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Derivative Classifier

VERIFICATION OF AXAIRQ(U)

A. A. Simpkins

Technical Reviewer

October 1995

Savannah River Technology Center
Westinghouse Savannah River Company
Aiken, SC 29808

SAFETY • RESPONSIBILITY • SECURITY
SRS
SAVANNAH RIVER SITE

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. DE-AC09-88SR18035

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ABSTRACT

AXAIR89Q has been improved to include many new features. The new verified version is AXAIRQ. The improvements include: deposition option, new diffusion coefficients, ability to calculate 95% dose at user selected distances, and user-input mixing height. Other improvements also have been made to the format of the output. The user has the option to select the new features or operate the code as AXAIR89Q.

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1.0 INTRODUCTION

AXAIRQ is a new, improved version of AXAIR89Q, which was designed to determine downwind doses following acute atmospheric releases. AXAIR89Q is based on the NRC-145 Code (Pendergast and Huang 1980), which strictly follows the guidance in US Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145 (USNRC 1982). New features in AXAIRQ include: diffusion coefficients more appropriate for the Savannah River Site (SRS), deposition/depletion option, user-input mixing height, and 95% doses for user-selected distances. The code still has the ability to execute as before to reproduce previous calculations.

AXAIR89Q has been verified (Hamby 1990a) but since changes to the program were major, the complete verification process was repeated. This verification report has been prepared to show that AXAIRQ is properly coded to execute algorithms and to transfer data. Hand calculations were performed for a number of scenarios covering a wide range of release conditions.

2.0 CODE ORGANIZATION

The AXAIRQ computer program is designed to provide dose estimates to individuals and populations exposed to radioactive materials following an unplanned release from facilities at SRS. The complete AXAIRQ package consists of six modules. The modules, in their sequence of execution, are shown in Figure 1. The subroutines of each module are shown in Figures 2 through 7. A brief description of each module is given below. All modules whose name ends in "95" were modified during the creation of AXAIRQ.

AXAIN95. This module reads user input data and archived data files and writes temporary files for use by one or more of the remaining modules. AXAIN95 determines minimum boundary distances in each of 16 sectors relative to the release point. This module also reads wind speed and joint frequency meteorological data and writes these data as the percentage of total time the wind is blowing in a given direction with a given stability and speed. The dose factors are also read within this subroutine.

AXATERL. The AXATERL module reads terrain data from an Oak Ridge National Laboratory binary data base and generates an array (by compass sector) of maximum relative terrain heights at eleven distinct distances (out to 50 miles). The array is generated in concentric rings about the release point.

AXAPOP89. This module generates a temporary file of the projected offsite population (for a user-specified year) by sector and radial distance with respect to the release location. For purposes of the inhalation dose calculation for the 50-mile population, the population is distributed by age group as follows: Adult 51.3%, Teen 10.9%, and Child 37.8%. AXAPOP89 also calculates an array of the onsite population (all adult) in the same format.

AXAMET95. Relative concentrations in air are calculated in the AXAMET95 module for all user-specified sectors and distances. Within this module depletion factors are calculated for each of the downwind distances for iodines and remaining particulates separately.

PRIMUSL. The PRIMUSL module prepares the radionuclide daughter ingrowth library from all nuclides specified in the source term. PRIMUSL is a modified version of PRIMUS (Herman 1984). Modifications to PRIMUS are only those required for compilation on the IBM 3083 and compatibility with the other AXAIRQ modules. A reference copy of ORNL-5912 can be found in the QA files maintained by the Environmental Dosimetry Group.

AXADOS95. The last module, AXADOS95, computes individual and population doses by radionuclide and pathway. Pathways considered in AXADOS95 include inhalation, gamma-shine from plume immersion, and ground shine. Estimates can be obtained for maximum individual doses that are not exceeded 99.5% of the time, dependent on sector. Maximum individual doses for meteorological conditions that are not exceeded either 50% or 95% of the time are calculated independent of sector. Population doses are estimated for meteorological conditions that are not exceeded 99.5% of the time.

AXAIRQ is available for execution on the IBM Mainframe. The modules are linked through IBM Job Control Language (JCL). A separate file used for input data is linked with the JCL for execution. For a complete guide on executing AXAIRQ refer to Simpkins(1995).

Figure 1. AXAIRQ Module Execution Sequence

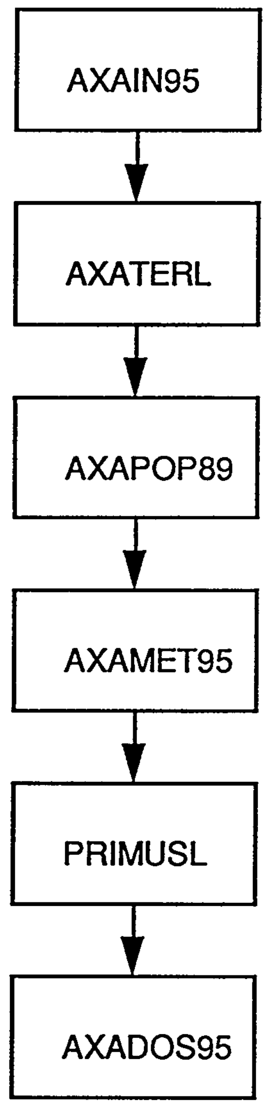


Figure 2. Subroutine Paths for the AXAIN95 Module

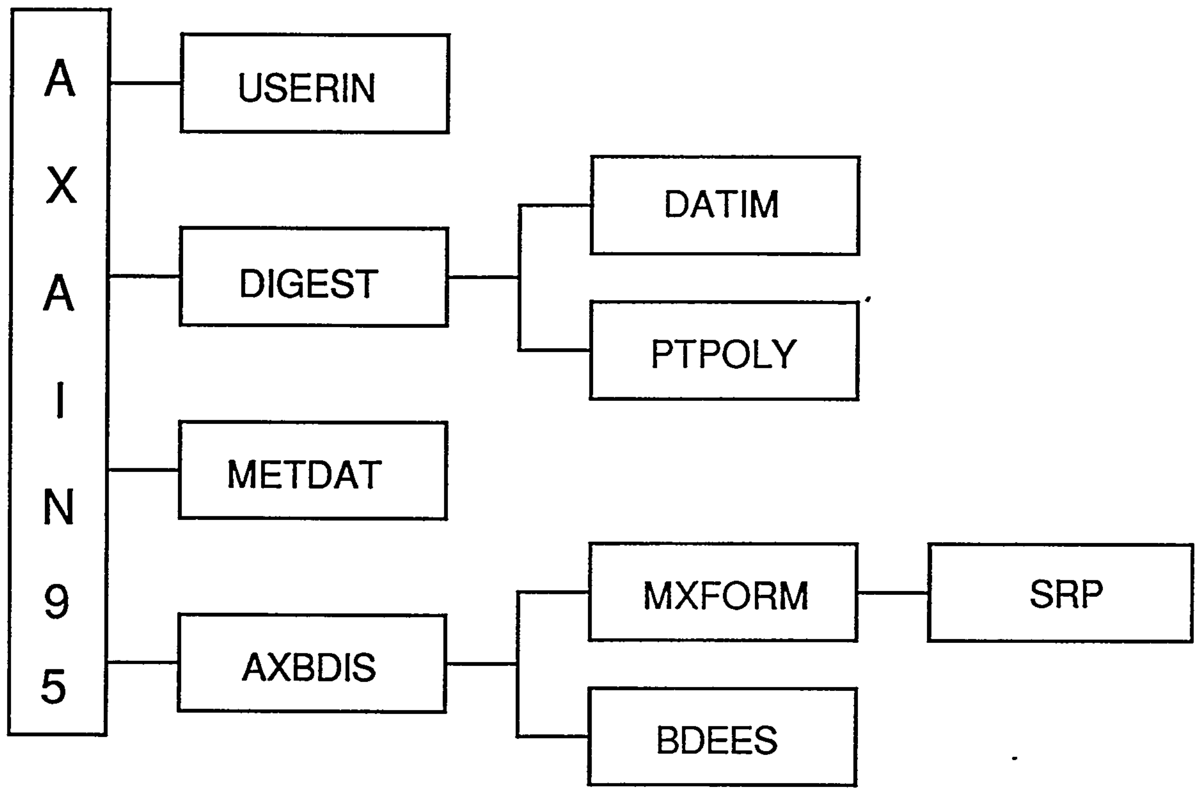


Figure 3. Subroutine path for AXATERL

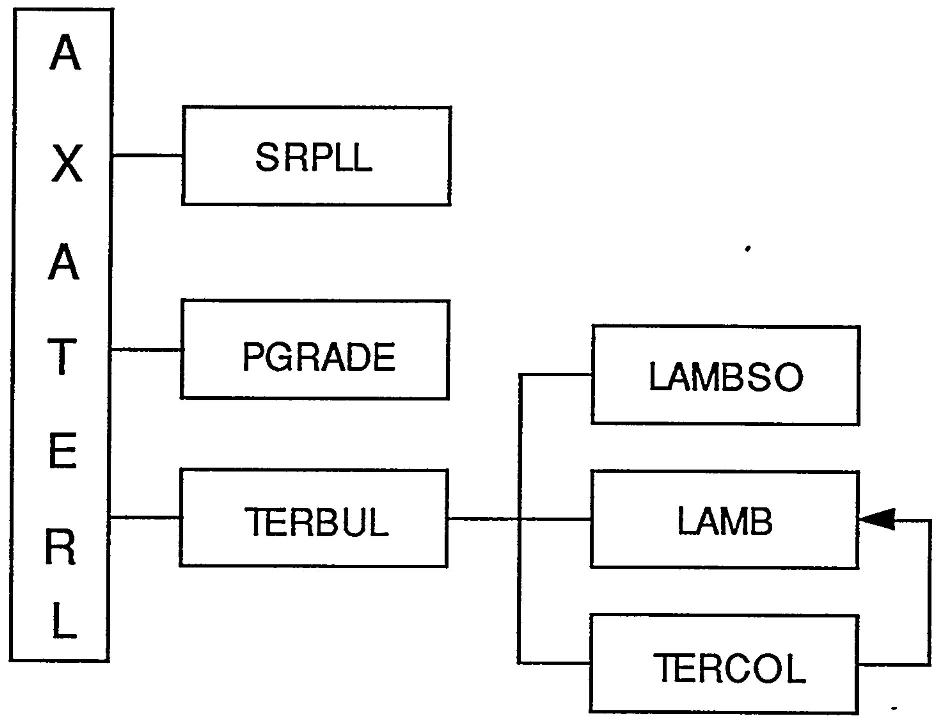


Figure 4. Subroutine Paths for the AXAPOP89 Module

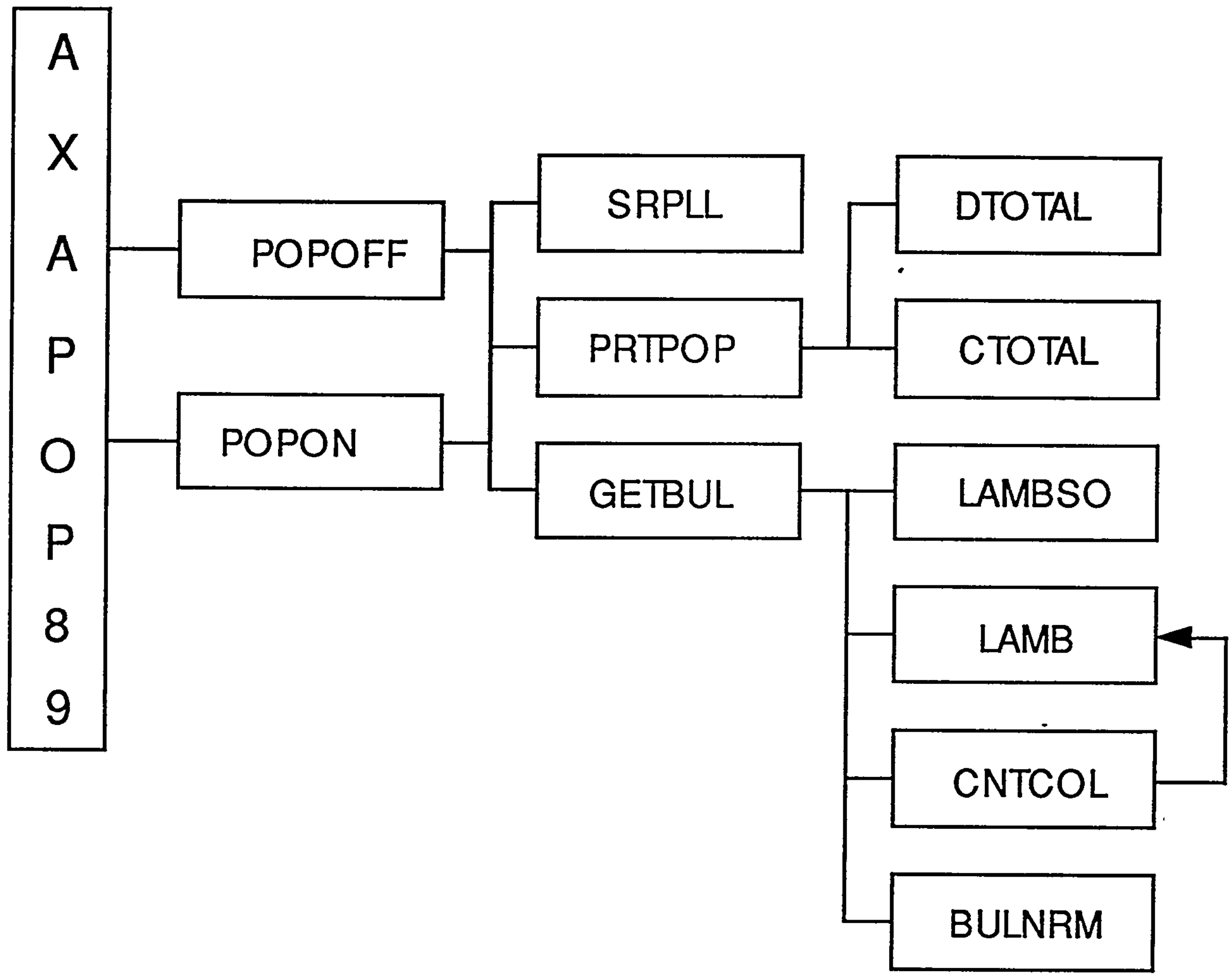


Figure 5. Subroutine Paths for the AXAMET95 Module

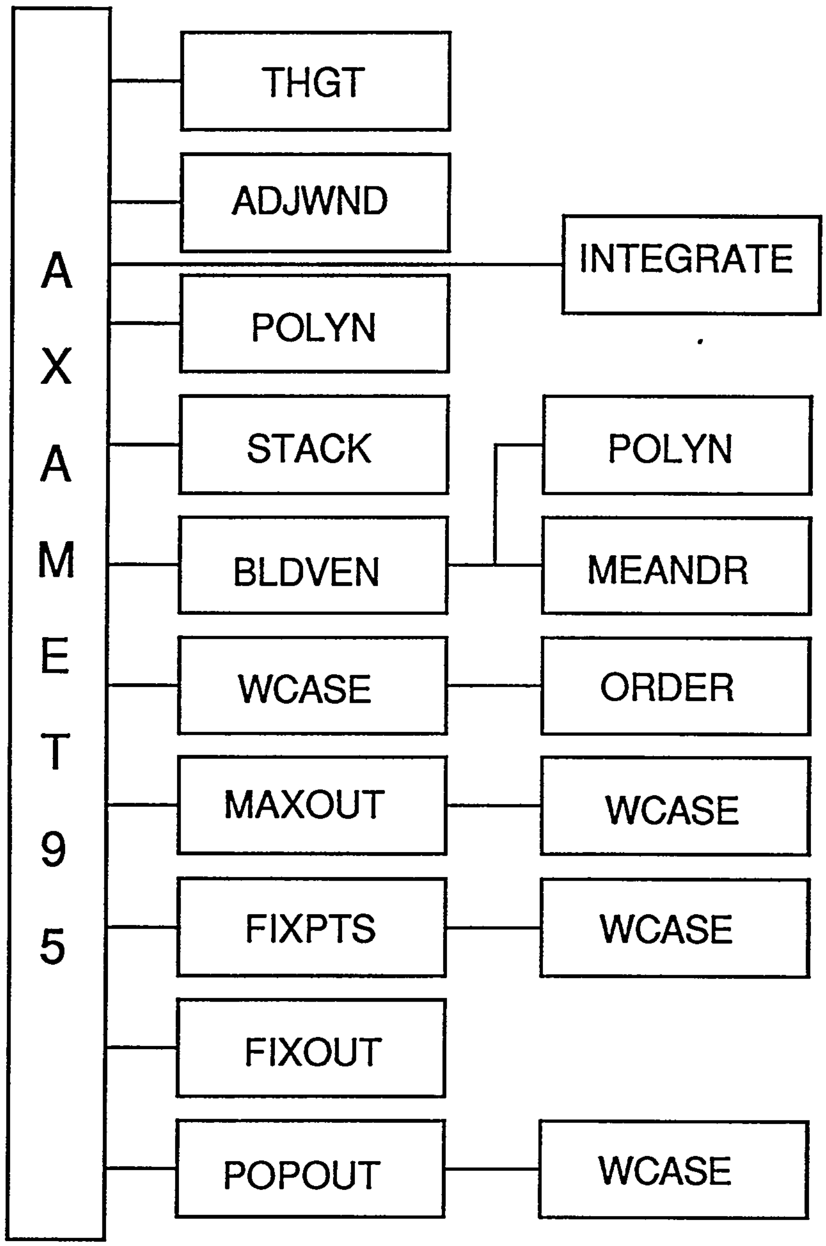
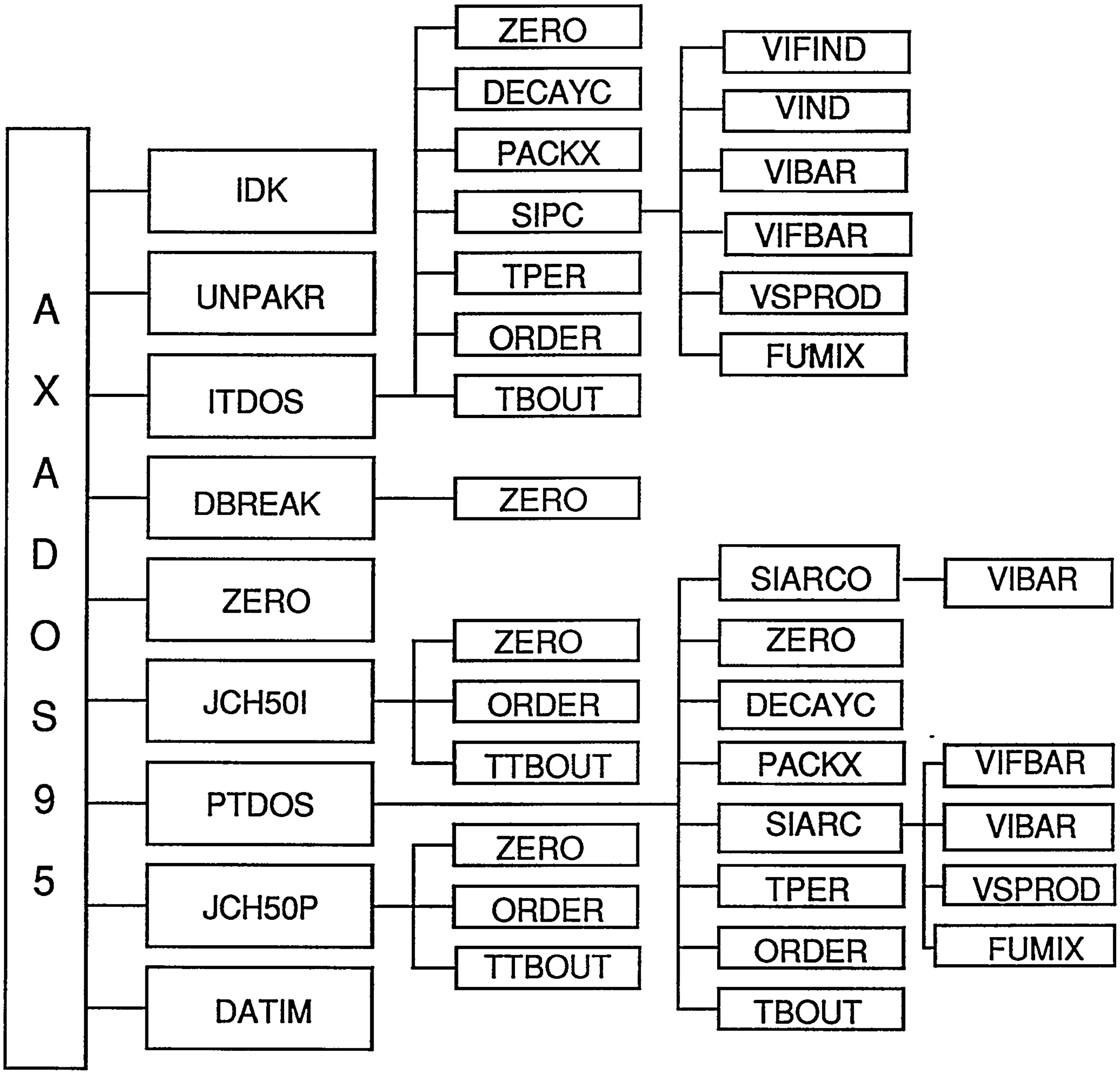


Figure 6. Subroutine Paths for the AXADOS95 Module



3.0 THEORETICAL MODELS

This section discusses the theoretical models and data files that are employed within AXAIRQ.

3.1 Atmospheric Dispersion

The Gaussian plume, straight-line trajectory model is used in AXAIRQ for estimating ground level radionuclide concentrations at given distances from a point source. Relative concentration values are applied to all nuclides regardless of physical form, i.e., gases and particulates are not treated separately. As radioactive pollutants move downwind they are assumed to be normally distributed around the central axis of the plume with the atmospheric stability and wind speed determining atmospheric dispersion characteristics. The standard deviations, or diffusion coefficients, in the horizontal and vertical planes relative to the plume centerline, σ_y and σ_z, describe the spread of the plume at a given downwind distance. The atmospheric dispersion calculations in the AXAIRQ code are based on a reflecting Gaussian plume model (Pasquill 1961).

