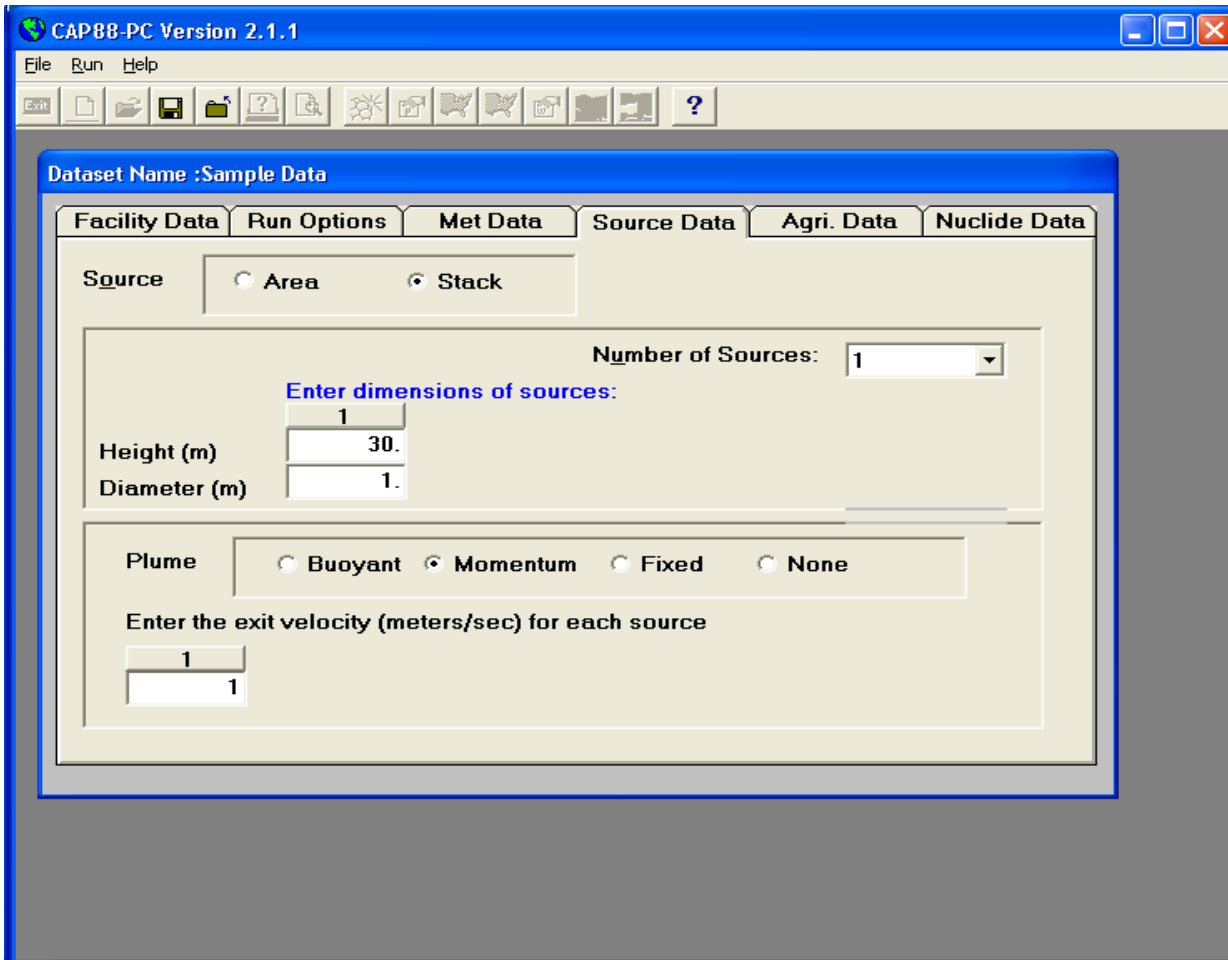
7. The next tab to be selected is the <Agri. Data> tab, which allows entry of the food pathway information for the dataset. The various options for the food sources determine the fraction of the food products grown either local to the analysis location, within the overall assessment area, or from outside the assessment area. Foods produced outside the assessment area are considered in the CAP88-PC code to be uncontaminated. The populated fields for the sample dataset will result in a screen appearing as follows:
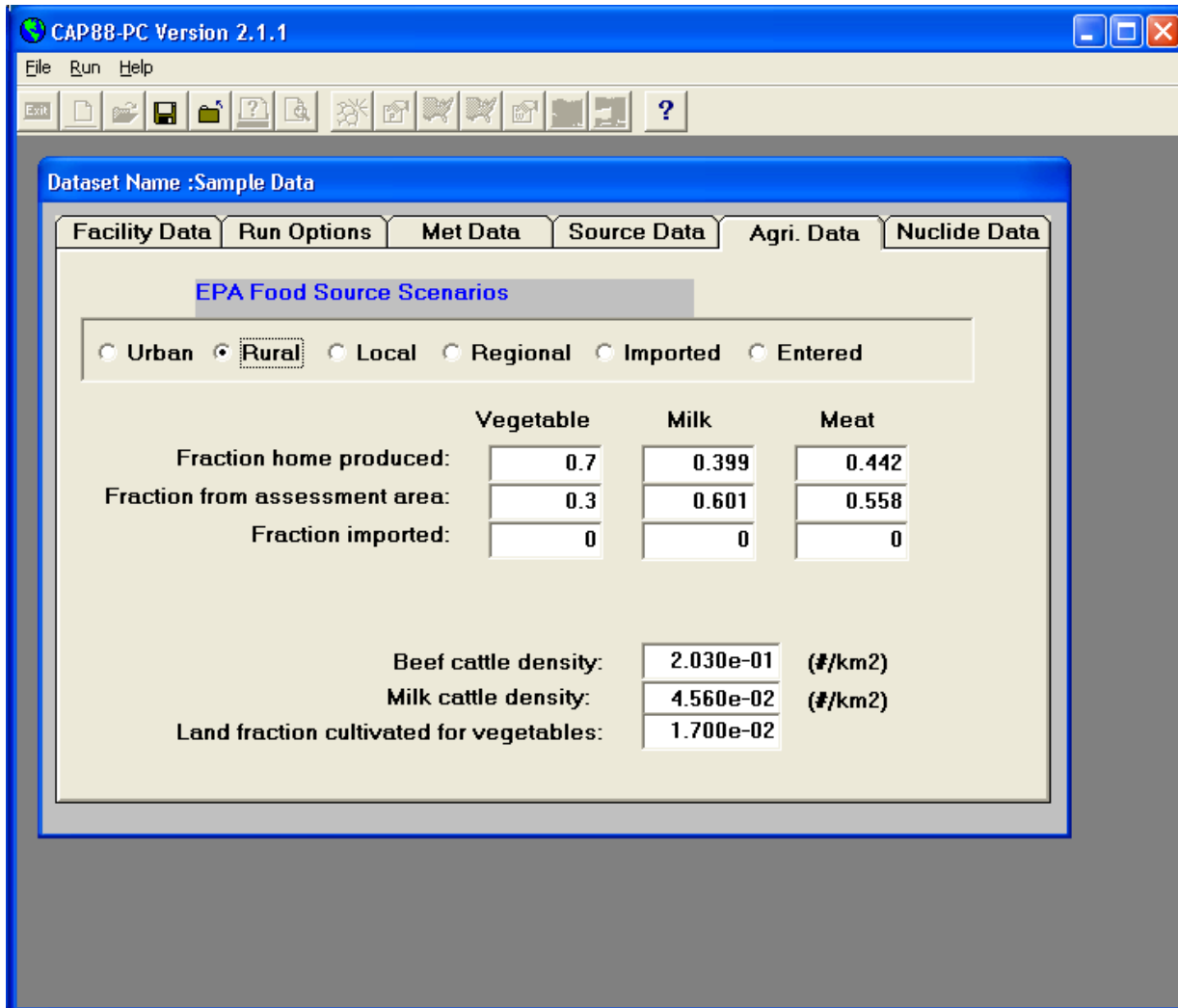
8. The final tab to be selected is <Nuclide Data>. This tab has been modified from Version 2.0 to include a <Save and Close> button, and, more significantly, to add a sub-form where all additions or modifications to radionuclide data is performed. Initially, the <Nuclide Data> tab will have the following appearance:
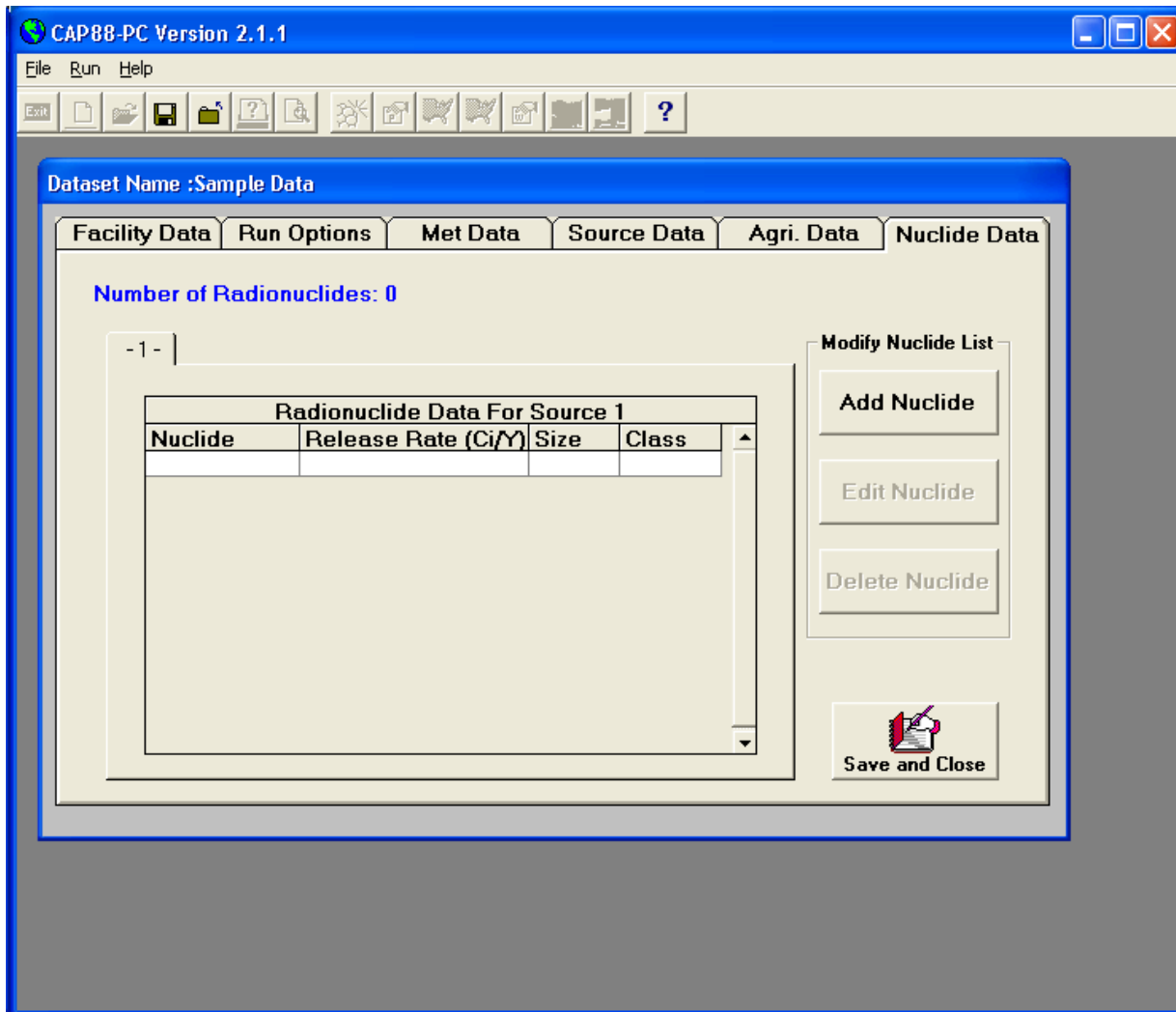
To begin adding nuclides, click <Add Nuclide>, which displays the nuclide data entry sub-form displayed in the next graphic. Use the Nuclide drop down list to select the first nuclide to be included in the analysis, which in the sample case is Am-241. After the nuclide is selected, the remaining three nuclide data fields are activated. Enter the release rate for the radionuclide (in Curies per year) from the currently selected source. Use 10 Ci/yr for the sample dataset. Note that in this example only one source tab is available on the form.

