Innovative Research and Technology Development for Site Characterization

Deanne Rider
SERDP & ESTCP

DoD's Environmental Technology Programs

SERDP DOD • EPA • DOE

ESTCP

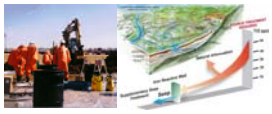
Science and Technology

Demonstration / Validation

Environmental Drivers

Reduction of Current and Future Liability

Contamination from Past Practices



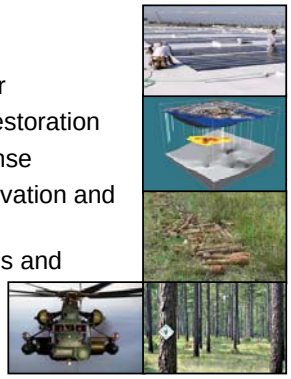
- Groundwater, Soils and Sediments
- Large UXO Liability
- Emerging Contaminants

Pollution Prevention to Control Life Cycle Costs

- Elimination of Pollutants and Hazardous Materials in Manufacturing Maintenance and Operations
- Achieve Compliance Through Pollution Prevention

Program Areas

1. Energy and Water
2. Environmental Restoration
3. Munitions Response
4. Resource Conservation and Climate Change
5. Weapons Systems and Platforms



Overview

- Focus has been on improved site characterization and monitoring for most difficult sites
- Also, improved characterization of relevant biotic and abiotic processes
- Goal of the presentation is to provide an overview of the projects currently underway

Overview

- SERDP Solicitations
  - FY13: Improved Assessment and Optimization of Remediation Technologies for Treatment of Chlorinated Solvent-Contaminated Groundwater
  - FY14: Improved Remediation Operation Through Fine Scale Delineation of Contaminated Subsurface Environments
  - FY15: Improved Understanding of Long Term Natural Attenuation Processes on Contaminants in Groundwater
- ESTCP Projects
- Upcoming Efforts

FY2013 SERDP SON

Improved Assessment and Optimization of Remediation Technologies for Treatment of Chlorinated Solvent-Contaminated Groundwater

- To improve the understanding of how to assess and optimize treatment of complex contaminated groundwater plumes and to determine cost effectively the performance limitations of a remedial approach. Specific objectives include:
  - Determination of which parameters or processes may be measured to quickly determine the feasibility of a treatment approach.
  - Development of field measurements or methodologies that provide predictive capability of performance to reduce the uncertainty associated with long-term performance so that decisions can be made early in the remedial process to avoid years of suboptimal operation.
  - Development of field measurements or methodologies that provide data to optimize treatment if current operations are not expected to meet performance objectives.
  - Development of assessment procedures and methodologies that aid in the decision to discontinue operation of a technology and implement an alternative technology.

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ER-2308: Practical Assessment and Optimization of Redox-Based Groundwater Remediation Technologies

Performers: Paul Tratnyek and Rick Johnson (OHSU/IEH)

Technology Focus

- Assessment and optimization of redox for in situ remediation

Research Objective

- Develop methods for characterization of in situ redox conditions that explain or predict remedial performance.

Progress and Results

- Methods selected, validated and calibrated in batch experiments; Implementation with push-pull tests underway.

Technology Transition

- Test deployment at field sites with various collaborators.

TOC Art for Fan et al. 2015

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ER-2309: Development of Field Methodology to Rapidly Detect Dehalococcoides and Dehalobacter Spp. Genes On-Site

Performers: Alison Cupples, Syed Hashsham, Robert Stedtfeld (Michigan State University), Paul Hatzinger (CB&I Federal Services)

Technology Focus

- Develop molecular methods to quantify dechlorinating bacteria from contaminated sites

Research Objectives

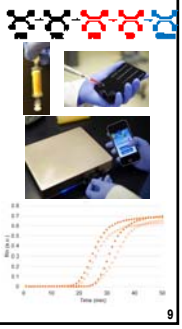
- Develop rapid, sensitive and specific methods to accurately quantify *Dehalococcoides & Dehalobacter* spp. genes from groundwater samples without DNA extraction

Project Progress and Results

- Loop mediated isothermal amplification (LAMP) assays have been designed and validated for key reductive dehalogenase genes. The assays were successful for both extracted DNA and cell cultures (without DNA extraction). The assays produce comparable results to and are faster than current methods (qPCR).

