Northwest Hazardous Waste Research, Development, and Demonstration Center

Program Plan

February 1988

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

**Pacific Northwest Laboratory
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Pacific Northwest Laboratory
Richland, Washington 99352

FOREWORD

The Northwest Hazardous Waste Research, Development, and Demonstration Center was created as part of an ongoing federal effort to provide technologies and methods that protect human health and welfare and environment from hazardous wastes. The Center was established by the Superfund Amendments and Reauthorization Act (SARA) to develop and adapt innovative technologies and methods for assessing the impacts of and remediating inactive hazardous and radioactive mixed-waste sites.

The Superfund legislation authorized \$10 million for Pacific Northwest Laboratory to establish and operate the Center over a 5-year period. Under this legislation, Congress authorized the U.S. Department of Energy and the U.S. Environmental Protection Agency to provide \$5 million each to support research, development, and demonstration (RD&D) on hazardous and radioactive mixed-waste problems in Idaho, Montana, Oregon, and Washington, including the Hanford Site.

In 1987, the Center initiated its RD&D activities (see Appendix B) and prepared this Program Plan that presents the framework within which the Center will carry out its mission. This Program Plan is divided into three sections:

- Section 1.0 describes the Center, its mission, objectives, organization, and relationship to other programs.
- Section 2.0 describes the Center's RD&D strategy and contains the RD&D objectives, priorities, and process to be used to select specific projects.
- Section 3.0 contains the Center's FY88 operating plan and describes the specific RD&D projects to be carried out and their budgets and schedules. This section of the Center's Program Plan will be revised annually to reflect progress in existing projects and the initiation of new projects consistent with budget guidance.

EXECUTIVE SUMMARY

The Northwest Hazardous Waste Research, Development, and Demonstration (RD&D) Center (the Center) is one element of an ongoing federal effort to provide technologies and methods that protect human health and the environment from hazardous wastes. The Center was established by the Superfund Amendments and Reauthorization Act (SARA) to develop and adapt innovative technologies and methods for assessing the impacts of and remediating inactive hazardous and radioactive mixed-waste sites.^(a) While other federal RD&D programs are developing technologies to address hazardous wastes found throughout the United States, there is a need to focus on waste types and site conditions specific to the Northwest.

The mission of the Center's RD&D program is to advance the state of the art of technologies needed to manage hazardous and radioactive mixed-waste sites in the states of Idaho, Montana, Oregon, and Washington, including the Hanford Site. These advances may come about by developing new technologies or by adapting existing technologies. To carry out this mission, the Center prepared multiyear RD&D objectives (Section 2.0) that set the priorities and establish a framework for the Center's RD&D program over the next 5 years. The Center's fiscal year 1988 (FY88) operating plan (Section 3.0) describes the specific projects that support the technology needs and RD&D objectives.

The Center conducts its RD&D program at Pacific Northwest Laboratory's facilities in Richland and Sequim, Washington. The Center will use Northwest universities as prime contributors of research and development of new and innovative concepts. Private industry will be encouraged to further develop and demonstrate these concepts. Through its RD&D program, the Center is investigating concepts that will more accurately and efficiently characterize Northwest hazardous and radioactive mixed-waste sites and assess the potential impact of these sites on public health and the environment. This program is

(a) Mixed waste is hazardous waste containing radionuclides that may or may not constitute the hazard.

also identifying, developing, and demonstrating concepts that can be used to remediate the hazardous and radioactive mixed-waste sites by destroying, stabilizing, reclaiming, or isolating the wastes.

The Center has identified two specific technology RD&D areas that support Superfund remedial investigations, feasibility studies, and remedial action design and implementation. These two technical areas are described as follows:

1. **Remedial Investigation Technologies.** This RD&D area consists of technologies for:
 - **Site Characterization.** The technologies in this area are used to determine the nature and extent of contamination and the environmental processes that control the movement of contaminants. In this RD&D area, the Center will
 - Develop and demonstrate methods for obtaining representative samples to determine hydrogeologic characteristics for unsaturated soils.
 - Develop and demonstrate methods for detecting and quantifying contaminants in unsaturated soils.
 - Adapt, develop, and demonstrate improved techniques for assessing the movement of contaminants from hazardous waste sites.
 - Develop improved sample scheme designs and methods for interpreting data to more efficiently characterize a site.
 - Provide opportunities for controlled demonstrations of innovative site characterization technologies.
 - **Environmental and Human Health Assessment.** The technologies in this area are used to assess the current and future threat posed by a waste site to human health and the environment. In this RD&D area, the Center will
 - Develop and validate methods for assessing the risk and damage to organisms from exposure to contaminants.

- Adapt, develop, and demonstrate methods for determining the exposure of organisms to complex mixtures of contaminants.
- Evaluate, develop, and demonstrate the effective methods for communicating risk information related to hazardous waste sites.

2. **Waste Treatment Technologies.** These technologies are used to destroy, stabilize, reclaim, and isolate hazardous wastes from the environment. In this RD&D area the Center will

- Adapt, develop, and demonstrate technologies that destroy nonchlorinated aromatics, chlorinated aliphatics, chlorinated aromatics, nonchlorinated aliphatics, pesticides, and toxic ions.
- Adapt, develop, and demonstrate innovative separations methods that reduce the volume, quantity, and toxicity of waste by separating hazardous from nonhazardous components to improve efficiency and effectiveness of final waste treatment.
- Adapt, develop, and demonstrate stabilization methods that will fix heavy metals, organics, or other inorganic compounds.
- Support ongoing efforts to improve or develop isolation techniques that can be applied to milling, refining, and smelting sites, landfills, and radioactive mixed-waste sites.
- Improve the application and transfer of results from RD&D programs by integrating waste treatment technologies with site characterization and risk assessment methods and by developing methods or technologies that address scale-up issues associated with the complexity of an actual waste site versus the laboratory environment.

To support the implementation of the specific RD&D activities noted above, the Center will also provide an integrated testing and demonstration capability and identify the procedures needed to use the technologies to support the decisions inherent in SARA investigations.

These goals will be reviewed on an annual basis and will be implemented through updates to the Center's operating plan (Section 3.0).

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This work was funded by the U.S. Department of Energy (DOE) and the DOE-Richland Operations Office. We thank Mrs. Paula K. Clark and Mr. Richard B. Goranson of the Richland Operations Office for their support and guidance.

The preparation of this Program Plan involved reviews and discussions with various individuals and organizations. A review workshop held in August was an important step in ensuring that this Plan focussed on Northwest needs regarding the issue of hazardous waste. Representatives from the following organizations participated in the review workshop: DOE Richland Operations Office, Operating and Engineering Contractor (OEC) for the Hanford Site, EPA Region X, Northwest state agencies, Idaho Commission on Hazardous Waste, U.S. Bureau of Mines-Spokane Research Center, and Pacific Northwest Laboratory. We thank the participants of the workshop for providing comments and helping clarify multiyear objectives for the Northwest Hazardous Waste RD&D Center. We also thank Brian L. Steelman, of Pacific Northwest Laboratory, for his extensive and timely reviews of previous drafts of this Plan.

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GLOSSARY

Aquifer--An underground rock formation composed of materials such as sand, soil, or gravel that can store and supply ground water to wells and springs. Most aquifers used in the United States are within a thousand feet of the earth's surface.

Cleanup--Actions taken to deal with a release or threatened release of hazardous substances that could affect public health and/or the environment. The term "cleanup" is often used broadly to describe various response actions or phases of remedial responses such as the remedial investigation/feasibility study.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)--A federal law passed in 1980 and modified in 1986 by the Superfund Amendments and Reauthorization Act. The Acts created a special tax that goes into a Trust Fund, commonly known as Superfund, to investigate and clean up abandoned or uncontrolled hazardous waste sites. Under the program, EPA can either:

- Pay for site cleanup when parties responsible for the contamination cannot be located or are unwilling or unable to perform the work.
- Take legal action to force parties responsible for site contamination to clean up the site or pay back the Federal government for the cost of the cleanup.

Enforcement Decision Document (EDD)--A public document that explains EPA's selection of a cleanup alternative at a Superfund site through an EPA enforcement action. Similar to a Record of Decision.

Feasibility Study (FS)--See Remedial Investigation/Feasibility Study.

Hazard Ranking System (HRS)--A scoring system used to evaluate potential relative risks to public health and the environment from releases or threatened releases of hazardous substances. EPA and States use the HRS to calculate a site score, from 0 to 100, based on the actual or potential release of hazardous substances from a site through air, surface water, or ground water to affect people. This score is the primary factor used to decide if a hazardous waste site should be placed on the National Priorities List.

Monitoring Wells--Special wells drilled at specific locations on or off a hazardous waste site where ground water can be sampled at selected depths and studied to determine such things as the direction in which ground water flows and the types and amounts of contaminants present.

National Priorities List (NPL)--EPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial response using money from the Trust Fund. The list is based primarily on the score a site receives on the Hazard Ranking System (HRS). EPA is required to update the NPL at least once a year.

Parts Per Billion (ppb)/Parts Per Million (ppm)--Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm; 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition-size swimming pool, the water will contain about 1 ppb of TCE.

Potentially Responsible Party (PRP)--Any individual(s) or company(s) (such as owners, operators, transporters, or generators) potentially responsible for, or contributing to the contamination problems at a Superfund site. Whenever possible EPA requires PRPs, through administrative and legal actions, to clean up hazardous waste sites they have contaminated.

Record of Decision (ROD)--A public document that explains which cleanup alternative(s) will be used at National Priorities List sites where the Trust Fund pays for the cleanup. The Record of Decision is based on information and technical analysis generated during the remedial investigation/feasibility study and consideration of public comments and community concerns.

Remedial Action (RA)--The actual construction or implementation phase that follows the remedial design of the selected cleanup alternative at a site on the National Priorities List.

Remedial Investigation/Feasibility Study--Two distinct but related studies. They are usually performed at the same time, and together referred to as the "RI/FS." They are intended to:

- Gather the data necessary to determine the type and extent of contamination at a Superfund site;
- Establish criteria for cleaning up the site;
- Identify and screen cleanup alternatives for remedial action; and
- Analyze in detail the technology and cost of the alternatives.

Resource Conservation and Recovery Act (RCRA)--A federal law that established a regulatory system to track hazardous substances from the time of generation to disposal. The law requires safe and secure procedures to be used in treating, transporting, storing, and disposing of hazardous substances. RCRA is designed to prevent new, uncontrolled hazardous waste sites.

Risk Assessment--An evaluation performed as part of the remedial investigation to assess conditions at a Superfund site and determine the risk posed to public health and/or the environment.

Site Inspection (SI)--A technical phase that follows a preliminary assessment designed to collect more extensive information on a hazardous waste site. The information is used to score the site with the Hazard Ranking System to determine whether response action is needed.

Superfund--The common name used for the Comprehensive Environmental Response, Compensation, and Liability Act, also referred to as the Trust Fund.

Superfund Amendments and Reauthorization Act (SARA)--Modifications to CERCLA enacted on October 17, 1986.

ACRONYMS

ATSDR	Agency for Toxic Substance and Disease Registry
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CERCLIS	List of CERCLA sites undergoing evaluation and ranking
CDC	U.S. Public Health Services Centers for Disease Control
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DP	Defense Programs (DOE)
EDD	Enforcement Decision Document
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ERC	Environmental Research Center (EPA)
ESH	Office of Environment, Safety, and Health (DOE)
ETP	Emerging Technology Program (EPA)
FS	Feasibility Study
HAZWRAP	Hazardous Waste Remedial Actions Program (DOE)
HEMP	Hanford Environmental Management Program
HRS	Hazard Ranking System
HWERL	Hazardous Waste Engineering Research Laboratory (EPA)
HWMP	Hanford Waste Management Plan
HWMTTP	Hanford Waste Management Technology Plan
IRP	Installation Restoration Program (DOD)
MOA	Memorandum of Agreement
NPL	National Priorities List

NSF	National Science Foundation
OEC	Operating and Engineering Contractor
ORO	Office of Research and Development (EPA)
PNL	Pacific Northwest Laboratory
ppm/ppb	parts per million/parts per billion
PRP	Potentially Responsible Party
RCRA	Resource Conservation and Recovery Act of 1976
RD&D	Research, Development, and Demonstration
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act of 1986
SI	Site Inspection
SITE	Superfund Innovative Technology Evaluation (EPA)
USBM	U.S. Bureau of Mines

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OVERVIEW OF THE NORTHWEST HAZARDOUS WASTE RESEARCH,
DEVELOPMENT, AND DEMONSTRATION CENTER

1.0 OVERVIEW OF THE NORTHWEST HAZARDOUS WASTE RESEARCH, DEVELOPMENT, AND DEMONSTRATION CENTER

1.1 INTRODUCTION

The Northwest Hazardous Waste Research, Development, and Demonstration (RD&D) Center (referred to as the Center) was established at Pacific Northwest Laboratory (PNL) in accordance with the provisions of the Superfund Amendments and Reauthorization Act (SARA), which was signed into law by the President on October 17, 1986 (U.S. Congress 1986). According to SARA, the purpose of the Center is to

"...carry out a program of research, evaluation, testing, development, and demonstration of alternative or innovative technologies which may be utilized in response actions to achieve more permanent protection of human health and welfare and the environment."

The Center's RD&D program addresses technologies that can be used to assess the impacts of and remediate inactive hazardous and radioactive mixed-waste^(a) sites in the Northwest region, which includes the states of Idaho, Montana, Oregon, and Washington. SARA also authorizes the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) to

"...enter into interagency agreements with one another for the purpose of providing for research, evaluation, testing, development, and demonstration into alternative or innovative technologies to characterize and assess the nature and extent of hazardous waste (including radioactive mixed waste) contamination at the Hanford site..."

This legislation authorizes \$10 million for PNL to operate the Center over a 5-year period, with the DOE providing half of the funding to support RD&D at hazardous and radioactive mixed-waste sites located on the Hanford Site in southeastern Washington and EPA providing the other half of the funding to support RD&D for other Northwest sites.

This Program Plan describes the organization and Center activities that will support the objectives outlined in the SARA legislation. It includes three parts: Section 1.0 presents an overview of the Center including the

(a) Radioactive mixed waste contains both hazardous chemicals and radionuclides.

Center's mission and objectives, organization, and relationship to other programs; Section 2.0 presents the Center's multiyear RD&D strategy, which includes a description of Northwest hazardous waste sites and the Center's multiyear RD&D priorities; Section 3.0 presents the FY88 operating plan, which describes priority and contingency projects. Appendix A is a listing of Northwest NPL sites, and Appendix B summarizes FY87 RD&D activities conducted by the Center.

1.2 FEDERAL LEGISLATION

Federal legislation to regulate waste disposal and to identify, characterize, assess, and remediate existing hazardous waste sites has been promulgated to ensure protection of the public health and natural resources. For example, the Solid Waste Disposal Act of 1970 recognizes the environmental problems created by prior methods of disposal and acknowledges the need for further federal regulation of solid waste disposal practices.

The Resource Conservation and Recovery Act (RCRA), enacted in 1976 as an amendment to the Solid Waste Disposal Act and further amended in 1978, 1980, and 1984, establishes the framework for a comprehensive, "cradle-to-grave" scheme for regulating the management of hazardous wastes. It imposes specific requirements on waste generators, on those who transport waste, and on those who treat, store, or dispose of waste. RCRA applies to current and future hazardous waste management activities and does not address inactive sites, unless they are located on land contiguous to RCRA-permitted facilities.

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund) established a \$1.6-billion fund to begin identifying, assessing, and cleaning up hazardous waste spills and inactive hazardous waste sites not addressed by RCRA. Superfund identifies parties responsible for cleaning up hazardous wastes and guidelines for determining who may be ordered to conduct cleanup activities or reimburse the fund for government cleanup expenditures.

SARA expanded the Superfund program and imposed stringent requirements on remedial action measures chosen for Superfund sites. SARA requires that preference be given to permanent remediation methods that reduce the mobility,

toxicity, or volume of hazardous waste over those methods that encapsulate wastes without actually destroying the wastes. SARA also requires consideration of in situ and onsite remediation techniques for those sites requiring cleanup. These regulatory requirements will accelerate the development of remedial technologies that provide for the permanent disposal of waste materials.

The process outlined by SARA involves a series of steps beginning with site discovery and notification and ending with remediation of the site, if it is determined that such action is warranted. The steps involved in this Superfund investigations and remedial actions process are illustrated in Figure 1.1. The preliminary assessment and site inspection step leads to an assessment and ranking of the hazard posed by the site. This step can lead to the site being included on the National Priorities List (NPL) of hazardous waste sites. Once a site is placed on the NPL, an extensive remedial investigation/feasibility study (RI/FS) is conducted by the government or potentially responsible parties (PRPs) with the intent of characterizing and quantifying the risk that the site poses to public health and the environment. If necessary, the study will identify the scope of contamination (RI) and determine the preferred remedial

FIGURE 1.1. Superfund Investigations and Remedial Actions Process

action (FS) based on the nature of the hazard at the site. After completion of the Superfund-financed (or DOE-financed, in the case of Hanford) RI/FS, the remedial action chosen for implementation at the Superfund site is documented in a Record of Decision (ROD). The ROD also includes a discussion of alternative remedial actions, their costs, and public comments. If the PRPs undertake the RI/FS, the government will oversee and review the privately performed and financed RI/FS and, in an Enforcement Decision Document (EDD), identify the remedial alternative to be implemented. Following this step (ROD and possibly an EDD), the design, construction, and operation of the remedial action occurs. This step includes a validation process that can include site monitoring to verify the effectiveness of the remedial action taken.

Implementation of the process outlined by SARA requires the application of a broad range of technologies to complete the Superfund investigations and remedial actions process. The cleanup of inactive sites involves the assessment of the nature and extent of the hazard posed to human health and the environment by the site and, if required, the selection of an appropriate method for remediating the site. The following technical areas are involved in this assessment process:

- **Site characterization** determines the nature and extent of contamination and the environmental processes that control the movement of contaminants. Site characterization technologies include sample scheme design, monitoring, detection, sample collection, and data interpretation. Data obtained under these technologies support the assessment of the overall hazard posed by a site before and after remedial action as well as the selection of alternative remedial actions.
- **Environmental and human health assessment** involves evaluating the current and future threat of a site to human health and the environment thus supporting the assessment of the overall hazard. This area also helps set design/performance criteria for alternative remedial actions. Research, development, and demonstration related to these

assessment technologies can be grouped into the following areas: risk and damage assessment, exposure and bioavailability assessment, and risk communication/public awareness and perception.

- **Waste treatment technologies** destroy, separate, stabilize, and/or isolate hazardous wastes from the environment. Information on these technologies is used in the evaluation, selection, design, and implementation of an acceptable remedial action.

Together, these technical areas provide the necessary tools for conducting all steps of the Superfund remedial investigations, feasibility studies, and remedial action design implementation and validation. As indicated in Figure 1.1, site characterization and environmental and human health assessment support RI activities, and waste treatment technology supports both the FS activities and the subsequent remedial action design and implementation.

1.3 MISSION AND OBJECTIVES OF THE CENTER

The Northwest Hazardous Waste RD&D Center manages a program to meet technology development needs specific to the types of hazardous and radioactive mixed wastes and sites in the Northwest (Idaho, Montana, Oregon, and Washington). This information is summarized in Section 2.0 of this Program Plan. Some of the inactive hazardous wastes sites in the Northwest have been identified as proposed or final NPL sites requiring further characterization, assessment, and possibly remediation. These waste disposal sites have released, or pose a significant potential for releasing, toxic substances to the environment. In addition, the waste disposal sites located at the Hanford Site in southeastern Washington contain radioactive mixed wastes. Other federal RD&D programs address development of some waste site assessment and remediation technologies, but there is a need to focus and integrate technology development on waste types and site conditions specific to the Northwest, including the Hanford Site.

The mission of the Center's RD&D program is to advance the state of the art of technologies needed to manage hazardous and radioactive mixed-waste sites in the states of Idaho, Montana, Oregon, and Washington. The Center's primary goals in support of this technology development mission are

- to adapt or improve existing technologies or develop new and innovative technologies for characterizing, assessing, and remediating hazardous and radioactive mixed-waste sites located in the Northwest and elsewhere in the nation.
- to transfer these technologies to DOE, EPA, other federal and state agencies, communities, and the private sector for application to hazardous and radioactive mixed-waste problems in the Northwest.

In conducting this primary mission of technology development, the Center will seek to involve Northwest universities, federal, state, and local agencies, and private industry in the planning and conduct of its RD&D program. The Center will manage cooperative RD&D involving these groups.

Specific objectives for the Center include

- identifying the most important hazardous waste and radioactive mixed-waste RD&D needs of the Northwest region
- selecting those projects to be funded through the Center that are technically, economically, and institutionally feasible for the region
- serving as a technology information base for the Northwest region and maintaining knowledge of the state of the art of available technologies to ensure that the Center's efforts complement other national and regional RD&D programs
- securing support from DOE-HQ, DOE-RL, EPA-HQ, and EPA Regions VIII and X
- providing for effective technology transfer to the Northwest region and to other regions as applicable.

An additional Center goal is to facilitate the exchange of technical information within the region. In support of this goal, the Center has several important roles:

- providing universities, federal, state, and local governments, private industry, and the public with access to technical expertise and fostering dialogue among site managers, regulators, technology developers, and technology users.
- communicating and applying the results of RD&D conducted by parties outside the Northwest region to those involved in waste disposal problems in the Northwest.
- integrating regional RD&D findings and communicating them to interested parties both within and outside of the region.

1.4 CENTER ORGANIZATION

The Northwest Hazardous Waste RD&D Center includes a central program office^(a) and an RD&D program consisting of two technology RD&D tasks (Figure 1.2):

- remedial investigation technology (including site characterization and environmental and human health assessment technology)
- waste treatment technology.

The Remedial Investigation task is composed of site characterization and environmental and human health assessment technologies. Technologies developed

FIGURE 1.2. Northwest Hazardous Waste RD&D Center Organization

(a) The program office coordinates the the technical activities conducted within each task and maintains an interface with the DOE, EPA, and other agencies.

under this task will support 1) assessment of the potential for adverse impact on human health and the environment and 2) selection of design/performance criteria for alternative remedial actions. The waste treatment task is composed of technologies that destroy, stabilize, reclaim, and/or isolate hazardous wastes from the environment. These technologies support the selection, design, and implementation of an acceptable remedial action.

