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Agency Task Force on Environmental Regulatory Modeling: Conclusions and Recommendations

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In March 1992, the Deputy Administrator, in his role as Chair of the Risk Assessment Council, established the ad hoc Task Force on Environmental Regulatory Modeling. Its charge was to "...complete within 12 months a recommendation to the Agency on specific actions that should be taken to satisfy the needs for improvement in the way that models are developed and used in policy and regulatory assessment and decision-making." In addition, the following was to be addressed:

- Acceptability criteria for model use, generally and in particular circumstances.
- Formal technical and policy guidance on model development.
- Agency requirements for peer review and for documentation of models prior to use.
- Expansion of training and technical support activities for the U.S. Environmental Protection Agency (EPA) personnel who oversee model applications.

The Task Force was cochaired by Steve Cordle of the Office of Research and Development (ORD) and Larry Reed of the Office of Solid Waste and Emergency Response (OSWER). Members came from all headquarters' offices, seven regions, and two ORD laboratories. The final report of the Task Force was transmitted to the Deputy Administrator on April 25, 1994. It contained four sections: Training and Technical Support Needs, Model Use Acceptability Criteria, Agency Guidance for Conducting External Peer Review of Environmental Regulatory Modeling, and Proposed Charter for a Permanent Committee on Regulatory Environmental Modeling.

Training and Technical Support Needs

There is a need to support those models developed and used to further specific program objectives. Such support could come from Agency technical experts or by training that makes use of the latest technologies. Personnel responsible for model use or interpretation need to be properly trained in the exercise of that responsibility. More technical support needs to be provided to model users in general, so that these decision support tools can be fully exploited. Technical support can be provided in the form of training, direct help to users, and

information transfer. Short-term technical support needs could be met by panels of experts, or forums, until more formal support programs are needed and instituted.

Model Use Acceptability Criteria

Model code acceptability should be judged on the basis of appropriateness, accessibility, reliability, and usability. There is a need for a "Model Information System," which lists models that meet the acceptability criteria. Once a collection of acceptable models is assembled, there is a need for a process to periodically assess the models being used to support rulemaking decisions and regulatory impact assessments.

Agency Guidance for Conducting External Peer Review of Environmental Regulatory Modeling

Peer review is an important tool in EPA's campaign to document the quality and credibility of the science upon which its regulatory and policy decisions are based. Not all managers who must consider the utility of peer reviews are aware of their importance. Many of those who are aware do not have a clear description of the procedures by which peer review is needed now. There is a need to begin external peer review as early in the model development phase as possible to maximize its value.

External peer review of a model's applicability needs to be conducted well in advance of any decision-making that depends upon the model's results. Information gathered from the peer review of scientific issues is critical in understanding the uncertainties and usefulness of a model in regulatory decision-making. Therefore, such information needs to be available to the decision-maker before decisions based on the model are made.

Proposed Charter for a Permanent Committee on Regulatory Environmental Modeling

There is a need for a centralized focus to promote the goal of providing EPA's senior policymakers with a set of well-developed, well-documented, and well-understood modeling tools to support environmental decision-making.

The History of Decision Support Tools in the Region 7 RCRA Program

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During the last 10 years, Region 7 has strived to develop strategies by which ground-water reviews of Resource Conservation and Recovery Act (RCRA) facilities could be accomplished faster and with more confidence. The advent of tools such as the ground-water workstation and the Ground-Water Information Tracking System (GRITS), and models such as MODFLOW and BIOPLUME attached to the Surfer program, have significantly improved our ability to meet the ever increasing demands on our ground-water staff. Our history can be broken down into four distinct eras. The precomputer years, the ground-water workstation, GRITS, and the present.

Even in our precomputer years (1984-1985), the RCRA Branch recognized the increasing load of ground-water documents, which needed a rapid review. To meet the expectations of our engineering staff, a plan was developed to incorporate ground-water information on land disposal facilities into a specific file. This file, which was available to the geologist, contained geological information specific to the site in question. Included in this file were all pertinent maps of the area, including soil maps as well as ground-water data. These files enabled the ground-water staff to focus their time reviewing the site rather than collecting data.

During the period of time between 1986-1989, the ground-water workstation was actively used as a tool to evaluate different ground-water parameters. The workstation, which consisted of an IBM 286 computer (4-meg RAM, 40-meg hard drive math coprocessor) a digitizer, a six-pen plotter, and a 24-pin printer, enabled the ground-water staff to initiate rudimentary modeling. The workstation contained software from which contours, both two and three dimensional, could be developed using data from a facility. Additionally, the workstation contained two simple models, plume and slug. During the later part of 1986, Region 7 had developed a database program, which was compatible with the workstation. This enabled Region 7, with the help of a contractor, to place individual site ground-water information on disk, which could be transferred directly to the workstation software.

During the early part of 1990, Region 7, with the help of our contractor, the Center for Environmental Research Information (CERI), HDQRS, and Region 5, developed GRITS. This database system is capable of storing data from both soils and ground water. Additionally, modules have been added to this program, which make it possible to determine statistically the status of the ground-water data. Future additions will enable staff to draw contours and connect data to models. This system is currently being used by some states, regions, and private companies.

Currently, each member of the RCRA Branch in Region 7 has at least a 286 computer. The Geology Section staff all have 386 computers with a 466 computer workstation. We are using data generated by GRITS and sent to Surfer to develop two- and three-dimensional models of plumes and ground-water flow. We are currently developing ways in which our support staff will become more familiar with the more complex models.

We are now discovering it is no longer possible to have a staff schooled in geology or engineering without some education in the use of computers. Each year we are aware of the need to become increasingly literate in the use of models and graphics, something that was unheard of 10 years ago.

Strategic Directions for Achieving Data Integration in Region 10

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Strategic Theme

In every area of environmental protection, from enforcement to public outreach, from state/U.S. Environmental Protection Agency (EPA) information exchange to environmental monitoring, the ability to access the right data with which to make sound policy decisions will play a large part in the success or failure of our overall mission.

The Agency's IRM strategic plan, drafted by the Office of Information Resource Management (OIRM) in 1992, clearly underscores the fact that our information resources such as computers, software, and communication links have become the "engine" of the Agency; an engine that is underpowered for the future demands of Agency decision-makers.

Data integration, which is a key theme in the strategic plan, can be defined as "the ability to integrate data from various sources into a tangible format for decision-making." Our ability to accomplish the automation of this critical function is key to having the right information for making sound environmental decisions. Yet, we cannot provide that decision-making capability necessary for success with existing technology.

Current State of Computing in Region 10

According to OIRM's strategic vision, "(EPA) workers will have access to greater power, more information sources, and larger communication networks. Enhanced processing and communication capabilities will improve the productivity of workers and the effectiveness of government decision-making and services. Graphical User Interfaces (GUIs) and object-oriented programs will make these technologies easier to learn and use."

Looking at our current strengths in the IRM area, we have improved electronic communication greatly throughout the Region in the past 4 years and have provided users with improved automation tools to perform administrative tasks more efficiently. Looking at our weaknesses, we have not been able to provide the technological tools to improve our ability to make better environmental decisions. The key steps that we are taking to meet the future needs of the Agency are:

- Expanding and upgrading our hardware and software infrastructure.
- Expanding and upgrading our communications infrastructure.

- Targeting decision support tools for use at the desktop; leveraging Geographic Information Systems (GIS) technology.
- Targeting our user training and information outreach efforts effectively.
- Partnering with ESD and outside organizations to develop better scientific support systems.

Forces Affecting Change

The success of our ability to build a workable infrastructure to support data integration and decision support mechanisms will depend on two things. First, our ability to predict trends in the rapidly changing information technology field. Second, our ability to attain the necessary resources to complete the task.

One of the major platforms for data integration is the local area network (LAN), as well as our GIS/UNIX system. Microsoft Windows and X-Windows products will play a large role in how the products will look and act for all levels of users. Lotus Notes is an information manager for group computing. Notes concentrates many disparate PC functions such as word processing, spreadsheets, databases, E-mail, and communications in one environment. This is a product that has the greatest potential for changing the way that the Agency leverages administrative resources on the LAN. In fact, OIRM has recently endorsed Lotus Notes as the Agency standard for "groupware" computing. Other products that are key to data integration and decision support are ArcInfo and ArcView. These products will play a significant role in the visual display of critical Agency data.

Multiplatform integration will be the key to moving information easily between disparate systems. We have been working on the integration of our LAN platform and our GIS/UNIX platform and we will continue to invest and expand in this area to bring decision support tools to the desktop.

The Internet and public-information access are key growth areas for us as well. We have developed a public-access BBS in the Region, and we hope to have an Internet connection available to the BBS by the end of fiscal year 1994. We are also addressing the security concerns with the Internet and our internal access and availability issues in conjunction with our user training on the Internet and public systems.

Conclusion

Region 10 will continue to invest in infrastructure and cross-platform integration at a moderate rate for the next 5 years. We will build on our successful LAN platform and provide our users with the necessary tools for data integration and decision support on the desktop. We will continue to seek new ways of opening up access to EPA information to the business community, educational community, and general public through available technology such as our BBS and the Internet.

Sound environmental decision-making will depend more and more on the ability to extract and use critical data easily. For Region 10, this will mean a comprehensive, integrated approach to information management of both scientific and administrative information, which carefully considers all the available options and implements those with the highest payback for the Agency and the public.