Technology Transition

- The results will be published in peer reviews journals, presented at conferences and shared with those involved in chlorinated solvent bioremediation.



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ER-2310: A Practical Approach for Remediation Performance Assessment and Optimization at DNAPL Sites for Early Identification and Correction of Problems

Performers: Jack Parker (University of Tennessee); Ungtae Kim (Cleveland St Uni i) Bob Borden (N h Car li St e Uni i) Ji Gallig

Research Objectives

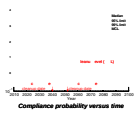
- Develop computational tools that remediation contractors can use routinely to assess and optimize remediation systems and monitoring of DNAPL contaminated sites.

Project Progress and Results

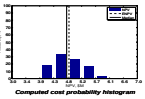
- Cost and performance models for enhanced bioremediation, thermal source treatment, and chemical oxidation have been developed and coupled with calibration and stochastic optimization methods to enable iterative performance assessment and optimization. Field sites have been identified for testing and demonstration.

Technology Transition

- Successful transition to practical application will require development of a user friendly interface, effective training tools, and getting information of the benefits of the program to potential users.



Compliance probability versus time



Computed cost probability histogram

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ER-2311: Development of an Integrated Field Test/Modeling Protocol for Efficient In Situ Bioremediation Design and Performance Uncertainty Assessment

Performers: Linda Abriola, Kurt Pennell, Natalie Capiro, Eric Miller (Tufts University), Liyang Chu (Nobis Engineering), John Christ (US Air Force Academy)

Technology Focus

- Combine field testing with experimental and modeling results

Research Objectives

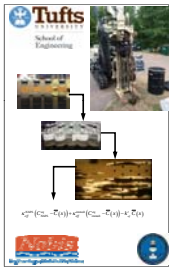
- Develop and demonstrate a remedial design and performance assessment protocol that integrates field characterization, laboratory treatability testing, down-hole treatability testing (DHT), and mathematical modeling to efficiently assess remediation technology suitability

Project Progress and Results

- Source zone and plume characterization (Phase I field work) is complete. Site is likely suitable for bioremediation.

Technology Transition

- Disseminate research findings in refereed journal publications, presentations at remediation conferences, participation in ITRC teams and training activities, develop web-based training tools and modules for inclusion in commercial software packages



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ER-2312: Advanced Environmental Molecular Diagnostics to Assess, Monitor, and Predict Microbial Activities at Complicated Chlorinated Solvent Sites

Performers: Frank Löffler (University of Tennessee), Karuna Chourey, Robert Hettich (Oak Ridge National Laboratory)

Technology Focus

- Design of high-throughput quantitative PCR and proteomics tools to advance bioremediation treatment and contaminated site monitoring.

Research Objectives

- Advance understanding of the microbiology contributing to chlorinated solvent degradation, and apply the new knowledge and tools to support contaminated site decision-making, to increase bioremediation efficacy, to improve monitoring regimes, and to ultimately reduce cost.

Project Progress and Results

- A high-throughput qPCR array plate (RD-qChip v. 1.0) and proteomics workflows were designed and validated for identifying and monitoring dechlorination biomarkers in laboratory systems and groundwater.

Technology Transition

- Expand the reductive dechlorination quantitative PCR array plate or RD-qChip to include a broader suite of biomarkers and develop a targeted proteomics approach for quantitative applications. RD-qChip technology adopted by Microbial Insights, Inc.

Work in progress

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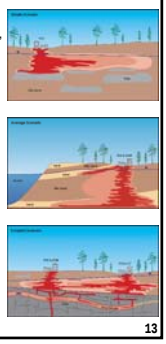
ER-2313: Forecasting Effective Site Characterization and Early Remediation Performance

Performers: Michael Kavanaugh, Dave Reynolds (Geosyntec Consultants), Bernie Kueper, Kevin Mumford (Queens University), Peter Kitanidis (Stanford University), Dave Major (Savron)



Technology Focus
- Improving remediation cost-effectiveness

Research Objectives
- Develop a decision framework that reduces the total cost of investigation and remediation to achieve remedial goals, and maximizes the likelihood of successful remedial strategies