In addition to its RD&D program, the Center conducts activities to support this program. These activities are carried out under program management and provide for overall program integration and planning, administrative assistance, technical communications, and technology transfer for the Center. Program integration and planning activities ensure that the Center's RD&D program is responsive to advances in technology outside the Center, including ongoing activities at other government RD&D programs and changes in technology needs for the Northwest. Administrative assistance includes financial and budget control. Technical communication includes the preparation and dissemination of program information and the organization of workshops, seminars, and project review meetings. Technology transfer activities facilitate the orderly progression of Center-sponsored technologies as well as the transfer of technologies developed under other programs to field application in the Northwest. To accomplish this transfer, the Center will help identify and resolve institutional issues related to the process, such as permitting, cost sharing, and regulatory and public acceptance of field demonstration projects. To ensure long-term effectiveness of technologies, the Center will support activities for technology maintenance.

The program manager and task leaders act as liaisons with key organizations within the Northwest: state and federal agencies, the Hanford Site Operating and Engineering Contractor (OEC), and Northwest universities.

1.5 RELATIONSHIP TO OTHER PROGRAMS

An important aspect of the Center's activities is its interaction with other RD&D programs in the field of hazardous waste. While the Center is distinctly different in purpose and focus from these other programs because of its broad range of activities (i.e., from basic research to demonstration) and

regional focus, the efforts of these other programs are essential to maximizing benefits from the Center's RD&D program. It is therefore important that the Center's program complement and build on these other programs. The RD&D programs of particular interest to the Center are managed by DOE, EPA, U.S. Department of Defense (DOD), U.S. Bureau of Mines (USBM), Agency for Toxic Substance and Disease Registry (ATSDR), and the National Science Foundation (NSF). The Center is also interested in several other organizations within the region that have ongoing programs related to Northwest hazardous wastes.

DOE Programs

The Pacific Northwest Laboratory, which manages the Center for DOE, conducts RD&D related to the Hanford Site. The Hanford facilities are operated and managed for DOE by the Hanford Site Operating and Engineering Contractor (OEC). The coordination of site-related RD&D is managed by DOE's Richland Operations field office. The Hanford Environmental Management Program coordinates and integrates compliance-related activities for hazardous and radioactive mixed waste at active and inactive sites on the Hanford Site. The Hanford Waste Management Plan and the Hanford Waste Management Technology Plan identify reference technologies and RD&D needs for treating active discharges and remediating inactive waste sites located at the Hanford Site.

The OEC and its contractors are preparing a number of other plans that will define methods and schedules for treating wastes and remediating waste disposal sites. Among these are the Hazardous Waste Management Plan, the Defense Waste Management and Environmental Restoration Program Plan, and Remedial Investigation (RI) plans for specific sites. A Memorandum of Agreement among DOE, EPA, and the Washington State Department of Ecology concerning the implementation of RCRA and CERCLA/SARA at the Hanford Site is also being prepared. These and other plans will serve as bases for identifying technology gaps and planning Center activities that address specific Hanford Site needs. The Center has established a liaison to facilitate the communication of needs and Center capabilities among DOE, the OEC, and the Center.

- **The Center's RD&D program will coordinate closely with the OEC to ensure that the OEC's waste treatment technology needs are met.**

In addition to RD&D activities related to the Hanford Site, DOE-Defense Programs (OP), through its Oak Ridge Operations Office, funds and manages the Hazardous Waste Remedial Actions Program (HAZWRAP). Elements of this program include a hazardous waste information network and technical development and demonstration of remedial technologies (both generic and site specific). The HAZWRAP waste R&D is focused primarily on adapting technologies, including innovative ones, for remediating specific sites. HAZWRAP also has a technology demonstration program designed to expedite the evolution of innovative technologies for the destruction, stabilization, or delisting of DOE-DP hazardous and mixed wastes.

- **The Center will review HAZWRAP findings for possible adaptation to Hanford and other Northwest sites, and where appropriate, cooperative technology demonstrations will be developed. The Center will also provide technical support for HAZWRAP activities managed or conducted by PNL, and will closely coordinate those activities with DOE.**

The DOE Office of Defense Programs has recently established a new budget category, Environmental Restoration (ER), for remediating inactive hazardous and radioactive waste sites. HAZWRAP will provide overall program management of the ER program and will coordinate the development of a program-wide ranking system for project submittals to this program. Part of the ER budget will be used for technology development and demonstration.

- **The Center will coordinate its activities with the ER program, and where appropriate, cooperative technology demonstrations will be developed.**

The DOE Office of Environment, Safety and Health (ESH) is responsible for developing department environmental policies, orders, and implementation guidance. The ESH also conducts a DOE-wide environmental survey to identify and prioritize DOE environmental problems. The DOE Office of Energy Research is responsible for coordinating fundamental research in environmental and human health areas.

EPA Programs

EPA's hazardous waste RD&D program activities are primarily conducted and managed by EPA's Office of Research and Development (ORD). Several key offices at ORD are involved in hazardous waste research: Office of Environmental Engineering and Technology, Office of Environmental Processes and Effects Research, and Office of Exploratory Research. In addition, specific RD&D activities are managed through the Office of Solid Waste and Emergency Response, Office of Policy Planning and Evaluation, and EPA's regional offices.

EPA's Hazardous Waste Engineering Research Laboratory (HWERL) in Cincinnati, Ohio, manages and conducts remedial action technology RD&D. Included in its activities are the Superfund Innovative Technology Evaluation (SITE) Program and the Environmental Research Centers (ERC) Program. The Environmental Monitoring Systems Laboratory (EMSL) in Las Vegas, Nevada, manages and conducts remedial investigation technology RD&D.

At HWERL, research is directed toward alternative disposal methods including incineration, chemical/physical treatment, fixation processes, and pre-treatment before disposal.

- **The Center will coordinate RD&D and share results with HWERL and other EPA groups such as the Office of Solid Wastes, Office of Policy Planning and Evaluation, and EPA regional offices. Where appropriate, cooperative RD&D programs will be developed.**

The SITE Program was initiated to help identify, test, and encourage the use of new methods for destroying, stabilizing, or otherwise treating hazardous wastes. The overall goal of the SITE Program is to maximize the use of alternatives to land disposal at Superfund sites. To accomplish this, full-scale demonstrations of alternative technologies that are considered of commercial scale are planned at actual Superfund sites. The Emerging Technology Program (ETP) of the SITE Program is fostering further development of emerging, alternative technologies not yet ready for full-scale demonstration.

- **The Center will transfer findings for application to the Northwest from specific demonstration and development work at Superfund sites under SITE and ETP Programs. When mutual benefit exists, the Center will work together with SITE and ETP Programs to further develop and demonstrate technologies.**

As part of EPA's strategy for approaching long-term research needs, ORD created the ERC Program to support environmental research in science and engineering. There are eight ERCs at universities; these ERCs work in four general areas: 1) industrial and municipal waste abatement and control, 2) pollutant transport and transformation, 3) ecological effects of pollutants, and 4) environmental epidemiology.

- **The Center will monitor the findings of the ERCs and share results as appropriate with those groups working in the field of hazardous waste disposal.**

At EMSL, research is directed toward development, evaluation, and application of methods and strategies for monitoring the environment. Major program areas are analytical methods, quality assurance, monitoring methods, remote sensing, and exposure assessment.

- **The Center will coordinate its RI RD&D activities and share results with EMSL, and where appropriate, will develop cooperative RD&D programs.**

DOD Programs

The Installation Restoration Program (IRP) is the DOD program for identifying, assessing, and remediating contamination at toxic and hazardous waste sites. The IRP is carried out by the military services and defense agencies.

There are many contaminated military sites, and IRP is now in a 5-year planning phase to address these problems and find appropriate solutions. This includes coordinating activities among the Army, Navy, and Air Force. At this time, DOD is focusing their RD&D in the areas of in situ treatment/degradation of hazardous contaminants in soil and groundwater; in situ cleanup using biological, chemical, thermal, and solid reduction techniques; containment; and site assessment.

- **The Center will monitor DOD projects, especially those at Northwest military sites and, where appropriate, share findings and develop cooperative programs.**

DOD/EPA/DOE Working Group

A DOD/EPA working group was established in 1985 to address the high cost of hazardous waste cleanup and the need for innovative technology development; the group's intention was to develop cooperative efforts in hazardous waste cleanup demonstrations and innovative RD&D technologies.

DOE joined the working group in 1986. A meeting was held at which the EPA's SITE Program and the development of innovative hazardous waste cleanup technologies were discussed. As a result of this and subsequent meetings, many cooperative efforts have been proposed and initiated.

- **The Center will monitor the results of cooperative projects and participate in working group meetings as appropriate.**

U.S. Bureau of Mines

The U.S. Bureau of Mines conducts a hazardous waste RD&D program in the Northwest through its Spokane Research Center. This center focuses on hazardous wastes resulting from mining, milling, smelting, and refining operations.

- **The Center will monitor the results of this RD&D program, coordinate activities on technologies relevant to any Northwest Superfund site and, where appropriate, develop cooperative RD&D projects.**

Agency for Toxic Substance and Disease Registry

The Agency for Toxic Substance and Disease Registry (ATSDR) is part of the U.S. Public Health Services Centers for Disease Control (CDC) in Atlanta, Georgia. Although it is part of the Public Health Service, the ATSDR was legislated into existence by and receives its appropriations from SARA. The ATSDR is responsible for maintaining exposure and disease registries to track persons who are exposed to hazardous wastes at NPL sites or from chemical spills or releases. The ATSDR maintains state registries through EPA regional offices, which in turn distribute funds to the state. The ATSDR has an emergency response team that goes into the field when there are spills of toxic

chemicals or when there is serious concern over NPL sites (e.g., Missouri dioxin spills). The ATSDR produces toxicology profiles on the most common toxic chemicals found at NPL sites (see Federal Register, April 17, 1987), and identifies where there are insufficient data to write toxicology profiles; in the latter case, funds are then sent to the National Toxicology Program to perform toxicology assessments. In addition to these programs, the ATSDR has a large-scale epidemiology program within the Center of Environmental Health at CDC that conducts a general research program, many components of which are related to activities of the Northwest Hazardous Waste RD&D Center.

- **The Center will maintain close relations with the ATSDR through its liaison to EPA so that research findings from both the ATSDR and the Center are shared through routine seminars. To avoid duplication of effort in the areas of risk perception, communication, and management, the Center will also coordinate through the EPA liaison any of its research efforts that bear on the research needs of the ATSDR.**

Other Organizations and Programs

Other organizations located in the Northwest conduct R&D activities related to Superfund sites. These organizations include government regulatory agencies, universities, and private industries. The principal regulatory agencies are EPA Regions VIII and X and their state counterparts. These agencies are the Center's principal source for identifying regional technology needs from a regulatory perspective.

- **The Center will communicate with these agencies to ensure that the Center's RD&D program is responsive to their needs.**

Universities make up a significant portion of the Northwest region's research capability in hazardous waste technologies.

- **The Center will draw on faculty from Northwest universities to conduct research. The Center will also consult with university experts on the technical aspects of program planning and evaluation.**

Based on their field experience, private industries involved in hazardous waste management as a business are important resources in identifying technology needs.

- The Center will communicate with private industries and, through their assistance and field experience, will identify Northwest needs and transfer technology to ensure that its research program is responsive to their needs. In addition, as part of its technology transfer effort, the Center will seek opportunities to cooperate with industry in the demonstration of technologies.

MULTIYEAR RESEARCH, DEVELOPMENT AND DEMONSTRATION STRATEGY

2.0 MULTIYEAR RESEARCH, DEVELOPMENT, AND DEMONSTRATION STRATEGY

This part of the Center's Program Plan contains the multiyear RD&D strategy and establishes a framework within which the Center intends to conduct its RD&D program over the next 5 years. This framework identifies the primary RD&D priorities for the Center and indicates how the Center will carry out this work. Specific projects for FY88, including budgets and schedules, are listed in Section 3.0 of this Program Plan.

2.1 OVERVIEW

The manufacture of chemicals and other industrial materials, in many instances, generates waste streams that pose potential threats to public health and the environment. If not properly treated and disposed of, such waste streams can contaminate soil, surface water, groundwater, and/or air. A growing national concern about the release of hazardous substances to the environment has resulted in legislative actions to remediate unsafe waste disposal sites and to promote safe treatment and disposal of newly generated wastes.

The Center is part of an ongoing federal effort to provide technologies and methods that protect human health and welfare and the environment from hazardous wastes. The Center manages a program to meet technology development needs specific to the types of hazardous and radioactive mixed wastes and sites in the Northwest (Idaho, Montana, Oregon, and Washington), as summarized in Section 2.2 of this Program Plan. Some of the inactive hazardous wastes sites in the Northwest have been identified as proposed or final National Priorities List (NPL) sites requiring further characterization, assessment and possibly remediation. These waste disposal sites have released or pose a significant potential for releasing toxic substances to the environment. In addition, the waste disposal sites located at the Hanford Site in southeastern Washington contain radioactive mixed waste. While other federal RD&D programs address development of some waste site assessment and remediation technologies, there is a need to focus and integrate technology development on waste types and site conditions specific to the Northwest, including the Hanford Site.

The Center is conducting a long-term program of technology development that supports the assessment and cleanup of Northwest hazardous and radioactive mixed-waste sites. This RD&D program will support SARA investigations and remedial actions in two distinct ways:

1. It will adapt or develop those technologies that are needed to characterize, assess, and remediate Northwest hazardous and radioactive mixed-waste sites.
2. It will develop procedures for using the technologies and interpreting results to support the decision processes inherent in SARA investigations.

The RD&D objectives listed in this section provide a framework within which the Center intends to conduct its multiyear RD&D program. These objectives address 1) the technology needs for remediating hazardous and radioactive mixed-waste sites in the Northwest (as summarized in Section 2.0) and 2) technology gaps identified in the Center's review of technology needs for site characterization, environmental and human health assessment, and waste treatment technology.

The RD&D objectives were selected to address the hazardous waste technology needs pertaining to Northwest problems and to be consistent with SARA legislation. More areas were identified for RD&D than could be accomplished with the base funding for the Center. Therefore, under each objective, areas with the highest priority for accomplishment within the first 5 years of the Center's operation and within base funding have been emphasized. The Center will seek additional funds for expanding the RD&D program; these funds could be obtained through cofunding, grants, etc.

The Center will use an annual planning process (see Section 2.4) to select specific projects to meet its objectives. RD&D projects will be conducted at PNL, at Northwest universities, or in conjunction with other government or private programs. Pursuit of objectives will depend on 1) funding available to the Center from the DOE, EPA, and other sources, 2) the extent to which

identified projects support each objective, and 3) the extent to which the Center's projects complement other programs such as those conducted by the DOE, EPA, DOD, USBM, and private industry.

2.2 DESCRIPTION OF NORTHWEST WASTE SITES

Site types and waste types prevalent within the Northwest region must be examined before priorities are established for developing technologies to characterize, assess, and remediate Northwest hazardous and radioactive mixed-waste sites. While specific site characteristics determine the design of remedial actions for that site, more general regional characteristics can provide valuable insight with which to guide the development of a wider technology base. This section summarizes the Center's analysis by defining and describing three distinct geographic subregions within the Northwest, summarizing the predominant waste types at Northwest sites, comparing waste and site characteristics across the three subregions, and summarizing the implications of this analysis for technology development needs.

Geographic Description of the Northwest Region

For purposes of analyzing variations in site characteristics, the Northwest region can be divided into three distinct subregions. These subregions, as shown in Figure 2.1, are identified as

- Cascade West--the Cascade Mountains and the region west of those mountains
- Intermountain--the region between the Cascade and Rocky Mountains
- Rocky Mountain--the Rocky Mountain areas of Idaho and all of Montana.

The geographic characteristics within these subregions have influenced the development of industry and commerce and hence the types of hazardous wastes and disposal sites. The geographic characteristics have also influenced the manner in which hazardous wastes threaten resident populations and the environment.

The Cascade West subregion is characterized as a marine environment. Rainfall in most of this area exceeds 30 inches per year. A major portion of the soils of this subregion are volcanic in origin and have been transported by

FIGURE 2.1. Location of Northwest Hazardous Waste Sites

water and deposited in sedimentary layers. Groundwater tables in this region are generally shallow, typically less than 50 feet deep. The forests west of the Cascades are highly productive, resulting in a major forest products industry that produces pulp and paper, lumber, telephone and power poles, and railroad ties. The region contains large metropolitan areas such as Seattle and Portland. These areas hold numerous secondary industries that take advantage of the international trade opportunities afforded by major seaports and support the primary industries of the Northwest.

The Intermountain subregion lies in the rain shadow of the Cascade Mountains. This subregion is characterized by less than 30 inches of rainfall per year and by porous volcanic soils that have generally been wind deposited. The groundwater tables in this subregion are much deeper, typically 150 feet to 200 feet, than those west of the Cascades. The economy of the area is dominated by dry land and irrigated agriculture and by food-processing industries. In addition to agriculture, the economy is influenced by the defense and the energy research and development operations conducted at the Hanford Site. Located in the Columbia Basin, the Hanford Site receives very little precipitation (approximately 7 inches per year) and is relatively isolated from major population centers.

The Rocky Mountain subregion was formed by nonvolcanic geologic processes, resulting in an area rich in minerals. Precipitation is somewhat higher than in the Intermountain subregion, facilitating significant timber production. The soils in this subregion are a mixture of volcanic (from eruptions outside the region) and nonvolcanic soils; the region is also characterized by deep groundwater tables. Predominant economic activities in this area are those associated with the mineral (mining, milling, smelting, and refining) and timber industries. The eastern regions of Montana have some characteristics common to the intermountain region as well as those general characteristics of the Rocky Mountain subregion.

Analysis of Waste and Site Characteristics

Characteristics of Northwest hazardous waste sites were analyzed by considering 47 final and proposed NPL sites in the Northwest region (Idaho, Montana, Oregon, and Washington) and those sites on EPA's Region X list of CERCLA sites. Figure 2.1 shows the location of each of the 47 final or proposed NPL sites (as of 1987) and the Hanford Site. Appendix A lists these sites and provides a brief description of their characteristics. Waste sites designated as CERCLA sites are potentially contaminated sites that have been identified as such, but either do not have a hazard ranking score sufficient to warrant placement on the NPL or about which there is insufficient information to compute a hazard ranking score. This analysis included the CERCLA list of 648 sites within the states of Idaho, Oregon, and Washington that are not on the NPL. Because complete information is lacking, not all sites were included in the analysis. Data for EPA Region VIII CERCLA sites in the state of Montana were not available at the time of this analysis, so the Rocky Mountain subregion is represented by those sites within northern Idaho and northeastern Washington. Consequently, the results may not be truly representative of the Rocky Mountain subregion. A more complete analysis will be conducted in early FY88 as additional data become available.

In analyzing waste and site characteristics, two questions were addressed:

1. Are there significant differences between the NPL and CERCLA sites that lead to different priorities for technology development?

2. Do waste types and site characteristics support the definition of three distinct subregions, and do those characteristics lead to different priorities for technology development?

The following sections describe the Center's preliminary analysis of these questions.

Prevalence of Hazardous Waste Types for the Northwest Region

Figure 2.2 compares the prevalence of nine categories of hazardous waste for the NPL and CERCLA sites in the Northwest region. These nine categories were selected because they potentially represent different transport properties and probably different remediation technologies. Because of these differences, organics were divided into the four categories shown in Figure 2.2. Figure 2.2 also indicates the mixture complexity (which is defined as the average number

*Average number of waste categories per site.

FIGURE 2.2. Comparison of Hazardous Waste Categories for Northwest Sites

of waste categories per site) for both NPL and CERCLA sites. While some variations do exist between the two sets of sites, data indicate that the CERCLA sites have roughly the same distribution of waste categories as the NPL sites. Consequently, technology needs for CERCLA sites will be similar to those for NPL sites. For this analysis, 511 CERCLA sites contained usable information.

Based on these nine categories, the single most extensive problem in the Northwest with regard to hazardous waste is the remediation of sites contaminated by heavy metals. More than half of the NPL and CERCLA sites have been or are suspected of being contaminated by this category of waste. As a combined category, organics are the most prevalent waste group seen in these data. Nevertheless, when classified into the categories shown in Figure 2.2, three of the four categories of organic hazardous wastes remain prevalent at 30% or more of the sites. In addition, treatment of complex waste mixtures will need to be addressed as shown by the mixture complexity factor.

Comparison of Site Characteristics for Northwest Subregions

Waste and site characteristics were further analyzed within each of the three subregions and compared across the subregions to determine important differences. For these analyses, data for the NPL and CERCLA sites were combined. The analysis included 284 Cascade sites, 184 Intermountain sites, and 43 Rocky Mountain sites.

Figure 2.3 indicates the percentage of sites within each region that are known to contain wastes in the nine hazardous waste categories defined in Figure 2.2. Figure 2.3 also shows that differences exist among the subregions relative to the types of hazardous wastes requiring remediation. For example, because pesticide disposal is associated with agricultural activities in the Intermountain subregion, pesticide disposal is a more significant problem there than in the Cascade or Rocky Mountain subregions. Chlorinated and nonchlorinated aliphatics are associated with more complex industries such as electronic and chemical processing, which are more prevalent west of the Cascades. Consequently, this subregion has the greater number of sites containing chlorinated aliphatics. From an economic viewpoint, industry west of the Cascades would be classified principally in the secondary and tertiary economic sectors. These sectors produce hazardous wastes classified as complex organic mixtures, as

FIGURE 2.3. Percentage of Sites Containing Nine Hazardous Waste Categories

indicated by higher mixture complexity factors. These data support the conclusion that significant differences in waste types and characteristics do exist among the three subregions.

