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Reassessment of Selected Factors Affecting Siting of Nuclear Power Plants

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U.S. Nuclear Regulatory Commission

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ABSTRACT

Brookhaven National Laboratory has performed a series of probabilistic consequence assessment calculations for nuclear reactor siting. This study takes into account recent insights into severe accident source terms and examines consequences in a risk based format consistent with the quantitative health objectives (QHOs) of the NRC's Safety Goal Policy.

Simplified severe accident source terms developed in this study are based on the risk insights of NUREG-1150. The results of the study indicate that both the quantity of radioactivity released in a severe accident as well as the likelihood of a release are lower than those predicted in earlier studies.

The accident risks using the simplified source terms are examined at a series of generic plant sites, that vary in population distribution, meteorological conditions, and exclusion area boundary distances. Sensitivity calculations are performed to evaluate the effects of emergency protective action assumptions on the risk of prompt fatality and latent cancers fatality, and population relocation.

The study finds that based on the new source terms the prompt and latent fatality risks at all generic sites meet the QHOs of the NRC's Safety Goal Policy by margins ranging from one to more than three orders of magnitude.

TABLE OF CONTENTS

Section		Page
ABSTRACT		iii
ACRONYMS		ix
1	EXECUTIVE SUMMARY	1-1
2	INTRODUCTION	2-1
2.1	Current Regulatory Position	2-2
2.2	Regulatory Guidance	2-2
2.3	Review of Sandia Siting Study	2-3
2.4	References	2-4
3	APPROACH	3-1
3.1	Objectives of Present Study	3-1
3.2	Review of NUREG-1150 and LaSalle Integrated Risk Assessments of Severe Accidents	3-1
3.2.1	Core Damage Frequency Analysis	3-2
3.2.2	Accident Progression and Containment Performance Analysis	3-3
3.2.3	Source Term Analysis	3-3
3.3	Development of Representative Source Terms	3-10
3.3.1	Representative Source Terms for Grand Gulf	3-13
3.3.2	Representative Source Terms for LaSalle	3-13
3.3.3	Representative Source Terms for Peach Bottom	3-15
3.3.4	Representative Source Terms for Sequoyah	3-15
3.3.5	Representative Source Terms for Surry	3-18
3.3.6	Representative Source Terms for Zion	3-20
3.3.7	Prompt and Latent Fatalities	3-20
3.4	Population Assumptions	3-20
3.5	Meteorological Data	3-26
3.6	Land Use and Economics	3-36
3.7	Protective Actions	3-36
3.7.1	Emergency Protective Actions	3-36
3.7.2	Sheltering Schemes	3-37
3.7.3	Population Relocation Criteria	3-37
3.8	References	3-38
4	RESULTS	4-1
4.1	Base Case – QHO Comparison	4-1
4.2	Individual Risks of Consequences as a Function of Distance	4-4
4.2.1	Risk of Prompt Fatality vs. Distance	4-4
4.2.2	Risk of Latent Cancer Fatality vs. Distance	4-7
4.2.3	Risk of Permanent Relocation vs. Distance	4-7

TABLE OF CONTENTS (continued)

Section **Page**

4.3 References 4-12

5 TECHNICAL FINDINGS 5-1

APPENDICES

A DETAILED DISCUSSION OF INPUT PARAMETERS A-1
B ZION-ATMOS B-1
C(a) EARLY-Z3 .... C(a)-1
C(b) EAR-Z3-N .... C(b)-1
D CHRONC D-1
E SITE C5Z3 .... E-1

LIST OF FIGURES

Section		Page
3.1	Conditional Probability of Accident Progression Bins for Internal Events at Grand Gulf ...	3-4
3.2	Conditional Probability of Accident Progression Bins for Internal Events at LaSalle	3-5
3.3	Conditional Probability of Accident Progression Bins for Internal Events at Peach Bottom ..	3-6
3.4	Conditional Probability of Accident Progression Bins for Internal Events at Sequoyah	3-7
3.5	Conditional Probability of Accident Progression Bins for Internal Events at Surry	3-8
3.6	Conditional Probability of Accident Progression Bins for Internal Events at Zion	3-9
3.7	Frequency of Release for Key Radionuclide Groups (Internal Events)	3-11
3.8	Lateral Diffusion, σ_y, vs. Downwind Distance from Source for Pasquill's Turbulence Types. (Reproduced from U.S. Nuclear Regulatory Commission Regulatory Guide 1.145)	3-28
3.9	Vertical Diffusion, σ_z, vs. Downwind Distance from Source for Pasquill's Turbulence Types. (Reproduced from U.S. Nuclear Regulatory Commission Regulatory Guide 1.145)	3-29
4.1	Prompt Fatality Risk Comparison with the QHO as a Function of Exclusion Area Distance	4-2
4.2	Latent Cancer Risk Comparison with the QHO as a Function of Exclusion Area Distance	4-3
4.3	Estimated Individual Risk of Prompt Fatality vs. Distance (Mean) (1/yr)	4-5
4.4	Estimated Individual Risk of Prompt Fatality vs. Distance (Mean and 95th Percentile) (1/yr)	4-6
4.5	Estimated Individual Risk of Latent Cancer Fatality vs. Distance (Mean) (1/yr)	4-8
4.6	Estimated Individual Risk of Latent Cancer Fatality vs. Distance (Mean and 95th Percentile) (1/yr)	4-9
4.7	Estimated Individual Risk of Permanent Relocation vs. Distance (Mean)	4-10
4.8	Estimated Individual Risk of Permanent Relocation vs. Distance (Mean and 95th Percentile) (1/yr)	4-11

LIST OF TABLES

Section		Page
2.1	Sandia Siting Study Source Terms	2-5
3.1	Summary of Core Damage Frequency Results (Internal Events)	3-2
3.2	Principal Contributors to Internal Core Damage Frequency	3-2
3.3	Characteristics of Grand Gulf Release Categories	3-14
3.4	Radionuclide Release Characteristics into Environment for Grand Gulf	3-14
3.5	Characteristics of LaSalle Release Categories	3-16
3.6	Radionuclide Release Characteristics into Environment for LaSalle	3-16
3.7	Characteristics of Peach Bottom Release Categories	3-17
3.8	Radionuclide Release Characteristics into Environment for Peach Bottom	3-17
3.9	Characteristics of Sequoyah Release Categories	3-19
3.10	Radionuclide Release Characteristics into Environment for Sequoyah	3-19
3.11	Characteristics of Surry Release Categories	3-21
3.12	Radionuclide Release Characteristics into Environment For Surry	3-21
3.13	Characteristics of Zion Release Categories	3-22
3.14	Radionuclide Release Characteristics into Environment for Zion	3-22
3.15	Comparison of Early Fatality Risks at all Plants (Due to Internal Events) in NUREG-1150 with the Simplified Source Terms	3-23
3.16	Comparison of Latent Cancer Fatality Risks at all Plants (Due to Internal Events) in NUREG-1150 with the Simplified Source Terms	3-23
3.17	Population Distributions per Sector	3-24
3.18	Exclusion Area Distances	3-26
3.19	Meteorological Data of the 29 National Weather Service (NWS) Sites	3-31
3.20	Comparison of Best Four Sites Based on Absolute Errors with Respect to Means	3-34
3.21	Comparison of Best Four Sites Based on Absolute Errors with Respect to Medians	3-35
3.22	Emergency Protective (EP) Parameters	3-37
3.23	Shielding and Sheltering Dose Reduction Parameters (Based on average of five plants in NUREG-1150)	3-37

ACRONYMS

Acronym	Definition
AC	Alternating Current
ATWS	Anticipated Transient Without Scram
BAF	Bottom of Active Fuel
BNL	Brookhaven National Laboratory
BWR	Boiling Water Reactor
CCI	Core Concrete Interaction
CD	Core Damage
CDF	Core Damage Frequency
CFR	Code of Federal Regulation
EP	Emergency Protective
ESF	Emergency Safety Feature
LOCA	Loss of Coolant Accident
LPZ	Low Population Zone
LWR	Light Water Reactors
MACCS	MELCOR Accident Consequence Code System
MELCOR	A Computer Code for Nuclear Reactor Severe Accident Source Term and Risk Assessment Analysis
MSLB	Main Steam Line Break
MW	Megawatt
MWth	Megawatt Thermal
NRC	Nuclear Regulatory Commission
NWS	National Weather Service
PWR	Pressurized Water Reactor
QHO	Quantitative Health Objective
RCS	Reactor Coolant System
RES	Office of Nuclear Regulatory Research, US NRC
RSS	Reactor Safety Study
RY	Reactor Year
SBO	Station Blackout
SNL	Sandia National Laboratories
SRP	Standard Review Plan
SST	Standard Source Term
STCP	Source Term Code Package
TID	Technical Information Document

1 EXECUTIVE SUMMARY

Brookhaven National Laboratory has performed a series of probabilistic consequence assessment calculations for nuclear reactor siting. This study considered (i) the insights into severe accident source terms that have been gained in the past decade, (ii) the advances in the models of the health risks of radiation embodied in a newer consequence code, and (iii) a desire to examine accident consequences in a risk based format consistent with the quantitative health objectives of the NRC's Safety Goal Policy.

The approach taken was to develop sets of simplified accident source terms which were assessed in NUREG-1150. Results from the study indicate that both the quantity of radioactivity released in a severe accident, as well as the likelihood of a release, are considerably lower than predicted by earlier studies (e.g., the Sandia Siting Study of 1982). For this reason, the severe accident risks estimated in earlier studies are concluded to be unduly pessimistic, based on a revised understanding of severe accidents.

The accident risks using these sets of source terms were examined at a series of generic plant sites that varied in population distributions, meteorological conditions, and exclusion area boundary distances. Sensitivity calculations were performed to assess the effects of emergency protective action assumptions on the risk of prompt fatality and latent cancers fatality, and population relocation.

The U. S. Nuclear Regulatory Commission's Safety Goal Policy quantitative health objectives (QHOs) were examined for the five sets of simplified source terms at a reactor power level of 3800 MWth and at the generic sites. In all of the cases examined, the quantitative health objectives were met by margins ranging from one to more than three orders of magnitude.

From the complete set of simplified source terms, a source term (designated RZ1) was used to perform selected sensitivity studies. The risks of prompt and latent fatalities, and the relocation of affected population were examined. Additional population distributions, reactor power levels, and meteorological conditions were also considered.

Exclusion area boundary distances ranging from 0.17 to 0.50 miles were studied. The study found that the prompt and latent fatality risks for all exclusion area boundary distances examined were less than the QHOs of the NRC's Safety Goal by at least one order of magnitude, for all five plants considered in NUREG-1150.

Risk sensitivity calculations were performed for a very large fission product release. These showed that the risk of prompt fatality was greatest within the first few miles of the reactor and became very small beyond about five miles, even where little or no protective actions were assumed. Prompt fatality risk was found to be very sensitive to reactor power level and decreased markedly with low power levels.

Latent cancer fatality risk decreased monotonically with distance in contrast to the risk of prompt fatality. The risk of latent fatality was well below the QHO of the Safety Goal for all exclusion area boundary distances. Latent cancer risk was found to vary linearly with reactor power level or radioactive inventory of the core.

Possible relocation of people was also examined. The risks of relocation of people were found to be very low, since only about two percent of the core melt sequences were found to result in significant contamination. The individual risk of permanent relocation for people located within 10 miles was about 2×10^{-7} per reactor year. Beyond about 20 miles, the risk of permanent relocation was found to be less than 1×10^{-8} per reactor year.

2 INTRODUCTION

The current regulation governing reactor siting, Code of Federal Regulations Title 10 Part 100 (10 CFR 100),[1] is outlined in Section 2.1 below. This regulation uses a particular hypothetical accident source term in the assessment of site suitability by evaluating the dimensions of an exclusion area and a low population zone based on a deterministic dose calculation given site meteorological conditions. Regulatory Guide 4.7,[2] "General Site Suitability Criteria for Nuclear Power Stations," briefly discussed in section 2.2, contains additional general site suitability criteria.

A revision of the existing regulation on siting is being considered. The TID-14844[3] source term was developed in 1962. Since its adoption, there has been further research on severe accident source terms, especially that developed in NUREG-1150.[4] The Commission has also adopted explicitly risk-based quantitative health objectives (QHOs) as part of the Safety Goals[5] for plant operation. These QHOs set goals on the risk of prompt and latent fatalities calculated within specified distances from the plant from the entire spectrum of possible releases. These considerations, among others, have prompted an effort to re-assess reactor siting.

A reassessment of the factors affecting site suitability should include a current understanding of severe accidents. This study incorporates the insights of NUREG-1150 by developing sets of accident source terms (for both boiling water reactors (BWRs) and pressurized water reactors (PWRs)) in terms of frequency, timing, and release fractions. These source terms are applied to a set of hypothetical sites with various population densities and location of urban centers which would encompass most of the existing reactor sites. The site meteorology has been selected such that, from a meteorological standpoint, the calculation of consequences would be likely to bound 80 percent of the existing reactor sites.

Section 3 discusses the approach used in this study. Section 3.3 contains a description of the simplified source terms based on insights derived from NUREG-1150 and of the validation that was performed. Subsequent sections describe the definition of a generic site including: population distributions, urban center size and location (Section 3.4), weather categories and meteorological data (atmospheric stability, rainfall, windspeed, etc. in Section 3.5), land use and economics (Section 3.6), and the selection of other parameters such as emergency response and long term interdiction criteria (Section 3.7). Sections 3.4 through 3.7 also list the various parameters and values used in carrying out the sensitivity analyses.

Section 4 describes the results which were obtained using the MACCS code.[6] Section 4.1 presents the QHOs comparison obtained for the five sets of simplified source terms (SSTs). A sensitivity study has been performed using different population distributions and exclusion zone boundary distances. Section 4.2 describes the sensitivity studies performed for population distribution, meteorological conditions, exclusion area boundary distance, reactor power level and emergency response on consequences. In Section 4.2.1, the effect of sensitivity studies on prompt fatality risk is presented. The results of the sensitivity studies for latent fatality risk are provided in Section 4.3.

Section 5 presents the calculational results and comparisons with the Safety Goal and the guidelines of Regulatory Guide 4.7.

2.1 Current Regulatory Position

The Nuclear Regulatory Commission's (NRC) regulation concerning the siting of nuclear power plants is currently governed by Title 10, Part 100 of the Code of Federal Regulations (10 CFR 100). Part 100.1 of this regulation refers to the criteria which guide the NRC in its evaluation of the suitability of proposed sites. Part 100.2 specifies that the regulation applies to existing reactors but can also be applied to other reactor types.

Part 100.10 enumerates the factors to be considered in site evaluation including the design, operation and power level of the reactor, the population density and use characteristics of the site environs, and the physical characteristics of the site such as seismology, meteorology, geology and hydrology. Part 100.11 establishes a methodology for determining the exclusion area, the low population zone, and distance to the population center from the reactor. This methodology is based on two main elements: first, the assumption of a particular accident source term into the containment and a leak rate from the containment into the environment, and second, the calculation of a dose to an exposed individual at the boundary of the exclusion area and the outer boundary of the low population zone.

The source term in 10 CFR 100 used to assess the suitability of reactor siting is a postulated fission product release into containment that is assumed to result from a "substantial meltdown of the core with subsequent release of appreciable quantities of fission products." Part 100 specifies two performance objectives. First, an individual located at any point on the exclusion area boundary for two hours immediately following the onset of the radioactive release would not receive a total radiation dose to the whole body in excess of 25 rem or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure. Second, individuals located at any point on the outer boundary of the low population zone who are exposed to the radioactive cloud during the entire period of its passage would not receive the total radiation dose of 25 rem whole body exposure.

2.2 Regulatory Guidance

The Regulatory Guides and the Standard Review Plan (SRP)[7] provide guidance in assumptions regarding fission product release, plant performance, and dose calculation methodology.

The fission product release into containment is derived from TID-14844, referenced in Part 100. The fission product release used for site evaluation is given in Regulatory Guides 1.3,[8] "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors," and 1.4[9] "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors." These specify a release into containment of (a) 100 percent of the noble gas inventory of the core, and (b) 50 percent of the iodine fission product inventory of the core (half of which is assumed to deposit on interior surfaces very quickly). In addition, Regulatory Guides 1.3 and 1.4 specify that the fission products are to be assumed to be instantaneously available for release from the containment. The chemical form of the iodine fission products are assumed to be 91 percent elemental, 5 percent particulate, and 4 percent organic iodine. Fission product cleanup systems are given credit for reduction of iodine concentrations in containment.

In evaluating the site acceptability, the containment is assumed to maintain its integrity for the duration of the accident and is assumed to leak at the maximum Technical Specification leak rate. For BWRs, the containment is assumed to leak at its maximum leak rate for the entire duration of the accident. For PWRs, the containment leak rate stays at its maximum value for a 24 hour period following the accident, after which its leak rate is assumed to be half the value for the remainder of the accident duration.

Doses to individuals at the exclusion area boundary and at the low population zone (LPZ) outer radius are calculated using conservative assumptions. Individuals are assumed to be directly under the plume, no protective actions are assumed to be taken, and highly unfavorable meteorological conditions are assumed that would result in higher doses no more than about 5 percent of the time for the actual site conditions.

Regulatory Guide 4.7 provides guidance on a minimum exclusion area distance (0.4 miles), minimum LPZ outer radius (3 miles), and population density in the vicinity of the site. This Guide states that if the population density projected at the time of initial operation of a nuclear power station exceeds 500 people per square mile averaged over any radial distance out to 30 miles (cumulative population at a distance divided by the area at that distance), or the projected population density over the lifetime of the facility exceeds 1000 people per square mile, consideration should be given to alternative sites with lower population densities.

Finally, it should be noted that reactor siting is determined by other considerations, which are not addressed in this study. These include such diverse conditions as seismic characteristics, nearby industrial and military facilities, potential for flooding, and the availability of a suitable ultimate heat sink. Consideration of these as well as other site characteristics is given in Regulatory Guide 4.7.

2.3 Review of Sandia Siting Study

Previously, the Sandia National Laboratory (SNL) performed a study of the technical aspects of siting for nuclear power reactors.[10] The results of this study were published in NUREG/CR-2239,[10] "Technical Guidance for Siting Criteria Development," in 1981. This study used standard source terms (SSTs) at 91 existing or proposed reactor sites. These source terms were derived from the Reactor Safety Study (RSS) WASH-1400[11] and its immediate successors.

The Sandia Siting Study sought to develop technical guidance regarding (1) criteria for population density and distribution surrounding future sites and (2) standoff distances of plants from offsite hazards. Studies were performed in each of these two areas of concern.

The Sandia Siting Study involved analyses in four areas, each of which could play a role in evaluating the impact of a siting policy. The four areas were: (1) consequences of possible plant accidents, (2) population distribution characteristics for existing sites, (3) availability of sites, and (4) socio-economic impacts.

Accident consequence analyses were performed to help define the hazards associated with existing sites and with alternative siting criteria. Consequence analyses also help to evaluate the dependence of risk on factors which are intrinsic to the site such as meteorology, population distribution, and emergency response. Population distributions at existing sites were examined. The site availability analysis examined the impact of various population distribution criteria on the amount of land restricted from siting. Impacts of environmental and legal constraints were also examined. In addition, studies were performed to evaluate the extent of socio-economic impacts and the degree to which they are dependent on site demographic characteristics.

Consequence analyses also were performed to identify other factors that could also have a significant impact upon risk. These include: source term magnitude, reactor size, plume heat content, dry deposition velocity, and criteria for the interdiction of contaminated land. CRAC2[12] was the computer model used to perform these consequence analyses.

The source terms (SSTs) used in the Sandia Siting Study are shown in Table 2.1. These have been included for the purpose of comparison with the simplified source terms developed in Section 3.3. SST1 represents severe core damage, loss of all installed safety systems, and severe direct breach of containment. SST2 represents severe core damage and failure of containment isolation; however, fission product release mitigation systems (e.g., sprays, suppression pool, fan coolers) operate to reduce the release. SST3 represents severe core damage and failure of containment by basemat melt-through but all other release mitigation systems function as designed. SST4 leads to modest core damage; containment systems operate in a degraded mode. SST5 involves limited core damage and no failures of engineered safety features beyond those postulated in design basis accidents. The Sandia Siting Study stated that based on the probabilistic risk assessments which were available at that time, representative probabilities for the SSTs are: P_1 for SST1 = 1×10^{-5}, P_2 for SST2 = 2×10^{-5}, and P_3 for SST3 = 1×10^{-4}.

2.4 References

1. U. S. Nuclear Regulatory Commission, Title 10, Chapter 1, Code of Federal Regulation, Part 100, "Reactor Site Criteria," May 1984.
2. U. S. Nuclear Regulatory Commission, Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Revision 1, November 1975.
3. DiNunno, J. J., et al., "Calculation of Distance Factors for Power and Test Reactor Sites," U. S. Atomic Energy Commission, TID-14844, March 1962.
4. U. S. Nuclear Regulatory Commission, "Severe Accident Risks: An Assessment for Five U. S. Nuclear Power Plants," NUREG-1150, December 1990.
5. U. S. Nuclear Regulatory Commission, Office of Policy Evaluation, "Safety Goals for Nuclear Power Plant Operation," NUREG-0880, Rev. 1, December 1985.
6. Jow, H.-N., et al., "MELCOR Accident Consequence Code System (MACCS)," Vol. 2 — Model Description, NUREG/CR-4691, February 1990.
7. U. S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," NUREG-0800, July 1981.
8. U. S. Nuclear Regulatory Commission, Regulatory Guide 1.3, "Assumption Used for Evaluating the Potential Radiological Consequence of Loss of Coolant Accident for BWR," June 1974.
9. U. S. Nuclear Regulatory Commission, Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors," Rev. 2, June 1984.
10. Aldrich, D. C., et al., "Technical Guidance for Siting Criteria Development," NUREG/CR-2239, December 1982.
11. U. S. Nuclear Regulatory Commission, "Reactor Safety Study," N. C. Rasmussen, Study Director, WASH-1400, 1975.
12. Ritchie, L. T., et al., "Calculation of Reactor Accident Consequences – CRAC2," NUREG/CR-2326, 1983.

Table 2.1 Sandia Siting Study Source Terms[a]

Release Characteristics[b]	**Source Term**				
	SST1	**SST2**	**SST3**	**SST4**	**SST5**
Accident Type	Core Melt	Core Melt	Core Melt	Gap Release	Gap Release
Containment Failure Mode	Over-pressure	H_2 Explosion or Loss of Isolation	—	—	—
Containment Leakage	Large	Large	1%/day	1%/day	0.1%/day
Time of Release (hr)	1.5	3	1	0.5	0.5
Release Duration (hr)	2	2	4	1	1
Warning Time (hr)	0.5	1	0.5	—	—
Release Height (meters)	10	10	10	10	10
Release Energy	0	0	0	0	0
Inventory Release Fractions					
Xe-Kr Group	1.0	0.9	6×10^{-3}	3×10^{-6}	3×10^{-7}
I Group	0.45	3×10^{-3}	2×10^{-4}	1×10^{-7}	1×10^{-8}
Cs-Rb Group	0.67	9×10^{-3}	1×10^{-5}	6×10^{-7}	6×10^{-8}
Te-Sb Group	0.64	3×10^{-2}	2×10^{-5}	1×10^{-9}	1×10^{-10}
Ba-Sr Group	0.07	1×10^{-3}	1×10^{-6}	1×10^{-11}	1×10^{-12}
Ru Group	0.05	2×10^{-3}	2×10^{-6}	0	0
La Group	9×10^{-3}	3×10^{-4}	1×10^{-6}	0	0

[a] Reproduced from the Sandia Siting Study,[10] p. 2-13

[b] As defined in the Reactor Safety Study[11]

3 APPROACH

This section discusses the approach used for this study. The objectives of the study are outlined in Section 3.1. Sections 3.2 and 3.3 provide a description of the development of the representative source terms in terms of their timing, release characteristics and frequencies. The consequences determined with the representative source terms are compared to the consequence analyses of NUREG-1150.[1] Section 3.4, Population Distributions, provides a discussion of the assumed population distributions. Section 3.5, Meteorological Data, details the selection of two cases. One represents the "mean" meteorology within the continental U.S. and the other represents an 80th percentile "conservative" case. The mean and 80th percentile selections were based on meteorological characteristics that are believed to affect the calculation of consequences, such as frequency and intensity of rain, atmospheric stability class and windspeed, mixing heights, and wind rose. Section 3.6, Land Use and Economics, contains a discussion of the assumptions that were included in the calculations for the generic sites' land use and economics data. Section 3.7, Protective Actions, discusses the different protective action assumptions. Information for the reader to reconstruct the input files used to run the MACCS[2] consequence code is provided in Appendices A through D.

3.1 Objectives of Present Study

Recently, a significant effort (NUREG-1150) has been made to understand fission product behavior and release characteristics under severe accident conditions. The objective of this study is to provide reactor siting offsite consequence calculational results which consider current understanding of source terms and advances in calculational techniques.

The approach taken in this study is to develop and use sets of surrogate source terms for each of the NUREG-1150 plants. The actual process of source term and accident frequency selection is discussed in Reference 3 and is summarized in Section 3.3 of this report. These source terms are used to calculate accident consequences at a series of generic sites. This is a major distinction of the present study in comparison to the Sandia siting study,[4] where a single set of siting source terms were applied in a standard fashion to the 91 actual (operating or proposed) reactor sites. In combination, the selection of source terms and generic site data, including reference meteorology, is aimed at obtaining a reasonably conservative estimate of the accident consequences. A further objective of this study is to perform sensitivity studies. The parameters considered are reactor power, exclusion area distance, population density and distribution, emergency protective action, and relocation criteria. The major risk attributes that are calculated are prompt and latent fatalities, the population dose, the individual prompt and latent fatality risks, and the population relocated.

3.2 Review of NUREG-1150 and LaSalle Integrated Risk Assessments of Severe Accidents

NUREG-1150 and the integrated risk assessment for LaSalle[5] provide the most up-to-date insights into severe accident risks from Light Water Reactors (LWRs) through the analysis of six plant types.

The analysis performed for each plant includes the risk assessment elements needed to estimate the off-site risk. The key elements are the estimate of core damage frequency, accident progression through containment response to phenomena leading to possible failures of the containment, estimates of the source term resulting from the various accident progressions, and estimates of the consequences resulting from each source term. In addition to the estimate of off-site risk, the uncertainties in the risk were estimated.

In order to provide a framework for developing representative source terms for LWR severe accidents, the results of key elements of NUREG-1150 and LaSalle integrated risk assessment studies are summarized in this section.

3.2.1 Core Damage Frequency Analysis

The core damage frequency analysis considered accidents initiated by events occurring during normal full-power operation of the plants (internal events). This analysis excludes consideration of accidents initiated by external events for Surry, Peach Bottom, and LaSalle (e.g., earthquakes, floods, fires). The core damage frequency analysis lead to a number of core melt sequences having similar safety system and support system failures. They were grouped into the plant damage states according to similar failures of equipment function and reactor system conditions as vessel failure approaches.

A summary of internal event core damage frequency estimates for each plant is provided in Table 3.1. The principal internal core damage contributors for each plant are summarized in Table 3.2. Contribution to core damage is expressed in percent of total mean core damage frequency.

Table 3.1 Summary of Core Damage Frequency Results (Internal Events)

	5%	Median	Mean	95%
Grand Gulf	1.7×10^{-7}	1.2×10^{-6}	4.0×10^{-6}	1.2×10^{-5}
LaSalle	2.2×10^{-6}	1.5×10^{-5}	4.5×10^{-5}	1.5×10^{-4}
Peach Bottom	3.5×10^{-7}	1.9×10^{-6}	4.5×10^{-6}	1.3×10^{-5}
Sequoyah	1.2×10^{-5}	3.7×10^{-5}	5.7×10^{-5}	1.8×10^{-4}
Surry	6.8×10^{-6}	2.3×10^{-5}	4.1×10^{-5}	1.3×10^{-4}
Zion	1.1×10^{-4}	2.4×10^{-4}	3.4×10^{-4}	8.4×10^{-4}

Table 3.2 Principal Contributors to Internal Core Damage Frequency

Accident Type	Grand Gulf	LaSalle	Peach Bottom	Sequoyah	Surry	Zion
	(Values in Percent)					
Station Blackout	97	[a]	49	26	67	1.9
Loss of Coolant (LOCA)	<1	1.1[b]	5.8	63	15	93
Failure to Scram (ATWS)	2.7	<1	42	3.3	3.9	<1
Transients	<1	98	3.1	4.4	5.1	4.2
Interfacing LOCA	<1	<1	<1	1.1	3.9	<1
Steam Generator Tube Rupture	N/A	N/A	N/A	3.0	4.4	<1

(a) Station blackout accidents are included in transients
(b) Includes transient-LOCA

3.2.2 Accident Progression and Containment Performance Analysis

For each general type of accident, defined by the plant damage states, an analysis was performed to develop phenomenological conditions and containment response for each accident progression path which determine the timing and failure mode of containment and influence the transport and release of radionuclides. Accident progression event trees were used to identify, sequentially order, and probabilistically quantify the important events in the progression of a severe accident.

The available severe accident experimental and calculational data base was used extensively in development of an accident progression event tree. Calculational results from a number of accident simulation computer codes were used, including the STCP,[6] CONTAIN,[7] MELCOR,[8] and MELPROG.[9] The expert opinion elicitation process was used in NUREG-1150 as a means to quantify the uncertainty of major issues in the accident progression analysis. Additional discussion of the methods used to develop and quantify the accident progression event trees may be found in References 1 and 5. Similar accident progression paths were grouped into accident progression bins to limit the number of source terms required to be developed. Each bin consists of a group of postulated accidents (with associated possibilities for each plant damage state) that has similar outcomes with respect to the analysis of radioactive material transport.

The mean conditional containment response probabilities in matrix form (accident progression bin probabilities based on the mean core damage frequency for each of the major plant damage states) for the plants analyzed in NUREG-1150 and the integrated risk assessment for LaSalle are presented in Figures 3.1–3.6.

3.2.3 Source Term Analysis

The magnitude and composition of radioactive materials released to the environment with associated energy content, time, initial elevation and duration of release together are termed the "source term."

The source term analysis tracks the release and transport of radioactive materials from the core, through the reactor coolant system, then to the containment and other buildings, and finally into the environment. The removal and retention of radioactive materials by natural processes, such as deposition on surfaces, and by engineered safety systems, such as sprays, are accounted for in each location.

For the NUREG-1150 risk analysis and integrated risk assessment for LaSalle, the source term for the variety of accidents was calculated using simplified parametric algorithms. The parametric equations do not contain any chemistry or physics (except mass conservation) but describe the source terms as the product of release fractions and transmission factors at successive stages in the accident progression for a variety of release pathways, a variety of accident progressions, and nine classes of radionuclides. This approach led to development of separate computer codes for each plant, i.e., the XSOR codes.[10] It should be emphasized that the parametric models used in the XSOR codes are not time dependent. These codes generate source terms only in terms of early and delayed releases. The timing of release is particularly important for the prediction of early health effects.

None of the basic parameters used in the XSOR codes are internally calculated. The values for the parameters must be specified by the user or chosen from a distribution of values by a sampling algorithm. The input data on the more important

SUMMARY ACCIDENT PROGRESSION BIN GROUP	SUMMARY PDS GROUP (Mean Core Damage Frequency)				
	STSB (3.85E-06)	LTSB (1.04E-07)	ATWS (1.12E-07)	Transients (1.87E-08)	All (4.09E-06)
VB, early CF, early SPB, no CS	0.168	0.292	0.006	0.011	0.158
VB, early CF, early SPB, CS	0.031	0.017	0.237	0.202	0.049
VB, early CF, late SPB	0.006	0.005	0.003	0.003	0.007
VB, early CF, no SPB	0.182	0.531	0.505	0.331	0.218
VB, late CF	0.308	0.129	0.074	0.232	0.284
VB, venting	0.032	0.003	0.109	0.075	0.038
VB, No CF	0.053	0.003	0.036	0.092	0.050
No VB	0.201	0.015	0.025	0.050	0.180

CF = Containment Failure
CS = Containment Sprays
CV = Containment Venting
SPB = Suppression Pool Bypass
VB = Vessel Breach

Figure 3.1 Conditional Probability of Accident Progression Bins for Internal Events at Grand Gulf

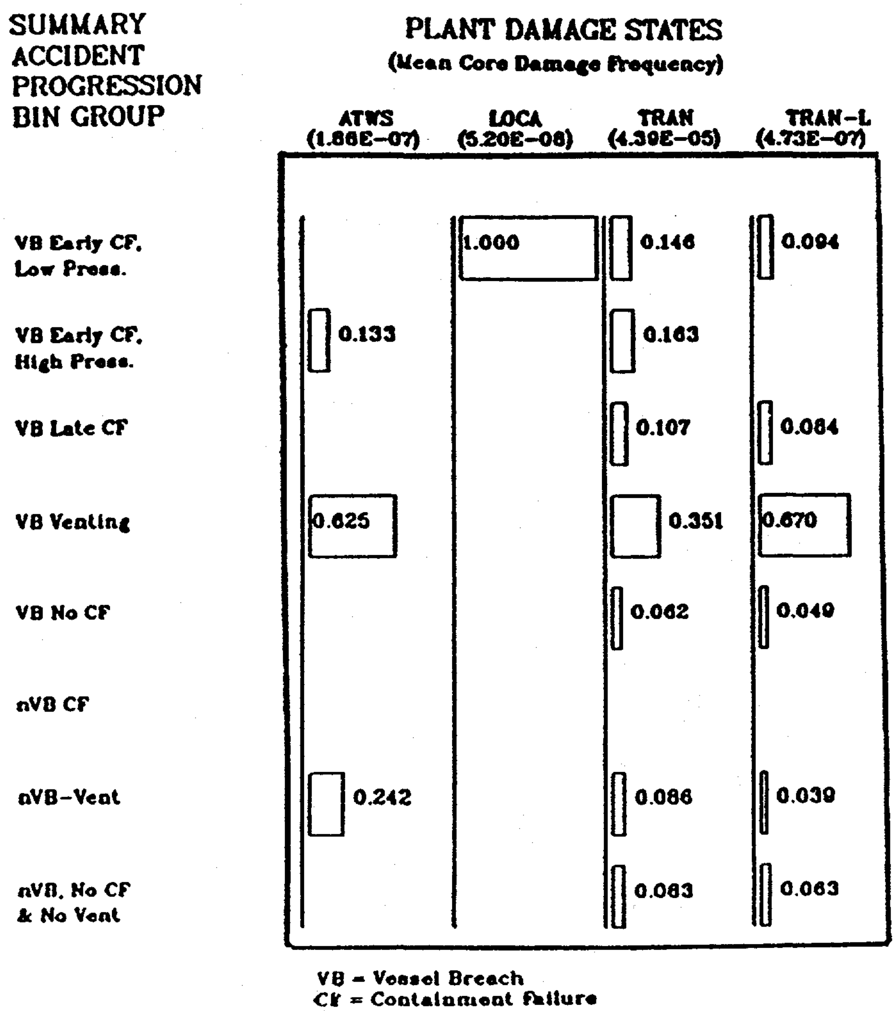


Figure 3.2 Conditional Probability of Accident Progression Bins for Internal Events at LaSalle