Project Progress and Results
- Project has developed three realistic, highly detailed virtual sites through numerical simulation that are being investigated by leading industry practitioners using a variety of common and innovative tools and approaches

Technology Transition
- Development of a training system for site managers and decision makers to improve skills in understanding the costs and benefits of site investigation and remedy selection and performance

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FY2014 SERDP SON
Improved Remediation Operation Through Fine Scale Delineation of Contaminated Subsurface Environments

- Improve the operation of remedial technologies through fine-scale delineation of contaminated subsurface environments. Clear linkage between the proposed techniques and resulting data interpretation, and contaminated site management decisions should be demonstrated with the recognition that many sites are likely to have already completed initial characterization efforts, but site challenges necessitate additional investigation. Specific objectives include:
  - Improved delineation of contaminant distribution after initial characterization activities have been conducted and while the remedial action-operation phase is in progress.
  - Improved measurements of key biogeochemical processes at relevant scales.
  - Improved resolution of key hydrogeological features.

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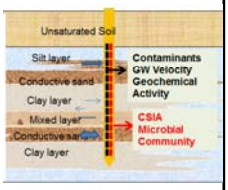
ER-2419: High Resolution Delineation of Contaminant Concentrations, Biogeochemical Processes, and Microbial Communities in Saturated Subsurface Environments

Performers: W. Andrew Jackson, Stephen Morse (TTU), Paul Hatzinger, Paul van Groos, David Lippincott (CB&I)



Technology Focus
- *Development of a High Resolution Passive Profiler (HRPP) as a fine-scale delineation tool for the saturated subsurface.*

Demonstration Site
- *Identify the demonstration site location including state*

Demonstration Objectives
- *Delineate contaminant concentration, groundwater velocity, microbial population and CSIA analysis at 10cm resolution.*

Project Progress and Results
- *HRPP design structurally valid; Microbial profile using HRPP similar to traditional samplers, Equilibration ~3 weeks, Confirmed method for equilibration determination, Observed relationship between mass transfer coefficient and ground water velocity.*

Implementation Outlook
- *Demonstrate at mesoscale in complex systems*

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ER-2421: Investigating the Sensitivity of Emerging Geophysical Technologies to Immobile Porosity and Isolated DNAPL and Dissolved/Sorbed VOC Mass in Fractured Media

Performers: Lee Slater, (Rutgers University), Fred Day-Lewis (USGS), Beth Parker (University of Guelph)

Technology Focus
- Develop emerging geophysical technologies (nuclear magnetic resonance [NMR] and complex resistivity [CR]) for non-invasive determination of immobile porosity, permeability and contaminant mass (within the immobile porosity) of fractured rock

Demonstration Sites
- [1] Naval Air Warfare Center (NJ); [2] Santa Susanna Field Laboratory (CA); [3] Pease International Tradeport (NH); Hydrite,(WI)

Demonstration Objectives
- Quantitative non-invasive geophysical characterization of rock properties controlling contaminant mass storage in fractured rock; evaluated against direct measurements on cores

Project Progress and Results
- Conducted field NMR and CR logging at 2 of 4 field sites
- Developed laboratory protocol for comprehensive rock core measurements

Implementation Outlook
- Identify implementation issues, current or planned end-user coordination, and next steps

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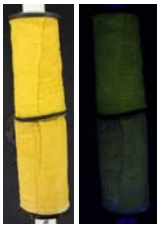
ER-2420: A High Resolution Passive Flux Meter Approach Based on Colorimetric Responses

Performers: Michael D. Annable, Michael C. Brooks, Kirk Hatfield (University of Florida)



Technology Focus
- Develop a Colorimetric Passive Flux Meter

Demonstration Site
- Looking for Field application site (perhaps NAS Jacksonville, Florida.

Demonstration Objectives
- Develop and field test a new PFM based on colorimetric measurements.

Project Progress and Results
- Dye selection is underway
- Conducted preliminary lab testing

Implementation Outlook
- Primary challenge is to find a day and sorbent suitable for slow groundwater flow rates.

