RASCAL 4.3 Inputs for Site Boundary Dose Projections

The Radiological Assessment System for Consequence Analysis (RASCAL), developed for the U.S. Nuclear Regulatory Commission, is designed to be used in the independent assessment of dose projections during response to radiological emergencies.

RASCAL Version 4.3 uses different tools to model reactor accidents, spent fuel accidents, and fuel cycle facility accidents as described in RASCAL 4: Description of Models and Methods and RASCAL 4.3 Technical Supplement. The RASCAL Source Term to Dose (STDose) tool is a source term release path model that determines what nuclides and how much activity of each nuclide is available for release to the environment. STDose also determines how the activity gets from the source to the environment and how much activity is actually released as a function of time.

Defining and Running a Problem

The basic steps to setup a modeling run, calculate doses, and view results are as follows (the bold headings correspond to the STDose tool buttons):

1. **Event Type** - Select the type of event to be modeled (See RASCAL User's Guide Section 2.1).

2. **Event Location** - Pick a location from the list of sites in the facility database (See RASCAL User's Guide Section 2.2.1).

3. **Source Term** - Select a source term type and define the source term characteristics (See RASCAL User's Guide Section 2.2.2).

4. **Release Pathways** - Select a release pathway type and define the release characteristics (See RASCAL User's Guide Section 2.2.3).

5. **Meteorology** - Select the meteorological data set to be used for the calculations. A number of test data sets have been provided in the Predefined Data area to be used for any location at any time (See RASCAL 4.3 User's Guide Section 2.6).

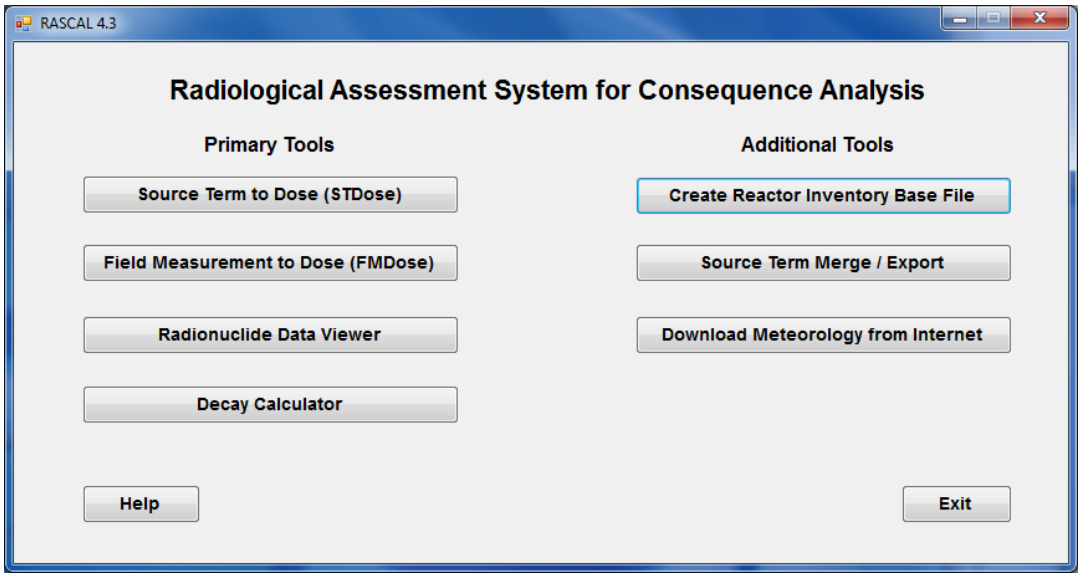
6. **Calculate Doses** - Calculations are started from this screen. Set the desired calculation distance, dose conversion factors, and end date and time for the simulation, and enter a case description (See RASCAL User's Guide Section 2.7).

7. **Detailed Results** - Results are viewable from the main screen tabs. Specifically, the maximum dose values and the computed source term summary are viewed by clicking the appropriate tab. More detailed source term details are available from the Details button (See RASCAL User's Guide Section 2.8).

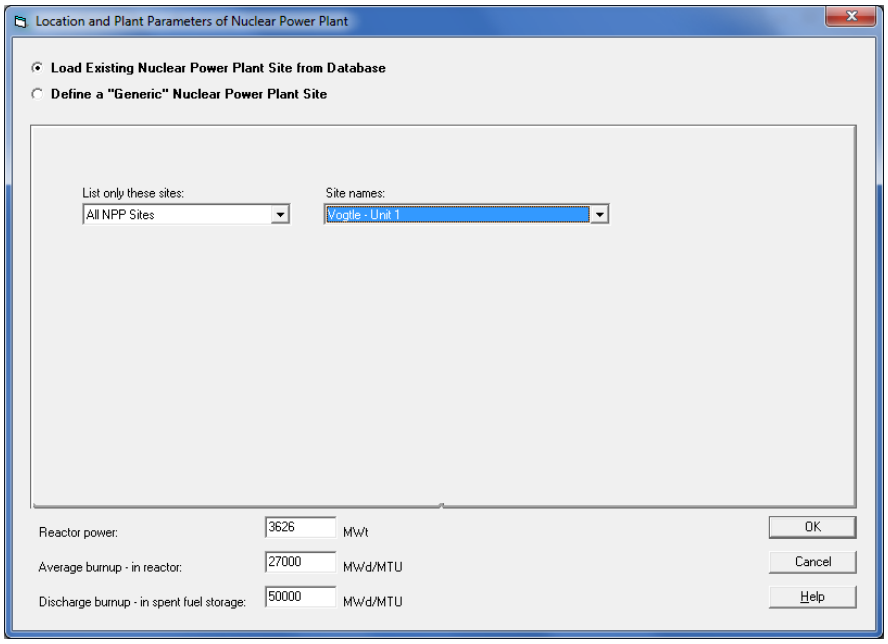
8. **Save Case** - A modeling run can be saved as a single file (extension .std) for later recall (See RASCAL User's Guide Section 2.9).

For each run provided in the table in Enclosure 1, the permutations of source term, release start time, core damage end state, release pathway/characteristics, and meteorology were specified following the steps above as detailed in the following.