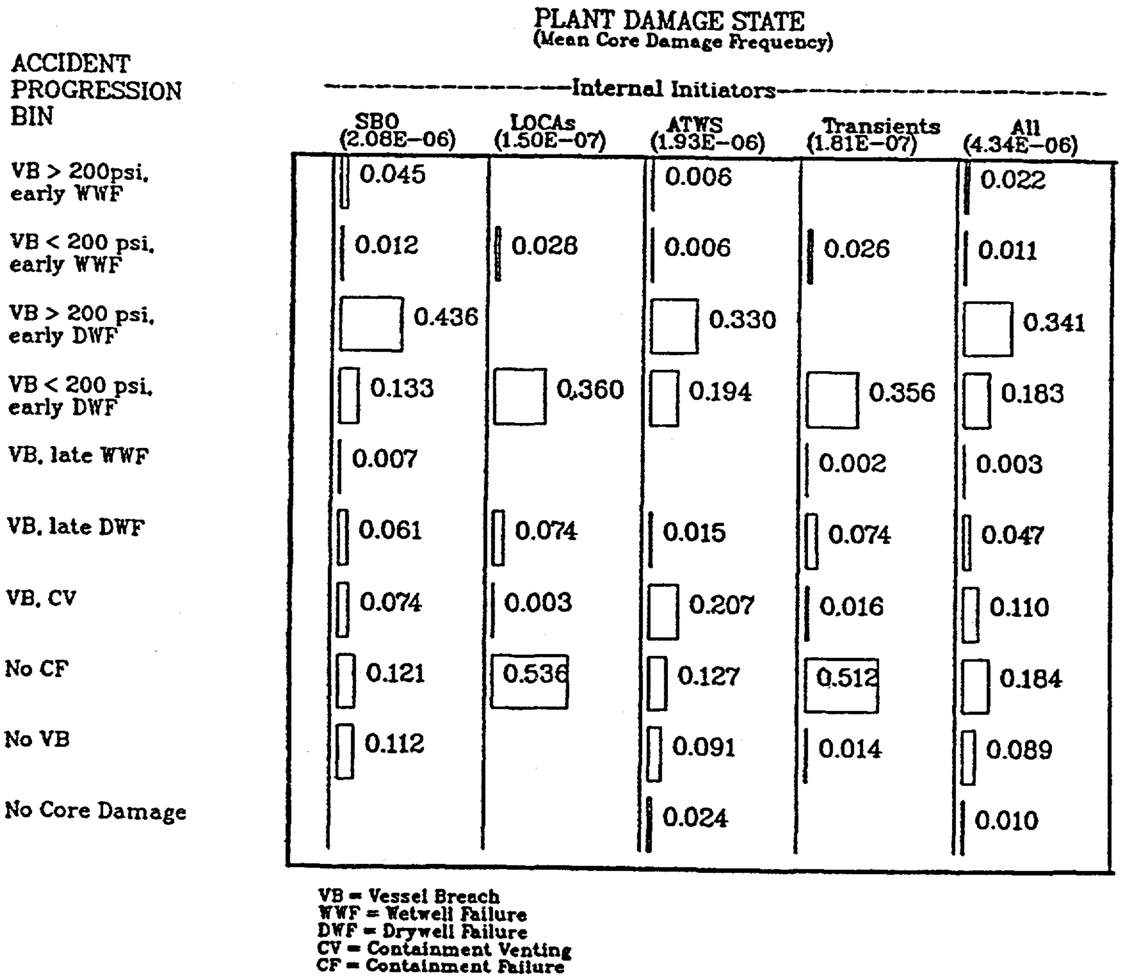


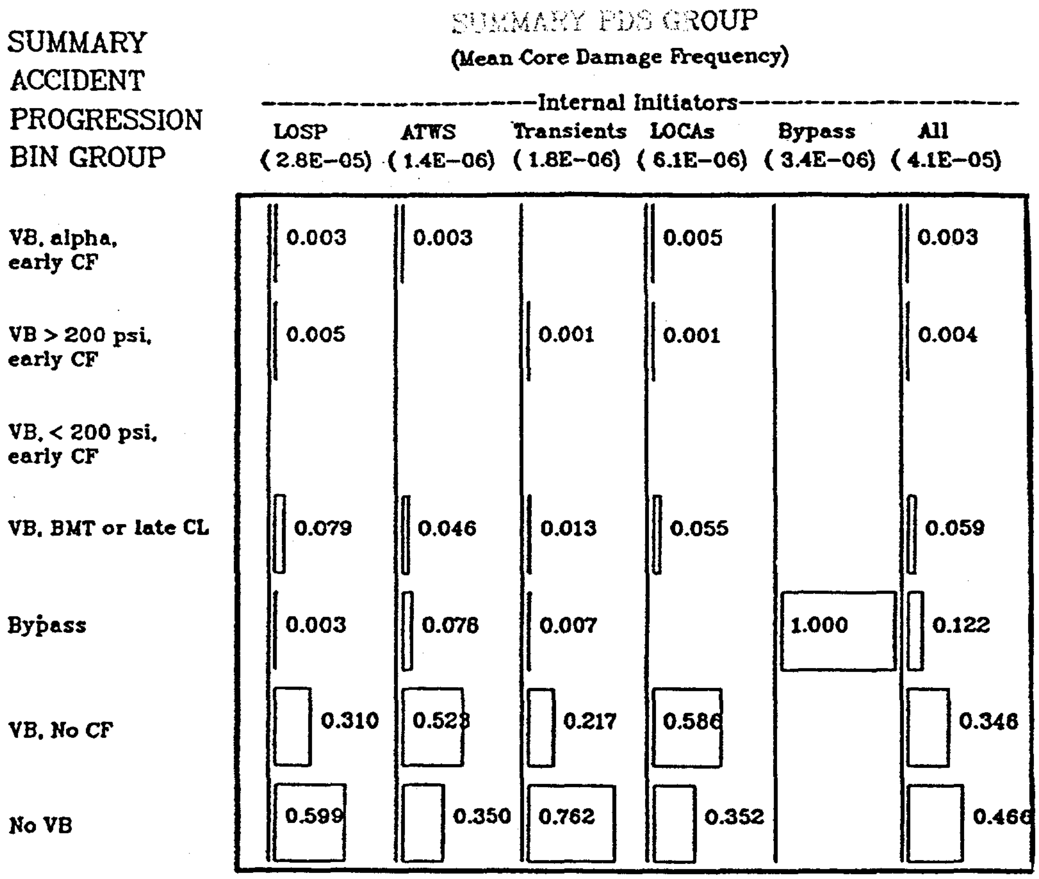
Figure 3.3 Conditional Probability of Accident Progression Bins for Internal Events at Peach Bottom

PLANT DAMAGE STATE
(Mean Core Damage Frequency)

ACCIDENT PROGRESSION BIN	LOSP (1.36E–05)	ATWS (2.07E–06)	Transients (2.32E–06)	LOCAs (3.52E–05)	Bypass (2.39E–06)	All (5.58E–05)
VB, early CF (during CD)	0.014	0.003		0.002		0.005
VB, alpha, early CF (at VB)	0.002	0.003		0.002		0.002
VB > 200 psi, early CF (at VB)	0.064	0.023	0.014	0.031		0.035
VB < 200 psi, early CF (at VB)	0.054	0.020	0.004	0.014		0.023
VB, late CF	0.153	0.001		0.001		0.038
VB, BMT, very late CF	0.065	0.151	0.039	0.260		0.171
Bypass	0.001	0.134	0.006		0.996	0.056
VB, No CF	0.200	0.471	0.137	0.301		0.269
No VB, early CF (during CD)	0.036	0.001	0.005	0.002		0.011
No VB	0.384	0.171	0.785	0.367		0.371

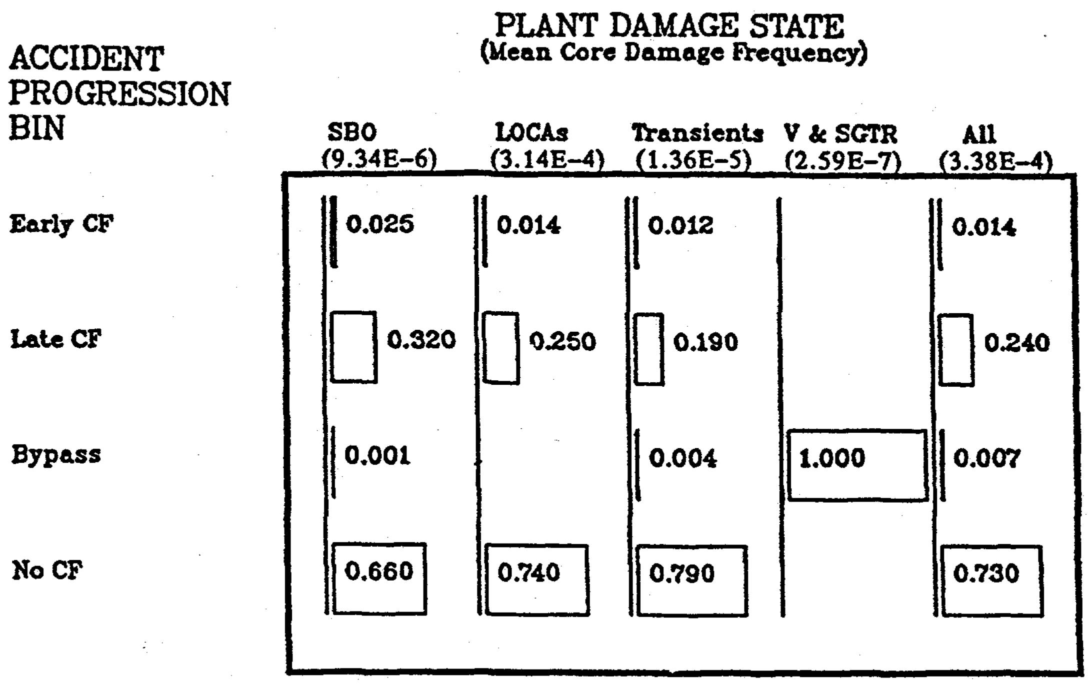
BMT = Basemat Meltthrough
CF = Containment Failure
VB = Vessel Breach
CD = Core Degradation

Figure 3.4 Conditional Probability of Accident Progression Bins for Internal Events at Sequoyah



Key: BMT = Basemat Melt–Through
CF = Containment Failure
CL = Containment Leak
VB = Vessel Breach

Figure 3.5 Conditional Probability of Accident Progression Bins for Internal Events at Surry



Key: CF = Containment Failure

Figure 3.6 Conditional Probability of Accident Progression Bins for Internal Events at Zion

parameters were constructed in the form of probability probability distributions. Such distributions were developed using expert judgement in NUREG-1150 to interpret the available data or calculations. For a few parameters that were judged of lesser importance or not considered as uncertain, single-valued estimates were used in XSOR models. These estimates were derived from other calculations and adjusted as needed for the boundary conditions associated with the accident progression characteristics.

The source term analysis resulted in characterizing thousands of source terms (20,000 for Surry and 75,000 for Grand Gulf) associated with tens of plant damage states, hundreds of accident progression bins, and the variation in the source term phenomenological issues which were included in the propagation of uncertainties. Figure 3.7 includes curves depicting the mean frequency of exceeding specified release fractions of the core inventory of iodine, cesium, strontium, and lanthanum for each of the six plants studied. These data are for internal initiated events only.

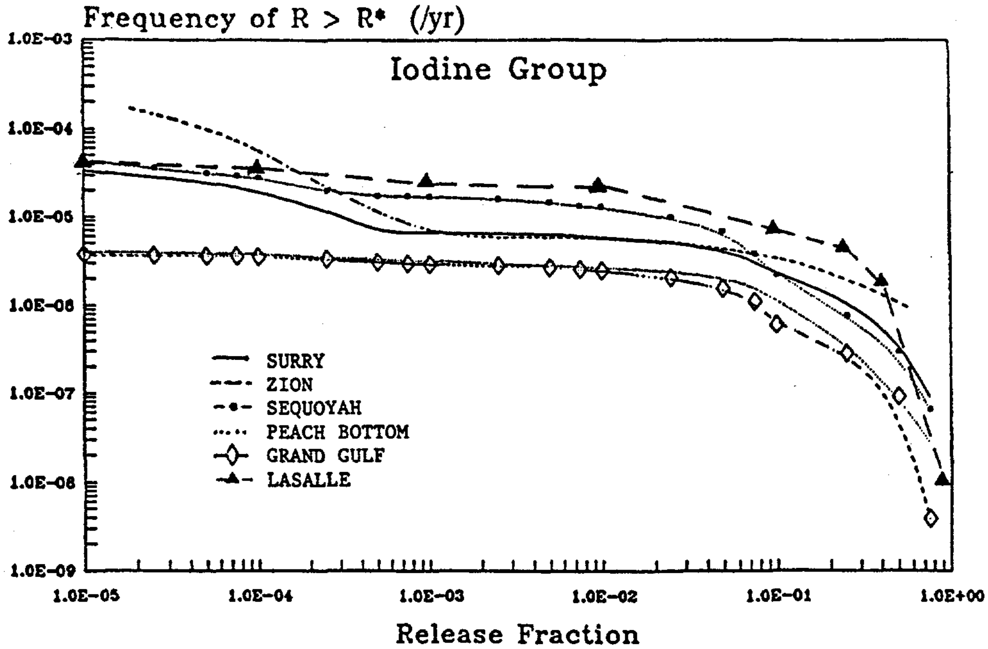
For these risk analyses, radioactive releases were grouped according to their potential to cause early or latent cancer fatalities and warning time. Through this "partitioning" process, the large number of radioactive releases calculated with the XSOR codes were collected into a small set of source term groups (30 to 60 in number for each plant). This set of groups was then used in the offsite consequence calculations.

3.3 Development of Representative Source Terms

Developing representative source terms involves the determination of a set of reactor accident progression groups, the dominant plant damage states and the associated release characteristics for each reactor design which will serve to represent the full spectrum of severe accidents. This has been done by using the insights from the results of the NUREG-1150 and the LaSalle independent risk assessment studies on accident sequences and associated source term parameters.[3]

A key insight that has emerged from research on severe accidents is the mode and timing of containment failure strongly influences the offsite consequences. The primary concerns are how well the containment can withstand the pressure and temperature loads associated with severe core damage accidents and whether or not the containment is bypassed. For scenarios in which the containment integrity is maintained, fission product release will be small. For those scenarios leading to containment failure, fission product release depends on the timing as well as the size of break in containment. The mode of containment failure (i.e., gross failure versus leakage through failure of penetrations) influences the amount of radioactive materials released to the environment.

A small set of source terms (4 to 7 for each plant) was developed[3] by considering release categories which account for a spectrum of possible timing and modes of containment failure. For each containment failure mode the source terms were selected based on the dominant accident progression characteristics leading to the containment failure. The magnitude of releases for each release category were obtained by using the mean values of the probability distributions of source term parameters used in NUREG-1150 and the LaSalle integrated risk assessment studies. A discussion of source term categories and their associated plant damage states and accident progression characteristics for each representative light water reactor designs is provided in this section.



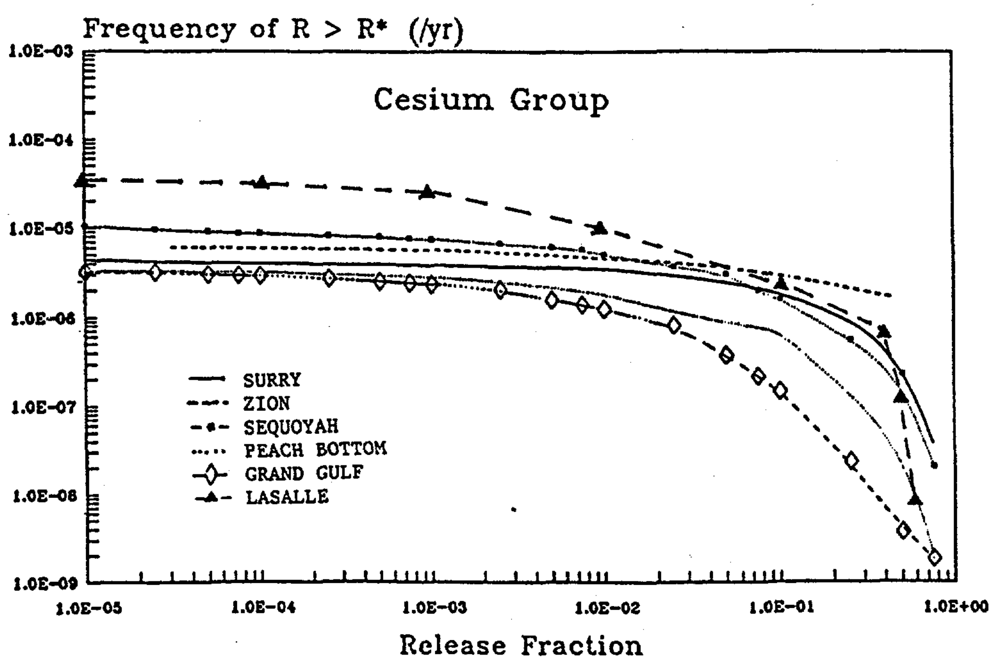
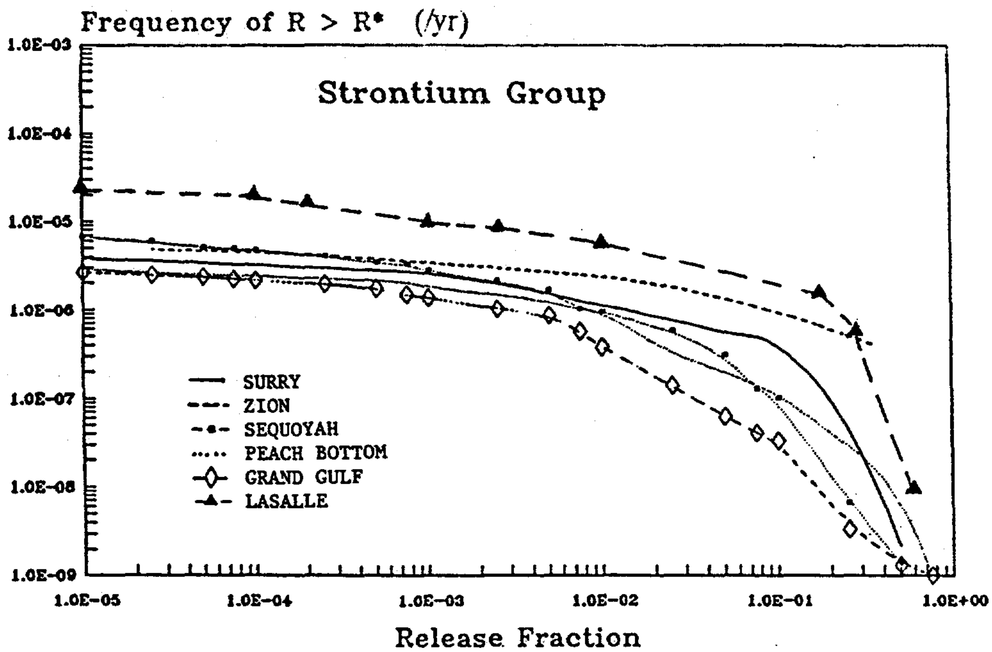


Figure 3.7 Frequency of Release for Key Radionuclide Groups (Internal Events)



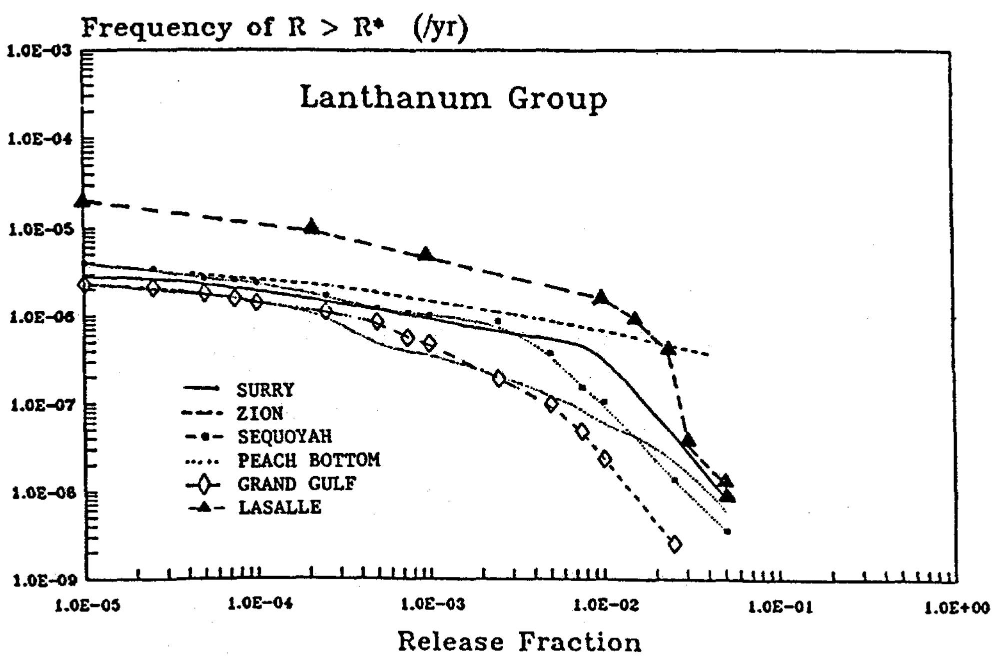


Figure 3.7 Frequency of Release for Key Radionuclide Groups (Internal Events) (Continued)

3.3.1 Representative Source Terms for Grand Gulf

A total of five release categories were selected to represent the spectrum of the timing and mode of containment failure for Grand Gulf. The characteristics of these release categories are presented in Table 3.3. Short term station blackouts are the largest contributor to mean core damage frequency and the dominant plant damage state for all five release categories defined for Grand Gulf.

The potential for early containment or drywell failure for Grand Gulf as compared to Peach Bottom involves significantly different considerations. Of particular significance with regard to the potential for large radioactive releases from Grand Gulf is the prediction of the combined probabilities of simultaneous early containment and drywell failure, which in turn produce a direct radioactive release path to the environment (5). There is a relatively high probability of early containment failure with a large bypass of suppression pool scrubbing effects (Release Category RGG1). The principal threats to the combined efficacy of the Mark III containment and drywell are hydrogen combustion events.

The pedestal region communicates with the drywell region through drains in the drywell floor. The effect of water in the pedestal is either to result in debris coolability (no CCI in RGG5) or to mitigate the source term to containment for the radionuclide released during core-concrete interaction (FLD CCI in RGG1, RGG2, and RGG3). Water in the pedestal does, however, also introduce some potential for ex-vessel steam explosion. In all of the Grand Gulf release categories, containment sprays do not operate and no stuck open tailpipe vacuum breakers were assumed.

The radionuclide release characteristics into the environment for Grand Gulf are presented in Table 3.4. The fractional releases were obtained by using the basic parametric equation of GGSOR. The energy, timing, and duration of releases are based on the results of STCP calculations in support of NUREG-1150.

3.3.2 Representative Source Terms for LaSalle

The representative source terms for LaSalle consist of seven release categories as summarized in Table 3.5. The release categories account for a spectrum of possible containment failure modes:

- early containment failure (before vessel breach) in the rupture mode in the wetwell above the water line (RLAS1),
- early containment failure (at vessel breach) in the leak mode in the wetwell above the water line (RLAS2),
- early containment failure (at vessel breach) by a rupture in the drywell wall (RLAS3),
- early wetwell venting (RLAS4),
- late wetwell venting (RLAS5),
- late containment failure in the rupture mode at the drywell wall (the failure is caused by late failure of the reactor pedestal) (RLAS6), and
- no containment failure (RLAS7).

The events that result in containment failure before vessel breach are slow pressurization events that result from the accumulation of steam and non-condensibles during accidents in which containment heat removal is lost or inadequate. Events that result in containment failure at vessel breach include fast pressurization of the containment from loads accompanying vessel breach.

For the LaSalle release categories, all of the in-vessel releases pass through the SRV tailpipe and are discharged into the suppression pool. Except for the no containment failure release category (RLAS6), the reactor cavity floor fails at the time of vessel breach.

Table 3.3 Characteristics of Grand Gulf Release Categories

Release Category	Plant Damage State	Accident Progression Characteristics							
		Containment Failure Time	Containment Failure Mode	VB	DCH-SE	CCI	SP Bypass	Sprays	SRVBkr
RGG1	STSB	ECF (at VB)	Rupture	HIP-nLPI	LoDCH	FLD CCI	Yes	No	Closed
RGG2	STSB	ECF (Before VB)	Rupture	LOP-nLPI	LoExSE	FLD CCI	No	No	Closed
RGG3	STSB	LCF	Rupture	LOP-nLPI	LoExSE	FLD CCI	L	No	Closed
RGG4	STSB	ECF	Rupture	No VB	No DCH-SE	No CCI	Yes	No	Closed
RGG5	STSB	No CF	No CF	LOP-nLPI	LoExSE	No CCI	No	No	Closed

Table 3.4 Radionuclide Release Characteristics into Environment for Grand Gulf

Release Category	Frequency	Elevation (m)	Energy (W)	Time of Accident Recognition[a]	Time of Release (hrs)	Release Duration	Fractional Releases								
							Ng	I	Cs	Te	Sr	Ba	Ru	La	Ce
RGG1	8.4E-7	32	0.0E+0	1.0 hr	3.6	3 min	7.5E-1	3.0E-2	3.0E-2	8.0E-3	4.0E-3	5.0E-3	5.0E-3	1.4E-3	1.4E-3
		32	0.0E+0		3.65	4 hrs	2.5E-1	2.0E-1	8.0E-2	4.0E-2	2.0E-2	2.0E-2	2.0E-4	1.0E-3	2.0E-3
RGG2	9.2E-7	32	1.1E+6	1.0 hr	2.3	1.3 hrs	7.5E-1	5.0E-3	5.0E-3	2.0E-3	7.0E-4	6.0E-4	4.0E-4	1.2E-4	1.8E-4
		32	6.7E+6		3.6	4 hrs	2.5E-1	3.0E-2	1.0E-2	8.0E-3	4.0E-3	3.0E-3	3.0E-5	1.6E-4	3.0E-4
RGG3	1.16E-6	32	3.0E+7	1.0 hr	14.0	3 min	9.0E-1	1.3E-1	1.0E-2	7.0E-3	3.5E-3	3.0E-3	3.0E-4	2.0E-4	3.0E-4
		32	1.4E+5		14.05	4 hrs	1.0E-1	1.5E-2	1.0E-3	8.0E-4	4.0E-4	3.0E-4	3.0E-5	2.0E-5	3.0E-5
RGG4	7.3E-7	32	1.2E+7	1.0 hr	2.3	1.3 hrs	1.0E+0	3.0E-3	2.5E-3	1.3E-3	3.0E-4	3.6E-4	9.0E-5	1.5E-5	8.0E-5
		32	0.0E+0		3.6	4 hrs	0.0E+0	3.0E-2	1.5E-2	6.0E-3	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
RGG5	2.4E-7	32	7.5E+5	1.0 hr	14.0	2 hrs	2.5E-3	3.7E-6	3.5E-9	1.4E-9	5.0E-10	4.0E-10	2.8E-10	8.5E-11	1.3E-10
		32	4.7E+5		16.0	6 hrs	2.5E-3	3.7E-6	3.5E-9	1.4E-9	5.0E-10	4.0E-10	2.8E-10	8.5E-11	1.3E-10

[a]Time when the reactor water level reaches two feet above bottom of the active fuel.

The radionuclide release characteristics into the environment associated with LaSalle release categories are presented in Table 3.6. The magnitude of releases were calculated by using the basic parametric equation used in LASOR.[5] The energy, timing, and duration of releases are based on the results of the LaSalle integrated risk assessment study.

3.3.3 Representative Source Terms for Peach Bottom

Six release categories were chosen to represent the spectrum of the timing and modes of containment failure for Peach Bottom. The characteristics of Peach Bottom release categories are summarized in Table 3.7. Station blackout sequences as a class are the largest contributor to mean core damage frequency and are the dominant plant damage state leading to early, late, and no containment failures. Anticipated transients without scram (ATWS) accidents as a group are the second largest contributor to mean core damage frequency. ATWS accidents are also the dominant plant damage state leading to early wetwell venting (RPB3).

There is a high probability that the Peach Bottom containment will fail early for the dominant plant damage states (RPB1 and RPB2). Early containment failure will primarily occur in the drywell structure resulting in a bypass of the suppression pool's scrubbing effects for radionuclide releases after vessel breach. The principal cause of early drywell failure is drywell shell melt-through (DWMTH) due to its interaction with the molten core materials released from the breached reactor pressure vessel. The most probable cause of late containment failure is the drywell rupture (DWR) due to overpressurization (RPB4).

For the release categories RPB1, RPB2, RPB4, and RPB6 the reactor pressure vessel is at high pressure at vessel breach and low pressure injection is not available during or after vessel breach (HIP-nLPI). For these release categories a small amount of debris participate in direct containment heating (LoDCH). The pressure suppression pool is particularly effective in the reduction of the in-vessel release component of the source terms for Peach Bottom. There is no early suppression pool bypass in any of the release categories defined for Peach Bottom.

The radionuclide release characteristics into environment for Peach Bottom release categories are presented in Table 3.8. The release fractions were obtained by using the basic parametric equation for PBSOR code.[10] The energy, timing, and duration of releases are based on the results of STCP calculations in support of NUREG-1150.

3.3.4 Representative Source Terms for Sequoyah

The representative source terms for Sequoyah consist of five release categories (RSEQs) as summarized in Table 3.9. The release categories account for a spectrum of possible containment failure modes:

- very early containment failure (during core degradation),
- early containment failure (at vessel breach),
- very late containment failure including the basemat melt-through, no containment failure, and
- containment bypass due to interfacing-system LOCA.

The results of NUREG-1150 indicate that the loss of coolant accidents (LOCAs) as a group are the largest contributors to the mean core damage frequency and are the dominant plant damage state leading to very late or no containment failure (see Figure 3.3). Station blackout sequences as a group are the second largest contributor to the mean core damage frequency and are the dominant plant damage state leading to early containment failure.

Table 3.5 Characteristics of LaSalle Release Categories

Release Category	Plant Damage State	Accident Progression Characteristics								
		Containment Failure Time	Containment Failure Mode	VB	DCH-SE	CCI	DW Sprays	(Cavity Failure at VB)	RB Bypass	SRV Bypass
RLAS1	TRAN	ECF (Before VB)	WWAWR	HIP-nLPI	n-DCH-SE	Dry CCI	No	Yes	No	nSRVBY
RLAS2	TRAN	ECF (at VB)	WWAW-LK	LOP-LPI	n-DCH-SE	INJ CCI	No	Yes	No	nSRVBY
RLAS3	TRAN	ECF (at VB)	DWR	LOP-LPI	LoExSE	INJ CCI	No	Yes	No	nSRVBY
RLAS4	TRAN	ECF (Before VB)	WWVENT	HIP-nLPI	n-DCH-SE	Dry CCI	No	Yes	No	n-SRVBY
RLAS5	TRAN	LCF	WWVENT	LOP-LPI	n-DCH-SE	INJ CCI	No	Yes	No	n-SRVBY
RLAS6	TRAN	LCF	CF-Ped	LOP-nLPI	n-DCH-SE	Dry CCI	No	Yes	Yes	n-SRVBY
RLAS7	TRAN	NCF	NCF	LOP-LPI	n-DCH-SE	INJ CCI	Yes	No	No	n-SRVBY

Table 3.6 Radionuclide Release Characteristics into Environment for LaSalle

Release Category	Frequency	Elevation (m)	Energy (W)	Time of Accident Recognition[a]	Time of Release (hrs)	Release Duration	Fractional Releases								
							Ng	I	Cs	Te	Sr	Ba	Ru	La	Ce
RLAS1	6.3E-6	30	7.2E+6	53.5 hrs	58.3	7.3 hrs	7.5E-1	8.7E-4	6.5E-4	3.7E-4	8.7E-5	8.7E-5	2.5E-5	5.0E-6	2.5E-5
		30	1.3E+7		65.6	15 min	1.5E-4	1.5E-5	2.0E-3	4.6E-5	1.7E-6	1.7E-6	0.0E+0	0.0E+0	0.0E+0
		30	1.7E+7		65.85	6 hrs	2.5E-1	1.6E-1	1.7E-1	1.2E-1	7.0E-2	6.0E-2	1.0E-3	6.0E-3	8.0E-3
RLAS2	6.2E-6	30	4.9E+8	1.3 hrs	3.8	15 min	7.5E-1	1.0E-3	1.0E-3	4.3E-4	1.0E-4	1.2E-4	3.0E-5	6.0E-6	3.0E-5
		30	1.2E+8		4.05	7 hrs	2.5E-1	1.5E-1	2.5E-2	2.5E-2	1.3E-2	1.2E-2	2.0E-4	1.0E-3	1.5E-3
RLAS3	1.2E-6	30	4.4E+8	11.1 hrs	16.9	15 min	7.5E-1	1.4E-2	1.7E-2	5.0E-3	2.0E-3	2.6E-3	2.7E-3	8.0E-4	8.0E-4
		30	3.2E+7		17.15	6 hrs	2.5E-1	1.0E-1	5.0E-2	4.0E-2	2.0E-2	2.0E-2	3.0E-4	1.5E-3	2.5E-3
RLAS4	2.4E-6	30	3.6E+7	23.2 hrs	23.7	1.5 hrs	7.5E-1	2.0E-3	1.6E-3	9.0E-4	2.3E-4	2.5E-5	6.6E-5	1.2E-5	6.6E-5
		30	1.3E+7		25.2	15 min	1.5E-4	1.1E-5	2.0E-3	5.3E-5	1.9E-6	1.9E-6	0.0E+0	0.0E+0	0.0E+0
		30	1.7E+7		25.45	6 hrs	2.5E-1	1.8E-1	1.2E-1	1.0E-1	6.0E-2	5.0E-2	8.4E-4	4.5E-3	6.0E-3
RLAS5	1.7E-5	30	0.0E+0	1.3 hrs	6.11	15 min	9.0E-1	8.0E-2	7.0E-3	9.0E-3	5.0E-3	4.3E-3	8.0E-5	3.7E-4	5.6E-4
		30	0.0E+0		6.36	6 hrs	1.0E-1	9.0E-3	7.0E-4	1.1E-3	5.0E-4	4.8E-4	9.3E-6	4.1E-5	6.2E-5
RLAS6	4.8E-6	30	7.3E+8	1.27 hrs	7.5	15 min	9.0E-1	8.8E-2	9.6E-2	7.6E-2	4.7E-2	4.1E-2	1.9E-3	3.8E-3	4.9E-3
		30	3.0E+8		7.75	6 hrs	1.0E-1	9.8E-3	8.0E-3	8.0E-3	5.0E-3	4.6E-3	2.1E-4	4.2E-4	5.4E-4
RLAS7	6.4E-6	30	1.5E+5	1.3 hrs	7.5	2.5 hrs	2.5E-3	1.5E-5	1.2E-8	7.5E-9	2.5E-9	2.0E-1	3.0E-10	4.0E-10	1.3E-10
		30	2.5E+5		10.0	6 hrs	2.5E-3	1.2E-5	1.2E-8	7.5E-9	2.5E-9	2.0E-10	3.0E-10	4.0E-10	1.3E-10

[a]Time when the reactor water level reaches two feet above bottom of the active fuel.

Table 3.7 Characteristics of Peach Bottom Release Categories

Release Category	Plant Damage State	Accident Progression Characteristics							
		Containment Failure Time	Containment Failure Mode	VB	DCH-SE	CCI	DW Sprays	SP Bypass	RB Bypass
RPB1	LOSP	ECF (at VB)	DWMTH	HIP-nLPI	LoDCH	Dry CCI	No	NOBY	SMBY
RPB2	ATWS	ECF (at VB)	DWMTH	HIP-nLPI	LoDCH	Dry CCI	No	NOBY	SMBY
RPB3	ATWS	ECF (CF During or Before Core Degradation)	WWVENT	LOP-nLPI	n-DCH-SE	Dry CCI	No	NOBY	LGBY
RPB4	LOSP	LCF	DWR	HIP-nLPI	LoDCH	Dry CCI	No	NOBY	LGBY
RPB5	LOSP	NCF	NCF	LOP-LPI	n-DCH-SE	FLD CCI	Yes	NOBY	SMBY
RPB6	LOSP	ECF (at VB)	DWMTH	HIP-nLPI	LoDCH	Dry CCI	No	NOBY	LGBY

Table 3.8 Radionuclide Release Characteristics into Environment for Peach Bottom

Release Category	Frequency	Elevation (m)	Energy (W)	Time of Accident Recognition[a]	Time of Release (hrs)	Release Duration	Fractional Releases								
							Ng	I	Cs	Te	Sr	Ba	Ru	La	Ce
RPB1	1.2E-6	30	6.4E+7	8.0 hrs	11.5	15 min	7.6E-1	1.0E-2	1.0E-2	3.0E-3	1.0E-3	1.2E-3	1.2E-3	3.0E-4	3.0E-4
		30	3.7E+5		11.75	4 hrs	2.4E-1	1.0E-1	9.0E-2	7.0E-2	4.0E-2	3.0E-2	6.0E-4	3.0E-3	4.0E-3
RPB2	1.0E-6	30	6.4E+7	4.8 hrs	7.3	15 min	7.6E-1	1.0E-2	1.0E-2	3.0E-3	1.0E-3	1.2E-3	1.2E-3	3.0E-4	3.0E-4
		30	2.3E+6		7.55	4 hrs	2.4E-1	1.0E-1	9.0E-2	7.0E-2	4.0E-2	3.0E-2	6.0E-4	3.0E-3	4.0E-3
RPB3	6.0E-7	30	0.0E+0	4.8 hrs	4.8	2.5 hrs	7.6E-1	2.3E-3	1.0E-3	1.5E-3	5.0E-4	6.0E-4	5.0E-5	1.0E-5	5.0E-5
		30	0.0E+0		7.3	4 hrs	2.4E-1	4.0E-2	4.0E-2	3.0E-2	2.0E-2	2.0E-2	3.0E-4	1.5E-3	2.0E-3
RPB4	2.0E-7	30	7.7E+6	8.0 hrs	13.0	15 min	1.0E+0	1.0E-2	5.4E-3	4.0E-3	2.2E-3	1.7E-3	1.0E-4	1.8E-4	2.3E-4
RPB5	8.0E-7	30	1.5E+5	8.0 hrs	13.0	2.5 hrs	2.5E-3	5.6E-4	6.0E-9	2.6E-9	2.8E-9	2.2E-9	1.5E-11	1.5E-11	2.9E-10
		30	2.5E+5		15.5	6 hrs	2.5E-3	5.6E-4	6.0E-9	2.6E-9	2.8E-9	2.2E-9	1.5E-11	1.5E-11	2.9E-10
RPB6	3.0E-8	30	7.7E+6		11.5	15 min	7.6E-1	4.0E-2	4.0E-2	1.2E-2	4.0E-3	5.0E-3	5.0E-3	1.2E-3	1.2E-3
		30	1.9E+6	8.0 hrs	11.75	4 hrs	2.4E-1	4.0E-1	3.6E-1	2.8E-1	1.6E-1	1.2E-1	2.4E-3	1.0E-2	2.0E-2

[a]Time when the reactor water level reaches two feet above bottom of the active fuel.