To further identify subregional differences, the potentially responsible parties (PRPs or disposers) were examined to determine the sources of hazardous wastes across the three subregions. The results of this analysis are presented in Figure 2.4. These results add further support to the concept of subregional differences regarding waste types and sources. Heavy metals contamination is

FIGURE 2.4. Sources of Hazardous Waste

one of the problems associated with milling, refining, and smelting activities in the Rocky Mountain subregion. That government agencies, responsible for solid waste disposal, would be a major source of hazardous wastes released to the environment was not obvious from other approaches to the data. Of the five municipal landfills assigned to the NPL, four are located in the greater Spokane area (Intermountain), and one is located in the Kent, Washington, area (Cascade). This analysis included data from 284 Cascade sites, 179 Intermountain sites, and 40 Rocky Mountain sites.

While data from the foregoing analyses provide some guidance as to the types of technologies needed for remediation, additional analyses would be useful. Two additional statistical comparisons were made: the method of waste disposal used at the sites (Figure 2.5) and the original form of the waste or its form at the time it was identified as a hazardous waste (Figure 2.6).

No. of sites used in analysis: Cascade - 284,
Intermountain - 172, Rocky Mountain - 43

FIGURE 2.5. Disposal Methods for Hazardous Waste

No. of sites used in analysis: Cascade - 277,
Intermountain - 173, Rocky Mountain - 45

FIGURE 2.6. Forms of Hazardous Waste at Disposal

A review of Figures 2.5 and 2.6 suggests a need for developing a remediation method that treats wastes in both the vadose (unsaturated soil column) and groundwater zones. The most prevalent form of disposal was the discharge of liquids (at 78% of the sites) to the land (at 88% of the sites). This allowed these wastes to percolate through the vadose zone to the groundwater.

Finally, an analysis of disposal site area was performed, because the types of remediation technology needed will depend on this characteristic to some extent. These estimates are listed in Table 2.1. The Rocky Mountain region has the largest sites because of the mining and mineral processing activities within the region. Small sites are found in the Cascade West region. This analysis is far more tenuous because the data were extracted from the CERCLA sites list, and at CERCLA sites area affected is only an estimate, based on visual inspection. The true extent of site contamination will remain unknown until complete site characterization studies are performed. Smaller site areas will be more likely to receive remediation by removal and treatment, while larger sites will probably be treated in situ.

TABLE 2.1. Estimates of Disposal Site Areas

	<u>Average</u>	<u>Standard Deviation</u>	<u>No. of Sites</u>
Cascade West	31.4 acres	± 60 acres	116
Intermountain	84 acres	± 343 acres	103
Rocky Mountain	586 acres	± 2577 acres	27

Analysis of the Hanford Site

For this analysis, data were used from 584 inactive, CERCLA sites located on the Hanford Site. Of these 584 disposal sites, a recent DOE study^(a) identified 125 sites as those needing further site characterization. Data on these two sets of sites were used to determine whether technology needs for the Hanford Site were similar to the technology needs for EPA CERCLA sites. Table 2.2 lists the results of this analysis. Based on the study of disposal sites located on the Hanford Site, 72% of the 584 disposal sites received liquid waste, and 28% of the disposal sites received solid waste. The predominance of the liquid waste forms suggests the potential need for remediation technologies that are applicable to treating wastes in the vadose, or unsaturated, zone and the groundwater zone.

Conclusions and Implications for Technology Development

The foregoing analysis is not comprehensive at this time because data on the Montana CERCLA sites were not available. However, some guidelines on technology development needs for the Northwest region can be identified:

- More than half the NPL and CERCLA sites in the Northwest have heavy-metal contamination. These heavy metals have resulted from various types of industrial activities, including finishing, processing, milling, smelting, and refining. Heavy-metal contamination is prevalent at sites within each of the three subregions analyzed and at disposal

(a) This draft document was prepared for the U.S. Department of Energy and is entitled Phase I Installation Assessment of Inactive Waste-Disposal Sites at Hanford. Volumes 1 and 2.

TABLE 2.2. Hazardous Waste Categories for Hanford Disposal Sites^(a)

	125 Sites	584 Sites
Radionuclides	84%	81%
Heavy metals (nonradioactive)	42%	10%
Solvents (aliphatics)	3%	2%
Aromatics	5%	(not identified)
Other (nitrates, etc.)	56%	(not identified)
Complexity factor (based on categories listed above)	1.90X	(b)

-
- (a) This table was compiled using data from a draft document prepared for the U.S. Department of Energy, entitled Draft Phase I Installation Assessment of Inactive Waste-Disposal Sites at Hanford. Vol. 1 and 2.
- (b) For the 584 sites, almost all sites had two or more categories of waste deposited. A few, particularly the solid waste disposal sites, contained only one category of waste (e.g., lead shielding).
-

sites located at the Hanford Site. Consequently, remediation technologies that address heavy metals would have broad applicability throughout the Northwest and should have a priority for the Center's RD&D program.

- This analysis has shown that there are important differences in waste and site characteristics across the three subregions within the Northwest. Over 50% of the sites within the Intermountain subregion are contaminated with pesticides and related substances. By contrast, this category of waste is present at only about 15% of the sites in the other two subregions. Chlorinated aliphatics (solvents), which are typically associated with electronics and chemical processing industries, are more prevalent west of the Cascades than in the other two subregion. Consequently, the individual regions may have different priorities for technology development needs.
- As indicated by the mixture complexity index (2.1 for NPL sites and 1.74 for CERCLA sites), effective site remediation will necessitate

treatment of more than one waste category at many sites in the region. As a result, site characterization and risk assessment techniques will need to address the presence of complex waste mixtures rather than single waste forms. In addition, treatment methods will need to address multiple waste forms (e.g., liquids, sludges, etc.) and disposal methods (e.g., tanks, drums, tailings, etc.).

- Three of the four categories of organic wastes, chlorinated aliphatics, chlorinated aromatics, and nonchlorinated aromatics, are significant problems in the Northwest. Technologies used to remediate these wastes must be efficient under varying conditions and varying waste forms.
- Many of the sites, especially in the Intermountain subregion, have wastes in the unsaturated or vadose zone. Consequently, technologies will need to effectively assess and remediate hazardous wastes in both the vadose zone and groundwater.
- Technology needed to assess and remediate the NPL and EPA CERCLA sites would also be appropriate for the individual Hanford CERCLA sites. Technologies must address mixtures of more than one category of waste, consisting primarily of heavy metals and aliphatic organics (solvents). In addition, the Hanford Site has disposal sites contaminated with nitrates, a waste material not common to NPL and EPA CERCLA sites in the Northwest, but often detected as a groundwater contaminant due to agricultural activities.

2.3 CENTER MULTIYEAR RD&D PRIORITIES

RD&D objectives are grouped below according to an RD&D integration area and two technology development areas: remedial investigation technology with site characterization and environmental and human health assessment components and waste treatment technology. Figure 2.7 displays the RD&D objectives that have been identified for remedial investigation technology and waste treatment technology.

FIGURE 2.7. Center Multiyear Objectives

RD&D Integration

One of the principal gaps identified by the Center's review of Northwest needs for hazardous waste research was the integration of overall RD&D programs. The programs within each of the technology areas should be combined into an integrated program that considers all aspects of site remediation and the need for interactive development and application of technologies between the two technology areas. Two categories of need are common to each of the technology areas:

- Demonstration projects are needed for testing technologies on a large to full scale and for transferring the proven technologies to the end users. Concurrent demonstration of technologies from each of the three areas would provide a unique tool for Northwest investigators to demonstrate innovative technologies.
- An integrated approach to site characterization, risk assessment, and remediation is needed to ensure that data collected during remedial investigation (RI) (i.e., site characterization and environmental and human health assessment) is adequate for evaluating risk and subsequent treatment options during the feasibility study (FS).

Remedial investigation (site characterization and environmental and human health assessment) and waste treatment have been identified as distinct areas for technology development. This distinction was made because each area requires different scientific and engineering disciplines to develop technology, and because, organizationally, it reflects the Center's goal of addressing the whole problem of waste site assessment and remediation. However, technical integration is necessary for successful application and transfer of technology from each of the task areas. Technical integration requires that task leaders and researchers are aware of work conducted in the other technology (task) areas and that they use the information resulting from this work to strengthen their technology development. Integration will also require that the consequences of implementing the technology with respect to the whole program be considered before projects are selected and developed.

The concept of technical integration can be illustrated by example. If in situ biological methods are developed for waste sites containing biodegradable organics and heavy metals, one of the primary questions from the waste treatment perspective will be the rate of degradation in the presence of heavy metals, because heavy metals can be toxic to the microbes. This rate can be determined in the laboratory, and a biological process for in situ treatment can be conceptualized and developed. To apply this technology, however, appropriate site characterization data must be collected, an understanding of potential adverse health effects of this complex mixture must be established, and methods for in situ control and monitoring must be available. Specifically, the types of biological, chemical, and physical properties under which in situ biodegradation can be used to successfully remediate a site must be determined as part of the waste treatment development work. This information would be transferred to researchers developing site characterization technology to ensure that appropriate methods for this type of data collection are available or could be developed.

In addition, the developers of the process would investigate not only the rate of organic degradation in the presence of heavy metals, but also the effect that exocellular enzymes or intermediate reaction products might have on metal complexation and subsequent mobility. This information would then be transferred to researchers developing environmental and human health assessment technology to ensure that adverse health effects would not result from the treatment process. Finally, in situ process control would be required for application of the technology. The detection devices used for initial in situ site characterization could be adapted for this purpose. This process of information exchange and the subsequent technology development compose technology integration.

Technology integration is a process for technology development and application. The Center's organizational and operational structure will ensure that integration occurs. At the laboratory scale, integration will be achieved through information exchange. As technologies are demonstrated at an actual site or in large-scale, controlled ecosystems, the Center will identify

opportunities for jointly demonstrating site characterization, environmental and human health assessment, and waste treatment technologies.

Remedial Investigation

Remedial investigation comprises two technology areas: site characterization and environmental and human health assessment. The RD&D needs for these areas were identified after reviewing Northwest needs. More RD&D areas were identified than could be accomplished within the Center's base program funding. Therefore, in support of each objective, those goals to be accomplished within the first 5-years of the Center's operation and within the funding base have been identified. Additional funding will be sought for expansion of the RD&D program. The objectives and approaches for each of these areas will be discussed separately in the following sections.

Site Characterization

Site characterization technologies address detection, monitoring, sample collection, contaminant transport, sample scheme design, and data interpretation. Data are collected and analyzed to enable description of the distribution of hazardous substances at and around a site and to identify the mechanisms that control the movement of wastes. Consequently, the site characteristics are used to assess the hazard posed and to provide a basis for evaluating alternative remedial technologies that may be applied to the site.

Detection, Monitoring, and Characterization Data Collection. There is a significant need to improve methods used to characterize the hydrogeologic properties of the unsaturated (or vadose) zone and to monitor and detect contaminants in the unsaturated zone. The unsaturated zone is over 200 feet thick in some areas of the Pacific Northwest. Even where the unsaturated zone is thin, contaminants from waste sites may be contained within this zone. Therefore, determining contaminant distributions and fates in the unsaturated zone in soils is needed to develop more effective strategies for groundwater protection and waste site remediation.

The Center's objectives in the areas of detection, monitoring, and sample collection and analysis include developing and demonstrating methods for obtaining representative samples to determine hydrogeologic characteristics for

unsaturated soils, and developing and demonstrating methods for detecting and quantifying contaminants in unsaturated soils.

The Center will identify and evaluate concepts for collecting water and undisturbed sediment samples for laboratory analysis and for in situ analysis of water and contaminant properties. The most promising concepts will be further developed and demonstrated.

Environmental Pathways of Contaminant Transport. Well-founded and viable mathematical models of the environment play a crucial role in the site characterization process. Mathematical models are essential in forming an overall conceptual model of a site that integrates the geology, hydrology, and engineered systems. Models are commonly used to evaluate alternative management strategies (e.g., alternative remediation methods). The need to determine the consequence of a specific action or to determine the origin of a current contamination problem has led to the use of models as predictors of outcomes. Significant issues exist, however, concerning the scientific basis of models: the relationship between model parameters and field-measured parameters, spatial variability observed at the field scale that is not represented in commonly used models of the environment, and the absence of sensitivity or uncertainty factor when predicting environmental consequences.

The Center's objective is to adapt, develop, and demonstrate techniques that will address current issues concerning the movement of contaminants from hazardous waste sites in the Northwest.

The Center will identify and establish models of environmental pathways that

- have an established and clear scientific basis
- include process and reaction submodels whose parameters are measurable in the environment
- provide relevant field-scale simulations that acknowledge and incorporate spatial variability
- provide, in the case of predictions, some estimate of the solution sensitivity or uncertainty.

In addition to studies of specific environmental pathways and process or reaction submodels, the Center will actively support the development of integrated computational packages that provide an assessment of contaminant migration and fate for Northwest sites.

Sample Scheme Design and Data Interpretation. The establishment of sampling plans at a waste site is often left to professional judgment, but the field-sampling aspects of site characterization are extremely expensive and time consuming. This cost is particularly significant at large or complex Northwest sites, such as mining sites or landfills, or, as in the case of the Hanford Site, where numerous smaller sites require a large number of sample locations. Methods used to optimize sample location and minimize data requirements, such as compositing and geostatistical strategies, are needed to reduce time requirements and costs and to ensure that sample collection is complete and technically defensible.

An iterative approach to site characterization would reduce the total number of sample locations required to characterize a site. This approach involves the collection of data based on a preliminary sample scheme design followed by data interpretation and modeling. Modeling results would then be used to direct the next phase of data collection. Such an iterative approach should lead to a better understanding of the site at a lower overall cost.

Much of the site characterization information gathered initially is subjective in nature, and current statistical approaches to sample scheme design cannot use this limited but critical data. Consequently, well-defined approaches are needed for incorporating subjective information in the interpretation of site characterization data sets.

Site characterization emphasizes the determination of spatial distribution of contaminants (plume definition). The concurrent determination of the important geologic, hydrologic, geochemical, and atmospheric properties, however, is also necessary to understand the physical processes at the waste site and thus provide a basis for assessing risk and selecting a remedial action.

The Center's objective for this technology area is to develop improved sample scheme designs and methods for interpreting data to improve the cost effectiveness of sample collection activities required to monitor and characterize a site.

Formal methods for iterative sampling of waste sites will be developed to minimize the total number of samples and locations necessary to monitor and characterize a site. Emphasis will be placed on evaluating adaptive estimation and multistage estimation approaches that have been successfully applied in sampling designs for characterizing surface water.

Research will also be conducted to determine the feasibility of incorporating subjective evaluation of site characteristics into models that guide the development of an optimized sampling scheme design. Methods that use expert systems, fuzzy data set theory, and soft kriging techniques^(a) will be evaluated and tested.

Tests will identify what key data need to be obtained from collected samples before risks can be assessed or remedial techniques can be selected. This research will require close interaction with the environmental and human health assessment component of this task and the waste treatment task.

Finally, methods will be developed to use improved nonparametric statistical analyses in sample scheme designs. Incorporation of these methods will improve the quality of the sample schemes.

Demonstration Projects. A major obstacle to adapting existing and developing site characterization technologies for use in actual site investigations has been the lack of opportunity for controlled demonstration and testing. Sampling scheme design and data interpretation methods can benefit from technology demonstration projects in which controlled comparisons of these methods are possible.

The Center's objective is to provide opportunities for controlled demonstrations of innovative site characterization technologies.

(a) A family of techniques used for interpolating between spatial data or observations.

These demonstrations can best be accomplished through the development of numerical and physical models to test methods at laboratory-, intermediate-, and field-scale demonstration sites. High-resolution computer models will offer the convenience of a "numerical laboratory." In these models, many features that cannot be accounted for in traditional models are explicitly accounted for by a high-resolution synthetic data set. Sampling scheme design and data interpretation methods will be tested under controlled conditions using numerical models that approximate the spatial variability of actual field conditions.

Some of the methods and technologies to be developed in the site characterization task, especially measurement technology, can be demonstrated using laboratory- or intermediate-scale physical models. The applicability of this type of demonstration will be evaluated.

Some waste sites located on the Hanford Site would be viable candidates for remedial investigation/feasibility studies. One or two of these sites may be selected for a highly scrutinized, field-scale demonstration of site characterization techniques. A baseline data base will be developed by conducting a detailed characterization of the site using current state-of-the-art technologies and methods. Innovative or alternative technologies will be selected and compared to the baseline data base.

Additional Research Needs. In the Center's review of site characterization technologies, several additional technology needs were identified as important but were assigned a lower priority for Center RD&D at this time. These technology needs include

- remote sensing capabilities
- methods for characterizing aquifers with minimal disturbance
- detection of multiphase transport
- model validation strategies.

The Center's objective is to ensure that these additional technology needs are developed, as necessary, to address specific Northwest region and Hanford Site needs.

The Center will conduct limited RD&D on these technology needs. Methods of determining subsurface characteristics or plume distribution using either remote or minimal disturbance techniques will be catalogued according to their feasibility and potential application to hazardous waste sites in the Pacific Northwest. Potential methods of detecting multiphase transport of hazardous waste constituents in the subsurface will also be identified. The most feasible and applicable methods of remote sensing, minimal disturbance field testing, and multiphase migration detection will be the subject of research and demonstration studies. The relationship of model validation to site characterization will be developed to ensure the strategy for characterization is complete. Validation data are essential if confidence in model results is to be great enough to warrant the expenditure of resources for remediation efforts.

Environmental and Human Health Assessment

The legislation for RCRA, CERCLA, and SARA requires environmental and human health endangerment assessments that characterize the risks associated with inactive and active hazardous waste sites. These assessments play an important role in selecting and designing the appropriate remedial action and its proper implementation by establishing criteria for site cleanup. Research, development, and demonstration related to these endangerment assessment technologies can be grouped into the following fields or research areas:

- risk and damage assessment
- exposure and bioavailability assessment
- risk communication/public awareness and perception.

RD&D programs that include these areas were identified after reviewing Northwest needs for environmental and human health assessment. More RD&D areas were identified than could be accomplished within the base program funding for the Center. Therefore, in each objective, those goals to be accomplished within the first 5 years of the Center's operation and within the funding base have been identified. Additional funding will be sought for expansion of the RD&D program.

Risk and Damage Assessment. Complex mixtures of hazardous wastes were identified as a characteristic of the current NPL sites as well as the Hanford

Site. While variations exist between each subregion within the Northwest, all subregions average more than 1.5 waste categories per site (see Section 2.0). The primary wastes of concern typically found at the NPL sites, CERCLA sites, and the Hanford Site are heavy metals and chlorinated aliphatics (solvents). Chlorinated and nonchlorinated aromatics are also common at all sites except the Hanford Site.

One of the most significant problems in complex hazardous waste sites is characterizing the risk associated with a mixture of chemicals that are certain to have different forms of interaction. These interactions will influence the resulting toxicity and risks associated with the complex mixture. In the past, risk assessments have been performed assuming 1) that the total risk was equivalent to the most toxic or carcinogenic chemical present at the site, or 2) that the risk was additive over all substances present.

The Center's objective is to develop and validate methods for assessing the risk and damage to organisms from exposure to complex mixtures of contaminants typical of Northwest sites.

During the next 5 years, the Center will begin to evaluate the toxicity or carcinogenic risk from exposure to complex mixtures typical of Northwest sites. Areas of emphasis will include the following:

- developing improved techniques for evaluating the actual risks associated with exposure to complex mixtures
- evaluating surrogate species tests for determining risk to other organisms, including humans
- evaluating models used to characterize risk as well as the data used by those models.

Both short- and long-term effects of complex waste mixtures will be evaluated for a range of waste concentrations (i.e., high and low doses). Intermediate-scale physical models (i.e., controlled ecosystems or mesocosms) supplemented with "bench-top" studies will be used to determine interactive effects of specific complex waste mixtures and will help to assess the validity of extrapolating from high-dose to low-dose effects for those complex mixtures.

A potential benefit of this work will be to assess the validity of site cleanup standards in light of waste interaction effects and potential threshold effects.

Exposure and Bioavailability Assessment. The exposure of organisms to contaminants is controlled not only by the physical movement of those contaminants but also by the availability of those contaminants to the organisms (i.e., bioavailability). While bioavailability and exposure studies have been conducted in controlled laboratory settings, not enough is known about exposure scenarios in "natural" settings. The Northwest region contains a variety of hazardous waste sites contaminated with mixtures of toxic organic materials and heavy metals, and the bioavailability of these substances when contained in complex waste mixtures is not well understood. A technique for measuring biological exposure to metals as well as to toxic organics needs to be developed to assess the significance of many complex mixtures found within the Northwest. An improved understanding of organism/contaminant interactions will assist in the assessment of the hazard, and eventually will support the selection of cleanup criteria for waste sites.

The Center's objective is to adapt, develop, and demonstrate methods for determining the exposure of organisms to complex mixtures of contaminants.

During the next 5 years, the Center will use intermediate-scale physical models (controlled ecosystems or mesocosms) to evaluate the bioavailability of selected mixtures of chemical contaminants common to Northwest hazardous waste sites. In these evaluations, the availability of the chemical contaminants to various levels of an ecosystem will be estimated with testing procedures such as

- exposure markers for individual substances (e.g., pophyrin production patterns, protein, hemoglobin and DNA adducts, body fluid contamination, enzyme induction) that provide proxies for true dose
- effects measurement techniques (e.g., histology, bioassays)
- surrogate bioassays for application to human systems
- exposure markers for complex mixtures of chemicals.

Risk Communication and Social Perception. In conducting the RI/FS process and site remediation activities, risk information must be communicated among site managers, regulatory agencies, and the public. Risk information describes the nature and extent of a particular hazard, and what can be done to alleviate or eliminate the hazard. Many individuals, organizations, and agencies will be involved in, or affected by, both the assessment and remediation processes and thus need to understand the relevant risk information. Remediation technologies, both existing and new, will have little value, however, if they cannot be applied because of conflicts over their social or economic acceptability. Difficulties in communicating risk information have been experienced in the Northwest region and throughout the nation, such that the public, site managers, and government organizations have identified a need to improve risk communication on hazardous waste issues.

The Center's objective is to evaluate, develop, and demonstrate effective methods for communicating risk information.

