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Concepts of a Framework for Risk Analysis In Multimedia Environmental Systems

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Summary

Assessments of hazardous waste problems have been a central focus of the U.S. Environmental Protection Agency (EPA) for decades. The U.S. Department of Energy (DOE) has also been more intimately involved in the assessment process during the last decade, especially since the breakup of the Former Soviet Union and the downsizing and subsequent decommissioning and decontamination of nuclear production installations within the DOE complex. An end to the “cold war” has resulted in a major shift in DOE policy to accelerate the cleanup process at DOE installations. Because EPA and DOE are involved with many of the waste problems that exist across the country, concurrent assessment approaches represent the next logical step in intergovernmental cooperation.

Areas of commonality lie in the utility of waste assessment tools that are currently used by both governmental organizations. In areas where there is sufficient overlap, common tools can be combined and mutually supported by both agencies to the betterment of the waste assessment, regulatory, and compliance processes. For example, both EPA and DOE support the development of single-medium and multiple-media models used in the assessment process. Providing each governmental institution access to the others models and assessment techniques, where appropriate, would result in a more consistent and cooperative environment to meet the needs associated with regulatory and compliance issues.

The DOE Office of Environmental Management (DOE-EM), the EPA Office of Research and Development (EPA-ORD), and the EPA Office of Radiation and Indoor Air (EPA-ORIA) have realized the need for a common platform to access and link models with differing attributes to address the problems confronted by both EPA and DOE. The objective of this effort is to 1) combine existing models and approaches that assess hazardous and radioactive releases in and their impacts on the environment into a single framework and 2) structure the framework into a flexible and versatile, user-friendly tool that meets the needs of both organizations. The long-term focuses of this intergovernmental tool are to provide federal facility and EPA-national support for cleanup and cleanup standards, provide decision-makers with traceable assessments, build a structure that represents variable needs to different users, make the best use of available data, and present a “tool-kit” approach that supplies the user with options to select the appropriate model or tool for the job.

The goals are to 1) develop a scientific and technical approach that can integrate diverse modeling components to support DOE and EPA regulatory problems and 2) implement technology transfer of the approach so DOE and EPA can successfully apply it to individual-source term analyses, installation- and complex-wide assessments, and national-regulatory issues. Past resources have already been allocated and invested by DOE and EPA, and it is imperative that as much of the previous effort be used to support current efforts. The decision about which models to use, who gathers the information, and who performs the actual analyses (i.e., implementation of the computer runs) is irrelevant to this study. Activities described herein 1) are intended to support DOE and EPA by making the assessment more flexible and versatile and by providing a platform from which analyses can be performed, and 2) will produce a product that will be relatively “independent” of personnel, models, and organizations. This platform which is titled the *Framework for Risk Analysis in Multimedia Environmental Systems* (FRAMES), should represent a tool that all organizations can use to support their needs.

This report documents the technical and functional requirements of the proposed next generation multimedia model, reviews the historical background of multiple-media model

development and reviews regulatory problems for which multimedia models were used, documents the philosophical foundation of the new framework, and presents detailed documentation of specifications outlining the technical functionality of linking and implementing the next generation of multimedia modeling.

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1.0 Introduction

The U.S. Environmental Protection Agency (EPA) is charged with developing, implementing, and enforcing regulations concerned with protecting human and ecological health from chemical and non-chemical stressors imposed on the environment as a result of anthropogenic activities. In response to existing and emerging regulatory requirements for environmental protection, the U.S. Department of Energy (DOE) has developed and supported a significant program for assessing exposure and risk at its installations.

The EPA and DOE regulatory programs require approaches that address the comprehensive site-specific, and regional- or national-scale human and ecological exposure and risk assessments. Inherently included in these programs are science, policy, stakeholder concerns, practicality, and resource constraints. These programs require scientifically defensible approaches that do not overly burden limited resources. In many instances, resource constraints do not allow for the most detailed, comprehensive analyses, and, in many situations, detailed, comprehensive, quantitative assessments are not necessary in the decision-making process, because they are eventually rolled up into the qualitatively based decision.

Each government program has unique features and criteria that drive the scientific, policy, and decision-making processes. This one “generic” program cannot represent all regulatory programs. This is not to state that the same tools cannot be used by different regulatory programs; in fact, similar tools (e.g., computer models) can be used to support programs with different endpoints.
But, because of the complexities associated with science, policy, politics, stakeholder concerns, practicality, and resource constraints, it is difficult to coordinate all environmental activities into one coherent program. The following needs have been identified for a more comprehensive approach:

- Better coordination, consistency, and consensus on modeling approaches.
- Tangible and usable short-term products, time- and resource-intensive, long-term projects tend to yield few such products.
- More standardization of acceptable approaches.
- Concurrent use of limited site-specific data and more generalized regional- and national-scale information.
- A more holistic approach to address the partitioning and re-distribution of contaminants into multiple media and movement through multiple pathways.
- Probabilistic analyses that provide insight to the conservativeness of the assessment and the importance of each parameter.
- Identification of chemicals, radionuclides, and mixed-waste issues.

The need for environmental systems modeling is growing rapidly due to increasing technical scope and complexity related to questions of risk-based cause and effect and the need to explicitly address cost effectiveness in both development and implementation of environmental regulations. From the technical perspective, the movement is away from chemical and media specificity and toward a more holistic analysis of balancing human-health and ecological risk/hazard. Intermedia-based analyses assess risks/hazards from a more comprehensive environmental systems perspective, crossing the boundaries of scientific disciplines and considering an increased number of interactions between stressors (e.g., contaminants), environmental media (e.g., groundwater, surface water, air, and soil), and receptors.

For example, the Hazardous Waste Identification Rule (HWIR), which is designed to determine exit criteria for constituents below which listed hazardous wastes would be reclassified as nonhazardous wastes under RCRA, addresses many aspects of the environment. Although the release, transport, fate, and impacts to sensitive receptors are important, HWIR also considers broader scientific and policy issues. Typical HWIR assumptions, constraints, and/or endpoints include the following:

1. Consider five different realistic waste management units: ash monofill, land application unit, waste pile, quiescent surface impoundment, and aerated tank.
2. Implement a multiple-transport (groundwater, surface water, air, and soil) and exposure-route (ingestion, inhalation, and dermal contact) approach.
3. Address chemicals and hazardous constituents.
4. Ensure mass balance at and from the source and in the environment at specified locations.
5. Integrate transport and exposure routes to receptors at specified locations.
6. Consider human-health and ecological risk/hazard assessments.
7. Account for total dose to receptor through multiple transport pathways and exposure routes.
8. Anchor the results to real sites.
9. Incorporate site-specific, environmental, physicochemical, geochemical, hydrodynamic, hydrogeologic, meteorologic, climatic, and toxicological characteristics into the assessment.
10. Account for uncertainties in parameter values.
11. Implement an outside, independent peer review.
12. Ensure that the assessment is clear, reproducible, consistent, and scientifically defensible.
13. Ensure that the conclusions drawn from the science are identified separately from policy judgements, and the use of assumptions in the risk assessment are clearly articulated.
14. Address episodic and long-term events, when possible and where appropriate.
15. Address biodegradation and transformation, when possible and where appropriate.
16. Employ applicable models.
17. Employ reasonable chemical characteristics, including solubility limits, when possible and where appropriate.
18. Provide adequate quality assurance and quality control (QA/QC) for the assessment.

Since 1984, DOE has been developing and applying integrated systems software to installation- and complex-wide problems. Tools developed by and for DOE have been applied at SUPERFUND sites and are currently used at a number of universities. Since 1977, DOE researchers have been involved in the development and application of numerous physics-based, multimedia models and approaches, including the following:

- Modular Risk Approach (MRA) (Whelan et al. 1996) -- An approach that is used to integrate the impacts of multiple waste sites, constituents, environmental settings, environmental media, and exposure routes, loosely coupled to GIS capabilities, on an installation-wide scale.

- Remediation Options (ReOpt 1989) -- ReOpt is software that provides suggestions for remedial clean-up alternatives.

- Remedial Action Assessment System (RAAS) (Hartz and Whelan 1990) -- Fully coupled remedial assessment package that investigates remedial alternatives associated with waste-site clean-up and risk reduction associated with the clean-up.
- Multimedia Environmental Pollutant Assessment System (MEPAS) (Whelan et al. 1992) -- Sequentially linked analytically, semianalytically, and empirically based models, which were fully coupled, to address the release, migration, fate, exposure, and impacts to chemicals and radionuclides at past-practice and active waste sites.
- Remedial Action Priority System (RAPS) (Whelan et al. 1986) -- Sequentially linked analytically, semianalytically, and empirically based models, which were fully coupled, to address the release, migration, fate, exposure, and impacts to chemicals and radionuclides at past-practice waste sites.
- Multimedia Contaminant Environmental Exposure Assessment (MCEEA) approach (Onishi et al. 1982) -- Sequentially arranged models, which remained uncoupled, to address typical environmental problems associated with the utility industry.
- Chemical Migration and Risk Assessment (CMRA) methodology (Onishi et al. 1985) -- Sequentially arranged individual detailed numerical models, which remained uncoupled, to address contaminant migration and fate from agricultural watersheds.

Other multi-faceted DOE and EPA environmental tools include the Sandia Environmental Decision-Support System (SEDSS), which is being developed to help facilitate decision-making by helping analysts conceptualize the problem they are trying to address. Although it has never been applied to real-world problems, its prototype is currently under review.

DOE has performed a number of installation-wide assessments, including the following:

- U.S. Department of Energy's (DOE's) Hanford Remedial Action Environmental Impact Statement (HRA-EIS), which evaluated and integrated the impacts associated 1200 past-practice waste sites for 150 constituents, for four land-use options, to an 80-km radius (DOE 1994).
- DOE's Hanford Tank Waste Remediation System (TWRS), which evaluated and integrated the impacts associated 237 tanks containing 177 million curies in 212 million liters to an 80-km radius (DOE 1996).
- Single-Shell Tank Release and Exposure/Risk Assessments, which provided an evaluation 1) of public health impacts for the Hanford High-Level Waste tanks (Buck et al. 1995), 2) for preparing waste characterization plans (Droppo et al. 1991), and 3) for design and characterization recommendations for closure decisions (Buck et al. 1991).

DOE complex-wide assessments include the following:

- DOE's Baseline Environmental Management Report (BEMR), which evaluated DOE's environmental wastes problems from a life-cycle assessment perspective (Gelston et al. 1995).
- DOE's Programmatic Environmental Impact Statement (PEIS), which performed a preliminary risk evaluation of DOE's complex-wide waste sites.

- Spent Nuclear Fuels Environmental Impact Statement (SNF-EIS), which investigated options for stabilizing, transporting, and storing all portions of DOE-owned spent nuclear fuel (SNF), except for K-Basin SNF (DOE 1995a, Whelan et al. 1994).
- K-Basin Environmental Impact Statement (K-Basin EIS), which investigated options for stabilizing, transporting, and storing K Basin SNF (DOE 1995b).
- Molybdenum-99 Environmental Impact Statement (Moly 99 EIS), which investigated options for producing molybdenum-99 to provide medical needs in the nuclear medicine and diagnostic arena (DOE 1995c).
- DOE's Environmental Survey, which performed DOE's first preliminary risk evaluation of DOE's complex-wide waste sites.

Solutions to these problems require an objectively oriented systems approach that

- provides a focused, cost-effective, and defensible analysis for regulatory, compliance, and assessments needs.
- provides a system for that is flexible and versatile for use by those groups actually performing day-to-day analyses (e.g., [architecture and engineering (A&E) firms].
- provides a holistic systems approach to assessments.
- assesses both radioactive and hazardous wastes.
- provides standardized protocol for regulatory compliance review.
- integrates existing models that are problem specific, resulting in inclusion of EPA and DOE models.
- provides a framework that is model independent.
- results in framework ownership by more than one department, agency, or company.
- integrates existing site-specific, regional, and national data, resulting in consistent data sets and databases.
- produces short-term useable products.
- establishes an open-architecture protocol for future development.
- meets decision-maker's needs for probabilistic and risk assessments.

Single-medium and multimedia models are used within regulatory programs to help meet the growing need for environmental systems modeling. The HWIR list alludes to the benefits that can be gained from incorporating multimedia modeling into the national rule-making process, but the multimedia modeling is only one component within the overall structure. The design of the approach and associated components, which allows for a smooth integration and application of the multimedia tools, represents the bulk of the effort.

The goal is to 1) develop a scientific and technical approach that can integrate diverse modeling components to support DOE and EPA regulatory problems and 2) implement technology transfer of the approach to DOE and EPA so they can successfully apply it to source term analyses, assessments, and regulatory issues. As much of the previous effort as possible must be used to support current efforts. This study is intended to support DOE and EPA by 1) making the assessment more versatile, 2) providing a platform from which analyses can be performed, and which will produce a product relatively “independent” of personnel, models, and organizations. The platform described in this report, *Framework for Risk Analysis in Multimedia Environmental Systems* (FRAMES), represents a tool that all organizations can use to support their needs.

2.0 Environmental Modeling Frameworks

2.1 Historical Background

Over the past 35 years, medium specific models have been and will continue to be developed in an effort to understand and predict environmental phenomena, including fluid-flow patterns (e.g., groundwater, surface water, and air), contaminant migration and fate, human or wildlife exposures, impacts from specific toxicants to specific species and their organs, cost-benefit analyses, impacts from remediation alternatives, etc. The evolution of multiple-media assessment tools has followed a logic progression, as illustrated by Figure 1:

- In 1959, the Stanford Watershed Model (SWM) was developed and represented one of the first "integrated" models, as it linked multiple processes by simulating the land-phase of the hydrologic cycle for an entire watershed.
- In 1969, Oak Ridge National Laboratory presented the Unified Transport Approach (UTA), which coupled (i.e., "hard-wired") detailed numerical models, describing individual environmental media (e.g., groundwater, air, surface water, and soil). Because 1) the models were difficult to understand, operate, modify, and maintain; 2) data it operate the models were generally unavailable; and most importantly 3) computer power to drive the system was lacking at the time, the UTA did not progress into general use.
- In 1984, the first fully coupled sequential multimedia model, which accounted for temporally and spacially varying contamination within designated media, was introduced. Each medium-specific model was "hard-wired" into the system, so replacing medium-specific components was not built into the system. These multimedia models were made possible with the introduction of desk-top computing.
- Around 1990, the development of large multi-purpose frameworks began, which "hard-wired" a suite of codes together and investigated, not just the distribution of contaminants in the environment, but relationships between a suite of issues deemed valuable (e.g., regulatory criteria, data quality objectives, CERCLA and RCRA processes, etc.).

In all of these approaches, individual components (or models) are "hard-wired" into the systems, and to a certain degree, the legacy of the original model that has to be forced into the system is compromised. Any changes to the components will invariable result in changes to the system, because these systems were not designed to accommodate change.

If significant modifications are required in these existing systems, the changes tend to be cumbersome, as illustrated by Figures 2 and 3. Figure 2 illustrates the interrelationships and connections between components composing an existing system. In multiple-component systems, models, modules, attributes, or subroutines are usually linked to each other in the typical "spider-web" arrangement. Each time a new attribute is added to the system, connections (e.g., data processor or mathematical algorithm) are arranged between the new feature and the existing ones. In many instances, modifications to the actual programs themselves must be initiated, thereby changing the legacy of the model. Experience has clearly demonstrated that modifications within the "spider-web" construct many times results in unnecessary and unexpected changes in other components. Although changes can be made, the process tends to be time- and resource-consuming.

A “cleaner” approach for incorporating new models, modules, attributes, or subroutines is to reduce the number of variations in the connections so that existing and new attributes maintain their original legacy, realizing that some relatively minor modifications may be necessary. If the interaction and connection of components is focused at the interface between the components, then adding new components or modifying existing ones would not impact the system as a whole, as illustrated by Figure 3. Changes in the assessment do occur over the life of the project, and a system should be able to adjust (within reason). By specifying interface specifications, models, modules, databases, and other frameworks can now effectively communicate, as each one will know *a priori* the connection requirements (e.g., “telephone numbers”) for communication.

Significant changes also occur with the computational power of computers, programing languages, new and innovative concepts and approaches, more enhanced databases, and access to new and improved databases, etc. Also, different organizations and people require different relationships between models and assessments to meet needs. A framework is needed to allow their users the flexibility to construct, combine, and couple attributes that meet their specific needs, without unnecessarily burdening the user with extraneous capabilities. The framework should represent a platform that links elements together and does not represent the models that are linked to or within it. Changes to elements that are linked to or within FRAMES does not change the framework.

2.2 Regulatory Use of Modeling Systems

Over the years, the U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency (EPA) have used models to support federal regulatory and compliance activities associated with National Environmental Policy Act (NEPA), Comprehensive Environmental Response Compensation and Liability Act (CERCLA), and Resource Conservation and Recovery Act (RCRA). Within the past 15 years, these agencies have also begun to support and maintain frameworks from which users can access and implement, in one sitting, multiple models. Because multiple media modeling and the linkages of models are still in their relative infancy, standardized protocols describing these linkages do not exist.

The EPA has sponsored the production of a number of desktop computer-based alternatives over the last 15 years. Moskowitz et al. (1992) analyzed 127 computer models. Other agencies and companies -- DOE, U.S. Department of Defense (DoD), Nuclear Regulatory Commission (NRC), National Aeronautic and Space Administration (NASA), and the Electric Power Research Institute (EPRI) -- as well as foreign organizations have been involved in sponsoring computer-based, multimedia-type modeling systems. Other sources for PC-based pollutant models -- which serve as module alternatives for inorganic (non-fertilizer) chemical, organic chemical, and/or radionuclide transport, fate, bioaccumulation, and effects -- include academic institutions in the United States; Canada, the United Kingdom, Australia, and western European countries. Tables A-1 through A-3 in Appendix A, provide a brief summary of national and international multimedia-type modeling systems. Attributes to some of these modeling systems are presented in Table A-3, with the exception of MEPAS, MMSOILS, and RESRAD, which have been documented by Cheng et al. (1995).

Table A-4 in Appendix A, presents three illustrative EPA software systems that serve as bases for integrating several environmental simulation models. The IMES package is a “merger of a model database and a software system for model selection purposes” (Pardi 1992). The ANNIE-Interactive Development Environment (ANNIE-IDE) tool kit is a “user interface development system for interactive environmental models and... provides the program designer/developer with a program tool kit that follows a consistent methodology for building interactive interfaces" (EPA 1995). PC-GEMS (Graphical Exposure Modeling System) "...supports exposure and risk assessments by providing access to single medium and multimedia fate and exposure models, physical chemical property estimation techniques, mapping, graphics, and statistical analysis programs with related data on environments, sources, receptors and populations..." providing "...analysts with an interactive, easily learned interface to various models, programs, and data needed for exposure and risk assessment" (EPA 1995).

Although these systems are extremely valuable, a more open-ended approach would allow for more modularity and object-oriented design. Model developers will be able to add their models and modules to meet the needs of the assessment as long as they follow framework protocol requirements. The systems listed in Table A-4 are restricted to simply making it easier for the user to select and access independent modeling packages that were available at the time the effort was developed. Some recently developed frameworks *prohibit* the use of legacy code and thereby limit the system's ability to address change.

3.0 A Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)

3.1 Structure

Over the past 10 years, researchers have focused on developing fully integrated, physics-based, intermedia models that allow for a more transparent connection between individual medium-specific modules. These models take a holistic approach to environmental assessment of potential contaminant impacts as they simulate 1) the release of contaminants into the environment, 2) migration and fate through various environmental media (i.e., groundwater, surface water, air, and overland surfaces), and 3) resultant exposures and impacts. The overall scope of these models includes evaluation of on- and off-site impacts from active and inactive sites involving both chemical and radioactive wastes. Although differing in their individual scope, these multimedia models tend to be "analytical" in nature (e.g., mainly compartmental, analytical, semi-analytical, and/or empirical algorithms). Just because numerical and structured-value (e.g., Hazard Ranking System) models are traditionally not associated with the physics-based multimedia models, this should not preclude their use within this holistic approach or from access as an outside model. In addition, there is no reason why a framework cannot be established that accounts for both the level of detail (i.e., resolution) of the models (e.g., structured-value, analytical, and numerical) and the scale of the assessment (e.g., medium-specific, watershed, regional, and global).

A number of government agencies and private companies have used single and multimedia models for federal regulatory and compliance activities associated with NEPA, CERCLA, and RCRA as well as for state regulatory and compliance activities. The advantage is in consolidating these single-medium and multimedia models into one standard tool. Consolidating the best aspects of these models could highlight their strengths and minimize their shortcomings. In addition, EPA and DOE have developed many other useful models that would benefit from access to this new framework (e.g., IEM, EPACMTP, EXAMS, WASP, TOXIWASP, HELP, PRZM, GENII, AT123D, etc.), thereby providing users with greater access to these models. As technology advances, a next-generation framework would eventually be needed to address regulatory, compliance, oversight, and site-specific applications, and would be linked to a GIS to facilitate data transfer and analysis and presentations. This expanded system could also link human-health/ecological impacts with remedial technology assessment, cost analyses, and risk reduction. The new framework (FRAMES) could service various agency's needs in defining soil cleanup levels and waste-site exit-concentration criteria, evaluating risk reduction by remediation technologies, generating end-point cost drivers, meeting regulatory applications, conducting programmatic studies, and assessing site-specific applications. The result could be a compositely constructed system, that greatly enhances versatility and flexibility to allow more focused and cost-effective multimedia modeling assessments.

3.2 Data Linkages and Information Transfer

Within the modeling-based FRAMES resides a collection of computer algorithms that simulate elements of a transport, exposure, and risk-assessment system, including contaminant source and release to environment (including surface hydrology); overland, vadose-zone, saturated-zone, atmospheric, surface water, food-supply (including animals and plants to humans); intake computation, and health impacts. Each of these elements, and many that are not listed, will be represented by separate modules. Each of these modules should:

- be object oriented. An object-oriented module represents a component that is independent of other components. Each component is viewed as an entity, where interactions and linkages occur at interfacing junctions and where a transfer of information can occur. Object-oriented design currently represents the state-of-the-art in design.
- import the data required for execution. The data may be imported from result files contained in FRAMES or directly from the user. It is a requirement of each module to read all data items correctly from the appropriated files in FRAMES.
- execute the model correctly, given the data gathered in the import process.
- correctly export data to FRAMES data files.
- not have data redundancy, as when data are accessible, visible, and transferable to all components. The data-overlap concept is contrary to object-oriented design, and results in a less efficient system. Object-Oriented designs do not usually require data to be visible to all components.

