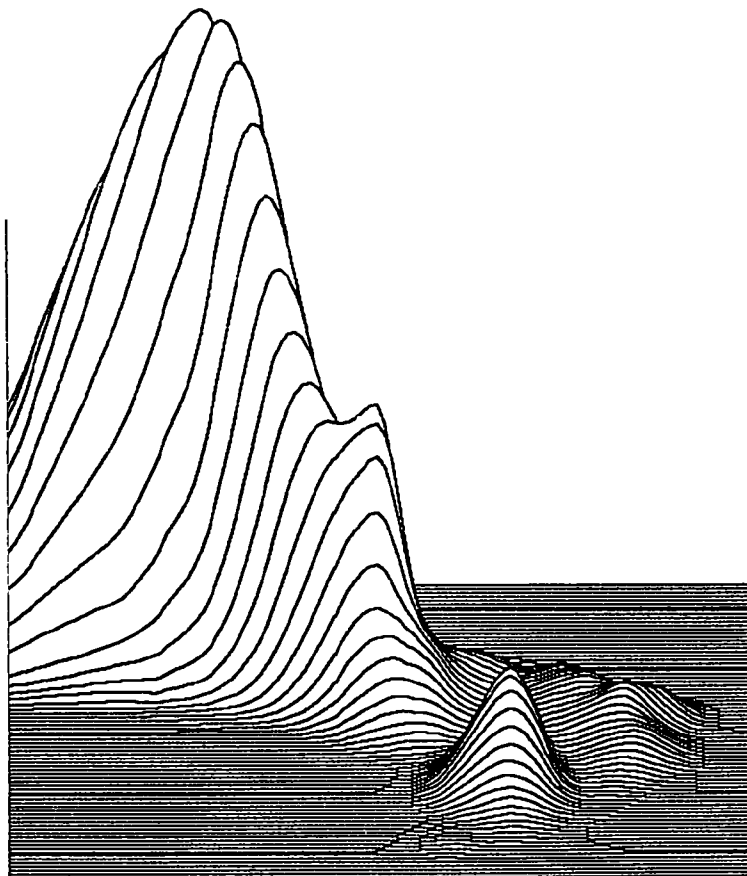




Computer Models Used To Support Cleanup Decision-Making At Hazardous And Radioactive Waste Sites



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**COMPUTER MODELS USED TO SUPPORT
CLEANUP DECISION-MAKING AT
HAZARDOUS AND RADIOACTIVE WASTE SITES**

March 1993

A Cooperative Effort By

**Office of Radiation and Indoor Air
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Washington, DC 20460**

**Office of Environmental Restoration
U.S. Department of Energy
Washington, DC 20585**

**Office of Nuclear Material Safety and Safeguards
Nuclear Regulatory Commission
Washington, DC 20555**

PREFACE

This report is the product of the Interagency Environmental Pathway Modeling Workgroup. The Workgroup is composed of representatives of the Environmental Protection Agency Office of Radiation and Indoor Air and Office of Solid Waste and Emergency Response, the Department of Energy Office of Environmental Restoration, and the Nuclear Regulatory Commission Office of Nuclear Material Safety and Safeguards. This report is one of several consensus documents being developed cooperatively by the Workgroup. These documents will help bring a uniform approach to solving environmental modeling problems common to these three participating agencies in their site remediation and restoration efforts. The conclusions and recommendations contained in this report represent a consensus among the Workgroup members.

SURVEY QUESTIONNAIRE

The following document is the result of a mail survey using a questionnaire similar to the one presented below. Without periodic update, due to new and expanding modeling efforts, this document may soon be obsolete. Therefore, in order to keep this living document a constant source of pertinent information it is important that we receive any additional information regarding models used in the field. Please advise us of any additional models, updated versions and/or novel applications. If you can furnish the authors with any of this information or have any comments regarding the accuracy of the information contained herein, please take the time to complete this survey.

RADIOLOGIC AND NONRADIOLOGIC ENVIRONMENTAL TRANSFER/PATHWAY COMPUTER MODELING ACTIVITIES

Name of Respondent:

Title:

Organization:

Street

City:

State:

Zip Code:

Telephone (Commercial)

Site type (E.G., EPA Superfund, DOE Defense, NRC Commercial Nuclear Facilities):

Media impacted (i.e., groundwater, surface water, soils, or structures):

Name of Code (e.g., PRESTO) implemented and literature reference:

Code prepared by:

Code prepared for:

Status of modeling efforts (planned, ongoing, or completed):

Radioisotopes and nonradiologic contaminants evaluated:

End-points evaluated (e.g., environmental concentration, dose commitment):

Level-of-effort expended or planned (man-months):

Have you conducted any site-specific model calibration/validation efforts: If so please briefly describe the nature of these efforts:

Have the results of these modeling and calibration/validation efforts been published? If so where?

Other comments:

=====RETURN TO=====

**Paul D. Moskowitz
Environmental Health Scientist
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Building 475
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Upton, New York 11973**

EXECUTIVE SUMMARY

Efforts are underway to cleanup hazardous and radioactive waste sites located throughout the U.S. To help determine cleanup priorities, computer models are being used to characterize the source, transport, fate and effects of hazardous chemicals and radioactive materials found at these sites. Although the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), and the U.S. Nuclear Regulatory Commission (NRC) have provided preliminary guidance on the use of computer models for remediation purposes, there is only limited directed guidance on model selection and application at radiation contaminated sites. As a result, model selection is currently done on an *ad hoc* basis. This is administratively ineffective and costly, and can result in technically inconsistent decision-making. To identify what models are actually being used to support decision-making at hazardous and radioactive waste sites, a project jointly funded by EPA, DOE and NRC was initiated. The purpose of this project was to: 1) Identify models being used for hazardous and radioactive waste site assessment purposes; and 2) describe and classify these models. This report presents the results of this study. A mail survey was conducted to identify models in use. The survey was sent to ~550 persons engaged in the cleanup of hazardous and radioactive waste sites; 87 individuals responded. They represented organizations including Federal Agencies, national laboratories and contractor organizations. Although the questionnaire received widespread distribution, we acknowledge that some important organizations (e.g., U.S Geological Survey) or personnel engaged in modeling at hazardous and radioactive waste sites were not contacted. Also, because respondents were asked to participate in this effort on a voluntary basis, it is possible that other ongoing modeling efforts were not reported. The respondents identified 127 computer models that were being used to help support cleanup decision-making. The identified models included: Multi-Media (41 models); Ground Water (34 models); Air (20 models); Engineering (19 models); Surface Water (7 models), Geochemical (5 models); and, Utilities (1 model). These models were used at EPA (SUPERFUND), DOE (e.g., Defense, UMTRA, FUSRAP and SFMP), and NRC sites. By

far, the largest representation was from DOE-related sites (> 75%). Many of the models in use were developed for EPA, DOE, and NRC. However, a substantial number of models identified (30 of the 127) were developed for other organizations. Although information was requested about the level-of-effort spent in the modeling exercises (e.g., data assembly and model implementation), there was little information provided by the respondents. Some efforts in model verification, calibration and/or validation were reported for 53 of 223 model applications. In the model applications, the overwhelming majority of the models were being used to calculate environmental concentrations of contaminants and radiation dose commitments. In summary, there were a few models that appeared to be used across a large number of sites (e.g., RESRAD). In contrast, the survey results also suggested that most cleanup efforts were using site-specific models.

CONTENTS

1.	INTRODUCTION	1
2.	THE SURVEY	2
3.	MODEL CLASSIFICATION SCHEME	5
4.	SURVEY RESULTS	7
4.1	Responses	7
4.2	Site Type	8
4.3	Sponsoring Agency	8
4.4	Media/Category	10
4.5	Level-of-Effort	10
4.6	Validation/Calibration	13
4.7	End-Points	13
4.8	Publications	13
5.	DISCUSSION AND CONCLUSIONS	15
6.	REFERENCES	39
	APPENDIX A - BACKGROUND INFORMATION ON IDENTIFIED MODELS	59
	ACKNOWLEDGMENT.....	103

TABLES

1.	Administrative Data and Models Used	17
2.	Alphabetical List of Models, Model Types and References	19
3.	Model, Site Type, Contaminant, End-Point, Effort, Validation and Publications	22
4.	Model - Sponsoring Agency	27
5.	Index of Existing Environmental Pathway Models	28

FIGURES

1.	Mail Survey Questionnaire.....	3
2.	Frequency of Respondent Site Type	9
3.	Frequency of Models/Media Category	11
4.	Frequency of Level-of-Effort.....	12
5.	Frequency Model/End-Points.....	14

1. INTRODUCTION

Efforts are underway to cleanup hazardous and radioactive wastes found at contaminated sites throughout the U.S. [e.g., U.S. Environmental Protection Agency (EPA) Superfund Sites, U.S. Department of Energy (DOE) weapon production sites, and the Nuclear Regulatory Commission (NRC) decommissioning sites]. The nature and extent of cleanup to be accomplished at many of these sites will be based on initial studies [e.g., Remedial Investigation/Feasibility Studies (RI/FS)] resulting from formally or informally negotiated agreements between the site and the governing Agency. In these evaluations, models (e.g., computerized environmental pathway or engineering) are often used to characterize the source, transport, fate and effects of hazardous chemicals and radioactive materials identified at the sites. The models may also be used to characterize benefits of alternative remediation options.

The EPA (e.g., USEPA, 1988, 1989a, 1989b), DOE (e.g., Case et.al., 1989) and NRC (e.g., Kozak, 1989, 1990a, 1990b) have begun preliminary efforts to promote the consistent use of models for site evaluation purposes at Superfund hazardous waste sites and low-level radioactive waste repository sites, respectively. Although, the EPA, DOE and NRC, have provided preliminary guidance on the use of computer models for remediation purposes, there is only limited directed guidance on model selection and application at radiation contaminated sites. As a result, model selection by site Remedial Project Managers (RPMs), or their equivalent, is currently done on an *ad hoc* basis. Some of the selected models are well known and have been subjected to wide-spread critical review. Others have been developed for site-specific applications and have not received outside evaluation. Consequently, Agency review of model choice and validity of the results must be done on a site-by-site basis. This is administratively ineffective and costly, and can result in technically inconsistent decision-making.

To assist EPA, DOE, and NRC site-level personnel (e.g., On-Scene Coordinators, RPMs, or Site Managers) select appropriate models for RI/FS-type studies and administrators

to review these submissions, this report: Identifies, through the use of a mail survey and a literature review, models being used for hazardous and radioactive waste assessment purposes at EPA Superfund, DOE, NRC and other hazardous and radioactive waste sites; and, describes and classifies these models according to their basic characteristics.

2. THE SURVEY

A mail survey was conducted to identify radiologic and nonradiologic environmental transfer or pathway computer models which have been used or are being used to support the cleanup of hazardous and radioactive waste sites. The intent of the survey was to gather basic administrative and technical information on the extent and type of modeling efforts being conducted by EPA, DOE, and NRC at hazardous and radioactive waste sites, and to identify a point of contact for further follow-up. The survey questionnaire is shown in Figure 1.

The survey was conducted in two phases: The first in the Spring of 1990; and, the second in the Summer of 1991. Mailing lists were developed by compiling names and addresses provided by EPA, DOE and NRC staff, and selecting names from various technical reports. The lists included representatives from the three sponsoring Agencies, national laboratories, universities and consulting engineering firms. The first questionnaire was mailed to ~350 persons; the second questionnaire was sent to an additional ~200 persons.

Although the questionnaire received widespread distribution, we acknowledge that some important organizations (e.g., U.S Geological Survey) or personnel engaged in modeling at hazardous and radioactive waste sites were not contacted. The survey, however, attempted to develop a "snapshot" of a dynamic, rapidly changing community of sites, models, and responsible parties (e.g., modelers and RPMs). In this context, we believe the list of respondents and models identified should be illustrative of those involved in the cleanup of hazardous and radioactive waste sites.

QUESTIONNAIRE

RADIOLOGIC AND NONRADIOLOGIC ENVIRONMENTAL TRANSFER/PATHWAY
COMPUTER MODELING ACTIVITIES AT EPA/DOE/NRC SITES

Prepared for

Office of Radiation Programs
U.S. Environmental Protection Agency

Office of Environmental Restoration and Waste Management
U. S. Department of Energy

Office of Nuclear Material Safety and Safeguards
U. S. Nuclear Regulatory Commission

Name of Respondent:

Title:

Organization:

Street:

City:

State:

Zip Code:

Telephone (Commercial):

Site type (e.g., EPA SUPERFUND, DOE Defense, NRC Commercial Nuclear Facilities):

Media impacted (i.e., groundwater, surface water, soils, or structures):

Name of code (e.g., PRESTO) implemented:

Code prepared by:

Code prepared for:

Status of modeling efforts (planned, ongoing, or completed):

Radioisotopes and nonradiologic contaminants evaluated:

End-points evaluated (e.g., environmental concentration, dose commitment):

Level-of-effort expended or planned (man-months):

Have you conducted any site-specific model calibration/validation efforts: If so, please briefly describe the nature of these efforts:

Have the results of these modeling and calibration/validation efforts been published? If so, where:

Other comments:

PLEASE RETURN COMPLETED QUESTIONNAIRE TO:

**Paul D. Moskowitz
Environmental Health Scientist
Biomedical and Environmental Assessment Group
Brookhaven National Laboratory
Upton, New York 11973
(516 282-2017) (FTS 666-2017)**

3. MODEL CLASSIFICATION SCHEME

While the survey was being conducted, we concluded early-on that a classification scheme would be needed to organize the discussions on modeling capabilities due to their wide range of focus. One way to classify models is according to their major purpose (e.g., environmental transport, accidents etc.). Another common way to classify models is by the environmental media they simulate (e.g., air, soil, surface water or ground water). Models could also be broken down into those groups which simulate only the physical transport of a contaminant through air, soil or water; and those which follow the contaminant through the food chain to man, producing estimates of dose or risk. A classification scheme based on a combination of these categories is used here.

The major categories used in this report are:

1. Multi-Media;
2. Air;
3. Surface Water;
4. Ground Water;
5. Aqueous Geochemistry;
6. Engineering/Performance/Accident;
7. Radiation Dose;
8. Utilities (Model Support Software).

The first four classes of models are concerned with the transport and fate of hazardous and radioactive materials in the environment. In the first class, Multi-Media models, some attempt is made to integrate several possible media (e.g., air, ground water, food chain, soil, etc.) into one simulation. Subclasses within the first group include Hazard Ranking, Radioactive Fate and Transport, General Purpose and Food Chain. Hazard Ranking models rank waste sites based on the risks they may present to the public; the numbers produced by these models are used relative to each other, and are not used to estimate risk at individual

facilities. In contrast, Radioactive Materials Fate and Transport, and General Purpose models provide an estimate of the environmental transport, exposure and risk presented by releases of radioactive materials or other types of pollutants, respectively.

Transport models predict the physical movement of contaminants through one media (e.g., air, surface water and ground water). Air models sometimes include consideration of other pathways (e.g., soil deposition and agricultural uptake). Similarly, many ground and surface water models evaluate unsaturated-zone transport of contaminants. This report, however, groups models as air, surface or ground water on the basis of their primary focus, rather than their potential applications or ancillary use. If the transport models predict contaminant transfer among the different media, they have been placed in the Multi-Media class.

The other four classes of models are used for more-specific purposes. Aqueous Geochemical and Hydrogeochemical models attempt to establish the relative abundance or concentration of various contaminant species. Geochemical models are often used to predict whether a given dissolved pollutant will be precipitated during transport in surface or ground water; or conversely, whether a solid pollutant might be dissolved under certain aqueous conditions.

The group of models classified as Engineering/Performance/Accident models evaluate safety and the potential for contaminant transport based on an analysis of human-engineered structures. Engineering models calculate volumes, slopes or stresses of engineered or natural structures. Accident models estimate the transport and ultimate effects of radionuclides released during an accident in a nuclear reactor or waste storage sites. Performance models assess the capability of engineered structures designed to isolate waste from the environment; models designed to assess the risk associated with releases from landfills and other engineered facilities; and models used to estimate the levels of contaminants that can remain after cleanup based on environmental transport and risk information.

Radiation dose models determine the amount of shielding needed in a radiation area, or calculate radiation dose from radioactive substances transported through the environment as established by the use of other transport models. The last category, Utilities, includes software which supports or enhances the use of the aforementioned classes of models.

4. SURVEY RESULTS

4.1 Responses

A total of 87 individuals responded; 61 in Phase 1, and 28 in Phase 2 (two individuals responded to both surveys). The persons and organizations responding to the survey are listed in Table 2, along with the models identified by each respondent. Model application responses were received from individuals, both modelers and division heads supervising a group of modelers, representing 38 different companies, facilities or Federal Agency Offices. In total, these respondents identified 127 different models. In later sections to this chapter further information on the models, the media impacted, etc., is presented.

Some of the organizations responding to the survey are DOE National Laboratories with strong research and development programs; and, a few of the models identified were developed by the respondents and applied at other sites. To the extent possible, these development responses are not included in the analysis of the survey responses. The information provided on model development, however, has been used in preparing Appendix A which gives a brief description of each of the models identified in the survey, including the sponsoring agency, a description of the model, and relevant references. These survey results can provide useful information for expanding and updating the knowledge-base on models being applied in the remediation of radiation contaminated sites.

Data from the survey allows for an analysis of both the type and numbers of unique models identified, as well as the number of model applications falling into a given category. Some models are used at many sites, particularly in the DOE community. In contrast, the survey also suggests that most sites were using models which were not reported in use elsewhere. Table 3 alphabetically lists the reported models. This Table also presents primary literature references for most of the models and gives a quick indicator of the model type (e.g., air and ground water). Finally, the Table indicates whether the model can be used for radioactive substances and whether it is a detailed or screening-level model. Codes used for the purpose of modeling non-radioactive substances were included in this table because such models are often used for radioactive materials with very long half-lives (e.g., K-40) relative to their transit time.

Table 4 lists the site type at which each model was applied (see section 4.2) as well as which contaminants were being modeled at the site, the end-points of the modeling effort (see section 4.7), and the amount of time needed to complete this effort (see section 4.5). Finally, the Table shows whether the model has been calibrated/validated at the site and whether these results have been published (see sections 4.6 and 4.8, respectively).

4.2 Site Type

In Figure 2 the types of sites (e.g., DOE Defense, EPA Superfund) under investigation are summarized. By far the largest representation is from DOE-related sites. These account for more than 75% of the reported site-types.

4.3 Sponsoring Agency

As Table 5 indicates, many of the models identified were developed by or for EPA (e.g., AIRDOS, RISC, PRESTO, RADRISK), DOE (e.g., BIOTRAN, MEPAS, RESRAD,

Frequency of Respondent Site Type

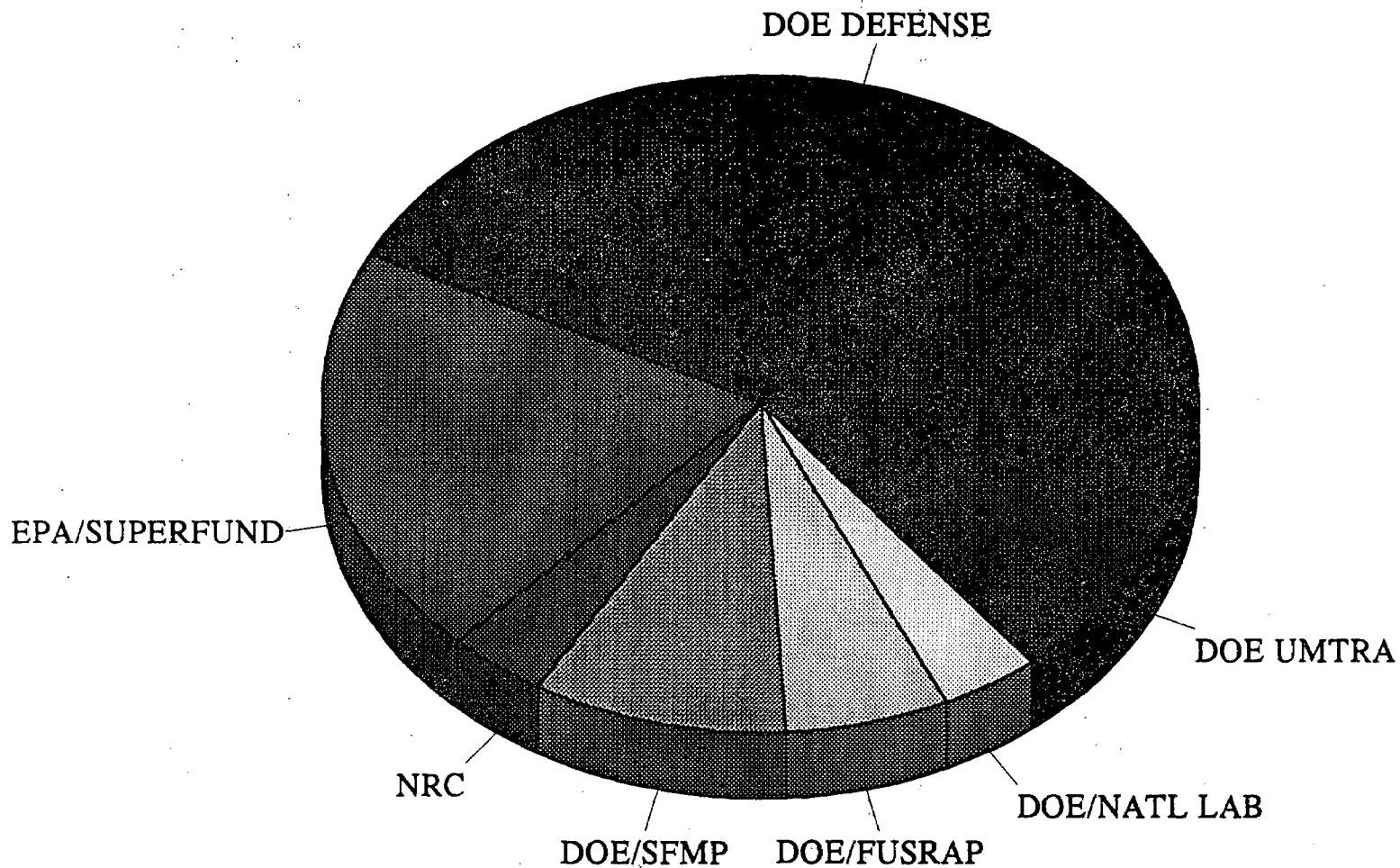


FIGURE 2

RSAC) or the NRC (e.g., MACCS, RAECOM, UDAD). A few of the models were developed for use at a specific site by the individual organizations. Note that the number of models sponsored by groups other than the three sponsoring Agencies is substantial (30 of 127). The "Other" group includes private corporations, universities, the U.S. Geological Survey, U.S. Department of Agriculture, Canadian government agencies, State agencies, and non-profit groups. It is evident that independent model development and support is vigorous.

