PNL--8286

DE93 005040

COMPUTER-BASED TOOLS FOR DECISION SUPPORT AT THE HANFORD SITE

P. G. Doctor
J. A. Mahaffey
P. J. Cowley
M. D. Freshley
N. L. Hassig
J. W. Brothers
C. S. Glantz
D. M. Strachan

November 1992

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

Pacific Northwest Laboratory
Richland, Washington 99352

ABSTRACT

To help integrate activities in the environmental restoration and waste management mission of the Hanford Site, the Hanford Integrated Planning Project (HIPP) was established and funded by the U.S. Department of Energy. The project is divided into three key program elements, the first focusing on an explicit, defensible and comprehensive method for evaluating technical options. Based on the premise that computer technology can be used to support the decision-making process and facilitate integration among programs and activities, the Decision Support Tools Task was charged with assessing the status of computer technology for those purposes at the Site. The task addressed two types of tools: tools need to provide technical information and management support tools. Technical tools include performance and risk assessment models, information management systems, data and the computer infrastructure to supports models, data, and information management systems. Management decision support tools are used to synthesize information at a high level to assist with making decisions.

The major conclusions resulting from the assessment are that there is much technical information available, but it is not reaching the decision-makers in a form to be used. Many existing tools provide components that are needed to integrate site activities; however, some components are missing and, more importantly, the "glue" or connections to tie the components together to answer decision-makers questions is largely absent. Examples that show that information exists, but is not integrated are that 1) costs of remediation options cannot be easily coupled to measures of performance or to schedule and 2) historical data are recognized as important, but no plan for their role in site remediation exists. Top priority should be given to decision support tools that support activities given in the TPA. Other decision tools are needed to facilitate and support the environmental restoration and waste management mission. The prioritization process for their development include addressing the following items: tools that are needed regardless of remediation options chosen; tools that have a bias for action and can be used immediately to help make decisions; tools that apply across multiple program areas; and tools that help implement the observational approach to environmental remediation.

EXECUTIVE SUMMARY

The primary mission at the Hanford Site has changed from producing plutonium for weapons to environmental restoration and waste management. Since the late 1950s, the Site has been managed for multiple programs with separate and unrelated objectives, resulting in limited interactions among the programs. However, with a shift to the mission of environmental restoration and waste management, many programs at the Site are focused on cleanup, and the coordination among programs have become critical to satisfying the Site mission.

To help integrate activities in environmental restoration and waste management, the Hanford Integrated Planning Project was established and funded by the U.S. Department of Energy (DOE). The Hanford Integrated Planning Project is divided into three key program elements: 1) an explicit, defensible and comprehensive method for evaluating technical options; 2) a public involvement process; and 3) a plan that focuses scientific and technology resources on the needs of the Hanford environmental restoration mission. The Decision Support Tools Task, which is a component of the first program element, was based on the premise that computer technology can be used as follows:

- to support the decision-making process
- facilitate integration among the programs.

The task addressed two types of tools: tools that are needed to provide technical information and management decision support tools. Technical tools include performance and risk assessment models, information management systems, data, and the computer infrastructure to support models, data, and information management systems. Management decision support tools are used to synthesize information at a high level to assist with making decisions. Some of these tools help in evaluating trade-offs. Others assist with cost estimation and scheduling. The number of management decision support tools that exist at Hanford are limited. Other computer-based tools, such as models, information management systems, and data, can support decision-making but are not decision support tools in themselves.

In the past, tools at the Hanford Site were developed on a project-by-project basis, without coordination across technically similar but administratively separate activities. As a result of these administrative separations, and even within administrative units, different tools were used to address similar problems, resulting in inconsistencies in reported results. For example, many different ground-water flow and transport models have been used for applications at Hanford, which has led to confusion among Hanford contractors, DOE, and the regulators. Most tools should be applicable across these administratively separate activities at the Hanford Site. The purpose of this task is to identify tools that are available to assist in making decisions and to identify associated issues so that the Site can determine what tools are needed.

The tools described in this report support major planning, characterization, compliance, and technology assessment and many other efforts underway at Hanford. They exist in varying states of applicability to the Site's environmental mission. In preparing this document, we considered tools that were available or familiar to staff at the Hanford Site.

It is clear, however, that the computer-based tools are not usually having a large impact on the decision-making process; in fact, their role in the process is not generally understood. The primary reason for this gap is that the output of the tools is often not suited for input to the decision-making process. In addition, the tools are not well integrated. For example, the results of performance and risk assessment tools should be integrated with cost, schedule, public opinion, and other input.

It is important that tools be integrated with other tools and that this integration facilitates easy use. Cases in which this integration is happening have been identified. For some tools, this integration is working well; for others, this integration has yet to be initiated. However, most existing tools were not designed or implemented to be decision support tools. They were designed to meet specific project/program needs. Although they can help facilitate the process, they do not feed directly into decision-making.

Although issues related to the tools have been identified and the status of various aspects of model documentation and testing has been compiled, this work has not provided in-depth evaluation. In some cases, it is unclear exactly how the tools would be used. Additional work would be required to inventory and evaluate tools available elsewhere, both at other DOE sites and outside the DOE complex.

The Tri-Party Agreement (TPA) is directing all environmental restoration work at Hanford and is the consent order that will bring Hanford into compliance with the major state and federal environmental laws. The application and development of only a few tools is mandated under the TPA. However, other tools not explicitly mandated by the TPA are needed to effectively support milestones. Decision-makers need to understand how these tools can be beneficial in meeting TPA milestones. In some cases, the regulators are calling for resources that require investment and development by Hanford contractors and DOE, such as computerized mapping data capable of being used in geographic information systems.

There are tools available that have been developed for the Hanford Site that are useful in predicting and estimating impact of environmental contamination. Many of these same tools will also be useful in evaluating alternative cleanup strategies. Supporting source, release, transport, conversion, exposure, and health effects models and databases can be used along with cost and schedule to help evaluate environmental restoration options.

Currently, it is very difficult to determine the cost of various remediation options independently of the cost of existing facilities so that the comparison of cost performances of competing options is also difficult. Also, the estimation of the costs of planning is not linked to the system for managing and tracking other costs; thus, obtaining feedback on the accuracy of cost estimates to improve the planning process is not currently possible.

Although some computer-based tools are available to support the decision-making process and are currently being used to support the cleanup process, existing tools must be made more functional, new tools must be developed where none now exist, and interfaces and a computer infrastructure must be built where available tools can be integrated to facilitate cleanup decisions.

MAJOR CONCLUSIONS

Major conclusions resulting from the assessment include the following:

- Technical information is not reaching decision-makers in a form to be used effectively.

- Although many existing tools provide components that are needed to integrate site activities, there are missing components, missing needed "glue" to tie the components together. The missing items currently prevent the full use of existing information, i.e.,

  - information on costs cannot be easily coupled to the performance of remediation options or to schedule

  - historic data is recognized as important but a plan for its role (both access and use) in site remediation does not exist

  - some capabilities still need to be developed, such as assessing the impact of exposure to individual chemicals or mixtures of chemicals (the impact of exposure to radionuclides is better understood than the impact of exposure to chemicals).

  - a methodology for evaluating decision trade-offs in a consistent manner is needed

  - computer-based tools to support the Hanford Site's environmental mission are not always recognized by management as an essential part of that mission

  - more standards and conventions to facilitate communication among information management systems and models are needed.

- A process for setting priorities for investment in computer-based tools is also needed. While top priority has to be given to activities identified in the TPA, the following prioritization process can be applied to tools not identified in the TPA:

  - tools that are needed regardless of which remediation options are chosen

  - tools that have a bias for action and can be used now to help make decisions

  - tools that apply across multiple mission areas

  - tools that implement the observational approach to environmental remediation.

In order to facilitate the integration of site activities, priority for development and implementation should be given to tools that further the basic information infrastructure for the Hanford Site and provide the technical information that is needed to evaluate proposed remediation options. The information infrastructure must be flexible enough to deal with different remediation options without requiring major changes. Therefore, priority should be given to using existing decision tools to provide information for decisions now, rather than investigating in the development of new tools that require long lead times to implement. This is consistent with providing information for the observational approach to environmental remediation that is endorsed by the U.S. Environmental Protection Agency (EPA).

Tools are needed that link or aggregate information from detailed technical analyses to a level that can be used in decision-making. This is particularly important for evaluating the impact of proposed remediation options for the entire Hanford Site.

ISSUES RELATED TO MODELS

- Source-term models that are technically appropriate for estimating inventories for waste sites at Hanford exist but have not been applied, and existing Hanford models are inadequate.
- Whereas adequate codes exist for subsurface flow and transport modeling, a Site-wide conceptual model that can generate subregional models is needed to ensure consistency among mission areas and the contractors involved.
- Atmospheric transport models need to be evaluated for applicability, including adequacy of addressing suspension of contamination and dust from remediation activities.
- Environmental pathway models for radionuclides are well developed; models for organic chemical transport and exposure are needed.
- Data are inadequate to estimate health risk coefficients for exposure to mixed wastes, as well as to some chemical agents.

ISSUES RELATED TO DATA

- Planning of data-acquisition activities requires a perspective beyond immediate data needs to include the data requirements of other activities, such as risk and performance assessment models, in order to ensure that data exist for all applicable uses at the Hanford Site.

- Characterization programs and modeling efforts need to be integrated. For example, when a well is drilled to collect a ground-water sample for monitoring, the planning should consider needs to collect data for modeling (e.g., soil hydraulic properties).

- A means will have to be found to use data obtained before the development of existing quality control standards and procedures. Because of the cost of collecting new data, the importance of historical data will increase, for example, in determining inventories of waste and constructing environmental conceptual models of the Hanford Site.

- When new data are to be gathered, serious consideration needs to be given to the data quality objectives that the data must meet in order to be useful across the Hanford Site.

- Data should be synthesized on a large scale at Hanford. Scientific visualization, geographic information systems, statistics, and modeling can be used to synthesize existing and new information and to synthesize the results of model applications.

ISSUES RELATED TO INFORMATION MANAGEMENT SYSTEMS

- The user community should commit to using integrated systems to facilitate sharing of data and to using information management systems to do regular business. This entails sufficient funding for computer infrastructure, software design and development, user support, documentation, and maintenance.

- An effective integrated planning process is needed for information management systems. Consistent with the Hanford Integrated Planning Process, identification of existing information management capabilities needs to be a multi-contractor activity and reflect a Site-wide perspective.

- We need to work with the user community to develop a clear set of expectations of what information management can do and how it can be an effective part of the environmental restoration process.

- Hanford should use new cost-effective technology and facilitate timely access to that technology.

FUTURE DIRECTIONS

To facilitate the development and maintenance of decision tools at Hanford, the following coordinated activities are recommended:

- Coordinate a process by which the needs for tools are matched with the development, maintenance, and upgrading of the tools themselves.
- Evaluate options for how best to establish an integrated software environment that meets the needs.
- Design, implement, test, and put into production the required tools.
- Provide on-going maintenance and support of decision-making tools. Ensure the periodic re-evaluation of new and alternative tools to be included in the integrated software environment.

ACKNOWLEDGMENTS

Thanks to Geraldine C. (Jerri) Main for providing information on site databases; Raymond W. Baalman, Jr., James R. Weber, and Michelle R. Peterson for editing; and Marianna Cross for text processing.

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

The primary mission at the Hanford Site has changed from producing plutonium for weapons to environmental restoration and waste management. Since the late 1950s, the Hanford Site has been managed for multiple programs with separate and unrelated objectives, resulting in limited interactions among the programs. However, with a shift to the mission of environmental restoration and waste management, many programs are focused on cleanup, and interactions among programs have become increasingly critical to satisfying the Hanford Site mission. Hanford's technical missions are divided into several areas: solid waste, tanks, environmental contamination, facilities decontamination and decommissioning, and nuclear materials. To help integrate activities across these areas, the Hanford Integrated Planning Project was established and funded by the U.S. Department of Energy (DOE). The Hanford Integrated Planning Project is divided into three key program elements: 1) an explicit, defensible, and comprehensive method for evaluating technical options; 2) a public involvement process; and 3) a plan that focuses scientific and technology resources on the needs of the Hanford environmental restoration mission. The Decision Support Tools Task, a component of the first program element, is intended to document the baseline status of computer-based decision support tools at the Hanford Site that exist, are currently being used, or are under development; to identify significant gaps; and to suggest general tool development or adaptation needs. This document is the product of that effort. Decision tools evaluated include management decision support tools, databases and information management systems, performance and risk assessment models, cost models, process and operations models, input data to support each type of model, and the computer infrastructure to support these tools. These tools will be used to support technical decisions in the mission areas identified above to support Hanford's Integrated Planning Process. Information management systems that support the administration of the Hanford Site, such as the financial system, are not included in this report.

1.1 OVERVIEW OF HANFORD INTEGRATED PLANNING

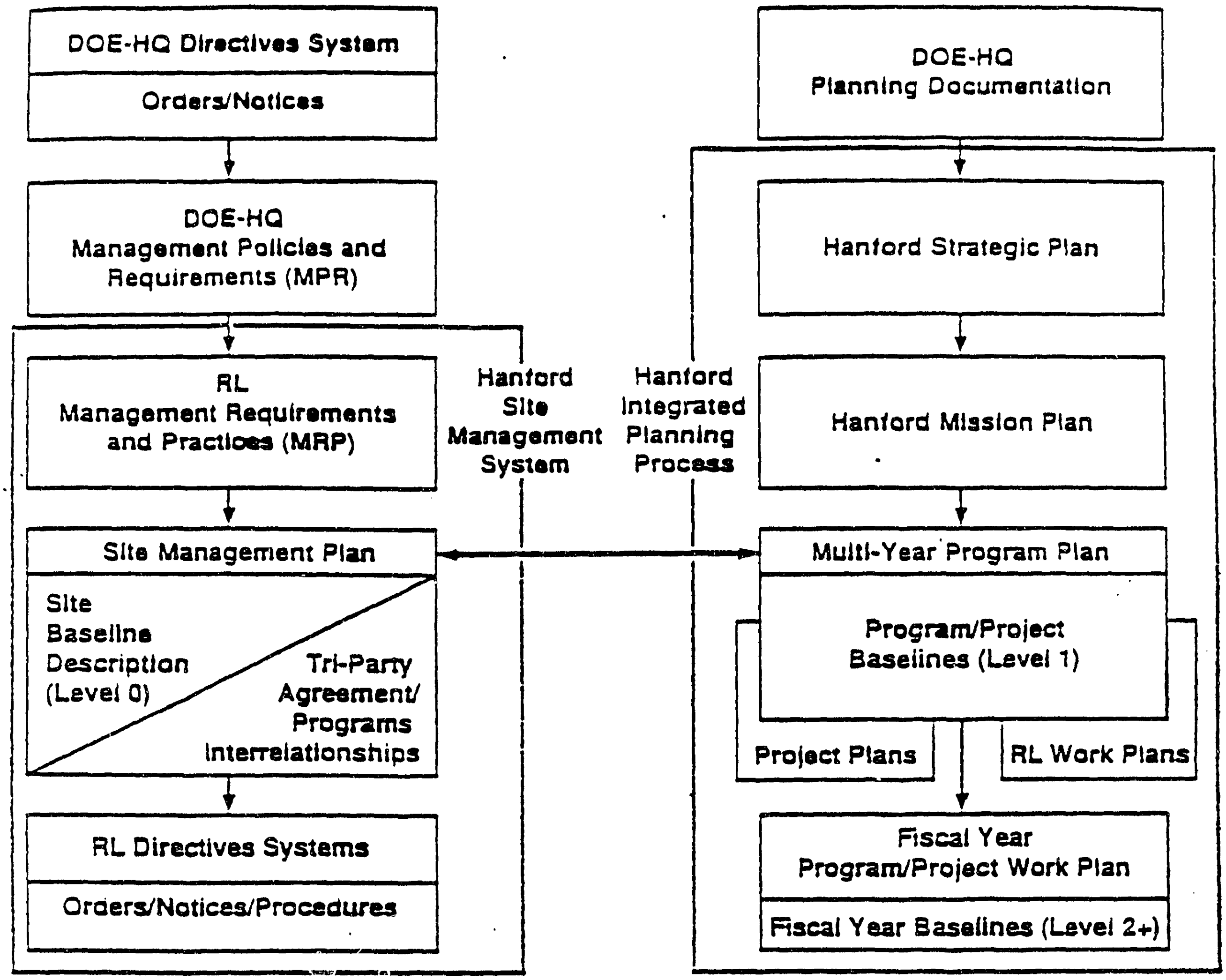
The objective of the multiyear Hanford Integrated Planning effort is to develop and maintain a technically sound and publicly acceptable plan that integrates environmental restoration and waste management activities. The effort is being conducted in three phases: Phase 1 (FY 1991) established the reference planning case and initial version of the Hanford Mission Plan (DOE/RL 1991f); Phase 2 (FY 1992-1993) develops and uses capabilities needed to support integrated planning and implementation; and Phase 3 (FY 1994 and beyond) provides reanalysis and long-term support for environmental restoration and waste management.

The Hanford Integrated Planning Project provides integrated, top-level program planning for all current and future Hanford activities in the DOE Office of Environmental Restoration and Waste Management (EM). Figure 1.1 shows the current relationships among the EM and Hanford documents related to integrated planning and management of the Hanford Site. In addition to the Hanford Mission Plan itself, which will be updated on a regular basis, the effort will include planning to resolve remediation issues and to make decisions as problems arise. Each version of the Hanford Mission Plan that results from this effort will be compatible with, or will supersede, existing integrated planning initiatives at the Site.

Integrated planning will enhance both interprogram and intercontractor coordination. It will help to minimize possible conflicts, inconsistencies, or duplications among programs and between contractors, and will further assure the consideration of appropriate offsite capabilities in completing Hanford programs. It will facilitate progress and public acceptance by assuring that efforts at Hanford are directed toward well-understood goals and cleanup strategies accepted by both remediators and other stakeholders.

1.2 DECISION SUPPORT TOOLS

In the past, decision support tools at the Hanford Site were developed on a project-by-project basis, without much coordination across technically similar but administratively separate activities. As a result, different tools were used to address similar problems including the evaluation of



Key Points

- Site management requirements and RL program/project management accountability is defined
- Site programs/projects baselines and contractor work scopes are defined and, changes are dispositioned by site change board
- Award Fee determinations are tied to contractors work scope and work plans
- Contractor work plans and funding authorization are formalized and contractors modifications are executed

FIGURE 1.1. Hanford Integrated Management System Document Hierarchy

mission options. This resulted in inconsistencies in reported results. A specific example is the use of different models for performance assessment analyses and environmental impact statements (EIS) at the Hanford Site.

Most decision support tools are applicable across administratively separate activities at the Hanford Site. Therefore, coordinated development and application will eliminate duplication of effort and result in greater comparability and consistency between results of different but similar analyses. It is also important to ensure that tools are integrated and coordinated, so that output of one tool can be used as input to another. For instance, the links among models have to be convenient so they are cost-effective and timely, and do not impede the process of applying the tools.

The need for integration of tools applies to both management and technical tools. Technical tools aid in data management, reporting, and analysis as well as performance, risk, and technology assessment. Management tools assist in decision-making by integrating cost, schedule, risk, output from technical tools, and other considerations.

The integrated and coordinated use of support tools also must involve a user training component. A high level of intelligence and technical proficiency does not necessarily imply that a user has the training or experience adequate to use a particular tool. A standard certification or mandatory training program for the users of key support tools would increase the probability that these tools are being used appropriately across the Hanford Site.

Staff on the Decision Support Tools Task of the Hanford Integrated Planning Project looked primarily at integration needs for technical tools, although some tools surveyed were management tools also. The next phase of the tools assessment activity would be to develop the input for and the structure of tool evaluation and tool selection. This phase identifies technical tools available at Hanford.

1.3 APPROACH

In order to evaluate the needs for computer-based decision tools to support the decision-making process, it is necessary to understand the relationship between the two. As the team discovered, there is no clear or generally accepted link and the team had to determine what that relationship currently is and what it should be to increase the effectiveness of the overall Hanford Integration Planning Process.

Our approach was to review available tools and to identify general development and modification needs. This was made more difficult because no clear technical objectives are defined for environmental restoration and waste management (such as land-use decisions which dictate cleanup levels or baseline programs against which cleanup options can be compared), and no clear priorities have been established for actions. Some technologies for remedial actions at DOE facilities, especially those technologies focusing on permanent cleanup solutions, do not exist, and not all of the key cross-cutting issues have been identified. As decisions are made at the DOE Headquarters (HQ) level and the Hanford level, there will be a need to link the HQ tools and decisions to the site-specific tools and decisions.

In addition, products of existing programs and changes in organizations, staff, and on-site contractors will affect the priorities for tool development and applications. Of major concern is the impact of the environmental restoration management contractor (ERMC) planned for the Site. As currently envisioned by DOE, the ERMC would be an integrating contractor assigning work to support subcontractors. The ERMC will bring new priorities, plans, and tools to the table. To date, the major contractors associated with computer-based tools have been Westinghouse Hanford Company (WHC), Pacific Northwest Laboratory (PNL), Kaiser Engineers Hanford (KEH), and Hanford Environmental Health Foundation (HEHF). The tacit understanding concerning data and supporting software is that the systems should be operated by the contractor responsible for the data. In most cases, this approach has been straightforward. With an ERMC, responsibilities and priorities must be readdressed. In addition, tools development and initial application is being done by the integrated demonstrations and integrated programs at HQ. These programs and changes will affect specific tool development and modification, but it will be a multi-year process. In the meantime, the tools being used at Hanford cannot remain fluid. Therefore, there is a need to address the issue of establishing, in concert with the regulators, a set of tools and approaches supporting Hanford cleanup activities.

To collect information for the Decision Support Tools Task, we reviewed documents, interviewed people about use of tools and needs for modification and development, and attended the Hanford Integrated Plan mission area workshops. The Decision Support Tools Task members focused on identifying existing and planned tools and associated issues. This document synthesizes that work.

1.4 INTEGRATION WITH OTHER PLANNING AND TECHNOLOGY ASSESSMENT EFFORTS

The Hanford Integrated Planning Decision Support Tools task must be coordinated with ongoing environmental management planning and coordination efforts at Hanford and at EM. These activities, which may appear duplicative at first, tend to operate at different programmatic levels, ranging from more detailed site-specific technical needs to complex-wide management needs. The interrelationships among the HQ and Hanford documents relating to integrated planning and management, as shown in Figure 1.1, are complex in themselves, but there are additional activities whose impact will affect the planning process as well.

Due to the large number of efforts underway, only those currently most important to the Decision Support Tools Task are mentioned. The Tri-Party Agreement (TPA), which is both Hanford-Site specific and a high-level contract between state and federal agencies, has several milestones that directly address decision tools (risk assessment, databases, and information management). The State of Washington, in addition to its participation in the TPA, has significant regulations that affect Hanford cleanup activities through the enforcement of the Model Toxics Control Act (MTCA). At HQ, EM's policies objectives and directions, in addition to the decision tools that are planned or are under development, affect the needs for decision tools at Hanford. There are also environmental management planning activities specific to the Hanford Site that are taking place locally and at HQ. Additionally, ongoing Hanford infrastructure planning and technical coordination activities need to be included in environmental management planning.

1.5 ORGANIZATION OF THIS REPORT

Section 1.0 provides an introduction to the Hanford Integrated Planning Project and summarizes the scope and approach for the Decision Support Tools Task. Section 2.0 contains a description of other planning and technology assessment activities. Section 3.0 gives a general status and assessment of decision support tools being used or currently available at the Hanford Site. Section 4.0 provides a description of the infrastructure requirements to support the development and application of decision support tools. Section 5.0 presents a set of guidelines for tool evaluation. Section 6.0 presents conclusions. The document also contains references and appendixes.

2.0 DISCUSSION OF OTHER PLANNING AND TECHNOLOGY ASSESSMENT EFFORTS

As described briefly in Section 1.5, the Hanford Integrated Planning tools task must be cognizant of and coordinate with ongoing environmental restoration planning and coordination efforts at Hanford and at EM. These activities, which may appear duplicative at first, tend to operate at different programmatic levels, ranging from more detailed site-specific technical needs to complex-wide management needs.

This section describes some activities underway to direct or support environmental restoration at the Hanford Site. Due to the large number of efforts underway, only those most important to the Decision Support Tools Task are mentioned. Section 2.1 describes the TPA, which is both Hanford Site-specific and a high-level contract between state and federal agencies, and explains how it affects the definition of decision tool needs. Section 2.2 describes activities underway by the State of Washington. Section 2.3 discusses major activities of HQ. Section 2.4 discusses environmental restoration planning activities specific to the Hanford Site. Section 2.5 describes ongoing Hanford infrastructure planning and technical coordination activities.

2.1 TRI-PARTY AGREEMENT

On May 15, 1989, RL, the Washington State Department of Ecology (Ecology) and the EPA signed the Tri-Party Agreement to clean up radioactive and chemical wastes at the Hanford Site over the following 30 years (Ecology, EPA, and DOE/RL 1990). The TPA is focused on the work needed to bring the Hanford Site into compliance with three major environmental laws: the federal Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or "Superfund"; and the Washington State Hazardous Waste Management Act (HWMA). The TPA is a blueprint for cleanup, and uses enforceable milestones to keep the program on schedule.

Milestones for the TPA vary from mission-specific (such as ones specifying that a particular facility must be on-line by a certain date) to detailed processes. Some of the milestones deal explicitly with decision tools, such as the ones pertaining to the Hanford Environmental Information System (HEIS). Recently, the TPA was amended to include three milestones under the general M-29-00 milestone (develop and submit documentation to EPA and Ecology describing Hanford risk assessment, which were due March 1992) that explicitly deal with performance and risk assessment:

- M-29-01 Identify and submit a description of codes and models to be used in risk assessment.
- M-29-02 Submit a plan for developing area-wide ground-water models to support risk assessment and to evaluate impacts of changing ground-water flow fields.
- M-29-03 Submit risk assessment methodology document.

Two committees, consisting of EPA, Ecology, and WHC representatives and DOE contractor staff, were charged with providing the documents to meet these milestones. The planning needed to meet the M-29-00 milestones should be integrated with the other aspects of the decision tool planning for Hanford.

2.1.1 Expedited Response Actions/Interim Remedial Actions

The high costs and long schedules associated with traditional past practice investigations have given the TPA parties a new perspective on the need to streamline the remedial investigation and feasibility study (RI/FS) and RCRA Facility Investigation/Corrective Measure Study (RFI/CMS). A new strategy, the Hanford Site Past-Practice Investigation Strategy (DOE/RL 1991a), agreed to by EPA, Ecology, and RL, streamlines the past practice corrective action process. It is a strategy for conducting site investigations and cleanups to maximize efficiency, maintain project schedules, and achieve earlier remedial action. This streamlined approach to RI/FS activities, required under both the National and Hazardous Substances Pollution Contingency Plan (NCP) and the Washington State Model Toxics Control Act Cleanup Regulation (MTCACR), resulted in a need to modify the application of risk assessment to support the strategy (see Section 2.1.2).

This strategy provides for accelerated decision-making by maximizing the use of existing data consistent with data quality objectives; it also undertakes expedited response actions (ERAs) and/or interim remedial measures (IRMs), either to remove threats to human health and the environment or to reduce risk by reducing the toxicity, mobility, or volume of contaminants. This streamlined process is defined as a combination of interim cleanup actions (involving concurrent characterization), field investigations for final remedy selection where interim actions are not clearly justified, and feasibility/treatability studies. Decision support tools are an integral part of the ERA and IRM process from the establishment of data quality objectives to the estimation of human and ecological risks to assess the need for and the potential effectiveness of interim actions. To date, three expedited response actions have been identified for early action at the Hanford Site.

2.1.2 Hanford Site Baseline Risk Assessment Methodology

TPA Milestone M-29-00 was to develop a risk assessment methodology for use at the Hanford Site. A Hanford Site Baseline Risk Assessment Methodology (DOE/RL 1991b) has been developed by a committee of technical representatives from the RL, Ecology, EPA, WHC, and the U.S. Army Corps of Engineers (COE). The committee identified two primary objectives for application of the methodology at the Hanford Site, based on the Hanford Site Past-Practice Investigation Strategy (see Section 2.1.1):

- to use the risk assessment methodology to assist in determining the need for IRMs by estimating the risk associated with a waste unit and the threshold values (i.e., initial cleanup levels) for cleanup
- to apply the risk assessment methodology to determine the cumulative, residual risk associated with a waste unit, an operable unit, or an aggregate area at a point in time after IRMs have been implemented. It is envisioned that waste unit IRMs will be undertaken well before finalization of operable unit characterizations.

The proposed methodology for human health evaluation is primarily based on the MTCACR, as opposed to the federal process set forth in the NCP. Although the MTCACR provides risk assessment procedures, the resulting cleanup standards are developed using risk-based calculations that are generic rather than site-specific. The MTCACR specifies that for multiple hazardous substances and/or pathways, the carcinogenic risk shall not exceed 10^{-5} and the hazard index shall not exceed 1. For individual carcinogens, the initial cleanup level will be based on an incremental cancer risk of 10^{-6}. For noncarcinogenic substances, the estimated cleanup concentration in a medium for individual substances is that which would result in an intake equivalent to a hazard quotient of 0.3.

Two considerations are important in the methodology used in a qualitative risk assessment:

- The qualitative assessment is intended to be only part of the justification for an IRM.
- The initial cleanup levels are only estimates. Final cleanup levels would be based on multiple considerations and documented in the Record of Decision.

Other more quantitative risk assessments will have to be completed throughout the process as information becomes available.

2.2 STATE OF WASHINGTON PLANNING ACTIVITIES

Until now, risk estimation that has been done for the Hanford Site in various EIS documents has focused on long-term population exposures. The primary federal statutes relevant to the risk assessment process are RCRA and CERCLA. The primary Washington State statutes are the MTCACR and HWMA. While EPA maintains authority for CERCLA, Ecology has received authorization from EPA to implement the state's dangerous waste program in lieu of the federal RCRA program.

With the Superfund Amendments Title III (SARA III), the requirements of the National Resource Damage Assessment (NRDA) are beginning to be evident. EPA, which has not yet defined what constitutes an ecological impact, has started from their approach for assessing human health risks from exposure to environmental contamination: first defining environmental pathways, then determining the contaminants distributed through the food chain that many lead to health effects, and then estimating the risks associated with these health effects. Of late, several workshops have dealt with the subject (Ecology 1991), and Ecology is developing guidelines for performing ecological risk assessments for the State of Washington that will apply to the Hanford Site.

2.2.1 Model Toxics Control Act

The MTCA is intended to protect human health and the environment from current and potential threats posed by hazardous substance releases. The set of regulations corresponding to the MTC statute is the MTCACR (Ecology 1991). The MTCA is the Washington State equivalent of the federal CERCLA and SARA programs. (The federal government cannot authorize states to administer CERCLA as they can RCRA.)

2.2.2 Human Health Evaluation

Although the MTCACR provides for risk assessment procedures, the resulting cleanup standards are developed using risk-based calculations that are generic rather than site-specific. All sites within the state are regarded as being either residential or industrial with specific exposure assumptions defined. Other land uses are recognized, such as for agriculture, but all cleanup standards must be at least as stringent as cleanup levels applied to industrial sites.

2.2.3 Ecological Evaluation

Unlike the human health evaluation, the current MTCACR cleanup standard development process provides no specific procedures for ecological evaluation in a baseline risk assessment, other than that cleanup standards must protect the environment. However, the NCP states that at a National Priority List site "...the lead agency shall conduct a site-specific baseline risk assessment to characterize the current and potential threats to the environment... especially sensitive habitats and critical habitats of species protected under the Endangered Species Act" (40 CFR 300.430).

Ecology has been given the task of writing the regulations to enforce the MTCA with respect to protecting the environment, and has done so in three phases: 1) setting definitions and administrative detail; 2) setting cleanup standards (including interim surface water approach, soil cleanup levels for chemical criteria and biological criteria; and 3) developing methods for ecological risk assessment.[a]

The regulations provide three options for establishing site-specific cleanup levels. Each option uses health risk in setting levels:

- Option A defines cleanup levels for 25 of the most common hazardous substances found at sites using the standards and health-based concentrations included in other applicable state and federal laws.
- Option B levels are set using a site risk assessment. The risk level of individual carcinogens cannot exceed 10^{-6}; total risk cannot exceed 10^{-5}. Levels for noncarcinogens cannot cause illness in humans.
- Option C levels are set when options A or B are technically impossible to achieve, or cleanup may cause more environmental harm than good.

The five ecological assessment tools to be used for a complete risk ecological assessment are soil and water analyses, tissue analysis, toxicity testing, community analysis, and food-chain modeling. Currently, Ecology is working with individual sites to tailor these tools to the appropriate conditions at the site. Five sites in Washington will be test sites for developing and applying specific tools. The specific details of the application of MTCA and MTCACR requirements to a site of the size and chemical complexity of Hanford have yet to be fully addressed. Decision tools, such as site-specific models of chemical fate, transport, and exposure, and the input for them, will play a large part in estimating the human health and ecological risks, which are the basis of the regulations. The determination of the feasibility of proposed remediation technologies will likely involve the application of performance assessment models. The results of modeling efforts will then have to be compared to compliance monitoring data as part of a partial model validation effort.

(a) See Project-Level Guidance Document for Addressing Environmental Protection under the Model Toxics Control Act Cleanup Regulation, working draft, October 1991, Washington State Department of Ecology, Olympia, Washington.

2.3 DOE HEADQUARTER'S ACTIVITIES

This section describes the major HQ activities and the associated documents which impact the Hanford Site environmental management planning process as it relates to decision support tools.

2.3.1 DOE Five-Year Plan for Environmental Restoration and Waste Management

In the Hanford Site Five-Year Plan, Fiscal Years 1993-1997 (DOE/RL 1991c), the EM identifies the technical and operational issues in environmental management of the weapons complex and sets out a high-level strategy. The Five-Year Plan prioritizes the major activities supporting environmental management across the complex for the years 1992 to 1996; although it does not specifically deal with future years, it is assumed that the cleanup will take at least 30 years.

2.3.2 Basic Research for Environmental Restoration

The Office of Health and Environmental Research (OHER) within the DOE Office of Energy Research (ER) has prepared a document (DOE 1990a) that presents the basic research required in the years 1992 to 1996 to provide a foundation for applied programs to correct and remediate past waste disposal practices. The report is coordinated with the EM Five-Year Plan and lists specific research needs in five areas of environmental restoration: environmental transport and transformation; advanced sampling, characterization, and monitoring methods; new remediation technology; performance assessment; and health and environmental effects. The report is not intended to serve as a research implementation plan, so no milestones or schedule were developed.

Since EM has set no priorities for site restoration after 1996, ER has set no priorities for research for those years. Although ER assumes that limited, fortuitous breakthroughs in basic research can be translated immediately into user applications, most basic research requires at least a 3- to 10-year timeframe for transfer to users, and this time excludes technology-permitting requirements, which normally add additional years. Thus, priorities for research will be set when mid- to long-term environmental restoration activities are identified so that a basic research plan can complement the future needs of EM programs.

2.3.3 The Integrated Technology Development Needs Assessment

A committee of DOE contractor personnel was assembled by the DOE Office of Technology Development (OTD) in EM to provide a basis for the FY 1991 and FY 1992 research, development, demonstration, testing, and evaluation proposals for funding. The needs assessment from this effort will also be used as input to the Industrial Integration Program, the National Robotics Technology Development Program, and other national laboratories providing technology development support for the national Environmental Restoration and Waste Management (ER/WM) program.[a]

2.3.4 DOE Environmental Restoration Priority System

The DOE priority system (DOE 1991) is being developed for use by EM's environmental restoration programs. The primary purpose of the priority system is to help DOE decide which sites within the DOE complex to evaluate and clean up first and to provide a technical basis for budget planning. The DOE developed this system to ensure that this purpose is achieved in a process that is formal, systematic, and analytical, is open to review, and considers and quantifies the importance of many factors, including health and safety risks, regulatory requirements and agreements, social and economic values and policies, and technical issues.

The conceptual design of the priority system was used in two ways during 1990. Parts of the system were used as an interim system to provide information for the FY 1992 budget process. Concepts were also used to focus discussions with outside parties regarding the development of the priority system. The priority system is being used and will continue to be used in the FY 1993 budget process.