3.1.1 Stack Releases

A stack release is considered for all release points that are *greater* than two-and-one-half times the height of the nearest solid structure. Any release height below this is a to vent release.

3.1.1.1 Non-Fumigation Conditions

For non-fumigation conditions, the dispersion factor or relative air concentration along the plume centerline, defined as the ratio of the pollutant concentration χ (kg/m^3 or Ci/m^3) to the source strength Q (kg/sec or Ci/sec), is shown in equation 1.

$$\frac{\chi}{Q} = \frac{1}{2\pi\sigma_y\sigma_z U_{HS}}\left[e^{-\left(\frac{(z-h_e)^2}{2\sigma_z^2}\right)} + e^{-\left(\frac{(z+h_e)^2}{2\sigma_z^2}\right)}\right] \qquad (1)$$

where:

χ/Q	dispersion factor (sec/m^3)
z	height above the ground surface (m)
h_e	effective release height (m)

U_{HS}	wind speed at the release height (m/sec)
σ_y	standard deviation of the concentration distribution in the horizontal cross-plume direction (m)
σ_z	standard deviation of the concentration distribution in the vertical direction

For centerline ground-level concentrations (i.e. y=z=0) the above equation reduces to:

$$\frac{\chi}{Q}=\frac{e^{-\left(\frac{(h_e)^2}{2\sigma_z^2}\right)}}{\pi\sigma_y\sigma_z U_{HS}} \tag{2}$$

For ground-level, sector-arc concentrations, equation 2 is averaged over all values of y for a sector width of 22.5° resulting in the following:

$$\left(\frac{\chi}{Q}\right)_{arc}(x,0)=\frac{2.032e^{-\left(\frac{(h_e)^2}{2\sigma_z^2}\right)}}{\sigma_z U_{HE} x} \tag{3}$$

where

U_{HE}	wind speed at release height adjusted for terrain

It follows that the two hour, sector-arc concentration is equal to the two-hour, centerline concentration multiplied by an averaging factor as given in the following equation:

$$\left(\frac{\chi}{Q}\right)_{arc}(x,0)=\frac{\chi}{Q}(x,0,0)\frac{6.38308\sigma_y}{x} \tag{4}$$

where the constant (6.38308) is equal to $(2\pi)^{0.5}$ divided by 22.5° expressed as radians. A limit is placed on the sector-arc average concentration so it cannot exceed the centerline concentration. Sector-arc concentrations are used to estimate population doses while centerline concentrations are used to estimate maximum individual doses.

3.1.1.2 Fumigation Conditions

Conditions of fumigation exist when the downwind plume is confined between ground level and the effective inversion height with uniform vertical mixing. At the SRS fumigation is assumed to occur 1) during stable atmospheric conditions (stability categories E, F, or G), 2) when the wind speed at the release point, U_{HS}, is less than 4 meters/sec, and 3) only out to a distance where the fumigation χ/Q does not exceed the non-fumigation χ/Q with an effective stack height of zero (i.e., where the effective inversion height is greater than SQRT($\pi/2$)σ_z). When these three criteria are met, the fumigation relative concentration, $(\chi/Q)_f$, is calculated by (Slade 1968):

$$\left(\frac{\chi}{Q}\right)_f(x,y,z) = \frac{e^{-\left(\frac{(y)^2}{2\sigma_y^2}\right)}}{\sqrt{2\pi}\sigma_y L_e U_{HS}} \qquad (5)$$

and reduces to (USNRC, 1982),

$$\left(\frac{\chi}{Q}\right)_f(x,0,0) = \frac{1}{\sqrt{2\pi}\sigma_y L_e U_{HS}} \qquad (6)$$

when y=z=0. The effective inversion height, L_e, is a function of the maximum terrain height and is given by,

$$L_e = L - H_t \qquad (7)$$

where L is the inversion height relative to the release point. The two-hour, sector-arc average χ/Q under fumigation conditions is determined from the centerline concentration using the same averaging factor as in equation 4.

Since SRS is considered an inland site, fumigation conditions are considered to occur only for the first half hour of the "two-hour" period. Therefore, if the fumigation conditions are met and $(\chi/Q)_f$ exceeds χ/Q, then $(\chi/Q)_f$ is utilized for the first half hour and χ/Q is utilized for the remainder of the two-hour period. This operation is accomplished by calculating a weighted sum of $(\chi/Q)_f$ (weight =0.25) and χ/Q (weight =0.75).

3.1.2 Vent Releases

A radioactive gaseous effluent is assumed to be released from a building vent if the release height is less than 2.5 times the height of the adjacent solid structure (Snyder and Lawson 1976).

The relative air concentration on plume centerline at ground level (y=z=0) for releases from building vents is determined in accordance with US NRC Regulatory Guide 1.145 (USNRC 1982). The three models given in the Regulatory Guide are as follows:

$$\frac{\chi}{Q}(x,0,0) = \frac{1}{U_{10}(\pi\sigma_y\sigma_z + \frac{A}{2})} \tag{8}$$

$$\frac{\chi}{Q}(x,0,0) = \frac{1}{U_{10}(3\pi\sigma_y\sigma_z)} \tag{9}$$

$$\frac{\chi}{Q}(x,0,0) = \frac{1}{U_{10}(\pi\Sigma_y\sigma_z)} \tag{10}$$

where

U_{10} 10-meter wind speed (m/s)

A minimum vertical cross-sectional area of adjacent building (m^2)

Σ_y lateral plume spread with meander and building wake corrections (m)

Horizontal plume meander is considered during neutral or stable atmospheric conditions (stability categories E, F, or G) and when the wind speed at the 10-meter level is less than 6 m/sec (USNRC 1982). The corrected lateral plume spread, Σ_y, for distances of x>800 m is

$$\Sigma_y = \sigma_y + (M-1)\sigma_{y(800)} \tag{11}$$

For distances of $x \leq 800$ m

$$\Sigma_y = \sigma_y M \tag{12}$$

where plume meander, M, is a function of the wind speed and stability at 10 meters. Values of M are depicted graphically in US NRC Regulatory Guide 1.145 (USNRC 1982). Within AXAIRQ equations are used to approximate the values from the graph. For wind speeds between 2-6 m/s the meander coefficient is defined as

$$M = e^{S \times \ln(U_{10}) + C} \tag{13}$$

where S and C are constants as a function of stability class shown in Table 1.

Table 1. Constants for Meander Calculations as a Function of Stability

	D	E	F	G
S	-0.6309	-1.0000	-1.2619	-1.6309
C	1.1304	1.7918	2.2610	2.9222

When the conditions do not exist for the inclusion of plume meander, the appropriate χ/Q is the larger value calculated in equations 8 and 9. However, when plume meander is considered, the appropriate χ/Q is the smaller value of equation 10 and the χ/Q without considering plume meander.

The two-hour, sector-arc concentration is determined using the same averaging factor as in equation 4 *after* the operations described above are performed.

3.1.3 Meteorological Data File

Meteorological data files for use with AXAIRQ exist for the following onsite areas : A, C, D, F, H, K, P and L. Two sets of SRS meteorological data files exist for use in the AXAMET95 routine, 1982-1986 data and 1987-1991 data. The meteorological data are obtained from hourly averages of measurements made at 1.5 seconds intervals. The files contain joint frequency distributions and reciprocal average wind velocities categorized by wind direction, speed, and stability class. Reciprocal average wind speeds are utilized since air concentration is inversely proportional to wind speed. Table 2 provides wind speed category definitions.

The L Area meteorological data base was added with this upgrade. The L Area tower was installed in 1985 so a complete set of data is available for 1987-1991 only. If the user selects L Area and the old meteorological database (1982-1986), K Area data will be accessed.

Validation of the meteorological data are the responsibility of the Environmental Transport Group. See Parker (1992) and Weber (1993) for details on the wind statistics obtained from the SRS area meteorological towers.

Table 2. Wind Speed Category Ranges

Speed Category	Range (m/sec)
1	$0<U\leq2$
2	$2<U\leq4$
3	$4<U\leq6$
4	$6<U\leq8$
5	$8<U\leq12$
6	$U\geq12$

Atmospheric stability is classified by standard deviations of the lateral or azimuthal wind direction. Area meteorological towers contain instrumentation at 61 m (200 ft) which measures horizontal (azimuth) and vertical (elevation) wind direction as well as direct measurements of turbulence, expressed as standard deviations of fluctuations about mean azimuth (noted either as σ_a or σ_θ) and elevation (σ_e) angles. Table 3 shows the relationship between stability category and values of σ_a.

Table 3. Standard Deviation of Wind Direction by Stability Categories

Stability Category	Standard Deviation of Wind Direction (degrees)
A	over 23
B	18 - 23
C	13 - 15
D	8 - 13
E	4 - 8
F	2 - 4
G	0 - 2

The location of the meteorological towers have been updated. When the code was written the location of the towers in the late 1970's was used. Since that time F and H Area meteorological towers were moved due to construction and forest removal near the previous location. Table 4 lists both the old and new locations of the meteorological towers (Parker and Addis 1993).

Table 4. Location of Meteorological Towers in Site Coordinates(ft)

Tower Location	OLD		NEW	
	Easting Coordinate	Northing Coordinate	Easting Coordinate	Northing Coordinate
A	50949.6	107585.8	50949.6	107585.8
C	47901.9	66163.3	47901.9	66163.3
D	21328.7	67167.8	21328.7	67167.8
F	51345.0	77687.0	50789.2	76773.2
H	64256.5	70415.0	66772.1	68834.0
K	41285.5	51712.4	41285.5	51712.4
P	66333.8	41457.5	66333.8	41457.5
L	NA	NA	53198.6	46650.0

AXAIRQ is programmed to automatically select the closest tower to the specific release location. The movement of the towers could potentially result in a different set of meteorological data being accessed than before. For a center-of-site release with coordinates E58000 and N62000, the new version of AXAIRQ is coded so that the H Area meteorological frequency distribution is accessed even though F Area is slightly closer. H Area is accessed because of completeness of data and similarity in forest conditions.

The meteorological towers also are used as the location of the release if the user enters a specific area. For this reason the user is expected to enter the exact location of the release since it is unlikely that the release occurs from the meteorological tower.

3.1.3.1 Vertical Wind Speed Profile

Measurements of wind speed at the Savannah River Site are taken at a height of 62 m. When radioactivity is released from heights other than 62 m, the 62 m wind speed must be multiplied by an adjustment factor to estimate wind speed at the release height (Stull 1988). The adjustment factor, F, is a function of stability and is calculated as follows:

$$F = \left(\frac{H_e}{62}\right)^{CE_i} \quad (14)$$

where H_e is the effective release height and CE_i is the exponent of the power law for a given stability category, i. The exponents have been determined empirically at SRS for all stability categories (Pendergast 1976) and the values are shown in Table 5.

Table 5. Power Law Exponents for Vertical Variation in Wind speed at SRS

Stability Category	CE_i
A	0.08
B	0.10
C	0.11
D	0.18
E	0.31
F	0.42
G	0.42

3.1.4 Terrain Data File

Terrain elevations downwind of a stack are necessary to calculate the effective stack height and the effective height of the inversion layer. The terrain data base accessed in the AXAMET95 module is a product of Oak Ridge National Laboratories and contains elevations above mean sea level referenced by coordinates of latitude and longitude. Terrain elevations, relative to the release point, are determined in a separate module (AXATERL) within the AXAIRQ computer code. The AXAMET95 module reads the file generated by AXATERL containing maximum relative terrain elevations between the release point and the point of interest, out to a distance of 50 miles. For more information on terrain height see Hamby (1990b).

3.1.5 Diffusion Coefficients

The user now has the option of selecting diffusion coefficients developed by Pasquill-Gifford or Pasquill-Briggs. Pasquill-Briggs coefficients are more relevant to elevated releases and much more experimental data was used in their development than with the Pasquill-Gifford coefficients. Pasquill-Briggs diffusion coefficients were added as an option for comparison with Emergency Response code PUFF-PLUME (Garrett and Murphy 1981). Justification for use of Pasquill-Briggs coefficients is reported in Simpkins (1994).

3.1.5.1 Pasquill-Gifford Diffusion Coefficients

The regulatory guidance in US NRC 1.145 provides graphical representation of the lateral and vertical diffusion coefficients for use in accident analysis. The lateral and vertical diffusion coefficients as a function of downwind distance for Pasquill's atmospheric stability categories are taken directly from the Turner Workbook (1967). These curves are often referred to as Pasquill-Gifford curves or the Pasquill-Gifford-Turner formulation. These graphical representations were fitted with Eimutus' and Konicek's (1972) analytical expressions for use in AXAIRQ. The expression used to determine the horizontal diffusion coefficients is

$$\sigma_y = Ax^{0.9031} \tag{15}$$

where A is represented by the values that are shown in Table 6 as a function of Pasquill's atmospheric stability categories and x is the downwind distance in meters.

Table 6. Values of A for Horizontal Diffusion Coefficients

Pasquill Category	A
A	0.3658
B	0.2751
C	0.2089
D	0.1471
E	0.1046
F	0.0722

The equation used to determine the vertical diffusion coefficients taken from Martin and Tikvart (1968) is

$$\sigma_z = Ax^B + C \tag{16}$$

where the constants A, B, and C are a function of Pasquill atmospheric stability categories and downwind distance from the source. These constants are depicted in Table 7.

Table 7. Constants used for Vertical Diffusion Coefficients

Pasquill Cat.	Valid Range (m)								
	< 100m			100 - 1000 m			> 1000 m		
	A	B	C	A	B	C	A	B	C
A	0.192	0.936	0	0.0015	1.941	9.27	2.4e-4	2.094	-9.6
B	0.156	0.922	0	0.028	1.149	3.3	0.055	1.098	2.0
C	0.116	0.905	0	0.113	0.911	0.0	0.113	0.911	0.0
D	0.079	0.881	0	0.222	0.725	-1.7	1.26	0.516	-13
E	0.063	0.871	0	0.211	0.678	-1.3	6.73	0.305	-34
F	0.053	0.814	0	0.086	0.74	-.035	18.05	0.18	-48.6

The vertical and horizontal diffusion coefficients for stability class G are determined using the following equation (Hamby 1990a):

$$\sigma_z(G) = 10^{\{2 * \log_{10}(\sigma_z(F)) - \log_{10}(\sigma_z(E))\}} \quad (17)$$

3.1.5.2 Pasquill-Briggs Diffusion Coefficients

The equation representing Pasquill's horizontal diffusion coefficients is shown below.

$$\sigma_y = \sigma_\theta \times f(x) \quad (18)$$

where

σ_θ standard deviation of lateral wind direction (radians)

x downwind distance (km)

f(x) function of distance as discussed below

Since the value of σ_θ is not readily available from the meteorological database that AXAIRQ accesses, an assumed average value of σ_θ is chosen for the atmospheric stability class of interest as defined in US NRC Regulatory Guide 1.23 (USNRC 1972). Values for σ_θ are shown in Table 8.

Table 8. Classification of Atmospheric Stability (USNRC 1972)

Pasquill Category	σ_θ (degrees)
A	25.0
B	20.0
C	15.0
D	10.0
E	5.0
F	2.5

Pasquill developed formulations for f(x) with the following equation for distances greater than 10 km with x in units of km:

$$f(x) = 0.33\sqrt{\frac{10}{x}} \quad (19)$$

Pasquill developed these formulations using data from experiments at various sites. Pasquill (1976) gives a detailed description on how the coefficients were developed.

At SRS, Garrett and Murphy (1981) developed an interpolating formula for values of f(x) based on a table of values (Pasquill 1976) supplied by Pasquill for distances less than or equal to 10 km. The equation follows with x in units of km:

$$f(x) = \frac{x^{-0.2}}{1.67 + 0.03\left[\frac{\left|1-x^{-0.2}\right|}{0.48}\right]^{0.5}} \qquad (20)$$

For open-country conditions, the vertical diffusion coefficients defined by Briggs (1973) and then refined by Briggs and published in Hanna (1982) are represented in Table 9 as a function of Pasquill's atmospheric stability classes.

Table 9. Brigg's Vertical Diffusion Coefficient Formulas

Pasquill Type	σ_z
A	0.20x
B	0.12x
C	$0.08x(1 + 0.0002x)^{-0.5}$
D	$0.06x(1 + 0.0015x)^{-0.5}$
E	$0.03x(1 + 0.0003x)^{-1}$
F	$0.016x(1 + 0.0003x)^{-1}$

Different methods were reviewed for determining the value of σ_z for the extremely stable class G. Values of σ_z for stability class G are extrapolated from the stability classes E and F in the same manner as in the previous version AXAIR89Q by applying equation 17.

As with the coefficients that were previously used within AXAIR89Q, σ_z is limited to a value of 0.8*H, with H being the effective mixing height.

3.1.5.3 Mixing Height

The mixing height in AXAIRQ is a user-input value with valid range from 200-1000 m. The vertical diffusion coefficients are limited to a value of 0.8* Mixing Height. Typically, the larger vertical diffusion coefficients are not associated with the 99.5% doses but this change can have an effect on the average relative air concentration, thereby affecting the relative air concentration for releases whose time periods are greater than two hours.

A comparison study of observed versus predicted mixing heights for SRS shows that the yearly average mixing height for 1978 was 1260 m (Garrett 1981). Monthly averages were below 1000 m for only two months of the year (December and January). Therefore, using the 200 m minimum value would yield conservative results.

3.1.6 Plume Depletion

Within the AXAMET95 subroutine of AXAIRQ plume depletion factors are calculated separately for particulates and iodine. The concept of deposition velocity is used in the determination of the depletion of the plume and the ground shine dose. Deposition velocity is defined as:

$$v_d = \frac{\omega}{C} = \frac{\text{deposition}}{\text{concentration}} = \frac{\text{Ci}/\text{m}^2\text{s}}{\text{Ci}/\text{m}^3} = \frac{\text{m}}{\text{s}} \qquad (21)$$

While deposition velocity is dependent on a variety of atmospheric and particle parameters, a constant value of 0.001 m/s is assigned to particulates and 0.01 m/s is assigned to iodines (EPA, 1991).

Though not a particulate, a deposition velocity of 0.001 m/s is assigned to tritium, which in AXAIRQ is all assumed to be of the form of tritium oxide (Murphy and Pendergast 1979). Ground shine from tritium is not an important exposure pathway but, a deposition velocity must be assigned to calculate depletion of the plume. As deposition velocity increases the percentage of tritium remaining in the plume decreases, therefore, the value chosen is conservative with respect to other values taken from literature (Feinhals and Bunnenberg, 1988). Higher values were shown for tritium deposition on vegetation (Murphy and Pendergast 1979) but the conservative soil deposition velocity was used.

The plume is assumed to be depleted by source depletion using the following equation (Slade 1968):

$$\frac{Q(x)}{Q(0)} = \left[\exp\int_0^x \frac{dz}{\sigma_z \exp\left(h_e^2/2\sigma_z^2\right)}\right]^{-\left(\frac{2}{\pi}\right)^{0.5}\frac{v_d}{U_{HS}}} \qquad (22)$$

where

$Q(x)$	residual source at distance x meters downwind (Ci)
$Q(0)$	source strength at release location (Ci)
x	downwind distance (m)
h_e	effective release height (m)
U_{HS}	wind speed at the release height (m/sec)
σ_z	the standard deviation of the concentration distribution in the vertical direction (m)
v_d	deposition velocity (m/sec)

For use within the program, this equation was integrated using the trapezoidal rule which is shown below:

$$\int_a^b f(x)dx = h\left[\frac{f(a)}{2} + f(a+h) + f(a+2h) + \ldots + f(a+(n-1)h) + \frac{f(b)}{2}\right] \quad (23)$$

where

a and b	are the beginning and endpoint of the interval of interest
h	(b-a)/n
n	number of increments, (100).

While other more sophisticated methods exist for the determination of plume depletion (surface depletion models) the increase in CPU time required for these calculations may not be worth the increased accuracy.

Depletion factors are calculated for each of the 42 stability class and wind speed combinations for each sector for the given distance of interest. The relative air concentration is reduced by the depletion factor, as necessary, depending on the nuclide that is released.

3.1.7 99.5% Relative Air Concentration Selection

Relative air concentrations are determined in each sector for meteorological conditions that are not exceeded 99.5% of the time and the highest of the sixteen sectors is selected as the worst case for each distance specified.

Table 10 shows a sample ranking of relative air concentrations that are used to determine the 99.5% value for the south sector, from a postulated H Area release. The first column shows the concentrations ranked starting with the highest. The second column shows the corresponding joint frequency associated with that particular combination of stability class and wind speed that resulted in the relative air concentration shown in column one. The third column is the cumulative frequency. When the cumulative frequency is greater than 0.5, an interpolation is performed between the two values bracketing 0.5 to determine the 99.5% relative air concentration. These interpolation values are marked with "*" in the table.

Table 10. Sample Ranking of Relative Air Concentration

	Relative Air Concentration s/m^3	Joint Frequency Distribution	Cumulative Frequency (%)	Stability Class	Wind Speed	
	7.97E-04	0.018	0.018	4	1	
	7.79E-04	0.012	0.030	5	1	
	4.43E-04	0.061	0.091	5	2	
	4.05E-04	0.103	0.194	4	2	
	4.01E-04	0.032	0.226	3	1	
	2.68E-04	0.071	0.297	5	6	
	2.65E-04	0.123	0.420	4	6	
*	2.32E-04	0.018	0.438	6	2	*
*	2.27E-04	0.174	0.612	3	2	*
	2.16E-04	0.075	0.687	2	1	
	1.98E-04	0.011	0.698	4	4	
	1.79E-04	0.374	1.072	1	1	
	1.46E-04	0.003	1.075	7	2	

The 95% overall two-hour χ/Q at the site boundary also is calculated. This value is shown as a check to see if the overall 95% χ/Q exceeds the two-hour sector-specific χ/Q. As discussed in USNRC 1.145, if the overall 95% χ/Q exceeds the 99.5% χ/Q, the 95% value should be used instead of the 99.5% sector-independent value.

For meteorological conditions that are not exceeded either 95% or 50% of the time, doses are computed independent of sector.