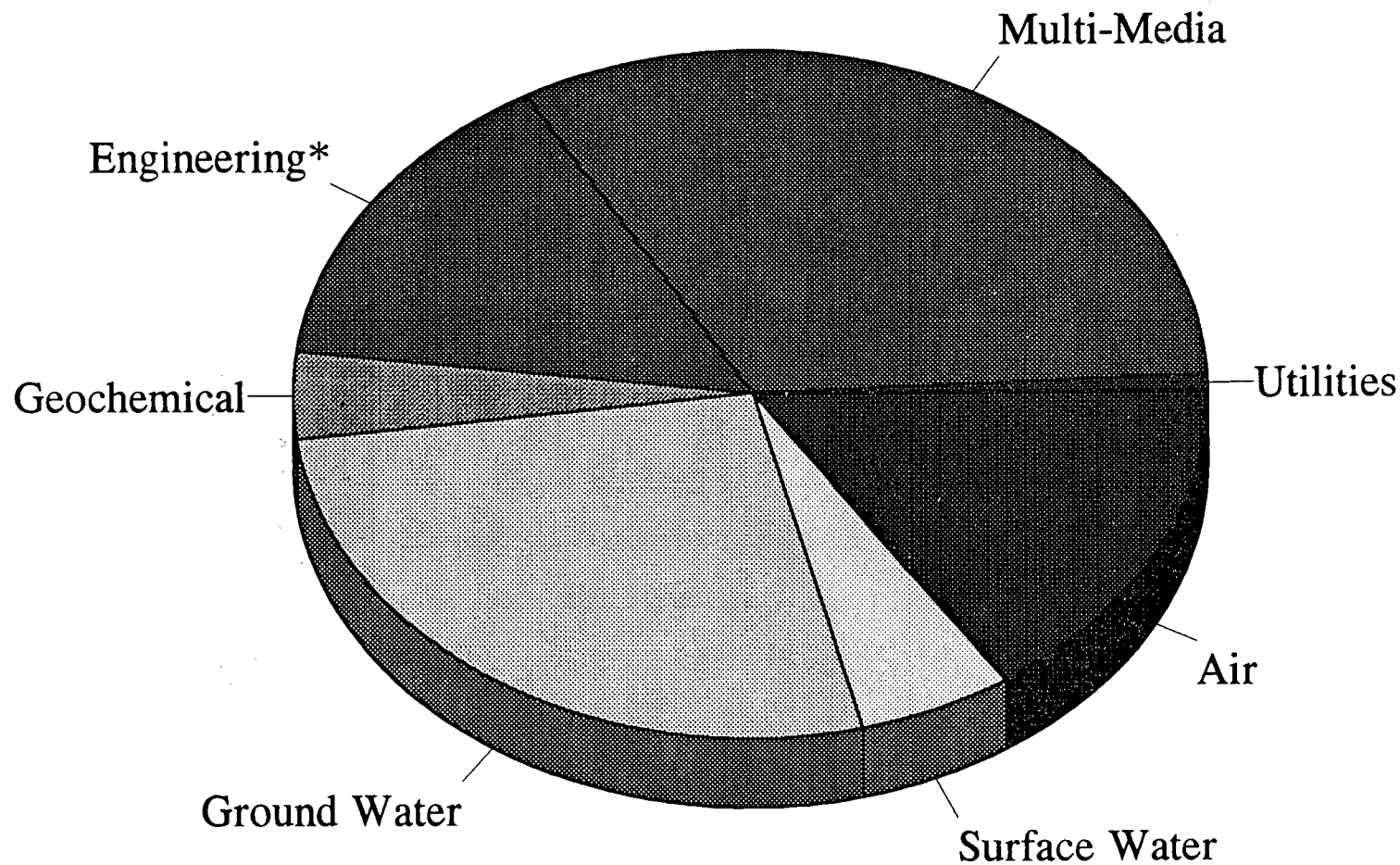
4.4 Media/Category

There are two important ways to look at the data further; by model, or by application. The models identified in the survey responses were categorized into the groupings discussed in Section 3. Figure 3 shows the distribution of the unique models identified among these categories. The Multi-Media category is the largest class where 41 models were reported. This was closely followed by the Ground Water transport category where 34 different models were identified. There were 20 reported Air models and seven reported Surface Water models. Engineering models which include Performance Assessment, Accident and Radiation Dose models were the next largest category with 19 models identified. Five Geochemical models and one Utility model were also reported.

4.5 Level-of-Effort

The level-of-effort required for the completion of a modeling task appears to be project specific, as opposed to model specific. The data obtained from both surveys show a wide range of man-months needed to complete a project. However, most respondents failed to answer this question. Figure 4 presents these data in groups of man-months needed to complete each reported modeling effort.

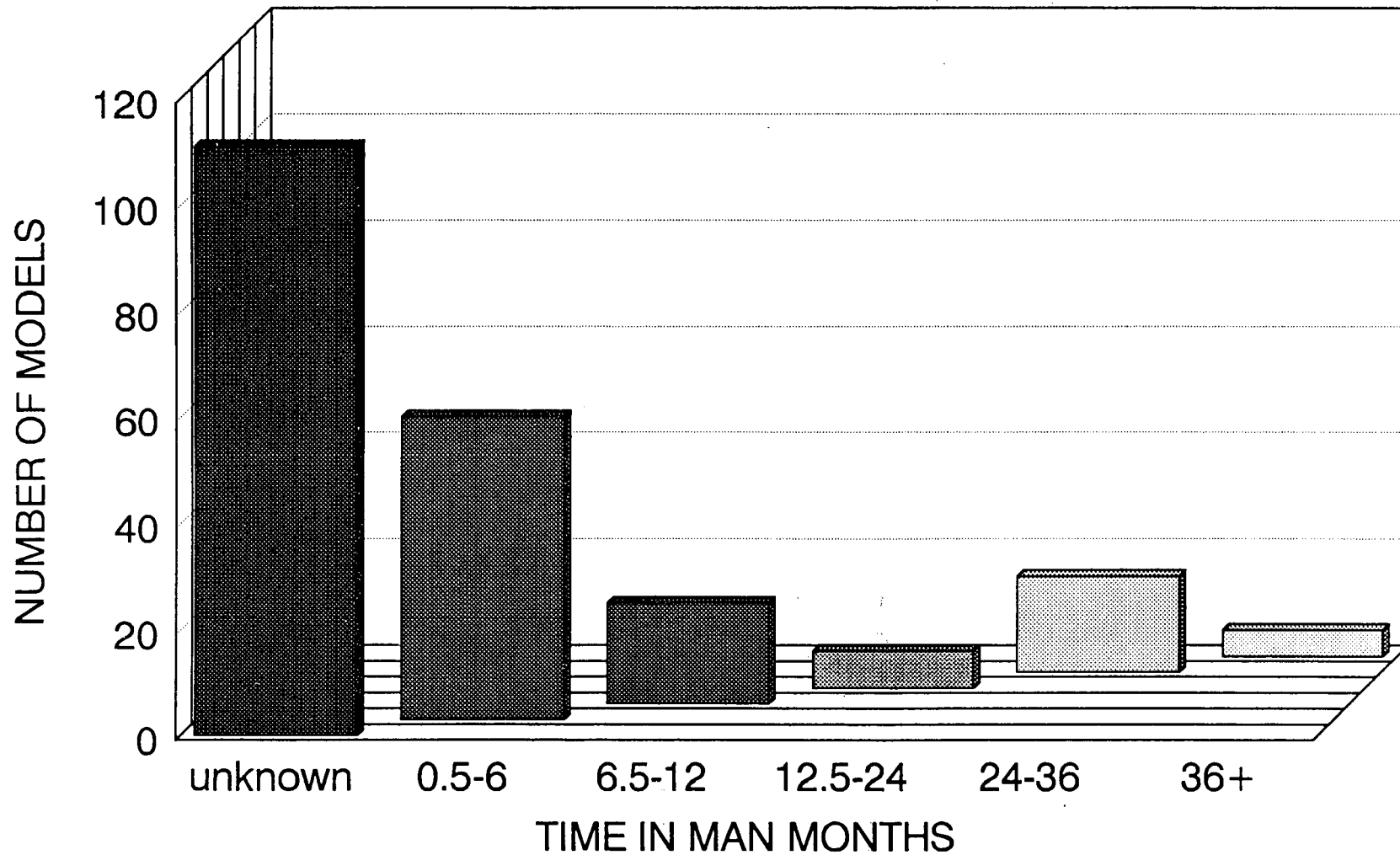
Frequency of Models/Media Category



* Including Performance, Accident & Rad. Dose Models

FIGURE 3

Frequency of Level of Effort



4.6 Validation/Calibration

Site-specific model validation/calibration efforts were conducted for 56 model applications. No validation/calibration studies were reported for the remaining 167 applications. This survey does not, however, describe how, or what level-of-effort was spent on validation/calibration. Further inquiry is needed here to determine which models have been validated/calibrated, and what was actually done.

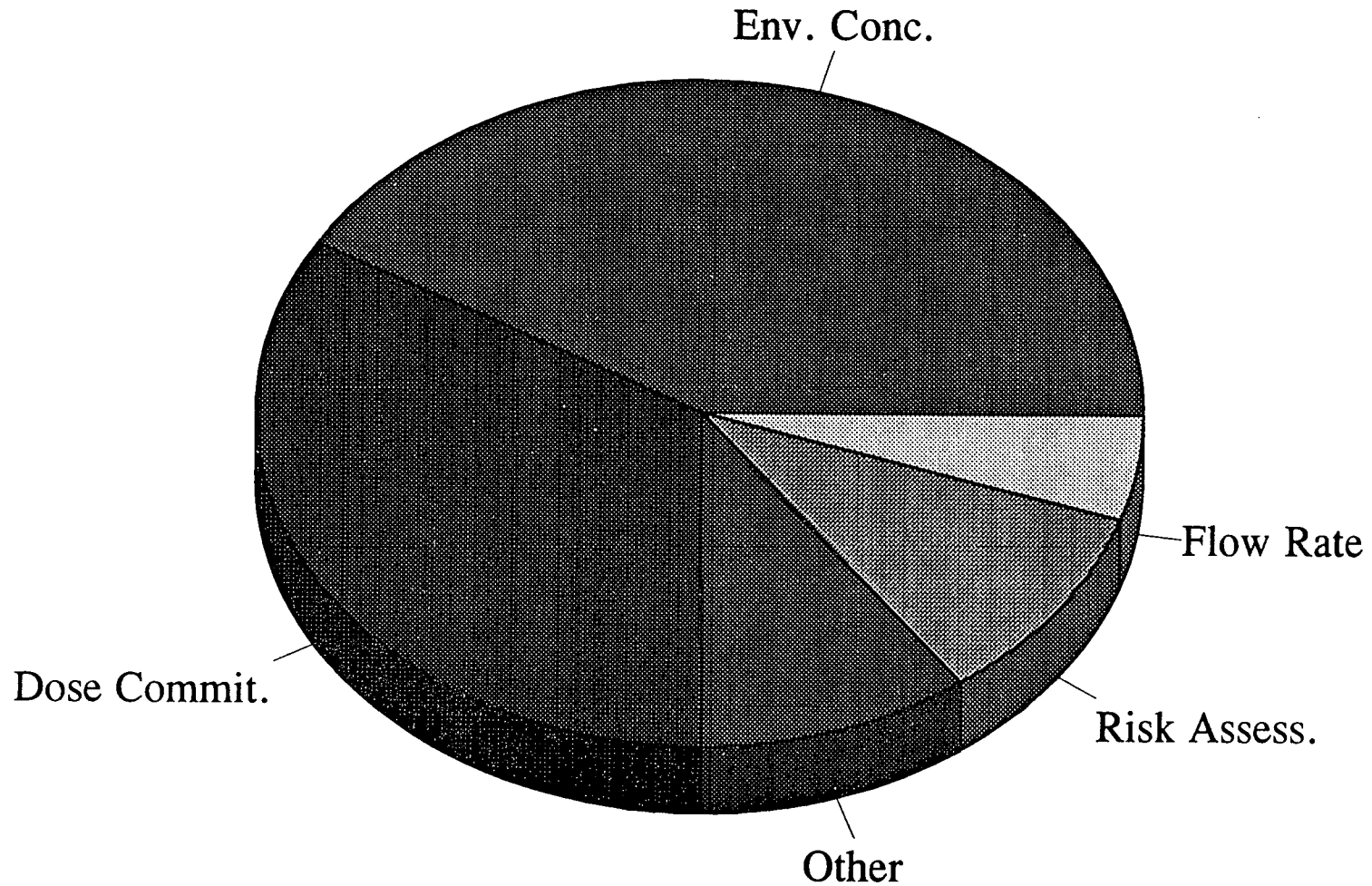
4.7 End-Points

Figure 5 depicts the frequency of end-points being evaluated by the reported models. The overwhelming majority of models are being used for the more general purpose of finding environmental concentrations of contaminants and radiation dose commitment. Several more task specific models are also reported with less frequency.

4.8 Publications

Results of the reported modeling and validation/calibration efforts of 56 applications were published in various journals and papers. For 167 of the model applications there were either no publications or no response to the survey question regarding publication.

Frequency of Models/End Points



Other includes: Water Levels, Flow Rates, Riprap Sizing, Radon Emanation, etc., (see Table 4).

5. DISCUSSION AND CONCLUSIONS

In any voluntary survey it is essential to question the representativeness of the results. In this context, the results of the two surveys reported here can be compared with each other and with previously published technical literature.

In comparing the data collected within the two surveys reported here, one of the most striking aspects of the results is the small overlap between the two. As Table 6 indicates only 17 models (13% of the total) were reported in both surveys. While this may suggest that each of the surveys sampled distinctly different populations, there is one very important reason that this might not be true. That is, we had originally hypothesized that because no formal guidance for model use exists, models would be chosen on an *ad hoc*, site-by-site basis. This hypothesis appears to be correct. Approximately 60% of the identified models in both surveys were used at only one site. This could also imply that there may be a substantial amount of model redundancy, especially in the application of General Purpose or Multi-Media models.

Based on published literature which includes surveys (e.g., Mangold and Tsang, 1991), review articles (e.g., Case, 1989) and technical literature on model development and application oriented studies, we know that many other models exist other than the models identified in this survey. In Table 6, we list and categorize many of these "unidentified" models. Whether these models are actually being used to support cleanup decisions remains unanswered. We speculate that these models were not identified because of the dynamic nature of the modeling community in which models and model applications are constantly being upgraded and changed. An index of known environmental pathway models, extrapolated from all referenced literature and reviews, and the agency which sponsored their development is also presented in Table 6. Models reported in the current survey represent approximately 25% of the known models used in environmental pathway analysis. One important example of an "unidentified" model is FEMWATER/FEMWASTE. No users of the

model were identified in the survey, yet the use of FEMWATER/FEMWASTE has been reported in the literature (Sullivan and Suen, 1989).

In conclusion, it is clear that a unified approach to model selection is needed. Ultimately, this will reduce administrative cost, while improving the technical quality of the decision-making process. Proactive guidance from the sponsoring Agencies for model selection is preferable to retroactive correction and improvement, through modification, of an inappropriately applied model.

TABLE 1 - Administrative Data and Models Used

Count	Name	Organization	Street Address	City	State	Zip	Telephone	Models Used
1	David Abbot	EG&G Mound Applied Tech	P O Box 3000	Miamaburg	OH	45343	513-865-3936	NUREG-0707
2	Peter F Anderson	GeoTrans, Inc	46050 Manekin Plaza	Sterling	VA	22170		FTWORK
3	Richard W Arnseth	Science Applications Inte	301 Laboratory Rd	Oak Ridge	TN	37830		MODFLOW/MOC
4	Burton R Baldwin	EG&G Idaho	P O Box 1625	Idaho Falls	ID	83415	208-526-4231	RSAC
5	Marcel P Bergernon	Pacific Northwest Lab	P O Box 999, MS K6-77	Richland	WA	99352	509-376-8410	CFEST
6	B G Blylock	Oak Ridge National Lab	P.O. Box 2008	Oak Ridge	TN	37831	615-576-2118	AIRDOS-EPA
7	William C Borden	Bechtel National, Inc	P.O. Box 350	Oak Ridge	TN	37831	615-482-0347	RESRAD
8	L.S. Cahn	UNC Geotech	P.O. Box 14000	Grand Junction	CO	81502	303-248-6563	GW Flow Model RESRAD
9	Daniel G Carbagno	EG&G/mound applied Techno	P O. Box 3000	Miamaburg	OH	45343		RESRAD
10	Dennis J Carr	Feed Materials Prod Cr	P O Box 398704	Cincinnati	OH	45239	513-738-6200	SWIFT III
11	Young-Soo Chang	Argonne National Lab	9700 S Cass Avenue	Argonne	IL	60439	708-972-4076	ISCST/ISCLT
12	David A Charlton	CHEM-NUCLEAR ENV. Svcs	2309 Renard Place, Suite 300	Albuquerque	NM		505-766-3061	RAECOM
13	Charles L. Cheever	Argonne National Lab	9700 S Cass Avenue	Argonne	IL	60439	972-3311	RADRSK AIRDOS
14	Christine Daily	U S NRC	RES/DRA NLS-139	Washington	DC	20555	301 492 3999	AIRDOS-PC DECHEM v 3 02 DECOM v 2 2 RESRAD
	Christine Daily	U S NRC	RES/DRA NLS-139	Washington	DC	20555	301 492 3999	IMPACTS-BRC v 2 0 RAECOM MicroAIRDOS v 2 0 GENII
15	Jerry D Davis	Westinghouse Hanford Co	P O Box 1970	Richland	WA	99352		MEPAS UNSAT-H v 2 0
	Jerry D Davis	Westinghouse Hanford Co	P.O. Box 1970	Richland	WA	99352		PATHRAE-HAZ PORFLO-3 v 1 0 PORFLO-3 v 2 0 PORMC-3 v 1 0 PATHRAE-EPA
18	T R Decker	U S NRC RII	101 Marietta St. NS Suite 2900	Atlanta	GA	30323		N/A
17	Nicoletta DiForte	Office of the Regional Ad	26 Federal Plaza Room 906	NY	NY	10278		
18	P G Doctor	Pacific Northwest Lab	3110 Port of Benton Blvd	Richland	WA	99352	509-376-4436	SUMO
19	James G Droppo Jr	Pacific Northwest Lab	P O Box 999	Richland	WA	99352	509-376-7652	MEPAS
20	Lisa A Durham	Argonne National Lab	9700 S Cass Avenue	Argonne	IL	60439	708-972-3170	CFEST
21	Roy Eckart	Feed Materials Prod Cr	P O Box 398704	Cincinnati	OH	45239	513-738-6200	
22	Kenneth J Eger	EBASCO Environmental	10900 NE 8th Street	Bellevue	WA	98004	206-451-4255	PATH
23	Mac Ennis	Los Alamos National Lab	P O Box 1663 MS K490	Los Alamos	NM	87545	505-665-1573	PRESTO-II SPUR GENII AIRDOS-EPA PART81 BIOTRAN
24	David E Farris	Feed Materials Prod Cr	P O Box 398704	Cincinnati	OH	45239	513-738-6200	DARTAB COMPLY AIRDOS
25	Michael J Fayer	Pacific Northwest Lab	3110 Port of Benton	Richland	WA	99352	509-376-8326	UNSAT-H
26	Alan Fellman	Rad Branch, USEPA Reg 2	26 Federal Plaza 2AWM-RAD	New York	NY	10278		AIRDOS
27	Joe Frazier	EG&G Idaho Inc	P.O. Box 1625	Idaho Falls	ID	83415	208-526-9039	FLASH/FLAME
28	Gary Gailot	IT Corp	2790 Mosside Blvd	Monroeville	PA	15146		STRIP 18 SWIFT III GEORFLOW ODAST
29	Bruce Gallaber	Los Alamos Natl Lab	Mail Stop K490	Los Alamos	NM	87545		TRACR3d
30	David Gallegos	SNL Org 6416		Albuquerque	NM	87185		DCM3D INUSLT
31	Richard O Gilbert	Pacific Northwest Lab	P O Box 999	Richland	WA	99352	509-375-2979	ML CODE
32	Giorgio N Gnugnoli	USNRC	Mail Stop 5-E-4	Washington	DC	20555	301-492-0578	RADON (RAECOM)
33	Tim Goering	Jacobs Engineering Group	5310 Central Ave NE, Suite 1400	Albuquerque	NM	87108	505-845-5671	USGS-MOC UNSAT-2
34	Mark Hansen	USEPA	1445 Ross Avenue	Dallas	TX	75202	214-635-7208	ISCST SCREEN SIMS CHARM
35	John Haselov	Savannah River Laboratory	773-42A	Aiken	SC	29808	803-725-5219	PATHRAE DOSTOMAN
36	Marvin W Henderson	MK-Ferguson Company	2309 Renard Place SE, Suite 300	Albuquerque	NM	87106	505-766-3047	HEC-2 STEPH RAECOM SFRIPD UNSAT-2 BRUNZOG
	Marvin W Henderson	MK-Ferguson Company	2309 Renard Place SE, Suite 300	Albuquerque	NM	87106	505-766-3047	PC-SLOPE HELP UTEXAS2 CONSOL SOIL
	Marvin W Henderson	MK-Ferguson Company	2309 Renard Place SE, Suite 300	Albuquerque	NM	87106	505-766-3047	STABR HEC-1 SBUHYD RETC F77 SFRIFE
	Marvin W Henderson	MK-Ferguson Company	2309 Renard Place SE, Suite 300	Albuquerque	NM	87106	505-766-3047	STABLE5
37	Bob Hlavacek	MK-Ferguson Company	7295 Highway 94 South	St Charles	MO	63303	314-441-8086	AIRDOS-EPA RAECOM RESRAD
38	F.O Hoffman	Oak Ridge National Lab	P O Box 2008	Oak Ridge	TN	37831	615-576-2118	AIRDOS-EPA
39	J D Hoover	Westinghouse Hanford Co	P.O. Box 1970	Richland	WA	99352		PHREEQE BALANCE
40	Cheng Yeng Hung	USEPA, Office Rad Prog	401 M Street, SW	Washington	DC	20460	475-9633	PRESTO-EPA-POP PRESTO-EPA-CPG
41	Victor J Janosik	EPA	841 Chestnut Bldg	Philadelphia	PA	19107		
42	Mark Kautsky	UNC Geotech	2597 B 3/4 Road	Grand Junction	CO	81503	303-248-6556	HEC-1 HEC-2 RANDOM WALK
43	Mark E Kaye	Bechtel National, Inc	800 Oak Ridge Turnpike, PO Box 350	Oak Ridge	TN	37831	615-576-0463	AIRDOS-PC RESRAD COMPLY
44	Elizabeth Keicher	EPA R9	75 Hawthorne St	San Francisco	CA	94105		3-d Mixing Cell SWIFT III MODFLOW