The NUREG-1150 results of the accident progression analysis for Sequoyah indicate that during both station blackout accidents and LOCAs, there is a high probability that the RCS will be at relatively low pressure at the time of vessel breach.

Hydrogen combustion is the most likely cause of early containment failure. In many LOCA sequences, the sprays are failed and the ice is melted at late times and thus, the probability of very late containment failure due to overpressure by steam and noncondensibles is quite high.

The radionuclide release characteristics into the environment for Sequoyah release categories are presented in Table 3.10. The fractional releases were obtained by using the basic parametric equation of the SEQSOR[10] code. The energy, timing, and duration of releases are based on the results of STCP calculations performed in support of NUREG-1150.

3.3.5 Representative Source Terms for Surry

The representative source terms for Surry consist of four release categories (RSURs) as shown in Table 3.11. These release categories correspond to early containment failure (i.e., containment failure at vessel breach), late containment failure (i.e., containment failure after corium-concrete interaction releases) including the basemat melt-through, no containment failure, and containment bypass due to interfacing-system LOCA (Event V).

The results of NUREG-1150 indicate that the station blackout sequences are the largest contributors to internal event mean core damage frequency for Surry (see Table 3.2) and are the dominant plant damage state leading to the first three release categories (see Figure 3.5). Within the general class of station blackout accidents, the most probable is the slow station blackout accidents in which all AC power is lost in the plant but the steam turbine-driven AFWS operates until the batteries deplete.

The results of the accident progression analysis for Surry are particularly noteworthy in that, for slow station blackout accidents, there is a high probability that the reactor coolant system (RCS) will be at relatively low pressure (less than 200 psia) at the time of vessel breach. There are several reasons for concluding that the RCS will be at low pressure such as operator depressurization and induced failure of RCS piping due to high temperatures. Accordingly, the in-vessel steam explosion (Alpha mode) is the most likely cause of early containment failure.

Water collecting on the floor of the Surry containment cannot flow into the reactor cavity. As a result, the cavity will be dry at the time of vessel melt-through unless the containment spray system has operated. The amount of water in the cavity can have a significant influence on phenomena that can occur after reactor vessel lower head failure such as the formation of coolable debris beds, and the retention of the radioactive material released during core-concrete interactions (CCI). For all of the Surry release categories it is assumed that the CCI takes place promptly following vessel breach (VB) and there is no overlaying water pool to scrub the releases (Prm Dry). Furthermore, it was assumed that the corium-concrete interaction involves a large amount of core (70−100%) for all release categories except for the early containment failure category where a medium amount of core (30−70%) was assumed to participate in core-concrete interaction.

The Surry plant has an injection spray system that uses the refueling water storage tank as a water source and a recirculation spray system that recirculates water from the containment pump. Sprays are an effective means for removing airborne radioactive aerosols. For sequences in which sprays

Table 3.9 Characteristics of Sequoyah Release Categories

Release Category	Plant Damage State	Accident Progression Characteristics							
		Containment Failure Time	Containment Failure Mode	CCI	Amt CCI	RCS Pres.	VB Mode	ARF	Sprays
RSEQ1	LOSP	Early CF (During CD)	Cat. Rupture	Prm Dry	Large	Low	Pour	No	No
RSEQ2	LOSP	CF at VB	Cat. Rupture	Prm Dry	Large	Low	Pour	No	No
RSEQ3	LOCA	Very Late CF	Rupture	Prm Dp	Large	Low	Pour	E+L	No
RSEQ4	LOCA	No CF	No CF	Prm Dp	Large	Low	Pour	E+L	No
RSEQ5	Bypass	No CF	Bypass	Prm Dry	Large	Low	Pour	E+L	No

Table 3.10 Radionuclide Release Characteristics into Environment for Sequoyah

Release Category	Frequency	Elevation (m)	Energy (W)	Time of Core Uncovery	Time of Release (hrs)	Release Duration	Fractional Releases								
							Ng	I	Cs	Te	Sr	Ba	Ru	La	Ce
RSEQ1	2.8E-7	10	2.8E+7	5.0 hrs	5.5	200 sec	1.0E+0	3.7E-1	2.7E-1	1.3E-1	2.5E-2	3.0E-2	8.0E-3	1.6E-3	8.0E-3
		10	1.6E+6		6.0	2 hrs	0.0E+0	2.2E-1	3.5E-1	3.0E-1	1.3E-1	1.2E-1	3.0E-3	1.3E-2	1.8E-2
RSEQ2	3.6E-6	10	2.8E+7	5.0 hrs	6.0	200 sec	1.0E+0	5.0E-2	4.0E-2	2.0E-2	4.0E-3	4.0E-3	1.0E-3	2.0E-4	1.0E-3
		10	1.6E+6		6.06	2 hrs	0.0E+0	1.3E-1	1.5E-1	1.1E-1	4.5E-2	4.5E-2	1.0E-3	5.0E-3	6.0E-3
RSEQ3	1.2E-5	10	3.5E+6	5.0 hrs	24.0	200 sec	1.0E+0	3.3E-2	6.5E-6	3.2E-6	1.5E-6	1.5E-6	3.2E-8	1.6E-7	1.6E-7
RSEQ4	3.5E-5	0	0.0E+0	5.0 hrs	6.0	10 hrs	2.5E-3	1.5E-5	1.0E-7	7.0E-8	2.0E-8	2.0E-8	1.9E-9	2.5E-9	4.0E-9
		0	0.0E+0		16.0	10 hrs	2.5E-3	1.5E-5	1.0E-7	7.0E-8	2.0E-8	2.0E-8	1.8E-9	2.5E-9	4.0E-9
RSEQ5	3.1E-6	0	1.9E+6	20 min	1.0	30 min	1.0E+0	7.5E-2	6.0E-2	2.0E-2	5.0E-3	5.0E-3	1.0E-3	3.0E-4	1.0E-3
		0	1.7E+5		1.5	2 hrs	0.0E+0	4.0E-2	6.0E-2	5.0E-2	2.0E-2	2.0E-2	6.0E-4	3.0E-3	3.0E-3

operate it is most likely that the containment will not fail and the leakage to the environment will be minor. Containment sprays are assumed to operate only in late and very late periods for the no containment failure release category (RSUR3).

The radionuclide release characteristics into environment for different Surry release categories are presented in Table 3.12. The magnitudes of releases for each release category were obtained by utilizing the basic parametric equation of SURSOR.[10] The mean values of the probability distributions of source term parameters associated with the corresponding accident progression characteristics were used in these calculations.

The energy, timing, and duration of releases are based on the result of STCP calculations performed in support of NUREG-1150.

3.3.6 Representative Source Terms for Zion

A total of four release categories (RZs) was selected to represent the spectrum of containment failure modes of the Zion plant. The characteristics of these release categories are presented in Table 3.13. Loss of coolant accidents (LOCAs) are the largest contributor to mean core damage frequency for Zion (see Table 3.2) and the dominant plant damage state leading to the release categories of RZ1, RZ2, and RZ3.

The NUREG-1150 results of the accident progression analysis for Zion indicate that for the loss of coolant accidents, there is a high probability that the RCS will be at relatively low pressure at the time of vessel breach and thus the in-vessel steam explosion (Alpha mode) is the most likely cause of early containment failure.

The Zion cavity is referred to as a wet cavity in that the accumulation of a relatively small amount of water on the containment floor will lead to overflow into the cavity. As a result, there is a substantial likelihood of scrubbing the CCI releases by an overlying pool of water. For all of the Zion release categories it is assumed that the CCI takes place promptly following VB. For release category of RZ1, there is a shallow overlying water pool to scrub the CCI releases. For release categories of RZ2 and RZ3, there is a deep overlying water pool to scrub the CCI releases.

The radionuclide release characteristics into environment associated with different Zion release categories are presented in Table 3.14. The magnitude of release were calculated by using the basic parametric equations used in ZISOR.[10] The energy, timing, and duration of releases are based on the results of STCP calculations which were performed in support of the NUREG-1150 study.

3.3.7 Prompt and Latent Fatalities

Consequence calculations are performed with the representative source terms and are compared to the consequences analyses of NUREG-1150. A comparison of early and latent cancer fatality risks using the representative source terms and NUREG-1150 results are shown in Tables 3.15 and 3.16. To allow for comparison with the NUREG-1150 results, the older version of the MACCS[2] (which incorporates the BEIR-III correlation for latent cancer fatalities) is used in these calculations.

3.4 Population Assumptions

To examine the effect of various population distribution assumptions on the QHOs and on the other consequence attributes considered, six distributions are used. These are shown in Table 3.17. These population distributions are referred to as cases 1 through 6, and are denoted as C1 through C6. Cases 1 through 5 are constructed to be consistent with the guidance in Regulatory Guide 4.7. Specifically for cases 1 through 4, the population density averaged out to 30 miles (at any radial distance) is 500 people/sq. mile which reflects the

Table 3.11 Characteristics of Surry Release Categories

Release Category	Plant Damage State	Accident Progression Characteristics						
		Containment Failure Time	Containment Failure Mode	CCI	Amt CCI	RCS Pres.	VB Mode	Sprays
RSUR1	LOSP	CF at VB	Rupture	Prm Dry	Medium	Low	Alpha	No
RSUR2	LOSP	Late CF	Leak	Prm Dry	Large	Low	Pour	No
RSUR3	LOSP	No CF	No CF	Prm Dry	Large	Low	Pour	L+VL
RSUR4	Bypass (V)	No CF	Bypass	Prm Dry	Large	Low	Pour	No

Table 3.12 Radionuclide Release Characteristics into Environment For Surry

Release Category	Frequency	Elevation (m)	Energy (W)	Time of Core Uncovery	Time of Release (hrs)	Release Duration	Fractional Releases								
							Ng	I	Cs	Te	Sr	Ba	Ru	La	Ce
RSUR1	2.9E-7	10	2.8E+7	5.0 hrs	6.0	200 sec	1.0E+0	2.5E-1	1.8E-1	8.0E-2	2.0E-2	2.0E-2	5.0E-3	1.0E-3	5.0E-3
		10	1.6E+6		6.06	2 hrs	0.0E+0	1.0E-1	1.3E-1	1.0E-1	4.0E-2	4.0E-2	1.0E-3	5.0E-3	5.0E-3
RSUR2	2.4E-6	10	5.2E+5	5.0 hrs	12.0	3 hrs	1.0E+0	6.0E-2	3.0E-2	9.0E-2	3.0E-3	3.0E-3	1.0E-3	4.0E-4	4.0E-4
RSUR3	3.3E-5	0	0.0E+0	5.0 hrs	6.0	10 hrs	2.5E-3	1.5E-5	1.2E-8	7.5E-9	2.5E-9	2.5E-10	2.0E-10	3.0E-10	4.0E-10
		0	0.0E+0		16.0	10 hrs	2.5E-3	1.5E-5	1.2E-8	7.5E-9	2.5E-9	2.5E-10	2.0E-10	3.0E-10	4.0E-10
RSUR4	1.6E-6	0	1.9E+6	20 min	1.0	30 min	1.0E+0	7.5E-2	6.0E-2	2.0E-2	5.0E-3	5.0E-3	1.0E-3	3.0E-4	1.0E-3
		0	1.7E+5		1.5	2 hrs	0.0E+0	4.0E-2	6.0E-2	6.0E-2	2.0E-2	2.0E-2	6.0E-4	3.0E-3	3.0E-3

Table 3.13 Characteristics of Zion Release Categories

Release Category	Plant Damage State	Accident Progression Characteristics						
		Containment Failure Time	Containment Failure Mode	CCI	Amt CCI	RCS Pres	VB Mode	Sprays
RZ1	LOCA	CF at VB	Rupture	Prm Shlw	Medium	Low	Alpha	No
RZ2	LOCA	Late CF	Leak	Prm Dp	Large	Low	Pour	No
RZ3	LOCA	No CF	No CF	Prm Dp	Large	Low	Pour	Yes
RZ5	Bypass	No CF	Bypass	Prm Dry	Large	Low	Pour	No

Table 3.14 Radionuclide Release Characteristics into Environment for Zion

Release Category	Frequency	Elevation (m)	Energy (W)	Time of Core Uncovery	Time of Release (hrs)	Release Duration	Fractional Releases								
							Ng	I	Cs	Te	Sr	Ba	Ru	La	Ce
RZ1	4.6E-6	10	8.6E+5	5.0 hrs	6.0	10 min	1.0E+0	2.5E-1	1.8E-1	8.0E-2	2.0E-2	2.0E-2	5.0E-3	1.0E-3	5.0E-3
		10	1.5E+6		6.167	2 hrs	0.0E+0	2.0E-2	3.0E-2	2.0E-2	1.0E-2	1.0E-2	2.0E-4	1.0E-3	1.0E-3
					3										
RZ2	7.8E-5	10	1.9E+5	5.0 hrs		3 hrs	1.0E+0	3.0E-2	6.0E-6	7.0E-6	1.0E-6	1.0E-6	2.0E-8	1.0E-7	1.0E-7
					12.0										
RZ3	2.4E-4	0	0.0E+0	5.0 hrs		10 hrs	2.5E-3	1.5E-5	1.2E-8	7.5E-9	2.5E-9	2.5E-9	2.0E-10	3.0E-10	4.0E-10
		0	0.0E+0		6.0	10 hrs	2.5E-3	1.5E-5	1.2E-8	7.5E-9	2.5E-9	2.5E-9	2.0E-10	3.0E-10	4.0E-10
					16.0										
RZ4	2.3E-6	10	5.5E+6	20 min		30 min	1.0E+0	7.5E-2	6.0E-2	2.0E-2	5.0E-3	5.0E-3	1.0E-3	3.0E-4	1.0E-3
		10	9.9E+5		1.0	2 hrs	0.0E+0	4.0E-2	6.0E-2	5.0E-2	2.0E-2	2.0E-2	6.0E-4	3.0E-3	3.0E-3
					1.5										

Table 3.15 Comparison of Early Fatality Risks at all Plants (Due to Internal Events) in NUREG-1150 with the Simplified Source Terms

	NUREG-1150				Simplified Source Terms (Mean)
	5%	Median	Mean	95%	
Grand Gulf	2.5E-12	6.1E-10	8.2E-09	2.6E-08	0[a]
Peach Bottom	1.7E-11	5.1E-09	2.6E-08	1.3E-07	0[a]
Sequoyah	4.7E-08	2.4E-06	2.6E-05	1.2E-04	6.53E-05
Surry	7.6E-10	7.0E-08	2.0E-06	5.4E-06	1.7E-06
Zion	5.93E-07	4.59E-06	1.10E-04	1.16E-04	1.99E-04

(a)The source term is below the threshold to cause any prompt fatality

Table 3.16 Comparison of Latent Cancer Fatality Risks at all Plants (Due to Internal Events) in NUREG-1150 with the Simplified Source Terms

	NUREG-1150				Simplified Source Terms (Mean)
	5%	Median	Mean	95%	
Grand Gulf	1.4E-05	2.4E-04	9.5E-04	2.3E-03	1.44E-03
Peach Bottom	2.3E-04	1.6E-03	4.6E-03	1.3E-02	6.31E-03
Sequoyah	5.6E-04	4.8E-03	1.4E-02	5.3E-02	1.76E-02
Surry	3.1E-04	2.2E-03	5.2E-03	1.9E-02	3.78E-03
Zion	1.50E-03	7.04E-03	2.44E-02	5.91E-02	3.48E-02

Table 3.17 Population Distributions per Sector

Radius (miles)	Case 1 Population in Sectors	Case 2 Population in Sectors			Case 3 Population in Sectors		Case 4 Population in Sectors	
	1-16	1-13	14, 15	16	1-14	15, 16	1-13	14, 15, 16
0.25	6	1	1	1	1	1	6	6
0.33	5	1	1	1	1	1	5	5
0.4	5	1	1	1	1	1	5	5
0.5	9	2	2	2	2	2	9	9
1.25	129	26	26	26	26	26	129	129
1.33	20	4	4	4	4	4	20	20
1.4	19	4	4	4	4	4	19	19
1.5	28	6	6	6	6	6	28	28
2	172	34	34	34	34	34	172	172
3	491	98	98	98	98	98	491	491
4	687	137	137	137	137	137	687	687
5	884	177	177	177	177	177	884	884
8	3829	766	30,631	7190	766	766	3829	3829
10	3534	707	28,274	707	707	707	3534	3534
13	6774	1355	1355	1355	1355	74,515	6774	6774
15	8541	1708	1708	1708	1708	93,953	8541	8541
20	14,137	2827	2827	2827	2827	81,532	14,137	14,137
25	22,089	4418	4418	4418	4418	4418	22,089	22,089
30	26,998	5400	5400	5400	5400	5400	26,998	26,998
40	38,485	38,485	38,485	38,485	38,485	38,485	38,485	1,511,891
50	49,480	49,480	49,480	49,480	49,480	49,480	49,480	1,821,442
70	94,248	94,248	94,248	94,248	94,248	94,248	94,248	94,248
100	200,277	200,277	200,277	200,277	200,277	200,277	200,277	200,277
150	490,874	490,874	490,874	490,874	490,874	490,874	490,874	490,874
200	687,223	687,223	687,223	687,223	687,223	687,223	687,223	687,223
350	3,239,767	3,239,767	3,239,767	3,239,767	3,239,767	3,239,767	3,239,767	3,239,767
500	5,006,913	5,006,913	5,006,913	5,006,913	5,006,913	5,006,913	5,006,913	5,006,913
Total	9,898,624	9,824,939	9,882,371	9,831,363	9,824,939	10,069,049	9,895,624	13,140,992

Cases:

1: Uniform population density of 500 people/sq. mile out to 30 miles; then uniform population density of 280 people/sq. mile between 30-50 miles

2: Uniform population density of 100 people/sq. mile out to 30 miles + city of 125,000 between 5 and 10 miles (small city at 5 miles); then uniform population density of 280 people/sq. mile between 30-50 miles

3: Uniform population density of 100 people/sq. mile out to 30 miles + city of 500,000 between 10 and 20 miles (medium city at 10 miles); then uniform population density of 280 people/sq. mile between 30-50 miles

4: Uniform population density of 500 people/sq. mile out to 30 miles + city of 10,000,000 between 30 and 50 miles (large city at 30 miles); then uniform population density of 280 people/sq. mile between 30-50 miles

Uniform population density of 200 people/sq. mile between 50-500 miles for all cases.

Table 3.17 Population Distributions (continued)

Radius (miles)	Case 5 Population in Sectors		Case 6 Population in Sectors	
	1-13	14, 15, 16	1-13	14, 15, 16
0.25	12	12	25	25
0.33	9	9	18	18
0.4	10	10	20	20
0.5	18	18	35	35
1.25	258	258	515	515
1.33	41	41	81	81
1.4	38	38	75	75
1.5	57	57	114	114
2	344	344	687	687
3	982	982	1963	1963
4	1374	1374	2749	2749
5	1767	1767	3534	3534
8	7658	7658	15,315	15,315
10	7069	7069	14,137	14,137
13	13,548	13,548	27,096	27,096
15	10,996	10,996	21,991	21,991
20	34,361	34,361	68,722	68,722
25	44,179	44,179	88,357	88,357
30	53,996	53,996	107,992	107,992
40	38,485	1,511,891	38,485	1,511,891
50	49,480	1,821,442	49,480	1,821,442
70	94,248	94,248	94,248	94,248
100	200,277	200,277	200,277	200,277
150	490,874	490,874	490,874	490,874
200	687,223	687,223	687,223	687,223
350	3,239,767	3,239,767	3,239,767	3,239,767
500	5,006,913	5,006,913	5,006,913	5,006,913
Total	9,983,984	13,229,352	10,160,693	13,406,061

Cases:

5: Uniform population density of 1000 people/sq. mile out to 30 miles; city of 10,000,000 between 30 and 50 miles; uniform population density of 280 people/sq. mile between 30-50 miles.

6: Uniform population density of 2000 people/sq. mile out to 30 miles; city of 10,000,000 between 30 and 50 miles; uniform population density of 280 people/sq. mile between 30-50 miles.

Uniform population density of 200 people/sq. mile between 50-500 miles for all cases.

"start of plant life" population density given in Regulatory Guide 4.7. In case 5 the population density out to 30 miles is 1000 people/sq. mile which is the "end of plant life" population density given in Regulatory Guide 4.7. Case 6, having a population density of 2000 people/sq. mile out to 30 miles, is selected to provide a higher population density case.

In the first case, the population is uniformly distributed axially. Radially, it is uniform in three regions. The regions are: zero to 30 miles, 30 to 50 miles, and 50 to 500 miles; and the population densities assumed are 500, 280, and 200 people/sq. mile, respectively. The value of 280 people per sq. mile is based on a current average site population density. The value of 200 people/sq mile is twice the current national average for the contiguous lower 48 states. Its selection reflects a consideration of future population growth, and adds an additional degree of conservatism in the assessment of latent fatalities at a large distance from the point of release. The latter regions and their respective population densities of 280 and 200 people/sq. mile are used in all the cases to estimate the surrounding populations.

In cases 2 and 3, the surrounding population density in the region 0 to 30 miles is taken to be 100 people/sq. mile. Case 2 has a small city of 125,000 people located in basically two sectors over a distance of 5 to 10 miles from the plant. The radial location is linked to the guidance in Regulatory Guide 4.7. The area occupied by the small city is based on the assumed population and a mean value for the population density (~4000 people/sq. mile) of similar sized cities obtained from an analysis of 1980 Census data. In case 3, a medium sized city of 500,000 was located over two sectors at a distance of 10 to 20 miles beyond the plant. The radial location and area of this city are determined by similar considerations of Regulatory Guide 4.7 and a mean density of ~5400 people/sq. mile for cities of similar size.

To be consistent with Regulatory Guide 4.7 a very large city of 10,000,000 is located radially between 30 to 50 miles (Case 4). Based upon a mean density of ~12,000 people/sq. mile for cities with populations above 1 million, the large city extends over three sectors. Cases 4, 5, and 6 are identical with the exception of the population density that is assumed in the region 0 to 30 miles. In cases 5 and 6, the population density was assumed to be 1000 people/sq. mile and 2000 people/sq. mile, respectively.

In this study four assumed sizes for the exclusion area distance radii were taken as shown in Table 3.18 below. The site data files used the population distributions shown in Table 3.17; however, there is no population within the various exclusion radii.

Table 3.18 Exclusion Area Distances

Designation	Distance (miles)
Z1	0.25
Z2	0.33
Z3	0.4
Z4	0.5

3.5 Meteorological Data

Meteorology and its variability plays an important role in a probabilistic consequence assessment. The meteorological conditions at the time of an accident influence the extent of transport and dispersion and thus control atmospheric concentration and the extent of deposition on the land.[11]

One case is selected to represent the mean meteorological conditions within the continental United States. The second case is selected to represent conservative meteorological conditions. In the former case, all meteorological attributes are given equal weight. The working premise for selecting a conservative case meteorology is to give weight to those meteorological attributes that would increase near reactor effects—namely, increase in-close dose.

Dose is due to the three exposure pathways: cloudshine, i.e., exposure due to immersion in a cloud of radioactive material; groundshine, exposure due to proximity to material deposited on the ground or other surfaces; and inhalation, exposure due to breathing contaminated air. At a given distance x, downwind of the point of release, the doses due to cloudshine and inhalation exposures are directly proportional to the atmospheric concentration of radioactive material at that distance. Within the Gaussian plume approximation modeled in the MACCS code, the time integrated atmospheric concentration $\chi(x,y,z)$ at ground level (z=0) along the centerline (y=0) of the plume, neglecting a limit on vertical dispersion due to an inversion layer, is given by

$$\chi(x,y=0,z=0) = \frac{Q}{2\pi\bar{u}\sigma_y\sigma_z} \exp(-h^2/2\sigma_z^2)$$

where σ_y and σ_z are the standard deviations of the normal distributions of material concentrations in the horizontal and vertical directions (dispersion factors), respectively, $\bar{u}$ is the mean windspeed in the direction of transport, Q is the amount of material released, and h is the height of the release. χ can be seen to be inversely proportional to the wind speed, $\bar{u}$, σ_y and σ_z. Therefore, low wind speed and small dispersion factors will cause χ and the delivered dose to increase.

Both σ_y and σ_z vary with distance (x) and with atmospheric stability class. For a given stability class, both σ_y and σ_z increase consistently with distance (see Figures 3.8 and 3.9). At a given distance, the dispersion factors increase as the atmospheric stability becomes less stable. The range of increase of σ_y from class F (moderately stable) to class A (unstable) is about a factor of 6 at any downwind distance. The range of increase of σ_z is also about a factor of 6 at 330 feet downwind; however, it increases rapidly to about a factor of 30 at 0.6 miles, and it continues to increase with distance. The vertical dispersion will eventually be capped by the mixing ceiling, and the vertical concentration profile will eventually become uniform. For the unstable classes, this should occur close to the point of release—within several miles downwind. The distance at which the vertical concentration of cloud in more stable classes will become well mixed, progressively increases. For the most stable wind classes, E and F, this distance can be about 60 miles. These large variations in the dispersion factors with stability class have a commensurate effect on the cloud concentration.

Doses due to groundshine are proportional to the amount of material deposited on the ground (or other fixed surfaces such as building roofs, etc.) due to both dry and wet deposition as the plume is transported in the direction of the wind. In the MACCS code, both dry and wet deposition over a spatial segment are treated as first-order rate processes, with the deposition rate $dQ/dt = -kQ$. For dry deposition of particulate material from the plume, which occurs due to gravitational settling or impaction, the factor k is proportional to v_d divided by a characteristic length (which becomes equal to the height of the inversion layer after the plume becomes well-mixed in the vertical direction), where v_d is the deposition velocity (assumed to be constant, 0.01 m/s, in the calculations reported below). For wet deposition or washout due to rain, the proportionality factor k is equal to aI^b where a and b are (dimensionless) constants and I is the rainfall rate over a spatial segment (mm/hour). Previous results[4] indicate that rainfall during or shortly after a release of radioactive material can efficiently remove material from the atmosphere resulting in higher doses from groundshine.

Hence, the criteria for the selection of a bounding case should be based on the amount of rainfall and the frequency of high stability wind patterns and low

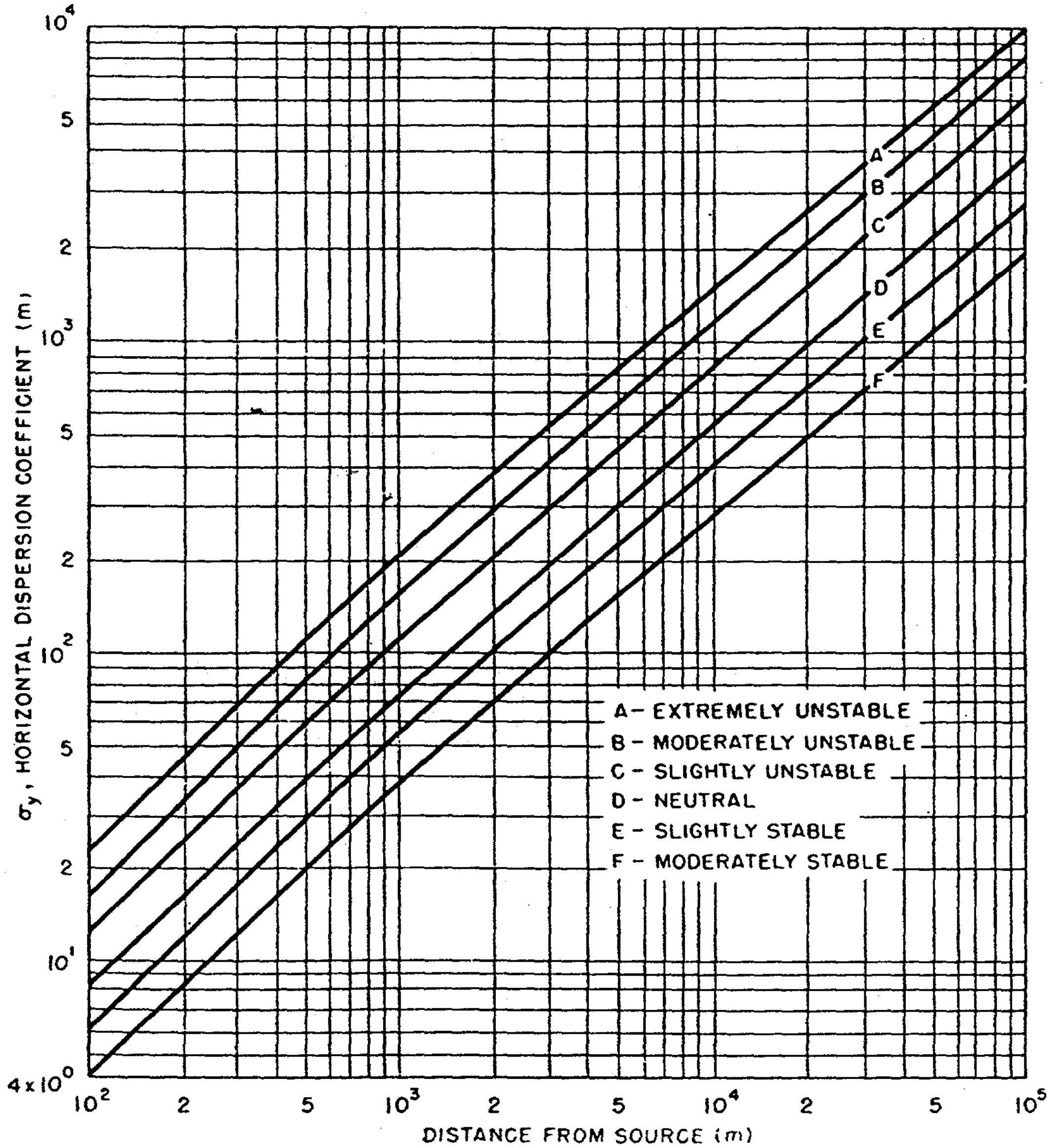


Figure 3.8 Lateral Diffusion, σ_y, vs. Downwind Distance from Source for Pasquill's Turbulence Types. (Reproduced from U.S. Nuclear Regulatory Commission Regulatory Guide 1.145)

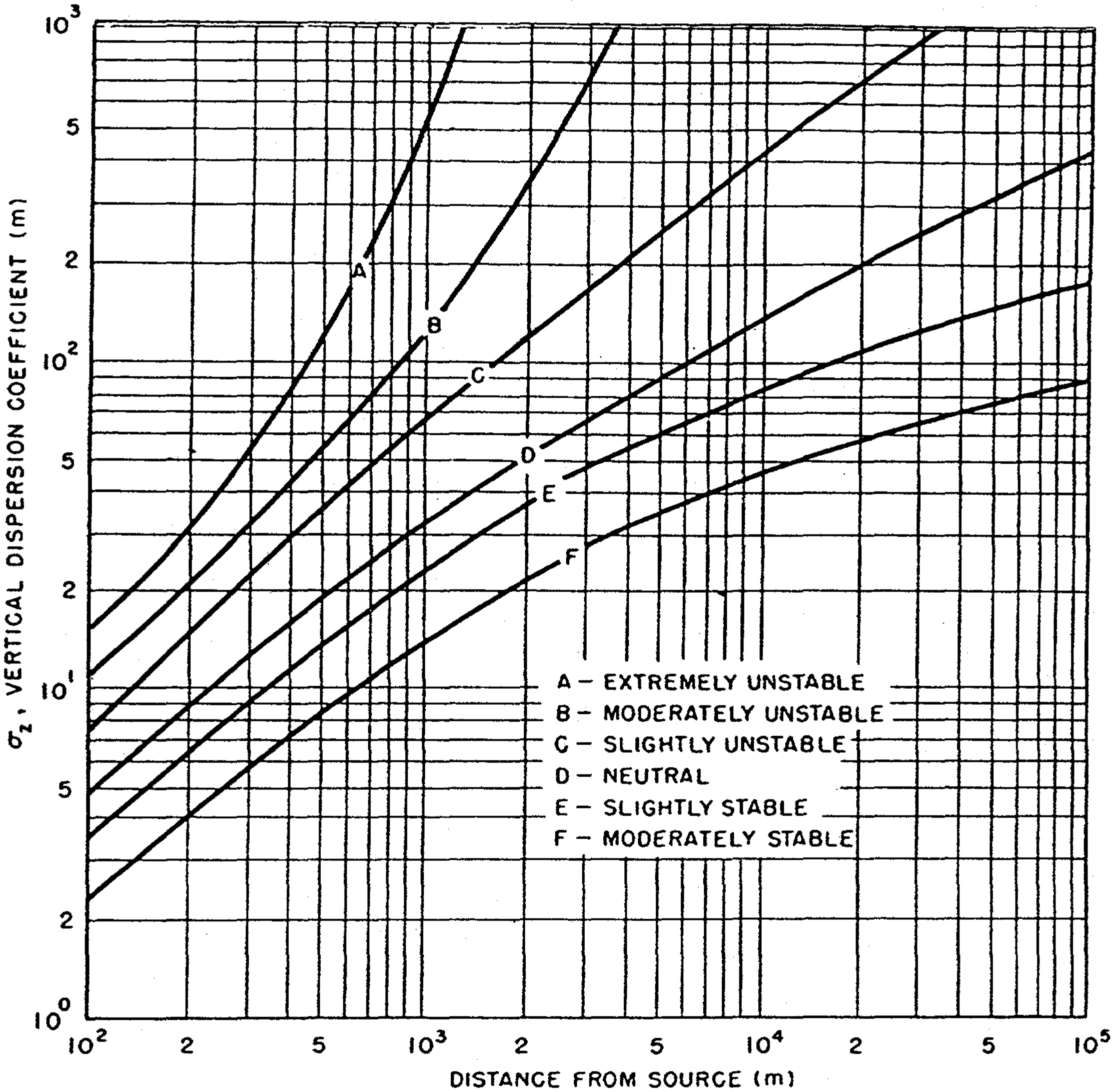


Figure 3.9 Vertical Diffusion, σ_z, vs. Downwind Distance from Source for Pasquill's Turbulence Types. (Reproduced from U.S. Nuclear Regulatory Commission Regulatory Guide 1.145)

wind speed. Historically, the authors and users of the MACCS code have used a binning scheme that has clustered meteorological data into the following categories: rain classes, wind slowdown classes, and wind stability classes. Table 3.19 contains the frequency distribution in this binning scheme of the 29 National Weather Service (NWS) sites used in the Sandia Siting Study (NUREG/CR-2239) sites. The first 29 rows of numerical data are the percent of total time each of the sites exhibit meteorological data characteristic of the 29 bins. The last two entries in each column are the annual rainfall (Rain) in inches and the mean annual mixing height (Mix-Ht) in meters. This data was also taken from NUREG/CR-2239. The complete data set was used to obtain the statistical information tabulated in columns Min(imum value), Max(imum value), Mean, Median, and 80th (percentile). The low emphasis placed on dry-unstable and dry-neutral groups, which comprise only 7 of the 29 categories, clearly indicate a consensus regarding those conditions that strongly influence the consequence assessment.

In the Sandia Siting Study report, the 29 NWS sites were chosen as a representative set of the nation's meteorological conditions. Furthermore, the actual meteorological files that were used in that consequence study were constructed from several decades of data collected for each site and thus were argued to be more representative of long-term behavior and less influenced by short-term anomalies. Additionally, the study stated that the NWS data was generally more complete than records from the actual reactor sites. We have, therefore, adopted these 29 NWS sites as a representative basis set herein for establishing reasonable ranges of meteorology conditions that might be expected in the continental United States.

For these 29 National Weather Service (NWS) sites, frequency and cumulative distributions (CD) for annual hours of rainfall, annual amount (inches) of rainfall, and percent of time in each of the 29 weather bins are constructed. This study attempts to define the bounding case meteorology, in the sense that the predicted consequences in this study will equal or exceed those at a spectrum of reactor sites at the 80th percentile, by selecting a site which has the important weather attributes at the 80th percentile values, see Table 3.19.

Inspection of the CDs for rainfall indicates the 80th percentiles fall at 550 hours and 48 inches of rain per year. The three sites closest to these values are Charleston, SC; Cape Hatteras, NC; and Nashville, TN. These sites are, therefore, the prime candidates for the bounding meteorology. Other sites close to the 80th percentiles, but not as close as the former, are Chicago, IL; Columbia, MO; and Moline, IL.