Lessons Learned in the Application of Decision Support Tools by Sandia National Laboratories' Environmental Restoration Project*

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Sandia National Laboratories (SNL) has been tasked by the U.S. Department of Energy to assess and remediate waste sites associated with past laboratory activities in testing and disposal operations. The Environmental Restoration (ER) project at SNL is responsible for this work at approximately 200 potential waste sites. Current funding scenarios do not permit unlimited spending and/or the pursuit of scientific curiosity in addressing regulatory concerns at these sites, and future funding is limited. Decision support tools (DSTs) are proving to be a great asset in the effort to reduce costs and to make defensible decisions. DSTs provide information to aid the decision-making process by combining 1) U.S. Environmental Protection Agency (EPA) risk methodology, 2) probabilistic estimates of key model parameters, 3) site-specific contaminant information, and 4) realistic exposure scenarios. Areas of interest for DST supplied information include: What risk does a site pose? What cleanup levels are appropriate? How many samples are needed? How many monitor wells are needed? Which sites should be investigated first with the limited funding that exists? What is the worth of collecting additional information? What remediation technology is best? What is the cost uncertainty in the assessment or remediation alternatives?

DST work is being done under the scrutiny of the New Mexico Environment Department (NMED) and EPA Region 6. SNL's interactions and negotiations with the regulatory community regarding DST methodologies and codes have been ongoing for over 2 years. The lessons learned in these interactions and regulatory negotiations have influenced the attributes of DSTs currently under development at SNL. Some of the regulatory concerns and the solutions to problems with DSTs can be summarized as: 1) concern about conservatism in risk assessment, 2) concern about the treatment of uncertainty, 3) documentation of assumptions and data/parameter selection, 4) "what if" (or hypothetical) case study analyses, 5) visualization of results, and 6) statistical and/or geostatistical approaches.

DSTs used at SNL are adhering to the Risk Assessment Guidance for Superfund (RAGS) methodology, but have the added attribute of performing quantitative uncertainty analyses in the form of probabilistic Monte Carlo simulation techniques. This provides conservatism in the quantification of risk and identifies possible impacts to human health and the environment. The quantification of the uncertainty in risk using the Monte Carlo techniques allows for more defensible decisions that are not overly conservative.

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Regulators have expressed concern about how the distributions of uncertain parameters are established when implementing uncertainty analyses. SNL's ER project approaches these concerns by using 1) actual site data, 2) analog site data (i.e, data from a similar or adjacent site at SNL), 3) published literature values, and 4) subjective or expert judgement. Regulators have some concern about using expert judgement in establishing parameter distributions; therefore, SNL will concentrate on obtaining information from the other three classes of data, as these might be less biased. Each DST will prompt the user for documentation of his or her assumptions for the data/parameter inputs, as well as the assumptions for the conceptual model under investigation. This concept has been praised, since typical contractor reports submitted to the regulator do not contain an explicit list of assumptions used in support of data analysis and modeling. Explicit definitions of assumptions and data distributions should help facilitate understanding between the regulators, stakeholders, and potentially responsible parties.

With the advent of the current sophistication in hardware and software packages for desktop computers, the ability to do real-time, or near real-time, computer simulations has been greatly improved. In addition, the computer graphics/visualization capabilities of the systems in use today are outstanding. As a result, DSTs at SNL are employing Monte Carlo analyses of flow and transport simulations, with contaminant plume visualizations, to aid in the understanding of uncertainties in contaminant plume distributions. Many variations of hypothetical conceptual model scenarios may be tested to achieve a greater understanding of the physical system. One such scenario, which proved beneficial, was the ability to simulate buried stream channel deposits between existing monitor wells as part of the spatial variability within an aquifer to evaluate the effects of dispersion within the contaminant plume. Because the flow and transport simulators are constrained by physics, the result was a better understanding of the contaminant movement through and about this zone. The visualization aspects helped to better understand the problem, and also can serve as educational tools.

The statistical sampling and geostatistical simulation work required of DSTs to aid in the definition of the adequacy of sampling and analysis plans have come under scrutiny by regulators. The basic concern in this area is the appropriateness of the methods employed in defining the nature and extent of contamination. Again, the visualization capabilities of DSTs have helped with the initial attempts at regulatory acceptance of these techniques.

DSTs employed, or to be employed, in SNL's ER project are 1) the Probabilistic Risk Evaluation and Characterization Investigation System (Precis), 2) the Borehole Optimization Support System (BOSS), 3) the Environmental Decision Support System (EDSS), and 4) the Cost/Risk Performance Assessment (CRPA) tool.

Preliminary estimates of the relative impact of DST use in the ER project are available. DSTs reduce the time to perform risk assessments and other computer simulation tasks, typically from weeks to days or even hours, depending on the complexity of the analysis. This performance boost allows SNL to perform risk estimates at the outset of a site investigation to decide whether a site is a logical candidate for No Further Action (NFA), requires additional site characterization, or poses a possible threat and therefore should have remedial alternatives defined early in the process, almost in real time. An estimated 40 percent of the sites at SNL may be candidates for early NFA petitions, thereby eliminating needless characterization. The cost savings in this area of DST use totals approximately $20 million.

The cost savings associated with the use of DSTs in defining borehole and monitor well installations, as well as sampling strategies, are estimated to be approximately $10 million. The time savings are significant as well, allowing SNL to concentrate early on the sites that pose a possible threat, to make optimal use of limited funds, and to compress overall site characterization schedules by several years.

Technical Requirements for the Application of Decision Support Tools at a Private Superfund Site

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At Superfund sites, decision support tools (DSTs) provide owners with the ability to employ integrated technologies, such as a Geographical Information System (GIS), to develop conceptual models of subsurface transport processes. Requirements for the application of DSTs include compilation of hydrogeological database/computer-aided design (CAD) files, development of a conceptual model, development of the technical approach (modeling, statistical, expert system), and experience with the application of the tools. The implementation of DSTs leads to the application of ground-water models to address specific questions in the areas of hydrogeological investigation, risk assessment, feasibility study, remedial design of ground-water extraction systems, and improvement of monitoring well design. These technologies require comprehensive and consistent construction and maintenance of relational database and CAD files. The models often require that point-based or inferred knowledge of aquifer parameters (hydraulic conductivity, leakage rates) and hydrogeological boundaries (stream elevation, conductance, recharge) be extrapolated to span beyond the site boundary as defined by the modeled area. Difficulties often arise when data (hydraulic head and water concentration) are clustered on site or are intended to determine the extent of waste plume migration without specific regard for plume characterization.

While many of the technical requirements for the application of DSTs are scientific and generally straightforward, the requirements for regulatory acceptance are often less tangible. Acceptance issues include model selection (public versus proprietary), parameter assignment (acceptable range or distribution of hydraulic parameters), and "conservative bias" (perpetuation of worst case assumptions). Through the negotiation process, we can often resolve many of the differences though training and face-to-face informal technical exchange. Problems encountered often include unclear definition of DST objectives and limitations, application of generic models without regard to site-specific details, necessity of modeling as determined by regulation rather than remediation objectives, lack of appreciation of the uncertainty, and error propagation from measurement to predictive simulation.

Decision Support Systems in the Public Domain: Issues and Considerations

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Decision support systems (DSSs) describe a class of software for supporting executive decision-making. The introduction of DSSs for solving environmental problems is relatively new, and their acceptance and widespread use has been somewhat slow. One of the questions that needs to be answered regarding decision support tools (DSTs) is whether they should be developed as proprietary software or in the public domain. This paper addresses some of the issues and concerns that need to be addressed when developing a DST in the public domain.

Development Platform

One of the key decision-making steps in designing DSTs is the selection of hardware and software environments to be used. Prior to undertaking such a project, a choice needs to be made between personal computers and workstations, and whether DSTs would support multiple users across a network or be solely intended for single users. Then the question of which software platform(s) should be used to develop DSTs arises: Should one use commercial software or develop DST-specific software? These considerations are not to be taken lightly since they greatly impact the extent of use of the DST. The average public-domain DST user likely has access to a personal computer and has a somewhat limited knowledge of software, for example, familiarity with word processors and spreadsheet programs. These constraints preclude the development of "sophisticated" DSTs in the public domain and dictate the use of personal computers and commonly used software tools.

User Profile and User Needs

A misconception related to DSTs may be that they are intended for technically oriented users. The fact is that there may be a broader spectrum of users which includes technical project staff as well as site managers and regulators. The main purpose of public-domain DSTs should be to facilitate interaction and collaboration between project team members and to accelerate and enhance the decision-making process at the management level. As such, consideration has to be given to issues of usability, applicability, and acceptance by the users.

Software Upgrades and Software Support

A main impediment to the success of public-domain DSTs is the lack of commitment on the part of the funding agency for the maintenance and support of these tools. The majority of commercial software development companies invest significant resources toward upgrading and responding to their users. Public-domain software requires the same commitment from the funding source and the developers toward responding to questions about the software and improving on the system performance.

To demonstrate the feasibility of public-domain DSTs, two such systems developed at Rice University will be presented.

The OASIS Decision Support System for Ground-Water Contaminant Modeling (1)

The OASIS system was the first of its kind in ground water. The DSS was developed using hypertext on a Macintosh platform and utilized graphical interfaces to create a more intuitive form of communication with the computer. At the time of its development, IBM compatibles did not allow for the graphical nature of the OASIS system. As a result, the federal- and private-user base of OASIS was limited. The current users of OASIS are mostly in the educational and research communities. Rice University has invested in in-house support of OASIS, which is currently allowing us to upgrade the software and bring it to the PC platform.

A Decision Support System for Evaluating Remediation Performance With Interactive Pump-and-Treat Simulator (P&T DSS)

The P&T DSS is a second-generation OASIS-like tool that can be used to manage, analyze, and model site data and remediation activities. The key differences between OASIS and the P&T DSS are: 1) the P&T system uses a color hypertext interface instead of the black-and-white interface in OASIS, 2) the P&T DSS incorporates a site ORACLE database and two-dimensional and three-dimensional visualization tools, and 3) the P&T DSS will run on Macintosh and IBM-compatible computers.

