Deep Vadose Zone–Applied Field Research Initiative

Fiscal Year 2012 Annual Report

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Contents

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Message from the Deep Vadose Zone-Applied Field Research Initiative Project Manager

The Deep Vadose Zone-Applied Field Research Initiative (DVZ-AFRI) was established in 2010 by the U.S. Department of Energy (DOE) Office of Environmental Management and the Richland Operations Office to develop effective, science-based solution for remediating, characterizing, monitoring, and predicting the behavior and fate of deep vadose zone contamination in order to protect our nation's water resources. To that end, the DVZ-AFRI is developing the technical basis to quantify, predict, and monitor natural and post-remediation contaminant discharge from the vadose zone to groundwater, and facilitating development of in situ solutions that limit this discharge and protect water resources.

The features and processes of the DVZ both enable and complicate the remediation process. Two critical needs confronting vadose zone remediation and closure are as follows:

1) Determining the acceptable contaminant flux from the vadose zone to the groundwater receptor
2) Devising means to implement and monitor flux reduction strategies to reduce vadose zone contamination below levels requiring control.

A regulatory basis exists for leaving contamination in place in the vadose zone, monitored natural attenuation, provided flux to groundwater is limited and monitored. However, determining the acceptable level of residual contaminant to meet groundwater resource protection goals and how to appropriately measure when this residual has been attained are key challenges for establishing remediation objectives in the vadose zone. The project is developing systems-based approaches that can be used to establish and implement alternate endpoints.

During this past year, the DVZ-AFRI project team made significant progress translating strategy into action and provided new technologies and approaches to solve these complex challenges in a collaborative environment that leverages technology and scientific expertise from DOE, Pacific Northwest National Laboratory, CH2M HILL Plateau Remediation Company, Washington River Protection Solutions, and the broad scientific research community. As project manager for the DVZ-AFRI, I have had the privilege the past two years to team with creative, talented members of the scientific community nationwide to develop effective long-term solutions to address deep vadose zone contamination.

This report highlights how the DVZ-AFRI project team is delivering results by achieving significant programmatic accomplishments, developing and field-testing transformational technologies, and generating new strategies to address the nation's most pressing environmental contamination problems to ensure our water resources are available for future generations.

Dawn Wellman
Deep Vadose Zone-Applied Field Research Initiative Project Manager

Responding to the Challenge

Our mission is to protect our nation's water resources for our generation and generations to come. Through the Deep Vadose Zone-Applied Field Research Initiative, we are working to deliver transformational science and technology-based solutions to clean up contamination in deep vadose zones across the DOE complex. To meet these challenges, DOE is bringing experienced scientists and engineers from the government, academic and commercial sectors to work together in a collaborative framework to develop solutions that are cost-effective, sustainable, and protective of human health and the environment.

—John Morse, U.S. Department of Energy, Richland Operations Office

Remediation of vadose zone contamination is a significant challenge in the United States, particularly in arid and semiarid regions where the vadose zone can be hundreds of feet thick. At U.S. Department of Energy (DOE) Office of Environmental Management (EM) sites, subsurface contaminants include radionuclides, metals, organics, and liquid waste that originated from various sources, including legacy waste from the nation's nuclear weapons complexes. Past-practice waste disposal operations allowed waste to be discharged to retention basins, trenches, or cribs where the waste percolated into the soil, and eventually to the vadose zone and groundwater. Contaminated deep vadose zones are a potential source of impact to groundwater and other environmental receptors. At the same time, the vadose zone is characterized by unique features and processes that can be exploited to attenuate contaminant movement and flux to groundwater.

The Deep Vadose Zone-Applied Field Research Initiative (DVZ-AFRI) seeks to use systems-based approaches to achieve the following:

1) Define scientifically and technically defensible risk-informed endpoints or conditions that represent progress or completion of cleanup
2) Provide scientifically and technically defensible risk-informed priorities for protection of human health and the environment
3) Provide the scientific and technical understanding for technology development and implementation of advanced scientific approaches in subsurface characterization, monitoring, and remediation to achieve alternate endpoints and meet cleanup and closure goals of DOE sites.

Efforts of the DVZ-AFRI advance fundamental principles and understanding of the vadose zone provided through basic science investigations. The DVZ-AFRI provides a framework for definition and development of alternative endpoint cleanup standards. In association with the Advanced Simulation Capability for Environmental Management (ASCEM) initiative, the DVZ-AFRI is providing deeper insight to the important remedial and transport processes and developing mass flux-based site conceptual models. These approaches are significantly more predictive and provide defensible criteria and data for defining risk-informed alternate endpoints for site cleanup, supporting remediation decisions, and developing and implementing systems-based remediation approaches and monitoring strategies (e.g., Scientific Opportunities for Monitoring at Environmental Remediation Sites). Working with DOE site contractors, the DVZ-AFRI provides critical scientific and technical underpinnings linking vadose zone processes, contaminant nature and extent, and remedial processes necessary to conduct treatability tests, quantify how technologies change the site and contaminant conditions, and evaluate the performance of remediation options.

This annual report highlights programmatic accomplishments and scientific and technical advancements made during fiscal year (FY) 2012 to advance our abilities to characterize, monitor, and remediate contaminants in deep vadose zone environments.

Demonstrating Impacts

The technical objectives of the DVZ-AFRI effort are focused on four research and development (R&D) areas.

1) **Remedial design.** Perform applied research to broaden the suite of remedies available for contamination and enhance the technical basis for evaluating remedy effectiveness, implementability, and cost.

2) **Controlling processes.** Quantify coupled hydrologic, geochemical, and microbial processes to develop reliable conceptual models of moisture flux, contaminant movement, and define appropriate endpoints for remediation.

3) ***In situ* characterization and monitoring.** Characterize the distribution of geochemical and hydrologic properties governing contaminant transport. Monitor subsurface behavior, contaminant movement, and remediation performance.

4) **Predictive modeling and data integration.** Simulate the integrated processes controlling moisture flux, contaminant transport, and remediation performance.

These technical areas provide a comprehensive structure to define and develop technically-based approaches to achieve alternative endpoint strategies, which are risk-based, cost-effective, sustainable, and protective of public health and environment. Figure 1 presents the systems-based framework for developing and implementing remediation at a site where an alternate endpoint is expected. The framework provides a means to define the nature and extent of the problem to determine which risks are most critical and establish alternative endpoint cleanup decisions. The framework is based on a strong mass flux-based conceptual model in conjunction with assessing risks and potential endpoints as part of a system-based assessment that integrates site data with scientific understanding of processes that control the distribution and transport of contaminants in the subsurface and pathways to receptors. This system-based assessment and subsequent implementation of the remediation strategy with appropriate monitoring are targeted at providing a holistic approach to addressing risks to human health and the environment. Goals of the framework are to provide the following:

- Deeper insight into the important remedial/transport processes
- Platform for integrating new knowledge into flux-based conceptual site models that are significantly more predictive to provide defensible criteria/data for making long-term decisions
- Holistic assessment of risk to human health and the environment
- Flexible approach for application to a range of sites, from simple to complex
- Appropriate path for transitioning to long-term monitoring and stewardship.

Implementation of this framework and alternative approaches therein requires cooperative involvement from technical experts, site owners, federal and state regulators, and stakeholders.

