# SUMMARY OF NEAR-FIELD METHODS FOR ATMOSPHERIC RELEASE MODELING

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# ABSTRACT

This report includes a summary of near-field atmospheric release models including building wake effects for both normal operations and short-term accidental releases. Near-field atmospheric release models can be used to estimate consequences to individuals located near potential release points and buildings. Methods presented here are not intended to comprise an exhaustive list, but rather focus on current industry-accepted methods. Several different models are presented, and example graphical comparisons are included. For the short-term release models, the lowest concentrations were produced by the ARCON/RSAC model and the GENII model for different stability class and wind speed combintations. Currently, the Department of Energy indicates they will use ARCON/RSAC models which may yield lower concentrations than other models such as the no building and GENII models. A no-building modeling assumption using a standard Gaussian plume model produced the highest concentrations. For the normal operations model, the lowest concentrations were produced when the receptor was not on the same surface as the release; however, the downwind distance where the receptor was in the cavity zone, concentrations were greater than for other methods.

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# ACKNOWLEDGMENTS

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# QUALITY OF DATA, ANALYSIS, AND CODE DEVELOPMENT

**DATA:** No CNWRA-generated original data are contained in this report. Data from other sources are included with references to their source. Sources for these non-CNWRA data should be consulted for determining the level of quality for those data.

**ANALYSES AND CODES:** A Microsoft® Excel® spreadsheet was used to develop the graphs that are contained in this report.

# 1 INTRODUCTION

The U.S. Department of Energy (DOE) is preparing a license application for a potential high level waste repository at Yucca Mountain, Nevada. As part of the license application to be reviewed by the U.S. Nuclear Regulatory Commission (NRC), DOE would submit a preclosure safety analysis. In preparation for a regulatory review of a potential DOE license application containing the preclosure safety analysis, the Center for Nuclear Waste Regulatory Analyses (CNWRA) has evaluated various methods that DOE could use to estimate air concentrations around buildings. These air concentrations could be used to estimate dose to occupational workers and members of the public to demonstrate compliance with 10 CFR Part 20 and 10 CFR Part 63 (CFR, 2007, 2001).

DOE has indicated (Dexheimer, et al., 2006) that they will be using ARCON96 (Ramsdell and Fosmire, 1995) models for building wake effects and GENII (Napier, et al., 2004) for dose estimates. The decision of DOE to use GENII for short term accidental release dose estimates was expressed in 2006 and prior to that they were planning to use a different method. For CNWRA and NRC to be prepared for receipt of a license application that could contain different methods, several industry-accepted methods for building wake effects will be reviewed and compared.

Gaussian plume modeling is typically used to estimate airborne concentration and dose from short-term releases of radioactive materials from facilities (NRC, 1983); however, air flow and atmospheric dispersion are affected close to buildings. For this reason, building wake models are often used to estimate concentrations near buildings. The building wake models usually include some modification to the diffusion coefficients. A summary and comparison of near-field atmospheric release methods are included. The methods included are not intended to comprise an exhaustive list, but rather include those methods that are predominately used throughout industry.

Preliminary design information DOE presented at a technical exchange on facility layout indicated that the canister receipt and closure facility will have a maximum building height of 30 m [100 ft] and a maximum width of 100 m, [300 ft] (Slovic, 2007). These dimensions will be used for the building wake model comparison.

# 2 METHODOLOGY

An exact mathematical solution to the plume interaction with air flow does not exist. However, a great deal of useful quantitative information has been obtained using wind-tunnel simulations of flow around model buildings and a limited number of measurements around full-scale buildings of relatively simple geometry. Semiempirical models consolidating these simulations and experiments are available for estimating pollutant concentrations around buildings. Hanna, et al. (1982) summarized the methods available for determining flow patterns and pollutant concentrations near buildings with a simple blocklike structure.

Building wake effect model needs for the potential Yucca Mountain geologic repository operations area include assessing the doses from the atmospheric release of radioactive material as a result of normal operations or potential Category 1 event sequences to workers or those individuals in the vicinity of buildings. Category 1 event sequences are those which are expected to occur one or more times during the operation of the facility. Different building wake effect methods are used based on whether the release occurs from normal operations or from a potential Category 1 release. For this reason, the methods are presented separately.