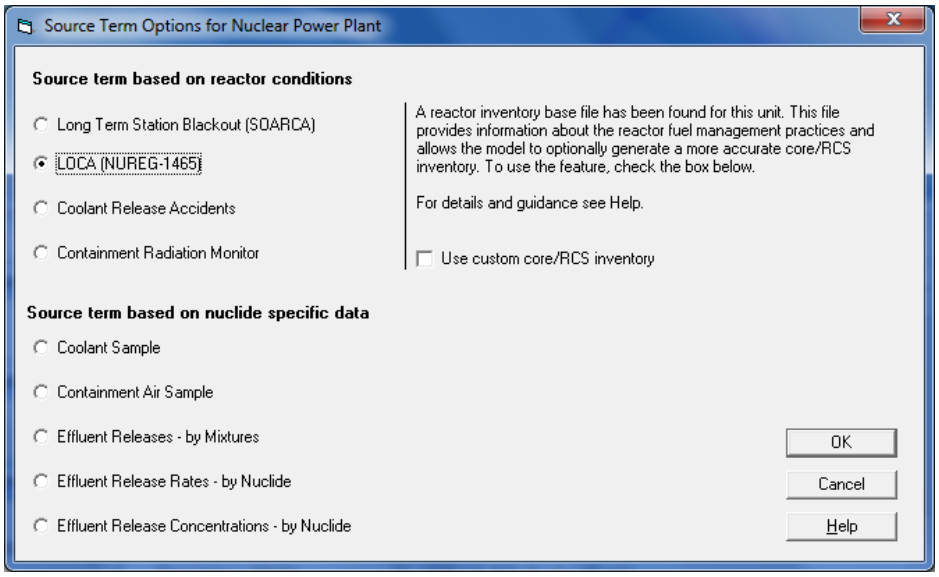
The **Source Term to Dose (STDose)** tool is selected to begin the case setup.



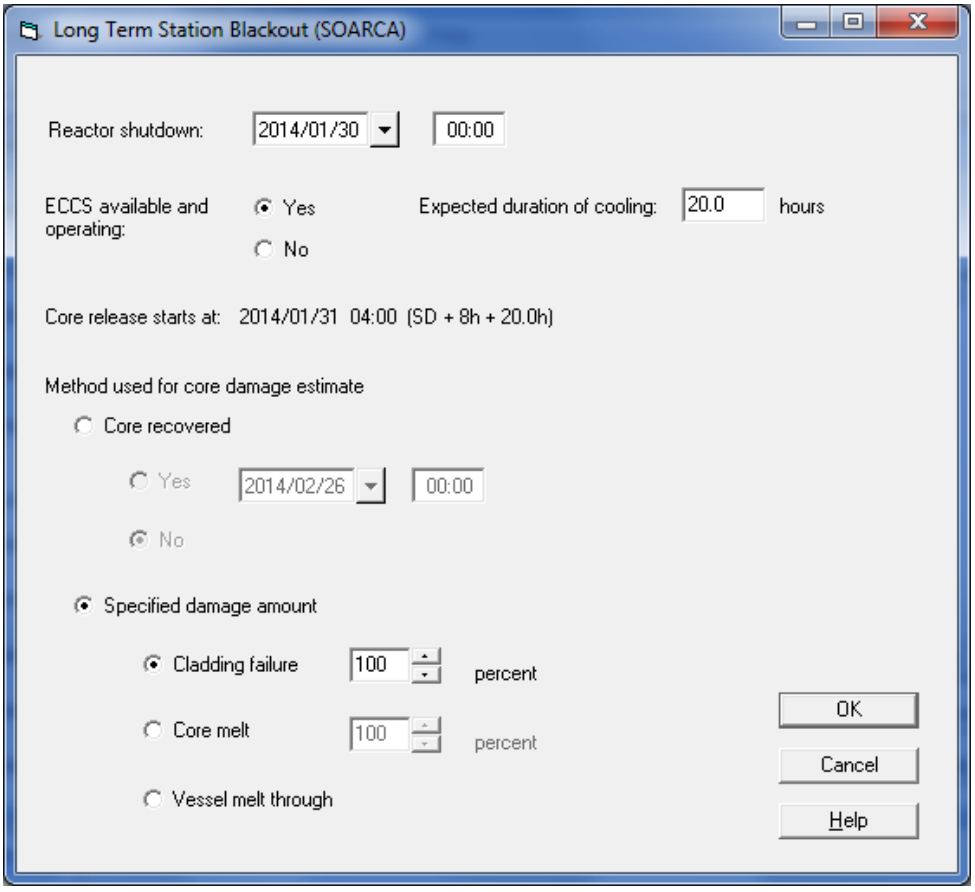
Event Type - After selection of the **Source Term to Dose (STDose)** tool, and the Nuclear Power Plant event type, default core inventories are provided for existing nuclear power plant sites. For all calculations, "Vogtle – Unit 1" was selected and the average burnup adjusted to 27,000 MWd/MTU as specified in Enclosure 1.



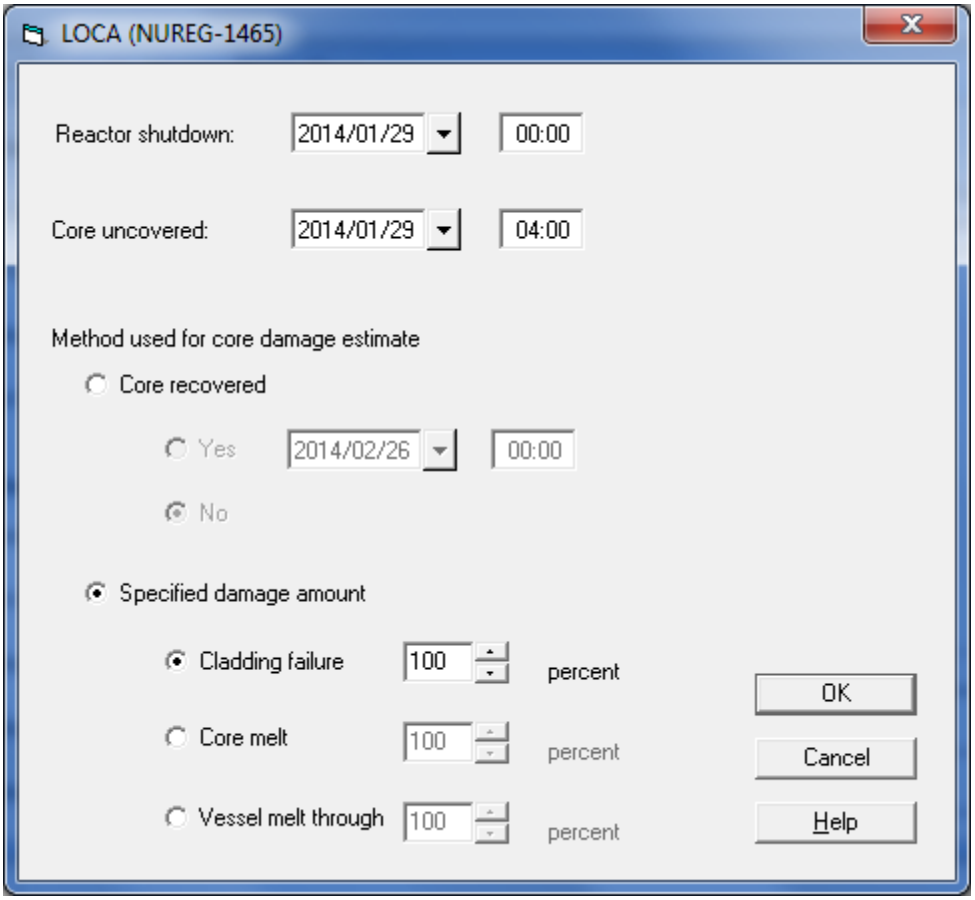
Source Term - RASCAL has four methods for estimating source terms that are defined accident sequences, including two core melt-accidents: *Long Term Station Blackout (SOARCA)* and *Loss of Cooling Accident (LOCA) (NUREG-1465)*. These source term models are described in RASCAL 4: Description of Models and Methods. The modeling runs were performed using either the SOARCA or LOCA (NUREG-1465) source terms as specified in Enclosure 1.



