LONG-TERM STEWARDSHIP OF DOE LEGACY WASTE SITES—A STATUS REPORT

Committee on Long-Term Institutional Management
of DOE Legacy Waste Sites: Phase 2

Board on Radioactive Waste Management

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, DC 20001

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Support for this study was provided by the U.S. Department of Energy under Grant DE-FC01-99EW59049. All opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Department of Energy.

Copies of this report are available from:

The Board on Radioactive Waste Management
500 Fifth Street, N.W.
6th Floor
Washington, DC 20001
202-334-3066

Printed in the United States of America

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ACKNOWLEDGMENTS

This study was made possible by assistance from many people outside and within the National Academies. DOE staff provided essential support, particularly in setting up useful site visits. At the sites, DOE and contractor staff devoted time and effort in providing presentations, touring the sites, answering questions, and following up on unresolved points. Citizens, public officials, and activist groups in the communities that host the sites were likewise generous with their time and willingness to talk frankly with the committee. The committee specifically acknowledges the following groups: Miamisburg Environmental Safety and Health (MESH), Fernald Residents for Environmental Safety and Health (FRESH), and the Fernald Citizens Advisory Board (FCAB).

In writing and completing this report the study director, Micah Lowenthal, was indispensable: energetic, thoughtful, thorough, and generous in helping at every stage in helping to weave the many strands of expertise in this group into a coherent statement. The committee is also indebted to the Board on Radioactive Waste Management, especially senior project assistant Laura Llanos, research assistant Darla Thompson, and board director Kevin Crowley, who spent much time at our meetings and whose counsel was sensible and precise.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council (NRC) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The content of the review comments and draft manuscript remains confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

David E. Daniel, University of Illinois, Urbana-Champagne
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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by George M. Hornberger. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with NRC procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the NRC.

Contents

SUMMARY

The Department of Energy (DOE) is responsible for cleanup and care of over 140 sites contaminated with radioactive and chemical wastes, the residue of a half-century's production of nuclear weapons and research. DOE has embarked on an ambitious remediation program at these waste sites. Even so, more than 100 of these sites cannot be cleaned up enough to permit unrestricted human access and will require long-term management, in some cases indefinitely. DOE thus faces the challenge of protecting human health and environmental quality at these "legacy" sites, a process it calls "long-term stewardship" (LTS).

This study, initiated at the request of DOE's Office of Environmental Management, was undertaken to analyze long-term institutional management[1] plans and practices for a small group of representative DOE legacy waste sites, and to recommend improvements to these plans. (See Appendix A for the full statement of task.) To inform its deliberations, the committee visited two DOE sites in Ohio, Mound and Fernald, as well as the Moab Site in Utah, which was examined as a side study requested by Congress. The committee's observations from the Ohio sites are discussed in some detail in Appendix E, and the committee's work on the Moab Site was published previously (NRC 2002a).

At the request of DOE's assistant secretary for environmental management, the National Academies' Board on Radioactive Waste Management asked the committee to end its information-gathering activities early and to prepare a status report based on its work to date. The report is based on what the committee has found in visiting three DOE sites, reviewing documents relevant to LTS at these three and other DOE sites, and engaging in discussions with DOE staff and others. The findings and recommendations are necessarily somewhat limited, in some cases raising more questions than answers, partly because the study did not run its full course.

The report addresses the task statement by developing lessons that could be learned from the sites the committee visited and the documents it reviewed, and

[1]Long-term institutional management (LTIM) is an approach to planning and decision making that balances the use of measures available to site managers in protecting public and worker health and safety, and the environment: contaminant reduction, contaminant isolation, and long-term stewardship (NRC 2000a).

focusing on high-level issues related to improving planning and implementation of LTS at DOE legacy waste sites.

WHAT IS STEWARDSHIP?

DOE uses the term "long-term stewardship" to describe the activities required at contaminated sites where cleanup is complete, that is, after site closure. The word "stewardship" has been readily accepted by many people who have different understandings of the word. In this committee's view, stewardship comprises several tasks: A steward of very long-lived hazards acts as

- a *guardian*, stopping activities that could be dangerous;
- a *watchman* for problems as they arise, via monitoring that is effective in design and practice, activating responses and notifying responsible parties as needed;
- a *land manager*, facilitating ecological processes and human use;
- a *repairer* of engineered and ecological structures as failures occur and are discovered, as unexpected problems are found, and as re-remediation is needed;
- an *archivist* of knowledge and data, to inform the future;
- an *educator* to affected communities, renewing memory of the site's history, hazards, and burdens; and
- a *trustee*, assuring the financial wherewithal to accomplish all of the other functions;

This range of activities requires the human and institutional capacity to fulfill these roles as needed, through the decades and centuries in which the risks persist. The human and institutional demands of these activities are broader than the traditional engineering expertise of DOE, so questions arise regarding how best to meet the federal government's responsibilities over the long term.

CHIEF FINDING: The committee observed a compartmentalization of cleanup planning and LTS planning at the sites visited: cleanup planning and execution will conclude at a site, and LTS is left to address the resultant end state.

The committee has found no evidence that DOE (a) is considering requirements for and the likely effectiveness of LTS measures when establishing cleanup goals and approaches, or (b) has worked out practical and enduring means of implementing LTS so as to realize its goals for protection over the long term. In the recent emphasis by DOE on the objective of accelerating cleanup, the committee has seen no statement of how DOE will balance that objective against future risks. There is the possibility of a need for additional cleanup in the future if remediation is poorly planned or carried out. Moreover, if greater reliance on LTS is chosen over contaminant reduction, the consequences and in turn the risks of LTS failures may increase. Explicit consideration of LTS issues when establishing cleanup goals and approaches would demonstrate that DOE is taking its responsibilities seriously—a key step in building trust among wary stakeholders. The failure to link LTS to cleanup undermines credibility and strengthens the fear among skeptical stakeholders and regulators that a hollow promise of stewardship is being imposed as a substitute for more costly and complete near-term cleanup.

The committee has seen some progress in DOE efforts on LTS in recent DOE documents, but despite statements embracing LTS, the way in which DOE has selected, developed, and implemented remedies means that LTS continues to be an afterthought in practice.

CHIEF RECOMMENDATION: DOE should explicitly plan for its stewardship responsibilities, taking into account stewardship capabilities, when making cleanup decisions. DOE should also implement steps to anticipate and carry out those responsibilities in concert and conjunction with the cleanup process.

DOE's plans and practices today fall short of meeting the requirements of stewardship, in part because the Department focuses narrowly on complying with regulations. While compliance is necessary, it is not sufficient, because today's regulations do not fully address LTS challenges. Accordingly, the committee calls for a national dialogue on the broad challenge presented by the stewardship of industrial legacies and natural resources, and on the federal government's responsibilities.

The long-term effectiveness of a remedy is a criterion to be used in remedy selection under CERCLA, the law that frames decision making for many of DOE's cleanups. But this formal criterion has not resulted in thorough examinations of stewardship so far, nor even of the specific institutional controls stipulated in regulatory documents. On the contrary, regulators have agreed to remedies at DOE sites with only scant provisions for LTS, assuming that institutional controls are self-executing and self-enforcing. Experience with institutional controls demonstrates some of their limitations and fallibility, particularly over the long term. The point is not that institutional controls should not be used; they are among the few tools available. But the uncertainties of both institutional controls and engineered containment mean that simply complying with today's regulations is not enough. Compliance now does not ensure fulfillment of the responsibility to protect human health and the environment for the long term, because one cannot assume that the conditions set forth in regulations will endure.

Society needs a responsible authority to ensure that the LTS job is carried out adequately. Regulators have this role in principle. It will be important for DOE, as the responsible party at these sites, to make its own efforts in this area, exceeding the demands of regulators when necessary.

DOE bears an enduring responsibility—and a corresponding liability—for problems that arise in the future at its legacy-waste sites. The liability is in the form of the risks to human health and ecosystems that, at some sites, are likely to be unacceptable if planned or contemplated stewardship measures fail. For example, if controls at uranium tailings sites fail, anyone residing on or using waste materials from those sites could encounter risks that remain unacceptably high, indefinitely. It is in the long-term interest of DOE and the nation for DOE to recognize and act to fulfill its obligations, even when they carry the agency beyond existing regulations.

For a public agency to act in this fashion responsibly requires explicit attention to the values at stake in making choices and committing resources. This is because the process of remediation makes value commitments—apportioning costs and risks over time among populations, and altering the environment and the hazards posed. These values are expressed through decisions that are influenced by the state of the site and its surroundings, scientific understanding, and technological and institutional capabilities. The committee has not seen the values entering into DOE's decisions articulated in a way that connects to the people affected (in both present and future), or to human obligations for care of natural systems. Without clearly articulated value premises, DOE lacks a basis on which to defend its decisions, except by complying with regulations that are as yet unable to address adequately the long-term demands of the legacy waste sites.

At many of its contaminated sites, DOE operates in a social environment of public distrust.[2] Yet DOE needs public trust if the agency is to have sufficient flexibility to reach its cleanup objectives and to undertake LTS. DOE continues to face a challenge in rebuilding public trust and strengthening confidence in the constancy of the institutions charged with stewardship. Social science provides some insight into organizations that enjoy public trust and exhibit constancy, and into processes that tend to build public trust and confidence. These are described in the report.

Because stewardship raises difficult technical and social issues, it is important that choices made during the cleanup phase take into account the needs of LTS from the outset instead of treating LTS as an afterthought, as is now the case. The report provides recommendations for incorporating LTS into each phase of environmental management:

- Recognize that both natural and social environments will change at the legacy sites. Design and select remedies that accommodate or benefit from natural communities and processes, so as to enhance the durability of remedies.

- Involve the stakeholders from the earliest phases of decisions that involve risk management. DOE should foster a positive working relationship with interested parties to work together to achieve common goals of protecting human health and the environment. Specific steps described in the report would support these efforts.

- Plan for fallibility, because unforeseen events and some failures of remedies will occur at DOE's legacy waste sites over the long term. Analyze the consequences of failures in engineered barriers and institutional controls, and the implications of environmental changes at the sites, to inform decisions.

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[2]This environment is by no means uniform across the sites, and the committee notes that in its visits to Mound, Fernald, and Moab, members of the local public said they work with and trust their local DOE office, but not DOE headquarters or DOE overall. Probst and Lowe (2000) describe another kind of relationship with DOE, apathy and indifference, although the committee again notes that the public appeared engaged and interested at all of the committee's site visits.

- Tailor monitoring to the specific risks and circumstances of each site, while providing national-level guidance for reporting formats and record-preservation protocols. Both goals are important for providing reliable knowledge of the legacy sites, so that problems can be detected and protection can be assured in the long term.

- Build understanding of DOE's approach during the remaining period of cleanup, so as to make LTS a welcome step as sites are closed. Activities during the ground water cleanup phase provide important opportunities to build credibility. Given the uncertainties of stewardship, it is important that DOE make learning a part of the mission of cleanup and LTS.

- Select remedies recognizing that cleanup and LTS are complementary stages in the long-term management of hazards that cannot be eliminated completely. The task is to allocate risks and costs over time in ways that will protect health and environment over the decades and centuries to come.

- Initiate a national dialogue, involving DOE and other agencies facing stewardship responsibilities, on these enduring responsibilities for wastes created by industrial activities.

The current leadership of DOE cannot assure that the proper actions are taken one hundred years hence. What they can do is to make decisions with an eye on the distant goal and to implement LTS in a way that assures that future generations have what they need to carry out the responsibilities of stewardship.

OVERVIEW

The Department of Energy (DOE) is responsible for cleanup and closure[1] at over 140 contaminated sites in the United States. These sites are part of the legacy of nuclear-weapons production during the Manhattan Project and the Cold War. Contamination at many of these sites will continue to pose hazards that make unrestricted access unacceptable and thus entail management burdens into the indefinite future. DOE calls its activities beyond closure of contaminated sites “long-term stewardship” (LTS).[2] While DOE is exploring the possibility of handing off LTS responsibilities to another agency, it currently seems likely that DOE will remain the steward at most closed sites.[3]

The Committee on Long-Term Institutional Management of DOE Legacy Waste Sites: Phase 2 was formed by the National Research Council at DOE’s request to

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[1]“Cleanup/remediation is considered complete when deactivation or decommissioning of all facilities is complete, excluding long-term surveillance and monitoring; releases to the environment have been cleaned up in accordance with agreed-upon standards; ground water contamination has been contained, or long-term treatment or monitoring is in place; nuclear materials and spent fuel have been stabilized and/or placed in safe long-term storage; and “legacy” wastes (i.e., produced by past nuclear weapons production activities, with the exception of high-level waste) have been disposed of in an approved manner” (DOE 2002a).

[2]In its Long-Term Stewardship Study (DOE 2001a) DOE uses the following definition from the 1998 Settlement Agreement that prompted DOE’s efforts on LTS. “[LTS comprises] the physical controls, institutions, information and other mechanisms needed to ensure protection of people and the environment at sites where DOE has completed or plans to complete ‘cleanup’ (e.g., landfill closures, remedial actions, removal actions, and facility stabilization). This concept of long-term stewardship includes, inter alia, land-use controls, monitoring, maintenance, and information management” (DOE 2001a).

[3]David Geiser (director, DOE Office of Long-Term Stewardship) stated that DOE is now less hopeful that another entity will take over LTS for DOE because of resistance by the potential recipients of the program (Geiser 2002). The U.S. Fish and Wildlife Service will take over some duties at Rocky Flats, but DOE retains LTS responsibilities for residual hazards at the site. An alternative is to create a separate entity to carry out the LTS mission. Secretary of Energy Abraham has announced a proposal to create a DOE Office of Legacy Management, which will handle DOE’s LTS mission and the missions of the current Office of Worker and Community Transition (ECA 2003). This proposal is described in the FY2004 Budget Request.

analyze long-term institutional management[4] plans and practices for a small group of representative DOE legacy waste sites and to recommend improvements. (See Appendix A for the full statement of task and Appendix B for brief biographies of the committee members.) The committee selected the first two sites for its data-gathering meetings, Fernald and Mound. The third site visit, to the uranium mill tailings pile and surrounding land at the Moab Site, was part of a congressionally mandated study that was added to the committee's original effort. The committee issued a report addressing issues at Moab in June 2002 (NRC 2002a), as requested by Congress. Appendix C lists the presentations, discussions, and tours that were part of the committee's public meetings.

In July 2002, the assistant secretary of energy for environmental management, Jessie Roberson, requested that the study be wrapped up in advance of its planned October 2003 completion date. Following consultation with the committee and deliberations concerning the request, the Board on Radioactive Waste Management, which oversees the committee's work, asked the committee to end its information-gathering activities and to prepare a status report based on its work to date (see Appendix D) with the understanding that the committee would therefore be limited in its ability to address fully the statement of task.

