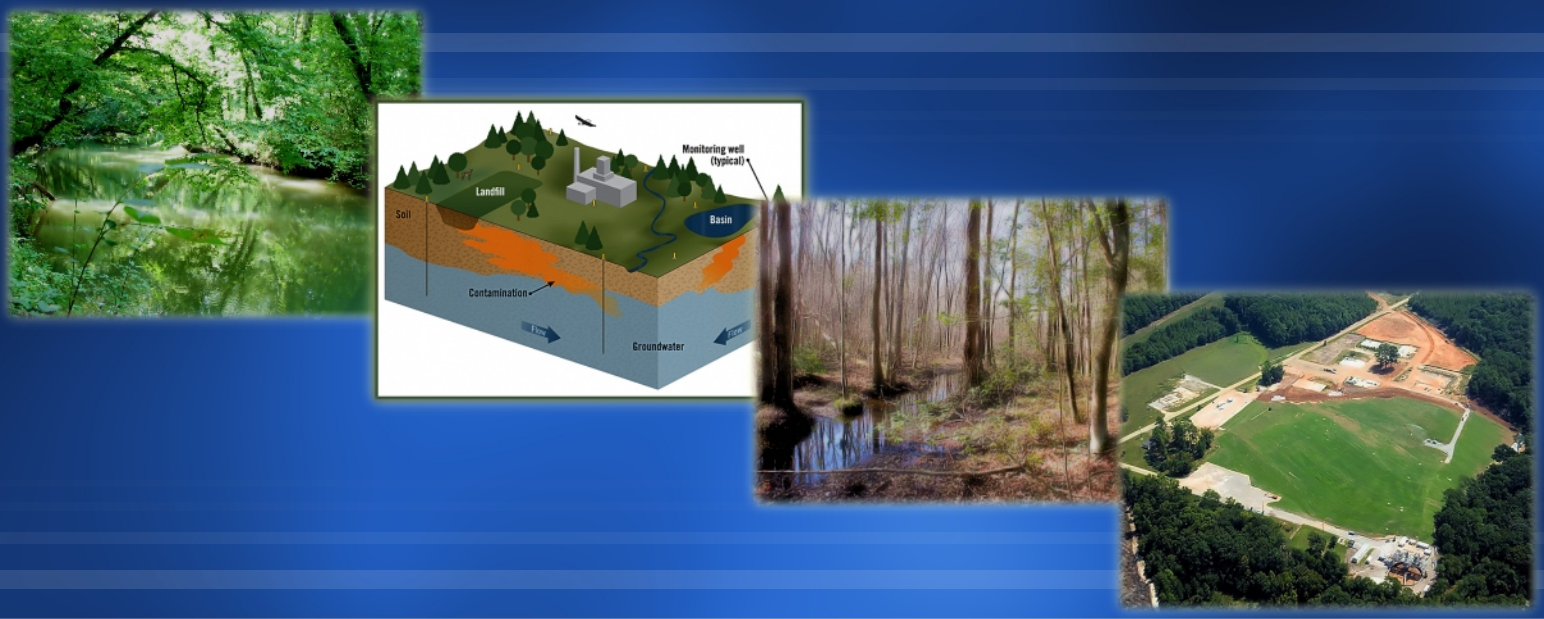
United States Department of Energy
Office of Environmental Management

Office of Soil and Groundwater Remediation



Program Accomplishments

Fiscal Year 2015

safety ❖ performance ❖ cleanup ❖ closure

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2015
Focused Results

Kurt Gerdes, Director
Office of Soil and Groundwater Remediation

While some of the Department of Energy (DOE) Office of Soil and Groundwater Remediation (EM-12) Program's primary environmental research remains unaffected, 2015 saw a shift in research initiatives to better address high-priority needs. A primary concern remains the objective of successfully controlling and neutralizing hazardous chemicals and substances in sub-surface environments. As such, programs have been aligned to confront the dangers associated with high-priority contaminants of concern - technetium, iodine, and mercury.

Utilizing new innovations and new approaches, the collective goal of the program is to efficiently manage the risk of hazardous substances to human health and the environment. Approaches focus on the mitigation of risks directly at the source (in situ) of the problem area. This focus has produced remarkable and positive results. The outcome of these approaches is more effective hazard resolution that requires significantly less direct worker involvement (much safer) and substantially improved long term cost-effectiveness and sustainability. All of these factors are inspiring improvements, and the year ahead portends many more breakthroughs and benefits.

Several of the DOE national laboratories are at the forefront of these advancements. Technetium and iodine solutions are being championed by Savannah River National Laboratory (SRNL) and Pacific Northwest National Laboratory (PNNL). Oak Ridge National Laboratory (ORNL) advances mercury remediation. Los Alamos National Laboratory and Lawrence Berkeley National Laboratory (LBNL), as well as others, play key roles in data integration and advanced modeling. While all groups have their own tasks to undertake, cooperation and knowledge sharing has been critical to the overall successes.

