Thank you for signing in early

The webinar will begin promptly at 12:00 pm ET, 9:00 am PT

SERDP and ESTCP Webinar Series

- The webinar will begin promptly at 12:00 pm ET, 9:00 am PT
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    - (669) 900-6833 or (929) 205-6099
    - Required webinar ID: 216-674-424
- For questions or technical issues, please email serdp-estcp@noblis.org or call 571-372-6565

Advances in Managing Contaminated Groundwater Using High Resolution Site Characterization and Contaminant Mass Flux Reduction

October 24, 2019

Welcome and Introductions

Jennifer Nyman, Ph.D., P.E.
Webinar Facilitator

SERDP
DOD • EPA • DOE
ESTCP

Webinar Agenda

- **Webinar Logistics** (5 minutes)
  Dr. Jennifer Nyman, Geosyntec Consultants
- **Overview of SERDP and ESTCP** (5 minutes)
  Dr. Robin Nissan, SERDP and ESTCP
- **Cost-Effective and High-Resolution Subsurface Characterization Using Hydraulic Tomography** (25 minutes + Q&A)
  Dr. Bill Mok, GSI Environmental, Inc.
- **Contaminant Flux Reduction Barriers for Managing Difficult-to-Treat Source Zones in Unconsolidated Media** (25 minutes + Q&A)
  Ms. Poonam Kulkarni, GSI Environmental, Inc.
- **Final Q&A session**

In Case of Technical Difficulties

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- If material is not showing on your screen or if screen freezes
  - Key in Ctrl + F5 to do a hard refresh of your browser
- If connecting to computer audio
  - Click the arrow next to the “Join Audio” button
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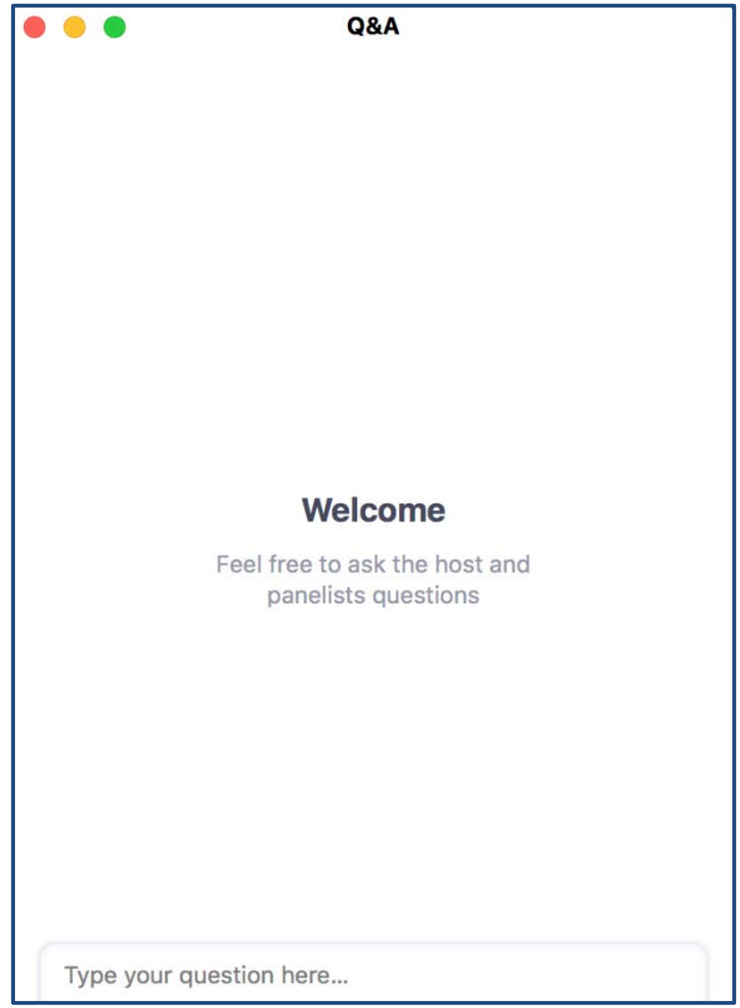
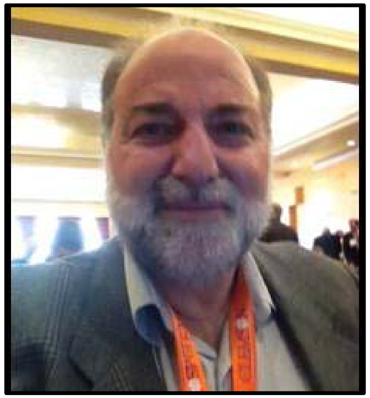
- Find the Q&A button on your control bar and type in your question(s)
- Make sure to add your organization name at the end of your question so that we can identify you during the Q&A sessions



SERDP and ESTCP Overview



Robin Nissan, Ph.D.
SERDP and ESTCP

SERDP DOD • EPA • DOE | ESTCP

SERDP

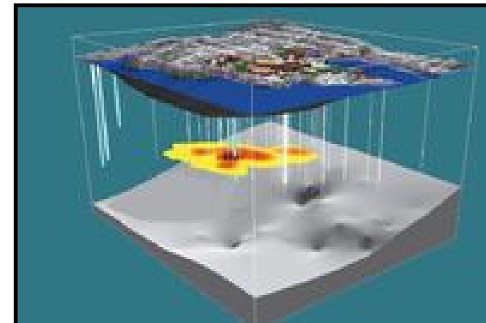
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management

ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance

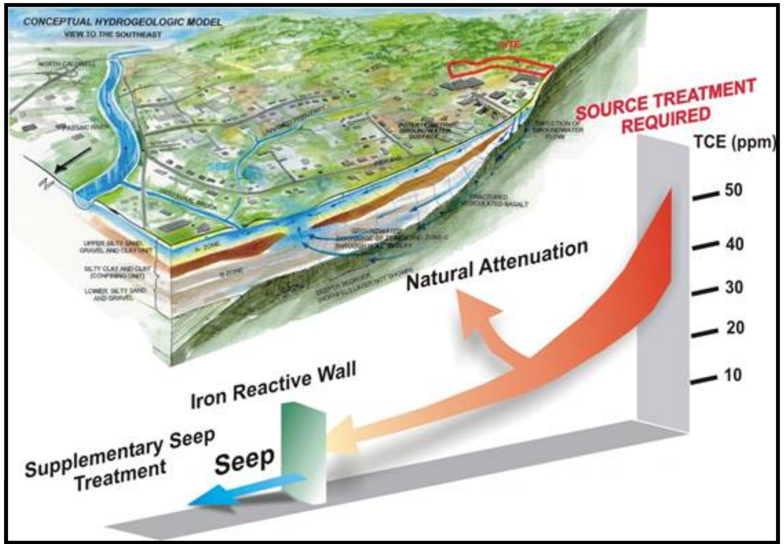
Program Areas

- Environmental Restoration
- Installation Energy and Water
- Munitions Response
- Resource Conservation and Resiliency
- Weapons Systems and Platforms



Environmental Restoration

- Major focus areas
  - Contaminated groundwater
  - Contaminants on ranges
  - Contaminated sediments
  - Wastewater treatment
  - Risk assessment



SERDP and ESTCP Webinar Series

Date	Topic
October 31, 2019	Developing and Demonstrating Non-Toxic and Sustainable Coating Systems for Military Platforms
November 7, 2019	Overview of SERDP and ESTCP Environmental Restoration PFAS Efforts
December 12, 2019	Monitoring and Remediating Groundwater Contaminated with Chlorinated Solvents

For upcoming webinars, please visit

http://serdp-estcp.org/Tools-and-Training/Webinar-Series

Save the Date

SERDP ◆ ESTCP
SYMPOSIUM

A three-day symposium showcasing the latest technologies that enhance DoD's mission through improved environmental and energy performance

December 3-5, 2019

Washington Marriott Wardman Park

Registration is open

Cost-Effective and High-Resolution Subsurface Characterization Using Hydraulic Tomography

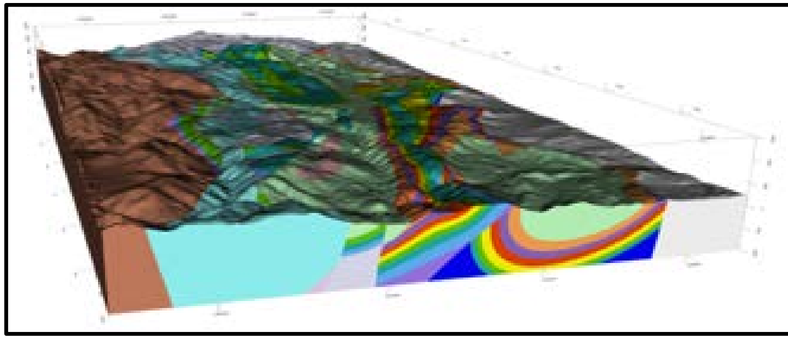
Chin Man W. Mok, Ph.D.
GSI Environmental Inc.

Agenda

- Project motivation, objective, approach
- Source-scale demonstration
- Facility-scale demonstration
- Applications
- Implementation guidance
- Conclusions
- Benefits to DoD
- Further advancements

Project Motivation

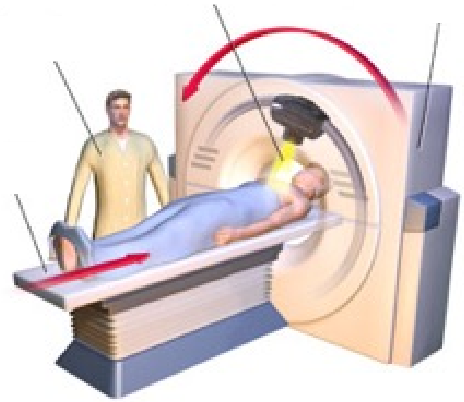
- Hydrogeologic heterogeneity dictates subsurface chemical fate and transport
  - High hydraulic conductivity (K): preferential pathways
  - Low K: potential residual sources
- High-resolution site characterization (HRSC) is critical for successful remediation
- Challenging by conventional techniques
  - Information: local, indirect
  - Interpretation: subjective, uncertain, inconsistent
  - Costs: expensive at high-resolution

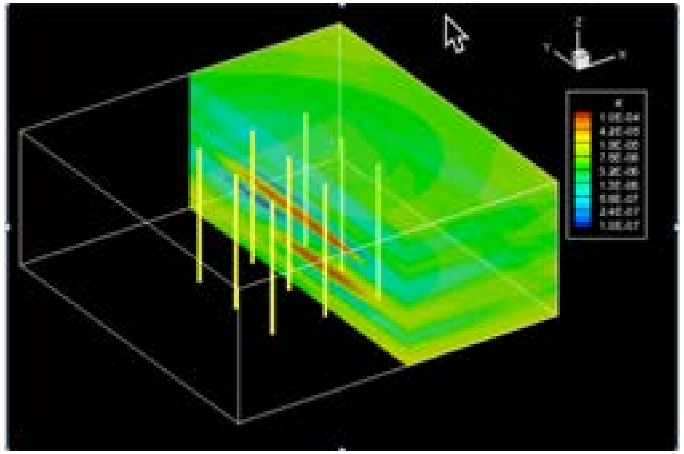



Project Objective and Approach

- Demonstrate that hydraulic tomography (HT) is cost-effective for delineating K spatially
  - Hydraulic subsurface scan
  - Consistent data analysis
- Demonstration at two scales
  - Source-scale
    - North Campus Research Site (NCRS) at University of Waterloo
  - Facility-scale
    - Air Force Plant 44 (AFP44) in Tucson, Arizona

