End-State Land Uses, Sustainably Protective Systems, and Risk Management: A Challenge for Remediation and Multigenerational Stewardship

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This article discusses creating a sustainably protective engineered and human management system in perpetuity for sites with long-lived radiological and chemical hazards. This is essential at this time because the federal government is evaluating its property as assets and attempting to reduce its holdings, while seeking to assure that health and ecosystems are not put at risk. To assist those who have a stake in the remediation, management, and stewardship of these and analogous privately owned sites, this article discusses current end-state planning by reviewing the federal government's accelerated efforts to reduce its footprint and how those efforts relate to sustainability. The article also provides a list of questions organized around six elements of risk management and primary, secondary, and tertiary disease and injury prevention. Throughout the article, the U.S. Department of Energy (DOE) is used as an example of an organization that seeks to reduce its footprint, manage its budget, and be a steward of the sites that it is responsible for. However, the approach and questions are appropriate for land controlled by the Department of Defense (DOD), the General Services Administration (GSA), and other public and private owners of sites with residual contamination. © 2005 Wiley Periodicals, Inc.

INTRODUCTION

There is a widely held expectation supported by some laws and precedents that federal agencies such as the Department of Energy (DOE) and Department of Defense (DOD), just like other government and private organizations, will not leave materials on site that will endanger people and ecosystems. One way of meeting that expectation is to choose a future land use that minimizes exposure. But a conservative land-use plan surrounded by a buffer zone may not be appropriate at many sites where the contaminated land is otherwise a valuable asset. Whatever the land-use choices, the responsible organization needs an unambiguous mechanism that ties its land-use choices to risk through a sustainably protective system that can be operated as long as it is needed, in perpetuity if necessary. Such a sustainable plan rests on a sound remediation and monitoring program and then requires both engineered systems and human operations.

A sustainable system is particularly critical during a period when the current owners and managers of federal government property are evaluating all federal properties as assets and where in some case they are shrinking their footprint by turning over, easing, and selling sites to other federal agencies, states, local governments, and private organizations (Baxa, 2004; Bush, 2004).

Published online in Wiley Interscience (www.interscience.wiley.com). DOI: 10.1002/rem.20072

The goal of efficient asset management is challenging at sites where contamination by long-lived radiological and chemical agents is a legacy (Burger et al., 2003b, 2004). At these sites, it is incumbent on site managers; natural resource damage committees; other federal, state, and local government officials; and other stakeholders to understand the risk implications while assessing these assets, whether it leads to reducing the footprint, or, alternatively, to keeping the land but optimizing/modifying its potential uses, or plans for its management (for example, considering different remediation approaches).

Future land use depends not only on the desires and needs of individuals and communities, but on the residual risks that might result from past uses of the land.

With asset management as context, the objectives of this article are (1) to define and discuss the relationship between end-state land uses; sustainably protective engineered and human systems; and human and ecological risk at locations where multigenerational stewardship is anticipated and (2) to offer a self-assessment list of questions to assist stewards as they consider what is needed to sustain an end-state environment that includes residual hazards.

The article is divided into three parts. It begins by defining end state, sustainability, and risk. Then, the second part provides context for current end-state planning by reviewing the federal government's accelerated efforts to reduce its footprint and how those efforts relate to the sustainable communities movement. The third part of the article provides a list of questions organized around six elements of risk management and primary, secondary, and tertiary disease and injury prevention. Throughout the article, we use DOE as an example of an organization that seeks to reduce its footprint, manage its budget, and be a steward of the sites that it is responsible for. However, our approach and the questions are appropriate for land controlled by DOD, General Services Administration (GSA), and other public and private owners of sites with residual contamination. The list of questions can guide any agency in determining whether the transition to an end state has matured to the point where sustainability is likely. It identifies the many components that should be addressed and their site-specific relevance. The questions are ordered according to the six stages of risk described later.

END-STATE LAND USES, SUSTAINABLY PROTECTIVE SYSTEMS, AND RISK

Future land use depends not only on the desires and needs of individuals and communities, but on the residual risks that might result from past uses of the land. Notably, some lands with chemical or radiological contamination have not been, or cannot be, cleaned up to residential standards with present-day technology and/or within reasonable cost parameters. This leaves public policy makers, managers, and the public with land whose uses must be related to residual contamination, and with the need for extensive risk analyses for both human and eco-receptors. The risk analysis and land-use literatures are voluminous and largely independent of one other. But it is essential for them to be connected when future land use is influenced by residual hazards on the massive scale found at many DOE and DOD and some private sites. We believe that lands with such knotty legacies should not be transferred without a sustainably protective risk management system in place. The greater the hazard and the longer it will last, the more critical this need. In this section, we review the concepts of end states, sustainability, and risk. These reviews are not meant to be exhaustive. Rather, they highlight those elements of each concept that intersect and illuminate our problem.

