VERIFICATION OF THE MAXIGASP AND POPGASP COMPUTER CODES FOR ENVIRONMENTAL DOSE ASSESSMENT

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MASTER

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David M. Hamby

January 19, 1995

Technical Review

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SUMMARY

MAXIGASP and POPGASP are environmental dosimetry codes that are based on the NRC dispersion module, XOQDOQ, and the NRC dosimetry module, GASPAR. XOQDOQ and GASPAR have been verified previously. The four remaining modules of MAXIGASP and POPGASP control input/output functions and data transfer. The results of MAXIGASP and POPGASP have been verified by comparison of hand calculated doses with program output.

INTRODUCTION

Pursuant to software quality assurance requirements contained in DOE Orders 5700.6C, "Quality Assurance," 1330.1C, "Computer Software," and 5400.1, "General Environmental Protection" and in WSRC Manual L1, Procedure 8.20, "Software Management and Quality Assurance," and as per instructions contained in WSRC-RP-94-1159, "Software Quality Assurance Plan for Environmental Dosimetry" this report was prepared to complete the documentation for verification and validation of the MAXIGASP and POPGASP computer codes, which are used for environmental dose assessments.

The MAXIGASP and POPGASP codes are used to estimate offsite dose to the maximum individual and the 50-mile population, respectively. Each code consists of two primary and four secondary computer routines. The two primary modules of MAXIGASP and POPGASP have been verified separately. Atmospheric dispersion is calculated with XOQDOQ, a routine developed by the NRC based on the Regulatory Guide 1.111 (NRC77b) and verified on the SRS IBM mainframe (Ba91). The dosimetry routine, GASPAR, is based on the NRC Regulatory Guide 1.109 (NRC77a) and has been verified for SRS (Ha92a).

The purpose of this document is to verify the execution of MAXIGASP and POPGASP with regard to the secondary computer routines that handle data transfers. These modules control operations such as reading input and preparing data files, reading dispersion outputs from XOQDOQ, creating inputs for GASPAR, and printing results in a usable format. XOQDOQ and GASPAR are utilized in the same manner for both MAXIGASP and POPGASP with the exception that one code calculates dose to an

individual while the other calculates dose to the population. Details on the functions of XOQDOQ and GASPARG can be found in the supporting documentation (Ec80; Sa82; Ba91; Ha91a; Ha92a).

This report is organized into two main sections. In the first section, brief descriptions of the four secondary modules are given along with their independent functions and their interactions with the other modules of the code. The second section goes through a hand verification of both MAXIGASP and POPGASP using an atmospheric tritium release as a benchmark case. Although not all subroutines within the two primary modules are accessed using this scenario, the detailed verifications on these primary routines are complete (Ba91; Ha92a) and this verification is designed only to demonstrate that the input/output functions are performed correctly between the primary and secondary modules.

ORGANIZATION OF CODE MODULES

MAXIGASP. The MAXIGASP program operates on the unclassified IBM mainframe using two primary and four secondary program modules. The two primary modules (XOQDOQ and GASPARG) have been described and verified separately (Ba91; Ha92a). The four secondary modules (MGPROTEM, MGPREXOQ, MGPREGAS, and MGDOSSES) control input/output functions and data transfers between XOQDOQ and GASPARG. Operations of the secondary modules are described below.

The input template is read, printed, and written as a computer dataset by the MGPROTEM module. This routine is relatively short and non-complex. The resulting dataset is read by the MGPREXOQ module which prepares all input data necessary for the XOQDOQ program. MGPREXOQ reads the dataset created by MGPROTEM, the SRS boundary file, the local terrain file, and the meteorological data. The pertinent data from each of these files is written to a second dataset as input to XOQDOQ.

After the relative concentration factors are calculated by XOQDOQ, the MGPREGAS routine is invoked. MGPREGAS reads the XOQDOQ output and the original input and writes a dataset to be used as input for GASPARG. GASPARG calculates pathway- and organ-specific doses and writes the unformatted data to an output file. The last MAXIGASP module, MGDOSSES, reads the datasets generated by MGPROTEM, XOQDOQ, and GASPARG and writes the results to the printer in the requested format.

Typically, execution of MAXIGASP takes less than one minute (real-time) and utilizes five input datasets including the input template; boundary, topography, and meteorological data; and the external and internal DOE dose factors (DOE88a; DOE88b). These datasets have been verified separately (Ba91; Ha91b; Ha91c; Ha92a; Pa92).

POPGASP. The POPGASP program also operates on the unclassified IBM mainframe, again using two primary and four secondary program modules. The two primary modules (XOQDOQ and GASPARG) have been described and verified separately (Ba91;

Ha92a) and are the same modules used in MAXIGASP. The four secondary modules (PGPROTEM, PGPREXOQ, PGPOP90, and PGPREGAS) control input/output functions and data transfers between XOQDOQ and GASPAR. Operations of the secondary modules are described below.

