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Software Integration for Environmental Radiological Release Assessments (SIERRA)

Atmospheric Transport and Diffusion Module User's Guide

March 2025

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Prepared for the U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
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Acronyms and Abbreviations

ARCON	computer code for Atmospheric Relative CONcentration in Building Wakes
ATD	atmospheric transport and diffusion
CFD	cumulative frequency distribution
CFR	Code of Federal Regulations
DBA	design basis accident
dll	dynamic link library
DOE	U.S. Department of Energy
EAB	exclusion area boundary
Fortran	FORmula TRANslator
HDI	How Do I?
ISC	Industrial Source Complex Dispersion Model
JSON	JavaScript Object Notation
LPZ	outer boundary of the low population zone
NPP	nuclear power plants
NPUF	nonpower production or utilization facility
NRC	U.S. Nuclear Regulatory Commission
PAVAN	computer code for ground-level χ/Q for accidental release
P-G	Pasquill–Gifford diffusion coefficients
PNNL	Pacific Northwest National Laboratory
RAMP	Radiation Protection Computer Code Analysis and Maintenance Program
RG	Regulatory Guide
SIERRA	Software Integration for Environmental Radiological Release Assessments
SQA	software quality assurance
SRP	standard review plan
XOQDOQ	computer code for evaluation of routine effluent releases at commercial nuclear power stations

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1.0 SIERRA Atmospheric Transport and Diffusion Module User's Guide

1.1 Introduction

The Software Integration for Environmental Radiological Release Assessments (SIERRA) application provides a consolidated framework for separate "functional engines" that can be used, individually or in certain combinations, for dose assessment to support licensing actions for the existing and potential fleet of nuclear power plants (NPPs) and potential nonpower production or utilization facilities (NPUFs) located in the contiguous (lower 48) United States. Facilities located in extreme and persistent cold regions (e.g., Alaska) may require further modification of these approaches.

The software consolidates and modernizes various existing codes within the U.S. Nuclear Regulatory Commission's (NRC's) Radiation Protection Computer Code Analysis and Maintenance Program (RAMP). RAMP develops, maintains, improves, distributes, and provides training on NRC-sponsored radiation protection and dose assessment computer codes. The SIERRA software is designed based upon existing RAMP codes for environmental (e.g., air or water) transport, diffusion, and dose assessment of radionuclides.

This document provides a brief overview of the Atmospheric Transport and Diffusion (ATD) module software version 1.0.X.X and installation steps. Section 2.0 describes the user interface for SIERRA, while Section 3.0 describes the ATD module's user interface[1]. The quality assurance applied for this effort is described in Section 4.0, and references are listed in Section 5.0.

Some of the features and/or available options in the ATD models discussed in this document represent departures from or alternatives to current guidance corresponding to the legacy versions of these codes. Nevertheless, the NRC's regulatory guidance is flexible enough to allow for the proposal and use of alternate dispersion models and/or modeling approaches. If a potential applicant or licensee proposes to use an alternate model, modeling approach, and/or input data, sufficient justification should first be provided to and approved by the NRC staff including a demonstration that the relevant regulatory requirements are met.

See Appendix A for a description of the directory structure for the SIERRA software. Appendix B contains brief descriptions of the simulation input and output files. Appendix C contains an example with steps for how to run the SIERRA application. Appendix D contains brief descriptions of the example test cases that are included within the SIERRA directory, which may be used to confirm the success of the software installation. A description of the technical basis of the atmospheric transport and diffusion model is presented in Appendix E.

1.2 Getting Started

This section contains basic information about the computer requirements for the SIERRA software application and a brief overview of the software installation process.

[1] The SIERRA application currently only holds the atmospheric engine. However, in the future, SIERRA will allow users to access multiple modules (e.g., source term, river/lake dispersion, dose).

1.2.1 Computer Requirements

The following are computer requirements to run the SIERRA software:

- Windows 10 or later operating system
- .NET Framework
- 64-bit system
- computer display scale set to 125 percent for optimal user interface display (recommended).

1.2.2 Installation Instructions

Note: If a previous version of SIERRA is already installed, users may need to use the “Apps & Features” tool within “Windows Settings” to remove the “Sierra_Install” application from the computer.

The basic steps required to install the SIERRA software are as follows:

1. Navigate to and open the “SIERRA_Install” folder.
2. Double-click on the installation executable (e.g., SIERRA_Install_V_1.exe) file in the folder.
3. Upon startup, the installation software will display a license agreement for the installation of the .NET framework (Figure 1-1). Click on the “Accept” button to continue the installation and follow the subsequent window prompts.

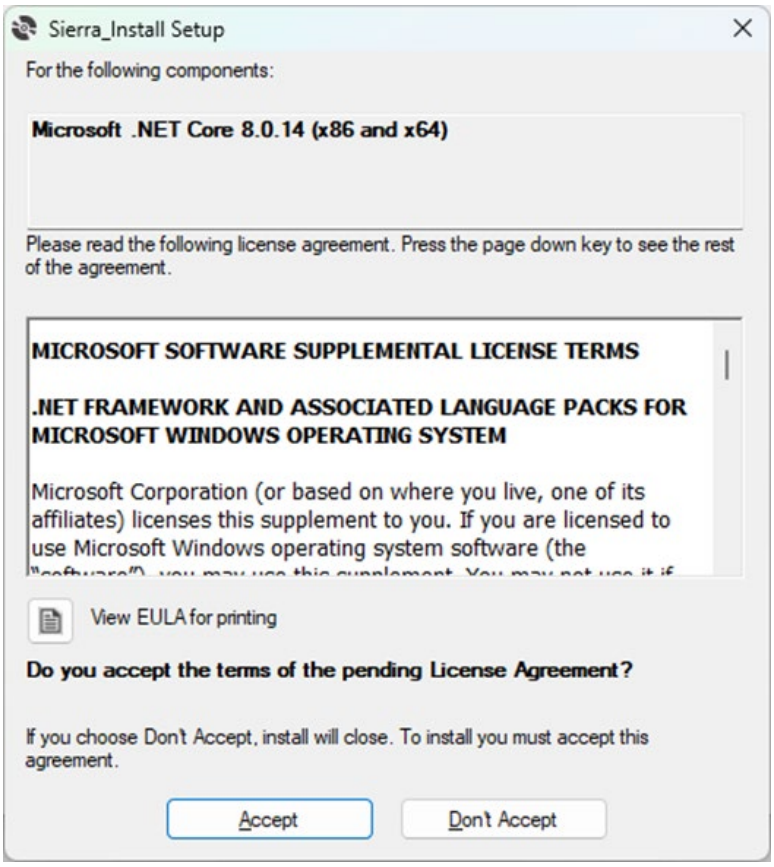


Figure 1-1. SIERRA Install Setup Screen to Install the .NET Framework.

4. Once the .NET framework installation is complete, an “Installation was successful” dialog box will be displayed. Click on the “Close” button to continue to the SIERRA installation.
5. The SIERRA installation “Welcome” screen is then displayed, as shown in Figure 1-2. Click on the “Next” button to continue the installation and proceed through the subsequent window prompts.

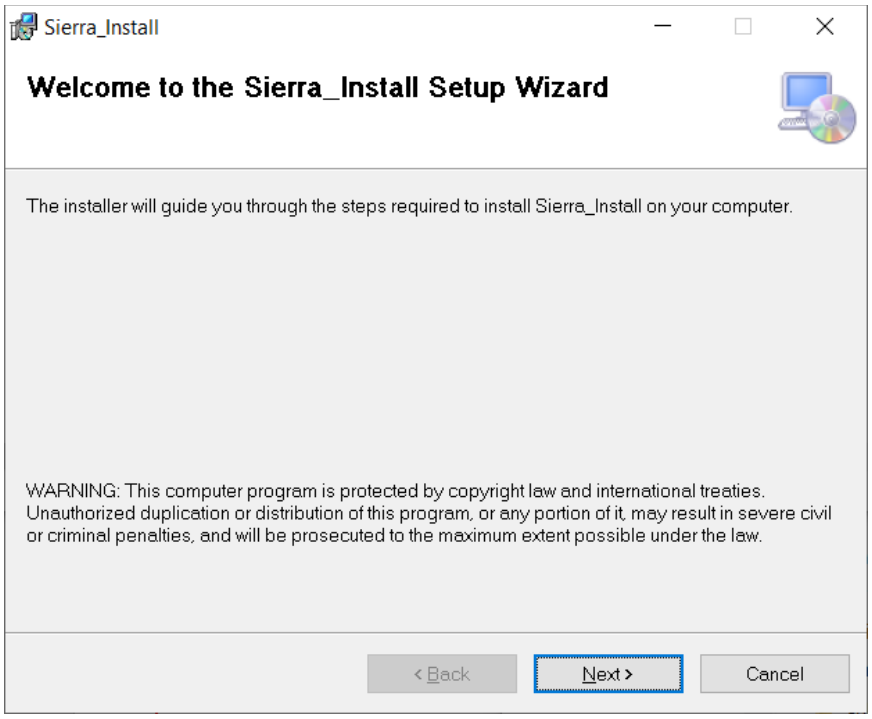


Figure 1-2 SIERRA Install Setup Wizard.

6. Once the software is successfully installed, an “Installation Complete” screen will be displayed, as shown in Figure 1-3. Click the “Close” button to close the installation program.

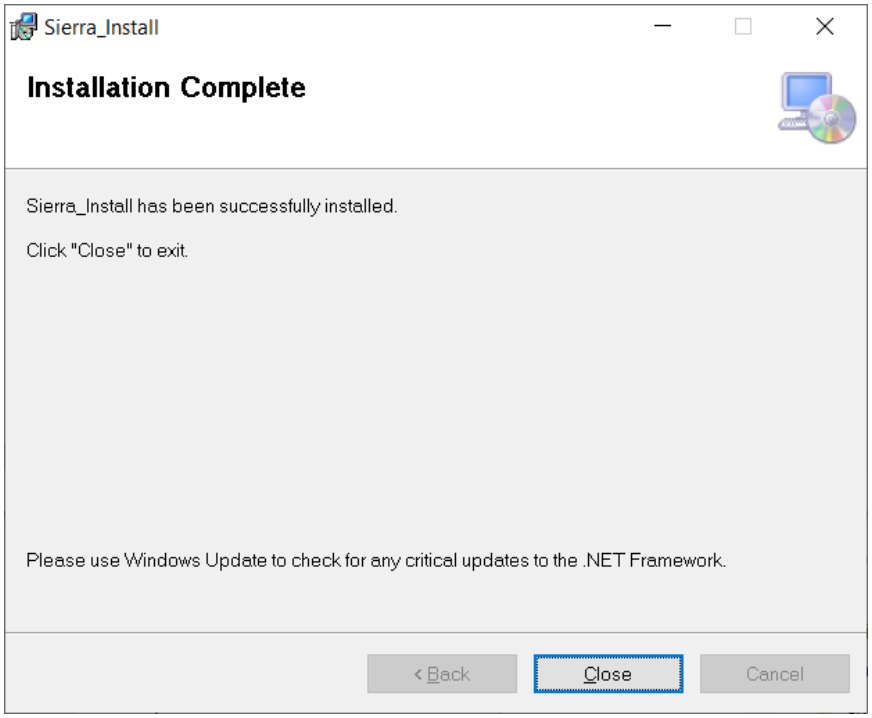


Figure 1-3. Installation Complete Screen.

7. The SIERRA software can then be started by double clicking the “SIERRA” shortcut that has been created on the computer’s desktop or by single-clicking the Windows Start Menu item.

2.0 SIERRA User Interface Guide

The SIERRA user interface application provides the ability to enter information characterizing the overall simulation that the user intends to run. Through this interface, the user will select the assessment type (Regulatory or Research) and the analysis type and provide a name for the simulation. Available analysis types include the following:

- onsite control room design basis accident (DBA) analysis (referred to as “Control Room Analysis” in SIERRA)
- offsite DBA analysis (referred to as “Design Basis Accidents” in SIERRA)
- routine release analysis (referred to as “Routine Analysis” in SIERRA).

Once the user has made their selection, the “Overview” panel of the interface is then used to start an “Atmospheric Dispersion” simulation.

Manual user selections made using the SIERRA interface will be used to control the order in which the modules (e.g., Source Term, Atmospheric Dispersion, River/Lake Dispersion, Dose) will be executed[2]. Sections 2.1 through 2.5 provide a description of each of the current SIERRA interface panels along with the controls present on each panel.

2.1 Splash Screen

Once the SIERRA application has been started, a splash screen (Figure 2-1) with information about the software will be displayed while the main SIERRA user interface is loading. Once the SIERRA user interface has completed loading, the splash screen will automatically close.

[2] Current development has focused on the ATD module. Future development will incorporate source terms, river/lake dispersion, environmental accumulation, nonhuman biota exposure, human exposure, and dose modules.

Figure 2-1. SIERRA Splash Screen.

When the splash screen closes, the Disclaimer page will be present on the screen. Users may review the disclaimer content and either “Exit” the software or “Continue” to the next step in the software, which is the Assessment Type Selection panel.

2.2 Assessment Type Selection Panel

This panel is used to select the type of assessment that the user intends to perform (Figure 2-2). There are two options available: “Regulatory” and “Research.” Each option is defined in the following sections.

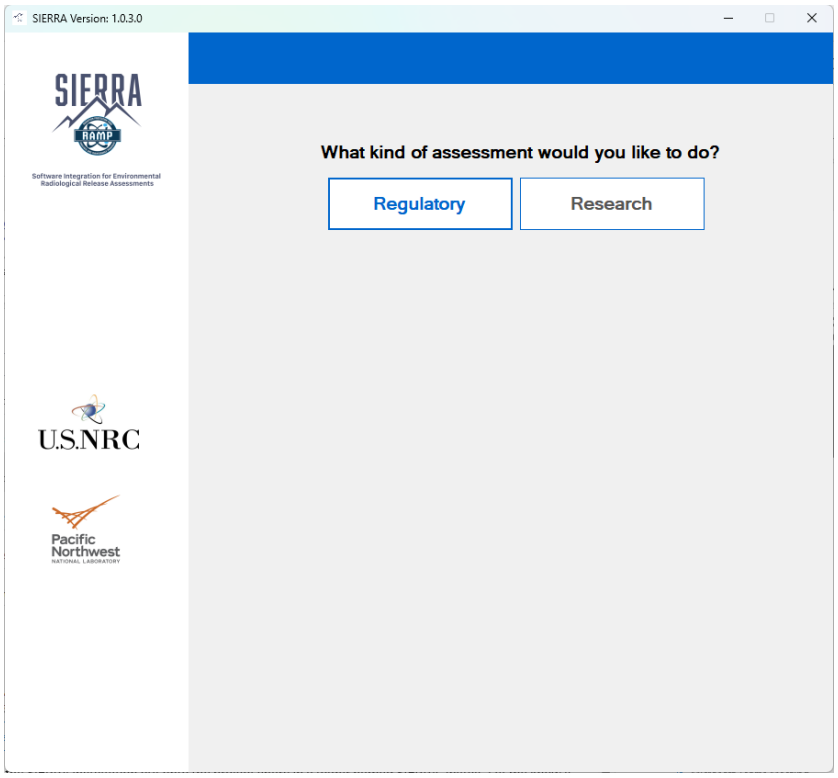


Figure 2-2. SIERRA Assessment Panel.

2.2.1 Regulatory

The regulatory option, when selected, results in a simulation that uses predefined modules and follows a specific execution path through various modules, when those modules are developed[3].

2.2.2 Research

The research option is intended to provide the user more flexibility in comparison with the regulatory option when selecting the modules to be used in the simulation and how they are to be executed. This option is not available in this version (1.0.X.X) of the software.

2.3 Simulation Case Name

Once the assessment type has been selected, a dialog window will be displayed, prompting the user to enter a name for the simulation case that is to be executed (Figure 2-3). Alternatively, users may select from a list of recently used case names from a list below the text entry box. Selecting a recent case name will populate that name in the box so that users may modify the name. The list of recently used case names will be populated with up to 10 unique names. Case names must not contain spaces or any special characters and are limited to 50 characters. This simulation name will be used to create the appropriate directories that store the input and output files used and generated by the simulation modules. The directory structure used by the

[3] The ATD module is the only module currently available to the user with this version of SIERRA.

SIERRA software to store input and output files generated during a simulation run are defined in Appendix A.

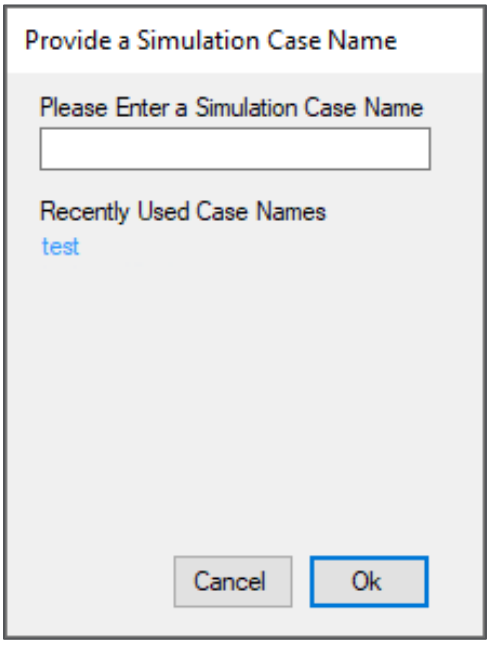


Figure 2-3. SIERRA Simulation Case Name Dialog Panel.

2.4 Analysis Type Selection Panel

Following the entry of a simulation name, the software will then display the Analysis Type Selection panel (Figure 2-4), which will be used to select the type of analysis the user wants to simulate. There are three types of analyses available to select from. They are designated as follows:

- onsite control room DBA analysis (referred to as “Control Room Analysis” in SIERRA)
- offsite DBA analysis (referred to as “Design Basis Accidents” in SIERRA)
- routine release analysis (referred to as “Routine Analysis” in SIERRA).

The three different options are further clarified in the following sections. Selecting the button corresponding to each of the analysis types will result in a description of the analysis type being displayed in the center of the panel.

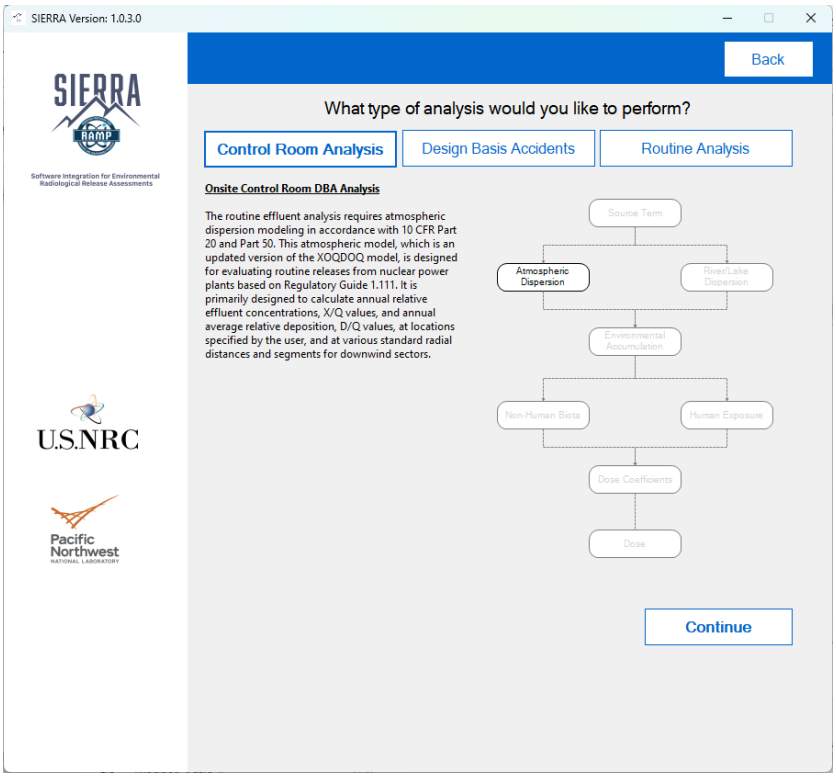


Figure 2-4. SIERRA Analysis Type Selection Panel.

2.4.1 Onsite Control Room Design Basis Accident Analysis

This analysis type is used to calculate onsite, DBA atmospheric relative concentrations (χ/Q) in support of control room habitability assessments required by Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, General Design Criterion 19. Habitability assessments are also called for by NUREG-0696 (NRC 1981) and NUREG-0737 (NRC 1980) when a technical support center is located on site. This analysis uses hourly meteorological data and the atmosphere's influence (i.e., transport and diffusion) in the vicinity of buildings to calculate the values of χ/Q at the control room normal and/or emergency air intakes and at points of ingress and egress (e.g., directly to the control room, control building, personnel and equipment hatches). The 95th percentile relative concentrations are calculated for moving-average periods that range from one hour to 30 days in duration.

2.4.2 Offsite Design Basis Accident Analysis

The offsite DBA analyses for license applications and renewals call for applicants, if required, to estimate values of χ/Q for specific averaging time periods at specified offsite distances. The modeling approach is based on the guidance in Regulatory Guide (RG) 1.145 (NRC 1982). These assessments are required by 10 CFR Parts 50, 52, and Part 100. Per guidance in RG 1.145, the averaging periods are 2, 8, and 16 hours, and 3 and 26 days corresponding to accident time intervals of 0–2 hours, 0–8 hours, 8–24 hours, 1–4 days, and 4–30 days, respectively. The distances usually correspond to the exclusion area boundary (EAB) and the outer boundary of the low population zone (LPZ) and are assigned to each of the 16 standard 22.5° directional sectors and as specified Regulatory Position 1.2 of RG 1.145.

2.4.3 Routine Release Analysis

The routine airborne release effluent analysis requires ATD modeling in accordance with 10 CFR Part 20 and Part 50. This atmospheric model is designed for evaluating routine releases from NPPs based on RG 1.111 (NRC 1977). It is primarily designed to calculate annual relative effluent concentrations, χ/Q values, and annual average relative deposition (D/Q) values at locations specified by the user and at 22 standard radial distances and 10 distance segments for each of the 16 downwind sectors.

2.4.4 Module Display

The diagram displayed on the right side of the analysis selection panel in Figure 2-4 shows what modules are available for use in the simulation and the active connections for simulations between modules. Modules that are not available for use in a simulation are grayed out, and connections that are not available are displayed as dashed lines. Connections that are active will be displayed as solid black lines.

2.4.5 Back Button

Located on the upper right corner of the Analysis Type Selection panel, the “Back” button can be used to step back to a prior panel of the interface.

2.4.6 Continue Button

Located at the lower right corner of the Analysis Type Selection panel, the “Continue” button, when clicked, will advance the user interface to the “Overview” panel. One of the three analysis options (i.e., onsite control room DBA analysis, offsite DBA analysis, or routine release analysis) must be selected to continue.

2.5 Module Overview Panel

The “Module Overview” panel of the SIERRA user interface (Figure 2-5) provides a listing of the modules that are available for use in the simulation. The listing shows a set of buttons that can be used to start the applicable module. Buttons representing modules that are not available for use are disabled and grayed out. Clicking anywhere within an active button in the list will start the module’s user interface application. Once a module’s application is started, the SIERRA interface software is locked and only becomes active again after the previously selected module application ends.

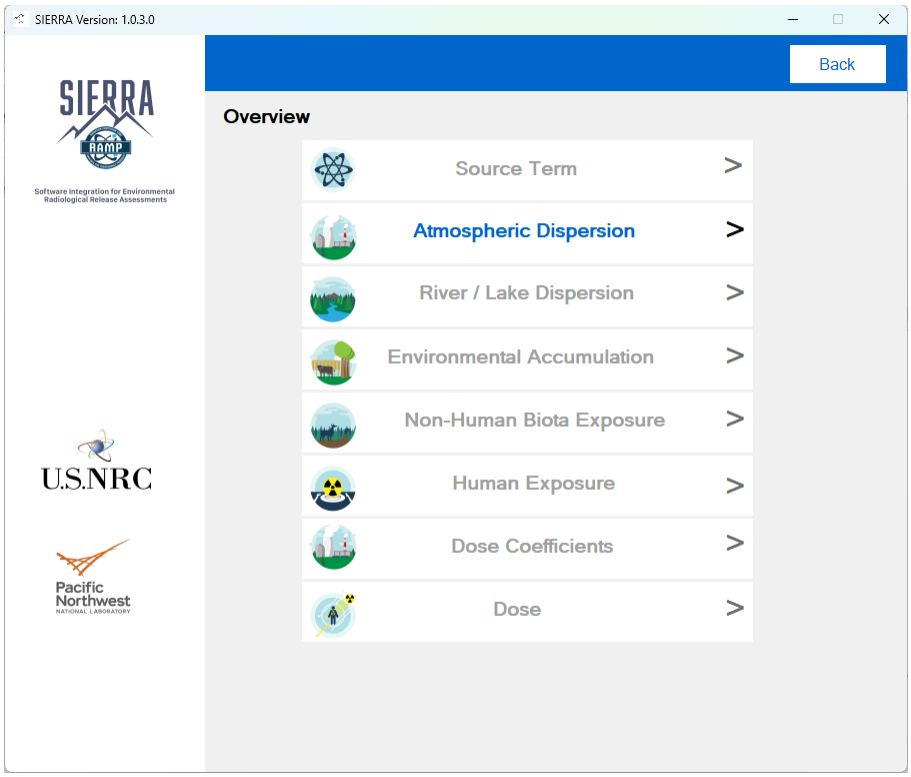


Figure 2-5. SIERRA Module Overview Panel.