The breadth of these programs does not end with fellow national laboratories, however. Two-way collaboration from the DOE, other Federal agencies, international partnerships and industry-related alliances continue to provide win-win scenarios at all levels of program development. The Minority Serving Institutions Partnership Program (MSIPP) and student internships proved to be popular successes, providing real-world opportunity for students – while helping rejuvenate the DOE talent pool.

The new approaches and breakthroughs of 2015 have only served to invigorate those at the center of these programs. With continued research, development, and collaboration, all indications are that these approaches will prove beneficial to DOE environmental remediation operations in terms of even more efficient, safer, and more cost-effective solutions. 2015 had many successes. Expectations for 2016 are even more exciting.

Kurt Gerdes

Next-Generation Scientists

Strong relationships with top universities have always been a priority of EM and the Office of Soil and Groundwater Remediation. Research universities are a natural testing ground for students' technical skills, and many of these universities are also involved in trailblazing work of their own. EM encourages talented university students to become constructive members of its workforce. During 2015, EM reenergized many of its established student internship programs and also invested in new, minority-focused programs, all of which have been successful.

Minority-Serving Institutions Partnership Program

The DOE Office of Environmental Management has created the Minority Serving Institutions Partnership Program (MSIPP). In 2015, $7 million was provided to the SRNL to administer the MSIPP. This was utilized across a variety of programs, research collaborations, and laboratory internships. SRNL, PNNL, ORNL, and Argonne National Laboratory (ANL) all actively participated in the program. Minority Serving Institutions include Black, Hispanic, and Tribal colleges and universities that support science, technology, engineering and mathematics. More than 30 students participated in the past year.

Science and Technology Workforce Development Program

The DOE-FIU Science and Technology Workforce Development Program is a pioneering program directed by the DOE-EM and Florida International University's Applied Research Center (FIU-ARC). This fellowship-based venture is designed to create a pipeline of minority engineers, specifically trained and mentored to enter the DOE workforce, contributing to technical areas of need. Students selected as fellows perform applied research at FIU and a DOE site, and are able to integrate FIU research, DOE field work, and active course-work into a well-structured and career-ready academic concentration.

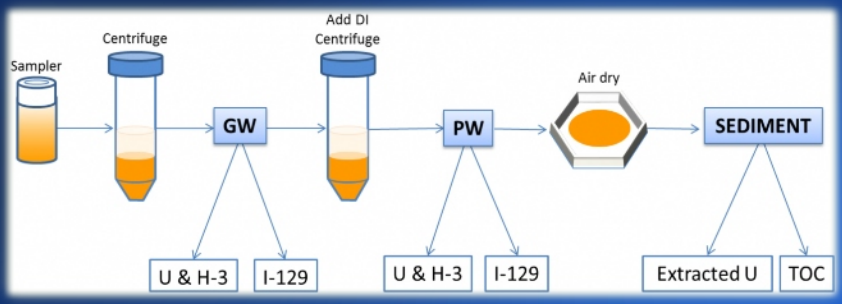
Savannah River
National Laboratory

Remediation of complex subsurface contamination is a significant challenge facing the U.S. Department of Energy Office of Environmental Management (EM). Although traditional standards-based closure goals have been successful at many sites, these approaches may not be technically or economically feasible at many of the remaining complex sites. Opportunities exist to implement systems for characterization, monitoring, and remediation, in order to facilitate transition of sites with groundwater and soil contamination from active to more passive attenuation-based remedies.

Enhanced Attenuation Using Humate

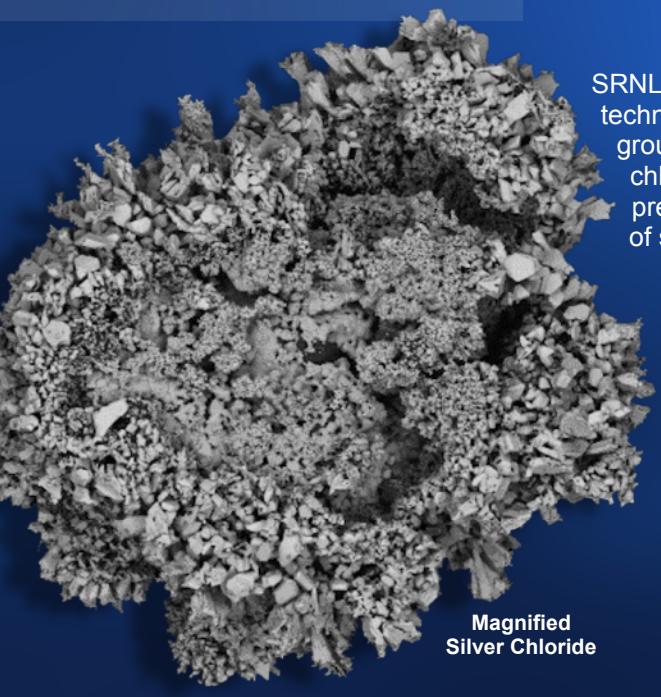
One important pathway to alternate endpoints is development of effective long-lived attenuation-based remedies. SRNL is investigating the use of humate solutions to create in situ treatment zones that will enhance attenuation of contaminants in groundwater. To date, successful results show that absorption of uranium from contaminated groundwater was enhanced by humate.