The Center's research in this area will evaluate different modes of communicating risk to the public. Research questions will focus on understanding what information needs to be communicated and how the necessary information should be communicated. Appropriate research questions include

- How are perceptions of a site and associated cleanup activities linked to methods used to communicate risk information about the hazard and proposed remediation technologies?
- What kinds of risks are of greatest concern to the public-- environmental, human health, or economic?
- Is better information needed concerning the environmental and health risks posed by the hazardous substances and sites or how the sites and its risks are being managed?

During the next 5 years, at least one project will be initiated to help provide guidelines for communicating risk information about new treatment technologies that emerge from the Center's RD&D activities.

Waste Treatment

Waste treatment technologies can be used to destroy, stabilize, separate, or isolate hazardous substances associated with hazardous or radioactive mixed-waste sites and the adjacent offsite environment. Destruction using biological, chemical, or thermal processes can convert hazardous materials to nonhazardous materials. Stabilization using chemical or thermal processes can incorporate or fix hazardous chemicals in waste form matrices that significantly reduce the rate at which chemicals are released to the environment. Biological, chemical, physical, and thermal processes or some combination of these processes can be used to separate hazardous from nonhazardous compounds or media. After separation, the hazardous wastes can then be destroyed, stabilized, or recycled. Isolation using chemical or physical barriers can prevent or reduce the rate of migration of hazardous materials from the waste source to the surrounding environment. Isolation, which reduces the rate of contaminant migration, can be used in concert with in situ destruction technologies that may have reaction rates too slow to be effective without the reduced migration rates.

Waste treatment technologies can be further divided into two types of applications: 1) those that treat wastes after retrieving them or 2) those that treat wastes in situ. In situ treatment can reduce the risk of exposing the public and the environment to hazardous or radioactive chemicals dispersed during removal of wastes from the site. SARA requires that in situ treatment processes be considered for remediating hazardous waste disposal sites.

Within the Northwest, hazardous substances found in wastes at NPL and CERCLA sites are heavy metals (including radionuclides), nonchlorinated aromatics, chlorinated aliphatics, chlorinated aromatics, and pesticides, in descending order of frequency. Hazardous substances found less frequently include toxic anions, cyanides, nonchlorinated aliphatics, and substances associated with munitions. At the Hanford Site, inactive waste sites often contain heavy metals including radionuclides, toxic anions usually originating as inorganic acids, chlorinated and nonchlorinated aliphatics, and cyanides. Most of the Northwest waste sites are complex, containing more than one type of chemical waste existing in more than one physical state and in more than one waste zone.

The hazardous waste is likely to be located in the unsaturated (or vadose) zone in the soil column and in the groundwater as a result of past disposal practices. These general features of the Northwest sites influence the type of waste treatment technology required for remediation. The Center's RD&D program will reflect these needs.

For example, technology development is needed for separating, stabilizing, or isolating heavy metals from soils in the vadose zone, both near and deep subsurface, and from groundwater and surface waters. Current practice for the cleanup of Superfund sites contaminated with heavy metals has relied heavily on removal and subsequent isolation of wastes found in the soil column. Increasing emphasis is being placed on more permanent solutions for site cleanup, especially in situ remediation techniques. Therefore, the Center's RD&D program in waste treatment technology will emphasize innovative methods for separating heavy metals from soils in the vadose zone and from groundwater and surface waters to reduce the volume of waste or, where economically feasible, to recover the metals. Innovative methods for stabilizing and isolating heavy metals will also be developed.

Similarly, technology development is needed for destroying, separating, stabilizing, or isolating the various classes of organic and some inorganic wastes such as toxic anions found in the vadose zone or groundwater. Techniques for treating these types of wastes in the waste zone are also needed. Emphasis will be placed on converting these types of wastes to innocuous products (i.e., destruction). Separation technologies to improve waste removal or to concentrate the organic component as a pretreatment for destruction or recovery will also be developed. To a lesser extent, the Center will support development of innovative stabilization and isolation technologies.

Finally, the Center will support those activities needed to successfully transfer waste treatment technology to the end users. To facilitate this transfer, the Center will emphasize the need to address the complexity of the sites and to communicate results of the RD&D program in a manner accessible to the end user. For example, when transferring technology developed through the Center's RD&D program or other programs throughout the country, an effort will be made to answer the following questions:

- Can these technologies be used in combination to address the problems at Northwest waste sites?
- Has appropriate consideration been given to the need for pre- and post-treatment?
- Are interactions of the waste and waste matrix as they affect performance of the remediation technique known or understood?
- Have the effects of secondary chemical and physical factors (i.e., corrosion or fouling of equipment) on the treatment process been considered?
- Is there a screening parameter that can be readily determined during site characterization which can be correlated to efficiency of a treatment technology? This correlation could facilitate selection of alternative treatment technologies.
- Is proper guidance on the type of site characterization data required to ensure that adequate information will be available for evaluating alternative treatment technology?

To facilitate technology transfer, activities such as the development of an expert system for selecting alternative treatment technologies based on waste type will be supported. In addition, communication techniques developed in the human health and environmental assessment task will be used to transfer results of waste treatment technology development to the end user.

Based on these needs, five RD&D areas have been identified for waste treatment technology:

1. destruction of organic and some inorganic compounds
2. separation of hazardous constituents from nonhazardous constituents in waste
3. stabilization of hazardous waste
4. isolation technologies
5. application of waste treatment technologies.

These RD&D areas are sufficiently broad to encompass a variety of waste treatment technology development activities that are consistent with the Center's goals, Northwest needs, and SARA legislation. More activities are identified than can be accomplished with the base funding for the Center. Therefore, for each objective, those goals to be accomplished within the first 5 years of the Center's operation and within base funding have been identified. The Center will seek additional funds from grants, cofunding, etc. to expand its RD&D program. Specific projects in each of these areas will be selected annually based on the criteria presented in Section 4.2.2. Criteria include need, innovativeness, feasibility, cost effectiveness, and acceptability.

Destruction of Organic and Some Inorganic Compounds

The need exists to advance, adapt, or develop innovative technologies to destroy organic and some inorganic hazardous chemicals found at waste sites in the Northwest.

The Center's objective is to adapt, develop, and demonstrate technologies that destroy nonchlorinated aromatics, chlorinated aliphatics, chlorinated aromatics, nonchlorinated aliphatics, pesticides, and toxic anions.

These classes of compounds are found in the vadose zone and groundwater at many Northwest sites. The goal is to demonstrate destruction processes for at least one class of organic compounds and one type of toxic anion within the first 5 years of Center operation. In addition, adaptation or development of other destruction processes will be conducted at various levels of development for demonstration beyond the first 5 years.

The Center's research approach will include certain activities under each of the following three destruction technologies:

- Biological Destruction

- Identify and evaluate microbes that destroy targeted organic and inorganic compound(s) in a specific medium.

- Alter the microbes through stress, mutation, or genetic engineering as needed based on conditions that enhance and inhibit microbial growth and metabolic rate for a specific site.
- Chemical Destruction
 - Identify and evaluate chemical or electrochemical techniques to destroy target compound(s). This step includes identifying catalysts that may enhance the process.
- Thermal Destruction
 - Adapt and develop innovative thermal technologies that destroy target compound(s) efficiently while reducing the generation of secondary toxic effluents.
 - Develop methods for monitoring off gases resulting from the thermal process and the effects on the surrounding environment (may be developed in conjunction with remedial investigation technology development)
 - Develop methods for stabilizing residual solids after processing (i.e., determine the need for both pre- and post-treatment).

Separation of Hazardous Constituents from Nonhazardous Constituents in Waste

The need exists to advance, adapt, or develop innovative separation methods that can be used in pre- or post-treatment steps for destroying, stabilizing, or reclaiming hazardous chemicals from the waste media.

The Center's objective is to adapt, develop, and demonstrate innovative separations methods to reduce the volume, quantity, and toxicity of waste by separating hazardous from nonhazardous components and/or to separate hazardous materials in the hazardous components to improve efficiency and effectiveness of final waste treatment.

The goal for the first 5 years of Center operation will be to demonstrate at least one innovative technology for separating heavy metals. In addition, adaptation or development of other technologies for separating heavy metals or

organic or inorganic compounds will be pursued at various levels of development for demonstration beyond the first 5 years of Center operation. The Center's research approach in this area will

- Identify and evaluate bioaccumulators, either microbes or vegetation, for separation and/or concentration of heavy metals or radionuclides from soils, groundwater, or surface water.
- Identify and evaluate innovative uses of chemicals that enhance the separation, concentration, and/or recovery of hazardous constituents from contaminated media or from other hazardous or nonhazardous chemicals.
- Identify and evaluate innovative uses of physical technologies to separate hazardous waste from the media or from other hazardous or nonhazardous chemicals.
- Identify and evaluate innovative applications of thermal technology to drive hazardous wastes from contaminated media or separate individual hazardous constituents in a waste stream.

Stabilization of Hazardous Waste

The need exists for advancing or developing innovative technologies for stabilizing hazardous chemicals that cannot be destroyed into a waste matrix for permanent remediation.

The Center's objective is to adapt, develop, and demonstrate stabilization methods that will fix heavy metals, organics, or other inorganic compounds.

The goal for the first 5 years of Center operation is to adapt or develop innovative methods for stabilizing heavy metals such as radionuclides (i.e., transuranics, fission products, and uranium) and residual organics that are frequently found in disposal mixtures on the Hanford Site, or metals such as Pb, As, Cr, Cu, Cd, Hg, Be, or Zn, that may be found in mixtures in the vadose zone or in groundwater from metal finishing or mining, milling, smelting, and refining sites. The Center's research approach in this area will

- Identify and evaluate innovative uses of chemical stabilizers to fix hazardous wastes in at-grade or in situ processes.

- Identify and evaluate uses of thermal processes to fix hazardous wastes in at-grade or in situ processes.

Isolation Technologies

The need exists for continued improvement of isolation technologies used at complex sites that are not amenable to alternative remediation technologies.

The Center's objective for this RD&D area will be to support ongoing efforts to improve or develop isolation techniques that can be applied to milling, smelting, and refining sites and landfills in the Northwest as well as to radioactive mixed-waste sites at the Hanford Site.

The goals for the next 5 years of Center operation will be to support at least one activity in this area. The Center's research approach in this area will

- Identify and evaluate improved barrier materials and designs.
- Develop and demonstrate improved methods for screening barrier materials for compatibility with chemical and physical conditions at Northwest waste sites other than the Hanford Site. (An ongoing DOE program is addressing the materials compatibility for Hanford Site conditions.)
- Develop and demonstrate improved methods for evaluating barrier design with respect to long-term performance.
- Develop and demonstrate improved methods for emplacement of barriers.

Application of Waste Treatment Technologies

The need exists to improve methods for technology transfer from RD&D programs to the end user for application at Northwest waste sites.

The Center's objective is to improve the application and transfer of RD&D results by integrating waste treatment technologies with site characterization and risk assessment methods, and by developing methods or technologies that address scale-up issues associated with the complexity of an actual waste site versus the laboratory environment.

The goal for the first 5 years of Center operation is to support activities in each of the areas identified below. The Center's research approach in this area will be to

- Develop a computer tool with decision analysis features for use by site managers to screen treatment technologies. The site manager will be able to use the system to evaluate alternative technologies using preliminary data available from initial hazard ranking activities. The information will help the site manager guide site characterization activities to ensure that adequate data are collected for full appraisal of alternative technologies. The evaluation of alternative technologies can then be further refined as additional site data become available from remedial investigations.
- Identify site characterization data requirements for waste treatment in conjunction with data required for risk assessment to ensure adequate information is available for full evaluation of all treatment options. This activity would also include development of data requirements for determining the potential for in situ treatment.
- Identify indicators (or screening parameters) analogous to biological oxygen demand (BOD) that could be quickly and easily detected during site characterization and could be correlated to treatment technology efficiency, facilitating identification of appropriate treatment processes.
- Explore the potential for using technologies in concert or for using appropriate sequences of unit processes such as pre- and post-treatment for cleanup of complex sites.
- Determine the synergistic or antagonistic effects of the waste and waste matrices or the potential for interference of secondary chemical and physical factors on the treatment process.
- Develop tools for in situ application of waste treatments that monitor nutrient or chemical flow, microbial growth, production of intermediate products, and the presence of wastes in the final product to ensure complete conversion of wastes (may be developed in conjunction

with remedial investigation technology development). Also, the Center researchers will develop engineering systems for injection and withdrawal of chemicals or microbes to ensure distribution throughout the treatment zone.

- Determine the secondary effects of chemicals used to treat wastes, intermediate products, and secondary waste effluents on environmental and human health (in conjunction with remedial investigation technology development). This step is particularly important for in situ applications.
- Demonstrate the technology in a mesocosm or at an actual site, in conjunction with the demonstration of techniques developed in the remedial investigation technology task, if possible, to facilitate technology transfer.

2.4 PROJECT EVALUATION AND SELECTION PROCESS

Establishment of the Center's RD&D program includes an annual process of evaluating the progress of existing projects and assessing new projects and their potential for meeting Center objectives and addressing Northwest technology needs.

Both long- and short-term RD&D activities will be conducted in support of technologies to characterize, assess, and remediate Northwest sites. Where possible, such technologies will be adapted from the existing technology base; new, innovative technologies will be developed when adaptation is not feasible. The Center's program will therefore comprise a mixture of research, development, and demonstration at laboratory, bench, pilot, and field scales. Such a mixture allows the Center to have an integrated and continuous program in which technologies are developed and transferred to field applications. In addition to developing and transferring these technologies, the Center recognizes the importance of also providing the necessary information that will facilitate the proper decisions concerning the application of these technologies. These decisions can be supported by the design of more efficient sampling strategies, methods for comparing the risk present at various waste sites, and methods for selecting and implementing waste treatment technologies.

The Center uses two sets of criteria for evaluating and selecting projects: technical and strategic criteria. The technical criteria include need, acceptability, feasibility, cost effectiveness, and innovativeness and are defined in Table 2.3. These criteria are used to determine the potential of a project for successfully addressing Northwest needs and to evaluate the relative merits of candidate projects within each of the technology areas. The technology areas are Remedial Investigation, which includes site characterization and environmental and human health assessment technologies, and Waste Treatment. Once the preferred projects within each area are evaluated, the overall mix or portfolio of projects to be conducted is selected based on the following set of strategic criteria:

- A balance of technology development projects in Remedial Investigation (site characterization, environmental and human health assessment) and Waste Treatment will be maintained. Waste treatment

TABLE 2.3. Technical Evaluation Criteria

Technical Criteria (Considerations in selecting priorities within each of the technology areas, the appropriate criteria, or the way in which the criteria are interpreted, may vary slightly across technology areas.)

1. Need/Risk - The technology could be applied to Northwest and/or Hanford sites that may pose risks to human health and the environment.
 2. Acceptability - The approach is consistent with SARA legislation (e.g., emphasis on destruction), and DOE and EPA guidance within the region, and it shows promise for being favorably accepted by the public.
 3. Technical Feasibility - The technology or approach shows promise for field demonstration, transfer to the private sector, or commercialization within a reasonable time frame (less than 5 years).
 4. Cost Effectiveness - The technology has the potential for improved cost effectiveness relative to current technologies. Opportunities are available for cofunding.
 5. Innovation - The technology or approach is not presently being addressed within other RD&D programs. The approach complements work being done by other organizations. The approach adapts existing technology to regional needs.
-

technologies will be emphasized because SARA has placed an emphasis on remediation technologies that provide permanent solutions.

- A mix of projects at various levels of development (i.e., from laboratory-scale to field demonstrations) will be maintained to ensure continuing technology transfer and development of a long-term technology base.
- Projects selected will complement one another and will constitute an integrated program of technology development. (An integrated program is defined as one in which technologies within the three technical areas are developed in concert or with a knowledge of the technical needs of the other technical areas. This will improve the overall approach to site remediation. For further discussion, see Section 3.3.)
- Ongoing RD&D programs at PNL, the Hanford Site, other federal facilities, private industry, and elsewhere will be considered during project selection to take advantage of this technology base without duplicating effort.
- Projects selected will have national applicability in addition to their Northwest and Hanford Site focus.

The Center seeks to involve federal, state, and local government agencies, universities, and private Northwest contractors and industries to carry out its RD&D program. At any one time, the types of projects will range from basic research to full-scale demonstrations (Figure 2.8) and will involve PNL, Northwest universities, and private industry in the conduct of the Center's projects. University participation is expected to be greatest in the basic research and proof-of-principle stages. Cost sharing will be used to supplement Center funding, especially in the pilot and demonstration projects. Involvement of the private sector will be greatest for projects at the pilot or demonstration stage of development. This involvement will ensure that technology developed by the Center is directly applicable to end-user needs and will increase the impact of the Center's program and facilitate technology transfer.

FIGURE 2.8. Resource Allocation by Stage of Technology Development and RD&D Participation

FY88 OPERATING PLAN

3.0 FY88 OPERATING PLAN

The Northwest Hazardous Waste RD&D Center will conduct RD&D projects in support of the goals and objectives defined in Section 2.0 of this Program Plan. The operating plan for the Center is based on an anticipated annual baseline budget of \$2 million: one-half to be provided by DOE and the other half to be provided by EPA. In addition, the Center will seek cost sharing from other government agencies and private industry to expand the scope of existing projects (e.g., conduct full-scale demonstrations) or to add new projects. This section describes the priority projects to be funded by the Center and an initial set of contingency projects to be considered for funding if more funds are made available to the Center. An ongoing project selection and review process will be used to identify new projects and to further evaluate existing projects.

3.1 OVERVIEW/SUMMARY

The evaluation process described in the previous section defines the criteria used in evaluating, selecting, and setting priorities for projects in each of the technology RD&D areas (i.e., remedial investigation technologies and waste treatment technologies). The selected projects are listed in Table 3.1. Several projects were also identified within the Program Planning and Support task. Within each technology area, the projects are listed from highest priority to lowest. For each project, Table 3.1 indicates the anticipated budget level for FY88, the primary focus for the work (i.e., Hanford Site versus other Northwest sites), whether university participation is expected, and the projected startup schedule. The FY88 budget level is indicated in two columns: the first number represents each project budget assuming only DOE funding, and the second number indicates the budget allocation with EPA funding. The primary focus, Hanford versus Northwest, indicates the present emphasis of each project. Many projects have direct applicability to both Hanford Site issues and other Northwest site issues. A few, however, focus primarily on one set of issues or the other. Participating universities include those with which contracts have been established: University of

TABLE 3.1. FY88 Priority Projects, Budgets^(a) and Schedules^(b)

TASK OR PROJECT	FY88 \$s DOE, EPA	PRIMARY FOCUS	UNIVERSITY PARTICIPATION	FY88 SCHEDULE											
				-OCT-	-NOV-	-DEC-	-JAN-	-FEB-	-MAR-	-APR-	-MAY-	-JUN-	-JUL-	-AUG-	-SEP-
				KEY: ☐ NEW STARTS PENDING EPA FUNDING											
				☐ ONGOING PROJECTS											
REMEDIAL INVESTIGATION TECHNOLOGY PROJECTS															
Site Characterization															
Improved Methods for Sample Scheme Design and Interpretation of Site Characterization Data (ongoing/new)	15, 230	BOTH	YES	☐											
Improved Methods for Collecting Field Samples (new)	0, 110	BOTH	YES	☐											
Characterization of Complex Waste Mixture Composition (new)	0, 40	BOTH	YES	☐											
Subtotal	15, 380														
Environmental and Human Health Assessment															
Risk Assessment for Complex Mixtures of Hazardous Wastes (new)	0, 50	BOTH	YES	☐											
Evaluation of Complex Mixture Exposure Markers (new)	0, 60	NW	YES	☐											
Demonstration of a Method to Evaluate Capping Concepts for Sediments Disposed of in Aquatic Systems (new)	0, 80	NW		☐											
Subtotal	0, 190														
WASTE TREATMENT TECHNOLOGY PROJECTS															
Catalytic Destruction of Hazardous Organics in Aqueous Solutions (ongoing)	150, 30	BOTH		☐											
Biodegradation of Aqueous Hazardous Waste Containing both Organics and Nitrates (ongoing)	100, 35	HMF		☐											
Concurrent Removal of Heavy Metals and Organics from Groundwater or Surface Water (new)	25, 25	BOTH	YES	☐											

(a) Separate project budgets are given for DOE funds ("DOE" column) and EPA funds ("EPA" column).

(b) February project starts are predicated upon receiving EPA funding in January 1988.

TABLE 3.1. (contd)

TASK OR PROJECT	FY88 \$s DOE, EPA	PRIMARY FOCUS	UNIVERSITY PARTICIPATION	FY88 SCHEDULE											
				-OCT-	-NOV-	-DEC-	-JAN-	-FEB-	-MAR-	-APR-	-MAY-	-JUN-	-JUL-	-AUG-	-SEP-
WASTE TREATMENT TECHNOLOGY PROJECTS															
Pilot-Scale Testing of In Situ Vitrification of PCB-Contaminated Soils (ongoing)	116, 0	BOTH													
In Situ Biodecontamination of Hazardous and Radioactive Mixed-Waste Sites (ongoing)	6, 55	HANF	YES												
Electrochemical Oxidation of Organic Wastes (ongoing)	100, 0	BOTH													
Chemical/Physical Destruction of Chlorinated Organic Wastes (new)	0, 50	BOTH	YES												
Optimal Pumping and Siting of Wells in Contaminated Aquifers (ongoing)	80, 0	BOTH													
Subtotal	576, 195														
PROGRAM PLANNING AND SUPPORT PROJECTS															
Technology Needs Documents (ongoing)	30, 0	BOTH													
Annual Northwest Conference on Hazardous Waste Technology (new)	0, 50	BOTH													
Data base of Northwest Hazardous Waste Site Characteristics (ongoing)	30, 0	BOTH	YES												
Microcomputer System for Selecting Appropriate Remediation Technologies Based on Site Characteristics (new)	0, 50	BOTH	YES												
Subtotal	60, 100														
PROGRAM MANAGEMENT (Technical R&D Management, Administration, Liaison Activities, Preparation of Planning Documents, and Technical Communications)	349, 135														
TOTAL	1000, 1600														

Washington, Washington State University, University of Idaho, University of Montana, and the Oregon Graduate Center. Based on these contracts and initial expressions of interest, the Center anticipates that about one-third of the Center's RD&D funds will support university RD&D in FY88, if the full base funding is received.