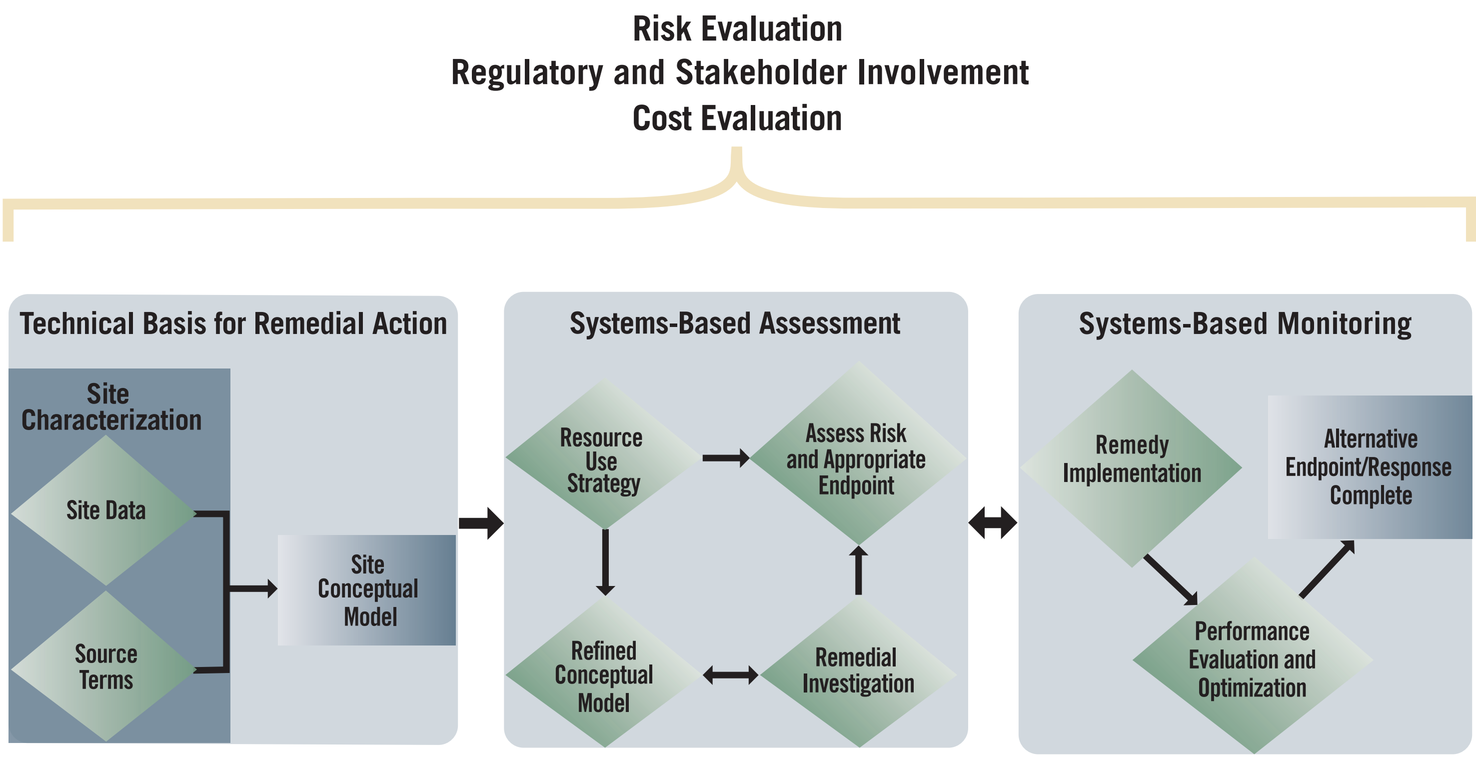


Figure 1. Systems-based framework for defining and achieving alternate endpoint

Key scientific and technical issues to define alternate endpoints and develop technically-based approaches to achieve alternative endpoint were realized through the following DVZ-AFRI critical site cleanup and closure elements in FY 2012:

Key Technical Accomplishments

- **Scientific and technical peer review of 100-KR-4 Operable Unit pump-and-treat operations.** Effluent from the pump-and-treat system was undergoing a final treatment step to raise the pH from pH ~6 to 7 prior to reinjection into the aquifer. DVZ-AFRI staff evaluated the natural buffering capacity and considered co-contaminant mobility implications of the subsurface system. This evaluation supported the Hanford Site contractor's request to cease pH adjustment of effluent streams prior to reinjection and substantially reduce operational costs while remaining protective of human health and the environment.
  - Wellman DM and RJ Serne. 2012. *Review of SGW-51721, REV. 0 "KW Pump and Treat Resin Tech SIR-700 Test Results and Recommendations for Use Across 100-KR-4 Operable Unit*. PNNL-SA-87984, Pacific Northwest National Laboratory, Richland, Washington.
- **Scientific expertise to support optimization of the 200 West pump-and-treat system for carbon tetrachloride and nitrate remediation.** The biological communities present in the 200 West pump-and-treat fluidized bed reactors (FBR) removes carbon tetrachloride and nitrate from groundwater. Biological community functions rely on the interactions between individual members of the community as well as the individual members (abundance, activity). DVZ-AFRI staff are applying molecular tools

(i.e., microbial fingerprinting and sequencing) to determine the spatiotemporal identity, composition, and function of the microbial community within the FBR to support performance optimization.

- Jansik DP and DM Wellman. 2012. *Analysis of 200 West Pump and Treat System Samples via Total Suspended Solids and Anthrone Carbohydrate Concentration Methods*. PNNL-SA-90685, Pacific Northwest National Laboratory, Richland, Washington.
- Lee MH. Draft – 2012. *Prospective for Microbial Immobilization/Degradation of Contaminants and Predicting the Long-Term Outcome(s) for These Strategies*. Pacific Northwest National Laboratory, Richland, Washington.
- Bunn AL and MH Lee. 2012. *Characterization of Microbial Biomass from 200 Pump and Treat Facility: Contrast Imaging and Classification.* PNNL- SA-91077, Pacific Northwest National Laboratory, Richland, Washington.

- **Implementation of an in-line Tc-99 Sensor within the 200 West pump-and-treat system.** By applying advanced radioanlytical chemistry, DVZ-AFRI staff partnered with Burge Environmental to provide real-time analysis of aqueous Tc-99 concentrations in effluent streams from the 200 West pump-and-treat system. The in-line sensor provides the necessary data, on-demand, to evaluate and optimize operations of the 200 West pump-and-treat system for Tc-99. Previously, this could only be accomplished through extensive sampling and analysis.
  - O'Hara MJ, EC Golovich, and DM Wellman. 2012. *Mini-Column ^{99}Tc Sensor Performance Requirements for Monitoring the 200W Area ZP-1 Pump and Treat System*. PNNL-SA-90778, Pacific Northwest National Laboratory, Richland, Washington.
- **Leveraging investments from EM, DOE Office of Science (SC), and U.S. Department of Defense (DOD) to develop state-of-the-art advanced geophysical imaging software.** DVZ-AFRI staff integrated investments from DOE and DOD to develop an advanced high-performance geophysical imaging code that reconstructs subsurface images using electrical resistivity tomography (ERT). This technology provides advancements for site-specific customization that uses high-performance computing resources to "see" subsurface contaminant plumes in three dimensions and in unprecedented resolution. Critical applications of this code included the Hanford Site B Complex to delineate previously unknown detail concerning contaminant distribution beneath former waste sites and real-time monitoring of the spatial and temporal process performance of subsurface remedial activities. Developing and deploying advanced subsurface geophysical imaging technologies provides a critical scientific and technical capability required to make sound and defensible remedial decisions that will successfully meet target cleanup goals.
  - Johnson TC, D Rucker, and J Greenwood. In Press. "Three-Dimensional Parallel Inversion of a Massive Resistivity Data Set to Characterize Contaminant Distribution Beneath the Hanford Site B-Complex, Washington, USA." Geophysics.
- **Technical evaluation of nature and extent of chromate impact to groundwater within the 100 Area 100-C-7 Operable Unit.** Deep excavation of soil at two adjacent sites within the 100-C-7 Operable Unit to remove chromate contamination has been conducted with excavations reaching to near the water table. Verification sampling shows that chromate concentrations downgradient have increased significantly since excavations began and contamination is still present at the bottom of the excavations.

DVZ-AFRI staff conducted the key analyses and developed the technical understanding of the nature and extent of chromium to quantify the overall impact of the excavation site on groundwater and the potential long-term risk to groundwater.

- Truex MJ, VR Vermeul, BG Fritz, RD Mackley, JA Horner, CD Johnson, and DR Newcomer. 2012. *Investigation of Hexavalent Chromium Flux to Groundwater at the 100-C-7:1 Excavation Site*. PNNL-21845, Pacific Northwest National Laboratory, Richland, Washington.
- Truex MJ and VR Vermeul. 2012. *Sampling Instruction: Investigation of Hexavalent Chromium Flux to Groundwater at the 100-C-7:1 Excavation Site*. PNNL-21393, Pacific Northwest National Laboratory, Richland, Washington.

- **Scientific understanding to define the impacts historical waste disposal practices had on contaminant transport and fate.** Waste disposal chemistry has significantly impacted the contaminant chemistry and/or sediment and pore-water chemistry in the vadose zone. To effectively develop and implement options to remediate uranium in the vadose zone, it is critical to first understand the nature and controlling processes; however, it is not fiscally viable to thoroughly characterize every waste site. DVZ-AFRI staff evaluated and documented the range of important waste disposal chemistries at the Hanford Site and quantified their impact on attenuation mechanisms, transport and fate for uranium. This effort provides necessary information to cost effectively characterize subsurface contamination, identify and develop remedial options, and provide the scientific and technical support for remedial decisions for uranium.
  - Szecsody JE, MJ Truex, NP Qafoku, DM Wellman, DC Dage, C Resch, and L Zhong. Draft – 2012. "Influence of Acidic and Alkaline Waste Solution Properties on Uranium Migration in the Vadose Zone." Journal of Contaminant Hydrology.
  - Szecsody JE, MJ Truex, and CT Resch. Draft – 2012. *AFRI Uranium Geochemistry Project: Geochemical Controls on Uranium in Acidic and Alkaline Wastes Migrating in Hanford Sediments.* Pacific Northwest National Laboratory, Richland, Washington.
  - Serne RJ, NP Qafoku, JE Szecsody, and MJ Truex. Draft – 2012. *Hanford Site Vadose Zone Sediment Mineralogy – Emphasis on Central Plateau*. Pacific Northwest National Laboratory, Richland, Washington.
  - Szecsody JE, MJ Truex, L Zhong, TC Johnson, NP Qafoku, MD Williams, JW Greenwood, EL Wallin, JD Bargar, and DK Faurie. In Press. "Geochemical and Geophysical Changes During NH_3 Gas Treatment of Vadose Zone Sediments for Uranium Remediation." *Vadose Zone Journal*.