3.2 Dosimetry Models within AXAIRQ

AXADOS95, the dosimetry module within AXAIRQ, was designed to estimate individual and population doses due to the unplanned release of radioactive materials. Since the duration times of these unplanned releases are assumed to be relatively short (on the order of several hours), the dose estimates considered in AXADOS95 include those pathways responsible for "instantaneous dose", i.e., inhalation, ground-shine, and plume-shine. The ingestion pathway is not considered since, in the case of an actual acute release with high contamination levels, DOE would initiate an interdiction plan to remove the contaminated food source and remove people from contaminated land.

Ingrowth of daughter products is simulated in AXADOS95 by estimating daughter concentrations at the receptor from parent concentrations at the same location. The parent nuclide decays for a time equal to the transport time. During transport, the daughter also decays.

3.2.1 Inhalation Dose Model

Inhalation dose is estimated by the product of the radionuclide concentration in the air that is breathed, the rate at which the air is breathed, and a factor to convert intake quantities to dose. The radionuclide concentration is determined by estimating the concentration at a given downwind distance relative to the radionuclide release rate (see Section 3.1). The inhalation dose to a given individual or population, assuming exposure during the entire plume passage, is calculated in AXADOS95 using the following general equation,

$$D = 3.17E-08(Q)(\frac{\chi}{Q})(DF)(B)e^{-\lambda t}(DEP) \qquad (24)$$

where

3.17E-08	conversion factor (years per second)
Q	total release (Ci)
χ/Q	relative concentration at receptor (s/m^3)
DF	effective dose equivalent dose factor for inhalation (rem/Ci)
B	adult maximum breathing rate, 12,000 m^3/yr (Huang and Marter 1983)
λ	decay constant (1/s)
t	travel time from release to receptor (s)
DEP	depletion factor (fraction of plume remaining), unitless

The exponential factor in equation 24 provides for the decay of radionuclides during the time between release from the facility and uptake by the receptor.

Two dose factor data bases can be accessed by AXADOS95 including, 1) the ICRP2 dose factor library (ICRP 1959), and 2) the ICRP30 dose factor library (ICRP 1979). The Department of Energy (DOE) mandates the use of ICRP30 dose factors in all DOE related dose assessments (DOE 1988a and b). The option to use ICRP2 dose factors is included in AXADOS95 to enable the user to reconstruct previously determined dose estimates which originally used the ICRP2 factors. In this report, only dose estimates derived using ICRP30 dose factors will be checked by hand calculation.

ICRP30 dose factors for inhalation are taken from DOE-EH-0071 (DOE 1988b) and are provided for estimates of committed effective dose equivalent (CEDE) and for dose estimates to the following organs: red bone marrow, liver, bone surface, thyroid, lower large intestine, and lungs. By selecting the proper dose factor, equation 24 can be used to estimate organ doses or the CEDE. The ICRP30 inhalation dose factor library uses the lung-clearance-class-specific dose factors that resulted in the highest CEDE. See ICRP2 (ICRP 1959) for more on the implications of this practice.

The population inhalation dose is obtained in the same manner as the maximum individual dose with the following exceptions: 1) age-specific breathing rates are applied; 2) the 50-mile population is subdivided into annular groups with the following inner and outer radii, 0-1,1-2, 2-3, 3-4, 4-5, 5-10, 10-20, 20-30, 30-40, and 40-50 miles; and 3) the population within a given annulus is exposed to the same nuclide concentration regardless of location within the annulus. This concentration is equal to the sector-arc concentration at the midpoint of the annulus. The population dose is then the sum, over all annuli, of the product of the population in a given annulus by the "average" dose in that annulus.

lCRP30 dose factors do not exist for age groups other than adults, however, the population-weighed breathing rate takes into account the distribution of adults, teens, and children. For population dose calculations, the breathing rates for adults, teens, and children are 10,500 m^3/yr, 10,500 m^3/yr, and 6,840 m^3/yr, respectively (Huang and Marter 1983). The fraction of population assumed to be adults, teens and children is 0.513, 0.109, and 0.378, respectively. The population dose calculated by the lCRP30 methodology, therefore, takes credit for the age distribution of the population but not for age-specific dose factors.

3.2.2 Plume Shine Dose Model

External dose from gamma irradiation is estimated in AXAIRQ by one of three methods: 1) the uniform plume model, 2) the non-uniform plume model, or 3) an upper-bound approximation of the non-uniform plume model. Shine doses are independent of age and body organ.

3.2.2.1 Uniform Plume Model

The uniform plume model assumes that the exposed individual is located in a time integrated uniform concentration of a given nuclide throughout the infinite hemisphere above ground level. The gamma-shine external dose is therefore directly proportional to the integral air concentration and is determined by multiplying the integral concentration by an infinite-plume shine dose factor. The external dose for a given nuclide, n, is expressed as:

$$D_n = (\frac{\chi}{Q})(Q_n)(DF_s)_n e^{-\lambda_n t} DEP \qquad (25)$$

where

χ/Q	relative air concentration at the receptor integrated over time (s/m^3)
Q_n	total release (Ci)
$(DF_s)_n$	shine dose factor for nuclide n (mrem/yr per Ci/m^3)
λ	decay constant for nuclide n (s^{-1})
t	transit time between release and exposure (s)
DEP	depletion factor (amount of plume remaining), unitless

No attenuation is assumed for calculations of dose to the maximum individual.

The shine dose to a given population is determined in the same way as above except that an attenuation factor is included to account for partial shielding by building structures. AXAIRQ currently provides a population dose reduction of 50% due to attenuation. The population dose from a given nuclide is calculated by:

$$D_n(pop) = (0.5)(Q_n)(DF_s)_n \sum_j [(\frac{\chi}{Q})_j (P_j) e^{-\lambda_n t}] DEP_j \qquad (26)$$

where

0.5	factor for building attenuation
$(\chi/Q)j$	the average relative concentration in the sector/radial region j (s/m^3)

P_j the population in that region

DEPj depletion fraction (amount of plume remaining), unitless

3.2.2.2 Nonuniform Plume Model

In the non-uniform plume model, the Gaussian nature of the downwind plume is accounted for when determining air concentrations at and around exposed individuals. Because gamma attenuation between the point source and the receptor is a function of energy, gamma shine integrals are determined for a number of energy categories. These categories or ranges each have a characteristic photon energy on which exposure calculations are based. The shine integral for a given nuclide and energy category is the product of the integral air concentration at the receptor, the point source at the receptor integrated over the dimensions of the plume, the buildup factor, and the air absorption coefficient. The relative shine integral, S(x), is:

$$S(x) = C_a \times I \qquad (27)$$

where

C_a relative air concentration model

I integral function for a given set of meteorological conditions (i.e., fumigation vs. non-fumigation, two-hour vs. annual average concentrations, etc.)

The two-hour, non-fumigation integral function, I, is defined as,

$$I = \mu_a \int_{z=0}^{\infty} \int_{y=-\infty}^{\infty} \int_{x=-\infty}^{\infty} \frac{B(\mu r)e^{-\mu r}}{4\pi r^2} e^{-y^2/2\sigma_y^2} H(z)\,dx\,dy\,dz \qquad (28)$$

where

μ_a photon energy absorption coefficient for photons of energy E_m in air (m^{-1})

μ photon attenuation coefficient for photons of energy E_m in air (m^{-1})

$B(\mu r)$ gamma ray buildup function- fifth order polynomial with constants as a function of energy (Pillinger & Huang 1986), dimensionless,

r $(x^2+y^2+z^2)^{0.5}$ (m)

$$H(z) = e^{[-(z-h)^2/2\sigma_z^2]} + e^{[-(z+h)^2/2\sigma_z^2]} \qquad (29)$$

The two-hour, fumigation integral function, I_F, is defined as

$$I_F = 2\mu_a \int_{z=0}^{L} \int_{y=-\infty}^{\infty} \int_{x=-\infty}^{\infty} \frac{B(\mu r)e^{-\mu r}}{4\pi r^2} e^{-y^2/2\sigma_y^2} dxdydz \quad (30)$$

The highest concentrations are expected to be found on the plume centerline so that an upper-bound approximation of the integral functions given above can be determined by letting y=0 in equations 28 and 30. The upper-bound approximation of the two-hour, non-fumigation integral function becomes,

$$\bar{I} = \mu_a \int_{z=0}^{\infty} \int_{x=-\infty}^{\infty} \frac{B(\mu r)e^{-\mu r}}{4\pi r^2} H(z)dxdz \quad (31)$$

and the upper-bound approximation of the two-hour, fumigation integral function is,

$$\bar{I}_F = 2\mu_a \int_{z=0}^{\infty} \int_{x=-\infty}^{\infty} \frac{B(\mu r)e^{-\mu r}}{4\pi r^2} dxdz \quad (32)$$

The annual average integral function is determined by multiplying the upper-bound approximation (y=0) integral function for non-fumigation by 6.353 σ_y/x, the sector arc averaging factor, where x is the downwind distance between the receptor and the release point.

The shine integrals introduced above and their analytical solutions can be found in Appendix E of Pillinger and Huang (1986). The FORTRAN subroutines that calculate the shine integrals were found to be consistent with these solutions. The shine integral calculations are performed in the subroutines found in member GRAYSUB located in the TENVT.TMECA.FORT dataset. Pillinger and Huang (1986) should be consulted for a detailed discussion on the estimation of the shine integrals.

Individual and population doses are determined in a fashion similar to the semi-infinite plume methodology, i.e., the dose estimate is the product of the shine integral and the energy-category dose factor summed over all energy categories and source nuclides as follows:

$$D_n = \sum_n \sum_m [DF_{mn} S(x)_{mn} DEP] \quad (33)$$

where

m ranges from 1 to 23 for each gamma-ray energy group n ranges over all nuclides in the source term that contribute to the shine dose

DF_{mn} shine dose factor for nuclide n and energy range (m)

$S(x)_{mn}$ defined in equation 27.

The external dose factors for the 23 energy groups referenced above are determined for a point source exposing a receptor in space. As evidenced in Equations 28 through 32, the non-uniform model (and the upper-bound approximation) evaluates the exposure region integral in the vertical direction from ground level to the inversion lid. Since the uniform plume model does not inherently assume a hemispherical exposure region, one-half the sum of the 23 external dose factors for a given nuclide is used as the uniform plume dose factor to calculate the semi-infinite plume external dose.

3.2.2.3 Comparison of Different Plume Shine Models

The uniform plume model assumes that the concentration of a given nuclide is uniform throughout the hemisphere above ground level and is equal to the concentration at the receptor. The non-uniform plume model on the other hand, estimates the nuclide concentration at all locations that could potentially expose the receptor. Therefore, higher dose estimates would result from use of the uniform plume model rather than the more rigorous non-uniform plume model. The upper-bound approximation of the non-uniform plume model assumes that the nuclide concentration in the lateral direction is equal to the concentration at the centerline of the plume (i.e., y=0). This assumption means that the upperbound approximation will result in doses larger than the rigorous non-uniform method yet smaller than the uniform plume method. Results from the three gamma-exposure models of AXAIRQ are given in Table 11.

Table 11. External Shine Dose Using AXAIRQ's Three Plume Models*

Receptor	Uniform	Upper Bound Non-Uniform Plume	Non-Uniform Plume
99.5% Maximum Individual(mrem)			
100 m (0.06 miles)	5.13E-05	5.78E-06	2.71E-06
Boundary	6.58E-08	2.13E-08	2.10E-08
80.5 m (50 miles)	6.72E-09	2.55E-09	2.55E-09
50-Mile Population(person-rem)	3.39E-07	1.31E-07	1.31E-07
50% Individual doses (mrem)			
100 m (0.06 miles)	1.94E-05	1.54E-06	7.57E-07
Boundary	1.02E-08	3.96E-09	3.96E-09
80.5 m (50 miles)	2.05E-09	7.97E-10	7.97E-10

* Release is Vent release with 1 Ci of Pu-238 from center-of-site.

As predicted, the uniform plume model produces the highest doses, the non-uniform plume model produces the lowest doses, and the upper-bound approximation results in doses between the two.

3.2.3 Ground Shine Dose

The model for the determination of the ground shine dose is taken from EPA (EPA 1991). Dose factors are taken from DOE/EH-0070 (DOE 1988a) for the committed effective dose equivalent. The equation used to determine the dose to an individual follows:

$$D_{GR} = 0.03171(V_D)(DF_{GR})(Q)(\frac{\chi}{Q})(\frac{1-e^{-\lambda t}}{\lambda})DEP_n \qquad (34)$$

where

D_{GR}	ground shine dose (mrem)
0.03171	conversion factor (μCi-yr/Ci-s)
V_D	deposition velocity (m/s
DF_{GR}	ground shine dose conversion factor ((mrem/yr)/(μCi/m^2))
Q	release amount (Ci)
χ/Q	relative air concentration (s/m^3)
λ	decay constant (1/s)
t	duration of exposure (4 days or 345600 s)
DEP_n	depletion fraction (amount of plume remaining) unitless

The duration of exposure (4 days) is the EPA recommended value which accounts for ingrowth of short-lived daughters in the deposited material. (EPA 1991). The deposition velocity is 0.01 m/s for iodines and 0.001 m/s for particulates and tritium. Although tritium does not contribute a ground shine dose, a deposition velocity is assigned for the purpose of plume depletion.

Slight changes were made to the dose factor file for the nuclides shown in Table 12. In AXAIR89Q these nuclides were not assigned a decay constant and the assumed value was, therefore, zero. In equation 34 a value of zero would result in a FORTRAN error of division by zero so the decay constants were added as shown in Table 12 (Walker, 1983). These nuclides are not typically released from SRS. This is one area where AXAIR89Q could differ from AXAIRQ for the same set of input conditions due to the newly assigned decay constants.

Table 12. Decay Constants Added to AXAIRQ Dose Factor Library

Isotope	Half Life	Units	Half Life (s)	Decay (1/s)
Si-32	100	y	3.154E+09	2.198E-10
P-33	25.3	d	2.190E+06	3.171E-07
Ar-39	269	y	8.483E+09	8.171E-11
Cd-113	13.7	d	1.184E+06	5.856E-07
In-115	4.40E+14	y	1.388E+22	4.995E-23
Sm-147	1.06E+11	y	3.343E+18	2.074E-19
Gd-152	1.10E+14	y	3.469E+21	1.998E-22
Re-187	4.50E+10	y	1.419E+18	4.885E-19
Os-186	2.00E+15	y	6.307E+22	1.099E-23
Pb-209	3.25	h	1.170E+04	5.924E-05
Po-212	.298	μs	2.980E-07	2.326E+06
Po-218	3.11	m	1.866E+02	3.715E-03
Cm-250	7.40E+03	y	2.334E+11	2.970E-12
Bk-249	3.20E+02	d	2.765E+07	2.507E-08
Bk-251	57	m	3.420E+03	2.027E-04
Fm-256	2.63	h	9.468E+03	7.321E-05

3.2.4 Selection of the 99.5% and 50% Doses

Like the calculations of 99.5% relative air concentration, the AXADOS95 dose calculations are performed for every combination of wind speed and stability class for each sector. The whole array of doses are determined since the amount of radioactive decay is dependent upon the transit time from release to receptor (i.e., wind speed). Once all of the doses are calculated and the three exposure pathways are summed, the method of choosing the 99.5% dose is identical to the method in Section 3.1.7 for choosing the 99.5% relative air concentration.

A 50% or 95% dose will be calculated and presented if specified by the user. This sector-independent dose estimate is determined by calculating the individual dose for all 672 meteorological combinations and selecting the 50th or 95th percentile dose from the cumulative probability distribution.

The 99.5% dose does not necessarily correspond to the 99.5% χ/Q values due to short half lives of some of the nuclides considered.

3.3 Data Files Accessed by AXAIRQ

Several data files are accessed by the six modules that make up AXAIRQ. Those data files include: 1) boundary coordinates, 2) offsite population distribution, 3) onsite population distribution, 4) terrain heights, 5) meteorological joint frequency distributions, 6) dose factors, and 7) daughter ingrowth libraries. Table 13 gives the dataset parameters and names of each of these files.

Where possible, data files have been reviewed for accuracy. Some databases, however, are stored as binary files and are, therefore, inaccessible. The contents of binary files are verified by examination of the products generated from operations on these files, i.e., relative terrain heights and population distributions. The arrays generated by these files have been checked against similar arrays generated by POPGASP (Hamby 1990b).

Table 13. Data Files Accessed by AXAIRQ routines

Description	File Name	Binary/ ASCII	Reference
Boundary Coordinates	TMECA DATA(SRSBNDRY)	A	Bauer 1990
Offsite Population	POP90 DATA(GRIDTOT)	B	Hamby 1990
Onsite Population	AXAIRDB ONPOP90	B	East 1993
Terrain Elevations	TPGY100 DATA	B	Hamby 1990b
Meteorological JFDs	SRP62M WINDS	A	Weber 1993
ICRP2 Dose Factors	AXAIR DFLIB	A	*
ICRP 30 Dose Factors	DATA TMECA(DFAXA30)	A	Hamby 1990c
Daughter Ingrowth Library	PRIMUS DECAYLIB	A	Hamby 1990a

* ICRP2 dose factor library not verified.

4.0 VERIFICATION OF CALCULATIONS

Different scenarios have been executed to test each of the modules within AXAIRQ. Many combinations of variables have been tested and are shown here. AXAIRQ is not expected to agree with AXAIR89Q when the new parameters are accessed. A separate report will show the expected differences due to the code changes. This report demonstrates that the new version is performing the intended calculations. Some of the parameters that were verified are not part of the output of AXAIRQ so temporary modifications were made to the FORTRAN to test the parameters.

Tables 14 and 15 show the comparison of hand calculations versus computer output for lateral and vertical diffusion coefficients, respectively. Randomly chosen distances of 0.805 km (0.5 miles) and 16.09 km (10 miles) were used. Results are shown to four significant digits. There are minimal differences seen between the hand calculations and those determined by the AXAMET95 subroutine for each of the categories listed.

Table 14. Verification of Lateral Diffusion Coefficients

	Downwind Distance = 0.805 km		Downwind Distance = 16.09 km	
Stability Category	σ_y (m) Hand	σ_y (m) AXAMET95	σ_y (m) Hand	σ_y (m) AXAMET95
A	208.0	208.0	1825	1825
B	166.5	166.5	1461	1461
C	125.0	125.0	1097	1097
D	83.49	83.49	732.5	732.5
E	41.51	41.51	364.2	364.2
F	20.99	20.99	184.2	184.2
G	14.31	14.31	125.6	125.6

Table 15. Verification of Vertical Diffusion Coefficients

	Downwind Distance = 0.805 km		Downwind Distance = 16.09 km	
Stability Category	σ_z (m) Hand	σ_z (m) AXAMET95	σ_z (m) Hand	σ_z (m)** AXAMET95
A	160.9	160.9	3218.	800.0
B	96.54	96.54	1931.	800.0
C	59.73	59.73	626.8	626.7
D	32.49	32.49	192.6	192.6
E	19.44	19.44	82.84	82.84
F	10.37	10.37	44.18	44.18
G	5.53	5.53	23.56	23.56

** Within AXAIRQ the vertical diffusion coefficients are limited to a value of 0.8*(Mixing Height).

The input parameters used for the scenario to test the stack release option are shown in Table 16. Several EXCEL Spreadsheets were developed to verify AXAIRQ. First the 99.5% relative air concentrations were verified for each of the sectors along with the annual average concentrations for each sector. Table 17 shows the results of the comparison. See Appendix A to view the spreadsheet calculations similar to those used to produce Table 17. Differences in hand calculations versus AXAIRQ output are minimal and due to rounding.

Table 16. Input for Sample Run

Release Location	East 63380 ft North 71900 ft
Vent or Stack	1 (Stack)
Stack Height	61
Single sector or all sectors	0 (All Sectors)
Meteorological Data (old or new)	NEW
Calendar Year of Release	1995
Gamma Shine Methodology (0,1,2)	0
Full Daughter Ingrowth	YES
Include 95% or 50% Dose	0 (neither)
Do you wish to include deposition	YES
Diffusion Coefficients 1-PB, 2-PG	1
Mixing Height	1000 m
Dose Factor Library	30
Number of user distances	0
Printout Type	BOTH
Release	1.0 Ci H-3, 2 hr 2.0 Ci I-128, 2 hr 2.0 Ci I-131, 2 hr 2.0 Ci, Xe-135, 2hr

Table 17. Comparison of Hand Calculations to AXAIRQ Output for 99.5% χ/Q and Annual Average χ/Q Values for Stack Release

Sector	Distance (km)	99.5% χ/Q (s/m^3) AXAIRQ	99.5% χ/Q (s/m^3) Hand Calcs	Annual Average χ/Q (s/m^3) AXAIRQ	Annual Average χ/Q (s/m^3) Hand Calcs
S	17.85	2.230E-07	2.230E-07	2.510E-09	2.510E-09
SSW	16.67	2.651E-06	2.651E-06	7.448E-09	7.450E-09
SW	14.33	2.905E-06	2.906E-06	1.486E-08	1.486E-08
WSW	12.81	3.330E-06	3.330E-06	1.360E-08	1.360E-08
W	12.79	3.241E-06	3.241E-06	1.152E-08	1.152E-08
WNW	11.83	4.786E-06	4.786E-06	1.406E-08	1.407E-08
NW	11.74	6.058E-06	6.057E-06	1.959E-08	1.958E-08
NNW	12.54	6.309E-06	6.314E-06	2.967E-08	2.978E-08
N	16.54	5.194E-06	5.202E-06	2.016E-08	2.021E-08
NNE	16.09	4.757E-06	4.758E-06	1.745E-08	1.746E-08
NE	19.08	4.505E-06	4.523E-06	1.449E-08	1.457E-08
ENE	16.25	3.483E-06	3.492E-06	1.269E-08	1.270E-08
E	13.66	2.998E-06	2.998E-06	1.127E-08	1.126E-08
ESE	13.66	3.307E-06	3.307E-06	1.091E-08	1.091E-08
SE	14.07	2.910E-06	2.911E-06	7.372E-09	7.374E-09
SSE	17.71	2.403E-06	2.403E-06	4.525E-09	4.526E-09

Additional scenarios were run to verify doses under various conditions. Several EXCEL Spreadsheets were created to verify the results. Table 18 shows the results of these comparisons for a wide range of input conditions. The first column shows a portion of the input. For a complete discussion of the input and all of the hand calculations see Appendix A. Differences are less than 1% for all cases.

