PNNL-13568
DOE-RL-2001-03, Rev. 0

Hanford Site Cleanup Challenges and Opportunities for Science and Technology

February 2001, Revision 0

A Strategic Assessment

The graphic on the title page provides an analysis of the existing Hanford Site S&T needs statements using an information processing tool known as SPIRE. The tool interrogates the collection of needs statements, generates common themes, and then displays these themes — both in terms of magnitude (number of occurrences shown as height of the themes) as well as relationship of the themes to the other themes (shown as the distance between the peaks). Overlaid on the graphic is an abstract representation of the fundamental Hanford Site closure challenges and S&T opportunity areas discussed in this assessment that coincide with the theme landscape.

DISCLAIMER

This effort is based on the continuation of work initiated under a collaborative "National Laboratory-University-industrial Three-party Program" namely: Pacific Northwest National Laboratory (PNNL), Massachusetts Institute of Technology (MIT) and Electro-Pyrolysis, Inc. (EPI). Those three organizations pooled their efforts in order to demonstrate the technology using the graphite electrode DC arc furnace for treatment hazardous waste. Electro-Pyrolysis, Inc., the industrial participant, currently provides the DC arc technology on a commercial basis, in connection with its licensee Svedala Industries, Inc. through its Pyro-Systems Division.

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for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

DOE/RL-2001-03 Rev. 0

Hanford Site Cleanup Challenges and Opportunities for Science and Technology—A Strategic Assessment

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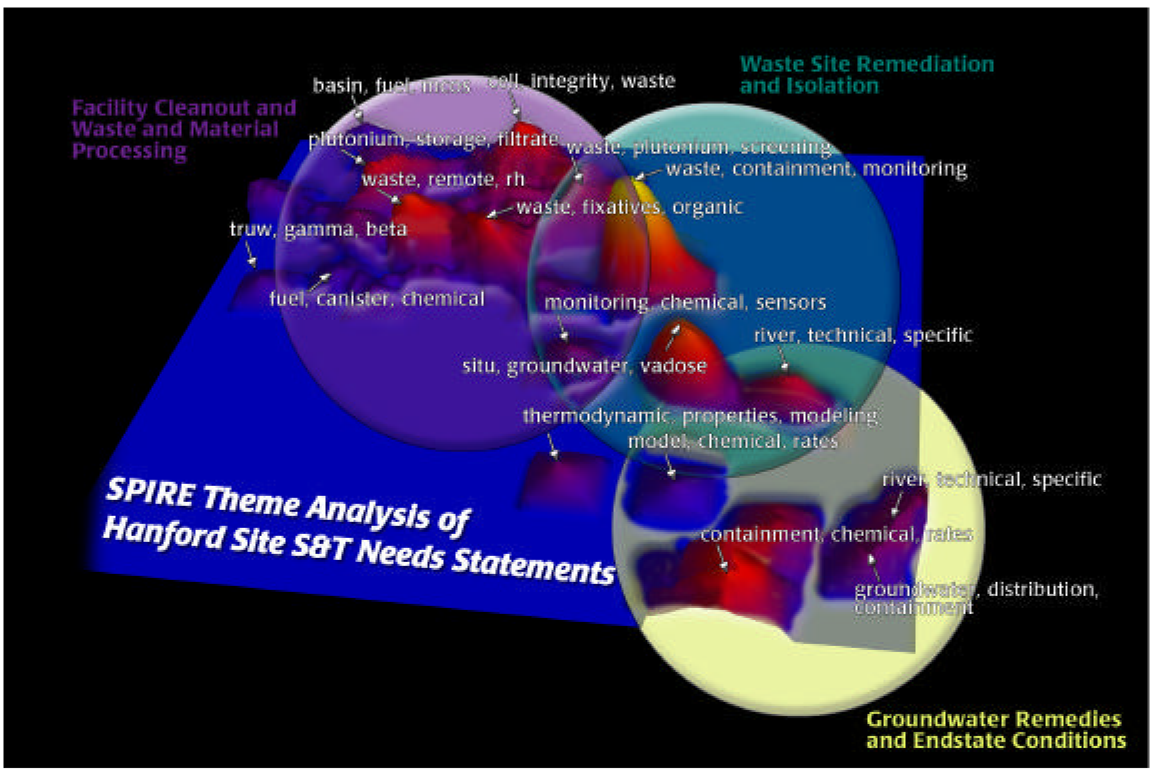

U.S. Department of Energy
Richland Operations Office
Richland, Washington 99352

Summary

Over the past year, the U.S. Department of Energy (DOE) Richland Operations Office (RL) has formulated a focused, outcomes-based vision for accelerated cleanup of the Hanford Site: "Hanford 2012: Accelerating Cleanup and Shrinking the Site" (Hanford 2012 Vision). The primary elements of this vision are to accelerate restoration of the Columbia River Corridor and transition the Central Plateau to long-term waste management, thereby shrinking the footprint of active site cleanup. Ultimate success of cleanup in the Hanford 2012 Vision and the difficult work scope beyond FY 2012 requires vigorous and sustained efforts to enhance the science and technology (S&T) basis of the cleanup, develop and deploy innovative solutions, and provide firm scientific bases to support site cleanup and closure decisions at Hanford.

The sheer expanse of the Hanford Site, the inherent hazards associated with the significant inventory of nuclear materials and wastes, the large number of aging contaminated facilities, the diverse nature and extent of environmental contamination, and the proximity to the Columbia River make the Hanford Site perhaps the worlds largest and most complex environmental cleanup project. It is not possible to address the more complex elements of this enormous challenge in a cost-effective manner without strategic investments in S&T.

Purpose of this Assessment:

Provide a single, strategic perspective on RL Site closure challenges and associated S&T opportunities that

- Supports planning and implementation of the Hanford 2012 Vision and beyond
- Identifies possible breakthrough opportunities
- Ensures S&T opportunities are linked to and driven by outcomes consistent with revised project baselines and Hanford 2012 Vision
- Identifies where S&T opportunities are tied to key site cleanup decisions
- Is consistent with the outcome based contracting strategy for the Site
- Considers both near-term and long-range cleanup challenges.

It is generally understood that new technologies and scientific research are needed to successfully clean up the Hanford Site and support closure decisions. The *baseline* plan for RL's portion of the Environmental Management (EM) mission has been developed to guide the Hanford cleanup process at an estimated cost of approximately $24 billion in constant FY 2000 dollars through FY 2046. The baseline plan is founded on a broad range of enabling assumptions concerning the application of technologies for various cleanup elements. In some cases, work can proceed as planned, although enhanced technologies could increase the efficiency with which the work is performed, thereby freeing funds for additional cleanup. In other cases,

uncertainty in site conditions and hazards as well as uncertainty in the ability of baseline technologies to achieve the cleanup objectives suggest a need for better understanding and the potential for dramatically different approaches.

Hanford must have a balanced S&T program that promotes the development of near-term tools and technologies. The program must enhance our confidence in meeting immediate cleanup goals within anticipated budgets. The program must also invest in the long-term technology and scientific understanding needed to achieve final cleanup end states. The cleanup objectives in the out years present some of the biggest opportunities for savings and greatest potential for reducing uncertainties. Enabling continued progress on these objectives to realize the potential long-term dividends will require an investment in S&T now.

Scope of this Assessment:

This strategic assessment covers all life-cycle elements of RL's cleanup mission consistent with both the near-term goals of the Hanford 2012 Vision as well as the longer-range final closure objectives. While this assessment deals specifically with the RL scope of work, common challenges faced by DOE's Office of River Protection (ORP) were identified. RL & ORP are committed to working together to solve common Hanford Site challenges affecting both operations offices.

To date, formulation and development of S&T needs within DOE-EM has logically focused on a subset of the Site's life-cycle needs. Since 1994, DOE-EM has organized S&T development around the EM Focus Areas that interact with Site Technology Coordinating Groups (STCGs) to identify S&T needs and develop technologies to serve cleanup at the site. Because only a few years (typically 3 to 5) of project work is planned in detail at any time, and because S&T needs identification favors content that is user supported for near-term deployment, there is bias built into this process against addressing fundamentally difficult, long-term problems. To address this issue, this assessment identified and described the *strategic closure challenges* associated with the cleanup of the Hanford Site (Table S.1).

Criteria Used to Identify Strategic Closure Challenges:

- Challenges require large investments or long time frames to complete
- Confidence in achieving the desired outcomes for the challenge is low or very uncertain
- Feasibility of desired endpoints or end states is still uncertain or undefined
- Breakthrough opportunities are possible by simplifying requirements, accelerating schedules, or improving efficiencies.

Table S.1. Hanford Site Strategic Closure Challenges[(a)]

Challenge	Scope	Issues
Retrieval of Remote-Handled Waste	Includes numerous buried waste sources and sites with high dose-rate materials such as the 618-10/11 burial grounds, 200 Area caissons, and other potential sites.	Work has large technical uncertainties, is labor and dose intensive, has environmental control issues and very high projected costs.
RH-TRU Handling and Disposition	Treatment and disposition of remote-handled TRU wastes from contaminated facilities, burial grounds, and underground caissons. Includes operation of new and/or modification to existing waste management facilities.	Work is labor intensive, has high degree of uncertainty, presents potential worker protection issues, and is very costly, both in terms of operation and construction of new capabilities.
Highly Contaminated Facilities Deactivation and Decommissioning	Deactivation/decommissioning of 200 and 300 Area process and laboratory facilities with high levels of contamination.	Work is labor and dose intensive, presents potential worker protection issues, is very costly, and in many cases has large uncertainties.
Nuclear Material Management	Includes all aspects of material management for SNF, cesium and strontium capsules, and plutonium and plutonium residues.	Very high base operations costs (high potential returns for accelerating schedules) for stabilization (where needed), safe storage, and offsite disposal.
Groundwater/ Vadose Zone Phenomenology	Crosscutting activity to enhance understanding of contamination sources, vadose zone, groundwater, and river interactions.	Common basis of understanding and data for remedial action decisions along with S&T roadmap for remediation.
Groundwater Remediation	Applicable to all chemical and radioactive groundwater contamination plumes.	Existing interim action technologies are inadequate to meet cleanup standards necessary for final remediation.
Subsurface Soil Access	Crosscutting applications for difficult-to-access contamination in deep subsurface sites under buildings or other structures.	High costs and technical drivers for investigations, monitoring, and remediation of the deep vadose zone and groundwater all require better access.
Surface Barrier Implementation	Applicable primarily to 200 Area closures (burial grounds, canyons, structures, and other soil contamination sites).	The large costs projected for surface barriers, environmental impacts of obtaining raw materials, and long-term surveillance and maintenance costs are all issues.
Canyon Disposition	Applicable to all 200 Area canyon facilities disposition.	Large potential savings as consolidated waste facilities. Challenge will be the acceptance of the existing structure and systems as a compliant storage/disposal facility.
Final Reactor Disposition	Applicable to all production reactors in Interim Safe Storage (ISS). Potentially applicable to FFTF.	Work is labor intensive, has high degree of uncertainty, presents potential worker protection issues, and is very costly.
Integration with ORP	Final closure and remediation of waste tanks and surrounding areas have challenges similar to those described above.	Common areas of concern include characterization, equipment size reduction, treatment and packaging, groundwater/vadose zone interaction, and barrier performance.

(a) Implicit in resolving these specific challenges is the crosscutting need to enhance worker protection tools necessary to safely accomplish these difficult tasks.

This assessment is intended to complement the existing STCG process (which addresses important and urgent needs and solutions that affect near-term baseline performance) by identifying strategic life-cycle challenges in the site cleanup baseline for which there currently are no readily available solutions, where existing solutions have proven to be ineffective, or where existing solutions are prohibitively expensive or pose significant health and safety risks. The analysis of these challenges have led to a broad understanding that advances in S&T could have a positive effect on several significant portions of the baseline plan. Some of these challenges involve $100's of millions in baseline scope and are fundamental for successfully achieving the Hanford 2012 Vision and beyond. RL strongly believes that S&T investments in these areas are needed and will support the DOE Office of Science and Technology (OST) in defending funding requests to meet these challenges during programmatic reviews.

Each of the challenges provides a strong driver and opportunity for S&T development to advance the Hanford 2012 Vision. Near-term S&T investments are needed for resolution of both near-term issues and long-term closure objectives in order to enhance the credibility of the technical baselines by identifying opportunities to reduce the expected costs, potentially accelerating scheduled completion, and reducing programmatic uncertainties associated with the cleanup activities. However, there is insufficient funding to develop every available technology option or scientific research endeavor. Therefore, this document serves as a strategy to help RL focus its financial resources on *fundamental S&T opportunities* that will provide the most significant schedule, cost, and safety impacts in the overall cleanup effort.

Criteria Used to Identify Fundamental S&T Opportunities:

As an organizing concept, an "S&T Opportunity" is a set of one or more challenges that satisfy any of the following additional criteria:

- There is a reasonable prospect for successful resolution of the technical issue(s) in a sufficiently complete and timely manner at reasonable cost
- The same or similar technical issue(s) in different projects or challenges may be combined to frame problems in a fundamental, generic manner, addressing multiple needs
- The potential solutions satisfy a previously unresolved need to reduce risk and further cleanup objectives.

Although high level, this assessment was sufficiently complete to substantiate several significant and urgent S&T priorities. These activities (identified in terms of fundamental S&T opportunities) should be addressed in an expeditious manner:

Fundamental S&T Opportunity Recommendations:

- **RH Waste Retrieval and Disposition**: Initiate an integrated effort to identify and develop technologies for the retrieval and disposition of remote-handled wastes and nuclear materials. A road-mapping process should be undertaken to identify specific technology gaps and the S&T activities needed. This effort should focus on a cross-project assessment of the systems needed for size reduction, processing, packaging, transportation, and storage of RH wastes and nuclear materials and should also include an emphasis on the S&T required for retrieval of buried RH wastes at the 618-10 and –11 burial grounds. On this basis, initiate an S&T effort to develop, test, validate, and deploy the selected technologies.

- **Groundwater and Subsurface Technology**: Focus on developing, demonstrating, and deploying groundwater and deep soil remediation technologies and tools, including innovative access technologies. The first step in this process will be to complete the remediation S&T road map to identify an overall approach and S&T activities needed to develop appropriate soil and groundwater remediation technologies and tools. Expand the knowledge of S&T needs for groundwater and deep soil remediation and initiate the S&T activities necessary to develop, validate, and deploy the selected remedial technologies and tools.

- **Surface Barrier Development and Performance Monitoring**: Initiate full-scale surface barrier testing and performance monitoring to optimize and validate barrier designs for long-term application at Hanford waste sites and engineered disposal facilities.

- **Massive Facility Disposition Options Development**: Support reactor block and canyon disposition key decisions required in FY 2002; identify, plan, and conduct more detailed S&T road-mapping following selection of the preferred disposition paths.

To implement this strategy, detailed roadmaps will be developed in the next phase of S&T planning to identify specific S&T activities and potential breakthrough opportunities, provide linkage to outcomes consistent with revised project baselines, and establish ties to key site cleanup decisions. Detailed definition of the depth and breadth of the fundamental S&T opportunities and the relative priority and urgency of each will be a natural product of this follow-on activity. Full integration of the strategic closure challenges into RL's research and development processes will ensure investments made result in the maximum benefits across the Hanford Site and are fully supportive of the Hanford 2012 Vision. This assessment will serve to focus and identify the challenges and issues Hanford believes the DOE OST Program can support in meeting its cleanup objectives. RL will work closely with OST to justify DOE-EM budgets that will address Hanford's unique challenges and S&T opportunities.

Intended Use of this Document:

This assessment is the first step in developing a Site level S&T strategy for RL and does not yet address how to structure and implement future S&T efforts. To realize the full benefits of this assessment RL and Site contractors will work with the Hanford STCG to ensure:

- Identified challenges and opportunities are reflected in project baselines
- Detailed S&T road maps reflecting both near- and long-term investments are prepared using this assessment as a starting point
- Integrated S&T priorities are incorporated into EM Focus Areas, EMSP and other R&D programs to meet near-term and longer range challenges
- This assessment is periodically updated to reflect new challenges and S&T opportunities as work scope is completed

Acronyms

ACP	Accelerated Closure Plan
ACS	Accelerated Characterization System
ASTD	Accelerated Site Technology Deployment
CDI	Canyon Disposition Initiative
CVD	Cold Vacuum Drying Facility
Cs	cesium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH	contact-handled (waste)
CSB	Canister Storage Building
D&D	decontamination and decommissioning
DNAPL	dense nonaqueous phase liquid
DNFSB	Defense Nuclear Facility Safety Board
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
EM	Office of Environmental Management
EM-50	DOE Environmental Management Technology Development Division
EMSP	Environmental Management Science Program
EPA	U.S. Environmental Protection Agency
ERC	Environmental Restoration Contractor
ERDF	Environmental Remediation Disposal Facility
FFTF	Fast Flux Test Facility
FMD	fissile material disposition
FS	feasibility study
FSB	fuel storage basin
FY	fiscal year
GW/VZ	groundwater/vadose zone
HAB	Hanford Advisory Board
HANSF	Hanford Spent Fuel
HLW	high-level waste
HVAC	heating, ventilation, and air conditioning
HWVP	Hanford Waste Vitrification Plant

ID	identification
IHAW	immobilized high-activity waste
Integration Project	Groundwater/Vadose Zone Integration Project
ILAW	immobilized low-activity waste
IPABS	Integrated Planning, Accountability, and Budgeting System
ISOCS	In Situ Object Counting System
ISRM	In Situ Redox Manipulation
ISS	interim safe storage
ITRD	Innovative Treatment Remediation Demonstration
IX	ion exchange
LAW	low-activity waste
LLW	low-level waste
MSE	maintenance support equipment
MSM	master-slave manipulator
MYWP	multi-year work plan
NDA	nondestructive analysis
NETL	National Energy Technology Laboratory
NFDI	National Facility Deactivation Initiative
OCRWM	Office of Civilian Radioactive Waste Management
ORP	Office of River Protection
OST	Office of Science and Technology
OVS	Overview Video System
PBM	plutonium-bearing material
PBS	Project Baseline Summary
PCB	polychlorinated biphenyl
PFP	Plutonium Finishing Plant
PRTR	Plutonium Recycle Test Reactor
PSVE	Passive Soil Vapor Extraction
PUREX	Plutonium-Uranium Extraction (Plant)
RA	remedial action
RAWD	remedial action and waste disposal
RCRA	Resource Conservation and Recovery Act
Redox	reduction-oxidation (facility)
RFETS	Rocky Flats Environmental Test Site
RH	remote-handled (waste)
RI/FS	remedial investigation/feasibility study

RL	U.S. Department of Energy, Richland Operations Office
ROD	record of decision
ROI	return on investment
ROM	rough order of magnitude
RPP	River Protection Project
RTD	resistance temperature detector
S&M	surveillance and maintenance
S&T	science and technology
SAC	system assessment capability
SCW	special case waste
SDGLS	Small Diameter Geophysical Logging System
SNF	spent nuclear fuel
SNM	special nuclear material
Sr	strontium
SST	single-shell tank
STCG	Site Technology Coordination Group
TIP	technology insertion point
TPA	Tri-Party Agreement
TRU	transuranic
UHP	ultra-high pressure
WESF	Waste Encapsulation and Storage Facility
WIPP	Waste Isolation Pilot Project
Wireline-CPT	Wireline-Cone Penetrometer System
WRAP	waste receiving and packaging
WSCF	Waste Sampling and Characterization Facility
WTP	waste treatment plant

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1.0 Introduction

Cleanup of the Hanford Site is a complex, costly, and long-term endeavor. While considerable progress has been achieved, great challenges lie ahead. To provide more focus on achieving tangible progress on Hanford cleanup, the U.S. Department of Energy (DOE) Richland Operations Office (RL) has formulated an outcomes-based vision called "Hanford 2012: Accelerating Cleanup and Shrinking the Hanford Site" (DOE 2000a). This strategy (hereafter referred to as the "Hanford 2012 Vision") will accelerate the cleanup schedules dramatically, resulting in a reduced "footprint" of active site cleanup activities, thereby reducing costs to the taxpayer and freeing the land for other uses.

This document summarizes a recent assessment of science and technology (S&T) needs in the context of the Hanford 2012 Vision and identifies several strategic closure challenges and S&T opportunities.

1.1 Background

The Hanford Site is a large and geographically diverse land area (approximately 1,450 square kilometers) in southeastern Washington State (Figure 1.1). The Site is bisected by the last free-flowing stretch of the Columbia River and contains large areas of pristine shrub-steppe habitat. While DOE maintains primary responsibility for the Hanford Site, portions of the Site (the Wahluke Slope and the Fitzner-Eberhardt Arid Lands Ecology Reserve) are under the jurisdiction of the U.S. Fish and Wildlife Service.

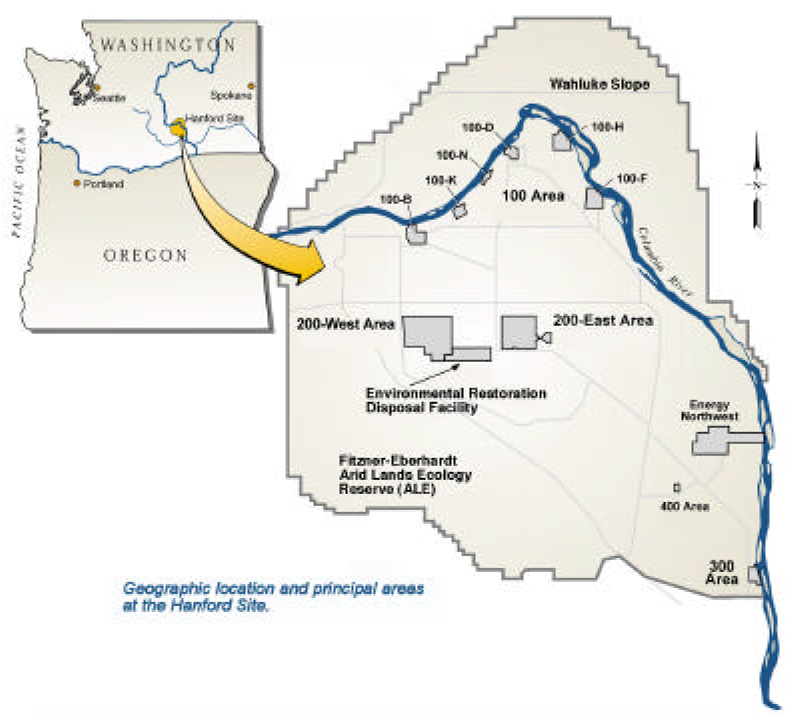


Figure 1.1. Geographic Location and Principal Areas of the Hanford Site

Plutonium production activities at the site between 1942 and 1988 left a legacy estimated at over 400 million curies of radioactive wastes and materials, 300,000 tons of chemical wastes, and hundreds of contaminated facilities. Wastes were introduced into the ground and contaminated the vadose zone (the soil above the groundwater), the groundwater, and the Columbia River. The soil and groundwater beneath Hanford is estimated to contain 1 million curies of radioactivity and 100,000 to 300,000 tons of chemicals. Contaminated groundwater plumes underlie approximately 250 square kilometers.

The sheer expanse of the Hanford Site, the inherent hazards associated with the significant inventory of nuclear materials and wastes, the large number of aging contaminated facilities, the diverse nature and extent of environmental contamination, and the proximity to the Columbia River make the Hanford Site perhaps the world's largest and most complex environmental cleanup project. It is not possible to address the more complex elements of this enormous challenge in a cost-effective manner without strategic investments in science and technology.

1.2 Organization of the Cleanup Mission

As described above, Hanford is engaged in the world's largest environmental cleanup project, with many challenges to be resolved in the face of overlapping technical, political, regulatory, and cultural interests. Despite the complex nature of the work, RL is making progress toward restoring the Columbia River Corridor, transitioning Hanford's Central Plateau for long-term waste treatment and storage, and putting Hanford's assets to work for the future. At the same time, DOE's Office of River Protection (ORP), established by Congress in 1998, is safely managing Hanford's tank waste retrieval, treatment, and disposal. The ORP and RL are working together to safely clean up and manage the Site's legacy wastes. RL's Hanford 2012 Vision for the Central Plateau is predicted upon providing ORP with infrastructure and Site services, while phasing cleanup operations consistent with the ORP mission.

Although this document deals specifically with the cleanup work managed by RL, some of the strategic challenges facing ORP have much in common with those facing RL. RL and ORP are committed to working together to solve common challenges affecting both operations offices. In particular, issues associated with tank farm closure (related to soils characterization, groundwater/vadose zone interaction, barrier development, removal and processing of remote-handled equipment, and deactivation of highly contaminated facilities) are very similar to the cleanup challenges facing RL.

The ORP is performing an assessment of their strategic challenges that will be completed later this fiscal year. Their assessment will include the responsibilities of both the newly selected waste treatment plant (WTP) contractor and the tank farms operations contractor. The ORP assessment will evaluate strategic technical challenges in tank waste storage, retrieval, treatment, disposal, and final closure to determine whether additional focus or emphasis is needed in any of these areas.

1.3 Overview of the Hanford 2012 Site Cleanup Vision

RL's approach to cleaning up the Hanford Site has changed recently. The Hanford 2012 Vision is aimed at accomplishing three distinct "outcomes." Together, these outcomes represent a progress-oriented approach to cleanup that will protect the environment, maximize the return on the taxpayer's investment, and demonstrate RL's commitment to the community.

Embracing the priorities of the regulators, stakeholders, and area Tribal Nations—and understanding the absolute necessity to make real, visible progress sooner rather than later—RL has restructured their work activities to allow completion of important pieces of the Hanford cleanup by FY 2012. This approach will effectively shrink the active waste site cleanup portion of the Hanford Site from 1450 square kilometers to about 190 square kilometers (Figure 1.2). Recognizing that some parts of Hanford cleanup are long term, Hanford 2012 Vision lays out what is achievable by FY 2012 and covers the strategies for:

- Restoring the Columbia River Corridor
- Transitioning the Central Plateau
- Preparing for the Future.