SRNL is working to further refine the effectiveness of this technique, which will allow extension of enhanced attenuation strategies to sites across the DOE complex - such as the LANL chromate plume and the Paducah technetium plume.



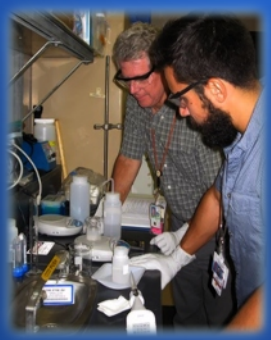
Processing of Diffusion Samplers to Test Remediation of Uranium by Humate

Enhanced Attenuation of I-129



Magnified Silver Chloride

SRNL has developed a technology to remediate iodine 129 in groundwater. The technique involves injection of silver chloride particles into the contaminated groundwater. When dissolved, iodide in the groundwater contacts a silver chloride particle. The iodide is removed from the groundwater solution by precipitation of silver iodide. SRNL is working to optimize the broader use of silver chloride to attenuate iodine 129 in groundwater.



Savannah River
National Laboratory

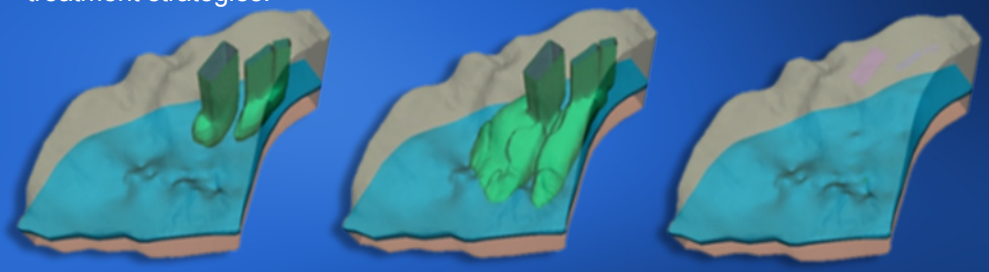
Long-Term Monitoring

Many government and private industry sites contaminated with radioactive and chemical wastes cannot be remediated adequately to permit unrestricted human access. Such sites will require long-term monitoring (LTM); perhaps indefinitely. Long-term monitoring of such sites is associated with significant projected life-cycle costs.

Researchers at Savannah River National Laboratory are conducting pilot field tests of alternative protocols and remote sensors for long-term monitoring of metals and radionuclides. These tests involve low-cost measurements of hydrologic and chemical conditions that control contaminant migration, as well as a set of "master variables" that may indicate plume instability, and thus can be used to predict plume migration. The proposed strategy is expected to be a more cost-effective, adaptable, early identifier of potential risks and plume evolution.

F-Area Virtual Testbed & ASCEM Application

Implementation of long-lived attenuation-based remedies requires adequate levels of monitoring to ensure that the remedies continue to be effective over very long periods of time. A fundamental issue associated with development of long term monitoring strategies is the ability to test the new LTM paradigm without doing years of monitoring. SRNL, LBNL and the Advanced Simulation Capability for Environmental Management (ASCEM) project are using over fifty years of contaminant-monitoring data, available at the SRNL F-Area field site, to establish a three-dimensional (3-D) model and "virtual testbed" which can be used to evaluate the effectiveness of the long-term monitoring and engineered treatment strategies.



(a)1966 (b)1991 (c)2050

(d)1966 (b)1991 (c)2050

-The simulated evolution of (a - c) low-pH plume (pH> 4) and (d - f) uranium plume (concentration>1x10-6 mol/L).
-The sky blue region is the low permeable Tan Clay Confining Zone, which separates the upper and lower aquifers.
-Vertical exaggeration = 15X.

Pacific Northwest
National Laboratory

In 2015, Pacific Northwest National Laboratory led several critical projects to address the environmental risks of technetium, iodine and uranium. The PNNL contributions have generated improved frameworks for monitoring the environmental impact of these hazardous substances. These improvements have also led to the development of effective solutions for characterizing, remediating, monitoring, and predicting the fate and transport of subsurface contamination.