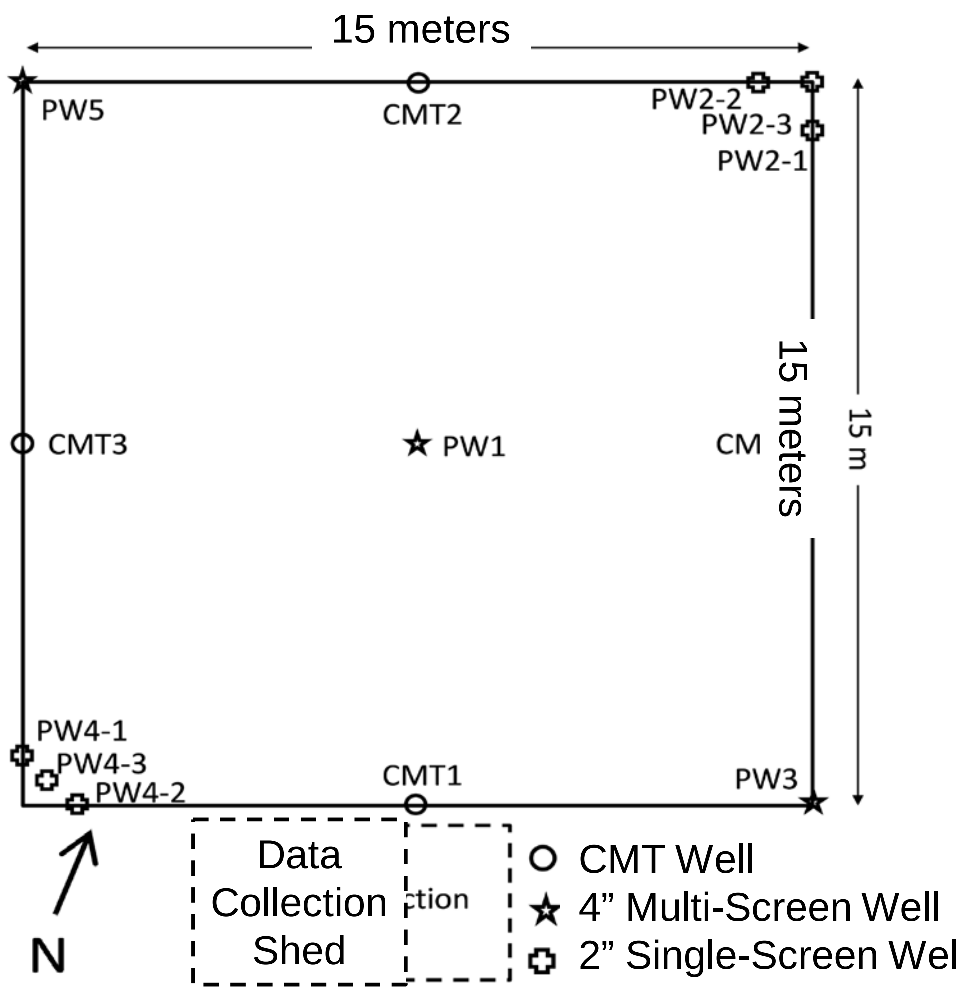
Computerized Axial Tomography Scan





Source-Scale Demonstration at NCRS

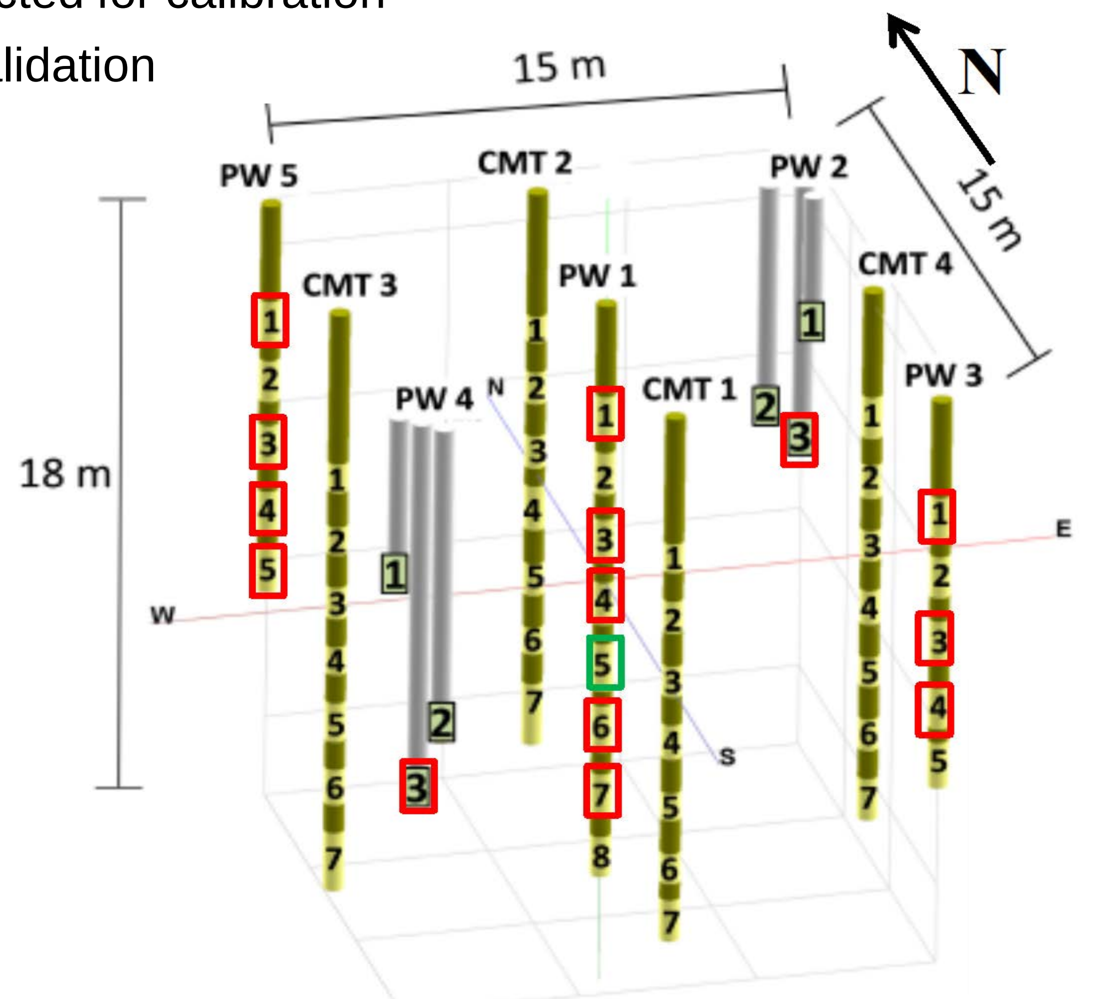
- 7.5 meter spacing
- 18 meter depth
- Multiple ports
  - Groundwater extraction
  - Water injection
  - Hydraulic monitoring
  - Sampling
- Pressure transducers in multiple ports



Port Configuration

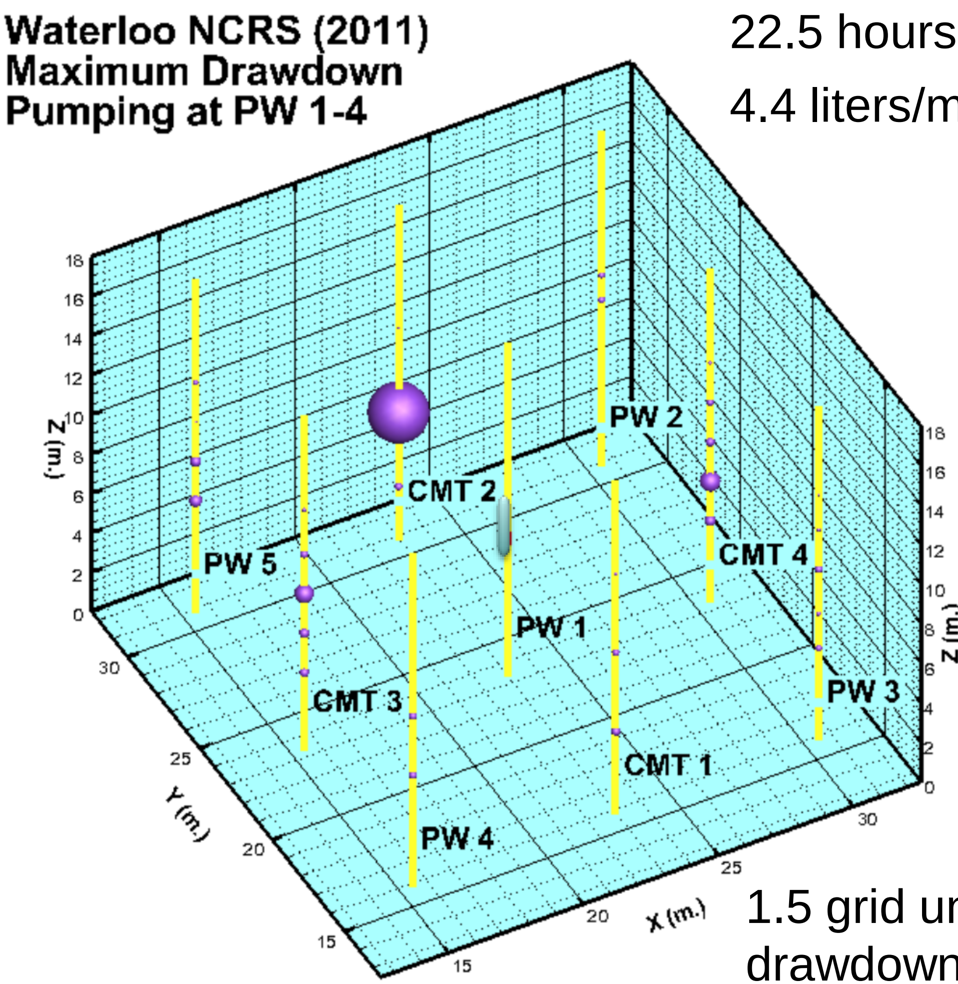
- Pumping/injection tests selected for calibration
- Pumping test selected for validation

- Bentonite seal
- Well pipe
- Sand pack
- Well screen



Drawdown Responses

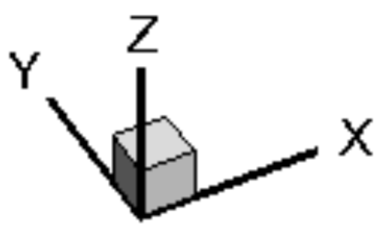
- 15 pumping or injection tests
- 4-27 hours duration