The P&T DSS contains the Global, Site-Specific, and Simulator modules. The Global module includes hydrogeologic and chemical databases, a remediation technologies library, and remediation decision flowcharts. The Site-Specific module is built around an ORACLE database for the U.S. Air Force Plant 44 site in Tucson, Arizona. The ORACLE database was linked to a user-friendly interface that allows the user to analyze and visualize data using a series of two-dimensional and three-dimensional plots. The Simulator module includes analytical models, an analytical simulator, and a numerical simulator, built around the BIOPLUME II model (2).

Thus far, the P&T DSS has received significant interest from the federal sector because of its simple-to-use interfaces for site data analyses and decision-making. A key element in developing those interfaces, however, has been the use of third-party software such as

ORACLE and ORACLE CARD (database). This implies that the user needs to make an investment in software to have the intended functionality and flexibility of the DSS. On the positive side, the DSS can be used by technical persons as well as by site managers and decision-makers. The P&T DSS will not be ready for distribution until later in the year. More information about the success of the adopted approach will emerge at that time.

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Advantages of Commercialized Products Versus Publicly Developed Products Remaining in the Public Domain

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Commercial software products—models, databases, database managers, expert systems, mapping applications, and the like—generally have advantages over publicly developed software products where there must be a fixed budget and timeframe for development and implementation. Software products solve "information problems" for the various customers who have stakes in Superfund or Resource Conservation and Recovery Act (RCRA) sites. A commercialization proposal, or "the business case," for new-product development is generally easy to make when 1) the information problem to be solved arises in analogous form at dozens of different privately managed sites and 2) the cost of solving the information problem is a small fraction of the cost of the physical site work that must be done.

Where these conditions do not hold true, the case for commercialized products weakens, but interestingly enough, so does the case for using software tools in the first place.

Commercial incentives move both producers and users more quickly toward such goals as a) establishing workable standards, b) setting measurable performance benchmarks, c) customer satisfaction, d) maintenance, e) technology transfer to the next analogous problem sites, f) cost reduction over time, and g) introduction of innovation at appropriate times and settings. In contrast—and here is where the commercial advantages tend to accrue—the public-agency contract and grant mechanisms under which "public-domain" products are developed can create disincentives to achieving the same goals. The history of publicly developed Contract Lab Program data standards and related software products offers useful illustrations of the operation of public-development incentive systems, in contrast to private-sector developments in a commercial context.

In nearly every area of public- and private-information system work today, trends point toward decentralized, smaller-scale, private initiatives and away from centralized solutions, even where the centralized solution appears to be "free." Public development induces the developer to pay attention primarily to the needs of the public sponsor. In contrast, reliance on commercial incentives necessarily forces the developer to pay attention to the needs of the many "local" customers at sites, and to the technologies available to meet those needs at a finite price within a finite time.

Environmental Modeling Resources at the U.S. Environmental Protection Agency's Center for Exposure Assessment Modeling

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The Center for Exposure Assessment Modeling (CEAM) provides microcomputer-based software for modeling aquatic, terrestrial, and multimedia exposure pathways for organic chemicals and metals. CEAM models range from simple desktop techniques suitable for screening analysis, through computerized steady-state models, to sophisticated, state-of-the-art continuous simulation models. Currently distributed software includes simulation models and databases that can be applied to urban runoff, leaching and runoff from soils, conventional pollution of streams, toxic pollution of streams, toxic pollution of lakes and estuaries, conventional pollution of lakes and estuaries, tidal hydrodynamics, geochemical equilibrium, and aquatic food chain bioaccumulation. CEAM software is available through diskette exchange, an electronic bulletin board system, and over the Internet via anonymous file transfer protocol.

The Center for Subsurface Modeling Support (CSMoS)

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The Center for Subsurface Modeling Support (CSMoS) provides ground-water and vadose zone modeling software and services to public agencies and private companies throughout the nation. CSMoS is located in Ada, Oklahoma, at the Robert S. Kerr Environmental Research Laboratory (RSKERL), the U.S. Environmental Protection Agency's (EPA's) Center for Ground-Water Research.

The primary aims of CSMoS are to provide direct technical support to EPA and state decision-makers in subsurface model applications and to manage and support the ground-water models and databases resulting from the research at RSKERL. This research encompasses the transport and fate of contaminants in the subsurface, the development of methodologies for protection and restoration of ground-water quality, and the evaluation of subsurface remedial technologies. As a result, a major focus of CSMoS entails coordinating the use of models for risk assessment, site characterization, remedial activities, wellhead protection, and Geographic Information Systems (GIS) application. In these ways, CSMoS performs an active role in protecting, restoring, and preserving our nation's ground-water resources.

Modeling Services

CSMoS integrates numerous individuals and organizations with expertise in all aspects of the environmental field in its effort to apply models to better understand and resolve ground-water problems. Internally, CSMoS is supported by the scientists and engineers of RSKERL, whose specialties include hydrology, chemistry, soil science, biology, mathematics, and environmental engineering. This forms the nucleus of CSMoS. Externally, CSMoS is supported by technical support contractors and extramural experts. Through this network, CSMoS is able to interface with a wide variety of experts to provide the comprehensive modeling services required to resolve complex environmental problems.

CSMoS provides assistance in the following modeling areas:

- Conceptualization
- Model development
- Model verification
- Model validation

- Model application
- Model distribution
- Modeling training and education

Technical Assistance

CSMoS is an integral part of RSKERL's Technology Support Center. CSMoS distributes and services all models and databases developed by RSKERL and provides general support on model application to ground-water and vadose zone problems. Technical assistance activities include developing educational documents, providing training courses, and distributing update notices and other pertinent information for all software developed at RSKERL as well as software developed under laboratory grants and contracts.

CSMoS provides direct technical assistance for a broad spectrum of modeling applications. Models and/or databases are available to assist in the following areas:

- Site assessment
- Site characterization
- Soil remediation
- Ground-water remediation
- Treatability studies
- Remedial action management
- Ground-water resource development
- Wellhead protection
- Environmental planning
- Geostatistics
- Resource Conservation and Recovery Act (RCRA) corrective action
- Superfund activities

Strategic Use of Decision Support Tools Throughout the Remediation Process

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At most hazardous waste sites, site characterization results in the generation of a tremendous amount of data. The data can be thought to have a life cycle that begins when the need for a decision is established. Subsequently, a sampling plan and a health and safety plan are generated, data quality objectives are established, a sample tracking system is identified, samples are produced and analyzed, data are produced, data quality is determined, and data are entered into a data management system from which they are displayed and analyzed as appropriate to support a decision about remedial action at the site.

Frequently, data generation has occurred in cycles: an initial site assessment has been performed, followed by two, three, or even more phases of remedial investigation, producing staggering amounts of data in the process of reaching a decision about remedial action at the site. Decision tools have largely focused on the analysis of all of this data to reach the "ultimate" decision: the remedial action at the site.

While the remedy selection decision may receive the most attention, decisions are actually made throughout the cycles of data generation. Better decisions at every point in the cycle can greatly reduce the cost of the investigation and remediation process. Thus, opportunities to make beneficial use of decision support tools are present at every step of the site characterization and remediation process. The challenge is to recognize a decision as an opportunity to use a decision support tool, identify an appropriate tool(s), and apply the tool appropriately. Frequently, the limiting factor in the use of decision support tools is either a lack of awareness of the tools' existence or an inability to identify appropriate uses for the tools.

A model for identifying a decision as warranting use of a decision support tool, selecting an appropriate tool, and understanding the resources needed to properly use the tool is outlined in this paper. Examples of successful uses of decision support tools are included as support for the model.

Information Systems for Site Management: Current Use and Future Trends

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The concept of an integrated, computer-based model of a site has been developed to the point where project managers, engineers, scientists, and others involved with its cleanup can access all or part of the available data from an integrated set of applications. Currently, most systems are used primarily to manage project data and to perform technical analysis. Recently, there has been increased interest in using this information as part of the broader decision process. This interest is motivated by the desire to base decisions on the most comprehensive and accurate information available as well as the need to communicate information and decisions to the stakeholder community in a trusted manner. Increasingly, the accessibility of data requires the adoption of a variety of organizational standards. These include a) data-related standards that standardize database syntax and semantics, b) standard operating procedures that allow interoperability across management authorities, and c) system-related standards that facilitate, rather than exclude, interoperability between vendor-specific system components. This paper will use examples from existing sites to illustrate how systems are currently implemented and used. It also will discuss current efforts by government and industry consortia to develop and promote standards.

Application of a Ground-Water Monitoring Trigger for Underground Storage Tank Sites

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This paper describes the application of a user-friendly software tool to decide whether to sample ground water at underground storage tank (UST) sites. Development of the software was funded by the New Jersey Department of Environmental Protection and Energy (NJDEPE) Division of Research, and the software is designed for use by NJDEPE case managers.

The desire for a methodical, consistent approach to the treatment of UST sites served as the impetus for this project. In the past, the excavation of a UST typically has been accompanied by soil sampling in the immediate area of the tank. A decision to sample ground water has been made in an ad hoc manner, depending upon the magnitude of contamination detected (if any) in the soil samples and other factors such as depth to ground water and site cover. The goal of this research was to analyze and codify the procedures used by case managers in UST investigations.