TABLE 1 – Administrative Data and Models Used

Count	Name	Organization	Street Address	City	State	Zip	Telephone	Models Used
45	Malcolm R. Krapp	U S NRC	475 Allendale Road	King of Prussia	PA	19406		
46	Robert Knowlton	U S DOE/Environ Rest 7723	1000 Independence Ave	Washington	DC	20585		RESRAD
47	F C Konegay		P O Box 2008	Oak Ridge	TN	37831	615-574-5776	MESOI
48	Tim LeGore	Westinghouse Hanford Co	P O Box 1970	Richland	WA	99352	509-376-1225	VAM2D
49	Herbert Levine	EPA	75 Hawitorne St	San Francisco	CA	94105		MODFLOW FLOWPATH CFEST
50	F Tom Ludstrom	SPS DWMD REECO INC	3281 S Highland	Las Vegas	NV	89109		TDRECH23 GCOT3DH3 ODRECH6 TDRECH21 CASCADER
	F Tom Ludstrom	SPS DWMD REECO Inc	3281 S Highland	Las Vegas	NV	89109		TDRECH11 GCOT3DH4 ODRECH7 GCOT3DH5 TDRECH12
51	Paul Mattingly	EGG Waste Mangement	200 Woodruff Avenue	Idaho Fall	ID	83415		PAGAN TRACR3D
52	Tim McCartin	U S NRC		Washington	DC	20555		DCM3D TOUGH NEFRAN II DPCT SWIFT II
53	Jere Millard	Jacobs Engineering Group	5301 Central NE	Albuquerque	NM	87108	505-845-5700	DECHEM
54	S J Morrison	UNC Geotech	P O Box 14000	Grand Junction	CO	81502	303-248-6373	HYDROGEOCHEM
55	William E. Murpbe	U S DOE	EM-423	Washington	DC	20545	301-353-5896	RESRAD
56	Robert Murphy	Jacobs Engineering Group	5301 Central Ave NE Suite 1400	Albuquerque	NM	87108	505-845-5713	LTSAMP
57	R L Murri	UNC Geotech	P O Box 14000	Grand Junction	CO	81502	303-248-6024	RESRAD
58	T E Myrick	Martin Marietta Energy Systems	P O Box 2001 Bldg K-1037	Oak Ridge	TN	37831	615-574-3955	BARRIER USGS-MOC UTM
59	B A Napier	Battelle-Northwest	P O Box 999	Richland	WA	99352	509-375-3896	DITY ONSITE/MAXI GENII
60	Jeff Neff	USDOE	505 King Avenue	Columbus	OH	43221	614-424-3990	AIRDOS RESRAD
61	Eric Nichols	Weiss Associates (LLNL)	5500 Shellmound Street	Emeryville	CA	94608		CFEST
62	F R O'Donnell	Oak Ridge National Lab	P O Box 2008	Oak Ridge	TN	37831	615-576-2132	DOSES CAP-88 MACCS AIRDOS-EPA
	F R O'Donnell	Oak Ridge National Lab	P O Box 2008	Oak Ridge	TN	37831	615-576-2132	CONDOS-II ISCT/ISCT RASCAL, v 1 3
63	Natahe Olgne	Waste Ma	SNL	Albuquerque	NM	87185		NEFRAN II
64	Linda Pegues	Weston/Jacobs UMTRA Proj	5301 Central Ave NE Suite 1700	Albuquerque	NM	87108	505-845-4030	HELP ver 2 02 UNSAT-H, ver 1 1 STABL UNSAT-2 1 RETC F77
65	J W Ray	Battelle	505 King Avenue	Columbus	OH	43201	614-429-5522	RESRAD
66	Larry G Reed	EPA Office of ERR	401 M Street SW	Washington	DC	20466		
67	Jon Richards	USEPA Region IV	4291 East Meadow Dr	Duluth	GA	30136	404-347-3907	SWIFT II MOD3D IMPACT PATHRAE
68	Paul Rittmann	Westinghouse Hanford Co	P O Box 1970	Richland	WA	99352	509-376-8191	GENII AIRDOS-PC
69	Barry Roberts	EG&G Rocky Flats Inc	P O BOX 464 Trailer T130B EMAD	Golden	CO	80402		VAM2d TARGET MODFLOW MOC
70	C J Roberts	West Valley Nuclear Svcs	P O Box 191	West Valley	NY	14171	716-942-4271	MINTEQ RESRAD PHREEQE ISOSHLD HELP
	C J Roberts	West Valley Nuclear Svcs	P O Box 191	West Valley	NY	14171	716-942-4271	MILDOS AFTOX PLASM MODFLOW AIRDOS-PC
	C J Roberts	West Valley Nuclear Svcs	P O Box 191	West Valley	NY	14171	716-942-4271	PATHRAE-EPA INPUFF COMPLY MAXII
71	Rene R. Rodriguez	Decontam and Decomm	P O Box 1625	Idaho Falls	ID	83401	526-8078	RESRAD
72	Budhi Sagar	Southwest Research Instit	6220 Culebra Road	San Antonio	TX	78228		DITY
73	Susan J Sladek	OERR/OPM/ro	Wateraide Mall	Washington	DC	20460		
74	John L. Smoot	Pacific Northwest Lab	P O Box 999	Richland	WA	99352	509-376-1352	CFEST PORFLO-3 v 1 0
75	Dwayne R. Speer	Westinghouse Hanford Co	P O Box 1970 MSIN R2-77	Richland	WA	99352	509-373-1382	ARCL
76	Robert Stenner	Battelle-Northwest	P O Box 999	Richland	WA	99352	509-375-2916	RHRS-LC HRS-I
77	David J. Thorne	UNC Geotech	2597 B 3/4 Road	Grand Junction	CO	81503	303-248-6749	Micro AIRDOS
78	Edward C. Thornton	Westinghouse Hanford Co	P O Box 1970	Richland	WA	99352		MINTEQ EQ3/6
79	D Tomasko	Argonne National Lab	9700 S Cass Avenue	Argonne	IL	60439	708-972-3170	CFEST
80	Thomas J. Walsh	Feed Materials Prod Cr	P O Box 398704	Cincinnati	OH	45239	513-738-6200	ISCT HARM-II
81	A. A. Walker	Oak Ridge National Lab	P O Box 2008	Oak Ridge	TN	37831	615-574-4432	USGS-MOC
82	W J. Waugh	UNC Geotech	P O Box 14000	Grand Junction	CO	81502	303-248-6431	RAECCOM
83	Victor L. Weeks	EPA IV/Waste Mng/RCRA Fed Fac	345 Courtland St. N.E	Atlanta	GA	30365		HELP PATH RAY RAD PATH-RAY HAZ FT WORK
84	R K White	Martin Marietta	P O Box 2008 ORNL	Oak Ridge	TN	37831		RESRAD Bechtel proprietary SOURCE 2 MEPAS
	R K White	Martin Marietta Energy Systems	P O Box 2008, ORNL	Oak Ridge	TN	37831		MT3D HELP CREAMS SOLUTE
	R K White	Martin Marietta Energy Systems	P O Box 2008, ORNL	Oak Ridge	TN	37831		MODFLOW NEWBOX, FLOWTHROUGH CYLSEC SWIFT Rockware & SURFER
	R K White	Martin Marietta Energy Systems	P O Box 2008, ORNL	Oak Ridge	TN	37831		SEFRAN HSPF PATHRSK MOC THEM
85	W Alexander Williams	U S DOE	EM-421	Washington	DC	20585		RESRAD
86	Steve Yabusaki	Pacific Northwest Lab	P O Box 999	Richland	WA	99352	509-376-3290	TEMPST/FLESCOT
87	Charley Yu	Argonne National Lab	9700 S Cass Avenue	Argonne	IL	60439	708-972-5589	MAT123D RESRAD PRESTO-EPA UDAD MILDOS-AREA

TABLE 2 - Alphabetical List of Models, Model Types and References

16-Mar-93

MODEL	M	A	S	G	E	S	D	R	Reference 1	Reference 2	Reference 3
	u	r	r	n	o	g	r	e			
	i	f	d	h	P	e	i	a			
	t	W	e	e	n	i	M				
	M	a	m	r	i	e	a				
	e	t	t	i	f	n	d				
	d	e	e	c	a	r					
	i	r	r	c	o	g					
	a										
3d Mixing Cell											
AFTOX	•								U. S. Army, 19xx		
AIRDOS (-EPA,-PC)	•						•		Moore et al., 1979	Till et al, 1987	U.S EPA, 19xx
ARCL	•								• Napier & Piepel, 1988		
BALANCE				•			•		Parkhurst et al, 1982		
BARRIER					•		•		• Shuman et al., 1989		
Bechtel Proprietary			•						Bechtel Corporation, 19xx		
BIOTRAN	•								• Gallegar et al, 1980		
BRUNZOG					•				Chamberlain, 19xx		
CAP-88	•						•		see AIRDOS		
CASCADE	•										
CFEST			•				•		Gupta et al., 1982	Gupta et al, 1987	
CHARM	•								USEPA, 19xx		
COMPLY	•								• USEPA, 1989		
CONDOS-II	•								• USNRC, 19xx		
CONSOL						•			U.C. Berkeley, 19xx		
CREAMS			•	•					• Knisel, 1980		
CYLSEC									•		
DARTAB	•								• Begovich et al., 1981		
DCM3D			•								
DECHEM	•								• Radiological Assessment Corp, 19xx		
DECOM	•								•		
DITTY	•								• Napier et al, 1986		
DOSES	•								• ORNL, 19xx		
DOSTOMAN	•								• Root, 1981	King et al., 1985	
DPCT			•				•		• Schwartz & Crowe, 1980	Schwartz, 1978	
EQ3/6				•					Wolery & Watters, 1975	Wolery et al., 1988	Delaney, 1986
FLASH/FLAME				•		•					
FLOWPATH				•							
FLOWTHROUGH											
FT WORK	•										
GCDT3DH	•										
GENII	•								• Napier et al, 1988		
GENMOD	•								• Atomic Energy of Canada, 19xx		
GEOFLOW				•					D'Appolonia Consulting Eng., 1980		
GW FLOW				•		•			Natural Sci. & Eng. Counc., Canada		
HARM-II	•										
HEC-1,-2		•					•		U S. Army Corps of Eng., 1981	U S Army Corps of Eng, 1982	

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16-Mar-93

MODEL	M	A	S	G	E	S	D	R	Reference 1	Reference 2	Reference 3
	u	r	r	n	o	g	r	e			
	i	r	r	n	o	g	r	e			
	t	r	r	n	o	g	r	e			
	t	r	r	n	o	g	r	e			
	i	r	r	n	o	g	r	e			
	M	W	W	P	P	P	M				
	e	a	a	e	e	e	a				
	d	t	t	t	t	t	d				
	i	e	e	e	e	e	e				
	a	r	r	r	r	r	r				
HELP									Schroeder et al , 1984		
HRS-1	•								Stenner et al., 1986		
HSPF			•						Johanson et al , 1984		
HYDROGEOCHEM				•			•		Yeh & Tripathi, 19xx		
IMPACTS (PART61) (-BRC)	•								Oztunali et al , 1986	Oztunali & Roles, 1986	
INPUFF	•								Peterson & Lavdas, 1986	General Sciencs Corp , 1986	
ISCST/ISCLT	•								Bowers et al., 1979	TRC Environmental Cons , Inc , 19xx	TRC Environmental Cons , Inc , 1988
ISOSHL D (-I)	•								Engle et al , 1966	Sumnar et al., 1967	
LTSAMP	•								Jacobs Engineering, 19xx		
MACCS									Sandia National Lab., 19xx		
MAT123D			•						Yu, 19xx		
MEPAS	•								Dropo et al., 1989	Doctor et al , 1990	Whelan et al , 1987
MESOI	•								Ramsdell, et al , 1983		
MILDOS (-AREA)	•								Strange and Bander, 1981	Yuan et al., 1989	
MINTEQ (-A1, -A2)			•	•					Krupka & Morrey, 1985	Allison et al., 1990	Peterson et al., 1987
ML CODE	•								Napier, 19xx		
MOC			•						Konikow & Bredehoeft, 1978		
MOD3D			•						McDonald & Harbough, 1984		
MODFLOW			•						McDonald & Harbough, 1989		
MT3D			•						Zheng, C. 1990		
NEFRAN II			•						Longsine, Bonano & Harlan, 1987		
NEWBOX							•				
NUREG - 0707	•								Eckerman & Young, 19xx		
ODAST			•				•		Javendal et al , 1984		
ODRECH6.7	•										
ONSITE/MAXI1	•								Napier et al , 1984	Kennedy et al , 1986	
PAGAN	•								Kozak et al , 1990a		
PATH	•								Lee, 19xx		
PATHRAE EPA, HAZ, RAD	•								Rogers & Hinz, 1987		
PATHRISK	•										
PC-SLOPE							•		Geo-Slope, Inc , 19xx		
PHREEQE				•					Parkhurst et al , 1980		
PLASM			•						Prickett & Lonngquist, 1971		
PORFLO-3			•						Runchal & Sagar, 1985		
PORMC-3			•						Analytic & Comput Res , Inc , 19xx		
PRESTO-II EPA,CPG,POP	•								Fields et al , 1986	Rogers & Hinz, 1987	Fields et al 1897a,b

TABLE 2 – Alphabetical List of Models, Model Types and References

16-Mar-93

MODEL	M	A	S	G	G	E	S	D	R	Reference 1	Reference 2	Reference 3
	u	r	r	n	n	n	n	n	n			
	t	r	d	c	h	p	e	a	.			
	i	W	W	e	n	i	e	M				
	M	a	m	r	i	f	n	d				
	e	t	t	t	c	c	o	g				
	d	e	e	c	a	r						
	i	r	r	a	r							
	a											
RAECOM	•									• Rogers et al., 1984		
RADRIK	•									• Dunning et al., 1980		
RANDOM WALK				•						Prickett et al., 1981		
RASCAL						•				• ORNL & Phoenix Associates, 19xx		
RESRAD	•									• Gilbert et al., 1988		
RETC F77				•						Muaem, 1976		
RHRS-LC	•							•		• Stenner et al., 1986		
RSAC-3		•						•		• Wenzel, 1982		
SBUHYD			•							Stubenhaer, 1975		
SCREEN	•									USEPA, 19xx		
SEFTRAN				•								
SFRIPE						•				MK Environmental, 19xx		
SIMS		•								USEPA, 19xx		
SOIL				•						Ei-Kadi, 1985		
SOLUTE				•			•					
SOURCE 2												•
SPUR	•									USEPA, 19xx		
STABL, STABL5						•				Siegel, 19xx	U.S. DOT & Purdue Univ., 19xx	
STABR						•				U.C Berkeley, 19xx		
STEPH						•				MK Environmental, 19xx		
STRIP 1B	•											
SUMO	•									USDOE, 19xx		
SWIFT (II,III)				•				•		• Reeves et al., 1986	Reeves & Cromwell, 1981	Ward, Reeves & Duda, 1984
TARGET												
TDRECH	•											
TEMPEST/FLESCOT			•							Trent et al., 1983	Onishi, Trent & Klontz, 1985	Trent & Onishi, 1989
THEM												
TOUGH				•				•		• Pruess & Wang, 1984	Pruess, 1986	
TRACR3D				•				•		• Travis et al., 1984		
UDAD	•									• Momeni et al., 1979		
UNSAT-2 (-H)				•				•		Davis & Neuman, 1983	Fayer et al., 1986	
UTEXAS2								•		Wnght, 19xx		
UTM	•									• Luxmore & Huff, 1989		
VAM2D (-3D)				•				•		• Huyakorn et al., 1989	Huyakorn, 19xx	

Table 3—Model, Site Type, Contaminant, Endpoint, Effort, Validation, Publication

Count	MODEL	SITE TYPE	CONTAMINANT	ENDPOINT	EFFORT	V/C*	PUBLICATION	NAME
1	3-d Mixing Cell	EPA Superfund	voc's	environmental concentration	unknown	YES	NO	Elizabeth Kalcher
2	AFTOX	DOE	non radiologic	environmental concentration	as needed	NO		C J Roberts
3	AIRDOS	DOE Defense	radionuclides	effective dose-equivalent				Alan Fallman
	AIRDOS	DOE National Laboratory		dose commitment	5 mm/yr	NO	YES ANL-E env reports	Charles L. Cheever
	AIRDOS	SFMP	radionuclides	dose commitment	4 mm	YES	NO	David E. Farris
	AIRDOS	DOE Defense	Pu, Co, Am, U, CS	dose commitment	8-12 mm/yr	NO	NO	Jeff Neff
	AIRDOS-EPA	EPA Superfund	all natural series isotopes	env conc and dose commitment	8 mm	NO	NO	Bob Hlavacek
	AIRDOS-EPA	Federal Facility		dose commitment, risk		NO		F O Hoffmann/B G Blaylock
	AIRDOS-EPA	Federal Facility	radionuclides	env conc dose - eq, risk	8mm	YES		F R O'Donnell
	AIRDOS-EPA	DOE Defense	radionuclides	env conc, comm eff dose eq, risk	24-36mm nt	YES	NO	Mac Enns
	AIRDOS-PC	FUSRAP	alkaline earths, actinides, etc	effective dose equivalent	as needed		NO	Christine Daly
	AIRDOS-PC	DOE Defense	radionuclides	dose commitment	as needed	NO		C J Roberts
	AIRDOS-PC	NRC	U-238 and Th-232 decay chains	dose commitment	1mm	NO		Mark E. Kaye
	AIRDOS-PC	DOE	41 radionuclides	dose commitment	1 FTE/yr	NO	NO	Paul Ritzmann
4	ARCL	SFMP	see manual	max allowable residual levels		NO		Dwayne R. Speer
5	BALANCE	DOE Defense	non radiologic	env conc in aqueous systems	none	NO	NO	J D Hoover
6	BARRIER	DOE Defense	nat, enr U, transuranics, fission	dose	8m/yr	NO	NO	T E Myrick
7	Bechtel proprietary	EPA Superfund						R K White
8	BIOTRAN	DOE National Laboratory	radionuclides	env conc, comm eff dose eq, risk	24-36mm nt	YES	NO	Mac Enns
9	BRUNZOG	UMTRA	NA	depth of thaw penetration		NO	NO	Marvin W Henderson
10	CAP-88	Federal Facility	radionuclides	env conc, dose - eq, risk	3	NO		F R O'Donnell
11	CASCADER	DOE Defense	Tritium and Radon	environmental concentrations				F Tom Ludstrom
12	CFEST	DOE Defense	Chlorinated aliphatics, Tritium	environmental concentration	38mm	YES	YES LLNL 1991	Eric Nichols
	CFEST	DOE Defense	tritium, U		6mm, 8mm	NO	YES WHC-EP-0133, PNL-6315-2	John L. Smoot
	CFEST	EPA CERCLA NPL DOE Nat'l b	U-238, Th-232, metals, nitroaromat	environmental concentration	12mm			Lisa A. Durham/D Tomasko
	CFEST	SFMP, Superfund	tritium, uranium	environmental concentration	15 my	NO		Marcel P. Bergerson
	CFEST	EPA Superfund		concentration		NO	NO	Herbert Levine
13	CHARM	EPA Superfund	particulates, voca	env conc, risk assessment	variable	YES	NO	Mark Hansen
14	COMPLY	DOE	radionuclides	annual dose commitment	as needed	NO		C J Roberts
	COMPLY	FUSRAP	radionuclides	dose commitment	3-4 mm	NO	NO	David E. Farris
	COMPLY	DOE Defense	U-238 and Th-232 decay chains	dose commitment	1mm	NO		Mark E. Kaye
15	CONDOS-II	Federal Facility	radionuclides	air, food conc, dose from objects	05	NO		F R O'Donnell
18	CONSOL	UMTRA	NA	calculates settlement		NO	NO	Marvin W Henderson
17	CREAMS	EPA Superfund	NA-Water Balance	Percent Runoff, Evaporation, Infiltration etc		YES		R K White
18	CYLSEC	EPA Superfund	All radionuclides	Concentrations	0.5mm/Update	YES	YES Bechtel Proprietary Documents	R K White
19	DARTAB	DOE Defense	U-234, U-235, U-238, U-238,	dose commitment	4 mm			David E. Farris
	DARTAB	DOE Defense	radionuclides	dose commitment	4 mm	YES	NO	David E. Farris
20	DCM3D							David Gallegos
	DCM3D		Highlevel waste radionuclides	hydraulic flow/integrated discharge	12 mm	NO	NO	Tim McCartin
21	DECHEM	UMTRA	As, Se, V, U, Mo, Pb, limited orgs	soil, gw conc, risk (see note)	3500 + 500	NO		Dr. Jere Millard
	DECHEM v 3 02	DOE NRC	U, Th, Ra, As	reference value	as needed	NO	NO	Christine Daly
22	DECOM v 2 2	NRC	U, Th, Ra	concentration, doses	1	NO	NO	Christine Daly
23	DITTY	NRC H-L Waste repository	more than 250 radionuclides	individual and population doses	several my	NO	YES DOE/EIS-0113	B A Nagler
	DITTY	DOE Defense	Radionuclides - Iodine neptunium etc	dose commitment	2-8mm	NO	NO	Dr. Buchi Sager
24	DOSES	Federal Facility	radionuclides	dose	2	NO		F R O'Donnell
25	DOSTOMAN	DOE Defense	Pu-238, Pu-239, Cs-137, Sr-90, 3H,	dose commitment	24 mm			John Haselaw

Table 3--Model, Site Type, Contaminant, Endpoint, Effort, Validation, Publication

Count	MODEL	SITE TYPE	CONTAMINANT	ENDPOINT	EFFORT	VC*	PUBLICATION	NAME
26	DPCT		Sr-90	concentration	6 mm	YES	NO	Tim McCartin
27	EQ3/8	DOE Defense	radionuclides and nonradiologic	env conc , che Interaction water/soil	see note	NO	NO	Dr Edward C. Thornton
28	FLASH/FLAME	EPA Superfund		environmental concentration	38 mm	NO	NO	Joe Frazier
29	FLOWPATH	EPA Superfund		concentration		NO	NO	Herbert Levine
30	FTWORK	EPA Superfund Savannah Rv	lead, mercury, nitrate,	constituent concentrations	6 MM		NO	Victor L Weeks
	FTWORK	EPA Superfund (DOE)	30 contaminants of concern	environmental concentration RA	12 mm	YES	YES reports to SRS	Peter F. Anderson
31	GCDT3DH3	DOE Defense	Tritium and Radon	environmental concentrations				F Tom Ludstrom
32	GCDT3DH4	DOE Defense	Tritium and Radon	environmental concentrations				F Tom Ludstrom
33	GCDT3DH5	DOE Defense	Tritium and Radon	environmental concentrations				F Tom Ludstrom
34	GENII	DOE Defense_SFMP	more than 280 radionuclides	conc , dose,dose comm, integ dose	> 5 my	NO	YES PNL-8825, DOE/ES-01180	B.A. Nazar
	GENII	DOE National Laboratory	any related to decommissioning	dose	1mm	NO	NO	Christine Dady
	GENII	DOE Defense	radionuclides	dose commitment	unknown	YES	YES	Dr Roy Eckert
	GENII	DOE, NRC	radionuclides	env conc , comm eff dose eq, risk	24-38mm nt	NO	NO	Mac Ennis
	GENII	DOE Defense	240 radionuclides	env conc , dose commitment	5 FTE/yr	NO	NO	Paul Rittmann
35	GENNMOD	DOE Defense	radionuclides	internal dosimetry	30 mm	YES	NO	Dr Roy Eckert
36	GEOFLOW	DOE Defense						Gary Gallois
37	GW Flow Model	Federal Facility	flow	gw flux	2 years ex	NO	NO	LS Cahn
38	HARM-II	DOE Defense	U-234, various liquids and gases	environmental concentration	3 man- yrs	NO	NO	Thomas J Walsh
39	HEC-1	UMTRA	U, VOC's, toxic metals, aromatics	env conc	6 mm note	YES	YES AML symposium, 1989	Mark Kuslky
	HEC-1	DOE,DOE Defense,SFMP,SF		flow	water levels and flow rates	NO	YES	Marvin W Henderson
40	HEC-2	UMTRA	U, VOC's, toxic metals, aromatics	environmental concentration	6 mm note	YES	YES AML symposium, 1989	Mark Kuslky
	HEC-2	DOE,DOE Defense,SFMP,SF		flow	water levels, flow rates and veloc	NO	YES	Marvin W Henderson
41	HELP	DOE			as needed	NO		C.J Roberts
	HELP	EPA Superfund	flow	recharge and discharge rates		NO	YES	Marvin W Henderson
	HELP	UMTRA						R K White
	HELP	EPA Superfund -DOE Savann	tetrachloroethylene	constituent concentrations	6 MM		NO	Victor L Weeks
	HELP ver 2 02	UMTRA						Linda Pogue
42	HRS-I	EPA Superfund	radionuclides and nonradiologic	HRS scores	24 mm	NO	YES PNL-8458	Robert Sterner
43	HSPF	EPA Superfund	All contaminants	Time series of contaminant passing a point	13 mm	NO	NO	R K White
44	HYDROGEOCHEM	DOE, NE, DP		to be determined, U likely	to be determined	YES	NO	B.J Morrison
45	IMPACT	EPA Superfund	H-3, C-14, Co-60, Sr-90, (see note)	70 year short-term dose eq	unknown	NO	NO	Jon Richards
	IMPACTS-BRC v 2 0	NRC	any in library	dose	2 mm	NO	NO	Christine Dady
46	INPUFF	DOE	non radiologic	environmental concentration	as needed	NO		C.J Roberts
47	INUSLT	GW					NO	David Galleago
48	ISCS	EPA Superfund	particulates, vocs	env conc , risk assessment	variable	YES	NO	Mark Hansen
	ISCS	DOE Defense	SO2	environmental concentration	unknown	NO		Thomas J Walsh
	ISCS/ISCLT	SFMP	rad, nonrad and generic releases	ground-level air conc	0 5	NO		F R O'Donnell
	ISCS/ISCLT	Federal Facility	PM10 and TSP	long/short term env conc	5 mm	NO	NO	Young-Soo Chung
49	ISOSHL	DOE	radionuclides	external dose and dose rates	as needed	NO		C.J Roberts
50	LTSAMP	UMTRA	particulates, radon	conc at receptor locations	unknown	NO	YES UMTRA Env Assessments	Robert Murphy
51	MACCS	Federal Facility	fission products	env conc , dose-eq, rak	2	NO		F R O'Donnell
52	MAT123D	FUSRAP/SFMP	U, radium-226	conc in ground water	6 mm	YES	YES	Dr Charley Yu
53	MAXI	DOE	radionuclides	dose commitment	as needed	NO		C J Roberts
54	MEPAS	EPA Superfund, DOE Defence	78 rads, 318 nonradiologic	env conc , dose comm, risk factors	\$500,000	YES	YES PNL-7102, SF'88	Dr James G Droppo Jr
	MEPAS	Ranking model for CERCLA	radionuclides and nonradiologic	dose, hazard index, risk	2 years	YES	YES Whelan et al	Dr Jerry D Davis
	MEPAS	DOE Defense						R K White
55	MESOI	Federal Facility	toxic gases	short-term ground level conc	0	YES	YES	F C Kornegay
56	Micro AIRDOS	SFMP	Ra-222,Ra-226,Pu-238,Pu-239	env conc , dose commitment, uptake	unknown	NO	NO	David J Thorne
	MicroAIRDOS v 2 0	NRC	U,Th,Ra	dose	1mm		NO	Christine Dady

