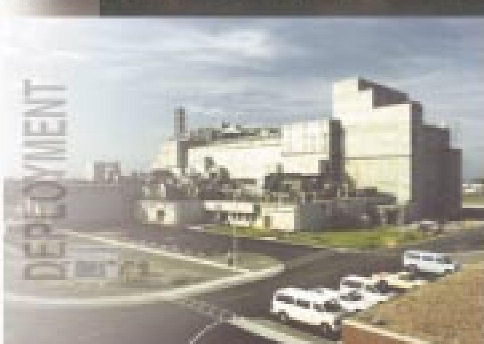
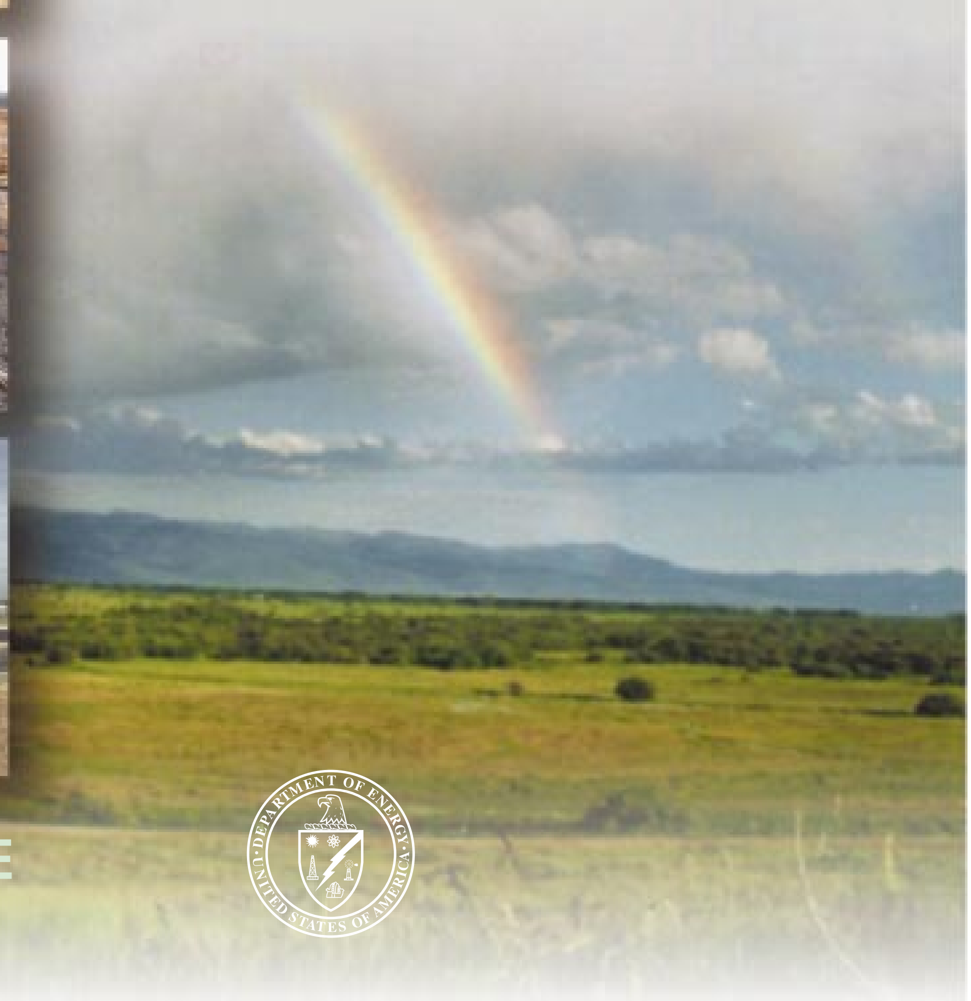


Environmental Management Research and Development Program Plan

Solution-Based Investments in Science and Technology

November 1998



About the cover

The cover photographs depict the four phases of science and technology investments that will produce usable tools and processes for EM's cleanup mission—research, development, demonstration, and deployment.

Research: Studies of deep-subsurface microbes provide information that may lead to new bioremediation applications for subsurface contamination.

Development: Characterizing the radioactive material in EM's high-level waste tanks requires a variety of remote-operated tools. The in-tank waste probes shown here are being developed for use as end-effectors on the Light-Duty Utility Arm to measure the depth of the waste on the tank floor.

Demonstration: Six-Phase Soil Heating is a method for removing organic contaminants from beneath the surface. The technology depicted in the photograph was demonstrated at a cleanup site in 1993. The technology is now commercially available and has been used to clean up both government and private sites.

Deployment: The need for a technology required to immobilize high level waste in a glass matrix resulted in the development and deployment of the glass melter that has been incorporated in the Defense Waste Processing Facility.

End State: The EM cleanup mission is to achieve an end state for each site that returns as much land as possible to the public domain and unrestricted usage.

[Second printing, December 1998]

November 1998

Dear Colleague

It is my pleasure to release the Environmental Management Research and Development Program Plan. This Plan is the culmination of many months of effort involving many employees of the Department, numerous contractors complex wide, the national laboratories, and industry. Their support, contributions, and dedication are greatly appreciated.

First and foremost this Plan was written to help ensure that EM is making the best possible investments in science and technology. We have to make the correct investments now and in the future if we are going to achieve what we have set out to do in our "Paths to Closure" strategy plan. Having said that, there are several key aspects of this Plan that I want to highlight.

- EM's science and technology investments must be driven by cleanup project managers. Implementation of the processes in this Plan will ensure that EM's investments are fully integrated with our cleanup projects and have the maximum possible impact.
- EM is committed to measure the results of our investments in science and technology. This includes not only improving the way we manage the investments, but our ability to put the results of those investments to good use.
- EM will effectively use science and technology investments to rapidly provide solutions to our highest priority needs. This solution-oriented approach will reduce the cost and programmatic risk associated with our projects.
- EM must maintain a balanced investment portfolio. For example: investments in accelerating deployment must be weighed against investments in science. Investments to solve our high level waste issues must be weighed against investments associated with soil and groundwater contamination. There is no simple or easy answer; these are complex issues that we face.

Finally, this Plan describes EM's contribution to the overall investment being made by the Department in helping to provide a more secure future for all Americans. Implementation of this Plan will significantly contribute to achieving the objectives of the Department's Environmental Quality business line.

Sincerely,

James M. Owendoff

James M. Owendoff

Acting Assistant Secretary for Environmental Management

Restoring and ensuring a quality environment for future generations through the discovery, development, and application of science and technology

FOREWORD

The Environmental Management Research and Development Program Plan was written to describe the investments EM will make in science and technology to support the cleanup mission of the Department of Energy. The success of the cleanup program will ultimately depend on whether cleanup project managers have the tools and information they need to complete their projects on time and within budget. The cleanup project manager is the customer (sometimes called the “end user”) of EM’s science and technology development efforts. This plan therefore stresses that supplier-customer relationship, and it describes an improved approach to planning and management of science and technology investments that will facilitate that relationship and provide integrated solutions to cleanup needs. The plan incorporates roadmapping as a means to identify the science and technology areas that promise the greatest return on investment by reducing cleanup project cost or schedule, technical risk, or risk to workers, the public, and the environment.

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EXECUTIVE SUMMARY

The DOE Assistant Secretary for Environmental Management (EM) has responsibility for cleanup of the radioactive, chemical, and other hazardous waste left after 50 years of U.S. government nuclear operations, particularly weapons production—the largest environmental management program in the world. Resources to achieve cleanup are limited, programmatic risks are often high, and schedules for meeting compliance agreements are often very ambitious.

The investment strategy outlined in the EM Research and Development Program Plan is aimed at meeting cleanup project manager needs for new tools and information, reducing technology risks, and helping achieve accelerated cleanup goals. Implementation of this plan will provide the scientific foundation, new approaches, and new technologies needed to reduce risk, and achieve or reduce the baseline costs and schedule of the DOE cleanup plan described in *Accelerating Cleanup: Paths to Closure*.

Accelerating Cleanup: Paths to Closure provides for the first time, a site-by-site, project-by-project projection of the technical scope, cost, and schedule required to complete all 353 projects at DOE's 53 remaining cleanup sites in the United States. Cost, schedule, and scope projections are based on the cleanup "end-state" that has been identified for each site. The end state of a site is achieved by completing all activities and requirements associated with the safe management of any nuclear materials and spent nuclear fuel; treatment, storage and disposal of waste; the deactivation, decontamination, and decommissioning of facilities; and, the remediation of contaminated soil and groundwater. The current life-cycle cost estimate for this cleanup is $147 billion.

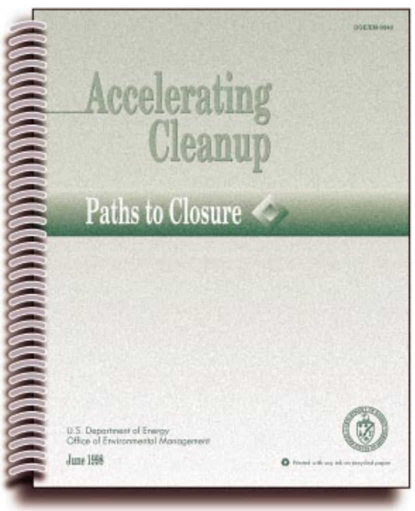
Site-specific cleanup activities in *Accelerating Cleanup: Paths to Closure* have identified over 500 technology needs, 86 pathways or events on the critical path to closure with medium to high technology risk, and over 200 waste streams with medium to high technology risk. In addition, a review of 37 EM cleanup projects, representing an estimated life-cycle cost of $33 billion, has identified more than 80 technology-based opportunities to exceed EM's accelerated cleanup goals. The potential savings for exceeding the accelerated cleanup goals for those 37 projects is $4 billion.

Investments in science and technology have already provided solutions to a number of problems once thought to be intractable. These earlier investments by EM have also provided better, safer, and cheaper alternatives to the baseline technologies originally considered at the start of the cleanup. However, to achieve the goals of *Accelerating Cleanup: Paths to Closure* we must do more.

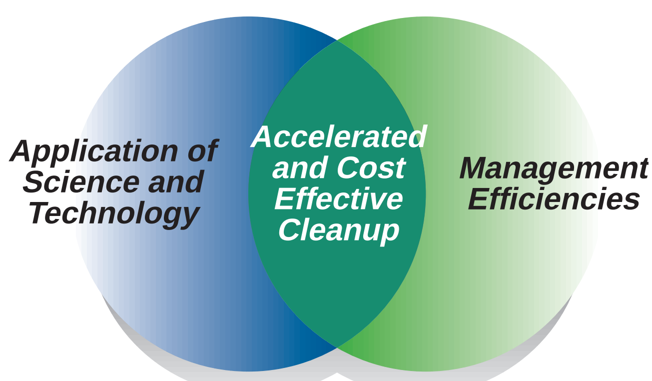
The EM R&D program is cleanup project manager driven and solution oriented. For each project, sites have identified specific science and technology needs that must be met to enable or to improve cleanup, accelerate the schedule, or reduce cost. Information about how, where, and when new technologies are being deployed, a prioritized set of cleanup project manager needs, specific cost savings opportunities, and an assessment of technology risk are all crucial to building the optimal science and technology investment portfolio. EM is collecting and analyzing these data to develop and prioritize its science and technology activities. Such highly focused investments will help achieve challenging accelerated cleanup

The Department of Energy is responsible for the world's largest environmental cleanup program. This enormous technical challenge is a national priority that must be based on thorough, scientific analyses.

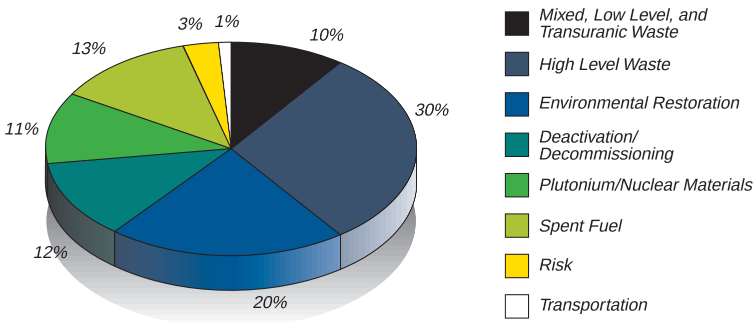
Secretary of Energy
June 1998



Accelerating Cleanup: Paths to Closure ***reflects the most recent evolution of DOE's ability to accurately project the cost, schedule and scope of its massive cleanup effort (available at www.em.doe.gov).***



Enhanced Performance goals can only be met through a combination of managerial improvements and advances in science and technology.



EM's $1.2 billion five-year investment portfolio is organized in problem areas plus crosscutting investments.

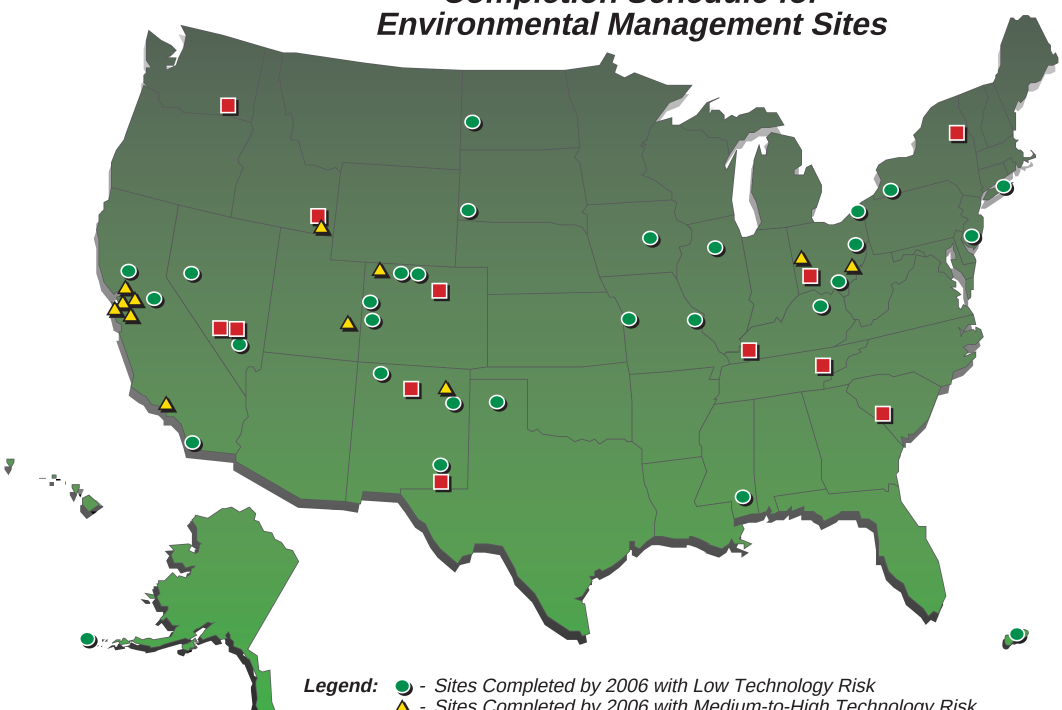
goals and reduce the technology risk associated with projects that are on the critical path to site completion.

The EM R&D Program Plan establishes EM's $1.2 billion investment strategy for the next five years (4% of EM's total budget) as shown in the chart above. The plan describes the problems and end states, the approach we are using to both determine and maximize the impact of our investments, and provides a summary of the investment portfolio. The investment portfolio is organized into the six major problem areas facing EM: mixed/low level/TRU waste; high level waste; environmental restoration; deactivation/decommissioning; nuclear material; and spent nuclear fuel. Detailed information on the investments being made for each problem area are contained in Problem Area Roadmaps (Focus Area Multi-Year Program Plans). This Plan encompasses and focuses activities from science through deployment assistance to meet cleanup project manager needs. The Plan also includes references to other DOE program elements (e.g. Science and Civilian Radioactive Waste Management) and other federal agencies whose research contributes to the EM cleanup effort.

The EM R&D Program Plan provides a fully integrated approach that ensures that we are working on the highest priority needs, meeting our commitments to stakeholders, focusing on the greatest cost savings opportunities, reducing technology risk, and driving accelerated technology deployment. Implementation of this plan will help achieve EM's aggressive accelerated site cleanup plan. The accelerated cleanup will reduce health and environmental risks, make many sites available for community re-use, and achieve compliance with federal and state laws and agreements.

Twenty-four sites have identified medium to high risk pathways in the critical path to site closure. One half of those sites are to be closed by 2006.

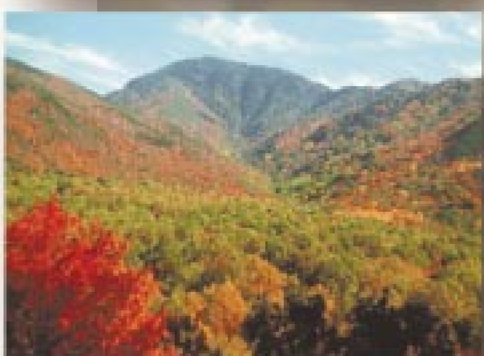
Completion Schedule for Environmental Management Sites

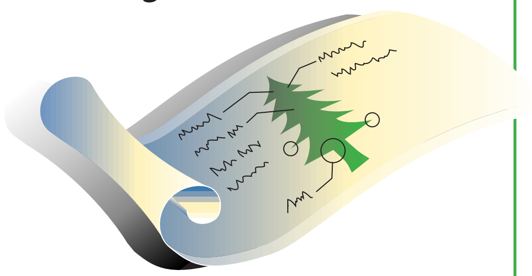


Legend:
- Sites Completed by 2006 with Low Technology Risk
- Sites Completed by 2006 with Medium-to-High Technology Risk
- Sites Remaining After 2006.

Environmental Management Research and Development Program Plan

Solution-Based Investments in Science and Technology





The EM R&D Program Plan is part of an overall DOE roadmapping effort to delineate and integrate the Department's research efforts into a cohesive strategy.

1.0 INTRODUCTION — A ROADMAP FOR EM R&D

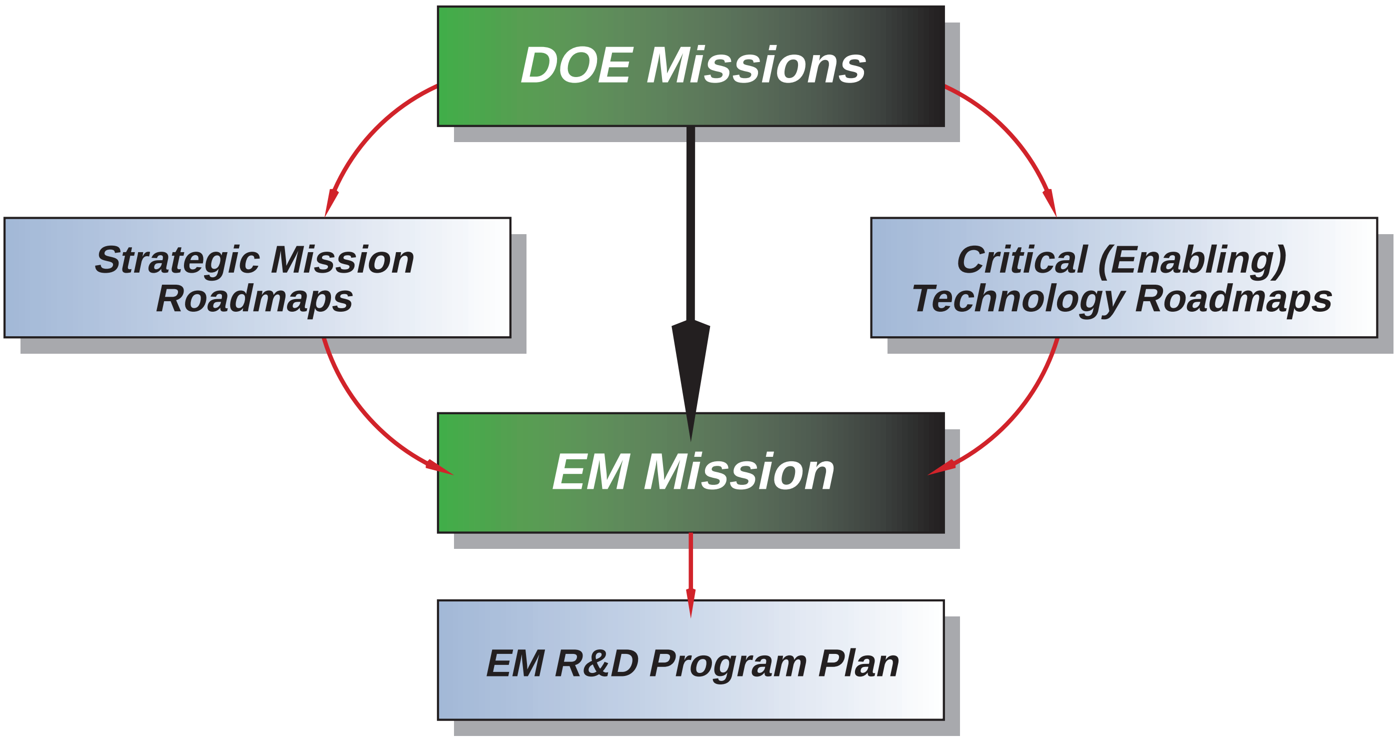
This Program Plan articulates a set of common goals and objectives for the research and development (R&D) programs within the Department of Energy's Office of Environmental Management (EM). It describes the relationship between the Department's missions, EM's specific missions, the programs established to accomplish these missions, the technical opportunities and barriers within these programs, and the science and technology efforts needed to support the programs.

The EM R&D Program Plan is part of an overall DOE roadmapping effort to delineate and integrate the Department's research efforts into a cohesive strategy. DOE is currently pursuing a three-pronged approach to roadmapping: strategic mission roadmaps, critical or enabling technology roadmaps, and R&D program plans.

- Strategic Mission Roadmaps are prepared for a small number of critical missions that involve more than one program. Two examples are Clean Power and Genomics. The accomplishment of each of these missions is an important goal for the Department and the country. The end result is important in its own right, not simply a tool for accomplishing other R&D objectives.
- Enabling or Critical Technology Roadmaps provide integrated plans for the development of technologies that are necessary for the accomplishment of some larger DOE mission. Examples include robotics, strategic simulation, advanced materials, and major national research facilities. Enabling technologies are often required by more than one program area.
- R&D Program Plans are prepared by each major DOE program. They describe how the program's R&D investments support the program's own mission as well as DOE's overall mission areas.

Figure 1.1 shows the relationships between these basic components.

Figure 1.1 DOE Roadmapping — Strategic Mission and Critical (or enabling) Technology Roadmaps describe science and technology efforts that support DOE missions, while the EM R&D Program Plan describes science and technology investments directly supporting EM's missions.



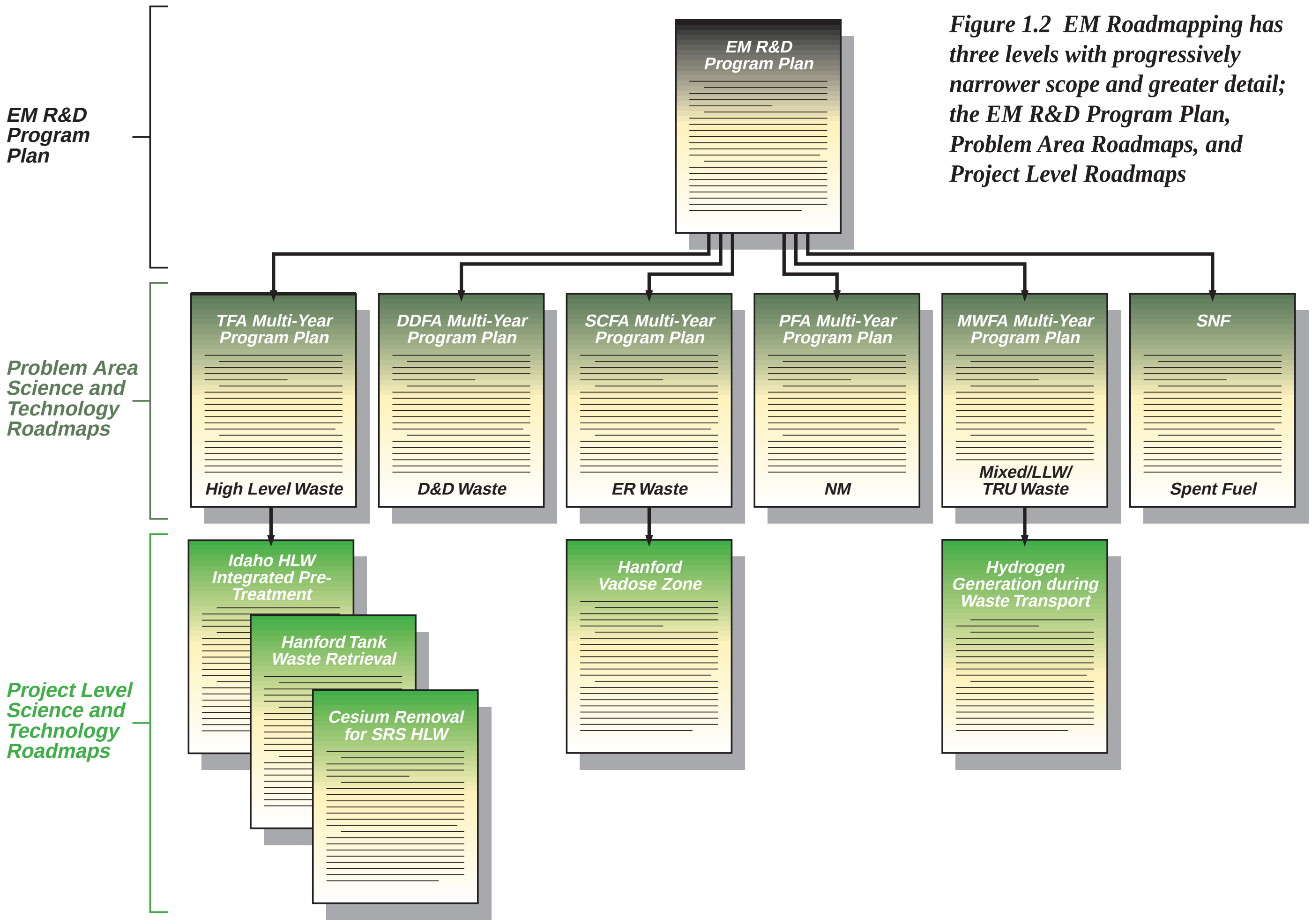


Figure 1.2 EM Roadmapping has three levels with progressively narrower scope and greater detail; the EM R&D Program Plan, Problem Area Roadmaps, and Project Level Roadmaps

The EM R&D Program Plan represents the highest level of roadmapping strictly within EM. Subordinate to this Program Plan are two lower levels with successively more detail. The second level of EM Roadmapping is at the "Problem Area" level and will consist of a series of six Multi-Year Program Plans that address EM's major Problem Areas, e.g., high-level waste, nuclear materials, etc. The lowest level and most detailed roadmaps are generated for a number of specific, critical science and technology projects. These roadmaps describe where science and technology efforts can make a significant contribution to cleanup project success. Figure 1.2 shows the relationship between these three levels of EM roadmaps.

The EM R&D Program Plan represents the highest level of roadmapping within EM.

1.1 Mission —Bringing Solutions to Environmental Management

This plan embodies a paradigm shift from developing technologies that cleanup project managers could *use to developing technologies that cleanup project managers* will *use.*

EM's mission is to clean up the environmental legacy of U.S. nuclear weapons production and other sources of pollutants such as DOE nuclear research. EM's goal is to clean up the majority of sites by the year 2006, allowing the focus of efforts thereafter to concentrate on the most complicated and difficult problems. The EM cleanup effort is expensive, technologically complex, closely regulated, and relatively unique in the world. Achieving the goal of accelerated cleanup within the current budget requires targeted investments to respond to hundreds of needs identified by cleanup project managers at the affected sites. EM's investments can provide more effective, less expensive, and safer environmental remedies, including technologies where no effective remedy currently exists. These investments can also provide the data or alternative approaches that reduce the risk that cleanup will be delayed or will exceed the available budget. Science and technology efforts within EM span the full spectrum from research to direct assistance for cleanup projects and lead to fully integrated, technically defensible solutions for cleanup and long-term environmental stewardship at DOE sites.

EM has designated four major objectives for its science and technology investments, shown in Figures 1.3a-d:

- Figure 1.3a — EM science and technology investments will meet the highest priority needs identified by cleanup project managers, including those on the critical path to site closure and those that represent major technology gaps in project completion.
- Figure 1.3b — EM science and technology investments will reduce the cost of EM's costliest cleanup projects.
- Figure 1.3c — EM science and technology investments will reduce technology risk. Technology risk is the programmatic risk (as opposed to risk to the environment or the safety and health of workers) that critical cleanup projects may not be completed on time and/or within budget due to a technology deficiency (denoted by Technology Risk >3, in the *Paths to Closure* data).
- Figure 1.3d — EM science and technology investments will accelerate and increase technology deployment by bridging the gap between development and use.

Figure 1.3a Meet the sites' high priority needs

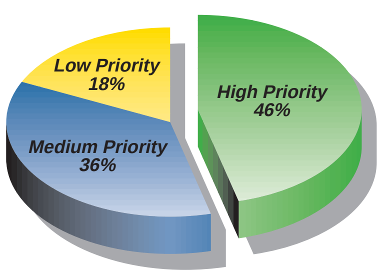


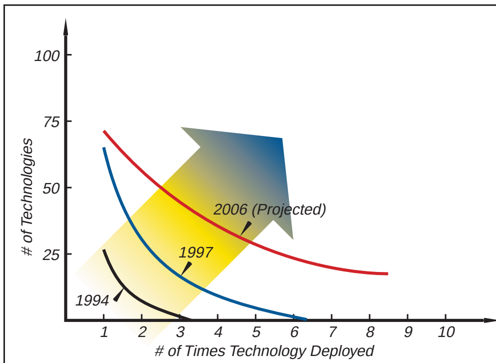
Figure 1.3b Reduce the cost of EM's major cost centers (constant FY '98 $)

FY97-FY70	$ Billions
High Level Waste	47
TRU/Mixed Low Level Waste	20
Deactivation and Decommissioning	11
Environmental Restoration	15
Plutonium and Nuclear Material	7
Spent Fuel	6

Figure 1.3c Reduce EM's technology risk

	Critical Path to Closure	
Field Office	# PBS Tech Risk > 3	# Pathways and/or Events Tech Risk > 3
AL	5	9
ID	5	11
OR	6	20
RL	5	11
SR	16	18
All Other	13	17
TOTAL	50	86

Figure 1.3d Accelerate technology deployment



1.2 Vision — Science and Technology Working for Cleanup

Science and technology investments will provide the scientific foundation, technical assistance, new approaches, and new technologies that contribute, as an integral part of DOE-EM programs, to significant reductions in risk (both technology and safety and health), cost, and schedule for completion of the EM mission. The strongest advocates for investing in science and technology will be the DOE-EM cleanup project managers.

1.3 Strategy — Maximizing the Value to EM

EM's investments in science and technology are:

- Solution Driven — All science and technology investments must support implementation decisions, enable action where solutions are lacking, enable actions that significantly reduce cost and schedule while maintaining or enhancing health and safety, or fundamentally transform the nature of the problem.
- Fully Integrated with Cleanup Project — All activities will be linked directly to cleanup goals that reflect stakeholder values and site compliance agreements, with financial accountability transitioning from the technology developers to the cleanup project manager as efforts mature toward technology deployment.
- Comprehensive in Scope — Activities will cover the full range of science and technology; i.e., from basic research to technology development to technology demonstration to technical assistance supporting implementation.
- Credible Decision Process — Processes used to establish priorities, set program and project direction, allocate funding, and select project teams are based on a clear set of criteria and are applied in an open, transparent manner.

1.4 Success Indicators/Metrics — Performance Measured by Cleanup Project Managers

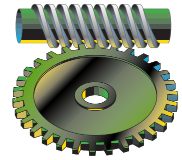
Performance measures and the appropriate associated metrics are critical to the evaluation and ultimate success of a program. Within EM, the performance measures associated with science and technology investments have evolved with the program; they will continue to evolve as the program changes. Performance measures for EM's investments in science and technology must address both the performance of individual investments and the success of the overall program. This section of the Plan briefly discusses how we intend to evaluate the overall success of the investment portfolio.