The input template is read, printed, and written as a computer dataset by the PGPROTEM module. This routine is very similar to the MGPROTEM routine. The resulting dataset is read by the PGPREXOQ module which prepares all input data necessary for the XOQDOQ program. PGPREXOQ reads the dataset created by PGPROTEM, the local terrain file, and the meteorological data. The pertinent data from each of these files is written to a second dataset as input to XOQDOQ.

After the relative concentration factors are calculated by XOQDOQ, the PGPOP90 routine determines the 50-mile population distribution centered on the release point. The fourth secondary module, PGPREGAS, reads the input data from PGPROTEM, reads the population distribution from PGPOP90, and reads agricultural and site-specific data from two data files. PGPREGAS compiles all of the data and writes an input file for the GASPAR program.

Typically, execution of POPGASP takes less than one minute (real-time) and utilizes seven input datasets including the input template; topography, meteorological, and population data; agricultural, humidity, and land usage factors; and the external and internal DOE dose factors (DOE88a; DOE88b). These datasets have been verified separately (Ba91; Ha91b; Ha91c; Ha92a; Ha93; Pa92).

OPERATIONAL VERIFICATION

The intent of the verification of MAXIGASP and POPGASP is to show that input and output data are transferred to and from each module appropriately. This verification will be carried out using an atmospheric tritium release scenario. Table 1 shows the input values used to execute MAXIGASP and POPGASP and the valid ranges for each input parameter.

Table 1. Input parameter values for the benchmark case and valid ranges of inputs for code execution.

Parameter	MAXIGASP Value	POPGASP Value	Valid Range
Released Nuclides	1	*	1 - 100
Release Points	1	*	1 - 5
Operating Period (yr)	40	201 [†]	1 - 201
Consumption	MAX	*	AVG; MAX
Milk Ingestion	COW	*	COW; GOAT
Grade Elevation (ft)	0		0 - 1000
SRS East Coordinate	58000		any onsite value
SRS North Coordinate	62000		any onsite value
Met Tower Database	H		A,C,D,F,H,K,L,P
Vent Air Velocity (m/s)	0		0 - 1000
Vent Diameter (m)	0		0 - 50
Release Height (m)	62		0 - 100
Building Height (m)	0		0 - 100
Cross-Section (m)	0		0 - 2000
Wind Height (m)	62		0 - 100
Heat Emission (cal/s)	0		0 - 500
Elemental Iodine	1		0 - 1
Release Amount (Ci)	10 ⁵		0 - 10 ⁶

*parameter not used in POPGASP; [†]value of 201 indicates that Environmental Dose Commitment is to be calculated.

MAXIGASP Results. The MAXIGASP code has been verified for proper data transfer during execution. Output generated by MAXIGASP was carefully examined to confirm the appropriate transfer of data from one module to the next. Verification will proceed in a step-by-step fashion for each of the six modules.

The input template is read and printed by MGPROTEM. Examination of the MAXIGASP output shows that the printed template is consistent with the input template. Furthermore, based on parameter specifications printed as part of the XOQDOQ or GASPAR output, each input parameter value has been found to be written to the temporary dataset correctly. Output of the boundary and topographic files was confirmed with the SRS sitewide facilities map. These files are processed by MGPREXOQ. Meteorological data for the tower specified in the input template were inspected and no discrepancies were found.

The XOQDOQ module reads the temporary datasets created by MGPROTEM and MGPREXOQ. Relative concentrations and relative deposition rates are calculated and printed as functions of distance and direction from the specified release point. The XOQDOQ module has been verified as a stand-alone computer code (Ba91).

Data from XOQDOQ is read into MGPREGAS which then prepares input for GASPAR. This module was verified based on examination of the MAXIGASP printout wherein relative concentrations from XOQDOQ were compared with the relative concentrations used in the GASPAR dose calculations. The comparison showed that the four concentration values needed in GASPAR were consistent with the concentration tables calculated by XOQDOQ. Three relative concentration values and one relative deposition rate are passed through MGPREGAS from XOQDOQ to GASPAR.

The GASPAR module uses the XOQDOQ input to estimate individual dose at the highest receptor location on the SRS boundary. This module also has been verified as a stand-alone computer code (Ha92a). The final module of MAXIGASP is MGDOSSES where the output from GASPAR is formatted and the results printed.