- **Flux-based measurement and assessment framework for metals and radionuclides in vadose zone environments.** Remediation of inorganic and radionuclide contaminants in vadose zone environments is based on protection of groundwater. The mass flux/discharge of contaminants through the vadose zone is a primary factor controlling the impact of vadose zone contaminants on groundwater. Most remediation approaches are based on mitigating contaminant mass flux, and implementation of monitored natural attenuation (MNA) relies on demonstrating that the natural attenuation processes are sufficient to limit the vadose zone contaminant flux such that groundwater contaminant concentrations remain below compliance goals. The DVZ-AFRI is developing

1) the necessary methods to collect and assess information from the vadose zone in terms of contaminant flux and related controlling processes needed to support remedy evaluation, implementation, and monitoring in the vadose zone; and 2) a conceptual-model-based framework that integrates flux-related measurements and predictive analyses to understand and quantify moisture and contaminant flux in the vadose zone with a focus on supporting remediation assessment.

- Truex MJ and KC Carroll. 2012. *Remedy Evaluation Framework for Inorganic, Non-Volatile Contaminants in the Deep Vadose Zone*. PNNL-21815, Pacific Northwest National Laboratory, Richland, Washington.
- Johnson TC, M Oostrom, MJ Truex, JN Thomle, and TW Wietsma. In Press. "Determination of Water Saturation Using Gas Phase Partitioning Tracers and Time-Lapse Electrical Conductivity Measurements." *Vadose Zone Journal*.
- Oostrom M, JN Thomle, TW Wietsma, TC Johnson, and MJ Truex. In Press. "Formation Factors and Cementation Exponents of Laboratory Sands." *Vadose Zone Journal*.

- **Development of the remedial investigation work plan for the pre-Hanford orchards lands operable unit.** Farmstead communities existed in the upland environment adjacent to the Columbia River from 1880 to 1943. The Hanford River Corridor includes approximately 3,359 ha (8,300 ac) of historical farmsteads of which approximately 2,023 ha (5,000 ac) are historical orchard lands. Based on what is known about the history of the site, and the current preliminary site conceptual model, the major contaminant for this operable unit is residual lead arsenate, which was used as a pesticide on fruit orchards that occupied much of the land near the Columbia River during the pre-Hanford era. DVZ-AFRI staff are leading the development of the remedial investigation work plan to determine whether there is risk to human health or the environment from contamination within the operable unit.
  - Bunn AL and BG Fritz. Draft - 2012. *Data Quality Objectives for the Remedial Investigation/Feasibility Study Work Plan to Evaluate 100-OL-1, Pre-Hanford Orchard Lands Operable Unit*. Pacific Northwest National Laboratory, Richland, Washington.
  - Bunn AL, BG Fritz, MJ Nimmons, and DM Wellman. Draft. *Remedial Investigation/Feasibility Study Work Plan to Evaluate 100-OL-1, Pre-Hanford Orchard Lands Operable Unit*. Pacific Northwest National Laboratory, Richland, Washington.
- **Technical expertise to support remediation decisions and risk-informed endpoint for 300 Area uranium remediation.** DVZ-AFRI staff are integrating scientific and technical information gained from years of investments by SC and EM to assist CH2M Hill Plateau Remediation Company (CHPRC) in developing a technically feasible approach for remediating uranium in the Hanford 300 Area. DVZ-AFRI staff are updating the 300 Area site conceptual model and conducting advanced predictive simulations to identify and mitigate scientific and technical uncertainties limiting successful remedy implementation and provide the scientific understanding necessary to support risk-informed endpoint.
  - Zachara JM, MD Freshley, GV Last, RE Peterson, and BN Bjornstad. 2012. *Updated Conceptual Model for the 300 Area Uranium Groundwater Plume*. PNNL-22048, Pacific Northwest National Laboratory, Richland, Washington.

- Szecsody JE, L Zhong, M Oostrom, VR Vermeul, JS Fruchter, and MD Williams. 2012. *Use of Polyphosphate to Decrease Uranium Leaching in Hanford 300 Area Smear Zone Sediments*. PNNL-21733, Pacific Northwest National Laboratory, Richland, Washington.
- Wang G, RJ Serne, MJ Lindberg, W Um, BN Bjornstad, BD Williams, IV Kutnyakov, Z Wang and NP Qafoku. 2012. *Uranium in Hanford 300 Area: Extraction Data on New Borehole Sediments.* PNNL-22032, Pacific Northwest National Laboratory, Richland, Washington.

- **Scientific and technical understanding necessary to develop and implement risk-informed alternative endpoint strategies for site closure and long-term management.** Current endpoint and closure requirements often are overly conservative, costly, and technically impractical. Active treatment systems are inefficient and ill-suited to achieve sustainable cleanup goals within acceptable timeframes and cost. Moreover, the sheer mass of contaminated materials within the subsurface makes it impractical to completely restore many sites to predisposal conditions. DVZ-AFRI staff are providing the expertise to define and achieve alternative endpoint cleanup standards, using systems-based remediation approaches and systems-based monitoring strategies, as well as the more traditional source terms and pathways to receptors data (i.e., legacy facilities, tanks, special nuclear materials, and soil and groundwater), which provide deeper insight to the *important* remedial and transport processes, and a platform for integrating new knowledge into conceptual site models. These approaches are significantly more predictive and provide defensible criteria and data for making long-term decisions. Current critical efforts include the following:
  - **Endpoint and remediation strategies for iodine.** Define the scientific and technical understanding of iodine biogeochemistry under Hanford Site relevant conditions to define risk-informed endpoints for remediation; and evaluate and develop remedial options to attain risk-informed endpoint for iodine in the groundwater of the 200 Area West UP-1 Operable Unit.
    - Kaplan DI, C Yeager, ME Denham, S Zhang, C Xu, KA Schwehr, HP Li, YF Ho, R Brinkmeyer, and PH Santschi. 2012. *Biogeochemical Considerations Related to the Remediation of ^{129}I Plumes.* SRNL-STI-2012-00425, Savannah River National Laboratory, Aiken, South Carolina.
    - Santschi PH, C Xu, S Zhang, YF Ho, HP Li, KA Schwehr, and DI Kaplan. *Laboratory Report on Iodine (^{129}I and ^{127}I) Speciation, Transformation, and Mobility in Hanford Groundwater, Suspended Particles and Sediments.* SRNL-STI-2012-00592, Savannah River National Laboratory, Aiken, South Carolina.
  - **Endpoint for plutonium and americium.** Define the scientific and technical understanding of Pu and Am mobility under Hanford Site relevant conditions necessary to develop a strategy to define and attain risk-informed endpoint.
    - Cantrell KJ and AR Felmy. 2012. *Plutonium and Americium Geochemistry at Hanford: A Site Wide Review*. PNNL-21651, Pacific Northwest National Laboratory, Richland, Washington.