As discussed in Section 1.1, EM's science and technology investments have four major objectives: to meet high priority needs; to reduce the cost of EM's major cleanup efforts; to reduce EM's technology risk; and to accelerate the deployment of new technology. Technology deployment and technology based cost savings (as a component of accelerated cleanup goals) are part of EM's current corporate performance measures. These two measures will be enhanced to better measure the outcomes of EM's science and technology investments. To properly monitor performance of EM's science and technology programs, two additional measures will be added.

EM Corporate Measures with Science and Technology Components:

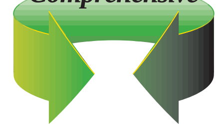
- Reduction in the cost of cleanup is described by the achievement of EM's accelerated cleanup goals. EM will review, on a site-by-site basis, by cleanup project, progress towards accelerated cleanup goals and what portion of that progress is attributable to specific investments made by EM in science and technology.
- Corporate performance measures for technology deployment will be retained as an output measure. However, EM will evaluate, by project, how many of these new technologies are provided as a result of EM's investments and, more importantly, what impact those technologies are having on cleanup projects.

Solution-Driven



Fully Integrated

Comprehensive



Credible Decision Process

EM investment philosophy is founded on four values: solution-focused activities, direct linkage with cleanup goals, full scope from research through demonstration, and positive and purposeful direction.

Investments in science and technology include scientific research; technology development, demonstration and deployment; and technical assistance to support technology deployment.

Performance measures will be used to: 1) evaluate the impact of EM's investments in science and technology and 2) determine how effectively EM's project managers use both the advancements in science and the availability of new technology to execute their projects.

EM's Multi-Year Program Plans contain the problem sets, the planned technical investments, the performance measures, and the projected outcomes associated with those investments.

Additional Corporate Performance Measures Specifically for EM Science and Technology Investments:

- Investments against, and solutions to, high priority needs is a measure of the responsiveness of the investments to the cleanup project manager community and the ability to effectively manage EM science and technology investments. EM will measure both the numbers of high priority needs that we are trying to address and our success in meeting those needs.
- Reduction in technology risk will not only reduce cleanup costs, it will allow us to evaluate and track investments in areas where EM baselines have technology gaps or uncertainties. EM will evaluate on an annual basis how science and technology have served to lower technology risk levels. This evaluation will include both science and technology developed through EM's investments as well as externally developed science and technology brought to bear on EM's cleanup problems.

These four performance measures will be evaluated and documented by the cleanup project managers and will help EM evaluate the impact of EM's investments in science and technology. The results of the evaluation will also be used to modify and improve the investment strategy to continually increase the effectiveness of the science and technology investment portfolio.

1.5 Multi-Year Program Plans — Roadmaps to Solutions

The technical strategy, scope, and performance measures summarized in this Plan are derived from the Problem Area roadmaps, which are the Focus Area Multi-Year Program Plans (MYPPs). The MYPPs describe in detail EM's planned investment portfolio, science through deployment, for each problem area. Each MYPP is a result of extensive discussion and planning between the science and technology community and the cleanup project managers. The MYPPs are developed in conjunction with and endorsed by the cleanup project manager community and approved by senior EM management from the Field Offices and Headquarters.

These documents are EM's primary science and technology roadmaps; they contain the problem sets, the planned technical investments, the performance measures, and the projected outcomes associated with those investments. They are used for planning purposes by both the cleanup project manager community and the science and technology community and provide the basis for EM's science and technology budget requests. Short summaries of the MYPPs are contained in Appendix A. Access to the complete documents is available through the Internet on the EM Home Page at www.em.doe.gov.

1.6 Project-Level Roadmaps: A Close-Up View of the Challenge

EM is beginning to prepare project-level roadmaps, its lowest and most detailed level of science and technology roadmaps, for a number of specific, critical activities. These activities may be projects, technologies, or technical issues. A project-level roadmap is an analysis of the current status of that activity ("where we are"), the hoped-for end state ("where we want to go"), and the science and technology investments needed to successfully achieve that end state ("how to get there").

EM will use project-level roadmapping to identify critical needs for investments in science and technology and the timeline for meeting those needs. The roadmaps will include a set of logical, time-sequenced steps showing project activities and decision points along with the complete set of science and technology activities needed to address technology gaps and reduce the cost, schedule, and technology risk associated with cleanup. This roadmap will represent the cleanup project manager's definition of the science and technology investments needed to ensure the success of the project and when the products of those investments are needed. The cleanup project manager will then use this document to drive federal science and technology investments.

The value added by roadmapping is that it reduces programmatic risk within the projects and, potentially, their cost and schedule; helps ensure a sound technical basis for each project; gives the project manager more control over the science and technology program; and aligns the resources of the cleanup programs and the science and technology programs. The goal of EM science and technology roadmapping is to align and optimize the science and technology investment portfolio by identifying both gaps in the current program and activities that do not support the cleanup projects.

1.7 Relationship to Other R&D Programs

EM takes advantage of research programs elsewhere within DOE, other Federal agencies, universities, industry, and the international community. Other offices within DOE execute research programs that address EM's cleanup project manager needs, including the Offices of Science, Civilian Radioactive Waste Management, and Materials Disposition. EM participates in jointly funded and managed programs with these other DOE offices that provide benefit to both the EM cleanup project managers and the partnering sponsors.

EM also engages other federal agencies performing research that support EM objectives. DOE jointly funds or manages programs with the Department of Defense and the Environmental Protection Agency. These agencies have science and technology efforts focused on cleanup, environmental compliance, resource conservation, and pollution prevention technologies, all of which are integral elements of the EM mission. A summary of these activities is provided in Appendix B.

DOE has reached out to the international community, especially to the former Soviet Union, in order to share experience and resources in solving unique needs for cleanup of radioactively contaminated sites.

Collaboration with industry and academia, through efforts such as Cooperative Research and Development Agreements, Small Business Innovative Research grants, technology transfer initiatives, Research Opportunity Announcements, Program Research and Development Announcements, and DOE-sponsored university research, provide the Department with outside perspectives on how to accomplish EM's cleanup goals. DOE has also reached out to the international community, especially to the former Soviet Union, in order to share experience and resources in solving unique needs for cleanup of radioactively contaminated sites.

1.8 How the Needs are Met — A Preview

In this document, Section 2 describes the cost, duration, scope, and complexity of the EM cleanup problem and provides some insight into the kinds of science and technology investments needed to reduce the cost and duration, and eliminate technology barriers. Section 3 of this Program Plan describes the process used to identify specific project needs, to plan and prioritize the science and technology investment portfolio, to execute the science and technology program, and to implement the solutions it produces. EM manages this portfolio through a number of technical programs ranging from scientific research through technology development and deployment. "Focus Areas" coordinate the overall science and technology investments within each of six problem areas. Section 4 contains a summary of the investment portfolio and provides several examples of how past investments have paid off, what work is currently in the pipeline, and how fundamental advances in science will benefit EM in the future. Finally, Section 5 discusses the integration of the science and technology program with cleanup projects to ensure that technical solutions developed through the science and technology investments are implemented.

2.0 EM'S INVESTMENT RATIONALE — PROBLEMS, END STATES, NEEDS

The EM cleanup mission includes the remediation of contaminated soil and groundwater, the deactivation and decommissioning of facilities, treatment, storage and disposal of waste, and the safe management of nuclear materials and spent nuclear fuel. Accordingly, EM's investments in science and technology focus on these areas and are both extensive and diverse. This section describes the rationale for the science and technology investment portfolio and includes:

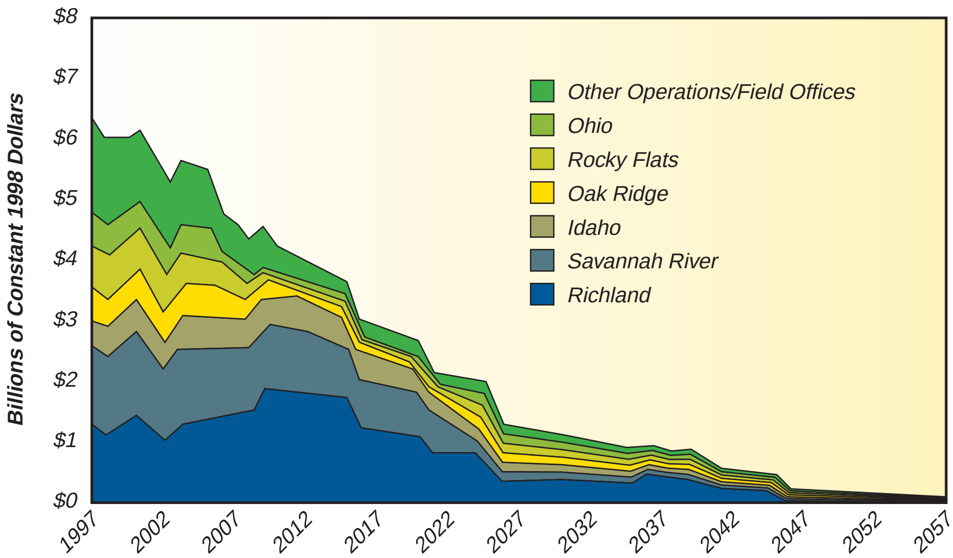
- The problems that must be resolved to complete the EM program mission,
- The end states that represent program completion, and
- The pathway to the end states and the needs that must be met to traverse that path to completion.

2.1 The Challenge — High Life Cycle Costs, Risks and Technology Gaps

EM's investments in science and technology are driven by the need to reduce high life-cycle costs, reduce environmental, safety and health risks, and to provide solutions to problems that cannot currently be solved. EM's cleanup efforts will continue well into the 21st century with annual costs continuing to exceed $3 billion after 2010, and with cleanup work scheduled past the year 2030.

The cost, duration, scope, and complexity of the cleanup are documented in *Accelerating Cleanup: Paths to Closure* (available via the Internet at www.em.doe.gov), and are important factors to understand in reviewing EM's investment portfolio. The EM program baseline encompasses 353 cleanup projects with a cost estimate (1997 through 2070) of $147 billion (constant FY1998 dollars). Figure 2.1a shows the contribution by Operations/Field Office to the aggregate cost.

Figure 2.1a. Environmental Management cleanup costs by operations/field office over time



While EM is aggressively moving forward to close 90% of its sites prior to 2006, EM's greatest challenge will be to complete cleanup at some of the largest and most technically complex sites. In fact, 77% of the estimated costs after 2006 are accounted for by the Savannah River Site, the Hanford Site, and the Idaho National Engineering and Environmental Laboratory. The $147 billion life-cycle cost estimate includes the costs of completing all known EM work scope, but there will also be continuing site stewardship costs that are not included in this total.

Much of what needs to be done has never been done before, or even attempted. Not all of the work scope (i.e., complete set of required activities) has been completely determined, and often the cleanup of one site is dependent upon another for completion. A review of the critical paths to achieve site closures, prepared by the Field Offices, show medium to high risks as being the norm. That is, programmatic risks associated with technology, work scope, and intersite dependency must be substantially reduced in order for EM to achieve its aggressive schedule while maintaining or reducing cost. Technical issues, regulatory changes, and funding constraints all require that advances in science and technology be achieved and applied in order for EM to succeed with planned cleanup activities

2.2 End States and Investment Areas Needed to Reach Them

The definition of the end state for an EM activity is the basis for the development of the life-cycle baseline. The end state is defined by the complete set of requirements that must be met in order to declare a site closed or activity completed, and may include subsequent stewardship costs. In addition to technical requirements, the end state is also defined by all applicable NEPA, CERCLA, RCRA; and local, state, and federal statutes and regulations; and stakeholder and Tribal Nation requirements. End states for site-specific activities are provided in the Field Offices' Paths to Closure documents. The end state for an EM programmatic area is the summation of the site-specific end states in that area.

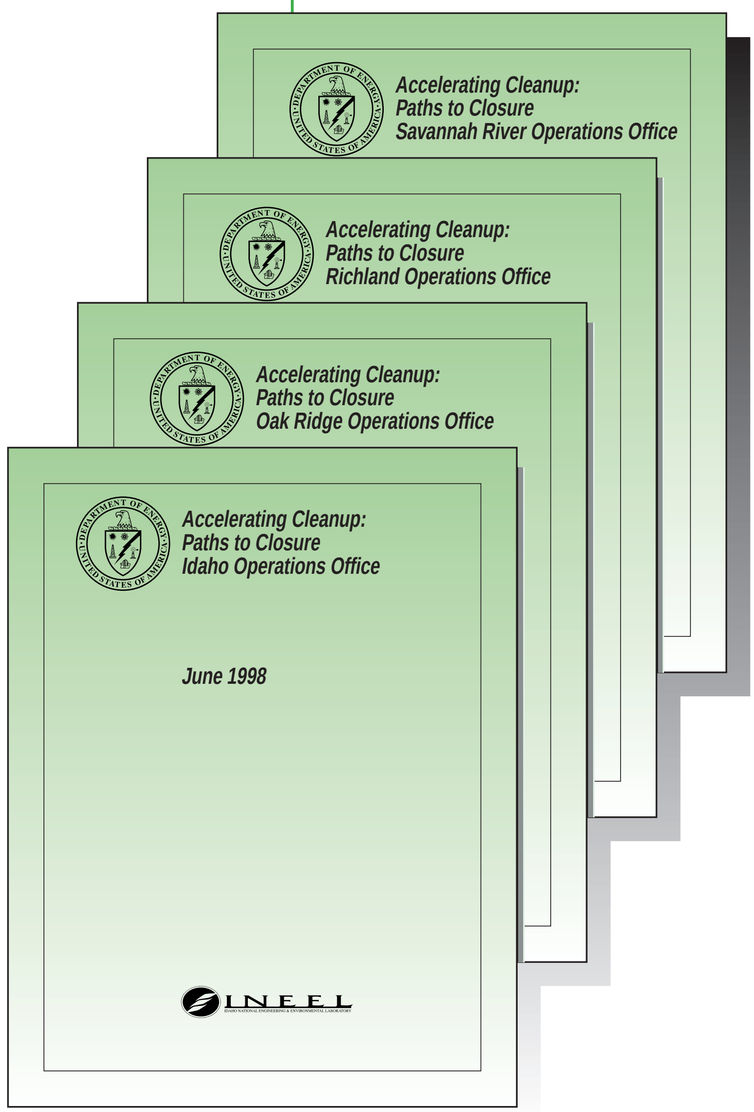
End states for site-specific activities are provided in the Field Offices' Paths to Closure documents.

To get to an end state, a pathway is defined that describes all the activities that must be executed in order to achieve that end state. An analysis of both the pathway to site closure and of stewardship activities identifies areas of risk, opportunities for major cost savings or risk reduction, and technology gaps that may benefit from science and technology activities. In order to achieve efficiency and create synergy in reaching defined end states, EM has identified six key Problem Areas grouped by waste type. These six major Problem Areas describe and integrate similar activities across the complex.

The Problem Areas are:

- Mixed, Low Level, and Transuranic Waste
- High Level Waste
- Environmental Restoration
- Deactivation and Decommissioning
- Nuclear Material (Pu, SNM)
- Spent Nuclear Fuel

The following discussions present a summarized overview of the six Problem Areas according to the major problem, the end state(s), and cleanup project manager needs. In addition to the Problem Areas, there are also some science and technology activities that address cross-cutting issues. Two of these – risk and transportation – are discussed in the Appendix in sections A.7 and A.8.



2.2.1 Mixed, Low Level, and Transuranic Waste Problem Area

Problem Description: Mixed, low level, and transuranic waste was generated during weapons production and testing projects, defense related experimental projects, and environmental management projects. Disposal practices for the waste generated from these operations generally included long-term retrievable storage. The site treatment plans identify 165,000 cubic meters of mixed and transuranic waste in storage that include over 2,300 mixed waste streams at 36 sites. The Environmental Management Program is responsible for the storage, treatment, and disposal of approximately 130,000 cubic meters of contact handled and remote handled transuranic waste. This estimate includes volumes of transuranic waste that are currently stored or are expected to be generated. Before it can be shipped, transuranic waste requires safe storage and sometimes requires treatment. EM must also manage millions of cubic meters of other types of waste including low level radioactive waste, hazardous waste, and mixed low level waste (containing both radioactive and hazardous constituents). Some of that waste is in storage awaiting treatment and disposal; more such waste will be generated during the cleanup process. Virtually all sites manage one or more of these types of waste. The projected life-cycle cost for disposition of this waste is shown in Figure 2.2.1a.

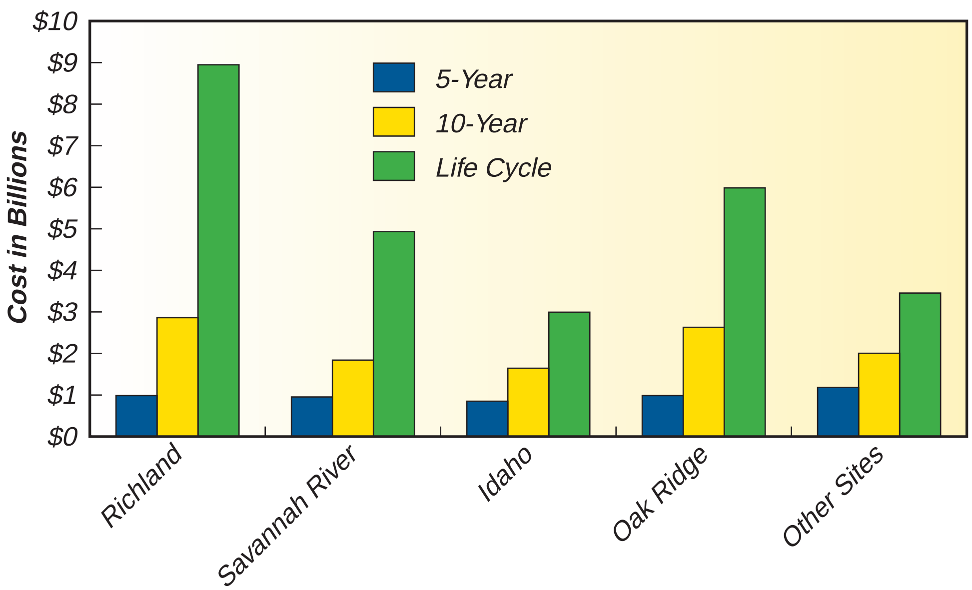


Figure 2.2.1a. Five-Year, Ten-Year, and Life Cycle Costs for treating and disposing mixed, low level, and transuranic waste at Department of Energy sites

End States: There are two end state definitions that drive mixed, low level and transuranic waste treatment: waste acceptance criteria for disposal off-site and waste acceptance criteria for disposal on-site. All sites plan to dispose of transuranic waste at Carlsbad, New Mexico. Regional disposal sites for low level waste and mixed waste will be determined in the Waste Management Programmatic Environmental Impact Records of Decision scheduled to be released by the end of the calendar year 1998.

Problem Area Needs: These waste streams present significant challenges to current capabilities in multiple areas including: adequate characterization, safe handling, adequate treatment to multiple requirements, and identification of available disposal facilities. Figure 2.2.1b illustrates the generic steps in transuranic waste treatment and disposal. The following key problems in this process have been identified by the sites:

- Significant waste characterization problems arise due to alpha contamination, high surface area dose rates (greater than 200 millirem per hour), physical and chemical heterogeneity, and the volume packaged in boxes.
- Radioactive and hazardous components coupled with the non-homogeneous nature of mixed waste present significant problems with material handling, sorting, segregating, repackaging, and volume reduction.

Field Offices identified in* Accelerating Cleanup: Paths to Closure *for the MLLW and TRU Problem Area

- ***31 high priority needs***
- ***34 waste streams with high technology risk***
- ***10 of 48 pathways/events on the critical path with high technology risk***

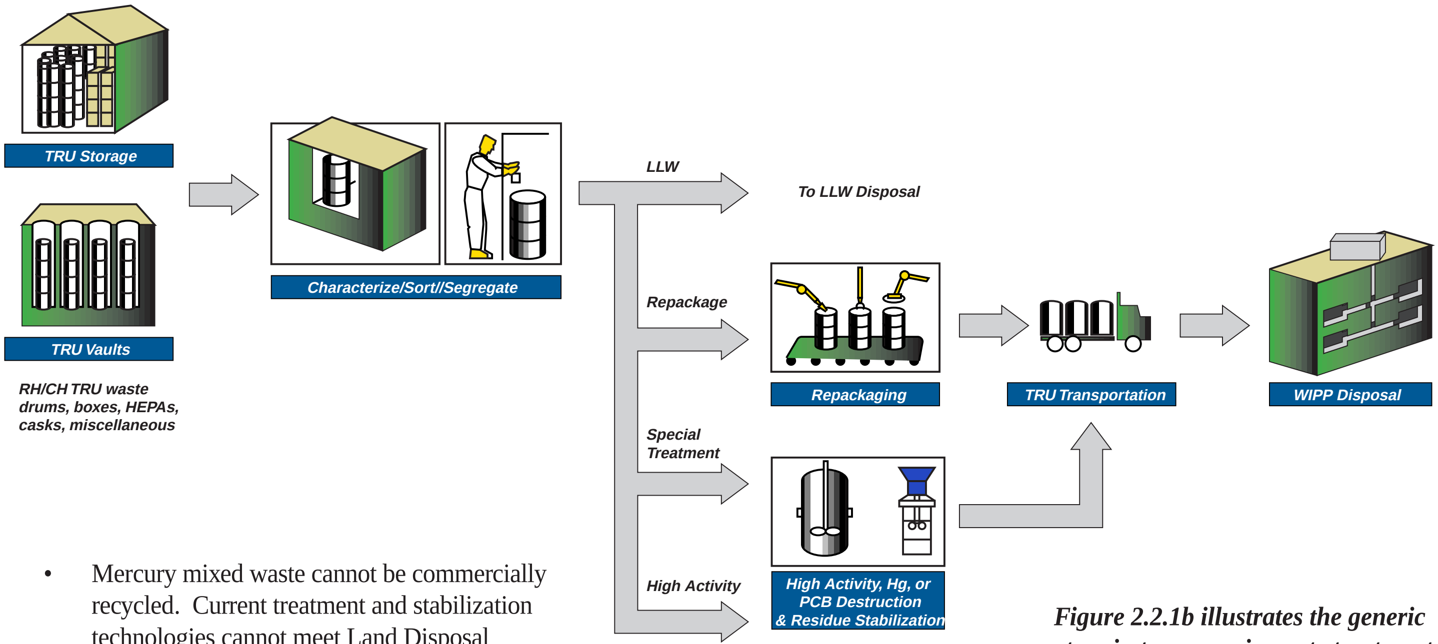


Figure 2.2.1b illustrates the generic steps in transuranic waste treatment and disposal.

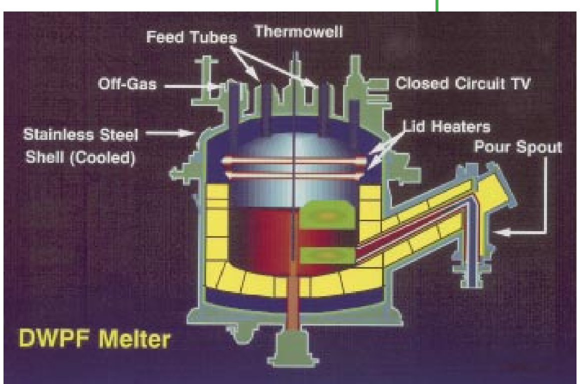
- Mercury mixed waste cannot be commercially recycled. Current treatment and stabilization technologies cannot meet Land Disposal Restrictions.
- Current stabilization methods for high metal content salts and ash waste streams often result in a significant volume increase, leading to high disposal costs.
- Transuranic waste transportation utilizing Type B containers (e.g., TRUPACT shipping container, 72-B shipping cask) is limited by potential flammable gas generation.
- There are currently only three DOE incinerator facilities treating significant quantities of DOE mixed waste. Two of these are identified as treatment facilities in other site's compliance agreements. Due to limited abilities to monitor and remove hazardous and radioactive contaminants from off-gas streams, these incinerators may be unable to comply with the Maximum Achievable Control Technology Rule and be forced to shut down, causing significant programmatic impacts.
- Some organic mixed waste streams cannot be destroyed using open flame thermal technologies, like incineration, due to problems encountered with off-gas emissions. In fact, some States will not allow incineration as a mixed waste treatment option. Alternatives to incineration to reduce emissions hazard are needed for several Department of Energy mixed transuranic wastes with high organic content, which are subject to severe transportation limitations due to hydrogen gas generation.
- Ten to fifteen percent of the mixed waste inventory does not have an identified disposition path due to the unique nature of these waste streams. Virtually every site has small quantities of reactive and pyrophoric wastes, problematic polychlorinated biphenyl wastes, non-transuranic/non-defense alpha contaminated wastes, and high activity wastes that are difficult to manage due to technological, regulatory, or other reasons.
- Low volume problematic waste streams resulting from 10 to 15 percent of legacy waste classified as unknown, and wastes from environmental restoration and decontamination and decommissioning operations will present distinctive management challenges. Problems associated with these waste streams include inability to adequately characterize, inability to safely handle, inability to adequately treat to multiple requirements, and inability to identify available disposal facilities.
- Certain inventories of legacy transuranic (both contact handled and remote handled) waste, future transuranic waste streams, and fissile material not meeting the legal definition of transuranic waste or other requirements for disposal at the Waste Isolation Pilot Plant will remain in storage until acceptable methods are available to allow for disposal. Some waste forms cannot be treated at current or planned facilities.

The Environmental Management Program expects to dispose of tens of thousands of cubic meters of mixed, low-level and transuranic waste generated from continuing and future missions as well as decommissioning and other defense related projects of the Department of Energy.

2.2.2 High Level Waste Problem Area

Problem Description: High level waste (HLW) was generated during production of nuclear weapons and reprocessing of reactor fuels. The waste is currently stored in underground tanks or bins, some of which have leaked and many of which have exceeded their design life.

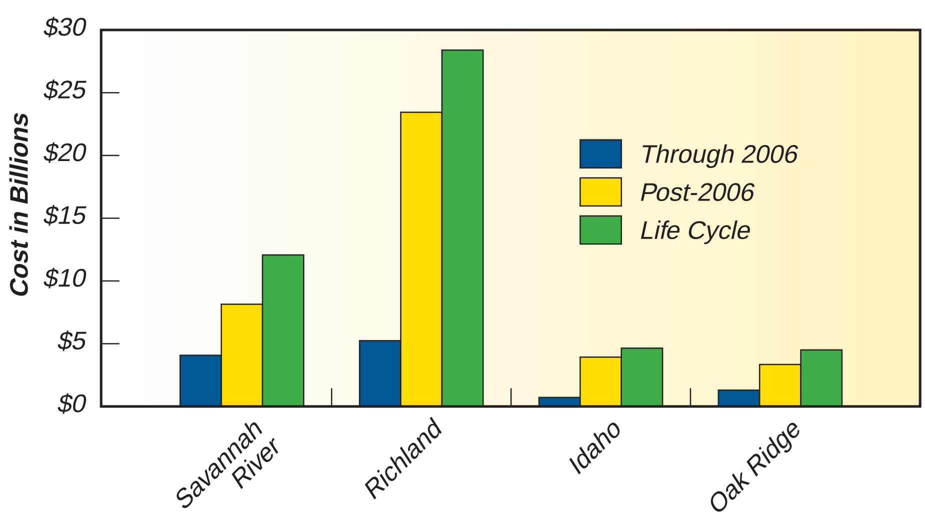
- The Savannah River Site (SRS) in South Carolina has 51 underground high level waste storage tanks. Two tanks were closed in 1997. The remaining 49 tanks store about 34 million gallons of waste containing approximately 450 million Curies (MCi) of radioactivity. SRS is currently removing waste sludge from the tanks and vitrifying it in the Defense Waste Processing Facility (DWPF).
- In Washington State, Hanford has 177 tanks that store 55 million gallons of waste containing approximately 200 MCi of radioactivity.
- The Idaho National Engineering and Environmental Laboratory (INEEL) has 19 tanks with 1.4 million gallons of liquid waste containing 0.5 MCi of radioactivity and 1.1 million gallons of calcined waste with approximately 50 MCi of radioactivity stored in six bin sets, which contain 35 tanks.



- The Oak Ridge National Laboratory (ORNL) in Tennessee has 825,000 gallons of waste containing 235,000 Ci of radioactivity in 34 tanks. (Though not HLW, this is included in the HLW problem area because the waste and tank problems are similar to those faced by HLW sites.)
- West Valley in New York State is currently processing waste from their tank and solidifying the waste into glass logs for disposal in a geologic repository. To protect the public and the environment, this waste must be retrieved from the tank and converted into an appropriate form for long-term disposal.
- DOE has signed Federal Facility Compliance Agreements (FFCAs) with state and federal regulators that drive the scope and schedule for cleanup and closure of the tanks. The total life-cycle cost projected for HLW cleanup is $47 billion. Figure 2.2.2a breaks down the life-cycle cost by site and between the pre-2006 and post-2006 time frames.

End States: High level waste will be retrieved from the tanks and processed to produce an acceptable waste form for storage and disposal. Baseline plans include separation of tank waste into a smaller amount of high-activity waste (which is costly to dispose of) and a large fraction consisting of common chemicals contaminated with low levels of radioactivity. Both fractions will then be immobilized, creating durable solid wastes.

Figure 2.2.2a. Pre-2006, Post-2006 and Life Cycle costs for treating HLW at DOE sites



Field Offices identified in* Accelerating Cleanup: Paths to Closure *for the HLW Problem Area

- ***34 high priority needs***
- ***9 waste streams with high technology risk***
- ***6 of 32 pathways/events on the critical path with high technology risk***

The high-activity waste will be shipped to a monitored geologic repository, while the low-activity waste will be disposed of on-site. The tanks will be closed in accordance with regulatory agreements that are not yet established in most cases. HLW cleanup will take many years to complete; current project plans predict that all waste will be treated and tanks closed by 2046. In many cases, institutional management measures such as land use restrictions and groundwater monitoring will be applied following tank closure. Figure 2.2.2b shows a generic flow sheet for waste processing.

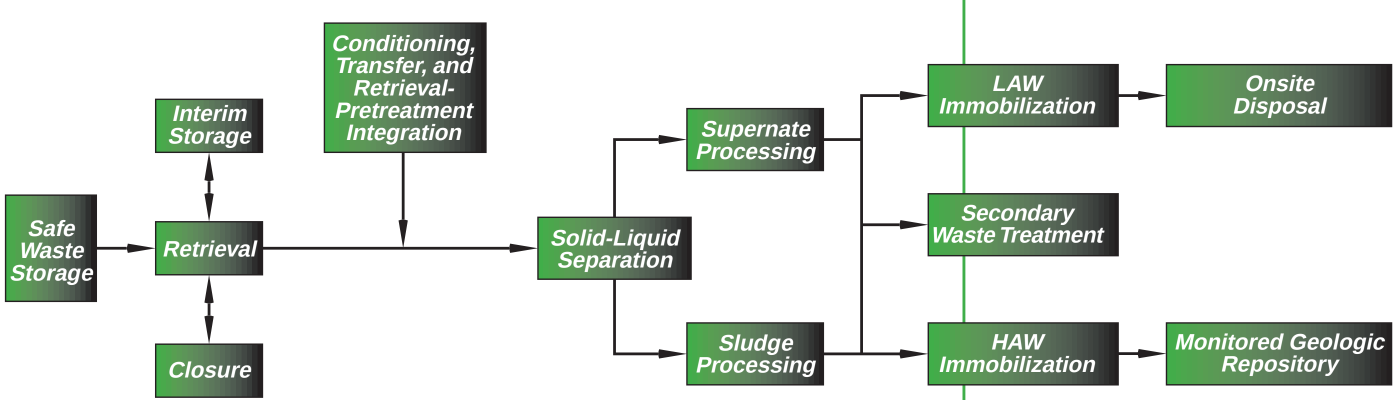
Problem Area Needs: In order to address the HLW problem and reduce cleanup costs, EM must address the following major sets of problems:

- Improved methods to retrieve and monitor waste transfer are needed to detect leaks and prevent line plugging, particularly in aging or failed tanks. The detection, location and removal of pipeline plugs and tank cleaning are still major problems associated with waste retrieval.
- Efficient methods for separating the waste into high- and low-activity fractions, including separation of solids from liquids and radionuclide extraction from the liquids are needed. Reducing the volume of the high-activity waste fraction will significantly reduce disposition costs.
- The development and characterization of the long-term performance of glass waste forms is necessary before waste products can be sent to long-term storage. Waste product performance must be better understood and improved through glass formulation and feed processing, such as has been successfully demonstrated at SRS.
- Tank closure activities need better methods for stabilizing contaminated tanks and a technically defensible and measurable definition of when a tank may be declared "closed", as demonstrated at SRS for Tanks Number 17 and 20.
- Improved methods and equipment are needed to characterize and monitor waste, waste products, processing facilities, and the environment during all aspects of waste storage, treatment, and disposal to reduce environmental, safety and health risks associated with these activities. A better understanding of waste chemistry and physics is required to identify and mitigate potentially hazardous events such as flammable gas generation.