3.0 Atmospheric Transport and Diffusion Module Interface User Guide

This section provides an overview of the ATD module user interface. The primary objective of this section is to document the various panels used for simulation entries. A description of the technical basis of the ATD model is presented in (Ghosh et al. 2025). A brief overview of the relevant regulatory guidance and the parameters included in the three assessment types are included in Appendix E.

3.1 Overview Panel

Located on the left side of the ATD module user interface, the “Overview” panel (Figure 3-1) displays simulation information such as the analysis type and a graphic showing the module’s place in the simulation’s execution. The panel also contains a set of buttons that can be used to navigate through the interface, access and change module default options, load or save user inputs, and view outputs after an analysis is run.

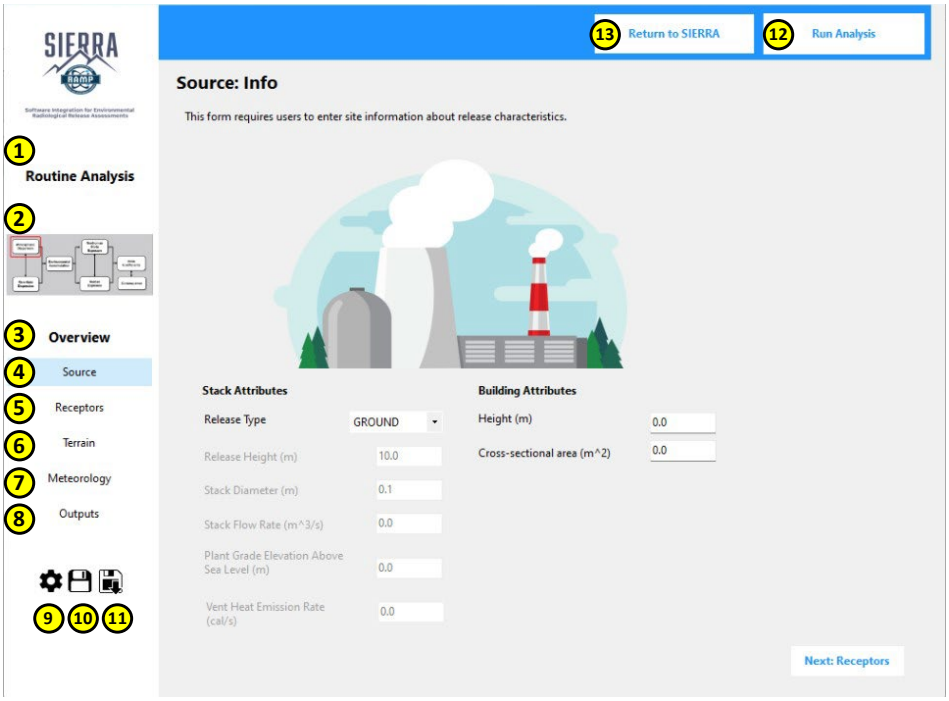


Figure 3-1. ATD Overview Panel.

The following list briefly describes the control and functionality of the ATD Overview Panel. The numbered items correspond to the numbers shown in Figure 3-1.

1. Analysis Type - Indicates which model is currently selected.
2. Module Map - An image to indicate which module is being run. Currently, only the ATD module is available.
3. Overview Section - Provides navigation buttons for the ATD application.

4. Source Button - Initial page seen when the ATD application is loaded. Navigates the ATD application to the “Source” panel.
5. Receptors Button - Navigates the ATD application to the “Receptor” panel.
6. Terrain Button - Navigates the ATD application to the “Terrain” panel.
7. Meteorology Button - Navigates the ATD application to the “Meteorology” panel.
8. Outputs Button - Navigates the ATD application to the “Outputs” panel.
9. Module Default Settings Icon - The icon opens a new window to set defaults for the simulation. The window that is opened depends upon the analysis type selected.
10. Save Module Input Icon - The icon opens a Windows dialog to allow the user to select the location to save their current inputs and name that input file. Files are saved in JavaScript Object Notation (JSON) format.
11. Load Module Input Icon - The icon opens a Windows dialog to allow the user to select a saved input JSON file to be loaded into the ATD application.
12. Run Analysis Button - Runs the analysis.
13. Return to SIERRA Button - Closes the window and returns users to the SIERRA Module Overview panel.

3.1.1 Module Default Settings

Located in the lower left corner of the “Overview” panel, the “Module Default Settings” icon can be selected to display the default settings dialog window for the analysis. Each analysis type has its own set of default values that can be changed for the simulation. Only the default values that apply to the selected analysis type will be displayed in the “Settings” dialog window. The following sections list the default values that are available for each of the analysis types.

3.1.1.1 Onsite Control Room Design Basis Accident Analysis

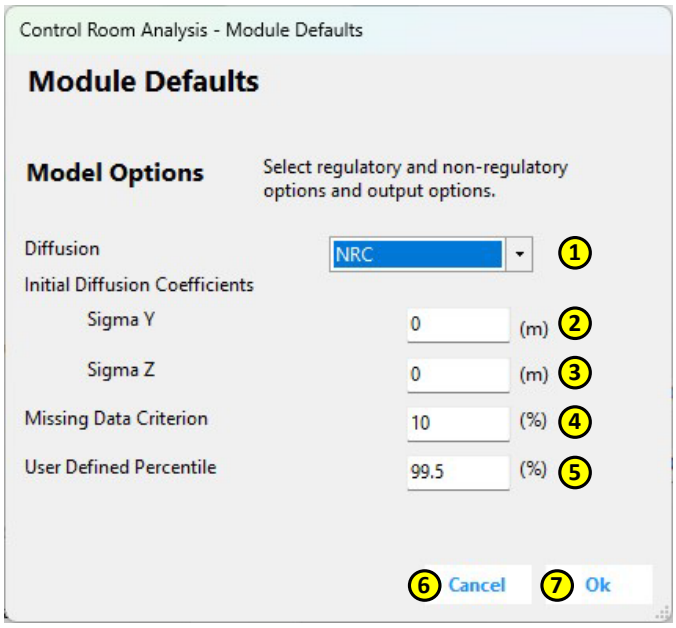


Figure 3-2. ATD Onsite Control Room Design Basis Accident Analysis – Module Defaults Window.

The list below briefly describes the module defaults as numbered in Figure 3-2.

1. Diffusion - The diffusion scheme, set to NRC.
2. Sigma Y - The user provides an initial diffusion coefficient (in meters) of Sigma Y for a diffused source.
3. Sigma Z - The user provides an initial diffusion coefficient (in meters) of Sigma Z for a diffused source.
4. Missing Data Criterion - The user provides a value that specifies the acceptable missing data criterion when calculating average values. Range: 0–30 percent.
5. User Defined Percentile - The user provides a value to calculate an additional statistic. Range: 0–100 percent.
6. Cancel Button - When clicked, any changes made to module default settings are not saved, and the Module Defaults dialog window is closed.
7. Ok Button - Saves the current module default settings and closes the Module Defaults dialog window.

3.1.1.2 Offsite Design Basis Accident Analyses

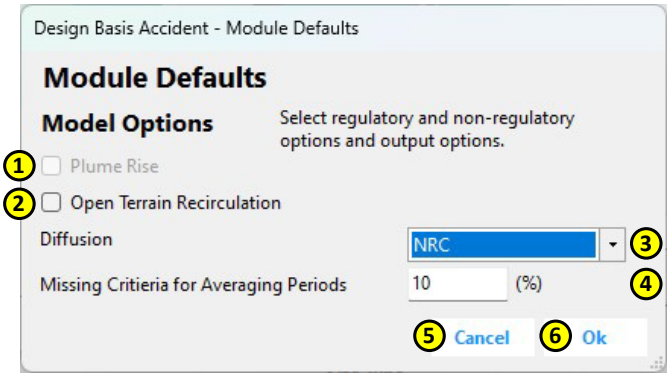


Figure 3-3. ATD Offsite Design Basis Accident – Module Defaults Window.

The following list briefly describes the module defaults as numbered in Figure 3-3:

1. Plume Rise - The user checks this box if calculating the plume rise for an elevated release.
2. Open Terrain Recirculation - The user checks this box if calculating open terrain recirculation.
3. Diffusion - The user selects the diffusion scheme. Options are NRC and DESERT_SIGMA (alternative to NRC regulatory default).
4. Missing Criteria for Averaging Periods - The user provides a value that specifies the acceptable missing data criterion when calculating average values. Range: 0–30 (percent).
5. Cancel Button - When clicked, any changes made to module default settings are not saved, and the Module Defaults dialog window is closed.
6. Ok Button - Saves the current module default settings and closes the Module Defaults dialog window.

3.1.1.3 Routine Release Analysis

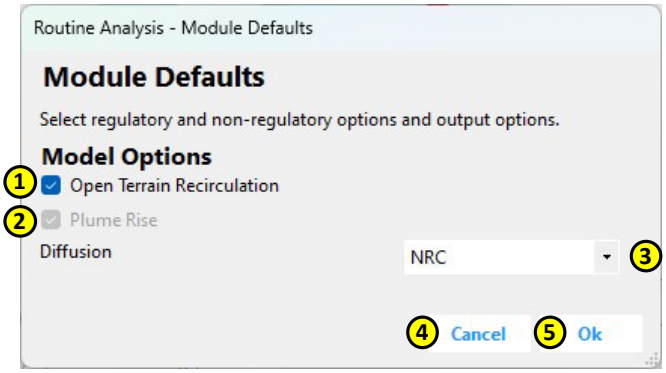


Figure 3-4. ATD Routine Release Analysis – Module Defaults Window.

The following list briefly describes the module defaults as shown in Figure 3-4:

1. Open Terrain Recirculation - The user checks the box for using open terrain recirculation factors to correct χ/Q and D/Q.

2. Plume Rise - Plume rise is computed for all elevated and vent cases.
3. Diffusion - The user selects the diffusion scheme. Options are NRC, ISC, BRIGGS_RURAL, BRIGGS_URBAN, and DESERT_SIGMA. NRC is the regulatory default, while other options are alternatives.
4. Cancel Button - When clicked, any changes made to module default settings are not saved, and the Module Defaults dialog window is closed.
5. Ok Button - Saves the current module default settings and closes the Module Defaults dialog window.

3.2 Onsite Control Room Design Basis Accident Analysis Panels

The control room analysis type is used to calculate atmospheric relative concentrations (χ/Q) in support of onsite control room habitability DBA assessments required by 10 CFR Part 50, Appendix A, General Design Criterion 19. Habitability assessments are also called for by NUREG-0696 (NRC 1981) and NUREG-0737 (NRC 1980), as indicated in Section 2.4.1, when a technical support center is located on site. These concentrations are calculated for five averaging periods: 0 to 2 hours, 2 to 8 hours, 8 to 24 hours, 24 to 96 hours (or 1 to 4 days), and 96 to 720 hours (or 4 to 30 days).

The dispersion model for these calculations uses hourly meteorological data. The model accounts for the atmosphere's influence (i.e., transport and diffusion) in the vicinity of buildings. The χ/Q values are estimated at the normal and/or emergency air intakes, at various points of ingress and egress to the control room and control building, at personnel and equipment hatches, and, if applicable, at equivalent receptor locations at the technical support center. When the "Control Room Analysis" option is selected, the ATD user interface automatically configures itself to only present the appropriate input parameters. The following sections define the controls and functionality presented in this set of input panels.

3.2.1 Source Panel

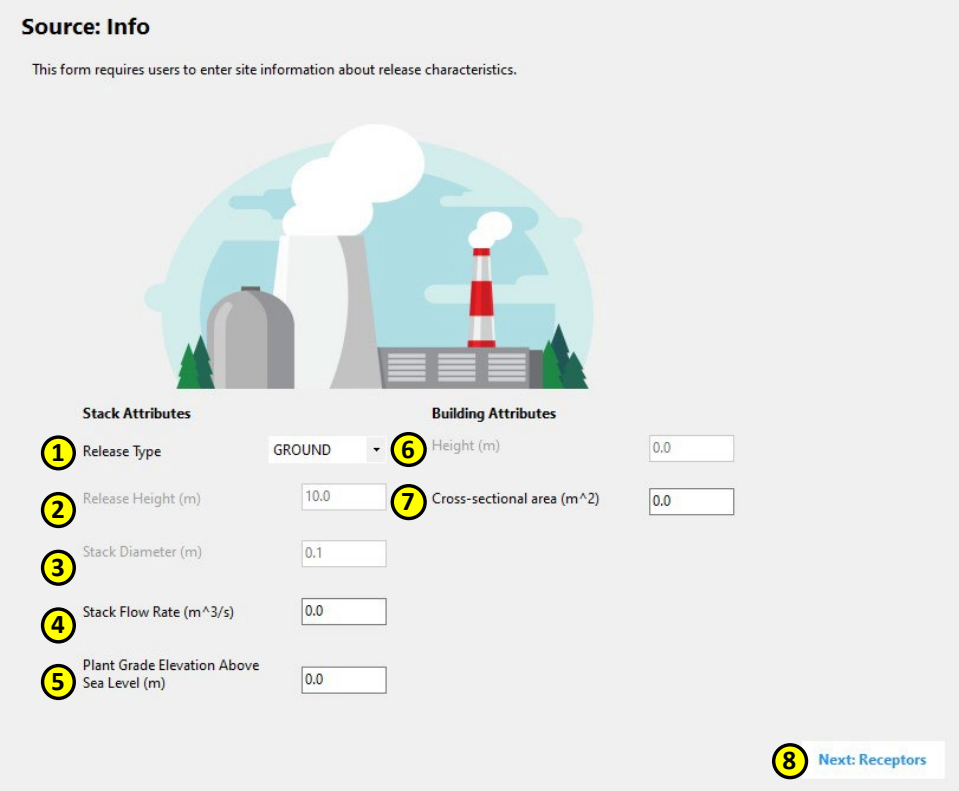


Figure 3-5. ATD Onsite Control Room Design Basis Accident Analysis, Source Panel.

The following list briefly describes the source-related inputs as numbered in Figure 3-5:

1. Release Type Selection - The user selects the release type as either GROUND or ELEVATED.
2. Release Height - The user provides the release height. Range: 0–300 m. This parameter is disabled when Release Type is set to GROUND.
3. Stack Diameter - The user provides the stack inside diameter. Range: 0–20 m. This parameter is disabled when Release Type is set to GROUND.
4. Stack Flow Rate - The user provides the flow rate. Range: 0–100 m^3/s.
5. Plant Grade Elevation Above Sea Level - The user provides the base elevation. Range: 0–4,000 m.
6. Height - The user provides the building height. Range: 0–300 m. This parameter is disabled when Release Type is set to GROUND.
7. Cross-sectional Area - The user provides the building cross-sectional area, perpendicular to the source-to-receptor wind direction, if the structural wake is to be included in the dispersion analysis. Range: 0–10,000 m^2. This parameter is disabled when Release Type is set to ELEVATED.
8. Next: Receptors Button - When clicked, the ATD application will navigate to the “Receptors” panel.

3.2.2 Receptor Panel

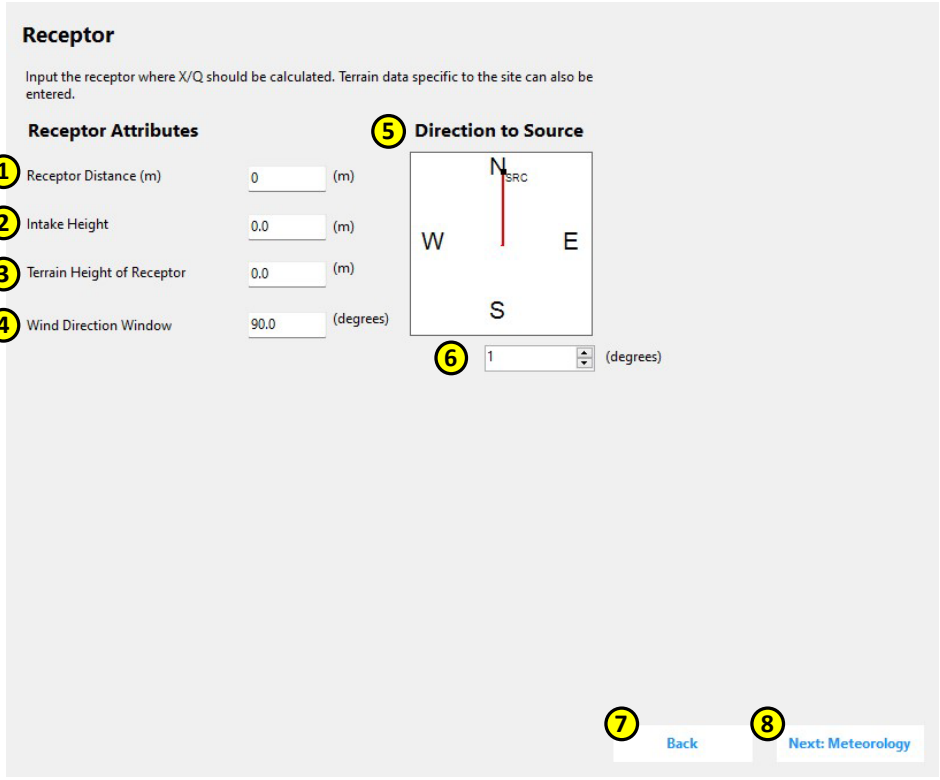


Figure 3-6. ATD Onsite Control Room Design Basis Accident Analysis, Receptor Panel.

The following list briefly describes the receptor-related inputs as numbered in Figure 3-6:

1. Receptor Distance - The user provides the linear (ground-level) distance of the receptor (intake) from the release point (source). Range: 0–10,000 m.
2. Intake Height - The user provides the height of the receptor (intake). Range: 0–100 m.
3. Terrain Height of Receptor - The user provides the terrain height at the receptor (intake) location. Range: 0–4,000 m.
4. Wind Direction Window - The user provides the range of wind directions (centered on the direction from the intake to the source) to be included in the plume calculation. The default wind direction window is 90 degrees.
5. Direction to Source - Visually displays the direction from the receptor to the source, based on the direction selected in the “Direction Select” portion of the panel.
6. Direction Select - The user provides the direction from the receptor (intake) to the source. Range: 1–360 degrees.
7. Back Button - When clicked, the ATD application will navigate back to the “Source” panel.
8. Next: Meteorology Button - When clicked, the ATD application will navigate to the “Meteorology” panel.

3.2.3 Meteorology Panel

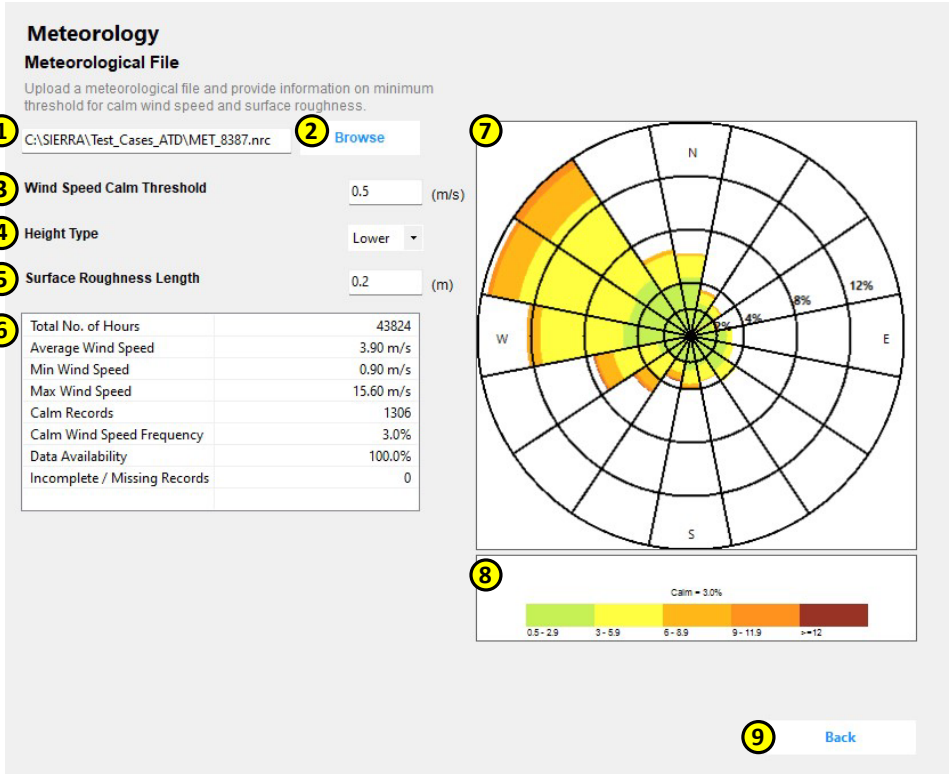


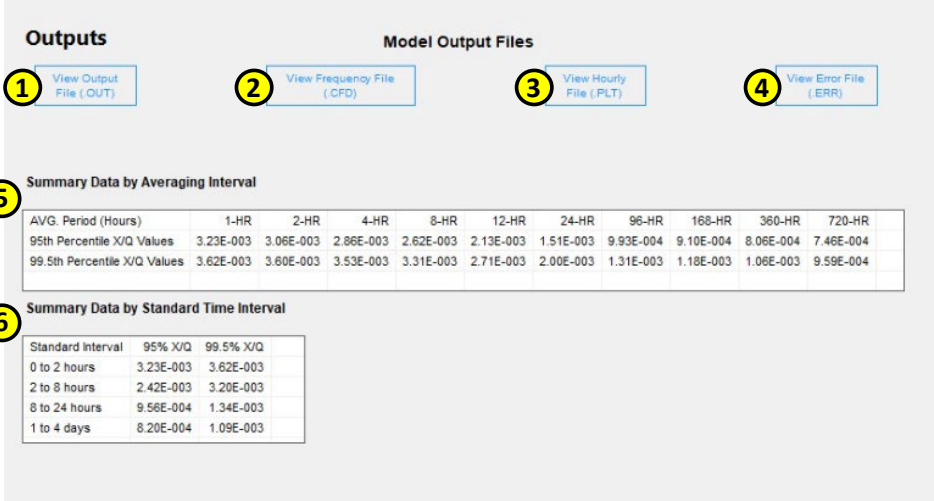
Figure 3-7. ATD Onsite Control Room Design Basis Accident Analysis, Meteorology Panel.

The following list briefly describes the meteorology-related inputs as numbered in Figure 3-7:

1. Meteorology File Textbox - Displays the path to a selected meteorological data file. An error message will display below the input window if the selected file is invalid.
2. Browse Button - Opens a window dialog that allows users to select an NRC-formatted meteorological data file.
3. Wind Speed Calm Threshold - Wind speeds below the value entered here are considered calm in the dispersion calculation. Range: 0–1 m/s. If an entered value is out of an indicated range, then error text will display below.
4. Height Type - The user can select a value from the choices provided: Lower, Upper. This selection updates the meteorological statistics view and wind rose plot, and does not determine the measurement height used in the simulation.
5. Surface Roughness Length - The user provides a value for the surface roughness length at the meteorological measurement location. Range: 0–10 m.
6. Meteorological Statistics View - Shows the meteorological data generated from an NRC-formatted file.
7. Wind Rose Plot - Displays a wind rose generated from the NRC-formatted file.
8. Legend - Shows the calm wind speed frequency and the colors associated with the wind speed categories.

9. Back Button - When clicked, the ATD application will navigate back to the “Receptors” panel.

3.2.4 Outputs Panel



AVG. Period (Hours)	1-HR	2-HR	4-HR	8-HR	12-HR	24-HR	96-HR	168-HR	360-HR	720-HR
95th Percentile X/Q Values	3.23E-003	3.06E-003	2.86E-003	2.62E-003	2.13E-003	1.51E-003	9.93E-004	9.10E-004	8.06E-004	7.46E-004
99.5th Percentile X/Q Values	3.62E-003	3.60E-003	3.53E-003	3.31E-003	2.71E-003	2.00E-003	1.31E-003	1.18E-003	1.06E-003	9.59E-004

Standard Interval	95% X/Q	99.5% X/Q
0 to 2 hours	3.23E-003	3.62E-003
2 to 8 hours	2.42E-003	3.20E-003
8 to 24 hours	9.56E-004	1.34E-003
1 to 4 days	8.20E-004	1.09E-003

Figure 3-8. ATD Onsite Control Room Design Basis Accident Analysis, Outputs Panel.

The following list briefly describes the various dispersion model outputs available as numbered in Figure 3-8. See Section B.2 of Appendix B for a general summary of the output files produced by the ATD engine of SIERRA.

1. View Output File Button - Opens the ATD Output Viewer that displays the OUT file.
2. View Frequency File Button - Opens the ATD Output Viewer that displays the cumulative frequency distribution (CFD) file.
3. View Hourly File Button - Opens the ATD Output Viewer that displays the PLT file.
4. View Error File Button - Opens the ATD Output Viewer that displays the ERR file.
5. Summary Data by Averaging Interval Grid - Displays summary data for the averaging intervals generated by the analysis.
6. Summary Data by Standard Time Interval Grid - Displays summary data for the standard time intervals generated by the analysis.

