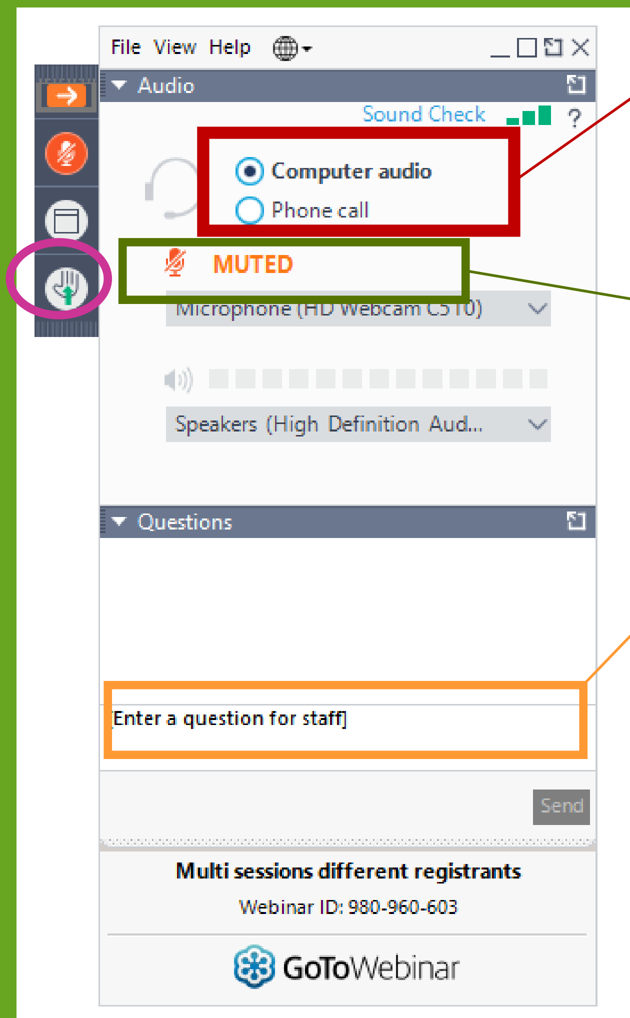
USING GOTOWEBINAR



Two Options for Audio:
1. Use your **computer's** speakers
2. Call in by **phone** using the call-in number and access code in the Audio section of the control box.

All participants are **muted** by default.

Questions: Use the "send question" option in the chat panel to ask questions throughout the presentation.

Ask for help! Use the questions box to let us know if you have technical difficulties. You can also **raise your hand** for help.

NE IW PCC

NTC WEBINAR SERIES:

LUST CORRECTIVE ACTION: RESOURCES, CASE STUDY, AND A DISCUSSION ON REMEDIAL DESIGN CHARACTERIZATION AND IN-SITU REMEDIAL METHODS

NEIWPCC

10/14/2020

TANKS PROGRAM

- Webinar Series
- L.U.S.T.Line
- National Tanks Conference & Expo

NTC WEBINAR SERIES:

LUST CORRECTIVE ACTION: RESOURCES, CASE STUDY, AND A DISCUSSION ON REMEDIAL DESIGN CHARACTERIZATION AND IN-SITU REMEDIAL METHODS

NEIWPCC

10/14/2020

Today's Speakers

Kristopher McCandless, CPG

Environmental Geologist | *VA DEQ*

Vicki Voisard, PG

Geologist Registered | *KY DEP*

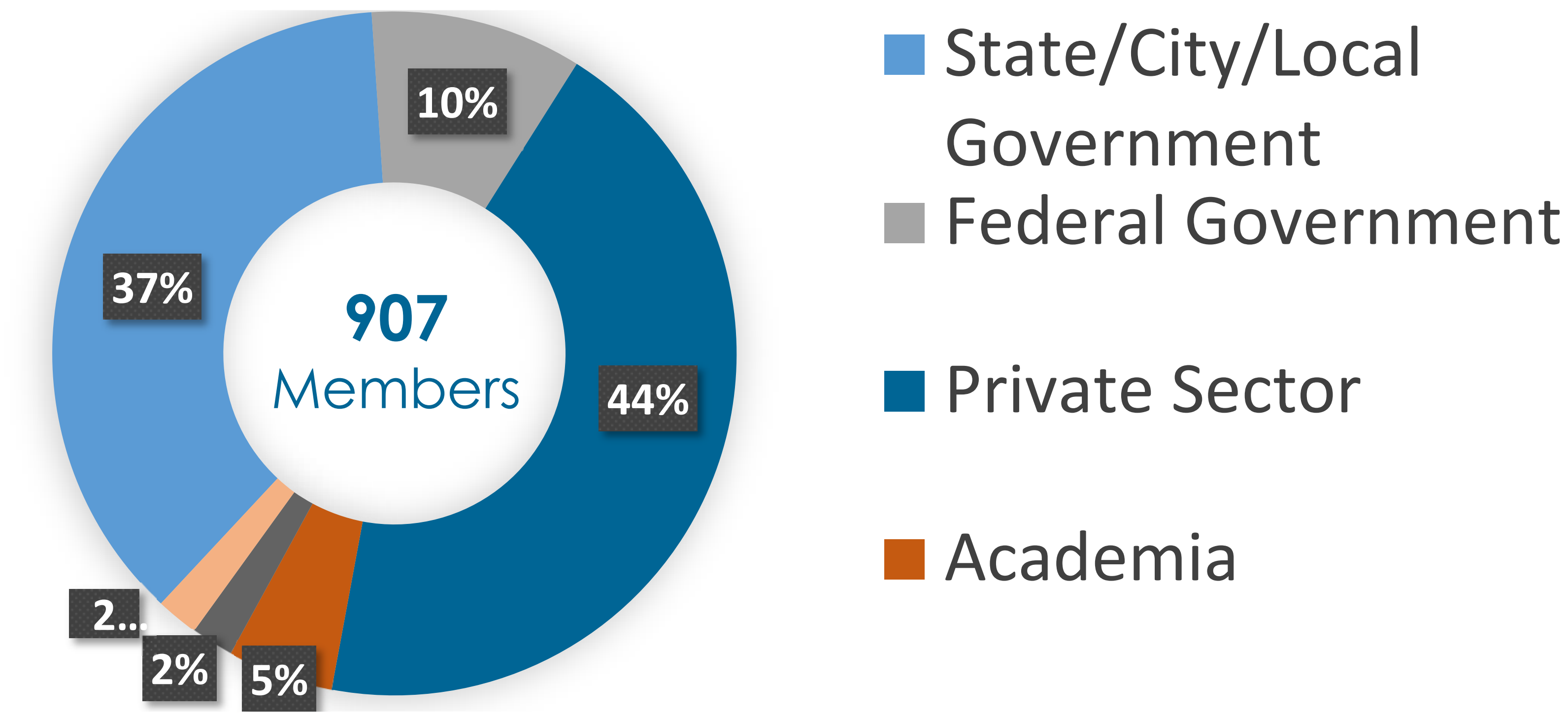
Bill Brab, CPG, PG

Senior Remediation Geologist | *AST Environmental, Inc.*

What is ITRC?

ITRC is a state-led coalition working to advance the use of innovative environmental technologies and approaches to translate good science into better decision-making.

Unique Network



ITRC Accomplishments

Educates state regulators on the use of innovative technologies

Promotes the use of innovative technologies

Unites state approaches to complex topics

Inspires collaboration over adversarial relationships

How Can YOU Benefit from ITRC?

Use ITRC Documents

Take ITRC Training Courses

Join ITRC Teams

ITRC Internet Based Documents and Training Used for LUST Sites

- Characterization and Remediation of Fractured Rock (Dec. 2017)
  - https://fracturedrx-1.itrcweb.org/
  - Internet-Based Training offered 3 times in 2020
- Implementing Advanced Site Characterization Tools (Dec. 2019)
  - https://asct-1.itrcweb.org/
  - Videos built into web document
- Optimizing Injection Strategies & In situ Remediation Performance (Feb2020)
  - https://ois-isrp-1.itrcweb.org
  - Internet-Based Training offered 3 times in 2020
- TPH Risk Evaluation at Petroleum-Contaminated Sites (Nov. 2018)
  - https://tphrisk-1.itrcweb.org/
  - Internet-Based Training offered 3 times in 2020

EXPLORE THIS LINK FOR MORE ITRC DOCUMENTS:
https://www.itrcweb.org/Guidance

How Important is the CSM?

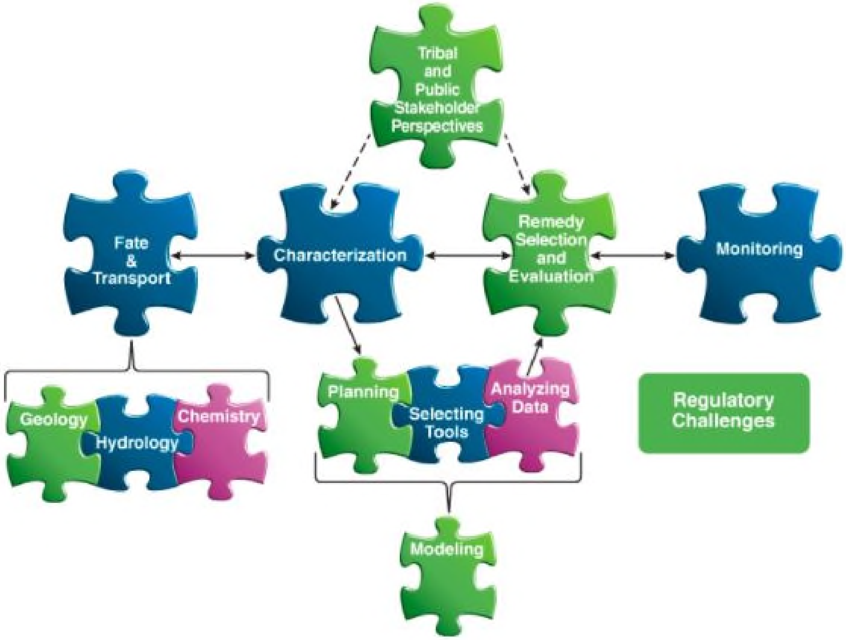
It is CRITICAL!