The report addresses the task statement by developing lessons that could be learned from the sites it visited and the documents it reviewed, focusing on high-level issues related to improving planning and implementation of LTS at DOE legacy waste sites:

- what LTS is;
- what it means to incorporate LTS in all phases of environmental management;
- DOE's need for a discussion of values and principles for decision making, so as to
- enable DOE to pursue its unfamiliar responsibilities in LTS, instead of being limited by its current emphasis on compliance with existing regulations. That emphasis hinders DOE's ability to fulfill its LTS obligations.

Public participation, trust, and confidence are essential elements of success for DOE, and are also a discussed in this report. A description of the committee's observations from the site visits can be found in Appendix E.

Individual members of the committee are familiar with environmentally hazardous sites both within the DOE complex and outside it. The report is based on what the

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[4]Long-term institutional management (LTIM) is a term coined by the National Research Council committee that preceded this one. LTIM is an approach to planning and decision making that balances the use of measures available to site managers in protecting public and worker health and safety, and the environment: contaminant reduction, contaminant isolation, and long-term stewardship (NRC 2000a).

committee has found in visiting three DOE sites, reviewing documents relevant to LTS at these three and other DOE sites,[5] and engaging in discussion with DOE staff and others.

BACKGROUND

For fifty years following the beginning of the Manhattan Project in 1942, the U.S. government produced and processed nuclear materials for the nation's defense. The industrial complex built for this effort was assembled in haste during World War II, took its mature form before environmental awareness and regulations were in place in the 1970s, and produced substantial waste and contamination at well over a hundred sites (see Figure 1) (Crowley and Ahearne, 2002).

During the decades of the Cold War the Atomic Energy Commission and its successors, the Energy Research and Development Administration and DOE, made many choices with respect to waste storage, waste disposal, routine emissions, and operations that shaped the hazards that remain at sites across the complex. These hazards, in turn, created some of the LTS problems and framed the options for dealing with them. For example, it is infeasible to relocate for disposal much of the waste that was injected underground or has leaked into the soil at Hanford because it is now contamination in the subsurface rather than discretely contained waste. These choices distributed costs and risks across geography and between present and future generations, often with limited understanding of their long-term implications for humans and the environment.[6] DOE and its predecessors have been making choices with serious LTS implications for a long time. Those choices were made implicitly, as part of decisions about our national defense program. The current DOE remediation and site management program is different: Its decisions center on allocations of costs and risks, without being subordinated to another mission. The combination of current technological capabilities and funds for cleanup leave little doubt, however, that many of the contaminated sites cannot be cleaned up enough to permit unrestricted human access. Some of the remaining hazards are likely to pose significant risks indefinitely.

Contaminants are found in buildings, equipment, surface and subsurface materials, surface water, ground water, flora, and fauna. Some contaminated materials can be removed to disposal facilities specifically selected and designed to isolate chemical and radioactive wastes or they can be removed and remediated by treatment; some of the contaminated media at a site can be excavated and sequestered in on-site disposal cells; and some of the contaminants will remain in the subsurface, including ground water, under conditions that make their removal time-consuming or prohibitively costly. Wastes to be sent to disposal facilities are found in storage tanks, containers, and old disposal areas, some of which were little more than trenches that provided meager

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[5]DOE provided many documents for this study. Near the end of the project, DOE provided some key documents on current planning and guidance from headquarters (DOE 2002a, 2002b; INEEL 2002) to the committee less than one week before the final committee meeting, with hardcopies of one document arriving during the meeting. As a result, the committee has had limited opportunities for discussion and follow up on the documents.

[6]Choices that allocated costs and risks did not involve deliberate decisions to distribute known costs and risks to identified groups or generations. Rather, choices like discharging liquid wastes into the soil at Hanford *de facto* allocated unknown risks to some future generations.

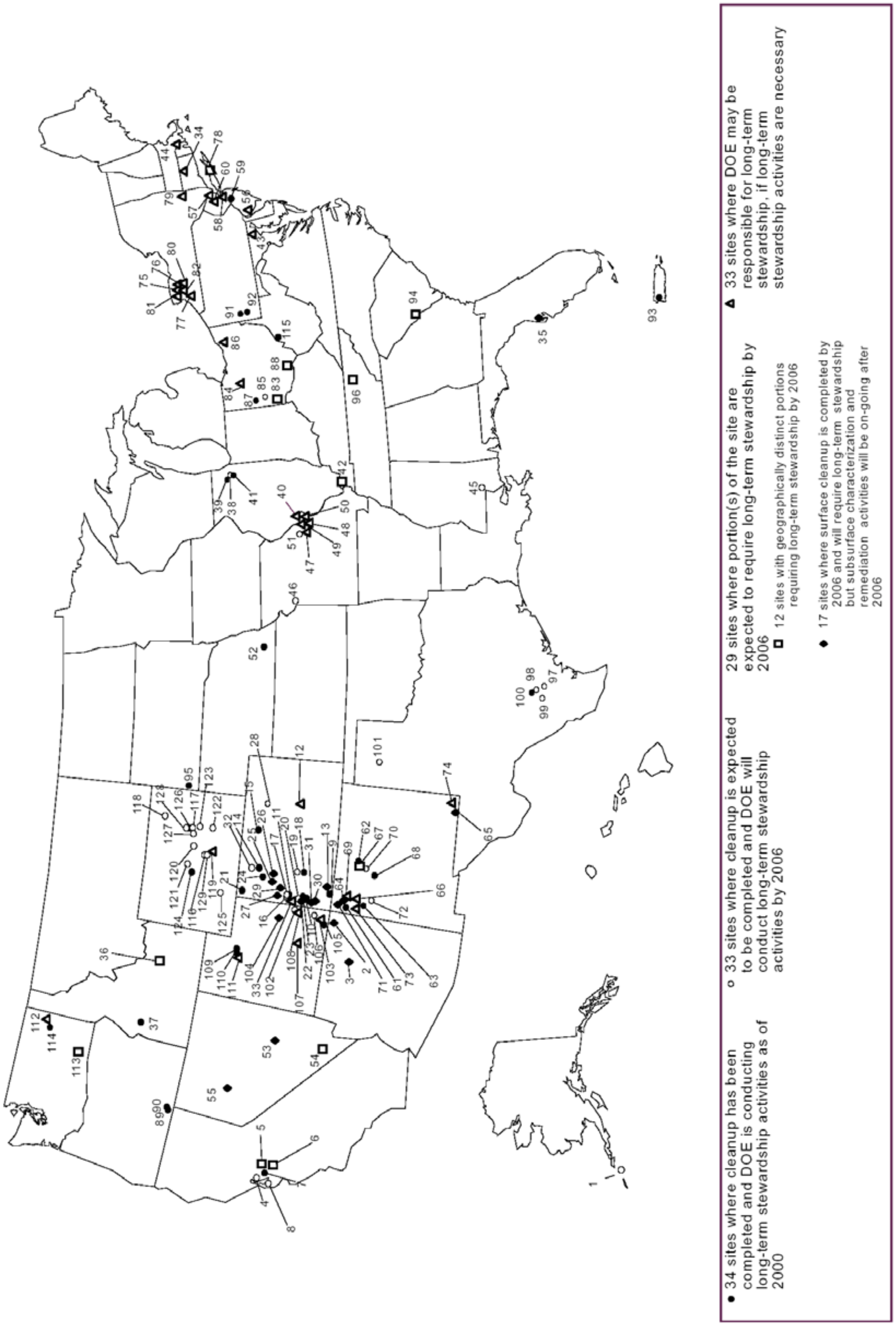

FIGURE 1. Map of sites anticipated to requrie long-term stewardship by DOE (DOE 2001b).

isolation and created additional contamination that requires cleanup. The disposal facilities and contaminated media that remain in place will require LTS.

At some sites the residual hazards will decline relatively quickly because of rapid radioactive decay or biodegradation, for example, sites contaminated with tritium, which has a half-life of 12.3 years. At many sites the hazards will persist for centuries (e.g., Cs-137 and Sr-90 have half-lives of about 30 years), millennia (e.g., Pu-239 has a 24,000-year half-life), or essentially forever (e.g., uranium and stable heavy metals).

Quantified examples of the consequences if institutional controls[7] or other planned LTS measures fail are few. This is because there are few risk assessments that examine loss-of-control scenarios. But it is useful to consider the case of uranium ore processing sites. If institutional controls for cleanup and disposal of wastes fail at such sites, lifetime cancer risks to persons exposed to these wastes could easily be in excess of 10^{-2}, and in some cases could far exceed this risk level.[8] The U.S. Environmental Protection Agency (U.S. EPA) requires in its regulations assurance that passive physical (engineered) controls be effective for at least 200 years and recognizes the need for institutional controls as a backup to physical control measures,[9] yet the hazard will endure far longer than that.[10] Simply meeting the standard and initially complying with the regulation could result in risks that would likely be unacceptable at sites operating under different regulations. For example, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) allows for consideration of cost-risk tradeoffs for risks below 10^{-4}, but requires action above that risk level. As a consequence of the duration of the hazards and of the potentially significant consequences of failure, the challenge of long-term management of these and other DOE legacy waste sites is both

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[7]DOE's guidance on institutional controls in RCRA and CERCLA response actions defines institutional controls as "any mechanism(s) used to restrict inappropriate uses of land, facilities, and environmental media by limiting exposure to residual contaminants left behind as part of a CERCLA or RCRA remedy…. Institutional controls can include physical barriers (fences) and legal and communication devices (deed restrictions, zoning, and signs)" (DOE 2000, p. 1).

[8]In establishing the standards that govern cleanup and disposal of wastes at these sites, the U.S. Environmental Protection Agency estimated that the risk to a person living in a home over soil uniformly contaminated throughout the subsurface to 5pCi/g radium-226 corresponds to a lifetime increased risk of fatal cancer of approximately 10^{-2} (U.S. EPA 1983). Concentrations of radium-226 in wastes far in excess of this value will exist at these sites for many thousands of years.

[9]The Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) requires that these sites be permanently retained in federal control under U.S. Nuclear Regulatory Commission licenses. U.S. EPA noted in establishing its standards for these sites that institutional control is an essential backup to passive controls for such long-term hazards (48 FR 597).

[10]The regulation directly addresses only radium-226 in its soil concentration limits. Radium-226 has a half-life of 1,600 years, but the concentration of this isotope can be sustained or increased by the presence of radioactive precursors, such as thorium-230 (half-life 75,400 years), uranium-234 (half-life 254,000 years), and uranium-238 (half-life 4.5 billion years) also found in these wastes. Thus the hazard can diminish at different rates, depending on the concentrations of these precursors, but in all cases the duration of the hazard is long compared to most institutional timescales.

novel and difficult: to assure the protection of human health and environment far beyond the conventional time frame of public policy or institutional endurance.[11]

DOE recognized, earlier than did many other government agencies facing similar problems, that it needed help in understanding LTS and in formulating strategies for addressing its unusual requirements. Several researchers and organizations have provided analyses, among them Probst et al. (1998, 2000), the National Research Council (NRC 2000a), Russell (1998, 2000, 2002), the Environmental Law Institute (ELI 1998), and Pendergrass (1999). Citizen and stakeholder groups have provided ideas and perspectives of their own (RFSWG 2001; EUWG 1998a, 1998b; STGWG 1999; Stewardship Working Group 1999). In the last several years, DOE's Office of Long-Term Stewardship has begun to flesh out the LTS challenge and to develop policy guidance (DOE 2001a, 2001b, 2002a, 2002b; INEEL 2002).

DOE also is pressing to accelerate cleanup and reduce cleanup costs at its sites. One way to end cleanups sooner and to reduce near-term costs is to rely more on LTS. Some people, however, are wary of DOE's promises regarding LTS, and this wariness undermines and constrains DOE's ability to speed remediation.[12]

SUMMARY OF FINDINGS AND OBSERVATIONS FROM THE VISITS TO MOUND AND FERNALD

To inform its deliberations, the committee visited two DOE sites in Ohio, Mound and Fernald, as well as the Moab Site in Utah. The committee's observations from the Ohio sites are discussed in some detail in Appendix E, and the committee's work on the Moab Site was published previously (NRC 2002a).

In Ohio, the committee found that if the remedial actions now underway at Mound and Fernald succeed (including, ultimately, the relocation of the silo wastes from Fernald), both sites seem to present low environmental risks even if their projected LTS activities were to fail. This cannot be stated without reservation, however, because assessments of failure scenarios have not been carried out at either location. At both sites a measure of trust has developed among the local public, site contractors, regulators, and DOE's Ohio Office. All parties mentioned good working relationships, within which conflicts can be aired and addressed. Engineering analyses at Fernald seemed to be of high caliber and work on habitat development at the site is remarkable if only for the fact that ecology is being addressed at all. The process of releasing

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[11]The committee uses the term "institution" in a sociological sense, to include social arrangements like marriage or property. The committee's usage is compatible with the usage in "institutional controls", which includes physical controls like fences, as well as rules (implying enforcement mechanisms, courts, etc.).

[12]Concern about DOE's commitment to LTS was expressed by public participants at all of the committee's site visits and is stated in a letter from the Association of State and Territorial Solid Waste Management Officials (ASTSWMO 2002). At the committee's meetings, the declared basis for concern was twofold: mistrust of DOE in general because of past secrecy and disregard for public health and safety (voiced at Fernald and Moab); and a worry that those in charge of cleanup have incentives to choose less costly strategies now, even if it results in increased risks in the future (all sites).

buildings for reuse one by one at Mound—rather than the standard approach of dividing the site into a small number of operable units, so as to develop a more comprehensive, integrated understanding of the site—seemed to encourage cleanup managers to make do with the information and tools already available.

Chief Finding: The committee observed a compartmentalization of cleanup planning and LTS planning at the sites visited: cleanup planning and execution will conclude at a site, and LTS is left to address the resultant end state.

The Ohio sites are only now beginning to address LTS issues, as they near the end of cleanup. The committee concurs with DOE's own finding that "In many cases, long-term stewardship issues were identified, and remedies were proposed, but detailed plans and procedures to effectively carry out the remedies were not developed" (DOE 2001c).

CHIEF RECOMMENDATION

The committee has observed that DOE treats cleanup and LTS as activities to be planned and executed separately. LTS must cope with what is left behind when cleanup ends, but cleanup is shaped by regulations and takes little account of the obligations of stewardship or the likely limitations of LTS.