- **Controlling processes for technetium.** Advance the scientific and technical understanding of biogeochemical and hydrogeologic controls on Tc mobility under Hanford Site relevant conditions necessary to develop a strategy to define and attain risk-informed endpoint.
  - Jansik, DP, J Istok, DM Wellman, E Cordova. In Press. "The Impact of Water Content on the Transport of Technetium in Hanford Sediments."
- **Mass flux based framework for soil vapor extraction (SVE) shutdown.** Lead a multi-agency, multi-disciplinary collaboration of scientists from the DOE, U.S. Environmental Protection Agency, and the U.S. Army Corps of Engineers to develop the approach and provide guidance for defining endpoints for volatile contaminants in the vadose zone, and provide decision support for termination of SVE operations at the Hanford Site. The approach and framework are being adapted and implemented at other sites (e.g., Los Alamos National Laboratory) throughout the United States with volatile organic contaminants in the vadose zone.
  - Truex MJ, DJ Becker, M Simon, M Oostrom, and AK Rice. 2012. *SVE System Optimization, Transition, and Closure Guidance.* PNNL-21843, Pacific Northwest National Laboratory and U.S. Army Corp of Engineers, Richland, Washington.
  - Truex MJ, KC Carroll, VJ Rohay, RD Mackley, and KR Parker. 2012. *Treatability Test Report: Characterization of Vadose Zone Carbon Tetrachloride Source Strength Using Tomographic Methods at the 216-Z-9 Site*. PNNL-21326, Pacific Northwest National Laboratory, Richland, Washington.
  - Truex MJ, KC Carroll, and M Oostrom. 2012. "Assessing Soil Vapor Extraction Remediation Performance and Closure: A Review." *In Waste Management Symposia 2012*. PNNL-SA-84158, Pacific Northwest National Laboratory, Richland, Washington.
  - Oostrom M, MJ Truex, AK Rice, and KC Carroll. In Press. "Estimating Groundwater Concentrations of Volatile Organic Compounds Emanating from a Vadose Zone Source." *Ground Water Monitoring and Remediation*.
  - Truex MJ, M Oostrom, AK Rice, CD Johnson, DJ Becker, and MA Simon. In Press. "Using Pre-Modeled Scenarios to Estimate Groundwater VOC Concentrations Resulting from Vadose Zone Sources." *Ground Water Monitoring and Remediation.*
  - Brusseau ML, KC Carroll, MJ Truex, and DJ Becker. Draft – 2012. "Characterization and Remediation of Chlorinated Volatile Organic Contaminants in the Vadose Zone: An Overview of Issues and Approaches." *Vadose Zone Journal*.
  - Carroll KC, MJ Truex, ML Brusseau, KR Parker, RD Mackley, and VJ Rohay. In Press. "Characterization of Persistent Volatile Contaminant Sources in the Vadose Zone." *Ground Water Monitoring and Remediation*.

- **Hanford deep vadose zone integrated roadmap.** Currently, R&D, treatability testing, characterization, and feasibility study (remedy evaluation) needs are not sufficiently integrated. DOE does not have a well-articulated plan for obtaining all of the information needed to support forthcoming deep vadose remedial evaluation and selection decisions necessary to protect groundwater. Future remedy decisions are at risk without a well-developed plan that specifies all of the work needed for success and relationships among work elements. The DVZ-AFRI is defining the logic and sequence of R&D and field activities that are necessary to support decisions for selecting interim and final remedies within the Central Plateau.
  - Triplett, MB, DM Wellman, MD Freshley, and MJ Truex. Draft – 2012 Roadmap for Groundwater Protection through Deep Vadose Zone Remediation.
- **200-BP-1 prototype Hanford Site barrier.** Continued research efforts are critical for thorough evaluation and understanding of Hanford Site barrier performance. This monitoring effort, which has been ongoing for 20-plus years, has provided the largest and most extensive monitoring data set that exists for this type of activity at the Hanford Site. The scientific and technical knowledge obtained from this study provides critical understanding and technical validation for the use of engineered, natural barriers for vadose zone cleanup and closure activities.
  - Fayer M, F Zhang, and DM Wellman. Draft – 2012. *Hanford Surface Barrier Strategy: Fiscal Year 2013 and Beyond*. Pacific Northwest National Laboratory, Richland, Washington.
- **Hanford Central Plateau deep vadose zone treatability tests.** DVZ-AFRI scientific contributions for pore water extraction are enabling Site contractors to proceed with design of field tests for these technologies and provided the scientific basis for the processes and how they impact long-term contaminant transport.
  - Truex MJ, M Oostrom, TW Wietsma, GV Last, and D Lanigan. 2012. *Pore-Water Extraction Scale-Up Study for the SX Tank Farm*. PNNL-21882, Pacific Northwest National Laboratory, Richland, Washington.
- **Scientific Opportunities for Monitoring Environmental Remediation Sites (SOMERs).** The *Scientific Opportunities for Monitoring Environmental Remediation Sites (SOMERS):* Integrated Systems-Based Approaches to Monitoring (Bunn et al. 2012) document will be completed, and collaboration with site regulators and the Interstate Technology and Regulatory Council (ITRC) will begin to develop guidance for implementation of systems-based monitoring across the DOE complex. Systems-based monitoring provides the scientific foundation to advance monitoring approaches beyond traditional sampling of wells and point-source based compliance monitoring to whole system (e.g., watershed, disposal facility, and ecosystem) approaches necessary for monitoring complex sites. Relative to conventional compliance monitoring approaches, a monitoring framework that provides insight to the important remedial and transport processes; encompasses the remediation phases of design, implementation, and performance assessment; and integrates with conceptual site models and predictive analyses will improve the effectiveness, reduce risk and costs associated with long-term environmental management.

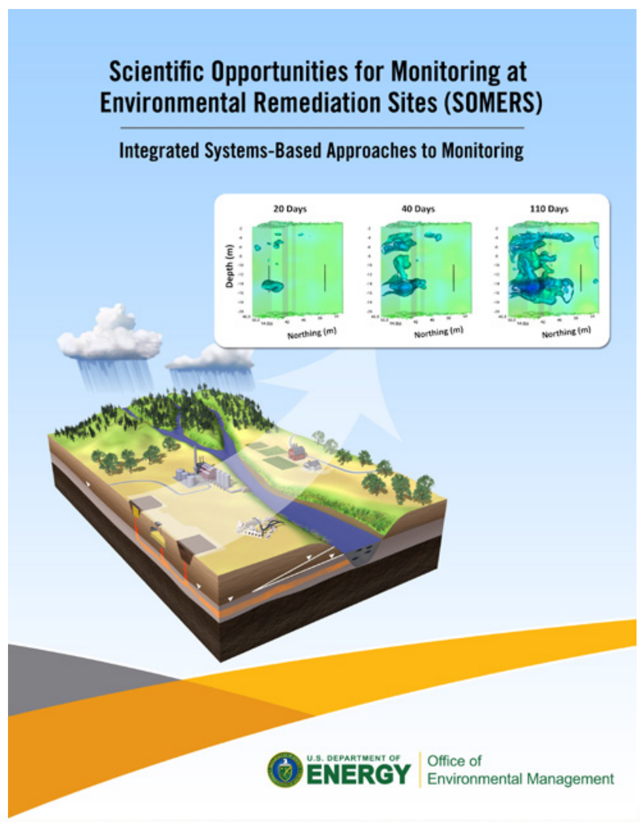
- Bunn AL, DM Wellman, RA Deeb, EL Hawley, MJ Truex, M Peterson, MD Freshley, EM Pierce, J McCord, MH Young, TJ Gilmore, R Miller, AL Miracle, D Kaback, C Eddy-Dilek, J Rossabi, MH Lee, RP Bush, P Beam, GM Chamberlain, J Marble, L Whitehurst, KD Gerdes, and Y Collazo. 2012. *Scientific Opportunities for Monitoring at Environmental Remediation Sites (SOMERS): Integrated Systems-Based Approaches to Monitoring*. PNNL-21379, Pacific Northwest National Laboratory, Richland, Washington.

Key Programmatic Accomplishment

- **NQARD NQA-1 quality assurance program throughout the science and technology supporting EM.** EM cleanup efforts are driven by various site contractors and site owners. As such, quality assurance requirements are highly varied and inconsistent. PNNL has implemented a consistent NQARD NQA-1 quality assurance program across all science and technology efforts supporting EM. This protocol provides enhanced levels of rigor beyond those being required, to assure the scientific understanding and technologies being provided to meet cleanup actions and support long-term decisions are defensible.
    - MacPherson DB. 2012. *Deep Vadose Zone Applied Field Research Initiative Quality Assurance Plan*. QA-DVZ-AFRI-001, Rev. 0., Pacific Northwest National Laboratory, Richland, Washington.

Highlight Projects

Scientific Opportunities for Monitoring at Environmental Remediation Sites



DOE assembled a team of multidisciplinary technical experts from EM and the Office of Legacy Management (LM), national laboratories, academia, and consulting firms to work collaboratively to identify Scientific Opportunities for Monitoring at Environmental Remediation Sites (SOMERS). This document is the first of three peer-reviewed documents for DOE being prepared by the SOMERS team to state the vision and plan for monitoring and provide guidance to DOE site managers. DOE's vision for advancing monitoring through an integrated systems-based approach is presented. Scientific and technical challenges and opportunities associated with systems-based monitoring at DOE sites are identified in detail. Specific opportunities include the following:

- Reliance on conceptual site models (CSM) and evolution of CSMs throughout the range of monitoring phases to improve understanding of the system as a whole and thereby improve monitoring design and interpretation
- Promote lines-of-evidence approaches and flux-based approaches as alternatives to strict reliance on point measurements and to improve integration of monitoring information with remedy management and long-term site management

- Develop and apply innovative monitoring tools, including surrogates, early indicator parameters, bioassessments, geophysics and remote sensing, predictive analyses and models, and information management that can reduce the cost of monitoring and associated site remediation and provide improved information to address risk management.

