# MANAGING SUBSURFACE CONTAMINATION

Improving Management of the Department of Energy's Science and Engineering Research on Subsurface Contamination

Prepared for the U.S. Department of Energy by

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## Acronyms and Abbreviations

| | |
|---|---|
| ASTD | Accelerated Site Technology Deployment [program] |
| DARPA | Defense Advanced Research Projects Agency (in the Department of Defense) |
| DDR&E | Office of the Director of Defense Research and Engineering (in the Department of Defense) |
| DOE | U.S. Department of Energy |
| DOE-EM | Office of Environmental Management, U.S. Department of Energy |
| EMSP | Environmental Management Science Program |
| GAO | General Accounting Office of the U.S. Congress |
| INEEL | Idaho National Engineering and Environmental Laboratory |
| ITRD | Innovative Treatment and Remediation Demonstration |
| M&I | management and integration |
| M&O | management and operations |
| NIH | National Institutes of Health (in the Department of Health and Human Services) |
| NRC | National Research Council (advisory study arm of the National Academy of Sciences and National Academy of Engineering) |
| OST | Office of Science and Technology |
| R&D | research and development |
| RD&D | research, technology development, and deployment |
| S&T | science and technology |
| SCFA | Subsurface Contaminants Focus Area (of the Office of Science and Technology) |
| WAG | The Washington Advisory Group, LLC |
| WIPP | Waste Isolation Pilot Plant |

# Contents

# Executive Statement

The Department of Energy (DOE) has recently agreed that its responsibilities for environmental management at weapons production and material storage sites include a significant amount of *long-term stewardship*, as well as the previously planned cleanup of sites in accordance with applicable requirements. DOE has defined long-term environmental stewardship as "all activities required to protect human health and the environment from hazards remaining after cleanup is complete" (DOE, 1999, p. 9). In the spring of 1999, DOE asked the Washington Advisory Group (WAG) to evaluate the Department's management and policy framework for subsurface science and technology (S&T) programs, with an emphasis on the balance between near-term project needs and long-term site remediation goals. The results of the WAG study are particularly relevant to the emergence of environmental stewardship as a major complement to site cleanup in accordance with legal and regulatory requirements. Because WAG sees cleanup (or remediation) and stewardship, as defined by DOE, as interrelated, continuing roles for DOE at the sites with subsurface contamination problems, this report uses the phrase "remediation and stewardship" to refer to a coherent approach to both.

While WAG recognizes the difficult budgetary environment in which DOE and the Office of Environmental Management (DOE-EM) must operate, we found that the current level of funding for long-term scientific research and technology development is inadequate to meet DOE's remediation and stewardship responsibilities. In particular, the budget for research, technology development, and deployment (RD&D) in subsurface science should be sized to reflect a meaningful investment in reducing the long-term costs and improving the effectiveness of remediation and stewardship through new knowledge and technology. A key element in bolstering the basic science component of an appropriate RD&D program is a significantly increased investment in the Environmental Management Science Program (EMSP). This program has not been funded or managed to achieve the purpose for which Congress created it. To match the basic research expenditures across all of DOE and to have the impact Congress intended, EMSP funding should be increased about fourfold from recent levels.

Inadequate funding is not the only barrier to providing the S&T needed for long-term remediation and stewardship. EMSP and all the technology RD&D programs in DOE-EM must be administered as elements in a coherent strategy for moving research and new technology to maturation and operational deployment. At present, these programs are still plagued by funding gaps in the maturation process that abandon promising research results and technological innovations. These gaps are less a consequence of inadequate funding for environmental management—which constitutes a third of DOE's budget—than a result of the continued existence of long-acknowledged barriers to introduction of innovative technology into site operations. Nevertheless, WAG found numerous examples of programs and activities that have been successful in overcoming these barriers. At all levels from the Secretary to the Assistant Secretary for Environmental Management and the field offices with site manager responsibilities, DOE must recognize these internal "best practices" and learn to expand on their success.

Similarly, there are models for best practices in other government agencies with major mission-oriented RD&D programs and in private-sector companies whose success depends on technological innovation. Adoption of both internal and external best practices could go a long way to overcoming the barriers to innovative cleanup technologies that both internal DOE studies and external advisory groups have documented.

The continued existence of many of these barriers, which WAG confirmed during its own site visits and interviews, is a serious impediment to success in the remediation and stewardship mission. Underlying many of these barriers, WAG found a diffusion of accountability, stemming from complex lines of authority and responsibility throughout DOE-EM activities concerned with managing S&T to address subsurface contamination. Changes are needed to achieve direct lines of responsibility with fewer decision points, but with the capacity for each decision to be based on sound technical judgment. Although significant reforms in management of the relevant subsurface science and technology have been instituted during this period, the Department still faces formidable challenges to effective management. Similar views have been repeated by many studies by highly qualified groups in the past; now is the time to act on the recommendations not yet implemented. Chapter 2 of this report highlights key recommendations from other studies that could be implemented now.

A lack of technical strength within the Office of Science and Technology (OST) in DOE-EM is another factor constraining the success of the S&T programs. WAG recommends that the technical capacity of the OST be strengthened to oversee the scientific and technological aspects of the subsurface contamination area. The WAG team recognized that there are advantages and disadvantages to moving the technical leadership of the Subsurface Contaminants Focus Area to DOE headquarters in Washington, D.C., while maintaining the technical competence at the sites. We suggest that DOE consider the benefits of such a move in simplifying responsibility and authority in subsurface contaminant S&T management. The establishment of focus areas has been a major improvement for integrating and coordinating programs across DOE field offices, laboratories, and clean-up sites, but simplification of lines of authority and decision processes is critical to overcoming the diffuse accountability and difficulty of decision making that still hampers progress.

At the field offices and sites, WAG found excellent examples of DOE and contractor teams working in partnership with regulators and community stakeholders to achieve the regulatory flexibility needed to demonstrate and deploy innovative technologies. WAG believes DOE should be proactive in working with regulators, stakeholders, and government officials on regulatory changes that could improve remediation and stewardship options while reducing costs.

Beyond the subsurface contamination problems at DOE sites, contamination of potable groundwater is a nationwide and global problem to which DOE's mission-directed RD&D could make a major contribution. Other federal agencies, including the Environmental Protection Agency, the U.S. Geological Survey, and the U.S. Department of Defense, also have significant research and development (R&D) programs in studying subsurface and groundwater contamination. WAG urges DOE to take the initiative in establishing a subcommittee of the National Science and Technology Council, with the aim of coordinating a national research effort, involving these and other programs, to address groundwater contamination from all human sources.

The report contains the following recommendations, numbered by chapter. Within the report chapters are an implementation strategy and the supporting rationale for each recommendation.

**Recommendation 2-1.** The Secretary of Energy, the Assistant Secretary for Environmental Management, and the Office of Science and Technology should now act on the advice received from the plethora of studies that have been done and the abundant advice that has been sought and given.

**Recommendation 3-1**. The Assistant Secretary for Environmental Management and the Deputy Assistant Secretary for Science and Technology should apply the best RD&D practices from successful S&T organizations within the federal government, as well as adapting appropriate practices of the private sector, to improve DOE-EM's effectiveness in exploiting and disseminating new scientific and technical knowledge relevant to subsurface characterization and remediation..

**Recommendation 3-2.** DOE should identify and improve mechanisms already existing in DOE for the interchange of research results and transfer of technical know-how (practical experience with technologies).

**Recommendation 3-3.** DOE-EM and the field offices should apply the lessons learned from the Waste Isolation Pilot Plant and the Yucca Mountain Project to long-term remediation and stewardship at the cleanup sites.

**Recommendation 3-4.** Models should be used with caution because the underlying science may be insufficient, the mathematical representation cannot be complete, significant data are usually missing, and exogenous events will be difficult to incorporate in the representation.

**Recommendation 4-1.** DOE, at the Departmental, DOE-EM, and field office levels, must recognize programs and activities that have been successful in overcoming acknowledged barriers and must expand on these successes.

**Recommendation 4-2.** The Deputy Assistant Secretary for Science and Technology and the Assistant Secretary for Environmental Management must take action to arrest the downward spiral in funding of long-term R&D and gain support for adequate funding.

**Recommendation 4-3.** DOE should revise its complex management structure to achieve direct lines of responsibility, fewer decision points, and the capacity at each decision point for good technological judgment.

**Recommendation 4-4.** OST should strengthen the focus area approach in OST by increasing the S&T capability at headquarters, but without diminishing the S&T strength at the field offices. Consideration should be given to whether the advantages of moving the technical management of the Subsurface Contaminants Focus Area to OST headquarters in Washington D.C. outweigh the disadvantages.

**Recommendation 4-5.** In meeting regulatory requirements, DOE should fully explore options for greater regulatory flexibility that will better address the realistic limits of available technology and expectations for new technology.

**Recommendation 4-6.** OST and the DOE site managers responsible for S&T roadmapping should ensure that realism about costs, schedules, and budgets are incorporated in the roadmapping process and the products. Long-term needs should be identified and included in a roadmap's schedules and budgets, although the uncertainties arising from projection of long-term progress in S&T must also be captured.

**Recommendation 5-1.** DOE must recognize the importance of long-term commitments in scientific research and technological innovation as investments toward reducing the costs and improving the effectiveness of environmental remediation and stewardship. The Secretary of Energy should instruct the Assistant Secretary of Environmental Management to make the Environmental Management Science Program (EMSP) the flagship program for basic research in environmental management and remediation. The funding for EMSP should be increased about fourfold from recent levels.

**Recommendation 5-2**. The Assistant Secretary for Environmental Management should administer the RD&D programs supporting DOE's environmental management mission as elements in a coherent strategy for moving technologies and new knowledge to maturation and operational deployment.

**Recommendation 5-3.** DOE-EM should estimate the magnitude of expected annual subsurface remediation and stewardship costs at the long-term stewardship sites as a function of the cost stream over time (including all the life-cycle components of cost). It should then size its annual subsurface RD&D budget according to a reasonable projection of the return on investment from reducing these costs through new knowledge and technological advances.

**Recommendation 5-4.** DOE should take the lead in establishing a subcommittee of the National Science and Technology Council to pursue a coordinated national program for addressing groundwater contamination from all human sources.

# 1

# Introduction

The U.S. Department of Energy (DOE) requested that the Washington Advisory Group (WAG) provide an independent evaluation of DOE's current and planned environmental research, technology development, and deployment (RD&D) efforts related to contaminant flow through the vadose zone and related groundwater systems at DOE cleanup sites. Other independent groups are also providing broad evaluations of RD&D efforts at these sites and throughout DOE. WAG was asked to focus on policy and management issues in DOE's subsurface science and technology (S&T) programs, with the aim of suggesting improvements applicable to the Hanford site and across the DOE complex. Of special interest was the balance of research and engineering efforts between near-term project needs and long-term site cleanup goals. (The charge to the WAG project team is in Appendix A.)

The WAG project was divided into two phases. In Phase 1, the WAG team conducted a survey of recent relevant literature, including DOE and Hanford reports, studies and evaluations by committees of the National Research Council (NRC) and other outside groups, reports to Congress by the General Accounting Office (GAO), and peer-reviewed scientific journals. Team members interviewed current and former DOE managers and government officials. They visited DOE facilities and interviewed staff at Sandia National Laboratory, Idaho National Engineering and Environmental Laboratory (INEEL), the Las Vegas offices of the Yucca Mountain Project, and the Savannah River Site. All WAG team members visited the Hanford site. The information gathered from these sources, together with the broad experience of the team members, provided the basis for a set of tentative findings and recommendations presented in the first, preliminary draft of this report in August 1999. In addition, a review of the S&T plan and roadmap for the Hanford Integration Project was issued in June 1999 (WAG 1999); pertinent results and findings from that review have been incorporated in this report.

In Phase 2, the WAG convened three workshops of selected experts, chosen for their expertise in relevant scientific and engineering disciplines, private-sector technology management, and leadership in major governmental technology programs. They joined the WAG team members in evaluating and contributing to the report's factual basis and analyses. Each workshop provided an independent assessment of the validity of the draft conclusions and the practicality of the tentative recommendations. The workshop results were then used to prepare this final report. Unless otherwise stated, all budget references are to the proposed fiscal year 1999 (FY 99) DOE budget, which was the most recent version available when the workshops met.

In government as in the private sector, reorganization of an entity is considered whenever it is not functioning as well as needed. While the WAG team was gathering information for this report, a public debate was intensifying over the apparent lack of accountability for activities and practices affecting national security within the weapons-related programs, offices, and laboratories of DOE. Now, in the fall of 1999, that debate has culminated in legislation to establish an agency within DOE with full responsibility—and accountability—for safeguarding nuclear weapons information and the weapons-grade material stockpiles at DOE sites. We found an interesting parallel with DOE's mission in environmental management at current and former weapons production sites. During our interviews with current and former DOE officials in the spring of 1999, several former high-level managers of DOE's environmental management programs suggested radical organizational changes to address problems, similar to the proposals made for the weapons stewardship mission. Among the options suggested to us were (1) a semi-independent agency for environmental management within the Department of Energy, reporting to the Secretary of Energy; (2) an independent agency for environmental stewardship and remediation of DOE sites; or (3) transfer of the entire environmental management operation to another federal agency.

In the third WAG workshop, which was attended by former executive managers of S&T-oriented government agencies and commercial companies, a consensus emerged about the problems in the DOE environmental management programs. This experienced group of managers thought that a diffusion of *accountability*, stemming from complex lines of authority and responsibility, was central to the pattern of problems observed by WAG or reported by others.

After reflecting on the potential advantages and disadvantages of radical organizational change and discussing them in the WAG workshops, the WAG team decided that changes at this scale were beyond its charge. The environmental remediation and stewardship of the sites must be managed effectively within modest changes in the present organizational structure. Any form of institutional restructuring, however modest, will only be effective if accompanied by significant improvements, as recommended in this report, in the systems for RD&D management and site contracting of environmental management. The WAG team has therefore focused on opportunities for improving these systems, whether within the present structure of the Office of Environmental Management (DOE-EM) or in some alternative structure. As noted in one WAG workshop, the problems have been with DOE for twenty years, and they will not be solved until the assignment of accountability and the hierarchy of managerial responsibility are clarified.

# 2

# A Surfeit of Advice, A Dearth of Action

> **Recommendation 2-1**. *The Secretary of Energy, the Assistant Secretary for Environmental Management, and the Office of Science and Technology should now act on the advice received from the plethora of studies that have been done and the abundant advice that has been sought and given.*

**Implementation Strategy.** From among the many insightful and useful findings and recommendations presented in many reports during the past decade, the WAG recommends action on the following: Remediation endpoints and schedules negotiated and renegotiated in compliance agreements must be derived from a solid scientific and technical foundation. Technology development projects should be based on specific needs at DOE sites. End users, stakeholders, and regulators should be consulted in planning every demonstration that DOE-EM funds. The organizational structure of DOE-EM should provide focused and consistent line management authority and responsibility for project performance. Where appropriate and applicable to the DOE-EM environment, the Office of Science and Technology (OST) should adopt basic principles of the use of S&T in private-sector decision-making and implementation practices.

**Rationale.** The leaders and staff of DOE-EM are operating the world's largest and most costly environmental remediation project. They are trying to do so under a barrage of criticism, and sometimes litigation, from members of Congress, state and local governments, other federal agencies, advisory groups, stakeholders, and national interest groups. Many of the impediments to progress arise from laws, regulations, budget allocations, and other limitations set by Congress or federal and state regulatory agencies. However, many other impediments are within the control of DOE-EM. The externalities are here to stay, and success in the subsurface cleanup mission will depend on DOE actions.

Since the early 1990s, reports and comments by the GAO, NRC committees, congressional committees, and DOE-appointed advisory committees have commented on DOE management and other practices in cleaning up contaminated sites. Appendix B lists reports in this vein that have been reviewed by the WAG team. Although the charge to WAG focuses on management of the S&T program for subsurface contamination problems, the team's study of the literature, interviews with senior officials, and field site visits leads it to agree with many of these oft-repeated appraisals. The characterization, remediation, and management of subsurface contamination problems at DOE sites cannot be divorced from a range of issues that go beyond these problems. During our study of S&T management by DOE-EM, the WAG team found that many of the findings and recommendations by other advisory bodies also apply to management of S&T for subsurface contamination.

DOE has attempted over the years to address some of the problems identified by prior reports, and follow some of the advice they offered. Other problems have been beyond DOE or DOE-EM control, as they are consequences of congressional action, federal and state legal and regulatory constraints, and stakeholder interests. Yet, many internal impediments remain that could be removed or ameliorated by management action and policy redirection. The WAG team has summarized here some of the past findings and recommendations about S&T programs, organizations, and management practices, not only to recognize the contributions of our predecessors but also to synthesize common themes. WAG recognizes that its recommendations addressing management of subsurface contaminant S&T can only be effective if DOE responds in a forthright manner to the substance of many of the criticisms and recommendations in prior reports.

The plethora of advice, criticism, and recommendations from so many sources within and outside DOE can easily overwhelm even the most responsive managers of a government agency. A series of reports released in 1997 and 1999 by the NRC and a letter report by the Laboratory Advisory Committee of Pacific Northwest National Laboratory update the many earlier studies. In the remainder of this section, we will draw on these more recent documents to begin pulling together the most significant themes. In the supporting discussion of our recommendations in Chapters 3 through 5, we refer to the key findings and recommendations selected here, as well as citing some of the supporting evidence and analysis provided in these documents.

