RISKIND: An Enhanced Computer Code for National Environmental Policy Act Transportation Consequence Analysis*

B.M. Biwer, D.J. LePoire, and S.Y. Chen

Argonne National Laboratory
Argonne, Illinois

for submission to

WM '96 Conference
February 25-29, 1996
Tucson, Arizona

sponsored by

WM Symposia, Inc.

*Work supported by the U.S. Department of Energy, Assistant Secretary for Environmental Management, under contract W-31-109-ENG-38.

RISKIND: An Enhanced Computer Code for National Environmental Policy Act Transportation Consequence Analysis*

B.M. Biwer, D.J. LePoire, and S.Y. Chen
Argonne National Laboratory

ABSTRACT

The RISKIND computer program was developed for the analysis of radiological consequences and health risks to individuals and the collective population from exposures associated with the transportation of spent nuclear fuel (SNF) or other radioactive materials. The code is intended to provide scenario-specific analyses when evaluating alternatives for environmental assessment activities, including those for major federal actions involving radioactive material transport as required by the National Environmental Policy Act (NEPA). As such, rigorous procedures have been implemented to enhance the code's credibility and strenuous efforts have been made to enhance ease of use of the code. To increase the code's reliability and credibility, a new version of RISKIND was produced under a quality assurance plan that covered code development and testing, and a peer review process was conducted. During development of the new version, the flexibility and ease of use of RISKIND were enhanced through several major changes: 1) a Windows™ point-and-click interface replaced the old DOS menu system, 2) the remaining model input parameters were added to the interface, 3) databases were updated, 4) the program output was revised, and 5) on-line help has been added. RISKIND has been well received by users and has been established as a key component in radiological transportation risk assessments through its acceptance by the U.S. Department of Energy community in recent environmental impact statements (EISs) and its continued use in the current preparation of several EISs.

INTRODUCTION

The RISKIND computer program was developed by Argonne National Laboratory under the support of the U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The program was developed for analyzing the potential radiological health consequences to individuals or specific population subgroups exposed to radiation associated with the transportation of spent nuclear fuel (SNF). RISKIND is designed to address the local, scenario-specific (i.e., "what if") concerns frequently encountered in environmental assessment activities (including public scoping processes) performed under the National Environmental Policy Act (NEPA) of 1969 or other environmental regulatory requirements. As such, rigorous procedures have been implemented to enhance the code's credibility and strenuous efforts have been made to enhance ease of use of the code.

BACKGROUND

Currently, RISKIND is used in conjunction with the latest version of RADTRAN, RADTRAN 4 (1), for performing comprehensive transportation risk assessments (2,3). RADTRAN was originally developed pursuant to the U.S. Nuclear Regulatory Commission (NRC) report *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (4), which was issued to demonstrate compliance with NEPA.

---

* Work supported by the U.S. Department of Energy, Assistant Secretary for Environmental Management, under contract W-31-109-ENG-38.

The NRC report is primarily concerned with estimating the collective population risk from the transportation of radioactive materials under incident-free or accident conditions. Traditionally, such an analysis has been supplemented by other models so that consequences to individuals or population subgroups could be estimated. These latter analyses are documented in DOE environmental assessment reports (5-9). However, different models were used in these reports, which has resulted in inconsistent approaches and findings subject to uncertainties.

RISKIND (version 0) was initially developed in 1993 (10), in light of public comments and the need for a more complete and consistent methodology for addressing radiological consequence issues. Since that time, RISKIND has undergone a number of substantial improvements and enhancements resulting from user feedback, new methodologies for some models, revised databases, and a peer review process. The new version 1 (11) represents the updated program since its original release.