3.3 Offsite Design Basis Accident Analysis Panels

DBA analyses are used to estimate relative ground-level χ/Q values at offsite receptor locations for assessing potential airborne releases of radioactive material from nuclear facilities. The results are direct inputs to accident safety- and environment-related dose calculations. These assessments are required by 10 CFR Parts 50, 52, and 100.

The dispersion model for these calculations uses hourly meteorological data. Per the guidance in RG 1.145 (NRC 1982), the averaging time periods are 2, 8, and 16 hours; 3 and 26 days corresponding to the accident time intervals of 0–2 hours, 0–8 (sometimes used for 2–8) hours, 8–24 hours, 1–4 days, and 4–30 days, respectively. The receptor distances usually correspond to the EAB and LPZ. When the “Design Basis Accidents” option is selected as the analysis type,

the ATD user interface automatically configures itself to only present the appropriate input parameters. The following sections define the controls and functionality presented in this set of input panels.

3.3.1 Source Panel

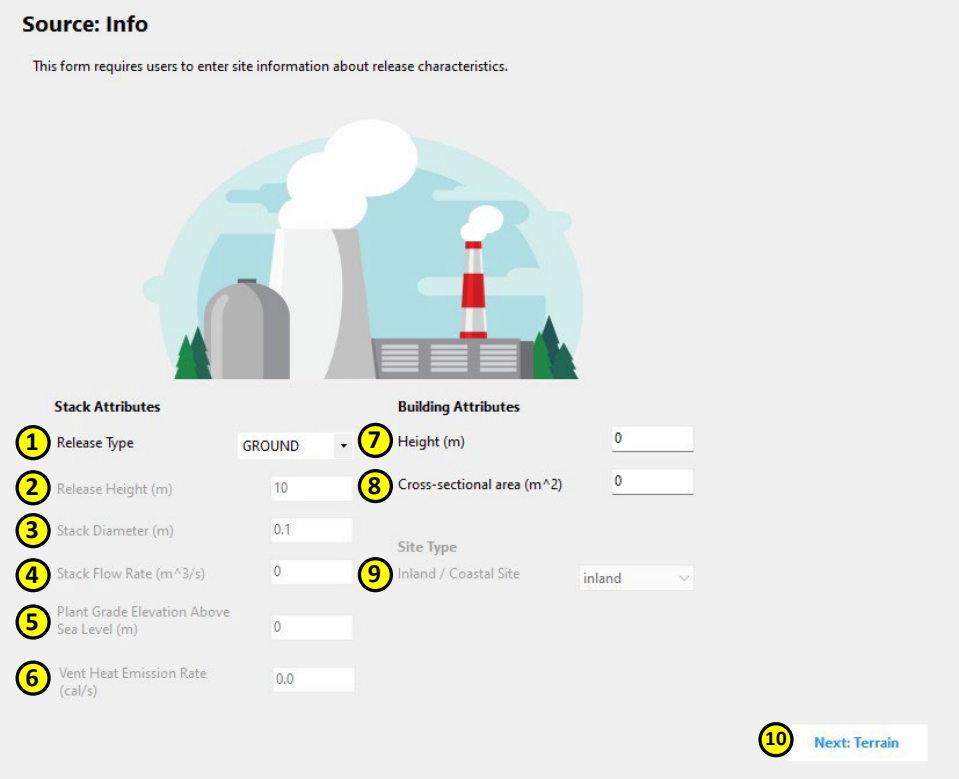


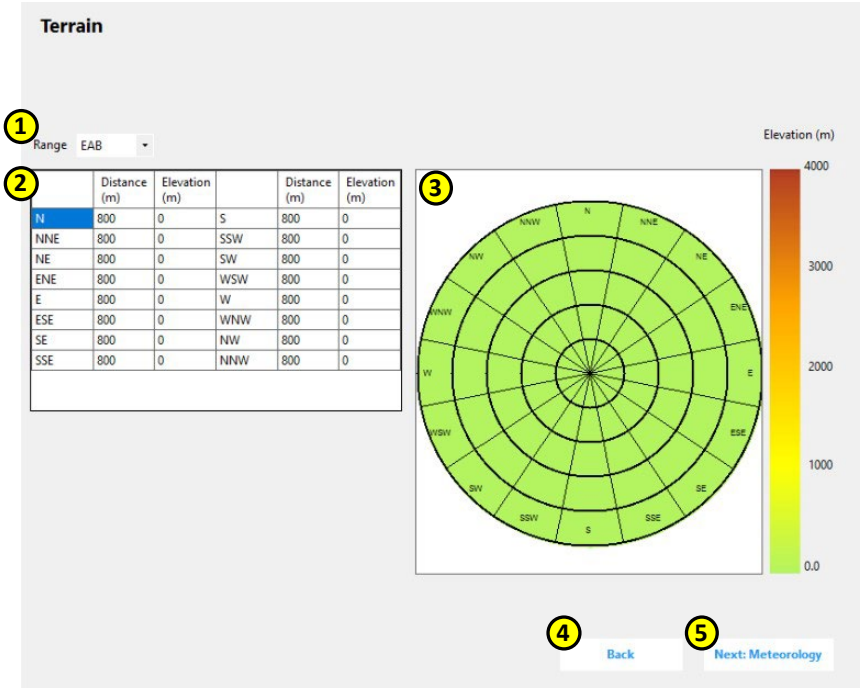
Figure 3-9. ATD Offsite Design Basis Accident Analysis, Source Panel.

The following list briefly describes the source-related inputs as numbered in Figure 3-9:

1. Release Type Selection - The user selects the release type as either GROUND or ELEVATED.
2. Release Height - The user provides the release height above plant grade. Range: 0–300 m. This parameter is disabled when Release Type is set to GROUND.
3. Stack Diameter - The user provides the stack inside diameter. Range: 0–20 m. This parameter is disabled when Release Type is set to GROUND. This parameter is also disabled when Release Type is set to ELEVATED unless Plume Rise is checked in the Module Defaults panel.
4. Stack Flow Rate - The user provides the flow rate. Range: 0–100 m^3/s. This parameter is disabled when Release Type is set to GROUND. This parameter is also disabled when Release Type is set to ELEVATED unless Plume Rise is checked in the Module Defaults panel.
5. Plant Grade Elevation Above Sea Level - The user provides the base elevation. Range: 0–4,000 m. This parameter is disabled when Release Type is set to GROUND.

6. Vent Heat Emission Rate - The user provides the heat emission rate for the stack exhaust for an ELEVATED release if Plume Rise is checked in the Module Defaults panel. Range: 0–1,000,000 cal/s.
7. Height - The user provides the building height for a GROUND release. Range: 0–300 m.
8. Cross-sectional Area - The user provides the smallest vertical plane cross-sectional area of the reactor building (or for other structures or directional considerations, if justified) if the structural wake is to be included in the dispersion analysis for a GROUND release.. This parameter is disabled when Release Type is set to ELEVATED. Range: 0–10,000 m^2
9. Site Type Selection - The user indicates whether a site is located near a large body of water (i.e., within 2 miles) or farther inland. Fumigation typically applies to elevated stack releases but may also apply to extremely buoyant low-level releases. Options are Inland and Coastal. This parameter is disabled when Release Type is set to GROUND.
10. Next: Terrain Button - When clicked, the ATD application will navigate to the “Terrain” panel.

3.3.2 Terrain Panel



	Distance (m)	Elevation (m)		Distance (m)	Elevation (m)
N	800	0	S	800	0
NNE	800	0	SSW	800	0
NE	800	0	SW	800	0
ENE	800	0	WSW	800	0
E	800	0	W	800	0
ESE	800	0	WNW	800	0
SE	800	0	NW	800	0
SSE	800	0	NNW	800	0

Figure 3-10. ATD Offsite Design Basis Accident Analysis, Terrain Panel.

The following list briefly describes the terrain-related inputs as numbered in Figure 3-10:

1. Range Selection - The user can select a range to edit. Range: EAB or LPZ.
2. Sectors, Distances, and Elevations Grid - The user can enter the Distance (Range: 0–80,467 m) and Elevation (Range: 0–4,000 m) for a sector. Users should review Regulatory Position 1.2 of RG 1.145 to determine distances. Elevation values shall be consistent with the basis (i.e., relative to sea level) used for the Plant Grade Elevation Above Sea Level, Release Height, and Building Height on the Source panel and be defined according to NUREG/CR-2858 (Bander 1982).

3. Distances and Elevations Polar Grid Display - Displays the data from the Sectors, Distances, and Elevations grid.
4. Back Button - When clicked, the ATD application will navigate back to the “Source” panel.
5. Next: Meteorology Button - When clicked, the ATD application will navigate to the “Meteorology” panel.

3.3.3 Meteorology Panel

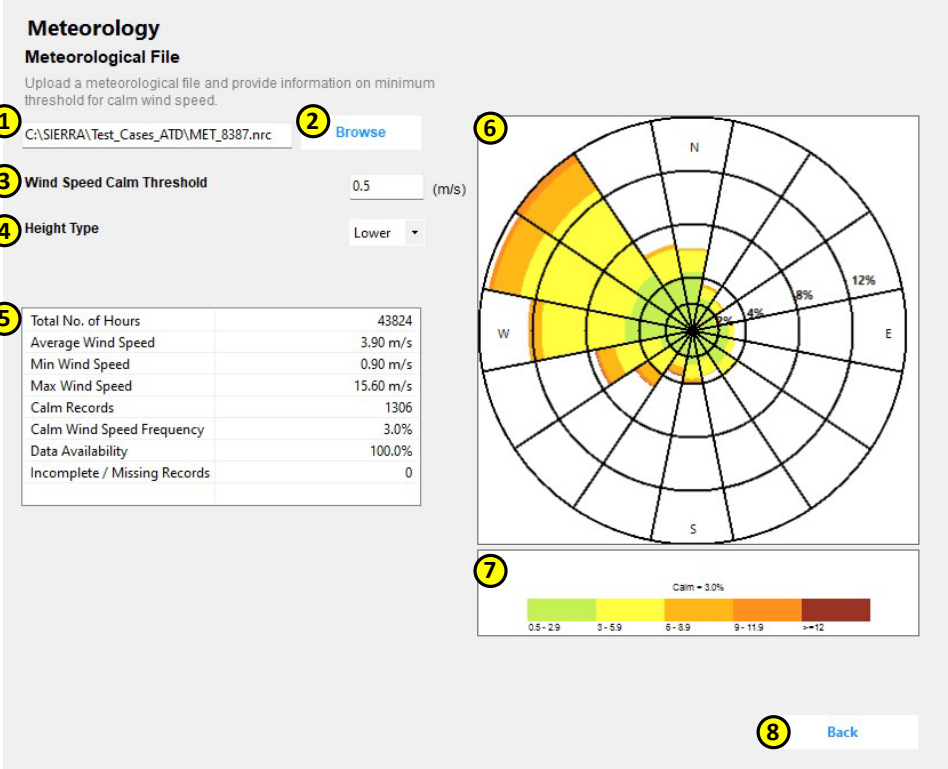


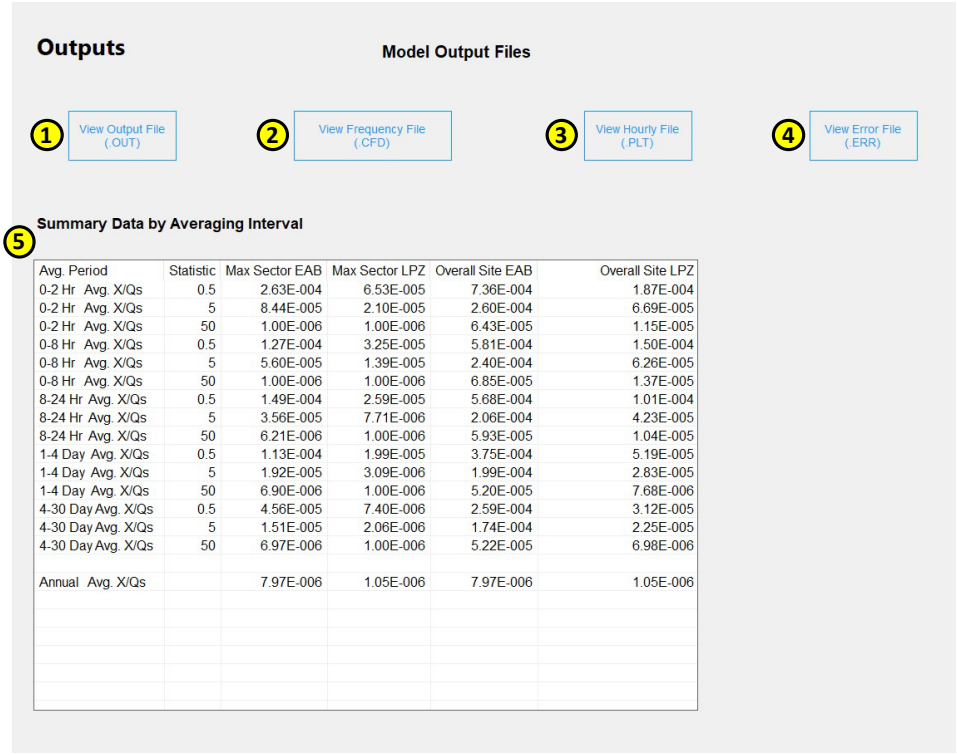
Figure 3-11. ATD Offsite Design Basis Accident Analysis, Meteorology Panel.

The following list briefly describes the meteorology-related inputs as numbered in Figure 3-11:

1. Meteorology File Textbox - Displays the path to a selected meteorological data file. An error message will display below if the selected file is invalid.
2. Browse Button - Opens a window dialog to allow users to select an NRC-formatted meteorological data file.
3. Wind Speed Calm Threshold - Wind speeds below the value entered here are considered calm in the dispersion calculation. Range: 0–1 m/s. If an entered value is out of an indicated range, then error text will display below.
4. Height Type - The user can select a value from the choices provided: Lower or Upper. This selection updates the meteorological statistics view and wind rose plot, and does not determine the measurement height used in the simulation.
5. Meteorological Statistics View - Shows the meteorological data generated from an NRC-formatted file.
6. Wind Rose Plot - Displays a wind rose generated from the NRC-formatted file.

7. Legend - Shows the calm wind speed frequency and the colors associated with the wind speed categories.
8. Back Button - When clicked, the ATD application will navigate back to the “Terrain” panel.

3.3.4 Outputs Panel



Avg. Period	Statistic	Max Sector EAB	Max Sector LPZ	Overall Site EAB	Overall Site LPZ
0-2 Hr Avg. X/Qs	0.5	2.63E-004	6.53E-005	7.36E-004	1.87E-004
0-2 Hr Avg. X/Qs	5	8.44E-005	2.10E-005	2.60E-004	6.69E-005
0-2 Hr Avg. X/Qs	50	1.00E-006	1.00E-006	6.43E-005	1.15E-005
0-8 Hr Avg. X/Qs	0.5	1.27E-004	3.25E-005	5.81E-004	1.50E-004
0-8 Hr Avg. X/Qs	5	5.60E-005	1.39E-005	2.40E-004	6.26E-005
0-8 Hr Avg. X/Qs	50	1.00E-006	1.00E-006	6.85E-005	1.37E-005
8-24 Hr Avg. X/Qs	0.5	1.49E-004	2.59E-005	5.68E-004	1.01E-004
8-24 Hr Avg. X/Qs	5	3.56E-005	7.71E-006	2.06E-004	4.23E-005
8-24 Hr Avg. X/Qs	50	6.21E-006	1.00E-006	5.93E-005	1.04E-005
1-4 Day Avg. X/Qs	0.5	1.13E-004	1.99E-005	3.75E-004	5.19E-005
1-4 Day Avg. X/Qs	5	1.92E-005	3.09E-006	1.99E-004	2.83E-005
1-4 Day Avg. X/Qs	50	6.90E-006	1.00E-006	5.20E-005	7.68E-006
4-30 Day Avg. X/Qs	0.5	4.56E-005	7.40E-006	2.59E-004	3.12E-005
4-30 Day Avg. X/Qs	5	1.51E-005	2.06E-006	1.74E-004	2.25E-005
4-30 Day Avg. X/Qs	50	6.97E-006	1.00E-006	5.22E-005	6.98E-006
Annual Avg. X/Qs		7.97E-006	1.05E-006	7.97E-006	1.05E-006

Figure 3-12. ATD Offsite Design Basis Accident Analysis, Outputs Panel.

The following list briefly describes the various ATD model outputs available as numbered in Figure 3-12. See Section B.2 of Appendix B for a general summary of the output files produced by the ATD engine of SIERRA.

1. View Output File Button - Opens the ATD Output Viewer that displays the OUT file.
2. View Frequency File Button - Opens the ATD Output Viewer that displays the CFD file.
3. View Hourly File Button - Opens the ATD Output Viewer that displays the PLT file.
4. View Error File Button - Opens the ATD Output Viewer that displays the ERR file.
5. Summary Data by Averaging Interval Grid - Displays summary data for the averaging intervals generated by the analysis.

3.4 Routine Release Analysis Panels

Routine effluent release analyses require ATD modeling in accordance with 10 CFR Part 20 and Part 50. This atmospheric model is designed for evaluating routine releases from NPPs based on RG 1.111 (NRC 1977). It is primarily designed to calculate annual average relative effluent concentrations, χ/Q values, and annual average relative deposition, D/Q values, at locations specified by the user and at 22 standard radial distances and 10 distance segments for the

sixteen standard 22.5-degree downwind sectors. When the “Routine Analysis” option is selected as the analysis type, the ATD user interface automatically configures itself to only present the appropriate input parameters to the user. The following sections define the controls and functionality presented in this set of input panels.

3.4.1 Source Panel

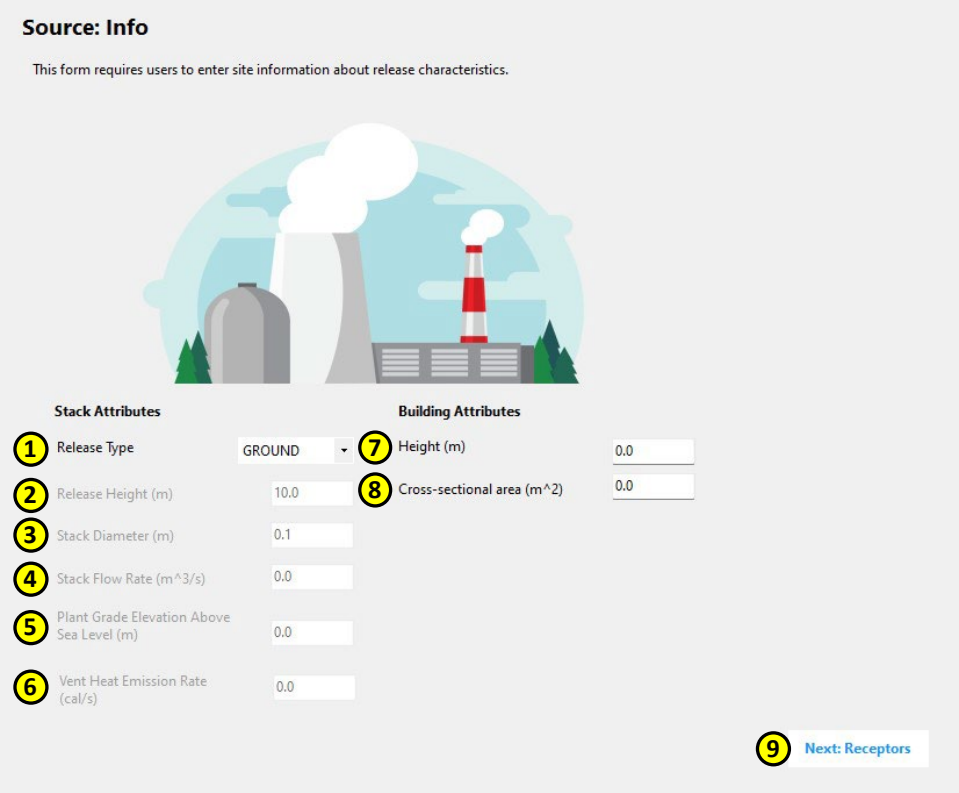


Figure 3-13. ATD Routine Release Analysis, Source Panel.

The following list briefly describes the source-related inputs as numbered in Figure 3-13.

1. Release Type Selection - The user selects the release type as either GROUND, VENT, or ELEVATED.
2. Release Height - The user provides the release height above plant grade for ELEVATED or VENT releases. Range: 0–300 m.
3. Stack Diameter - The user provides the stack inside diameter for ELEVATED or VENT releases. Range: 0–20 m.
4. Stack Flow Rate - The user provides the flow rate for ELEVATED or VENT releases. Range: 0–100 m^3/s.
5. Plant Grade Elevation Above Sea Level - The user provides the base elevation for ELEVATED or VENT releases. Range: 0–4,000 m.
6. Vent Heat Emission Rate - The user provides the heat emission rate for the stack exhaust for ELEVATED or VENT releases. Range: 0–1,000,000 cal/s.

7. Height - The user provides the building height for GROUND or VENT releases. Range 0–300 m.
8. Cross-sectional Area - The user provides the minimum cross-sectional area for the vent's (e.g., on the reactor) building if the structural wake is to be included in the dispersion analysis for GROUND or VENT releases. Range: 0–10,000 m^2.
9. Next: Receptors Button - When clicked, the ATD application will navigate to the "Receptors" panel.

3.4.2 Receptors Panel

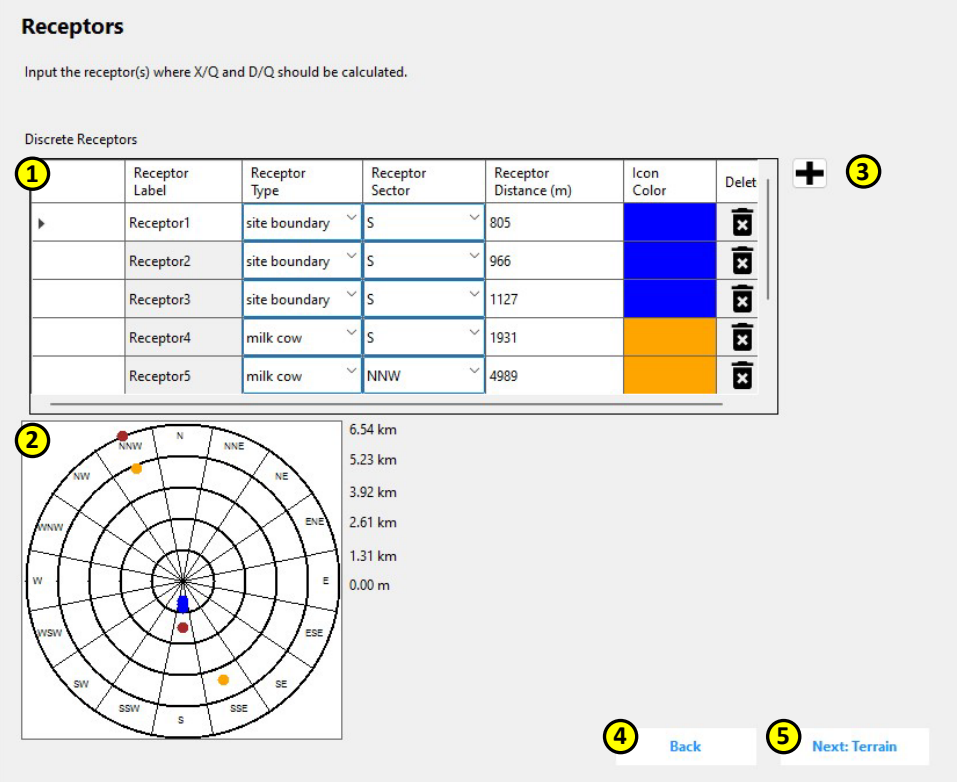


Figure 3-14. ATD Routine Release Analysis, Receptors Panel.

The following list briefly describes the discrete receptor-related inputs as numbered in Figure 3-14:

1. Discrete Receptors Data Grid - Displays the discrete receptors that are to be used in the analysis. Users may enter a discrete receptor label to identify the discrete receptor, select from the drop-down list of discrete receptor types or enter a unique discrete receptor type, select from the drop-down list of discrete receptor sectors, enter the discrete receptor distance, and select an icon color for the polar grid. Default icon colors are assigned for each discrete receptor type, although users can modify the colors. The delete icon allows users to delete the entry row.
2. Discrete Receptors Polar Grid - Displays the polar grid of where the discrete receptors are located.
3. Add Icon - Adds a new row to the Discrete Receptors data grid. The new row is populated with a default receptor type of "milk cow" and default receptor sector of "N."

4. Back Button - When clicked, the ATD application will navigate back to the “Source” panel.
5. Next: Terrain Button - When clicked, the ATD application will navigate to the “Terrain” panel.