The priority system process is conducted in four phases; the first two concern local and field office issues and decisions, and the others concern national and HQ issues and decisions:

(a) Lien, S. C., and K. E. Hain. 1992. Interoffice memo to EM Technical Program Officers, dated January 31, 1992. Copy available form U.S. Department of Energy, Office of Research and Development, Washington, D.C.

- Identify, classify, and rank activities. Environmental program managers at the field offices group activities described in the Activity Data Sheets (ADSs) into three priority classes. There are currently 323 ADS in the Hanford Five-Year Plan.

- Propose alternative budget cases. Sets of activities that could be conducted at varying funding levels are grouped into budget cases.

- Evaluate budget cases. The priority system is used to evaluate and compare all budget cases from all DOE sites. The field offices use quantitative performance scales to score each budget case on the basis of how well it meets each of six ER funding objectives:

  - reduce health risk
  - reduce environmental risk
  - reduce socioeconomic impacts
  - comply with regulatory requirements
  - reduce uncertainties
  - achieve DOE policy milestones.

  A score is assigned to each proposed budget case. Because health risk is the single most important consideration in the priority system, HQ reviews (and possibly revises) the health risk scores. HQ also reviews (and possibly revises) the cost estimates used in the budget cases to ensure consistency with cost estimates used in the Five-Year Plan.

- Analyze and allocate the budget. HQ managers examine and compare the utility or benefit of the budget cases proposed by all the installations and choose the budget cases that best meet DOE's objectives and produce the greatest benefits for the costs incurred.

The analysis tools used by the priority system tend to be of a broader scope and higher level than the tools likely to be used for determining a specific cleanup criterion, such as those required by the MTCACR. However, the results of the models – at local site-specific and national planning levels – should not be contradictory; it is important for Hanford planning activities to understand how HQ uses site-specific Hanford information to make decisions. Decision tools that provide the flow of information to HQ and then are able to transmit decisions on priorities back to Hanford and track the implementation at the mission level will help use environmental management resources in an effective and consistent manner.

2.3.5 Environmental and Molecular Sciences Laboratory

DOE has initiated significant programs to address Hanford Site cleanup issues. Two programs, the Molecular Science Research Center (MSRC) and the Environmental Science Research Center (ESRC), will use facilities of the Environmental and Molecular Sciences Laboratory (EMSL), which provides scientists developing solutions to environmental restoration and waste management problems the opportunity to collaborate with researchers investigating basic chemical and physical processes. Research will provide technology in the areas of

- fundamental knowledge of natural systems to better predict contaminant movement through complex environments
- advanced sampling, characterization, and monitoring methods
- new remediation technologies for inactive facilities, concentrated wastes, and contaminated environments (including in situ treatment, isolation, and containment methods)
- environmental and health effects of innovative technology applications.

It is crucial for EMSL capabilities to be strongly linked to other Hanford environmental remediation activities to ensure efficient transfer of information and technology. EMSL resources include an initial complement of research equipment, computers, and information architecture, theoretical and experimental programs, and general laboratory infrastructure supporting research across a broad spectrum of environmental and molecular phenomena. Proposed research equipment includes one-of-a-kind research instruments designed and developed for specific EMSL applications and a wide variety of other leading-edge instrumentation. Major capabilities will include

- environmental simulation and modeling
- environmental materials and interfaces
- materials synthesis and characterization
- molecular science computing
- molecular structure and dynamics
- theory and modeling

- biomolecular structure and dynamics.

The EMSL (with ESRC and MSRC) will influence the decision tools used at Hanford in several ways. These tools include new and improved models for use in performance or risk assessments (as physical processes become better understood). New decision tools will be developed out of the information gained from the research, and more precise data will be obtained for the existing models. The research will develop new data quality objectives, which could then be incorporated into required monitoring programs.

2.4 HANFORD SITE ENVIRONMENTAL MANAGEMENT ACTIVITIES

The planning activities described here deal specifically with the Hanford Site, although they may have been initiated in response to a directive by HQ.

2.4.1 Technology Logic Diagrams

EM asked the field offices to develop site-specific plans that flow logically from the Five-Year Plan by using the "technology logic diagram" methodology (Keller et al. 1991), which is an application of the formal logic diagrams described in Section 3.2.4.

Within each major EM mission area, linkages flow from the national problem identified in the Five-Year Plan to the comparable Hanford problem, and then through the options for solving the problem to activities needed to implement the options. These activities, in addition to routine operations of existing facilities, may include the development of new technology, decision tools, and data collection efforts. The Five-Year Plan is in the form of mission area technology logic diagrams representing a second-tier (level-1) planning activity (see Figure 1.1) that identifies remediation options and the activities needed to implement those options. Where there are existing EM-funded activities that address an issue, they are identified by ADS numbers.

The technology logic diagrams have several purposes. First, at HQ, the technology logic diagram allows EM to determine if (and how) the field offices are addressing their environmental management problems. (In the future, any request for funding from EM must identify where the activity fits into the technology logic diagrams.) Second, the technology logic diagrams developed by the OTD will be used by HQ to determine common science and technology development needs across the DOE complex that could be addressed by activities funded and coordinated by OTD (instead of having each site perform the same activity). Such programs would include the Integrated Demonstrations and Programs. Third, at the site level, technology logic diagrams are used to identify operational activities and science and technology development needs that are specific to accomplishing the site environmental restoration and waste management mission.

At Hanford, detailed logic diagrams have been prepared for contaminated soils and ground water, waste stabilization, waste retrieval, waste processing, decontamination and decommissioning, and waste minimization mission areas (see Keller et al. 1991).

Technology development needs identified in the technology logic diagrams are being synthesized for OTD in the Hanford Site-Specific Technology Plan (DOE/RL 1991e) to provide information on the needs and bases for technology development and science support required to complete the Hanford environmental restoration and waste management mission. The science and technology program needs are also translated into top-level infrastructure and facility functional requirements.

The logic diagrams identify issues, needs, and activities, but they do not automatically develop linkages among common needs in different parts of the logic diagram. They also do not provide time phasing of the activities, so prioritization of activities is not a direct by-product of the technology logic diagrams. A major role for the Hanford Integrated Planning Project will be to help develop program priorities and time-phasing information needed to implement the technology logic diagrams.

2.4.2 Hanford Strategic Analysis

The purpose of the Strategic Analysis, begun by WHC in FY 1991, is to take a global view, rather than separately by mission area, of the disposal of the entire inventory of Hanford wastes, including decommissioned facilities and contained inventories of nuclear materials. Three scenarios of possible future post-remediation land use (exclusive, unrestricted, 200-Area disposal) were defined to determine the range of endpoint criteria for cleanup that would need to be met. Given these land-use scenarios, three options for each were defined for dealing with the waste through decontamination, separations, and disposal. Combinations of treatment options for each land-use scenario were then described on flowsheets. WHC now intends to develop software to analyze the flowsheet options for comparative cost and schedule.

A major application of decision tools in the Strategic Analysis is the development of a site-wide baseline risk assessment to describe the current human health risks associated with various mission areas. This risk baseline will provide a basis for comparing the human health impacts of various remediation options. The coupling of human health, and eventually an ecological risk and performance assessment capabilities, to the cost and schedule assessments currently being developed will provide the Hanford Integrated Planning Process with the decision tools to systematically analyze the trade-offs among proposed remedial options across the Hanford Site.

There are several committees looking at land-use issues. A team of facilitators has been selected by Ecology, EPA, and RL to bring interested parties together to envision alternative future uses at the Hanford Site. After meeting with interested parties, the facilitators will make recommendations to an informal "organizing committee" made up of representatives of the TPA parties, two affected Indian Tribes, three counties, and the National Park Service. The facilitators will recommend the makeup of a larger "working group" and make suggestion about structuring the process.

The initial objective for the future site use planning process is the development of alternative future visions that can be used to scope the Hanford Remedial Action EIS. Scoping for this EIS is expected in mid-1992.

2.4.3 Hanford Macroengineering Study

The macroengineering approach to environmental restoration of contaminated soils and buried waste at the Hanford Site is being investigated as a more expedient alternative to the currently used operable-unit approach. The current approach is to plan and implement separate RI/FS at each operable unit at the Hanford Site. However, since many of the operable units are located close together, or are often overlapping, so that even the RI activities pertaining to one affect another, a larger perspective seems reasonable and efficient. A macroengineering study was undertaken by WHC during FY 1991 to evaluate the potential for and impacts of using a larger-scale remediation approach based on aggregate areas. Under the macroengineering approach, co-located operable units will be combined into aggregate areas for remediation. Some of the environmental restoration issues, such as ground-water contamination, which by their nature cross many operable unit boundaries, are better addressed on a Hanford Site-wide basis.

The current macroengineering scenario, which is based on an extensive reliance on existing technology to meet cleanup needs, is to excavate the operable unit sites in the 1100, 300, and 100 Areas, separate and reduce volumes at those locations, and transport the contaminated portions to the 200-Area plateau for permanent disposal. The clean portion would be returned to the sites. Ground water beneath the 200 Areas would be isolated and wastes already in the ground in these areas would be disposed of in situ. Ground water within the 1100, 300, and 100 Areas would be restored to the degree that would be cost-beneficial, and the 200 Areas would be devoted to waste disposal and management in perpetuity. At this time, the macroengineering concept has not been discussed in detail with EPA and Ecology.

A major key to the acceptance of a macroengineering approach would be the assessment of the human health risk aspects of this option for Hanford Site remediation. That assessment requires the use of risk assessment models. If the methodology for assessing site-wide risks, which is being developed for the Hanford Strategic Analysis described in the previous section, were applied to the macroengineering approach, then it could be compared directly to other remedial options.

2.4.4 Science and Technology Assessments

Over the past several years, WHC and PNL have done several assessments of science and technology needs for environmental management, some specifically as they relate to decision tools. The science and technology assessments that have been done so far tend to have a narrow, rather than a site-wide, perspective. These assessments have usually not been focused on answering questions oriented toward Site-level decisions. They have tended either to focus on the technologies associated with a single mission area or a single environmental medium at a time, or on very specific data needs related to these two aspects of the environmental management mission at Hanford. Usually, they have not focused on the relative impact of activities in one mission area (or environmental medium) on other mission areas (or environmental media). They have tended to focus on what is not known rather than what is known, and usually have not taken the view of how existing decision tools or data can be used more effectively to answer cross-cutting environmental management questions.

The Hanford Integrated Planning Process is taking a site-wide, rather than a narrow, approach to dealing with environmental management issues. The needs for science and technology developments in one mission area will be evaluated against the needs in another area based on an assessment of baseline risk, expected technical performance, risk reduction, cost, and ability to meet schedules. Decision support tools will be required in order to assess science and technology needs and evaluate the trade-offs among performance, risk reduction, cost, and schedule. Therefore, the same types of decision tools that are needed to evaluate environmental management options are also needed to evaluate the science and technologies needed for these options.

Some of the past science and technology needs assessments are described below for an historical perspective.

Performance Assessment Technology Development for Cleanup and Disposal of Hanford Defense Wastes

This report (WHC 1988) presents a strategy for identifying, adapting, improving, and using the technology needed to evaluate the long-term environmental consequences of actions proposed for Hanford cleanup. The objective of this strategy is to advance the technology sufficiently to do the analyses identified by the final EIS for disposal of Hanford Site defense wastes (DOE 1987). This report recommends developing computer-based mathematical models and a database suitable for simulating performance of the proposed waste remediation and disposal systems with adequate confidence. Also included is the description of work needed to address each performance assessment issue. Plans are included for assigning waste form and barrier functions and allocating associated performance goals and required confidences. By this means, in conjunction with marginal utility cost-benefit analyses specific to each waste-form remediation and disposal program, the comparative merits of alternative designs can be evaluated. Site characterization or materials test data that may be needed can also be identified.

Hanford Site Environmental Restoration and Waste Management Technology Plan for the Calendar Year 1990

Descriptions of individual technical issues presented in this report (Anantatmula 1990) underscore the need for performance assessments (PAs) and risk assessments (RAs) in resolving technical issues. A credible evaluation of the effects on the environment of actions proposed for disposal of Hanford defense wastes is required to ensure that the incidence of adverse health effects does not exceed the limits defined in the regulations and complies with applicable regulations. Additional impetus is derived from CERCLA and RCRA requirements to perform RAs on each operable unit during the RI/FS or RFI/CMS.

Assessments will be made on the basis of models; they will include the overall site-wide performance of the disposal of wastes. The technology required to perform these assessments in an integrated fashion is discussed.

Hanford Science and Technology Program

This document was prepared in response to an October 4, 1990, request from RL to PNL to develop a proposal for a Science and Technology Program supporting the Hanford Site's environmental mission.[a] The document describes the purpose, need, and approach for involving national laboratories in Hanford's planning, science, and technology development activities. The Hanford Integrated Planning Project is an outgrowth of this document. The scope of the tools development task, which is the antecedent of the Hanford Integrated Planning Project Decision Support Tools Task, had the following scope:

(a) Pacific Northwest Laboratory. 1990. Hanford Science and Technology Program. Hanford Site distribution.

- Performance assessment – A variety of performance and exposure assessment analyses have been conducted for various purposes at the Hanford Site (e.g., DOE Site Survey, PUREX Restart EIS, Hanford Defense Waste EIS, Surplus Production Reactors EIS, Grout Performance Assessment). From these specific analyses and from a review of regulatory and institutional requirements (i.e., under RCRA, CERCLA, SARA, and TPA), a comprehensive picture of Hanford Site performance assessment needs will be developed. This subtask will determine the levels of modeling sophistication and detail required to obtain a baseline (no-action) analysis of the Hanford Site and analyses of specific operable units, aggregate area management units, or remediation technologies. Based on these analyses, a comprehensive plan for performance and exposure assessment technology tools would be produced.

- Risk/safety assessment – Although Hanford waste operations contractors are preparing Preliminary Safety Analysis reports and Final Safety Analysis reports for waste processing and retrieval operations, safety analyses are not well developed for the non-operations ER/WM functions. The possible accident scenarios and their probability of occurrence for developing and applying various ER/WM technologies have not been developed. However, once such scenarios have been developed, the risk and safety analysis techniques for probabilistic risk assessment can be used to assess the significance of accident scenarios. The performance assessment estimate near-term affects workers and the public associated with alternative options or strategies being considered within the integration and priority-setting process.

- Cost/analysis – Assessments of costs and benefits are important inputs to integration and priority-setting activities. A need exists to develop generic cost analysis tools, approaches, and data. Generic tools and controlled data would be desirable to permit benchmarking and site-to-site comparisons, and to enhance the credibility of the integration and priority-setting activities.

Preliminary Performance Assessment Strategy for Single-Shell Tank Waste Disposal

Recently, Sonnichsen (1991) published a performance assessment strategy for disposal alternatives for wastes from single-shell tanks at the Hanford Site. A comprehensive program to dispose of single-shell tank wastes in compliance with applicable laws and regulations has been initiated. Different disposal alternatives will be considered; the performance of each disposal alternative will be evaluated with numerical models. A set of 16 waste-disposal alternatives has been defined and is currently under review as part of a systems engineering evaluation. This list will be reduced by a screening analysis, and the performance of the reduced list will be evaluated and documented in a supplemental EIS to the Hanford Defense Waste Environmental Impact Statement. Sonnichsen (1991) presents a strategy for conducting these analyses, including the computer codes, conceptual models, and scenarios.

A brief evaluation of the proposed codes, including description, operational status on Hanford Site computer systems, testing and documentation, and data needs are summarized in an appendix of the report. Specifically, the UNSAT-H code (Fayer and Gee 1985) is planned for evaluation of the air-soil-water balance at the land surface to predict recharge. Characterization of releases from the single-shell tank wastes will be determined by laboratory studies. MINTEQ (Felmy, Girvin, and Jenne 1984) and EQ3/EQ6 (Wolery and Davler 1989) are planned for evaluation of the effects of varying chemistry on transport of contaminants in the unsaturated zone. Laboratory studies will also be used to determine transport properties of the different contaminants. The VAM2DH (Huyakorn et al. 1988) and PORFLO-3 (Sagar and Runchal 1990) codes are planned for modeling flow and transport of contaminants from the single-shell tanks in the unsaturated zone. The VTT (Reisenauer 1979) and CFEST (Gupta et al. 1982) codes are planned for analysis of flow and transport in the saturated zone (ground water).

2.5 HANFORD SITE INFRASTRUCTURE AND COORDINATION ACTIVITIES

In parallel with the environmental restoration programmatic planning, there are planning activities that relate to the long-term functioning of the Hanford Site. These activities provide the infrastructure platform upon which the programmatic efforts must be performed. Also, in a few cross-cutting areas, committees exist at Hanford that attempt to coordinate technical approaches. The planning activities that affect the Decision Support Tools Task are listed below:

- Hanford Information Resource Management: An Architecture for the 1990s – This document (DOE/RL 1989) provides a direction for information management development and the framework within which it will be implemented between now and the year 2000. Update of this document will begin soon.

- Hanford Information Technology Resources Long-Range Site Plan – This plan (DOE/RL 1991g) constitutes a strategy for Hanford Site computing and telecommunications. It is updated annually and includes infrastructure needs. The team responsible for the maintenance of the plan must be kept informed of current and future definition of tool requirements and developments, as typified by the Hanford Integrated Planning Decision Support Tools Task.

- Hanford Environmental Dose Overview Panel – The Hanford Environmental Dose Overview Panel (HEDOP) is the technical representative for RL for matters related to environmental and health dose assessments of operations and facilities on the Hanford Site. Environmental and health dose assessments may include 1) the use of various types of models to project the environmental transport of potentially harmful materials, 2) the development of exposure and/or dose estimates, and 3) application of health risk conversion factors. The purposes of the Panel are to ensure that appropriate radiological and nonradiological environmental and health dose assessment methods are used at Hanford, that all Hanford-related environmental and health dose assessments are technically consistent, and that Hanford contractors communicate among themselves regarding environmental and health dose assessments. Besides ensuring that all applicable environmental and health dose assessments are reviewed for technical consistency, HEDOP also reviews and approves methods (e.g., computer codes and the associated input parameters) that may used routinely to conduct environmental and health dose assessments, establishes an *ad hoc* working group to address specific issues, and approves individuals to serve as Panel-Approved Reviewers.

- Exposure Information Steering Committee – The Exposure Information Steering Committee (EISC) is established, by the agreement of RL and the Hanford contractors, to provide guidance, direction, development, and information for multi-contractor cooperation in implementing an occupational health and exposure information management system. The purpose is to develop an integrated occupational health and exposure information management system that will provide assistance to the Hanford Contractors, with the capability

  - to detect and minimize health risk occurrences at the Hanford Site
  - to promote the health and safety of employees
  - to improve compliance with applicable laws, regulations, and directives
  - to reduce cost by developing common systems for the Hanford Site, thus reducing redundance of data, hardware, software, and processing.

EISC will define the strategic approach and direction for a comprehensive and uniform program for occupational health and exposure information development and management for DOE activities at Hanford. The program will address integration and development of appropriate employee exposure records, employee medical records, and interaction of appropriate information sources and exposure controls and data.

3.0 GENERAL ASSESSMENT OF DECISION SUPPORT TOOLS

This section contains descriptions of decision support tools ranging from general and higher-level management decision tools to more technically oriented media-specific tools and data. Section 3.1 describes how the decision support tools fit together; Section 3.2 describes management decision support tools, performance and risk assessment models, information management systems, and data.

The Decision Support Tools Task was concentrated on identifying decision support tools available at the Hanford Site, as well as gaps or issues. These are discussed throughout and are summarized in Section 5.0 of this report. Later, decision support tools from elsewhere (e.g., other DOE sites, private industry) will be evaluated for applications at the Hanford Site, and more specific deficiencies in decision support tools will be identified.

3.1 HOW DECISION SUPPORT TOOLS FIT TOGETHER

Figure 3.1 shows in a general way how different decision support tools may be used together to aid decision-making in environmental management at the Hanford Site. The tools needed include management decision support tools and performance and risk assessment models and tools.

A major issue that has to be addressed in evaluating options, i.e., the risk to human health or the environment, can reval how the decision support tools can be used together. The physical characteristics of the problem include material balances, environmental data, and technology performance; the physical pathways include air, water (surface and ground), and direct contact; the exposure pathways include breathing, eating, drinking, and dermal contact. Dose and dose response refer to the contaminant, intake, amount or concentration, length of exposure, and biological effects.

However, not all of these decision support tools will be applied together in all cases, as some of the following applications of the tools show; they can be applied singly or together:

- Management decision support tools often require input derived from other models or input accessed using information management systems.

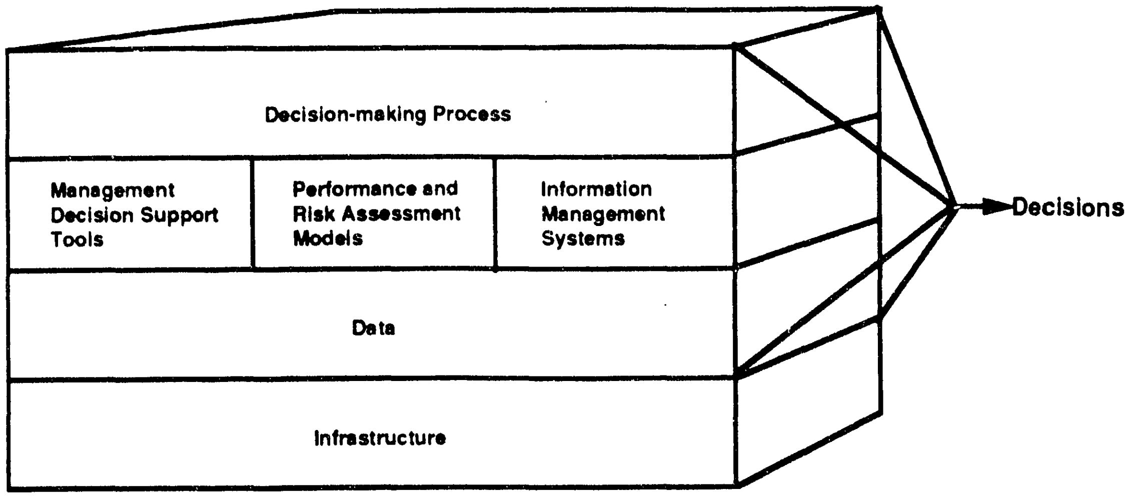


FIGURE 3.1. Tools that Support Hanford Site Decisions

- When no direct measurements are available, or when direct measurements are not applicable due to temporal or spatial discrepancies, source-term release models provide contaminant release rates for environmental transport models.
- Environmental transport models are often applied to predict concentrations in the environment to locations of human or ecological uptake and travel times to predict human health or ecological risk.
- Performance assessment models provide input to decisions without predicting risk.
- Information management systems can be used to access databases and provide summary information or specific data used to calibrate and/or validate environmental transport models.

A number of issues are associated with how decision support tools can be combined for specific applications. Although most issues are specific to the individual tools being combined, some common issues have been identified: transferring information between tools, modifying tools to obtain intermediate results useful for decisions, and managing results from multiple model applications.

Transfer of results or information from one decision support tool (model or database) to another is generally difficult and labor-intensive. The difficulties are typically caused by decision support tools from different computer systems or tools not being designed to be used with other tools.

This issue can be resolved by providing a coupling function to overlay existing codes and by developing new codes that can be easily coupled with other tools.

Producing intermediate results may require modifying an existing code. Codes and models are generally designed for specific applications. In some cases, intermediate results from a model are as useful as the final output from a code. In a code designed for conducting a risk assessment, such as MEPAS, the final output is expressed as a risk indicator. However, the predicted environmental concentrations may be of interest for model calibration or for comparison with regulatory limits. Modifying codes to produce intermediate results can be cumbersome. This issue can be resolved by modifying the model itself, coupling the model to another model, or capturing the output that needs to be transferred.

Some applications of models require multiple simulations of a computer model. Results from multiple applications of performance and risk assessment models can be cumbersome to manage. Information management systems can be designed to assist with managing large volumes of output from computer models and rapidly accessing the results for further processing and visualization.

3.2 GENERAL APPROACHES

There are several general approaches that are useful in making decisions, but are less specific in their purpose than most tools reported in this document. These can be used in combination with specific tools.

3.2.1 The Observational Approach

The observational approach was first investigated by DOE in 1989 as a method to help streamline the RI/FS efforts. The DOE has endorsed the use of the method in the 1990 Five-Year Plan (DOE 1990c). EPA has similarly endorsed streamlining concepts equivalent to the observation approach in OSWER Directive 9355.3-06 (EPA 1989). Presentations, implementation guidance, and site-specific applications were conducted at a majority of installations. The potential benefits of conducting remediation efforts using the observational approach framework include:

- inherent "bias for action"
- integration of the characterization and remediation phases of the project
- a proactive, responsive technical product
- enhanced protection of human health and the environment
- reduced time to begin remediation
- use of decision tools for maximum effectiveness.

EM and EH are currently pursuing the integration DQOs (Section 3.5.2) into the observational approach framework.

The tools discussed in this document can be used in conjunction with the observational approach to better implement waste site characterization and remediation. Logic diagrams can be used to identify critical decisions and tasks. Models can help design a conceptual model, identify probable conditions, and assess impacts of deviation occurrences. DQOs can help identify data needs and develop a sample plan that can meet these needs to obtain data sufficiency.

The observational approach can help site managers plan characterization and remediation activities under RCRA Corrective Action or CERCLA. Application of the method has occurred at two National Priorities List sites: the Whittier Narrows ground-water operable unit in Southern California and the Weldon Spring Site Remedial Action Project which is a quarry excavation. Both have completed the FS phase of the process. Los Alamos National Laboratory is using the observation approach framework to streamline corrective actions. Oak Ridge National Laboratory is using the approach to help plan remedial activities at their waste area groups. Several other DOE installations are beginning to use the approach or the principles to plan remediation effectively.

3.2.2 Decision Analysis

Decision analysis tools assist the decision-maker in taking output from technical tools and using this output to make selections among alternatives. Decision analysis is required for risk management: selecting an acceptable level of human health risk, considering all other aspects of the problem such as cost, schedule, ecological risk, and technological risk. Decision analysis can also help make risk trade-offs, answering questions such as: "Is it worth it to increase remediation worker exposure now, for a lower level of population exposure in the future?"

Decision analysis tools are currently being applied to the Hanford Site to look at the tank waste disposal program redefinition (Gryrel et al. 1991). The decision being analyzed is which process/facility option is best for disposing of single- and double-shell tank wastes. The decision process included

- stakeholder involvement to ensure consideration of relevant viewpoints
- technical analysis of options to provide a common and complete basis for comparison of options
- use of multi-attribute utility analysis to link stakeholder input and technical analysis of options and to weight all relevant information.

Deriving weights that assign relative importance to the relevant information is the most controversial and confrontational step. Often, as with the tank waste application, one outcome of the decision analysis process is that strong value differences among stakeholder groups indicate the need for strategies that improve consensus.

Some of the most advanced applications of decision analysis tools have been those developed by the Department of Defense (DoD). The DoD has developed a set of tools for managing high-risk projects (DoD 1986). The risk management method focuses on identifying and controlling areas or events that have the potential of causing unwanted change. Large programs are broken down into activities, and each activity is quantified as to uncertainty of cost, time, and probability of success. Individual activities are assigned an integrated ranking. The program can thus be assigned an overall risk.

There are several commercial decision analysis software packages available for solving decision analysis problems. A comparison of these software packages has recently been completed (Call and Miller 1990).

3.2.3 Decision Simulation

Decision simulation, one step beyond decision analysis, combines traditional decision analysis with simulation to provide a tool that can be used to test the quality of a decision when a limited amount of relevant sampling data is available. The specific application to the Hanford Site was a "leave versus retrieve" decision associated with single-shell tanks (Chamberlain 1991).

The problem addressed by this decision simulation application was whether to leave or retrieve tank contents or to defer the decision until more information became available. The decisions depended on the validity of the probability distributions of contaminant mix and concentration in the tanks. There were insufficient samples to estimate these probability distributions with the level of certainty required by regulatory requirements. Thus, a simulation was used to repeatedly generate core sample sets "similar" to samples obtained from the tanks to understand the spatial variability using data from existing risers. Decision rules were then applied using the simulated data. By simulating all possible conditions and exceptions that represented the full range of costs, schedules, and technical considerations, decision rules were developed that were robust under a wide range of tank contents and concentrations. This information was used to direct future sampling efforts and identify clearly dominant decision rules.

3.2.4 Formal Logic Diagrams

To reliably determine the needs associated with remediating the Hanford Site, a structured approach has been taken to identify questions that need answers and that require applying tools to obtain the answers. This approach could also be used to set priorities for each of the tasks defined in a logic diagram. The formal logic diagram requires input and team work from a variety of disciplines; it yields what has been called a structured logic diagram.

This approach has been used in the nuclear industry and is the subject of a book (Henley and Kumamoto 1981). The formal logic diagram is developed by asking high-level questions, the answers to which define logical pathways toward basic needs. In the logic network, a series of "gates" or connections is used to define success. An illustration of using the approach to define the alternatives to "ensure safe site remediation" is given in Figure 3.2.

3.3 MANAGEMENT DECISION SUPPORT TOOLS

Management decision support tools are used to synthesize information at a high level to assist with making decisions. The key tasks in decision-making (after clearly stating the problem) are identifying alternatives, characterizing the alternatives with respect to a set of attributes, providing a preference function (e.g., priority ranking system, value system) for assigning value to the attributes, and finally ranking alternatives according to their assigned value to select the alternative with the highest value. Attributes such as health risk, ecological risk, cost, and schedule are often considered in environmental restoration problems. Technical considerations (Is the remedy suggested technically feasible? Is there a sound scientific basis for the remedy?) play a part in that it is usually assumed that the suggested alternatives have passed the science and technology review. This is often not the case. Additionally, there is often a trade-off between technical considerations versus cost and schedule - the idea that if enough money is targeted for a problem, any technical problem can be solved. This often is not the case, either. Section 3.3.1 discusses tools that help in evaluating the trade-offs that must be made. Also discussed in this section are generic decision tools that many Hanford contractors have embodied in specific analyses. Section 3.3.2 discusses cost estimation tools, and Section 3.3.3 discusses scheduling tools.

3.3.1 Tools That Can Be Used to Integrate Technical Considerations, Cost, and Schedule

Tools developed at Hanford or commercial decision software that is being used at Hanford can both be used concurrently to examine technical trade-offs, costs, and schedules.

Remedial Action Assessment System

The Remedial Action Assessment System (RAAS) is currently under development by PNL for ER. The RAAS methodology is intended to support feasibility

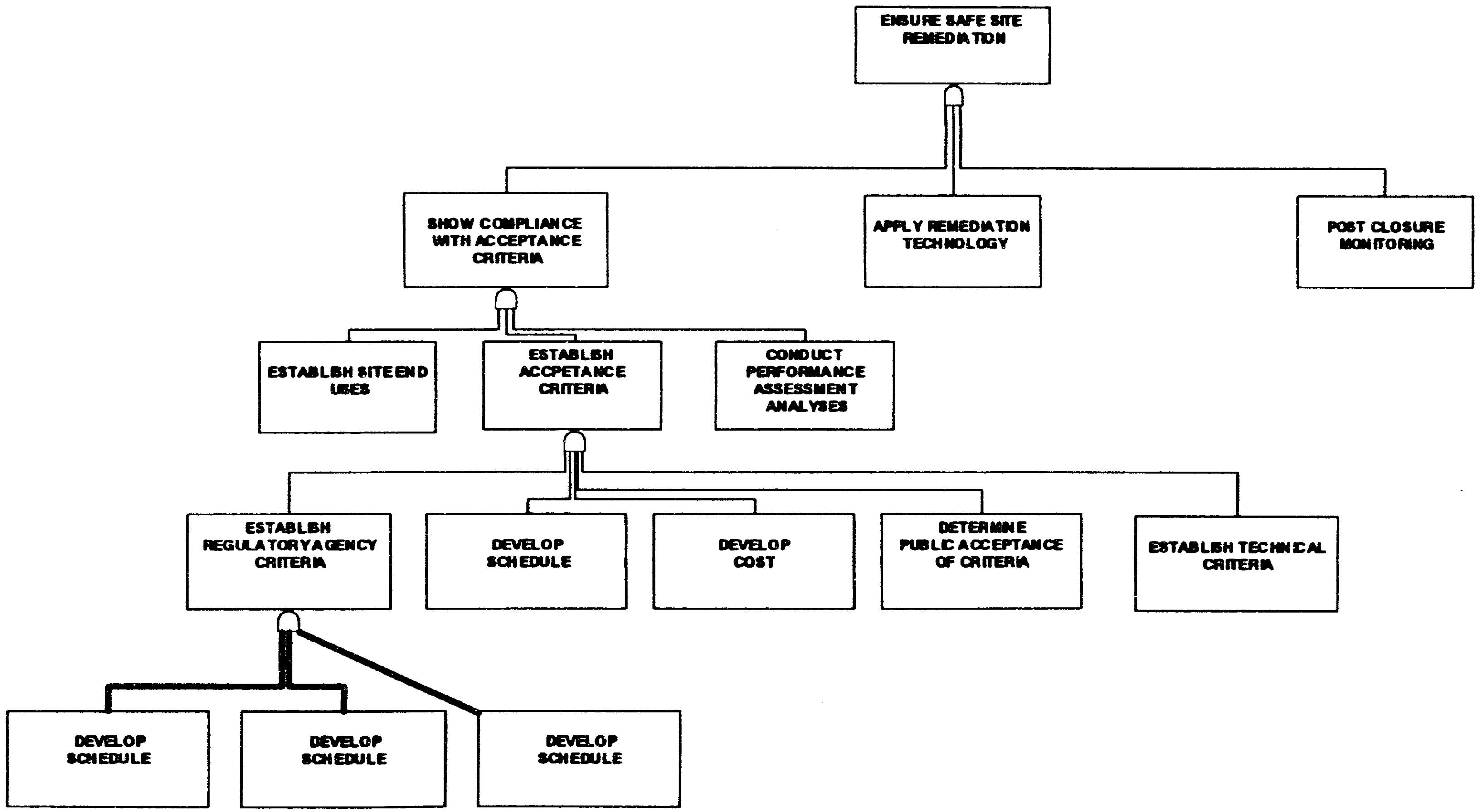


FIGURE 3.2. Formal Logic Diagram to Determine Alternatives to "Ensure Safe Site Remediation"

study activities that are conducted in parallel with site characterization and treatability study activities. It is anticipated that the RAAS methodology will be employed iteratively throughout the development of the RI/FS. Initially, preliminary or engineering judgement data will be used before actual site data is available to allow preliminary consideration of potential general response actions and technologies that might be used for cleanup. These preliminary evaluations will help identify key site or technology information that is required from site characterization and treatability study activities. As the RAAS methodology is successively applied when site characterization and treatability study information becomes available, the identification and evaluation of the general response actions to be included in the record-of-decision can be continuously refined.

The primary RAAS application is a computational tool used to derive and evaluate complete remedial alternatives, and to access and document the reasoning behind the software's construction of these alternatives. The RAAS methodology selects, screens, links, and evaluates remedial alternatives in support of the feasibility studies required for every DOE operable unit. Some of the methodology's features include

- screening and linking of technology unit processes into remedial alternatives
- comparatively evaluating remedial alternatives in terms of established EPA criteria (e.g., risk, cost)
- documenting assumptions and decisions made by the user
- making recommendations for treatability tests and site characterization requirements for streamlining the remedial investigation portion of the RI/FS process
- providing internal consistency checks for input data
- applying an internal risk assessment model to back-calculate cleanup objectives from health-based risk criteria and a data gate for accessing user-selected technology risk assessment model.

The RAAS methodology produces its results using a hybrid system (combination of quantitative models with qualitative reasoning) designed and constructed using object-oriented tools and techniques.

RAAS's development is ongoing, and the initial prototype has been completed that will allow potential users to preview how the full methodology will operate. The current prototype allows the user to describe a location, describe a contaminated site (contaminated medium parameters and contaminants), choose potential responses (containment, removal/treatment/disposal, etc.), determine cleanup objectives, identify potential technologies, and determine the effects of applying those technologies in a remedial action treatment train (complete remedial alternative). Features such as attribute comparisons (i.e., cost, risk, etc.), annotation of user input, and generation of RI/FS documentation have not yet been implemented. Plans for FY 1992 include work to determine how MEPAS can be incorporated into RAAS.

