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TRECII: A Computer Program for Transportation Risk Assessment

A. L. Franklin

May 1980

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
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TRECII:
A COMPUTER PROGRAM FOR TRANSPORTATION RISK ASSESSMENT

A. L. Franklin

May 1980

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO-1830

Pacific Northwest Laboratory
Richland, Washington 99352

PREFACE

This study was initiated in FY79 in the Transportation Safety Studies Project performed at Pacific Northwest Laboratory for DOE's Division of Environmental Control Technology. In FY80, responsibility for this work was transferred to the Division of Transportation and Fuel Storage and an overview of the work was assigned to the Transportation Technology Center (TTC) at Sandia Laboratories, DOE's lead laboratory for Nuclear Materials Transportation Technology. This work was substantially complete when assigned to TTC overview and TTC funds were only used for incorporation of review comments and for publication. Funds for completion and publication of this study have been provided to PNL through TTC.

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FIGURES

TABLES

1.0 INTRODUCTION

A risk-based fault tree analysis method has been developed at the Pacific Northwest Laboratory (PNL) for analysis of nuclear fuel cycle operations.[1] This methodology was developed for the Department of Energy (DOE) as a risk analysis tool for evaluating high level waste management systems. A computer package consisting of three programs was written at that time to assist in the performance of risk assessment: ACORN[2] (draws fault trees), MFAULT[3] (analyzes fault trees), and RAFT[4] (calculates risk).* The rectangles in this figure represent user inputs to the various codes. The codes are represented by the diamond shapes and the ovals represent code outputs. Outputs from some codes are used as input to others. This interrelationship is shown with the arrows connecting the functional blocks of the diagram. Figure 1 gives a summary of the interrelationships of these programs. This methodology evaluates release consequences and estimates the frequency of occurrence of these consequences. Evaluation of consequences involves the extension of hypothetical releases to population exposures by way of standard airborne particulate dispersion and inhalation dose conversion techniques. Inhalation exposure is quite often the greatest risk contributor to the general public from the transport of radioactive material. Occasionally other factors such as ingestion or ground shine from particulate deposition become significant. In these cases additional risk analyses will be necessary to account for their absences in this methodology.

This document describes an additional risk calculating code which can be used in conjunction with two of the three codes for transportation risk assessment as shown in Figure 2. TRECII modifies the definition of risk used in RAFT (prob. x release) to accommodate release consequences in terms of fatalities. Throughout this report risk shall be defined as probability times consequences (fatalities are one possible health effect consequence). This methodology has been applied to a variety of energy material transportation

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* The author assumes the reader has a basic understanding of fault tree analysis techniques and terminology. For those requiring additional information, references 1, 2, 3, and 4 are suggested reading.

systems. Typically the material shipped has been radioactive, although some adaptation to fossil fuels has occurred. The approach is normally applied to truck or train transport systems with some adaptation to pipelines and aircraft. Examples of these applications can be found in References 5-8.

TRECII is designed to be used primarily in conjunction with MFAULT; however, with a moderate amount of effort by the user, it can be implemented independent of the risk analysis package developed at PNL.

The following sections provide code description and user instructions necessary for the implementation of the TRECII program.

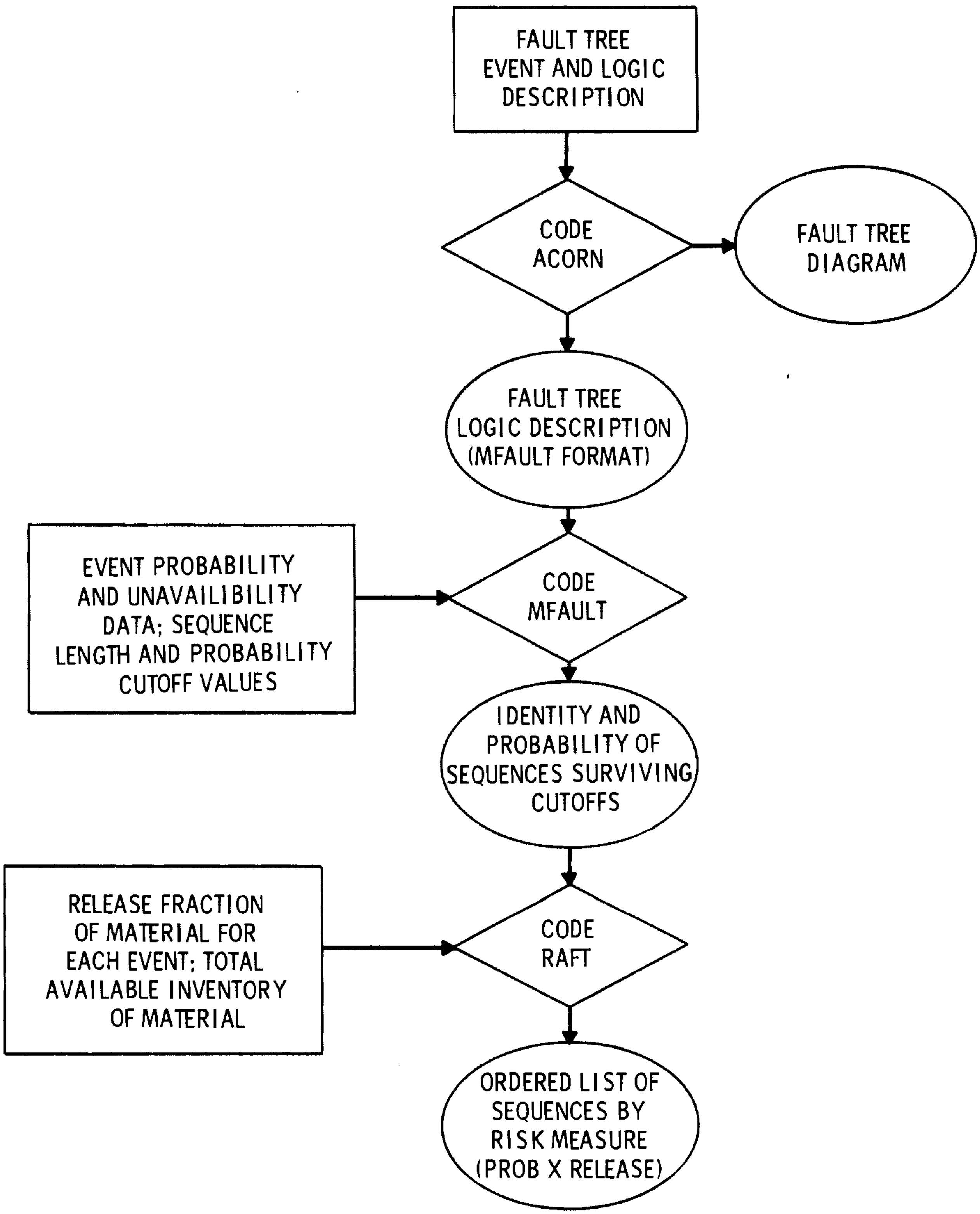


FIGURE 1. Risk Assessment Computer Package

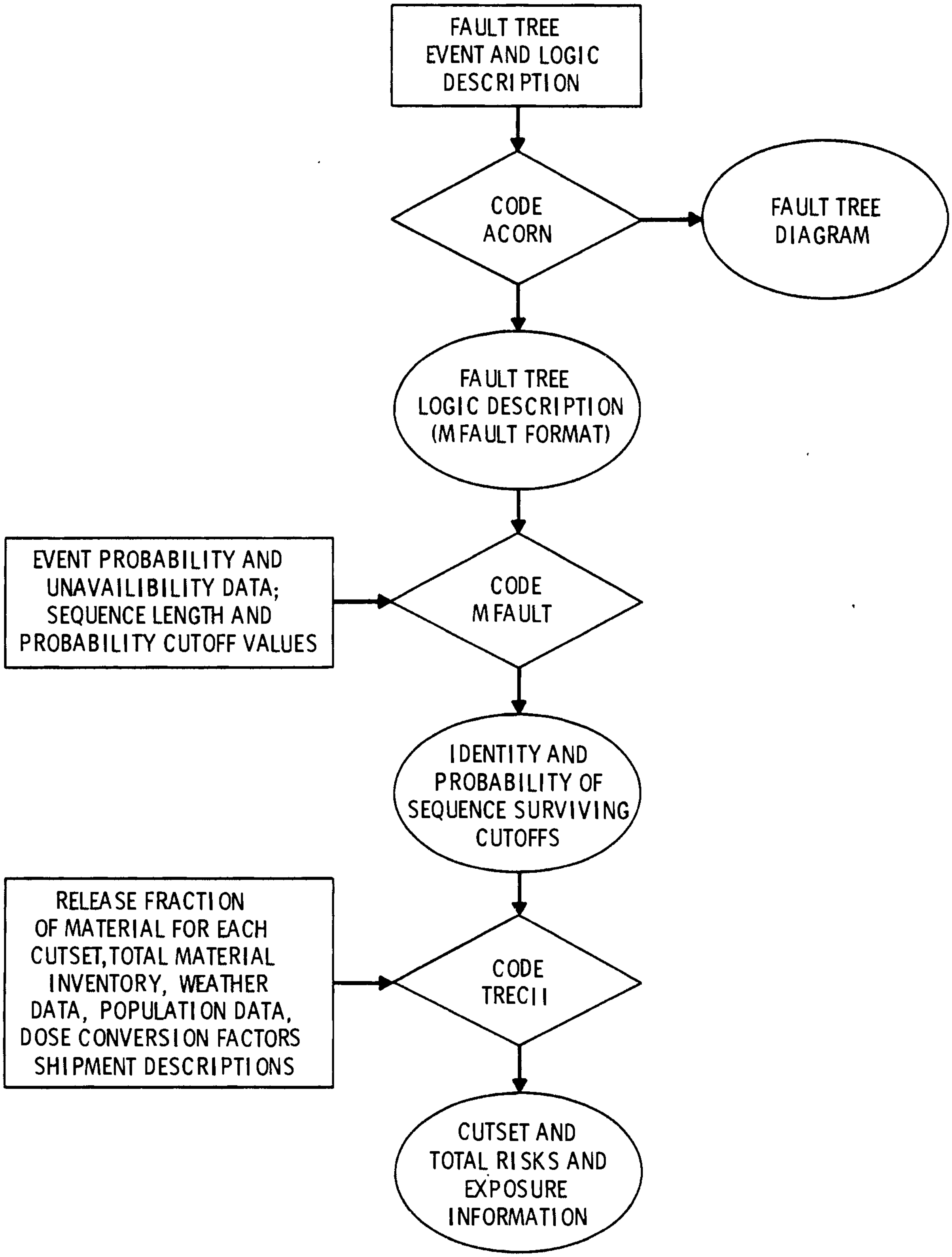


FIGURE 2. Risk Assessment Package Employing TRECII

2.0 PROCEDURES FOR SOLUTION

2.1 RISK DEFINITION

The risk assessment methodology used in the PNL studies provides a flexibility not available in previous transportation risk studies. It permits the risk to be analyzed for a spectrum of population densities and weather conditions that can be encountered along shipping routes. The model uses one fundamental equation:

$$R = \sum_i R_i \qquad (2\text{-}1)$$

The total system risk, R, is the sum of the risks of all accidental releases as denoted by the subscript i. Risk contributed by routine exposure during normal transport is not considered in this model. The risk of an individual release is the product of the consequences of the release and the probability of its occurrence. In the current formulation of the model, each term in Equation (2-1) is expanded into two expressions which have more physical significance. The expanded equation for R_i is:

$$R_i = \left(A\ F_{R_i} \times P_{R_i}\right) \times \sum_q \left(C_{E_{iq}} \times P_{E_q}\right) \qquad (2\text{-}2)$$

The first expression, $A\ F_{R_i} \times P_{R_i}$, can be thought of as a probabilistic source term for each identified release sequence. The first factor in this term, $A\ F_{R_i}$, represents the amount of material released in the i^{th} release sequence. It is the product of the amount of material present in a shipment, A, and the fraction of that material lost to the environment in the i^{th} release sequence, F_{R_i}. This factor can be considered a source term for the i^{th} chain of events of failures which end with a release of material. The second factor, P_{R_i}, is the probability that the release sequence will happen during transport.

The second expression in Equation (2-2), $\sum_q \left(C_{E_{iq}} \times P_{E_q}\right)$; represents the consequences of a unit release of material (unit source term) under probabilistically weighted weather conditions and population distributions. The consequences of a unit release of material are evaluated in the expression $C_{E_{iq}}$. The subscript q is added to show that this factor is a function of the specific weather conditions existing at the time of the release and the population exposed to the release. The consequences can be expressed in a variety of ways, depending on the material being studied. Risk comparisons can be made most advantageously if the consequences are expressed in similar health effects. The final factor in this expression, P_{E_q}, is the joint probability of encountering a particular set of weather conditions within a specific population zone.

2.2 ISOPLETH CALCULATION

Atmospheric dispersion of released radioactive material is modeled using a bivariate Gaussian distribution equation.[9]

$$E\,(x,y,z;H) = \frac{Qt}{2\pi \sigma_y \sigma_z U} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \qquad (2\text{-}3)$$

where E = time integrated concentration at (x,y,z); (g-sec/m^3)

H = release height; (m)

σ_y, σ_z = Pasquill dispersion parameters representing standard deviation of crosswind and vertical plume concentration distribution; (m)

(x,y,z) = Cartesian coordinates of the point at which the concentration is being determined. (Release occurs at the origin); (m)

t = time; (sec)

Q = source emission rate; (g/sec)

U = windspeed; (m/sec).

It is necessary to note several important features of this equation. First it represents the steady-state concentrations downwind from a continuous and constant source. The inclusion of time, t, in the numerator of the right hand expression results in E representing a time integrated concentration. A second important feature is the dependence of the dispersion parameters, σ_y and σ_z, on the atmospheric stability at the time of release. A discussion of this dependence can be found in Reference 9. Finally, the equation begins to lose validity at downwind distances greater than 100 km. Specifically, the dispersion parameters become difficult to predict at these distances. In TRECII, the downwind distance is limited to 100 km.

TRECII uses a sequential search technique and Equation (2-3) to locate isopleths, lines of constant concentration. Eleven isopleths are located; one represents the maximum concentration (minimum distance from the release and directly downwind) and the others represent incremental reductions in concentration. Each increment is one order of magnitude from the preceding isopleth. Areas within these isopleths are determined by Simpson's Rule for integration.[10] These areas will eventually be used to determine population exposure. To prevent overestimation of exposure, the isopleth areas are manipulated to represent differential areas between higher and lower concentration isopleths. The average concentration of these differential areas is found by numerically averaging the concentration of 50 evenly distributed points within the isopleth. The differential areas and average concentrations are overlaid on various uniform population distributions to determine the number of people exposed and the average atmospheric concentration they experience.

The diffusion climatology along the transport route must be incorporated into any risk analysis where the atmosphere is an important pathway for dosage to man. The important atmospheric variables are 1) wind direction - indicates the initial direction of travel, 2) wind speed - indicates the rate of transport, and 3) atmospheric stability - indicates the rate of dilution and plume rise potential. Certain characteristics of release (e.g., height and temperature) are also important in the evaluation of the atmospheric pathway.

Assuming a postulated accident with a surface release and little or no release-related plume rise, the immediate and greatest impact will be in the region surrounding the location of the event. Transport and diffusion are often determined by local influences. Wind speeds and directions show considerable variation that cannot always be summarized by large geographic regions. Consideration of local influences in the present analysis is not possible, principally because information is not available either from a data base or from current modeling capabilities.

Estimates of long-term diffusion averages are determined from the average persistence of winds by sectors. Considering wind direction persistences alone, the actual sector annual-average air concentrations can be considerably different than an average. Based on reported values from 129 weather bureau surface stations in the continental U.S., the concentrations range from one half to five times the average. Air concentrations near a particular population center can be expected to vary by the same factor depending on the direction of the population center from the selected route. Such a factor could be quite important in determining the effects of releases near large population centers. Over a sufficiently long route, the effect of different wind direction persistences may tend to cancel if there is a random relationship between the prevailing wind directions and population centers. The alternative of picking a route based on known diffusion climatologies to minimize risk could be beneficial; however, at the present time it is not included in the model.

Meteorological data used in this analysis are shown in Table 1. These values were developed from micrometeorological data collected for diffusion calculations for reactor sites. Seven sets of micrometeorological data were selected from 26 compilations from reactor sites to account for the range of conditions that could reasonably occur along a route. Use of a single averaged distribution allows for the typical range of windspeeds without undue weighting to any particular site. Although this result cannot be expected to necessarily represent any particular portion of a route, it does represent the type of conditions that may be encountered on the average.

The correlation of atmospheric stability classes to wind speeds was done using the temperature differential method described in the Nuclear Regulatory Commission Regulatory Guides 1.21 and 1.23. This technique allows very low probability situations to be included in the analysis. Section 3.2 describes input techniques should the user decide to select values different than those given in Table 1.

TABLE 1. Average Wind Speed/Stability Characteristics

Wind Speed			Pasquill Stability Classification			
			$P_{j/k}$			
U_k m/sec	k	P_k	B(j=1)	D(j=2)	E(j=3)	F(j=4)
1	1	0.255	0.136	0.202	0.299	0.363
3.5	2	0.508	0.243	0.274	0.272	0.211
7	3	0.161	0.190	0.290	0.339	0.181
10	4	0.052	0.240	0.312	0.358	0.090
18	5	0.024	0.276	0.348	0.356	0.020

2.3 POPULATION EXPOSURE

To determine the number of people exposed to radioactive material release resulting from a transportation accident, the population distribution along the shipping route must be characterized. In TRECII, this was done by dividing the Continental U.S. into four zones based roughly on population density and degree of urbanization. A representative state was chosen for each of the zones shown in Appendix D. Then for the purpose of the study, the population data of the selected states were used in forecasting population characteristics of their respective zones. The states chosen to represent these zones are shown below.