The exact timing for initiating new projects will depend on the availability of EPA funds for the Center. The schedule shown in Table 3.1 assumes that those funds will be available in time to allow new projects to start by February 1988. Until these funds are available, existing projects will be continued to the extent allowed by DOE funding. Funds from EPA will enhance the support for ongoing projects and will be used to initiate new projects as shown in Table 3.1.

The linkage between the RD&D objectives outlined in Section 2.0 and the proposed RD&D projects within the two technology areas [i.e., Remedial Investigation (including both site characterization and environmental and human health assessment) and Waste Treatment] is demonstrated in Figure 3.1. The proposed mix of projects addresses most of the Center's objectives. Those objectives not addressed relate primarily to the conduct of demonstration-scale projects and to the communication of results from technology and risk assessments. These objectives will be addressed in the future as the RD&D program matures, as more results become available, and as demonstration projects are conducted.

Project summaries for each of the selected projects are provided in the following sections. Each project description includes the scope of the project, its rationale, anticipated budget for FY88 and beyond, and major milestones or deliverables for the project. Funding to the Center will determine actual project initiation and milestones.

3.2 REMEDIAL INVESTIGATION TECHNOLOGY PROJECTS

Remedial investigation (RI) technologies are needed to characterize and assess hazardous and radioactive mixed-waste sites. The RI projects include two related technology areas: site characterization and environmental and human health assessment.

FIGURE 3.1. Linkage Between Proposed FY88 Projects and Center Multiyear Objectives

Site Characterization

The objective of site characterization is to determine the distribution and movement of contaminants at a waste site. Site characterization technology provides information with which to assess the risk of a hazardous waste site, select and design a remedial action, and verify the effectiveness of the remedial action.

As determined in an assessment of site characterization technology needs for Hanford and the Northwest (summarized in Section 2.3), the primary issues or gaps related to this technology area are described as follows:

- An integrated approach to sample scheme design, data interpretation, and numerical modeling is needed instead of the current linear approach. A better approach to site characterization would be cyclic, which implies that data collection is based on a preliminary sample scheme design, data interpretation, and numerical modeling. The results of the numerical modeling would be used to indicate the next step in data collection based on a modified sample scheme design. This iterative process would lead to a better understanding of the system and in turn improved predictions, as well as provide for more cost-effective data collection. The current approach is linear in nature and may not produce the required information for characterizing a hazardous waste site. The integrated approach will also provide insight into determining how much characterization is enough.
- Because the bulk of contamination from inactive waste sites on the Hanford Site is still in the thick soil column, the key technology gap for Hanford inactive waste sites is monitoring, sampling, and detection in the unsaturated zone. Methods do not currently exist for detecting contaminants, obtaining representative samples, or monitoring the movement of contaminants in the unsaturated zone.
- The current state of practice for site characterization emphasizes determination of spatial distribution of contaminants only. Quantification of important geologic, hydrologic, surface water,

atmospheric, and geochemical properties is also necessary to understand the physical processes at the waste site and to assess risk and possible remediation.

- Current methods of sample analysis are expensive, time consuming, and often inaccurate because large numbers of chemicals that may be present at sites are not measured with current methods. Cost-effective and efficient methods for evaluating the relevant characteristics of complex chemical mixtures are needed.
- The need exists for demonstration projects (i.e., field sites, physical laboratory models, and numerical models using synthetic data) for testing and demonstrating sample scheme design and data interpretation methods.

The following three site characterization projects proposed for FY88 address these issues and are consistent with the multiyear RD&D objectives listed in Section 2.3.

Project Title: Improved Methods for Sample Scheme Design and Interpretation of Site Characterization Data

Rationale

Present methods for obtaining and interpreting site characterization data are not always adequate for determining the nature and extent of contamination at waste sites. Present methods are costly and time consuming, and the data that are obtained are often insufficient for purposes of assessing risk, designing an appropriate remedial action, or setting cleanup criteria. There are several problems or issues that have arisen in site characterization activities conducted to date in the Northwest and at the Hanford Site. For example, current practices for developing sample collection schemes do not adequately consider information gained from initial sampling activities. Also, the design of sampling plans for waste sites is often left to professional judgment alone. These practices often result in use of grid sampling systems that may not adequately define chemical heterogeneities. Consequently, additional field sampling may be required that is extremely expensive and time consuming. Moreover, the data obtained from sampling activities form the basis for setting cleanup criteria and designing appropriate remedial actions. The cost of these actions is particularly significant at large or complex Northwest sites, such as mining sites or landfills, or, as in the case of the Hanford Site, where numerous smaller sites require a large number of sample locations.

Methods for optimizing sample location and minimizing data requirements are needed to reduce the cost and duration and to ensure that sample collection is complete and technically defensible.

Specific issues that need to be addressed include

- How can monitoring well networks be designed to provide the information needed not only for characterization but also for design of the remedial action and verification of the action?
- How can site characterization data be integrated with predictive transport models to provide a more complete basis for assessing a site and designing an appropriate remedial action?

- How can sample collection activities be made more cost-effective to enable iterative revision of sampling based upon information received from prior samples?
- How can best use be made of available site characterization data including expert judgments and subjective assessments of the site to interpret the present extent of contamination?
- How can the availability and usability of site assessment and modeling tools be improved?

Description/Scope

The intent of this project is to advance the state of the art of site characterization methods to make current practice more cost-effective and to improve the quality and utility of the data that are generated. The specific scope of these activities addresses the design and implementation of sampling strategies and methods used to interpret site characterization data (including predictive models of waste transport). This set of activities does not deal with the technology (hardware) of sample collection, but rather focuses on providing the software to support sample scheme design and model development required during site characterization. This project will strive to make state-of-the-art site characterization methods available to site managers and regulators. The primary direction of the work will be the adaptation and transfer of statistical modeling and analysis methods applicable to site characterization. Specific methods will be tested and demonstrated in conjunction with site characterization activities at the Hanford Site and other hazardous waste sites in the Northwest. Special emphasis will be placed on ensuring that methods are packaged in a manner that facilitates their use in the field.

In FY88, the structure and specifications for a microcomputer system that provides an integrated approach to site characterization will be developed. This system will eventually include the software necessary to perform site performance assessments and will provide the operational framework for transferring the results of other work conducted in this project.

In FY88, four activities will be emphasized:

1. Iterative Optimization Approaches to Monitoring Well Network Design-- This activity will compare the relative merits of alternative methods for using data from prior samples to modify subsequent sample collection activities.
2. Use of Subjective Information for Site Characterization. This activity will adapt existing statistical and data analysis methods to enable incorporation of subjective information on hazardous waste sites into the overall site characterization and assessment.
3. Methods for Statistical Analysis of Site Characterization Data. This activity will examine statistical methods for analyzing site characterization data to obtain a more accurate representation of the nature and extent of contamination at hazardous waste sites.
4. Microcomputer System to Evaluate Groundwater Contamination. This activity will initiate development of a microcomputer system that will integrate site characterization and modeling tools into a single package. This will integrate the results of the other activities within this project as well as state-of-the-art techniques developed under other projects. The intent is to provide site operators and regulators with an integrated performance assessment package.

The techniques developed under this task will be demonstrated on a site characterization demonstration waste site being established at Hanford under DOE Environmental Restoration funding.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY88

- Develop initial iterative optimization approach to monitoring well network design.
- Prepare technical progress letter report.

- Finalize and issue report on FY87 work on statistical sampling schemes ("Field Sampling Designs Based on Bayes Strategies and Sample Compositing Schemes for Cost-Effective Detection of Hazardous Waste").
- Develop specifications for microcomputer system for review.

FY89

- Demonstrate iterative optimization approach and enhanced statistics on the Hanford demonstration waste site.
- Develop and test microcomputer system.
- Issue status report on methodology to incorporate subjective information into statistical analyses.

FY90

- Finalize methodology on subjective information, issue report, and incorporate into microcomputer system.
- Issue final documentation and conduct training on microcomputer system.

Schedule/Cost

FY88/\$245K, FY89/\$230K, FY90/\$250K

Participants

PNL, Universities

Project Title: Improved Methods for Collecting Field Samples

Rationale

Representative samples of soils and groundwaters are required to define the extent of contamination and hydrogeologic properties of the waste site that influence the movement of these contaminants and thus the effectiveness of remediation techniques. Present methods for obtaining these samples are often neither cost-effective nor adequate for quantifying important site characterization parameters.

Cost-effective methods for collecting samples of soils, rocks, and sediments (geologic samples) in a manner that preserves the physical structure of the samples do not exist. This type of sample is important, however, because it is the physical structure of samples that influences the movement of contaminants in the subsurface environment. Another important need for sample collection technology lies in the area of groundwater sampling devices. Water chemistry data obtained from samples collected from monitoring wells should represent actual concentrations in the aquifers. Although proven groundwater sampling devices exist for most wastes and waste-site environments, there is a specific need to determine the ability of these devices to provide representative samples from groundwater contaminated with metals in acidic mine wastes.

Specific issues that need to be addressed are

- What are the best methods for collecting representative geologic samples at waste sites located at the Hanford Site and in the Northwest?
- Do existing groundwater sampling devices provide representative samples for aquifers contaminated with heavy metals and acid mine wastes?

Description/Scope

The intent of this project is to improve methods for collecting samples from waste sites. This set of activities deals with the testing and development of hardware and field procedures. The work will focus on adapting and testing existing sampling capabilities. The devices will be tested and evaluated on demonstration waste sites at Hanford.

Two activities will be emphasized in FY88:

1. Methods to Collect Undisturbed Geologic Samples--This activity will evaluate, compare, and enhance, as necessary, several existing drilling and sampling technologies for collecting undisturbed samples, including extensions of existing and advanced technologies.
2. Evaluation of New Groundwater Sampling Technologies--This activity will determine the capability of existing groundwater sampling devices to obtain representative samples of groundwater contaminated by heavy metals in acid mine waste sites.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY88

- Publish report on results of tests of groundwater sampling devices to obtain representative groundwater samples of mine wastes.
- Develop test plan for testing sampling methods of geologic media.

FY89

- Evaluate geologic sampling methods for Hanford environments (technical progress letter report).

FY90

- Evaluate geologic sampling methods for other Northwest environments (technical progress letter report).

FY91

- Publish final report in the form of handbook.

Schedule/Cost

FY88/\$110K, FY89/\$100K, FY90/\$100K, FY91/\$40K

Participants

Universities, PNL

Project Title: Characterization of Complex Waste Mixtures

Rationale

Complex mixtures of hazardous materials are a dominant feature of Northwest CERCLA and Hanford hazardous and radioactive mixed-waste sites. Present chemical analytical procedures are expensive (\$2,000 to \$5,000 per sample) and time consuming (weeks to months), provide minimal chemical identification (200 out of 10,000 potential chemical compounds), and do not account for interactions among individual components within the mixture. A potentially more cost-effective method of analyzing complex mixture composition is quantitative Fourier transform infra-red (FTIR) spectroscopy, which is relatively inexpensive (\$40-50 per sample), provides rapid analysis (minutes to hours), and examines the extracted sample as a total mixture rather than as individual components.

Description/Scope

FTIR is a promising combination of instrumentation and computer analysis that allows identification of complex chemical mixtures. It has been used to determine the purity of chemicals during their manufacture, to identify various sources of oily materials in the marine environment, and to characterize oils from different places in the world (McClure 1987; Word et al. 1987a,b). This method has not yet been used as a tool for characterizing complex chemical mixtures at hazardous waste sites. The Fourier transform capability of the computer portion of the apparatus allows a numerical description of the curves associated with the different chemicals within a sample. This characterization of the chemical "signature" allows identification of different sources of contamination. The objective of this project will be to use FTIR spectroscopy to characterize samples composed of a wide variety of chemical mixtures from hazardous waste sites throughout the Northwest. This project will use an FTIR apparatus that is currently available either at PNL or at a Northwest university to determine the composition of hazardous waste mixtures. In addition, complex mixtures of hazardous organic wastes (e.g., creosote, fuel oils, organic solvents) will be exposed to water and soils or sediments for a period of weeks to determine whether that exposure will modify the FTIR "signature." In subsequent years, a portable FTIR instrument may be tested to determine if

the instrument can be used to provide measurements for in situ applications. This would allow rapid, cost-effective, real-time characterization of a hazardous waste site.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY88

- Evaluate the effectiveness of FTIR spectroscopy for characterizing different types of complex mixtures found in the Northwest and at the Hanford Site.
- Prepare technical progress letter report.

Schedule/Cost

FY88/\$40K, FY89/\$100K

Participants

PNL, University

Environmental and Human Health Assessment

Environmental and human health assessment technology includes the development and evaluation of tools and methodologies for determining potential risk to public health and natural resources resulting from uncontrolled releases of hazardous contaminants to the environment. This technology area comprises the following components: assessment of the availability of the hazardous material and the degree of its exposure to organisms, assessment of the degree of risk and level of damage associated with the exposure, and determination of the best ways to characterize and communicate that risk to the public so they are cognizant of the true risks associated with uncontrolled release of specific quantities and types of hazardous materials at each site.

State-of-the-art assessment technologies were identified during FY87 as part of the Center's long-range planning activities. Based on this study, technology gaps that could be filled by the Center's RD&D program were identified and included in the multiyear RD&D objective discussed in Section 2.3. Such gaps were identified for each of three technical areas: 1) availability and exposure, 2) risk and damage, and 3) risk communication and social perception. For FY88, projects were selected that are consistent with the stated RD&D areas and 5-year objectives.

The projects described in this section address the issues of measuring versus predicting risks posed to the public and the environment by uncontrolled releases of complex mixtures of hazardous materials. Current methodologies provide inadequate evaluations of the risks associated with complex mixtures because they assume that there is no interaction among the individual chemicals and that the chemicals measured (as many as 250) are the only ones of the tens of thousands of chemicals that occur in these mixtures that we need to be concerned with.

The topic of risk associated with complex mixtures was selected for study based on 1) an evaluation of the characteristics and features of the inactive hazardous and radioactive mixed-waste sites in the Northwest, where it was found that these sites contain an average of 1.74 broad classes of chemicals, while the Hanford waste sites contain an average of 1.9 classes of chemicals (see Section 2.2 for further discussion) and 2) because the state-of-the-art

review in environmental and human health assessment showed that the largest gap to understanding risk at hazardous waste sites was understanding the interactions of complex mixtures of hazardous chemicals.

Complex mixtures pose specific problems for regulators and site managers. First, current risk models rely on determining the total risk of a complex mixture by simply adding the risks associated with each of the measured contaminants in a sample. Therefore, well-characterized samples that contain many more compounds are always found to have higher risks than those that are not as well characterized. To determine the actual risks associated with the hazardous waste, risk assessment models need to be evaluated using complex chemical mixture toxicology. The use of inappropriate risk data could result in an overly conservative estimate of risk requiring too costly a remedial action at some sites, while at other sites the risks may be underestimated.

Biological effects from exposure to toxic substances are probably a function of the bioavailability of a hazardous chemical modified by interaction with other chemicals rather than simply a function of the concentration of that single chemical. Therefore, improved methods of evaluating the actual exposure (markers of exposure) of hazardous materials to organisms and their resultant effect need to be found.

Cost-effective tools to assess the performance of proposed remedial actions on an intermediate scale are needed to demonstrate the effectiveness of the remedial action while directly determining the risk associated with the remediation technique.

The three environmental and human health assessment projects proposed for FY88 address these issues and are consistent with the Center's multiyear RD&D objectives.

Project Title: Risk Assessment for Complex Mixtures of Hazardous Wastes

Rationale

Risk assessment models are necessary for evaluating risk associated with each hazardous waste site in the Northwest. Evaluation of the risks associated with hazardous materials contained in the complex chemical mixtures that are predominant at CERCLA sites and the Hanford Site are based on adding all risks associated with each of the measured components in the mixture or on an evaluation of the degree of risk associated with the most hazardous component of the mixture. The potential hazard of some complex wastes can be modified by the interaction of the different chemicals present in the waste. The current risk assessment models do not take this interaction into account. Consequently, the true risks associated with sites containing complex mixtures may be greater or less than those estimated by current models. Improving the estimation of complex mixture risks would improve the basis for assessing the risk a site poses and for setting site cleanup priorities.

Description/Scope

This project will assess the suitability of using current health risk models to set priorities for remediating Hanford waste sites. It will evaluate these models by comparing calculated risk, using EPA's current risk assessment model, to observed biological effects during exposure to complex mixtures in laboratory experiments. Existing chemical data from Battelle's Synfuels Program, its EPA Criteria and Standards Sediment Quality Criteria Program, and various literature sources containing data on chemical mixture toxicant concentrations coupled with biological effects measurements will be used as inputs and as means to evaluate the model. Comparisons will be made between the modeled effect and the actual observed effects. In addition, a sensitivity analysis of simulated complex mixtures representative of Hanford Site wastes will be performed by varying the predicted toxicity components of the health risk models and evaluating the change in the risk value. These results will be evaluated to determine the relative advantages and disadvantages of using the existing models to rank Hanford waste sites for remediation.

Various types of mixtures will be evaluated using an appropriate risk model to determine if there are characteristics of the mixtures that would aid in the prediction of hazardous waste impacts on humans and the environment. These characteristics will be evaluated to determine the areas of research that the Center should pursue in its RD&D research program during subsequent years.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY88

- Complete comparison of predicted versus measured risk associated with exposure to complex mixtures.
- Prepare technical progress letter report.

Schedule/Cost

FY88/\$50K, FY89/(based on findings in FY88)

Participants

PNL, Battelle Seattle Research Center (BSRC), University

Project Title: Evaluation of Complex Mixture Exposure Markers

Rationale

Heavy metals are the most frequently occurring hazardous waste materials at sites in the Northwest, including the Hanford Site. The actual availability of these metals to organisms (referred to as bioavailability) may be greater or less than the actual concentration of the material at the site, and that availability may be related to the process that produced the hazardous material. A direct measure of the bioavailable fraction of these metallic wastes is needed to evaluate the actual toxicity of the waste. Valid exposure markers indicating the availability of hazardous metallic material in aquatic environments will improve estimates of potential damage to human health and the environment from these hazardous waste sites. These markers would also aid in setting priorities for site cleanup. In addition, differences in porphyrin production patterns before and after a site has been remediated could indicate the degree of success of site cleanup.

Description/Scope

The primary objective of this project is to determine if the heavy metals in complex hazardous waste mixtures are available to organisms in proportion to their concentrations in the mixtures and to determine if mixtures from other sites have the same relative availability. The initial step will be to evaluate benthic and pelagic fish as candidates for use in this procedure. Porphyrins (compounds that form the active nucleus of hemoglobin) appear to be a reasonable indicator for estimation of the bioavailable fractions of several metals at the same time. Hemoglobin synthesis requires the formation of porphyrin compounds. Porphyrin compounds can indicate both the type and relative quantity of bioavailable heavy metals. The structure of the porphyrin compounds, which varies for different heavy metals, indicates the type of heavy metal present. The abundances of the different porphyrins indicate the relative availability of the metals to the organisms. It is already known that porphyrins in other vertebrates will respond to metallic stress and it is suspected that fish porphyrins will behave similarly. During the first year fish will be exposed to bioavailable heavy metals in order to provide a dose response relationship between metal loads and porphyrin distribution patterns.

Near the end of the first year, fish will be introduced into the alternative capping project and an evaluation of the availability of metals contained beneath the various caps will be made.

Major Milestones/Deliverables

FY88

- Complete exposure of fish to various metals and determine porphyrin patterns.
- Complete technical progress letter report.

FY89

- Complete plan describing application of porphyrin distribution patterns in intermediate-scale experiments (see following project).
- Complete exposure of fish in intermediate-scale experiments.
- Complete letter report on effectiveness of capping strategies for reducing exposure to fish as measured by porphyrin distribution patterns.

Schedule/Cost

FY88/\$60K, FY89/\$60K

Participants

University, PNL, BSRC

Project Title: Demonstration of a Method to Evaluate Alternative Capping Concepts for Sediments Disposed of in Aquatic Systems

Rationale

Throughout the Northwest there are accumulations of sediments produced during the mining of heavy metals. Four areas affected extensively are the Clark Fork River in Montana, the Coeur d'Alene River in Idaho, the Ruston shoreline in Commencement Bay, Washington, and Harbor Island in Elliott Bay, Washington. Currently proposed solutions to these problem areas are to either allow natural sedimentation to bury submerged piles of contaminated sediments or cap them with clean sediments. Conducting a capping operation in aquatic environments is expensive and because the effectiveness and long-term performance of these capping operations is not currently known, it would be very useful to have a method to evaluate the performance of capping concepts. Small-scale laboratory tests could be performed but the applicability of the results to environmentally scaled disposal efforts is suspect. Larger, intermediate-scale physical tests need to be performed in what are termed "mesocosm" environments.

Description/Scope

Intermediate-scale physical models (also referred to as mesocosms) will be evaluated for their ability to test the relative effectiveness of alternative capping structures for containing hazardous waste materials. The hazardous waste materials will be residual sediments from mineral processing: mining, milling, smelting, leaching, and/or refining. Alternative capping structures will include a clean control sediment, a residual processed sediment without a cap, a residual sediment with only a clean cap, a residual sediment with an organically enriched cap covered by a clean sediment cap, and a residual sediment with a clay layer cap covered by clean sediment. Figure 3.2 illustrates a typical mesocosm for testing the effectiveness of sediment capping.