Select the particle size and the class for the release from their respective drop down lists, for the radionuclide. The only options available for the nuclides are those that are included in the CAP88-PC data environment, which is derived from the data contained in the RADRISK dose and risk coefficient files used by CAP88-PC. Since four radionuclides are used in the sample dataset, select <Enter/Add Another>

Repeat the selection process for U-238, Co-60, and Sr-90. When selecting U-238, the default particle size is 3 microns, which will need to be modified to 1 micron using the drop down list. Also, when adding U-238, a prompt will appear asking if you wish to add the rest of the U-238

decay chain. Do not add the decay chain for the sample problem dataset. A similar message will appear for Sr-90, but in this case add the decay chain, and CAP88-PC will automatically include the Y-90 progeny to the list.
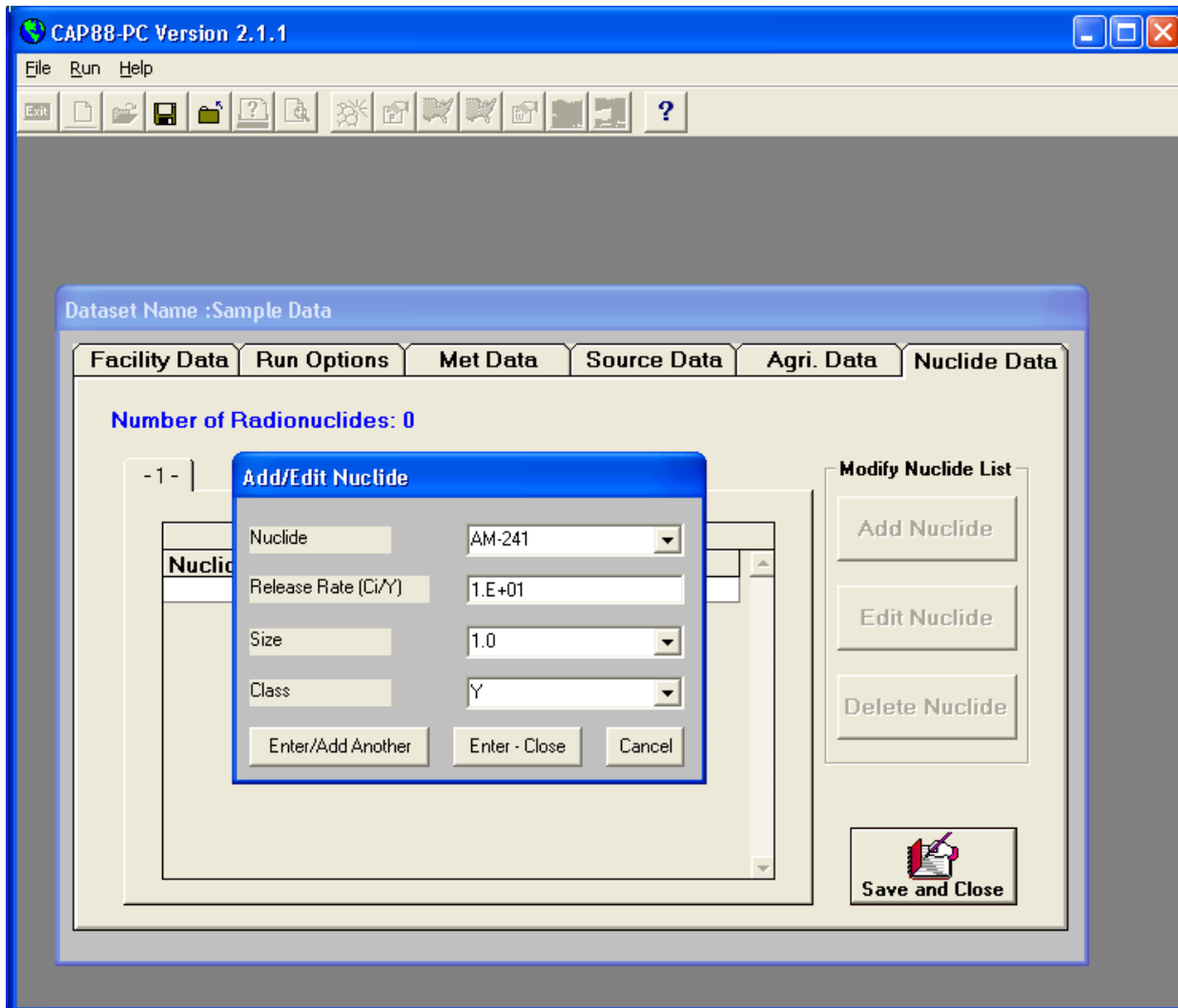
Following entry of the last nuclide, select <Enter-Close> to terminate entry of radionuclides and return to the <Nuclide Data> tab. If <Enter/Add Another> is erroneously used, clicking <cancel> will terminate entry of nuclide data but will not remove the previously entered information.