Zone	Representative State
I - Highly urbanized	New Jersey
II - Densely populated	Massachusetts
III - Moderately populated	Missouri
IV - Low population	Washington

The initial approach was to establish a set of population data for the representative states. The population densities for each of the four zones were grouped into three classes: urban for densely populated urban areas; suburban for areas of moderate population density; and rural for the non-urbanized areas. The suburban area data were obtained by taking the Standard Metropolitan Statistical Area (SMSA) data, which include urban, and subtracting out the population and land area of the cities. Census data for 1960 were used as a data base and extended to 1970 with information available from the 1970 census. Population projections were also made to the year 2000, and, using the compound interest formula to model population growth, estimates were made for 1980 and 1990.

The next step was to obtain the same data for 1970 and then determine the population and land area change for major cities (100,000 population) from 1960 to 1970. The 1970 census data were obtained from the Statistical Abstracts of the U.S.[11]

The extrapolation of 2000 was then made based on information presented in an article by J. P. Pickard.[12] Pickard states that by the year 2000, the urban land area will double. He also states that 85% of the total population growth will occur in major urban areas. Using this, the total population increase is the urban increase divided by 0.85. This leaves the rural population increase at 15% of the total growth.

Based on Pickard's projections, the land areas and rural populations were calculated for the year 2000. The data for 1980 and 1990 were filled in using the compound interest formula. The resultant population characteristics for each of the four zones in the years 1980, 1990, and 2000 are presented in Table 2. Projections for 1980 are used as default values in TRECII. The probability of an accidental release of material in a particular zone and population class is assumed to be proportional to the land area percentage of that zone and population class.

TABLE 2. Projected Population Density and Land Area by Zone and Population Classes

Zone and Population Classes		1980		1990		2000	
		Land Area, %	Density People/m^2	Land Area, %	Density People/m^2	Land Area, %	Density People/m^2
I	Urban	3.8	3.587E-3	4.8	3.239E-3	6.0	2.923E-3
	Suburban(a)	66.9	3.174E-4	84.3	3.448E-4	94.0	3.880E-4
	Rural	29.3	2.363E-4	10.9	2.687E-4	--	--
II	Urban	11.5	1.224E-3	14.5	1.208E-3	18.2	1.089E-3
	Suburban(a)	35.5	3.263E-4	44.8	2.942E-4	56.5	2.649E-4
	Rural	53.0	9.189E-5	40.7	1.351E-4	25.3	2.452E-4
III	Urban	0.8	1.537E-3	1.0	1.517E-3	1.2	1.502E-3
	Suburban(a)	17.3	8.726E-3	21.8	8.610E-5	27.5	8.533E-5
	Rural	81.9	6.564E-6	77.2	9.266E-6	71.3	1.120E-5
IV	Urban	0.5	1.695E-3	0.6	1.730E-3	0.8	1.761E-3
	Suburban(a)	15.0	5.058E-5	18.9	5.560E-5	23.7	5.676E-5
	Rural	84.5	9.653E-6	80.6	1.120E-5	75.5	1.313E-5

(a) SMSA-Cities.

2.4 HEALTH EFFECTS

The dose to an individual from inhalation of radionuclides is a function of the duration of the release, the concentration during the release period, the particle size, the isotopic composition of the released material, the individual's ventilation rate, the solubility of the inhaled material in body fluids, and the retention time of the radionuclide in body organs. Doses of this type are typically calculated using the lung model recommended by the International Commission on Radiological Protection (ICRP) Task Group on Lung Dynamics. This model, referred to as the Task Group Lung Model (TGLM), characterizes the metabolic pathways of the inhaled material.[13] A detailed discussion of the lung model and a program for calculating the dose to the lungs and other organs can be found in Reference 14.

In general, the inhalation dose to an individual exposed to a passing cloud can be expressed by:

$$D_j = K'P \qquad (2\text{-}4)$$

where: K' is the dose conversion factor
P is the quantity inhaled.

The quantity of material inhaled is dependent upon the time-integrated air concentration as expressed by:

$$P = bc_a\tau = bE \qquad (2\text{-}5)$$

where:

- b is human ventilation rate; (cm^3/sec)
- c_a is air concentration; (g/cm^3)
- τ is duration of inhalation exposure; (sec)
- E is time-integrated air concentration; ($g\text{-}sec/cm^3$).

The time-integrated air concentration, E, is obtained from the atmospheric dispersion model discussed in Section 2.2.

Combining Equation (2-4) with Equation (2-5) and normalizing the result to the quantity released yields:

$$\frac{D_j}{Q} = K'b\,\frac{E}{Q} \qquad (2\text{-}6)$$

where:

Q is the quantity released

or

$$\left(\frac{D_j}{Q}\right) = K\left(\frac{E}{Q}\right)$$

where: K is the inhalation dose conversion factor (K'b) for an accidental atmospheric release.

The array of conversion factors, CNV1 (discussed in Section 3.2.2), are values of K for individual isotopes. Note that the evaluation of these conversion factors is done external to TRECII and the factors themselves are considered input.

The health effects that could be associated with a radioactive material release can be divided into three categories. These are early fatalities (fatalities that occur within one year), early illnesses (people needing medical treatment), and late health effects that are estimated from the total population dose. In general, early effects are associated with individual total body doses of 100 rads or more and would be limited to persons in the immediate vicinity of rather large releases of radioactivity, such as severe reactor accidents covered in WASH-1400.[15]

The transportation of radioactive material involves small amounts of activity and the public is assumed to be excluded from the immediate area of an accident. On this basis, potential doses to maximum individuals would be below levels that could produce early health effects.

Late health effects, including latent cancer fatalities, are assumed to result from the exposure of populations to low levels of radioactivity. Predicted magnitudes of these effects are based on observed health effects produced at high dose levels, primarily by low linear energy transfer (LET) radiations, and a hypothesis of linearity between effect and dose. It is probable that these estimators are significantly dependent on the LET of the ionizing radiation and upon the dose levels actually encountered.[16] Determination of these factors is not within the scope of this study. Detailed discussions of health effects and health effects models can be found in References 16, 17, and 18. Conversion of population doses in man-rem to estimated possible excess cancer deaths was based on the factors presented in Table 3. These conversion factors enable a comparison of radioactive material transportation risk estimates with other societal risks.

TABLE 3. Health Effects Conversion Factors: Population Dose to Maximum Number of Health Effects

Organ of Reference	Estimated Excess Cancer Deaths Per 10^6 man-rem[a] Range of Values	Value Used[b]
Lung	16-110	50
Thyroid	1-15	5
Bone	2-17	6
Total Body	50-450	200

(a) Derived from the BEIR Report.[17]

(b) From EPA-520/4-73-002 based on BEIR statistics.[18]

The above discussions of health effects applies primarily to the default values for the dose conversion factors CNV1 and CNV2 (see Section 3.2.2). The discussion of the derivation of these factors has been included to provide the reader some familiarity with the concepts involved in determining these values. The dose conversion factors are basic input elements to TRECII and the burden of assigning their values lies with the TRECII user.

2.5 RISK SPECTRUM AND TOTAL RISK

Risk calculations proceed along two parallel and interrelated paths. One path characterizes the consequences of an accidental release, and the other path determines the frequency of occurrence for each event in the consequence analysis.

As briefly discussed earlier, risk is expressed by the equation:

$$R_i = \left(AF_{R_i} \times P_{R_i}\right) \times \sum_q \left(C_{E_{iq}} \times P_{E_q}\right) \qquad (2\text{-}7)$$

where:

q represents a number of indices as indicated below.

The terms inside the first set of parentheses represent the product of the amount of material present in a shipment, A, times the fraction of that material which is lost to the environment in the i^{th} release sequence, F_{R_i}, times the expected frequency of occurrence of the release sequence, P_{R_i}. The two terms in the second set of parentheses represent the consequences of a unit release, $C_{E_{iq}}$, as discussed in Section 2.4, and the expected frequency of encountering a given set of environmental conditions, P_{E_q}. The expected frequency of encountering a given set of environmental conditions can be expressed as:

$$P_{E_q} = P_{E_{jk\ell m}} = P_k P_{j/k} P_{\ell/m} P_m{}^{(a)} \qquad (2\text{-}8)$$

where:

j is the atmospheric stability classification index
k is the wind speed index
ℓ is the population density index in zone m of the U.S.
m is the zone index for the shipping routes.

(a) $P_{j/k}$ should be read as the probability of index j given index k has occurred.

The notation j/k indicates that the expected frequency of encountering the j^{th} stability class is a function of the wind speed existing at the time of release. Similarly, the expected frequency of encountering the ℓ^{th} population density is dependent on the expected frequency that a shipment will pass through zone m. The values correspond to the TRECII variables (defined in Section 3.2.2) as follows:

$$P_k = PU$$
$$P_{j/k} = PS$$
$$P_m = PZ$$
$$P_{\ell/m} = PD$$

The default values for the "P" in Equation (2-8) are obtained from the following tables in this section:

P_k - Table 1, Column 3

$P_{j/k}$ - Table 1, Columns 4-7

$P_{\ell/m}$ - Table 2

P_m - Table 2

By specifying a value for j, k, ℓ, and m, one can obtain the expected frequency that an environmental condition will be experienced during a shipment. Associated with that frequency is a corresponding value for the environmental consequences. The relationship is best summarized by the following equation for the environmental term in the risk equation:

$$\sum_q \left(C_{E_{iq}} \times P_{E_q} \right) = \sum_{jk\ell mn} \left(K_{1i} K_2 A_{njk} \overline{(E/Q)}_{njk} N_{\ell/m} P_k P_{j/k} P_{\ell/m} P_m \right) \qquad (2\text{-}9)$$

where:

K_{1i} converts grams received to organ dose

K_2 converts organ dose to health effects

A_{njk} is the area between isopleths n and n-1

$(\overline{E/Q})_{njk}$ is the time integrated air concentration received in A_{njk} per gram released

$N_{\ell/m}$ is the population density in the release plume.

The subscripts and the values for P in Equation 2-9 have been defined following Equation 2-8. The product $(C_{E_{iq}} \times P_{E_q})$ has units of fatalities per gram of material released. If several organs received a dose as a result of a release, then the product $K_{1i}K_2$ for each organ receiving a dose must be summed to get the overall effect to the individual.

By moving the first term in Equation (2-7) inside the summation sign the total risk then becomes:

$$R = \sum_{i,j,k,\ell,m,n} \left[K_{1i}K_2AF_{R_i}A_{njk}(\overline{E/Q})_{njk}N_{\ell/m}\right] \times \left[P_{R_i}P_kP_{j/k}P_{\ell/m}P_m\right] \quad (2\text{-}10)$$

Equation (2-10) has been arranged so that the frequency of occurrence terms are separated from the consequence terms.

In Equation (2-10) the frequencies of occurrence and the consequences of all accidents are summed to obtain a single annual risk number. This number can be thought of as the expected frequency of occurrence of a fatality attributable to radioactive material transportation. In addition to the total risk number, a risk spectrum must also be considered to differentiate between an event which occurs once a year and results in one fatality and an event which occurs once in a thousand years but results in 1000 fatalities. In order to distinguish between these two events which have the same risk but different severities, curves are constructed which plot accident severity versus the expected frequency of accidents with that severity or greater. The two events described above have discrete contributions to this graph. Thus for the risk of two operations to be truly comparable, they must have both the same risk number and the same risk spectrum.

Both the risk and the risk spectrum can be obtained from the terms in Equation (2-10). The number of fatalities from an accident release sequence is expressed by the term inside the first set of brackets. The frequency of the consequence is obtained by calculating the terms within the second set of brackets. These two terms can be thought of as pairs of numbers. The risk spectrum curves can be obtained by choosing a value for N, the number of fatalities, and then scanning the paired sets of numbers for any first terms which exceed N. The summation of all second terms which have a first term greater than or equal to N is the expected frequency of occurrence of accidents which result in N or more fatalities. This is one point on the risk spectrum curve. The operation is continued until points on the risk spectrum curve are calculated for selected values of N down to one fatality. A plot of a sample risk spectrum curve is given in Figure 3.

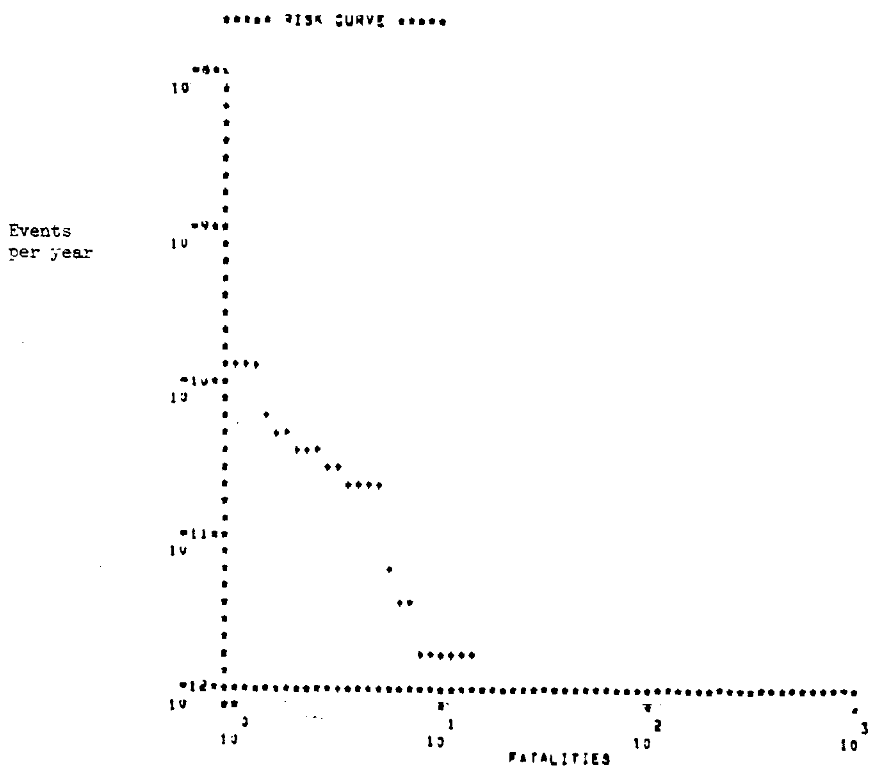


FIGURE 3. Sample Risk Spectrum

3.0 INFORMATION TO THE USER

3.1 GENERAL DESCRIPTION OF THE PROGRAM

The TRECII output describes the risk of transporting radioactive material under specific conditions. To accomplish this, TRECII applies a main program and eight subroutines (see Appendix A for program listings). The interactions of these subroutines with each other and the main program are depicted in Figure 4.

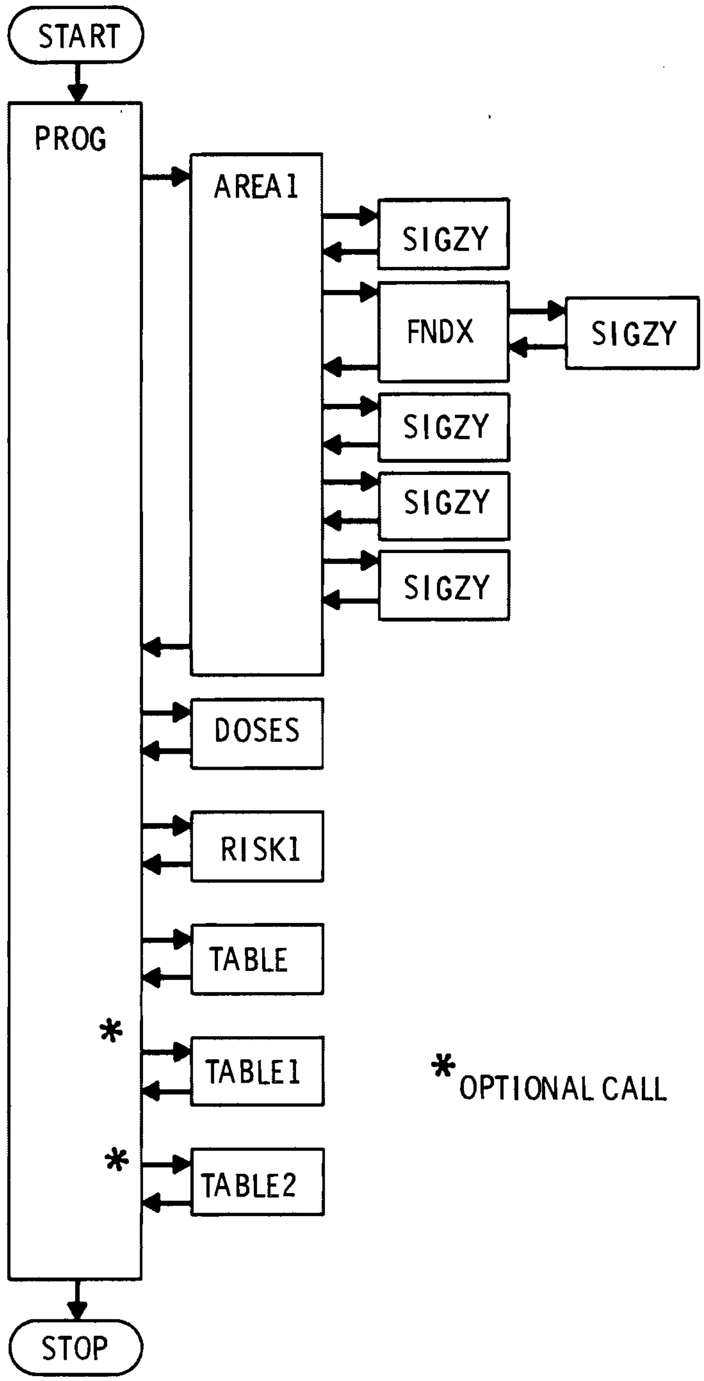
The main program is titled PROG. Within PROG, all default values are assigned (see Appendix B) variable types and common blocks are declared, input and output formatting is accomplished, and a small number of summary calculations are performed. PROG also implements the majority of the subroutine calls and coordinates the various model interactions.