<u>Venture Evaluation Review Technique</u>

Venture Evaluation Review Technique (VERT 2000) is a commercial product (copyrighted by MSW and Associates, 1991) currently used by WHC for programmatic risk management at Hanford. Beginning with a problem, alternative action plans are identified. Activities in each action plan are identified and assigned three values: probability of success, time distribution, and cost distribution. These activities, called ARCs, are linked by nodes. Nodes are decision points and contain the logic structure for the decision (AND, OR, ALL, etc.). The key advantages of VERT over the earlier generation of program planning tools, such as PERT or CPM, is that VERT is stochastic, has enhanced node logic (the user can put in filters or sorts), incorporates inter/intra-arc mathematical relationships (relates the past to the future), and integrates performance, time, and cost. The output of VERT is a list of activities, ranked according to an integrated scale that combines time, cost, and success. VERT provides variability estimates for the individual time, cost, and success rankings, all of which are input to a multi-attribute utility function to get an integrated ranking.

<u>Solid Waste Projection Model</u>

The Solid Waste Projection Model (SWPM), Version 1.0 (DOE 1990d), a tool developed at Hanford, integrates technical considerations with other factors, that can be translated into cost and schedule requirements, such as waste storage, treatment, and disposal capacity, thus providing a tool that can be used for waste management decision-making. SWPM provides the ability to

- develop detailed projections of the volumes of wastes to be managed and the characteristics of these wastes
- characterize and evaluate the impact of alternative treatment, storage, and disposal (TSD) technologies on facilities and operations
- assess the impact upon TSD cost and capacity requirements when waste volumes or waste characteristics vary
- track actual versus projected quantities of wastes, for evaluating waste volume-reduction activities.

Version 2.0 will be available during FY 1993.

3.3.2 Cost Estimation Tools

A variety of groups at WHC are doing cost estimation for the Hanford Site remediation activities. The methods used have been based on previous work using a unit cost approach that can be dealt with using a spreadsheet.

What would help most immediately is a database of standard component costs that everyone could use for estimating the cost of remediation alternatives. The standard will provide comparability to the basis for cost estimates.

Hanford Site Cost Models

Costing packages currently used at the Hanford Site consist of various spreadsheets and databases that contain unit costs (e.g., cost to drill a ground-water monitoring well, cost to move 1 ft^3 of soil) which get extended by the units of work required to accomplish a job (e.g., number of wells required, number of cubic feet of soil) to arrive at a total cost.

A more standard costing system is currently being implemented by RL.[a] All Hanford Site contractors have been told to implement a management control system (MCS) for TPA activities by October 1991. The TPA milestones are to be

(a) Letter dated May 16, 1991. J. Wagoner to C. Gregoire and D. A. Rasmussen. "Hanford Federal Facility Agreement and Consent Order Change Packages." U.S. Department of Energy, Richland Operations, Richland, Washington.

planned, controlled, and managed within the MCS. Specific work-scope elements for each milestone are to be identified and maintained in the work breakdown structure for MCS. Cost is to be collected and reported by major milestone based on the identification of TPA milestones within the work breakdown structure. A working group of EPA, Ecology, RL, and WHC staff will be established to review milestone cost and schedule status, ensure that any changes to milestone designation in the ADS are incorporated in the TPA-MCS baseline, and establish a DOE certification of progress for meeting milestones. The MCS is currently being implemented and should be operational by late 1992.

Cost of Remedial Action Model

The need to accurately estimate hazardous waste cleanup costs has led to the development of several computerized cost-estimating tools and models. The development of these tools has been sponsored by EPA or DOE, and increasingly by private industry. A good catalog of computerized environmental restoration cost-estimating tools has been published (DOE 1990b). The report categorizes the tools that have been developed:

- estimation stage – order-of-magnitude, intermediate (budget), and definitive
- environmental restoration stage – RI/FS, remedial design/remedial action
- underlying methodology – detailed method[a], parametric approach[b]
- contaminants addressed – hazardous chemical, mixed chemical.

Developed by EPA and routinely used by EPA at Superfund sites, the Cost of Remedial Action (CORA) Model is the most widely used cost-estimating tool in the field. CORA serves as the industry benchmark against which other cost-estimating tools are judged. CORA contains both a technology system and a cost estimation system.

(a) Knowledge is captured in a unit cost database with procedural methods for aggregating the component costs. The report gives references for commonly used and commercially available unit cost databases.
(b) Expertise is embedded in the models and the relationships established with historical data.

Micro-Computer-Aided Cost Engineering Support Systems

The COE developed Micro-Computer-Aided Cost Engineering Support Systems (M-CACES) and the mainframe version as a detailed bottoms-up construction-cost estimating tool, typically applied to heavy civil engineering projects. The COE is in the process of building an environmental restoration unit cost library so that both codes can be used for hazardous waste clean-up projects.

Future Development

The DOE needs to invest resources to validate current and future tools. So far, of all the costing models reviewed in the report referenced above, only CORA has been validated (12 out of 12 sites fell within the acceptable range of -30% to +50% when CORA estimates were compared to actual costs). The DOE also needs to build unit cost databases for both the mixed and radioactive waste areas.

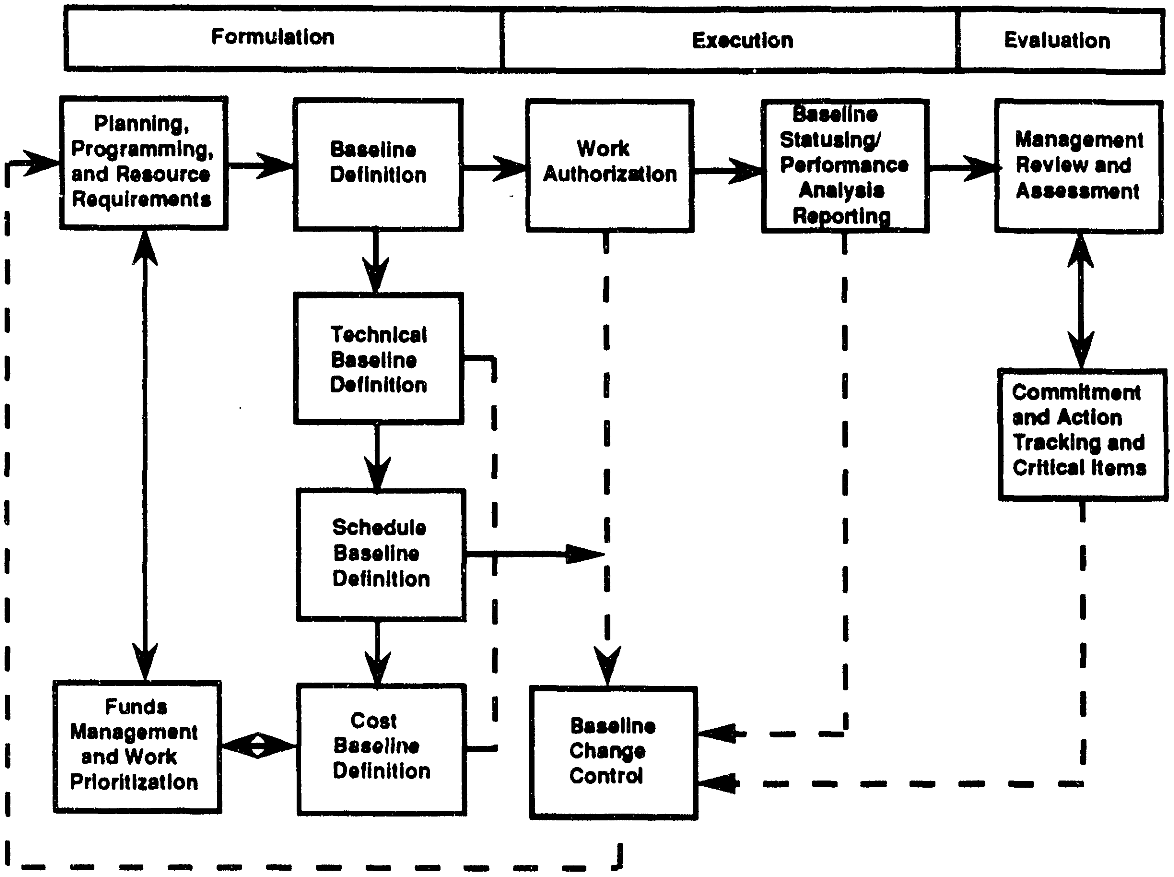
3.3.3 Scheduling Tools

A variety of scheduling tools are used at the Hanford Site by the various contractors. Tools currently in use include commercial scheduling programs (such as VERT), user-generated spreadsheets, and time-line charts. Efforts are being made to standardize the scheduling of environmental restoration projects at Hanford and incorporate costs into the progress.

RL is establishing the Site Management System (SMS) as the central system for planning and executing programs (DOE/RL 1991d). The management approach embodied by the SMS is characterized by the control of approved program baselines that provide a standard against which accomplishments, progress, and expenditures are measured and programs are controlled. All RL program/project participants have been instructed to use the SMS management approach for program/project formulation, execution, and evaluation. Figure 3.3 is a schematic of the RL Site Management System Architecture.

3.4 PERFORMANCE AND RISK ASSESSMENT MODELS

Risk and performance assessment models include capabilities for evaluating release from sources and transport through different environmental media and exposure pathways to reach humans (Figure 3.4). The air, surface-water,



Program/Project Formulation	Program/Project Execution	Program/Project Evaluation
Outputs: • Site planning documentation • Program/project planning documentation • Baseline data • Budget documentation	*Outputs:* • RL program guidance and work plans • RL projects guidance and work plans • Site baseline change requests • Site baseline monthly status reports • MSA Reports	*Outputs:* • Programs/projects status reports and reviews • RL and contractors commitment control reports

FIGURE 3.3. Site Management System Architecture

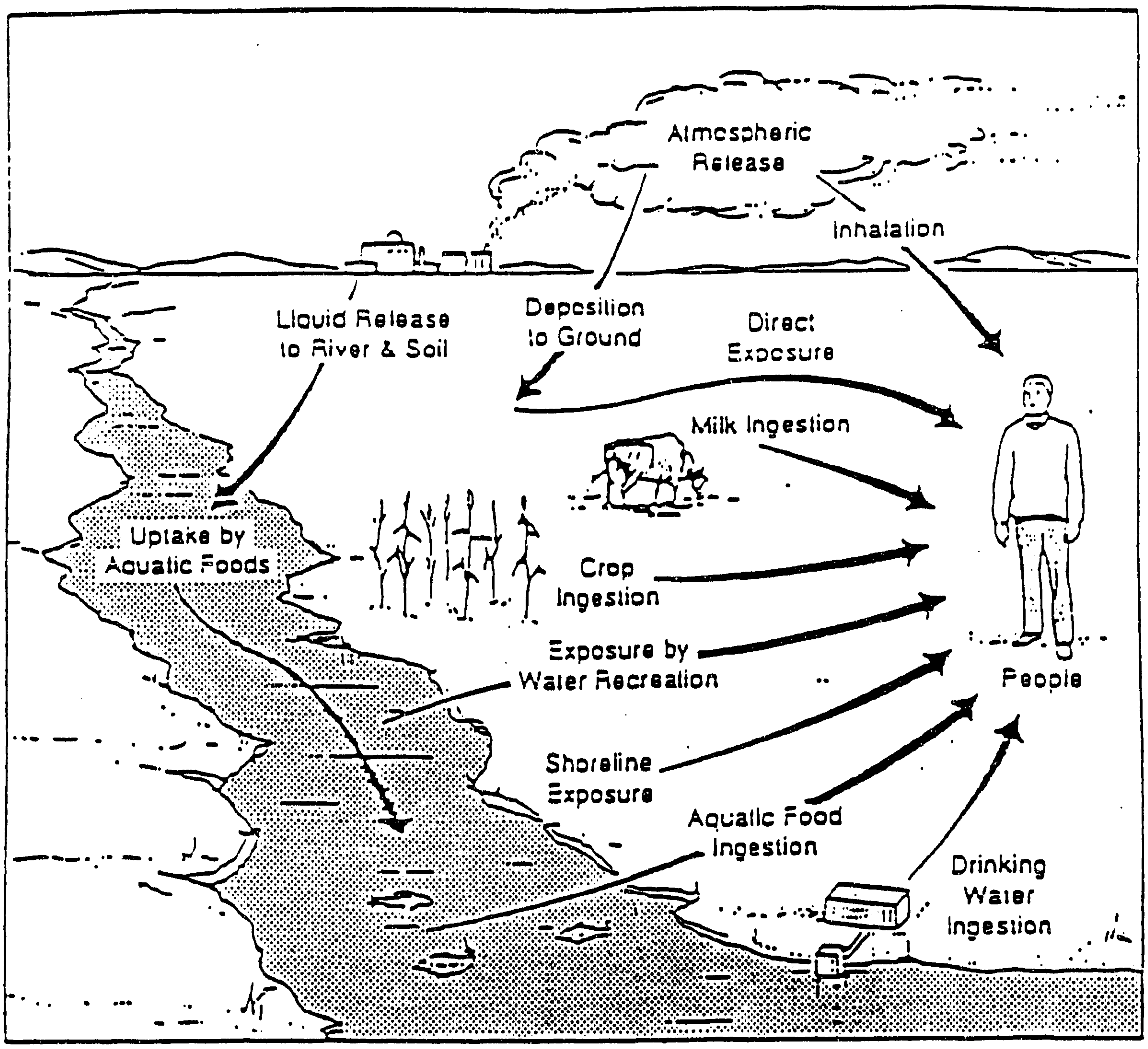


FIGURE 3.4. Environmental Exposure Pathways for the Hanford Site

ground-water, and unsaturated zone pathways may be important for evaluating risks from contamination and remedial actions planned at the Hanford Site. The release models are combined with the environmental pathway models and exposure pathway models to assess the risks from existing contamination or remedial actions. Any of the individual models can be used separately to address aspects of the different components of the problem.

It will be necessary to demonstrate to regulatory agencies, the general public, and other stakeholders the effectiveness of waste management and environmental restoration options proposed for each major activity at the Site. In most cases, options can be demonstrated by applying source-term release environmental transport, exposure assessment, and risk assessment models either by themselves or in sequence. Models must rely on information derived from measured data.

Combination of source-term release, transport, and environmental pathway models is termed "pathway modeling" and is required in the CERCLA regulations as part of a baseline risk assessment for hazardous waste sites. Figure 3.5 illustrates the required activities and how these activities are interrelated. Data is input to models, and higher-level information is produced in the form of model results. The areas where models are used include process and operations, environmental and biosphere transport, and exposure.

Source-term release models may include source-term inventory models used to estimate inventories in waste sites or storage facilities, such as the single- and double-shell tanks, and geochemical models used to predict release from different waste forms. Source-term release models are also used to estimate quantities of contaminants released from a waste site so that transport through the environment can occur. Environmental transport models include capabilities to predict transport in the atmosphere, surface water, unsaturated zone between the ground-surface and water table, and ground water. Often, in conducting exposure and risk assessments, these different pathways must be linked. Environmental pathway models include models for predicting transport through the biosphere (plants and animals) by different exposure pathways to humans by routes of ingestion, inhalation, and absorption. Health risk assessment models are generally combined with exposure assessment models and other information to estimate the risk of exposure to chemicals and radionuclides. Models to predict ecological effects or ecological risks may be derived, in part, from the human exposure models because they provide constituent concentrations in various ecosystem components as intermediate steps in predicting human health impacts. However, different end-points may be needed.

Existing codes for environmental transport and environmental pathways vary in complexity from models appropriate for screening different sites or remedial alternatives to models of detailed physical and chemical processes. The complexity of the model used must be consistent with the technical requirements of its intended application to support a decision and the amount of data available. Simple models can be based on analytical solutions or

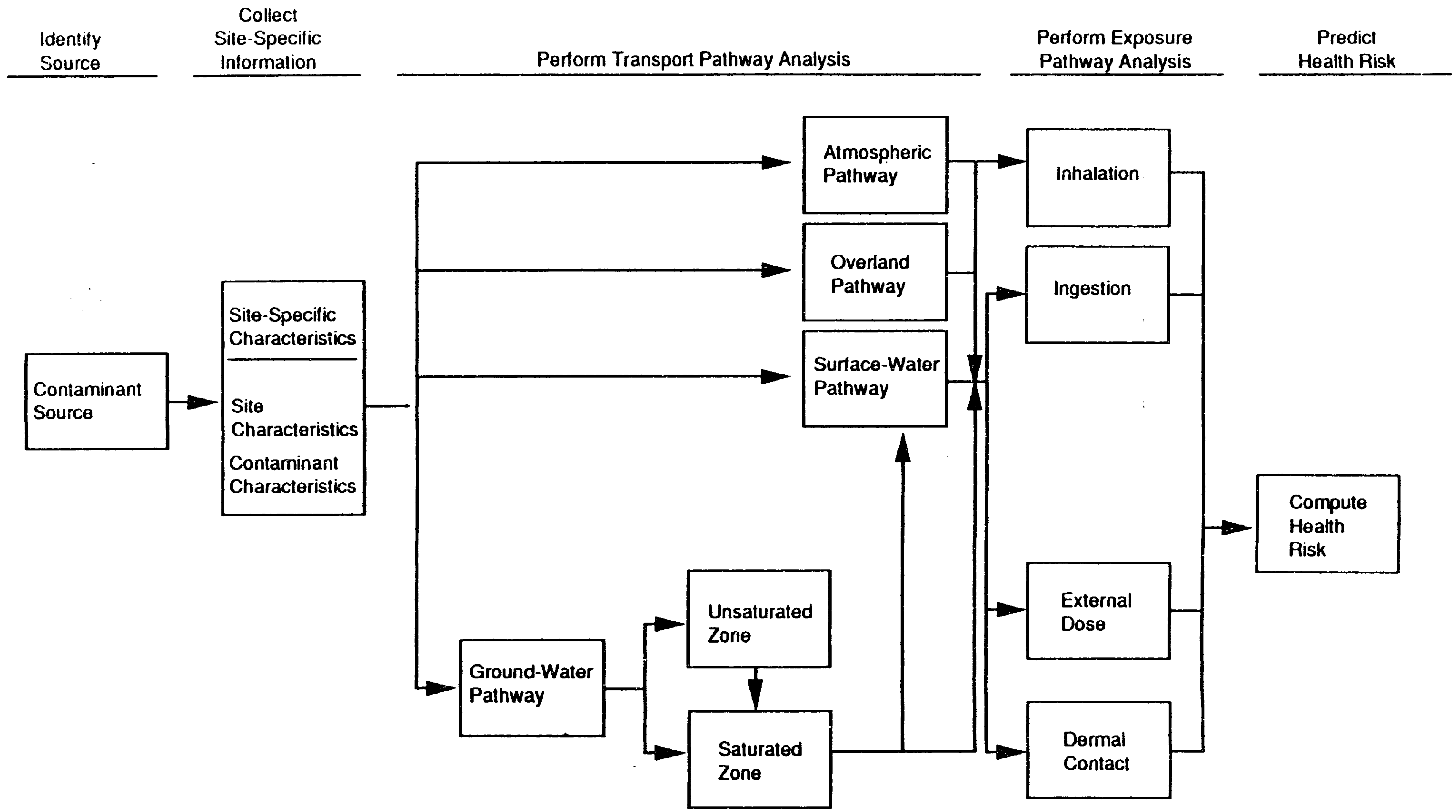


FIGURE 3.5. Steps in a Source-to-Receptor Analysis and Their Interrelationships

simple numerical codes that can be implemented on personal computers. More complex models require specialized solution methods and larger computers for implementation. The following categories of models are used:

- source-term inventory
- source-term release
- subsurface flow and transport – unsaturated-zone, ground-water, and surface-water pathways
- surface water
- airborne transport
- environmental pathways
- health risk assessment – worker and general population.

Quality assurance characteristics of codes described in the following sections are summarized in Appendix C, which includes information on the codes' design documentation, users' manuals, verification/benchmarking, and validation.

3.4.1 Source-Term Inventory Models

Source-term inventory models are used to simulate material flow and the physical processes in production facilities. In general, no process codes exist for design of and use in chemical processing plants at Hanford. Although several commercial codes are available, most, if not all, are designed for use with organics and do not work well when applied to inorganic chemical processes. These codes are summarized in Table 3.1.

Three codes have been used and are receiving attention during this fiscal year. Of these, ASPEN is a commercially available code for performing mass balance calculation. The code SEPHIS has been used for calculation mass balances for processing plants in which solvent extraction is carried out. The code PREDICT was developed to calculate the effect on solutions by use of the crystal evaporators.

ASPEN

ASPEN (ASPEN PLUS, Aspen Technology, Cambridge, MA) is a commercially available code that was developed with sufficient flexibility that it might be

TABLE 3.1. Summary of Capabilities for Source-Term Inventory Models

Code	Application: Material Balance	Application: Radioisotope Decay	Application: Radioisotope Generation	Purpose
ASPEN	x			calculates material balances in process plants
SEPHIS	x			calculates material balances in solvent extraction processes
PREDICT	x			calculates the concentration of solutions processed through Hanford evaporators

applicable to the chemical processes at Hanford. This process-oriented, mass-balance code has been applied to single-shell tank system studies and may in the future find a role in material balance calculations for Hanford process plants.

SEPHIS

Mass balance calculations for the processing plants at Hanford are usually done by "hand," or a code specific to that plant is used, e.g., PUREXNEW (Allen 1991). At the Plutonium-Uranium Extraction (PUREX) Plant, a code developed in-house is used, and a portion of this code incorporates the SEPHIS code (Richardson and Swanson 1975). The SEPHIS code was developed at Oak Ridge National Laboratory for calculating mass balances through ion exchange columns. This code has been adapted for use on the solvent extraction columns at PUREX.

PREDICT

The PREDICT code (Allison 1984) was developed for use at crystallizer-evaporators. This code can be used to determine the effect on a solution that enters the evaporator and has been processed there. However, only six of the main solution constituents are currently in the database and, hence, PREDICT has limited utility.

3.4.2 Source-Term Release Models

Source-term release models are used to estimate inventories and predict releases of contaminants from waste forms. Several codes exist for use in calculating the chemistry of the waste streams at Hanford. These are summarized in Table 3.2.

Three codes, PROCHEM, EQ3/6, and MINTEQ, are used for essentially the same purpose, i.e., to calculate the chemical speciation of aqueous solutions and determine the saturation state of that solution with respect to solid phases. One of the release models is embodied in the TRAC code to determine the pathway of chemicals through the Hanford waste tank system. The ORIGEN code was used to calculate the decay and growth of radioisotopes in a radio-decay scheme.

Of these, the best known is the TRAC code (Jungfleisch 1984), written to follow the waste from each chemical processing plant at Hanford through the waste tanks to the cribs and other discharges. Developers planned for this code to be used to calculate the contents of the Hanford waste tanks. However, several computational conveniences gave rise to inaccuracies in the calculated contents of the waste tanks. For example, because the organic complexants represented a chemical of unknown behavior in the Hanford waste system, the organic fraction in a waste being pumped from a tank was allowed to be transferred and also to remain behind. This inaccuracy has caused unresolved questions concerning the content of tanks such as BY-104, which has been calculated to contain ferrocyanide, while at the same time doubling the calculated organic inventory according to results from the TRAC code. Analyses of tank BY-104 samples need to be performed to determine the actual organic and ferrocyanide inventories.

TRAC

The TRAC code (Jungfleisch 1984) has not been used since 1985. Since the code was written for use on a CYBER computer, TRAC needs to be updated and modified to correct shortcomings, including the use of an old version of the ORIGEN code (Croff 1980), and the chemistry of organics. To make TRAC yield more accurate waste compositions, more accuracy must be included in the chemical database and the chemical mass balance equations in TRAC.

TABLE 3.2. Summary of Capabilities for Source-Term Release Models

Code	Application					Purpose
	Material Balance	Radioisotope Decay	Radioisotope Generation	Chemical Speciation	Saturation Indication	
TRAC	x	x	x			tracks radio-chemicals through the Hanford waste tank system
ORIGEN		x	x			calculates the decay and ingrowth of radioisotopes in a decay scheme
EQ3/6	x			x	x	calculates chemical equilibrium and speciation; includes kinetic calculations
PROCHEM	x			x	x	calculates chemical equilibrium and speciation code
MINTEQ	x			x	x	calculates chemical equilibrium and speciation

ORIGEN

The ORIGEN code (Croff 1980) has been used for a number of years to calculate the radionuclide composition of the waste resulting from the fission of nuclear fuel and the time evolution of that fission product mix or of an input isotope mix. This code continues to be the reference code for such calculations.

PROCHEM, EQ3/6, and MINTEQ

Other codes used (or with potential to be used) to calculate the chemical species from the gross chemical composition are the PROCHEM (ULI Systems, Morris Plaines, NJ), EQ3/6 (Wolery and Davler 1989; Wolery 1983), and MINTEQ (Peterson et al. 1987) codes. These codes are speciation and equilibrium codes. Given the gross composition of a solution, the individual chemical species, including aqueous soluble organics, can be calculated. For instance, if a solution contains calcium, the codes can be used to calculate the concentrations of Ca^{2+}, $CaCO_3$, and $CaOH^-$ in solution, subject to constraints of the solution composition. These codes have associated databases containing information on more than 500 chemical species. However, these databases may not contain all the information needed to perform an accurate calculation on Hanford wastes. Because of the limited associated thermodynamic database internal to the code for highly saline solutions, these codes have limited applicability to the wastes at Hanford.

Analytical Respiratory Source-Term Code

The Analytical Respiratory Source-Term computer code, AREST, implements a model of the near-field performance (up to 10 meters) of waste packages in a deep geological repository for high-level radioactive wastes (e.g., spent nuclear fuel from commercial reactors). The code models corrosion of the waste package containers and, if the container fails, simulates the release of radionuclides to the environment. Release estimates for individual waste packages are integrated with respect to a sequence of waste package failure times to produce a time-dependent estimate of total repository release (Liebetrau et al. 1987).

AREST uses detailed support codes such as ORIGEN to calculate release inventories, EQ3/6 to determine chemical and radionuclide transport, and TEMPEST to calculate temperature profiles for each simulated waste package.

3.4.3 Subsurface Flow and Transport Models

A variety of different models for simulating flow and transport in both the unsaturated zone and ground water exist at the Hanford Site. In this section, a historical perspective of these models is presented, followed by a discussion of issues associated with the different models. A summary is presented in Table 3.3.

UNSAT-H

Codes for simulating flow and transport in the unsaturated zone have been applied at the Hanford Site for a number of years. The UNSAT-H code was developed to simulate water flow in the unsaturated zone in one dimension (Fayer and Gee 1985). It has been applied to evaluate water balance near the land surface within the root zone of vegetation and to evaluate the effects of barriers over waste sites. The water-balance simulations provide estimates of water drainage below the root zone of vegetation, which becomes recharge to the unsaturated zone. The UNSAT-H code is operational on computers at the Hanford Site and is under active configuration management.

TRANSS

Transport calculations for radionuclides evaluated for the Hanford Defense Waste EIS and other waste-site evaluations were based on the TRANSS code (Simmons, Kincaid, and Reisenauer 1986). TRANSS is a simplified code that describes radionuclide transport along streamlines based on analytical solutions of the advection-dispersion equation. The analytical solutions along each streamline are combined in a streamtube. Thus, transverse dispersion associated with contaminant movement is not included in the solutions, although defining a streamtube of finite width accounts for transverse spreading of a contaminant plume. Longitudinal dispersion is accounted for explicitly in the code. The code is capable of simulating the release of contaminants from sources in the unsaturated zone and either predicting contaminant mass transfer to the river or to a well downgradient of the waste site. The flow component for the TRANSS code in the Hanford Defense

TABLE 3.3. Summary of Capabilities for Subsurface Flow and Transport Codes

	Application					
Code	Saturated Flow	Unsaturated Flow	Multiphase Flow/Transport	Contaminant Transport	Heat Transport	Purpose
UNSAT-H		x				quantify air-soil-water balance to estimate recharge in arid environments
TRANSS				x		simulate contaminant migration assuming one-dimensional transport along a streamline
TRACR3D	x	x	x			simulate saturated and unsaturated flow and contaminant transport in 2- and 3-dimensions
S301				x		simulate contaminant transport in 2- and 3-dimensions based on a flow field from a different code
PORFLO-3	x	x	x		x	simulate flow and contaminant transport in variably saturated porous and fractured media in 2- and 3-dimensions

TABLE 3.3. (continued)

	Application					
Code	Saturated Flow	Unsaturated Flow	Multiphase Flow/Transport	Contaminant Transport	Heat Transport	Purpose
VTT	x					simulate 2-dimensional flow in confined and unconfined aquifers
CFEST	x			x	x	simulates flow, contaminant transport and heat transport in confined and unconfined aquifers in 2- and 3-dimensions
SLAEM	x					simulates flow and streamlines in confined and unconfined aquifers in 2- and 3-dimensions
VAM2DH	x	x		x		simulates for and contaminant transport in unsaturated and saturaded media in 2-dimensions

Waste EIS was derived from calculating unsaturated zone flow based on the assumption of gravity drainage. TRANSS is under configuration management but currently is not supported by any Hanford program.

TRACR3D and S301

The TRACR3D and S301 codes were applied to performance assessment analyses of the grout disposal system. TRACR3D is a finite-difference code (Travis and Birdsell 1990) used in the grout performance assessment because it is capable of being applied in two dimensions to simulate drastic contrasts in hydraulic properties in the unsaturated zone, such as that expected between clay, sand, and gravel layers. The S301 code, developed at Winfrith, England (Wikramaratna and Farmer 1987), was used in conjunction with TRACR3D to simulate contaminant transport in the unsaturated zone. Both TRACR3D and S301 are active on Hanford Site computer systems and are under active configuration management.

PORFLO-3

PORFLO-3 is an integrated finite-difference code developed to describe fluid flow, heat, and mass transport in variably saturated (saturated and unsaturated) geologic media (Runchal and Sagar 1989; Sagar and Runchal 1990). The code has capabilities for simulating flow through both porous media and fractured rock under both saturated and unsaturated conditions. Westinghouse Hanford Company funded the development of PORFLO-3 by Analytic and Computational Research, Inc., and testing at PNL. The code has been verified by comparison with analytical solutions and tested for its ability to simulate actual conditions of infiltration and contaminant transport by comparison with a field experiment conducted near Las Cruces, New Mexico. Simulating the Las Cruces trench experiment, Rockhold and Wurstner (1991) produced water content changes that matched the observed data reasonably well, but resulted in only fair agreement between simulated and observed solute concentrations. In addition to testing, the PORFLO-3 code was applied to evaluate the 241-T-106 single-shell tank leak (Smoot and Sagar 1990). The evaluation included simulating both liquid and contaminants (^{106}Ru and ^{137}Cs) in three dimensions. The conclusions reached from the simulation were that the PORFLO-3 code is capable of simulating the three-dimensional behavior of a contamination plume in the unsaturated zone, but additional characterization data are needed to support the site-specific model. In addition, the code is currently being applied to several other field investigations at the Hanford Site. The PORFLO-3 computer code is operational on computer systems at the Hanford Site and is under active configuration management.

Variable Thickness Transient Code

Codes for simulating flow and transport in the ground water have been applied at the Hanford Site longer than the codes used to simulate flow and transport in the unsaturated zone. The Variable Thickness Transient (VTT) flow code (Kipp et al. 1972) was developed to simulate transient water-table changes in the unconfined aquifer resulting from changes in waste-management operations and river-stage fluctuations. The two-dimensional flow model of the unconfined aquifer, calibrated with an iterative trial-and-error procedure based on flow in streamtubes (Cearlock, Kipp, and Friedrichs 1972), was applied to a number of different evaluations. These evaluations are documented in Cearlock and Mudd (1970), Arnett (1975), Gephart et al. (1979), Arnett et al. (1977), Murthy et al. (1983), and DOE (1987). The VTT code is operational on one computer at PNL and was previously under configuration management. No program is currently funding maintenance of the VTT code, but it is being configured for future use at the Hanford Site to support environmental restoration.

Coupled Fluid, Energy, and Soluble Transport Code

The Coupled Fluid, Energy, and Solute Transport (CFEST) code (Gupta et al. 1982) was developed for non-Hanford applications. Its predecessor, the Finite Element 3D Ground-Water (FE3DGW) Flow code, was modified to simulate simultaneous heat and contaminant transport as part of an Aquifer Thermal Energy Storage project conducted by staff at PNL. Further development of CFEST was f' ıded by the high-level nuclear waste program investigating the potential repository in salt deposits in Texas. The code can be applied to simulate water table (unconfined conditions), even though CFEST was formulated for confined aquifer simulations. In addition, the code has capabilities for generating submodels from larger regional models. For example, boundary conditions for an operable unit at Hanford could be generated from a Hanford

Site-wide model. This capability will be important for generating models of specific waste sites while maintaining consistency with site-wide conditions. CFEST has been applied to the unconfined aquifer at the Hanford Site and calibrated to describe ground-water flow in two dimensions, based both on the transmissivity data in VTT and a modification of this transmissivity data with an inverse calibration technique (Jacobson and Freshley 1990). CFEST has been applied to describe the movement of tritium between the sources in the 200-East Area and the Columbia River. A preliminary model of ground-water flow in three dimensions was developed for the unconfined aquifer based on CFEST. CFEST is operational on computer systems at the Hanford Site and is under configuration management (not active) but is not currently supported by any Hanford program.

VAM2DH

The VAM2DH code (Huyakorn et al. 1988) is capable of simulating water flow and solute transport in unsaturated and saturated porous media (sediments). The code is applied in two dimensions for both heterogeneous and anisotropic media and can be used to simulate single-specie transport, including decay. VAM2DH is proprietary and WHC has a license agreement with the developer, HydroGeologic, Inc., to use a version of the code. Documentation of the theory and a user's manual are provided by Huyakorn et al. (1988) and aspects of quality assurance (configuration control) are being pursued by WHC with the developer.

SLAEM

The SLAEM (Strack 1989) code was applied to simulate ground-water flow and contaminant transport in the unconfined aquifer for the grout performance assessment analysis. SLAEM is an analytical element code for predicting ground-water flow and advective transport. In the grout performance assessment, SLAEM was applied to predict ground-water flow and contaminant transport in the unconfined aquifer.

Discussion

Some of the issues associated with unsaturated-zone and ground-water flow and transport codes at the Hanford Site are as follows (each is discussed in the remainder of the discussion section):

- the need for a regional model of three-dimensional ground-water flow and contaminant transport in the unconfined aquifer at the Hanford Site
- the need for a three-dimensional model of flow and transport in the unsaturated zone with the capabilities to simulate nonisothermal effects and multiphase contaminants
- the need for verification and validation of Hanford Site flow and transport models
- consistency of codes to facilitate transfer of information
- the need for computer systems for performing calculations and effectively visualizing results.

The need for a regional model of three-dimensional ground-water flow and contaminant transport in the unconfined aquifer has been identified by staff with the United States Geological Survey (USGS) and EPA Region 10. Because of the large volumes of process cooling water that have been discharged to the unconfined aquifer, three-dimensional gradients exist that must be accounted for in design of remediation systems for ground-water contamination at the Hanford Site.

Models of the unsaturated zone used to assist with design of remedial actions must be able to describe flow and transport in three dimensions. The three-dimensional capability is needed to describe contaminant plumes which have been demonstrated to be affected by subsurface geology (Smoot and Sagar 1990). Multiphase contaminants are present in the unsaturated zone. The Arid Site Integrated Demonstration Project is addressing carbon tetrachloride in the unsaturated zone beneath the 200-West Area. In addition, some of the waste forms, such as grout, and potential remedial actions, such as in-situ vitrification, require that the unsaturated flow and transport code also be capable of addressing nonisothermal conditions.

Environmental transport models must be consistent and be interfaced with appropriate source-term release and exposure pathway codes. Consistency between the environmental transport and exposure pathway codes is a measure of whether the important exposure pathways can be linked with each appropriate transport pathway (i.e., inhalation from showering with river water or ground water). Because transfer of data files manually between codes is cumbersome, interfacing the codes means that interface coding must be developed to easily pass information between the codes.

Computers and programs for visualizing model results and complex data sets reflecting current technology will be needed. Visualization is a means of summarizing large volumes of model output or site characterization for effective use by technical staff and managers in decisions about different remedial actions. Visualization may be the only way to understand some three-dimensional data sets. In addition, solution of highly complex environmental transport problems will require application of high-performance computing, possibly including technologies such as massively parallel processing, which is currently under development. An example of such a complex problem is bioremediation of volatile organics in the unsaturated zone beneath the 100-West Area. Simulation of this problem will require description of highly complex coupled physical, chemical, and microbiological processes.