The Conceptual Site Model (CSM) is the <u>foundation</u> for

- Remedial Action
- Alternate Water Supply
- Risk Assessment

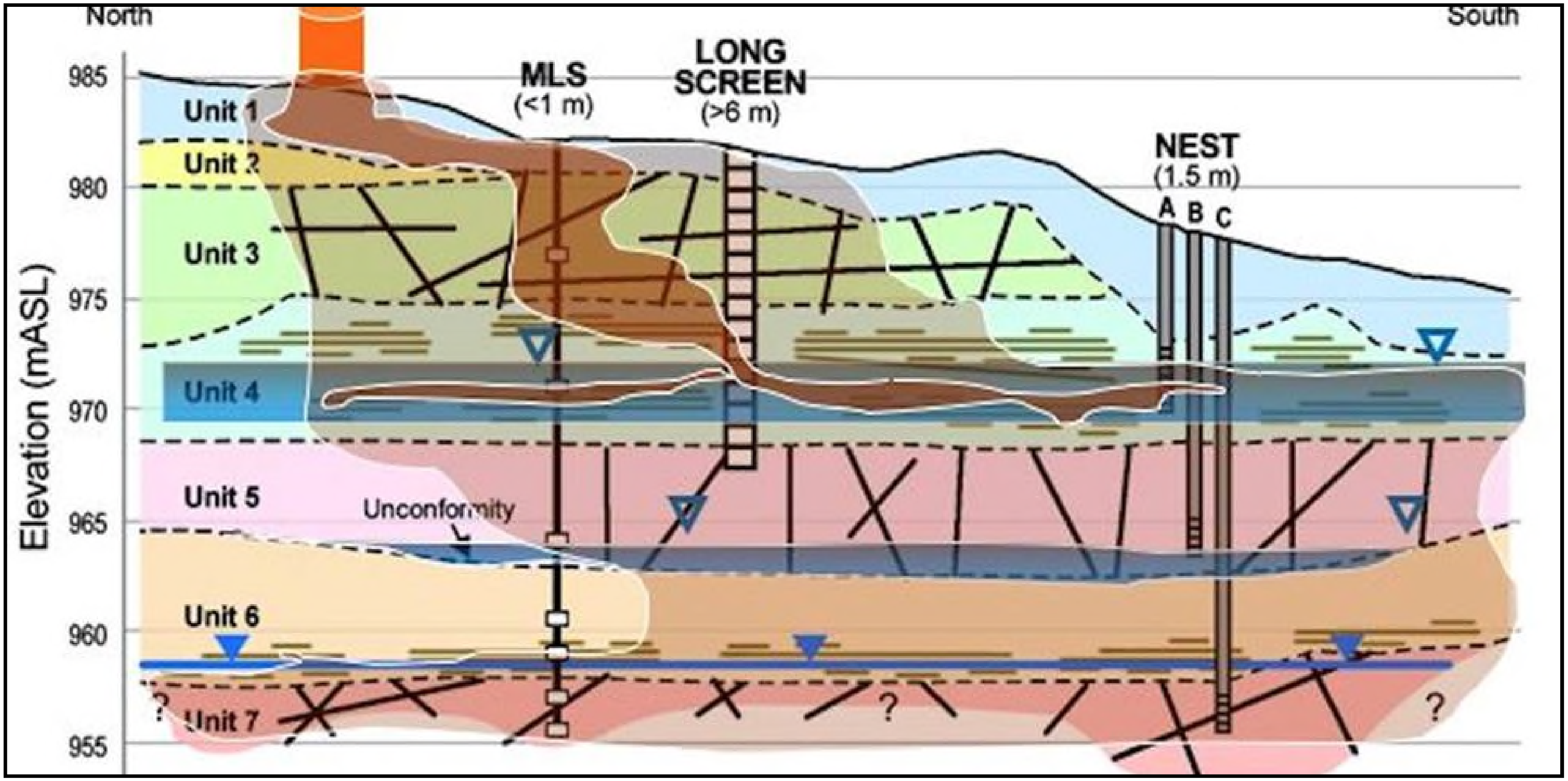
ITRC's Characterization and Remediation of Fractured Rock

The Fractured Rock Puzzle



Free Online Access at: https://fracturedrx-1.itrcweb.org/

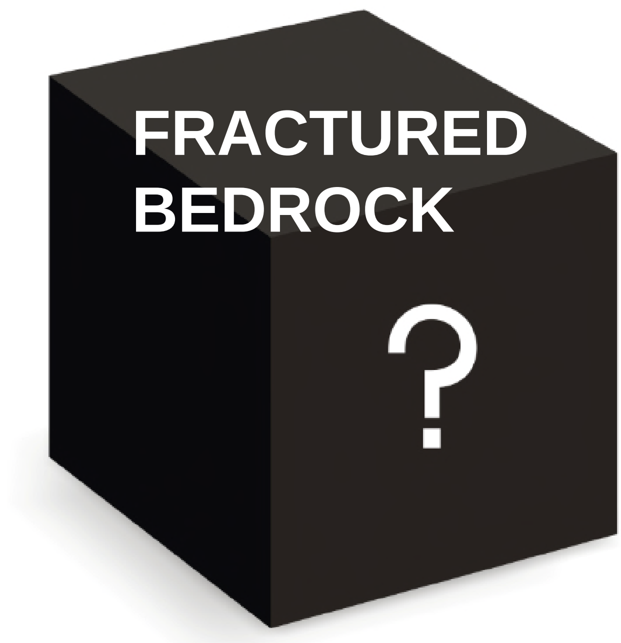
Bedrock Sites are Complex



ITRC FracRx-1 Figure D-6

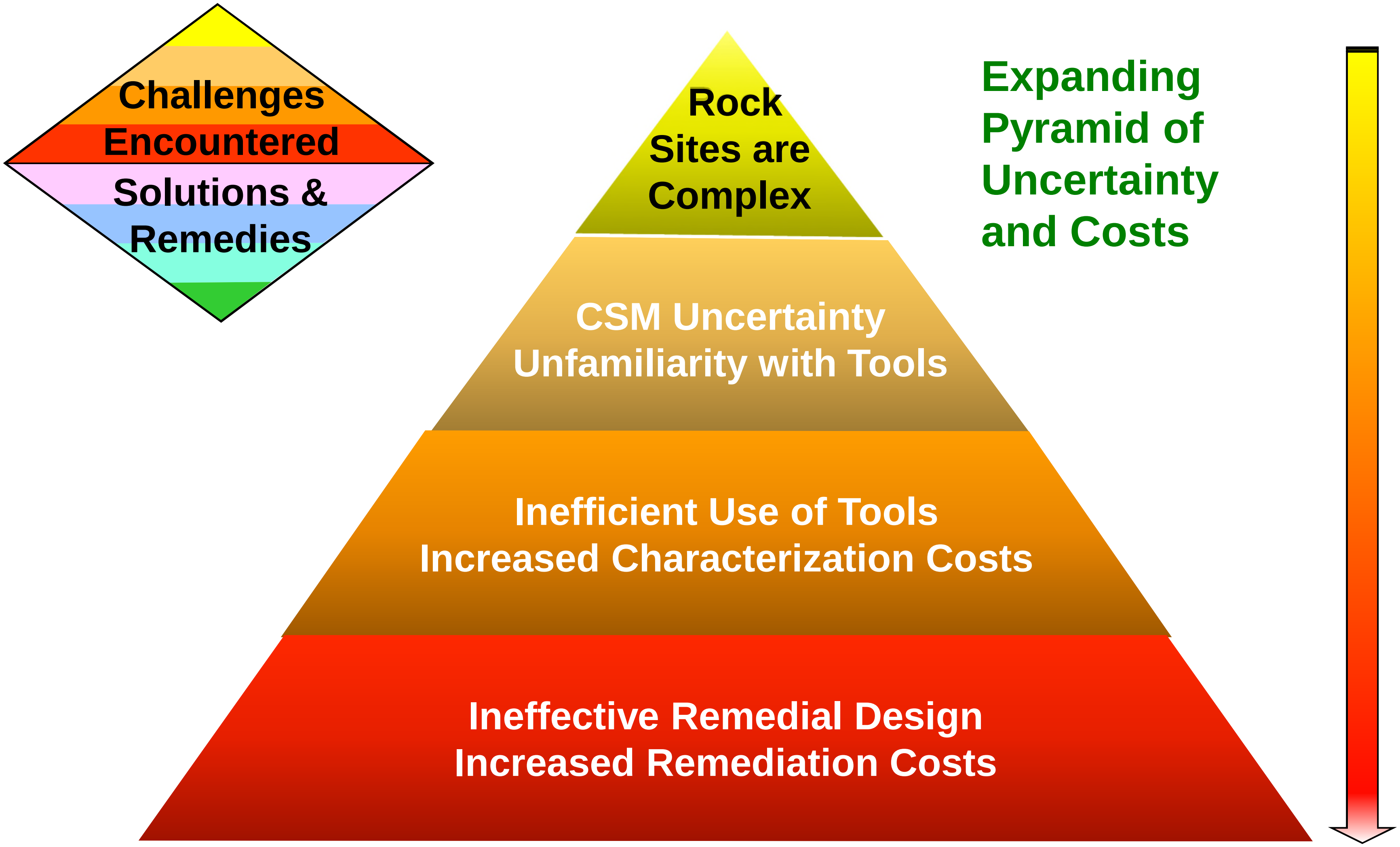
“Black Box Trance”

The mysterious “black box trance” seems to pervade common thinking when it comes to the non-homogeneous, anisotropic realm of groundwater within fractured bedrock.