Recommendation: DOE should explicitly plan for its stewardship responsibilities, taking into account stewardship capabilities, when making cleanup decisions. DOE should also implement steps to anticipate and carry out those responsibilities throughout the cleanup process.[13]

Remediation encompasses contaminant reduction, contaminant isolation, and continuing care (NRC 2000a).[14] In DOE decision-making the first two constitute cleanup, while the last is LTS. In fact, however, all choices about each of these tasks affect the others: Decisions about how much to spend on contaminant reduction or on engineered barriers to isolate remaining hazards need to take into account the capabilities of LTS to prevent harm from residual contamination. This basic consideration is still lacking in the actual implementation of DOE's remediation program.

Cleanup and LTS are complementary elements of a single task: protecting human health and the environment now and for the long term. Cleanup decisions cannot be decoupled from LTS considerations. As linked elements of a site remedy, they form a

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[13]Several other advisory bodies have made similar recommendations (NRC 2000a; Probst and Lowe 2000; Pendergrass and Kirshenberg 2001;INEEL 2002; ECA 2003), and DOE has noted this in some documents (EMAB 1999; DOE 2001a). The predecessor to this committee called the consideration of LTS in concert with other tools for remedial action long-term institutional management (see footnote 4).

[14]Note that isolation of contaminants is a way of delaying exposures and, for wastes whose hazard diminishes with time, reducing risk both now and in the future. Continuing care of a site and its remaining contaminant burden, as explained in this report, is a part of the remedy in that it may be needed to support continuing effectiveness in protecting human health and the environment.

continuum of overlapping choices to be made about long-term management of legacy sites. Choices made before and during cleanup apportion risk and cost across time, as discussed above. Several groups, including this committee's predecessor and a recent R&D Roadmap team, have provided details on why LTS needs to be considered when establishing cleanup goals and approaches (NRC 2000a; INEEL 2002). They have also provided conceptual models useful for strategic planning, descriptions of limitations in the effectiveness of various LTS measures, and ideas useful in developing implementation plans for LTS.

The committee has found no evidence that DOE (a) is considering requirements for and the likely effectiveness of LTS measures when establishing cleanup goals and approaches, or (b) has worked out practical and enduring means of implementing LTS so as to realize its goals for protection over the long term. In the recent emphasis on accelerated cleanup by DOE, the committee has seen no statement of how DOE will balance that objective against future risks. There is the risk of a need for additional cleanup in the future if remediation is poorly planned or carried out. Moreover, if greater reliance on LTS is chosen over contaminant removal, the consequences and in turn the risks of LTS failures may increase. Explicit consideration of LTS issues when establishing cleanup goals and approaches would demonstrate that DOE is taking its responsibilities seriously—a key step in building trust among wary stakeholders and the wider public, including Congress and state and local governments. The failure to link LTS to cleanup undermines credibility and strengthens the fear among skeptical stakeholders and regulators that a hollow promise of stewardship is being put forward as a substitute for more costly near-term cleanup.

The committee has seen some progress in DOE efforts on LTS. Progress can be seen, for example, in written statements at two sites: Hanford, a large site in Washington state where cleanup is expected to take decades; and Weldon Spring in Missouri, the first medium-sized unit of the DOE complex where long-term stewardship has begun. Both sites have produced LTS planning documents (Hanford 2002; DOE 2002c). These written statements suggest a recognition of LTS, although the documents leave significant questions unanswered.[15]

A working draft for the Hanford remediation program (Hanford 2002) identifies six LTS program functions,[16] with reasonable suggestions for implementation of each. The draft acknowledges that managing remaining contaminants at the site will compete with other priorities (p. 3-1), but there is no articulation of how cleanup and LTS decision making will interact. Managers at Hanford states that they will "work to integrate long-term stewardship concepts into the cleanup decision-making process to ensure consistency and provide opportunities to gain efficiencies" (p. 2-3), but there is no implementation action identified for this objective. Instead, cleanup choices continue to be made without consideration of LTS, and the "starting condition" for LTS (Hanford 2002, Fig. 1-5, p. 1-7) is the residual hazard—even though many choices remain to be made about what that residual hazard should be. The committee also reviewed the "Performance Management Plan for the Accelerated Cleanup of the Hanford Site" (DOE

[15]The committee has not undertaken a detailed review of either Weldon Spring or Hanford. Both sites were being considered for site visits when DOE requested early wrap-up of this study.

[16](1) Managing post-cleanup completion residual risks, (2) managing site resources, (3) managing stewardship information, (4) using science and technology, (5) providing post-cleanup completion infrastructure, and (6) integrating long-term stewardship responsibilities (Hanford 2002).

2002d), a document that spells out substantial changes in the schedule and budget for the Hanford remediation program. LTS is mentioned with little discussion, for example in the statement that "With plans for long-term stewardship integrated into the cleanup, we can take the proper actions at the appropriate time to allow a smooth transition into necessary stewardship activities after the EM cleanup mission is complete" (p ii-iii). There is no mention of the working draft of the site's own LTS draft report (Hanford 2002). LTS is a critical aspect of remediation at sites like Hanford, where complete cleanup is likely to be impossible. Performance management plans are incomplete when they do not articulate how LTS fits into the decision-making process and when they ignore the criteria or factors that should influence those decisions.

The largest site so far where cleanup has been declared complete, Weldon Spring, was opened to limited public access in the summer of 2002. Management of the site was transferred to DOE's Grand Junction Office, where its Long-Term Surveillance and Maintenance Program[17] resides, even though one of the final regulatory records of decision—the definitive statement that cleanup remedies are in place—remains unsigned.[18] Thus, activities that are logically part of cleanup have been shifted into LTS, or placed in a limbo between cleanup and LTS.

This approach may prove innocuous at Weldon Spring, where the ground-water remedy is intended to be natural attenuation combined with active remediation *in situ*. If the end of cleanup is treated so casually at other sites, however, one might fear that a site like Fernald would enter LTS with neither a place nor a method to send its silo wastes (see Appendix E) for disposal. One might envision similar difficulties with the single-shell tank wastes at Hanford, which have a long and troubled history. In effect, the stewards could be saddled with either cleanup or maintenance problems that are much more hazardous and technically challenging than the program is being equipped to handle. Without proper integration of decisions on clean-up and LTS, there is no mechanism to stop the transfer of inappropriate responsibilities and risks to an LTS program that does not have the resources or capabilities to manage the continuing liabilities. Indeed, clean-up authorities face incentives to do just that.[19]

Despite statements embracing LTS in recent DOE documents (DOE 2002a, 2002b), the way in which DOE has selected, developed, and implemented remedies means that LTS continues to be an afterthought in practice. Recognizing the interdependent nature of cleanup and LTS would enable DOE, and the many other government agencies facing similar problems, to make better decisions and construct more credible plans for the long term. Adopting this way of thinking about environmental management at legacy waste sites would entail incorporating LTS into every stage of environmental management. This means looking at issues that will be important during the long term in all phases and activities related to the remedy: site investigation, option

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[17]The Long-Term Surveillance and Maintenance Program is the operating arm of DOE in carrying out LTS at closed sites, directing and overseeing contractors that physically care for all of the uranium mill tailings sites and a number of other sites for which DOE is responsible.

[18]See DOE (2002c) for an acknowledgment that the record of decision governing continuing ground-water treatment has not been agreed to by regulators.

[19]The committee discussed the question of whether cleanup and LTS functions should be housed in the same entity to reduce incentives for shifting costs and liabilities, but the committee had not gathered data that would provide a foundation for a conclusion either way.

development and remedy selection, monitoring, and future adaptation to changing circumstances.[20] Each of these is discussed below in the section titled Incorporating LTS into environmental management, following a discussion of how defining DOE's mission of LTS solely in terms of regulatory compliance is insufficient.

WHAT IS STEWARDSHIP?

DOE uses the term "long-term stewardship" to describe the activities required at contaminated sites where cleanup is "complete" (see Footnote 1), that is, after site closure. As part of LTS, DOE explicitly takes responsibility for complying with all applicable regulations for the environmental management of the site into the indefinite future (see, e.g., DOE 2001b).

The word "stewardship" is resonant in our language and has been readily accepted by many people who have different understandings of the word (see La Porte 2000). In this committee's view, stewardship comprises several tasks: A steward of very long-lived hazards acts as

- a *guardian*, stopping activities that could be dangerous;
- a *watchman* for problems as they arise, via monitoring that is effective in design and practice, activating responses and notifying responsible parties as needed;[21]
- a *land manager*, facilitating ecological processes and human use;
- a *repairer* of engineered and ecological structures as failures occur and are discovered, as unexpected problems are found, and as re-remediation is needed;
- an *archivist* of knowledge and data, to inform the future;
- an *educator* to affected communities, renewing memory of the site's history, hazards, and burdens; and
- a *trustee*, assuring the financial wherewithal to accomplish all of the other functions.[22]

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[20]The committee's charge directs the committee to look at legacy waste sites. The approach, of course, also applies to decisions at sites that could become legacy waste sites. That is, DOE would benefit from considering the long-term implications of current and future actions that might lead to contamination or waste generation.

[21]A watchman might alert responsible parties of needs or opportunities for re-remediation or application of new technologies to reduce contaminant inventories. The question of what actions to take is a separate decision, as with the cleanup and LTS decisions that are being made today.

[22]An additional factor to consider is how to address future cases where people are injured by residual hazards at one of the sites. Whether the steward is the appropriate party to

This range of activities requires the human and institutional capacity to fulfill these roles as needed, through the decades and centuries in which the risks persist. The human and institutional demands of these activities are broader than the traditional engineering expertise of DOE, raising questions of how best to meet the federal government's responsibilities over the long term.

Moreover, a steward does not act in a vacuum. Technological capabilities are likely to change. Study of monitoring data and the accumulating experience of stewards is likely to improve both understanding of the sites and of how to manage them effectively. Both sets of changes will likely prompt reappraisal of risks and consideration of additional remediation. The likelihood of such development implies a responsibility for stewardship at the national level, in addition to the site-centered roles listed above. The committee calls for a national dialogue at the end of this report, in part to articulate these programmatic responsibilities so that they may be taken up in a sensible fashion.

Beyond a Compliance Culture

LTS begins with a recognition of the dimensions of the long-term obligations of the legacy wastes. DOE's actions observed by the committee do not yet reflect such an understanding. Instead, the committee has seen a more narrow focus on meeting compliance agreements and regulations, as if DOE's responsibilities were grounded only in these: Regulators agree to a remedy, creating a compliance agreement, and the requirement of LTS is that DOE sustain the remedy. Compliance is necessary, of course, but the problem with a strict reliance on compliance is that today's regulations do not fully address LTS challenges.[23]

Under its agreements with state and federal regulators, DOE undertakes to manage the residual contamination at the legacy waste sites; compliance with those agreements is a means to that end. Yet the regulations on which the agreements rest do not engage all of the difficult issues presented by the legacy wastes. This is so even though the long-term effectiveness and permanence of a remedy is one of the criteria to be used in remedy selection under CERCLA,[24] the law that frames decision making for

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compensate people who are found to have legitimate claims of injury is a complex issue that the committee has not explored.

[23]DOE's 2001 report to Congress on LTS (DOE 2001b) makes this point, too: "Some long-term stewardship activities have been mandated by regulation, compliance agreements, DOE Orders, or site-specific documents, while others are yet to be defined. Although statutory and regulatory requirements provide guidelines for long-term stewardship, existing requirements do not clearly delineate the measures needed in the future for long-term stewardship; nor do they ensure the development of effective implementation strategies" (p. 2-11).

[24]CERCLA states that cleanup remedies "...shall take into account the total short- and long-term costs of such actions, including the costs of operation and maintenance for the entire period during which such activities will be required" (CERCLA par. 121(a)), and that the selected remedy "...utilizes permanent remedies...to the maximum extent practicable." (CERCLA par. 121(b)(1)). According to the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300), which is the set of regulations that implements CERCLA, remedies are to be selected from among remedial alternatives using nine evaluation criteria: (1) overall protection of human health and the environment; (2) compliance with the chemical-specific standards that are considered the statutorily required "applicable or relevant and appropriate requirements"

many of DOE's cleanups. This formal criterion has not resulted in thorough examinations of stewardship so far, nor even of the specific institutional controls stipulated in regulatory documents. On the contrary, regulators have agreed to remedies at DOE sites with only scant provisions for LTS, not considering in some cases the risks of LTS failures, leaving the functions of trustee, educator, and land manager unaddressed, and assuming that institutional controls are self-executing and self-enforcing. CERCLA provides for recurring reviews at five-year intervals for closed sites that do not meet criteria for unrestricted use, but the extent of that obligation and the effectiveness of the review program are as yet uncertain. The Resource Conservation and Recovery Act (RCRA) governs many of the DOE facilities and cleanups that CERCLA does not, and RCRA's requirements do not take a long or broad view with respect to LTS.[25] Experience with institutional controls demonstrates their limitations and fallibility, particularly over the long term (Applegate and Dycus 1998; ELI 1995; Pendergrass 1996, 1999, 2000). The point is not that institutional controls should not be used; they are among the few tools available. But their fallibility and the uncertainties that surround many engineered containment methods mean that simply assuming that compliance conditions will continue into the future (e.g., land-use controls administered by elected local officials), is not likely to provide long-term protection of humans and the environment.

To address the long-term aspect of LTS, DOE staff (Geiser 2002) has advanced the concept of rolling stewardship. Rolling stewardship means a succession of stewards tending to needs, one generation after another.[26] DOE's Site Transition Framework (DOE 2002b) is a step in the direction of rolling stewardship, identifying documents that should be passed to new site owners or stewards. It is, however, only a checklist—it helps to ensure that a document is passed, not that the document contains what it should, or even that the relevant underlying information is available and accessible. DOE relies on external regulatory mechanisms—that is oversight by state and federal regulators—to ensure that needed data are provided.

(ARARs); (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, or volume through the use of treatment; (5) short-term effectiveness; (6) implementability; (7) cost; (8) state acceptance; and (9) community acceptance.

[25]To implement RCRA, a section of the code of federal regulations (40 CFR 264 G) describes post-closure requirements for hazardous waste disposal facilities. "Post-closure care for each hazardous waste management unit subject to the requirements of Secs. 264.117 through 264.120 must begin after completion of closure of the unit and continue for 30 years after that date and must consist of at least the following: (i) Monitoring and reporting in accordance with the requirements of subparts F, K, L, M, N, and X of this part; and (ii) Maintenance and monitoring of waste containment systems in accordance with the requirements of subparts F, K, L, M, N, and X of this part…. For each hazardous waste management unit subject to the requirements of this section, the post-closure plan must identify the activities that will be carried on after closure of each disposal unit and the frequency of these activities."

[26]First published use of the term and concept of rolling stewardship as related to hazardous wastes appears to have been in M. Russell's testimony before a subcommittee of the Senate Committee on Environment and Public Works (Russell 1995). A version of rolling stewardship is described in Improving the Environment (NRC 1996a), which envisions a succession of interim actions (20 year increments) taken until permanent solutions are developed. Several examples of long-lived institutions have been discussed in other studies. For example, Applegate and Dycus (1998) discuss the longevity of the Catholic Church and British monarchy, and Probst and McGovern (1998) draw parallels to cemetery preservation.