There are three software considerations with respect to data-transfer linkages:

1. Data redundancy: Data redundancy occurs when the same information is stored more than once. Within a given element classification (e.g., vadose zone), certain data requirements exist. For example, moisture content is a traditional characteristic of the vadose zone. Specifying the exact form of the data in each element could limit access by new modules that may be added to the system, and any data storage and retrieval system should not be developed that may limit access. For example, even though two vadose-zone modules require moisture content as a characteristic of the element, one module may require the

information as a dry-mass fraction and the other may require the same information as a volumetric fraction. Mandating the exact form of the characteristics describing the element would mandate wholesale changes to the data input requirements of each module. In addition, this approach would limit flexibility and versatility by not allowing FRAMES to address future new and innovative trends contained in potentially new models trying to gain access to the framework. Therefore, a new system must easily allow for change without constraining access to future developments. The burden to absorb change should never be on the framework; if so designed, FRAMES would become obsolete in a short period of time.

To meet these needs and constraints, FRAMES structures its data linkages to allow for the following types of data files:

- Primary Data Communication Files (PDCF): PDCFs are the data files that are used to transfer information between modules. These files embody the concept of object-oriented design by specifically identifying and segregating data associated with the linkages at the boundaries of the modules.
- Global Input Data (GID) Files: The GID files will be stored where all user input is stored. Each module is responsible for deciding what data are included for itself. The GID files contain Modular User Interface Sections (MUIS). The MUIS represent the user-supplied information that is transferred through the Modular User Interface (MUI). These sections allow for updates to each module, new data requirements for each module, and changes without constraining access to future developments.
- Other Data Files: Under the design, FRAMES has unlimited access to data and databases. Other data files could include, but are not limited to:
  - Imported Data Files: Data files that contain information needed for models. (i.e., laboratory results of soil, air, and water samples, which are typically in spreadsheet for).
  - Exported Data Files: Data files that serve as input to larger assessments [e.g., results of a site assessment are reformatted for efficiency in the Modular Risk Approach (MRA)].
  - Maintained Databases: Databases that are maintained by other individuals (e.g., IRIS for toxicological data, GEMS for population data. etc.).

2. Dynamically Linked Modules: The modules must be linked as the direct result of user selection. This requires strict protocols to determine the validity of various linkages and resolve all data-transfer needs. Linkage concerns include the following:

   - A system should be constructed such that 1) data, specific and unique to each module but not produced by other modules, can be user-supplied and 2) data, specific and unique to each module but produced by other modules, can be supplied by other modules.
   - Individual modules must be linked in such a manner as to facilitate data transfer at the interface between modules.

   File specifications describe how all information is to be stored within the framework and passed between modules. These file specifications are not associated with information storage or transfer within each module, only with the transfer of information to the framework or another module. The input and/or output data files used for transferring information have the following attributes:

- The files should be easily used by the most common modeling languages and software. Typical languages include FORTRAN, C, C++, Pascal, and Visual Basic; typical software includes Excel and Lotus.
- Where appropriate, the files should include both the numerical values and their corresponding units.
- The files should be self-descriptive. When a user with no knowledge of the file or its specifications views the file, the user should be able to correctly interpret the data stored therein.
- As much as possible, the files need to be computer platform independent. Platform independence will allow part of an assessment to be completed on more powerful computers.
- Separate input and output data files should be developed. The input data refer to those required for a successful completion of a module's application. All input data will be stored in the GID file, which is required to successfully operate the module. User input data are isolated from all calculated results to ensure that the sensitivity/uncertainty analysis runs efficiently and aids in the ability to reproduce results. Output data refer to calculated results.

3. A framework User Interface (FUI) must be designed and implemented that will 1) allow for relatively easy inclusion of additional modules and models, 2) promote access to national databases; 3) minimize data-exchange requirements within FRAMES, 4) allow for unlimited access to data, and 5) address linkage concerns. The responsibilities for the FUI need to be established so each module can function within the system without added restrictions but still allow the responsibilities to be defined. The FUI is responsible for the following

   - Ensuring that the modules are connected properly and appropriately.
   - Ensuring that the module has access to an unlimited supply of data, where appropriate.
   - Allowing for unique forms of data entry (i.e., selecting soil properties from a map of the United States or from the Soil Conservation Service soil triangle, or retrieving data directly from sources on the Internet).
   - Establishing protocols for implementing components of the FUI. For example, the FUI will not allow a module to be run until input data requirements through the MUI are complete and data required from other modules are available.
   - Ensuring that if a module behaves inappropriately, then the data for the other modules are protected from the errant module, and inform the user of errant behavior of modules.
   - Managing storage of user data and results.
   - Managing information to inform the user of which modules are available in FRAMES.

Other data linkage and information transfer approaches were also considered in the initial design of the system, although their exclusion does not permanently eliminate them from future consideration as an added feature of the system. One such approach centered on the Master and Key file concept.

The Master file would contain all the descriptions of data needed for the models currently in FRAMES, Parameter Name, Type of Data, Cardinality of Data, User Prompt, Units, Maximum Value, Minimum Value, Long Description, and Relationships to Other Parameters. The Parameter Name is used for identification of the data item. The Type of Data would describe what type of information is to be stored (i.e. Integer, Real, Logical, String). Cardinality of Data is the number of datum values including dimensionality and a count of those items. For example, total porosity would be a scalar data item, but a series of flux rates would be 2 by N matrix. Where N is the number of flux/time pairs. N would also have some maximum value that would need to be described. The User Prompt is the text that is presented to the user when those data are needed. Units are what the data are in when stored. Maximum Value and Minimum Value represent the bounds on the data item. Long Description would include text and graphics that will be presented to the user if additional information is needed for the user to properly fill in data item. Relationships to Other Parameters will impose moving bounds on values. For example, %Sand, % Silt, %Clay and %Organic Matter Content =100 %. Other attributes for the data item could be stored also.

Each module would have an associated Key file that would take data item descriptions from the Master file. Using this approach it would be possible to quickly implement a User Interface (UI) for a module if the descriptions of its data items are in the Master file. The Key file for a model would be a listing of whether a data item described in the Master file is needed by a module. The advantages of this system are that 1) data input to every model would be consistent, 2) if a user wanted to switch between one model and another, and if both models used the same parameters, the overlapping data items would be preserved 3) it is nearly trivial to create a UI for a new model as long as the descriptions are already in the Master file. Drawbacks of this system are that the Master file might need to be changed for any model added to the system the Master file also might need to be changed if a model changed what data item it requires; the difference in Cardinality between the models. For example, one model might assume that Kd is a function of time and space, yet another assumes it is a constant for all time and space. One model would like Kd to be described in the Master file as a X by Y by Z by T matrix, where X, Y, Z, and T have some upper bound; the other would see it as a simple scalar. Similar cases occur in joint frequency data in the air transport modules.

Positive attributes of the Master file and Key file concept are 1) the user interfaces would be consistent in appearance, 2) switching models will preserve data and 3) it is trivial in many cases to create a "new" UI, but maintenance of the Master file would be difficult. FRAMES currently has at least 20 separate models in it, and the inputs to those models change daily to accommodate scientific changes in the model. It has been difficult to get the modelers to not change the specifications of data exchange between the models. Adding the burden of collecting and coalescing like data items would be very difficult.

An alternative approach that has many of the same attributes as the Master file and Key file is using a Script file. The primary difference with this approach is that the information contained in one file in the Master/Key file system is distributed in the Script file approach. The Script file would contain the information description equivalent to the Master file, but rather than being a database of descriptions, the Script file would be closer to an interpreted UI language. PNNL has already done Laboratory Directed Research and Development into such a software package. General User Interface for Data Entry (GUIDE) is a prototype program that allows the user to write a Script file similar in format to Internet HyperText Transfer Protocol (HTTP) Forms but that contains the descriptive information on the parameter. The Script file shares the advantages of consistent, data preserving, and easy implementation of UIs. The data preserving is done by models simply agreeing to use certain parameter names for data items. This is a requirement of either the Master/Key or Script file system. But since the Script file maintenance is distributed to the model writers, FRAMES is not burdened with the additional task of finding agreement among all the modelers who have a model in FRAMES.

Another problem in finding agreement between modelers on parameter is when a parameter has slightly different definition for different models. For example, even though two vadose-zone modules require moisture content as a characteristic of the media, one vadose-zone module may require the information as a dry-mass fraction, but the other may require the same information as a volumetric fraction. Mandating the exact form of the characteristics describing the element would necessitate wholesale changes to the data input requirements of each module; it would limit flexibility and versatility by not allowing FRAMES to address future new and innovative trends contained in potential new models trying to gain access to FRAMES. Therefore, a system must allow change without constraining access to future developments. Otherwise, FRAMES would become obsolete in a short period of time.

FRAMES would benefit from a system that made writing user interfaces for scientific models easier. Making those interfaces consistent and preserving data between models is important as well. But FRAMES at the highest level should not be concerned with the needs of every model, just those of connecting one model to another. Either the Master/Key or the Script file concept are implementable and serve the purpose of FRAMES. The Script file system has the additional advantage that the task of creating a user interface for models is still left to the modeler alone, not to the modelers and FRAMES.

It is clear though that neither the Master/Key or Script file approach is enough for all user interfaces for FRAMES. FRAMES needs to maintain the capability of using any executable as a user interface for a model. This is needed to take advantage of legacy user interfaces as well as legacy models. The minimum requirement of a user interface for a model is that it

1. be object oriented. An object-oriented module represents a component that is independent of other components. Each component is viewed as an entity, where interactions and linkages occur at interfacing junctions and where a transfer of information occurs.
2. import data required for execution. The data may be imported from result files contained in FRAMES or input by the user. It is a requirement of each module that it reads all data items correctly from the appropriated data files in FRAMES.

A model has the minimum requirements that it

1. execute the model correctly, given the data gathered in the import and input processes.
2. correctly export data to FRAMES data files.

3.3 Object-Oriented Design

A structure should be developed so that the type of model employed within it is (more or less) unimportant. In effect, the structure should view all of its components as real-world objects, uninterested in the inner workings of the objects. For example, FRAMES should not discriminate between an analytical or numerical model. If time-varying concentrations at a location are required, FRAMES should not be concerned with the model that produced them. If the objects represent real-world components, the user will be able to conceptualize the problem and construct modules that address the conceptualization.

To develop an “object-oriented” framework, specifications for structuring FRAMES must be identified: 1) the form of the boundary conditions between modules, 2) units, 3) storage protocol for input and output data, 4) user-interface requirements, 5) scale (physical size and attributes of the assessment), 6) mesh resolution (i.e., level of detail associated with the boundary conditions between modules), etc. FRAMES should allow the user to choose models to use. FRAMES should allow the user the option to 1) incorporate these models into the framework as a working module or access the model from outside FRAMES, 2) access outside data, 3) pick and choose and match modules, 4) obtain help/guidance, and 5) interact with other frameworks. FRAMES should represent a constant among the ever-changing models and modules that are replaced over time. By developing an approach that uses an object-oriented framework, a system can be developed that provides a mechanism for using models that have been previously developed, as well as models that will be developed be developed in the future.

Figure 4 represents a framework that encompasses, interacts with, and connects modules that are typically associated with current physics-based multimedia assessments (e.g., MMSOILS, MEPAS, RESRAD, PRESTO, etc.); illustrates how FRAMES surrounds and interacts with medium- or attribute-specific modules; and 3) presents the interrelationships between a FUI and the modules housed within the FUI. Typical modules include those identified in the figure, where modules can be added or deleted depending on the assessment. For example, if ecological or GIS modules are required, they can simply be added, as long as they meet framework specifications. Likewise, a probabilistic module can be added when Monte Carlo assessments are required. The FUI helps the user define the problem, which establishes protocol to 1) select the appropriate modules needed to address the problem, 2) controls the flow of information to and from the modules chosen for the problem, and 3) segregates input from output data by placing the data into special input and output data files (i.e., GIDs and GODs).

Figure 5 presents a more detailed illustration of the actual implementation of a module within FRAMES. As illustrated in Figure 4, each module is contained within the FUI. The user initially interacts with the FUI, identifying the constituents of interest, developing the Conceptual Site Model (CSM), and initiating the sequence of selected modules from within FRAMES and models from outside FRAMES. The FUI input and output data are stored in the GIDs and GODs, respectively. The first module, which is chosen by the user with the help of the FUI, is then initiated as part of the CSM. The first MUI is then activated, and the user inputs the appropriate information for that module. Additional information could also be supplied to the MUI from previous modules. The GIDs and GODs interact with the MUI through a data-processing program (i.e., circles in Figure 5). The output from the MUI is converted to the appropriate units and stored in the GID using a data-processing program. Other parameters calculated from input data (e.g., retardation factors, which are calculated from moisture content, distribution coefficient, and bulk density) are likewise stored in the appropriate GOD for use by succeeding modules (including GIS or sensitivity/uncertainty modules) from within FRAMES or other, outside frameworks.

As Figure 5 shows, the MUI interacts directly with the GIDs and GODs through data-processing programs. The FUI actually initiates each module’s application (i.e., runs the module). A data-processing program reads input from a GID, which originated from the MUI. The boundary conditions for the module are read from a GOD. These boundary conditions may originate from the FUI, MUI, or a model outside of FRAMES. The outside model’s output would be stored in a GOD in FRAMES by way of a data-processing program (see Figure 5). All data from the GIDs and GODs are processed into the appropriate units and formats by data-processing programs, which in effect reformat the information so the individual module does not have to be modified.

After the module is implemented, it writes its information to its normal files and processes selected data output for a GOD by way of a data-processing program. Therefore, multiple data-processing programs may be required for each module. These programs basically convert the information to the correct units and store data within the proper time and space scales, where appropriate. Technical specifications for these data-processing programs should contain as few constraints as possible. Because all input data are stored in a GID, sensitivity/uncertainty analyses are easy to implement. All output is stored in GODs, allowing for easy access and analysis, including plotting, statistical analyses, QA/QC, report writing, summations, etc. As Figure 5 shows, if more than one module was selected by the user, the FUI would call up the next module's UI, and the process would be repeated.

Because the analysis is dependent on the constraints of the problem to be solved, different problems may require different models or features. Any framework should be structured to take advantage of the appropriate models required for the analysis. As opposed to trying to convert all needed models or programs to meet its constructs, FRAMES should provide an access port for these models. Under FRAMES, these models would have access to GODs though a data-processing program. The specifications for this program would identify the format for easy access without unduly burdening the pre-existing model or program. Figure 5 illustrates the means by which these outside programs could access and interact with FRAMES.

3.4 Framework User Interface

The user or an automated-access program (also referred to as a "user") interacts through the FRAMES FUI. The FUI is the interface that accesses the contaminant database and subroutines for setting up the problem and establishing the CSM. The chemical database contains between 500 and 800 chemicals and radionuclides. Information includes physical and chemical characteristics of each constituent, environmental partitioning data, transfer and uptake rates, and exposure and risk data. Databases traditionally used by EPA, DOE, and ICRP are included, where appropriate, so the user can meet specific needs dictated by the problem at hand. The CSM includes the construction of the problem that the user needs solved. With the help of the FUI, the user describes the problem and chooses the appropriate modules and models to address it. All modules under FRAMES would be available for selection from a pop-down menu. The user sequentially selects the appropriate source-term modules, transport pathways, and exposure routes that specifically address the problem. The FUI organizes the selection process to ensure that only appropriate selections are available. All input data to the system resides in GIDs. Input data are segregated from other data so sensitivity/uncertainty analyses can be easily performed within FRAMES. Any input data modified within the FUI would be stored in designated GODs. Access to both GIDs and GODs would be made available to all modules that reside within FRAMES. Both GIDs and GODs would also be available for access by outside frameworks, models, or control programs (see Figure 4). Following selection of the appropriate modules and models, the FUI would automatically call up each individual MUI of the selected modules in the correct order. When the user has interacted with each MUI and addressed all inquiries sequentially, the FUI would implement all analyses in the appropriate order. Therefore, all MUIs would be sequentially accessed and implemented prior to running each of the modules in their appropriate order.

Real-world, object-oriented design represents the foundation of FRAMES. By structuring FRAMES so the objects represent real entities (e.g., 3-m thick, sandy-loam, vadose-zone layer), the FUI is able to visually capture the essence of the CSM for the user. In effect, the FUI offers a tool for “laying out the plumbing” to perform waste site assessments. From 50 to 80% of the learning that is generated occurs during the CSM-development phase (i.e., prior to model simulation). Learning results from asking and answering basic questions such as,

> 'What is connected to what?'
> 'How does the process really work?'
> 'What is consumed when this and that are produced?'.

Once the “plumbing” has been arrayed, the software shifts to serve as a vehicle for tracing the dynamics that are implied by the “plumbing.”

Figures 6 and 7 present very simple illustrative examples of how the user visually constructs the CSM using the FUI. Icons are available that describe the modules housed within the FUI (e.g., source, vadose zone, saturated zone, river, air, receptors, food chain, etc.). The user chooses and connects icons that recreate the actual or potential path of the contaminants as they move from the source to the receptor.

Figure 6 (i.e., Site 1) illustrates the emission of a contaminant from a source, as it partitions to the air (e.g., volatilization or suspension) and to a saturated zone (e.g., leaching or direct discharge). Two receptor locations are identified. Both receptors are breathing air and drinking water contaminated by the source, and risk calculations are being computed for each receptor location. The lines connecting the source to the receptor via the air and saturated zone visually show the path that the contaminant follows.

Figure 7 (i.e., Site 2) illustrates the emission of a contaminant from a source, as it partitions to 1) the air (e.g., volatilization or suspension), 2) the first of two vadose zones (e.g., leaching or direct discharge), and 3) a river (e.g., direct discharge). Three receptor locations are identified. The first receptor is directly in the path of the atmospheric plume emanating from the source and breathes the contaminated air. The second receptor eats contaminated crops that were irrigated from water taken from the river, which was contaminated by the source. The third receptor is directly exposed to contaminated drinking water from contamination that migrated through two vadose zones and a saturated zone to a drinking-water well. Three sets of risk calculations are performed, but only two icons are defined because the assumptions forming the basis of the risk calculations are the same for two of the receptors.Figure 8 presents a detailed illustrative example of what the current FUI looks like and illustrates the release of contaminants from a source (i.e., Hanford Tanks), as it partitions to the air (Hanford Air) and the first of two vadose zones (Zone 1 and Zone 2). Vadose-zone contamination eventually migrates and contaminants the saturated zone (Hanford Aqu), which discharges to two different rivers (Columbia and Yakima). Two receptors are identified (Native American and Adult Pop) and are exposed to air and water contamination that has made its way through three different food chain locations and routes (Richland, Kennewick, and Pasco). The Native American and Adult Pop live in all three locations but have different life styles and breathe air and consume food and water differently. Separate risk calculations are, therefore, computed for each receptor (Native Risk and Adult Pop Risk).

Each icon in Figure 8 contains three circles (see left side of icon in Figure 8) of which only one circle is visible. If the top-most circle (red light on the actual screen) is visible, this denotes that a model has been chosen to represent the icon; this conditions is not illustrated in Figure 8. If the center circle is visible, as illustrated in all but one of the icons (yellow light on the actual screen), then this denotes that the module’s database has been populated. Finally, if the lower-most circle is viable, as illustrated with the “Contaminants” icon, then the module has been run. This street-light approach provides the user with an instantaneous visualization of the status of the assessment.

As one can imagine, the pictures, in Figures 6 through 8, can quickly become very messy and appear to be fairly complex. If the pictures do become too detailed, it conveys to the user that a very complex problem IS being assessed.

In addition to presenting a flow diagram of the CSM, the FUI it is also responsible for coordinating icon names and three-dimensional locations, which are relative to a reference point for the geographic location. For example, nearly all the sites at the Hanford installation in Richland, Washington, are given coordinates related to the most northwest corner of the installation. The third dimension is the elevation of the icon. A unique name is required for each icon, and the same name for two icons implies that the icons are the same icon. By allowing multiple icons with the same name, the FUI can account for different activities impacting the same icon.

Even though the pull-down-icon approach is flexible and versatile, certain protocol are enforced. For example,

- One icon can represent and encompass a rather detailed and complex model type. For example, a source-term release module may include many different types of sources (e.g., elevated and heated stacks, landfills, ponds, etc.), although the source is only represented by one icon.
- Every problem must begin somewhere. In FRAMES, the source represents the beginning, and the user designates what the source is. For example, the source could be designated by groundwater concentrations at a drinking-water well, where no transport calculations are required. The water concentrations would be directly used in any dose/risk computations.
- The FUI does not allow cyclic dependencies. Contamination from a source will not be allowed to cycle through several modules and return to its point of origin, as illustrated by Figure 9. In Figure 9, there is an emission from the source to the air, which then deposits contamination back on the original source. Because the results from one module sequentially interact with the next module, concurrent and simultaneous analyses with feedback loops between modules are not addressed.

3.5 Scale and Resolution Considerations

The world is an extremely complex place. Any attempt to develop a framework that is all-encompassing will result in an extremely cumbersome tool that is difficult to use or contains an undue amount of constraints. The most efficient frameworks are developed to address specific problems. By developing an approach that solves too many broad questions, unnecessary constraints are placed on the system.

If a global assessment is required, then this framework should not have to also meet requirements to address site-specific analyses. This is not to say that a site-specific analysis may not be important, but the site-specific analysis should represent a boundary condition to the global assessment. The temporal, spacial, and data requirements for a global assessment are different from those associated with a site-specific assessment. Frameworks should be developed separately for these differences in scale and resolution, but the different frameworks should be structured so they can communicate with each other. In this manner, the site-specific release at Chornobyl, for example, can be included as a boundary condition to an ensuing regional assessment. Any tool that is developed to solve ALL problems is a tool that usually is too cumbersome to use for most problems. Dividing the problem into manageable components allows for an efficient and effective analysis.