Microbial Reduction of Technetium-99

Critical to the remediation of subsurface contaminants is the development of an understanding of speciation (chemistry) and biogeochemistry that controls fate and transport. Through supplementation with different carbon sources, PNNL investigated the potential to stimulate reduction of technetium 99. The understanding of microbial processes provides critical input to develop strategies for remediation of contaminants in place, which reduces the overall cost of cleanup.

In addition, PNNL has shown that microbes can transform mixtures of contaminants - including technetium 99, uranium, iodine 129, and nitrate - when provided with various carbon and electron sources. Results from these studies are important, because they demonstrate the potential for bioremediation of contaminant mixtures in the subsurface.

Pump and Treat Performance Optimization

In addition to remediation technologies for the vadose zone, PNNL is developing solutions and approaches for groundwater treatment. A common approach for contaminant removal is conducted by pump-and-treat (P&T) systems, which are effective when operated at maximum efficiency. The Hanford Site 200 West P&T system includes a novel bioreactor that relies on a microbial community to treat carbon tetrachloride, hexavalent chromium, and nitrate.

As a result of excessive biofilm material formation, the system had been losing efficiency. PNNL applied molecular tools to characterize the microbial community and nutrients.

Changes were made to optimize performance of the system, allowing for uninterrupted operation and more efficient contaminant removal.

PNNL's 200-West P&T Facility (*left*)

Pacific Northwest
National Laboratory

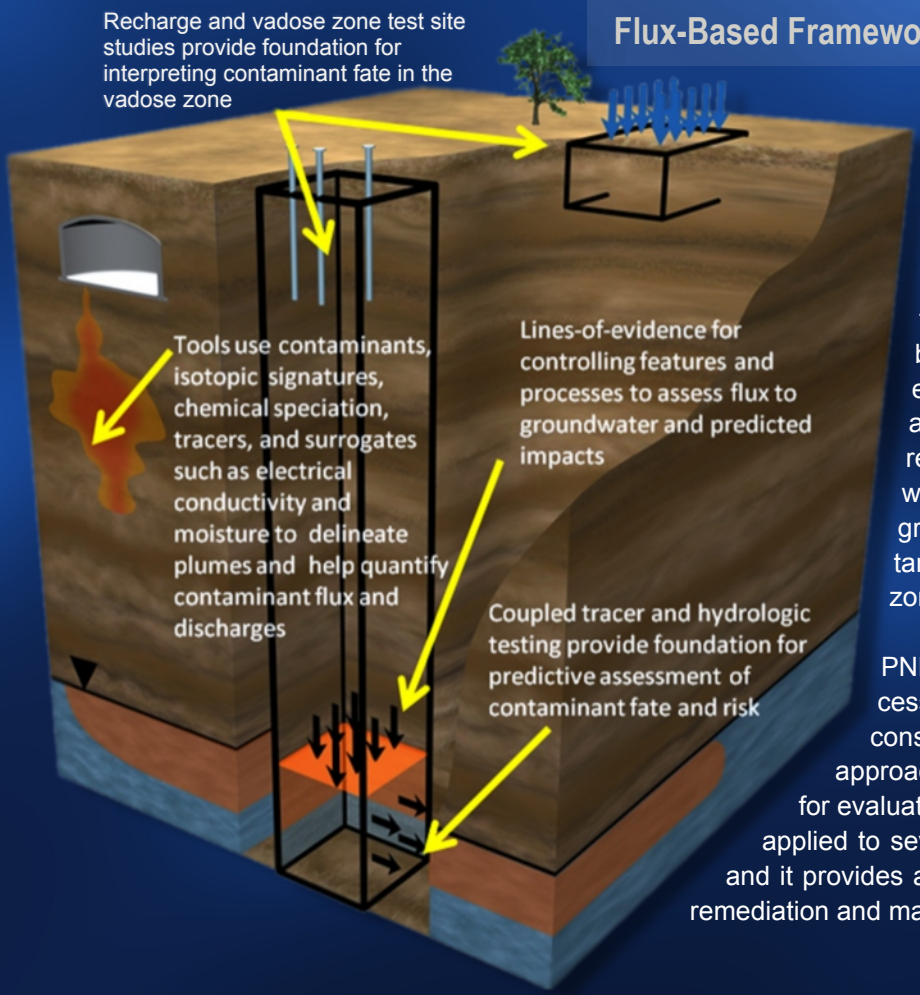
Exit Strategy for Pump and Treat Systems

Although P&T systems are effective at removing contaminant mass, they require adjustment and optimization - and eventually reach a point of diminishing return. PNNL gathered information on P&T systems, and then developed a structured approach for optimizing system performance and determining when it is appropriate to transition to other remedy approaches. Case studies at the Idaho National Laboratory Test Area North; the Fernald Site in Ohio; DoD sites in California, Utah, and Nebraska; and EPA Superfund sites in California, Nebraska, New Jersey, and Washington State were included.