Preliminary design information (Dexheimer, et al., 2006) indicates that stacks will not be built in accordance with good engineering practice as specified by the U.S. Environmental Protection Agency (EPA) (EPA, 1985). Therefore, credit cannot be taken for the stack height when performing safety analysis dose estimates, and the releases must be assumed to occur from ground level.

## 2.1 General Building Wake Effects

Wind passing over and around buildings creates a complicated dispersion pattern. Figure 1 (Wilson, 1979) shows a cross section of the flow over a building with the wind perpendicular to the face of the building. The recirculation cavity (Zone I-ZI) is created when the flow separates from the upwind edge of the roof. The flow recirculates and the turbulence levels are very high. Only if the roof is long enough will the flow reattach to the roof. The boundary of the high turbulence region (Zone II-ZII) is not precisely defined. Turbulence generated in the shear layers at the edge of the recirculation cavity results in accelerated diffusion of any gases to the roof level. Zone II is defined such that it also includes Zone I. The roof wake region (Zone III-ZIII) is depicted in Figure 1 in an exaggerated form. The boundary of this region is essentially straight and parallel with the flow. Gases that are released in this region will have some downwash and more rapid spreading than the gases above Zone III. Zone III also includes Zones I and II. The area just beyond the building (on the leeward side of the wind direction) is often referred to as the cavity zone (EPA, 1980). This stagnant region is highly turbulent with recirculating air, causing workers present in this cavity zone location to experience higher air concentrations. For long-term release (normal operations), methods have been developed that account for this cavity zone (International Atomic Energy Agency, 2001); however, for potential Category 1 releases (short term), appropriate methods are not available for the cavity zone, and calculations will not be performed (EPA, 1980). Potential Category 1 atmospheric release models and normal operations release models are discussed separately.

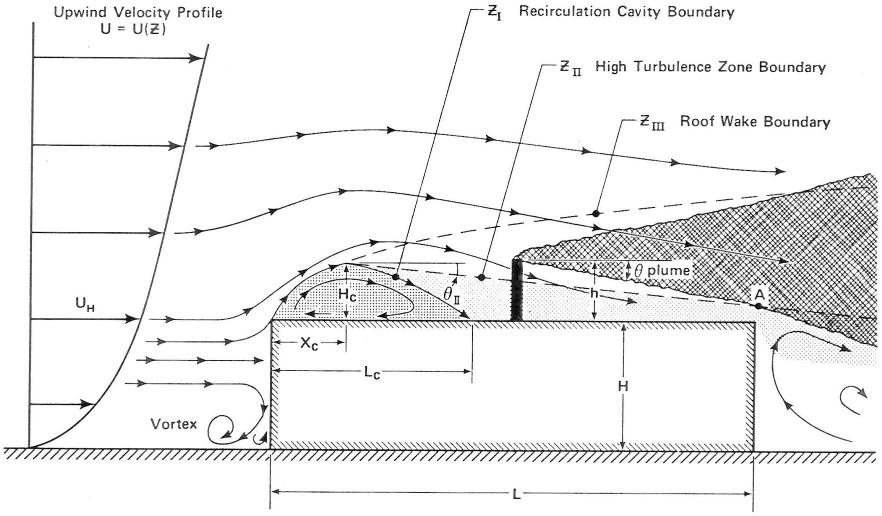

**Figure 2-1. Flow Patterns Around Buildings (Reprinted with Permission)**

## 2.2 Potential Category 1 Release Methods

### 2.2.1 Straight-Line Gaussian Plume Model (No Building)

Downwind air concentrations at the ground surface are determined using the universal diffusion equation (Slade, 1977)

$$\frac{X}{Q}(x,y,0)=\frac{1}{\bar{u}\,\pi\sigma_y\sigma_z}\exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2}+\frac{h^2}{\sigma_z^2}\right)\right] \tag{2-1}$$

where

$\frac{X}{Q}$ — relative concentration [s/m$^3$], air concentration divided by emission rate
$\bar{u}$ — wind speed at 10 m [30 ft] above the ground surface [m/s]
$\sigma_y$ — lateral plume spread as a function of atmospheric stability [m]
$\sigma_z$ — vertical plume spread as a function of atmospheric stability [m]
$y$ — horizontal distance from plume centerline [m]
$h$ — elevation of the point release above the ground plane [m]

For a release that is assumed to originate from ground level [h = 0], the plume centerline [y = 0] concentration would be

$$\frac{X}{Q}(x,y,0)=\frac{1}{\bar{u}\,\pi\sigma_y\sigma_z} \tag{2-2}$$

where

$\frac{X}{Q}$ — relative concentration [s/m$^3$]
$\bar{u}$ — wind speed at 10 m [30 ft] above the ground surface [m/s]
$\sigma_y$ — lateral plume spread as a function of atmospheric stability [m]
$\sigma_z$ — vertical plume spread as a function of atmospheric stability [m]

Variations of this model exist for addressing wake effects. Each will be discussed separately, and then a comparison of the models will be made.