Table 18. Hand Calculations vs. AXAIRQ for Various Scenarios

Brief Description of Input	Dose Compared	AXAIRQ	Hand Calc EXCEL	% Difference
Vent Release I-130, 2 Ci, 2 hr	99.5% Site Boundary Max Individual	5.80E-02 mrem	5.80E-02 mrem	0.0
Stack Release I-131, 2 Ci, 72 hrs	99.5% Site Boundary Max Individual	9.37E-03 mrem	9.30E-03 mrem	0.7%
Vent Release H-3, 1 Ci, 2 hr	50 Mile Offsite Population	1.57E-05 person-rem	1.56E-05 person-rem	0.6%
Vent Release Pu-238, 7 Ci, 2hr	95% Boundary Dose	1.40E+04 mrem	1.40E+04 mrem	0.0%

5.0 CONCLUSIONS

A new and improved version of AXAIR89Q, called AXAIRQ has been verified and is available for use on the IBM Mainframe. Hand Calculations demonstrate that the modules are operating as expected. New models more accurately predict atmospheric releases and the resulting doses.

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Appendix A. Hand Calculations

A1. Hand Calculations for Individual Dose with Vent Release

The following calculations were performed by EXCEL spreadsheet using the input parameters shown in the following table.

Location	51345E, 77687N	50% or 95%	0
Vent or Stack	VENT	Deposition	YES
X-Section	10000	Dispersion Coeff.	1
Sector	ALL(0)	Mixing Height	1000 M
Met Data	NEW	ICRP	30
Year	1990	User Distance	0
Shine Model	2	Source Term	I-130 2 Ci, 2hr
Ingrowth	YES		

The meteorological observation distribution and frequency distribution for F Area for the WSW Sector are shown in the following tables. The total number of records is listed between the two tables. The frequency is:

$$\frac{\text{\# Observations for a Specific WS and Stability Class Combination}}{\text{Total Number of Observations}}$$

As an example, for stability class A, using wind speed category 1, the frequency is 176/41806=4.21E-03.

Wind Speed Category	WSW A	B	C	Observation Distribution Stability Category D	E	F	G
1	176	32	29	8	1	0	0
2	320	168	322	470	146	20	1
3	37	92	264	583	447	110	9
4	5	5	54	173	65	26	1
5	1	1	2	35	5	0	0
6	0	0	0	0	0	0	0
Total Records	41806						

Wind Speed Category	WSW A	B	C	Frequency Distribution Stability Category D	E	F	G
1	4.21E-03	7.65E-04	6.94E-04	1.91E-04	2.39E-05	0.00E+00	0.00E+00
2	7.65E-03	4.02E-03	7.70E-03	1.12E-02	3.49E-03	4.78E-04	2.39E-05
3	8.85E-04	2.20E-03	6.31E-03	1.39E-02	1.07E-02	2.63E-03	2.15E-04
4	1.20E-04	1.20E-04	1.29E-03	4.14E-03	1.55E-03	6.22E-04	2.39E-05
5	2.39E-05	2.39E-05	4.78E-05	8.37E-04	1.20E-04	0.00E+00	0.00E+00
6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Next the wind speeds at the release height were determined based on the wind speeds collected at the meteorological tower for stability class A and wind speed category 1. For a ground level release, the height the wind speed was calculated at 10 m from the ground surface using the following equation:

$$UHS = UA * F = 1.37\left(\frac{H_e}{62}\right)^{CE_i} = 1.37\left(\frac{10}{62}\right)^{0.08} = 1.18 m/s$$

Stability Class	CE	UHS Factor
A	0.08	0.8642
B	0.1	0.8332
C	0.11	0.8182
D	0.18	0.7201
E	0.31	0.5680
F	0.42	0.4647
G	0.42	0.4647

WIND Speed Category	WSW A	B	C	Average Wind Speeds (UA) (meters/sec) Stability Category D	E	F	G
1	1.37	1.61	1.69	1.49	1.21	0.00	0.00
2	2.67	2.92	2.92	3.10	3.39	3.36	3.75
3	4.24	4.50	4.73	4.75	4.79	5.05	5.15
4	6.91	6.34	6.45	6.61	6.40	6.31	6.20
5	5.13	8.32	8.39	8.56	8.52	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Wind Speed Category	WSW A	B	C	Average Wind Speeds (UHS) (meters/sec) Stability Category D	E	F	G
1	1.18	1.34	1.38	1.07	0.69	0.00	0.00
2	2.31	2.43	2.39	2.23	1.93	1.56	1.74
3	3.66	3.75	3.87	3.42	2.72	2.35	2.39
4	5.97	5.28	5.28	4.76	3.64	2.93	2.88
5	4.43	6.93	6.86	6.16	4.84	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Next the horizontal and vertical diffusion coefficients were calculated using the equations shown in Section 3.1.5.2 for a downwind distance of 8970 m. Within the code the vertical diffusion coefficients are limited to a value of 0.8*Mixing Height, which is shown as the constrained values. Horizontal coefficients were also calculated for a downwind distance of 800 m since these values will be needed for the meander calculations.

Calculated Sigma

Stability	Sigma Y	Sigma Z
A	1307.98	1794.00
B	1046.98	1076.40
C	785.99	429.31
D	524.99	141.56
E	261.00	72.91
F	132.00	38.88
G	90.00	20.74

Constrained Sigma

Stability	SigmaY	Sigma Z	Meander Sigy 800
A	1307.98	800.00	206.93
B	1046.98	800.40	165.64
C	785.99	429.31	124.35
D	524.99	141.56	83.06
E	261.00	72.91	41.29
F	132.00	38.88	20.88
G	90.00	20.74	14.24

Within AXAIRQ equations are used to approximate the meander coefficients. For wind speed between 2-6 m/s the following equation is used:

$$M = e^{S \times \ln(U_{10}) + C}$$

where S and C are constants as a function of stability class. Table A.1 shows the values of S and C.

Table A.1. Constants for Meander Calculations as a Function of Stability

	D	E	F	G
S	-0.6309	-1.0000	-1.2619	-1.6309
C	1.1304	1.7918	2.2610	2.9222

For stability class G and wind speed category 3 the following calculation was performed:

$$M = e^{S \times \ln(U_{10}) + C} = e^{-1.6309 \times \ln(2.39) + 2.922} = 4.48$$

NNW

Meander Coefficient(M) Stability Category

WS Category	A	B	C	D	E	F	G
1				2.00	3.00	1.00	1.00
2				1.87	3.00	4.00	6.00
3				1.43	2.21	3.27	4.48
4				1.16	1.65	2.47	3.31
5				1.00	1.24	1.00	1.00
6							

The relative air concentration without meander was calculated for stability class G and the third wind speed category by taking the highest value determined from the following two equations:

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{U_{10}(\pi\sigma_y\sigma_z + \frac{A}{2})}$$

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{U_{10}(3\pi\sigma_y\sigma_z)}$$

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{2.39(\pi 90.0 * 20.74 + \frac{10000}{2})}$$

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{2.39(3\pi 90.0 * 20.74)}$$

$$\frac{\chi_2}{Q}(x,0,0) = 3.85E-05\frac{s}{m^3}$$

$$\frac{\chi_2}{Q}(x,0,0) = 2.38E-5\frac{s}{m^3}$$

The value of 3.85E-05 s/m^3 was recorded for no meander. Next, the effects of meander were considered and the two values are compared with the lower of the two being the final value used for the relative air concentration. The equation for relative air concentration including the effects of meander follows:

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{U_{10}(\pi\Sigma_y\sigma_z)}$$

Once again for stability class G with the third wind speed category and for distances greater than 800 m the following equation was used to determine Σy:

$$\Sigma_y = (M-1)\sigma_{y800m} + \sigma_y = (4.48-1)14.24 + 90.0 = 139.56$$

The relative air concentration including the effects of meander was then calculated using the following equation:

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{U_{10}(\pi\Sigma_y\sigma_z)}$$

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{2.39(\pi 139.56 * 20.74)}$$

$$\frac{\chi_2}{Q}(x,0,0) = 4.60E-05\frac{s}{m^3}$$

Shown below are the values for relative air concentration both with and without meander for each of the 42 wind speed and stability class combinations.

Wind Speed Category	NNW A	B	C	X/Q without meander Stability Category D	E	F	G
1	2.57E-07	2.83E-07	6.79E-07	3.91E-06	2.25E-05	0.00E+00	0.00E+00
2	1.32E-07	1.56E-07	3.93E-07	1.88E-06	8.02E-06	3.03E-05	5.28E-05
3	8.29E-08	1.01E-07	2.43E-07	1.23E-06	5.67E-06	2.02E-05	3.85E-05
4	5.09E-08	7.18E-08	1.78E-07	8.81E-07	4.25E-06	1.61E-05	3.19E-05
5	6.85E-08	5.47E-08	1.37E-07	6.80E-07	3.19E-06	0.00E+00	0.00E+00
6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Wind Speed Category	NNW A	B	C	Meander X/Q Stability Category D	E	F	G
1				3.45E-06	1.85E-05	0.00E+00	0.00E+00
2				1.69E-06	6.60E-06	2.69E-05	5.46E-05
3				1.17E-06	5.16E-06	1.94E-05	4.60E-05
4				8.78E-07	4.17E-06	1.72E-05	4.34E-05
5				6.95E-07	3.33E-06	0.00E+00	0.00E+00
6							

The relative air concentration with meander was compared to the relative air concentration without meander and the smaller of the two values was used. The following table shows the final relative air concentrations along with their associated frequency.

The next table shows the values ranked from highest to lowest along with their associated frequency and cumulative frequency. When the cumulative frequency exceeds 0.005 interpolation was performed to determine the 99.5% χ/Q value for the distance of interest. The value determined by the code was 1.346E-05 s/m^3 which agrees with the number calculated by the spreadsheet.

STABILITY	WS	χ/Q	FREQUENCY
A	1	2.57E-07	4.21E-03
A	2	1.32E-07	7.65E-03
A	3	8.29E-08	8.85E-04
A	4	5.09E-08	1.20E-04
A	5	6.85E-08	2.39E-05
A	6	0.00E+00	0.00E+00
B	1	2.83E-07	7.65E-04
B	2	1.56E-07	4.02E-03
B	3	1.01E-07	2.20E-03
B	4	7.18E-08	1.20E-04
B	5	5.47E-08	2.39E-05
B	6	0.00E+00	0.00E+00
C	1	6.79E-07	6.94E-04
C	2	3.93E-07	7.70E-03
C	3	2.43E-07	6.31E-03
C	4	1.78E-07	1.29E-03
C	5	1.37E-07	4.78E-05
C	6	0.00E+00	0.00E+00
D	1	3.45E-06	1.91E-04
D	2	1.69E-06	1.12E-02
D	3	1.17E-06	1.39E-02
D	4	8.78E-07	4.14E-03
D	5	6.80E-07	8.37E-04
D	6	0.00E+00	0.00E+00
E	1	1.85E-05	2.39E-05
E	2	6.60E-06	3.49E-03
E	3	5.16E-06	1.07E-02
E	4	4.17E-06	1.55E-03
E	5	3.19E-06	1.20E-04
E	6	0.00E+00	0.00E+00
F	1	0.00E+00	0.00E+00
F	2	2.69E-05	4.78E-04
F	3	1.94E-05	2.63E-03
F	4	1.61E-05	6.22E-04
F	5	0.00E+00	0.00E+00
F	6	0.00E+00	0.00E+00
G	1	0.00E+00	0.00E+00
G	2	5.28E-05	2.39E-05
G	3	3.85E-05	2.15E-04
G	4	3.19E-05	2.39E-05
G	5	0.00E+00	0.00E+00
G	6	0.00E+00	0.00E+00

Stability	WS	χ/Q	Frequency	Cumulative Frequency	99.5% Value
G	2	5.28E-05	2.39E-05	2.392E-05	
G	3	3.85E-05	2.15E-04	0.0002392	
G	4	3.19E-05	2.39E-05	0.00026312	
F	2	2.69E-05	4.78E-04	0.00074152	
F	3	1.94E-05	2.63E-03	0.00337272	
E	1	1.85E-05	2.39E-05	0.00339664	
F	4	1.61E-05	6.22E-04	0.00401856	
E	2	6.60E-06	3.49E-03	0.00751088	1.35E-05
E	3	5.16E-06	1.07E-02	0.01820313	
E	4	4.17E-06	1.55E-03	0.01975793	
D	1	3.45E-06	1.91E-04	0.01994929	
E	5	3.19E-06	1.20E-04	0.02006889	
D	2	1.69E-06	1.12E-02	0.0313113	
D	3	1.17E-06	1.39E-02	0.04525666	
D	4	8.78E-07	4.14E-03	0.04939482	
D	5	6.80E-07	8.37E-04	0.05023202	
C	1	6.79E-07	6.94E-04	0.0509257	
C	2	3.93E-07	7.70E-03	0.05862795	
B	1	2.83E-07	7.65E-04	0.05939339	
A	1	2.57E-07	4.21E-03	0.06360331	
C	3	2.43E-07	6.31E-03	0.06991819	
C	4	1.78E-07	1.29E-03	0.07120987	
B	2	1.56E-07	4.02E-03	0.07522844	
C	5	1.37E-07	4.78E-05	0.07527628	
A	2	1.32E-07	7.65E-03	0.08293068	
B	3	1.01E-07	2.20E-03	0.08513132	
A	3	8.29E-08	8.85E-04	0.08601636	
B	4	7.18E-08	1.20E-04	0.08613596	
A	5	6.85E-08	2.39E-05	0.08615988	
B	5	5.47E-08	2.39E-05	0.0861838	
A	4	5.09E-08	1.20E-04	0.0863034	
A	6	0.00E+00	0.00E+00	0.0863034	
B	6	0.00E+00	0.00E+00	0.0863034	
C	6	0.00E+00	0.00E+00	0.0863034	
D	6	0.00E+00	0.00E+00	0.0863034	
E	6	0.00E+00	0.00E+00	0.0863034	
F	1	0.00E+00	0.00E+00	0.0863034	
F	5	0.00E+00	0.00E+00	0.0863034	
F	6	0.00E+00	0.00E+00	0.0863034	
G	1	0.00E+00	0.00E+00	0.0863034	
G	5	0.00E+00	0.00E+00	0.0863034	
G	6	0.00E+00	0.00E+00	0.0863034	

Depletion factors were calculated for a downwind distance of 8970 m with a deposition velocity of 0.01 m/s using the equations in Section 3.1.6. Numerical integration was performed using the Trapezoid Rule with 100 increments for each given distance. These factors also incorporate decay. If the wind speed and stability class combination did not occur in the five year period, a value of one was assigned to avoid a division by zero error. This assumption will not effect the results since relative air concentrations have an assigned value to zero for these combinations.

A	B	C	D	E	F	G
0.7398	0.7104	0.6251	0.3435	0.0885	1.0000	1.0000
0.8567	0.8282	0.7619	0.5984	0.4209	0.1972	0.1363
0.9072	0.8849	0.8455	0.7152	0.5420	0.3396	0.2343
0.9420	0.9168	0.8842	0.7860	0.6323	0.4213	0.2996
0.9227	0.9360	0.9097	0.8303	0.7087	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Using the internal and external dose equations discussed in Section 3.2 the doses were calculated for each of the stability class and wind speed combinations. The following shows a sample calculation of dose for stability class A with wind speed category 1. First the inhalation dose was calculated. The DD term in the following equation is the decay and depletion term combined as taken from the previous table.

$$D = 3.17E-08(Q)(\frac{\chi}{Q})(DF)(B)DD$$

$$D = 3.17E-08\frac{yr}{s} * 2Ci * 2.57E-07\frac{s}{m^3} 2.5E+06\frac{mrem}{Ci} * 12000\frac{m^3}{yr} * 0.7398$$

$$D = 3.61E-03 mrem$$

Next the dose from plume shine was calculated.

$$D_{PS} = (\frac{\chi}{Q})(Q_n)(DF_s)_n DD$$

$$D_{PS} = 2.565E-07\frac{s}{m^3} * 2Ci * 1.09E+04\frac{mrem/yr}{\mu Ci/m^3} * 0.7398 * 0.0317\frac{\mu Ci * yr}{Ci * s}$$

$$D_{PS} = 1.31E-04 mrem$$

Finally, the dose due to ground shine was determined.

$$D_{GR} = 0.03171(V_D)(DF_{GR})(Q)(\frac{\chi}{Q})(\frac{1-e^{-\lambda t}}{\lambda})DD$$

$$D_{GR} = 0.0317\frac{\mu Ci * yr}{Ci * s}(0.01\frac{m}{s})(218\frac{mrem / yr}{\mu Ci / m^2})(2Ci)(2.565E-07\frac{s}{m^3})(\frac{1-e^{(-1.56E-5*345600)}}{1.56E-5})(0.7398)$$

$$D_{GR} = 1.67E-03 mrem$$

$$D_{TOTAL} = D_{INH} + D_{PS} + D_{GR}$$

$$D_{TOTAL} = 3.6E-4 + 1.31E-4 + 1.67E-03 = 2.16E-3 mrem$$

The sum of the three dose pathways is shown in the following table along with the frequency of occurrence for the stability class and wind speed combination.

Next the doses were ranked from highest to lowest along with their associated frequency and a cumulative frequency distribution was determined. As with the relative air concentration, the 99.5% value was calculated by interpolation. This value agrees exactly with the value determined by the code.

Stability Class	Wind Speed Category	Inhalation, Ground, & Plume Shine Dose	Frequency
A	1	2.17E-03	4.21E-03
A	2	1.29E-03	7.65E-03
A	3	8.58E-04	8.85E-04
A	4	5.47E-04	1.20E-04
A	5	7.21E-04	2.39E-05
A	6	0.00E+00	0.00E+00
B	1	2.29E-03	7.65E-04
B	2	1.47E-03	4.02E-03
B	3	1.02E-03	2.20E-03
B	4	7.51E-04	1.20E-04
B	5	5.84E-04	2.39E-05
B	6	0.00E+00	0.00E+00
C	1	4.84E-03	6.94E-04
C	2	3.42E-03	7.70E-03
C	3	2.34E-03	6.31E-03
C	4	1.80E-03	1.29E-03
C	5	1.42E-03	4.78E-05
C	6	0.00E+00	0.00E+00
D	1	1.35E-02	1.91E-04
D	2	1.15E-02	1.12E-02
D	3	9.58E-03	1.39E-02
D	4	7.88E-03	4.14E-03
D	5	6.45E-03	8.37E-04
D	6	0.00E+00	0.00E+00
E	1	1.87E-02	2.39E-05
E	2	3.17E-02	3.49E-03
E	3	3.19E-02	1.07E-02
E	4	3.01E-02	1.55E-03
E	5	2.58E-02	1.20E-04
E	6	0.00E+00	0.00E+00
F	1	0.00E+00	0.00E+00
F	2	6.06E-02	4.78E-04
F	3	7.54E-02	2.63E-03
F	4	7.76E-02	6.22E-04
F	5	0.00E+00	0.00E+00
F	6	0.00E+00	0.00E+00
G	1	0.00E+00	0.00E+00
G	2	8.22E-02	2.39E-05
G	3	1.03E-01	2.15E-04
G	4	1.09E-01	2.39E-05
G	5	0.00E+00	0.00E+00
G	6	0.00E+00	0.00E+00

STAB	WS	DOSE	FREQ	CUM FREQ	DOSE 0.995
G	4	1.09E-01	2.39E-05	0.00002	
G	3	1.03E-01	2.15E-04	0.00024	
G	2	8.22E-02	2.39E-05	0.00026	
F	4	7.76E-02	6.22E-04	0.00089	
F	3	7.54E-02	2.63E-03	0.00352	
F	2	6.06E-02	4.78E-04	0.00399	
E	3	3.19E-02	1.07E-02	0.01469	0.0580
E	2	3.17E-02	3.49E-03	0.01818	
E	4	3.01E-02	1.55E-03	0.01973	
E	5	2.58E-02	1.20E-04	0.01985	
E	1	1.87E-02	2.39E-05	0.01988	
D	1	1.35E-02	1.91E-04	0.02007	
D	2	1.15E-02	1.12E-02	0.03131	
D	3	9.58E-03	1.39E-02	0.04526	
D	4	7.88E-03	4.14E-03	0.04939	
D	5	6.45E-03	8.37E-04	0.05023	
C	1	4.84E-03	6.94E-04	0.05093	
C	2	3.42E-03	7.70E-03	0.05863	
C	3	2.34E-03	6.31E-03	0.06494	
B	1	2.29E-03	7.65E-04	0.06571	
A	1	2.17E-03	4.21E-03	0.06992	
C	4	1.80E-03	1.29E-03	0.07121	
B	2	1.47E-03	4.02E-03	0.07523	
C	5	1.42E-03	4.78E-05	0.07528	
A	2	1.29E-03	7.65E-03	0.08293	
B	3	1.02E-03	2.20E-03	0.08513	
A	3	8.58E-04	8.85E-04	0.08602	
B	4	7.51E-04	1.20E-04	0.08614	
A	5	7.21E-04	2.39E-05	0.08616	
B	5	5.84E-04	2.39E-05	0.08618	
A	4	5.47E-04	1.20E-04	0.08630	
A	6	0.00E+00	0.00E+00	0.08630	
B	6	0.00E+00	0.00E+00	0.08630	
C	6	0.00E+00	0.00E+00	0.08630	
D	6	0.00E+00	0.00E+00	0.08630	
E	6	0.00E+00	0.00E+00	0.08630	
F	1	0.00E+00	0.00E+00	0.08630	
F	5	0.00E+00	0.00E+00	0.08630	
F	6	0.00E+00	0.00E+00	0.08630	
G	1	0.00E+00	0.00E+00	0.08630	
G	5	0.00E+00	0.00E+00	0.08630	
G	6	0.00E+00	0.00E+00	0.08630	

A2. Individual Dose Calculations For Stack Release With Release Period Greater Than 2 Hrs

The following calculations are for a distance of 11740 m to the NW of a release near H Area. Calculations are shown for dose to a maximally exposed offsite individual. The input parameters are as follows:

Location	63380, 71900	50% or 95%	1
Vent or Stack	STACK	Deposition	YES
Release Ht	61 M	Dispersion Coeff.	1
Sector	7	Mixing Ht	1000 m
Met Data	NEW	ICRP	30
Year	1990	User Distance	0
Shine Model	0	Source Term	I-131,2 Ci, 72 hrs
Ingrowth	YES		

The meteorological frequency distribution for the NW Sector in H Area is shown next. The total number of records is shown in bold. The frequency is determined by dividing the number of times that a specific wind speed and stability class combination occurred by the total number of data for the location (Note: not the total number of data for the sector).