When frameworks are developed to integrate the effects of multiple components, scale must be considered in the development process. Scale is defined as the physical size and attributes of the problem that is being addressed. Four basic scales could be defined as follows: medium-specific, watershed, regional, and global. Medium-specific refers to those models and assessments that address specific media during the analysis, such as, waste site, vadose zone, saturated zone, river, air, estuary, overland runoff, even geochemical modules. In other words, a specific code has been developed to address a particular aspect of the environment. The information is generally site-specific, although regional and national data may be incorporated into the model. Examples of a multimedia framework composed of medium-specific modules include PRESTO, RESRAD, HRS, SSL, MEPAS, MMSOILS, MULTIMED, GEOTOX, SMCM, and DPM. Watershed scale refers to watershed analyses and the aspects of dealing with watersheds as an entity; typical models include DHSVM, ARM, HSPF, CREAMS, and NPS. Similar comments could be made about assessments and tools used on regional and global scales. It should be noted that a model of any level of detail could be associated with each of these scales. For example, analytical and numerical models can be used in a medium-specific assessment; likewise, global assessments are not necessarily limited to numerically based models.

Resolution refers to the temporal- and spacial-mesh resolution associated with the assessment (i.e., the requirements associated with the transfer of data). Although the mesh resolution could be defined a number of different ways, it is defined herein based on the types of assessments that are typically performed. Three mesh sizes have been identified: low, medium, and high. A typical low-resolution approach would be represented by a structured-value approach or an approach that lends itself to being self-contained, even if simple quantitative calculations are involved. With this approach, these models would most likely not be subdivided into components but be used as a single entity; examples include HRS, DPM, and SSL. A low-resolution approach could be associated with any of the four scales identified earlier (e.g., medium-specific, watershed, regional, or global).

A typical medium-resolution approach is physics-based (e.g., compartmental, analytical, empirical, or numerical) and lends itself to “uniform or average conditions” over an area or plane. The assessment is not unduly burdened with detailed temporal and spacial discretizations. Although the type of model may inherently influence the level of resolution (e.g., structured-value for low resolution and analytical for medium resolution), specifications of the boundary conditions between models will tend to dictate the mesh resolution. For example, spacially uniform flow conditions are traditionally associated with a medium-resolution-based problem. Spacially uniform flow conditions could be supplied by an analytically or numerically based model. The boundary conditions dictate the mesh resolution (i.e., medium), not the model that is employed in the assessment.

A typical high-resolution approach is traditionally physics-based, where finer resolution is required both temporally and spacially. For example, the high-resolution framework may require the ability to track three-dimensional variations in time with concurrent interactions at all locations. These types of requirements are typical of numerical models. Although numerical models are traditionally used in these situations, analytical models can also be used, if desired. FRAMES should be flexible enough to allow a less complex model to be used, where appropriate; therefore, the level of detail associated with the model does not dictate the resolution associated with FRAMES; the boundary conditions between modules dictate the resolution.

A matrix correlating mesh resolution with scaling dependency is presented in Table 1. Because no methodology or framework can efficiently and effectively address every level dealing with scale and resolution, the shaded areas in the table represent the resolution and scale envisioned for the first framework silo. Additional silos would be developed for other scale and resolution combinations. Figures 10 and 11 illustrate the interrelationships and interactions between frameworks representing different scales. By housing approaches as they differ by scale and resolution, efficient frameworks can be developed. Because the frameworks have similar constructs, and because GIDs and GODs form the basis of each framework, multiple frameworks can communicate. Because units, types and forms of data and formats are known for each framework, data-processing programs can be developed to access the GIDs and GODS of other frameworks. Therefore, if a medium-specific analysis is required as a boundary condition to a regional analysis, the regional analysis would have access to this assessment, and a data-processing program would transfer the information from the medium-specific framework to the regional framework. Outside access to another model or framework would be similar.

Table 1. Matrix Correlating Mesh Resolution with Scaling Dependency[(a)]

RESOLUTION	**SCALE**			
	MEDIUM SPECIFIC	WATERSHED	REGIONAL	GLOBAL
LOW	▨			
MEDIUM	▨	▨	▨	
HIGH				

(a) Shaded areas represent resolution and scale envisioned for the first framework silo. Additional silos would be developed for other scale and resolution combinations

The scale and resolution category is important for comparing the different modeling systems with FRAMES. The different categories of scale are, but are not limited to, site-specific, field/facility, regional, watershed/airshed, and global. The different resolution categories will include, but not be limited to, screening, analytical, and numerical. It is important to match the scale and resolution requirements of an assessment to the appropriate modeling system. FRAMES is being designed to meet the needs of a single waste site, multiple waste site, and multiple waste site/multiple geographical area assessments. Although FRAMES is being designed for these types of assessments, its design allows for linkages with modeling systems of different scale and resolution for special analysis. Tables A-1 through A-3 in Appendix A, present representative lists of other modeling systems.

3.6 Access to Databases

Considerable effort has been devoted to establishing site- and installation-specific and national databases. Databases exist for meteorological and climatological data (NOAA climatological database), population statistics (U.S. census data), watershed information (U.S. Geological Survey), and chemical toxicity data(IRIS/HEAST), as examples. Direct access to such databases is desirable for the framework because it would allow analyses to be performed with the current data that apply to a specific waste unit, chemical, or situation. Such databases are not likely to have the same levels of availability or methods of access; for example, text-based databases (e.g., IRIS) are more difficult to access and navigate than number-based databases (e.g., GEMS). Therefore, the framework should be flexible enough to access these databases.

Traditional databases that are periodically accessed include, but are not limited to, the following:

- **Population Census Data**: The EPA Office of Air Quality Planning and Standards currently maintains the 1990 census database of population numbers at the block level. They also have software for extraction of data to generate distributions of population about a defined point.
- **NOAA Climatological Database**: The EPA Office of Air Quality Planning and Standards currently maintains a climatological database for over 250 locations in the United States plus several thousand sites for precipitation data. This database and associated software will be included in the review.
  - 184 first-order NOAA weather stations distributed across the nation, which are ready accessible for models like PRZM and CEAM.
  - 97 weather stations across the nation, which are readily accessible for models like HELP.
  - Wind STAR arrays across the nation, which are available from OAQPP SCRAM BBS.
- **USGS Gaging Station Database**: The U.S. Geological Survey has data from a system of surface water gaging stations useful for evaluation surface water transport of contaminants. The availability of these data will be investigated for applicability to the Framework. In the past, these types of data were available through the EPA Graphic Exposure Modeling System (GEMS) software package.
- **Soils Databases**: One soils database is the 1992 National Resources Inventory (NRI)/Soil Interpretations Records database. The PATRIOT database uses the linked 1987 Nation Resources Inventory/SOILS5 database, where the 1987 NRI database reports the occurrence of nearly 62,000 different soil series at 336,000 sample points. The 1992 database should be similar to the 1987 one. Data elements listed for the NRI database (consistent for the 1982, 1987, and 1992 NRIs) include: land cover/use, soils information, irrigation, erosion data for wind and water, streams, wetlands, type of earth cover, and other agriculturally related data such as cropping history.
- **Hydrogeologic Databases**: The API Hydrogeologic Groundwater Database (HGDB), developed by Rice, can be used in groundwater analyses. The database provides site-specific groundwater parameters (aquifer thickness, depth to groundwater, hydraulic gradient, and hydraulic conductivity) collected by independent investigations for approximately 400 hazardous waste units throughout the nation. The geographical

locations of the sites are maintained in the database; data are grouped into twelve hydrogeologic environments, based on the USGS classification of aquifer regions.

- **Toxicological Databases**: Toxicological databases include IRIS and HEAST.
- **Chemical Databases**: Chemical databases include handbooks and databases that are associated with models (e.g., MEPAS, MULTIMED, CHEMFATE , RESRAD, GENII).
- **Exposure Parameter Databases**: Exposure Parameter databases include handbooks and databases that are associated with models (e.g., MEPAS, RESRAD, GENII, CalTOX).
- **Waste Management Unit Databases**: Waste management unit databases include the following:
  - OPPI Survey of Waste Management Units. A survey was conducted in 1986 by Westat Inc. The data included 824 observations on landfills, 1926 observations on surface impoundments, 847 observations on waste piles, 352 observations on land application units. Data includes the area, volume, location, and relative weight of the facility.
  - RCRA Corrective Action Database.
  - HWIR Databases: These databases include, but are not limited to, chemical database for physicochemical properties of the approximately 200 HWIR chemicals and 12 hydrogeologic environments for subsurface characterizations that can be directly implemented.
  - Patriot Database: Meteorological data for 184 first-order NOAA weather stations distributed across the U.S. and soil characteristics from the National Resources Inventory/Soils5 database (62,000 soil series). The emphasis of soil data is for agricultural land uses.

Several options are potentially available for interfacing the databases with the framework including 1) development of a general utility module that is activated at the FUI level, 2) development of a module that can be activated by specific component drivers (e.g., a population database access module activated by the Intake or Health Impact components), and 3) a stand-alone processor (not activated by the FUI or specific components) that generates files that the FUI or user component can reference directly. The first option is the most desirable because it makes the database access available to all modeling components at the highest level of control.

3.7 Protocol for Linking Modules

This section represents a summary of the information that is presented in Appendix B: Module Interface Specifications. For a complete description of any files described below, refer to Appendix B.

A brief list of file extension and meanings are

Global Input Data File	*.GID
Terminal Error File	*.ERR
Source Concentration File	*.SCF
Air Flux File	*.AFF
Water Flux File	*.WFF
Water Concentration File	*.WCF

Atmospheric Transport Output File	*.ATO
Exposure Pathway File	*.EPF
Receptor Intake File	*.RIF
Health Impacts File	*.HIF
Module Description File	*.DES

A FRAMES module contains two major components, the user interface and the model itself. Adding a module into FRAMES consists of describing the module so that the FUI will not use the model improperly. This description of the module is in the DES file for that module. For a module to be useful within FRAMES it needs to conform to the specifications. A module does not need to conform to all the specifications, only the ones that it is expected to interface with other modules. If information is written to a non-specified file, it can be stored and used later by the same module but cannot be used by other modules.

In the list below, extensions that are listed in braces "{}" are optional. A module does not need to read or write them but should create the files that are needed. It is also important to note that a module must create an ERR file, then delete it if the module ran properly, which ensures that, if the module has a component "crash," the system will assume it failed.

Import Tool:
    Read (GID)
    Write(GID,ERR,{WFF,AFF,SCF,WCF,ATO,EPF,HIF,RIF})

Source UI:
    Read (GID)
    Write(GID,ERR)
Source Model:
    Read (GID)
    Write(ERR,{WFF,AFF,SCF})

Air UI:
    Read (GID, {AFF})
    Write(GID, ERR)
Air Model:
    Read (GID,AFF)
    Write(ATO,ERR)

Vadose Zone UI:
    Read (GID,{WFF})
    Write(GID,ERR)
Vadose Zone Model:
    Read (GID, WFF)
    Write(WFF, ERR)

Aquifer UI:
    Read (GID, {WFF})
    Write(GID,ERR)
Aquifer Model:
    Read (GID,WFF)
    Write(ERR, {WFF, WCF})

River UI:
  Read (GID,{WFF})
  Write(GID,ERR)
River Model:
  Read (GID,WFF)
  Write(WCF, ERR)

Overland UI:
  Read (GID,{WFF})
  Write(GID,ERR)
Overland Model: FUIName RunName Site# Overland# Name
  Read (GID,WFF)
  Write(SCF, ERR)

Exposure Pathway UI:
  Read (GID,{WCF, ATO, SCF})
  Write(GID, ERR)
Exposure Pathway Model:
  Read (GID, {WCF, ATO, SCF})
  Write(EPF, ERR)

Receptor Intake UI:
  Read (GID,{EPF})
  Write(GID,ERR)
Receptor Intake Model:
  Read (GID, EPF)
  Write(RIF, ERR)

Health Impacts UI:
  Read(GID, {RIF})
  Write(Gid, ERR)
Health Impacts Model:
  Read (GID, RIF)
  Write(HIF, ERR)

Export Tool:
  Read(GID,{WFF, AFF, SCF, WCF, ATO, EPF, HIF, RIF})
  Write(GID, ERR)

Viewer Tool:
  Read(GID,{WFF, AFF, SCF, WCF, ATO, EPF, HIF, RIF})
  Write(GID, ERR)

The Module Description file is the mechanism that tells the FUI how to run a module. It is a simple format and is used to describe the module and consists of a module type (e.g., vadose zone), short text description, location of UI, location of model, and long text description. The long text description at the bottom of the file includes the following information, which the user will see when presented with a choice of modules:

1. A description of what the model is typically used for

2. Any limiting assumptions (such as on radionuclides; can only do 20 contaminants at a time)
3. Typical time scale of runs
4. Reference to formulation documents
5. Reference to verification documents if they exist
6. Reference to validation documents if they exist
7. Hardware requirements
8. Contact point for question regarding the model

The Error File (ERR) signals an error to the FUI and represents the file that is created at the end of a module component execution., if an error exists. All executables will create the ERR file before **ANY** processing is done and delete it only after **ALL** processing is complete. There is no format for this file, but it will be text information given to the user if the model does not complete properly or crashes. If it exists when control is given back to the FUI, it is read and shown to the user.

3.8 Framework Installation

The FRAMES installation disks comes in three separate installation disk sets. The disk sets are the FRAMES User Interface (FUI), MEPAS, and MMSOILS models. In the current implementation version of FRAMES, the user is **REQUIRED** to install all software in the same directory as the FUI, because this prototype makes no allowances for files and the FUI being in separate locations. Future versions of FRAMES will allow the modules and the FUI to be in separate locations. Also, installation of each disk set follows the same protocol.

In Windows 3.1:
In Program Manager, choose the "File" menu item. Then click on the "Run" sub-menu item. A dialog box will appear. In the text field of the dialog box, type "a:\setup" and press return.

In Windows 95:
From the "Start" menu, choose "Run." A dialog box will appear. In the text field of the dialog box, type "a:\setup" and press return.

Then follow the directions on the screen. Leaving the default directories in the installation is recommended. **Minimally install all three disk sets in the same directory.**

A new Framework group (Windows 3.1) and menu item (Windows 95) have been added to your system. Double click on the FUI icon to run the FUI in Windows 3.1. Windows 95 users simply choose the FUI menu item.

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Appendix A: Aspects Related to Multiple Modeling Frameworks

It is important to view the development of a flexible computerized framework for environmental issues from the perspective of a computer model, which basically can be considered a set of hypotheses. Young (1993) stated that a

> "... mathematical model of an environmental system can be considered as a scientific hypothesis which needs to be tested as a theory about the behavior of the environmental system under study. In this sense, mathematical model building can be viewed as an inherent part of scientific inquiry and, as such, should be carried out as a scientific exercise, conforming to the major tenets of the scientific method."

Table A-1. Initial List of Multimedia Modeling Framework System

Name of Modeling System	Funding Organization(s)	Development Group	Brief Description of Modeling System
MODELS3	EPA Office of Research and Development	National Exposure Research Laboratory/ MCNC/North Carolina State University/System Development Center	The initial version of Models-3 focuses on urban to regional scale air quality simulations of ground level ozone, acid deposition, visibility and fine particulate. The next challenge is to extend the system to handle integrated cross-media assessments.
Groundwater/Surface Water/Soil Modeling System (GMS/WMS/SMW))	DoD/Army, & EPA Office of Radiation and Indoor Air	DoD, U.S. Army Corps of Engineers Waterways Experiment Station (WES), Vicksburg, MS	
Total Human Exposure Risk database and Advance Simulation Environment (THERdbASE)	EPA Office of Research and Development	Harry Reid Center for Environmental Studies - UNLV	THERdbASE is a PC-based computer modelbase and database system that contains exposure and risk related information. The system provides an optimal framework for the construction of a suite of models within a modelbase module that accesses data from a database module.

Table A-1. Initial List of Multimedia Modeling Framework System

Name of Modeling System	Funding Organization(s)	Development Group	Brief Description of Modeling System
Sandia Environmental Decision Support System (SEDSS)	DOE Office of Technology Development, Uranium Mill Tailings Remedial Action Program/NRC Office of Research/EPA Office of Emergency and Remedial Response, Office of Radiation and Indoor Air	Sandia National Laboratory (SNL)	SEDSS is designed to incorporate probabilistic methods for evaluating site safety or remedial options into a decision framework for accommodating the effects of uncertain site-specific information, balancing the costs versus benefits of site data collection, and facilitating a consistent decision approach across all involved or affected parties.
Total Risk from Utility Emissions (TRUE)	EPRI		
Total Risk Integrated Model (TRIM)	EPA Office of Research and Development		

Table A-1. Initial List of Multimedia Modeling Framework System

Name of Modeling System	**Funding Organization(s)**	**Development Group**	**Brief Description of Modeling System**
SELECT	DOE	Orlando Lawrence Berkeley National Laboratory	The purpose of the SELECT project is to provide a computational framework that will support an integrated, scientific assessment of an environmental problem that can be continually updated with the most advanced computational methods, decision tools that primarily focus on selecting cost-effective environmental remediation that maximizes health-risk reduction, and information visualization tools that will enhance communication with stakeholders.

Table A-1. Initial List of Multimedia Modeling Framework System

Name of Modeling System	Funding Organization(s)	Development Group	Brief Description of Modeling System
RESRAD Family of Software	DOE/NRC	Argonne National Laboratory	ANL has developed a series of computer codes for environmental risk assessment. These computer codes can be applied to evaluate sites contaminated with radioactive materials and hazardous chemicals. All of the RESRAD family codes have user-friendly interfaces and provide on-line help messages throughout their operation.
Environmental Decision Support System (EDSS)	EPA Office of Research and Development, National Exposure Research Laboratory	MCNC's North Carolina Supercomputing Center	The current focus of EDSS is air quality. The three main components of air quality are chemistry and transport model, meteorology model to predict atmospheric conditions, and an emissions model. FEDMOD is a modeling tool, developed using an object-oriented design, which allows multiple process models to be coupled to improve simulations of forest ecosystems.

Table A-1. Initial List of Multimedia Modeling Framework System

Name of Modeling System	Funding Organization(s)	Development Group	Brief Description of Modeling System
Forest Ecosystem Dynamics Modeling Environment (FEDMOD)	NASA Office of Mission to Planet Earth	NASA/Goddard Flight Center, Biospheric Sciences Branch and Laboratory for Terrestrial Physics, and Hughes STX Corporation	The Multimedia Model Development Tool was developed as a rapid implementation tool for interactive live display on the Internet.
Ecotox Threshold Software (ET)	EPA Superfund Program		The Superfund Program has initiated a project to develop media-specific benchmark values for those chemicals commonly found in surface water, sediments, and soil samples at sites. The values are referred to as Ecotox Thresholds (ETs) and are defined as media-specific contaminant concentrations above which there is sufficient concern regarding adverse ecological effects to warrant further site investigation.

Table A-1. Initial List of Multimedia Modeling Framework System

Name of Modeling System	Funding Organization(s)	Development Group	Brief Description of Modeling System
Environmental Information System (ENFORMS)	International Earth Science Information Network and EPA	Michigan State University, Department of Computer Science	ENFORMS is an object-oriented, distributed multimedia system consisting of an integrated collection of software tools that allow a user to manipulate disparate data sets through a graphical user interface. The system archive contains a wide variety of information ranging from documents to audio files and animations.

Table A-2. List of International Modeling Systems

Name of Modeling System	Funding Organizations	Development Group	Brief Description of Modeling System
Chemical Exposure Model System (CemoS)		Institute of Environmental Systems Research, University of Osnabruek, Germany	Exposure prediction of hazardous chemicals in air, water, soil, and plants via modular structure object-oriented programming.
Geography-Referenced Regional Exposure Assessment Tool for European Rivers (GREAT-ER)	Environmental Risk Assessment Steering Committee (ERASM) of the Association Internationale de la Savonnerie, de la Detergence et des Produits d'Entretien (AISE) and the Comite Eutopean des Agents de Surface et Intermediaires Organiques (CESIO); Environment Agency of England and Wales; RIVM, Netherlands	Institute of Environmental Systems Research, University of Osnabruek, Germany	An exposure prediction tool that is a linkage of chemical fate models, water quality models and hydrological models within a GIS framework to provide regional environmental risk assessment across the European Union for local river stretches and regional catchments.
Model of Uptake of Organic Chemicals into Plants (PLANTX)	EPA Office of Research and Development	Institute of Environmental Systems Research, University of Osnabruek, Germany	FORTRAN-based generic model of organic chemicals uptake from soil and air and translocation among plant organs.

Leaching Estimation and Chemistry Model (LEACHM)	Cornell University, and USDA Agricultural Research Service	Soil, Crop, and Atmospheric Sciences Department, Cornell University, Utah State University, University of California at Davis; Soil and Irrigation Research Institute, Pretoria, and University of Natal, South Africa	Process-based FORTRAN model of water and solute movement, plant uptake, transformations, and chemical reactions in the soil vadose zone.