### 2.2.2 NRC Regulatory Guide 1.145 Methods

The U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145 has two classifications of release: vent/ground level and elevated. Vent releases are to include “all release points or areas that are effectively lower than two and one-half times the height of adjacent solid structures” (NRC, 1983). Although final DOE design information for the geologic repository operations area has not been made publicly available, DOE has indicated that the stacks will be shorter than the two and one-half times criterion necessary for classification as elevated releases and, therefore, all dose modeling will need to be performed assuming the releases are from ground level.

NRC Regulatory Guide 1.145 has two classifications for releases based on meteorological conditions: (i) neutral (D stability class) or stable (E, F, or G stability class) or (ii) all other meteorological conditions. For neutral or stable conditions, the relative air concentration is determined using the following three equations.

$$\frac{X}{Q}=\frac{1}{\overline{U}_{10}(\pi\sigma_y\sigma_z+A/2)} \tag{2-3}$$

$$\frac{X}{Q}=\frac{1}{\overline{U}_{10}(3\pi\sigma_y\sigma_z)} \tag{2-4}$$

$$\frac{X}{Q}=\frac{1}{\overline{U}_{10}\pi\Sigma_{My}\sigma_z} \tag{2-5}$$

where

$\frac{X}{Q}$ — relative concentration [s/m$^3$]
$\overline{U}_{10}$ — wind speed at 10 m [30 ft] above the ground surface [m/s]
$\sigma_y$ — lateral plume spread as a function of atmospheric stability [m]
$\sigma_z$ — vertical plume spread as a function of atmospheric stability [m]
$A$ — smallest vertical-plane cross-sectional area of the building perpendicular to the plume [m$^2$]
$\Sigma_{My}$ — lateral plume spread with meander and building wake effects [s/m$^3$]

Using the above equations for neutral or stable conditions (D, E, F, or G stability class), Eqs. (2-3) and (2-4) are compared and the highest value is selected. The selected value is compared with the result of Eq. (2-5), and the minimum is selected. For a determination of $\Sigma_{My}$ and a complete discussion on plume meander, refer to Appendix A and Figure 3 of NRC (1983).

For all other meteorological conditions, the higher value of Eqs. (2-3) and (2-4) is selected and Eq. (2-5) is not used. Methods such as this are simple and conservative. Referring to the cross-sectional area of the building, the area should represent the building face that is perpendicular to the plume as it travels.

### 2.2.3 RSAC Methods

A computer code that is frequently used for building wake effects calculations is RSAC (Schrader, 2005), which employs the methods in the computer code developed by Ramsdell in ARCON95 (Ramsdell and Fosmire, 1995) and ARCON96 (Ramsdell and Simonen, 1997). Using Eq. (2-2), the $\sigma_y$ and $\sigma_z$ are replaced with composite wake diffusion coefficients, $\Sigma_y$ and $\Sigma_z$, which are defined by

$$\Sigma_y = \left( \sigma_y^2 + \Delta\sigma_{y1}^2 + \Delta\sigma_{y2}^2 \right)^{1/2} \qquad (2\text{-}6)$$

$$\Sigma_z = \left( \sigma_z^2 + \Delta\sigma_{z1}^2 + \Delta\sigma_{z2}^2 \right)^{1/2} \qquad (2\text{-}7)$$

where

$\Sigma_y$ — lateral composite wake diffusion coefficients [m]
$\Sigma_z$ — vertical composite wake diffusion coefficients [m]
$\sigma_y$ and $\sigma_z$ — diffusion coefficients [m]
$\Delta\sigma_{y1}$ and $\Delta\sigma_{z1}$ — low wind speed corrections {defined in Eqs. (2-8) and (2-9) [m]}
$\Delta\sigma_{y2}$ and $\Delta\sigma_{z2}$ — building wake corrections {defined in Eqs. (2-10) and (2-11) [m]}