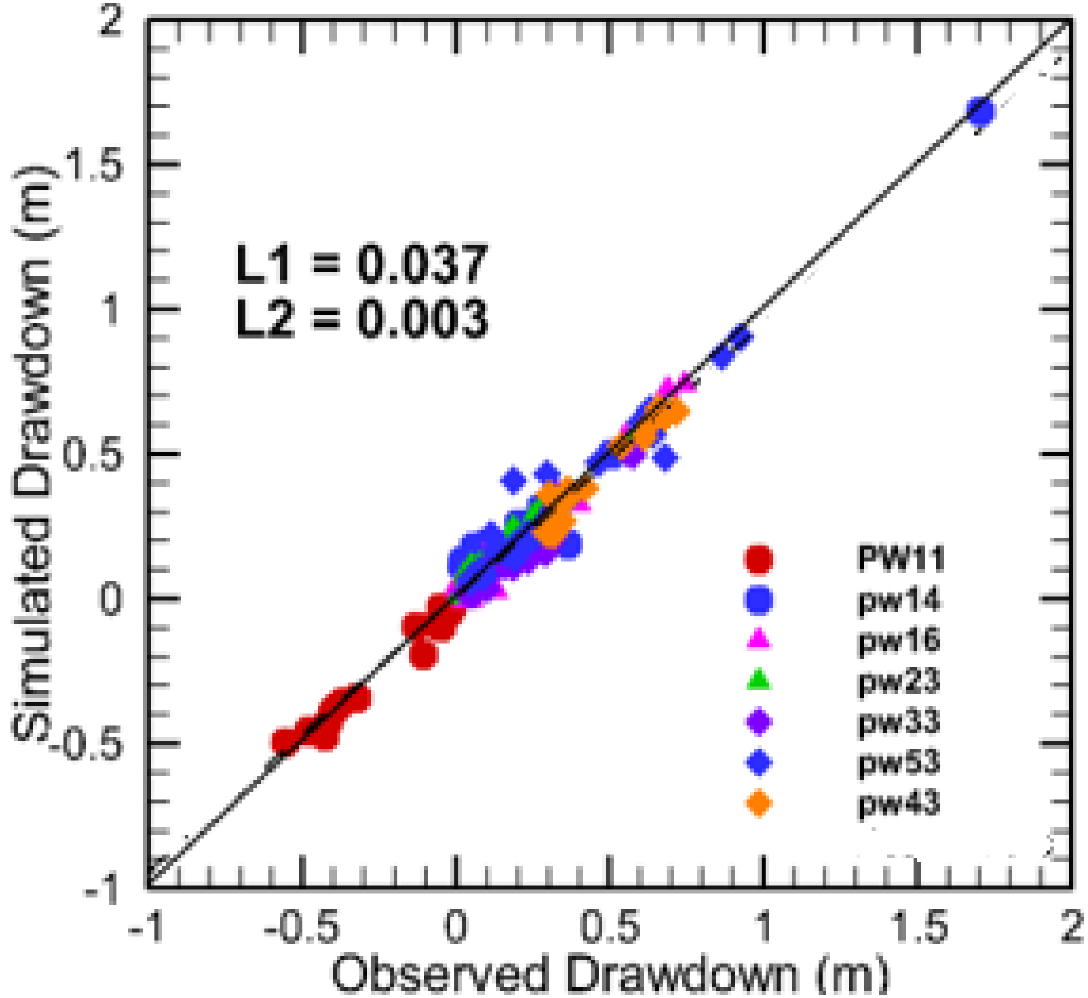
22.5 hours

4.4 liters/minute

1.5 grid unit/meter drawdown

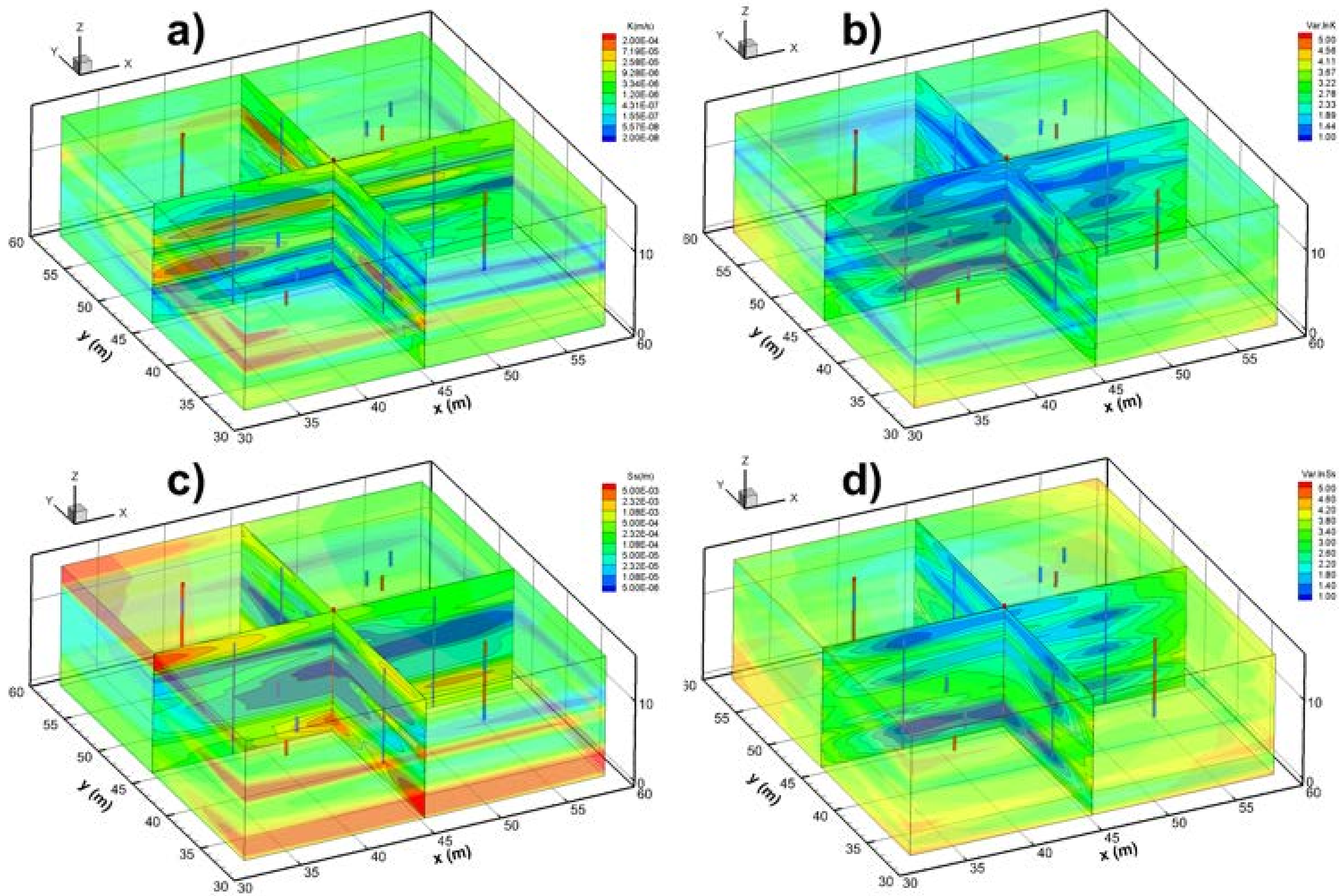


HT Calibration Performance



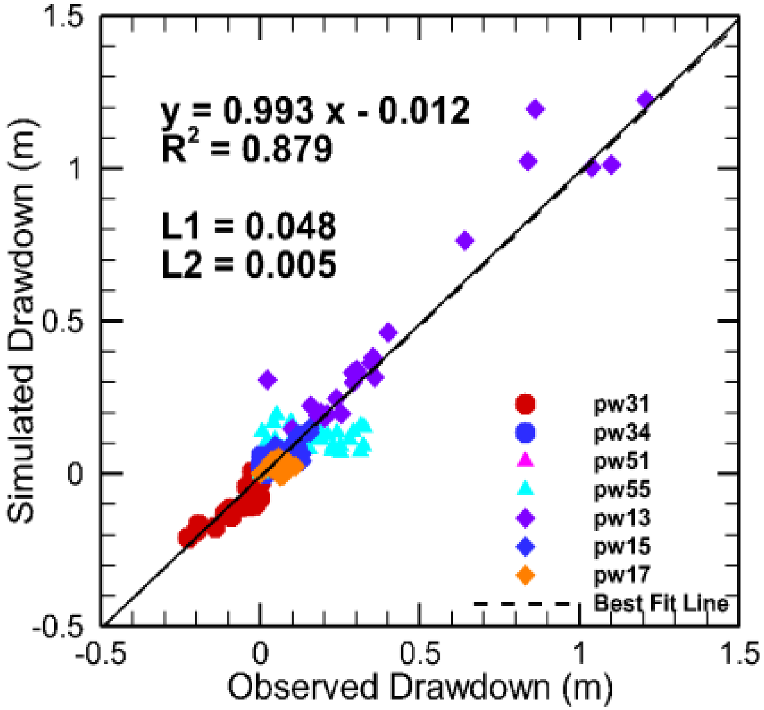
Delineated K and S_s Distributions

Associated Uncertainties

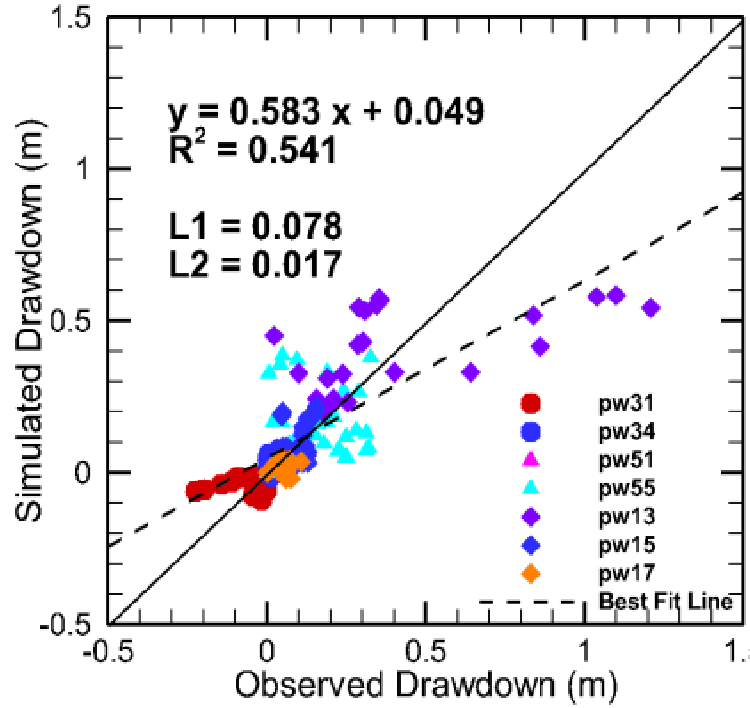


Note: Ss = specific storage

HT Validation: Hydraulic



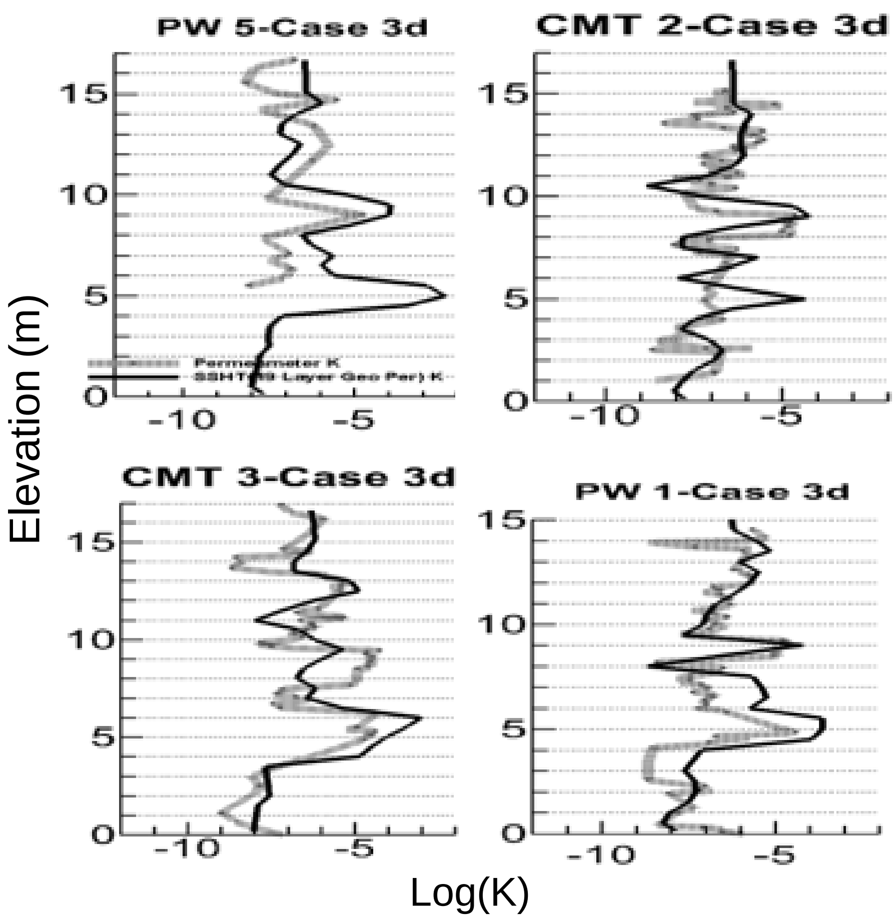
HT

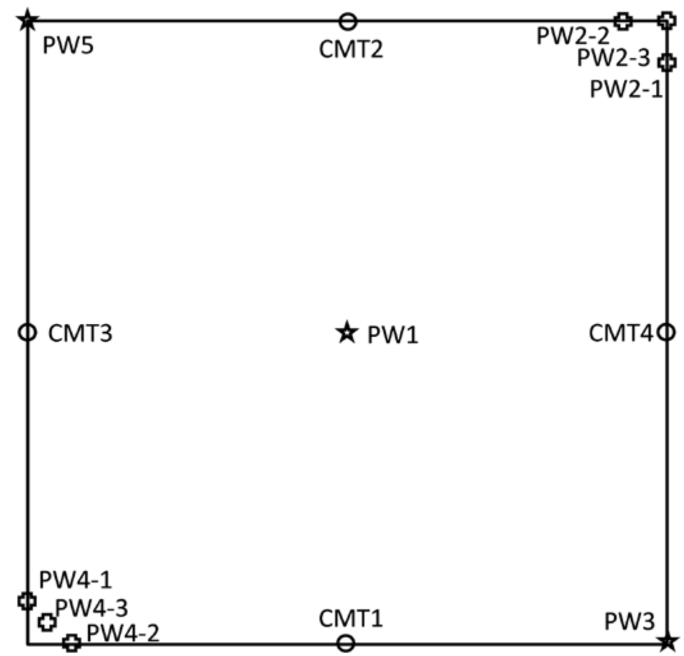


5-layer model based on geology

HT performed better than conventional modeling

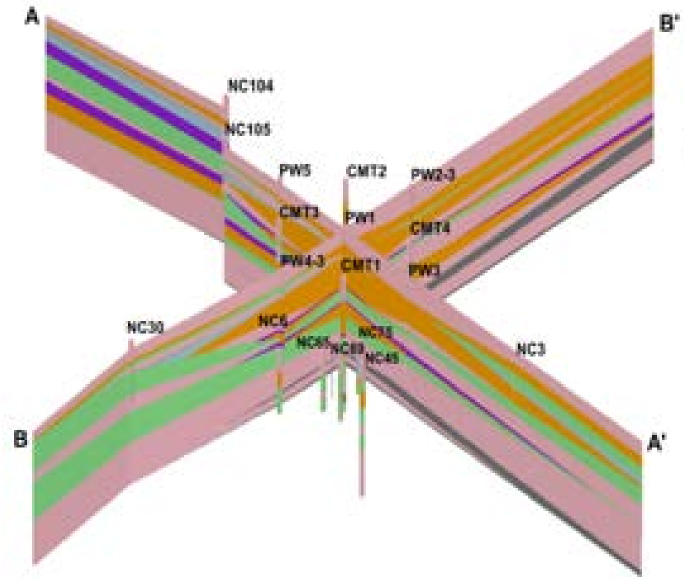
HT Validation: Permeameter Data

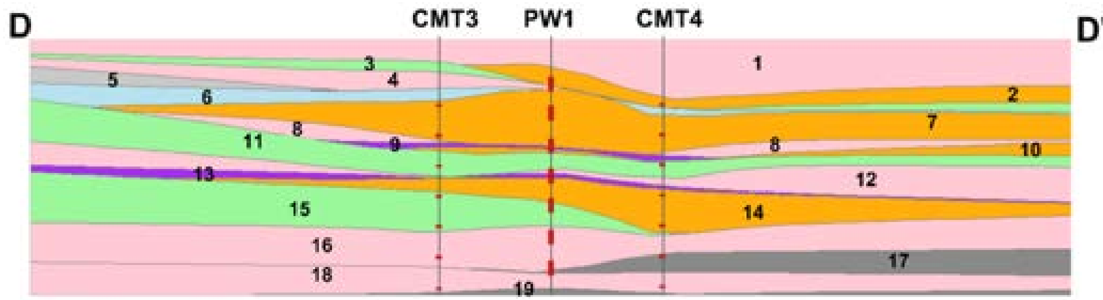


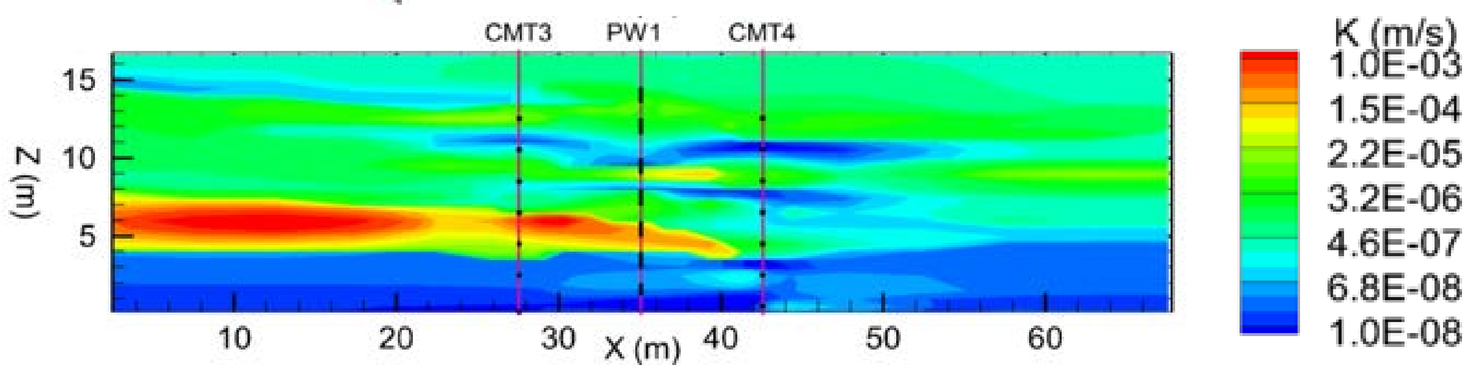


Good agreement with permeameter data

HT Validation: Geologic Data

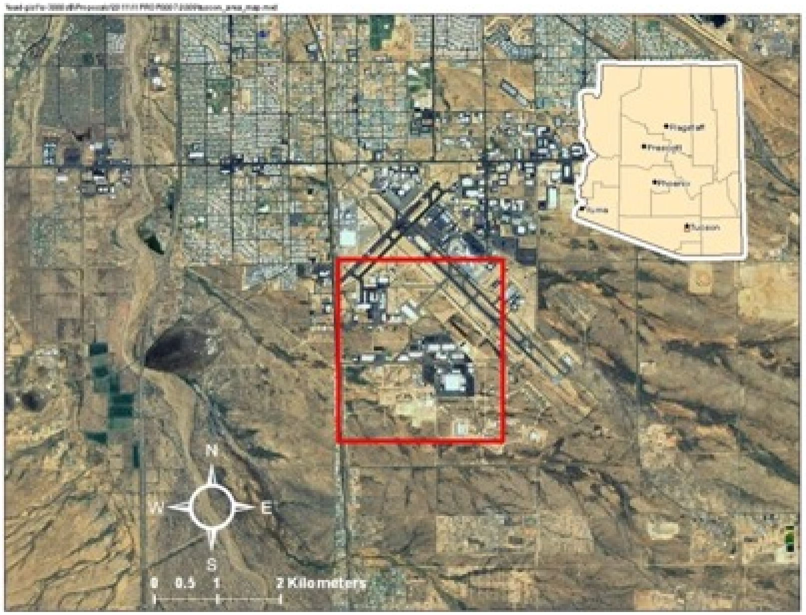