SCOPE

The major objective of RISKIND is to provide data for addressing public concern regarding the transport of SNF along a specific route. The data consist of calculations of incident-free and accident impacts for a particular radioactive material shipment at specific locations along a truck or rail transport route. Public comments on transportation risk analyses for individuals may include the following scenarios:

- An individual stuck in traffic next to a radioactive materials shipment;
- An individual working near heavily traveled transport routes;
- An individual living near heavily traveled transport routes, such as shipment origin or destination site entrances;
- An individual near rail grade-crossings where accident rates are higher;
- Individuals in an area near a postulated SNF transportation accident location;
- An individual eating locally grown food following a SNF transportation accident; and
- An individual drinking water that has been contaminated by an accidental release near a drinking water supply.

The radiological consequences and health risks from these "what if" situations are of great interest and concern to the public. These concerns can only be addressed on the basis of a methodology that analyzes the risk of a specific situation. Substantial databases and technologies relevant to the transportation of SNF and other radioactive materials have been made available through the efforts of various research organizations. These databases and technologies were used to develop RISKIND in accordance with the needs of the local community.

OVERVIEW

The primary function of the RISKIND code is the estimation of radiological risk to individuals and to local population subgroups under various site-specific environmental settings. The radiological risks analyzed by RISKIND include incident-free transportation as well as accident conditions. The code is designed to be responsive to scenarios associated with truck or rail transport of SNF. Therefore, the coding approach in RISKIND emphasizes the scenario descriptions, environmental settings, receptor locations, and potential health effects. The code also incorporates the latest available methodologies and databases to facilitate the analysis of radiological risks. Figure 1 is a flow diagram of RISKIND showing the radiological risk to an individual from the transportation of SNF or other radioactive materials.

Place Fig. 1 here.

Incident-Free Transportation

Exposure from incident-free (i.e., routine) transportation results solely from the external doses received by individuals from the neutron and gamma radiation emitted from the SNF cask or other radioactive material shipping package. Incident-free exposure includes those occurrences when the transport vehicle is in transit (i.e., moving) or at a stop. The receptors for the in-transit exposure may include the residents living adjacent to a highway or railway and the passengers sharing the traffic route with the transport vehicle; exposed individuals at a stop may include the vehicle inspector, a gas station attendant, a nearby person in a traffic jam, and so forth.

The model used by RISKIND for predicting external exposure is based on dose rates (12) derived specifically for a spent fuel cask and takes into account the ground/air scattering of the emitted gamma or neutron radiation. The model also contains provisions for adjusting the dose rate for changes in cask sizes (i.e., outer radius and length) and provides a realistic, although still somewhat conservative, estimate of the external doses to a receptor.

Accident Conditions

Potential exposure to individuals under accident conditions can occur through many environmental pathways if an accident leads to the environmental release of the radioactive contents of the cask. In RISKIND, the estimated exposure, as well as the resulting health effects, are presented individually and for each potential pathway.

Various scenarios in RISKIND have been characterized according to an array of SNF cask responses as described in the NRC modal study (13). In that study, all accidents are represented by discrete response regions (severity categories). These response regions range from likely events (with minor consequences) to highly unlikely events (with severe consequences). Twenty response regions are characterized according to two major accident parameters: impact force and thermal force (i.e., heat from a fire). Thus, accident conditions would be affected by vehicle speed, object hardness, impact angle and orientation, and fire duration and location. In the NRC modal study, the bounding case release fractions have also been estimated for each response region. All potential accident scenarios are thus fully represented by the 20 response regions.

To support the consistency of release estimates, the SNF radionuclide source inventory was derived from the database developed by ORNL (14,15). In addition, potential release from crud (i.e., a mixture of reactor coolant corrosion products) spalling off (breaking loose from) the fuel rods is also incorporated. The estimate of crud release is based on a study by Sandia National Laboratories (16).

The atmospheric transport module in RISKIND includes models that simulate dispersion phenomena following a short release. RISKIND's transport model estimates levels of air and ground contamination on the basis of specific meteorological conditions, geometry, and elevation of the release. Plume rise from the thermal buoyancy of a release involving fire and dispersion effects near the release are also considered. The uncertainty of the effect of weather conditions on the calculated doses can be considered by constructing a cumulative probability distribution of dose values with wind-rose data for a given site. This probabilistic dose distribution is then used to determine the "median" (50% weather probability) and reasonable "maximum" (95% weather probability) dose values at a given receptor.