The low wind speed corrections are defined as

$$\Delta\sigma_{y1}^2 = 9.13 \times 10^5 \left[ 1 - \left( 1 + \frac{x}{1000u} \right) \exp\left( \frac{-x}{1000u} \right) \right] \qquad (2\text{-}8)$$

$$\Delta\sigma_{z1}^2 = 6.67 \times 10^2 \left[ 1 - \left( 1 + \frac{x}{100u} \right) exp\left( \frac{-x}{100u} \right) \right] \qquad (2\text{-}9)$$

where

$\Delta\sigma_{y1}$ — lateral low wind speed correction [m]
$\Delta\sigma_{z1}$ — vertical low wind speed correction [m]
$x$ — distance from the release point [m]
$u$ — wind speed [m/s]

The building wake correction is defined as

$$\Delta\sigma_{y2}^2 = 5.24\,\mathrm{x}10^{-2} u^2 A \left[ 1 - \left( 1 + \frac{x}{10A^{1/2}} \right) \exp\left( \frac{-x}{10A^{1/2}} \right) \right] \qquad (2\text{-}10)$$

$$\Delta\sigma_{z2}^2 = 1.17 \times 10^{-2} u^2 A \left[ 1 - \left( 1 + \frac{x}{10A^{1/2}} \right) \exp\left( \frac{-x}{10A^{1/2}} \right) \right] \qquad (2\text{-}11)$$

where

$\Delta\sigma_{y2}$ — lateral building wake correction [m]
$\Delta\sigma_{z2}$ — vertical building wake correction [m]
$u$ — wind speed [m/s]

$A$ — cross-sectional building area perpendicular to the plume [m$^2$]
$x$ — distance from the release point [m]

The maximum value of $\Sigma_y$ is constrained to a value equal to the sector width or approximately equal to 1.81$x$.

The research supporting this method is discussed in detail in Ramsdell (1990). Modifications were made to the NRC Regulatory Guide 1.145 building wake model primarily because of the conservative relative air concentration at low wind speeds. This overestimation was determined by comparison with actual data for distances less than 400 m [1,300 ft] from the release point. For this reason, the $\Delta\sigma_{y1}$ and $\Delta\sigma_{z1}$ terms, known as the low wind speed correction terms, were added.

### 2.2.4 Model Within GENII: Schulman-Scire Method

GENII (Napier, et al., 2004) is an environmental pathway model that is widely used in industry to estimate dose to receptors from atmospheric releases of radioactive materials. GENII implements the same Ramsdell model as the one employed in RSAC and has some other models as well. An alternative to the Ramsdell model is application of the two plume models found in the EPA Industrial Source Complex (ISC3) model (EPA, 1995). Within ISC3, two different methods are used to account for building wakes: (i) the Huber-Snyder method and (ii) the Schulman-Scire method. The Schulman-Scire method is used for stack heights less than the building height plus half the lesser of the building height or width. Based on preliminary design information of the potential Yucca Mountain geologic repository operations area, the Schulman-Scire method is expected to be applicable and, therefore, it will be discussed here.

For the Schulman-Scire building wake method (Napier, et al., 2004), a modified vertical dispersion coefficient is calculated first based on building dimensions. A squat building is one in which the width is greater than or equal to the height, and a tall building is one in which the height is greater than the width. Preliminary design of various buildings in the geologic repository operations area indicates that buildings will be considered squat buildings. Modifications to the dispersion coefficients are handled differently for squat or tall buildings. The dispersion coefficients are only modified if the distance from the source to the receptor is greater than three building heights.

For distances less than three building heights, the receptor is assumed to be in the cavity region, and the equations are not applicable. (Note GENII sets concentrations to zero in this region.) Setting the concentrations to zero does not imply that the receptor would not receive a dose in this region, but rather is assigned to show the inappropriateness of these methods for the cavity region. For short-term releases such as these, the recirculation within this cavity zone would likely result in an increased dose to the receptor, but specific calculational methods have not been reported within GENII or ISC3 to support this. For a squat building, the modified vertical dispersion coefficient is defined as follows for those instances where $3h_b \leq x < 10h_b$

$$\sigma_{z'} = 0.7h_b + 0.067(x - 3h_b) \qquad (2\text{-}12)$$

where

$\sigma_{z'}$ — modified vertical diffusion coefficients [m]
$h_b$ — building height [m]
$x$ — distance from the release point [m]

For distances where x $\geq 10h_b$

$$\sigma_{z'} = \sigma_z(x + x_z) \tag{2-13}$$

where

$\sigma_{z'}$ — modified vertical diffusion coefficients [m]
$\sigma_z$ — vertical diffusion coefficients [m]
$x$ — downwind distance [m]
$x_z$ — calculated by solving Eqs. (2-12) and (2-13) for $x_z$ at $x = 10h_b$

For squat buildings, the vertical dispersion coefficient is the greater of the modified and unmodified ($\sigma_z$) coefficients.