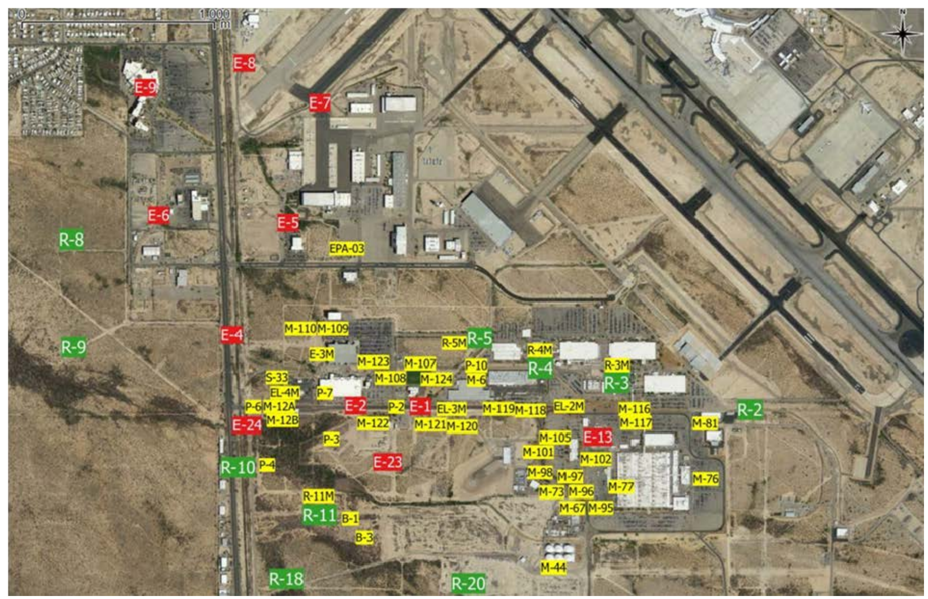




Facility-Scale Demonstration at AFP44

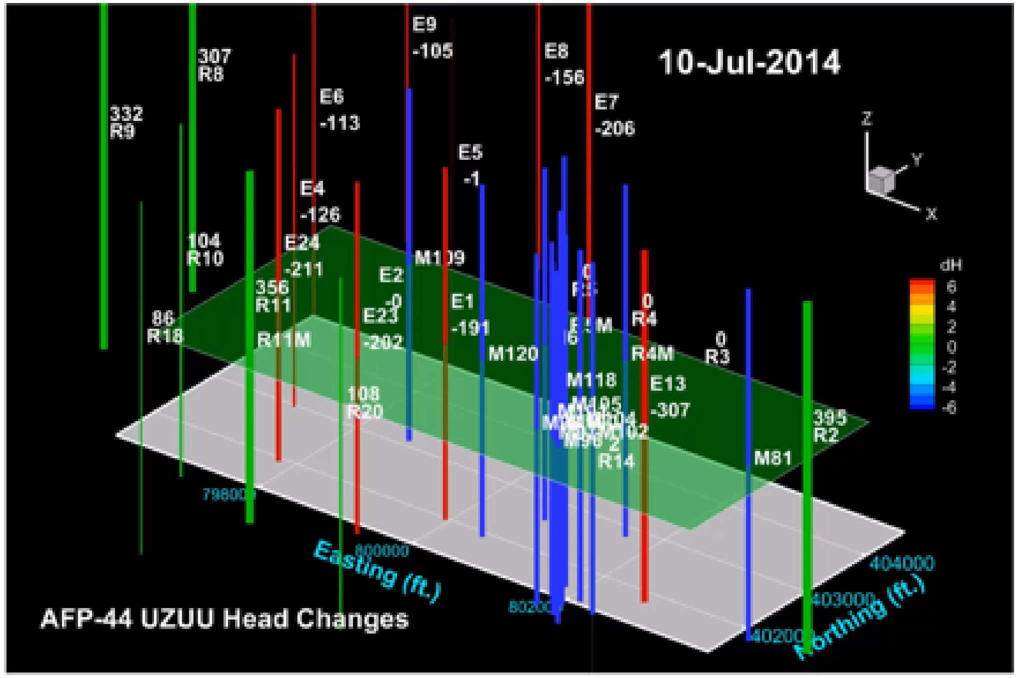
- Existing pumping-and-treat system
- Hydraulic scanning by altering distribution of extraction and injection rates





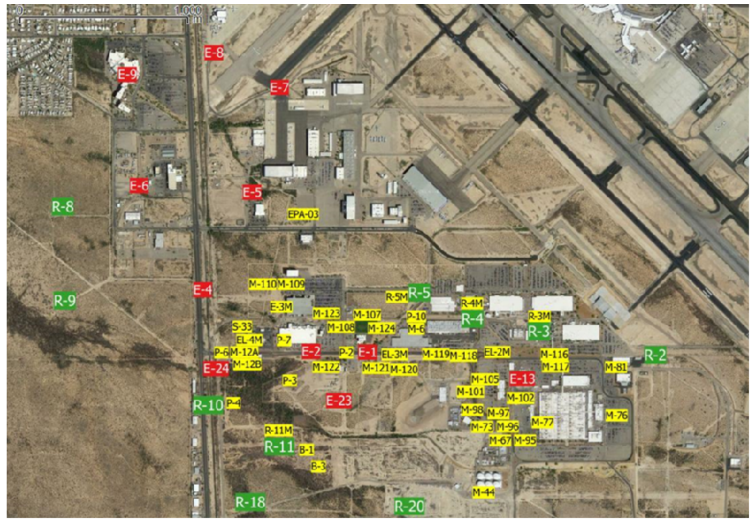
HT Data Collection at AFP44

- Pressure transducers 44 wells
- Hydraulic responses to pumping changes
- June 2015-August 2016

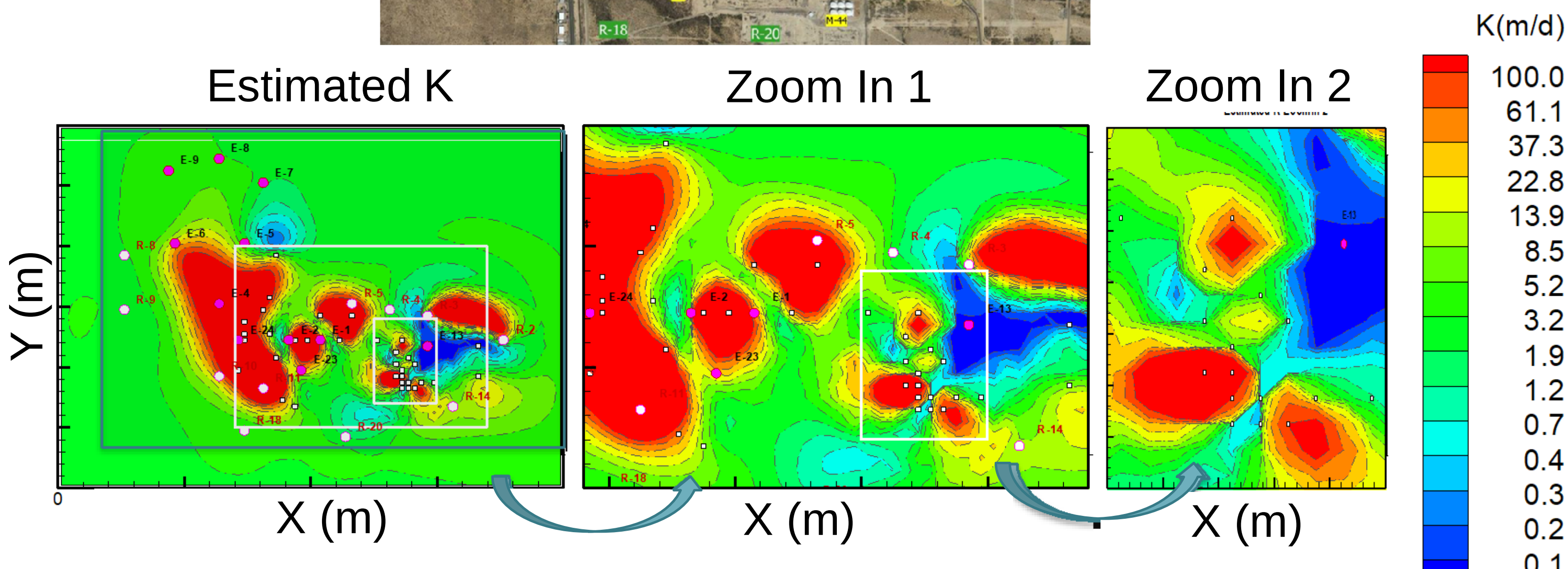


2-D HT Results

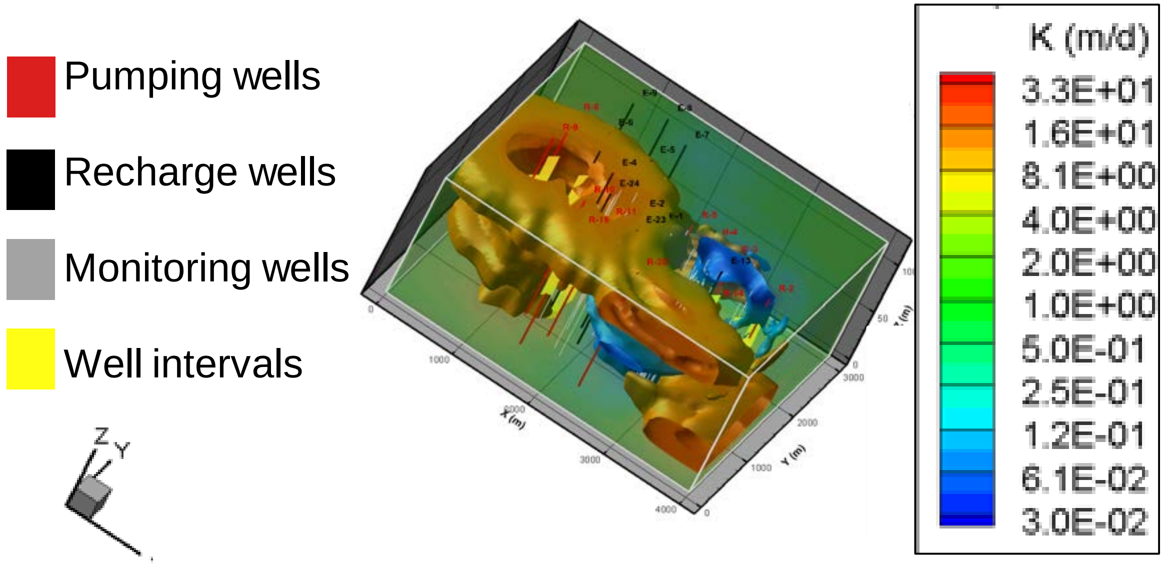
- Extraction Wells
- Monitoring Wells
- Recharge Wells



Spatial resolution depends on well density

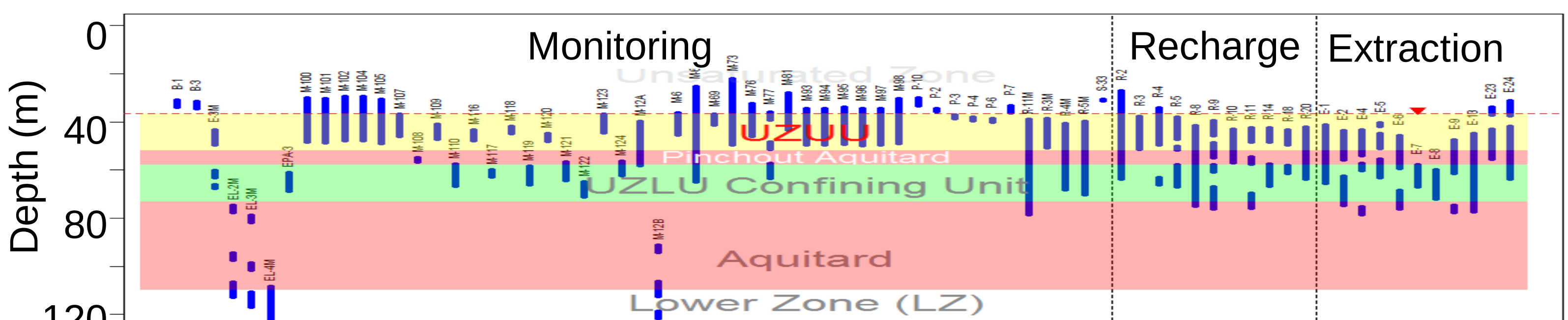


3-D HT Results



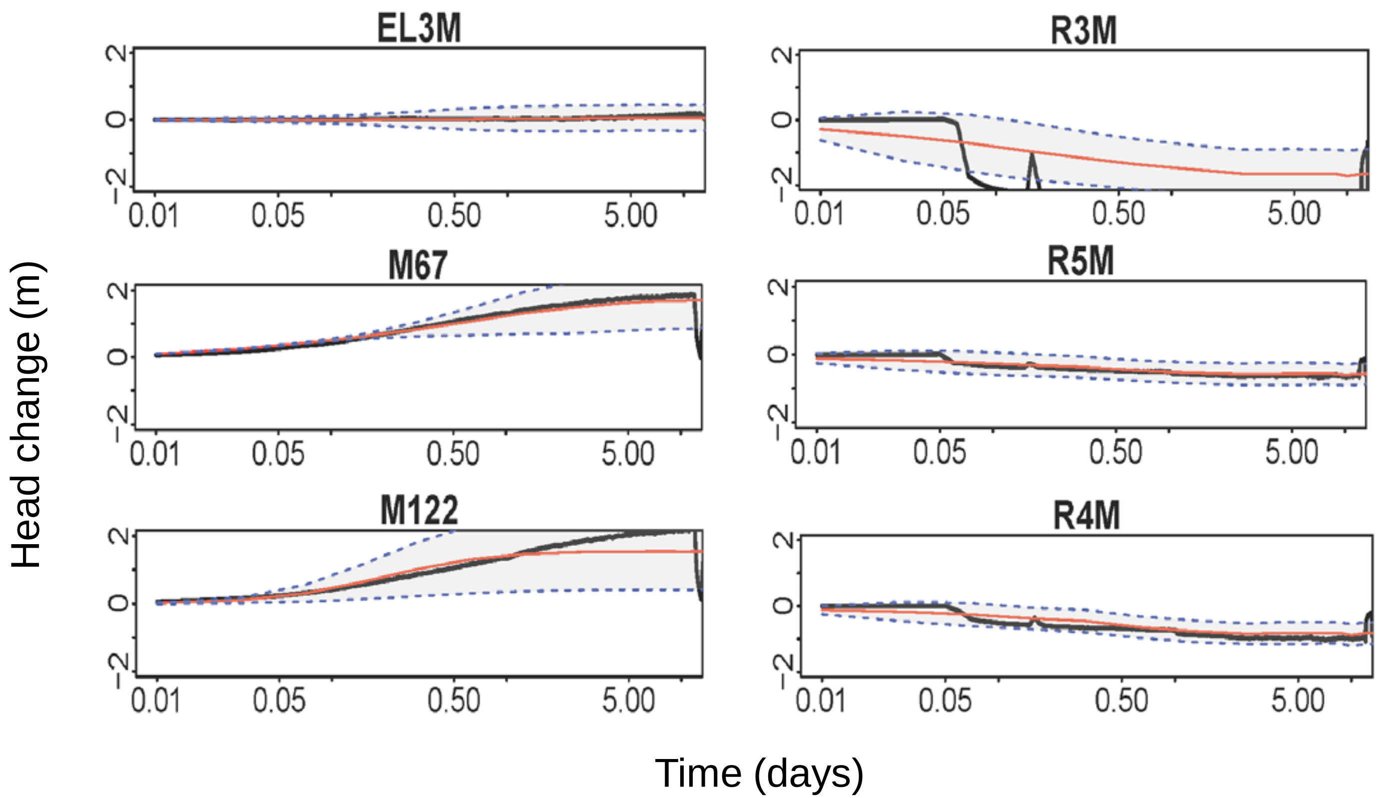
Vertical resolution depends on well screen distribution