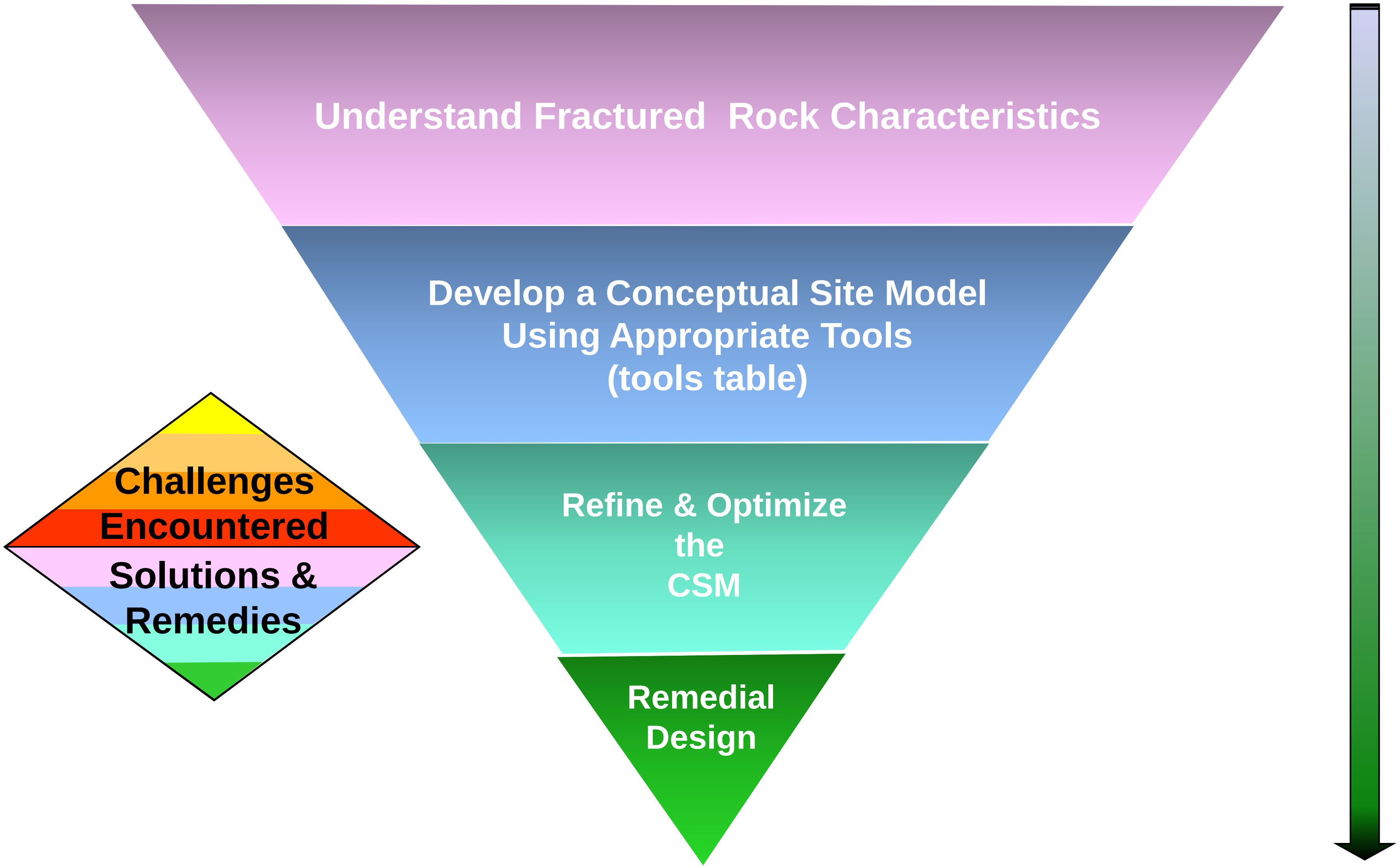


ITRC FracRx-1 Figure 11-3

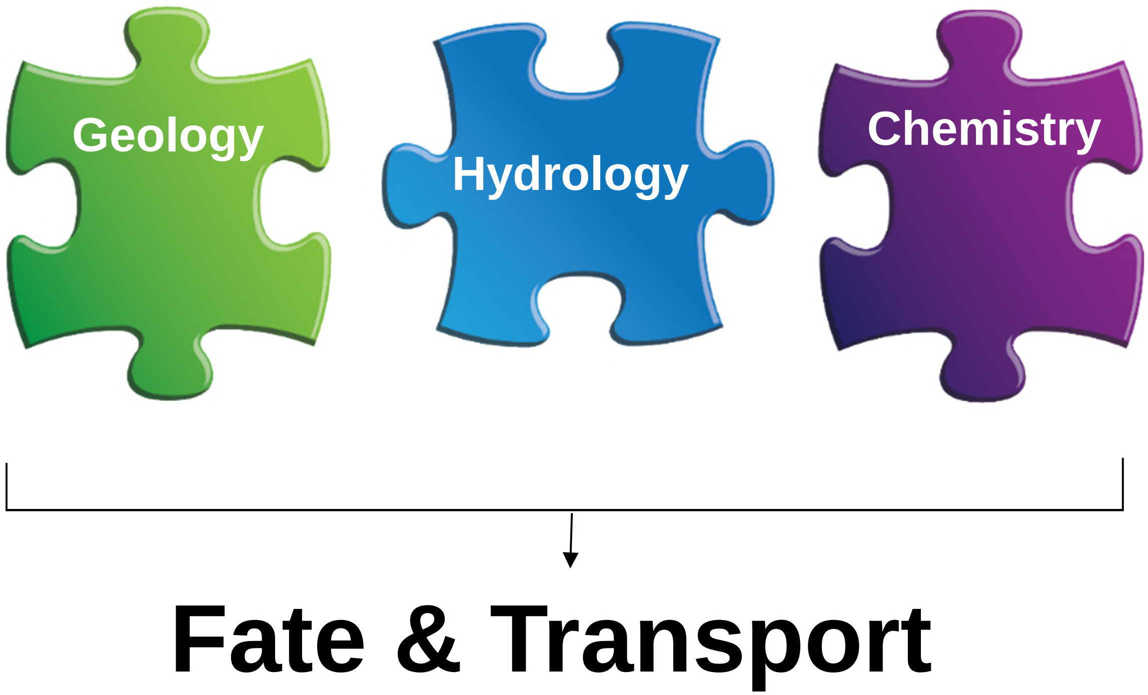
The Problems and Site Challenges with Fractured Rock Remediation



The Solution



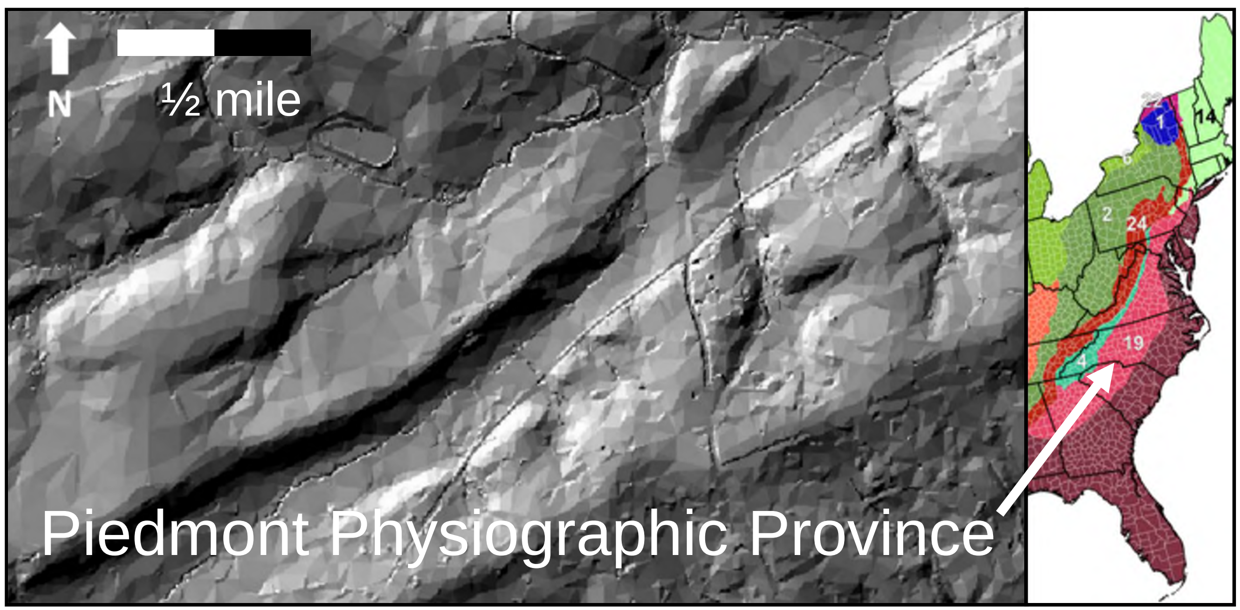
Building a Quality Conceptual Site Model – You Need the Right Pieces