The pathway model includes exposure pathways from direct external radiation from the cask (due to loss of shielding), external exposure from the radioactive cloud and ground contamination, and internal exposure from inhalation of radionuclides in the air and potential ingestion of contaminated foods and water.

Health effects to individuals are estimated in terms of expected acute or latent fatalities, latent nonfatal cancer incidence, and latent adverse genetic effects from short-term exposure during initial plume passage and long-term exposure originating from deposited radioactive material. Acute fatalities are estimated using the latest NRC health effects model (17,18,19). The latent health effects are estimated using dose-to-risk conversion factors suggested in Publication 60 of the International Commission on Radiological Protection (20).

The consequence model of RISKIND includes provisions for incorporating the consequence reduction benefits of indoor shielding, evacuation, interdiction of contaminated foods, and other protective actions such as cleanup of contamination to comply with U.S. Environmental Protection Agency (EPA) protective action guide (PAG) levels (21). Consequences can be presented either deterministically (i.e., with fixed accident parameters and weather conditions) or probabilistically (analyzed over the spectrum of accident response regions and weather conditions).

REVISIONS TO RISKIND

Acceptance of the code by the user community is contingent on its flexibility and ease of use (i.e. user-friendliness). Another design goal was the enhancement of risk communication, that is, to help the user better understand and appreciate the complexities of the problems to be analyzed and the relevant input parameters, as well as the resulting consequences. On the basis of these objectives, several major changes were made to the original version of the program (10) prior to release of version 1: a Windows™ point-and-click interface replaces the old DOS menu system, the remaining model input parameters have been added to the interface, databases have been updated, the program output has been revised, and on-line help has been added.

New User Interface

The user interface has been totally revamped. The original DOS menu system has been replaced by the now familiar look and feel of a Windows™ application. The Windows™ interface provides for easy navigation among the input screens and selection of the appropriate program options as well as providing a platform for better graphic displays of the calculated results. Even users unfamiliar with the Windows™ operating system will quickly become accustomed to the intuitive interface. The main input window (Figure 2) provides for selection of the major input options and a quick visual summary of the case under analysis. All input parameters are grouped logically according to function and are only one or two windows away from the main input window. The use of a mouse is preferred for navigating the input windows and displaying results; however, input from the keyboard for navigation is also supported. Another benefit of the Windows™ interface is its support of graphics. The original graphical display of results for certain consequences and risks has been enhanced and upgraded. The user is able to gain a better understanding of the results through studying the data in a clearer pictorial format.

Place Fig. 2 here.

Model Input Parameters

To enhance the flexibility of the program, the remaining model input parameters for dose calculations previously unmodifiable by the user have been made user accessible. The interface can now accept user-supplied receptor shielding values and dose rate curves for incident-free calculations, and, for accident calculations, user-supplied shipment inventories, release characteristics, the remaining ingestion pathway input parameters, and receptor shielding values.

Receptor shielding values for incident-free and accident calculations had been user selectable from a predefined list, but custom values could not be input. This restriction has been lifted and users may now input their own shielding values for a custom analysis if the data are available.

Previously, the user was confined to the use of the default gamma and neutron dose rate curves for estimating external exposures from stopped or passing shipments. These dose rate curves are based on representative radiation spectra from commercial spent fuel. To accommodate fuel-specific dose rate curves, RISKIND, version 1, is equipped to accept user input values for the dose rate curve coefficients. This new feature allows the user to input external dose rate information that can be derived from realistic data such as actual measurements. In addition, this capability provides the means for adjusting dose rates for nonstandard SNF or other radioactive materials.