Atmospheric dispersion modeling of released radionuclides is done by the subroutine AREA1. Airborne concentrations are determined by applying a bivariate Gaussian dispersion model. Distances to various airborne concentrations are determined by subroutines FNDX and SIGZY. Isopleths, lines of constant concentration, are identified by AREA1, and land areas within these isopleths are estimated by Simpson's Rule for numerical integration. Average concentrations with each isopleth are calculated by numerical averaging techniques.

Population exposures are calculated by combining average isopleth concentration and isopleth area data calculated in AREA1 with population distribution data provided in PROG. All dose conversion factors are accounted for the DOSES subroutine. Data produced in DOSES describes all of the potential consequences of every release sequence under consideration.

Probability information describing the likelihood of the above consequences is accounted for by the subroutine RISK1. The probabilities of all of the possible weather conditions, population distributions, and release scenarios are combined with the consequence terms from DOSES. These new values comprise the risk terms and are summed to arrive at the total risk for the transportation system under consideration. In addition to the risk terms and total risk outputs, TRECII estimates the maximum number of persons exposed to the release. This is done by sweeping the largest of the isopleth downwind distances over the length of the transportation path. This area is then multiplied by a probabilistically weighted population density to determine the largest number of persons likely to be exposed to the release. The code also calculates the estimated risk to an unspecified individual.

Finally, TRECII sorts the risk terms according to the magnitudes of the consequence. This information is used to create a risk spectrum, such as shown in Figure 4. In this figure the units of the abscissa are normally fatalities and the units of the ordinate are events per year. If need be, the ordinate units can be changed to events per shipment, events per mile, or any other units the user finds convenient. The sorting and tabulation of these values is performed by subroutine TABLE while the presentation of the information is done by TABLE1 and TABLE2.



NOTE: Multiple entries into subroutine SIGZY are needed to establish dispersion limits and isopleth boundries.

FIGURE 4. Subroutine Interactions

3.2 INPUT DESCRIPTION

Information input into TRECII covers the following areas:

- program control
- weather
- population distribution
- radiation health effects
- shipment characterization
- failure mode description

A portion of these are generic in nature and apply to essentially all risk assessments. (Default values are listed in Appendix B). Inclusion of these variables in the input deck is optional since default values would generally apply to all systems. TRECII also has several parameters which are required input. These values are normally specific to each transportation network under consideration. Default values also exist for these parameters but the values are specific to the quality assurance (QA) test case and do not generally apply to all transportation networks. Two input formats are used to supply this information to TRECII.

3.2.1 Free Field Format

For the analysis of large, complex transportation networks, TRECII is used in conjunction with the other risk assessment programs as shown earlier in Figure 2. For smaller simpler networks, the interaction with these programs can be eliminated, in which case additional inputs must be provided by the user. The tape control card, used to modify the input procedure to accommodate these two input options, uses free field formatting. With this format, the values of the variables to be read appear in the same order as in the READ statement. The values are separated from one another by commas or blanks. Only one variable uses this input format in TRECII. Data on this card consists of a single integer. A value of zero for this integer results in by-passing the interaction with the other risk assessment programs. Any other value will initiate data entry from tape unit 2. Discussion of external file assignment to this tape unit can be found in Section 4.1. This is the only free field input in TRECII.

3.2.2 Namelist Format

The remaining user inputs all use the namelist format. Namelist formats differ from free field formats in that the variables do not have to appear in any particular order. Also, the variable names appear with the values, to identify which values apply to which variables (variable name followed by an equal sign precedes the value). Variables may appear more than once in the namelist group and the last value assigned will be used in the program. Array values may be entered sequentially with the left most array indices incrementing first. Array value assignment may begin anywhere within the array. All variables and sequential values are separated by blanks or commas. Several examples of these input options are given in Figure 5. Note that the namelist group starts with a "$VARIS" and ends with "$END". All namelist input cards must be between these two cards. Also, column one is always left blank in the namelist group. Table 4 presents a list and description of all namelist input variables.

```
$VARIS
IORG = 2,ISO = 4
LEVEL (1) = 2,2,4,6,8,7(a)
CNV2 (4) = 4.0,
ISO = 3
PC (76) = 4,93E-7
$END
```

[a] For arrays starting with all indices equal to one, the bracketed indices may be omitted, i.e., LEVEL (1) = is the same as LEVEL =.

FIGURE 5. Sample Namelist Group

TABLE 4. Namelist Input Variables

Variable Name	Variable Type	Parameter Description
CNV1	real array (5,5)	Factor converting g/m^3 to rems/sec. Value is unique to each isotope and organ.
CNV2	real array (5)	Factor converting million man-rems to fatalities. Value is unique to each organ.
DEP	real array (4,3)	Population density for each of 4 zones and 3 population regions (persons/m^2).
DMIN	real scalar	Minimum dose to an individual that will be considered (mrem/yr).
FRC	real array (5,250)	Fraction of material released from shipment. Value is unique to each isotope and cutset.
HT	real scalar	Height at which material release occurs. (m) Normally zero for ground level release.
ISO	integer scalar	Indicates number of isotopes to be considered. Maximum of 5.
IORG	integer scalar	Indicates number of organs to be considered. Maximum of 5.
KEY	integer scalar	Identifies cutset for which details of risk calculations will be provided.
LEVEL	integer array (250)	Assigns release conditions to each cutset and specifies the set of release fractions to be taken from LEVTAB.
LEVTAB	real array (8,5)	Presents appropriate release fractions for each of the release conditions (frac/sec).
LL	integer scalar	Identifies the total number of cutsets.
PC	real array (250)	Cutset probability.
PD	real array (4,3)	Probability of a particular population region within the 4 population zones.
PRT2	integer scalar	Printout priority indicator.
PS	real array (4,3)	Probability of a particular atmospheric stability class.
PU	real array (5)	Probability of a particular windspeed.
QUTY	real array (5)	Quantity of each isotope per package (grams).
SHIPS	real scalar	Number of shipments per year.
TIME	real scalar	Duration of the release (seconds).
U	real array (5)	Windspeed (m/s).
WD	real array (4)	Distance in each population zone per shipment (km).
XMIN	real scalar	Minimum distance to the point of release allowed for the exposure of general public (m).

3.3 OUTPUT OPTIONS

The amount of output produced by the program is controlled by assigning particular values to the namelist variable PRT2. The printout options and their corresponding values of PRT2 are given in Table 5. A sample of the TRECII output for option 4 can be found in Appendix C. Options 5, 6, and 7 create large amounts of output and are generally used for QA purposes only. An explanation of the terms in Table 5 can be found in Section 2.0.

TABLE 5. Output Options

Printout Option	PRT2 Value	Output Description
1	Any value	Returns input data and accumulated total risk.
2	2	Returns all the above plus the values describing the risk spectrum and an estimate of the total number of people exposed.
3	3	All the above plus the risks for each cutset and isotope. Also plots the risk spectrum.
4	4	All the above plus isopleth areas, boundary concentrations and average concentrations. Accumulated individual risk and estimated number of people exposed.
5	5	All the above plus the values used to calculate the risk for a particular cutset. This cutset is identified by the namelist variable KEY. (If KEY equals zero, the risk data is provided for all cutsets).
6	6	All the above plus values used to calculate KEY cutset consequences.
7	7	All the above plus values used to calculate KEY cutset exposures.

3.4 SAMPLE CASE

To demonstrate the order and number of cards required for a specific TRECII run, a sample case has been constructed. This case involves the shipment by truck of 180-day-cooled spent fuel. The required input deck is shown in Figure 6. The cards beginning with 7/8 in this figure are control cards and will differ from one system to another.

```
7/8 RUN TITLE/65/0/0/0, BCA562/USER ID, PROJECT ID, 10, 200
7/8 IDENT . USER NAME/USER ADDRESS
7/8 PASSWD PASSWORD
7/8 ASG, A FILE 1.
                            OPTIONAL (SEE SECTION 3.2.1)
7/8 USE 2.,FILE 1.
7/8 ASG, A TREK*TREK
7/8 XQT TREK. TRECII
      0
    $VARIS
    PRT2 = 4, XMIN = 100.0, SHIPS = 469.0, LL = 5,
    CNV1 = 1.8, 0.043, 0.16, 1400.0, 0.0
    49E-4, 0.0, 0.0, 0.0, 0.0,
    4.3, 8.0, 2.7, 0.0, 0.0,
    39.0, 207.0, 55.0, 0.0, 0.0,
    7.0E2, 1.5E4, 1.7E3, 0.0, 0.0,
    QUTY = 1.5E-2, 4.4E3, 3.0E5, 6.6E5, 6.1E4,
    PC = 2.3E-6, 7.7E-8, 4.4E-6, 4.4E-7, 6.3E-4
    LEVEL = 1.2,3,4,5,
    LEVTAB (1,1) = 0.1, 0.1, 0.1, 0.1, 0.1,
    LEVTAB (1,2) = 0.3, 0.3, 0.3, 0.3, 0.3,
    LEVTAB (1,3) = 3E-4, 4E-4, 3.2E-5, 3.0E-4.3, 3.0E-5,
    LEVTAB (1,4) = 1.2E-6, 1.5E-6, 2.0E-6, 1.0E-5, 1.0E-7,
    LEVTAB (1,5) = 1.2E-6, 1.0E-6, 2.0E-6, 1.0E-5, 1.0E-7,
    WD = 38.11, 104.17, 245.3, 42.68
    $END
7/8 FIN
7/8 7/8
```

FIGURE 6. Sample Case Input Deck

This sample case makes use of the default values of several of the optional input variables. Default values are listed in Appendix B. The output produced by this sample case is given for output option 4 in Appendix C.

4.0 ADDITIONAL PROGRAMMING INFORMATION

4.1 EXTERNAL FILE

TRECII uses one external file. This file, produced as output by MFAULT,[3] contains the resultant cutset information for a particular fault tree analysis. Information from this file which is pertinent to TRECII is LL, the number of cutsets, and PC, the probability of each cutset. To use this file it must first be produced by MFAULT and then assigned to the TRECII run. The assignment of this file requires the use of two control cards.

7/8 ASG, A PROJECT ID *FILE

7/8 USE 2., FILE.

These cards identify where the file is recorded and assigns the logical unit 2 as its input unit to TRECII.

4.2 SUBROUTINE DESCRIPTIONS

As described earlier, TRECII uses eight subroutines in addition to the executive program to process risk assessments. A description of these nine program elements follows:

PROG : Executive program which reads input, reprints input, controls subroutine sequences, and tabulates several output data (Figure 7).

AREA1 : Determines atmospheric concentrations and isopleth geometries (Figure 8).

FNDX : Locates the distance to a particular atmospheric concentration (Figure 9).

SIGZY : Calculates proper dispersion parameters for various atmospheric conditions (Figure 10).

DOSES : Determines number of persons exposed, tabulates the extent of the exposure, and converts exposure to fatalities (Figure 11).

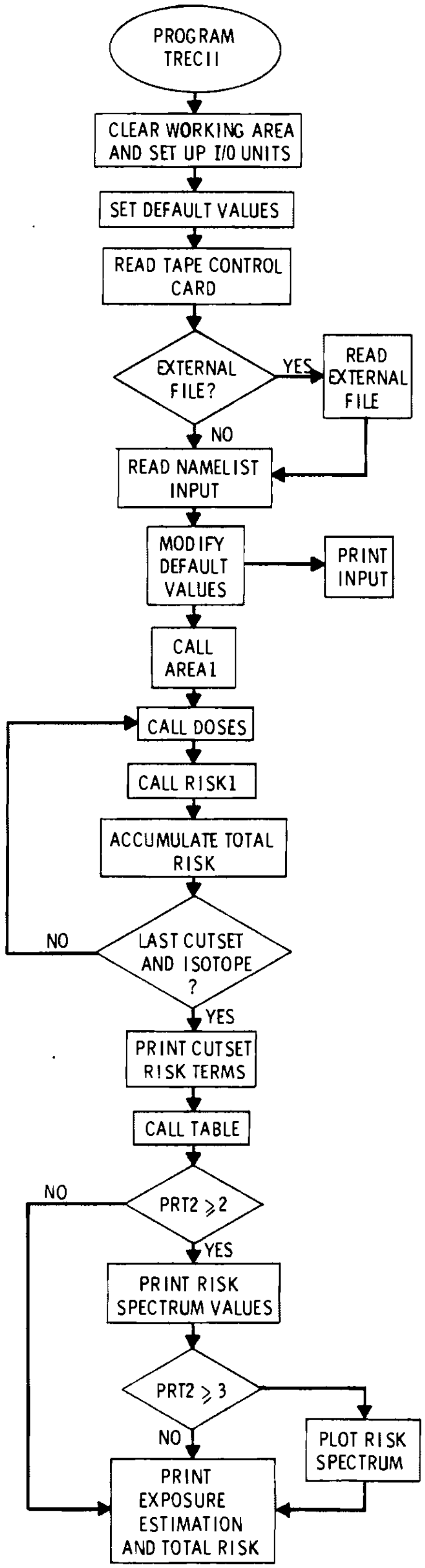


FIGURE 7. Executive Program

RISK1 : Evaluates probability of particular situations and combines with consequence information to produce risk terms (Figure 12).

TABLE : Examines risk terms and accumulates risk terms into a risk spectrum format (Figure 13).

TABLE1 : Presents risk spectrum in tabular form (Figure 14).

TABLE2 : Presents risk spectrum in graphic form (Figure 15).