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FY2015 SERDP SON:
Improved Understanding of Long Term Natural Attenuation Processes on Contaminants in Groundwater

- Quantify the long term impacts of natural processes on contaminants in groundwater and estimate the resulting contaminant attenuation rate. Specific objectives include:
  - Develop and validate field-scale methods for estimating important parameters such as back diffusion, sorption, and degradation (both biotic and abiotic) of contaminants.
  - Develop a greater understanding of the effect of physical, chemical, and biological processes and their associated rates on contaminant behavior in lower mobility zones to support improved predictive modeling of plume behavior.
  - Develop tools to estimate the natural contaminant assimilative capacity of an aquifer.
  - Develop mathematical and simulation estimation methodologies for these important natural processes that can be incorporated into commonly-used models to predict contaminant behavior in groundwater.
  - Develop cost-effective diagnostic methods to determine whether natural attenuation processes are still occurring.
  - Develop networks of relatively inexpensive sensors for key contaminant attenuation rate indicators that are capable of measuring parameters associated with each of the contaminant destruction process.

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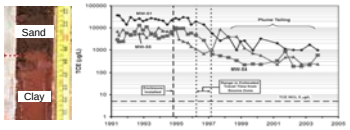
Estimating Mobile-Immobile Mass Transfer Parameters using Direct Push Tools (ER-2529)

- **Principal Investigator**: Robert Borden (Solutions-IES)
- **Objective**: Develop methods to better characterize and model the mass transfer of contaminants between higher and lower mobility zones and its impact on the long-term release of contaminants in groundwater.



Field study of aquifer recovery following source removal
(Chapman and Parker, WRR, 2005)

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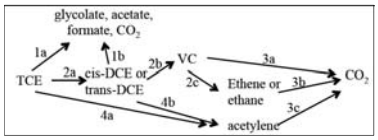
Biogeochemical Processes that Control Natural Attenuation of Trichloroethylene in Low Permeability Zones (ER-2530)

- **Principal Investigator**: Charles Werth (University of Texas at Austin)
- **Objective**: Quantify the biotic and abiotic attenuation mechanisms that impact the fate of TCE within and at the boundaries of LPZs comprised of clays and silts, and incorporate these processes into a computationally efficient model that can be used to directly address key questions regarding natural attenuation time scales and cleanup at TCE-impacted sites.



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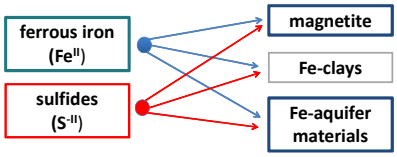
Biologically Mediated Abiotic Degradation of Chlorinated Ethenes: A New Conceptual Framework (ER-2532)

- **Principal Investigator**: Michelle Scherer (University of Iowa)
- **Objective**: Apply a new conceptual framework based on solid-state mineral chemistry to understand biologically mediated abiotic degradation (BMAD) of PCE and TCE by magnetite, iron (Fe) sulfides, and Fe-bearing clays.



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A Field Method to Quantify Chlorinated Solvent Diffusion, Sorption, Abiotic and Biotic Degradation in Low Permeability Zones (ER-2533)

- **Principal Investigator**: Richelle Allen-King (University at Buffalo, The State University of New York)
- **Objective**: Develop and test a field method capable of concurrently quantifying site-specific CVOC diffusion and degradation rates and sorption coefficients in low-permeability zones.

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NMR-Based Sensors for In Situ Monitoring of Changes in Groundwater Chemistry (ER-2534)

- **Principal Investigator**: Julie Konzuk (Geosyntec Consultants)
- **SEED Effort:** 1-year proof of concept
- **Objective**: Develop novel in situ sensors based on nuclear magnetic resonance (NMR) capable of providing improved temporal and spatial monitoring of natural attenuation processes in order to improve current monitoring practices and reduce long-term monitoring costs.

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Extending the Applicability of Compound-Specific Isotope Analysis to Low Concentrations of 1,4-Dioxane (ER-2535)

- **Principal Investigator:** Peter Bennett (Haley & Aldrich, Inc.)
- **SEED Effort:** 1-year proof of concept
- **Objective:** Develop a reliable method for performing compound-specific isotope analysis (CSIA) on low levels of 1,4-dioxane in groundwater; assess whether CSIA can be used to document the co-metabolic degradation of 1,4-dioxane; and assess the use of CSIA as a tool to evaluate the degradation of 1,4-dioxane and chlorinated volatile organic compounds (CVOCs) at DoD sites with different groundwater conditions.