Long Term Station Blackout - For the SOARCA modeling runs, RASCAL assumes a delay of at least 8 hours before the core is uncovered and a release begins. Additional delay time is specified by adjusting the amount of time core cooling is available. For SOARCA runs with 8 hours delay until core release, the expected duration of cooling was set to 0 hours (or ECCS available and operating set to "No"); and for runs with 28 hours delay, the expected duration of cooling was set to 20 hours.



LOCA (NUREG-1465) - For LOCA modeling runs, the amount of fission products released from the core is estimated based on the amount of time the core remains uncovered. The delay time between shutdown and when the core is uncovered and the release starts can be specified by entering the time the respective events occur. As specified in Enclosure 1, the time between shutdown and the start of the release was set to either 4 or 24 hours.

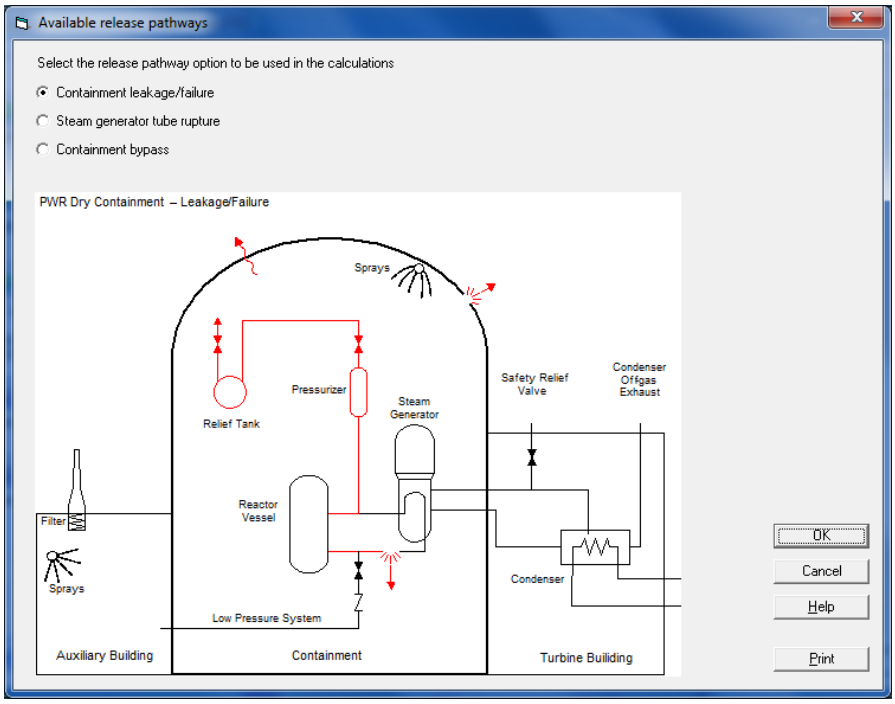


For simplicity, the time of reactor shutdown was assumed to occur at midnight in all cases.

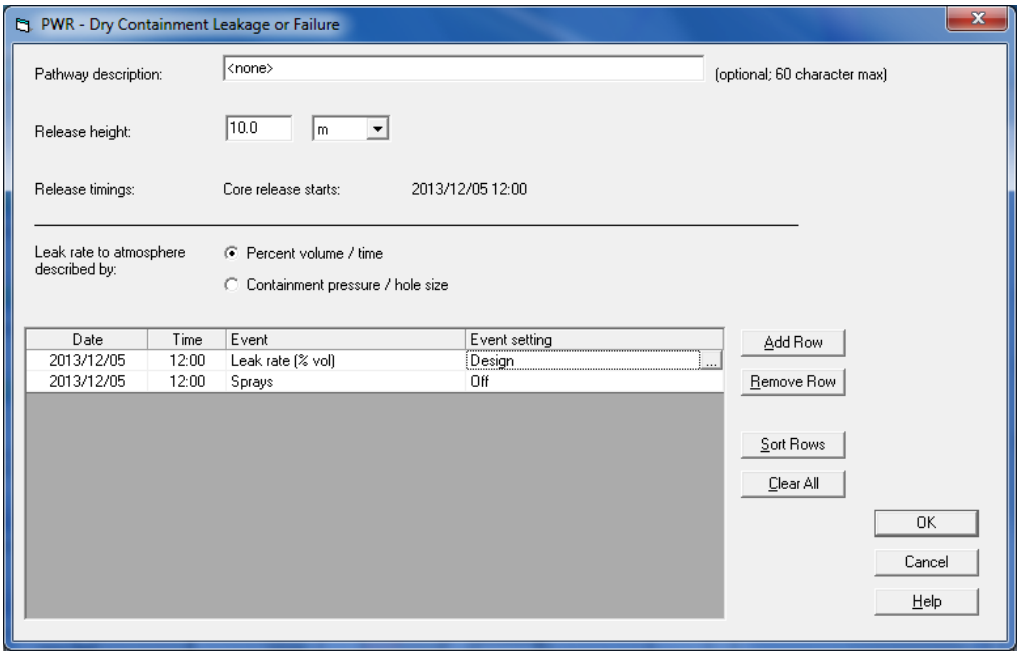
Core Damage State - For all runs the core damage end state was specified by selecting either 100% cladding failure, 100% core melt, or 100% vessel melt through.