Hand calculations using the MAXINE spreadsheet (Ha94) are presented in Appendix A. The pathway-specific dose estimates calculated with MAXINE are identical (within rounding) to those generated by MAXIGASP. The MAXIGASP code resulted in inhalation, vegetable ingestion, meat ingestion, and milk ingestion maximum individual doses of 0.0351, 0.0244, 0.00413, and 0.00977 mrem, respectively. As seen in the Appendix, MAXINE's pathway specific results are 0.035, 0.024, 0.0041, and 0.0097 mrem, respectively. The MAXIGASP printout is maintained in the Environmental Dosimetry document management system.

POPGASP Results. Most of the data transfers occurring between modules of the POPGASP code are similar to those in MAXIGASP and have been verified in the same manner. The PGPOP90 module generates a population distribution, centered on the release point, based on data from the 1990 census. This database was developed by the University of South Carolina for SRS. The total population within 50-miles of the Savannah River reservation is approximately 620,000. Each of these persons is assumed to be an adult since a complete library of age-specific dose factors is not available. Since the data are shown to be transferring correctly, verification efforts are focused on the calculation of population dose. Again, as with the verification of MAXIGASP, an atmospheric release of 100,000 Ci HTO from the center of the SRS is assumed as the release scenario. The dose calculations are not being tested so much as the handling of data.

Population dose is calculated utilizing site-specific agricultural and demographic data. The necessary information includes the 50-mile population distribution and the meat, milk, and vegetation production distributions (see Appendix B, Tables 1-4). These distributions are in the form of arrays of 16 compass sectors x 5 receptor distances, creating 80 area segments in which population dose is calculated. Average individual dose (Appendix B, Table 5), as a function of receptor distance and direction from the

release point, is calculated in GASPAR and also has been calculated and verified by hand for this exercise. Table 6 of Appendix B contains the 50-mile population dose, D , for each area segment and is calculated using the formula:

$$D = (P_t D_i) + (P_v D_v) + (P_m D_m) + (P_b D_b) \quad (1)$$

where D_i , D_v , D_m , and D_b are pathway-specific doses via inhalation, vegetation, milk, and meat consumption, respectively, and where P_t , P_v , P_m , and P_b are the total population in a given area segment and the effective populations involved in the consumption of vegetation, milk, and meat, respectively.

The effective populations are determined for each area segment based on the production yields and the average consumption rate of each commodity. For example, the consumption rate of milk is assumed to be 230 L/yr per person (Ha92b) and the milk production yield for a given area segment is 480,000 L/yr. Therefore, the milk-consumption effective population, P_m , for that area segment is:

$$P_m = (480,000 \text{ L/yr} / 230 \text{ L/yr/person}) = 2087 \quad (2)$$

indicating the number of persons that the amount of milk produced in that segment will support. Since it is assumed that a commodity consumed in a given segment was also produced in that segment, the number of persons assumed for the pathway-specific dose calculation will be the lesser of the true population or the effective population.

The average dose distribution (Table 5, Appendix B) was obtained by hand calculation of the tritium dose using the segment-specific relative concentration calculated by XOQDOQ. Doses calculated for each area segment in the population dose distribution (Table 6, Appendix B) are determined using Equation 1. The total population dose of 5.2 person-rem was determined by integrating the population dose distribution over all 80 segments. The comparison run of POPGASP resulted in a total population dose of 5.22 person-rem. The POPGASP output is maintained in the Environmental Dosimetry document management system.

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APPENDIX A
MAXINE Output

MAXINE

Version 1.4

Bench Mark Run for MAXIGASP Comparison (Verification of MAXIGASP & POPGASP Report)

EXPOSURE PARAMETERS

Relative Concentration (X/Q):	1.5E-08	(sec/m3)	
Decayed X/Q:	1.4E-08	(sec/m3)	
Depleted X/Q:	1.3E-08	(sec/m3)	
Relative Deposition (D/Q):	6.0E-11	(1/m2)	
Distance to Receptor:	15479	(m)	
Vegetable Consumption (AVG, MAX, value):	Max	276	(kg/yr)
Leafy Veg Consumption (AVG, MAX, value):	Max	43	(kg/yr)
Milk Consumption (AVG, MAX, value):	Max	230	(L/yr)
Meat Consumption (AVG, MAX, value):	Max	81	(kg/yr)
Origin of Milk (Cow or Goat):	Cow		
Deposition Buildup Time:	40	(yr)	
Breathing Rate:	8,000	(m3/yr)	
Elemental Iodine Fraction:	1.00		
Absolute Humidity:	0.01140	(kg/m3)	
Tritium Plant-to-Air Ratio:	0.50		
Shielding Factor:	0.70		
Fraction of Year C-14 Released:	1.00		
Retained Fraction (iodines):	1.00		
Retained Fraction (particulates):	0.20		
Weathering Rate Constant:	18.1	(1/yr)	
Crop Exposure Time:	0.192	(yr)	
Pasture Grass Exposure Time:	0.0822	(yr)	
Pasture Grass Productivity:	1.8	(kg/m2)	
Produce Productivity:	0.7	(kg/m2)	
Surface Soil Density (15 cm):	240	(kg/m2)	
Pasture Grass Holdup Time:	0.00000	(yrs)	
Stored Feed Holdup Time:	0.24700	(yrs)	
Leafy Vegetable Holdup Time:	0.00274	(yrs)	
Produce Holdup Time:	0.16400	(yrs)	
Milk Cattle Feed Consumption (52):	44	(kg/day)	
Beef Cattle Feed Consumption:	44	(kg/day)	
Feed-Milk-Man Transport Time:	0.00822	(yr)	
Fraction of Year on Pasture (beef):	1.00		
Fraction of Year on Pasture (milk):	1.00	1.00 suggested	
Fraction Intake from Pasture (beef):	0.75		
Fraction Intake from Pasture (milk):	0.56	0.56 suggested	
Slaughter to Consumption Time:	0.0164	(yr)	
Fraction of Produce from Garden:	0.76		
Fraction of Leafy Veggies from Garden:	1.00		