Radionuclide shipment inventories input by the user are now supported by RISKIND, version 1. This new feature offers additional capabilities to accommodate fuel types that are outside the spectrum represented by BWR or PWR fuels; thus, the user is able to input a set of specific radionuclides and their respective amounts for nonstandard spent fuel. Furthermore, inventories input by the user offer the flexibility of conducting analyses for shipments of radioactive materials other than SNF.

Shipping cask release characteristics (response region conditional probabilities and radionuclide release and dispersion fractions) can now be input by the user with RISKIND, version 1. The user is able to use the latest available data and can evaluate results using different cask or shipping container designs. This new feature also permits user input of accident classification schemes other than those used in the modal study (13), such as that employed in NUREG 0170 (4).

Potential accident consequences are highly dependent on weather conditions for the dispersion of released radioactivity. RISKIND is now capable of reading joint frequency data in Stability Array (STAR) format. Data in this standard format are widely available, and this new capability frees the user from having to convert data to the format used in RISKIND. The data from the STAR file is averaged over all directions for a complete risk analysis, or, in keeping with the site-specific capabilities of RISKIND, the weather data for a particular direction may be selected for conducting a direction-specific risk analysis.

Databases Revised and Updated

The original SNF radionuclide database (14) has been updated in RISKIND, version 1, with new data (15). These updated data have been qualified by an OCRWM-sponsored peer review as meeting the requirements of the OCRWM Quality Assurance Program.

The dose conversion factor (DCF) file database has been revised and now reflects the values from EPA Federal Guidance Reports (FGR) 11 and 12 (22,23). Dose conversion factors for internal exposure from inhalation and ingestion are taken from FGR 11, and factors for external exposure are taken from FGR 12. The DCF data are now maintained in an ASCII text file that also contains the data format for those who wish to substitute custom values for exposure calculations. This accessibility allows for the analysis of sensitive populations such as children or the elderly, if the appropriate DCFs are available.

Output Revised

The output file has been reformatted for a clearer presentation of results. In addition, a complete input echo of all RISKIND input parameters to the output file has been added in version 1. The presence of the input echo adds a new level of quality assurance and provides a permanent record of the input data used to calculate the accompanying results.

Isopleth contours for ground-level air concentrations and ground contamination are determined for estimating the risks to a population subgroup from a potential accidental release of radioactivity. version 1 reports the number of persons per isopleth and their associated risks separately on an isopleth-by-isopleth basis, as well as collectively. This breakdown of the results in conjunction with graphic plots of the isopleths enables the user to better understand where the highest areas of risk are located in the affected area.

On-Line Help Added

On-line help with explanatory diagrams and definitions of all input parameters has been added to aid the user in program input. Scenario diagrams (Figure 3) are available under the Help menu to aid the user in visualizing the situation to be modeled and to inform the user of the pertinent input parameters. Other diagrams are available that depict various input parameters to help the user understand their meaning. Pressing the F1 function key while a certain input parameter is selected will bring up the Help support with a description of the parameter. Help on individual input parameters may be accessed from the main menu bar as well.

Place Fig. 3 here.

QUALITY ASSURANCE

To establish the credibility of the code, a quality assurance (QA) plan was adopted to cover code development, a peer review process was organized, and benchmarking studies were conducted. The QA plan ensures documentation and traceability of code development. It also provides for user feedback so that future versions of the program will meet user needs and errors will be corrected promptly. Before version 1 of RISKIND was released, it was peer reviewed by experts in transportation risk who approved, with revisions, the models and their implementation. Proper operation of the program was tested through comparison of results with parallel spreadsheet calculations and benchmarking of the different models within RISKIND against other codes with the same or similar models.

CONCLUSIONS

The use of RISKIND supports traditional transportation risk analysis and enhances public acceptance of DOE transportation risk assessments. This acceptance can be attributed to procedures implemented to establish credibility and efforts aimed at increasing the code's ease of use. RISKIND has been well received by users and has been established as a key component in radiological transportation risk assessments in recent environmental impact statements (EISs). RISKIND was used for the final Idaho National Engineering Laboratory SNF EIS (2) and is currently being used for several major DOE NEPA programs, including the Foreign Research Reactor SNF EIS (24). Because RISKIND can now handle radioactive material shipments other than SNF, it was used for the Waste Management Programmatic EIS (3) and is being used in the preparation of the National Ignition Facility EIS and the depleted uranium hexafloride (DUF_6) EIS.