Current regulations do not directly address LTS, as defined by the committee or by DOE. It is possible that requirements to take many of the actions the committee recommends and fulfill the needed roles could be seen as compatible with current regulations (particularly using the criteria for remedy selection under CERCLA), but most requirements are not spelled out in the regulations. Regulators have neither interpreted broader LTS requirements as implicit in the regulations nor been demanding in enforcement of the LTS aspects of even those that are specifically listed. Furthermore, DOE (like all federal entities) refuses to accept any land-use restrictions imposed under state law (e.g., Colorado's environmental covenants law) on property owned by the federal government.

Such a compliance-driven approach encourages a view of LTS as little more than routine monitoring, maintenance, and record-keeping. That view rests on a bold assumption: that the U.S. government will endure in essentially its current form into the indefinite future. This may not be a prudent basis on which to embrace a responsibility projected to last far longer than the history of the republic so far.

DOE bears an enduring responsibility—and a corresponding liability—for problems that arise in the future at its legacy waste sites. It is in the long-term interest of DOE and the nation for DOE to recognize and act to fulfill its obligations, even when they carry the agency beyond existing regulations. As the committee explains below, for a public agency to act in this fashion responsibly requires explicit attention to the values at stake in making choices and committing resources.

INCORPORATING LTS INTO ENVIRONMENTAL MANAGEMENT

Here the committee offers its view of what it means to incorporate LTS considerations throughout the remediation process (site investigation, option development and remedy selection, monitoring, and future adaptation to changing circumstances), emphasizing factors that go beyond a compliance-driven engineering approach. Such an alternative approach raises questions that are fundamental as well as practical, so questions are woven throughout the discussions of each part of the remediation process. The questions are framed deliberately as open-ended concerns, because in many cases the committee can offer only limited strategies and recommendations to address the questions and challenges DOE faces.

Two broad questions, discussed here and toward the end of the report, are fundamental to all of DOE's remediation efforts.

Question*: Can DOE develop a coherent set of guiding principles for making choices among the burdens to be borne by present and future generations in addressing enduring risks, and would application of such a set of principles result in better, more defensible decisions?*

The process of remediation makes value commitments—apportioning costs and risks over time, among populations, and altering the environment and the hazards posed. These values are expressed through decisions that are influenced by the state of the site and its surroundings, scientific understanding, and technological and institutional capabilities. The committee has not seen the values entering into DOE's decisions articulated in a way that connects to the people affected (in both present and future), or to human obligations for care of natural systems. Without clearly articulated value premises, DOE lacks a basis on which to defend its decisions (Russell 2002), except by complying with regulations that were written without regard to the long-term demands of legacy waste sites that will require LTS.

***Question**: How can DOE carry out its mission of environmental management in such a way that when people learn more about DOE's activities, they are likely to gain confidence in the institution and its actions?*

In pursuing its unprecedented responsibilities of remediation, DOE needs public trust if the agency is to have sufficient flexibility to reach its cleanup objectives and to begin LTS. As the magnitude of its waste-management problem has become more widely appreciated, DOE has labored under a deficit of public trust and confidence (DOE 1993). There has been significant progress in gaining trust as DOE shared information and worked with stakeholders; the committee found this in its site visits. Yet difficulties remain (see, for example, the mistrust evident in written exchanges concerning Weldon Spring [Mahfoud 2002]). Trust is essential if DOE is to undertake negotiations and sound decision making regarding cleanup and LTS. The stewardship relationship "rests significantly on the underlying strength of trust in the person[s] involved" (La Porte 2000),[27] and much of DOE's efforts will depend on public confidence in the capabilities and continuity of those speaking for the institutions undertaking this unprecedented commitment. As discussed below, building and maintaining trust requires continued support for changes in organizational culture at all levels of DOE and its contractors.

The work of stewardship will require candor in acknowledging knowledge gaps, followed by sustained learning from experience over the coming decades as DOE proceeds with cleanup and maintenance of its legacy sites. The committee is not, however, a management consultant, and the questions and recommendations below emphasize natural and social science and technology, rather than managerial tools. The assistance that the committee is able to provide on these questions has been limited by the truncation of the study.

Each of the following subsections examines ways in which DOE could incorporate LTS into environmental management. Some of these ideas have also been brought up by other advisory bodies. The subsections address planning for changing environments, working with stakeholders, factoring LTS into decisions about cleanups and end states, and planning for fallibility, monitoring, and institutional challenges.

Planning For Changing Environments

Stasis is a standard engineering goal of environmental remediation, as currently conceived: keeping containment structures intact and design features unchanged (consider, for example, a dam or a waste cell). But ecological settings are dynamic rather than static, and change in natural community structure is often a sign of environmental health, as a habitat develops. Each LTS site is embedded in a dynamic

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[27]See Applegate and Dycus (1998) for examples of unusually long-lived continuous organizations that enjoy a great deal of trust from their stakeholders.

landscape. This change can be seen in the local ecological community, in the physical environment, and in society's needs and pressure on the site. Physical and institutional controls must be designed for and adapt to the landscape if they are to survive the long time horizons for which they will have to be effective.

***Question**: How can DOE identify paths of ecological change for each LTS site, and how can DOE design for and accommodate change with resilient engineered solutions?*

At the Moab and Fernald sites, the land surface is now designed for near-term soil and slope stability, using a narrow palette of plantings to prevent soil erosion. A cover engineered in this fashion is not a substrate that can support a healthy natural community over time. Nor is it likely to remain in the engineered form for long without extensive management and care. The kind of prairie landscape envisioned for Fernald, for example, will require weeding to eliminate the larger plants and trees that are natural to the area. Moreover, a responsible design must consider the natural community that is likely to emerge. One of the few biotic concerns that is mentioned in current LTS documents is rare and endangered species, but these are uncommonly found at legacy waste sites, almost by definition. All sites, however, have locally common species, or will have them soon. Encouraging their presence by initiating populations and designing engineered structures to meet the basic habitat needs of locally common species allows the site to function ecologically over a long time period. This can be done so that ecological change will be more likely to reinforce engineered barriers, rather than undermine them. At the same time, engineered barriers must be designed with both the health of local biota and also the likely interactions between local biota and the barrier in mind.

Many geological processes take place slowly over years to hundreds of thousands of years (e.g., weathering) or even longer, whereas others are infrequent, unfold rapidly at unpredictable intervals, and are sometimes of sufficient magnitude to alter landscapes (e.g., floods). Both kinds of process are important influences on hazards that persist over long time scales (see NRC 2002a). Some of these processes are readily mitigated by engineered barriers and preventive actions, while others will proceed without significant human intervention, leaving stewards to react. Current regulations are written for time periods where historical experience provides a baseline of institutional experience; as a result, slow geological change is ignored and simplified analyses are used to bound stochastic change.[28] The aim in remedy design must instead work toward remedies that are resilient to slow change, as well as toward ways to maintain response capabilities to react to sudden disturbances. For example, DOE might choose permanent relocation of hazardous materials away from threatening erosional forces, if the risks of erosion warrant concern. Where relocation is deemed not to be feasible or appropriate, mitigative measures and some funding mechanism could be established to respond to major failures.

Human activity, too, is dynamic. Land use can undergo rapid changes, as illustrated by the recent encroachment of residential communities toward Rocky Flats and by the commercial growth of ecotourism in Moab. Some sites that once were little known and remote are being affected by the growth of nearby cities and towns, with

[28]See NRC (2002a) for a discussion of the shortcomings of these approximations at Moab.

attendant pressures for development of land, use of water, and alternatives for employment. These historically rapid changes, which often have no precedent at a site, limit the reliability of institutional controls.

Finally, it is worth noting that scientific understanding is changing. In the 20th century, environmental regulations supplemented or superseded the older law of nuisance with demands for ways of anticipating and preventing pollution. This new approach was adopted in response to growing scientific and technological capabilities both to understand and to affect our environment (Rodgers 1994). Similarly, the realization that legacy sites cannot be cleaned up completely is stimulating research and innovation that is likely to strengthen the technical and institutional bases of LTS in the future. Thus, LTS measures themselves need to be adaptable.

Recommendation: Design and select remedies that accommodate or benefit from natural communities and processes, so as to enhance durability of the remedies.

Involving The Local Community

As noted in this committee's report on the Moab Site (NRC 2002a), decisions that involve risk management should involve the stakeholders from the earliest phases of defining the problem through the making of binding decisions.[29] Such involvement is an important element of risk analysis and characterization (NRC 1996b; Sandman *et al.* 1993) and also tends to foster public trust and confidence in the institutions that analyze and characterize risk.

Question: *How can DOE develop and manage LTS measures in partnership with the stakeholders who will bear the impacts of their failure and who may be willing to share with DOE responsibility for their implementation?*

Site remediation aims to improve the environmental circumstances of local communities. Remediation often entails significant changes, however, and for this reason members of the community often have interests to advance or defend. Yet the community as a whole can also add value to the decision-making process in the following ways and for the following reasons (see Susskind and Field 1996; Sandman 1994):

- they often have relevant information (e.g., about past activities on-site, about desirable or potential future uses of the site);

- they often have creative solution options, including alternatives difficult for a federal agency to propose or develop;

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[29]A joint study by the Environmental Law Institute and the Energy Communities Alliance (Pendergrass and Kirshenberg 2001) recommends that DOE include local governments in the entire decision-making process where LTS will be involved. This study also found that local government capacity for LTS varies but is often limited by lack of experience with contaminated sites and lack of funding.

- they may have institutional capabilities to undertake cleanup or LTS activities, including ones unavailable to a federal agency or available at a much lower cost; and
- their values must be a factor in any responsible effort to balance costs, benefits, and risks, both as a matter of right and because they have political power to make the process easy or difficult for DOE.

In a democracy, the local community also has a right to know what remediation measures will have been taken, what are the risks of failure for both the remedy and LTS, and what contingencies have been provided (Applegate 1998a).

At all three sites the committee visited, stakeholders asserted that they were willing to share some of the responsibility for implementing LTS measures with DOE, a noteworthy similarity across sites varying widely in other respects.

To the extent that local communities or other non-DOE stewards are to exercise stewardship responsibilities, adequate resources (information, expertise, and funding) must be assured, and DOE would be prudent to confirm that other stewards have the capacity to fulfill the LTS functions they seek to assume.[30]

Work by Susskind (see, e.g., Susskind and Field 1996), Sandman (Sandman et al. 1993; Sandman 1994), and others on public participation in planning and decision making emphasizes lessons learned from site-specific environmental controversies over the past generation. The committee's site visits reinforced these lessons, which are distilled into the recommendation below.

Recommendation: DOE should foster a positive working relationship with interested parties to work together to achieve common goals of protecting human health and the environment. DOE can foster such relationships by the following actions: (1) explicitly acknowledge the nature and extent of its stewardship responsibilities, (2) help to frame the issues and uncertainties of stewardship for the public, (3) inform and educate the public on the options, constraints, and other factors influencing its own decision-making, expanding on what DOE has done with respect to clean-up; (4) solicit ideas and information from the public on these questions, (5) work with the public toward mutually agreeable decisions, where possible. All of this requires that DOE have a coherent model for framing the values at stake in stewardship and for incorporating views on the nature of the risks and the uncertainties, as discussed above.

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[30]At the Mound site, the local government stated its willingness to accept administrative responsibility for the anticipated future use of the site, but expressed concern about the adequacy of its financial resources to do so in the long term. Specifically, if the planned business park were unsuccessful, the city could not rely on city coffers to maintain the facilities at the site. DOE has taken efforts to provide LTS planning, at least with respect to monitoring, at the Fernald site, but acknowledged that no funding was currently available to implement monitoring. The local community at Fernald has initiated discussions about maintaining records and community memory of the environmental conditions at the facility, but has not yet identified the resources to undertake this effort.

Developing And Selecting A Remedy

DOE's current practice at the sites examined by the committee aims at remediating a site enough to secure agreement on a record of decision (ROD) for site closure. Because current regulations do not capture all of DOE's responsibilities, as discussed above, the DOE's practice ignores factors important to LTS.

The legacy wastes are the permanent responsibility of the U.S. government, a fact reflected incompletely in the regulatory structure within which DOE operates. (EPA is beginning to spell out detailed requirements, but these efforts are still incomplete.) In principle, decision making must

- identify and describe each cleanup option, assessing its features under normal functioning and failure scenarios. These features include the health and ecological risks averted and incurred, costs (including opportunity costs), and cultural and aesthetic impacts;

- assess how people view the features of these options;

- identify and describe associated stewardship requirements (including long-term monitoring, re-remediation in the case of failure or advances in technology, institutional controls, maintenance of records, and public education);

- assess the feasibility of each cleanup option and its associated stewardship requirements, including technical feasibility, institutional feasibility,[31] and cost; and

- make choices taking into account the information developed during this process about both near-term cleanup and LTS.

Those developing the remedies at sites will need to decide to go through these decision-making steps, and they will need the time to go through the process. In the case of the Moab Site, the legislation passing responsibility for the abandoned uranium mill site to DOE mandated choices before there was time for an adequate site characterization, and indeed DOE has since found unexpected contamination of soil, particularly in the cover material on the pile. In addition, the local community's willingness to be part of a solution that encompasses both cleanup and stewardship lay outside the planned scope of decision. At other sites, the committee saw cleanup decisions made without adequate understanding or consideration of LTS. As mentioned above, the recent emphasis on early closure needs to be accompanied by an equally strong mandate for quality in planning and operations for the long term, with full accounting for the resources and institutions required for continuing success—including provision for possible additional cleanup in the future.

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[31]Institutional feasibility includes appraisal of which organizations will exercise which responsibilities, whether those organizations are likely to be capable of doing so in the long term, whether the organizations are willing to undertake those responsibilities in the long term, and whether funds and other resources, including technical resources, are likely to be available at the times needed.

At both Mound and Fernald, where cleanup is well advanced, site characterization efforts had overlooked potentially significant interactions between the site and its surroundings. For example, at Mound, proper understanding of how an underlying bedrock system might hydraulically connect the site with surrounding areas appeared to be lacking. At Fernald, interactions between the site and an adjacent contaminated site where pump-and-treat remediation was being proposed had not been considered. Understanding potential interactions between a site and its surroundings is key to predicting long-term contaminant behavior at a site and designing sensible monitoring programs. Yet, in these two locations such interactions had not been taken into account.

Protecting public health is the chief objective of cleanup and LTS. In addition to its intrinsic value, the health of people in communities surrounding DOE legacy waste sites and of people working on or near those sites is a potential indicator of contaminant or radiation exposures. Their health could be monitored. The committee has not examined public health activities and research at DOE sites, but was considering how plans to monitor the health of local communities, and specifically people who interact with the site, could be incorporated as part of the surveillance needed for LTS.