SOURCE TERM ENTRY

Nuclide	Released Activity (Ci/yr)	Nuclide	Released Activity (Ci/yr)
H-3 (oxide)	1.00E+05		
C-14	0.00E+00		
Ar-41	0.00E+00		
Cr-51	0.00E+00		
Co-60	0.00E+00		
Zn-65	0.00E+00		
Se-75	0.00E+00		
Kr-85	0.00E+00		
Kr-85m	0.00E+00		
Kr-87	0.00E+00		
Kr-88	0.00E+00		
Sr-90	0.00E+00		
Zr-95†	0.00E+00		
Nb-95	0.00E+00		
Ru-103	0.00E+00		
Ru-106†	0.00E+00		
Sb-125	0.00E+00		
I-129	0.00E+00		
I-131	0.00E+00		
I-133	0.00E+00		
I-135	0.00E+00		
Xe-131m	0.00E+00		
Xe-133	0.00E+00		
Xe-135	0.00E+00		
Cs-134	0.00E+00		
Cs-137	0.00E+00		
Ce-141	0.00E+00		
Ce-144†	0.00E+00		
Pm-147	0.00E+00		
Eu-154	0.00E+00		
Eu-155	0.00E+00		
Os-185	0.00E+00		
U-234	0.00E+00		
U-235†	0.00E+00		
U-238	0.00E+00		
Np-237	0.00E+00		
Pu-238	0.00E+00		
Pu-239	0.00E+00		
Am-241†	0.00E+00		
Am-243	0.00E+00		
Cm-242	0.00E+00		
Cm-244†	0.00E+00		
Cf-252	0.00E+00		

†Denotes preferred isotope when isotopic breakdown is not available.