Remediation DOI: 10.1002.rem

End-State Land Uses

In the U.S. context, the expression "end-state land uses" is virtually an oxymoron. "End-state" conjures up an image of a use in perpetuity, or at least for many generations. Contrary to the image of a petrified end use, thousands of land-use changes take place every day as businesses open and close; people move; green space is converted to shopping malls and new houses; farms are closed and slowly become forests, grasslands, and other ecological uses again; and brownfield sites are remediated and redeveloped. The norm in the United States and elsewhere is a "temporary" state, not an "end" state. Even land uses that we imagine to be neighborhood fixtures, such as churches, schools, and cemeteries, cannot be expected to last in perpetuity, although they usually survive generations. A viable church or neighborhood school built in the early twentieth century may now be a restaurant or housing. Locations that are too remote to be altered by human activity, such as an inaccessible mountain range, have a good chance of remaining in the same uses in the distant future. Yet we know that even these lands are not inviolate because many current oil fields, mines, and off-road vehicle recreation areas once were inaccessible or protected open space.

Local zoning ordinances, if they exist, are intended to capture the currently envisaged end or planned state. But U.S. cities are full of high-rise buildings whose zoning rules only permitted single-family homes. The zoning ordinance should be regarded as the local government's very initial determination, one that is subject to change through negotiation, variances, and legal challenge. Covenants, conditions, and restrictions (CC&Rs) are more likely to last. The builder/owner indicates what can and cannot be done on a site. But many CC&Rs failed because their authors failed to specify in perpetuity in the legal document, and courts have ruled that the next owner need not follow the restriction unless it was stated in perpetuity. So, for example, if we sold part of a farm with the CC&Rs that it could not be turned into a manufacturing facility, the buyer would be precluded from producing gadgets on the site. But if we did not say "in perpetuity," the courts would likely declare that the next buyer could produce gadgets on the site. Also, CC&Rs may not be permanent end states because they violate other moral or legal principles. For example, racial covenants were declared invalid in 1948 in a famous Supreme Court case (*Shelley* v. *Kraemer*, 334 US 1, 1948). CC&Rs can be used as sustainable institutional policy tools to support an end state at DOE, DOD, and other sites with substantial residual hazards.

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In spite of the reality that the United States is a country of temporary land uses, with some exceptions of some lands held by government or well-established religious and educational institutions, the idea of permanent or at least a multigenerational end state makes perfect sense where the nation makes a decision that it wants to memorialize something of particular importance to its history or freeze a particular set of natural wonders or treasures—and, alternatively, when it needs to maintain enduring public safety protections, as when high-level waste is stored, where land contains buried unexploded ordinance, or where soil and aquifer contamination and other hazards make it too dangerous to allow the kind of land-use changes that normally occur in the United States. Following the precautionary principle, a decision to specify an obvious protective low-risk end state for land contaminated with nuclear and chemical wastes is to exclude all unnecessary personnel, leaving land fallow to pursue its own ecologic destiny while providing ecological services such as aquifer recharge (Burger et al., 2003a, 2003b, 2004). A less restrictive end state is low-intensity ecological uses that include research, hunting, fishing, camping, or some combination of these on parts of sites. A low-intensity ecological end state makes sense when the owner wants to limit access to the site because of concerns about human exposure, fear of ecological damage caused by human access and/or by remediation, and because of the value of the land to the local people and the nation in its current form. A low-intensity use ecological end state also means that the land could be taken back for more intensive federal government use if the need arises.

As noted earlier, the national government, however, has made it abundantly clear that as a general matter it wants to treat all of its properties as assets and typically shrink its footprint. DOE's efforts, DOD's Base Realignment and Closure (BRAC) program, and the GSA's efforts are intended to give, lease, or sell land to private or public owners. Some of the land transfers would be for open space with limited human access. But others surely would be for unrestricted public access open space, factories, warehouses, research facilities, homes, schools, and community facilities. If the federal government relinquishes control of land, then it is imperative that the transfer be done with a clear understanding of what hazards exist and an implementable plan for maintaining management of any residual hazards so that the chance of public exposure is negligible. Not to do so would substantially undermine the public's trust in the federal government and lead to legal action and political consequences. The issue is particularly salient for DOE sites because there is a long history of mistrust of DOE, exacerbated by public fear of nuclear materials. If the federal government wants to use any of these lands for new energy-related missions, we believe that it is imperative that a plan exist and be implemented for sustaining protective engineered and institutional mechanisms, and that this program be backed by a financial commitment.