REFERENCES

1. K.S. NEUHAUSER, and F.L. KANIPE, "RADTRAN 4: Volume 3, User's Guide," SAND-89-2370, Sandia National Laboratories, Albuquerque, N.M. (1992).
2. U.S. Department of Energy, "Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement," DOE/EIS-0203-F, Office of Environmental Management, Idaho Operations Office, Idaho Falls, Idaho (1995).
3. S.Y. CHEN et al., "Assessment of Transportation Risk for the U.S. Department of Energy Environmental Management Programmatic Environmental Impact Statement," proceedings of Waste Management '95, February 26-March 2, 1995, Tucson, Arizona, CD-ROM, Folio Infobase (1995).
4. U.S. Nuclear Regulatory Commission, "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes," NUREG-0170 (1977).
5. U.S. Department of Energy, "Environmental Assessment, Deaf Smith Site, Texas," DOE/RW-0069, vols. 1-3, Office of Civilian Radioactive Waste Management (May 1986).
6. U.S. Department of Energy, "Environmental Assessment, Reference Repository Location, Hanford Site, Washington," DOE/RW-0070, vols. 1-3, Office of Civilian Radioactive Waste Management (May 1986).
7. U.S. Department of Energy, "Environmental Assessment, Yucca Mountain Site, Nevada Research and Development Area, Nevada," DOE/RW-0071, vols. 1-3, Office of Civilian Radioactive Waste Management (May 1986).
8. U.S. Department of Energy, "Supplemental Environmental Impact Statement, Waste Isolation Pilot Plant," DOE/EIS-0026-FS, Washington, D.C. (Jan. 1990).
9. U.S. Department of Energy, "Environmental and Other Evaluations of Alternatives for Siting, Constructing, and Operating New Production Reactor Capacity," DOE/NP-0014, vol. 1, Office of New Production Reactors (1992).
10. Y.C. YUAN et al., "RISKIND — A Computer Program for Calculating Radiological Consequences and Health Risks from Transportation of Spent Nuclear Fuel," ANL/EAIS-6, rev. 0, Argonne National Laboratory (Feb. 1993).
11. Y.C. YUAN et al., "RISKIND — A Computer Program for Calculating Radiological Consequences and Health Risks from Transportation of Spent Nuclear Fuel," ANL/EAD-1, Argonne National Laboratory (Nov. 1995).
12. S.Y. CHEN and Y.C. YUAN, "Calculation of Radiation Dose Rates from a Spent Nuclear Fuel Shipping Cask," Transactions of American Nuclear Society, *56:*110-112 (1988).
13. Lawrence Livermore National Laboratory, "Shipping Container Response to Severe Highway and Railway Accident Conditions," NUREG/CR-4829, UCID-20733, prepared for U.S. Nuclear Regulatory Commission (Feb. 1987).
14. K.J. NOTZ et al., "Characteristics of Potential Repository Wastes," vols. 1-6, DOE/RW-0184, prepared by Oak Ridge National Laboratory, Oak Ridge, Tenn., for U.S. Department of Energy, Office of Civilian Radioactive Waste Management (1987).
15. U.S. Department of Energy, "Characteristics of Potential Repository Wastes," DOE/RW-184-R1, prepared by Oak Ridge National Laboratory, Oak Ridge, Tenn., for U.S. Department of Energy, Office of Civilian Radioactive Waste Management (1992).
16. R.P. SANDOVAL et al., "Estimate of CRUD Contribution to Shipping Cask Containment Requirements," SAND-88-1358, Sandia National Laboratories, Albuquerque, N.M. (Jan. 1991).