The ground-water trigger (i.e., the decision to install a well and sample ground water) is based on a statistical analysis of cases taken from the files of NJDEPE's Bureau of Underground Storage Tanks. The files were used to evaluate the ability of variables such as soil concentration, depth to ground water, soil texture, and simple estimates of travel time to indicate exceedances of NJDEPE ground-water standards. Explanatory variables identified as good indicators were ranked and incorporated into the tiers of the trigger according to indicative ability and ease of characterization. By employing multiple tiers, the trigger enables the user to refine the decision to monitor ground water in response to site conditions and to make these decisions in a consistent manner.

A menu-driven spreadsheet interface has been created to make the trigger easy to use. The interface was written in the macro programming language of a commonly used spreadsheet program, Quattro Pro, and is intended to provide a comfortable and familiar user environment. The software prompts the user to input values of indicator variables required by each tier, advances the user through the tiers as necessary, and provides the user with the conclusions of the analysis.

Applications of the software are presented using input 1) obtained from NJDEPE case studies (i.e., the data used to develop the trigger) and 2) derived for hypothetical sites. The software is available for hands-on demonstration on a portable PC, and individuals are invited to test the algorithm by applying it to example cases of their choosing.

Software Products From the Environmental Monitoring Systems Laboratory*

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A number of software products for the personal computer have been produced at the U.S. Environmental Protection Agency (EPA)-Las Vegas in the areas of statistics, risk assessment, site characterization, and quality assurance. This software will be briefly described with more details being provided during the poster session. Problems in the production and distribution of this software will be highlighted, and future directions for the production of software at the Environmental Monitoring Systems Laboratory (EMSL)-Las Vegas will be described.

Increased emphasis will be devoted to the integration of software modules into more comprehensive software packages. EMSL-Las Vegas proposed a standard for the exchange of data between software modules. Other standards also have been proposed. Production and eventual acceptance of software products from EMSL-Las Vegas will be dependent on the ability of the software to interface easily with other software products and databases.

Production of sophisticated, environmental software has become increasingly difficult because of the need to draw upon greater numbers of people in university, private, and government sectors. Frequent changes in technical expertise, personnel, and contracting procedures can slow the long-term developmental efforts that are required to produce this software. The financial resources that are required to distribute and support the software can also be a limiting factor.

The successes and problems experienced at EMSL-Las Vegas in the development of software may serve as lessons to others in their production of software for environmental problems.

*The research described in this abstract has been funded by EPA through its Office of Research and Development (ORD). This abstract and the oral presentation it summarizes have not been subjected to ORD's peer and administrative review and do not necessarily reflect the views of EPA or ORD.

SmartRISK 1.0: Risk Assessment Software for Windows

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SmartRISK is a complete multichemical, multipathway human health risk assessment modeling package for Microsoft Windows. SmartRISK eliminates the time-consuming process of developing exposure models in spreadsheets for calculating risks. SmartRISK also provides tools for managing risk assessment information such as exposure factors, toxicity values, and references.

Exposure models are built by selecting media, chemicals, and exposure routes from easy to use pick lists. This information is used with exposure point concentrations and data in user-defined default databases, such as exposure factors, to evaluate exposure and calculate risk. Exposure point concentrations can be hand entered or imported from a variety of file formats. Users can change, update, or customize any of the information in the default media, chemicals, exposure routes, exposure factors, toxicity values, and physical constants databases. Four different exposure scenarios can be evaluated at one time for reasonable maximum exposed (RME) and alternate exposed populations. The results of a risk assessment can be evaluated using interactive tools to ask "what if" questions to determine the media, exposure routes, and chemicals that are responsible for the majority of the risks. Noncarcinogenic risks can be summed by toxic endpoint. Users can select from 25 standard documentation reports to print out assumptions and the results of the assessment, or they can create their own custom documentation reports using the integrated report writer. Data can also be exported to a variety of file formats for analysis and presentation using numerous applications. Planned upgrades include Monte Carlo Simulation, Geographic Information System (GIS) compatibility, and a Cleanup Level Calculator.

Risk-On-Site: A Tool for Characterizing Site Contamination

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Risk-On-Site is a software tool designed to evaluate the pattern and magnitude of contamination at hazardous waste disposal sites. The program provides four features that aid in site characterization. First, Risk-On-Site constructs false-color contamination maps from on-site sampling data (pollutant concentrations and geographic coordinates). Maps are defined using a nearest neighbor principle.[1] A two-dimensional area is divided into a series of polygons (one for each sample). The shape and size of each polygon is determined by the relative locations of sampling points and site boundaries, such that each polygon represents the portion of the site closest to the measurement it circumscribes. For a given configuration of sampling points, a contamination map is both unique and intuitive. Only one map can be drawn for a given pattern of sampling locations, and the closest neighbor approach is easily grasped.

Risk-On-Site's topological algorithms are implemented in an efficient, automatic, and reproducible manner. On a 50 MHz 80486DX platform, the algorithms process a site with more than 800 sampling points in less than 10 seconds.

Risk-On-Site maps facilitate efforts to characterize contamination by providing a visual display of measurements that illustrates the extent and pattern of contamination, hot spots, and undersampled areas that may warrant additional investigation. "What if" scenarios are easily investigated; for example, the consequences of adding sampling points into existing diagrams can be evaluated within seconds.

Estimation of exposure point concentrations is the second feature provided by Risk-On-Site. Area-weighted concentrations are easily calculated using measurements and their associated areas, as defined by the contamination map. Area-weighted averages provide an objective comparison to other statistical measures such as arithmetic averages and associated parameters, such as upper 95th percentile confidence limits of arithmetic means, which are recommended in Superfund risk assessment guidance. In cases where exposure is equally probable across a site, an area-weighted average is arguably the best estimate of the exposure point concentration. The nearest neighbor approach embodied by Risk-On-Site provides an objective estimate of area-weighted averages that—unlike methods such as interpolation, kriging, and other statistical techniques—requires no application of professional judgment regarding underlying data distributions and parameters.

Risk-On-Site's third advantage is its rapid ability to evaluate the consequences of remedial action alternatives. For a given contamination map, target cleanup levels are easily

[1]Delaunay/Voronoi diagrams and Thiessen polygons use this technique.

investigated by substituting remediated levels at sampling points at which concentrations exceed the target criterion. For a given target cleanup level, Risk-On-Site 1) updates the contamination map by highlighting the areas to be remediated, and 2) estimates the postremediation area-weighted average concentration and total area of remediation.

Finally, additional capabilities of Risk-On-Site encompass the elements needed for exposure and risk assessment. The modular style used to program Risk-On-Site facilitates interfacing with additional models. In a Risk-On-Site application at a complex, multiuse site,[2] fate and transport algorithms have been used to estimate exposure point concentrations in environmental media in which measurements were unavailable (e.g., pollutant concentrations in air due to evaporation from surface water or ground water). Receptor networks were constructed to superimpose on contamination maps, and exposure scenarios were used to describe the rate and frequency of human contact with site-related contamination. The exposure estimates provided by the integration of this information were combined with dose-response data to generate geographic distributions of risk estimates.

A demonstration disk of Risk-On-Site's capabilities is available upon request. The demonstration runs on a DOS-based PC. A color monitor is preferable to display the graphic portions of the demonstration.

[2]The site encompasses 90 acres, and is to be redeveloped for mixed industrial, commercial, and residential land usage. A copy of the risk assessment of this site, in which Risk-On-Site was extensively applied, will be provided upon request.

THERdbASE: A Modeling and Database System for Making Total Human Exposure Assessments

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THERdbASE is being developed as a PC-based computer modeling and database system that contains exposure-related information. The system provides an optimal framework for the construction of a suite of exposure-related models within the Modeling Engine by using information available in data files within the Database Engine. It will be possible to use information available in THERdbASE to determine *total* (multiple pollutants present in multiple media and crossing the human envelope through multiple pathways) human exposure estimates. Scientists and engineers will be able to use THERdbASE to make better exposure assessments for various population(s) of interest and determine contributions of different variables to total exposure.

The state-of-the-art models and submodels within THERdbASE are being organized into the following categories:

- Human population distributions
- Human location/activity patterns
- Human food consumption patterns
- Pollutant releases from sources
- Microenvironmental pollutant concentrations (microscale)
- Ambient pollutant concentrations (macroscale)
- Exposure patterns

The submodels belonging to these categories are being integrated to obtain estimates of *total* human exposure.

Data input to models is achieved through a standardized procedure. Input can be provided as single values, custom distributions (normal, lognormal, beta, gamma, etc.), distributions based on data files present in THERdbASE, or specific percentile values. When distributions

based on data files are required as inputs, only the appropriate THERdbASE data files are provided as choices. Model execution is based on the mathematics behind the model itself. Efficient algorithms are provided to access optimally input data and generate appropriate output data. Multiple runs of a model can be executed through a batch process. Data output from models is done in the following two ways: 1) as THERdbASE data files or 2) as preset graphs. Any THERdbASE data analysis feature can be performed on the data files. The preset graphs allow viewing of model results immediately after execution. Provision has been made to save output data for multiple executions of the same model.