Note that the user interface will allow a simulation to run without any discrete receptors entered, and the model will generate only output data at the standard distances. If a simulation is run without any discrete receptors being entered, the user interface will display a warning dialog stating that no discrete receptors were identified and asks the user if they would like to continue with the simulation. Figure 3-15 shows an example of the warning dialog that will be displayed.

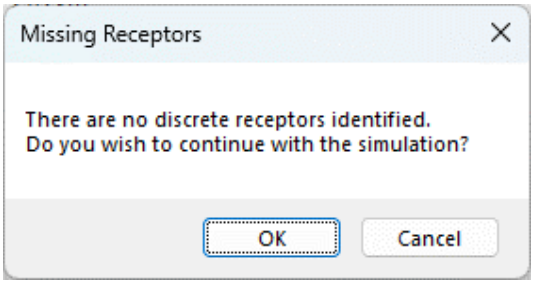


Figure 3-15. Warning Dialog Box when a Simulation Run is Attempted Without Discrete Receptor Data.

3.4.3 Terrain Panel

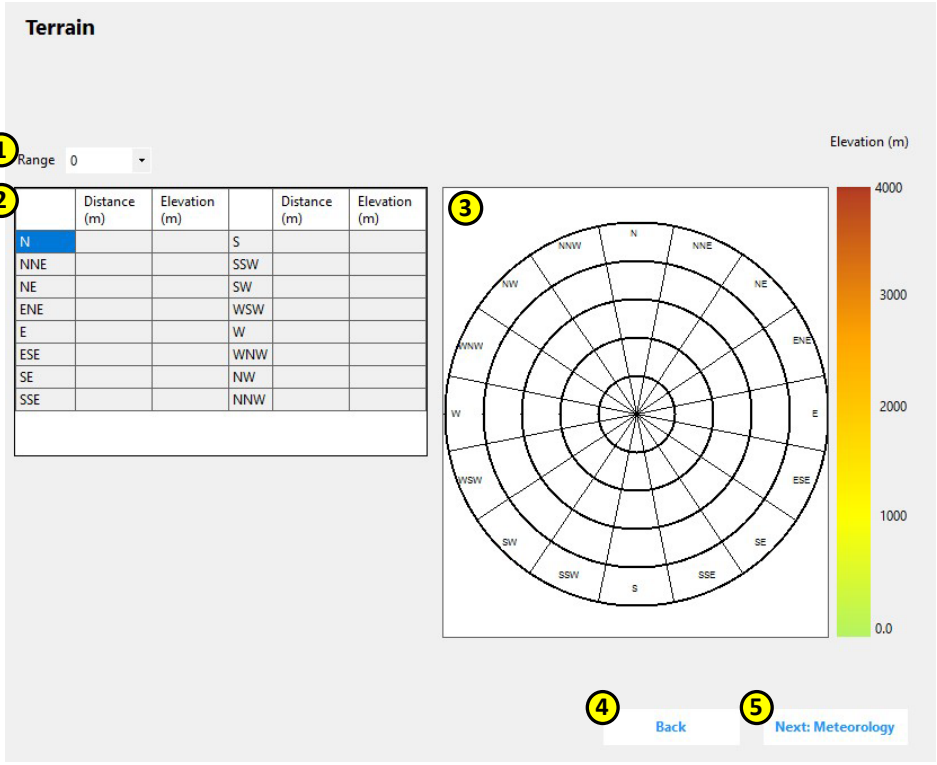


Figure 3-16. ATD Routine Release Analysis, Terrain Panel.

The following list briefly describes the terrain-related inputs as numbered in Figure 3-16:

1. Range Selection - The user can select a range to edit. Range: 0–10.

2. Sectors, Distances and Elevations Grid - The user can enter the distance (Range: 0–80,467 m) and elevation (Range: 0–4,000 m) for a sector. Elevation values shall be consistent with the basis (i.e., relative to sea level) used for the Plant Grade Elevation Above Sea Level, Release Height, and Building Height on the Source panel and be defined according to NUREG/CR-2919 (Sagendorf et al. 1982).
3. Distances and Elevations Polar Grid Display - Displays the data from the Distances and Elevations grid.
4. Back Button - When clicked, the ATD application will navigate back to the “Receptors” panel.
5. Next: Meteorology Button - When clicked, the ATD application will navigate to the “Meteorology” panel.

Note that the user interface will allow a simulation to run without any terrain data being entered. If a simulation is run without any terrain data being entered, the user interface will display a warning dialog stating that no terrain and distance data were entered and asks the user if they would like to continue with the simulation. Figure 3-17 shows an example of the warning dialog that will be displayed.

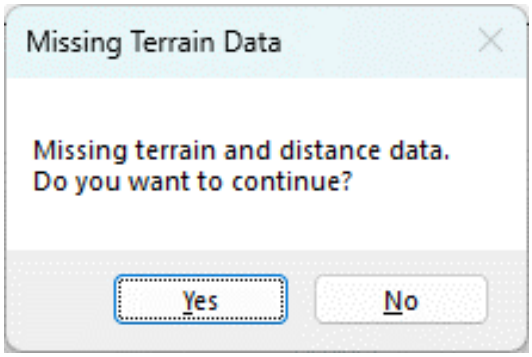


Figure 3-17. Warning Dialog Box when a Simulation Run is Attempted Without Terrain Data.

3.4.4 Meteorology Panel

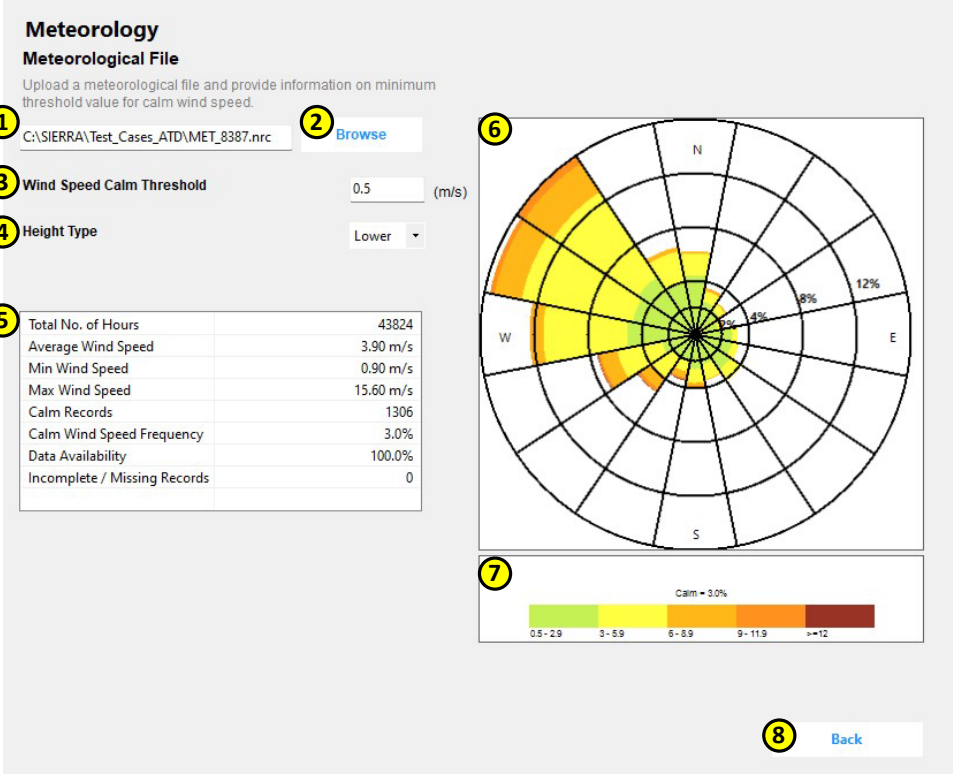


Figure 3-18. ATD Routine Release Analysis, Meteorology Panel.

The following list briefly describes the meteorology-related inputs as numbered in Figure 3-18:

1. Meteorology File Textbox - Displays the path to a selected meteorological data file. An error message will display below if the selected file is invalid.
2. Browse Button - Opens a window dialog to allow users to select an NRC-formatted meteorological data file.
3. Wind Speed Calm Threshold - Wind speeds below the value entered here are considered calm in the dispersion calculation. Range: 0–1 m/s. If an entered value is out of an indicated range, then error text will display below.
4. Height Type - The user can select a value from the choices provided: Lower or Upper. This selection updates the meteorological statistics view and wind rose plot, and does not determine the measurement height used in the simulation.
5. Meteorological Statistics View - Shows the meteorological data generated from an NRC-formatted file.
6. Wind Rose Plot - Displays a wind rose generated from the NRC-formatted file.
7. Legend - Shows the calm wind speed frequency and the colors associated with the wind speed categories.
8. Back Button - When clicked, the ATD application will navigate back to the “Terrain” panel.

3.4.5 Outputs Panel

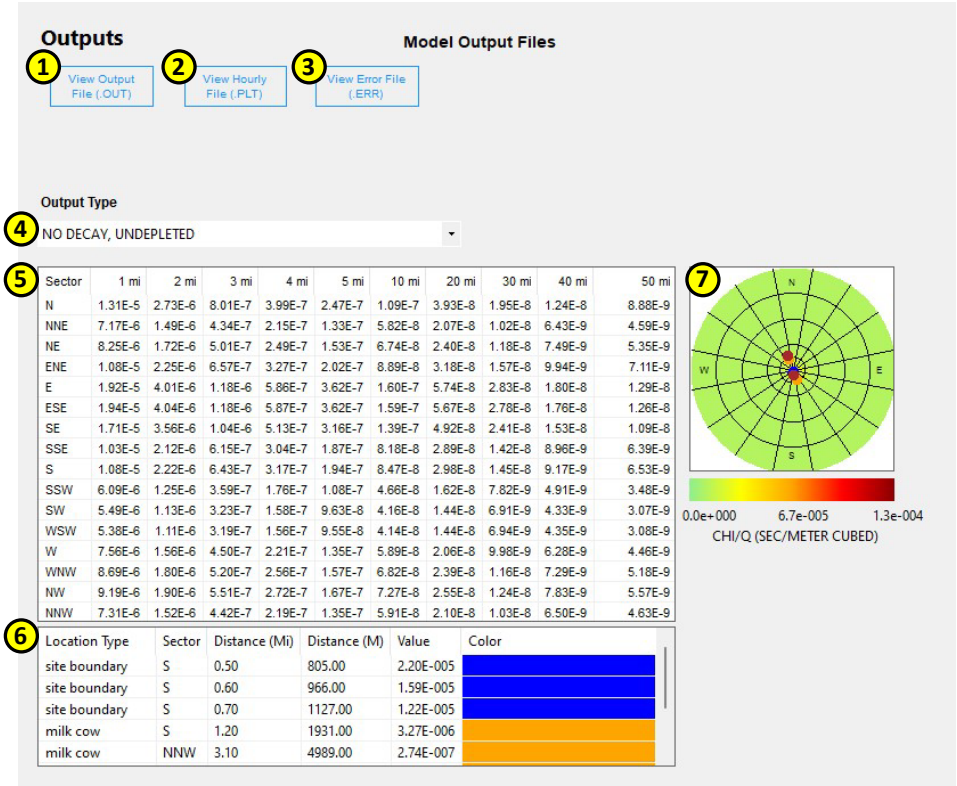


Figure 3-19. ATD Routine Release Analysis, Outputs Panel.

The following list briefly describes the various dispersion model outputs available as numbered in Figure 3-20. See Section B.2 of Appendix B for a general summary of the output files produced by the ATD engine of SIERRA.

1. View Output File Button - Opens the ATD Output Viewer that displays the OUT file.
2. View Hourly File Button - Opens the ATD Output Viewer that displays the PLT file.
3. View Error File Button - Opens the ATD Output Viewer that displays the ERR file.
4. Output Type Selection - User selects which output type to view: NO DECAY/UNDEPLETED, 2.260 DAY DECAY/UNDEPLETED, 8.000 DAY DECAY/DEPLETED, or RELATIVE DEPOSITION PER UNIT AREA (PER METER SQUARED).
5. Output Type Summary Data Grid - Displays the selected output type summary data.
6. Discrete Receptors Summary Data Grid - Displays the output summary data for the grid of discrete receptors.
7. Polar Grid Display - Displays the polar grid.

4.0 Quality Assurance

4.1 Software Quality Assurance – Graded Approach

The NRC and subscribers to RAMP (e.g., licensees and applicants) intend to use the SIERRA ATD software solely as a confirmatory tool for independent safety and environmental projections related to atmospheric dispersion, dose, and consequences for NPP licensing, emergency responses, and site decommissioning. The Pacific Northwest National Laboratory (PNNL) project team, its software quality practitioner, and the NRC have determined the intended use of the SIERRA ATD software shall be qualified per NUREG/BR-0167 as Level 1 software: Technical application used in a safety decision by the NRC.

The SIERRA ATD software is maintained by PNNL using a graded software quality assurance (SQA) approach compliant with the requirements specified in NUREG/BR-0167. The applicable SQA process for the project team is the PNNL “How Do I?” (HDI) “Develop Software for Delivery” workflow. The level of rigor applied to the software life cycle phases is based on the following identified risks, given the intended use:

- Software results could significantly impact PNNL’s customer (i.e., NRC) decisions; therefore, data quality is a key parameter.
- Software failure or performance other than as intended could result in a violation of NRC’s regulatory limits.

Any software use beyond this intended purpose requires additional SQA evaluation.

4.2 Software Testing

The SIERRA ATD Software Test Plan was executed per the Software Quality Assurance Plan requirements, resulting in the Software Test Report, which documents all verification and validation results. The project software verification and validation methodology was used to perform testing to demonstrate the software correctly performs all intended functions. For this software, tests of the mathematical models and user interfaces were performed. A brief description of software testing is described in the sections below.

Integrated testing addressed a range of possible conditions, but given the flexibility in the software, not all permutations of conditions could be evaluated. If users encounter a set of conditions that produces an unexpected output, please send the case information to the RAMP email inbox (ramp@nrc.gov).

4.2.1 Mathematical Model Testing

Tests are implemented to determine whether the codes executing the mathematical models are performing as expected. This testing falls into two general categories: unit testing and integrated testing (or functional testing). Unit testing is performed on the methods and functions in the software codes that either generate or modify data values. This testing is done against the individual function code separate from the testing performed against the software. Unit testing on a function is done by running function code using a set of predefined input values and comparing the results against the expected result values. Unit testing is focused on the smallest separable functions of the underlying coding.

Following unit testing, integrated testing is implemented on the executable to test that the mathematical models are performing as executed together (i.e., at a level above unit testing). Integrated testing of the mathematical model involved numerous cases with varying input parameters performed with a set of meteorological data. These cases were replicated, to the extent possible, with the corresponding legacy software.

Ghosh et al. (2025) document some of the integrated mathematical testing that was performed for the ATD model. A comparison of the mathematical outputs of the ATD and legacy codes is presented, along with a description of the primary technical differences between the codes.

4.2.2 User Interface Testing

User interface testing is performed to determine that the user experience is performing as expected as a user interacts with the interface (e.g., buttons function, screens progress, etc.). This testing must identify that the user interface will also provide the correct error message or restrict the user if an input falls outside an acceptable range. Unit tests of the user interface have been performed to assess the performance of the navigation between screens and data input. Functional testing of SIERRA and the ATD Module user interfaces was performed using several different types of tests including the following:

- invalid input (e.g., string instead of number)
- out-of-range input (e.g., 1,001 in the field that has an upper limit of 1,000)
- valid input and running the analysis
- control testing (e.g., the functionality of buttons, checkboxes, drop-down lists)
- input values with a large number of decimal places (e.g., 0.1111111111)
- form navigation (e.g., “Next” buttons and navigation menu)
- saving and loading input (JSON) files
- application logic (e.g., does clicking on “Run Analysis” run the model).

5.0 References

Bander, T. J. 1982. *PAVAN: An Atmospheric-Dispersion Program for Evaluating Design-Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations*. U.S. Nuclear Regulatory Commission NUREG/CR-2858. Washington, D.C.

Ghosh, S., J. E. Flaherty, G. C. Cornwell, and C. D. Mangini. 2025. *Software Integration for Environmental Radiological Release Assessments (SIERRA) Atmospheric Transport and Diffusion (ATD) Model: Technical Bais and Comparisons with Legacy Codes*. Pacific Northwest National Laboratory PNNL-36658, Revision 1. Richland, WA.

NRC (U.S. Nuclear Regulatory Commission). 1977. *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors*. U.S. Nuclear Regulatory Commission Regulatory Guide 1.111. Washington, D.C.

NRC (U.S. Nuclear Regulatory Commission). 1980. *Clarification of TMI Action Plan Requirements*. NUREG-0737. Washington, D.C.

NRC (U.S. Nuclear Regulatory Commission). 1981. *Functional Criteria for Emergency Response Facilities*. NUREG-0696. Washington, D.C.

NRC (U.S. Nuclear Regulatory Commission). 1982. *Atmospheric Dispersion Models for Potential Accident Consequence Assessment at Nuclear Power Plants*. U.S. Nuclear Regulatory Commission Regulatory Guide 1.145, Revision 1 (Reissued February 1983). Washington, D.C.

NRC (U.S. Nuclear Regulatory Commission). 2003. *Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Nuclear Power Plants*. U.S. Nuclear Regulatory Commission Regulatory Guide 1.194. Washington, D.C.

NRC (U.S. Nuclear Regulatory Commission). 2007a. “Design Basis Accident Radiological Consequence Analyses for Advanced Light Water Reactors.” Section 15.0.3 in *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*. NUREG-0800, Revision 3. Washington, D.C.

NRC (U.S. Nuclear Regulatory Commission). 2007b. “Emergency Planning.” Section 13.3 in *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*. NUREG-0800, Revision 3. Washington, D.C.

NRC (U.S. Nuclear Regulatory Commission). 2007c. “Long-Term Atmospheric Dispersion Estimates for Routine Releases.” Section 2.3.5 in *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*. NUREG-0800, Revision 3. Washington, D.C.

NRC (U.S. Nuclear Regulatory Commission). 2007d. *Meteorological Monitoring Programs for Nuclear Power Plants*. U.S. Nuclear Regulatory Commission Regulatory Guide 1.23, Revision 1. Washington, D.C.

NRC (U.S. Nuclear Regulatory Commission). 2007e. “Short-Term Atmospheric Dispersion Estimates for Accident Releases.” Section 2.3.4 in *Standard Review Plan for the Review of*

Safety Analysis Reports for Nuclear Power Plants: LWR Edition. NUREG-0800, Revision 3. Washington, D.C.

Ramsdell, J. V., and C. J. Fosmire. 1995. *Atmospheric Dispersion Estimates in the Vicinity of Buildings*. Pacific Northwest National Laboratory PNNL-10286. Richland, WA.

Ramsdell, J. V., and C. J. Fosmire. 1998. “Estimating Concentrations in Plumes Released in the Vicinity of Buildings: Model Development.” *Atmospheric Environment* 32 (10): 1663–1677.

Ramsdell, J. V., and C. A. Simonen. 1997. *Atmospheric Relative Concentrations in Building Wakes*. U.S. Nuclear Regulatory Commission NUREG/CR-6331. Washington, D.C.

Sagendorf, J. F. 1994. *A Program for Evaluating Atmospheric Dispersion from a Nuclear Power Station*. NOAA Tech Memo ERL-ARL-42. Idaho Falls, ID.

Sagendorf, J. F., J. T. Goll, and W. F. Sandusky. 1982. *XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations*. U.S. Nuclear Regulatory Commission NUREG/CR-2919. Washington, D.C.

Slade, D. H. (ed.). 1968. *Meteorology and Atomic Energy*. Air Resources Laboratories TID-24190. Silver Spring, MD.

Appendix A — SIERRA ATD Directory Structure

To standardize the implementation of additional Software Integration for Environmental Radiological Release Assessments (SIERRA) software modules into the modeling framework, a well-defined and standardized directory structure is necessary to manage the files required to run a simulation. This directory structure must be defined in such a manner that it allows for file paths to be created during simulations without additional user input. The directory structure needs to be easily accessible by users who wish to review simulation files for audit or debugging purposes. The following provides a description of the different directories and subdirectories contained within the directory structure to be used by the modeling framework.

A.1 SIERRA Parent Directory

By default, the SIERRA parent directory is installed on the C: drive of the user's computer when the SIERRA software is installed. This directory acts as the main directory for the modeling framework. All files and directories needed to run a simulation will be managed from within this parent directory. Files that reside at this level are the executables for the system interface and the backend system software as well as all libraries, dynamic link libraries (dlls), and configuration information required by the executables. The directory also contains the Models and Users subdirectories.

A.1.1 Models Directory

The "Models" directory stores the files required for the individual modules (e.g., Atmospheric Transport and Diffusion, Source Term) to execute properly. This directory will contain a subdirectory for each model integrated with the modeling platform.

These subdirectories contain all files required for the model to execute properly when called from the modeling platform's backend system. Files that reside at this level include the executable files as well as all libraries, dlls, and configuration information required by the executables. There is one subdirectory present in the Models directory for each model integrated with the modeling platform, which will be labeled using an abbreviated name of the model (e.g., ATD, ST).

A.1.2 Users Directory

This directory stores simulation data for each user that has run simulations using the modeling framework. When the software is first installed, the Users directory will be empty. Once a simulation has been performed, this directory will contain a set of subdirectories, each identified by the appropriate User ID (if multiple users have run simulations). Each user subdirectory (named according to the User ID) contains a set of directories representing data and information from simulation runs that will be labeled with the case name assigned to that simulation. User IDs will be automatically pulled from the machine's operating system.

While creating a new simulation, the modeling framework prompts the user to provide a name for the simulation case (see Section 2.3). This case name is used to label the scenario case directories stored in the SIERRA user directory. This scenario directory contains a date/time labeled subdirectory for each of the simulation runs performed by the user.

For every simulation performed by the modeling platform, there is a simulation date directory created in the appropriate scenario directory. Simulation date directories are labeled based upon the system date and time that the simulation was run. The format to be used for the naming of these simulation directories will be yyyy_mm_dd_hr_mn_ss where yyyy is the four-digit year, mm is the two-digit month, dd is the two-digit day of the month, hr is the hour in 24-hour format, mn is the two-digit minute, and ss is the two-digit second. This simulation directory will contain all data generated by the simulation, with the data being stored in subdirectories labeled Inputs and Outputs.

The Inputs directory located within a simulation date directory will be used to store all data files that are used as input files for the modeling platform and simulation models.

The Outputs directory located within a simulation date directory will be used to store all data files that are generated by the modeling platform and simulation models.

Figure A-1 shows an example directory structure with cases saved from two different users that makes use of the structure described above.

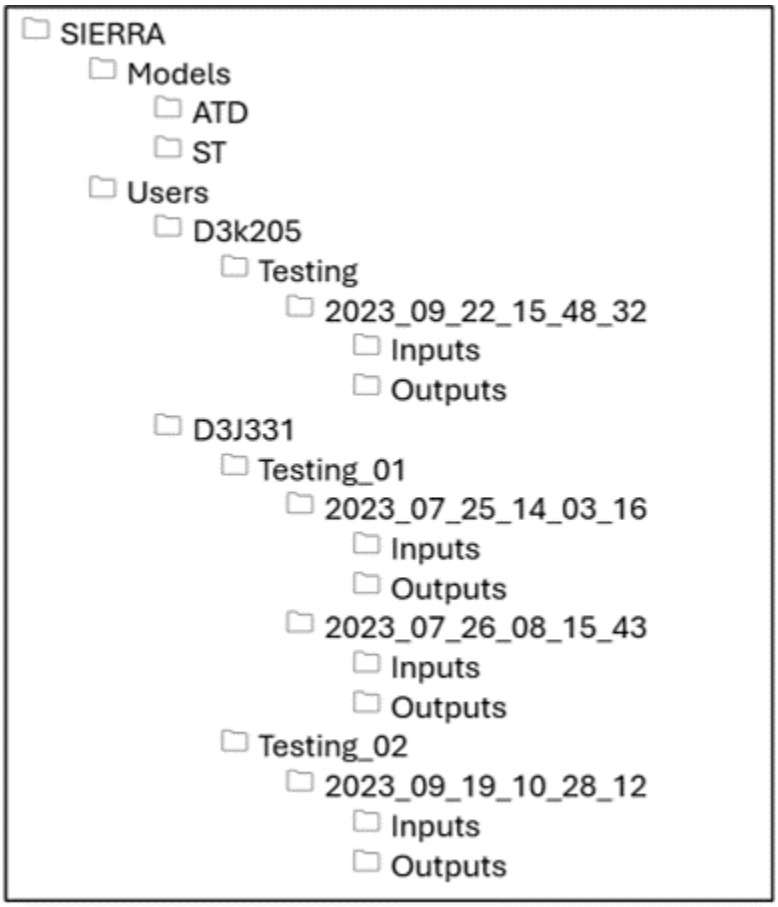


Figure A-1. Example SIERRA Directory Structure.