There is a distinct difference in the approach for each of these outcomes. In the River Corridor, the scope of work is well defined and most projects will be completed by FY 2012. In the Central Plateau, where waste treatment, storage, and disposal operations are expected to last for another 40 years, the plan is more strategic and long term. And, finally, the outcome on Preparing for the Future will establish the guiding principles for the future of the Hanford Site as RL seeks to support the local community's economic diversification efforts and derive the maximum taxpayer benefit from the nation's multi-billion dollar investment at Hanford.

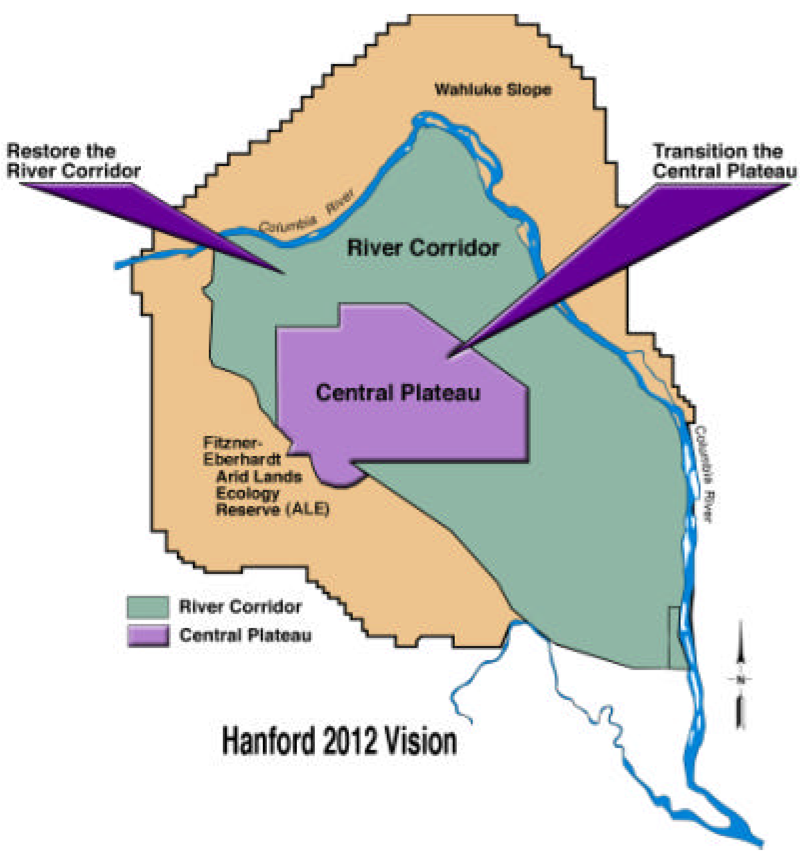


Figure 1.2. Hanford 2012 Vision

The following are the three primary elements of the Hanford 2012 Vision:

1. **Restore the Columbia River Corridor**. Successful cleanup of the river corridor will allow more than 550 square kilometers of Hanford land to be available for other uses, providing opportunities for public access to key recreational areas, protecting cultural resources, and shrinking the footprint for active cleanup operations to approximately 190 square kilometers. Key challenges include the need to remove and process buried high-activity wastes, deactivate contaminated facilities, isolate and ultimately disposition the reactor blocks, and remediate widespread groundwater and vadose zone contamination in accordance with the approved Records of Decision (RODs). Once cleanup work is under way, it will then be possible to propose portions of the Hanford Site for deletion from the U.S. Environmental Protection Agency's (EPA) National Priority List (NPL). Significant cleanup goals will have been accomplished once the Columbia River Corridor Restoration Outcome is realized in FY 2012 (DOE 2001). These goals are illustrated on Figure 1.3.

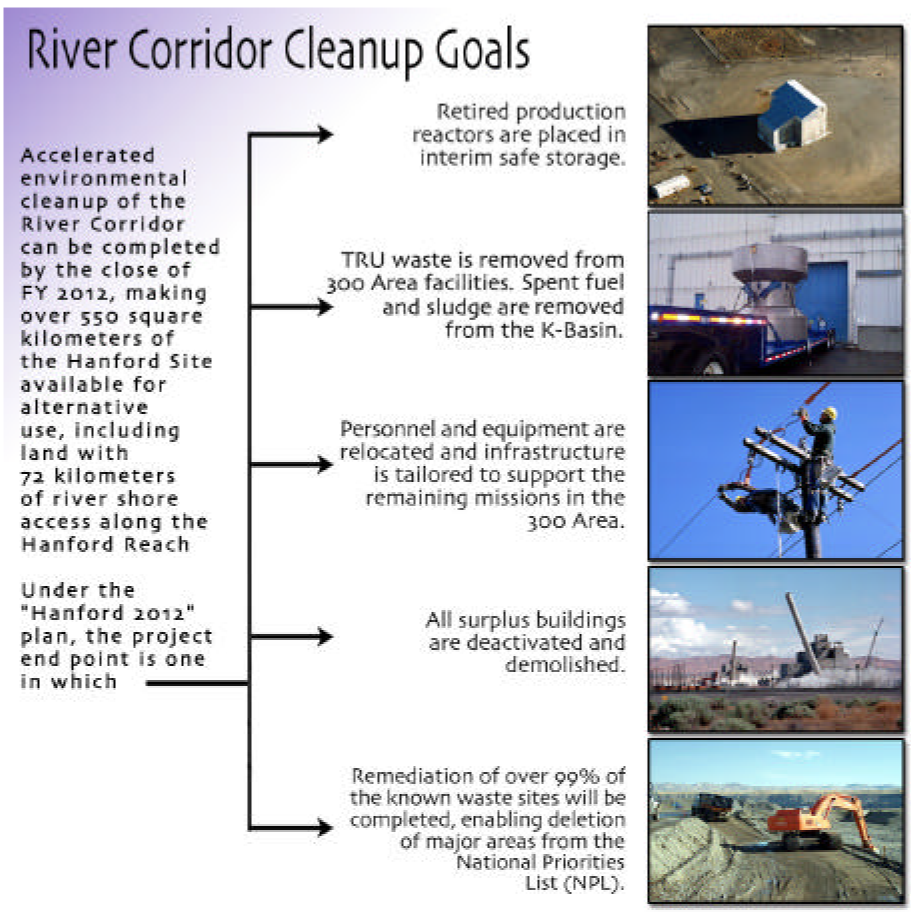


Figure 1.3. River Corridor Outcome Cleanup Goals

2. **Transition the Central Plateau** to long-term waste management. DOE is transitioning the Central Plateau from ongoing waste storage activities to more active waste treatment, storage, and disposal operations. New, state-of-the-art, environmentally compliant facilities will be used to support completion of the Hanford cleanup and the ORP mission. Some of these facilities, including the Canister Storage Building (CSB) and Waste Receiving and Packaging Facility (WRAP), have already begun operation. Key remaining challenges for this outcome on the Central Plateau include requirements for canyon disposition, special nuclear materials (SNM) stabilization and storage, deactivation and decommissioning of facilities, and barriers for final closure of waste disposal sites. The transition objective specifically includes significant goals that are to be met before FY 2012 (Figure 1.4).

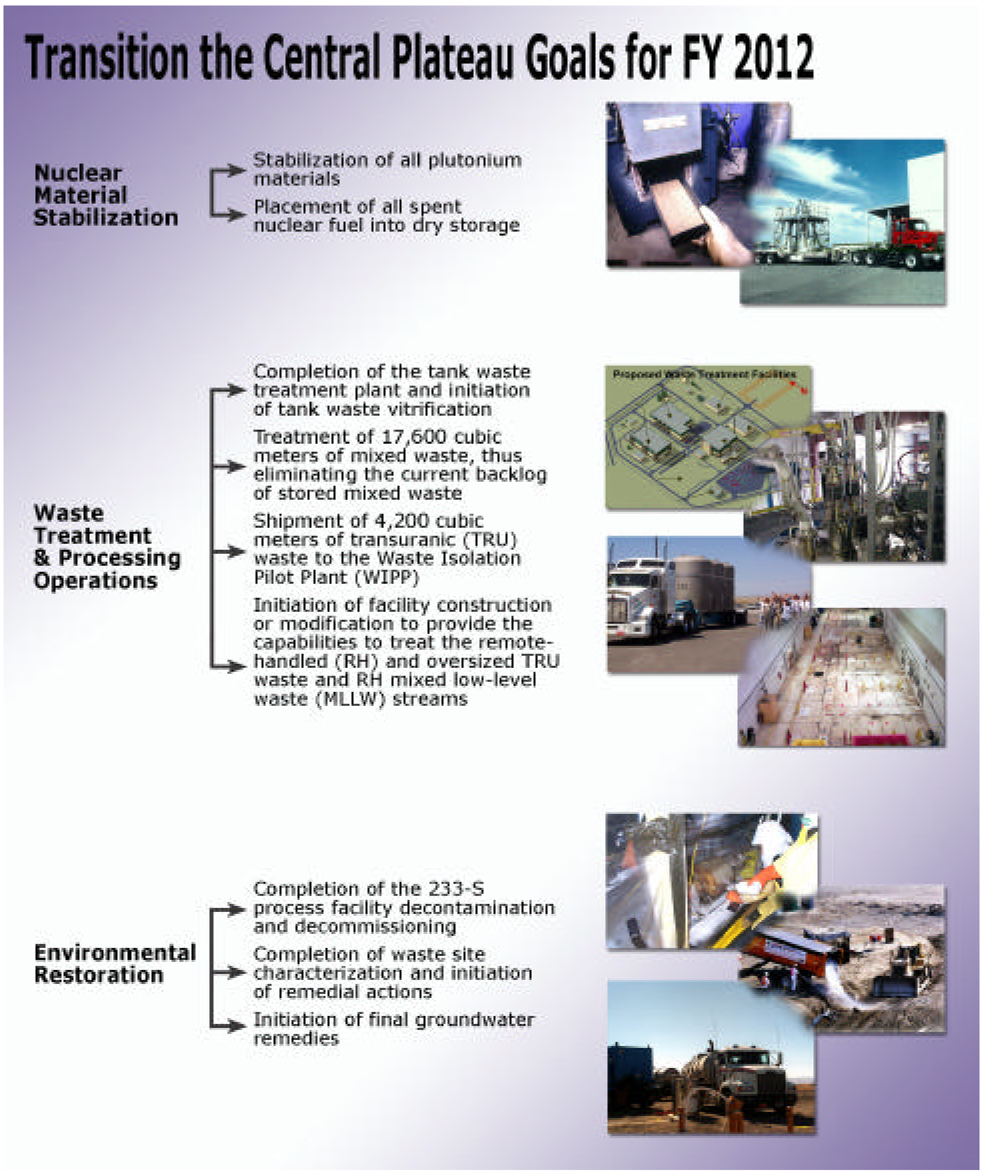


Figure 1.4. Central Plateau Outcome Goals for FY 2012

3. **Prepare for potential multiple future uses** of the Hanford Site, including the long-term S&T mission (e.g., Pacific Northwest National Laboratory's [PNNL] support of the national DOE missions in environmental health, global warming, energy efficiency, environmental cleanup, scientific computing, and nonproliferation of weapons of mass destruction), other DOE missions, non-DOE federal missions, and other public and private land uses. It is expected that the S&T mission will play a major role in the research, development, testing, and deployment of a variety of new or emerging technologies needed to address the Site closure challenges and will lay the foundation for Hanford's future. By leveraging all of Hanford's resources, including those of, PNNL, RL will not only create a climate for successful accomplishment of the Hanford 2012 Vision but will also position the Site well for the future. RL is committed to engaging the DOE S&T mission for ensuring successful resolution of the Site's technical challenges. S&T activities will also be used to further the understanding of the physical environment, not only to ensure the successful implementation of the remedial actions but also to provide a basis for longer-term stewardship activities and reduce uncertainties and risk.

1.4 The Baseline Cleanup Plan

Hanford's EM cleanup mission is scheduled to go through fiscal year (FY) 2046 at an estimated total cost of approximately $24 billion in constant FY 2000 dollars (for RL's portion of Hanford's EM cleanup). This estimate is based on the planned technical, schedule, and cost elements associated with known or assumed methods and technologies that will be used for cleanup. Appendix A provides Hanford cleanup summary-level schedules and logics depicting the site baseline.

This baseline for the cleanup work is now being updated during FY 2001 to reflect the Hanford 2012 Vision. When reformulated into the elements of that vision, the baseline life-cycle cleanup costs fall roughly into five major work breakdown structure elements (in constant FY 2000 dollars), as shown in Table 1.1 and Figure 1.5. This baseline cost estimate reflects a major long-term investment in cleanup. The fact that it embodies many assumptions on technology performance makes it subject to considerable uncertainty.

Table 1.1. Life-Cycle Cleanup Costs

River corridor restoration contract and spent nuclear fuel (SNF)	$2.6 B
River corridor final closure (including final reactor disposition)	$2.8 B
Central Plateau transition	$8.3 B
Site services (crosscutting)	$9.6 B
Stewardship (crosscutting)	$1.0 B
Total	**$24.3 B**

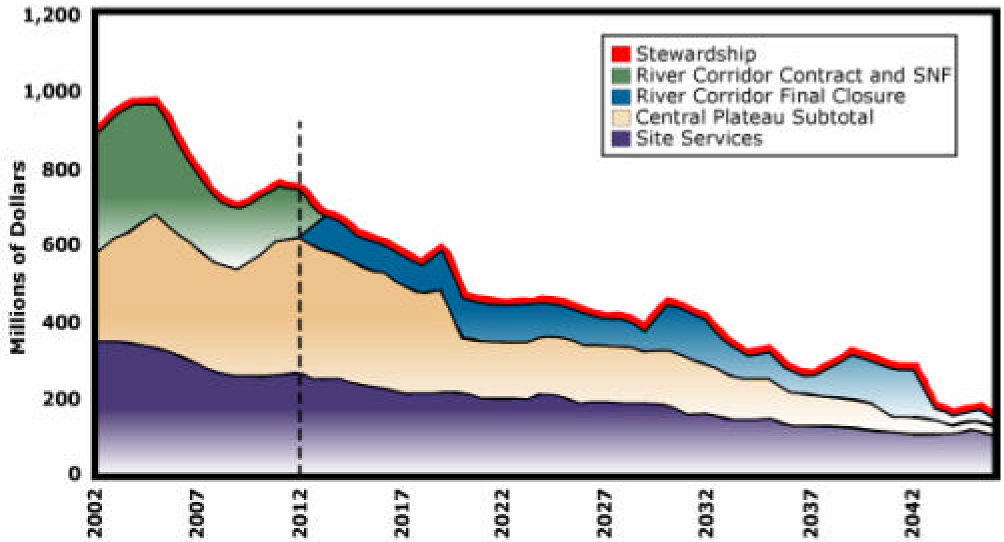


Figure 1.5. Hanford Baseline Cleanup Cost Estimate

New technologies and new scientific research are needed to achieve the Hanford 2012 cleanup vision. Strategic S&T investments will reduce the expected costs, potentially accelerate scheduled completion, and reduce programmatic uncertainties associated with the cleanup activities. This document highlights the areas where investments could and should be made to increase our confidence in achieving desirable cleanup outcomes.

Some of the strategic closure challenges and associated S&T opportunities are directly linked with successfully accomplishing near-term activities. However, several of the challenges and opportunities are more directly associated with work scope that will be completed after FY 2012. After the River Corridor cleanup has been completed in FY 2012 and significant accomplishments made on the Central Plateau, the following tasks will remain to be done:

- Ongoing groundwater remediation, monitoring, and stewardship activities will be required based on enhanced groundwater remedies that will be selected in the FY 2006–FY 2007 time frame in support of EPA's five-year remedy review. Final groundwater remedies (RODs) for the River Corridor are to be implemented after FY 2012 in conjunction with completion of source site remediation.

- The 618-10 and 618-11 burial grounds cannot be remediated until remote-handled processing facilities, retrieval methods, and equipment are developed.

- Disposition of other complex, contaminated facilities such as the canyon facilities, Plutonium Finishing Plant (PFP), Fast Flux Test Facility (FFTF), various 200 Area Laboratories (222-S and the Waste Sampling and Characterization Facility [WSCF]), Plutonium-Uranium Extraction (PUREX) tunnels, 200 Area Waste Management Facilities, and ORP facilities will be required.

- The remaining operating facilities in the 300 Area will undergo decommissioning and decontamination (D&D) upon completion of their mission.
- The production reactors (with the exception of B Reactor) will be placed in interim safe storage (ISS) by 2012. Final reactor disposition will still need to be accomplished.
- Waste site remediation on the Central Plateau will have only just begun in FY 2012 and will continue for some years. This work must be integrated with the closure of the tank farms following completion of ORP's mission.
- Retrieval, handling, and processing of large and remote-handled TRU and mixed wastes will still need to be accomplished.

These challenges in the out years present some of the biggest opportunities for savings and greatest potential for reducing uncertainties.

1.5 Identification of Hanford Site Closure Challenges

The primary focus of this assessment was to identify Hanford's strategic closure challenges. The strategic closure challenges were identified and refined through a series of workshops with participants from the planning and project organizations within RL, ORP, Site Contractors, and PNNL. Strategic input was also provided from the regulators (EPA and Washington State Department of Ecology). Because of the crosscutting nature of this assessment, it could only have been assembled with insight and strong support from all the participants (see Section 6). The objective was to develop a Site-level S&T strategy by identifying S&T opportunities where additional investments above the baseline plan could reduce time, cost, and/or risks. The criteria for identifying strategic closure challenges and associated S&T opportunities, and the relationship of this assessment to ongoing Hanford S&T needs identification process through the STCG, illustrated on the process flow diagram provided in Figure 1.6. Appendix B provides a discussion of the current S&T research and development efforts being undertaken at Hanford. A description of the needs identification and integration processes is provided. In addition, Appendix B provides a summary of recent S&T accomplishments that have benefited the Hanford Site. The identified closure challenges are briefly introduced below. Section 2 and Table A.1 contain a more detailed description of these strategic closure challenges that provide the framework for this assessment.

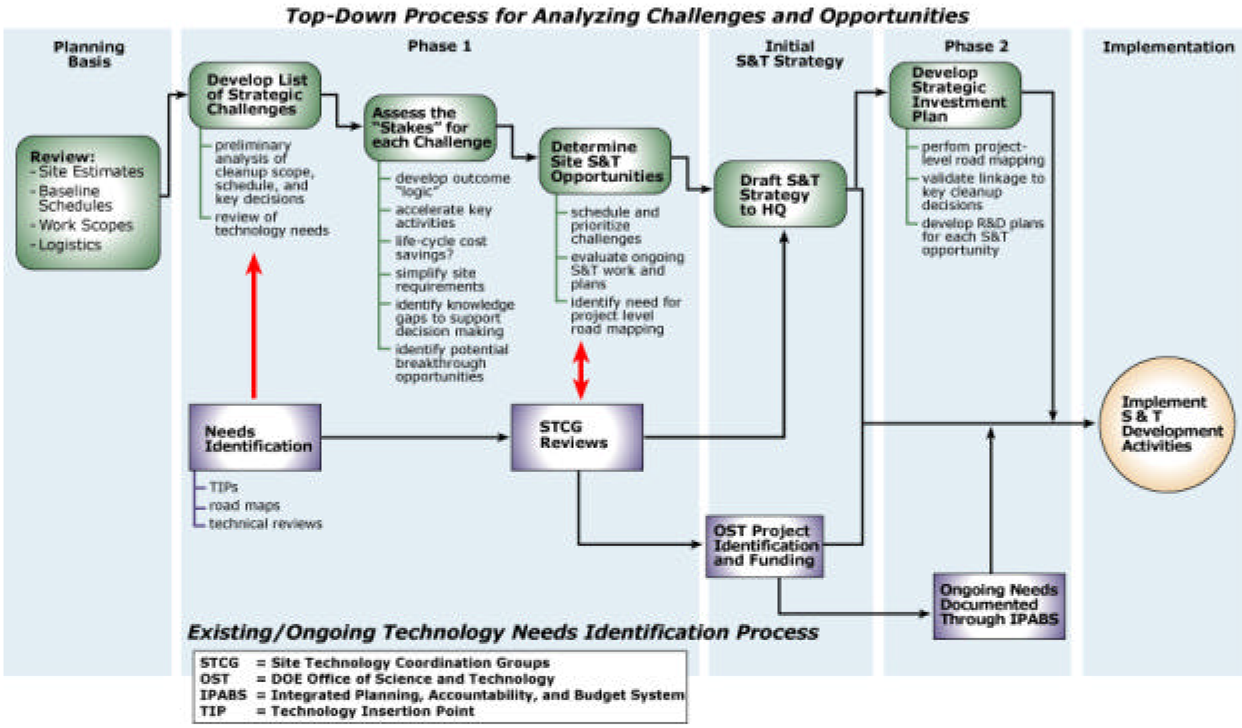


Figure 1.6. Hanford Site Integrated Science and Technology Assessment Process

Retrieval of RH Waste: While the Hanford 2012 vision does not include retrieval of buried wastes at the 618-10/11 waste disposal sites (those are targeted to be cleaned up after FY 2013), remediation of these and other high-activity waste burial sites poses significant technical challenges and risks. Tri-Party Agreement (TPA) milestone M-16-00 requires remediation of these Sites to be completed by FY 2018. Stakeholders and regulators (HAB 2000) have indicated that advances in the retrieval of RH waste are a high priority. In addition, the ability to characterize and process these wastes could substantially affect the safety and cost-effectiveness of these projects in achieving cleanup objectives. The technology-driven path forward has not been determined for characterizing and retrieving wastes from these sites safely at this time, making it a primary and real-time S&T need.

RH-TRU Handling and Disposition: RH-TRU and other high-activity wastes retrieved from Hanford burial grounds and removed from contaminated facilities require processing for disposition, including characterization, segregation, size reduction, and packaging. Development of innovative technologies to address these requirements, either in the field at waste retrieval or facility deactivation sites or at a central 200 Area location, are key near-term S&T opportunities to support achievement of Hanford cleanup objectives. Technology for size reduction of large contaminated objects has been identified as a particularly pressing S&T need in this area.

Highly Contaminated Facilities Deactivation and Decommissioning: Accelerated facility deactivation and decommissioning of highly contaminated facilities presents significant technical challenges and potential S&T opportunities. Innovative technologies are needed for in-place characterization of contaminated equipment. In addition, development of improved portable/ modular and central size reduction and waste processing systems would significantly enhance the safety, efficiency, and cost performance of the facility disposition mission if addressed early in project planning and execution. Safe and cost-effective tools and systems for characterization, decontamination and fixation of contaminants and dismantling and/or removal, size reduction, packaging and disposition of contaminated components are key S&T needs in this area.

Nuclear Materials Management: Substantial work will be required to transition the Central Plateau to support the Site's longer-term waste management mission. Part of that transition is stabilizing and storing nuclear materials, including SNF, plutonium, and cesium and strontium capsules. Due to the inherent hazards these materials present and the age of some of these facilities, significant resources are required for safe storage. The sooner these materials can be stabilized and shipped offsite for final disposition, the greater the potential savings. This cost incentive challenges DOE to streamline the materials management mission, thus speeding up the process and freeing up some of that funding for cleanup. Possible opportunities include modifications to the Spent Nuclear Fuel Project to change the configuration of storage canisters and modifications to plutonium stabilization and storage processes. Enhanced technologies (based on these key S&T needs) may be identified in these areas that could 1) lead to improvements in shortening the schedule for moving the fuel away from the Columbia River and 2) lower plutonium processing and storage costs.

Groundwater/Vadose Zone Phenomenology: The Groundwater/Vadoze Zone (GW/VZ) Integration Program now in place at Hanford is structured to provide the necessary scientific basis for understanding long-term risks and to develop and assess alternative remedial actions. However, there remain significant challenges to enhance knowledge of GW/VZ contamination and to improve GW/VZ phenomenological models that support development and validation of surface barriers and other remedial technologies and support both near-term and long-range cleanup decisions. Completion of the groundwater remediation road map (linking S&T research and development activities to the Site baseline as driven by TPA milestones) is a key S&T need that supports the urgent groundwater remediation challenge discussed below. The GW/VZ Integration Program must focus on, and be driven by, the pressing S&T needs associated with soils and groundwater remediation decisions.

Groundwater Remediation: The eventual replacement of interim groundwater remediation projects now ongoing in the River Corridor and Central Plateau is required under the applicable groundwater remediation RODs. No remediation technology exists to meet this requirement for all the groundwater contamination plumes. Indefinite operation of the existing pump and treat systems adds costs to the program with only limited benefits. Current baseline plans call for implementation of enhanced remedies midway through this decade. Developing innovative groundwater remediation technologies and solutions, therefore, represents a major cleanup challenge and a key S&T need for the Site. This challenge is urgent. Stakeholders (HAB 2000) and regulators (EPA 2000) have both expressed that advances in groundwater remediation are urgently needed.

Subsurface Soil Access: Development of improved capabilities for accessing deep soils and groundwater would enable application of innovative in situ characterization, monitoring, and remediation technologies. Enhanced subsurface access is a key S&T need for in situ characterization and monitoring that support surface barrier development, GW/VZ integration S&T efforts, and groundwater and deep soil remediation options.

Surface Barrier Implementation: In addition to the near-term challenges and S&T opportunities arising from the Hanford 2012 Vision, additional challenges and opportunities arise from long-range Site closure objectives that extend out to FY 2046. For instance, surface barriers are a primary requirement to enable final in situ disposal of wastes on the Central Plateau. The need to refine and optimize surface barrier design and validate performance in a timely manner is therefore a strategic S&T need for supporting key cleanup decisions and ultimate site closure and long-term stewardship requirements.