Table A-3. Alternative PC-Based Environmental Pollutant Models [aside from MEPAS, RESRAD, and common EPA models(a)]

MODEL NAME:	BIOTRAC	COMIDA	CALDOS	BIOPORT	BIOSHERE/ SYVAC3	LERAM	TRUE-1	CemoS	DECOS
INSTITUTION or COUNTRY:	Canada	USA	Canada	USA/PNNL	Canada	USA	USA/EPRI	Germany	UK
SOURCE CODE AVAILABILITY:	unknown	Yes	unknown	Yes	unknown	Yes	Yes	unknown	unknown
REFERENCE:	b	c	d	e	f	g	h	I	j
ENVIRONMENTAL CATEGORY									
Chemical Source	unknown	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**
Air Transport	**U**		**U**		**U**	**U**	**U**	**U**	unknown
Surface Water	**U**		**U**		**U**	**U**	**U**	**U**	**U**
Vadose Zone	**U**	**U**	**U**		**U**	**U**	**U**	**U**	**U**
Saturated Zone	**U**				**U**		**U**	unknown	unknown
Food Chain	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**
Human Exposure Dose	**U**		**U**				**U**	unknown	**U**
Human Health Impacts							**U**		

(a) EPA (1993). On CD-ROM, where the following software is found: Air, Surface Water, and Groundwater Models; Non-Point Source, Multimedia. Other multimedia models not reviewed include MEPAS, MMSOILS, and RESRAD (Cheng et al. (1995).
(b) Reid and Corbett (1993), Davies et al. (1993), Reid et al. (1994).
© Abbott and Rood (1994).
(d) Zach and Sheppard (1991).
(e) McKensie et al. (1985).
(f) Goodwin et al. (1987).
(g) Hanratty and Stay (1994).
(h) Constantinou and Seigneur (1994).
(I) UFIS (1996a).
(j) Nancarrow et al. (1990).

Table A-4. PC-Based Computer Software Systems Integrating Several Environmental Simulation Models

SYSTEM	PURPOSE
IMES - Integrated Model Evaluation System	Aid in the selection of virtually stand-alone model programs (Pardi 1992).
ANNIE-IDE - ANNIE Interactive Development Environment	Provide a tool kit for building interactive interfaces to individual self-contained programs (EPA 1995).
PC-GEMS - Graphical Exposure Modeling System	Enable easy access and useful utilities to self-contained model programs (EPA 1995).

In effect, several models that are lined together represent sets of multiple working hypotheses. There is a long tradition in the philosophy of science for following the *Method of Multiple Working Hypotheses*. Advanced and argued by the geologist Chamberlin (1897) almost a century ago, well before electricity, much less computers, became a part of our tools for coping with nature. At that time, Chamberlin (1897) advised,

> “In developing the multiple hypotheses, the effort is to bring up into view every rational explanation of the phenomenon in hand and to develop every tenable hypothesis relative to its nature, cause or origin, and to give to all of these as impartially as possible a working form and a due place in the investigation. The investigator thus becomes the parent of a family of hypotheses; and by his parental relations to all is morally forbidden to fasten his affections unduly upon any one.”

More than half a century later, Platt (1964) continued to emphasize this scientific philosophy for impartially conducting investigations:

> “When multiple hypotheses become coupled to strong inference, the scientific search becomes an emotional powerhouse as well as an intellectual one.”

The essence of this approach (i.e., Method of Multiple Working Hypotheses) is that no one hypothesis describing a problem situation should be considered the only path to truth. In this perspective, different models and frameworks (i.e., platforms for linking models) can be considered as different sets of hypotheses. Models are, after all, only abstract representations of the real complexity of nature. Evaluating multiple working hypotheses and showing some to be falsifiable enables investigators and decision makers to maintain some degree of objectivity in analyzing a situation, rather than attempting to "sell" only one possible explanation (e.g., one hypothesis, model, or framework).

A framework embracing a suite of models that are implemented as *objects* in computer software and regarded as *modules* of the framework provides the ability and power for applying some aspects of objectivity associated with the philosophy of the Method of Multiple Working Hypotheses in terms of picking and choosing among alternative modules and models.

A number of environmental object-oriented modeling publications have appeared in the last few years (Bennett et al. 1993; Saarenmaa 1992; Silvert 1993). The lengthy publication by Silvert is easily one of the most thorough tutorials in print on object-oriented computer programming for environmental simulation models. Although written in the context of ecological modeling, his advice applies across the range of environmental modeling,

> "Object-oriented programming offers many advantages for developers of ecosystem models. There is a close connection between objects and populations or other natural groupings, and the concept of inheritance is directly borrowed from the biological literature. With object-oriented programming one can develop models that are simpler and closer to natural ecosystem structure than with procedural languages, it is also possible to modify and refine these models far more efficiently."

But, while object-oriented coding is related to the idea of a framework, it is more than simply object-oriented computer programming.

A number of different kinds of frameworks for non-chemical environmental modeling in various stages of development have been reported in the scientific literature (Rao et al. 1989; Reynolds et al. 1989; Acock and Reynolds 1990; Bennett et al. 1993; Jones 1993; Dakins et al. 1994; He et al. 1994; Reckhow 1994; Saarenmaa et al. 1994; Caldwell and Fernandez 1996). A number of different descriptors have been used in an attempt to capture the essence of or classify these frameworks; typical descriptors include object-oriented, environmental management decision analysis, multiple environmental computer modelbase, environmental planning, and hierarchical objectives. Typical comments in the literature include the following:

- To combat the problems inherent in developing a large, comprehensive, computer model that has inflexible computer codes and lacks user-friendly interfaces for entering inputs and obtaining outputs, Rao et al. (1989) state that,

  > "An attractive alternative is to develop a modular computer code which offers the model user multiple options for modeling a given system process. An efficient, front-end, user-friendly interface can be written such that a potential user can, in fact, customize his own model for a specific application by selecting among the various submodel modules that are available as a part of the computer code."

- In a DOE-funded study by Reynolds et al. (1989) to develop a conceptual framework for a generic, modular structure of vegetation growth, in contrast to the conventional isolationistic working style of most environmental modelers and their monolithic models, the authors state that,

  > "Generic modules will result in the following advantages: (a) it will be easier to validate individual modules; (b) error detection will be simplified; © it will facilitate the interaction of specialists who will not

> have to understand the entire model; (d) individual modules developed along interdisciplinary lines will be more intelligible; (e) long term model maintenance will be easier; (f) it will be easier to interchange code between models, test alternative hypotheses and employ alternative formulations of model structure and (g) the development of models for new systems can be based on existing modules with an emphasis on searching for similarities rather than looking for unique differences."

- The impetus toward framework development has been emphasized by Acock and Reynolds (1990), as they state that,

> "One method to increase participation in model development would be to identify the key processes that need to be incorporated in our models, group related processes into modules to provide a generic modular structure, and specify what the output from each of the modules should be. Given agreement on a structure, any researcher could concentrate on those modules within his area of specialization, collect the data needed to develop or validate those modules, and write improved versions."

- In describing their Geographical Modeling System (GMS), Bennett et al. (1993) state that,

> "The GMS provides an operational framework in which spacial knowledge can be stored and managed, theory can be modeled and tested, and alternative resource management strategies can be evaluated. Our goal is to provide users with the materials and tools needed to construct sophisticated geographic models that accurately represent both the structure and behavior of natural systems. To accomplish this goal we employed object-oriented analysis and design methods to integrate modelbase management and GIS technologies into a single system."

- An environmental management decision analysis framework has been developed under the sponsorship of the U.S. Agency for International Development (U.S. AID) over the last several years, as Jones (1993) notes that,

> "An international team of scientists has recently developed a decision support system for agrotechnology transfer (DSSAT) to estimate production, resource use, and risks associated with different crop production practices. The DSSAT contains crop-soil simulation models, data bases for weather, soil, and crops, and strategy evaluation programs integrated with a user-friendly interface for microcomputers." The DSSAT is identified as a management analysis framework and not a modeling framework because its flexibility resides in being able to select from among a number of models, databases, and management strategy evaluation programs, as opposed to limiting the selection process to only models.

- Dakins et al. (1994) described and applied a risk-based decision framework by noting that,

> "The framework utilizes Monte Carlo uncertainty analysis to examine alternative decisions and to determine the value of information for the problem .... Value-of-Information analysis provides a conceptual framework for assessing the benefits of including a realistic assessment of uncertainty in the decision-making process and the subsequent benefits of reducing this uncertainty."

- He et al. (1994) describe their "Blackboard Interfacing System" (BIS) by noting that,

  > "This BIS provides a mechanism and framework for organizing information or representing knowledge for users to perform model interfacing activities."

- A different type of framework, for decision making and planning, is described by Reckhow (1994) and applied to the eutrophication problem in Lake Okeechobee, Florida. Reckhow (1994) note that,

  > "A decision analytic approach is proposed for environmental planning and analysis under scientific uncertainty. This approach begins with the creation of a planning framework that consists of all relevant objectives and attributes, along with all feasible management options; this planning framework defines the inputs and outputs for subsequent work."

- In Finland, for forest health management, Saarenmaa et al. (1994) state that,

  > "Object-oriented modeling and programming provide new tools for managing this complexity (of the real world), but they also require new techniques for planning the reuse of object bases. ... We then implement this with a computational framework that enables extension and reusability."

- Although they do not allow the use of legacy code, Caldwell and Fernandez (1996) describe their JanuSys generic, object-oriented modeling framework in these terms:

  > "The framework provides a set of rules for designing model objects and simulating their interactions. The generic nature of JanuSys permits applications in which *the number of hierarchical levels and the number of objects in each level are determined dynamically -- as the simulation is running*."

- The Department of Defense, Defense Modeling and Simulation Office (DMSO 1996), is pursuing the framework effort, titled "Conceptual Models of the Mission Space (CMMS)". In the context of military actions, training, combat operations, and others, this could be regarded as a conceptual objectives framework.

It is important to define the *process* by which such a modeling framework can be designed, because no one project can develop frameworks that can encompass situations across multiple time and spacial scales. There are certain specifications for defining a framework and the modules that are to work within it, which must be considered mandatory. Other specifications can be considered to be suggested. Still others can be considered optional and at the discretion of the module developers contributing to the framework implementation. The EPA has used a similar approach in defining the Agency's Locational Data Policy for spacial environmental measurements (EPA 1996a). For many years, module and framework specifications have been promulgated in professional-level standards of documentation for simulation model development; typical references include Swartzman (1979), McLeod (1982), Harrison et al. (1990), CIESIN (1996), CAMASE 1996), IBSNAT (1996), IIASA (1995), UFIS (1996b), and EPA (1996b). Table A-5 presents a summary of the characteristics that the various authors feel are important to include in any documentation of computer models and modules for quality assurance and quality control. The characteristics are listed beneath each author in such a way that the identification of model and module specifications for documentation can be cross-correlated along a given row. Although the information in any particular row may not be exactly the same, it has been subjectively categorized as being similar. Also included in the last column is a subjective description of whether the information in a row is deemed mandatory, suggested, or optional.

Mandatory specifications are required to 1) achieve standardization and quality control so that the computer implementation is adequately documented and useful to others and 2) ensure that various modules within the framework can correctly transfer information. Mandatory specifications refer to high-risk pieces of information that can jeopardize the operation of the entire framework if they are not followed by module developers. For sequential modeling, one such mandatory specification is that there can be *no feedback* connections *between modules*, although feedback dynamics may be allowable within any one module. Another example is that all object that 1) are able to be counted, 2) represent real world entities, or 3) are measurable against an interval or ratio reference scale must have specified dimensional units. In such cases, a number referring to a count or a measurement by itself is meaningless if no units are given by which its magnitude can be interpreted by users.

Some specifications can be considered as suggested, but not mandatory, because they improve the completeness of the documentation of modules, but they do not affect the computer's ability to adequately perform the intended operation. Still, other no-risk optional specifications exist when it makes little difference to other users or to execution of the computational framework software whether or not the user or module developer provides items of information.

A framework consists of a variety of models, considered as modules within the framework, because linkages are possible through user-controlled software interfaces (Rao et al. 1989; Reynolds et al. 1989; Acock and Reynolds 1990). Modules are objects that are programmed as computer software. Recently, Schmidt (1995) emphasized the degree of specification, being mindful of and considering model implementation. During the specification stage he suggests that there are two mandatory requirements an object-oriented specification should meet:

Table A-5. Comparative Documented Source Evidence of Standards for Documenting Computer Models and Modules for Quality Assurance and Quality Control

McLeod (1982)	Harper (1973)	Swartzman (1979)	UFIS (1996a)	CIESIN (1996)	CAMASE (1996)	EPA (1996b)	M=Mandatory S=Suggested O=Optional NA=Not Applicable
ID of sources of antecedent models (pedigree). Current and subsequent models.	Program history	Flow chart of relations of antecedent models for current module.			Parentage for earlier models.	Previous names, related models, and databases.	S
	Resident library name						O
			Mode of execution: interactive or batch		Stand-alone-model?		O
			List of files structure				O
Maximum memory size	Execution program file storage size and executable RAM		Type of computer, operating system, RAM, and disk space	Computer requirements	Minimum hardware requirements and configuration	Hardware requirements	M
Execution time for run				Typical run time			O
Programming language	Programming language		Programming language	Programming language	Programming language	Model software	O

Table A-5. Comparative Documented Source Evidence of Standards for Documenting Computer Models and Modules for Quality Assurance and Quality Control

McLeod (1982)	Harper (1973)	Swartzman (1979)	UFIS (1996a)	CIESIN (1996)	CAMASE (1996)	EPA (1996b)	M=Mandatory S=Suggested O=Optional NA=Not Applicable
			Peripheral software requirements		Other software requirements	Auxiliary software	M
	Latest release version number and date		Model version number		Model version number and date		M
Type and classification	Program archive procedures			Model type and How model functions	Program type		O
	File descriptions and format specifications						M
	User operating instructions						M
Simulation schematic		Environmental system flow chart	Model structure conceptual diagram				M
Exogenous/Endogenous							O
Model logic flow chart		Model “dependency tree”					O

Table A-5. Comparative Documented Source Evidence of Standards for Documenting Computer Models and Modules for Quality Assurance and Quality Control

McLeod (1982)	Harper (1973)	Swartzman (1979)	UFIS (1996a)	CIESIN (1996)	CAMASE (1996)	EPA (1996b)	M=Mandatory S=Suggested O=Optional NA=Not Applicable
				Data shortfalls that prohibit use or degrade performance			O
					Internal mass balance check		O
Real-Time period model is intended to simulate			Time scale, step, and aggregation		Time interval		M
			Spacial scale (range) and aggregations		Basic spacial unit		M
			Object modeled (i.e., spacial scale)		Aggregation level		M
Number of parameters and state variables					Number of state and rate variables		O
Data requirements: sources and quality				Data quality and amount	Number of input variables	Information source	M

Table A-5. Comparative Documented Source Evidence of Standards for Documenting Computer Models and Modules for Quality Assurance and Quality Control

McLeod (1982)	Harper (1973)	Swartzman (1979)	UFIS (1996a)	CIESIN (1996)	CAMASE (1996)	EPA (1996b)	M=Mandatory S=Suggested O=Optional NA=Not Applicable
			Ability to couple inputs to and outputs from other models				O
List of variable names and units			List of state variables		State and rate variables and names		O
			Lists of inputs, key word, abbreviations, descriptions, units, dimensions, and value sources and ranges	Input data required, source of model input, and model output	Input variables, names, bounds, and input checking	Model inputs	M
User changeable parameter names and units, initial conditions, and values of parameters		Parameter values, sources, methods to obtain, and graphs of curve families for nonlinear relations	List of parameter names				M
Methods of estimating parameters and coefficients			Status of calibration and sources of data				M

Table A-5. Comparative Documented Source Evidence of Standards for Documenting Computer Models and Modules for Quality Assurance and Quality Control

McLeod (1982)	Harper (1973)	Swartzman (1979)	UFIS (1996a)	CIESIN (1996)	CAMASE (1996)	EPA (1996b)	M=Mandatory S=Suggested O=Optional NA=Not Applicable
			Required parameter changes when applied to new area				O
		Specific equations, definition of terms, and units	Equation charts for each functional relation in process hierarchy: process name, key words, description, equation type, equation in math notation, boundary conditions, numerical solution, constraints, time and space resolution, equation references	Time and space scales			S/M
Output variable names and units			List of outputs		Number of output variables and names	Model outputs	M

Table A-5. Comparative Documented Source Evidence of Standards for Documenting Computer Models and Modules for Quality Assurance and Quality Control

McLeod (1982)	Harper (1973)	Swartzman (1979)	UFIS (1996a)	CIESIN (1996)	CAMASE (1996)	EPA (1996b)	M=Mandatory S=Suggested O=Optional NA=Not Applicable
			State of model development		Developmental status	Frequency of model updates	O
			Status of model				O
Sources for validation test results			Output variables validation and sources	Validation procedure description	General validation references	QA/QC	S
Sources for sensitivity analysis results							O
Model experience			Limitation conditions for application elsewhere			Model features	S
			Number of current users				O
			Recommended uses aimed at areas of application				O
Simulation run, purposes, and results							O

Table A-5. Comparative Documented Source Evidence of Standards for Documenting Computer Models and Modules for Quality Assurance and Quality Control

McLeod (1982)	Harper (1973)	Swartzman (1979)	UFIS (1996a)	CIESIN (1996)	CAMASE (1996)	EPA (1996b)	M=Mandatory S=Suggested O=Optional NA=Not Applicable
Availability of model and user's manual		Logbook of running changes to modules over time giving date, mechanics, and reasons for changes	Availability of model and user's manual		Availability of model user's guide	Means of access	O/M
			Technical user support requirements				O
					Availability of technical reference material		O
			User experience level				O
Source code listing		Source code listing	Source of availability of program files		Source code availability		O
					Executable code availability		M
Typical simulation results behavior mode			Model behavior analysis				O

Table A-5. Comparative Documented Source Evidence of Standards for Documenting Computer Models and Modules for Quality Assurance and Quality Control

McLeod (1982)	Harper (1973)	Swartzman (1979)	UFIS (1996a)	CIESIN (1996)	CAMASE (1996)	EPA (1996b)	M=Mandatory S=Suggested O=Optional NA=Not Applicable
Sample tabulation of typical output							O
Estimated accuracy of simulation results							O
Recommendations based on simulation results							O
Literature used in model development and application					Application reports		O
Reports produced from model simulations			Detailed model documentation				O
Bibliography of related materials							O
					User contract requirements		NA
						Outreach efforts available	O

Table A-5. Comparative Documented Source Evidence of Standards for Documenting Computer Models and Modules for Quality Assurance and Quality Control

McLeod (1982)	Harper (1973)	Swartzman (1979)	UFIS (1996a)	CIESIN (1996)	CAMASE (1996)	EPA (1996b)	M=Mandatory S=Suggested O=Optional NA=Not Applicable
					Cost	Fees	NA

1. Each component should result in a self-contained software process.
2. The order of component specifications should have no influence on their run-time behavior.

Schmidt (1995) goes on to argue that model specification should be built around the object-oriented concepts of "Modularity," "Types and Classes," and "Hierarchical structure," but for model implementation purposes, model specifications should avoid the object-oriented computer programming concepts and practices of "Encapsulation," "Inheritance," and "Communication only via narrow message passing between model components," because they do not represent how real world system dynamics behave.

Objects represent entity sets perceived to be related in a hierarchy of the modeled system's structure. A particular object is identified as an entity set whose internal dynamics (processes) are assumed to be significantly different in behavior from those of other entity sets in the overall system being modeled. The perception of "significantly different" is part of the art of modeling, and no objective rule can be defined for all circumstances. It is helpful for the framework modeler to define hierarchical structure of the system, which shows grouping relationships between the entity sets (objects) conceived as defining the overall system. An additional criterion for deciding on how to identify an "object" is psychological in terms of risk communication. Entities identified as objects need to be readily understandable by non-technical decision-makers, such as government environmental manager and legislators. Lackey (1996) advises the following:

> "A formidable problem in many risk assessments, and especially for complex questions such as addressing the challenge of sustainability, is selecting *what* ecological component or system is to be considered at risk."

The consideration of *what* things could become at risk must include concern for communication. The importance of science- and risk-communication effectiveness has been described by Bunnell (1978):

> "Effective communication is essential if environmental analysis is to have an impact on decision making. Our experience is that at least as much effort must go into communication as goes into the analysis ... Communication is the bridge between environmental analysis and decision making."

Some of the desired modules in this initial development are not directly related to the medium of transport [e.g., sensitivity/uncertainty analysis, geographical information system (GIS)]. A number of module alternatives are identified in Table A-6. With linkages between various types of modules with different functional relationships, it is useful to consider a variety of questions that can be investigated when various combinations of modules are activated. With the phenomenological modules that refer to the source term, transport media, and food chain and human-health response, one can ask:

> *What would be the effect of a specified chemical loading as seen in the health risk to people engaged in certain specified activities, i.e., life style?*

With the sensitivity/uncertainty analysis module, one can also ask:

To which chemicals, loadings, and specified environmental conditions are human-health risks most sensitive?

What is the probability that a health risk, equal to or greater than "X," will be exceeded?

Table A-6. Alternative PC-Based Medium-Independent Modules for Possible Support Links with Other Multimedia Models

MODULE CATEGORY	SOFTWARE NAME	INSTITUTION or COUNTRY
Sensitivity Analysis	SUM^3	PNNL, USA
Sensitivity/Uncertainty Analysis(a)	@RISK w/ RISKVIEW	Palisade Corp., USA
	SUM^3	PNNL, USA
	Crystal Ball	USA
	“DATA”	Palisade, USA
	FuziCalc	FUziWare, USA
	Pulcinella	IRIDIA, Belgium
GIS Spacial Display	ArcView	USA
	IDRISI	USA
	Map-Maker	UK
	SAGE-GIS	Australia
	OSU-MAP	USA
	ILWIS	Netherlands
	PC RASTER	Netherlands
	RAISON (GEMS)	Canada
Technology Costs	RACER(b)	Delta Research Corp., USA
Optimization/Trade-Off/Decision Support	What’s Best?	
	LINGO/LINDO	Palisade, USA
		General Optimization, USA

(a) On the World Wide Web. This topic is covered under a variety of “labels,” such as Decision Analysis, Risk Analysis, Belief Systems, aside from Uncertainty. Lumina Decision Systems may have a version of their software program Analytica available only through interfacing via the World Wide Web for PC users, which would not be in a stand-alone mode.

(b) Remedial Action Cost Engineering and Requirements System, Delta Research Corporation, http://www.deltabtg.com/racer.html.