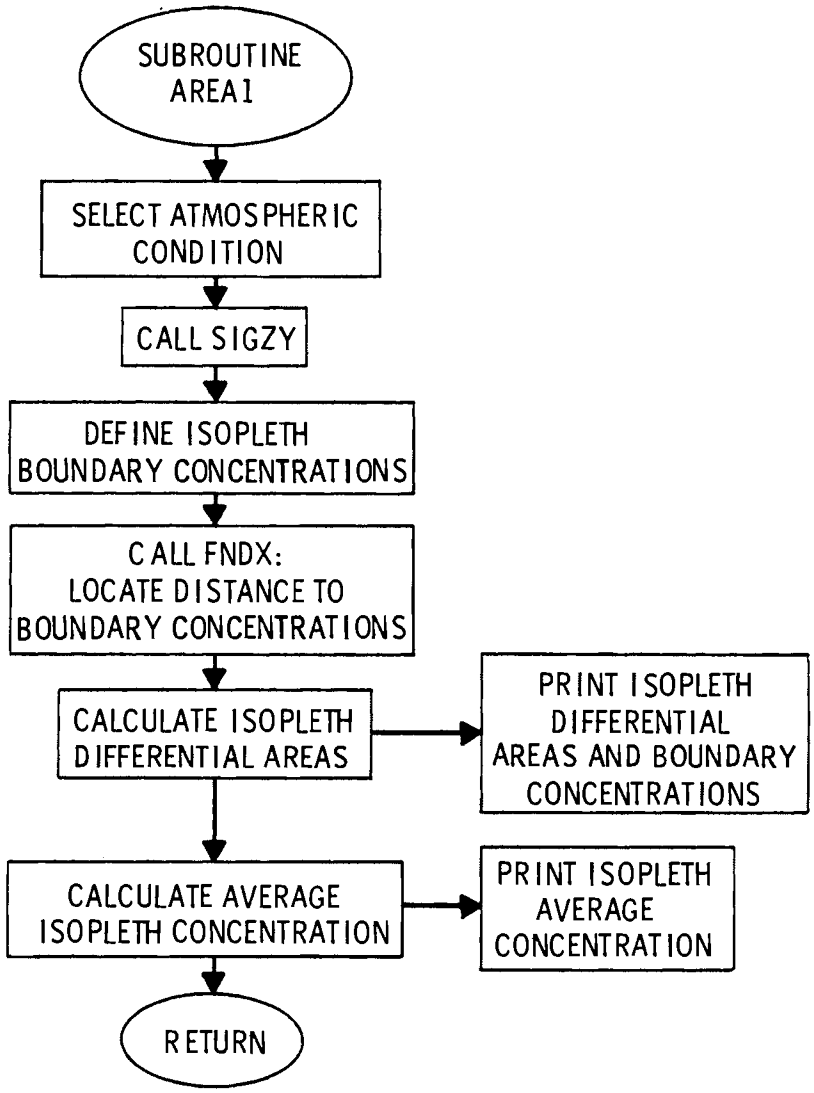


FIGURE 8. AREA1

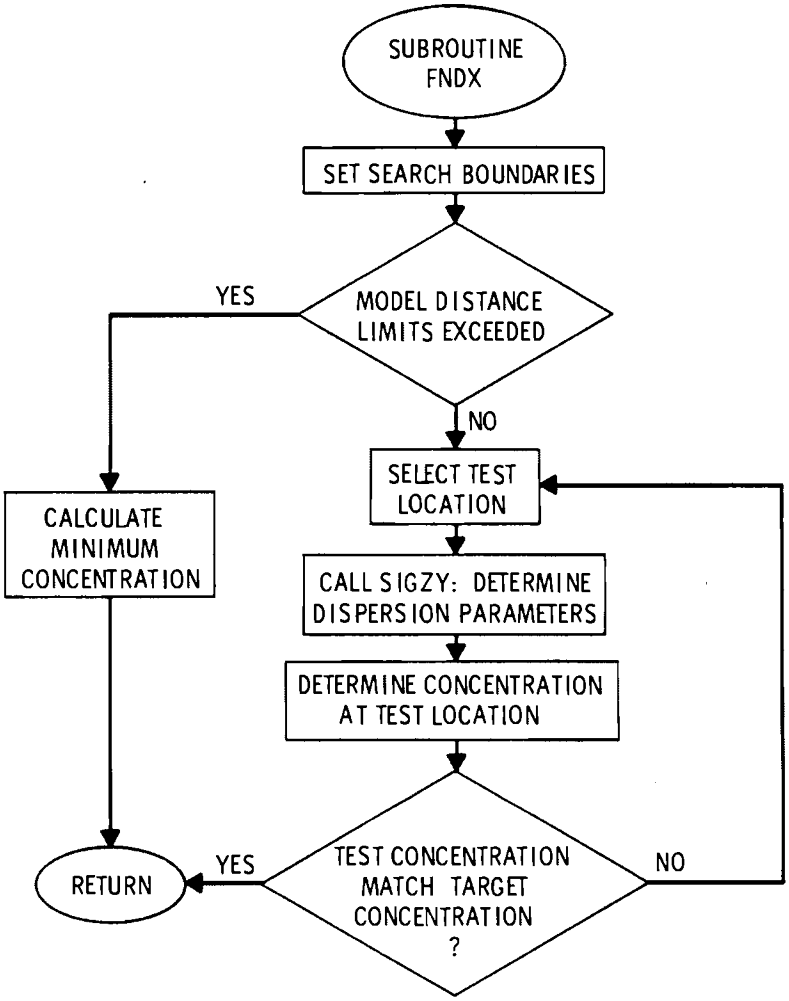


FIGURE 9. FNDX

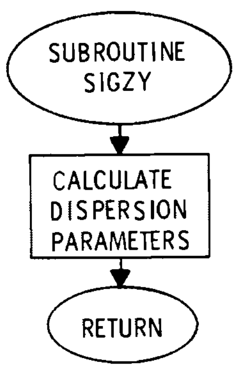


FIGURE 10. SIGZY

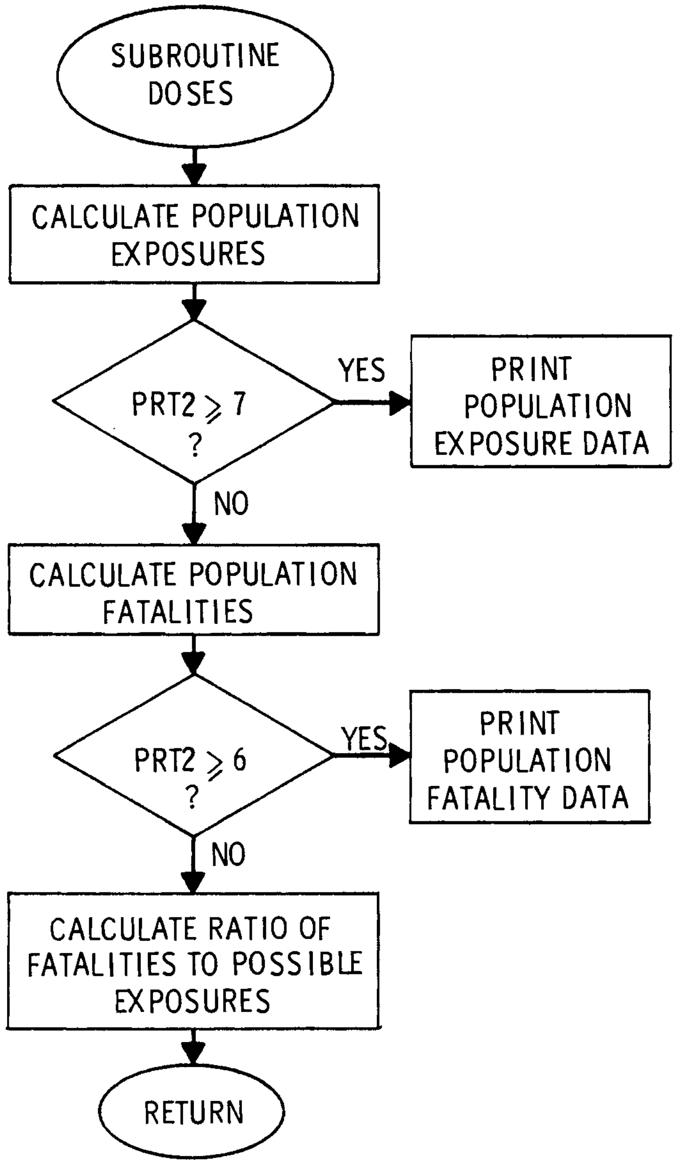


FIGURE 11. DOSES

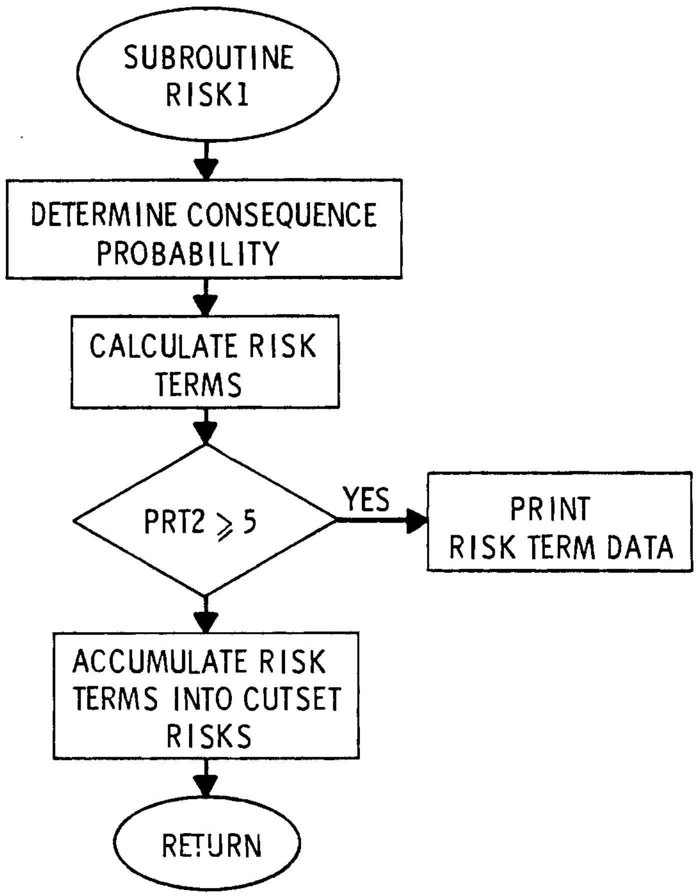


FIGURE 12. RISK1

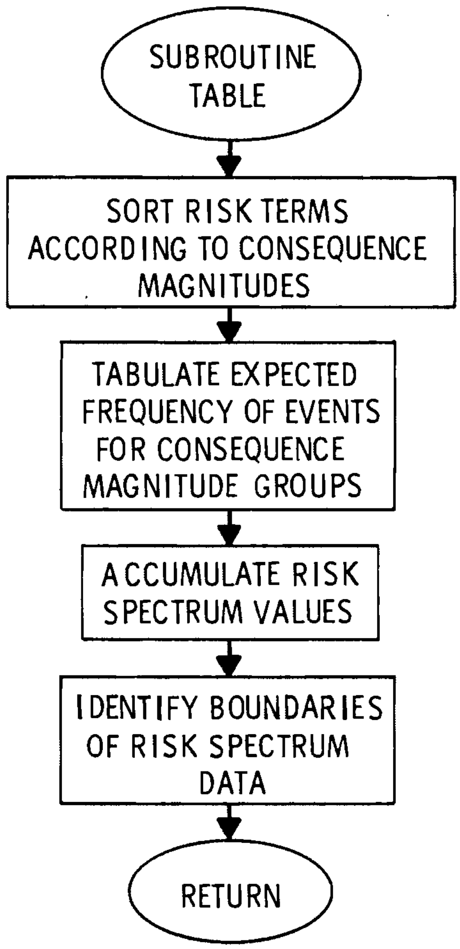


FIGURE 13. TABLE

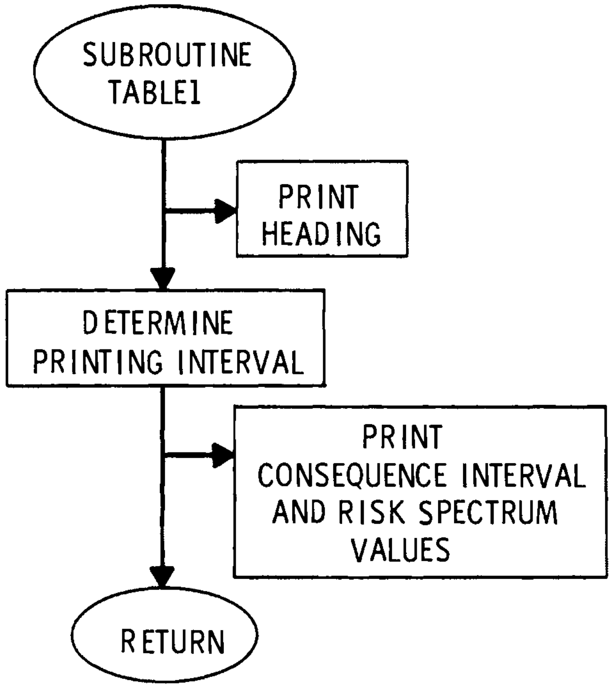


FIGURE 14. TABLE1

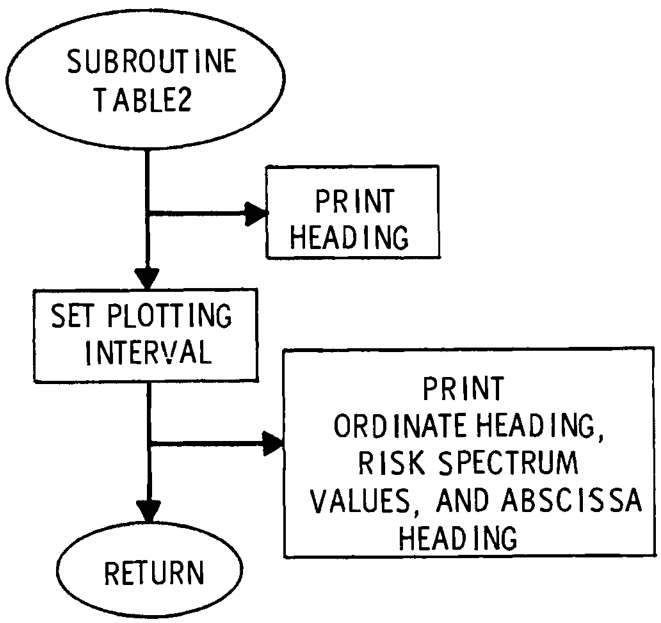


FIGURE 15. TABLE2

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APPENDIX A

PROGRAM LISTING

```
$FTN,SORFI TRAK,PROG

MS NOW IS        0 TRKS LIMIT  10000 MEM MAX IS      2000 WORDS LIMIT       55000
FTN 5R1  +10/22/79-08105(,0)
      COMMON/AA/XMIN,HT,J,CMIN,PRT2,QTY
      COMMON/BB/AREA,CHI,XDST
      COMMON/CC/ICOT,L1,LL,KEY
      COMMON/DD/DEP,CNV1,CNV2,IORG
      COMMON/FF/PRB,RSKT,PJ,PS,PZ,PO,PC
      COMMON/EE/TFAT,PEOPT,FATRAT,TOTFAT
      COMMON/HH/TIME
      COMMON/II/SHIPS
      REAL LEVTAB
      INTEGER PRT2,YRNG1
      DIMENSION TFAT(5,4,4,3,5),TOTFAT(5,4,4,3),FATRAT(5,4,4,3),
     +IAS(52),PRB(5,4,4,3),RSKT(5,250)
      DIMENSION ANS1(4),PC(250),FRC(5,250)
      DIMENSION U(5),CNV1(5,5),CNV2(5),WO(4)
      DIMENSION DEP(4,3),AREA(5,4,11),CHI(5,4,11),XDST(5,4,11)
      DIMENSION PO(4,3),PJ(5),PS(5,4),PZ(4)
      DIMENSION INDTAB(100),IRNKTB(5,100),QOTY(5)
      DIMENSION KS(5)
      DIMENSION ITERM(10,250),LEVEL(250),LEVTAB(8,5)
      CHARACTER*12 DATE
      NAMELIST/VARIS/PRT2,ISU,IORG,J,PJ,PS,PO,WO,XMIN,QOTY,SHIPS,
     +DEP,TIME,HT,LEVEL,LEVTAB,CNV1,CNV2,LL,PC,FRC,KEY,DMIN
      DATA((DEP(I,J),I=1,4),J=1,3)/3.595E-3,1.34E-3,1.536E-3,1.693E-3,
     +3.17E-4,3.25E-4,8.7E-5,5.0E-5,2.35E-4,9.2E-5,7.0E-6,1.0E-5/
      DATA (ANS1(I),I=1,4)/'B','D','E','F'/
      DATA(CNV2(I),I=1,4)/200.0,6.0,50.0,5.0/
      DATA(QOTY(I),I=1,4)/3.1E4,1.1E-1,8.4E5,9.5E6/
      DATA(CNV1(I,1),I=1,4)/4.9E-4,0.0,0.0,0.0/
      DATA(CNV1(I,2),I=1,4)/1.8,4.3E-2,9.9,1.4E3/
      DATA(CNV1(I,3),I=1,4)/9.2,8.2,3.0,0.0/
      DATA(CNV1(I,4),I=1,4)/20.0,110.0,32.0,0.027/
      DATA(CNV1(I,5),I=1,4)/700.0,1.5E4,1.7E3,0.0/
      DATA(LEVTAB(I,1),I=1,8)/0.0,0.0,.3,.31,.3,.3,.31,.3/
      DATA(LEVTAB(I,2),I=1,8)/0.0,0.0,.1,.12,.1,.1,.12,.1/
      DATA(LEVTAB(I,3),I=1,8)/3.6E-5,1.2E-9,4.2E-8,4.5E-4,1.5E-4,
     +1.5E-4,4.5E-4,1.5E-4/
      DATA(LEVTAB(I,4),I=1,8)/0.0,0.0,6.5E-9,1.5E-6,1.0E-5,
     +2.0E-5,1.5E-5,1.0E-5/
      DATA(LEVTAB(I,5),I=1,8)/0.0,0.0,5.3E-9,1.0E-6,1.0E-5,1.5E-6,
     +1.0E-5,1.0E-5/
      DATA(LEVEL(I),I=1,185)/2,2,2,2,2,2,3,2,2,3,2,2,8,2,2,3,8,
     +2,2,2,2,2,2,3,3,3,2,3,2,2,4,4,4,3,3,3,2,2,2,2,2,4,4,8,2,2,
     +3,3,2,2,2,5,3,8,2,2,8,8,2,8,2,5,3,8,8,2,2,2,2,2,5,3,3,8,5,
     +3,8,3,8,8,5,3,3,3,3,3,3,3,8,8,8,4,4,3,2,4,4,8,8,8,8,8,8,
     +4,4,4,4,4,4,4,4,8,8,8,8,5,8,3,3,3,8,8,8,8,5,8,3,3,3,
     +3,3,3,8,8,8,5,3,3,3,3,6,3,3,2,3,3,8,7,3,7,3,3,3,7,3,3,3,
     +7,3,3,6,3,2,3,3,2,6,6,3,6,3,2,3,3,3,3,6,3,3,3,6,3,2,6,6/
      DATA (WO(I),I=1,4)/38.11,104.17,245.3,42.58/
      DATA ((PO(I,J),I=1,4),J=1,3)/.038,.115,.008,.005,
     1.569,.305,.173,.15,.293,.53,.519,.845/
      DATA (U(I ),I=1,5)/1.0,3.5,7.0,10.0,13.0/
      DATA (PJ(I),I=1,5)/.235,.508,.161,.052,.024/
      DATA ((PS(I,J),I=1,5),J=1,4)/.136,.243,.19,.26,.275,
```

```
        1.292,.274,.29,.312,.348,.299,.272,.339,.358,.356,
        1.303,.211,.131,.09,.02/
         DATA LL/0/,ISO/1/,IORG/1/,PC(1)/4.4E-5/,CNV2(1)/200.0/,
        +MT/0.0/,(P2(J),J=1,4)/.0896,.2421,.5701,0.0992/,
        +FRC(1,1)/2.0E-4/,CMIN/1.0E-10/,XMIN/100.0/,
        +PEOPT2/0.0/,TIME/1.0/
         ISO=5
         IORG=4
         SHIPS=459
         PRI2=3
         NUM=30
         KEY=0
         ANS='YES'
         RSKTOT=0.0
         DMIN=100.0
         READ(5,12) TAP
      12 FORMAT()
         IF(TAP.EQ.0) PRINT 14
   14    FORMAT(1H1,T30,35('*')//1H ,T34,'INPUT TAPE UNIT 2, NOT USED'//
        +T30,35('*'))
         IF(TAP.EQ.0) GO TO 13
         DO 1 JP=1,3
1        READ(2,END=2)DATE,LL,(LEVEL(J),PC(J),(ITERM(I,J),I=1,10),J=(JP
1       +-1)*100+1,LL+(JP-1)*100)
1  1     CONTINUE
   2     LL=(JP-2)*100+LL
         PRINT 17
   17    FORMAT(1H1,T30,31('*')//1H ,T34,'INPUT TAPE UNIT 2, USED'//
        +T30,31('*'))
      13 READ(5,VARIS)
         IF(LL.EQ.0) GO TO 920
         DO 4 I=1,LL
1        DO 4 J=1,ISO
2        FRC(J,I)=LEVTAB(LEVEL(I),J)
2  4     CONTINUE
         PRINT 9
   9     FORMAT(1H,///T30,38('*')/)
         PRINT 11,PRI2
   11    FORMAT(1H,T35,'THE PRINT OUT PRIORITY IS ',I2,/)
         PRINT 16
   16    FORMAT(1H,T30,38('*'),///)
         PRINT 6
   6     FORMAT(1H,T30,38('*'),//)
         PRINT 10,LL
   10    FORMAT(1H,T35,'THE NUMBER OF CUTSETS ARE ',I3,//)
         PRINT 7
   7     FORMAT(1H,T30,38('*'),///)
         PRINT 8
   8     FORMAT(1H,T30,38('*'),//)
         PRINT 20,ISO
   20    FORMAT(1H,T35,'THE NUMBER OF ISOTOPES ARE',I2)
         PRINT 3
   3     FORMAT(1H,//T30,38('*'),////)
         DO 105 K9=1,3
1        K8(K9)=K9
1  105   CONTINUE
         PRINT 950
```

```
  950 FORMAT(1H1)
      PRINT 106
  106 FORMAT(1H,T4,18(1X,'*'),'R  E  L  E  A  S  E   F  R  A  C  T  I
     +O  N  ',18(1X,'*'),///)
      PRINT 108,(K8(K9),K9=1,5)
  108 FORMAT(1H,T5,'COUTSET',T19,'PROBABILITY',T38,5('ISOTOPE ',I1,8X),
     +///)
      DO 101 ICUT=1,LL
   29 PRINT 30, ICUT,PC(ICUT),(FRC(L1,ICUT),L1=1,ISO)
   30 FORMAT(1H ,T5,I3,T18,1PE11.4,T36,5(1PE11.4,6X))
  101 CONTINUE
      PRINT 41
   41 FORMAT(1H1)
      PRINT 42
   42 FORMAT(1H,T13,61('*'),/)
      PRINT 40,IORG
   40 FORMAT(1H,T13,'*',3X,'THIS RUN CALCULATES THE DOSEAGE BASED ON
     + ',I1,2X,'ORGAN(S)',1X,'*',/)
      PRINT43
   43 FORMAT(1H,T13,61('*'),/////)
  140 DO 145 LO=1,IORG
      PRINT 70, LO,CNV2(LO)
   70 FORMAT(1H,T17,'EXCESS DEATHS PER MILLION MAN-REMS FOR ORGAN ',I2,
     +' ',1PE10.3//)
  145 CONTINUE
      DO 150 L1=1,ISO
      PRINT 142, L1
  142 FORMAT(//1H ,T30,'I S O T O P E ',I2,//)
      DO 150 LO=1,IORG
      PRINT 144, LO,CNV1(LO,L1)
  144 FORMAT(1H,T20,'REM-SEC PER UNIT/CUBIC METER FOR ORGAN',I2,2X,
     +'IS',2X,1PE10.3)
  150 CONTINUE
      PRINT 80
   80 FORMAT(1H1,T40,'THE ATMOSPHERIC PROBABILITIES ARE AS FOLLOWS')
      PRINT 81
   81 FORMAT(1H,T33,49('*'))
  499 PRINT 500
  500 FORMAT(////1H,T30,'W I N D   S P E E D',T70,'S T A B I L I T Y
     +C L A S S')
      PRINT 501
  501 FORMAT(1H,T23,21('*'),T68,33('*'))
      PRINT 502
  502 FORMAT(//1H,T70,'B',T81,'D',T92,'E',T100,'F')
      PRINT 503
  503 FORMAT(1H ,T23,'(M/S)',T83,'P(I1/I0)'/)
      PRINT 504
  504 FORMAT(1H,T25,'U(I0)',T37,'I0',T44,'P(I0)',T68,'U1=1',T79,'I1=2',
     +T90,'U1=3',T100,'I1=4',//)
      DO 508 I0=1,5
      PRINT 506, U(I0),I0,PU(I0),PS(I0,1),PS(I0,2),PS(I0,3),
     1PS(I0,4)
  506 FORMAT(1H,T23,F4.1,T37,I1,T44,F5.3,T67,F5.3,T78,F5.3,T89,F5.3,
     +T99,F5.3/)
  508 CONTINUE
      PRINT 180
  180 FORMAT(////1H,T40,'THE POPULATION DENSITIES ARE AS FOLLOWS')
```

```
              PRINT 181
        181   FORMAT(1H,T33,46('='),//)
              PRINT 170
        170   FORMAT(1H,T30,'( R E G I O N )',T88,'( Z O N E )',/
             +T30,15('='),T56,71('=')/T83,'(PEOPLE/SQUARE METER)')
              PRINT 178
        178   FORMAT(1H,T61,'1',T84,'2',T104,'3',T124,'4')
              DO 180 M1=1,3
1             PRINT 171,M1,(DEP(M0,M1),M0=1,4)
1       171   FORMAT(1H,T35,I1,T58,1PE10.3,T78,1PE10.3,T98,1PE10.3,T118,1PE10.3
1            +)
1       180   CONTINUE
              PRINT 172
        172   FORMAT(//)
              NOO=0
              DO 700 MO=1,4
1             NOO=NOO+NO(MO)
1       700   CONTINUE
              DO 550 MO=1,4
1             PZ(MO)= NO(MO)/NOO
1             PRINT 554, MO,PZ(MO)
1       554   FORMAT(1H,T35,'THE PROBABILITY OF BEING IN ZONE ',I2,' IS '
1            +,F8.4,//)
1       550   CONTINUE
              PRINT 702, ROD
        702   FORMAT(/1H ,T35,38('*')/1H ,T35,'*',' THE SHIPPING DISTANCE IS',
             +F8.2,T73,'*',/1H ,T35,38('*'))
              PRINT 197
        197   FORMAT(1H1,T35,38('*'))
              PRINT 191,XMIN
        191   FORMAT(1H,T35,'*  THE MINIMUM DISTANCE IS ',F8.2,2X,'*')
              PRINT 900
        900   FORMAT(1H,T35,38('*'),//)
              DO 5 L1=1,ISO
1             PRINT 193
1             PRINT 192, L1,QUTY(L1)
1       192   FORMAT(1H,T35,'*  THE QUANTITY OF ISOTOPE ',I1,' PER SHIPMENT IS
1            + ',1PE10.3,2X,'*')
1             PRINT 193
1       193   FORMAT(1H,T35,60('*'))
1             PRINT 194
1       194   FORMAT(/)
1       5     CONTINUE
              PRINT 31,SHIPS
        31    FORMAT(1H,T35,'*  THE NUMBER OF SHIPMENTS PER YEAR ARE ',F5.0,