Atmospheric Transport and External Dose Factors

Nuclide	Deposition Rate ($\mu\text{Ci}/\text{m}^2 \text{ yr}$)	Atmospheric Concentration ($\mu\text{Ci}/\text{m}^3$)	Plume-Shine	Plume-Shine	Ground-Shine	Ground-Shine
			EDE DFs (mrem m^3) ($\text{yr } \mu\text{Ci}$)	Skin DFs (mrem m^3) ($\text{yr } \mu\text{Ci}$)	EDE DFs (mrem m^2) ($\text{yr } \mu\text{Ci}$)	Skin DFs (mrem m^2) ($\text{yr } \mu\text{Ci}$)
H-3		4.6E-05				
C-14		0.0E+00				
Ar-41		0.0E+00	6.63E+03	1.22E+04		
Cr-51	0.0E+00	0.0E+00			3.41E+00	4.53E+00
Co-60	0.0E+00	0.0E+00			2.27E+02	3.10E+02
Zn-65	0.0E+00	0.0E+00			5.48E+01	7.45E+01
Se-75	0.0E+00	0.0E+00			4.32E+01	5.65E+01
Kr-85		0.0E+00	1.12E+01	1.58E+03		
Kr-85m		0.0E+00	8.17E+02	2.62E+03		
Kr-87		0.0E+00	4.47E+03	1.65E+04		
Kr-88*		0.0E+00	1.49E+04	3.92E+04		
Sr-90*	0.0E+00	0.0E+00			0.00E+00	1.27E+03
Zr-95*	0.0E+00	0.0E+00			1.52E+02	2.10E+02
Nb-95	0.0E+00	0.0E+00			7.76E+01	1.10E+02
Ru-103*	0.0E+00	0.0E+00			5.01E+01	7.19E+01
Ru-106*	0.0E+00	0.0E+00			2.10E+01	1.66E+03
Sb-125	0.0E+00	0.0E+00			4.43E+01	6.71E+01
I-129	0.0E+00	0.0E+00			2.20E+00	5.30E+00
I-131*	0.0E+00	0.0E+00			4.04E+01	7.56E+01
I-133*	0.0E+00	0.0E+00			6.67E+01	5.39E+02
I-135	0.0E+00	0.0E+00			1.45E+02	5.62E+02
Xe-131m		0.0E+00	4.29E+01	5.61E+02		
Xe-133		0.0E+00	1.76E+02	5.81E+02		
Xe-135		0.0E+00	1.25E+03	3.64E+03		
Cs-134	0.0E+00	0.0E+00			1.58E+02	2.50E+02
Cs-137*	0.0E+00	0.0E+00			5.78E+01	2.09E+02
Ce-141	0.0E+00	0.0E+00			8.78E+00	1.60E+01
Ce-144*	0.0E+00	0.0E+00			5.10E+00	1.47E+03
Pm-147	0.0E+00	0.0E+00			4.10E-04	4.96E-04
Eu-154	0.0E+00	0.0E+00			1.21E+02	3.12E+02
Eu-155	0.0E+00	0.0E+00			7.15E+00	9.39E+00
Os-185	0.0E+00	0.0E+00			7.29E+01	1.07E+02
U-234	0.0E+00	0.0E+00			8.07E-02	6.40E-01
U-235	0.0E+00	0.0E+00			1.71E+01	2.30E+01
U-238	0.0E+00	0.0E+00			6.46E-02	5.30E-01
Np-237	0.0E+00	0.0E+00			3.24E+00	7.50E+00
Pu-238	0.0E+00	0.0E+00			8.58E-02	7.20E-01
Pu-239	0.0E+00	0.0E+00			3.78E-02	2.80E-01
Am-241	0.0E+00	0.0E+00			2.99E+00	6.40E+00
Am-243	0.0E+00	0.0E+00			6.61E+00	1.06E+01
Cm-242*	0.0E+00	0.0E+00			1.79E-01	1.45E+00
Cm-244	0.0E+00	0.0E+00			8.29E-02	6.60E-01
Cf-252	0.0E+00	0.0E+00			6.34E-02	4.70E-01

Nuclides in BOLD have modified deposition and atm. concentration models.

*These dose factors include contributions from daughter radiations (as per SRL-ETS-910233).

CONVERSION FACTORS

Nuclide	Decay Constant (1/yr)	Inhalation EDE Dose Factor (rem/uCi)	Ingestion EDE Dose Factor (rem/uCi)	Vegetable to Soil Ratio	Cow Milk Transfer (d/L)	Intake To Meat Transfer (d/kg)
H-3	5.61E-02	9.5E-05	6.3E-05	4.8E+00	1.0E-02	1.2E-02
C-14	1.21E-04	2.4E-05	2.1E-03	5.5E+00	1.2E-02	3.1E-02
Ar-41	3.31E+03					
Cr-51	9.13E+00	2.6E-04	1.3E-04	2.5E-04	2.2E-03	2.4E-03
Co-60	1.32E-01	1.5E-01	2.6E-02	9.4E-03	1.0E-03	1.3E-02
Zn-65	1.03E+00	1.8E-02	1.4E-02	4.0E-01	3.9E-02	3.0E-02
Se-75	2.11E+00	8.2E-03	8.8E-03	1.3E+00	4.5E-02	1.5E-02
Kr-85	6.46E-02					
Kr-85m	1.36E+03					
Kr-87	4.76E+03					
Kr-88	2.14E+03					
Sr-90	2.38E-02	1.3E+00	1.3E-01	1.7E-02	8.0E-04	6.0E-04
Zr-95	3.85E+00	1.9E-02	3.4E-03	1.7E-04	5.0E-06	3.4E-02
Nb-95	7.22E+00	4.5E-03	2.2E-03	9.4E-03	2.5E-03	2.8E-01
Ru-103	6.37E+00	7.8E-03	2.7E-03	5.0E-02	1.0E-06	4.0E-01
Ru-106	6.84E-01	4.4E-01	2.1E-02	5.0E-02	1.0E-06	4.0E-01
Sb-125	2.50E-01	9.8E-03	2.6E-03			
I-129	4.35E-08	1.8E-01	2.8E-01	2.0E-02	6.0E-03	2.9E-03
I-131	3.14E+01	3.2E-02	5.3E-02	2.0E-02	6.0E-03	2.9E-03
I-133	2.92E+02	5.4E-03	1.0E-02	2.0E-02	6.0E-03	2.9E-03
I-135	9.21E+02	1.1E-03	2.0E-03	2.0E-02	6.0E-03	2.9E-03
Xe-131m	2.14E+01					
Xe-133	4.82E+01					
Xe-135	6.68E+02					
Cs-134	3.37E-01	4.7E-02	7.4E-02	1.0E-02	1.2E-02	4.0E-03
Cs-137	2.25E-02	3.2E-02	5.0E-02	1.0E-02	1.2E-02	4.0E-03
Ce-141	7.79E+00	8.5E-03	2.6E-03	2.5E-03	6.0E-04	1.2E-03
Ce-144	8.92E-01	3.5E-01	2.0E-02	2.5E-03	6.0E-04	1.2E-03
Pm-147	2.64E-01	3.4E-02	9.5E-04			
Eu-154	7.88E-02	2.6E-01	9.1E-03			
Eu-155	1.40E-01	3.9E-02	1.3E-03			
Os-185	2.70E+00	1.0E-02	2.1E-03	5.0E-02	5.0E-03	4.0E-01
U-234	2.84E-06	1.3E+02	2.6E-01	2.5E-03	5.0E-04	3.4E-04
U-235	9.81E-10	1.2E+02	2.5E-01	2.5E-03	5.0E-04	3.4E-04
U-238	1.55E-10	1.2E+02	2.3E-01	2.5E-03	5.0E-04	3.4E-04
Np-237	3.25E-07	4.9E+02	3.9E+00	2.5E-03	5.0E-06	2.0E-04
Pu-238	7.88E-03	4.6E+02	3.8E+00	2.5E-04	2.0E-06	1.4E-05
Pu-239	2.84E-05	5.1E+02	4.3E+00	2.5E-04	2.0E-06	1.4E-05
Am-241	1.60E-03	5.2E+02	4.5E+00	2.5E-04	5.0E-06	2.0E-04
Am-243	9.39E-05	5.2E+02	4.5E+00	2.5E-04	5.0E-06	2.0E-04
Cm-242	1.55E+00	1.7E+01	1.1E-01	2.5E-03	5.0E-06	2.0E-04
Cm-244	3.88E-02	2.7E+02	2.3E+00	2.5E-03	5.0E-06	2.0E-04
Cf-252	2.62E-01	1.3E+02	9.4E-01	2.5E-03	5.0E-06	2.0E-04