Release Pathways - For both core-melt accident source terms the available release pathways are *Containment leakage/failure*, *Steam generator tube rupture*, and *Containment bypass*.

Containment Leakage - The following diagram is representative of the containment release pathway.



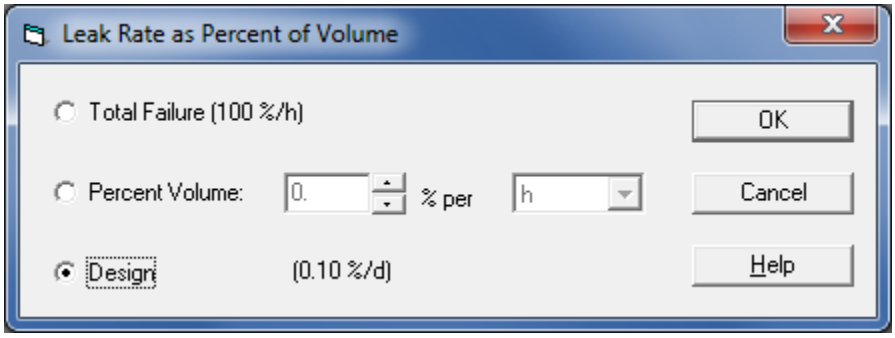
The options for controlling the amount of leakage and contributing factors include options for specifying leak rate, containment spray, and release height. The leak rates and use of sprays are adjustable over time by adding or removing event rows.

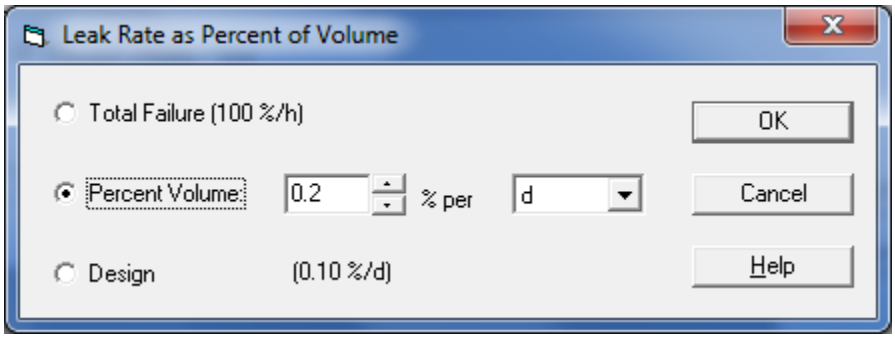


Leak Rate - There are two options for describing the leak. The first is to specify the containment leak rate as *percent volume/time*, and the other is to describe the leak by *containment pressure and hole size*.

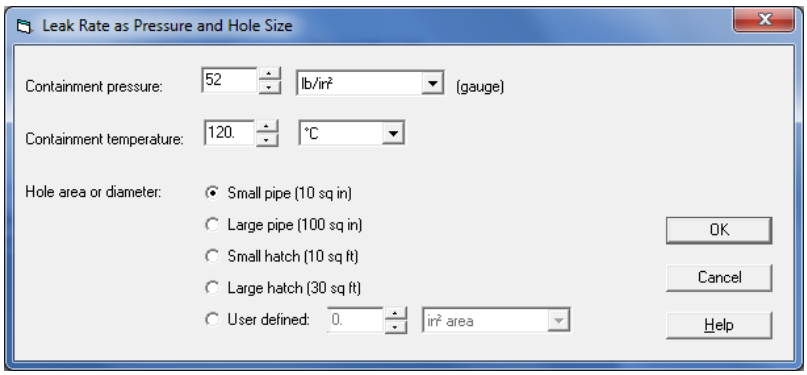
For the modeling runs, containment leakage was specified to occur at the design leak rate for the duration of the release, or at the design leak rate until containment failure 48 hours after the start of the release. The containment failure was assumed to be a leak rate equivalent to a 1 inch hole at 125 psig containment pressure.

When the *percent volume/time* option is selected, RASCAL sets the leak rate to a default design leak rate of 0.1 %/d. However, per Enclosure 1 a design leak rate is 0.2 %/day is to be modeled which was manually entered in the *Percent Volume* option.





When the *containment pressure/hole size* option is selected, RASCAL calculates the leak rate based on the user inputs for containment pressure, temperature, and hole size. Although this method can be used to calculate the leak rate for the assumed containment failure, RASCAL only allows the user to describe the leak rate by one of the two methods (percent volume/time or containment pressure/hole size) in a particular run and the user cannot mix methods.



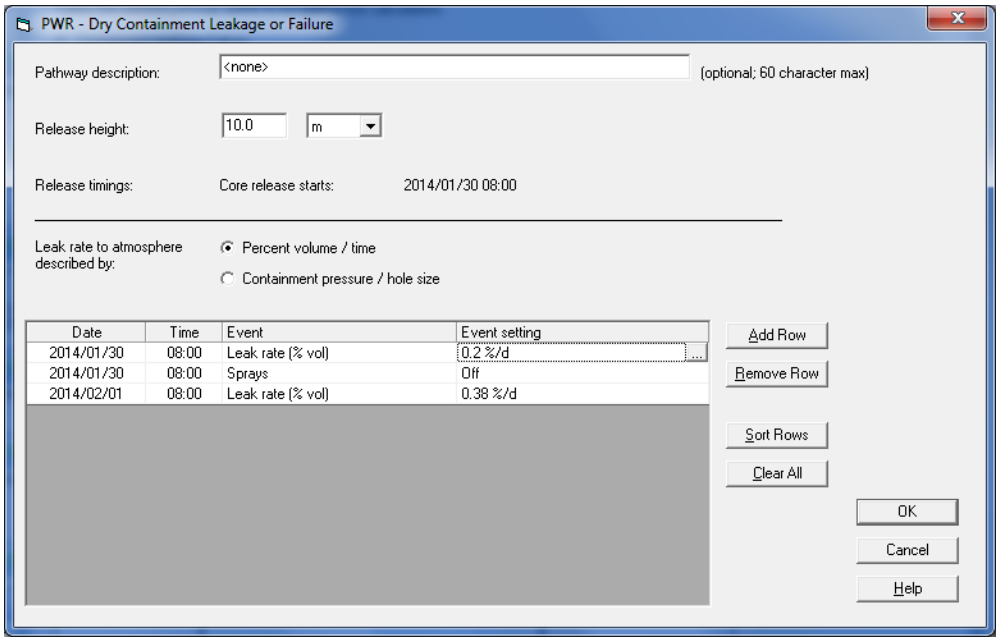
For the runs with design leakage followed by an assumed containment failure 48 hours after the start of release, the increased leak rate was accounted for by manually calculating the leak rate based on the assumed hole size and containment pressure following the method outlined in RASCAL 4: Description of Models and Methods, Section 1.5.2., and adding this value to the design leak rate of 0.2 %/day. First, the mass flow rate for time step *k* is computed from:

$$MFR(k) = C\left(\frac{\pi D}{4}\right)\sqrt{2\rho(P_1(k) - P_2)}$$

where C = 0.63, D is the hole diameter, ρ is the density of the containment atmosphere, $P_1(k)$ is the containment pressure at time step k, and P_2 is atmospheric pressure. Then, the leakage fraction from the containment during time step k is computed from:

$$LF(k) = \frac{MFR(k)t}{\rho V_c}$$

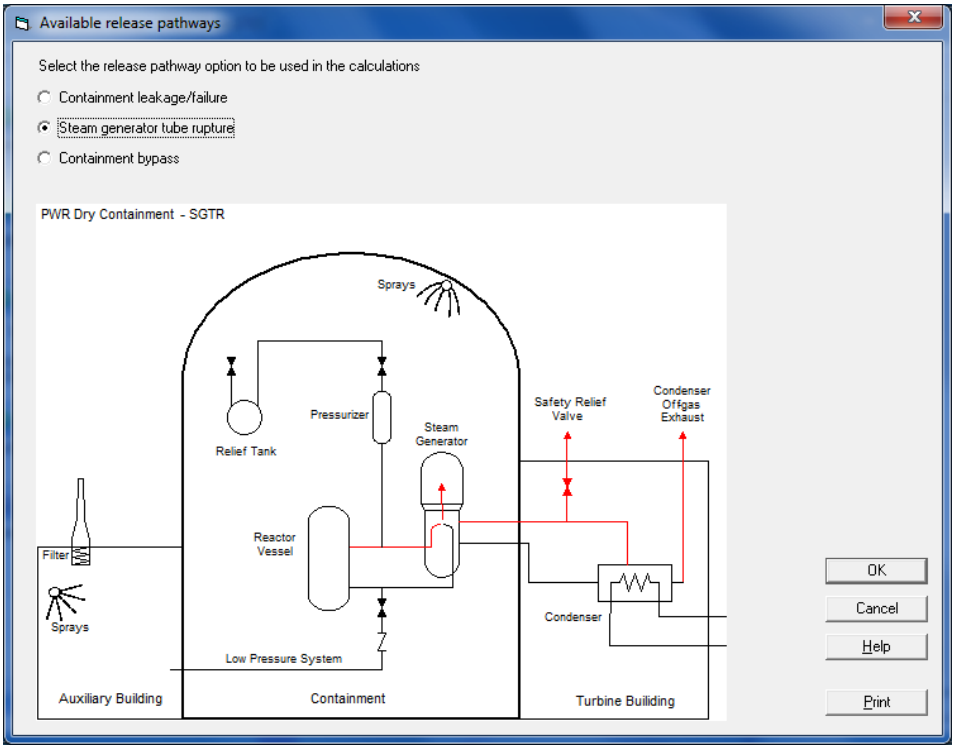
where t is the duration of time step k in seconds and V_c is the containment volume. RASCAL default time steps are 15 minutes and the default containment volume for Vogtle is 2.7×10^6 ft^3. Simplified static values of containment pressure and containment temperature of 40C (with containment sprays operating) and 200C (without containment sprays) were used as specified in Enclosure 1. The computed leak rate for the assumed containment failure amounts to an additional 0.18 %/day. To change the leak rate once containment failure occurs, a row was added to describe the event (leak rate 0.38 %/d) and the time set to 48 hours after the start of release.



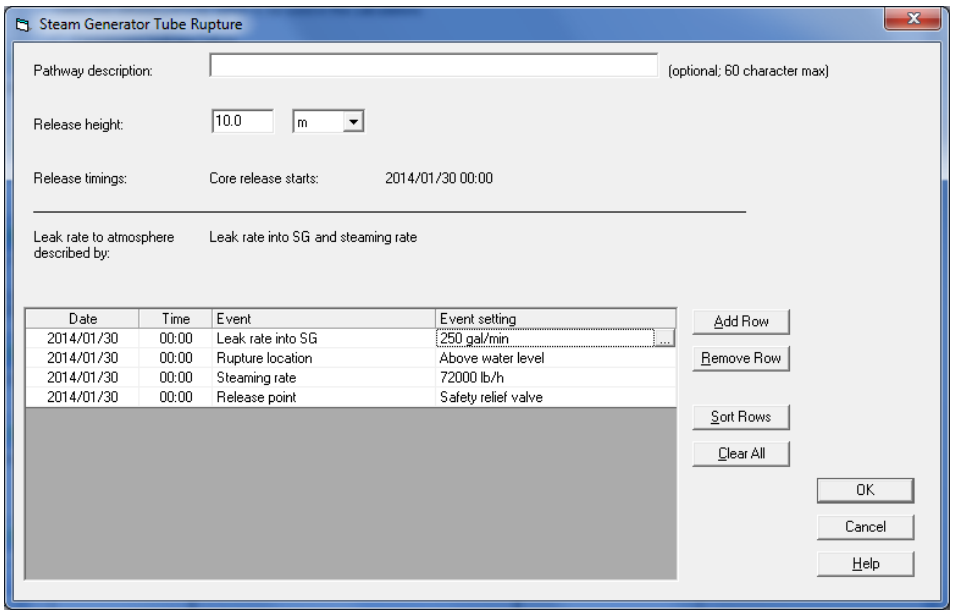
Containment Spray - For each run, the sprays were set to either “On” or “Off” and remained so for the entire duration of the release. RASCAL 4: Description of Models and Methods describes the modeling of containment sprays.

Release Height - A release height of 10 m was used in all runs.