In 1997, a study committee of the NRC released its final assessment of DOE's Environmental Management Science Program (EMSP). Referring to the intent of Congress in setting up the EMSP and the design under which it was operating, the study committee characterized EMSP as a "mission-directed basic research program." The committee noted the value of such a program for generating new knowledge; training future generations of scientists and engineers; and promoting partnerships among universities, the DOE national laboratories, other federal agencies, and the private sector. The committee also stressed that the EMSP potentially could have a special value, not found in other federal programs for basic research in the core scientific disciplines for environmental management, if the program followed the committee's advice on establishing explicit links to the problem holders at the DOE sites (NRC, 1997b, pp. 25-26).

> The movement of new knowledge and insights from investigators to full-scale application is a slow and diffuse process—a process without clear pathways in most cases. As a way of facilitating this information flow and stimulating new research ideas, the EMSP should convene annual workshops, seminars, and symposia that bring together EMSP investigators, program managers from [DOE-EM and the Office of Science] (including those in [DOE-EM] focus areas), site contractors and other "problem holders," and, when appropriate, other stakeholders, regulators, and principal investigators and managers from other research programs.
>
> (NRC, 1997b, p. 66)

As we discuss below under Recommendation 5-1, the committee was also concerned about the low level of initial funding for EMSP, given its ambitious charter, but hoped that success in the program would lead to growth in funding. Some of the committee's suggestions, such as the recommendation for regular meetings of EMSP investigators with program managers, site contractors, and others responsible for remediation and stewardship activities, are now being implemented, but other issues noted by this NRC committee remain. In Chapter 5, WAG provides its own assessment of how EMSP has fared in the years since this NRC report and recommends management actions needed to make it DOE's "flagship program" for basic research in environmental remediation and stewardship.

In January 1999, the Laboratory Advisory Committee for the Pacific Northwest National Laboratory sent a letter to the Secretary of Energy, addressing barriers to progress in cleaning up the Hanford site (PNNL Advisory Committee 1999). While all the strategies for reform listed in the letter are worth attention, the WAG team selected those shown in Box 1 as having particular relevance to improving DOE management and policy relevant to subsurface contamination S&T.[1]

A major institutional and regulatory barrier at Hanford, according to the Laboratory Advisory Committee, consists of compliance endpoints and commitments

**BOX 1. Selected Recommendations of the Laboratory Advisory Committee for PNNL**

LAC-1. [To address *institutional and regulatory* barriers:] Endpoints and schedule commitments negotiated in compliance agreements must be derived from a solid technical scope of work with clear requirements. Processes to define scope, schedule, and cost need to be linked, not decoupled. Regulators and DOE need to establish and own the technical requirements for cleanup, and these must have a solid technical and scientific foundation.

LAC-2. [To address *budget and resources allocation* barriers:] Improve funding continuity. Provide multi-year or total project funding for specific projects that have defined endpoints and technically valid baselines that DOE, regulators, and contractors agree to and will be held accountable for achieving.

LAC-3. [To address *scientific and technical* barriers:] The Department's scientific and technical expertise must be an integral part of the processes that assess the nature and magnitude of cleanup problems and that define endstates for cleanup efforts. These fundamental cleanup requirements must be based on the best available technical information. . . . Actively assess new information to support "responsible stewardship." For those portions of the cleanup effort that are addressed through stewardship, the scientific and technical community must be involved on an ongoing and long-term basis in the assessment of risks to human health and the environment. There will be continuing assessments of new information and the potential for new solutions.

Source: PNNL Advisory Committee 1999, pp. 4–6.

[1] The numbering scheme used in the boxes in this chapter is introduced for this report and is not from the original documents.

negotiated without an adequate scientific and technical foundation (LAC-1). Uncertainties and discontinuities in funding not only stymie progress in finding and developing better cleanup methods but also undermine accountability on both the RD&D and operational sides of DOE (LAC-2).

Finally, WAG agrees with the advisory committee that a major scientific and technical barrier is the lack of effective mechanisms within DOE for addressing the lack of adequate scientific knowledge and technical knowledge at all levels of the cleanup system. This barrier is particularly important for those problems where the only technically defensible goal at this time is stewardship (LAC-3). WAG recommendations that support and expand on these three important issues are presented in Chapters 3 through 5.

In June 1999, a NRC committee under the auspices of the Board on Radioactive Waste Management released its report, *Groundwater and Soil Cleanup: Improving Management of Persistent Contaminants* (NRC 1999a). Many of the findings and recommendations in this thorough and well-written review of the state of the art in subsurface contaminant cleanup pertain to specific technologies relevant to the RD&D programs of OST's Subsurface Contaminants Focus Area (SCFA). In addition, in Chapter 5 the NRC committee gave a more general assessment of DOE's progress in selecting innovative technologies to develop and deploying them in site operations. A number of this committee's findings and recommendations, particularly those abstracted in Box 2, are consistent with the WAG team's analyses and recommendations.

The committee stressed that SCFA (and indirectly, OST and DOE-EM) need to keep abreast of scientific and technical progress outside DOE's own subsurface contaminant programs (NRC-1 in Box 2). It endorsed the finding by an earlier NRC study that "a major failing of national policy in creating a healthy market for environmental remediation technologies is the lack of sufficient mechanisms linking the prompt cleanup of contaminated sites with the financial self interest of the organization

**BOX 2. Selected Findings and Recommendations from *Groundwater and Soil Cleanup***

NRC-1. SCFA should develop and maintain a system for updating technology evaluations for remediation of metals, radionuclides, and DNAPLs [dense non-aqueous phase liquids]. *In order to avoid duplicating the work of others, SCFA needs to keep apprised of and selectively use results from remediation technology development projects by outside organizations*.

NRC-2. **Finding:** SCFA technology development projects have been most successful when they have been based on specific needs identified by DOE installations and have involved DOE end users in planning the demonstrations. . . .

**Recommendation 1:** SCFA should strive to increase the involvement of technology end users in planning the technology demonstrations it funds. *End users should be involved in planning every demonstration that SCFA funds, as in the Accelerated Site Technology Deployment Program*

**Recommendation 2:** SCFA should continue efforts to improve its success metrics for individual technology development projects. *The metrics should be based on a careful analysis of factors that have led to success or failure of past projects . . .*

**Recommendation 3:** SCFA should *identify successful technology demonstration projects to serve as models* for future demonstrations.

NRC-3. **Finding:** Contractors at DOE installations are reluctant to try innovative technologies developed by SCFA and others in part because of uncertainties about technology performance and the risk that the innovative technology will fail to perform as predicted. [This finding is followed by four detailed recommendations of actions that OST and DOE-EM, as well as the focus area, can take to overcome this barrier to innovation.]

NRC-4. SCFA's [and DOE-EM's] progress has been limited in part by large budget swings. In fiscal year 1998, SCFA's budget was reduced to a level that was insufficient to support significant progress on the development of innovative remediation technologies. The budget was cut from a 1994 level of $82 million to a 1998 level of $15 million, *which included a $5 million congressional earmark, leaving an effective budget of $10 million*. *This budget was inadequate to fund the types of large-scale demonstrations needed to transition innovative remediation technologies from the research and development phase to full-scale application.* It also was too small to allow open bidding for project funding. The fiscal year 1999 budget of $25 million, while representing a significant increase, will allow for funding of only a limited number of projects.

Source: NRC 1999a. pp. 211-215. Emphasis added in italics.

responsible for the contamination" (NRC 1997a). The committee then recounted how, within DOE, this point applies to the relation of SCFA (and OST) to the technology application offices of DOE-EM, to DOE field offices, and to DOE's site management contractors (NRC 1999a, pp. 176-191).

The WAG site visits to Hanford and other sites corroborate the picture drawn by the NRC committee, and we endorse the committee's findings and recommendations on this issue (NRC-2 and NRC-3 in Box 2.) The committee also commented on the damage done to programs for introducing and demonstrating innovative cleanup technology by vicissitudes in funding—including congressional earmarking of a major portion of the SCFA budget for fiscal year 1998 (NRC-4). Again, the WAG site visit teams found ample evidence to confirm the committee's statement.

In July 1999, a study committee from another part of the NRC, the Board on Infrastructure and the Constructed Environment, released its report, *Improving Project Management in the Department of Energy* (NRC 1999b). The scope of this report and its recommendations for addressing the serious problems found by the committee extend far beyond OST or even DOE-EM project management problems. Nevertheless, the WAG team views a number of its findings, listed in Box 3, as directly applicable to problems we found affecting the S&T program for subsurface contaminants.

WAG found that DOE has an incredibly complex set of procedures for documenting projects at cleanup sites. Yet this complexity often seems to disperse responsibility in so many directions that no one seems accountable for the day-to-day management actions that add up to project success or failure. This dispersion is characteristic of a lack of systems engineering and project engineering principles in the way that DOE plans and manages its major projects, a point made in *Improving Project Management* and other NRC studies (e.g., NRC 1999d). The WAG team considers the findings extracted in Box 3 as NRC-5, NRC-6, and NRC-7 to be particularly relevant to management problems we saw or heard about. The problems of organizational structure captured in NRC-8 also contribute to the dispersion of responsibility and accountability. Chapter 3 will return to the issue of whether organizational changes are needed to improve lines of authority and responsibility, and thus establish a basis for accountability.

**BOX 3. Selected Findings from**
***Improving Project Management in the Department of Energy***

NRC-5. Policies, Procedures, Documentation, and Reporting

- DOE does not have adequate policies and procedures for managing projects. No single authority is responsible for enforcing or ensuring that project management tools are used.
- DOE has developed comprehensive practice guidelines for the design and construction phases of projects but has not developed comparable guidelines for the early conceptual and preconceptual phases, when the potential for substantial savings is high.
- DOE does not effectively use value engineering to achieve project savings, even though federal agencies are required to do so.
- DOE does not have a consistent system for controlling changes in project baselines.

NRC-6. Project Planning and Controls

- DOE often sets project baselines too early, usually at the two- to three-percent design stage, sometimes even lower. (An agreement between Congress and DOE's chief financial officer for establishing baselines at the 20- to 30-percent design stage is scheduled to be implemented in fiscal year 2001.)
- DOE does not always use proven techniques for assessing risks of major projects in terms of costs, schedules, and scopes.

NRC-7. Acquisition and Contracting

- Traditional DOE contracting mechanisms, such as cost-plus-award-fee and manage-and-operate (M&O) arrangements, are not always optimal for DOE's complex mission. These approaches are being replaced with more effective approaches based on objective performance incentives, *but change has been slow*.
- DOE's long history of hiring contractors to manage and operate its sites on the basis of cost-plus-award-fee contracts has created a culture in which *neither DOE nor its contractors is sufficiently accountable for cost and schedule performance.*
- *DOE does not use effective performance-based incentives and does not have standard methods for measuring project performance*.

NRC-8. Organizational Structure, Responsibility, and Accountability

- DOE's organizational structure makes it much more difficult to carry out projects than in comparable private and public sector organizations. *Successful corporations and agencies responsible for major projects arrange their organizations to provide focused and consistent management attention to projects.*
- Too many people in DOE act as if they were project managers for the same project, and *too many organizations and individuals outside the official project organizations and lines of accountability can affect project performance.*

Source: NRC 1999b, pp. 3–8. Emphasis added in italics.

Also in July 1999, another study committee under the Board on Radioactive Waste Management released its report, *Decision Making in the U.S. Department of Energy's Environmental Management Office of Science and Technology* (NRC 1999c). From among the excellent recommendations presented in this report, the WAG team found those listed in Box 4 to be particularly germane to the team's own analysis and recommendations.

This NRC committee distinguished between the user-driven process appropriate for addressing near-term needs and the larger perspective needed to guide the long-term RD&D that can address fundamental knowledge gaps and explore radical alternatives to the technologies accepted in existing project baselines (NRC-9a and NRC-9b). This important distinction, as it applies to subsurface contaminant RD&D, will be explored at length in Chapter 5. Given the practical constraints on increasing the funding for environmental remediation, including subsurface contaminant issues, recommendation NRC-10 offers useful guidance on providing transparency and a defensible basis for decisions on which candidate projects received OST funding. The last two recommendations point out OST management and decision-making problems akin to the DOE-wide problems identified by the committee on improving project management. Both committees stressed that the private sector uses tools and techniques that DOE would do well to emulate.

This brief review of prior work has covered only those points from the more recent appraisals that relate closely to key elements of the WAG evaluation. There is much more of value in these reports and the numerous others cited in Appendix B.

**Box 4. Selected Recommendations from *Decision Making in the U.S. Department of Energy's Office of Science and Technology***

NRC-9a. [For relatively near-term site technology needs:] OST should use the best available information on DOE-EM site technology needs as a guide for tailoring program goals and RD&D projects. *As one way to acquire this information, OST should establish (or increase) its direct contact with site personnel at the problem-solving and decision-making levels.*

NRC-9b. [For longer-term technology needs:] In conjunction with other DOE-EM offices responsible for site cleanups, OST should participate to the extent possible (e.g., by establishing a role for its contractors) in a review of site remediation functional flowsheets. OST's technology development projects should be responsive to technology needs identified from baseline remediation plans *and from alternatives*.

NRC-10. To aid program planning in the institutional environment, a decision methodology should be employed [by OST] that is structured using quantifiable attributes wherever applicable, but that also allows for managerial flexibility.[a]

a. Important funding decisions and their rationales should be documented and made publicly available.

b. OST should do "cost avoidance" (or return on investment) calculations on its more expensive technologies in a more credible manner than was done in past efforts and should communicate the results to potential technology users in the most effective way possible. Initial estimates of costs and benefits should be developed at the inception of large R&D [research and development] projects. Refinements of the estimates should be a part of the project as it progresses, and followed up by a comparison of the estimates with the actual incurred costs.

NRC-11. A better-coordinated, less duplicative, and less cumbersome system should be established for integration of technology procurement activities. Since decisions to develop technologies should be made only if warranted following a "make-or-buy" review, the ability to assess available technology is crucial. These assessments should be done through up-to-date surveys of commercially available technologies that are coordinated across OST organizational units.

NRC-12. OST should adopt, where applicable and appropriate in the OST environment and to the extent practicable, basic principles of private-sector formal decision making and follow-up practices:

- Understand, focus on, and monitor changes in customer needs and requirements.
- Agree on clear and measurable goals.
- Use a formal (i.e., common, consistent, structured, and rational) technology development decision making process and apply it uniformly.
- Think strategically (i.e., long-term and high impact).
- Measure and evaluate to guide resource allocation.
- Communicate across organizational boundaries (i.e., with technology users [in other EM offices]).
- Continually improve the R&D management process.
- Hire the best people possible and maintain expertise.

[a] The three parts of this recommendation are presented in the original report as three equal recommendations on the general process element of program planning. We have related the latter two as subelements of the first to express the WAG team's interpretation of the relation implicit among them.
Source: NRC 1999c, pp. 3–8. Emphasis added in italics.

# 3

# Capitalizing on the State of the Art

The remaining chapters of this report contain the WAG team's recommendations on a range of topics pertinent to the management and policy framework for DOE subsurface S&T programs that support environmental management operations across the complex. Each recommendation, numbered by chapter, is followed by an implementation strategy and the rationale for the recommendation. In keeping with WAG's task, we focus on examples and issues from Hanford, the other visited sites, and interviews with knowledgeable individuals.[2] Examples of RD&D are drawn from DOE work on the subsurface environment (subsurface characterization; contaminant identification, transport, and fate; site monitoring; remediation and containment; etc.).

> **Recommendation 3-1**. *The Assistant Secretary for Environmental Management and the Deputy Assistant Secretary for Science and Technology should apply the best RD&D practices from successful S&T organizations within the federal government, as well as adapting appropriate practices of the private sector, to improve DOE-EM's effectiveness in exploiting and disseminating new scientific and technical knowledge relevant to subsurface characterization and remediation..*

**Implementation Strategy.** The scientific capacity within DOE-EM must be strengthened. There must also be greater consultation with DOE's best scientists and most experienced engineers on the technical feasibility of procedures and milestones being negotiated or renegotiated with regulatory agencies and other stakeholders. One approach is to assign more staff positions with technical and scientific expertise to headquarters positions, although this is likely to require a reversal of congressional and

[2] The WAG project team did not visit all the DOE cleanup sites with subsurface contamination problems that will require long-term remediation and stewardship. Others include Rocky Flats in Colorado, the Oak Ridge site in Tennessee, and the Nevada Test Site.

executive branch policies throughout the last decade, which aimed at reducing the DOE headquarters staff.[3] The Defense Advanced Research Projects Agency (DARPA) and the National Science Foundation use scientists and engineers on leave from universities. DOE-EM should consider similar use of rotators, but changes may be needed in DOE policies that constrain the ability of S&T experts to return to their previous positions after serving in a rotating position with DOE.

**Rationale.** The S&T disciplines broadly relevant to subsurface characterization and environmental remediation are advancing on many fronts. Much new scientific knowledge and innovative technology is being generated both within the DOE complex (including the national laboratories) and outside it, in academia, industry, other federal agencies, and internationally.