FOOD AND FODDER CONCENTRATIONS

Nuclide	Other Vegetables (uCi/kg)	Leafy Vegetables (uCi/kg)	Milk (uCi/L)	Meat (uCi/kg)	Pasture Grass (uCi/kg)	Stored Feed (uCi/kg)
H-3 *	1.5E-03	1.5E-03	6.7E-04	8.0E-04	1.5E-03	1.5E-03
C-14 *	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ar-41						
Cr-51	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Co-60	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zn-65	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Se-75	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85						
Kr-85m						
Kr-87						
Kr-88						
Sr-90	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nb-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-103	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-125	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129 *	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-131 *	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-133 *	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135 *	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-131m						
Xe-133						
Xe-135						
Cs-134	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-137	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-144	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pm-147	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-154	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Os-185	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U-234	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U-235	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Np-237	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Am-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Am-243	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-242	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cf-252	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

* concentrations determined using element specific model.

Dose to Maximum Individual Living at the SRS Boundary
50-year CEDE from a 1-Year Intake (mrem)

Nuclide	Shine Dose† (mrem)	Inhalation (mrem)	Vegetables (mrem)	Cow Milk (mrem)	Meat (mrem)	TOTAL (mrem)
H-3		3.5E-02	2.4E-02	9.7E-03	4.1E-03	7.3E-02
C-14			0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ar-41	0.0E+00					0.0E+00
Cr-51	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Co-60	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zn-65	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Se-75	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85	0.0E+00					0.0E+00
Kr-85m	0.0E+00					0.0E+00
Kr-87	0.0E+00					0.0E+00
Kr-88	0.0E+00					0.0E+00
Sr-90		0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Zr-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nb-95	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-103	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ru-106	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sb-125	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-129	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-131	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-133	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-135	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xe-131m	0.0E+00					0.0E+00
Xe-133	0.0E+00					0.0E+00
Xe-135	0.0E+00					0.0E+00
Cs-134	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cs-137	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-141	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ce-144	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pm-147	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-154	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu-155	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Os-185	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U-234	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U-235	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Np-237	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-238	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pu-239	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Am-241	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Am-243	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-242	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cm-244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cf-252	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	0.0E+00	3.5E-02	2.4E-02	9.7E-03	4.1E-03	7.3E-02

†Plume-shine doses calculated for noble gases only; others in column are ground-shine doses.