The <Nuclide Data> tab should now appear as follows:
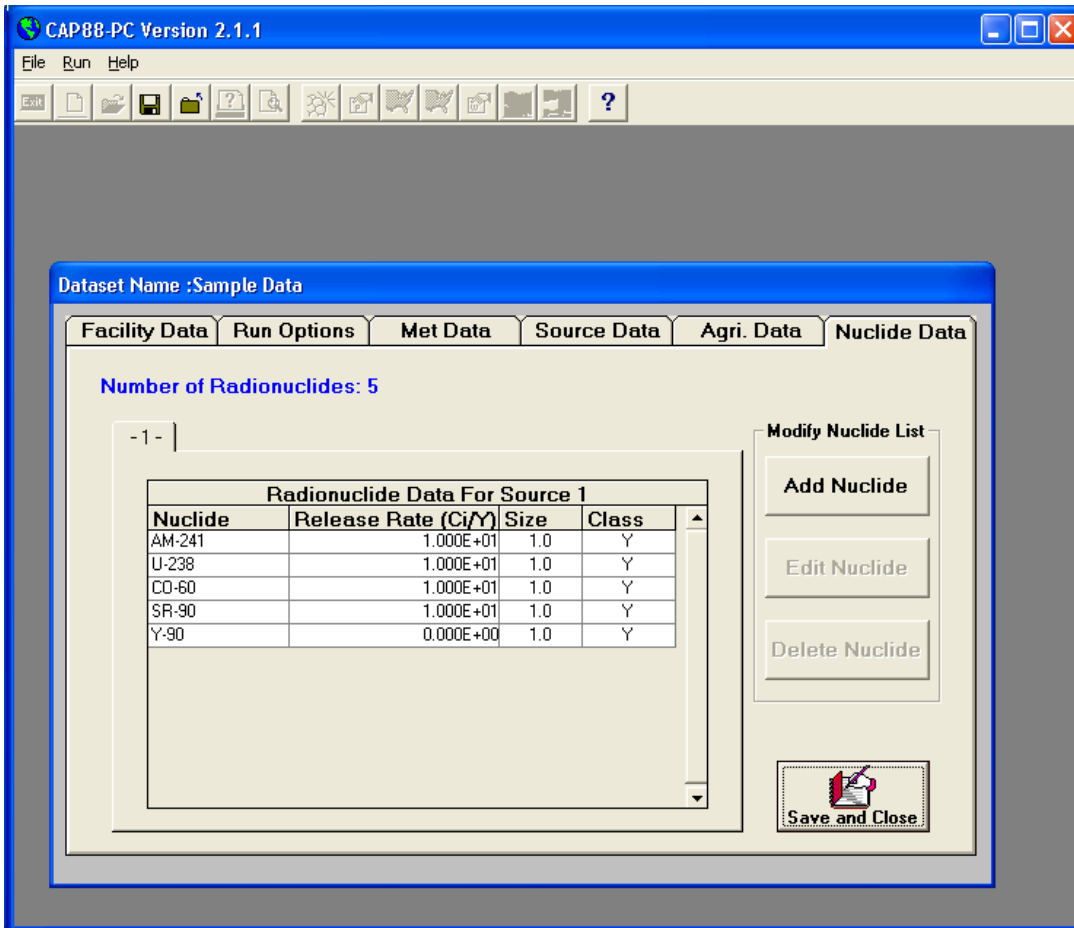
Once the data has been completely entered, click <Save and Close> to return to the initial startup form for CAP88-PC Version 2.1. At this time the dataset has been saved as the file named sample1.dat in the Datasets subdirectory of the Cap88-PC Version 2.1 installation directory. The case may be run by selecting <Run>, and <Execute> from the menu bar. Select the [Sample Data] dataset from the Dataset Name dropdown list, and then click <OK>. Output files will be written to the Output subdirectory, and are viewable within the code environment by clicking on the <print preview> icon on the button bar and selecting [Sample Data] from the dataset name dropdown list.

2.4   Uninstall CAP88-PC Version 2.1

The Uninstall process will uninstall only those files that were installed with CAP88-PC Version 2.1. Any extracted or created Population and Wind Files, as well as any Datasets and Output Files, will not be deleted. Uninstall is best performed using the Add/Remove Programs option in the Control Panel.

3. FILE MENU

3.1   New Dataset

Open a New Dataset by providing descriptive information in the New Dataset Information form and selecting OK. A set of six tabbed forms appears to assist in the preparation of an input file (dataset) containing the data needed to execute CAP88-PC.

3.2   Open Dataset

An existing dataset is selected and opened for review and modification. If the dataset name does not appear in the dataset list (down arrow), use the Maintenance option to locate and Restore an existing dataset.

3.3   Close Dataset

Close the open dataset without making any changes. Data revisions for a current session are made to a copy of the dataset. If Close Dataset is selected, the dataset will not have been updated, possibly resulting in a loss of data. If a New Dataset was opened, it will have been created and added to the dataset list, but will not have any data revisions saved.

3.4   Save Dataset

Save all data and any changes made to the opened dataset, using the filename of the opened dataset. The data entry tab forms are then closed. The user must save or close a dataset before the dataset may be used to execute the CAP88 Model (see Run/Execute).

3.5   Save Dataset As

Save all data and any changes made to the opened dataset, using the filename provided by the user. This operation creates a new dataset and a new file. The filename must be unique, or the file with the same name may be overwritten, with user approval.

3.6   Print Setup

This is a standard Windows form for reviewing and setting printer options. The Floating Toolbar can not be selected or moved when this form is open.

3.7   Print Preview

Select Print Preview to display and print CAP88-PC output reports. The output reports have the same filename as the dataset, but with CAP88-PC standard file extensions. Use the tabs on the Print Preview form to move from one report to another. Use the scroll bar to scroll down or up to view each report. When the Print Current View option is selected, the entire report shown in the tab window is printed. To print several reports at once, check the report boxes and choose the Print button.

3.8   Maintenance

There are two maintenance options, File Maintenance and List Maintenance. These options assist the user in archiving, deleting, restoring, and renaming Datasets, Population Files, and Wind Files, as well as maintain the lists that describe the Population Files and Wind Files.

3.9   File Maintenance

This menu item assists the user in archiving, deleting, restoring, and renaming Datasets, Population Files, and Wind Files. File Maintenance will perform the indicated operation and also maintain the file selection lists used in the data entry portion of the program. If the Windows File Manager is used to perform these operations, files selected from drop down lists may not be found.

3.10 List Maintenance

This menu item assists the user in maintaining Location Descriptions and Census Dates or Reference Dates, for Population Files and Wind Files, respectively. Select each file name and enter or revise descriptive information, then select OK to update the lists. If Cancel is selected, the lists will not be updated.

3.11 Convert SCR File

Use this option to locate, read, and reformat a dataset file (.SCR) that was created using the CAP88-PC Version 1 (DOS) program. CAP88-PC Version 2.1 stores and reads dataset files in the format of the INPUT.DAT file that is read by the FORTRAN programs comprising the CAP88 Model.

3.12 Create INPUT.DAT File

Some users will find difficulty executing the CAP88 FORTRAN programs from Windows (shell to DOS) due to the computer's memory constraints. The user may select this option to copy the selected dataset to a file named INPUT.DAT in the CAP88-PC working directory. (The working directory can be viewed in Windows by selecting the File/Properties menu item when the CAP88-PC 2.1 icon is highlighted.) The user then may exit Windows and, from DOS, change directory (CD) to the working directory and run the following programs to generate desired output (this order is mandatory for proper results):
DEFAULT,
AIRDOS,
DARTAB

After successful completion of these three programs, return to CAP88-PC Version 2.1 to view (Print Preview) the output files or view them from any text viewer.

3.13 Exit

Close all files and exit the CAP88-PC Version 2.1 program. Any open dataset should be saved or closed to exit the program properly.