The effort was executed in collaboration with the U.S. Army Corps of Engineers, with input from the EPA and other branches of the DoD - as well as DOE reviewers. The exit strategy is being highlighted by several EPA publications, because it provides a technical foundation for P&T optimization or transition to more sustainable cost-effective passive solutions.

Fluidized Bed Bioreactor at PNNL's 200-W P&T Facility (*right*)

Flux-Based Framework in Support of Vadose Zone Remediation



Systems-based approaches are useful for transitioning remedies from active to passive approaches, such as monitored natural attenuation (MNA). A technical basis for MNA did not exist for the vadose zone, but several different attenuation mechanisms were recognized. Contaminant transport through the vadose zone, beneath aqueous waste disposal sites, is affected by; 1) attenuation caused by unsaturated flow, and 2) attenuation caused by biogeochemical reactions and/or physical/chemical interaction with sediments. Mixing processes with the groundwater are also important for estimating contaminant concentrations resulting from vadose zone contaminant flux.

PNNL used understanding of these attenuation processes to develop a structured approach to enable consideration for MNA in the vadose zone. The approach provides guidance, based on EPA protocols for evaluating MNA. The framework has been successfully applied to several contamination issues at the Hanford Site, and it provides an effective means for addressing vadose zone remediation and management.

Oak Ridge
National Laboratory

Dating back to the 1950s, the DOE's Oak Ridge Reservation used large amounts of mercury in its processing facilities. During peak usage years from 1950 through 1963, approximately 11 million kg of mercury was processed, of which about 3% was released into the surrounding environment. Remediation efforts from the 1980s onward have helped greatly, but elevated levels still exist in infrastructure, water and soil.

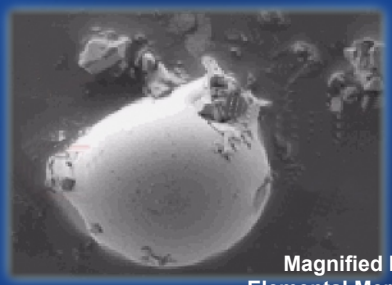
Recently, Oak Ridge National Laboratory has conducted research to improve mapping of mercury sources near buildings at the Y-12 National Security Complex, developed methods for in situ stabilization of mercury in soil, and identified thermodynamic parameters for mercury modeling. It is also helping Oak Ridge site managers to implement ORR's mercury remediation strategy; ORNL is well-positioned to translate the fundamental mercury biogeochemistry and mercury methylation discoveries being supported by DOE's Office of Science to practical solutions for mercury mitigation, such as water chemistry manipulation, stream bank stabilization, and aquatic species management. ORNL continues to be a significant contributor to worldwide mercury research, frequently sharing knowledge and case studies with experts from industry, academia, and other agencies. The laboratory also actively participates in EM's Minority Serving Institutions Partnership Program and has hosted numerous faculty and student interns engaged in mercury research.

Formation of Soluble Mercury Oxide Coatings: Transformation of Elemental Mercury in Soils

This project is focused on developing a better understanding of the transformation of elemental mercury (Hg(0)) that is lost to the subsurface. Characterization of the coatings observed on elemental mercury beads that have been recovered in core samples indicates that contaminant mobility may be underestimated - due to formation of different mercury species in the ground.

Laboratory studies were conducted to understand how Hg(0) beads are transformed through exposure to soils and mineral assemblages (i.e., manganese and iron oxides, clay, and silicates). By investigating the solid-phase oxidation of Hg(0) beads, ORNL was the first to observe the formation of mercury oxide (HgO) on the surface of the Hg(0) beads, primarily due to exposure to manganese oxides.

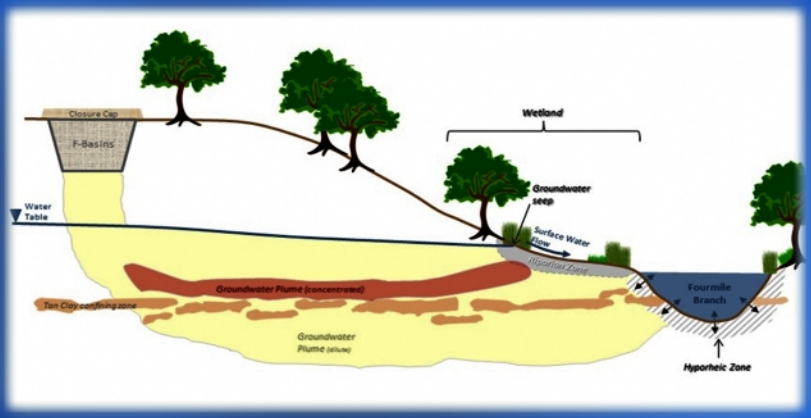
The formation of HgO on Hg(0) could substantially increase Hg(II) mobility, because HgO is three orders of magnitude more soluble than Hg(0) and has a high rate of dissolution. The rate at which Hg distributes through the environment may be greatly underestimated, if the formation of soluble HgO coatings is not considered at Hg(0) contaminated sites.