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Sustainably Protective Systems

The concept of sustainability is broad, subject to many different understandings and interpretations. Before defining what it means in the present context (DOE and other federal agency land and public health protection), we summarize some of these interpretations. Kidd (1992) finds the idea of sustainability in the following literatures: (1) the ecological or carrying capacity, (2) critique of technology, (3) environment or natural resources management, (4) eco-development, and (5) biosphere. Brown et al. (1987) finds the idea of sustainability applied to carrying capacity, agriculture, energy, economy, cities, and biological resource use.

Each of these literatures and applications shares four ideas. They have a common root in the idea of ecological carrying capacity and typically are Malthusian or neo-Malthusian insofar as they assert that current world economic policies are unsustainable and need to be changed or altered. Second, these literatures make it clear that sustainability means a long-term effort requiring thinking, planning, execution, monitoring, and readjustment. In other words, none suggests that sustainability is a short-term fix or something typically accomplished when done once. The third common element is that, with a few exceptions, the concept of sustainability is more about the search for a balance between ecological systems and economic development than it is antigrowth. The fourth commonality among these literatures is that, at least in a democracy, local public involvement is understood to be essential in achieving sustainability or indeed of being able to continue or maintain a project over any even modest time frame. There is a clear recognition that local government and local people support or conscious acquiescence are essential to assure sustainability.

 Remediation DOI: 10.1002.rem

The concepts of sustainable development have been in the literature for decades but gained international attention less than two decades ago when a United Nations commission issued a report titled "Our Common Future." This so-called Brundtland report (named after the commission chair, the former Norwegian Prime Minister Gro Harlem Brundtland) defined development as "meet[ing] the needs of the present without compromising the ability of the future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 8). What is particularly notable in this definition is the explicit emphasis on future generations.

The definition that comes closest to signaling the task faced by DOE and other federal agencies that house the legacy of weapons and waste is Robinson et al.'s suggestion that sustainability requires "persistence over an apparently indefinite future of certain necessary and desired characteristics of the sociopolitical systems and its natural environment" (Robinson et al., 1990, p. 39). This is a daunting challenge for any federal agency that functions with annual budget appropriations.

Risk

In order to tailor a sustainably protective program to land-use choices, we must understand the risks associated with the hazards in the context of the plausible land uses. For purposes of organizing our questions, we have divided risk into six sequential elements. Risk is a function of (1) the toxicity and amount of the hazardous substance present; (2) containment of the substance; (3) known and potential dispersal, if containment was breached and the substance was bioavailable; (4) human and ecological populations exposed in the event the hazard escaped containment; (5) dose to and response of public and ecosystems exposed; and (6) response of authorities to the immediate event and the long-term threat.

An information list is a written diagnostic tool to be used like a thermometer that measures temperature, or a colonoscopy that surveys the health of the intestine. In this case, the public health objective is to put a sustainable system in place that will protectively manage risk for the selected end state. Continuing with the public health analogy, we have divided the questions under each of the six risk categories into primary, secondary, and tertiary equivalents of public health prevention options (see Exhibit 1 for a visual depiction). By "primary" prevention, we mean that human and technical resources are available to update engineered systems and worker operations to prevent contaminant leakage or, if a leak occurs, to provide engineered systems to control and/or neutralize the hazard. "Secondary" prevention means the anticipation, recognition, evaluation, and control of a problem as soon as possible before it can lead to human health impacts and system damage. In the DOE case, this means regular inspection of containment barriers; continuous on-site and regular off-site air, groundwater, and ecological monitoring; modeling of failure scenarios and known fugitive contaminants; and regular system maintenance and operator training. "Tertiary" prevention means repairing damaged containment systems, the response of federal, state, and local public and environmental health agencies, changing land uses (which may include evacuation), and the medical and psychological treatment and compensation of residents and communities. As the gears in Exhibit 1 suggest, the three levels of prevention intersect with one another in critically important ways. A failure to build and maintain any one properly can cause the system to fail.