A statistical comparison of the 29 NWS sites with the 80th percentiles for rain bins, slowdown bins, and class E and F bins has been performed. The best agreement observed occurs for Charleston, SC; Miami, FL; and Nashville, TN, respectively. Thus, within the analysis presented here, either Charleston, SC or Nashville, TN would appear to be reasonable choices for a 80th percentile bounding meteorology, since these sites are very close to both the rainfall and the ancillary meteorological criteria. The Charleston, SC weather file has been selected for this study.

Similar statistical comparisons of the meteorological data of the NWS sites to the means and the medians have been performed. The results are shown in Tables 3.20 and 3.21. The four sites, which have the lowest deviations in each analysis, are shown. Both analyses rank the Omaha, NE; Madison, WI; and Moline, IL sites in the same order. Additional analyses, which weight the errors to force the selection of sites that best fit the rain, slowdown, and high stability (E and F) bins, also rank the Omaha site first; changes in the ranking of other sites are observed. Hence, all of the comparisons performed to determine the mean weather rank Omaha first. The meteorological data for Omaha, thus, can represent either the mean or Median values. This results from the close agreement of mean to median values.

Table 3.19 Meteorological Data of the 29 National Weather Service (NWS) Sites

Weather Bin	Albu-querque	Appalach	Bismarck	Boston	Browns-ville	Cape Hatteras	Caribou	Charleston	Chicago	Columbia	Dodge	El Paso
R (0)	1.46	4.50	3.94	8.89	2.25	6.69	10.14	5.87	6.19	6.26	3.69	1.30
R (0-5)	0.09	0.70	0.15	0.17	0.06	0.11	0.38	0.29	0.15	0.11	0.11	0.06
R (5-10)	0.31	1.14	0.40	0.79	0.39	0.75	1.26	0.88	0.68	0.75	0.27	0.26
R (10-15)	0.55	1.34	0.67	1.24	0.49	1.12	1.60	1.32	1.21	0.91	0.58	0.51
R (15-20)	0.33	1.11	0.76	0.82	0.54	1.02	1.28	0.81	0.87	0.91	0.37	0.34
R (20-25)	0.33	0.99	0.55	0.90	0.53	0.83	1.12	0.87	0.68	0.76	0.55	0.32
R (25-30)	0.40	0.96	0.66	0.94	0.42	0.83	1.29	0.99	0.86	0.76	0.50	0.34
S (0-10)	2.00	1.36	1.02	0.55	0.34	0.14	0.53	0.51	0.51	0.53	0.24	0.98
S (10-15)	2.01	1.02	0.90	0.43	0.27	0.08	0.42	0.43	0.41	0.42	0.25	0.96
S (15-20)	1.78	1.04	0.63	0.50	0.27	0.09	0.40	0.33	0.35	0.39	0.14	0.91
S (20-25)	1.55	1.02	0.73	0.37	0.21	0.07	0.29	0.39	0.38	0.32	0.15	0.71
S (25-30)	1.62	1.19	0.88	0.45	0.31	0.14	0.33	0.39	0.28	0.45	0.18	0.89
A-C 1,2,3	12.97	6.44	4.22	1.51	1.18	1.66	4.29	3.05	2.66	3.32	2.48	11.08
A-C 4,5	11.08	15.70	7.11	7.52	11.46	12.48	5.48	13.11	10.98	13.53	13.03	14.74
D 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D 2	1.51	2.19	1.71	0.74	0.59	0.21	1.82	1.06	1.02	0.92	0.43	1.31
D 3	3.07	2.81	3.18	1.77	1.95	1.67	4.49	3.41	3.62	3.05	1.61	2.91
D 4	4.81	7.72	8.56	9.63	7.33	8.50	10.92	12.45	11.90	11.18	7.39	5.89
D 5	19.29	12.31	35.99	45.75	43.07	38.66	31.10	19.92	32.15	27.92	49.13	20.50
E 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E 2	1.26	1.85	1.11	0.23	0.54	0.26	0.53	0.83	0.48	0.50	0.09	1.53
E 3	3.15	2.48	1.91	0.79	2.44	1.23	2.43	4.01	2.20	2.00	0.67	3.15
E 4	7.87	5.34	6.21	6.36	7.28	9.68	6.71	7.57	7.25	9.06	7.68	6.45
E 5	2.35	1.85	1.67	3.13	2.69	3.01	2.09	1.80	2.84	2.23	3.74	2.51
F 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F 2	6.94	14.51	7.71	1.13	3.69	1.56	3.11	8.17	2.75	2.32	0.72	9.59
F 3	7.50	6.46	5.48	1.80	6.40	4.20	4.75	6.92	4.93	4.73	2.24	8.32
F 4	5.78	4.01	3.85	3.58	5.30	5.00	3.28	4.61	4.60	6.74	3.74	4.42
F 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rain	7	65	16	41	16	49	31	52	37	37	26	6
Mix-Ht	2600	1200	1500	1100	1300	1000	1300	1300	1200	1200	1600	2600

Table 3.19 Meteorological Data of the 29 National Weather Service (NWS) Sites (continued)

Weather Bin	Ely	Fort Worth	Fresno	Great Falls	Lake Charles	Madison	Medford	Miami	Milwaukee	Moline	Nash-ville	New York
R (0)	3.06	3.97	2.09	5.56	3.73	6.08	4.61	4.37	6.12	5.84	6.60	7.96
R (0-5)	0.36	0.10	0.11	0.40	0.32	0.24	1.37	0.32	0.18	0.11	0.18	0.14
R (5-10)	0.65	0.47	0.56	0.94	1.00	0.98	1.56	1.14	0.66	0.79	0.79	0.71
R (10-15)	0.65	0.66	0.49	1.11	0.98	1.28	1.59	1.34	1.20	1.03	1.04	1.16
R (15-20)	0.66	0.45	0.32	0.82	0.68	1.03	1.13	1.15	0.84	0.83	0.90	0.86
R (20-25)	0.57	0.45	0.40	0.59	0.76	0.84	1.13	1.02	0.71	0.66	0.01	0.76
R (25-30)	0.51	0.48	0.39	0.76	0.66	0.98	1.19	1.31	0.88	0.80	0.73	0.70
S (0-10)	0.86	0.49	0.90	0.59	0.51	0.94	1.47	0.62	0.59	0.47	0.73	0.27
S (10-15)	0.32	0.33	0.81	0.39	0.43	0.73	1.37	0.50	0.40	0.32	0.66	0.18
S (15-20)	0.73	0.25	0.70	0.40	0.35	0.75	1.30	0.49	0.34	0.35	0.65	0.21
S (20-25)	0.28	0.33	0.62	0.34	0.38	0.58	1.27	0.41	0.32	0.41	0.68	0.16
S (25-30)	0.64	0.33	0.78	0.33	0.42	0.68	1.29	0.53	0.43	0.35	0.70	0.21
A-C 1,2,3	9.60	4.12	16.69	4.49	3.97	3.38	15.49	3.46	2.25	3.50	4.40	1.92
A-C 4,5	13.70	14.92	7.45	8.12	11.58	8.64	6.06	15.70	9.68	10.73	11.18	10.18
D 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D 2	1.54	0.67	4.65	1.36	1.35	2.40	10.54	0.95	1.26	1.71	2.23	0.70
D 3	3.12	2.35	5.91	2.92	4.87	3.90	7.31	2.39	2.53	4.68	3.86	2.58
D 4	8.57	9.57	4.94	8.64	13.79	11.86	4.50	8.89	10.61	10.82	9.66	10.82
D 5	25.41	31.63	7.21	42.24	19.93	29.43	5.27	17.64	36.80	29.33	19.65	37.96
E 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E 2	0.59	0.43	2.40	0.55	0.75	1.26	2.93	1.16	0.78	1.63	1.36	0.31
E 3	1.78	2.10	3.85	2.34	3.89	1.97	3.26	3.73	0.70	2.56	3.36	1.91
E 4	10.75	8.80	6.37	6.28	6.29	5.40	2.11	8.20	6.90	5.74	6.06	7.79
E 5	3.78	2.88	2.39	2.79	0.99	1.24	0.45	1.97	2.11	1.47	1.07	3.08
F 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F 2	2.82	2.90	13.63	2.32	6.95	8.12	13.89	8.06	5.22	8.24	7.25	1.32
F 3	4.29	5.14	11.28	3.09	9.62	4.32	7.65	8.54	3.78	5.32	8.26	3.54
F 4	4.81	6.18	5.07	2.64	5.75	2.96	1.26	6.12	3.71	3.49	4.41	4.59
F 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rain	10	33	7	16	41	29	17	53	27	37	49	49
Mix-Ht	2400	1500	1600	2000	1100	1200	1600	1200	1200	1200	1600	1200

Table 3.19 Meteorological Data of the 29 National Weather Service (NWS) Sites (continued)

Weather Bin	Omaha	Phoenix	Santa Maria	Seattle	Washing-ton	Min	Max	Mean	Median	80th	EPRI
R (0)	5.43	1.00	2.24	8.72	5.79	1.00	10.14	4.98	5.30	6.52	5.86
R (0-5)	0.13	0.08	0.19	0.42	0.39	0.06	1.37	0.26	0.18	0.38	0.80
R (5-10)	0.62	0.31	0.40	1.87	1.28	0.26	1.87	0.78	0.72	1.11	1.67
R (10-15)	0.89	0.25	0.62	2.12	1.14	0.25	2.12	1.00	1.05	1.29	1.36
R (15-20)	0.70	0.23	0.41	1.90	0.88	0.23	1.90	0.79	0.83	1.06	1.28
R (20-25)	0.51	0.24	0.32	1.53	0.87	0.01	1.53	0.68	0.67	0.90	1.14
R (25-30)	0.59	0.22	0.43	1.77	0.86	0.22	1.77	0.77	0.75	0.95	1.08
S (0-10)	1.16	1.27	2.41	1.36	0.71	0.14	2.41	0.83	0.63	1.25	0.67
S (10-15)	0.90	1.21	1.84	1.44	0.67	0.08	2.01	0.69	0.49	1.01	0.46
S (15-20)	0.75	1.20	1.63	1.02	0.48	0.09	1.78	0.64	0.49	1.01	0.56
S (20-25)	0.67	0.91	1.45	0.98	0.63	0.07	1.55	0.57	0.43	0.91	0.53
S (25-30)	0.86	1.13	1.77	1.21	0.63	0.14	1.77	0.67	0.55	1.10	0.59
A-C 1,2,3	3.79	16.02	7.96	5.15	7.33	1.18	16.69	5.81	4.10	9.13	12.85
A-C 4,5	12.36	15.92	12.53	6.87	11.30	5.48	15.92	11.14	11.50	13.77	12.97
D 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05
D 2	1.26	1.52	11.16	2.95	2.98	0.21	11.16	2.16	1.70	2.55	5.53
D 3	3.23	3.18	8.66	6.55	6.08	1.61	8.66	3.71	3.30	4.78	6.38
D 4	8.87	6.69	6.97	16.12	10.64	4.50	16.12	9.25	8.90	11.01	6.32
D 5	30.39	6.30	13.40	19.46	16.20	5.27	49.13	26.35	28.00	37.68	2.55
E 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.95
E 2	0.99	1.96	2.44	0.72	1.85	0.09	2.93	1.08	0.90	1.82	7.16
E 3	2.24	3.57	2.41	2.07	3.52	0.67	4.01	2.47	2.30	3.50	4.58
E 4	6.53	6.35	2.42	4.82	5.27	2.11	10.75	6.67	6.50	7.93	3.32
E 5	1.77	0.92	0.81	1.02	1.23	0.45	3.78	2.06	2.10	2.90	0.71
F 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.82
F 2	7.63	11.20	11.16	3.46	9.81	0.72	14.51	6.42	7.20	9.84	9.05
F 3	4.17	12.09	4.81	3.80	6.38	1.80	12.09	5.86	5.20	8.26	2.89
F 4	3.56	6.22	1.54	2.68	3.09	1.26	6.74	4.24	4.20	5.51	0.70
F 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Rain	30	4	10	40	32	4.00	65.00	29.90	31.30	48.50	47.64
Mix-Ht	1300	2400	800	1200	1500	800	2600	1479.3	1300	1200	1500

Table 3.20 Comparison of Best Four Sites Based on Absolute Errors with Respect to Means[a]

BIN	Avg. Hrs	Omaha	Madison	Moline	Washington
R 0	436	476	533	512	507
R 5	22	11	21	10	34
R 10	68	54	86	69	112
R 15	88	78	112	90	100
R 20	69	61	90	73	77
R 25	60	45	74	58	76
R 30	67	52	86	70	75
S 10	73	102	82	41	62
S 15	61	79	64	28	59
S 20	56	66	66	31	42
S 25	50	59	51	36	55
S 30	59	75	60	31	55
AC 1,3	509	332	296	307	642
AC 4,5	976	1083	757	940	990
D 1	0	0	0	0	0
D 2	190	110	210	150	261
D 3	325	283	342	410	533
D 4	810	777	1039	948	932
D 5	2308	2662	2578	2569	1419
E 1	0	0	0	0	0
E 2	95	87	110	143	162
E 3	217	196	173	224	308
E 4	585	572	473	503	462
E 5	181	155	109	129	108
F 1	0	0	0	0	0
F 2	562	668	711	722	859
F 3	513	365	378	466	559
F 4	372	312	259	306	271
F 5	0	0	0	0	0
Rain	30	30	29	37	32
Mix	1479	1300	1200	1200	1500

[a]Table entries are in hours except for rain which is in inches and mixing height in meters.

Table 3.21 Comparison of Best Four Sites Based on Absolute Errors with Respect to Medians[a]

BIN	Median Hrs.	Omaha	Madison	Moline	Fort Worth
R 0	464	476	533	512	348
R 5	16	11	21	10	9
R 10	63	54	86	69	41
R 15	92	78	112	90	58
R 20	73	61	90	73	39
R 25	59	45	74	58	39
R 30	66	52	86	70	42
S 10	55	102	82	41	43
S 15	43	79	64	28	29
S 20	43	66	66	31	22
S 25	38	59	51	36	29
S 30	48	75	60	31	29
AC 1,3	359	332	296	307	361
AC 4,5	1007	1083	757	940	1307
D 1	0	0	0	0	0
D 2	149	110	210	150	59
D 3	289	283	342	410	206
D 4	780	777	1039	948	838
D 5	2453	2662	2578	2569	2771
E 1	0	0	0	0	0
E 2	79	87	110	143	38
E 3	201	196	173	224	184
E 4	569	572	473	503	771
E 5	184	155	109	129	252
F 1	0	0	0	0	0
F 2	631	668	711	722	254
F 3	456	365	378	466	450
F 4	368	312	259	306	541
F 5	0	0	0	0	0
Rain	31	30	29	37	33
Mix	1300	1300	1200	1200	1500

[a]Table entries are in hours except for rain which is in inches and mixing height in meters.

An additional variable, the mixing height, has also been considered independently. A cumulative distribution of mean annual afternoon mixing heights of the NWS sites has been constructed. The range of values extends from 0.5 to 1.6 miles. A low mixing height can result in high cloud concentration and resultant dose. The 80th percentile is about 0.75 miles; approximately 85 percent of the NWS sites have mixing heights equal to or greater than 0.75 miles. This value is a reasonable choice for the bounding case meteorology. The mean and median values of the mixing height were found to be 0.93 and 0.81 miles, respectively. Hence, the distribution of mixing heights is skewed towards lower values, with several particularly high values causing the elevated value of the mean. The mean value, 0.93 miles, is selected for inclusion in the mean case meteorology. The last weather attribute that needs specification to execute the MACCS code is the wind rose. NUREG/CR-2239 provided the actual wind roses for 74 actual reactor sites. Again a purely statistical assessment yields 13.3% and 15% for the mean and 80th percentile values. Simple forward peaked wind roses have been constructed for use in this study. For the mean case, a single sector is assigned a frequency of 13.3%. The adjacent sectors are assigned an 11% frequency. The remaining sectors are uniformly assigned the balance, i.e., ~5% per sector. For the conservative case, the peak sector is assigned a 15% frequency, the adjacent sectors remain at 11%, while the remaining sectors are assigned a frequency of ~4.8%. These wind roses are superimposed on the generic sites such that all city populations are located downwind of the wind rose peak frequency.

In summary, the mean case used in this study is a composite of the Omaha windspeed, stability and rain data, coupled with the independently analyzed mean mixing height and mean wind rose frequencies. The 80th percentile case is a composite of the Charleston windspeed, stability and rain data, and the independently determined 80th percentile mixing height and wind rose.

3.6 Land Use and Economics

The population distributions discussed in Section 3.4 are input into the program through the site data file. This site data file also includes the land use and economics data. The land use data specifies the value of the residential property and information about the surface water. In this study, a mean value of non-farm wealth of $73,570/person is assumed. Given Omaha, Nebraska's central location within the contiguous 48 states and the maximum, 500 miles, radius of interest, this region represents one-fourth of the area in the continental United States. The economic values of wealth are used within MACCS to test the cost-effectiveness of decontamination actions which, in turn, influence the number of people permanently relocated.

3.7 Protective Actions

There are several protective actions that are modeled in the MACCS code: three emergency responses modeled in the EARLY module, and two long term responses modeled in the CHRONC module. The three emergency responses are evacuation, sheltering, and normal activity for the population that does not participate in the emergency actions. One long term response is the relocation of people who are expected to receive a radiation dose in excess of the interdiction level. For those who are relocated, the MACCS code makes an assessment if and when they can safely return to the area. If not, the land is permanently condemned for habitation. The second long term action addresses farm land contamination.

3.7.1 Emergency Protective Actions

In this study three emergency protective (EP) schemes are considered.

(1) "Mean EP": This case is based on the mean of the evacuation time and speed determined for five NUREG-1150 sites. The delay from

warning to the start of evacuation is 1.9 hours, and the evacuation speed is 5.8 miles/hour. The evacuation is out to 10 miles, and has a 99.5% participation, consistent with the NUREG-1150 study;

(2) "Conservative EP": This case assumes a slower and later evacuation than the NUREG-1150 case. The assumptions are a 6 hour delay from the warning to start of evacuation and an evacuation speed of 2.5 miles/hour (based on the analysis of Hans and Sell[12]). Evacuation is out to 10 miles, and the participation is 95%;

(3) "No Evacuation": This case assumes that no evacuation occurs and that people in the affected area carry on normal activity. This is clearly an unlikely response, but the case should bound the maximum consequences associated with a given release.

Table 3.22 shows the values of the selected parameters in the mean and conservative EP cases.

Table 3.22 Emergency Protective (EP) Parameters

Parameter	Mean EP Case	Conservative EP Case
Evacuation Speed	5.8 mph	2.5 mph
Delay Time	1.9 hrs	6 hrs
% Evacuated	99.5%	95%

3.7.2 Sheltering Schemes

An alternative to immediate evacuation is sheltering of the people in a building structure during the passage of the release plume, followed by relocation. There are some outlying cases where an early evacuation can actually increase the number of consequences, if the timing of the release and the evacuation are close. This occurs when the evacuees travel with the radioactive plume. Though it is available in MACCS, sheltering as a protective action has not been considered in this siting study. However, some sheltering credit is given in the code as part of "normal activity" to those who do not evacuate and some credit is also given to those participating in the evacuation after the release has started but before the evacuees start to move.

Table 3.23 shows the values of the shielding and sheltering dose reduction parameters for different exposure pathways for the evacuees (while in the process of evacuation), those continuing normal activity and those taking shelter, respectively.

Table 3.23 Shielding and Sheltering Dose Reduction Parameters (Based on average of five plants in NUREG-1150)

	Cloudshine	Groundshine	Skin
Evacuees	1.0	0.5	1.0
Normal	0.75	0.33	0.41
Sheltered	0.6	0.2	0.33

3.7.3 Population Relocation Criteria

In the EARLY module of MACCS (covering the first seven days), if the dose to individuals living outside the evacuation zone is predicted to exceed set values (50 rem to whole body in one week for the hot spot and 25 rem to whole body in one week for the normal activity), then relocation of those individuals is effected.

In the CHRONC MODULE (covering the time following the EARLY period), if the dose commitment to individuals living on a particular spatial element is predicted to exceed 2 rem in the first year and 14.5 rem over the next 29 years, then those individuals are relocated. The habitability of a spatial element can be restored following mitigative actions. These include three successively higher levels of decontamination with the maximum level of decontamination followed by a temporary interdiction period during which the affected population stays relocated. If the mitigative actions are not successful in reducing the projected dose commitment below the level specified above, the property is permanently condemned. The longest possible period of temporary interdiction for restoring habitability is 30 years. However, a cost-effectiveness criterion is also used along with the projected dose commitment for deciding on habitability; if the costs of decontamination and temporary interdiction equal or exceed the value of the property, then the property is permanently condemned. The output of the MACCS code does not report the physical area of the property either temporarily interdicted or permanently condemned for purposes of habitability; only the number of people relocated temporarily or permanently are reported by the code.

3.8 References

1. U. S. Nuclear Regulatory Commission, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," NUREG-1150, 1990.
2. Chanin, D. I., H.-N. Jow, J. A. Rollstin, et. al., "MELCOR Accident Analysis Consequence Code System," Sandia National Laboratories, NUREG/CR-4691, SAND86-1562, Vols. 1–3, February, 1990.
3. Nourbakhsh, H. P., "Representative Source Terms for Severe LWR Accidents," Brookhaven National Laboratory, Technical Report, June 1992.
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5. Brown, T. D., et al., "Integrated Risk Assessment of the LaSalle Unit 2 Nuclear Power Plant: Phenomenology and Risk Uncertainty Evaluation Program (PRUEP)," Los Alamos National Laboratory, NUREG/CR-5305, August 1992.
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8. Summers, R. M., et. al., "MELCOR 1.8.0: A Computer Code for Nuclear Reactor Severe Accident Source Term and Risk Assessment Analyses," Sandia National Laboratories, NUREG/CR-5531, SAND90-0364, January 1991.
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10. Jow, H.-N., W. B. Murfin and J. D. Johnson, "XSOR Codes User's Manual," Sandia National Laboratories, NUREG/CR-5360, December 1993.
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12. Hans, J. M., Jr. and T. C. Sell, "Evacuation Risks: An Evaluation," U. S. Environment Protection Agency, June 1974.

4 RESULTS

This section presents the results of the siting analyses. The important variables examined in this study are the population densities at various distances from the reactor site, the location of urban centers, and the radius of the exclusion zone. Regulatory Guide 4.7[1] contains recommended values of these parameters. The objective of the siting analyses is to study the impact of revised source terms using NUREG-1150[2] methodology, meteorology, emergency response, and reactor power level (a surrogate for the inventory of fission products potentially available for release) on the Regulatory Guide 4.7 values for the population density and exclusion boundaries. For each of the above parameters the effect on consequences was evaluated in terms of the quantitative health objectives (QHOs) of the Safety Goal Policy,[3] that is the mean values of the population weighted prompt fatality risks to 1 mile from the exclusion area of the plant boundary and the latent cancer risks to 10 miles from the plant. If the QHO goals are satisfied with a significant margin, the implication is that the combination of the key site variables, population density and distance to the exclusion area boundary is acceptable in terms of qualifying the site for initial consideration. The QHOs are also calculated for a more conservative range of parameter values than those recommended in Regulatory Guide 4.7. The QHO goals are also met in the latter cases.

4.1 Base Case – QHO Comparison

For comparison with the QHOs the following sets of parameters were used:

- the reactor power level of 3800 MWth
- the 5 sets of simplified source terms defined in Section 3.3 above,
- the four exclusion zones defined in Section 3.4 above,
- the mean meteorology (as evaluated in Section 3.5), which pertains to the Omaha, Nebraska area,
- the mean value of the wind rose peak sector frequency,
- the mean value of the height of the mixing layer,
- the mean values of the emergency protection (EP) parameters as shown in Table 3.21,
- long-term interdiction criterion of 16.5 rem in 30 years (2 rem in the first year and 0.5 rem per year for the remaining 29 years).

The shielding and sheltering dose reduction parameters for three groups of people in the emergency planning zone (evacuees, those continuing normal activities, and those taking shelter) are based on the average of the five plants in NUREG-1150. The values of these dose reduction parameters for exposure due to cloudshine, groundshine, and skin doses are displayed in Table 3.23. The dry deposition velocity during plume transport is 0.4 inches/sec, the value recommended by the NRC for use in the NUREG-1150 consequence calculations.

The latest version of the MACCS code,[4] which incorporates the BEIR-V correlation for latent cancer fatalities, is used for all the consequence calculations reported below.

The results are shown in Figs. 4.1 and 4.2. Figure 4.1 shows the mean value of the population-weighted risk of prompt fatalities for each set of simplified source terms out to one mile beyond the exclusion zone boundary for each of the four exclusion zones. Figure 4.2 shows the mean value of the population-weighted risk of latent cancer fatalities for each set of simplified source terms to 10 miles beyond each of the four exclusion zone boundaries.

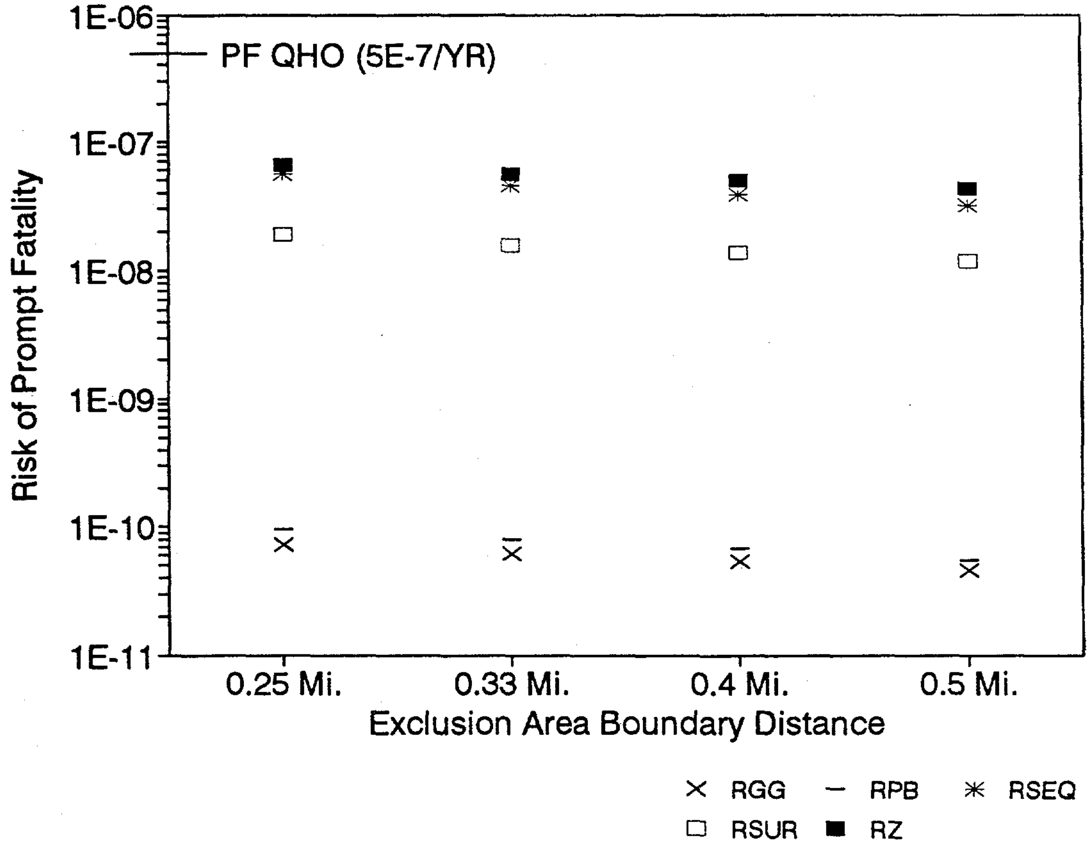

Figure 4.1 Prompt Fatality Risk Comparison with the QHO as a Function of Exclusion Area Distance

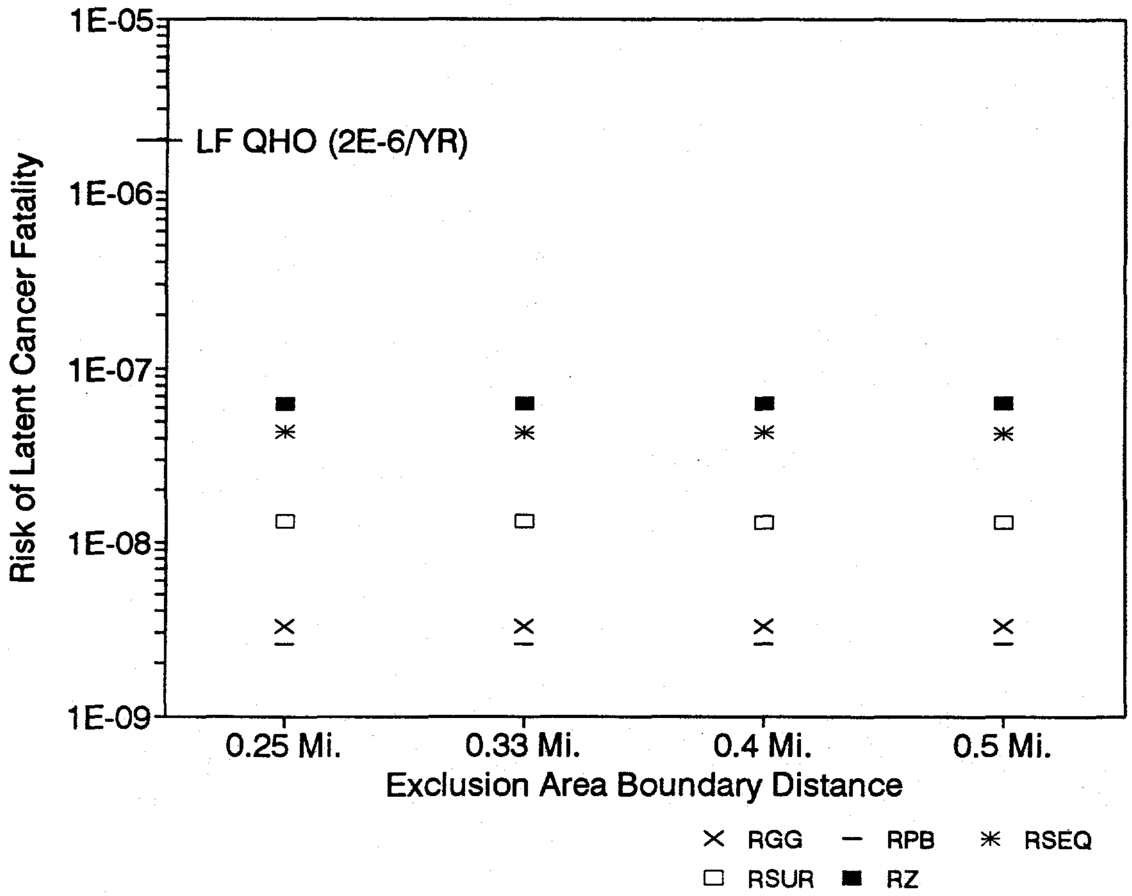

Figure 4.2 Latent Cancer Risk Comparison with the QHO as a Function of Exclusion Area Distance

Examination of the calculated values shows that for the RGG and RPB sets of source terms the one-mile, population-weighted prompt fatality risks are almost four orders of magnitude below the prompt fatality QHO of 5×10^{-7} per year. The risk for prompt fatalities that comes closest to the QHO is from the RZ set of source terms; its mean value is about an order of magnitude below the QHO. The prompt fatality risks based on the RSEQ and RSUR source terms are about a factor of two and four, respectively, smaller than that based on RZ.

The RGG and RPB sets of source terms are derived from the boiling water reactor (BWR) plants in NUREG-1150. The values of the frequencies of severe releases are low in these cases due to the small values of the core damage frequency. These low numbers ensure that the QHO goal is met by a very large margin.

Similarly, examination of the calculated values for the 10-mile, population weighted latent cancer risks show that the RGG and RPB source terms meet the latent cancer QHO of 2×10^{-6} per year with a margin of almost three orders of magnitude. The RZ set of source terms meet this goal with a factor of about 25 and the RSEQ and RSUR source terms with factors of 40 and 125, respectively.

4.2 Individual Risks of Consequences as a Function of Distance

In addition to the Safety Goal QHO comparisons, the individual risk of various consequence measures (prompt and latent cancer fatalities and permanent relocation) have been calculated as a function of the distance from the plant. These calculations have been performed assuming: 80th percentile weather (i.e., Charleston, SC weather), a power level of 3800 MWth, an exclusion area boundary of 0.25 mile, and a uniform population density of 1000 persons per square mile. For the prompt and latent cancer fatalities, the risks are based on the most severe source term, RZ1, under the three types of emergency protective actions defined above, namely, Mean EP, Conservative EP, and No EP. The risk of permanent relocation (i.e., condemnation of non-farm property) as a function of distance has been evaluated for both RZ1 and RZ4 source terms.

4.2.1 Risk of Prompt Fatality vs. Distance

Figure 4.3 shows the mean value and Figure 4.4 the mean and 95th percentile values of the individual risk of prompt fatality versus distance for the RZ1 source term for all of the three EP actions. In all cases, including No EP, the mean value of the risk decreases below 10^{-8} per year at about 3 miles, and becomes less than about 10^{-9} at about 6 miles from the plant. The figures display an interesting feature, that over a certain range of distances the mean and 95th percentile risks for the mean EP exceed the corresponding values for the Conservative and No EP cases. This result appears to be due to the coincidence of the time of release of the RZ1 source term (2 hours after declaration of the emergency) with the start of the evacuation in the mean EP case (1.9 hours after declaration of the emergency). Hence, in the mean EP case, a portion of the evacuees are moving with the plume. The MACCS code provides almost no credit for shielding during evacuation. The Conservative EP has a 6-hour delay before evacuation begins and the plume has passed before people begin to move, so the population benefits from some shielding while inside their homes or carrying on normal activity. In the No EP case, there is no movement and the only shielding benefit people receive is from the "normal activity" sheltering factors. The major risk is from the 7-day groundshine pathway dose. However, the 95th percentile for the mean EP case is driven by the effect of rainout during evacuation under the plume and this leads to a higher risk for the bins in which rain occurs.