3.4.4 Surface-Water Models

A number of codes are available for modeling flow and transport in surface water. Two codes, DWOPER and SERATRA, have been applied to simulate flow and transport in the Hanford Reach of the Columbia River between Priest Rapids and McNary dams. Most of the available codes are summarized in Onishi et al. (1981). The codes that are available vary from one-dimensional flow to three-dimensional flow and transport with interactions between the sediment and contaminants in the river. All of the codes are available for applications to Hanford Site problems; some development of data for their applications may be necessary.

- DWOPER, which provides one-dimensional solutions of unsteady flow in open channels or rivers, has been applied to the Hanford Reach to estimate flows in the Columbia River.

- TODAM (Onishi et al. 1981) is a one-dimensional code with capabilities for contaminant transport and contaminant-sediment interactions in the river.

- FETRA (Onishi 1981) is a two-dimensional (depth-averaged) contaminant transport code with capabilities for interactions between contaminants.

- SERATRA (Onishi 1977) is a two-dimensional (laterally averaged) contaminant transport code with capabilities for simulating sediment-contaminant interactions in the river. Onishi, Yabusaki, and Kincaid (1982) summarize the performance testing of SERATRA.

- TEMPEST (Trent and Eyler 1989) provides three-dimensional solutions to the Navier-Stokes flow equation with salinity- and temperature-dependent densities. Onishi, Trent, and Koontz (1985) summarize application of TEMPEST to simulating flow and sewage effluent migration in the Strait of Juan De Fuca, Washington.

- FLESCOT (Onishi and Trent 1985) is a modification of TEMPEST with added capabilities for sediment-contaminant interactions and contaminant transport.

3.4.5 Airborne Transport Models

A wide variety of models are used to estimate pollutant transport, diffusion, chemistry, deposition, and other atmospheric processes. This broad spectrum of airborne transport models covers the range from simple algorithms to complex numerical codes. Many airborne transport models are designed to run on personal computers and require limited user experience in the fields of meteorology and atmospheric dispersion; other models require mainframe or supercomputers and highly trained and experienced users. Some models are designed to examine a large variety of atmospheric conditions, pollutants, and release scenarios; others focus on a very narrow set of atmospheric and pollutant release conditions.

The airborne transport models used at Hanford include both EPA-approved codes and those that have not been submitted for EPA approval. This latter category includes many models that were developed for other federal agencies (e.g., the Nuclear Regulatory Commission [NRC] or DOE) for applications that EPA-approved models do not adequately address. It is important to note that the process of receiving EPA approval for a model is expensive and time-consuming and is, therefore, generally not pursued if the model is not intended for applications that require formal EPA approval. Because of the difficult and lengthy approval process, many EPA-approved models are often less sophisticated and less accurate than their newer, more sophisticated, non-approved counterparts.

In the following subsections, we review some of the airborne transport models that are available for use at Hanford. This group includes models that are used to generate estimates of three-dimensional wind fields, simple pollutant dispersion, detailed pollutant dispersion and deposition, atmospheric chemical processes, and visibility attenuation. Table 3.4 summarizes these models.

MESOscale Interactive Model

MESOscale Interactive (MESOI) is a mesoscale Lagrangian puff model that simulates the release, transport, diffusion, deposition, and radioactive decay of pollutants emitted to the atmosphere (Ramsdell et al. 1983). The model was developed by PNL researchers for the NRC and DOE. The MESOI model computes ground-level pollutant concentrations, time-integrated pollutant concentrations (exposures), and deposition values. The model can accommodate four point sources with time-varying emission rates. Atmospheric transport is modeled using a horizontal wind field that is defined in three dimensions. The spatially and temporally varying wind field is computed using data from surface and upper-level wind observations. A Gaussian puff approach is used to model atmospheric diffusion. The model treats both wet (precipitation) and dry deposition processes and allows for the exponential decay of reactive pollutants. Model results can be printed to formatted data files or plotted. Versions of MESOI are available for mainframe and personal computers (PC). The PC is used operationally for emergency response applications at the Hanford Site. This version of the model uses user-friendly forms, menus, and output display programs.

Pacific Gas and Electric Modeling System

The Pacific Gas and Electric Modeling System (PGEMS) (Allwine and Athey 1986; Allwine et al. 1989) is designed for studying atmospheric dispersion in complex terrain. The micro-computer-based modeling system was created for the Pacific Gas and Electric Company for use in environmental impact analyses, licensing activities, and emergency response planning. PGEMS uses a three-dimensional, diagnostic wind model to determine the temporally and spatially varying winds over the modeling domain. The model uses shifted Chebyshev polynomials and a Froude number modification to represent the wind field on up to nine terrain-following surfaces. A Lagrangian puff model is used to compute diffusion.

TABLE 3.4. Summary Table for Airborne Transport Models

Code Acronym	Type of Model: Gaussian Plume	Gaussian Puff	Numerical Windfield	Reactive Chemical	Summary
CRSTER	x				estimates steady-state point source pollutant concentrations
HANCHI	x				uses a polar grid to estimate long-term cumulative exposures and pollutant concentrations exceeded 50, 10, 5, and 1% of the time based on simple striaght line model
ISC	x				estimates pollutant concentrations from a wide variety of steady-state sources; can operate in both short- and long-term modes
MELSAR		x			models a 3-dimensional mass-consistent flow using a mesoscale Lagrangian puff model designed for application in complex terrain environments; designed for domains of ten to hundreds of kilometers and 1 to 24 h concentration averaging times
MESOI		x			computes mesoscale release, dispersion, and deposition; uses spatially and temporally varying wind fields
MESOPUFF II		x			calculates short-term, regional scale, concentrations of up to five pollutant species; uses spatially and temporally varying wind fields

TABLE 3.4. (continued)

Code Acronym	Type of Model: Gaussian Plume	Gaussian Puff	Numerical Windfield	Reactive Chemical	Summary
MESORAD		x			computes radiological doses and pollutant concentrations; dispersion is based on the MESOI model
MPADD	x			x	simulates behavior of a single or multicomponent plume through dispersion, wet and dry deposition, and chemical reactions; designed to study air pollutants in a wide variety of below-cloud scavenging situations
MPTER	x				estimates pollutant concentrations from steady-state multiple point sources; can operate in short- and long-term modes
MTDDIS	x				simulates long-range transport; computes spatial and temporal varying wind fields
PAL-DS	x				assesses the short-term air quality impact of urban-type sources over level terrain on scales of tens to hundreds of meters
PGEMS		x			uses a three-dimensional, diagnostic wind Lagrangian puff model to estimate temporally and spatially-varying wind fields on up to nine terrain-following surfaces

TABLE 3.4. (continued)

Code Acronym	Type of Model: Gaussian Plume	Gaussian Puff	Numerical Windfield	Reactive Chemical	Summary
PLUVIUS			x	x	simulates the formation of storm systems and characterizes the behavior of air pollutants as they flow through, react with, and are scavenged by storms
PLUVUE II	x			x	estimates visibility impairment resulting from emissions of particles, nitrogen oxides, and sulfur oxides by a single source
RAM	x			x	estimates pollutant concentrations of relatively stable, steady-state pollutants; can be applied to short- or long-term problems
RAMS			x		non-hydrostatic, quasi-Boussinesq, primitive equation model that simulates a wide variety of local and mesoscale meteorological phenomena
RPM-II		x		x	reactive plume model that estimates short-term concentrations of primary and secondary pollutants resulting from point or area source emissions
VALLEY		x			straight line Gaussian plume model that provides screening estimates of 24-h and annual pollutant concentrations in areas where the elevation of neighboring terrain may exceed the emission stack height

MELSAR

MELSAR (Allwine and Whiteman 1985) is a mesoscale Lagrangian puff model designed for application in complex terrain. The model was developed by PNL for EPA. MELSAR is designed to be applied at long source-to-receptor distances (tens to hundreds of kilometers) and short concentration averaging times (1 to 24 h). The model uses a three-dimensional mass-consistent flow model to determine the spatial and temporal variation in winds over the model domain. Puffs diffuse in a standard Gaussian fashion with the vertical distribution of pollutants modified by reflection from the ground and an upper mixing lid.

Hanford Chi Model

Hanford Chi (HANCHI) is a simple straight-line model developed for DOE (Glantz and Ramsdell 1986). The model is designed to provide estimates of long-term cumulative exposures at receptors positioned on circular arcs at user-specified distances downwind from the pollutant source. The model also computes for each receptor location the pollutant concentrations that are exceeded 50%, 10%, 5%, and 1% of the time.

PLUVIUS

PLUVIUS (Easter and Hales 1984) is a reactive-storm model that simulates the formation of storm systems and characterizes the behavior of air pollutants as they flow through, react with, and are scavenged by the storms (Easter and Hales 1984). The model allows for variable diffusion in height and time, generalized boundary conditions at both the top and bottom of the computational grid (allowing a versatile characterization of the deposition/resuspension process), flexible vertical grid spacing, the capability to describe cloud and precipitation phenomena, the versatile incorporation of aqueous-phase and gaseous-phase chemical conversion for multiple-component systems, and the capability to describe wet removal processes. One-, two-, and three-dimensional versions of the model are available for different applications.

MPADD

MPADD simulates the behavior of a single or multicomponent plume of airborne material as the material undergoes atmospheric transport, diffusion, wet and dry deposition, and chemical reactions (Hales et al. 1983). The model was designed to study the behavior of hazardous air pollutants, particularly in a wide variety of below-cloud scavenging situations. The model is modularized to allow the ease in modifying various algorithms and upgrading the code.

Mesoscale Model

The Colorado State University (CSU) Mesoscale Model (Mahrer and Piekle 1977, 1978; McNider and Pielke 1984) is a three-dimensional, hydrostatic, incompressible, primitive equation model that includes terrain and detailed boundary-layer parameterizations. The model's winds are driven by surface heating and a large-scale geostrophic pressure gradient. The model was originally developed by Dr. R. Pielke while at the University of Virginia, and has been upgraded by Dr. Pielke and his students at CSU. Researchers at PNL have further modified this model (e.g., the model now computes turbulent fluxes using the turbulent kinetic energy budget) and are using it to study a variety of terrain and surface-forced flows.

Regional Atmospheric Modeling System

The Regional Atmospheric Modeling System (RAMS) is a nonhydrostatic, quasi-Boussinesq, primitive equation model designed to simulate a wide variety of local and mesoscale meteorological phenomena. The model was originally developed by Dr. W. Cotton (Tremback et al. 1985) and his research group at CSU to simulate the detailed structure of convective storms. PNL researchers have been involved in expanding the capability of the model to simulate local and mesoscale boundary layer processes over both flat and mountainous terrain.

Nested Grid Model

Clark's Nested Grid Model (Clark 1977) is a three-dimensional, nonhydrostatic, finite difference model, which uses the anelastic approximation to filter out sound waves. The model uses a terrain-following coordinate transformation to allow the Nested Grid Model to be applied in regions of irregular terrain. The model includes two-way nesting so that regions of interest can be studied with a higher resolution grid than is applied to the bulk of the model. Up to three levels of nesting are possible in the current code configuration. The model can also be used to generate additional models from an initial condition, enabling the user to examine a variety of regions, parameterization schemes, surface flux conditions, etc., without repeating the sometimes costly initialization steps.

Gaussian-Plume Multiple Source Air Quality Algorithm

The Gaussian-Plume Multiple Source Air Quality Algorithm (RAM) is a steady-state Gaussian plume model (Turner and Novak 1978; EPA 1986b) designed to estimate pollutant concentrations of relatively stable pollutants. The model can be applied to short- or long-term problems. The RAM model is appropriate for simple terrain, modeling domains with a radius of less than 50 km and urban or rural environments. Input requirements include a variety of information that defines the source configuration and pollutant emission parameters. The user may define both point and area sources. Plume rise and stack-tip downwash can be computed for point sources. Building wake processes are not treated. The model uses hourly meteorological data to compute straight-line plume transport. The model does not treat deposition processes, but allows the exponential decay of pollutants. The model output consists of 1- to 24-h average pollutant concentrations and annual average pollutant concentrations at user-specified grid points or on a gridded receptor array. The RAM model is EPA-approved for specific regulatory applications.

Industrial Source Complex Model

The Industrial Source Complex (ISC) model is a steady-state Gaussian plume model designed to estimate pollutant concentrations from a wide variety of sources associated with industrial complexes (EPA 1986a). The model can operate in both short- and long-term modes. The ISC model is appropriate for flat or rolling terrain, modeling domains with a radius of less than 50 km and urban or rural environments. A PC version of the model is available. Input requirements include a variety of information that defines the source configuration and pollutant emission parameters. The user may define a variety of point, line, area, and volume sources. Plume rise, stack-tip downwash, and building wake can be computed. In the short-term mode, the model uses hourly meteorological data to compute straight-line plume transport. In the long-term mode, the model uses joint frequency distribution data to compute straight-line plume transport. The model computes a variety of short- and long-term averaged products at user-specified receptor locations and receptor rings. The model treats deposition processes and allows the exponential decay of pollutants. The ISC model is EPA-approved for specific regulatory applications.

Multiple Point Gaussian Dispersion Algorithm with Terrain Adjustment Model

The Multiple Point Gaussian Dispersion Algorithm with Terrain Adjustment (MPTER) model (Pierce and Turner 1980; Chico and Catalano 1986) is a steady-state Gaussian plume model designed to estimate pollutant concentrations from multiple point sources. The model can operate in both short- and long-term modes. MPTER is appropriate for flat or rolling terrain, modeling domains with a radius of less than 50 km and urban or rural environments. A PC version of the model is available. Input requirements include a variety of information that defines the source configuration and pollutant emission parameters. Plume rise and stack-tip downwash can be computed. The model uses hourly meteorological data to compute straight-line plume transport. The model does not treat deposition processes, but allows the exponential decay of pollutants. MPTER output consists of a variety of short- and long-term averaged products at user-specified receptor locations. This model is EPA-approved for specific regulatory applications.

CRSTER

The Single Source (CRSTER) model (EPA 1977; Catalano 1986) is a steady-state Gaussian plume model designed to estimate pollutant concentrations from point sources. The model can operate in both short- and long-term modes. The CRSTER model is appropriate for flat or rolling terrain, modeling domains with a radius of less than 50 km and urban or rural environments. Input requirements include a variety of information that defines the source configuration and pollutant emission parameters. Plume rise and stack-tip downwash can be computed. The model uses hourly meteorological data to compute straight-line plume transport. CRSTER assumes no vertical variation in wind direction or speed. The model output consists of a variety of short- and long-term averaged products at up to five user-specified receptor rings. The model does not treat deposition processes, but allows for the exponential decay of pollutants. The CRSTER model is EPA-approved for specific regulatory applications.

MESOPUFF II

The MESOPUFF II model (Scire et al. 1984) is a short-term, regional scale, Gaussian puff model designed to calculate concentrations of up to five pollutant species. The model allows spatial and temporal variations in winds, but does not explicitly treat complex terrain. Input requirements include a variety of information that defines the source configuration and pollutant emission parameters. The model uses hourly meteorological data from up to 25 surface stations and 10 upper air stations. Plume rise can be computed. MESOPUFF II can simultaneously examine up to five pollutant species in a single simulation. Up to 25 point sources and 5 area sources can be modeled. The model uses a gridded field of receptors and allows the user to specify additional receptor locations. MESOPUFF II model treats both wet (precipitation) and dry deposition processes. Hourly chemical rate constants are computed from empirical expressions derived from photochemical model simulations. The EPA has determined that the use of this model may be considered on a case-by-case basis for particular regulatory applications.

Mesoscale Transport Diffusion and Deposition Model for Industrial Sources

The Mesoscale Transport Diffusion and Deposition Model for Industrial Sources (MTDDIS) (Wang and Waldron 1980) is a Gaussian puff model designed to simulate long-range transport. The model allows spatial and temporal variations in winds, but does not explicitly treat complex terrain. The model can be used for releases in simple or rolling terrain. MTDDIS can be used to determine 3-h maximum and 24-h average pollutant concentrations. Input requirements include a variety of information that defines the source configuration and pollutant emission parameters. Plume rise can be computed. The model can treat up to 10 point sources. The MTDDIS model uses hourly meteorological data from up to 10 surface stations and a single upper air station. Up to three rectangular receptor grids may be specified by the user. The model treats both wet (precipitation) and dry deposition processes. Chemical transformations are treated using the exponential decay of pollutants. The EPA has determined that the use of this model may be considered on a case-by-case basis for particular regulatory applications.

PLUVUE II

The PLUVUE II model (Seigneur et al. 1984) is a Gaussian plume model designed to estimate visibility impairment resulting from emissions of particles, nitrogen oxides, and sulfur oxides from a single source. Input requirements include a variety of information that defines the source configuration, pollutant emission parameters, and background pollutant concentrations. Plume rise can be computed. The model assumes a constant wind direction and wind speed during a simulation. The PLUVUE II model treats dry deposition and the chemistry of key pollutant compounds. The model output consists of plume concentrations and visual effects at specified downwind distances for calculated or specified lines of sight. The EPA has determined that the use of this model may be considered on a case-by-case basis for particular regulatory applications.

Point, Area, Line Source Algorithm Model

The Point, Area, Line Source Algorithm (PAL-DS) model (Petersen 1978; Rao and Snodgress 1982) is a short-term Gaussian plume model. The model is intended to assess the air quality impact of particular urban-type sources (e.g., airports, shopping centers, parking lots) over level terrain on scales of tens to hundreds of meters. A PC version of the model is available. Input requirements include a variety of information that defines the source configuration and pollutant emission parameters. Up to 99 sources are allowed. Sources may be of six types: point, area, and four types of line sources. The PAL-DS model can compute plume rise, but not downwash. The model requires data on wind direction and speed, wind profile exponents, stability class, mixing height, and air temperature. The model output includes hourly concentration, hourly deposition flux, and average concentrations (for up to 24 h) for each source type at each receptor. The model can compute dry deposition but does not handle chemical transformations. The EPA has determined that the use of this model may be considered on a case-by-case basis for particular regulatory applications.

Reactive Plume Model II

The Reactive Plume Model (RPM-II) (Stewart et al. 1983) is a designed to estimate short-term concentrations of primary and secondary pollutants resulting from point or area source emissions. The model offers a realistic treatment of the entrainment process (by which ambient air mixes with the plume) through enhanced horizontal resolution within the plume. The model also offers the user the option of choosing various chemical kinetic mechanisms (including the Carbon-Bond II Mechanism). A PC version of the model is available. Model input requirements include a variety of information that defines the source configuration and pollutant emission parameters. The RPM-II model requires data on wind speeds as a function of time and other meteorological parameters. Wind direction data are not used. The model also requires that the user specify the initial concentration of pollutant species. The user can specify a single point, area, or volume source. The model can compute plume rise. The RPM-II model can compute short-term concentrations of primary and secondary pollutants at either user-specified times or downwind distances. The EPA has determined that the use of this model may be considered on a case-by-case basis for particular regulatory applications.

Estimate Toxic Transport Model

The Estimate Toxic Transport model (EXTRAN) is used to assess the effects of accidental releases of radioactive or toxic substances on the habitability of nuclear facility control rooms (Ramsdell 1991). The model simulates a storage tank failure and the resultant environmental release of a hazardous gas, liquified gas, volatile liquid, or airborne particulates. Both a direct release to the atmosphere and the evaporation of a liquid pool can be treated in one simulation. A Gaussian puff model is used to model the straightline transport and diffusion of pollutant material as the material moves toward a control room air intake. The model uses building-wake diffusion algorithms to estimate wake-enhanced dispersion. As a final product, the model outputs estimates of time-dependent pollutant concentrations at the user-specified air intake location.

Discussion

Airborne transport models are used to address a variety of technical questions including those related to wind patterns, pollution concentration estimates, atmospheric chemical processes, pollutant deposition, and visibility impairment. Airborne transport models are also used to provide pollutant concentration and deposition input to dose assessment models, environmental impact models, health risk models, and other operational models. In some cases, airborne transport models are incorporated into multi-media and related modeling systems.

Airborne transport models are used at Hanford to plan and schedule site activities, monitor environmental impacts during operational activities, and assess impacts after activities have been completed. The model used for a particular application can range from a simple code that may run on a personal computer (or field-based laptop) and require limited operator training or experience, to a complex series of numerical codes that may require extensive computer resources and an expert user. The tendency in many newer models is to provide more sophisticated computational techniques in packages that require less extensive computer resources and minimize the need for extensive operator training or experience. This tendency is increasing the ability of researchers and operational personnel to produce more timely and realistic estimates of atmospheric dispersion and related processes than were formerly achievable for many applications.

Most airborne transport models, particularly those designed for regulatory applications, are designed for sites that have limited meteorological data. As a result, gross assumptions must often be made about the spatial (both horizontal and vertical) and temporal variation in winds. These assumptions can often lead to the generation of poor estimates of atmospheric dispersion. On the other side of the scale, models that are designed for research applications generally require detailed characterizations of atmospheric parameters. Few sites have sufficient meteorological monitoring capabilities and trained personnel to allow the routine use of such models.

The Hanford Site has a much more extensive meteorology monitoring program than that found at most sites for which airborne transport models need to be applied. The Hanford program allows for a detailed assessment of near-surface meteorological conditions (more than can be used by most airborne transport models); however, the program does not provide a comparable assessment of the meteorological conditions above the near-surface level. This lack of an extensive monitoring capability for meteorological conditions aloft and the need for airborne transport modeling by researchers in a variety of disciplines, makes it difficult to use many of the more advanced research models for Hanford-related applications.

At the Hanford Site, there is a need for airborne transport models that have regulatory approval, can make full use of the available meteorological data to produce reasonable estimates of atmospheric transport, and are relatively easy to use for routine applications. Unfortunately, most of the airborne transport models currently used at the site may meet one or more of these criteria; few, if any, achieve all three.

3.4.6 Environmental Pathway Models

Environmental pathway models are applied to predict doses to individuals or critical population groups from release of radioactive materials or hazardous chemicals. These models are typically coupled with the output from environmental transport and the results are input to health risk models to perform a complete risk assessment. For several environmental pathway models described in this section, there is also an environmental transport component; for these models, the environmental transport is based on simple assumptions and algorithms. More complicated coupled models with both nonsimplistic environmental transport and environmental pathway models are discussed in Section 3.4.8.

Exposure pathways are the environmental routes through which people may be exposed to radiation, radionuclides, chemicals, or other hazards. For purposes of radionuclide or chemical dose assessment, primary environmental exposure pathways are shown in Figure 3.4. These pathways include external exposure to penetrating radiation from contaminated soil or immersion in contaminated air or water; dermal absorption; inhalation; and ingestion of water, and terrestrial or aquatic foods. In a risk assessment, a collection of exposure pathways with specific modeling assumptions and data is used to construct exposure scenarios. Exposure scenarios are designed to be conceptual models of potential human activity (actions, events, lifestyles, and other processes) that result in exposures.

Environmental pathway models are applied to estimate potential doses associated with routine facility operation, accident situations, environmental cleanup, decommissioning of facilities, or disposal of wastes. Analyses can be retrospective (historical) or prospective (future). Environmental pathway models are also applied to set environmental standards or regulations, show compliance with existing standards or regulations, and conduct basic research. The primary differences among these applications are the types of data sets required (i.e., generic data or detailed site-specific data) and the complexity of the mathematical formulations used.

To facilitate environmental risk assessments, environmental pathway models have been developed. Some of these are summarized in Table 3.5.

CAP-88 Code

For determining compliance with the regulations promulgated by the EPA under the Clean Air Act, the EPA has mandated the use of the CAP-88 code (Beres 1990). This code is available and maintained for application at Hanford to evaluate doses resulting from airborne releases of radioactive materials. CAP-88 was originally called AIRDOS-EPA, and is a steady-state Gaussian plume model. The code is also one of those approved by the Hanford Environmental Dose Overview Panel for use at Hanford. CAP-88 evaluates doses from atmospheric releases through a wide variety of pathways, including plume immersion, inhalation, and ingestion of food or water after deposition of airborne materials.

Hanford Unified Dose Utility Code

The Hanford Unified Dose Utility (HUDU) code was developed to provide rapid initial assessment of radiological emergency situations (Scherpelz 1991). The HUDU code uses a linear Gaussian atmospheric dispersion model to estimate the transport of radionuclides released from an accident site. For points on the center line of the plume, HUDU calculates internal doses due to inhalation and external doses due to plume immersion. The code uses a number of features unique to the Hanford Site, including a library of source terms

TABLE 3.5. Summary of Environmental Pathway Analysis Models

Code	Application: Active Release from Cleanup Activities	Application: Long-term Performance Assessment	Purpose
CAP88	x		evaluates doses from airborne releases to determine Clean Air Act compliance
HUDU	x		evaluates doses during radiological emergencies
EMS	x		evaluate impacts from accidental radiological or toxic chemical releases
ONSITE/ MAXI1	x	x	evaluate doses to intruders at buried radioactive waste sites
TABLES		x	evaluates license termination for residual radioactivity in buildings or soil
RESRAD		x	implements DOE guidelines for residual radioactivity in FUSRAP and SFMP

derived from various facilities' safety analysis reports. The HUDU code is designed to run on an IBM-PC or compatible personal computer. The code is operational and maintained for application to emergency situations at the Hanford Site.

Emergency Management Support System

The Hanford Emergency Management Support (EMS) system provides the capability of rapid, comprehensive response for both radiological and toxic chemical releases from the Hanford Site (Probasco and Stephan 1991). The EMS system allows for data acquisition from the Hanford Site-wide meteorological station complex and source-term libraries and also allows access to dose assessment and dispersion models. This system provides emergency response personnel with the ability to assess the impacts or potential impacts from Site releases and to communicate data among the Hanford Site emergency centers during an accident.

Some applications available include graphical displays of near real-time meteorological conditions and a color plot of areas potentially affected by a given Hanford emergency; a straight-line atmospheric dispersion/radiation dose model (HUDU) for rapid assessment of potential radiological impacts in the environment; a puff-trajectory model (MESOI) for comprehensive assessment of potential transport of material; and a comprehensive dose assessment model (MESORAD) for evaluating radiological impacts in the environment.

ONSITE/MAXI1 Code

The ONSITE/MAXI1 code (Kennedy et al. 1987) was designed to evaluate the potential dose to human intruders at buried low-level radioactive waste sites. The code is a modified version of the computer code MAXI, and it has been used by the NRC when reviewing applications for onsite radioactive waste disposal under 10 CFR 20.302. The code was developed for three computer systems: CDC 6600-7600, VAX-780, and IBM-PC and compatible systems. Sample problems for purposes of benchmarking are documented in all three versions. Although not under a formal QA protocol during development, extensive testing of the pathway analysis was conducted. The final version of the ONSITE/MAXI1 code allows the user to select radiation dose conversion factors published by the International Commission on Radiological Protection (ICRP) in ICRP Publications 2 or 30 (ICRP 1959; 1980). This code has largely been replaced by the GENII code package for most applications.

TABLES Code

The TABLES code (Kennedy et al., in preparation) is currently being developed for the NRC to translate residual radioactive contamination levels from decommissioning to annual dose. The final version of this code, scheduled to be released in early 1992, will include a user-friendly shell to permit modifications to base scenarios.

RESRAD Code

The RESRAD (RESidual RADioactive Material) code (Gilbert et al. 1989) was developed by Argonne National Laboratory to provide a tool for implementing DOE guidelines for residual radioactive material at sites identified by the Formerly Utilized Sites Remedial Action Program and the Surplus Facilities Management Program. The code uses models to derive site-specific guidelines for allowable residual concentrations of radionuclides in soil. The documentation of RESRAD, "A Manual for Implementing Residual Radioactive Material Guidelines," describes the analysis and models used, and describes procedures for implementing DOE policy for reducing residual radioactivity to levels that are as low as reasonably achievable. No information is given on software quality assurance procedures used in the development of the code. Documentation indicates that copies can be distributed to DOE contractors.

Discussion

Environmental pathway models are used to evaluate potential doses both during and after site cleanup. Modeling estimates can be used instead of or in addition to actual measurements on individuals, and can be used to estimate population exposures or exposures of individuals for which no measurements are available. During site cleanup, results from pathway models are useful for determining whether workers and the public are protected adequately and whether environmental protection regulations are being complied with. After site cleanup, pathway models can be used for conducting performance assessments. Results of applications both during and after site cleanup should be integrated into a decision-support information system.

Currently, environmental pathway models to assess exposure from inorganic chemicals, including radionuclides, are well developed for the Hanford Site. The methodology is appropriately sophisticated to account for important determinants of dose and risk. The implementations are versatile and user-friendly, and the validity of the models has often been established. Similar models to assess exposure or risk from organic chemicals or from mixed exposures are not generally available at Hanford or at other DOE sites.

Whereas environmental monitoring data are available for both organic and inorganic chemicals, these data are unlikely to meet current requirements for environmental pathway modeling or health risk assessment. In addition, actual exposure measurements relevant to workers or the public are often unavailable. Finally, the research required to translate such exposures to population or individual worker risks is often based on inadequate animal experiments or other data.

3.4.7 Health Risk Models

Health risk models are used to convert environmental or occupational exposures from radiation, chemicals, and other hazards (e.g., dust, noise, heat, falling objects) to estimates of health risk (probability of disease) or impact (numbers of cases of disease). Health risk models currently in use are not Hanford Site-specific, but apply generally to any health risk assessment situation. Of most interest to the Hanford Integrated Plan are those models used for evaluating risk from exposures to radiation and chemicals. The status of health risk models for assessing risk from radiation exposure are much more advanced than those for chemicals; however, models for both radiation and chemical exposures have been developed using the same basic approach. The approach relies heavily on the use of appropriate data.

In this approach, results are synthesized from research in molecular and cellular biology, laboratory studies in animals, and studies of human populations to develop models that can be used to calculate risk as a function of exposure. Further, the models developed are tested and calibrated using information from epidemiological, pathological, bioassay, and/or other studies in humans. Molecular and cellular studies elucidate mechanisms involved, and animal or human studies allow validation of these mechanisms in whole organisms. Animal studies also allow investigation of the impact of diet, environment, and other confounding factors. Epidemiological, pathological, bioassay, and other studies are absolutely essential to ensure that results found in animals are applicable to humans, but require human populations that have been exposed to the agent in question or to an agent that acts through a similar mechanism. These studies aid in the fundamental understanding of mechanisms of development and progression of disease and how disease is affected by lifestyle and environmental factors, and generates information useful for extrapolating beyond available data. Such information is required to develop and validate health risk models.

This approach has been applied to a more limited extent in assessing risks and impacts from chemical exposures than from radiation exposures. Data are generally unavailable or very limited for assessing risks from chemical exposures. Further, the application of this approach to assess mixed exposures to chemicals and radionuclides has been extremely limited, again by unavailability of appropriate data. Thus, the quality of health risk assessment information varies from comparatively good data based on many scientific studies for radiation exposures, to nearly missing data based almost entirely on modeling and assumptions for chemicals and for mixed exposures.

Ionizing Radiation Risk Assessment

The DOE, other federal agencies, and international organizations have used the above approach for health risk assessment from radiation exposures. In humans, epidemiologic studies of exposed worker populations and others have been conducted to verify that the much more precise risks at acute high levels in populations with a different genetic pool (e.g., atomic bomb survivors) are consistent with available low-level data from other groups. Information on external radiation hazards are based on the strongest data, with information on deposited radionuclides (internal emitters) being much more limited, except in isolated instances (e.g., radon daughters, radium).

Studies in larger laboratory animals (e.g., beagle dogs) exposed to internal emitters are just now being completed and becoming available for statistical evaluation. The results from canine studies will be compared with results from studies in rodents to understand the validity of various approaches to interspecies extrapolation. These experimental data are used to fill gaps in knowledge about the risk of exposure to ionizing radiation where human data are limited or unavailable.

To date, molecular-level studies have produced limited information from which human health risk can be assessed; the understanding of how molecular-level changes relate to cancer or other disease risks in animals or in humans is not generally available. However, both DOE and NIH have programs to sequence the human genome and produce the molecular-level information that can be related to animal or human exposures that may provide major breakthroughs in the health risk assessment arena. Even if this occurs, however, molecular-level studies in whole organisms will be necessary in a health-effects program to verify and bridge the gaps between basic research at the molecular or cellular level and observational studies in laboratory animals and humans.

Internationally, integration of available data on radiation health effects is done to a large extent by two bodies: the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the ICRP develop risk estimates considering all available information. Nationally, the National Academy of Sciences has chartered the Biological Effects of Ionizing Radiation (BEIR) committees to synthesize results. Information used by the BEIR committees and other information is used by the National Council on Radiation Protection and Measurements (NCRP) when recommending health risk parameters. Health risk estimates are based on sophisticated statistical modeling of available data. The modeling generally has the following characteristics:

- accurate information is available on temporal characteristics of exposure, so that age at exposure, time since cessation of exposure, and patterns of exposure can be investigated
- baseline risks are appropriately taken into account
- the shape of the dose-response curve is investigated so that low-dose extrapolation can be attempted.

Scholarly documents have been produced by UNSCEAR, ICRP, and NCRP, defining methods, assumptions, limitations, and conclusions. These documents are considered by government and industry as the definitive documents on health risk from exposure to radiation, and they are used by regulatory authorities to develop protective standards. These results are also used to assess risk from exposure to ionizing radiation in diverse situations.

Health endpoints considered most extensively in radiation risk assessment are cancer and genetic effects; these are the endpoints of most concern at low exposure levels. Only limited data exist on other health endpoints.

There are numerous tools to assess health risk from exposure to ionizing radiation. Those available at Hanford that are not coupled to environmental transport models include CINDY, GENMOD-PC, BIOSC, and MOX. CINDY and GENMOD-PC calculate radiation doses; BIOSC is a screening tool to identify bioassay samples that need further investigation. MOX is a tool to assess the dose-response relationship of occupational exposure and mortality from several specific causes in a large cohort or follow-up study, without reference to an external population. These tools are summarized in Table 3.6.

TABLE 3.6. Summary of Health Risk Assessment Models

Code	Application: Interpretation of Bioassays	Application: Bioassay Screening	Application: Health Risk Assessment	Purpose
CINDY	x			calculates organ radiation dose equivalent and effective dose equivalent
GENMOD-PC	x			evaluates radionuclide intake and dose
BIOSC		x		screens routine bioassay specimens to identify those that require more detailed followup
MOX			x	assesses the dose-response relationship of occupational exposure and cause-specific mortality in a cohort

The Code for Internal DosimetrY (CINDY) (Strenge et al. 1990) addresses the DOE Order 5480.11 (DOE 1989) by providing capabilities to calculate organ radiation dose equivalents and effective dose equivalents using the ICRP Publication 30 (ICRP 1980) approach. Flexible biokinetic models are used to determine organ doses for chronic or acute intakes. Doses are expressed as organ dose equivalents, effective dose equivalents or committed dose equivalents as appropriate to the specific calculation being performed. The code assists in interpreting bioassay data, evaluates committed and calendar-year doses from intake or bioassay measurement data, and provides output consistent with revised DOE Orders. The code is designed for easy use and general applicability to DOE sites.

CINDY is documented in a two-part report: a description of dosimetry concepts and design features, and a user's guide, including installation procedures, tutorials, reference section, and sample problems. CINDY was externally technically peer reviewed before being released and is currently under software configuration control. CINDY has been extensively tested and verified. Formalization of the test plan and software verification and validation report are currently under development.

GENMOD-PC (Dunford and Johnson 1987) was developed at the Chalk River Laboratory in Canada; the developer is now at PNL. GENMOD-PC was designed to assist in carrying out reliable and accurate radionuclide intake and dose evaluations on an IBM-PC or compatible. GENMOD-PC, which can be used as both a research and an analytical tool, is based on the ICRP-30 lung model, Eve's gastrointestinal model, and a compartmental organ model. User documentation with examples of applications is available.

The BIOassay Screening System (BIOSC) was developed by PNL (Watson et al. 1990) to aid the U.S. Air Force's Armstrong Laboratory in using routine bioassay specimens to identify personnel with potential for radionuclide exposure that require more detailed followup. Rather than comparing each bioassay result with a radionuclide-specific action level, BIOSC combines the results from all radionuclides detected and determines interesting specimens rather than interesting results. Specimens determined to be interesting are further analyzed on a case-by-case basis: additional specimens are acquired, the individual's work history is ascertained, the probable exposure route and date are estimated, and an internal dosimetry code is used to estimate the dose to the individual. Thus, BIOSC provides a rapid method for pre-screening specimens before resorting to elaborate codes such as CINDY.