17. U.S. Nuclear Regulatory Commission, "Health Effects Model for Nuclear Power Plant Accident Consequence Analysis," NUREG/CR-4214, prepared by Harvard School of Public Health (1985).
18. S. ABRAHAMSON et al., "Health Effects Model for Nuclear Power Accident Consequence Analysis," NUREG/CR-4214, rev. 1, U.S. Nuclear Regulatory Commission (1989).
19. S. ABRAHAMSON et al., 1991, "Health Effects Model for Nuclear Power Plant Accident Consequence Analysis, Modifications of Models Resulting from Recent Reports on Health Effects of Ionizing Radiation," NUREG/CR-4214, rev. 1, Part II, Addendum 1, U.S. Nuclear Regulatory Commission (1991).
20. International Commission on Radiological Protection, "1990 Recommendations of the International Commission on Radiological Protection," ICRP Publication 60, Pergamon Press, Oxford, United Kingdom (1991).
21. U.S. Environmental Protection Agency, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," EPA 520/1-75-001-A (1991).
22. K.F. ECKERMAN et al., "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," EPA-520/1-88-020, Federal Guidance Report No. 11, prepared by Oak Ridge National Laboratory, Oak Ridge, Tenn., for U.S. Environmental Protection Agency, Office of Radiation Programs (1988).
23. K.F. ECKERMAN and J.C. RYMAN, "External Exposure to Radionuclides in Air, Soil, and Water: Exposure to Dose Coefficients for General Application Based on the 1987 Federal Radiation Protection Guidance," EPA 402-R-93-076, Federal Guidance Report No. 12, prepared by Oak Ridge National Laboratory, Oak Ridge, Tenn., for U.S. Environmental Protection Agency, Office of Radiation and Indoor Air (1993).
24. U.S. Department of Energy, "Draft Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel; Appendix E: Evaluation of Human Health Effects of Overland Transportation," vol. 2, DOE/EIS-0218D, Assistant Secretary for Environmental Management (1995).