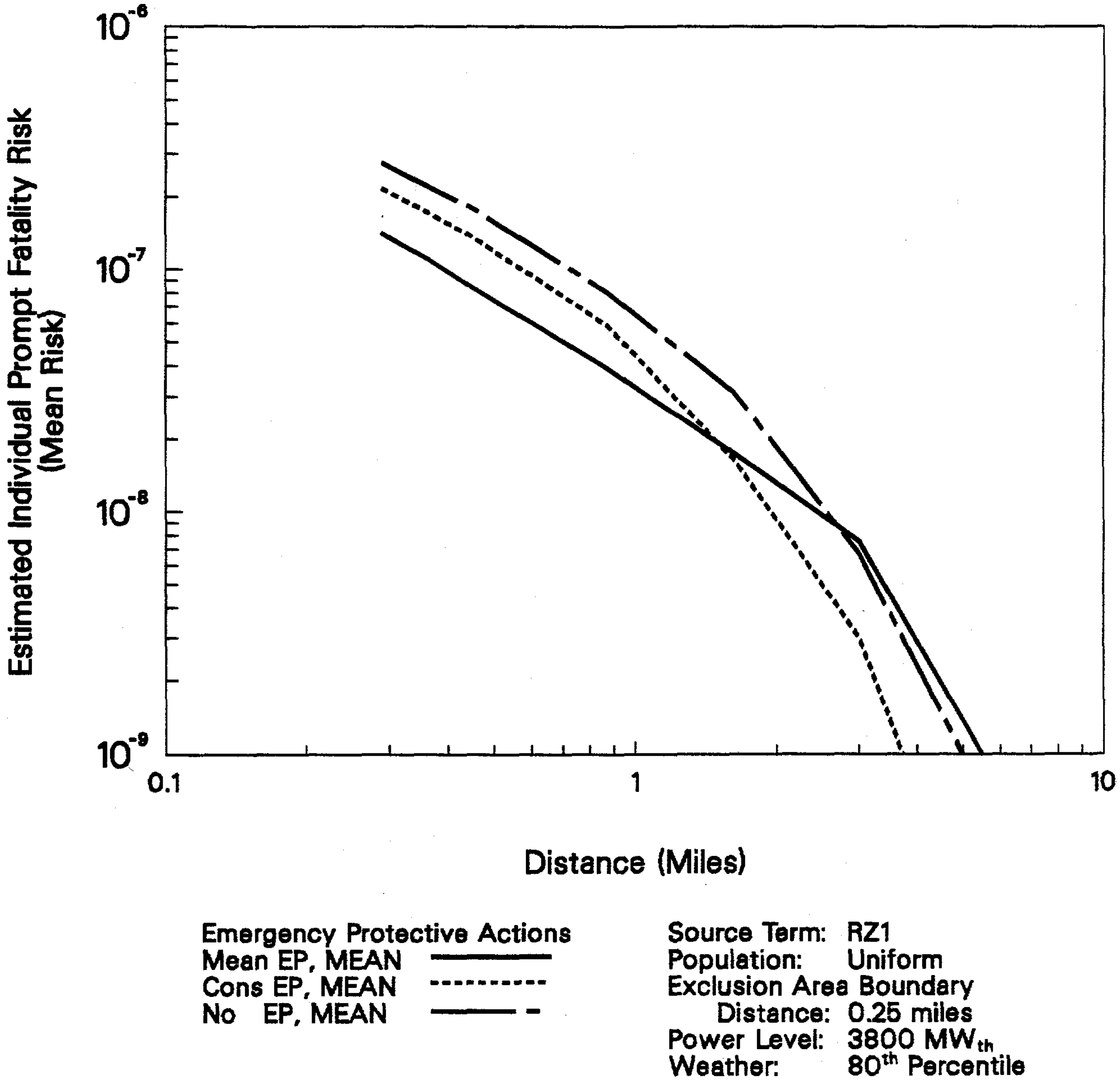

Figure 4.3 Estimated Individual Risk of Prompt Fatality vs. Distance (Mean) (1/yr)

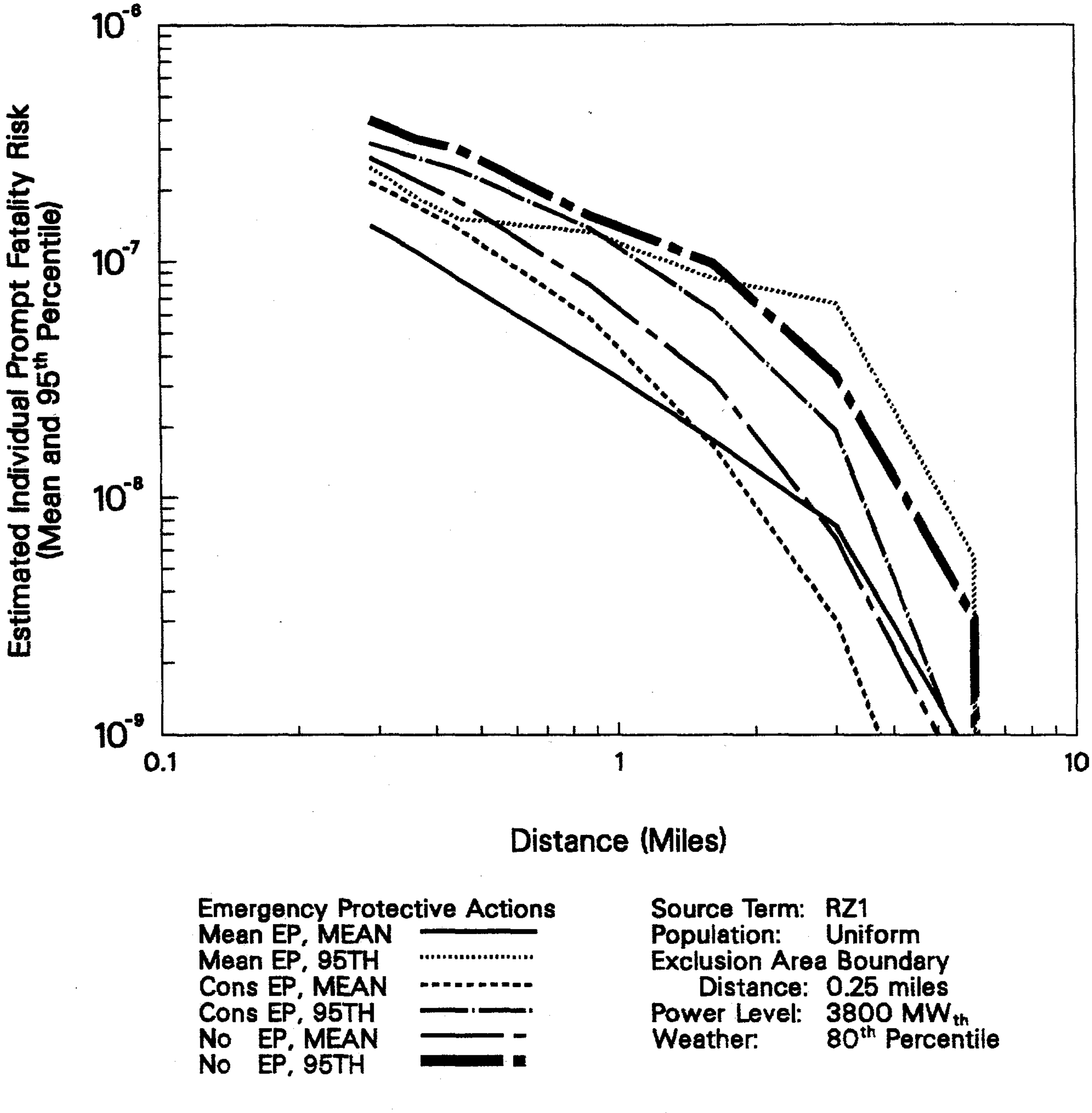

Figure 4.4 Estimated Individual Risk of Prompt Fatality vs. Distance (Mean and 95th Percentile) (1/yr)

4.2.2 Risk of Latent Cancer Fatality vs. Distance

Figures 4.5 and 4.6 show the individual risk of latent cancer fatality versus distance for the source term RZ1 for the three evacuation schemes. In evaluating latent cancers the MACCS code's CHRONC module uses long-term protective action assumptions to reduce chronic doses from the long-term exposure pathways, groundshine, resuspension inhalation and ingestion. The long-term dose criterion used in the mean EP and Conservative EP cases for relocating the population from contaminated areas is 16.5 rem to an individual over 30 years (2 rem in the first year following the accident and 0.5 rem/year for the remaining 29 years). In the No EP case, no long-term protective actions were assumed to limit dose (and thus the number of latent cancers).

The total population dose which contributes to latent cancer fatalities comes both from exposures during the early (or emergency) phase and the long-term (or chronic) phase. One thus expects to see large differences in the risk of latent cancers between the various EP cases; a large difference between the "No EP" and the other cases and a smaller difference between the mean EP and conservative EP cases (close to the plant) due to differences in exposure during the emergency phase. This expected behavior is shown in Figures 4.5 and 4.6. The No EP risk is between one and two orders of magnitude higher than the other cases out to about 30 miles from the plant. The mean risk (when long-term protective actions are applied) become less than 10^{-8} per year at about 15 miles and become less than about 10^{-9} per year at about 100 miles from the plant.

4.2.3 Risk of Permanent Relocation vs. Distance

Another consequence measure of interest is the individual risk of permanent relocation. This measure refers to the permanent condemnation of an individual's non-farm property from the standpoint of habitability, in other words, the permanent relocation of individuals from areas which cannot be decontaminated (either through natural decay and weathering or, in a cost-effective manner, via the physical measures specified in the code) over a period of 30 years. The habitability criterion is defined in terms of the long-term dose limit specified above, i.e., 16.5 rem projected dose to an individual over 30 years (2 rem in the first year and 0.5 rem/year for the remaining period).

The mean and 95th percentiles values of this risk for the source terms RZ1 and RZ4 are shown in Figures 4.7 and 4.8. For RZ1, the mean risk of permanent relocation becomes less than 10^{-8} per year at about 20 miles and falls below 10^{-9} per year at about 30 miles; for RZ4 the corresponding values are about 10 and 15 miles, respectively.

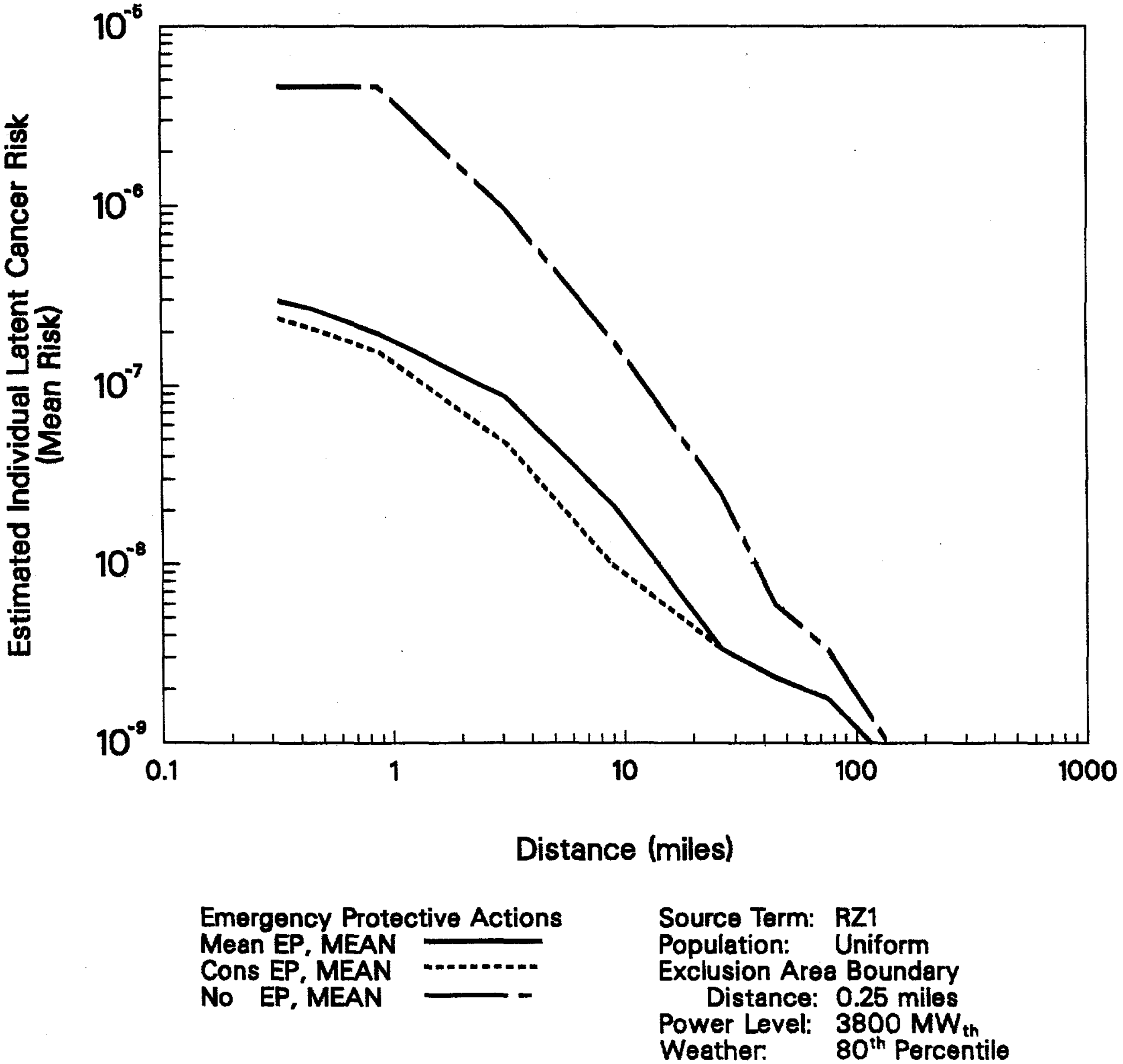

Figure 4.5 Estimated Individual Risk of Latent Cancer Fatality vs. Distance (Mean) (1/yr)

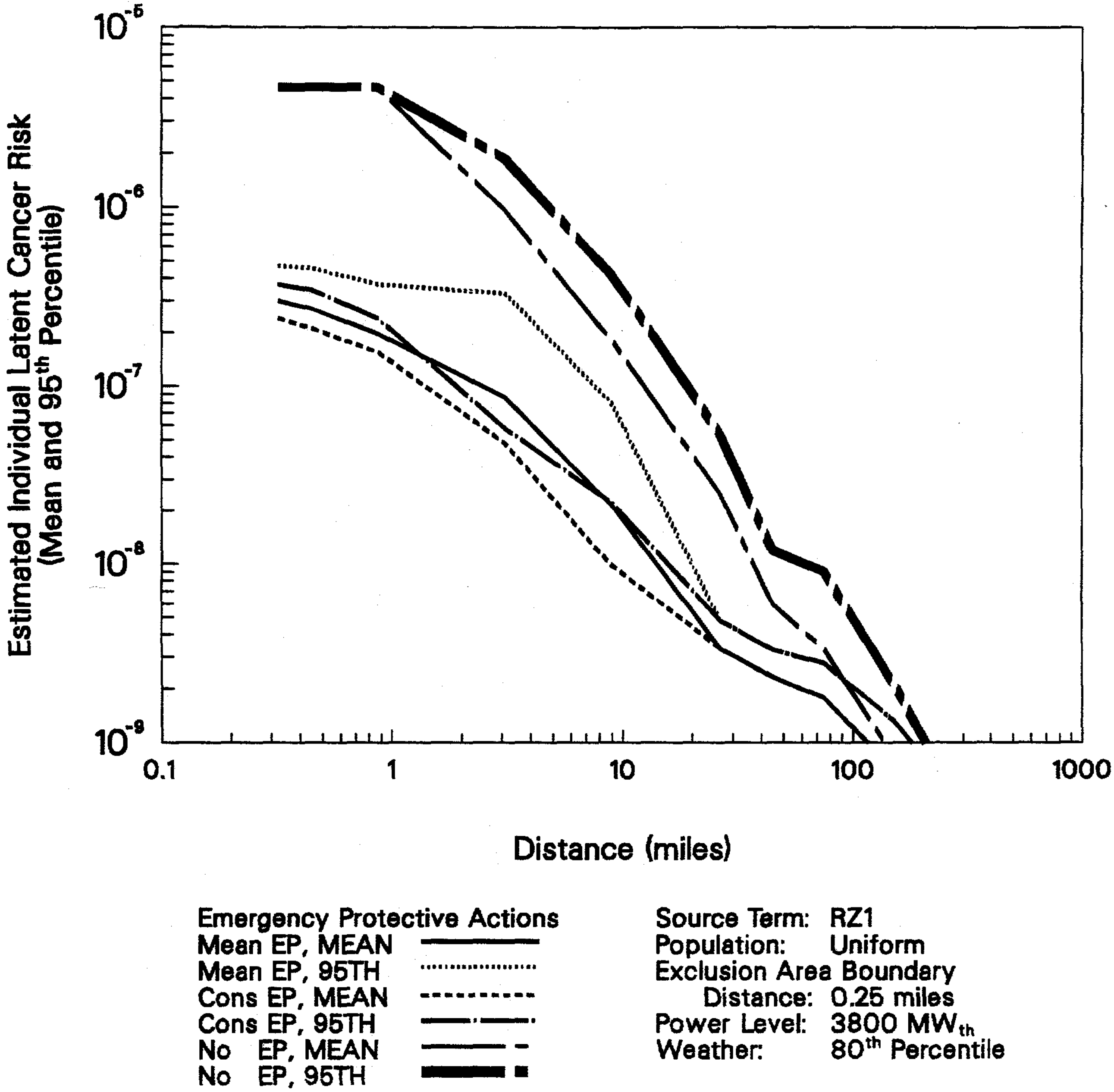

Figure 4.6 Estimated Individual Risk of Latent Cancer Fatality vs. Distance (Mean and 95th Percentile) (1/yr)

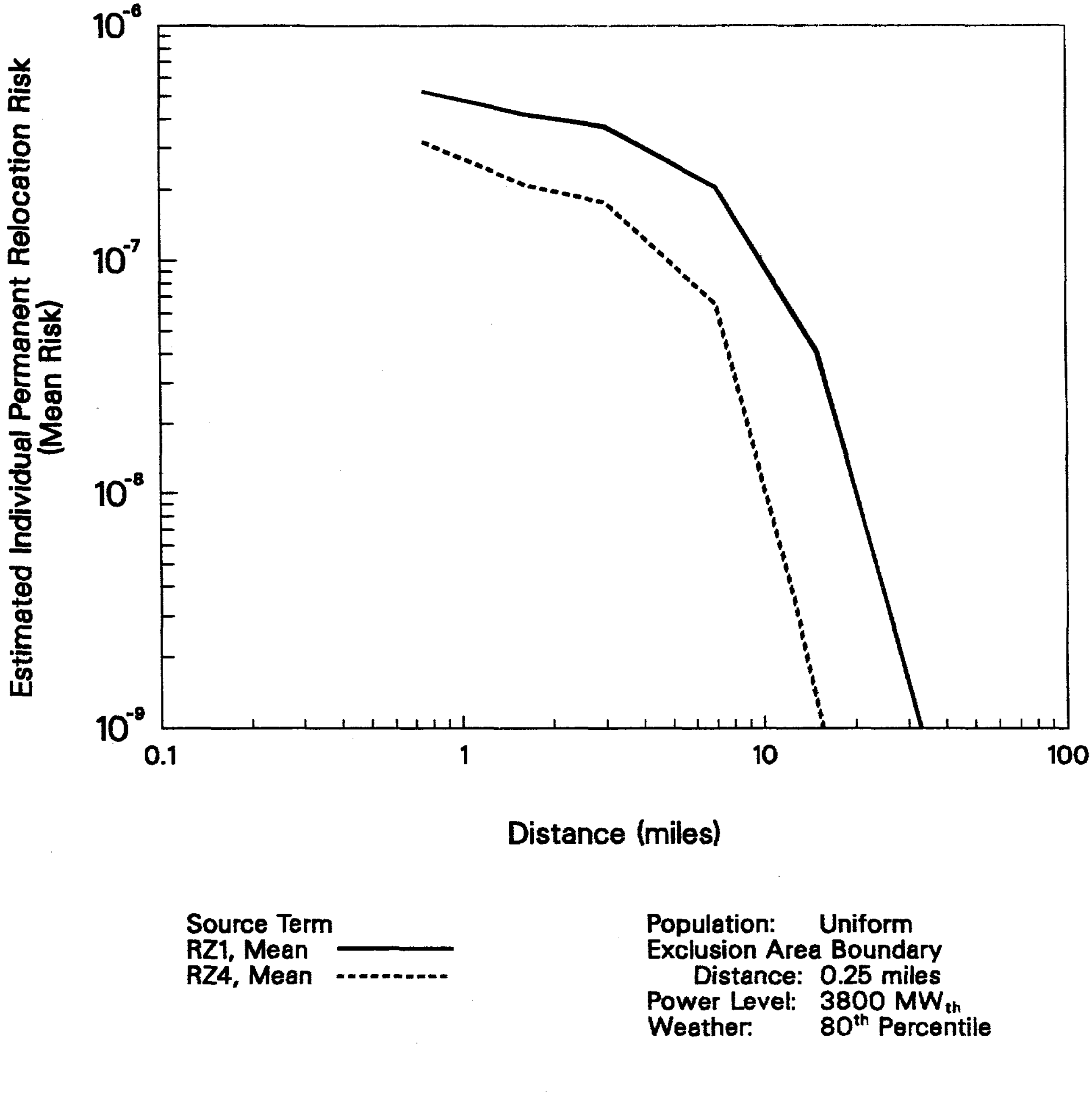

Figure 4.7 Estimated Individual Risk of Permanent Relocation vs. Distance (Mean) (1/yr)

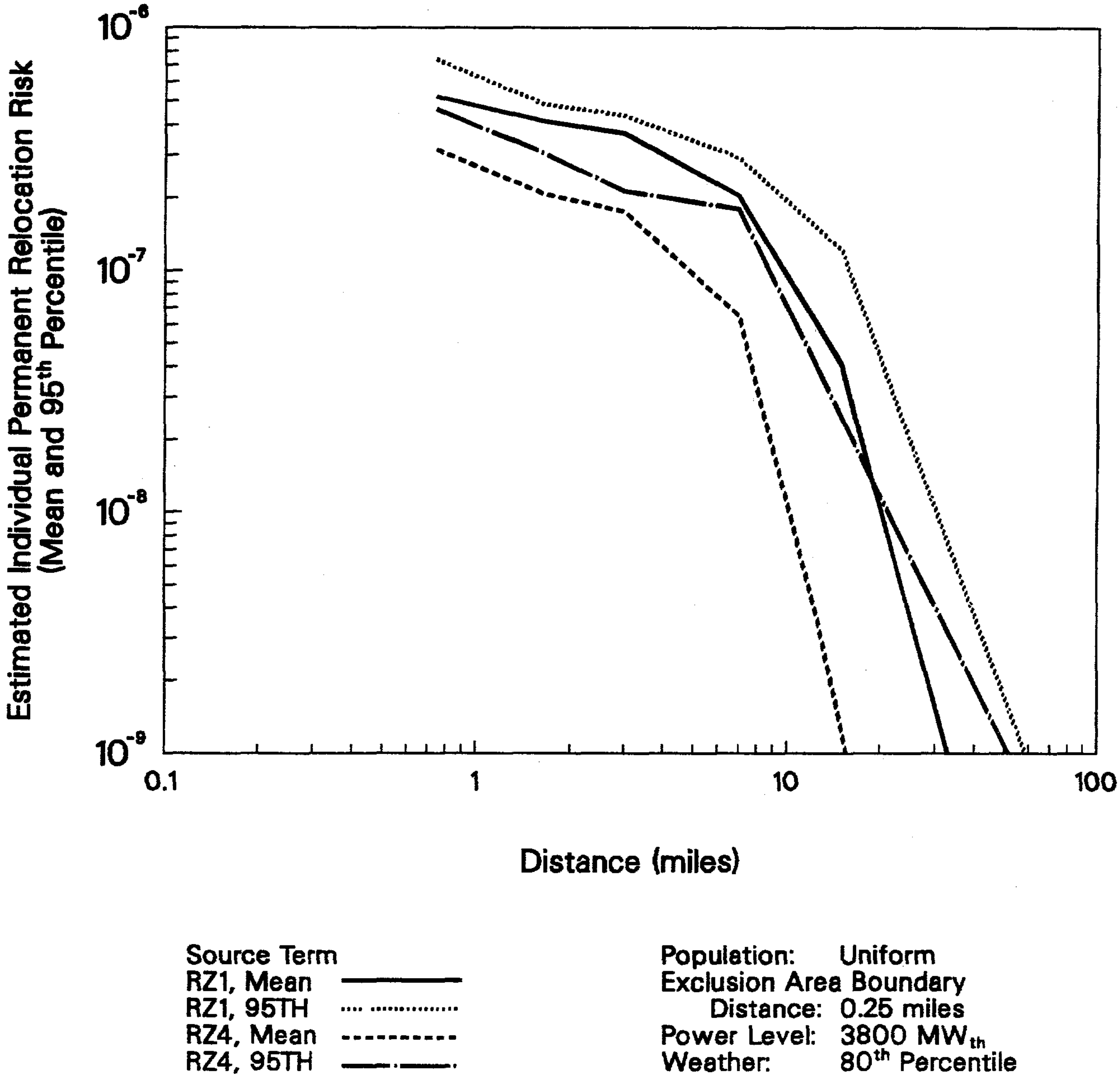

Figure 4.8 Estimated Individual Risk of Permanent Relocation vs. Distance (Mean and 95th Percentile) (1/yr)

4.3 References

1. U. S. Nuclear Regulatory Commission, Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Revision 1, November 1975.
2. U. S. Nuclear Regulatory Commission, "Severe Accident Risks: An Assessment for Five U. S. Nuclear Power Plants," NUREG-1150, 1990.
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5 TECHNICAL FINDINGS

The current siting regulation contained in the Code of Federal Regulations Title 10, Part 100[1] is based on a 1962 source term to containment and a calculational methodology which allows engineered safeguards and containment leak rates to compensate for unfavorable site characteristics. Regulatory Guide 4.7[2] contains recommended values of parameters which affect the pre-qualification of sites for nuclear power plants. These parameters include: (i) the population density in the vicinity of the site, (ii) the location of urban concentrations in relation to the site and (iii) existence of unused (uninhabited) areas to allow a sufficiently large exclusion boundary to be defined around the proposed site. Lastly, the population surrounding the site should be such as to allow protective action to be taken for the population within the proposed site vicinity.

The objectives of the study reported here are to calculate, for various source terms and site parameters, the quantitative health objective (QHO) for the population-weighted risks of prompt fatalities to 1 mile and latent cancers to 10 miles and compare them with the values of the safety goals set by the Nuclear Regulatory Commission.

For all combinations of site parameters and source terms, the safety goals were met, often by large margins.

In addition to the evaluation of site acceptability criteria, sensitivity studies of selected site parameters (reactor power level, emergency response, and long-term dose criteria) on appropriate consequence measures including the individual risks of prompt fatalities, permanent relocation, and latent cancers were carried out for the most severe source terms. These calculations show: that the mean value of the individual risks of prompt fatalities drops below 10^{-8} per year at about 3 miles; the mean value of the individual risk of latent cancer fatalities drops below 10^{-8} per year (when long-term protective actions are applied) at about 15 miles; and the mean value of the individual risk of permanent relocation drops below 10^{-8} per year at about 20 miles from the plant.

References

1. U. S. Nuclear Regulatory Commission, Title 10, Chapter 1, Code of Federal Regulation, Part 100, "Reactor Site Criteria," May 1984.
2. U. S. Nuclear Regulatory Commission, Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations," Revision 1, November 1975.

Appendix A

Detailed Discussion of Input Parameters (For the Files Reproduced in Appendices B–E)

The MACCS code requires input through a total of six input files:

1. the ATMOS input file
2. the EARLY file
3. the CHRONC input file
4. the MET file
5. the SITE file
6. the DOSDATA file

Types of Data Input

The types of data in each file are briefly described below. Some of the data are generic to most cases, some are strictly reactor dependent, and some depend on the judgment of the analyst.

ATMOS. This includes the fission product inventory at shutdown, their groupings, and release characteristics; data concerning deposition of radioisotopes; data concerning the transport of the plume; data dictating how the weather data will be manipulated; and boundary conditions for the weather. An example of an ATMOS file is in Appendix B.

EARLY. This file contains data needed for the evacuation, sheltering, relocation, and the organs to be used in the early health effects model. The number of prompt fatalities are calculated with this data. Two examples of EARLY files are in Appendices Ca and Cb for the NUREG-1150 and the NO EVACUATION case, respectively. Differences between the NUREG-1150 and conservative cases are described in section 3.7.1. (In the text of the report, the NUREG-1150 case is designated as the "Mean EP" case.)

CHRONC. This module includes data for intermediate and long-term exposures from groundshine, resuspended inhalation and ingestion. This along with the exposures received during the early phase are used to determine the population dose and the latent cancers. An example of the CHRONC module is shown in Appendix D.

MET. This file contains 8760 records of hour-by-hour meteorological data: wind direction, speed, precipitation, and wind stability. The met data used for much of this work was the Charleston (80th percentile) weather with a mixing layer height assumed to be 0.75 miles. In some cases, the consequences were evaluated using the mean weather sequences (Omaha) with a mixing layer height of 0.93 miles.

SITE. This contains information for the spatial grids, population distribution, land use data, and land value. An example of the site data file is in Appendix E.

DOSDATA. This file contains the dose conversion factors for the 60 radioisotopes supported by the current version of MACCS.

Examples of the input files are provided in Appendices B through E with the exception of the DOSDATA and the MET files. Standard inputs were used (per NUREG/CR-4691) with deviations and/or exceptions mentioned below.

ATMOS. RDCORSCA001 - The value of RDCORSCA001 was generally set so that the base case reactor power level for this study was at 3800 MWth. The inventories in ATMOS are based on a 3412 MWth PWR and a 3578 MWth BWR. Thus for BWRs this value was set to 1.062 and for PWRs to 1.114.

M4RNDSTS001 3.22, 6.44, 12.87, 20.95, 80.45 - The rain distance break points. These values were set to encompass the large city located between 48 and 80 km (30-50 miles).

M4RNRATC001 1.5, 4.3, 10.4 - The rain rate break points were set for equal washout in each rain rate bin.

All of the reactor specific parameters, including the timing of the release, the release energy and the release fractions of various radionuclide groups are shown in Tables 3.4, 3.6, 3.8, 3.10, 3.12, and 3.14.

EARLY. The early file contains the emergency response parameters, such as evacuation and sheltering. There were three versions of the EARLY file for each exclusion zone: one for the NUREG-1150 response (also called "mean EP" in the text) one for the conservative response (called "conservative EP" in the text) and one for the no evacuation. For all three cases, the wind rose derived from the data in the MET file was overridden as discussed in section 3.5.

a. The basic early file contains information concerning the "average" evacuation parameters found in NUREG-1150. SECSFACT - the cloud shielding factors for the evacuees, normal activity, and sheltering are 1, 0.75, and 0.6. The evacuation was assumed to be 99.5 percent out to 10 miles, with the evacuees disappearing after 10 miles. The other 0.5 percent do not evacuate.

EZEDELAY - 0, 0, 6840. The average delay time for the evacuation was 1.9 hours (delay from alarm to evacuation).

EZESPEED - 2.6. The evacuees move at an average speed of 2.6 m/sec.

b. The CONSERVATIVE evacuation data were identical to the NUREG-1150 base case file except that 95 percent of the people evacuated with a speed of 1.1 m/sec with a delay of 6 hours. The other 5 percent do not evacuate and are treated as "normal activity."

c. The NO EVACUATION file was identical to the NUREG-1150 base case except that no one is evacuated during this phase.

<u>CHRONC</u>. There are two versions of CHRONC, one allows for relocation (run with NUREG-1150 and conservative early modules) using the NUREG-1150 relocation criteria, and one has no relocation (run with the no evacuation early module).

CHTMIPND = 3.2E7 sec and CHTMPACT = 9.4608E8. There are the two time intervals for relocation. The first is the length of the intermediate phase (1 year) and the second is the length of time for the long-term dose criteria (30 years).

CHDSCRT1 = 0.02 - the criterion for intermediate phase relocation is 0.02 Sv over 1 year.

CHDSCRLT = 0.165, the long-term relocation is 0.165 Sv over 30 years (0.02 Sv in the first year and 0.005 Sv/year for the next 29 years).

For the no-evacuation case, the values for CHDSCRTI and CHDSCRLT were set to 1E5, so no evacuation or relocation are triggered. CHVALWF = 2094, the U.S. average farm value in $/hectare; CHVALWNF = 73570, the U.S. average non-farm land value in $/person.

<u>SITE.</u> This contains different population distributions used in this study. They are shown in Table 3.17. The land fraction was taken from the Omaha region. Other parameters are the same as in the MACCS Users Guide.

APPENDIX B – ZION-ATMOS

```
* GENERAL DESCRIPTIVE TITLE DESCRIBING THIS "ATMOS" INPUT
*
RIATNAM1001  'IN1A.INP, ZION AT 3800MW: LR PROJECT, ATMOS INPUT'
*******************************************************************************
* GEOMETRY DATA BLOCK, LOADED BY INPGEO, STORED IN /GEOM/
*                                                  changes made by alh 7/17/91
* NUMBER OF RADIAL SPATIAL ELEMENTS
*
GENUMRAD001  27
*
*  SURRY
*
GESPAEND001    0.40    0.53     0.64    0.80    2.01     2.14     2.25    2.41
GESPAEND002    3.22    4.83     6.44    8.04   12.87    16.09    20.92   24.14
GESPAEND003   32.18   40.22    48.27   64.36   80.45   112.63   160.90  241.35
GESPAEND004  321.80  563.15   804.50
*******************************************************************************
* NUCLIDE DATA BLOCK, LOADED BY INPISO, STORED IN /ISOGRP/, /ISONAM/
*                                           values per Surry sample, alh 7/17/91
* NUMBER OF NUCLIDES
*
ISNUMISO001 60
*
* NUMBER OF NUCLIDE GROUPS
*
ISMAXGRP001  9
*
* WET AND DRY DEPOSITION FLAGS FOR EACH NUCLIDE GROUP
*
*              WETDEP     DRYDEP
*
ISDEPFLA001    .FALSE.    .FALSE.
ISDEPFLA002    .TRUE.     .TRUE.
ISDEPFLA003    .TRUE.     .TRUE.
ISDEPFLA004    .TRUE.     .TRUE.
ISDEPFLA005    .TRUE.     .TRUE.
ISDEPFLA006    .TRUE.     .TRUE.
ISDEPFLA007    .TRUE.     .TRUE.
ISDEPFLA008    .TRUE.     .TRUE.
ISDEPFLA009    .TRUE.     .TRUE.
*
* NUCLIDE GROUP DATA FOR 9 NUCLIDE GROUPS
*
*               NUCNAM      PARENT   IGROUP        HAFLIF
*
ISOTPGRP001     CO-58        NONE      6         6.160E+06
ISOTPGRP002     CO-60        NONE      6         1.660E+08
ISOTPGRP003     KR-85        NONE      1         3.386E+08
ISOTPGRP004     KR-85M       NONE      1         1.613E+04
```