HLW and Waste Tank Drivers

- *Federal Facility Compliance Agreements at SRS, ORNL*
- *Tri-Party Agreement, Richland*
- *Idaho Settlement Agreement, INEEL*
- *Waste Acceptance Criteria at HLW Repository and WIPP*
- *Site-specific LAW acceptance criteria*

Figure 2.2.2b. Generic Tank Remediation Flowsheet.



2.2.3 Environmental Restoration Problem Area

Problem Description: Approximately 3 million cubic meters of solid radioactive and hazardous wastes are buried in the subsurface throughout the DOE Complex. The largest contamination challenges are found at Oak Ridge, Savannah River, Hanford, the Idaho National Environmental and Engineering Laboratory, and Rocky Flats sites. Contaminants are located in the subsurface both above the water table (in the vadose zone) and below the water table (in the saturated zone). Reflecting the geology of the United States, contamination at DOE sites is present in a wide variety of geologic matrices. An estimated 75 million cubic meters of soil and 475 billion gallons of groundwater are contaminated and will require remediation. Contaminants include hazardous metals such as chromium, mercury, and lead; radioactive laboratory and processing waste; explosive and pyrophoric materials; solvents; and numerous radionuclides.

Very large quantities of chlorinated organic solvents, such as carbon tetrachloride, trichloroethylene, and tetrachloroethylene were used and now impact underground water across the complex. Because these dense non-aqueous phase liquids (DNAPLs) are heavier than and sparingly soluble in water, they tend to seep downward and form pools wherever local geology offers some impediment to seepage. Such DNAPL pools serve as continuing sources of contamination to ground water and vadose zone soils.

As demonstrated in Figure 2.2.3a, the total anticipated life cycle cost associated with soil and groundwater remediation using current baseline technology is nearly $15 billion.

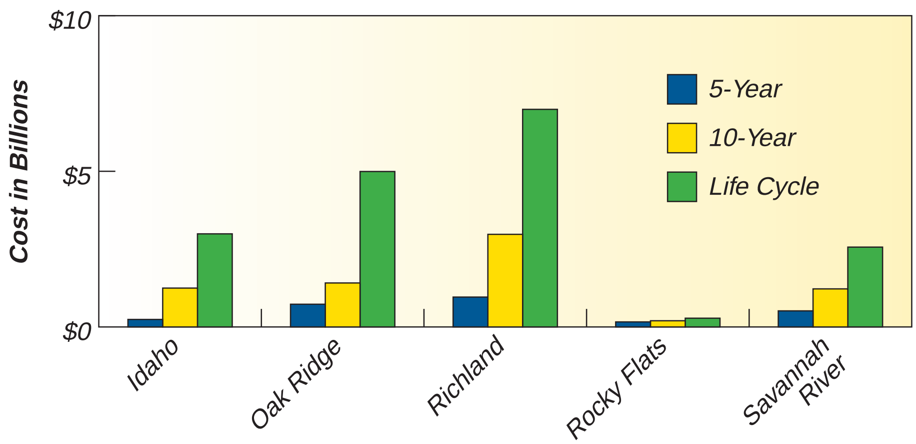


Figure 2.2.3a. Five-Year, Ten-Year, and Life Cycle Costs for the remediation of subsurface contamination at five major DOE Operations Offices

End States: In general, the end state of subsurface cleanup operations is defined within the Federal Facility Compliance Agreement(s) or RCRA permit of each site. Cleanup standards for specific Operable Units or Waste Units will, in most cases, be negotiated with the appropriate regulatory agencies. The ultimate end state is for the department to restore these contaminated sites to a condition acceptable by the public and compliant with all legal and regulatory requirements.

Problem Area Needs: EM has developed an investment strategy responding to needs identified for the set of actions involved in a soil and/or groundwater remediation process, illustrated in Figure 2.2.3b. Environmental Restoration needs fall into five major program areas.

- Cost effective remediation plans require characterization of the inventory, distribution, and movement of contaminants in the vadose and saturated zones that are adequate for decision making and initial remedial actions, if any are required. Improved analytical tools, in situ monitoring devices, understanding of permeability patterns, and tools to predict groundwater flow and transport are required to characterize and quantify these contaminants.

Field Offices identified in* Accelerating Cleanup: Paths to Closure *for the Environmental Restoration Problem Area

- ***57 high priority needs***
- ***25 waste streams with high technology risk***
- ***42 of 281 pathways/events on the critical path with high technology risk***

- The ability to contain or stabilize leaks and buried waste hotspots in situ requires resolution of problems in several areas. Improved surface barrier systems are needed to provide effective containment of leaking landfills, trenches, tanks, and high concentration plumes. Methods are needed to stabilize buried wastes in situ to prevent leaching and contaminating the vadose zone. Cover systems that provide robust waste isolation over a range of climatic conditions and extreme events for periods over 100 years are needed for many applications. Finally, in situ barriers need to be developed to provide effective containment of dispersed contaminant plumes.
- The ability to treat or destroy mobile contaminants in situ is dependent on resolution of problems in several areas. Biological treatment methods are needed for remediation of low to moderate concentrations of organic solvents in soils and groundwater. Chemical treatment technologies to destroy or immobilize highly concentrated contaminant sources (metals, radionuclides, explosive residues, and solvents) in the vadose and saturated zones are needed to increase remediation rates. Finally, improved deep drilling technology is needed to provide access to deep contaminant plumes for sampling, retrieval, and delivery activities.
- Highly radioactive, explosive, and pyrophoric wastes pose unacceptable risks to remediation workers during retrieval and treatment. The capability must be developed for on-site characterization and remote retrieval of these hot spots which are not amenable to in situ treatment.
- In order to obtain regulator and stakeholder acceptance of containment, stabilization and treatment technologies in remediation plans, methods to validate and verify containment and treatment system performance and integrity must be developed.

The Subsurface Cleanup Challenge:*

- *475 billion gallons of contaminated groundwater in 5700 distinct plumes*
- *75 Million cubic meters of contaminated soil*
- *3 Million cubic meters of leaking waste buried in landfills, trenches, and spill areas*

** from* "Linking Legacies Report" *January 1997, DOE/EM-319*

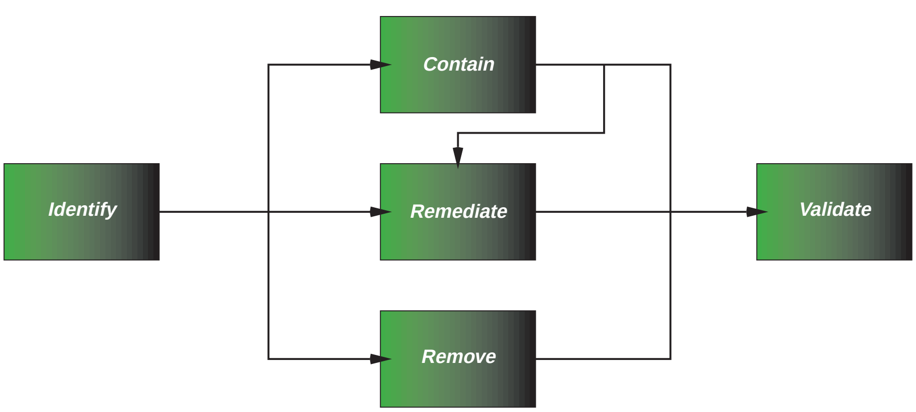
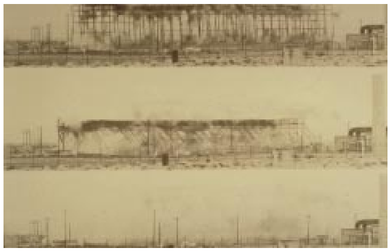


Figure 2.2.3b. Generic flowchart for the remediation of subsurface contamination



2.2.4 Deactivation and Decommissioning Problem Area

Problem Description: DOE constructed over 20,000 facilities to support nuclear weapons production and other activities, many of which are now contaminated with radioactive materials, hazardous chemicals, asbestos, and lead (including lead paint), have exceeded their design life and no longer serve a mission for the DOE. The potential for release of radioactive and hazardous materials to the environment and local communities and the risk of industrial safety accidents due to deterioration of these old facilities require monitoring and maintenance activities. DOE is planning to deactivate and decommission these facilities to reduce these risks and associated costs.

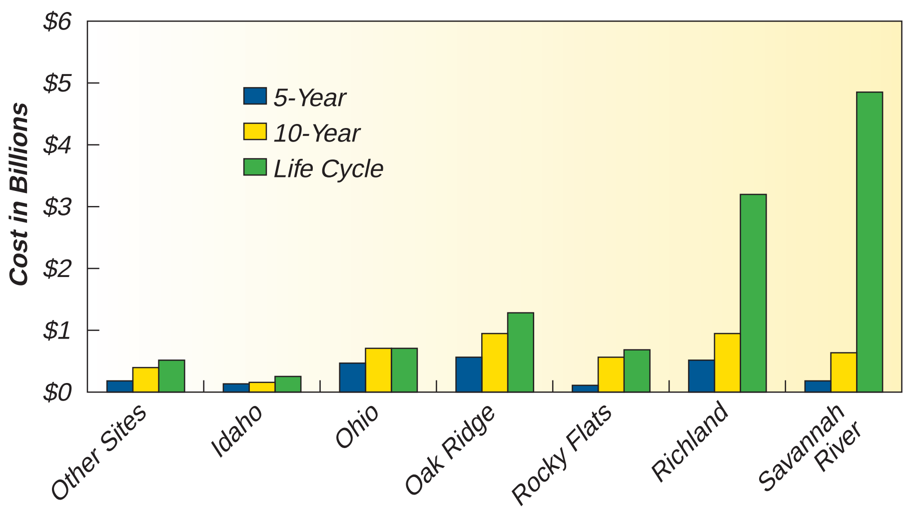


Figure 2.2.4. Five-Year, Ten-Year, and Life-Cycle Costs for deactivation and decommissioning at the major DOE Operations Offices

EM's deactivation and decommissioning life cycle cost is $11.3 billion. This is about 36% of the total estimated cost ($31B) for all DOE deactivation and decommissioning activities. Figure 2.2.4 shows the deactivation and decommissioning 5-year, 10-year and life-cycle costs at the Operations Office level. EM's deactivation and decommissioning problem is grouped into 76 site projects with each such project described in a Project Baseline Summary (PBS). Even within this complex-wide planning process, it should be noted that these PBSs do not include all of the buildings, and do not capture all of the outyear costs/ mortgages for their cleanup and disposition. As shown in Table 2.2.4, deactivation and decommissioning costs are broken down into five major categories: pre-deactivation surveillance and maintenance, deactivation, facility decommissioning assessments, pre-decommissioning surveillance and maintenance (S&M), and decommissioning.

Table 2.2.4. Life-Cycle Costs for DOE-EM deactivation and decommissioning ($ in millions)

	FY97-06	FY07-70	Total
Pre-Deactivation S&M	745	1,627	2,356
Facility Deactivation	771	575	1,381
Deactivation subtotal	**1,516**	**2,202**	**3,737**
Pre-Decommissioning S&M	297	3,186	3,359
Facility Assessments	155	83	247
Facility Decommissioning	2,167	1,669	3,932
Decommissioning subtotal	**2,619**	**4,938**	**7,538**
Totals	**4,135**	**7,140**	**11,275**

EM typically performs decommissioning under CERCLA as a non-time-critical removal action. In fact, there are few regulatory compliance agreements at DOE sites that specify deactivation and decommissioning activities. Most site Federal Facility Agreements deal with legacy waste (HLW, TRU, MLLW, etc.) and contaminated soil and groundwater problems, not with contaminated buildings. The exceptions are Fernald, Mound, Rocky Flats, and portions of Hanford, INEEL, Oak Ridge, and Savannah River. Fernald, Mound, and Rocky Flats are designated as closure sites. Under current planned funding scenarios, Mound is expected to close by the end of FY2003, Fernald by the end of FY2006, and Rocky Flats in the FY2006-2010 period.

End States: The end states for most DOE-EM facilities and buildings have not been defined. These may range from institutional controls to brownfields to a few greenfields (i.e., from sites having controlled access, to sites having restricted access and limited usage such as industrial use, to sites having completely unrestricted access and usage.) End states are negotiated by the Department working with regulators (State and Federal) and local stakeholders. In many instances it is desirable and economically advantageous to transition the facilities to non-EM uses.

Field Offices identified in **Accelerating Cleanup: Paths to Closure** ***for the Deactivation and Decommissioning Problem Area***

- ***34 high priority needs***
- ***11 of 30 pathways/events on the critical path with high technology risk***

Problem Area Needs: In *Accelerating Cleanup: Paths to Closure* the site problem holders for deactivation and decommissioning activities have identified ninety-two technology and eight basic science needs that must be met to accomplish the current baselines. Life Cycle Asset Management has only recently been emphasized within DOE. As more close-out activities are identified and planned it is anticipated that the list of technology needs will expand. The current set of major problem areas include:

- remote characterization, decontamination and dismantlement technologies for tritium or plutonium contaminated facilities and highly radioactive environments.
- underwater characterization, video inspections, sample collection, radiological surveys, sizing, handling, packaging and decontamination problems associated with fuel storage pools and associated facilities.
- remote characterization of chemical reprocessing facilities (canyons) to enable possible end states to be assessed and appropriate disposition path(s) to be developed.
- methodologies capable of characterizing and detecting hazardous species to release limit levels for treatment and recycle of contaminated scrap metal.
- remote and/or robotic technologies for deactivation and decommissioning of hot cells and gloveboxes which are contaminated with high levels of radioactivity and which are often confined spaces.
- identification of the quantity and location of radioactive contamination and control and containment of aerosols and airborne contamination (graphite particles) generated by dismantlement operations during the deactivation and decommissioning of graphite reactors.
- evaluation of the option of disposing of chemical reprocessing facilities (canyons) by removing all contaminants above the TRU threshold (100nCi/g), filling the structure with low level waste, and entombing the canyon as a permanent LLW disposal facility.

The estimated cost for deactivation and decommissioning DOE's facilities is $31 billion. EM is currently responsible for only about one third of that cost.

Considerable deactivation and decommissioning expertise resides in the commercial nuclear sector within both nuclear utilities and commercial deactivation and decommissioning contractor firms. EM has partnered with the commercial nuclear industry to exchange lessons learned and best practices and to develop a leveraged research, development and deployment program that meets deactivation and decommissioning technology needs for both DOE and the commercial sector.

2.2.5 Nuclear Material (Pu, SNM) Problem Area

Problem Description: Environmental Management has responsibility for nuclear materials at many sites around the DOE Complex. The material categories include metric ton quantities of fissile material in the form of metals and oxides, residues, and other processing intermediates left from nuclear weapons production. It also includes varying quantities of radioactive material in the form of laboratory samples, neutron sources, rare and man-made isotopes, and other materials determined to be excess to national needs. Recent safety vulnerability analyses and recommendations by the Defense Nuclear Facilities Safety Board (94-1, 97-1) have resulted in a major effort to stabilize nuclear materials, principally plutonium and uranium, to a form more suitable for safe interim storage, pending disposition.

In the context of these safety activities, the nuclear materials are being converted to a form that has a defined path forward: either disposition using acceptance criteria being established by the DOE Office of Fissile Materials Disposition or disposition via direct disposal as waste. For some sites, issues involving management of large inventories of material and the disposition of all excess radioactive materials must be resolved in order to enable significant mortgage reduction. Shipment to disposition or central storage locations will enable significant life cycle cost savings for the DOE Complex, significant reduction in safety vulnerabilities, and the eventual closure of some DOE sites.

The projected life cycle costs for dealing with special nuclear materials are shown in Figure 2.2.5 for the three major EM sites. These sites retain the bulk of nuclear materials that require stabilization for long-term storage or direct disposal as waste. Several other sites have either relatively small nuclear material holdings or materials that are already in the appropriate safe storage forms.

End States: Near term activities will stabilize these materials in a form suitable for safe interim storage. For some materials, minimal treatment is required for packaging and certification for disposal at the Waste Isolation Pilot Plant. Stabilization activities will affect the transfer of other nuclear materials in safe storage to the Immobilization Facility (managed by the Office of Fissile Materials Disposition) for treatment to meet nonproliferation goals and Monitored Geologic Repository acceptance criteria. For some types of radioactive materials, the end states and baseline pathways to achieve disposition are not completely defined at present.

Problem Area Needs: In order to address the near-term safety requirements, and accelerate the schedule for disposition, science and technology needs in the following areas must be addressed:

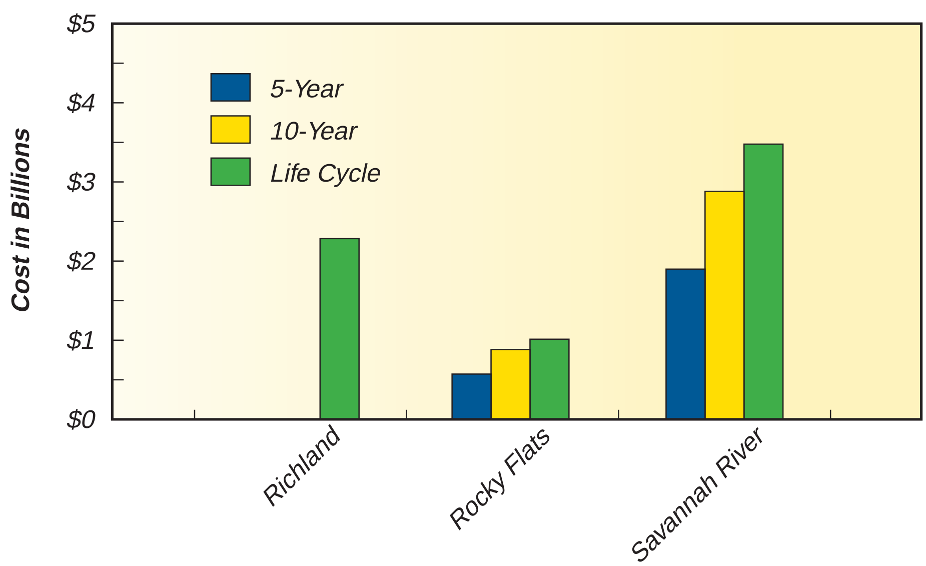


Figure 2.2.5. Five-Year, Ten-Year, and Life Cycle Costs for nuclear material management and dispositioning selected sites

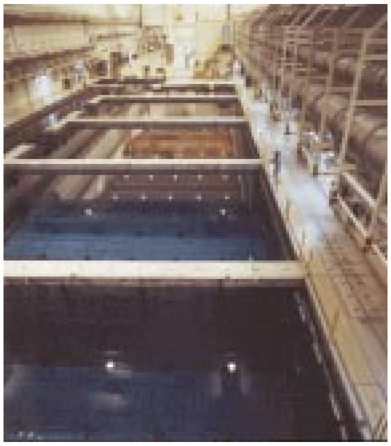
- development of storage standards that meet safety requirements and also meet the acceptance criteria for WIPP or the Immobilization Facility. Long-term storage standards and acceptance criteria must be based on proven technical bases. Research and development and testing on materials can reduce the risk for failure and lead to cost efficiencies associated with mortgage reduction.
- development of stabilization and packaging technologies to meet safe storage standards. There is no single stabilization method applicable to all materials, given the complexity of the materials and the variety of physical forms. Alternate stabilization technologies can significantly reduce waste generation, worker exposure and cost of operations. Complex-wide initiatives for common packaging technologies reduce failures in materials packaging.
- development of both baseline and backup stabilization and packaging technologies until it is certain the baseline approaches are implementable and workable. The simultaneous development of alternative technologies reduces long-term schedule risk and escalating development costs. It also promotes competition in technology development, as well as offering tools to solve multiple complex-wide issues beyond nuclear materials.
- development of safety surveillance technologies and shelf-life programs to monitor stored materials. Advanced surveillance and monitoring technologies can reduce environmental, safety and health related issues when problems are identified. Centralized storage facilities reduce complex-wide mortgage costs.

For the longer-term, science and technology needs in the following areas must be addressed:

- improvement in the underlying science of nuclear material stabilization and storage in order to improve the understanding of material behavior and increase the ability to anticipate problems. This will also promote cross-cutting areas within the DOE complex.
- definition of end states and baseline pathways for the disposition of all nuclear materials presently identified by the Office of Environmental Management. This promotes better use of resources, leads to better long-term strategic planning, and reduces the schedule risks beyond operations identified in the EM Accelerating Cleanup Plan.

Field Offices identified in* Accelerating Cleanup: Paths to Closure *for the Nuclear Materials Problem Area

- ***21 high priority needs***
- ***4 of 19 pathways/events on the critical path with high technology risk***



2.2.6. Spent Nuclear Fuel Problem Area

Problem Description: The Idaho National Engineering and Environmental Laboratory, the Savannah River Site, and the Hanford Site manage most of the existing spent nuclear fuel (SNF) in the DOE Complex. The safe, reliable, and efficient management of DOE SNF and preparation for its final dispositioning is a major challenge due to the multiple sites involved and the wide variety in SNF types.

- Hanford Site - Over 2,100 metric tons heavy metal (MTHM) of SNF are currently in inventory. After washing, packaging, and drying, this SNF is expected to be transferred to dry storage. Final disposition in a geologic repository may require additional processing and packaging.
- Idaho National Engineering and Environmental Laboratory (INEEL) - Approximately 60 MTHM of SNF will be received from off-site sources. Currently, there are 270 MTHM (640 cubic meters) of SNF in inventory. After on-site storage, drying, and packaging, all SNF is expected to be shipped off-site to a repository for disposal.
- Oak Ridge National Laboratory (ORNL) - Less than one MTHM of SNF will be managed. After disassembly and repackaging, this SNF will be transferred to the Savannah River Site and the Idaho National Engineering and Environmental Laboratory.
- Savannah River Site (SRS) - Approximately 20 MTHM of SNF are in inventory and 30 MTHM of spent fuel are expected to be received. After on-site management, the spent fuel is expected to be placed in an off-site geologic repository.

End States: Prior to 1992, most DOE SNF was reprocessed. In 1992, DOE began to phase out reprocessing operations. In 1995, DOE decided upon a planning base that identified disposal of DOE SNF in the first geologic repository. Since then, deliberations between EM and RW have determined a need to articulate the requirements that must be met in order for DOE SNF to be accepted in a monitored geologic repository. In June 1995, the Record of Decision for the Programmatic SNF Management Environmental Impact Statement defined the path forward for the management (40-year period) of DOE SNF as regionalization-by-fuel-type. Under this alternative, as modified by the Idaho Settlement Agreement, SNF management occurs at three sites until a repository is opened. The sites are: Hanford, the INEEL, and the SRS. The fuel type distribution is: Hanford fuel will remain at its present location with the exception of its sodium-bonded fuel, which will be transported to the INEEL for treatment; aluminum clad fuel will be consolidated at the SRS; and non-aluminum clad fuels (including the Naval SNF, but excluding the Fort St. Vrain SNF, which will be safely maintained at its present location in Colorado) will be transferred to the INEEL.

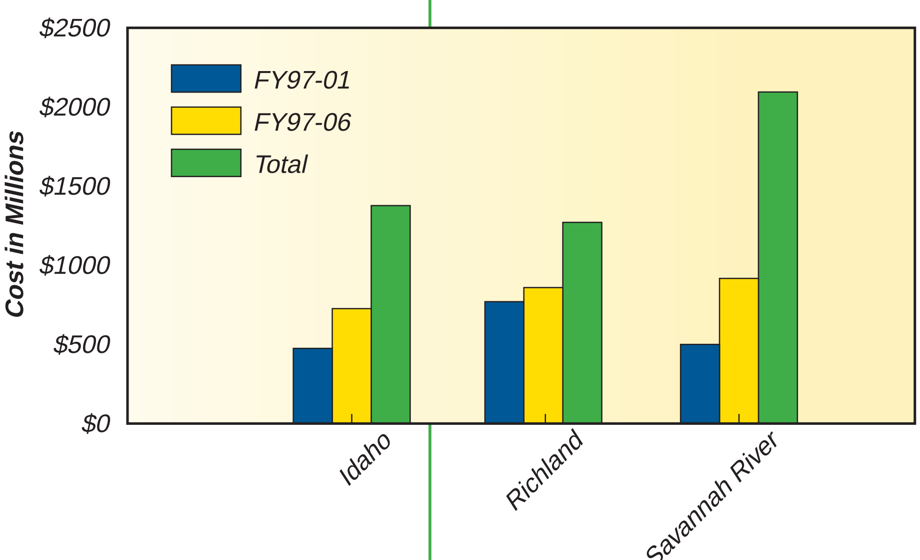


Figure 2.2.6. Five-Year, Ten-Year, and Total Life Cycle Costs for management and disposition of Spent Nuclear Fuel

End states for DOE spent nuclear fuel include two features: safe and effective interim dry storage, followed by shipment of prepared SNF to a Monitored Geologic Repository (MGR). At the MGR, SNF is to be inserted into waste disposal packages and emplaced in geologic strata, while maintaining a recovery capability for up to 300 years.

Field Offices identified in* Accelerating Cleanup: Paths to Closure *for the SNF Problem Area

- ***13 high priority needs***
- ***7 waste streams with high technology risk***
- ***5 of 16 pathways/events on the critical path with high technology risk***

Problem Area Needs: Each of the SNF projects has particular needs related to the type(s) of fuel and storage configurations at that site. The major objectives in each case are to mitigate existing risk sources, establish and maintain safe interim storage conditions, and prepare for final geologic disposition.

The safe management, storage, and geologic disposition of SNF requires solutions in the following problem areas:

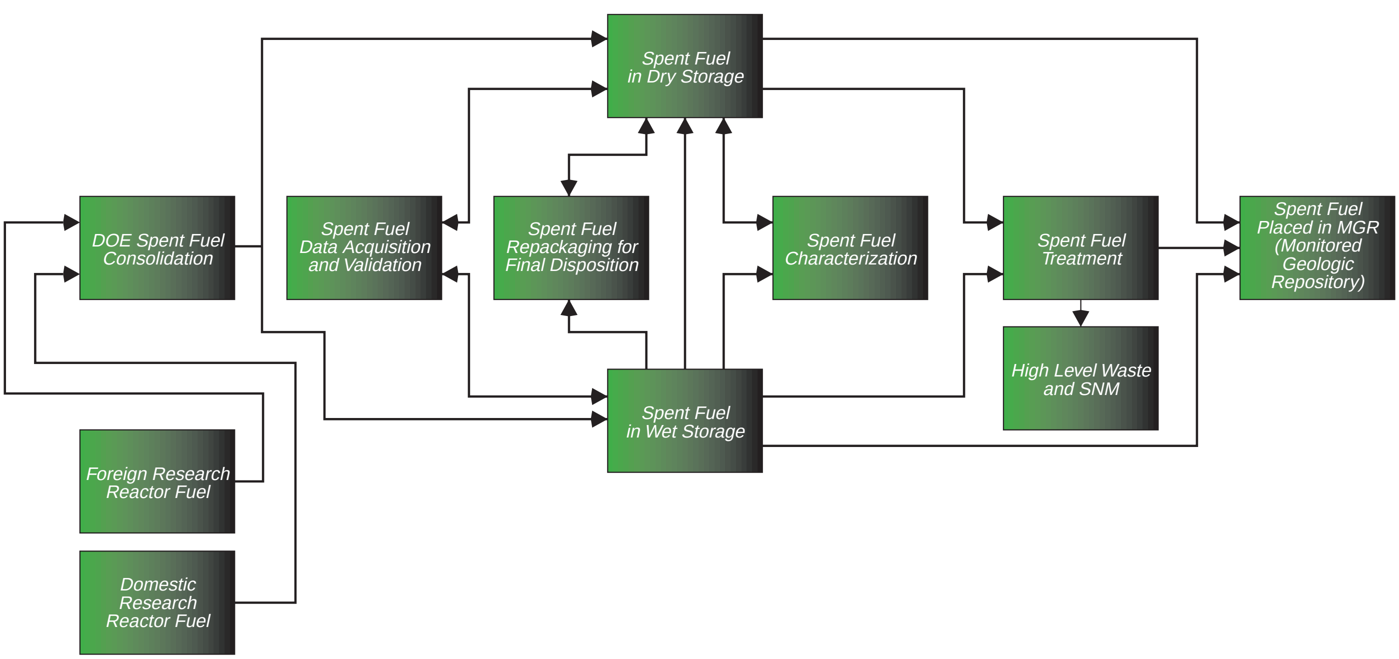
- nondestructive assay/examination (NDA/E) systems to provide characterization (and qualification) of SNF and acceptance criteria data,
- treatment methodologies for sodium-bonded SNF (Hanford and INEEL), aluminum-based SNF (SRS), and others as needed,
- drying and conditioning processes to prepare SNF for long-term storage, and disposal,
- characterization and safe dry storage of Hanford metal SNF, and
- development of performance models for criticality, heat-transfer, radionuclide source terms, and other calculations for all fuel types in dry storage and at the repository.

The National SNF Program will interface with the Office of Civilian Radioactive Waste Management (OCRWM) during all phases of storage, management, and planned geologic disposition of DOE SNF. The National SNF Program will integrate EM development activities with OCRWM to reduce overlap and obtain maximum advantage of OCRWM development activities on commercial SNF.

SNF Drivers

- *Federal Facility Compliance Agreement ORNL*
- *Tri-Party Agreement, Richland*
- *Idaho Settlement Agreement, INEEL*
- *Waste acceptance criteria for material at MGR*

Figure 2.2.7 Pathway for SNF Disposition to a Monitored Geologic Repository



3.0 PROGRAM DEVELOPMENT PROCESS — CREATING SOLUTIONS TO CLEANUP NEEDS

This section describes the process being institutionalized within EM to make science and technology investments. The process is in various stages of implementation and is expected to be fully implemented in time to support formulation of the FY-2000 budget.

EM has adopted systems engineering and technology roadmapping as key tools in its approach to business. The systems engineering approach provides the foundation for EM cleanup program and project decisions and implementation that are requirements driven, technically defensible, cost-effective, and satisfy stakeholders and regulators. Technology roadmapping provides a methodology to define and focus science and technology investments and activities to obtain the maximum benefit to the EM cleanup program.

EM cleanup project manager participation, review, validation, and ultimate ownership is essential to ensure that the science and technology investments address real needs and result in the implementation of solutions.

The development and execution of EM's science and technology investments can be described in four steps: 1) identification of cleanup project manager needs through data collection and analysis; 2) technical response development; 3) program prioritization and budget request; and, 4) program execution and solution implementation. These four steps are shown in Figure 3.1, and are described in the following sections. In addition to science and technology investments that directly address cleanup-project-related needs, EM also invests in basic research. The process for determining how these investments are made is described in Section 3.5. Merit review, a critical component of managing research and development activities, is an integral part of the program development and execution process. It is discussed in Section 3.6.