Canyon Disposition: The key challenge of the 200 Area chemical processing canyons is to establish a final approach for disposition of the canyon structures and the wide spectrum of wastes they contain to achieve final closure of the sites. Disposition options range from cleanout, demolition, and removal to entombment in place, possibly serving as disposal sites for other Hanford wastes. The key S&T needs for the canyon disposition challenge is 1) evaluation and screening of technologies in support of selection of the preferred disposition option (including both waste placement and facility decommissioning needs) and 2) development of technologies needed to implement the preferred disposition option.

Final Reactor Disposition: The Environmental Impact Study (EIS) ROD pertaining to final reactor disposition requires that after the ISS period the reactors will be transported intact to the Central Plateau for disposal. However, TPA negotiations between RL and the regulators have established a TPA milestone (M-93-12) that requires this decision to be revisited in FY 2002 to determine whether technology has evolved sufficiently to require that other options and requirements be considered. This evaluation will examine removal techniques and timing for disposition, including potentially accelerating final disposition of the reactor building. Accelerating final disposition would replace the safe storage enclosure part of the Reactor Interim Safe Storage action (i.e., new roof and monitoring system for long-term surveillance and maintenance). An incentive for additional S&T investment is that the prospect of simplifying the disposal process for the reactor blocks could lead to reduced worker risk and fewer environmental impacts. The key S&T needs for the reactor disposition challenge is, therefore, evaluation and future development of technologies in support of the selected disposition option.

Integration with ORP: RL and ORP will continue to work together to solve challenges that are common to both operations offices. These include tank farm closure challenges related to soils characterization, GW/VZ interaction, barrier development, removal and processing of RH contaminated equipment and wastes, and deactivation of highly contaminated facilities. Final closure of the tank farms presents unique challenges, but many of these challenges share S&T needs similar to those facing RL. Resolution of these key S&T needs should be integrated to maximize the benefits to both operations offices.

2.0 Hanford Site Strategic Closure Challenges

This section describes the strategic closure challenges identified as a result of this top-down assessment in more detail. An analysis of these challenges and potential S&T opportunities derived from them are then described in Section 3. The S&T opportunities arising from addressing these strategic closure challenges will lead to the identification of specific S&T activities where investments are likely to have a major impact in the overall success of the Hanford Site cleanup.

2.1 Retrieval of RH Waste

Retrieval of RH Waste:

Scope—Burial Sites in River Corridor and Central Plateau

Costs—High (>$500M)

Schedule—Execution planned to begin in FY 2013 with retrieval extending for many years

Worker Health and Safety Risks—Very high dose rate materials, criticality concerns, and hazardous chemicals

End States—Well defined (remove and process) for most sites

Retrieval of RH waste from burial grounds represents a significant technological challenge. Of particular concern are the 618-10 and -11 burial grounds associated with the 300-FF-2 Operable Unit. The 618-10 and -11 burial grounds contain diverse wastes from 300 Area fuel fabrication operations and various research and development activities supporting separations process development (e.g., PUREX) and other activities such as the Plutonium Recycle Test Reactor (PRTR) facility. Because of the high radiation levels associated with the wastes, their relatively unknown current condition and configuration, and, in the case of 618-11, their proximity to the Energy Northwest operational commercial nuclear power plant and the Columbia River, these burial grounds constitute major elements of the overall RH waste management challenge at Hanford. The location of the 681-11 burial ground is illustrated in Figure 2.1.

The 618-10 and -11 burial grounds consist of trenches, vertical pipe units, and caissons. There are 15 trenches of various sizes and configurations at the two sites (618-10 and -11). There are up to 149 vertical pipe units that consist of five 55-gallon drums welded end-to-end positioned vertically in the ground. Up to five caissons, used only at 618-11, made of 2.4-m (8-ft)-diameter metal pipe, 3 m (10 ft) long are buried vertically 4.6 m (15 ft) below grade and connected to the surface by offset 91.4-cm- (36-in.)-diameter pipe. All vertical pipe units and caissons are capped with concrete and covered with soil. It is not clear whether or how units were sealed at the bottom. The buried caissons and pipe systems used for RH waste storage are illustrated in Figure 2.2.

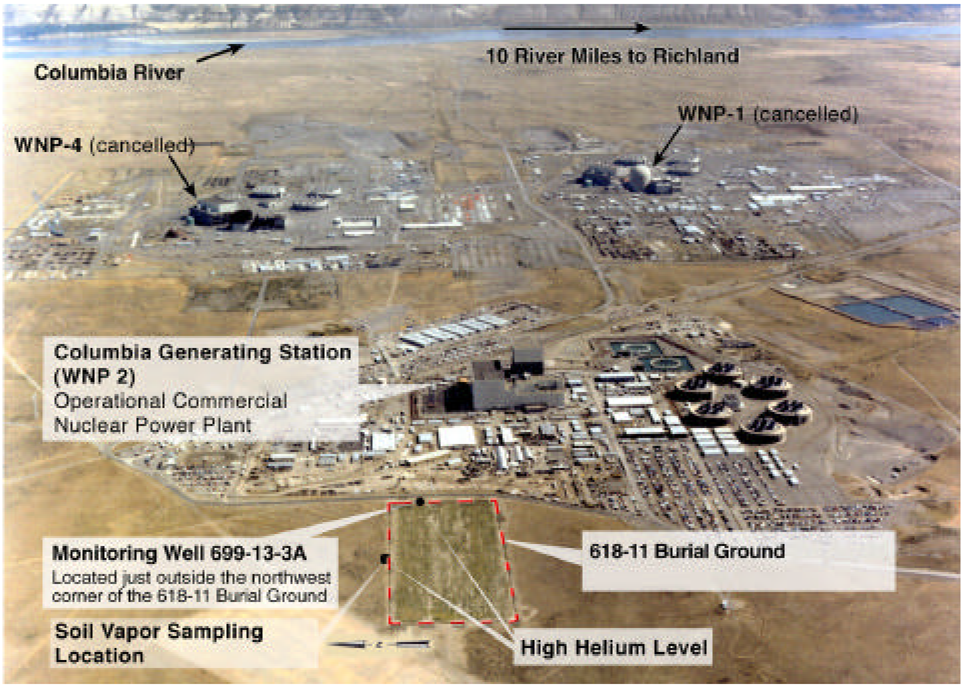


Figure 2.1. 618-11 Burial Ground

Inventory records for these sites are limited and often contradictory; however, it is known that the 618-10 was used from 1954 to 1963 to emplace about 100,000 cubic meters of mostly mixed low-level wastes (MLLW) but including at least 10 cubic meters of remote-handled (RH) TRU. The 618-11 burial ground operated from 1962 to 1967, emplacing a similar volume of mostly contact-handled (CH) wastes but containing about 90 cubic meters of RH-TRU. While general practice was to place higher-activity wastes in buried pipes and caissons, significant RH waste (potentially over 100 cubic meters) is likely to be buried in the trenches on both sites. Primary radiological contaminants include cesium, strontium, plutonium, americium, and neptunium.

The potential for criticality risks also needs to be considered. In addition, high concentrations of tritium (>8 million pCi/liter) have been discovered in groundwater at the 618-11 burial site. Other contaminants include beryllium, zirconium, uranium, aluminum/lithium targets, and sodium/potassium metals, some of which are pyrophoric. Both 618-10 and -11 are south of the Wye barricade. The 618-10 is near the FFTF, and 618-11 is adjacent to the Energy Northwest complex, 5.8 kilometers west of the Columbia River. The combined risks of the buried TRU and the tritium plume near the operating commercial nuclear power plant and the river make 618-11 an especially serious concern.

A ROD for the Hanford 300 FF-2 Operable Unit is scheduled for completion in the spring of 2001. The 618-10 and -11 burial grounds will be identified in this ROD with the preferred alternative of remove, treat, and dispose. The main challenge at the 618-10 and -11 burial grounds is that the technology-driven path forward has not yet been determined for safely

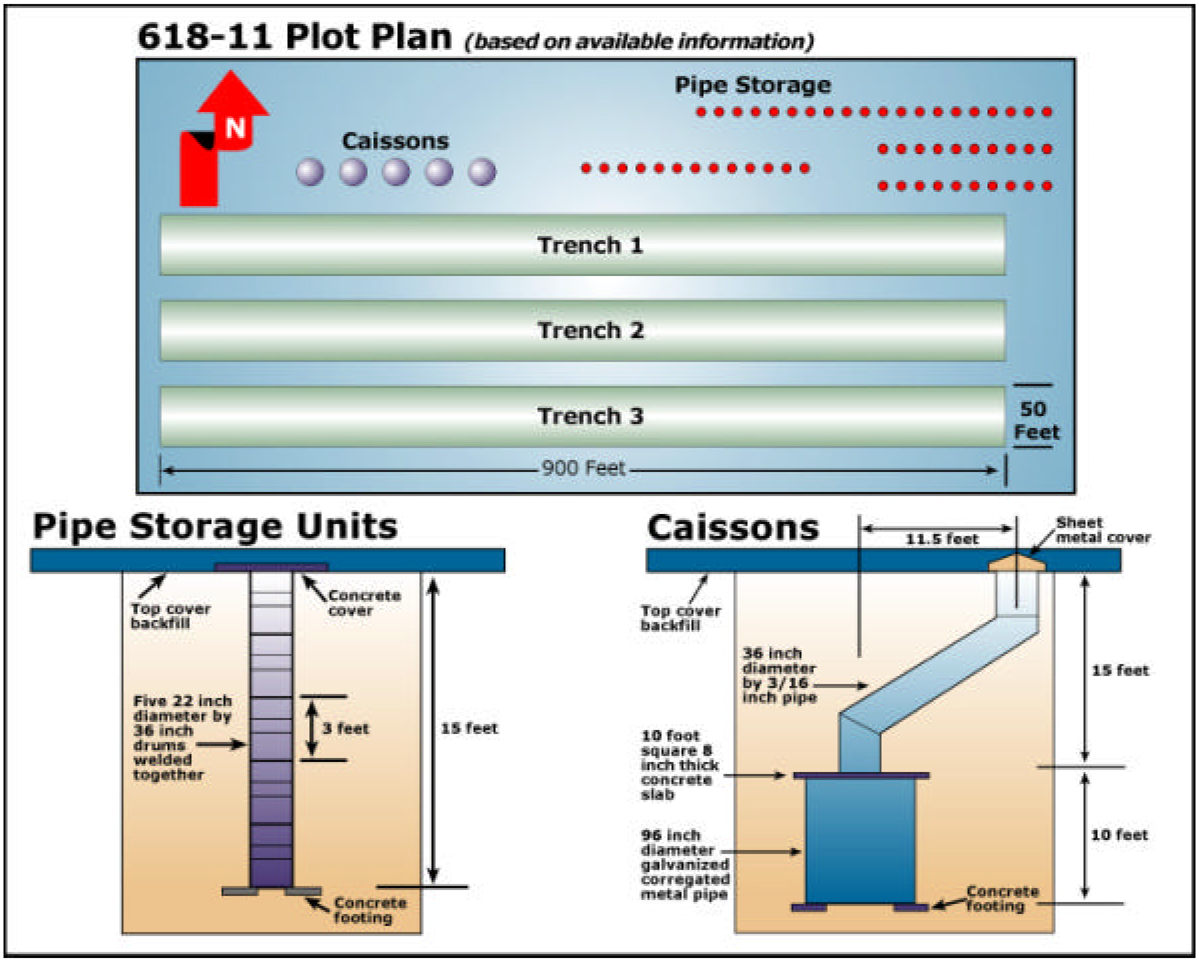


Figure 2.2. Caisson and Pipe Units at the 618-10 and 618-11 Burial Grounds

removing the high-activity waste in the vertical pipes and caissons. Therefore, the desired end point for remediation of the burial grounds cannot be reached until appropriate technologies are identified, developed, and integrated into an overall system.

In addition to the 618-10 and -11 sites, similar burial sites (caissons) with high dose-rate wastes are also located on the Central Plateau. The potential for encountering RH wastes within some of the 100 Area burial grounds is also a real possibility. Numerous facilities located in both the 300 and 200 Areas also contain significant qualities of high dose-rate materials and would benefit from developments in this area. The deactivation and decommissioning of highly contaminated facilities are discussed in greater detail in Section 2.3. Remediation of the 618-10 and -11 burial grounds will precede retrieval of the 200 Area caissons. Therefore technologies, methods, and scientific understanding developed for these burial grounds will be directly applicable to the retrieval of the 200 Area caissons. In addition, the RH-TRU processing facilities, discussed in Section 2.2 are needed soon after retrieval operations begin to minimize the costs and space commitment required for storage. Thus these two challenges are very closely related.

2.2 RH-TRU Handling and Disposition

RH-TRU Handling & Disposition:

Scope—Processing of RH-TRU originating from facilities and buried waste sites

Costs—Very high (>$1B)

Schedule—Design and construction of new capabilities planned to begin in FY 2006 with operations beginning in FY 2013

Worker Health and Safety Risks—Very high dose rate TRU and mixed wastes

End States—Well defined (package, certify, and ship to WIPP) for most waste forms

Safe, efficient management of RH-TRU waste is critical to the ultimate remediation of the Hanford Site. It is projected to cost about $1.7 billion and take up to 35 years to retrieve, treat, and dispose of the over 13,000 cubic meters of RH and oversized TRU and RH-MLLW waste at Hanford. The capability to process these unique waste streams is often referred to as the "M-91 Facilities" after the TPA Milestone governing their development. Figure 2.3 provides a high-level logic and material flow for the waste management system for these difficult waste streams.

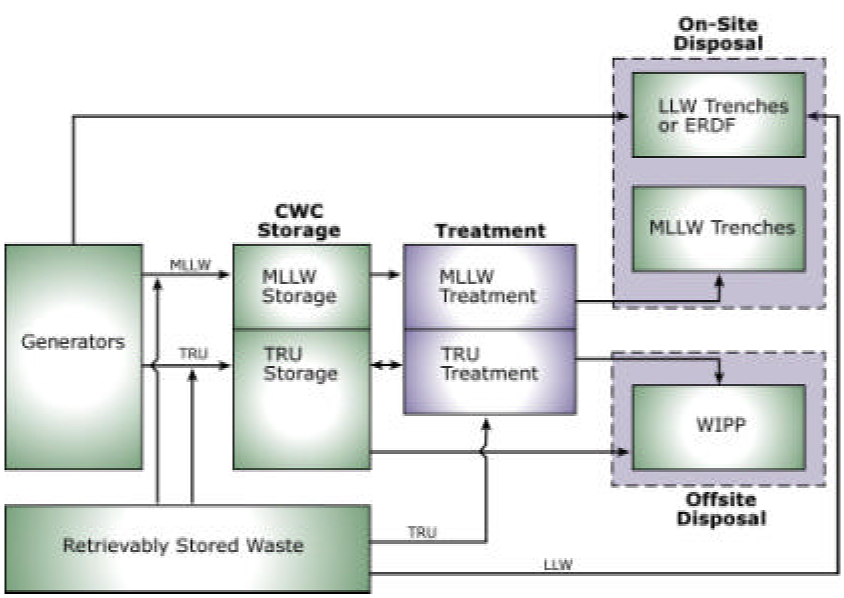


Figure 2.3. Waste Management System

The technical challenges of both RH-TRU and CH-TRU cleanup at Hanford are driven by the large waste volumes, the large sizes of some waste components, the high radiation levels and associated risk to workers, and the uncertain composition, configuration, and physical condition of wastes buried in trenches or interim-stored in underground pipes and caissons (see Figure 2.4). There is substantial uncertainty and schedule risk associated with the baseline elements for RH-TRU disposition activities.

Key capabilities needed for RH-TRU management at Hanford, as well as at other DOE sites, include characterization, retrieval, segregation, treatment, storage, transport, and disposal. The needed capabilities are generally available and relatively mature for management of CH-TRU. However, capabilities for processing and disposition of RH-TRU are limited and in some cases nonexistent at this time. The costs of construction and operation of the M-91 waste processing capabilities could be significantly impacted by S&T advances in developing improved waste treatment technologies. Current high-priority gaps for RH-TRU include technologies for remote retrieval and size reduction, which, if available, could improve worker and environmental safety, accelerate progress, and reduce the costs of RH-TRU cleanup at Hanford substantially. Improved non-intrusive characterization technology could facilitate classification/segregation of wastes, leading to a major reduction in the volumes of waste requiring treatment as TRU and thereby reducing disposal costs significantly.

Figure 2.4. Remote-Handled and Large-Packaged Transuranic Waste

At the present time, RH-TRU management is further constrained by DOE Complex and Hanford Site schedules and funding priorities/profiles as well as unresolved regulatory drivers, including establishment of final Waste Isolation Pilot Plant (WIPP) waste acceptance criteria and closure dates. Figure 2.5 shows the current projections for generation, storage, treatment, and shipment of RH-TRU waste from Hanford. The source of this waste stream is both the deactivation and cleanout of contaminated facilities as well as the retrieval of buried RH-TRU.

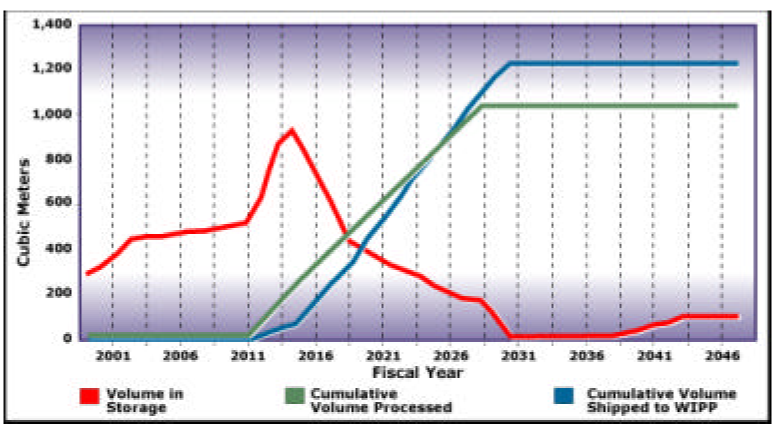


Figure 2.5. Remote-Handled TRU Waste Volume Projections

2.3 Highly Contaminated Facilities Deactivation and Decommissioning

Highly Contaminated Facilities Deactivation and Decommissioning:

Scope—Cleanout and decommissioning of laboratories and process facilities in both the River Corridor and Central Plateau

Costs—Very high (>$1B)

Schedule—Facility deactivation and decommissioning is ongoing for a number of surplus facilities and will continue throughout the duration of the cleanup mission

Worker Health and Safety Risks—Very high dose rate radioactive and mixed wastes, in a wide range of configurations

End States—Well defined (cleanout to the level needed for decommissioning/demolition) for River Corridor facilities, less well defined for Central Plateau facilities

As the Hanford Site cleanup mission is carried out in the coming years, dozens of highly contaminated facilities will be dispositioned. This work will require the characterization, decontamination, and fixation of contaminants and dismantling and/or removal, size reduction, packaging, and disposal of various types of contaminated equipment and structures (see Figure 2.6). Examples of difficult situations include cleanout and disposition of hot cells, glove boxes, piping, ducting, concrete basins, metal floors, walls, and ceilings. Deactivation and decommissioning of the 200 Area plutonium concentration facilities (Facilities designated in the "224" series) are representative of the difficult challenges to be faced in the deactivation and decommissioning of highly contaminated facilities that have not yet been sufficiently addressed in cleanup planning.

Figure 2.6. Hot Cell Technician Using a Plasma Arc Torch to Remove Contaminated Equipment

Facility disposition (e.g., deactivation and decommissioning) activities are ongoing at Hanford and will continue throughout the life cycle of Hanford's cleanup mission. Some facilities have completed their operating missions and are ready for disposition. Other facilities (both existing and planned) will be used to support the cleanup and waste management activities and will need to be deactivated and/or decommissioned in the future. The Hanford 2012 Vision focus on the River Corridor outcome places additional near-term emphasis on the early deactivation and decommissioning of contaminated hot cell and fuel fabrication facilities within Hanford's 300 Area. Investments in S&T can lead to dramatic improvements in the technologies and processes available to deal with these challenging facilities. Accelerating the work scope associated with the deactivation and decommissioning activities in the River Corridor will avoid significant life-cycle costs by eliminating long-term surveillance and maintenance activities. However, the benefits of the Hanford 2012 Vision go beyond schedule and cost savings.

These benefits include earlier reduction of hazards and remediation of the environment, tangible improvements to worker and public safety, and enhanced protection of the Columbia River.

Figure 2.7 illustrates the overall scope and challenges of facility deactivation and decommissioning and the respective drivers and S&T opportunities that emerge.

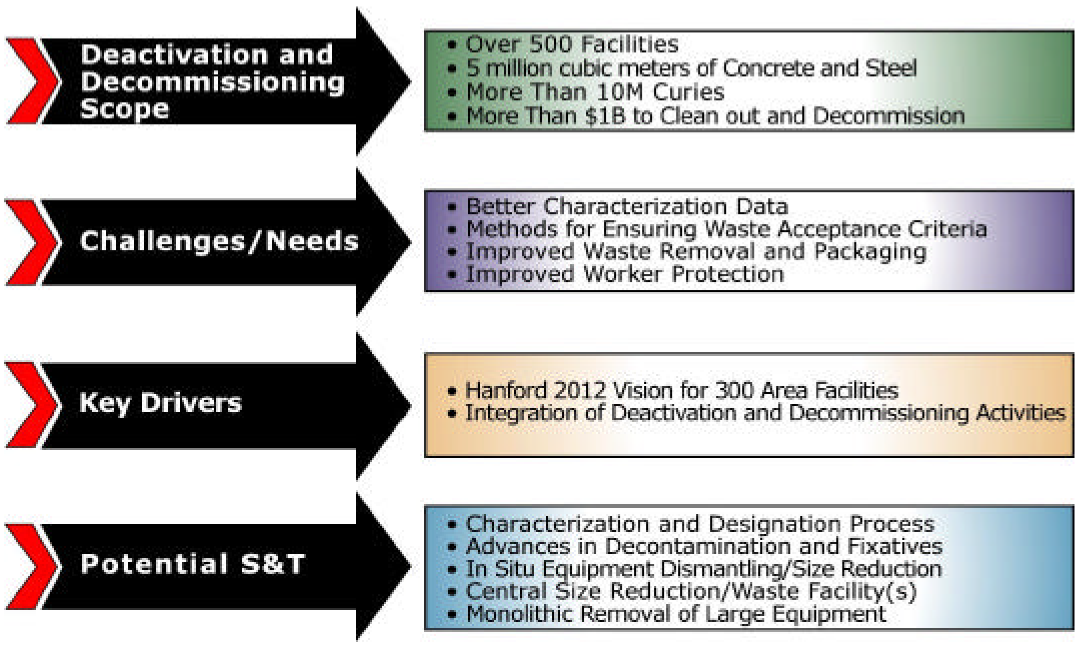


Figure 2.7. Deactivation and Decommissioning Scope and Challenges

2.4 Nuclear Material Management

The Hanford 2012 Vision requires stabilization, enhanced storage, and ultimate removal of nuclear materials that constitute the highest safety, security, and environmental threats at the Site. Safe, efficient management of plutonium-bearing material (PBM), spent nuclear fuel (SNF), cesium/strontium (Cs/Sr) capsules, and other forms of special nuclear materials (SNM) are part of this challenge (see Figures 2.8 and 2.9). A large fraction of the DOE excess nuclear materials resides

Nuclear Material Management:

Scope—Covers stabilization and storage of SNF, plutonium, Cs/Sr capsules, and other forms of SNM

Costs—Very high (>$1B)

Schedule—Work is ongoing on the SNF and PU stabilization – storage will continue well into the next decade

Worker Health and Safety Risks—Very high, some of the materials have very high dose levels.

End States—Well defined (stabilize, store, ship offsite)

Figure 2.8. Plutonium Processes at Plutonium Finishing Plant

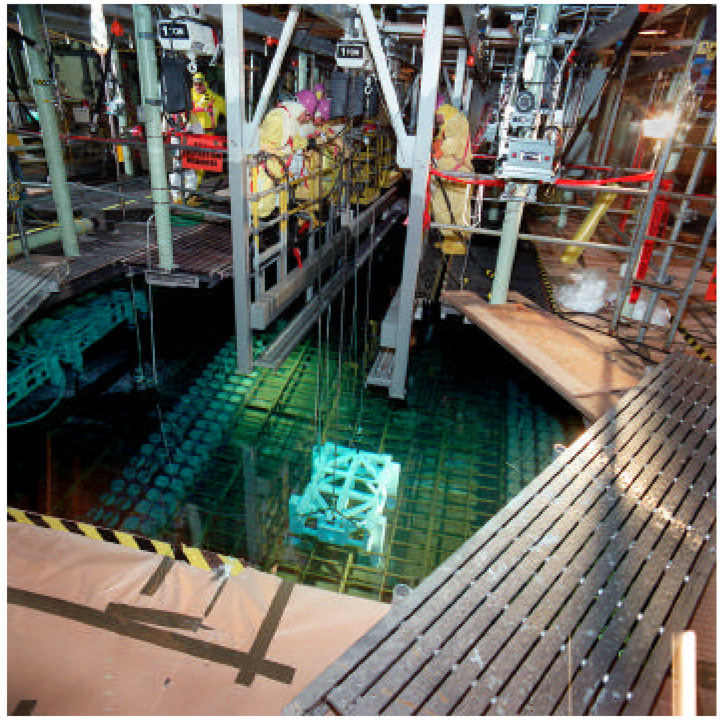


Figure 2.9. Workers Preparing to Move Spent Nuclear Fuel from Hanford's K Basins

at Hanford, including nearly 4 metric tons of plutonium, 2,100 metric tons of SNF, 47 million curies in cesium capsules, and 20 million curies in strontium capsules.