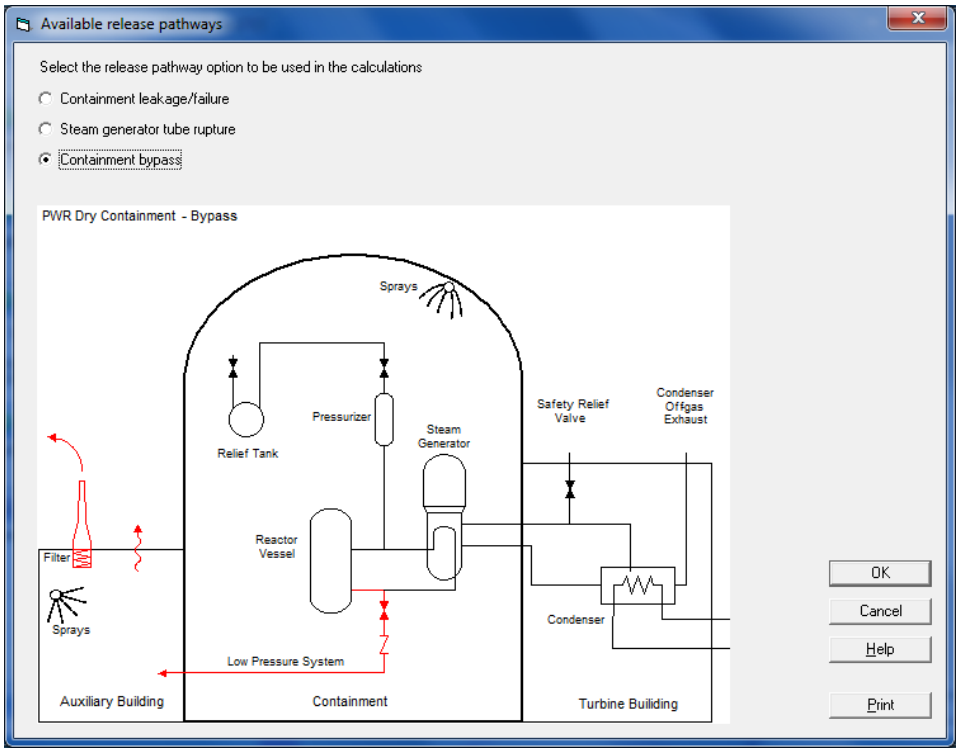
Steam Generator Tube Rupture - The SGTR release path has adjustable parameters for controlling the leak rate into tubes, location of rupture (above or below water line), steaming rate, and release point (safety relief valve or condenser exhaust).



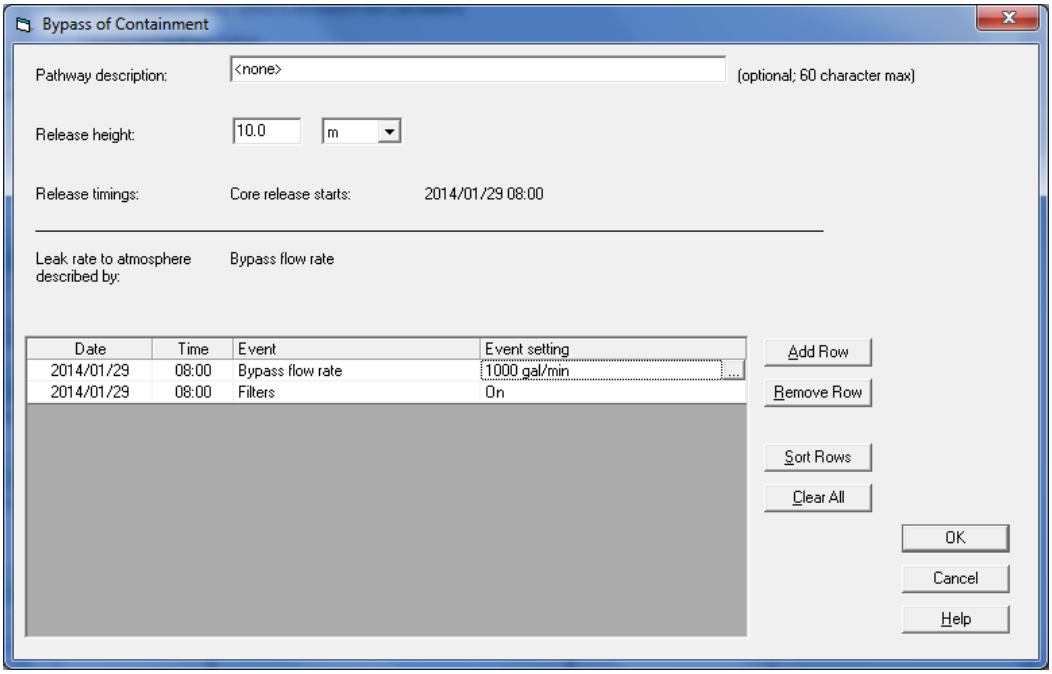
As specified in Enclosure 1, for each of the runs with a SGTR release pathway, the leakage was assumed to be into 0.5 tubes, above the water level, at a steaming rate of 72,000 lbm/hr, and release through the safety relief valve. RASCAL assumes leakage into the steam generator from 1 failed tube to be equivalent to 500 gpm, so the leak rate was set to 250 gpm for the assumed 0.5 tube leakage.



Containment Bypass - The containment bypass release allows the user to control bypass flow rate and whether the release is filtered or not.