WAG reviewed the recent peer-reviewed technical literature and spoke with outstanding scientists from outside DOE (academic and industry experts). We assessed the work being done by experts from the national laboratories (e.g., Sandia, Los Alamos, INEEL) and DOE technical centers (Savannah River Technical Center), as well as from other agencies, such as the U.S. Geological Survey. There is a wealth of exciting, new fundamental knowledge; ingenious application of this knowledge to new methods, instruments, and techniques; and motivation to put the emerging know-how to use. A sense of the breadth of opportunity can be gained quickly just from the NRC report, *Groundwater and Soil Cleanup* (NRC 1999a) or from Internet sites for subsurface environmental technology.[4] As another example, nearly 200 papers with direct relevance to subsurface contamination were presented at the 1999 annual meeting of the Geological Society of America. The covered topics included characterization, modeling and visualization, and remediation.

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[3] Further reductions in DOE headquarters staff were included in the FY2000 budget appropriations.

[4] An excellent starting point is the website for the Federal Remediation Technologies Roundtable, <http://clu-in.org/partnerl.htm>. This site covers all governmental agencies, as well as industrial, academic, and foreign work. Another good site is the Sandia National Laboratories homepage for subsurface environment technology, <http://www.sandia.gov/Subsurface/>.

Although recent reforms appear to be taking hold, DOE-EM can take more steps to improve its performance. The practices of the private sector and certain government organizations suggest ways that DOE-EM can perform better. DOE-EM and OST need a more coherent approach to identifying and selecting the most promising new S&T opportunities from outside, as well as inside, the DOE research community and moving them through the stages of applied research, development, and demonstration required for successful application to site remediation and stewardship. Useful private-sector models have been presented in recent NRC reports to OST. Useful models for managing RD&D among government agencies include DARPA in the Office of Defense Research and Engineering (DDR&E) in the Department of Defense (DOD), the National Institutes of Health (NIH) in the Department of Health and Human Services, and the Office of Science within DOE.

WAG and other observers have concluded that DOE cannot fulfill its mission without developing and fielding new and better technologies based on a fuller understanding of the subsurface environment. However, WAG agrees with previous observers that there is an underappreciation across DOE-EM for the role of an S&T program in deriving new fundamental understanding and technologies that can accelerate cleanup and achieve acceptable end states. This is particularly so for the longer-term research needed for the sites with difficult cleanup problems. We strongly endorse the recommendations by others, as noted in Chapter 2, that DOE look to industry and government for examples of best practices in program management generally and particularly in managing RD&D programs. The authors of *Improving Project Management in the Department of Energy* "compared DOE's general project management practices with the standard practices used by private industry and other government agencies and found that DOE falls far short of best practices in a number of areas . . ." (NRC 1999b, p. 2). The committee for *Decision Making in the U.S. Department of Energy's Environmental Management Office of Science and Technology* expanded on work by the R&D Decision Quality Association to develop a list of 20 best practices for better decision making in RD&D management (NRC 1999c, Chapter 3 and Appendix F).

To this excellent advice, the WAG team adds that DOE-EM and OST can learn much about administering a coherent RD&D program from other federal agencies, which face many of the same managerial constraints and pressures with which DOE must contend. This environment includes contractual and personnel procedures, intense congressional oversight and budget management, and the vicissitudes of governmental and electoral politics. Yet certain agencies, including DARPA/DDR&E and NIH, have sustained track records of RD&D excellence. These models show that successful innovation, measured in terms of cheaper, more productive, and successfully implemented new technologies, is feasible even within an environment of political and regulatory pressures, stakeholder involvement, difficult budget negotiations, and pressure to show results.

DARPA is generally viewed as successful in keeping DOD at the technological forefront in military RD&D. Box 5 summarizes a list of management policies and practices that a recent director of DDR&E cited as key to the success of DARPA and DDR&E. While there are substantial differences in the situations confronting agencies, there are also substantial similarities. Some practices of other agencies will need modification to be applicable to DOE. For example, the analogy for DOE of item 10 in Box 5 would be to find and use the best S&T opportunities internationally, as well as nationally.

Research sponsored by NIH, primarily as research grants to universities, has enabled conceptual breakthroughs in understanding the most important diseases and devising innovative treatments. These breakthroughs opened the modern era of molecular biomedicine, the genetic basis of disease, and the biotechnology revolution. The management practices at NIH include:

- A disciplined peer review system for the allocation of research and development (R&D) funds
- The ability to obtain and sustain stable funding
- Programs of graduate traineeships and facility construction to develop and sustain the intellectual and physical infrastructure for productive R&D
- High standards—in both the relevant S&T disciplines and in the management of R&D—for selecting staff and directors

BOX 5. Best Practices Underlying DDR&E/DARPA Success
in Research and Technology Innovation

1. Keep the mission in focus; it does not drive out basic research; it helps set visionary objectives; it protects the budget.
2. Seek strong technical leaders to manage programs; empower them.
3. Encourage risk-taking when exploring new technologies.
4. Use competition and merit review to select the best ideas.
5. Fund the best performer; do not favor in-house versus out-of-house performers.
6. Keep connection with the customer by involving military officers [e.g., knowledgeable end users of the S&T results] in programs.
7. Create "quantum-jump" initiatives that have the possibility of enabling entirely new capabilities.
8. Be fickle where appropriate: free up funds for priority initiatives by stopping low priority programs.
9. Transfer technology. Involve industry and representative customers in demonstrations of innovation so that they can advocate its application..
10. Avoid "technological surprise."—i.e., assure that no nation develops a technology that is unknown to the U.S. Avoid surprise by investing in new promising ideas even when they appear to be very high-risk.
11. Maintain a level of investment in fundamentals (e.g., mathematics and engineering research).
12. Maintain the technology base in relevant fields—i.e., the research engineers and scientists in the universities, laboratories, and industry.
13. Seek excellence unremittingly.
14. Maintain credibility by telling the truth.

Source: Anita K. Jones, former Director, DDR&E

- Outstanding advisory committees, whose recommendations the agency implements more often than not.

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**Recommendation 3-2.** *DOE should identify and improve mechanisms already existing in DOE for the interchange of research results and transfer of technical know-how (practical experience with technologies).*

**Implementation Strategy.** Improved mechanisms for exchange and transfer of knowledge are needed among DOE units—for example between the national laboratories and the field offices—and between DOE units and the broader technological communities in the universities, the private sector, and other government agencies with expertise relevant to site cleanup. In particular, support should be increased for S&T staff in DOE-EM, the laboratories, and the field offices to participate in research publication and other communication channels appropriate to their disciplines and their responsibilities.

**Rationale.** The DOE national laboratories contain a wealth of scientific and technical talent and ongoing R&D activity of immense potential value to the subsurface contamination problems at Hanford, other DOE sites, and the nation's other environmental restoration needs. OST programs, including those under the SCFA and the EMSP, currently tap only a small portion of this potential. The mechanisms for information exchange and technology transfer with the wider scientific and technology communities continue to be limited transactions, rather than a robust and sustained dialogue.

The national laboratories are heavily involved in a wide range of projects with direct application to specific DOE cleanup sites and to development of technology and techniques potentially useful at multiple sites, as well as some excellent research contributing to the fundamental knowledge base. We found that the DOE laboratories are not being used nearly enough in the research and development for subsurface characterization and remediation.

The explanation typically given for this under-utilization of the laboratories is inadequate funding. Scientists and engineers at the laboratories told us story upon story of working projects being shut down or delayed by funding crises. Significant opportunities for innovation have been missed because the crucial step of on-site demonstration could not be funded. Research programs that are highly regarded in the scientific community must go outside OST or even DOE for the funds to continue work. Highly successful programs aimed entirely at DOE site cleanup, like the Innovative Treatment and Remediation Demonstration (ITRD) program, which is run for the SCFA out of Sandia National Laboratories, are being overwhelmed by their own success. The demand for participation in the ITRD is now so great that current participants are told funding may no longer be available for on-site demonstrations. Yet these demonstrations are critical in providing a selected technological alternative with the proof of site-specific adaptability and cost and performance data necessary for acceptance by site contractors.

Inadequate funding appears to be only one manifestation of more deep-seated causes. The DOE "business line" for all environmental management had a budget of $5.6 billion for fiscal year 1999 (OMB scoring, as reported on the DOE website). The total budget for OST was $243 million, or 4.3 percent. If funding for R&D, at the national laboratories and elsewhere, is inadequate, the reason may be that a lower priority is assigned to R&D than to other EM expenditures by those who control the OST budget line in Congress and the administration. Another reason may be a lack of appropriate selection among candidates for funding, as work progresses through the stages of RD&D. Chapters 4 and 5 explore some of the many factors the WAG team believes are contributing to this structural under-utilization of a key DOE resource for S&T research and development. The recommendations in Chapters 4 and 5 suggest changes that could influence the flow of resources.

There have been a number of notable recent successes in overcoming the insular culture within DOE. One management approach to solving past problems was the focus area concept for organizing S&T programs across the complex to deal with the most important cleanup challenges. Now that there is ongoing site-level participation in formulating focus area needs and assigning funding priorities, the focus area approach seems to be working better for subsurface contamination issues. The series of conferences held by the Hanford Integration Project, which involved groups from many of the DOE laboratories in contributing to the S&T plan for the project specification, is another positive example. Another is the workshop series conducted by the SCFA to collect lessons learned and incorporate them in a Vadose Zone Book. Where these and other mechanisms for internal (within DOE) knowledge transfer have worked, they need to be identified and strengthened into ways of conducting business, not just one-shot events.

Knowledge transfer between DOE and the scientific and technical communities outside of DOE remains focused on two mechanisms: advisory boards or committees and calls for proposals for research grants or technology development projects. Although these are valuable mechanisms, they should be supplemented with additional contacts with the relevant technical communities outside the DOE complex. Much more outreach is needed to pertinent industries, such as petroleum production and chemical manufacturing. For example, although the workshops for the Vadose Zone Book had some industry and foreign participation, much more could be done to bring in industry (petroleum and mineral extraction sectors, as well as environmental remediation companies), academic, and international participants to these workshop series. Workshops with broad participation from leaders in S&T from these sectors outside DOE should be a routine way of doing business for DOE-EM and the sites, not isolated instances. Another way to increase contacts with the broader S&T communities would be for DOE, perhaps through OST, to become more active as a joint or sole sponsor of broadly attended conferences on research and technology development in areas of core importance to the environmental management mission.

DOE must also accept and encourage the participation of DOE staff in the knowledge transfer channels that exist in every established S&T community. An effort is needed to alert Congress that continued cuts in the budget for travel needed to maintain knowledge transfer defeats the goal of achieving cost-effective solutions to the long-term remediation and stewardship problems at DOE sites. Changes are needed in current Departmental policies that restrict and obstruct the ability of its R&D personnel to participate fully in key community events within their disciplines. These policies include lack of funding for time and travel to attend meetings of scientific associations and inadequate financial support for preparing accounts of R&D for publication in peer-reviewed scientific and technical journals.

Enduring information and technology development networks are essential to the rapid innovation, short lifecycles, and economic efficiencies of highly competitive commercial sectors that rely on scientific advances and complex technology. DOE could build a network of this kind for subsurface characterization and remediation through such means as strategic partnerships of one or more cleanup sites with one or more national laboratory groups, university-based researchers, and industry R&D leaders (companies with subsurface characterization and remediation experience, beyond just the DOE contractors). Mission-oriented government agencies such as DDR&E, NASA, NIH, and

DOE/OS have found universities to be particularly creative partners, at relatively lower cost, for conducting research relevant to the agency's mission.

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> **Recommendation 3-3.** *DOE-EM and the field offices should apply the lessons learned from the Waste Isolation Pilot Plant and the Yucca Mountain Project to long-term remediation and stewardship at the cleanup sites.*

**Implementation Strategy.** Despite significant differences in mission and in details of hydrogeology among the DOE repository sites and the long-term cleanup sites, there are important programmatic and methodological lessons that apply to the cleanup sites. Among these lessons is the need to refine and test subsurface models against observations, as an iterative, long-term process. The scientific understanding of a site (whether for a repository or a cleanup site) should be used to test assumptions about the subsurface structure and dynamics. Long-term field studies are needed at both the repository sites and the difficult cleanup sites such as Hanford, INEEL, and Savannah River. Finally, involvement from the larger scientific community must be sought for all DOE long-term programs in which subsurface contamination is an issue. Workshops, research support, elicitation panel reports, and external review panels are among the useful mechanisms to achieve this involvement.

**Rationale.** WAG was specifically tasked with assessing what the Yucca Mountain Project could contribute to solving the subsurface contamination problems at Hanford and other cleanup sites. Yucca Mountain, Hanford, and INEEL (along with other DOE sites that the WAG team did not visit) have in common the problem of vadose zone and groundwater systems in a complex geological setting involving sedimentary and volcanic rocks. Nevertheless, there are important geophysical and hydrologic differences among these sites. Furthermore, their missions differ in important external factors, such as regulatory involvement, community stakeholder issues, and availability of resources to support long-term R&D. The subsurface hydrogeology at Yucca Mountain is important for the goal of preventing possible future contamination of these systems from nuclear utility wastes that are not yet present on the site.[5] At Hanford and INEEL (and other cleanup sites), the goal is to clean up or stabilize subsurface contamination that has occurred or could worsen if appropriate and timely action is not taken. Despite these differences, there are important methodological and programmatic lessons from the Yucca Mountain Project and the Waste Isolation Pilot Plant (WIPP) that have application to Hanford and other cleanup sites.

The WAG did not evaluate the level of effort dedicated to understanding the hydrogeologic system at Yucca Mountain. Reports of the Nuclear Waste Technical Review Board and the Total System Performance Assessment–Viability Assessment Peer Review Board discuss the quality and effectiveness of these programs.[6] WAG knows that qualified professionals have been drawn from the national laboratories, the U.S. Geological Survey, and DOE staff to work on the Yucca Mountain Project. Differences in level of effort between Yucca Mountain and the DOE cleanup sites such as Hanford reflect the far more modest S&T budgets at the cleanup sites for subsurface characterization. But it also reflects different management styles in programs characterized by differences in the politics and priorities.

Although there are lessons from the Yucca Mountain Project worth sharing with Hanford, INEEL, and other cleanup sites, the work of understanding the subsurface system at Yucca Mountain is incomplete. The assessment from site personnel is that they have completed only the first phase for a basic understanding of vadose zone characteristics and processes. They have narrowed the universe of unknowns to critical questions that need to be answered for the program to proceed toward its goal of licensing the repository. Much remains to be done to satisfy the Nuclear Regulatory Commission and prepare for licensing.

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[5] Yucca Mountain is also planned to become the depository for high-level radioactive wastes from government reactors, including those at Hanford and other DOE sites. The Yucca Mountain mission of becoming a depository for the nuclear power industry is significant for this report because the special trust fund set up by federal law for such a depository provides major financial resources for R&D at the site.

[6] The reports of the Nuclear Waste Technical Review Board are available on line <http//:www.nwtrb.gov>, The final report of the Total System Performance Assessment–Viability Assessment Peer Review Board is available on line at <http//:domino.ymp.gov/va/support/tspa_peer.nsf>.

One important lesson from the Yucca Mountain Project is the necessity of planning for field experiments to improve and test the understanding of how subsurface hydrological flow is controlled by physical phenomena such as fracture systems, regional stress, precipitation patterns, and infiltration. Much work has been done in testing simulations and models against field observations. A crucial lesson, now accepted at Yucca Mountain, is that the process of refining and validating the project's working set of subsurface models by testing model results against observations is never finished. The same lesson was learned through sometimes difficult experience several years earlier at WIPP (Sandia 1999). Hanford, INEEL, and other sites should be able to learn this and other lessons by knowledge transfer, rather than by costly trial and error at each site. This need for continuing, planned interaction between field observation, experiment, and modeling is discussed further under Recommendation 3-4.

Some of the experts in subsurface characterization from outside DOE with whom we spoke praised the Yucca Mountain Project for the series of elicitation panels used to gather opinions from the scientific community on specific topics. These elicited views have been documented in a series of reports. However, some of these same experts also noted a concern that the scientific planning for Yucca Mountain has at times seemed directed too narrowly at proving the case for licensing (the site mission), rather than seeking good tests of critical assumptions made about the geology and hydrology of the site. One result has been a number of uncomfortable surprises when field work, such as the chlorine-36 tests on seepage into the test facility, showed some of those assumptions to be wrong. The track record from subsurface characterization at Yucca Mountain, WIPP, and sites like Hanford is that some initial assumptions about hydrogeology are likely to be wrong. This result is not surprising; it highlights the importance of a stronger S&T component at the front end of a long-term project, especially for projects for which there is little prior experience.

Four years ago, the management and operations (M&O) contractor at Yucca Mountain was given the responsibility for integration. Gradually, the earlier culture of protecting turf and work scope is yielding to the imperative of "Work as a team or out!" Outside reviewers have noted improvements in the integration effort. Senior managers at

Yucca Mountain described this improved integration as a major achievement. The DOE office and the contractors had to work to create an environment where everyone supports the customer and knows what the (common) product is. Field investigations by different groups are coordinated. Once a project is completed, it is shared through technology exchanges and workshops. A site requirement is that all data must be placed in a technical data base accessible to all those working at the site. The importance of an accessible technical data base is a lesson learned at WIPP, as well The data base technology developed by Sandia for WIPP appears well suited for use at other DOE sites and even for a complex-wide multisite data system. DOE-EM should develop site-wide technical data bases, leading to a complex-wide, multisite data system.