Appendix B — Input and Output Files

B.1 JSON Input Structure

JavaScript Object Notation (JSON) is an open standard file format for storing and sharing electronic data. JSON is human readable and lightweight and can be transferred between different programming languages and operating systems. Data are written in JSON objects, which are a combination of key/value pairs condensed in curly braces ({ }). Key/value pairs have a colon between them as in “key”:“value”. Each key/value pair is separated by a comma. A “key” is provided on the left side of the colon with double quotation marks. It is a field name with “string” data type. On the right side of the colon, a JSON value is provided, which can be a string, numbers, objects, arrays, or Booleans. Arrays are provided in square brackets ([ ]). A JSON format file can store nested objects and nested arrays. These objects and arrays will be passed as values assigned to keys and may comprise key/value pairs as well. An example JSON format file that can be provided as input to the Atmospheric Transport and Diffusion (ATD) engine for onsite control room design basis accident (DBA) analyses is shown in Figure B-1. Users can validate their JSON files with tools available online.

An ATD input file in JSON format contains the following primary keys:

- control_info – A key that sets up the modeling scenario with a user-provided string.
- model_info – A key that provides a model or assessment type. Options are (1) “arcon,” (2) “pavan,” and (3) “xoqdoq.”
- source_info – A key that provides release information such as Release Type, stack characteristics, and nearby building information. Release Type can be “GROUND,” “VENT” (primarily limited to XOQDOQ),” or “ELEVATED.”
- receptor_info – A key that provides receptor information such as the distance and terrain within arrays. For onsite control room DBA analysis (similar to the computer code for Atmospheric Relative CONcentrations in Building Wakes [ARCON]), specific receptor information, such as the receptor height, the wind direction window, and the direction of the receptor to the source, is required. For routine release assessment (similar to the computer code for the evaluation of routine effluent releases at commercial nuclear power stations [XOQDOQ]), the distances for fixed radial receptors are not required. A default of 22 distances on 16 radial sectors from 0.5 to 50 miles is used internally. The “receptor_info” key can also be used to provide any terrain information for the site.
- discrete_info – An optional key that can provide information on discrete receptors for routine release analyses, similar to the existing XOQDOQ model with NRCDose.
- met_info – A key that provides a pathname to the meteorological file formatted according to specification in Regulatory Guide (RG) 1.23 (NRC 2007). In addition, the user can set the minimum threshold for the calm wind speed below which wind data will be treated as calms.
- prog_defaults_info – A key that provides the defaults for models that users can choose to modify such as plume rise calculations, accounting for the recirculation factor for routine release, diffusion coefficient calculation methods, and missing criteria for averaging for different time periods.

```
{
"control_info": {
"scenario":"Test_Cases_ATD"
},
"model_info":"arcon" ,
"source_info":{
"release_type":"GROUND",
"stack_height":10.0,
"stack_dia":0.1,
"stack_flow":0.0,
"stack_height":10.0,
"stack_terrain":0.0,
"stack_heat_emis":0.0,
"building_area":1900.0
},
"receptor_info":{
"arcon":{"intake_ht":15.0, "wd_window":90.0, "dir2source":326.0},
"distance": [45.0],
"terrain": [0.0]
},
"met_info":{
"met_file":"C:/SIERRA/Test_Cases_ATD/MET_8387.nrc",
"ws_calm_threshold":0.1,
"surface_roughness":0.2
},
"prog_defaults_info":{
"arcon":{"sigY0":0.0, "sigZ0":0.0},
"diffusion_option":"NRC",
"missing_criteria":10.0,
"additional_percentile":99.5
}
}
```

Figure B-1. Example JSON Input File with a Scenario for the Onsite Control Room Design Basis Accident Analysis of a Ground-Level Source.

B.2 Output Files

The ATD engine generates the following seven output files:

- ATD_ENGINE.OUT – Summary output text file containing information about inputs, a summary of meteorological data, and statistical outputs specific to the assessment.
- ATD_ENGINE.PLT – Hourly values of centerline and sector average χ/Q along with the wind speed at the measurement height, the wind speed adjusted for the release height, the wind direction, flags for calm and missing, the stability class, and diffusion coefficients (without corrections for the building wake).
- ATD_ENGINE.CFD – Cumulative frequency distributions (CFDs) of running χ/Q averages for specific time periods. No output for routine release analyses.
- ATD_ENGINE.JFD – Joint frequency distribution summary of meteorological input data. This dataset is not used in calculations and provided only for reference.

- ATD_ENGINE.ERR – Text file providing warning and error messages.
- ATD_ENGINE_ERR.JSON – JSON format file for warning and error messages.
- ATD_ENGINE_OUT.JSON – JSON format file with statistical outputs.

Appendix C — Running the Application

The following is an example of a regulatory routine release analysis simulated using the Software Integration for Environmental Radiological Release Assessments (SIERRA) software. The following steps can be used to set up and run the simulation example.

1. Double-click the SIERRA desktop shortcut or single-click the SIERRA icon in the Windows Start Menu item to start the SIERRA application.
2. The SIERRA splash screen (Figure C-1) will be displayed while the SIERRA application loads.

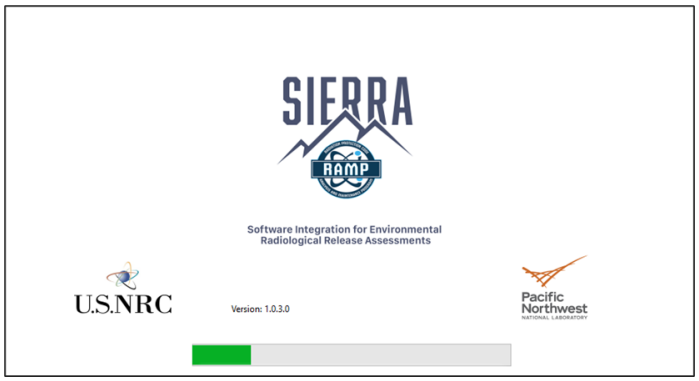


Figure C-1. SIERRA Splash Screen.

3. Once the splash screen has closed, a disclaimer page will appear, and if the user selects the “Continue” button, the SIERRA application user interface will be displayed with the assessment type (Figure C-2).

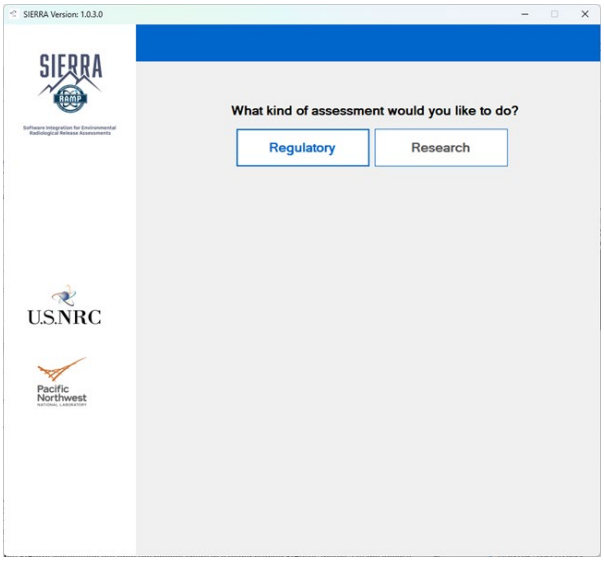


Figure C-2. SIERRA Assessment Selection Screen.

4. Click on the “Regulatory” button to select the regulatory assessment simulation option.
5. After the “Regulatory” button is clicked, a dialog window will be displayed, prompting for the entry of a simulation name (Figure C-3).

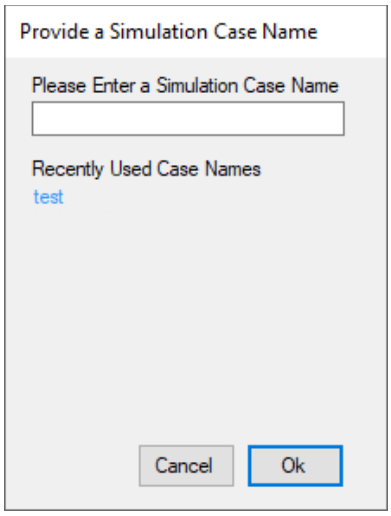


Figure C-3. SIERRA Dialog Window Prompting the User to Enter a Simulation Name.

6. Type the desired name into the dialog window text box or select an existing name and then click on the “Ok” button.
7. The interface will then advance to the Analysis Type Selection panel (Figure C-4).

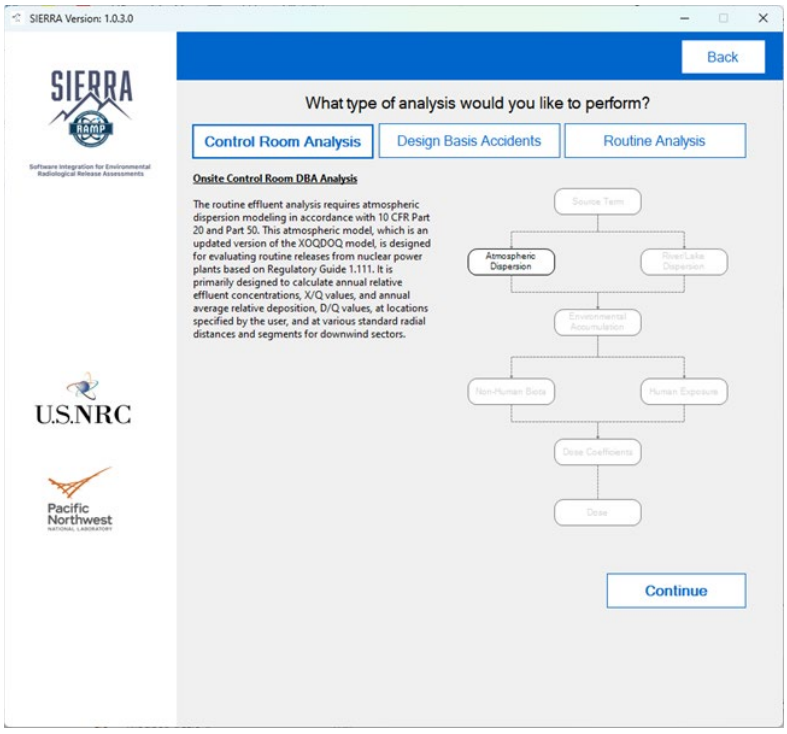


Figure C-4. SIERRA Analysis Type Selection Panel.

8. Once displayed, click on the “Routine Analysis” button to select the routine release analysis type.
9. With the routine release analysis type selected, click the “Continue” button to advance the interface to the simulation “Overview” panel (Figure C-5).

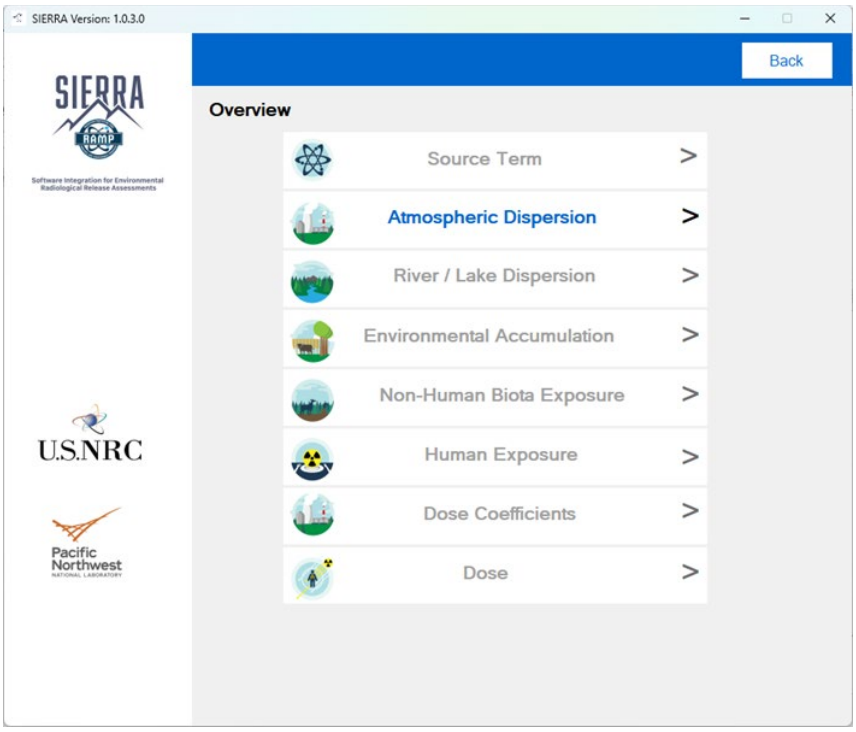


Figure C-5. SIERRA Overview Panel.

10. Click on the “Atmospheric Dispersion” button to start the Atmospheric Transport and Diffusion (ATD) module interface.
11. With the interface of the “Atmospheric Dispersion” module now displayed, the left panel of the interface should show the “Source” option highlighted and the “Source” input panel displayed on the right of the interface (Figure C-6).

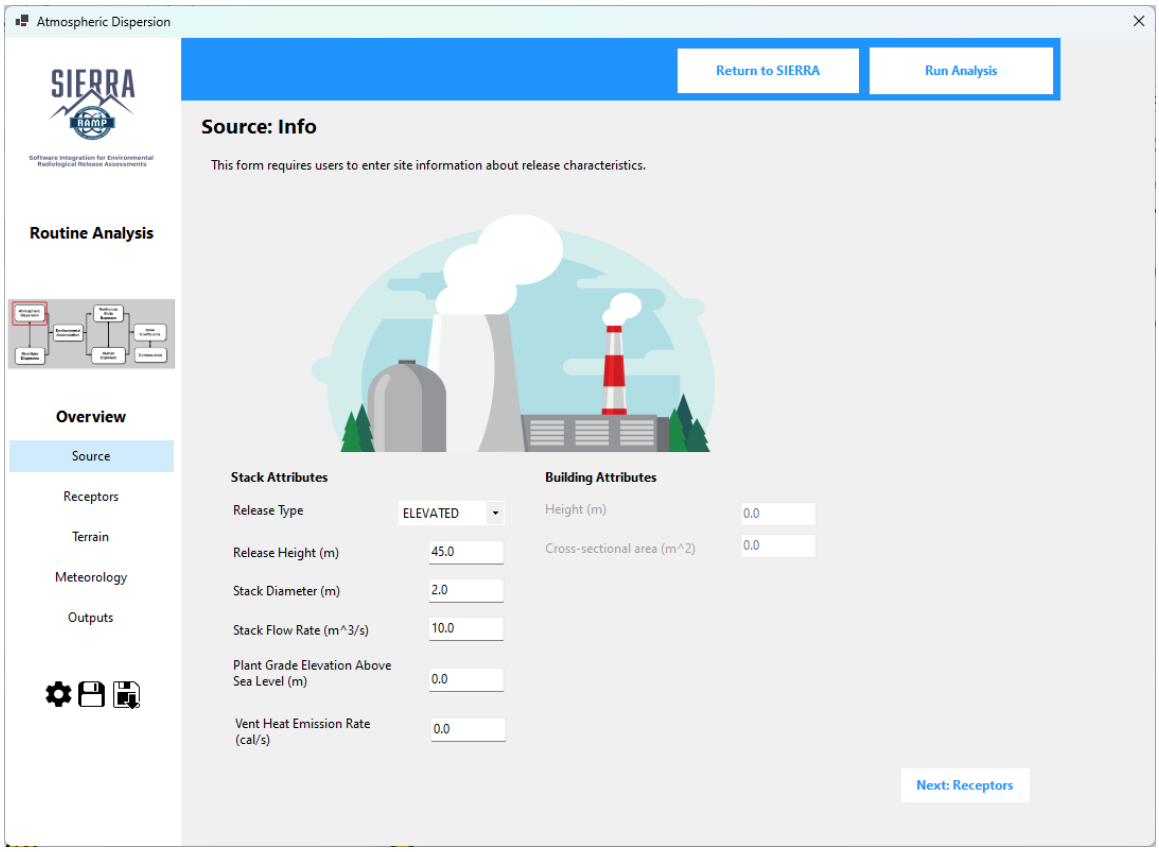


Figure C-6. Completed Routine Release Analysis Source Panel.

12. Under “Stack Attributes,” select the “ELEVATED” Release Type using the “Release Type” drop-down list control.
13. Enter a release height of 45.0 m in the “Release Height” text box.
14. Enter 2.0 in the “Stack Diameter” text box.
15. Enter 10.0 in the “Stack Flow Rate” text box.
16. Retain the default value of 0.0 in the “Plant Grade Elevation Above Sea Level” text box.
17. Retain the default value of 0.0 in the “Vent Heat Emission Rate” text box.
18. The “Height” and “Cross-sectional area” text boxes under “Building Attributes” should be disabled and will not be used for this simulation.
19. Click on the “Next: Receptors” button at the lower right corner of the panel to advance the interface to the “Receptors” panel (Figure C-7).

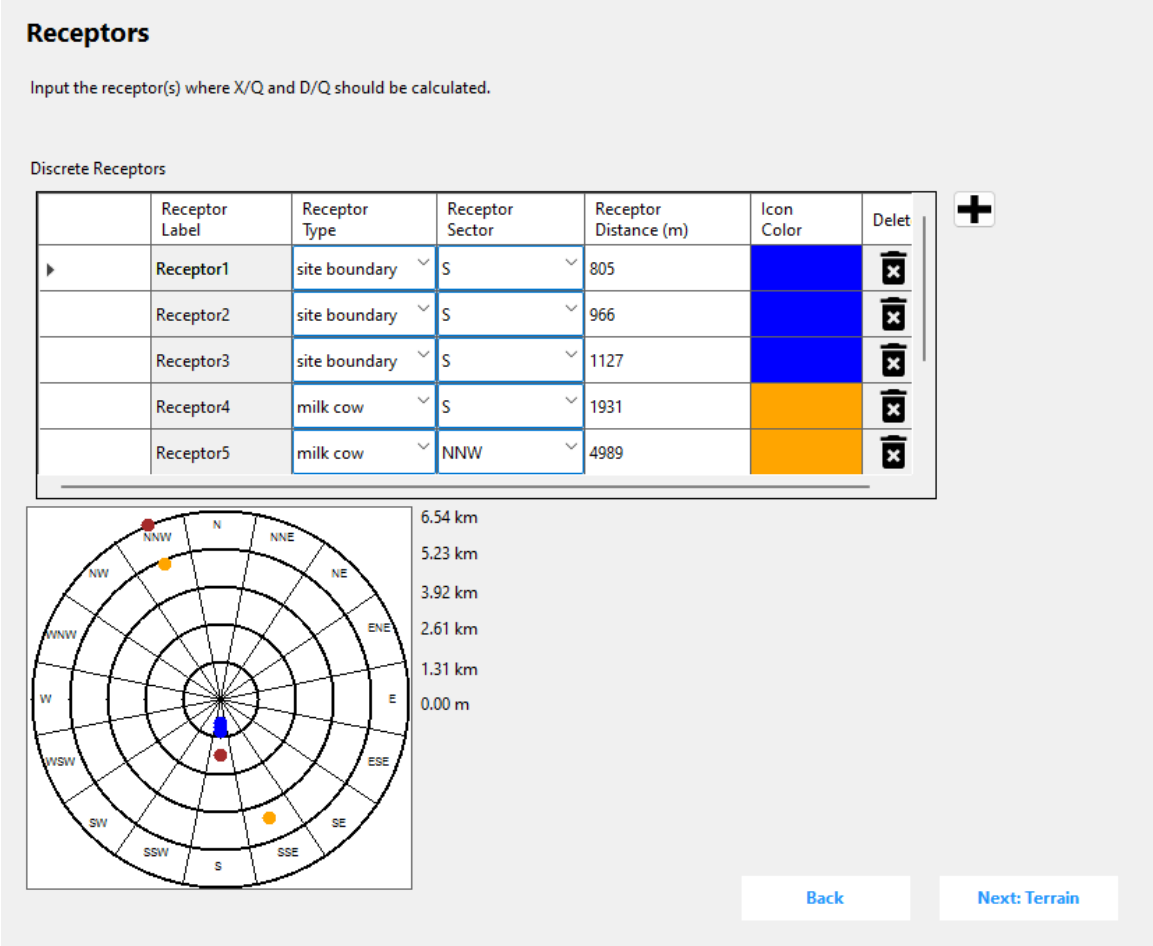


Figure C-7. Completed Routine Release Analysis Discrete Receptors Panel.

20. With the “Receptors” panel displayed, click on the “Add” icon (plus sign near the top right corner of the Discrete Receptors table) to add a new discrete receptor to the simulation.
21. Enter a label for the new discrete receptor into the “Receptor Label” text box (e.g., “Receptor1”).
22. Select the “site boundary” option for the Receptor Type using the drop-down list box.
23. Select the South (“S”) option for the sector using the “Receptor Sector” drop-down list box.
24. Enter a distance of “805” in the “Receptor Distance (m)” text box.
25. Each prepopulated Receptor Type has been assigned a prepopulated color. When the site boundary receptor type is selected, the Icon Color is populated with a blue color.
26. To modify the prepopulated color, double-click in the box with the Icon Color, and select a new color from the color select dialog that appears.
27. Once the icon color has been prepopulated or selected, the receptor display will update, showing the location of the added receptor.
28. Repeat this process to add seven additional discrete receptors.
    a. Label: Receptor2, Type: site boundary, Sector: S, Distance: 966 m.

b. Label: Receptor3, Type: site boundary, Sector: S, Distance: 1,127 m.

c. Label: Receptor4, Type: milk cow, Sector: S, Distance: 1,931 m.

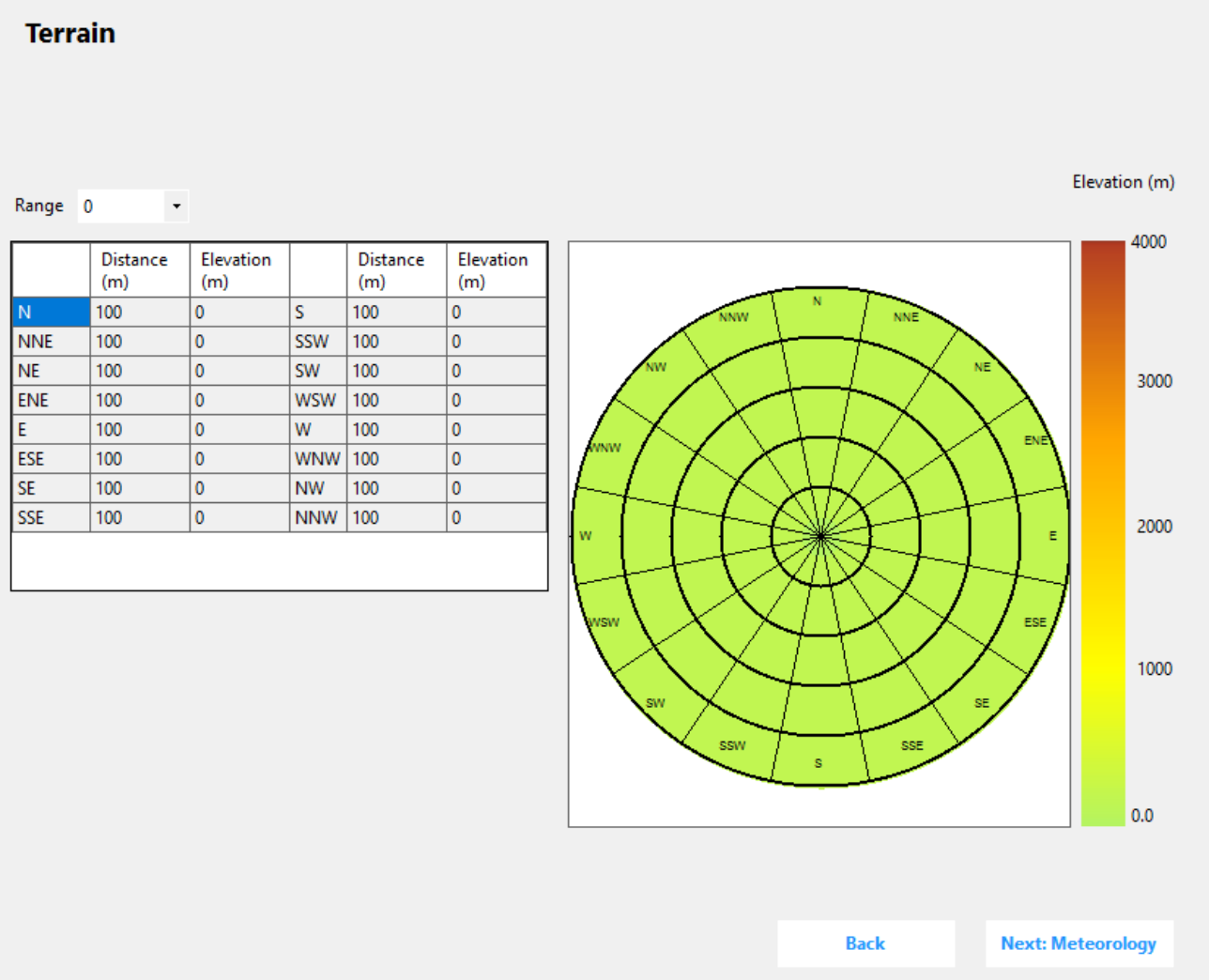
d. Label: Receptor5, Type: milk cow, Sector: NNW, Distance: 4,989 m.

e. Label: Receptor6, Type: milk cow, Sector: SSE, Distance: 4,345 m.

f. Label: Receptor7, Type: residence, Sector: S, Distance: 1,931 m.

g. Label: Receptor8, Type: residence, Sector: NNW, Distance: 6,437 m.