The data files within THERdbASE are being organized into the following nine categories:

- Human population distributions
- Human location/activity patterns
- Human food consumption patterns
- Pollutant properties
- Pollutant sources (+ use patterns)
- Environmental characterizations
- Environmental pollutant concentrations
- Food contamination
- Human physiological parameters

Contents of data files can be viewed in tabular form (records and fields/rows and columns). Data files are mostly organized by codes. The built-in relational structure allows users to switch between coded and decoded information with the click of a button. While viewing, columns of data can be set either to "show" or to "hide" mode. Multiple data files can be viewed at the same time. While viewing contents of a data file, users can access records based on simple queries (filters) on field values. Queries can be performed on both coded and uncoded information. While viewing contents of a data file, users can perform simple statistics on appropriate data fields. Only those fields relevant to statistics are highlighted. Given a numerical data field, the following can be determined: a) summary statistics (mean, standard deviation, minimum, and maximum), b) percentile values at desired intervals, and c) distribution parameters. Given two numerical data fields, a correlation analysis can be done. For text data fields, statistics will produce occurrence frequencies. "Smart" graphs allow viewing model output results in pregraphed formats. Through the print function, the following can be output to any printer: a) contents of a data file, b) query results, c) statistics results, and d) graphs. Subsets of data files can be saved while viewing. Entire data files or subsets thereof can be exported out of THERdbASE to standard formats (e.g., ASCII, dbf). Those data files, external to THERdbASE, existing in most popular formats and conforming to the structure of existing THERdbASE data files can be imported into THERdbASE.

Development of RESRAD and Other Environmental Pathway and Health Risk Models at Argonne National Laboratory

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Several multimedia environmental pathway computer models have been, or are in the process of being, developed at Argonne National Laboratory (ANL). These models are centered on the existing RESRAD code, although each has a separate computer package design and serves different objectives.

RESRAD has been developed to implement the U.S. Department of Energy's (DOE's) residual radioactive materials guidelines for contaminated soils (DOE Order 5400.5). It is currently a participating code in the international verification and validation (BIOMOVS) effort. The code has been used widely by DOE and its contractors, and to a certain extent outside of DOE. To date, some 30 RESRAD workshops have been conducted by ANL. Several major DOE programs have successfully utilized the code in assessing human health risks and developing site cleanup criteria.

Several pathways can be analyzed by RESRAD: direct external exposure; inhalation of particulates and radon progeny; and ingestion of foodstuffs (plants and animals), water, and soil. All of these pathways are modeled in relationship to the contaminated area(s). As such, the code has been equipped with modeling of above-surface (air, surface water, vegetation, etc.) as well as subsurface (ground water) transport mechanisms. The code calculates human health risk as the endpoint for each individual pathway and for all pathways aggregated, and computes allowable soil contaminant concentrations. Analysis is performed in a time-dependent fashion (up to 10,000 years).

Over the years, RESRAD has undergone major improvements in terms of both added modeling capability and input database. The latest updates have been described in the RESRAD Manual, Version 5.0 (ANL/EAD/LD-2, September 1993). The following have been accomplished:

- Information regarding input parameters has been published in the *Data Collection Handbook.*
- Sensitivity analytical capability now enables users to identify key input parameters and set priorities for data collection efforts.
- Models for special nuclides (tritium and C-14) have been added.
- The menu system is improved and more user-friendly.

Plans for improving RESRAD in the future include developing the capabilities for benchmarking and performing uncertainty analysis, among other things.

RESRAD-CHEM analyzes hazardous chemicals. The design of RESRAD-CHEM is parallel to that of RESRAD, except for the addition of chemical properties and their related human toxicity data. Chemical health risk (slope) factors (for cancer incidence) are taken from the U.S. Environmental Protection Agency's (EPA's) IRIS and HEAST databases. Another major design difference lies in the environmental pathways included. For instance, the external exposure pathway is absent in RESRAD-CHEM, while the dermal absorption pathway is unimportant in RESRAD (for radionuclides other than tritium). A draft version of RESRAD-CHEM has been completed and has undergone DOE review.

RESRAD-BUILD analyzes human health risks from contaminants during building dismantling (for workers) and occupancy (for the general public) through decommissioning or rehabilitation. The RESRAD-BUILD code is based on a room compartmental model that analyzes the effects on room air quality of contaminant emission and resuspension (as well as radon emanation), the external radiation pathway, and other pathways such as air immersion and indirect ingestion. Because of the proximity of human-to-contaminant contact during building decommissioning or dismantling, RESRAD-BUILD requires more precise pathway modeling and input data than does RESRAD. For instance, a detailed description of contaminant distribution is needed to better define the source-to-receptor configuration. The same applies to the room air quality. RESRAD-BUILD is currently completed as draft and has undergone DOE review. The code has been used successfully in a separate DOE effort to assess potential release standards by calculating human health risks from radioactive scrap metal recycle and reuse.

RESRAD-BASELINE and RESRAD-PROBABLISTIC are separate models currently under development. RESRAD-BASELINE is a convenient tool designed to implement EPA's guidance on human health risk assessment. RESRAD-PROBABLISTIC is intended to perform uncertainty analysis for RESRAD using the Monte Carlo approach based on the Latin-Hypercube sampling scheme.

In summary, a RESRAD code series is under development at ANL. These codes are designed to perform human health risk analyses based on multimedia environmental pathway models. Each code is tailored to meet a specific objective of human health risk assessment, which requires specific parameter definition and data gathering. The combined capabilities of these codes serve to satisfy various risk assessment requirements in environmental restoration and remediation activities.

ProTech: The Prospective Technology Communication System

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ProTech, the Prospective Technology Communication System, describes innovative environmental cleanup technologies to a wide audience. The technologies described are funded through the U.S. Department of Energy's (DOE's) Office of Technology Development (OTD). The primary audience for ProTech is individuals and/or groups who are interested in or feel they have a stake in waste management activities at each Integrated Demonstration (ID) site. These stakeholders include the interested public, regulators, Native Americans, and technology users. ProTech's objective is to provide three main benefits. First, ProTech functions as a communication tool which can greatly enhance ID and Integrated Program (IP) public-involvement activities. Second, ProTech describes innovative technologies to varied stakeholders with the intent of soliciting input on technology acceptance. Finally, ProTech increases national exposure for technologies and enhances technology transfer activities. ProTech's secondary objectives include providing management support to Integrated Demonstration Coordinators (IDCs) and OTD personnel and increasing communication between people involved in technology development activities throughout the DOE complex. A demonstration of ProTech and its capabilities will be provided.

ProTech was developed in 1992, as a communication tool to describe innovative technologies being demonstrated at DOE sites. The intended audience for ProTech is stakeholders interested in or concerned about OTD's activities. Currently, ProTech focuses on IDs being conducted across the DOE complex. ProTech includes site maps, summary fact sheets, technology profiles, and technology diagrams. A prototype version of ProTech has been developed for the Volatile Organic Compound (VOC)-Arid Site ID. Customized applications of ProTech were available in January 1994. These versions describe technologies supporting the following:

- VOCs at Arid Sites ID
- Underground Storage Tank ID
- Mixed Waste Landfill ID
- VOCs at Non-Arid Sites
- Uranium in Soils ID
- Buried Waste ID

As public-involvement activities were developed for the VOC-Arid ID, it was clear that the traditional sources of information for stakeholders were Technical Test Plans (TTPs), technical reports, and presentations. These sources, however, were often unavailable, difficult to understand because they were too technically written, or incomplete because the information wanted was not available or the uncertainties about the information were too great. It became clear that no tool provided information on these technologies in one place and in an understandable format, and that a new approach to disseminating information about new technologies was needed.

ProTech was initially conceived as a tool to assist in stakeholder involvement activities and to thereby evaluate and enhance public, regulator, and technology user acceptance of VOC-Arid ID technologies. The tool was expected to 1) describe to stakeholders what they wanted to know about the technologies in a form they could understand and 2) describe how technologies relate to one another.

ProTech filled an identified consumer need for data to make informed decisions about new technologies. The development requirements were to create a tool that was appropriate for meeting that consumer need; therefore, ProTech's design is user friendly, based on existing hardware and software, understandable, and low cost.

ProTech allows users to learn about innovative technologies by displaying fact sheets and comparing innovative cleanup technologies to established baseline technologies or to other innovative technologies. The fact sheets include a text description (the need, process, advantages, and challenges) and a diagram of each technology. They are simple and can be used in a number of ways, such as press releases. For example, the fact sheet on a drilling technology called cone penetrometer appeared in "Tech Trends." The fact sheet on Hybrid Plasma Technology, developed by the Massachusetts Institute of Technology, was used by the Boston Globe in a news article.

The technology comparison feature allows the user to compare technologies based on criteria of interest in five categories: effectiveness, environmental safety and health, sociopolitical interests, and regulatory objectives. ProTech then looks up the two technologies (two innovative or one innovative and one baseline), retrieves data on the selected criteria for both technologies, and summarizes the results in a comparison chart. Technology information for both the fact sheets and the comparisons comes from a ProTech technology profile, a detailed form based on interests and concerns identified in over 40 stakeholder interviews and two workshops.

The comparison capability is an important function of ProTech in that it allows the user to compare apples to apples to understand the advantages and, in some cases, the limitations of the innovative technologies in comparison to the baselines or other innovative technologies. This comparison feature has been found to be important to industry. Each application of ProTech also allows users to get an overview of the problem addressed by and the technologies supporting the ID. A series of site maps is also provided for each of the six ID sites; the maps progress from a map of the United States to a cross-sectional view of the site and the problem that the ID addresses. ProTech also furnishes contact names for those who require further information.

To gain access to the ProTech technology profiles you can call the file transfer protocol server address at 131.167.239.40.

Remedial Action Cost Engineering and Requirements (RACER) System

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The U.S. Air Force (USAF) has established an ambitious goal of cleaning up all of its known hazardous waste sites by the year 2000. This goal, combined with increasing pressure to conclude studies and perform remediation activities sooner, prompted the USAF to look for better and more efficient ways to do its work. RACER was developed to assist the USAF in meeting these objectives by providing automated tools and data to characterize sites, consider alternative remediation approaches, document the decision process, accurately predict the costs of remediation, and manage those costs throughout the design process. RACER is a knowledge-based system designed to aid in selecting appropriate remediation approaches, estimating the cost of alternative remediation technologies, and preparing remedial investigation/feasibility study (RI/FS) documentation. RACER includes two major components: 1) the Remedial Action Assessment System (RAAS), an integrated object-oriented expert system used to select remediation approaches, and 2) the Environmental Cost Engineering System (ENVEST), a parametric cost model used to estimate the cost of all phases of the remediation process.