These materials must be stabilized, packaged, stored, and eventually shipped to disposition sites over the next 15 years at an estimated overall cost in current planning of more than $5 billion. If these objectives can be accomplished sooner, the significant cost savings from reduced monitoring and maintenance of nuclear materials can be applied to other cleanup priorities.

The key technical challenges of nuclear material management include the need for safe and cost-effective processes for characterization, stabilization, packaging, monitoring, and surveillance to minimize worker exposure and to meet safeguards and transportation requirements. Most nuclear material at Hanford and other DOE sites will require stabilization prior to storage, shipment, and acceptance at disposition sites. Stabilization is a facility-, labor-, dose-, and cost-intensive process. Although functionally adequate stabilization technologies have been identified and are generally available for most nuclear material needs, significant opportunities exist for improvements in efficiency and reducing overall worker dose and costs. The dimensions of the nuclear material challenge at Hanford are enormous, and the potential savings of dose and cost through process and technology improvements are substantial. Stabilization process and technology improvement are therefore the most critical technical need for nuclear material management at Hanford.

The key challenges in nuclear material management at Hanford are also schedule-driven to meet TPA and Defense Nuclear Facilities Safety Board (DNFSB) milestones. Of equal importance, substantial cost savings are available by accelerating nuclear material processing and removal from the Site. Specific schedule drivers for nuclear material disposition are provided in Figure 2.10. An illustration of the schedule-driven nature of these challenges is that completion of all plutonium stabilization activities in FY 2004 provides very little time for implementing process improvements.

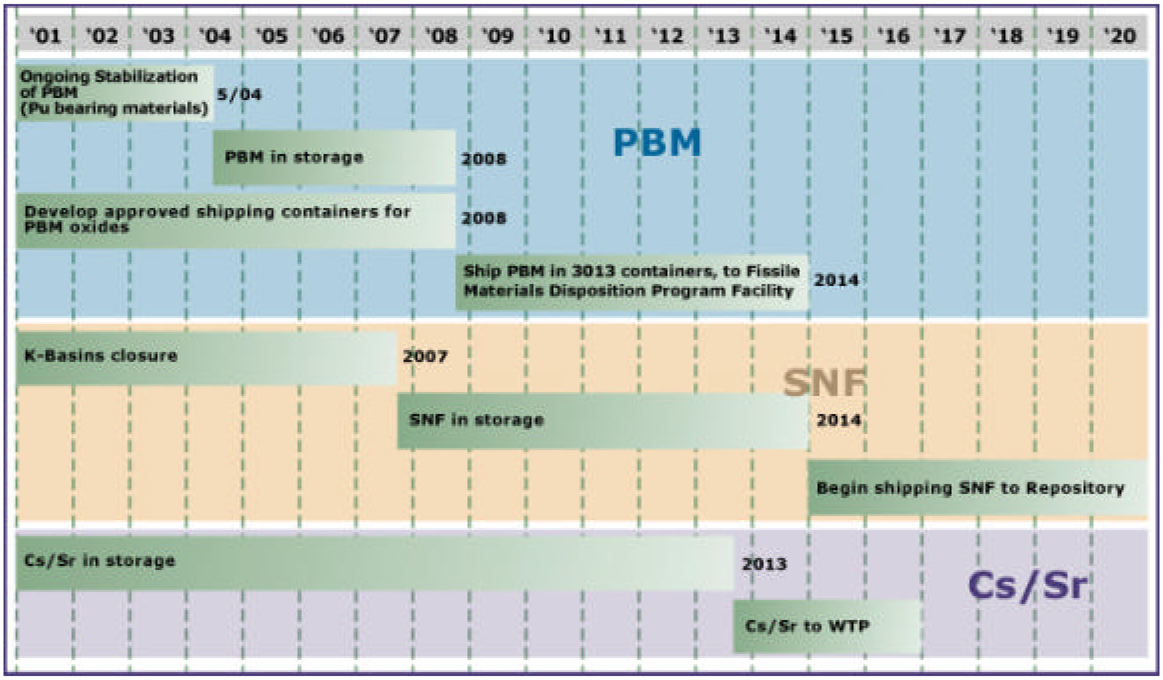


Figure 2.10. Key Schedule Drivers Associated with Nuclear Materials Management

2.5 Groundwater/Vadose Zone Phenomenology

There are significant uncertainties and data gaps in the current understanding of the inventory, distribution, and movement of contaminants in the vadose zone, groundwater, and Columbia River at Hanford. To obtain a thorough understanding of the potential impacts of radioactive and hazardous contaminant releases to the vadose zone, groundwater, and Columbia River, contaminant transport mechanisms and pathways in the Hanford environment need to be understood. Cost-effective characterization and monitoring technologies must be

Groundwater/Vadose Zone Phenomenology:

Scope—Very broad, addressing all site areas with contaminated soils and groundwater

Costs—Uncertain; without the tools and data to make informed cleanup decisions, costs could escalate and cleanup objectives could go unmet

Schedule—Work is ongoing on the GW/VZ integration project and needs to support remedial decisions in the next 4 to 6 years

Worker Health and Safety Risks—Moderate; however, some source sites do contain high dose rate radioactive and mixed wastes

End States—Critical element in supporting cleanup decisions and defining end states developed to gain access to difficult and highly variable conditions in the vadose zone and groundwater, as discussed in Section 2.7. These technologies and enhanced understanding can lead to improved approaches to protect the groundwater and Columbia River during future Site cleanup activities. The data generated also provides input to Site-wide assessments of the cumulative long-term effects of Hanford-derived contaminants to the Columbia River and the region after the Hanford Site closes.

Additional focus is needed on technical options for soil and groundwater remediation. A detailed S&T roadmap for soil and groundwater remediation should be developed in the very near future to drive technology development activities. In addition, future enhancement of scientific understanding and transport models must include a focus on supporting near-term cleanup decisions and remedial action alternatives. These actions should be pursued as key elements of the Groundwater/Vadose Zone Integration Project (GW/VZ Integration Project) describe below.

The GW/VZ Integration Project was established to integrate the efforts of various organizations that are evaluating the impacts of Hanford contamination on human health and the environment. An S&T component was established to improve basic understanding of contaminant transport and migration pathways. The scientific and technical issues identified by the GW/VZ Integration Project through development of an S&T roadmap (DOE-RL 2000b) include data and conceptual models for both the Site-wide assessment of impacts from Hanford and the specific needs of individual projects. The resolution of these issues can clarify assumptions about the extent and nature of environmental contamination and lead to improved baseline cleanup approaches and breakthroughs in how critical site problems are perceived and eventually resolved.

The GW/VZ Integration Project S&T component has successfully linked with 1) projects performing site characterization and assessments to provide data and knowledge to support compliance milestones and 2) other tasks within the Integration Project to develop conceptual models, address key issues, and assess site-wide cumulative impacts. The GW/VZ Integration Project has also engaged other national laboratories and advanced DOE user facilities such as the W. R. Wiley Environmental Molecular Sciences Laboratory (EMSL) at PNNL and the Advanced Photon Source at Argonne National Laboratory to resolve critical issues. In addition to these activities, the GW/VZ Integration Project, in collaboration with other national laboratories and private industry, is conducting a vadose zone transport field study (Figure 2.11) to test advanced characterization technologies and collect data to describe vadose zone flow and transport phenomena.

Figure 2.11 Advanced Tensiometer Installation at the Vadose Zone Transport Field Study Experimental Site

The scope of the GW/VZ Integration Project S&T effort is necessarily broad—it must address data needs and processes across a broad range of technical elements, inventory, vadose zone, groundwater, the Columbia River, and ultimate risk of wastes in the Hanford environment. The management challenge is linking the S&T activities and other GW/VZ Integration Project activities to decisions that may reduce long-term funding for cleanup. A National Academy of Sciences (NAS) committee is reviewing the GW/VZ Integration Project, focusing on the technical approach of the project and linkages of S&T activities to Site decisions. The recommendations of the NAS committee and results from the Site-wide assessment anticipated later in FY 2001 will be used to shape the future direction of the GW/VZ Integration Project S&T component.

2.6 Groundwater Remediation

According to estimates, over 1.7 billion cubic meters of hazardous and radioactive materials were discharged to the ground at the Hanford Site through engineered drainage structures, ponds, retention basins, and spills. As a result of these past disposal practices, over 250 square kilometers of groundwater beneath the Hanford Site is contaminated. In addition, some plumes of contaminated groundwater have reached the Columbia River. Contaminants of primary concern in the Hanford groundwater include tritium, strontium, uranium, technetium, chromium, and carbon tetrachloride, but other species (such as nitrate, plutonium, and radioactive iodine) are also present. Figures 2.12 and 2.13 illustrate the distribution of radioactive and chemical contaminants in Hanford groundwater, respectively.

Groundwater Remediation:

Scope—Covers over 250 square kilometers of contaminated groundwater plumes in both the River Corridor and the Central Plateau

Costs—Moderate (>$100M) but could escalate

Schedule—Interim actions are ongoing in both the River Corridor and Central Plateau; enhanced actions are to be implemented beginning in FY 2006 with final actions occurring after FY 2012

Worker Health and Safety Risks—Low to moderate depending on the concentration of radioactive and hazardous constituents present in the groundwater

End States—Uncertain—partially related to the effectiveness of technologies—no final RODs in place

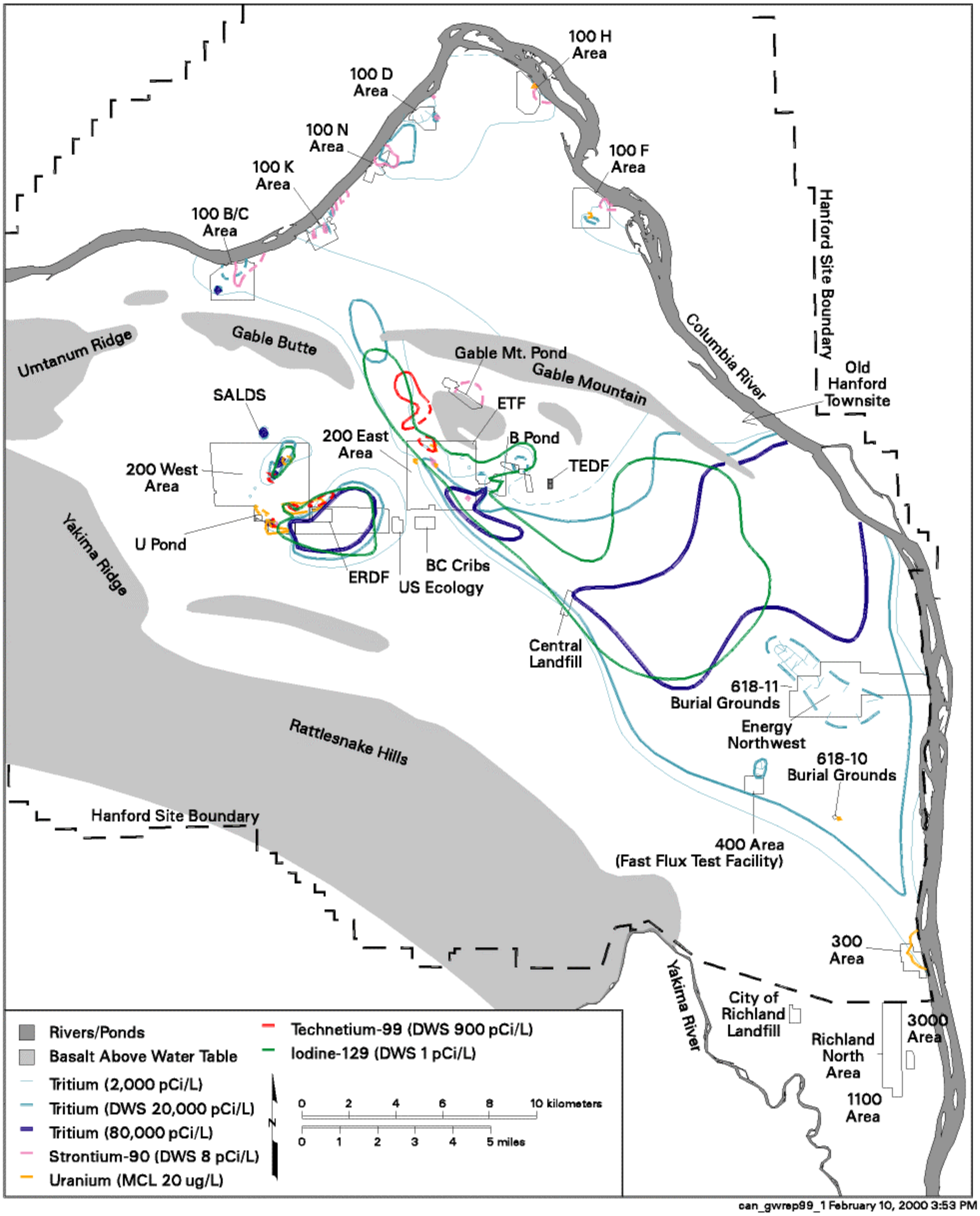


Figure 2.12. Distribution of Radioactive Contaminants in Groundwater during FY 1999

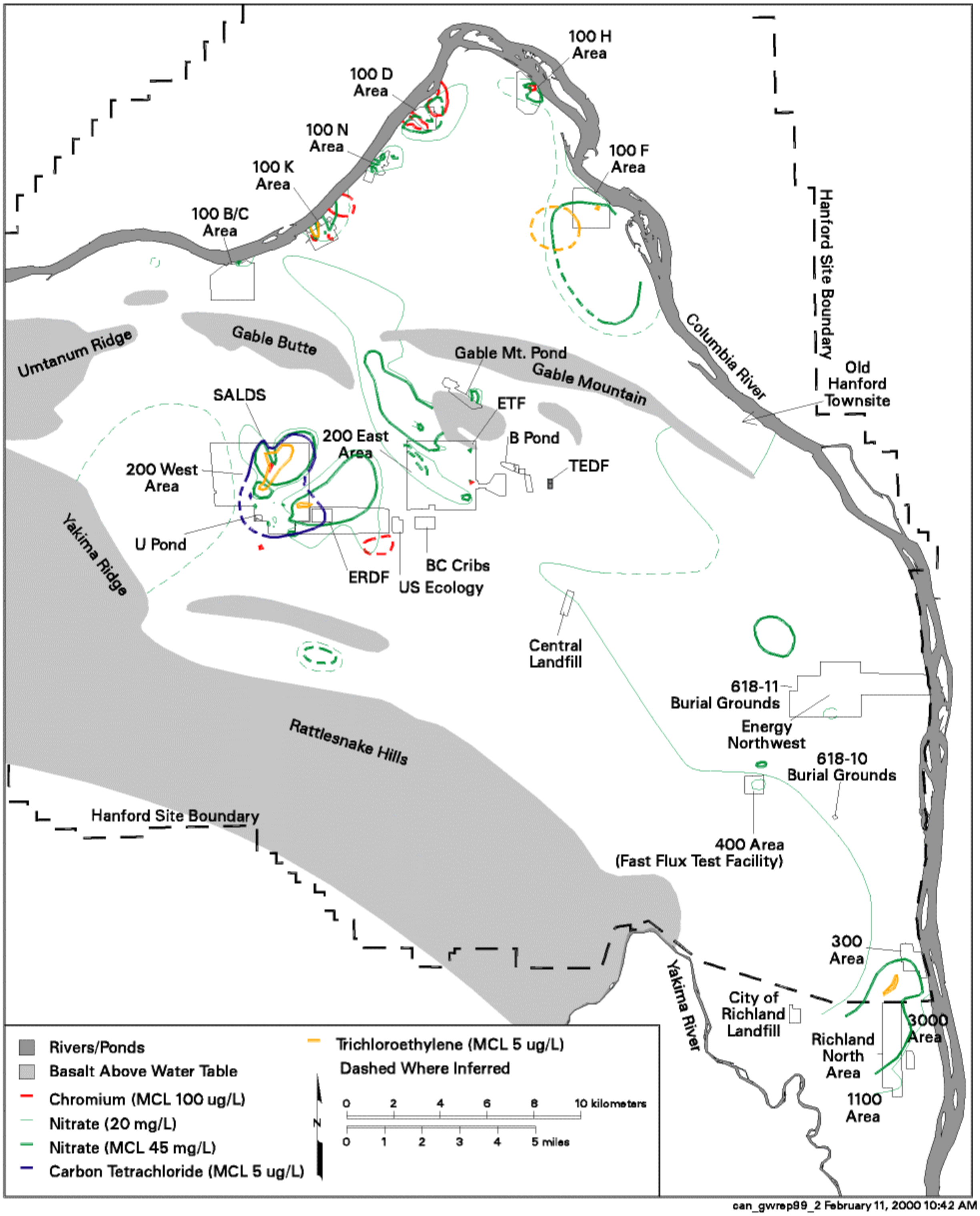


Figure 2.13. Distribution of Chemical Contaminants in Groundwater during FY 1999

Pump-and-treat systems are the baseline technology in use for interim remediation of several of the most contaminated plumes to minimize their migration off the Central Plateau and into the Columbia River. Although pump-and-treat operations have helped limit the flux of selected plumes to the Columbia River, they have not been entirely effective for reducing the contaminant inventory in the groundwater to regulatory limits. Hanford does not yet have a baseline groundwater treatment approach beyond interim pump-and-treat methods, constituting a major gap in future plans for final remediation and closure of the site. In Situ Redox (reduction-oxidation) Manipulation (ISRM) has seen limited deployment and some success at the 100-D and 100-H Areas to reduce chromium contamination reaching the Columbia River (see Figure 2.14). This technology was developed at PNNL and is a good example of how PNNL and the Hanford cleanup contractors can work together to address Hanford cleanup challenges. In the ISRM process, a non-toxic chemical reducing agent, sodium dithionite, is pumped from tanker trucks into groundwater wells to create an in situ treatment zone within a contaminant plume. The treatment alters or immobilizes chemically reducible metallic and organic contaminants as insoluble forms under natural flow conditions.

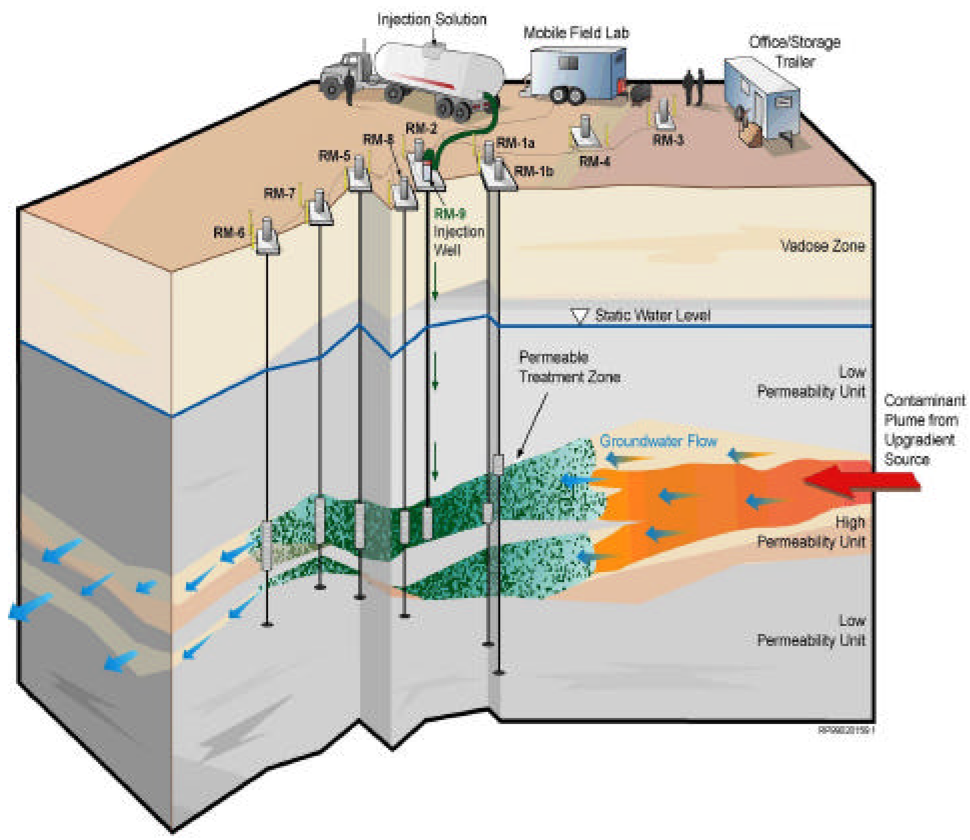


Figure 2.14. In Situ Redox Manipulation Remediation Process

However, unless significant breakthroughs are made in groundwater remediation approaches and technologies, remediation cannot progress beyond these interim measures that have not proven to provide effective long-term cleanup of the contaminants to regulatory standards. Lacking a firm technical baseline, cost and schedule estimates for groundwater cleanup are highly uncertain. In any case, groundwater remediation at Hanford and at other contaminated DOE sites is likely to be a complex, long-term, and costly endeavor.

The key challenges for remediation of widespread groundwater/vadose zone plumes at Hanford include development of cost-effective technologies:

- to remediate contaminated groundwater plumes in accordance with the approved RODs

- to monitor performance of groundwater remediation during and after completion of operations.

Of these, innovative remediation technology has the highest priority. Alternative cleanup standards might also be proposed in connection with innovative groundwater remediation approaches, but only if based on a solid science and technical foundation. Vadose zone remediation (e.g., source removal, control, containment, or treatment) will need to be integrated with groundwater remediation in a comprehensive cleanup program.

The timing of technology development also is crucial to success in meeting Site cleanup milestones. The need has been identified for new or innovative technologies for remediation of plumes of chromium in the 100 Area, strontium in the 100-N Area, and carbon tetrachloride in the 200 Areas. By addressing groundwater remediation as a Site-level challenge and focusing the S&T development efforts on these and other plumes, new remediation approaches may be identified in time to support EPA's five-year remedy review in FY 2005. Following this review, decisions on alternative technologies will be made on whether to initiate new or enhanced groundwater remedial actions. The need to identify and validate new groundwater remediation technologies is therefore urgent. Interim actions will continue until improved remediation actions have begun. The carbon tetrachloride, strontium, chromium, and uranium plumes are excellent candidates for pilot-scale demonstrations or deployments of innovative remediation technologies or approaches.

2.7 Subsurface Soil Access

The Hanford Site holds large volumes of contaminated vadose zone soils and aquifers containing an estimated 1 million curies of radioactive waste and 300,000 metric tons of hazardous chemicals, covering 250 square kilometers of surface area at depths up to 150 meters, that require cost-effective access for characterization, monitoring, and remediation. Due to difficult and highly variable geological conditions and limited access (e.g., under buildings), subsurface sampling and monitoring beyond a few meters depth is feasible only by conventional drilling technologies that can cost over $1,800 per meter. Taking into account future GW/VZ remediation requirements across Hanford (and the DOE complex as a whole), it is apparent that the potential cost savings achievable by developing advanced deep subsurface access technologies could be enormous.

Subsurface Soil Access:

Scope—Covers difficult-to-access subsurface areas for vadose zone and groundwater characterization, monitoring, and remediation

Costs—Individual boreholes can cost up to $1,800 per meter, and hundreds of such boreholes are likely to be required

Schedule—Ongoing need throughout the duration of the cleanup effort

Worker Health and Safety Risks—Low to high depending on source contamination

End States—Not relevant to this challenge

The geology that must be accessed at Hanford comprises unconsolidated silts, sands, cobbles, and boulders, some of which are cemented with calcium carbonate (caliche). Penetration into even the shallow vadose zone by push technologies (e.g., cone penetrometer) can be very difficult. In addition, accessing contaminated soils beneath buildings and liquid and solid waste disposal sites involves difficulties such as installing angle holes in unstable geology (see Figure 2.15), preventing drag-down of contamination into underlying soils and groundwater, and preventing increased worker risk from the facilities overlying the soils.

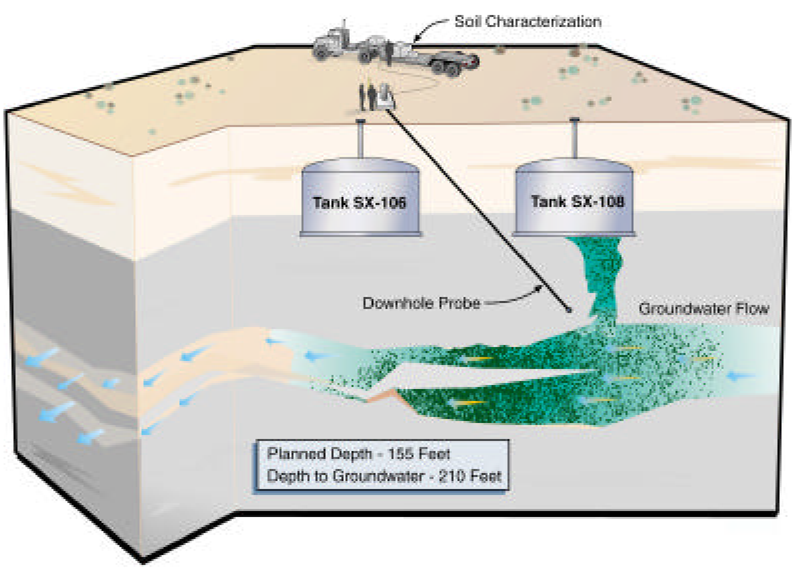


Figure 2.15. Use of Slant Boreholes for Characterizing Soils under Waste Tanks

In addition to subsurface access, technologies are needed for cost-effective, real-time, in situ measurement of hazardous contaminants (e.g., hexavalent chromium, mercury, lead, and sodium) and radionuclides at depth. Such measurement techniques are required to define the contaminant plume boundaries more efficiently and effectively prior to remediation and to support long-term monitoring of performance during and after remediation operations.