4. RUN MENU

4.1 Execute

Run the CAP88 Model. Before actually executing the assessment, the program will check to make sure that you have selected the following items in the dataset: a State, a Population File (if the run is a population assessment), a Wind File, and at least one Radionuclide. If the preceding items are present, the program will execute the selected dataset by shelling out to DOS to run the FORTRAN programs DEFAULT, AIRDOS, and DARTAB. If one or more of the required data items are missing, a message will be displayed so you will know to modify the dataset accordingly. If, for some reason, a Population File or Wind File has been selected but no longer exists, a message will be displayed and the programs will not be executed. Note that the user may elect to just use the Windows interface to create the input file for that case, and then run the programs DEFAULT, AIRDOS, and DARTAB from the DOS environment. In this case, see Create INPUT.DAT File in section 3.12 for instructions.

4.2 Scan Population File Format

This menu item reads the indicated Population File and determines if the data is in proper format. No guarantees are made to the correctness of the data, though the distance increments are checked to be consecutively increasing.

The Population File Editor can be used to create or modify a Population File and maintain the proper file format. The Population file format should be as follows:

Row 1 should have a dollar sign ($) in the first column. The location description, latitude, and longitude on row 1 are for information only to verify that the file desired is the file the user has selected. The number of distances associated with the population file must be in columns 68 and 69. The number of distances may be any integer between 2 and 20; single digit distances (2-9) should be in column 69.

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 edgepoints of each sector (the midpoints used in the calculations will be 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 sample 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. Only distances up to 80 kilometers should be used. The assessment is not valid for distances above 80 kilometers.

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

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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.

4.3   Population File Editor

This utility program assists the user in creating or displaying a Population File. An 'empty' Population File, TESTDATA.POP is provided as a template for building a properly formatted Population File. Any Population File intended for use with a CAP88-PC dataset should be able to be read, displayed, or printed by this program.

4.4   Population File Library

This utility program provides Population Files that were distributed with CAP88-PC Version 1. The files in the library are stored in a compressed format. Choose a location from the grid by clicking (highlighting) the grid row and download the Population File by selecting the Extract button. The Extracted Population File is in the proper format to be used by CAP88-PC.

4.5   Scan Wind File Format

This menu item reads the indicated Wind File and determines if the data is in the proper format. No guarantees are made as to the correctness of the data, though the sum of frequencies is checked. Frequencies should sum to 1.0000, within a tolerance of 0.0005 for rounding. The format of a Wind File is as follows:

Record 1 - three hexadecimal file marks are written by the GETWIND program. This record is ignored.
Record 2 - average wind speed (not used). [0000.00000]
Record 3 - wind direction frequency totals for each of the 16 wind directions. [0.0000] The numbers on this record should sum to 1.0000 within a tolerance of .0005 for rounding.
Records 4 through 10 - each record has 16 reciprocal-averaged wind speeds, for each of the 7 stability categories. [0.000]
Records 11 through 17 - each record has 16 true-averaged wind speeds, for each of the 7 stability categories. [0.000]
Records 18 through 33 - each record has frequencies for the 7 stability categories, for each of the 16 wind directions. [00000.0000] The numbers on these 16 records should sum to 1.0000 within a tolerance of .0005 for rounding.

4.6   Wind File Library

This utility program provides Wind File data for many National Weather Service (NWS) stations in a compressed format. The Wind File Library also contains the meteorological data issued with CAP88-PC Version 1. Choose a weather station from the grid by clicking (highlighting) the grid row and download the station file by selecting the Extract button. The Extracted Wind File is in the proper format to be used by CAP88-PC.

4.7   Stability Array/Wind File Generator

The STAR Distribution Program assists the user in extracting and processing National Climactic Data Center (NCDC) or site-specific meteorological data based on several popular methods. Each of the processing methods creates a Stability Array file (.STR) that is then used to create a Wind File for input to CAP88-PC. If the user is not an experienced meteorologist-modeler, it is strongly suggested that the user work with a meteorologist-modeler to prepare NCDC or on-site meteorological data for input to CAP88-PC.

There are 96 records in the Stability Array file, one for each of the 16 wind directions (N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, and NNW) and Stability Category (A-F) Sixteen records are entered for Stability Category A, then Stability Category B, etc., through Stability Category F. Stability Classes used for CAP88-PC are: A - extremely unstable, B - unstable, C - slightly unstable, D - neutral, E - slightly stable, and F - stable.

All records are of the same format. The total of all the frequencies entered on the 96 records should add to 1.00000 within a tolerance of .05 percent. The format of a Stability Array (STAR) record follows:

Column 1 is blank.
Columns 2-4 contain the wind direction, right justified (E would be in column 4, and NE would be in columns 3 and 4). Column 5 is blank.
Column 6 contains the Stability Category, A through F.
Column 7 is blank.
Columns 8-14 contain the frequency for winds 1-3 knots (for example 0.00041).
Columns 15-21 contain the frequency for winds 4-6 knots.
Columns 22-28 contain the frequency for winds 7-10 knots.
Columns 29-35 contain the frequency for winds 11-16 knots.
Columns 36-42 contain the frequency for winds 17-21 knots.
Columns 43-49 contain the frequency for winds greater than 21 knots.

Once a Stability Array file has been created, use the button Create Wind File for CAP88-PC to run the program which converts the STAR file to a Wind File for input to CAP88-PC. A common dialog box will appear for the user to identify the STAR file to be converted. The Create Wind File option runs the program WINDGET.EXE. WINDGET.EXE is identical to the GETWIND.EXE program used by CAP88-PC Version 1, but is now compatible with the filenames and pathnames provided by the call from a Windows program.

For the format of a Wind File, see Scan Wind File Format.

5. NEW DATASET INFORMATION

5.1   New Dataset Information Form

Use this form to locate, name, and describe the dataset to be created. A new dataset is created, even if the user later closes a file without saving changes.

Drive, Dataset

Select a drive that the new dataset will be copied to. The current drive is suggested. Choosing a network drive or a floppy drive that will not always be available to the program will create an error if the drive is not found when the dataset is selected again for modification or execution.

Directory, Dataset

Select a directory that the New Dataset will be copied to. The datasets subdirectory in the program directory is suggested. Change the directory chosen by double-clicking on the main directory and selecting the desired subdirectory.

Name, Dataset

Enter a Dataset Name, up to 20 characters; do not use apostrophes or double quotes. This name will appear in the drop down list on the Select Dataset screen, and in the label of the data entry tabbed forms. The Dataset Name should be descriptive enough to allow accurate selection of a Dataset.

Filename, Dataset

Enter a Dataset Filename, up to 8 characters. This filename must not contain any spaces, piping (vertical dashes), or asterisks, as these are not valid for DOS naming conventions. This filename must be unique in the directory in which it will be created.

Comment, Dataset

Enter Comments, up to 50 characters. Do not use an apostrophe or double quotes, all other characters and spaces are allowed. The Comments should accurately describe the assessment scenario.

Comment Additional, Dataset

Enter Comments, up to 50 additional characters. Do not use an apostrophe or double quotes, all other characters and spaces are allowed. The Comments should accurately describe the assessment scenario.

Cancel Button

Select the Cancel button to exit the New Dataset form without creating a new Dataset.

OK Button

Select the OK button to create the New Dataset with the parameters defined. The New Dataset Information form will be closed and the CAP88-PC data input tab forms will appear.

6. SELECT DATASET INFORMATION

6.1   *Select Dataset Form*

Use this form to select a dataset for the desired operation. Except for the Dataset Name List, all other fields on this form are read-only and will be filled with appropriate data when a dataset is selected. When the code is run for the first time, no datasets may be available for opening. In this case, the code will produce a message box stating that no datasets are available in the system, and asking if you wish to open from a dataset input file stored elsewhere in the system or if you wish to create a new dataset. If you choose to open a dataset stored elsewhere on the system, you will be provided a file selection box from which you can navigate to the directory where your dataset input file is stored. The default location for stored dataset input files is the Datasets subdirectory of the install directory.

Name List, Dataset
Click on the down arrow to display the list of datasets recognized by CAP88-PC. Select a dataset name from the list by clicking once on the name. To add a dataset to the dataset name list, either open a new dataset or use the file maintenance function to restore an existing dataset.

Cancel Button, Select Dataset
Close the Select Dataset form, without performing the desired operation.

OK Button, Select Dataset
Use the selected dataset for the desired operation. The Select Dataset form will be closed and the CAP88-PC data input tab forms will appear.