Table 3-- Model, Site Type, Contaminant, Endpoint, Effort, Validation, Publication

30-OCT-91

Count	MODEL	SITE TYPE	CONTAMINANT	ENDPOINT	EFFORT	V/C*	PUBLICATION	NAME
57	MILDOS	DOE	radionuclides	dose commitment	as needed	NO		C.J. Roberts
	MILDOS - AREA	FUSRAP/SFMP	Uranium series isotopes	dose commitment	12 mm	YES	YES ANL/ES - 181	Dr. Charley Yu
58	MINTEQ	DOE Defense			as needed	NO		C.J. Roberts
	MINTEQ	DOE	nonradiologic	env conc, che interaction water/soil	see note	NO	NO	Dr. Edward C. Thornton
59	ML CODE	DOE Defense	Iodine - 131	dose commitment	12 mm	NO		Richard O. Gilbert
60	MOC	DOE Defense	VOC's	groundwater concentration	5mm	YES	NO	Barry Roberts
	MOC	Performance Assessment	All contaminants	Concentration as a function of time	Ongoing effort	NO		R. K. White
61	MOD3D	DOE Defense	radionuclides	environmental concentration				Jon Richards
62	MODFLOW	DOE	flow		as needed	NO		C.J. Roberts
	MODFLOW	EPA Superfund		water levels	3 mm	NO		Barry Roberts
	MODFLOW	DOE Defense	voc's	environmental concentration	unknown	YES	NO	Elizabeth Keicher
	MODFLOW	EPA Superfund		concentration		NO	NO	Herbert Levine
	MODFLOW	EPA Superfund		Flow Rates				R. K. White
	MODFLOW/MOC	EPA Superfund			12 mm	NO	NO	Richard W. Arnsperg
63	MT3D	EPA Superfund	All contaminants and radionuclides	Concentration and travel time				R. K. White
64	NEFRAN II			cumulative curies/specbound/aspectime		NO	NO	Natalie Clagne
	NEFRAN II	DOE NRC	nuclides I 10 CFR Part 60	integrated discharge	8 mm	NO	NO	Tim McCartin
65	NEWBOX, Flowthrough	Performance Assessment	Most radionuclides	concentration and dose	8 mm	NO	YES	R. K. White
66	NUREG - 0707	DOE	rad and selected nonrads	dose commitment	8 mm	NO	YES NUREG - 0707	David Abbot
67	ODAST	DOE Defense						Gary Gailot
68	ODRECH6	DOE Defense	Tritium and Radon	environmental concentrations				F. Tom Ludstrom
69	ODRECH7	DOE Defense	Tritium and Radon	environmental concentrations				F. Tom Ludstrom
70	ONSITE/MAXI	DOE Defense, SFMP, FUSRAP	more than 250 radionuclides	env conc, indiv max annual dose	several my	NO	YES DOE/ES - 0113	B.A. Nagler
	ONSITE/MAXI I	DOE Defense	radionuclides	dose commitment	unknown	YES	YES	Dr. Roy Eckart
71	PAGAN	DOE	Radionuclides and nonradiologic	environmental concentration	several	NO	NO	Paul Mattingly
72	PART81	DOE National Laboratory	radionuclides	env conc, comm eff dose eq, risk	24-36mm nt	NO	NO	Mac Erns
73	PATH	FUSRAP	Co-60, Cs-137, Sb-125, europium-152	dose commitment	4mm + 8mm	NO	NO	Kenneth J. Egan
74	Path Ray Rad	EPA Superfund Savannah Rv	tritium, radium, cesium, strontium,	constituent concentrations	8 MM		NO	Victor L. Weeks
75	PATHRAE	DOE Defense	see DPST - 88 - 291	dose commitment	48 mm			John Haselaw
	PATHRAE	DOE Defense	radionuclides	dose				Jon Richards
	PATHRAE - EPA	DOE	radionuclides	dose commitment	as needed	NO		C.J. Roberts
	PATHRAE - EPA	DOE Defense	radionuclides	dose	unknown	NO	YES SRL - EIS on lhw	Dr. Jerry D. Davis
	PATHRAE - HAZ	DOE Defense	hazardous chemicals	hazard index, risk	unknown	NO	YES SRL EIS on lhw sites	Dr. Jerry D. Davis
	PATHRAE - HAZ	EPA Superfund	arsenic, barium, cadmium, chromium,	constituent concentrations	8 MM		NO	Victor L. Weeks
76	PATHRISK	UMTRA	All radionuclides	Dose	8 mm	NO	YES ORNL/ER/Sub - 87/89053/5/V3 - V8	R. K. White
77	PC - SLOPE	DOE	NA	failure surfaces, factors of safety		NO	NO	Marvin W. Henderson
78	PHREEQE	DOE Defense			as needed	NO		C.J. Roberts
	PHREEQE	DOE	non radiologic	env conc in aqueous systems	none	NO	NO	J. D. Hoover
79	PLASM	DOE Defense	flow		as needed	NO		C.J. Roberts
80	PORFLO - 3 v 1 0	DOE Defense	radionuclides and nonradiologic	heat, gw/cont flux, conc 1,2,3 - D	3 FTE, +3mm	YES	YES Smoot and Sagar 1990	Dr. Jerry D. Davis
	PORFLO - 3 v 1 0	DOE Defense	at users discretion	env conc	8 mm	YES	YES PNL - 7221	John L. Smoot
	PORMC - 3 v 1 0	DOE Defense	radionuclides and nonradiologic	heat, gw/cont flux, conc 1,2,3 - D	8 mm 1990	NO		Dr. Jerry D. Davis
81	PORFLO - 3 v 2 0	FUSRAP	radionuclides and nonradiologic	heat, gw/cont flux, conc 1,2,3 - D	8 mm 1990	YES		Dr. Jerry D. Davis
82	PRESTO - EPA	Generic	Ra-226	dose commitment	1 mm	YES	YES Conference proceedings	Dr. Charley Yu
	PRESTO - EPA - CPG	Generic	40 rads comm only found in lhw	dose commitment, fatal health eff	4 my, dev	YES	YES	Cheng Yang Hung
	PRESTO - EPA - POP	DOE National Laboratory	40 rads comm only found in lhw	dose commitment, fatal health eff	4 my, dev	YES	YES	Cheng Yang Hung
	PRESTO - II	UMTRA	radionuclides	env conc, comm eff dose eq, risk	24-36mm nt	NO	NO	Mac Erns
83	RADON (RAECOM)	DOE National Laboratory	Radon-222	surface radon flux	3-5mm NRC	NO	YES NUREG/CR - 3533	George N. Grunholt
84	RADRSK	DOE NRC		dose commitment	5 mm/yr	NO	YES ANL - E env reports	Charles L. Cheever
85	RAECOM	UMTRA	all natural series isotopes	env conc and dose commitment	8 mm	NO	NO	Bob Hlavacek

Table 3-- Model, Site Type, Contaminant, Endpoint, Effort, Validation, Publication

30-OCT-91

Count	MODEL	SITE TYPE	CONTAMINANT	ENDPOINT	EFFORT	V/C*	PUBLICATION	NAME
	RAECOM	EPA Superfund	Ra	concentration/flux	3 mm	YES	NO	Christine Daily
	RAECOM	SFMP	Ra-226	estimated interior WLe	1mm	NO	NO	David A. Charlton
	RAECOM	UMTRA	radon	radon fluxes and concentrations		NO	YES	Marvin W Henderson
	RAECOM	DOE, DOE Defense, SFMP, SF	Radon - 222	radon emanation from soil		NO	NO	W.J. Waugh
86	RANDOM WALK	Federal Facility	U, VOC's, toxic metals, aromatics	environmental concentration	6 mm note	YES	YES AML symposium, 1988	Mark Kaulsky
87	RASCAL, v 1.3	DOE Defense	reactor (fission product) radi	acute/long term dose-eg, health eff	0	NO		F R O'Donnell
88	RESRAD	SFMP	U, Th, Ra, Co	concentration	as needed	NO	NO	Christine Daily
	RESRAD	DOE FUSRAP	Site specific radionuclides	dose	3 m - m	YES	NO	Robert Knowlton
	RESRAD	FUSRAP	all natural series isotopes	env conc and dose commitment	6 mm	NO	NO	Bob Hlavacek
	RESRAD	FUSRAP/SFMP	radionuclides	dose commitment	as needed	NO		C J Roberts
	RESRAD	SFMP	Pu-238, Th	dose commitment		NO	NO	Daniel G Carfagno
	RESRAD	SFMP/FUSRAP	Pu-238, Th	dose commitment		NO	YES Internal Reports	Daniel G Carfagno
	RESRAD	DOE FUSRAP	U, Cs - 137	dose commitment	20 mm	YES	YES ANL/ES - 160, DOE/CH 8801	Dr Charley Yu
	RESRAD	DOE	radionuclides	dose commitment	unknown	YES	NO	Dr Roy Eckert
	RESRAD	DOE, NRC	Pu, Co, Am, U, CS, RCRA Haz, PCBs	dose commitment	8-12 mm/yr	NO	NO	Jeff Neff
	RESRAD	SFMP	Cs, U, CO, Pu, Am	dose		NO	NO	J W Ray
	RESRAD	DOE Defense	U-238, U-234, Th-230	soil conc - cleanup guidelines	1 mm	NO	NO	L S Cahn
	RESRAD	EPA Superfund	U-238 and Th-232 decay chains	dose commitment	1mm	YES		Mark E. Keye
	RESRAD	SFMP	Co-60, Cs-137	dose	1 mm	NO	NO	Rene R Rodriguez
	RESRAD	DOE Defense	All radionuclides and decay products	guideline values for radionuclides				R K White
	RESRAD	DOE Defense	U-238, U-234, Th-230	soil conc - cleanup guidelines	1 mm	NO	NO	R L Murti
	RESRAD	SFMP	U-238, U-234, Th-230	soil conc - cleanup guidelines	1 mm	NO	NO	R L Murti
	RESRAD	DOE Defense	40 isotopes, 38 daughters	eff and comm eff dose equivalent	as needed			William C Borden
	RESRAD	EPA Superfund	radionuclides	dose commitment		YES	YES	William E. Murphy
	RESRAD	EPA Superfund	Radionuclides - D&D	dose commitments, clean up guides	Y	YES		W Alexander Williams
89	RET C F77	UMTRA	NA	hydraulic pars of partial sat soils		NO		Linda Pegues
	RET C F77	UMTRA	NA	hydraulic pars of partial sat soils		NO	YES	Marvin W Henderson
90	RHRS-LC	EPA Superfund	radionuclides and nonradiologic	revised hazard ranking system score	8-10 mm	NO	NO	Robert Stinner
91	Rockware & SURFER	EPA Superfund						R K White
92	RSAC	INEL	radionuclides	CI/m2, photon flux, exp, dose, eds	3mm 1890		YES	Burton R Baldwin
93	SBUHYD	UMTRA	NA	hydrograph computations		NO	YES	Marvin W Henderson
94	SCREEN	EPA Superfund	particulates, vocs	env conc, risk assessment	variable	YES	NO	Mark Hansen
95	SEFTRAN	Performance Assessment						R K White
96	SFRIPE	UMTRA	NA	factor of safety for riprap sizing		NO	NO	Marvin W Henderson
	SFRIPE	UMTRA	NA	factor of safety for riprap sizing		NO	NO	Marvin W Henderson
97	SIMS	EPA Superfund	particulates, vocs	env conc, risk assessment	variable	YES	NO	Mark Hansen
98	SOIL	UMTRA		hydraulic pars of part saturat soil		NO	YES	Marvin W Henderson
99	SOLUTE	EPA Superfund						R K White
100	SOURCE 2	EPA Superfund	Radionuclides	Cocentration	5mm/updates	YES	YES Bechtel proprietary documents	R K White
101	SPUR	DOE National Laboratory	radionuclides	env conc, comm eff dose eq, risk	24-36mm nt	NO	NO	Mac Ennis
102	STABL	UMTRA	NA	failure surfaces, factors of safety		NO		Linda Pegues
	STABL5	UMTRA	NA	failure surfaces, factors of safety		NO	NO	Marvin W Henderson
103	STABR	UMTRA	NA	failure surfaces, factors of safety		NO	NO	Marvin W Henderson
104	STEPH	UMTRA	NA	riprap sizing		NO	NO	Marvin W Henderson
105	Strip 1B	DOE Defense						Gary Gallot
106	SUMO		transuranics, fission products	env conc, dose, health effects	36 mm	NO		P G Doctor
107	SWIFT	EPA Superfund Portsmouth						R K White
108	SWIFT II		radionuclides	environmental concentration				Jon Richards
	SWIFT II	DOE Defense		ground water flow	6 m	YES	YES NUREG 1249 Hydrocolin	Tim McCartin
109	SWIFT III	DOE Defense	uranium, others as necessary	conc at offsite receptors	150 + 50	YES	YES draft 6/80	Dennis J Carr

Table 3--Model, Site Type,Contaminant, Endpoint, Effort, Validation, Publication

30-OCT-91

Count	MODEL	SITE TYPE	CONTAMINANT	ENDPOINT	EFFORT	V/C*	PUBLICATION	NAME
	SWIFT III	EPA Superfund	voc's	environmental concentration	unknown	YES	NO	Elizabeth Kelcher
	SWIFT III	DOE Defense						Gary Gaillet
110	TARGET	DOE Defense	VOC's	groundwater concentration	5mm	NO	NO	Barry Roberts
111	TDRECH11	DOE Defense	Tritium and Radon	environmental concentrations				F Tom Ludstrom
112	TDRECH12	DOE Defense	Tritium and Radon	environmental concentrations				F Tom Ludstrom
113	TDRECH21	DOE Defense	Tritium and Radon	environmental concentrations				F Tom Ludstrom
114	TDRECH23	DOE Defense	Tritium and Radon	environmental concentrations				F Tom Ludstrom
115	TEMPEST/FLESCOT	EPA Superfund	PCB's	environmental concentration	100 mm	YES	YES	Steve Yabusaki
118	THEM	EPA Superfund						R K. White
117	TOUGH		Non-reactive solute	two-phase flow and concentration	6 mm	YES	NO	Tim McCartin
118	TRACR3D	DOE	TCA Pu-238,239	environmental concentration	6mm	YES	YES LANL Report LA-9987-MS n	Bruce Oslawer
	TRACR3D	DOE R&D	radionuclides and nonradiologic	environmental concentrations	12 mm	NO	NO	Paul Mattingly
119	UDAD	FUSRAP/SFMP	Uranium series isotopes	dose commitment	2 mm	NO	YES publ in an EIS	Dr Charley Yu
120	UNSAT-2	UMTRA	flow	hyd head distr and degree of sat		NO	YES	Marvin W Henderson
	UNSAT-2	UMTRA	variably saturated flow	soil tension	as needed	NO		Tim Goering
121	UNSAT-2 1	UMTRA	variably saturated flow			NO		Linda Pegues
122	UNSAT-H	DOE Defense	recharge	rate of recharge to unconfined aquifer	36mm, 36mm	YES	NO	Michael J Fayer
	UNSAT-H v 2 0	DOE Defense	flow	gw flux of meteoric w to w table	1-2 FTE	YES		Dr Jerry D Davis
123	UNSAT-H, ver 1 1	UMTRA	variable saturated flow			NO		Linda Pegues
124	USGS-MOC	DOE Defense	8CE,TCE,1,1-DCE	env conc and worst case dose	6 mm	YES	YES ORNL draft report 1990	KA. Water
	USGS-MOC	DOE Defense	PCE,TCE,1,2-DCE,1,1-DCE, Bvium	env conc and worst case dose	8 mm	YES	YES ORNL/M-1045	KA. Water
	USGS-MOC	DOE Defense	U, NO3, SO4	conc in ground water	as needed	NO		Tim Goering
	USGS-MOC	UMTRA	nat. enr U, transuranics, fission	dose	6my/yr	YES	YES	T E Myrick
125	UTEXAS2	UMTRA	NA	failure surfaces, factors of safety		NO	NO	Marvin W Henderson
126	UTM	Performance assessment	Most radiobtopes	concentration and dose	2 mm	NO	YES	R K. White
	UTM	DOE Defense	nat. enr U, transuranics, fission	dose	6my/yr	YES	YES	T E Myrick
127	VAM2D	DOE Defense	VOC's	groundwater concentrations	2.5mm	NO	NO	Barry Roberts
	VAM2D	DOE Defense	radionuclides and nonradiologic	conc at water table, downstr wells	2-3 FTE	YES	YES	Tim LeGore

*V/C = Model Validation/Calibration as reported by survey respondent

Department of Energy		
ARCL	FEMWATER/FEMWASTE	MAT123D
BIOTRAN	GENII	PORFLO
CFEST	HARM–II	PORMC–3
DECHEM	ISOSHLD	RHS–LC
DITTY	LTSAMP	RSAL
DOSES	MEPAS	SUMD
DOSTOMAN	ML CODE	TRACR3D
EQ3/6	RESRAD	

Environmental Protection Agency		
AIRDOS (–EPA, –PC, MICRO–)		INPUFF
CAP–88		ISCST,LT
CHARM		MINTEQ
COMPLY		PATHRAE (–EPA, –HAZ)
CREAMS		PRESTO
DARTAB		RADRISK
HELP		SCREEN
HRS–I		SIMS
HSPF		UTM

Nuclear Regulatory Agency		
CONDOS–II		ONSITE
DPCT		PAGAN
IMPACTS (PART61, –BRC)		PATHRISK
MACCS		RAECOM (RADON)
MAXI1		RASCAL
MESOI		SWIFT (–II, –III)
MILDOS (–AREA)		TEMPEST/FLESCOT
NEFTRAN II		TOUGH
NUREG–0707		

Other		
3d Mixing Cell	MOC	SFRIPE
AFTOX	MODFLOW (MOD3D)	SOIL
BALANCE	ODAST	STABL
BARRIER	PATH	STABL5
Bechtel	PC–SLOPE	STABLR
BRUNZOG	PHREEQE	STEPH
GENNMOD	PLASM	SURFER
GW FLOW	RANDOM WALK	UNSAT(–2, –H)
GEOFLOW	RETC.F77	UTEXAS2
HEC–1, –2	STRIPD	VAM2D

Unknown		
CASCADER	FLOWPATH	SOLUTE
CONSOL	FTWORK	SOURCE 2
CYLSEC	GCDT3DH3,4,5	SPUR
DCM3D	HYDROGEOCHEM	STRIP 1B
DECOM	NEWBOX	TDRECH11,12,21,23
FLASH/FLAME	ODRECH6,7	THEM
	SEFTRAN	

TABLE 5: Index of Existing Environmental Pathway Models

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Agency

Multi-Media			
<i>Hazard Ranking</i>			
		DPM	• DOD
		HRS-I	• EPA
		RHRS-LC	• DOE
<i>Radioactive Materials Fate & Transport</i>			
		COMPLY (-II)	• EPA
		DECHEM	• DOE
		DECOM	•
		DITTY	• DOE
		DOSES	• ORNL/DOE
		DOSTOMAN	• DOE
		GENII	• Hanford/DOE
		GENMOD	• AECL
		GRDFLX	• NRC
		IMPACTS (PART61) (-BRC)	• RSIC/NRC
		MILDOS (-AREA)	• NRC
		NUREG-0707	• NRC
		ONSITE/MAXI1	• PNL/NRC
		PAGAN	• NRC
		PATH	• General Electric Corp.
		PATHRAE (-EPA,-HAZ)	• EPA
		PRESTO-II	•
		PRESTO-EPA (-DEEP,-BRC,-CPG,-POP)	• DOE/EPA
		RESRAD	• ANL/DOE
		UDAD	• NRC
<i>General Purpose</i>			
		ARCL	• DOE
		Bechtel proprietary	• Bechtel Corp
		CASCADER	•
		CONDOS (-I)	• NRC
		ENPART (cf. GEMS)	• EPA
		FLOWPATH	•
		FTWORK	•
		GCDT3DH (-3,-4,-5)	•
		GEMS	• EPA
		MICROBE-SCREEN (cf GEMS)	• EPA
		MEPAS	• DOE
		MULTIMED	•
		ODRECH(-6,-7)	•
		PATHRISK	• NRC
		SPUR	•
		STRIP 1B	•
		SUMO	• DOE
		TDRECH (-11,-12,-21,-23)	•
		TOX-SCREEN (cf GEMS)	• EPA
		UTM (-TOX) (cf GEMS)	• ORNL/EPA
<i>Foodchain</i>			
		BIOTRAN	• LASL/DOE
		INGDOS	•
		TERRA	•
		THEM	•

TABLE 5: Index of Existing Environmental Pathway Models

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I II

Agency

Air						
		ADPIC				•
		AFTOX		•		U.S. Army
		AIRDOS (-EPA, -PC, MICRO-, -AIRI)		•	•	RSIC/ORNL/EPA/Galson T. S Inc.
		ANEMOS (CRRIS)				•
		AVACTRA II				• AeroEnvironment Inc
		AVLAGPAR				• AeroEnvironment Inc.
		BOXMOD				•
		CALINE-3				• California DOT
		CAP-88		•		EPA
		CHARM (EIS)		•		EPA/Radian Corp./Res Alt Inc.
		COMPLY		•		EPA
		COMPLEX-1				•
		CRAC2				•
		DACRIN				•
		DARTAB		•	•	EPA
		GAMS				•
		GASPAR				•
		HARM-II		•		DOE
		INPUFF (cf. GEMS)		•		EPA/Bowman Env
		ISC (-LT, -ST, BREEZE -AIR, -HAZ, -WAY)		•		EPA/Bowman Env/Trinity Cons.
		KRONIC				•
		LTSAMP		•		DOE
		MESOI		•		NRC
		ML CODE		•		DOE
		PAVAN				•
		PHAST				• Technica Inc.
		PTPLU-2				•
		RAECOM		•	•	NRC
		RSAC-3		•		
		RISKPRO-ACSI				• General Services Corp.
		SCREEN		•		EPA
		SIMS		•		EPA
		SUBDOSA				•
		TECJET				• Technica Inc
		TOXBOX				•
		UNAMRP				• Bowman Env /Env. Inc./Clary Ass.
		XOQ/DOQ				• NRC

TABLE 5: Index of Existing Environmental Pathway Models

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Agency

Surface Water							
<i>Runoff</i>							
<i>Agricultural</i>							
		GLEAMS (CREAMS)			•		USDA
		HSPF			•		EPA
		MRI			•		
		PRZM (PREPRZM) (cf GEMS)			•		EPA
		STREAMS			•		
		WQAM			•		
<i>Urban/Suburban</i>							
		HSPF			•		EPA
		MRI			•		
		STORM			•		
		SWMM			•		EPA
		WQAM			•		
<i>Landfill</i>							
		HELP			•	•	EPA
		MRI			•		
		SARAH			•		
		WQAM			•		
<i>Undeveloped</i>							
		GLEAMS (CREAMS)			•		USDA
		HSPF			•		EPA
		MRI			•		
		WQAM			•		
<i>Streams</i>							
<i>Flow</i>							
		DYNHYDS (see WASP4)			•		
		HEC (-1,-2)			•		Army Corps of Engineers
		HYDRO2D-V			•		
		QUALZE			•		
		SBUHYD			•		Univ Calif Santa Barbara
		TEMPEST/FLESCOT			•		NRC
		TR-20			•		
<i>Transport</i>							
		DYNTOX			•		
		EUTRO4 (see WASP4)			•		
		MEXAMS			•		
		MICHRIV			•		
		REACHSCAN			•		
		SARAH2			•		
		SLSA			•		
		TOX14 (cf WASP4)			•		EPA
		WQAM			•		