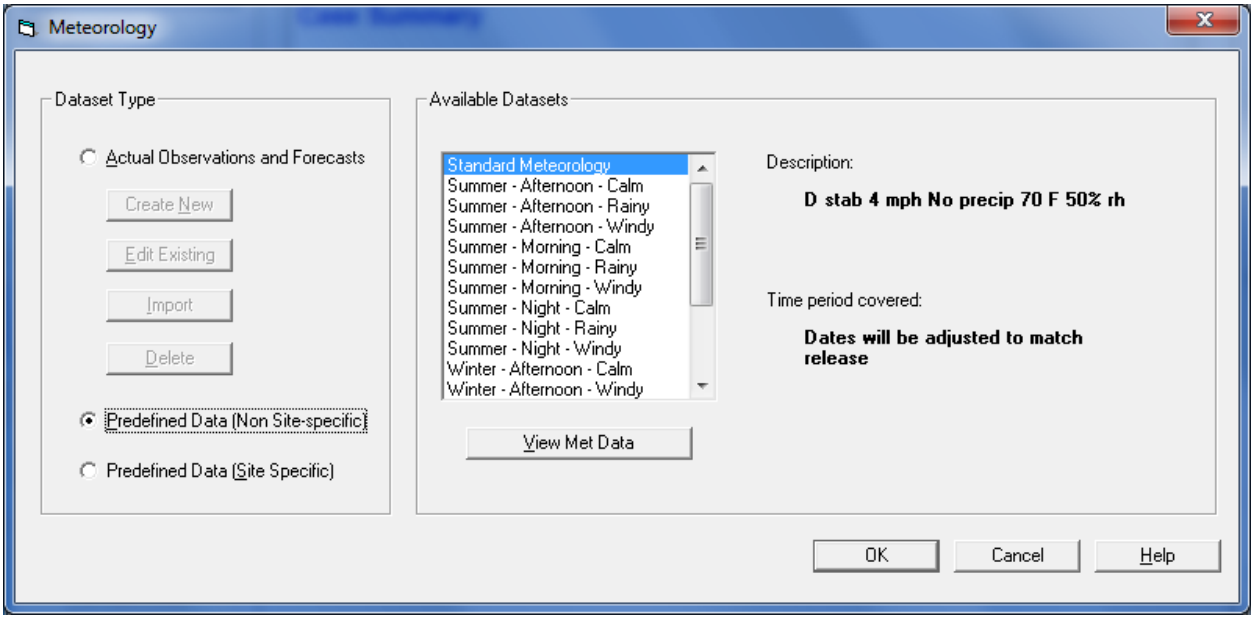


For the bypass runs, bypass flow rate was set to 1000 gal/min and filters either “On “ or “Off” as specified in Enclosure 1. Release height remained 10 m for all the runs.



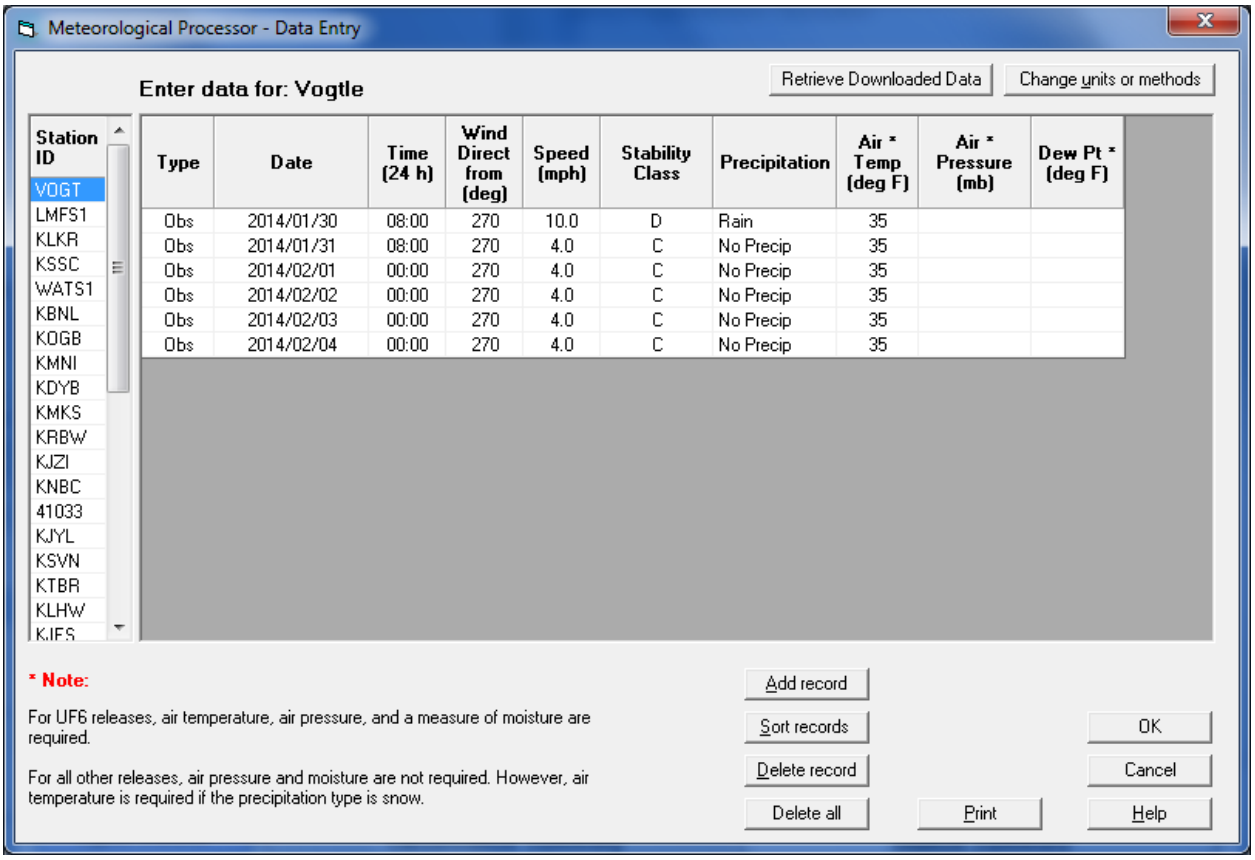
Meteorology - RASCAL has a number of predefined weather conditions that include conditions for different seasons, time of day, and precipitation. The wind is assumed to be coming from the West in all predefined non site-specific weather datasets. Options exist to use actual observations and forecasts or Predefined Data for the site, but the following predefined weather conditions were selected for use in the modeling runs.

Meteorology	Stability Class	Wind Speed	Precipitation	Temperature	Relative Humidity
Summer - Afternoon - Calm	A	4 mph	No precip	85 F	40%
Summer - Afternoon - Windy	B	15 mph	No precip	85 F	40%
Winter - Rainy	D	10 mph	Rain	35 F	95%
Winter - Afternoon - Calm	C	4 mph	No precip	35 F	75%



Weather conditions persist through the duration of the calculation unless the user specifies different meteorology, and the dose calculations are projected out to 96 hours from the start of release. For the Winter – Rain conditions it is unlikely these conditions would persist for 4 days straight, therefore, some practical assumptions were made. It was assumed the worst case precipitation would last for 24 hours from the start of release. The reasonableness of this assumption was validated by comparing the RASCAL modeling assumptions to the actual site weather conditions.

From the RASCAL 4.3 Workbook, for moderate rain, RASCAL assumes a precipitation rate of 0.04 in/hr to 0.2 in/hr, or approximately 1 to 4 inches/day. From Chapter 2.3 of the Vogtle Final Safety Analysis Report (FSAR), Table 2.3.2-1, the maximum 24 hour rainfall in the winter months is approximately 3.5 inches. Thus, 24 hours of moderate rain in the RASCAL model is a reasonable approximation of the worst case precipitation the site is likely to experience. The weather conditions persisting after the rain were specified as Winter – Afternoon – Calm. The other predefined weather conditions compare favorably to the climatological data tabulated in Chapter 2.3 of the FSAR.