7. PRINT/VIEW

7.1   Print/View

Use this form to view CAP88-PC Output Reports and select which reports, if any, will be printed.

Tabs, Output Report
Click on these tabs to change the CAP88-PC Output Report being displayed. If a tab is missing, that report was not created, or was deleted from the directory. Return to the Run Option tab of the data entry form to view report selection information. If necessary, select a new report option (Yes/No), save the data, and re-execute CAP88-PC.

Print Check Boxes , Output Report
Select the boxes next to the report names for reports to be printed (in their entirety). An X will appear in the selected box. Click again to remove the X and un-select a report. The selected reports will not be sent to a printer until the Print button is selected.

Print Current View Button
Print the entire CAP88-PC Output Report shown in the view window. Partial reports cannot be printed with this viewer. If partial reports are desired, another text editor may be used to view and print relevant portion of the report.

Cancel Button, Print Preview
Close the Print Preview form.

Print Button
Any Output Reports for the dataset that have an X in the check box will be printed (in their entirety).

8. MAINTENANCE OPERATIONS

8.1 File Maintenance Operations Form

The File Maintenance Operations described below will perform the operation described as well as maintain the drop-down file lists supported by CAP88-PC Version 2.1. **Warning:** Using the Windows File Manager to perform these operations will result in the drop-down file program lists not accurately reflecting the true list of available files. Files deleted using the Windows File Manager will not be found when selected from the Dataset list, the Population File list, or the Wind File list. Files renamed or copied using the Windows File Manager will not appear in the Dataset list, Population File list, or the Wind File list until Restored using this option.

Archive, Delete, Restore, Rename
Select the operation to be performed. Archive will copy the selected file(s) to a location (diskette, directory, etc.) indicated by the user and remove the filename from any lists maintained by the CAP88-PC Version 2.1 program. Archive does not compress the files (all CAP88-PC files, excluding Output Reports, are rather small text files). Delete will erase file(s) from the location selected and removes the filename(s) from the Dataset list, Population File list, or Wind File list, as appropriate. Restore copies file(s) from another location and adds the filename(s) to the Dataset list, Population File list, or Wind File list, as appropriate. Restore checks each filename to be restored for uniqueness, and will ask before overwriting a file with the same name. Rename changes the name of the file indicated by the user and revises the Dataset list, Population File list, or Wind File list, as appropriate. For example, the user may wish to rename Wind Files extracted from the Wind File Library to change the filename from the Station ID to a city or location name that is more easily recognizable.

Select Type of File for File Maintenance Operation
Selection of the Dataset file type will allow the user to select an existing dataset from the Dataset Name list. Selection of the Dataset file type will also perform the identical operation on any Output Report files that exist for the Dataset. Selection of the Population File type will remove from, add to or revise the Population File list when files are deleted, restored, or renamed. Selection of the Wind File type will remove from, add to or revise the Wind File list when files are deleted, restored, or renamed. Use the List Maintenance option to revise file descriptions and date information for the Population Files or Wind Files.

Cancel Button, Select Maintenance Operation
This closes the Select Maintenance Operation form.

OK Button, Select Maintenance Operation
If both a File Maintenance Operation and a File Type have been selected, the OK button will submit the request and the appropriate form will appear for selecting the particular file to be altered. If either the File Maintenance Option or the File Type has not been selected, an error message will appear.

8.2   Select File

Select a file from the current directory or locate a file in another directory.

Population File Directory
Choose this option if the Population File appears in the Population File list in the current directory. The current directory is a subdirectory named Popfiles that is subordinate to the directory where CAP88-PC Version 2.1 was installed.

Custom Population File
Choose this option to locate a Population File in a directory other than the Popfiles subdirectory. The user is provided a form to select a drive, directory, and filename for the desired file.

Population File List
If the Population File resides in the Population File Directory, a Population File list will be displayed and a Population File may be chosen from that list. If the Population File is not in the default directory, then select the Locate button to choose the drive and directory of the desired file.

Wind File Directory
Choose this option if the Wind File appears in the Wind File list in the current directory. The current directory is a subdirectory named Wndfiles that is subordinate to the directory that CAP88-PC Version 2.1 was installed to.

Custom Wind File
Choose this option to locate a Wind File in a directory other than the Wndfiles subdirectory. The user is provided a form to select a drive, directory, and filename for the desired file.

Wind File List
If the Wind File resides in the Wndfiles subdirectory, a Wind File list will be displayed and a Wind File may be chosen from that list. If the Wind File is not in the current directory, then select the Locate button to choose the drive and directory of the desired file.

Cancel Button
Close the Select File form.

OK Button
If a filename appears on this form, the next archive form will appear. If no file has been selected, an error message will appear.

8.3   Save File As Form

Change the name of the file if desired. The name of the selected file appears at the top of the form.

Dataset Filename
Filenames are limited to 8 alphanumeric characters and exclude blanks, asterisks, and pipe (vertical dishes) characters.

Population Filename
Filenames are limited to 8 alphanumeric characters and exclude blanks, asterisks, and pipe (vertical dashes) characters.

Wind Filename
Filenames are limited to 8 alphanumeric characters and exclude blanks, asterisks, and pipe (vertical dashes) characters.

Cancel Button
Close the Save File As form.

OK Button
Perform the desired operation.

8.4   Change List Information Form

Use this form to enter list information for both the Population File list and the Wind File list. NO CHANGES ARE MADE UNTIL THE OK BUTTON IS SELECTED, at which time both the Population File list and the Wind File list are updated. If changes are made and the Cancel button is selected, THE LISTS WILL NOT BE UPDATED.

Population File Directory
Choose this option to change the list of Population File information (description and census date) for files in the Popfiles subdirectory.

Population File List
Select the down arrow to display and select the Population File description and census date to be displayed and altered.

Population File Description
Enter a location description, limited to 36 characters, which will identify the Population File.

Population File Census Date
Enter the year that the population assessment was performed.

Wind File Directory
Choose this option to change the list of Wind File information (description and reference dates) for files in the Wndfiles subdirectory.

Wind File List
Select the down arrow to display and select the Wind File description and reference dates to be displayed and altered.

Wind File Description
Enter a weather station description, limited to 36 characters, which will identify the Wind File.

Wind File Period of Record
Enter the year(s) that meteorological data was collected for frequency distribution analysis.

Cancel Button
Close the Change List Information form, WITHOUT updating either the Population or Wind File lists.

OK Button
Close the Change List Information form, after updating both the Population File list and the Wind File list.

9. DATASET DATA

9.1 Facility Data

The Facility Data tab form is used to describe the facility and time period to be modeled. On the Facility Data tab form, a State must be selected from the list provided. The State selected will determine the agricultural values used on the Agricultural Data Tab Form. After all known Facility Information is entered, use the Page Down key to advance to the next tab form.

Facility Name (Optional)
The Facility Name is used for identification purposes only. The Facility Name appears on each Output Report.

Address Line 1 (Optional)
The Facility Address (line 1) appears on each Output Report

Address Line 2 (Optional)
The Facility Address (line 2) appears on each Output Report

City (Optional)
The City that the Facility is located in or near appears on each Output Report.

State Name (Required)
The State name is required because it is used by the program to establish values for agricultural arrays of beef cattle, milk cattle, and crop production according to EPA-accepted state-wide averages. A state name must have been selected for an assessment to be executed. State names are chosen from a list box, which appears when you click on the down arrow when the state field is selected. To use the list box search feature, press any letter key and the list box automatically goes to the first state beginning with that letter. Selection of Hawaii, Alaska, or the District of Columbia will result in zeros being loaded on the Agricultural Data tab form.

Zip Code (Optional)
Enter the Zip Code and Zip+4 Code, if known.

Emission Year (Optional)
Choose the year in which the radionuclide emissions occurred from the drop down list. If a year is desired that is not in the drop down list, advanced users can use a database file editor to add the year to the YEAR table in the DATA.mdb Access database in the Data subdirectory.

Source Category (Optional)
The Source Category is for information only. No particular category is enforced at this time.

Comments Line 1 (Optional)
Comments are restricted to 50 characters and appear on the first page of each Output Report. Comments also appear on the Select Dataset form for additional identification of the dataset.

Comments Line 2 (Optional)
Comments are restricted to 50 characters and appear on the first page of each Output Report.
Comments also appear on the Select Dataset form for additional identification of the dataset.