             +14X,'*',/)
              PRINT 193
        102   FORMAT(A1)
        300   CONTINUE
              CNVA=0.0
              DO 32 ICUT=1,LL
1             QZ=0.0
1             DO 33 L1=1,ISO
2             QZ=QZ+QUTY(L1)*FRC(L1,ICUT)
2       33    CONTINUE
1             DO 34 LJ=1,LORG
2             CNVB=0.0
```

```
2           DO 35 L1=1,180
3           CNVB=CNVB+QUTY(L1)*CNV1(L0,L1)*FRC(L1,ICUT)/QZ
3     35    CONTINUE
2           IF(CNVB.LE.CNVA) GO TO 34
2           CNVA=CNVB
2           CNVD=0.0
2           DO 36 L1=1,180
3           CNVC=QUTY(L1)*FRC(L1,ICUT)/(TIME*3600)
3           IF(CNVC.GT.CNVD) CNVD=CNVC
3     36    CONTINUE
2     34    CONTINUE
1     32    CONTINUE
            DMIN=DMIN/(3.1558*10**10)
            CMIN=DMIN/(CNVA*CNVD)
            PRINT 21, CMIN
      21    FORMAT(/1H ,T35,45('*')/T35,'*    THE MINIMUM CONCENTRATION IS ',
           +1PE10.3,' *'/T35,45('*'))
            XMAX= 0.0
            CALL AREA1
            DO 400 ICUT=1,LL
1           DO 395 L1=1,180
2           RSKT(L1,ICUT)=0.0
2           QTY=QUTY(L1)*FRC(L1,ICUT)/(TIME*3600.)
2           CALL DOSES
2           CALL RISK1(PRT2,RSKA)
2           REQPT2=REQPT2+REQPT
2     395   CONTINUE
1           DO 840 I0=1,5
2           DO 840 I1=1,4
3           DO 840 M0=1,4
4           DO 840 M1=1,3
5           IF(TOTFAT(I0,I1,M0,M1).LT.1.0) GO TO 19
5           DO 18 L1=1,180
5           RSKT(L1,ICUT)=RSKT(L1,ICUT)+FAT(I0,I1,M0,M1,L1)*PRB(I0,I1,M0,M1)
5     18    CONTINUE
5     19    CONTINUE
5           IF(TOTFAT(I0,I1,M0,M1).LT.1.0) GO TO 840
5           RSKTOT=RSKTOT+PRB(I0,I1,M0,M1)*TOTFAT(I0,I1,M0,M1)
5     840   CONTINUE
1           CALL TABLE(ICUT,LL,TOTFAT,PRB,TAB,YRNG1,DELRNG)
1     400   CONTINUE
            DO 310 ICUT=1,LL
1           IF(ICUT.EQ.1) PRINT 913
1     913   FORMAT(1H1,T38,'CUTSET    RISKS')
1           IF(ICUT.EQ.1) PRINT 914
1     914   FORMAT(/1H ,2X,'CUTSET',T15,'ISOTOPE 1',T33,'ISOTOPE 2',T50,
1          .'ISOTOPE 3',T67,'ISOTOPE 4',T84,'ISOTOPE 5')
1           PRINT 442,ICUT,(RSKT(L1,ICUT),L1=1,180)
1     310   CONTINUE
            DO 15 I0=1,5
1           DO 15 I2=1,4
2           IF(XOST(I0,I1,11).GT.XMAX) XMAX= XOST(I0,I1,11)
2     15    CONTINUE
            IF(PRT2.GE.2)CALL TABLE1(TAB)
            IF(PRT2.GE.3)CALL TABLE2(YRNG1,DELRNG,TAB)
            PRINT 830
      830   FORMAT(1H,T10,51('*'))
```

```
      PRINT 851
  851 FORMAT(1H,T11,'*',T71,'*')
      IF(PRTP.GE.2) PRINT 852,PEOPTE
  852 FORMAT(1H,T11,'*',5X,'THE TOTAL AMOUNT OF PEOPLE AFFECTED IS ',
     +1PE15.4,5X,'*')
      PRINT 851
      PRINT 854
  854 FORMAT(1H,T10,62('*'),///T10,61('*'))
      PRINT 850
      IF(PRTP.GE.4) PRINT 855,RSKA
  855 FORMAT(1H,T10,'*',5X,'ACCUMULATED INDIVIDUAL RISK IS ',1PE15.4,
     +10X,'*')
      PRINT 850
  850 FORMAT(1H,T10,'*',T70,'*')
      PRINT 851
  851 FORMAT(1H,T10,61('*'),///T10,90('*'))
      PEOPC=0.0
      DO 855 IA=1,4
      DO 855 IB=1,5
      PEOPC= PEOPC+AO(IA)*2*X*AX*1509.55*DEP(IA,IB)*PO(IA,IB)
  855 CONTINUE
      IF(PRTP.GE.4) PRINT 857, PEOPC
  857 FORMAT(1H,T10,'*',5X,'THE ESTIMATE OF EXPOSED POPULATION BY
     + ISOPLETH SWEEP IS',5X,1PE15.4,5X,'*')
      PRINT 858
  858 FORMAT(1H,T10,90('*'),///)
  842 FORMAT(1H ,5X,I4,3X,5(1PE12.4,5X))
      PRINT 843, RSKTOT
  843 FORMAT(1H,T50,'****** T H E   T O T A L   R I S K   I S ******'//
     +T75,1PE10.3)
      GO TO 999
  920 PRINT 921
  921 FORMAT('  NUMBER OF CUTSETS EQUALS ZERO')
      GO TO 999
  999 STOP
      END
```

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#FTN,SORFI TRAK,AREA1

MS NOW IS        155 TRKS LIMIT   10000 MEM MAX IS      21000 WORDS LIMIT         65000
FTN 881   *10/22/79-08:03:(,0)
                      SUBROUTINE AREA1
                      COMMON/AA/XMIN,HT,U,CMIN,PRT2,KTY
                      COMMON/BB/AREA,CHI,XDST
                      COMMON/CC/IOUT,L1,LL,KEY
                      COMMON/HH/TIME
                      DIMENSION Y(11),XDST(5,4,11),AREA(5,4,11),CHI(5,4,11),Q(5),
                     *QUTY(5),FRC(5,25)
                      INTEGER PRT2
                      YS(A,B,C,D,E)=-2*A**2*ALOG(A*B*C*D*3.1415)+E**2/(2*B**2)
                      CA(A,B,C)=1/(A*B*C*3.1415)
                C          DETERMINE THE ISOPLETH BOUNDRY CONCENTRATIONS
                      DO 100 IO=1,5
 1                    DO 100 I1=1,4
 2                    CALL SIGZY(XMIN,I1,SZ,SY)
 2                    XDST(IO,I1,1)=XMIN
 2                    CHI(IO,I1,1)=CA(SY,SZ,Q(IO))
 2                    IF(CMIN.GE.CHI(IO,I1,1)) CMIN=CHI(IO,I1,1)/(1*10**5)
 2                    CALL FNDX(Q(IO),I1,CMIN ,PRT2,DIST)
 2                    XDST(IO,I1,11)=DIST
 2                    CALL SIGZY(DIST,I1,SZ,SY)
 2                    CHI(IO,I1,11)=CA(SY,SZ,Q(IO))
 2              100   CONTINUE
                      PRINT 5
                5     FORMAT(1H1,45X,'**** BOUNDRY DISTANCES ****')
                      PRINT 145
                      DO 150 IO=1,5
 1                    DO 150 I1=1,4
 2                    XTRY= XMIN
 2                    DLX=(ALOG(XDST(IO,I1,11)-XDST(IO,I1,1)))/10.0
 2                    DO 140 I2=1,11
 3                    AREA(IO,I1,I2)=0.0
 3                    XDST(IO,I1,I2)=XDST(IO,I1,1)+EXP(DLX*(I2-1))
 3                    XTRY=XDST(IO,I1,I2)
 3                    IF(XTRY.LE.0.0) PRINT 6,XDST(IO,I1,1),XDST(IO,I1,11),DLX
 3              6     FORMAT(/1X,3(1PE10.3,5X))
 3                    CALL SIGZY(XTRY,I1,SZ,SY)
 3                    CHI(IO,I1,I2)=CA(SY,SZ,Q(IO))
 3              140   CONTINUE
 2                    PRINT 145,IO,I1,(XDST(IO,I1,I2),I2=1,11)
 2              150   CONTINUE
 2              C          DETERMINE THE ISOPLETH AREAS
                      DO 200 IO=1,5
 1                    DO 200 I1=1,4
 2                    DO 190 I2=1,11
 3                    IF(I2.NE.1) GO TO 10
 3                    DLX=(XMIN-1)/10.0
 3                    GO TO 11
 3              10    IF(I2.GT.1)DLX=(XDST(IO,I1,I2)-XDST(IO,I1,I2-1))/10.0
 3                    IF(DLX.LT.0.01) GO TO 190
 3              11    DO 175 I3=2,11
 4                    DO 155 I4=1,11
 5                    IF(I2.GT.1)XTEST=XDST(IO,I1,I2-1)+DLX*(I4-1)
 5                    IF(I2.EQ.1) XTEST=1+DLX*(I4-1)
```

```
5            CALL SIGZY(XTEST,I1,SZ,SY)
5            Y2=YA(SY,SZ,CHI(IO,I1,I3),U(IO),HT)
5            IF(Y2.LT.0.0) Y2=0.0
5            Y(I4)= SQRT(Y2)
5            Y3=1.4E5
5            IF(I2.EQ.1) Y3=SQRT(XMIN**2-XTEST**2)
5            IF(Y3.LE.Y(I4)) Y(I4)=Y3
5     155    CONTINUE
4            IF(I2.EQ.1.OR.I2.NE.I5) GO TO 175
4     C           FIND POINT WHERE XMIN RADIUS INTERCEPTS ISOPLETH
4            X0=1.0
4            X1=XMIN
4     156    XX=(X0+X1)/2
4            Y2=SQRT(XMIN**2-XX**2)
4            CALL SIGZY(XX,I1,SZ,SY)
4            YY=YA(SY,SZ,CHI(IO,I1,I3),U(IO),HT)
4            YY=SQRT(YY)
4            Y3=ABS(Y2-YY)/YY
4            IF(Y3.LE.0.001) GO TO 157
4            IF(YY.LT.Y2) X0=XX
4            IF(YY.GT.Y2) X1=XX
4            GO TO 156
4     157    ARE=ABS(XMIN*XX)*YY-((XMIN**2)/2)*(ATAN2(YY,XX)-SIN(ATAN2(YY,XX)))
4            AREA(IO,I1,I3)=ARE+AREA(IO,I1,I3)
4      150 AREA=(Y(1)+4*Y(2)+2*Y(3)+4*Y(4)+2*Y(5)+4*Y(6)+2*Y(7)+4*Y(8)+2*Y(9)
4           *+4*Y(10)+Y(11))*DELX*2.0/3.0
4            IF(I2.GT.1) AREA(IO,I1,I3)=AREA(IO,I1,I3)+ARE
4            IF(I2.EQ.1) AREA(IO,I1,1)=ARE
4     175    CONTINUE
3     180    CONTINUE
3     C           DETERMINE THE DIFFERENTIAL ISOPLETH AREAS
2            DO 190 I2=1,9
3            AREA(IO,I1,12-I2)=AREA(IO,I1,12-I2)-AREA(IO,I1,11-I2)
3            IF(AREA(IO,I1,12-I2).LT.0.0) AREA(IO,I1,12-I2)=0.0
3     190    CONTINUE
2            IF(PRT2.LT.4) GO TO 200
2            IF(IO.NE.1.OR.I1.NE.1) GO TO 195
2            PRINT 192
2     192    FORMAT(1H1,45X,'**** DIFFERENTIAL ISOPLETH AREAS ****')
2            PRINT 193
2     193    FORMAT(1H ,T9,30('* '),'I2',29('* ')/T2,'IO I1 ',T13,'1',T24,'2',
2           *T35,'3',T46,'4',T57,'5',T68,'6',T79,'7',T90,'8',T101,'9',T112,
2           *'10',T123,'11'/)
2     195    PRINT 196,IO,I1,(AREA(IO,I1,I2),I2=1,11)
2     196    FORMAT(1H ,2(I2,1X),11(1PE10.3,1X))
2     200    CONTINUE
             IF(PRT2.LT.4) GO TO 300
             PRINT 220
      220    FORMAT(1H1,45X,'**** ISOPLETH BOUNDARY CONCENTRATIONS ****')
             PRINT 193
             DO 240 IO=1,5
1            DO 240 I1=1,4
2            PRINT 196, IO,I1,(CHI(IO,I1,I2),I2=1,11)
2     240    CONTINUE
      300    IF(PRT2.LT.4) GO TO 350
             PRINT 320
      320    FORMAT(1H1,45X,'**** AVERAGE ISOPLETH CONCENTRATIONS ****')
```