Well Screen Intervals below 2,600 feet above sea level



HT Validation: Hydraulic

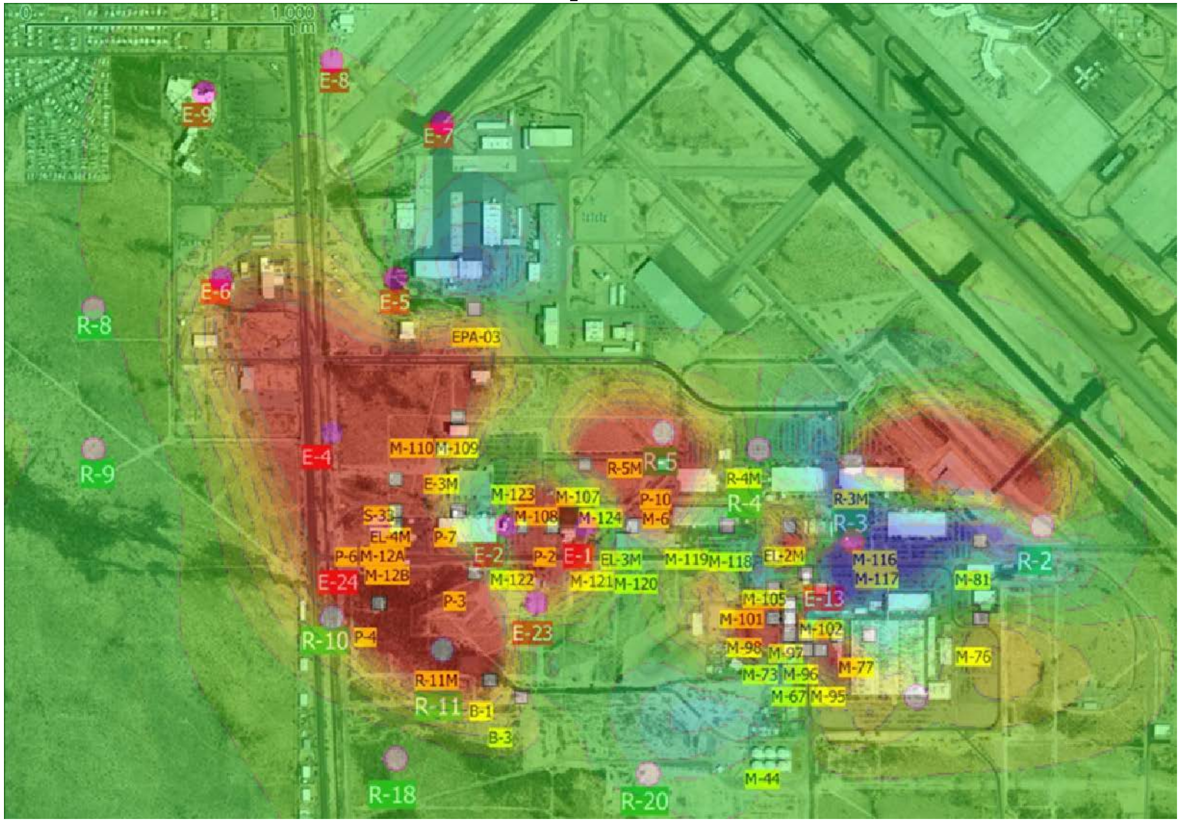
Validation of Drawdown Responses



Red: Simulated drawdown; **Black**: Observed drawdown; **Blue**: Uncertainty bounds

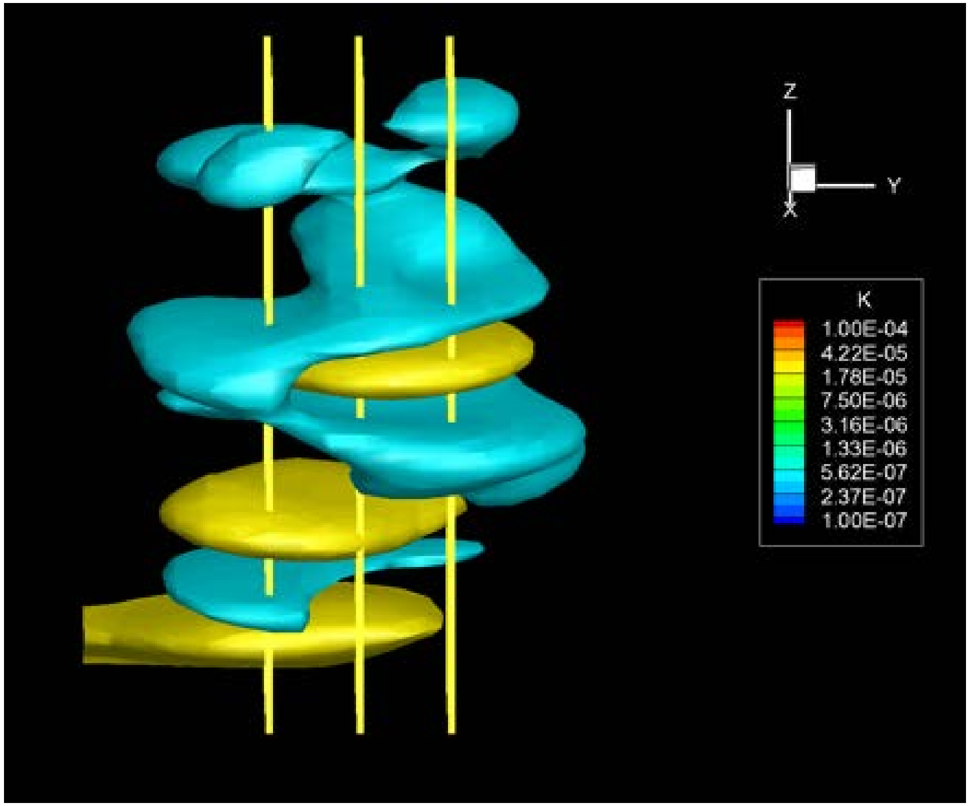
HT Validation: Site Condition

K distribution is consistent with observed drawdown and previous studies



HT Application: Remedial Design

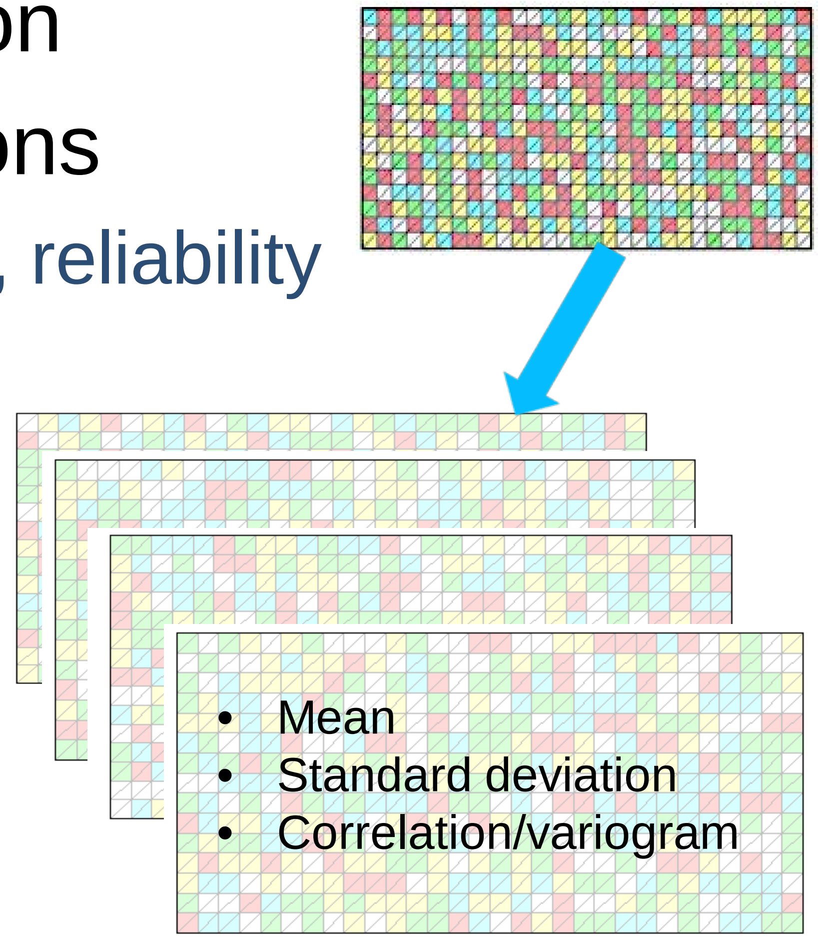
- Delineating K distribution
- Examples
  - Pump and treat optimization
  - Substrate delivery
  - Slurry wall
  - Hydrogeologic change monitoring
    - Augmentation



HT Application

Reliability Evaluation and Optimization

- Uncertainty information
- Monte Carlo simulations
  - Evaluate performance, reliability
    - Remediation
    - Long-term monitoring
- Optimization
  - Most reliable solution
  - Cost-effective solution



HT Implementation

- Cost-effectiveness considerations
  - Site characterization objectives
  - Spatial resolution
  - Existing well network
  - On-site treatment and disposal
- Site access and operation constraints

Conclusions

Benefits of HT

- Accurate HRSC technology
- Cost-effective
  - For sites with existing pump-and-treat system and/or data
- Knowledge of subsurface condition and uncertainty
  - Critical to successful remediation and monitoring
- Data gaps, needs

Benefits to DoD

- Critical subsurface information
  - Reliable and targeted remediation
  - Long-term monitoring
- Save costs
- Reduce liability

Further Advancements

- Additional information
  - Geology
  - Geophysical tomography
  - Flux measurements
  - Well profiling
  - Air Force Plant 4 – geophysics
  - Edward Air Force Base – tracer, geophysics, and flux
- Computational methods
  - Simulation approach
    - Simulation model independent
  - Multi-stage approach
    - Geologic categories

For additional information, please visit
https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-201212

Speaker Contact Information
cmmok@gsienv.com; 510-316-8445

Q&A Session 1

Contaminant Flux Reduction Barriers for Managing Difficult-to-Treat Source Zones in Unconsolidated Media

Poonam Kulkarni, P.E.
GSI Environmental Inc.