Wind Speed Category	NW			Observation Distribution Stability Category			
	A	B	C	D	E	F	G
1	177	25	24	24	13	1	0
2	284	107	180	309	200	39	4
3	29	31	95	286	285	58	11
4	2	1	14	20	1	0	1
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
TOTAL RECORDS	43824						

Wind Speed Category	NW			Frequency Distribution Stability Category			
	A	B	C	D	E	F	G
1	4.04E-03	5.70E-04	5.48E-04	5.48E-04	2.97E-04	2.28E-05	0.00E+00
2	6.48E-03	2.44E-03	4.11E-03	7.05E-03	4.56E-03	8.90E-04	9.13E-05
3	6.62E-04	7.07E-04	2.17E-03	6.53E-03	6.50E-03	1.32E-03	2.51E-04
4	4.56E-05	2.28E-05	3.19E-04	4.56E-04	2.28E-05	0.00E+00	2.28E-05
5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Wind Speed Category	NW			Average Wind Speeds (UA) (meters/sec) Stability Category			
	A	B	C	D	E	F	G
1	1.20	1.63	1.41	1.43	1.59	1.67	0.00
2	2.55	2.76	2.92	3.08	3.19	3.05	3.66
3	4.43	4.65	4.70	4.60	4.60	4.79	4.57
4	5.63	6.67	6.47	6.53	6.54	0.00	6.13
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Next the wind speeds at the release height were determined based on the wind speeds collected at the meteorological tower. The release height was 61 m, but this value must be adjusted for terrain. The effective release height is the release height reduced by the terrain height at the receptor location. The terrain height at 11740 m NW is 35.7 m resulting an effective release height of 25.3 m. For stability class A and wind speed category 1, UHS & UHE was calculated as follows:

$$UHS = UA * F = 1.20\left(\frac{H_s}{62}\right)^{CE_i} = 1.20\left(\frac{61.0}{62}\right)^{0.08} = 1.20$$

$$UHE = UA * F = 1.20\left(\frac{H_s}{62}\right)^{CE_i} = 1.20\left(\frac{35.7}{62}\right)^{0.08} = 1.12$$

Values of UHS were used to determine the maximum centerline relative air concentration and values of UHE were used to determine the sector arc relative air concentrations.

Stability	CE	UHS Factor	UHE factor
A	0.08	0.9987	0.9309
B	0.1	0.9984	0.9144
C	0.11	0.9982	0.9063
D	0.18	0.9971	0.8512
E	0.31	0.9950	0.7578
F	0.42	0.9932	0.6867
G	0.42	0.9932	0.6867

Wind Speed Category	NNW			Average Wind Speeds (UHS) (meters/sec) Stability Category			
	A	B	C	D	E	F	G
1	1.20	1.63	1.41	1.43	1.58	1.66	0.00
2	2.55	2.76	2.91	3.07	3.17	3.03	3.64
3	4.42	4.64	4.69	4.59	4.58	4.76	4.54
4	5.62	6.66	6.46	6.51	6.51	0.00	6.09
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Wind Speed Category	NW			Average Wind Speeds (UHE) (meters/sec) Stability Category			
	A	B	C	D	E	F	G
1	1.12	1.49	1.28	1.22	1.20	1.15	0.00
2	2.37	2.52	2.65	2.62	2.42	2.09	2.51
3	4.12	4.25	4.26	3.92	3.49	3.29	3.14
4	5.24	6.10	5.86	5.56	4.96	0.00	4.21
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The diffusion coefficients were calculated in the same manner as shown in the above example except the downwind distance is now set at 11740 m.

	Calculated Sigma		Constrained Sigma	
Stability	Sigma Y	Sigma Z	SigmaY	Sigma Z
A	1.559E+03	2.348E+03	1.559E+03	8.000E+02
B	1.248E+03	1.409E+03	1.248E+03	8.000E+02
C	9.368E+02	5.133E+02	9.368E+02	5.133E+02
D	6.257E+02	1.633E+02	6.257E+02	1.633E+02
E	3.111E+02	7.789E+01	3.111E+02	7.789E+01
F	1.573E+02	4.154E+01	1.573E+02	4.154E+01
G	1.073E+02	2.215E+01	1.073E+02	2.215E+01

For a stack release the two-hour fumigation relative air concentration is calculated for stability class A and wind speed category 4 as follows:

$$\frac{\chi}{Q}=\frac{e^{-\left(\frac{(h_e)^2}{2\sigma_z^2}\right)}}{\pi\sigma_y\sigma_z U_S}$$

$$\frac{\chi}{Q}=\frac{e^{-\left(\frac{(25.3)^2}{2\times 800^2}\right)}}{\pi 1559\times 800\times 5.62}=4.54E-08 s/m^3$$

Fumigation conditions only occur for stability classes E, F, and G with wind speeds less than 4 m/s. For stability class F with wind speed category 1 the fumigation relative air concentration was calculated as follows:

$$\frac{\chi_{2f}}{Q}(x,0,0)=\frac{1}{\sqrt{2\pi}\sigma_y L_e U_S}$$

$$\frac{\chi_{2f}}{Q}(x,0,0)=\frac{1}{\sqrt{2\pi}157.3(1000-25.33)1.66}=1.59E-06 s/m^3$$

The next two tables show the fumigation and non-fumigation relative air concentrations.

Wind Speed Category	NW			NON-FUMIGATION X/Q Stability Class			
	A	B	C	D	E	F	G
1	2.13E-07	1.96E-07	4.70E-07	2.16E-06	7.88E-06	2.44E-05	0
2	1.00E-07	1.16E-07	2.27E-07	1.00E-06	3.93E-06	1.33E-05	1.92E-05
3	5.77E-08	6.86E-08	1.41E-07	6.71E-07	2.72E-06	8.50E-06	1.53E-05
4	4.54E-08	4.79E-08	1.02E-07	4.73E-07	1.91E-06	0	1.14E-05
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0

Wind Speed Category	NW			FUMIGATION X/Q Stability Class			
	A	B	C	D	E	F	G
1					8.41E-07	1.59E-06	0
2					4.19E-07	8.68E-07	1.06E-06
3							
4							
5							
6							

Depletion factors were calculated for a downwind distance of 11740 m with a deposition velocity of 0.01 m/s using the equations in Section 3.1.6. Numerical integration was performed with 100 increments for each given distance.

WS	A	B	C	D	E	F	G
1	0.8331	0.8392	0.7244	0.5125	0.4104	0.3261	1.0000
2	0.9176	0.9016	0.8559	0.7332	0.6415	0.5414	0.6517
3	0.9517	0.9404	0.9078	0.8124	0.7350	0.6766	0.7097
4	0.9618	0.9581	0.9322	0.8638	0.8053	1.0000	0.7744
5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

The following table shows the depletion factors corrected for decay. The numbers below represent the percentage of the plume left at a downwind distance of 11740 m for each of the stability and wind speed combinations.

For stability class A wind speed category 1 the decay corrected depletion factor was determined as follows:

$$DD = DEP * DEC$$

$$DD = DEP * e^{-\lambda t}$$

$$DD = 0.8331 * e^{\frac{\ln 2}{8dy*24hr*3600s} \frac{11740m}{1.20m/s}}$$

$$DD = 0.8250$$

WS	A	B	C	D	E	F	G
1	0.8250	0.8331	0.7184	0.5083	0.4074	0.3238	0.0000
2	0.9134	0.8978	0.8524	0.7304	0.6392	0.5393	0.6496
3	0.9492	0.9380	0.9056	0.8103	0.7332	0.6749	0.7079
4	0.9598	0.9564	0.9305	0.8623	0.8039	0.0000	0.7729
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Since the release period was greater than two hours the annual average concentration must be calculated. The annual average relative air concentration values were adjusted for both depletion and decay of the nuclide. The annual average was determined as follows:

$$\frac{\chi}{Q_{ANN}} = \sum_{ij} \frac{\chi}{Q_{arc}} (JFD)(DD)$$

where

$\frac{\chi}{Q_{arc}}$ = Sector arc relative air concentration

JFD = Joint frequency distribution,

DD = Depletion and Decay Correction Factor

For stability class A wind speed category 1 the contribution to the annual average:

$$\frac{\chi}{Q_{arc}}(x,0) = \frac{2.032e^{-\left(\frac{(h_e)^2}{2\sigma_z^2}\right)}}{\sigma_z U_{HE} x}$$

$$\frac{\chi}{Q_{arc}}(x,0) = \frac{2.032e^{-\left(\frac{(25.33)^2}{2\times 800^2}\right)}}{800 \times 1.12 \times 11740} = 1.936E-07 s/m^3$$

$$\frac{\chi}{Q_{arc}}(x,0) \times JFD \times DEP = 1.936E-07 \times 4.039E-3 \times 0.8250 = 6.44E-10 s/m^3$$

Similar calculations were performed for each of the 42 combinations and the results were summed. The table on the following page shows the results for each of the 42 wind speed and stability class combinations. The sum of these values is shown at the bottom of the table.

Stab and WS	Annual Average
A-1	6.45E-10
A-2	5.39E-10
A-3	3.29E-11
A-4	1.81E-12
A-5	0.00E+00
A-6	0.00E+00
B-1	6.90E-11
B-2	1.88E-10
B-3	3.37E-11
B-4	7.74E-13
B-5	0.00E+00
B-6	0.00E+00
C-1	1.04E-10
C-2	4.46E-10
C-3	1.55E-10
C-4	1.71E-11
C-5	0.00E+00
C-6	0.00E+00
D-1	2.40E-10
D-2	2.06E-09
D-3	1.41E-09
D-4	7.41E-11
D-5	0.00E+00
D-6	0.00E+00
E-1	2.11E-10
E-2	2.54E-09
E-3	2.88E-09
E-4	7.80E-12
E-5	0.00E+00
E-6	0.00E+00
F-1	2.23E-11
F-2	7.93E-10
F-3	9.39E-10
F-4	0.00E+00
F-5	0.00E+00
F-6	0.00E+00
G-1	0.00E+00
G-2	9.58E-11
G-3	2.30E-10
G-4	1.70E-11
G-5	0.00E+00
G-6	0.00E+00
TOTAL	1.38E-08

For a release period 72 hrs in length, interpolation was performed between the 2-hour χ/Q and the annual average decayed and depleted χ/Q. Logarithmic interpolation was performed using the following equation:

$$\frac{\chi}{Q_{TP}} = \frac{\chi}{Q_{Ann}} e^{\ln\left(\frac{\chi/Q_{2hr(dep)}}{\chi/Q_{Ann}}\right)\left(\frac{\ln 8760 - \ln TP}{\ln 8760 - \ln 2}\right)}$$

$$\frac{\chi}{Q_{72}} = (1.376E-08)e^{\ln\left(\frac{2.129E-07*0.825}{1.376E-08}\right)\left(\frac{\ln 8760 - \ln 72}{\ln 8760 - \ln 2}\right)}$$

$$\frac{\chi}{Q_{72}} = 5.79E-08 s/m^3$$

A similar interpolation was performed for each of the 42 values. The next table shows the relative air concentration found by interpolation for each of the 42 stability class and wind speed combinations.

The next table shows the dose calculations. These calculations were performed in a similar manner to the previous set of calculations. The next page shows the doses ranked in order from highest to lowest and the 99.5% dose.

STABILITY	WS	X/Q	FREQUENCY
A	1	5.79E-08	4.04E-03
A	2	4.01E-08	6.48E-03
A	3	3.00E-08	6.62E-04
A	4	2.64E-08	4.56E-05
A	5	0.00E+00	0.00E+00
A	6	0.00E+00	0.00E+00
B	1	5.55E-08	5.70E-04
B	2	4.30E-08	2.44E-03
B	3	3.29E-08	7.07E-04
B	4	2.71E-08	2.28E-05
B	5	0.00E+00	0.00E+00
B	6	0.00E+00	0.00E+00
C	1	8.37E-08	5.48E-04
C	2	6.11E-08	4.11E-03
C	3	4.84E-08	2.17E-03
C	4	4.10E-08	3.19E-04
C	5	0.00E+00	0.00E+00
C	6	0.00E+00	0.00E+00
D	1	1.63E-07	5.48E-04
D	2	1.30E-07	7.05E-03
D	3	1.10E-07	6.53E-03
D	4	9.31E-08	4.56E-04
D	5	0.00E+00	0.00E+00
D	6	0.00E+00	0.00E+00
E	1	3.12E-07	2.97E-04
E	2	2.71E-07	4.56E-03
E	3	2.38E-07	6.50E-03
E	4	2.05E-07	2.28E-05
E	5	0.00E+00	0.00E+00
E	6	0.00E+00	0.00E+00
F	1	5.23E-07	2.28E-05
F	2	4.96E-07	8.90E-04
F	3	4.35E-07	1.32E-03
F	4	0.00E+00	0.00E+00
F	5	0.00E+00	0.00E+00
F	6	0.00E+00	0.00E+00
G	1	0.00E+00	0.00E+00
G	2	6.78E-07	9.13E-05
G	3	6.28E-07	2.51E-04
G	4	5.58E-07	2.28E-05
G	5	0.00E+00	0.00E+00
G	6	0.00E+00	0.00E+00

Stability Class	Wind Speed Category	INH & GRD Dose	Frequency
A	1	1.83E-03	4.04E-03
A	2	1.27E-03	6.48E-03
A	3	9.53E-04	6.62E-04
A	4	8.38E-04	4.56E-05
A	5	0.00E+00	0.00E+00
A	6	0.00E+00	0.00E+00
B	1	1.76E-03	5.70E-04
B	2	1.37E-03	2.44E-03
B	3	1.05E-03	7.07E-04
B	4	2.03E-04	2.28E-05
B	5	0.00E+00	0.00E+00
B	6	0.00E+00	0.00E+00
C	1	2.65E-03	5.48E-04
C	2	1.94E-03	4.11E-03
C	3	1.54E-03	2.17E-03
C	4	1.30E-03	3.19E-04
C	5	0.00E+00	0.00E+00
C	6	0.00E+00	0.00E+00
D	1	5.15E-03	5.48E-04
D	2	4.11E-03	7.05E-03
D	3	3.48E-03	6.53E-03
D	4	2.96E-03	4.56E-04
D	5	0.00E+00	0.00E+00
D	6	0.00E+00	0.00E+00
E	1	9.88E-03	2.97E-04
E	2	8.61E-03	4.56E-03
E	3	7.56E-03	6.50E-03
E	4	6.52E-03	2.28E-05
E	5	0.00E+00	0.00E+00
E	6	0.00E+00	0.00E+00
F	1	1.66E-02	2.28E-05
F	2	1.58E-02	8.90E-04
F	3	1.39E-02	1.32E-03
F	4	0.00E+00	0.00E+00
F	5	0.00E+00	0.00E+00
F	6	0.00E+00	0.00E+00
G	1	0.00E+00	0.00E+00
G	2	2.15E-02	9.13E-05
G	3	1.99E-02	2.51E-04
G	4	1.77E-02	2.28E-05
G	5	0.00E+00	0.00E+00
G	6	0.00E+00	0.00E+00

STAB	WS	DOSE	Frequency	Cumulative Frequency	Dose 99.5%
G	2	2.15E-02	9.13E-05	9.13E-05	
G	3	1.99E-02	2.51E-04	3.42E-04	
G	4	1.77E-02	2.28E-05	3.65E-04	
F	1	1.66E-02	2.28E-05	3.88E-04	
F	2	1.58E-02	8.90E-04	1.28E-03	
F	3	1.39E-02	1.32E-03	2.60E-03	
E	1	9.88E-03	2.97E-04	2.90E-03	
E	2	8.61E-03	4.56E-03	7.46E-03	9.30E-03
E	3	7.56E-03	6.50E-03	1.40E-02	
E	4	6.52E-03	2.28E-05	1.40E-02	
D	1	5.15E-03	5.48E-04	1.45E-02	
D	2	4.11E-03	7.05E-03	2.16E-02	
D	3	3.48E-03	6.53E-03	2.81E-02	
D	4	2.96E-03	4.56E-04	2.86E-02	
C	1	2.65E-03	5.48E-04	2.91E-02	
C	2	1.94E-03	4.11E-03	3.32E-02	
A	1	1.83E-03	4.04E-03	3.73E-02	
B	1	1.76E-03	5.70E-04	3.78E-02	
C	3	1.54E-03	2.17E-03	4.00E-02	
B	2	1.37E-03	2.44E-03	4.24E-02	
C	4	1.30E-03	3.19E-04	4.28E-02	
A	2	1.27E-03	6.48E-03	4.92E-02	
B	3	1.05E-03	7.07E-04	4.99E-02	
A	3	9.53E-04	6.62E-04	5.06E-02	
A	4	8.38E-04	4.56E-05	5.07E-02	
B	4	2.03E-04	2.28E-05	5.07E-02	
A	5	0.00E+00	0.00E+00	5.07E-02	
A	6	0.00E+00	0.00E+00	5.07E-02	
B	5	0.00E+00	0.00E+00	5.07E-02	
B	6	0.00E+00	0.00E+00	5.07E-02	
C	5	0.00E+00	0.00E+00	5.07E-02	
C	6	0.00E+00	0.00E+00	5.07E-02	
D	5	0.00E+00	0.00E+00	5.07E-02	
D	6	0.00E+00	0.00E+00	5.07E-02	
E	5	0.00E+00	0.00E+00	5.07E-02	
E	6	0.00E+00	0.00E+00	5.07E-02	
F	4	0.00E+00	0.00E+00	5.07E-02	
F	5	0.00E+00	0.00E+00	5.07E-02	
F	6	0.00E+00	0.00E+00	5.07E-02	
G	1	0.00E+00	0.00E+00	5.07E-02	
G	5	0.00E+00	0.00E+00	5.07E-02	
G	6	0.00E+00	0.00E+00	5.07E-02	

A.3. Population Dose Calculations For Vent Release

Fifty-mile offsite population dose calculations are demonstrated with the following input parameters:

Location	A	50% or 95%	1
Vent or Stack	VENT	Deposition	YES
Cross Section	0	Diffusion Coeff.	1
Sector	16	Mixing Ht	1000 m
Met Data	NEW	ICRP	30
Year	1990	User Distance	0
Shine Model	0	Source Term	H-3,1 Ci, 2 hrs
Ingrowth	YES		

Calculations were performed at each of the radial distances (10, 20, 30, 40, & 50 miles). The following calculations are for a distance of 16090 m to the SSE of a release near A Area. Shown below is the joint frequency distribution for A Area.

Wind Speed Category	SSE			Observation Distribution Stability Category			
	A	B	C	D	E	F	G
1	111	22	5	8	6	1	0
2	220	75	102	75	59	12	1
3	80	43	46	92	131	35	4
4	15	7	12	12	4	2	1
5	5	0	4	0	3	0	0
6	0	0	0	0	0	0	0

Total Records 39224

Wind Speed Category	SSE			Frequency Distribution Stability Category			
	A	B	C	D	E	F	G
1	2.830E-03	5.609E-04	1.275E-04	2.040E-04	1.530E-04	2.549E-05	0.000E+00
2	5.609E-03	1.912E-03	2.600E-03	1.912E-03	1.504E-03	3.059E-04	2.549E-05
3	2.040E-03	1.096E-03	1.173E-03	2.346E-03	3.340E-03	8.923E-04	1.020E-04
4	3.824E-04	1.785E-04	3.059E-04	3.059E-04	1.020E-04	5.099E-05	2.549E-05
5	1.275E-04	0.000E+00	1.020E-04	0.000E+00	7.648E-05	0.000E+00	0.000E+00
6	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Wind speeds are calculated in the same manner as shown in previous examples and the corrected values (UHS) are shown below. Values of UHE are not needed for a vent release since UHE=UHS.

Wind Speed Category	SSE			Average Wind Speeds (UA) (meters/sec) Stability Category			
	A	B	C	D	E	F	G
1	1.20	1.34	1.76	1.13	0.96	0.46	0.00
2	2.67	2.72	2.97	3.09	3.20	3.47	3.73
3	4.57	4.70	4.68	4.65	4.66	4.76	5.08
4	6.54	6.11	6.35	6.36	6.63	6.07	6.04
5	8.80	0.00	9.94	0.00	8.95	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Wind Speed Category	NNW			Average Wind Speeds (UHS) (meters/sec) Stability Category			
	A	B	C	D	E	F	G
1	1.04	1.12	1.44	0.81	0.55	0.21	0.00
2	2.31	2.27	2.43	2.22	1.82	1.61	1.73
3	3.95	3.92	3.83	3.35	2.65	2.21	2.36
4	5.65	5.09	5.20	4.58	3.77	2.82	2.81
5	7.60	0.00	8.13	0.00	5.08	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00

For a downwind distance of 16090 m the horizontal and vertical diffusion coefficients were calculated with values shown in the following table.

	Calculated Sigma		Constrained Sigma		
Stability	Sigma Y	Sigma Z	SigmaY	Sigma Z	Sigma Y 800
A	1825.07	3218.00	1825.07	800.00	206.93
B	1460.89	1930.80	1460.89	800.00	165.64
C	1096.71	626.75	1096.71	626.75	124.35
D	732.54	192.56	732.54	192.56	83.06
E	364.18	82.84	364.18	82.84	41.29
F	184.18	44.18	184.18	44.18	20.88
G	125.58	23.56	125.58	23.56	14.24

The value of M, the coefficient for meander was determined for wind speed between 2-6 m/s using the following equation:

$$M = e^{S \times \ln(U_{10}) + C}$$

where S and C are constants as a function of stability class as shown previously in Table A.1.

For stability class G and Wind speed category 4 the following calculation was performed:

$$M = e^{S\times\ln(U_{10})+C} = e^{-1.6309\times\ln(2.81)+2.922} = 3.45$$

The meander coefficients are shown below.