TABLE 5: Index of Existing Environmental Pathway Models

S	S	N
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Agency

			S	S	N
<i>Flow and Transport</i>					
		CEQUALRIV1			•
		CEQUALW2			•
		CODELL			• NRC
		HSPF		•	EPA
		QLPLOT			•
		QUAL2E (AQUAL2)			•
		RIVMOD			•
		WASP4			• EPA
<i>Multiple Surface Water Flow and Transport</i>					
		CORMIX			•
		EXAMS2 (II) (cf GEMS)			• EPA
<i>Foodchain</i>					
		BIODOSE			•
		FGETS			•
		LADTAP II			•
		PABLM (FOOD,ARRRG)			•

TABLE 5: Index of Existing Environmental Pathway Models

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Agency

Groundwater			
	<i>Groundwater Flow</i>		
	<i>Well Analysis</i>		
	AQUIX		•
	FASTEP		•
	GWAP		•
	PARADOP		•
	PTDPS (-I, -II,III)		•
	PUMP		•
	PUMPING TEST PROGRAM PACKAGE		•
	SLUGIX		•
	STEP-MATCH		•
	THEISFIT		•
	TS-MATCH		•
	TYPURV		•
	WELLFRAC		•
	WHIP		•
	<i>Drawdown</i>		
	ANALYTICAL MODELS		•
	GLOVER		•
	HYDROPAL/I		•
	THEIS		•
	THEIS2		•
	UTIL2		•
	WATER-VEL		•
	<i>Unsaturated-1d</i>		
	HELP	•	EPA
	VADOFT (cf RUSTIC)	•	EPA
	<i>Unsaturated-2d</i>		
	MLTRAN		•
	<i>Unsaturated-3d</i>		
	DCM3D	•	
	VADOSE		•
	<i>Saturated-1d</i>		
	ODAST	•	American Geophys Union
	SOIL	•	IGWMC
	<i>Saturated-2d</i>		
	AQUIFEM		•
	BEWTA		• Nova Scotia Dept Env
	COOLEY		• R L Cooley, Nevada Univ.
	FLUMP		• S.P. Neuman, Univ Arizona
	FRESURF (-1,-2)		•
	NUSEEP		• Northwestern Univ , Dept CE
	USGS2D		• USGS
	V3		• Illinois State Water Surv
	VTT		• PNL/DOE
	WELFLO		•

TABLE 5: Index of Existing Environmental Pathway Models

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Agency

Saturated-3d							
		DPCT		•			
		EPA-WHPA			•		
		FE3DGW			•	PNL/WISAP	
		GWFL3D			•		
		MAT123D		•	•		
		RADIAL FINITE DIFFERENCE MODEL			•		
		RETC F77		•		USDA	
		TERZAGI			•	T.N. Narasimhan, Univ California	
		USGS3D (Modular,Trescott)			•	USGS	
		WELLFLO			•		
Unsaturated/Saturated-1d							
		UNSAT1D			•	U.S. Salinity Lab/DOE/NRC/PNL	
Unsaturated/Saturated-2d							
		FEMWATER (cf FEMWASTE)			•	DOE	
		MAGNUM 2D			•	EG&G Idaho	
		MMT			•		
		TRUST (-II)			•		
		UNSAT (-H,-2)		•		U.S. Salinity Lab./DOE/NRC/PNL	
		MOD2D (-FD)			•	USGS	
		PATHS			•	PNL/WISAP	
Unsaturated/Saturated-3d							
		FREEZE			•	R.A. Freeze, Univ. Waterloo	
		GEOFLOW		•			
		GW FLOW		•		NSEL, Canada	
		MAGNUM 3D			•	EG&G Idaho	
		MOD3D (-FD) (MODFLOW) (MODINV) (MACMODFLOW)		•	•	USGS	
		PATH3D			•		
		PC HST3D			•		
		PLASM		•		Illinois State Water Survey	

TABLE 5: Index of Existing Environmental Pathway Models

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Agency

Groundwater Flow and Transport			
<i>Unsaturated-1d</i>			
	CHEMFLO		•
	GLEAMS		•
	ICE-1		•
	PRZM (cf RUSTIC)		•
	RITZ		•
	TETRANS		•
	VADOFT		•
<i>Unsaturated-2d</i>			
	BIOPLUMEII		•
	FLAWS		•
	GS2		•
	PORFLO-2D		• Hanford/DOE
	TRIPM		•
	WAFE		•
<i>Unsaturated-3d</i>			
	CHAMP		•
	GS3		•
	PERCOL		• ANL/PNL/ORNL
	PORFLO-3D	•	Hanford/DOE
	PORMC-3	•	Hanford/DOE
	TOUGH		•
<i>Saturated-1d</i>			
	AGU-10 PKG (ODAST)		• American Geophys. Union
	GETOUT		• PNL/DOE
	GWMTM1.2		• Princeton Univ.
	LAYFLO		•
	MMT		• PNL/DOE
	NWFT/DVM		•
<i>Saturated-2d</i>			
	ASM		•
	CATTI		•
	CONMIG		•
	DPCT	•	CGS, Inc
	DUGUID-REEVES		• ORNL
	EPA-VHS		• EPA
	FTRANS		•
	GWMTM2		•
	GW THERM		• Dames & Moore, Inc.
	HYDROPAL		•
	ISQUAD (-2)		• Princeton Univ./Univ Waterloo
	KONBRED (cf MOC (USGS))	• •	USGS
	MAGNUM2D-CHAINT		•
	OGRE		• LLNL
	PATHS		•
	PLUME (-2D)		•
	PORFLO2D		• EPA
	PTC		•
	RANDOM WALK	•	Illinois State Water Survey
	RESTOR		•
	ROBERTSON (-1,-2)		• USGS
	SAFTMOD (cf RUSTIC)		•
	SALTRP		•
	SHALT		• AECL

TABLE 5: Index of Existing Environmental Pathway Models

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			v	v	n	
			e	e	e	
			y	y	y	
			I	II		
		TRAFRAP-WT			●	
		TRANS			●	USGS
<i>Saturated-3d</i>						
		AT123D (cf GEMS)			●	ORNL
		CFEST	●	●		PNL/DOE
		GROVE/GALERKIN			●	USGS/Water Resources
		GWTR3D			●	
		IIST3D			●	
		PINDER			●	Princeton Univ.
		PLUME			●	
		PRINCETON			●	
		SOLUTE PKG		●		
		SWENT			●	INTERA Env Cons. Inc.
		SWIP2			●	SNL/USGS/INTERA Env. Cons Inc.
		TRANSAT2			●	GTC, Canada
<i>Unsaturated/Saturated-1d</i>						
		CHAIN			●	EG&G Idaho
		CHAINT			●	Hanford
		CXPMPM			●	
		HYDRUS			●	
		ONE-D			●	
		PULSE			●	
		SESOIL (cf EMS)			●	
		SUMATRA-I			●	U.S. Salinity Lab.
		WORM			●	
<i>Unsaturated/Saturated-2d</i>						
		FEMWASTE (cf FEMWATER)			●	DOE
		GROUNDWATER PACKAGE			●	
		LPMM			●	
		MOC (USGS)	●	●		USGS
		MOD3D			●	USGS
		RW-ANALYT			●	
		SATURN			●	GEOTRANS, Inc.
		SUTRA			●	USGS/GWMC/NWWA
		TDPLUME			●	
		TRANSAT			●	GTS, Ltd
		TWODPLME			●	
		VAM2D	●	●		Hydrogeologic
		VS2DT			●	USGS
		WOAM			●	

TABLE 5: Index of Existing Environmental Pathway Models

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Agency

		<i>Unsaturated/Saturated-3d</i>			
		3-d MIXING CELL		•	
		BEAVERSOFT			•
		FLOWTHROUGH		•	
		KINZALBACH			•
		MAT123D		•	DOE
		MT3D (cf MODFLOW)			• S.S. Popadopoulos & Associates
		NEFTRAN II		•	
		NUTRAN			•
		NWFT/DVM			• SNL/NRC
		PORFLO3D	•		Hanford/DOE
		RUSTIC			•
		SEFTRAN		•	
		SEGOL			•
		SLM			•
		SWANFLOW			•
		SWIFT (-II, -III)	•	•	SNL/NRC/GeoTrans, Inc
		TARGET			•
		TRACER3D		•	LANL/DOE
		TRIPM			•
		TRUST (MLTRAN) (-II)			• LBL/NRC
		WALTON PKG (35)			•

TABLE 5: Index of Existing Environmental Pathway Models

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Agency

Aqueous Geochemistry				
<i>Geochemical</i>				
		BALANCE	•	USGS
		ECHEM		•
		EQ3/6	•	DOE
		EQUILB		•
		GCSOLAR		•
		HYDROGEOCHEM	•	
		MINTEQ (-A2) (PRODEFA)	•	EPA
		PHREEQE	•	USGS
		SOILCHEM		•
		TRANSCHEM		•
		WATEQ4F		•
<i>Hydrochemical</i>				
		CHEMTRN		•
		CHEMTRNS		•
		CPT		•
		CTMID		•
		DYNAMIX		•
		FASTCHEM (cf. ECHEM)		•
		FIESTA		•
		MININR		•
		TRANQL		•
		THCC		•
Engineering/Performance/Accident				
		ANISN		•
		BARRIER	•	EPRI
		BRUNZOG	•	U.S. Army
		BLT (cf. FEMWASTE)		• DOE/EPA
		CONSOL	•	
		DOT		•
		FLASH/FLAME	•	
		HELP	•	EPA
		MACCS	•	NRC
		MORSE-SGS/S		•
		NUTRAN		• AECL/UCRL
		NEWBOX	•	
		ORIGEN-S		•
		PC-SLOPE	•	Geo-Slope, Canada
		RADTRAN (-II)		•
		RASCAL	•	NRC
		RSAC	•	DOE/EXXON
		SFRIPD	•	MK Environmental, Inc
		SFRIPE	•	MK Environmental, Inc
		STABLS	•	DOT
		STABL	•	R.A. Siegel, Purdue Univ
		STABR	•	Univ. Calif. Berkeley
		STEPH	•	MK Environmental, Inc
		UTEXAS2	•	Texas St. Dept. Hwy. & Pub. Trans.

TABLE 5: Index of Existing Environmental Pathway Models

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Agency

Radiation Dose					
		ANDROS			•
		ANISN/PC			• RSIC/ANL
		CRAC2			•
		CYLSEC		•	
		DACRIN (cf. PABLM)			•
		DOSHEM			•
		HUMTRN			•
		ISOSHLD	•		RSIC/BNWL/DOE
		LADTAP			• NRC
		ORIGEN2			• RSIC/ORNL/DOE
		QAD - FN			• RSIC/INEL
		RADRISK		•	EPA
		REDIQ			•
		SOURCE 2		•	
Utilities					
		ANNIE - IDE			•
		GKS			• ANSI/Spectragraphics, Inc
		SURFER		•	Golden Software, Inc.

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Appendix A - BACKGROUND INFORMATION ON IDENTIFIED MODELS

Model Classification	Model Descriptions and References	Page
MULTI-MEDIA		
HAZARD RANKING		62
HRS-1		62
MEPAS		62
RADIOACTIVE MATERIALS TRANSPORT & FATE		
ARCL		63
DECHEM		63
DITTY		63
DOSES		63
DOSTOMAN		64
GENII		64
GENMOD		64
MILDOS		64
MILDOS-AREA		65
NUREG-0707		65
PATH		65
PATH1		65
RESRAD		66
IMPACTS (PART61)		67
ONSITE/MAXII		68
PATHRAE (-EPA)		68
PRESTO-II		68
PRESTO-EPA		69
PRESTO-EPA-CPG		69
PRESTO-EPA-DEEP		69
PRESTO-EPA-POP		70
UDAD		70
GENERAL PURPOSE		
CONDOS-II		71
FLASH/FLAME		71
SPUR		71
SUMO		71
UTM		71
FOODCHAIN		
BIOTRAN		73
AIR TRANSPORT		
AFTOX		74
AIRDOS (MICROAIRDOS, AIRDOS-PC)		74
CAP88 (-PC)		74
CHARM		75
COMPLY		75
DARTAB		75
HARM-II		76
INPUFF		76

ISC(LT/ST)	76
LTSAMP	77
MESOI	77
MLCODE	77
PREPAR	77
RAECOM	78
SCREEN	78
SIMS	78
XOQ/DOQ	78
SURFACE WATER FLOW AND TRANSPORT	80
Codell Models	80
CREAMS	80
HEC-1	80
HEC-2	81
HSPF	81
SBUHYD	81
TEMPEST/FLESCOT	82
GROUND WATER	
FLOW	83
FEMWATER	83
GW FLOW	83
MAGNUM (2D/3D)	83
MOD3D	84
MODFLOW	84
PLASM	85
RETC.F77	85
SOIL	85
TRUST	85
UNSAT2 (-H)	86
TRANSPORT	87
CFEST	87
CHAINT	87
DPCT	87
FEMWASTE	88
MAT123D	88
MT3D	88
NEFTRAN (-II)	89
ODAST	90
PATHS	90
PORFLO (2D/3D)	91
PORMC-3	91
RANDOM WALK	92
SUTRA	92
SWIFT (II,III)	92
TRACR3D	93
USGS MOC	93
VAM2D (H,3D,3DCG)	94
GEOCHEMICAL/HYDROCHEMICAL	95
BALANCE (-A)	95
EQ3/6	95

HYDROGEOCHEM	95
MINTEQ (A1).....	95
PHREEQE	96
ENGINEERING/PERFORMANCE/ACCIDENT	97
BARRIER	97
BRUNZOG.....	97
CONSOL	97
HELP	97
MACCS.....	98
ORIGEN2	98
PAGAN.....	98
PC-SLOPE	98
RASCAL	99
RSAC	99
SFRIPD.....	99
SFRIFE	99
STABL.....	99
STABL5	100
STABR.....	100
STEPH.....	100
UTEXAS2.....	100
RADIATION DOSE.....	101
ISOSHLD (-II).....	101
LADTAP	101
RADRISK	101
UTILITIES.....	102
SURFER.....	102

NOTE: This appendix includes expanded listings for all of the models reported in the two Surveys and some models not reported by respondents but known by the authors to be in use. Model descriptions included here have been taken with minor editing from descriptions contained in the references. Any errors or omissions in these descriptions are unintentional and are the responsibility of the authors of this report. We would appreciate receiving notice of any such errors or omissions so that we can correct any future editions of the text.

MULTI-MEDIA - HAZARD RANKING

Model Name: HRS-I (Hazard Ranking System-I)
Sponsor: USDOE

Description: Hazard ranking.

Reference: Stenner, R.D., R.A. Peloquin and K.A. Hawley. 1986. Modified Hazard Ranking System/Hazard Ranking System for Sites With Mixed Radioactive and Hazardous Wastes - Software Documentation. PNL-6066. Pacific Northwest Laboratory, Richland, Washington.

Model Name: MEPAS (Multimedia Environmental Pollutant Assessment System)
Sponsor: USDOE

Description: MEPAS is a risk computation system developed for hazard ranking applications. MEPAS is designed to integrate the information available for defining chronic public health risks associated with a problem, or a series of problems. This system includes multi-pathway transport and fate models. Potential problems may be characterized by either modeling the environment transport or by input of concentrations at the receptor.

Individual and population environmental risks are evaluated from radioactive materials, chemical carcinogens, and noncarcinogens by considering all major exposure pathways. An internal database provides chemical, physical, and risk evaluation parameters for 297 constituents. Outputs include intermediate files (input values, emission rates, environmental concentrations) and a file with impact information including maximum individual and total population impact magnitudes, timing, and location.

Models are imbedded for air emissions (VOLATE), air transport processes (RAPSCD) and water transport processes (RADCOND), and effects computation (HAZ). Gaseous and particulate emissions/fluxes may be estimated based on site conditions, or input as known parameters. The air transport is a sector average Gaussian model with deposition and complex terrain modules that account for local terrain influences. The soil transport can use dimensional advection and dispersion. In the vadose zone, the model has one dimensional advection and dispersion. In the saturated zone, the model has one dimensional advection and three dimensional dispersion. Various linkages of transport through soil, ground water, surface water and overland runoff are supported.

MEPAS is implemented in MS-DOS for use on an IBM-PC or compatible with a computer shell designed for application to a large number of problems. This Shell allows problem definition, data entry, reference tracking, and model running. A set of data input worksheets are generated for each problem for purposes such as external review or project records.

Reference: Doctor, P.G., T.M. Miley and C.E. Cowan. 1990. Multimedia Environmental Pollutant Assessment System (MEPAS) Sensitivity Analysis of Computer Codes. Prepared for the U.S. Department of Energy. PNL-7296, UC-602, 630. Pacific Northwest Laboratory, Richland, Washington.

Droppo, J.G., Jr., G. Whelan, J.W. Buck, D.L. Strenge, B.L. Hoopes and M.B. Walter. 1989. Supplemental Mathematical Formulations: The Multimedia Environmental Pollutant Assessment System (MEPAS). PNL-7201. Pacific Northwest Laboratory, Richland, Washington.

Whelan, G., D.L. Strenge, J.G. Droppo Jr., and B.L. Steelman. 1987. The Remedial Action Priority System (RAPS): Mathematical Formulations. PNL-6200. Pacific Northwest Laboratory, Richland, Washington.

MULTI-MEDIA - RADIOACTIVE MATERIALS TRANSPORT AND FATE

Model Name: ARCL

Sponsor: USDOE

Description: Method to evaluate decommissioning alternatives by using a site-specific radiation scenario/exposure pathway analysis to determine the acceptable levels of residual radioactive contaminants that remain.

Reference: Napier, B.A., and G.F. Piepel. 1988. A Manual for Applying the Allowable Residual Contamination Level Method For Decommissioning Facilities On The Hanford Site. Pacific Northwest Laboratory, Richland, Washington. PNL-6348/UC602.

Model Name: DECHEM

Sponsor: USDOE

Description: Multiple pathway model developed for use in determining acceptable levels of chemicals in soil after clean-up of Uranium Mill Tailings Remedial Action Project Sites (UMTRA). The model considers exposure through ingestion of contaminated drinking water, ingestion of contaminated food and inhalation of resuspended soil contaminants.

Reference: Model prepared by the Radiological Assessments Corporation, Neeses, South Carolina. Complete citation not provided by respondents.

Model Name: DITTY (Dose Integrated Over Ten Thousand Years)

Sponsor: USDOE

Description: DITTY was developed to determine the collective dose from long term nuclear waste disposal sites resulting from ground water pathways. DITTY estimates the time integral of collective dose over a ten-thousand year period for time-variant radionuclide releases to surface waters, wells or the atmosphere.

Reference: Napier, B.A., R.A. Peloquin, and D.L. Strenge. 1986. DITTY- A Computer Program for Calculating Population Dose Integrated Over Ten Thousand Years. PNL-4456. Pacific Northwest Laboratories, Richland, Washington.

Model Name: DOSES

Sponsor: ORNL

Description: Being developed/used to simplify QC requirements. DOSES calculates dose to man from measured environmental samples.

Reference: Developed by ORNL for use at ORNL. Complete citation not provided by respondents.

Model Name: DOSTOMAN
Sponsor: USDOE

Description: Model is designed to provide estimates of long-term dose to man from buried waste. The model consists of compartments which represent different portions of the environment, including vegetation, herbivores, atmosphere, ground water, surface water and man.

Reference: Root, R.W. 1981. Documentation and User's Guide for DOSTOMAN - A Pathways Computer Model of Radionuclide Movement. DPST-81-549, E.I. DuPont de Nemours & Co.

C.M. King, E.L. Wilhite, R.W. Root, Jr., D.J. Fauth, K.R. Routt, R.H. Emslie and R.R. Beckmeyer, R.A. Fjeld, G.A. Hutto and J.A. Vandeven. 1985. The Savannah River Laboratory DOSTOMAN Code - A Compartmental Pathways Model of Contaminant Transport. Proceedings of the DOE Low-Level Waste Management Program Seventh Annual Participants Information Meeting, Las Vegas, Nevada, 1985. CONF-8509121-13.

Model Name: GENII (Hanford Env. Dosimetry System Generation II)
Sponsor: USDOE

Description: Comprehensive set of environmental pathway and internal dosimetry models. Composed of seven linked computer codes and their associate data libraries

Reference: Napier, B.A., R.A. Peloquin, D.L. Strenge and J.V. Ramsdell. 1988. Hanford Environmental Dosimetry Upgrade Project. GENII - The Hanford Environmental Radiation Dosimetry System. 3 Volumes. PNL-6584. Pacific Northwest Laboratories, Richland, Washington.

Model Name: GENMOD
Sponsor: Atomic Energy of Canada

Description: Calculation of internal dose.

Reference: Prepared by Atomic Energy of Canada for use by the Canadian Nuclear Industry. Complete citation not provided by respondents.

Model Name: MILDOS
Sponsor: USNRC

Description: MILDOS was designed to compute environmental radiation doses from uranium recovery operations.

Reference: Strenge, D.L. and T.J. Bander. 1981. MILDOS - A Computer Program For Calculating Environmental Radiation Doses From Uranium Recovery Operations. NUREG/CR-2011, PNL-3767. Pacific Northwest Laboratory, Richland, Washington.

Model Name: MILDOS-AREA
Sponsor: USDOE

Description: MILDOS-AREA is an improved version of MILDOS. The MILDOS-AREA code provides improved capability for handling large area sources and updates the dosimetry calculations. Runs on an IBM-PC computer.

Reference: Yuan, Y.C., J.H.C. Wang; and A. Zielen. 1989. MILDOS-AREA: An Enhanced Version of MILDOS for Large Area Sources. ANL/ES-161. Argonne National Laboratory, Illinois.

Model Name: NUREG-0707
Sponsor: NRC

Description: Site-specific limits for allowable residual contamination.

Reference: Eckerman and Young. Complete citation not provided by respondents.

Model Name: PATH
Sponsor: GE

Description: Used to implement residual radioactive material guidelines during decommissioning.

Reference: Prepared by Dr. Jaikai Lee for use at the General Electric Shippingport Station. Based on guidelines in: A Manual for Implementing Residual Radioactive Material Guidelines, USDOE.

Model Name: PATH1
Sponsor: USNRC - SNL

Description: . PATH1 models the physical and biological processes that result in the transport of radionuclides through the Earth's surface environment and eventual human exposure to these radionuclides. PATH1 is divided into two submodels. The Environmental Transport Submodel represents the long-term distribution and accumulation of radionuclides in the environment. The Transport-to-Man Submodel simulates the movement of radionuclides from the environment to humans.

PATH1 uses a generalized approach to the simulation of radionuclide transport from the ground water through the environment and food chain to humans. The code is not tied to any specific site characteristics. The Environmental Transport Submodel of PATH1 requires that the study area be divided into a number of compartments, and radionuclide movement between these compartments is represented by a system of linear differential equations. The user must specify the transfer and decay coefficients for this system of compartments. In the Transport-To-Man Submodel, radionuclide ingestion is calculated on the basis of simple food chains and concentration ratios, while the amount of each radionuclide inhaled is determined from the amount of radionuclide-containing soil suspended in the air. These calculated ingestion and inhalation rates are input to the Sandia Dose and Health Effects model, DOSHEM which is incorporated into PATH1.

The code can be run with the ground water code NWFT/DVM using a Latin hypercube sampling routine.

Reference: Helton, J.C., and Kaestner, P.C., 1981. Risk Methodology for Geologic Disposal of Radioactive Waste: Model Description and User's Manual, the Pathways Model, NUREG/CR-1636, vol. 1, SAND 78-1711 AN.

Campbell, J.E., Longsine, D.E., and Cranwell, R.M., 1981. Risk Methodology for Geologic Disposal of Radioactive Waste: The NWFT/DVM Computer Code User's Manual. NUREG/CR-2081, Sandia National Laboratory.

Model Name: RESRAD
Sponsor: USDOE

Description: RESRAD (Gilbert, 1988) is an implementation of the analytical methodology recommended by the Department of Energy in its guidelines (DOE Order 5400.5, Gilbert et al., 1989) for allowable concentrations of residual radioactive material in soil encompassed by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and Surplus Facilities Management Program (SFMP). RESRAD is a multi-media model which incorporates within it a number of media-specific models all of which have been chosen for their reliability but general conservatism. Guideline values derived by the models are based on the method of concentration factors (NRC, 1977; ICRP, 1984; Till and Meyer, 1983; NCRP, 1984).