29. Click on the “Next: Terrain” button in the lower right corner of the Receptors panel to advance the interface to the “Terrain” panel (Figure C-8).



	Distance (m)	Elevation (m)		Distance (m)	Elevation (m)
N	100	0	S	100	0
NNE	100	0	SSW	100	0
NE	100	0	SW	100	0
ENE	100	0	WSW	100	0
E	100	0	W	100	0
ESE	100	0	WNW	100	0
SE	100	0	NW	100	0
SSE	100	0	NNW	100	0

Figure C-8. Completed Routine Release Analysis Terrain Panel.

30. Using the “Range” drop-down list box, select the “0” option.

31. In the row labeled “N,” enter 100 in the “Distance” cell and 0 in the “Elevation” cell.

a. To ensure that the next two steps are executed correctly, users must enter the distance and elevation value sequentially or otherwise ensure that the entries are considered “completed” by the software by selecting another cell, clicking a separate space from the

entry itself, or pressing the “Enter” key. Entries are not considered “completed” if the cursor in the box is flashing.

32. Left-click the “Distance” cell containing the value of 100 to highlight the entry and then right-click to select the “Fill all distances” option from the drop-down menu that is displayed. This will fill in all distance cells with the value of 100.
33. Left-click the “Elevation” cell containing the value 0 to highlight the entry and then right-click to select the “Fill all elevations” option from the drop-down menu that is displayed. This will fill in all elevation cells with the value of 0.
34. The distance/elevation diagram will automatically update to show the changes to the data.
35. Follow the same directions to add two more sets of range data to the interface.
    a. Range 1: Distance: 800 m, Elevation: 16 m.
    b. Range 2: Distance: 10,000 m, Elevation: 200 m.
36. Click on the “Next: Meteorology” button in the lower right corner of the panel or select “Meteorology” from the Overview panel to advance the interface to the “Meteorology” panel.
37. With the “Meteorology” panel displayed (Figure C-9), click on the “Browse” button next to the “Meteorological File” text box to display an “Open” file dialog window that can be used to select the meteorology file that will be used in the simulation. The meteorological data must be hourly data in Regulatory Guide (RG) 1.123 format.
38. Use the default “Wind Speed Calm Threshold” value of 0.1 m/s in the corresponding text box.
39. Note: The “Lower” option from the “Height Type” drop-down list box impacts the data displayed in the table and the polar plot but does not impact the simulation.

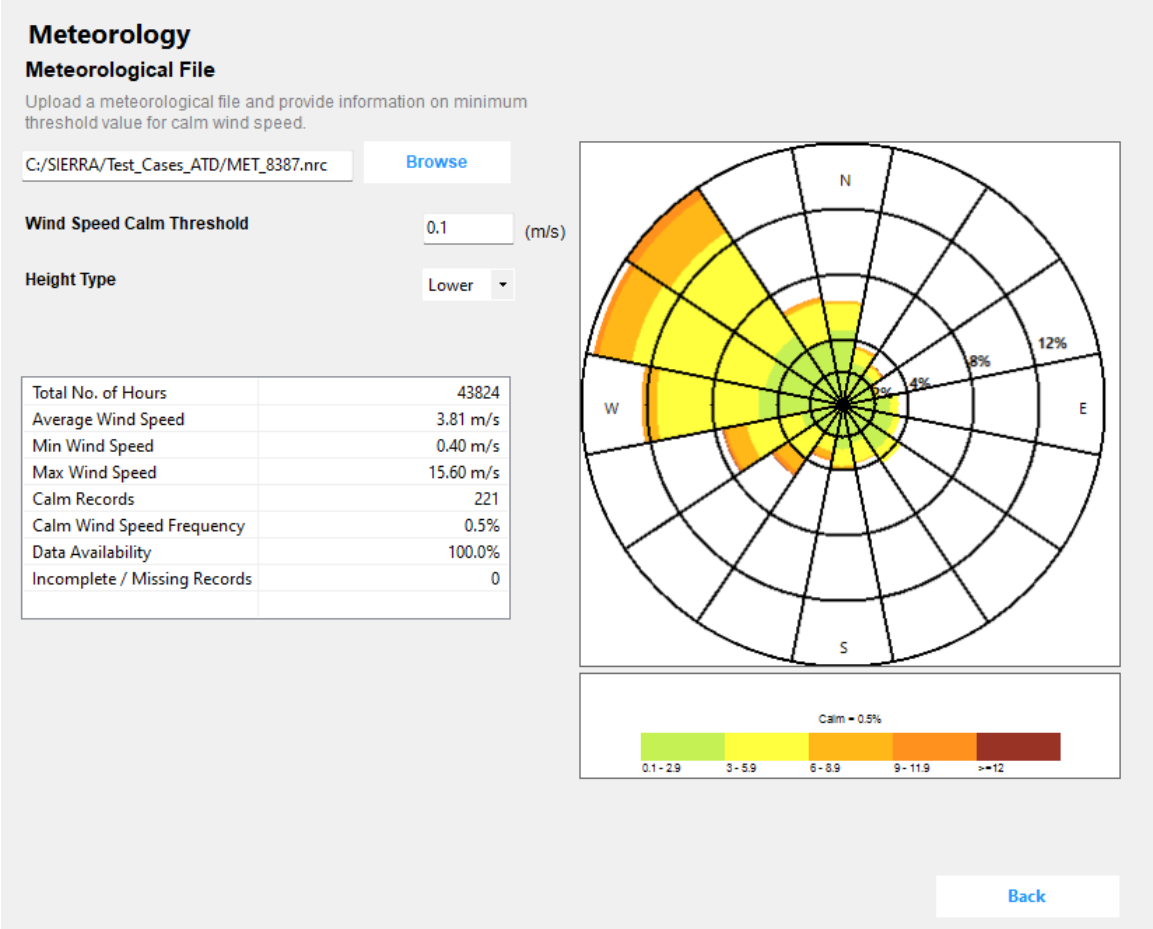
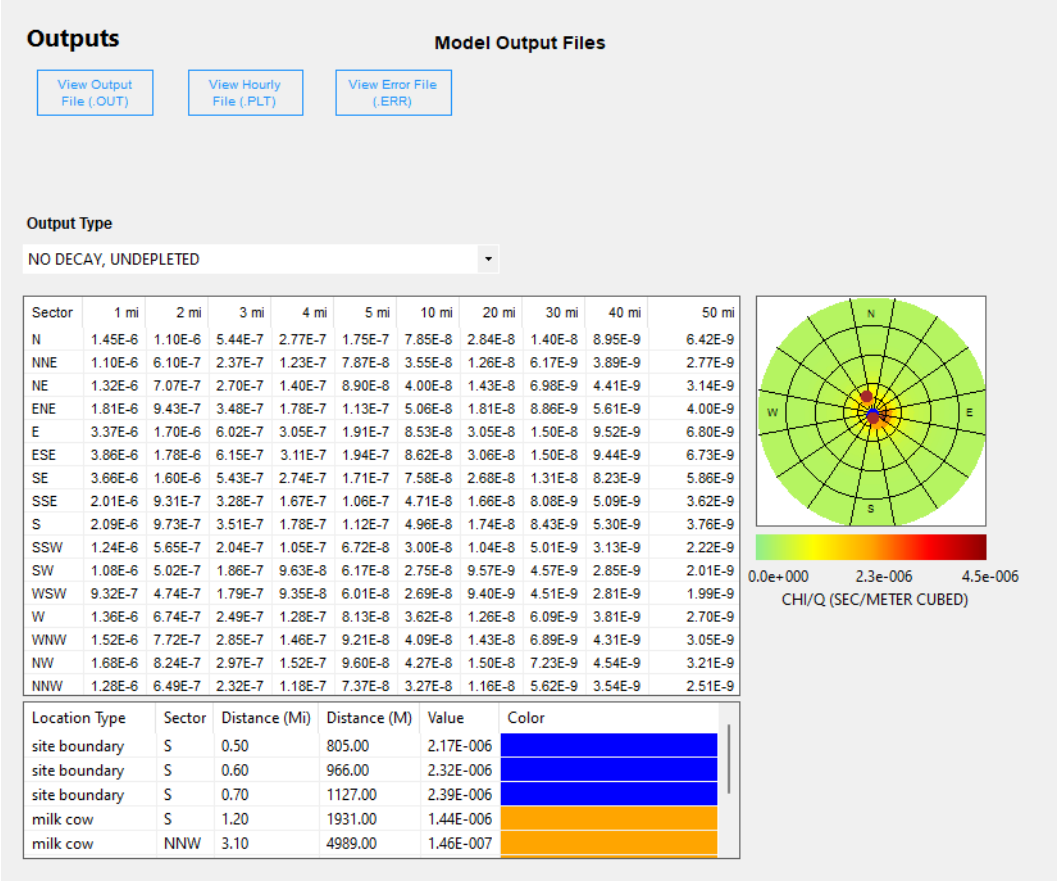


Figure C-9. Completed Routine Release Analysis Meteorology Panel.

40. The wind rose diagram and the summary table displayed on the panel will be automatically updated to reflect data inputs.
41. Click the “Run Analysis” button located in the upper right corner of the interface to start the ATD simulation engine.
42. Once the simulation engine has finished its execution, the results of the simulation will be processed by the ATD module, and the “Outputs” panel (Figure C-10) will be displayed, showing the results of the simulation.
43. The Model Output Files portion of the “Outputs” panel has three output files from the simulation that can be viewed from the user interface. The .OUT file is the simulation output file with various distances, decay rates, and sectors included. The .PLT file is the hourly records of χ/Q for different decay rates and D/Q, along with the wind speed, wind direction, and diffusion coefficients (among other meteorological information). Finally, the .ERR file is the error information associated with the run. Each of these files can also be accessed from the simulation case folder associated with the run.
44. The Output Type portion of the “Outputs” panel allows users to select from one of four output types, which will update the contents of the Output Type Summary Data Grid as well as the Discrete Receptors Summary Data Grid.



Sector	1 mi	2 mi	3 mi	4 mi	5 mi	10 mi	20 mi	30 mi	40 mi	50 mi
N	1.45E-6	1.10E-6	5.44E-7	2.77E-7	1.75E-7	7.85E-8	2.84E-8	1.40E-8	8.95E-9	6.42E-9
NNE	1.10E-6	6.10E-7	2.37E-7	1.23E-7	7.87E-8	3.55E-8	1.26E-8	6.17E-9	3.89E-9	2.77E-9
NE	1.32E-6	7.07E-7	2.70E-7	1.40E-7	8.90E-8	4.00E-8	1.43E-8	6.98E-9	4.41E-9	3.14E-9
ENE	1.81E-6	9.43E-7	3.48E-7	1.78E-7	1.13E-7	5.06E-8	1.81E-8	8.86E-9	5.61E-9	4.00E-9
E	3.37E-6	1.70E-6	6.02E-7	3.05E-7	1.91E-7	8.53E-8	3.05E-8	1.50E-8	9.52E-9	6.80E-9
ESE	3.86E-6	1.78E-6	6.15E-7	3.11E-7	1.94E-7	8.62E-8	3.06E-8	1.50E-8	9.44E-9	6.73E-9
SE	3.66E-6	1.60E-6	5.43E-7	2.74E-7	1.71E-7	7.58E-8	2.68E-8	1.31E-8	8.23E-9	5.86E-9
SSE	2.01E-6	9.31E-7	3.28E-7	1.67E-7	1.06E-7	4.71E-8	1.66E-8	8.08E-9	5.09E-9	3.62E-9
S	2.09E-6	9.73E-7	3.51E-7	1.78E-7	1.12E-7	4.96E-8	1.74E-8	8.43E-9	5.30E-9	3.76E-9
SSW	1.24E-6	5.65E-7	2.04E-7	1.05E-7	6.72E-8	3.00E-8	1.04E-8	5.01E-9	3.13E-9	2.22E-9
SW	1.08E-6	5.02E-7	1.86E-7	9.63E-8	6.17E-8	2.75E-8	9.57E-9	4.57E-9	2.85E-9	2.01E-9
WSW	9.32E-7	4.74E-7	1.79E-7	9.35E-8	6.01E-8	2.69E-8	9.40E-9	4.51E-9	2.81E-9	1.99E-9
W	1.36E-6	6.74E-7	2.49E-7	1.28E-7	8.13E-8	3.62E-8	1.26E-8	6.09E-9	3.81E-9	2.70E-9
WNW	1.52E-6	7.72E-7	2.85E-7	1.46E-7	9.21E-8	4.09E-8	1.43E-8	6.89E-9	4.31E-9	3.05E-9
NW	1.68E-6	8.24E-7	2.97E-7	1.52E-7	9.60E-8	4.27E-8	1.50E-8	7.23E-9	4.54E-9	3.21E-9
NNW	1.28E-6	6.49E-7	2.32E-7	1.18E-7	7.37E-8	3.27E-8	1.16E-8	5.62E-9	3.54E-9	2.51E-9

Location Type	Sector	Distance (Mi)	Distance (M)	Value	Color
site boundary	S	0.50	805.00	2.17E-006	
site boundary	S	0.60	966.00	2.32E-006	
site boundary	S	0.70	1127.00	2.39E-006	
milk cow	S	1.20	1931.00	1.44E-006	
milk cow	NNW	3.10	4989.00	1.46E-007	

Figure C-10. Completed Routine Release Analysis Model Output Panel.

Appendix D — Example Test Cases

Test cases for each of the Atmospheric Transport and Diffusion (ATD) models (i.e., onsite control room design basis accident [DBA] analysis, offsite DBA analysis, and routine release analysis), which may be performed by users to confirm their installation, are presented. In many instances, these test cases are modeled after the test cases from the legacy software documentation. The JavaScript Object Notation (JSON) input files, along with the corresponding output files, are included with the Software Integration for Environmental Radiological Release Assessments (SIERRA) installation and may be found in subfolders to the SIERRA\Test_Cases_ATD folder. While the JSON input files may be used, brief descriptions of the cases are presented below. After loading the JSON input file, users should check the Meteorology panel to confirm the file path for the meteorological data file, which is SIERRA\Test_Cases_ATD\MET_8387.nrc.

Users may enter inputs manually into the user interface following the values presented in the subsections within this appendix or load them from the JSON input files in the input folder. To check that the installation was performed correctly and that the outputs are correct, users should check the output file that is produced after the analysis is run. To manually check some of the outputs, a portion of the output file is presented in the following subsections. A more complete check can be performed by using a text comparison tool (such as “Compare Files…” within TextPad) to compare the output file saved to the user folder with the output delivered with the software in the SIERRA\Test_Cases_ATD folder.

D.1 Onsite Control Room Design Basis Accident Analysis Test Cases

D.1.1 User Interface Inputs for the Onsite Control Room Design Basis Accident Analysis, Elevated Test Case

- Source Values
  - Release Type: ELEVATED
  - Release Height: 65 m
  - Stack Diameter: 1.0 m
  - Stack Flow Rate: 10.0 m^3/s
  - Plant Grade Elevation: 0.0 m
  - Building Height: 0 m (default)
- Receptor Values
  - Receptor Distance: 210 m
  - Intake Height: 25 m
  - Terrain Height: 0.0 m
  - Wind Direction Window: 90.0 degrees
  - Direction from Receptor to the Source: 284 degrees
- Meteorology Values
  - 5 years of meteorological station data from 1983 through 1987

  - Wind Speed Calm Threshold: 0.1 m/s
  - Surface Roughness: 0.2 m
- Module Defaults
  - Diffusion: NRC
  - Initial Diffusion Coefficients: 0 m
  - Missing Data Criterion: 10 percent
  - User Defined Percentile: 99.5th

D.1.2 Outputs for the Onsite Control Room Design Basis Accident Analysis, Elevated Test Case

The Processing Information and Output Information sections from the Elevated Test Case output file (ATD_ENGINE.OUT) are presented in Figure D-1.

```
*************** PROCESSING INFO*****************

   METEOROLOGY PROCESSING INFORMATION
   Total number of hours processed:         43824
   Hours of missing data:                       0
   Hours of calm winds:                       221
   Measurement Height Selected:             15.00

   ARCON specific:
   Wind direction window (deg):             239 -   329
   Hours direction in window:               21972
   Hours direction not in window:           21631

*************** OUTPUT INFO*****************

   SUMMARY DATA BY AVERAGING INTERVAL
   AVG. PERIOD (HOURS)            1-HR       2-HRs       4-HRs       8-HRs       12-HRs      24-HRs      96-HRs      168-HRs     360-HRs      720-HRs
                  UPPER LIMIT    1.00E-03    1.00E-03    1.00E-03    1.00E-03    1.00E-03    1.00E-03    1.00E-03    1.00E-03    1.00E-03    1.00E-03
                  LOWER LIMIT    1.00E-07    1.00E-07    1.00E-07    1.00E-07    1.00E-07    1.00E-07    1.00E-07    1.00E-07    1.00E-07    1.00E-07
   95th PERCENTILE X/Q VALUES
                                 1.28E-05    1.25E-05    1.13E-05    9.42E-06    7.20E-06    4.53E-06    2.96E-06    2.63E-06    2.34E-06    2.20E-06
   99.5th PERCENTILE X/Q VALUES
                                 4.39E-05    3.27E-05    2.51E-05    1.89E-05    1.41E-05    8.18E-06    4.44E-06    3.65E-06    2.89E-06    2.60E-06

   SUMMARY DATA BY STANDARD TIME INTERVAL
   STANDARD INTERVAL              95% X/Q   99.5% X/Q
   0 to 2 hours                  1.28E-05    4.39E-05
   2 to 8 hours                  8.29E-06    1.06E-05
   8 to 24 hours                 2.08E-06    2.82E-06
   1 to 4 days                   2.43E-06    3.20E-06
   4 to 30 days                  2.09E-06    2.32E-06

   HOURLY VALUE RANGE
                        MAX X/Q              MIN X/Q
             CENTERLINE    7.26E-04       0.00E+00
          SECTOR-AVERAGE    4.23E-04       0.00E+00

   NORMAL PROGRAM COMPLETION
```

Figure D-1. Outputs for the Onsite Control Room Design Basis Accident Analysis, Elevated Test Case.

D.1.3 User Interface Inputs for the Onsite Control Room Design Basis Accident Analysis, Ground Test Case

- Source Values
  - Release Type: GROUND
  - Release Height: 10 m (default)
  - Stack Diameter: 0.1 m (default)
  - Stack Flow Rate: 0.0 m^3/s
  - Plant Grade Elevation: 0.0 m
  - Building Height: 0.0 m (default)
  - Building Cross-sectional Area: 1,900 m^2
- Receptor Values
  - Receptor Distance: 45 m
  - Intake Height: 15 m
  - Terrain Height: 0.0 m
  - Wind Direction Window: 90.0 degrees
  - Direction from Receptor to the Source: 326 degrees
- Meteorology Values
  - 5 years of meteorological station data from 1983 through 1987
  - Wind Speed Calm Threshold: 0.1 m/s
  - Surface Roughness: 0.2 m
- Module Defaults
  - Diffusion: NRC
  - Initial Diffusion Coefficients: 0 m
  - Missing Data Criterion: 10 percent
  - User Defined Percentile: 99.5th

D.1.4 Outputs for the Onsite Control Room Design Basis Accident Analysis, Ground Test Case

The Processing Information and Output Information sections from the Ground Test Case output file (ATD_ENGINE.OUT) are presented in Figure D-2.

```
*************** PROCESSING INFO*****************

   METEOROLOGY PROCESSING INFORMATION
   Total number of hours processed:         43824
   Hours of missing data:                       0
   Hours of calm winds:                       221
   Measurement Height Selected:             15.00

   ARCON specific:
   Wind direction window (deg):             281 -    11
   Hours direction in window:               19313
   Hours direction not in window:           24290

*************** OUTPUT INFO*****************

   SUMMARY DATA BY AVERAGING INTERVAL
   AVG. PERIOD (HOURS)             1-HR       2-HRs       4-HRs       8-HRs       12-HRs      24-HRs      96-HRs      168-HRs     360-HRs     720-HRs
                  UPPER LIMIT    1.00E-02    1.00E-02    1.00E-02    1.00E-02    1.00E-02    1.00E-02    1.00E-02    1.00E-02    1.00E-02    1.00E-02
                  LOWER LIMIT    1.00E-06    1.00E-06    1.00E-06    1.00E-06    1.00E-06    1.00E-06    1.00E-06    1.00E-06    1.00E-06    1.00E-06
   95th PERCENTILE X/Q VALUES
                                 3.23E-03    3.06E-03    2.86E-03    2.62E-03    2.13E-03    1.51E-03    9.93E-04    9.10E-04    8.06E-04    7.46E-04
   99.5th PERCENTILE X/Q VALUES
                                 3.62E-03    3.60E-03    3.53E-03    3.31E-03    2.71E-03    2.00E-03    1.31E-03    1.18E-03    1.06E-03    9.59E-04

   SUMMARY DATA BY STANDARD TIME INTERVAL
   STANDARD INTERVAL               95% X/Q   99.5% X/Q
   0 to 2 hours                  3.23E-03    3.62E-03
   2 to 8 hours                  2.42E-03    3.20E-03
   8 to 24 hours                 9.56E-04    1.34E-03
   1 to 4 days                   8.20E-04    1.09E-03
   4 to 30 days                  7.08E-04    9.04E-04

   HOURLY VALUE RANGE
                        MAX X/Q              MIN X/Q
             CENTERLINE    3.89E-03       0.00E+00
          SECTOR-AVERAGE   2.27E-03       0.00E+00

   NORMAL PROGRAM COMPLETION
```

Figure D-2. Outputs for the Onsite Control Room Design Basis Accident Analysis, Ground Test Case.

D.2 Offsite Design Basis Accident Analysis Test Cases

D.2.1 User Interface Inputs for the Offsite Design Basis Accident Analysis, Elevated Test Case

- Source Values
  - Release Type: ELEVATED
  - Release Height: 45 m
  - Stack Diameter: 0.1 m (default)
  - Stack Flow Rate: 0 m^3/s (default)
  - Plant Grade Elevation: 0.0 m
  - Vent Heat Emission Rate: 0.0 cal/s (default)
  - Building Height: 0 m (default)
  - Building Cross-sectional Area: 0 m^2 (default)
  - Site Type: Inland
- Terrain Values
  - Exclusion area boundary (EAB) Distance: 800 m, Elevation: 0 m
  - Low population zone (LPZ) Distance: 3,000 m, Elevation: 0 m
- Meteorology Values
  - 5 years of meteorological station data from 1983 through 1987
  - Wind Speed Calm Threshold: 0.1 m/s
- Module Defaults
  - Plume Rise: Not checked
  - Open Terrain Recirculation: Not checked
  - Diffusion: NRC
  - Missing Criterion for Averaging Periods: 10 percent

D.2.2 Outputs for the Offsite Design Basis Accident Analysis, Elevated Test Case

The Processing Information and a portion of the Output Information sections from the Design Basis Accident, Elevated Test Case output file (ATD_ENGINE.OUT) are presented in Figure D-3. The outputs shown are the 0.5%, 5.0%, and 50% exceedance values at the EAB distance (800 m) for each of the 16 sectors at various standard averaging periods. The .OUT file contains these same sets of output types for the LPZ distance, along with a summary of the maximum sector and overall site χ/Q values at each of the standard averaging periods.