Wind Speed Category	NNW A	B	C	Meander Coefficients Stability D	E	F	G
1				2.00	3.00	4.00	1.00
2				1.87	3.00	4.00	6.00
3				1.44	2.27	3.52	4.58
4				1.19	1.59	2.59	3.45
5							
6							

For a vent release the relative air concentration without meander is calculated for stability class G and the fourth wind speed class by taking the higher result of the two following equations:

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{U_{10}(\pi\sigma_y\sigma_z + \frac{A}{2})} \qquad \frac{\chi_2}{Q}(x,0,0) = \frac{1}{U_{10}(3\pi\sigma_y\sigma_z)}$$

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{2.81(\pi 125.58 * 23.56 + \frac{0}{2})} \qquad \frac{\chi_2}{Q}(x,0,0) = \frac{1}{2.81(3\pi 125.58 * 23.56)}$$

$$\frac{\chi_2}{Q}(x,0,0) = 3.83E-5\frac{s}{m^3} \qquad \frac{\chi_2}{Q}(x,0,0) = 1.28E-5\frac{s}{m^3}$$

The higher of these two values (3.83E-05 s/m^3) was the relative air concentration value without meander.

Now meander must be considered. For distances greater than 800 m the following equation was used to determine Σy:

$$\Sigma_y = (M-1)\sigma_{y800m} + \sigma_y = (3.45-1)14.24 + 125.58 = 160.47$$

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{U_{10}(\pi\Sigma_y\sigma_z)}$$

$$\frac{\chi_2}{Q}(x,0,0) = \frac{1}{2.81(\pi 160.47 * 23.56)}$$

$$\frac{\chi_2}{Q}(x,0,0) = 3.00E-05\frac{s}{m^3}$$

The values calculated for all wind speeds and stability classes are shown below.

Wind Speed Category	SSE A	B	C	X/Q without meander Stability Category D	E	F	G
1	2.10E-07	2.44E-07	3.22E-07	2.77E-06	1.93E-05	1.83E-04	0.00E+00
2	9.45E-08	1.20E-07	1.91E-07	1.01E-06	5.80E-06	2.43E-05	6.21E-05
3	5.52E-08	6.95E-08	1.21E-07	6.74E-07	3.99E-06	1.77E-05	4.56E-05
4	3.86E-08	5.35E-08	8.91E-08	4.93E-07	2.80E-06	1.39E-05	3.83E-05
5	2.87E-08	0.00E+00	5.69E-08	0.00E+00	2.08E-06	0.00E+00	0.00E+00
6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Wind Speed Category	SSE A	B	C	Meander X/Q Stability Category D	E	F	G
1				2.49E-06	1.58E-05	1.37E-04	0.00E+00
2				9.23E-07	4.73E-06	1.81E-05	3.96E-05
3				6.42E-07	3.49E-06	1.38E-05	3.24E-05
4				4.83E-07	2.63E-06	1.17E-05	3.00E-05
5							
6							

The relative air concentration with meander was compared to the relative air concentration without meander and the smaller of the two values was used. The value would then be 3.00E-05 s/m^3 for stability class G with wind speed category 4.

The sector arc relative air concentration for stability class wind speed category 4 the concentration was determined using the following equation:

$$\frac{\chi}{Q}(x,0) = \frac{\chi}{Q}(x,0,0)\frac{6.38308\sigma_y}{x}$$

$$\frac{\chi}{Q}(x,0) = 3.00E-05\frac{6.38308*125.58}{16090} = 1.49E-6 s/m^3$$

Wind Speed Category	SSE			Sector Arc X/Q for Distance 16090 m Stability Category			
	A	B	C	D	E	F	G
1	1.52E-07	1.41E-07	1.40E-07	7.24E-07	2.28E-06	9.98E-06	0.00E+00
2	6.84E-08	6.96E-08	8.29E-08	2.68E-07	6.84E-07	1.32E-06	1.97E-06
3	4.00E-08	4.03E-08	5.26E-08	1.86E-07	5.04E-07	1.00E-06	1.61E-06
4	2.79E-08	3.10E-08	3.88E-08	1.40E-07	3.79E-07	8.58E-07	1.49E-06
5	2.08E-08	0.00E+00	2.48E-08	0.00E+00	3.00E-07	0.00E+00	0.00E+00
6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Shown below are the depletion factors. See the previous example for how the depletion factors were determined.

Depletion Factors

WS	A	B	C	D	E	F	G
1	0.9743	0.9674	0.9587	0.8471	0.6626	0.1760	1.0000
2	0.9884	0.9838	0.9753	0.9411	0.8838	0.7943	0.7225
3	0.9932	0.9906	0.9842	0.9605	0.9187	0.8455	0.7877
4	0.9952	0.9928	0.9884	0.9709	0.9421	0.8766	0.8182
5	0.9965	1.0000	0.9926	1.0000	0.9568	1.0000	1.0000
6	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Shown below are the doses that were calculated for each of the 42 stability class and wind speed combinations. Although age-dependent dose conversions factors are not given for use by DOE, the two are reported separately because breathing rates for the two age groups are different.

The first two columns show the stability and wind speed combinations. The third column shows the sector arc relative air concentration adjusted for depletion. The fourth column shows the associated frequency of occurrence. The following example shows inhalation dose calculations for the adult for stability class G with wind speed category of 4. The doses were calculated as follows:

Adult dose

$$D = 3.17E-08(Q)(\frac{\chi}{Q})(DF)(B)DD * P$$

$$D = 3.17E-08(1)(1.49E-06)(95)(10500 * 0.622)(50.3)(0.8182)$$

$$D = 1.21e-06$$

A similar calculation was done for the child dose using a breathing rate of 6840 m^3/yr and a population fraction of 0.378. The results were summed as shown in the following table.

ST	WS	Sector Arc X/Q Dep & Dec	Frequency	ADULT DOSE	CHILD DOSE	TOTAL DOSE
A	1	1.48E-07	2.83E-03	1.47E-07	5.81E-08	2.05E-07
A	2	6.76E-08	5.61E-03	6.69E-08	2.65E-08	9.34E-08
A	3	3.97E-08	2.04E-03	3.93E-08	1.56E-08	5.48E-08
A	4	2.78E-08	3.82E-04	2.75E-08	1.09E-08	3.84E-08
A	5	2.07E-08	1.27E-04	2.05E-08	8.10E-09	2.86E-08
A	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B	1	1.37E-07	5.61E-04	1.35E-07	5.36E-08	1.89E-07
B	2	6.85E-08	1.91E-03	6.78E-08	2.68E-08	9.47E-08
B	3	3.99E-08	1.10E-03	3.95E-08	1.56E-08	5.52E-08
B	4	3.08E-08	1.78E-04	3.05E-08	1.21E-08	4.25E-08
B	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C	1	1.34E-07	1.27E-04	1.33E-07	5.26E-08	1.85E-07
C	2	8.09E-08	2.60E-03	8.00E-08	3.17E-08	1.12E-07
C	3	5.18E-08	1.17E-03	5.13E-08	2.03E-08	7.15E-08
C	4	3.83E-08	3.06E-04	3.79E-08	1.50E-08	5.29E-08
C	5	2.46E-08	1.02E-04	2.43E-08	9.63E-09	3.40E-08
C	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
D	1	6.13E-07	2.04E-04	6.07E-07	2.40E-07	8.47E-07
D	2	2.52E-07	1.91E-03	2.50E-07	9.89E-08	3.49E-07
D	3	1.79E-07	2.35E-03	1.77E-07	7.02E-08	2.47E-07
D	4	1.36E-07	3.06E-04	1.35E-07	5.33E-08	1.88E-07
D	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
D	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	1	1.51E-06	1.53E-04	1.49E-06	5.92E-07	2.09E-06
E	2	6.04E-07	1.50E-03	5.98E-07	2.37E-07	8.35E-07
E	3	4.63E-07	3.34E-03	4.58E-07	1.81E-07	6.39E-07
E	4	3.57E-07	1.02E-04	3.54E-07	1.40E-07	4.94E-07
E	5	2.87E-07	7.65E-05	2.84E-07	1.12E-07	3.96E-07
E	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F	1	1.76E-06	2.55E-05	1.74E-06	6.88E-07	2.43E-06
F	2	1.05E-06	3.06E-04	1.04E-06	4.12E-07	1.45E-06
F	3	8.49E-07	8.92E-04	8.41E-07	3.33E-07	1.17E-06
F	4	7.52E-07	5.10E-05	7.45E-07	2.95E-07	1.04E-06
F	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
G	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
G	2	1.43E-06	2.55E-05	1.41E-06	5.59E-07	1.97E-06
G	3	1.27E-06	1.02E-04	1.26E-06	4.98E-07	1.76E-06
G	4	1.22E-06	2.55E-05	1.21E-06	4.79E-07	1.69E-06
G	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
G	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Similar calculations were performed at the remaining distances of 20, 30, 40, and 50 miles from the release location. The next table shows these values along with their corresponding frequency.

ST	WS	10	20	30	40	50	SUM	FREQUENCY
A	1	2.05E-07	7.34E-07	1.31E-06	1.94E-06	1.13E-06	5.32E-06	2.83E-03
A	2	9.34E-08	3.37E-07	6.05E-07	9.03E-07	5.33E-07	2.47E-06	5.61E-03
A	3	5.48E-08	1.98E-07	3.57E-07	5.34E-07	3.16E-07	1.46E-06	2.04E-03
A	4	3.84E-08	1.39E-07	2.51E-07	3.75E-07	2.22E-07	1.03E-06	3.82E-04
A	5	2.86E-08	1.03E-07	1.87E-07	2.80E-07	1.66E-07	7.65E-07	1.27E-04
A	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B	1	1.89E-07	6.78E-07	1.21E-06	1.80E-06	1.05E-06	4.93E-06	5.61E-04
B	2	9.47E-08	3.42E-07	6.14E-07	9.16E-07	5.41E-07	2.51E-06	1.91E-03
B	3	5.52E-08	1.99E-07	3.59E-07	5.38E-07	3.18E-07	1.47E-06	1.10E-03
B	4	4.25E-08	1.54E-07	2.78E-07	4.16E-07	2.46E-07	1.14E-06	1.78E-04
B	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
B	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C	1	1.85E-07	5.22E-07	9.36E-07	1.39E-06	8.20E-07	3.86E-06	1.27E-04
C	2	1.12E-07	3.16E-07	5.68E-07	8.49E-07	5.01E-07	2.35E-06	2.60E-03
C	3	7.15E-08	2.03E-07	3.65E-07	5.47E-07	3.24E-07	1.51E-06	1.17E-03
C	4	5.29E-08	1.50E-07	2.71E-07	4.06E-07	2.40E-07	1.12E-06	3.06E-04
C	5	3.40E-08	9.64E-08	1.74E-07	2.61E-07	1.55E-07	7.20E-07	1.02E-04
C	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
D	1	8.47E-07	2.08E-06	2.97E-06	3.74E-06	1.93E-06	1.16E-05	2.04E-04
D	2	3.49E-07	8.89E-07	1.30E-06	1.68E-06	8.85E-07	5.10E-06	1.91E-03
D	3	2.47E-07	6.28E-07	9.19E-07	1.19E-06	6.26E-07	3.61E-06	2.35E-03
D	4	1.88E-07	4.75E-07	6.96E-07	8.98E-07	4.75E-07	2.73E-06	3.06E-04
D	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
D	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	1	2.09E-06	5.59E-06	7.84E-06	9.25E-06	4.34E-06	2.91E-05	1.53E-04
E	2	8.35E-07	2.70E-06	4.50E-06	6.29E-06	3.48E-06	1.78E-05	1.50E-03
E	3	6.39E-07	2.08E-06	3.52E-06	5.01E-06	2.83E-06	1.41E-05	3.34E-03
E	4	4.94E-07	1.60E-06	2.73E-06	3.92E-06	2.24E-06	1.10E-05	1.02E-04
E	5	3.96E-07	1.28E-06	2.18E-06	3.14E-06	1.80E-06	8.79E-06	7.65E-05
E	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F	1	2.43E-06	2.47E-06	1.34E-06	6.31E-07	1.20E-07	6.99E-06	2.55E-05
F	2	1.45E-06	4.40E-06	6.81E-06	8.81E-06	4.53E-06	2.60E-05	3.06E-04
F	3	1.17E-06	3.69E-06	5.93E-06	7.98E-06	4.26E-06	2.30E-05	8.92E-04
F	4	1.04E-06	3.28E-06	5.36E-06	7.34E-06	3.99E-06	2.10E-05	5.10E-05
F	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
F	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
G	1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
G	2	1.97E-06	5.55E-06	7.90E-06	9.32E-06	4.35E-06	2.91E-05	2.55E-05
G	3	1.76E-06	5.20E-06	7.84E-06	9.83E-06	4.88E-06	2.95E-05	1.02E-04
G	4	1.69E-06	5.05E-06	7.75E-06	9.95E-06	5.07E-06	2.95E-05	2.55E-05
G	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
G	6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Next the doses are shown ranked from highest to lowest along with their respective frequency and cumulative frequency. The last column shows the 99.5% interpolated value.

ST	WS	DOSE	Frequency	Cumulative Frequency	Interpolated Dose(person rem)
G	3	2.95E-05	1.02E-04	1.02E-04	
G	4	2.95E-05	2.55E-05	1.27E-04	
E	1	2.91E-05	1.53E-04	2.80E-04	
G	2	2.91E-05	2.55E-05	3.06E-04	
F	2	2.60E-05	3.06E-04	6.12E-04	
F	3	2.30E-05	8.92E-04	1.50E-03	
F	4	2.10E-05	5.10E-05	1.56E-03	
E	2	1.78E-05	1.50E-03	3.06E-03	
E	3	1.41E-05	3.34E-03	6.40E-03	1.564E-05
D	1	1.16E-05	2.04E-04	6.60E-03	
E	4	1.10E-05	1.02E-04	6.71E-03	
E	5	8.79E-06	7.65E-05	6.78E-03	
F	1	6.99E-06	2.55E-05	6.81E-03	
A	1	5.32E-06	2.83E-03	9.64E-03	
D	2	5.10E-06	1.91E-03	1.15E-02	
B	1	4.93E-06	5.61E-04	1.21E-02	
C	1	3.86E-06	1.27E-04	1.22E-02	
D	3	3.61E-06	2.35E-03	1.46E-02	
D	4	2.73E-06	3.06E-04	1.49E-02	
B	2	2.51E-06	1.91E-03	1.68E-02	
A	2	2.47E-06	5.61E-03	2.24E-02	
C	2	2.35E-06	2.60E-03	2.50E-02	
C	3	1.51E-06	1.17E-03	2.62E-02	
B	3	1.47E-06	1.10E-03	2.73E-02	
A	3	1.46E-06	2.04E-03	2.93E-02	
B	4	1.14E-06	1.78E-04	2.95E-02	
C	4	1.12E-06	3.06E-04	2.98E-02	
A	4	1.03E-06	3.82E-04	3.02E-02	
A	5	7.65E-07	1.27E-04	3.03E-02	
C	5	7.20E-07	1.02E-04	3.04E-02	
A	6	0.00E+00	0.00E+00	3.04E-02	
B	5	0.00E+00	0.00E+00	3.04E-02	
B	6	0.00E+00	0.00E+00	3.04E-02	
C	6	0.00E+00	0.00E+00	3.04E-02	
D	5	0.00E+00	0.00E+00	3.04E-02	
D	6	0.00E+00	0.00E+00	3.04E-02	
E	6	0.00E+00	0.00E+00	3.04E-02	
F	5	0.00E+00	0.00E+00	3.04E-02	
F	6	0.00E+00	0.00E+00	3.04E-02	
G	1	0.00E+00	0.00E+00	3.04E-02	
G	5	0.00E+00	0.00E+00	3.04E-02	
G	6	0.00E+00	0.00E+00	3.04E-02	

A.4. Hand Calculations for 95% Individual Dose with Vent Release

The following calculations were performed by EXCEL spreadsheet using the input parameters shown in the following table.

Location	51345E, 70000N	50% or 95%	0
Vent or Stack	VENT	Deposition	YES
X-Section	1000	Dispersion Coeff.	1
Sector	0 (ALL)	Mixing Height	1000 M
Met Data	NEW	ICRP	30
Year	1990	User Distance	0
Shine Model	0	Source Term	Pu-238 7 Ci, 2hr
Ingrowth	YES		

The same EXCEL Spreadsheet that was used to calculated the 99.5% dose by sector was utilized to determine the 95% dose to an offsite individual. The spreadsheet was executed 16 times for each of the sectors using the downwind distances shown in the following table.

Distance to Site Boundary for C Area Release

Sector	Downwind Distance (km)
S	15.58
SSW	12.96
SW	10.74
WSW	10.74
W	10.25
WNW	10.25
NW	11.56
NNW	11.84
N	12.73
NNE	14.49
NE	16.17
ENE	16.43
E	15.65
ESE	15.65
SE	16.45
SSE	16.39

The following table shows the dose that was determined for each of the 16 sectors with 42 wind speed and stability class combinations for each.

Sector	Stability Class	Wind Speed	χ/Q	Frequency	EDE (mrem)
SOUTH-1	A	1	1.76E-07	0.30%	2.11E+02
1	A	2	9.39E-08	0.70%	1.14E+02
1	A	3	5.52E-08	0.60%	6.72E+01
1	A	4	4.08E-08	0.12%	4.97E+01
1	A	5	2.91E-08	0.01%	3.56E+01
1	A	6	0.00E+00	0.00%	0.00E+00
1	B	1	2.00E-07	0.03%	2.39E+02
1	B	2	1.17E-07	0.18%	1.42E+02
1	B	3	7.08E-08	0.11%	8.59E+01
1	B	4	4.68E-08	0.01%	5.69E+01
1	B	5	0.00E+00	0.00%	0.00E+00
1	B	6	0.00E+00	0.00%	0.00E+00
1	C	1	3.86E-07	0.02%	4.50E+02
1	C	2	2.01E-07	0.12%	2.40E+02
1	C	3	1.28E-07	0.08%	1.54E+02
1	C	4	8.70E-08	0.02%	1.05E+02
1	C	5	0.00E+00	0.00%	0.00E+00
1	C	6	0.00E+00	0.00%	0.00E+00
1	D	1	1.69E-06	0.01%	1.86E+03
1	D	2	1.03E-06	0.05%	1.18E+03
1	D	3	6.64E-07	0.07%	7.81E+02
1	D	4	4.78E-07	0.03%	5.69E+02
1	D	5	0.00E+00	0.00%	0.00E+00
1	D	6	0.00E+00	0.00%	0.00E+00
1	E	1	0.00E+00	0.00%	0.00E+00
1	E	2	4.81E-06	0.05%	5.22E+03
1	E	3	3.63E-06	0.08%	4.08E+03
1	E	4	2.85E-06	0.00%	3.28E+03
1	E	5	0.00E+00	0.00%	0.00E+00
1	E	6	0.00E+00	0.00%	0.00E+00
1	F	1	0.00E+00	0.00%	0.00E+00
1	F	2	1.73E-05	0.01%	1.71E+04
1	F	3	1.42E-05	0.04%	1.47E+04
1	F	4	0.00E+00	0.00%	0.00E+00
1	F	5	0.00E+00	0.00%	0.00E+00
1	F	6	0.00E+00	0.00%	0.00E+00
1	G	1	0.00E+00	0.00%	0.00E+00
1	G	2	4.39E-05	0.01%	3.81E+04
1	G	3	3.37E-05	0.01%	3.23E+04
1	G	4	0.00E+00	0.00%	0.00E+00
1	G	5	0.00E+00	0.00%	0.00E+00
1	G	6	0.00E+00	0.00%	0.00E+00
SSW-2	A	1	1.94E-07	0.34%	232.8844
2	A	2	1.04E-07	0.79%	125.7087
2	A	3	6.07E-08	0.30%	73.8999
2	A	4	4.30E-08	0.06%	52.49136
2	A	5	3.39E-08	0.01%	41.4353

2	A	6	0.00E+00	0.00%	0
2	B	1	2.70E-07	0.05%	320.3445
2	B	2	1.26E-07	0.36%	152.1295
2	B	3	7.56E-08	0.29%	91.74401
2	B	4	5.74E-08	0.09%	69.89366
2	B	5	4.30E-08	0.01%	52.46548
2	B	6	0.00E+00	0.00%	0
2	C	1	4.60E-07	0.03%	538.9867
2	C	2	2.38E-07	0.32%	284.4234
2	C	3	1.49E-07	0.37%	179.8161
2	C	4	1.11E-07	0.13%	134.8681
2	C	5	7.10E-08	0.00%	86.31844
2	C	6	0.00E+00	0.00%	0
2	D	1	3.24E-06	0.02%	3393.913
2	D	2	1.14E-06	0.29%	1322.103
2	D	3	7.60E-07	0.40%	899.0083
2	D	4	5.79E-07	0.15%	691.5092,
2	D	5	3.90E-07	0.02%	470.188
2	D	6	0.00E+00	0.00%	0
2	E	1	1.22E-05	0.01%	11736.59
2	E	2	5.45E-06	0.18%	5987.64
2	E	3	3.79E-06	0.36%	4336.613
2	E	4	3.09E-06	0.15%	3588.965
2	E	5	0.00E+00	0.00%	0
2	E	6	0.00E+00	0.00%	0
2	F	1	3.83E-05	0.00%	32501.83
2	F	2	2.13E-05	0.02%	21303.43
2	F	3	1.48E-05	0.18%	15923.58
2	F	4	1.27E-05	0.10%	13988.86
2	F	5	1.10E-05	0.00%	12345.99
2	F	6	0.00E+00	0.00%	0
2	G	1	1.18E-03	0.00%	1134.287
2	G	2	4.97E-05	0.01%	45028.06
2	G	3	3.63E-05	0.03%	36585.9
2	G	4	3.27E-05	0.02%	34352.86
2	G	5	0.00E+00	0.00%	0
2	G	6	0.00E+00	0.00%	0
SW-3	A	1	2.24E-07	0.29%	2.69E+02
3	A	2	1.12E-07	0.72%	1.36E+02
3	A	3	7.06E-08	0.17%	8.60E+01
3	A	4	4.65E-08	0.01%	5.67E+01
3	A	5	3.68E-08	0.00%	4.50E+01
3	A	6	0.00E+00	0.00%	0.00E+00
3	B	1	2.53E-07	0.06%	3.02E+02
3	B	2	1.39E-07	0.37%	1.68E+02
3	B	3	8.48E-08	0.25%	1.03E+02
3	B	4	6.36E-08	0.03%	7.74E+01
3	B	5	0.00E+00	0.00%	0.00E+00
3	B	6	0.00E+00	0.00%	0.00E+00