Pathway analysis for deriving soil concentration guidelines for a specified dose limit is done in four stages:

- Source analysis
- Environmental transport analysis
- Dose/response analysis
- Scenario Analysis

Source analysis is done using a nondispersive equilibrium model of the leaching process. This is an idealized process in which the rate of leaching is constant until a radionuclide has been completely removed from the contaminated zone. Ingrowth and decay of radioactive materials are treated as if they occurred entirely in the contaminated zone. A contaminated zone is treated as a single homogeneous or inhomogeneous source of changing thickness, depth, and radionuclide concentrations due to leaching, erosion, ingrowth, and decay. Principal radionuclides are those with half-lives greater than 1 year.

Environmental transport pathways include air (dust, radon, and other gases) and water (surface and ground water). Air transport is accomplished by use of a simple mixing model rather than a Gaussian plume model. The surface water is assumed to be a pond or lake for which (1) the water inflow and outflow are in steady-state equilibrium, and, (2) the annual inflow of radioactivity into the pond or lake equals the annual quantity of radioactivity leached from the contaminated zone. Two models are used for calculating the water/soil concentration ratio for the ground water pathway segment of RESRAD: a mass balance (MB) model and a dispersionless flow (DF) model. The ground water pathway models implemented in the RESRAD code apply only to situations for which the hydrological strata can reasonably be approximated by a sequence of uniform, horizontal layers.

Dose equivalents in organs or tissues of the body are calculated with models that (1) describe the entrance of materials into the body (respiratory and gastrointestinal tract) and the deposition and subsequent retention of the radionuclides in body organs (referred to as metabolic models); and, (2) estimate the energy deposition in tissues of the body (ICRP, 1979).

Soil guidelines are based on a family-farm exposure scenario. RESRAD code was developed by Argonne National Laboratory for AEC/NRC.

Reference: T.L. Gilbert, M.J. Jusko, K.F. Eckerman, W.R. Hansen, W.E. Kennedy, Jr., B.A. Napier and J.K. Soldat. 1988. A Manual for Implementing Residual Radioactive Material Guidelines. January 1988. For the U.S. Department of Energy.

T.L., Gilbert, C.Yu, Y.C. Yuan, A.J. Ziefen, M.J. Jusko, and A. Wallo III, 1989. A Manual for Implementing Residual Radioactive Material Guidelines. June 1989. For the U.S. Department of Energy.

Model Name: IMPACTS (PART61)

Sponsor: USNRC

Description: IMPACTS is used to determine disposal facility radiological impacts, including ground water migration and overflow impacts, intrusion and exposed waste impacts and exposures from potential operational accidents.

PART61 is a system of codes and data files that implements an expansion of the IMPACTS analysis methodology used during the development of the 10 CFR 61 rule and includes:

- CLASIFY: Classifies waste streams into four classes
- IMPACTS: Determines radiological impacts
- INVERSE: Activity or concentration limits
- ECONOMY: Costs of disposal
- INTRUDE: Impacts of an intruder
- VOLUMES: Waste stream annual volumes

Modifications of the IMPACTS methodology included in PART61 are:

1. an update of the low-level radioactive waste source term
2. consideration of additional alternative disposal technologies
3. expansion of the methodology used to calculate disposal costs
4. consideration of an additional exposure pathway involving direct human contact with disposed waste due to a hypothetical drilling scenario; and,
5. use of updated health physics analysis procedures (ICRP-30)

Based on input from CLASIFY, IMPACTS is used to determine most disposal facility radiological impacts for a given combination of:

1. waste streams and processing options
2. disposal technology alternatives, and
3. disposal site environmental settings.

Reference: Oztunali, O.I., W.D. Pon, R. Eng and G.W. Roles. 1986. Update of Part 61 Impacts Analysis Methodology. Codes and Example Problems. Volume 2. NUREG/CR-4370-Vol.2

Oztunali, O.I., and G.W. Roles. 1986. Update of Part 61 Impacts Analysis Methodology. Methodology Report. Volume 1. NUREG/CR-4370-Vol.1

Model Name: ONSITE/MAXII
Sponsor: NRC - PNL

Description: ONSITE/MAXII was developed for use by NRC in reviewing license applications for onsite disposal of radioactive waste. Several exposure pathways can be simulated to conduct a dose pathway analysis for human intrusion scenarios.

Exposure pathways that can be evaluated include direct external exposure to contaminated soil or building surfaces, inhalation of resuspended material, and ingestion of drinking water or terrestrial or aquatic foods. The user may optionally select ICRP-26 or ICRP-30 dose conversion factors.

Reference: Napier, B.A., R.A. Peloquin, W.E. Kennedy, Jr., and S.M. Neuder. 1984. Intruder Dose Pathway Analysis for the Onsite Disposal of Radioactive Wastes: The ONSITE-/MAXII Computer Program. NUREG/CR-3620 (PNL-4054).

Kennedy, W.E., R.A. Peloquin, B.A. Napier and S.M. Neuder. 1986, 1987. Intruder Dose Pathway Analysis for the Onsite Disposal of Radioactive Wastes: The ONSITE/MAXII Computer Program. NUREG/CR-3620, Supplement 1, 1986, Supplement 2, 1987.

Model Name: PATHRAE (-EPA)
Sponsor: USEPA

Description: Estimates annual whole-body doses to a critical population group from the land disposal of below regulatory concern (BRC) wastes. PATHRAE-EPA is expanded from the PRESTO-EPA-CPG and PRESTO-EPA-BRC models.

PATHRAE-EPA can be used to calculate maximum annual effective dose equivalent to a critical population group and to an offsite population at risk. Maximum annual doses are calculated to workers during disposal operations, to offsite personnel after site closure, and to reclaimers and inadvertent intruders after site closure. The offsite pathways include ground water transport to a river and to a well, surface (wind or water) erosion, disposal facility overflow, and atmospheric transport. The onsite pathways of concern arise principally from worker doses during operations and from postclosure site reclamation or intruder activities such as living and growing edible vegetation on site and drilling wells for irrigation or drinking water.

Reference: Rogers, V. and C. Hung. 1987. PATHRAE-EPA: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Methodology and Users' Manual. EPA 520/1-87-028

Model Name: PRESTO-II (Prediction of Radiation Effects from Shallow Trench Operations)
Sponsor: USDOE

Description: PRESTO-II is designed to serve as a non-site-specific screening model to evaluate possible health effects from shallow land and waste disposal trenches for a 1000-year period following the end of disposal operations. PRESTO-II has been applied to simulate radionuclide transport at several DOE low-level waste sites and for the USNRC in support of a *de minimis* classification for waste.

Human exposure scenarios considered include normal releases (including leaching and operational spillage), human intrusion, and limited site farming or reclamation. Pathways and processes of transit from the trench to an individual or population include ground water transport, overland flow, erosion, surface water dilution, suspension, atmospheric transport, deposition, inhalation, external exposure, and ingestion of contaminated beef, milk, crops, and water. Both population doses and individual doses, as well as doses to the intruder

and farmer, may be calculated. Cumulative health effects in terms of cancer deaths are calculated for the population over the 1000-year period using a life-table approach.

Reference: Fields, D.E., C.J. Emerson, R.O. Chester, C.A. Little and H. Hiromoto. 1986. PRESTO-II: A Low-Level Waste Environmental Transport and Risk Assessment Code. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ORNL-5970.

Model Name: PRESTO-EPA
Sponsor: USEPA

Description: Simulates transport of low-level radioactive waste material from a shallow trench site and assesses human risks associated with such transport. This model was modified and added to create the PRESTO family of models: PRESTO-EPA-POP, PRESTO-EPA-CPG, PRESTO-EPA-DEEP, PRESTO-EPA-BRC and PATHRAE-EPA.

Reference: PRESTO-EPA: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code - Methodology and User's Manual. 1983.

Model Name: PRESTO-EPA-CPG
Sponsor: USEPA

Description: Estimates maximum annual whole-body dose to a critical population group from land disposal of low-level waste by shallow or deep methods. The maximum annual dose associated with the post-operational phase of low-level waste disposal facilities is determined. All major non-intrusive human exposure pathways are considered. Time periods up to 10,000 years following the end of disposal may be assessed.

The conceptual logic and control modifications made in developing the PRESTO-EPA-CPG code include the simultaneous modeling of leaching from multiple waste forms, the output of organic dose summaries for specified intervals of time, the calculation of nuclide-specific dose conversion factors used in determining the total dose for each year, the determination of the maximum annual dose and the year in which it occurs, and the output of the corresponding dose summaries and detailed DARTAB tables..

Reference: Rogers, V. and C. Hung. 1987. PRESTO-EPA-CPG: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Methodology and User's Manual. EPA 520/1-87-026.

Cheng Yeng Hung, 1989. User's Guide for the SYSCPG Program - A PC Version of the Presto-EPA-CPG Operation System, EPA 520/1-89-017

Model Name: PRESTO-EPA-DEEP
Sponsor: USEPA

Description: Estimate cumulative population health effects to local and regional populations from land disposal of low-level waste by deep methods. The PRESTO-EPA-DEEP code considers low-level waste disposal by deep well injection, hydrofracture, and deep geologic disposal. The code can be used for simulating the behavior of a facility for up to 10,000 years following the end of disposal operations.

The deep disposal scenarios implemented in the PRESTO-EPA-DEEP code consider only the naturally occurring pathways such as natural ground water and surface water flows and atmospheric transport. Intrusion scenarios such as accidental drilling, geological faulting, and the failure of the access shaft sealing, have a probabilistic nature and are not considered. However, a reinterpretation of certain PRESTO-EPA-DEEP variables will permit a consideration of such stochastic events.

Reference: Rogers, V., and Hung, C., 1987. PRESTO-EPA-DEEP A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code - Methodology and User's Manual. EPA 520/1-87-025.

Model Name: PRESTO-EPA-POP
Sponsor:

Description: Estimates cumulative population health effects from land disposal of low level waste by shallow methods. Health effects to the basin population are calculated for a time period of up to 10,000 years. The code simulates the leaching of radionuclides from the waste matrix, hydrological, hydrogeological, and biological transport, the resultant human exposures, and finally the assessment of the probable health effects for the entire regional water basin population.

The PRESTO-EPA-POP code allows the user to select special human exposure scenarios such as an inadvertent intruder residing or farming the site, as well as routine migration of radionuclides from the trench through the hydrologic and atmospheric environmental pathways to crops and drinking water.

Reference: Fields, D.E., C.A. Little, F. Parraga, V. Rogers and C. Hung. 1987. PRESTO-EPA-POP: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Volume 1, Methodology Manual. EPA 521/1-87-024-1.

Fields, D.E., C.A. Little, F. Parraga, V. Rogers and C. Hung. 1987. PRESTO-EPA-POP: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Volume 2, User's Manual. EPA 521/1-87-024-2.

Cheng Yeng Hung, 1992. User's Guide for the SYSPOP Program - A PC Version of the Presto-EPA-POP Operation System, EPA 400R 92003.

Model Name: UDAD
Sponsor: USNRC

Description: UDAD provides estimates of potential radiation exposure to individuals and to the general population in the vicinity of a uranium processing facility.

Reference: M.H. Momeni, Y. Yuan and A.J. Zielen. 1979. Uranium Dispersion and Dosimetry (UDAD) Code. NUREG/CR-0553. Argonne National Laboratory, Illinois.

MULTI-MEDIA - GENERAL PURPOSE

Model Name: CONDOS-II

Sponsor: USNRC

Description:

Reference: Complete citation not provided by respondents.

Model Name: FLASH/FLAME

Sponsor:

Description:

Reference: Complete citation not provided by respondents.

Model Name: SPUR

Sponsor:

Description:

Reference: Complete citation not provided by respondents.

Model Name: SUMO

Sponsor: USDOE

Description:

Reference: Complete citation not provided by respondents.

Model Name: UTM

Sponsor: ORNL

Description: UTM does complete ecological interactions modeling (ground water and surface water transport, vegetation uptake, nutrient recycling) through compartments in a watershed system.

UTM's air, land, and aquatic sub-systems are designed to be run in sequence. The atmospheric component is based upon a Gaussian plume model and calculates deposition rate of aerosols for any point within a watershed. Concentrations of airborne aerosols at ground level are also calculated. The model includes point, area, line, and windblown sources for air pollutants. Deposition occurs by dry fallout and also by washout caused by rain falling through the plume. Air concentrations and depositions depend upon source strength, atmospheric stability, and wind speed and direction patterns. The deposition values calculated by the atmospheric model are used for input to the land component of UTM.

The basic assumption underlying the land component of the UTM is that water is the major carrier of material through the terrestrial system. Thus, trace-material transport can be modeled by combining hydrologic calculations with consideration of the chemistry of trace materials in aqueous media. The terrestrial component is structured to receive atmospheric wet- and dryfall input to a watershed canopy and then to simulate its movement until it is discharged in stream flow. The model simulates the amount of material washed from the canopy to the land surface during rainfall and allows for the exchange and uptake or adsorption of materials on surface soil. Surface runoff and scouring of soil particles are considered, together with leaching of trace elements into the soil profile. An experimentally derived equilibrium distribution coefficient is used to estimate the concentrations of contaminants in subsurface soil water. This estimated concentration and the rate of soil water drainage are combined to estimate a subsurface input to the stream channel.

The outputs from the terrestrial component of UTM enter the channel component, where flows are calculated using the Chezy-Manning equation. This portion of the program simulates transport of dissolved and particulate materials in stream flow. Suspended and bed-load transport are considered by the model. Mixing and exchange between aqueous and solid phases for the particular chemical species of concern are also simulated. If point-source discharges of known strength are released in the stream, the channel component is capable of simulating their introduction and subsequent transport.

Reference: Patterson, M.R., et. al. , 1974. A User's Manual for the FORTRAN IV Version of Wisconsin Hydrologic Transport Model, ORNL-NSF-EATC-7, Oak Ridge National Laboratory, Oak Ridge, TN.

R.J. Luxmore and D.D. Huff. 1989. Analysis of Biogeochemical Cycling in Walker Branch Watershed. pp. 164-196. Springer and Verlag, New York, New York.

MULTI-MEDIA - FOODCHAIN

Model Name: BIOTRAN

Sponsor: LASL

Description: Model is used to predict the flow of transuranic elements (TRU) through specified plant and animal environments using biomass as a vector.

Reference: Gallegos, A.F., B.J. Garcia. and C.M. Sutton. 1980. Documentation of TRU Biological Transport Model (BIOTRAN). LA-8213-MS. Los Alamos Scientific Laboratory.

AIR TRANSPORT

Model Name: AFTOX

Sponsor: U.S. Army

Description: Atmospheric transport.

Reference: Complete citation not provided by respondents.

Model Name: AIRDOS (MICROAIRDOS, AIRDOS-PC)

Sponsor: USEPA - Radiological Assessments Corporation

Description: A modified Gaussian plume equation is used to estimate horizontal and vertical dispersion of radionuclides released from one (MICROAIRDOS) to six (AIRDOS) stacks or area sources within a polar-gridded assessment area. Radionuclide concentrations (up to 12 in MICROAIRDOS and 36 in AIRDOS) in food are estimated by coupling the output of the atmospheric transport code to the USNRC Regulatory Guide 1.109 terrestrial food chain models. Dose conversion factors are input to the code, and doses to man for each distance and direction specified are estimated for total body, red marrow, lungs, endosteal cells, stomach wall, LLI wall, thyroid, liver, kidneys, testes, and ovaries throughout the following exposure modes:

- 1) immersion in air containing radionuclides
- 2) exposure to ground surfaces contaminated by deposited radionuclides
- 3) immersion in contaminated water
- 4) inhalation of radionuclides in air
- 5) ingestion of food in the area.

The code may be run to estimate highest annual individual dose in the area or annual population dose. Ground concentrations of radionuclide and intake rates by man are tabulated for each environmental location. Exposures are also calculated and tabulated for inhalation of ²²²Rn short-lived progeny.

Reference: Moore, R.E., C.F. Baes III, L.M. McDowell-Boyer, A.P. Watson, F.O. Hoffman, J.C. Pleasant and C.W. Miller. 1979. AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man From Airborne Releases of Radionuclides. ORNL-5532, EPA 520/1-79-009, U.S. EPA, Office of Radiation Programs, Washington, D.C..

Till, J.E., K.R. Meyer and R.E. Moore. 1987. MICROAIRDOS User's Manual and Documentation. Radiological Assessments Corporation, Neeses, South Carolina.

Model Name: CAP88 (-PC) (Clean Air Act Assessment Package-1988)

Sponsor: USEPA -USDOE - RSIC

Description: The CAP-88 model is a set of computer programs, databases and associated utility program for estimation of dose and risk from radionuclide emissions to air. CAP-88 is composed of modified versions of AIRDOS-EPA and DARTAB.

CAP88 allows users to perform full-featured dose and risk assessments for the purpose of demonstrating compliance with 40 CFR 61.93. CAP88 differs from the dose assessment software AIRDOS in that it

estimates risk as well as dose, it offers a wider selection of radionuclide and meteorological data, it provides the capability for collective population assessments, and it allows users greater freedom to alter values of environmental variables.

CAP88 uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six sources. The sources may be either elevated stacks, such as a smokestack, or uniform area sources, such as a pile of uranium mill tailings. Plume rise can be calculated assuming either a momentum or buoyancy-driven plume. Assessments are done for a circular grid of distances and directions for a radius of 80 km around the facility.

The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food and intake rates to people from ingestion of food products produced in the assessment area. Estimates of the radionuclide concentrations in produce, leafy vegetables, milk and meat consumed by humans are made by coupling the output of the atmospheric transport models with the USNRC Guide 1.109 terrestrial food chain models.

Dose and risk are estimated by combining the inhalation and ingestion intake rates, air and ground surface concentrations with the doses and risk conversion factors in ICRP Publication 26.

Reference: Parks, B.S., 1991. User's Guide for CAP88-PC: Version 1.0. EPA 520/6-91/022, U. S. Environmental Protection Agency, Washington D.C.

Model Name: CHARM (Complex Hazardous Air Release Model)
Sponsor: USEPA/Radian Corp.

Description: Atmospheric transport and risk estimates.

Reference: Radian Corp., CHARM, 8501 Mopac Blvd., P.O. Box 9948, Austin TX 78766.

Model Name: COMPLY
Sponsor: USEPA

Description: Model is used to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAPS) for Radionuclides in 40 CFR 61, Subpart I. It has various levels of complexity, the simplest being a list of tables of concentration and possession limits in EPA89. The most complicated level is an air dispersion calculation using a wind rose.

Reference: U.S. Environmental Protection Agency, 1989. User's Guide for the COMPLY Code. EPA 520/1-89-003, U.S. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C.

Model Name: DARTAB
Sponsor: USEPA

Description: DARTAB combines radionuclide environmental exposure data with dosimetric and health effects data to generate tabulations of the predicted impact of radioactive airborne effluents. DARTAB is independent of the environmental transport code used to generate the environmental exposure data and the codes used to produce the dosimetric and health effects data. DARTAB is often used with AIRDOS and RADRISK.

Reference: Begovich, C.L., K.F. Eckerman, E.C. Schlatter, S.Y. Ohr and R.O. Chester. 1981. DARTAB: A Program to Combine Airborne Radionuclide Environmental Exposure Data with Dosimetric and Health Effects Data to Generate Tabulations of Predicted Health Impacts. ORNL-5692. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Model Name: HARM-II (Hazardous Atmosphere Release Model)

Sponsor: USDOE

Description: HARM-II performs dispersion calculations for both chemical and radiological releases. Both heavy and simple gases can be modeled.

Reference: NOAA Atmosphere and Diffusion Turbulence Laboratory. Complete citation not provided by respondents.

Model Name: INPUFF

Sponsor: USEPA - Bowman Engineering

Description: INPUFF simulates dispersion from semi-instantaneous or continuous point sources over a spatially and temporally variable wind field. The algorithm is based upon Gaussian puff assumptions including a vertically uniform wind direction field and no chemical reactions. The code can estimate concentrations at up to 100 from multiple point sources.

INPUFF uses three distinct dispersion algorithms. For short travel time dispersion, the user has the option of using either the Pasquill-Gifford (P-G) scheme or the on-site scheme. The third dispersion algorithm was designed for use in conjunction with the P-G or on-site scheme when there are long travel times involved.

Features of the code include:

- Optional stack downwash
- Optional buoyancy induced dispersion
- Wind speed extrapolated to release height
- Temporally variable source characteristics
- Temporally and spatially variable wind field (user supplied)
- Consideration of terrain effects through user-supplied wind field
- Consideration of moving source
- Optional user-supplied subroutine for selecting dispersion coefficients
- Optional user-supplied subroutine for estimating plume rise, and
- Removal through gravitational settling and deposition.

Reference: Peterson, W.B. and L.G. Lavdas. 1988. INPUFF 2.0 - A Multiple Source Gaussian Puff Dispersion Algorithm User's Guide. U. S. Environmental Protection Agency, 1986 and Supplement, 1988.

Model Name: ISC(LT/ST) (Industrial Source Complex Dispersion Model)

Sponsor: USEPA

Description: Combines and enhances dispersion model algorithms to consider pollutant sources other than emissions from isolated stacks, such as fugitive emissions, aerodynamic wake effects, gravitational settling

and dry deposition in assessing the air quality impact of emissions from a wide variety of industrial source complex sources. Two major programs: the ISC Short Term (ISCST) and ISC Long Term (ISCLT).

ISCST uses hourly meteorological data to calculate concentrations for time periods up to 24 hours. ISCLT is and advance Gaussian plume model for atmospheric dispersion of pollutants, using statistical wind summaries to calculate quarterly or annual ground-level concentrations of emissions.

Reference: Bowers, J.F., J.B. Bjorklund, and C.S. Cheney. 1979. Industrial Source Complex (ISC) Dispersion Model User's Guide. EPA-45015-79-030. H.E. Cramer Co., Salt Lake City, Utah.

Model Name: LTSAMP
Sponsor: USDOE

Description: air transport?

Reference: Prepared by Jacobs Engineering for DOE UMTRA Project. Complete citation not provided by respondents.

Model Name: MESOI
Sponsor: USNRC

Description: Atmospheric transport and dispersion model.

Reference: Ramsdell, J.V., G.F. Athey and C.S. Glantz. 1983. MESOI Version 2.0: An Interactive Mesoscale Lagrangian Puff Dispersion Model With Deposition and Decay. NUREG/CR-3344 , PNL-4753. Pacific Northwest Laboratory, Richland, Washington.

Model Name: MLCODE
Sponsor: USDOE

Description: Used to estimate dose and uncertainties in dose estimates resulting from air releases.

Reference: Prepared by B. Napier for use in the Hanford Dose Reconstruction Project. Complete citation not provided by respondents.

Model Name: PREPAR
Sponsor: USEPA

Description: Pre-processor for AIRDOS-EPA

Reference: Oak Ridge National Laboratory, 19xx . PREPAR: A User-Friendly Preprocessor to Create AIRDOS-EPA Input Data Sets. ORNL-5952, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Model Name: RAECOM

Sponsor: USNRC

Description: Code is used to calculate cover thickness and surface fluxes of radon emissions from uranium mill tailings.

Reference: Rogers, V.C., K.K. Nielson and D.R. Kalkwarf. 1984. Radon Attenuation Handbook for Uranium Mill Tailings Cover Design. NUREG/CR-3533

Model Name: SCREEN

Sponsor: USEPA

Description: SCREEN incorporates a number of simple screening procedure for estimating the maximum ground-level concentration of radionuclides for sources in simple flat or elevated terrain. SCREEN:

- accepts user-specified distances,
- performs inversion break-up and shoreline fumigation estimates,
- includes building downwash effects in the wake region,
- performs calculations for the cavity region, and
- includes an optional complex terrain screening procedure based on the VALLEY Model 24-hour screening technique

Reference: Brode, R.W., 1988. Screening Procedures for estimating the air quality impact of stationary sources. EPA-450/4-88-010.

Model Name: SIMS

Sponsor: USEPA

Description:

Reference: Complete citation not provided by respondents.

Model Name: XOQ/DOQ

Sponsor: USNRC

Description: XOQ/DOQ is used in the meteorological evaluation of routine releases from commercial nuclear power reactors. The model uses a steady-state Gaussian plume assumption to implement Section C of Regulatory Guide 1.111.