The Yucca Mountain Project, along with other major DOE sites, has long suffered from a shifting complexity of often conflicting objectives, a multiplicity of independently contracted projects, and frequent breaking and renegotiation of compliance agreements on end-states, milestones, and schedules. We return to this issue in Chapter 5 as a characteristic problem for DOE.

Some features of the Yucca Mountain experience and methodology are not applicable to Hanford. The field studies at Yucca Mountain tend to have a short-term focus, rather than providing for long-term monitoring. The short-term S&T planning at Yucca Mountain shows a lack of understanding of how scientifically informed technology development is most likely to contribute new and better solutions to difficult problems. Where long-term field studies are needed, such as at the difficult cleanup sites, expert oversight panels can provide continuing peer evaluation of the studies to ensure that they continue to provide value and are not abandoned in short-term budget fluctuations.

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**Recommendation 3-4.** *Models should be used with caution because the underlying science may be insufficient, the mathematical representation cannot be complete, significant data are usually missing, and exogenous events will be difficult to incorporate in the representation.*

**Implementation Strategy.** Because of the interactions among models, experiments, observations, and operations, model development and refinement must be conducted as an iterative process. A good approach is to use models together with field observations, controlled experimentation in the field and laboratory, and large-scale field operations in an interactive system for understanding and interpreting the subsurface environment, especially its structures and processes that determine the transport and fate of contaminants. The visualization of a site's subsurface environment and the four-dimensional characterization of its contaminants and remediation processes should be updated frequently with better data, more realistic representations of physical structures and processes, and increased precision in testing model projections against observational data.

The sources of error, uncertainty, and sensitivity in models should be identified and acknowledged when modeling results are reported and used. Iterations of the visualization system (models, experiments, etc.) should aim at reducing errors and uncertainty and confirming assumptions. There should be a balance between modeling and field observation, including appropriate long-term field experiments, in the site's resource allocations. Part of the R&D mission for a site should be to assess the appropriateness of the site's models and the uses to which model results are applied.

**Rationale.** Subsurface modeling is a critical component of the site-specific S&T work to support long-term remediation and stewardship. The complexity of the subsurface system requires that models be used with care. For example, in some cases subsurface flow parameters may be nonlinear, chaotic, and therefore have inherently limited predictability. This puts a premium on field observations, including well-designed field experiments, to select among candidate models, refine the set of models employed in site-wide assessment, and evaluate the utility of the modeling on which significant near-term and long-term decisions depend.

Modeling the distribution, transport, and fate of subsurface contaminants is a major element in the site-specific research at Hanford, INEEL, and other cleanup sites, as it has been for WIPP and the Yucca Mountain Project. Realistic expectations about what subsurface modeling can contribute are essential, and the WAG urges care in interpreting the results of numerical models for subsurface contamination. At many of these sites, subsurface conditions are highly variable over space and time, often showing a high degree of lateral heterogeneity and anisotropy in important hydrogeologic parameters such as permeability.

Of necessity, these subsurface models will be based on limited knowledge about—and incomplete representation of—real conditions. Flow rates and front speeds of subsurface contaminant plumes will be difficult if not impossible to predict accurately over durations of relevance to long-term regulatory decisions and strategies for remediation and stewardship. Models must be tested against reality before making major investments or decisions based on long-term projections. And model projections must be frequently reconfirmed against field observations to ensure that the assumptions and approximations built into the model have not led to significant deviations from reality. The complexities of the subsurface system at many sites will require greater emphasis on field test facilities and more intensive three-dimensional and four-dimensional field experiments and monitoring.

Modeling, subsurface characterization, and site assessment are interrelated components essential to the S&T support of a coherent strategy for the remediation and stewardship of a site and for regulatory decisions. As discussed under the preceding recommendation, both WIPP and the Yucca Mountain Project learned from experience the necessity of a systems engineering approach to iterated development of a validated set of site models to support a site-wide performance assessment. Field observations, including field tests specifically designed to select among candidate models, refine working models, and validate the modeling capability, have proven necessary for scientifically defensible assessments. At INEEL, work on a sitewide model has suggested that important features of subsurface flow through the fractured basalt beds exhibit complex behavior, restricting the precision and temporal range of useful projection.

The assessment of the modeling experts with whom we conferred is that DOE relies too heavily on modeling, to the exclusion of the fundamental science needed to refine, calibrate, and test the models. Subsurface models need to be assessed from the perspective of both experimentalists and modelers. When models are used, there should be much more openness about the sources of uncertainty in them, and systematic methods are needed to test the assumptions built into the models.

The site-specific S&T planning for long-term sites should emphasize how the site's subsurface models will be tested continually over the life of site remediation and stewardship, as well as how field verification will be incorporated in near-term site assessments. The use of models for near-term engineering decisions on cleanup should be distinguished from long-term extrapolation, in which limitations of the model cannot be tested by present observations. OST could undertake a major initiative in this area to collect the many valuable lessons to be learned from past mistakes and wrong turns, as well as from the substantial achievements in refining the techniques, field work, and technology to support important site decisions. Uncertainty will always be present.

# 4
# Managing for Effective Results

The reason for having an office of science and technology within the operationally oriented DOE Office of Environmental Management is to develop innovative technologies to support environmental management and transfer them to site operations. A recurring criticism of DOE-EM is that only a small fraction of the technologies brought through the stage of initial development have progressed to operational deployment (as opposed to proof-of-concept demonstration). Some of the technological approaches now in use at the DOE problem sites are inadequate to achieve reasonable cleanup objectives. Moreover, technologies do not yet exist to manage the most difficult contaminated sites (NRC 1999a, see especially pp. 15-24 and 211). These sites will present problems for decades into the future. If current practices continue, the cleanup program could cost hundreds of billions of dollars, with poor results from the inadequate technologies being employed.

The answer to this alarming state of affairs is neither obfuscation nor abandonment of the task but a determined and disciplined search for better tools and the knowledge to employ them effectively. From the rich technological literature and our discussions with experts in the universities, national laboratories, and industry, we are convinced that a national research base can be created that, if properly used, would enable the needed technological solutions to be developed. Some of the end states prescribed by current compliance agreements may be impossible, but safe and improvable end states may be achievable in most cases. For remediation and stewardship of the difficult sites, the practical objectives can be, first, cleanup where possible; second, stabilization, monitoring, and supervision where full cleanup is not possible with current understanding and know-how. Essential in all cases is an openness to grasp an opportunity to improve a baseline or surpass an interim goal when new knowledge and innovative technique allow. With a credible R&D program and this openness as an affirmed goal, it should be possible to find support for remediation and stewardship approaches from stakeholders and regulators.

Even if such technologies can be developed, we often heard concerns that current management styles, budget allocations, contractual arrangements, regulatory processes, and stakeholder relationships will impede their implementation. Yet none of these impediments are immutable or insurmountable. The recommendations in this chapter explore different aspects of the barriers we saw and heard about, with the objective of identifying practical ways to lessen, remove, or circumvent these obstacles.

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**Recommendation 4-1.** *DOE, at the Departmental, DOE-EM, and field office levels, must recognize programs and activities that have been successful in overcoming acknowledged barriers and must expand on these successes.*

**Implementation Strategy.** Individual projects at the sites that have overcome often-cited barriers to successful RD&D of innovative technology should be used as case studies for approaches adaptable to similar situations across the complex. Too many of these barriers still exist in DOE-EM, in OST, and at the field offices and sites. At every level in DOE, successful programs such as ITRD and the Accelerated Site Technology Deployment program (ASTD) should be identified and careful consideration given to how best to expand and support them, including assessing their susceptibility to remaining barriers to success.

**Rationale.** In June 1995, the Office of Environmental Restoration in DOE-EM held a full-day workshop at the annual meeting of the Hazardous Waste Action Coalition. The workshop was an attempt to find explanations for the results of an earlier analysis, which showed that "usable technologies that are commonplace in private industry are often not identified as feasible in DOE environmental restoration applications" (DOE 1996). The workshop participants identified "barriers impeding the implementation of innovative/improved technology into the DOE's environmental management activities" and evaluated solutions to these barriers. A noteworthy feature of the list of barriers that DOE staff assembled from this workshop and other sources in 1996 is that it includes all the barriers that have been pointed out by: (1) all the GAO reports since 1992 on DOE cleanup technologies, (2) many NRC reports covering the same period, and (3) the former DOE officials and contractor executives whom WAG interviewed in March and April 1999.

Although significant constructive steps have been taken during the past several years, too many of these barriers still impede success. The WAG team found many of these same barriers or discussed perceptions of them during our site visits in May through July of 1999.

The 1996 draft report from this DOE-EM workshop identifies more than 80 barriers in 10 categories (DOE 1996). Table 1 lists the categories and the number of barriers in each category. Some barriers occur in two or more categories. The table illustrates each category with barriers from the report that were observed by or described to the WAG team as still active. Some of the barriers are clearly of DOE's making and can be lessened or removed. Others are not controlled by DOE but can be mitigated by DOE actions. Still others are probably beyond mitigation, and DOE needs ways to work around them. The point really is not how many or how severe the barriers and impediments are, but what DOE is doing and can do to overcome them.

DOE can learn a great deal about how to fix its systemic problems and overcome external impediments by studying its own successes. Within DOE's environmental RD&D activities are good examples of projects and programs that overcome the barriers and obstacles identified by WAG and many others. DOE-EM, the field offices, and the site project personnel have been able to get some things done well. The WAG team found instances of successful programs and projects that have contributed to the knowledge base on subsurface contamination or have resulted in operational improvements through deployment of innovative technologies. When we discussed these success stories with the personnel directly involved with them, we almost always found valuable information on ways to overcome the litany of barriers and impediments that have so often been cited. Too often, though, it seems that the important lessons to be gleaned from these successes have not been used to improve the system of S&T management or the larger system of

TABLE l. Barriers to Implementation of Improved or Innovative Cleanup Technologies

| **Category** | **No. of Barriers Identified** | **Examples** |
|---|---|---|
| Attitudinal barriers | 15 | Adverse employment impacts of new technologies. "Not Invented Here" syndrome. |
| Management barriers | 6 | System rigidity, bureaucracy. Field is not given enough authority to select available technologies |
| Technical barriers | 4 | Lack of cost and performance data. Difficult to entice vendors to develop technologies with limited applicability outside DOE. |
| Lack of teamwork/coordination | 8 | Lack of interstate cooperation. Lack of teamwork and coordination between all DOE participants (including contractors). EM-50's technical experts not part of the decision-making process where technology choices for particular sites are made. |
| Lack of communication | 5 | Knowledge is not shared across the DOE complex or between DOE-EM organizations. Lack of stakeholder involvement in selecting technology solution. |
| Barriers to industry participation | 7 | DOE not encouraged to buy improved technology—no incentive to take the search "out of house." |
| Procurement barriers | 17 | Lack of economic incentives. Contracts do not provide incentives for or reward risk-taking. |
| Budget process barriers | 9 | Entire life-cycle cost of project not considered. Uncertain and inconsistent project funding. |
| Regulatory barriers | 14 | Uncertainty of success. Rigid interpretation of the law. |
| Miscellaneous impediments | 8 | Conflicting priorities among stakeholders tend to prevent the approval of innovative approaches. Difficulty in measuring and selling efficiency, time, and cost savings. |

Source: DOE 1996.

DOE environmental management activities. We also found that initial successes are often threatened or restricted by other barriers in the DOE system.

The following brief list highlights several of these promising examples and the limitations they still face. The examples have been selected for their relevance to subsurface contamination S&T and the lessons that can be gleaned from them.

- The ITRD program incorporates excellent methods for bringing together key players in implementing an improved technology alternative at a cleanup site. The interest in the program is so great that it may become a victim of its own success. With an increasing number of projects in the program, funding may be curtailed for a project after the initial stages of gathering technology options and selecting those which seem most promising to the site group for an ITRD project. This limitation would cut off support at the critical point of demonstrating site-specific applicability and establishing cost and performance parameters.

- The ASTD program has a number of successes to its credit. Unfortunately, it continues to be plagued by vagaries of funding delivery for even its most promising projects. The vicissitudes of congressional budgets and imposition of earmarks on already strained budgets may account for much of the problem. But we suspect that the DOE management structure within and above the program level also contributes to funding delays, unannounced cuts in projects, uncertain responses from program administrators, and other unnecessary impediments to moving proven technologies into operations. The history of the SmartSampling technology application at the Mound, Ohio, site illustrates both the promise of this program and the administrative difficulties that technology developers encounter in it.
- The Groundwater/Vadose Zone Integration Project at Hanford brings together many elements of site-wide communication and cooperation, including good mechanisms for S&T interactions with the laboratories, DOE-EM, and other sites. It provides for effective interactions with stakeholders and multiple contractors at this complex and difficult cleanup site. However, doubts about the ability to make progress at Hanford under existing constraints are expressed by former and current DOE and contractor officials external to the highly motivated Integration Project team. These doubts could easily undermine what should become a prototype and test bed for "putting it all together" for a site-specific approach to remediation and long-term stewardship.
- The successful demonstration of in situ redox manipulation for treatment of a chromium plume at Hanford illustrates the potential for SCFA and the focus area approach of OST to get better cleanup alternatives into site operations. An NRC report (NRC 1999a) describes the technology and expands on the lessons to be learned from it for improving DOE technology management. This technology originated from research funded by the DOE Office of Science, and insiders have attributed its success in surviving DOE's internal barriers to a determined "champion."
- The history of the GeoSyphon/GeoFlow technology at Savannah River Site illustrates how the close interaction between R&D personnel and operators at a site can apply a broad technological principle in an innovative way to site conditions. This case is particularly interesting because the first application was funded by the site contractor without DOE-EM support; only with the second demonstration of the technology did it make the cut on OST funding priorities.

A number of additional successes are discussed under the other recommendations in this chapter. There are also many examples beyond the area of subsurface contamination, on which the WAG project focused.

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> **Recommendation 4-2.** *The Deputy Assistant Secretary for Science and Technology and the Assistant Secretary for Environmental Management must take action to arrest the downward spiral in funding of long-term R&D and gain support for adequate funding.*

**Implementation Strategy.** First, DOE-EM and OST must improve the management of the RD&D process across all of DOE-EM, to establish that DOE can use research and development funds effectively. They must become the champions for long-term R&D, able to explain in concrete terms why it is needed to address subsurface contamination problems confronting DOE's environmental remediation and stewardship responsibilities. At headquarters and in the field offices, DOE policy must reassert the Department's role as the responsible "owner" of the sites and their problems. Finally, the Assistant Secretary for Environmental Management and the Deputy Assistant Secretary for Science and Technology need to identify and advertise DOE-EM and OST successes, to convince DOE officials, as well as administrative and congressional budget authorities, of the value of the RD&D programs for environmental management in general and subsurface contamination S&T in particular.

**Rationale.** A downward spiral of resources threatens the DOE-EM and OST program base for RD&D, not just for programs relevant to subsurface problems but for all of environmental management. Large expenditures by DOE-EM programs for RD&D, including those under OST and other DOE-EM offices, and slow progress in achieving promised results have fostered an attitude of uncertainty in Congress and the executive branch about the value of that research effort. As the Groundwater and Soil Cleanup committee noted, a shrinking real-dollar budget for the SCFA has been exacerbated in some years by congressional earmarks of a substantial portion of the appropriated funding (see NRC-4 in Box 2, Chapter 2). Consequently, funding for long-term research on the vadose and saturated zones relevant to DOE cleanup mission is inadequate.

Support for additional funding appears unlikely without fundamental shifts in attitude of budgetary authorities toward the value of research.

Unless there is either reallocation of DOE resources or an increase in funding for long-term research, this spiral is likely to continue and may accelerate. Without an adequate R&D budget, the efforts to use statements of technology needs from the sites to establish RD&D priorities will become an exercise in futility. Even the most promising opportunities for addressing the best-documented cleanup needs, such as those in the Hanford Integration Project Science and Technology Plan, are likely to be underfunded or unfunded. Over time the success rate for solving cleanup problems is unlikely to improve substantially. This lack of success will "confirm" the skeptics' view that DOE's environmental RD&D programs cannot deliver.

In our earlier evaluation of the initial version of an S&T Plan and Roadmap for the Hanford Groundwater/Vadose Zone Integration Project, we described the plan and roadmap as "overall, . . . a comprehensive and expert shopping list for applied science to support Hanford near-term remediation projects. It also does well in listing the scientific deficiencies that require resolution" (WAG 1999). Yet, our next finding in that evaluation sounds a warning that applies not just to cleanup at Hanford but to all the long-term sites:

> It is questionable how much of this shopping list can be accomplished with the level of funding that can be expected, the complexity of the problem, and the lack of fundamental scientific understanding of subsurface contaminant migration generally and specifically in the Hanford vadose and groundwater zones. Expertise in so many different scientific disciplines is called for that a national effort will be required, raising issues of who will do the work and how it will be organized, monitored, and coordinated.
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> (WAG 1999, p. 12)

The WAG team doubts that the success rate in demonstrating and deploying innovative technologies will improve without a recovery from this resource shrinkage.