The involvement of EM cleanup project managers is essential at each step in the program development and execution process. EM cleanup project managers are the operations facility and process owners throughout the DOE complex. They are responsible for: remedial action, pollution prevention, deactivation and decommissioning, the safe

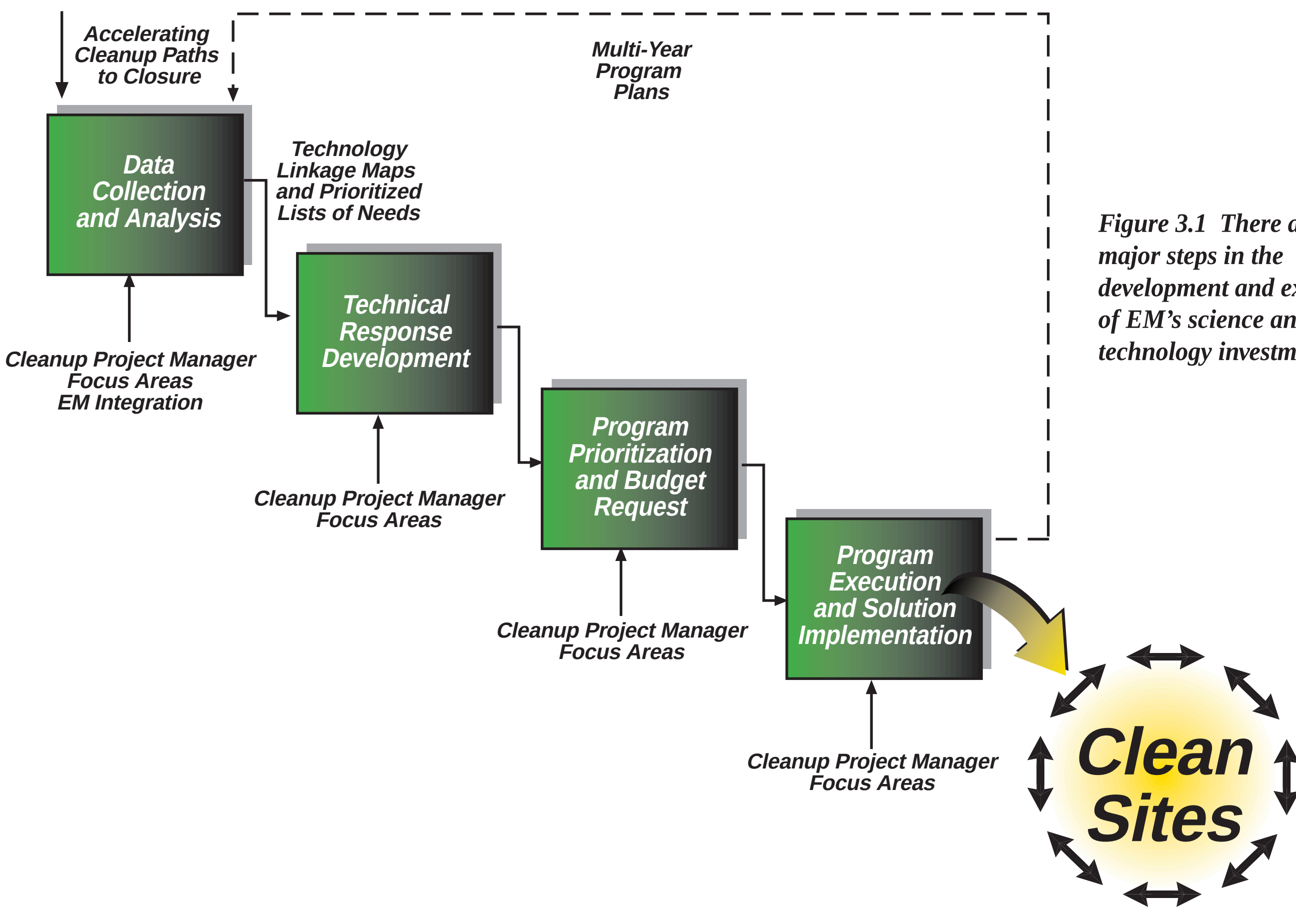
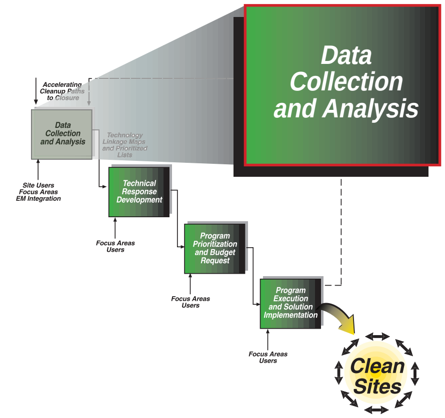


Figure 3.1 There are four major steps in the development and execution of EM's science and technology investments.

management of waste, and the disposition of nuclear material and spent fuel. EM cleanup project manager participation, review, validation, and ultimate ownership ensures science and technology investments properly flow through the technology development process and result in the implementation of solutions to EM cleanup problems.

Oversight for user involvement is provided by User Steering Committees, one committee for each Focus Area. These User Steering Committees provide managerial review of the science and technology investments in their area of responsibility. Cleanup project manager involvement also serves to ensure stakeholder involvement is provided during the development, demonstration, and deployment of new technologies.



3.1 Data Collection and Analysis — Defining the Problems to be Solved

Identification of cleanup project manager needs is the first step in the development of solutions to EM cleanup problems. Input from cleanup project managers is essential to accurately define and validate the needs to be addressed by EM's science and technology investments. EM relies heavily on their input as the primary source for the definition and communication of site-specific needs. The needs identified by cleanup project managers reflect stakeholder values as a result of stakeholder participation in establishing site-specific compliance agreements and identifying site needs.

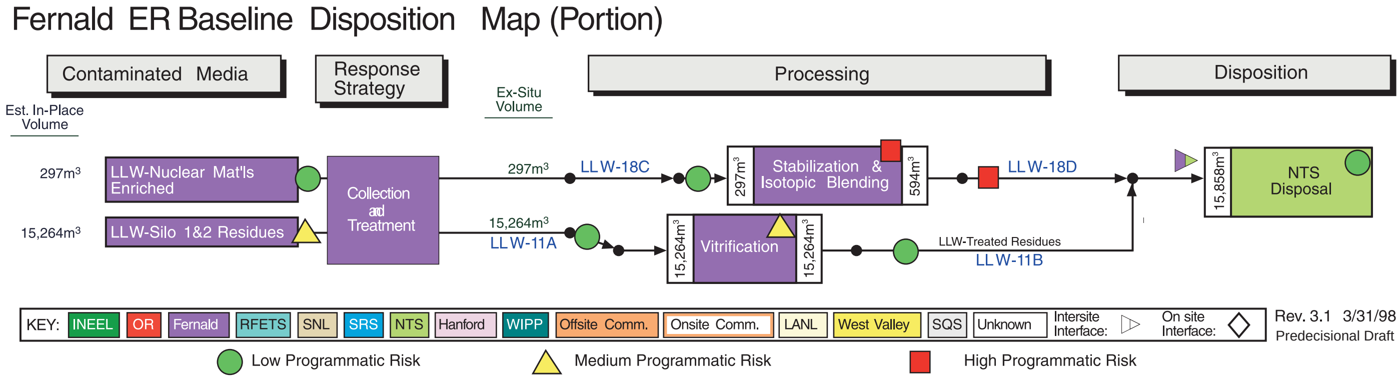
Program needs are currently derived from needs developed by cleanup project managers and documented in cleanup project manager need statements, disposition map technology risk levels, critical pathway technology risk levels, and information in the Project Baseline Summaries (PBSs), which are the highest level project descriptions.

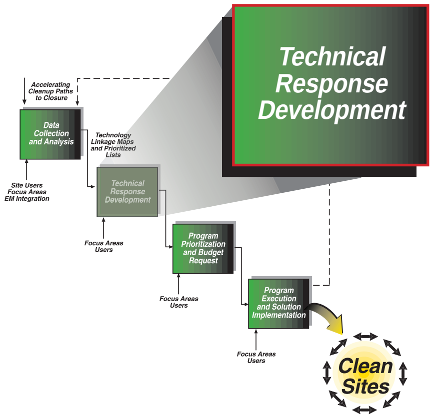
EM's critical pathway analysis provides keen insight into the cleanup project manager's schedule requirements, the priority of the science or technology need on a site wide basis, and the impact of failing to adequately address the need in the time allotted.

- Cleanup project manager need statements include information on the priority, the timing, (including potential deployment/implementation schedule) and the technical detail associated with a site problem.
- Disposition map technology risk levels illustrate the maturity of the planned technological solution (e.g., bench scale prototype to an existing operating facility). An example disposition map with programmatic risk level indicators is shown in Figure 3.2.
- Critical pathway analysis also provides an understanding of the maturity of the technological solution, but links the risk to key activities and events in the path to complete cleanup of the site.
- Project Baseline Summary information includes life-cycle cost, schedule, current technical approach, and environment, safety and health risk.

These data sets provide insight as to the size (cost and pervasiveness) and complexity of the technical issues facing EM. They also identify the cleanup project manager, when the solution is needed, and the impact of not addressing the need. Taken in aggregate, they provide the fundamental basis for the development of a technical response.

Figure 3.2 Disposition maps display the cradle to grave management strategy for the waste streams at each site.





3.2 Technical Response Development — New and Improved Solutions

The development of a satisfactory technical response is an iterative process that begins with data collection and analysis. The technical response is developed through continuous dialogue between the cleanup project managers and the science and technology developers. In this step the Focus Areas develop fully integrated, multi-year responses to the site needs.

The Focus Areas work closely with cleanup project managers to identify and document the specific science and technology requirements a solution must meet. The Focus Areas are the liaisons between the cleanup project managers and the scientists working on research projects. Information such as target waste streams, waste quantities to be processed, work-off schedule, system processing rate requirements, regulatory requirements and issues, commercialization potential, stakeholder issues, environmental risks, programmatic risks, technology availability and maturity, disposition of treatment residuals, and stewardship requirements are all considered.

Strategic planning and documentation are key to developing sound technical responses to cleanup project manager needs. The Focus Areas establish life-cycle planning for the solutions they are providing. The planning level of detail associated with these activities is commensurate with the particular program stages of science, development, demonstration, or implementation. Documentation of the technical response strategy and performance metrics provides a framework with which to develop test plans, commercialization strategies, and project review criteria.

The technical response is developed through continuous dialogue between the cleanup project manager and the science and technology community. This dialogue results in fully integrated multi-year responses to site needs.

The preparation of the technical response includes integration of the specific science and technology investment with the cleanup project manager's project, an essential requirement for successful implementation. It is through this process of integration that joint planning is done to ensure budgets are adequate to support the development efforts, schedules line up with technology insertion points, and the cleanup programs have the financial resources and technical support to enable implementation and deployment of new solutions.

Finally, ongoing science and technology investments are evaluated at key decision points to determine if an effort should be continued or if an alternate strategy should be adopted. Cleanup project managers are involved in these project evaluations to ensure continued commitment to implementation of the solution. This iterative set of cleanup-project-manager approved, technical responses provide the basis for the complete investment portfolio.

3.3 Program Prioritization/Budget Request — Investment Strategy to Maximize Returns

The complexity and duration of the EM cleanup effort, combined with budget constraints and regulatory changes, requires EM to carefully prioritize and sequence cleanup projects. These same factors drive a continuous effort within EM to rank and prioritize science and technology investments. The prioritization efforts are used to assist in decision-making and are the basis for outyear budget requests.

The prioritization process is iterative and integrative, beginning at the site problem level and progressing to higher levels and greater breadth with each iterative step. While Focus Areas develop technical responses to each need, to ensure an optimum investment portfolio the responses must be integrated and prioritized. To ensure that a technical response meets a cleanup need, only those that are endorsed by a project manager will be considered for integration and prioritization in the portfolio. Prioritization is first done by the Focus Areas, and then thoroughly reviewed, changed as necessary, and approved by the Focus Area's User Steering Groups.

At this point the technical responses are compiled into work packages. These Focus-Area-developed work packages represent a set of related technical responses to site problems. A national prioritization process is then applied through a multi-attribute analysis using the data sets illustrated in Figure 3.3 on a work package basis. In this manner, the work packages and technical responses are listed in priority order. The output of the prioritization system goes through a final review cycle. DOE's Field Office Managers and EM's Deputy Assistant Secretaries determine the final integrated priority list. This integrated priority list is the basis for the Congressional budget request for EM's investment portfolio.

Using* Accelerating Cleanup: Paths to Closure *data, EM can determine and prioritize, on a national level, the optimum set of technology investments.

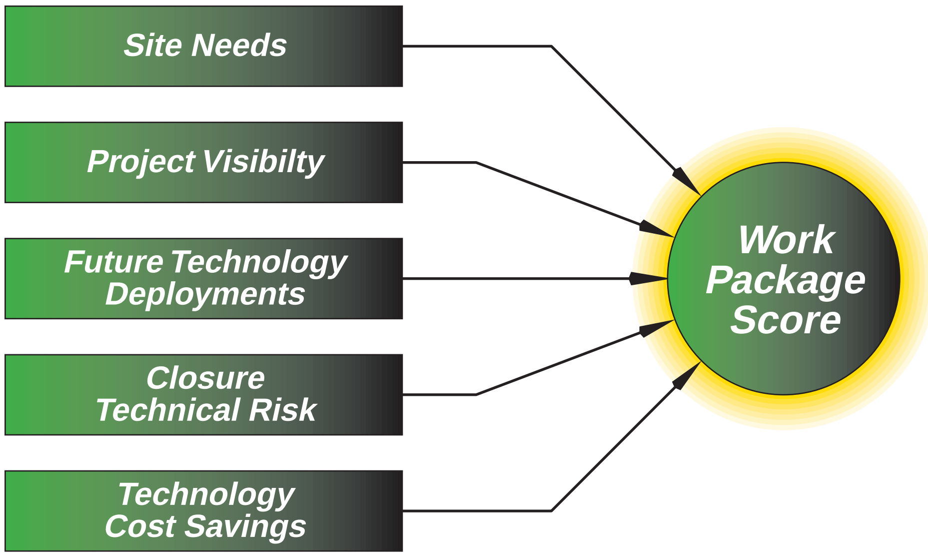
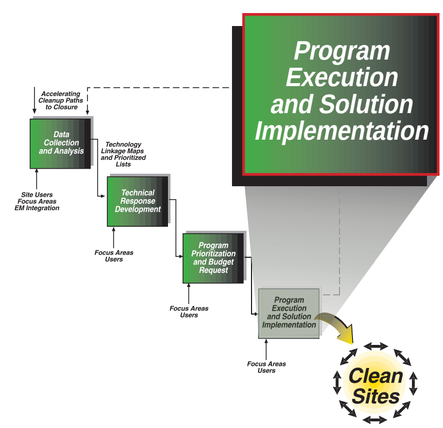


Figure 3.3 Use of a national prioritization system allows a priority listing of cleanup project manager approved work packages that are connected to EM cleanup projects, site needs, waste streams, and critical pathways.

EM's national level prioritization process for science and technology was first used in March 1998 to prioritize the Fiscal Year 2000 budget request. The process used data provided by the sites in support of the *Accelerated Cleanup: Paths to Closure*. As the process is used, improvements will be made. The prioritization methodology and criteria will be modified as necessary to establish a stronger and more effective national prioritization system.

3.4 Program Execution and Implementation—Making it Work

The final step in the program development process is to make the planned investments in science and technology and then to ensure that the results are deployed in cleanup projects. This section describes the execution of the portfolio investments and the implementation of the results to enable and enhance cleanup activities.



3.4.1 Program Execution — Creating Solutions

Each fiscal year, Congress provides EM funding for cleanup projects and investments in science and technology. These funds are allocated according to the integrated priority list described in Section 3.3, and a set of work packages are authorized.

In general, a significant fraction of the investment portfolio will be applied to the continuation of existing work scope, as most research and development activities are multi-year efforts. However, when new work scope is to be initiated, the work is announced and competed. This competition ensures that the best talent is brought to bear on EM's key problems. The requests for proposals are conducted through either targeted or broad solicitations depending on the work scope. That is, new research efforts are broadly announced to the larger scientific audience, while near term deployment opportunities, requiring a more rapid response, may be biased toward the private sector.

The investment portfolio is managed through the Focus Areas. This approach means that for any given problem area, the complete set of activities ranging from science to deployment is managed as an integrated investment. This requires the Focus Areas to coordinate the research and development efforts of universities, national laboratories, industry, and site management contractors and also to be aware of other federal and state programs investing in related research and development.

The Focus Areas function as national programs, and therefore they preferentially support science and technology that addresses the needs of multiple EM sites. In general, national programs within DOE are difficult to manage because they require the cooperation of diverse sites that are progressing with cleanup under different schedules and regulatory requirements. In addition, no two waste streams, facilities, or site geology's are quite the same. The Focus Areas understand and take into account the differences between the sites, whether they are regulatory, political, or technical, to ensure the rapid and widespread implementation of solutions.

3.4.2 Program Implementation — Delivering Solutions

Implementation of solutions at the sites is the driving force behind EM's science and technology investments. To meet the goals set in *Accelerating Cleanup: Paths to Closure*, the investment portfolio must enable or accelerate the cleanup effort and reduce cost and risk. In FY 1998, there are literally hundreds of science and technology activities within EM that are focused on performing cleanup better, safer, faster, and cheaper.

While cleanup technologies are often developed at national laboratories, universities, and other academic institutions, EM procures many cleanup services and equipment from commercial providers through a competitive bidding process. The implications for EM's science and technology program are twofold. First, technology developers must successfully transfer their innovations to the commercial sector before they can be fully deployed. Second, even if technology providers, the EM science and technology program, and cleanup project managers work closely together to develop a new technology, there is no guarantee that the technology will win in a competitive procurement. The technology must stand on its own merits, be cost effective, and offer significant and desired advantages over other approaches without introducing unacceptable technical risk.

3.5 EM Investments in Basic Research—Development, Implementation, and Execution

The development, implementation, and execution of EM's investments in basic research is accomplished through a partnership between the Office of Environmental Management and the Office of Science. Environmental Management has the lead for soliciting research needs from the cleanup project managers, ensuring that selected research projects have application to the Department's cleanup problems, and ensuring that results of the research are communicated to Department and contractor personnel having cleanup responsibilities. Environmental Management also manages the financial aspects of the EM basic research investments. The Office of Science manages the solicitation of research proposals and the scientific review process, and assists the Focus Areas with the technical management of the research program. The DOE Idaho Operations Office conducts needs analyses, provides financial management and procurement support, and serves as an interface with other DOE field offices and the Focus Areas.

EM's merit review provides credible and independent evaluation for scientific and engineering merit of science and technology projects. Merit review is done at various stages of development from basic research to late-stage demonstration and deployment.

The Environmental Management-Office of Science partnership was created to ensure that EM basic research investments directly support development of new and improved solutions to DOE cleanup problems and that the research is scientifically meritorious. The call for research grant proposals is based on research needs identified by EM, focusing the EM basic research on intractable cleanup problems or problems needing better solutions. The Office of Science reviews the scientific merit of research proposals. Only proposals that successfully pass both reviews are recommended for funding. Researchers are required to submit annual reports on the progress of the research projects.

3.6 Review and Evaluation - Ensuring a Quality and Focused Program

Internal and external review by peers and sponsors is generally recognized in the science and technology community as important to sound decision making. Reviews by independent peers are widely used to evaluate research proposals and to assess the productivity and progress of ongoing work. In addition, reviews present an opportunity to enable EM cleanup project managers to ensure that the technologies being supported can be implemented. Two issues are foremost during EM reviews—scientific or technical merit and programmatic relevance (potential to meet cleanup project manager needs).

Scientific merit review is performed by independent peer reviewers from universities and DOE laboratories, selected by the Office of Science on the basis of their professional qualifications and expertise. These reviewers perform a rigorous, formal external peer review and evaluation of each proposal or progress report. The evaluation criteria include scientific and/or technical merit, appropriateness of the proposed method or approach, competency of applicant's personnel and adequacy of proposed resources, reasonableness and appropriateness of the proposed budget, and other appropriate factors. The relevance review for research projects is performed by Environmental Management subject matter experts. The criteria for the relevance review include reduction in time required to achieve EM mission goals, decrease in risk (to public and workers, or the environment), major cost savings, new knowledge or a solution to an intractable problem.

Technical merit reviews of technology and technology maturity are conducted for EM by the American Society of Mechanical Engineers (ASME). ASME review panels provide independent, external evaluation of the technical merits of a technology. Merit review is done at various stages of development from basic research to late-stage demonstration and deployment. These reviews provide an important input to technology development managers for "go/no-go" decisions for project selection or continuation. They provide a common basis on which to assess and manage performance, expectations, and transition of science and technology projects. Merit reviews are required for all new projects, at least every three years for continuing projects, and for projects that are entering the Engineering Development Stage (i.e., passing Gate 4), as discussed in Section 4.1.

Programmatic Relevance Reviews (Midyear Reviews) are conducted by each Focus Area to evaluate research projects for programmatic relevance and technical, schedule, and cost performance. Of paramount interest is project maturity and progress toward meeting cleanup project manager requirements. Project maturation from research through deployment is tracked and facilitated. Programmatic relevance review panels include DOE program managers, subject matter experts, cleanup project managers, stakeholder representatives, and technology developers, as appropriate. Projects which do not progress or for which cleanup project managers endorsement wanes are considered for termination.

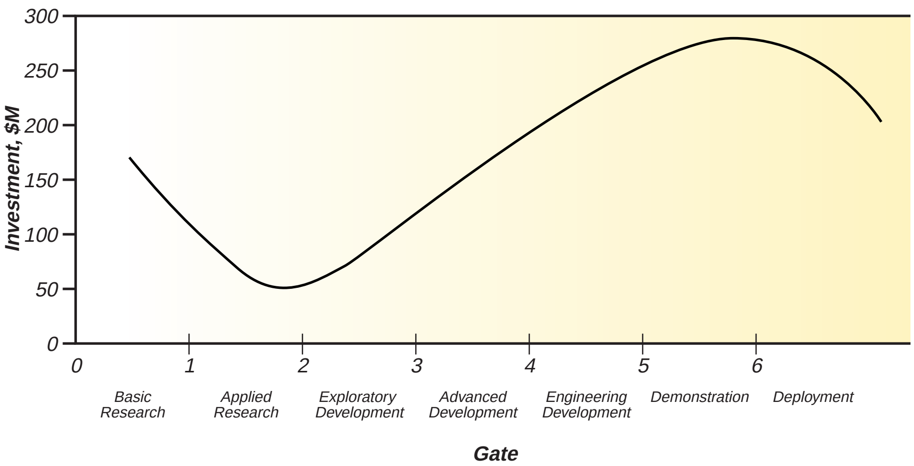
Ad hoc reviews are conducted for EM by the National Academy of Sciences-National Research Council (NAS/NRC). In addition to the NAS, the Environmental Management Advisory Board reviews programmatic aspects of EM investments in science and technology. These ad hoc reviews generally address broad program issues and help guide EM in addressing problems of greatest significance to DOE. For example, following reviews by its Board on Radioactive Waste Management (Committees on Environmental Management Technologies, Remediation of Buried and Tank Waste, and the Waste Isolation Pilot Plant) and Board on Engineering and Environmental Systems (Committee on Deactivation and Decommissioning (D&D) of Uranium Enrichment Facilities), NAS/NRC provided comments on the EM approach to addressing technology needs as well as peer review, priority setting and decision making.

All reviews culminate in written documentation and an action plan that delineates steps to correct deficiencies and take advantage of new opportunities. Information from reviews is considered by program managers and line management in selecting or continuing projects for funding, for developing new areas of investigation, and for evaluating programmatic progress. Such information is also used to document the progress and productivity of EM programs for DOE senior management, Congress and the public.

4.0 SCIENCE AND TECHNOLOGY INVESTMENTS AND IMPACTS

EM invests 4% of its budget in science and technology. EM's investment portfolio must provide a balance across the full spectrum of science and technology — research through deployment. The portfolio must also balance investments across each of the problem areas. The proper long-term balance is determined using information from *Accelerating Cleanup: Paths to Closure* and is based on the distribution of cleanup cost and programmatic risk. Opportunities for the specific application of science results and the deployment of new technology, as determined by the projects, are key factors contributing to that analysis. Achieving the right balance between these competing factors is difficult. This section summarizes EM's investment portfolio and through a series of examples, shows how the investments have, and will, make a difference in achieving EM's mission.

Figure 4.1. Five Year Investment Portfolio: Research through Deployment



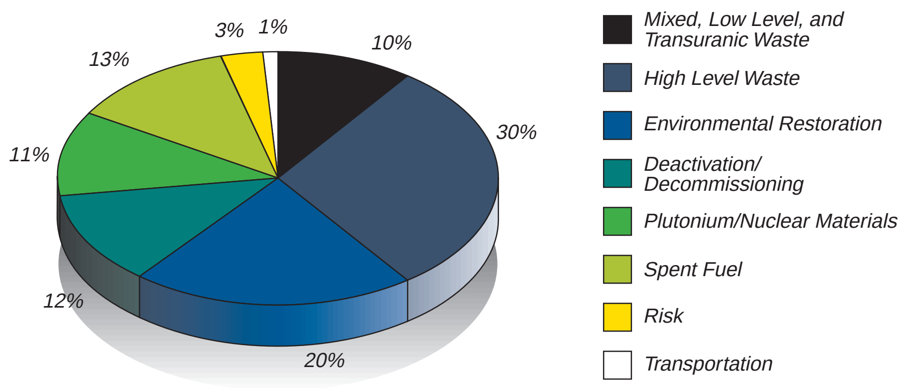
4.1 Investing Across the Full Spectrum — Research through Deployment

EM's investment portfolio includes research, technology development, and deployment. These activities are managed using seven technology maturity stages with intervening review gates. Figure 4.1 shows the planned distribution of EM's five-year investment across these technology maturity stages. The planned portfolio reflects EM's renewed commitment and strategy to solve problems encountered in the cleanup mission and to accelerate cleanup. Investment in research to increase scientific understanding will provide the bases for long-term solutions to our most difficult and intractable problems. Investment in the demonstration and deployment of technologies will accelerate the cleanup mission near-term. The investments in the Demonstration and Deployment stages are cost-shared with operations for the demonstration and deployment of new technology. This leveraging of the science and technology investment is discussed in greater detail in Section 5.1. A better understanding of the basis for the overall investment strategy can be gained by reading Appendix A.

4.2 Investing by Problem Area — Addressing the Most Important Problems

EM's investment portfolio establishes not only a distribution between research and deployment but across the problem areas as well. Figure 4.2 illustrates the current plan for investing by problem area. A detailed explanation of the planned EM investment, by problem area, is contained in Appendix A.

Figure 4.2. Five Year Portfolio Planned Investment by Problem Area.



4.3 Yesterday — Solutions Already in the Field

EM's past investments have already made a significant impact on the cleanup effort. Solutions mentioned here and in the following section on today's achievements are based on earlier investments.

- **Mixed Waste Treatment and Disposal:** The DOE has developed and commercialized several technologies for treatment of mixed waste. Polymer macroencapsulation is currently being used at Envirocare of Utah, Inc. for treatment of radioactively contaminated lead and certain types of mixed waste debris. The macroencapsulated waste is subsequently disposed in the Envirocare mixed waste disposal cell. Waste from over 20 sites has been treated in this manner. Three other DOE-developed technologies have been commercialized at Envirocare including: extrusion polymer microencapsulation, kinetic mixing polymer microencapsulation, and chemically bonded phosphate ceramics (CBPC). This suite of technologies provides a very robust, flexible system for treating various DOE mixed waste streams including soils, salts, ash, sludges, and other finely divided solids. The kinetic mixer and CBPC processes have already been used, on a small scale, to stabilize DOE mixed waste for disposal. All these technologies are expected to be online, at full scale, by early FY1999.

- **Working inside Tanks:** Remotely operated machines must be used to perform work in extremely hazardous environments, such as inside radioactive waste tanks. Robots, however, must be designed or adapted, tested and shown to reliably perform the necessary tasks. Such machines have been adapted and deployed by EM to characterize and clean up tanks at Oak Ridge, and testing is underway at Hanford.

- **NAPLs Remediation:** When EM was formed in 1989, eminent ground water authorities pronounced the contamination of fine-grained soils with non-aqueous phase liquids (NAPLs) as beyond state-of-the-art and recommended that certain aquifers be classified as "terminally ill." Many sites within DOE and in private industry contain NAPLs, but the 1989 baseline technology for cleaning up such aquifers, pump-and-treat, was simply too slow and ineffective and, consequently, many decades of treatment would be required before sites could be cleaned up and closed. The situation for remediation has become much brighter—rapid and effective new technologies for NAPL remediation have been commercially applied and are being deployed at DOE sites to shorten closure pathways.

- **Implementation of Mature Solutions:** Not all solutions require that new technologies be developed, and many technologies that are commercially available or are readily adaptable to DOE applications are now being deployed through large scale demonstrations. From FY96 to FY98, the DDFA has demonstrated 55 technologies at full-scale, and 24 of these have been deployed a total of 91 times. As a result of side-by-side comparisons with conventional baseline methods, technologies that have existed for several years, but not been used at DOE sites (e.g., the oxygasoline cutting torch), are being widely used both within DOE and beyond.

Shown below is the Houdini vehicle working by remote operation in a tank, and the oxygasoline torch which is now widely used at DOE sites.

4.4 Today — Providing Solutions to EM's Urgent Problems

Providing scientific and technical solutions to EM problems requires a combination of rapid response to unanticipated complications that affect critical pathways, development and adaptation of new technologies to solve intractable problems, side-by-side comparison of potential new technology applications with existing practices and, above all, sustained communication with cleanup project managers. Examples of specific ongoing problem solving actions include:

- **Enabling TRU Waste Transportation:** Efficient waste management on a national scale requires the capability to transport hazardous materials safely, and the path to closure for many sites relies on transporting TRU wastes to the Waste Isolation Pilot Plant (WIPP). A significant number of waste containers do not qualify for shipping, however, because the wastes may generate flammable gases. Improved non-destructive methods for measuring the amount of flammable gases and methods to destroy the gases or prevent their generation are being developed with the aim of enabling shipment of more than 90% of the currently rejected containers.

- **Cesium Removal:** The previously selected process to separate cesium from tank waste liquids at Savannah River, In-Tank Precipitation (ITP), was found to be impractical, and a new approach is needed. Today a systematic pursuit of an alternative is underway. Based on prior work, EM has proceeded from identification of over one hundred possible methods through a comprehensive evaluation to down-select four approaches for detailed assessment. The best method will be selected during the next year, and will result in delivery of an integrated and tested system.

- **Subsurface Barriers:** The first logical step in contaminated site remediation is containment to prevent the cleanup task from growing larger. An array of barrier solutions that prevent contaminant migration is being made available for adaptation to solve site specific problems. Such solutions include reactive barriers that destroy or selectively immobilize the contaminants and inert barriers such as jet grout, soil freezing, in situ redox manipulation, thin-walled diaphragms, and viscous liquids. Monitoring and performance verification systems are included with these barriers.

- **Reactor Deactivation:** Production reactors at Hanford and Savannah River constitute one of DOE's greatest deactivation and decommissioning problems. The first production reactor to be addressed, C Reactor at Hanford, has been prepared for low-cost, environmentally safe storage for up to 75 years. Twenty improved and innovative solutions have been demonstrated and evaluated during this project, including a laser tracking and data system, the STREAM data management and integration system, and anti-contamination clothing for workers with a personal heat-

Reactor Deactivation: Before and after pictures of the C Reactor at Hanford; the first production reactor to be addressed.