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  - FY15: Improved Understanding of Long Term Natural Attenuation Processes on Contaminants in Groundwater
- ESTCP Projects
- Upcoming Efforts

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ESTCP Projects

- **ER-201121:** Direct Push Optical Screening Tool for High Resolution, Real-Time Mapping of Chlorinated Solvent DNAPL Architecture
- **ER-201208:** Validation of Stable Isotope Ratio Analysis to Document the Biodegradation and Natural Attenuation of RDX
- **ER-201212:** Cost-Effective and High-Resolution Subsurface Characterization Using Hydraulic Tomography
- **ER-201425:** Validation of Biotechnology for Quantifying the Abundance and Activity of Vinyl-Chloride Oxidizers in Contaminated Groundwater
- **ER-201426:** A Practical Approach for Modeling Matrix Diffusion Effects in REMChlor

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ER-201121: Direct Push Optical Screening Tool for High Resolution, Real-Time Mapping of Chlorinated Solvent DNAPL Architecture

Performers: Murray Einarson (Haley & Aldrich) (Dakota Technologies, University of Guelph, AMEC)

Technology Focus:
- A new laser-induced fluorescence (LIF) tool, called DYE-LIF, that can be used for real-time, high-resolution mapping of chlorinated solvent DNAPL source zones.

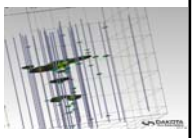
Demonstration Site: Former industrial site in Lowell, MA.

Demonstration Objectives:
- Compare DYE-LIF technology to high resolution soil sampling. High resolution soil sampling included laboratory analysis, hydrophobic dye shake tests, and PID screening.

Project Progress and Results
- Field demonstrations completed with Geoprobe and CPT rigs in 2013 and early 2014.
- DYE-LIF consistent with soil sampling in 41 of 42 samples above 0.7% DNAPL saturation.
- Final Report available in Fall 2015

Implementation Outlook
- Technology will be commercially available from Dakota Technologies.

CPT deployment of DYE-LIF



3D high-resolution of DNAPL source zone from field demonstration site

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ER-201208: Validation of Stable Isotope Ratio Analysis to Document the Biodegradation and Natural Attenuation of RDX

Performers: Paul Hatzinger (CB&I Federal Services); (University of Delaware; US Geological Survey, Naval Surface Warfare Center, China Lake, CA)

Technology Focus
- Compound Specific Isotope Analysis (CSIA) of C and N in RDX

Demonstration Site
- Naval Surface Warfare Center, Dahlgren, VA
- Umatilla Chemical Depot, OR

Demonstration Objectives
- Develop a CSIA approach to document RDX biodegradation in groundwater.

Project Progress and Results
- Current project results indicate that C and N stable isotope analysis can be an effective technique to measure biodegradation of RDX in field samples. (Anticipated Completion 2016)

Implementation Outlook
- Additional experimental work is ongoing to improve the precision of the CSIA method, but implementation outlook is excellent.

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ER-201212: Cost-Effective and High-Resolution Subsurface Characterization Using Hydraulic Tomography

Performers: Chin Man W. Mok (GSI Environmental), T.-C. J. Yeh (University of Arizona), and Walter Illman (University of Waterloo)

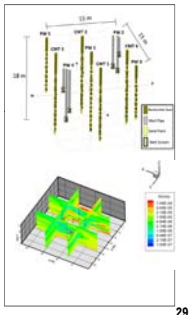
Technology Focus
- Hydraulic Tomography for delineating spatial distribution of hydraulic conductivity and storativity

Demonstration Sites
- (1) North Campus Research Site (NCRS), University of Waterloo
- (2) Air Force Plant 44 Site (AFP44), Tucson, Arizona

Demonstration Objectives
- Demonstrate HT is superior to conventional methods
- Illustrate that HT can be readily conducted at DoD sites using existing well network
- Develop guidance for HT field implementation and compare costs associated with HT and conventional methods

Project Progress and Results
- Completed data collection and HT analysis at NCRS (Anticipated Completion 2016)

Implementation Outlook
- Evaluate technical performance and cost comparison at NCRS
- Collect field test data at AFP44, perform HT analysis, evaluate technical performance and cost comparison.