3	C	1	6.14E-07	0.05%	7.19E+02
3	C	2	2.98E-07	0.67%	3.57E+02
3	C	3	1.86E-07	0.77%	2.25E+02
3	C	4	1.37E-07	0.30%	1.67E+02
3	C	5	1.09E-07	0.01%	1.33E+02
3	C	6	0.00E+00	0.00%	0.00E+00
3	D	1	3.82E-06	0.03%	4.06E+03
3	D	2	1.35E-06	0.80%	1.58E+03
3	D	3	9.15E-07	1.72%	1.09E+03
3	D	4	7.00E-07	0.71%	8.38E+02
3	D	5	5.51E-07	0.11%	6.63E+02
3	D	6	0.00E+00	0.00%	0.00E+00
3	E	1	1.13E-05	0.01%	1.16E+04
3	E	2	5.89E-06	0.24%	6.58E+03
3	E	3	4.33E-06	0.91%	4.99E+03
3	E	4	3.42E-06	0.48%	4.00E+03
3	E	5	2.95E-06	0.01%	3.48E+03.
3	E	6	0.00E+00	0.00%	0.00E+00
3	F	1	3.04E-04	0.00%	3.86E+04
3	F	2	2.41E-05	0.05%	2.47E+04
3	F	3	1.67E-05	0.21%	1.83E+04
3	F	4	1.40E-05	0.34%	1.58E+04
3	F	5	1.23E-05	0.01%	1.40E+04
3	F	6	0.00E+00	0.00%	0.00E+00
3	G	1	1.59E-04	0.00%	9.29E+04
3	G	2	5.10E-05	0.00%	4.93E+04
3	G	3	4.01E-05	0.04%	4.18E+04
3	G	4	3.57E-05	0.08%	3.87E+04
3	G	5	3.30E-05	0.00%	3.64E+04
3	G	6	0.00E+00	0.00%	0.00E+00
WSW-4	A	1	2.32E-07	0.30%	2.79E+02
4	A	2	1.12E-07	0.74%	1.36E+02
4	A	3	6.94E-08	0.10%	8.45E+01
4	A	4	4.77E-08	0.03%	5.82E+01
4	A	5	0.00E+00	0.00%	0.00E+00
4	A	6	0.00E+00	0.00%	0.00E+00
4	B	1	2.44E-07	0.05%	2.92E+02
4	B	2	1.39E-07	0.34%	1.68E+02
4	B	3	8.60E-08	0.26%	1.04E+02
4	B	4	5.94E-08	0.01%	7.23E+01
4	B	5	0.00E+00	0.00%	0.00E+00
4	B	6	0.00E+00	0.00%	0.00E+00
4	C	1	6.31E-07	0.06%	7.38E+02
4	C	2	3.03E-07	0.66%	3.63E+02
4	C	3	1.91E-07	0.73%	2.31E+02
4	C	4	1.42E-07	0.06%	1.72E+02
4	C	5	0.00E+00	0.00%	0.00E+00
4	C	6	0.00E+00	0.00%	0.00E+00
4	D	1	2.62E-06	0.04%	2.91E+03

4	D	2	1.35E-06	1.08%	1.58E+03
4	D	3	9.57E-07	1.21%	1.13E+03
4	D	4	6.97E-07	0.23%	8.35E+02
4	D	5	5.63E-07	0.02%	6.77E+02
4	D	6	0.00E+00	0.00%	0.00E+00
4	E	1	1.16E-05	0.03%	1.19E+04
4	E	2	5.93E-06	0.56%	6.62E+03
4	E	3	4.52E-06	0.77%	5.19E+03
4	E	4	3.59E-06	0.15%	4.19E+03
4	E	5	0.00E+00	0.00%	0.00E+00
4	E	6	0.00E+00	0.00%	0.00E+00
4	F	1	0.00E+00	0.00%	0.00E+00
4	F	2	2.39E-05	0.14%	2.45E+04
4	F	3	1.72E-05	0.25%	1.86E+04
4	F	4	1.47E-05	0.10%	1.64E+04
4	F	5	1.23E-05	0.00%	1.40E+04
4	F	6	0.00E+00	0.00%	0.00E+00
4	G	1	0.00E+00	0.00%	0.00E+00
4	G	2	4.85E-05	0.00%	4.74E+04
4	G	3	4.04E-05	0.04%	4.19E+04
4	G	4	3.55E-05	0.03%	3.85E+04
4	G	5	0.00E+00	0.00%	0.00E+00
4	G	6	0.00E+00	0.00%	0.00E+00
W-5	A	1	2.27E-07	0.31%	2.73E+02
5	A	2	1.18E-07	0.79%	1.43E+02
5	A	3	7.25E-08	0.11%	8.83E+01
5	A	4	4.68E-08	0.00%	5.70E+01
5	A	5	3.89E-08	0.00%	4.75E+01
5	A	6	0.00E+00	0.00%	0.00E+00
5	B	1	2.75E-07	0.06%	3.28E+02
5	B	2	1.45E-07	0.40%	1.75E+02
5	B	3	9.12E-08	0.21%	1.11E+02
5	B	4	6.77E-08	0.01%	8.24E+01
5	B	5	5.73E-08	0.00%	6.98E+01
5	B	6	0.00E+00	0.00%	0.00E+00
5	C	1	5.95E-07	0.03%	7.00E+02
5	C	2	3.13E-07	0.52%	3.76E+02
5	C	3	2.06E-07	0.44%	2.49E+02
5	C	4	1.54E-07	0.05%	1.87E+02
5	C	5	0.00E+00	0.00%	0.00E+00
5	C	6	0.00E+00	0.00%	0.00E+00
5	D	1	2.48E-06	0.02%	2.78E+03
5	D	2	1.41E-06	0.66%	1.65E+03
5	D	3	1.01E-06	0.66%	1.19E+03
5	D	4	7.42E-07	0.09%	8.89E+02
5	D	5	5.40E-07	0.01%	6.50E+02
5	D	6	0.00E+00	0.00%	0.00E+00
5	E	1	1.24E-05	0.01%	1.27E+04
5	E	2	6.01E-06	0.30%	6.74E+03

5	E	3	4.51E-06	0.66%	5.20E+03
5	E	4	3.70E-06	0.08%	4.33E+03
5	E	5	0.00E+00	0.00%	0.00E+00
5	E	6	0.00E+00	0.00%	0.00E+00
5	F	1	0.00E+00	0.00%	0.00E+00
5	F	2	2.29E-05	0.04%	2.39E+04
5	F	3	1.71E-05	0.23%	1.88E+04
5	F	4	1.51E-05	0.08%	1.69E+04
5	F	5	0.00E+00	0.00%	0.00E+00
5	F	6	0.00E+00	0.00%	0.00E+00
5	G	1	0.00E+00	0.00%	0.00E+00
5	G	2	0.00E+00	0.00%	0.00E+00
5	G	3	4.20E-05	0.02%	4.36E+04
5	G	4	3.81E-05	0.01%	4.11E+04
5	G	5	0.00E+00	0.00%	0.00E+00
5	G	6	0.00E+00	0.00%	0.00E+00
WNW-6	A	1	2.26E-07	0.30%	2.71E+02
6	A	2	1.20E-07	0.80%	1.46E+02
6	A	3	6.95E-08	0.08%	8.46E+01
6	A	4	5.34E-08	0.01%	6.51E+01
6	A	5	0.00E+00	0.00%	0.00E+00
6	A	6	0.00E+00	0.00%	0.00E+00
6	B	1	2.27E-07	0.04%	2.73E+02
6	B	2	1.44E-07	0.33%	1.74E+02
6	B	3	9.24E-08	0.07%	1.12E+02
6	B	4	6.01E-08	0.01%	7.32E+01
6	B	5	0.00E+00	0.00%	0.00E+00
6	B	6	0.00E+00	0.00%	0.00E+00
6	C	1	5.91E-07	0.03%	6.95E+02
6	C	2	3.27E-07	0.35%	3.92E+02
6	C	3	2.04E-07	0.24%	2.46E+02
6	C	4	1.49E-07	0.04%	1.80E+02
6	C	5	0.00E+00	0.00%	0.00E+00
6	C	6	7.79E-08	0.00%	9.49E+01
6	D	1	2.64E-06	0.02%	2.95E+03
6	D	2	1.43E-06	0.48%	1.66E+03
6	D	3	9.84E-07	0.58%	1.17E+03
6	D	4	7.21E-07	0.05%	8.63E+02
6	D	5	5.96E-07	0.01%	7.17E+02
6	D	6	4.14E-07	0.00%	5.01E+02
6	E	1	1.17E-05	0.01%	1.21E+04
6	E	2	6.22E-06	0.23%	6.95E+03
6	E	3	4.55E-06	0.54%	5.24E+03
6	E	4	3.67E-06	0.04%	4.30E+03
6	E	5	0.00E+00	0.00%	0.00E+00
6	E	6	0.00E+00	0.00%	0.00E+00
6	F	1	4.08E-05	0.00%	3.75E+04
6	F	2	2.46E-05	0.03%	2.54E+04
6	F	3	1.73E-05	0.12%	1.90E+04

6	F	4	1.50E-05	0.04%	1.69E+04
6	F	5	0.00E+00	0.00%	0.00E+00
6	F	6	0.00E+00	0.00%	0.00E+00
6	G	1	0.00E+00	0.00%	0.00E+00
6	G	2	4.98E-05	0.01%	4.91E+04
6	G	3	4.09E-05	0.02%	4.30E+04
6	G	4	3.78E-05	0.01%	4.09E+04
6	G	5	0.00E+00	0.00%	0.00E+00
6	G	6	0.00E+00	0.00%	0.00E+00
NW-7	A	1	2.27E-07	0.27%	2.73E+02
7	A	2	1.12E-07	0.58%	1.36E+02
7	A	3	7.00E-08	0.06%	8.52E+01
7	A	4	5.48E-08	0.01%	6.68E+01
7	A	5	0.00E+00	0.00%	0.00E+00
7	A	6	0.00E+00	0.00%	0.00E+00
7	B	1	2.28E-07	0.02%	2.73E+02
7	B	2	1.37E-07	0.22%	1.66E+02
7	B	3	8.51E-08	0.08%	1.03E+02
7	B	4	6.14E-08	0.01%	7.47E+01
7	B	5	0.00E+00	0.00%	0.00E+00
7	B	6	0.00E+00	0.00%	0.00E+00
7	C	1	5.49E-07	0.04%	6.43E+02
7	C	2	2.74E-07	0.33%	3.28E+02
7	C	3	1.79E-07	0.20%	2.16E+02
7	C	4	1.26E-07	0.04%	1.52E+02
7	C	5	0.00E+00	0.00%	0.00E+00
7	C	6	0.00E+00	0.00%	0.00E+00
7	D	1	2.47E-06	0.03%	2.73E+03
7	D	2	1.26E-06	0.42%	1.47E+03
7	D	3	8.68E-07	0.69%	1.03E+03
7	D	4	6.66E-07	0.10%	7.96E+02
7	D	5	5.31E-07	0.01%	6.38E+02
7	D	6	0.00E+00	0.00%	0.00E+00
7	E	1	1.04E-05	0.01%	1.07E+04
7	E	2	5.97E-06	0.28%	6.60E+03
7	E	3	4.12E-06	0.75%	4.73E+03
7	E	4	3.37E-06	0.05%	3.93E+03
7	E	5	0.00E+00	0.00%	0.00E+00
7	E	6	0.00E+00	0.00%	0.00E+00
7	F	1	3.86E-05	0.00%	3.44E+04
7	F	2	2.33E-05	0.04%	2.35E+04
7	F	3	1.61E-05	0.20%	1.74E+04
7	F	4	1.40E-05	0.04%	1.56E+04
7	F	5	0.00E+00	0.00%	0.00E+00
7	F	6	0.00E+00	0.00%	0.00E+00
7	G	1	0.00E+00	0.00%	0.00E+00
7	G	2	5.92E-05	0.00%	5.34E+04
7	G	3	3.94E-05	0.05%	4.00E+04
7	G	4	3.57E-05	0.01%	3.79E+04

7	G	5	0.00E+00	0.00%	0.00E+00
7	G	6	0.00E+00	0.00%	0.00E+00
NNW-8	A	1	2.32E-07	0.27%	2.78E+02
8	A	2	1.12E-07	0.70%	1.36E+02
8	A	3	6.73E-08	0.14%	8.19E+01
8	A	4	5.08E-08	0.01%	6.19E+01
8	A	5	3.90E-08	0.00%	4.76E+01
8	A	6	0.00E+00	0.00%	0.00E+00
8	B	1	2.46E-07	0.03%	2.93E+02
8	B	2	1.31E-07	0.27%	1.58E+02
8	B	3	8.36E-08	0.15%	1.01E+02
8	B	4	5.69E-08	0.02%	6.93E+01
8	B	5	4.85E-08	0.00%	5.91E+01
8	B	6	0.00E+00	0.00%	0.00E+00
8	C	1	5.76E-07	0.04%	6.72E+02
8	C	2	2.70E-07	0.33%	3.23E+02
8	C	3	1.70E-07	0.30%	2.06E+02
8	C	4	1.27E-07	0.07%	1.54E+02
8	C	5	9.22E-08	0.02%	1.12E+02
8	C	6	0.00E+00	0.00%	0.00E+00
8	D	1	2.77E-06	0.03%	3.01E+03
8	D	2	1.23E-06	0.58%	1.43E+03
8	D	3	8.29E-07	1.14%	9.82E+02
8	D	4	6.49E-07	0.32%	7.75E+02
8	D	5	4.56E-07	0.02%	5.49E+02
8	D	6	0.00E+00	0.00%	0.00E+00
8	E	1	1.01E-05	0.01%	1.03E+04
8	E	2	5.56E-06	0.40%	6.17E+03
8	E	3	4.06E-06	1.54%	4.66E+03
8	E	4	3.34E-06	0.19%	3.89E+03
8	E	5	0.00E+00	0.00%	0.00E+00
8	E	6	0.00E+00	0.00%	0.00E+00
8	F	1	5.92E-05	0.00%	4.38E+04
8	F	2	2.26E-05	0.12%	2.28E+04
8	F	3	1.61E-05	0.36%	1.73E+04
8	F	4	1.38E-05	0.07%	1.53E+04
8	F	5	0.00E+00	0.00%	0.00E+00
8	F	6	0.00E+00	0.00%	0.00E+00
8	G	1	0.00E+00	0.00%	0.00E+00
8	G	2	4.42E-05	0.01%	4.28E+04
8	G	3	3.87E-05	0.03%	3.93E+04
8	G	4	3.45E-05	0.02%	3.67E+04
8	G	5	0.00E+00	0.00%	0.00E+00
8	G	6	0.00E+00	0.00%	0.00E+00
N-9	A	1	2.20E-07	0.26%	263.5215
9	A	2	1.07E-07	0.66%	129.6898
9	A	3	6.61E-08	0.13%	80.43847
9	A	4	4.47E-08	0.01%	54.45966
9	A	5	3.63E-08	0.00%	44.25935

9	A	6	0.00E+00	0.00%	0
9	B	1	2.39E-07	0.05%	284.4659
9	B	2	1.21E-07	0.29%	146.5123
9	B	3	7.87E-08	0.17%	95.51963
9	B	4	5.85E-08	0.03%	71.19363
9	B	5	4.12E-08	0.01%	50.27728
9	B	6	0.00E+00	0.00%	0
9	C	1	4.58E-07	0.05%	537.1482
9	C	2	2.50E-07	0.44%	298.9708
9	C	3	1.57E-07	0.41%	189.7058
9	C	4	1.10E-07	0.11%	133.782
9	C	5	8.54E-08	0.03%	103.7973
9	C	6	0.00E+00	0.00%	0
9	D	1	2.40E-06	0.04%	2626.449
9	D	2	1.15E-06	0.72%	1332.068
9	D	3	7.88E-07	1.22%	931.883
9	D	4	5.98E-07	0.28%	713.8821
9	D	5	4.35E-07	0.04%	523.1964
9	D	6	0.00E+00	0.00%	0
9	E	1	9.66E-06	0.02%	9815.852
9	E	2	5.40E-06	0.52%	5959.473
9	E	3	3.91E-06	1.39%	4465.257
9	E	4	3.18E-06	0.13%	3690.522
9	E	5	0.00E+00	0.00%	0
9	E	6	0.00E+00	0.00%	0
9	F	1	0.00E+00	0.00%	0
9	F	2	2.24E-05	0.04%	22275.89
9	F	3	1.55E-05	0.28%	16569.29
9	F	4	1.30E-05	0.05%	14330.61
9	F	5	0.00E+00	0.00%	0
9	F	6	0.00E+00	0.00%	0
9	G	1	0.00E+00	0.00%	0
9	G	2	4.55E-05	0.00%	42571.04
9	G	3	3.67E-05	0.05%	37063.68
9	G	4	3.30E-05	0.02%	34773.24
9	G	5	0.00E+00	0.00%	0
9	G	6	0.00E+00	0.00%	0
NNE-10	A	1	2.01E-07	0.27%	2.41E+02
10	A	2	1.00E-07	0.64%	1.21E+02
10	A	3	5.99E-08	0.12%	7.28E+01
10	A	4	3.95E-08	0.03%	4.82E+01
10	A	5	3.12E-08	0.00%	3.80E+01
10	A	6	0.00E+00	0.00%	0.00E+00
10	B	1	2.09E-07	0.05%	2.49E+02
10	B	2	1.22E-07	0.34%	1.47E+02
10	B	3	7.50E-08	0.21%	9.10E+01
10	B	4	5.29E-08	0.05%	6.44E+01
10	B	5	4.02E-08	0.01%	4.90E+01
10	B	6	0.00E+00	0.00%	0.00E+00

10	C	1	4.36E-07	0.05%	5.08E+02
10	C	2	2.17E-07	0.44%	2.59E+02
10	C	3	1.33E-07	0.46%	1.61E+02
10	C	4	9.54E-08	0.20%	1.16E+02
10	C	5	7.37E-08	0.05%	8.95E+01
10	C	6	0.00E+00	0.00%	0.00E+00
10	D	1	1.96E-06	0.03%	2.15E+03
10	D	2	1.00E-06	0.67%	1.16E+03
10	D	3	6.97E-07	0.80%	8.23E+02
10	D	4	5.14E-07	0.21%	6.13E+02
10	D	5	4.08E-07	0.04%	4.90E+02
10	D	6	0.00E+00	0.00%	0.00E+00
10	E	1	1.03E-05	0.03%	9.94E+03
10	E	2	4.94E-06	0.44%	5.40E+03
10	E	3	3.69E-06	1.06%	4.18E+03
10	E	4	2.94E-06	0.06%	3.39E+03
10	E	5	0.00E+00	0.00%	0.00E+00
10	E	6	0.00E+00	0.00%	0.00E+00
10	F	1	3.78E-05	0.00%	3.04E+04
10	F	2	1.89E-05	0.09%	1.88E+04
10	F	3	1.42E-05	0.30%	1.50E+04
10	F	4	1.23E-05	0.04%	1.34E+04
10	F	5	0.00E+00	0.00%	0.00E+00
10	F	6	0.00E+00	0.00%	0.00E+00
10	G	1	0.00E+00	0.00%	0.00E+00
10	G	2	4.38E-05	0.01%	3.93E+04
10	G	3	3.41E-05	0.01%	3.37E+04
10	G	4	3.14E-05	0.01%	3.22E+04
10	G	5	0.00E+00	0.00%	0.00E+00
10	G	6	0.00E+00	0.00%	0.00E+00
NE-11	A	1	1.85E-07	0.30%	2.22E+02
11	A	2	9.53E-08	0.78%	1.15E+02
11	A	3	5.43E-08	0.13%	6.61E+01
11	A	4	3.85E-08	0.03%	4.70E+01
11	A	5	2.75E-08	0.02%	3.36E+01
11	A	6	0.00E+00	0.00%	0.00E+00
11	B	1	2.16E-07	0.06%	2.57E+02
11	B	2	1.10E-07	0.43%	1.33E+02
11	B	3	6.86E-08	0.27%	8.33E+01
11	B	4	5.14E-08	0.05%	6.25E+01
11	B	5	0.00E+00	0.00%	0.00E+00
11	B	6	0.00E+00	0.00%	0.00E+00
11	C	1	4.05E-07	0.05%	4.70E+02
11	C	2	1.88E-07	0.67%	2.24E+02
11	C	3	1.19E-07	0.54%	1.43E+02
11	C	4	8.42E-08	0.19%	1.02E+02
11	C	5	6.29E-08	0.04%	7.64E+01
11	C	6	0.00E+00	0.00%	0.00E+00
11	D	1	1.71E-06	0.03%	1.87E+03