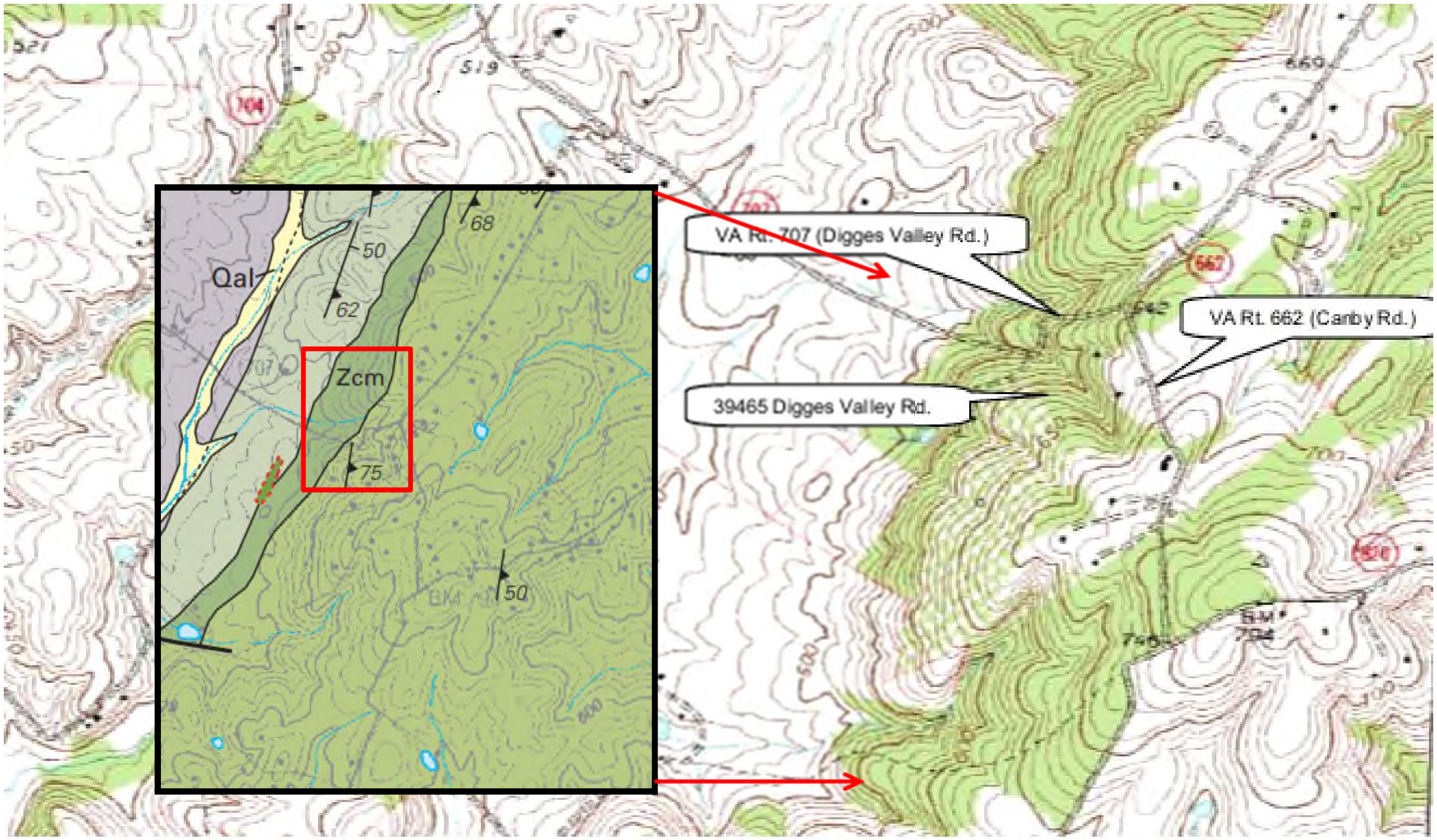
- Key to your success - a team with broad expertise: hydrogeology, structural geology, geophysics, geochemistry, and engineering

Geology: Desk Study & Mapping

- Published data
  - Physiographical province, geologic maps, aerial photography, LIDAR
- Physical characteristics
  - Structure, foliation, fracture patterns, strike & dip



7.5-Minute Quadrangle Geologic Maps



m 200 400 600
yds 200 400 600

Image courtesy of the U.S. Geological Survey

Loudon Co., Virginia, United States 01 Jul 1984

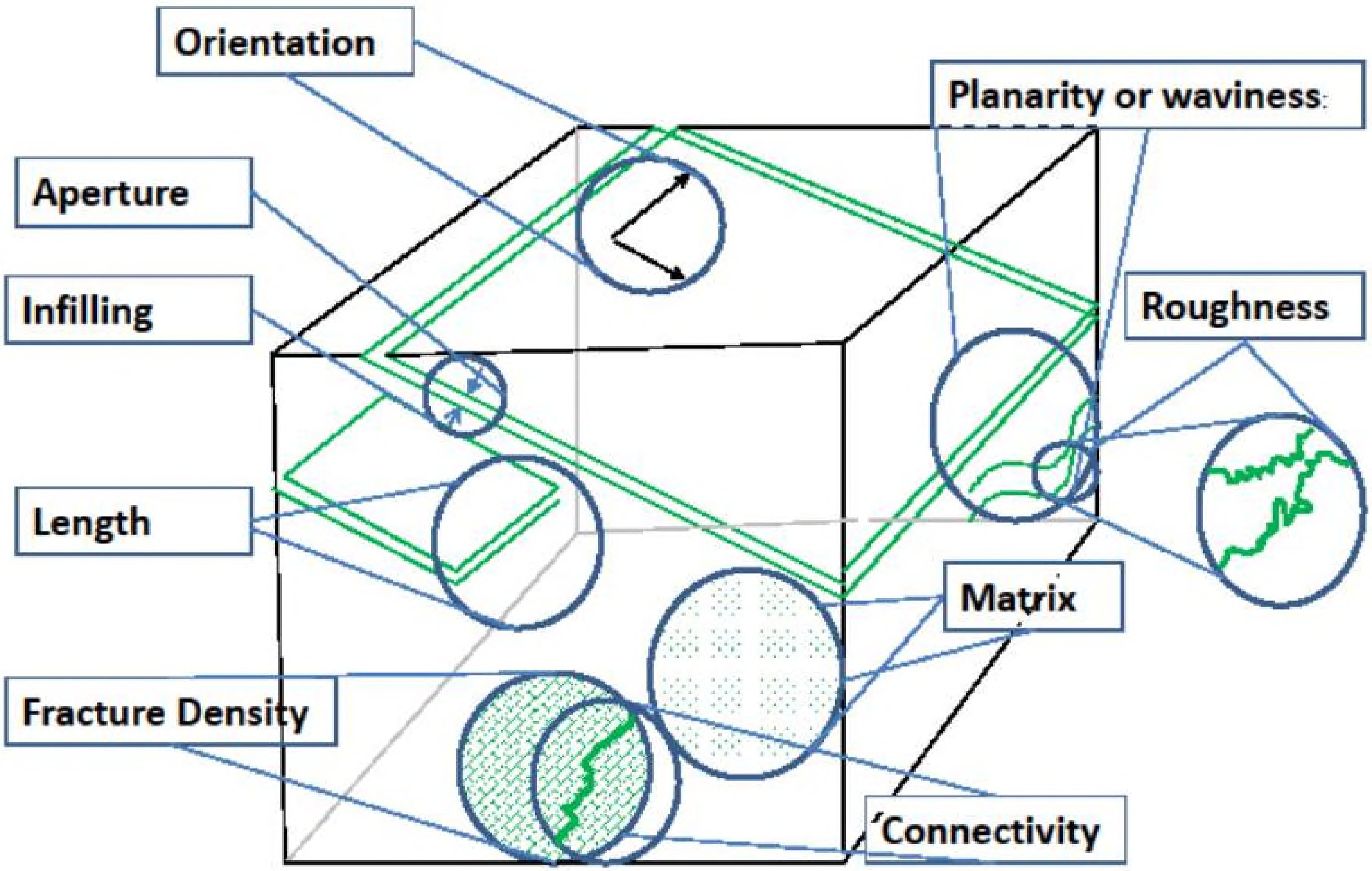
Field Mapping

Photos by K.K.McCandless

Hydrology

- Fluid flow through the bedrock fractures
  - Groundwater
  - LNAPL, DNAPL, other Contaminants

What Bedrock Characteristics Control Fluid Flow?