This project is both a waste treatment, isolation concept and a risk assessment project that will serve as an integrated research program tying two technology areas together. Distribution of contaminants within and above the three caps and controls will be measured and evaluated in terms of pathways for

TREATMENT

Sequestering

POSSIBLE MEASUREMENTS

- Water Column Contaminants *1
- Microlayer Contaminants *1
- Sediment Contaminants
 - Organic Rich Layer *1
 - Dredge Materials *1
 - Clean Sediments *1
- Organisms in Sediments
 - Recruitment *1,2
- Add Axiopsis
 - Determine Burrowing Behavior *1
 - Bioassay Clean Sediments *2,3
 - Bioavailability *2
- Add Bivalves
 - Measure Contaminant Uptake *2,3

*1 Pathway
*2 Exposure
*3 Risk

FIGURE 3.2. Mesocosm for Evaluating Alternative Capping Concepts for Sediments Disposed of in Aquatic Systems

exposure to organisms. The bioavailability of those metals will be evaluated using porphyrin distribution patterns in fish living within the mesocosm environment (see previous project). Risk to those fish will then be determined by evaluation of their health as a result of the exposure and resultant uptake. The capping concept that most effectively reduces those risks will then be determined.

The mesocosms can simulate communities of organisms present in the surrounding environment that may influence the success of a treatment technology (e.g., deep burrowing shrimp and cap integrity). Once the mesocosm environment begins to function in a manner similar to the surrounding ecosystem, it can be manipulated by introducing hazardous materials. After the response stabilizes, treatment technology can be applied and the success of that treatment can be evaluated by comparison to the surrounding ecosystem or to controlled mesocosm environments.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY88

- Complete design and construction of four intermediate-scale test chambers.
- Complete installation of three alternative capping concepts and initiate exposure studies.
- Complete technical progress letter report.

Schedule/Cost

FY88/\$80K, FY89/\$100K

Participants

PNL, BSRC

3.3 WASTE TREATMENT TECHNOLOGY PROJECTS

Waste treatment technologies can be used to destroy, stabilize, separate, or isolate hazardous substances associated with hazardous or radioactive mixed-waste sites and the adjacent offsite environment. Destruction using biological, chemical, or thermal processes can convert hazardous materials to nonhazardous materials. Stabilization using chemical or thermal processes can incorporate or fix hazardous chemicals in waste-form matrices that significantly reduce the rate at which they are released to the environment. Biological, chemical, physical, and thermal processes, or some combination of these processes, can be used to separate hazardous from nonhazardous compounds or media. After separation, the hazardous wastes can then be destroyed, stabilized, or recycled. Isolation using chemical or physical barriers can prevent or reduce the rate of migration of hazardous materials from the waste source to the surrounding environment. Isolation, which reduces the rate of contaminant migration, can be used in concert with in situ destruction technologies that may have reaction rates too slow to be effective without the reduced migration rates.

Currently available waste treatment technologies and features of the Northwest inactive waste sites were reviewed to support the Center's long-term planning effort. Technology gaps that could be filled by the Center's RD&D program were identified and were incorporated into the multiyear RD&D objectives listed in Section 2.3. Five RD&D areas for waste treatment technology development were identified:

1. destruction of organic and some inorganic compounds
2. separation of hazardous constituents from nonhazardous constituents in waste
3. stabilization of waste
4. isolation technologies
5. application of waste treatment technologies.

For each of these five areas, technical and strategic criteria for project selection and 5-year goals for the RD&D program were developed. These goals and criteria served as the basis for selecting the following projects for FY88.

The FY88 projects comprise a mixture of innovative biological, chemical, physical, and thermal technologies to destroy, stabilize, separate, and isolate hazardous and radioactive mixed wastes. The issues addressed by each group of projects, description/scope statements, rationale for developing the specific technology, cost, schedule, participants, and major milestones are presented for each project. Specific issues include 1) groundwater cleanup, 2) remediation of contaminated soils, 3) destruction of concentrated wastes, and 4) groundwater well siting. The projects are presented by issue group.

Groundwater Cleanup Issue

Contaminated groundwater is a problem associated with nearly all Northwest NPL sites, and contaminated groundwater is an issue at most Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) sites in the four Northwest states and at the Hanford Site. (See Section 2.2 for further discussion.) Contaminants include chlorinated and nonchlorinated aliphatics and aromatics, heavy metals (including radionuclides), and inorganic anions such as nitrates. Both radionuclides and nitrates are present in wastes resulting from nuclear production operations. In general, the groundwater contains a mixture of various classes of organics or a combination of organic compound(s), heavy metals, or inorganic anions. Therefore, processes that remove heavy metals for subsequent immobilization and remove organics and anions, such as nitrates, for destruction will be needed to clean up these waters.

Current technologies rely on separation processes. For example, organics can be removed by air stripping or carbon adsorption. However, the organic compound is not destroyed and can be released back to the environment from the offgas during airstripping or from the solid wastes generated from carbon adsorption. A cost-effective method for destroying mixtures of organic compounds present at dilute concentrations in aqueous streams is needed to permanently protect human health and natural resources, as encouraged by the SARA legislation.

Currently, heavy metals are also removed from groundwater by applying separation techniques such as precipitation/filtration or ion exchange. Innovative technologies for separation and subsequent immobilization would be useful, especially if both organic and heavy metals could be removed in one step, resulting in reduced operating and capital costs. Finally, inorganic anions can also be removed from groundwater using separation techniques. Techniques for destroying anions such as nitrates exist but have not been applied to groundwater treatment. Such treatment would constitute a permanent remedial solution.

The first three waste treatment projects proposed for FY88 address the groundwater cleanup issue. Selection of these projects is consistent with the 5-year goals listed in Section 2.3.

Project Title: Catalytic Destruction of Hazardous Organics in Aqueous Solutions

Rationale

If successful, the technology developed under this project could be used to destroy mixtures of organics in groundwater both at the Hanford Site and at Northwest NPL and CERCLIS sites. It has several possible advantages over currently used separation technologies:

- Organics are destroyed resulting in a permanent remedial solution that protects human health and natural resources.
- The range of organic loading in the feed stream is broader than any currently available treatment technology (0.01 to 50 wt%).
- Methane is produced as a by-product that can be used to produce the required process heat. Feed streams containing >1 wt% organic will generate sufficient methane to supply all required process energy. Consequently, this process will have cost benefits.
- The technology is being adapted from a process developed in the DOE-sponsored Biomass Program. Therefore, the time between development and adaptation can be reduced and cost benefits will be realized.
- The process may complement existing treatment processes such as carbon adsorption. Specifically, the carbon may be regenerated by feeding spent carbon to the reactor to destroy the adsorbed organics and then recycled to the process.
- The process equipment can be readily sized for a mobile unit for onsite processing. Onsite processing will reduce capital investment and reduce impact to total capacity for treatment, storage, and disposal of hazardous waste within the Northwest.

Description/Scope

A process will be developed to convert hazardous organics in aqueous solutions to nonhazardous gases [primarily methane (CH_4) and carbon dioxide (CO_2)] (see Figure 3.3). Wastes containing 10 wt% or less of organic will be treated using a transition metal catalyst; operating conditions include

FIGURE 3.3. Catalytic Destruction of Hazardous Organic Waste

temperatures of 300° to 460°C and pressures of 2000 to 5000 psig. This technology is being adapted from a process used to generate fuel gases from high-moisture-content biomass. At feedstream concentrations of greater than 1 wt% organics, the resulting fuel gas (CH₄) will provide all of the process energy requirements. The concept will be demonstrated in both a bench-scale batch and a continuous-feed unit. Process conditions such as temperature, pressure, residence time, catalyst type and loading, and rate of catalyst deactivation will be determined. The need for pre- and post-treatment of the process stream will also be determined. A prototype transportable system will be designed and an economic evaluation will be conducted based on laboratory results. If the process is economically feasible, a field demonstration will be conducted.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY87

- Completed technical evaluation in batch system.
- Prepared technical progress letter report.

FY88

- Evaluate technical feasibility in a continuous system.
- Design a mobile unit.
- Conduct an economic feasibility study.
- Prepare technical progress letter report.

FY89

- Build a mobile unit for field demonstration (for FY89 and beyond).

Schedule/Cost

FY87/\$70K, FY88/\$150K, FY89/\$250K^(a)

Participants

PNL

(a) There is a strong potential for cofunding after FY88.

Project Title: Biodegradation of Aqueous Hazardous Waste Containing Both Organics and Nitrates

Rationale

Groundwater containing mixtures of organics such as carbon tetrachloride (CCl_4) and inorganic anions such as nitrates can be found at the Hanford Site. This groundwater also contains heavy metals that may need to be removed in a pump-and-treat separation process. If these aquifers are treated for heavy metals contamination, a process for degrading both organics and nitrates remaining in the treated water could be demonstrated. This process may be beneficial or required in the future for treatment of aquifers, wastewaters (including water pumped during well development), or stored tank wastes. If successful, this technology has the following benefits:

- The process will destroy both organic and nitrate constituents in a single-step process, permanently protecting human health and natural resources.
- Because it is an adaptation of existing technology used at other DOE facilities, the time between development and application will be reduced and cost benefits will be realized.
- A strong potential exists for cofunding. The Center will support laboratory development leading to pilot-scale demonstration, which will be funded under the DOE Environmental Restoration (ER) Program in FY88.
- It can be used for many waste streams or disposal sites at the Hanford Site and may have application to some NPL sites. (Application to NPL sites would likely be limited to biological destruction of organics, because nitrate contaminants are not common at these sites.)

Description/Scope

A biological process will be developed to convert nitrates and CCl_4 in aqueous solutions to innocuous gases (see Figure 3.4). Adaptation of biodegradation processes demonstrated at other DOE facilities will be used as a

FIGURE 3.4. Process Concept for Biodegradation of Aqueous Hazardous Waste Containing Heavy Metals, Organics, and Nitrates

basis for process development. A bench-scale bioreactor will be used to evaluate candidate microbes. This evaluation will include identification of a consortium of microbes capable of denitrifying and degrading CCl_4 , followed by determination of optimum conditions for cell growth and of the efficiency of the process to destroy nitrates and CCl_4 using simulated waste. The conditions include temperature, pH, nutrient type, and ratio of nutrients to nitrate and CCl_4 needed to sustain a degradation rate that leads to a reasonable residence time within a specified reactor volume. A preliminary economic analysis will then be completed. Based on technical and economic feasibility, the process will then be demonstrated. A pilot-scale system, such as a 20-L suspended growth or fluidized bed bioreactor, will be designed and tested. Based on results, a full-scale process will be designed.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY87

- Identified and evaluated microbes capable of degrading both nitrates and CCl_4 .
- Identified and evaluated engineering requirements for process development.

- Prepared technical progress letter report.

FY88

- Conduct laboratory tests to optimize process conditions.
- Conduct pilot-scale verification tests under the DOE Environmental Restoration (ER) program.
- Prepare technical progress letter report.

FY89

- Provide engineering design support for a full-scale system.

Schedule/Cost

FY87/\$47K, FY88/\$100K, \$200K^(a)

Participants

PNL/OEC

-
- (a) This funding is scheduled for pilot-plant design and testing in FY88 in a cooperative program with the OEC through the DOE Environmental Restoration Program.

Project Title: Concurrent Removal of Heavy Metals and Organics from Groundwater or Surface Water

Rationale

Cost-effective technology to treat groundwater contaminated with mixtures of organics and heavy metals as proposed in this project will be needed to remediate many disposal sites at the Hanford Site and throughout the Northwest. If successful, the proposed project could meet these needs by providing the following benefits:

- Separation and subsequent volume reduction of waste could be handled in a single process step, potentially reducing capital and operating costs.
- The proposed technology could be used as a pretreatment step for organic destruction and heavy metal stabilization.
- The process equipment and operating procedures for the precipitation process are well known, facilitating advancement to pilot-scale testing if laboratory tests and economic analysis indicates further development is warranted.
- Some technical evaluation of the technology has been conducted at Washington State University and will serve as a basis for this work, improving the chances for further technology development and timely transfer of the technology.

Description/Scope

An innovative separation technology for concurrent removal of heavy metals and organic solvents will be evaluated. The envisioned process is shown in Figure 3.5. The method involves the formation of $[(Al_{13})_4(OH)_{28} \cdot (H_2O)]^{+3}$ using the correct ratio of aluminum chloride and sodium hydroxide. The "pseudo-polymer" that is formed contains properties similar to activated carbon with regard to adsorption, surface area, and affinity for organic compounds. The aluminum polymer product also has the ability to coprecipitate heavy metals. The resulting insoluble product forms a denser sludge (and thus a higher concentration of hazardous waste) than traditional precipitating and

FIGURE 3.5. Process Concept for Concurrent Removal of Heavy Metals and Organics from Groundwater

polymerizing waste treatment agents, such as standard alum or ferric hydroxide flocculants. These traditional precipitants can remove heavy metals; however, the proposed process can also remove organics due to its polymer-like chemical characteristics. Sorptive properties are controlled by various process conditions including pH, eH, and reactant ratios. This project will attempt to determine the optimum conditions and dose rates for the coremoval of chromium and trichloroethylene (TCE) from simulated, contaminated groundwater.

In FY88, the work will be conducted on a laboratory scale in proof-of-principle studies. A process flow sheet and a preliminary economic analysis will be developed. After the first year, this work could be expanded to evaluate other heavy metal and organic compound mixtures. If the technology appears feasible, it will be demonstrated on a pilot scale.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY88

- Conduct laboratory tests.
- Develop preliminary flow sheet and conduct preliminary economic analysis.
- Prepare technical progress letter report.

Schedule/Cost

FY88/\$50K

Participants

University

Remediation of Contaminated Soil Issue

Based on CERCLIS site data for both the Northwest and the Hanford Site, wastes were most frequently disposed of as liquids. (See Section 2.2 for further discussion.) Consequently, soil columns have been contaminated by these wastes at virtually all CERCLIS sites. Soil columns act as reservoirs of heavy metals and organic compounds that are released to groundwater, surface water, air (via evaporation and physical dispersal), and directly to animal and human populations by ingestion, potentially posing a risk to the public and the environment.

Current practices for cleaning up soil-contaminated sites throughout the country have relied on exhumation and relocation of the waste to an isolated facility. This practice can be costly in terms of health risk to operators and the general public exposed to dust and fumes during excavation and transportation and in terms of dollars for this labor-intensive operation. In addition, such remediation practices constitute a significant burden to available disposal capacity within the Northwest. As a result, available capacity may be insufficient and the cost for new permitted disposal facilities could be high, given current design requirements and slow permitting processes. In situ treatment would substantially reduce these problems.

The following two waste treatment projects proposed for FY88 address the soil cleanup problem. Selection of these projects is consistent with the 5-year goals found in Section 2.3.

Project Title: Pilot-Scale Testing of In Situ Vitrification (ISV) of PCB-Contaminated Soils

Rationale

Polychlorinated biphenyls (PCBs) are found in soils throughout the Northwest and at a few sites on the Hanford Site. If successful, the proposed project would have the following benefits:

- The process provides concurrent destruction of organics and stabilization of remaining inorganic compounds such as heavy metals including radionuclides, constituting a permanent remedial action.
- Because it is an in situ process, labor-intensive exhumation will be avoided, and exposure of the public to hazardous constituents during exhumation and transportation will be eliminated. This feature is particularly important for radioactive mixed wastes.
- The technology is cost-effective for treating radioactive mixed wastes and cost competitive for hazardous wastes.
- The equipment design is complete and ready for technology transfer.

Description/Scope

The fate of PCBs in contaminated soils treated with the ISV process in FY87 will be determined. In situ vitrification is a thermal process that can concurrently destroy organics and fix inorganics such as heavy metals in a glass-like waste form. As shown in Figure 3.6, electrodes are emplaced in the soil at a contaminated site. An offgas system including a hood and scrubber system is placed over the electrode and surrounding soils to capture volatile material that could potentially be driven from the soil during heatup. An electric current is used to heat the soil until it becomes molten.

The soil temperature during processing reaches 2000°C, thermally degrading organics in the soils. A test run was completed in FY87 on soil contaminated with 1000 ppm PCBs. During the operation, offgas samples were collected from the hood and stack. In FY88, additional samples from soils, the glass waste form, and offgas components such as the filter, activated carbon absorber, and scrubber water will be collected. All samples will be analyzed for PCBs,

FIGURE 3.6. ISV Processing Equipment Setup and Operating Sequence

furans, and dioxins to determine the destruction efficiency of the process, to determine the migration of PCBs, if any, to adjacent soils during heatup, and to verify that PCBs were completely destroyed rather than partially degraded.

Permitting/Regulatory Requirements

Toxic Substances Control Act (TSCA)

Major Milestones/Deliverables

FY87

- Obtained TSCA permit.
- Conducted ISV pilot-scale test.

FY88

- Prepare recovery plan.
- Evaluate test results.
- Prepare test report.

Schedule/Cost

FY87/\$88K, FY88/\$116K, \$20K^(a)

Participants

PNL/Private industry

(a) Cofunding to be provided by EPRI in FY88.

Project Title: In Situ Biodecontamination of Hazardous and Radioactive
Mixed-Waste Sites

Rationale

Many NPL and CERCLIS sites have soils contaminated with organic constituents that can be biodegraded in the presence of heavy metals. These sites also have indigenous populations of microbes that have adapted to the soil environment and can degrade organics in the presence of heavy metals. The rates of biodegradation can be increased by adding nutrients or changing the environment to optimize the process. This process offers potential benefits for site remediation, including cost effectiveness and permanent, in situ treatment as indicated below. However, the technology is still in the early stage of development and needs to be further developed to understand its applicability.

In situ biodecontamination offers the following advantages:

- The process results in destruction of organics, a permanent remedial action.
- Because it is an in situ process, both cost and human health benefits will be realized.
- The process is conducted at ambient temperatures and pressures, resulting in cost benefits.
- Raw materials, including nutrients and indigenous microbes, are inexpensive, resulting in cost benefits.
- Compared to many destruction technologies, in situ biodecontamination is not equipment intensive, resulting in cost benefits.

Description/Scope

The feasibility of using indigenous microbial populations for destruction of organic wastes in soils in the presence of heavy metals will be determined. Specifically, a research strategy for in situ degradation will be developed and tested.

The approach will be to determine the chemical and biological profiles of a site and to catalogue microbes to facilitate the use of bacteria at this site and other sites with similar chemical characteristics. In addition, the impact of heavy metals on the rate of organic biodegradation will be determined so that an in situ process can be conceptualized and developed. This conceptualization may include the need for applying isolation technologies to reduce the rate of offsite migration to allow time for biodegradation. It will identify the conditions necessary to achieve degradation, thus providing a basis for determining engineering design requirements needed to perform an economic evaluation.

This project will have wide application throughout the Northwest. However, initial emphasis will be on the treatment of those inactive sites at the Hanford Site that once received metal finishing wastes. The goal of this 2-year program is to develop an implementation strategy if the process appears technically feasible. The possibility of increasing metal mobility through complexation with intermediate products or by-products, extracellular enzymes, or nutrients will also be determined to evaluate the applicability of in situ biodegradation at a site. If mobility is increased, the potential for transport through the media to a bioreceptor is increased. These data will be required before further decisions on applicability can be made.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY87

- Characterized chemical, physical, and biological systems in a 300-Area waste site.

FY88

- Conduct tests to optimize conditions for biodegradation.
- Develop a process development strategy.
- Prepare technical progress letter report.

Schedule/Cost

FY87/\$45K, FY88/\$60K(a)

Participants

University, PNL

(a) If results appear promising, we will proceed to demonstration.

Destruction of Concentrated Waste Issue

Concentrated, liquid organic wastes can be found at NPL, CERCLIS, and Hanford waste sites. Many of these wastes can be shipped to permitted incinerators for destruction. However, permitted incinerators are located only in the states of Illinois, Texas, and Alabama, and therefore, transportation costs can be high. Liquid organics mixed with radionuclides at the Hanford Site cannot readily be sent off site for incineration, and a permitted unit does not exist on site. Alternative destruction technologies may be required and should be developed to meet future needs in a timely manner. The public and regulatory agencies are receptive to alternative treatment technologies to incineration.

The development of two chemical destruction technologies is proposed for FY88. These technologies will meet the need for safely converting liquid organics to innocuous products such as CO_2 and H_2 . The projects involve electrochemical oxidation of organics and chemical destruction of organics; they are described in the following project summaries. Selection of these projects is consistent with the stated 5-year goals in Section 2.3.

Project Title: Electrochemical Oxidation of Organic Wastes

Rationale

This process could provide an alternative to destroying liquid organic wastes that cannot be destroyed by incineration for technical, regulatory, or other reasons. If successful, it would have the following advantages:

- Operations can be conducted at ambient pressures and temperatures, providing cost benefits with respect to energy input.
- Readily available equipment can easily be scaled up.
- Metal or radionuclide contaminants could be removed from the liquid as precipitates to be stabilized in downstream treatment steps, thus reducing the possibility of dispersing these constituents in the offgas or scrubber wastewaters.
- This technology is being adapted from decontamination technology developed under a DOE-funded program at Richland and Rocky Flats operations. As a result, the time between development and application can be reduced and cost benefits will be realized.

Description/Scope

An electrochemical method will be developed for destroying hazardous organic wastes, including chlorinated and nonchlorinated aromatics and aliphatics; these classes of compounds are found frequently at NPL, CERCLIS, and Hanford sites. The proposed process, shown in Figure 3.7, uses a strong oxidizing metal ion in nitric (HNO_3) or sulfuric acid (H_2SO_4) to degrade organics. This mixture of organics, acid, and metal ions is added to the anode compartment of an electrochemical cell. The metal ion oxidizes the organic. It is reduced during the destruction reaction, but is subsequently reoxidized electrochemically. The process will be demonstrated on a laboratory and bench scale (1/50 full scale). The conditions to be tested will include type of metal ions used, concentration and types of acid, temperature, and electrode material. Batch and continuous systems will both be used on a laboratory scale. The conceptual design of a transportable unit and an economic analysis will be completed. Based on technical and economic feasibility, the process

FIGURE 3.7. Simplified Electrochemical Oxidation System Configuration

may be demonstrated on a pilot scale. Initial focus is on remediating hexone (MIBK) waste at the Hanford Site, because 114,000 L of this material are currently stored on the site and remediation options will be reviewed in FY88. However, the process can be used to destroy phenols, aromatic hydrocarbons, and chlorinated hydrocarbons found at Hanford or Northwest sites.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY87

- Completed batch laboratory-scale tests to optimize operating conditions for hexone destruction.
- Prepared technical progress letter report.