Magnified Bead of Elemental Mercury with a Mercury Oxide Coating

Testbed Initiatives

Innovative technologies offer the potential to improve operational performance, accelerate schedules, and reduce costs for contaminated soil and groundwater remediation. A challenge that often limits the acceptance of new technologies is the lack of information about their performance in real-world conditions, especially the radiological and chemical conditions that exist at many DOE sites. Testbeds, which will support replicable testing of innovative technologies under "real world" physical and chemical conditions, are being established to address this limitation. In addition, this devised side-by-side testing of technologies allows for more effective evaluation of overall technology performance. Along with the DOE laboratories, private industry and academia can demonstrate cutting edge technology and obtain the necessary performance data, so that innovative solutions can be more readily incorporated into DOE-EM operations.



SRNL F-Area Testbed

SRNL has developed a testbed at the SRS F-Area, where an acidic plume containing a wide variety of radionuclides and dissolved metals (strontium 90, uranium isotopes, iodine 129, tritium, and nitrate) is being treated with a passive treatment system that uses a funnel-and-gate with in situ treatment zones. To date, more than twenty innovative characterization and treatment technologies have been evaluated at this site.

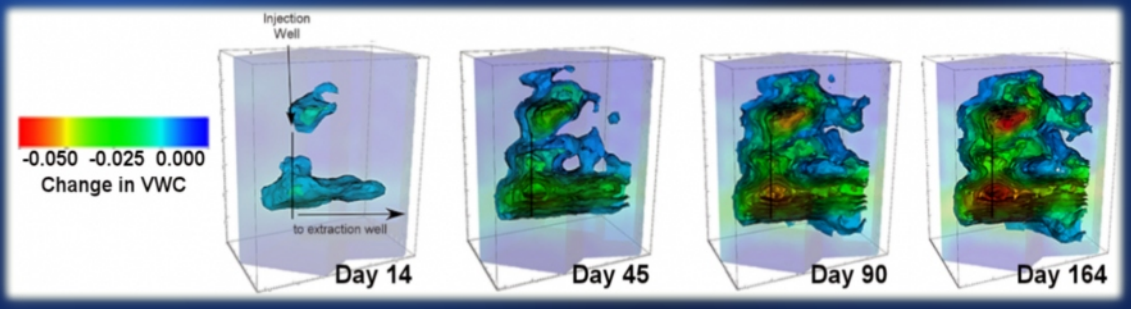
Anionic contaminants, such as technetium 99 and iodine 129, remain a significant remedial challenge for DOE-EM. The F-area seepline, which attenuates anions due to naturally reducing conditions, is being characterized to develop a new testbed - to support evaluation of amendments for attenuation and long-term monitoring of anions.

East Fork Poplar Creek and Y-12 Facility Testbeds

Mercury poses a unique environmental hazard, because of its ability to transform and bioaccumulate as a neurotoxin in ecosystems. The East Fork Poplar Creek (EFPC) watershed, located at the DOE Oak Ridge Reservation and the Y-12 National Security Complex, serves as a testbed to investigate techniques that can control the flux of contaminants in soil and water - to protect surface water, groundwater, and ecological receptors. This testbed supports field testing of innovative mercury treatment, recovery, containment, and stabilization/immobilization techniques, as well as enhanced conceptual and numerical modeling.

Hanford Subsurface Remediation Testbed

The Hanford Central Plateau includes multiple co-mingled contaminants, including technetium 99, iodine 129, and uranium. These contaminants are present in large, dilute groundwater plumes, but a large portion of the subsurface inventory is present in the thick vadose zone - representing a potential long-term source of groundwater contamination. A key remediation development challenge is scaling potentially effective remediation processes for application in the vadose zone and for groundwater of the Central Plateau. These historic and ongoing efforts – which include a previous vadose zone test site, treatability tests and interim measures, and numerical modeling using high-performance computing - will provide an excellent foundation to use the Central Plateau as a testbed, with the aim of accelerating and enhancing remediation technology development in support of upcoming feasibility studies.



Desiccation Site Treatability Test Monitoring

Partnerships
& Outreach Initiatives

Whether top science and research universities, other DOE groups and Federal agencies, or international alliances, the DOE Office of Environmental Management continually fosters both well-established and newfound partnerships that advocate common goals and mutually-beneficial outcomes. The Office of Soil and Groundwater Remediation plays a critical role in sharing technical information and lessons learned across EM sites. Sharing of resources, innovations, information and leading personnel generates real-world, positive solutions and serves to enhance the DOE mission.