> *What is the spacial variability of sensitivity of human-health risks to chemicals, loadings, and specified environmental conditions?*
>
> *What is the spacial variability of the probabilities of human-health risks?*

With an additional technological-cost module activated, one can ask:

> *What would be the effect of a specified chemical loading as seen in the costs of technological cleanup to reduce the health risk by a specified amount to people engaged in certain specified activities?*

With an added optimization decision-support module activated, one could investigate the following question:

> *To achieve a human-health risk level of "X," what balance is best achieved, subject to the constraints of minimizing technological costs and maximizing the decrease in the chemical source term?*

With a technological cost module activated along with a spacial GIS module, one could ask the following questions:

> *What would be the spacially variable effect of a specified chemical loading as seen in the spacial fields of technological costs for clean-up and the spacial variation in reduction of health risk to people engaged in certain specified activities by a specified amount?*
>
> *In order to achieve a specified spacial variability of human-health risk level of "X", what balance is best achieved, subject to the constraints of a minimal technological cost spacial field and a maximal spacial field in the decrease of the chemical source term?*

Obviously, there are many other combinations of questions that could be asked. In fact, if all of the phenomenological modules are considered as one set, the sensitivity and/or uncertainty analysis module as a second set, the spacial GIS module as a third set, a technological cost module as a fourth set, and an optimization module as a fifth set, then the number of questions and information objectives that could be formulated, addressed, and evaluated as 2^n -1, if n = 5, results in 31 different types of questions and uses. This does not consider individual transport medium-specific questions. If one were to consider questions that focus on specific transport pathways *individually*, rather than as one set, then the total number of addressable questions and objectives would be immensely larger than 31.

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Appendix B: Module Interface Specifications(a)

Global Input Data (GID) File

Unlike many other files in the framework, the parameter file contains all the data the user inputs. These data, because they may be changed at will by the user, need to be able to be changed or added to in an efficient way. To this end, and in keeping with the idea that all values should be readily understood by the user, the specification for the Global Input Data (GID) file is:

For each parameter

Line with:	Parameter Name	(string)
	Index 1	(integer)
	Index 2	(integer)
	Index 3	(integer)
	Index 4	(integer)
	Index 5	(integer)
	Index 6	(integer)
	Reference	(integer)
	User Units	(string)
	Units	(string)
	Value	(string), (integer), or (float)

Example Lines

```
"Sites",0,0,0,0,0,0,112,"N/A","N/A",1
"NumCon",1,0,0,0,0,0,16,"N/A","N/A",10
"VadVeloc",1,1,1,0,0,0,1000,"ft/d","cm/s",10.6
```

All values are stored as text; this allows each module to use its own storage format (Big-Endian, Little-Endian, 32 bit real, 64 bit real ...). The number of digits of precision should be set by the model developer when floating point numbers are being written. The choice of 6 dimensions is somewhat arbitrary because it is the dimensional limit of some versions of FORTRAN.

To make reading the GID file more efficient, markers are set at the beginning of a section of data for a particular module. A marker consists of a name and the number of lines in that block of information.

Line with: Module Name (string)
Number of Lines (integer)

In any GID file there will be a "FUI" data block that contains the information maintained by the Framework User Interface (FUI).

The following pages contain information that specifies what the FUI will maintain. The dimension and names of data for a Module User Interface(MUI) is up to the individual modeler. In the listing below, every entry is made up of two lines; the first is a short text description of the parameter,

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[a] These Specifications are a draft version as of May 1, 1997.

and the second contains four pieces of information: name of the parameter, dimensions of the parameter, model units of the parameter, and type. Dimensions are given a name such as <site> or <RCP>. Some dimensions may be not always be used; this is indicated by a {}, for example, {Progeny}. Type is limited to (integer), (float), or (string). In some instances, extra lines of information follow the two required lines to list or describe further the information stored with a parameter name.

General Information
Number of Sites
    Sites N/A (integer)
Name of Sites
    SiteName <Site> N/A (string)
X Coordinate of Site
    SiteX <Site> km (float)
Y Coordinate of Site
    SiteY <Site> km (float)
Z Coordinate of Site
    SiteZ <Site> km (float)

Constituent Information
Number of Constituent for a Site
    NumCon <Site> N/A (integer)
Number of Progeny for a Site for a Constituent
    NDS <Site> <Constituent> N/A (integer)
Constituent Name
    FSCNAME <Site> <Constituent> {progeny} N/A (string)
Constituent Id (unique identifier for the database)
    FSCASID <Site> <Constituent> {progeny} N/A (string)

Source Information
Name of Source
    SrcName <Site> N/A (string)
X Coordinate of Source
    SrcX <Site> km (float)
Y Coordinate of Site
    SrcY <Site> km (float)
Z Coordinate of Site
    SrcZ <Site> km (float)
Name of Module Used
    SrcModel <Site> N/A (string)
Status of Module Used
    SrcModelStat <Site> N/A

Air Information
Number of Air Models
    AirNum <Site> N/A (integer)
Name of Air Zone
    AirName <Site> <Air> N/A (string)
Name of Air Zone Source

AirSrcName <Site> <Air> N/A (string)
X Coordinate of Air Zone
AirX <Site> <Air> km (float)
Y Coordinate of Air Zone
AirY <Site> <Air> km (float)
Z Coordinate of Air Zone
AirZ <Site> <Air> km (float)
Name of Module Used
AirModel <Site> <Air> N/A (string)
Status of Module Used
AirModelStat <Site> <Air> N/A (string)

Vadose Zone Information
Number of Vadose Zones
VadNum <Site> N/A (integer)
Name of Vadose Zone
VadName <Site> <Vadose> N/A (string)
Name of Source Zone
VadSrcName <Site> <Vadose> N/A (string)
X Coordinate of Vadose Zone
VadX <Site> <Vadose> km (float)
Y Coordinate of Vadose Zone
VadY <Site> <Vadose> km (float)
Z Coordinate of Vadose Zone
VadZ <Site> <Vadose> km (float)
Name of Module Used
VadModel <Site> <Vadose> N/A (string)
Status of Module Used
VadModelStat <Site> <Vadose> N/A (string)

Aquifer Information
Number of Aquifers
AquNum <Site> N/A (integer)
Name of Aquifer
AquName <Site> <Aquifer> N/A (string)
Name of Source Zone
AquSrcName <Site> <Aquifer> N/A (string)
X Coordinate of Aquifer Zone
AquX <Site> <Aquifer> km (float)
Y Coordinate of Aquifer Zone
AquY <Site> <Aquifer> km (float)
Z Coordinate of Aquifer Zone
AquZ <Site> <Aquifer> km (float)
Name of Module Used
AquModel <Site> <Aquifer> N/A (string)
Status of Module Used
AquModelStat <Site> <Aquifer> N/A (string)

River Information

Number of Rivers
    RivNum <Site> N/A (integer)
Name of River
    RivName <Site> <River> N/A (string)
Number of River Source Zones
    RivSrcNum <Site> <River> N/A (integer)
Name of River Source Zones
    RivSrcName <Site> <River> <Source> N/A (string)
X Coordinate of River Zone
    RivX <Site> <River> km (float)
Y Coordinate of River Zone
    RivY <Site> <River> km (float)
Z Coordinate of River Zone
    RivZ <Site> <River> km (float)
Name of Module Used
    RivModel <Site> <River> N/A (string)
Status of Module Used
    RivModelStat <Site> <River> N/A (string)

Exposure Pathway Information

Number of Food Chain Models
    ExpNum <Site> N/A (integer)
Name of Exposure Pathways
    ExpName <Site> <Exp> N/A (string)
Number of Food Chain Types
    ExpTypeNum <Site> <Exp> N/A (integer)
Array of Types for a Exp
    ExpType <Site> <Exp> <Count> N/A (string)
        "GW"
        "SW"
        "Air"
        "Soil"
Name of Exposure Source Zone
    ExpSrcName <Site> <Exp> <Source> N/A (string)
X Coordinate of Exposure Pathway Zone
    ExpX <Site> <Exp> km (float)
Y Coordinate of Exposure Pathway Zone
    ExpY <Site> <Exp> km (float)
Z Coordinate of Exposure Pathway Zone
    ExpZ <Site> <Exp> km (float)
Name of Module Used
    ExpModel <Site> <Exp> N/A (string)
Status of Module Used
    ExpModelStat <Site> <Exp> N/A (string)

Receptor Information

Number of Receptors
    RcpNum <Site> N/A (integer)
Receptor Name

RcpName <Site> <RCP> N/A (string)
Name of Receptor Source Zone
RcpSrcName <Site> <RCP> <Source> N/A (string)
X Coordinate of Receptor
RcpX <Site> <RCP> km (float)
Y Coordinate of Receptor
RcpMY <Site> <RCP> km (float)
Z Coordinate of Receptor
RcpZ <Site> <RCP> km (float)
Name of Module Used
RcpModel <Site> <RCP> N/A (string)
Status of Module Used
RcpModelStat <Site> <RCP> N/A (string)

Health Impacts Information
Number of HE Reports
HENum <Site> N/A (integer)
Number of Receptors for First Report
HERCPNum <Site> <HE> N/A (integer)
Array of Receptors for First Report
HERCP <Site> <HE> <Receptor> N/A (string)
Name of Module Used
HEModel <Site> <HE> N/A (string)
Status of Module Used
HEModelStat <Site> <HE> N/A (string)

Viewer Information
Number of viewers
VwrNum <Site> N/A (integer)
Name of Viewer Source Zone
VwrSrcName <Site> <Vwr> N/A (string)
Name of Module Used
VwrModel <Site> <Vwr> N/A (string)

Export Information
Number of Exports
OutNum <Site> N/A (integer)
Name of Viewer Source Zone
OutSrcName <Site> <Out> N/A (string)
Name of Module Used
OutModel <Site> <Out> N/A (string)

Import Information
Number of Viewers
InNum <Site> N/A (integer)
Name of Viewer Source Zone
InSrcName <Site> <In> N/A (string)
Name of Module Used

InModel <Site> <In> N/A (string)

Constituent Information

Constituent Type
CLKTYPE <Site> <Constituent> {Progeny} N/A (integer)
1 = radionuclide
2 = chemical: carcinogen by inhalation and ingestion
3 = chemical: carcinogen by inhalation
4 = chemical: carcinogen by ingestion
5 = chemical: non-carcinogen

Uncertainty Factor:
CLIPPI <Site> <Constituent> {Progeny} N/A (integer)

Molecular Weight
CLWM <Site> <Constituent> {Progeny} g/mole (float)

Water Solubility
CLSOL <Site> <Constituent> {Progeny} mg/L (float)

Vapor Pressure
CLVAP <Site> <Constituent> {Progeny} "mm Hg" (float)

Henry's Law Constant
CLHLC <Site> <Constituent> {Progeny} "atm m^3/mole" (float)

Octanol-Water Partition Coefficient
CLCKOW <Site> <Constituent> {Progeny} "ml/g" (float)

Carbon Matter Partition Coefficient
CLKOC <Site> <Constituent> {Progeny} "ml/g" (float)

Skin Permeability in aqueous solutions
CLKPERM <Site> <Constituent> {Progeny} "cm/hr" (float)

Removal Half-times in Air (days)
CLTHALF <Site> <Constituent> {Progeny} days (float)

Removal Half-times in Groundwater
CLGHALF <Site> <Constituent> {Progeny} days (float)

Removal Half-times in Surface Water (days)
CLWHALF <Site> <Constituent> {Progeny} days (float)

Removal Half-times in Soil (days)
CLSHALF <Site> <Constituent> {Progeny} days (float)

Uncertainty Factor
CLITFI <Site> <Constituent> {Progeny} N/A (integer)

Bioaccumulation in Fish
CLBFF <Site> <Constituent> {Progeny} N/A (float)

Bioaccumulation in Shellfish
CLBFI <Site> <Constituent> {Progeny} N/A (float)

Soil-to-edible Plant
CLBFV <Site> <Constituent> {Progeny} N/A (float)

Feed-to-animal Meat
CLRBMT <Site> <Constituent> {Progeny} d/kg (float)

Feed-to-cow Milk
CLRBMK <Site> <Constituent> {Progeny} d/kg (float)

Water Purification Factor
CLRWPF <Site> <Constituent> {Progeny} N/A (float)

Deposition Velocity

CLRVDP <Site> <Constituent> {Progeny} m/sec (float)
Atmospheric Deposition Class
CLKCLASS <Site> <Constituent> {Progeny} N/A (integer)
Absorption Fraction GI Tract
CLFONE <Site> <Constituent> {Progeny} fract (float)
Absorption Fraction Skin from Soil Exposure
CLABSKN <Site> <Constituent> {Progeny} N/A (float)
Ingestion Dose Factor
CLDFG <Site> <Constituent> {Progeny} 1/kg (float)
Ingestion Dose Factor Uncertainty Factor
CLITXIG <Site> <Constituent> {Progeny} N/A (integer)
Inhalation Dose Factor
CLDFA <Site> <Constituent> {Progeny} 1/kg (float)
Inhalation Dose Factor Uncertainty Factor
CLITXIH <Site> <Constituent> {Progeny} N/A (integer)
Chemical Slope Factor Ingestion
CLCPFG <Site> <Constituent> {Progeny} 1/(mg/kg/d) (float)
Chemical Slope Factor Ingestion Source Quality
CLKCPFG <Site> <Constituent> {Progeny} N/A (integer)
Chemical Slope Factor Inhalation
CLCPFH <Site> <Constituent> {Progeny} 1/(mg/kg/d) (float)
Chemical Slope Factor Inhalation Source Quality
CLKCPFH <Site> <Constituent> {Progeny} N/A (integer)
Chemical Reference Dose Ingestion
CLRFDG <Site> <Constituent> {Progeny} mg/kg/d (float)
Chemical Reference Dose Ingestion Source Quality
CLKRFDG <Site> <Constituent> {Progeny} N/A (integer)
Chemical Reference Dose Inhalation
CLRFDH <Site> <Constituent> {Progeny} mg/kg/d (float)
Chemical Reference Dose Inhalation Source Quality
CLKRPFDH <Site> <Constituent> {Progeny} N/A (integer)
Radiological Ingestion Dose Factor
CLRDFG <Site> <Constituent> {Progeny} rem/pCi (float)
Radiological Ingestion Dose Factor Uncertainty Factor
CLITXIG <Site> <Constituent> {Progeny} N/A (integer)
Radiological Inhalation Dose Factor
CLDFA <Site> <Constituent> {Progeny} rem/pCi (float)
Radiological Inhalation Dose Factor Uncertainty Factor
CLITXIH <Site> <Constituent> {Progeny} N/A (integer)
Air Immersion Factor
CLDEX <Site> <Const.> {Progeny} "(rem/hr)/(pCi/m^3)" (float)
Ground Exposure Factor
CLDSH <Site> <Const.> {Progeny} "(rem/hr)/(pCi/m^2)" (float)
Water Immersion Factor
CLDIMR <Site> <Const.> {Progeny} "rem/hr per pCi/L" (float)
Radiological Slope Factor Ingestion
CLCPFG <Site> <Constituent> {Progeny} 1/pCi (float)
Radiological Slope Factor Inhalation
CLCPFH <Site> <Constituent> {Progeny} 1/pCi (float)

Radiological Slope Factor External Surface Contamination
    CLRFDH <Site> <Constituent> {Progeny} 1/pCi (float)
Radiological Reference Dose Dermal Absorption
    CLRFDG <Site> <Constituent> {Progeny} rem/pCi (float)