The software was implemented using a structured systems analysis approach and a fourth generation information management language (PARADOX) on an IBM PS2/70 microcomputer. BIOSC is fully documented in the User's Guide for the Bioassay Screening System, and BIOSC Programmer's Manual.

The Mortality and Occupational Exposure Code (MOX) (Buchanan and Gilbert 1984; Gilbert and Buchanan 1984) is a tool to assess the dose-response relationship of occupational exposure and mortality from several specific causes in a large cohort or followup study, without reference to an external population. The ability to use an internal control population is a method for controlling for the healthy worker effect. Statistical tests allow control for age, sex, race, calendar year, length of employment, length of followup and other user-defined variables.

MOX is most useful for analyzing populations with good exposure data and considerable variability in exposure, and/or a relatively large subgroup with little or no exposure. MOX is the primary analysis tool used in the Hanford Health and Mortality Study, has been used to study worker populations at other DOE sites, and has been widely distributed throughout the world. User documentation is available.

Chemical Risk Assessment

Dosimetry to assess the exposure to chemicals is in its infancy compared to radiation dosimetry; risk assessments for chemicals are similarly undeveloped. For most new chemicals, acute rather than chronic toxicity studies in laboratory animals have been emphasized. Since chronic toxicity is generally of interest in risk assessment, methods to extrapolate these data to the workplace or environmental situation are problematic. Suitable human studies are limited in number and scope. Inadequate documentation of exposure levels compounded by multifactorial exposures and lack of appropriate control groups renders many epidemiological studies unsuitable for chemical risk assessment. Thus, in general, appropriate data are unavailable for the types of health risk assessments for chemical exposures that will be required for Hanford Site environmental restoration. There are two resources, however, that provide much of the available data—the National Toxicity Program (NTP), which develops data on laboratory animals, and the Integrated Risk Information System (IRIS), which provides available information on chemical risks in a central resource.

The NTP has provided much scientific knowledge about chemical risk to humans. The NTP was established about 10 years ago to coordinate and strengthen government activities in characterization of chemical toxicity. The program evaluates multiple toxicologic endpoints in laboratory animals using assay protocols tailored to each chemical. The traditional 2-year carcinogenesis bioassays have been strengthened into a comprehensive toxicologic evaluation that provides information not only on a chemical's carcinogenic potential in laboratory animals, but also in its genetic toxicity, chemical disposition, target-organ toxicity, and adverse reproductive effects. In specific cases, neurobehavioral, immunologic, hematopoietic, respiratory physiologic, and endrocrinal effects have been studied. Currently, the NTP is changing its focus to become more molecular-based.

The NTP has produced quality data on numerous chemicals of importance to society. However, gaps still exist in the current understanding of health risks from chemical exposures. This includes a limited scientific understanding of molecular mechanisms and little data on humans with which to calibrate the interspecies or high- to low-dose extrapolation models.

EPA's IRIS is a major resource for chemical health risk assessment. IRIS is an electronic on-line database developed and maintained by EPA to contain health risk and EPA regulatory information on specific chemicals. IRIS was developed for EPA staff in response to growing demand for consistent risk information on chemical substances for use in decision-making and regulatory activities. At the heart of the IRIS system is a collection of computer files on individual chemicals containing descriptive and quantitative information in the following categories:

- oral and inhalation references doses (RfDs)
- oral and inhalation slope factors and unit risks for carcinogens
- drinking water health advisories from EPA's Office of Drinking Water
- EPA regulatory action summaries
- supplementary data on acute health hazards and physical/chemical properties.

Information presented in IRIS undergoes careful review prior to being entered into the system. All quantitative values in the test files have been developed by EPA staff using their standardized methods and procedures. When information is insufficient to develop numerical values for RfDs or slope factors for a specific chemical, no information is provided in IRIS. The database is not the panacea for the problem of obtaining up-to-date risk information on chemicals. Many important chemicals are not included in the database, the information is not always accurate and information is often missing.

Tools available at Hanford to assess risk from exposure to chemicals are limited to MOX, applicable to an occupation cohort (described above). However, chemical exposure data are unavailable and are not being collected in a manner to support the use of this tool.

Risk Assessment of Mixed Exposures

Information on mixed exposures (radiation and chemicals) is extremely limited. Results from a number of studies are available on the synergism of radiation (particularly radon) and cigarette smoke. Experimental studies of heavy metals and radiation in laboratory animals have been conducted to a limited extent. However, experimental studies on the combination of chemicals and radiation likely to be encountered in Hanford Site cleanup do not exist.

Since toxicological data on specific waste streams is lacking, numerous assumptions must be made when predicting risk. Risk coefficients developed for individual substances can be applied to a mixture, using additive or other models. Risk coefficients for an individual substance based on acute studies are applied to estimate risk for a chronic situation. Whether these coefficients are adequate or accurate is generally unknown.

Tools available at Hanford to assess risk from mixed exposure are limited to MOX (described above). Radiation data are sufficient to use MOX to investigate risks from mixed exposure, but chemical exposure data are unavailable and are not being collected in a manner to support the use of this tool.

Discussion

The state-of-the-art in health risk assessment as it applies to environmental restoration is in its infancy. This is a DOE complex-wide deficiency, not just at Hanford, and needs to be addressed globally. The lack is not in models or other tools, but is a lack of methodology and technology to assess chemical and mixed exposures and a lack of human data or other data to assess health risk. The data requirements and modeling approaches required to assess health risk are well developed and proven for assessing radiation risks. These methods need to be applied, with appropriate modification to account for several simultaneous exposures, to estimate risk coefficients for chemical and mixed exposures.

Thus, research is needed to study exposure and response to mixtures and to develop an approach with scientific credibility for estimating health risks. Research is needed to develop capabilities in the following areas:

- quantify acute and chronic toxicity of a substance or mixture from its structure (e.g., relate structure and function) or from short-term in vitro or in vivo bioassays

- verify that structure/function approaches or short-term assays produce comparable results to conventional approaches

- devise families of radiations, chemicals, and mixtures so that risks within families are quantified in a known way (e.g., additive) and relationships to other families are explored and can also be quantified

- develop approaches to combine risk factors and their uncertainties from exposures to different substances to get an improved composite risk factor

- develop biomarkers of exposure so that prior exposure to a particular substance can be detected without being quantified

- develop quantitative biomarkers of exposure and susceptibility, so that the relationship of relevant exposure and a particular health outcome is better estimated

- develop improved methods of individual chemical dosimetry or exposure estimation

- appropriately study workers being exposed as a result of Hanford Site cleanup to verify research results, and monitor deviations from predicted health outcomes.

3.4.8 Coupled Models

Up to this point, tools that have been discussed address only one component of the release or environmental transport for predicting human health risks or impacts, or address other components using simple assumptions and algorithms. A few codes exist, or are under development, that directly couple two or more components of the source to the receptor pathway shown in Figure 3.4. These are summarized in Table 3.7.

GENII Code

The primary code used for conducting radiological environmental transport and pathway analysis at the Hanford Site is the GENII code (Napier et al. 1988). The GENII acronym stands for GENeration II, the second generation of Hanford environmental pathway analysis models. The purpose of the GENII system is to provide a coupled system of computer codes for prediction of radiation doses to man from environmental sources of radioactive materials.

TABLE 3.7. Summary of Coupled Environmental Transport, Health Risk, and Economic Assessment Models

Code	Application: Environmental Transport	Health Risk Assessment	Economic Assessment	Purpose
GENII	x	x		predicts environmental pathways and public radiation doses
MEPAS	x	x		simulates environmental transport and exposure pathways to predict exposure and indicators of risk for radionuclides and hazardous chemicals
SUMO	x	x		simulates source term, hydrologic transport, and environmental exposure and dose of radionuclides
MACCS	x	x	x	assesses the progression of reactor accidents from the initiating event through the resulting health and economic consequences

The GENII system is designed to operate on an IBM-AT or compatible and is under active configuration management.

The environmental pathways considered in GENII include the following exposure pathways: surface water (swimming, boating, and fishing), soil (surface and buried sources), air immersion (semi-infinite cloud and finite cloud geometries), inhalation, ingestion of drinking water, and ingestion of both terrestrial and aquatic food products. GENII can be used to calculate radiation doses from both acute (short-term/accidental) and chronic (routine/long-term) releases of radioactive materials. The system incorporates the internal dosimetry models recommended by the ICRP. The system has options for calculating annual dose, committed dose, and accumulated dose.

GENII is documented in three volumes. Volume 1 contains a theoretical description of the system, including the conceptual diagrams, mathematical representations of the solutions, and descriptions of solution techniques, where appropriate. Volume 2 is a user's manual, providing code structure, user's instructions, required system configurations, and topics related to quality assurance. Volume 3, the code maintenance manual, is designed for the user who requires knowledge of code details, including code logic diagrams, global dictionary, worksheets for hand calculations, and listings of the code and associated data libraries. GENII was given external technical peer review prior to release and is currently under configuration control.

MEPAS Code

A code for simulating pathways and predicting exposure and indicators of risk at PNL is the Multimedia Environmental Pollutant Assessment System (MEPAS). MEPAS methodology was developed for DOE to assist with assigning a ranking or priority to environmental problems at DOE sites across the country. The code describes the release and transport of contaminants from waste sites through ground water, surface water, and the atmosphere. Exposure of individuals and populations to these contaminants is accounted for through a wide variety of exposure pathways. Rankings of waste sites and radioactive and chemical constituents in those waste sites are based on health risk predictions.

MEPAS has been applied to the DOE Headquarter's Environmental Survey (Droppo et al. 1989a; 1989b). It is now being modified to provide the human health risk portion of the priority system used by ER, which is an outgrowth of the environmental survey. MEPAS has also been applied at Hanford to rank constituents in the single-shell tanks for sampling and characterization based on their relative contribution to risk (Droppo et al. 1991). MEPAS is being modified to provide input to RAAS (see Section 3.3.1), which will provide risk-based screening of remedial action alternatives at specific waste sites.

SUMO Code

The System Unsaturated MOdel (SUMO) (Eslinger et al. 1991) was developed by PNL for the DOE Office of Civilian Radioactive Waste Management for assessing performance and risk in mined geologic disposal systems in partially saturated media. It is a coupled system of codes that contains modules for a source term, hydrologic transport of radionuclides in partially saturated and saturated media, and environmental exposure and dose.

SUMO can be used to analyze the performance and predict the human health risks of sites that release radioactive contaminants to ground water at either the scoping stage or for more detailed performance assessments. The source term may be represented by a range of scenarios from a single release profile over time to the simulation of individual waste container failure or composite contaminant releases from failure of multiple waste containers. The hydrologic system can be represented as one-dimensional with a few hydrologic zones or as two- or three-dimensional with many hydrologic zones. The exposure and dose modules are the same as the chronic-release individual and population modules contained in the GENII suite of codes (Napier et al. 1988). A variety of model output can be obtained: 1) radionuclide release rates from the waste site, 2) radionuclide concentrations at a location, and 3) individual or population doses.

MACCS Code

MELCOR Accident Consequence Code System (MACCS) (Chanin et al. 1987) was developed for NRC by Sandia National Laboratory. The MELCOR code system provides a tool for assessing the progression of severe nuclear reactor accidents from the initiating event through the resulting health and economic consequences. The MACCS code is a subsystem of separate, stand-alone codes designed to be used after the source terms have been calculated. The code has undergone extensive review and testing, and several documents are available describing the models used and providing user information. An uncertainty and sensitivity analysis has also been performed on the codes in the MACCS system.

The code has been obtained (from NESC) and installed on the Sigma 5 VAX cluster and can be used on all three types of reactors for the New Power Reactor project: heavy water, light water, and high-temperature gas reactors.

MACCS has a limited list of radionuclides tailored to reactor accidents and may not include all of the long-lived radionuclides that are found in nuclear wastes.

Discussion

As can be seen from Table 3.7, relatively few codes for coupled risk assessment modeling exist. Most of the existing codes were developed for specific applications (MEPAS was developed for application to the DOE Environmental Survey and SUMO for applications in the DOE high-level nuclear-waste program). None of the existing codes will be applicable to all aspects of risk assessments at the Hanford Site.

Coupled models, or a methodology where connections between models are well established, will be useful for conducting risk assessments at the Hanford Site. Coupled models will be useful for providing consistency between analyses and conducting large numbers of the same analysis. Approaches to risk and performance assessment analyses have been developed as part of the TPA at the Hanford Site.

3.5 INFORMATION MANAGEMENT SYSTEMS

This section focuses primarily on computer-based information management systems that are technically related in some way to the support of Hanford Site environmental restoration. Some discussion of systems not specifically implemented for Hanford but applicable to Hanford are included. However, at this writing, no attempt is made to completely cover systems not specific to Hanford or systems implemented at other DOE sites. Plans call for these systems to be covered in a later version of this document. Administrative systems are not addressed.

Section 3.5.1 discusses the types of information management systems that can be implemented and compares the capabilities each provides. Section 3.5.2 discusses existing information management systems related to Hanford environmental restoration. The systems are classified according to the type of data they manage.

3.5.1 Components of Information Management Systems

For the purposes of this document, an information management system is defined as the integration of

- a set of data
- a software package that provides management, manipulation, and retrieval of the data
- a user interface through which the user accesses and manipulates the data
- capabilities to query, report, and use the data.

Typically, a commercially available software package provides management and retrieval of the data. This package can be a database management system such as Oracle, Sybase, dBase, or specialized software custom written for the manipulation of data files. Even when a database management system is used, the software may need to be adapted or extended to meet user needs.

Each information management system must provide a user interface through which the user works to access and manipulate the data. In some cases, the same software package that provides data management provides the user interface. In other cases, other software can be used. The "user friendliness" of a system is usually judged by the quality and useability of its user interface. User interfaces are improving dramatically. They are moving away from styles that can be used only by highly trained users towards interfaces that use a fill-in-the-blanks, mouse-driven, multi-window environment.

Capabilities to query, report, and use the data can be provided by the same software package that provides data management, or additional packages can be used.

Information management systems operate differently from the models discussed in the previous section. Information management systems are often tied directly to the operations of an activity such as environmental monitoring or status tracking. The databases are usually updated on a regular basis with some databases receiving data almost continually. These systems become an integral part or even the major product of the activity. The models tend to run on an as-needed basis, may be dependent on the data management process, and generally come later in the decision-making process.

For the purposes of this document, we have classified information management systems into three types:

- information systems
- database systems
- file-based systems.

The three types differ primarily in the way the data is managed and the number and the complexity of the components they provide. Figure 3.6 shows the three types and the components each provides. As ordered above, these systems represent decreasing levels of sophistication in information management and decreasing support for automated data sharing. All support information management to one degree or another.

In this document, we assume that effective information management is achieved through either an information system or a database. File-based systems tend to be limited to specifically implemented functions that are provided by special-purpose software. Other methods of managing data, such as spreadsheets and paper-based systems, may be adequate for a few users, but do not promote the type of multi-user information sharing that are the focus of this document.

Both information systems and database systems use some type of database management system. An information system is differentiated from a database system by the existence of several integrated components in addition to the multi-user database. While the key component of an information system is a database, preferably one based on relational database management system, an information system can include components such as graphics, query support, report writing, advanced visualization capabilities, geographic information systems, and document retrieval. Advanced visualization capabilities can be used to display large volumes of information in ways that can provide visual insight. Geographic information systems can be used to display information on Hanford Site maps. Support for effective document retrieval is also required.

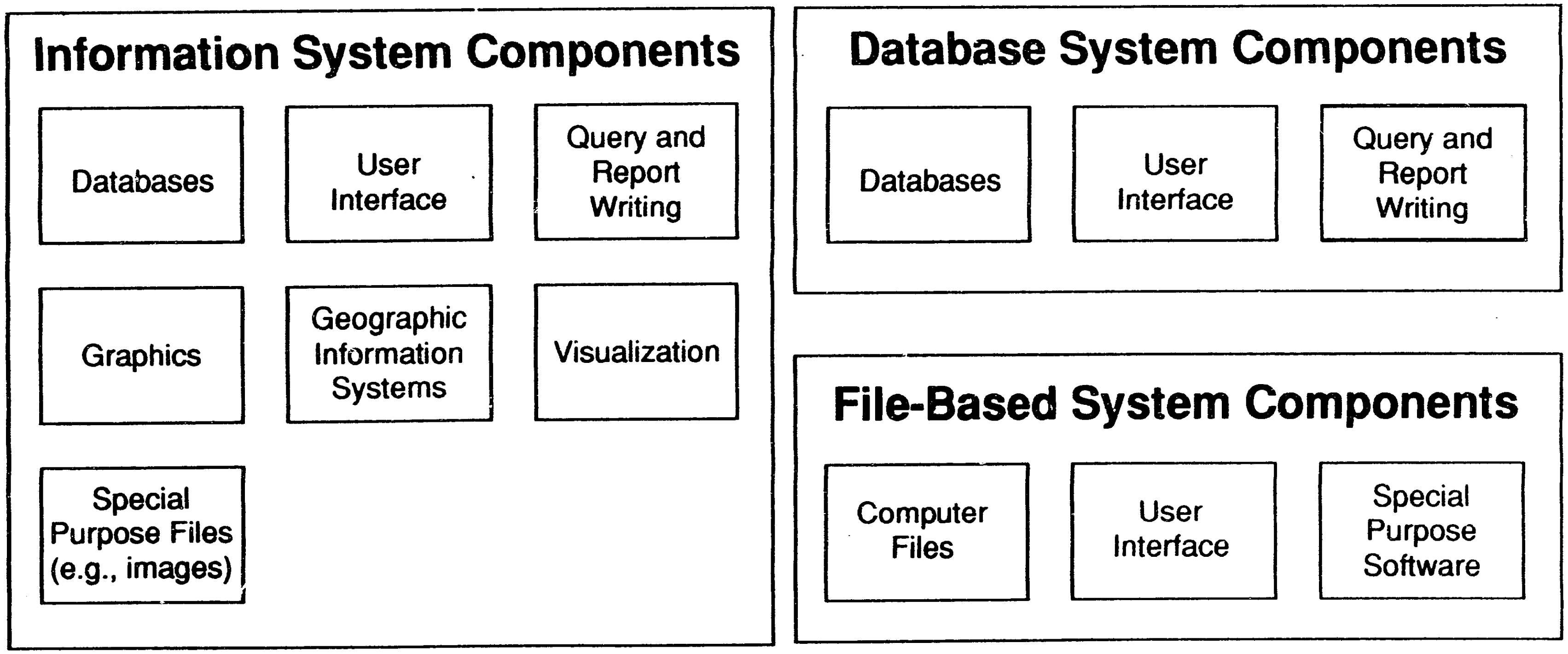


FIGURE 3.6. Types of Information Management Systems and Their Components

As Hanford moves towards the environmental restoration and waste management mission and as computer systems, software, and networking improve, tools become more and more essential to support integrated information management and meet user needs.

Sophistication in information management has improved significantly in recent years. Similar gains are expected in the future. Hanford's strategy for information management should be to position Hanford to take advantage of new technology as the technology arrives and is demonstrated as stable.

Additional work is required to determine the existing systems' relevance to the Hanford mission. Some information management systems may be too limited. Others may not be in a useful form. Several systems cannot be expected to be directly useable by the general Hanford community in their current state.

As discussed in the next section, many new systems are being implemented, and existing systems have been or are being replaced. No comprehensive integrated planning for these systems is being performed. Any integrated planning is largely dependent on the support management gives to integration and informal networking by those doing the work.

Before design and implementation begins, a requirements analysis and/or work flow analysis should be required. Systems are supposed to be presented to the Hanford Site Data Administration Council (DAC) at the end of the requirements analysis phase to determine whether the requirements justify the costs associated with design and implementation. Design and implementation should not begin without DAC concurrence. Design should include a formal data modeling activity so the database design reflects the actual structure of the data rather than being based on the needs of particular reports, which can happen when the data modeling phase is skipped. Databases of any significant size require the use of a Computer-Aided Software Engineering (CASE) package that supports entity relationship modeling and data dictionaries.

When choosing a computer platform and database management system on which the system will be implemented, integration with already existing systems and compatibility with those systems should be considered.

Some elements that should be considered in the system design and implementation include

- availability to the user community
- conformation to evolving data naming and value standards and conventions security
- backup and recovery capabilities
- hardware and software delivery platforms
- ease of use
- the user interfaces documentation
- the need for ongoing support.

3.5.2 Existing Databases and Information Systems

Information management systems are needed to organize, manage, and provide access to several classes of information including

- results of sample analysis and monitoring activities
- tracking and status
- model assumptions, input, and output
- decision support systems input and output
- spatial data
- document and electronic image data
- generic data.

Table 3.8 lists technical information management systems that are related to the Hanford environmental mission. Systems that are being replaced are not discussed below.

Results of Sample Analysis and Monitoring Activities

A variety of environmental monitoring, production monitoring, and Site characterization activities have been conducted and are continuing at Hanford. Much of this data needs to be organized, maintained, and made available to the Hanford community. Systems either being planned or currently in operation

TABLE 3.8. Hanford Environmental Mission Databases

Nickname	Database	Contractor	Environment	Status	Access via LAN	Classi-fication
AIRSYSTEM	Air Sample Data Analysis System (AIRSYSTEM)	WHC	Data General/Files	Operational	Local	FB
CASS	Computed Automated Surveillance System	WHC		Operational	Local	FB
CWM	Crib Waste Management (CWM) (to be replaced by MEM)	WHC	IBM/Nomad	Operational	Y	DB
EFFLUENT	Effluent Data for 200 Areas (EFFLUENT) (to be replaced by MEM)	WHC	PC and Data General/Paradox	Operational	Y	DB
MEM	Modified Environmental Monitoring System (to replace ERS, CWM, EFFLUENT, and OPENMODS)	WHC		Development		
EPDS	Environmental Planning Data System (EPDS)	WHC	PC/Paradox	Operational	Y	DB
ERS	Environmental Release Summary (ERS) Program	WHC	Nuclear Data/Fortran	Operational	?	FB
ETS-I	Environmental Commitment Tracking System---Internal WHC Commitments	WHC	PC/Paradox	Operational	Y	DB
ETS-TPA	Environmental Tracking System---TPA Milestone Reporting	WHC	PC/Paradox	Operational	Y	DB
FDS	Financial Data System (FDS) (Hanford-wide)	WHC	IBM/DB2, Nomad	Operational	Y	DB
GWT	Generator Waste Tracking (GWT) (to be replaced by SWITS)	WHC	IBM/Nomad	Operational	Y	DB
HECR	Hanford Environmental Compliance Report (HECR)	WHC	PC/Lotus	Retired	N	FB
HEIS	Hanford Environmental Information System (HEIS)	PNL/WHC	Sequent/Oracle	Operational	Y	IS
HHMS	Hanford Health and Mortality Study Master File	PNL	VAX/Flat Files	Operational	Y	FB
HIH	Hanford Industrial Hygiene System	HEHF	VAX/Flow Gemini	Operational	N	FB
HMS	Hanford Meteorological Station	PNL	VAX/Flat Files	Operational	Y	FB
HMID	Hazardous Materials Inventory Database (HMID)	WHC	IBM/Nomad	Operational	Y	DB
HWTD	Hazardous Waste Tracking Database (HWTD) (to be replaced by SWITS)	WHC	PC/Revelation	Operational	Y	DB
ID-CTS	Internal Dosimetry-Computer Tracking System	PNL	PC/DBASE III+	Operational	N	DB
INTERTRAC	Hanford Internal Dose Accounting and Reporting System	PNL		Operational		
LCSYSTEM	Liquid Composite Sample Data Analysis System (LCSYSTEM)	WHC	Data General/Files	Operational	Local	FB
LEAD	Liquid Effluent Analytical Data (LEAD)	WHC	Cray/Files and PC/Symphony	Operational	Y	FB
MSDS	Material Safety Data Sheets (MSDS)	HEHF	PC/Relational	Operational	Y	FB?
OIL	Open Item List	KEH	PC/DBase	Operational	Y	DB
OPENMODS	Operational Environmental Monitoring Data System (OPENMODS) (to be replaced by MEM)	WHC	PC/Lotus	Operational	N	FB
ORE	Occupation Radiation Exposure System (to be replaced by REX)	PNL	Sperry/Mapper	Operational	Y	DB
PCB nonR	PCB Report---Non Radioactive PCB Inventory	WHC	PC/Lotus	Operational	?	FB
PDMS	Project and Data Management System (Surface Monitoring Data) (PDMS)	PNL	VAX/Rdb	Operational	Y	DB
QST	Quality Safety Trending System (WHC-wide)	WHC	Mainframe/Nomad	Operational	Y	DB
REX	Radiation Exposure System	PNL	LSIS/DB2	Planning	?	DB
RSWIMS	Richland Solid Waste Information Management System (RSWIMS) (to be replaced by SWITS)	WHC	IBM/Nomad	Operational	Y	DB
SACS	Surveillance Analysis Computer System	WHC	Sun/Oracle	Operational	Local	DB
SWITS	Solid Waste Information Tracking System	WHC	Sun/Oracle	Development	Y	IS
TCD	Tank Characterization Database	WHC	HEIS Sequent/Oracle	Planning	Y	IS
TRI	Training Records Information (WHC)	WHC		Operational	Y	
WIDS	Waste Information Data Systems (WIDS)	WHC	PC/Paradox	Operational	Y	DB

Classification
FB - File-Based
DB - Database
IS - Information System

that contain such data include Hanford Environmental Information System (HEIS), Hanford Meteorological Station (HMS) files, PDMS (surface environmental monitoring data), Modified Environmental Monitoring (MEM) System, Liquid Effluent Analytical Data (LEAD), the Tank Characterization Database (TCD), the Computer Automated Surveillance System (CASS), and the Surveillance Analysis Computer System (SACS).

DOE Orders form the basis for the requirements for environmental monitoring at Hanford. Samples of environmental media are collected to determine radionuclide and chemical concentrations at locations on the Hanford Site as well as offsite. The results are analyzed and reported in annual reports (see, e.g., PNL 1990). Monitoring results (e.g., concentration levels) are reported and compared with state and federal regulatory limits. Results are reported for ground water, surface water, air, food and farm products, wildlife, soil, and vegetation. Dose rates of external penetrating radiation measured in local residential areas are reported and compared with historical values.

HEIS is a major repository for data related to environmental restoration and monitoring, RCRA monitoring, and site-wide environmental monitoring. HEIS is implemented as an information management system that runs in a distributed environment of a Sequent database computer, Sun workstations for GIS, and personal computers for access to the HEIS database. HEIS uses Oracle as its database management system and ARC/INFO as its GIS. Since HEIS will be the repository for scientific and technical data related to Hanford Site cleanup, integration of information is a primary goal. HEIS is an example of successful data integration. Ground-water data from Site-wide and RCRA monitoring efforts from the older Hanford Ground-water Database has been integrated with the newer restoration data. This permits all user groups to have access to each others' data.

The HMS files contain Hanford meteorological data collected hourly throughout the year. The current files include data for

- wind telemetry stations
- doppler acoustic sounders (SODAR)
- 200-ft towers

- 410-ft tower at the HMS
- surface weather observations at the HMS.

The wind telemetry station data, 410-ft tower data, and surface weather observation data are permanently archived into yearly ASCII files, and the remaining components are permanently archived in binary form on magnetic tape. In the future, all data is planned to be archived into yearly ASCII files. Quality assurance programs are planned and new archival programs are planned. Work is underway to replace the VAX system on which the data were originally archived.

The MEM System supports WHC environmental monitoring and protection responsibilities. The system currently collects and processes effluent and surface monitoring data and provides information for annual effluent and monitoring reports. Further development to integrate data from multiple Hanford areas and historic records is planned.

LEAD contains process liquid effluent analytical data, including chemicals and radionuclides, and is used to develop treatment systems and support permitting license applications.

The TCD is being incorporated into HEIS. Activities planned for FY 1992 call for the implementation of a tank subject area in the HEIS database. Current plans call only for incorporation of results of tank sampling and cores. While this work represents a significant advance, a single source of data about Hanford waste tanks is required to

- provide a single source of results of tanks sampling and cores
- facilitate easy user access to these data
- facilitate access for the entire DOE complex to Hanford tank data via the Tanks Waste Information Network System, which is discussed in the following section
- maintain data integrity over an extended period of time
- manage complexities of maintaining multiple databases
- improve administrative efficiency.

The Computer Automated Surveillance System (CASS) that captures realtime monitoring data from the tanks needs to be upgraded. CASS was originally implemented in 1976 and many of its components have failed, leaving a limited set of instrumentation. Data validation is non-existent. Data integrity is questionable. The data are available to only a few, who must be extremely familiar with the data to use them since they are stored in raw form. Minimally, linking the data acquisition system to a data repository is required. This linking will permit data conversion to a useful form for the general user community. It was planned that CASS would be replaced by the Supervisory Control and Data Acquisition (SCADA) system. That activity has been cancelled. SCADA was to be a distributed system to monitor instrumentation in the tank farm so operations staff would be able to respond to changing tank farm conditions. SCADA was to be larger than CASS with more capabilities. Tank data from CASS are made available to users through SACS, implemented on Sun workstations.

Some of the issues related to this class of data include the following:

- Scientific and technical data related to cleanup should be integrated into a single system where these data can be universally available to the user community. HEIS serves as the database for a major portion of the data. Any additional scientific and technical data required during the process should be considered for integration into this already existing framework.

- PDMS data needs to be integrated into HEIS so its current and historic surface environmental monitoring data can be utilized by those doing environmental restoration work since the data provide a broad historic perspective on the status of the environment. There is currently no funding for the conversion activity although some funding is available for conversion planning.

- HEIS' focus has been on supporting the Site characterization process. Support for other parts of the remediation process has not been scoped, much less implemented.

- Although most of the crucial subject areas for the site characterization process (e.g., ground-water, geologic, biota, atmospheric, etc.) have been implemented in HEIS, other subject areas for such as surface soil and water, aquifer testing, concrete corings, and ecology have not yet been addressed. Additional functionality to support all subject areas is needed.

- Effective access to HMS data needs to be provided. Recent HMS data are available on a PNL VAX in flat files, which makes use difficult. The data structures and some software are in place to incorporate the data into HEIS, but the activity is unfunded. An assessment of needs for access to HMS data should be performed and form the basis for planning integration of HMS data into HEIS.

- MEM is being planned. Since MEM contains environmental monitoring data, such as HEIS and PDMS, the issue of whether MEM should be incorporated into HEIS needs to be considered.
- How should MEM data be integrated with the other geographic data?
- SCADA was not funded for FY 1992. What will be the impact of continued use of CASS?

Tracking and Status Systems

This section discusses tracking and status systems such as the Waste Information Data System (WIDS), Solid Waste Information and Tracking System (SWITS), Hazardous Materials Inventory Database (HMID), Tank Waste Information Network System (TWINS), a new radiation exposure system named the Radiation Exposure Database (REX), the Hanford Health and Mortality Study (HHMS) Master File, the Hanford Internal Dose Accounting and Reporting System (INTERTRAC), and the Internal Dosimetry Computer Tracking System (ID-CTS).

WIDS contains general information about waste sites, including physical and environmental characteristics of radioactive and hazardous waste sites at Hanford and some associated administrative data. WIDS is supplemented by a library of documentation, which is available at the 450 Hills Building.

SWITS has just become operational and replaces the overlapping requirements currently met by Generator Waste Tracking, the Hazardous Waste Tracking Database, and the Richland Solid Waste Information Management System. Its purpose includes generator waste tracking, waste shipment documentation support, and disposition tracking of hazardous, mixed, and solid wastes through treatment, storage, and disposal. SWITS is implemented as a database on a Sun workstation using the Oracle database management system. Users will be able to access SWITS from their PCs via the Hanford local area network (LAN). Additional functionality for SWITS is being implemented during FY 1993.

HMID contains chemical release and hazardous material inventory data. All contractors provide HMID data, which is collected by approximately 50 staff using a PC-based version of HMID. Once data is collected on the PC, it is uploaded to the LSIS, collated, checked, and loaded into the Nomad-based LSIS version of HMID. The system was implemented to meet the requirements of the Emergency Planning and Community Right-To-Know Act (EPCRA). The PC portion of the system is to be re-implemented as HMID2 in order to meet newer requirements, provide support for more data validation checks at the PC level, and allow the software to be more compatible with other software supported by WHC/IRM. The LSIS HMID data is synthesized and made available to users through soft reporting. Users do not have direct access to the database itself.

TWINS is being implemented by PNL for HQ as a method of supporting integrated access to data about DOE waste tanks. Users throughout the DOE complex will access a network controller implemented on a Sun file server located at PNL. The controller will know how to communicate with each site's tanks database. Sites will be asked to conform to a set of standards and conventions.

REX is in the requirements analysis phase and is scheduled to replace the Occupational Radiation Exposure (ORE) system, which runs on the Sperry computer that is being phased out in early FY 1993. REX is to be implemented on the LSIS using DB2 so database tables can be shared with People-CORE. REX requirements are not yet finalized.

The HHMS master file contains information, protected under the Privacy Act, for operations workers employed at Hanford since 1944. This information consists of demographic data, occupational summary data, annual radiation exposure data, and vital status data for each worker. The radiation exposure histories are provided by PNL; the remainder of the information is provided by HEHF. The master file is created at PNL by consolidating all of the information on each worker.

The INTERTRAC system was developed by the Hanford Internal Dosimetry Program to assist in the complex processes involved in dose assessment and accounting. The system was designed to maintain calculated internal dose data in files that could be easily accessed for creating various occupational radiation exposure reports for individuals, their employer, and RL.

ID-CTS uses a dBaseIII+ menu-driven program maintained on an IBM-PC workstation to track internal dosimetry activities in four different areas: special requests, notifications, assessments, and reports. In addition to its tracking functions, the database is used to generate summary statistics in each of the defined areas and to monitor and project program workload.

Some of the needs and issues related to this class of data include the following:

- As the RI/FS site characterization process proceeds, locations of additional contamination are being identified. At this time, WIDS, which contains the "official" list of waste sites, requires extensions to identify these newly identified pockets of contamination and track how they were dealt with.
- SWITS developers and users are considering the addition of a geographic information system. How can they take advantage of the work that has already been done for HEIS?
- Since both HEIS and SWITS run on UNIX platforms using Oracle, should they reside on the same platform?
- An *ad hoc* query facility for non-programming SWITS users needs to be identified and procured.
- SWITS has a requirement to interface with offsite users and systems, such as a national database. How can these needs be most effectively met? How can offsite SWITS users be granted access to only a portion of the SWITS data? Will the environment be able to handle many varying interfaces?
- SWITS is currently implemented on a Sun Sparc2 platform. Will this platform be sufficient to support the entire user community?
- Can the requirements for REX be completed in time to allow sufficient time for design and implementation before the Sperry computer is removed or becomes not cost-effective?
- How can personal data from systems such as REX be made available to those who are making field work assignments? Issues include privacy and restrictive regulations.
- TWINS requires access to Hanford Site tank data. How can tank data be integrated and made available to the TWINS user community?
- Many organizations within WHC need to track data about hazardous material. Should a single integrated database be developed that meets the needs of all of these organizations?

- Some systems implemented in Nomad do not support concurrent use of the data by several users. Should systems using this technology continue to be developed or should only systems that support multiple concurrent users be developed?

Model Assumptions, Input, and Output

There will be voluminous amounts of data associated with models, including assumptions, data input, and model output. Often, the process of assembling the input for a model and processing the output may involve more costs than the costs of running the model. Better methods of managing these data are required. In some cases, the model results should be stored for further use and analysis. A case in which model results have been extensively used is the output of the TRAC model, which has been used to project the radionuclide content of the waste tanks. Results of TRAC have been used at WHC as the best available projection of total radionuclide content. Consideration is being given to incorporating TRAC results into HEIS. Since the TRAC model cannot be run on any of the existing computers at Hanford, no TRAC runs have been performed in many years.

Methods need to be developed for effectively managing model assumptions, input, and output. The assumptions used for running a model must be captured since the model results can only be correctly assessed within the context of those assumptions. The process of preparing model input and getting that input into the model at run time needs to become more cost-effective.