XOQ/DOQ calculates average relative effluent releases and average relative deposition values at locations specified by the user and at standard radial distances and segments for downwind sectors. The code also calculates these values at the specified locations for intermittent releases. XOQ/DOQ provides the following options:

- both elevated and ground-level sources can be modeled;
- the effluent plume of elevated releases can undergo plume rise due to buoyancy and/or momentum;
- ground-level releases can be affected by the additional dispersion due to local building or terrain induced wakes;
- measured wind speeds can be extrapolated to other elevations;

- topography can be varied;
- the plume may be depleted by dry deposition; and
- relative effluent concentrations and average relative deposition values can be amended to reflect the effects of local air recirculation or stagnation.

This code can be used to estimate ground-level radionuclide concentrations and deposition amounts associated with atmospheric releases from waste repository operations. XOQ/DOQ calculates only normalized radionuclide concentrations and deposition rates; it does not model the subsequent transport of these radionuclides through the environment and food chain to man.

Reference: Sagendorf, J.F., and Gall, J.T., 1977. XOQ/DOQ program for meteorological evaluation of routine effluent releases at nuclear power stations, USNRC, Washington, D.C., NUREG/CR-0324.

SURFACE WATER FLOW AND TRANSPORT

Model Name: Codell Models
Sponsor: USNRC

Description: The Codell series of models are a collection of simple programs used by the Hydrologic Engineering Section for computing the fate of routinely or accidentally released radionuclides in surface water and ground water. The models are straightforward simulations of dispersion with constant coefficients in simple geometries. Models included can be used for rivers, lakes and ground water. Programs STTUBE and TUBE are useful for two-dimensional dispersion of a continuous source into a river after steady-state has been attained. Program RIVLAK also simulates dispersion in a river, but the source can be either steady or unsteady. RIVLAK can be used to calculate two-dimensional dispersion in the near-shore regime of large lakes. The surface water models in the Codell codes ignore uptake of radionuclide on sediments.

GROUND is used for calculating dispersion in a three-dimensional aquifer and is most useful for determining the concentration at wells downgradient of a source released from a vertical plane. Program GRDFLX provides the same function, but it considers the source to be horizontal.

Reference: Codell, R.B., Key, K.T., and Whelan, G., 1982. A Collection of Mathematical Models for Dispersion in Surface Water and Ground Water. NUREG-0868, U.S. Nuclear Regulatory Commission, Washington, D.C.

Model Name: CREAMS
Sponsor: USDA-Agricultural Research Service, Southeast Watershed Research Lab

Description: The CREAMS model can simulate pollutant movement on and from a field site, including such constituents as fertilizers (N & P), pesticides, and sediment. The effects of alternative agricultural practices on water and land resources can be assessed by simulation of the potential water, soil, nutrient, and pesticide losses in runoff from agricultural fields. By integrating climatic, geomorphic, agronomic, and soil data with structural, cultural, and management systems, the model computes relative yields of sediment, nutrients, and pesticides at the edge of field-sized units. The model structure consists of three major components: hydrology, erosion/sedimentation, and chemistry. The hydrology component estimates the volume and rate of runoff, evapotranspiration, soil moisture content, and percolation. The erosion/sedimentation portion of the model considers the processes of soil detachment, transport, and deposition. The chemistry portion of the model considers nutrients and pesticides. The transport of soluble and sediment-attached chemicals is evaluated. Interaction between plants and chemicals within the root zone is also considered. The model is designed to require a bare minimum of calibration parameters and land use strategies. The spatial scale of the model is intended to be the size of an agricultural field. When calibrated with observed data CREAMS can be used to provide predictive information.

Reference: Knisel, W.G., ed., 1980. CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U.S. Department of Agriculture, Science and Education Administration, Conservation Research Report 26, 643 pp.

Model Name: HEC-1
Sponsor: U.S. Army Corps of Engineers

Description: Calculation of flood hydrographs.

Reference: HEC-1 Flood Hydrograph Package, User's Guide. 1981. U.S. Army Corps of Engineers, The Hydrologic Engineering Center.

Model Name: HEC-2
Sponsor: U.S. Army Corps of Engineers

Description: The HEC -2 model calculates water surface profiles for open channels with steady, gradually-varied flow. The effects of obstructions such as bridges etc. can be considered.

Reference: HEC-2 Water Surface Profiles, User's Manual. 1982. U.S. Army Corps of Engineers, The Hydrologic Engineering Center.

Model Name: HSPF
Sponsor: USEPA, Environmental Research Lab, Athens, GA

Description: HSPF is a continuous simulation model that simulates the time history of the quantity and quality of runoff from multiple-use watersheds and simulates processes occurring in streams or fully-mixed lakes receiving watershed runoff. Water quality algorithms include BOD/DO dynamics, carbon, nitrogen, and phosphorous cycles, suspended and attached phytoplankton, and one species of zooplankton. Submodels also include sediment transport, pesticide routing and degradation kinetics, and sediment-pesticide interaction. HSPF is a series of coupled computer codes designed to simulate: 1) watershed hydrology; 2) land surface runoff; and 3) the fate and transport of pollutants in receiving water bodies. The hydrologic portions of the model include 1) a watershed hydrology model similar to the Stanford Watershed Model; 2) a runoff model using algorithms similar to the Non-Point Source (NPS) model; and 3) a stream routing component using a kinematic wave approximation. The degradation/transformation process included in the model are: hydrolysis, photolysis, oxidation, volatilization, and biodegradation. The kinetic reactions are formulated as second-order processes. Secondary or "daughter" chemicals are also simulated; up to two daughter chemicals can be analyzed in a single simulation. The one dimension formulation limits application of the model to river systems where pollutants are uniformly mixed both laterally and vertically; the kinematic wave formulation of flow in rivers is not applicable to rivers where the gradient is very small or where backwater effects are present; data requirements for the model may be quite extensive depending on the particular application; and the zero-dimensional representation of lakes assumes that pollutants are uniformly mixed throughout and that the lake is not stratified.

Reference: Johanson, R.C., Imhoff, J.C., Kittle, Jr., J.L., and Donigian, Jr., A.S., 1984. Hydrological Simulation Program -- FORTRAN (HSPF): User's Manual for Release 8.0. EPA-600/3-84-066, NTIS PB84 157155.

Model Name: SBUHYD
Sponsor: U.C. Santa Barbara

Description: Calculates hydrographs.

Reference: Stubenhaer, J.M. 1975. The Santa Barbara Urban Hydrograph Method. National Symposium on Urban Hydrology and Sediment Control. University of Kentucky, July 1975.

Model Name: TEMPEST/FLESCOT

Sponsor: USNRC

Description: FLESCOT simulates radionuclide transport in estuaries to obtain accurate radionuclide distributions which are affected by time-variance, three-dimensional flow, temperature, salinity and sediments. FLESCOT is a modification of the hydrothermal model TEMPEST.

Reference: Trent, D.S. and Y. Onishi. 1989. Proceedings of the ASCE Specialty Conference: Estuarine and Coastal Circulation and Transport Modeling. Model - Data Comparison. November 15-17, 1989, Newport Rhode Island.

Onishi, Y. and D.S. Trent. 1982. Mathematical Simulation of Sediment and Radionuclide Transport in Estuaries: FLESCOT. Battelle Pacific Northwest Labs, Richland, Washington. Prepared for USNRC. NUREG/CR-2423.

Onishi, Y. and D.S. Trent. 1985. Three-Dimensional Simulation of Flow, Salinity, Sediment and Radionuclide Movements in the Hudson River Estuary. Proceedings of the Specialty Conference, Hydraulics and Hydrology in the Small Computer Age. Hydrology Division/ASCE, Lake Buena Vista, Florida, August 12-17, 1985.

Onishi, Y., D.S. Trent and A.S. Koontz. 1985. Three-Dimensional Simulation of Flow and Sewage Effluent Migration in the Strait of Juan de Fuca, Washington. Proceedings of the 1985 Specialty Conference on Environmental Engineering. EE Division/ASCE. Northeastern University, Boston, Mass. July 1-5, 1985.

GROUND WATER - FLOW

Model Name: FEMWATER

Sponsor: USDOE - AECL

Description: FEMWATER simulates ground water dynamics in saturated-unsaturated subsurface systems and is a complimentary code to FEMWASTE which simulates waste transport .

FEMWATER is a revised finite-element model of water flow through porous media. Modifications from a previous version include:

1. computing the flow field in a way consistent with the finite-element approach;
2. evaluating the moisture content increasing rate within the region by a new method consistent with solving for moisture content and pressure fields; and
3. treating the terms to ensure that a unique relationship between any nonlinear variable and pressure is preserved.

The expansion provides four alternative numerical schemes that are more appropriate for many situations.

Reference: Pickens, J.F. and Grisak, G.E., 1979. Finite Element Analysis of Liquid Flow, Heat Transport and Solute Transport in a Ground Water Flow System: Governing Equations and Model Formulation. AECL-TEC-REC-81, National Hydrology Research Institute Inland Waters Directorate, Environment Canada, for Atomic Energy of Canada Limited, Whiteshell Nuclear Research Establishment.

Model Name: GW FLOW

Sponsor: Natural Sciences and Engineering Council of Canada.

Description: Saturated ground water flow. Stochastic, finite-element, two-dimensional, fully saturated steady state ground water flow.

Reference: Complete citation not provided by respondents.

Model Name: MAGNUM (2D/3D)

Sponsor: USDOE - EG&G Idaho

Description: MAGNUM simulate coupled heat and ground water flow in a saturated, fractured-porous media. The MAGNUM computer code is available in two versions - a two-dimensional version, MAGNUM-2D; and a three-dimensional version, MAGNUM-3D.

MAGNUM-2D simulates transient or steady-state ground water flow and/or coupled heat transport in a two-dimensional Cartesian or axisymmetric domain. MAGNUM-3D simulates heat conduction or ground water flow but does not account for the fully coupled processes. Both versions of the code have been extensively verified and benchmarked.

Both versions of MAGNUM use a dual permeability approach to represent the hydraulic behavior of a fractured-porous media. The porous zones in the domain are modeled using standard two- and three-dimensional isoparametric finite elements. Discrete fractures are modeled using line or plate elements which are embedded along the sides of the continuum elements. MAGNUM provides flow field calculations for input to transport and pathline-travel time models.

Both MAGNUM codes are interfaced with a number of pre- and postprocessors for input/output generation. In addition, MAGNUM-2D is generally used in conjunction with the CHAINT mass transport model. In a similar fashion, MAGNUM-3D is interfaced with the FECTRA mass transport code.

Reference: Baca, R.G., Arnett, R.C., and Langford, D.W., 1984. "Modeling fluid flow in fractured porous-rock masses by finite element techniques," *International Journal for Numerical Methods in Fluids*, v. 4, p. 337-348.

England, R.L., Kline, N.W., Ekblad, K.J., and Baca, R.G., MAGNUM-2D Computer Code: User's Guide, RHO-CR-143 P, Rockwell Hanford Operations, Richland, Washington.

Estey, S.A. Arnett, R.C., and Aichele, D.B., 1985. User's Guide for MAGNUM-3D: A Three-Dimensional Ground Water Flow Numerical Model, RHO-BW-ST-67 P, Rockwell Hanford Operations, Richland, Washington.

Model Name: MOD3D
Sponsor: USGS

Description: MOD3D simulates three-dimensional ground water flow in a porous, heterogeneous and anisotropic medium with irregular boundaries.

Reference: McDonald, G., and Harbaugh, A.W., 1989. A Modular Three-Dimensional Finite Difference Ground Water Flow Model: MOD3D. U.S.G.S. *Techniques of Water Resource Investigations*, Book, 6, Chapter A1, TWI 6-A1, Washington, D.C.

Model Name: MODFLOW
Sponsor: USGS/IGWNC

Description: MODFLOW is a finite-difference model that simulates flow in three dimensions. Ground Water flow within the aquifer is simulated using a block-centered finite-difference approach. Layers can be simulated as confined, unconfined, or a combination of the two. Flow associated with external stresses, such as wells, can also be simulated. The finite-difference equations can be solved using either the Strongly Implicit Procedure (SIP) or Slice-Successive-Overrelaxation (SSOR).

Reference: McDonald, M.G. and A.W. Harbaugh. 1984. A Modular Three-Dimensional Finite Difference Ground Water Flow Model: MODFLOW. U.S. Geological Survey Open File Report. 83-875.

Harbaugh, A.W., 1990. A Computer program for Calculating Subregional Water Budgets Using Results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground Water Flow Model: MODFLOW, USGS Open-File Report 90-392, 46 pp.

Harbaugh, A.W., 1990. A Simple Contouring Program for Gridded Data, USGS Open-File Report 90-144, 37 pp.

Model Name: PLASM
Sponsor: Illinois State Water Survey

Description: Saturated, two dimensional ground water flow. Available for mainframe or PC computers.

Reference: Prickett, T.A. and C.G. Lonquist. 1971. Selected Digital Computer Techniques for Ground Water Resource Evaluation. Illinois State Water Survey, Urbana, Illinois.

Model Name: RETC.F77
Sponsor: USDA

Description: Estimation of hydraulic conductivity of unsaturated and porous media.

Reference: Mualem, Y. 1976. A New Model for Predicting the Hydraulic Conductivity of Unsaturated and Porous Media. Water Resources Research, Vol 12, No.3

Model Name: SOIL
Sponsor: IGWMC

Description: Variably Saturated Flow.

Reference: El-Kadi, 1985. SOIL, version IBM-PC 1.0, International Ground Water Modeling Center, Butler University, Indianapolis, Indiana.

Model Name: TRUST
Sponsor: USNRC - PNL

Description: TRUST provides a versatile tool to solve a wide spectrum of fluid flow problems arising in variably-saturated, deformable, porous media. The governing equations express the conservation of fluid mass in an elemental volume that has a constant volume of solid. Deformation of the skeleton may be nonelastic.

Permeability and compressibility coefficients may be nonlinearly related to effective stress. Relationships between permeability and saturation with pore water pressure in the unsaturated zone may include hysteresis. The code developed by T.N. Narasimhan grew out of the original TRUMP code written by A.L. Edwards. The code uses an integrated finite difference algorithm for numerically solving the governing equation. Marching in time is performed by a mixed explicit-implicit numerical procedure in which the time step is internally controlled. The time step control and related feature in the TRUST code provide an effective control of the potential numerical instabilities that can arise in the course of solving this difficult class of nonlinear boundary value problems.

Reference: Reisenauer, A.E., Key, K.T., Narasimhan, T.N., and Nelson, R.W., 1982. TRUST: A Computer Program for Variably Saturated Flow in Multidimensional, Deformable Media, NUREG/CR-2360, PNL-3975, U.S. Nuclear Regulatory Commission, Washington, D.C..

Edwards, A.L., 1968. TRUMP: A Computer Program for Transient and Steady State Temperature Distributions in Multidimensional Systems, Rep. UCRL-14754, NTIS, Springfield, VA (Third Revision, 1972)

Model Name: UNSAT2 (-H)
Sponsor: USDOE

Description: The UNSAT-H model simulates the water and heat balance of soils to predict ground water recharge rates and to assess the ability of earthen covers to prevent drainage into underlying waste zones. Version 2.0 of the UNSAT-H model simulates the process of water infiltration, redistribution, evaporation, soil-water extraction by plants, deep drainage that becomes recharge, surface energy balance, and soil heat flow. The mathematical bases are Richards equation for liquid flow, Fick's law for diffusion of water vapor, Fourier's law for heat conduction, and the theory of coupled water and heat flow in soils proposed by Philip and de Vries. The model is implemented in FORTRAN as a 1-dimensional finite-difference code with variable time stepping and mass balance control. Verification and validation testing has been performed. Future versions of the model are expected to address hysteresis, snow melt, freezing soil, the temperature dependence of soil properties, a separate air phase, and multiple dimensions.

Reference: L.A. Davis and S.P. Neuman, 1983. Documentation and User's Guide UNSAT-2. NUREG/CR-3390.

Fayer, M.J., G.W. Gee and T.L. Jones. 1986. UNSAT-H Version 1.0: Unsaturated Flow Code: Documentation and Applications for the Hanford Site. PNL-5899, Pacific Northwest Laboratory, Richland, Washington.

Fayer, M.J., and T.L., Jones, 1990. UNSAT-H Version 2.0: Unsaturated Soil Water and Heat Flow Model. PNL-6779, Pacific Northwest Laboratory, Richland, Washington.

GROUND WATER - TRANSPORT

Model Name: CFEST

Sponsor: USDOE

Description: Energy and Solute Transport.

Reference: Gupta, S.K., C.R. Cole, C.T. Kincaid and A.M. Monti. 1987. Coupled Fluid, Energy and Solute Transport (CFEST) Model: Formulation and User's Manual BMI-ONWI-660. Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus Ohio.

Model Name: CHAINT

Sponsor: USDOE - Hanford

Description: CHAINT simulates multicomponent mass transport in a saturated, fractured-porous media.

The CHAINT computer code can simulate transient or steady-state mass transport including chain decay. The two-dimensional code has been extensively verified and benchmarked.

The CHAINT code utilizes a dual permeability approach to represent a fractured-porous medium. The code can handle heterogeneous, anisotropic systems with networks of discrete fractures. The porous zones in the domain are modeled using standard two-dimensional isoparametric finite elements, i.e., triangles and quadrilaterals. Discrete fractures are modeled using line elements which are embedded along the sides of the continuum elements. In addition, the code can accommodate a variety of initial and boundary conditions.

The primary outputs of the CHAINT code are contaminant concentrations and fluxes at specified locations. CHAINT is interfaced with MAGNUM-2D and with several pre- and post-processes.

Reference: Baca, R.G., Arnett, R.C., and Langford, D.W., 1984. "Modeling fluid flow in fractured porous-rock masses by finite element techniques," *International Journal for Numerical Methods in Fluids*, v. 4, p. 337-348.

Kline, N.W., England, R.L., and Baca, R.G., 1986. CHAINT Computer Code: User's Guide RHO-CR-144 P, Rockwell Hanford Operations, Richland, Washington.

Model Name: DPCT

Sponsor: NRC

Description: DPCT (Deterministic-Probabilistic Contaminant Transport) predicts ground water flow and contaminant transport accounting for advection, dispersion, radioactive decay, and equilibrium sorption for a single contaminant.

The code treats a two-dimensional vertical cross-section. Almost any water table and geologic configuration is permissible, and there are a variety of allowable boundary conditions. Water flow is steady state.

The cross section is divided into a rectangular array of cells. The head distribution is found by the finite-element method. Solute transport is then treated by tracking the motion of individual particles.

The principal assumptions of the code are:

1. a treatment in two-dimensional cross-section is acceptable;
2. the solute transport equation is valid;
3. sorption may be represented as equilibrium adsorption with a specified distribution coefficient;
4. principal axes of the transmissivity tensor are parallel to coordinate axes everywhere; and
5. ground water flows are steady state.

References: Schwartz, F.W., Crowe, A., 1980. A Deterministic-Probabilistic Model for Contaminant Transport: DPCT. U.S. Nuclear Regulatory Commission Report NUREG/CR-1609.

Model Name: FEMWASTE
Sponsor: USDOE - AECL

Description: FEMWASTE simulates waste transport through porous media under dynamic ground water conditions.

FEMWASTE is a finite-element model of waste transport through porous media which simulates the spatial and temporal distributions of both waste concentration and flux under dynamic ground water conditions. The transport mechanisms include advection, hydrodynamic dispersion, chemical sorption, and first-order decay.

Reference: Pickens, J.F. and Grisak, G.E., 1979. Finite Element Analysis of Liquid Flow, Heat Transport and Solute Transport in a Ground Water Flow System: Governing Equations and Model Formulation. AECL-TEC-REC-81, National Hydrology Research Institute Inland Waters Directorate, Environment Canada, for Atomic Energy of Canada Limited, Whiteshell Nuclear Research Establishment.

Model Name: MAT123D
Sponsor: USDOE

Description: The computer model MAT123D was developed to simulate waste disposal systems. It can be used to analyze the environmental impacts resulting from disposal of radioactive and chemical wastes in geologic media. The process of infiltration through disposal cell caps, transient source leaching and solute transport in geologic media are included. Situations involving saturated-unsaturated media under either fractured or homogeneous conditions can be modeled.

Reference: Yu, C., 1987. A Simulation Model for Analyzing the Environmental Impact of Waste Disposal Systems. Argonne National Laboratory, Illinois.

Model Name: MT3D
Sponsor: Papadopolus Inc.

Description: MT3D is a modular three-dimensional transport model capable of simulating advection, dispersion, and chemical reactions of dissolved constituents in ground water flow systems (Geeing 1990). MT3D was developed with support from the U.S. EPA and is distributed by the Kerr Laboratory.

MT3D was developed using a similar modular structure as MODFLOW, the U.S. Geological Survey modular three-dimensional finite-difference ground water flow model (McDonald and Harbaugh 1988). The modular structure facilitates linking of the program with a ground water flow model such as MODFLOW, simulating transport processes independently thereby conserving computer memory for unused options, and also

simplifies code modifications. It can be used in conjunction with any block-centered finite-difference flow model, but is especially well-suited for linking with MODFLOW. The ground water flow model is constructed and calibrated independently assuming that changes in the concentration field will not affect the flow field measurably. MT3D uses the same spatial discretization and layer types as MODFLOW. In addition, the following transport boundary conditions are supported: 1) specified concentration or mass flux boundaries; and 2) the solute transport effects of external sources and sinks such as wells, drains, rivers, areal recharge and evapotranspiration.

MT3D includes four methods for solving the three-dimensional advective-dispersive-reactive equation: Method of Characteristics (MOC), Modified Method of Characteristics (MMOC), Hybrid Method of Characteristics, and the explicit finite-difference technique. The first three techniques solve the advection term using a method-of-characteristics scheme and the other terms using the finite-difference technique. The MOC technique uses a conventional particle tracking technique for solving the advection term. MOC virtually eliminates numerical dispersion, but can be slow and computationally intensive. This technique is well-suited for problems where sharp concentration fronts exist. The MMOC technique is similar to MOC in that it uses particle tracking techniques, but it involves fewer computations. The MMOC technique is best suited for problems where sharp concentration fronts are not present and the error caused by numerical dispersion can be considered insignificant. The HMOC technique is a mixture of MOC and MMOC, and attempt to combine the strength of both through an automatic adaptive procedure. The HMOC technique is well-suited for problems where sharp concentration fronts are present and can be more efficient computationally than the standard MOC technique. The finite-difference technique uses Taylor-series to approximate the derivatives, and is susceptible to numerical dispersion. The finite-difference technique is normally more efficient computationally than the three method-of-characteristics schemes and is best-suited for problems where sharp concentration fronts are not present.

When modeling dispersion, MT3D can accept a different value for longitudinal dispersivity at each node. One value per layer is then accepted for the horizontal and vertical transverse dispersivity ratios. Chemical reaction currently supported by the MT3D model include equilibrium-controlled sorption reactions and first-order irreversible rate reactions, such as radioactive decay or biodegradation. A single value per layer is specified for bulk density of the porous medium and distribution coefficient. Porosity can be specified individually for each node in the model. These parameters are used by MT3D to compute a retardation factor.

Reference: Zheng, C., 1990. A Modular Three-Dimensional Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Ground Water Systems, U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, OK.

Model Name: NEFTRAN (-II)

Sponsor: USNRC - SNL

Description: NEFTRAN simulates ground water flow and radionuclide transport in the saturated zone, and in the unsaturated zone if moisture content and flow are constant. The code assumes that all flow is along one-dimensional paths which are then assembled into multidimensional networks. Flow is determined by the application of Darcy's law and by requiring conservation of mass at segment junctions. Dispersion is accounted for by the distributed velocity method described by Campbell et al. (1981). The code accounts for multiple straight and branched decay chains. The code has the capability to model the source term either as a leach-limited or a solubility-limited source. In addition, the source term is decoupled from the flow and transport sections so that each can be run independently. NEFTRAN is an improved version of the NWFT/DVM (Campbell et al., 1981) code and has been shown to reproduce NWFT/DVM results.

Reference: Longsine, D.E., Bonano, E.J., and Harlan, C.P., 1987. User's Manual for the NEFTRAN Computer Code. NUREG/CR-4766, SAND86-2405.

Olague, N.E., Longsine, D.E., Campbell, J.E., and Leigh, C.D., 1991 User's Manual for the NEFTRAN II Computer Code, NUREG/CR-5618, SAND90-2089, Sandia National Laboratories, Albuquerque, N.M.