The modified horizontal dispersion coefficient for a squat building for distances where $3h_b \leq$ x $< 10h_b$ is

$$\sigma_{y'} = 0.35h_w + 0.067(x - 3h_w) \tag{2-14}$$

where

$\sigma_{y'}$ — modified horizontal diffusion coefficients [m]
$h_w$ — building width [m]
$x$ — distance from the release point [m]

For distances where $x \geq 10h_b$

$$\sigma_{y'} = \sigma_y(x + x_z) \tag{2-15}$$

where

$\sigma_{y'}$ — modified horizontal diffusion coefficients [m]
$\sigma_y$ — horizontal diffusion coefficients [m]
$h_b$ — building height [m]
$x$ — downwind distance [m]
$x_z$ — calculated by solving Eqs. (2-14) and (2-15) at $x = 10h_b$

Schulman-Scire building wake methods also include a linear decay factor that is applied to the modified vertical diffusion coefficient $\sigma_{z'}$. For ground-level releases such as those considered here, the linear decay factor is equal to one, and therefore no change is needed for the modified vertical diffusion coefficient.

## 2.3 Normal Operations Release Methods

For ground-level releases from normal operations, the relative air concentration is estimated as (NRC, 1977)

$$\frac{X}{Q} = \frac{2.032}{\overline{U}_{10} x \sigma_z} \tag{2-16}$$

where

$\frac{X}{Q}$ — relative concentration [s/m$^3$]

$\overline{U}_{10}$ — wind speed at 10 m [30 ft] above the ground surface [m/s]

x — downwind distance [m]
$\sigma_z$ — vertical plume spread as a function of atmospheric stability [m]

The International Atomic Energy Agency has produced a Safety Series document (International Atomic Energy Agency, 2001), which addresses building wake effects for normal releases. The scope of the International Atomic Energy Agency document (2001) clearly states that approaches described are applicable to continuous release with the assumption that equilibrium has been established with the environment.

The International Atomic Energy Agency report includes a section on building considerations that discusses the flow of air around buildings using slightly different terms than those shown in Figure 1. The document provides detailed calculations that are dependent on where the receptor is located. The cavity zone is on the leeward side of the building, and the wake zone is considered further downwind of the building. The remainder of this section presents the wake and cavity zone calculations.

For the International Atomic Energy Agency model, the Gaussian plume model is adjusted based on the relationship between the height of the release and the height of the building. For ground-level releases that are considered here, dispersion is handled differently based on the receptor located relative to the building. For ground-level releases, the receptor is assumed to be in the wake zone when the downwind distance meets the following

$$x > 2.5\sqrt{A_B} \tag{2-17}$$

where

$x$ — downwind distance [m]
$A_B$ — cross-sectional area of the building [m$^2$]

The relative air concentration for the wake zone is estimated by

$$\frac{x}{Q} = \frac{B}{u_a} \tag{2-18}$$

where

$\frac{x}{Q}$ — relative concentration [s/m$^3$]
$B$ — diffusion factor (defined next) [1/m$^2$]
$u_a$ — wind speed at 10 m [30 ft] above the ground surface [m/s]

$$B = \frac{2.032}{x\Sigma_z} \tag{2-19}$$

where

$B$ — diffusion factor [1/m$^2$]
2.032 — $16\sqrt{(2\pi^3)}$ Note IAEA (2001) used 12 sectors so different value was used.
$x$ — downwind distance [m]
$\Sigma_z$ — corrected vertical dispersion (defined next) [m]

The corrected vertical dispersion is calculated as

$$\Sigma_z = \left(\sigma_z^2 + \frac{A_B}{\pi}\right)^{0.5} \tag{2-20}$$

$\Sigma_z$ — corrected vertical dispersion [m]
$\sigma_z$ — vertical diffusion coefficient as a function of atmospheric stability [m]
$A_B$ — cross-sectional area of the building [m$^2$]

For ground-level releases, dispersion inside the cavity zone is defined for distances where $x \leq 2.5\ \sqrt{A_B}$. Different situations are presented for the cavity zone depending on whether the receptor is on the same building surface as the release. If the receptor is on the same building surface as the release and the downwind distance is less than three times the diameter of the stack, no dilution occurs. During these conditions, the relative concentration is assumed to be that which is exiting the stack or is equal to the inverse of the flow rate, which is highly conservative because it assumes the receptor is breathing the concentration as it exits the stack. For distances considered in this report {>100 m [300 ft]}, the undiluted condition would not be appropriate because stack diameters will likely be less than 10 m [30 ft], and it is not explored further.