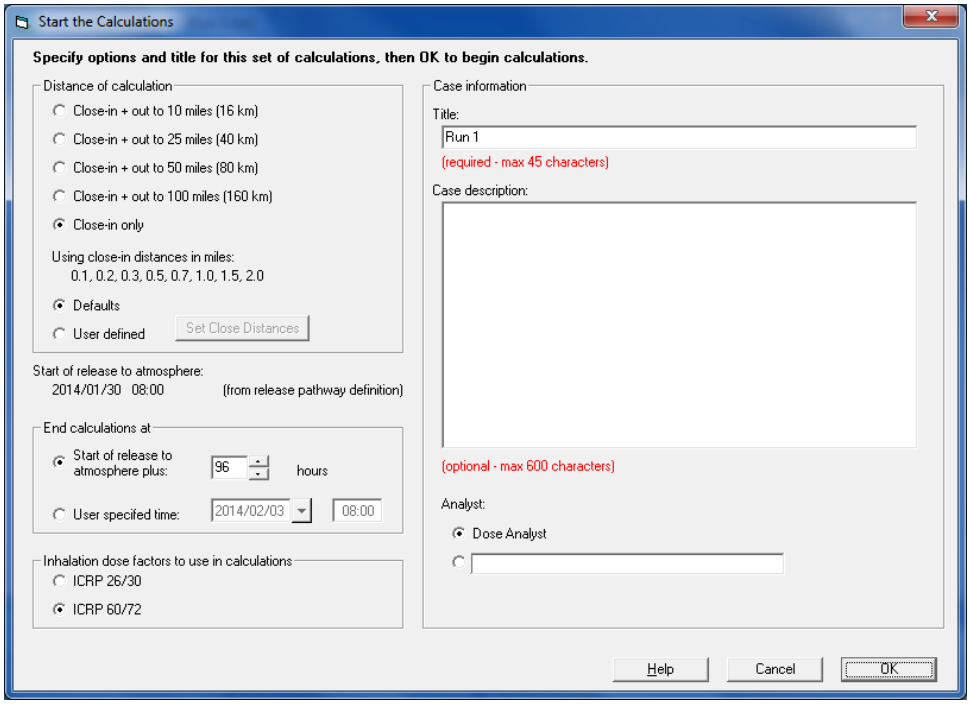


Calculate Doses - The dose calculations are being performed to provide site area boundary doses for comparison to the entry criteria for SAMGs. Since the meteorological conditions always assume the wind is coming from due West, an appropriate calculation distance is the distance from the release point to the Eastern site area boundary. From Chapter 2.3 of the Vogtle FSAR, Table 2.3.4-2, the assumed distance to the Eastern boundary ranges from approximately 0.7 to 1.15 miles (NE to SE direction). Therefore, dose projections at 1 mile are used to compare against entry conditions into the SAMGs.

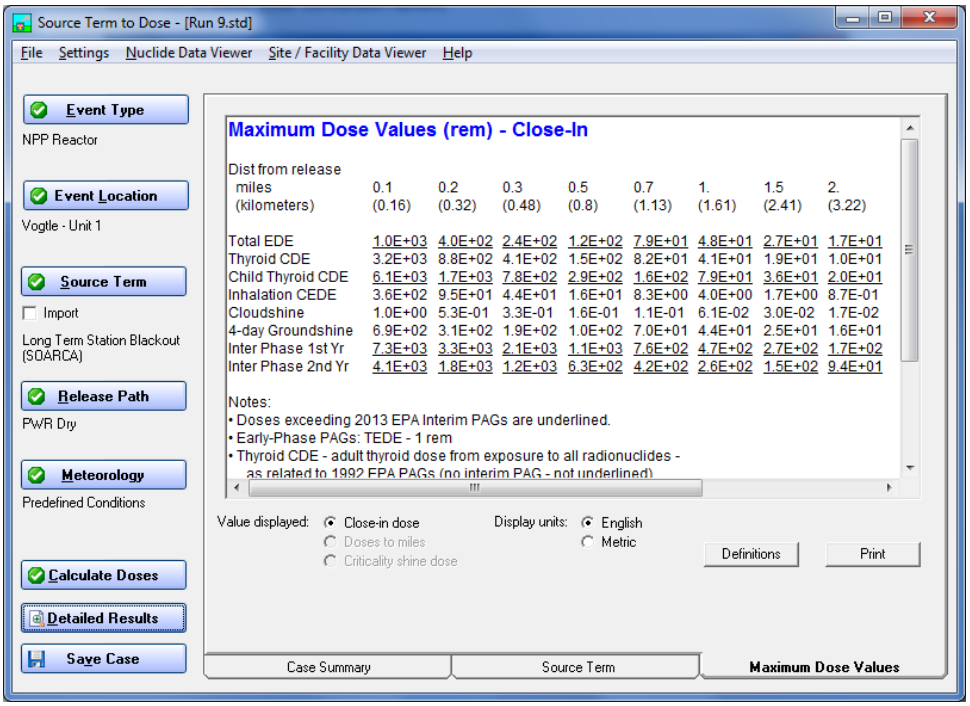
Since dose projections are only needed at 1 mile, the *Distance of Calculation* was set to "Close-in only" which computes doses for distances of 0.1, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, and 2.0 miles for computational efficiency.

The end of calculations was set to 96 hours form the start of release, consistent with U.S. Environmental Protection Agency Protective Action Guides (EPA PAG) dose metrics.

RASCAL 4.3 includes two sets of inhalation dose conversion factors, i.e., dose conversion factors from the International Commission on Radiological Protection (ICRP) 26 (Federal Guidance Report (FGR) 11) and ICRP-60 (FGR-13). In general, the differences in CEDE dose conversion factors are small compared to the uncertainties in the source term and dispersion. However, for comparison to EPA PAG doses, the ICRP-60 inhalation dose conversion factors must be used and was selected for all runs. See RASCAL 4: Description of Models and Methods, Section 2.7 and the RASCAL 4.3 User's Guide for a more detailed discussion of these dose conversion factors.



Detailed Results - When the calculations are completed the Maximum Dose Values for the Close-In dose are displayed. The values of Total Effective Dose Equivalent (EDE) and Thyroid Committed Dose Equivalent (CDE) at 1 mile were used to determine entry into SAMGs with the results provided in the table in Enclosure 1.



Save Case - All the modeling runs in Enclosure 1 were saved for recall and verification purposes.