```
                 PRINT 195
         350     DO 340 I0=1,5
1                DO 340 I1=1,4
2                DO 327 I2=1,11
3                IF(I2.EQ.1) GO TO 327
3                DEL=(XDST(I0,I1,I2)-XDST(I0,I1,I2-1))/50.0
3                CHIC=0.0
3                DO 325 I5=1,51
4                XTEST=XDST(I0,I1,I2-1)+DEL*(I5-1)
4                CALL SIGZY(XTEST,I1,SZ,SY)
4                CHIA=CA(SY,SZ,Q(I0))
4                CHIC= CHIC+CHIA
4        325     CONTINUE
3                CHI(I0,I1,I2)= CHIC/51.0
3        327     CONTINUE
2                IF(PRI2.GE.4) PRINT 196,I0,I1,(CHI(I0,I1,I2),I2=1,11)
2        340     CONTINUE
         900     CONTINUE
                 RETURN
                 END
```

```
@FTN,SORFI TRAK,FNDX

MS NOW IS        156 TRKS LIMIT  10000 MEM MAX IS     21000 WORDS LIMIT        55000
FTN 8R1   *10/22/79-05105(,0)
                SUBROUTINE FNDX(U,I1,CTRY,PRTZ,DIST)
      C            THIS SUBROUTINE DETERMINES, BY SUCCESSIVE APPROXIMATIONS, THE
      C              DISTANCE TO A PARTICULAR CONCENTRATION
      C                        U' WINDSPEED IN METERS PER SECOND
      C                        I1' ATMOSPHERIC STABILITY CLASS INDICATOR
      C                        XTRY' ESTIMATION STARTING POINT
      C                        CTRY= TARGET CONCENTRATION
      C                        DIST' RESULTANT DISTANCE
      C
                COMMON/GG/ XMAX
                INTEGER A1,PRTZ
                DIMENSION A1(4)
                DATA A1/'S','D','E','F'/
      C            CHECK FOR DISTANCES EXCEEDING THE MODEL LIMITS
                X0=1.0*10**5
                CALL SIGZY(X0,I1,SZ,SY)
                CHI=1/(U*SZ*SY*3.1415)
                IF(CTRY.LE.CHI) GO TO 750
                X1=0.0
      600       X2=X0
      700       X0=(X1+X2)/2
                CALL SIGZY(X0,I1,SZ,SY)
                CHI=1/(U*SZ*SY*3.1415)
                TEST=ABS(CHI-CTRY)/CTRY
      C            CHECK FOR SUFFICIENT RESOLUTION
                IF(TEST.LE.0.001) GO TO 800
      C            DETERMINE NEXT ESTIMATE
                IF(CHI-CTRY.LT.0.0) GO TO 600
                X1=X0
                GO TO 700
      750       PRINT 200
      200       FORMAT(//1H,T10,'THE X DISTANCE HAS REACHED 1.0*10**5 METERS')
      780       X0=1.0*10**5
                CALL SIGZY(X0,I1,SZ,SY)
                CHIN=1/(U*SZ*SY*3.1415)
                PRINT 751, CHIN ,U,A1(I1)
      751       FORMAT(1H,T10,'THE NEW MINIMUM CONCENTRATION IS ',1PE15.3,5X,
               +'WIND SPEED ',1X,0PF4.2,5X,'STABILITY CLASS ',1X, '(',A1,')')
      800       DIST= X0
      C            SET XMAX FOR USE IN ESTIMATING EXPOSED POPULATION
                IF(DIST.GT.XMAX)XMAX=DIST
                RETURN
                END
```

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$FTN,SORFI TRAK,SIGZY

MS NOW IS       136 TRKS LIMIT  10000 MEM MAX IS      21100 WORDS LIMIT       65000
FTN 8R1  *10/22/79-08105(,))
              SUBROUTINE SIGZY(X,I,SZ,SY)
      C
      C            THIS SUBROUTINE USES FORMULAS DEVELOPED BY PASQUILL TO CALCULATE
      C             THE EXPECTED DISPERSION PARAMETERS: SIGMA Z AND SIGMA Y
      C                         X: DISTANCE TO CALCULATION POINT
      C                         I: ATMOSPHERIC STABILITY CLASS INDICATOR
      C                         SZ: SIGMA Z
      C                         SY: SIGMA Y
      C
              DIMENSION A(2,4),B(3,4)
              DATA ((A(K,J),K=1,2),J=1,4)/-0.0147,.248,-0.0059,.108,
             *-0.0059,.088,-0.0029,.054/
              DATA ((B(K,J),K=1,3),J=1,4)/-0.985,.82,.0165,-1.35,.793,
             *.0022,-2.55,1.255,-0.042,-3.8,1.419,-0.055/
              SY=(A(1,I)*ALOG(X)+A(2,I))*X
              SZ=EXP(B(1,I)+B(2,I)*ALOG(X)+B(3,I)*ALOG(X)**2)/2.15
              RETURN
              END
```

```
@FTN,SORFI TRAK,DOSES

MS NOW IS        135 TRKS LIMIT   10.00 MEM MAX IS      21000 WORDS LIMIT         65000
FTN 8R1  *10/22/79-08:35(,0)
              SUBROUTINE DOSES
        C
        C        THIS SUBROUTINE DETERMINES THE NUMBER OF FATALITIES RESULTING
        C          FROM A PARTICULAR RELEASE. IN ADDITION IT COMPUTES THE
        C          NUMBER OF PEOPLE EXPOSED AND THE RATIO OF FATALITIES TO
        C          NUMBER OF PEOPLE EXPOSED.
        C                 COMMON BLOCK VARIABLES ARE DEFINED IN MAIN PROGRAM
        C                 PEOP; NUMBER OF PEOPLE EXPOSED FOR PARTICULAR RELEASE
        C                 PEOPT; TOTAL PEOPLE EXPOSED FOR THIS CUTSET
        C                 I0; IDENTIFIES WINDSPEED
        C                 I1; IDENTIFIES ATMOSPHERIC STABILITY CLASS
        C                 M0; IDENTIFIES ZONE
        C                 M1; IDENTIFIES POPULATION DENSITY
        C                 I2; IDENTIFIES ISOPLETHS
        C                 L0; IDENTIFIES ORGAN
        C
              COMMON/AA/AMIN,HT,J,CMIN,PRT2,QTY
              COMMON/BB/AREA,CHI,XDST
              COMMON/CC/ICUT,L1,LL,KEY
              COMMON/DD/DEP,CNV1,CNV2,IORG
              COMMON/EE/TFAT,PEOPT,FATRAT,TOTFAT
              COMMON/HH/TIME
              INTEGER PRT2
              DIMENSION AREA(5,4,11),CHI(5,4,11),DEP(4,5),TOTFAT(5,4,4,5)
              DIMENSION TFAT(5,4,4,5,5),FATRAT(5,4,4,5),ANS1(4),J(5)
              DIMENSION CNV1(5,5),CNV2(5)
              IF(L1.EQ.1) PEOPT=0.0
              GO TO 25
         25   DO 100 I0=1,5
 1            DO 100 I1=1,4
 2            DO 100 M0=1,4
 3            DO 100 M1=1,5
 4            IF(L1.EQ.1) TOTFAT(I0,I1,M0,M1)=0.0
 4            TFAT(I0,I1,M0,M1,L1)=0.0
 4            PEOP=0.0
 4            PEOPL=0.0
 4            IF(QTY.LE.0.0) GO TO 110
 4            DO 200 I2=1,11
 5            PP=AREA(I0,I1,I2)*DEP(M0,M1)*CHI(I0,I1,I2)*QTY
 5            IF(KEY.EQ.ICUT.AND.PRT2.GE.7)PRINT 150,
 5           +I0,I1,I2,M0,M1,AREA(I0,I1,I2),DEP(M0,M1),CHI(I0,I1,I2),
 5           +QTY,PP
 5      150   FORMAT(1H ,5(I2,2X),5(1PE10.3,2X))
 5            PEOPL=PEOPL+PP
 5            PEOP=PEOP+PP/(CHI(I0,I1,I2)*QTY)
 5      200   CONTINUE
 4      110   PEOPT=PEOPT+PEOP
 4            DO 300 L0=1,IORG
 5            DOSE=PEOPL*CNV1(L0,L1)*TIME*3600/10**6
 5            FAT=DOSE*CNV2(L0)
 5            TFAT(I0,I1,M0,M1,L1)=TFAT(I0,I1,M0,M1,L1)+FAT
 5            TOTFAT(I0,I1,M0,M1)=TOTFAT(I0,I1,M0,M1)+FAT
 5            IF(KEY.EQ.ICUT.AND.PRT2.GE.6)PRINT 160,
```

```
5                 +I0,I1,M0,M1,L0,PEOPL,CNV1(L0,L1),TIME,DOSE,CNV2(L0),FAT,
5                 +TOTFAT(I0,I1,M0,M1)
5          150     FORMAT(1H ,5(I1,2X),7(1PE10.3,2X))
5          500     CONTINUE
4                  IF(QTY.LE.0.0) PEOP=1.0
4                  FATRAT(I0,I1,M0,M1)=TFAT(I0,I1,M0,M1,L0)/PEOP
4          100     CONTINUE
                   RETURN
                   END
```

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$FTN,SORFI TRAK,RISK1

MS NOW IS        155 TRKS LIMIT   10000 MEM MAX IS      21100 WORDS LIMIT        55000
FTN RK1   *10/22/79-08105(,0)
              SUBROUTINE RISK1(PRT2,RSKA)
      C
      C          THIS SUBROUTINE COMBINES THE FATALITIES CALCULATED IN DOSES
      C            WITH SITUATION PROBABILITIES TO DETERMINE THE RISKS INVOLVED
      C
              COMMON/CC/IOUT,LT,LL,KEY
              COMMON/EE/TFAT,PEOPT,FATRAT,TOTFAT
              COMMON/FF/PRB,RSKT,PO,PS,PZ,PD,PC
              COMMON/II/SHIPS
              INTEGER PRT2
              DIMENSION TFAT(5,4,4,5,5),PRB(5,4,4,5),FATRAT(5,4,4,5),
             +TOTFAT(5,4,4,5),RSKT(5,250)
              DIMENSION PO(5),PD(4,5),PS(5,4),PZ(4),PC(250)
              IF(IOUT.EQ.1.AND.LT.EQ.1) RSKA=0.0
              RSKT(LT,IOUT)=0.0
              DO 200 IO=1,5
              DO 200 II=1,4
              DO 200 MO=1,4
              DO 200 MI=1,5
      C          CALCULATE TOTAL PROBABILITY
              PRB1=PO(IO)*PS(IO,II)*PZ(MO)*PD(MO,MI)*PC(IOUT)
              PRB(IO,II,MO,MI)=PRB1*SHIPS
      C          CALCULATE RISK
              RS=PRB(IO,II,MO,MI)*TFAT(IO,II,MO,MI,LT)
      C          CALCULATE RISK TO AN INDIVIDUAL
              RSA=PRB(IO,II,MO,MI)*FATRAT(IO,II,MO,MI)
              TFT=TFAT(IO,II,MO,MI,LT)
              RSKA=RSKA+RSA
              IF(PRT2.LT.5.OR.(IOUT.NE.KEY.AND.KEY.NE.0)) GO TO 400
              PRINT 300,IO,II,MO,MI,TFT,PRB(IO,II,MO,MI),RS
      300     FORMAT(1H ,'IO ',I1,2X,'II ',I1,2X,'MO ',I1,2X,'MI ',I1,2X,
             + 'FAT ',1PE10.3,2X,'PRB ',E10.3,2X,'RISK ',E10.3)
      400     CONTINUE
      200     CONTINUE
              RETURN
              END
```

```
@FTN,SORF1 TRAK,TABLE

MS NOW IS      135 TRKS LIMIT  10000 MEM MAX IS      21000 WORDS LIMIT        55000
FTN 8R1  *10/22/79-08135(,0)
                SUBROUTINE TABLE(ICUT,LL,TOTFAT,PRB,TAB,YRNG1,DELRNG)
          C
          C         THIS SUBROUTINE EXAMINES THE FATALITIES AND THE RESPECTIVE
          C           PROBABILITIES AND CONSTRUCTS THE RISK SPECTRUM
          C                   TAB: TABLE OF PROBABILITIES THAT COMPRISES ABSCISSA
          C                   YRNG1: UPPER LIMIT OF ORDINANCE
          C                   YRNG2: LOWER LIMIT OF ORDINANCE
          C                   DELRNG: ORDINANCE PLOTTING INTERVAL
          C                   CHK: LOG OF FATALITIES UNDER CONSIDERATION
          C
                INTEGER YRNG1,YRNG2
                DIMENSION TOTFAT(5,4,4,3),PRB(5,4,4,3),TAB(52)
                IF(ICUT.NE.1) GO TO 50
                DO 25 KO=1,52
1               TAB(KO)= 0.0
1         25    CONTINUE
          50    DEL= 3.0/50.0
                DO 100 IO=1,5
1               DO 100 I1=1,4
2               DO 100 MO=1,4
3               DO 100 M1=1,3
4               IF(TOTFAT(IO,I1,MO,M1).LE.0.0) GO TO 100
4               CHK= ALOG10(TOTFAT(IO,I1,MO,M1))
4         C        CHECK FOR FATALITIES LESS THAN ONE
4               IF(CHK.LT.0.0) GO TO 900
4         C        CHECK FOR FATALITIES GREATER THAN OR EQUAL TO 1000
4               IF(CHK.GE.3.0) GO TO 901
4         C        SEQUENCE THROUGH ABSCISSA TO FIND PROPER ENTRY POINT
4               DO 99 JK=1,50
5               IF(CHK.LT.(JK*DEL).AND.CHK.GE.((JK-1)*DEL)) GO TO 902
5         99    CONTINUE
4               PRINT 903
4         903   FORMAT(1H ,'ONE ELEMENT DID NOT FACTOR INTO THE TABLE')
4               GO TO 100
4         C        ADD PROBABILITIES TO PROPER ABSCISSA LOCATION
4         900   TAB(1)= TAB(1)+PRB(IO,I1,MO,M1)
4               GO TO 100
4         901   TAB(52)= TAB(52)+PRB(IO,I1,MO,M1)
4               GO TO 100
4         902   TAB(JK+1)= TAB(JK+1)+PRB(IO,I1,MO,M1)
4         100   CONTINUE
                YMIN=1.0
          C        CHECK FOR LAST CUTSET
                IF(ICUT.NE.LL) GO TO 500
          C        ACCUMULATE SPECTRUM VALUES TO OBTAIN CURVE
                DO 200 JK=1,51
1               TAB(52-JK)=TAB(52-JK)+TAB(53-JK)
1               IF(TAB(52-JK).LT.YMIN.AND.TAB(52-JK).NE.0.0)YMIN=TAB(52-JK)
1         200   CONTINUE
1         C        DETERMINE PLOTTING PARAMETERS
                IF(TAB(1).EQ.0.0) TAB(1)=1.0
                YMA=ALOG10(TAB(1))
                YMN=ALOG10(YMIN)
```

```
          YRNG1= INT(YMX)
          YRNG2= INT(YMN)-1
          DELRNG=(YRNG1-YRNG2)/56.0
    800   RETURN
          END
```

```
@FTN,SORFI TRAK.TABLE1

MS NOW IS      135 TRKS LIMIT  1000 MEM MAX IS      21000 WORDS LIMIT        55000
FTN 8R1   *10/22/79-06:05(,0)
              SUBROUTINE TABLE1(TAB)
      C
      C          THIS SUBROUTINE PRINTS THE RISK SPECTRUM VALUES
      C                    ANM1: SORTING BUCKET LOWER LIMIT
      C                    ANM2: SORTING BUCKET UPPER LIMIT
      C
              DIMENSION TAB(52)
              PRINT 100
      100     FORMAT(////1H,T51,'*****  RISK CURVE DATA  *****',//)
              PRINT 110
      110     FORMAT(1H,T54,'(R A N G E)',T71,'(PROBABILITY OF BEING IN)',/
             +T75,'THAT',2X,'RANGE')
              DEL=5.0/50.0
              ANM1= 0.0
              ANM2= 1.0
      C          PRINT FIRST BUCKET
              PRINT 130,ANM1,TAB(1)
              DO 120 JK=1,50
              ANM1=10**((JK-1)*DEL)
              ANM2=10**(JK*DEL)
      C          PRINT INTERMEDIATE BUCKETS
              PRINT 130,ANM1,TAB(JK+1)
      130     FORMAT(1H,T25,1PE9.3,' OR MORE FATALITIES ',T82,1PE9.3,/)
      120     CONTINUE
              ANM1=1000.0
              ANM2= 1E27
      C          PRINT LAST BUCKET
              PRINT 140,ANM1,TAB(52)
      140     FORMAT(1H,T25,1PE9.3,' OR MORE FATALITIES ',T82,1PE9.3,/)
              RETURN
              END
```