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**Recommendation 4-3.** *DOE should revise its complex management structure to achieve direct lines of responsibility, fewer decision points, and the capacity at each decision point for good technological judgment.*

**Implementation Strategy.** The Department of Energy should accept and enforce its authority as the owner of the cleanup sites and their problems. The DOE site manager, acting as a committed site owner, should foster a culture conducive to technological innovation, including performance-based incentives for innovation. Within the existing site-operating system, which depends on an M&O or management and integration (M&I) contractor for implementation, contractual, legal, and financial disincentives for contractors to seek innovative ways to improve site should be removed or at least lessened. Incentives should be introduced for improving cost effectiveness and finding better ways to achieve long-term site goals. Routine interactions between R&D personnel and operators, which can overcome many of the structural barriers to deployment of promising technology, should be the norm, not the exception, at all the DOE cleanup sites with difficult subsurface contamination problems.

**Rationale.** A cumbersome and redundant field structure that lacks management efficiency continues to be a major obstacle to effective transfer of the new knowledge and innovative technologies needed to improve cleanup plans in progress and achieve long-term remediation and stewardship objectives. For people with S&T management experience outside DOE, the system is inflexible, unable to redirect funds, unable to respond to innovation opportunities, liable to make major decisions without adequate S&T input, and vulnerable to political intrusion in technical decision making. Among the management changes needed are direct lines of responsibility, fewer decision points, and the capacity at each decision point for good technological judgement. At present some DOE decision makers are too specialized, fail to grasp implications for the whole system, and make decisions on the basis of narrow specialties.

The existing managerial and contractual system disperses responsibility for site cleanup to the site M&O or M&I contractor and project-specific contractors. The difficult cleanup sites typically have multiple contractors and subcontractors, each protecting territory and scope, each insisting on the rights and privileges that follow from its interpretation of contracts and memoranda of understanding. Although specialized contractors are necessary, the numbers are too large at some sites, with too much overlap.

DOE guidelines are huge mounds of documentation, heavy on procedure and process but often lacking technical rigor. Conflict resolution typically requires appeal to the DOE field office to which the site is assigned. Yet, at most sites, the DOE office acts in conformity with the headquarters attitude that the M&O or M&I contractor at a site is the "problem owner," not DOE. None of these typical features is conducive to lean and effective management. The repeated conflicts between DOE and the lead site contractor, reflected in frequent turnovers of site contractors, deter cleanup progress and further discourage innovation. During the WAG site visit to Hanford, several long-term participants (operators, stakeholders, DOE and PNNL personnel) noted that *no one*—neither DOE nor the site contractor nor the regulators—appears to truly "own the site and own the long-term problems."

The legacy thus far of performance-based incentives for DOE site contractors has typically been to create strong economic incentives to proceed with a contracted baseline of conventional technology aimed at meeting stipulated regulatory milestones. There is widespread recognition that in many cases the milestones are unrealistic and do not deal with the long-term issues effectively. Often they divert resources that could be put to better use in addressing a site's high-risk, near-term problems or its long-term needs. Nevertheless, contractors are financially rewarded for pressing forward with a conventional technology acceptable to regulators, whether or not it is effective. In most circumstances, there are strong financial and contractual disincentives to undertaking the serious consideration and developmental engineering of innovative technologies that deviate from the contractual baseline.

The Groundwater/Vadose Zone Integration Project is supposed to address many of the RD&D management problems as they occur at Hanford. On paper and in discussion with the project management team, the approach looks promising, but its effectiveness in practice remains to be seen. We see two potential weaknesses. First, the Hanford M&O contractor and the Integration Project lead contractor are different companies, operating under contracts with different performance conditions. The arbiter if conflicts should arise is the DOE field office, which in the past has acted—in accordance with Departmental policy—as a contract administrator rather than the owner of the site, with all the responsibilities and authority proper to a concerned owner. Second, even the core projects that come under the Integration Project remain driven by compliance milestones and project baseline technologies locked into the performance metrics by which project success (and contractor award fee) is measured, even when the technical foundations of the compliance agreements are flawed and the specified technologies are of dubious merit.

On several points, we found that the Savannah River Site provides some interesting counterpoints to this general portrait of DOE site management. First, the M&O contractor at Savannah River sees the site (and thus the company) as having a continuing, long-term role in the nation's energy programs. It therefore seeks to sustain and cultivate the historically strong ties with the communities around the site and with state and federal regulators. This "enlightened self interest" provides a fundamental motivation toward long-term remediation and stewardship, which seems to us and others we interviewed to be lacking at many DOE sites.

Second, the Savannah River DOE office has instilled a culture in which environmental restoration contractors are expected to seek out better technologies and approaches than those specified in their project baselines. Their performance (the award fee) is judged in part on what they have done to identify and apply innovative technology, and this point is conveyed in day-to-day interactions. We found that this expectation from a DOE manager acting as a committed "site owner" has percolated through the site culture. Field technicians at the Savannah River Technical Center and their counterparts in operational (contractor) units repeatedly mentioned the attitude of the DOE office as a driver for finding and adapting better solutions and deploying them operationally. Advocates for a new approach or technique still must make a convincing argument to management (and to the site regulators and community advisory bodies) that their approach is likely to do a job better—and usually, that it will cost less in the long run—than the alternatives, including doing less or doing nothing for now. Nonetheless, we observed that contractors' field staff view these steps to acceptance as reasonable tests of the feasibility and desirability of a new approach, not as barriers stemming from hostility to change or innovation.

Third, we witnessed the positive effects of daily interaction between operators trying to meet restoration and remediation commitments and an R&D staff with a strong emphasis on applied research and technology demonstration. At Hanford, the Integration Project staff at several levels also cited this daily interaction as a significant benefit of that project—and a change from the past. The Savannah River Technical Center historically has been a service entity whose principal job was to support the line organizations of the M&O contractor, of which it is organizationally a part. Although 60 percent of the center's work in fiscal year 1998 was for DOE sites other than Savannah River, the staff retains a strong orientation toward problem-solving for operations. Because of its strong service orientation, the center is relatively weak, compared with academia or some of the national laboratories, on the basic research required to address the more intractable subsurface contamination problems. And the close ties with one site have at times raised issues about the equity of SCFA programs in meeting the needs of other sites. Yet, these close working relations between R&D personnel and their operator counterparts, whether at Savannah River or the Hanford Integration Project, provide the means to work around or through major obstacles to adapting, demonstrating, and deploying new knowledge and better technology.

At the headquarters level, the management structures are also complex. Although the WAG team sought to understand the relative roles and mechanisms of coordination between the SCFA and the complex-wide vadose-zone roadmapping project assigned to INEEL, uncertainty remains about how these elements of the complex-wide S&T strategy relate to each other. Where lines of authority and responsibility are unclear, accountability suffers and can disappear altogether. Limited resources of funding and technical expertise are expended fruitlessly, either through "friction" between competing entities or a lack of traction because no one has unquestioned authority. Much heat and noise is produced, but little forward motion. This fundamental principle of management applies to subdivisions of an organization, individual managers; and project structures.

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**Recommendation 4-4.** *OST should strengthen the focus area approach in OST by increasing the S&T capability at headquarters, but without diminishing the S&T strength at the field offices. Consideration should be given to whether the* *advantages of moving the technical management of the Subsurface Contaminants Focus Area to OST headquarters in Washington D.C. outweigh the disadvantages.*

**Implementation Strategy.** DOE-EM in general and OST in particular should consider ways to build and maintain a cadre of technically grounded managers, perhaps by rotating qualified personnel among field office and headquarters assignments and through technical support positions across DOE-EM. OST should also consider ways to simplify the management and decision structure for at least the SCFA, if not for its other focus areas and cross-cutting programs. Among the range of options, the following should be considered: (a) Maintain the current field office location of the focus area technical lead but simplify and clarify the lines of responsibility and authority for decisions on work package formation and evaluation and for the distribution of funding among projects relevant to a funded work package. (b) Manage the focus area from headquarters. An essential part of this option must be the establishment of adequate scientific and technical strength in OST headquarters staff.

Also, OST should clarify the respective missions and responsibilities of INEEL with respect to long-term remediation and stewardship and of DOE/Savannah River as the technical lead for the SCFA.

**Rationale.** In 1994 OST reorganized its programs for environmental RD&D into five focus areas and five crosscutting programs (OST 1999a). As a mechanism for integrating and coordinating programs across the DOE field offices, laboratories, and cleanup sites, this "focus area–centered approach" is by and large a great improvement on the previous site-centered, highly redundant approach.

WAG agrees with the general support it found for the management concept of focus areas. Although the subsurface cleanup sites differ in geology, hydrology, and the nature of contaminants, there is much in common in the technologies for characterization and in the engineering and the biological and physicochemical processes that will be involved in remediation. An integrated approach to management that shares experience across the DOE sites has much to offer. It will improve performance at all sites and lead to more informed decisions on priority setting, resource allocations, negotiations, and RD&D.

However, there is a management issue relevant to the present approach of assigning focus area technical management responsibilities to a field site. The decision process for formulating work packages and distributing funding to projects after a work package is funded needs further simplification and transparency for OST's customers at the cleanup sites and in the R&D communities. For subsurface contamination, the DOE Savannah River Office has been chosen for the good reason that it is technically strong and experienced in this area. Nevertheless, since final decisions on all matters are made at headquarters, this practice adds to the complex decision-making process in DOE that has been criticized repeatedly in many of the reports by advisory groups. Negotiating the complex series of steps on the circuitous road to a decision was called an "obstacle course" in discussions during our site visits. The possibility was also raised of a conflict of interest in placing one site with important subsurface contamination problems in a position that influences decisions over other sites. In addition, the relation between the SCFA program and planning and the long-term stewardship roadmapping project of the DOE Idaho Office needs clarification.

WAG believes that, regardless of where focus area technical management is located, the technical strength of OST and DOE-EM needs to be deepened. DOE-EM makes final decisions and allocates a major portion of a $6 billion budget to activities that are basically technical in nature. Advice and recommendations should flow in from the field, but there is no substitute for on-the-spot technical input to the discussions involved in routine decision-making in headquarters. WAG is impressed with the present leadership in OST, but it needs to be strengthened. Strong technical capabilities at the cleanup sites are also essential and should not be diminished.

WAG understands the prior history of headquarters staffing decisions made by previous DOE administrations, often with congressional direction. The change we suggest is the addition of a small number of highly qualified, broadly experienced scientists and engineers to the OST staff. If implemented this action will also permit consideration of managing the SCFA from Washington. An advantage of this approach is that it reduces the complexity of decision making while increasing the robustness of the technical basis for those decisions. This change may also prove useful for other focus areas.

The S&T personnel needed at headquarters are not narrow specialists but individuals who can make broad technological judgements and know how to acquire specialized advice from experts when they need it. Building and maintaining a headquarters staff with this broad technical background while maintaining necessary technical strength in the field offices is admittedly difficult. Other government agencies that face similar problems, such as DOD, the National Weather Service, and the National Science Foundation, have used various devices to develop a pool of managers who maintain their technical expertise while gaining management experience in different parts of the organization. Some rotate their technical experts through management positions in headquarters and the field. Others have a system for exposing staff to varied roles in the organization. Rotation in some form is also a common industry practice.

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> **Recommendation 4-5.** *In meeting regulatory requirements, DOE should fully explore options for greater regulatory flexibility that will better address the realistic limits of available technology and expectations for new technology.*

**Implementation Strategy.** At the Departmental, DOE-EM, and site levels, DOE should be proactive in reaching out to work with regulators, stakeholders, and government officials on regulatory changes that may be needed to seize opportunities to improve remediation and lower costs through innovative environmental remediation and management approaches. At the field office and site levels, there are excellent examples of R&D and operator teams working in partnership with regulators and community stakeholders to achieve the flexibility needed to demonstrate and deploy innovative technologies. The lessons from these successes have not been fully incorporated in the way DOE does business at the Departmental and DOE-EM levels.

**Rationale.** We found many indications that the regulatory and stakeholder deterrents to the use of new technology are changing, in recognition of the need for new remediation and stewardship approaches. Regulators from the Environmental Protection Agency and the states appear willing to provide the flexibility to demonstrate a new approach when it has the potential to outperform a baseline technology. The Interstate Technology and Regulatory Cooperation working group is reducing the barriers to interstate deployment of innovative technologies, resolving the Catch-22 dilemma that a technology cannot be deployed before it has been successfully used elsewhere.

Changes to the compliance agreements for the long-term sites should aim not at relaxing requirements but at recognizing the realities of the situation and the state of current knowledge and capabilities. Allowing a compliance agreement based on inadequate knowledge, impossible schedules, or an irrelevant paradigm (cleanup to a "releasable" state, instead of long-term remediation and stewardship) to drive the application of scarce resources invites failure on a grand scale. But stakeholders and overseers of the cleanup program will not allow significant deviation from current commitments until they are convinced that there are better approaches and that the search for them is motivating the site management to change the compliance status quo.

Strong working relations with stakeholders and a commitment to site remediation and stewardship have had positive effects at the Savannah River Site. The state and federal regulators for Savannah River and community stakeholders are willing partners in developing and testing new alternatives to existing compliance agreements. They work closely with R&D staff and operators in reconsidering requirements, provided there is a plan to achieve the long-term goal more effectively. We heard about flexibility and a willingness to cooperate, grounded in a sense of shared values in pursuit of a common goal.

Partnering with stakeholders and regulators has also worked well at the Sandia National Laboratories (illustrated by a difficult landfill cleanup on the Sandia site) and at Hanford. Examples at Hanford include the in situ redox manipulation technology for a chromium plume and an ITRD project to seek an in situ alternative for remediation of a carbon tetrachloride plume. An innovative regulatory approach was also applied to a bioremediation demonstration at INEEL. Thus, at each site WAG visited, we found instances where regulators and community stakeholders willingly supported and furthered efforts to try a new cleanup approach, if they were involved at an early phase as partners in problem assessment, technology selection, and demonstration planning. Effective use of this trend in regulatory flexibility will require leadership from DOE at all levels, rather than relying on site contractors.

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> **Recommendation 4-6.** *OST and the DOE site managers responsible for S&T roadmapping should ensure that realism about costs, schedules, and budgets are incorporated in the roadmapping process and the products. Long-term needs should be identified and included in a roadmap's schedules and budgets, although the uncertainties arising from projection of long-term progress in S&T must also be captured.*

**Implementation Strategy.** WAG's principal concern with the roadmaps we have reviewed, particularly the Hanford Integration Project Roadmap but also to some extent the multi-year program plan for the SCFA, is a lack of realism about costs, schedules, and budgets. Reduction of a roadmap to a plan of action requires additional steps beyond those we found in current versions of these second and third tier roadmaps. The scheduling for completion of each activity essential to the outcome must be realistic. Allocations of responsibilities and resources must be based on the best current assessments of which elements are needed and how they will be provided. In short, a roadmap must be more than a wish list of everything that might help to achieve desired goals. It must be grounded in realism about budgets and other constraints, about priorities, and about the unpredictability of R&D outcomes. Choke points must be identified and show stoppers anticipated.

One comment the WAG team heard at Hanford is that, if full funding for the S&T roadmap was not provided, the plan would simply be stretched out over a longer time. However, from a system perspective informed by long-term objectives, slow-down may be less optimal than reconfiguration. It may be better in the long run to consider relaxing promised near-term deliverables (except where a crisis is imminent) while doing the best that can be done within budgetary constraints. This approach is likely to incur legal challenges unless compliance agreements are renegotiated. Nevertheless the alternative is to proceed with expensive site projects that meet the letter of a compliance agreement but make little progress toward ultimate goals of environmental remediation and stewardship.

**Rationale.** The three-tier S&T roadmapping approach being implemented by OST appears promising as a means of identifying near-term and long-term S&T needs, setting priorities among these needs, and planning effectively to meet them through a rationally managed R&D program. As part of its review of how OST is managing R&D to address subsurface contamination issues, the WAG team reviewed documents at all three tiers of the current OST roadmapping approach. The top tier in this strategy, a programmatic roadmap for all R&D programs in DOE-EM, is the report, *Environmental Management Research and Development Program Plan: Solution-Based Investments in Science and Technology* (DOE 1998a). Forming the second tier are multiyear program plans for each of the five complex-wide S&T focus areas, such as the *Subsurface Contaminants Focus Area Multi-Year Program Plan: FY 1998–FY 2006*. The roadmaps at the third tier, like the S&T Plan and Roadmap for the Hanford Integration Project, are intended to "describe where science and technology efforts can make a significant contribution to cleanup project success" (DOE 1998a).

The WAG project team understands that, like all roadmaps, the S&T roadmaps prepared by OST and the sites, at all three tiers, are works in progress. They will be updated and modified in light of external reviews and ongoing experience at the site. Roadmapping is a process to identify goals and the science and technology knowledge gaps that need to be filled if those goals are to be achieved. Indeed, the roadmapping process is just as important as the product. Done well, it can establish a shared view—shared by government officials, site contractors, advisory boards, scientists and engineers, and stakeholders—of remediation goals and the science and technology needed in both the near and long term to achieve them. The process requires the collective efforts of R&D and operating staffs working in concert to define milestones, identify bottlenecks that research must remove, and create new solutions for unsolved problems, so that effective technologies can be introduced at the right time to achieve agreed-upon end states.