Some of the issues related to this class of data include the following:

- Using a database as a source of model input needs to be investigated.
- Once a model is run, there needs to be a method by which the output can be-made available to the user community. Using an information system as a source of model output also needs to be investigated.
- There needs to be a way of effectively storing data, objectives of the run, assumptions, and results in a way that minimizes the stored data and yet assures traceability and accessibility.
- Should TRAC data be incorporated into HEIS?

Decision Support Systems Input and Output

As with models, data are required for decision support systems. Some of these systems may use internal data resources, but in some cases, data may need to be tapped from other sources. Storage of assumptions may also be useful. Investigation of information management systems for decision support needs to be performed.

Spatial Data and Geographic Information System

Spatial data in the form of maps and map layers needs to be developed and maintained for the site. Duplication of effort in this area needs to be eliminated. Work is underway to develop a series of maps for general use at the site. By the end of FY 1991 most of the areas were "flown," the resulting data digitized into electronic form, and the resulting data were undergoing further processing. At this writing, data for the 200 Area has been checked, annotated, and converted by the HEIS team from AutoCAD into the HEIS GIS, which is being implemented using ARC/INFO, a commercially available GIS software package.

GIS tools are also being used by the Hanford Environmental Dose Reconstruction (HEDR) project. HEDR is using a PC-based version of ARC/INFO to display and analyze estimates of spatially distributed environmental contamination and dose from historical releases of radioactive material from Hanford operations. These estimates are calculated by large-scale environmental transport and food-chain models. The GIS will be used to graphically present the model results in a form that can be easily communicated to and understood by the general public.

Some of the issues related to spatial data and GIS include the following:

- How can the development of a Site-wide spatial data resource be adequately funded when it is not tied to a specific TPA milestone?
- How can spatial data be managed as a site-wide resource?
- There are fundamental philosophical differences among drawing packages. GIS education is required to help the user community understand the role of drawing packages like AutoCAD versus a GIS which supports analysis as well as display functions.

- How can the spatial data needs for environmental restoration and other applications, such as facilities planning and tracking, be reconciled so everyone's needs are met?
- Since GIS software packages are being used at Hanford, should a site-wide standard GIS be adopted, or should standards and conventions be adopted for data exchange between packages?

Electronic Image Storage and Retrieval

Computer-based methods of document and electronic image storage and retrieval are just beginning to be applied to Hanford. This type of data needs to be integrated into information management systems and made readily available to users.

Recent advances in computer technology make it possible to store images of pages of a document so they can be retrieved from an optical disk and displayed on a high-resolution screen. This includes the ability to view signatures and figures as well as text. Capabilities for searching for text strings within documents are also available. While database management systems can provide some search capabilities, these text retrieval systems are optimized for finding text within a user-supplied context. Such systems can save much paper, space, and duplication effort by using the electronic rather than the paper form of documents. Hardcopy can be routinely generated as needed.

Paper documents plus microfilm are considered to be the "official" version of legal documents. The role of the electronic storage of documents as official documents needs to be explored.

High-resolution, color display monitors coupled with computers with sufficient storage and processing power make it possible to support the interactive storage and retrieval of a variety of electronic images. The types of images that can be stored include maps, satellite imagery, photographs, and other types of graphics. These types of images should be available for integration with other types of data. For example, satellite imagery can be integrated with vector-based maps in a GIS to provide context that is useful for both data display and data analysis. Another example of using image data is the ability to simultaneously call up a photograph of a waste site on the screen while analyzing its data.

Generic Data Requirements

Most of the systems discussed above contain data that is Hanford-specific. Other data can be considered generic and cross-cutting regardless of the application. Examples of generic data not tied specifically to Hanford are health risk coefficients and ecological risk data which can be used to evaluate health and ecological risks.

Issues related to this type of data include the following:

- Is there a source of data? Are these data of sufficient quality? Do we know the objectives and assumptions under which the data were gathered?
- Can the data be procured rather than being developed?
- How will the data be developed if they are not available from others?

An example of cross-cutting data is the regulatory limits that apply to various contaminants. They exist in several systems now. Regulatory limits need to become a common resource for all those concerned with such issues.

Issues related to this type of data include the following:

- Who is responsible for compiling regulatory limits and maintaining them?
- What other types of data should be maintained as a site-wide resource?
- Should there be a single repository for this data?
- There is a need for a user friendly database so those involved with environmental restoration can ascertain regulatory requirements and relate them to their work.

3.5.3 Discussion

While recent advances by the computer industry have been substantial, much research and development work remains to be done by the computer industry and by those applying the technology to Hanford's problems. Some of the issues and problems we face when planning how computer-based tools can be applied include the following:

- Communication of complex scientific information is essential. Computer technology has not been applied effectively in this area.

- While individual pieces of this technology exist,
  - some technology (e.g., GISs) is immature and does not fully meet needs
  - the technologies are not effectively integrated.
- Models do not have effective, easy access to data. Models and their data sources need to be integrated. Where data do not exist, decisions must be made about whether the data are cost-effective to obtain.
- Customization of computer technology is required for application to Hanford.
- Integration of models with scientific visualization capabilities is a powerful means of communicating results to the general user community, but work is required to support this capability.
- An effective, computerized method of managing and providing access to data must be in place before significant amounts of data begin to arrive.
- GIS technology must be integrated with software that handles volumes (three-dimensions) and surfaces (two-dimensions).
- Work is needed to determine how three-dimensional graphics can effectively depict geology and contamination.
- Work is needed to evaluate what constitutes a legal document. At this time, only paper constitutes a legal document. This definition should be expanded to take advantage of media such as optical disk.
- Work is needed to explore how multimedia computer technology can be applied at Hanford.
- More sharing of technological capabilities and technology transfer can lead to more cost-effective system development.
- Investigate advantages and disadvantages of moving towards a client/server architecture with more integrated databases and more distributed processing (using workstations).

3.6 DATA

A primary product of the early stages of environmental restoration is data. Data are the basis on which plans will be developed and decisions made. The data must be of known quality and be capable of being defended during litigation. These data must be made available to the analysts and decision-makers in a useable form. The data used for analysis must be appropriate to the analysis (i.e., most historic data were gathered for compliance purposes and may be inappropriate for some analyses). According to one estimate, typically more than 50% of the costs of an RI/FS are primarily information- or analysis-driven (Geffen et al. 1989). The RI/FS characterization requirement, a major task in every environmental restoration project, is the reason data synthesis and analysis are being given such high priority at Hanford. Data from sampling and monitoring, data from experiments, output data from performance and risk assessment models—and the synthesis of these data—are the basis for Hanford Site characterization.

Remediation of the Hanford Site also involves the acquisition, reporting, analysis, and publication of data and information related to inventories of hazardous materials, state of the Hanford environment, and progress of cleanup. Types of data and/or information range from raw data to reports and public information. Access is required for a wide variety of data and information users including technicians, analysts, scientists, engineers, managers, reviewers, and regulators.

Data are currently being generated faster than they are being processed. The TPA has strict requirements on how data must be processed and made available to the regulators. After receipt of analytical data from a laboratory, contractors are allowed 21 calendar days to validate the data and an additional 15 calendar days to make the data available, which is currently being accommodated by getting the data into HEIS. Problems with data that was gathered before formal procedures were in place have caused delays in making the data available to the user community.

3.6.1 Problems Associated with Using Historic Data

Data at Hanford have been accumulated for a number of years in a variety of forms. Data for a variety of purposes are being collected today. Using older, historic data for Hanford's environmental mission presents a particularly difficult set of challenges. In some cases, using historic data may be of great benefit and cost effective. In some cases, historic data may be the only source of information. In other cases, problems with the quality of the data and/or the difficulty in preparing it for use precludes its use. Nonetheless, access to these historical data is critical.

The first problem in using historic data is associated with obtaining the data. The data may have to be assembled from a variety of sources or documents created over many years and distributed throughout the site or even located offsite. The HEDR project has gone through this process to assemble data for estimating dose. This proved to be a difficult, time-consuming, and expensive process.

Since the data are likely to come from multiple sources, consistency in the data will be the exception rather than the rule. A consensus must be reached about how to deal with these inconsistencies. Steps in this process include assessing

- what standards were used when the data were originally gathered?
- what are the quality of the data?
- how well do the data conform to the standards that currently exist?
- how can gaps between original and current standards be handled? In some cases, it may simply be best to mark data as not conforming to standards and make it clear to the users that the data must be used with caution.

To make data available to the large user community through an information management system, data structures and software to manage the data must be designed and implemented, and data must be made available from within the information management system. The costs associated with obtaining and incorporating the data into the information management system may greatly exceed the software development costs.

3.6.2 Tools to Facilitate the Data Collection and Synthesis Process

The major reason that most data are collected is to support the decision-making process. With the high costs of sampling, sample analysis, data processing and data analysis, the best use should be made of all data. Figure 3.7 depicts the role of data in the decision-making process. The plan to acquire data usually begins with the statement of a problem. The decisions

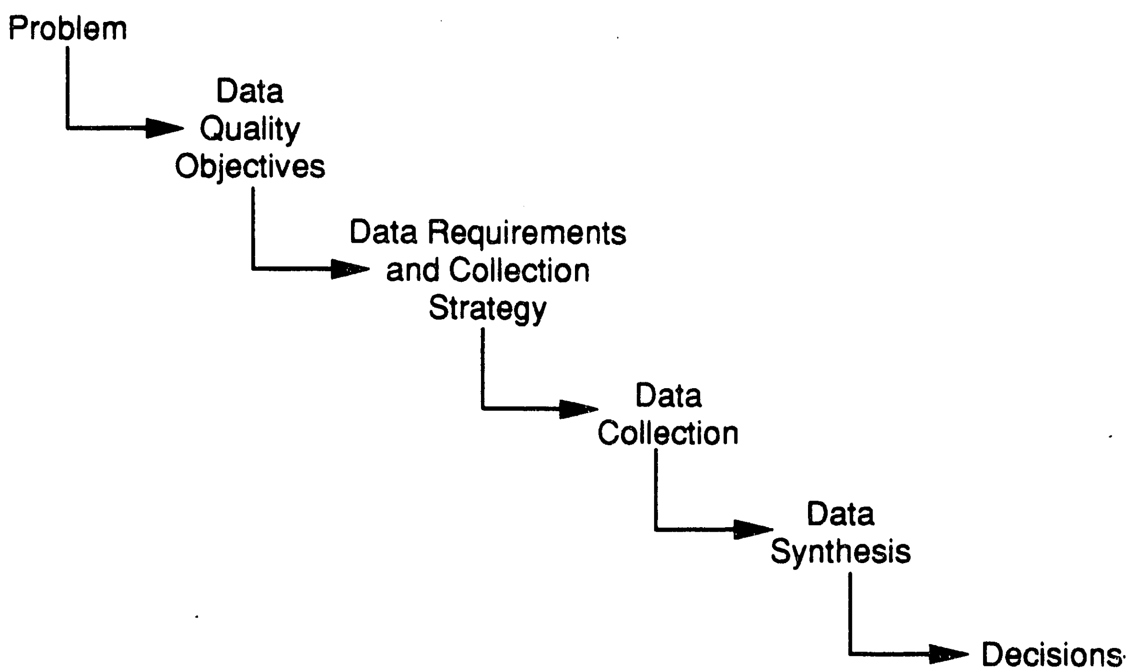


FIGURE 3.7. The Role of Data in the Decision-Making Process

on what data are to be gathered need to be based on a set of data quality objectives (DQOs), which look at the end use of the data and are establishedto ensure that the data are sufficient and of adequate quality for their intended use. (Section 3.5.2 discusses DQOs and provides some examples of how they have been applied.)

Data Quality Objectives

Data quality objectives offer decision-makers a tool to answer two types of questions: 1) What type of data do we need? and 2) What quality of data do we need? DQOs provide a qualitative and quantitative framework around which data collection surveys are designed, and can serve as performance criteria for assessing ongoing or completed RI/FS studies. DQOs allow remedial project managers to make decisions based on data with a predetermined and acceptable level of confidence.

Both DOE and EPA have embraced the DQO concept (Neptune et al. 1990). Neptune describes several EPA Superfund sites where DQOs have been applied. In some of the case studies, DQOs have been applied retrospectively and have suggested that a dramatic redirection of effort might have occurred had DQOs been considered early in the planning phases of the project. The DQO planning process recognizes that decision making at remediation sites such as Hanford is driven by risks to public health and that the uncertainty in decisions will be affected by the type and quality of data collection.

Data Requirements and Collection Strategy

Once the DQOs have been established, data requirements and a strategy for the collection of the data must be developed. The strategy should include 1) looking at data that has already been collected to see if the data can supply insight for the strategy, and 2) considering how the data can be used by people working on other problems. The perspectives on the data-collection process at Hanford need to be focused more broadly so that each project considers how to extend their data acquisition plans so their data supports parallel data needs of other projects.

Data Collection

Many methods are used to collect data. Monitoring, surveillance, and direct data acquisition methods are examples of methods used at the Hanford Site. One subset of collection worth special mention is sampling because it is a key component of the waste characterization process. Minimal sampling is desired due to the expense of sampling and analyzing the sample results in analytical labs. The number of samples collected, the location of sample collection, the methods used to analyze sample results, the level of statistical confidence placed on estimates of population parameters based on sample results, the levels of type I and type II errors (false positives, false negatives) for decisions based on sample results are all issues involved in the data collection and characterization process.

More automated support for the data collection process is needed. Some projects have already automated some of the process. For example, the Ground-Water Surveillance Program makes use of automated sample scheduling and tracking software that generates sample labels, generates customized paper forms for use in the field and for the laboratory, and tracks samples through collection and analysis. This software is used for both site-wide monitoring work and RCRA ground-water work. Work is currently underway to determine requirements for sample tracking for WHC's CERCLA work. Other techniques, such as bar coding and use of portable computers in the field, are being considered and, in some cases, applied.

One example of an automated tool that has been developed at Hanford to support the data collection process is a quality control software package called the Dynamic Linear Model (DLM). Developed for data quality control for meteorological instruments, the DLM software package[a] is applicable for a wide variety of real-time processing of geophysical processes. Whether it is ground-water monitoring, air sampling, monitoring of ISV melter processes, tank temperature and pressure monitoring, statistical quality control provides a method for detecting anomalous behavior.

Standard statistical quality control techniques are used with stationary processes, where the objective is to establish control of the process within acceptable limits. Non-stationary processes such as weather conditions, chemical reactions, and ground-water movement require special techniques for establishing statistical quality control. Those acquainted with the process under consideration can specify relevant types of anomalous behavior. These specifications, tailored to the given process, can then be modeled mathematically and incorporated into the key component of the monitoring scheme—the dynamic time series model.

DLM is a software package that can be used for data collection quality control and data filtering when a non-stationary process is being monitored. It is a Hanford Integrated Planning tool that can be used in the data preprocessing step to control the quality of data prior to use.

Data Synthesis

Once data has been received, verified, and validated, synthesis of the data can begin. The purpose of data synthesis is to prepare the data for use in the decision-making process. The process of data synthesis may use tools such as statistical analysis, modeling, scientific visualization, summarization, use of expert opinion, or interpretation.

(a) Blough, D. K. 1991. "Real-Time Statistical Quality Control of Meteorological Instruments." Submitted to the Journal of American Statistical Association.

Some specific data-synthesis tools that can be used to identify the variables and their interactions that are input to the performance and risk assessment models discussed in Section 3.4 are

- GIS systems that simultaneously map two or more variables so associative and correlative relationships are evident
- data quality control systems that filter out extraneous trends or errors so that true patterns become evident
- statistical routines that separate components of variability into systematic and random error
- data reduction that is capable of compressing multiple attributes and complex response surfaces into simpler sets and/or principal components
- data summarizations that reduce large data sets to a few key summary statistics, thus making the problem more manageable and amenable to analysis.

Data synthesis provides the parameter values and variable relationships required to run the models. Raw data such as the HEIS sampling data and monitoring data must be transformed before they can be used directly by the models. Data synthesis also facilitates model validation and verification. Comparing model predictions to scaled experimental data and observed data usually requires preprocessing of the data in order for the comparisons to be meaningful.

Generally, the automated tools for data analysis that have been developed for specific Hanford Site applications are limited and more capability is required. Some of the tools that are actively being applied include reports, queries, graphics, statistics, models, and trend checking. Tools being used to a limited extent include GISs, scientific visualization techniques, and expert systems. Much more application of these tools will be needed in the near future. Other types of specialized software can also be applied.

One specialized data synthesis tool that is under development at Hanford is the Integrated Characterization System (ICS). ICS can be used in performing the Site Characterization phase of the RI/FS required for hazardous waste sites. ICS can be used to predict critical unknowns (ranging from site hydrogeology and actual extent of contamination, to performance of treatment and engineering controls) and characterize their uncertainties through modeling and visualization technology.

ICS is a system that incorporates multiple modules. Raw geophysical data are screened for outliers and noise in a process filter module. Supporting data (chemical data, map information, monitoring data) are brought into the system using a common platform. Multiple data sets can be displayed together in the visualization module. The parameter estimation module synthesizes the data, using conversions, summarizations, curve fitting, least squares regressions, etc., to generate model input parameters from the refined data. Model output may be combined with the refined data to generate the probabilities used in baseline risk assessments, or to update prior subjective probabilities to generate posterior probability distributions for use in risk-based cleanup levels, as defined in the Hanford Site Baseline Risk Assessment Methodology.

An important characteristic of environmental data is that they vary as a function of spatial location. Data that are close together in time or space are usually more highly correlated than those that are far apart. Geostatistics is a method for analyzing spatially correlated data. A spatial estimation method known as *kriging* (a key tool in geostatistics) can be used to estimate the values of a spatially distributed variable at points between actual sample locations and to provide an associated estimation error.

Kriging has been used at Hanford to map the water table depth on the Site (Doctor 1979), and Jacobsen and Freshley (1990) attempted to use a geostatistical representation of the water table across the Site to calibrate a ground-water flow model. Recently, Gaylord et al. (1989) have used geostatistics to generate a suite of possible stratigraphic cross-sections from geologic descriptions at boreholes to help develop a three-dimensional hydrologic conceptual model at the Hanford town site.

Role of Data in Decision-Making

Models can be applied in other ways than those described in Section 3.4. For example, environmental transport models, specifically unsaturated-zone and ground-water flow and transport models, can be used for evaluation and summary of site characterization data, designing characterization and monitoring systems, and designing and evaluating the performance of remedial alternatives. Models are efficient means of synthesizing often limited data from a site and interpreting the data. With numerical models, different conceptual ideas or conceptual models can be tested for a site during the early stages of site characterization. In addition, exercising a model iteratively with collecting site characterization data provides information useful for identifying locations where additional site characterization data are needed. Finally, unsaturated-zone and ground-water flow and transport models can be used in design of remediation schemes. A specific example is optimization models for placing ground-water extraction wells for pump-and-treat remediation of contaminated ground-water.

Once this entire process is complete, we are finally in the position to make decisions.

The process is not entirely as serial as shown in Figure 3.5. At any point in the process, return to a previous part of the process may be required. For example, early data analysis may show that DQOs need to be refined so that a more effective data collection can be performed. A more likely scenario would be that further analysis is required to develop more refined data predictions that support the decision-making process.

4.0 INFRASTRUCTURE TO SUPPORT DECISION SUPPORT TOOLS

Infrastructure is the underlying computer base or foundation required to support Hanford mission areas. Infrastructure includes databases, commercially available hardware and software, Hanford-specific methods, and applications of a general nature. For the purposes of the Decision Support Tools Task, infrastructure does not include specific tools and/or models that focus on a particular technical problem.

4.1 COMPUTERS AND RELATED EQUIPMENT

Computer technology is advancing continuously, providing a challenge to the suppliers of the computational infrastructure. The evolution must be planned in a cost-effective way, while providing necessary service.

4.1.1 Computers

Different classes of computers and networks can contribute to a cost-effective infrastructure. Specific resources acquired to satisfy Hanford mission and infrastructure needs must be carefully planned to obtain synergistic integration while satisfying specific performance requirements. Classes of computers and networks currently envisioned are depicted in Figure 4.1.

Supercomputers can be beneficially used to apply some of the modeling tools. Other smaller, special purpose and general purpose computers will be required for specific tasks and general technical support. Hanford networks will be required for workstation access to Site-wide capabilities. Examples include centralized mainframe and high-performance computers, Hanford information, Technical Library services, and electronic mail. The entire Hanford computational capability must satisfy the demanding needs of all types of tools and users involved in the mission.

The logical blocks and connections in Figure 4.1 depict the evolution to specialized computing that satisfies the demanding requirements of diverse use typified by Hanford Site users. This figure is not meant to be exhaustive. Rather, it shows that the Hanford Site needs a different computing environment than its current environment. For example, the advent of client/server

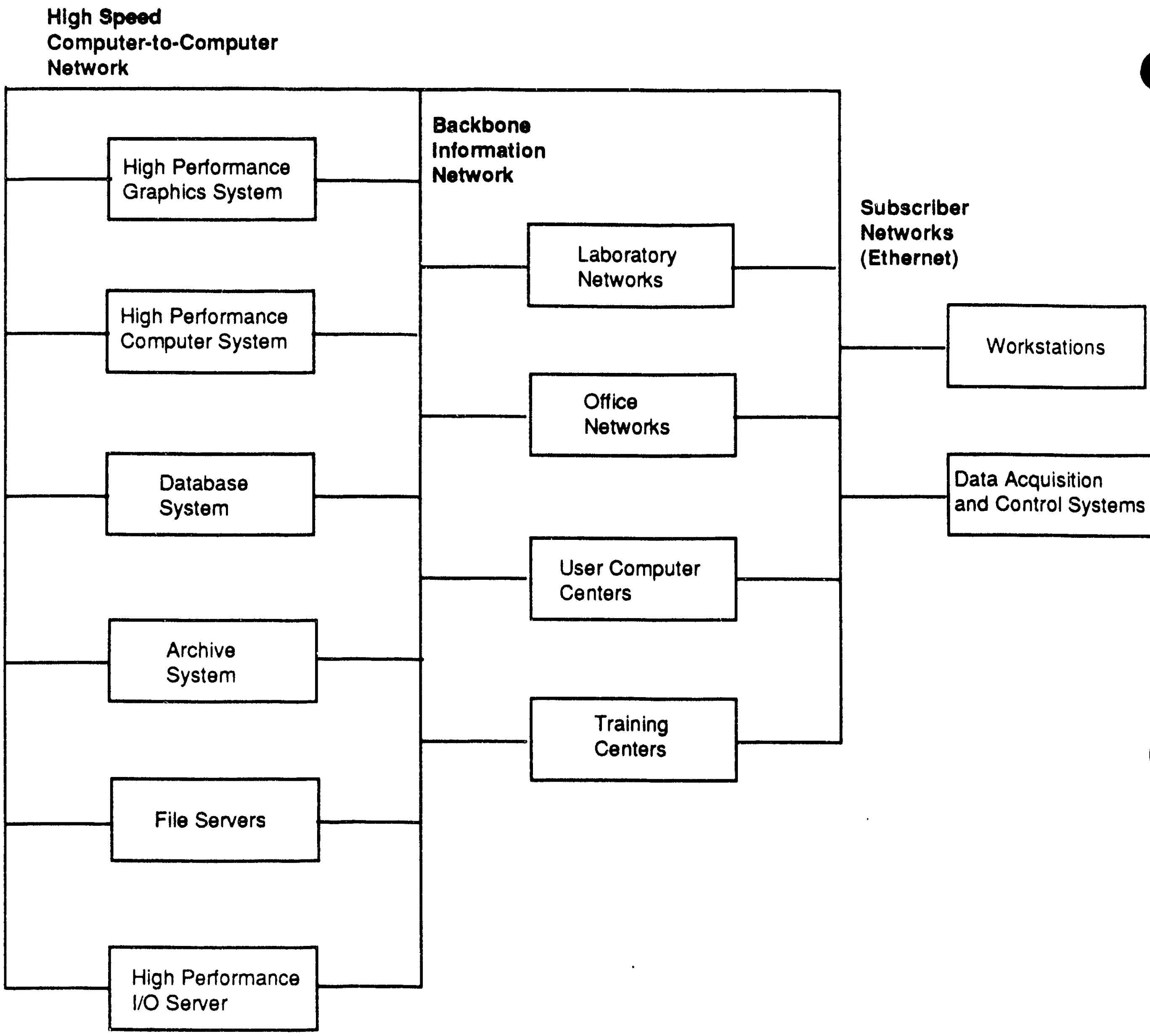


FIGURE 4.1. Computer Architecture

computing has changed the requirements for computers and networks at the Hanford Site. The term client/server is used to denote the use of a client computer for user interaction while the computations are taking place on a server computer. This architecture is cost-effective because it minimizes the duplication of expensive computational resources. The client/server model is flexible, allowing for varying mixes of client and server participation in the total computational task at hand. Its performance is dependent on the performance of the network, client workstation, server computer, operating system and network software, and, of course, the applications software. The future Hanford architecture must be flexible and evolutionary to allow us to satisfy our needs with limited budgets. The capabilities depicted in Figure 4.1 are typically scalable in size and numbers, and are modular enough to replace individual capabilities when the need and the technology demand.

High-performance computer systems will support scientific modeling tools, while high-performance graphics systems will be required to visualize the complex output from the tools. These two systems need to be tied closely together. High-speed computer-to-computer networks, backbone networks, and subscriber networks represent data communication capabilities designed around specific requirements of the applications.

The database management system, in conjunction with the archive system, file servers, and high performance input/output (I/O) server, will be used to satisfy all aspects of data management. These functional capabilities are shown separately because the function they provide may independently service other functions. For example, the high-performance I/O server may directly connect the high-performance computer system with the archive system, bypassing some of the other functional capabilities. Many combinations are possible.

4.1.2 Networks

Laboratory networks are the source of data of interest. A good example is the Laboratory Information Management System (LIMS), currently being procured.

Office networks represent both scientific and administrative use of mission-related computational resources. Workstations include office computers, desktop PCs, terminals, diskless and dataless workstations. Group computer centers represent those systems and networks focussed on a particular technical problem, such as atmospheric or environmental modeling. These user facilities house specialized computer equipment and peripherals required for the technical applications at hand, while providing an optimum environment for staff to perform their functions. For example, geologic characterization may require high-performance graphics devices, including displays, plotters, and digitizers with supporting computers and software. Integration of user facilities with other Hanford Site computational capabilities places new demands on the network and computers. High volumes of data may have to be rapidly transported into and out of the user facility for analysis and visualization.

4.1.3 Training

Training centers are facilities and computational capabilities designed to facilitate two types of learning: learning to use the systems, and learning to use the data and results. Tools must be available and well supported. Users of the tools, data, and results must be properly trained. The integrated and coordinated use of support tools also must involve a user training component. A common error in the design of decision support systems is the failure to maintain a balance between the capabilities of the tool and those of its users. Just as limited tools may restrict the capabilities of a superior research staff, so may untrained or undertrained users limit the performance of sophisticated tools.

It is important to keep in mind that a high level of intelligence and technical knowledge does not necessarily imply that a user has the training or experience adequate to use a particular tool. The development of user-friendly interfaces has tended to increase the number of instances in which inexperienced users misuse support tools. These interfaces may allow users to operate a tool even though they may have a limited understanding of the way input data are to be used, the different modes of model operations, and the conditions under which the model tends to perform most and least reliably. The inexperienced user also may encounter problems in correctly interpreting model output.

A standard certification or mandatory training program for the users of key support tools would increase the probability that these tools are being used by individuals or groups who have demonstrated a minimum level of technical proficiency with the tool. Such a program would help improve the reliability of model-generated results.

4.1.4 Use of Computers to Manage Data

Data acquisition and control systems include those automated systems that provide worthwhile data to maintain within the data management system.

One type might be an interface to the LIMS, while another might include process and environmental monitoring systems.

With the advent of the contemporary information management system technology, the way data are managed is changing. The evolution to specialized data management capabilities provides a unique opportunity to design a better data management system for the Hanford Site. Better data management can be accomplished through the distributed hardware/software architecture described above and shown in the Figure 4.1. Because of client/server technology, the Hanford Site will be able to realize the benefits of an easily accessible single repository for data. Data should be generally available, but once they have been verified, data should be controlled (such as read-only for most users). Data will need to be well documented because users will not typically be experts. Standards and conventions for data are required to provide an understanding for the several types and numbers of data users.

4.2 SOFTWARE

Computer infrastructure software includes operating systems, computer languages, network/user interface, database management systems, query languages, report writers, and other software not directed to any particular cleanup or management operation.

Planners of the computational infrastructure must focus on ways to realize the benefits of contemporary software applications, systems, and practices. Current and evolving technology in the areas of database management, scientific visualization, GISs, and multimedia technology are of particular interest in support of Hanford Integrated Project tools.

Existing capabilities for data management and statistical analysis need to be linked and integrated to facilitate the management and analysis of environmental restoration or environmental-related data. Data quality objectives and data strategies from data acquisition and management through information development and management need to be integrated by coupling tools and capabilities. Some of the areas in which this coupling is required include

- database management – high performance database systems, computer systems engineering, real-time data acquisition systems

- visualization – GISs, scientific visualization, animation, and multimedia technology
- statistics – environmental sampling design, statistical analysis, statistical quality control
- modeling – probabilistic and empirical modeling, spatial and temporal modeling.

This integration could encourage and foster collaboration and better communications among the various members of the cleanup team (planners, samplers, laboratories, analysts, report preparers, and regulators). Data management and analysis methods could be designed up front to accomplish DQOs and automate quality assurance and control functions.

4.2.1 Database Management

Databases can provide an infrastructure capability to facilitate consistent, controlled, reproducible management of data and information. At this time, conventional relational database management systems are not suitable for managing all types of information, but are critical for data and information that fit well in tables of rows and columns and is deemed to be important, accessed by many, structured, and maintained over a long period of time. Research is being performed related to the management of the different types of information. We can assume that the types of information managed will grow. The application of advances in multimedia systems to support the use of data not well handled by relational database management systems is discussed below.

Database administration is needed to provide data that have defensible quality, origin, derivation, access, and longevity. To ensure these characteristics, well-defined administration of the database must be maintained. Required administrative functions include access control, definition of data structures and tables, database backup and recovery, and upgrade planning.

Database access is different for people who enter data, internal users of invalidated data, and users who view published data. Access must be controlled to limit modification of data to authorized users.

User interfaces, query languages, report writers, and graphics are all important components for supporting the user's access to databases. Some users can also benefit from capabilities that support access from user-written software, access to databases from statistical analysis packages, and the use of natural query languages that allow users to query the database in an English-like language.

4.2.2 Scientific Visualization

Scientific visualization is increasingly being used to present complex scientific and engineering information to a wide audience. Of all computer-based methods of data presentation, visualization techniques are often the best choice. To understand the increasing amount of complex data that characterize the cleanup problems at hand, innovative color, multidimensional, and animated data displays using engineering workstations are useful for data synthesis and increased understanding. For example, scientific visualization could be used to display the results of a ground-water flow model. The visualization could be used to support a color, three-dimensional cutaway showing how contamination is distributed beneath the surface of the earth. The user could rotate the three-dimensional volume in order to view it from a number of perspectives.

Recent and continuing advances in hardware and software mean that scientific visualization is becoming an increasingly available tool. Workstations are affordable. Programmers can use commercially-available visualization software packages and customize them to their application. Some packages are even designed for end-user application so a programmer does not have to be involved. Visualization capabilities should be considered an integral part of any scientific-oriented information management system.

4.2.3 Geographic Information Systems

Geographic information systems can be viewed as a special type of scientific visualization technique where the context of the visualization is a map. A GIS allows users to compose maps onto which spatially oriented data can be displayed. What differentiates GIS from computer-based drawing packages, which also support the building and display of maps, is the ability to perform analysis with the data. For example, GIS packages support the ability to exclude areas based on criteria, generate contours from point data, and support buffering operations that, for example, identify areas within a certain distance of the Columbia River or some other feature known to the GIS.

Since much of the scientific and technical data related to Hanford Site cleanup can be identified with a location on a map, GIS will be an extremely valuable tool in the decision-making process. A GIS is being implemented as an important component of the HEIS.

4.2.4 Multimedia Technology

Multimedia technology supports the processing, storage, and transmission of data types such as images, graphics, text, audio, and video. As with scientific visualization and GIS, workstation technology with local storage of the data is an appropriate platform for using multimedia technology. Integration with other capabilities, such as a GIS and a database, can provide an valuable environment for conveying many aspects of complex technical issues. Images can include satellite imagery and photographs. Graphics can include scientific visualization products that are stored for display. These stored products are useful when recreation of the product would be difficult or too time-consuming to recreate. Storage of multimedia text is different from storing word processing files because what is being stored are final products rather than working documents. It is possible to store images of the documents, including figures and signatures, so the documents can be displayed as they exist in final form. Documents stored electronically can also be cross-references and searched for easy reference. Storing documents as images on optical disk should be considered as an alternative to microfilm and can be used instead of distributing paper copies of documents. Not only does it reduce storage space requirements, substantial natural resources could be conserved. It is always possible to print documents when they are needed.

4.2.5 Statistical Software

There are three levels of commercial software packages that can be used to solve statistical problems. Unlike other general-purpose software tools with similar conceptual frameworks, each statistical package has a unique approach and includes its own unique set of statistical algorithms. Several comparisons of statistical software packages have been published (Raskin

1989); these should be used to find the package that is best suited for a particular problem. The three levels of software are

- packages specifically designed for personal computers – These are user-friendly, interactive data analysis packages that use pre-packaged and pre-programmed algorithms. These packages are for the beginning user of statistical software packages. They include Statgraphics, Systat, and Gauss.
- packages adapted from mainframe standard packages – These are more functional and are able to handle large data sets more efficiently. The algorithms are pre-programmed, but have options that expand the breadth and scope of problems that can be addressed. Examples are SAS, SPSS, and BMDP.
- high-level programming packages that contain many standard statistical functions available to the user through "calls" executed within the code – These packages are for the seasoned programmer/ statistician who is willing to trade increased key strokes for control over algorithms. These packages can create data displays suitable for technical publications. An example is Splus.

4.3 INFORMATION MANAGEMENT ENVIRONMENTS FOR COMPLEX PROBLEM SOLVING

Many decisions must be made in the process of cleaning up Hanford. A major motivation for collecting data is to support the decision-making process. Once data are available, methods for analyzing the data must be determined and the analyses must be performed. The analysis process for the complex problems we face can be facilitated by a computer environment that supports this analysis. The purpose of this section is to discuss the problem of computational integration at Hanford as it relates to environmental restoration and waste management, to describe the characteristics of an integrated computational environment, and to present requirements for creating this environment.

To perform the assessment required in decision-making, modeling will be required using many of the models previously described. In only a few cases are the various aspects of the source-to-receptor models linked to facilitate required modeling. To integrate models used in performance assessments with the decision support information system, a system of linkages or "hooks" needs to be established between the codes and databases. These hooks will allow the software to be operated to share output, input, or data for conducting comprehensive assessments. The Hanford Integrated Plan can help develop an integrated software environment by exploring ways of establishing hooks or linkages between computer software.

Some existing codes, such as GENII, already have hooks with the ability to accept, as input, the output from more sophisticated atmospheric or ground-water transport codes. However, to create an integrated software environment, additional or modified hooks need to be established. These hooks or linkages are needed in the following areas:

- to provide linkages with prior processes in an assessment – Environmental pathway analysis relies on estimates of air, water, or soil concentrations that are provided as input to the dose assessment. These concentrations can be entered through the creation of standardized input files, such as GENII uses to read in concentrations in air or ground water. The establishment of these hooks or linkages will assure optimum use of shared data in long-term performance assessments.

- to assure the automatic use of standardized model assumptions and scenario definitions – The HEDOP Committee is charged with oversight of the model and scenario parameter selections used in Hanford Site dose assessments. For more complex scenarios, these parameter selections could be maintained in a single Site-wide database providing standardized scenario parameters and assumptions to codes. To accomplish this, hooks or linkages in the existing codes would need to be established.

- to provide linkages to standardized health risk evaluation methods – As the methodology for assessing health risks from radionuclides, chemicals, and combinations of both are developed and improved, the radiological pathway analysis codes need hooks or linkages to provide standardized input to the health risk models. These hooks will assure consistency in usage of health risk methods within overall performance assessments.

- to provide linkages with decision support systems – Radiation dose is one factor in the decision support process that must be considered along with such other factors as cost and schedule. Hooks or linkages need to be developed with decision support systems so that the results from dose assessments can be used in an optimum manner.