9.2   Run Options

The Run Options tab form is used to describe the population to be assessed and select optional
output tables and reports. CAP88-PC Version 2.1 uses population arrays in the same format as the
mainframe CAP88 program. A sample population assessment is provided with CAP88-PC Version
2.1. Other population assessments may be downloaded from the Population File Library. Users are
encouraged to create their own population arrays using the Population File Editor supplied with the
CAP88-PC Version 2.1 program. Census data or population survey data should be obtained for the
facility and area to be modeled.

Assessment Run Type
The Assessment Run Type must be selected to determine the source of the population data. If an
Individual Assessment is chosen, the midpoint distances for the assessment areas must be entered.
If a Population Assessment is chosen, the data will be read in from a Population File. The
Population File may be selected from the drop down list.

Location Index of Exposed Individual
When the Individual Assessment is chosen, a button labeled "Location Index of Exposed
Individual" will be shown on the screen. Users can click this button to open the "Location Index of
Exposed Individual" screen. There are two input boxes to let users enter a direction index and a
distance index for the exposed individual. The default values for these indices are 0, which means
that users let CAP88 to calculate the maximum exposed individual. Note that these values are
sector information, not distances in meters. Circumferential sectors are denoted 1 to 16, with 1
being N, 2 being NNW, and 16 being NNE. Radial sectors are denoted as 1 to j, where j is a
number corresponding to the midpoint distances input by the user.

Population File Directory
A Population File is required for a Population Assessment Run Type. The Population File Editor in
the Run Menu can be used to generate a Population File in the proper format. Note that when a
population is created manually, the distances entered in the population file are endpoint distances
for each sector; these are converted to midpoint distances by CAP88-PC. Also, a sample population
assessment may be extracted from the Population File Library, which will place that population file
name in the population file dropdown list.   Population Files that are in the population file
dropdown list are assumed by the code to be located and maintained in the Popfiles subdirectory.
Alternatively, population files can be selected from another directory by choosing the Custom
Population File option.

Custom Population File

If the Population File resides anywhere except in the Popfiles subdirectory, choose this option and select the Locate button to locate and select the Population File for the assessment. The default initial directory for this directory locator box is the POPLIB subdirectory of the CAP88-PC installation directory. This subdirectory contains the distribution library of population files available for extraction. To get a Custom Population File into the Population File Directory, use the File Maintenance option to Restore a Population File, and then use the List Maintenance option to record the population description or location and census date (year of population estimation, adjustment or assessment). Note that it is not required that the population file be located in the Popfiles subdirectory (see below).

Population File Location

Enter the drive, directory, and filename of the desired Population File or select the Locate button to browse the drives and directories to locate the Population File to be used for the assessment.

Generate Genetic Effects?

If No is selected, genetic effects tables will be suppressed in the Synopsis (.SYN) Output Report.

Create Dose and Risk Factor File?

Select Yes to generate a Dose and Risk Factor Output Report file (.FAC) when this assessment is used to execute CAP88-PC. Dose and Risk are estimated by combining the inhalation and ingestion intake rates, air and ground surface concentrations with the dose and risk conversion factors used in CAP88-PC. The effective dose equivalent is calculated using the weighting factors in ICRP Publication 26. Risks are based on lifetime risk from lifetime exposure, with a nominal value of 4E-4 cancers/rem. Doses and risks can be tabulated as a function of radionuclide, pathway, location and organ. CAP88-PC also tabulates the frequency distribution of risk, showing the number of people at various levels of risk. The risk levels are divided into orders of magnitude, from one in ten to one in a million. 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 cannot be used for either short-term or high-level radionuclide intakes.

Create Concentration Table File?

Select Yes to generate a Concentration Table Output Report file (.CON) when this assessment is used to execute CAP88-PC. The Concentration Table may be quite large if many radionuclides are selected. Radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food and intake rates to people from ingestion of food produced in the assessment area are calculated by the model. Estimates of the radionuclide concentrations in food, leafy vegetables, milk and meat consumed by humans are made by coupling the output of the atmospheric transport models with the US Nuclear Regulatory Commission Regulatory Guide 1.109 terrestrial food chain models.

Create Chi/Q Table File?

Select Yes to generate a Chi/Q analysis (.CHI) of the scenario provided for execution of CAP88-PC. Chi/Q values are used to convert radionuclide release values to concentrations.

Midpoint Distances

Midpoint distances are required for an Individual Assessment. These distances are the distances at which the doses and risks are calculated, in meters. The distances must be integers between 1 and 80000 meters (inclusive). A message will be displayed if you enter a distance outside this range. At least one distance must be entered for the dataset to execute. If no distances are entered, the AIRDOS program will abort. The distances entered in the cells 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. Cells (at the end) may be left blank after the midpoint distances have been entered.

Population File List

Select the down arrow to see the descriptive information and Population File names in the Popfiles subdirectory.

Locate Button

Select this button to get a form to browse the drives and directories for a particular Population File.

9.3   Meteorological Data

The Meteorological Data Tab Form is used to supply site meteorological data for the dispersion modeling.

Wind File Directory

A Wind File is required for CAP88 execution. The Wind File Library in the Run Menu can be used to obtain a Wind File in the proper format. These Wind Files were created from the National Weather Service data which is available for many weather station sites. If the user has on-site meteorological data, select the Stability Array Distribution program in the Run Menu to process and convert on-site data to a properly formatted Wind File. Wind Files can be located and maintained in the Wndfiles subdirectory, or can be located by choosing the Custom Wind File option.

Custom Wind File

If the Wind File resides anywhere except in the Wndfiles subdirectory, choose this option and select the Locate button to locate and select the Wind File for the assessment. The default initial directory for this directory locator box is the WINDLIB subdirectory of the CAP88-PC installation directory. This subdirectory contains the distribution library of wind files available for extraction. To get a Custom Wind File into the Wind File Directory, use the File Maintenance option to Restore a Wind File, and then use the List Maintenance option to record the location and dates for which the meteorological data was collected. Note that it is not necessary to use a wind file that is located in the Wndfile subdirectory (see below).

Wind File Location

Enter the drive, directory, and filename of the desired Wind File or select the LOCATE button to browse the drives and directory to locate the Wind File to be used for the assessment.

Annual Precipitation

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

Annual Ambient Temperature
Enter the average annual ambient temperature (in degrees Celsius) at or near the site. Temperatures above 200 degrees are assumed to be in degrees Kelvin and will be converted and shown as degrees Celsius when the dataset is re-opened.

Height of Lid
This value represents the height of the troposphere mixing layer (in meters) at or near the site. This field must contain a positive non-zero value. A zero value will cause the AIRDOS program to abort when the dataset is executed.

Absolute Humidity (New in Version 2.1)
Enter the absolute humidity in air (in grams per cubic meter) at or near the site. This value is used for the dose and risk calculation of tritium ingestion. This field must contain a positive non-zero value. A zero value will cause the AIRDOS program to abort when the dataset is executed.

9.4   Source Data

The Source Data Tab Form 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. In the CAP88-PC implementation of the Gaussian Plume model, area sources are treated as uniform and 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.

Number of Sources
Up to six (6) 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.

Area Dimensions
This value is the height (in meters) and area (in square meters) of the Area Source.

Plume Rise 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 Rise for Pasquill Categories

Plume Rise for each Pasquill Category for a Fixed Plume Rise Type. Enter the actual plume rise (in meters) for each of the seven Pasquill Categories (A through G) if a Fixed Plume Rise Type is selected. If a Zero Plume Rise Type is selected, zero is entered for each of the seven Pasquill Categories (A through G), and no further action is required.

Heat Release Rate or Exit Velocity
Enter the heat release rate (in calories per second) for a Buoyant Plume Rise Type or enter the exit velocity (in meters per second) for a Momentum Plume Rise Type.

Stack Dimensions
This parameter specifies height (in meters) and diameter (in meters) of each stack or point source.

9.5   Agricultural Data

The Agricultural Data Tab Form is used to enter agricultural factors which will be applied to the dispersion data to estimate uptake of emitted radionuclides into the food chain.

EPA Food Source Scenarios
Selection of each EPA Food Source Scenario (Urban, Rural, Local, Regional, and Imported) will result in different fractions appearing in the 9 cells which describe the fraction of Vegetable, Milk, and Meat produced in the area, or imported to the area. The 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 or the user will be asked to re-enter the fractions or make another scenario selection.