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ER-201425: Validation of Biotechnology for Quantifying the Abundance and Activity of Vinyl-Chloride Oxidizers in Contaminated Groundwater

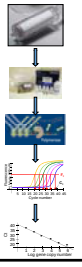
Performers: Timothy Mattes, Yi Liang, Xikun Liu, Dora Ogles (The University of Iowa)

Technology Focus
- qPCR and RT-qPCR methods for vinyl chloride-oxidizing bacteria

Demonstration Site
- NAS Oceana, VA; NSB Kings Bay, GA; MCRD Parris Island, SC

Demonstration Objectives
- Cost and time-effectiveness; usefulness to site managers; regulatory acceptance; correlation with VC degradation

Project Progress and Results
- Completed preliminary qPCR/RT-qPCR analysis of samples from NAS Oceana (2008-2014), NSB Kings Bays (2013) and MCRD Parris Island (2013-2014)
- Anticipated Completion Summer 2017



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ER-201426: A Practical Approach for Modeling Matrix Diffusion Effects in REMChlor

Performers: Ron Falta (Clemson), Chuck Newell (GSI Environmental), Shahla Farhat (GSI Environmental), Kira Lynch (US EPA Region 10), Dave Burden (US EPA NRMRL)

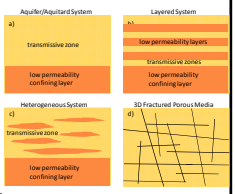
Technology Focus
- Development of a practical method for modeling matrix diffusion during contaminant transport in heterogeneous and fractured systems. Implementation in a new version of REMChlor

Demonstration Site
- Mathematical and computer software development

Demonstration Objectives
- Implement a fast, accurate, and easy to use model that accounts for matrix diffusion, along with the effects of source and plume remediation

Project Progress and Results
- Developed a new semi-analytical method for modeling matrix diffusion and tested with existing analytical models for diffusion into and out of aquitards. The results are very promising. (Anticipated Completion Summer 2017)

Implementation Outlook
- The next steps in this work are to implement the semi-analytical method for heterogeneous and fractured media, and then develop a new version of REMChlor that includes these capabilities: REMChlor-MD



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FY2016 SERDP SON
Measurement and Enhancement of Abiotic Attenuation Processes in Groundwater

- Develop methodologies that can improve our ability to accurately measure, quantify, and/or enhance natural abiotic transformations of contaminants in groundwater. Abiotic transformations that occur in transition zones such as the capillary fringe and deep vadose zone also are of interest. Specific objectives include the following:
  - Develop methodologies that estimate the contribution and impact of productive abiotic transformation processes on contaminant fate, transport, and toxicity under intrinsic or enhanced conditions.
  - Determine requirements for in situ enhancement of abiotic processes considering biogeochemical conditions, substrates or reactive minerals (i.e., magnetite and iron sulfides), assessing both when it is valuable to enhance abiotic processes and ultimately how to enhance these processes in a cost effective way.
  - Determine and manage short- and long-term uncertainties and risks associated with processes that can be realistically enhanced.

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ESTCP FY15 Solicitation
Innovative Technology Transfer Approaches

- Objective: To develop innovative technology transfer approaches.
  - Primary target audience are end users
  - Different communities will benefit from approaches targeted to their needs and manner of receiving information.
- Approaches may be applicable to a broad array of SERDP and ESTCP investment areas or narrowly focused.
- Approaches of interest include but are not limited to:
  - Short courses (either live or on-line); Videos; Webinars; Monographs; Updates to Standards, Drawings, and Regulations; Endorsements by Regulatory Bodies; Fact Sheets; Websites; and Workshops

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ESTCP FY15 Solicitation
Post-Remediation Performance Assessment

- Evaluate the long term performance and impacts of site restoration technologies
- Specific questions to address include:
  1. How long do remediation impacts persist?
  2. What technologies and site conditions are most likely to lead to long-term performance concerns?
- Specifically for groundwater sites, additional questions to address include:
  1. How do different groundwater quality parameters change over time?
  2. What mechanisms control long-term groundwater quality?
- Monitoring approaches can combine standard and innovative approaches; however, the focus is on the analysis of data and comparison to results collected at the completion of the initial demonstration period.

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