If the source and receptor are on the same building surface and the downwind distance is greater than three times the diameter of the stack (which is assumed here), then

$$\frac{X}{Q} = \frac{B_0}{u_a x^2} \tag{2-21}$$

where

$\frac{x}{Q}$ — relative concentration [s/m$^3$]
$B_0$ — constant (30) to conservatively account for potential increases in the concentration [unitless]
$u_a$ — wind speed at 10 m [30 ft] above the ground surface [m/s]
$x$ — downwind distance [m]

The constant $B_0$ was likely calculated by using some relation to sector width and therefore may actually need to be a higher value here where 16 sectors are used than what was used for the 12-sector example shown in the report. This would likely only increase the air concentration by 30 percent. A constant $B_0$ value of 30 will be maintained because the determination of this value was not displayed in detail within the International Atomic Energy Agency report (2001).

If the source and receptor are not on the same surface and $x \leq 2.5\sqrt{A_B}$, the relative air concentration would be

$$\frac{X}{Q} = \frac{1}{\pi u_a H_B K} \tag{2-22}$$

where

$\frac{x}{Q}$ — relative concentration [s/m$^3$]
$u_a$ — wind speed at 10 m [30 ft] above the ground surface [m/s]
$H_B$ — height of the building [m]
K — constant value of 1 [m] [3 ft]

If the width of the building is less than the height, the width of the building should replace the building height in Eq. (2-22).

## 2.4 Demonstration of Models

### 2.4.1 Demonstration of Category 1 Release Models

For each of the methods described above, relative air concentrations are estimated using a Microsoft® Excel® spreadsheet for various downwind distances for conditions in which no building is present and for applying of the various models with a building present.

Building wake effects calculations performed as part of the safety analysis will need to consider the local meteorology for Yucca Mountain. According to a Yucca Mountain Site Environmental Report for 2001 (DOE, 2002), the average hourly wind speeds range from 2.6 to 4.3 m/s [8.5 to 14 ft/s], and calm periods are rare. The winds at Yucca Mountain generally blow to the south or southeast during the day and to the north or northwest at night (DOE, 2002). Different meteorological conditions should be used for modeling of releases following event sequences. According to DOE (1997), meteorological conditions recommended for DOE use in unexpected short-term release situations correspond to D stability and 4.5 m/s [15 ft/s], whereas NRC recommends F stability and 1 m/s [3 ft/s]. While these may not be required for estimates at the potential Yucca Mountain site geologic repository operations area, they give a good representation of appropriate meteorological conditions for use during unexpected short-term releases. Both sets of meteorological conditions will be used to perform the calculations. Diffusion coefficients were taken from Appendix A of Ramsdell and Simonen (1997) which includes a FORTRAN listing of ARCON96. The diffusion coefficient parameters are listed with the subroutine titled “NSIGMAI.”

Figure 2-2 shows the relative air concentration in the wake zone as a function of distance for conditions in which no building is present and with a building using the various models discussed previously for F stability class and a wind speed of 1 m/s [3 ft/s]. Cavity zone calculations were not performed for short-term releases; the cavity zone is assumed to be contained within 100 m [300 ft]. The GENII method curve changes shape because different methods are applied based on the number of building heights that the receptor is downwind.

Figure 2-3 shows the relative air concentration in the wake zone as a function of distance for D stability class and a wind speed of 4.5 m/s [15 ft/s]. Cavity zone calculations were not performed for short-term releases; the cavity zone is assumed to be contained within 100 m [300 ft]. Once again, the GENII method curve shape difference occurs because different methods are applied based on a comparison of number of building heights to downwind distances.