ITRC FracRx-1 Figure 3-2

Hydrogeologic Characteristics affecting GW Flow through Bedrock Fractures

Infilling

Aperture

Orientation

Planarity or waviness

Length

Photographs by K.K.McCandless

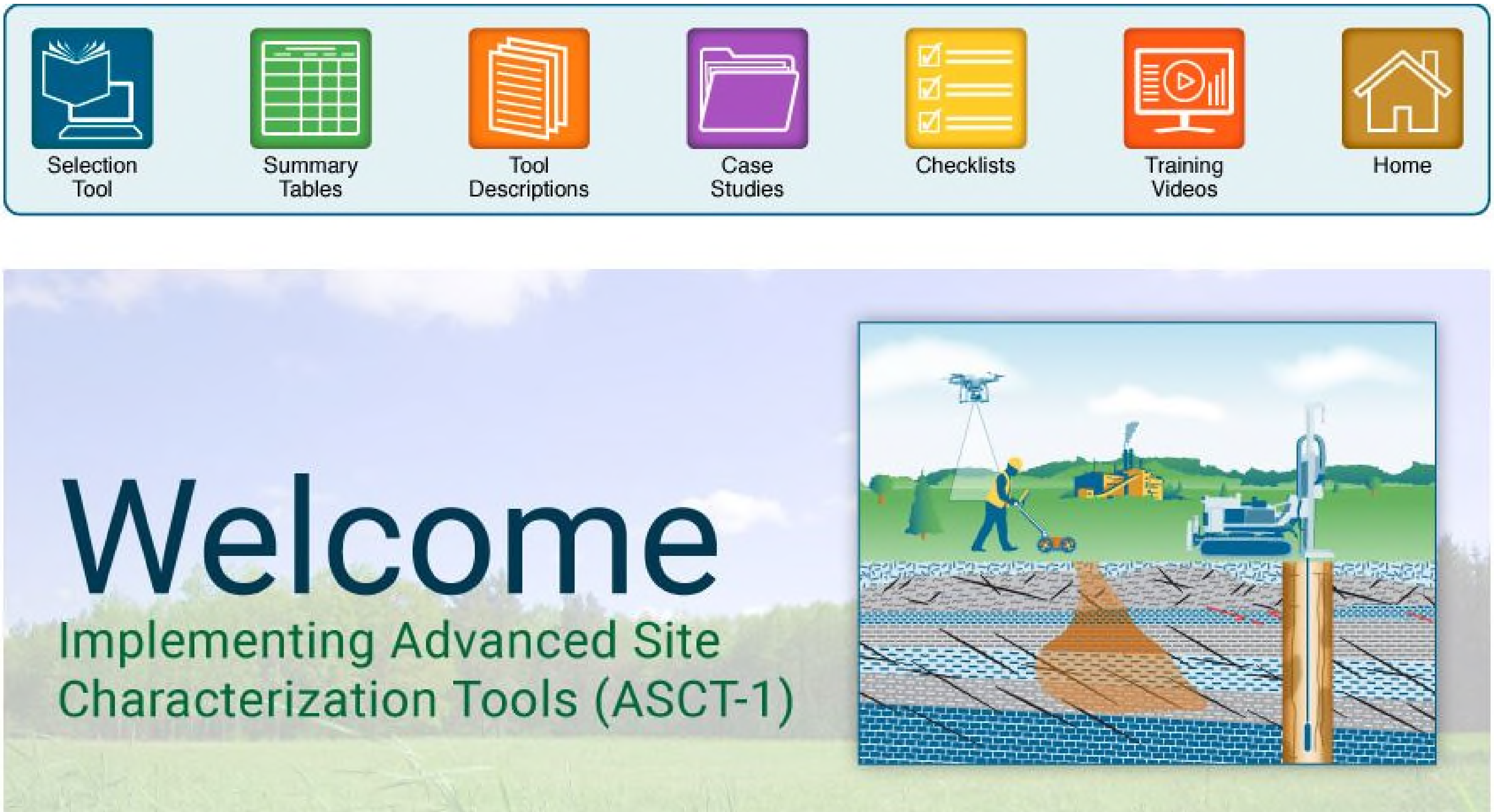
The Tool Table

- Contains over **100** tools
- Sorted by:
  - Characterization objective
    - Geology
    - Hydrogeology
    - Chemistry
  - Effectiveness in media
    - Unconsolidated/Bedrock
    - Unsaturated/Saturated
- Ranked by data quality
  - Quantitative
  - Semi-quantitative
  - Qualitative

Tool	Data Quality	Sub surface		Zone	
		Bedrock	Unconsolidated	Unsaturated	Saturated
Geophysics					
Surface Geophysics					
Ground Penetrating Radar (GPR)	QL - Q	✓	✓	✓	✓
High Resolution Seismic Reflection (2D or 3D)	QL - Q	✓	✓		✓
Seismic Refraction	QL - Q	✓	✓	✓	✓
Multi-Channel Analyses of Surface Waves (MASW)	QL - Q	✓	✓	✓	✓
Electrical Resistivity Tomography (ERT)	QL - SQ	✓	✓	✓	✓
Very Low Frequency (VLF)	QL	✓	✓	✓	✓
ElectroMagnetic (EM) Conductivity	QL	✓	✓	✓	✓
Downhole Testing					
Magnetometric Resistivity	QL	✓	✓		✓
Induction Resistivity (Conductivity Logging)	QL - Q	✓	✓	✓	✓
Resistivity (Elog)	QL - SQ	✓			✓
GPR Cross-Well Tomography	QL - Q	✓	✓	✓	✓
Optical Televiewer	QL - Q	✓	✓	✓	✓
Acoustic Televiewer	QL - Q	✓			✓
Natural Gamma Log	QL - Q	✓	✓	✓	✓
Neutron (porosity) Logging	QL - Q	✓	✓		✓
Nuclear Magnetic Resonance Logging	QL - Q	✓	✓	✓	✓
Video Log	QL - SQ	✓	✓	✓	✓
Caliper Log	QL - Q	✓	✓	✓	✓
Temperature Profiling	QL - Q	✓	✓		✓
Full Wave Form Seismic	Q - QL	✓			✓

Tools Table can be downloaded on the opening page of ITRC FracRx-1

ITRC's Advanced Site Characterization Tools



Free Online Access at: https://asct-1.itrcweb.org/

Data Needed: Geology
Subsurface/Surface: Consolidated /Bedrock
Data Collection: All
Data Quality: All

ITRC ASCT Selection Tool

SEARCH

Tool	Data Needed				Subsurface/Surface			Data Quality			Data Collection		Additional Info		
	Geology	Hydrogeology	Chemistry	Topography	Consolidated /Bedrock	Unconsolidated	Surface	Quantitative	Semi-Quantitative	Qualitative	Invasive	Non-Invasive	Summary Table	Checklist	Case Study
Direct Sensing													DS_ST	DS_CL	
Membrane Interface Probe (MIP)			X		X[1]	X			X		X				9.1 (9.2)
Optical Image Profiler (OIP-UV, OIP-G)			X		X[1]	X			X		X				9.3
Laser Induced Fluoresence (LIF)			X		X[1]	X			X		X				9.4 (9.5/9.6)
Cone Penetrometer Testing (CPT)	X	X			X[1]	X		X			X				9.7
Hydraulic Profiling (Waterloo[APS] and HPT)	X	X			X[1]	X		X	X	X	X				9.8
Electrical Conductivity (EC)	X		X		X[1]	X			X	X	X				
Flexible Underground Technology (FLUTe)		X	X		X			X	X	X	X				
Borehole Geophysics													BG_ST	BG_CL	
Fluid Temperature			X					X			X				9.9
Fluid Resisitivity			X		X				X		X				9.9
Mechanical Caliper	X				X				X		X				9.9
Optical Televiewer (OTV)	X	X			X				X		X				9.9
Acoustic Televiewer (ATV)	X	X			X				X		X				9.9
Natural Gamma	X				X	X			X		X				9.9
Heat Pulse Flow Meter		X							X		X				9.9
Impeller Flowmeter	X	X							X		X				
Electrical Resitivity			X		X				X		X				9.11
Nuclear Magnetic Resonance (NMR)		X	X		X	X		X			X				9.9
Borehole Video	X				X	X				X	X				9.9
Surface Geophysics													SG_ST	SG_CL	
Electrical Resistivity Imaging (ERI) (Tomography (ERT))	X	X	X		X	X			X	X		X			9.13 (9.10/9.15)
Ground Penetrating Radar (GPR)	X	X			X	X				X		X			9.12 (9.11/9.13)
Multichannel Analysis of Surface Waves (MASW)	X				X	X			X	X		X			9.15 (9.14)
Seismic Reflection	X				X	X			X	X		X			
Seismic Refraction	X				X	X			X	X		X			9.14
Frequency Domain Electromagnetics (FDEM)	X	X			X	X			X	X		X			9.11
Time Domain Electromagnetics (TDEM)	X	X	X		X	X		X	X	X		X			9.16
Remote Sensing													RS_ST	RS_CL	
Visual Spectrum Camera				X			X	X		X		X			9.17 (9.18/9.19)
Multispectral Camera			X				X	X		X		X			9.18 (9.17)
Hyperspectral Camera			X				X	X		X		X			
Thermal/Long-Wave Infra-Red Camera	X	X	X				X	X		X		X			9.18 (9.17)
LiDAR				X			X	X				X			
Water Sampling			X				X	X			X				
Air Sampling			X				X	X			X				9.19

X[1] - these methods are typically direct-push, so may only be used in softer consolidated materials or in pre-drilled boreholes in bedrock.