Cost-effective subsurface access and characterization technologies are broad needs applicable to multiple operable units at Hanford and other DOE sites. Other Hanford projects that list such technologies as high-priority needs include GW/VZ Integration Project, 100/200/300 Area Remediation, Groundwater Management, and ORP Waste Tank Soils Characterization and Remediation projects.

Schedule requirements are also important drivers. Initial characterization of vadose zone soils in the 200 Areas is scheduled to be completed in FY 2008 with remediation to be completed in FY 2018. A technology review activity has been established for 200 Area burial ground remediation to addresses this need during FY 2001 in support of the first feasibility study.

2.8 Surface Barrier Implementation

Surface Barrier Implementation:

Scope—Covers final closure of many Central Plateau waste sites, disposal facilities, and buildings

Costs—Very high (>$1B)

Schedule—Feasibility studies and testing are ongoing remedial actions for 200 Area waste sites will begin in FY 2008

Worker Health and Safety Risks—Low, because most work is performed above the waste zones

End States—Moderately well defined (use of surface barriers as final actions is assumed but RODs have not yet been issued)

The Hanford 2012 Vision is predicated on an optimized mix of two options: 1) removal, packaging, and disposal in engineered, onsite facilities (e.g., the Environmental Restoration Disposal Facility [ERDF]) or offsite (e.g., TRU to WIPP) and 2) in-place disposal (DOE-RL 1999a). In-place disposal will rely on surface barriers as an integral part of final closure strategies for certain Hanford projects over the next 40 years. Surface barrier construction and maintenance are expensive, and for the Hanford barrier and most other surface barrier concepts, extremely large volumes of natural construction materials are required (DOE-RL 1996). For the 200 Area environmental restoration waste sites alone, it is estimated that over 14 million loose cubic meters of silt, sand, gravel, basalt riprap and native fill will be required. In addition, it is estimated that 200 barriers will be required to cover over 3.2 million square meters for closure of Hanford waste sites (see Figure 2.16). This estimate does not include unique barriers for canyon facilities or other structures or large area (macro) barriers for deep vadose zone contamination or to limit horizontal water movement along geologic features. Proven barrier designs are required, and robust monitoring techniques are needed (DOE-RL 1999b). Monitoring system requirements for barriers are substantial, including the sensitivity and selectivity to monitor slowly changing conditions, the durability to maintain deep remote operation in corrosive environments, and reliability and maintainability for long-term operation. Figure 2.17 illustrates the primary constituents, structure, environmental interactions, and functional performance of a generic barrier design.

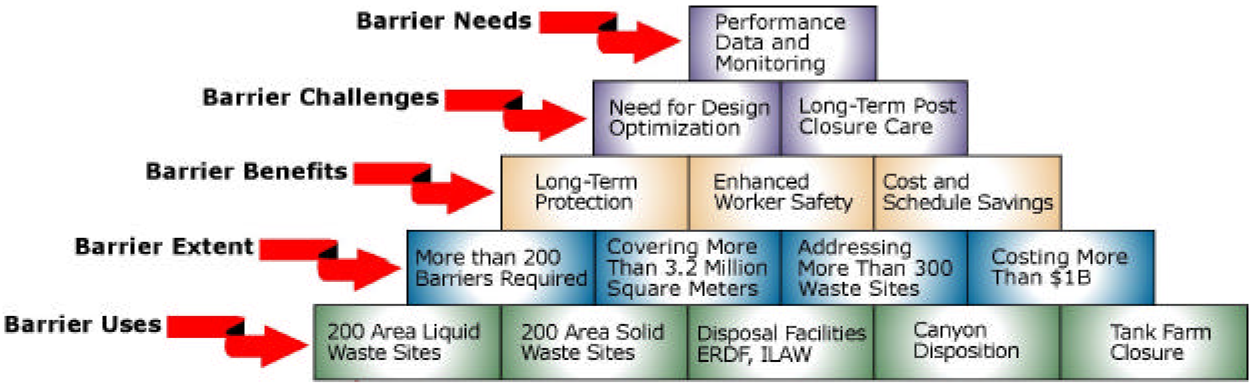


Figure 2.16. Surface Barrier Cross-Cutting Impacts

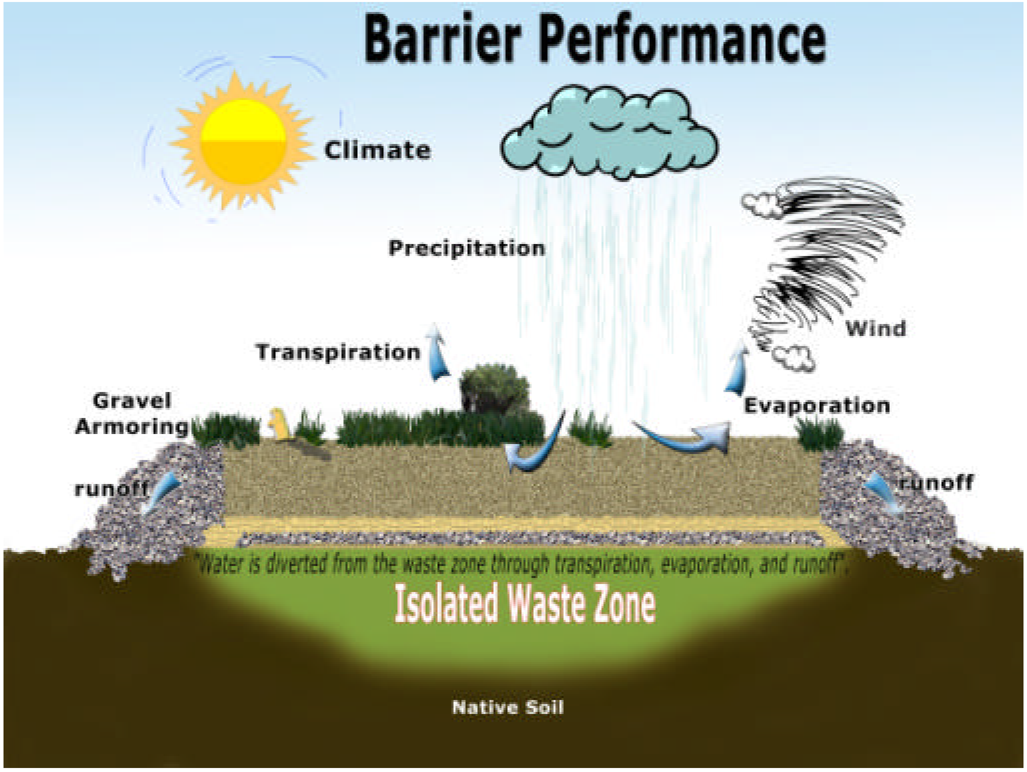


Figure 2.17. Functional Performance of Surface Barriers

Regulatory agencies and stakeholders need barrier performance data before a ROD can be issued for their application. This has the potential to impact TPA milestone completion schedules and costs. DOE and the regulators recently identified the need for barrier performance data on the modified Resource Conservation and Recovery Act (RCRA) Subtitle C barrier, which is thought to be needed for most 200 Area closures but has not yet been tested or proven for the Hanford Site. The critical challenges are to obtain the required field-scale barrier performance data and to develop more robust, long-lived, cost-effective monitoring techniques. Barrier performance data and improved monitoring techniques are necessary for design optimization, which could reduce costs, reduce environmental impacts at borrow sites (sources of raw materials for barrier construction), and minimize long-term post-closure care and monitoring needs. Wastes left in place (either from an isolated waste site or closure of engineered disposal facilities) represent the single largest concern for post-closure stewardship. Therefore, it is essential that the long-term monitoring and maintenance requirements be considered in the design optimization as a critical design parameter.

2.9 Canyon Disposition

Five chemical irradiated fuel processing plants, called canyons, are located on the 200 Area plateau. These facilities are large monolithic structures with thick reinforced concrete walls (see Figure 2.18).

The processing plants have either been deactivated or are in a state that would prevent any future chemical processing of irradiated fuel. An Agreement in Principle was reached in 1996 between DOE, EPA, and Ecology to pursue a ROD on U Plant. The goal of the ROD is to determine the end state of U Plant and, in turn, to use the knowledge gained to pursue RODs for the remaining four canyons. One of the largest and most complex canyons, PUREX, is shown in Figure 2.19.

Canyon Disposition:

Scope—Covers final disposition of the five Central Plateau canyon facilities, including the potential for placement of other site wastes

Costs—High (>$500M) and very uncertain

Schedule—Canyon Disposition (CDI) decision planned for FY 2002, disposition efforts not planned until after FY 2012 (but waste placement could occur sooner)

Worker Health and Safety Risks—High levels of residual radioactive and chemical contamination still reside within the process cells and systems

End States—Undefined; the purpose of CDI is to support a ROD for U Plant

The disposition options for the canyons range from green field remediation to using them as waste disposal facilities and covering them with surface barriers. Figure 2.20 illustrates such an entombment approach. Completion of the alternative analysis and preparation of a proposed plan for the U-Plant canyon is scheduled for FY 2002.

At the present time, there are no TPA milestones associated with obtaining a ROD for canyon disposition, but it is fully expected that TPA milestones will be adopted after the ROD is issued. Using the canyons as waste disposal facilities, particularly for high dose-rate wastes, could reduce waste processing and disposal costs significantly, including reassessment of needed facilities for dealing with RH wastes. The safety and environmental impacts of such alternatives need to be assessed in evaluating the alternatives.

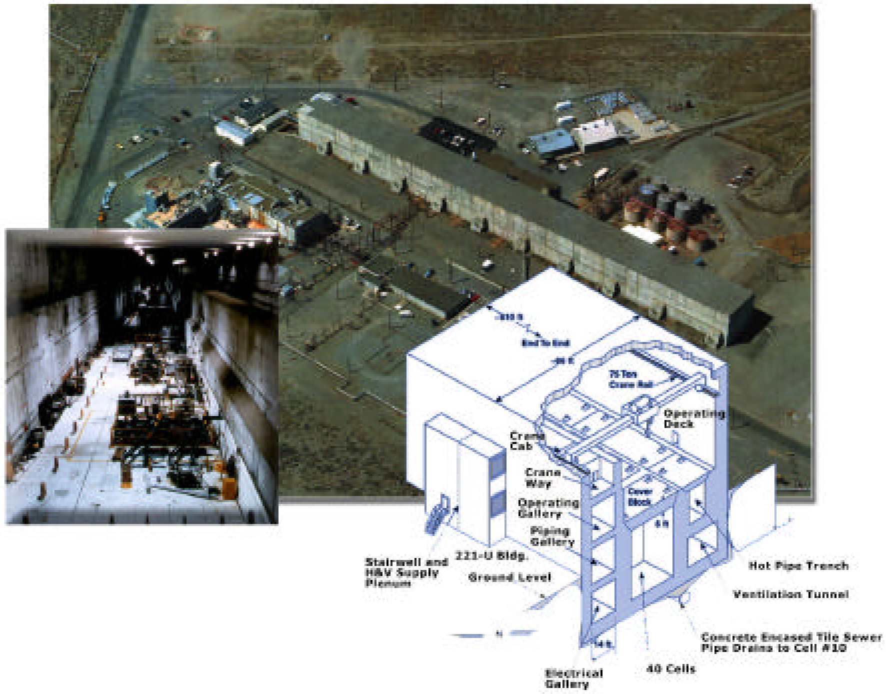
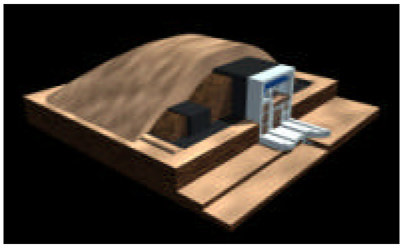


Figure 2.18. U Plant Canyon

Figure 2.19. Plutonium-Uranium Extraction Plant



Alternative 0: No Action
Alternative 1: Full Removal and Disposal
Alternative 2: Decontaminate and Leave in Place
Alternative 3: Entombment with Internal Waste Disposal
Alternative 4: Entombment with Internal/External Waste Disposal
Alternative 5: Close in Place - Standing Structure
Alternative 6: Close in Place - Collapsed Structure

Figure 2.20. Canyon Disposition Alternatives

The rough order of magnitude (ROM) costs associated with the final disposition of the processing facilities presently range from $80M to $160M for each canyon, depending on the disposition alternative selected. However, the uncertainties in approach, cost, and schedule requirements for canyon disposition are very large at this time.

S&T research and development activities will support the selection of a preferred disposition alternative and will be needed to implement the selected alternative. Technology needs associated with the disposition alternatives include demolition technology, large equipment size reduction, remote handling of waste, methods for the final-stage filling of the facility, and development of an acceptable long-term surface barrier and monitoring capabilities. Similar technology needs and gaps exist for potential disposition paths for other highly contaminated facilities at Hanford (such as waste evaporator facilities) as well as at other DOE sites.

While final disposition of the canyons can wait, an early decision is strategic because it could greatly simplify the Site waste management logic. In particular, the M-91 waste management capability (for remote-handled and oversized waste forms) could be impacted significantly by this decision by fundamentally altering the waste volumes and classifications requiring disposition.

2.10 Final Reactor Disposition

Nine surplus production reactors are situated along the Columbia River on the Hanford Site. The reactors have been shut down for several years and have undergone varying degrees of deactivation in preparation for interim safe storage (ISS) and final disposition. The ROD for an environmental impact statement (EIS) completed in 1989 indicates that final disposition for eight of the

Final Reactor Disposition:

Scope—Covers final disposition of the River Corridor reactors placed in ISS

Costs—High (>$450M)

Schedule—Reassessment of final disposition will be undertaken in FY 2002, final disposition is scheduled to begin in FY 2015

Worker Health and Safety Risks—High levels of residual radioactive contamination still exist within the reactor blocks

End States—TPA milestone M-93-12 requires a reevaluation of final reactor disposition in FY 2002 reactors will be one-piece removal and burial in the 200 West Area of the Site. B Reactor was one of the eight reactors considered in the EIS but, because B Reactor is on the National Register of Historic Places, it will be converted to become a museum instead. The ninth reactor, N Reactor, was not considered in the EIS/ROD and still requires a decision on final disposition.

The disposition of the reactors covered by the EIS is being conducted in two phases. The first phase is the ISS of the facilities (see Figure 2.21). The successful conversion of C Reactor to ISS status was a significant accomplishment for RL and DOE-EM in the cleanup mission at Hanford.

Figure 2.21. C Reactor Complex before and after Interim Safe Storage

Placing a reactor in ISS involves removing the ancillary structures around the reactor shield walls and placing a safe storage enclosure on the reactor that will last up to 75 years. The M-93-00 TPA Milestones have established targets for the ISS portion of reactor disposition. The second phase will be the final disposition of the reactors. While the EIS ROD selected the one-piece removal alternative, it was agreed in the TPA milestones (M-93-12) to review the technical baseline for the removal decision and to evaluate innovative approaches and technology developments. A decision is scheduled for FY 2002 to validate the one-piece removal approach or support alternative disposition paths for the reactors. Placing the reactors in ISS is to be completed by FY 2012 as part of the accelerated River Corridor activities. Final reactor disposition is scheduled to begin in FY 2015 under current baseline plans.

S&T efforts for the reactor final disposition could affect the end-point decision on the reactors with fewer impacts to the environment. The primary issues are worker safety, environmental impacts, and costs of one-piece removal versus other alternatives for final reactor disposition. Reactor disposition alternatives will focus on the timing and methods for dismantlement. S&T efforts may be needed to provide technical support for evaluating alternatives leading to the scheduled FY 2002 reevaluation of the reactor disposition decision. Key issues to be addressed in evaluating disposition alternatives include potential environmental impacts of roads, structural stability of the blocks, and worker dose in the transport scenario versus technical, environmental, and worker safety impacts of other demolition/removal approaches. This evaluation will examine potentially accelerating final disposition, thus potentially replacing the safe storage enclosure required for Reactor ISS Action (i.e., new roof and monitoring system for long-term surveillance and maintenance). The roadmapping of baseline and alternative approaches needs to be completed quickly, and, if S&T needs are identified, the time for follow-up is limited.

The final disposition costs for the reactors are based on the EIS ROD and escalated from the original report. The final disposition costs, minus the costs for the ISS portion, are estimated as $54M each (range from $42 to 78M) for a total of approximately $381M for the seven reactors. The N Reactor is a significantly different design than the other reactors, and its final disposition is estimated at $69M, an amount that will be reevaluated during the decision process for N Reactor by FY 2009.

2.11 Integration with the Office of River Protection

Integration with ORP:

Scope—Covers tank farm closure challenges that are similar to challenges facing RL

Costs—Very High (>$1B)

Schedule—Closure actions will begin in the FY 2015 time frame

Worker Health and Safety Risks—High levels of residual radioactive and chemical contamination will likely still exist after retrieval operations

End States—Final closure end states for the tank farms have not been decided and will be affected by retrieval operations

The Hanford 2012 Vision includes support for the ORP mission as a primary objective of the initiative to transform the Central Plateau to a long-term waste management mission. ORP is responsible for safe storage, retrieval, treatment, and disposal of 53 million gallons of highly toxic, high-level radioactive waste stored in 177 underground tanks located within 11 kilometers of the Columbia River. One-hundred-forty-nine of these tanks have a single carbon steel liner inside the concrete tank and are decades beyond their design life. Sixty-seven of these "single-shell" tanks are known or assumed to have leaked an estimated 4 million liters of waste into the soil. Some of this waste has reached the groundwater, threatening the Columbia River. It is urgent that the tank waste be vitrified (turned to glass) and stored or disposed of in a more secure location before more leaks occur and tanks and infrastructure deteriorate to the point at which the cost and schedule for cleanup become prohibitive. The fundamental project elements of River Protection Project (RPP) are illustrated in Figure 2.22.

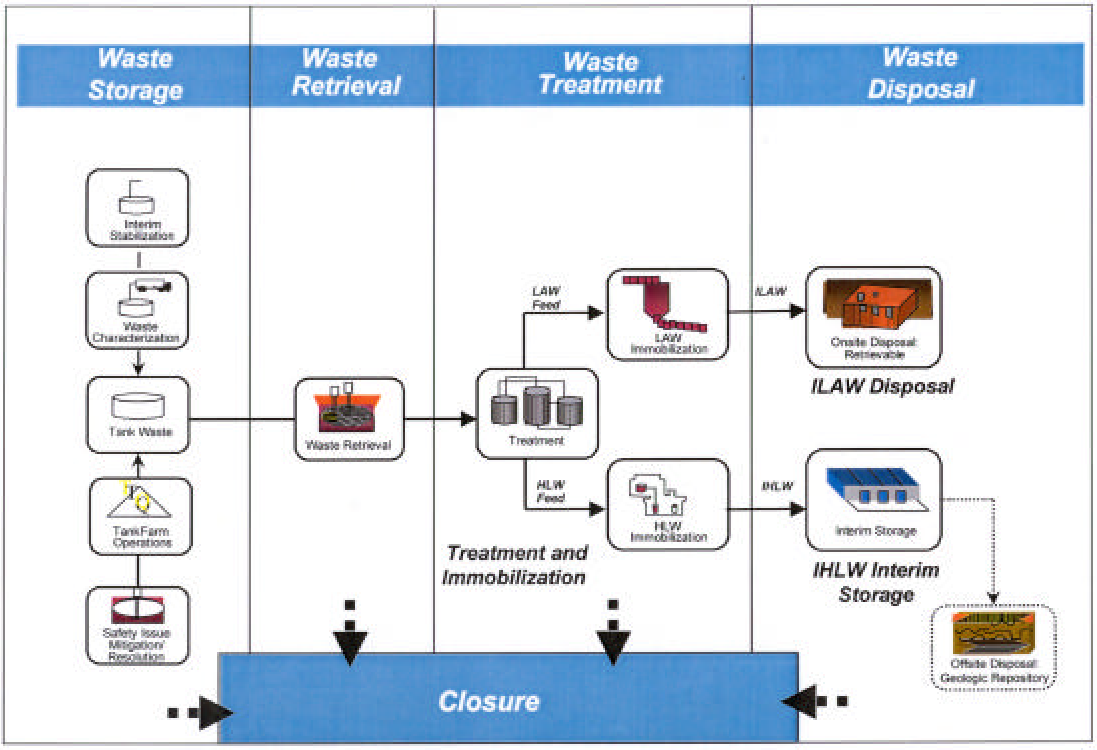


Figure 2.22. River Protection Project Flow Diagram

The plan to treat the tank waste is divided into two phases, with 10 percent of the waste volume containing 25 percent of the radioactivity treated in Phase 1.

The treatment plan is to separate the waste into high-level waste (HLW) and low-activity waste (LAW) portions and then to immobilize both portions in glass waste forms for disposal. This plan and the technologies selected meet regulatory requirements and public expectations and are the best available for immobilizing these wastes.

The waste treatment plant (WTP) has the capacity to process the Phase 1 waste by 2018. Requirements to complete the full mission were considered carefully, and provisions for future expansion of capacity enable completion of the mission within the WTP design life. Figure 2.23 presents a high-level schedule for accomplishing the goals of the RPP.

The ORP will perform an assessment of their strategic S&T challenges, similar in concept to this assessment, later this fiscal year. This assessment will include the responsibilities of both the newly selected WTP contractor and the tank farms operations contractor. The ORP assessment will evaluate strategic technical challenges in tank waste storage, retrieval, treatment, disposal, and final closure to determine whether additional focus or emphasis is needed in any of these areas.

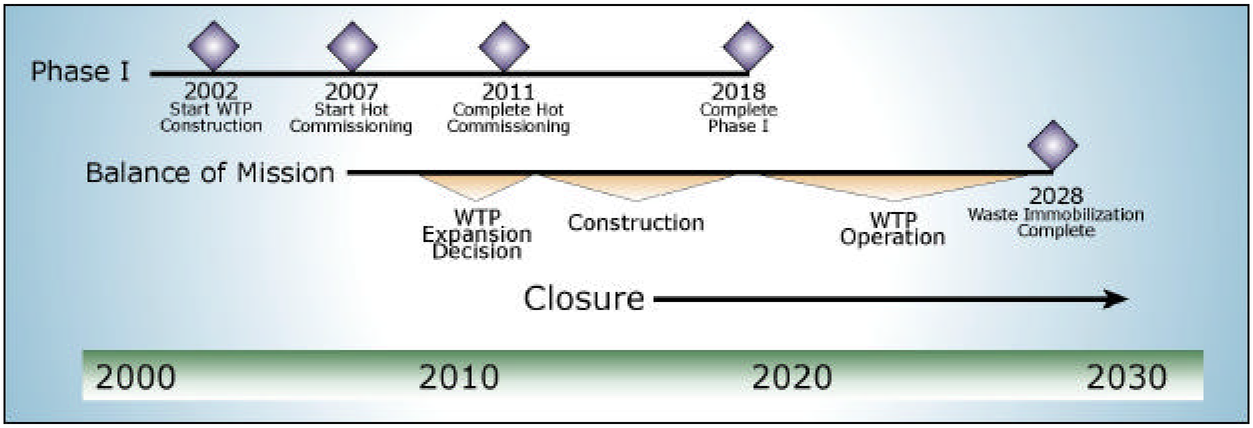


Figure 2.23. River Protection Project Schedule

Several of the strategic challenges identified by RL will apply directly to the closure of the tanks and underlying contaminated soils and the deactivation of ORP facilities. RL and ORP are committed to working together to solve common challenges. In particular, issues associated with tank farm closure (related to soils characterization, GW/VZ interaction, barrier development, remote subsurface access, removal and disposition of RH equipment, and deactivation of highly contaminated facilities) are very similar to the cleanup challenges facing RL. Examples of the already close integration between ORP and RL are the consistent statements of S&T needs, the involvement of both organizations in planning groundwater and vadose zone characterization activities, and the sharing of data from S&T activities. Through the GW/VZ Integration Project, RL has collaborated with ORP to address efficiencies in site characterization and have provided data to support assessments where tank leaks have impacted groundwater. As RL and ORP develop detailed S&T roadmaps for addressing these challenges, close collaboration will be maintained where common and/or interrelated technical challenges exist. As the RL S&T opportunities (discussed in the following section) mature, the needs of ORP will be considered in the planning and execution of these opportunities.

3.0 Formulation of Hanford Site S&T Strategy

Section 2 provided a description of the scope, technical issues, and S&T needs associated with each strategic closure challenge, along with the projected baseline costs and schedule drivers. In order to understand the relative magnitude and urgency of each challenge, some qualitative analysis has been conducted. This comparative information is provided in the subsequent sections and was used as initial input for formulating fundamental S&T opportunities and providing a structure for follow-on S&T planning and road-mapping activities.

3.1 Analysis of Strategic Closure Challenges

3.1.1 Research and Development Time Frame

Figure 3.1 illustrates the challenges in relation to the time frame needed for their resolution. The figure also provides a conceptual depiction of where each of the challenges lies on the research and development spectrum. The time frame shown for each challenge provides a general indication of when technology insertion must be made to allow project execution to proceed as planned. S&T development activities must be conducted prior to these time frames. For example, the groundwater remediation challenge is shown in the FY 2006–FY 2007 time frame. It is at this point that decisions will made to enable implementation of enhanced groundwater remedies. Therefore, new remedial technologies or approaches must be developed before that time.

This simple illustration provides important information with respect to both the urgency of each challenge and to the form of the anticipated S&T efforts that might be required to resolve the challenge. This figure also provides a means for relating some of the needs that are common to all the challenges, such as characterization of high dose rate materials, size reduction of contaminated components, and subsurface access.