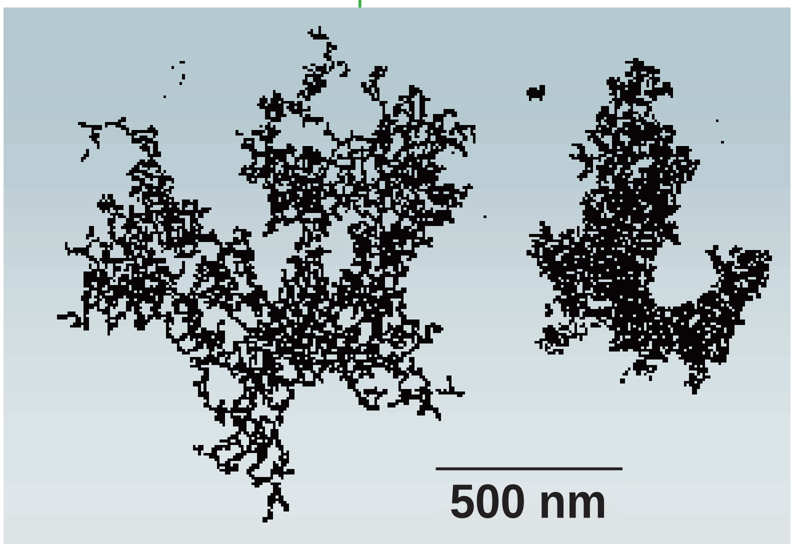
stress monitoring system to prevent overheating. Cost effective solutions will be promoted for deployment in the deactivation and decommissioning of the remaining twelve production reactors.

4.5 Tomorrow — Enabling New Critical Paths

The very nature of science and technology, dealing with what is not yet known, makes the prediction of specific future accomplishments imprecise. Nonetheless, it may be expected that EM's research and early-stage technology development activities will yield long-term dividends. By concentrating investments in areas that are high-cost, and are of relatively long duration with significant technology risks, EM increases the potential for return. High level waste management and facility deactivation and decommissioning, for example, both extend well beyond the 2006 accelerated cleanup target and thus present opportunities for high-yield investment. Additionally, research is concentrated in technology areas that are relatively poorly developed and especially where new knowledge is needed to solve problems.

- **Colloids:** One poorly understood technology area is the role of colloids in contaminant transport. Colloids are particles that are so small as to defy simple physical separations such as filtration or settling but large enough to also disobey the rules of solution chemistry. Such particles complicate many EM actions from the processing of tank waste to remediation of ground water. Colloids sometimes transport adsorbed contaminants through natural and man-made barriers. In other situations, colloids form gels that clog pipes, filters, or ion exchange columns. Today, the lack of understanding of their behavior makes it impossible to confidently model the role of colloids in transporting contaminants, especially through fractured, porous media. Tomorrow, these complications will be accurately predicted and avoided. As a bonus, colloids may even be usefully applied to enhance some separations.

The clumping or dispersal of colloids (tiny, suspended particles) can strongly affect the character of liquid wastes.



- **Advanced Separations:** Processing high level waste is made difficult by the varied properties of the multiple constituents of the wastes and the different requirements for their disposal. The waste is heavily loaded with nonradioactive constituents (such as sodium and nitrate) that create large volumes for disposal when treated; high radiation constituents (such as Cs-137 and Sr-90) that require heavy shielding to protect personnel; and long-lived radioactive constituents (such as the actinides) that make it necessary to isolate the product for very long times. Tomorrow, advanced separation techniques for these different constituents will enable treatment that is more cost-effective in specifically meeting the individual requirements of the different materials. Efficient and reliable computational and experimental methods will be used to design and test new extraction reagents to enable such separations.

- **Dilute Contaminant Cleanup:** Contaminants in subsurface plumes are typically most concentrated near the source and are surrounded by much larger volumes of less contaminated soils or ground water. Initial remediation is appropriately focused on the concentrated zones where risks are greatest. But determining how much of the plume requires active remediation and what can be left to natural attenuation must be based on sound knowledge of the effectiveness of microbial degradation and chemical attenuation as barriers to further migration and for cleanup. Research now underway will enable better risk-based choices between natural attenuation and enhanced remediation to be fitted to site-specific conditions with high confidence.

- **Actinide Storage and Disposal:** Complex actinide metal residues from weapons production, including plutonium, highly enriched uranium, and other nuclides, must be efficiently converted to forms that can be safely stored or disposed. Tomorrow, research that is now ongoing will enable such materials to be treated and their long-term safety assured.
- **Spent Nuclear Fuels:** Spent nuclear fuels are by-products of the Atomic Age for which there is no experience in long term management. Research is underway to understand the radiolytic and corrosion processes that will operate on fuels stored in both wet and dry conditions and after disposition. Tomorrow, the results will provide a foundation for developing, evaluating, selecting, and matching waste forms for safe disposition and for developing models of their long-term performance.
- **Finding and Removing Contaminants on Surfaces:** Although lasers have become ubiquitous in medicine, commerce, and industry, the potential range of their application for EM solutions to characterization and treatment needs is in the future. Characterization using Laser Induced Fluorescence Imaging has already been demonstrated at full scale. Tomorrow, the surfaces of metals and concrete will be scanned quickly and safely using lasers, and the identified contaminants will be removed by laser ablation without generating large volumes of wastes. Other selective decontamination methods such as plasma etching or specifically designed extractants will also be available.

Tomorrow, the surfaces of metals and concrete will be scanned quickly and safely using lasers.

5.0 PROGRAM IMPROVEMENT STRATEGIES — MAKING IT BETTER

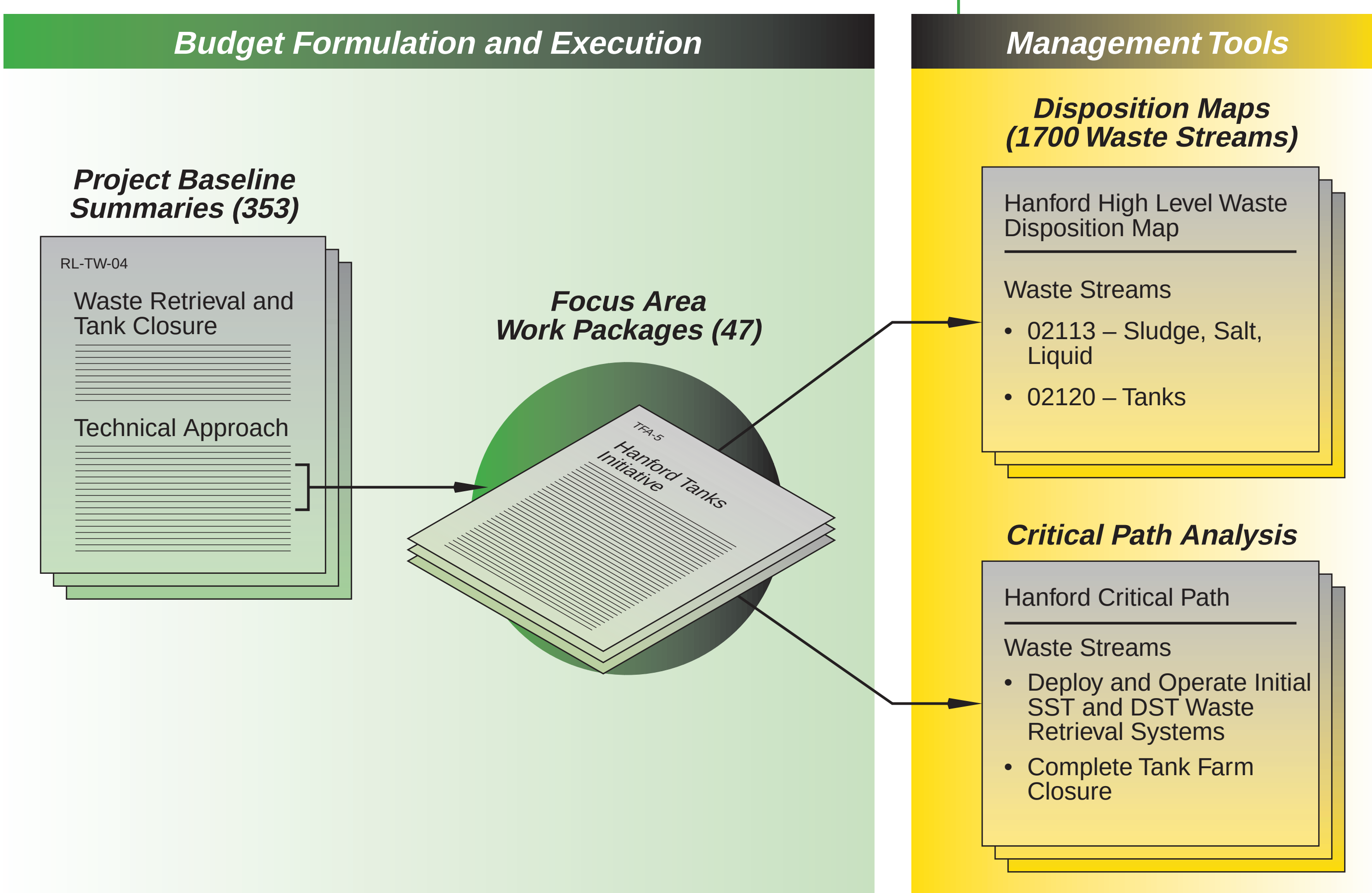
Institutional changes are required in the way EM manages its cleanup effort and investment portfolio to optimize the return on its science and technology investments. This section describes those changes and provides strategies for making them. To ensure that the products of these investments meet the needs of its internal customers, EM strives to be cleanup-project-manager driven, relying on "project pull" from EM project managers responsible for cleanup rather than "technology push" from technology developers. EM also strives to involve the cleanup project managers at all stages of the development process. However, there are still several significant challenges to incorporating science and technology solutions into site baselines that EM must overcome to be successful. The strategies discussed in the following sections have been identified to address these challenges. Many of these strategies were recommended by EM cleanup managers at a recent workshop. A series of such workshops is planned for FY99 to build on these recommendations and to help EM implement this plan by creating a partnership between those who need science and technology solutions and those who provide them.

The focus-area-centered approach means that for any given problem area, the complete set of activities, science through deployment, is managed as an integrated investment.

5.1 Improved Planning and Integration—Building Partnerships that Enhance Execution and Implementation

Improving the integration of EM's investments in science and technology with site cleanup projects will enable and, in some cases enhance, execution and implementation. To accomplish this goal, the Focus Areas must work directly with the site programs and project staff, as discussed in Section 3, to identify the correct cleanup needs and to develop technical responses that make sense. That is, the technical responses must adequately solve a specific problem, not a generic one, and be delivered in time to meet the cleanup project manager's schedule. Significant progress has been made in the last

As illustrated in the figure below, in EM's integrated approach, project descriptions in **Accelerating Cleanup: Paths to Closure** *will specify which science and technology projects support them. These will in turn be linked to other EM management tools such as Waste Disposition Maps and Critical Path Analyses.*



Partnerships between the cleanup project managers and the Focus Area will ensure that work packages are tied to cleanup projects, that the Focus Area will be responsive to the cleanup project manager, and ultimately allows the cleanup project manager to measure Focus Area performance.

year. The Focus Areas are working hard to connect every work package to specific cleanup projects and prepare technical responses that provide solutions to specific cleanup project manager needs. Investments in basic research must also be related to cleanup problems, but at a foundational level. This research provides new or additional knowledge that is needed to address programmatic or technology challenges.

In Fiscal Year 1999, EM will take the next step in integrating its science and technology investments with the needs of the cleanup projects. Project managers will be asked to partner with the Focus Areas in developing specific work packages that support the execution of their project. This connection, as identified by the cleanup project manager, between the project needs and the work package represents a partnership between the project manager and the Focus Area. Modification of this partnership must be agreed to by both the cleanup project manager and the Focus Area. Starting in Fiscal 2000, EM will only fund new Focus Area work packages that have been planned in partnership with a cleanup project manager. For basic research investments, EM will continue to solicit proposals based on science and technology needs identified by the cleanup project managers and subject matter experts, and will fund basic research projects based on the scientific quality and relevancy of the proposed research. EM will facilitate the formation of partnerships between the researchers, the Focus Areas, and the cleanup project managers to ensure that the research is relevant and is integrated into technology development and deployment.

The partnership achieves a number of goals. It makes science and technology integral to compliance because the investments are driven by site cleanup. As such, it requires the cleanup project manager and the technology developer to work together to gain regulatory acceptance throughout the development process. The cleanup project manager will now be planning to use the output of the science and technology investments; this enables a well planned "hand-off," in terms of both dollars and scope, between the developer and the cleanup project manager. EM science and technology funding for technology deployment is leveraged with operations funding for a deployment project. A minimum cost-share of one-to-one (science and technology to operations funds) is required for deployment projects, however, the cost-share often ranges up to one-to-four or higher, especially when indirect operational costs for the project are considered. Of course, developed technologies must be handed off through a commercial vendor, and though there is no guarantee that the technology will be selected in a procurement, the partnership will at least ensure that the developed technology meets all requirements and presents genuine advantages. Finally, in this partnership approach the cleanup project managers and the Focus Areas are creating the right balance between near-term deployments and long-term/high return-on-investment activities.

5.2 Technical Assistance: Helping to Solve Problems in Real Time

The Focus Areas have recently begun to add a technical assistance function to their set of responsibilities. In the past, the Focus Areas were limited primarily to the development of technologies and were rarely asked to provide direct support to the cleanup project manager. The technical assistance function requires a more direct link to the cleanup project. A more rapid response is required when an immediate solution is needed. In short, EM will redirect funding from technology development and deployment to technical assistance to solve near-term problems.

This technical assistance capability will be provided by a group of Subject Matter Experts (SMEs) assembled by the Focus Areas from the sites, laboratories, and other technology providers. When requested, these technical experts will work real-time with the cleanup project managers to define the problem in technical terms and rapidly develop a solution to that problem. This technical assistance function will provide valuable short-term resources to help address immediate problems, develop sound technical solutions, and gain regulatory and stakeholder support.

5.3 Site Deployment Plans: Managing the Accelerated Deployment of New Technology

In Fiscal Year 1998, every Field Office took on the challenge of identifying and preparing strategies for overcoming the barriers to deployment of new technologies. The resulting strategies identified a number of common problems and proposed solutions. In general, the problems result from inertia associated with the baseline; that is, when budgets are allocated, schedules developed, and regulatory agreements made based on a given baseline technology there is great resistance to change the technology. A new technology must demonstrate an overwhelming advantage over the baseline technology before the cleanup project manager will change the baseline.

The budget of many DOE sites is only sufficient to meet regulatory compliance agreements; some even face a compliance gap. Consequently, project managers are understandably cautious about inserting untried technology into the baseline. This cautious attitude reduces the opportunity for science and technology investments to support actual site cleanup even though the investments are meant to reduce cost, schedule or technology risk. As a result, science and technology investments often have limited opportunities to impact the baseline. To deploy new technologies, EM must continue to fund development and early deployment until the technology has been demonstrated to be a substantial improvement over the baseline.

__At SRS a performance incentive of $1.0M has been approved for technology deployments to retrieve the waste held in HLW Tank 19, and to sample and characterize waste in an HLW Evaporator. At Hanford, deployments of the Light Duty Utility Arm and Cone Penetrometer are part of a performance agreement soon to be completed.__

Performance-based contracting currently used in negotiating M&O and M&I contracts needs to be modified to provide incentives to take risks and to remove disincentives associated with the deployment of new technology. Current M&I and M&O contracts provide rewards for low-risk, relatively high-cost approaches to address legacy problems, and disincentives for taking the risks associated with deploying new technologies that have the potential for long-term cost savings and enhanced performance. The present contracting approach also rewards achievement of near term schedule and budget, with those aims taking precedent over the introduction of better technology. Restructuring incentives could help address this problem. Contractors should be incentivized to plan and budget an initial parallel path for both established and new technologies up to the decision point of whether or not the new technology is deployable. After the decision point, only the selected approach would be used for planning and budgeting. The Department must support the contractors by helping stakeholders and regulators understand that all commitments for events after these decision points are tentative and may require renegotiation based on the technology decision. The Department must also

Government-Funded R&D in an Era of Privatization

Contract reform efforts in the federal government have recently encouraged the consideration of new contracting approaches, including privatization of some of the cleanup activities. Privatization is an alternative to traditional government-owned facilities and cost-reimbursement contracts. Under privatization, privately financed facilities are selected in competitive bids, usually operate on a fixed-price basis, and receive a fee once cleanup goals (as specified in contracts) are met. The potential for profit provides the incentive for the private sector to bid competitively for contracts and to operate efficiently, which can lead to lower total costs to the government.

Technical feasibility and a clear understanding of the problem is key to the success of privatization, because no company will submit an acceptable bid on work with large uncertainties or severe technical risk. Investments in science and technology by both the government and private industry have been, and remain, critical to the success of privatization by:

- "Seeding the marketplace" with new technologies;
- Enabling problem definition, allowing contracts to be written that describe, clearly and precisely, "what" needs to be done, but not "how" it is supposed to be done;
- Preparing the site operating contractor to integrate successfully with the vendors' work; and
- Providing demonstration sites where technologies can be "test-driven" under DOE field conditions.

accept, and incentivize project rebaselining as needed to reflect the results of the technology decisions. Technology decisions and related contract incentives should both be based on measurable objectives such as cost savings, accelerated or more effective cleanup, enhanced performance over the lifecycle, and on achieving long term goals.

Regulatory flexibility and additional funding is needed for the demonstration of new technology. EM must do a better job at demonstrating the potential of new technologies and providing technology performance data. The cleanup project managers can then better understand and control technology risk. This provides the basis for a smooth transition from the current baseline technology to a new technology, and from demonstration to deployment. EM will continue to work with regulators to provide better cost and performance data on new technology. This will enable increased understanding of technology risk, allow EM and its regulators to renegotiate Records of Decision where applicable, and help regulators from different states and regions enable cleanup to progress faster and more effectively.

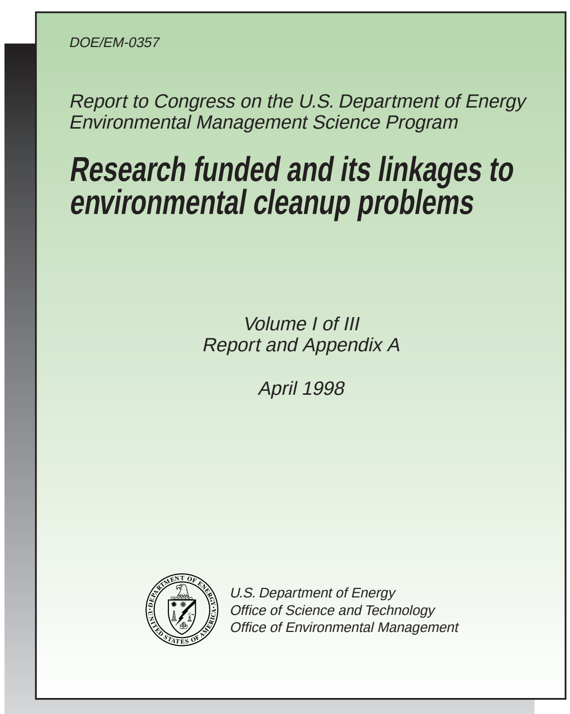
The Focus Areas will assist cleanup project managers by updating them on recent scientific discoveries that have impact on their projects.

5.4 Improved Communication of Scientific Results: Making an Impact Now and Later

Improving our fundamental understanding of the problems we face will provide a basis for both near- and long-term returns on science and technology investments. Near-term impacts from science investments depend on the rapid and accurate communication of potential new scientific and technological applications to specific cleanup project managers.

Improved communication of scientific results is being addressed in several ways. First, EM is working to connect each of the research projects directly to cleanup projects. Often the results of scientific research improve our understanding of the problems we are addressing or the processes we are operating. This improved understanding enables us to make better decisions as we move forward with cleanup. This contribution to the cleanup objectives, though difficult to quantify, is significant.

Secondly, EM is working to disseminate research and research results using a variety of information exchange tools, including the world wide web, workshops, and symposiums. Site specific workshops and topical workshops are facilitating information exchange on specific problem areas and scientific disciplines. These workshops are providing opportunities to identify and validate research needs, disseminate research results, review and discuss the current site-specific cleanup plans, and communicate research activities that may address cleanup problems. National workshops and symposiums are being used to provide opportunities to disseminate information across sites and scientific disciplines.


DOE/EM-0357

Report to Congress on the U.S. Department of Energy Environmental Management Science Program

Research funded and its linkages to environmental cleanup problems

Volume I of III
Report and Appendix A

April 1998

U.S. Department of Energy
Office of Science and Technology
Office of Environmental Management

Thirdly, the use of the focus area-centered approach contributes to the improved communication of science. The Focus Areas assist cleanup project managers in evaluating operational needs and identifying how investments in science, as well as in technology, help provide solutions. The Focus Areas are a liaison between the cleanup project managers and the hundreds of scientists working on research projects. This allows the scientists to better target their research and allows the cleanup project managers to receive and apply scientific results more quickly.

APPENDIX A – TECHNICAL PROGRAM

EM's technology challenges can be divided by waste type into "Problem Areas" such as spent nuclear fuel, high level radioactive waste, nuclear materials, or contaminated environmental media (soil and groundwater) requiring restoration. For each of these major Problem Areas, EM has built a set of integrated investments managed by Focus Areas.

Section 2 provided an overview of the Problem Areas. This Appendix provides information on the investments we are making to meet the needs of the Problem Areas and crosscutting activities. Detailed information by Focus Area is available by reading the Focus Area Multi-Year Program Plans. These plans are updated periodically and are available on the EM Home Page at www.em.doe.gov. The investment areas that support the Problem Areas are:

Problem Area	Investment Area
Mixed, Low Level and Transuranic Waste	Mixed Waste Focus Area
High Level Waste	Tank Focus Area
Environmental Restoration	Subsurface Contaminants Focus Area
Deactivation and Decommissioning	Deactivation and Decommissioning Focus Area
Nuclear Materials	Nuclear Materials Focus Area
Spent Nuclear Fuel	Spent Nuclear Fuel Focus Area

A.1 Mixed Low Level and Transuranic Waste Focus Area

Problems associated with these waste streams include multiple inabilities (i.e., adequate characterization, safe handling, adequate treatment to multiple requirements, and identification of available disposal facilities.)

In order to address the mixed, low level and transuranic waste problem, Environmental Management investments span the full range of technical endeavor, from scientific research through technology development and deployment. For example, basic research answers fundamental questions of how dioxins are formed, while technologies developed through prior Environmental Management investment are currently being deployed to encapsulate radioactive lead waste streams. Table A.1 shows the FY-98 and FY-99 investments in these areas and Figure A.1.1 depicts the anticipated investment at each level of technical maturity (which Environment Management calls "gates") over the next five years.

Figure A.1.2 shows the general process for transuranic waste treatment and disposal. The key problems faced by the sites, and indicated by their submitted needs, fall into eight general areas. Figure A.1.3 shows the cumulative investment in each of these areas over the next five years.

The investment strategy in each of these technology areas is described below. Success indicators and performance metrics have been identified for each technology area. Since most of the transuranic and mixed waste issues are related to reducing technology risk by filling technology gaps, the performance metrics are related to getting technical solutions to the cleanup project managers. The technology solutions include both data for key decisions and deployment to treat and dispose waste.

Table A.1 shows the Mixed Waste Focus Area investments by work package.

Investment Areas	*$ Millions*	
	FY-98	*FY-99*
Non-Destructive Characterization	*2.9*	*7.5*
Treatment of Hg-bearing MW	*3.0*	*2.6*
Handling Mixed Waste	*1.8*	*3.0*
Stabilization of Salts and Ash	*–*	*0.5*
Payload Enhancement	*2.3*	*1.8*
Off-Gas Streams	*1.6*	*5.0*
Alternatives to Incineration	*–*	*2.3*
Unique Waste Streams	*2.9*	*1.0*
Science	*3.0*	*2.3*

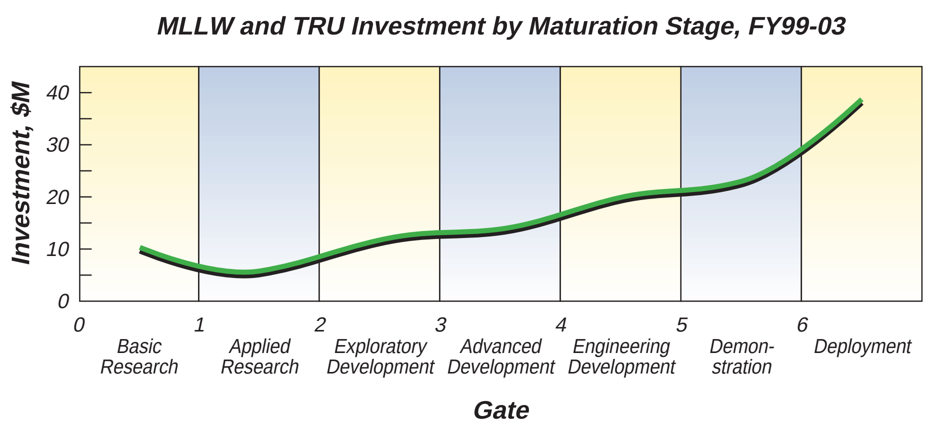


Figure A.1.1 Forecast Mixed, Low Level and Transuranic Waste science and technology investment in millions of dollars by technical maturity, Fiscal Years 1999 to 2003 (constant 1998 dollars).

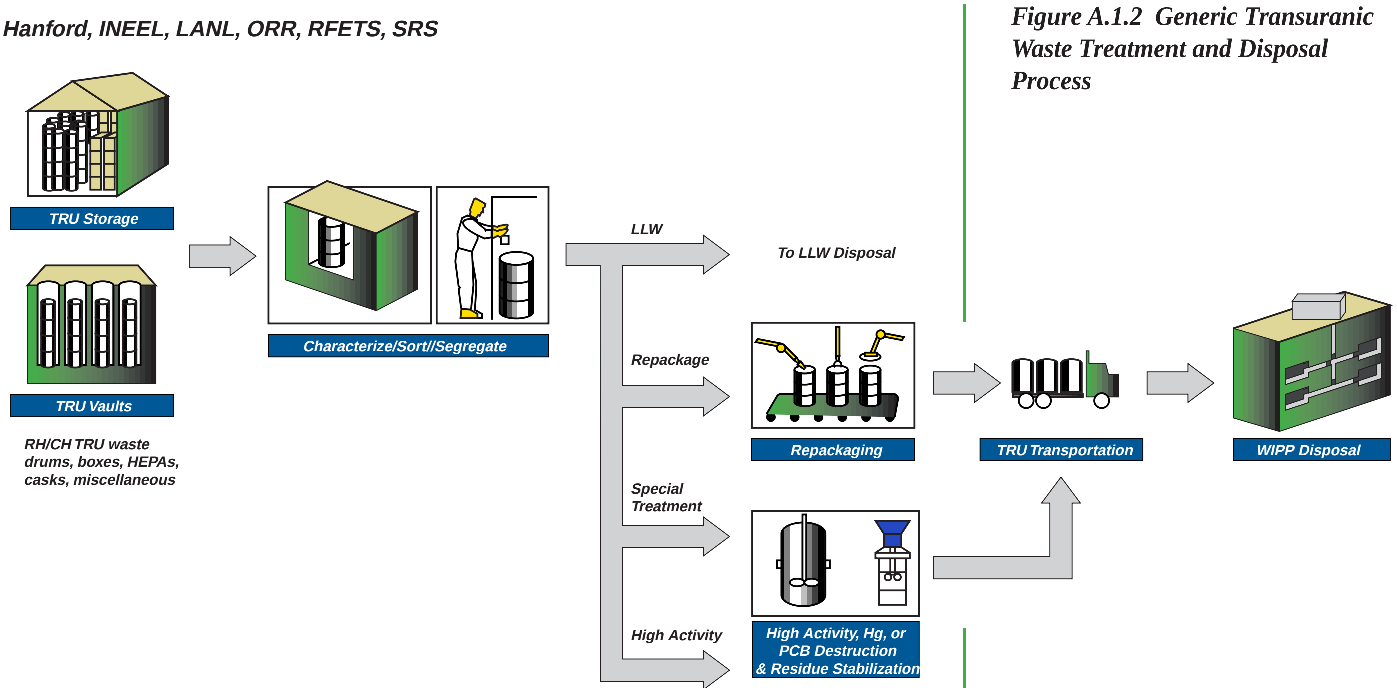


Figure A.1.2 Generic Transuranic Waste Treatment and Disposal Process

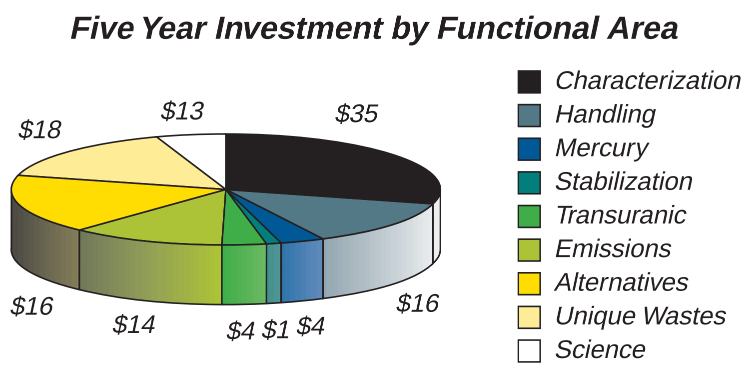


Figure A.1.3 Cumulative investments ($121M total) in Mixed, Low Level and Transuranic Waste Functional Areas over Five-Year Period (FY99–FY03).