Selection Tool: Filtered Results Table

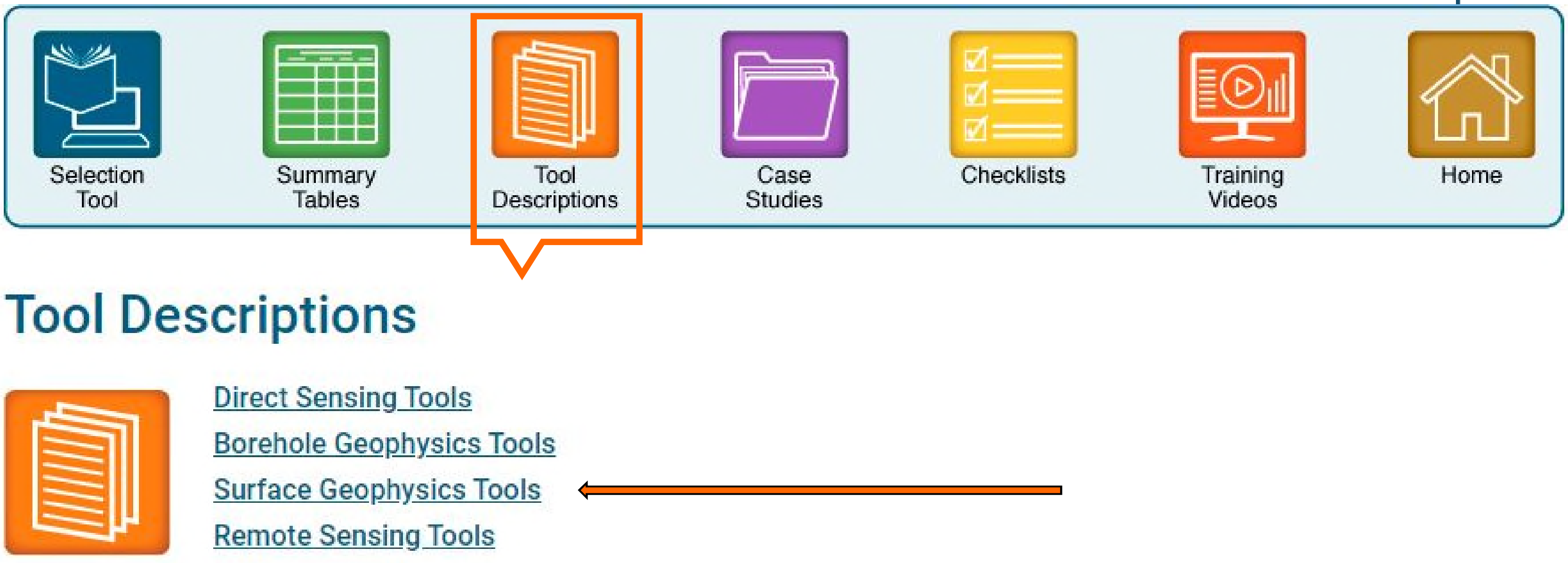
Type: Geology; Subsurface: Consolidated /Bedrock ; Quality: All; Data: Al

Tool	Data N		Additional Info		
	Geology	Hydrogeology	Summary Table	Checklist	Case Study
Direct Sensing			DS_ST	DS_CL	
Cone Penetrometer Testing (CPT)	X	X			9.7
Hydraulic Profiling (WaterlooAPS and HPT)	X	X			9.8
Electrical Conductivity (EC)	X				
Borehole Geophysics			BG_ST	BG_CL	
Mechanical Caliper	X				9.9
Optical Televiewer (OTV)	X	X			9.9
Acoustic Televiewer (ATV)	X	X			9.9
Natural Gamma	X				9.9
Borehole Video	X				9.9
Surface Geophysics			SG_ST	SG_CL	
Electrical Resistivity Imaging (ERI) (Tomography (ERT))	X	X			9.13 (9.10/9.15)
Ground Penetrating Radar (GPR)	X	X			9.12 (9.11/9.13)
Multichannel Analysis of Surface Waves (MASW)	X				9.15 (9.14)
Seismic Reflection	X				
Seismic Refraction	X				9.14
Frequency Domain Electromagnetics (FDEM)	X	X			9.11
Time Domain Electromagnetics (TDEM)	X	X			9.16

Appendix A. Tool Tables and Checklists

Title	Document File Name
ASCT Selection Tool	ASCT Selection Tool
Section 3 – ASCT Direct Sensing	
Tool Summary Table	ASCT Direct Sensing Tool Summary Table
Checklists	ASCT Direct Sensing Checklists (.xlsx version)
Section 4 – ASCT Borehole Geophysics	
Tool Summary Table	ASCT Borehole Geophysics Tool Summary Table
Checklists	ASCT Borehole Geophysics Checklists (.xlsx version)
Section 5 – ASCT Surface Geophysics	
Tool Summary Table	ASCT Surface Geophysics Tool Summary Table
Checklists	ASCT Surface Geophysics Checklists (.xlsx version)
Section 6 – ASCT Remote Sensing	
RPAS Summary Table	ASCT Remote Sensing RPAS Summary Table
Checklists	ASCT Remote Sensing Checklists (.xlsx version)

ITRC’s Advanced Site Characterization Tools (Home Page)

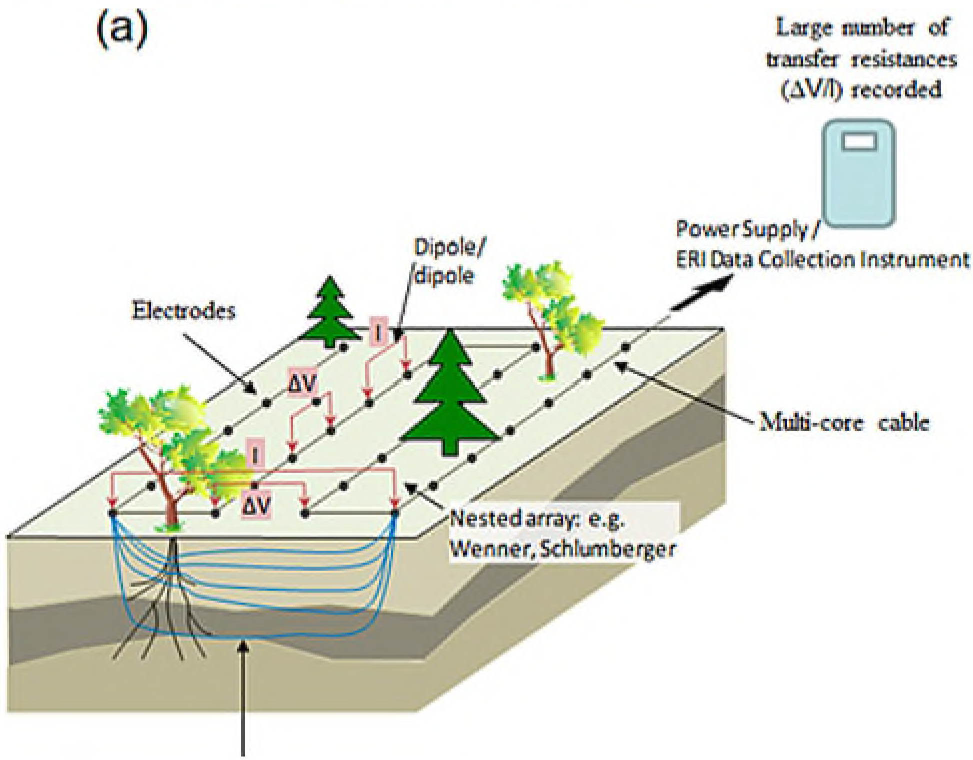


- Surface Geophysics is in Section 5.0; Subheadings for Each Tool:
  - Use
  - Data Collection Design
  - Data Processing and Data Visualization
  - Quality Control
  - Limitations
  - Cost
  - Cast Studies

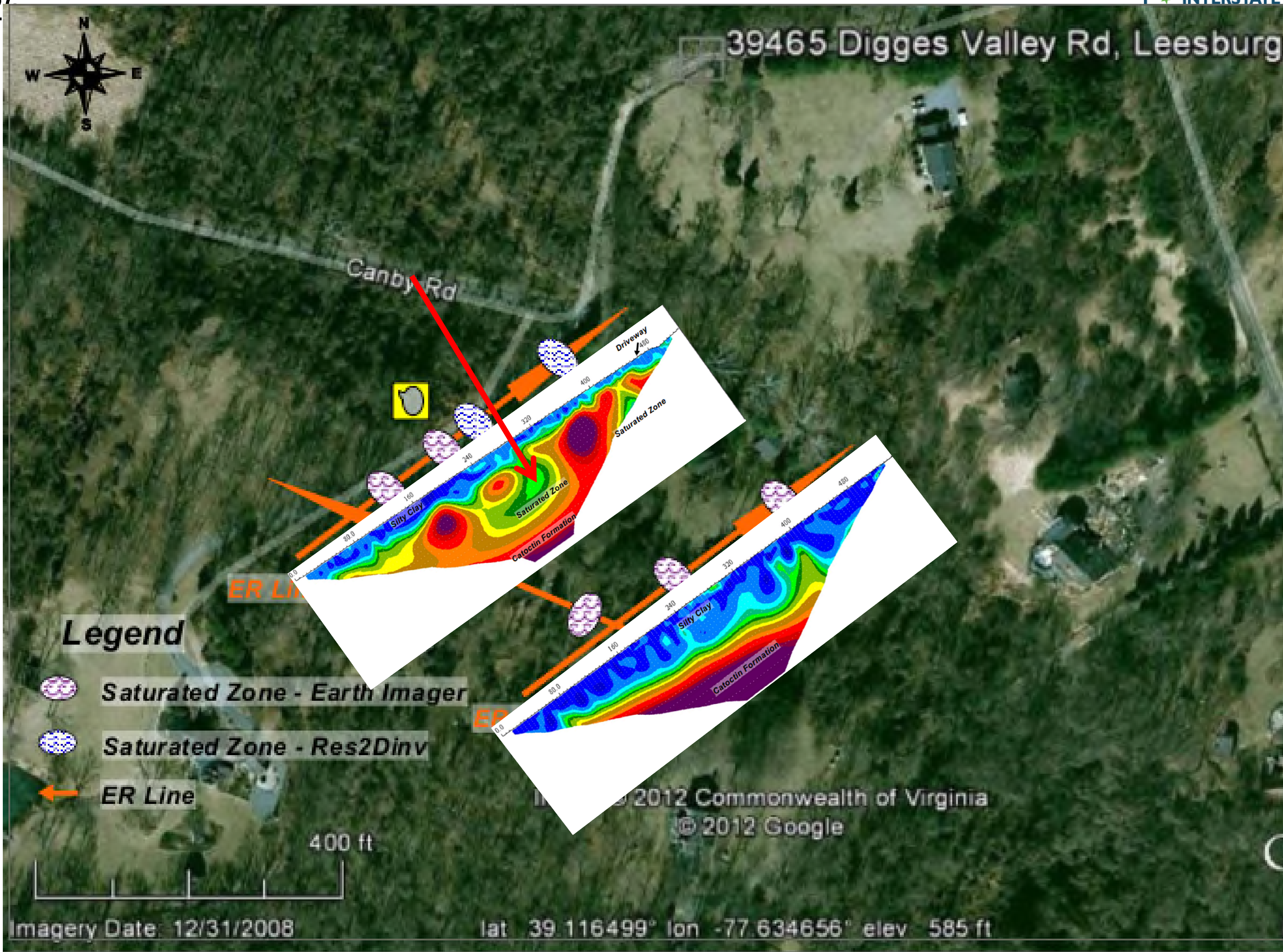
Electrical Resistivity (ER)