Question*: How can DOE incorporate the evolving understanding of the requirements, likely capabilities, and limitations of LTS into choices about targets and end states of cleanup at DOE sites?*

Explicitly considering LTS issues when making cleanup decisions entails asking what is at risk, and how important is it? What are our capabilities for LTS with respect to what is at risk? How do these fit with our capabilities for cleanup? How might all these change over time? These all lead to the summary question whose answer depends on the above, what is the appropriate mix of cleanup and LTS? Asking and addressing these questions closes the loop on remedy development and selection, recognizing that LTS is an essential part of the remedy and not an afterthought. In addition, by openly discussing LTS, DOE can build trust as it carries out cleanup, strengthening the understanding and support for LTS when stewardship begins.

The institutional components of LTS are discussed at the end of this report, but here it is important to point out that the institutional aspects of remediation need to be analyzed with other elements of a remedy, taking into account the capabilities and limitations of institutional controls (Applegate and Dycus 1998; ELI 1995; Pendergrass 1996,1999, 2000). Unfortunately, while DOE has devoted substantial resources to research into such matters as how to assure that concrete barriers surrounding wastes will endure, DOE has devoted little effort to the design of and provision for institutional controls, on which long-term protection of health and environment will depend. Suggestions for remedying this failure are discussed below.

Planning For Fallibility

Unforeseen events will occur at DOE's legacy waste sites. These events might include failure of a remedy to prevent degradation of a waste cell, a concern at the Moab Site (NRC 2002a); the failure of remedies to meet prescribed cleanup or containment goals; discovery of "unexpected" contamination (NRC 1997, 2000b);[32] or unintended use of the land by humans, animals, or plants. LTS at each site is unavoidably a complex system made up of interactions among engineered environments, natural environments, and human institutions, which makes them somewhat unpredictable.[33] At each site the committee visited, the committee saw little consideration of the question "what are the consequences if controls fail?" "Plan for fallibility" was a principal recommendation of this committee's predecessor (NRC 2000a).

Question: *What are the consequences of LTS failures at DOE's sites?*

DOE appears to have considered only the intended future land uses at Mound and Fernald in its assessments of risks in the future. Yet institutional controls have sometimes failed, endangering public health and environmental quality.[34] When asked to describe the risks if unintended uses (specifically, residential uses) were to emerge at these sites despite prohibitions, however, DOE was unable to provide an answer at any of the sites the committee visited, because only the intended uses had been examined.

The probability and harms associated with failures must be factored into decisions about the scope, extent, redundancy, and diversity of controls and other LTS provisions. All risks are not created equal. A failure of one type could result in an increase in human health risk that, while undesirable, is not catastrophic. Construction of residences on parts of Fernald designated to be held as open space might be an example of this category of risk, while excavation and use of the mill tailings at Moab for building material could lead to more significant exposures. These factors must be considered when determining the level of assurance sought in decision making. Some have provocatively asked, "Does anyone actually think that people are going to die at these sites?" The answer must be that we do not know if people will die as a result of contaminants at these sites, because the analyses have not been done.

There is another kind of uncertainty: programmatic risk. Suppose the selected remedial actions are implemented as planned, but fail to achieve their goals? The committee observed scant recognition or consideration of this possibility, which is salient with respect to the cleanup of ground water. Several analyses (NRC 1994, 1997, 2000b) have concluded that pump-and-treat remedies for ground-water contamination may be much less successful than hoped. Pump and treat can provide adequate *containment* of the dissolved contaminant plume if the pumping strategy is designed and operated to provide hydraulic capture of the plume. Yet containment may fail to achieve site cleanup in any reasonable time frame when sufficient contaminant mass is not removed. As a result, contaminant rebound has been noted at numerous CERCLA sites once pumping is terminated (NRC 1994); in these situations, pump-and-treat systems may have to be

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[32]DOE discovered additional contamination at Moab when it took over the site, and has found unexpected amounts of volatile organic compounds (VOCs) in the ground water at Mound.

[33]See Perrow (1984) concerning accidents and predictability in complex systems.

[34]Failure of institutional controls at Love Canal near Buffalo, New York, led in part to enactment of CERCLA in 1980 (Epstein et al. 1982; Landy et al. 1994). U.S. EPA Region 5 guidance in the RCRA Corrective Action Program explicitly asks the question "What is the potential for future residential, recreational, or agricultural uses for all or part of the facility? What are the potential risks to these other receptors?" (U.S. EPA 2000). In other words, at an industrial-use site, what is the potential for residential or agricultural use and what are the risks to those users?

maintained indefinitely. Failure of pump-and-treat to achieve cleanup is especially likely if the site has a mixture of radioactive contaminants and organic chemicals (e.g., chlorinated solvents or fuels). Alternatives to pump-and-treat can be considered at some sites, but at others, recognition has to be given to the fact that hazards may endure in ground water for periods far longer than originally intended.

Guidance for doing risk assessments for contaminated sites is reasonably mature, but estimates of risks far into the future inevitably become progressively less certain. Methods for assessing risks from the failure of waste containment cells are not consistent or well developed. U.S. EPA, U.S. Nuclear Regulatory Commission (U.S. NRC), and different sites within DOE have different approaches for assessing risks of failure of engineered barriers, and it would be worthwhile to develop a method to characterize the various approaches and to seek consensus on best practices.

Recommendation: Plan for fallibility. Conduct failure analyses to inform decisions. Seek consensus on best practices in risk analysis for failure of disposal cells.

Planning for fallibility is a central component of earning trust. Acknowledging fallibility builds credibility. Planning for fallibility entails considering in decision making the consequences of failures of institutional and engineered controls, and designing robust mechanisms to respond to such failures.

Monitoring

Monitoring is an essential part of LTS. It provides the mechanisms for detecting anticipated possible failures, detecting unanticipated events, and evaluating the effectiveness of remedial actions. Monitoring is also essential to learning as LTS proceeds. Monitoring cannot be de-coupled from an understanding of the design decisions that were made at sites: for example, failure detection requires a quantitative understanding of the acceptable bounds of system behavior. Thus, an important challenge of a durable monitoring program will be transfer of knowledge, and not simply data, to successive generations of stewards in a way that supports the mission.

Monitoring must be tailored to the characteristics of a site and its residual contaminants; the variables to monitor, as well as protocols for measurement, need to reflect the site and the risks it poses, for both practical and economic reasons. There is enormous variation across the legacy sites within the DOE complex, but that does not mean that each site should have its own scheme for reporting and retrieving monitoring data—just the reverse is true. A shared framework for reporting monitoring data is essential to assure that the information is preserved and useful. Comparisons among sites, so as to detect failures and problems, will be difficult or impossible without monitoring data that can be compared. It is also important to preserve accessibility of electronic records, since many forms of technical information, such as simulation models and geographic information systems, can only be read in electronic form. The tools for reading such data, together with the formats used to encode them, have been changing rapidly over the past two decades, and it is unclear that durable standards will evolve soon. The distinction between monitoring, which reflects the characteristics of the site, and reporting, which reflects the enduring national responsibility for LTS, must be reflected in policies, budgets, and practices. The committee saw evidence at each of the sites studied that these issues were recognized, but national guidance is lacking, so that the process of implementation is undermining consistent, retrievable reporting of monitoring.

Recommendation: DOE should tailor its monitoring to the specific risks and circumstances of its sites, while at the same time providing national-level guidance for reporting formats and record-preservation protocols.

Institutional Challenges—*Trust, Constancy, Learning*

Long-term management of the legacy wastes remaining after cleanup will be shaped by two precarious societal conditions: trust in implementing institutions, and confidence that those institutions will exercise stewardship satisfactorily over many generations. In addition, the technological and organizational means to implement LTS are still being developed as sites reach closure. DOE accordingly needs to learn from this experience. These are significant challenges, but there is some relevant experience in the operation of high-reliability organizations as well as in the management of natural resources. High-reliability organizational tasks, such as air-traffic control, require high levels of trust, both within the operating organization and in its social environment. A central finding of studies of high-reliability organizations is that public confidence reflects the way in which the operations of an organization are carried out. In the present context, this means that how planning and cleanup are carried out shapes the confidence the public, stakeholders, and political leadership will place in DOE as cleanup ends. Not only is the substance of LTS affected by choices made in the cleanup process, but so is the social setting in which LTS will be conducted. That setting is critically important to the ability of the steward to discharge its responsibilities. Thus, a question posed at the beginning of the section on incorporating LTS into environmental management is restated here.

***Question**: How can DOE carry out its mission of environmental management in such a way that when people learn more about DOE's activities, they are likely to gain confidence in the institution and its actions?*

Trust and constancy

The confidence level of stakeholders and the public—their trust in DOE—bears a direct relationship to the latitude, resources, and esteem afforded to, or withheld from, the agency. If there is a surplus of trust in implementing organizations, leaders are likely to have a good deal of discretion, adequate resources, and considerable esteem, resulting in technological autonomy. If, however, the implementing institutions face a deficit of public trust and confidence, conflict is likely to rise (even over technical issues), regulatory constraints can multiply, and resources can become more difficult to obtain.

The greater the deficit the more institutional leaders are pressed to recover it. Where there is a great deficit, some argue that recapturing trust may be impossible (Slovic 1993). Sidebar 1 summarizes means of maintaining and rebuilding trust. The essentially permanent responsibility of LTS and the inherent uncertainties involved make it especially challenging to cultivate trust in institutions implementing LTS. The longer a project, and the more generations of managerial leadership required, the greater the

SIDEBAR 1

MEANS OF MAINTAINING AND ENHANCING TRUST

Interaction with External Parties

- Early, continuous involvement of stakeholders' advisory groups with frequent contact, complete candor, rapid, and full response.
- Timely accomplishment of agreements unless modified through an open process agreed to in advance.
- Consistent, respectful reaching out to state and community leaders and the general public to inform, consult about technical, operational, societal, and equity aspects of agency activities.
- Active, periodic presence of leaders at the highest echelons, visible and accessible to citizens at sites and in neighboring communities.
- Consistency in approach, willingness to acknowledge mistakes.
- Visible agency and contractor presence in neighbor communities, with staff contributing to community affairs and paying their fair share of taxes and other common burdens.
- Assurance of negotiated benefits to the community, including resources to the affected host communities that are needed to detect and respond to unexpected costs. (This objective conflicts with the need to downsize work forces as a site is closed.)

Internal Organizational Conditions

- High professional and managerial competence and discipline in meeting technically realistic schedules with high transparency in the meeting of schedules and goals.
- Fostering of an organization culture emphasizing safety for workers and the public by executives at the highest echelons of participating organizations.
- Technical options whose implications are connected to public concerns and clearly demonstrable to broad segments of the public.
- Processes of self-assessment that permit the agency to "get ahead of problems" and openly acknowledge them before they are discovered by outsiders.
- Tough internal processes of reviewing and discovering actual operating errors that include stakeholders.
- Clear, institutionalized assignment of responsibility for regaining and sustaining public trust and confidence and for ensuring constancy.

Sources: La Porte and Metlay (1996), DOE (1993), La Porte (2001).

SIDEBAR 2

CHARACTERISTICS ASSOCIATED WITH INSTITUTIONAL CONSTANCY

Assurance of Steadfast Political Will

- A culture of commitment, including periodic reaffirmation of unswerving adherence to the spirit of the initial agreement.
- Strong articulation of commitments by leaders at the upper echelons of all participating organizations, calling on staff to sustain constancy.
- Clear evidence of organizational continuity with institutional norms that nurture the persistence of commitments across many generations.
- Vigorous external reinforcement from regulatory agencies, stakeholders, and attentive public.

Organizational Infrastructure of Constancy

- Administrative and technical capacity to carry out constancy-reinforcing activities backed by agency incentives.
- Adequate resources to assure the transfer of requisite technical, cultural, and institutional knowledge from one worker and management generation to another.
- Analytical and resource support for careful examination of technical changes on future impacts.
- Capacity to detect and remedy inevitable failures and their effects, with the assurance of remediation when failures occur.

Sources: La Porte and Keller (1996), La Porte (2000, 2001).

likelihood of a loss of institutional memory and diffusion of commitment—and the greater the need for institutional constancy. No formal human institution has endured as long as the projected life of some of these hazards. Institutional constancy entails organizational perseverance and faithful adherence to the mission and its imperatives over long time periods. The goal of constancy is to give confidence that organizations will keep their word from one management generation to another. Characteristics of institutional constancy are listed in Sidebar 2 (La Porte and Keller, 1996). A deficit of trust and limited assurance of institutional constancy make implementing LTS arduous under the best of circumstances, given industrial societies' practice of discarding most materials as wastes. It is therefore important for institutions and their leaders to tackle the deficit of trust openly.

Learning

Even under an accelerated schedule, active remediation of DOE's legacy waste sites will last for decades and involve activities at more than 100 locations in different geographic settings. As cleanup concludes at each site, the resources flowing in from DOE are expected to decline substantially, not only in funding but also in the technical expertise on-site, and in the information produced by a declining profile of activity. The diversity of sites and length of time that cleanup will take both provide useful opportunities for learning from experience, strengthening the knowledge base for LTS.[35]

Reduced resource flows also mean that stewardship will unfold in a far different social and political environment than today's cleanup program. What is unclear, in light of the problem of trust and constancy, is whether a different social setting will make LTS harder or easier than is currently anticipated.

Ground-water cleanup is expected to continue at most sites for a long period after they enter LTS, because of the slow pace at which subsurface contamination can be treated. The decades-long duration of ground-water operations means that DOE will be tending the site, and monitoring containment long enough that DOE will enact rolling stewardship before the remedial actions are complete. This provides a time period in which to build trust and to test institutional constancy, while gaining experience with containment measures.

A study panel of the National Research Council (NRC 2003b) recently recommended to the U.S. Navy an approach to conducting its ground-water cleanup so as to improve its understanding of the hydrogeological behavior of contaminated sites. The primary innovation is to use a conceptual site model to bring together the technical and institutional understanding of the site and the environment of its surrounding land and water. The conceptual site model creates a framework for selecting monitoring locations and protocols, together with expected values of contaminants and other environmental indicators over time. The conceptual site model is *expected to be incorrect*, because predictions of site behavior are based upon incomplete understanding. But as cleanup proceeds and land use and other conditions change, the conceptual site model can be updated and corrected by the monitoring process. In essence, this is a way of incorporating learning into management by making development of understanding and adaptation to change an explicit core component of the mission. In this approach, known as adaptive management (Holling 1978; Walters 1986; Lee 1993), surprise is expected and surveillance yields improved understanding. Adaptive staging, a related idea advanced by another National Research Council committee (NRC 2003a), could serve as a model for thinking about these issues with respect to management of long-term hazards, especially for cleanups that will take a long time.