RAAS, which is being developed by Battelle Pacific Northwest Laboratories for the U.S. Department of Energy, will be used to select remediation technology trains. It includes descriptions and performance data for approximately 100 different remediation technologies and 200 different contaminants. Other criteria for selection include laws, regulations, and site applicability.

ENVEST, which is being developed by Delta Research Corporation, Niceville, Florida, for the USAF, will be used to estimate the total cost of remediation approaches, including RI/FS or RFI/CMS, remedial design, remedial action, and postremediation operations and maintenance modules. The system uses a hierarchical structure: parameters, system, subsystem, assembly category, and assembly and line items.

The EnviroText Retrieval System

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EnviroText, a full-text retrieval knowledge base, is being developed by the U.S. Environmental Protection Agency with matching funds and data from the Departments of the Army, Defense, Energy, Interior/Bureau of Mines, and Justice. In August 1993, users in the sponsor agencies began a one-year pilot test of the system, while the U.S. Army Construction Engineering Research Laboratories (CERL) completes the data acquisition, software development, and establishment of the EnviroText Support Center at the University of Illinois. Resident on the UNIX mainframe of the University, EnviroText will be opened to the public in early 1995 as a not-for-profit national resource.

This shared federal/state system provides a one-stop library for government staffs, environmental justice proponents, citizen groups, site managers, project reviewers, environmental media specialists, planners, researchers, and lawyers. Topics include ecosystem protection, natural resource trusteeship, pollution prevention, site restoration, occupational safety and health protection, Resource Conservation and Recovery Act (RCRA) compliance, and identification of potential federal and state Applicable or Relevant and Appropriate Requirements (ARARs) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Environmental data sets will include U.S. and state laws and regulations (full texts and abstracts), U.S. Executive orders, U.S. Indian policies and Indian tribal codes, international treaties and agreements, pending Congressional legislation, Federal Register, and policies of federal agencies.

Designed to provide easy public access to environmental requirements, EnviroText—even in its pilot phase—promotes interagency and intergovernmental cooperation, as well as faster, more thorough research and economical use of public funds for information collection and distribution. To realize the advantages of this system, the Superfund Program is currently providing training to regional staff in the use of EnviroText as a means of saving research and decision-making time in the CERCLA remedy selection process.

Quality Assurance Issues and Suggestions for Environmental Software Development*

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Environmental software has been under development for some time. Some software has proven to be quite useful, but a variety of issues impede greater acceptance of the software. The first problem is knowing what software is available, and the second problem is determining if the software is adequate and acceptable for solving an environmental problem. Distribution of software has been mixed with private and public domain software being distributed through a variety of channels. Major considerations in using a software product are whether the software is current, easy to use, and produces quality results.

One area in which quality software can be ensured is through a rigorous quality assurance/quality control (QA/QC) program. Periodic testing of code to ensure that algorithms have been properly captured, recording changes in code, updating documentation, and beta testing of code before it is widely released are some of the traditional ways to enhance the quality of software. Unfortunately, as software becomes more complex, the resources required to ensure quality code become larger. Developers of environmental software have an especially difficult task in ensuring quality code because of the complexity of the problems the code is trying to address.

A significant problem in environmental software is whether the models and algorithms are correctly chosen and applied to the problem. A wide variety of potential users exist as well as a wide variety of potential applications of the software. Precautions must be taken to ensure that the environmental software is appropriately applied to the problem at hand.

Finally, there is the problem of inputting and outputting data. A large variety of interrelated software is being developed by a number of parties; unfortunately, few widely accepted data exchange standards exist to allow data to be easily interchanged. In addition, standard definitions for data are usually weak, and ancillary data required to accompany critical data in an environmental program are often poorly handled or neglected.

Suggestions are provided on steps that can be taken to promote the development and use of environmental software.

*The research described in this abstract has been funded by the U.S. Environmental Protection Agency (EPA) through its Office of Research and Development (ORD). This abstract and the oral presentations it summarizes have not been subjected to ORD's peer and administrative review and do not necessarily reflect the views of EPA or ORD.

Software Development Process: The Key to Success

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The keys to a successful software development process are 1) an open approach that includes the customer as an important member of the team and gives the customer access to all aspects of the development process; 2) a team approach that includes the customer, the conceptual or methodology developers (if different than the customer), and the software developers, testers, and document writers; and 3) a control system consisting of two parts: a) a tracking system (preferably electronic) and b) a control board composed of the development team including, and in many cases led by, the customer.

The control system maintains consistency and control over all aspects of the software development cycle. Once documentation and/or software has been accepted as the standard and has been entered into the control system, they can only be changed with a change request (also entered into the system). These change requests' status and resolution are maintained in the control system and can be accessed for review at any time.

The process above only works if: 1) quality and product excellence is assumed to be the responsibility of each and every member of the team and begins on Day 1 of the project (quality is considered intrinsic to every step in the process, not an external exercise); 2) each member of the team respects each other and allows the experts in any one aspect to assume leadership when discussions or actions are required in that area; 3) each member of the team, including the customer, agrees to be actively involved in all steps of the process; 4) all members review the documentation and come to an agreement on the version to be considered the standard; 5) all members enter into the electronic control system all changes necessary to make the product successful and correct; 6) all members, including the customer, log onto the control system to view and test the software as each new version is finished, and each person who tests the system follows through by entering all changes or problems into the electronic control system; and 7) all members of the team feel that the final product is a reflection on their professionalism, and so insist on excellence from themselves and each other.

Getting the Right Answer

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The most effective decision support tools (DSTs) enable science to deliver the best available answers, at any given time, to managers, policy makers, and the general public. DSTs must perform two major functions: first, they must demonstrably increase the productivity of practicing scientists and aid in the decision-making process; and second, they must convey highly technical results, accurately and in context, to technical nonexperts. These are especially critical functions in Superfund/Resource Conservation and Recovery Act (RCRA) actions, where advanced fate and transport models and site-specific hydrogeologic characterizations are at the heart of evaluations for controlling and remediating toxic materials in the environment, reducing risks, minimizing the economic and social consequences of toxic materials, and maximizing the effectiveness of public policy.

Successful development and use of DSTs face a basic dilemma, arising when physics models, which were originally built as science tools by specialists, often wary of misapplications, become the engines of DSTs that will be used by technical nonexperts, who simply want to get the right answer. On the one hand, DSTs should represent the best available science, which is fundamentally uncertain and constantly advancing. On the other hand, firm answers are needed with little uncertainty. Pragmatic environmental predictions must be made prior to knowing final outcomes while recognizing intrinsic physical and representative uncertainties.

The key to resolving this dilemma is in asking the right questions with appropriate technical expectations. I will draw from successful historical paradigms that have resolved some of these complex dilemmas now faced in applying DSTs to RCRA actions.

The Defense Environmental Corporate Information Management (DECIM) Program: Software Development and Data Standardization

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The U.S. Departments of Defense (DOD) Corporate Information Management (CIM) initiative intends to adopt standard business practices and standard information systems throughout DOD. The CIM initiative is DOD's version of "reinventing government." One CIM goal is to reduce costs by eliminating the development, operation, and maintenance of redundant information systems. The DECIM program is the environmental component of the CIM initiative.

The general DECIM strategy is to select and deploy "migration" systems, i.e., existing information systems that may be "reengineered" to meet initial requirements and will then evolve to support improved business practices as they are implemented.

Migration systems are selected through a process that includes group sessions where subject matter experts (SME) representing DOD components use an electronic meeting system (EMS) environment to examine business practices and information needs. These sessions lead to the development of activity models and data models corresponding to current requirements. Similar sessions identify system selection criteria and evaluate candidate systems. The functionally acceptable candidate systems are then evaluated for technical merit, and a selection recommendation follows.

Migration systems will be used primarily by environmental coordinators at DOD installations. Initially, systems must be targeted to the host platform commonly available to this user community, i.e., a 386-based machine running DOS. Data transfer will occur either electronically via file transfers or by mailing floppy disks.

Ultimately, the intent is to provide the necessary information infrastructure, such that all users have high-speed access to common database servers and data sharing can occur via client-server applications. It is envisioned that Geographic Information Systems (GIS) will play a large role in the future infrastructure.

DECIM has adopted software development practices that comply with DOD mandates and satisfy pragmatic requirements. Four development centers collaborate, adhere to common practices, and use common tool sets. Data models are developed, object-based design methods are used, and Ada is the standard programming language. AdaSage is currently the

standard tool set. Each center has recently acquired a Rational software engineering environment.

Data standardization is a primary goal for DECIM. Logical data models are produced early in the analysis process for each business activity. These models will be integrated and conflicts and inconsistencies resolved. A comprehensive standard DECIM data dictionary is a goal. The integrated DECIM data model and data dictionary will ultimately become part of the global CIM data model and data dictionary.