These opportunities contribute to the design and implementation of monitoring programs that support long-term remedial objectives for site cleanup and closure.

Throughout the development of this document, team members and peer reviewers provided valuable technical input beyond identification of the scientific challenges and opportunities associated with monitoring. Therefore, two additional documents are being prepared by the SOMERS team: a SOMERS program plan and a SOMERS guidance document. The objectives of the program plan are to 1) prioritize monitoring challenges and associated research needs at DOE sites; 2) correlate research priorities with the opportunities and challenges for an integrated systems-based monitoring approach; 3) identify potential collaborations with other federal agencies, universities and other organizations; 4) identify opportunities to engage stakeholders, including regulatory agencies; and 5) pinpoint methods to enhance communication within and beyond DOE. The overall objective of the guidance document is to provide guidance to site managers on how to implement an integrated systems-based approach to monitoring at DOE sites. The guidance document will provide a number of case studies demonstrating the use of integrated systems-based monitoring approaches and highlighting the benefits from this approach. The guidance document will also provide recommendations for site managers to improve implementation of integrated systems-based monitoring.

This document is intended for a broad audience, including DOE leadership within EM (at DOE Headquarters and the sites) and LM, as well as other federal agencies facing similar monitoring challenges and opportunities. In addition, the document is intended to benefit site contractors by providing a broader, cross-disciplinary perspective of monitoring opportunities and challenges in different media, hydrogeologic settings, contaminant types, tools, and approaches.

Advanced Geophysical Imaging Technology Characterizes Contaminants in the Deep Vadose Zone

Cold-war era waste disposal practices resulted in both planned and unplanned releases of large amounts of radionuclide and heavy metal contamination into the subsurface throughout the DOE complex. Characterizing the distribution of the resulting environmental contamination remains one of the single most significant challenges limiting subsurface remediation and closure, particularly for the unsaturated soil region between the surface and the water table—the vadose zone.

Through the DVZ-AFRI, Pacific Northwest National Laboratory (PNNL) is addressing this problem by developing and deploying advanced subsurface geophysical imaging technologies. By leveraging investments from DOE and the DOD, DVZ-AFRI staff developed an advanced high-performance geophysical imaging code that reconstructs subsurface images using ERT. This technology provides advancements for site-specific customization that uses high-performance computing resources to "see" subsurface contaminant plumes in three dimensions and in unprecedented resolution.

In partnership with DOE and Hanford Site contractor CHPRC, the DVZ-AFRI is leveraging this capability to delineate subsurface vadose contamination. Large scale three-dimensional surface ERT data were collected from the Hanford Site B-Complex by site contractors to image contaminant distribution beneath former waste infiltration galleries surrounding the B, BX, and BY Tank Farms in the 200 East Area (CHPRC 2007). Figure 2 shows the computational mesh constructed to invert the data and the electrode lines, tank farms, and former infiltration galleries. In total, the mesh includes approximately 1.08 million imaging elements (or pixels), and the electrical conductivity (EC) was estimated for each element during the inversion. The survey consisted of 301,918 measurements collected using 4858 electrodes. Customized aspects of the inversion enabled by FERM3D include the following:

- LiDar-derived surface topography was incorporated into the mesh, which improves image resolution by reducing simulation errors
- Refinement about electrodes to improve simulation accuracy and reduced imaging artifacts
- Tanks explicitly incorporated into mesh to improve simulation accuracy and improve resolution
- Inversion estimates tank EC and sharp boundaries at tank-soil interface are permitted
- A sharp EC boundary at the water table is also permitted.

These data were inverted on the PNNL Institutional Computing System using ~2500 processors, requiring approximately 12 hours of computation time.

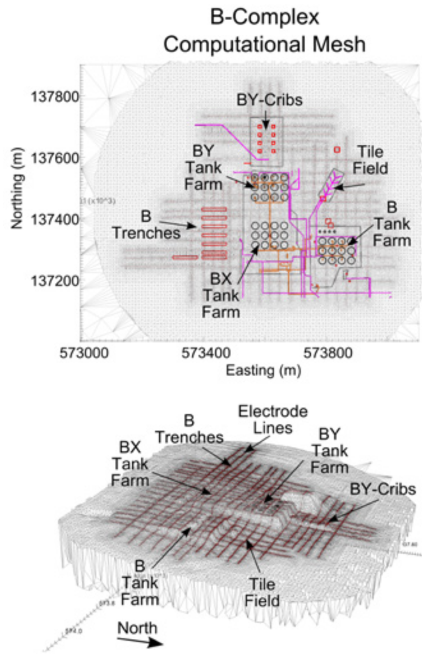


Figure 2. Hanford B-Complex FERM3D computational mesh showing electrode lines, surface topography, tank farms, and waste infiltration galleries (cribs, trenches, and tile field) locations. Smaller volumes of high-level nuclear waste leaked from the tank farms into the vadose zone. High volumes of low-level waste were infiltrated through the cribs, trenches, and tile field.

A plan view of the B-Complex FERM3D inversion is shown in Figure 2. The image is presented in terms of elevated EC iso-surfaces. The most notable features of the image are in the tank farm areas, that exhibit elevated EC throughout. These elevated conductivities are caused primarily by the dense network of metallic test wells within the tank farm areas, and thus do not necessarily indicate widespread soil contamination. However, the waste infiltration regions outside of the tank farms boundary (tile field, trenches, and cribs) are not significantly influenced by infrastructure. In these regions, the EC iso-surfaces bound zones of unnaturally elevated EC caused by contamination.

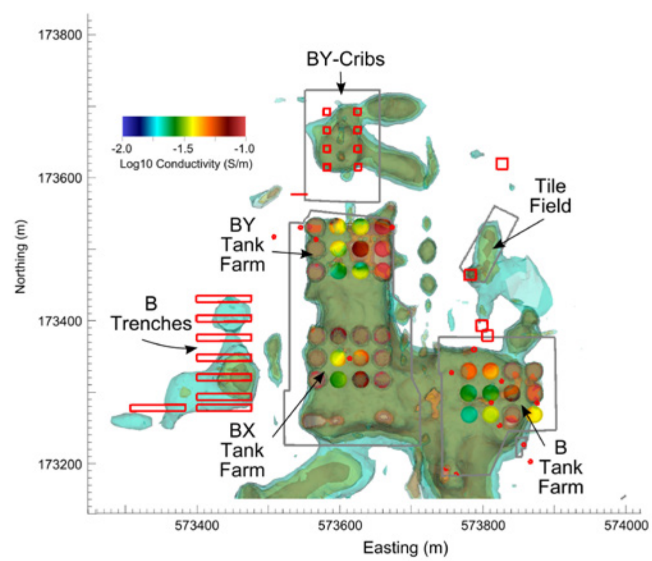


Figure 3. Plan view of B-Complex three-dimensional ERT inversion results. Unnaturally elevated EC regions are bounded by iso-surfaces. Elevated EC within the tank farm is caused primarily by the tanks and by the dense placement of metallic test wells. Elevated EC outside of the tank farms (i.e., beneath the cribs, trenches, and tile field) is caused by contamination.

The contaminant plumes revealed within the tile-field, trench, and cribs areas exhibit significant vertical relief that is not evident in the plan view representation shown in Figure 3. Figure 4 shows both plan and oblique views of the BY-Cribs that illustrate the depth dimension of the contaminant plumes in this area. Figure 4 also shows that test and sample wells in the cribs area do not intersect the eastward trending contaminant plumes, and thus do not indicate their existence. This further illustrates the need for and utility of the remote subsurface imaging capability enabled by parallel ERT inversion with FERM3D.

To illustrate the improvement in resolution in comparison to commercially available software, Figure 5 compares horizontal depth section images of the FERM3D inversion to those produced with a leading commercially available code (courtesy Dale Rucker, hydroGEOPHYSICS, Inc., 2012). While both images identify a major conductive target beneath the disposal site, the FERM3D images delineate details concerning the distribution of contaminants that are not evident in the commercially-generated results. For example, the FERM3D inversion reveals the vertical and horizontal extend of two eastward trending contaminant plumes that are not as well resolved by the commercial inversion. Such details significantly reduce sampling and cleanup costs and assist effective cleanup and monitoring designs by reducing uncertainty and enabling efforts to focus on contaminated zones.

Reanalysis of data collected at the Hanford Site B Complex revealed previously unknown detail concerning contaminant distribution beneath former waste infiltration galleries. Visualizations of the results using ASCEM are now being used to guide subsurface sampling investigations. The ability to "see" vadose zone contamination in high resolution images using ERT provides a critical scientific and technical capability required to make sound and defensible remedial decisions that will successfully meet target cleanup goals.