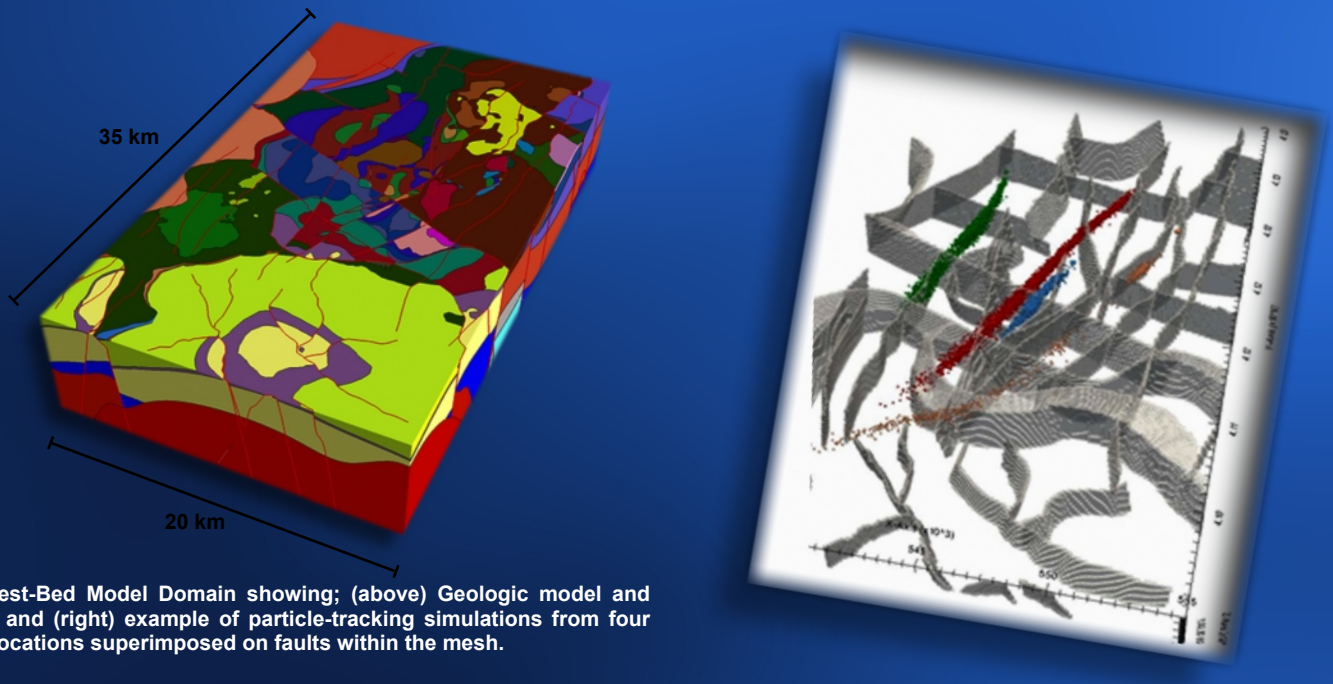
Federal Partners

Working with the Department of Defense and the Environmental Protection Agency, the DOE-EM established an interagency team, through the Federal Remediation Technologies Roundtable, to integrate and leverage fiscal and technical resources. This team is developing strategies that cover a range of environmental management issues – from facility closure and remediation, to better use of technology and tools, to risk management of environmental contamination. The nature of this interagency alliance allows for more timely communication, better collaboration, and more effective leveraging of resources.

In addition, DOE has a formal partnership with the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP), which are environmental research programs of the Department of Defense. The aim of this alliance is to harness the latest science and technology, improve the DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities. This collaborative partnership ensures two-way communication between the community that develops new science and technology and the organizations and agencies whose acceptance is critical to the ultimate implementation of innovative solutions.

Advanced Simulation Capability for Environmental Management (ASCEM)

Created to address waste storage and environmental cleanup, ASCEM (http://esd1.lbl.gov/research/projects/ascem/) is a DOE-EM program that aims to develop next-generation, science-based reactive flow-and-transport simulation capabilities within a high-performance computing framework. By focusing on site applications, ASCEM is modeling radionuclide transport in the subsurface at a number of DOE sites. For example, at the Nevada National Security Site Underground Test Area (UGTA), in Pahute Mesa, where 85 deep underground nuclear tests occurred, ASCEM models will be used to define use-restriction boundaries and develop a public-protective groundwater-monitoring network.