ISOTPGRP005	KR-87	NONE	1	4.560E+03	
ISOTPGRP006	KR-88	NONE	1	1.008E+04	
ISOTPGRP007	RB-86	NONE	3	1.611E+06	
ISOTPGRP008	SR-89	NONE	5	4.493E+06	
ISOTPGRP009	SR-90	NONE	5	8.865E+08	
ISOTPGRP010	SR-91	NONE	5	3.413E+04	
ISOTPGRP011	SR-92	NONE	5	9.756E+03	NEW
ISOTPGRP012	Y-90	SR-90	7	2.307E+05	
ISOTPGRP013	Y-91	SR-91	7	5.080E+06	
ISOTPGRP014	Y-92	SR-92	7	1.274E+04	NEW
ISOTPGRP015	Y-93	NONE	7	3.636E+04	NEW
ISOTPGRP016	ZR-95	NONE	7	5.659E+06	
ISOTPGRP017	ZR-97	NONE	7	6.048E+04	
ISOTPGRP018	NB-95	ZR-95	7	3.033E+06	
ISOTPGRP019	MO-99	NONE	6	2.377E+05	
ISOTPGRP020	TC-99M	MO-99	6	2.167E+04	
ISOTPGRP021	RU-103	NONE	6	3.421E+06	
ISOTPGRP022	RU-105	NONE	6	1.598E+04	
ISOTPGRP023	RU-106	NONE	6	3.188E+07	
ISOTPGRP024	RH-105	RU-105	6	1.278E+05	
ISOTPGRP025	SB-127	NONE	4	3.283E+05	
ISOTPGRP026	SB-129	NONE	4	1.562E+04	
ISOTPGRP027	TE-127	SB-127	4	3.366E+04	
ISOTPGRP028	TE-127M	NONE	4	9.418E+06	
ISOTPGRP029	TE-129	SB-129	4	4.200E+03	
ISOTPGRP030	TE-129M	NONE	4	2.886E+06	
ISOTPGRP031	TE-131M	NONE	4	1.080E+05	
ISOTPGRP032	TE-132	NONE	4	2.808E+05	
ISOTPGRP033	I-131	TE-131M	2	6.947E+05	
ISOTPGRP034	I-132	TE-132	2	8.226E+03	
ISOTPGRP035	I-133	NONE	2	7.488E+04	
ISOTPGRP036	I-134	NONE	2	3.156E+03	
ISOTPGRP037	I-135	NONE	2	2.371E+04	
ISOTPGRP038	XE-133	I-133	1	4.571E+05	
ISOTPGRP039	XE-135	I-135	1	3.301E+04	
ISOTPGRP040	CS-134	NONE	3	6.501E+07	
ISOTPGRP041	CS-136	NONE	3	1.123E+06	
ISOTPGRP042	CS-137	NONE	3	9.495E+08	
ISOTPGRP043	BA-139	NONE	9	4.986E+03	NEW
ISOTPGRP044	BA-140	NONE	9	1.105E+06	
ISOTPGRP045	LA-140	BA-140	7	1.448E+05	
ISOTPGRP046	LA-141	NONE	7	1.418E+04	NEW
ISOTPGRP047	LA-142	NONE	7	5.724E+03	NEW
ISOTPGRP048	CE-141	LA-141	8	2.811E+06	PARENT ADDED
ISOTPGRP049	CE-143	NONE	8	1.188E+05	
ISOTPGRP050	CE-144	NONE	8	2.457E+07	
ISOTPGRP051	PR-143	CE-143	7	1.173E+06	
ISOTPGRP052	ND-147	NONE	7	9.495E+05	
ISOTPGRP053	NP-239	NONE	8	2.030E+05	
ISOTPGRP054	PU-238	CM-242	8	2.809E+09	
ISOTPGRP055	PU-239	NP-239	8	7.700E+11	
ISOTPGRP056	PU-240	CM-244	8	2.133E+11	
ISOTPGRP057	PU-241	NONE	8	4.608E+08	
ISOTPGRP058	AM-241	PU-241	7	1.366E+10	

```
ISOTPGRP059     CM-242      NONE      7      1.408E+07
ISOTPGRP060     CM-244      NONE      7      5.712E+08
********************************************************************************
* WET DEPOSITION DATA BLOCK, LOADED BY INPWET, STORED IN /WETCON/
*                                      values per Surry sample, alh 7/17/91
* WASHOUT COEFFICIENT NUMBER ONE, LINEAR FACTOR
*
WDCWASH1001  9.5E-5   (JON HELTON AFTER JONES, 1986)
*
* WASHOUT COEFFICIENT NUMBER TWO, EXPONENTIAL FACTOR
*
WDCWASH2001  0.8      (JON HELTON AFTER JONES, 1986)
********************************************************************************
* DRY DEPOSITION DATA BLOCK, LOADED BY INPDRY, STORED IN /DRYCON/
*                            values per NRC memo to BNL 7/1/91, alh 7/17/91
* NUMBER OF PARTICLE SIZE GROUPS
*
DDNPSGRP001   1
*
* DEPOSITION VELOCITY OF EACH PARTICLE SIZE GROUP (M/S)
*
DDVDEPOS001   0.01
********************************************************************************
* DISPERSION PARAMETER DATA BLOCK, LOADED BY INPDIS, STORED IN /DISPY/, /DISPZ/
*                                      values per Surry sample, alh 7/17/91
* SIGMA = A X ** B  WHERE A AND B VALUES ARE FROM TADMOR AND GUR (1969)
*
* LINEAR TERM OF THE EXPRESSION FOR SIGMA-Y, 6 STABILITY CLASSES
*
* STABILITY CLASS: A        B        C        D        E        F
*
DPCYSIGA001   0.3658   0.2751   0.2089   0.1474   0.1046   0.0722
*
* EXPONENTIAL TERM OF THE EXPRESSION FOR SIGMA-Y, 6 STABILITY CLASSES
*
* STABILITY CLASS: A        B        C        D        E        F
*
DPCYSIGB001    .9031    .9031    .9031    .9031    .9031    .9031
*
* LINEAR TERM OF THE EXPRESSION FOR SIGMA-Z, 6 STABILITY CLASSES
*
* STABILITY CLASS: A        B        C        D        E        F
*
DPCZSIGA001   2.5E-4   1.9E-3      .2       .3       .4       .2
*
* EXPONENTIAL TERM OF THE EXPRESSION FOR SIGMA-Z, 6 STABILITY CLASSES
*
* STABILITY CLASS; A        B        C        D        E        F
*
DPCZSIGB001    2.125   1.6021    .8543    .6532    .6021    .6020
*
*  LINEAR SCALING FACTOR FOR SIGMA-Y FUNCTION, NORMALLY 1
*
DPYSCALE001    1.
```

```
*
*  LINEAR SCALING FACTOR FOR SIGMA-Z FUNCTION,
*  NORMALLY USED FOR SURFACE ROUGHNESS LENGTH CORRECTION.
*  (Z1 / Z0) ** 0.2,   FROM CRAC2 WE HAVE  (10 CM / 3 CM) ** 0.2 = 1.27
*
DPZSCALE001    1.27
******************************************************************************
* EXPANSION FACTOR DATA BLOCK, LOADED BY INPEXP, STORED IN /EXPAND/
*                                        values per Surry sample, alh 7/17/91
* TIME BASE FOR EXPANSION FACTOR (SECONDS)
*
PMTIMBAS001    600.   (10 MINUTES)
*
* BREAK POINT FOR FORMULA CHANGE (SECONDS)
*
PMBRKPNT001   3600.   (1 HOUR)
*
* EXPONENTIAL EXPANSION FACTOR NUMBER 1
*
PMXPFAC1001      0.2
*
* EXPONENTIAL EXPANSION FACTOR NUMBER 2
*
PMXPFAC2001      0.25
******************************************************************************
* PLUME RISE DATA BLOCK, LOADED BY INPLRS, STORED IN /PLUMRS/
*                                        values per Surry sample, alh 7/17/91
* SCALING FACTOR FOR THE CRITICAL WIND SPEED FOR ENTRAINMENT OF A BOUYANT PLUME
* (USED BY FUNCTION CAUGHT)
*
PRSCLCRW001   1.
*
* SCALING FACTOR FOR THE A-D STABILITY PLUME RISE FORMULA
* (USED BY FUNCTION PLMRIS)
*
PRSCLADP001   1.
*
* SCALING FACTOR FOR THE E-F STABILITY PLUME RISE FORMULA
* (USED BY FUNCTION PLMRIS)
*
PRSCLEFP001   1.
******************************************************************************
* WAKE EFFECTS DATA BLOCK, LOADED BY INPWAK, STORED IN /BILWAK/
*                                        values per Surry sample, alh 7/17/91
* BUILDING WIDTH (METERS)
*
WEBUILDW001   40.
*
* BUILDING HEIGHT (METERS)
*
WEBUILDH001   50.
```

```
******************************************************************************
* PARTICLE SIZE DISTRIBUTION OF EACH NUCLIDE GROUP
* YOU MUST SPECIFY A COLUMN OF DATA FOR EACH OF THE PARTICLE SIZE GROUPS
*                                              values per Surry sample, alh 7/17/91
*
RDPSDIST001      1.
RDPSDIST002      1.
RDPSDIST003      1.
RDPSDIST004      1.
RDPSDIST005      1.
RDPSDIST006      1.
RDPSDIST007      1.
RDPSDIST008      1.
RDPSDIST009      1.
*
* 3412 MWTH PWR CORE INVENTORY, END-OF-CYCLE
*          SUPPLIED BY D.E. BENNETT, 5/14/86
* NOTE: THIS IS A GENERIC INVENTORY FOR PWR'S THEY DID NOT CALCULATE AN
* INVENTORY FOR EACH PLANT
*                NUCNAM        CORINV(BQ)
*
RDCORINV001      CO-58         3.223E+16
RDCORINV002      CO-60         2.465E+16
RDCORINV003      KR-85         2.475E+16
RDCORINV004      KR-85M        1.159E+18
RDCORINV005      KR-87         2.118E+18
RDCORINV006      KR-88         2.864E+18
RDCORINV007      RB-86         1.888E+15
RDCORINV008      SR-89         3.590E+18
RDCORINV009      SR-90         1.938E+17
RDCORINV010      SR-91         4.616E+18
RDCORINV011      SR-92         4.803E+18
RDCORINV012      Y-90          2.079E+17
RDCORINV013      Y-91          4.374E+18
RDCORINV014      Y-92          4.821E+18
RDCORINV015      Y-93          5.454E+18
RDCORINV016      ZR-95         5.526E+18
RDCORINV017      ZR-97         5.759E+18
RDCORINV018      NB-95         5.224E+18
RDCORINV019      MO-99         6.098E+18
RDCORINV020      TC-99M        5.263E+18
RDCORINV021      RU-103        4.542E+18
RDCORINV022      RU-105        2.954E+18
RDCORINV023      RU-106        1.032E+18
RDCORINV024      RH-105        2.046E+18
RDCORINV025      SB-127        2.787E+17
RDCORINV026      SB-129        9.872E+17
RDCORINV027      TE-127        2.692E+17
RDCORINV028      TE-127M       3.564E+16
RDCORINV029      TE-129        9.267E+17
RDCORINV030      TE-129M       2.443E+17
RDCORINV031      TE-131M       4.680E+17
RDCORINV032      TE-132        4.658E+18
RDCORINV033      I-131         3.206E+18
```

```
RDCORINV034      I-132            4.725E+18
RDCORINV035      I-133            6.779E+18
RDCORINV036      I-134            7.440E+18
RDCORINV037      I-135            6.392E+18
RDCORINV038      XE-133           6.782E+18
RDCORINV039      XE-135           1.273E+18
RDCORINV040      CS-134           4.324E+17
RDCORINV041      CS-136           1.316E+17
RDCORINV042      CS-137           2.417E+17
RDCORINV043      BA-139           6.282E+18
RDCORINV044      BA-140           6.216E+18
RDCORINV045      LA-140           6.352E+18
RDCORINV046      LA-141           5.826E+18
RDCORINV047      LA-142           5.616E+18
RDCORINV048      CE-141           5.651E+18
RDCORINV049      CE-143           5.494E+18
RDCORINV050      CE-144           3.405E+18
RDCORINV051      PR-143           5.395E+18
RDCORINV052      ND-147           2.412E+18
RDCORINV053      NP-239           6.464E+19
RDCORINV054      PU-238           3.664E+15
RDCORINV055      PU-239           8.263E+14
RDCORINV056      PU-240           1.042E+15
RDCORINV057      PU-241           1.755E+17
RDCORINV058      AM-241           1.159E+14
RDCORINV059      CM-242           4.436E+16
RDCORINV060      CM-244           2.596E+15
*
*  SCALING FACTOR TO ADJUST THE CORE INVENTORY FOR POWER LEVEL
*
RDCORSCA001   1.114    *    ZION SCALED TO 3800MW
*****************************************************************************
* OUTPUT CONTROL DATA BLOCK, LOADED BY INPOPT, STORED IN /STOPME/, /ATMOPT/
*                                        values per Surry sample, alh 7/17/91
* FLAG TO INDICATE THAT THIS IS THE LAST PROGRAM IN THE SERIES TO BE RUN
*
OCENDAT1001  .FALSE. (SET THIS VALUE TO .TRUE. TO SKIP EARLY AND CHRONC)
*
OCIDEBUG001  0
*
* NAME OF THE NUCLIDE TO BE LISTED ON THE DISPERSION LISTINGS
*
*OCNUCOUT001  CS-137
*****************************************************************************
* METEOROLOGICAL SAMPLING DATA BLOCK
*                                        values per Surry sample, alh 7/17/91
* METEOROLOGICAL SAMPLING OPTION CODE:
*
* METCOD = 1, USER SPECIFIED DAY AND HOUR IN THE YEAR (FROM MET FILE),
*          2, WEATHER CATEGORY BIN SAMPLING,
*          3, 120 HOURS OF WEATHER SPECIFIED ON THE ATMOS USER INPUT FILE,
*          4, CONSTANT MET (BOUNDARY WEATHER USED FROM THE START),
*          5, STRATIFIED RANDOM SAMPLES FOR EACH DAY OF THE YEAR.
*
```

```
M1METCOD001  2
*
* LAST SPATIAL INTERVAL FOR MEASURED WEATHER
*
M2LIMSPA001  27
*
* BOUNDARY WEATHER MIXING LAYER HEIGHT
*
M2BNDMXH001  1000.  (METERS)
*
* BOUNDARY WEATHER STABILITY CLASS INDEX
*
M2IBDSTB001  4      (D-STABILITY)
*
* BOUNDARY WEATHER RAIN RATE
*
M2BNDRAN001  5.     (MM/HR)
*
* BOUNDARY WEATHER WIND SPEED
*
M2BNDWND001  5.     (M/S)
*
* NUMBER OF RAIN DISTANCE INTERVALS FOR BINNING
*
M4NRNINT001  5
*
* ENDPOINTS OF THE RAIN DISTANCE INTERVALS (KILOMETERS)
*
* NOTE: THESE MUST BE CHOSEN TO MATCH THE SPATIAL ENDPOINT DISTANCES
*       SPECIFIED FOR THE ARRAY SPAEND (10 % ERROR IS ALLOWED).
*
M4RNDSTS001  3.22  6.44  12.87  20.92  32.19
*
* NUMBER OF RAIN INTENSITIY BREAKPOINTS
*
M4NRINTN001   3
************************************************************************
* RAIN INTENSITY BREAKPOINTS FOR WEATHER BINNING (MILLIMETERS PER HOUR)
* SET FOR EQUAL WASHOUT                                        alh 7/19/91
M4RNRATE001  0.762    2.286    6.858
*
* NUMBER OF SAMPLES PER BIN
*
M4NSMPLS001  4  (THIS NUMBER SHOULD BE SET TO 4 FOR RISK ASSESSMENT)
*
* INITIAL SEED FOR RANDOM NUMBER GENERATOR
*
M4IRSEED001   79
*****************************************************************************
* RELEASE DATA BLOCK, LOADED BY INPREL, STORED IN /ATNAM2/, /MULREL/
*                                              changes made by alh 7/17/91
*
RDATNAM2001 'SOURCE TERM 1:  RZ1'
*
```

```
* TIME AFTER ACCIDENT INITIATION WHEN THE ACCIDENT REACHES GENERAL EMERGENCY
* CONDITIONS (AS DEFINED IN NUREG-0654), OR WHEN PLANT PERSONNEL CAN RELIABLY
* PREDICT THAT GENERAL EMERGENCY CONDITIONS WILL BE ATTAINED
*
RDOALARM001      18000.
*
* NUMBER OF PLUME SEGMENTS THAT ARE RELEASED
*
RDNUMREL001       2
*
* SELECTION OF RISK DOMINANT PLUME
*                           this version of MACCS only allows the first plume
RDMAXRIS001         1
*
* REFERENCE TIME FOR DISPERSION AND RADIOACTIVE DECAY
*                                                assumption on plume ref. time
RDREFTIM001       0.50    0.50
*
* HEAT CONTENT OF THE RELEASE SEGMENTS (W)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLHEAT001     8.6E6      1.5E6
*
* HEIGHT OF THE PLUME SEGMENTS AT RELEASE (M)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLHITE001         10.        10.
*
* DURATION OF THE PLUME SEGMENTS (S)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLUDUR001       600.       7200.
*
* TIME OF RELEASE FOR EACH PLUME (S AFTER SCRAM)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPDELAY001       21600.    22201.
*
*
* RELEASE FRACTIONS FOR ISOTOPE GROUPS IN RELEASE
*
*  ISOTOPE GROUPS:
*
*             XE/KR    I      CS      TE      SR      RU      LA      CE      BA
*
RDRELFRC001   1.0    0.25    0.18    0.08    0.02    0.005   0.001   0.005   0.02
RDRELFRC002   0.0    0.02    0.03    0.02    0.01    0.0002  0.001   0.001   0.01

******************************************************************************
* RELEASE DATA BLOCK, LOADED BY INPREL, STORED IN /ATNAM2/, /MULREL/
*                                                   changes made by alh 7/17/91
*
RDATNAM2001 'SOURCE TERM 3:  RZ3'
*
```

```
* TIME AFTER ACCIDENT INITIATION WHEN THE ACCIDENT REACHES GENERAL EMERGENCY
* CONDITIONS (AS DEFINED IN NUREG-0654), OR WHEN PLANT PERSONNEL CAN RELIABLY
* PREDICT THAT GENERAL EMERGENCY CONDITIONS WILL BE ATTAINED
*
RDOALARM001     18000.
*
* NUMBER OF PLUME SEGMENTS THAT ARE RELEASED
*                       MACCS can only handle 10hrs/plume total of 20hrs.
*                       we are breaking this into 2 10hr puffs
RDNUMREL001       2
*
* SELECTION OF RISK DOMINANT PLUME
*                          this version of MACCS only allows the first plume
RDMAXRIS001          1
*
* REFERENCE TIME FOR DISPERSION AND RADIOACTIVE DECAY
*                                                 assumption on plume ref. time
RDREFTIM001       0.50       0.50
*
* HEAT CONTENT OF THE RELEASE SEGMENTS (W)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLHEAT001     0.       0.
*
* HEIGHT OF THE PLUME SEGMENTS AT RELEASE (M)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLHITE001         0.       0.
*
* DURATION OF THE PLUME SEGMENTS (S)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLUDUR001       34200.    34199.
*
* TIME OF RELEASE FOR EACH PLUME (S AFTER SCRAM)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPDELAY001       21600.    55801.
*
*
* RELEASE FRACTIONS FOR ISOTOPE GROUPS IN RELEASE
*
*  ISOTOPE GROUPS:
*
*            XE/KR    I      CS     TE     SR     RU     LA     CE     BA
*
RDRELFRC001  0.0025 1.5E-5 1.2E-8 .75E-8 2.5E-9 2.E-10 3.E-10 4.E-10 2.5E-9
RDRELFRC002  0.0025 1.5E-5 1.2E-8 .75E-8 2.5E-9 2.E-10 3.E-10 4.E-10 2.5E-9

*******************************************************************************
* RELEASE DATA BLOCK, LOADED BY INPREL, STORED IN /ATNAM2/, /MULREL/
*                                                  changes made by alh 7/17/91
*
RDATNAM2001 'SOURCE TERM 4:  RZ4'
```

```
*
* TIME AFTER ACCIDENT INITIATION WHEN THE ACCIDENT REACHES GENERAL EMERGENCY
* CONDITIONS (AS DEFINED IN NUREG-0654), OR WHEN PLANT PERSONNEL CAN RELIABLY
* PREDICT THAT GENERAL EMERGENCY CONDITIONS WILL BE ATTAINED
*
RDOALARM001      1200.
*
* NUMBER OF PLUME SEGMENTS THAT ARE RELEASED
*
RDNUMREL001       2
*
* SELECTION OF RISK DOMINANT PLUME
*                          this version of MACCS only allows the first plume
RDMAXRIS001          1
*
* REFERENCE TIME FOR DISPERSION AND RADIOACTIVE DECAY
*                                                 assumption on plume ref. time
RDREFTIM001       0.50       0.50
*
* HEAT CONTENT OF THE RELEASE SEGMENTS (W)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLHEAT001      5.5E6       9.9E5
*
* HEIGHT OF THE PLUME SEGMENTS AT RELEASE (M)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLHITE001         10.        10.
*
* DURATION OF THE PLUME SEGMENTS (S)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLUDUR001       1800.      7200.
*
* TIME OF RELEASE FOR EACH PLUME (S AFTER SCRAM)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPDELAY001       3600.      5401.
*
*
* RELEASE FRACTIONS FOR ISOTOPE GROUPS IN RELEASE
*
*  ISOTOPE GROUPS:
*
*           XE/KR    I      CS     TE     SR     RU     LA     CE     BA
*
RDRELFRC001  1.0   0.075  0.06   0.02   0.005  0.001  3.E-4  0.001  0.005
RDRELFRC002  0.0   0.04   0.06   0.05   0.02   6.E-4  0.003  0.003  0.02
```

APPENDIX Ca – EARLY-Z3

```
* Large Release (LR) EARLY, based on the SURRY input file, LN, 07.18.91
* WITH THE "AVERAGE" NUREG-1150 EMERGENCY PLANNING
* GENERAL DESCRIPTIVE TITLE DESCRIBING THIS "EARLY" INPUT FILE
*
MIEANAM1001  ' Large Release, Base Case'
*
* FLAG TO INDICATE THAT THIS IS THE LAST PROGRAM IN THE SERIES TO BE RUN
*
MIENDAT2001  .FALSE.    (SET THIS VALUE TO .TRUE. TO SKIP CHRONC)
*
* DISPERSION MODEL OPTION CODE:  1  *  STRAIGHT LINE
*                                2  *  WIND-SHIFT WITH ROTATION
*                                3  *  WIND-SHIFT WITHOUT ROTATION
*
MIIPLUME001  2
*
* NUMBER OF FINE GRID SUBDIVISIONS USED BY THE MODEL
*
MINUMFIN001  7    (3, 5 OR 7 ALLOWED)
*
* LEVEL OF DEBUG OUTPUT REQUIRED, NORMAL RUNS SHOULD SPECIFY ZERO
*
MIIPRINT001  0
*
* LOGICAL FLAG SIGNIFYING THAT THE BREAKDOWN OF RISK BY WEATHER CATEGORY
* BIN ARE TO BE PRESENTED TO SHOW THEIR RELATIVE CONTRIBUTION TO THE MEAN
*
*             RISBIN
*
MIRISCAT001   .FALSE.
*
* FLAG INDICATING IF WIND-ROSES FROM ATMOS ARE TO BE OVERRIDDEN
*
* MIOVRRID001 .FALSE. (USE THE WIND ROSE CALCULATED FOR EACH WEATHER BIN)
MIOVRRID001 .TRUE.
*     AH, LN: imposed wind rose as per July 1 NRC Memo. 7.22.91
*             Cities are located in and around sector 15 (NW)
*
MIWINROS001 0.04977 0.04977 0.04977 0.04977 0.04977 0.04977 0.04977 0.04977
MIWINROS002 0.04977 0.04977 0.04977 0.04977 0.04977 0.11 0.133 0.11
*******************************************************************************
* POPULATION DISTRIBUTION DATA BLOCK, LOADED BY INPOPU, STORED IN /POPDAT/
*
PDPOPFLG001  FILE
*
*PDPOPFLG001  UNIFORM
*PDIBEGIN001  1    (SPATIAL INTERVAL AT WHICH POPULATION BEGINS)
*PDPOPDEN001  50. (POPULATION DENSITY (PEOPLE PER SQUARE KILOMETER))
*******************************************************************************
```

```
* ORGAN DEFINITION DATA BLOCK, LOADED BY INORGA, STORED IN /EARDIM/ AND /ORGNAM/
*
* NUMBER OF ORGANS DEFINED FOR HEALTH EFFECTS
*
ODNUMORG001   10
*
* NAMES OF THE ORGANS DEFINED FOR HEALTH EFFECTS
*
ODORGNAM001 'SKIN', 'EDEWBODY', 'LUNGS', 'RED MARR', 'LOWER LI', 'STOMACH',
ODORGNAM002 'THYROIDH', 'BONE SUR', 'BREAST', 'BLAD WAL'
*******************************************************************************
* SHIELDING AND EXPOSURE FACTORS, LOADED BY INDFAC, STORED IN /EADFAC/
*
* THREE VALUES OF EACH PROTECTION FACTOR ARE SUPPLIED,
* ONE FOR EACH TYPE OF ACTIVTY:
*
* ACTIVITY TYPE:
*      1 - EVACUEES WHILE MOVING
*      2 - NORMAL ACTIVITY IN SHELTERING AND EVACUATION ZONE
*      3 - SHELTERED ACTIVITY
*
* CLOUD SHIELDING FACTOR
*
*    SITE         GG   PB   SEQ  SUR  ZION
*    SHELTERING   0.7  0.5  0.65 0.6  0.5
*
* VM and LN 07.18.91
* Shielding factor for sheltering. Consistent with the NRC request
* for averaving the evacuation speed: it is also a site characteristic.
* Use an average value of 0.6 for the cloud (based on NUREG-1150 sites).
*
*             EVACUEES  NORMAL  SHELTER
*
SECSFACT001      1.      0.75      0.6    *  average NUREG-1150 value
*
* PROTECTION FACTOR FOR INHALATION
*
SEPROTIN001      1.      0.41       0.33  * VALUES FOR NORMAL ACTIVITY AND
*                                           SHELTERING SELECTED BY NRC STAFF
*                                           for NUREG-1150
*
* BREATHING RATE (CUBIC METERS PER SECOND)
*
SEBRRATE001  2.66E-4  2.66E-4  2.66E-4
*
* SKIN PROTECTION FACTOR
*
SESKPFAC001  1.0      0.41     0.33     * VALUES FOR NORMAL ACTIVITY AND
*                                         SHELTERING SELECTED BY NRC STAFF
*                                         for NUREG-1150
* GROUND SHIELDING FACTOR
*
*    SITE         GG   PB   SEQ  SUR  ZION
*    SHELTERING   0.25 0.1  0.2  0.2  0.1
```

```
*
* VM and LN 07.18.91: ground shielding factor.
* Use an average value of 0.2 (NUREG-1150 sites) for the ground
* shielding factor for sheltering.
*
SEGSHFAC001       0.5     0.33    0.2    * VALUE FOR NORMAL ACTIVITY SELECTED BY
*                                          NRC STAFF for NUREG-1150
*
* RESUSPENSION INHALATION MODEL CONCENTRATION COEFFICIENT (/METER)
*
*   RESCON = 1.E-4 IS APPROPRIATE FOR MECHANICAL RESUSPENSION BY VEHICLES.
*   RESHAF = 2.11 DAYS CAUSES 1.E-4 TO DECAY IN ONE WEEK TO 1.E-5, THE VALUE
*   OF RESCON USED IN THE FIRST TERM OF THE LONG-TERM RESUSPENSION EQUATION
*   USED IN CHRONC.
*
SERESCON001   1.E-4     (RESUSPENSION IS TURNED ON)
*
* RESUSPENSION CONCENTRATION COEFFICIENT HALF-LIFE (SEC)
*
SERESHAF001   1.82E5    (2.11 DAYS)
******************************************************************************
* EVACUATION ZONE DATA BLOCK, LOADED BY EVNETW, STORED IN /NETWOR/, /EOPTIO/
*
* SPECIFIC DESCRIPTION OF THE EMERGENCY RESPONSE SCENARIO BEING USED
*
EZEANAM2001  'Large Release, NRC: evac. within 10 mi, reloc. elsewhere'
*
* THE TYPE OF WEIGHTING TO BE APPLIED TO THE EMERGENCY RESPONSE SCENARIOS
* YOU MUST SUPPLY A VALUE OF 'TIME' OR 'PEOPLE'
*
EZWTNAME001  'PEOPLE'
*
* WEIGHTING FRACTION APPLICABLE TO THIS SCENARIO
*
EZWTFRAC001  0.995   NRC Memo to BNL, 06.04.91
*
* LAST RING IN THE MOVEMENT ZONE
*
EZLASMOV001      17     (EVACUEES DISAPPEAR AFTER TRAVELING TO 20 MILES)
*                       07.29.91, as per NRC population Memo
*
* FIRST SPATIAL INTERVAL IN THE EVACUATION ZONE
*
EZINIEVA001       1     (NO INNER SHELTER ZONE)
*
* OUTER BOUNDS ON 3 EVACUATION ZONES (ZERO MEANS THE ZONE IS NOT DEFINED)
*
EZLASEVA001      0    0    14  (SINGLE EVACUATION ZONE OUT TO 10 MILES)
*                      07.29.91, as per NRC population Memo
* EVACUATION DELAY TIMES FOR THE 3 EVACUATION ZONES
* THIS IS THE DELAY TIME FROM OALARM (ATMOS) TO WHEN PEOPLE START MOVING
*
EZEDELAY001  0. 0. 6840.  average NUREG-1150 value (C. Conrad, 07.10.91)
*                         1.9 hr
```

```
* RADIAL EVACUATION SPEED (M/S)
*
EZESPEED001    2.6        average NUREG-1150 value (C. Conrad, 07.10.91)
**********************************************************************
* SHELTER AND RELOCATION ZONE DATA BLOCK, LOADED BY INPEMR,
*                                          STORED IN /INPSRZ/, /RELOCA/
*
* TIME TO TAKE SHELTER IN THE INNER SHELTER ZONE (SECONDS FROM OALARM)
*
SRTTOSH1001      0.     (THERE IS NO INNER SHELTER ZONE)
*
* SHELTER DURATION IN THE INNER SHELTER ZONE (SECONDS FROM TAKING SHELTER)
*
SRSHELT1001      0.     (THERE IS NO INNER SHELTER ZONE)
*
* LAST RING OF THE OUTER SHELTER ZONE
*
SRLASHE2001      0      (THERE IS NO OUTER SHELTER ZONE)
*
* TIME TO TAKE SHELTER IN THE OUTER SHELTER ZONE (SECONDS FROM OALARM)
*
SRTTOSH2001      0.     (THERE IS NO OUTER SHELTER ZONE)
*
* SHELTER DURATION IN THE OUTER SHELTER ZONE (SECONDS FROM TAKING SHELTER)
*
SRSHELT2001      0.     (THERE IS NO OUTER SHELTER ZONE)
*
* DURATION OF THE EMERGENCY PHASE (SECONDS FROM PLUME ARRIVAL)
*
SRENDEMP001  604800.    (ONE WEEK)
*
* CRITICAL ORGAN FOR RELOCATION DECISIONS
*
SRCRIORG001 'EDEWBODY'
*
* HOT SPOT RELOCATION TIME (SECONDS FROM PLUME ARRIVAL)
*
SRTIMHOT001  43200.     (ONE-HALF DAY)
*
* NORMAL RELOCATION TIME (SECONDS FROM PLUME ARRIVAL)
*
SRTIMNRM001  86400.     (ONE DAY)
*
* HOT SPOT RELOCATION DOSE CRITERION THRESHOLD (SIEVERTS)
*
SRDOSHOT001  0.5    (50 REM DOSE TO WHOLE BODY IN 1 WEEK TRIGGERS RELOCATION)
*
* NORMAL RELOCATION DOSE CRITERION THRESHOLD (SIEVERTS)
*
SRDOSNRM001  0.25   (25 REM DOSE TO WHOLE BODY IN 1 WEEK TRIGGERS RELOCATION)
******************************************************************************
```

```
* EARLY FATALITY MODEL PARAMETERS, LOADED BY INEFAT, STORED IN /EFATAL/
*
* NUMBER OF EARLY FATALITY EFFECTS
*
EFNUMEFA001   3
*
*             ORGNAM       EFFACA   EFFACB   EFFTHR
*
EFATAGRP001 'RED MARR'      3.8      5.0     1.5
EFATAGRP002 'LUNGS'        10.0      7.0     5.0
EFATAGRP003 'LOWER LI'     15.0     10.0     8.0
******************************************************************************
* EARLY INJURY MODEL PARAMETERS, LOADED BY INEINJ, STORED IN /EINJUR/
*
* NUMBER OF EARLY INJURY EFFECTS
*
EINUMEIN001  7
*
*             EINAME             ORGNAM    EISUSC EITHRE EIFACA EIFACB
*
EINJUGRP001 'PRODROMAL VOMIT' 'STOMACH'  1.      .5     2.     3.
EINJUGRP002 'DIARRHEA'        'STOMACH'  1.      1.     3.     2.5
EINJUGRP003 'PNEUMONITIS'     'LUNGS'    1.      5.    10.     7.
EINJUGRP004 'SKIN ERYTHEMA'   'SKIN'     1.      3.     6.     5.
EINJUGRP005 'TRANSEPIDERMAL'  'SKIN'     1.     10.    20.     5.
EINJUGRP006 'THYROIDITIS'     'THYROIDH' 1.     40.   240.     2.
EINJUGRP007 'HYPOTHYROIDISM'  'THYROIDH' 1.      2.    60.     1.3
******************************************************************************
* ACUTE EXPOSURE CANCER PARAMETERS, LOADED BY INACAN STORED IN /ACANCR/.
*
* NUMBER OF ACUTE EXPOSURE CANCER EFFECTS
*
LCNUMACA001   7
*
* THRESHOLD DOSE FOR APPLYING THE DOSE DEPENDENT REDUCTION FACTOR
*
LCDDTHRE001   0.2  (LOWEST DOSE FOR WHICH DDREFA WILL BE APPLIED)
*
* DOSE THRESHOLD FOR LINEAR DOSE RESPONSE (SV)
*
LCACTHRE001   0.0  (LINEAR-QUADRATIC MODEL IS NOT BEING USED)
*
*             ACNAME     ORGNAM    ACSUSC DOSEFA DOSEFB CFRISK    CIRISK   DDREFA
*
LCANCERS001 'LEUKEMIA' 'RED MARR'  1.0    1.0    0.0   9.70E-3   9.70E-3  2.0
LCANCERS002 'BONE'     'BONE SUR'  1.0    1.0    0.0   9.00E-4   9.00E-4  2.0
LCANCERS003 'BREAST'   'BREAST'    1.0    1.0    0.0   5.40E-3   1.59E-2  1.0
LCANCERS004 'LUNG'     'LUNGS'     1.0    1.0    0.0   1.55E-2   1.73E-2  2.0
LCANCERS005 'THYROID'  'THYROIDH'  1.0    1.0    0.0   7.20E-4   7.20E-3  1.0
LCANCERS006 'GI'       'LOWER LI'  1.0    1.0    0.0   3.36E-2   5.75E-2  2.0
LCANCERS007 'OTHER'    'BLAD WAL'  1.0    1.0    0.0   2.76E-2   5.52E-2  2.0
******************************************************************************
```

```
* RESULT 1 OPTIONS BLOCK, LOADED BY INOUT1, STORED IN /INOUT1/
* TOTAL NUMBER OF A GIVEN EFFECT (LATENT CANCER, EARLY DEATH, EARLY INJURY)
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE1NUMBER      0
*
*TYPE1OUT001    'ERL FAT/TOTAL'          1   2      (0.25 TO  0.33 MILES)
*TYPE1OUT002    'ERL FAT/TOTAL'          2   3      (0.33 TO  .4 MILES)
*TYPE1OUT003    'ERL FAT/TOTAL'          3   4      (.4 TO .5 MILES)
*TYPE1OUT004    'ERL FAT/TOTAL'          4   5      (.5 TO 1.25 MILES)
*TYPE1OUT005    'ERL FAT/TOTAL'          5   6      (1.25 TO 1.33 MILES)
*TYPE1OUT006    'ERL FAT/TOTAL'          6   7      (1.33 TO 1.4 MILES)
*TYPE1OUT007    'ERL FAT/TOTAL'          7   8      (1.4 TO 1.5 MILES)
*TYPE1OUT008    'ERL FAT/TOTAL'          8   9      (1.5 TO 2 MILES)
*TYPE1OUT009    'ERL FAT/TOTAL'          9  10      (2 TO 3 MILES)
*TYPE1OUT010    'ERL FAT/TOTAL'         10  11      (3 TO 4 MILES)
*TYPE1OUT011    'ERL FAT/TOTAL'         11  12      (4 TO 5 MILES)
*TYPE1OUT012    'ERL FAT/TOTAL'         12  13      (5 TO 8 MILES)
*TYPE1OUT013    'ERL FAT/TOTAL'         13  14      (8 TO 10 MILES)
*
*TYPE1OUT014    'CAN FAT/TOTAL'           1   3      (0.25 TO  .4 MILES)
*TYPE1OUT015    'CAN FAT/TOTAL'           3   4      (.4  TO  .5 MILES)
*TYPE1OUT016    'CAN FAT/TOTAL'           4   5      (.5 TO 1.25 MILES)
*TYPE1OUT017    'CAN FAT/TOTAL'           5   9      (1.25 TO 2 MILES)
*TYPE1OUT018    'CAN FAT/TOTAL'           9  10      (2 TO 3 MILES)
*TYPE1OUT019    'CAN FAT/TOTAL'          10  11      (3 TO 4 MILES)
*TYPE1OUT020    'CAN FAT/TOTAL'          11  12      (4 TO 5 MILES)
*TYPE1OUT021    'CAN FAT/TOTAL'          12  13      (5 TO 8 MILES)
*TYPE1OUT022    'CAN FAT/TOTAL'          13  14      (8 TO 10 MILES)
*TYPE1OUT023    'CAN FAT/TOTAL'          14  15      (10 TO 13 MILES)
*TYPE1OUT024    'CAN FAT/TOTAL'          15  17      (13 TO 20 MILES)
*TYPE1OUT025    'CAN FAT/TOTAL'          17  18      (20 TO 25 MILES)
*TYPE1OUT026    'CAN FAT/TOTAL'          18  19      (25 TO 30 MILES)
*TYPE1OUT027    'CAN FAT/TOTAL'          19  20      (30 TO 40 MILES)
*TYPE1OUT028    'CAN FAT/TOTAL'          20  21      (40 TO 50 MILES)
*TYPE1OUT029    'CAN FAT/TOTAL'          21  23      (50 TO 100 MILES)
*TYPE1OUT030    'CAN FAT/TOTAL'          23  25      (100 TO 200 MILES)
*TYPE1OUT031    'CAN FAT/TOTAL'          25  26      (200 TO 350 MILES)
*TYPE1OUT032    'CAN FAT/TOTAL'          26  27      (350 TO 500 MILES)
*
*TYPE1OUT009    'CAN FAT/TOTAL'               1  20
*TYPE1OUT010    'CAN FAT/LUNG'                1  20
*TYPE1OUT011    'CAN FAT/THYROID'             1  20
*TYPE1OUT012    'CAN FAT/BREAST'              1  20
*TYPE1OUT013    'CAN FAT/GI'                  1  20
*TYPE1OUT014    'CAN FAT/LEUKEMIA'            1  20
*TYPE1OUT015    'CAN FAT/BONE'                1  20
*TYPE1OUT016    'CAN FAT/OTHER'               1  20
*TYPE1OUT017    'CAN INJ/TOTAL'               1  20
*
*
```

```
*TYPE1OUT018    'ERL FAT/TOTAL'                 1  13   (0 TO 10 MILES)
*TYPE1OUT019    'ERL INJ/PRODROMAL VOMIT'       1  13
*TYPE1OUT020    'ERL INJ/DIARRHEA'              1  13
*TYPE1OUT021    'ERL INJ/PNEUMONITIS'           1  13
*TYPE1OUT022    'ERL INJ/THYROIDITIS'           1  13
*TYPE1OUT023    'ERL INJ/HYPOTHYROIDISM'        1  13
*TYPE1OUT024    'ERL INJ/SKIN ERYTHEMA'         1  13
*TYPE1OUT025    'ERL INJ/TRANSEPIDERMAL'        1  13
*TYPE1OUT026    'CAN FAT/TOTAL'                 1  13
*****************************************************************************
* RESULT 2 OPTIONS BLOCK, LOADED BY INOUT2, STORED IN /INOUT2/
* FURTHEST DISTANCE AT WHICH A GIVEN RISK OF EARLY DEATH IS EXCEEDED.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE2NUMBER  0
*
*             FATALITY RISK THRESHOLD
*TYPE2OUT001  0.
*****************************************************************************
* RESULT 3 OPTIONS BLOCK, LOADED BY INOUT3, STORED IN /INOUT3/
* NUMBER OF PEOPLE WHOSE DOSE TO A GIVEN ORGAN EXCEEDS A GIVEN THRESHOLD.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE3NUMBER  0
*
*                ORGAN NAME   DOSE THRESHOLD (SV)   DOSE FLAG
*
*TYPE3OUT001    'RED MARR'        1.5                  ACUTE
*TYPE3OUT002    'LUNGS'           5.0                  ACUTE
*TYPE3OUT003    'EDEWBODY'        0.05                LIFETIME
*****************************************************************************
* RESULT 4 OPTIONS BLOCK, LOADED BY INOUT4, STORED IN /INOUT4/
* 360 DEGREE AVERAGE RISK OF A GIVEN EFFECT AT A GIVEN DISTANCE.
*
* POSSIBLE TYPES OF EFFECTS ARE:
*
*   'ERL FAT/TOTAL'
*   'ERL INJ/INJURY NAME'
*   'CAN FAT/CANCER NAME'
*   'CAN FAT/TOTAL'
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE4NUMBER  0
* TYPE4NUMBER  5
*
*             RADIAL INDEX   TYPE OF EFFECT
*
*TYPE4OUT001       1          'ERL FAT/TOTAL'
*TYPE4OUT002       2          'ERL FAT/TOTAL'
*TYPE4OUT003       3          'ERL FAT/TOTAL'
*TYPE4OUT004       4          'ERL FAT/TOTAL'
*TYPE4OUT005       5          'ERL FAT/TOTAL'
```

```
*****************************************************************************
* RESULT 5 OPTIONS BLOCK, LOADED BY INOUT5, STORED IN /INOUT5/
*
* TOTAL POPULATION DOSE TO A GIVEN ORGAN BETWEEN TWO DISTANCES.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE5NUMBER     0
*
*              ORGAN        I1DIS5 I2DIS5
*
*TYPE5OUT001 'EDEWBODY'        1    5      (0 TO  1.25 MILES)
*TYPE5OUT002 'EDEWBODY'        1   12      (0 TO  5  MILES)
*TYPE5OUT003 'EDEWBODY'        1   14      (0 TO 10  MILES)
*TYPE5OUT004 'EDEWBODY'        1   27      (0 TO 500 MILES)
*
*TYPE5OUT001 'EDEWBODY'      1         13         (0-10 MILES)
*TYPE5OUT002 'EDEWBODY'      1         20         (0-50 MILES)
*TYPE5OUT003 'EDEWBODY'      1         20         (0-50 MILES)
*****************************************************************************
* RESULT 6 OPTIONS BLOCK, LOADED BY INOUT6, STORED IN /INOUT6/
*
* CENTERLINE DOSE TO AN ORGAN VS DIST BY PATHWAY, PATHWAY NAMES ARE AS FOLLOWS:
TYPE6NUMBER     0
TYPE7NUMBER     0
*
* RESULT 8 OPTIONS BLOCK, LOADED BY INOUT8, STORED IN /INOUT8/
*
* POPULATION WEIGHTED FATALITY RISK BETWEEN 2 DISTANCES
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE8NUMBER   19
*
*                 NAME       I1DIS8  I2DIS8
*
TYPE8OUT001    'CAN FAT/TOTAL'         2   3      (0.25 TO  .4 MILES)
TYPE8OUT002    'CAN FAT/TOTAL'         4   4      (.4  TO  .5 MILES)
TYPE8OUT003    'CAN FAT/TOTAL'         5   5      (.5 TO 1.25 MILES)
TYPE8OUT004    'CAN FAT/TOTAL'         6   9      (1.25 TO 2 MILES)
TYPE8OUT005    'CAN FAT/TOTAL'        10  10      (2 TO 3 MILES)
TYPE8OUT006    'CAN FAT/TOTAL'        11  11      (3 TO 4 MILES)
TYPE8OUT007    'CAN FAT/TOTAL'        12  12      (4 TO 5 MILES)
TYPE8OUT008    'CAN FAT/TOTAL'        13  13      (5 TO 8 MILES)
TYPE8OUT009    'CAN FAT/TOTAL'        14  14      (8 TO 10 MILES)
TYPE8OUT010    'CAN FAT/TOTAL'        15  15      (10 TO 13 MILES)
TYPE8OUT011    'CAN FAT/TOTAL'        16  17      (13 TO 20 MILES)
TYPE8OUT012    'CAN FAT/TOTAL'        18  18      (20 TO 25 MILES)
TYPE8OUT013    'CAN FAT/TOTAL'        19  19      (25 TO 30 MILES)
TYPE8OUT014    'CAN FAT/TOTAL'        20  20      (30 TO 40 MILES)
TYPE8OUT015    'CAN FAT/TOTAL'        21  21      (40 TO 50 MILES)
TYPE8OUT016    'CAN FAT/TOTAL'        22  23      (50 TO 100 MILES)
TYPE8OUT017    'CAN FAT/TOTAL'        24  25      (100 TO 200 MILES)
TYPE8OUT018    'CAN FAT/TOTAL'        26  26      (200 TO 350 MILES)
TYPE8OUT019    'CAN FAT/TOTAL'        27  27      (350 TO 500 MILES)
```

```
.
******************************************************************************
* EVACUATION ZONE DATA BLOCK, LOADED BY EVNETW, STORED IN /NETWOR/, /EOPTIO/
*
* SPECIFIC DESCRIPTION OF THE EMERGENCY RESPONSE SCENARIO BEING USED
*
EZEANAM2001  'Large Release, NRC: no evacuation of 0.5% of population'
*
* THE TYPE OF WEIGHTING TO BE APPLIED TO THE EMERGENCY RESPONSE SCENARIOS
* YOU MUST SUPPLY A VALUE OF 'TIME' OR 'PEOPLE'
*
EZWTNAME001  'PEOPLE'
*
* WEIGHTING FRACTION APPLICABLE TO THIS SCENARIO
*
EZWTFRAC001  0.005   NRC Memo to BNL, 06.04.91
*
* LAST RING IN THE MOVEMENT ZONE
*
EZLASMOV001      0     (EVACUEES DISAPPEARANCE)
*
* No evacuation, no sheltering: as per NRC population Memo
* FIRST SPATIAL INTERVAL IN THE EVACUATION ZONE
*
* Data below are not needed...
* EZINIEVA001      1     (NO INNER SHELTER ZONE)
*
* OUTER BOUNDS ON 3 EVACUATION ZONES (ZERO MEANS THE ZONE IS NOT DEFINED)
*
* EZLASEVA001     0   0   0  (no evacuation)
* EVACUATION DELAY TIMES FOR THE 3 EVACUATION ZONES
* THIS IS THE DELAY TIME FROM OALARM (ATMOS) TO WHEN PEOPLE START MOVING
*
* EZEDELAY001  0. 0. 0.
```