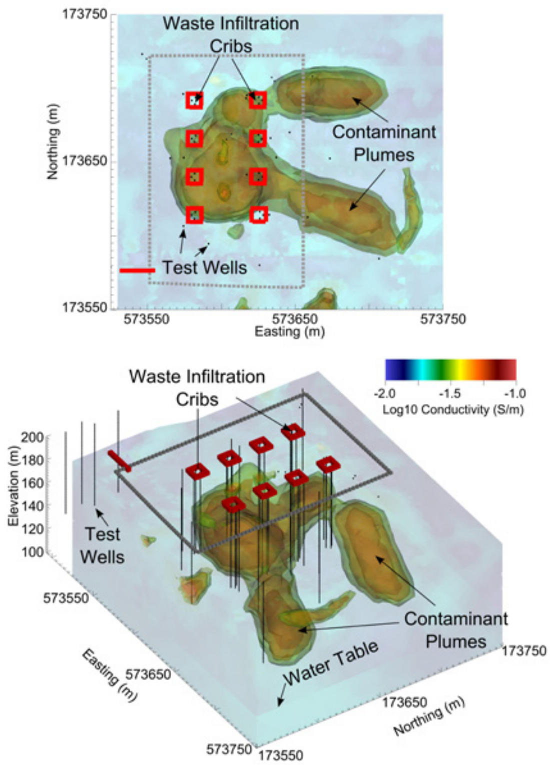


Figure 4. Plan view (top) and oblique view (bottom) of elevated EC contaminant plumes beneath the Hanford Site BY-Cribs and Trenches produced by FERM3D.

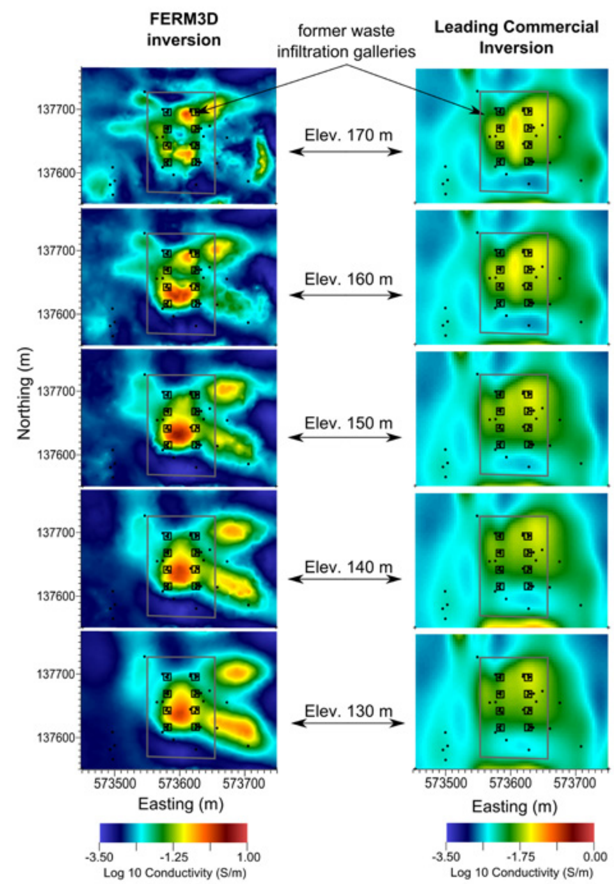


Figure 5. Comparison of contaminant plume images at the Hanford Site BY-Cribs Area produced by FERM3D compared to those produced by a leading commercially available ERT imaging software.

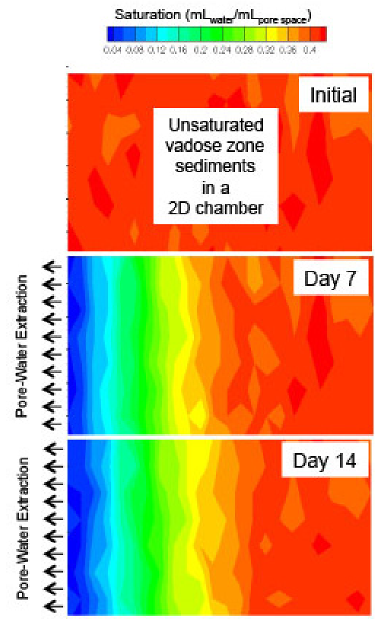
Pore-Water Extraction Scale-Up Study for the SX Tank Farm

As a remedial approach, pore-water extraction offers the possibility of contaminant and water removal from the vadose zone, which may be beneficial in reducing the flux of vadose zone contaminants to the groundwater. Previous laboratory and modeling efforts examining pore-water extraction have focused on two implementation approaches: 1) application of negative pressure (vacuum) via soil gas extraction at a well to induce coincident pore-water extraction and; 2) deploying super-absorbent polymers in a well to extract water from the surrounding soil. Developing and evaluating pore-water extraction has been collaboratively funded and conducted with contributions by PNNL, DOE Richland Operations Office, Office of River Protection, Washington River Protection Solutions, and CHPRC.

The phenomena related to pore-water extraction from unsaturated sediments have been previously examined with limited laboratory experiments and numerical modeling. However, key scale-up issues have not yet been addressed and additional information was needed to enable consideration of this technology for field application.

Laboratory experiments and numerical modeling were conducted to specifically examine pore-water extraction for sediment conditions relevant to the vadose zone beneath the SX Tank Farm at the Hanford Site, the target site for planned field testing of the technology (Truex et al. 2012). These experiments build from previous laboratory and modeling efforts conducted to examine pore-water extraction at a proof-of-principle level (Oostrom et al. 2011, 2012). Available SX Tank Farm data were evaluated to generate a conceptual model of the subsurface in areas with elevated moisture and Tc-99 concentration. This conceptual model formed the basis to select materials for subsequent laboratory hydraulic property analyses and for conducting numerical modeling to simulate a targeted application of pore-water extraction.

Hydraulic properties of the types of sediment in the targeted zone of the SX Tank Farm sub-surface were determined in the laboratory. Sediment mixtures were prepared in the laboratory based on borehole sediment particle size data for each type of sediment. Measurements quantified the sediment porosity, hydraulic conductivity, and the nature of pressure-saturation relationships, thereby extending the available sediment characterization data. This sediment characterization data was used to estimate the pore-water extraction potential for each sediment type as a function of initial moisture content and applied suction. In summary, study results showed that pore-water extraction through application of vacuum or absorbent polymers can extract water from SX Tank Farm sediments primarily when initial volumetric moisture content is above 20% and applied suction is greater than 300 cm H_2O. Another important finding was that the hydraulic properties of the sediments in the targeted pore-water extraction area are similar. Thus, inefficiencies in pore-water extraction caused by hydraulic property heterogeneity may not be extreme for the targeted vadose zone depth intervals at the SX Tank Farm. Future laboratory flow cell tests will provide more specific information to evaluate the impact of sediment property differences on pore-water extraction performance, and are also required to select appropriate well filter-pack materials to ensure efficient pore-water extraction.



Water saturations for initial conditions, after 7 days, and after 14 days of desiccation.

Numerical modeling was used as an evaluation tool to examine scale-up of pore-water extraction. In the numerical simulations, the pore-water extraction rate declined rapidly from initial extraction rates to a steady-state rate under conditions with an infinite water supply (e.g., a laterally extensive high moisture zone). Although not simulated, a finite water supply would result in a continued decline of pore water extraction rates over time. The rate of pore-water extraction is relatively slow for the simulated SX Tank Farm conditions because water content reduction near the extraction well resulted in a decreased water relative permeability. In general, unless the hydraulic conductivity encountered in the field is significantly different (greater or smaller) from the values determined in the laboratory, pore-water extraction rates are expected to be on the order of 5 to 15 L/day. As an example, these pore-water extraction rates translate to remediation time frames on the order of decades for the goal of decreasing volumetric moisture content by 5% in a 10-m radius around an extraction well. Hence, the remedy must be applied over a relatively long timeframe to meet objectives, much like other contaminant extraction technologies (e.g., pump-and-treat of groundwater). These estimates of pore-water extraction rates (and corresponding remediation timeframes) should be considered as an approximation. Additional data from planned laboratory flow cell experiments and field testing will provide more specific remedy performance information.