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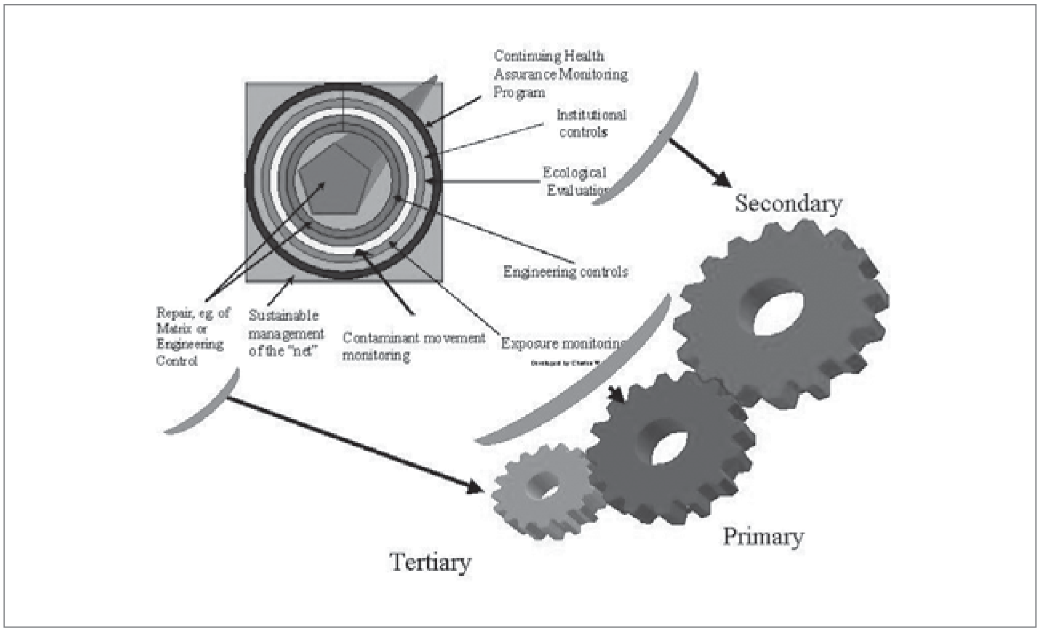

Exhibit 1. Primary, secondary, and tertiary elements of a sustainably protective system

MANAGING THE ASSETS AND PLAUSIBLE END STATES: IMMEDIATE CONTEXT FOR THE NEED TO PROVIDE A SUSTAINABLY PROTECTIVE SYSTEM

Federal departments and agencies are under pressure to more efficiently manage their land. The government's major reasons for shrinking the footprint include (1) reducing liability, (2) improving operational efficiency, and (3) eliminating sites with inefficient technologies. Briefly, after the Second World War, the federal government began to reduce its physical footprint by turning land over to local, state, and private organizations (Montgomery, 2003). During the last 15 years, the GSA (2003) reported that $3 billion worth of federal property left the inventory. Beginning in 1988, 115 military bases were closed and over a half-million acres were turned over (Government Accountability Office [GAO], 2002; Hansen, 2004; Sorenson, 1998). But while the Army and Air Force are most commonly associated with facility closure, the Coast Guard and other federal units have also initiated analyses of their facility performance, with the goals of increasing efficiency and shrinking their footprint (Dembeck, 2002; Fahrenthold, 2004; Hammond & Dempsey, 2002; Silva, 2000).

The process of asset management and shrinking the footprint appears to be accelerating. For example, the U.S. Congress approved another round of military base closures to commence in 2005 that could close a fourth of all bases (Public Law 107-107, the Defense Authorization Act of 2002) (GAO, 2004). DOD would need to divest itself of approximately 1.25 million of its 5-million-acre inventory (GAO, 2004).

On February 4, 2004, President George W. Bush issued Executive Order 13327 that requires federal agencies to examine their properties as assets and develop plans to shrink their footprint, as appropriate (Baxa, 2004). The order applies to over 650 million acres of federal property (including DOD and DOE land).

 Remediation DOI: 10.1002.rem

The pressure to shrink the footprint is constrained by the marketplace, location, and land-use constraints, such as CC&R's, as described earlier. We believe that the federal government's objectives will increasingly confront growing public interest in surrounding land uses and the growing sustainable communities movement in the United States (Greenberg et al., 2005; Portney, 2003; Roseland, 1998). With regard to public concerns at DOE sites, public surveys are a good initial tool for assessing what residents would like and not like to see on these sites. For example, Burger (2004) asked residents living near the Savannah River, the Idaho National Engineering and Environmental Laboratory (INEEL), Los Alamos, and Brookhaven sites for their future land-use preferences. The clear preference at all four sites was for environmental research park, outdoor activities such as hiking, bird watching, hunting, camping, and fishing. More intensive uses such as cattle grazing and growing of crops were less desirable to respondents, and the building of factories and housing was the least desired.

These findings are consistent with surveys of brownfield redevelopment in urban areas that show that residents want recreation and community facilities on remediated sites (Greenberg & Lewis, 2000), even though the original concept behind brownfield redevelopment was to replace lost production jobs with other jobs. Furthermore, contrary to the assertion that no one would want to live on a former brownfield site, a New Jersey survey (Greenberg et al., 2001) found that 14 percent of respondents were both planning to move during the next five years and would be willing to live in housing on top of cleaned-up brownfield sites. In other words, community preferences for future use need to be determined rather than assumed and, when measured, they appear to favor open space, recreation, and community facilities rather than commercial uses.