EXAMPLE GID FILE

```
"FUI",223
"Sites",0,0,0,0,0,0,0,"n/a","n/a",1
"SiteName",1,0,0,0,0,0,0,"n/a","n/a","Hanford"
"SiteX",1,0,0,0,0,0,0,"n/a","n/a",0
"SiteY",1,0,0,0,0,0,0,"n/a","n/a",0
"SiteZ",1,0,0,0,0,0,0,"n/a","n/a",0
"NumCon",1,0,0,0,0,0,0,"n/a","n/a",2
"FSCASID",1,1,0,0,0,0,0,"n/a","n/a",56235
"NDS",1,1,0,0,0,0,0,"n/a","n/a",1
"FSCASID",1,2,0,0,0,0,0,"n/a","n/a",7738945
"NDS",1,2,0,0,0,0,0,"n/a","n/a",1
"CLWM",1,1,0,0,0,0,0,"n/a","n/a",154
"CLSOL",1,1,0,0,0,0,0,"n/a","n/a",757
"CLVAP",1,1,0,0,0,0,0,"n/a","n/a",113
"CLHLC",1,1,0,0,0,0,0,"n/a","n/a",0.0302
"CLKOC",1,1,0,0,0,0,0,"n/a","n/a",502
"CLKOW",1,1,0,0,0,0,0,"n/a","n/a",436
"CLDIFCO",1,1,0,0,0,0,0,"n/a","n/a",0
"CLCPFH",1,1,0,0,0,0,0,"n/a","n/a",0.053
"CLCPFG",1,1,0,0,0,0,0,"n/a","n/a",0.13
"CLRFDH",1,1,0,0,0,0,0,"n/a","n/a",0.0007
"CLRFDG",1,1,0,0,0,0,0,"n/a","n/a",0.0007
"CLFONE",1,1,0,0,0,0,0,"n/a","n/a",0
"CLRFDG",1,1,0,0,0,0,0,"n/a","n/a",0
"CLDEX",1,1,0,0,0,0,0,"n/a","n/a",0
"CLDIMR",1,1,0,0,0,0,0,"n/a","n/a",0
"CLDSH",1,1,0,0,0,0,0,"n/a","n/a",0
"CLCPFH",1,1,0,0,0,0,0,"n/a","n/a",0
"CLCPFG",1,1,0,0,0,0,0,"n/a","n/a",0
"CLRFDH",1,1,0,0,0,0,0,"n/a","n/a",0
"CLABSKN",1,1,0,0,0,0,0,"n/a","n/a",0
"CLKPERM",1,1,0,0,0,0,0,"n/a","n/a",0.022
"CLWPF",1,1,0,0,0,0,0,"n/a","n/a",1
"CLVDP",1,1,0,0,0,0,0,"n/a","n/a",0
"CLBFF",1,1,0,0,0,0,0,"n/a","n/a",150
"CLBFI",1,1,0,0,0,0,0,"n/a","n/a",0
"CLBMT",1,1,0,0,0,0,0,"n/a","n/a",0
"CLBMK",1,1,0,0,0,0,0,"n/a","n/a",0
"CLBFV",1,1,0,0,0,0,0,"n/a","n/a",0
"CLTHALF",1,1,0,0,0,0,0,"n/a","n/a",0
"CLGHALF",1,1,0,0,0,0,0,"n/a","n/a",0
"CLWHALF",1,1,0,0,0,0,0,"n/a","n/a",0.153
"CLSHALF",1,1,0,0,0,0,0,"n/a","n/a",12.1
"CLRCLS",1,1,0,0,0,0,0,"n/a","n/a",5
"CLKTYPE",1,1,0,0,0,0,0,"n/a","n/a",2
"FSCNAME",1,1,0,0,0,0,0,"n/a","n/a","CARBON TETRACHLORIDE"
"CLWM",1,2,0,0,0,0,0,"n/a","n/a",118
"CLSOL",1,2,0,0,0,0,0,"n/a","n/a",0
```

```
"CLVAP",1,2,0,0,0,0,0,"n/a","n/a",0
"CLHLC",1,2,0,0,0,0,0,"n/a","n/a",0
"CLKOC",1,2,0,0,0,0,0,"n/a","n/a",0
"CLKOW",1,2,0,0,0,0,0,"n/a","n/a",0
"CLDIFCO",1,2,0,0,0,0,0,"n/a","n/a",0
"CLCPFH",1,2,0,0,0,0,0,"n/a","n/a",41
"CLCPFG",1,2,0,0,0,0,0,"n/a","n/a",41
"CLRFDH",1,2,0,0,0,0,0,"n/a","n/a",5.7E-07
"CLRFDG",1,2,0,0,0,0,0,"n/a","n/a",0.005
"CLFONE",1,2,0,0,0,0,0,"n/a","n/a",0.01
"CLRFDG",1,2,0,0,0,0,0,"n/a","n/a",0
"CLDEX",1,2,0,0,0,0,0,"n/a","n/a",0
"CLDIMR",1,2,0,0,0,0,0,"n/a","n/a",0
"CLDSH",1,2,0,0,0,0,0,"n/a","n/a",0
"CLCPFH",1,2,0,0,0,0,0,"n/a","n/a",0
"CLCPFG",1,2,0,0,0,0,0,"n/a","n/a",0
"CLRFDH",1,2,0,0,0,0,0,"n/a","n/a",0
"CLABSKN",1,2,0,0,0,0,0,"n/a","n/a",0
"CLKPERM",1,2,0,0,0,0,0,"n/a","n/a",0.002
"CLWPF",1,2,0,0,0,0,0,"n/a","n/a",0.9
"CLVDP",1,2,0,0,0,0,0,"n/a","n/a",0.001
"CLBFF",1,2,0,0,0,0,0,"n/a","n/a",200
"CLBFI",1,2,0,0,0,0,0,"n/a","n/a",2E+03
"CLBMT",1,2,0,0,0,0,0,"n/a","n/a",0.0055
"CLBMK",1,2,0,0,0,0,0,"n/a","n/a",0.0015
"CLBFV",1,2,0,0,0,0,0,"n/a","n/a",0.00113
"CLTHALF",1,2,0,0,0,0,0,"n/a","n/a",0
"CLGHALF",1,2,0,0,0,0,0,"n/a","n/a",0
"CLWHALF",1,2,0,0,0,0,0,"n/a","n/a",0
"CLSHALF",1,2,0,0,0,0,0,"n/a","n/a",0
"CLRCLS",1,2,0,0,0,0,0,"n/a","n/a",1
"CLKTYPE",1,2,0,0,0,0,0,"n/a","n/a",3
"FSCNAME",1,2,0,0,0,0,0,"n/a","n/a","CHROMIC ACID"
"ConName",1,1,0,0,0,0,0,"n/a","n/a","Contaminants"
"ConModelStat",1,1,0,0,0,0,0,"n/a","n/a",2
"ConScrX",1,1,0,0,0,0,0,"n/a","n/a",25
"ConScrY",1,1,0,0,0,0,0,"n/a","n/a",25
"ConNum",1,0,0,0,0,0,0,"n/a","n/a",1
"SrcName",1,1,0,0,0,0,0,"n/a","n/a","Tanks"
"SrcX",1,1,0,0,0,0,0,"n/a","n/a",0
"SrcY",1,1,0,0,0,0,0,"n/a","n/a",0
"SrcZ",1,1,0,0,0,0,0,"n/a","n/a",0
"SrcModel",1,1,0,0,0,0,0,"n/a","n/a","MEPAS Source Version 1.0"
"SrcModelStat",1,1,0,0,0,0,0,"n/a","n/a",0
"SrcScrX",1,1,0,0,0,0,0,"n/a","n/a",51.12835
"SrcScrY",1,1,0,0,0,0,0,"n/a","n/a",276.9461
"SrcNum",1,0,0,0,0,0,0,"n/a","n/a",1
"ClsNum",1,0,0,0,0,0,0,"n/a","n/a",0
"InNum",1,0,0,0,0,0,0,"n/a","n/a",0
```

```
"AirNum",1,0,0,0,0,0,0,"n/a","n/a",0
"VadName",1,1,0,0,0,0,0,"n/a","n/a","200EastSoil"
"VadX",1,1,0,0,0,0,0,"n/a","n/a",0
"VadY",1,1,0,0,0,0,0,"n/a","n/a",0
"VadZ",1,1,0,0,0,0,0,"n/a","n/a",0
"VadModel",1,1,0,0,0,0,0,"n/a","n/a","MEPAS Vadose Zone"
"VadModelStat",1,1,0,0,0,0,0,"n/a","n/a",0
"VadScrX",1,1,0,0,0,0,0,"n/a","n/a",98.73061
"VadScrY",1,1,0,0,0,0,0,"n/a","n/a",516.467
"VadSrcName",1,1,1,0,0,0,0,"n/a","n/a","Tanks"
"VadSrcNum",1,1,0,0,0,0,0,"n/a","n/a",1
"VadNum",1,0,0,0,0,0,0,"n/a","n/a",1
"AquName",1,1,0,0,0,0,0,"n/a","n/a","HanfordAqu"
"AquX",1,1,0,0,0,0,0,"n/a","n/a",0
"AquY",1,1,0,0,0,0,0,"n/a","n/a",0
"AquZ",1,1,0,0,0,0,0,"n/a","n/a",0
"AquModel",1,1,0,0,0,0,0,"n/a","n/a","MEPAS Saturated Zone"
"AquModelStat",1,1,0,0,0,0,0,"n/a","n/a",0
"AquScrX",1,1,0,0,0,0,0,"n/a","n/a",171.0155
"AquScrY",1,1,0,0,0,0,0,"n/a","n/a",741.0179
"AquSrcName",1,1,1,0,0,0,0,"n/a","n/a","200EastSoil"
"AquSrcNum",1,1,0,0,0,0,0,"n/a","n/a",1
"AquNum",1,0,0,0,0,0,0,"n/a","n/a",1
"RivName",1,1,0,0,0,0,0,"n/a","n/a","Yakima"
"RivX",1,1,0,0,0,0,0,"n/a","n/a",0
"RivY",1,1,0,0,0,0,0,"n/a","n/a",0
"RivZ",1,1,0,0,0,0,0,"n/a","n/a",0
"RivModel",1,1,0,0,0,0,0,"n/a","n/a","MEPAS Surface Water"
"RivModelStat",1,1,0,0,0,0,0,"n/a","n/a",0
"RivScrX",1,1,0,0,0,0,0,"n/a","n/a",315.5853
"RivScrY",1,1,0,0,0,0,0,"n/a","n/a",785.9282
"RivSrcName",1,1,1,0,0,0,0,"n/a","n/a","HanfordAqu"
"RivSrcNum",1,1,0,0,0,0,0,"n/a","n/a",1
"RivName",1,2,0,0,0,0,0,"n/a","n/a","Columbia"
"RivX",1,2,0,0,0,0,0,"n/a","n/a",0
"RivY",1,2,0,0,0,0,0,"n/a","n/a",0
"RivZ",1,2,0,0,0,0,0,"n/a","n/a",0
"RivModel",1,2,0,0,0,0,0,"n/a","n/a","MEPAS Surface Water"
"RivModelStat",1,2,0,0,0,0,0,"n/a","n/a",0
"RivScrX",1,2,0,0,0,0,0,"n/a","n/a",305.007
"RivScrY",1,2,0,0,0,0,0,"n/a","n/a",179.6407
"RivSrcName",1,2,1,0,0,0,0,"n/a","n/a","200EastSoil"
"RivSrcName",1,2,2,0,0,0,0,"n/a","n/a","HanfordAqu"
"RivSrcNum",1,2,0,0,0,0,0,"n/a","n/a",2
"RivNum",1,0,0,0,0,0,0,"n/a","n/a",2
"ExpName",1,1,0,0,0,0,0,"n/a","n/a","Richland"
"ExpX",1,1,0,0,0,0,0,"n/a","n/a",0
"ExpY",1,1,0,0,0,0,0,"n/a","n/a",0
"ExpZ",1,1,0,0,0,0,0,"n/a","n/a",0
```

```
"ExpModel",1,1,0,0,0,0,0,"n/a","n/a","MEPAS Exposure Pathways"
"ExpModelStat",1,1,0,0,0,0,0,"n/a","n/a",0
"ExpScrX",1,1,0,0,0,0,0,"n/a","n/a",530.677
"ExpScrY",1,1,0,0,0,0,0,"n/a","n/a",122.2555
"ExpType",1,1,1,0,0,0,0,"n/a","n/a","GW"
"ExpSRCName",1,1,1,0,0,0,0,"n/a","n/a","HanfordAqu"
"ExpType",1,1,2,0,0,0,0,"n/a","n/a","SW"
"ExpSRCName",1,1,2,0,0,0,0,"n/a","n/a","Yakima"
"ExpType",1,1,3,0,0,0,0,"n/a","n/a","SW"
"ExpSRCName",1,1,3,0,0,0,0,"n/a","n/a","Columbia"
"ExpTypeNum",1,1,0,0,0,0,0,"n/a","n/a",3
"ExpName",1,2,0,0,0,0,0,"n/a","n/a","Kennewick"
"ExpX",1,2,0,0,0,0,0,"n/a","n/a",0
"ExpY",1,2,0,0,0,0,0,"n/a","n/a",0
"ExpZ",1,2,0,0,0,0,0,"n/a","n/a",0
"ExpModel",1,2,0,0,0,0,0,"n/a","n/a","MEPAS Exposure Pathways"
"ExpModelStat",1,2,0,0,0,0,0,"n/a","n/a",0
"ExpScrX",1,2,0,0,0,0,0,"n/a","n/a",541.2553
"ExpScrY",1,2,0,0,0,0,0,"n/a","n/a",469.0619
"ExpType",1,2,1,0,0,0,0,"n/a","n/a","SW"
"ExpSRCName",1,2,1,0,0,0,0,"n/a","n/a","Columbia"
"ExpTypeNum",1,2,0,0,0,0,0,"n/a","n/a",1
"ExpName",1,3,0,0,0,0,0,"n/a","n/a","Pasco"
"ExpX",1,3,0,0,0,0,0,"n/a","n/a",0
"ExpY",1,3,0,0,0,0,0,"n/a","n/a",0
"ExpZ",1,3,0,0,0,0,0,"n/a","n/a",0
"ExpModel",1,3,0,0,0,0,0,"n/a","n/a","MEPAS Exposure Pathways"
"ExpModelStat",1,3,0,0,0,0,0,"n/a","n/a",0
"ExpScrX",1,3,0,0,0,0,0,"n/a","n/a",546.5444
"ExpScrY",1,3,0,0,0,0,0,"n/a","n/a",798.4032
"ExpType",1,3,1,0,0,0,0,"n/a","n/a","SW"
"ExpSRCName",1,3,1,0,0,0,0,"n/a","n/a","Columbia"
"ExpTypeNum",1,3,0,0,0,0,0,"n/a","n/a",1
"ExpNum",1,0,0,0,0,0,0,"n/a","n/a",3
"RcpName",1,1,0,0,0,0,0,"n/a","n/a","NativeAmerican"
"RcpX",1,1,0,0,0,0,0,"n/a","n/a",0
"RcpY",1,1,0,0,0,0,0,"n/a","n/a",0
"RcpZ",1,1,0,0,0,0,0,"n/a","n/a",0
"RcpModel",1,1,0,0,0,0,0,"n/a","n/a","MEPAS Receptor Model"
"RcpModelStat",1,1,0,0,0,0,0,"n/a","n/a",0
"RcpScrX",1,1,0,0,0,0,0,"n/a","n/a",703.4556
"RcpScrY",1,1,0,0,0,0,0,"n/a","n/a",294.4112
"RcpSrcName",1,1,1,0,0,0,0,"n/a","n/a","200EastSoil"
"RcpSrcName",1,1,2,0,0,0,0,"n/a","n/a","HanfordAqu"
"RcpSrcName",1,1,3,0,0,0,0,"n/a","n/a","Richland"
"RcpSrcName",1,1,4,0,0,0,0,"n/a","n/a","Kennewick"
"RcpSrcName",1,1,5,0,0,0,0,"n/a","n/a","Pasco"
"RcpSrcNum",1,1,0,0,0,0,0,"n/a","n/a",5
"RcpName",1,2,0,0,0,0,0,"n/a","n/a","OffsiteReceptor"
```

```
"RcpX",1,2,0,0,0,0,0,"n/a","n/a",0
"RcpY",1,2,0,0,0,0,0,"n/a","n/a",0
"RcpZ",1,2,0,0,0,0,0,"n/a","n/a",0
"RcpModel",1,2,0,0,0,0,0,"n/a","n/a","MEPAS Receptor Model"
"RcpModelStat",1,2,0,0,0,0,0,"n/a","n/a",0
"RcpScrX",1,2,0,0,0,0,0,"n/a","n/a",710.5078
"RcpScrY",1,2,0,0,0,0,0,"n/a","n/a",678.6427
"RcpSrcName",1,2,1,0,0,0,0,"n/a","n/a","Richland"
"RcpSrcName",1,2,2,0,0,0,0,"n/a","n/a","Kennewick"
"RcpSrcName",1,2,3,0,0,0,0,"n/a","n/a","Pasco"
"RcpSrcNum",1,2,0,0,0,0,0,"n/a","n/a",3
"RcpNum",1,0,0,0,0,0,0,"n/a","n/a",2
"HEIName",1,1,0,0,0,0,0,"n/a","n/a","NativeAmericanRisk"
"HEIModel",1,1,0,0,0,0,0,"n/a","n/a","MEPAS Health Impacts"
"HEIModelStat",1,1,0,0,0,0,0,"n/a","n/a",0
"HEIScrX",1,1,0,0,0,0,0,"n/a","n/a",851.5515
"HEIScrY",1,1,0,0,0,0,0,"n/a","n/a",299.4012
"HEIRCP",1,1,1,0,0,0,0,"n/a","n/a","NativeAmerican"
"HEIRcpNum",1,1,0,0,0,0,0,"n/a","n/a",1
"HEIName",1,2,0,0,0,0,0,"n/a","n/a","OffsiteRisk"
"HEIModel",1,2,0,0,0,0,0,"n/a","n/a","MEPAS Health Impacts"
"HEIModelStat",1,2,0,0,0,0,0,"n/a","n/a",0
"HEIScrX",1,2,0,0,0,0,0,"n/a","n/a",870.945
"HEIScrY",1,2,0,0,0,0,0,"n/a","n/a",676.1477
"HEIRCP",1,2,1,0,0,0,0,"n/a","n/a","Offsite"
"HEIRcpNum",1,2,0,0,0,0,0,"n/a","n/a",1
"HEINum",1,0,0,0,0,0,0,"n/a","n/a",2
"OutNum",1,0,0,0,0,0,0,"n/a","n/a",0
"VwrNum",1,0,0,0,0,0,0,"n/a","n/a",0
```

ERROR FILE (ERR)

The Error File (ERR), if it exists at the end of a Model, Tool, or UI execution, signals an error to the FUI. All executables will create the ERR file before **ANY** processing is done and delete it only after **ALL** processing is complete. There is no format for this file, but it will be text information given to the user if the model does not complete properly or crashes. If it exists when control is given back to the FUI it is read and shown to the user.

PRIMARY DATA COMMUNICATION FILE (PDCF)

Each Primary Data Communication File (PDCF) will have similar structural components but different specific content. The files will have a heading area and data area; the content of the heading area is defined by each module/code developer and gives general information on the code and analysis represented by the current file. Information included here would be variable (or nothing); however, as a minimum, the following are recommended.

- Identification of the module/code used to generate the file
- Identification of the analyst responsible for generation of the file
- Date of file generation
- Description of the situation being modeled by the data in the file
- Descriptive information giving basic assumptions of the analysis, with key differences between related analyses.

The first line of the file will contain a numerical value (integer) indicating the number of lines that follow devoted to the heading information. The second part of the file starts after the end of the heading information. The extension is used to distinguish what information is contained in the file.

The file formats that follow are:

Source Concentration File	*.SCF
Air Flux File	*.AFF
Water Flux File	*.WFF
Water Concentration File	*.WCF
Atmospheric Transport Output File	*.ATO
Exposure Pathway File	*.EPF
Receptor Intake File	*.RIF
Health Impacts File	*.HIF

The descriptions below are meant to serve as pseudo-code for the algorithm to read or write the file. "Line with:" represents a call to Read in FORTRAN, INPUT# in BASIC and fscanf in C. The list after "Line with:" represents variables and types that are to be read or written. "For each" is used to represent the DO loop in FORTRAN and the for loop in BASIC, and C. Lines that begin with ";" are formatting comments and should not appear in the actual file.

SOURCE CONCENTRATION FILE (SCF)

The concentration is a spacial average throughout the volume of the source zone. The concentrations are in pCi/mL or g/mL (pCi/Kg or g/Kg in vadose zone) depending on whether the constituent is a radionuclide or chemical. These concentration values are the instantaneous values at that time, not an average. There are NO limits on the number of constituents, progeny, or layers. Aqueous concentrations are limited to the solubility of contaminants.

```
Line with: number of lines of header-(integer)
  For each line of header
  Line with: run information-(string)
Line with: number of media-(integer)
  For each medium
  Line with: medium name-(string)
          Medium Type-{"Vadose","Aquifer","Pond"}
          x Dimension of rectangular area-(float)
          x Dimension units-"m"
          y Dimension of rectangular area-(float)
          y Dimension units-"m"
          z Dimension of rectangular area-(float)
          z Dimension units-"m"
               Number of constituents-(integer)
            For each constituent
              Line with: constituent name-(string)
             Constituent ID-(string)
             Time units-"yr"
             Concentration units,
                  If  Vadose "pCi/Kg" or "g/Kg"
                  Else       "pCi/mL" or "g/mL"
             Number of time-concentration pairs-(integer)
             Number of progeny-(integer)
               For each concentration
                  Line with: Time-(float)
                            Concentration-(float)
                  For each progeny
             Line with:Progeny Name-(string)
                      Progeny ID-(string)
                      Time units-"yr"
                      Concentration units-"Ci/mL" or "g/mL"
                      Number of concentrations-(integer)
                      Parent Name-(string)
                      Parent ID-(string)
                        For each concentration
                          Line with: Media Time-(float)
                                   Concentration-(float)
```

SOURCE CONCENTRATION FILE EXAMPLE

```
7,
"================================================",
"  Source Term Release Module Version 1.00  June-1-1996 ",
"  Run:","frm-tst1",
"  Site:","Test Site",
"  Run Performed:","6/6/1996","10:56:32",
"  Output Filename:","frm-tst1.scf",
"================================================",
1,
"Test Name","Vadose", 1.000e+02,"m", 1.000e+02,"m", 3.650e+02,"m", 1.490e+00,"m^3/yr",3,
"STRONTIUM-90","SR90","yr","pCi/Kg",10,1,
 1.000e+00, 3.220e+10,
 2.000e+00, 3.144e+10,
 3.000e+00, 3.069e+10,
 4.000e+00, 2.996e+10,
 5.000e+00, 2.925e+10,
 6.000e+00, 2.856e+10,
 7.000e+00, 2.789e+10,
 8.000e+00, 2.722e+10,
 9.000e+00, 2.658e+10,
 1.000e+01, 2.595e+10,
"YTTRIUM-90","Y90","yr","pCi/Kg",10,"STRONTIUM-90","SR90",
 1.000e+00, 0.000e+00,
 2.000e+00, 0.000e+00,
 3.000e+00, 0.000e+00,
 4.000e+00, 0.000e+00,
 5.000e+00, 0.000e+00,
 6.000e+00, 0.000e+00,
 7.000e+00, 0.000e+00,
 8.000e+00, 0.000e+00,
 9.000e+00, 0.000e+00,
 1.000e+01, 0.000e+00,
"AMERICIUM-241","AM241","yr","pCi/Kg",10,0,
 1.000e+00, 1.025e+12,
 2.000e+00, 1.023e+12,
 3.000e+00, 1.022e+12,
 4.000e+00, 1.020e+12,
 5.000e+00, 1.018e+12,
 6.000e+00, 1.017e+12,
 7.000e+00, 1.015e+12,
 8.000e+00, 1.013e+12,
 9.000e+00, 1.012e+12,
 1.000e+01, 1.010e+12,
```

AIR FLUX FILE (AFF)

The air flux is a spacial average through an exit area into unconstrained air passing by the area. The exit area is normally defined by physical characteristics of the source. In all cases, the exit area is the area used to define the spacial average of the air flux. The air fluxes are in pCi/yr or g/yr, depending on whether the constituent is a radionuclide or chemical. These flux values are the instantaneous values at a specified time (i.e., the value is not a time-average). There are NO limits on number of constituents, progeny, fluxes, or layers. The number of contaminant types is limited to a maximum of 4.

```
Line with:Number of Lines of Header Information-(integer)
For each
   Line with: Run information-(string)
Line with:Air Source Type Name-(string)
          ;If Stack, vent, etc.   "POINT"
          ;If Landfill, pond, etc.   "AREA"
Line with:Exit Area of Source-(float)
        Units-"m2"
Line with:Exit Height-(float)
          ;If AREA fixed value = 0
        Units-"m"
Line with:Adjacent Structure Height-(float)
          ;If AREA, fixed value = 0
        Units-"m"
Line with:Exit Velocity-(float)
          ;If AREA, fixed value = 0
        Units-"m/s"
Line with:Exit Temperature-(float)
        Units-"Deg C"
Line with:Ambient Air Temperature-(float)
        Units-"Deg C"
Line with:Number of Flux Types-(integer)
For each Flux type
  Line with: Flux Type Name-(string)
              ; If Gas "Gas 1"
              ; If particle 1 used "Particle 1"
              ; If particle 2 used "Particle 2"
              ; If particle 3 used "Particle 3"
            Flux Type Parameter-(float)
              ; If Gas, not defined  (=0.0)
              ; If Particle, radius   (µm)
           Units-"um"
Line with: Number of constituents-(integer)
  For each constituent
   Line with: Constituent Name-(string)
             Constituent ID-(string)
             Media Time units-"y"
             Flux units-"pCi/y" or "g/y"
             Number of fluxes-(integer)
```

```
         Number of progeny-(integer)
For each flux
     Line with: Media Time-(float)
         Flux for 1st flux entry-(float)
         Flux for 2nd flux entry-(float)
         Flux for 3rd flux entry-(float)
         Flux for 4th flux entry-(float)

  For each progeny
   Line with: Progeny Name-(string)
              Progeny ID-(string)
              Media Time units-"y"
              Flux units-"pCi/y" or "g/y"
              Number of fluxes-(integer)
          Parent Name-(string)
              Parent ID-(string)
   For each flux
    Line with: Media Time-(float)
         Flux for 1st flux entry-(float)
         Flux for 2nd flux entry-(float)
         Flux for 3rd flux entry-(float)
         Flux for 4th flux entry-(float)
```

AIR FLUX FILE EXAMPLE

```
7,
"============================================================",
"  Source Term Release Module Version 1.00  June-1-1996 ",
"  Run:","frm-tst1",
"  Site:","Test Site",
"  Run Performed:","6/6/1996","10:56:32",
"  Output Filename:","frm-tst1.aff",
"============================================================",
"AREA",
 1.520e+12,"m2",
0,"m",
0,"m",
0,"m/s",
 1.176e+01,"Deg C",
 1.176e+01,"Deg C",
4,
"Gas 1", 0.000e+00,"um",
"Particle 1", 7.500e+00,"um",
"Particle 2", 3.000e+00,"um",
"Particle 3", 3.000e-01,"um",
2
"STRONTIUM-90","SR90","yr","pCi/yr",10,1,
 1.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 2.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 3.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 4.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 5.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 6.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 7.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 8.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 9.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 1.000e+01, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
"YTTRIUM-90","Y90","yr","pCi/yr",10,"STRONTIUM-90","SR90",
 1.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 2.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 3.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 4.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 5.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 6.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 7.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 8.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 9.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 1.000e+01, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
"AMERICIUM-241","AM241","yr","pCi/yr",10,0,
 1.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 2.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
 3.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
```

```
4.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
5.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
6.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
7.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
8.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
9.000e+00, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
1.000e+01, 0.000e+00, 0.000e+00, 0.000e+00, 0.000e+00,
```

WATER FLUX FILE (WFF)

The flux is a spacial average through a rectangular plane segment that is the interface between one layer and the next. The fluxes are in pCi/yr or g/yr, depending on whether the constituent is a radionuclide or chemical. These flux values are the instantaneous values at that time, not an average. There are NO limits on number of constituents, progeny, fluxes, or layers.

```
Line with: Number of Lines of Header Information-(integer)
For each
   Line with: Run information-(string)
Line with: Number of Media-(integer)
For each medium
  Line with: Medium Name-(string)
             Medium Type-(string)
               ;"Vadose"
               ;"Aquifer"
               ;"Surface water"
               ;"Wetlands"
               ;"Estuary"
            x Dimension of rectangular area-(float)
            x Dimension units-"m"
            y Dimension of rectangular area-(float)
            y Dimension units-"m"
            z Dimension of rectangular area-(float)
              ;Only used in plume in aquifer as a source case
            z Dimension units-"m"
            Water Flux-(float)
            Water Flux Units-"m^3/yr"
             Number of constituents-(integer)
  For each constituent
    Line with: Constituent Name-(string)
               Constituent ID-(string)
               Time units-"yr"
               Flux units-"pCi/y" or "g/y"
               Number of time-fluxes pairs-(integer)
               Number of progeny-(integer)
    For each flux
      Line with: Time-(float)
              Flux-(float)
    For each progeny
      Line with: Progeny Name-(string)
                   Progeny ID-(string)
                   Time units-"yr"
                   Flux units-"pCi/y" or "g/y"
                   Number of fluxes-(integer)
              Parent Name-(string)
                   Parent ID-(string)
      For each flux
        Line with: Media Time-(float)
```