As the committee argues above, regulations do not provide adequate guidance on the risks to be managed in the long term. An adaptive approach, using a conceptual

[35]Recent National Academies studies on risk and adaptive staging have emphasized the value of a recursive, iterative process that allows for the use of knowledge obtained in the future (NRC 2002b, NRC 2003a). This is particularly important over the long time periods at issue with LTS; it is improbable the knowledge available to stewards in 100 or 1000 years—if only from experience—will be the same as that of the present day.

site model, provides an explicit set of understandings and predictions, which can, in turn, frame a discussion among DOE, regulators, and stakeholders on how to go beyond the existing regulations in protecting the site and affected populations and habitats.

Recommendation: During ground water remediation, rolling stewardship should become explicitly adaptive, adopting learning as an explicit objective. This can serve as a pilot effort for incorporating learning into all elements of LTS. Use of an adaptive management framework, such as a conceptual site model, should be explored as a means of organizing learning at the DOE legacy sites.

At the national level, this means that the experiences of sites in different political jurisdictions should be studied, with the aim of assuring that the variations in performance are due to differences in local environmental conditions, rather than differences in the capacities of local managers and institutions. A process with some parallels (not all reassuring) is the periodic re-accreditation of colleges and universities to provide assurance of national quality control while permitting substantial autonomy and variation.

It is important to note that adaptive management of natural resources has not been successfully implemented (Lee 1999). Although it is technically straightforward, adaptive management has encountered institutional difficulties, rooted in the reality that managers are reluctant to be proven wrong—even when correcting understanding that is known to be incomplete is a stated mission. If DOE wishes to build trust and a reputation for constancy, however, it is timely for the Department to admit something that is obvious to all observers of radioactive waste management: The task is difficult and understanding is incomplete. Paradoxically, building trust is a strong reason to admit the possibility of errors and to seek open ways of recognizing error and improving understanding going forward.

Recommendation: DOE should build understanding during the remaining period of cleanup, so as to make LTS a welcome step as sites are closed. Activities during the ground-water cleanup phase provide important opportunities to build credibility.

In its work the committee has come to appreciate the substantial gaps in the nation's organizational, operational, and social understanding of how to manage the hazardous residues of industrial economies over very long periods of time. Addressing these gaps will be critical to long-term institutional management, and social science research should be carried out as an integral component of research and development in waste management.

Other reports (INEEL 2002; NRC 2000a) have called for case studies and comparisons among sites to bring together the lessons of past experience (NRC 2002a). In the decades to come, as cleanup proceeds, it is also worthwhile investing in social science studies that can improve trust, constancy, and learning. In particular, the characteristics of high-reliability organizations are related to trust and constancy (La Porte 2001), and the continuing efforts to improve the ability of organizations to learn in the face of uncertainty (Walters and Holling 1990; Lee 1999) are priorities to be considered.

ALLOCATING RISKS & COSTS WITHIN AND ACROSS GENERATIONS: A NATIONAL DIALOGUE

At any given point in time, each DOE site imposes a mix of risks, costs to maintain the risk within acceptable levels, and uncertainty as to future risks and costs (Russell 2002). Consequently, each decision at the site incorporates compromises and tradeoffs among these factors, and should reflect and implement societal values concerning each. Long-term costs, liabilities, and benefits are difficult to take into account: Their estimates are inherently uncertain, and there is no consensus on how to value their consequences and translate those as a guide to current decisions (see e.g., Portney and Weyant 1999 and NAPA 1997).[36] Yet DOE's cleanup program cannot entirely eliminate the risks; the program only alters the mix of risk and costs to be borne at different places and times. As noted near the beginning of this report, all remediation decisions are choices that affect that mix and what burden is borne in cleanup and in long-term stewardship. Thus, DOE has been making decisions that affect the well-being of this and future generations, usually without recognizing that fact or explicitly weighing its implications.

Many of these decisions will have consequences that are costly to reverse—materials may be moved or barriers may be built to immobilize contaminants, property may change hands, and other steps may be taken that would be difficult or impossible to undo. In particular, choices made in the past have created responsibilities that endure, such as the decisions made to precipitate liquid wastes in the Hanford tanks, which created solidified materials that are difficult and expensive to deal with (see, e.g., Gerber 1992). For this reason, a deliberate and transparent decision-making process is needed to spell out the implications of remediation decisions for risks and costs in the future. Those implications go beyond expectations of technical outcomes and include how those outcomes will be valued in an individual and societal context.

Sharing the Burden: The DOE Cleanup Program is not alone in needing LTS

As noted earlier in this report, without a coherent set of guiding principles for making choices among the burdens to be borne by present and future generations in addressing enduring risks, DOE's decisions will continue to be made *ad hoc* and will remain difficult to justify. DOE is the nation's agent in these decisions on allocations of risks and costs within and across generations, and needs guidance on how to make them.

That some sites contaminated by industrial activities cannot be completely cleaned up is still being recognized by landowners and governments responsible for safety, health, and environment. When the predecessor to this committee issued its report in the year 2000, the primary finding regarded as newsworthy by the American press was the sheer number of contaminated sites in the DOE complex that would require LTS. There are many other sites that are also likely to remain contaminated, mostly with chemical toxins, in this and other nations.

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[36]Discounting with either zero or non-zero rates arouses debates even within groups that accept a benefit-cost accounting framework. Other bases for making tradeoffs are often in conflict with the benefit-cost framework.

The management of potentially hazardous sites over extended periods of time is a burden shared by many federal agencies. While DOE's approach to this issue is the focus of this study, the responsibility of DOE for its legacy sites bears strong similarity to EPA's responsibility for closed Superfund sites or hazardous waste landfills, DOD's responsibilities for its former and present facilities, the Department of Interior's responsibilities at thousands of sites including abandoned mines, and states' responsibilities at "brownfield" sites that are not on the National Priorities List. In the CERCLA program alone, over 600 sites include institutional controls in their RODs (U.S. EPA 2001). The federal government has hundreds of complex, multicontaminant sites, which are difficult to clean up. It therefore makes sense to approach them in a coherent fashion. Similarly, while the goal is preservation of the good rather than protection from the bad, the National Park Service and National Wildlife Refuge System face open-ended responsibilities that also fall within a common notion of stewardship.

These are national issues, they involve deeply held values, and they have substantial consequences for present and future generations. In short, they demand and deserve broad public discussion. Instead, however, they have been treated mostly as technical issues with only parochial attention paid to the values that are involved. The beginning point for resolving these issues and providing DOE and other agencies with the guidance they need would be a public dialogue to inform and engage people in a process that allows their values to be expressed and heard. Reaching resolution may well require national leadership. DOE and the other affected agencies can take responsibility for initiating such a dialogue, perhaps by making the implicit value predicates of their decisions apparent and requesting comment. They are the bodies that are both most knowledgeable and most directly involved in these issues.

Subsequently, of course, the criteria and methods for decision-making for such situations would need to be devised. To the extent that DOE sites are comparable to those of other federal agencies, a coordinated effort across agencies could help develop systematic methods for addressing such decisions. Within DOE, generic problems such as long-term site management have been the subject of programmatic environmental impact statements. A similar interagency process could lead to the implementation of methods that gain general public acceptance. Such a broad national approach could also lead to better interagency coordination to improve stewardship.

An effort is underway to develop a memorandum of understanding on LTS at federal facilities among the Environmental Council of the States, DOE, the U.S. Department of Defense, the U.S. Department of Interior, and the U.S. Environmental Protection Agency. The purpose is to provide a basis for discussion and coordination on LTS issues by establishing shared principles for LTS and seeking agreement on how LTS fits into the remedy process, what LTS goals are, what is expected from LTS, who is responsible for fulfilling LTS functions, and what is needed to support them.[37] This is a commendable step toward the kind of national dialogue that the committee recommends.

The legacy wastes pose an unfamiliar and difficult challenge to society and to DOE. Sites that cannot be cleaned up enough to permit unrestricted access remain

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[37]Howard Roitman, acting director of environmental programs, Colorado Department of Public Health and Environment, informed the committee via personal communication of the status of a resolution by ECOS (2001) on this topic.

hostage to technology and organization. Engineered barriers may fail; ground-water cleanup may not succeed; most of all, organizations comprised of human beings need to remember, monitor, and respond when problems are discovered. Humans are fallible, a frailty inherited by organizations. This is the legacy that matters most. Stewardship of religious, educational, and civic institutions has succeeded for centuries, and in a few cases for longer. Stewardship has succeeded when people have sustained their attention and capacity in the face of adversity and distraction. Long-term stewardship of the legacy sites needs to be taken into account at all stages of remediation, not only because LTS is an important social goal, but because it tests society's diligence to an unusual degree.

DOE managers today stand at the starting point of a journey. Future generations will need to find their own way with the legacy waste sites. What the current generation needs to do is to make its choices about cleanup and LTS in ways that will give future generations the knowledge and resources to make their choices responsibly. DOE is choosing a course on which to embark and a vessel in which to sail.

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APPENDIXES

Appendix A

Statement of Task

The objective of this study is to analyze long-term institutional management plans and practices for a small group of representative DOE legacy waste sites and recommend improvements. To accomplish this objective, the study will

1. Identify a small number of sites that are representative of the larger population of DOE sites that will require long-term institutional management. Selection of these representative sites will be based on characteristics such as amounts and types of waste and contaminants present; hazards; site characteristics; proximity of human development; long-term land uses; and uncertainties in the performance of waste and contaminant isolation technologies.

2. Evaluate the adequacy of DOE's long-term institutional management plans and programs for these representative sites against the conceptual framework and criteria developed in the phase 1 report and, if appropriate, information from related reports.

3. Provide recommendations to improve DOE's long-term institutional management plans or practices at these sites, and for contaminated sites in general, including recommendations for scientific (including social science) and engineering research and development to improve long-term institutional management capabilities.

Appendix B

Biographical Sketches of Committee Members

Kai N. Lee, *Chair*, is Rosenburg Professor of Environmental Studies and former director of the Center for Environmental Studies at Williams College. He previously taught political science and environmental studies at the University of Washington and has been a visiting professor, lecturer, or research fellow at the Kyoto Institute of Economic Research, Kyoto University, Stanford University, the University of California at Berkeley, Trent University, the University of Wisconsin, Memorial University of Newfoundland, and an on-line education program at the Western Behavioral Sciences Institute. Dr. Lee earned his A.B. in experimental physics from Columbia College and his Ph.D. in experimental physics from Princeton University. In 1971 he was awarded a research training fellowship by the Social Science Research Council, after which he began his professional career in political science and environmental studies.

Chris G. Whipple, *Vice Chair*, is a principal in ENVIRON International Corporation in Emeryville, California, which provides consulting services mainly to private industry. His professional interests are in risk assessment, and he has consulted widely in this field for private clients and government agencies. Prior to joining ENVIRON, he worked at ICF Kaiser Engineers and the Electric Power Research Institute. Dr. Whipple holds a Ph.D. and M.S. in engineering science from the California Institute of Technology and a B.S. in engineering science from Purdue University. Dr. Whipple is a member of the National Academy of Engineering.

John S. Applegate is Walter W. Foskett Professor of Law at the Indiana University School of Law—Bloomington. He teaches and writes about environmental law, regulation of hazardous substances, risk, environmental remediation, and the Department of Energy. Mr. Applegate co-chaired the Long-Term Stewardship and Accelerated Cleanup subcommittees of the Department of Energy's Environmental Management Advisory Board. He was previously the James B. Helmer, Jr., Professor of Law at the University of Cincinnati College of Law and chaired the Fernald Citizens Advisory Board and has been a visiting professor at Vanderbilt University Law School, a judicial clerk to the United States Court of Appeals for the Federal Circuit, and an attorney in private practice. He is the author or co-author of over 20 articles and one book on risk and environmental law. Mr. Applegate received a B.A. in English from Haverford College and a J.D. from Harvard Law School.

Susan L. Brantley is professor of geosciences and director of the Center for Environmental Chemistry and Geochemistry at Pennsylvania State University. Dr. Brantley's research focuses on chemical processes associated with the circulation of aqueous fluids in shallow hydrogeologic settings and deep in the earth's crust. Her research incorporates field and laboratory work, and theoretical modeling of observations to better understand what controls the chemistry of natural water and how water interacts with the rocks through which it flows. Dr. Brantley was a Fulbright Scholar and has been a visiting scientist at both the U.S. Geological Survey and Stanford University. She has received both the NSF Presidential Young Investigator Award and the David and Lucile Packard Fellowship. Dr. Brantley received her B.A. in chemistry and received her M.A., and a Ph.D., both in geological and geophysical sciences, all from Princeton University.

Thure E. Cerling is professor of geology and geophysics at the University of Utah. His research interests focus on the use of isotopes as hydrologic tracers, geology of Old World paleoanthropologic sites, soils as climatological indicators, and environmental geochemistry (contaminant migration in ground water, rivers, and soils), among others. Dr. Cerling has been a visiting professor or fellow at the Scripps Institution of Oceanography; Yale University; the Université de Lausanne; Hebrew University, Israel; and the California Institute of Technology. He is a fellow of the Geological Society of America and a member of the National Academy of Sciences. Dr. Cerling received his B.S. in geology and chemistry and his M.S. in geology, both from Iowa State University, and received his Ph.D. in geology from the University of California at Berkeley.

Allen G. Croff is manager of Environmental Technology Program Development in the Biological and Environmental Sciences Directorate at Oak Ridge National Laboratory (ORNL). Prior to this position he was associate director of the Chemical Technology Division at ORNL. His area of focus is initiation of research and development involving waste management and nuclear fuel cycles. Since joining ORNL in 1974, he has been involved in numerous technical studies that have focused on waste management and nuclear fuel cycles. He has served on several National Research Council committees, including the Committee on Remediation of Buried and Tank Wastes, which produced the Phase 1 report on long-term institutional management of DOE sites, in 2000. Mr. Croff holds a B.S. in chemical engineering from Michigan State University, a Nuclear Engineer degree from the Massachusetts Institute of Technology, and an M.B.A. from the University of Tennessee.

Patricia J. Culligan is an associate professor of civil and environmental engineering at the Massachusetts Institute of Technology. Dr. Culligan's research interests lie in the field of geo-environmental engineering and focus primarily on the experimental and numerical modeling of flow and contaminant transport processes in geologic systems. Her current research addresses the effectiveness of in situ remediation strategies for the cleanup of waste sites. In addition, she has worked in the design of land-based disposal cells. Dr. Culligan has received numerous awards including the Arthur C. Smith Award for Undergraduate Service, and the NSF CAREER Award. She is also the author or co-author of over 50 journal articles, book chapters, and refereed conference papers. Dr. Culligan received her B.Sc. degree from the University of Leeds, England, and her M.Phil. and Ph.D., both from Cambridge University, England.