Technical Program	Success Indicators/Metrics
Non-Destructive Characterization for Treatment, Transportation, and Disposal of Mixed Low Level and Mixed Transuranic Waste	
Significant waste characterization problems arise due to alpha contamination, high surface area dose rates (greater than 200 millirem per hour), physical and chemical heterogeneity, and volume packaged in boxes.	• Deploy Performance Demonstration Program Non-Destructive Assay Standards at Idaho, Lawrence Livermore, Oak Ridge, Hanford, and Rocky Flats Sites
Carlsbad, Idaho, Los Alamos, Oakland, Hanford, Rocky Flats, Savannah River, and West Valley Sites have identified limitations in their project baseline processes associated with characterization of large waste components and packages, high surface dose rates, and variable and complex radioisotopes.	• Deploy Combined Thermal Epithermal Neutron Instrument (for non-destructively assaying waste in contact handled drums) at Los Alamos Site

Technical Program	Success Indicators/Metrics
Handling Mixed Waste Contaminated Materials during Characterization, Treatment, Packaging, and Disposal	
Problems associated with material handling, sorting, segregating, repackaging, and volume reduction result from radioactive and hazardous components coupled with the non-homogeneous nature of mixed waste. Carlsbad, Hanford, and Savannah River Sites have identified limitations in their project baseline processes associated with management and disposition of remote handled and plutonium-238 contaminated debris wastes.	• Deploy Remote Modular Waste Conditioning System (mobile size reduction of equipment application) at Hanford Site to reduce worker exposure and to segregate transuranic waste. • Deploy Remote Modular Waste Conditioning System (for repackaging plutonium-238 job control waste) at Savannah River Site
Treatment and Stabilization Alternatives for Mercury Bearing Mixed Waste	
Mercury mixed waste cannot be commercially recycled, and must be stabilized to meet Land Disposal Restrictions. Full scale permitted processes are very limited, and cannot accept portions of Department of Energy inventory. Chicago, Los Alamos, Oak Ridge, and Savannah River Sites have identified limitations in their project baseline processes associated with radioactive waste contaminated with mercury.	• Deploy Mercury Amalgamation and Stabilization Processes through national initiatives to provide cost effective means of treatment for small quantity generators • Deliver operational data on Mercury Amalgamation and Mercury Stabilization Processes to Oak Ridge Site for use in Balance of Inventory Procurement • Deploy operational data on Mercury Separation and Removal Processes to Oak Ridge Site for use in addressing their Y-12/State of Tennessee Mercury-in-Waste Agreement
Efficient Stabilization of High Metal Content Salts and Ash Waste	
Waste streams with high concentrations of salt and/or hazardous metals, such as fly ash, scrubber blowdown, and other sludges cannot be cost effectively stabilized. Those that can be treated often result in significant volume increase, leading to high disposal costs. Fernald, Idaho, Los Alamos, Oak Ridge, Pantex, and Rocky Flats Sites have identified limitations in their project baseline processes associated with innovative stabilization treatment systems.	• Deploy Phosphate Based Chemistry Stabilization Process (for use on solar pond waste streams) at Rocky Flats Site • Deliver operational data on high salt and ash content stabilization process (for use in stabilizing secondary Waste Streams) at Idaho's Waste Experimental Reduction Facility, Oak Ridge's Toxic Substances Control Act Incinerator, and Savannah River's Consolidated Incineration Facility
Payload Enhancement for Transporting Transuranic Waste within Restrictive Regulatory Limits	
Transuranic waste transportation utilizing Type B containers (e.g., TRUPACT shipping container, 72-B shipping cask) is limited by potential flammable gas generation. Carlsbad, Idaho, Los Alamos, Rocky Flats, and Savannah River have identified limitations in their project baseline processes associated with transportation problems due to hydrogen generation.	• Deploy expanded payload TRUPACT-II shipping containers (modified to reflect new requirements in Safety Analysis Report for Repackaging) at Idaho, Los Alamos, Rocky Flats, and Savannah River Sites • Deliver operation data on baseline gas generation measurement in remote handled containers for use in transporting this waste to Waste Isolation Pilot Plant

Technical Program	Success Indicators/Metrics
Monitoring and Removing Hazardous and Radioactive Contaminants from Off Gas Streams	
Three Department of Energy incinerators (Idaho's Waste Experimental Reduction Facility, Oak Ridge's Toxic Substances Control Act Incinerator, and Savannah River's Consolidated Incineration Facility) are the only facilities currently treating significant quantities of Department of Energy mixed waste. Of these, the Waste Experimental Reduction Facility and the Toxic Substance Control Act Incinerator are identified as treatment facilities in other site compliance agreements. If these incinerators cannot comply with the Maximum Achievable Control Technology Rule and are forced to shut down, several sites with significant programmatic drivers will be impacted. Idaho, Oak Ridge, and Savannah River Sites have identified limitations in their project baseline facilities that will impact compliance agreements, statutes, settlement agreements, and court orders.	• Deploy Graphite Direct Current Arc Melter at Hanford Site to treat mixed waste streams under Allied Technologies Group Thermal Privatization Contract • Deliver off-gas testing operational and performance data for use at Idaho's New Waste Calcining Facility, Idaho's Waste Experimental Reduction Facility, Oak Ridge's Toxic Substances Control Act Incinerator, and Savannah River's Consolidated Incineration Facility
Alternatives to Incineration to Reduce Emissions Hazard	
Some organic mixed waste streams cannot be destroyed using open flame thermal technologies, like incineration, due to problems encountered with off-gas emissions. In fact, some States will not allow incineration as a mixed waste treatment option. Several Department of Energy sites have mixed transuranic wastes with high organic content, which are subject to severe transportation limitations due to hydrogen gas generation. Other Department of Energy sites have waste streams that exceed waste acceptance criteria of any available treatment facility. Los Alamos, Oakland, Oak Ridge, Pantex, Hanford, and Savannah River Sites have identified limitations in their project baseline processes associated with alternative treatment technologies to address disposition of complex organic waste streams.	• Deploy technology process (alternative to incineration) at Savannah River Site to treat plutonium-238 job control waste
Facilitating Deployment for Unique Waste	
Ten to fifteen percent of the Department of Energy's mixed waste inventory cannot be disposed using existing capabilities. Reasons include the nature and concentrations of hazardous contaminants, the presence and concentrations of radioactive isotopes, new or changing requirements, stakeholder concerns with preferred treatment solutions, and resource limitations. These waste streams include organic, highly energetic, radioactive sources, and other problematic waste streams.	• Deliver Strategic Plan for addressing site identified needs associated with treatment and disposition of waste streams without disposal options • Deliver Strategic Plan for addressing site identified needs associated with treatment (including use of non-thermal processes from industry) and disposal of polychlorinated biphenyl waste streams
Science	
Science investments will provide better understanding of non-intrusive, nondestructive characterization and monitoring, waste volume reduction and materials stabilization techniques, shipping and storage issues, and long-term behavior of waste disposal forms and containment media. Scientific research will be conducted in inorganic chemistry, separations chemistry, analytical chemistry, microbial science, materials science, and engineering science.	• Develop a radiation resistant bacterium for biodegradation of mixed wastes • Develop a high fluence neutron source for nondestructive characterization of nuclear waste

A.2 Tanks Focus Area

In order to address the High Level Waste (HLW) problem, EM investments span the full range of technical endeavor, from research through technology development and deployment. Research answers fundamental questions of waste behavior, while technologies developed through prior EM investments are currently being used to characterize, treat, and immobilize waste safely. Table A.2 shows the investments, by work packages, for FY-98 and FY-99 for the investment areas of the Tanks Focus Area. Figure A.2.1 depicts the anticipated investment at each level of technology maturity over the next five years.

Figure A.2.2 shows the generic process for HLW treatment. The key problems faced by the sites, as indicated by their submitted needs, fall into six technology areas reflecting the steps in this process: safe waste storage, waste mobilization and retrieval, waste pretreatment, waste immobilization, tank closure, and the characterization and monitoring required for each of these functions. Figure A.2.3 shows the cumulative investment in each of these areas over the next five years. The investment strategy in each of these technology areas is described below. Characterization and monitoring is discussed in the context of the other technology areas it supports.

Success indicators and performance metrics have been identified for each technology area. Since most of the HLW issues are related to reducing technology risk by filling technology gaps, the performance metrics are related to getting technology solutions to the cleanup project managers. The technology solutions include both data for key decisions and deployments to remediate tanks.

Table A.2 shows the Tanks Focus Area investment by work package.

Investment Areas	$ Millions	
	FY-98	FY-99
Tank Closure	9.6	8.9
Immobilization/Product Acceptance	2.8	1.8
Alternative Paths to ITP	3.9	3.8
Slurry Preparation	3.2	4.0
Hanford Tank Initiative	6.5	1.8
Pretreatment to Reduce Volume	3.8	1.6
Immobilization Process for Idaho	2.9	3.7
Enhancements to Melter Operations	1.1	1.6
Retrieval and Waste Transfer	3.1	2.4
On Site Disposal Preparation	0.5	0.9
Waste Tanks Deployment	8.0	9.5
Science	16.3	9.7

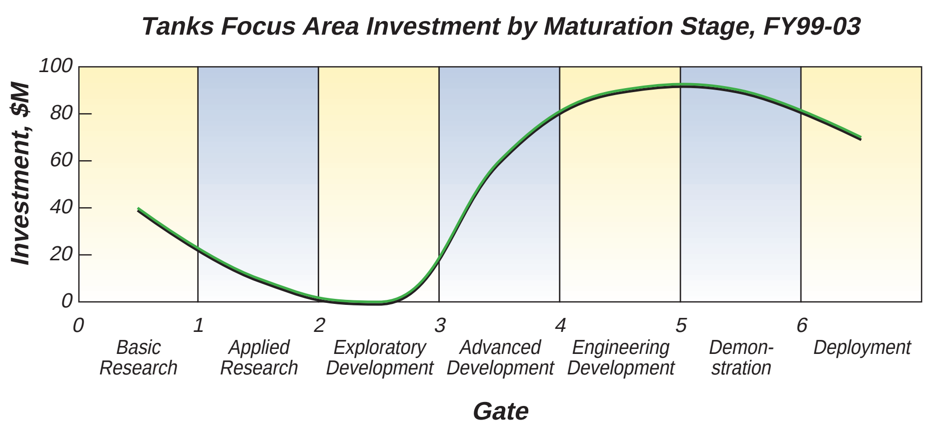


Figure A.2.1 Forecast HLW science and technology investment in millions of dollars by technical maturity, Fiscal Years 1999 to 2003 (constant 1998 dollars)

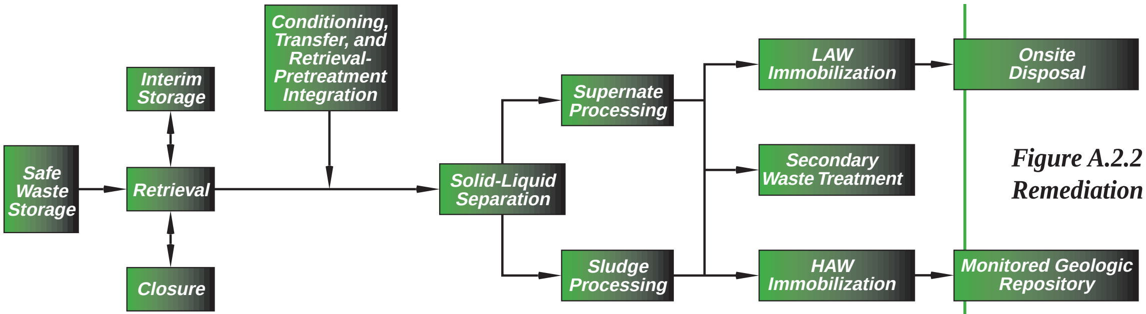


Figure A.2.2 Generic Tank Remediation Flowsheet.

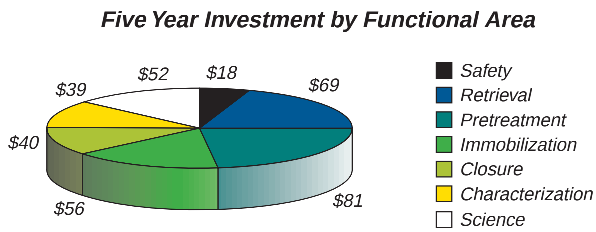


Figure A.2.3 Cumulative investments ($355M) in High Level Waste Functional Areas over Five-Year Period (FY99–FY03).

Technical Program	Success Indicators/Metrics
Safe Storage Investments in safe waste storage are needed both to fill technology gaps and reduce costs while ensuring protection of the public and the environment. Focuses include: tank and transfer line inspection, repair, and monitoring to avoid leakage during retrieval and waste transfer operations; corrosion monitoring to ensure tank integrity; and tank farm operations associated with less expensive, washable HEPA filters and passive ventilation systems with lower maintenance costs.	• Deploy two types of corrosion monitors - one at Hanford, one at SRS • Deploy regenerable HEPA filters at SRS • Deploy tank inspection system and heel characterization system at INEEL
Waste Retrieval Investments in waste mobilization and retrieval fill technology gaps and reduce costs while ensuring safe operations. There is a strong link between retrieval requirements, waste pretreatment requirements, and the tank closure end state. Hence, all of these functions are integrated to ensure compatibility of technological solutions within the overall process. The program includes bulk waste mobilization, salt dissolution, heel retrieval, and waste transfer including monitoring requirements. Over the next five years, commercially available mixing technology is being adapted and deployed in small tanks to suspend sludge for transfer. Additionally, less expensive mixer pumps are being adapted from commercially available equipment for both large and small tank applications that reduce cost and improve efficiency of bulk waste mobilization. In salt retrieval, the investment strategy is to progress from dissolution and retrieval of salt from a tank annulus, to a million-gallon tank with no leaks, and finally to large, potentially leaking tanks. The program in heel retrieval includes retrieval of soft sludges and hard sludges from tanks with simple internal configurations, i.e., minimal surface area and no evaporation coils. It also includes situations where water addition must be limited, such as a tank with the potential to leak. Tank cleaning approaches are also included in this program to ensure that the tank meets closure requirements. Investments over the next five years include initiation of heel retrieval from tanks with recalcitrant sludge and salt mixtures and from tanks with complex internal configurations. Transfer line issues include avoidance of pipe plugging as well as detection of plug location and removal if one is formed.	• Provide technical solutions to complete waste retrieval from 26 tanks at ORNL • Deploy characterization and salt retrieval system in annulus at SRS • Deploy one sludge retrieval system at Hanford and one at SRS • Provide technical data to operators to avoid transfer line plugging at SRS, Hanford, and ORNL • Provide technical data to operators to operators to support waste mixing and mobilization at Hanford

Technical Program	Success Indicators/Metrics
Waste Pretreatment Investments in waste pretreatment must be fully integrated with waste immobilization, which it feeds, as well as the retrieval process which feeds waste pretreatment. The pretreatment step is critical to reducing the volume of both low and high level waste products, which reduces disposal costs. Investments include solid-liquid separations, radionuclide removal from liquids, sludge treatment, and waste volume reduction. The solid-liquid separations effort is directed at improvements in the settle-decant of sludge feed to DWPF as well as to the Hanford Phase 1 privatization contract and sets the basis for a request for proposals for Phase 2 privatization at Hanford. The program also includes crossflow filtration for water management of waste discharged to active tanks at ORNL and for processing dissolved calcine at Idaho. Radionuclide removal from HLW liquids allows this stream to be disposed as a low level waste at much reduced cost. Hence, the technical requirements are set by the LLW form and disposal requirements. The science and technology program includes cesium removal from the waste salt at SRS and from INEEL's dissolved calcine wastes, which are acidic. This unit operation testing must be followed by integrated testing. At SRS, the pretreated stream must be compatible with the existing grouting process for LLW and the existing vitrification process for HLW. At INEEL, integrated testing includes additional separation of TRU, strontium, technetium, and cesium removal from dissolved calcine waste and the subsequent immobilization of the low-activity waste stream. The program also includes continued deployment of mobile cesium removal units as well as technical assistance to DOE-Oak Ridge for privatization of tank waste pretreatment during the transition to startup. Monitoring of cesium will be applied at SRS, Hanford, and ORNL; monitoring of technetium will be applied at Hanford. Investments in sludge treatment include providing the requirements for Hanford's Phase 1 privatization feed delivery and providing the basis for a request for proposals for Phase 2 privatization. The program for waste volume reduction includes treatment of the DWPF recycle stream at SRS and of the INTEC streams at INEEL to avoid increasing tank waste volumes. Alternatives for reducing the volumes of low and high level waste forms are also included in the program to reduce cost for disposal at the SRS. Implementation of innovative mobile skid-mounted evaporators at SRS for reducing the volume of Consolidated Incinerator Facility blowdown that requires immobilization and at ORNL to maintain much needed tank space to sustain cleanup operations.	• Implement mobile evaporator at SRS and ORNL • Deploy and implement DWPF Recycle Stream treatment system at SRS • Deliver data to operators for settle-decant at Hanford • Complete integrated testing of Cesium removal system at SRS • Deliver feed system operations data to Hanford for Phase 1 and Phase 2 privatization • Deploy multi-level feed staging tank sampler at Hanford for Phase 1 privatization operations • Deliver solid-liquid separation and sludge washing data required for Phase 2 privatization call for proposals • Deliver integrated system data for radionuclide removal at Idaho to support their EIS and Title 1 design • Complete implementation of Cesium removal system at ORNL
Waste Immobilization Investments in waste immobilization are driven by both technology gaps and cost reduction. The program includes glass formulation and processing, feed preparation, and waste product performance. Optimization of waste loading for the SRS, Hanford, and INEEL is included. Another focus will be improvement in melter operations with emphasis on pour spout issues at DWPF. Feed preparation includes level and density monitoring in process tanks at SRS to reduce the costs for DWPF operations. Efforts in both low and high activity waste form product acceptance and performance testing are filling a technology gap. Hanford requires the LLW form product acceptance tests for Phase 1 privatization. Hanford, West Valley and Idaho require HLW form product acceptance tests.	• Deliver operational data to enhance throughput for the DWPF at SRS • Deliver data required for Phase 2 privatization RFP at Hanford • Deliver data to support LLW product acceptance test standard and methodology at Hanford for Phase 1 • Deliver data on melter technology to support INEEL EIS and Title 1 design and SRS melter enhancements

Technical Program	Success Indicators/Metrics
Tank Closure Investments in tank closure include modification of grout formulation and composition to reduce costs for immobilizing residuals and stabilizing SRS tanks. It includes all aspects of tank isolation and stabilization for ORNL and establishes a basis for closure definition at Hanford and Idaho.	• Close two additional tanks at SRS. Close ten tanks at ORNL • Deploy tank heel characterization system at Hanford and INEEL • Prepare two Hanford tanks for closure
Science Science investments will provide better understanding of waste properties, characterization and monitoring techniques, treatment processes, and waste/storage structure interactions. Scientific research will be conducted in actinide and technetium chemistry, sorption/desorption, hydrothermal oxidation, multiphase/gaseous and solid/solution chemistry, bubble mechanics and sonification, laser ablation, mass spectrometry, subsurface imaging and sensor techniques, ligand design and ion-exchange, catalyst chemistry and waste treatment, chemical and structural properties of storage materials, and radiation and surface chemistry effects on storage and waste materials.	• Provide new understanding of colloidal agglomerates in tank sludge to improve retrieval of highlevel waste and potentially reduce cost of retrieval • Develop ligand designs and crown compounds for selective complexation to improve solvent extraction and ion exchange processes to separate contaminants in high level and mixed wastes • Provide new knowledge on properties of heat-treated silicotitanate to improve high level waste treatment process

The scope and funding described here include all EM activities. The HLW problem is unique to DOE, so less opportunity exists for leveraging with sources outside DOE. Some scope, external to DOE, from which DOE can benefit is within the Army Corp of Engineers and is related to characterization of soils as part of defining tank closure. In addition, the Office of Civilian Radioactive Waste Management is actively engaging in science and technology activities associated with preparation of a national repository for HLW. EM's investment in HLW forms is directly related to the design and construction of the repository. Likewise, EM's investment in HLW containers is directly related to the transportation requirements established through RW.

A.3 Subsurface Contaminants Focus Area

In order to address the widespread and diverse problem of subsurface contaminants , EM investments will span the full range of technology development; from research to full scale technology demonstration and implementation support. Research is required to answer questions regarding contaminant transport, soil interaction, and sorption to underground substrates. Innovative technologies are required to locate deep contamination and the scientific principles underlying these technologies must be discovered. Many subsurface contaminant technology needs are enabling; i.e., remediation of the contaminant will not be possible without such a technology. Table A.3 shows the investment, by work packages, for FY-98 and FY-99. Figure A.3.1 depicts the anticipated investment at each level of technology maturity over the next five years.

Technology Development Strategies

The technology needs in the *Accelerating Cleanup: Paths to Closure* fall into groups according to the type of action or effect needed. For example, there are needs for contaminant characterization, containment, and treatment. SCFA has developed a technology development strategy based on the principle actions involved in soil and ground water remediation. This strategy is to develop technologies that support the following activities:

1. **Identify** and quantify subsurface contamination accurately;
2. **Contain** or stabilize leaks and buried waste hotspots in situ;
3. **Remediate** or destroy mobile contaminants in situ;
4. **Remove** hot spots not amenable to in situ treatment; and
5. **Validate** and verify system performance for regulators and stakeholders.

Figure A.3.2 depicts a generic process for the location, characterization, and remediation of subsurface contamination. The key problems faced by the Operations Offices in this process include the characterization of the contaminants, precise location and delineation, deep access, the development of enabling and effective treatment technologies, and the verification of technology efficacy to regulatory agencies, stakeholders, and the public.

Figure A.3.3 shows the cumulative investment in each of these areas over the next five years that will be required to address site needs.

Over the next five years, the key problems faced by the sites and reflected in their submitted needs, fall into eleven areas of technical workscope: characterization, monitoring, modeling and analysis; subsurface barrier systems; stabilization in the vadose

Table A.3 shows the Subsurface Contaminants Focus Area investment by work package

Investment Areas	*$ Millions*	
	FY-98	*FY-99*
Characterization	*7.1*	*4.7*
Barrier Systems	*1.5*	*0.8*
Stabilization in the Vadose Zone	*0*	*0.5*
Long-Lived Caps	*0.5*	*2.7*
In Situ Passive Treatment	*6.4*	*5.1*
Bioreactive Treatment	*0.2*	*1.9*
Vadose Zone Chemical Treatment	*4.6*	*4.5*
Saturated Zone Chemical Treatment	*2.6*	*1.9*
Deep Access and Delivery Methods	*0.8*	*2.3*
Hot Spot Removal	*3.7*	*2.1*
Verification and Monitoring	*1.0*	*0.9*
Science	*14.1*	*11.5*

zone; long-term caps; in situ treatment barriers; bioreactive treatment; vadose zone chemical treatment; saturated zone chemical treatment; deep access and delivery methods; hot spot removal; and, containment/stabilization/treatment verification and monitoring.

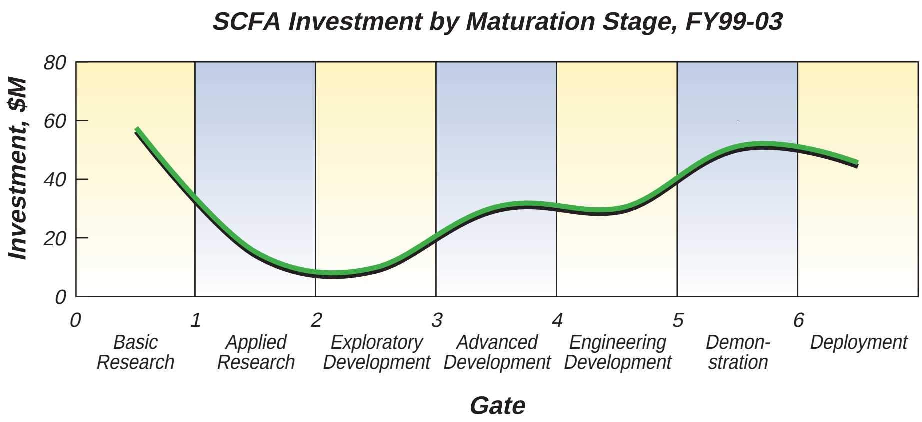


Figure A.3.1 Forecast Subsurface Contaminant investment in millions of dollars by technology maturity, Fiscal Years 1999 to 2003 (constant 1998 dollars)

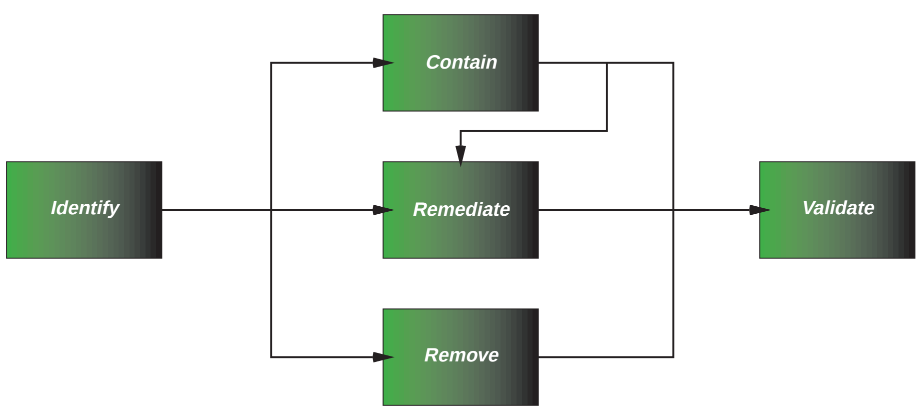


Figure A.3.2 A Generic Flowchart for the remediation of subsurface contamination

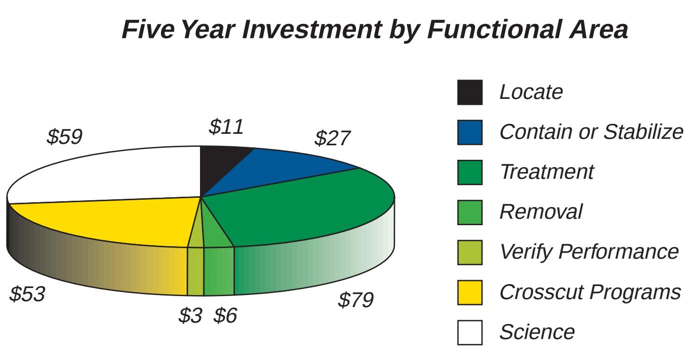


Figure A.3.3 Cumulative investments ($238M) in Contaminants Functional Areas over Five-Year Period (FY98–FY03).

Technical Program	Success Indicators
Vadose and Saturated Zone Characterization, Monitoring, Modeling, and Analysis Investment in this technology area is needed to fill the significant technology gaps that limit our ability to understand the inventory, distribution, and movement of contaminants in the vadose and saturated zones. The sites need better technologies to predict the long term movement and fate of these contaminants, especially in support of remediation efforts. Areas of development include: improved analytical tools; in situ monitoring devices that eliminate the need to retrieve and transport samples; improved understanding of permeability patterns in order to locate contaminants, including DNAPLs, in fractured and karstic rocks at depth with a minimum of drilling; improved understanding of contaminant inventory, distribution and movement in the vadose zone; and tools to better predict ground water flow, transport, or the effects of pumping or reinjection scenarios in order to more effectively target remediation technologies.	• To locate and quantify subsurface DNAPL contamination accurately, deploy Laser Induced Fluorescence, Alcohol Microinjection/Extraction, and Hydrophobic Flexible Membrane technologies at SR. These all provide indications of DNAPL presence, but require conventional or direct-push drilling methods for emplacement. • Amplitude variation with offset Seismic Reflection technology for non-invasive determination location/distribution of free phase DNAPL is planned for deployment at SR pending results of a peer review. • Demonstrate improved vadose zone contaminant fate and transport models.
Subsurface Barrier Systems in the Vadose Zone Investment in subsurface barriers is needed to provide effective containment of leaking landfills, trenches, tanks and high concentration plumes. For high concentration plumes, subsurface barriers can be an interim measure to mitigate risk until a permanent remedial solution is found or, more significantly, they can be used as the final remedy for waste units and or plumes with only moderate risk.	• To contain or stabilize leaks and buried waste hotspots in situ, demonstrate a Viscous Liquid Barrier at BNL • Demonstrate Subsurface Contaminant System at greater than 100 ft. at SRS
Stabilization in the Vadose Zone Investments in buried waste stabilization will fill technology gaps and allow effective stabilization of unstable buried wastes which continue to leach and therefore contribute to increase risks and long-term liability. Subsidence of waste zones due to waste degradation will compound the problem by focusing contamination percolation through the vadose zone, resulting in contaminant migration to aquifers. Areas of development include innovative grouts to stabilize contaminants and improved methods to perform in situ vitrification.	• In Situ Vitrification using a novel approach that begins below the targeted waste and melts upward will be demonstrated in an arid environment at LANL. This bottom-up plasma vitrification technology was demonstrated at SRS (a moist environment) in October, 1996.

Technical Program	Success Indicators
Long-Lived Caps Most DOE sites have discrete masses of contaminants buried within trenches or pits or resulting from spills or leaks of contaminants. These represent high concentrations of materials that must be prevented from spreading in soil or ground water. Much of this buried waste includes radioactive material that should be isolated from the environment for hundreds of years. Long-term cover systems must be developed to provide robust waste isolation over a range of climatic conditions and extreme events. The current RCRA cap design life is 30 years. DOE Facility Agreements with state regulators require containment in the 100 to 1000 years time frame. There is currently no way to prove that a new design will last for such periods. There is currently no cap design that provides the needed long-term containment. The current baseline technology is repeated construction of currently approved RCRA caps every thirty years. Various field office sites require long-lived caps for waste sites or technology, including improved modeling capability, to demonstrate or predict long term performance of closure measures for buried waste sites.	• Enable deployment of Long-term Covers
In Situ Passive and Reactive Barriers Investment in in situ treatment barriers will fill technology gaps and allow the effective remediation of dispersed contaminant plumes. Remediation of these dispersed plumes by pump and treat is inefficient, expensive, and produces significant secondary waste and in some hydrogeologic settings, it is not practical to install pumping systems. These barriers trap or destroy radionuclide, metal and chlorocarbon contaminants moving in the ground water.	• Complete performance verification of a Reactive Barrier (Funnel and Gate) installed at Rocky Flats SWMU 059 to treat or destroy mobile contaminants in-situ. Additional barriers may be installed at three to four other Rocky Flats SWMU's in FY00 if performance is good. • A Reactive Barrier (Funnel and Gate) will be demonstrated at Oak Ridge Y-12/S-3 Ponds • Performance verification will be completed for the Geosiphon Treatment System installed at SRS • Deploy an Iron Treatment Wall at the Kansas City Plant "Northeast Area" Plume. Additional planned outyear deployment at LLNL Site 300 • Deploy a Permeable Reactive Treatment wall at the Grand Junction Office, Monticello, Utah Superfund/NPL site

Technical Program	Success Indicators
Advanced Bioremediation and Enhanced Natural Attenuation Investments in bioreactive treatment fill technology gaps and will allow remediation of low to moderate concentrations of organic solvents which are common in soil, in ground water, and in leaking buried waste at many DOE Sites. Additional sites have wastes that are explosive, reactive, or pyrophoric. Chemical and physical methods of remediation, such as reagent treatments, thermal treatment, or pumping are not universally applicable. Areas of development include: microbial attacks on fuels or solvents, microbially enhanced barriers, and the application of vascular plants to remove contaminants from soil or ground water. Biological treatments can be done with a minimum amount of disturbance.	• Bioremediation Deployment, at site TBD
Vadose zone chemical treatment Investments in vadose zone chemical treatment will provide effective methods to remediate metals, radionuclides, explosive residues, DNAPLs, and solvents in the vadose zone. These are less costly and produce minimal secondary waste compared to conventional remediation, such as, excavation, treatment and disposal of contaminated soil. Areas of development include: in situ methods to destroy, immobilize, remove, stabilize or otherwise mitigate dispersed contaminants in the vadose zone. The contaminants include metals, radionuclides (fission and activation products, and transuranics), explosive residues, DNAPLs and other solvents.	• Demonstrate In Situ Gaseous Reduction (of Chromate) at Hanford • Deploy ACT*DE*CON at Mound. This deployment includes testing of NTS soils at Mound to investigate possible second deployment at NTS • Deploy in situ treatment of DNAPLs in low permeability matrix at Portsmouth
Saturated Zone Chemical Treatment Investments in saturated zone chemical treatment will fill technology gaps and replace traditional recovery-type remediation technologies that are too inefficient and time consuming to support the *Accelerating Cleanup: Paths to Closure* goals. Technologies to destroy highly concentrated contaminant source terms are needed to increase remediation rates and reduce the term of remediation. Areas of development include in situ methods to destroy, immobilize, remove, stabilize or otherwise mitigate dispersed contaminants in the saturated zone. The contaminants include metals, radionuclides (fission and activation products, transuranics, tritium), explosive residues, DNAPLs and other solvents.	• Demonstrate In Situ Soil Flushing for mobilization/ extraction of metals and radionuclides (Sr90 emphasis) at Hanford • Deploy Hydrous Pyrolysis at Portsmouth X701 B • Deploy Steam Heating Hydrous Pyrolsis at SRS 321-M Solvent Tank Leakage Area • Deploy Surfactant Enhanced Aquifer Remediation at ID • Deploy In Situ Chemical Oxidation of DNAPLs at OR • Demonstrate Off-Site In Well Air Stripping, NOVocs ™ at BNL for offsite DNAPLs

Technical Program	Success Indicators
Deep Access and Delivery Methods Investments in deep access and delivery methods will fill technology gaps and provide the capability to provide access, sampling, and delivery methods to place characterization and treatment technologies in DOE's deep plumes. These plumes will be the most costly to remediate due to contaminant depth and geologic complexity. Improved technologies are needed to improve cost and schedule. Focuses include: improved drilling technology for sampling, delivery of treatment chemicals, and contaminant removal methods which minimize secondary waste and can be used at great depth.	• Demonstrate deep DNAPL treatment capability at OR
Hot Spot Removal Investments in hot spot removal will fill technology gaps and provide the capability to effectively characterize and remove highly radioactive, explosive, and pyrophoric wastes which pose unacceptable risks to remediation workers during excavation. Technologies that allow onsite characterization of waste to be exhumed and for remote retrieval of high-risk waste will reduce risk to remediation workers.	• Deploy Dig Face Characterization (Warthog) at FEMP to remove hot spots not amenable to in situ treatment • Deploy Segmented Gate Soil Processing at SNL, Pantex, NTS and FEMP
Containment/Stabilization/Treatment Verification and Monitoring: Investments in containment/stabilization/treatment verification and monitoring will fill technology gaps and provide methods to validate the integrity of containment systems and to predict long-term performance to meet stakeholder and regulatory concerns and thereby enable their use as a remedy. Regulatory agencies require technology system validation and verification prior to use. Focuses include: methods to verify and validate the long-term performance of containment, stabilization, or treatment systems. This is especially important because data must be adequate to demonstrate that new containment systems are capable of meeting their design lifetimes. This activity will be coordinated with the EPA SITE Program and DoD programs.	• To validate and verify system performance for regulators and stakeholders, SCFA plans to deploy the Evapotranspiration Cover/Integrated Fiber-Optic Performance Monitoring System at AL (SNL)
Science Science investments will provide better understanding of characterization and location of contamination in soil and groundwater, removal/remediation of contaminants in groundwater and soils, separations of radionuclides from hazardous contaminants for treatment and disposal, and prediction of future contamination and migration of contaminants. Scientific research will be conducted in geochemistry, biogeochemistry, bioscience, bioengineering, geophysics, hydrogeology, inorganic chemistry, separations chemistry, and plant science.	• Provide new knowledge and processes on plant genes and the mechanisms by which plants uptake metals, radionuclides, and chlorinated hydrocarbons to develop phytoremediation cleanup methods for soils and groundwater • Provide better understanding of the mineral surface processes responsible for movement of cesium into the vadose zone from high level waste tank discharges at Hanford • Provide new understanding of fluid flow and contaminant transport in a fractured vadose zone at Hanford and the INEEL

A.4 Deactivation and Decommissioning Focus Area

The Deactivation and Decommissioning Focus Area (DDFA) mission is to develop, demonstrate and assist the deployment of improved deactivation and decommissioning technology systems which reduce costs/mortgages, reduce risks to the workers/public/ environment, and accelerate schedules for the deactivation, decontamination and decommissioning of DOE's radiologically-contaminated surplus facilities. (The mortgage is the cost incurred to maintain a surplus facility in a safe condition until it is deactivated and decommissioned.)