Flux-(float)

WATER FLUX FILE FORMAT EXAMPLE

```
7,
"=============================================================",
"  Source Term Release Module Version 1.00  June-1-1996 ",
"  Run:","frm-tst1",
"  Site:","Test Site",
"  Run Performed:","6/6/1996","10:56:32",
"  Output Filename:","frm-tst1.wff",
"=============================================================",
1,
"Test Name","Vadose", 1.000e+02,"m", 1.000e+02,"m", 3.650e+02,"m", 1.490e+00,"m^3/yr",3,
"STRONTIUM-90","SR90","yr","pCi/yr",10,1,
 1.000e+00, 2.995e+10,
 2.000e+00, 2.924e+10,
 3.000e+00, 2.855e+10,
 4.000e+00, 2.788e+10,
 5.000e+00, 2.721e+10,
 6.000e+00, 2.657e+10,
 7.000e+00, 2.594e+10,
 8.000e+00, 2.533e+10,
 9.000e+00, 2.473e+10,
 1.000e+01, 2.414e+10,
"YTTRIUM-90","Y90","yr","pCi/yr",10,"STRONTIUM-90","SR90",
 1.000e+00, 0.000e+00,
 2.000e+00, 7.628e+06,
 3.000e+00, 7.447e+06,
 4.000e+00, 7.271e+06,
 5.000e+00, 7.099e+06,
 6.000e+00, 6.930e+06,
 7.000e+00, 6.766e+06,
 8.000e+00, 6.606e+06,
 9.000e+00, 6.450e+06,
 1.000e+01, 6.297e+06,
"AMERICIUM-241","AM241","yr","pCi/yr",10,0,
 1.000e+00, 2.803e+11,
 2.000e+00, 2.798e+11,
 3.000e+00, 2.794e+11,
 4.000e+00, 2.789e+11,
 5.000e+00, 2.785e+11,
 6.000e+00, 2.780e+11,
 7.000e+00, 2.776e+11,
 8.000e+00, 2.771e+11,
 9.000e+00, 2.767e+11,
 1.000e+01, 2.762e+11,
```

WATER CONCENTRATION FILE (WCF)

The concentrations are in pCi/mL or g/mL, depending on whether the constituent is a radionuclide or chemical. These concentration values are the instantaneous values at that time, not an average at the location specified. There are NO limits on number of constituents, progeny, concentrations, or receptors. The x is the easterly distance of the receptor from the source, y is the northerly; and z is the relative altitude from the source.

```
Line with: Number of Lines of Header Information-(integer)
For each
   Line with: Run information-(string)
Line with: Number of Usage Location-(integer)
For each Usage Location
  Line with:Usage Location name-(string)
            Usage Location Type-(string)
             ;"Aquifer"
              ;"Surface water"
             ;"Overland"
              ;"Wetlands"
              ;"Estuary"
            Number of constituents-(integer)
  For each constituent
    Line with: Constituent Name-(string)
               Constituent ID-(string)
               Time units-"yr"
               Concentration units-"pCi/ml" or "g/ml"
               Number of progeny-(integer)
               Number of time-concentrations pairs-(integer)
    For each concentration
      Line with: Time-(float)
                 Concentration-(float)
    For each progeny
      Line with: Progeny Name-(string)
                   Progeny ID-(string)
                   Time units-"yr"
                   Concentration units-"pCi/ml" or "g/ml"
                   Number of time-concentrations pairs (integer)
               Parent Name-(string)
                   Parent ID-(string)
      For each concentration
        Line with:Time-(float)
                  Concentration-(float)
```

WATER CONCENTRATION FILE FORMAT EXAMPLE

```
7,
"==============================================================",
"  Aquifer Transport Module Version 1.00  June-1-1996 ",
"  Run:","frm-tst1",
"  Site:","Test Site",
"  Run Performed:","6/6/1996","10:56:32",
"  Output Filename:","frm-tst1.wcf",
"==============================================================",
2
"Test Well 1","Aquifer",2
"Benzene","71432","y","g/ml",5,0
0.0,1.0e-10
2.5,1.0e-7
3.5,1.0e-7
6.5,1.0e-7
1.0e3,1.0e-7
"Arsenic","12312","y","g/ml",2,0
0.0,1.0e-10
1.0e3,1.0e-7
"Test Well 2","Groundwater",0.5,"km",2.5,"km",3
"Benzene","71432","y","g/ml",5,0
1.0,1.0e-10
3.5,1.0e-7
4.5,1.0e-7
5.5,1.0e-7
1.0e3,1.0e-7
"Arsenic","12312","y","g/ml",2,0
0.0,1.0e-10
1.0e3,1.0e-7
"Ethylbenzene","34534","y","g/ml",2,0
0.0,1.0e-10
1.0e3,1.0e-7
```

ATMOSPHERIC TRANSPORT OUTPUT FILE (ATO)

This file provides data for use by exposure pathway modules for airborne releases and atmospheric transport and deposition of pollutants. The following is an attempt to describe the basic information important to the exposure pathway modules. The basic data sets are provided as point values at specific locations relative to the release point. Use of keywords is suggested, although other methods of describing data types could be used (e.g., logical or integer flags).

```
Line with:  Number of Lines of Header Information:(integer)
For each
   Line with: Run information-(string)
First line of data: Number of data sets in this file-(integer)
For each data set
        Line with: Data set type-"acute" or "chronic"
                        Co-ordinate type-"polar" or "Cartesian"
                        Number of Constituents (parent) - (integer)
```

The data in each set is defined according to the data set type and coordinate type defined on the first line for the data set. The program reading the information will process the information as necessary (e.g., put values into arrays).

For "acute" release data sets, information is provided as statistical distributions of the output parameters. The distribution is provided as parameter break points (divisions of histogram data), and numbers of observations within the bins. For cases in which only one value is desired, one bin is defined and one value is given. The data is provided by constituent and location as follows.

```
  For each constituent
    line with: Constituent Name-(string)
                        Constituent ID-(string)
                     Number of Time Integrations - (integer)
                        Number of Progeny-(integer)

    For Each Time Integration
        line with: time-(float)
                  units-"yr"
                         Number of Output Products - (integer)
                         ;For Air Concentration, Deposition Rate,
                         ;and External Dose -this would be 3
        For Each Output Product:
      Line with: Name of Output - (string)
                         ;If Air Concentrations (time-integral) would
                         ;be "Air Concentration", for Deposition Rate
                         ;it would be "Deposition Rate", for External
                         ;Dose it would be "External Dose"
                         Unit of Output - (string)
                         ;If "Air Concentration" either "kg/m3" or
                         ;"Bq/m3" OR If "Deposition Rate" either
                         ;"kg/m2/yr" or "Bq/m2/yr" OR If "External Dose"
```

```
                             ;"Sv"
                             Number of values on axis 1 - (integer)
                             ;If "polar", then number of radial distances
                             ;If "Cartesian", then number of x - distances
                             Unit of values of axis 1 - "m"
                             Number of values on axis 2 - (integer)
                             ;If "polar", then number of directions
                             ;If "Cartesian", then number of y-distances
                             Unit of values of axis 2 - (string)
                             ;if "polar", then "deg"
                             ;if "Cartesian", then "m"
                             Number of bins for output product - (integer)
        Line with: Values of axis 1 - (set of float)
        Line with: Bin break point values - (set of float)
                             ;the number of break point values should be
                             ;the number of bins plus 1

        For Each values on axis 2
         Line with: Value of axis 2 (float)
                             ;If "polar" then direction
                             ;If "Cartesian" then y-distance
                             Output product information (set of float)
                            ;Bin observation values (number given above)          ;for each value on
                     axis 1

For each progeny
        line with: Progeny Name-(string)
                      Progeny ID-(string)
                         Number of Time Integrations - (integer)
                             Parent Constituent Name - (string)
                             Parent Constituent ID - (string)
    For Each Time Integration
        line with: time-(float)
                     units-"yr"
                             Number of Output Products - (integer)
                             ;For Air Concentration, Deposition Rate,
                             ;and External Dose -this would be 3
        For Each Output Product:
   Line with: Name of Output - (string)
                             ;If Air Concentrations (time-integral) would
                             ;be "Air Concentration", for Deposition Rate
                             ;it would be "Deposition Rate", for External
                             ;Dose it would be "External Dose"
                             Unit of Output - (string)
                             ;If "Air Concentration" either "kg/m3" or
                             ;"Bq/m3" OR If "Deposition Rate" either
                             ;"kg/m2/yr" or "Bq/m2/yr" OR If "External Dose"
                             ;"Sv"
                             Number of values on axis 1 - (integer)
```

```
                         ;If "polar", then number of radial distances
                         ;If "Cartesian", then number of x - distances
                         Unit of values of axis 1 - "m"
                         Number of values on axis 2 - (integer)
                         ;If "polar", then number of directions
                         ;If "Cartesian", then number of y-distances
                         Unit of values of axis 2 - (string)
                         ;if "polar", then "deg"
                         ;if "Cartesian", then "m"
                         Number of bins for output product - (integer)
          Line with: Values of axis 1 - (set of float)
          Line with: Bin break point values - (set of float)
                         ;the number of break point values should be
                         ;the number of bins plus 1

          For Each values on axis 2
           Line with: Value of axis 2 (float)
                         ;If "polar" then direction
                         ;If "Cartesian" then y-distance
                         Output product information (set of float)
                         ;Bin observation values (number given above)     ;for each value on
                     axis 1
```

The "chronic" release data sets contain information in a format similar to the above, except that point values are defined instead of bin distributions.

```
  For each constituent
    line with: Constituent Name-(string)
                        Constituent ID-(string)
                      Number of Time Integrations - (integer)
                        Number of Progeny-(integer)
    For Each Time Integration
          line with: time-(float)
                     units-"yr"
                         Number of Output Products - (integer)
                         ;For Air Concentration, Deposition Rate,
                         ;and External Dose -this would be 3
          For Each Output Product:
     Line with: Name of Output - (string)
                         ;If Air Concentrations (time-integral) would
                         ;be "Air Concentration", for Deposition Rate
                         ;it would be "Deposition Rate", for External
                         ;Dose it would be "External Dose"
                         Unit of Output - (string)
                         ;If "Air Concentration" either "kg/m3" or
                         ;"Bq/m3" OR If "Deposition Rate" either
                         ;"kg/m2/yr" or "Bq/m2/yr" OR If "External Dose"
                         ;"Sv"
                         Number of values on axis 1 - (integer)
```

```
                              ;If "polar", then number of radial distances
                              ;If "Cartesian", then number of x - distances
                              Unit of values of axis 1 - "m"
                              Number of values on axis 2 - (integer)
                              ;If "polar", then number of directions
                              ;If "Cartesian", then number of y-distances
                              Unit of values of axis 2 - (string)
                              ;if "polar", then "deg"
                              ;if "Cartesian", then "m"
         Line with: Values of axis 1 - (set of float)

         For Each values on axis 2
          Line with: Value of axis 2 (float)
                              ;If "polar" then direction
                              ;If "Cartesian" then y-distance
                             Output information (set of float)
                             ;output values for each values on axis 1
                             ;(number given above)

For Each Progeny
         Line with: Progeny Name-(string)
                              Progeny ID-(string)
                          Number of Time Integrations - (integer)
                              Parent Constituent Name - (string)
                              Parent ID - (sting)
  For Each Time Integration
         line with: time-(float)
                      units-"yr"
                              Number of Output Products - (integer)
                              ;For Air Concentration, Deposition Rate,
                              ;and External Dose -this would be 3
         For Each Output Product:
    Line with: Name of Output - (string)
                              ;If Air Concentrations (time-integral) would
                              ;be "Air Concentration", for Deposition Rate
                              ;it would be "Deposition Rate", for External
                              ;Dose it would be "External Dose"
                              Unit of Output - (string)
                              ;If "Air Concentration" either "kg/m3" or
                              ;"Bq/m3" OR If "Deposition Rate" either
                              ;"kg/m2/yr" or "Bq/m2/yr" OR If "External Dose"
                              ;"Sv"
                              Number of values on axis 1 - (integer)
                              ;If "polar", then number of radial distances
                              ;If "Cartesian", then number of x - distances
                              Unit of values of axis 1 - "m"
                              Number of values on axis 2 - (integer)
                              ;If "polar", then number of directions
                              ;If "Cartesian", then number of y-distances
```

```
              Unit of values of axis 2 - (string)
              ;if "polar", then "deg"
              ;if "Cartesian", then "m"
Line with: Values of axis 1 - (set of float)

For Each values on axis 2
 Line with: Value of axis 2 (float)
              ;If "polar" then direction
              ;If "Cartesian" then y-distance
              Output information (set of float)
              ;output values for each values on axis 1
              ;(number given above)
```

Multiple data sets can be included in one file (all related to the heading information). This allows input of acute and chronic information in one file, and use of polar co-ordinates and Cartesian co-ordinates in the same file.

AIR TRANSPORT FILE EXAMPLE

```
6
"======================================================================",
" Air Transport Output Module Version 1.00 August 8, 1996",
" Run: ","test",
" Run Performed:","8/8/96","10:05:23",
" Output Filename:","test.ato",
"======================================================================",
1,
"chronic","polar",2,
"STRONTIUM-90","SR90",2,1,
1,"yr",3,
"Air Concentration","Bq/m3",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-6, 1.00E-7, 1.00E-8, 1.00E-9,
90,3.00E-7, 2.00E-8, 1.00E-9, 0.00E0,
180,2.00E-6, 2.00E-7, 2.00E-8, 2.00E-9,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"Deposition Rate","Bq/m2/yr",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-7, 1.00E-8, 1.00E-9, 1.00E-10,
90,3.00E-8, 2.00E-9, 1.00E-10, 0.00E0,
180,2.00E-7, 2.00E-8, 2.00E-9, 2.00E-10,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"External Dose","Sv",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-9, 1.00E-10, 1.00E-11, 1.00E-12,
90,3.00E-9, 2.00E-10, 1.00E-11, 0.00E0,
180,2.00E-8, 2.00E-9, 2.00E-10, 2.00E-11,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
2,"yr,3,
"Air Concentration","Bq/m3",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-6, 1.00E-7, 1.00E-8, 1.00E-9,
90,3.00E-7, 2.00E-8, 1.00E-9, 0.00E0,
180,2.00E-6, 2.00E-7, 2.00E-8, 2.00E-9,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"Deposition Rate","Bq/m2/yr",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-7, 1.00E-8, 1.00E-9, 1.00E-10,
90,3.00E-8, 2.00E-9, 1.00E-10, 0.00E0,
180,2.00E-7, 2.00E-8, 2.00E-9, 2.00E-10,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"External Dose","Sv",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-9, 1.00E-10, 1.00E-11, 1.00E-12,
90,3.00E-9, 2.00E-10, 1.00E-11, 0.00E0,
180,2.00E-8, 2.00E-9, 2.00E-10, 2.00E-11,
```

```
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"YTTRIUM-90","Y90",2,"STRONTIUM-90","SR90",
1,"yr",3,
"Air Concentration","Bq/m3",4,"m",4,"deg"
100, 200, 400, 600,
0,0.00E0, 0.00E0, 0.00E0, 0.00E0,
90,0.00E0, 0.00E0, 0.00E0, 0.00E0,
180,0.00E0, 0.00E0, 0.00E0, 0.00E0,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"Deposition Rate","Bq/m2/yr",4,"m",4,"deg"
100, 200, 400, 600,
0,0.00E0, 0.00E0, 0.00E0, 0.00E0,
90,0.00E0, 0.00E0, 0.00E0, 0.00E0,
180,0.00E0, 0.00E0, 0.00E0, 0.00E0,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"External Dose","Sv",4,"m",4,"deg"
100, 200, 400, 600,
0,0.00E0, 0.00E0, 0.00E0, 0.00E0,
90,0.00E0, 0.00E0, 0.00E0, 0.00E0,
180,0.00E0, 0.00E0, 0.00E0, 0.00E0,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
2,"yr,3,
"Air Concentration","Bq/m3",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-7, 1.00E-8, 1.00E-9, 1.00E-10,
90,3.00E-8, 2.00E-9, 1.00E-10, 0.00E0,
180,2.00E-7, 2.00E-8, 2.00E-9, 2.00E-10,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"Deposition Rate","Bq/m2/yr",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-8, 1.00E-9, 1.00E-10, 1.00E-11,
90,3.00E-9, 2.00E-10, 1.00E-11, 0.00E0,
180,2.00E-8, 2.00E-9, 2.00E-10, 2.00E-11,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"External Dose","Sv",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-10, 1.00E-11, 1.00E-12, 1.00E-13,
90,3.00E-10, 2.00E-11, 1.00E-12, 0.00E0,
180,2.00E-9, 2.00E-10, 2.00E-11, 2.00E-12,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"Chlorine","7782505",1,0
1,"yr",3,
"Air Concentration","kg/m3",4,"m",4,"deg"
100, 200, 400, 600,
0,1.00E-6, 1.00E-7, 1.00E-8, 1.00E-9,
90,3.00E-7, 2.00E-8, 1.00E-9, 0.00E0,
180,2.00E-6, 2.00E-7, 2.00E-8, 2.00E-9,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"Deposition Rate","kg/m2/yr",4,"m",4,"deg"
```

```
100, 200, 400, 600,
0,1.00E-7, 1.00E-8, 1.00E-9, 1.00E-10,
90,3.00E-8, 2.00E-9, 1.00E-10, 0.00E0,
180,2.00E-7, 2.00E-8, 2.00E-9, 2.00E-10,
270,0.00E0, 0.00E0, 0.00E0, 0.00E0,
"External Dose","Sv",0,"m",0,"deg"
```

EXPOSURE PATHWAY FILE FORMAT

The output from the Exposure Pathways component is the intake of each pollutant. This is the input to the Health Impacts Component (which produces estimates of health impacts - risk of developing cancer). The input to the Health Impacts Component is provided in the Primary Data Communication File, "runname".EPF. Following the header information, intake information is provided for all receptor locations, exposure pathways, and constituents.

```
Line with: Number of Lines of Header Information-(integer)
For each
  Line with: Run information-(string)
Line with: Number of data sets included in this file
For each data set
 Line with: Data set type-"acute" or "chronic"
                  Co-ordinate type-"polar" or "Cartesian"
                  Number of integrating times/periods-(integer)
                  Number of age groups-(integer)
 Line with:Age group break points-(set of float)
               units-"yr"
                  ;The number of age break point is determined by the ;number given for the
                  number of age groups, plus one ;for the age at the start of the first age group.
                  If ;only one age group is defined, two values are given ;representing the lower
                  and upper ages limits for the ;range.)
 For each integrating time
  Line with: Start of time period, units-(float)
                   Start Time Units-"yr"
                   Duration of time period-(float)
                   Duration Units-"yr"
                   Number of receptor locations-(integer)
  For each receptor location
       Line with: Receptor location name-(string)
                    Receptor medium type-(string)
                            ;"air"
                            ;"aquifer"
                            ;"surface water"
                            ;"wetlands"
                            ;"soil"
                            ;"foods"
                            ;"other"
                    Location radial distance for polar-(float)
                       OR x direction for Cartesian-(float)
          Location radial distance or x dir. units-"km"
                    Location direction for polar-(string)
                       OR y direction for Cartesian-(float)
                    If "Cartesian" y direction units-"km"
                    Number of exposure pathways for location-(integer)
   For each exposure pathway
        Line with: Exposure pathway name-(string)
                            ;"air"
```

```
                                ;"food"
                              ;"shower"
                                ;"shoreline"
                                ;"soil"
                                ;"swimming"
                                ;"water"
                                ;"other"
                             Exposure route-(string)
                                ;"ingestion"
                                ;"inhalation"
                                ;"dermal"
                                ;"external"
                             Population Exposed-(set of float)
                             Number of constituents-(integer)
For each constituent
  Line with: Constituent name-(string)
                               Constituent ID-(string)
                               Number of progeny-(integer)
  Line with: Intake/dose measure-(set of float)
                                     Intake/dose measure unit-(string)
                                      ;"Bq"
                                      ;"mg/kg/d"
                                      ;"Sv"
                                      ; intake units are Bq for radionuclides
                                      ; and mg/kg/d for chemicals.  For
                                      ; external exposure, dose units are
                                      ; used, Sv.  The number of values is
                                      ; equal to the number of age groups
                                      ; defined for the current data set.
  For each progeny
   Line with: Constituent name-(string)
                                Constituent ID-(string)
   Line with: Intake/dose measure-(set of float)
                                     Intake/dose measure unit-(string)
                                      ;"Bq"
                                      ;"mg/kg/d"
                                      ;"Sv"
                                      ; intake units are Bq for radionuclides
                                      ; and mg/kg/d for chemicals.  For
                                      ; external exposure, dose units are
                                      ; used, Sv.  The number of values is
                                      ; equal to the number of age groups
                                      ; defined for the current data set.
```