Steven N. Handel, professor of ecology and evolution at Rutgers, The State University of New Jersey, New Brunswick, studies the population biology of native plants in many habitats. He is currently director of the Center for Urban Restoration Ecology. Prior to joining the faculty at Rutgers, he was associate professor of biology and director of the Marsh Botanic Garden at Yale University, and also taught at the Rocky Mountain Biological Laboratory, Mountain Lake Station, and the University of South Carolina. He is a fellow of the American Association for the Advancement of Science, a fellow of the Australian Institute of Biology, an Aldo Leopold Leadership Fellow of the Ecological Society of America, and an associate editor of the journal, Restoration Ecology. Dr. Handel previously served as president of the Torrey Botanical Society and as a member of the board of directors of the Society for Ecological Restoration. Dr. Handel received his B.A. in biological sciences from Columbia College and received his M.S. and his Ph.D. from Cornell University in ecology and evolution.

Robert J. Huggett is vice president for research and graduate studies at Michigan State University (MSU). Before joining MSU in June 1997, he was assistant administrator for research and development at the U.S. Environmental Protection Agency and led committees on environmental issues within the White House Office of Science and Technology Policy. He is professor emeritus at the College of William and Mary, where he was a faculty member for 20 years. During those years he also served as chair of environmental science in the School of Marine Science and head of the Division of Chemistry and Toxicology. Dr. Huggett has studied the fate and effects of hazardous chemicals in aquatic environments, publishing more than 80 articles. He has served on several committees of the National Research Council. Dr. Huggett attended the College of William and Mary and then earned a M.S. in marine chemistry from the Scripps Institute of Oceanography at the University of California at San Diego and a Ph.D. in marine science at William and Mary.

Todd R. La Porte is professor of political science at the University of California at Berkeley. His fields of specialization are theories of public organization and administration; and science, technology, and politics. Dr. La Porte teaches courses on public organization theory, administrative behavior, and technology and politics. His current research focuses on high-reliability organizations and the relationship of large-scale technical systems to political legitimacy. Dr. La Porte chaired the Secretary of Energy Advisory Board's Task Force on Radioactive Waste Management. He was elected to the National Academy of Public Administration in 1985, but is no longer an active member. Dr. La Porte received his B.A. in social sciences and mathematics from the University of Dubuque and received his M.A. and his Ph.D., both in political science from Stanford University.

P. Suresh C. Rao is the Lee A. Rieth Chair & Distinguished Professor in the School of Civil Engineering at Purdue University and he holds a joint appointment in the Agronomy Department in the School of Agriculture. Prior to arriving at Purdue, Dr. Rao was on the faculty at the University of Florida for 24 years where he now holds an appointment as an emeritus graduate research professor. Dr. Rao teaches contaminant hydrology and remediation engineering. His research has involved development of innovative technologies for characterization of hazardous waste sites, and for enhanced remediation of contaminated soils and aquifers. Dr. Rao has received several awards including the Environmental Quality Research Award and the EPA Scientific & Technology Achievement Award. He is a fellow of the Soil Science Society and the American Society of Agronomy. Dr. Rao received his B.Sc. in Agriculture from the A.P. Agriculture University in India, his M.S. in soil science from Colorado State University, and his Ph.D. in soil science from the University of Hawaii.

Allan C.B. Richardson is an independent consultant on issues related to cleanups involving radioactive contaminants. Prior to retiring in 1998, he was associate director for radiation policy in the U.S. Environmental Protection Agency's Office of Radiation and Indoor Air. Mr. Richardson joined the EPA when it was formed in 1970 and led or played a key role in the development of most of EPA's standards for radiation. Prior to joining the EPA, he was a nuclear physicist at the National Bureau of Standards. Mr. Richardson has served as a committee member for the International Commission on Radiological Protection. He has consulted for international organizations, such as the International Atomic Energy Agency, and has served as advisor to the peoples of Bikini, Enewetak, and Rongelap, and the Rocky Flats Citizens Advisory Board. He received several awards for distinguished service in EPA. He is the author of many publications in professional journals and technical reports. Mr. Richardson received his B.S. in chemistry from the College of William and Mary and his M.S. in molecular physics from the University of Maryland.

Milton Russell is a senior fellow and was founding director of the Joint Institute for Energy and Environment; he is also professor emeritus of economics at the University of Tennessee. His current research focuses on analysis and policy direction for managing the environmental legacy of Department of Energy facilities. Dr. Russell has taught at several universities in the United States and abroad. He served as senior staff economist for the President's Council of Economic Advisers, and later as director of the Center for Energy Policy Research at Resources for the Future. Dr. Russell served as assistant administrator of the U.S. Environmental Protection Agency, directing its policy, planning, regulatory development, and evaluation functions. He was a member of the Secretary of Energy Advisory Board, and has been elected a fellow of the Society for Risk Analysis. He is currently chair of the Westinghouse Savannah River Site Environmental Advisory Committee. Dr. Russell received his B.A. from the Texas College of Arts and Industries and his M.A. and his Ph.D., both in economics from the University of Oklahoma.

Michele Straube is co-founder of CommUnity Resolution, Inc., which provides mediation, facilitation, and environmental-policy consulting services to local, state, and federal governments focusing on RCRA and Superfund issues. She is also adjunct professor at the University of Utah College of Law. Much of her current work involves designing and implementing collaborative processes to involve communities and citizens in government and corporate environmental decision making. Ms. Straube previously served as director of the State Superfund Network, senior attorney at the Environmental Law Institute, an attorney in private practice, director of the Alaska Consumer Advocacy Program, and an enforcement attorney with the Pennsylvania Department of Environmental Resources. Ms. Straube received a B.A. in linguistics and German from Rice University, and she received a J.D. from the Franklin Pierce Law Center in Concord, New Hampshire.

Appendix C

Presentations to the Committee

August 6-7, 2001, Washington, DC

What is DOE Asking?, Gerald Boyd, Office of Science and Technology in the Office of Environmental Management (EM) at the U.S. Department of Energy (DOE)

Clean-up and Stewardship: The Big Picture, David Geiser, Office of Long-Term Stewardship DOE EM

LTS Portfolio of Sites and Challenges, Jeffrey Short, Office of Long-Term Stewardship DOE EM

Tribal Perspective on LTS, Russell Jim, Yakama Indian Nation, Environmental Restoration and Waste Management Program

U.S. EPA Perspective on Clean-up and LTS under RCRA and CERCLA, Murray Newton, U.S. Environmental Protection Agency (U.S. EPA)

State Concerns with Long-Term Stewardship, Howard Roitman, State of Colorado & Environmental Council of the States (ECOS)

U.S. NRC Perspectives on LTS, John Greeves, U.S. Nuclear Regulatory Commission (U.S. NRC)

Implementing Long-Term Stewardship under Local, State, and Federal Law, Mervyn Tano, International Institute for Indigenous Resources Management and John Pendergrass, Environmental Law Institute

Institutional Challenges for High-Reliability Systems Across Many Operational Generations, Charles Powers, Consortium for Risk Evaluation with Stakeholder Participation II; and Todd La Porte, Long-Term Institutional Management Committee Member

October 31, 2001, Miamisburg, Ohio

Speaking With One Voice, Mayor Dick Church, Jr.City of Miamisburg

Historical Overview of Mound Site, Rick Provencher, DOE Ohio

BWXT of Ohio Project Overview, P. Sandy Baker, BWX Technologies, Inc. of Ohio (BWXTO)

Sale of the Site Overview and Post Closure Stewardship Overview, Oba Vincent, DOE Miamisburg Mound Environmental Management Project (MEMP)

Mound 2000 Overview, Brian Nickel, Ohio Environmental Protection Agency

Environmental Restoration Project Overview, Monte Williams, BWXTO

PCS Information Management, Dave Rakel, BWXTO

Layered Approach to Implementation of Institutional Controls, Graham Mitchell, U.S. EPA

PCS Responsibilities—DOE Perspective, Sue Smiley, DOE Ohio

PCS Working Group Overview, Dann Bird, Miamisburg Mound Community Improvement Corporation (MMCIC)

Hazards and Risks, Dave Rakel, BWXTO and Oba Vincent, MEMP

Ownership and Responsibilities, Susan Brechbill, DOE Ohio and Mike Grauwelman, MMCIC

Panel Discussion on Goals and Progress, Susan Brechbill, DOE Ohio, Mike Grauwelman, MMCIC, Graham Mitchell, U.S. EPA, Dave Wood, City Councilman, Sharon Cowdrey, Miamisburg Environmental Safety and Health

Committee Tour of the Mound Site

November 1, 2001, Harrison, Ohio

Committee Tour of the Fernald Site

Physical Drivers/Goals and Progress, Johnny Reising, DOE Fernald

Long-Term Stewardship Plans, Gary Stegner, DOE Fernald

Future of Fernald Process, Doug Sarno, Fernald Citizens Advisory Board

Hazards and Risks, J.D. Chiou, Fluor and Kathleen Nickel, DOE Fernald

Long-Term Surveillance/Monitoring, Marty Prochaska, Fluor Fernald

January 14-15, 2002, Moab, Utah

Update on LTS Planning and Organization at DOE Headquarters, David Geiser, Office of Long-Term Stewardship, DOE EM

DOE's Long-Term Surveillance and Maintenance Program and Long-Term Stewardship, Art Kleinrath, DOE Grand Junction Office (GJO)

Experience with Managing Moved Piles, Art Kleinrath, DOE GJO

Experience Remediating Mill Tailings Piles (Title I), Russell Edge, DOE Albuquerque Office (AL)

Committee Tour of the Atlas Mill Tailings Pile

DOE Draft Plan for Remediating the Moab Site, Ray Plieness and the Moab Project Team, DOE GJO

Groundwater Studies by Oak Ridge National Laboratory (ORNL), Frank Gardner, ORNL

Groundwater Studies by Shepherd Miller, Toby Wright, Shepherd-Miller, Loren Morton, Utah Division of Radiation Control, and Pete Penoyer, National Park Service

Studies of contaminant Effects on Larval Fish, Ann Allert, USGS and Bruce Waddell, U.S. Fish and Wildlife Services (U.S. F&WS)

Human Health and Environmental Impacts of Management Options, Mike Fliegel and Mike Layton, U.S. NRC

Cost Estimates, Russell Edge, DOE AL and Don Metzler, DOE GJO

Comments from DOE, Grand Junction, Donna Bergman-Tabbert, DOE GJO

State of Utah Perspectives and Possible Future Regulation, Diane Nielson, Utah Department of Environmental Quality and Loren Morton, Utah Division of Radiation Control

Existing Regulations and Standards, Mike Fliegel, U.S. NRC

The Endangered Species Act, Yvette Converse, U.S. F&WS

UMTRA Title 1, Richard Graham, U.S. EPA Region 8

Perspectives on Tailings Management, Kimberly Schappert, County Commissioner, William Hedden, Grand Canyon Trust/Utah, Mark Buehler, Los Angeles Metropolitan Water District

October 14, 2002, Washington, DC

DOE LTS Strategic Plan, Questions and Answers, David Geiser, DOE/Office of Long-Term Stewardship

Appendix D

Board on Radioactive Waste Management Letter to Jessie Roberson

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

Board on Radioactive Waste Management

August 20, 2002

Jessie Roberson
Assistant Secretary for Environmental Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Ms. Roberson:

I am writing on behalf of the Board on Radioactive Waste Management in response to your request that the National Academies' study entitled *Long-Term Institutional Management of DOE Legacy Waste Sites/Phase 2* be wrapped up in advance of its planned October 2003 completion date. The Board met in closed session on July 31 to discuss your request and agree on a course of action. The chair of the committee that is carrying out this study (Dr. Kai Lee, Williams College) participated in this discussion.

The Board recognizes that you inherited this study from the previous assistant secretary and, as reported to us by board director Dr. Kevin Crowley, that you do not yet feel ready to engage the National Academies in an examination of the DOE long-term stewardship program. Accordingly, the board has asked Dr. Lee and his committee to terminate its information-gathering activities and prepare a status report based on its work to date. This report will address both technical and institutional aspects of long-term stewardship planning and execution at the sites the Department plans to close in the next several years and related issues that have arisen during the study. We believe that this report will be useful to your current planning efforts because the long-term stewardship choices being made at those sites to be declared closed in the coming decade will set important precedents for future site-closure decisions.

We hope that Dr. Lee's committee will be able to deliver its report to you before the end of the current calendar year. The committee is now trying to schedule a meeting to begin work on this report, and Dr. Lee will be able to provide you with a better estimate of a report-completion date once the committee has held this meeting.

500 5th Street, NW, 6th Floor, Washington, DC 20001 *Telephone* (202) 334-3066 *Fax* (202 334-3077 www.nas.edu/brwm

Ms. Jessie Roberson
August 20, 2002
Page 2

Dr. Crowley has informed the Board of your desire to re-engage the National Academies on long-term stewardship in the future, and also of a potential Congressional request for a study of the long-term stewardship program. The Board will be in a position to respond in a timely manner to possible future requests and would expect to take advantage of the considerable expertise on Dr. Lee's committee and its familiarity with the issues. The Board remains willing to assist the Department in its efforts to carry out its clean-up and long-term stewardship responsibilities in a technically sound and societally responsible manner.

Sincerely yours,

John F. Ahearne
Chairman
Board on Radioactive Waste Management

cc: BRWM members
Kai Lee, chair, LTIM/2 committee
Kevin Crowley, director, BRWM
Micah Lowenthal, study director, LTIM/2 committee

Appendix E

The Committee's Observations at Mound and Fernald

Introduction

The committee visited two DOE sites, Mound and Fernald, on October 31 and November 1, 2001. The sites are near each other in southwestern Ohio. During these visits, the committee talked with DOE managers, contractors, community leaders, and interested citizens. The committee also toured each site. (See Appendix C for a list of presentations and discussions.)

Mound and Fernald present striking contrasts: Managers of the two sites have taken different paths through the regulatory process resulting in different approaches to site characterization, remedy selection, and remedial action. They, along with state and local stakeholders, also have chosen different future land-use plans (industrial reuse at Mound, and open parkland at Fernald) making for stark differences in the physical, ecological, and institutional conditions in which LTS will begin.

Mound[1]

Located near Dayton, Ohio, in the city of Miamisburg, the Mound Plant (now the Miamisburg Environmental Management Project, MEMP) manufactured radioactive components for nuclear weapons, such as neutron generators, and provided a variety of services to the Atomic Energy Commission and DOE using radioactive and stable isotopes. At its peak, the facility employed 2400 people,[2] and the community's desire to find sustainable replacements for the largest employer in the area influenced the positions of local stakeholders in negotiating with DOE on both the future uses of the site and on how cleanup was to be carried out.