The WAG report on the Hanford Integration Project S&T Plan and Roadmap provides specific suggestions for ways to improve that roadmap in upcoming revisions (WAG 1999). The limitations of the Revision 0 (zero) documents we reviewed were acknowledged by the Integration Project staff even before our report, and we applaud the approach by which the staff is attempting to address the deficiencies in these initial efforts. As the roadmapping process continues at all three tiers, it is imperative to bear in mind the requisites for the process to be truly useful: realism about costs, schedules, and budgets, combined with anticipation of choke points and show stoppers. These requisites apply to focus area roadmapping and the complex-wide S&T roadmap for vadose zone R&D being undertaken by INEEL, as well as to site-specific project roadmaps (tier 3), like the Hanford roadmap.

# 5
# Supporting the New Policy of Remediation and Stewardship

In 1996, DOE-EM established a policy goal of reducing the long-term cost and resource burdens of the DOE sites under environmental management. A major objective of this policy was to complete cleanup operations by 2006 for as many of the sites as could reasonably be scheduled in the intervening ten-year period. The plans for achieving this objective were presented in the report, *Accelerating Cleanup: Paths to Closure* (DOE 1998b). In October 1999, DOE-EM released a "companion report" to *Accelerating Cleanup*, titled *From Cleanup to Stewardship*. This new report discusses DOE's continuing responsibilities for controlling residual contamination and the exposure of people and the environment to these contaminants, even after cleanup requirements are met. It also describes the stewardship role for the ten or so sites where major cleanup operations are planned to continue beyond 2006 (DOE, 1999).

In *From Cleanup to Stewardship*, "stewardship" is defined as "all activities required to protect human health and the environment from hazards remaining after cleanup is complete."[7] By implication, stewardship is something done *after cleanup*, which is defined as:

> The process of addressing contaminated land, facilities, and materials in accordance with applicable requirements. Cleanup does not imply that all hazards will be removed from the site. The term 'remediation' is often used synonymously with cleanup.

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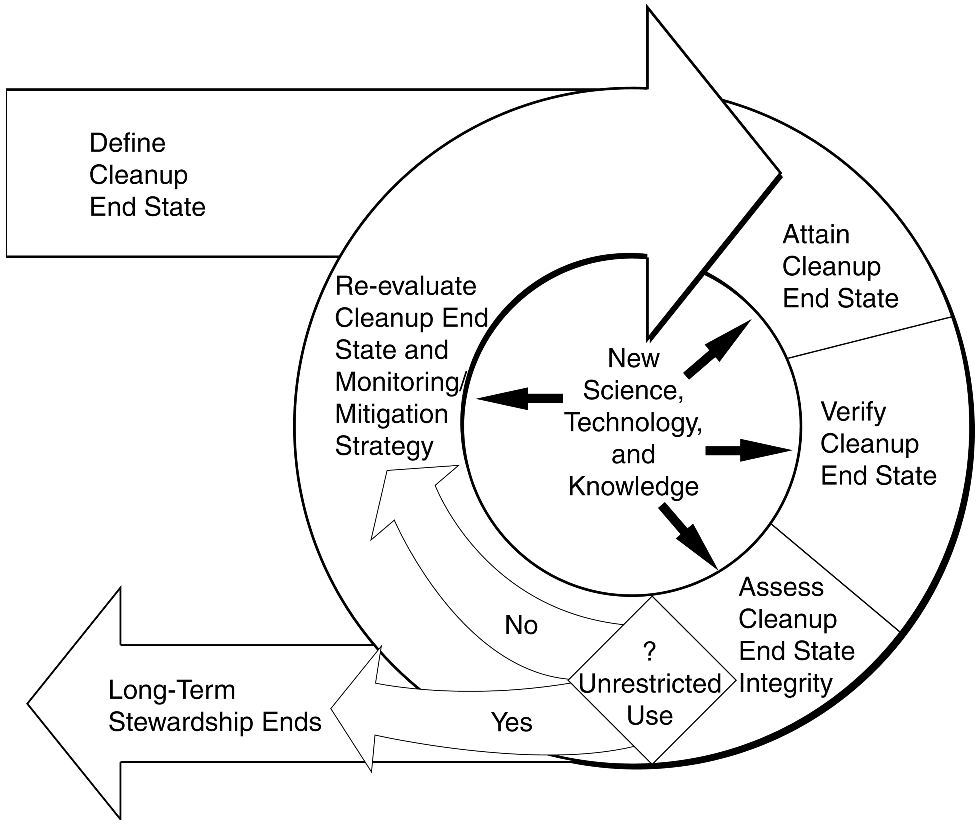
[7] The quoted definitions occur in the text box on page 9 of DOE 1999. A slightly different formulation for stewardship occurs in Appendix D, the Glossary of Terms:

> **Stewardship (or long-term stewardship):** encompasses all activities required to maintain an adequate level of protection to human health and the environment posed by nuclear and/or chemical materials, waste, and residual contamination remaining after cleanup is complete.

The report divides stewardship activities at DOE sites into two general categories: *active controls*, which are activities performed continuously or relatively frequently to control risk of exposure at a site, and *passive controls*, which include physical barriers (fences), governmental controls (ordinances and permit requirements), or proprietary controls (deeds or easements) (DOE 1999, pp. 14–17). According to this latest assessment by DOE-EM of its stewardship responsibilities, 109 sites will be in some state of remediation and/or stewardship for several decades beyond 2000. Even after 2050, some form of active-control stewardship will be needed at 103 sites across the country. Passive controls only will still be needed at six sites. No stewardship will be needed at 35 sites after 2050 (DOE 1999, p. 40).

WAG applauds the increased realism, evident in this new policy of long-term stewardship, about the extent of residual contamination at the cleanup sites and the responsibility to control its consequences. Existing technology cannot fully and satisfactorily bring some of the affected locations to the end states required by existing compliance agreements and sought by concerned stakeholders. Over time, advances in science and technology change the range of options for remediation and stewardship. This dynamic relationship between remediation and stewardship is illustrated by Exhibit 13 in *From Cleanup to Stewardship* (reproduced below). The phrase "remediation and stewardship" has been used throughout the rest of this report to express the importance of a holistic approach to assessing and implementing the options for residual contamination in the subsurface environment or elsewhere at the DOE sites.

As the site owner responsible for contamination problems that can be ameliorated by advancing science and technology, DOE has both an interest in these advances and a responsibility to foster them. It must consider what portion of its resources to allocate to basic research and to the maturation of research results and technological innovation into its remediation and stewardship operations.




The relationship between cleanup, end states, and long-term stewardship requirements outlined in this report represents a static projection, or snapshot in time, based on existing knowledge and technologies. However, technologies will improve over time, creating opportunity for improved efficiencies in both the cleanup and stewardship phases. Efforts to accelerate cleanup will more rapidly reduce risks posed by hazards at DOE™s sites and also will reduce ongoing maintenance costs significantly. This, in turn, should make more resources available for investments in new science and technologies.

*Changing knowledge and technology will affect cleanup goals and strategies*. New scientific understanding or regulatory changes may affect end state requirements such as residual contamination levels. New technologies may provide more economical approaches to achieve the same end state or may allow currently infeasible end states to be achieved. A key focus of efforts to attain different end states will be the ability to reduce long-term stewardship requirements.

*Changing knowledge and technology will affect long-term stewardship activities*. New scientific understanding and new technologies may lead to more economical and effective strategies for verifying that a desired end state actually is achieved, for monitoring the long-term integrity of the end state, and for developing and implementing contingency plans to anticipate and mitigate failures. Changes in information technology will affect strategies for generating, preserving, and providing access to critical long-term stewardship data.

*Changing knowledge and technology will require periodic re-evaluation of existing end states*. If history is our guide, we can expect profound changes in human economics, culture, science, and technology over time. For example, patterns of land and other resource use at and near long-term stewardship sites will change, and knowledge and technology will evolve in a variety of fields. At some point in the future, existing engineered controls will begin to fail unless additional actions are taken. At the same time, new technology can translate to more robust engineered controls requiring less intensive long-term stewardship activities. A critical part of long-term stewardship will be a systematic re-evaluation and modification of existing end states over time to ensure that developments in science, technology, and other knowledge are incorporated into long-term stewardship strategies.

Source: DOE 1999, p. 50.

> **Recommendation 5-1.** *DOE must recognize the importance of long-term commitments in scientific research and technological innovation as investments toward reducing the costs and improving the effectiveness of environmental remediation and stewardship. The Secretary of Energy should instruct the Assistant Secretary of Environmental Management to make the Environmental Management Science Program (EMSP) the flagship program for basic research in environmental management and remediation. The funding for EMSP should be increased about fourfold from recent levels..*

**Implementation Strategy.** The Assistant Secretary of Environmental Management can redirect the role of EMSP by emulating the best practices of mission-directed basic research programs in the DOE Office of Science, DOD, NIH, the National Science Foundation, and elsewhere in the federal R&D enterprise. The Assistant Secretary and other DOE officials must be prepared to make a convincing case to those who control resource allocations that, once the program has been successfully redirected toward the mission for which it was intended, it deserves increased resources. Given adequate funding, the scope of the program can be expanded to sustain basic research in core disciplines while targeting broad areas (strategic research objectives) of special relevance to the unmet S&T needs of the cleanup sites.

**Rationale.** To support long-term remediation and stewardship, a concerted research initiative is needed to advance our fundamental knowledge of the subsurface system and its interactions with human-introduced contaminants. The EMSP was intended to support this kind of basic research, but its current funding levels and administration severely restrict its role.

The EMSP was created in 1995 by a specific congressional appropriation. The language of the conference report is of interest, in light of the WAG team's assessment of the current status of the EMSP and the value of a concerted research initiative to support environmental remediation and stewardship.

> The conferees agree with the concern expressed by the Senate that the Department [of Energy] is not providing sufficient attention and resources to longer term basic science research which needs to be done to ultimately reduce cleanup costs. The current technology development program continues to favor near-term applied research efforts while failing to utilize the existing basic research infrastructure within the Department and the Office of Energy Research [now the DOE Office of

> Science]. As a result of this, the conferees direct that at least $50,000,000 of the technology development funding provided to the environmental management program in fiscal year 1996 be managed by the Office of Energy Research and used to develop a program that takes advantage of laboratory and university expertise. This funding is to be used to stimulate the required basic research, development, and demonstration efforts to seek new and innovative cleanup methods to replace current conventional approaches which are often costly and ineffective.
>
> (Public Law 104-46, 1995, as quoted at NRC 1997b, p.10)

Clearly, Congress was moving in the right direction, although funding was modest. As the NRC committee that studied the EMSP pointedly noted, this first-year investment of $50 million was "modest compared to the Department's $6.1 billion annual investment in cleanup" (NRC 1997b, p. 12). Given that Congress saw the program as covering development and demonstration, as well as basic research, the investment was insufficient. The size of the annual budget never grew much and, in the fiscal year 2000 request, began dwindling. The fiscal year (FY) 1998 and 1999 adjusted appropriations were $46.1 million and $47 million, respectively, for "basic science." (An additional $7 million in FY 1998 and $9 million in FY 1999 were directed to the risk policy program.) The congressional request for FY 2000 fell to $32 million for basic science (OST 1999b).

The administration of this small program has unfortunately succumbed to the same bias toward near-term results and neglect of the requisites for productive long-term, fundamental research that prompted Congress to establish the EMSP in the first place. In DOE's words, the EMSP is "jointly managed" by DOE-EM and the Office of Science. In fact, the role of the latter is limited to providing a panel of external scientific peer reviewers for EMSP grant proposals. The NRC committee that evaluated the EMSP in 1997 did not reach consensus on whether this "joint management' arrangement was a good idea. However, with the exception of one dissenter, the committee thought this approach could work *if EMSP were managed by a strong director reporting directly to the Under Secretary of Energy* (NRC 1997b, pp. 58–61 and Appendixes D and E). DOE has not adopted that recommendation.

In WAG's view, the EMSP continues to suffer from short-term managerial thinking aimed at near-term problem solving instead of long-term R&D to support environmental remediation and stewardship. The following examples illustrate the difficulties that the EMSP faces in achieving the mission for which it was intended.

- In 1999 the decision was made not to provide follow-on funding for any of the research "graduating" from the first three-year class of grantees. The FY 2000 call for proposals is in specific areas, and researchers would need to be working in those areas to apply for continued funding. We understand that this decision reflects the desirability of not tying up the shrinking EMSP budget in a "mortgage" to existing grantees. However, there is no other EM-sponsored research program to which promising fundamental research can graduate for support. Three years is far too short a time to expect truly fundamental and "breakthrough" research to yield applications. Thus, much of the investment in the EMSP will be lost unless the researchers are able to find funding elsewhere than in DOE. This is unworthy of a vital program to address a serious problem of importance to the nation. The decision suggests a lack of appreciation of the role of fundamental research and the time frame required to pursue it successfully to results of eventual utility.
- During visits to national laboratories, the WAG team spoke with researchers doing frontline, fundamental research of obvious long-term value to DOE environmental remediation problems and possessing the potential for true "breakthroughs" in addressing problems that currently have no adequate solution. These researchers complained of EMSP application and reporting requirements for specific year estimates when the results of their research would be put into operations. Again, this suggests a lack of understanding of how fundamental research contributes to long-term problem solving.

The EMSP has been described as a "needs-driven or mission-directed basic research program" (NRC 1997b, p. 25). The WAG assessment is that, at its current scale and with its current approach to research management, the EMSP is inadequate as a basic research program and as a long-term contributor to meeting DOE's responsibilities for long-term remediation and stewardship.

Although it is difficult to define precisely what level of EMSP funding would be adequate, there are several relevant metrics that provide a useful ballpark estimate.[8] The DOE's proposed FY 99 budget was $18 billion, of which the total for science and technology is $2.7 billion, or 15 percent. The proposed environmental management budget was $6.7 billion, or 37 percent of the total DOE mission resource. If 15 percent of

[8] Proposed FY 2000 budget numbers are used in this example because final FY 2000 appropriations were not available when the report was being reviewed by the workshops.

the environmental management budget were allocated to R&D, that amount would be $1 billion. In FY 99, the R&D budget for DOD[9] was $7.8 billion, of which basic research was $1.1 billion, or 14 percent. (The corresponding value for DOD in the FY 2000 proposed budget is 15 percent.) If the basic research, or EMSP, portion of the DOE-EM budget were 14 percent of a DOE-EM R&D budget of $1 billion, it should be $140 million, or about four times the recent funding level.

If the EMSP is to succeed and grow into a basic research program directed to the mission of reducing the costs and improving the effectiveness of DOE's long-term environmental remediation and stewardship commitments, then the Department as a whole, as well as DOE-EM and OST, must have a clear and shared vision of that mission. DOE-EM—particularly OST through its focus area approach—has moved decisively in the direction of becoming more responsive to user needs, where the "users" are site contractors and, to a lesser extent, the DOE field offices for the sites. For moving new knowledge into potential applications (i.e., applied research) and for moving innovative technologies through the existing gaps (the "valleys of death") in program support and funding for demonstration and cost-and-performance testing, these changes can be a very good thing. However, for management of a severely resource-constrained program in basic research, these changes are likely to exacerbate the historical weaknesses of DOE-EM and OST in supporting and administering a balanced program of basic research. Whether the EMSP stays in its position as a partnership of DOE-EM and the Office of Science or is moved elsewhere on the organization chart, it needs to function better as an engine for basic research. It also needs funding commensurate with the mission assigned to it.

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**Recommendation 5-2**. *The Assistant Secretary for Environmental Management should administer the RD&D programs supporting DOE's environmental management mission as elements in a coherent strategy for moving technologies and new knowledge to maturation and operational deployment.*

[9] R&D numbers given for DOD represent the sum of basic research (6.1), applied research (6.2), and advanced technology development (6.3).

**Implementation Strategy.** The RD&D system for expanding the knowledge base and maturing new technology must apply consistently across all of DOE-EM to be effective. Implementation of a systematic approach to research and technology development within OST alone is inadequate. Program funding, in both magnitude and administration, should be linked to a coherent strategy for research and technology maturation, as well as funding for large-scale demonstration projects.

This DOE-EM strategy for RD&D should provide a stable base of funding for research to acquire new fundamental knowledge in relevant core disciplines. A major portion of this research should be constrained by only the broadest implications for long-term mission relevancy, analogous to the Army's Strategic Research Objectives.

**Rationale.** DOE could benefit from a more coherent approach to funding RD&D programs by which fundamental knowledge can be acquired, moved into development and demonstration of practical solutions, and eventually applied to solving site remediation and stewardship problems. The WAG team found three funding gaps, or "valleys of death," in the existing program structure for moving from research through development to demonstration and deployment.

1. As noted in Recommendation 5-1, there is inadequate funding of basic research, and this gap is compounded by the weak links to academia and industry (see Recommendations 3-1 and 3-2). As noted in Box 5, item 11, even a mission-oriented agency such as DOD recognizes the importance of maintaining investment in core disciplines fundamental to its knowledge base.
2. A funding gap curtails the movement of EMSP successes into follow-on funding or applied research. As noted in the rationale for Recommendation 5-1, promising lines of research from the first years of the EMSP will probably be delayed or abandoned by the lack of any systematic process for "graduating" research projects from the EMSP to a next phase of basic research support or to applied research.
3. Many critics have pointed to the funding gap between advanced development of cleanup technologies, which OST has often done well, and the subsequent stages of demonstration to show site-specific applicability and acquire valid cost and performance data. Thus, many OST technologies have had a prototype demonstration at a cleanup site, funded by OST or another unit of DOE-EM, but the path to operational deployment stops at that point. The problem is not that projects do not meet valid exit criteria. Rather, they drop

> off a cliff of available funding because there are no DOE programs to continue them and no incentives for site contractors to assume the risks.