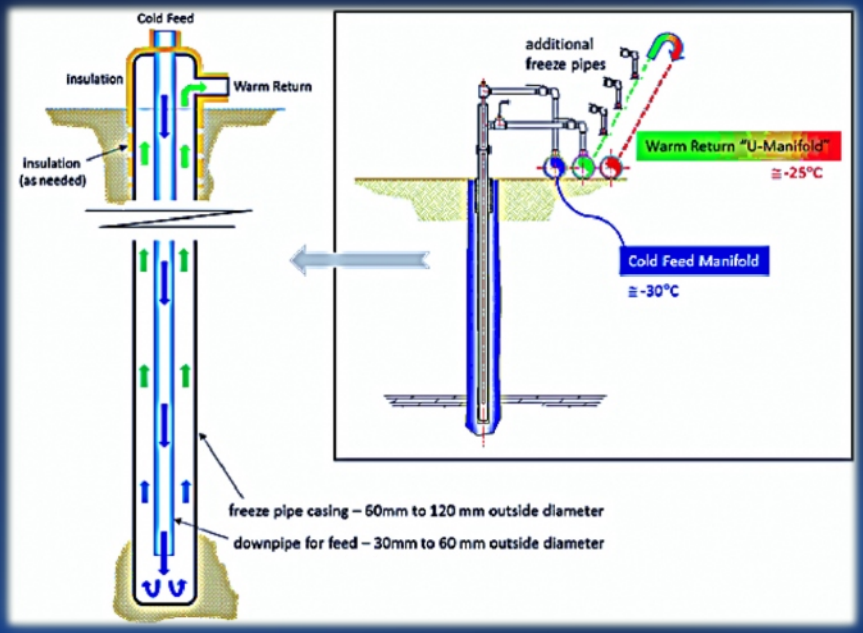


NNSS Test-Bed Model Domain showing; (above) Geologic model and domain, and (right) example of particle-tracking simulations from four source locations superimposed on faults within the mesh.

Partnerships
& Outreach Initiatives

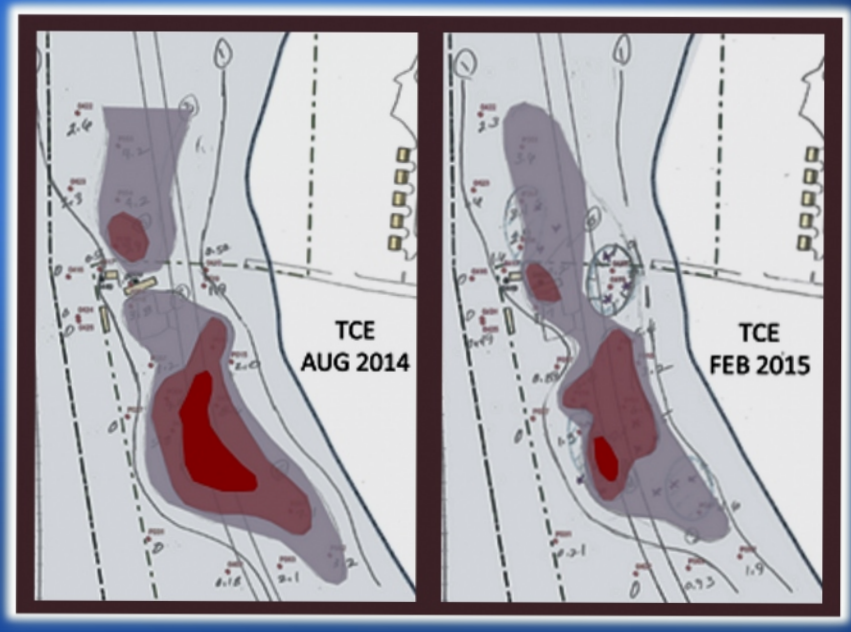
Japan

The ramifications of Japan's Fukushima incident are well known. Interfacing with EM and the DOE Office of Nuclear Energy (NE), SRNL and PNNL have hosted and attended numerous technical exchanges and workshops with groups at all levels – from the Japanese Parliament to the Japanese Atomic Energy Agency. SRNL and PNNL staff have participated on expert teams, providing advice on best practices and lessons learned. The joint effort has been both positive and beneficial, and DOE-EM's contributions have been invaluable to the international community.



Mound Site, Ohio

Knowledge transfer and knowledge sharing of technological successes is a cornerstone strategy of the EM-12. At Miamisburg, Ohio's Mound Site landfill, groundwater remediation guidance has been provided to the DOE Office of Legacy Management (DOE-LM), the EPA, the Ohio EPA, and others to assist with and complete the cleanup. EM-12 provided assistance with the design and implementation of a passive enhanced bioremediation strategy that can easily be transitioned to monitored natural attenuation (MNA). This directed assistance will help accelerate the progress, by converting the active P&T remedy into a passive attenuation-based remedy. Not only is this solution a better, forward-moving strategy, but also it is a more cost-effective process.



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