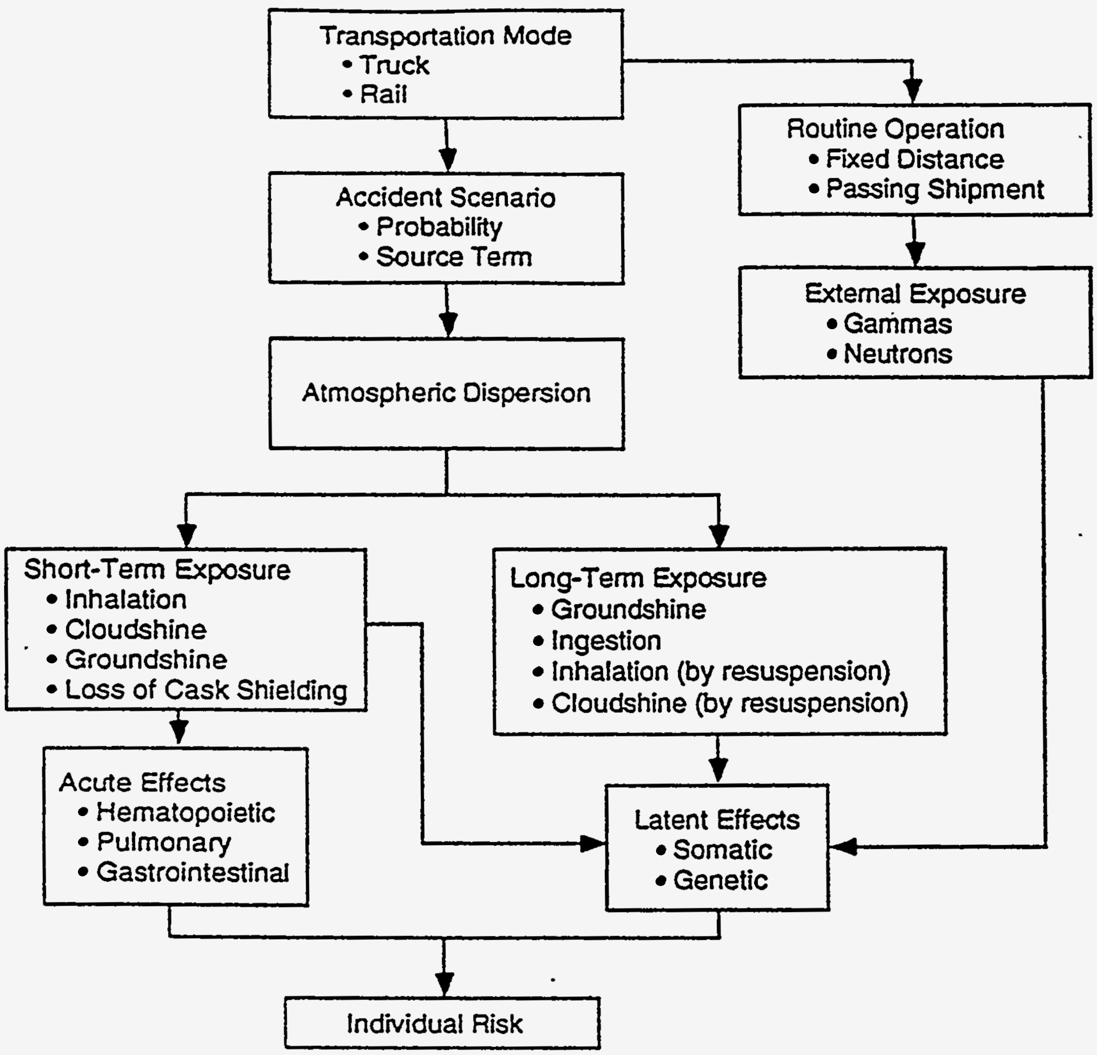

FIGURE 1. Flow Diagram for Calculating the Radiological Risk to an Individual from Transportation of Spent Nuclear Fuel