There are three possible ways to develop an integrated software environment for conducting performance assessments at the Hanford Site. They are 1) to develop integrated software from scratch, 2) to modify existing software, expanding on the hooks concept, and 3) to "wrap" control or user interface software around existing codes. The Hanford Integrated Plan can help establish the protocols for evaluating how to best establish an integrated software environment.

There are several factors that must be considered in deciding how best to develop an integrated software environment:

- The capabilities that are needed must be evaluated and compared with existing software to determine if the development of additional software is needed.
- The importance of quality assurance needs to be evaluated. For example, it may be easier to develop new software under strict quality assurance procedures that to verify the operation of existing software. In addition, it is difficult to predict the level of verification/validation that will be necessary in the future, especially when regulatory decisions are at stake.
- To best fit an integrated software environment, codes need to be constructed in a modular fashion to permit the alternative selection of component models within an overall performance assessment. Existing codes need to be evaluated to determine if they fit into the modular definition, or if they need to be modified or replaced. One approach might be to lift modules from existing codes and wrap them under a common control/user interface. This means that only selected functions of existing codes would be required in the integrated environment.

The standard set of models should be periodically evaluated and compared with new and alternative methods. When new methods are developed and approved, they should be incorporated into the standard set of software as modules or alternatives for specific applications. The role of the Hanford Integrated Plan can be to ensure that the periodic evaluation occurs and to identify new and alternative methods to be included in the integrated software environment.

A computer hardware and software infrastructure must be designed and implemented to support these needs. This type of environment does not exist today, but some important steps are being made. The four fundamental architecture requirements are

- model integration
- documentation and record-keeping
- user guidance

- data access and integration.

Analysis of data from databases and information systems is often the motivation for the collection of the data in the first place and is often required before conclusions can be drawn. These conclusions can influence planning for environmental restoration. The data currently stored in data collection systems such as HEIS tend to be relatively raw. After the data have been verified and validated, interpretations must be made to generalize from a set of relatively sparse samples to the larger geographic areas that the samples are supposed to represent. Generating interpreted data can be a time-consuming and difficult task that often requires subject area specialists and/or experts.

Models that already exist do not always reflect recent advances in operating systems, computer languages, user interfaces, database access techniques, and visualization. However, re-implementing the models is not cost-effective and will, in some cases, require recertification of the model. Rather than re-implementing, a better option is to "wrap" the new technologies around the models so the new technology can facilitate the modeling process.

As analysis is applied during the decision-making process, the analyst must document and keep records to record how decisions are made, and support reanalysis and iterative analysis. In the best situation, the information-gathering process is facilitated by the user's environment so that less of the user's effort is consumed by documentation and record-keeping, and more effort is available for the creative parts of the analysis. Having a record of what was done can be valuable to "tweak" the analysis and determine where things might have gone wrong and what has been tried.

Providing the user with guidance during the analysis process is particularly valuable when the user is first introduced to an architecture or a new piece of software. Where possible, guidance should not be limited to mechanics only, but should include guidance about ramifications of various activities.

4.4 ARCHITECTURE CAPABILITIES

The type of architecture that addresses the requirements discussed above is a continually evolving, adaptable, generic information architecture that

- enables incorporation of different software (e.g., models) into an organized environment without modifying the software
- supports access to diverse data sets regardless of the form in which they are stored, as long as the form is known and implemented in the architecture
- provides the ability to structure the tasks a user performs so they can easily be run repetitively
- records annotations and history as the user performs the tasks.

When this architecture is applied to a model, the model can be run without modifying the source code; it can access the required data whether those data are in a database or a standard file; it can be accessed by the user through a friendly user interface; and it can record information such as options and parameters as the user runs the model.

The process of preparing a model to run in this environment is not trivial. However, models and other processes that will be used extensively on the Hanford Site are candidates for incorporation into this emerging information architecture.

4.5 STANDARDS AND CONVENTIONS

4.5.1 Data Standards and Conventions

It is crucial that data standards and conventions be developed, implemented, and enforced consistently at the Hanford Site. If data are not gathered and maintained using standards and conventions, their usefulness to the general user community is significantly reduced. When each project and organization simply does "its own thing," duplication, inconsistency, and diminished useability result.

A data administration board chartered by RL has been established for the Hanford Site. The board has a representative from RL and each contractor. To date, however, most of the board's focus has been on administrative data rather than scientific/technical data. Westinghouse Hanford Company has a data administration council that complements the RL-chartered data administration board. Westinghouse Hanford Company items for submission to the Hanford Site board are presented to the council and then put out for review within WHC for 90 days. If no objections are raised, the submission becomes a standard. This infrastructure appears sufficient to deal with approval of standards and conventions but does not develop the standards and conventions, which need to be developed by experienced subject-area experts who understand the general conventions currently being used at Hanford.

Most standards and conventions currently in place have resulted from project or organizational needs. A good example is the Hanford Site-wide well-naming convention, by which WHC and PNL are working effectively together to make each well-name unique. However, the convention being used is based on the obsolete Hanford coordinate system, and the convention itself should be re-examined.

An example of a project-oriented convention that may become a Hanford Site standard is the use of HEIS sample numbers. Several projects whose data do not currently go into HEIS are considering using HEIS sample numbers to ensure unique sample numbers.

4.5.2 Computer Standards

Implementation of the Hanford computational infrastructure based on well-supported government and industry standards can facilitate the process. Some standards are well defined and widely supported already; others, no less important, are still evolving; examples of the first type include programming language and some network standards. Examples of the second type include heterogenous database access protocols, user interface standards, and distributed hierarchical file management and storage. At a minimum, we must stay current with the standards to realize a cost-effective and well-supported computational architecture.

Implementation of the Hanford computational infrastructure based on well-supported government and industry standards can facilitate the implementation process delivering the best computer technology to Hanford users in a timely manner.

Hanford computer and user staff must actively involve themselves in the selection of the optimum computational environment. For example, the adoption of UNIX and UNIX-based software is an issue that should be pursued. Hanford computer staff must advise on the trade-offs that are involved, and Hanford users and management must use that information and their own knowledge to set the direction that ensures success.

4.6 ISSUES RELATED TO THE TOOLS INFRASTRUCTURE

The continuing advancement and evolution of applied computer technology has changed the way computer-based decision support tools are used at the Hanford Site. Now, the focus must be on integrating the individual parts of the decision-making process and viewing the enterprise (Hanford mission) as a whole. Our resources, including people, information, and facilities, must be linked in a way that provides Hanford management with maximum flexibility. Issues related to this integration include the following:

- Adoption of an open systems philosophy by adherence to computer standards can support integration by providing the freedom to choose where and how information is used, regardless of which computer platforms are involved.
- Transition toward a UNIX-like environment at Hanford is important for its compatibility with the open systems philosophy, its portability, and the ability to position Hanford to take advantage of new technology.
- The use of CASE tools, conformance to standards and integration of heterogeneous systems can all contribute toward the goal of a more cost-effective implementation of Hanford-specific software systems.
- Hanford data managers must force the consistent use of Site-specific data standards and conventions.
- The computer and communications infrastructure for the Hanford site needs to be the agent for change to a more responsive and effective operation. The implementation of systems designed for an integrated Hanford mission (for example, HEIS) can be that agent of change.
- Complex systems consisting of many separate functional subsystems need to be implemented in a planned and modular architecture so the evolution of different parts do not impose impossible constraints on the rest of the overall system.

- Rather than forcing conformity to a certain hardware platform or set of software products, Hanford management should force conformance to interoperability.

5.0 GUIDELINES FOR TOOL EVALUATION

A further step in the process begun by the Decision Support Tools Task is to critically evaluate existing tools. The criteria can be diverse, including quality assurance aspects (see Appendix C for four aspects of quality assurance in the development and application of models). However, specific quality assurance criteria have been developed by numerous groups and were not duplicated by the Decision Support Tools Task. Other criteria involve the technical adequacy and appropriateness of the tools for a specific application. Tools must accomplish the intended technical functions, evaluations, or predictions using reasonable input and assumptions, and must output the information of interest in a usable form. These aspects of tool evaluation were not rigorously conducted, although some issues and significant known strengths and deficiencies of tools are identified in Sections 3 and 4.

A third category of criteria for tool evaluation is captured in the following general guidelines, which are intended to be applied to set priorities on tool application, modification, or development in the current political and programmatic climate. The guidelines are expected to be useful in selecting the tools to be developed, modified, or applied for estimating schedule, cost, technical performance, health risk, and ecological risk. Tools should be selected that

- must be available, no matter what, to meet regulations or to provide general infrastructure
- have a bias for action
- apply across different mission areas to integrate activities
- implement the observational approach.

Note that the guidelines were not applied to the tools discussed in this document. Application of these guidelines to existing and proposed tools would require further work.

5.1 TOOLS THAT MUST ALWAYS BE AVAILABLE

These tools will be required regardless of the remediation technologies or cleanup scenarios that are chosen. Emphasis should be placed on tools that are required to meet regulations or provide general infrastructure for environmental restoration and waste management.

An example of a tool that must always be available is any tool required by the TPA, e.g., an area-wide ground-water model specified under TPA Milestones 29-00-00. Various databases also required to assure consistency in data used by diverse people or activities that will eventually generate information for comparison or assimilation. In addition, specific computational hardware and networking capabilities are required for access by DOE and effective use of databases at different Hanford Site locations.

5.2 TOOLS THAT HAVE A BIAS FOR ACTION

Emphasis should be placed on tools having a bias for action that can be applied now, that use existing data or models, or that take advantage of existing technology. While existing models may not have the resolution or sophistication of future models, existing models are known by regulators and have a previous history of Hanford Site applications. Models that cannot be used to make decisions until extensive data are collected or that depend on results of long-term studies should have lower priority than models that can be applied now, even with some limitations. Similarly, although previously collected data may not be as precise, accurate, or relevant as data that is currently being collected, such data should be made available for situations requiring immediate decisions. Other models or data may allow no alternative except to embark on long-term studies or projects.

Tools that have a bias for action focus alternatives rather than create new independent alternatives. For example, a decision tool can be applied to identify preferred land-use scenarios, which is turn allows cleanup levels to be determined. Tools that narrow the options and try to reach agreement on them should be emphasized. Tools that develop or quantify the impacts of unlikely scenarios should be de-emphasized.

5.3 TOOLS THAT APPLY ACROSS DIFFERENT MISSION AREAS

Decision tools for integrating various mission areas can be used to assemble and summarize information. All models integrate existing knowledge about a physical system, but some do so to a greater degree than others. Emphasis should be placed on models and databases that are based on coordinated data-collection efforts and minimize duplication. In addition, the number of different models being used should be minimized, but not to the detriment of technical appropriateness. Maintaining and applying a smaller set of models will make easier the tasks of achieving quality assurance, code support, and regulatory acceptance of modeling results.

Visualization tools, such as GIS, help integrate data from diverse sources. For example, contours of ground-water contaminant concentrations generated from field sample collection and analysis can be overlaid on a background map to display information for interpretation. In a like manner, predictions from a contaminant transport model can also be overlaid on the same background map to provide information on how well the model agrees with observations.

HEIS is an example of a tool that is being applied across mission areas and programs. HEIS has integrated ground-water monitoring data from the Hanford Site Ground-Water Surveillance Program, the RCRA monitoring activities, and the newer environmental restoration activities. HEIS is accessible via the Hanford LAN to support the diverse programs that require such data.

5.4 TOOLS THAT CAN BE USED TO IMPLEMENT THE OBSERVATIONAL APPROACH

Tools that can be used to implement the observational approach should be given high priority. The observational approach is gaining increased favor with regulators facing remediation of monumental contamination problems with limited resources. Too often, after spending large sums of money, a decision is reached that could have been made intuitively or using existing models and data, before detailed study was done. Tools that can be used to identify the most likely scenario, regardless of technology or the remediation approach most likely to succeed for any cleanup level, need to be emphasized over those tools that develop and evaluate a wide range of potential cleanup scenarios and approaches. Contingency plans can be developed to handle some exceptional cases, but these should not be the focus of extensive tools development.

The MEPAS model is an example of a tool that implements the observational approach. MEPAS is currently being applied to screen radionuclides and chemicals in single-shell tanks. Based on present knowledge of the tank inventories, the results will be used to determine high-priority constituents for sampling and analysis.

6.0 CONCLUSIONS

6.1 GENERAL ISSUES

A variety of tools are described in this report that support major planning and technology assessment efforts underway at Hanford. They can currently be applied in varying degrees to Hanford's environmental restoration mission. In preparing this document, we considered tools that were available or familiar to staff at Hanford.

It is clear that the computer-based tools discussed in Sections 3 and 4 are not always having a large impact of the decision-making process. In fact, their role in the decision-making process is not generally understood. The primary reason for this gap is that the output of the tools is often not at the right level to serve as input to the decision-making process. In addition, the tools are not well integrated. For example, the results of performance and risk assessment tools need to be integrated with cost, stakeholder values, priorities, and interest along with other input.

It is important that decision support tools be integrated with other tools and that this integration facilitates easy use. In Section 3, we identified cases in which this integration is happening. For some tools, this integration is working well; for others, integration has yet to begin. However, most existing tools were not designed or implemented to be decision support tools. They were designed to meet specific project or program needs. Although they can help facilitate the process, they do not directly support decision-making.

Although issues related to the tools have been identified and the status of various aspects of model documentation and testing has been compiled, this document does not provide in-depth evaluation of these tools. In some cases, it is unclear exactly how the tools would be used. Additional work would be required to inventory and evaluate tools available elsewhere, either at other DOE sites or outside the DOE complex.

The decision support tools implemented at the Hanford Site should allow for improvements in modeling and computer technologies and for changes in restoration technologies. One way to improve the tools available at Hanford (and throughout the DOE complex) is to engage in technology transfer among DOE sites. Surveys and investigations of activities in the DOE complex need to be shared with the people at the working level doing the planning for each DOE site. For that purpose, a DOE-wide environmental restoration technical information exchange workshop is being held periodically.

The TPA is directing all environmental restoration work at Hanford and is the consent order that will bring Hanford into compliance with the major state and federal environmental laws. Although the application and development of only a few tools is mandated under the TPA, other tools not explicitly mandated are needed to meet other milestones. Decision-makers need to understand how these tools can be beneficial in meeting TPA milestones. In some cases, the regulators are calling for resources, such as computerized mapping data capable of being used in GISs, that require Hanford Site contractors and DOE to invest in developing capabilities for the site.

Codes, models, and information management systems developed for the Hanford Site are useful in predicting and estimating environmental contamination. Many of these same codes, models, and systems will also be useful in evaluating alternative cleanup strategies and in determining costs in terms of time, money, and risk.

Currently, it is very difficult to determine the cost of various remediation options apart from the cost of existing site facilities, so that the comparison to technical performance is difficult. Also, the estimation of costs for planning purposes is not coupled to the system for managing and tracking costs; thus, obtaining feedback on the accuracy of cost estimates to improve the planning process is not currently possible.

The good news is that some computer-based tools that support the decision-making process are available and are currently being used to support the cleanup process; the bad news is that more work needs to be done to make existing tools more functional, to develop new tools where none now exist, and to build interfaces and a computer infrastructure where the tools that are available can be integrated to facilitate cleanup decisions. If codes and models can be linked, they can help reduce the complexity and multiple components of environmental problems. Because of the large amount of environmental data that must be processed and managed, codes and models must support and be supported by information management systems.

6.2 DATA ISSUES

Planning data acquisition activities involves looking beyond the immediate data needs to consider the data requirements of other activities, such as risk and performance assessment models, in order to ensure that data exist for all applicable uses at the Hanford Site. To this end, the characterization programs and modeling efforts need to be integrated. For example, drilling a well to collect a ground-water sample should also include collecting data that will be needed for modeling, e.g., data on soil hydraulic properties.

Moreover, existing data at the Hanford Site should be reviewed to determine how it can be used. Sensitivity and uncertainty analyses will be useful for determining the importance of different types of data used in performance and risk assessments. This can be done with existing information; additional data can be collected as needed for model calibration and validation activities. In considering how historic (existing) data at the Hanford Site can be used effectively, data quality and quantity must be considered: identifying what quality of data are needed and assessing whether the existing data are adequate.

There has not been a thorough review of existing Hanford Site databases nor much integrated planning for their future. Various organizations have reviewed different parts of the databases, but these efforts have not been coordinated to provide a comprehensive assessment of the data available for implementing decision-support tools and identifying gaps. It is unclear how the current focus on using historic data will impact existing databases.

Tools exist at Hanford for data synthesis, but have not been applied on a large scale. Scientific visualization, GISs, statistics, and modeling are methods that can be used to synthesize existing and new information for making decisions. They can also be used to synthesize results of model applications for interpretations. However, there is little experience in applying them to data at Hanford.

One area where data and methods are inadequate is in health-risk coefficients for assessing health risk to chemicals, e.g., carbon tetrachloride. This is an issue that is not unique to problems at Hanford. Nor is there knowledge of how to deal with exposures to multiple compounds (mixed radioactive and hazardous chemicals). In the area of mixed wastes, synergisms are important. One recommendation is to expand what is already known so a classification scheme (classes of compounds versus human health effects) can be developed for risk assessments.

6.3 MODEL ISSUES

Environmental pathway models for radionuclides are relatively well developed, but are less developed for chemicals. These models include both environmental transport and exposure pathways. Codes are currently available at the Hanford Site for use in performance and risk assessment analyses. Current exceptions where inadequacies may exist are in dealing with the transport and chemistry of mixed wastes and multiphase contaminants. As modeling technologies improve from development efforts at the Hanford Site and elsewhere and better codes become available, the improved codes should be incorporated.

Consistency, integration, and ease of use are needed in the transfer of data and results between models. This includes capturing the level of detail and assumptions for models that will be coupled to conduct performance and risk assessments. Often, more detailed models for components of a system are combined with less detailed models of other components.

Most of the models discussed in this document address only one component of predicting items, such as release, transport, or exposure; some models attempt to compensate by using simple assumptions or algorithms. A few models exist or are under development that directly couple two or more components together. Where models are coupled, they may have components that are not appropriate or would be better handled by other models. Models should ultimately be developed in a modular fashion, so that they can be coupled easily. This would also facilitate the replacement of weak components with stronger or more appropriate components, when they are available. Models should also be made easier to use and should include provisions for documenting the model's assumptions.

6.4 INFORMATION MANAGEMENT SYSTEMS ISSUES

Listed below are the issues that must be addressed to establish successful, integrated computer-based information management systems that support the Hanford Site's mission of environmental restoration:

- a commitment by the user community to integrate systems that facilitate data sharing and to use information management systems as the standard way of doing business
- an effective integrated planning process for information management systems that support the Hanford Site mission – This document, with its identification of existing information management capabilities, is the first step in this process. As is consistent with the Hanford Integrated Planning Process, this effort needs to be a multi-contractor activity and reflect a Site-wide perspective.
- a clear set of expectations among users of what information management can do and how it can be an effective part of the environmental restoration process
- a commitment by management to computer-based information management along with sufficient funding for computer infrastructure, software design and development, user support, documentation, and maintenance
- use of new cost-effective technology and timely access to that technology.

6.4.1 Data Sharing Through Integrated Systems

The vast amount of data required for the environmental restoration process needs to be treated as a valuable Hanford asset. The data needs to be accessible, protected, and legally defensible. Data will be used not only to demonstrate compliance, but also will be analyzed and used as a basis for decision-making. A significant portion of the cost of an RI/FS is data- and analysis-driven. The data are expensive to generate. Every effort should be made to make the data useful for a variety of purposes. Planning is needed to take into account all possible uses of the data and make cost-effective decisions for data acquisition.

Sharing of historic data is also important. Because of the Hanford Site's current focus on an aggregate area-level planning and the high cost of acquiring new data, the Site must place more value on historic data. Because historic data were typically gathered to meet the needs of a specific program, it use and incorporation into integrated information management systems are not always simple. Historic data may be of uncertain quality, and it may be difficult to ascertain whether it should be used for specific analytical or decision-making purposes. Moreover, historic data will be expensive to assemble and make available. Difficult decisions will have to be made to determine how and when historic data can be used.

6.4.2 Integrated Planning for Information Management Systems

Information management is an example of a cross-cutting technology that can provide support to all mission areas and promote the sharing of common data among the mission areas. No comprehensive integrated planning for Site-wide information management systems for environmental restoration has been performed at the Hanford Site. We need to facilitate more sharing of technological capabilities and focus on technology transfer. This can lead to more cost-effective systems development efforts. This document, with its identification of existing information management capabilities, is a first step in this process. Consistent with the Hanford Integrated Planning Process, this effort needs to be a multi-contractor activity and reflect a Site-wide perspective. The need for integrated information management systems is becoming better recognized.

There is a great deal of interest in systems like SWITS and HEIS because they represent sources of integrated data and are oriented towards users, instead of being systems in which data is largely unavailable to users. People are beginning to recognize the need for integrated systems and taking advantage of what others are doing. However, there is no formal, well-recognized process that facilitates this. Knowledge of the systems and their capabilities tends to be by word-of-mouth. Although integrated planning is not normally actively supported by management, it depends largely on management support for informal networking among those doing the work. Management needs to be more involved in facilitating and encouraging integration of planning and networking.

DOE Headquarters also needs to access the site-specific data from all the sites within the DOE complex. The DOE is imposing some information management system requirements on the DOE sites and more of this can be expected in the future. Hanford contractors must be aware of DOE's needs and actively attempt to anticipate those needs, rather than react and wait for requirements to be improved. An active approach is being used on the TWINS Project. A site-specific database for tank sampling results is being implemented within HEIS. TWINS, which is being implemented by PNL for HQ, will use the HEIS database as well as other site-specific databases as a method of supporting integrated access to data about DOE waste tanks.

6.4.3 Setting Information Management Expectations

Although significant hardware and software advances are being made that support effective information management, most users are unaware of the current state of the art. In some cases, their expectations are less than can be delivered. In other cases, their expectations greatly exceed what can be cost-effectively delivered. The users need to maintain an open mind while the computer professionals need to be realistic about what they can provide.

6.4.4 Management Support for Information Management Systems

Effective information management systems require management support. Developing these systems is an expensive and time-consuming process that requires significant staff resources. On-going support for the systems and their infrastructure is required once the systems are in place. Management must value data as an asset rather than as an expendable commodity and set the expectation that data will be shared for the good of all.

Another management issue related to computer-based systems is the issue of what constitutes an "official" record. At this time, paper documents and microfilm are being used. Information management systems as the official repositories of data and computer-based, electronic storage of document both need to be considered.

6.4.5 New Technology

Newer computer technology is being applied in some cases at Hanford. Relational database management systems are generally available. Geographic information systems are being applied in some cases and being studied for other applications. Engineering workstations are being applied in a number of scientific arenas. However, for systems larger than personal computers, the current procurement cycle is too long, difficult, and inefficient. The process can actually preclude computer-based tools from being applied to appropriate problems.

In most cases, the information management systems must be built; the Hanford contractors cannot buy finished products "off the shelf." However, they can buy tools such as database management systems, GISs, and computer-aided software engineering systems that facilitate the development of the technology, but much work would still be required to analyze, design, and implement needed systems. Although the Hanford contractors have made and are continuing to make significant progress in developing tools to manage and report data, they have not adequately addressed requirements for synthesis, interpretation, and analysis of data. Computer-based tools are needed to support these activities.

6.5 COMPUTER INFRASTRUCTURE ISSUES

The Hanford Site's strategy for the incorporation of computer technology must involve an integrated planning activity with the flexibility to respond to advances in technology. Since computer technology is changing rapidly, it is impossible to predict the directions that technologies will take and what products will become viable. Thus, the strategy must be flexible enough to investigate new technology as it becomes available and acquire it when appropriate and cost-effective. An "open systems" philosophy is needed that remains open to evolving computer standards to integrate separate functional subsystems into complex interoperable systems.

There are site-based computer infrastructure planning efforts underway, and any infrastructure planning activity undertaken as part of Hanford Mission Planning should be coordinated with existing efforts.

7.0 REFERENCES

10 CFR 20.302. 1991. U.S. Nuclear Regulatory Commission, "Standards for Protection Against Radiation: Method for Obtaining Approval of Proposed Disposal Procedures." U.S. Code of Federal Regulations.

40 CFR 300.430. 1990. U.S. Environmental Protection Agency, "Remedial Investigation/Feasibility Study and Selection of Remedy." U.S. Code of Federal Regulations.

Allen, G. K. 1991. PUREXNEW - A Generalized Material Balance Flowsheet Simulator. WHC-SD-CP-ER-037, Westinghouse Hanford Company, Richland, Washington.

Allison, J. M. 1984. Computer Prediction of Evaporator Operation. SD-WM-ADP-004, Rockwell Hanford Operations, Richland, Washington.

Allwine, K. J., and G. F. Athey. 1986. User's Guide to the Pacific Gas and Electric Modeling System (PGEMS) - An Interactive Atmospheric Transport and Diffusion Model for Application in Complex Terrain. Prepared by Battelle, Pacific Northwest Laboratories for Pacific Gas and Electric Company, San Francisco.

Allwine, K. J., G. F. Athey, and C. S. Glantz. 1989. "PGEMS - An Interactive, Real-Time, Atmospheric Transport and Diffusion Modeling System Developed for Complex Terrain Applications." In Proceedings of the Sixth Joint Conference on Applications of Air Pollution Meteorology, Anaheim, California.

Allwine, K. J., and C. D. Whiteman. 1985. MELSAR: A Mesoscale Air Quality Model for Complex Terrain. PNL-5460, Vol. 1., Pacific Northwest Laboratory, Richland, Washington.

Anantatmula, R. P. 1990. Hanford Site Environmental Restoration and Waste Management Technology Plan for the Calendar Year 1990. WHC-EP-0212-1, Westinghouse Hanford Company, Richland, Washington.

Arnett, R. C. 1975. Assessment of the Hydrologic Impact of Cooling Water and Condensate Discharges from 242-A Radioactive Waste Evaporator. ARH-CD-475, Atlantic Richfield Hanford Company, Richland, Washington.

Arnett, R. C., D. J. Brown, and R. G. Baca. 1977. Hanford Ground-Water Transport Estimates for Hypothetical Radioactive Waste Incidents. ARH-LD-162, Atlantic Richfield Hanford Company, Richland, Washington.

Beres, D. A. 1990. The Clean Air Act Assessment Package-1988 (CAP-88) A Dose and Risk Assessment Methodology for Radionuclide Emissions to Air: Volume 1 User's Manual. SC&A, Inc., McLean, Virginia.

Bierman, H. Jr., C. P. Bonini, and W. H. Hausman. 1969. Quantitative Analysis for Business Decisions. 3rd Edition. Richard D. Irwin, Inc., Homewood, Illinois.

Buchanan, J. A., and E. S. Gilbert. 1984. MOX: A User's Guide. PNL-5023, Pacific Northwest Laboratory, Richland, Washington.

Call, H. J., and W. A. Miller. 1990. "A Comparison of Approaches and Implementation for Automating Decision Analysis." In Reliability Engineering and Systems Safety, 0951-8320/90. Elsevier Science Publishers Ltd., England.

Catalano, J. A. 1986. Single Source (CRSTER) Model: Addendum to the User's Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. (Distributed as part of UNAMAP, Version 6, Documentation.)

Cearlock, D. B., and R. D. Mudd. 1970. Analysis of Hydrological Factors Influencing the Operation of the 100-N Emergency Waste Disposal Crib. BNWL-1503, Pacific Northwest Laboratory, Richland, Washington.

Cearlock, D. B., K. L. Kipp, and D. R. Friedrichs. 1972. The Transmissivity Iterative Calculation Routine - Theory and Numerical Implementation. BNWL-1706, Pacific Northwest Laboratory, Richland, Washington.

Chanin, D. I., L. T. Ritchie, and J. L. Sprung. 1987. MELCOR Accident Consequence Code System. NUREG/CR-4691, SAND86-1562, prepared by Sandia National Laboratories for the U.S. Nuclear Regulatory Commission, Washington, D.C.

Chico, T., and J. A. Catalano. 1986. Addendum to the User's Guide for MPTER. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. (Distributed as part of UNAMAP, Version 6, Documentation.)

Clark, T. L. 1977. "A Small-Scale Dynamic Model Using a Terrain-Following Coordinate Transformation." J. Comput. Phys. 24:186-215.

Croff, A. G. 1980. ORIGENII - A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code. ORNL-5621, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Doctor, P. G. 1979. An Evaluation of Kriging Techniques for High-Level Radioactive Waste Repository Site Characterization. PNL-2903, Pacific Northwest Laboratory, Richland, Washington.

Droppo, J. G., Jr., D. L. Strenge, J. W. Buck, B. L. Hoopes, R. D. Brockhaus, M. B. Walter, and G. Whelan. 1989a. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance: Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Vol. 2, Pacific Northwest Laboratory, Richland, Washington.

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

Droppo, J. G., Jr., J. W. Buck, J. S. Wilbur, D. L. Strenge, and M. D. Freshley. 1991. Single-Shell Tank Constituent Rankings for Use in Preparing Waste Characterization Plans. PNL-7572, Pacific Northwest Laboratory, Richland, Washington.

Dunford, D. W., and J. R. Johnson. 1987. GENMOD - A Program for Internal Dosimetry Calculations. AECL-9434, Atomic Energy of Canada Limited, Chalk River, Ontario, Canada.

Easter, R. C., and J. M. Hales. 1984. PLUVIUS: A Generalized One-Dimensional Model of Reactive Pollutant Behavior, Including Dry Deposition, Precipitation Formation, and Wet Removal. PNL-4046, Edition 2, Pacific Northwest Laboratory, Richland, Washington.

Eslinger, P. W., T. B. Miley, and D. W. Engel. 1991. SUMO--System Performance Assessment for a High-Level Nuclear Waste Repository: Mathematical Models. PNL-7581, Pacific Northwest Laboratory, Richland, Washington.

Fayer, M. J., and G. W. Gee. 1985. UNSAT-H, An Unsaturated Soil Water Flow Code for Use at the Hanford Site: Code Documentation. PNL-5585, Pacific Northwest Laboratory, Richland, Washington.

Felmy, A. R., D. C. Girvin, and E. A. Jenne. 1984. MINTEQ: A Computer Program for Calculating Aqueous Geochemical Equilibria. EPA 600/3-84-032, U.S. Environmental Protection Agency, Washington, D.C.

Gaylord, D. R., E. P. Poeter, W. Belcher, P. Townsend, W. Wingle, K. A. Lindsey, H. J. Corner, L. D. Stetler, and C. Knaack. 1989. Geology and Geohydrology of the 300 Area: Recommendations for FY90-91 Research. WHC-EP-0500, Pacific Northwest Laboratory, Richland, Washington.

Geffen, C. A., B. A. Garrett, C. E. Cowan, M. R. Siegel, and J. F. Keller. 1989. Remediation of DOE Hazardous Waste Sites: Planning and Integration Requirements. PNL-6972, Pacific Northwest Laboratory, Richland, Washington.

Gephart, R. E., R. C. Arnett, R. G. Baca, L. S. Leonhart, and F. A. Spane, Jr. 1979. Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge. RHO-BWI-ST-5, Rockwell Hanford Operations, Richland, Washington.

Gilbert, E. S., and J. A. Buchanan. 1984. "An Alternative Approach to Analyzing Occupational Data." J. Occup. Med. 26:822-828.

Gilbert, T. L., C. Yu, Y. C. Yuan, A. J. Zielen, M. J. Jusko, and A. Wallo III. 1989. A Manual For Implementing Residual Radioactive Material Guidelines. ANL/ES-160, DOE/CH/8901, Argonne National Laboratory, Argonne, Illinois.

Glantz, C. S., and J. V. Ramsdell. 1986. Preliminary Examination of the Impacts of Repository Site Characterization Activities and Facility Construction and Operation Activities on Hanford Air Quality. PNL-5687, Pacific Northwest Laboratory, Richland, Washington.

Gryrel, M. L., C. A. Augustine, M. A. Cahill, J. S. Garfield, M. E. Jackson, M. J. Kupfer, G. A. Meyer, J. H. Reecker, L. K. Hotton, V. L. Hunter, and M. B. Triplett. 1991. Tank Waste Disposal Program Redefinition. WHC-EP-0475, Westinghouse Hanford Company, Richland, Washington.

Gupta, S. K., P. R. Meyer, C. A. Newbill, and C. R. Cole. 1982. A Multi-Dimensional Finite Element Code for the Analysis of Coupled Fluid, Energy, and Solute Transport (CFEST). PNL-4260, Pacific Northwest Laboratory, Richland, Washington.

Hales, J. M., T. W. Horst, and M. T. Dana. 1983. MPADD - A Generalized Code for Reactive Scavenging and Deposition Calculations. U.S. Environmental Protection Agency, Environmental Research Laboratory, Research Triangle Park, North Carolina.

Henley, E. J., and H. Kumamoto. 1981. Reliability Engineering and Risk Assessment. Prentice-Hall, Englewood Cliffs, New Jersey.

Huyakorn, P. S., J. E. Buckley, J. B. Kool, and H. O. White, Jr. 1988. VAM2DH: A Variably Saturated Flow and Transport Analysis Model in 2-Dimensions and User's Manual, Version 1.0. Hydrogeologic, Inc., Herndon, Virginia.

International Commission on Radiological Protection (ICRP). 1959. Report of Committee II on Permissible Dose for Internal Radiation. ICRP Publication 2, Pergamon Press, Oxford.

International Commission on Radiological Protection (ICRP). 1980. Limits for Intakes of Radionuclides by Workers. ICRP Publication 30, Pergamon Press, Oxford. (Supercedes ICRP Publication 2.)

Jacobson, E. A., and M. D. Freshley. 1990. An Initial Inverse Calibration of the Ground-Water Flow Model for the Hanford Unconfined Aquifer. PNL-7144, Pacific Northwest Laboratory, Richland, Washington.

Jungfleisch, F. M. 1984. Preliminary Estimation of the Waste Inventories in Hanford Tanks Through 1980. SD-WM-TI-057, Rockwell Hanford Operations, Richland, Washington.

Keller, J. F., R. E. Gephart, J. O. Honeyman, M. T. Thomas, S. D. Colson, and T. H. Dunning. 1991. The Hanford Model: Environmental Cleanup Problems, Science and Technology Needs, and Facility Requirements. PNL-7805, Pacific Northwest Laboratory, Richland, Washington.

Kennedy, W. E., Jr., R. A. Peloquin, B. A. Napier, and S. M. Neuder. 1987. Intruder Dose Pathway Analysis for the Onsite Disposal of Radioactive Wastes: the ONSITE/MAXI1 Computer Program. NUREG/CR-3620 (Supplement 2), prepared by Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C.

Kennedy, W. E. Jr., D. L. Strenge, and R. A. Meck. 1992. Residual Radioactive Contamination form Decommissioning: Technical Basis for Translating Contamination Levels to Annual Doses. NUREG/CR-5512, PNL-7212, prepared by Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C.

Kipp, K. L., A. E. Reisenauer, C. R. Cole, and C. A. Bryan. 1972. Variable Thickness Transient Groundwater Flow Model, Theory and Numerical Implementation. BNWL-1703, Pacific Northwest Laboratory, Richland, Washington.

Liebetrau, A. M., M. J. Apted, D. W. Engel, M. K. Altenhofen, D. M. Strachan, C. R. Redi, C. F. Windisch, R. L. Erickson, and K. I. Johnson. 1987. The Analytical Repository source-Term (AREST) Model: Description and Documentation. PNL-6346, Pacific Northwest Laboratory, Richland, Washington.

Mahrer, Y., and R. A. Pielke. 1977. "A Numerical Study of the Air Flow Over Irregular Terrain." Contributions in Atmospheric Physics 50:98-113.

Mahrer, Y., and R. A. Pielke. 1978. "A Test of an Upstream Spline Interpolation Technique for the Advection Terms in a Numerical Mesoscale Model." Monthly Weather Review 105:1151-62.

McNider, R. T., and R. A. Pielke. 1984. "Numerical Simulation of Slope Mountain Flows." Journal of Climate and Applied Meteorology 23:1441.

Murthy, K. S., L. A. Stout, B. A. Napier, A. E. Reisenauer, and D. K. Landstrom. 1983. Assessment of Single-Shell Tank Residual Liquid Issues at Hanford Site, Washington. PNL-2624, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell. 1988. GENII - The Hanford Environmental Radiation Dosimetry Software System. PNL-6584, Vols. 1, 2, and 3, Pacific Northwest Laboratory, Richland, Washington.