11	D	2	8.98E-07	0.82%	1.04E+03
11	D	3	6.20E-07	0.98%	7.31E+02
11	D	4	4.58E-07	0.39%	5.46E+02
11	D	5	3.53E-07	0.13%	4.23E+02
11	D	6	0.00E+00	0.00%	0.00E+00
11	E	1	9.26E-06	0.02%	8.90E+03
11	E	2	4.56E-06	0.55%	4.96E+03
11	E	3	3.42E-06	1.11%	3.86E+03
11	E	4	2.68E-06	0.14%	3.09E+03
11	E	5	0.00E+00	0.00%	0.00E+00
11	E	6	0.00E+00	0.00%	0.00E+00
11	F	1	0.00E+00	0.00%	0.00E+00
11	F	2	1.81E-05	0.08%	1.75E+04
11	F	3	1.34E-05	0.33%	1.40E+04
11	F	4	1.11E-05	0.08%	1.20E+04
11	F	5	0.00E+00	0.00%	0.00E+00
11	F	6	0.00E+00	0.00%	0.00E+00
11	G	1	0.00E+00	0.00%	0.00E+00
11	G	2	4.61E-05	0.01%	3.86E+04
11	G	3	3.28E-05	0.03%	3.13E+04
11	G	4	2.87E-05	0.01%	2.92E+04
11	G	5	0.00E+00	0.00%	0.00E+00
11	G	6	0.00E+00	0.00%	0.00E+00
ENE-12	A	1	1.78E-07	0.34%	2.14E+02
12	A	2	9.08E-08	0.80%	1.10E+02
12	A	3	5.43E-08	0.16%	6.60E+01
12	A	4	3.85E-08	0.03%	4.69E+01
12	A	5	2.84E-08	0.01%	3.46E+01
12	A	6	0.00E+00	0.00%	0.00E+00
12	B	1	2.22E-07	0.06%	2.63E+02
12	B	2	1.09E-07	0.43%	1.31E+02
12	B	3	6.93E-08	0.33%	8.40E+01
12	B	4	5.05E-08	0.05%	6.15E+01
12	B	5	4.04E-08	0.00%	4.92E+01
12	B	6	0.00E+00	0.00%	0.00E+00
12	C	1	3.39E-07	0.07%	3.97E+02
12	C	2	1.87E-07	0.56%	2.24E+02
12	C	3	1.15E-07	0.60%	1.38E+02
12	C	4	8.21E-08	0.32%	9.95E+01
12	C	5	6.48E-08	0.07%	7.87E+01
12	C	6	4.16E-08	0.01%	5.06E+01
12	D	1	1.69E-06	0.04%	1.85E+03
12	D	2	8.75E-07	0.85%	1.01E+03
12	D	3	6.15E-07	1.06%	7.24E+02
12	D	4	4.50E-07	0.35%	5.36E+02
12	D	5	3.48E-07	0.12%	4.17E+02
12	D	6	2.36E-07	0.01%	2.85E+02
12	E	1	9.53E-06	0.02%	9.04E+03
12	E	2	4.47E-06	0.40%	4.85E+03

12	E	3	3.35E-06	1.09%	3.77E+03
12	E	4	2.71E-06	0.10%	3.11E+03
12	E	5	0.00E+00	0.00%	0.00E+00
12	E	6	0.00E+00	0.00%	0.00E+00
12	F	1	0.00E+00	0.00%	0.00E+00
12	F	2	1.97E-05	0.03%	1.87E+04
12	F	3	1.35E-05	0.14%	1.39E+04
12	F	4	1.15E-05	0.02%	1.23E+04
12	F	5	0.00E+00	0.00%	0.00E+00
12	F	6	0.00E+00	0.00%	0.00E+00
12	G	1	0.00E+00	0.00%	0.00E+00
12	G	2	3.73E-05	0.00%	3.33E+04
12	G	3	3.23E-05	0.02%	3.09E+04
12	G	4	0.00E+00	0.00%	0.00E+00
12	G	5	0.00E+00	0.00%	0.00E+00
12	G	6	0.00E+00	0.00%	0.00E+00
E-13	A	1	1.78E-07	0.42%	2.13E+02
13	A	2	9.44E-08	0.98%	1.14E+02
13	A	3	5.73E-08	0.19%	6.98E+01
13	A	4	4.17E-08	0.05%	5.09E+01
13	A	5	2.70E-08	0.01%	3.29E+01
13	A	6	0.00E+00	0.00%	0.00E+00
13	B	1	2.07E-07	0.08%	2.47E+02
13	B	2	1.14E-07	0.47%	1.37E+02
13	B	3	6.99E-08	0.35%	8.48E+01
13	B	4	5.07E-08	0.07%	6.17E+01
13	B	5	3.04E-08	0.00%	3.71E+01
13	B	6	0.00E+00	0.00%	0.00E+00
13	C	1	3.52E-07	0.07%	4.12E+02
13	C	2	1.99E-07	0.71%	2.37E+02
13	C	3	1.21E-07	0.58%	1.46E+02
13	C	4	8.60E-08	0.28%	1.04E+02
13	C	5	6.40E-08	0.19%	7.78E+01
13	C	6	4.84E-08	0.00%	5.89E+01
13	D	1	1.71E-06	0.02%	1.88E+03
13	D	2	9.05E-07	0.81%	1.05E+03
13	D	3	6.43E-07	1.29%	7.58E+02
13	D	4	4.71E-07	0.51%	5.61E+02
13	D	5	3.53E-07	0.27%	4.23E+02
13	D	6	2.56E-07	0.01%	3.09E+02
13	E	1	8.69E-06	0.01%	8.55E+03
13	E	2	4.73E-06	0.37%	5.15E+03
13	E	3	3.47E-06	1.06%	3.92E+03
13	E	4	2.74E-06	0.08%	3.16E+03
13	E	5	0.00E+00	0.00%	0.00E+00
13	E	6	0.00E+00	0.00%	0.00E+00
13	F	1	0.00E+00	0.00%	0.00E+00
13	F	2	2.03E-05	0.03%	1.94E+04
13	F	3	1.38E-05	0.12%	1.44E+04

13	F	4	1.17E-05	0.01%	1.26E+04
13	F	5	0.00E+00	0.00%	0.00E+00
13	F	6	0.00E+00	0.00%	0.00E+00
13	G	1	0.00E+00	0.00%	0.00E+00
13	G	2	0.00E+00	0.00%	0.00E+00
13	G	3	3.27E-05	0.01%	3.19E+04
13	G	4	0.00E+00	0.00%	0.00E+00
13	G	5	0.00E+00	0.00%	0.00E+00
13	G	6	0.00E+00	0.00%	0.00E+00
ESE-14	A	1	2.01E-07	0.32%	2.41E+02
14	A	2	9.47E-08	0.87%	1.15E+02
14	A	3	5.77E-08	0.24%	7.02E+01
14	A	4	4.58E-08	0.03%	5.58E+01
14	A	5	2.86E-08	0.01%	3.49E+01
14	A	6	0.00E+00	0.00%	0.00E+00
14	B	1	2.08E-07	0.03%	2.48E+02
14	B	2	1.15E-07	0.31%	1.38E+02
14	B	3	6.85E-08	0.28%	8.31E+01
14	B	4	4.80E-08	0.11%	5.85E+01
14	B	5	3.89E-08	0.02%	4.75E+01
14	B	6	0.00E+00	0.00%	0.00E+00
14	C	1	3.60E-07	0.03%	4.22E+02
14	C	2	1.96E-07	0.46%	2.34E+02
14	C	3	1.23E-07	0.46%	1.49E+02
14	C	4	8.51E-08	0.27%	1.03E+02
14	C	5	6.52E-08	0.20%	7.92E+01
14	C	6	4.66E-08	0.02%	5.67E+01
14	D	1	1.71E-06	0.03%	1.88E+03
14	D	2	9.48E-07	0.54%	1.09E+03
14	D	3	6.34E-07	0.78%	7.47E+02
14	D	4	4.71E-07	0.42%	5.61E+02
14	D	5	3.44E-07	0.25%	4.13E+02
14	D	6	2.59E-07	0.01%	3.13E+02
14	E	1	9.27E-06	0.00%	8.99E+03
14	E	2	4.72E-06	0.30%	5.13E+03
14	E	3	3.40E-06	0.78%	3.85E+03
14	E	4	2.79E-06	0.08%	3.22E+03
14	E	5	0.00E+00	0.00%	0.00E+00
14	E	6	0.00E+00	0.00%	0.00E+00
14	F	1	3.30E-05	0.01%	2.70E+04
14	F	2	1.83E-05	0.07%	1.79E+04
14	F	3	1.36E-05	0.15%	1.42E+04
14	F	4	1.18E-05	0.01%	1.27E+04
14	F	5	0.00E+00	0.00%	0.00E+00
14	F	6	0.00E+00	0.00%	0.00E+00
14	G	1	0.00E+00	0.00%	0.00E+00
14	G	2	0.00E+00	0.00%	0.00E+00
14	G	3	3.41E-05	0.01%	3.23E+04
14	G	4	2.94E-05	0.00%	3.00E+04

14	G	5	0.00E+00	0.00%	0.00E+00
14	G	6	0.00E+00	0.00%	0.00E+00
SE-15	A	1	1.90E-07	0.25%	2.28E+02
15	A	2	9.34E-08	0.54%	1.13E+02
15	A	3	5.77E-08	0.16%	7.02E+01
15	A	4	3.98E-08	0.02%	4.85E+01
15	A	5	3.39E-08	0.01%	4.14E+01
15	A	6	0.00E+00	0.00%	0.00E+00
15	B	1	1.91E-07	0.03%	2.28E+02
15	B	2	1.12E-07	0.17%	1.35E+02
15	B	3	6.94E-08	0.14%	8.42E+01
15	B	4	4.92E-08	0.06%	5.99E+01
15	B	5	4.03E-08	0.01%	4.91E+01
15	B	6	0.00E+00	0.00%	0.00E+00
15	C	1	3.52E-07	0.03%	4.11E+02
15	C	2	1.97E-07	0.28%	2.35E+02
15	C	3	1.14E-07	0.19%	1.37E+02
15	C	4	7.80E-08	0.09%	9.45E+01
15	C	5	5.74E-08	0.03%	6.97E+01
15	C	6	0.00E+00	0.00%	0.00E+00
15	D	1	1.86E-06	0.03%	2.01E+03
15	D	2	8.96E-07	0.29%	1.03E+03
15	D	3	6.16E-07	0.36%	7.25E+02
15	D	4	4.54E-07	0.11%	5.41E+02
15	D	5	3.21E-07	0.02%	3.85E+02
15	D	6	0.00E+00	0.00%	0.00E+00
15	E	1	0.00E+00	0.00%	0.00E+00
15	E	2	4.56E-06	0.20%	4.94E+03
15	E	3	3.39E-06	0.49%	3.81E+03
15	E	4	2.71E-06	0.04%	3.12E+03
15	E	5	0.00E+00	0.00%	0.00E+00
15	E	6	0.00E+00	0.00%	0.00E+00
15	F	1	3.23E-05	0.00%	2.59E+04
15	F	2	1.78E-05	0.06%	1.73E+04
15	F	3	1.34E-05	0.11%	1.39E+04
15	F	4	1.16E-05	0.01%	1.24E+04
15	F	5	0.00E+00	0.00%	0.00E+00
15	F	6	0.00E+00	0.00%	0.00E+00
15	G	1	0.00E+00	0.00%	0.00E+00
15	G	2	3.90E-05	0.00%	3.43E+04
15	G	3	3.29E-05	0.01%	3.10E+04
15	G	4	0.00E+00	0.00%	0.00E+00
15	G	5	0.00E+00	0.00%	0.00E+00
15	G	6	0.00E+00	0.00%	0.00E+00
SSE-16	A	1	1.87E-07	0.27%	2.23E+02
16	A	2	9.43E-08	0.49%	1.14E+02
16	A	3	5.43E-08	0.18%	6.61E+01
16	A	4	3.73E-08	0.03%	4.55E+01
16	A	5	2.76E-08	0.02%	3.37E+01

16	A	6	0.00E+00	0.00%	0.00E+00
16	B	1	2.82E-07	0.04%	3.32E+02
16	B	2	1.14E-07	0.15%	1.38E+02
16	B	3	7.02E-08	0.10%	8.52E+01
16	B	4	4.97E-08	0.01%	6.05E+01
16	B	5	3.67E-08	0.01%	4.47E+01
16	B	6	0.00E+00	0.00%	0.00E+00
16	C	1	4.08E-07	0.02%	4.73E+02
16	C	2	1.79E-07	0.16%	2.14E+02
16	C	3	1.19E-07	0.14%	1.43E+02
16	C	4	8.14E-08	0.03%	9.86E+01
16	C	5	6.26E-08	0.01%	7.60E+01
16	C	6	0.00E+00	0.00%	0.00E+00
16	D	1	1.61E-06	0.04%	1.76E+03
16	D	2	9.22E-07	0.21%	1.06E+03
16	D	3	6.36E-07	0.21%	7.48E+02
16	D	4	4.81E-07	0.01%	5.71E+02
16	D	5	0.00E+00	0.00%	0.00E+00
16	D	6	0.00E+00	0.00%	0.00E+00
16	E	1	8.28E-06	0.01%	8.13E+03
16	E	2	4.77E-06	0.16%	5.14E+03
16	E	3	3.50E-06	0.27%	3.93E+03
16	E	4	2.70E-06	0.01%	3.11E+03
16	E	5	0.00E+00	0.00%	0.00E+00
16	E	6	0.00E+00	0.00%	0.00E+00
16	F	1	3.72E-05	0.00%	2.81E+04
16	F	2	1.83E-05	0.03%	1.77E+04
16	F	3	1.34E-05	0.07%	1.39E+04
16	F	4	1.16E-05	0.00%	1.24E+04
16	F	5	0.00E+00	0.00%	0.00E+00
16	F	6	0.00E+00	0.00%	0.00E+00
16	G	1	0.00E+00	0.00%	0.00E+00
16	G	2	0.00E+00	0.00%	0.00E+00
16	G	3	3.20E-05	0.01%	3.08E+04
16	G	4	0.00E+00	0.00%	0.00E+00
16	G	5	0.00E+00	0.00%	0.00E+00
16	G	6	0.00E+00	0.00%	0.00E+00

The following table shows the doses ranked from highest to lowest along with their respective frequencies. The table was truncated for values where the cumulative frequency is greater than 6%. Since the doses are ranked from highest to lowest, the 95% dose interpolation is performed at 5% to find the dose. The values used for the interpolation are as follows:

Sector	Stab	WS	EDE (mrem)	Cumulative Frequency
4	F	5	1.40E+04	4.76%
15	F	3	1.40E+04	5.09%

Interpolating between these two values results in a dose of 1.40E+04 mrem which is in exact agreement with the output of the code.

Sector	Stab	WS	c/Q	Frequency	EDE (mrem)	Cumulative Frequency
3	G	1	1.59E-04	0.00%	9.29E+04	0.00%
7	G	2	5.92E-05	0.00%	5.34E+04	0.01%
3	G	2	5.10E-05	0.00%	4.93E+04	0.01%
6	G	2	4.98E-05	0.01%	4.91E+04	0.01%
4	G	2	4.85E-05	0.00%	4.74E+04	0.02%
2	G	2	4.97E-05	0.01%	4.50E+04	0.03%
8	F	1	5.92E-05	0.00%	4.38E+04	0.03%
5	G	3	4.20E-05	0.02%	4.36E+04	0.05%
6	G	3	4.09E-05	0.02%	4.30E+04	0.07%
8	G	2	4.42E-05	0.01%	4.28E+04	0.07%
9	G	2	4.55E-05	0.00%	4.26E+04	0.07%
4	G	3	4.04E-05	0.04%	4.19E+04	0.11%
3	G	3	4.01E-05	0.04%	4.18E+04	0.15%
5	G	4	3.81E-05	0.01%	4.11E+04	0.16%
6	G	4	3.78E-05	0.01%	4.09E+04	0.18%
7	G	3	3.94E-05	0.05%	4.00E+04	0.22%
8	G	2	4.38E-05	0.01%	3.93E+04	0.23%
8	G	3	3.87E-05	0.03%	3.93E+04	0.25%
3	G	4	3.57E-05	0.08%	3.87E+04	0.33%
3	F	1	3.04E-04	0.00%	3.86E+04	0.33%
15	G	2	4.61E-05	0.01%	3.86E+04	0.34%
4	G	4	3.55E-05	0.03%	3.85E+04	0.37%
1	G	2	4.39E-05	0.01%	3.81E+04	0.37%
7	G	4	3.57E-05	0.01%	3.79E+04	0.38%
6	F	1	4.08E-05	0.00%	3.75E+04	0.39%
9	G	3	3.67E-05	0.05%	3.71E+04	0.43%
8	G	4	3.45E-05	0.02%	3.67E+04	0.45%
2	G	3	3.63E-05	0.03%	3.66E+04	0.48%
3	G	5	3.30E-05	0.00%	3.64E+04	0.48%
9	G	4	3.30E-05	0.02%	3.48E+04	0.49%
7	F	1	3.86E-05	0.00%	3.44E+04	0.50%
2	G	4	3.27E-05	0.02%	3.44E+04	0.51%
15	G	2	3.90E-05	0.00%	3.43E+04	0.51%
8	G	3	3.41E-05	0.01%	3.37E+04	0.53%
12	G	2	3.73E-05	0.00%	3.33E+04	0.53%
2	F	1	3.83E-05	0.00%	3.25E+04	0.53%
14	G	3	3.41E-05	0.01%	3.23E+04	0.54%
1	G	3	3.37E-05	0.01%	3.23E+04	0.54%
8	G	4	3.14E-05	0.01%	3.22E+04	0.55%
13	G	3	3.27E-05	0.01%	3.19E+04	0.55%
15	G	3	3.28E-05	0.03%	3.13E+04	0.58%
15	G	3	3.29E-05	0.01%	3.10E+04	0.59%

12	G	3	3.23E-05	0.02%	3.09E+04	0.61%
16	G	3	3.20E-05	0.01%	3.08E+04	0.62%
8	F	1	3.78E-05	0.00%	3.04E+04	0.62%
14	G	4	2.94E-05	0.00%	3.00E+04	0.62%
15	G	4	2.87E-05	0.01%	2.92E+04	0.63%
16	F	1	3.72E-05	0.00%	2.81E+04	0.63%
14	F	1	3.30E-05	0.01%	2.70E+04	0.63%
15	F	1	3.23E-05	0.00%	2.59E+04	0.64%
6	F	2	2.46E-05	0.03%	2.54E+04	0.66%
3	F	2	2.41E-05	0.05%	2.47E+04	0.71%
4	F	2	2.39E-05	0.14%	2.45E+04	0.85%
5	F	2	2.29E-05	0.04%	2.39E+04	0.88%
7	F	2	2.33E-05	0.04%	2.35E+04	0.93%
8	F	2	2.26E-05	0.12%	2.28E+04	1.04%
9	F	2	2.24E-05	0.04%	2.23E+04	1.09%
2	F	2	2.13E-05	0.02%	2.13E+04	1.11%
13	F	2	2.03E-05	0.03%	1.94E+04	1.14%
6	F	3	1.73E-05	0.12%	1.90E+04	1.26%
5	F	3	1.71E-05	0.23%	1.88E+04	1.49%
8	F	2	1.89E-05	0.09%	1.88E+04	1.58%
12	F	2	1.97E-05	0.03%	1.87E+04	1.61%
4	F	3	1.72E-05	0.25%	1.86E+04	1.86%
3	F	3	1.67E-05	0.21%	1.83E+04	2.07%
14	F	2	1.83E-05	0.07%	1.79E+04	2.14%
16	F	2	1.83E-05	0.03%	1.77E+04	2.17%
15	F	2	1.81E-05	0.08%	1.75E+04	2.25%
7	F	3	1.61E-05	0.20%	1.74E+04	2.45%
8	F	3	1.61E-05	0.36%	1.73E+04	2.80%
15	F	2	1.78E-05	0.06%	1.73E+04	2.86%
1	F	2	1.73E-05	0.01%	1.71E+04	2.88%
5	F	4	1.51E-05	0.08%	1.69E+04	2.95%
6	F	4	1.50E-05	0.04%	1.69E+04	2.99%
9	F	3	1.55E-05	0.28%	1.66E+04	3.27%
4	F	4	1.47E-05	0.10%	1.64E+04	3.36%
2	F	3	1.48E-05	0.18%	1.59E+04	3.54%
3	F	4	1.40E-05	0.34%	1.58E+04	3.88%
7	F	4	1.40E-05	0.04%	1.56E+04	3.92%
8	F	4	1.38E-05	0.07%	1.53E+04	3.99%
8	F	3	1.42E-05	0.30%	1.50E+04	4.29%
1	F	3	1.42E-05	0.04%	1.47E+04	4.33%
13	F	3	1.38E-05	0.12%	1.44E+04	4.45%
9	F	4	1.30E-05	0.05%	1.43E+04	4.50%
14	F	3	1.36E-05	0.15%	1.42E+04	4.65%
3	F	5	1.23E-05	0.01%	1.40E+04	4.66%
2	F	4	1.27E-05	0.10%	1.40E+04	4.76%
4	F	5	1.23E-05	0.00%	1.40E+04	4.76%
15	F	3	1.34E-05	0.33%	1.40E+04	5.09%
12	F	3	1.35E-05	0.14%	1.39E+04	5.23%
16	F	3	1.34E-05	0.07%	1.39E+04	5.30%

15	F	3	1.34E-05	0.11%	1.39E+04	5.41%
8	F	4	1.23E-05	0.04%	1.34E+04	5.45%
14	F	4	1.18E-05	0.01%	1.27E+04	5.46%
5	E	1	1.24E-05	0.01%	1.27E+04	5.47%
13	F	4	1.17E-05	0.01%	1.26E+04	5.47%
16	F	4	1.16E-05	0.00%	1.24E+04	5.47%
15	F	4	1.16E-05	0.01%	1.24E+04	5.48%
2	F	5	1.10E-05	0.00%	1.23E+04	5.48%
12	F	4	1.15E-05	0.02%	1.23E+04	5.50%
6	E	1	1.17E-05	0.01%	1.21E+04	5.51%
15	F	4	1.11E-05	0.08%	1.20E+04	5.59%
4	E	1	1.16E-05	0.03%	1.19E+04	5.61%
2	E	1	1.22E-05	0.01%	1.17E+04	5.63%
3	E	1	1.13E-05	0.01%	1.16E+04	5.64%
7	E	1	1.04E-05	0.01%	1.07E+04	5.65%
8	E	1	1.01E-05	0.01%	1.03E+04	5.66%
8	E	1	1.03E-05	0.03%	9.94E+03	5.69%
9	E	1	9.66E-06	0.02%	9.82E+03	5.70%
12	E	1	9.53E-06	0.02%	9.04E+03	5.72%
14	E	1	9.27E-06	0.00%	8.99E+03	5.72%
15	E	1	9.26E-06	0.02%	8.90E+03	5.74%
13	E	1	8.69E-06	0.01%	8.55E+03	5.75%
16	E	1	8.28E-06	0.01%	8.13E+03	5.76%
6	E	2	6.22E-06	0.23%	6.95E+03	5.99%

Verification of AXAIRQ

DISTRIBUTION (30)

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L.M. Papouchado, 773–A
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A.A. Simpkins, 773–A

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