********** PROCESSING INFO**********

METEOROLOGY PROCESSING INFORMATION
Total number of hours processed: 43824
Hours of missing data: 0
Hours of calm winds: 221
Measurement Height Selected: 15.00

PAVAN specific - ELevated release:
Hours with fumigation: 372

********** OUTPUT INFO**********

SUMMARY DATA BY DIRECTION SECTOR

PERCENT OF TIME CHI/Q IS EQUALED OR EXCEEDED: 0.50%

SECTOR	DISTANCE(M)	0-2 HOURS	0-8 HOURS	8-24 HOURS	1-4 DAYS	4-30 DAYS	ANNUAL AVERAGE
N	800.0	2.96E-05	1.70E-05	1.00E-05	7.41E-06	4.97E-06	3.01E-07
NNE	800.0	2.03E-05	1.15E-05	7.18E-06	7.93E-06	2.64E-06	2.38E-07
NE	800.0	2.00E-05	1.17E-05	7.72E-06	7.51E-06	4.23E-06	2.52E-07
ENE	800.0	2.65E-05	1.19E-05	6.71E-06	7.59E-06	6.57E-06	2.93E-07
E	800.0	2.94E-05	1.49E-05	9.64E-06	7.95E-06	6.80E-06	3.99E-07
ESE	800.0	3.31E-05	1.38E-05	8.62E-06	6.73E-06	7.27E-06	4.80E-07
SE	800.0	2.93E-05	1.37E-05	8.39E-06	6.76E-06	5.14E-06	5.60E-07
SSE	800.0	2.93E-05	1.21E-05	7.50E-06	7.49E-06	5.17E-06	4.12E-07
S	800.0	4.12E-05	1.59E-05	8.95E-06	5.65E-06	6.43E-06	5.08E-07
SSW	800.0	3.01E-05	1.24E-05	7.67E-06	5.37E-06	6.62E-06	3.60E-07
SW	800.0	2.96E-05	1.35E-05	8.30E-06	5.17E-06	6.66E-06	3.47E-07
WSW	800.0	2.88E-05	1.24E-05	8.34E-06	6.85E-06	6.36E-06	3.01E-07
W	800.0	4.09E-05	1.71E-05	1.17E-05	7.82E-06	1.98E-06	3.83E-07
WNW	800.0	4.18E-05	2.15E-05	1.32E-05	8.22E-06	5.34E-06	3.97E-07
NW	800.0	4.02E-05	1.59E-05	1.00E-05	7.08E-06	6.67E-06	3.78E-07
NNW	800.0	2.82E-05	1.20E-05	7.61E-06	6.65E-06	2.03E-06	2.35E-07

PERCENT OF TIME CHI/Q IS EQUALED OR EXCEEDED: 5.00%

SECTOR	DISTANCE(M)	0-2 HOURS	0-8 HOURS	8-24 HOURS	1-4 DAYS	4-30 DAYS	ANNUAL AVERAGE
N	800.0	3.09E-06	3.58E-06	2.44E-06	1.06E-06	8.82E-07	3.01E-07
NNE	800.0	1.73E-06	2.49E-06	1.56E-06	6.86E-07	8.96E-07	2.38E-07
NE	800.0	3.00E-06	2.81E-06	1.71E-06	7.53E-07	4.94E-07	2.52E-07
ENE	800.0	4.07E-06	3.48E-06	2.03E-06	8.62E-07	4.48E-07	2.93E-07
E	800.0	7.58E-06	4.99E-06	2.86E-06	1.14E-06	6.76E-07	3.99E-07
ESE	800.0	8.00E-06	5.53E-06	3.39E-06	1.43E-06	8.36E-07	4.80E-07
SE	800.0	8.40E-06	5.96E-06	3.73E-06	1.68E-06	1.18E-06	5.60E-07
SSE	800.0	5.68E-06	4.37E-06	2.63E-06	1.16E-06	7.98E-07	4.12E-07
S	800.0	6.55E-06	5.22E-06	3.36E-06	1.62E-06	1.16E-06	5.08E-07
SSW	800.0	1.48E-06	3.61E-06	2.56E-06	1.14E-06	7.04E-07	3.60E-07
SW	800.0	6.88E-07	3.50E-06	2.51E-06	1.11E-06	6.48E-07	3.47E-07
WSW	800.0	1.00E-07	3.08E-06	1.88E-06	1.14E-06	7.12E-07	3.01E-07
W	800.0	1.54E-06	4.77E-06	2.71E-06	1.57E-06	1.31E-06	3.83E-07
WNW	800.0	2.01E-06	4.91E-06	2.92E-06	1.46E-06	1.30E-06	3.97E-07
NW	800.0	3.92E-06	4.65E-06	2.75E-06	1.28E-06	8.76E-07	3.78E-07
NNW	800.0	2.02E-06	3.41E-06	2.10E-06	1.05E-06	8.43E-07	2.35E-07

PERCENT OF TIME CHI/Q IS EQUALED OR EXCEEDED: 50.00%

SECTOR	DISTANCE(M)	0-2 HOURS	0-8 HOURS	8-24 HOURS	1-4 DAYS	4-30 DAYS	ANNUAL AVERAGE
N	800.0	1.00E-07	1.00E-07	1.00E-07	1.33E-07	1.71E-07	3.01E-07
NNE	800.0	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.31E-07	2.38E-07
NE	800.0	1.00E-07	1.00E-07	1.00E-07	1.08E-07	1.45E-07	2.52E-07
ENE	800.0	1.00E-07	1.00E-07	1.00E-07	1.60E-07	1.85E-07	2.93E-07
E	800.0	1.00E-07	1.00E-07	2.63E-07	2.97E-07	2.90E-07	3.99E-07
ESE	800.0	1.00E-07	2.89E-07	4.20E-07	3.74E-07	3.53E-07	4.80E-07
SE	800.0	1.00E-07	2.40E-07	4.34E-07	4.32E-07	3.93E-07	5.60E-07
SSE	800.0	1.00E-07	1.00E-07	1.00E-07	2.68E-07	2.84E-07	4.12E-07
S	800.0	1.00E-07	1.00E-07	1.00E-07	3.03E-07	3.87E-07	5.08E-07
SSW	800.0	1.00E-07	1.00E-07	1.00E-07	1.78E-07	2.32E-07	3.60E-07
SW	800.0	1.00E-07	1.00E-07	1.00E-07	1.33E-07	2.11E-07	3.47E-07
WSW	800.0	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.45E-07	3.01E-07
W	800.0	1.00E-07	1.00E-07	1.00E-07	1.52E-07	2.39E-07	3.83E-07
WNW	800.0	1.00E-07	1.00E-07	1.00E-07	1.44E-07	2.12E-07	3.97E-07
NW	800.0	1.00E-07	1.00E-07	1.00E-07	1.63E-07	2.12E-07	3.78E-07
NNW	800.0	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.38E-07	2.35E-07

Figure D-3. Outputs for the Offsite Design Basis Accident Analysis, Elevated Test Case.

D.2.3 User Interface Inputs for the Offsite Design Basis Accident Analysis, Ground Test Case

- Source Values
  - Release Type: GROUND

  - Release Height: 10 m (default)
  - Stack Diameter: 0.1 m (default)
  - Stack Flow Rate: 0 m^3/s (default)
  - Plant Grade Elevation: 0.0 m (default)
  - Vent Heat Emission Rate: 0.0 cal/s (default)
  - Building Height: 25 m
  - Building Cross-sectional Area: 900 m^2
  - Site Type: Inland (default)
- Terrain Values
  - EAB Distance: 800 m, Elevation: 0 m
  - LPZ Distance: 3,000 m, Elevation: 0 m
- Meteorology Values
  - 5 years of meteorological station data from 1983 through 1987
  - Wind Speed Calm Threshold: 0.1 m/s
- Module Defaults
  - Plume Rise: Not checked (default)
  - Open Terrain Recirculation: Not checked
  - Diffusion: NRC
  - Missing Criterion for Averaging Periods: 10 percent

D.2.4 Outputs for the Offsite Design Basis Accident Analysis, Ground Test Case

The Processing Information and a portion of the Output Information sections from the Design Basis Accident Analysis, Ground Test Case output file (ATD_ENGINE.OUT) are presented in Figure D-4. The outputs shown are the 0.5%, 5.0%, and 50% exceedance values at the EAB distance (800 m) for each of the 16 sectors at various standard averaging periods. The .OUT file contains these same sets of output types for the LPZ distance, along with a summary of the maximum sector and overall site χ/Q values at each of the standard averaging periods.

********** PROCESSING INFO**********

METEOROLOGY PROCESSING INFORMATION
Total number of hours processed: 43824
Hours of missing data: 0
Hours of calm winds: 221
Measurement Height Selected: 15.00

********** OUTPUT INFO**********

SUMMARY DATA BY DIRECTION SECTOR

PERCENT OF TIME CHI/Q IS EQUALED OR EXCEEDED: 0.50%

SECTOR	DISTANCE(M)	0-2 HOURS	0-8 HOURS	8-24 HOURS	1-4 DAYS	4-30 DAYS	ANNUAL AVERAGE
N	800.0	2.55E-04	1.24E-04	1.49E-04	1.13E-04	4.56E-05	4.96E-06
NNE	800.0	1.94E-04	7.20E-05	4.69E-05	5.66E-05	1.65E-05	2.95E-06
NE	800.0	2.09E-04	8.32E-05	6.03E-05	5.88E-05	2.82E-05	3.38E-06
ENE	800.0	2.40E-04	9.30E-05	5.44E-05	6.22E-05	3.57E-05	4.40E-06
E	800.0	2.55E-04	1.23E-04	7.42E-05	7.01E-05	3.63E-05	7.75E-06
ESE	800.0	2.63E-04	1.23E-04	7.49E-05	6.42E-05	3.72E-05	7.97E-06
SE	800.0	2.60E-04	1.27E-04	7.91E-05	4.28E-05	3.53E-05	7.12E-06
SSE	800.0	2.18E-04	9.39E-05	6.20E-05	5.73E-05	2.74E-05	4.33E-06
S	800.0	2.55E-04	1.10E-04	7.27E-05	5.74E-05	2.87E-05	4.61E-06
SSW	800.0	1.46E-04	6.86E-05	4.65E-05	5.01E-05	2.68E-05	2.72E-06
SW	800.0	1.33E-04	6.79E-05	4.73E-05	4.10E-05	3.69E-05	2.44E-06
WSW	800.0	1.37E-04	6.81E-05	4.52E-05	5.11E-05	3.31E-05	2.37E-06
W	800.0	2.00E-04	8.90E-05	6.13E-05	4.13E-05	2.21E-05	3.28E-06
WNW	800.0	2.52E-04	9.76E-05	7.33E-05	5.96E-05	2.29E-05	3.76E-06
NW	800.0	2.16E-04	9.89E-05	7.47E-05	5.28E-05	3.15E-05	3.93E-06
NNW	800.0	2.13E-04	8.75E-05	5.68E-05	3.53E-05	1.39E-05	3.03E-06

PERCENT OF TIME CHI/Q IS EQUALED OR EXCEEDED: 5.00%

SECTOR	DISTANCE(M)	0-2 HOURS	0-8 HOURS	8-24 HOURS	1-4 DAYS	4-30 DAYS	ANNUAL AVERAGE
N	800.0	2.14E-05	2.81E-05	2.14E-05	1.35E-05	1.51E-05	4.96E-06
NNE	800.0	7.91E-06	2.26E-05	1.52E-05	8.63E-06	1.03E-05	2.95E-06
NE	800.0	2.42E-05	2.64E-05	1.86E-05	9.93E-06	9.14E-06	3.38E-06
ENE	800.0	4.53E-05	3.43E-05	2.30E-05	1.15E-05	8.13E-06	4.40E-06
E	800.0	8.44E-05	5.60E-05	3.56E-05	1.82E-05	1.38E-05	7.75E-06
ESE	800.0	7.74E-05	5.52E-05	3.51E-05	1.88E-05	1.41E-05	7.97E-06
SE	800.0	6.81E-05	4.96E-05	3.32E-05	1.92E-05	1.47E-05	7.12E-06
SSE	800.0	3.37E-05	3.06E-05	2.23E-05	1.26E-05	1.21E-05	4.33E-06
S	800.0	3.07E-05	3.16E-05	2.30E-05	1.56E-05	1.07E-05	4.61E-06
SSW	800.0	2.14E-06	1.62E-05	1.41E-05	8.90E-06	6.90E-06	2.72E-06
SW	800.0	1.00E-06	1.53E-05	1.36E-05	8.36E-06	6.34E-06	2.44E-06
WSW	800.0	1.00E-06	1.49E-05	1.38E-05	8.96E-06	5.71E-06	2.37E-06
W	800.0	2.23E-06	2.37E-05	1.87E-05	1.17E-05	9.17E-06	3.28E-06
WNW	800.0	3.16E-06	2.66E-05	2.26E-05	1.30E-05	1.19E-05	3.76E-06
NW	800.0	2.34E-05	2.89E-05	2.29E-05	1.37E-05	1.26E-05	3.93E-06
NNW	800.0	1.51E-05	2.68E-05	1.97E-05	1.07E-05	8.01E-06	3.03E-06

PERCENT OF TIME CHI/Q IS EQUALED OR EXCEEDED: 50.00%

SECTOR	DISTANCE(M)	0-2 HOURS	0-8 HOURS	8-24 HOURS	1-4 DAYS	4-30 DAYS	ANNUAL AVERAGE
N	800.0	1.00E-06	1.00E-06	1.00E-06	1.89E-06	2.78E-06	4.96E-06
NNE	800.0	1.00E-06	1.00E-06	1.00E-06	1.55E-06	2.02E-06	2.95E-06
NE	800.0	1.00E-06	1.00E-06	1.00E-06	2.01E-06	2.56E-06	3.38E-06
ENE	800.0	1.00E-06	1.00E-06	1.00E-06	3.08E-06	3.49E-06	4.40E-06
E	800.0	1.00E-06	1.00E-06	4.92E-06	6.60E-06	6.96E-06	7.75E-06
ESE	800.0	1.00E-06	1.00E-06	6.21E-06	6.90E-06	6.97E-06	7.97E-06
SE	800.0	1.00E-06	1.00E-06	4.56E-06	5.71E-06	5.76E-06	7.12E-06
SSE	800.0	1.00E-06	1.00E-06	1.00E-06	2.67E-06	3.16E-06	4.33E-06
S	800.0	1.00E-06	1.00E-06	1.00E-06	2.52E-06	3.38E-06	4.61E-06
SSW	800.0	1.00E-06	1.00E-06	1.00E-06	1.03E-06	1.69E-06	2.72E-06
SW	800.0	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.38E-06	2.44E-06
WSW	800.0	1.00E-06	1.00E-06	1.00E-06	1.00E-06	1.14E-06	2.37E-06
W	800.0	1.00E-06	1.00E-06	1.00E-06	1.20E-06	2.07E-06	3.28E-06
WNW	800.0	1.00E-06	1.00E-06	1.00E-06	1.51E-06	2.23E-06	3.76E-06
NW	800.0	1.00E-06	1.00E-06	1.00E-06	1.72E-06	2.55E-06	3.93E-06
NNW	800.0	1.00E-06	1.00E-06	1.00E-06	1.59E-06	2.20E-06	3.03E-06

Figure D-4. Outputs for the Offsite Design Basis Accident Analysis, Ground Test Case.

D.3 Routine Release Analysis Test Cases

D.3.1 User Interface Inputs for the Routine Release Analysis, Elevated Test Case

- Source Values
  - Release Type: ELEVATED

  - Release Height: 45 m
  - Stack Diameter: 2 m
  - Stack Flow Rate: 10.0 m^3/s
  - Plant Grade Elevation: 0 m
- Discrete Receptor Values
  - Type: site boundary, Sector: S, Distance: 805 m
  - Type: site boundary, Sector: S, Distance: 966 m
  - Type: site boundary, Sector: S, Distance: 1,127 m
  - Type: milk cow, Sector: S, Distance: 1,931 m
  - Type: milk cow, Sector: NNW, Distance: 4,989 m
  - Type: milk cow, Sector: SSE, Distance: 4,345 m
  - Type: residence, Sector: S, Distance: 1,931 m
  - Type: residence, Sector: NNW, Distance: 6,437 m
- Terrain Values
  - Range 0, Distance: 100 m, Elevation: 0 m
  - Range 1, Distance: 800 m, Elevation: 16 m
  - Range 2, Distance: 10,000 m, Elevation: 200 m
- Meteorology Values
  - 5 years of meteorological station data from 1983 through 1987
  - Wind Speed Calm Threshold: 0.1 m/s
- Module Defaults
  - Use open terrain recirculation: Checked
  - Diffusion: NRC

D.3.2 Outputs for the Routine Release Analysis, Elevated Test Case

The Processing Information and a portion of the Output Information sections from the Routine Release Analysis, Elevated Test Case output file (ATD_ENGINE.OUT) are presented in Figure D-5. The outputs shown are the no decay, undepleted χ/Q values for each of the 16 sectors at various distances from 0.25 to 5 miles (distances from 7.5 to 50 miles have been truncated for the sake of readability). The .OUT file contains these same sets of output types for the 2.26 day decay, undepleted, 8.00 day decay, depleted, and relative deposition along with a summary of the various χ/Q and D/Q values at the specified receptor locations.

********** PROCESSING INFO**********

METEOROLOGY PROCESSING INFORMATION
Total number of hours processed: 43824
Hours of missing data: 0
Hours of calm winds: 221
Measurement Height Selected: 15.00

********** OUTPUT INFO**********

NO DECAY, UNDEPLETED

CORRECTED USING STANDARD OPEN TERRAIN FACTORS
ANNUAL AVERAGE CHI/Q (SEC/METER CUBED):

	DISTANCE IN MILES FROM THE SITE											
SECTOR	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
	DISTANCE IN METERS FROM THE SITE											
	402.	805.	1207.	1609.	2414.	3219.	4023.	4828.	5633.	6437.	7242.	8047.
N	8.17E-07	1.22E-06	1.67E-06	1.45E-06	1.22E-06	8.35E-07	5.25E-07	3.66E-07	2.74E-07	2.14E-07	1.74E-07	1.44E-07
NNE	6.31E-07	9.62E-07	1.30E-06	1.08E-06	6.36E-07	3.61E-07	2.28E-07	1.61E-07	1.21E-07	9.59E-08	7.82E-08	6.54E-08
NE	8.82E-07	1.24E-06	1.57E-06	1.28E-06	7.32E-07	4.13E-07	2.61E-07	1.83E-07	1.38E-07	1.09E-07	8.85E-08	7.39E-08
ENE	1.06E-06	1.70E-06	2.22E-06	1.79E-06	9.60E-07	5.33E-07	3.35E-07	2.34E-07	1.76E-07	1.38E-07	1.12E-07	9.34E-08
E	1.17E-06	3.08E-06	4.20E-06	3.34E-06	1.71E-06	9.27E-07	5.81E-07	4.04E-07	3.01E-07	2.35E-07	1.90E-07	1.58E-07
ESE	1.53E-06	4.09E-06	4.88E-06	3.61E-06	1.75E-06	9.49E-07	5.93E-07	4.12E-07	3.06E-07	2.39E-07	1.93E-07	1.60E-07
SE	2.42E-06	4.18E-06	4.53E-06	3.27E-06	1.57E-06	8.38E-07	5.23E-07	3.63E-07	2.70E-07	2.11E-07	1.70E-07	1.41E-07
SSE	1.58E-06	2.09E-06	2.39E-06	1.80E-06	9.35E-07	5.05E-07	3.16E-07	2.21E-07	1.65E-07	1.29E-07	1.05E-07	8.74E-08
S	2.07E-06	2.20E-06	2.43E-06	1.82E-06	9.91E-07	5.40E-07	3.38E-07	2.35E-07	1.75E-07	1.37E-07	1.11E-07	9.23E-08
SSW	1.29E-06	1.32E-06	1.44E-06	1.07E-06	5.66E-07	3.12E-07	1.96E-07	1.38E-07	1.04E-07	8.19E-08	6.68E-08	5.58E-08
SW	1.16E-06	1.14E-06	1.25E-06	9.29E-07	5.10E-07	2.84E-07	1.79E-07	1.26E-07	9.50E-08	7.52E-08	6.13E-08	5.13E-08
WSW	8.78E-07	8.85E-07	1.08E-06	8.54E-07	4.88E-07	2.73E-07	1.73E-07	1.22E-07	9.23E-08	7.31E-08	5.98E-08	5.00E-08
W	1.21E-06	1.31E-06	1.58E-06	1.23E-06	6.91E-07	3.82E-07	2.40E-07	1.68E-07	1.26E-07	9.93E-08	8.08E-08	6.73E-08
WNW	1.10E-06	1.37E-06	1.77E-06	1.42E-06	7.93E-07	4.37E-07	2.75E-07	1.92E-07	1.44E-07	1.13E-07	9.15E-08	7.61E-08
NW	1.03E-06	1.57E-06	2.00E-06	1.56E-06	8.35E-07	4.56E-07	2.86E-07	2.00E-07	1.50E-07	1.18E-07	9.54E-08	7.94E-08
NNW	7.29E-07	1.13E-06	1.53E-06	1.23E-06	6.61E-07	3.57E-07	2.24E-07	1.56E-07	1.16E-07	9.05E-08	7.32E-08	6.07E-08

CHI/Q (SEC/METER CUBED) FOR EACH SEGMENT:

	SEGMENT BOUNDARIES IN MILES FROM THE SITE									
SECTOR	0.5-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
N	1.47E-06	1.10E-06	5.44E-07	2.77E-07	1.75E-07	7.85E-08	2.84E-08	1.40E-08	8.95E-09	6.42E-09
NNE	1.13E-06	6.13E-07	2.37E-07	1.23E-07	7.87E-08	3.55E-08	1.26E-08	6.17E-09	3.89E-09	2.77E-09
NE	1.37E-06	7.12E-07	2.70E-07	1.40E-07	8.90E-08	4.00E-08	1.43E-08	6.98E-09	4.41E-09	3.14E-09
ENE	1.91E-06	9.55E-07	3.48E-07	1.78E-07	1.13E-07	5.06E-08	1.81E-08	8.86E-09	5.61E-09	4.00E-09
E	3.57E-06	1.72E-06	6.02E-07	3.05E-07	1.91E-07	8.53E-08	3.05E-08	1.50E-08	9.52E-09	6.80E-09
ESE	4.14E-06	1.81E-06	6.15E-07	3.11E-07	1.94E-07	8.62E-08	3.06E-08	1.50E-08	9.44E-09	6.73E-09
SE	3.89E-06	1.62E-06	5.43E-07	2.74E-07	1.71E-07	7.58E-08	2.68E-08	1.31E-08	8.23E-09	5.86E-09
SSE	2.06E-06	9.36E-07	3.28E-07	1.67E-07	1.06E-07	4.71E-08	1.66E-08	8.08E-09	5.09E-09	3.62E-09
S	2.11E-06	9.74E-07	3.51E-07	1.78E-07	1.12E-07	4.96E-08	1.74E-08	8.43E-09	5.30E-09	3.76E-09
SSW	1.25E-06	5.65E-07	2.04E-07	1.05E-07	6.72E-08	3.00E-08	1.04E-08	5.01E-09	3.13E-09	2.22E-09
SW	1.08E-06	5.03E-07	1.86E-07	9.63E-08	6.17E-08	2.75E-08	9.57E-09	4.57E-09	2.85E-09	2.01E-09
WSW	9.35E-07	4.74E-07	1.79E-07	9.35E-08	6.01E-08	2.69E-08	9.40E-09	4.51E-09	2.81E-09	1.99E-09
W	1.36E-06	6.74E-07	2.49E-07	1.28E-07	8.13E-08	3.62E-08	1.26E-08	6.09E-09	3.81E-09	2.70E-09
WNW	1.53E-06	7.73E-07	2.85E-07	1.46E-07	9.21E-08	4.09E-08	1.43E-08	6.89E-09	4.31E-09	3.05E-09
NW	1.71E-06	8.27E-07	2.97E-07	1.52E-07	9.60E-08	4.27E-08	1.50E-08	7.23E-09	4.54E-09	3.21E-09
NNW	1.31E-06	6.53E-07	2.32E-07	1.18E-07	7.37E-08	3.27E-08	1.16E-08	5.62E-09	3.54E-09	2.51E-09

Figure D-5. Outputs for the Routine Release Analysis, Elevated Test Case.

D.3.3 User Interface Inputs for the Routine Release Analysis, Ground Test Case

- Source Values
  - Release Type: GROUND
  - Release Height: 10 m (default)
  - Building Height: 0 m
  - Building Cross-sectional Area: 0 m^2
- Receptor Values
  - Type: site boundary, Sector: S, Distance: 805 m
  - Type: site boundary, Sector: S, Distance: 966 m
  - Type: site boundary, Sector: S, Distance: 1,127 m
  - Type: milk cow, Sector: S, Distance: 1,931 m
  - Type: milk cow, Sector: NNW, Distance: 4,989 m
  - Type: milk cow, Sector: SSE, Distance: 4,345 m
  - Type: residence, Sector: S, Distance: 1,931 m
  - Type: residence, Sector: NNW, Distance: 6,437 m
- Terrain Values
  - Range 0, Distance: 100 m, Elevation: 0 m
  - Range 1, Distance: 800 m, Elevation: 16 m
  - Range 2, Distance: 10,000 m, Elevation: 200 m
- Meteorology Values
  - 5 years of meteorological station data from 1983 through 1987
  - Wind Speed Calm Threshold: 0.1 m/s
- Module Defaults
  - Use open terrain recirculation: Checked
  - Diffusion: NRC

D.3.4 Outputs for the Routine Release Analysis, Ground Test Case

The Processing Information and a portion of the Output Information sections from the Routine Release Analysis, Ground Test Case output file (ATD_ENGINE.OUT) are presented in Figure D-6. The outputs shown are the no decay, undepleted χ/Q values for each of the 16 sectors at various distances from 0.25 to 5 miles (distances from 7.5 to 50 miles have been truncated for the sake of readability). The .OUT file contains these same sets of output types for the 2.26 day decay, undepleted, 8.00 day decay, depleted, and relative deposition along with a summary of the various χ/Q and D/Q values at the specified receptor locations.