Selection Tool | Summary Tables | Tool Descriptions | Case Studies | Checklists | Training Videos | Home

5.2 Electrical Resistivity Imaging



ITRC ASCT-1 Figure 5-2

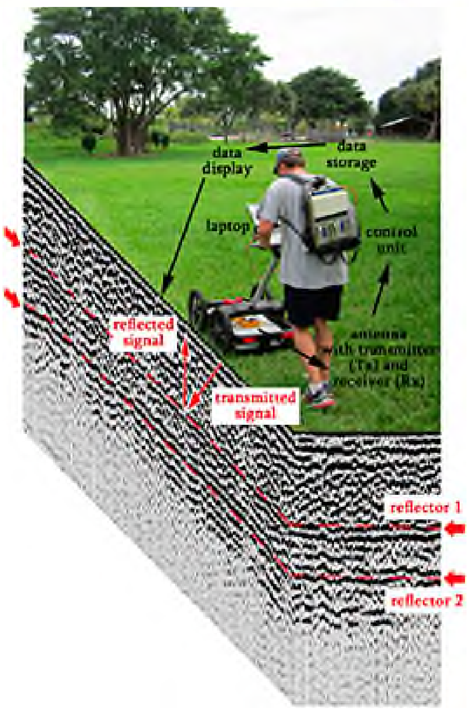


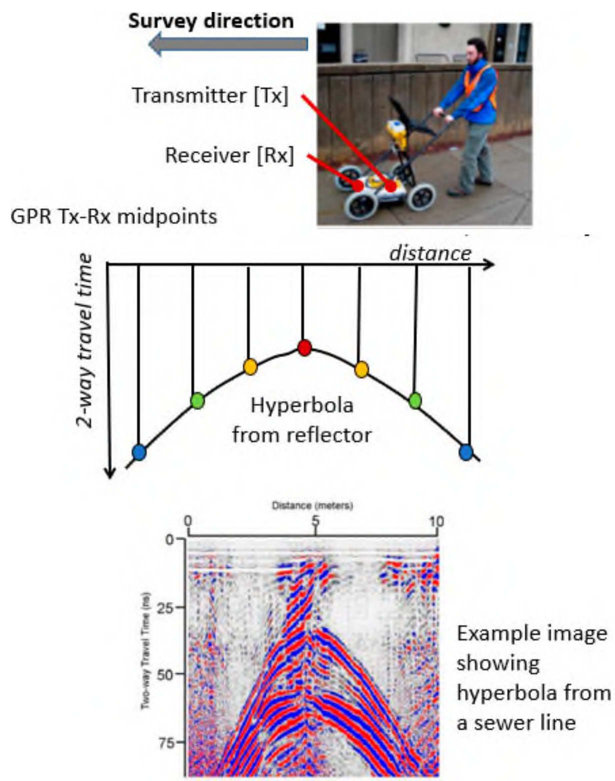
INTERSTATE TECHNOLOGY

Ground Penetrating Radar (GPR)

Selection Tool | Summary Tables | Tool Descriptions | Case Studies | Checklists | Training Videos | Home

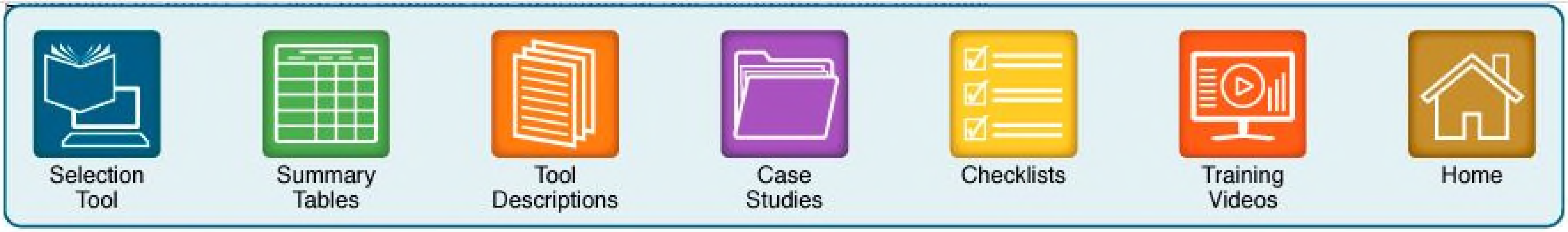
5.3 Ground Penetrating Radar



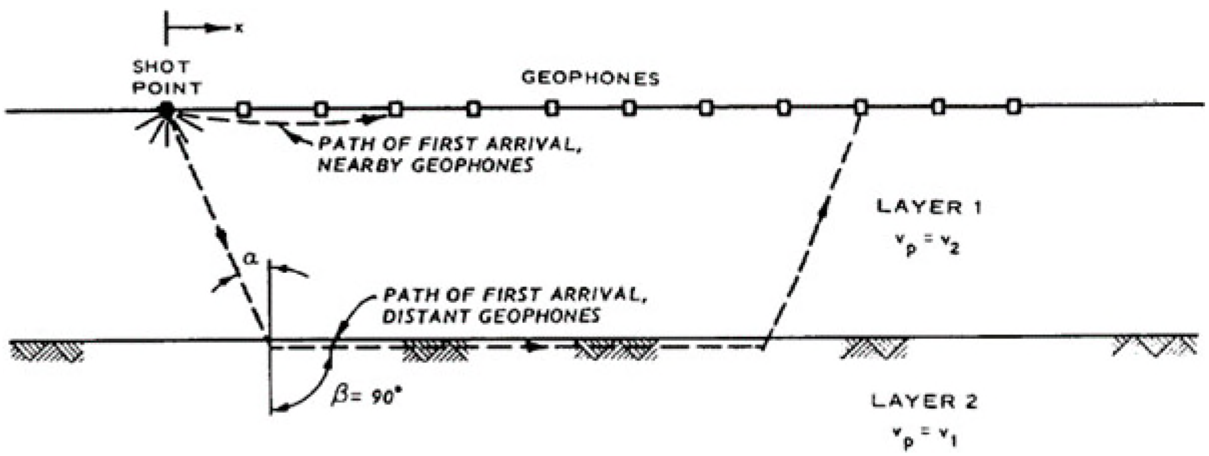


ITRC ASCT-1 Figures 5-4 & 5-5

Seismic Reflection & Refraction

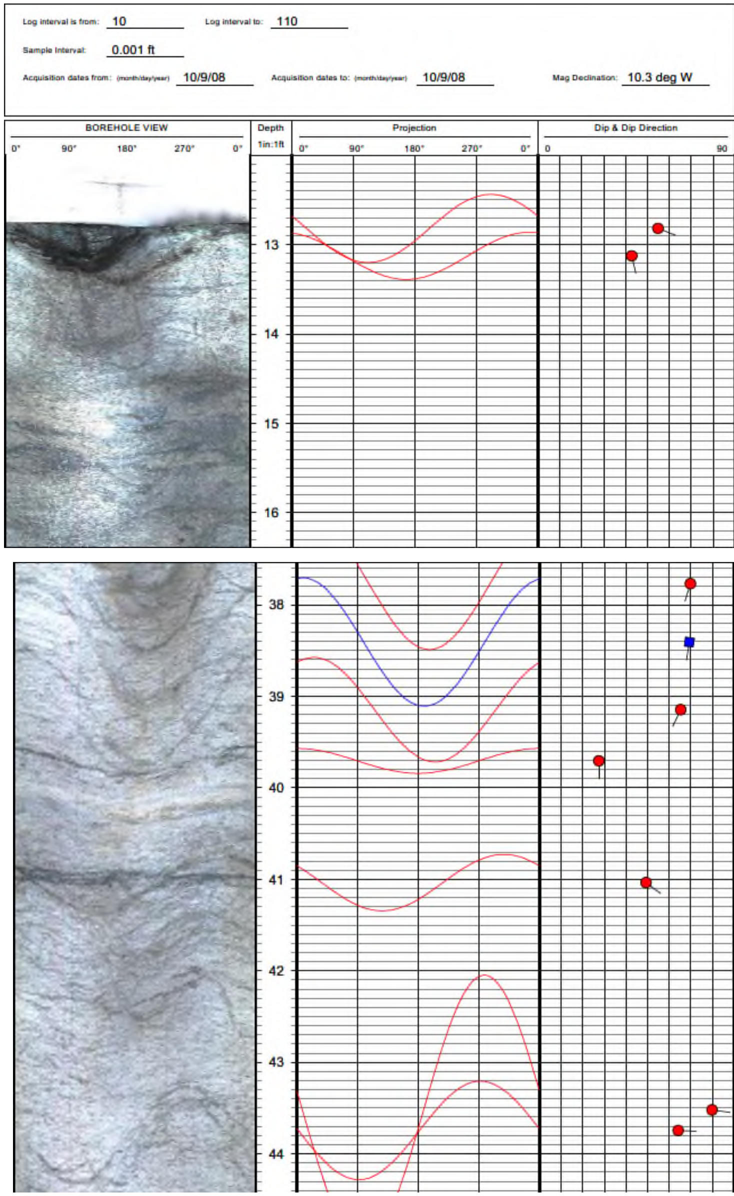


5.4 Seismic Methods



ITRC ASCT-1 Figure 5-9

Optical TeleViewer (OTV)