SERDP DOD • EPA • DOE | ESTCP

Agenda

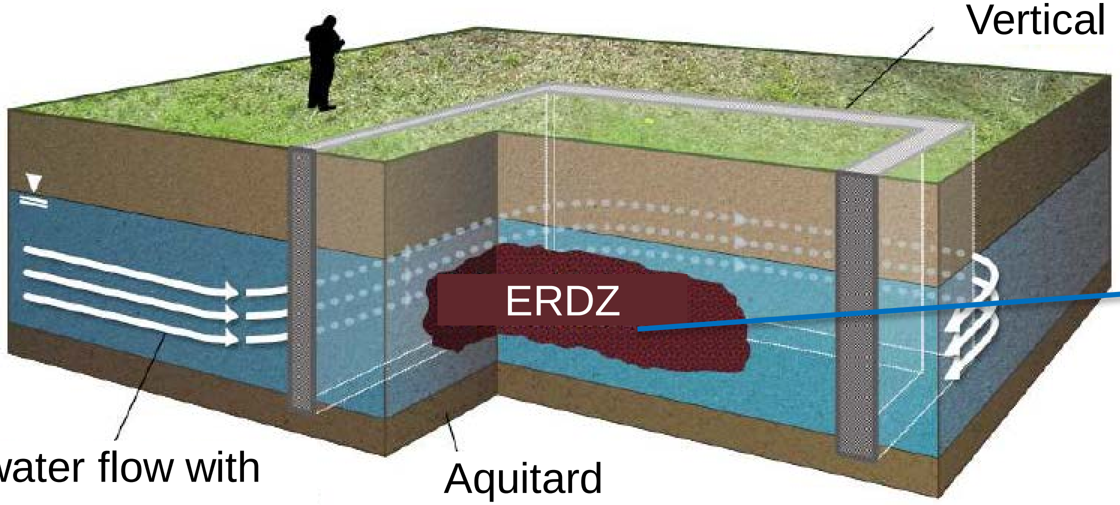
- Why flux reduction barriers?
- Source barrier tool
- Small-scale demonstration results
- Conclusions and benefits to DoD

Implications of Matrix Diffusion

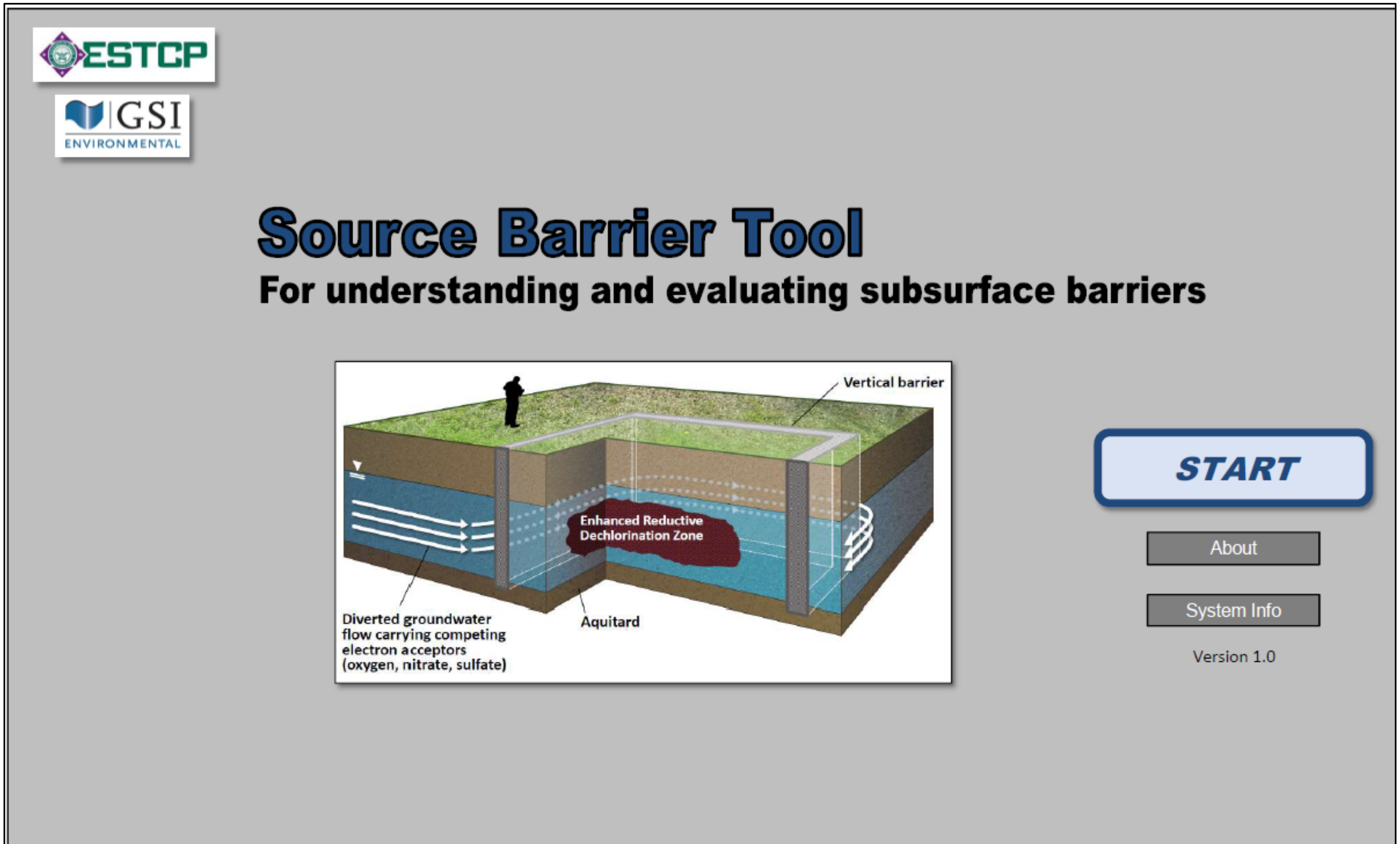
- SERDP Project ER-1740: Management of Contaminants Stored in Low Permeability Zones
  - State-of-the-Science Review
- Similar to emergence of dense non-aqueous phase liquid paradigm
  - More mass in subsurface than estimated
  - More difficult to remove
  - Long-term persistence
- Containment makes a comeback
  - More containment projects anticipated as End State
  - Vertical barriers, hydraulic containment
  - Flux clog, electron-acceptor diversion to enhance degradation

Benefits of Flux Reduction Barriers

1. Physically reducing mass flux of contaminants leaving source zone
2. Increasing the natural source zone depletion (NSZD) rate within source by diverting competing electron acceptors to create an enhanced reductive dechlorination zone (ERDZ)



Source Barrier Tool



Toolkit Overview

- Benefits of physical barrier around source zone
  - Reduces mass flux of contaminants leaving source zone
    - Mass flux calculation
    - Expected flow reduction
  - Enhanced Reductive Dechlorination Zone created by diverting electron acceptors
    - Source biodegradation
    - Modeling example
- Feasibility of barrier at site
  - Site suitability page
  - Compare barrier types
  - Barrier visualization tool
  - Recharge tool
- Additional resources for barrier understanding
  - Barrier survey studies
  - Flow vs. cross-sectional area

Potential Benefits of Physical Barrier

1. It reduces the mass discharge (mass flux) of contaminants leaving the source

A. Mass Flux Calculation — *If needed, use the ESTCP Mass Flux Toolkit to calculate the mass discharge*

B. Expected Flow Reduction — *See how much reduction in mass discharge (mass flux) you can expect.*

2. By diverting electron acceptors, barriers can create Enhanced Reductive Dechlorination Zones

C. Source Biodegradation — *Calculate the potential increase in biodegradation for your source zone.*

Potential Biodegradation Benefits Calculator

Step 1: Enter Site Information

Select Chlorinated Volatile Organic Chemical (CVOC): TCE

b = Saturated Aquifer Thickness	40.0	ft
i = Regional Hydraulic Gradient	0.007	ft/ft
K = Hydraulic Conductivity	14.00	ft/day
Width of Barrier / Treatment Zone Perpend. to Flow	500	ft
Porosity	0.3	
Groundwater (GW) Darcy Velocity	35.8	ft/yr
% Reduction in Flowrate After Barrier Construction	90%	%
Volumetric Groundwater Flowrate	5,351,192	gal/yr
Volumetric Groundwater Flow Rate After Barrier	535,119	gal/yr

tential Increase in Biodegradation

Efficiency (% of Hydrogen Going to Dechlorination):	10%
lbs of CVOC Degraded to Ethene per lb of H_2:	21.9

	Conc. in Upgradient Groundwater (mg/L)	Current Conc. in Source Zone (mg/L)	Diff. in Electron Acceptor Mass Discharge (lb/year)	H_2 Equiv. Consumed Per lb Analyte* (lb/lb)	H_2 Equivalents (lb/yr)	Increase in Biodegradation Rate for CVOC (lb/yr)
O_2	8.9	0.2	351.2	8.0	43.9	96.1
NO_3^-	5.5	0.1	218.7	12.4	17.6	38.6
SO_4^{2-}	76.7	0.1	3076.3	12.0	256.4	561.4

*Source: BIOBALANCE Tool (www.gsi-net.com)

Total 696 lb/yr CVOC

RESULT SUMMARY

Potential Increase in Biodegradation 696 lb/yr CVOC

C. Learn More About This Topic

Feasibility of Barrier at Site

1. It provides four key tools to help you understand flow details for different barrier designs

E. Site Suitability Page	*Is my site suitable for a barrier?*
F. Compare Barrier Types	*Which barrier technology is best for my site?*
G. Barrier Visualization Tool	*Does a barrier always have to competely encircle my site? How about a hanging barrier?*
H. Recharge Tool	*For an unpumped barrier, is recharge a concern when a barrier is constructed?*

Best Barrier for My Site

Type	Reliability	Depth Limit (ft bgs)	K (cm/s)	Other
Slurry wall	Proven, common	70+	10^{-7}	• Need ~15-foot perimeter area • Specialty contractors
Sheet pile	Proven, common	90	10^{-8}	• Specialty contractors
Permeation grouting*	Less common	40	10^{-5}	• Better for high K, small working area • Can use with injection-based technology

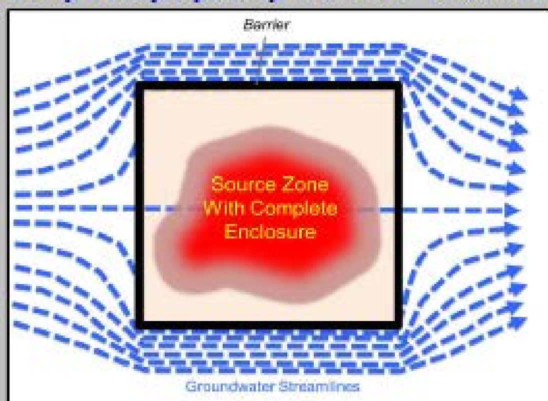
Notes: * = ESTCP field study; cm/s = centimeters per second; K = hydraulic conductivity

Barrier Visualization

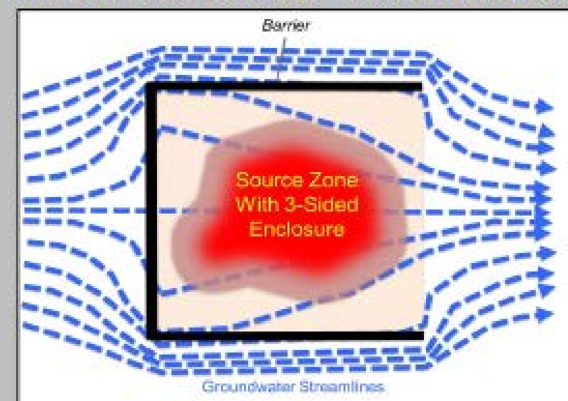
Effect of Different Variables

Base Case:

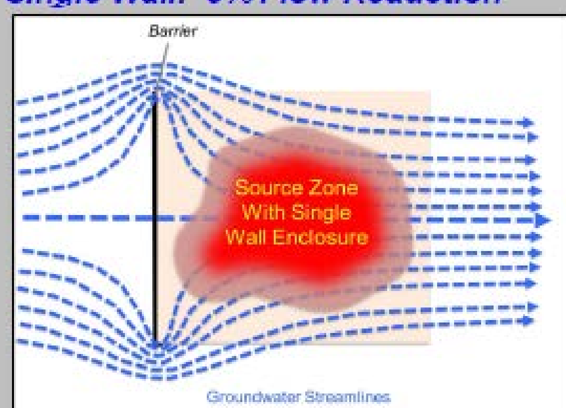
Complete (Square) Barrier: 97% Flow Reduction



Three-Sided Barrier: 79% Flow Reduction



Single Wall: 9% Flow Reduction



Barrier Understanding

Additional Resources

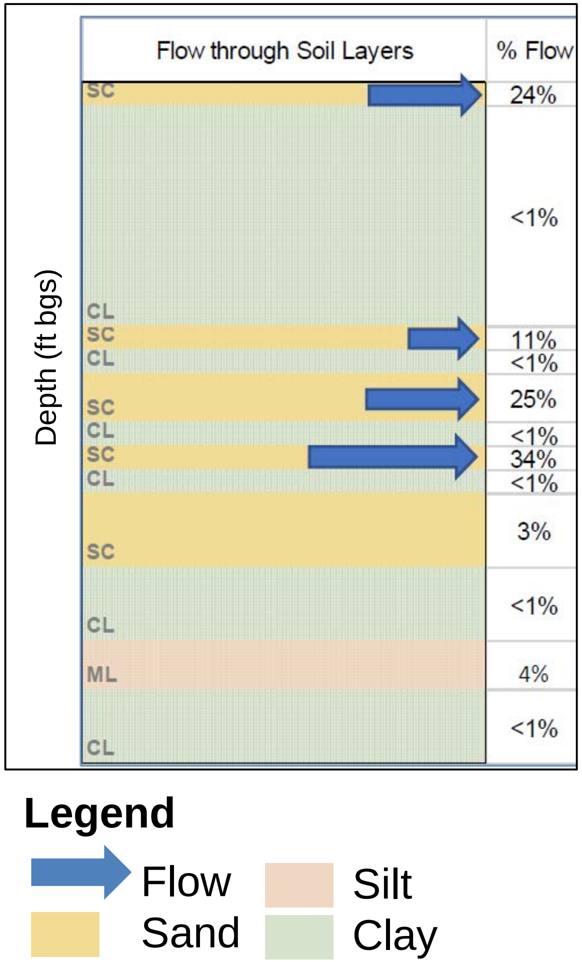
I. Barrier Survey Studies	*Survey of barriers for groundwater remediation applications.*
J. Flow vs. X-Sectional Area	*Survey of the distribution of groundwater flow vs. cross-sectional area.*