Model Name: ODAST

Sponsor: IGWMC - AGU

Description: ODAST is one program within the AGU-10 package of ground water flow and transport models which includes the following subprograms:

LTIRD simulates dispersion in a radial flow field, calculating the dimensionless concentration of a particular solute, injected into an aquifer, as a function of time and radius. It assumes fully penetrating injection wells with constant injection rate and concentration at source in a homogeneous and isotropic aquifer of uniform thickness. Background concentration of the contaminant is assumed to be zero. The evaluation of the analytical solution is based on numerical inversion of Laplace transform equations.

ODAST evaluates one-dimensional analytical solute transport including convection, dispersion, decay (at the source and in the aquifer) and adsorption. It can calculate relative concentration at any point downstream from the contaminant source at any specified time. It assumes a homogeneous isotropic aquifer of uniform thickness, steady-state flow field, and zero background concentration.

TDAST evaluates two-dimensional analytical solute transport. Convection, dispersion, decay (at source and in the aquifer), and adsorption. Relative concentration can be calculated at any point downstream from a finite strip source (orthogonal to the direction of flow) at any specified time. The model assumes a homogeneous, isotropic aquifer of uniform thickness, steady-state flow field, and zero background concentration.

RESSQ is a semi-analytical model of two-dimensional solute transport that calculates the streamline pattern in an aquifer, location of contaminant fronts about sources at specified times, and concentration versus time at sinks. The model assumes a homogeneous, isotropic, confined aquifer of uniform thickness, steady-state flow field, and advection and adsorption only (no dispersion or decay). Sources are represented by fully penetrating recharge wells and ponds, and sinks are represented by pumping wells.

RT converts a time series of concentration data from one or more observation wells into a spatial concentration distribution in the aquifer at specified times. The model assumes a single fully penetrating production well, steady-state radial flow field, and negligible regional flow.

Reference: Javendal, I., Doughty, C., and Tsang, C.F., 1984. Ground Water Transport: Handbook of Mathematical Models, American Geophysical Union, Water Resources Monograph 10, Washington, D.C.

Model Name: PATHS

Sponsor: PNL/DOE

Description: PATHS provides an approximate contaminant transport evaluation by direct solution of the pathline equations. The steady cases are evaluated by holding the uniform gradient, the head in the pond, and the well strengths constant. Under such steady-state conditions, only one set of flow paths, advancing fronts, and travel times must be calculated. In the transient cases, each new set of fluid particles leaving the pond or wells encounters changing velocity effects. Therefore, a range of typical departure times is selected and the flow paths, front configurations, and travel times are calculated successively for each selected set of fluid particles leaving the contaminant source. The approximate equilibrium coefficient approach is used to give the

ion exchange delay effects for a single constituent. There are, however, no dispersion effects considered in the preliminary model. The model can consider as many as 35 wells at optional locations. Wells are represented as numerically solved by the code to give the paths of the fluid particles and their advance within time toward the outflow boundary.

The main assumptions of the code are:

- 1) two-dimensional (horizontal plane) infinite aquifer of constant thickness;
- 2) confined flow;
- 3) homogeneous, isotropic material with constant properties;
- 4) uniform flow direction may include transient gradient (flow) strength;
- 5) round, fully-penetrating wells and caverns;
- 6) dissipation of the well and cavern heads occurs over a specific radial distance;
- 7) diffusion and dispersion processes are neglected; and
- 8) contaminant adsorption is based on linear equilibrium isotherms.

Reference: Nelson R.W. and Schur, J.S., 1980. PATHS -- Ground Water Hydraulic Assessment of Effectiveness of Geologic Isolation Systems. PNL-3162, Pacific Northwest Laboratory, Richland, WA.

Model Name: PORFLO (2D/3D)
Sponsor: Hanford - PNL

Description: PORFLO simulates coupled heat, ground water flow and solute transport in a saturated or unsaturated, porous media. The code is available in either two-dimensional, saturated flow (2D) or three-dimensional (3D), unsaturated flow versions.

Both versions of PORFLO utilize the equivalent porous continuum analogy to represent a porous medium. The codes can handle heterogeneous, anisotropic systems and can accommodate a variety of boundary conditions. In addition, the codes use a free-format input mode which makes it exceptionally easy to setup an input file. The codes also have various options that allow the user to select the processes to be modeled and the solution method to be used. The codes provide flow field calculations for input to pathline-travel time models and can be interfaced with a number of post-processors for graphical output.

References: Runchal, A.K., Sagar, B., R.B. Baca, and N.W. Kline, 1985. PORFLO - A Continuum Model for Fluid Flow, Heat Transfer and Mass Transport in Porous Media: Model Theory, Numerical Methods, and Computational Tests. Rep. RHO-CR.150 P, Basalt Waste Isolation Project, Rockwell Hanford Operations, Richland, WA.

Runchal, A.K., and Sagar, B., 1989. PORFLO-3: A Mathematical Model for Fluid Flow, Heat and Mass Transport in Variably Saturated Geologic Media - User's Manual - Version 1.0, Westinghouse Hanford Operations, Richland, Washington.

Sagar, B., and Runchal, A.K., , 1990. PORFLO-3: A Mathematical Model for Fluid Flow, Heat and Mass Transport in Variably Saturated Geologic Media - Theory and Numerical Methods, WHC-EP-0042, Westinghouse Hanford Operations, Richland, Washington.

Model Name: PORMC-3
Sponsor: Hanford

Description: Heat and solute transport.

Reference: Prepared by Analytic & Computational Research Inc. Complete citation not provided by respondents.

Model Name: RANDOM WALK
Sponsor: Illinois State Water Survey

Description: Solute transport, two-dimensional porous media.

Reference: Prickett, T.A., T.G. Naymik, and C.G. Lonquist, 1981. A Random Walk Solute Transport Model For Selected Ground Water Quality Evaluations. Bulletin 65, Illinois State Water Survey, Champaign, Illinois.

Model Name: SUTRA
Sponsor: USGS - International Ground Water Modeling Center - National Water Well Association

Description: SUTRA (Saturated-Unsaturated Transport) simulates fluid movement and the transport of either energy or dissolved substances in a subsurface environment. The model employs a two-dimensional hybrid finite-element and integrated finite-difference method to approximate the governing equations that describe the two interdependent processes that are simulated:

1. fluid density-dependent, saturated or unsaturated, ground water flow; and
2. a. transport of a solute in the ground water, in which the solute may be subject to equilibrium adsorption on the porous matrix, and both first-order and zero-order production or decay, or
2. b. transport of thermal energy in the ground water and solid matrix of the aquifer.

Reference Voss, C.I., 1984. SUTRA - Saturated-unsaturated Transport: A Finite-Element Simulation Model for Saturated-Unsaturated, Fluid density-Dependent Ground Water Flow with Energy Transport or Chemically-Reactive Single-Species Solute Transport, U.S. Geological Survey, Reston, Virginia. .

Model Name: SWIFT (II,III)
Sponsor: USNRC

Description: SWIFT II & III simulate the flow and transport of energy, solute and radionuclides in a geologic medium.

Reference: Reeves, M., D.S. Ward, N.J. Johns and R.M. Cranwell. 1986. The Sandia Waste-Isolation Flow and Transport Model For Fractured Media: Release 4.84; Theory and Implementation. USNRC, Washington, D.C. NUREG/CR-3328.

Reeves, M. and R.M. Cranwell. 1981. User's Manual for the Sandia Waste-Isolation Flow Transport Model (SWIFT). USNRC, Washington, D.C. NUREG/CR-2324.

Model Name: TRACR3D
Sponsor: USDOE - LANL

Description: TRACR3D simulates fluid flow and mass transport in a saturated or unsaturated, porous medium. The code is primarily applied to field problems involving unsaturated conditions.

TRACR3D utilizes the equivalent porous continuum analogy to represent a porous media. The code can handle heterogeneous, anisotropic systems and can accommodate a variety of boundary conditions. The code is relatively easy to use but can be run on a Cray computer only. The code has various options that allow the user to select the processes to be modeled and the solution method to be used.

Reference: Travis, B.J., 1984. TRACR3D: A Model of Flow and Transport in Porous Media, LA-9667-MS, Los Alamos National Laboratory, Los Alamos, New Mexico.

Model Name: USGS MOC
Sponsor: USGS

Description: MOC is a two-dimensional model for the simulation of non-conservative solute transport in saturated ground water systems. The model is both general in its applicability and flexible in its design. Thus, it can be applied to a wide range of problems. It computes changes in the spatial concentration distribution over time caused by convective transport, hydrodynamic dispersion, mixing or dilution from recharge, and chemical reactions. The chemical reactions include first order irreversible rate reaction (such as radioactive decay), reversible equilibrium controlled sorption with linear, Freundlich or Langmuir isotherms, and reversible equilibrium controlled ion exchange for monovalent or divalent ions. The model assumes that fluid density variations, viscosity changes, and temperature gradients do not affect the velocity distribution. MOC does allow modeling heterogeneous and/or anisotropic aquifers.

MOC couples the ground water flow equation with the non-conservative solute-transport equation. The computer program uses the ADI or SIP procedure to solve the finite difference approximation of the ground water flow equation. The SIP procedure for solving the ground water flow equation is most useful when areal discontinuities in transmissivity exist or when the ADI solution does not converge. MOC uses the method of characteristics to solve the solute transport equation. It uses a particle tracking procedure to represent convective transport and a two-step explicit procedure to solve the finite difference equation that describes the effects of hydrodynamic dispersion, fluid sources and sinks, and divergence of velocity. The explicit procedure is subject to stability criteria, but the program automatically determines and implements the time step limitations necessary to satisfy the stability criteria.

MOC uses a rectangular, block-centered, finite difference grid for flux and transport calculations. The grid size for flow calculations is limited to 40 rows and 40 columns. The grid size for transport calculations is limited to 20 rows and 20 columns which can be assigned to any area of the flow grid. The program allows spatially varying diffuse recharge or discharge, saturated thickness, transmissivity, boundary conditions, initial heads and initial concentrations and an unlimited number of injection or withdrawal wells. Up to five nodes can be designated as observation points for which a summary table of head and concentration versus time is printed at the end of the calculations.

An interactive preprocessor, PREMOC, is included with the program to facilitate user friendly data entry and editing.

Reference: Konikow, L.F. and J.D. Brederhott. 1978. Computer Model of Two-Dimensional Transport and Dispersion in Ground Water. USGS. Techniques of Water Resource Investigation, Book 7, Chapter 2.

Goode, D.J. and L.F. Konikow. 1989. Modification of a Method-of-Characteristics Solute Transport Model to Incorporate Decay and Equilibrium-Controlled Sorption or Ion Exchange. USGS Water Resources Investigations Report 89-4030.

Model Name: VAM2D (H,3D,3DCG)

Sponsor: Hydrogeologic Inc.

Description: VAM2D (NRC, 1989) is a finite element model that couples porous media water flow and contaminant transport through the saturated and unsaturated zones. The code was developed for the NRC. Specific features of the code and processes that the code is capable of simulating include:

- Two dimensional flow and transport
- Chain-decay transport
- Dispersion
- Retardation
- Anisotropic and/or heterogeneous lithology
- Confined and/or unconfined aquifers
- Aquitards
- Steady state or transient conditions
- Pulse and step releases from contaminated sources
- Point, line or areal sources

There are a whole range of flow and transport processes that VAM2D cannot simulate including vapor transport, complex geochemical reactions, three-dimensional fate and transport, and a variety of processes that may be essential in the evaluation of selected remedial alternatives. However, these limitations would generally not preclude the successful application of VAM2D to support the baseline risk assessment and characterization program.

VAM2D has been extensively tested through the INTERVAL Program and has been applied at numerous sites contaminated with radionuclides including: Los Alamos, West Valley, and Maxey Flats.

Reference: Huyakorn, P.S., 1989. VAM2D - Variably Saturated Analysis Model in Two Dimensions. NUREGY/CR-5352, Hydrogeologic Inc. for the U.S. Nuclear Regulatory Commission, Washington, DC.

Huyakorn, P.S., White, H.O., Kool, J.B., and Buckley, J.E., 1988. VAN2DH Version 1.0: A Variably Saturated Flow and Transport Analysis Model in 2-Dimensions. Documentation and User's Guide, Hydrogeologic Inc., Herndon, Virginia.

Huyakorn, P.S., and Panday, S., 1990. VAM3DCG: Variable Saturated Analysis Model in Three Dimensions with Preconditioned Conjugate Matrix Solvers - Documentation and User's Manual. Version 2.0, Hydrogeologic, Inc., Herndon, Virginia.

GEOCHEMICAL/HYDROCHEMICAL

Model Name: BALANCE (-A)

Sponsor: USGS

Description: Hydrochemical model.

Reference: Parkhurst, D.L., L.N. Plummer and D.C. Thorstenson, 1982. BALANCE-A Computer Program for Calculating Mass Transfer for Geochemical Reactions in Ground Water. U.S. Geological Survey, Water Resources Investigations 82-0014, 33 pp.

Model Name: EQ3/6

Sponsor: USDOE

Description: Solute transport.

Reference: Wolery, T.J., Jackson, K.J., Boucier, W.L., Bruton, C.J., Viani, B.E., and Delany, J.M., 1988. The EQ3/6 software package for geochemical modeling: Current status. American Chemical Society, Division of Geochemistry, 196th ACS National Meeting, Los Angeles, California, Sept. 25-30 (abstract).

Wolery, T.J., et al., 1990. Current Status of the EQ3/6 Software Package for Geochemical Modeling, Chemical Modeling in Aqueous Systems II, D.C. Melchior and R.L. Basset, eds., ACS Symposium Series 416, American Chemical Society, Washington, D.C.

Model Name: HYDROGEOCHEM

Sponsor:

Description: Hydrochemical model

Reference: G.T. Yeh and V.S. Tripathi. Complete citation not provided by respondents.

Model Name: MINTEQ (A1)(Equilibrium Metal Speciation Model)

Sponsor: USEPA

Description: Geochemical model; calculates equilibrium aqueous speciation, adsorption, gas phase partitioning, solid phase saturation states and precipitation-dissolution of eleven metals.

Reference: Brown, D.S. and J.D. Allison. 1987. MINTEQA1 Metal Speciation Model: A User's Manual. EPA/600/3-87/012, USEPA, Athens, Georgia.

Felmy, A.R., D.C. Girvin and E.A. Jenne. 1984. MINTEQ - A Program For Calculating Geochemical Equilibria. EPA/600/3-84-032, USEPA, Athens Georgia.

Model Name: PHREEQE

Sponsor: USGS

Description: PHREEQE is a FORTRAN IV computer program designed to model geochemical reactions. Based on an ion pairing aqueous model, PHREEQE can calculate pH, redox potential, and mass transfer as a function of reaction progress. The composition of solutions in equilibrium with multiple phases can be calculated. The aqueous model, including elements, aqueous species, and mineral phases, is exterior to the computer code and is completely user definable. PHREEQE can simulate several types of reactions including (1) addition of reactants to a solution, (2) mixing of two waters, and (3) titrating one solution with another. In each of these cases PHREEQE can simultaneously maintain the reacting solution at equilibrium with multiple phase boundaries. The program calculates the following quantities during the reaction simulation:

- 1) pH;
- 2) pe;
- 3) total concentration of elements;
- 4) amounts of minerals (or other phases) transferred into or out of the aqueous phase;
- 5) distribution of aqueous species; and
- 6) saturation state of the aqueous phase with respect to specified mineral phases.

Reference: D.L. Parkhurst, D.C. Thorstenson and L.N. Plummer, 1980. PHREEQE - A Computer Program for Geochemical Calculations. U.S. Geological Survey, Water-Resources Investigations 80-96, 209 pp.

ENGINEERING/PERFORMANCE/ACCIDENT

Model Name: BARRIER

Sponsor: EPRI

Description: Simulates the long-term performance of low-level radioactive waste disposal facilities. Predicts: long-term water balance; degradation of concrete structures over time and cracking and failure of concrete structures.

BARRIER projects the failure of facility structural components and water flow through the facility prior to and following failure. Unsaturated ground water flow modeling is based on Darcy's Law for water flow as extended to unsaturated systems. Facility degradation is modeled mechanistically, employing concrete deterioration and structural analysis algorithms pertinent to each facility design.

Reference: Shuman, R., V.C. Rogers, N. Chau and G.B. Merrel. 1989. The BARRIER Code: A Tool for Estimating the Long-Term Performance of Low-Level Radioactive Waste Disposal Facilities. NP-6218-CCML.

Model Name: BRUNZOG

Sponsor: US ARMY

Description: Calculates depth of thaw penetration.

Reference: Prepared by E.J. Chamberlin, U.S. Army Cold Regions Research and Engineering Laboratory. Complete citation not provided by respondents.

Model Name: CONSOL

Sponsor: ?

Description: Calculates settlement.

Reference: Prepared by U.C. Berkeley. Complete citation not provided by respondents.

Model Name: HELP (Hydrologic Evaluation of Landfill Performance)

Sponsor: USEPA

Description: Estimates the amount of surface runoff, subsurface drainage and leachate that may result from the operation of various landfill designs. The program models the effects of hydrologic processes including precipitation, surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage using a quasi-two-dimensional approach.

Reference: Schroeder, P.R., J.M. Morgan, T.M. Walski and A.C. Gibson. 1984. The Hydrologic Evaluation of Landfill Performance (HELP) Model. EPA/530-SW-84-009.

Model Name: MACCS (Reactor Accident Consequence Analysis Code)
Sponsor: USNRC

Description: Estimates environmental concentrations, intakes, dose-equivalents and risks resulting from a reactor accident.

Reference: Developed by Sandia National Laboratories. Complete citation not provided by respondents.

Model Name: ORIGEN2
Sponsor: RSIC

Description: ORIGEN2 is a revised and updated version of ORIGEN (Oak Ridge Isotope Generation). ORIGEN2 performs a point-depletion calculation on reactor fuel, irradiation of reactor components, and determines the composition, radiation, and spectra of any part of the fuel cycle. A matrix exponential technique is applied to compute nuclide concentrations. In some cases the Bateman equation and secular equilibrium are used. The cross sections are assumed to be constant, except for a number of key actinide reactions that are varied with burnup. Nuclear libraries supplied with the code provide space and spectrum-averaged cross-sections. One-group flux is assumed. Output values are used as source terms for radiation exposure and radiation shielding codes.

Reference: Croff, A.G., 1980. A User's Manual for the ORIGEN2 Computer Code. ORNL/TM-7175

Model Name: PAGAN (Performance Assessment Ground Water Analysis of low-level Nuclear waste)
Sponsor: USNRC - SNL

Description: The PAGAN code is used to assess the performance of low-level waste and contains the transport codes DISPERSE and SURFACE (Kozak et al., 1990). PAGAN calculates release from a source using either a rinse-release or a leach-limited source-term model. This release term is used as an area source into the aquifer at the water table, and radionuclide concentrations at various locations and times can be calculated. If the contaminated aquifer also discharges into a surface water body, the flux of radionuclides into the surface water can be calculated in a separate run of PAGAN. If the surface water body is a small flowing river, the radionuclide concentration in the river may be calculated using a simple dilution factor in PAGAN.

The surface and ground water capabilities of PAGAN have been incorporated into the GENII code (Napier et al., 1988).

Reference: Chu, M.S.Y., Kozak, M.W., Campbell, J.E., and Thompson, B.M., 1991. A Self-Teaching Curriculum for the NRC/SNL Low-Level Waste Performance Assessment Methodology, NUREG/CR-5539, SAND90-0585, U.S. Nuclear Regulatory Commission, Washington, D.C.

Model Name: PC-SLOPE
Sponsor: Geo-slope, Inc., commercial product

Description: Failure surface calculations.

Reference: Geo-Slope, Calgary Canada. Complete citation not provided by respondents.

Model Name: RASCAL

Sponsor: USNRC

Description: Estimates dose-equivalents and health effects due to reactor accidents.

Reference: Model prepared by ORNL and Phoenix Associates Inc. Complete citation not provided by respondents.

Model Name: RSAC (Radiological Safety Analysis Computer Program)

Sponsor: USDOE

Description: Evaluation of the impact of nuclear facilities, operation and accidents. The program can calculate: fission product buildup and decay, meteorological diffusion and/or depletion values, and individual or population doses resulting from inhalation, deposition or ingestion of or direct exposure to radionuclides released to the environment.

Reference: Wenzel, D.R. 1982. RSAC-3: Radiological Safety Analysis Computer Program. ENICO-1002. Exxon Nuclear Idaho Co., Inc., Idaho Falls.

Model Name: SFRIPD

Sponsor: MK Environmental

Description: Calculates safety factors for riprap sizing.

Reference: Developed in-house by MK Environmental, San Francisco, California. Complete citation not provided by respondents.

Model Name: SFRIFE

Sponsor: MK Environmental

Description: Calculates safety factors for riprap sizing.

Reference: Developed in-house by MK Environmental, San Francisco, California. Complete citation not provided by respondents.

Model Name: STABL

Sponsor: Indiana

Description: Calculates failure surfaces, factors of safety ?

Reference: Prepared by R.A. Siegel, Purdue University, for the Indiana State Highway Commission. Complete citation not provided by respondents.

Model Name: STABL5
Sponsor: US DOT

Description: Calculates failure surfaces, factors of safety.

Reference: Prepared by Purdue University for The Joint Highway Research Project, Federal Highway Administration, U.S. Department of Transportation. Complete citation not provided by respondents.

Model Name: STABR
Sponsor:

Description:

Reference: Prepared by U.C. Berkeley. Complete citation not provided by respondents.

Model Name: STEPH
Sponsor: MK Environmental

Description: Calculates riprap sizing.

Reference: Developed in-house by MK Environmental, San Francisco, California. Complete citation not provided by respondents.

Model Name: UTEXAS2
Sponsor: Texas

Description: Calculates failure surfaces and factors of safety.

Reference: Prepared by Stephen G. Wright for the Texas State Department of Highways and Public Transportation. Complete citation not provided by respondents..

RADIATION DOSE

Model Name: ISOSHL D (-II)

Sponsor: USDOE

Description: ISOSHL D is used to calculate radiation dose at a point from bremsstrahlung and/or gamma rays emitted from radioisotope sources. ISOSHL D-II is an extension of ISOSHL D with the added bremsstrahlung mode. Five shield regions can be handled with up to twenty materials per shield region, the source is considered to be the first shield region, i.e., bremsstrahlung and gamma rays are produced only in the source. Point kernel integration (over the source region) is used to calculate the radiation doses at a field point.

Data needed to calculate fission-product isotopic concentrations, source spectrum distributions, and attenuation coefficients are contained in libraries used by the code. Problem input data is thereby minimized; and information required specifies the source-shield configuration and identifies the relevant materials and their densities.

Reference: Engle, R.L., J. Greenborg and M.M. Hendrickson. 1966. ISOSHL D - A Computer Code For General Purpose Isotope Shielding Analysis. BNWL-236. Pacific Northwest Laboratory, Richland, Washington.

Simmons, G.L., J.J. Regimbal, J. Greenborg, E.L. Kelley, Jr., H.H. Van Tuyl. 1967. ISOSHL D-II: Code Revision to Include calculation of Dose Rate From Shielded Bremsstrahlung Sources. BNWL-236 Supplement 1, Pacific Northwest Laboratory, Richland Washington.

Model Name: LADTAP

Sponsor: USNRC/Oak Ridge NL

Description:

Reference: Simpson, D.B., and McGill, 1980. Users' Manual for LADTAP II - A computer Program for calculating radiation exposure to man from routine release of Nuclear Reactor Liquid Effluents, Oak Ridge National Lab., Oak Ridge, TN, NUREG/CR-1276 (ORNL/NUREG/TOMC-1).

Model Name: RADRISK

Sponsor: USEPA

Description: Life-table methodology to derive dosimetric and health effects data. Often used with AIRDOS and DARTAB.

Reference: Dunning, D.E., Jr., R.W. Leggett and M.G. Yalcintas. 1980. A Combined Methodology for Estimating Dose Rates and Health Effects From Radioactive Pollutants. ORNL/TM-7105.

UTILITIES

Model Name: SURFER

Sponsor: Golden Software

Description: 3-dimensional gridding, contouring and surface plotting software.

Reference: SURFER, Golden Software, Golden, CO.

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