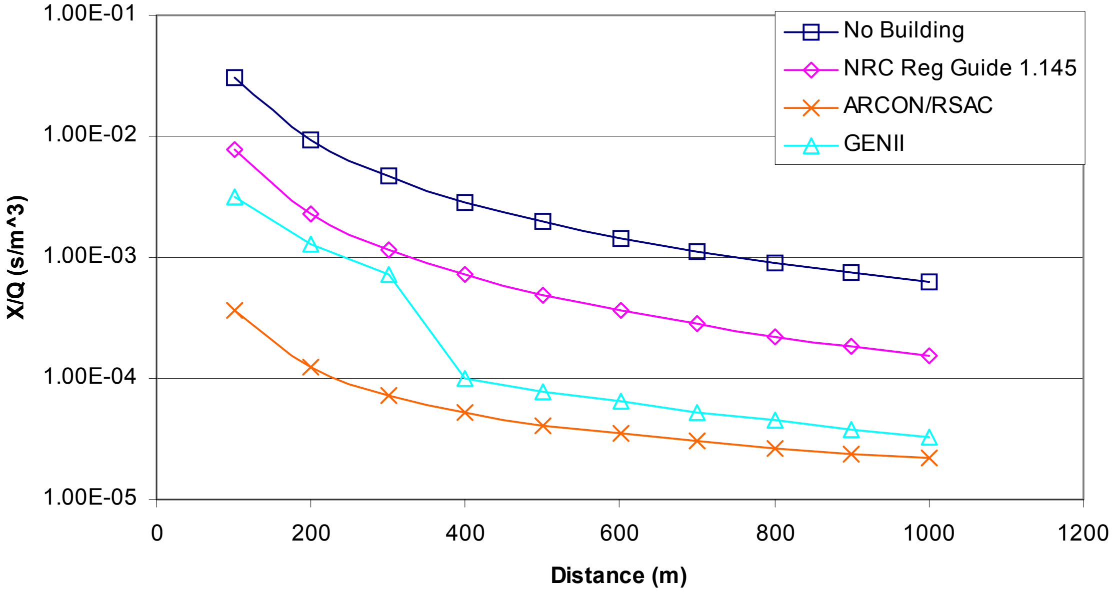

**Figure 2-2. Relative Air Concentration Comparison for F Stability, 1 m/s [3 ft/s], and an Assumed Ground-Surface Release Height**

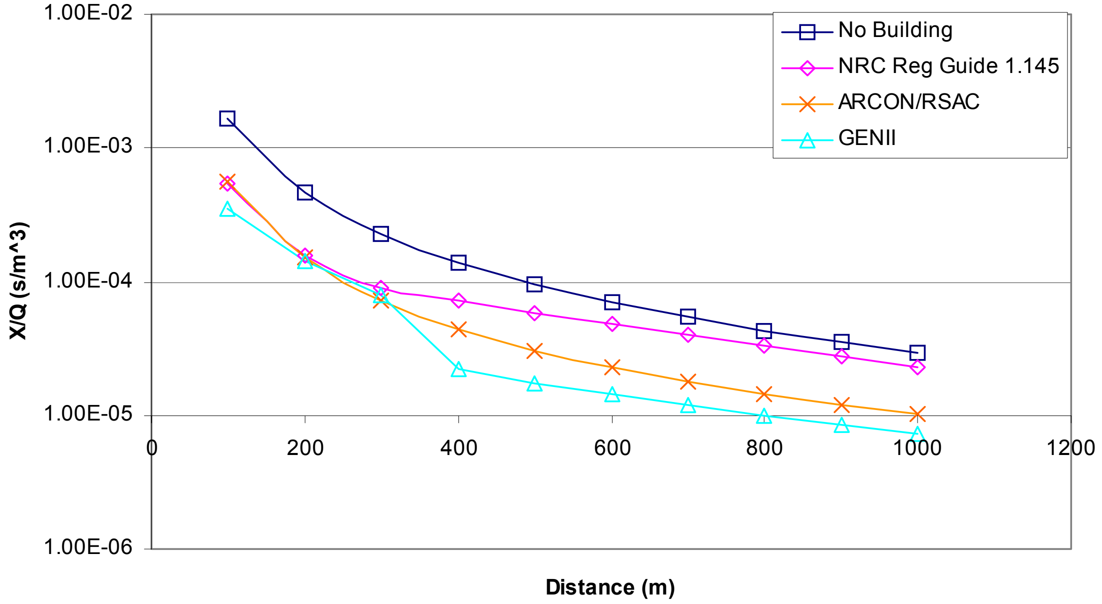

**Figure 2-3. Relative Air Concentration Comparison for D Stability, 4.5 m/s [15 ft/s], and an Assumed Ground-Surface Release Height**

Figures 2-2 and 2-3 show a wide range in concentrations between the no building and building models that is greater than an order of magnitude for some models. For the F stability class and 1 m/s wind speed combination, the lowest concentration is with the RSAC/ARCON model. For the D stability class and 4.5 m/s wind speed combination, the GENII methods produce lowest concentration.