APPENDIX B

Verification of POPGASP

Appendix B
Verification of POPGASP

Table 1. Meat Production Distribution (kg/yr)

Sector	Distance (miles)				
	5 to 10	10 to 20	20 to 30	30 to 40	40 to 50
N	0.0E+00	5.3E+04	8.8E+04	2.5E+05	9.8E+05
NNE	0.0E+00	5.3E+04	8.8E+04	2.0E+05	4.1E+05
NE	0.0E+00	7.1E+04	1.7E+05	3.5E+05	4.5E+05
ENE	0.0E+00	8.3E+04	2.0E+05	4.6E+05	5.7E+05
E	0.0E+00	8.3E+04	1.9E+05	3.4E+05	5.1E+05
ESE	0.0E+00	8.3E+04	1.9E+05	2.2E+05	2.5E+05
SE	0.0E+00	1.2E+05	2.1E+05	2.6E+05	3.0E+05
SSE	0.0E+00	1.1E+05	1.9E+05	2.6E+05	2.9E+05
S	0.0E+00	9.4E+04	1.5E+05	2.0E+05	2.7E+05
SSW	0.0E+00	9.5E+04	1.8E+05	2.9E+05	3.9E+05
SW	0.0E+00	9.5E+04	1.7E+05	2.7E+05	3.2E+05
WSW	0.0E+00	9.5E+04	1.6E+05	2.3E+05	4.0E+05
W	0.0E+00	5.8E+04	1.0E+05	2.1E+05	4.1E+05
WNW	0.0E+00	4.8E+04	6.2E+04	1.3E+05	2.9E+05
NW	0.0E+00	5.3E+04	8.0E+04	2.8E+05	2.7E+05
NNW	0.0E+00	5.3E+04	8.8E+04	3.3E+05	6.2E+05

Table 2. Milk Production Distribution (L/yr)

Sector	Distance (miles)				
	5 to 10	10 to 20	20 to 30	30 to 40	40 to 50
N	0.0E+00	4.2E+04	6.9E+04	1.0E+06	5.3E+06
NNE	0.0E+00	4.2E+04	6.9E+04	2.1E+05	5.0E+05
NE	0.0E+00	3.2E+04	1.0E+06	2.7E+06	2.0E+06
ENE	0.0E+00	2.5E+04	1.2E+06	4.4E+06	5.2E+06
E	0.0E+00	2.5E+04	1.4E+06	3.9E+06	4.9E+06
ESE	0.0E+00	2.5E+04	5.6E+05	3.0E+04	4.9E+05
SE	0.0E+00	2.5E+03	0.0E+00	0.0E+00	0.0E+00
SSE	0.0E+00	4.8E+05	8.6E+05	1.2E+06	1.2E+06
S	0.0E+00	1.0E+06	2.1E+06	3.0E+06	3.5E+06
SSW	0.0E+00	9.9E+05	3.8E+06	7.4E+06	7.6E+06
SW	0.0E+00	9.9E+05	2.2E+06	5.8E+06	4.8E+06
WSW	0.0E+00	9.9E+05	1.7E+06	2.4E+06	3.5E+06
W	0.0E+00	6.7E+05	1.3E+06	2.2E+06	3.6E+06
WNW	0.0E+00	2.3E+05	1.1E+06	1.2E+06	2.0E+06
NW	0.0E+00	4.2E+04	3.8E+05	1.4E+06	1.0E+06
NNW	0.0E+00	4.2E+04	6.9E+04	1.7E+06	3.4E+06

Appendix B
Verification of POPGASP

Table 3. Vegetable Production Distribution (kg/yr)

Sector	Distance (miles)				
	5 to 10	10 to 20	20 to 30	30 to 40	40 to 50
N	0.0E+00	3.6E+05	6.0E+05	8.4E+05	8.7E+05
NNE	0.0E+00	3.6E+05	6.0E+05	5.1E+05	6.3E+03
NE	0.0E+00	3.6E+05	6.9E+05	1.0E+06	5.0E+05
ENE	0.0E+00	3.6E+05	6.6E+05	1.2E+06	1.5E+06
E	0.0E+00	3.6E+05	5.9E+05	8.5E+05	1.4E+06
ESE	0.0E+00	3.6E+05	2.2E+06	1.9E+06	1.1E+06
SE	0.0E+00	2.5E+06	4.5E+06	3.0E+06	1.1E+06
SSE	0.0E+00	1.7E+06	2.9E+06	3.6E+06	1.1E+06
S	0.0E+00	7.2E+04	5.4E+05	8.4E+05	9.7E+05
SSW	0.0E+00	3.5E+02	1.2E+05	2.5E+05	1.1E+05
SW	0.0E+00	3.5E+02	7.8E+02	2.2E+03	3.1E+05
WSW	0.0E+00	3.5E+02	5.8E+02	9.9E+02	2.9E+03
W	0.0E+00	4.5E+04	2.3E+04	1.7E+04	5.2E+04
WNW	0.0E+00	2.6E+05	3.8E+04	4.5E+05	1.1E+06
NW	0.0E+00	3.6E+05	4.3E+05	8.4E+05	1.1E+06
NNW	0.0E+00	3.6E+05	6.0E+05	8.4E+05	1.1E+06