```
@FTN,SORFI TRAK,TABLE2

MS VOM IS       155 TRKS LIMIT  10000 MEM MAX IS     21000 WORDS LIMIT        55000
FTN 8R1  *10/22/79-081050(,0)
            SUBROUTINE TABLE2(YRNG1,DELRNG,TAB)
      C
      C        THIS SUBROUTINE PLOTS THE RISK SPECTRUM FROM DATA CREATED IN
      C          SUBROUTINE TABLE
      C                    YRNG1' ORDINANCE UPPER LIMIT
      C                    DELRNG' ORDINANCE PLOT INTERVAL
      C                    TAB' VALUES TO BE PLOTTED
      C                    LINE' PLOTTING VARIABLE
      C                    YAXIS' PRESENTS YAXIS MARKERS
            INTEGER YRNG1,YAXIS
            DIMENSION TAB(52),LINE(62)
            PRINT 100
      100   FORMAT(1H1,20X,'***** RISK CURVE *****'//)
            YAXIS= YRNG1
            IFLG= 0
            DO 120 JACK=1,38
      C        INITIALIZE PLOTTING VARIABLE
            DO 130 LN=2,52
            LINE(LN)=' '
            IF(JACK.EQ.37) LINE(LN)='-'
      130   CONTINUE
      C        SET ORDINANCE PLOT
            LINE(1)='*'
            P1= YRNG1-(JACK-1)*DELRNG
            P2=P1-DELRNG
            DO 140 JK=1,52
            IF(TAB(JK).LE.0.0) GO TO 140
            CHECK=ALOG10(TAB(JK))
      C        DETERMINE TABLE VALUES IN THIS PLOT RANGE
            IF(CHECK.LE.P1.AND.CHECK.GT.P2)LINE(JK)='*'
      140   CONTINUE
            PRINT 150,(LINE(LN),LN=1,52)
      150   FORMAT(1H ,20X,52A1)
      C        PLOT Y-AXIS MARKERS
            IF(IFLG.NE.1) GO TO 196
            PRINT 191
      191   FORMAT(1H+,T17,'10')
      196   IFLG= 0
            IF(YAXIS.LE.P2.OR.YAXIS.GT.P1) GO TO 195
            PRINT 190, YAXIS
      190   FORMAT(1H+,T19,I3,'*')
            YAXIS= YAXIS-1
            IFLG= 1
      195   CONTINUE
            IF(JACK.EQ.10) PRINT 200
      200   FORMAT(1H+,'EVENTS')
            IF(JACK.EQ.11) PRINT 201
      201   FORMAT(1H+,'PER YEAR')
      120   CONTINUE
            DO 160 JK=1,52
            LINE(JK)=' '
      160   CONTINUE
      C        PLOT X-AXIS MARKERS
```

```
                DO 180 JK=1,J
1               IBPT=(JK-1)*2)+2
1               LINE(IBPT)='*'
1        180    CONTINUE
                PRINT 155,(LINE(LN),LN=1,62)
         155    FORMAT(1H+,20X,62A1)
                PRINT 170
         170    FORMAT(1H ,22X,'0',19X,'1',19X,'2',19X,'3'/21X,
               +5('I0',19X),'I0')
                PRINT 210
         210    FORMAT(1H ,T50,'FATALITIES')
                PRINT 220
         220    FORMAT(1H1)
                RETURN
                END
```

APPENDIX B

DEFAULT VALUES

Variable Definitions Given in Section 3.0

CNV1: Default values do not apply

CNV2: Default values do not apply

DEP (i,j): Units are people/m^2

i	j = 1	j = 2	j = 3
1	3.586E-3	3.170E-4	2.36E-4
2	1.340E-3	3.260E-4	9.20E-5
3	1.536E-3	8.700E-5	7.00E-6
4	1.693E-3	5.000E-5	1.00E-5

DMIN: 100 mrem/yr

FRC: Default values do not apply

HT: 0.0 meters

IORG: Default values do not apply

ISO: Default values do not apply

KEY: 0.0

LEVEL: Default values do not apply

LEVTAB: 0.0

LL: Default values do not apply

PC: Default values do not apply

PD (i,j):

i	j = 1	j = 2	j = 3
1	0.038	0.669	0.293
2	0.115	0.355	0.530
3	0.008	0.173	0.819
4	0.005	0.150	0.845

PRT2: 3

PS (i,j):

i	j = 1	2	3	4
1	0.136	0.202	0.299	0.363
2	0.243	0.274	0.272	0.211
3	0.190	0.290	0.339	0.181
4	0.240	0.312	0.358	0.090
5	0.276	0.348	0.356	0.020

PU (i):

i	
1	0.255
2	0.508
3	0.161
4	0.052
5	0.024

QUTY: Default values do not apply

SHIPS: Default values do not apply.

TIME: 1 hour

V (i):

i	
1	1.0 meters/sec
2	3.5 meters/sec
3	7.0 meters/sec
4	10.0 meters/sec
5	18.0 meter meters/sec

WD: Default values do not apply.

XMIN: 100 meters

APPENDIX C

SAMPLE OUTPUT

****

INPUT TAPE UNIT 2, NOT USED

****

****

THE PRINT OUT PRIORITY IS 4

****

****

THE NUMBER OF CUTSETS ARE 5

****

****

THE NUMBER OF ISOTOPES ARE 5

****

* * * * * * * * * * * * * * * * * R E L E A S E F R A C T I O N * * * * * * * * * * * * * * * * *

CUTSET	PROBABILITY	ISOTOPE 1	ISOTOPE 2	ISOTOPE 3	ISOTOPE 4	ISOTOPE 5
1	2.3000-006	1.0000-001	3.0000-001	3.0000-004	1.2000-006	1.2000-006
2	7.7000-003	1.0000-001	3.0000-001	4.0000-004	1.5000-006	1.0000-006
3	4.4000-005	1.0000-001	3.0000-001	3.2000-005	2.0000-006	2.0000-006
4	4.4000-007	1.0000-001	3.0000-001	3.0000-004	1.0000-005	1.0000-005
5	6.3000-009	1.0000-001	3.0000-001	3.0000-005	1.0000-007	1.0000-007

```
*****************************************************************
*   THIS RUN CALCULATES THE DOSEAGE BASED ON     4  ORGAN(S) *
*****************************************************************


EXCESS DEATHS PER MILLION MAN-REMS FOR ORGAN  1 : 2.000+002

EXCESS DEATHS PER MILLION MAN-REMS FOR ORGAN  2 : 6.000+000

EXCESS DEATHS PER MILLION MAN-REMS FOR ORGAN  3 : 5.000+001

EXCESS DEATHS PER MILLION MAN-REMS FOR ORGAN  4 : 5.000+000


            I S O T O P E  1

   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 1  IS    1.900+000
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 2  IS    4.300-002
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 3  IS    1.600-001
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 4  IS    1.400+005

            I S O T O P E  2

   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 1  IS    4.900-004
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 2  IS     .000
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 3  IS     .000
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 4  IS     .000

            I S O T O P E  3

   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 1  IS    4.300+000
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 2  IS    8.000+000
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 3  IS    2.700+000
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 4  IS     .000

            I S O T O P E  4

   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 1  IS    3.900+001
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 2  IS    2.070+002
   REM/SEC PER UNIT/CUBIC METER FOR ORGAN 3  IS    5.500+001
```

```
REM/SEC PER UNIT/CUBIC METER FOR ORGAN 4  IS     .000

          I S O T O P E  5

REM/SEC PER UNIT/CUBIC METER FOR ORGAN 1  IS   7.000+002
REM/SEC PER UNIT/CUBIC METER FOR ORGAN 2  IS   1.500+004
REM/SEC PER UNIT/CUBIC METER FOR ORGAN 3  IS   1.700+005
REM/SEC PER UNIT/CUBIC METER FOR ORGAN 4  IS     .000
```

THE ATMOSPHERIC PROBABILITIES ARE AS FOLLOWS

WIND SPEED (M/S) U(IO)	IO	P(IO)	B P(I1/IO) I1=1	D I1=2	E I1=3	F I1=4
1.0	1	.255	.135	.202	.299	.363
3.5	2	.508	.243	.274	.272	.211
7.0	3	.161	.190	.290	.339	.181
10.0	4	.052	.240	.312	.358	.090
18.0	5	.024	.276	.348	.356	.020

THE POPULATION DENSITIES ARE AS FOLLOWS

(REGION)	(ZONE) (PEOPLE/SQUARE METER) 1	2	3	4
1	3.586-003	1.340-003	1.336-003	1.693-003
2	3.170-004	3.260-004	8.700-005	5.000-005
3	2.360-004	9.200-005	7.000-006	1.000-005

THE PROBABILITY OF BEING IN ZONE 1 IS .0886

THE PROBABILITY OF BEING IN ZONE 2 IS .2421

THE PROBABILITY OF BEING IN ZONE 3 IS .5701

THE PROBABILITY OF BEING IN ZONE 4 IS .0992

* THE SHIPPING DISTANCE IS 1.00 *

```
*************************************
*  THE MINIMUM DISTANCE IS   100.00  *
*************************************

***********************************************************
*  THE QUANTITY OF ISOTOPE 1 PER SHIPMENT IS    1.500-002  *
***********************************************************

***********************************************************
*  THE QUANTITY OF ISOTOPE 2 PER SHIPMENT IS    4.400+003  *
***********************************************************

***********************************************************
*  THE QUANTITY OF ISOTOPE 3 PER SHIPMENT IS    3.000+005  *
***********************************************************

***********************************************************
*  THE QUANTITY OF ISOTOPE 4 PER SHIPMENT IS    5.600+005  *
***********************************************************

***********************************************************
*  THE QUANTITY OF ISOTOPE 5 PER SHIPMENT IS    5.100+004  *
***********************************************************

*  THE NUMBER OF SHIPMENTS PER YEAR ARE  359.              *

***********************************************************

*********************************************
*   THE MINIMUM CONCENTRATION IS  1.090-009 *
*********************************************

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS         1.994-009     WIND SPEED       1.00     STABILITY CLASS  (B)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS         5.335-003     WIND SPEED       1.00     STABILITY CLASS  (D)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS         8.439-007     WIND SPEED       1.00     STABILITY CLASS  (E)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS         1.748-005     WIND SPEED       1.00     STABILITY CLASS  (F)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS         1.524-003     WIND SPEED       3.50     STABILITY CLASS  (D)
```

```
THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       2.410-007      WIND SPEED      3.50      STABILITY CLASS  (E)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       3.994-007      WIND SPEED      3.50      STABILITY CLASS  (F)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       7.621-009      WIND SPEED      7.00      STABILITY CLASS  (D)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       1.205-007      WIND SPEED      7.00      STABILITY CLASS  (E)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       2.497-007      WIND SPEED      7.00      STABILITY CLASS  (F)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       5.335-009      WIND SPEED     10.00      STABILITY CLASS  (D)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       8.456-008      WIND SPEED     10.00      STABILITY CLASS  (E)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       1.748-007      WIND SPEED     10.00      STABILITY CLASS  (F)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       2.964-009      WIND SPEED     13.00      STABILITY CLASS  (D)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       4.587-008      WIND SPEED     13.00      STABILITY CLASS  (E)