A coherent approach to RD&D programs across DOE-EM, together with rational funding allocations, would contribute immensely to overcoming these three gaps.

A major OST initiative has been the adoption of a stage-and-gate model to evaluate and monitor its projects (NRC 1999c, pp. 49-50). This model, which has seven stages in technology maturation from basic research through demonstration and implementation, is analogous to the seven stages used by DOD. Between each two stages is a gate; projects in one stage must pass specified exit criteria before moving to the next stage.

The WAG team is not certain that a system with seven stages and a rigid set of entrance and exit criteria between stages is the best approach for developing technology to meet the long-term environmental management needs of DOE. Seven stages may be too many. Furthermore, we recognize that innovation is nonlinear, and new ideas can enter at any stage in the RD&D process. New knowledge is crucial when effective solutions are absent. Thus, flexibility is needed to combine stages, move good ideas into the process at downstream stages, and provide feedback loops, as well as rapid-prototyping opportunities. However, what DOE-EM lacks, which a stage-and-gate model tries to provide, is a clear set of linkages from one stage in technology development to the next.

A valuable aspect of the DOD model is that funding of defense RD&D is directly keyed to these stages of research and technology maturation. These are the well-known 6.1 to 6.7 funding lines used in the overall DOD and individual military service budgets. Whether seven distinct categories or fewer are needed, the linkage of funds to stages of maturation is a key element. For a linked system of technology development programs to work as intended, funding must be rationally related to the requirements of the phase of maturation. When this does not happen, either because of external constraints such as congressional earmarks or vagaries in funding decisions within an agency, the entire process of RD&D suffers.

DOE can study and learn from some excellent models of mission-directed programs in RD&D elsewhere in the federal S&T support framework. In particular, DOE at the departmental level should study the role of DARPA at the joint-service level of DOD's mission and the roles played by the individual services' offices of research in providing mission-oriented core research programs. For example, the Army Research Office has successfully employed the concept of "strategic research objectives" to provide focus for its basic research investment portfolio. DDR&E has adopted this concept (and the initial set of Army Strategic Research Objectives) in the form of Defense Research Objectives. In addition, an NRC study committee recently made excellent recommendations to the Office of Research and Development in the Environmental Protection Agency about the proper balance between a core research program to support long-term environmental policy and problem-driven research to meet near-term decision needs (NRC 1997c).

As a guide to the range of possibilities an environmental management S&T initiative might pursue, with an adequately funded EMSP as its principal component for supporting basic research, we summarize some examples from other national research initiatives:

**NASA** During the buildup of the U.S. space program, facilities were constructed on university campuses and at space flight centers to support basic and applied research, as well as technology development and demonstration. Large numbers of grants and fellowships were created to stimulate the growth of fundamental knowledge in relevant disciplines. University scientists and engineers became fully engaged with their space program counterparts in designing experiments, building instruments, and analyzing space-derived data.

**NIH** The R&D budget was $14 billion for fiscal year 1999, allocated mostly as external grants. Currently NIH supports traineeships, is the world's largest research grants agency, and constructs facilities on university campuses.

**DOD** The world's best technology is needed in support of the national security mission. The R&D funding of $7.8 billion for FY 99 supports basic and applied research and technology development in universities, intramural and national laboratories, industry, and the services' development and engineering centers. This support system provides the technical basis for effective products: the most technologically advanced military systems in the world. DOD contracts include contractor-directed Independent Research and Development funding.

Other examples of integrated approaches to basic research, applied research, and technology development can be found among the S&T programs of the DOE Office of Science, the National Science Foundation, the Department of Agriculture, and the National Oceanic and Atmospheric Administration.

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**Recommendation 5-3.** *DOE-EM should estimate the magnitude of expected annual subsurface remediation and stewardship costs at the long-term stewardship sites as a function of the cost stream over time (including all the life-cycle components of cost). It should then size its annual subsurface RD&D budget according to a reasonable projection of the return on investment from reducing these costs through new knowledge and technological advances.*

**Implementation Strategy.** DOE-EM should follow industry experience in allocating a fraction of the estimated annual life-cycle costs of subsurface contamination activity to long-term RD&D that could lower those costs. The allocation fraction used by one or more industries with analogous long-term cost situations should be applied as a benchmark for the appropriate funding of RD&D in budget requests. Areas of scientific and technical uncertainty in near-term and long-term roadmaps should be used as guides to allocations within the overall budget request. The process of estimating expected annual costs over time and assessing the fraction to allocate to RD&D should be repeated in 5-year cycles.

**Rationale.** In the context of managing RD&D, a front-end strategy for investing in and managing science and technology is a major factor in finding cost-effective solutions and reducing life-cycle costs. For circumstances where a large mortgage of continuing costs could be reduced through RD&D, private-sector industries use an approximate, early estimate of life-cycle costs to frame their initial decisions on the size of the annual investment to make in RD&D to reduce these costs. The rationale is to achieve a reasonable long-term "return on investment" from RD&D that lowers the costs expected in the absence of better solutions to the problem.

As noted above, DOE recently estimated that 109 sites will be in some state of remediation and/or stewardship for several decades beyond 2000. These sites will incur the greatest total costs for remediation and long-term management. Robust characterization of the subsurface and its contaminants at these sites is not yet available. Remediation at some sites is at an early stage, with uncertain effectiveness. Many of the technologies needed for the more difficult cleanup sites have yet to be developed. Under these circumstances of great uncertainty, strategies for operations and RD&D investments are difficult to decide and defend, as are priorities, long-term R&D planning, operational arrangements with contractors, agreements with regulatory agencies, and consultations with stakeholders.

The entire process of estimating total cost over the life cycle of the problem and assessing near-term allocations to reduce it through R&D is iterative and needs to be repeated every 5 years or so. Over time, better estimates of the long-term cost as an annualized expense become available through experience in dealing with the problem and from the research being conducted to characterize and solve it. These new estimates of long-term continuing (annual) cost should be used to resize the RD&D budget as a reasonable investment.

The importance of beginning with a good estimate of annualized costs over time may justify commissioning several groups of experts to estimate these costs independently, to obtain a range of possibilities. Once this estimated range is available, alternative front end paths and costs can be weighed to achieve the best life-cycle outcome. These are among the most important decisions to be made because they determine overall costs, and the cost is high of reversing them downstream.

Another metric of interest to this estimation of return on an R&D investment is the amount spent on R&D by the private sector in markets where product innovation is a critical success factor. In 1995, the ratio of R&D funds to net sales in three high-technology sectors (electronic components; communication equipment; and office, computing, and accounting machines) was 8 percent. The ratio for drugs and pharmaceuticals was 10.4 percent (National Science Board, 1998, p. 4-19). For new business areas where technology innovation is a critical factor in market success, R&D ranges from 10 to 15 percent of sales. These numbers suggest that a ratio of R&D to total budget of 15 percent is appropriate for a technology-intensive operation such as DOE-EM.

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**Recommendation 5-4.** *DOE should take the lead in establishing a subcommittee of the National Science and Technology Council to pursue a coordinated national program for addressing groundwater contamination from all human sources.*

**Implementation Strategy.** The DOE programs in RD&D for subsurface contamination, as well as the experience gained in characterizing and cleaning up subsurface contaminants at the DOE sites, should be a major source of research and technology transfer aimed at solving broader national and international problems of subsurface contamination, particularly those where potable groundwater is threatened. A national program coordinating the work in this area by DOE, the Environmental Protection Agency, DOD, the U.S. Geological Survey, and other federal agencies should be established under the National Science and Technology Council, or whatever mechanism for interagency coordination succeeds it.

**Rationale**. From a broader perspective than just the remediation and stewardship of the DOE sites, the subsurface contamination problems at the sites are part of a larger context of subsurface contamination problems that occur across the nation and around the world. Some of these problems, particularly where potable groundwater is at stake, pose far more serious and near-term threats to human health and the environment than those posed by the DOE sites. Examples in this country include threats to local sources of potable water from overtaxed septic fields, as well as seepage of wastes from inadequately maintained storage tanks, landfills, and waste burial sites. Internationally, health and environmental hazards from subsurface contamination in parts of the former Soviet Union and eastern European countries are immediate and serious.

As we discussed under Recommendation 5-1, DOE’s long-term remediation and stewardship responsibilities require long-term research to improve our fundamental knowledge about complex hydrogeologic systems and foster technological innovation. Yet, this research offers additional benefits in contributing to solutions for water resource problems across the nation and around the world. The DOE mission in environmental management generally and in S&T to address subsurface contamination in particular should be viewed as a major resource in the larger effort needed to solve national and international problems resulting from subsurface contamination. By leading an effort to coordinate its RD&D programs with those of other federal agencies, through a new subcommittee of the National Science and Technology Council or an equivalent mechanism, DOE could help to reap these wider "spin-off" benefits of its environmental management responsibilities.

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# Appendix A
# Charge to the Washington Advisory Group

On December 16, 1998, Gerald G. Boyd, Deputy Assistant Secretary, Office of Science and Technology, provided the following guidance for this project in a letter to Robert M. White, President, The Washington Advisory Group.

> After reviewing your outline, we believe that the Washington Advisory Group could provide substantial benefit to the Department by taking an independent, critical look at the Department's efforts to deal with contaminant flow through the vadose zone and related ground water systems. . . .We would be interested in reviewing a modified proposal for an effort based on the attached preliminary statement of work, hopefully beginning in January or February 1999, . . .

The preliminary statement of work for the project included three major tasks, which were carried into the contractual statement of work:

1. Examine lessons learned from nearly 20 years of vadose zone research at Yucca Mountain to determine the relevance of modeling and performance assessment techniques to Hanford applications.
2. Review the long-range plan prepared by the [Hanford Groundwater/Vadose Zone] Integration Team. Determine the adequacy of the Science and Technology Roadmap as part of the long-range plan for Hanford. Recommend an appropriate balance between basic and applied vadose zone research for Hanford and overall DOE site needs.
3. Describe/recommend a policy/management framework for vadose zone research both in Hanford and across the complex, taking into account the current management structure of focus areas for applied research.

The contractual Statement of Work includes the following summary of the project:

> The Washington Advisory Group (WAG) proposes to undertake an independent critical evaluation of the Hanford and other Department of Energy (DOE) research and development efforts to address contaminant flow through the vadose zone and related ground water systems. The focus of its study will be on the policy/management structure of the present vadose zone and associated groundwater research program. It proposes to do this through a selected review of the appropriate literature and the DOE research portfolio, discussions with the management and scientific groups at Hanford and other DOE facilities, and by the

conduct of workshops to critique and contribute to WAG reports. It will undertake the evaluation in two phases: the first phase extending from March 1, 1999, through September 30, 1999, and an optional second phase from October 1, 1999, through December 31, 1999. . . .

# Appendix B
# Literature and Document Sources Reviewed by the WAG Project Team

## A. NATIONAL RESEARCH COUNCIL REPORTS


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13. *Groundwater and Soil Cleanup: Improving Management of Persistent Contaminants.* Committee on Technologies for Cleanup of Subsurface Contaminants in the DOE Weapons Complex. Board on Radioactive Waste Management, National Research Council. Washington, D.C.: National Academy Press. 1999.

14. *Improving Project Management in the Department of Energy.* Committee to Assess the Policies and Practices of the Department of Energy to Design, Manage, and Procure Environmental Restoration, Waste Management, and Other Construction Projects. Board on Infrastructure and the Constructed Environment, National Research Council. Washington, D.C.: National Academy Press. 1999.

15. *Decision Making in the U.S. Department of Energy's Environmental Management Office of Science and Technology*. Committee on Prioritization and Decision Making in the Department of Energy Office of Science and Technology. Board on Radioactive Waste Management, National Research Council. Washington, D.C.: National Academy Press. 1999.

16. *An End State Methodology for Identifying Technology Needs for Environmental Management, with an Example from the Hanford Site Tanks.* Committee on Technologies for the Cleanup of High-Level Wastes in Tanks in the DOE Weapons Complex, Board on Radioactive Waste Management, National Research Council. Washington, D.C.: National Academy Press. 1999.

## B. GENERAL ACCOUNTING OFFICE REPORTS

17. GAO/RCED-94-205. *Department of Energy: Management Changes Needed to Expand Use of Innovative Cleanup Technologies.* August 10, 1994.

18. GAO/RCED-97-18. *Department of Energy: Contract Reform is Progressing but Full Implementation Will Take Years.* December 1996.

19. GAO/T-RCED-97-161. *Cleanup Technology: DOE's Program to Develop New Technologies for Environmental Cleanup.* May 7, 1997.

20. GAO/RCED-98-80. *Nuclear Waste: Understanding of Waste Migration at Hanford is Inadequate for Key Decisions.* March 1998.

21. GAO/RCED-98-169. *Department of Energy: Alternative Financing and Contracting Strategies for Cleanup Projects.* May 1998.
22. GAO/RCED-98-223. *Department of Energy: Lessons Learned Incorporated into Performance-Based Incentive Contracts.* July 1998.
23. GAO/RCED-98-249. *Nuclear Waste. Further Actions Needed to Increase the Use of Innovative Cleanup Technologies.* September 1998.
24. GAO/RCED-98-274. *Department of Energy: DOE Lacks an Effective Strategy for Addressing Recommendations from Past Laboratory Advisory Groups.* Sept. 23, 1998.

## C. DOE/RICHLAND PUBLISHED REPORTS

1. *Groundwater/Vadose Zone Integration Project Specification.* [Main Report and Appendices A through I.] DOE/RL-98-48. Draft C. Richland Operations Office, U.S. Department of Energy. Richland, Washington. December 17, 1998.
2. Groundwater/Vadose Zone Integration Project: Long Range Plan. Richland Operations Office, U.S. Department of Energy. Richland, Washington.
3. *Groundwater/Vadose Zone Integration Project: Project Management Plan.* DOE-98-56. Revision 0 – Internal Draft. April 1998. Richland Operations Office, U.S. Department of Energy. Richland, Washington.
4. *Accelerating Cleanup: Paths to Closure, Hanford Site.* DOE/RL-97-57 (Draft), Richland Operations Office, U.S. Department of Energy. Richland, Washington.
5. *Hanford Science and Technology Needs Statements.* DOE/RL-98-0, Rev. 1. Richland Operations Office, U.S. Department of Energy. Richland, Washington.
6. *Management and Integration of Hanford Site Groundwater and Vadose Zone Activities.* DOE/RL-98-03. Richland Operations Office, U.S. Department of Energy. Richland, Washington. April 1998.
7. *Hanford Strategic Plan*. DOE/RL-96-92. Richland Operations Office, U.S. Department of Energy. Richland, Washington.
8. *Hanford Tank Farms Vadose Zone – Baseline Characterization Current Status and Issues Briefing*. GJO-98-55-TAR. Grand Junction Office, U.S. Department of Energy. Grand Junction, Colorado.
9. 200 Areas Soil Remediation Strategy. DOE/RL-96-67. Richland Operations Office, U.S. Department of Energy. Richland, Washington.
10. *Hanford Remedial Action Environmental Impact Statement and Comprehensive Land Use Plan.* (draft). DOE/EIS-0222D. Richland Operations Office, U.S. Department of Energy. Richland, Washington.
11. *Risk/Impact Technical Report for the Hanford Groundwater/Vadose Zone Integration Project.* Preliminary Working Draft, January 8, 1999. Prepared by the U.S. Department of Energy Center for Risk Excellence, Chicago Operations Office, for the Richland Operations Office, U.S. Department of Energy.

12. *Columbia River Comprehensive Impact Assessment Team. Screening Assessment and Requirements for a Comprehensive Assessment–Columbia River Comprehensive Impact Assessment.* DOE/RL-96-16, revision 1. UC-630. March 1998.

13. *TWRS Vadose Zone Contamination Issue Expert Panel Status Report.* DOE/RL-97-49 Revision 0. Richland Operations Office, U.S. Department of Energy. Richland, Washington. April 1997.

**D. PACIFIC NORTHWEST NATIONAL LABORATORY DOCUMENTS**

14. Roy E. Gephart. *An Overview of Hanford's Waste Generation History and the Challenges Facing Site Cleanup.* PNNL-11866 Review Draft. Pacific Northwest National Laboratory, U.S. Department of Energy. September 1998.

15. S.M. Narbutovskih. *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas B-BX-BY at the Hanford Site.* PNNL-18826, UC-502. Pacific Northwest National Laboratory, U.S. Department of Energy. February 1998.

16. F.N. Hodges. *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas T and TX-TY at the Hanford Site.* PNNL-11809, UC-502. Pacific Northwest National Laboratory, U.S. Department of Energy. January 1998.

17. V.G. Johnson and C.J. Chou. *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site.* PNNL-11810, UC-502. Pacific Northwest National Laboratory, U.S. Department of Energy. January 1998.

18. C.R. Cole et al. *Three-Dimensional Analysis of Future Groundwater Flow Conditions and Contaminant Plume Transport in the Hanford Site Unconfined Aquifer System: FY 1996 and 1997 Status Report.* PNNL-11801, UC-903. Pacific Northwest National Laboratory, U.S. Department of Energy. December 1997.