Goal: The overarching DDFA goal is to reduce EM's deactivation and decommissioning costs/mortgages by 50% (from the currently projected $11.3 billion to $5.3 billion). Based on cost reductions of 20-40% demonstrated and validated in 55 full-scale improved technology demonstrations, and in 91 subsequent deployments of 24 of these demonstrated technologies, the DDFA believes that the current EM D&D mortgage of $4 billion through FY2006 can be reduced by 25% for a net reduction of $1 billion, which would then be available to perform additional scope.

Furthermore, based on results achieved by best-in-class R&D organizations, investments in science can be expected to typically result in returns-on-investment of 20 to 100. It is reasonable to assume an average cost reduction of 70% for post-2006 deactivation and decommissioning projects, resulting in a $5 billion cost/mortgage reduction for DOE-EM.

Three large scale demonstration projects have been completed

- *CP-5 Research Reactor Decommissioning at ANL-E*
- *Plant 1 Uranium Processing Facility Decommissioning at Fernald*
- *105-C Production Reactor Interim Safe Storage at Hanford*

Technical Program: The DDFA strategy is to quickly access and demonstrate/validate the many commercially available deactivation and decommissioning technologies worldwide, which are not currently being used within the DOE Weapons Complex. Over 750 such technologies have been identified by the DDFA, and more are being added to the deactivation and decommissioning technology database almost every day as a worldwide technology search continues.

The DDFA created the concept of Large-Scale Demonstration and Deployment Projects (LSDDPs) in late FY1995. In these LSDDPs, the DDFA partners with site deactivation and decommissioning projects (selected competitively) to demonstrate/validate a suite of potentially improved deactivation and decommissioning technologies within these site projects. The LSDDP portion of the deactivation and decommissioning project is managed by an Integrating Contractor Team (ICT) composed of the site deactivation and decommissioning contractor, two or three commercial deactivation and decommissioning contractors and one or more members of the deactivation and decommissioning technical community. These ICTs identify, evaluate and select the deactivation and decommissioning technologies for demonstration; plan, manage and execute the demonstrations (usually side-by-side with a baseline technology); and evaluate and document the cost and performance results.

The first three LSDDPs (CP-5 Research Reactor D&D at ANL-E; Plant 1 Uranium Processing Facility D&D at Fernald; 105-C Production Reactor Interim Safe Storage at Hanford) were conducted in FY96-98, and resulted in 55 technology demonstrations, and 91 subsequent deployments of 24 of these demonstrated technologies, both within DOE and the commercial nuclear utilities. This LSDDP model is working very well.

Four new LSDDPs were initiated in March 1998. Additionally, the DDFA initiated the Canyon Disposition Initiative at Hanford in March 1998. This CERCLA RI/FS process utilizes the U-Plant (a chemical reprocessing canyon) and is working toward establishing a Record of Decision by the end of FY2000. One potential option is to remove all TRU contaminants, fill the structure with low level waste, and entomb the canyon as a permanent LLW disposal facility. This potential option could reduce the canyons D&D mortgage at Hanford by more than $1 billion, and is applicable to similar chemical

Investment Areas	$ Millions	
	FY-98	FY-99
LSDP #5 Mound Tritium D&D	0.6	2.6
LSDP #7 INEEL Fuel Storage Pool	0.6	3.7
Canyon Disposition Initiative	1.3	1.6
Scrap Metal Recycling	3.7	1.1
Fuel Storage Pool Deactivation	0.4	1.5
Processing Facilities D&D	0.2	0.4
Mortgage Reduction	4.2	2.8
TRU Contaminated Materials	0.6	1.5
C-Reactor Interim Safe Storage	2.7	0
D&D Accelerated Site Deployment	3.7	2.1
Verification and Monitoring	8.0	2.9
Science	6	1.8

Table A.4 shows the D&D Focus Area investments by work package

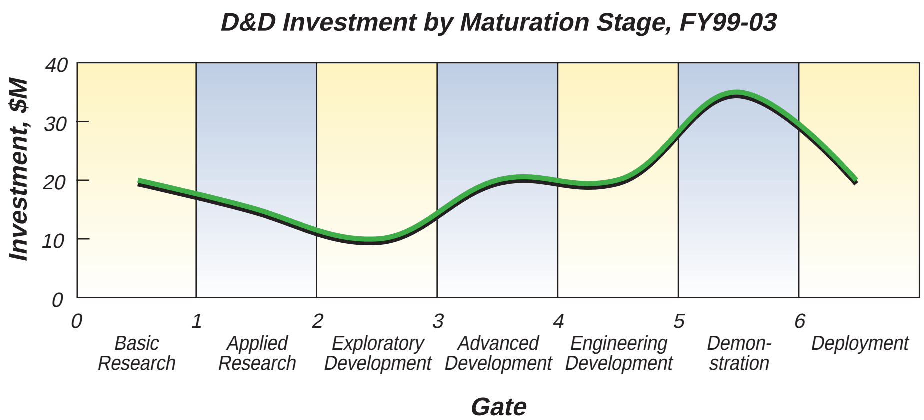


Figure A.4.1 Forecast Deactivation and Decommissioning investment in millions of dollars by technology maturity, Fiscal Years 1999 to 2003 (constant 1998 dollars)

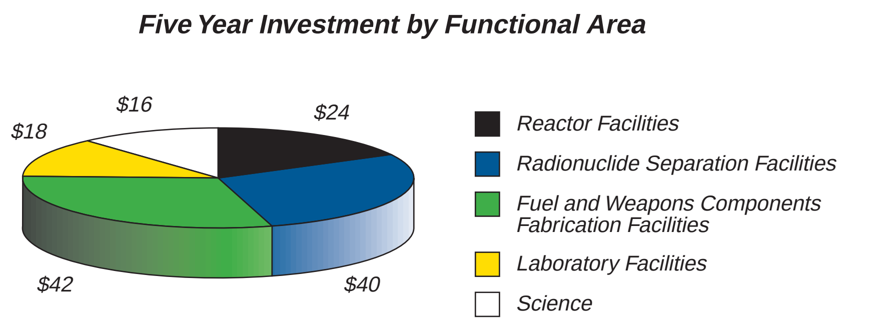


Figure A.4.2 Cumulative investments ($140M) in Deactivation and Decommissioning Functional Areas over Five-Year Period (FY99–FY03).

reprocessing facilities at SRS, Oak Ridge and INEEL. Four new work packages have been created for FY2000.

These are described within work packages in the four DDFA Product Lines (Reactor Facilities; Radionuclide Separation Facilities; Fuel and Weapons Component Fabrication Facilities, Laboratory Facilities).

The D&D Focus Area investments by work packages for FY-98 and FY-99 are shown in Table A.4 Figure A.4.1 shows the D&D investment strategy by technology maturity level for the next five years and Figure A.4.2 indicates the cumulative investment in the major functional areas over the next five years.

Technical Program	Success Indicators
Reactor Facilities	
Fuel Storage Canals and Associated Facilities Decommissioning at INEEL This work package will provide for the demonstration and deployment of safer, more efficient and cost effective alternative deactivation and decommissioning technologies emphasizing those which address problems associated with fuel storage pools and associated facilities. Over the course of the project, this cost-shared (with Office of Environmental Restoration) LSDDP will complete full-scale demonstrations of 10 to 15 cost-effective, innovative technologies for characterization, decontamination and dismantlement for deactivation and decommissioning of complex test and research facilities. Demonstration of underwater technologies that include characterization, video inspections, sample collection, radiological surveys, underwater sizing, handling, packaging and decontamination will have potential for significant mortgage reduction for deactivation and decommissioning of similar facilities as well as will benefit commercial nuclear decommissioning operations.	• 16-18 deactivation and decommissioning technologies demonstrated with validated cost and technical performance • 8 technologies deployed with 25% average cost savings • $25M mortgage reduction at INEEL after broad deployment • Deploy technologies Hanford K-Basins in FY2003-05 for major mortgage reduction
Radionuclide Separation Facilities:	
Canyon Disposition Initiative Applied R&D, demonstrations and deployments of technologies that address the ultimate disposition (final end state) of DOE's chemical reprocessing facilities (canyons). The Hanford U-Plant serves as the model for the ongoing CERCLA RI/FS process, which should result in the establishment of a Record of Decision during FY2000. During this regulatory period, there is a need to perform remotely-delivered characterization within the U-Plant to assist in discriminating among possible end states. A significant aspect of this work package is the creative approach which must be undertaken to satisfy the regulatory requirements. This work package is applicable to facilities at Hanford, Savannah River, Idaho and Oak Ridge, which are similar to the U-Plant. Many of these facilities have been excluded from the 2006 Plan, because of the high cost of deactivation and decommissioning and lack of a clearly defined path to a preferred final end state.	• Deploy 4-6 improved characterization systems (remote/robotic) • CERCLA RI/FS completed and Record of Decision established in FY2000 • Potential mortgage reduction of $1.1B at Hanford if end state is an in-place, entombed LLW facility • Major mortgage reductions at SRS, INEEL, and ORR for same end state
Scrap Metal Recycling and Release This work package will consist of research, development, demonstrations and deployments of technologies that address the recycle of radioactively contaminated scrap metal and the decontamination and free release of scrap metal. A fundamental activity within this work package will be to develop characterization techniques which can detect to release limits and thereby enhance DOE's ability to segregate contaminated from non-contaminated material. This project will also investigate improved treatment techniques and, where appropriate, conduct research in areas to improve metal treatment and recycle.	• 8-12 deactivation and decommissioning technologies demonstrated with validated cost and technical performance • 5 deactivation and decommissioning technologies deployed • Life-cycle costs documented for radioactive scrap metal decontamination/free release vs. reuse as useful products for DOE • Avoided cost determined for disposal of all potential radioactive scrap metal as low-level waste

Technical Program	Success Indicators
Deactivation and Decommissioning of Processing Facilities Processing facilities are typically massive in size, are aging structures, and have high levels of contamination. These facilities have been used to process plutonium, uranium and various hazardous materials, including waste treatment facilities. Removal and disposition of radioactive and hazardous materials and equipment, deactivation of nonessential systems and utilities, and reconfiguration of systems to facilitate long-term surveillance and maintenance within these facilities with baseline technologies is very costly and poses high safety and health risks. Technologies will be demonstrated and deployed which address characterization of specific contaminants, large-scale decontamination and dismantlement, waste disposition, worker health and safety, and remote operations.	• 8-12 deactivation and decommissioning technologies demonstrated with validated cost and technical performance • 5 deactivation and decommissioning technologies deployed
Fuel and Weapons Component Fabrication Facilities:	
Tritium Facilities Decommissioning at Mound This work package will provide for the demonstration and deployment of safer, more efficient and cost effective alternative deactivation and decommissioning technologies emphasizing those which address problems associated with tritium-contaminated facilities. Over the course of this project, this cost-shared (with Office of Environmental Restoration) LSDDP will showcase 10 to 15 innovative technologies by demonstration at full-scale during the early phase of a tritium production facility deactivation and decommissioning at Mound. Successful demonstration of remote characterization, decontamination and dismantlement technologies will provide mortgage reduction and address human health and safety issues related to clean up activities in highly radioactive environments.	• 20-25 deactivation and decommissioning technologies demonstrated with validated cost and technical performance • 10 deactivation and decommissioning technologies deployed with average 25% cost savings • Potential $25M mortgage eduction at Mound after broad deployment
HEU Fuel Fabrication Facility Deactivation at SRS The 321-M facility was used to manufacture fuel and target assemblies for irradiation in the Savannah River Site's production reactors. This facility is currently in the post-shutdown surveillance and maintenance phase. An estimated 1200 grams of highly enriched uranium is in the ventilation ducts, the processing systems and on open surfaces. Improved/innovative technologies will be demonstrated and deployed to remove residual highly enriched uranium that will permit DOE to complete stabilization of the facility, and reduce the ongoing costs of surveillance and maintenance and material control and accountability. Reduced surveillance and maintenance and material control and accountability requirements during post-deactivation surveillance and maintenance phase can be directly translated into a commensurate surplus facility mortgage reduction.	• 8-10 deactivation and decommissioning technologies demonstrated with validated cost and technical performance • 4 deactivation and decommissioning technologies deployed with average 25% cost savings • Complete deactivation of 321-M building at SRS with substantial reduction in surveillance & maintenance and material control & accountability costs • Potential $20M mortgage reduction at SRS after broad deployment
Deactivation and Decommissioning of Weapons Component Fabrication Facilities: Weapons component fabrication facilities include target fabrication, weapons components fabrication and assembly, dismantlement, modification and maintenance facilities. Cost and risk of using baseline technologies for deactivation and decommissioning of these facilities is staggering. Improved/innovative technologies will be demonstrated and deployed which address the cost effective characterization, decontamination and dismantlement of such facilities.	• 8-12 deactivation and decommissioning technologies demonstrated with validated cost and technical performance • 4 deactivation and decommissioning technologies deployed with average 25% cost savings

Technical Program	Success Indicators
Laboratory Facilities:	
Oversize Metallic TRU Waste Disposition at LANL This project will provide for the demonstration and deployment of improved technologies to lower the cost of characterizing, decontaminating, segmenting, and packaging.	• 10-12 deactivation and decommissioning technologies demonstrated with validated cost and technical performance • 5 deactivation and decommissioning technologies deployed with average 25% cost savings • Potential $75-180M mortgage reduction at LANL and Rocky Flats after broad deployment
Deactivation and Decommissioning of Laboratory Facilities This work package will address research, demonstrations and deployments of technologies and techniques for the deactivation and decommissioning of laboratory facilities including hot cells and gloveboxes. These facilities are typically contaminated with high levels of radioactivity and often require remote/robotic applications to reduce worker exposure risk. In addition, working space is often times constrained, which also results in increased worker risk to hazards. The DDFA also manages three projects aimed at accelerating technology deployment • the decontamination and volume reduction system at LANL, • enhanced in situ decontamination and size reduction of gloveboxes at Rocky Flats, and • INEEL/FEMP Integrated deactivation and decommissioning.	• 8-12 deactivation and decommissioning technologies demonstrated with validated cost and technical performance • 5 technologies deployed with average 25% cost savings
Science Science investments will support better understanding of methods for equipment size reduction, surface contamination removal, containment techniques, control of emissions, and reduction of wastes produced by remediation and decontamination through investigations in robotics sensors, solutions chemistry, surface chemistry, laser ablation, and ligand design.	• Develop laser ablation and spectrometric techniques for monitoring waste streams and decontaminating surfaces • Develop real time identification and characterization of asbestos and concrete materials with radioactive contaminants • Develop simple, multianalyte sensors for remote environmental analysis

A.5 Nuclear Materials Focus Area

The mission of the Nuclear Materials Focus Area (NMFA), is to address science and technology needs for the legacy nuclear materials inventories around the Complex for which EM has responsibility; to assure the materials are stored safely, removed from buildings that are scheduled for deactivation and decommissioning, and sent to either disposal facilities or Fissile Materials Disposition sites.

Baseline requirements (defined as those sets of requirements that must be addressed by existing or proposed programs) have been categorized and defined in these areas:

- Standards, Surveillance and Shelf-Life Programs
- Stabilization Process Development
- Core Technology
- Nuclear Materials Stewardship
- Russian Technology Collaboration

The investment strategy by work packages for FY-98 and FY-99, by technology maturity for the next five years, and by functional area for the next five years are shown in Table A.5, Figure A.5.1, and Figure A.5.2 respectively. This investment strategy is expected to evolve quickly as EM completes development of disposition paths and associated science and technology needs for all EM nuclear materials.

Investment Areas	$ Millions	
	FY-98	FY-99
Standards, Surveillance and Shelf-Life Programs	3.9	5.6
Stabilization Process Development	5.2	6.5
Core Technology	2.5	2.8
Nuclear Materials Stewardship	0.6	2.4
Russian Technology Collaboration	0.1	0.4
Science	1.8	1.9

Table A.5 shows the Nuclear Materials investment by work package.

Figure A.5.1 Forecast Nuclear Materials investment in millions of dollars by technology maturity, Fiscal Years 1999 to 2003 (constant 1998 dollars)

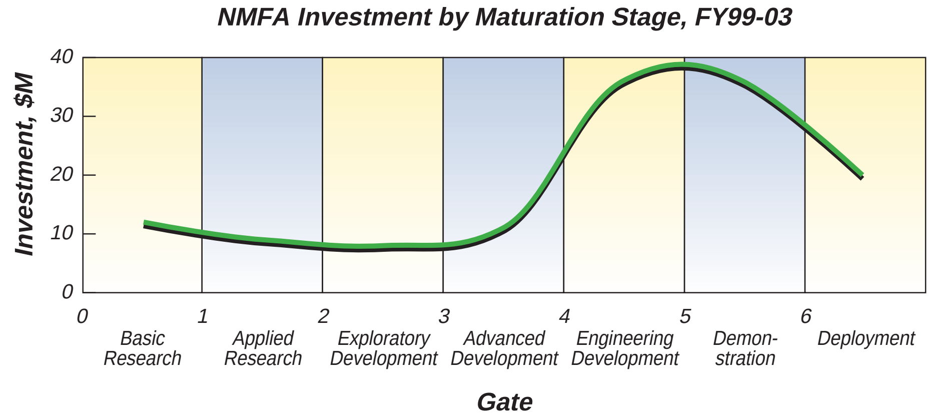
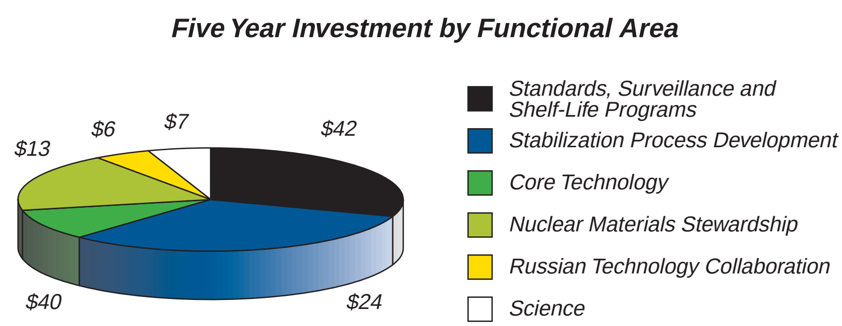


Figure A.5.2 Cumulative investments ($132M) in Nuclear Material Functional Areas over Five-Year Period (FY99–FY03).



Technical Program

Standards, Surveillance and Shelf-Life Programs

Continuing work on standards will provide a better understanding of requirements for the safe stabilization and storage of plutonium. A standard has been issued for storage of greater-than 50 weight percent plutonium metal and oxides (DOE-STD-3013-96). A standard for impure plutonium metal and oxides is currently being developed by EM-60, with research supporting the technology base for this new standard. Additionally, standards are required for stabilization and storage of other nuclear material inventories.

Many Pu-bearing inventories are not sufficiently characterized to allow high-confidence prediction of behavior in long-term storage; a need exits for surveillance of the stored material. EM has established a shelf-life program to gather representative samples of the plutonium inventory from Rocky Flats, Hanford, and Savannah River, to allow characterization of their behavior in storage conditions over time. In addition, EM-60 is developing specific approaches for non-intrusive surveillance of materials stored around the complex. NMFA initiated the Integrated Monitoring and Surveillance System (IMSS) as a testbed to provide information necessary for DOE sites to choose among alternate monitoring and surveillance technologies.

Success Indicators

- Completion of storage standards for all EM nuclear materials.
- Delivery of an integrated test bed where various configurations of surveillance sensors and protection systems can be integrated.
- Delivery of non-intrusive surveillance technologies that are implemented at storage sites.
- Success in early detection of failures during storage.
- Success criteria for surveillance of nuclear materials.

Technical Program	Success Indicators
Stabilization Process Development Stabilization process development applies to plutonium and other nuclear materials that require treatment before being placed in a safe storage condition. In addition, materials are being treated to meet either waste disposal criteria or Material Disposition acceptance criteria to reduce mortgage costs. The complexity of the nuclear material inventory and the variety of physical forms (e.g., oxides, salts, ash, solutions, etc.) creates the greatest need for developing safe treatment technologies. The NMFA annually evaluates the technical maturity of baseline processes established by the site implementation plans. This provides the basis for science and technology prioritization and identification of back-up approaches when a baseline is relatively immature. The baseline approach for a majority of the RFETS and Hanford plutonium-bearing residues involves treatment for disposal to WIPP. Rocky Flats has developed a pipe-overpack to provide extra containment and robustness for shipment and emplacement. Stabilization process development has been addressing many aspects of waste acceptance requirements. Several immobilization approaches have been developed, using cementation and vitrification. The NMFA is developing an alternative immobilization approach that employs chemically-bonded phosphate ceramics (CBPC) for stabilizing Pu-bearing incinerator ash and ash heel. CBPC has been demonstrated in the laboratory as a highly stable, leach-resistant means for immobilization of Pu-bearing incinerator ash and ash heel used to meet DNFSB 94-1 science and technology concerns. Several back-up approaches are being maintained until the baseline approaches begin an implementation phase. This provides necessary robustness to the overall strategy, motivated by the fact that stabilization and removal of nuclear materials is on the critical path to facility closure and significant mortgage reduction. Develop and demonstrate automation technologies to support the plutonium packaging and storage effort, and automated glovebox process development. Develop material handling and processing for transfer of both inter- and intra-site levels, assays and characterization, and advanced stabilization and storage processes.	• Delivery of chemically-bonded phosphate ceramic technology to treat Pu-bearing residues in a low-temperature process. (Ash, Salt, Sand, and Crucible) • Back-up technologies are available if problems are encountered with baseline approaches • Sites complete implementation plans for DNFSB 94-1 stabilization requirements • Materials are placed in a form suitable for disposal or transfer to MD
Core Technology The Core Technology program addresses the specific DNFSB 94-1 sub-recommendation that DOE improve the understanding of the underlying science of plutonium stabilization and storage. This program provides basic research in plutonium and its interactions with material it contacts in stabilization and storage conditions. The objective is to improve the understanding of observed phenomena and increase the ability to anticipate problems. In addition, the personnel involved in the core technology efforts are available to support specific issues in the applied research, development and demonstration activities.	• Plutonium behavior understood sufficiently to develop stabilization and storage approaches and safe management practices for all managed materials

Technical Program	Success Indicators
Nuclear Materials Stewardship The Nuclear Materials Stewardship program is addressing the requirements for effective management of the EM nuclear material inventory until they can be transferred to the MD program or placed in a disposal facility. The Stewardship program is developing disposition maps for all categories of EM nuclear materials, and evaluating the technical maturity for storage, treatment, and final disposition approaches. This will determine areas where science and technology is needed to improve or accelerate the implementation of these plans.	• All materials have an identified disposition path. • R&D needs for all disposition paths defined • Response plans developed and implemented for all R&D needs • Assurance for the availability of technical experts until high-confidence stabilization and safe storage is established
Russian Technology Collaboration Many plutonium solutions have not been stabilized because technologies have not been developed as rapidly as forecast. DOE commitments in the Recommendation 94-1 Research & Development Plan call for all solutions to be stabilized as expeditiously as feasible, including the 15,000 liters of solution containing isotopes of Am/Cm currently stored at Savannah River Site. The continued storage of this solution was identified as an item of urgent concern in DNFSB Recommendation 94-1. Am/Cm has a commercial value and is desired for use by the heavy isotopes program at the Oak Ridge National Laboratory. In FY 1999, the PFA will establish a joint research program with Khlopin Radium Institute in St. Petersburg, Russia, to investigate a technology recently developed in Russia for stabilization of liquid high level waste. The technology is based on using a porous crystalline matrix, which absorbs liquids at room temperature. The final waste form is a stable ceramic material, suitable for safe long-term storage and transportation. If a recovery of the isotopes is desired, it can be accomplished by dissolving the ceramic in an acidic solution.	• Demonstration of porous crystalline matrix absorption and recovery of surrogate americium/curium solutions, and if successful, initiation of deployment
Science Science investments will provide better understanding of nuclear materials stabilization, characterization, treatment, and monitoring methods, including detection and/or prevention of hydrogen buildup. Scientific research will be conducted on fissile materials behavior, thermodynamics and kinetics, and interactions between organometallics, surfaces and organic residues.	• Provide a new understanding of the chemical and structural properties of actinides and radionuclides for safe storage of nuclear materials • Provide new information on the thermodynamics involved with the volatilization of actinide metals in high temperature of radioactive wastes

A.6 Spent Nuclear Fuel Focus Area

Per DOE policy, Spent Nuclear Fuel (SNF) will be directly disposed into the first Monitored Geologic Repository (MGR). The few exceptions to this policy are for specific SNF which are at risk during the expected long interim storage period (up to 40 years), and for sodium-bonded fuels which might contain chemically active materials. Although the remaining fuel types appear ready for MGR disposition, deliberations between EM and RW have determined a need to articulate the requirements that must be met in order for DOE SNF to be accepted in the repository. Thus, the technology needs identified by the SNF storage sites span a full range of research (e.g., MGR release rates of unique SNF types) to implementation (e.g., non-destructive assay systems to examine SNF cans/canisters). Figure A.6.1 depicts the anticipated investment at each level of technology maturity over the next five years.

Figure A.6.2 shows the general pathway for SNF disposal and activities needed to support SNF consolidation, followed and accompanied by transfer into long-interim dry storage, prior to transfer to a MGR. The general process is supported SNF data acquisition and

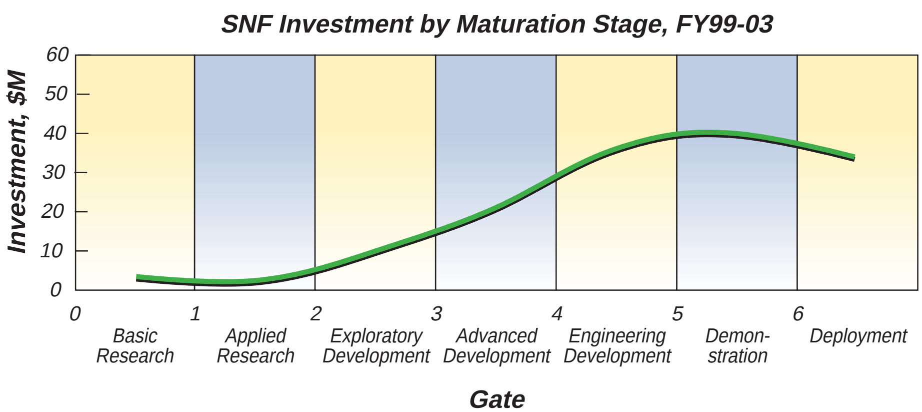


Figure A.6.1 Forecast SNF science and technology investment in millions of dollars by technical maturity, Fiscal Years 1999 to 2003 (constant 1998 dollars)

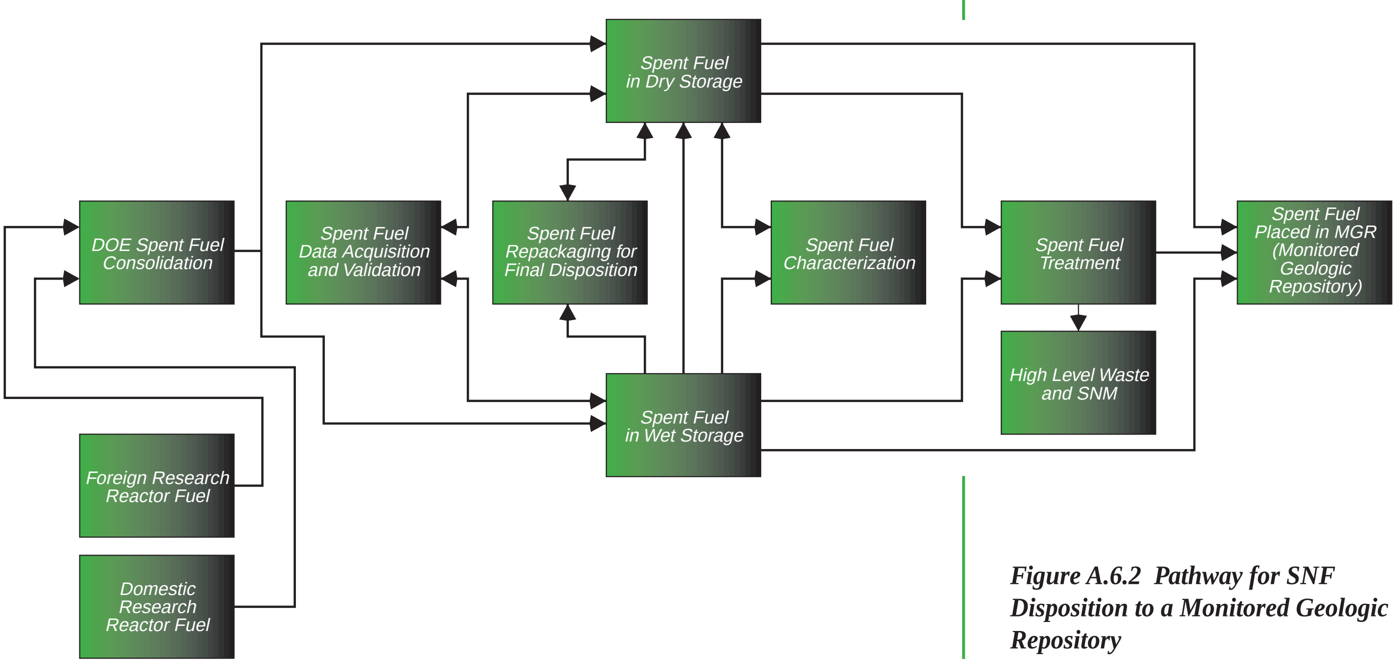
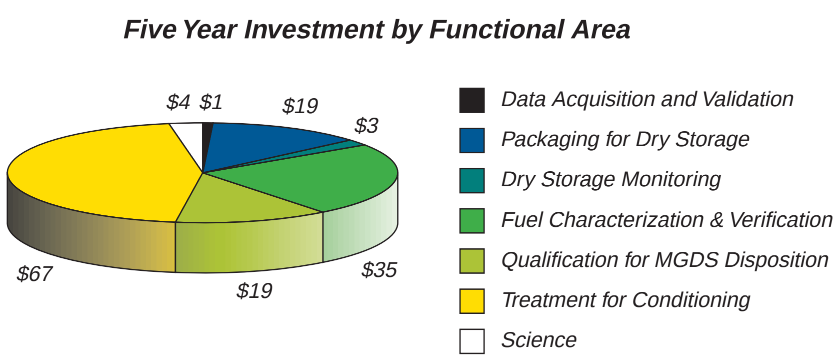


Figure A.6.2 Pathway for SNF Disposition to a Monitored Geologic Repository verification, fuel characterization, and SNF treatment, if needed. The key technology needs areas are SNF data acquisition and validation, packaging for dry storage, dry storage monitoring, fuel characterization, qualification for final disposition, and SNF treatment (if needed).