3.1.2 Cost Reduction Incentives

Figures 3.2 and 3.3 provide a high-level analysis of the planned funding profile for baseline activities associated with each challenge. The data were derived through a parametric assessment of the overall scope within major site baseline elements. Only those portions of the baseline deemed relevant to each challenge were selected. This analysis assesses the funding levels and timing for each challenge. However, the costs presented on these curves are taken from the existing site baseline and, as discussed in the challenge descriptions, are based on a broad range of assumptions and contain varying levels of uncertainty. It would not be appropriate to use these data as sole discriminators for determining site S&T priorities. However, for

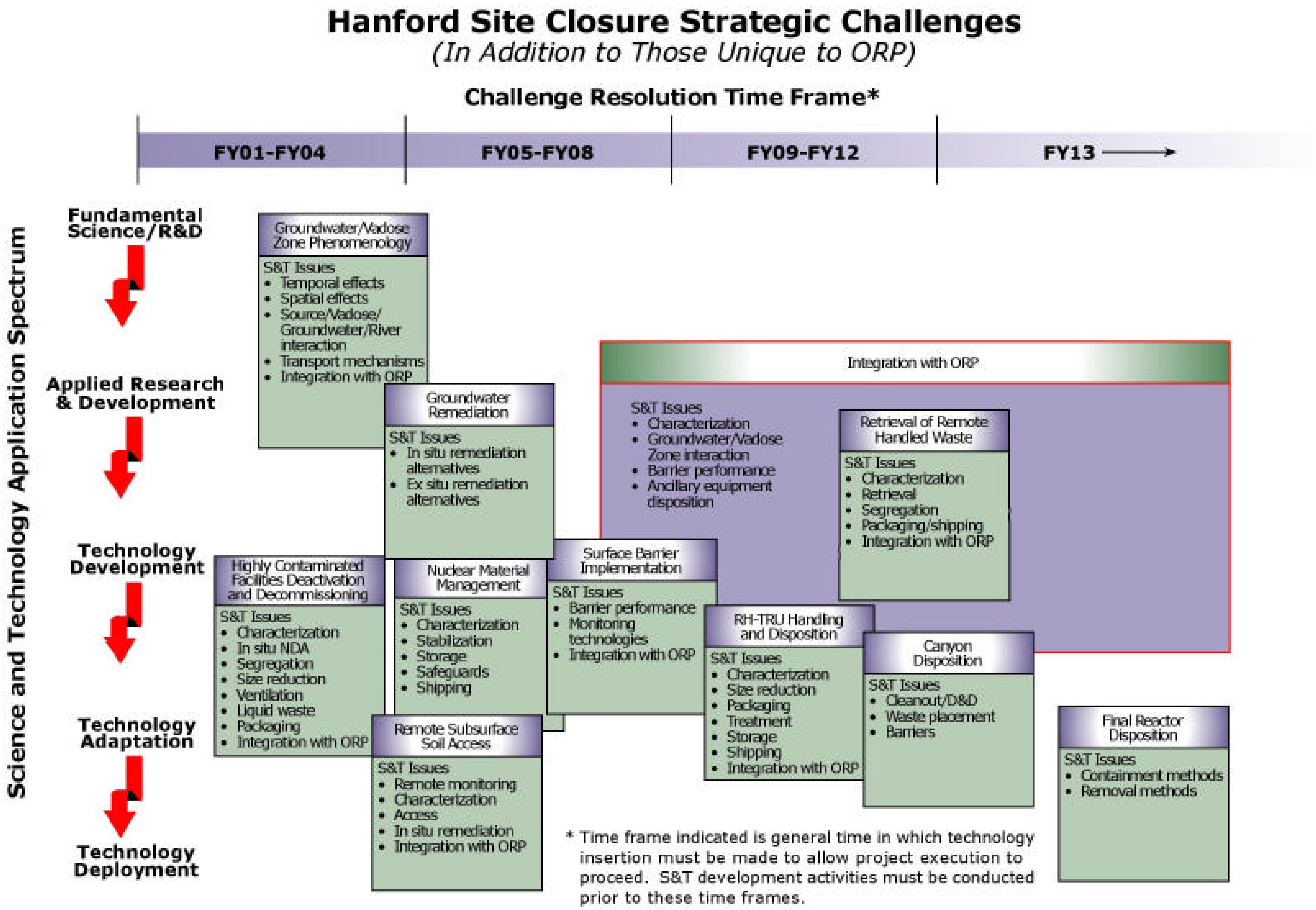


Figure 3.1. Hanford Site Closure Strategic Challenges

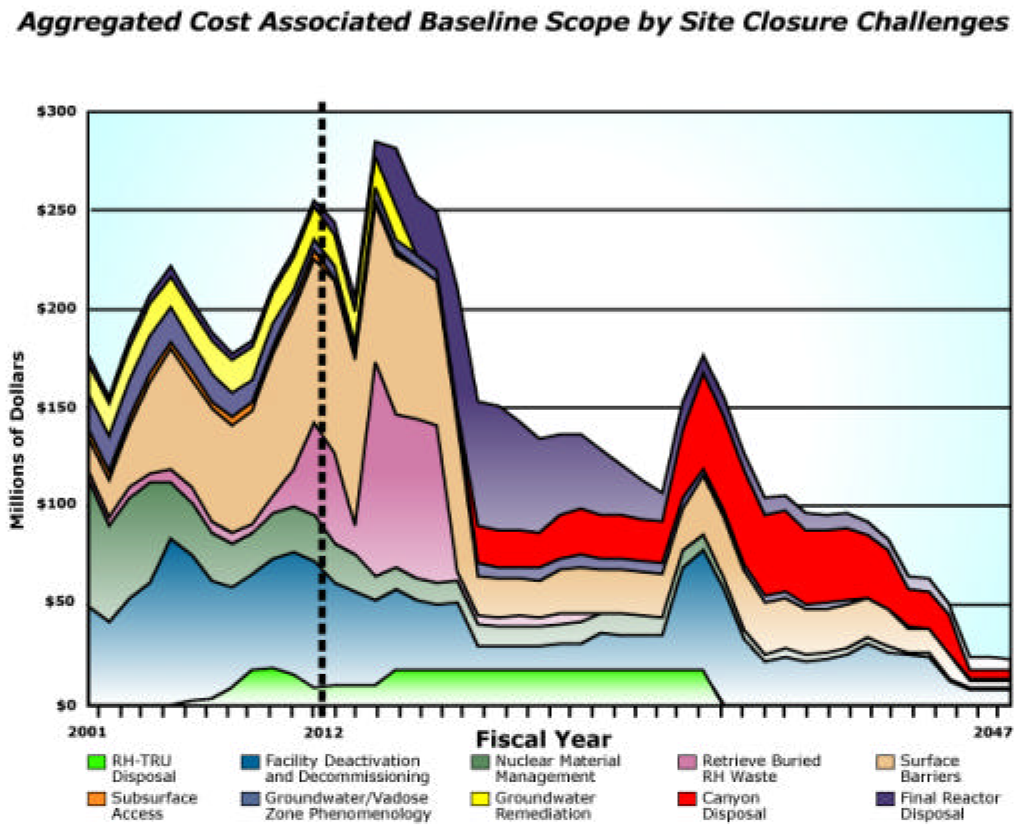


Figure 3.2. Aggregated Cost of Associated Baseline Scope by Site Closure Challenges

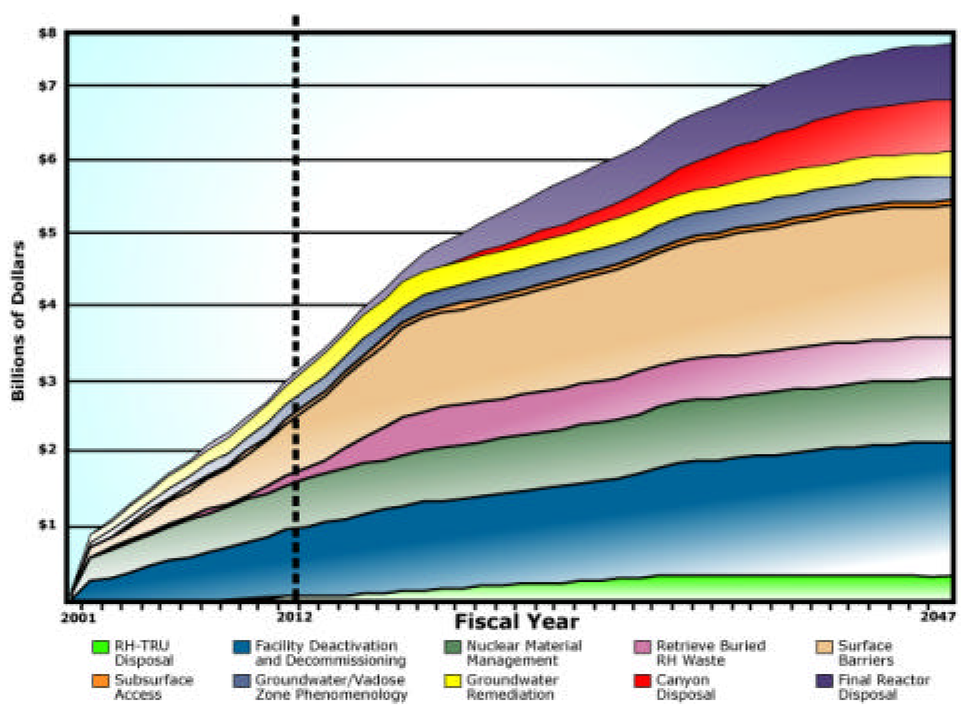


Figure 3.3. Accumulated Cost of Associated Baseline Scope by Site Closure Challenges

providing an early assessment of S&T opportunities with potentially large paybacks, this approach is useful. As a result, both Figures 3.2 and 3.3 show that very near-term investments are needed in S&T to support the facility disposition and nuclear material management challenges if we are to receive the maximum cost-reduction benefit. These peaks are a result of the accelerated disposition of facilities in the River Corridor and the stabilization efforts at PFP. Mid-range funding needs are dominated by the retrieval and processing of buried RH waste (driven by the 618-10 and -11 burial ground remediation efforts) and the application of barriers on the Central Plateau waste sites. Final reactor disposition, canyon disposition, and final deactivation and D&D of remaining facilities (both in the Central Plateau and River Corridor) dominate the later stages of the program. Figure 3.3 illustrates that the surface barrier and facility disposition challenges have the highest life-cycle impacts, followed closely by the retrieval of RH waste, canyon disposition, and nuclear material management.

3.2 Framing Fundamental S&T Opportunities

The challenges previously discussed represent a high-level view of the Site's strategic cleanup problems and briefly introduce the associated S&T needs necessary to resolve these challenges. In most cases, the identified S&T needs cut across several of the primary cleanup challenges and therefore could be addressed collectively as "fundamental" S&T opportunities. The fundamental S&T opportunity areas are those areas where investments in S&T can have the biggest impact on Hanford's cleanup outcomes. Development of these S&T opportunities must be tied to key Site decisions and milestones to provide an enhanced technical basis for cleanup plans and actions. The suggested S&T opportunity set was created by aligning common elements of the technical challenges into specific opportunities where postulated solutions could be pursued, resulting in broad benefits across the Hanford Site. The S&T opportunities also represent common ground for performing specific scientific research and technology development activities.

Therefore, to better organize and address the major components of these needs, a set of fundamental S&T "opportunity areas" is suggested. By collectively addressing related S&T needs from across the spectrum of challenges, it will be possible to optimize the planning and execution of S&T activities. Addressing the challenges in an integrated fashion should present opportunities to streamline elements of the work, address common worker safety and environmental protection issues, develop common approaches for waste acceptance, and optimize offsite interfaces and schedule constraints.

Detailed definition of the depth and breadth of the fundamental S&T opportunities, and the relative priority and urgency of each, will be a natural product of the focused planning and road-mapping efforts that are proposed as a follow-on activity to this assessment. However, as a result of the assessment of the strategic closure challenges, one possible view of the fundamental S&T opportunities is illustrated in Figure 3.4. This list of opportunities could be used as a starting point for the follow-on detailed S&T planning and road-mapping efforts and is described in greater detail in Section 3.3.

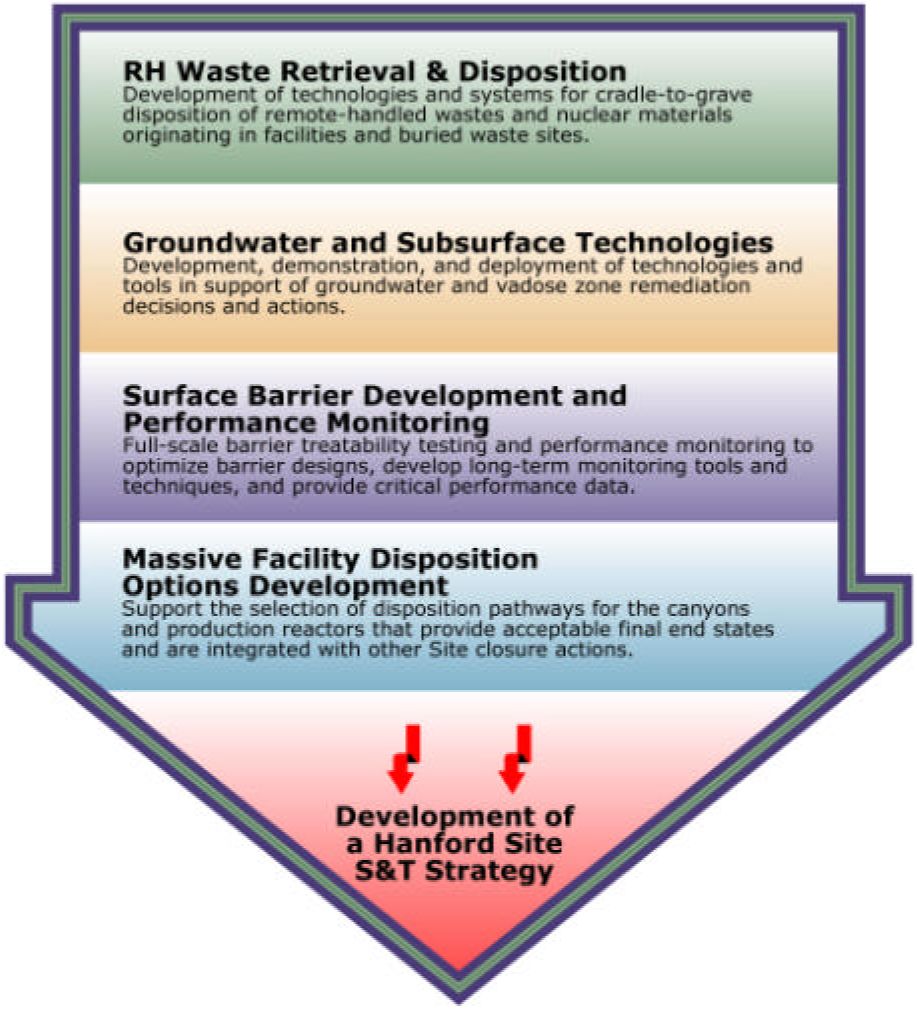


Figure 3.4. Framing Fundamental S&T Opportunities

The Hanford Site cleanup is a large and complex undertaking with hundreds of contaminated facilities and waste sites and extensive groundwater and subsurface contamination. The site map included as Figure 3.5 provides a high-level view of where the S&T opportunities and underlying challenges are located on the Site in the context of the River Corridor and Central Plateau.

Many of the Site closure challenges have unique technical, regulatory, and programmatic drivers. To better understand the urgency associated with each challenge, a fundamental knowledge is required of the baseline schedule and plans for Site cleanup. Appendix A presents a high-level schedule (Figure A.1) and technical logic diagram (Figure A.2) from which to understand the sequence and interrelationship among the planned cleanup activities. In addition to the information provided in Appendix A, Figure 3.6 gives a summary list of the key existing milestones and decision points relevant to the challenges, grouped in terms of the fundamental S&T opportunities.

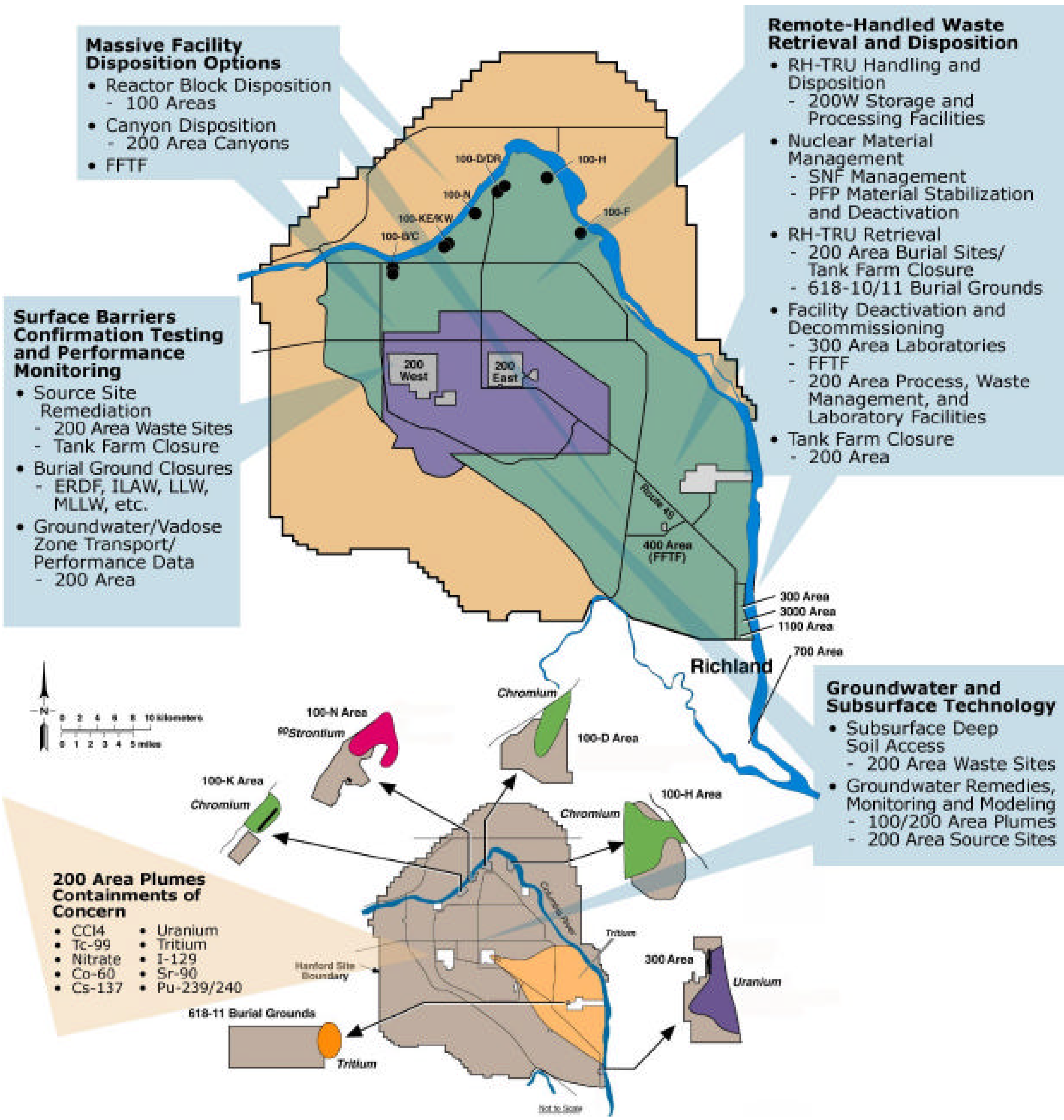


Figure 3.5. Hanford Site Operational Areas and Science and Technology Opportunities

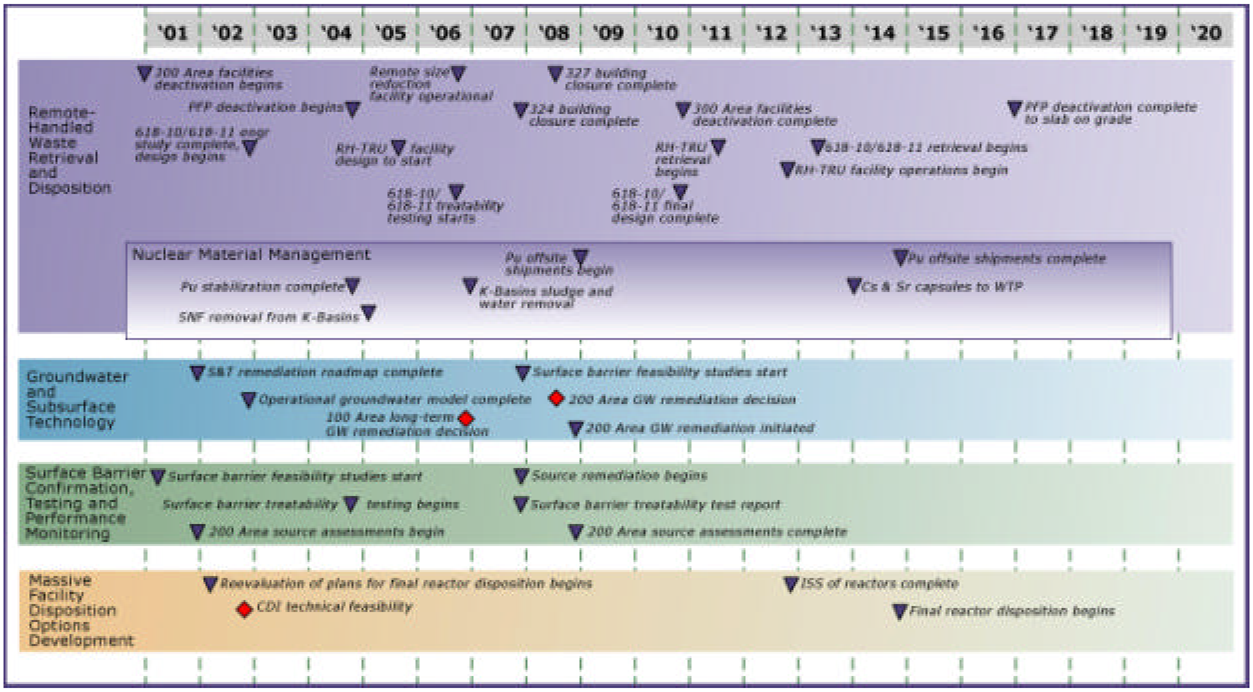


Figure 3.6. RL Cleanup Decisions and Milestones Related to Science and Technology Challenges

3.3 Implications for S&T Investments—Relationship to Site Outcomes

3.3.1 River Corridor Restoration

Most of the River Corridor restoration activities currently planned for completion by FY 2012 are well defined. The activity end states are determined and, for the most part, are supported by ROD documentation. Additional regulatory documentation will be required for the accelerated deactivation and decommissioning of the 300 Area facilities. The level of uncertainty associated with this work scope, as defined, can be characterized as moderate, and, for the most part, the cleanup objectives of the Hanford 2012 Vision can be accomplished using technology developed under previous, existing, or currently planned S&T activities. In particular, completion of the spent fuel removal project, reactor ISS projects, and associated soil site remediation all use existing technologies; in these areas, new S&T is needed only to optimize processes, reduce costs, or address special problems that arise. Implementation of enhanced groundwater remedies as part of the Hanford 2012 Vision will require investments in S&T.

DOE is assessing potential acceleration of the remediation at the 618-10 and 618-11 burial grounds, which are located within the River Corridor. This action will necessitate an investment in S&T because the technologies required for efficient retrieval of the RH waste in the vertical pipes and caissons has not been determined. TPA milestone M-16-00 requires the remediation of the burial grounds to be completed by FY 2018. This activity carries large uncertainty and high risks, making it just the type of activity where an investment in S&T can be expected to provide substantial payoffs. In addition to the waste retrieval at these burial grounds, implementation of enhanced groundwater remedies represents a second area where S&T investments potentially represent a substantial payoff. There are currently no well-formulated plans for achieving the desired cleanup objectives for most of the contaminated groundwater plumes.

The final River Corridor closure and final reactor disposition activities are planned after FY 2012, and the baseline shows completion in FY 2046. The estimated cost of this work represents approximately 12% of RL's total life-cycle baseline funding requirements and comprises primarily the 618-10 and 618-11 burial ground remediation, final reactor disposition, D&D of the final remaining laboratories in the 300 Area, and completion of groundwater remediation. Baseline plans for final reactor disposition (one piece removal to the Central Plateau) is an example of a defined solution where the costs associated with the activity appear prohibitive and the probability of securing the necessary funding is low, placing the successful completion of this activity at risk. An investment in S&T may provide an alternative solution that will reduce the estimated costs and schedule to accomplish this outcome.

3.3.2 Central Plateau Transition

The transition of the Central Plateau will continue until the end of the cleanup mission, scheduled for FY 2046. This outcome carries greater uncertainty than the River Corridor restoration. The activity end states are highly dependent upon completion of other Site cleanup activities and will be subject to future investigations and regulatory negotiations. As for the River Corridor, the Central Plateau also lacks any appropriate technology(ies) for final groundwater remediation. Many of the activities, like final waste site remediation, depend to some degree on the disposition decisions for the canyons and tank farms.

The planned costs in the transition of the Central Plateau represent about one-third of RL's total life-cycle baseline requirements. There are a number of areas in the Central Plateau where S&T investments could help increase the probability of successful outcome and reduce the projected costs associated with this work. Groundwater remediation technology, RH-TRU retrieval and disposition, nuclear materials management, surface barrier enhancement and performance testing, and subsurface access are all challenges discussed in this plan that provide areas of investment in S&T that could potentially have large payoffs by reducing uncertainties and risk.