FY88

- Conduct laboratory tests using selected organics and simulated wastes.
- Determine parameters needed for a continuous process.
- Complete pilot-scale process design.
- Prepare technical progress letter report.

Schedule/Cost

FY87/\$90K, FY88/\$100K(a)

Participants

PNL

(a) There is a strong potential for cofunding after FY88.

Project Title: Chemical/Physical Destruction of Chlorinated Organic Wastes

Rationale

Dilute and concentrated solutions of chlorinated organics are commonly found at Northwest waste sites (see Section 2.2 for further discussion). Some of these organics can be difficult to handle in destruction treatment processes for many reasons. For example, in thermal processes, chlorinated by-products can be corrosive, requiring changes in equipment design and materials of construction. In biological processes, some of the chlorinated organics can be refractory. The chemical/physical process(es) developed under this project may have the following benefits:

- These processes appear capable of dechlorinating organics as a pre-treatment step to currently available technologies or emerging technologies such as catalytic destruction of hazardous organics in dilute aqueous solutions (funded by the Center).
- These processes may also be used for complete destruction of organic wastes.
- The process has potential application to both dilute and concentrated wastes.

Description/Scope

The objective of this project will be to evaluate methods for dechlorinating and destroying chlorinated organics using chemical/physical destruction technologies. The approach taken will include a literature search followed by a preliminary evaluation of selected chemical/physical methods for concentrating, dechlorinating, and destroying selected organics. The selected organics may include CCl_4 and PCBs as representative chemical compounds, because both are found at inactive waste sites in the Northwest, including sites at the Hanford Site. The goal will be to develop optional process scenarios using selected concentration and destruction methods that could be used as a pre-treatment for dechlorination in conjunction with currently available technologies or with other destruction technologies being developed with Center

funding. In the first year, this project will focus on proof-of-principle screening studies that may be expanded in future years if the processes are technically feasible.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY88

- Complete literature search.
- Conduct screening studies.
- Prepare technical progress letter report.

Schedule/Cost

FY88/\$50K

Participants

University

Well Siting Issue

Virtually all NPL, CERCLIS, and Hanford waste sites have the potential for contaminating nearby groundwaters (see Section 2.2 for further discussion). Although a few in situ treatment techniques are available for aquifer restoration, the most common technique is groundwater withdrawal followed by at-grade treatment (generally referred to as pump and treat). The required withdrawal and injection wells can be very expensive. The placement and pumping rates of these wells directly affects the percent recovery and cost for groundwater cleanup. Currently, siting is based primarily on professional judgment; computer tools would aid the professional in making cost-effective selections of well sites. The well-siting project proposed for FY88 would provide this tool. Selection of this project is consistent with the 5-year goals stated in Section 2.3.

Project Title: Optimal Pumping and Siting of Wells in Contaminated Aquifers

Rationale

The technology developed under this project will allow a hazardous waste professional to efficiently design a cost-effective well network for aquifer restoration. This is marked improvement over current design practice, which relies on trial-and-error solutions and professional judgment. Subsurface remediation is typically a long-term (30 to 100+ years) proposition; therefore, any advantage gained through an optimized well scheme will be compounded over the duration of the solution.

Specific advantages of the optimal well network design technology are

- Operation of an optimally designed well network will cost less than a design based on traditional approaches, making this technology cost-effective.
- Various mitigative strategies, such as contaminant removal, isolation, or diversion, can be combined at a single site and modeled with this flexible tool.
- Pumping (and/or injection) rates for an existing well network can be updated if the regional potential surface changes during remediation, allowing for adaptability.
- The technology is based on existing optimization algorithms and groundwater flow models to facilitate technology development and transfer.
- The methodology is being developed on a microcomputer for use by professionals familiar with groundwater modeling.
- Data requirements for the methodology are consistent with the quantity and quality of site characterization data typically available for an NPL cleanup.

Description/Scope

A computer-based methodology is being developed to optimally specify well locations and discharge rates for the remediation of contaminated groundwater

supplies. The approach is based on the coupling of existing technologies in optimization and groundwater flow simulation (Figure 3.8). Software for this project is being developed on a microcomputer with the goal of creating a packaged system which will be as easy to use as the groundwater flow model alone.

In FY87, analytical and numerical groundwater flow simulations were successfully coupled with optimization algorithms; test cases included both confined and unconfined aquifers. The FY87 results demonstrated the capability of linear programming algorithms to efficiently solve problems where hundreds of unknowns and constraints were specified. Problems of this magnitude required only a few hours for solution on a microcomputer.

The linear programming approach was possible because contaminant transport was assumed to be nondispersive. Although this assumption limits the generality of the methodology, it is usually justified because data deficiencies prohibit the calibration of dispersion modeling parameters. In any case, an

FIGURE 3.8. Concept of Using Computer Software to Optimize Well Locations

accurate contaminant plume characterization will reduce the effect of this omission. The ability of linear programming algorithms to address extremely large and detailed problems suggests that the nondispersive transport assumption be exploited whenever possible.

One drawback to the methodology developed in FY87 is that it is deterministic, i.e., perfect knowledge of the aquifer behavior and plume extent is assumed. Real aquifers are infinitely detailed. Thus, all aquifer models are to some degree defective. In FY88, this uncertainty in the modeling description will be explicitly incorporated into the well network design methodology. The end user would then be able to choose a level of confidence with which a design would proceed. This capability will be demonstrated in FY88 and a field application of the software will be conducted, data permitting.

Permitting/Regulatory Requirements

None

Major Milestones/Deliverables

FY87

- Conducted literature search.
- Developed preliminary software package.
- Demonstrated software.

FY88

- Enhance software package.
- Verify with field data.
- Prepare technical progress letter report.

Schedule/Cost

FY87/\$40K, FY88/\$80K

Participants

PNL

3.4 PROGRAM PLANNING AND SUPPORT PROJECTS

Projects in this task area provide overall program planning, administrative assistance, and technical communications that facilitate technology transfer for the Center. These projects ensure that the Center's RD&D program is responsive to advances in technology outside the Center, including activities in other government and private industry RD&D programs and changes in technology needs for the Northwest. The following pages contain project descriptions for this task.

Project Title: Technology Needs Documents

Rationale

These reports provide a basis for the Center's multiyear RD&D objectives (Section 2.3) and the selection of projects to accomplish those objectives. In addition, the reports will provide information on the present state-of-the-art technology and gaps in it.

Description/Scope

Three state-of-the-art technology assessment studies were initiated in FY87. These studies addressed three technology areas: site characterization, environmental and human health assessment, and waste treatment. Letter reports will be completed, published, and distributed in FY88. These reports will contain reviews of the present state of the art of technologies in each of the three technology areas and will identify major gaps in the technologies. The three draft letter reports are entitled:

- "State-of-the-Art Assessment for Site Characterization Technologies"
- "State-of-the-Art Assessment for Environmental and Human Health Assessment Technologies"
- "State-of-the-Art Assessment for Waste Treatment Technologies."

To enhance the waste treatment technology needs document, a set of logic trees will be prepared that will enable readers to quickly access information on waste treatment options applicable to specific site and waste characteristics. This set of logic trees will also provide a basis for developing a microcomputer system for selecting remedial technologies as described later in this plan.

Permitting/Regulatory Requirement

None

Major Milestones/Deliverables

FY88

- Three separate PNL letter reports, one for each technology area, will be published in FY88.

Schedule/Cost

FY88/\$30K

Participants

PNL

Project Title: Annual Northwest Conference on Hazardous Waste Technology

Rationale

Most waste technology conferences are national in scope and are not readily accessible to many Northwest state and local agencies and site managers. A local conference oriented to the Northwest, however, would provide these individuals with valuable information. FY87 experience within the Center indicated a strong interest in a regular conference with a Northwest focus.

Description/Scope

This annual conference would provide individuals in the Northwest with access to information on the latest technology developments with an emphasis on Northwest needs. It would also provide a forum for reporting technology developments from throughout the country, with the information targeted for state and local interests and Northwest site managers. This conference would also provide interested parties within the Northwest with an opportunity to review and discuss the Center's RD&D objectives.

Permitting/Regulatory Requirement

None

Major Milestones/Deliverables

FY88

- The conference will be conducted and a proceedings will be prepared on an annual basis.

Schedule/Cost

\$50K^(a)/year

Participants

PNL^(b)

-
- (a) Cofunding from Northwest federal and state agencies and private industry will be sought for this activity.
 - (b) PNL will be responsible for organizing the Conference. Participants will include individuals from federal, state, and local government agencies, universities, and private industry.

Project Title: Database of Northwest Hazardous Waste Site Characteristics

Rationale

During FY87, Northwest and Hanford Site characteristics were analyzed to provide a basis for identifying technology needs for the region and setting RD&D priorities. Continued analysis of these sites will help ensure that Center programs are targeted on the proper set of technology needs. The database will also facilitate the identification of potential sites for demonstration projects and for application of technologies developed by the Center or other organizations. The database will also likely be useful to federal, state, and local agencies seeking information on Northwest hazardous waste sites.

Description/Scope

This project will continue the analysis of Northwest site characteristics begun in FY87 and develop a database that will facilitate the analysis of technology needs and targets for technology application. This project will provide analysts with information on Northwest (NPL and CERCLIS) and Hanford site characteristics. The primary emphasis will be on obtaining data on Northwest, rather than Hanford, waste sites. Information for the Hanford waste sites will be retrieved from existing databases. Information in the database will include waste categories present, waste form at time of disposal, disposal method, type of industry, and site location. The database will be able to identify the relative prevalence of various waste categories, their association with different industries, and the disposal methods used. The database will also be able to generate maps showing the locations of waste sites with various characteristics.

Permitting/Regulatory Requirement

None

Major Milestones/Deliverables

FY88

- Develop a microcomputer-compatible database for NPL and CERCLIS sites in the Northwest.

- Prepare a technical progress letter report containing initial crosstabulations and other results available from the database.

FY89

- Prepare updated technical progress letter report on Northwest site data.

Schedule/Cost

FY88/\$30K, FY89/\$30K

Participants

PNL, University

Project Title: Microcomputer System for Selecting Appropriate Remediation Technologies Based on Site Characteristics

Rationale

To select an appropriate remediation technology for a given hazardous waste site, the capabilities and limitations of candidate technologies must be matched to the specific characteristics of the waste site including, for example, the waste type present, its form, and location. This selection process needs to be carefully documented and the rationale for the selection presented. In addition, documenting the conditions for which a given technology is appropriate will help the Center in setting priorities for technology RD&D by linking developing technologies to their potential "markets" or sites at which they may be applied.

Description/Scope

This project will develop a demonstration rule-based system for use on a microcomputer that will aid the user in identifying appropriate remediation technologies for given site characteristics. In addition, this software package will generate the rationale for both selecting and eliminating candidate treatment technologies. The preliminary logic for screening and selecting waste treatment technologies has been described in the FY87 technology needs document prepared for waste treatment technologies. This document contains structured data tables that include information needed for evaluating alternative technologies. A small prototype PC-based expert system was also prepared demonstrating the feasibility of this concept. An important feature of expert systems is their ability to generate the rationale or justification for the choices they make. The software system produced by this project will include this capability.

Permitting/Regulatory Requirement

None

Major Milestones/Deliverables

FY88

- Prepare a microcomputer system that demonstrates the logic and rules that apply to selecting appropriate remediation technologies.

FY89

- Prepare a microcomputer system with expanded capacity to evaluate all technologies included in the present technology needs document.

Schedule/Cost: FY88/\$50K, FY89/\$75K

Participants: PNL, University

3.5 FY88 CONTINGENCY PROJECTS

The following projects have been identified by the Center as being consistent with the overall mission and objectives defined in this Program Plan. These projects, however, have been assigned lower priorities than those listed earlier in this section. As additional funds become available, these projects will become candidates for Center funding. However, they do not represent a comprehensive or prioritized list of candidate projects. New contingency projects will be identified throughout the year and will be prioritized. Table 3.2 lists the current contingency projects and their budgets.

TABLE 3.2. FY88 Contingency Projects and Budgets

<u>Project</u>	<u>Budget (\$K)</u>
<u>Remedial Investigation Technology Projects</u>	
In Situ Monitoring and Detection of Contaminants with Fiber Optics	60
Development of Numerical Laboratory for Hanford Unsaturated Zone	70
Improve Methods for Characterizing Heterogeneities in Geologic Media	60
In Situ Methods for Determining Hydraulic Properties	60
Fluorocarbon Tracers at Hazardous Waste Sites	70
Contaminant Transport in Aquatic Surface Layers	135
Extrapolation from Animal to Human in Dose-Response Modeling	50
Extrapolation from High to Low Dose in Dose-Response Modeling	75
Development of Biosensor Technology	100
Application of Remote Sensing Technology to Contaminant Transport	100
<u>Waste Treatment Technology Projects</u>	
Innovative Isolation Technique for Waste Disposal Sites	25
<u>Program Planning and Support Projects</u>	
Institutional Issues Related to Technology Transfer	75
Quarterly Center Update	20

Description of Contingency Projects

In Situ Monitoring and Detection of Contaminants with Fiber Optics. Analytical costs of groundwater samples represent a major fraction of the costs of site characterization. The ability to measure and detect contaminants in situ in the saturated and unsaturated zone will reduce costs and provide for more reliable and complete characterization of contaminants. Organic compounds prevalent at Hanford that can be detected by laser fluorescence fiber-optics will be identified. Using existing fiber optics sensor technology, an in situ detection system for monitoring these compounds in Hanford environments will be developed and tested. The data from this system will be validated by comparison with accepted analytical methods.

Development of Numerical Laboratory for Hanford Unsaturated Zone. A numerical laboratory representing unsaturated flow and transport conditions at the Hanford Site will be developed. As detailed site characterization data are collected, actual field data will be added to the model. Also, new sampling and data analysis strategies can be tested in the numerical laboratory. Further studies using the numerical laboratory will provide insight into the fundamental issue of how much characterization is enough.

Improve Methods for Characterizing Heterogeneities in Geologic Media. Heterogeneities in geologic media make data interpretation difficult and tend to complicate predictions from transport models. Field tests and theories used for data interpretation will be developed that consider the heterogeneous nature of the geologic media. In addition, simulation techniques will be applied to investigate various conceptual models based on measured or assumed spatial variability of the geologic and hydrologic properties. The results of this research will be used to better incorporate field data that contain spatial variations of key geologic and hydrologic properties.

In Situ Methods for Determining Hydraulic Properties. Research will be conducted to improve and develop techniques using fiber optic sensors for measuring in situ the fluid pressures and volumetric fluid contents in saturated and unsaturated porous material. Fiber optic technology offers a potential for reducing the cost and increasing the accuracy of the measurement of these properties.

Fluorocarbon Tracers at Hazardous Waste Sites. Current technologies do not offer an efficient means for detecting potential migration pathways from hazardous waste sites. Research will be conducted to evaluate the potential of using fluorocarbon compounds mixed with hazardous wastes as an efficient method to detect the potential migration pathways for hazardous materials off site and to monitor air emissions of volatile wastes at or near those sites.

Contaminant Transport in Aquatic Surface Layers. Previous research has shown that wind, wave, and tidal forces can transport hazardous wastes concentrated in the aquatic surface layer. These wastes are subsequently deposited and further concentrated on shorelines, leading to contamination of shellfish in shoreline ecosystems. Research will be conducted to study the role of aquatic surface layers in shoreline contamination within the Puget Sound area to provide better estimates of human health risk. Research will include the development of specialized sample collection and bioassay techniques, and laboratory- and intermediate-scale systems (mesocosms) to study this environmental pathway.

Extrapolation from Animal to Human in Dose-Response Modeling. A major concern in validating risk assessment models is extrapolating laboratory observations from animals to man. Research will be conducted to investigate the use of a small fish (Japanese Medaka) as an alternative to using mammals as a surrogate for man in measuring biological effects resulting from exposure to hazardous waste. Preliminary research results suggest that this species is sensitive to organic wastes and is easy to raise. It also has a relatively short life cycle that is advantageous in studies on effects spanning one or more generations.

Extrapolation from High to Low Dose in Dose-Response Modeling. A major concern in using dose-response models in risk assessment is the extrapolation of laboratory-derived effects from high-dose exposures to typical environmental exposures from lower doses. Laboratory experiments coupled with modeling activities will be conducted to address issues concerning the validity of extrapolating high-dose exposure models to low-dose exposure situations. Experiments will entail exposing test animals to a wide range of doses and evaluating their response. Various models for extrapolating from high to low dose will be compared to the empirical results, and their strengths and weaknesses determined.

Where deviations exist between model predictions and empirical data, further research may be necessary to determine if the deviations are a result of changes in the mechanism of toxic action upon moving from high to low dose exposure. The results of this research should provide significant insight into the appropriateness of extrapolating current dose-response models to low-dose exposure situations.

Development of Biosensor Technology. The development of biosensors that are sensitive to mixtures of organic hazardous chemicals would assist activities in site characterization and cleanup through in situ real-time detection of hot spots. Research will be conducted to investigate the natural capabilities of biosensors such those that have been found in Dungeness crabs and salmon to detect mixtures of hazardous materials. Mechanisms of detection will be examined to develop synthetic or seminatural sensors. These latter sensors could be used in robotic devices that survey areas for hot spots. Existing computer simulation programs that are based on the sensory and behavioral mechanisms used by animals like crabs to follow bait odor plumes to their source can be readily translated into robotic control programs.

Application of Remote Sensing Technology to Contaminant Transport. Determining the presence, distribution, and variation in environmental features as well as characterizing patterns in the distribution of hazardous waste materials can clarify mechanisms that result in the transport of contaminants from waste sites to adjacent or remote locations. Research will be conducted to investigate the use of remote sensing technologies to map the atmospheric transport of hazardous wastes off site. Existing technologies will be evaluated and adapted and new techniques developed to provide direct and/or indirect measurement of the atmospheric transport of these wastes.

Innovative Isolation Technique for Waste Disposal Sites. An innovative isolation technique for use at waste disposal sites will be evaluated in this project. The isolation technique would allow percolation through the waste zone while minimizing leaching. This technique would be an alternative to barrier protection. It features use of drain pipes, wick soils, and contouring to accomplish controlled percolation. If successful, advantages of using the

method include minimizing waste leaching, use of relatively inexpensive materials, no maintenance, and long-term effectiveness. The scope of this proof-of-principle study would include construction of a small demonstration model and preliminary design and cost estimate for a model site. Though directed toward Hanford waste sites (e.g., the U1/U2 crib and single-shell tanks), this technology may also be applied to many other Northwest sites. The primary utility of this method is to temporarily stabilize or reduce impacts of those sites where no available technologies are appropriate while technology development for permanent remediation continues.

Institutional Issues Related to Technology Transfer. Before hazardous waste technologies can be demonstrated at field scale, projects must meet a number of regulatory or permitting requirements. These requirements need to be clearly identified if projects sponsored by the Center are to progress smoothly from bench scale to field demonstration and eventually to commercial application. This project would examine the implications of existing regulations as they impact the development, transfer, and application of hazardous waste technology. The intent is to provide project managers with access to sources of information concerning the steps required to demonstrate new technologies and to facilitate transfer and commercialization of those technologies.

Quarterly Center Update. The Center can make an important contribution in the Northwest by helping to facilitate dialogue on hazardous waste issues, especially those related to technology development. Because potential users of this information are varied (e.g., federal, state and local governments, private industry, consultants) a periodic update on the Center's activities would help keep interested parties informed. This quarterly publication would provide periodic information to the individuals and organizations who are interested in Center activities. The publication would enable the Center to communicate progress from RD&D activities, would provide, to a limited extent, a forum for others within the region to summarize their activities, and would provide a vehicle for communicating relevant work from outside the region.

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APPENDIX A

LISTING OF NORTHWEST NPL SITES

TABLE A.1. Description of Proposed and Final NPL Sites in the Northwest and the Hanford Site^(a)

Site	Location	Source	Contaminant
<u>Cascade and Western Zone</u>			
American Lake Gardens	Tacoma, WA	McChord AFB degreasing activities	TCE, 1,2-transdichlorethylene, VOCs
Bangor Ordnance Disposal	Bremerton, WA	Munitions supply depot for Pacific Fleet munitions disposal activities	Trinitrotoluene, cyclonite, RDX
Fort Lewis Landfill #5	Tacoma, WA	Solvents, plating wastes, general refuse	Solvents, plating wastes, PCBs, chromic acid
McChord AFB Wash Rack/Treatment	Tacoma, WA	Airplane washing, other activities	Methylene chloride, chloroform, benzene, plating wastes, zinc chromate primer, TCE
Naval Air Station Ault Field	Whidbey Island, WA	Machine shop activities, general refuse	Likely PCBs, oils
Naval Air Station Whidbey Island Seaplane Base	Whidbey Island, WA	Operation and maintenance of aircraft and facility	Solvents, lead-based paints, heavy metals
Naval Undersea Warfare Station	Keyport, WA	Torpedo and mine testing, plating activities	TCE, solvents, plating waste
Frontier Hard Chrome	Vancouver, WA	Cr electroplating facility	Cr, Ni, Pb, CCL ₄ , TCE, TCA, PCE
Allied Plating	Portland, OR	Chrome plating facility	Cr, Pb, Cu, Ni, Zn, organics
United Chrome	Corvallis, OR	Chrome plating facility	Cr
Commencement Bay Nearshore/Tideflats	Tacoma, WA	Copper smelter, pulp mill, and many other industries	PCBs, dibenzofuran, heavy metals, PAHs
Commencement Bay South Tacoma Channel	Tacoma, WA	Railroad, oil, and other industries	Chlorinated hydrocarbons, VOCs, Pb

(a) These data are currently being reviewed and may be subject to change.