Looking Forward: Fiscal Year 2013 Tasks

Alternate endpoints and the associated implementation framework provide an improved mechanism for EM to address challenges, risks, and remediation costs of contamination at complex waste sites in place of more traditional approaches of contaminant removal and disposal. Developing and implementing an alternate endpoint-based approaches for remediation and waste site closure presents a number of challenges and opportunities (Figure 6) including scientific and technical, regulatory, institutional, and budget and resource allocation issues. Opportunities exist for developing and implementing systems-based approaches for determining remediation approaches and enabling implementation of alternate endpoints. Characterization, monitoring, predictive modeling, and risk assessments are critical components of the implementation framework. Technology development and evaluation, as well as attenuation-based approaches, are foundational elements supporting the ability to achieve remediation goals and close waste sites using alternate endpoints. Communication with regulators, Tribal Nations, and stakeholders is critical for implementation of alternate endpoint approaches, particularly with respect to risk assessments and choices for prioritizing resources. The transition of sites to long-term monitoring and stewardship is also a key component of an alternate endpoint approach. While some development and policy efforts are needed to enable broad implementation of alternate endpoints for EM, the alternate endpoint approach has the potential to expedite cleanup and reduce cost through understanding what should be accomplished through cleanup efforts, what endpoint(s) or condition(s) constitute progress or completion of Hanford Site cleanup, and schedule commitments with a defensible and credible technical scope of work, including clear requirements to achieve risk-informed endpoints.

Challenges	Key Issues	Opportunities
Scientific and Technical	Understand the nature and magnitude of problems to determine which risks are most critical and establish priorities for remediation needs and closure requirements	• Systems-based Approaches for Remediation and Decision Support • Characterization vs. Predictive Understanding (e.g. mass flux based conceptual models) • Technologies vs. Remedial Strategies • Point source vs. Systems-based Monitoring • Active/Passive Remediation Efforts–Transition and Exit Strategies.
Regulatory	Based on scientific and technical understanding, determine what must be accomplished through cleanup efforts	• Risk-informed definition of regulatory requirements • Priorities based on protection of human health and the environment
Institutional and Closure Management	Define what endpoint or condition would constitute progress or completion of cleanup	• Process to effectively define endpoints from scientifically and technically defensible understanding • Clearly defined and credible cleanup scope of work to achieve risk-based endpoints • Transition complex sites to LTM or MNA
Budget and Resource Allocation	Allocate limited resources (i.e., federal budget dollars) to provide benefit to society (e.g., reduced risk, recovered resources, etc.)	• Risk-informed choices to prioritize resources, drive 'cleanup demand' and complete site cleanup

Risk-Based Alternative Endpoint Strategies for Site Closure and/or Long-Term Management

Technically-based approaches to achieve alternative endpoint strategies, which are risk-based, cost-effective, sustainable, and protective of public health and environment

Figure 6. Challenges, issues, and opportunities associated with risk-based alternate endpoint strategy.

In FY 2013 the DVZ-AFRI will continue to make progress on critical scientific and technical issues to define alternate endpoints and develop technically-based approaches to achieve alternative endpoint through the following tasks:

Hanford Deep Vadose Zone Integrated Roadmap—Currently, R&D, treatability testing, characterization, and feasibility study (remedy evaluation) needs are not sufficiently integrated and DOE does not have a well-articulated plan for obtaining all of the information needed to support forthcoming deep vadose remedial evaluation and selection decisions necessary to protect groundwater. Future remedy decisions are at risk without a well-developed plan that specifies all of the work needed for success and relationships among work elements. DVZ-AFRI staff will define the logic and sequence of R&D and field activities that are necessary to support decisions for selecting interim and final remedies to protect groundwater.

Defining Risk-Informed Endpoints and Supporting Decisions for Hanford 300 Area Uranium Remediation—DVZ-AFRI staff are integrating scientific and technical information gained from years of investments by SC and EM to assist CHPRC in developing a technically feasible approach for remediating uranium in the Hanford Site 300 Area. DVZ-AFRI staff will use the 300 Area site conceptual model and conduct advanced predictive simulations to identify and mitigate scientific and technical uncertainties limiting successful remedy implementation, and provide the scientific understanding necessary to support risk-informed endpoint.

Deep Vadose Zone Pore-Water Extraction Treatability Test—In collaboration with DOE Richland Operations Office, Office of River Protection, Hanford Site contractors CHPRC and Washington River Protection Solutions, DVZ-AFRI scientists will apply advanced understanding of pore-water extraction processes and hydrogeophysical understanding of the S-SX Tank Farm to provide the expertise supporting the design and demonstration of pore-water extraction at the S-SX Tank Farm.

200 West Pump-and-Treat System Performance Optimization—The biological communities present in the 200 West pump-and-treat FBR removes carbon tetrachloride and nitrate from groundwater. Biological community functions rely on the interactions between individual members of the community as well as the individual members (abundance, activity). DVZ-AFRI staff will apply molecular tools (i.e., microbial fingerprinting and sequencing) to determine the spatiotemporal identity, composition, and function of the microbial community within the FBR to support performance optimization.

Flux-based Framework for Evaluation and Support of Vadose Zone Remediation Decisions—Remediation of inorganic and radionuclide contaminants in vadose zone environments is based on protection of groundwater. The mass flux/discharge of contaminants through the vadose zone is a primary factor controlling the impact of vadose zone contaminants in groundwater. Most remediation approaches are based on mitigating contaminant mass flux and implementation of MNA relies on demonstrating that the natural attenuation processes are sufficient to limit the vadose zone contaminant flux such that groundwater contaminant concentrations remain below compliance goals. The DVZ-AFRI will build upon the FY 2012 developments to 1) develop necessary methods to collect and assess information from the vadose zone in terms of contaminant flux and related controlling processes needed to support remedy evaluation, implementation, and monitoring in the vadose zone; and 2) apply the flux-based conceptual model framework to understand and quantify moisture and contaminant flux for priority Hanford Sites including perched water systems, BY Cribs, and the SX Tank Farm.

Waste Chemistry Impacts on Uranium Transport—Waste disposal processes significantly impacted the contaminant chemistry and sediment and pore-water chemistry in the vadose zone. To effectively develop and implement options to remediate uranium in the vadose zone, it is critical to first understand the nature and controlling processes; however, it is not fiscally viable to thoroughly characterize every waste site. DVZ-AFRI staff will integrate the understanding of the range of important waste disposal chemistries at the Hanford Site and quantified impacts on attenuation mechanisms, and transport and fate for uranium into the flux-based framework to provide the necessary knowledge to support remedial decisions for uranium.

Implementation of an in-line Tc-99 Sensor within the 200 West Pump-and-Treat System—By applying advanced radioanlytical chemistry, DVZ-AFRI staff have partnered with Burge Environmental to provide real-time analysis of aqueous Tc-99 concentrations in effluent streams from the 200 West pump-and-treat system. An in-line sensor design will be ruggedized and implemented within the 200 West pump-and-treat system to provide the necessary data, on-demand, to evaluate and optimize operations, which was previously only possible through extensive sampling and analysis.

200-BP-1 Prototype Hanford Barrier—Continued research efforts are critical for thorough evaluation and understanding of Hanford Site barrier performance. Researchers will continue to evaluate the performance of the 200-BP-1 Prototype Hanford barrier, which is critical for thorough evaluation and understanding of long-term performance. This monitoring effort, which has been ongoing for 20-plus years, has provided the largest and most extensive monitoring data set that exists for this type of activity at the Hanford Site. The scientific and technical knowledge obtained from this study provides critical understanding and technical validation for the use of engineered, natural barriers for vadose zone cleanup and closure activities

Field Lysimeter Test Facility—The Field Lysimeter Test Facility, located at the Hanford Site, will continue to be used by researchers to further scientific investigations to understand and define recharge rates for vadose zone environments, evaluate monitoring technologies, and quantify the performance of proposed barrier designs. The scientific and technical knowledge obtained provides critical scientific understanding for supporting remedial decisions on the design, implementation, and performance of barriers for site closure.