THE X DISTANCE HAS REACHED 1.0*10**5 METERS
THE NEW MINIMUM CONCENTRATION IS       9.711-008      WIND SPEED     13.00      STABILITY CLASS  (F)
```

**** BOUNDRY DISTANCES ****

I0	I1	I2: 1	2	3	4	5	6	7	8	9	10	11
1	1	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
1	2	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
1	3	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
1	4	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
2	1	1.010+002	1.041+002	1.104+002	1.297+002	1.889+002	3.702+002	9.252+002	2.625+003	7.829+003	2.376+004	7.256+004
2	2	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
2	3	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
2	4	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
3	1	1.010+002	1.040+002	1.098+002	1.259+002	1.775+002	3.276+002	7.715+002	2.085+003	5.970+003	1.746+004	5.147+004
3	2	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
3	3	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
3	4	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
4	1	1.010+002	1.039+002	1.094+002	1.256+002	1.724+002	3.084+002	7.055+002	1.853+003	5.193+003	1.490+004	4.312+004
4	2	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
4	3	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
4	4	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
5	1	1.010+002	1.035+002	1.090+002	1.235+002	1.645+002	2.802+002	6.070+002	1.529+003	4.153+003	1.148+004	3.223+004
5	2	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
5	3	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005
5	4	1.010+002	1.042+002	1.110+002	1.326+002	2.010+002	4.171+002	1.100+003	3.261+003	1.009+004	3.170+004	1.000+005

**** DIFFERENTIAL ISOPLETH AREAS ****

I0	I1	I2: 1	2	3	4	5	6	7	8	9	10	11
1	1	8.139+003	2.795+001	1.272+002	7.154+002	4.141+003	2.659+004	1.954+005	1.612+006	1.382+007	1.184+008	9.919+008
1	2	3.980+003	1.144+001	5.290+001	2.996+002	1.752+003	1.128+004	9.412+004	6.986+005	6.054+006	5.271+007	4.528+008
1	3	2.775+003	8.652+000	3.990+001	2.248+002	1.295+003	8.070+003	5.702+004	4.397+005	3.464+006	2.661+007	1.919+008
1	4	1.843+003	5.864+000	2.715+001	1.533+002	5.877+002	5.607+003	4.059+004	3.249+005	2.696+006	2.236+007	1.819+008
2	1	8.004+003	2.655+001	1.143+002	6.122+002	3.553+003	2.001+004	1.372+005	1.054+006	9.481+006	6.859+007	5.454+008
2	2	3.980+003	1.144+001	5.290+001	2.996+002	1.752+003	1.128+004	9.412+004	6.986+005	6.054+006	5.271+007	4.528+008
2	3	2.775+003	8.652+000	3.990+001	2.248+002	1.295+003	8.070+003	5.702+004	4.397+005	3.464+006	2.661+007	1.919+008
2	4	1.843+003	5.864+000	2.715+001	1.533+002	5.877+002	5.607+003	4.059+004	3.249+005	2.696+006	2.236+007	1.819+008
3	1	7.556+003	2.554+001	1.019+002	5.178+002	2.634+003	1.491+004	9.423+004	6.689+005	5.022+006	3.815+007	2.864+008
3	2	3.980+003	1.144+001	5.290+001	2.996+002	1.752+003	1.128+004	9.412+004	6.986+005	6.054+006	5.271+007	4.528+008
3	3	2.775+003	8.652+000	3.990+001	2.248+002	1.295+003	8.070+003	5.702+004	4.397+005	3.464+006	2.661+007	1.919+008
3	4	1.843+003	5.864+000	2.715+001	1.533+002	5.877+002	5.607+003	4.059+004	3.249+005	2.696+006	2.236+007	1.819+008
4	1	7.777+003	2.455+001	9.597+001	4.749+002	2.391+003	1.282+004	7.773+004	5.296+005	3.833+006	2.817+007	2.052+008
4	2	3.980+003	1.144+001	5.290+001	2.996+002	1.752+003	1.128+004	9.412+004	6.986+005	6.054+006	5.271+007	4.528+008
4	3	2.775+003	8.652+000	3.990+001	2.248+002	1.295+003	8.070+003	5.702+004	4.397+005	3.464+006	2.661+007	1.919+008
4	4	1.843+003	5.864+000	2.715+001	1.533+002	5.877+002	5.607+003	4.059+004	3.249+005	2.696+006	2.236+007	1.819+008
5	1	7.649+003	2.364+001	8.595+001	4.117+002	1.973+003	1.002+004	5.573+004	3.610+005	2.459+006	1.709+007	1.184+008
5	2	3.980+003	1.144+001	5.290+001	2.996+002	1.752+003	1.128+004	9.412+004	6.986+005	6.054+006	5.271+007	4.528+008
5	3	2.775+003	8.652+000	3.990+001	2.248+002	1.295+003	8.070+003	5.702+004	4.397+005	3.464+006	2.661+007	1.919+008
5	4	1.843+003	5.864+000	2.715+001	1.533+002	5.877+002	5.607+003	4.059+004	3.249+005	2.696+006	2.236+007	1.819+008

**** ISOPLETH BOUNDRY CONCENTRATIONS ****

IO	I1	I2= 1	2	3	4	5	6	7	8	9	10	11
1	1	1.600-003	1.509-003	1.358-003	9.545-004	4.322-004	1.063-004	1.515-005	1.907-006	2.016-007	2.027-008	1.994-009
1	2	7.948-003	7.533-003	6.744-003	4.948-003	2.401-003	6.746-004	1.251-004	1.903-005	2.704-006	3.784-007	5.334-008
1	3	1.483-002	1.404-002	1.255-002	9.139-003	4.485-003	1.325-003	2.837-004	5.652-005	1.205-005	2.928-006	8.436-007
1	4	3.445-002	3.256-002	2.893-002	2.096-002	9.984-003	2.847-003	5.918-004	1.162-004	2.481-005	6.083-006	1.748-006
2	1	4.572-004	4.320-004	3.364-004	2.844-004	1.390-004	3.822-005	5.471-006	8.367-007	9.567-008	1.034-008	1.089-009
2	2	2.271-003	2.152-003	1.927-003	1.414-003	6.850-004	1.927-004	3.573-005	5.438-006	7.725-007	1.081-007	1.524-008
2	3	4.237-003	4.012-003	3.587-003	2.626-003	1.282-003	3.785-004	8.105-005	1.615-005	3.443-006	8.365-007	2.410-007
2	4	9.844-003	9.301-003	8.279-003	5.990-003	2.853-003	8.156-004	1.591-004	3.320-005	7.089-006	1.738-006	4.994-007
3	1	2.285-004	2.164-004	1.953-004	1.433-004	7.817-005	2.418-005	4.610-006	6.568-007	8.210-008	9.604-009	1.090-009
3	2	1.135-003	1.075-003	9.634-004	7.059-004	3.430-004	9.637-005	1.787-005	2.719-006	3.863-007	5.406-008	7.621-009
3	3	2.119-003	2.006-003	1.793-003	1.313-003	6.409-004	1.892-004	4.053-005	8.074-006	1.722-006	4.183-007	1.205-007
3	4	4.922-003	4.651-003	4.139-003	2.995-003	1.425-003	4.068-004	8.454-005	1.660-005	3.545-006	8.691-007	2.497-007
4	1	1.600-004	1.516-004	1.374-004	1.059-004	5.794-005	1.901-005	3.958-006	5.814-007	7.582-008	9.242-009	1.090-009
4	2	7.948-004	7.533-004	6.744-004	4.948-004	2.401-004	6.746-005	1.251-005	1.903-006	2.704-007	3.784-008	5.334-009
4	3	1.483-003	1.404-003	1.255-003	9.139-004	4.485-004	1.325-004	2.837-005	5.652-006	1.205-006	2.928-007	8.436-008
4	4	3.445-003	3.256-003	2.893-003	2.096-003	9.984-004	2.847-004	5.918-005	1.162-005	2.481-006	6.083-007	1.748-007
5	1	8.890-005	8.433-005	7.599-005	6.072-005	3.519-005	1.270-005	2.857-006	4.710-007	6.628-008	8.655-009	1.089-009
5	2	4.415-004	4.183-004	3.747-004	2.749-004	1.334-004	3.748-005	5.930-006	1.057-006	1.502-007	2.102-008	2.964-009
5	3	8.239-004	7.802-004	6.974-004	5.105-004	2.492-004	7.359-005	1.576-005	3.140-006	6.696-007	1.627-007	4.687-008
5	4	1.914-003	1.809-003	1.610-003	1.165-003	5.547-004	1.582-004	3.283-005	6.455-006	1.378-006	3.380-007	9.711-008

**** AVERAGE ISOPLETH CONCENTRATIONS ****

IO	I1	I2 = 1	2	3	4	5	6	7	8	9	10	11
1	1	1.600-003	1.554-003	1.421-003	1.130-003	6.427-004	2.150-004	4.173-005	5.614-006	6.294-007	6.502-008	6.470-009
1	2	7.949-003	7.737-003	7.127-003	5.775-003	3.440-003	1.265-003	2.976-004	4.819-005	7.073-006	9.958-007	1.396-007
1	3	1.493-002	1.443-002	1.325-002	1.073-002	6.399-003	2.408-003	5.974-004	1.219-004	2.485-005	5.609-006	1.473-006
1	4	3.445-002	3.349-002	3.071-002	2.454-002	1.445-002	5.272-003	1.265-003	2.520-004	5.106-005	1.160-005	3.064-006
2	1	4.572-004	4.444-004	4.086-004	3.316-004	1.989-004	7.306-005	1.582-005	2.351-006	2.867-007	3.195-008	3.412-009
2	2	2.271-003	2.211-003	2.036-003	1.650-003	9.830-004	3.616-004	8.218-005	1.377-005	2.021-006	2.845-007	3.989-008
2	3	4.237-003	4.123-003	3.793-003	3.057-003	1.823-003	6.881-004	1.707-004	3.480-005	7.099-006	1.603-006	4.210-007
2	4	9.844-003	9.559-003	8.775-003	7.039-003	4.122-003	1.506-003	3.615-004	7.201-005	1.459-005	3.314-006	8.755-007
3	1	2.286-004	2.224-004	2.055-004	1.702-004	1.077-004	4.356-005	1.061-005	1.759-006	2.354-007	2.848-008	3.285-009
3	2	1.135-003	1.105-003	1.018-003	8.250-004	4.915-004	1.808-004	4.109-005	6.884-006	1.010-006	1.423-007	1.995-008
3	3	2.119-003	2.062-003	1.897-003	1.533-003	9.141-004	3.440-004	8.534-005	1.740-005	3.549-006	8.013-007	2.105-007
3	4	4.922-003	4.784-003	4.387-003	3.519-003	2.061-003	7.531-004	1.808-004	3.600-005	7.294-006	1.657-006	4.377-007
4	1	1.600-004	1.555-004	1.444-004	1.207-004	7.837-005	3.325-005	8.503-006	1.510-006	2.123-007	2.683-008	3.221-009
4	2	7.949-004	7.737-004	7.127-004	5.775-004	3.440-004	1.265-004	2.975-005	4.819-006	7.073-007	9.958-008	1.396-008
4	3	1.483-003	1.443-003	1.325-003	1.073-003	6.399-004	2.408-004	5.974-005	1.219-005	2.485-006	5.609-007	1.473-007
4	4	3.445-003	3.349-003	3.071-003	2.454-003	1.443-003	5.272-004	1.263-004	2.520-005	5.106-006	1.160-006	3.064-007
5	1	8.890-005	8.651-005	8.060-005	6.837-005	4.624-005	2.117-005	6.045-006	1.165-006	1.785-007	2.425-008	3.112-009
5	2	4.415-004	4.299-004	3.959-004	3.208-004	1.911-004	7.030-005	1.598-005	2.677-006	3.929-007	5.532-008	7.757-009
5	3	8.239-004	8.017-004	7.375-004	5.964-004	3.555-004	1.338-004	3.319-003	6.766-006	1.380-006	3.116-007	8.186-008
5	4	1.914-003	1.861-003	1.705-003	1.359-003	8.014-004	2.929-004	7.029-005	1.400-005	2.835-006	6.443-007	1.702-007

CUTSET RISKS

CUTSET	ISOTOPE 1	ISOTOPE 2	ISOTOPE 3	ISOTOPE 4	ISOTOPE 5
1	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000
4	3.0541-012	5.5736-011	2.5939-009	2.1505-003	5.3095-008
5	.0000	.0000	.0000	.0000	.0000

***** RISK CURVE DATA *****

(R A N G E)	(PROBABILITY OF BEING IN) THAT RANGE
.000 OR MORE FATALITIES	3.389-003
1.000+000 OR MORE FATALITIES	6.431-008
1.122+000 OR MORE FATALITIES	6.431-008
1.259+000 OR MORE FATALITIES	6.431-008
1.413+000 OR MORE FATALITIES	6.431-008
1.585+000 OR MORE FATALITIES	.000
1.778+000 OR MORE FATALITIES	.000
1.995+000 OR MORE FATALITIES	.000
2.239+000 OR MORE FATALITIES	.000
2.512+000 OR MORE FATALITIES	.000
2.818+000 OR MORE FATALITIES	.000
3.162+000 OR MORE FATALITIES	.000
3.548+000 OR MORE FATALITIES	.000
3.981+000 OR MORE FATALITIES	.000
4.467+000 OR MORE FATALITIES	.000
5.012+000 OR MORE FATALITIES	.000
5.623+000 OR MORE FATALITIES	.000
6.310+000 OR MORE FATALITIES	.000
7.079+000 OR MORE FATALITIES	.000
7.943+000 OR MORE FATALITIES	.000

8.913+000 OR MORE FATALITIES	.000
1.000+001 OR MORE FATALITIES	.000
1.122+001 OR MORE FATALITIES	.000
1.259+001 OR MORE FATALITIES	.000
1.413+001 OR MORE FATALITIES	.000
1.585+001 OR MORE FATALITIES	.000
1.778+001 OR MORE FATALITIES	.000
1.995+001 OR MORE FATALITIES	.000
2.239+001 OR MORE FATALITIES	.000
2.512+001 OR MORE FATALITIES	.000
2.818+001 OR MORE FATALITIES	.000
3.162+001 OR MORE FATALITIES	.000
3.548+001 OR MORE FATALITIES	.000
3.981+001 OR MORE FATALITIES	.000
4.467+001 OR MORE FATALITIES	.000
5.012+001 OR MORE FATALITIES	.000
5.623+001 OR MORE FATALITIES	.000
6.310+001 OR MORE FATALITIES	.000
7.079+001 OR MORE FATALITIES	.000
7.943+001 OR MORE FATALITIES	.000
8.913+001 OR MORE FATALITIES	.000
1.000+002 OR MORE FATALITIES	.000
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1.259+002 OR MORE FATALITIES	.000
1.413+002 OR MORE FATALITIES	.000
1.585+002 OR MORE FATALITIES	.000
1.778+002 OR MORE FATALITIES	.000
1.995+002 OR MORE FATALITIES	.000
2.239+002 OR MORE FATALITIES	.000

2.512+002 OR MORE FATALITIES	.000
2.818+002 OR MORE FATALITIES	.000
3.162+002 OR MORE FATALITIES	.000
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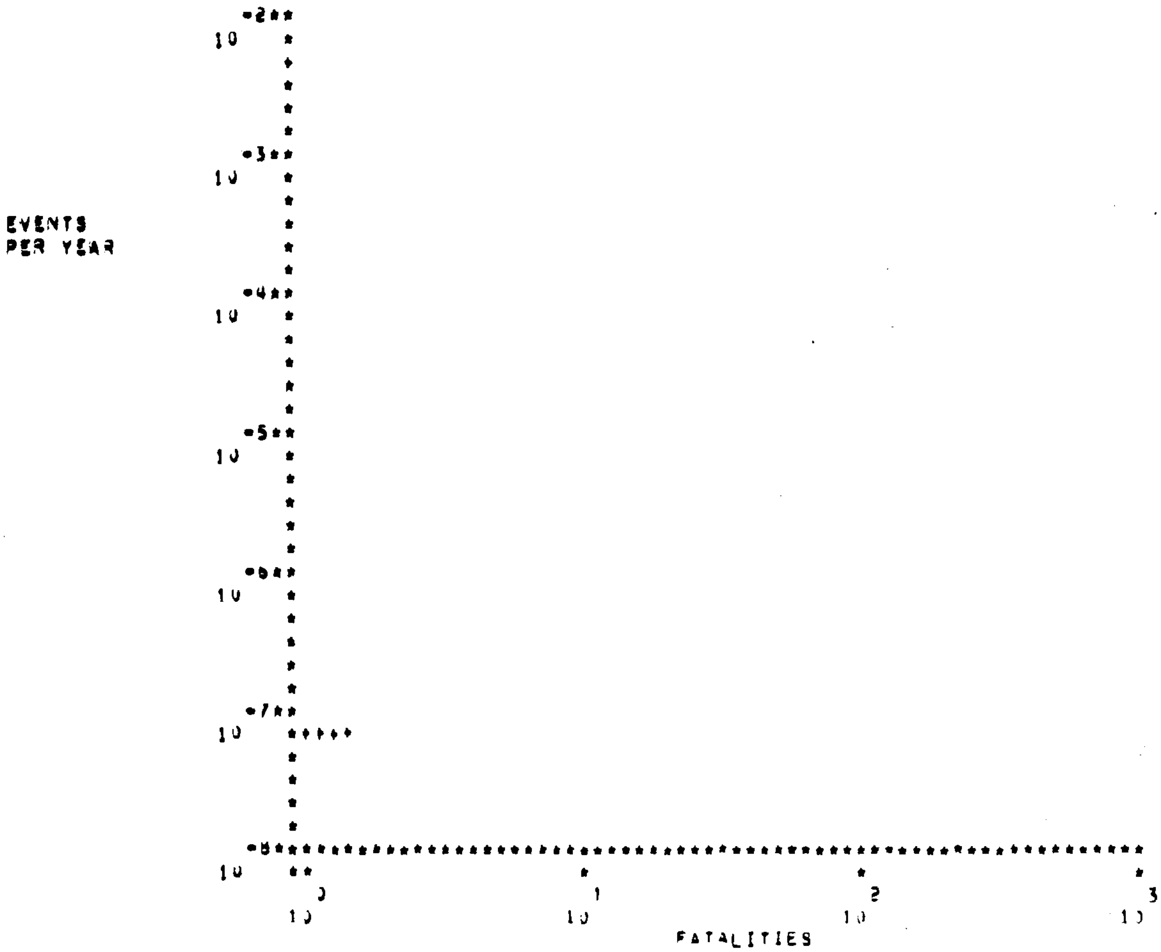
4.467+002 OR MORE FATALITIES	.000
5.012+002 OR MORE FATALITIES	.000
5.623+002 OR MORE FATALITIES	.000
6.310+002 OR MORE FATALITIES	.000
7.079+002 OR MORE FATALITIES	.000
7.943+002 OR MORE FATALITIES	.000
8.913+002 OR MORE FATALITIES	.000
1.000+003 OR MORE FATALITIES	.000

***** RISK CURVE *****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-2
10
-3
10
-4
10
-5
10
-6
10
-7
10
-8
10
0
10
1
10
2
10
3
10
FATALITIES

```
***************************************************************
*                                                             *
*   ACCUMULATED INDIVIDUAL RISK IS       4.1299-010           *
*                                                             *
***************************************************************

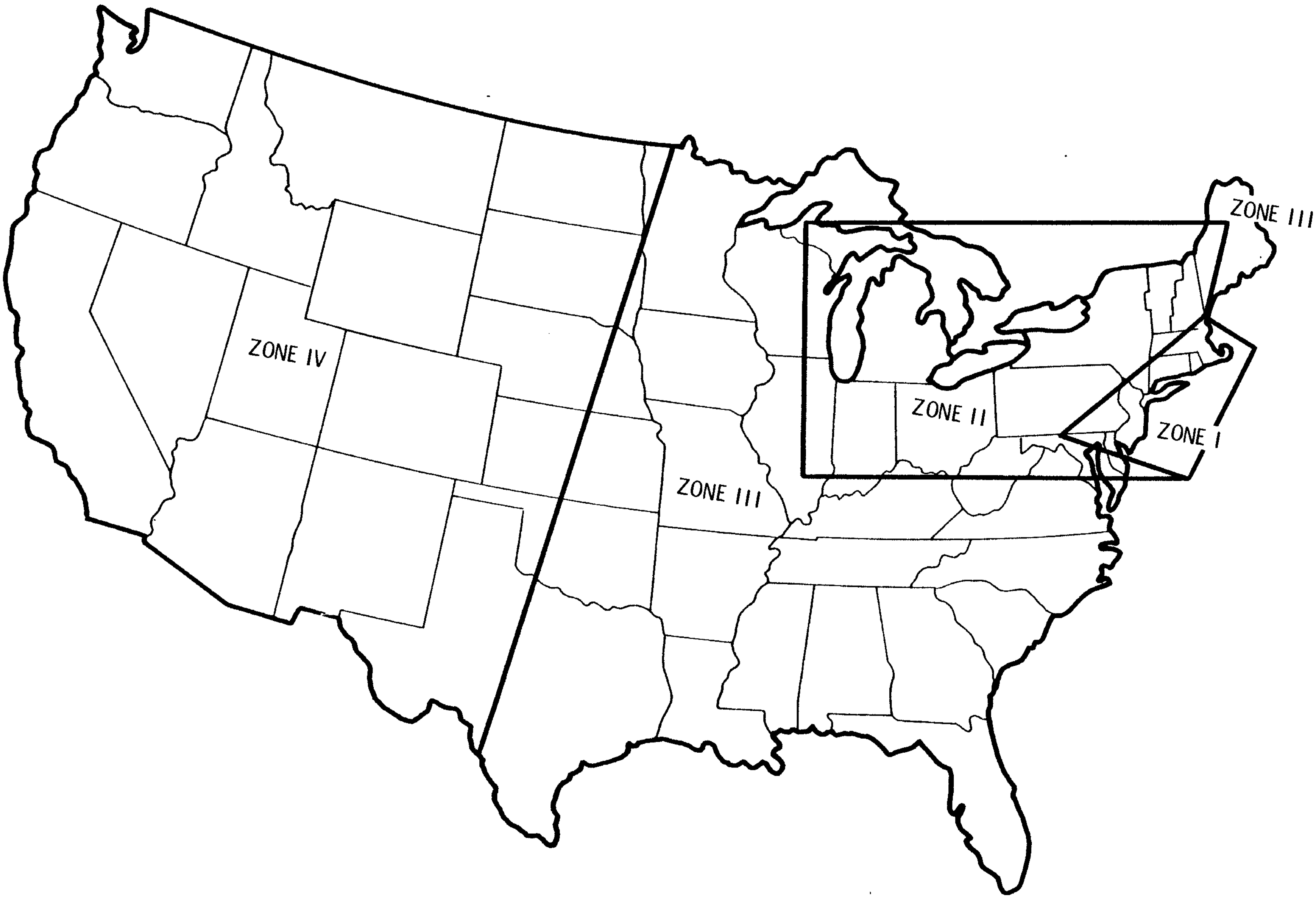
******************************************************************************************
*   THE ESTIMATE OF EXPOSED POPULATION BY        ISOPLETH SWEEP IS          1.5629-003   *
******************************************************************************************

                                  ****** T H E   T O T A L   R I S K   I S ******
                                                        1.006-007

@FIN
```

APPENDIX D

POPULATION ZONES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