Whatever public preference exists is important to know, but there is unlikely to be a public referendum on end-state land uses. The history of redevelopment in the United States is one in which elected officials and developers with a record of placing pecuniary interest above public preference have driven land-use decisions (Jonas & Wilson, 1999). Until about a decade ago, we would have assumed that more intensive industrial, commercial, and residential land uses would be the choices of local officials and their development supporters. But the growing sustainable communities movement has changed that prediction. In essence, many local governments have become wary of accepting federal land because of the stigma associated with contamination at many sites and a fear that manufacturing facilities lured to these sites have no loyalty to the communities that host them. If they want commercial uses, they will want the federal government to be responsible for cleanup and to accept liability. Increasingly, local governments would rather invest their limited resources in new schools, housing, amenities, and other sustainable local attributes rather than use government land to recruit and retain a large business.

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The sustainable communities movement has not taken hold in every jurisdiction, especially in more rural areas where the bulk of DOE's and DOD's waste legacy sites are found. For instance, local community reuse organizations formed by DOE in large weapon site regions have focused mostly on attracting industrial uses to re-employ downsized DOE site workers. Nevertheless, the overall trend suggests to us that DOE and DOD are likely to face local political and community opposition to an end-state plan to give surplus land to government and sell surplus land for private uses unless there is a clear agreement about permissible end states and there is a workable protective sustainability plan in operation with funds to support it in the future. Even with a sustainably protective plan in hand, we believe that the sustainable communities movement implies that industrial and commercial land-use end states will become less preferred than previously. They may be the choice, along with housing, for small particularly suitable parts of larger lands, especially if there is proof that there is no residual contamination on them. The norm we expect is low-intensity open space. Furthermore, we fully expect some local governments and private developers to request retrospective perpetuity at these sites—that is, request that the federal government return current land uses to open space and levels of contamination to predevelopment levels, and then to lock these in through CC&Rs. Clearly, ironically, such a request potentially implies destruction of existing ecosystems if large areas are disturbed to remove contamination.

> . . .we fully expect some local governments and private developers to request retrospective perpetuity at these sites. . .

LIST OF QUESTIONS

As noted earlier, we have divided the questions presented in Exhibit 2 into six sequential risk categories and into questions that are analogous to primary, secondary, and tertiary equivalents of public health prevention options. This list of questions is not meant to be exhaustive or prescriptive. It is meant to suggest broad categories of a sustainably protective system that should be considered for each site. Not every question is important at every site. The list contains 60 primary sets of questions, and these contain 203 questions. Furthermore, some questions are generic to all six risk stages, so that they are duplicated or only slightly changed at each.

Space does not permit a discussion of every question. Instead, we briefly review the first set of two questions under the risk category "Toxicity and Amount of the Hazardous Substance Present." The first two sets of questions ask about primary prevention information and personnel associated with this first stage of risk consideration.

> 1.1. What information is available about known hazards, about multiple chemical hazards, and about potential exposure pathways (direct contact, soil, surface and groundwater, air) to on-site hazards? When were the data last updated? How is the information processed, stored, and made available to those who need it? Is it in electronic forms? Is it on maps and/or in conceptual site models (CSMs)? How often is the information and equipment updated?
>
> 1.2. Who is responsible for the data? Whom do they report to? What is their academic background? How much training do they have and how often do they go for additional training?

If the site does not have the data to easily answer these two sets of questions, it suggests that developing a sustainably protective plan will be a major effort. If it has the answers but the data are not updated frequently and the personnel are not trained or familiar with the latest databases, then a good deal of work is needed. If it cannot immediately send the data to key personnel, another level of work is suggested.

The next set of "Toxicity and Amount of the Hazardous Substance Present" questions probe at the site's ability to inspect and monitor changes, or secondary prevention. The third, or tertiary, questions ask about the site's capacity to respond to problems that it identifies during its prevention efforts. If problems are found and cannot be quickly channeled to managers with resources, then the plan will not be sustainable.

SUMMARY AND IMPLICATIONS

It is recognized that the 203 questions pose a major challenge to site managers, to remediation teams, and to other interested parties working in the current context. They must

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1. Toxicity and Amount of Hazardous Substance Present

1.1. What information is available about known hazards, about multiple chemical hazards, and about potential exposure pathways (direct contact, soil, surface and groundwater, air) to on-site hazards? When were the data last updated? How is the information processed, stored, and made available? Is it in electronic forms? Is it on maps and/or in conceptual site models (CSMs)? How often is the information and equipment updated?

1.2. Who is responsible for the data? Whom do they report to? What is their academic background? How much training do they have and how often do they go for additional training?

1.3. What are the contaminants of greatest concern on the site? What kinds of human and/or ecological biomarkers are available for assessing and monitoring human and ecological exposure and risk associated with these contaminants? How does the site keep track of legal and administrative changes that affect the legal classification of these contaminants?

1.4. How does the site keep track of the amount of hazardous material that is added and lost because of chemical, physical, and biological changes and destruction? How often is this done?