EXPOSURE PATHWAY FILE FORMAT EXAMPLE

```
   5
"chronic","polar",2,2    (1st group, 2 time period, 2 age groups)
0,18,70,"yr"               (times for age groups)
1990.,1.,3,                  (1st time integration period, 1 yr long,)
"Resident Farmer Well","aquifer",0.1,"km","NNE",3,    (1st of 3)
"water","ingestion",1.0,2.0,2     (1st exposure pathway)
"radium-226","RA226",0      (1st constituent for water ingestion)
1.5E-8,3.2E-8,"Bq"          (intake for two age groups)
"cesium-137",CS137",0      (2nd constituent for water ingestion)
4.5E-6,3.5E-6,"Bq"
"shower","inhalation",1.0,2.0,1    (2nd exposure pathway)
"radium-226","RA226",1      (1st constituent for shower inhalation)
0.0,0.0,"Bq"
"radon-222","RN222"          (1st progeny of constituent 1)
6.2E-1,4.5E-2,"Bq"
"food","ingestion",1.0,2.0,3  (3rd exposure pathway)
"radium-226","RA226",0      (1st constituent for food ingestion)
3.9E-2,4.8E-2,"Bq"
"cesium-137",CS137",0      (2nd constituent for food ingestion)
3.1E-3,4.5E-2,"Bq"
"strontium-89",SR89",0      (3rd constituent for food ingestion)
2.9E-1,4.5E-1,"Bq"
"Residential Farmer Soil","Soil",0.1,"km","NNE",1,    (2nd of 3)
"Soil","external",4.0,5.0,1
"cobalt-60","CO60",0
1.5E-1,4.5E-1,"Sv"
"Residential Farmer Air","Air",0.1,"km","NNE",2,    (3rd of 3)
"Air","inhalation",6.0,7.0,1
"iodine-131",I131",0
9.1E+2,1.1E+1,"Bq"
"Air","external",1
"cobalt-60","CO60",0
5.2E-7,8.5E-6,"Sv"
1991.,1.,3,                  (2nd time integration period)
"Resident Farmer Well","aquifer",0.1,"km","NNE",3,    (1st of 3)
"water","ingestion",8.0,9.0,2,              (1st exposure pathway)
"radium-226","RA226",0      (1st constituent for water ingestion)
2.9E-8,6.9E-7,"Bq"
"cesium-137",CS137",0      (2nd constituent for water ingestion)
1.3E-6,4.5E-6,"Bq"
"shower","inhalation",8.0,9.0,1           (2nd exposure pathway)
"radium-226","RA226",1      (1st constituent for shower inhalation)
0.0,0.0,"Bq"
"radon-222","RN222"          (1st progeny of constituent 1)
8.2E-3,7.5E-4,"Bq"
"food","ingestion",8.0,9.0,3 (3rd exposure pathway)
"radium-226","RA226",0      (1st constituent for food ingestion)
```

```
4.1E-3,4.5E-3,"Bq"
"cesium-137",CS137",0      (2nd constituent for food ingestion)
4.1E-4,7.1E-4,"Bq"
"strontium-89",SR89",0     (3rd constituent for food ingestion)
4.5E-2,3.1E-3,"Bq"
"Residential Farmer Soil","Soil",0.1,"km","NNE",1, (2nd of 3) "Soil","external",10.0,11.0,1
"cobalt-60","CO60",0
1.9E-2,5.5E-3,"Sv"
"Residential Farmer Air","Air",0.1,"km","NNE",2,    (3rd of 3) "Air","inhalation",12.0,13.0,1
"iodine-131",I131",0
6.7E+1,3.7E+1,"Bq"
"Air","external",12.0,13.0,1
"cobalt-60","CO60",0
2.2E-6,9.2E-6,"Sv"
```

(start 2nd data set, etc)

INTAKE PATHWAY FILE FORMAT

The output Receptor intake (RIF) from the Exposure Pathways component is the intake of each pollutant. This is the input to the Health Impacts Component (which produces estimates of health impacts - risk of developing cancer). The input to the Health Impacts Component is provided in the Primary Data Communication File, "runname".RIF. Following the header information, intake information is provided for all receptor locations, exposure pathways, and constituents.

```
Line with: Number of Lines of Header Information-(integer)
For each
   Line with: Run information-(string)
Line with: Number of data sets included in this file
For each data set
  Line with: Data set type-"acute" or "chronic"
                    Co-ordinate type-"polar" or "Cartesian"
                    Number of integrating times/periods-(integer)
                    Number of age groups-(integer)
  Line with:Age group break points-(set of float)
                 units-"yr"
                    ;The number of age break point is determined by the ;number given for the
                    number of age groups, plus one ;for the age at the start of the first age group.
                    If ;only one age group is defined, two values are given ;representing the lower
                    and upper ages limits for the ;range.)
  For each integrating time
    Line with: Start of time period, units-(float)
                     Start Time Units-"yr"
                     Duration of time period-(float)
                     Duration Units-"yr"
                     Number of receptor locations-(integer)
    For each receptor location
            Line with: Receptor location name-(string)
                      Receptor medium type-(string)
                            ;"air"
                            ;"aquifer"
                            ;"surface water"
                            ;"wetlands"
                            ;"soil"
                            ;"foods"
                            ;"other"
                      Location radial distance for polar-(float)
                         OR x direction for Cartesian-(float)
              Location radial distance or x dir. units-"km"
                      Location direction for polar-(string)
                         OR y direction for Cartesian-(float)
                      If "Cartesian" y direction units-"km"
                      Number of exposure pathways for location-(integer)
      For each exposure pathway
            Line with: Exposure pathway name-(string)
```

```
                         ;"air"
                         ;"food"
                      ;"shower"
                         ;"shoreline"
                         ;"soil"
                         ;"swimming"
                         ;"water"
                         ;"other"
                     Exposure route-(string)
                         ;"ingestion"
                         ;"inhalation"
                         ;"dermal"
                         ;"external"
                     Population Exposed-(set of floats)
                     Number of constituents-(integer)
For each constituent
   Line with: Constituent name-(string)
                       Constituent ID-(string)
                       Number of progeny-(integer)
   Line with: Intake/dose measure-(set of float)
                               Intake/dose measure unit-(string)
                                ;"Bq"
                                ;"mg/kg/d"
                                ;"Sv"
                                ; intake units are Bq for radionuclides
                                ; and mg/kg/d for chemicals.  For
                                ; external exposure, dose units are
                                ; used, Sv.  The number of values is
                                ; equal to the number of age groups
                                ; defined for the current data set.
   For each progeny
    Line with: Constituent name-(string)
                         Constituent ID-(string)
    Line with: Intake/dose measure-(set of float)
                               Intake/dose measure unit-(string)
                                ;"Bq"
                                ;"mg/kg/d"
                                ;"Sv"
                                ; intake units are Bq for radionuclides
                                ; and mg/kg/d for chemicals.  For
                                ; external exposure, dose units are

                                ; used, Sv.  The number of values is
                                ; equal to the number of age groups
                                ; defined for the current data set.
```

INTAKE PATHWAY FILE FORMAT EXAMPLE

```
   5
"chronic","polar",2,2    (1st group, 2 time period, 2 age groups)
0,18,70,"yr"             (times for age groups)
1990.,1.,3,              (1st time integration period, 1 yr long,)
"Resident Farmer Well","aquifer",0.1,"km","NNE",3,    (1st of 3)
"water","ingestion",1.0,2.0,2,      (1st exposure pathway)
"radium-226","RA226",0     (1st constituent for water ingestion)
1.5E-8,3.2E-8,"Bq"         (intake for two age groups)
"cesium-137",CS137",0      (2nd constituent for water ingestion)
4.5E-6,3.5E-6,"Bq"
"shower","inhalation",1    (2nd exposure pathway)
"radium-226","RA226",1     (1st constituent for shower inhalation)
0.0,0.0,"Bq"
"radon-222","RN222"        (1st progeny of constituent 1)
6.2E-1,4.5E-2,"Bq"
"food","ingestion",3       (3rd exposure pathway)
"radium-226","RA226",0     (1st constituent for food ingestion)
3.9E-2,4.8E-2,"Bq"
"cesium-137",CS137",0      (2nd constituent for food ingestion)
3.1E-3,4.5E-2,"Bq"
"strontium-89",SR89",0     (3rd constituent for food ingestion)
2.9E-1,4.5E-1,"Bq"
"Residential Farmer Soil","Soil",0.1,"km","NNE",1,  (2nd of 3)
"Soil","external",1.0,2.0,1
"cobalt-60","CO60",0
1.5E-1,4.5E-1,"Sv"
"Residential Farmer Air","Air",0.1,"km","NNE",2,    (3rd of 3)
"Air","inhalation",1.0,2.0,1
"iodine-131",I131",0
9.1E+2,1.1E+1,"Bq"
"Air","external",1.0,2.0,1
"cobalt-60","CO60",0
5.2E-7,8.5E-6,"Sv"
1991.,1.,3,                (2nd time integration period)
"Resident Farmer Well","aquifer",0.1,"km","NNE",3,   (1st of 3)
"water","ingestion",1.0,2.0,2,      (1st exposure pathway)
"radium-226","RA226",0     (1st constituent for water ingestion)
2.9E-8,6.9E-7,"Bq"
"cesium-137",CS137",0      (2nd constituent for water ingestion)
1.3E-6,4.5E-6,"Bq"
"shower","inhalation",1.0,2.0,1    (2nd exposure pathway)
"radium-226","RA226",1     (1st constituent for shower inhalation)
0.0,0.0,"Bq"
"radon-222","RN222"        (1st progeny of constituent 1)
8.2E-3,7.5E-4,"Bq"
"food","ingestion",1.0,2.0,3        (3rd exposure pathway)
"radium-226","RA226",0     (1st constituent for food ingestion)
```

```
4.1E-3,4.5E-3,"Bq"
"cesium-137",CS137",0      (2nd constituent for food ingestion)
4.1E-4,7.1E-4,"Bq"
"strontium-89",SR89",0     (3rd constituent for food ingestion)
4.5E-2,3.1E-3,"Bq"
"Residential Farmer Soil","Soil",0.1,"km","NNE",1,    (2nd of 3)
"Soil","external",1.0,2.0,1
"cobalt-60","CO60",0
1.9E-2,5.5E-3,"Sv"
"Residential Farmer Air","Air",0.1,"km","NNE",2,    (3rd of 3)
"Air","inhalation",1.0,2.0,1
"iodine-131",I131",0
6.7E+1,3.7E+1,"Bq"
"Air","external",1.0,2.0,1
"cobalt-60","CO60",0
2.2E-6,9.2E-6,"Sv"

(start 2nd data set, etc)
```

HEALTH IMPACTS FILE FORMAT

The output from the Health Impacts Component is used by the report generator to prepare text reports. For radionuclides, the health impacts are expressed as the risk of developing cancer, either as total incidence, fatal incidence, or incidence of severe genetic effects. The input to the impacts report generator component is provided in the Primary Data Communication File, runname.HIF. Following the header information, is provided for all receptor locations, exposure pathways, constituents, and health endpoints.

```
Line with: Number of Lines of Header Information-(integer)
For each
  Line with: Run information-(string)
First line of data:Number of data sets included in this file
For each data set
  Line with: Data set type-(string)
                                    ;"acute"
                                    ;"chronic"
                            Co-ordinate type-(string)
                                    ;"polar"
                                    ;"Cartesian"
                            Number of integrating times/periods-(integer)
                            Number of age groups-(integer)
  Line with: Age group break points-(set of float)
                            Age group break points units-"yr"
                              ; The number of age break point is determined by
               ; the number given for the number of age groups,
               ; plus one for the age at the start of the first
                              ; age group.  If only one age group is defined, two
               ; values are given representing the lower and
               ; upper ages limits for the range.
  For each integrating time
    Line with: Start of time period-(float)units
               Start time units-"yr"
                              Duration of time period, units-(float)
                              Duration units-"yr"
                              Number of receptor locations-(integer)
    For each receptor location
            Line with: Receptor location name (string)
                            Receptor medium type (string)
               ; "air"
                              ; "aquifer"
                              ; "surface water"
                              ; "wetlands"
                              ; "soil"
                              ; "foods"
               ; "other"
                            Location radial distance for polar-(float)
                                    OR x direction for Cartesian-(float)
```

```
           Location radial distance or x dir. Units-"m"
           Location direction for polar-(string)
                OR y direction for Cartesian(float)
    If Cartesian y direction units-"m"
           Number of exposure pathways for location-(integer)
For each exposure pathway
    Line with: Exposure pathway name-(string)
                  ; "air"
                    ; "food"
                    ; "shower"
                    ; "shoreline"
                    ; "soil"
                    ; "swimming"
                    ; "water"
                    ; "other"
                0Exposure route-(string)
               ; "ingestion"
                    ; "inhalation"
                    ; "dermal"
                    ; "external"
             Population Exposed-(set of float)
                Number of constituents-(integer)
 For each constituent
   Line with: Constituent name-(string)
                   Constituent ID-(string)
                   Number of progeny-(integer)
   Line with: Health Impact measure-(float)
                     Health Impact measure units-(string)
         ; "risk"
                        ; "HI"
                        ; health impact units are "risk" for
                        ; carcinogenic effects, and "HI" for hazard
                        ; index values for non-carcinogenic
                        ; effects.
   For each progeny
    Line with:Constituent name-(string)
                Constituent ID-(string)
    Line with: Health Impact measure-(float)
                     Health Impact measure units-(string)
         ; "risk"
                        ; "HI"
                        ; health impact units are "risk" for
                        ; carcinogenic effects, and "HI" for hazard
                        ; index values for non-carcinogenic
                        ; effects.
```

HEALTH IMPACTS FILE FORMAT EXAMPLE

Example of .HIF file contents, after header information.

```
   5
"chronic","polar",2,2    (1st group, 2 time period, 2 age groups)
0,18,70,"yr"               (times for age groups)
1990.,1.,3,                          (1st time integration period)
"Resident Farmer Well","aquifer",0.1,"km","NNE",3,    (1st of 3)
"water","ingestion",1.0,2.0,2,      (1st exposure pathway)
"radium-226","RA226",0      (1st constituent for water ingestion)
1.5E-8,"risk"
"cesium-137",CS137",0       (2nd constituent for water ingestion)
4.5E-6,"risk"
"shower","inhalation",1.0,2.0,1    (2nd exposure pathway)
"radium-226","RA226",1      (1st constituent for shower inhalation)
0.0,"risk"
"radon-222","RN222"         (1st progeny of constituent 1)
6.2E-1,"risk"
"food","ingestion",1.0,2.0,3        (3rd exposure pathway)
"radium-226","RA226",0      (1st constituent for food ingestion)
3.9E-2,"risk"
"cesium-137",CS137",0       (2nd constituent for food ingestion)
3.1E-3,"risk"
"strontium-89",SR89",0      (3rd constituent for food ingestion)
2.9E-1,"risk"
"Residential Farmer Soil","Soil",0.1,"km","NNE",1,  (2nd of 3)
"Soil","external",1.0,2.0,1
"cobalt-60","CO60",0
1.5E-1,"Sv"
"Residential Farmer Air","Air",0.1,"km","NNE",2,    (3rd of 3) "Air","inhalation",1.0,2.0,1
"iodine-131",I131",0
9.1E+2,"risk"
"Air","external",1.0,2.0,1
"cobalt-60","CO60",0
5.2E-7,"Sv"
1991.,1.,3,                          (2nd time integration period)
"Resident Farmer Well","aquifer",0.1,"km","NNE",3,    (1st of 3)
"water","ingestion",1.0,2.0,2,      (1st exposure pathway)
"radium-226","RA226",0      (1st constituent for water ingestion)
2.9E-8,"risk"
"cesium-137",CS137",0       (2nd constituent for water ingestion)
1.3E-6,"risk"
"shower","inhalation",1.0,2.0,1    (2nd exposure pathway)
"radium-226","RA226",1      (1st constituent for shower inhalation)
0.0,"risk"
"radon-222","RN222"         (1st progeny of constituent 1)
8.2E-3,"risk"
"food","ingestion",1.0,2.0,3        (3rd exposure pathway)
```

```
"radium-226","RA226",0      (1st constituent for food ingestion)
4.1E-3,"risk"
"cesium-137",CS137",0       (2nd constituent for food ingestion)
4.1E-4,"risk"
"strontium-89",SR89",0      (3rd constituent for food ingestion)
4.5E-2,"risk"
"Residential Farmer Soil","Soil",0.1,"km","NNE",1,    (2nd of 3) "Soil","external",1.0,2.0,1
"cobalt-60","CO60",0
1.9E-2,"Sv"
"Residential Farmer Air","Air",0.1,"km","NNE",2,    (3rd of 3)
"Air","inhalation",1.0,2.0,1
"iodine-131",I131",0
6.7E+1,"risk"
"Air","external",1.0,2.0,1
"cobalt-60","CO60",0
2.2E-6,"risk"

(start 2nd data set, etc)
```

CALL ARGUMENTS FOR EACH OBJECT TYPE

The call arguments for each object type are defined below. An MS-DOS module may specify either a batch (.bat) file or executable (.exe) to run the user interface (UI) and model. A MS-Windows module may specify only executable (.exe) to run the user interface and model.

A brief list of file extension and meanings:

Global Input Data File	*.GID
Terminal Error File	*.ERR
Source Concentration File	*.SCF
Air Flux File	*.AFF
Water Flux File	*.WFF
Water Concentration File	*.WCF
Atmospheric Transport Output File	*.ATO
Exposure Pathway File	*.EPF
Receptor Intake File	*.RIF
Health Impacts File	*.HIF

There are typically four arguments passed to each Model, Tool or UI. They are "FUIName", "RunName", "Site#," and some object type count. In general, a program will **ONLY** read any filenames that start with "FUIName". "RunName" are the scratch space for all Model, Tool, and UI output. "Site#" is the number of the site the Model, Tool, or UI is to run. The last argument is the count for the instance of a object to run. For example if there are three vadose zones in a site then the Vadose Zone UI and Model could be called with a fourth argument of 1, 2, or 3. In the list below, extensions that are listed in braces "{}" are optional. A Model, Tool, or UI does not need to read or write them, but a model should create the files that are needed. It is also important to note that a Model, Tool, or UI must create a RunName.ERR file, then delete it if the Model, Tool, or UI ran properly.

Import Tool: FUIName RunName Site# Import# Name
Read (GID)
Write(GID,ERR,{WFF,AFF,SCF,WCF,ATO,EPF,HIF,RIF})

Source UI: FUIName RunName Site# Name
Read (GID)
Write(GID,ERR)
Source Model: FUIName RunName Site# Name
Read (GID)
Write(ERR,{WFF,AFF,SCF})

Air UI: FUIName RunName Site# Air# Name
Read (GID, {AFF})
Write(GID,ERR)
Air Model: FUIName RunName Site# Air# Name
Read (GID, AFF)
Write(ATO,ERR)

Vadose Zone UI: FUIName RunName Site# Vadose# Name

Read (GID,{WFF})
Write(GID,ERR)

Vadose Zone Model: FUIName RunName Site# Vadose# Name

Read (GID, WFF)
Write(WFF, ERR)

Aquifer UI: FUIName RunName Site# Aquifer# Name

Read (GID, {WFF})
Write(GID,ERR)

Aquifer Model: FUIName RunName Site# Aquifer# Name

Read (GID,WFF)
Write(ERR, {WFF, WCF})

River UI: FUIName RunName Site# River# Name

Read (GID,{WFF})
Write(GID,ERR)

River Model: FUIName RunName Site# River# Name

Read (GID,WFF)
Write(WCF, ERR)

Exposure Pathway UI: FUIName RunName Site# Exposure# Name

Read (GID,{WCF, ATO, SCF})
Write(GID, ERR)

Exposure Pathway Model: FUIName RunName Site# Exposure# Name

Read (GID, {WCF, ATO, SCF})
Write(EPF, ERR)

Receptor Intake UI: FUIName RunName Site# Receptor# Name

Read (GID,{EPF})
Write(GID,ERR)

Receptor Intake Model: FUIName RunName Site# Receptor# Name

Read (GID, EPF)
Write(RIF, ERR)

Health Impacts UI: FUIName RunName Site# HI# Name

Read(GID, {RIF})
Write(Gid, ERR)

Health Impacts Model: FUIName RunName Site# HI# Name

Read (GID, RIF)
Write(HIF, ERR)

Export Tool: FUIName RunName Site# Export# Name

Read(GID,{WFF, AFF, SCF, WCF, ATO, EPF, HIF, RIF})
Write(GID, ERR)

Viewer Tool: FUIName RunName Site# Viewer# Name

Read(GID,{WFF, AFF, SCF, WCF, ATO, EPF, HIF, RIF})
Write(GID, ERR)

THE MODULE DESCRIPTION FILE

The Description file is the mechanism that informs the FUI how to run a module. It is a simple format and is used to describe the model. The text string at the bottom of the file will include the following information:

- A description of what the model is typically used for
- Typical time scale of runs
- Reference to formulation documents
- Reference to verification documents if they exist
- Reference to validation documents if they exist
- Hardware requirements
- Contact point for questions regarding the model

```
Line with: Modeling framework check-"mf"
Line with: Model Type-(string)
                 ; "Source"
                 ; "Air"
                 ; "Vadose Zone"
                 ; "Aquifer"
                 ; "Surface Water"
                 ; "Exposure Pathway"
                 ; "Receptor Intake"
                 ; "Health Impacts"
                 ; "Viewer"
                 ; "Import"
                 ; "Export"
                 ; "Closed"
         Module Name-(string)
         Module UI executable or batch path-(string)
         Module Model executable or  batch path-(string)
                 ; Not used in the Viewer, Import, Export, or Closed
Multi-Line text string description of model
```

MODULE DESCRIPTION FILE EXAMPLE

```
mf
Source,MEPAS Source Version 1.0,mepsrcui.bat,.bat
"This is a page of description of the MEPAS Source term module.

Description

The MEPAS Source term module can be used to compute the release rates of radionuclides
and chemicals from a pond, unsaturated soil, and saturated soil sources.  The source term
module is also capable of calculating releases from different waste forms, including vitrified
waste, cement-solidified wastes, and waste sites with caps.  Typically, the Source Term Module
calculates annual releases over a user-specified waste site lifetime. A more complete
description of the assumptions and theoretical foundations can be found in MEPAS Source
Term Code (Streile et al. 1995), RAPS Formulations(Whelan et al. 1987), and Supplemental
Formulations (Droppo et el. 1989).

Requirements

   MS-DOS 3.1 or higher and at least 1 MB memory and a 80386 processor.

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