**E. OTHER DOE PUBLISHED REPORTS**

19. *Accelerating Cleanup: Paths to Closure.* DOE/EM-0362. Office of Environmental Management, U.S. Department of Energy. Washington, D.C. June 1998.

20. *Yucca Mountain Viability Assessment.* 5 volumes, plus technical baseline support documents. [The entire five volumes of the Viability Assessment plus supporting volume are available at the Yucca Mountain website at http://www.ymp.gov/va.htm.]

21. Environmental Management Research and Development Program Plan: Solution-Based Investments in Science and Technology. Office of Environmental Management, U.S. Department of Energy. Washington, D.C. November 1998. (second printing, December 1998).

22. Environmental Management Strategic Plan for Science and Technology. November 1998. Office of Environmental Management, U.S. Department of Energy. Washington, D.C.

23. Overview of Interagency DNAPL Consortium.

24. Magnuson, S.O. and A.J. Sondrup. 1998. Development, Calibration, and Predictive Results of a Simulator for Subsurface Pathway Fate and Transport of Aqueous- and Gaseous-Phase Contaminants in the Subsurface Disposal Area at the Idaho National Engineering and Environmental Laboratory. DOE Report No. INEEL/EXT-97-00609. June 1998. Idaho Falls, Idaho: Lockheed Martin Idaho Technologies Company.

25. Suzanne Rudzinski et al. Review of the Federal Management of the Tank Waste Remediation System (TWRS) Project at the Department of Energy's Hanford, WA Site. Executive Summary. January 15, 1998.

[For additional DOE documents and reports not formally published, see Unpublished Documents below.]

## F. RECENT WORK IN THE PEER-REVIEWED LITERATURE

The WAG project team has scanned the peer-reviewed literature to assess the nature and scope of recent research in groundwater/vadose zone contaminant identification, characterization, monitoring, containment, and remediation. The scan also showed the extent of research being done in academia, industry, and non-DOE governmental agencies, as well as by scientists in the DOE national laboratories. Examples of the kinds of items identified in this scan are listed below.

26. B.R. Scanlon, S.W. Tyler, and P.J. Wierenga. "Hydrological Issues in Arid, Unsaturated Systems and Implications for Contaminant Transport." *Reviews of Geophysics* **35** (1997): 461–490.

27. B. Kaelin and L.R. Johnson. "Using Seismic Cross-Well Surveys to Determine the Aperture of Partially Water Saturated Fractures." *Geophysics* **64** (1999): 13–23.

28. J.O. Parra, V. Price, C. Addington, B.J. Zook, and R.J. Cumbest. "Inter-Well Seismic Imaging at the Savannah River Site, South Carolina." *Geophysics* **63** (1998): 1858–1865.

29. *The Use of Isotopes and Environmental Tracers in Subsurface Hydrology. U.S. National Report to the IUGG for 1991–1994.* Published as *Reviews of Geophyiscs* **33** 1995). See especially the chapter on the vadose zone by F.M. Phillips.

30. *Scientific Basis for Nuclear Waste Management.* Proceedings of a symposium chaired by Walter Gray of Pacific Northwest National Laboratory and Ines Tria of Los Alamos National Laboratory, December 2-6, 1996. Materials Research Society.

## G. UNPUBLISHED DOCUMENTS

31. "The Imperative of Cleanup Reform." Letter from Pacific Northwest National Laboratory Advisory Committee to the Secretary of Energy, February 8, 1999.

32. Fabryka-Martin, J., A. Flint, and G. Gee. 1998. *Peer Review Team Report on Conceptual Models and Field Verification of Radionuclide Transport through the*

*Vadose Zone at INEEL.* Final Report, November 5, 1998. Prepared for Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

33. Steven Gorelick, Charles Andrews, and James Mercer. *Report of the Peer Review Panel on the Proposed Hanford Site-Wide Groundwater Model.* 1998.
34. *DOE Environmental Quality Research and Development Portfolio.* March 26, 1999 Final Draft.
35. EM Investments in Science and Technology: Understanding the Basis for the FY 2000 Congressional Budget Request. February 23, 1999. Office of Science and Technology, U.S. Department of Energy.
36. *Office of Science and Technology Management Plan.* Draft, February 1999. Office of Science and Technology, U.S. Department of Energy.
37. Cost/Performance Variance Analysis Reports. January 1999. Office of Science and Technology, U.S. Department of Energy.
38. Don Wodrich. Historical Perspective of Radioactively Contaminated Liquid and Solid Wastes Discharged or Buried in the Ground at Hanford. Briefing package presented to the Washington Advisory Group team, May 12, 1999, during site visit on the Groundwater/Vadose Zone Integration Project. Richland, Washington.
39. Tony Knepp. 200 Area ER Remedial Action Project. Briefing package presented to the Washington Advisory Group team, May 12, 1999, during site visit on the Groundwater/Vadose Zone Integration Project. Richland, Washington.
40. D. Hildebrand, et al. Groundwater/Vadose Zone Integration Project Science Workshop. April 22, 1999. Briefing package.
41. K. Michael Thompson and Mark A. Buckmaster. Hanford Groundwater Remediation Project. Briefing package for presentation to the Groundwater Technology End User Conference, April 15-16, 1998, Augusta, Georgia.
42. Groundwater/Vadose Zone Integration Project: Science and Technology Roadmap. [wall chart]. 12/16/98.
43. Lockheed Martin. TWRS Level-0 Logic: TWRS Program Logic. Drawing No. TWR-2086. Revision 1.

## H. INTERNET WORLD WIDE WEB HOME PAGES

The following websites contain substantial amounts of information reviewed by the team up to September 30, 1999.

1. DOE/Richland website: www.hanford.gov.
2. Bechtel Hanford, Inc., website for environmental restoration and the Groundwater/Vadose Zone Integration Project: www.bhi-erc.com.
3. Pacific Northwest National Laboratory website: www.pnl.gov, particularly the page for the Technical Library at www.pnl.gov/tech_lib/home.html.

4. DOE headquarters websites:
   - DOE Office of Environmental Management (EM): www.em.doe.gov
   - DOE/EM Office of Science and Technology: www.em.doe.gov/info/scitech.html and http://ost.em.doe.gov/IFD/OSThome.htm.
   - DOE Information Bridge: http://www.doe.gov/bridge/.
5. DOE Yucca Mountain Project homepage: http://www.ymp.gov.
6. Home page for the Subsurface Contaminants Focus Area: www.envnet.org/scfa.
7. General Accounting Office, Online Reports Access via GPO: http://www.access.gpo.gov/su_docs/aces/aces160.shtml.
8. National Research Council, Board on Radioactive Waste Management: http://www4.nas.edu/brwm/brwm-res.nsf.

# APPENDIX C
# Interviews, Principal Briefers for Site Visits, and Workshop Participants

## A. INTERVIEWS CONDUCTED IN THE WASHINGTON, D.C., AREA

1. John Ahearne, former and current member of NRC/BRWM committees and member of the DOE/EM Advisory Committee, interviewed by Frank Press and Robert White, March 27, 1999.
2. James Watkins, former Secretary of Energy, interviewed by Frank Press and Robert White, April 1, 1999.
3. Jane Long, chairwoman of NRC/BRWM committee on subsurface contamination, and Kevin Crowley, director of BRWM, interviewed by Frank Press and Robert White, April 5, 1999.
4. Alvin Alm, former Assistant Secretary of DOE/EM, interviewed by Frank Press and Robert White, April 6, 1999.
5. Thomas Grumbly, former Assistant Secretary of DOE/EM and Undersecretary of Energy, interviewed by Frank Press and Robert White, April 7, 1999.
6. Gerald Boyd, acting Director of the DOE/EM Office of Science and Technology, interviewed by Frank Press and Robert White, April 9, 1999. Also present: John Wengle and Skip Chamberlain.
7. Harold Forsen, former head of Bechtel Hanford, interviewed by Frank Press and Robert White, April 13, 1999.
8. Ernest Moniz, Undersecretary of Energy, interviewed by Frank Press and Robert White, April 19, 1999.
9. Dwight Cates, majority staff to the House Committee on Commerce, interviewed by Frank Press, Robert White, and Robert Katt, April 21, 1999.
10. Martha Krebs, Director, Office of Scientific Research, U.S. Department of Energy, interviewed by Frank Press and Robert White, May 4, 1999.
11. Michael Telson, Chief Financial Officer, U.S. Department of Energy, interviewed by Frank Press and Robert White, June 1, 1999.

## B. MEETINGS DURING HANFORD SITE VISIT, MAY 11–14, 1999

12. May 11, opening session, and project overview: Michael Graham, John Williams, Terri Stewart, Rich Holten, Jim Hanson, Michael Thompson, Mark Freshley, Dirk Dunning, Susan Pickering, Keith Klein (portion of session).

13. May 11, lunch. Terri Stewart, Mark Freshley, Rich Holten, Jim Hanson, Michael Graham, Tom Wintczak, John Williams.
14. May 11, site tour: George Henckel, Michele Gerber, Mark Freshley, Jim Hanson, Dave Myers, Dirk Dunning.
15. May 11, S&T roadmap overview: Terri Stewart, Jim Hanson, Michael Graham, Tom Wintczak, Keith Klein, Susan Pickering, Steve Leidle, Mike Thompson, Linda Bauer, Rich Holten.
16. May 11, contractor management, BHI: Steve Leidle, Mike Hughes, Michael Graham, Tom Wintczak.
17. May 11, DOE management: Linda Bauer, Rich Holten, Jim Popitti, Mike Thompson, Julie Erickson, Jim Hanson.
18. May 11, contractor management, Fluor Daniel Hanford: Anthony Umek, John Williams, Terry Walton, Carolyn Haas, Paul Scott.
19. May 11, ORP/RPP: John Williams, Paul Scott, Carolyn Haass, Ed Fredenburg.
20. May 11, Daily Closeout: Terri Stewart, Michael Graham, Jim Hanson.
21. May 12, STCG Interfaces: Jim Hanson, Paul Scott, Jerry White, Wayne Martin, William Bonner, Kim Koegler.
22. May 12, roadmapping process (at PNNL), Rod Quinn, Terri Stewart, Kellie Templeton.
23. May 12, 200 Area Assessment and Remediation: Tony Knepp, Mike Thompson (part of session).
24. May 12, S&T leads (at PNNL), John Zachara, Glendon Gee, Roger Dirkes, Terri Stewart, Rod Quinn.
25. May 12, Groundwater Remediation, Mike Thompson, George Henckel, Doug Hildebrand, Jerry White, Arlene Tortoso.
26. May 12, System Assessment Capability, Robert Bryce, Charles Kincaid, Robert Boutin, Mike Thompson, Susan Pickering, Michael Graham, Tom Wintczak.
27. May 12, lunch meeting, Terri Stewart, Michael Graham, John Williams, Rich Holten (part of session), Jim Hanson, Mark Freshley.
28. May 12, contractor management, PNNL: William Madia, Tom Page.
29. May 12, Environmental Management Science Program at PNNL: Roy Gephart, William Kuhn, Loni Peurrung, Terri Stewart, Dennis Brown, John Zachara, Glendon Gee, Andy Ward.
30. May 12, site background, Don Wodrich, Roy Gephart, Tom Wintczak, Mike Thompson.
31. May 12, stakeholder interfaces: Dru Butler, Linda Bauer, Robert Alvarez.
32. May 12, daily closeout (discussion of stakeholder interactions and CRCIA): Rich Holten, Jim Hanson, Terri Stewart, John Williams, Michael Graham, Linda Bauer.

33. May 12, dinner meeting: Edward Berkey, Robert Alvarez.
34. May 13, Environmental Molecular Sciences Laboratory: Teresa Fryberger, Terri Stewart, Jim Hanson.
35. May 13, final closeout meeting: Terri Stewart, Linda Bauer, Jim Hanson.

## C. MEETINGS DURING SITE VISIT TO DOE LAS VEGAS AND YUCCA MOUNTAIN PROJECT OFFICES, JUNE 9, 1999

1. June 9, Andrew Orrell, Sandia National Laboratory (Las Vegas Office).
2. June 9, Robert Andrews, Duke Energy, and Holly Dockery, Sandia National Laboratory.
3. June 9, John Pye (Morris Knudson) and others on Engineered Barrier Systems Lab Testing.
4. June 9, Russ Dyer, DOE-Las Vegas Office.
5. June 9, Kevin Leary, DOE-Las Vegas Office.
6. June 9, Alan Flint, U.S. Geological Survey.

## D. MEETINGS DURING SITE VISIT TO SANDIA NATIONAL LABORATORIES, JUNE 10–11, 1999

1. June 10, initial meeting, Les Shephard, Margaret Chu, Allen Lappin, Stephen Webb, Eric Lingren, Paul Kaplan, Rip Anderson, Randy Normann.
2. June 10, Flow Visualization and Process Laboratory, Robert Glass, Stephen Conrad, Paul Kaplan.
3. Tour of ER capillary barrier demonstration, Thomas Burford.
4. June 10, Discussion of WIPP lessons learned and application to Hanford, Rip Anderson, Margaret Chu, Les Shephard, Susan Pickering.
5. June 11, Innovative Treatment and Remediation Demonstration (ITRD) Program, Mark Tusker.
6. June 11, Monitor while drilling, Randy Normann.
7. June 11, The Sandia chemical waste landfill, a case history, Stephen Conrad.
8. June 11, Smart Sampling, a case history, Paul Kaplan.
9. June 11, Demonstration of Culebra monitoring database, M. Steele.

## E. MEETINGS DURING SITE VISIT TO SAVANNAH RIVER SITE, JUNE 15–16, 1999

1. June 15, Judy Bostock, Director, Savannah River Technical Center (SRTC), and Tom French, SRTC.

2. June 15, Thomas Heenan, Assistant Manager for Environmental Restoration, DOE-Savannah River Site (DOE-SRS).
3. June 15, Subsurface Contaminants Focus Area, John Geiger, Philip Washer, Tom Hicks.
4. June 15, Field projects discussion, Joette Sonnenberg, Cathy Lewis, Michelle Ewart, Brian Looney.
5. June 15, visits to environmental remediation field projects, Joette Sonnenberg, Cathy Lewis, Michelle Ewart.
6. June 16, F&H groundwater remediation project, Robert Baker, Ed McNamee.
7. June 16, GeoSyphon and GeoFlow technologies in the TNX area, Joette Sonnenberg, Cathy Lewis, Michelle Ewart.
8. June 16, Discussion of Vadose Zone Book project, Brian Looney.

## F. MEETINGS DURING SITE VISIT TO IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, JULY 6–8, 1999

1. July 6, Beverly Cook (DOE Site Manager) and Brooks Weingartner (DOE-Idaho).
2. July 6, Introduction and visit strategy, Clay Nichols (DOE-Idaho).
3. July 6, Overview of EM-50 innovative technologies at INEEL, George Schneider.
4. July 6, Environmental life sciences, Robert Snelling (LMITCo).
5. July 6, Field visit overview, Brooks Weingartner.
6. July 7, Basalt geology and chaos research, Dick Smith and Rob Podgorney.
7. July 7, Tour of Visitors Center, Nicole Owens.
8. July 7, RWMC overview, Swen Magnuson.
9. July 7, Engineered barriers, Indrek Porro and Joel Hubbell.
10. July 7, Studies by U.S.G.S., DeWayne Cecil.
11. July 7, RWMC field scale remediation studies, Tom Sherwood, Guy Loomis.
12. July 7, INTEC remediation and subsurface studies, Tom Stoops, Erik Neher.
13. July 7, Aquifer fast flow paths and ecosystem studies, Travis McLing, Paul Wichlacz.
14. July 7, Bioremediation studies, Lance Peterson, Kent Sorenson.
15. July 8, Summary and recapitulation, Clay Nichols.
16. July 8, Path forward discussion, question and answer session, Clay Nichols and other staff.
17. July 8, Outbriefing with DOE-Idaho Deputy Manager, Warren Bergholz.

## G. PARTICIPANTS IN DRAFT REPORT REVIEW WORKSHOP 1, WAG OFFICE, WASHINGTON, D.C., SEPTEMBER 8–9, 1999

Raphael Bras, Massachusetts Institute of Technology
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Robert Katt (WAG project team coordinator)
Perry McCarty, Stanford University
Shlomo Neumann, University of Arizona
Frank Press, WAG principal (WAG project team co-chair)
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Paul Witherspoon, University of California at Berkeley
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## H. PARTICIPANTS IN DRAFT REPORT REVIEW WORKSHOP 2, WAG OFFICE, WASHINGTON, D.C., SEPTEMBER 22–23, 1999

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Chris Whipple, ICF Consulting
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## I. PARTICIPANTS IN DRAFT REPORT REVIEW WORKSHOP 3, WAG OFFICE, WASHINGTON, D.C., OCTOBER 13–14, 1999

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D. Allan Bromley, WAG principal
Edward David, Jr., WAG principal
John Foster, Jr., TRW Inc.
Robert Frosch, WAG principal
Richard Mahoney, Washington University (former Chief Executive Officer, Monsanto Corporation)
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Frank Parker, Vanderbilt University (WAG project team associate)
Frank Press, WAG principal (WAG project team co-chair)
Robert White, WAG principal (WAG project team co-chair)