1.5. How does the site assess how changes in the amount and type of hazardous material affect the sustainability of the end state? How is new scientific information relative to the toxicity of site contaminants reevaluated in light of existing exposure pathways and end-state land uses? Is this done even if the legal rules for what is defined as a hazard do not change?

1.6. What formal and informal processes are used to bring important information about toxicity and amount of hazardous materials to the attention of the site leadership and resolve issues? How much discretionary authority and budgetary resources does the site leadership have to resolve problems that are identified?

1.7. What interactions occur between regulatory bodies responsible for environmental health regulations and on-site management about these hazards? At what level in the organizations do these interactions occur?

2. Containment of Substance

2.1. What exposure pathways are assigned the highest priority for containment? What data are available about the containment of these hazards and pathways and other on-site hazards? How redundant are the information systems? How is the information processed, stored, and made available to those who need it? Is it in electronic forms? Is it on maps and/or in CSMs? How often is the equipment and information base routinely updated?

2.2. What studies have been done about the likelihood of conditions that could produce a leak or a major failure, such as an earthquake, fires, flooding, terrorism, and the like? How often are these repeated? Under what circumstances?

2.3. What data are available about the monitoring and surveillance systems used to make sure that the containment systems are operating within defined or allowable limits? Are there automated alarm systems? How frequently are they maintained? How is the information processed, stored, and made available to those who need it? Is it in electronic forms? Is it on maps and/or in CSMs? How often is the equipment tested and replaced?

2.4. What personnel are responsible for the data in support of points 2.1–2.3? How much training do they have and how often do they go for additional training?

2.5. How often are the areas surrounding the containments and monitoring systems patrolled to prevent intrusions by wind, water, other forms of erosion, and animals?

2.6. Who is responsible for keeping track of legal changes that affect the suitability of the containments? How, how often, and to whom do they report their observations?

2.7. Who is responsible for keeping track of the amount of hazardous material that is added and lost in each containment system because of decay and destruction? How, how often, and to whom do they report their observations?

2.8. Who is responsible for assessing how changes in the amount and type of hazardous material affects the sustainability of containments that support the end state?

2.9. What process(es) are used to bring this information to the attention of the site leadership and resolve issues? How often does site leadership get a report and engage in a discussion of the status of containment, detection systems, inspections, maintenance, and repairs to key parts of the engineering systems?

2.10. When a site is remediated and structures above and below ground are removed, what precautions are taken to alert workers to the location of containments? Are there signs? Training? Are workers accompanied by someone who knows precisely where contained materials are located? Are certain excavation and removal practices not allowed? In the event of infrastructure maintenance or expansion, is there a system for ascertaining that the integrity of controls will not be compromised?

(*continued*)

Exhibit 2. List of questions for a sustainably protective system

(*continued*)

2.11. How will pathways and containment priorities change under alternative plausible end states? How will site management, natural resource trustees, and other key stakeholders be engaged about possible shifts in containment priorities? How do you assure the end-state land uses that are protective under current conditions will remain so? Will the site consider prohibitions of some land uses?

2.12. Is there a stakeholder/citizen advisory or oversight committee responsible for reviewing and influencing policy on shifts in containment priorities?

3. Potential Dispersal, if Containment Is Breached

3.1. What data are available about soils, geology, surface and aquifer systems, micro-organisms, vegetation, fish, birds, mammals, and other species that could disperse or chemically modify leaking materials? Is there a physical monitoring system in place? How are these data processed, stored, and made available to those who need it? Is the information in electronic forms? Is it on maps and/or in CSMs? How often is the equipment and information base updated?

3.2. What mathematical models are used to study transport of materials from the site? Are these state-of-the-art? How often are they tested? Are they used to develop containment after dispersal scenarios? Are there dispersal models that take into account sensitive species or ecosystems should containment be breached? Do these allow testing of exposure pathways associated with different end states?

3.3. Who is responsible for the baseline data? How much training do they have and how often do they go for additional training? Who is responsible for monitoring food-chain relationships for changes in dispersal of contaminants following potential dispersal?

3.4. Who is responsible for keeping track of on-site physical changes that could affect the dispersal of the hazard?

3.5. What process(es) are used to bring this information to the attention of the site leadership, natural resource trustees, and other key stakeholders, and to resolve issues?

3.6. Are there restrictions in place on groundwater use on and off site as a result of analyses of risk? Who enforces them? Is the state or the US EPA responsible for enforcement? How are local government officials and/or developers kept abreast of these restrictions?

3.7. Is there a stakeholder/citizen advisory or oversight committee responsible for reviewing and influencing policy on the implications of failed containment?