Decision Support System for Evaluating Remediation Performance With Interactive Pump-and-Treat Simulator

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Over the past decade, numerous Superfund sites have implemented pump-and-treat systems in an effort to remediate contaminated ground water. In 1989, the U.S. Environmental Protection Agency conducted a detailed evaluation of ground-water extraction systems at 112 sites and determined that the ground-water extraction systems were generally effective in maintaining hydraulic containment of contaminant plumes, thus preventing further migration of contaminants. Significant removal of contaminant mass from the subsurface is often achieved by ground-water extraction systems. When site conditions are favorable and the extraction system is properly designed and operated, it may be possible to remediate the aquifer to health-based levels. Contaminant concentrations usually decrease most rapidly soon after the initiation of extraction. After this initial reduction, the concentrations often tend to level off, and progress toward complete aquifer restoration is usually slower than expected or impossible to achieve. Data collection, both prior to system design and during operation, was frequently insufficient to fully assess contaminant movement and response of the ground-water system to extraction.

A graphical decision support system (DSS) is being developed that would be used for evaluating extraction networks at contaminated sites. The Pump-and-Treat DSS (P&T DSS) design includes three components: 1) a Global module, 2) a Site-Specific module, and 3) an Interactive Simulator module. The Global module is aimed at familiarizing the user with remediation technologies that can be used for cleanup of soils and ground water contaminated with petroleum hydrocarbons or solvent mixtures. The Site-Specific module develops a case study of evaluating a pump-and-treat system using data from the U.S. Air Force Plant 44 site in Tucson, Arizona. Finally, the Interactive Simulator module is a graphical modeling interface that allows the user to design a pump-and-treat system for a given site. The interface is built around the BIOPLUME II model.

Sandia's Environmental Decision Support System (SEDSS): A Tool To Guide Site Characterization, Risk Assessment, and Remedial Design Selection

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SEDSS is a process and supporting computer system designed to use probabilistic modeling and measures of risk to guide decisions related to site safety, remediation selection, and closure. This approach explicitly captures the inherent uncertainties associated with irregular physical/chemical systems, sources, transport pathways, exposure, and consequences so that these uncertainties can be factored into site-specific decisions. In addition, SEDSS provides a direct link between data analysis (risk assessment, etc.) and new data collection by guiding/optimizing new site characterization and site monitoring activities based on estimates of risk and cost. Potentially, this methodology can be applied to any environmental pathway, both radionuclide and hazardous contaminants, and works with any type of detection or site characterization tool.

The automated system is designed to provide a user-friendly computer-based system where the user works through a Graphical User Interface (GUI) to select the type of problem that is to be solved (Application). This in turn allows the user access to data in databases and Geographical Information Systems (GIS) and to probabilistic modeling tools, specific to site conditions, from an extensive toolbox.

For any of the system. applications, there is a set framework for solving the problem. This framework consists of several steps that are arranged to allow the user to iterate between analysis and data collection to solve the questions listed above. As shown in Figure 1, the automated system (following this framework) queries the user on the exact objective of the analysis to formulate a set of numerical performance measures for the site (1); provides access to data stored in a Geographic Information System or database (2); queries the user in a consistent manner to develop a comprehensive description of the user's understanding of site conditions, establishes probabilistic models to simulate the user-defined system, and accepts uncertainty in input parameters (3); performs the uncertainty analysis (4); and compares the analysis directly to the original performance measures for the user to then make a decision (5). If the user is faced with inadequate information to make a decision, sensitivity analysis (6), data worth, and cost/benefit functions (7) provide a comparison of the value of additional data versus their cost, and the user can decide to collect additional data or move to a new phase of action (8). New data would be collected and entered into the data management system (9), thereby completing the process.

The only baseline to which we can compare SEDSS is the subjective decision-making process that is currently being used at most sites. If the individual decision-maker was queried, you will find that they usually follow a process that either explicitly or implicitly covers most of

explicitly documented, the decision process becomes highly inconsistent, and in most cases extremely inefficient. Furthermore, subjective decision-making is usually full of qualitative assessments. SEDSS provides a consistent, explicit approach to defining and solving problems related to risk assessment, site characterization, remediation selection, and monitoring. It also speeds up the process by providing automated tools to facilitate the decision-maker's job.

SEDSS is being developed in stages. The first release will be a beta version which will be tested in fiscal year 1995. This version will contain applications to perform risk assessment for both radionuclides and hazardous constituents through the ground-water pathway.

SEDSS is funded in part by the U.S. Environmental Protection Agency (EPA) Office of Emergency and Remedial Response (Superfund) headquarters, EPA Radiation and Indoor Air, the Nuclear Regulatory Commission (NRC) Office of Research for Low-Level Waste, the U.S. Department of Energy (DOE) Mixed Waste Landfill Integrated Demonstration, DOE Uranium Mill Tailings Remedial Action Program, and DOE Environmental Restoration Albuquerque Project Office.

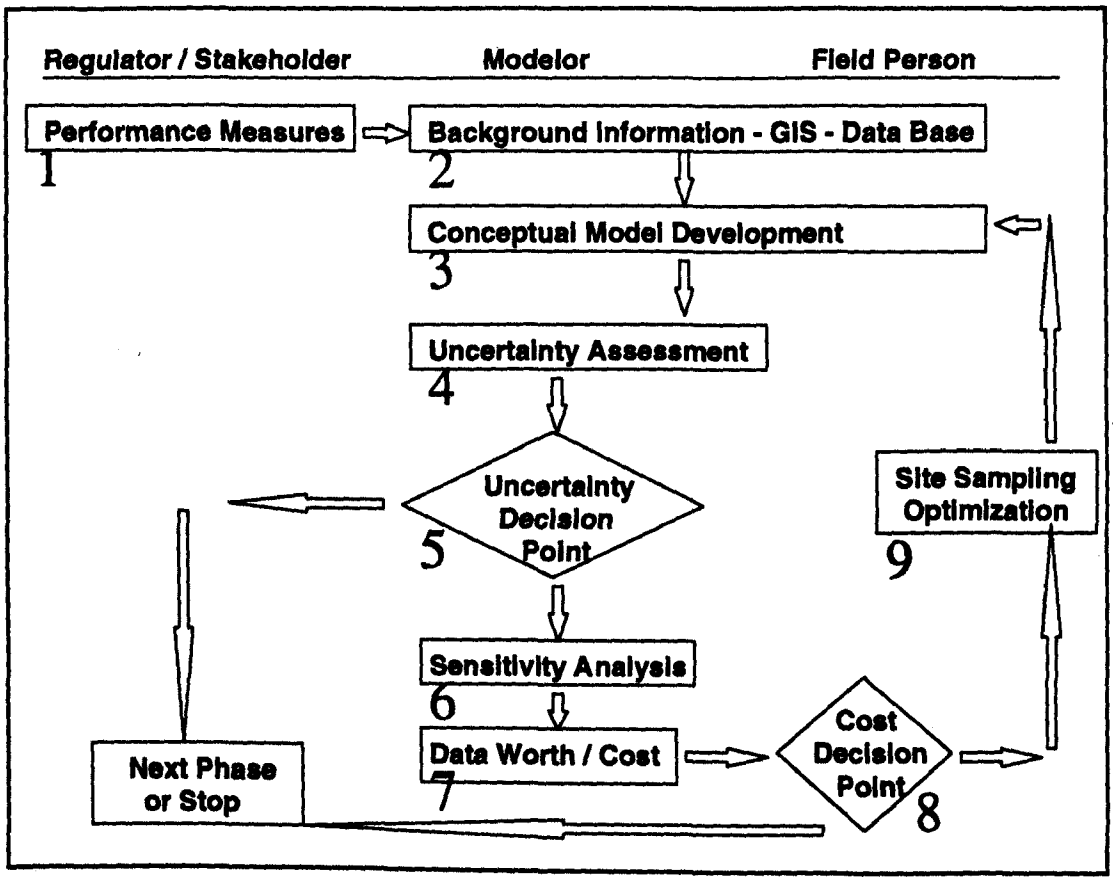

Figure 1.

DuPont's CD/ROM Decision Support System: HEART

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DuPont expends approximately $10 million annually on remediation technology development and many times that amount on cleanup operations. Technology development includes researching, developing, external networking, gathering, evaluating, interpreting, ranking, and disseminating. Faced with an "information glut," DuPont has developed a CD/ROM-based technology transfer and decision support system.

Philosophy: DuPont finds that information is most useful when it is the right information, delivered to the right place, at the right time, in a form that can easily be used. Information should be organized into multiple tiers, beginning with the simplest, most friendly tier, and progressing stagewise toward the most complex. Information may start out as data; as it is manipulated, it progresses through the stages of knowledge, know-how, and finally wisdom. As information progresses through these stages, the volume which must be communicated decreases, and the usefulness increases. The advent of personal computers and optical storage devices have made it possible to follow these rules.

Written entirely in Turbo Pascal for the DOS environment, DuPont's system consists of separate "objects" for displaying text, graphics, and multipage scanned and compound documents. Information elements are linked in hypertext fashion for developing decision trees and matrices. Smooth transitions between text and graphics are provided. The system includes internally generated guidance, U.S. Environmental Protection Agency (EPA) and U.S. Department of Defense (DOD) guidance, scanned technical articles, vendor brochures, photographs of equipment, and special decision support matrices and questionnaires.

EPA might consider CD/ROM as a means of disseminating remediation guidance and support tools. Numbers of important documents could be grouped on a CD/ROM, linked in a logical, tiered fashion through decision trees and matrices. EPA could say, "On this single CD are all the decision support tools for _____. The tools are backed up by the entire body of important information we are aware of on the subject, as of _____. If you have this CD, you have all that we have!"

Introduction to the Internet: Environmental Resources

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Internet History and Tools

The Internet started in the 1970s with the Advanced Research Projects Agency (ARPA) and has grown to be a global network with millions of users. Except for the very recent phenomenon of America On-line, it is the fastest growing network of users, and has the largest number of users (17 million as of 1993) of any collection, including CompuServe. It is unique in that there exists no one governing body, but a collection of people interested in its continuance. It connects a number of different networks and has a variety of protocols.