TABLE A.1. (contd)

Site	Location	Source	Contaminant
<u>Cascade and Western Zone</u>			
Harbor Island	Seattle, WA	General industrial waste	Pb, PCBs, oils, heavy metals
Hidden Valley	Puyallup, WA	General industrial waste	Mn, heavy metals
Northwest Transformer	Everson, WA	Salvage of electrical equipment	PCBs
Gould, Incorporated	Portland, OR	Battery recycling and disposal facility	Pb, PbO dust
Western Processing	Kent, WA	Solvent recovery, acid and caustic neutralization, and heavy metal precipitation operations	PCBs, PAHs, metals
Queen City Farms	Maple Valley, WA	Disposal of industrial waste	Phenols, heavy metals, PCB, cyanide, PAHs, ketones
Midway Landfill	Kent, WA	Refuse, demolitions waste	Methane, heavy metals
Lakewood Site	?	Commercial dry cleaning	Chlorinated organic compounds
Wycoff Company	Bainbridge Island, WA	Wood treatment facility	Creosote, PAHs, fuel oil, pesticides
Toftdahl Drum Site	Battleground, WA	Plywood manufacturing	PCBs, Cd, Cr, Cu, Pb
Teledyne Wah Chang	Albany, OR	Production of zirconium and other rare earth metals	Thiocyanate, MIBK, chlorinated solvents, Cd, radium, Ba, Cr, Pb, U, Th, Zr
<u>Intermountain Zone</u>			
Mica Landfill	Mica, WA	Municipal refuse, industrial waste (dross, baghouse dust, asbestos)	1,1,1-trichloroethane, chloroform, VOCs
Northside Landfill	Spokane, WA	Municipal waste, light industrial chemicals, sewage sludge	TCE, PCE, chlorides, nitrates, VOCs
Old Inland Pit	Spokane, WA	Industrial waste	Heavy metals
Colbert Landfill	Colbert, WA	Municipal and liquid solvent wastes	1,1,1-trichloroethane, methylene chloride, MEK, TCE

TABLE A.1. (contd)

Site	Location	Source	Contaminant
<u>Intermountain Zone</u>			
Greenacres Landfill	Greenacres, WA	Municipal refuse, nearby industries	Heavy metals, VOCs, chlorinated organic solvents
Kaiser Aluminum	Mead, WA	Spent aluminum pot liners	Cyanide
Martin Marietta	The Dalles, OR	Aluminum smelter	Cyanide, fluoride, PAHs
Silver Mountain Mine	Loomis, WA	Process of extracting gold from mine tailing	Primarily cyanide, also trace metals, Cd, Cu, Zn, Cr, Pb
Pesticide Experimental Laboratory	Yakima, WA	Pesticide storage/formulation/mixing facility	Pesticides, including DDT
FMC Corporation	Yakima, WA	Agricultural pesticide processing	Agricultural pesticides
Umatilla Army Depot Lagoons	Hermiston, OR	Bomb washout facility	RDX, nitrate, pesticides, DDT, lindane, tetrachloroethylene, TCE, caustic brine
Pacific Hide and Fur	Pocatello, ID	Scrap metal recycling (capacitors and transformers)	PCBs, naphthalene, phenanthrene, heavy metals
Union Pacific Sludge Pond	Pocatello, ID	Railroad oil/water separation plant	VOCs, Cu, Zn, pentachlorophenol
Hanford Site 100 Areas (Production Reactor Areas); 200 Areas (Chemical Separations and Waste Management Areas); 300 Areas; 300 Areas (Fuel Fabrication and Laboratories), 1100 Area (Site Services and Transportations)	Richland, WA	Production of special nuclear materials	Heavy metals, radionuclides, nitrates, cyanide, 1,1,1-trichloroethane, carbon tetrachloride

TABLE A.1. (contd)

Site	Location	Source	Contaminant
<u>Rocky Mountain Zone</u>			
Bunker Hill Smelter	Smelterville, ID	Lead and zinc smelter	Pb, Zn, As, Cd, Hg
Anaconda Smelter	Anaconda, MT	Zinc, copper, lead smelting	Pb, Cu, Cs, As, Zn, Be
Milltown Reservoir Sediments	Milltown, MT	Mine waste sediments	As, heavy metals
Mouat Industries	Columbus, MT	Chrome ore processing	NaCrO ₄ , Na ₂ Cr ₂ O ₇ , Cr, As, phenols
East Helena	East Helena, MT	Lead and zinc smelter	As, Pb, Cd, Zn, Ag, Hg, Se, Tl, Cu
Silverbow Creek	Butte, MT	Waste transport conduit for mining, other industrial, municipal wastes	Heavy metals, PCB
Montana Pole Treatment	Butte, MT	PCP, cresote wood treatment	PCP, creosote, dioxin, diesel oil
Libby Groundwater	Libby, MT	Wood-treating facility	PCP, PAHs, As, Pb
Burlington Northern Somers Tie Treating Plant	Somers, MT	Railroad tie treating facility	PAH, heavy metals
Idaho Pole	Bozeman, MT	Wood treatment facility	PCP, dioxin
Arrcom Corporation Drexler Enterprises Incorporated	Rathdrum, ID	Waste oils recycling facility	Chloroform, possible PCB-contaminated oils, Hg

APPENDIX B

SUMMARY OF FY87 ACTIVITIES

APPENDIX B

SUMMARY OF FY87 ACTIVITIES

In FY87, DDE provided \$1.015 million to establish the Center and initiate an RD&D program on hazardous and radioactive mixed-waste technology issues related to the Hanford Site. This section briefly summarizes the RD&D activities conducted by the Center in FY87. The Center's Annual Report for FY87 contains more detailed descriptions of the Center's activities and lists associated publications.

The Center initiated eight research projects in FY87. Two of the projects were related to Remedial Investigation Technologies and six were related to Waste Treatment Technologies. In addition, the Center conducted several program planning and support activities to define RD&D priorities for FY88 and beyond and to initiate interactions with organizations in the Northwest and elsewhere. The following subsections contain brief summaries of the rationale for and accomplishments of each project.

REMEDIAL INVESTIGATION TECHNOLOGIES

The projects conducted in FY87 under this task included two site characterization activities: Criteria for Waste Site Cleanup and Advanced Site Characterization Sampling Methodology. These projects are described in the following subsections.

Criteria for Waste Site Cleanup

One of the biggest challenges faced by the Superfund program is deciding when a hazardous waste site has been sufficiently remediated. Criteria selected to evaluate the success of cleanups have varied from site to site since the enactment of the Comprehensive Environmental Response Compensation Liability Act (CERCLA) in 1980. A variety of federal, state, and local standards, criteria, and guidelines have been used to date.

The goal of this project was to provide guidelines for defining appropriate endpoint cleanup criteria, based on a review of previous government and industry efforts and current cleanup criteria strategies. These guidelines will enable users to negotiate cleanup criteria in support of a Record of Decision (ROD) in a constructive and efficient manner.

Interviews were conducted with EPA Superfund Site Managers in Region X and in Region VIII at the Montana Field Office, as well as with regulators from state hazardous waste programs to review how cleanup endpoints were determined in past site cleanups. The associated reports on previous CERCLA site cleanups were reviewed, including Site Inspections (SI), Remedial Investigation/Feasibility Studies (RI/FS), Remedial Actions (RA), and Records of Decision (ROD) to determine specific cleanup standards used. Federal legislation addressing hazardous waste cleanup efforts was examined, including the Resource Conservation and Recovery Act (RCRA), CERCLA, SARA, Safe Drinking Water Act, Clean Water Act, Clean Air Act, and Toxic Substances Control Act. In the study, a review was conducted of statistical approaches for determining whether an endpoint is reached after remediation when a site contains areas of higher than average concentrations of hazardous material (e.g., "hot spots"). The results of this study provide the necessary background information for designing site monitoring programs to verify the effectiveness of remedial actions taken. A letter report with the findings of this study will be issued in FY88.

Advanced Site Characterization Sampling Methodology

Hazardous waste sites vary in size, in terrain, and in types and dispersal patterns of hazardous materials. A common problem associated with all sites is the identification and physical characterization of contamination. Traditional trial-and-error methods are inefficient and expensive because of the high cost of collecting and analyzing one sample. In addition, traditional sampling strategies used in estimating average concentrations or totals are highly inefficient when used to detect contamination or identify dispersal patterns. Sampling strategies specific to these goals need to incorporate prior information related to the dumping or spill history, expert opinion of contaminant migration or containment, and nonconventional techniques for "hot spot" detection.

To minimize the cost of site characterization, the sampling strategy must be optimized relative to both the number of samples taken and the number of samples undergoing chemical analysis. Thus, the use of oversampling and composite chemical analysis techniques plays an important role in strategy selection.

The goal of this project was to develop a system that could help the user tailor and optimize sampling strategies to each site's specific needs, based upon the use of prior information, and that could also analyze data to facilitate site characterization and cleanup. In FY87, a computer workstation design was completed that identified needed hardware and software. The workstation includes specialized graphic and modeling capabilities that address the spatial nature of waste site data.

Sampling strategies were developed that use prior information on the site to minimize the error associated with characterizing a hazardous waste site. Judicial use of sample compositing techniques in conjunction with oversampling designs was shown to enhance waste detection rates while minimizing the loss of spatial information.

Specialized software was developed to calculate the uncertainty associated with different sampling strategies under different waste disposal scenarios and the probabilities of waste detection based on site-specific prior information. This software is compatible with mainframe and MicroVAX workstations and will ultimately be applied to an expert system that will be used to determine sampling strategies at any hazardous waste site.

WASTE TREATMENT TECHNOLOGIES

The projects conducted in FY87 under this task included four waste destruction technologies, one separation technology, and one stabilization technology. Destruction techniques included thermal, chemical, and biological processes. The separation technology was a method for optimizing well placement to either improve the efficiency of withdrawing contaminated groundwater for at-grade treatment or isolate the contaminant plume. Finally, the stabilization technique was an in situ thermal process that concurrently destroys organics and stabilizes residual refractory material.

Catalytic Destruction of Hazardous Organics in Aqueous Solution

Research was conducted to develop a thermal process for destroying organic and chlorinated organic wastes in aqueous solutions at moderate temperatures. Aqueous solutions containing 0.1% to 10.0% organic material^(a) were treated with a transition metal catalyst in a 1-L autoclave; temperatures of 350° to 460°C and resulting pressures of 2000 to 5000 psig converted the wastes to innocuous gases. Conversions greater than 99% were achieved for hexone (methyl isobutyl ketone or MIBK), hexane, p-cresol, benzene, naphthalene, chlorobenzene, and trichloroethylene (TCE). Hexone was selected because it is stored at the Hanford Site; remediation options will be reviewed for this material in FY88. The remaining compounds were selected because they are representative of the classes of compounds found at Northwest waste sites. The process products for the nonchlorinated organic compounds were methane, carbon dioxide, and hydrogen. The major products from chlorobenzene destruction were benzene and hydrochloric acid. The major products from TCE destruction were carbon dioxide and hydrochloric acid. In tests with the chlorinated compounds, some of the nickel catalyst was converted to nickel hydroxide, possibly because of the presence of the hydrochloric acid. Additional research will be needed to further evaluate this deactivation mechanism and to evaluate pretreatment processes to dechlorinate the organics.

Electrochemical Oxidation of Hexone and Other Organic Wastes

Research was conducted to determine the technical feasibility of destroying concentrated, hazardous organic wastes, which are often present near a waste site's contaminant sources, using a catalytic electrochemical oxidation process. These types of wastes can be found at Superfund sites and at the Hanford Site; specifically 114,000 L of hexone that are slightly contaminated with radionuclides are stored on site, and remediation options will be reviewed in FY88. The process operates at atmospheric pressure and temperatures at or

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- (a) This process can treat a waste stream containing 0.01 to 0.50 wt% organics in aqueous solutions. The range of 0.1 to 10 wt% was chosen because streams with this composition cannot be treated economically by incineration or conventional water treatment methods. Consequently, this process represents a unique treatment solution for waste streams with this composition.

below 50°C. A liquid organic waste is mixed with HNO_3 or H_2SO_4 and transferred to the anode compartment of an electrochemical cell. The anolyte contains metal ions that are maintained in the higher oxidation states electrochemically. These metal ions are strong oxidizers that catalyze the organic destruction reaction. Experiments were conducted to determine the effectiveness of the technique for various hazardous chemicals that could be oxidized, process energy requirements, operating parameters, and the basic conversion mechanism.

The focus of the work was on destruction of hexone (MIBK); however, a limited number of tests were run using phenols, aromatic hydrocarbons, and chlorocarbons that have more general applicability at Hanford, in the Northwest, and across the nation. It was determined that electrolytes containing cobalt and nickel as the oxidant ion could destroy more than 99% of the organics tested. Manganese was a less effective catalyst and caused a rapid buildup of a dioxide precipitate on the Teflon® membrane used to separate the anolyte and catholyte; this phenomenon resulted in blocking of the cell. The energy requirements for destroying hexone were calculated to be 0.03 kW/g hexone.

Furthermore, it was determined that nitric acid was an effective agent for maintaining cobalt and nickel ions in solution because it was involved in the overall reaction. Sulfuric acid was much less effective. A higher temperature of 50°C appeared to be more effective at destroying hexone; however, elevated temperatures may have caused an increase in evaporation rate rather than an increase of destruction rate. Platinized titanium was found to be superior to graphite or stainless steel as the anode material. Graphite was more durable than stainless steel as the cathode material; however, graphite also caused the evolution of hydrogen.

In the future, project activities will be expanded to evaluate use of electrochemical oxidation to destroy other organic wastes found at Northwest

* Teflon is a trademark of E. I. Du Pont de Nemours of Wilmington, Delaware.

sites. A pilot-scale process will be designed, and an economic analysis conducted, and if it is economically feasible, the process will be demonstrated on a pilot scale.

Biodenitrification of Single-Shell Tank Wastes

Research was conducted to investigate the feasibility of using facultative anaerobic microorganisms to denitrify, in situ, salt cake contained in underground single-shell tanks at the Hanford Site. Candidate microorganisms that could denitrify simulated tank contents were isolated, identified, and tested. Through laboratory screening tests, important physicochemical parameters such as carbon sources, moisture, pH, and radiation fields were quantified to identify the environment required to support biodenitrification. Based on available information, engineering and process requirements for in situ biodenitrification were evaluated and key characteristics of the single-shell tank contents were identified. The conditions under which the microbes denitrified the simulated waste were compared to conditions within the tanks to determine the feasibility of the proposed in situ denitrification.

Experiments showed that it was possible to denitrify simulated single-shell tank wastes that had been diluted with 10 to 50 parts of water. Addition of water to these tanks is not desirable, however, from a waste management perspective, because excess liquid could result in leaks through failed tank walls. In addition, the process produced substantial quantities of biomass, sediments, and sodium sulfate or other sodium salts as by-products of the process. For these reasons, biodenitrification of the single-shell tanks is not recommended as a primary in situ treatment process. The results did suggest, however, that the concept may be appropriate for treating more dilute nitrate-containing waste streams and contaminated groundwaters found at the Hanford Site. Therefore, it was recommended that future work focus on these wastes.

In Situ Biological Decontamination of Hazardous Chemical Waste Sites

Research was conducted to characterize the types and activities of microorganisms indigenous to hazardous chemical waste sites (HCW) containing radioactive isotopes. Research focused on identifying and evaluating bacteria, fungi, and actinomycetes that inhabited a site at Hanford that had received

wastes from metal finishing. Inhibition of the microorganisms by heavy metals known to be present at this site was of particular interest. Experimental studies on the population densities of indigenous bacteria, actinomycetes, and fungi were found to be much higher than expected and, in some cases, were as large or larger than those populations found at an uncontaminated control site. In addition, the population densities of bacteria and actinomycetes did not decrease significantly with depth below ground surface. Bacteria were more abundant than either actinomycetes or fungi in the HCW sites; however, the density of actinomycetes approached that of bacteria in many samples. The proportion of fungi to bacteria and actinomycetes was less than is commonly seen in soils and may reflect greater sensitivity of fungi to the levels of heavy metals found at the HCW site.

Preliminary chemical and physical characteristics of the soil showed that heavy metals were present in large concentrations at this site. For example, copper (Cu) concentrations in some samples were $>8000 \mu\text{g/mL}$ (ppm). Therefore, bacteria and actinomycetes isolated from the site were tested for their resistance to Cu. Initial results suggest that microbial populations are resistant to Cu, with some isolates resistant to Cu concentrations of $300 \mu\text{g/mL}$. Some of these isolates grew in the presence of $3000 \mu\text{g/mL}$ Cu. Additional tests to quantify the resistance of microbial populations to mercury and chromium, to determine the rate of organic destruction in the presence of heavy metals, and to determine the effect of organic degradation and subsequent metal complexation and mobility are underway.

Optimal Pumping and Siting of Wells in Contaminated Aquifers

Groundwater contamination is often discovered at sites where casual and unmonitored waste handling have been practiced. In many cases, this contamination can be reduced and contained by the judicious use of monitoring, pumping, and injection wells. Although this remedial action has been used at a number of hazardous waste sites, its success (in terms of cost and recovery) is critically dependent on effective well placement and pumping rate specification.

Mathematical optimization techniques offer a systematic approach to many complex problems that defy solution by trial and error. The nature of the well network design problem dictates that groundwater modeling be an integral component of the design methodology. In this project, groundwater flow simulation is coupled with optimization (mathematical programming) techniques to design the required well networks. The resulting design will be more efficient and less labor-intensive than the alternative of trial and error simulation.

The objective of this project was to develop a software package that could be used for designing well networks by optimizing the placement of monitoring, withdrawal, and injection wells. In FY87, the main task was the coupling of optimization software with a groundwater computer code. The initial task, however, was to link an analytical groundwater flow solution to the optimization software. This simplified arrangement yielded an easy-to-use screening tool and also provided confirmation for the overall approach. Subsequently, a numerical simulation groundwater flow model was coupled with optimization software and a water table aquifer simulation was successfully completed. The main drawback to this methodology is its dependence on reliable field data for parameter input. Therefore, future activities will account for parameter uncertainties by allowing the user to choose the confidence level with which the design would proceed.

In Situ Vittrification of PCB-Contaminated Soils

The goal of this project is to verify the fate of polychlorinated biphenyls (PCBs) in contaminated soils following application of in situ vittrification (ISV) technology. This technology can be used to destroy and immobilize both concentrated waste source material and contaminated soils. Electrodes are emplaced into the ground and an electric current is used to heat the soils until they are melted. Extremely high temperatures are reached, resulting in destruction of organics. The resulting glass-like waste form immobilizes heavy metals. This technology has been successfully tested for immobilizing radionuclides in contaminated soils; in this test, the efficiency of PCB destruction will be determined. Previous bench-scale tests indicated that PCBs could be successfully destroyed in a soil medium; the Center sponsored a pilot-scale verification test of the technology.

A 26-hour test was performed on 525 kg of soil containing 1000 ppm PCBs. The soil was buried 0.8 m deep in a 0.9-m diameter by 0.6-m high configuration. Power was applied to the ISV electrodes over a 19.6-hour period and produced a 3500 kg melt with dimensions of 1.4 m by 1.4 m by 1.5 m.

The test was stopped earlier than planned because of apparent soil sluffing and collapse of part of the cold cap that had formed during the ISV test. This event resulted in loss of hood vacuum for a brief period of time; the hood covers the ISV site. Loss of vacuum resulted in release of dust containing a small amount of PCBs around the electrode ports in the hood. Initial calculations indicate that less than 0.01 g of PCBs left the hood area.

Tests are currently under way to evaluate the performance of this process. Samples of the treated soil, hood dust, surface soil, soil adjacent to the vitrified soil, offgas scrub solution, offgas filter, activated carbon adsorber, and hood and stack offgases will be taken and analyzed to determine destruction efficiency and the extent of migration, if any; selected samples will be subjected to analyses for furans and dioxins to determine any by-product formation.

FY87 PROGRAM PLANNING AND SUPPORT ACTIVITIES

The goal of FY87 program management and planning was to develop and initiate a focused RD&D program to develop technologies, as provided by SARA, that address hazardous and radioactive mixed-waste issues for the Northwest, including the Hanford Site.

The Center conducted research and planning activities under the Program Integration Research Task; these activities led to the preparation of this program plan. To support the identification of RD&D priorities, studies were conducted using experts from PNL, Northwest universities, and private industry to assess the current status of hazardous waste technologies and to identify technology issues relevant to the Hanford Site and the Northwest.

Three draft reports identifying these technology needs were prepared by Center staff and will be finalized and published in FY88. The three draft documents are entitled

- "State-of-the-Art Assessment for Site Characterization Technologies"
- "State-of-the-Art Assessment for Environmental and Human Health Assessment Technologies"
- "State-of-the-Art Assessment for Waste Treatment Technologies."

From the findings in these reports, the multiyear RD&D objectives were developed; these objectives will serve as the technical framework for future Center activities. To gather input to the Center's planning process, a draft Program Plan was distributed to representatives from many of the region's regulatory organizations, DOE-RL, and the OEC at a workshop held in August 1987. Comments obtained at the workshop were incorporated in a draft plan submitted to DOE-RL in early October 1987. The proposed projects in this operating and management plan are based on the technology needs and goals identified in the MYPP.

Other Center activities included establishing communication with the Northwest hazardous waste management community. Briefings were held with representatives at DOE-RL, the Hanford Site OEC, EPA Regions VIII and X, EPA-HQ, EPA-Hazardous Waste Engineering Research Laboratory (HWERL), DOE-HQ, DOE-Hazardous Waste Remedial Actions Program (HAZWRAP), Agency for Toxic Substances and Disease Registry (ATSDR), U.S. Bureau of Mines-Spokane Research Center (USBM-SRC), selected Northwest industries, Northwest state agencies, selected private industries, and Northwest universities to present the Center's goals, objectives, and activities and to obtain their support and assistance in the Center's planning activities.

Another of the Center's activities in FY87 was the involvement of universities in its RD&D program and planning activities. The Center provided approximately \$60,000 to Northwest universities for technical support, including two Northwest College and University Association for Science (NORCUS)

appointees who worked at PNL for the summer. The Center also established sub-contract arrangements with five Northwest universities so that FY88 collaborative RD&D efforts and funding can be more substantive. In addition, one Northwest university faculty member was granted a 1-year leave to participate in technical projects and serve as the Center's university liaison for FY88.

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