Neptune, D., E. P. Brantly, M. J. Messner, and D. I. Michael. May/June 1990. "Quantitative Decision Making in Superfund: A Data Quality Objectives Case Study." Hazardous Materials Control, pp. 19-27.

Onishi, Y. 1977. Mathematical Simulation of Sediment and Radionuclide Transport in the Columbia River. BNWL-2228, Pacific Northwest Laboratory, Richland, Washington.

Onishi, Y. 1981. "Sediment and Contaminant Transport Model." J. Hydraul. Div. ASCE 107(HY9):1089-1107.

Onishi, Y. and D. S. Trent. 1985. "Three-Dimensional Simulation of Flow: Salinity, Sediment, and Radionuclide Movements in the Hudson River Estuary." In Proceedings of the Hydraulics Division Conference, pp. 1095-1100. August 12-17, 1985. American Society of Civil Engineers, Lake Buena Vista, Florida.

Onishi, Y., D. S. Trent, and A. S. Koontz. 1985. "Three-Dimensional Simulation of Flow and Sewage Effluent Migration in the Strait of Juan De Fuca, Washington." In Proceedings of the 1985 ASCE Environmental Engineering Conference, pp. 1006-13. Boston.

Onishi, Y., G. Whelan, and R. L. Skaggs. 1981. Development of a Multimedia Radionuclide Exposure Model for Low-Level Waste Management. PNL-3370, Pacific Northwest Laboratory, Richland, Washington.

Pacific Northwest Laboratory (PNL). 1990. Hanford Site Environmental Report for Calendar Year 1990. PNL-7930, Pacific Northwest Laboratory, Richland, Washington.

Peterson, S. R., C. J. Hostetter, W. J. Deutsch, and C. E. Cowan. 1987. MINTEQ Users Manual. NUREG/CR-4808, PNL-6106, prepared by Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C.

Peterson, W. B. 1978. User's Guide for PAL - A Gaussian-Plume Algorithm for Point, Area, and Line Sources. EPA-600/4-78-013 (NTIS PB-281306), U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, North Carolina.

Pierce, T. D., and D. B. Turner. 1980. User's Guide for MPTER. EPA-600/8-80-016 (NTIS PB-80-197361), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Probasco, K. M., and E. G. Stephan. 1991. The Configuration Management Program for the Emergency Management Support System. PNL-7771, Pacific Northwest Laboratory, Richland, Washington.

Ramsdell, J. V., G. F. Athey, and C. S. Glantz. 1983. MESOI Version 2.0: An Interactive Mesoscale Lagrangian Puff Dispersion Model with Deposition and Decay. NUREG/CR-3344, perpared by Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C.

Ramsdell, J. V. 1991. EXTRAN: A Computer Code for Estimating Concentrations of Toxic Substances at Control Room Air Intakes. NUREG/CR-5656, PNL-7510, prepared by Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C.

Rao, K. S., and H. F. Snodgrass. 1982. PAL-DS Model: The PAL Model Including Deposition and Sedimentation. EPA 600/8-82-023 (NTIS PB-83-117739), U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, North Carolina.

Raskin, R. March 12, 1989. "Statistical Software for the PC: Testing for Significance." PC Magazine, pp. 103-110.

Reisenauer, A. E. 1979. Variable Thickness Transient Groundwater Flow Model (3 volumes). PNL-3160, Pacific Northwest Laboratory, Richland, Washington.

Richardson, G. L., and J. L. Swanson. 1975. Plutonium Partitioning in the PUREX Process with Hydrazine-Stabilized Hydroxylamine Nitrate. HEDL-TME 75-31, Hanford Engineering Development Laboratory, Richland, Washington.

Rockhold, M. L., and S. K. Wurstner. 1991. Simulation of Unsaturated Flow and Solute Transport at the Las Cruces Trench Site Using the PORFLO-3 Computer Code. PNL-7562, Pacific Northwest Laboratory, Richland, Washington.

Runchal, A. K., and B. Sagar. 1989. PORFLO-3: A Mathematical Model for Fluid Flow, Heat, and Mass Transport in Variably Saturated Geologic Media, Users Manual, Version 1.0. WHC-EP-0041, Westinghouse Hanford Company, Richland, Washington.

Sagar, B., and A. K. Runchal. 1990. PORFLO-3: A Mathematical Model for Fluid Flow, Heat, and Mass Transport in Variably Saturated Geologic Media, Theory and Numerical Methods, Version 1.0. WHC-EP-0042, Westinghouse Hanford Company, Richland, Washington.

Scherpelz, R. I. 1991. HUDU - The Hanford Unified Dose Utility Computer Code. PNL-7636, Pacific Northwest Laboratory, Richland, Washington.

Scire, J. S., F. W. Lurmann, A. Bass, and S. R. Hanna. 1984. User's Guide to the Mesopuff II Model and Related Processor Programs. EPA-600/8-84-013 (NTIS PB-84-181775), U.S. Environmental Protection Agency, Environmental Sciences Research Laboratory, Research Triangle Park, North Carolina.

Seigneur, C., C. D. Johnson, D. A. Latimer, R. W. Bergstrom, and H. Hogo. 1984. User's Manual for the Plume Visibility Model (PLUVUE II). EPA 600/8-84-005 (NTIS PB-84-158302), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Simmons, C. S., C. T. Kincaid, and A. E. Reisenauer. 1986. A Simplified Model for Radioactive Contaminant Transport: The Transs Code. PNL-6029, Pacific Northwest Laboratory, Richland, Washington.

Smoot, J. L., and B. Sagar. 1990. Three-Dimensional Contaminant Plume Dynamics in the Vadose Zone: Simulation of the 241-T-106 Single-Shell Tank Leak at Hanford. PNL-7221, Pacific Northwest Laboratory, Richland, Washington.

Sonnichsen, J. C., Jr. 1991. Preliminary Performance Assessment Strategy for Single-Shell Tank Waste Disposal. WHC-EP-0379, Westinghouse Hanford Company, Richland, Washington.

Stewart, D., M. Yocke, and M-K Liu. 1983. Reactive Plume Model--RPM-II, User's Guide. EPA 600/8-81-021 (NTIS PB-82-230723), U.S. Environmental Protection Agency, Environmental Sciences Research Laboratory, Research Triangle Park, North Carolina.

Strack, O.D.L. 1989. Groundwater Mechanics. Prentice Hall, Englewood Cliffs, New Jersey.

Strenge, D. L., R. A. Peloquin, M. J. Sula, and J. R. Johnson. 1990. Code for Internal Dosimetry (CINDY), Part 1: Conceptual Representation, and Part 2: User's Guide. PNL-7493, Pts. 1 and 2, Pacific Northwest Laboratory, Richland, Washington.

Travis, B. J., and K. H. Birdsell. 1990. TRACR3D: A Model of Flow and Transport in Porous Media - Model Description and User's Manual. LA-11798-M, Los Alamos National Laboratory, Los Alamos, New Mexico.

Tremback, C. J., G. J. Tripoli, and W. R. Cotton. 1985. "A Regional Scale Atmospheric Numerical Model Including Explicit Moist Physics and a Hydrostatic Time-Split Scheme." In Preprints of the American Meteorological Society's 7th Conference on Numerical Weather Prediction, June 17-20, 1985. Montreal.

Trent, D. S., and L. L. Eyler. 1989. TEMPEST -- A Three-Dimensional, Time-Dependent Computer Program for Hydrothermal Analysis, Vol. 1, Numerical Methods and Input Instructions. PNL-4348, Pacific Northwest Laboratory, Richland, Washington.

Turner, D. B., and J. H. Novak. 1978. User's Guide for RAM. EPA-600/8-789-016, Vols. A and B (NTIS PB-294791 and PB-294792), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Department of Defense (DoD). 1986. Best of Practices: How to Avoid Surprises in the World's Most Complicated Technical Process-the Transition from Development to Production. NAVSO P 6071, U.S. Department of Defense, Washington, D.C.

U.S. Department of Energy (DOE). 1987. Final Environmental Impact Statement: Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes. DOE/EID-0113, U.S. Department of Energy, Richland Operations, Richland, Washington.

U.S. Department of Energy (DOE). 1989. "Radiation Protection for Occupational Workers." DOE Order 5480.11, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1990a. Basic Research for Environmental Restoration. DOE/ER-0482T, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1990b. Cost Estimating Handbook for Environmental Restoration. U.S. Department of Energy, Environmental Restoration and Waste Management Team, Washington, D.C.

U.S. Department of Energy (DOE). 1990c. Environmental Restoration and Waste Management Five-Year Plan, Fiscal Years 1991-1996. DOE/S-0078P, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1990d. SWPM System Overview. DOE/NBM-1070, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1991. Preliminary Design Report: A Formal System for Environmental Restoration. Rev.1, U.S. Department of Energy, Office of Environmental Restoration, Washington, D.C.

U.S. Department of Energy, Richland Operations (DOE/RL). 1989. Hanford Information Resource Management: An Architecture for the 1990s. RL-ADP-89-02, U.S. Department of Energy, Richland Operations, Richland, Washington.

U.S. Department of Energy, Richland Operations (DOE/RL). 1991a. Hanford Past-Practice Strategy. DOE/RL-91-40 (Draft A), U.S. Department of Energy, Richland Operations, Richland, Washington.

U.S. Department of Energy, Richland Operations (DOE/RL). 1991b. Hanford Site Baseline Risk Assessment Metholodogy. DOE/RL-91-45 (Decisional Draft), U.S. Department of Energy, Richland Operations, Richland, Washington.

U.S. Department of Energy, Richland Operations (DOE/RL). 1991c. Environmental Restoration and Waste Management Site-Specific Plan for the Richland Operations Office, Hanford Site Five-Year Plan, Fiscal Years 1993-1997. DOE/RL-91-25, U.S. Department of Energy, Richland Operations, Richland, Washington.

U.S. Department of Energy, Richland Operations (DOE/RL). 1991d. Site Management System: Management Requirements and Practices. U.S. Department of Energy, Richland Operations, Richland, Washington.

U.S. Department of Energy, Richland Operations (DOE/RL). 1991e. Hanford Site Specific Technology Plan. DOE/RL-9148 (Draft), U.S. Department of Energy, Richland Operations, Richland, Washington.

U.S. Department of Energy, Richland Operations (DOE/RL). 1991f. Hanford Mission Plan. DOE/RL-91-37 (Draft), U.S. Department of Energy, Richland Operations, Richland, Washington.

U.S. Department of Energy, Richland Operations (DOE/RL). 1991g. Hanford Information Technology Resources Long-Range Site Plan, Fiscal Year 1993. U.S. Department of Energy, Richland Operations, Richland, Washington.

U.S. Environmental Protection Agency (EPA). 1977. User's Manual for Single Source (CRSTER) Model. EPA-450/2-77-013 (NTIS PB-271360), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (EPA). 1986a. Industrial Source Complex (ISC) Dispersion Model User's Guide. 2nd Edition, Vols. 1 and 2. EPA-450/4-86-005a and EPA-450/4-86-005b, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (EPA). 1986b. RAM Addendum. U.S. Environmental Protection Agency. (Distributed as part of UNAMAP, Version 6, Documentation.)

U.S. Environmental Protection Agency (EPA). 1989. RI/FS Streamlining. OSWER Directive 9355.3-06, U.S. Environmental Protection Agency, Washington, D.C.

Wang, I. T., and T. L. Waldron. 1980. User's Guide for MTDDIS Mesoscale Transport, Diffusion, and Deposition Model for Industrial Sources. EMSC6062.1UR(R2), Combustion Engineering, Newbury Park, California.

Washington State Department of Ecology (Ecology). 1991. Toxics Information, Cleaning Up Hazardous Waste Sites: Cleanup Standards and Cleanup Actions. Publ. No. 91-5, State of Washington Department of Ecology, Olympia, Washington.

Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Richland Operations (Ecology, EPA, and RL). 1990. Hanford Federal Facility Agreement and Consent Order. First amendment, two volumes, 89-10, Rev. 1; Washington Department of Ecology, Olympia, Washington; U.S. Environmental Protection Agency, Region X, Seattle; and U.S. Department of Energy, Richland Operations, Richland, Washington.

Watson, C. R., R. J. Traub, F. Carr, Jr., and J. R. Webber. 1990. User's Guide for Bioassay Screening System (BIOSC). PNL-7469, Pacific Northwest Laboratory, Richland, Washington.

Westinghouse Hanford Company (WHC). 1988. Performance Assessment Technology Development for Cleanup and Disposal of Hanford Defense Waters. WHC-EP-0072, Westinghouse Hanford Company, Richland, Washington.

Wikramaratna, R. S., and C. L. Farmer. 1987. The S301 High Resolution Miscible Simulator 2-D Version with User-Specified Velocities. Technical Report S301-2/1, Oil Recovery Projects Division, Winfrith Atomic Energy Establishment, Dorset, United Kingdom.

Wolery, T. J. 1983. EQ3NR A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: User's Guide and Documentation. UCRL-53414, Lawrence Livermore National Laboratory, Livermore, California.

Wolery, T. J., and S. A. Davler. 1989. EQ6 A Computer Program for Reaction-Path Modeling of Aqueous Geochemical Systems: User's Guide and Documentation. UCRL-MA-110662-PT-IV, Lawrence Livermore National Laboratory, Livermore, California.

APPENDIX A

GLOSSARY

APPENDIX A

GLOSSARY

converted data: data that has had some conversion factors applied---usually standard conversions not subject to dispute (example: millivolts converted to degrees Centigrade through appropriate reference tables).

client/server: the client part of a computer system (workstation or terminal) is utilized primarily to service the user and communicate between the user and another part of the computer system (another workstation or computer system), which is providing some centralized service such as storage, cpu cycles, or data (database).

database: a collection of data arranged for ease and speed of retrieval

data quality objectives (DQOs): objectives that specify required data quality to meet an analytical need. Characteristics used to define data quality are accuracy, precision, completeness, representativeness, and comparability. These are defined as follows:

- Accuracy is a measure of the bias in a measurement or predictive system. Accuracy determines if measurements or predictions are "on target." If the measurement or prediction devices are biased, they may repeatedly report values consistently in error by the same amount.

- Precision is a measure of the reproducibility of data for a given set of conditions. Specifically, precision is a quantitative measure of the variability for a group of data compared to their average value. Precision is generally stated in terms of standard deviation, but other estimates such as the coefficient of variation and range can be used.

- Completeness is a measure of the amount of validated data that was obtained from a particular sampling scheme, calculated by dividing the number of validated data points by the total number of samples collected.

- Representativeness is an expression of the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an engineered or environmental condition. Data representative of a physical system match the important characteristics of that system.

- Comparability expresses the confidence with which one data set can be compared with another. Comparable data for repeated experiments under the same conditions provide confidence that they are correct.

DBMS: database management system, usually a commercially available software package.

design documentation: specific design requirements, mathematics, derivations, and references used in developing software, including physical bases for the software (e.g., physical phenomena to be accounted for or known to be neglected, basic assumptions); performance requirements (e.g., maximum CPU time, memory, computer systems, interactive operation, etc.); regulatory requirements; codes and standards; and other documentation requirements (e.g., mathematical models, user instructions).

engineering data: data that has been collected, converted, and/or summarized in a way that enhances the engineering process (example: temperature averaged to minute averages with uncertainty quantified)

GIS: Geographic Information System: a collection of data that can be referred to by its geographic coordinates, geographic maps to overlay the information on, and hardware/software to manage and display the data

image: electronic high-resolution color screens stored on computer discs, such as maps, satellite imagery, photographs, and documents

infrastructure: (1) an underlying base or foundation especially for an organization or (2) the basic facilities, equipment, and installations needed for the functioning of a system or organization.

intermediate results: results that are not the final desired results, but the results of a single step of a multistep process (example: heat input and output to system under study to eliminate interferences for heat-balance contributors not of interest to the final objective)

map layer: a set of map features that pertain to a specific subject. Map layers can be at various levels of detail and can represent different types of data; e.g., cartographic, demographic, orphotographic data.

model: a computer program that uses input parameters and a computer program characterizing the process that operates on the input generating output of interest to the investigation of the technical issue at hand.

performance assessment: an analysis that (1) identifies the credible nature and human-caused events and processes (i.e., scenarios) that might adversely affect a waste remediation or disposal system, (2) predicts the performance of a system in terms of the containment and isolation of low-level radioactive and hazardous wastes, and (3) estimates the health risk and environmental consequences to determine if the system will comply with governmental regulations. Performance assessment arises from language in the regulations for licensing land disposal of both low-level and high-level radioactive wastes. The NRC published regulations set forth specific evaluation criteria contained in 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste." A specific requirement in Section 61.5, Subpart D is that the LLW site "... shall be capable of being characterized, modeled, analyzed, and monitored..." Implicit in these requirements is that applications for future LLW sites will include sufficient information and analyses to provide reasonable assurance that performance objectives stated in the regulations will be met. These analyses include the use of transport models for predicting radionuclide transport along the ground-water pathway for a prospective facility. To date, no LLW sites have been licensed under 10 CFR 61; the NRC technical staff can only speculate on the degree of complexity needed to predict the performance of future LLW sites with respect to the evaluation criteria specified in the regulations. The definition of performance assessment for high-level waste disposal is similar.

query: a command for use in retrieving data from a database by specifying the selection criteria

raw data: data that have not been modified from the original form in which data collection occurred (example: millivolts from thermocouple)

reference information: characteristics and regulatory limits used in some part of the clean-up process

related information: information that qualifies and explains results (example: discussion of homogeneity near thermocouples)

reports: a complete presentation of results and related information

results: explicit numbers and/or qualifiers that objectively quantify the output of a scientific process (example: calculation of amount of heat-generating material)

risk assessment: estimating the likelihood and severity of harm to human health and the environment occurring from exposure to a risk agent. Risk assessment consists of four phases:

- Hazard Identification---evaluating the likelihood of exposure and the quantity of releases of an identified hazard or the types, locations, and amounts of potentially hazardous releases from a runoff area, containment structure, or facility or the toxicity of identified releases.

- Exposure Assessment---modeling, otherwise estimating, or directly measuring the quantities or concentrations of risk agents (and byproducts or transformation products) received by individuals, populations, or ecosystems. Assessments try to discover 1) risk agents that organisms or environments are or may be exposed to, 2) how much exposure, 3) by what mode, 4) for how long, and 5) under what circumstances.

- Dose-Response Assessment---determining the dose (amount reaching a tissue or organ for potential to inflict damage) of a risk agent received by an individual or population and estimating the relationship between different doses and the magnitude of their adverse effects.

- Risk Characterization---estimating the types and magnitudes of adverse effects that the risk agent may cause to individuals or populations and the probabilities that each effect will occur, accompanied by a description and discussion of uncertainties and assumptions.

scientific visualization: looking at data and information in ways that provide insights that could not otherwise be obtained. A geographic information system is an example. Statistical graphs showing distributions, and variability are other examples.

uncertainty: a qualifier (usually numeric) that quantifies the accuracy and precision of data and/or results (example: a 95% confidence limit on an average that implies that obtaining the average again under the same conditions will result in a new average in the stated range 95% of the time)

verification: achieving confirmation that the conceptual model of the real system is adequately represented by the mathematical solution. Verification can thus be carried out, for example, by comparisons among several similar codes and by comparison of numerical codes with analytical solutions.

validation: achieving confirmation that the conceptual model and the derived computer code provide a good representation of the actual processes occurring in the real system. Validation is thus carried out by comparison of calculations with field observations and experimental measurements.

APPENDIX B

ACRONYMS (GENERAL, MODELS, AND INFORMATION SYSTEMS AND DATABASES)

APPENDIX B

ACRONYMS (GENERAL, MODELS, AND INFORMATION SYSTEMS AND DATABASES)

ADS:	Activity Data Sheets
AIRDOS-EPA:	(model) Dose from Airborne Radionuclides - EPA version
AIRSYSTEM:	(information system) Air Sample Data Analysis System
ARC/INFO:	Trademark for GIS software
AUTOCAD:	Trademark for Automated Computer-Aided Design
BEIR:	Biological Effects of Ionizing Radiation
BIOSC:	(model) Bioassay Screening System
CACES:	(model) Computed-Aided Cost Engineering Support System
CAP-88:	(model) Clean Air Act Assessment Package-1988
CASE:	Computer-Aided Software Engineering
CASS:	(information system) Computed Automated Surveillance System
CDC:	Computer Data Corporation
CERCLA:	Comprehensive Environmental Response, Compensation, and Liability Act (also known as Superfund)
CFEST:	(model) Coupled Fluid, Energy, and Solute Transport
CINDY:	(model) Code for Internal Dosimetry
CMS:	Corrective Measure Study
COE:	U.S. Arny Corps of Engineers
CORA:	(model) Cost of Remedial Action Model
CRSTER:	(model) Single Source Model
CWM:	(information system) Crib Waste Management
DAC:	Data Administration Council

DB-2: Trademark for IBM mainframe database management system

DLM: (model) Dynamic Linear Model

DoD U.S. Department of Defense

DOE: U.S. Department of Energy

DQO: Data Quality Objectives

Ecology: Washington State Department of Ecology

EFFLUENT: (information system) Effluent Data for 200 Areas

EH: two-letter acronym for the DOE Office of Environment, Safety and Health

EIS: Environmental Impact Statement

EM: two-letter acronym for the DOE Office of Environmental Restoration and Waste Management

EMS: (model) Emergency Management Support

EPA: U.S. Environmental Protection Agency

EPDS: (information system) Environmental Planning Data System

ER: two-letter acronym for the DOE Office of Energy Research

ERMC: Environmental Restoration Management Contractor

ER/WM: Environmental Restoration and Waste Management

ERS: (information system) Environmental Release Summary

ES&H: Environment, Safety, and Health

ETS-I: (information system) Environmental Commitment Tracking System---Internal WHC Commitments

ETS-TPA: (information system) Environmental Tracking System---TPA Milestone Reporting

EXTRAN: (model) Estimate Toxic Transport Model

FDS: (information system) Financial Data System

FE3DQW: (model) Finite Element 3D Ground-Water Flow

FS:	Feasibility Studies
FUSRAP:	Formerly Utilized Sites Remedial Action
GENII:	(model) Generation-II
GENMOD-PC:	(model) General Model-PC Version
GIS:	Geographic Information System
GWT:	(information system) Generator Waste Tracking
HANCHI:	(model) Hanford Chi
HDWEIS:	Hanford Defense Waste Environmental Impact Statement
HECR:	(information system) Hanford Environmental Compliance Report
HEDR:	Hanford Environmental Dose Reconstruction project
HEHF:	Hanford Environmental Health Foundation
HEIS:	(information system) Hanford Environmental Information System
HGWDB:	(information system) Hanford Ground-Water Data Base
HHMS:	(information system) Hanford Health and Mortality Study Master File
HIH:	(information system) Hanford Industrial Hygiene System
HLAN:	Hanford Local Area Network
HMID:	(information system) Hazardous Materials Inventory Database
HMS:	(information system) Hanford Meteorological Station
HUDU:	(model) Hanford Unified Dose Utility
HWMA	Hazardous Waste Management Act
HWTD:	(information system) Hazardous Waste Tracking Database
I/O:	Input/Output
IBM:	International Business Machines

ICRP:	International Commission on Radiological Protection
ICS:	(model) Integrated Characterization System
ID-CTS:	(information system) Internal Dosimetry Computer Tracking System
INTERTRAC:	(information system) Hanford Internal Dose Accounting and Reporting System
ISC:	(model) Industrial Source Complex
ISCLT:	(model) Industrial Source Complex Long-Term
ISCST:	(model) Industrial Source Complex Short-Term
IRIS:	Integrated Risk Information System
IRM:	Intermediate remedial measures
LCSYSTEM:	(information system) Liquid Composite Sample Data Analysis System
LEAD:	(information system) Liquid Effluent Analytical Data
LIMS:	Laboratory Information Management System
LOAEL:	Lowest Observed Adverse Effects Level
LSIS:	large-scale information system
M-CACES:	(model) Micro-Computer-Aided Cost Engineering Support System
MACCS:	(model) MELCOR Accident Consequence Code System
MAXI:	(model) Maximum Individual Dose
MCS:	Management Control System
MELSAR:	(model) Mesoscale Location-Specific Air Resource Model
MEM:	(information system) Modified Environmental Monitoring System
MEPAS:	(model) Multimedia Environmental Pollutant Assessment System
MESOI:	(model) MESOscale Interactive

MESOPUFF II: (model) Mesoscale Puff Model II

MESORAD: (model) Mesoscale Interactive Radiation Dose Model

MINTEQ: (model) Mineral Thermal Equilibrium

MOX: (model) Mortality and Occupational exposure

MPADD: (model) Multicomponent Reactive Plume Atmospheric Dispersion and Deposition

MPTER: (model) Multiple Point Gaussian Dispersion Algorithm with Terrain Adjustment

MSDS: (information system) Material Safety Data Sheets

MTCA: Model Toxics Control Act

MTCACR: Model Toxics Control Act Cleanup Regulations

MTDDIS: (model) Mesoscale Transport Diffusion and Deposition Model for Industrial Sources

MUA: Multi-attribute Utility Analysis

NCP: National Contingency Plan

NCRP: National Commission on Radiation Protection and Measurements

NESC:

NIH: National Institutes of Health

NOAEL: No Observed Adverse Effects Level

NRC: U.S. Nuclear Regulatory Commission

NRDA: National Resource Damage Assessment

NTP: National Toxicology Program

OIL: (information system) Open Item List

OPENMODS: (information system) Operational Environmental Monitoring Data System

ORE: (information system) Occupation Radiation Exposure System

ORIGEN: (model) Oak Ridge Isotope Generation

OSWER: U.S. EPA Office of Solid Wastes and Environmental Restoration

OTD: DOE Office of Technology Development (one of the offices in EM)

PA: Performance Assessment

PAL-DS: (model) Point, Area, Line Deposition System

PC: Personal Computer

PCB nonR: (information system) PCB Report---Non Radioactive PCB Inventory

PDMS: (information system) Project and Data Management System

PGEMS: (model) Pacific Gas and Electric Modeling System

PLUVIUS: (model) Atmospheric model named for the Roman god of rain

PLUVUE II: (model) Plume Visibility Model II

PNL: Pacific Northwest Laboratory

PROFLO-3: (model) Saturated-unsaturated flow and transport code

PS: Priority System

PUREX: Plutonium Uranium Extraction (Plant)

QST: (information system) Quality Safety Trending System

RA: Risk Assessment

RAAS: (model) Remedial Action Assessment Program

RAM: (model) Gaussian-Plume Multiple Source Air Quality Algorithm (also known as RAM)

RAMS: (model) Regional Atmospheric Modeling System

RCRA: Resource Conservation and Recovery Act

RDDT&E: Research, Development, Demonstration, Testing and Evaluation

RESRAD: (model) Residual Radioactive Material

REX:	(information system) Radiation Exposure System
RfDS:	Reference doses
RFI:	RCRA facility investigation
RI:	Remedial Investigations
RI/FS:	Remedial Investigations and Feasibility Studies
RL:	Richland Operations Office of the U.S. DOE
RPM-II:	(model) Reactive Plume Model-II
RSWIMS:	(information system) Richland Solid Waste Information Management System
S301:	(model) Contamination transport code
SACS:	(information system) Surveillance Analysis Computer System
SARA:	Superfund Amendments and Reauthorization Act
SCADA:	(information system) Supervisory Control and Data Acquisition System
SLAEM:	(model) Analytical Element Flow Code
SUMO:	(model) System Unsaturated Model
SWPM:	(model) Solid Waste Projection Model
SFMP:	Surplus Facilities Management Program
SIMS:	(information system) Spatial Information Management System
STP:	Science and Technology Program
SWITS:	(information system) Solid Waste Information Tracking System
TCD:	(information system) Tank Characterization Database
TPA:	Tri-Party Agreement between RL, EPA, and the Washington State Department of Ecology
TRAC:	(model) Track Radioactive Components
TRANSS:	(model) Transport Software

TRACR3D:	(model) Saturated-unsaturated flow and transport code
TRI:	(information system) Training Records Information
TSD:	treatment, storage, and disposal technologies
TWINS:	(information system) Tank Waste Information Network System
UNSAT-H:	(model) unsaturated flow model-Hanford Site Version
USGS:	U.S. Geological Survey
VAM2DH:	(model) saturated-unsaturated flow and transport code
VERT:	(model) Venture Evaluation Review Technique
VTT:	(model) Variable Thickness Transient flow code
WHC:	Westinghouse Hanford Company
WSSRAP:	Waldon Springs Remedial Action Project
WIDS:	(information system) Waste Information Data Systems

APPENDIX C

STATUS OF VARIOUS ASPECTS OF CODE DOCUMENTATION AND TESTING

APPENDIX C

STATUS OF VARIOUS ASPECTS OF CODE DOCUMENTATION AND TESTING

Code Acronym	Design Documentation[a]	Users' Manual[b]	Verification/ Benchmarking[c]	Validation[d]
AIRDOS-EPA	X	X	X	X
ASPEN	X	X	X	X
AREST	X	X	X	
BIOSC				
CACES	X	X	X	X
CAP-88	X	X	X	
CFEST	X	X	X	X
CINDY	X	X	X	X
CORA	X	X	X	X
CRSTER	X	X	X	X
DWOPER	X	X	X	
EMS				
EQ3/6	X	X	X	X
EXTRAN	X	X	X	
FE3DQW	X	X	X	
FETRA	X	X	X	
FLESCOT	X	X	X	
GENII	X	X	X	X
GENMOD-PC	X	X		
HANCHI	X			
HUDU	X	X	X	X
ISC	X	X	X	X
ISCLT	X	X	X	X
ISCST	X	X	X	X
M-CACES	X	X	X	X
MACCS	X	X	X	X
MAXI				
MELSAR	X	X	X	X
MEPAS	X	X	X	X
MESOI	X	X	X	X
MESOPUFF II	X	X	X	X
MESORAD	X	X	X	X
MINTEQ	X	X	X	X

STATUS OF VARIOUS ASPECTS OF CODE DOCUMENTATION AND TESTING (cont'd)

Code Acronym	Design Documentation[a]	Users' Manual[b]	Verification/ Benchmarking[c]	Validation[d]
MOX	x	x	x	x
MPADD	x			
MPTER	x	x	x	x
MTDDIS	x	x	x	x
ONSITE/MAXI2				
ORIGEN	x	x	x	x
PAL-DS	x	x	x	x
PGEMS	x	x	x	x
PLUVIUS	x	x		
PLUVUE II	x	x	x	x
PREDICT	x	x		
PROCHEM	x	x	x	x
PROFLO-3	x	x	x	x
PUREXNEW	x	x		
RAAS	x	x		
RAM	x	x	x	x
RAMS				
RESRAD		x		
RPM-II	x	x	x	x
S301		x	x	
SEPHIS		x	x	
SERETRA	x	x	x	
SLAEM		x	x	x
SUMO	x	x	x	
TABLES	x		x	
TEMPEST	x	x	x	Partial
TODAM	x	x	x	
TRAC		x		
TRANSS	x	x		
TRACR3D	x	x	x	x
UNSAT-H		x	x	x
VALLEY	x	x	x	x
VAM2DH	x	x	x	
VERT	x	x	x	x
VTT		x	x	x

Footnotes:

(a) Specific design requirements, mathematics, derivations, and references used in developing software.
(b) Description of how to execute codes and how to use special features, including examples of applications.
(c) Two types of software testing: benchmarking compares output of two codes for agreement, and verification confirms that calculations are correctly implemented.
(d) Confirms that the computer code provides a good representation of the physical system it is designed to simulate.

DISTRIBUTION

No. of Copies		
OFFSITE		
2	DOE/Office of Scientific and Technical Information	
	C. Cluett, HARC Battelle Seattle Research Center 4000 N.E. 41st Street Seattle, WA 98105	
OFFSITE		
17	Contractor HMP Steering Committee	
	B. A. Austin	B2-35
	G. D. Carpenter	B2-16
	C. DeFigh-Price	R2-31
	J. L. Deichman	B1-59
	D. R. Dillie	B3-50
	A. D. Gadeken	B4-52
	E. W. Gerber	L5-62
	J. O. Honeyman	B1-31
	J. F. Keller	K1-21
	R. E. Lerch	B2-35
	J. J. Maher	H1-53
	G. H. Moulthrop	B3-25
	J. O. Perkins	A2-50
	J. H. Roecker	B1-59
	W. G. Ruff	R3-50
	R. M. Schwenk	E6-64
	H. H. Yoshikawa	B1-31
76	Westinghouse Hanford Company	
	M. R. Adams	H4-55
	T. M. Anderson	B3-01
	M. L. Bell	T6-16
	J. D. Berger	L0-18
	T. D. Blankenship	R2-30
	R. J. Bliss	B3-04
	S. L. Bradley	B3-06
	G. R. Bopp	B5-30
	W. R. Brooksher	L4-01

No. of Copies		
	J. G. Burk, Jr.	B3-25
	M. J. Byrd	H3-08
	J. G. Cassady	B3-07
	G. L. Clogston	H2-18
	H. L. Debban	X0-43
	C. K. DiSibio	B3-03
	R. R. DiSibio	B3-02
	W. T. Dixon	B2-17
	B. P. Dole	A2-50
	T. O. Elsethagen	A2-50
	A. J. Fisher	R2-56
	K. I. Freeman	B5-25
	J. S. Garfield	H5-49
	C. J. Geier	B2-19
	L. R. Hafer	H1-63
	J. W. Hagan	B3-55
	W. H. Hamilton	N3-10
	J. H. Hammond	B3-03
	R. E. Harding	A3-90
	H. D. Harmon	R2-52
	J. M. Hawkins	B5-21
	R. E. Heineman, Jr.	R3-12
	B. A. Holmberg	G4-02
	K. R. Jordan	B3-51
	D. B. Klos	G6-55
	J. T. Knight	B5-21
	J. M. Knoll, Jr.	B3-59
	M. K. Korenko	B3-08
	D. C. Lini	H5-49
	S. Marchetti	R2-50
	H. E. McGuire	B3-63
	J. C. Midgett	S6-15
	G. J. Miskho	R2-50
	E. J. Murphy	B1-31
	D. J. Newland	S4-55
	S. M. O'Toole	B2-20
	A. A. Pajunen	H5-49
	M. L. Payne	R2-50
	F. R. Petkevicius (5)	B1-31
	R. W. Powell	H4-14
	D. K. Quigley	G1-56
	J. J. Ratcliffe	B5-25
	R. D. Redekopp	R3-50
	D. C. Richardson	R2-31
	D. E. Sandberg	B1-31

No. of Copies		
	A. R. Schade	B1-35
	W. J. Schlauder	R2-34
	L. K. Severud	H5-60
	H. A. Sieber	B2-67
	R. G. Slocum	B5-21
	R. A. Smith	G6-02
	R. M. Suyama	B3-08
	D. J. Swaim	N2-51
	L. E. Thiede	B3-35
	T. C. Varljen	H5-27
	T. B. Veneziano	B3-63
	E. P. Vodney	B3-50
	E. C. Vogt	T5-50
	J. L. Waite	B1-59
	J. C. Wiborg	R3-09
	M. R. Woychick	R1-08
	R. D. Wojtasek	L4-92
	Correspondence Control	A3-01
30	DOE Richland Field Office	
	W. A. Rutherford (30)	A5-04
	Hanford Environmental Health Foundation	
	W. D. Meader	H1-53
	Kaiser Engineers Hanford	
	R. T. French	E6-61

No. of Copies		
74	Pacific Northwest Laboratory	
	G. R. Bilyard	K6-25
	J. W. Brothers	K7-28
	P. J. Cowley	K7-22
	P. G. Doctor (50)	K6-98
	L. L. Fassbender	K6-61
	M. D. Freshley	K6-77
	C. S. Glantz	K6-98
	N. L. Hassig	K7-34
	C. W. Holmes	K6-65
	M. S. Madden	K6-40
	J. A. Mahaffey	P7-82
	W. G. Stillwell (5)	K6-30
	D. M. Strachan	K2-38
	W. R. Wiley	K1-46
	Publishing Coordination	
	Technical Report Files (5)	
	Routing	
	R. M. Ecker	SEQUI
	M. J. Graham	K6-80
	C. J. Hostetler	K6-81
	P. M. Irving	K6-98
	R. L. Skaggs	K6-77
	C. S. Sloane	K6-04
	P. C. Hays (last)	K6-86

☆ U.S. GOVERNMENT PRINTING OFFICE: 1988—790-808

END

DATE FILMED

4/19/93