EPA Food Source Scenarios - Fractions
Selection of each EPA Food Source Scenario will result in different fractions appearing in the 9 cells which describe the fraction of Vegetable, Milk, and Meat produced in the area or imported to the area. These 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, otherwise, the user will be asked to re-enter the fractions or make another scenario selection.

Beef Cattle Density
Sample distributions of beef cattle density 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. Using zero in this field will result in an error when the program is executed.

Milk Cattle Density
Sample distributions of milk cattle density 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. Using zero in this field will result in an error when the program is executed.

Land Fraction Cultivated for Vegetable Crops

Sample distributions of 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. Using zero in this field will result in an error when the program is executed.

9.6   Nuclide Data

The Nuclide Data Tab Form is used to display, select, and describe characteristics of the radionuclides emitted by each source. Information for a source is entered by first selecting the tab number corresponding to the source number. Radionuclide data for that source is then entered or modified using the Add/Edit Nuclide subform to this Nuclide Data Tab Form. To access the Add/Edit Nuclide subform, use the Add Nuclide button or the Edit Nuclide button located to the right of the nuclide data display table.

The <Save And Close> button on this form will save the current dataset using the dataset filename entered when the dataset was first opened for creation.

Nuclide List
At least one nuclide should be selected, otherwise the dataset will not be saved or executed (the dataset may, however, be closed). After clicking the Add Nuclide button, select a nuclide from the drop down list by clicking on the down arrow in the nuclide field and entering the first letter of the nuclide name. The list will jump to nuclides starting with the letter selected. Click on the nuclide name to be added. Nuclide names appear for each emitting source, but a release rate of zero will show that the nuclide is not emitted from a particular source. If the nuclide selected is a member of a chain, a message will appear to request if the nuclide will be treated as an individual or whether the chain members should be entered (see below). After each nuclide is selected, the nuclide's release rate, size and class information may be entered using their respective data entry fields or drop down selections. The nuclide size and class data applies to the nuclide emitted from every source. It is recommended that the user verify the applicability of the default size and class values prior to running the analysis.

Once data entry for a nuclide is complete, use the <Enter/Add Another> button to continue with another nuclide, or select Enter-Close to complete data entry for the last nuclide.

Adding Chains
Two complex chains of nuclides may be selected: U-238, Uranium; and Th-232, Thorium. CAP88 accounts for the buildup of decay products in each of the complex chains. There are also ten simple chains which each have one decay element: Cs-137, Cesium ; Ba-140, Barium; Mo-99, Molybdenum; Pb-210, Lead; Pu-241, Plutonium; Sr-90, Strontium; Zr-95, Zirconium; Ru-103, Ruthenium 103; Ru-106, Ruthenium 106; and Ce-144, Cerium. When one or more of these radionuclide chains are selected, a dialogue box will appear with the information that the nuclide is the beginning of a chain, and asking if the chain should be added. If Yes is selected, the entire chain will be added to the list. If No is selected, only the individual nuclide will be added to the list.

Nuclide Release Rate

The release rates can be entered in decimal or exponential notation. If a source does not emit a nuclide in the list, the Release Rate will be zero for that source.

Particle Size
The default particle size will appear for the selected nuclide. Select the down arrow to change the particle size, if necessary. Select one of the allowed Activity Medium Aerodynamic Diameter Micrometers (AMAD) for particulates. Particle size (AMAD) in micrometers for inhaled particles is 0.0, 0.3, 1.0, or 3.0. Some nuclides are restricted in their particle size allowances, and gases get a particle size assignment of 0.

Nuclide Class
Select one of the allowed lung clearance classes for inhaled particles. If a Class field contains 'None', then class is not applicable to that particular radionuclide. After each nuclide has been selected, the default clearance class appears. Some nuclides are restricted in their clearance class allowances. Use the drop down list as a guide to the valid classes for each nuclide.

10. DEFAULT FILE CHANGES

10.1   *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.

10.1.1 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).**

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.**

10.1.2 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.

10.2   *Changeable Defaults*

10.2.1 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

Meteorological Defaults

VARIABLE	UNITS	DEFAULT	DESCRIPTION
TG	^{N}K/m	.0728 .1090 .1455	Vertical temperature gradient for Pasquill categories E, F, and G (three element array)

Default Rates

BRTHRT	cm^3/hr	9.167E+5	Inhalation rate of man
DD1		0.5	Fraction of radioactivity retained on leafy vegetables and produce after washing
UF	kg/yr	85.0	Ingestion rate of meat by man
UL	kg/yr	18.0	Ingestion rate of leafy vegetables by man
UM	liter/yr	112.0	Ingestion rate of milk by man
UV	kg/yr	176.0	Ingestion rate of produce by man

Water Defaults

DILFAC	cm	1.0	Depth of water for dilution for water immersion doses
USEFAC		0.0	Fraction of time spent swimming

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)
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

<u>Miscellaneous Input Values</u>

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

10.2.2 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.

10.2.3 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. 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

```
                    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:
```

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.

10.2.4 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.

10.3   *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

> 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.

can only be changed at the direction of EPA.

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.

11. CONVERTING WEATHER DATA WITH GETWIND

11.1   Purpose

GETWIND is a utility program that allows users to customize CAP88-PC by supplying their own meteorological data, in stability array (STAR) format, to the selection of weather data files. A listing of weather data provided with CAP88-PC is provided in Appendix D. Users are encouraged to use site-specific weather data.

See Appendix B for an example of the STAR (Stability Array) format. The file SAMPLE.STR, which is included with CAP88-PC, also contains a copy of this STAR format file. This file can be used as a guide for creating meteorological files in STAR format.

11.2   Program Input

The user must supply the program with the name of the file that contains the STAR formatted meteorological data and the name of the file that will contain the converted STAR data (the CAP88-PC wind data file).

It is assumed that all the data files used by this program reside in the same directory as GETWIND. For this reason space is provided for only 12 characters name with a three character extension. Create or copy your file containing the STAR formatted meteorological data to your directory which contains GETWIND and run the program.

All valid DOS file names are accepted by the program, subject to the length restriction. However, file names must end with the extension ".WND", and be copied to the CAP88PC\WNDFILES subdirectory on your hard disk, in order to be recognized by CAP88-PC.

11.3   Program Output

Converted STAR wind data is written to the file specified by the user. It is a valid CAP88-PC wind file and can be chosen as a wind data file from the list box which is available in the Meteorological Data screen, provided a copy of the file is made to the CAP88PC\WNDFILES subdirectory on your hard disk.

11.4   Running GETWIND

Use DOS to get into the directory where the GETWIND.EXE program resides. Make sure that a copy of the file to be converted for use by CAP88-PC resides in this same directory.

To run the program, type:

      GETWIND <**Enter**>

The following message appears:

THIS PROGRAM CONVERTS STAR FORMAT WIND DATA

TO AIRDOS-EPA FORMAT

FILE WHICH CONTAINS THE WIND DATA TO BE CONVERTED:

<CNTRL> BREAK   TO ABORT

Enter the name of the file and press <enter>. If you have entered a valid DOS file name and the file can be found in the current directory, the following message is then displayed:

      FILE TO CONTAIN THE AIRDOS FORMATTED WIND DATA
      MUST HAVE THE EXTENSION .WND

Enter the name of the file that will contain the converted meteorological data. This is the file that you will be able to select in the list box located in the Meteorological Data input screen. If the file name already exists, the following message is displayed on the screen:

      WARNING OUTPUT FILE ALREADY EXISTS
      DO YOU WANT TO OVERWRITE IT? (Y/N):

Enter <**Y**> or <**y**> to overwrite the file. Press any other key to allow you to enter another file name.

While the data is being read and converted, informative messages are displayed on the screen. When the program is finished you will be returned to DOS.

Pressing <**ctrl**> <**break**> together at any time will cause the program to abort, and you will be returned to DOS.

11.5   Error Messages

FILE NAME CANNOT BE GREATER THAN 12 CHARACTERS
PRESS ANY KEY TO CONTINUE

If you type in a file name that has more than 12 characters, the above message is displayed. A DOS file name can only have eight characters followed by a '.' and a three character extension. Think of a shorter file name and enter it again.

ERROR INPUT FILE DOES NOT EXIST...
PRESS ANY KEY TO CONTINUE

If the name of the input file which contains the meteorological data cannot be

found in the current directory, the above message is displayed. Make sure you have spelled the name of the file correctly, and that it is located in the current directory.