There are a number of different things that the user can do on the internet. All of these are driven by the protocols that are collectively agreed upon using the Request for Comment (RFC) approach. The earliest protocol was telnet, wherein the user's computer connects with another computer and operates the other computer from his or her "terminal." The following list is some of the standard protocols that exist on the Internet:

- telnet — connect to a remote computer
- ftp — file transfer protocol for moving files between computers
- smtp — simple mail transport protocol for E-mail
- pop — post office protocol for handling mail on a server
- slip — serial line interface protocol for dialing into the Internet
- ppp — point to point protocol—similar to slip, only better

The other protocols are not listed as they are not commonly used, at least as far as the user sees. There are a number of different services that the Internet provides, based in part on the protocols listed above. These are:

- E-mail — electronic mail to anyplace
- finger — locate a user on a computer
- phone — locate a user in a "phone directory"
- gopher — information front end that relies on intelligent ftp clients

- mosaic — graphical information front end to world-wide web (WWW) servers
- wais — wide area information server—finds information based on phrases
- news — news posting on a variety of topics
- lists — information servers based on lists of users—sent via E-mail
- archie — search Internet sites for software

Connection to the Internet

There are a number of different ways to connect to the Internet. If the user's organization is connected, he or she should find it relatively easy to obtain access at a personal computer. If the user's organization is not connected and does not plan to in the near future, he or she will have to go with a personal connection provided by dial-up services. These range from "shell" accounts to slip and ppp services. Only through the use of slip or ppp will the user obtain the full connection capabilities of the Internet.

Guides to the Internet

There has been an explosion of books on the Internet in the past couple of years. These books often contain software for connection as well as many of the tools to get started. Some even contain offers from service providers to try out the Internet. Service providers have also grown in the past couple of years, and it is now hard to find a current listing as new areas are constantly being added by new and established providers.

Serving the Internet

If the user has a direct connection to the network, he or she can become one of the information providers—if not for the world, then for his or her own work group. These servers now run on desktop computers rather than on large mainframe computers, and many are free or relatively cheap to set up and administer. The cost, except for the Internet access, is minor and maintenance is easy.

WWW servers are very popular but require some work to establish; ftp sites are easier to run; and gopher servers fall between ftp and WWW servers in complexity. E-mail via pop servers is easy to administer. WAIS servers have not made the transition to desktop yet; but it will only be a matter of time.

Guidelines for serving the Internet will be discussed as well as recommendations for servers and clients. There will also be a general discussion of what the Internet does and does not provide.

Waste Management and Technologies Analytical Database System (WMTADS)

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Los Alamos National Laboratory, with U.S. Department of Energy (DOE) support, has been developing analytical tools for waste management and treatment. These tools have been directed toward the waste that DOE has generated and continues to generate. They center around the technologies and their selection to treat waste and have been applied to the Site Treatment Plans and to the Environmental Impact Statement (EIS), both of which are ongoing projects within the DOE complex.

We have collected a large number of different technology descriptions from industry, DOE, and the U.S. Environmental Protection Agency's databases of treatment technologies. We have reviewed these technologies and tagged them appropriately so that any given technology can be evaluated for a specific problem. We are in the process of further refining these tags to better match the technologies to wastes.

We have also implemented tools for analyzing wastes and the treatment systems necessary (type and size) to handle the wastes. These tools have been applied to the EIS work to generate waste volume loads for treatment modules in the various schemes proposed by DOE.

Finally, we are developing tools that combine both the technology selection and the treatment system analysis to help in the design of a treatment system appropriate for the problems. These tools will offer alternatives for treatment systems and provide cost information for these treatment systems. The goals of this effort are to provide a rapid way for managers to analyze various options available to handle waste problems and to aid in providing alternatives that are feasible, while helping to reject those that will not work well for a given situation.

Access to the U.S Environmental Protection Agency's High Performance Computing Resources for Environmental Decision Support

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The U.S. Environmental Protection Agency (EPA), as part of the Federal High Performance Computing and Communications Initiative, is developing an Environmental Modeling and Decision Support System to take maximum advantage of emerging high performance computing platforms and network technology. One main goal of EPA's program is to provide powerful, yet easy to use, environmental management tools to state, federal, and industrial organizations involved in day-to-day environmental problem-solving. The approach encompasses building high performance computing and communications environment within EPA to handle more complex regional multipollutant and multimedia environmental issues, while at the same time ensuring compatible low cost solutions for use at local levels. Thus with a distributed computing approach, a problem can transparently migrate to the most cost and time effective computing platform as the problem size grows or as time constraints become critical. Decision-makers at all levels will have the ability to access the most powerful resources necessary to resolve critical environmental issues.

EnviroTRADE: A Commercialization Case Study

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The U.S. Department of Energy (DOE) is developing the EnviroTRADE environmental information system for the purpose of managing large amounts of information on waste site and environmental technologies. The system uses decision support tools through an easy-to-use interface for matching technologies to sites and locating potential sites where technologies might be applied. Spatial data is managed using state-of-the-art geographic information system technology. The information will be delivered on a network and must be both accurate and current. DOE has begun the process of commercializing the EnviroTRADE information system because the private sector is well suited to market and deliver the data.

Products and Services of the National Technical Information Service

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The National Technical Information Service (NTIS), an agency of the U.S. Department of Commerce, operates a national clearinghouse for federal scientific, technical, engineering, and business information. The primary mission of NTIS is to make federal information products accessible to business and industry. This presentation describes some of the environmental software products available through NTIS and discusses services NTIS offers to federal agencies, including a case study of how the Superfund program office has partnered with NTIS to disseminate information.

NTIS helps federal agencies accelerate the distribution of their information products to a broad user community by offering a number of services:

- Basic information dissemination and order fulfillment services
- Special collection management, marketing, and distribution services
- Reproduction and electronic media production services
- Financial and contractual services

NTIS performs many of these services for the Office of Emergency and Remedial Response within the Office of Solid Waste and Emergency Response in support of the Superfund program. Superfund instituted a policy change in 1992, where the program office continues to pay for the U.S. Environmental Protection Agency's (EPA's) internal distribution of Superfund information, but NTIS would assume the burden of public dissemination. Several new subscription products are now offered based on topics of interest such as site assessment and remediation, technologies and analytical services, and program policies, where a customer automatically receives any document assigned that subject category when it is released. NTIS production staff currently are on site at the Superfund Document Center to handle the sizable number of internal orders.

Collection management services represent a large part of the EPA Superfund–NTIS partnership. There are about 2,000 documents in the Superfund collection including 600 active documents. Each type of document, publication, fact sheet, directive, etc. has its own format and printing specifications. NTIS maintains a separate inventory control system for Superfund internal copies, which are stored at NTIS in Springfield, Virginia.

NTIS can help announce and market new government reports and products. An example of how we help EPA Superfund get the word out on what's new is the Superfund early bird window on NTIS's FedWorld, an on-line service and bulletin board. The window lists the new Superfund documents available that month and has helped cut down on calls to EPA hotlines.

NTIS's Electronic Media Production Service provides complete production services for electronic media on magnetic tape, digital tape, floppy disks, microdiskettes, and CD-ROM. We assist our clients at every step of the development, production, and distribution process, adding value based on our experience with over 350 different projects and over 71 different agencies. The scope of this work has ranged from projects costing several thousand dollars to very large projects, such as National Library of Medicine's Grateful Med, which cost over $1 million. NTIS has in-house production capabilities as well as prescreened and prequalified contractors for all types of media. Most requests for quotations close after three to five business days.

NTIS also provides a complete spectrum of business services that support the production effort. NTIS's accounting services assist agencies by managing billing and collections for their information dissemination programs. This is a very time-consuming and labor-intensive activity, and NTIS is an excellent alternative to tying up scarce resources within your agency by performing these tasks.

NTIS receives over 50 new environmental documents a day and has over 4,000 computer data files, models, and software programs. Several environmental decision support tools available from NTIS will be described. Copies of the catalog of U.S. Government Environmental Datafiles & Software will be available at the presentation and the poster exhibit.

The U.S. Environmental Protection Agency's Environmental Monitoring Methods Index (EMMI): A Tool for Environmental Monitoring

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The U.S. Environmental Protection Agency (EPA) has developed a computerized database containing analytical testing method and regulatory information on environmentally significant analytes that are monitored by EPA. The database, the Environmental Monitoring Methods Index (EMMI), is the result of efforts by the Agency's Environmental Monitoring Management Council (EMMC) and the Office of Water. EMMI is designed to aid environmental program managers, and others who must develop lists of analytes to study, identify appropriate analytical methods, determine the most suitable methods for a particular purpose, evaluate available methods prior to developing new analytical procedures, locate sources for analytical standards, and identify contact points for environmental regulation and analytical methods.

The present version of EMMI is the result of an exhaustive search of the U.S. Code of Federal Regulations, the Federal Register, and published analytical methods. EMMI encompasses a total of 2,607 analytes, 49 regulatory and monitoring lists, 1,167 analytical methods, and a database cross-reference to 5,740 analytes. The Chemical Abstracts Service (CAS) Registry Number is used to unambiguously identify analytes contained in the database. This presentation will focus on using EMMI as a problem-solving tool to identify appropriate analytes and methods for environmental monitoring studies. A case study will be examined where EMMI was used to identify analytical methods that met the required analytical detection limits and other study data quality objectives. EMMI will be demonstrated to the audience during the presentation and a working demonstration copy will be provided to all attendees.