APPENDIX Cb – EAR-Z3-N

```
* Large Release (LR) EARLY, based on the SURRY input file, LN, 07.18.91
* THIS IS WITH NO EVACUATION
* GENERAL DESCRIPTIVE TITLE DESCRIBING THIS "EARLY" INPUT FILE
*
MIEANAM1001  ' Large Release, Base Case'
*
* FLAG TO INDICATE THAT THIS IS THE LAST PROGRAM IN THE SERIES TO BE RUN
*
MIENDAT2001  .FALSE.    (SET THIS VALUE TO .TRUE. TO SKIP CHRONC)
*
* DISPERSION MODEL OPTION CODE:  1  *  STRAIGHT LINE
*                                2  *  WIND-SHIFT WITH ROTATION
*                                3  *  WIND-SHIFT WITHOUT ROTATION
*
MIIPLUME001  2
*
* NUMBER OF FINE GRID SUBDIVISIONS USED BY THE MODEL
*
MINUMFIN001  7    (3, 5 OR 7 ALLOWED)
*
* LEVEL OF DEBUG OUTPUT REQUIRED, NORMAL RUNS SHOULD SPECIFY ZERO
*
MIIPRINT001  0
*
* LOGICAL FLAG SIGNIFYING THAT THE BREAKDOWN OF RISK BY WEATHER CATEGORY
* BIN ARE TO BE PRESENTED TO SHOW THEIR RELATIVE CONTRIBUTION TO THE MEAN
*
*             RISBIN
*
MIRISCAT001   .FALSE.
*
* FLAG INDICATING IF WIND-ROSES FROM ATMOS ARE TO BE OVERRIDDEN
*
* MIOVRRID001 .FALSE. (USE THE WIND ROSE CALCULATED FOR EACH WEATHER BIN)
MIOVRRID001 .TRUE.
*     AH, LN: imposed wind rose as per July 1 NRC Memo. 7.22.91
*             Cities are located in and around sector 15 (NW)
*
MIWINROS001 0.04977 0.04977 0.04977 0.04977 0.04977 0.04977 0.04977 0.04977
MIWINROS002 0.04977 0.04977 0.04977 0.04977 0.04977 0.11 0.133 0.11
******************************************************************************
* POPULATION DISTRIBUTION DATA BLOCK, LOADED BY INPOPU, STORED IN /POPDAT/
*
PDPOPFLG001  FILE
*
*PDPOPFLG001  UNIFORM
*PDIBEGIN001  1   (SPATIAL INTERVAL AT WHICH POPULATION BEGINS)
*PDPOPDEN001  50. (POPULATION DENSITY (PEOPLE PER SQUARE KILOMETER))
******************************************************************************
```

```
* ORGAN DEFINITION DATA BLOCK, LOADED BY INORGA, STORED IN /EARDIM/ AND /ORGNAM/
*
* NUMBER OF ORGANS DEFINED FOR HEALTH EFFECTS
*
ODNUMORG001   10
*
* NAMES OF THE ORGANS DEFINED FOR HEALTH EFFECTS
*
ODORGNAM001 'SKIN', 'EDEWBODY', 'LUNGS', 'RED MARR', 'LOWER LI', 'STOMACH',
ODORGNAM002 'THYROIDH', 'BONE SUR', 'BREAST', 'BLAD WAL'
******************************************************************************
* SHIELDING AND EXPOSURE FACTORS, LOADED BY INDFAC, STORED IN /EADFAC/
*
* THREE VALUES OF EACH PROTECTION FACTOR ARE SUPPLIED,
* ONE FOR EACH TYPE OF ACTIVTY:
*
* ACTIVITY TYPE:
*     1 - EVACUEES WHILE MOVING
*     2 - NORMAL ACTIVITY IN SHELTERING AND EVACUATION ZONE
*     3 - SHELTERED ACTIVITY
*
* CLOUD SHIELDING FACTOR
*
*    SITE        GG   PB   SEQ  SUR  ZION
*    SHELTERING  0.7  0.5  0.65 0.6  0.5
*
* VM and LN 07.18.91
* Shielding factor for sheltering. Consistent with the NRC request
* for averaving the evacuation speed: it is also a site characteristic.
* Use an average value of 0.6 for the cloud (based on NUREG-1150 sites).
*
*             EVACUEES  NORMAL  SHELTER
*
SECSFACT001      1.      0.75     0.6    *  average NUREG-1150 value
*
* PROTECTION FACTOR FOR INHALATION
*
SEPROTIN001      1.      0.41      0.33  * VALUES FOR NORMAL ACTIVITY AND
*                                          SHELTERING SELECTED BY NRC STAFF
*                                          for NUREG-1150
*
* BREATHING RATE (CUBIC METERS PER SECOND)
*
SEBRRATE001  2.66E-4  2.66E-4  2.66E-4
*
* SKIN PROTECTION FACTOR
*
SESKPFAC001  1.0      0.41     0.33     * VALUES FOR NORMAL ACTIVITY AND
*                                         SHELTERING SELECTED BY NRC STAFF
*                                         for NUREG-1150
* GROUND SHIELDING FACTOR
*
*    SITE        GG   PB   SEQ  SUR  ZION
*    SHELTERING  0.25 0.1  0.2  0.2  0.1
```

```
*
* VM and LN 07.18.91: ground shielding factor.
* Use an average value of 0.2 (NUREG-1150 sites) for the ground
* shielding factor for sheltering.
*
SEGSHFAC001      0.5     0.33     0.2    * VALUE FOR NORMAL ACTIVITY SELECTED BY
*                                          NRC STAFF for NUREG-1150
*
* RESUSPENSION INHALATION MODEL CONCENTRATION COEFFICIENT (/METER)
*
*   RESCON = 1.E-4 IS APPROPRIATE FOR MECHANICAL RESUSPENSION BY VEHICLES.
*   RESHAF = 2.11 DAYS CAUSES 1.E-4 TO DECAY IN ONE WEEK TO 1.E-5, THE VALUE
*   OF RESCON USED IN THE FIRST TERM OF THE LONG-TERM RESUSPENSION EQUATION
*   USED IN CHRONC.
*
SERESCON001   1.E-4     (RESUSPENSION IS TURNED ON)
*
* RESUSPENSION CONCENTRATION COEFFICIENT HALF-LIFE (SEC)
*
SERESHAF001   1.82E5    (2.11 DAYS)
*****************************************************************************
* EVACUATION ZONE DATA BLOCK, LOADED BY EVNETW, STORED IN /NETWOR/, /EOPTIO/
*
* SPECIFIC DESCRIPTION OF THE EMERGENCY RESPONSE SCENARIO BEING USED
*
EZEANAM2001  'Large Release, NRC: NO EVAC.'
*
* THE TYPE OF WEIGHTING TO BE APPLIED TO THE EMERGENCY RESPONSE SCENARIOS
* YOU MUST SUPPLY A VALUE OF 'TIME' OR 'PEOPLE'
*
EZWTNAME001  'PEOPLE'
*
* WEIGHTING FRACTION APPLICABLE TO THIS SCENARIO
*
EZWTFRAC001  1.
*
* LAST RING IN THE MOVEMENT ZONE
*
EZLASMOV001     0     (TURNS ON NO EVACUATION)
*
**********************************************************************
* SHELTER AND RELOCATION ZONE DATA BLOCK, LOADED BY INPEMR,
*                                         STORED IN /INPSRZ/, /RELOCA/
*
* TIME TO TAKE SHELTER IN THE INNER SHELTER ZONE (SECONDS FROM OALARM)
*
SRTTOSH1001      0.     (THERE IS NO INNER SHELTER ZONE)
*
* SHELTER DURATION IN THE INNER SHELTER ZONE (SECONDS FROM TAKING SHELTER)
*
SRSHELT1001      0.     (THERE IS NO INNER SHELTER ZONE)
*
* LAST RING OF THE OUTER SHELTER ZONE
*
```

```
SRLASHE2001       0      (THERE IS NO OUTER SHELTER ZONE)
*
* TIME TO TAKE SHELTER IN THE OUTER SHELTER ZONE (SECONDS FROM OALARM)
*
SRTTOSH2001       0.     (THERE IS NO OUTER SHELTER ZONE)
*
* SHELTER DURATION IN THE OUTER SHELTER ZONE (SECONDS FROM TAKING SHELTER)
*
SRSHELT2001       0.     (THERE IS NO OUTER SHELTER ZONE)
*
* DURATION OF THE EMERGENCY PHASE (SECONDS FROM PLUME ARRIVAL)
*
SRENDEMP001  604800.   (ONE WEEK)
*
* CRITICAL ORGAN FOR RELOCATION DECISIONS
*
SRCRIORG001 'EDEWBODY'
*
* HOT SPOT RELOCATION TIME (SECONDS FROM PLUME ARRIVAL)
*
SRTIMHOT001  43200.    (ONE-HALF DAY)
*
* NORMAL RELOCATION TIME (SECONDS FROM PLUME ARRIVAL)
*
SRTIMNRM001  86400.    (ONE DAY)
*
* HOT SPOT RELOCATION DOSE CRITERION THRESHOLD (SIEVERTS)
*
SRDOSHOT001  0.5    (50 REM DOSE TO WHOLE BODY IN 1 WEEK TRIGGERS RELOCATION)
*
* NORMAL RELOCATION DOSE CRITERION THRESHOLD (SIEVERTS)
*
SRDOSNRM001  0.25   (25 REM DOSE TO WHOLE BODY IN 1 WEEK TRIGGERS RELOCATION)
*******************************************************************************
* EARLY FATALITY MODEL PARAMETERS, LOADED BY INEFAT, STORED IN /EFATAL/
*
* NUMBER OF EARLY FATALITY EFFECTS
*
EFNUMEFA001   3
*
*            ORGNAM       EFFACA   EFFACB   EFFTHR
*
EFATAGRP001 'RED MARR'      3.8      5.0     1.5
EFATAGRP002 'LUNGS'        10.0      7.0     5.0
EFATAGRP003 'LOWER LI'     15.0     10.0     8.0
*******************************************************************************
* EARLY INJURY MODEL PARAMETERS, LOADED BY INEINJ, STORED IN /EINJUR/
*
* NUMBER OF EARLY INJURY EFFECTS
*
EINUMEIN001  7
*
```

```
*           EINAME              ORGNAM    EISUSC EITHRE EIFACA EIFACB
*
EINJUGRP001 'PRODROMAL VOMIT'  'STOMACH'  1.      5      2.     3.
EINJUGRP002 'DIARRHEA'         'STOMACH'  1.     1.      3.     2.5
EINJUGRP003 'PNEUMONITIS'      'LUNGS'    1.     5.     10.     7.
EINJUGRP004 'SKIN ERYTHEMA'    'SKIN'     1.     3.      6.     5.
EINJUGRP005 'TRANSEPIDERMAL'   'SKIN'     1.    10.     20.     5.
EINJUGRP006 'THYROIDITIS'      'THYROIDH' 1.    40.    240.     2.
EINJUGRP007 'HYPOTHYROIDISM'   'THYROIDH' 1.     2.     60.     1.3
*******************************************************************************
* ACUTE EXPOSURE CANCER PARAMETERS, LOADED BY INACAN STORED IN /ACANCR/.
*
* NUMBER OF ACUTE EXPOSURE CANCER EFFECTS
*
LCNUMACA001   7
*
* THRESHOLD DOSE FOR APPLYING THE DOSE DEPENDENT REDUCTION FACTOR
*
LCDDTHRE001   0.2  (LOWEST DOSE FOR WHICH DDREFA WILL BE APPLIED)
*
* DOSE THRESHOLD FOR LINEAR DOSE RESPONSE (SV)
*
LCACTHRE001   0.0  (LINEAR-QUADRATIC MODEL IS NOT BEING USED)
*
*           ACNAME      ORGNAM     ACSUSC DOSEFA DOSEFB CFRISK     CIRISK   DDREFA
*
LCANCERS001 'LEUKEMIA' 'RED MARR'  1.0    1.0    0.0    9.70E-3    9.70E-3  2.0
LCANCERS002 'BONE'     'BONE SUR'  1.0    1.0    0.0    9.00E-4    9.00E-4  2.0
LCANCERS003 'BREAST'   'BREAST'    1.0    1.0    0.0    5.40E-3    1.59E-2  1.0
LCANCERS004 'LUNG'     'LUNGS'     1.0    1.0    0.0    1.55E-2    1.73E-2  2.0
LCANCERS005 'THYROID'  'THYROIDH'  1.0    1.0    0.0    7.20E-4    7.20E-3  1.0
LCANCERS006 'GI'       'LOWER LI'  1.0    1.0    0.0    3.36E-2    5.75E-2  2.0
LCANCERS007 'OTHER'    'BLAD WAL'  1.0    1.0    0.0    2.76E-2    5.52E-2  2.0
*******************************************************************************
* RESULT 1 OPTIONS BLOCK, LOADED BY INOUT1, STORED IN /INOUT1/
* TOTAL NUMBER OF A GIVEN EFFECT (LATENT CANCER, EARLY DEATH, EARLY INJURY)
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE1NUMBER     0
*
*TYPE1OUT001    'ERL FAT/TOTAL'          1   2      (0.25 TO  0.33 MILES)
*TYPE1OUT002    'ERL FAT/TOTAL'          2   3      (0.33 TO  .4 MILES)
*TYPE1OUT003    'ERL FAT/TOTAL'          3   4      (.4 TO .5 MILES)
*TYPE1OUT004    'ERL FAT/TOTAL'          4   5      (.5 TO 1.25 MILES)
*TYPE1OUT005    'ERL FAT/TOTAL'          5   6      (1.25 TO 1.33 MILES)
*TYPE1OUT006    'ERL FAT/TOTAL'          6   7      (1.33 TO 1.4 MILES)
*TYPE1OUT007    'ERL FAT/TOTAL'          7   8      (1.4 TO 1.5 MILES)
*TYPE1OUT008    'ERL FAT/TOTAL'          8   9      (1.5 TO 2 MILES)
*TYPE1OUT009    'ERL FAT/TOTAL'          9  10      (2 TO 3 MILES)
*TYPE1OUT010    'ERL FAT/TOTAL'         10  11      (3 TO 4 MILES)
*TYPE1OUT011    'ERL FAT/TOTAL'         11  12      (4 TO 5 MILES)
*TYPE1OUT012    'ERL FAT/TOTAL'         12  13      (5 TO 8 MILES)
*TYPE1OUT013    'ERL FAT/TOTAL'         13  14      (8 TO 10 MILES)
```

```
*
*TYPE1OUT014    'CAN FAT/TOTAL'              1   3       (0.25 TO  .4 MILES)
*TYPE1OUT015    'CAN FAT/TOTAL'              3   4       (.4  TO  .5 MILES)
*TYPE1OUT016    'CAN FAT/TOTAL'              4   5       (.5 TO 1.25 MILES)
*TYPE1OUT017    'CAN FAT/TOTAL'              5   9       (1.25 TO 2 MILES)
*TYPE1OUT018    'CAN FAT/TOTAL'              9  10       (2 TO 3 MILES)
*TYPE1OUT019    'CAN FAT/TOTAL'             10  11       (3 TO 4 MILES)
*TYPE1OUT020    'CAN FAT/TOTAL'             11  12       (4 TO 5 MILES)
*TYPE1OUT021    'CAN FAT/TOTAL'             12  13       (5 TO 8 MILES)
*TYPE1OUT022    'CAN FAT/TOTAL'             13  14       (8 TO 10 MILES)
*TYPE1OUT023    'CAN FAT/TOTAL'             14  15       (10 TO 13 MILES)
*TYPE1OUT024    'CAN FAT/TOTAL'             15  17       (13 TO 20 MILES)
*TYPE1OUT025    'CAN FAT/TOTAL'             17  18       (20 TO 25 MILES)
*TYPE1OUT026    'CAN FAT/TOTAL'             18  19       (25 TO 30 MILES)
*TYPE1OUT027    'CAN FAT/TOTAL'             19  20       (30 TO 40 MILES)
*TYPE1OUT028    'CAN FAT/TOTAL'             20  21       (40 TO 50 MILES)
*TYPE1OUT029    'CAN FAT/TOTAL'             21  23       (50 TO 100 MILES)
*TYPE1OUT030    'CAN FAT/TOTAL'             23  25       (100 TO 200 MILES)
*TYPE1OUT031    'CAN FAT/TOTAL'             25  26       (200 TO 350 MILES)
*TYPE1OUT032    'CAN FAT/TOTAL'             26  27       (350 TO 500 MILES)
*
*TYPE1OUT009    'CAN FAT/TOTAL'                  1  20
*TYPE1OUT010    'CAN FAT/LUNG'                   1  20
*TYPE1OUT011    'CAN FAT/THYROID'                1  20
*TYPE1OUT012    'CAN FAT/BREAST'                 1  20
*TYPE1OUT013    'CAN FAT/GI'                     1  20
*TYPE1OUT014    'CAN FAT/LEUKEMIA'               1  20
*TYPE1OUT015    'CAN FAT/BONE'                   1  20
*TYPE1OUT016    'CAN FAT/OTHER'                  1  20
*TYPE1OUT017    'CAN INJ/TOTAL'                  1  20
*
*
*TYPE1OUT018    'ERL FAT/TOTAL'                  1  13   (0 TO 10 MILES)
*TYPE1OUT019    'ERL INJ/PRODROMAL VOMIT'        1  13
*TYPE1OUT020    'ERL INJ/DIARRHEA'               1  13
*TYPE1OUT021    'ERL INJ/PNEUMONITIS'            1  13
*TYPE1OUT022    'ERL INJ/THYROIDITIS'            1  13
*TYPE1OUT023    'ERL INJ/HYPOTHYROIDISM'         1  13
*TYPE1OUT024    'ERL INJ/SKIN ERYTHEMA'          1  13
*TYPE1OUT025    'ERL INJ/TRANSEPIDERMAL'         1  13
*TYPE1OUT026    'CAN FAT/TOTAL'                  1  13
*****************************************************************************
* RESULT 2 OPTIONS BLOCK, LOADED BY INOUT2, STORED IN /INOUT2/
* FURTHEST DISTANCE AT WHICH A GIVEN RISK OF EARLY DEATH IS EXCEEDED.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE2NUMBER  0
*
*           FATALITY RISK THRESHOLD
*TYPE2OUT001  0.
*****************************************************************************
```

```
* RESULT 3 OPTIONS BLOCK, LOADED BY INOUT3, STORED IN /INOUT3/
* NUMBER OF PEOPLE WHOSE DOSE TO A GIVEN ORGAN EXCEEDS A GIVEN THRESHOLD.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE3NUMBER  0
*
*               ORGAN NAME   DOSE THRESHOLD (SV)   DOSE FLAG
*
*TYPE3OUT001    'RED MARR'       1.5                  ACUTE
*TYPE3OUT002    'LUNGS'          5.0                  ACUTE
*TYPE3OUT003    'EDEWBODY'       0.05                LIFETIME
******************************************************************************
* RESULT 4 OPTIONS BLOCK, LOADED BY INOUT4, STORED IN /INOUT4/
* 360 DEGREE AVERAGE RISK OF A GIVEN EFFECT AT A GIVEN DISTANCE.
*
* POSSIBLE TYPES OF EFFECTS ARE:
*
*   'ERL FAT/TOTAL'
*   'ERL INJ/INJURY NAME'
*   'CAN FAT/CANCER NAME'
*   'CAN FAT/TOTAL'
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE4NUMBER  0
* TYPE4NUMBER  5
*
*            RADIAL INDEX   TYPE OF EFFECT
*
*TYPE4OUT001       1         'ERL FAT/TOTAL'
*TYPE4OUT002       2         'ERL FAT/TOTAL'
*TYPE4OUT003       3         'ERL FAT/TOTAL'
*TYPE4OUT004       4         'ERL FAT/TOTAL'
*TYPE4OUT005       5         'ERL FAT/TOTAL'
******************************************************************************
* RESULT 5 OPTIONS BLOCK, LOADED BY INOUT5, STORED IN /INOUT5/
*
* TOTAL POPULATION DOSE TO A GIVEN ORGAN BETWEEN TWO DISTANCES.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE5NUMBER     0
*
*             ORGAN        I1DIS5 I2DIS5
*
*TYPE5OUT001 'EDEWBODY'       1   5      (0 TO  1.25 MILES)
*TYPE5OUT002 'EDEWBODY'       1  12      (0 TO  5  MILES)
*TYPE5OUT003 'EDEWBODY'       1  14      (0 TO 10  MILES)
*TYPE5OUT004 'EDEWBODY'       1  27      (0 TO 500 MILES)
*
*TYPE5OUT001 'EDEWBODY'     1         13          (0-10 MILES)
*TYPE5OUT002 'EDEWBODY'     1         20          (0-50 MILES)
*TYPE5OUT003 'EDEWBODY'     1         20          (0-50 MILES)
```

```
*******************************************************************************
* RESULT 6 OPTIONS BLOCK, LOADED BY INOUT6, STORED IN /INOUT6/
*
* CENTERLINE DOSE TO AN ORGAN VS DIST BY PATHWAY, PATHWAY NAMES ARE AS FOLLOWS:
TYPE6NUMBER     0
TYPE7NUMBER     0
*
* RESULT 8 OPTIONS BLOCK, LOADED BY INOUT8, STORED IN /INOUT8/
*
* POPULATION WEIGHTED FATALITY RISK BETWEEN 2 DISTANCES
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE8NUMBER    11
*
*                 NAME        I1DIS8  I2DIS8
*
TYPE8OUT001    'CAN FAT/TOTAL'          2   3       (0.25 TO  .4 MILES)
TYPE8OUT002    'CAN FAT/TOTAL'          4   4       (.4  TO  .5 MILES)
TYPE8OUT003    'CAN FAT/TOTAL'          5   5       (.5 TO 1.25 MILES)
TYPE8OUT004    'CAN FAT/TOTAL'          6  12       (1.25 TO 5 MILES)
TYPE8OUT005    'CAN FAT/TOTAL'         13  15       (5 TO 13 MILES)
TYPE8OUT006    'CAN FAT/TOTAL'         16  20       (13 TO 40 MILES)
TYPE8OUT007    'CAN FAT/TOTAL'         21  21       (40 TO 50 MILES)
TYPE8OUT008    'CAN FAT/TOTAL'         22  23       (50 TO 100 MILES)
TYPE8OUT009    'CAN FAT/TOTAL'         24  25       (100 TO 200 MILES)
TYPE8OUT010    'CAN FAT/TOTAL'         26  26       (200 TO 350 MILES)
TYPE8OUT011    'CAN FAT/TOTAL'         27  27       (350 TO 500 MILES)
```

APPENDIX D - CHRONC

```
* Large Release (LR) CHRONIC, based on the SURRY input file, LN, 07.19.91
*
* GENERAL DESCRIPTIVE TITLE DESCRIBING THIS "CHRONC" INPUT FILE
*
CHCHNAME001   ' Large Release, Base Case'
*******************************************************************************
* EMERGENCY RESPONSE COST DATA BLOCK
*
* DAILY COST FOR A PERSON WHO IS EVACUATED (DOLLARS/PERSON-DAY)
*
CHEVACST001  27.00   (INCLUDES FOOD AND HOUSING COSTS BUT NOT LOST INCOME)
*
* DAILY COST FOR A PERSON WHO IS RELOCATED (DOLLARS/PERSON-DAY)
*
CHRELCST001  27.00   (INCLUDES FOOD AND HOUSING COSTS BUT NOT LOST INCOME)
*******************************************************************************
* LONG TERM PROTECTIVE ACTION DATA BLOCK
*
* END OF THE INTERMEDIATE PHASE PERIOD (SECONDS FROM ACCIDENT INITIATION)
*
CHTMIPND001  3.1536E7   LN 07.19.91: one year
*                       Task 3, Statement of work, May 30, 1991
*
* LONG-TERM PHASE DOSE PROJECTION PERIOD, THE DURATION OF THE EXPOSURE
* PERIOD OVER WHICH THE LONG-TERM DOSE CRITERION IS EVALUATED (SECONDS)
*
CHTMPACT001 9.4608E8 LN 07.19.91: accumulated dose period of 30 years
*                    Task 3, Statement of work, May 30, 1991
*
* DOSE CRITERION FOR INTERMEDIATE PHASE RELOCATION (SV)
*
CHDSCRTI001   0.02   LN 07.19.91: 2 rem, accumulated dose over one year
*
* DOSE CRITERION FOR LONG-TERM PHASE RELOCATION (SV)
*
CHDSCRLT001 0.165    LN 07.19.91: accumulated dose over 30 years;
*                    0.02 Sv in the first year plus 0.005 over 29 years
*
* CRITICAL ORGAN NAME FOR LONG-TERM ACTIONS
*
CHCRTOCR001 'EDEWBODY'
*******************************************************************************
* DECONTAMINATION PLAN DATA BLOCK
*
* NUMBER OF LEVELS OF DECONTAMINATION
*
CHLVLDEC001  2
*
* DECONTAMINATION TIMES CORRESPONDING TO THE LVLDEC LEVELS OF DECONTAMINATION
*  (SECONDS)
```

```
CHTIMDEC001   5.184E6  1.0368E7    (60, 120 DAYS)
*
* DOSE REDUCTION FACTORS CORRESPONDING TO THE LVLDEC LEVELS OF DECONTAMINATION
*
CHDSRFCT001   3.       15.
*
* COST OF FARM DECONTAMINATION PER FARMLAND UNIT AREA (DOLLARS/HECTARE)
* FOR THE VARIOUS LEVELS OF DECONTAMINATION
*
CHCDFRM0001   562.5    1250.
* COST OF NONFARM DECONTAMINATION PER RESIDENT PERSON (DOLLARS/PERSON)
* FOR THE VARIOUS LEVELS OF DECONTAMINATION
*
CHCDNFRM001   3000.    8000.
*
* FRACTION OF FARMLAND DECONTAMINATION COST DUE TO LABOR
* FOR THE VARIOUS DECONTAMINATION LEVELS
*
CHFRFDL0001  .3       .35
*
* FRACTION OF NON-FARM DECONTAMINATION COST DUE TO LABOR
* FOR THE VARIOUS DECONTAMINATION LEVELS
*
CHFRNFDL001  .7       .5
*
* FRACTION OF TIME WORKERS IN FARM AREAS SPEND IN CONTAMINATED AREAS
* FOR THE VARIOUS DECONTAMINATION LEVELS
*
CHTFWKF0001  .10      .33
*
* FRACTION OF TIME WORKERS IN NON-FARM AREAS SPEND IN CONTAMINATED AREAS
* FOR THE VARIOUS DECONTAMINATION LEVELS
*
CHTFWKNF001  .33      .33
*
* AVERAGE COST OF DECONTAMINATION LABOR (DOLLARS/MAN-YEAR)
*
CHDLBCST001   35000.
******************************************************************************
* INTERDICTION COST DATA BLOCK
*
* DEPRECIATION (DETERIORATION) RATE DURING INTERDICTION PERIOD (PER YEAR)
*
CHDPRATE001    .20    (VALUE OBTAINED FROM WASH-1400, APPENDIX 6)
*
* INVESTMENT INCOME RETURN (DISCOUNT RATE) DURING INTERDICTION PERIOD (PER YEAR)
* THIS VALUE SHOULD BE DERIVED AS A REAL RETURN RATE ADJUSTED FOR INFLATION
*
CHDSRATE001    .12    (VALUE OBTAINED FROM WASH-1400, APPENDIX 6)
*
* POPULATION RELOCATION COST (DOLLARS/PERSON):
* ALTERNATIVE HOUSING, MOVING COSTS, AND LOST INCOME FOR PEOPLE IN
* AREAS WHICH REQUIRE DECONTAMINATION, INTERDICTION, OR CONDEMNATION
*
CHPOPCST001   5000.
```

```
********************************************************************************
* GROUNDSHINE WEATHERING DEFINITION DATA BLOCK
*
* NUMBER OF TERMS IN THE GROUNDSHINE WEATHERING RELATIONSHIP (EITHER 1 OR 2)
*
CHNGWTRM001   2
*
* GROUNDSHINE WEATHERING COEFFICIENTS
*
CHGWCOEF001   0.5    0.5            (JON HELTON)
*
* HALF LIVES CORRESPONDING TO THE GROUNDSHINE WEATHERING COEFFICIENTS (S)
*
CHTGWHLF001   1.6E7  2.8E9          (JON HELTON)
********************************************************************************
* RESUSPENSION WEATHERING DEFINITION DATA BLOCK
*
* NUMBER OF TERMS IN THE RESUSPENSION WEATHERING RELATIONSHIP
*
CHNRWTRM001    3
*
* RESUSPENSION CONCENTRATION COEFFICIENTS    (/ METER)
*  RELATIONSHIP BETWEEN GROUND CONCENTRATION AND INSTANTANEOUS AIR CONC.
*
CHRWCOEF001  1.0E-5   1.0E-7   1.0E-9  (VALUES HERE SELECTED BY JON HELTON)
*
* HALF-LIVES CORRESPONDING TO THE RESUSPENSION CONCENTRATION COEFFICIENTS (S)
*
CHTRWHLF001  1.6E7    1.6E8    1.6E9   (6 MONTHS, 5 YEARS, 50 YEARS)
********************************************************************************
* SITE REGION DESCRIPTION DATA BLOCK
*
* FRACTION OF AREA THAT IS LAND IN THE REGION
*
CHFRACLD001   0.95   (ROUGH GUESS VALUE, SITE FILE OVERRIDES THIS VALUE)
*
* FRACTION OF LAND DEVOTED TO FARMING IN THE REGION
*
CHFRCFRM001   0.382  (VIRGINIA STATE VALUE, SITE FILE OVERRIDES THIS VALUE)
*
* AVERAGE VALUE OF ANNUAL FARM PRODUCTION IN THE REGION (DOLLARS/HECTARE)
*  (CASH RECEIPTS FROM FARMING PLUS VALUE OF HOME CONSUMPTION)/(LAND IN FARMS)
*
CHFRMPRD001   371.0  (VIRGINIA STATE VALUE, SITE FILE OVERRIDES THIS VALUE)
*
* FRACTION OF FARM PRODUCTION RESULTING FROM DAIRY PRODUCTION IN THE REGION
*  (VALUE OF MILK PRODUCED)/(CASH RECEIPTS FROM FARMING PLUS HOME CONSUMPTION)
*
CHDPFRCT001   0.198  (VIRGINIA STATE VALUE, SITE FILE OVERRIDES THIS VALUE)
*
* VALUE OF FARM WEALTH (DOLLARS/HECTARE)
*  (AVERAGE VALUE PER HECTARE OF FARM LAND AND BUILDINGS TO 100 MILES)
*
CHVALWF0001  2094.  LN, 07.19.91: BNL to NRC Memo of June 17, 1991.
```

```
*
* FRACTION OF FARM WEALTH IN IMPROVEMENTS FOR THE REGION
*
CHFRFIM0001   0.25  *  SURRY
*
* NON-FARM WEALTH, PROPERTY AND IMPROVEMENTS FOR THE REGION (DOLLARS/PERSON)
*  THE VALUE OF ALL RESIDENTIAL, BUSINESS, AND PUBLIC ASSETS WHICH WOULD BE
*  LOST IN THE EVENT OF PERMANENT INTERDICTION (CONDEMNATION) OF THE AREA
*
CHVALWNF001 73570.  LN, 07.19.91: BNL to NRC Memo of June 17, 1991.
*
* FRACTION OF NON-FARM WEALTH IN IMPROVEMENTS FOR THE REGION
*
CHFRNFIM001   0.8
******************************************************************************
* SPECIAL OPTIONS DATA BLOCK
*
* DETAILED PRINT OPTION CONTROL SWITCHES, LOOK AT THE CODE BEFORE TURNING ON!!
*         (KCEPNT, KDFPNT, KDTPNT, KGCPNT, KLTPNT, KWTPNT, KSWRSK, KSWDSC)
*
CHKSWTCH001   0       0       0       0       0       0       0       0
******************************************************************************
* NUMBER OF DEFINED CROPS IN THE CHRONC FOOD INGESTION MODEL
*
CHNFICRP001    7     (UP TO 10 ALLOWED)
*
* NOTE TO USER: THE CODE MAKES SPECIAL TREATMENT OF CROP NAMES BEGINNING
*  WITH 'PASTURE' DUE TO THE CONTINOUS NATURE OF THE HARVESTING PROCESS.
*  IF THE USER WISHES TO DEFINE A NEW CROP CATEGORY FOR RANGELAND PASTURE,
*  IT SHOULD BE CALLED 'PASTURE-RANGE' OR 'PASTURE-DRY'.
*
*                                FRACTION OF CROP CONSUMED BY
*
*                                        DAIRY    MEAT
*            CROP NAME            MAN   ANIMALS  ANIMALS
*
*            NAMCRP              FRCTCH  FRCTCM   FRCTCB
CHCRPTBL001 'PASTURE             ' 0.0    0.1      0.9
CHCRPTBL002 'STORED FORAGE       ' 0.0    0.13     0.87
CHCRPTBL003 'GRAINS              ' 0.35   0.040    0.61
CHCRPTBL004 'GRN LEAFY VEGETABLES' 1.0    0.0      0.0
CHCRPTBL005 'OTHER FOOD CROPS    ' 1.0    0.0      0.0
CHCRPTBL006 'LEGUMES AND SEEDS   ' 0.24   0.046    0.714
CHCRPTBL007 'ROOTS AND TUBERS    ' 1.0    0.0      0.0
******************************************************************************
* WATER PATHWAY NUCLIDE DEFINITIONS FOR CHRONC
*
* NUMBER OF NUCLIDES IN THE WATER INGESTION PATHWAY MODEL
*
CHNUMWPI001    4
*
* TABLE OF NUCLIDE DEFINITIONS IN THE WATER INGESTION PATHWAY MODEL
*  WATER PATHWAY NUCLIDES MUST BE A SUBSET OF THE INGESTION MODEL NUCLIDES
*
```