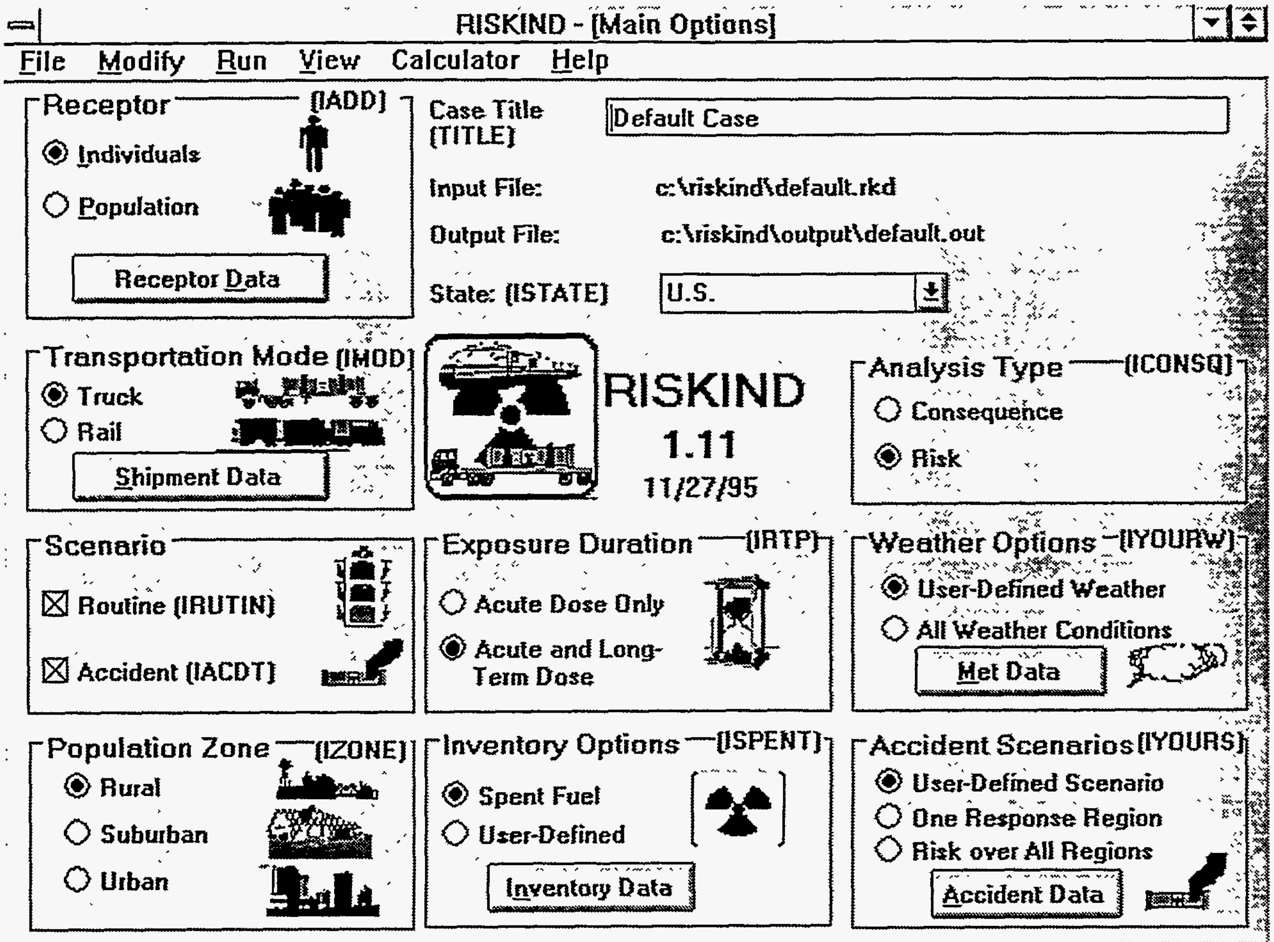

Figure 2. RISKIND Main Input Window

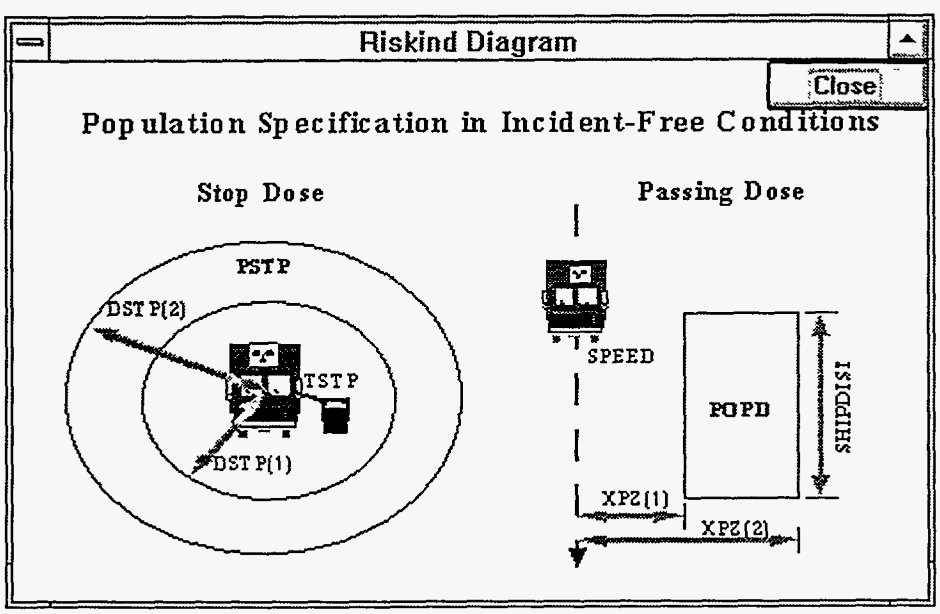

Figure 3. RISKIND On-Line Help Diagram