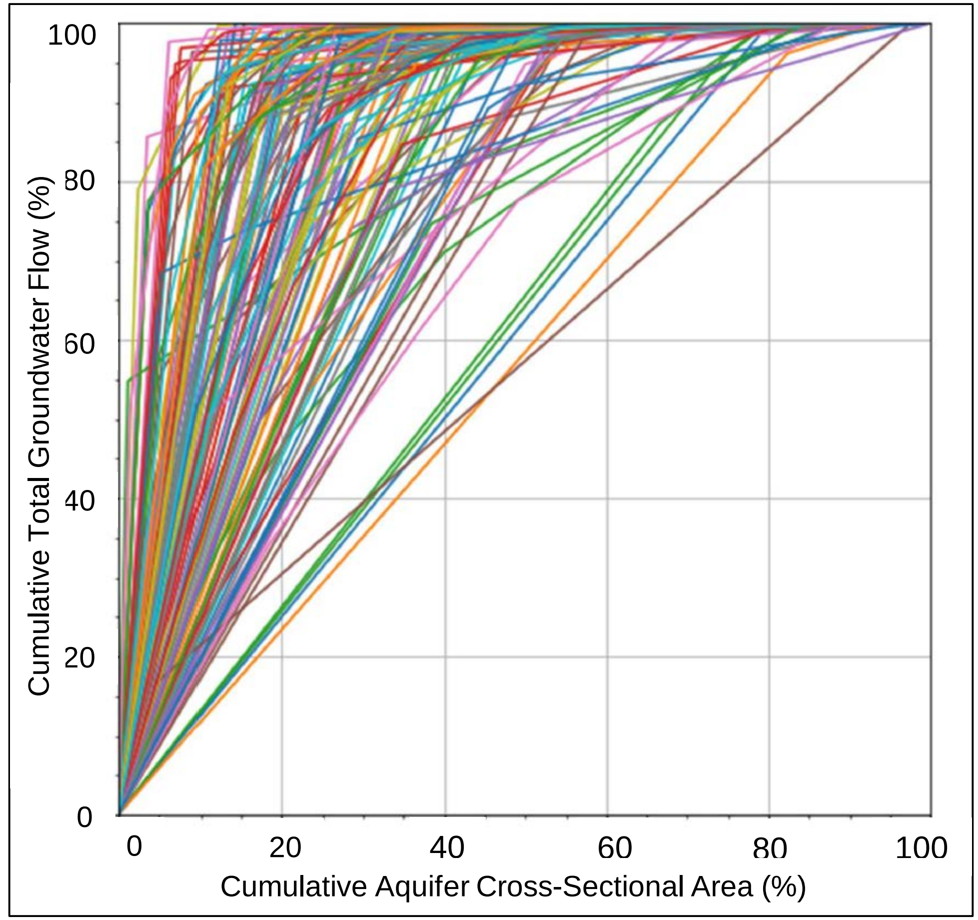
Flow vs. Cross-Sectional Area at Sites

Big Data Study

- Is this heterogeneity rule of thumb correct?
  - "90% of mass flux in 10% of cross-section"
  - Payne et al. (2008): 90% of aquifer flow was transmitted in only 20% of the aquifer cross section in most natural aquifers"
- 43 sites, 141 boring logs from GeoTracker

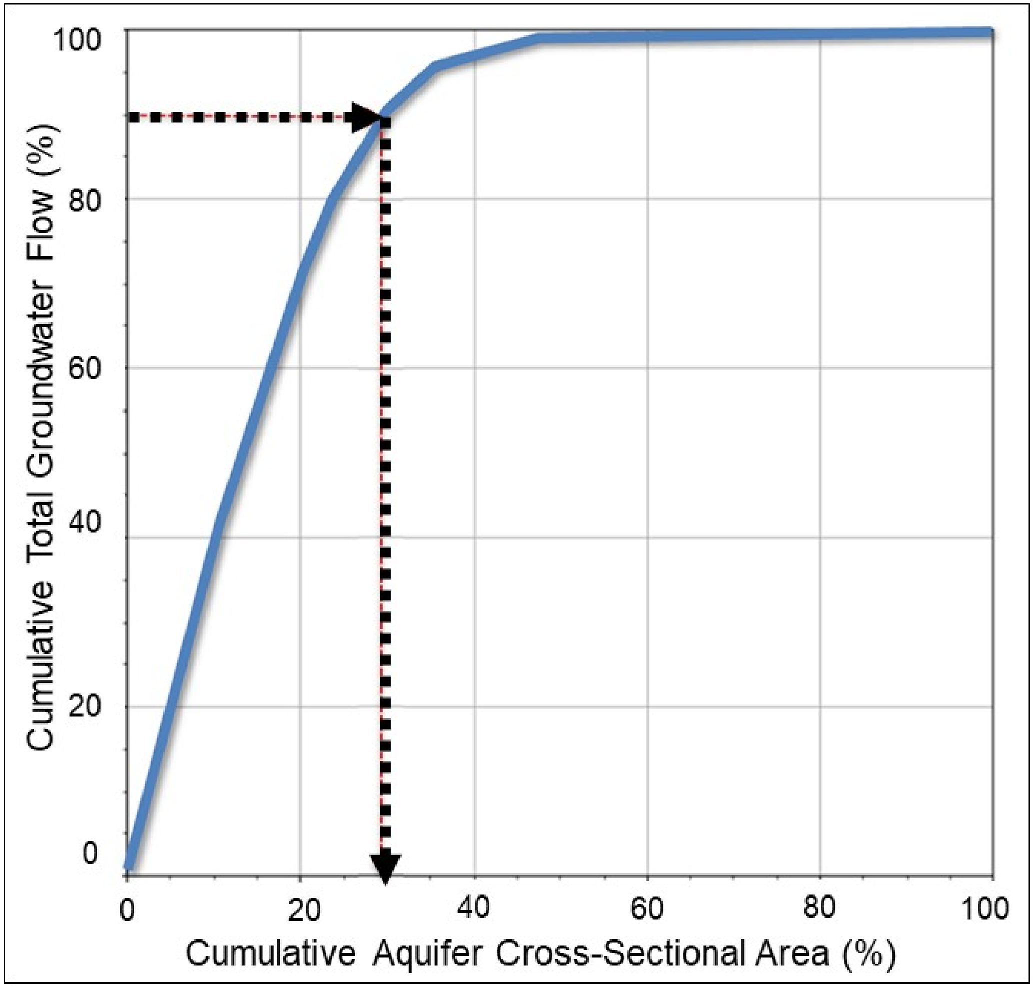
Individual Boring Log Analysis





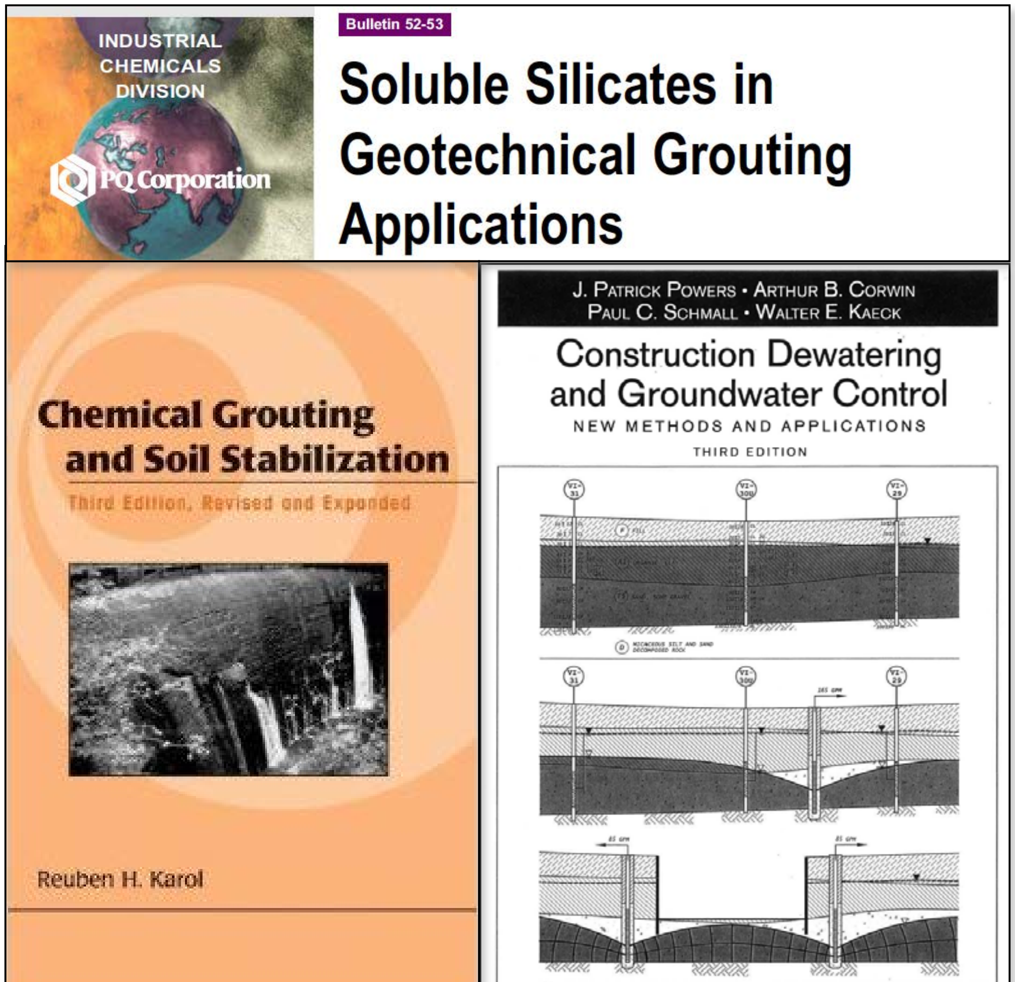
Key Point

- Approximately 90% of the groundwater flow is flowing through about 30% of the aquifer cross-section

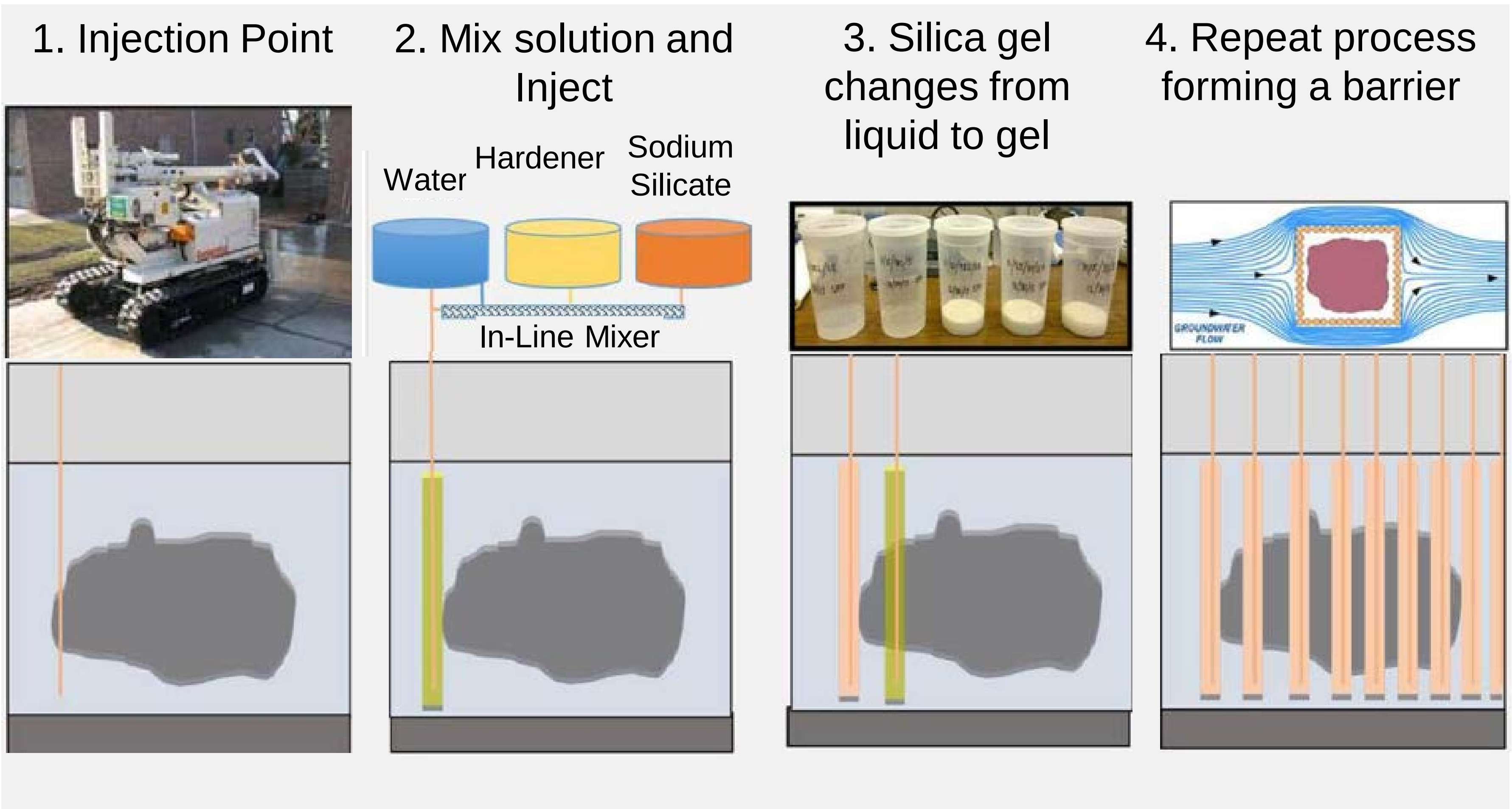


Permeation Grouting Technology

"Water Tightening"



Permeation Grouting Process



Laboratory Studies

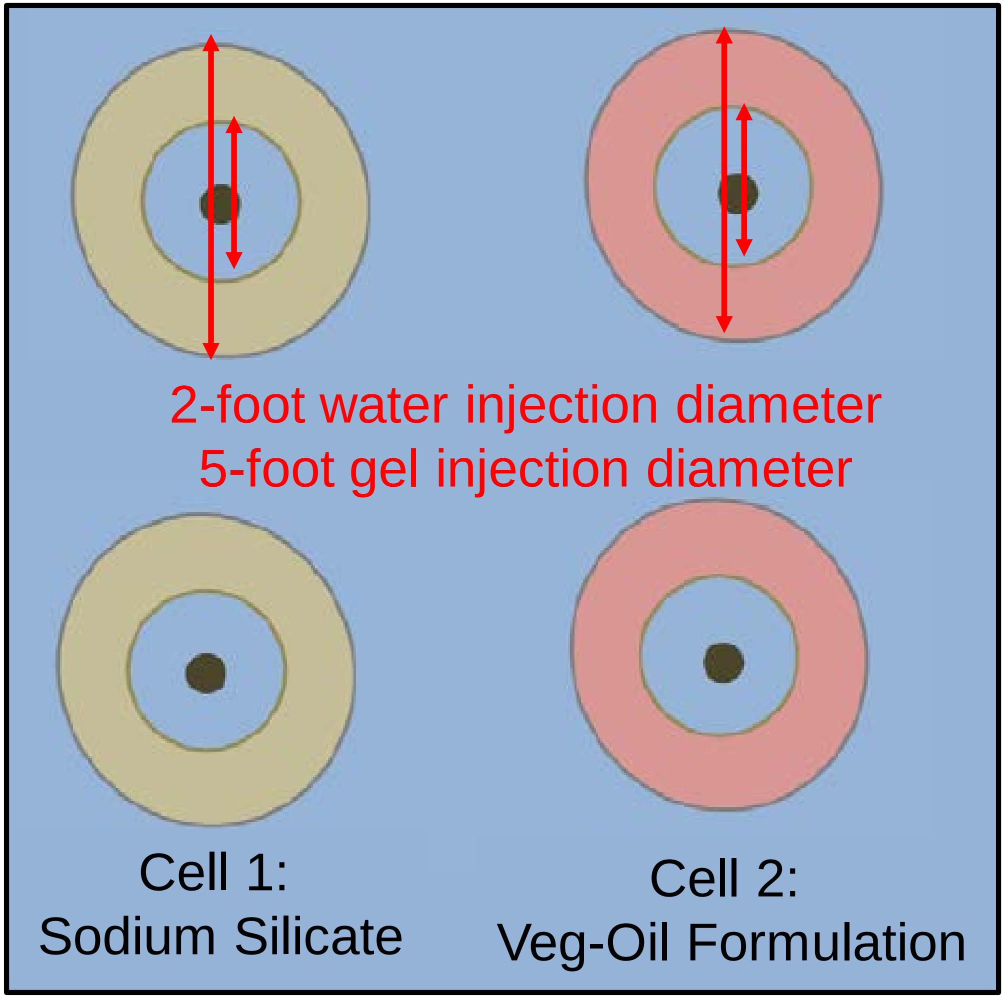
Sodium Silicate Grout

Vegetable Oil Formulation

Table 3 - Constant Head Test Summary			
Formulation	**E0-S30**	**E5-S10**	**E10-S10**
Gel Time (hours):	0.5	18	7
Elapsed Time	*Log Unit Reduction*		
40 hours	No Flow	2.8	1.3
1 week	No Flow	3.0	1.3
4 weeks	No Flow	4.5	1.7