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* IF A SITE DATA FILE IS DEFINED, THE DATA DEFINING THE WATERSHED INGESTION
*  FACTOR IS SUPERSEDED BY THE CORRESPONDING DATA IN THE SITE DATA FILE
*
*       WINGF VALUES BY DRAINAGE SYSTEM
*  NUCLIDE      SR-89   SR-90   CS-134  CS-137
*  RIVER        5.0E-6  5.0E-6  5.0E-6  5.0E-6
*  GREAT LAKE   2.0E-7  2.0E-7  2.0E-6  4.0E-6
*  OCEAN        0.0     0.0     0.0     0.0
*
*                         INITIAL     ANNUAL    INGESTION FACTOR
*             WATER       WASHOFF     WASHOFF    ((BQ INGESTED)/
*             NUCLIDE     FRACTION    RATE        (BQ IN WATER))
*
*             NAMWPI      WSHFRI      WSHRTA          WINGF
CHWTRISO001   SR-89        0.01       0.004           5.0E-6
CHWTRISO002   SR-90        0.01       0.004           5.0E-6
CHWTRISO003   CS-134       0.005      0.001           5.0E-6
CHWTRISO004   CS-137       0.005      0.001           5.0E-6
******************************************************************************
* FOOD PATHWAY DEFINITION DATA
*
* NUMBER OF NUCLIDES IN THE CHRONC FOOD INGESTION MODEL
*
CHNFIISO001  6  (UP TO 10 ALLOWED, BEWARE THAT DAUGHTER BUILDUP IS NOT TREATED)
*
* TABLE OF NUCLIDE DEFINITIONS IN THE CHRONC INGESTION PATHWAY MODEL
*
* NUCLIDES THAT WERE DEFINED IN THE WATER PATHWAY DATA ABOVE MUST BE
*  A SUBSET OF THE CHRONC INGESTION FOOD PATHWAY NUCLIDES.  THE WATER
*  PATHWAY NUCLIDES MUST BE LISTED FIRST IN THIS DATA BLOCK AND IN THE
*  SAME ORDER AS THEY WERE LISTED IN THE WATER PATHWAY DATA BLOCK
*
*                                              TRANSFER FACTORS
*                       RETENTION FACTORS    [(BQ TRANSFERED)/
*           INGESTION  PROCESSING AND DECAY    (BQ INGESTED)]
*            NUCLIDE    MILK/MAN  MEAT/MAN       MILK     MEAT
*
*            NAMIPI     DCYPMH     DCYPBH        TFMLK    TFBF
CHISODEF001  SR-89       0.66       0.77         0.022    0.00022
CHISODEF002  SR-90       1.0        1.0          0.022    0.00022
CHISODEF003  CS-134      1.0        1.0          0.11     0.023
CHISODEF004  CS-137      1.0        1.0          0.11     0.024
CHISODEF005  I-131       0.28       0.18         0.13     0.0024
CHISODEF006  I-133       0.002      0.0          0.062    0.0011
******************************************************************************
* TRANSFER FACTOR FROM SOIL TO PLANT BY ROOT-UPTAKE (AND BY SOIL INGESTION FOR
* GRAZING ON PASTURE) INTEGRATED OVER ALL TIME [(BQ TRANSFERED)/(BQ DEPOSITED)]
*
*                                          GREEN   OTHER   LEGUMES  ROOTS
*                           STORED         LEAFY   FOOD    AND      AND
*           NUCLIDE PASTURE FORAGE GRAINS  VEG     CROPS   SEEDS    TUBERS
*
*           NAMISO  TCROOT  TCROOT TCROOT  TCROOT  TCROOT  TCROOT   TCROOT
CHTCROOT001 SR-89   4.1E-4  1.3E-3 4.3E-5  1.7E-4  8.6E-6  3.7E-4   1.1E-4
CHTCROOT002 SR-90   2.6E-2  9.0E-2 3.3E-3  1.3E-2  6.6E-4  2.8E-2   8.4E-3
```

```
CHTCROOT003  CS-134    1.3E-3   7.1E-4   3.5E-5   1.4E-5   1.1E-4    9.3E-5   5.6E-5
CHTCROOT004  CS-137    6.9E-3   1.5E-3   7.6E-5   3.0E-5   2.3E-4    2.0E-4   1.2E-4
CHTCROOT005  I-131     1.6E-4     0.0      0.0      0.0      0.0       0.0      0.0
CHTCROOT006  I-133     1.7E-6     0.0      0.0      0.0      0.0       0.0      0.0
*******************************************************************************
*  RADIOACTIVE DECAY RETENTION FACTORS (I.E., 1 - F WHERE F = FRACTION OF
*  RADIOACTIVITY LOST BY DECAY) FOR NUCLIDES IN CROPS FROM TIME OF HARVEST
*  TO TIME OF CONSUMPTION BY HUMANS (FRACTION RETAINED)
*
*                                             GREEN    OTHER    LEGUMES  ROOTS
*                                STORED       LEAFY    FOOD     AND      AND
*            NUCLIDE  PASTURE   FORAGE   GRAINS   VEG      CROPS    SEEDS    TUBERS
*
*            NAMISO   DCYPCH    DCYPCH   DCYPCH   DCYPCH   DCYPCH   DCYPCH   DCYPCH
CHDCYPCH001  SR-89       0.0      0.0     0.18     0.67     0.21     0.18      0.18
CHDCYPCH002  SR-90       0.0      0.0     0.99     1.0      0.99     0.99      0.99
CHDCYPCH003  CS-134      0.0      0.0     0.84     0.96     0.85     0.84      0.84
CHDCYPCH004  CS-137      0.0      0.0     0.99     1.0      0.99     0.99      0.99
CHDCYPCH005  I-131      0.0      0.0     0.0099   0.21     0.024    0.0099    0.0099
CHDCYPCH006  I-133       0.0      0.0     0.0      0.0      0.0      0.0       0.0
*******************************************************************************
*  RETENTION FACTORS FOR NUCLIDES IN CROPS FROM TIME OF HARVEST TO TIME OF
*  CONSUMPTION BY MILK-PRODUCING ANIMALS (FRACTION RETAINED).  FACTOR REFLECTS
*  LOSSES DUE TO RADIOACTIVE DECAY.
*
*                                             GREEN    OTHER    LEGUMES  ROOTS
*                                STORED       LEAFY    FOOD     AND      AND
*            NUCLIDE  PASTURE   FORAGE   GRAINS   VEG      CROPS    SEEDS    TUBERS
*
*            NAMISO   DCYPCM    DCYPCM   DCYPCM   DCYPCM   DCYPCM   DCYPCM   DCYPCM
CHDCYPCM001  SR-89       1.0     0.37     0.20      0.0      0.0     0.20       0.0
CHDCYPCM002  SR-90       1.0     0.99     0.99      0.0      0.0     0.99       0.0
CHDCYPCM003  CS-134      1.0     0.92     0.85      0.0      0.0     0.85       0.0
CHDCYPCM004  CS-137      1.0     0.99     0.99      0.0      0.0     0.99       0.0
CHDCYPCM005  I-131       1.0     0.063    0.032     0.0      0.0     0.032      0.0
CHDCYPCM006  I-133       1.0     0.0068   0.0034    0.0      0.0     0.0034     0.0
*******************************************************************************
*  RETENTION FACTORS FOR NUCLIDES IN CROPS FROM TIME OF HARVEST TO TIME OF
*  CONSUMPTION BY MEAT-PRODUCING ANIMALS (FRACTION RETAINED).  FACTOR REFLECTS
*  LOSSES DUE TO RADIOACTIVE DECAY.
*
*                                             GREEN    OTHER    LEGUMES  ROOTS
*                                STORED       LEAFY    FOOD     AND      AND
*            NUCLIDE  PASTURE   FORAGE   GRAINS   VEG      CROPS    SEEDS    TUBERS
*
*            NAMISO   DCYPCB    DCYPCB   DCYPCB   DCYPCB   DCYPCB   DCYPCB   DCYPCB
CHDCYPCB001  SR-89       1.0     0.37     0.20      0.0      0.0     0.20       0.0
CHDCYPCB002  SR-90       1.0     0.99     0.99      0.0      0.0     0.99       0.0
CHDCYPCB003  CS-134      1.0     0.92     0.85      0.0      0.0     0.85       0.0
CHDCYPCB004  CS-137      1.0     0.99     0.99      0.0      0.0     0.99       0.0
CHDCYPCB005  I-131       1.0     0.063    0.032     0.0      0.0     0.032      0.0
CHDCYPCB006  I-133       1.0     0.0068   0.0034    0.0      0.0     0.0034     0.0
*******************************************************************************
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*   CROP PROCESSING AND PREPARATION RETENTION FACTORS FOR NUCLIDES IN FOOD
*   CROPS CONSUMED BY HUMANS (FRACTION RETAINED).  FACTORS REFLECT LOSS OF
*   NUCLIDES FROM FOODS DUE TO PROCESSING (E.G., WASHING OF FRUIT, PEELING
*   OF POTATOES, LOSSES DURING CANNING) AND FOOD PREPARATION (COOKING) FROM
*   THE TIME OF PROCESSING OF THE HARVESTED CROP TO THE TIME OF CONSUMPTION
*   BY HUMANS.  FACTORS DO NOT REFLECT LOSSES DUE TO RADIOACTIVE DECAY.
*
*                                                  GREEN    OTHER    LEGUMES   ROOTS
*                                 STORED           LEAFY    FOOD     AND       AND
*           NUCLIDE    PASTURE    FORAGE   GRAINS  VEG      CROPS    SEEDS     TUBERS
*
*           NAMISO     FPLSCH     FPLSCH   FPLSCH  FPLSCH   FPLSCH   FPLSCH    FPLSCH
CHFPLSCH001  SR-89        0.0        0.0     0.25     0.5     0.71      0.8       0.8
CHFPLSCH002  SR-90        0.0        0.0     0.25     0.5     0.71      0.8       0.8
CHFPLSCH003  CS-134       0.0        0.0     0.25     0.5     0.71      0.8       0.8
CHFPLSCH004  CS-137       0.0        0.0     0.25     0.5     0.71      0.8       0.8
CHFPLSCH005  I-131        0.0        0.0     0.33     0.5     0.71      0.8       0.8
CHFPLSCH006  I-133        0.0        0.0     0.33     0.5     0.71      0.8       0.8
*****************************************************************************
* DEFINE THE DIRECT DEPOSITION TO CROPS TRANSFER FUNCTION
*
* NUMBER OF TERMS IN THE DIRECT DEPOSITION TO CROPS TRANSFER FUNCTION
*
CHNTRTRM001    2
*
* LOSSES DUE TO WEATHERING FROM PLANT SURFACES AND DURING TRANSLOCATION
* FROM PLANT SURFACES TO INTERIOR EDIBLE PORTIONS OF PLANTS ARE MODELLED
* USING THE FOLLOWING EQUATION:
*
* FRACTION RETAINED = CTCOEF1*EXP(-LN2/CTHALF1) + CTCOEF2*EXP(-LN2/CTHALF2)
*
* FOR PASTURE, STORED FORAGE, GREEN LEAFY VEGETABLES, AND OTHER FOOD CROPS,
* THIS EQUATION IS USED AS A TWO TERM WEATHERING EQUATION.  FOR GRAINS,
* LEGUMES AND SEEDS, AND ROOTS AND TUBERS WHERE RADIOACTIVITY IS CONSUMED
* ONLY IF TRANSLOCATED TO EDIBLE PORTIONS OF THE PLANT, THIS EQUATION IS
* REDUCED TO A TRANSLOCATION TRANSFER FACTOR BY SETTING CTCOEF2 TO ZERO,
* CTHALF2 TO ONE SECOND, AND CTHALF1 TO ABOUT ONE MILLION YEARS (1E13
* SECONDS).  WHEN USED TO MODEL TRANSLOCATION, THE VALUE OF THE TRANSLOCATION
* TRANSFER FACTOR IS DEVELOPED FROM FALLOUT DATA AND IS INPUT AS THE VALUE
* OF CTCOEF1.
*
* TWO TIME PERIODS ARE USED FOR WEATHERING, THE FIRST IS 14 DAYS LONG (1.21E6
* SECONDS) AND THE SECOND IS 50 DAYS LONG (4.32E6 SECONDS).
*
* DIRECT DEPOSITION TRANSFER COEFFICIENTS BY CHRONC INGESTION MODEL NUCLIDE
*   ((BQ TRANSFERED)/(BQ DEPOSITED))
*
*                                                  GREEN    OTHER    LEGUMES   ROOTS
*                                 STORED           LEAFY    FOOD     AND       AND
*  TERM 1   NUCLIDE    PASTURE    FORAGE   GRAINS  VEG      CROPS    SEEDS     TUBERS
CHCTCOEF101  SR-89        0.3        0.2     0.01    0.24      0.2     0.005   0.0006
CHCTCOEF102  SR-90        0.3        0.2     0.01    0.24      0.2     0.005   0.0006
CHCTCOEF103  CS-134       0.3        0.2     0.05    0.24      0.2     0.01    0.025
CHCTCOEF104  CS-137       0.3        0.2     0.05    0.24      0.2     0.01    0.025
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CHCTCOEF105  I-131      0.3      0.2    0.0    0.24     0.2     0.0     0.0
CHCTCOEF106  I-133      0.3      0.2    0.0    0.24     0.2     0.0     0.0
*  TERM 2
CHCTCOEF201  SR-89      0.076    0.05   0.0    0.06     0.05    0.0     0.0
CHCTCOEF202  SR-90      0.076    0.05   0.0    0.06     0.05    0.0     0.0
CHCTCOEF203  CS-134     0.076    0.05   0.0    0.06     0.05    0.0     0.0
CHCTCOEF204  CS-137     0.076    0.05   0.0    0.06     0.05    0.0     0.0
CHCTCOEF205  I-131      0.076    0.05   0.0    0.06     0.05    0.0     0.0
CHCTCOEF206  I-133      0.076    0.05   0.0    0.06     0.05    0.0     0.0
*
*  CROP TRANSFER HALF-LIVES BY CHRONC INGESTION MODEL NUCLIDE (SECONDS)
*
*                                              GREEN   OTHER   LEGUMES  ROOTS
*                               STORED         LEAFY   FOOD    AND      AND
*  TERM 1     NUCLIDE  PASTURE  FORAGE  GRAINS VEG     CROPS   SEEDS    TUBERS
CHCTHALF101  SR-89    1.21E6   1.21E6    1E13  1.21E6  1.21E6     1E13    1E13
CHCTHALF102  SR-90    1.21E6   1.21E6    1E13  1.21E6  1.21E6     1E13    1E13
CHCTHALF103  CS-134   1.21E6   1.21E6    1E13  1.21E6  1.21E6     1E13    1E13
CHCTHALF104  CS-137   1.21E6   1.21E6    1E13  1.21E6  1.21E6     1E13    1E13
CHCTHALF105  I-131    1.21E6   1.21E6     1.0  1.21E6  1.21E6      1.0     1.0
CHCTHALF106  I-133    1.21E6   1.21E6     1.0  1.21E6  1.21E6      1.0     1.0
*  TERM2
CHCTHALF201  SR-89    4.32E6   4.32E6     1.0  4.32E6  4.32E6      1.0     1.0
CHCTHALF202  SR-90    4.32E6   4.32E6     1.0  4.32E6  4.32E6      1.0     1.0
CHCTHALF203  CS-134   4.32E6   4.32E6     1.0  4.32E6  4.32E6      1.0     1.0
CHCTHALF204  CS-137   4.32E6   4.32E6     1.0  4.32E6  4.32E6      1.0     1.0
CHCTHALF205  I-131    4.32E6   4.32E6     1.0  4.32E6  4.32E6      1.0     1.0
CHCTHALF206  I-133    4.32E6   4.32E6     1.0  4.32E6  4.32E6      1.0     1.0
******************************************************************************
* TABLE OF CROP DATA (GROWING SEASON AND FARMLAND SHARE) IN THE REGION.
*
* IF A SITE DATA FILE IS BEING USED (AS SPECIFIED ON THE EARLY USER INPUT FILE),
* THEN DATA FROM THE SITE FILE (AND NOT THE DATA BELOW) IS USED FOR THE
* CALCULATION OF DOSES AND COSTS FROM THE AGRICULTURE MODEL AND THE NUMBERS
* BELOW ARE NOT UTILIZED IN THE CALCULATIONS.
*
* IF A SITE DATA FILE IS NOT BEING USED, THE DATA BELOW IS USED IN ITS STEAD.
*
* IN ALL CASES, THE USER MUST SUPPLY VALID VALUES FOR THE PARAMETERS BELOW.
*
*                                 GROWING
*                              SEASON (DAYS) FARMLAND
*             CROP NAME         START  END    SHARE
*
*             NAMCRP           TGSBEG  TGSEND  FRCTFL
CHCRPRGN001 'PASTURE              '  90.   270.   0.41
CHCRPRGN002 'STORED FORAGE        ' 150.   240.   0.13
CHCRPRGN003 'GRAINS               ' 150.   240.   0.21
CHCRPRGN004 'GRN LEAFY VEGETABLES' 150.   240.   0.002
CHCRPRGN005 'OTHER FOOD CROPS     ' 150.   240.   0.004
CHCRPRGN006 'LEGUMES AND SEEDS    ' 150.   240.   0.15
CHCRPRGN007 'ROOTS AND TUBERS     ' 150.   240.   0.003
******************************************************************************
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```
* FLAG DETERMINING WHETHER OR NOT THE FOOD ACTIONS ARE COUPLED
*
CHCOUPLD001 .FALSE.  (GROWING-SEASON ACTIONS INDEPENDENT OF LONG-TERM ACTIONS)
*
* PROTECTIVE ACTION GUIDES FOR THE GROWING-SEASON PATHWAY FOR BOTH MILK
* AND NON-MILK CROPS, DEFINED SEPARATELY AS PSCMLK AND PSCOTH.
*
* THESE VALUES ARE CALCULATED OUTSIDE OF THE CODE BY ASSUMING THAT THE
* ACCIDENT OCCURED IN THE MIDDLE OF THE GROWING SEASON.  THESE VALUES
* ARE THE GROUND CONCENTRATION OF EACH NUCLIDE (ASSUMING A SINGLE NUCLIDE
* RELEASE) WHICH WOULD RESULT IN A MAXIMALLY EXPOSED INDIVIDUAL RECEIVING
* A DOSE NOT EXCEEDING 0.05 SIEVERT EFFECTIVE-WHOLE-BODY-DOSE-EQUIVALENT
* OR 0.15 SIEVERT TO THE THYROID. THE UNITS ARE (BECQUERELS / SQUARE-METER).
*
*                           MILK AND    OTHER CROPS
*            NUCLIDE        PRODUCTS    AND PRODUCTS
*
*              NAMIPI        PSCMLK       PSCOTH
CHPAGMCP001    SR-89         2.2E07       2.2E07
CHPAGMCP002    SR-90         2.4E05       2.4E05
CHPAGMCP003    CS-134        2.2E05       2.2E05
CHPAGMCP004    CS-137        2.7E05       2.7E05
CHPAGMCP005    I-131         1.3E06       8.0E06
CHPAGMCP006    I-133         1.1E10       1.0E20
*******************************************************************************
* PROTECTIVE ACTION GUIDES FOR LONG-TERM AGRICULTURAL PRODUCTION, GCMAXR, AND
* THE RATE AT WHICH EACH RADIONUCLIDE BECOMES UNAVAILABLE FOR UPTAKE, QROOT.
*
* GCMAXR VALUES ARE CALCULATED OUTSIDE OF THE CODE BY ASSUMING THAT THE ACCIDENT
* IS EQUALLY LIKELY THROUGHOUT THE YEAR.  THESE VALUES ARE THE GROUND
* CONCENTRATION OF EACH NUCLIDE (ASSUMING A SINGLE NUCLIDE RELEASE) WHICH
* WOULD RESULT IN A MAXIMALLY EXPOSED INDIVIDUAL RECEIVING A DOSE COMMITMENT
* NO GREATER THAN 0.005 SIEVERT EFFECTIVE-WHOLE-BODY-DOSE-EQUIVALENT OR
* 0.015 SIEVERT TO THE THYROID AS A RESULT OF AN EXPOSURE INTEGRATED
* FROM T=0 TO T=INFINITY.  THE DECISION TO CALCULATE GCMAXR VALUES
* BASED ON AN INFINITE EXPOSURE DURATION WAS MADE BY NRC STAFF.
* THE UNITS ARE (BQ/SQUARE-METER).
*
* QROOT VALUES ARE DERIVED TO TAKE ACCOUNT OF THE COMBINED EFFECT OF
* PERCOLATION, CHEMICAL BINDING AND RADIOACTIVE DECAY IN REDUCING THE AMOUNT
* OF MATERIAL AVAILABLE FOR LONG-TERM UPTAKE INTO FOOD IN UNITS OF (PER YEAR).
*
*              NAMIPI        GCMAXR          QROOT
CHPAGLTS001    SR-89         1.8E8           4.9
CHPAGLTS002    SR-90         3.7E4           0.065
CHPAGLTS003    CS-134        4.1E6           0.59
CHPAGLTS004    CS-137        1.8E6           0.28
CHPAGLTS005    I-131         1.E20          32.0
CHPAGLTS006    I-133         1.E20         290.0
*
* AN ALTERNATIVE METHOD FOR DERIVING VALUES FOR GCMAXR IS TO BASE THEM
* ON A ONE YEAR EXPOSURE PERIOD INSTEAD OF AN INFINITE EXPOSURE PERIOD.
* IF THE USER WOULD LIKE TO ADOPT THIS APPROACH, A SET OF APPROPRIATE
* VALUES CAN BE FOUND IN THE FOLLOWING COMMENT CARDS.  THE VALUES BELOW
```

```
* CORRESPOND TO A MAXIMALLY EXPOSED INDIVIDUAL RECEIVING A DOSE COMMITMENT
* NO GREATER THAN 0.005 SIEVERT EFFECTIVE-WHOLE-BODY-DOSE-EQUIVALENT OR
* 0.015 SIEVERT TO THE THYROID AS A RESULT OF CONSUMING CONTAMINATED FOOD
* OVER A ONE YEAR EXPOSURE PERIOD.
* IN ORDER TO USE A DIFFERENT DOSE LIMIT, RATIO THE VALUE OF GCMAXR.
*
*               NAMIPI       GCMAXR         QROOT
*CHPAGLTS001    SR-89        1.8E8          4.9
*CHPAGLTS002    SR-90        5.9E5          0.065
*CHPAGLTS003    CS-134       9.2E6          0.59
*CHPAGLTS004    CS-137       7.4E6          0.28
*CHPAGLTS005    I-131        1.E20         32.0
*CHPAGLTS006    I-133        1.E20        290.0
******************************************************************************
* DEFINE THE TYPE 9 RESULTS
*
* LONG-TERM POPULATION DOSE IN A GIVEN REGION BROKEN DOWN BY THE 12 PATHWAYS
*
* NUMBER OF RESULTS OF THIS TYPE THAT ARE BEING REQUESTED
* FOR EACH RESULT YOU REQUEST, THE CODE WILL PRODUCE A SET OF 12
*
TYPE9NUMBER   4      (UP TO 10 ALLOWED)
*
*               ORGNAM        INNER      OUTER
*
TYPE9OUT001    'EDEWBODY'      1           5     (0 TO   1.25 MILES)
TYPE9OUT002    'EDEWBODY'      1          12     (0 TO   5    MILES)
TYPE9OUT003    'EDEWBODY'      1          14     (0 TO  10    MILES)
TYPE9OUT004    'EDEWBODY'      1          27     (0 TO 500    MILES)
******************************************************************************
* ECONOMIC COST RESULTS IN A REGION BROKEN DOWN BY 12 TYPES OF COSTS
*
* NUMBER OF RESULTS OF THIS TYPE THAT ARE BEING REQUESTED
* FOR EACH RESULT YOU REQUEST, THE CODE WILL PRODUCE A SET OF 12
*
TYP10NUMBER   2      (UP TO 10 ALLOWED)
*
*               INNER      OUTER
*
TYP10OUT001      1           14     (0 TO  10    MILES)
TYP10OUT002      1           27     (0 TO 500    MILES)
******************************************************************************
* DEFINE A FLAG THAT CONTROLS THE PRODUCTION OF THE ACTION DISTANCE RESULTS
*
* SPECIFYING A VALUE OF .TRUE. TURNS ON ALL 8 OF THE ACTION DISTANCE RESULTS,
* A VALUE OF .FALSE. WILL ELIMINATE THE ACTION DISTANCE RESULTS FROM THE OUTPUT.
*
TYP11FLAG11  .TRUE.
******************************************************************************
* IMPACTED AREA/POPULATION RESULTS IN A REGION BROKEN DOWN BY 6 TYPES OF IMPACTS
*
* NUMBER OF RESULTS OF THIS TYPE THAT ARE BEING REQUESTED
* FOR EACH RESULT YOU REQUEST, THE CODE WILL PRODUCE A SET OF 8
*
```

```
TYP12NUMBER    9      (UP TO 10 ALLOWED)
*
*               INNER       OUTER
*
TYP12OUT001       1           12     (0 TO   5     MILES)
TYP12OUT002       1           14     (0 TO  10     MILES)
TYP12OUT003       1           16     (0 TO  15     MILES)
TYP12OUT004       1           17     (0 TO  20     MILES)
TYP12OUT005       1           18     (0 TO  25     MILES)
TYP12OUT006       1           19     (0 TO  30     MILES)
TYP12OUT007       1           20     (0 TO  40     MILES)
TYP12OUT008       1           21     (0 TO  50     MILES)
TYP12OUT009       1           26
```

APPENDIX E – SITE C5Z3

(For 1000 People/Sq. Mi. with a Large City; Area Distance of 0.4 Miles Exclusionary Boundary Distance)

```
MACCS SITE FILE: LR, LN: 7/29/91 (based on SURRY, JLS, 11/10/88) alh: 8/20/91
POPULATION BASED 4 SITES SPECIFIED BY NRC: L. Soffer, June 4 1991 case 1
 27 SPATIAL INTERVALS
 16 WIND DIRECTIONS
  7 CROP CATEGORIES
  4 WATER PATHWAY ISOTOPES
  1 WATERSHED
 59 ECONOMIC REGIONS
SPATIAL DISTANCES
     0.40      0.53      0.64      0.80      2.01      2.14      2.25      2.41
     3.22      4.83      6.44      8.04     12.87     16.09     20.92     24.14
    32.18     40.22     48.27     64.36     80.45    112.63    160.90    241.35
   321.80    563.15    804.50
POPULATION
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
```

```
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.    38485.    49480.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.  1511891.  1821442.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.  1511891.  1821442.    94248.   200277.   490874.
  687223.  3239767.  5006913.
       0.        0.        0.       18.      258.       41.       38.       57.
     344.      982.     1374.     1767.     7658.     7069.    13548.    10996.
   34361.    44179.    53996.  1511891.  1821442.    94248.   200277.   490874.
  687223.  3239767.  5006913.
LAND FRACTION
1.00 1.00 1.00 1.00 0.6  0.8  0.9  0.9  0.9  0.9  0.9  0.9  1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 0.9  1.00 1.00 0.9  0.9
1.00 1.00 1.00 1.00 0.7  1.00 1.00 1.00 1.00 1.00 1.00 0.9  1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 0.9  0.9  1.00 0.9  0.7
1.00 1.00 1.00 1.00 0.7  1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 0.9  0.9  1.00 1.00 0.9  0.8
1.00 1.00 1.00 1.00 0.7  1.00 1.00 1.00 1.00 1.00 1.00 0.9  1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.9  0.4
1.00 1.00 1.00 1.00 0.7  1.00 1.00 1.00 1.00 1.00 0.9  1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.9  0.9  0.9  1.00
1.00 1.00 1.00 1.00 0.6  1.00 0.8  1.00 1.00 1.00 0.9  1.00 1.00 1.00 1.00 1.00
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0.8  0.8  0.8  0.9  1.00 0.9  0.7  0.8  1.00 0.9  0.9
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1.00 1.00 1.00 1.00 0.4  0.5  0.5  0.6  0.9  1.00 0.9  1.00 1.00 1.00 1.00 1.00
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1.00 1.00 1.00 1.00 0.7  0.9  1.00 1.00 1.00 1.00 1.00 0.7  0.9  1.00 0.4  0.7
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REGION INDEX
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WATERSHED INDEX
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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CROP SEASON AND SHARE
  1 PASTURE                90. 270.   0.41
  2 STORED FORAGE         150. 240.   0.13
  3 GRAINS                150. 240.   0.21
  4 GRN LEAFY VEGETABLES  150. 240.   0.002
  5 OTHER FOOD CROPS      150. 240.   0.004
  6 LEGUMES AND SEEDS     150. 240.   0.15
  7 ROOTS AND TUBERS      150. 240.   0.003
```

WATERSHED DEFINITION

1	SR-89	5.0E-6
2	SR-90	5.0E-6
3	CS-134	5.0E-6
4	CS-137	5.0E-6

REGIONAL ECONOMIC DATA

1	EXCL ZONE	.0	.0	0.	0.	0.
2	ARIZ	.516	.104	110.	682.	74000.
3	ARK	.483	.041	466.	2049.	61000.
4	CALIF	.330	.144	1022.	4394.	93000.
5	COLO	.522	.048	211.	971.	83000.
6	CONN	.160	.294	1605.	4980.	107000.
7	DEL	.534	.042	1723.	3428.	82000.
8	FLA	.375	.080	832.	3341.	80000.
9	GA	.363	.060	613.	1885.	73000.
10	IDAHO	.279	.144	343.	1562.	61000.
11	ILL	.806	.044	709.	3900.	86000.
12	IND	.713	.079	611.	3283.	72000.
13	IOWA	.938	.060	695.	3133.	73000.
14	KANS	.917	.035	281.	1204.	81000.
15	KY	.571	.112	482.	1838.	61000.
16	LA	.354	.074	459.	3284.	61000.
17	MAINE	.079	.260	662.	1133.	70000.
18	MD	.429	.216	956.	4489.	93000.
19	MASS	.136	.249	1349.	2563.	97000.
20	MICH	.313	.247	658.	2187.	81000.
21	MINN	.597	.223	516.	2111.	82000.
22	MISS	.470	.054	403.	2084.	53000.
23	MO	.703	.102	322.	1647.	76000.
24	MONT	.657	.030	61.	563.	65000.
25	NEBR	.962	.031	318.	1148.	75000.
26	NEV	.127	.139	63.	601.	84000.
27	N.H.	.096	.482	518.	2018.	87000.
28	N.J.	.203	.129	1399.	6477.	102000.
29	N.MEX	.590	.144	53.	473.	63000.
30	N.Y.	.310	.589	711.	1378.	94000.
31	N.C.	.352	.065	860.	2658.	68000.
32	N.DAK	.924	.048	164.	948.	69000.
33	OHIO	.602	.175	581.	2686.	76000.
34	OKLA	.751	.060	204.	1508.	67000.
35	OREG	.292	.111	236.	1203.	73000.
36	PA	.303	.447	855.	2534.	78000.
37	R.I.	.108	.213	1062.	6438.	80000.
38	S.C.	.290	.084	472.	1843.	62000.
39	S.DAK	.915	.091	145.	587.	65000.
40	TENN	.509	.153	360.	1850.	66000.
41	TEX	.816	.064	164.	1492.	74000.
42	UTAH	.225	.259	123.	1286.	60000.
43	VT	.286	.789	628.	1472.	73000.
44	LR PROJ	.468	.173	534.	2094.	73574.
45	WASH	.377	.154	476.	1948.	82000.
46	W.VA	.246	.224	150.	1728.	58000.
47	WIS	.517	.591	723.	1751.	76000.
48	WYO	.561	.028	43.	380.	70000.

49	BRIT COL	.377	.154	476.	1948.	60000.
50	OCEAN	.000	.000	0.	0.	0.
51	SASKAT	.657	.030	61.	563.	60000.
52	MANITOBA	.924	.048	164.	948.	60000.
53	ONTARIO	.597	.223	516.	2111.	60000.
54	QUEBEC	.310	.589	711.	1378.	60000.
55	NOVA SCOT	.079	.260	662.	1133.	60000.
56	BAJA CAL	.330	.144	1022.	4394.	10000.
57	SONORA	.516	.104	110.	682.	10000.
58	CHIHUAHUA	.590	.144	53.	473.	10000.
59	COAHUILA	.816	.064	164.	1492.	10000.

END

NRC FORM 335 (2-89) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

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3. DATE REPORT PUBLISHED
MONTH: February YEAR: 1997

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B6331

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R.E. Davis, A.L. Hanson, V. Mubayi, H.P. Nourbakhsh

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Brookhaven National Laboratory
Upton, NY 11973

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Division of Systems Technology
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

10. SUPPLEMENTARY NOTES
J.N. Ridgely, NRC Project Manager

11. ABSTRACT *(200 words or less)*

Brookhaven National Laboratory has performed a series of probabilistic consequence assessment calculations for nuclear reactor siting. This study takes into account recent insights into severe accident source terms and examines consequences in a risk based format consistent with the quantitative health objectives (QHOs) of the NRC's Safety Goal Policy.

Simplified severe accident source terms developed in this study are based on the risk insights of NUREG-1150 and compared to those used in earlier studies, particularly the Sandia Siting Study. The results of the present study indicate that both the quantity of radioactivity released in a severe accident as well as the likelihood of a release are lower than those predicted in earlier studies.

The accident risks using the simplified source terms are examined at a series of generic plant sites, that vary in population distribution, meteorological characteristics, and exclusion boundary distances. Sensitivity calculations are performed to evaluate the effects of emergency protective action assumptions on the risk of prompt fatality and latent cancers fatality, and population relocation.

The study finds that based on the new source terms the prompt and latent fatality risks at all generic sites meet the QHOs of the NRC's Safety Goal Policy by margins ranging from one to more than three orders of magnitude.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*
nuclear power plants, site selection, reactor accidents, health hazards, risk assessment, maximum credible accident, population relocation, probabilistic estimation, public health, radioactive effluents, reactor safety, reactor sites, regulations

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