3.3.3 Preparing for the Future

The outcome on "preparing for the future" will establish the guiding principles for the future of the Hanford Site as RL seeks to support the local community's economic diversification efforts and derive the maximum taxpayer benefit from the nation's multi-billion dollar investment at Hanford. As cleanup activities proceed, RL and affected stakeholders and Tribal Nations will begin preparing for potential multiple future uses of the Hanford Site, including long-term S&T missions (supported by PNNL), other DOE missions, non-DOE federal missions, and other public and private land uses. Examples of possible future uses include a Consolidated Waste Management Mission on the Central Plateau, industrial development in the southern portions of the Site, increased recreational access to the Columbia River, and expansion of areas managed by U.S. Fish and Wildlife Service as a wildlife refuge.

As well as being a key element of the foundation for Hanford's future, it is expected that the S&T mission will play a major role in the research, development, testing, and deployment of a variety of new or emerging technologies needed to address the Site closure challenges. Recent organizational arrangements have been made to broaden the use of PNNL in the accomplishment of the EM work scope as well as have PNNL act as a conduit with other National Laboratories. Examples of these teaming arrangements include the union between PNNL and the Environmental Restoration Contractor for the GW/VZ Integration Project and the signing of a Memorandum of Agreement between PNNL and Central Plateau Contractor (Fluor Hanford, Inc.) to provide direct support in resolving critical Site cleanup issues.

The ongoing S&T mission will also be used to further the understanding of the physical environment, not only to ensure the successful implementation of the planned cleanup actions but also to provide a basis for long-term stewardship activities following completion of the cleanup mission.

3.4 Path Forward for S&T Opportunities

This document suggests a framework for further development of the four S&T opportunity areas or some more appropriate grouping that arises out of the detailed road-mapping activities for the identified strategic closure challenges. The follow-on S&T plans and road maps will be prepared in a proposed second phase later this fiscal year in conjunction with the Site Technology Coordination Group (STCG) subgroups and the Environmental Management (EM) Focus Areas.

The approach used to arrive at the strategic S&T challenges and opportunities was a top-down process that was not intended to comprehensively reflect all needs and challenges that exist onsite. A significant number of near-term (tactical) needs still exist within the various Site programs that are outside the challenges and opportunity areas described in this assessment and that are being addressed by the respective programs and EM Focus Areas. Each of the strategic S&T opportunity areas will need to be developed more fully into a cohesive, executable program as part of the follow-on (Phase 2) S&T planning effort for the Site. These programs must be linked to the Site outcomes, be in line with the Site schedule, support key Site decisions, and integrate with the ongoing Focus Area efforts.

For the identified strategic S&T opportunities, a review of ongoing or planned S&T activities will to be undertaken to determine the degree to which these opportunities are being addressed and where they must be augmented to more fully meet the Site's needs. In areas where there are gaps, planning will be conducted to determine logical first steps and priorities for the newly recommended S&T research and development activities. Two of these opportunity areas (RH Waste Retrieval and Disposition and Groundwater and Subsurface Technology Development) were identified as high-priority items by the Hanford Advisory Board (HAB) in Consensus Advice #113, which was provided on December 8, 2000 (HAB 2000). Each of the proposed fundamental S&T opportunity areas is described briefly below.

3.4.1 RH Waste Retrieval and Disposition

Significant challenges exist, both at Hanford and at other DOE sites, for dealing with RH waste. A number of the Site closure challenges identified in Section 2.1 have key needs in the characterization, designation, retrieval, segregation, size reduction, packaging, transportation, processing, and disposition of RH waste. The processing and disposition of these RH waste streams will require close coordination with the development of the M-91 processing facilities and potentially the Canyon Disposition Initiative.

A technology development program is needed that is aimed specifically at supporting these needs with a strong emphasis on waste retrieval and supporting actions for the buried RH wastes at 618-10 and 618-11 burial grounds within the River Corridor. This opportunity area should also focus on developing innovative characterization/designation techniques for high dose-rate TRU waste (including meeting certification requirements for WIPP). In addition to the 618-10 and 618-11 burial grounds, the development in this area will also support retrieval of the caissons in the 200 Area and removal of remote-handled equipment associated with the tank farms. Focusing on retrieval and disposition of high dose-rate wastes as an opportunity will help to ensure that the systems and facilities needed for dealing with these problematic wastes are well conceived and are designed to support the range of challenges Hanford must face.

This opportunity area would also support similar challenges facing the deactivation and decommissioning of highly contaminated facilities. A number of highly contaminated facilities with glove boxes, hot cells, chemical process cells, and other contaminated components are now at the end of their operational life and must undergo deactivation and decommissioning. These facilities have large inventories of radioactive materials and high levels of contamination. To safely and cost-effectively clean up and decommission these facilities, advanced technologies and approaches are required.

Technologies needed for deactivation and decommissioning of such facilities and retrieval of buried RH wastes include remote access, size reduction, and packaging of highly contaminated equipment and materials (glove boxes, hot cells, piping, ducts, large equipment, buried wastes, caissons, etc.). S&T is also needed to develop and improve capabilities for dismantlement and decommissioning of large contaminated structures. By considering these challenges together, possible solutions could be realized, such as the development of modular containment and ventilation systems, portable decontamination systems, centralized size reduction and waste processing facilities, streamlined waste handling and shipping processes, shared use of robust cutting systems, and improvements in worker training and execution.

Concepts in alternative ventilation options and enhanced worker monitoring and protection tools will need to be explored to protect the workforce during both the buried waste retrieval and facility deactivation and decommissioning operations. Liquid waste handling and transportation will also be important elements. Waste classification and segregation should be addressed within this opportunity area to minimize waste generation and reduce overall costs.

An S&T opportunity area for RH waste should also be closely tied to the "Management of Nuclear Materials" challenge (e.g., SNF and PBM). The near-term S&T needs to optimize stabilization processes, packaging techniques, transportation approaches, and storage methods could be of direct benefit to similar functions that will be required for RH wastes. When the RH waste retrieval and disposition opportunity area is more fully developed, both the RH waste and nuclear material challenges should be addressed in the overall context of satisfying needs to handle and disposition wastes and nuclear materials that are inherently dangerous.

3.4.2 Groundwater and Subsurface Technology

The Hanford Site has widespread vadose zone and groundwater contamination plumes. A number of interim actions are under way that involve groundwater pump-and-treat systems. However, current plans are to run these systems for only a limited time until a more effective and permanent remedy can be selected and implemented. The baseline assumes that a cost-effective technology will be available for remediating groundwater. The current long-range plan calls for decisions for enhancing groundwater remediation approaches to be made by the start of FY 2007. Without S&T activities leading to alternative remediation technologies, this schedule will not be met. The consequence of a failure to meet this schedule is that baseline groundwater remediation would continue well past FY 2015 until alternative actions have been identified and implemented. Thus, additional costs will be incurred without early identification and deployment of new groundwater technologies.

The GW/VZ Integration Project is well under way, and the S&T component is providing data and models to support Site-specific and Site-wide remediation decisions. The GW/VZ Integration Project is focused on decisions regarding interim corrective actions for tank farms where tank leaks have impacted groundwater and soil waste site characterization. Other areas of focus for the GW/VZ Integration Project (inventory, groundwater-river interface, and ecological risk) are providing data and conceptual models for Site-wide assessments. A primary recommendation for this opportunity area is that the S&T road map to address remediation of soil and groundwater contamination be developed as soon as possible so that scientific research and technology development activities can be focused on addressing remediation options.

This opportunity area must be closely aligned with the surface barrier and testing opportunity area as well as with the S&T process being used by ORP to identify important issues that need to be addressed. ORP issues related to this challenge area will be focused on the vadose zone beneath the tank farms and the impacts from past leaks as well as potential future impacts from retrieval operations.

3.4.3 Surface Barrier Development and Performance Monitoring

A surface barrier program, including the full-scale treatability testing of a modified RCRA Subtitle C barrier, is needed to provide performance data and development of more robust, long-lived, cost-effective monitoring technologies. Cost-effective and proven barrier designs that are acceptable to the regulators are needed to satisfy elements of a number of the challenge areas and are crucial for safe long-term isolation of waste sites on the Central Plateau.

A seven-year comprehensive treatability study is planned as part of the 200 Area Remedial Action Project to test a full-scale modified RCRA Subtitle C barrier. Acceleration and focusing of these activities are needed to ensure that the key cleanup RODs can be supported in a timely manner and that barrier designs can be optimized to minimize costs and environmental impacts. In addition, development of improved monitoring techniques and robust designs will factor directly into the scope of post-closure stewardship actions that are required following installation of these barriers over waste sites.

3.4.4 Massive Facility Disposition Options Development

A focused S&T effort is needed to support the selection of disposition pathways for the canyons and reactor blocks. For the canyons, the principal alternatives range from cleanout, dismantlement, demolition, and removal (in part or in whole) for disposal to various options involving conversion of the canyons for use as in-place waste disposal facilities. For the reactor disposition challenge, an evaluation of alternative disposition pathways for the reactor blocks is planned for FY 2002. In particular, S&T activities are needed to support evaluation of alternatives to the baseline approach selected in the 1989 reactor disposition EIS ROD, which requires moving the intact reactor blocks to the Central Plateau for disposal. Principal alternatives for disposition of the reactor blocks include various combinations of dismantlement, demolition, and removal (in part or in whole) to the Central Plateau for disposal.

The common ground of these two challenges is, therefore, the need to evaluate approaches and technologies for large equipment size reduction, remote handling and dismantlement of structures, and waste packaging and transportation options, as well as for barriers and for monitoring of wastes disposed in-place. This S&T opportunity area should include detailed S&T road-mapping activities as well as Site-level systems studies to evaluate approaches to make the most efficient use of the canyons as disposal facilities.

4.0 Conclusions and Recommendations

The long-term success of Hanford cleanup requires vigorous and sustained efforts to enhance the S&T basis of the cleanup, develop and deploy innovative solutions, and provide firm scientific bases for decisions that address cleaning up the nuclear waste legacy at the Site.

The results of this S&T assessment highlight strategic closure challenges in the Hanford cleanup baseline for which available solutions are inadequate and which therefore offer significant S&T opportunities to advance the Hanford 2012 Vision. Full integration of these strategic closure challenges into RL's S&T research and development processes will ensure that investments made will result in the maximum benefits across the Hanford Site and are fully supportive of the Hanford 2012 Vision.

4.1 Conclusions

The analyses of the strategic Site closure challenges has led to a broad understanding that advances in S&T could be used to positively impact several significant portions of the cleanup baseline. Certain advancements, such as the development of improved worker protection tools, provides broad benefits across the various project elements. Some of these challenges involve $100's of millions in baseline scope and are fundamental for successfully achieving the Hanford 2012 Vision and beyond. While some of the work is beginning now or is being accelerated, there still is sufficient time to conduct meaningful S&T research and development activities.

This assessment is the first step in developing a Site level S&T strategy for RL and does not yet address how to structure and implement future S&T efforts. Clearly, the strategic challenges and proposed S&T opportunity areas are highly related to the ongoing needs identification, technology development, and technology insertion/utilization processes. A convenient organization of S&T needs is suggested around the four proposed fundamental S&T opportunity areas that address multiple related strategic challenges:

- RH Waste Retrieval and Disposition
- Groundwater and Subsurface Technology
- Surface Barrier Development and Performance Monitoring
- Massive Facility Disposition Options Development.

These groupings have proven useful for collectively representing crosscutting long-term or strategic S&T needs. However, they will likely be refined as a result of subsequent detailed S&T planning and road-mapping activities.

Specific S&T needs are introduced under each strategic challenge described in Section 2. Specific S&T projects will need to be identified, technically specified, and validated through the Hanford planning process. The path forward for Site-level cleanup planning addresses S&T needs in parallel with rebaselining the detailed project execution plans. This S&T planning process will entail "road-mapping" activities for the S&T opportunities and integrating these with the evolving baseline for project execution. This planning process will provide an explicit priority basis for the S&T opportunities identified here, consistent with the schedules, end points, and contract incentives.

4.2 Recommendations

This strategic assessment of S&T needs for Hanford Site cleanup, though high level, was sufficiently complete to tentatively identify several significant and urgent S&T priorities. These items should be addressed in an expeditious manner:

- RH Waste Retrieval and Disposition: Initiate an integrated effort to identify and develop technologies for the retrieval and disposition of remote handled wastes and nuclear materials. A road-mapping process to identify appropriate technology and S&T activities needed should be undertaken. This effort should focus on a cross-project assessment of the systems needed for size reduction, processing, packaging, transportation, and storage of RH waste and nuclear materials and should also include an emphasis on the S&T required for retrieval of buried RH wastes at the 618-10 and -11 burial grounds. On this basis, initiate an S&T effort to develop, test, validate, and deploy the selected technologies.

- Groundwater and Subsurface Technology: Focus on developing, demonstrating, and deploying groundwater and deep soil remediation technologies and tools, including innovative access technologies. The first step in this process will be to complete the remediation S&T road map to identify an overall approach and S&T activities needed to develop appropriate soil and groundwater remediation technologies and tools. Expand the knowledge of S&T needs for groundwater and deep soil remediation and initiate the S&T activities necessary to develop, validate, and deploy the selected remediation technologies and tools.

- Surface Barrier Development and Performance Monitoring: Initiate full-scale surface barrier testing and performance monitoring to optimize and validate barrier designs for long-term applications at Hanford waste sites and engineered disposal facilities.

- Massive Facility Disposition Options Development: Support reactor block and canyon disposition key decisions required in FY 2002; identify, plan, and conduct more detailed S&T road-mapping following selection of the preferred disposition paths.

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6.0 Acknowledgments

This evaluation report was assembled by team members from Pacific Northwest National Laboratory (PNNL), Fluor Hanford, Inc. (FH), Bechtel Hanford, Inc. (BHI), and CH_2M HILL Hanford Group (CHG), and their subcontractors. Strategic direction and input were provided by DOE-RL, DOE-ORP, EPA, and Ecology. Key members of these teams are:

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Appendix A

Supporting Data and Figures

Contents

Table A.1. Hanford Site Closure Challenges

Challenge Title	Scope of Challenge	Challenge Time Frame	Science and Technology Opportunities (**Bolded** items are strategic S&T needs)	Potential Impacts of S&T Opportunities
Retrieval of Remote-Handled Waste	Includes numerous waste sources/sites: - 618-10/11 burial grounds - 200 Area burial grounds - PUREX tunnels - Tank Farms - Canyons	Engineering/ design activities FY 2001 to FY 2006, treatability testing in FY 2007, remediation beginning in FY 2013	Covers all technology aspects of remote handled waste retrieval and handling - **Characterization** - **Retrieval** - **Segregation/sorting** - **Packaging/shipping**	- Dose reduction - Worker protection - Cost savings - Waste minimization - Fill technology gaps (enabling)
RH-TRU Handling and Disposition	Handling and disposing of wastes from - 618-10/618-11 - 200 Area burial grounds - contaminated facilities Also facilities operation: - New M-91 Facility or other support facilities (T Plant, size reduction, etc).	Retrieval of buried wastes to begin in FY 2013 RH-TRU facility design to start in FY 2006 RH-TRU facility operations to begin in FY 2013	All technology aspects associated with RH-TRU management: - **Characterization** to enable better waste designation, segregation, and minimization - **Size reduction, treatment, and packaging** - Storage and shipping to the Waste Isolation Pilot Plant (WIPP) - Scientific analysis to support refinements to the WIPP acceptance criteria	- Dose reduction - Worker protection - Cost savings - Waste minimization
Highly Contaminated Facilities Deactivation and Decommissioning	Deactivation/decommissioning of 200 Area and 300 Area facilities: - PFP, 222-S, WESF, etc. - 308, 324, 325, 327, etc. - Evaporators	Work is ongoing in the 300 Area to be completed in the FY 2006 to FY 2010 time frame for a majority of the facilities. Other facilities won't undergo deactivation for several decades.	Development of alternative concepts for facilities deactivation and decommissioning, including: - **In situ nondestructive analysis (NDA)/characterization** - Ventilation for worker protection. - Liquid waste handling/transportation. - **Waste segregation, size reduction, packaging, disposal** - Definition of deactivation endpoints	- Dose reduction - Worker protection - Cost savings - Waste minimization - Schedule acceleration

Table A.1. (contd)

Challenge Title	Scope of Challenge	Challenge Time Frame	Science and Technology Opportunities (**Bolded** items are strategic S&T needs)	Potential Impacts of S&T Opportunities
Nuclear Materials Management	Includes all aspects of nuclear materials management: - spent nuclear fuel (SNF) - Cs and Sr capsules - Pu and Pu residues	Stabilization of plutonium and SNF will be complete in FY 2004, storage and monitoring will continue through FY 2014-FY 2017	Technological advances in nuclear materials management: - **Characterization** - **Stabilization and packaging** - Storage, monitoring, safeguards, and shipping	- Dose reduction - Worker protection - Cost savings
Groundwater/ Vadose Zone Phenomenology	Crosscutting activity to enhance understanding of - Contamination sources - Inventory and distribution - Vadose zone, groundwater, and river interactions	Final groundwater and 200 Area source remediation decisions will be made by FY 2006	Covers development of knowledge and models that address: - **Near-term/long-term temporal effects** - **Near-field/far-field spatial effects**	- Better decision basis for final groundwater and source control actions
Groundwater Remediation	Applicable to all nonrad/rad groundwater contamination plumes: - Carbon tetrachloride, chromium, etc. - Strontium, uranium, tritium, etc.	FY 2006-2008 decision time frame for final groundwater remedies	Technical/scientific advances necessary to remediate contamination plumes: - **In situ remediation alternatives** - **Ex situ remediation alternatives**	- Improved baseline technology for achieving remediation goals - Cost savings - Minimization of stewardship costs
Subsurface Soil Access	Crosscutting applications for difficult to access contamination: - Deep subsurface sites - Under buildings, etc.	200 Area source assessments in FY 2002 to FY 2006 and final groundwater remedies in FY 2007	Development of new remote access concepts for deep applications: - **Remote monitoring/characterization** - **In situ remediation**	- Cost savings - Groundwater remedies improvement - Minimization of long-term stewardship costs - Monitoring components

Table A.1. (contd)

Challenge Title	Scope of Challenge	Challenge Time Frame	Science and Technology Opportunities (**Bolded** items are strategic S&T needs)	Potential Impacts of S&T Opportunities
Surface Barrier Implementation	Applicable primarily to 200 Area closures: - Burial grounds - Structures (e.g., canyons) - Other soil contamination sites	Feasibility studies starting in FY 2001, remediation beginning in FY 2008	**Development of new/alternative barriers** to achieve: - Lower cost - Environmentally benign - Long-term performance **Development of improved monitoring**	- Cost savings - Environmental impacts minimization - Stewardship cost savings
Canyon Disposition	Applicable to all 200 Area canyon facilities disposition	CDI decision in FY 2002	Covers CDI as well as preparing for final facility disposition. Includes - **Evaluating alternative endpoints** - **Technologies for cleanout/D&D or waste disposal/entombment options**	- Cost savings - Waste minimization - Consolidation of storage/disposal capability needs
Final Reactor Disposition	Applicable to all production reactors in ISS	FY 2015 final disposition scheduled to begin, decision in FY 2002	Covers two primary considerations: - **S&T to establish the final end point** - Development of alternative methods for stabilizing or removing reactor blocks	- Cost savings - Worker protection - Environmental impacts
Integration with ORP	While not a unique challenge, final closure and remediation of waste tanks have challenges similar to other RL challenges - Tank structures and residues - Ancillary facilities/ equipment - Soil contamination	Closure plan in FY 2005, remediation in FY 2018	Covers all S&T necessary to achieve final remediation, including: - **Characterization** - **Size reduction, treatment, and packaging** - **GW/VZ interaction** - **Barrier performance**	- Integration of common site end states - Improved efficiency for remediation of sites near tank farms

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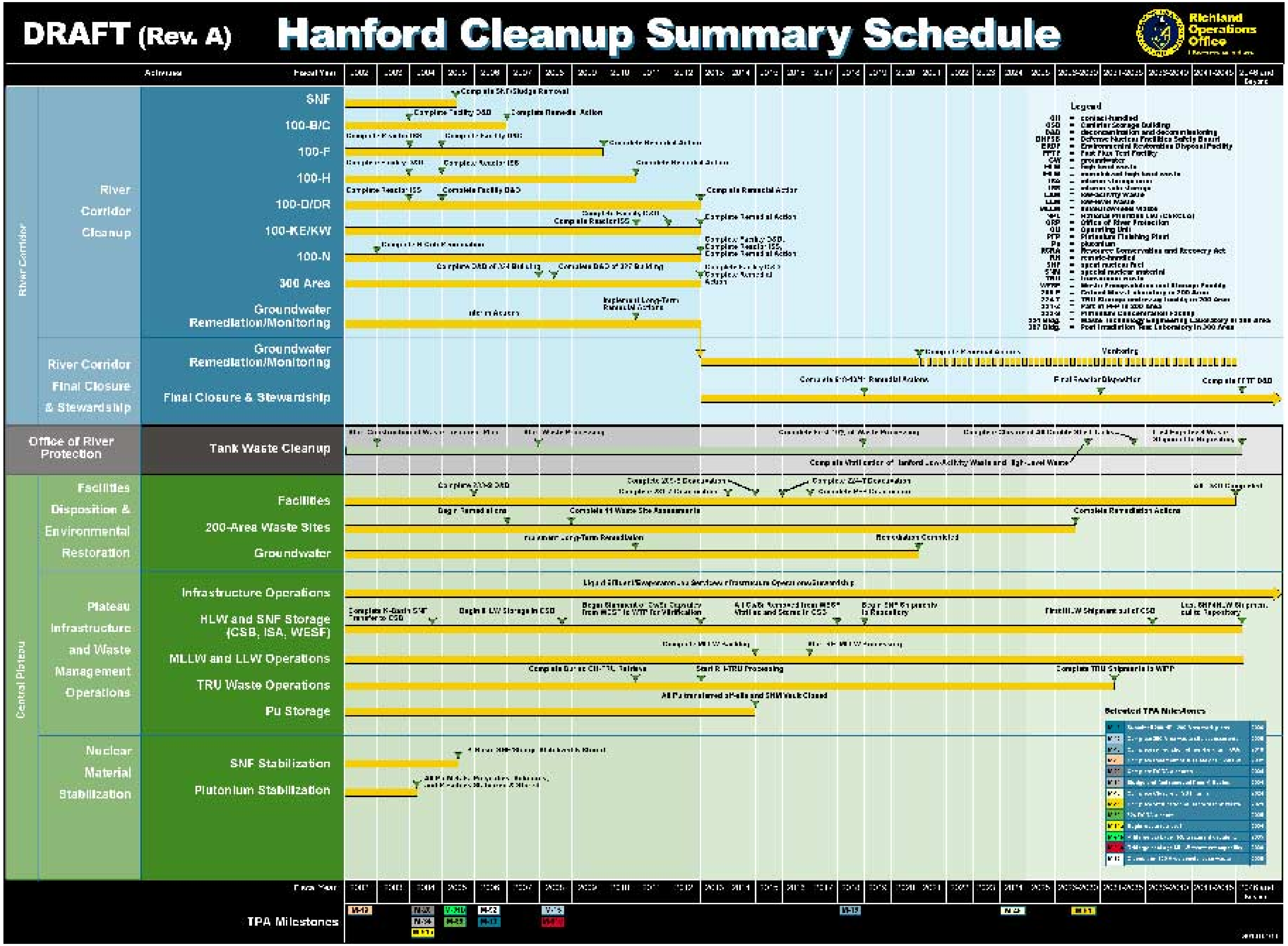


Figure A.1 Hanford Site (RL) Summary Schedule

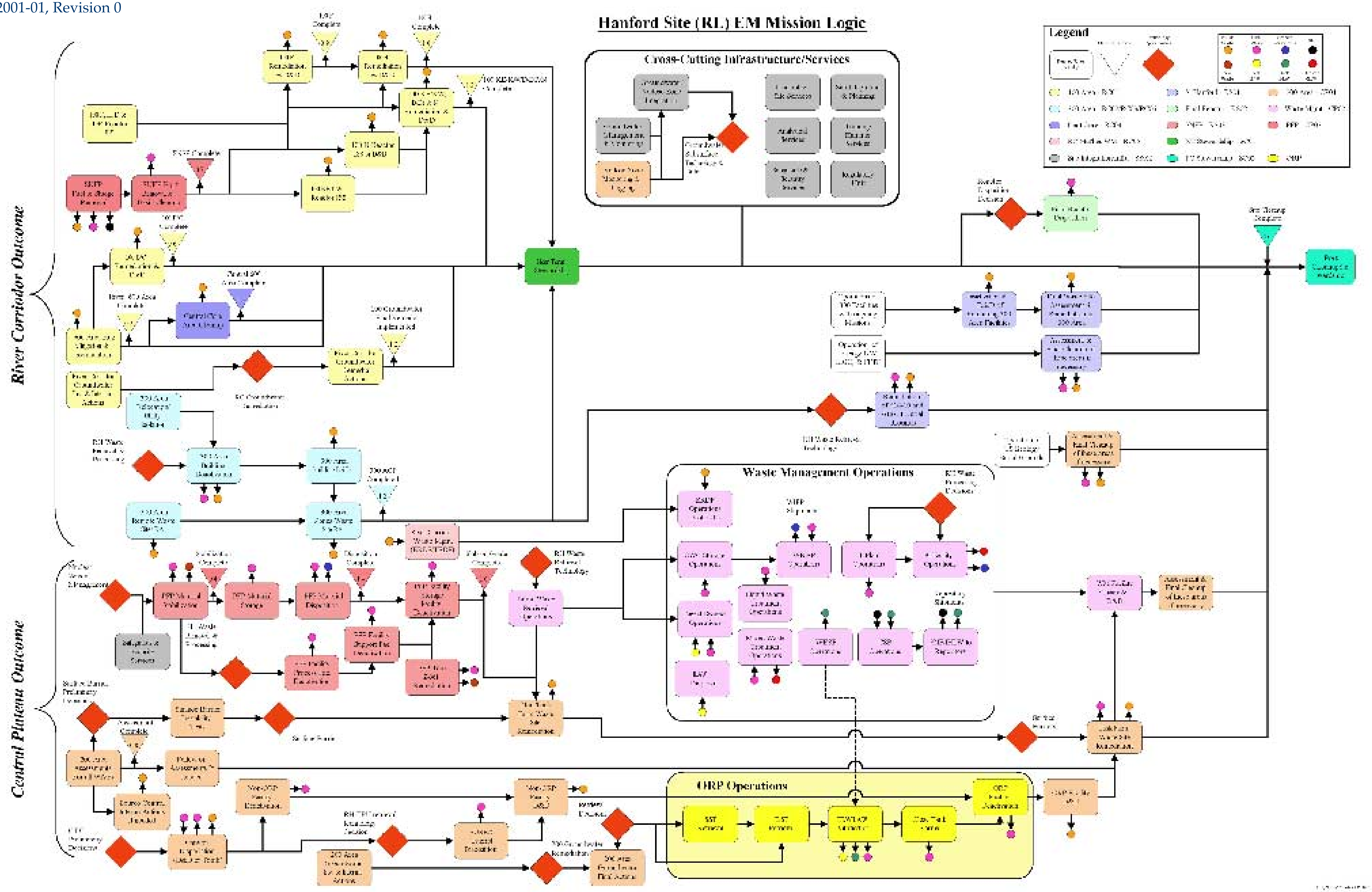


Figure A.2 Outcome Summary Logic

Appendix B

Current Hanford Site Science and Technology Development Efforts

Contents

Appendix B

Current Hanford Site Science and Technology Development Efforts

B.1 S&T Research and Development Process

Hanford Science and Technology (S&T) needs are identified and addressed through several interrelated efforts. The first is through the Site Technology Coordination Group (STCG) process and the DOE-EM Focus Areas. The second effort is through development and implementation of S&T road maps, as has been done by the Groundwater/Vadose Zone Integration Project.