Figure A.6.3 shows the cumulative investment in each of these technology needs areas over the next five years. The investment strategy for each area is described below. Success indicators and performance metrics have been identified for each technology area.

Figure A.6.3 Cumulative investments ($148M) in Spent Fuel Functional Area over Five-Year Period (FY99–03).



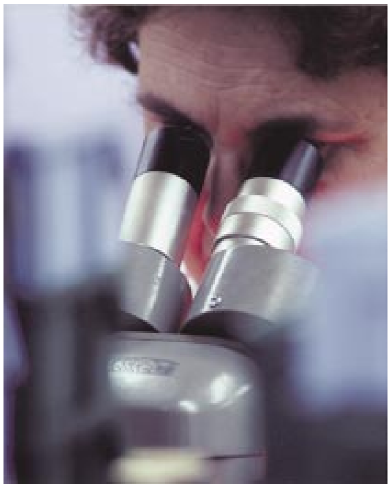
Technical Program	Success Indicators/Metrics
Data Acquisition and Validation Investments are needed in assembling and reviewing all data related to DOE SNF types including assembling original manufacturer data and drawings, reactor history, post-irradiation examinations, fissile loading, burnups, storage since reactor withdrawal, fuel quantities, fuel matrix, etc.	• NSNFP fuel data base • Reports on individual fuel types • Data qualified per OCRWM QA requirements
Packaging for Dry Storage Investments are needed into packaging requirements which will assure safe dry storage for periods up to 40 years. Packaging must maintain SNF integrity, prevent undue corrosion, and be able to be adequately monitored throughout the dry storage period. It also would ensure that at the end of the extended interim storage the SNF and canister would meet the MGR Disposability Interface Specifications. Focus also is on deactivation and decommissioning activities related to retired basin storage facilities.	• Standardized canister for stored SNF • Qualified data on fissile and radioisotope inventory. • Demonstrated drying of SNF packages • Detecting moisture in stored SNF
Dry Storage Monitoring Investments are needed to identify monitoring needs, designing and implementing monitoring stations, and for new systems to detect and measure SNF changes during the extended storage period.	• Detecting fuel or canister deterioration • Calorimeter testing of packaged SNF

Technical Program	Success Indicators/Metrics
Fuel Characterization & Verification Investments are needed into ensuring that SNF data may be qualified and verified prior to shipping to the MGR. Focus would be on NDA/NDE systems and techniques for fissile and radioisotopes, detecting water (bound or free) in SNF canister, and ensuring continuing fuel handling capabilities.	• NDA gamma neutron system demonstration for fissile and radioisotopes • NDE magnetic resonance imaging system demonstration for measuring water content
Qualification for MGR Disposition Investments are needed into systems which can independently verify SNF data collected before extended interim storage began. Focus would be on SNF canister contents and condition: fissile quantities, burnup, radioisotope quantities, criticality safety, fuel condition, and canister integrity.	• NDA gamma neutron system demonstration for fissile and radioisotopes • NDE magnetic resonance imaging system demonstration for measuring water content • Computer code for optimal loading of shipping canister • Detecting moisture in stored SNF & canister
Treatment or Conditioning Investments are needed to complete development of a process for conditioning specific fuel types, e.g., Na-bonded, small-lot scrap, disrupted fuel, and melt-dilute for SRS aluminum-based SNF.	• Complete demonstration of ANL electro-metallurgical treatment (EMT) process • Complete exploratory development of EMT on small lot oxide fuels • Complete design of high-integrity can for packaging of small-lot or disrupted fuels • Initiate detailed design of multi-dilute treatment system for aluminum-based SNF
Science Science investments will provide better understanding of monitoring/characterization, treatment, and disposition processes through the identification of pyrophoricity and combustion parameters for various fuel types. Processes contributing to corrosion, degradation, and radionuclide release, dissolution characteristics of fuel matrices, effects of microbes on fuel packages, long-term deterioration of fuel/canisters will be studied by conducting investigations of sensor techniques, process modeling, catalyst chemistry, and solid/solution geochemistry.	• Provide new understanding of the behavior of longlived radionuclides under high temperatures and over geologic time scales

A.7 Investments in Risk

Between 1999 and 2003, the Department plans to invest approximately $38 million in research to address issues related to health, ecology, and risk. Health, ecology, and risk is a cross-cutting problem area, therefore the research investment will impact cleanup work all across the DOE complex.

Many of the health, ecology, and risk research efforts are conducted in partnership with the Office of Science. Other research efforts in this cross-cutting areas are coordinated with both the Office of Environment, Safety, and Health and the Office of Science to leverage the results within the Department and to be able to build upon health, ecology, and risk efforts being conducted both within the Department and other Federal agencies.



Health, ecology, and risk research investments by the Office of Environmental Management address issues or problems in the following areas::

- Identification of biological pathways and effects of contaminants in order to determine levels of risk
- Identification of methods for determining the human health toxicity of contaminants
- Evaluation of low dose effects from radiation and evaluation of the toxic effects of radioisotope/chemical synergisms on humans and biota
- Improved detection of hazardous conditions and development of protective equipment
- Evaluation of methods for assessing worker exposure, including safety risks during restoration activities
- Understanding of soil properties and microorganism ecology to determine uptake of contaminants
- Understanding how restoration activities affecting surface water, groundwater, ecological systems, and emissions generated by restoration activities impact the environment
- Development of comprehensive long-term models of ecological systems
- Development of methods for relating cleanup levels to environmental risk
- Development of a credible risk assessment tool to evaluate residual and cumulative risk
- Developing scientific foundations to understand the observed drop in efficiency over time in pump and treat operations
- Merging and validation of air particulate models that predict future exposures
- Validation of biomarkers by linking them to DOE Worker data bases

The results are expected to assist the Department in protecting the public, workers and the environment and in the decision making process in such areas as land use issues and end states. Additional research efforts will be determined by the long range needs of the sites such as the need for improved methods to evaluate low dose radiation effects.

Examples of results to date or expected in the near term are:

- **Biomarkers and Risk Assessments to Ensure Health and Safety:** Researchers have identified biomarkers (T-lymphocytes) that can be used to improve human-sensitivity immunoassays for exposures to beryllium and other toxic metals used at DOE production facilities. Several researchers are also improving human and ecological risk assessments by: developing better measurement techniques for estimating exposure and dose; incorporating the effects of genetic repair mechanisms in dose/response calculations; and including new biological uptake pathways in risk models, such as estimating the bioavailability of organic solvents that can pass through the skin of humans during the handling of wastes or contaminated soils and groundwater.

- **Risk Assessment research and results to resolve concerns of stakeholders:** Research studies focusing on issues of contaminant uptakes in the food chain generally and by fish specifically have helped the Department in determining who may be at risk near a DOE site and in communicating to the stakeholders what the risks and benefits are associated with moderate consumption of fish. The studies linked a field examination of actual fish to state-of-the-art advanced techniques in contaminant measurement (both chemical and radionuclide) and in risk evaluation.
- **Understanding the knee in the curve of pump and treat operations:** Research studies are underway to improve the understanding of sediment chemistry and of the physics of contaminant movement in groundwater. The results will improve the understanding of what can and cannot be accomplished with current groundwater cleansing technologies. Today, pump and treat remedial activities are being conducted at many DOE sites and operations continue based on the regulatory requirements. Current research will provide a better understanding of what can be accomplished and when it would neither be practical nor effective to continue operation of pump and treat systems.
- **Improve risk estimates of low alpha radiation doses:** Research is being conducted to evaluate distributions of possible alpha radiation doses to the lung, bone, and liver and associated health-risk distributions for plutonium inhalation-exposure scenarios relevant to environmental management of plutonium contaminated sites. Current dosimetry/risk models do not apply to exposure scenarios where, at most, a small number of plutonium particles are inhaled. This research will provide a stochastic respiratory tract/dosimetry/risk computer model for evaluating the desired absorbed dose distributions and the associated health-risk distributions for workers and the public.
- **Determining significant endpoints for ecological risk analysis:** There is a need to establish a protocol for assessing risks to non-human populations exposed to environmental stresses typically found on many DOE sites. Researchers are working to understand the extent to which molecular damage from contaminant exposure is detrimental at the individual and population levels of biological organizations. The results of these studies will be used to develop a credible assessment tool for appraising ecological risks and to evaluate the effects of radionuclide/chemical synergisms on non-human species.

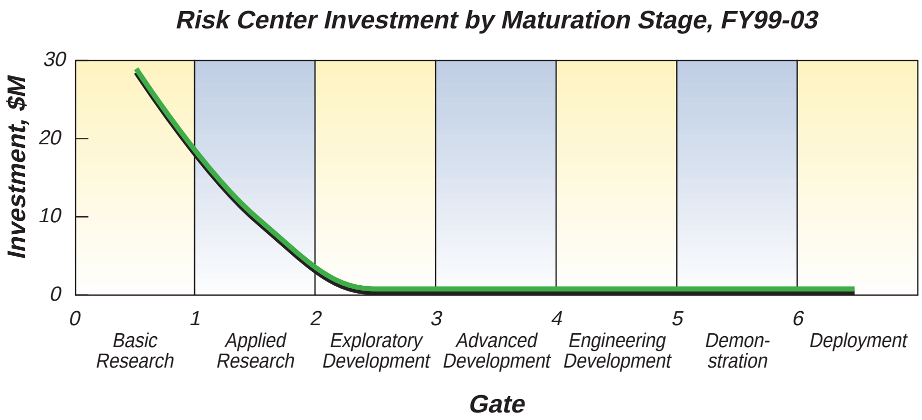


Figure A.7.1 Forecast investment in millions of dollars by technology maturity, Fiscal Years 1999 to 2003 (constant 1998 dollars)

A.8 National Transportation Program

The National Transportation Program (NTP) provides policy, guidance, and a transportation infrastructure to ensure availability of safe, efficient, compliant, and timely transport of all DOE materials with the exception of weapons and weapons components. An important NTP goal is to provide the Department's technical base services to support transportation and packaging requirement needs. The technical services also include support in packaging certification and regulatory issues.

Investment Areas:

- **Packaging Concepts:** Investment in this technology area is needed to develop and evaluate packaging concepts that utilize promising new technologies for radioactive material transportation. The technology is essential for DOE as significant quantities of radioactive material will be transported in the future through the form, quantity, and facility interfaces have yet to be determined.
- **Packaging Components Analysis:** This investment area develops technologies or systems not presently used in packages which could have generic economic and safety benefits. Materials characterization seeks to establish, on the basis of performance and cost, the viability of using nontraditional materials in package fabrication. Chemical characterization is used to identify candidate materials that will be compatible with hazardous components of mixed wastes. Components work determines dynamic properties of elastomeric O-rings which affect how they respond to deformations in the sealing surfaces. This activity also studies dynamic properties of four types of impact limiters.
- **Packaging Design and Analysis Tools:** This investment area provides improved design and analysis tools for shipping containers. It includes: providing accurate methods for determining package response to transportation environments, especially impact and puncture; providing enhanced packaging analysis methods to improve survival characteristics when packages are subjected to regulatory tests or accidents; and providing general and site-specific radiation measurements for transportation packaging.
- **Gas Generation:** Investment in this area provides technical assistance to contribute to improved container designs by evaluating gas formation in transport packaging, analyzing the effects of radiolytic and thermal degradation mechanisms on transportation safety, and developing gas generation monitoring devices.

- **Package Testing:** This investment area provides development, operation, and maintenance of test facilities and capabilities that are essential to support package development, analysis, and certification. Testing facilities are used to substantiate assumptions and techniques employed in analytical models, as well as to demonstrate structural and thermal responses of test items.

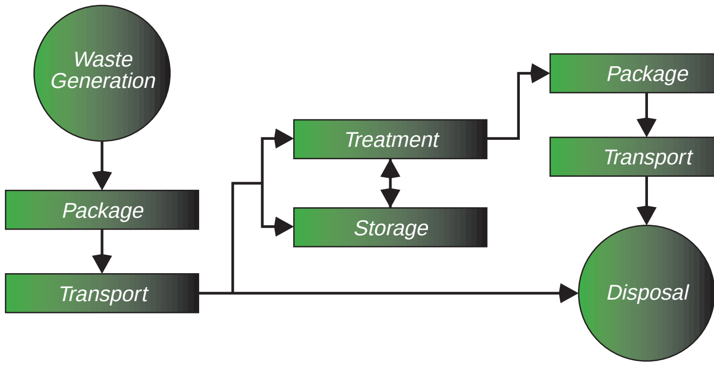


Figure A.8.1 Transportation flow chart

Table A.8 shows the transportation investments by work package

Investment Areas*	$ Millions	
	FY-98	FY-99
Packaging Concepts	.242	.230
Packaging Components Analysis	.723	.762
Packaging Design and Analysis Tools	.827	.951
Gas Generation Analysis	.076	.150
Package Testing	.330	.375

* Investment Areas are funded by the NTP

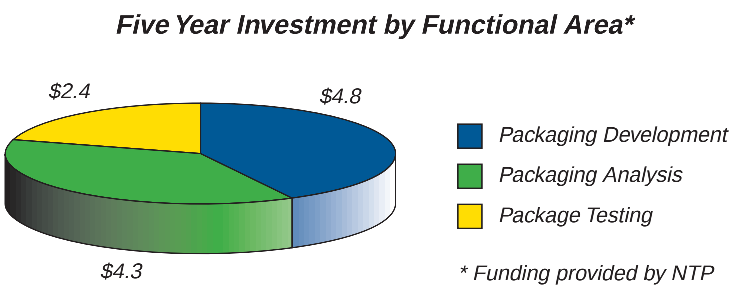
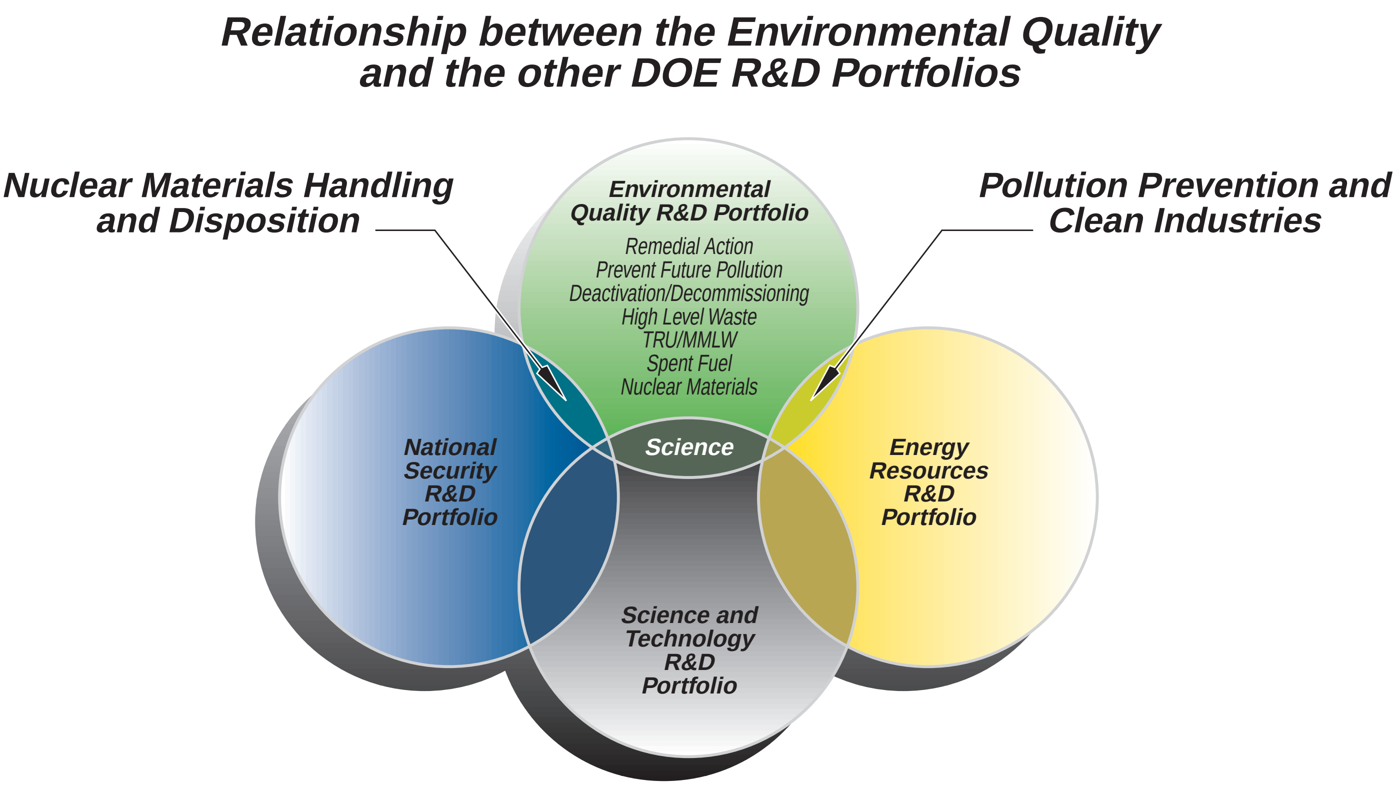


Figure A.8.2 Cumulative investment ($11.5M) in Transportation Functional Areas over Five-Year Period (FY99–FY03).

APPENDIX B – COORDINATION WITH OTHER RESEARCH AND DEVELOPMENT PROGRAMS

B.1 Coordination within the Department of Energy

EM's investments in science and technology, as well as those associated with other parts of DOE, are aimed at meeting the Department's cleanup goals. These investments, primarily focused on EM's cleanup mission, comprise the Environmental Quality R&D portfolio which is shown in Figure B.1. Each of the four DOE Business Lines: National Security, Science and Technology, Energy Resources, and Environmental Quality have R&D portfolios that describe and integrate the Department's research efforts. This appendix will briefly describe the R&D efforts in other DOE organizations that support EM's cleanup mission.



Office of Civilian Radioactive Waste Management
The Office of Civilian Radioactive Waste Management (OCRWM) conducts research associated with the disposition of high level waste and spent nuclear fuel in a monitored geologic repository. This research includes efforts to better understand site geology, geochemistry, transport modeling, and nuclear safety/criticality. While EM also conducts research in these areas, the focus of OCRWM is on the long term performance of the repository in protecting human health and the environment. This work is needed to evaluate whether the high level waste and spent fuel currently under EM's management can be safely dispositioned. As such there is a significant level of coordination between the high level waste and spent fuel programs in EM with the OCRWM program.

Office of Nuclear Energy
The Office of Nuclear Energy conducts research to help direct future development of technology for the treatment of spent fuel. Research is currently directed towards dispositioning of liquid metal reactor fuels, particularly that associated with the

Experimental Breeder Reactor II (EBR-II) located at the Argonne National Laboratory (ANL)-West. An integrated program is being conducted by ANL to evaluate the electrometallurgical treatment technology to help DOE reach a Record of Decision on proposed actions to treat EBR-II fuel, and possibly other sodium-bonded fuel. This R&D will provide data to ensure and support the ultimate disposition of the electrometallurgical waste forms to a Monitored Geologic Repository. The research has two major components: (1) Technology demonstration at ANL-West, and (2) electrometallurgical treatment R&D at ANL-East. The ANL-West demonstration is applying the technology to a limited quantity of EBR-II spent fuel (approximately 6%) to help DOE evaluate whether it should be used to convert sodium-bonded metal fuels into durable ceramic and metal waste forms. The ANL-East research supports the EBR-II demonstration by providing experimental data, modeling and analyses, and resolution of technical challenges encountered in the demonstration. The R&D program goals are to complete the ANL research in FY 1999, evaluate the results and reach a Record of Decision through the preparation of an Environmental Impact Statement by January 2000, and start inventory treatment operations in FY 2000.

Office of Materials Disposition

The Office of Materials Disposition conducts research associated with nuclear materials that are not under EM's purview and are not considered waste. This research includes efforts to safely handle, package, and transport nuclear materials for ultimate disposition. This research most closely ties to the work done under the auspices of the Nuclear Material Focus Area but also has potential ties to efforts within EM and OCRWM for the disposition of high level waste and spent fuel.

Office of Science, DOE

The Office of Science (SC) funds a large number of research projects that have the potential to provide a significant benefit to the EM cleanup. EM is partnered with SC in a number of ways, including a formal partnership with EM in the management of EM investments to fund the basic research necessary to develop breakthrough technologies for the cleanup program. Within SC, the Office of Biological and Environmental Research (BER) has active research programs in environmental remediation. The Environmental Remediation research portfolio, which includes joint EM/SC programs such as the Natural and Accelerated Bioremediation (NABIR) program, is focused on developing an understanding of the fundamental physical, chemical, geological, and biological processes required for the development of new, effective, and efficient remediation processes. BER also has a comprehensive research program in bioremediation, operates the William R. Wiley Environmental Molecular Science laboratory, and manages the Environmental Sciences Database, which tracks research focused on remediating soils, sediments, and groundwater that have undergone radioactive and chemical contamination.

BER and the Office of Computational and Technology Research (OCTR) jointly support the Environmental Technology Partnership Program (ETP) which awards grants to researchers to develop environmentally benign and innovative clean-up technologies. OCTR also funds programs in Advanced Computation for geological and petroleum reservoir modeling which have direct applications to modeling subsurface contamination (plumes, etc) and clean up.

The Office of Basic Energy Sciences (BES) within SC also plays a key role for the EM program, in that it supports fundamental research to advance scientific and technical knowledge and in a number of areas relevant to the EM program, including materials sciences, chemical sciences, biosciences, geosciences and engineering science. BES also operates several national user facilities critical to solving EM problems, particularly the four synchrotron light sources which are being used increasingly for the study of contaminated materials from EM sites.

Small Business Innovative Research
The contributions of EM and other DOE programs to the Department's Small Business Innovative Research program also result in a wide cross section of investments in science and technology that support the EM cleanup mission. This program specifically targets small businesses and provides multi-year grants that allow these companies to bring new and innovative ideas to fruition. While the grants provided by this program are not directly selected or managed by EM, the Focus Areas track the progress of these efforts and integrate the results of this research with related activities.

B.2 Coordination with other Federal Agencies

Since the inception of EM in 1989, the program has had an active outreach to other federal agencies involved in research and development activities associated with environmental cleanup. In a number of cases the DOE has jointly funded research and/or demonstrations with other federal agencies where both agencies would benefit. While many of EM's cleanup issues are unique to DOE, there are enough common problems, particularly in the area of groundwater and soil remediation to make this outreach worthwhile.

Department of Defense
The Department of Defense is managing a cleanup effort on the same order of magnitude as EM. DoD sites are distributed across the U.S., as well as abroad, and some of the challenges facing managers in DoD are identical to the ones being faced by the EM program. This is particularly true in the area of subsurface remediation and the prevention of future pollution. To date, DoD and DOE have collaborated on a number of research projects and demonstrations where jointly funded projects pay off for both agencies at reduced costs. Site schedules for either DOE or DoD can help accelerate the deployment of new technologies as well as provide needed cost and performance data which is shared between the two agencies. It is important to note that a fair number of technologies, developed by EM for application at DOE sites, have been successfully deployed at U.S. Air Force bases.

While there are a number of environmental programs within DoD that invest in research and development, the primary interface is done through the Strategic Environmental Research and Development program (SERDP). SERDP is a multi-agency program initiated through Public Law 101-510. As such, SERDP responds to the environmental requirements of the DoD and those that the DoD shares with the DOE, the EPA, and other government agencies. SERDP is the DoD corporate environmental R&D program, and focuses primarily on research and development associated with cleanup, compliance, conservation, and pollution prevention.

Environmental Protection Agency
EM shares many common goals and practices with the U.S. Environmental Protection Agency's (EPA) Superfund Programs and, in particular, with the Superfund Innovative Technology Evaluation (SITE) Program. The SITE Program was established in response to the 1986 Superfund Amendments and Reauthorization Act to demonstrate innovative technologies for site remediation. The SITE Demonstration Program encourages development and implementation of (1) innovative treatment technologies for hazardous waste site remediation and (2) monitoring and measurement. Technologies are field-tested on hazardous waste materials and engineering and cost data are gathered. Like the EM Science and Technology Program, the SITE Program is aimed at providing potential users with the information needed to assess the applicability of innovative solutions to a particular problem. At the conclusion of a SITE demonstration, EPA prepares an Innovative Technology Evaluation Report, Technology Capsule, and Demonstration Bulletin. These reports evaluate all available information on the technology and analyze its overall applicability to other site characteristics, waste types, and waste matrices. The majority of the coordination between EPA and EM is done through the Environmental Technology Roundtable.

Framework for Environmental Quality R&D Portfolio

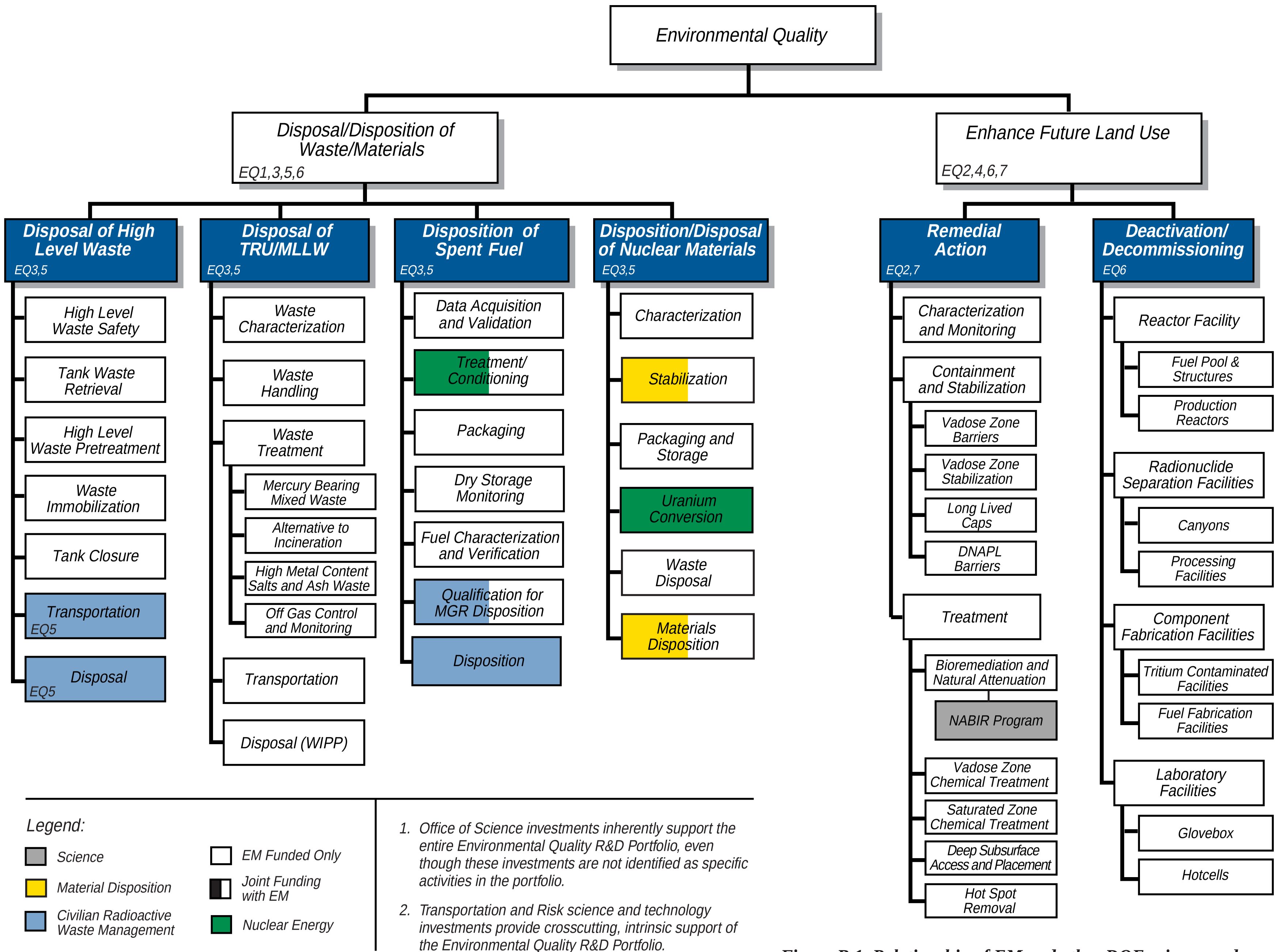


Figure B.1 Relationship of EM and other DOE science and technology investments in the Environmental Quality R&D Portfolio.

APPENDIX C – LIST OF ACRONYMS

AL	Albuquerque Operations Office
BER	Biological and Environmental Research
BES	Basic Energy Sciences
BNL	Brookhaven National Laboratory
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMST	Characterization, Monitoring, and Sensor Technology Crosscutting Area
Cs	Cesium
D&D	Deactivation and Decommissioning
DDFA	Deactivation and Decommissioning Focus Area
DNAPL	Dense Non-Aqueous Phase Liquid
DoD	Department of Defense
DWPF	Defense Waste Process Facility
EIS	Environmental Impact Statement
EM	Environmental Management
EMT	Electro-Metallurgical Treatment
EPA SITE	Environmental Protection Agency Superfund Innovative Technology Evaluation
ETP	Environmental Technology Partnership
FEMP	Fernald Environmental Management Project
FY	Fiscal Year
HEPA	High Efficiency Particulate Air
HEU	Highly Enriched Uranium
Hg	Mercury
HLW	High Level Waste
ICT	Integrating Contractor Team
ID	Idaho Operations Office
IMSS	Integrated Monitoring and Surveillance System
INTEC	Idaho Nuclear Technology and Engineering Center
ITP	In-Tank Precipitation
LAW Immobilization	Low Activity Waste Immobilization
LLW	Low Level Waste
LSDDP	Large-Scale Demonstration and Deployment Project
LSDP	Large-Scale Demonstration Project
M&I	Management and Integration
M&O	Management and Operations
MGR	Monitored Geologic Repository
MTHM	Metric Tons Heavy Metal
MWFA	Mixed Waste Focus Area
NABIR	Natural and Accelerated Bioremediation Research
NAPL	Non-Aqueous Phase Liquid
NDA/NDE	Non-Destructive Analysis/Non-Destructive Evaluation
NEPA	National Environmental Policy Act
NM	Nuclear Material
nm	Nanometer

NMFA	Nuclear Materials Focus Area
NTS	Nevada Test Site
OCRWM	Office of Civilian Radioactive Waste Management
OCTR	Office of Computational and Technology Research
OR	Oak Ridge Operations Office
ORNL	Oak Ridge National Laboratory
OST	Office of Science and Technology
PBS	Project Baseline Summary
PCB	Polychlorinated Biphenyl
PFA	Plutonium Focus Area
Pu	Plutonium
R&D	Research & Development
RCRA	Resource Conversation and Recovery Act
RFETS	Rocky Flats Environmental Technology Site
RFP	Request for Proposal
RH/CH	Remote Handled/Contact Handled
RI/FS	Remedial Investigation/Feasibility Study
RL	Richland Operations Office
RW	(Office of Civilian) Radioactive Waste (Management)
S&M	Surveillance and Monitoring
S&T	Science and Technology
SC	(Office of) Science (formerly Office of Energy Research)
SCFA	Subsurface Contaminant Focus Area
SERDP	Strategic Environmental Research and Development Program
SWMU	Solid Waste Management Unit
SNF	Spent Nuclear Fuel
SNM	Special Nuclear Material
Sr	Strontium
SRS	Savannah River Site
STREAM	System for Tracking Remediation, Exposure, Activities, and Materials
TBD	To be Determined
TFA	Tanks Focus Area
TRU	Transuranic
TRU/PACT	Transuranic Package Transporter
WIPP	Waste Isolation Pilot Plant