4. Human and Ecological Populations Exposed

On-Site Human

4.1. What information is collected about where DOE and contractor employees are working? Is there a personnel tracking system or database? Who is responsible for these data? How is it funded? How much training is provided to these workers regarding what to do if containment is breached? How is this training evaluated?

4.2. If an incident occurs (e.g., a breach or a leak), how are workers and nearby residents informed? How are natural resource trustees informed? Who is assigned these tasks? What technologies are used? How often are these processes tested?

4.3. What information is collected about where hunters, fishermen, and other recreational users are? What do they catch? What limits are attached to their access and use of the site? How are these enforced? Are advisories needed? If so, are they in place? Who is responsible for communicating and revising advisories? How are resource managers involved and kept abreast about changes in site access and limits on access?

4.4. What processes are in place to alert on-site officials about containment failures or hazard migration that jeopardizes sensitive on-site cultural attributes?

4.5. What data are collected, reviewed, and mapped about on-site areas that may be used for housing, commercial and industrial, school, nursing home, and recreational facilities? Likewise, what data are collected about road, rail, sewer, water, and other infrastructure on the site? Who has data and communicates about any negative-use easements or restrictions that govern nonpossessory easements?

4.6. Has the site performed a Geographic Information System (GIS)-based build-out of the site based on alternative on-site end states? Who is responsible for determining if these build-out scenarios are consistent with the sustainability plan? What modeling systems are available for exploring the impact of end states on the sequence of exposure through exposure pathways? How is the potential interaction of different hazards and pathways taken into account in these analyses?

4.7. What process is in place to contest proposed site actions that might jeopardize the ability to protect humans and the environment from exposure—that is, to provide a sustainable, safe end state? What formal and informal channels exist for these purposes? How often do they meet? Rehearse events? Problem-solve and other forms of lessons learned? Are there rules or guidelines based on human and ecological health that would be used to deny an end state?

(*continued*)

Exhibit 2. List of questions for a sustainably protective system (*continued*)

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(*continued*)

Off-Site Human
4.8. What data are collected, reviewed, and mapped about off-site areas, such as housing, commercial and industrial, school, nursing home, and recreational facilities? Are there population subgroups that are especially susceptible to contaminant releases because of their physiological characteristics or activity patterns? What data are collected about these groups? Likewise, what data are collected about road, rail, sewer, water, and other infrastructure? What information is collected about zoning, covenants, conditions, restrictions, nonpossessory easements, wildlife p-reservation areas, and other information that could affect an on-site sustainability plan and process? What forms are the data available in?
4.9. Whom are these data shared and discussed with? Are they shared with local and state governments, special jurisdictions such as school systems, sewer and water districts, and natural resource trustees? What process is in place to update the data as a method of keeping track of off-site population growth? What relationships exist between site and federal, state, and local public agencies charged with emergency response and surveillance of injury and illness?
4.10. Who on site is responsible for monitoring and reporting actions that could increase the off-site population at risk beyond what is anticipated in the end-state and sustainability plans?
4.11. What process is in place to contest proposed actions off site that might jeopardize the ability to provide a sustainable safe end state on site? What formal and informal channels exist for these purposes? How often do they meet? Rehearse events? Problem-solve and other forms of lessons learned? Has the site considered arguing for prohibitions of certain off-site land uses and activities? For changes in off-site zoning and for deed restrictions and other institutional restrictions that would limit the potential for a hazardous pathway being built between on-site facilities and off-site land uses and activities?
4.12.What communications exist to alert jurisdictions to a failure of the sustainable system? How often are they tested?
4.13. Is there a stakeholder/citizen advisory or oversight committee responsible for reviewing and influencing policy on screening human risk, land use, and other changes that might impact human risk?

On- and Off-Site Ecological Resources and Ecosystems
4.14. What information has been collected about on-site ecological systems? How is the information processed, stored, and made available to those who need it? Is it in electronic forms? Is it on maps and/or in CSMs? How often is the equipment and information base routinely updated?
4.15. How often are changes in the status of key indicator organisms monitored? Is there biodiversity monitoring?
4.16. Who on site is responsible for monitoring and reporting actions that could jeopardize important ecological systems, affect biodiversity, or impact threatened species on and off the site that are part of the end-state and sustainability plans?
4.17. What modeling of on-site containments, fate, and transport has been conducted to prove a temporal pattern of potential risks to on- and off-site ecosystems? Who is responsible for that modeling and transmitting the results to key stakeholders, including site managers and natural resource trustees?
4.18. Is there a vision for sustainable habitats, biodiversity, and ecosystems? Who is responsible for assessing and monitoring and reporting on these? Who has the authority to evaluate, recommend, and implement management actions relevant to sustainability?
4.19. What process is in place to contest proposed actions on and off the site that might jeopardize the ability to provide a sustainable safe site for ecological systems? What formal and informal channels exist for these purposes? Who is responsible for providing key data about this to resource managers, natural resource trustees, and other important stakeholders?
4.20. Is there a stakeholder/citizen advisory or oversight committee responsible for reviewing and influencing policy on screening ecological risk, land use, and other changes that might impact human exposure? How are they informed about these issues?