Table 4. Population Distribution

Sector	Distance (miles)				
	5 to 10	10 to 20	20 to 30	30 to 40	40 to 50
N	26	5321	10020	5067	12210
NNE	6	1320	2066	4445	14370
NE	1	2945	2928	5269	10200
ENE	27	3126	4483	5337	40770
E	155	6743	5305	8812	4334
ESE	36	1556	1931	2711	3253
SE	26	547	6511	6685	8577
SSE	40	391	769	1356	2539
S	1	558	1332	7251	3335
SSW	2	897	2008	4181	2944
SW	17	944	2240	2606	2660
WSW	60	1103	7112	2285	5818
W	55	3314	7941	7994	6780
WNW	449	3342	106900	50310	11550
NW	271	5899	87930	26570	3025
NNW	363	18030	27160	6665	6079

Appendix B
Verification of POPGASP

Table 5. Dose Distribution (mrem)

Sector	Distance (miles)				
	5 to 10	10 to 20	20 to 30	30 to 40	40 to 50
N	7.5E-02	3.3E-02	1.7E-02	1.1E-02	7.7E-03
NNE	6.1E-02	2.7E-02	1.4E-02	9.3E-03	6.6E-03
NE	6.4E-02	2.9E-02	1.5E-02	1.0E-02	7.3E-03
ENE	6.4E-02	2.6E-02	1.3E-02	8.8E-03	6.4E-03
E	5.2E-02	2.1E-02	1.1E-02	6.9E-03	5.1E-03
ESE	4.5E-02	1.8E-02	9.1E-03	6.0E-03	4.4E-03
SE	3.1E-02	1.3E-02	6.6E-03	4.3E-03	3.1E-03
SSE	2.5E-02	1.1E-02	5.7E-03	3.8E-03	2.8E-03
S	1.4E-02	6.2E-03	3.4E-03	2.4E-03	1.8E-03
SSW	4.1E-02	1.7E-02	9.1E-03	6.2E-03	4.6E-03
SW	6.9E-02	2.8E-02	1.5E-02	9.8E-03	7.2E-03
WSW	5.4E-02	2.2E-02	1.2E-02	7.9E-03	5.8E-03
W	3.9E-02	1.6E-02	8.8E-03	6.0E-03	4.3E-03
WNW	4.0E-02	1.7E-02	9.3E-03	6.3E-03	4.6E-03
NW	5.2E-02	2.2E-02	1.1E-02	7.2E-03	5.2E-03
NNW	6.9E-02	3.0E-02	1.5E-02	9.2E-03	6.6E-03

Table 6. Population Dose Distribution (person-rem)

Sector	Distance (miles)				
	5 to 10	10 to 20	20 to 30	30 to 40	40 to 50
N	1.5E-03	1.4E-01	1.4E-01	5.5E-02	8.6E-02
NNE	2.8E-04	3.3E-02	2.7E-02	3.7E-02	7.6E-02
NE	4.9E-05	7.4E-02	4.4E-02	5.3E-02	6.7E-02
ENE	1.3E-03	7.0E-02	5.7E-02	4.7E-02	2.3E-01
E	6.1E-03	1.1E-01	5.5E-02	5.7E-02	2.2E-02
ESE	1.2E-03	2.6E-02	1.8E-02	1.5E-02	1.4E-02
SE	6.1E-04	6.6E-03	3.9E-02	2.6E-02	2.3E-02
SSE	7.6E-04	4.3E-03	4.4E-03	5.2E-03	7.1E-03
S	1.1E-05	3.3E-03	4.5E-03	1.6E-02	6.0E-03
SSW	6.2E-05	1.3E-02	1.7E-02	2.4E-02	1.2E-02
SW	8.9E-04	2.3E-02	2.9E-02	2.2E-02	1.8E-02
WSW	2.5E-03	2.1E-02	7.3E-02	1.6E-02	2.9E-02
W	1.6E-03	4.6E-02	5.9E-02	4.1E-02	2.5E-02
WNW	1.4E-02	5.0E-02	7.6E-01	2.5E-01	4.9E-02
NW	1.1E-02	1.1E-01	7.4E-01	1.6E-01	1.6E-02
NNW	1.9E-02	4.2E-01	3.2E-01	5.9E-02	4.0E-02

Total Population Dose: 5.2E+00 person-rem