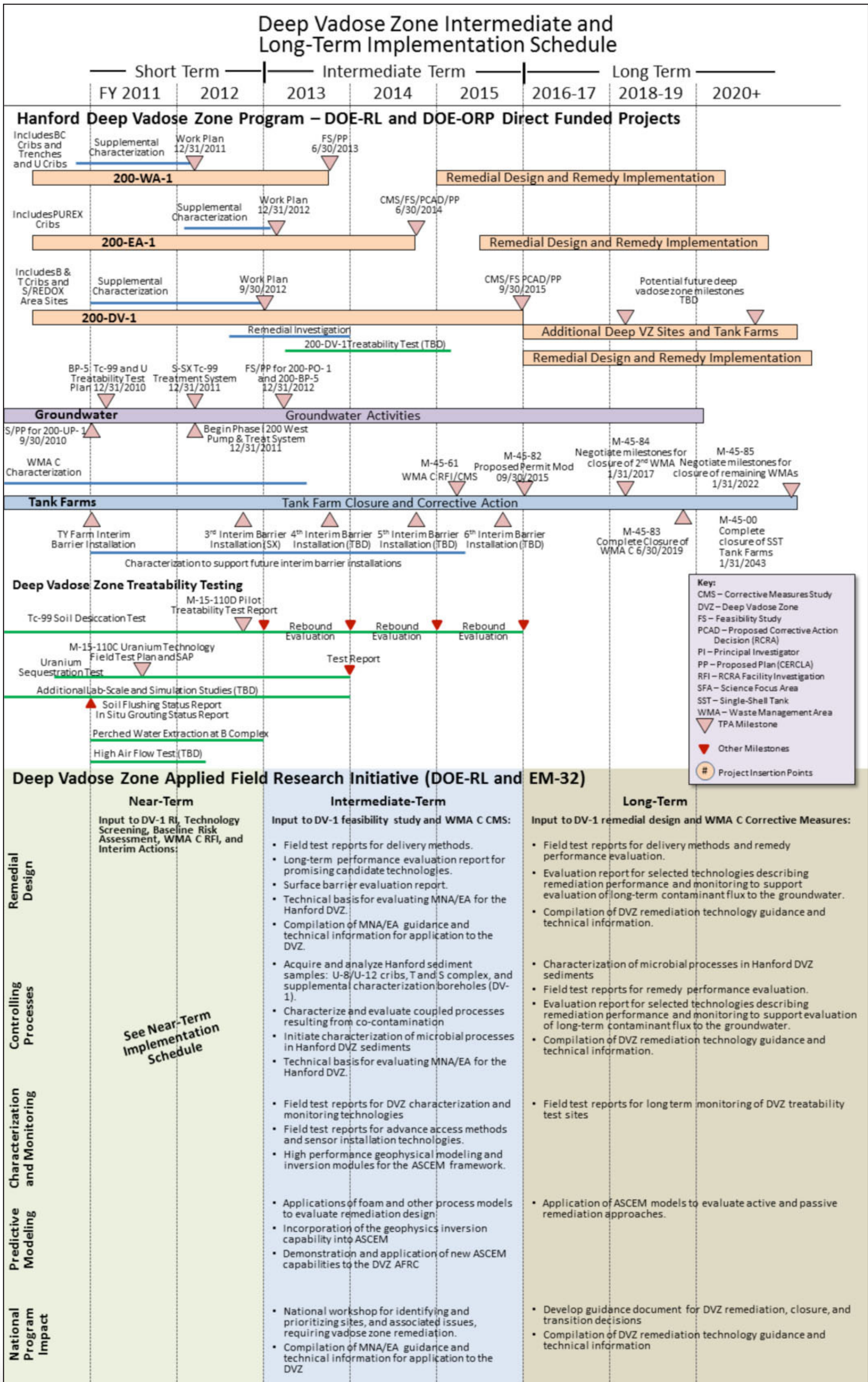
Imaging Subsurface Contamination in the Presence of Electrically Conductive Infrastructure—There is a recognized need for methods to characterize and monitor vadose contaminants originating from leaking subsurface infrastructure such as pipes or tanks. ERT is a robust, adaptable, and well-proven method, but is traditionally limited in the presence of electrical conductive materials such as buried pipes, tanks, and well casings. DVZ-AFRI scientists will develop additional capabilities within the high-performance computing geophysical imaging code FERM3D, enabling explicit ERT inversion modeling of infrastructure effects to distinguish between subsurface contamination and infrastructure conductivity.

Subsurface Process Monitoring—Complex resistivity (CR) is a sensitive geophysical technique that is responsive to important subsurface controlling mechanisms including biological growth and biological and geochemically induced precipitation reactions. CR has also been directly related to important mechanical properties such as soil surface area and permeability. Field-scale CR imaging is a computationally demanding problem, particularly in three dimensions. DVZ-AFRI scientists will develop a new CR inversion formulation module within the high-performance computing geophysical imaging code FERM3D. This code will provide a powerful and unique capability to monitor critical transport and fate processes at the field scale ERT using infrastructure already installed for ERT imaging.

Defining Risk-Informed Alternative Endpoint Strategies for Site Closure and Long-Term Management—Current endpoint and closure requirements often are overly conservative, costly, and technically impractical. Active treatment systems are inefficient and ill-suited to achieve sustainable cleanup goals within acceptable time-frames and cost. Moreover, the sheer mass of contaminated materials within the subsurface makes it impractical to completely restore many sites to predisposal conditions. The DVZ-AFRI will define alternative endpoint cleanup standards and develop methods to achieve them, using systems-based remediation approaches and systems-based monitoring strategies, as well as the more traditional source terms and pathways to receptors data (i.e., legacy facilities, tanks, special nuclear materials, and soil and groundwater), which provide deeper insight to the *important* remedial and transport processes, and a platform for integrating new knowledge into conceptual site models. These approaches are significantly more predictive and provide defensible criteria/data for making long-term decisions. Critical efforts include the following:

- Endpoint and Remediation Strategies for Iodine—Evaluate and develop remedial options to attain risk-informed endpoints for iodine in the Hanford Site 200 Area West UP-1 groundwater operable unit.
- Endpoint for Plutonium, Americium, and Technetium—Provide the scientific understanding necessary to define the transport, rate, and risks associated with Pu, Am and Tc mobility under Hanford Site relevant conditions necessary to develop a strategy to attain risk-informed endpoints.

Progress Chart



Major Milestones – Hanford Site

DVZ-AFRI supports milestones for the200-DV-1 remedial investigation/feasibility study process and WMA-C corrective measures study.

R&D Category	Near Term (FY11 to 12)	Intermediate Term (FY13 to 15)	Long Term (FY16 to 20)
Remedial Design	✓ Support 200-DV-1 technology screening ✓ Evaluate of foam delivery technology ✓ Establish framework for MNA evaluation of Hanford DVZ ✓ Evaluate improved access technologies	✓ Complete field tests for delivery methods ✓ Complete long-term performance evaluation report for candidate technologies ∗ Complete surface barrier evaluation ∗ Establish technical basis for evaluating MNA/Enhanced Attenuation (EA)	• Complete field tests for delivery methods and remedy performance ∗ Evaluate technologies for monitoring remediation performance and long-term flux to groundwater ∗ Compile DVZ remedial strategy guidance
Controlling Processes	✓ Evaluate controlling processes for delivery and access methods (including foam) ✓ Support development of T and S complex conceptual models ✓ Archive Hanford DVZ sample archival ✓ Support framework for MNA evaluation of Hanford DVZ	• Analyze Hanford sediment samples from U cribs, T and S complex and additional boreholes • Evaluate coupled processes with co-contaminants ∗ Initiate characterization of microbial processes ∗ Support technical basis for MNA/EA ∗ Support development of WMA A-AX plans	• Complete characterization of microbial processes ∗ Support field tests for remedy performance evaluation ∗ Support monitoring remediation performance and long-term flux to groundwater ∗ Support DVZ remedial strategy guidance
In Situ Characterization and Monitoring	✓ Evaluate potential DVZ characterization and monitoring technologies ✓ Develop high-performance geophysical modeling and inversion codes ✓ Apply geophysical methods at BC-cribs desiccation site ✓ Develop advanced geophysical methods to monitor amendment delivery ✓ Provide input to S-SX interim barrier monitoring plan ✓ Develop overview and guidance for systems-based monitoring	• Complete field tests of DVZ characterization and monitoring technologies • Complete field tests of advanced access methods and sensor installations ∗ Link high performance geophysical modeling to ASCEM framework	• Support field tests for long-term monitoring of DVZ treatability test sites ∗ Provide input to 200-DV-1 remedial design and WMA C corrective measures and long-term monitoring plans
Predictive Modeling and Data Integration	✓ Incorporate foam transport and other modules into ASCEM ∗ Collaborate with ASCEM DVZ working group	• Apply foam and other process models to evaluate remedial design ∗ Support incorporation of geophysics capability into ASCEM Demonstrate ASCEM capabilities for DVZ AFRI • Develop alternative conceptual models and uncertainty analysis for controlling processes and remedial design ∗ Support Hanford site fate and transport modeling path forward (Plateau Remediation Contractor) ∗ Assess need for developing waste site-specific models	∗ Apply ASCEM modules to evaluate active and passive remediation approaches

✓ Denotes completed milestones
∗ Denotes activities In Progress to meet milestone

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Appendix

FY2012 Products for the Deep Vadose Zone-Applied Field Research Initiative

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PNNL is located in Richland, Washington, has approximately 4,900 staff, and $1.1 billion in business volume in fiscal year 2010. In the quest for knowledge discovery, PNNL marshals interdisciplinary research teams, collaborates with a range of partners, and leverages research funding to maximize results. Our staff, facilities, capabilities, and approach to inquiry and innovation have established PNNL as a premier science and technology enterprise.

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