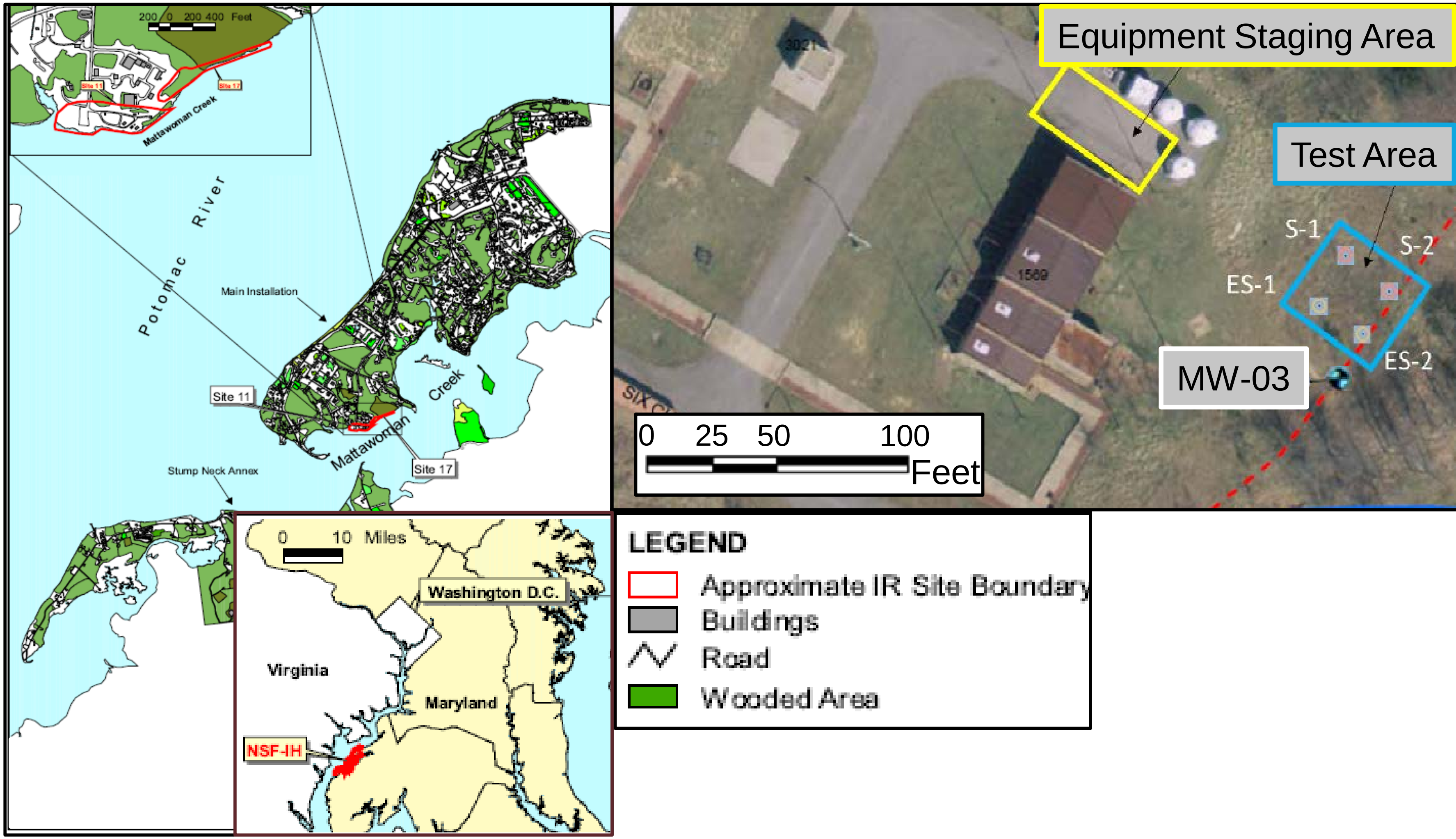
Solutions-IES
Industrial & Environmental Services

Small Scale Demonstration Overview



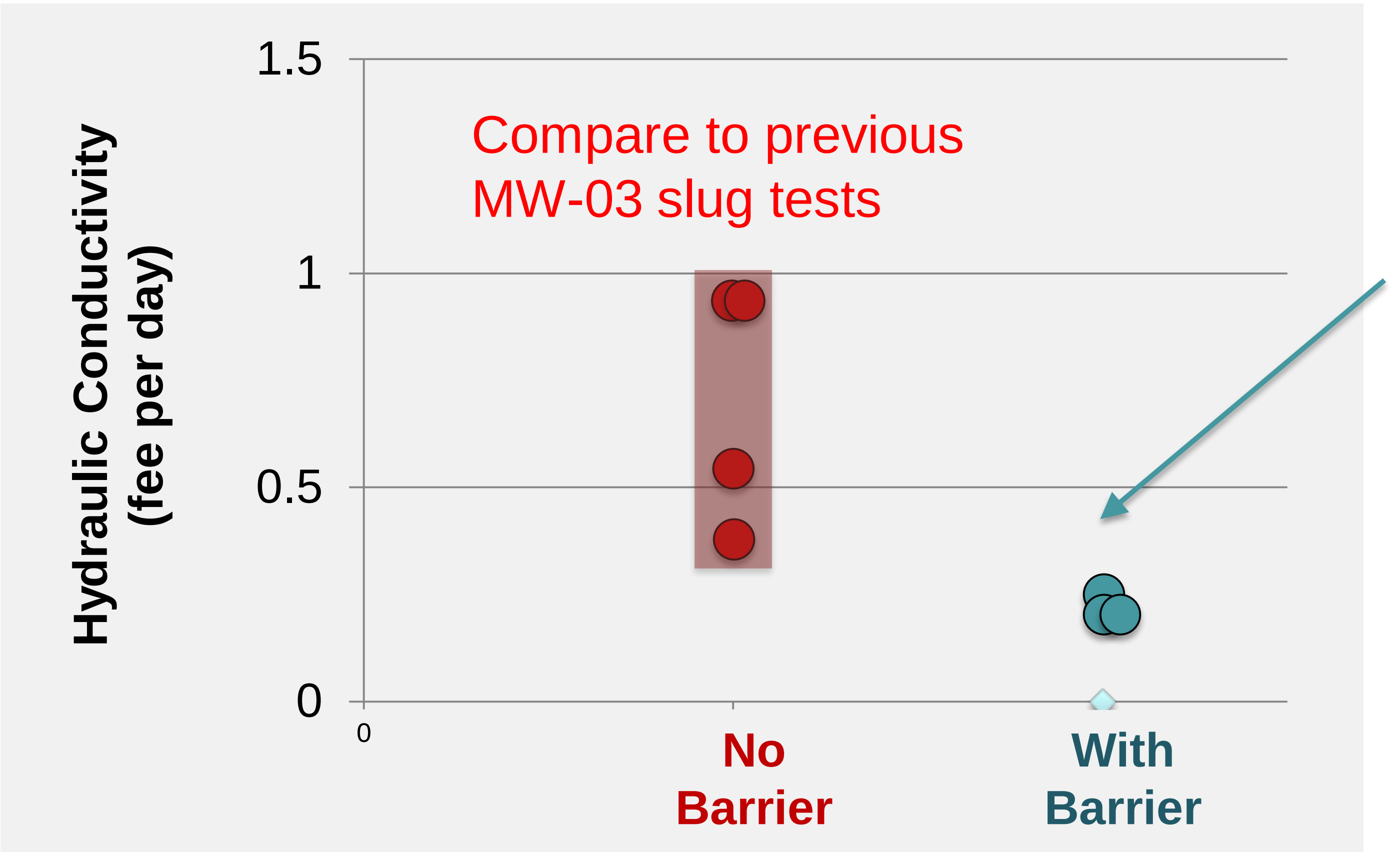
- Gain experience with the following:
  - Materials
  - Surface equipment
  - Injection process
- Four different barrier cells
- Two different grout types
- Before and after extraction tests
  - Determine volume reduction

Demonstration Site



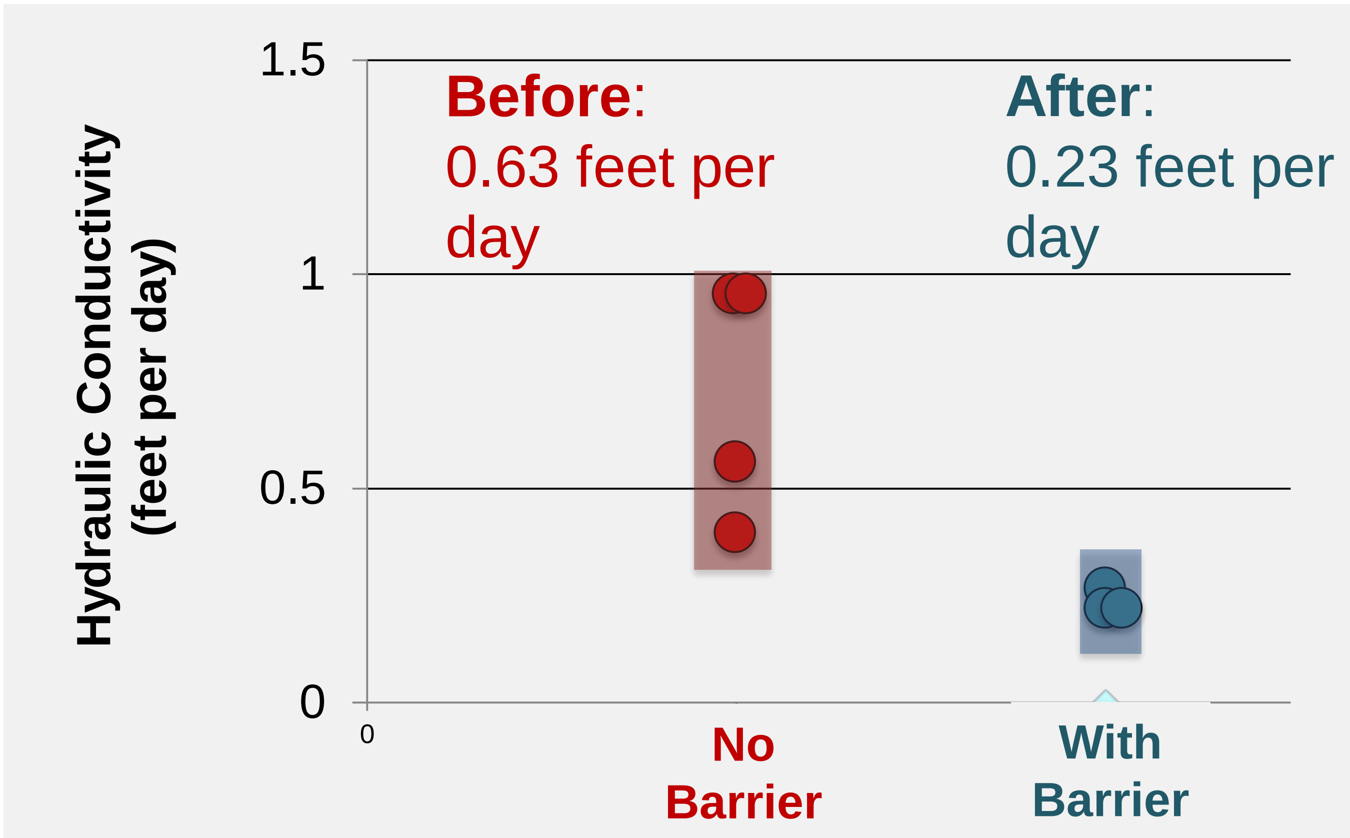
Injection Skid and Fieldwork

Results



- 5-Hour constant head injection test
- Solve for aquifer parameters
- Jacob-Lohman Type Curve Solution

Results



Indicates ~64% reduction

Conclusions

- Comeback of containment technologies due to matrix diffusion?
- Benefits of barriers at chlorinated solvent source zones
  - Reduced mass flux out
  - Reduce electron acceptors in
    - Improved source biodegradation
- The ESTCP Source Barrier Tool is a resource for
  - Slurry walls
  - Sheet piling
  - Permeation grouting
- Permeation grouting reduced flow through already low permeability zone by ~64%

Benefits to DoD

- Source Barrier Tool
  - Excel-based toolkit to help site managers evaluate potential benefits of and types of containment barriers to install
- Permeation grouting
  - Potential for implementation using injection-based technologies for barrier placement
- Heterogeneity rule of thumb
  - 90% of groundwater flow is occurring through 30% of cross-sectional area

For additional information, please visit

https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-201328

Speaker Contact Information

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Q&A Session 2

The next webinar is on October 31, 2019

Developing and Demonstrating Non-Toxic and Sustainable Coating Systems for Military Platforms

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Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends

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