In 1994, DOE-EM established STCGs at DOE sites to ensure that S&T needs were identified, described, prioritized, and addressed and that identified technology solutions were demonstrated and deployed. In addition, EM established Focus Areas to coordinate S&T investments within a set of high-priority problem areas across the DOE complex. The STCGs provide the EM Focus Areas with S&T needs and required technology deployment dates. The STCGs monitor technology development efforts and facilitate demonstrations and deployments of technologies at their sites.

The Hanford STCG includes representatives from RL, ORP, EPA, Ecology, Oregon Office of Energy, HAB, Yakama Nation, Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation, Fluor Hanford, Inc., Bechtel Hanford, Inc., and Pacific Northwest National Laboratory. It consists of a Management Council and five subgroups aligned with the EM Focus Areas: 1) Deactivation and Decommissioning, 2) Mixed Waste, 3) Subsurface Contaminants, 4) HLW Tanks, and 5) Nuclear Materials. Involvement of regulators, stakeholders, and tribes provides an opportunity for early input on issues or concerns as S&T needs are defined and specific technologies are identified for demonstration and/or deployment at the sites.

The EM Focus Areas develop and deliver technology solutions for needs identified at DOE sites across the nation. The Environmental Management Science Program (EMSP) sponsors basic research to address fundamental issues that may be critical to needed technology development. The objectives of the EMSP research and the EM Focus Area development are to decrease public and worker risks, provide major cost reduction opportunities, reduce the time required to achieve DOE's cleanup mission, and address problems considered intractable without new knowledge. The Hanford STCG subgroups provide detailed documentation of the Site's S&T needs to guide the Focus Areas' technology development efforts and the EMSP basic research activities.

Hanford's S&T needs are first identified and defined by contractor and RL project managers in consolidation with the appropriate regulatory project manager. These project managers prepare S&T needs statements that include information on priority, the timing requirement of technology deployments, and the technical details associated with an S&T need. The needs statements are then reviewed by the appropriate STCG subgroups, modified by the project managers as necessary, and finally endorsed by the subgroups. The information is then entered into the Integrated Planning, Accountability, and Budgeting System (IPABS) database for transmittal to the appropriate Focus Areas.

The Focus Areas are charged with developing fully integrated, multiyear responses to the Site's S&T needs. The development of technical responses is an iterative process involving the project managers and the Focus Areas. The Focus Area role is to ensure that the developers have a clear understanding of the specific technical requirements that a technology solution must meet. The Focus Areas develop implementation plans for the solutions they are providing. These plans are necessary to ensure that budgets are adequate to support the technology development efforts, development schedules are consistent with Technology Insertion Points (TIPs), and the cleanup projects have the financial resources and technical support to enable deployment of new technology solutions. Technology insertion points are used at the Hanford Site to clearly link the development of new or innovative technology to baseline schedules.

DOE-EM prioritizes and sequences its S&T development efforts consistent with available funding and Site needs. The prioritization process is iterative and occurs at several different levels. First, the individual sites identify and prioritize their S&T needs within each Focus Area and submit them to the Focus Areas. Then the Focus Area technical responses must be integrated and prioritized to ensure an optimum investment portfolio for EM. Once the Focus Areas have prioritized their technical responses, they are compiled into work packages. A national prioritization of the work packages is then done using multi-attribute utility analysis. The final product is a list of work packages and Focus Area technical responses in priority order. The final integrated priority list is approved by the DOE Field Office Managers and EM Deputy Assistant Secretaries. This is the basis for EM-50's Congressional budget request.

Although the current EM S&T needs process seems to function well, it is a complex approach that does not result in a clear picture of what the key S&T challenges are for any given site. Because different S&T needs are submitted to different Focus Areas, there is no mechanism for any site to develop an integrated site-wide priority list. Another feature of the process is that the primary focus is on near-term needs. There is little incentive for the sites to take a longer-term strategic view of the overall site cleanup outcomes. Thus, there is little opportunity for optimization of the S&T investment portfolio for any site.

For the case of the Groundwater/Vadose Zone Integration Project (GW/VZ), their project-level road map is used to guide S&T investment decisions and track process. Specifically, the GW/VZ Integration Project uses the S&T road map as input to developing detailed work plans each fiscal year. The road map is also used to influence calls for proposals by the EMSP, which is administered through the DOE Office of Science and Technology and invests in basic and applied science. During FY 1999, the EMSP awarded 31 new grants (worth $25M in work scope over three years) directed at the vadose zone problem at Hanford. The principal investigators participating in these projects are from across the DOE complex, universities, and private industry. Several workshops have been conducted with EMSP investigators to link their efforts with issues and challenges at the Hanford Site. The GW/VZ Integration Project has provided guidance and information to enhance the relevancy of planned EMSP research and to solicit involvement of the principal investigators in resolving key scientific issues that fall within the scope of their projects. In addition, the GW/VZ Integration Project has provided Hanford Site materials (e.g., sediment and water samples) for experiments and involved some of the principal investigators in field experiments at the Site.

B.2 Integration of S&T into Site Baselines

The Hanford Site contractors are expected to integrate technology into cleanup projects when it makes sense to do so. This integration is done by effectively planning and deploying S&T solutions to reduce technical risk, accelerate schedule, and satisfy Hanford Site S&T needs. The Hanford contractors have established a Technology Management function, with formal ties to PNNL, to champion this effort. Following are some routine S&T activities that are performed annually by Hanford contractors:

- Identify needs – Assess shortfalls and opportunities for improvement.

- Conduct technical reviews to identify and quantify areas of high technical risk/uncertainty and develop near- and long-term mitigation plans (e.g., S&T plans, technology road maps). These plans include TIPs and identify the necessary S&T work scope within the appropriate multiyear work plan (MYWP) baseline.

- Research and find existing technological solutions.

- Deploy technologies that provide solutions to areas of need, including those identified by the technical reviews.
- Ensure that the development of technologies that provide cross-cutting value to multiple projects, such as enhanced worker protection tools, received appropriate support.
- Document the benefits derived from the deployment of each technology using the return on investment (ROI) models similar to the approach/format used by the Pollution Prevention Program. Benefit analysis includes both quantitative data (cost) and qualitative data such as risk reduction and increased safety.

B.3 Recent S&T Accomplishments Supporting Hanford Cleanup

Each of the major cleanup activities on the Hanford Site has significant technical challenges and opportunities for improvement, and Hanford has demonstrated that successful integration of S&T with project activities can reduce technical risk and contribute to achieving the Hanford 2012 Vision. Since 1997, Hanford has deployed 96 technologies in the areas of waste management, river corridor restoration, spent nuclear fuels, tanks, infrastructure, decontamination and decommissioning (D&D), nuclear materials stabilization, and groundwater/vadose zone (see Figure B.1). These include technologies to remove, package, and ship 100,000 spent nuclear fuel assemblies to the Central Plateau; characterize, package, handle, store, and ship transuranic (TRU) waste to the Waste Isolation Pilot Project (WIPP); and stabilize or repackage plutonium to meet Defense Nuclear Facilities Safety Board (DNFSB) 94-1 recommendations. RL has had similar success with characterization and treatment technologies for soil and groundwater remediation and contaminated facility D&D, including hot cell deactivation, reactor decommissioning/interim safe storage, and disposition of the chemical processing canyons.

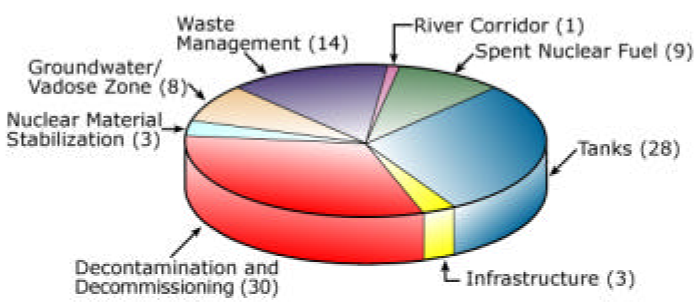


Figure B.1. Hanford Technology Deployments Since 1997

RL will continue to use S&T advances to further our understanding of the physical environment to ensure successful implementation of remedial actions, provide the basis for longer-term stewardship activities, and reduce uncertainties and risk. Examples of critical projects and areas of S&T application in recent years at the major Hanford Site areas are illustrated in Figure B.2 and described below.

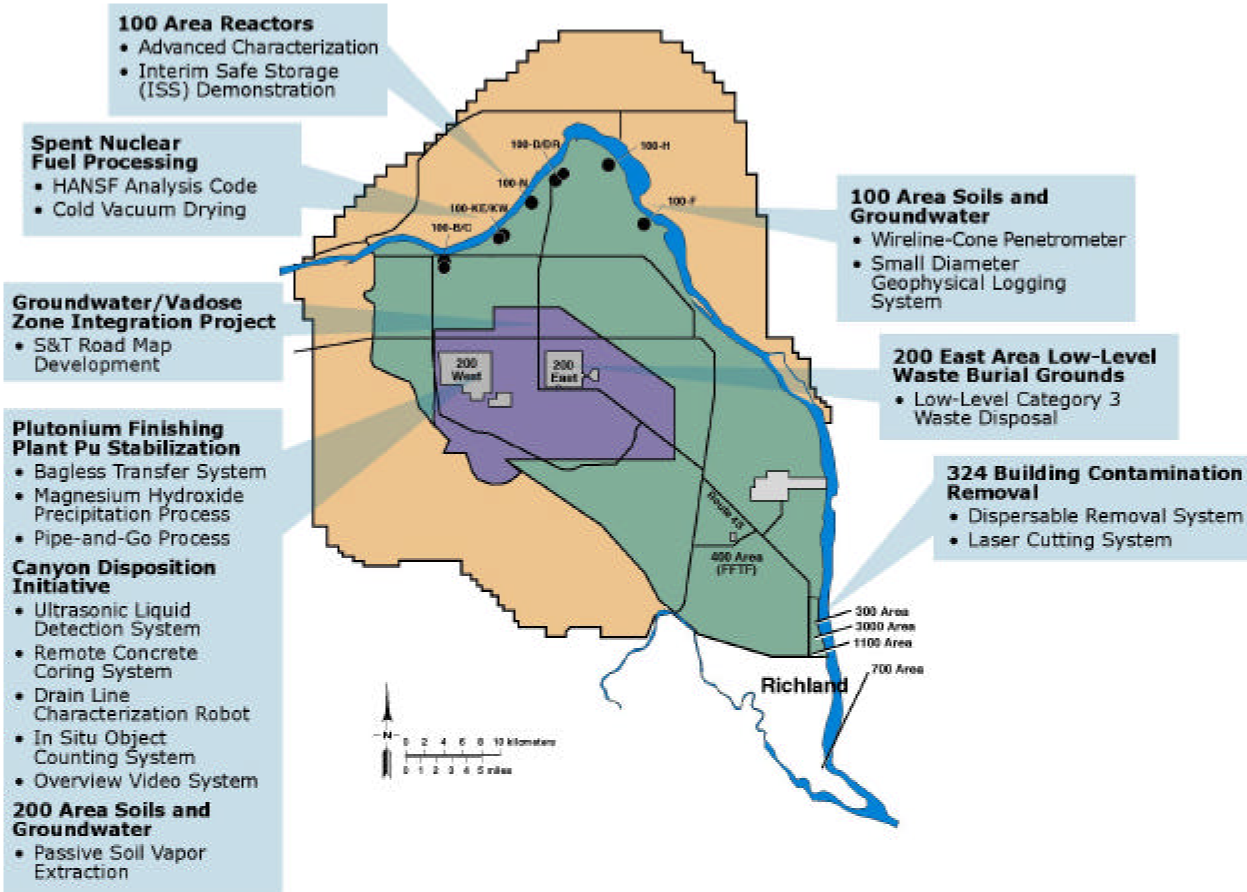


Figure B.2. Significant S&T Activities Conducted by RL in Fiscal Year 2000

B.3.1 100 Area Reactor Deactivation

Reactor Interim Safe Storage: The Large-Scale Demonstration and Deployment Project conducted at C Reactor demonstrated technology approaches for Interim Safe Storage (ISS) of the deactivated Hanford reactors. Hanford is now successfully continuing with ISS at other reactors with the aid of these technologies.

Characterization of Reactor Building Concrete: Conventional concrete coring and sampling generates waste, is manpower intensive, and requires expensive laboratory analysis. The **Advanced Characterization System** (ACS) was deployed on the D Reactor Interim Safe Storage Project to characterize and free-release portions of the D Reactor building concrete. Deploying the ACS provided cost savings by reducing waste from decontamination and decommissioning (D&D) activities, the number of samples required for characterization prior to D&D, and the manpower needed to perform radiological characterization.

B.3.2 100 Area K Basins Spent Nuclear Fuel Project

Spent Nuclear Fuel Removal: The development and deployment of fuel retrieval systems, sorters, vacuum-drying technologies and nonintrusive pressure-monitoring technologies are examples of how S&T advances have contributed to meeting a significant milestone for the movement of spent nuclear fuel away from the river. The **Cold Vacuum Drying (CVD) Facility** represents a one-of-a-kind, first-of-a-kind structure that is key to the K Basins project. Demonstration of loading of the first Multi-Canister Overpack (MCO) was accomplished in December 2000.

Technical Baseline Calculations for Spent Fuel Packaging and Storage: **HANSF** (for Hanford Spent Fuel) is a computer code developed and validated to model the complex heat transfer mechanisms and chemical reactions within MCO. The integrated model considers a wide variety of phenomena inside the MCO and provides the technical basis for the safety analysis that allows higher fuel density packing in the MCO.

B.3.3 100 Area Soils and Ground Water Cleanup

Innovative Site Characterization technologies: Two innovative technologies were deployed in FY 2000 to characterize subsurface soils and on other for remediation of groundwater:

- The **Wireline-Cone Penetrometer System** (Wireline-CPT) allows multiple CPT tools to be interchanged during a single penetration, without withdrawing the CPT rod string from the ground. This innovation reduces the time required to take samples or deploy sensors in the subsurface. The Wireline-CPT system was demonstrated at the 126-F-1 Ash Pit and the Vadose Zone Test Site in the 200 Area.

- The **Small Diameter Geophysical Logging System** (SDGLS) provides geophysical logging using a Geoprobe for access to the subsurface. The SDGLS investigation was conducted at a lower cost than baseline techniques and was able to minimize the volume of waste removed and disposed at the ERDF by accurately mapping the extent of subsurface contamination.

- The deployment of **in situ redox manipulation** (ISRM) for remediation of chromium-contaminated groundwater under the Accelerated Site Technology Deployment/Subsurface Contamination Focus Area is an example of a successfully deployed technology.

B.3.4 200 Area Soils and Ground Water Cleanup

Soil and Groundwater Cleanup Technology: Cleanup and protection of the soils and groundwater have been expedited through the development and implementation of **Passive Soil Vapor Extraction (PSVE)**. PSVE was deployed to use naturally induced pressure gradients between the subsurface and surface to drive carbon tetrachloride vapor to the surface for treatment. PSVE can provide ongoing remediation at lower cost per mass of contaminant removed than active systems under specific circumstances.

B.3.5 200 Area Plutonium Finishing Plant

Plutonium Stabilization and Packaging: Stabilization, packaging, and disposal of plutonium to comply with DNFSB recommendations has been expedited through the application of technology developed at Hanford and other DOE sites.

- Scientific breakthroughs that altered the treatment approach for plutonium encased in **styrene cubes (polycubes)** were developed and deployed at Hanford.

- The **magnesium hydroxide precipitation process**, which has been used at the Rocky Flats Environmental Test Site (RFETS) to treat low-level plutonium solutions for disposal, was adapted with assistance from the Pacific Northwest National Laboratory, Los Alamos National Laboratory, and RFETS to treat more concentrated plutonium solutions at Hanford.

- The **Bagless Transfer System** was adapted from a proven technology currently being used at the Savannah River Site to provide equipment for the Plutonium Finishing Plant (PFP) to remotely weld containers meeting the DOE Standard 3013-99 specifications for long-term storage of plutonium. This system provides cost savings and less technical complexity compared with the baseline system.

- The **Pipe-and-Go** process has been deployed at PFP to prepare plutonium residues for shipment offsite to the Waste Isolation Pilot Plant. Residues are simply placed into slip lid cans, which are placed into pipe overpacks for insertion into a standard Department of Transportation 55-gallon drum. The packaging process and regulatory path to success were based on the experience at RFETS. Deployment of this simple, proven technology reduces program risk and radiation exposure to workers associated with the baseline cementation process.

B.3.6 200 Area Canyon Disposition Initiative

Decommissioning of the Chemical Processing Canyons: As part of the study known as the Canyon Disposition Initiative (CDI), alternatives are being evaluated to provide the information needed for a Record of Decision (ROD). The CDI is jointly supported by several EM programs. Key developments in the CDI include the following:

- The **Ultrasonic Liquid Detection System** was deployed to assay selected equipment in the 221-U Facility for the presence of liquid. The system uses ultrasonic/acoustic wave transmission to noninvasively determine the liquid level inside vessels. This approach eliminates the need to physically open and inspect these vessels, reducing risks to workers of possible exposure to radioactive or contaminated materials.

- The **Remote Concrete Coring System** was initially deployed to collect concrete cores from cell 26 in the 221-U Facility. This deployment eliminated the need for personnel entry into the canyon process cells, thereby reducing the risk to workers.

- The **Drain Line Characterization Robot** was deployed to safely and economically inspect, characterize, and collect samples from 800 ft of subterranean piping in the Hanford Site's 221-U Facility. The remote capabilities of the Drain Line Characterization Robot greatly reduced radiological dose to operations personnel. No other methods have been identified to obtain similar characterization data.

- Use of the **In Situ Object Counting System** (ISOCS) provides the capability for in situ analysis of radiation sources. Using the ISOCS for in situ analysis eliminates the need to take samples of high dose sources and send them to a laboratory.

- An **Overview Video System** (OVS) was deployed to provide visual examination of below-deck canyon cells. Use of the OVS also requires significantly less design and planning compared to alternative methods, and may typically be accomplished using routine work procedures. The use of the OVS for initial examination of the drain line outfalls eliminated the need for personnel entry into below-deck cells and thus significantly reduced worker exposure.

B.3.7 300 Area River Corridor Cleanup

Contamination Removal from the 324 Building B Cell: The Hanford 324 facility hot cells contain highly radioactive fixed and dispersible mixed-waste contamination. Key developments in cleaning up the cells include the following:

- The **Dispersible Removal System** in the 324 Building employs a tele-operated robotic vehicle with an articulated boom and interchangeable end effectors to clean and remove these dispersible materials. This system remotely breaks up hardened materials, retrieves waste fragments, and vacuums dust and small size dispersible wastes. Benefits derived from this deployment are reduced program risk by ensuring critical project schedules are met and reaching difficult-to-access areas.

- A **laser cutting system** was developed and deployed to size-reduce large items of TRU waste for removal and disposal.

B.3.8 Groundwater/Vadose Zone Integration Project

Groundwater Vadose Zone Integration Project S&T plan and road map: FY 2000 marked the beginning of the implementation of the GW/VZ Integration Project S&T Road map that addresses the groundwater and vadose zone cleanup challenges at Hanford. Specifically, the following early successes and impacts have been realized from the GW/VZ S&T Road map.

- The S&T Road map was the **basis for the FY 1999 new EMSP call** for research proposals.

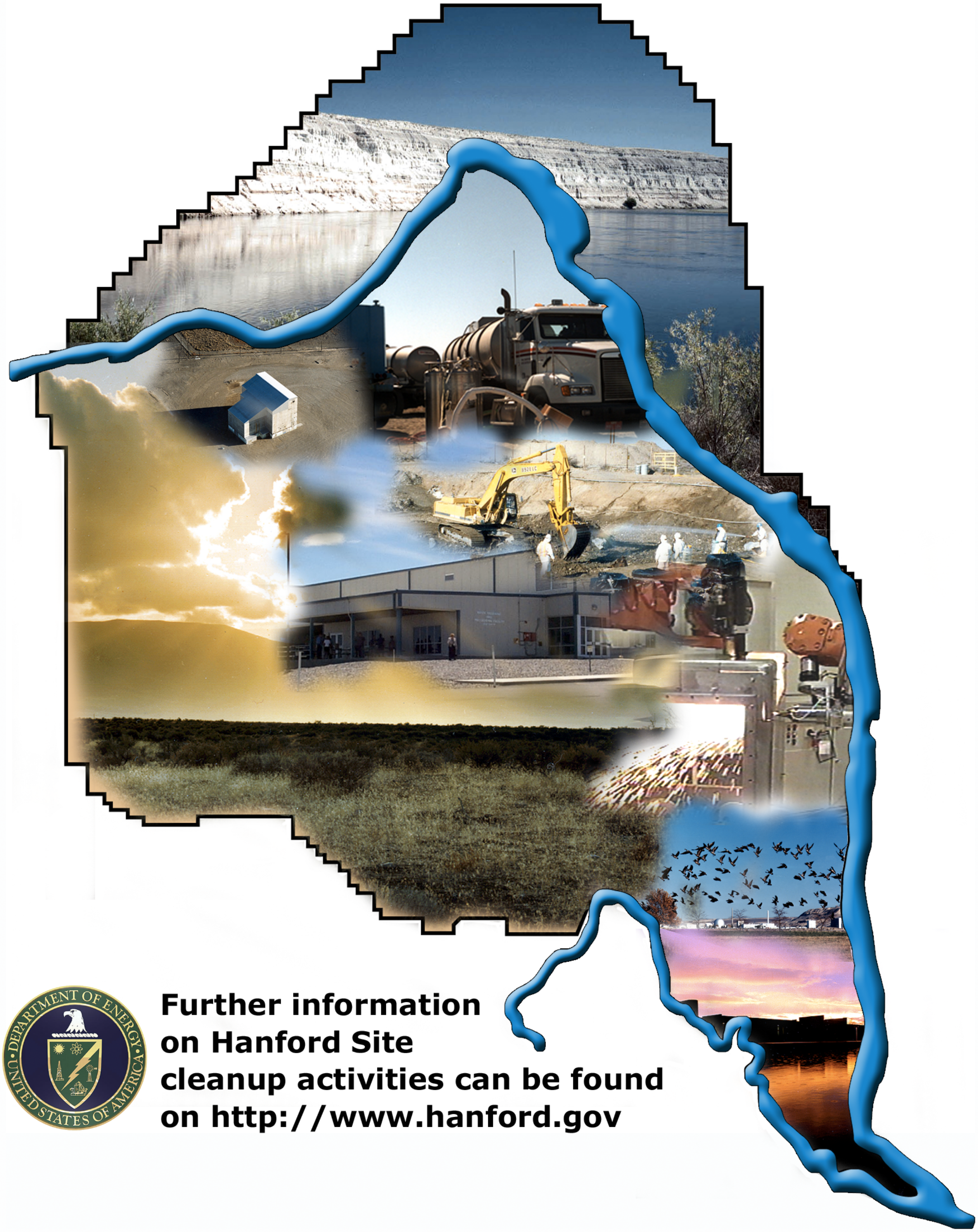
- The **soil inventory task** completed development of a computer model to derive waste inventories and uncertainties for contaminated soil sites on Hanford's Central Plateau. Estimates for nine waste streams were competed.

- The Soil Inventory team was able to fill critical gaps in **tank leak inventory estimates** for the tank farm vadose zone core project.

- The **field investigations at representative sites task** performed laboratory studies on core materials collected as part of the field investigations at single-shell tank leak sites.

- The **vadose zone transport field study task** completed the first field experiment in the 200 East Area, which involved injection of 40,000 liters of uncontaminated water with a sodium bromide tracer. Nine different characterization methods were deployed in the field experiments.

- The **groundwater/river interface task** completed conceptual and numerical model development of the groundwater/river interface at Hanford's 100 H Area.



Further information on Hanford Site cleanup activities can be found on http://www.hanford.gov