Hundreds of small patches of contaminated soil have been found at the site, in addition to the larger-scale problems due to landfills and ground-water contamination.

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[1]Except where otherwise noted, the information in this section was gathered during the committee's meeting in Miamisburg, Ohio on October 31, 2001.

[2]According to the Environmental Law Institute (ELI 1998), 2200 people were employed at the plant when it ended operations in 1994.

Contamination at Mound consists of volatile organic compounds (VOCs), tritium, plutonium, polonium, thorium, uranium and small quantities of some other actinides and fission products. Contamination is found both in structures and environmental media (soils, ground water, and seeps to surface water). At least one landfill on the site contains VOCs (see DOE 1996).

The current plan calls for cleanup activities at Mound to be completed in 2006, and for management of much of the site to be transferred to the Miamisburg-Mound Community Improvement Corporation (MMCIC), which is to be the site steward. This business development organization, created by local government, is developing an industrial park on the site, the Mound Advanced Technology Center. The Center is the only future use of the site considered in planning documents. The city views it as impossible that the land might convert to residential land use because the land is zoned industrial. No analyses seem to have considered the risks if zoning restrictions were to change or fail.

Some buildings on the site have already been transferred to the MMCIC and are in use, although the industrial reuse approach faces some difficulties. The MMCIC has complained that not enough of the site has been transferred to reach a threshold for viability of the industrial park. After terrorists attacked the U.S. in September 2001, security was stepped up, making it more difficult for visitors to meet with businesses even in the areas of the site released for redevelopment. The committee was told that most of the businesses that currently operate in the new industrial park are run by former Mound employees, taking advantage of the unique facilities at the site to carry out some of the same services and functions for DOE that the Mound Plant did.[3]

Progress toward "closure" at Mound has been accelerated by the unusual use of emergency removal authority under CERCLA (as opposed to the longer-term "remedial" actions that most of the other sites are using) and creation of an *ad hoc* decision making structure built around potential release sites (PRS). The intent is to enable DOE, U.S. EPA, and Ohio EPA to make triage judgments on small parcels and buildings, so that lightly contaminated buildings can be quickly returned to economic use.[4] That building-scale focus has accelerated decontamination and release of some buildings and areas, but it has deferred planning for harder problems and left overall site characterization incomplete.[5] The usual approach to reaching a record of decision (ROD) under CERCLA would have required a more comprehensive characterization and analysis of the site and the hazards it holds than is being obtained through the current approach. Without

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[3]The MMCIC website (www.mound.com, accessed 11/25/02) lists 30 companies employing 350 people. The businesses include several engineering services (precision machining, materials testing, and equipment testing) companies, as well as companies that consult on waste management and environmental cleanup.

[4]The multiplicity of different contaminated areas of the site potentially requiring different remedial actions motivated the parties to use this unusual approach. See (ELI 1998) for fuller descriptions of the motivations and the legal mechanisms for this approach.

[5]DOE's Office of Oversight, Environment, Safety, and Health stated that "to promote commercialization, which was authorized by Congress and strongly supported by DOE Headquarters, the DOE Ohio Field Office authorized leasing of MEMP facilities before clearly identifying hazards and controls, fully assessing the potential impact of accidental releases of radioactivity on lessees, or developing an effective emergency management program involving lessees." Quoted in (DOE 2001b).

adequate characterization of the site as a whole, the piecemeal cleanup may miss pockets of contamination and lead to poor understanding of the hyrdogeological behavior of the ground water.

Some of the largest technical challenges in cleaning up the site appear to have been pushed into the future: still to be determined were plans for dealing with the tritium-contaminated T Building,[6] remediating ground water contaminated with dense nonaqueous-phase liquids (DNAPLs), and means to prevent future occupants from pumping contaminated ground water downstream from one of several onsite landfills that contain radiological and chemical contaminants.[7] Drinking and process water are now drawn from three wells that are not currently contaminated (contaminant levels are on the order of one percent of maximum contaminant loads, MEMP 2001), and that sit directly downstream from the pump-and-treat wells that are being used to remediate contaminated ground water at the site; the persistence of the contaminants in the water is poorly understood.

There are many outstanding questions regarding the inventory of contaminants in the subsurface, including some that have not yet been asked by those in charge. Indeed, the site managers told the committee that they have not examined what data they will need to establish an environmental baseline for future monitoring.[8] During a tour of the facility, the committee was told that plutonium contamination was suspected in a drainage swale on the site, but plans for pursuing this were vague and seemed to suggest that further investigation would be done on an as-needed basis. The site's pump-and-treat program had removed ten times the total original estimated ground-water inventory of VOCs, by the time of the committee meeting. Yet this surprise apparently had not prompted a deeper investigation into the sources of these contaminants. Approximately $75 million is to be held in a contingency fund to deal with late discoveries of contamination.[9]

Consideration has not been given to whether dense non-aqueous phase liquids (DNAPLs) might travel through the fractured bedrock system that underlies the site and contaminate ground water beyond the site boundary. DNAPLs tend to sink in the subsurface and, unless retarded by lenses of low permeability material, are likely to end up in the bedrock. Once in the bedrock, their migration patterns are linked to the pattern of the fracture network, making off-site migration a possibility.

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[6]The T Building is a five-story concrete structure built into a hill. The building was used in work on triggers for nuclear weapons and tritium recovery and purification. The building is contaminated with tritium, polonium, and plutonium (ELI 1998, DOE 2001a). Tritium contamination in the building is such that it would take many decades for the tritium to decay to levels that might allow release (see ELI 1998).

[7]DOE-Ohio's response to headquarters' call for accelerated cleanup (DOE 2002d) notes as key assumptions of planning that cleanup of the T Building will meet regulatory requirements, and that unforeseen contamination will create no major problems.

[8]Apparently contradicting this account is a document indicating that DOE began assessing LTS data needs at Mound in 2000. A report of this assessment (DOE 2002e) was issued in April 2002, after the committee's visit.

[9]The current annual budget for cleanup at Mound is $90 million, according to the DOE-Ohio Office website, (http://www.ohio.doe.gov/site/sitememp.asp, accessed 11/27/02).

The parties involved would like to accelerate cleanup further (see DOE 2002d) through a covenant deferral request, which allows transfer of ownership of buildings before all required actions are completed, leaving the city to carry out demolition and cleanup activities through its own contractors. DOE would still pay for the work to be done. The city estimates that costs would be dramatically lower and timelines would be shorter because the city does not have the contract procurement requirements DOE has. U.S. EPA and some local residents expressed reservations about this approach at the time of the meeting, stating concerns that city contractors might not exercise the care required for work on the site.

At the time of the committee meeting, the MMCIC had a $50 thousand annual budget for long-term stewardship, which covers only the annual review and the report costs for parcels of land that have already been transferred to the MMCIC. DOE-Ohio at the same time had established a post-closure stewardship (PCS) working group that was looking at the possibility that in the future, an unauthorized person might remove contaminated soil from the site, contrary to the land-use restrictions envisioned for the site. The effort had started recently and was the first of MEMP's efforts to plan for long-term stewardship, aside from their efforts to encourage the MMCIC's success.

Fernald[10]

The Feed Materials Production Center (now the Fernald Environmental Management Project, FEMP) is located in a mostly rural area just beyond the suburbs of Cincinnati. The facility hosted a uranium refinery and foundry that produced high-purity uranium metal for the nuclear weapons complex. At its peak, the facility employed 3000 people; at the time of the committee meeting, FEMP had a workforce of 2500 (including subcontractors), most of whom also worked for the plant while it was active.[11]

The plant processed 227 thousand metric tons of uranium, and as much as 450 tons of that (0.2 percent) are estimated to have been released to the environment (Fluor Fernald 2001). Other contaminants on site include other constituents of radiological concern (thorium, radium, and technetium), inorganics (beryllium, cadmium, and lead), and organic compounds. Over 100 buildings that operated at the site are to have been demolished before the site is closed (see DOE 1996).

Like Mound, Fernald is a "closure site," on the same 2006 schedule for cleanup completion. Fernald, however, is on a path to become open space: all of the production-era buildings will be demolished, and the site will be a restricted-use parkland rather than a restricted-use industrial park. The future steward of the site has not yet been identified, and funding for LTS activities for the long term is still an unresolved issue. Memory of the site and the hazards it contains are expected to be preserved through a museum and education center, along with legal restrictions on land use.

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[10]Except where otherwise noted, the information in this section was gathered during the committee's meeting in Fernald, Ohio, on November 1, 2001.

[11]Site managers indicated that most of the attrition has been due to retirement, although mandatory attrition was foreseen.

Site characterization, remedy selection, and other planning at Fernald have proceeded with an unusually high degree of involvement by a citizens advisory board (FCAB). The FCAB was established in 1993 to answer four questions: future use of the site, how clean the remediation would make it, how to make use of onsite disposal, and the priorities to be followed (see Applegate 1998a). The FCAB published a blueprint for clean-up in 1995 that proposed answers to these questions, and recommended an engineering-based accelerated schedule that helped to set a pattern for the approach to be followed elsewhere in the DOE complex.

Cleanup levels at Fernald were established through CERCLA RODs: ground-water cleanup levels are based on U.S. EPA drinking water standards using maximum contaminant loads, and soil cleanup levels based on risks for people on undeveloped parkland onsite (10^{-6}) and for a resident farmer offsite (10^{-5}).[12] As at many sites, waste and environmental media contaminated above those levels (approximately 3100 cubic yards, a small portion of the waste by volume, but a high proportion by radiation hazard) are being shipped from Fernald for disposal at other sites, such as Envirocare and the Nevada Test Site, and wastes below those levels (mostly contaminated soil, but also some building materials) are being disposed of in an engineered cell on site (DOE 2001b). Citizens in the Fernald area view keeping some (lower-hazard) wastes onsite as a way of sharing the burden of Fernald with other communities, instead of simply imposing all of Fernald's wastes on others. Regulators and site contractors see removing high-hazard (but relatively low volume) wastes as a way to facilitate release of most of the site to low-intensity recreational use, while even the wastes remaining onsite pose an average hazard that would be modest in the event of containment failure. The ROD states that "The long-term effectiveness of the [on site disposal facility] would be ensured by federal ownership with access restrictions" (quoted in DOE 2001b). LTS was considered in decision-making for cleanup, but only implicitly. Federal ownership was regarded as the answer for long-term institutional and physical management—FCAB specifically insisted on permanent federal ownership of contaminated areas.

There is a major unresolved problem at Fernald, two above-ground silos containing radium-rich uranium ores.[13] The working assumption is that the silos and their contents will be removed during the cleanup process now underway, but uncertainties remain in developing a technically feasible method for doing so. It is accordingly unknown when the cleanup at Fernald will be achieved, despite the 2006 closure date. In other respects Fernald appeared to the committee to have put in place a sound cleanup strategy for its contamination and wastes.

In several other ways the Fernald staff inspired confidence. DOE and contractor staff responded to questions knowledgeably and candidly, sharing assumptions (such as the attempt to use empirically determined soil distribution coefficients for uranium in a conservative fashion) and admitting where more knowledge is needed. The committee found that many of the questions it asked had already been addressed or at least explored. In addition, DOE-EM's Office of Science and Technology was supporting new-technology development at Fernald, and the site has sought advice from acknowledged

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[12]A report by the Interstate Technology and Regulatory Council (ITRC) Radionuclides Team (ITRC 2002) describes the cleanup levels. A case study report by DOE (DOE 2001b) describes the considerations in the decision to create the onsite disposal facility.

[13]The silos also contain bentonite, which was added in 1991 as a diffusion barrier to reduce the amount of radon that accumulated in the headspace of the tanks.

experts. The Fernald plan also seems more comprehensive, thinking about how the site fits into the environment as the project aims to restore habitats that have been degraded by facility operations, including forest, pasture, stream, and wetland areas.

Site managers described one impediment to making progress on LTS: funds earmarked for cleanup could not be used for LTS planning, even if the cleanup goal requires LTS to follow. FCAB is now studying this problem and the FCAB has held community meetings to discuss it. The Fernald site is now actively working with stakeholders on an LTS plan.

The leading local activist group, Fernald Residents for Environmental Safety and Health (FRESH), was organized when people living next to the Feed Materials plant discovered that their water and land were contaminated, but that DOE had never disclosed the hazards. FRESH sued DOE in 1984 over environmental contamination, launching the process that has become the site cleanup. FRESH and the citizens advisory board (which includes FRESH members) are active, engaged, and knowledgeable, but it remains unclear how to sustain these organizations once the site is "closed." During the committee's meeting with the FCAB and other interested citizens, participants raised concerns that DOE will use LTS as an alternative to fulfilling commitments on cleanup.

Overall observations from the visits

If remediation succeeds, both Fernald and Mound seem to present low environmental risks even if their projected LTS activities fail (assuming that the silo wastes are relocated and properly disposed of), although this is just an impression since assessments of failure scenarios have not been carried out. Further, reaching the remediation goals at either site is far from certain: each site faces substantial challenges and unresolved issues (including the silos and uranium pump-and-treat system at Fernald, and the T Building and DNAPLs at Mound). The committee also doubts the stability and sustainability of LTS under the industrial-reuse scenario at Mound, particularly as one looks beyond the near term.

At both sites, a measure of trust has developed among the local public, site contractors, state EPA, regional EPA, and DOE in Ohio. All parties mentioned good working relationships, within which conflicts can be aired and addressed. The relationship between the local environmental watchdog group at Mound, MESH, and contractors and DOE Ohio is unusually amicable, compared to other DOE sites,[14] based on individual committee members' experience at other sites. This trust did not appear to extend to DOE HQ and budget makers, which were both regarded with greater suspicion by several participants in the meeting.

Engineering analyses at Fernald seemed to be of high caliber and work on habitat development at the site is remarkable if only for the fact that ecology is being addressed at all. The technological innovations the committee heard about (new instrumentation for monitoring the onsite disposal facility, sponsored by DOE/EM's Office

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[14]Sharon Cowdrey, chairwoman of MESH, said at the meeting "There were no villains here. Not even the site. We never saw it that way."

of Science and Technology) indicate that the site is seeking better technical solutions and engaging the research community. The approach at Mound was to emphasize existing technologies and to avoid the need for technological innovation in cleanup. The process of releasing buildings for reuse one by one at Mound seemed to encourage managers to make do with the information and tools already available.

In its report on the Moab Site, the committee tried to encourage a more inquisitive approach to understanding problems at the site. In this respect, the committee saw activities at Fernald as more promising than those at Mound. Fernald's work with outside experts and research programs might be a factor in (or possibly a result of) the higher quality of its technical work and its awareness of issues beyond cleanup and engineering.