FILE EXTENSION MUST BE .WND
PRESS ANY KEY TO CONTINUE

If the name of the file entered that is to contain the converted meteorological data does not end in '.wnd', the above message is displayed. All CAP88-PC wind data files must have the file extension '.wnd'. These are the only files that will be displayed for selection in the list box in the Meteorological Data input screen. Retype the file name and make sure the file extension is '.wnd'.

12. MATHEMATICAL MODELS

The purpose of this chapter is to present the 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.

12.1 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.

12.1.1 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:

$$\Delta h = \frac{1.5 \ vd}{\mu} \qquad \text{(Equation 1)}$$

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:

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

where:

Δh = plume rise [PR]
F = $3.7 \times 10^{-5} \ Q_H$
Q_H = heat emission from stack gases (cal/sec) [QH]

$$x \quad = \quad \text{downwind distance (m)}$$
$$\mu \quad = \quad \text{wind speed (m/sec)} \ [U]$$

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:

$$\Delta h \quad = \quad \frac{1.6 \, F^{1/3} \, (10h)^{2/3}}{\mu} \qquad\qquad \text{(Equation 3)}$$

Equation (2) is also used to a distance of $X = 2.4 \, \mu S^{-\frac{1}{2}}$ 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:

$$\Delta h \quad = \quad 2.9 (F/\mu S)^{1/3} \qquad\qquad \text{(Equation 4)}$$

in which:

$$S \quad = \quad (g/T_a)(dT_a/dz + \Gamma) \qquad\qquad \text{(Equation 5)}$$
$$g \quad = \quad \text{gravitational acceleration (m/sec}^2)$$
$$T_a \quad = \quad \text{air temperature (}^o\text{K)} \ [\text{TEMPERATURE}]$$
$$dT_a/dz = \quad \text{vertical temperature gradient (}^o\text{K/m)} \ [\text{TG}]$$
$$z \quad = \quad \text{vertical distance above stack (m)}$$
$$\Gamma \quad = \quad \text{adiabatic lapse rate of atmosphere (0.0098}^o\text{K/m)}$$

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.

12.1.2 Plume Dispersion

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

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

(Equation 6)

where:

χ = 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 χ 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:

$$\chi = \frac{Q}{\pi\,\sigma_y\,\sigma_z\,\mu}\exp[-\tfrac{1}{2}(H/\sigma_z)^2]$$

(Equation 7)

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

$$\chi_{ave} = f\chi$$

(Equation 8)

where f is the integral of the exponential expression:

$$\exp[-\tfrac{1}{2}(y/\sigma_y)^2]$$

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^o sector, which is the value of the downwind distance, x, multiplied by the tangent of half the sector angle. The expression is:

$$f = \frac{\int_0^\infty \exp\left[-\left(0.5/s_y^2\right)y^2\right]dy}{y_s} \qquad \text{(Equation 9)}$$

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

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

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

$$f \quad = \quad \frac{6.300836 \, \sigma_y}{x} \qquad \text{(Equation 10)}$$

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

$$\chi \quad = \quad \frac{Q}{0.15871 \, \pi \, x \, \sigma_z \, \mu} \, \exp[-\tfrac{1}{2}(H/\sigma_z)^2]$$

$$\text{(Equation 11)}$$

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 $s_z = 0.47$ 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:

$$c_{ave} = \int_0^\infty \frac{c}{L}dz \qquad \text{(Equation 12)}$$

where χ is taken from Equation (6) and L is lid height. The value of H in Equation (6) may be set at zero since χ_{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):

$$c_{ave} = \left(\frac{1}{L}\right)\int_0^\infty \left(\frac{Q}{ps_y s_z}\right)\exp\left(\frac{-z^2}{2s_z^2}\right)\exp\left(\frac{-z^2}{2s_y^2}\right)dz \qquad \text{(Equation 13)}$$

The result is:

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

(Equation 14)

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

$$\chi_{ave} \quad = \quad Q/(0.397825 \times L\ \mu) \qquad \text{(Equation 15)}$$

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 $2x \tan (11.25^o)$.

Gravitational settling is handled by tilting the plume downward after it has leveled off at height H by subtracting $V_g\ x/\mu$ 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.

12.1.3 Dry Deposition

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

$$R_d \quad = \quad V_d\ \chi \qquad \text{(Equation 16)}$$

where:

R_d = surface deposition rate $(pCi/cm^2\text{-sec})$
V_d = deposition velocity (cm/sec) [VD]
χ = 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.

12.1.4 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:

$$R_s \quad = \quad \Phi \, \chi_{ave} \, L \qquad\qquad\qquad \text{(Equation 17)}$$

where:

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

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

12.1.5 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:

$$\frac{Q^1}{Q} \quad = \quad e^{-\Phi t} \qquad\qquad\qquad \text{(Equation 18)}$$

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):

$$\frac{Q^1}{Q} = \exp\left\{ -\left(\frac{2}{p}\right)^{\frac{1}{2}} \left(\frac{V_d}{m}\right) \int_0^x \frac{\exp\left[-\left(H - V_g x/m\right)^2 / 2s_z^2 \right]}{s_z} dx \right\} \qquad \text{(Equation 19)}$$

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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 $\mu = 1$ 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 $\mu = 1$ m/sec. The value is then converted to the appropriate value for the actual deposition velocity and wind speed by use of the equation:

$$(Q^1/Q)_2 \quad = \quad (Q^1/Q)_1^{\,100\ V_d/\mu} \qquad\qquad \text{(Equation 20)}$$

in which subscript 2 refers to the desired value and subscript 1 refers to the value for $V_d = 0.01$ m/sec and $\mu = 1$ 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):

$$\frac{Q_x^1}{Q_{2x_L}^1} = \exp\left[-V_d \left(x - 2x_L \right) \Big/ L\boldsymbol{m} \right] \qquad\qquad \text{(Equation 21)}$$

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

The depletion fraction for radioactive decay is:

$$\frac{Q^1}{Q} = \exp\left(-\lambda_r t\right)$$ (Equation 22)

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:

$$f_1 = 1 - f_2 - f_3$$

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

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

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.

12.1.6 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

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

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.

12.1.7 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.

12.1.8 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 be one percent (1%) tritiated.

12.1.9 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)	Equilibrium 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

12.1.10 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 assumed to be 100 years. This value corresponds to establishing a 100-year cutoff for the time following a release when any significant intake or external exposure associated with deposition on soil might take place.

Ingrowth from a parent radionuclide is calculated using a decay product ingrowth factor. The ingrowth factor is the ratio of the decay product concentration resulting from a unit deposition rate of the parent and the decay product respectively. The factors are for a 100 year accumulation time and a removal rate from soil of 2 percent per year.

12.2   Dose and Risk Estimates

CAP88-PC uses a modified version of DARTAB (ORNL5692) and a database of dose and risk factors generated by RADRISK (ORNL7105, ORNL7745) for estimating dose and risk. Relevant portions of these documents are reproduced here, as referenced.

Dose and risk conversion factors include the effective dose equivalent calculated with the weighting factors in ICRP Publication Number 26 (ICRP26). Risk factors are based on lifetime risk from

lifetime exposure with a nominal value of 4E-4 fatal cancers/rem (EPA89). Dose and risk factors are provided for the pathways of ingestion and inhalation intake, ground level air immersion and ground surface irradiation. Factors are further broken down by particle size [SIZE], clearance class [CLEARANCE_CLASS] and gut-to-blood [GI_ING and GI_INH] transfer factors. These factors are stored in a database for use by the program.

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 gonads, breast, red marrow, lungs, thyroid, and endosteum in addition to the 50 year effective dose equivalent. Risks are estimated for these cancers: leukemia, bone, thyroid, breast, lung, stomach, bowel, liver, pancreas, and urinary. 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 1.3×10^5 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.

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.

12.2.1 Air Immersion

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

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

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, RISK, for DOSE. The risk conversion factor is in units of risk/nCi-yr/m^3 .

12.2.2 Surface Exposure

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

$$E_{ij}(k) \; DF_{ijl} \; K_j$$

$$P(k)$$

where:

$E_{ij}(k)$	=	exposure rate, person-pCi/cm^2 [EXPP]
DF_{ijl}	=	Dose rate factor, mrem/nCi-yr/m^2 [DOSE]
$P(k)$	=	number of exposed people [POP]
K_j	=	0.001 nCi/pCi x 10,000 cm^2/m^2 (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.

12.2.3 Ingestion and Inhalation

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

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

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.

12.2.4 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 risk for a lifetime exposure [AGEX] of 70.7565 years.

12.2.5 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.

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