## 2.4.2 Demonstration of Normal Operations Models

International Atomic Energy Agency methods (International Atomic Energy Agency, 2001) estimated downwind relative air concentrations for normal operations releases. Meteorological data were taken from DOE (1999). Frequency weighted relative air concentrations were calculated for the six stability classes and summed to determine results in an annual average air concentration. Frequency weighted average wind speeds were used for each stability class. Relative air concentrations were estimated with no building present and for two sets of conditions with a building present; the results are shown in Figure 2-4. In Figure 2-4, the no-building model produces the highest concentration except for downwind distances that are assumed to be within the cavity zone {<200m [650 ft]} and when the receptor not on same surface as release. Within this cavity zone, concentrations are about a factor of two higher than the no-building model.

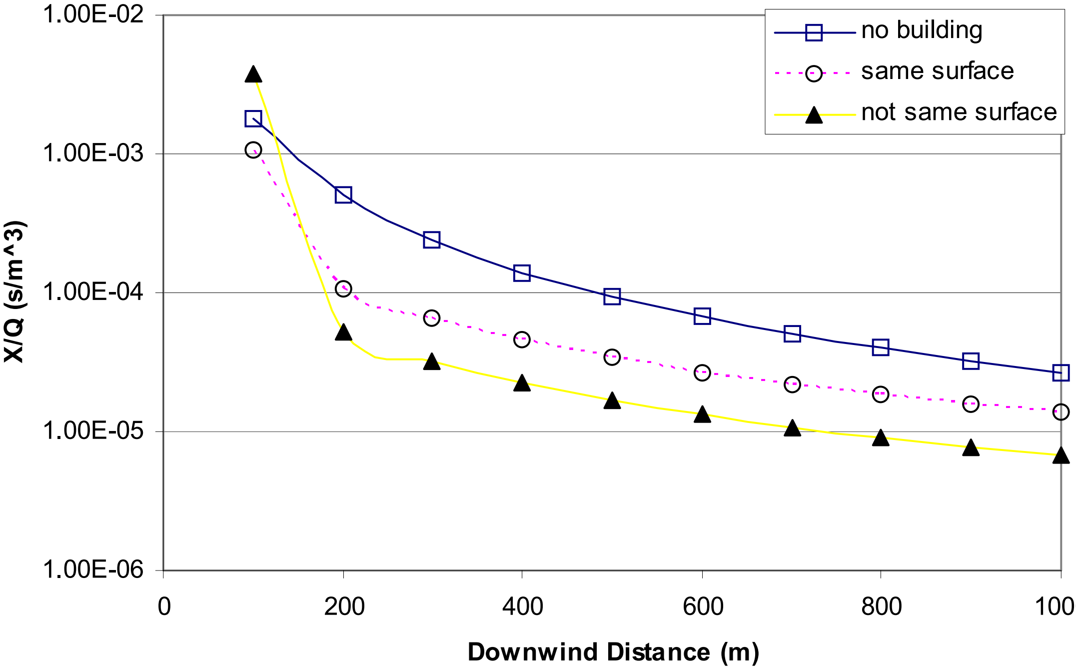

**Figure 2-4. Relative Air Concentration Comparison for Normal Operations, Ground-Level Release**

# 3 SUMMARY AND CONCLUSIONS

Several building wake effect models have been reviewed, and Microsoft® Excel® spreadsheet calculations have been developed to compare the results of each model for normal operations and short-term releases. The results of these model comparisons show the relative differences between the respective models. For the short-term release models, the lowest concentrations were produced by the ARCON/RSAC model and the GENII model for different stability and wind speed class combinations. Currently, the Department of Energy indicates they will use ARCON/RSAC methods which may yield lower concentrations than other models. For normal operations, an increase in concentration over no-building present model is seen when the receptor is in the cavity zone; otherwise the concentration decreases due to the presence of the building.

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