********** PROCESSING INFO**********

METEOROLOGY PROCESSING INFORMATION
Total number of hours processed: 43824
Hours of missing data: 0
Hours of calm winds: 221
Measurement Height Selected: 15.00

********** OUTPUT INFO**********

NO DECAY, UNDEPLETED

CORRECTED USING STANDARD OPEN TERRAIN FACTORS
ANNUAL AVERAGE CHI/Q (SEC/METER CUBED):

	DISTANCE IN MILES FROM THE SITE											
SECTOR	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
	DISTANCE IN METERS FROM THE SITE											
	402.	805.	1207.	1609.	2414.	3219.	4023.	4828.	5633.	6437.	7242.	8047.
N	9.13E-05	2.67E-05	1.31E-05	6.27E-06	2.36E-06	1.24E-06	7.72E-07	5.33E-07	3.93E-07	3.05E-07	2.45E-07	2.02E-07
NNE	5.01E-05	1.46E-05	7.19E-06	3.43E-06	1.29E-06	6.74E-07	4.18E-07	2.88E-07	2.12E-07	1.64E-07	1.31E-07	1.08E-07
NE	5.77E-05	1.68E-05	8.27E-06	3.94E-06	1.48E-06	7.77E-07	4.82E-07	3.32E-07	2.45E-07	1.89E-07	1.52E-07	1.25E-07
ENE	7.54E-05	2.20E-05	1.08E-05	5.16E-06	1.94E-06	1.02E-06	6.33E-07	4.36E-07	3.22E-07	2.49E-07	2.00E-07	1.65E-07
E	1.34E-04	3.92E-05	1.93E-05	9.21E-06	3.47E-06	1.82E-06	1.13E-06	7.82E-07	5.77E-07	4.47E-07	3.59E-07	2.97E-07
ESE	1.35E-04	3.95E-05	1.95E-05	9.29E-06	3.49E-06	1.83E-06	1.14E-06	7.83E-07	5.77E-07	4.47E-07	3.59E-07	2.96E-07
SE	1.20E-04	3.50E-05	1.72E-05	8.19E-06	3.07E-06	1.61E-06	9.97E-07	6.86E-07	5.05E-07	3.90E-07	3.13E-07	2.58E-07
SSE	7.22E-05	2.10E-05	1.03E-05	4.89E-06	1.83E-06	9.56E-07	5.92E-07	4.07E-07	2.99E-07	2.31E-07	1.85E-07	1.53E-07
S	7.65E-05	2.20E-05	1.08E-05	5.13E-06	1.92E-06	1.00E-06	6.19E-07	4.24E-07	3.12E-07	2.41E-07	1.92E-07	1.58E-07
SSW	4.34E-05	1.25E-05	6.10E-06	2.90E-06	1.08E-06	5.61E-07	3.46E-07	2.37E-07	1.73E-07	1.33E-07	1.07E-07	8.76E-08
SW	3.92E-05	1.12E-05	5.50E-06	2.61E-06	9.73E-07	5.05E-07	3.11E-07	2.12E-07	1.55E-07	1.20E-07	9.54E-08	7.84E-08
WSW	3.81E-05	1.10E-05	5.39E-06	2.56E-06	9.56E-07	4.97E-07	3.07E-07	2.10E-07	1.54E-07	1.19E-07	9.47E-08	7.78E-08
W	5.35E-05	1.55E-05	7.57E-06	3.60E-06	1.35E-06	7.01E-07	4.33E-07	2.97E-07	2.18E-07	1.68E-07	1.34E-07	1.10E-07
WNW	6.13E-05	1.78E-05	8.71E-06	4.15E-06	1.55E-06	8.09E-07	5.00E-07	3.43E-07	2.52E-07	1.94E-07	1.55E-07	1.28E-07
NW	6.45E-05	1.88E-05	9.21E-06	4.39E-06	1.64E-06	8.57E-07	5.30E-07	3.64E-07	2.67E-07	2.06E-07	1.65E-07	1.36E-07
NNW	5.11E-05	1.49E-05	7.33E-06	3.49E-06	1.31E-06	6.86E-07	4.26E-07	2.93E-07	2.16E-07	1.67E-07	1.34E-07	1.10E-07

CHI/Q (SEC/METER CUBED) FOR EACH SEGMENT:

	SEGMENT BOUNDARIES IN MILES FROM THE SITE									
SECTOR	0.5-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
N	1.31E-05	2.73E-06	8.01E-07	3.99E-07	2.47E-07	1.09E-07	3.93E-08	1.95E-08	1.24E-08	8.88E-09
NNE	7.17E-06	1.49E-06	4.34E-07	2.15E-07	1.33E-07	5.82E-08	2.07E-08	1.02E-08	6.43E-09	4.59E-09
NE	8.25E-06	1.72E-06	5.01E-07	2.49E-07	1.53E-07	6.74E-08	2.40E-08	1.18E-08	7.49E-09	5.35E-09
ENE	1.08E-05	2.25E-06	6.57E-07	3.27E-07	2.02E-07	8.89E-08	3.18E-08	1.57E-08	9.94E-09	7.11E-09
E	1.92E-05	4.01E-06	1.18E-06	5.86E-07	3.62E-07	1.60E-07	5.74E-08	2.83E-08	1.80E-08	1.29E-08
ESE	1.94E-05	4.04E-06	1.18E-06	5.87E-07	3.62E-07	1.59E-07	5.67E-08	2.78E-08	1.76E-08	1.26E-08
SE	1.71E-05	3.56E-06	1.04E-06	5.13E-07	3.16E-07	1.39E-07	4.92E-08	2.41E-08	1.53E-08	1.09E-08
SSE	1.03E-05	2.12E-06	6.15E-07	3.04E-07	1.87E-07	8.18E-08	2.89E-08	1.42E-08	8.96E-09	6.39E-09
S	1.08E-05	2.22E-06	6.43E-07	3.17E-07	1.94E-07	8.47E-08	2.98E-08	1.45E-08	9.17E-09	6.53E-09
SSW	6.09E-06	1.25E-06	3.59E-07	1.76E-07	1.08E-07	4.66E-08	1.62E-08	7.82E-09	4.91E-09	3.48E-09
SW	5.49E-06	1.13E-06	3.23E-07	1.58E-07	9.63E-08	4.16E-08	1.44E-08	6.91E-09	4.33E-09	3.07E-09
WSW	5.38E-06	1.11E-06	3.19E-07	1.56E-07	9.55E-08	4.14E-08	1.44E-08	6.94E-09	4.35E-09	3.08E-09
W	7.56E-06	1.56E-06	4.50E-07	2.21E-07	1.35E-07	5.89E-08	2.06E-08	9.98E-09	6.28E-09	4.46E-09
WNW	8.69E-06	1.80E-06	5.20E-07	2.56E-07	1.57E-07	6.82E-08	2.39E-08	1.16E-08	7.29E-09	5.18E-09
NW	9.19E-06	1.90E-06	5.51E-07	2.72E-07	1.67E-07	7.27E-08	2.55E-08	1.24E-08	7.83E-09	5.57E-09
NNW	7.31E-06	1.52E-06	4.42E-07	2.19E-07	1.35E-07	5.91E-08	2.10E-08	1.03E-08	6.50E-09	4.63E-09

Figure D-6. Outputs for the Routine Release Analysis, Ground Test Case.

D.3.5 User Interface Inputs for the Routine Release Analysis, Vent Test Case

- Source Values
  - Release Type: VENT
  - Release Height: 10 m
  - Stack Diameter: 2 m
  - Stack Flow Rate: 10.0 m^3/s
  - Plant Grade Elevation: 0 m
  - Building Height: 40 m
  - Building Cross-sectional Area: 2,000 m^2
- Receptor Values
  - Type: site boundary, Sector: S, Distance: 805 m
  - Type: site boundary, Sector: S, Distance: 966 m
  - Type: site boundary, Sector: S, Distance: 1,127 m
  - Type: milk cow, Sector: S, Distance: 1,931 m
  - Type: milk cow, Sector: NNW, Distance: 4,989 m
  - Type: milk cow, Sector: SSE, Distance: 4,345 m
  - Type: residence, Sector: S, Distance: 1,931 m
  - Type: residence, Sector: NNW, Distance: 6,437 m
- Terrain Values
  - Range 0, Distance: 100 m, Elevation: 0 m
  - Range 1, Distance: 800 m, Elevation: 16 m
  - Range 2, Distance: 10,000 m, Elevation: 200 m
- Meteorology Values
  - 5 years of meteorological station data from 1983 through 1987
  - Wind Speed Calm Threshold: 0.1 m/s
- Module Defaults
  - Use open terrain recirculation: Checked
  - Diffusion: NRC

D.3.6 Outputs for the Routine Release Analysis, Vent Test Case

The Processing Information and a portion of the Output Information sections from the Routine Release Analysis, Vent Test Case output file (ATD_ENGINE.OUT) are presented in Figure D-7. The outputs shown are the no decay, undepleted χ/Q values for each of the 16 sectors at various distances from 0.25 to 5 miles (distances from 7.5 to 50 miles have been truncated for the sake of readability). The .OUT file contains these same sets of output types for the 2.26 day

decay, undepleted, 8.00 day decay, depleted, and relative deposition along with a summary of the various χ/Q and D/Q values at the specified receptor locations.

********** PROCESSING INFO**********

METEOROLOGY PROCESSING INFORMATION
Total number of hours processed: 43824
Hours of missing data: 0
Hours of calm winds: 221
Measurement Height Selected: 15.00

********** OUTPUT INFO**********

NO DECAY, UNDEPLETED

CORRECTED USING STANDARD OPEN TERRAIN FACTORS
ANNUAL AVERAGE CHI/Q (SEC/METER CUBED):

	DISTANCE IN MILES FROM THE SITE										
SECTOR	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
	DISTANCE IN METERS FROM THE SITE											
	402.	805.	1207.	1609.	2414.	3219.	4023.	4828.	5633.	6437.	7242.	8047.
N	8.76E-05	2.59E-05	1.28E-05	6.14E-06	2.33E-06	1.23E-06	7.64E-07	5.28E-07	3.90E-07	3.03E-07	2.43E-07	2.01E-07
NNE	4.69E-05	1.39E-05	6.92E-06	3.32E-06	1.26E-06	6.61E-07	4.11E-07	2.84E-07	2.09E-07	1.62E-07	1.30E-07	1.07E-07
NE	5.27E-05	1.57E-05	7.86E-06	3.78E-06	1.44E-06	7.58E-07	4.72E-07	3.26E-07	2.41E-07	1.87E-07	1.50E-07	1.24E-07
ENE	6.61E-05	1.98E-05	9.98E-06	4.82E-06	1.85E-06	9.78E-07	6.12E-07	4.23E-07	3.13E-07	2.43E-07	1.95E-07	1.62E-07
E	1.14E-04	3.47E-05	1.76E-05	8.52E-06	3.28E-06	1.74E-06	1.09E-06	7.55E-07	5.60E-07	4.35E-07	3.50E-07	2.89E-07
ESE	1.11E-04	3.42E-05	1.74E-05	8.48E-06	3.27E-06	1.74E-06	1.09E-06	7.53E-07	5.58E-07	4.33E-07	3.48E-07	2.88E-07
SE	1.00E-04	3.06E-05	1.55E-05	7.53E-06	2.89E-06	1.53E-06	9.57E-07	6.61E-07	4.89E-07	3.79E-07	3.04E-07	2.51E-07
SSE	6.63E-05	1.96E-05	9.77E-06	4.69E-06	1.78E-06	9.34E-07	5.80E-07	4.00E-07	2.95E-07	2.28E-07	1.83E-07	1.51E-07
S	7.30E-05	2.14E-05	1.05E-05	5.03E-06	1.89E-06	9.89E-07	6.13E-07	4.21E-07	3.09E-07	2.39E-07	1.91E-07	1.58E-07
SSW	4.19E-05	1.22E-05	6.00E-06	2.86E-06	1.07E-06	5.57E-07	3.44E-07	2.35E-07	1.73E-07	1.33E-07	1.06E-07	8.73E-08
SW	3.80E-05	1.10E-05	5.42E-06	2.58E-06	9.64E-07	5.01E-07	3.09E-07	2.11E-07	1.55E-07	1.19E-07	9.50E-08	7.81E-08
WSW	3.72E-05	1.08E-05	5.33E-06	2.54E-06	9.50E-07	4.94E-07	3.05E-07	2.09E-07	1.53E-07	1.18E-07	9.44E-08	7.76E-08
W	5.19E-05	1.51E-05	7.44E-06	3.55E-06	1.33E-06	6.95E-07	4.30E-07	2.95E-07	2.17E-07	1.67E-07	1.34E-07	1.10E-07
WNW	5.93E-05	1.73E-05	8.56E-06	4.09E-06	1.54E-06	8.02E-07	4.96E-07	3.41E-07	2.50E-07	1.93E-07	1.55E-07	1.27E-07
NW	6.08E-05	1.79E-05	8.90E-06	4.26E-06	1.61E-06	8.43E-07	5.23E-07	3.59E-07	2.64E-07	2.04E-07	1.64E-07	1.35E-07
NNW	4.71E-05	1.40E-05	6.95E-06	3.34E-06	1.27E-06	6.68E-07	4.16E-07	2.87E-07	2.12E-07	1.64E-07	1.32E-07	1.09E-07

CHI/Q (SEC/METER CUBED) FOR EACH SEGMENT:

	SEGMENT BOUNDARIES IN MILES FROM THE SITE								
SECTOR	0.5-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
N	1.27E-05	2.68E-06	7.93E-07	3.96E-07	2.45E-07	1.09E-07	3.92E-08	1.94E-08	1.24E-08	8.87E-09
NNE	6.87E-06	1.45E-06	4.27E-07	2.12E-07	1.31E-07	5.77E-08	2.06E-08	1.01E-08	6.41E-09	4.58E-09
NE	7.79E-06	1.66E-06	4.90E-07	2.45E-07	1.51E-07	6.67E-08	2.39E-08	1.17E-08	7.45E-09	5.33E-09
ENE	9.88E-06	2.12E-06	6.34E-07	3.18E-07	1.97E-07	8.73E-08	3.14E-08	1.55E-08	9.87E-09	7.06E-09
E	1.74E-05	3.76E-06	1.13E-06	5.68E-07	3.53E-07	1.57E-07	5.66E-08	2.81E-08	1.79E-08	1.28E-08
ESE	1.72E-05	3.75E-06	1.13E-06	5.66E-07	3.51E-07	1.56E-07	5.59E-08	2.75E-08	1.75E-08	1.25E-08
SE	1.53E-05	3.32E-06	9.92E-07	4.96E-07	3.07E-07	1.36E-07	4.85E-08	2.39E-08	1.51E-08	1.08E-08
SSE	9.70E-06	2.05E-06	6.02E-07	2.99E-07	1.84E-07	8.09E-08	2.87E-08	1.41E-08	8.92E-09	6.37E-09
S	1.05E-05	2.19E-06	6.36E-07	3.14E-07	1.93E-07	8.43E-08	2.97E-08	1.45E-08	9.16E-09	6.52E-09
SSW	5.98E-06	1.24E-06	3.57E-07	1.75E-07	1.07E-07	4.64E-08	1.62E-08	7.80E-09	4.90E-09	3.48E-09
SW	5.40E-06	1.12E-06	3.21E-07	1.57E-07	9.59E-08	4.14E-08	1.43E-08	6.90E-09	4.32E-09	3.06E-09
WSW	5.31E-06	1.10E-06	3.17E-07	1.56E-07	9.52E-08	4.13E-08	1.44E-08	6.93E-09	4.35E-09	3.08E-09
W	7.42E-06	1.54E-06	4.47E-07	2.20E-07	1.35E-07	5.86E-08	2.05E-08	9.96E-09	6.27E-09	4.45E-09
WNW	8.52E-06	1.78E-06	5.16E-07	2.54E-07	1.56E-07	6.80E-08	2.38E-08	1.16E-08	7.28E-09	5.17E-09
NW	8.85E-06	1.86E-06	5.43E-07	2.69E-07	1.65E-07	7.22E-08	2.54E-08	1.24E-08	7.80E-09	5.55E-09
NNW	6.90E-06	1.46E-06	4.31E-07	2.15E-07	1.33E-07	5.84E-08	2.08E-08	1.02E-08	6.47E-09	4.61E-09

Figure D-7. Outputs for the Routine Release Analysis, Vent Test Case.

Appendix E — Atmospheric Transport and Dispersion Module Regulatory Context

The Atmospheric Transport and Diffusion (ATD) module within Software Integration for Environmental Radiological Release Assessments (SIERRA) is a unified code in FORmula TRANslator (Fortran) 90. At present, the SIERRA ATD module only allows computation for three different assessments: (1) onsite χ/Q values at the control room for design basis accidents (DBAs), (2) χ/Q values at offsite receptors for DBAs, and (3) χ/Q and D/Q values at offsite receptors due to routine operational releases. These estimates provide direct inputs to dose consequence analyses that support nuclear power plant licensing actions. U.S. Nuclear Regulatory Commission (NRC) staff and Radiation Protection Computer Code Analysis and Maintenance Program (RAMP) users historically employed the ARCON96 dispersion model (currently ARCON2) for short-term consequence DBA analyses at the control room. The PAVAN and XOQDOQ dispersion models, as implemented in SIERRA, are used for the latter two analyses. A summary of these assessments and their respective regulatory bases are provided in Table E-1.

Table E-1. Regulations and NRC Guidance Documents Related to Assessment Types.

SIERRA ATD Analysis Type	Legacy Model	NRC Guidance Documents	Regulations	Applicability
Onsite control room habitability design basis accident assessment	ARCON96	RG 1.194 and SRP 2.3.4	10 CFR 50, Appendix A, General Design Criterion 19 10 CFR 50.34(a)(1)	Input to evaluating personnel exposures in the onsite control room during accidents
Onsite control room habitability design basis accident assessment	ARCON96	SRP 15.0.3 and SRP 13.3	10 CFR Part 50, Paragraph IV.E.8 of Appendix E	Protection against radiation inside the onsite technical support center
Offsite design basis accident dispersion analyses	PAVAN	RG 1.145 and SRP 2.3.4	10 CFR 50.34(a)(1)(ii)(D) 10 CFR 52.47(a)(2)(iv) and 10 CFR 52.137(a)(2)(iv)	Offsite consequence at EAB and LPZ for plant design (Design Certifications and Standard Design Approvals, respectively)
Offsite design basis accident dispersion analyses	PAVAN	RG 1.145 and SRP 2.3.4	10 CFR 52.17(a)(1)(ix)	Offsite consequence at EAB and LPZ for safety assessment (Early Site Permits)
Offsite design basis accident dispersion analyses	PAVAN	RG 1.145 and SRP 2.3.4	10 CFR 52.79(a)(1)(vi)	Offsite consequence at EAB and LPZ for safety assessment (Combined Licenses)
Offsite design basis accident	PAVAN	RG 1.145 and SRP 2.3.4	10 CFR 52.157(d)	Offsite consequence at EAB and LPZ for safety

SIERRA ATD Analysis Type	Legacy Model	NRC Guidance Documents	Regulations	Applicability
dispersion analyses				assessment (Manufacturing Licenses)
Offsite design basis accident dispersion analyses	PAVAN	RG 1.145 and SRP 2.3.4	10 CFR 100.21(a)	Determine acceptable EAB and LPZ for siting
Offsite design basis accident dispersion analyses	PAVAN	RG 1.145 and SRP 2.3.4	10 CFR 100.21(c)(2)	Offsite consequence at EAB and LPZ for postulated accidents
Routine release analyses	XOQDOQ	RG 1.111 and SRP 2.3.5	10 CFR Part 20 Subpart D	Annual dose assessment to meet ALARA criterion during preliminary plant design and limiting conditions for operations
Routine release analyses	XOQDOQ	RG 1.111 and SRP 2.3.5	10 CFR Part 50, Appendix I	Annual dose assessment to meet ALARA criterion during preliminary plant design

ALARA = as low as is reasonably achievable; ARCON = computer code for Atmospheric Relative CONcentrations in Building Wakes; CFR = *Code of Federal Regulations*; PAVAN = atmospheric dispersion program for evaluating design basis accident releases; EAB = exclusion area boundary; LPZ = outer boundary of the low population zone; RG = Regulatory Guide; SRP = standard review plan; XOQDOQ = atmospheric dispersion program for the meteorological evaluation of routine releases.
Sources: NRC 1977, 1982, 2003, 2007a, 2007b, 2007c, 2007e

A summary of the guidance document content related to the onsite control room DBA habitability assessments is as follows:

- General Design Criterion 19 of 10 CFR Part 50, Appendix A, states, in part, that “Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures >5 rem whole body, or its equivalent to any part of the body, for the duration of the accident.”
- Regulatory Guide (RG) 1.194 (NRC 2003), “Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Nuclear Power Plants,” presents criteria acceptable to the NRC staff for characterizing atmospheric transport and diffusion conditions input to evaluate the dose consequences of radiological releases to the control room (and, if onsite and not part of the control room envelope, the technical support center).
- RG 1.194 (NRC 2003) requires the determination of 95th percentile χ/Q values (exceeded no more than 5 percent of the accident-related averaging time periods) for each of the source-to-receptor combinations.
- Currently, RG 1.194 (NRC 2003) prescribes ARCON96 as an acceptable methodology for assessing onsite DBA control room χ/Q values.
- ARCON96 is designed to estimate χ/Q values at receptors in the vicinity of buildings. The model includes an explicit treatment of low wind speed dispersion and building wakes. The stability, based on Pasquill–Gifford (P-G) diffusion coefficients, was modified based on field

experimental data, as described in Ramsdell and Fosmire (1998). These dispersion coefficients are valid only for distances within a few hundred meters from the source.

- ARCON96 currently considers ground-level releases, vent releases, or elevated releases. However, Regulatory Position C.3.2.3 indicates that the vent release mode within ARCON96 may not be sufficiently conservative and should not be used for DBA evaluations.
- Detailed user guidance for the ARCON96 dispersion model is provided in Revision 1 of NUREG/CR-6331 (Ramsdell and Simonen 1997).

A summary of the regulatory and guidance document content rated to offsite DBA analyses is provided next:

- According to 10 CFR 100.11, an applicant is required to determine the following for siting considerations:
  - An individual at an exclusion area boundary (EAB) does not receive a total whole body radiation dose over 25 rem over the first two hours of exposure.
  - An individual in a low population zone (LPZ) does not receive a total radiation dose over 25 rem over the entire period of the plume passage.
- RG 1.145 (NRC 1982) provides guidance on ATD models for potential DBA dispersion modeling input to consequence assessments at NPPs.
  - This guide provides specific χ/Q calculation methods for ground-level and elevated releases that are implemented in PAVAN. The sector-averaged Gaussian plume equation is modified with corrections for the building wake and meander for ground-level releases.
- RG 1.145 (NRC 1982) calls for the calculation of the 2-hour χ/Q values at the EAB that are exceeded 0.5 percent of the sector-specific time versus all time in the meteorological dataset for each of 16 direction sectors (22.5° each) as well as a 2-hour average χ/Q that is exceeded 5.0 percent of the total time in the dataset over all 16 sectors (for more information, see Appendix A of Ghosh et al. 2025).
- RG 1.145 (NRC 1982) also calls for the calculation of 8-hour, 16-hour, 72-hour (1- to 3-day), and 624-hour (4- to 30-day) average, sector-specific, 0.5 percent exceedance χ/Q values at the outer boundary of the LPZ as well as the corresponding overall 5.0 percent exceedance χ/Q values (for more information, see Appendix A of Ghosh et al. 2025).
- Detailed user guidance for the PAVAN dispersion model is provided in NUREG/CR-2858 (Bander 1982).

A summary of the regulatory and guidance document content related to offsite routine release analyses is provided:

- Appendix I of 10 CFR Part 50 requires that a nuclear facility be operated to meet the criterion “as low as is reasonably achievable” (ALARA).
- The radiational dose limits to the public from routine release of radioactive effluents from a nuclear facility are set in 10 CFR 20.1301, which regulates the amount of annual releases.
- RG 1.111 (NRC 1977) provides acceptable methods for the estimation of atmospheric transport and dispersion of gaseous effluents in routine releases.
- XOQDOQ implements the long-term dispersion and deposition calculation for routine releases based on Sagendorf (1994).

- Unlike the legacy models for onsite control room DBA analysis and offsite DBA analysis, XOQDOQ accounts for removal processes due to dry deposition and radioactive decay.
- This analysis considers ground-level, vent, or elevated releases.

Table E-2 highlights the differences in dispersion methods among these three types of assessments.

Table E-2. Summary of the Differences in Parameters Considered in the Three Modeling Assessment Types.

Parameter	Onsite Control Room DBA Analyses	Offsite DBA Analyses	Routine Release Analyses
Building wake	Ramsdell and Fosmire (1995)	Slade (1968)	Slade (1968)
Low wind speed (meander) effects	Ramsdell and Fosmire (1995)	RG 1.145	RG 1.145
Plume rise	No	Optional	Yes
Downwash	Yes	No	Yes
Recirculation factor	No	Yes	Yes
Finite flow corrections	Yes	No	No
Fumigation	No	Yes	No
Iteration for max χ/Q (elevated)	No	Yes	No
Terrain	Yes	Yes	Yes
Intake height	Yes	No	No
Slant height	Yes	No	No

DBA = design basis accident; RG = Regulatory Guide.

Although the objectives of these three assessments are different, the underlying technical basis is based on a simple near-field straight-line Gaussian plume model that takes a common input of meteorological fields of wind speed, wind direction, and atmospheric stability for a site. Therefore, for the SIERRA ATD software, these three separate legacy codes (i.e., ARCON96, PAVAN, and XOQDOQ) were reengineered and consolidated with a common input of hourly meteorological data based on the RG 1.23 (NRC 2007) format.

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