5. Dose to and Response of Public and Ecosystems
5.1. What data exists about fate, transport, and toxic effects of these substances to humans if they escape containment?
5.2. What data exists about fate, transport, and toxic effects of these substances to ecosystems and to individual populations and species if they escape containment? What models exist to better understand dose and response? How do the models incorporate temporal and spatial changes in the distribution of workers, on-site guests, the off-site public, and ecosystems? Are these models multimedia and multihazard?
5.3. Whom are these data shared and discussed with? Are they shared with local and state governments, special jurisdictions such as school systems, and sewer and water districts? Are they shared with federal, state, and local agencies, and with natural resource trustees?
5.4. What site-specific or other research is being conducted to increase our knowledge of food-chain effects, particularly relating to containment failures?

(*continued*)

Exhibit 2. List of questions for a sustainably protective system (*continued*)

(*continued*)

5.5. What research is being conducted to increase our knowledge of the impacts of location near prominent hazards on sensitive species?

5.6. What research is being conducted to increase our knowledge of dose and response and what process is in place to update the data as a method of keeping track of off-site population growth and land-use change?

5.7. Is there a stakeholder/citizen advisory or oversight committee responsible for reviewing and influencing policy on land use and other changes that might impact human and ecological dose and response? How are they informed about these issues?

6. Authorities' Response to the Immediate Event and the Long-Term Threat

6.1. What funds exist to support the sustainable end state? What is the form of those funds? (Annual set-aside, bonds, etc.?) Who governs the size of the resources? Who controls and manages the funds? What guarantees exist that the source of funds will not be removed? Specifically, what funds support primary, secondary, and tertiary prevention as described? What role do the responsible on-site parties have in this resource allocation? How is the budget issue transmitted to the state and local authorities?

6.2. What funds are set aside for updating the on-site land uses, the land-use plan, and the sustainability plan and coordinating these with risk considerations? What is the funding mechanism for this? Is it permanent? Does it increase over time?

6.3. What communication devices and educational programs exist to keep the public and key officials attuned to the need for vigilance about the site? How often do meetings and exercises occur and how often is literature distributed? What has been the experience with these outreach efforts?

6.4. Does the site have a natural resource damage group? Has it produced reports estimating damage? Has the site been sued for damaging natural resources? How is this information made available to site leadership? What procedures are in place to provide additional data on sensitive species or populations that are near hazardous substances that might be adversely impacted by failures and migration of contaminants?

6.5. Are there affirmative covenants in place on the site that requires signage be constructed and maintained, that a fence or other barriers be constructed and maintained? How is this enforced? Has the state adopted the Uniform Environmental Covenants Act (UECA), which was published in August 2003? If not, what is the status of the state in question with regard to the UECA? Has there been discussion between site, state, and local officials about how the UECA might be used to control off-site activities that might threaten the on-site end-state sustainability plan?

6.6. What personnel and funds are available to respond to a major or minor system failure? How rapidly can these be marshaled? Who is responsible for maintaining the readiness of response teams? How much money is available to compensate on- and off-site victims of exposure? Will this be sufficient if the off-site population and land use substantially increase?

6.7. Who on site is responsible for making the decision that containment failures require action? Who controls the funding and prioritization should failures occur? What federal, state, and local government regulations govern the cleanup of a breach in the system? In the use of personnel and funds to contain a problem? Who is responsible for this information? How often is it updated? Who receives it?

Exhibit 2. List of questions for a sustainably protective system (*continued*)

plan and implement mechanisms that require that containments and monitoring systems be inspected, maintained, fixed, and updated. Equally important, information about the end state, the risk, and the sustainable systems must be made available to future generations in a variety of forms. The sustainable system must persist despite the likelihood of natural events, wars, and economic crises that could reduce national, state, and perhaps even local interest in the system. Hence, the expectation is integrally linked to insistence on an unambiguous commitment of funds to support the sustainable system.

The challenge does not stop with answers to these questions in the current context. Most of the "who is responsible" questions that are listed in Exhibit 2 surely will not have the same answer in a postconstruction or postclosure time frame as they do now. The transition from operations to in-remediation precautions and to long-term stewardship will surely require different organizational and system characteristics. At these and various other times in the foreseeable future, site management will need to re-examine its organizational structure and resources to determine if the appropriate people and resources have been assigned to these six stages of risk and to primary, secondary, and tertiary prevention.

 Remediation DOI: 10.1002.rem

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 Remediation DOI: 10.1002.rem

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 Remediation DOI: 10.1002.rem