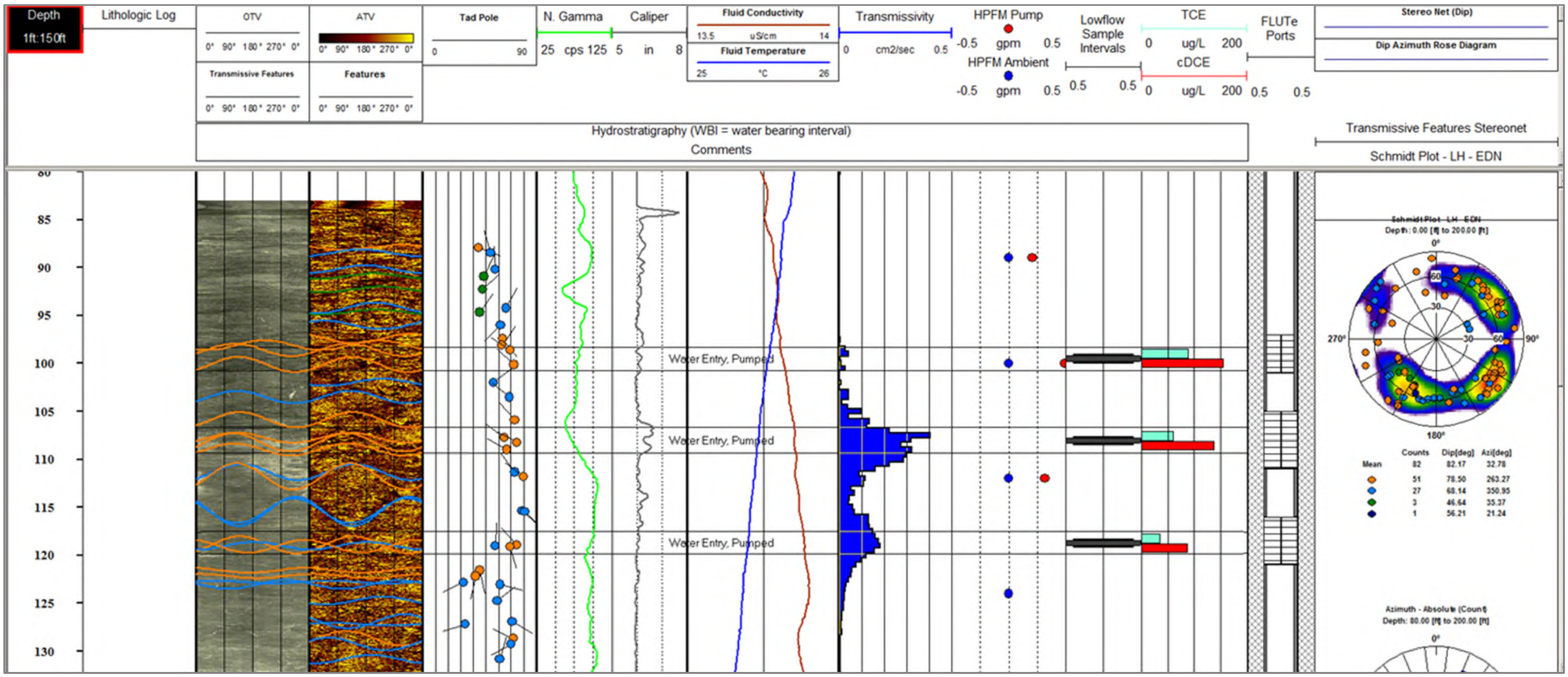


Red Tadpoles: Open Fractures
Blue Tadpoles: Bedding, Banding, Foliation

Strike & Dips fr tadpoles

Well ID	Depth (feet)	Dip Dir. (deg)	Dip (deg)	Type	Strike/Dip (Quadrant)	Strike Azimuth (Right-hand-rule)
BR-6	12.82	111.28	54.9	Foliation	N21E/55SE	21.3
BR-6	13.13	167.32	42.78	Foliation	N77E/43SE	77.3
BR-6	18.38	46.13	50.68	Fracture	N44W/51NE	316.1
BR-6	21.14	90.85	42.09	Foliation	N1E/42SE	0.8
BR-6	23.39	141.75	51.9	Fracture	N52E/52SE	51.8
BR-6	23.61	83.29	66.95	Fracture	N7W/67NE	353.3
BR-6	28.12	305.36	70.52	Fracture	N35E/71NW	215.4
BR-6	30.76	77.81	67.37	Fracture	N12W/67NE	347.8
BR-6	31.1	120.57	41.31	Foliation	N31E/41SE	30.6
BR-6	32.25	114.4	32.14	Fracture	N24E/32SE	24.4
BR-6	33.43	135.6	38.33	Foliation	N46E/38SE	45.6
BR-6	35.71	78.22	15.78	Foliation	N12W/16NE	348.2
BR-6	37.77	196.65	69.82	Fracture	N73W/70SW	106.7
BR-6	38.4	188.88	69.32	Foliation	N81W/69SW	98.9
BR-6	39.14	205.15	65.29	Fracture	N65W/65SW	115.2
BR-6	39.71	179.88	27.45	Fracture	N90E/27SE	89.9
BR-6	41.04	126.63	49.38	Fracture	N37E/49SE	36.6
BR-6	43.52	98.03	79.91	Fracture	N8E/80SE	8.0
BR-6	43.74	91.95	64.09	Fracture	N2E/64SE	2.0
BR-6	45.26	221.95	70.36	Fracture	N48W/70SW	132.0
BR-6	45.62	116.97	52.29	Fracture	N27E/52SE	27.0
BR-6	46.75	114.42	45.61	Foliation	N24E/46SE	24.4
BR-6	48.49	83.34	34.94	Foliation	N7W/35NE	353.3
BR-6	50.53	153.7	41.52	Foliation	N64E/42SE	63.7
BR-6	51.29	347.04	47.5	Fracture	N77E/48NW	257.0
BR-6	55.46	348.05	37.59	Fracture	N78E/38NW	258.1
BR-6	56.93	155.76	55.18	Fracture	N66E/55SE	65.8
BR-6	57.09	34.67	71.42	Fracture	N55W/71NE	304.7
BR-6	57.11	191.89	62.23	Fracture	N78W/62SW	101.9
BR-6	58.26	209.08	67.81	Fracture	N61W/68SW	119.1
BR-6	60.74	196.31	64.25	Fracture	N74W/64SW	106.3
BR-6	61.1	31.42	84.3	Fracture	N59W/84NE	301.4
BR-6	61.19	93.08	56.4	Fracture	N3E/56SE	3.1
BR-6	61.85	82.28	59.25	Fracture	N8W/59NE	352.3
BR-6	62.51	88.05	61.5	Fracture	N2W/62NE	358.1
BR-6	64.43	83.08	53.65	Fracture	N7W/54NE	353.1
BR-6	64.77	192.87	68.32	Fracture	N77W/68SW	102.9
BR-6	65.63	70.82	61.13	Fracture	N19W/61NE	340.8

Integrated Borehole Log - Example



Courtesy John Dougherty

ASCT Web-based Document: Training Videos

Search this website

Navigating this Website
1 Introduction
2 ASCT Implementation
3 Direct Sensing
4 Borehole Geophysics
5 Surface Geophysics
6 Remote Sensing
7 Stakeholder and Tribal Perspectives
8 Regulatory Perspective
9 Case Studies
Additional Information

Selection Tool | Summary Tables | Tool Descriptions | Case Studies | Checklists | Training Videos | Home

ITRC ASCT Training Videos

The Advanced Site Characterization Tools (ASCT) Team has created a series of short videos to help you navigate the document and provide examples of the application of these tools. The videos include:

- An Introduction to ASCT and the Web-Based Technical and Regulatory Guidance Document.
- An example of the application of Direct Sensing Tools (Section 3) using a LIF Survey with UVOST® to develop a representation of an LNAPL Plume.
- A discussion of the 3-D representation of the LNAPL Plume
- An example of the application of Borehole Geophysics tools (Section 4) using a suite of geophysical logs including borehole caliper, fluid temperature/resistivity, natural gamma, Optical Televiewer (OTV), Acoustic Televiewer (ATV), and Heat Pulse Flowmeter (HPFM) to evaluate the bedrock fracture geometry and groundwater quality, and to identify hydraulically active fractures.
- An example of the application of Surface Geophysics tools (Section 5) using seismic refraction, electric resistivity, and multichannel analysis of seismic waves to provide data to locate monitoring well locations in fractured bedrock.
- Example uses of Remote Sensing tools (Section 6).

ITRC's Optimizing Injection Strategies and In situ Remediation Performance

Free Online Access at: https://ois-isrp-1.itrcweb.org

What is Optimization?

- Optimization is the effort (at any clean-up phase) to identify and implement actions that improve effectiveness and cost-efficiency of that phase. (From ITRC-GRO-1)

- Optimizing in situ remediation is:

  The management of risks and uncertainties through sound science and engineering during different stages of in situ remedy planning and implementation

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ITRC's Optimization In Situ Remediation Toolbox

Guidance Layout

Remedial Design Characterization

The Design Wheel

Performance Monitoring & Feedback Loop

Stakeholder Considerations

Optimization Process

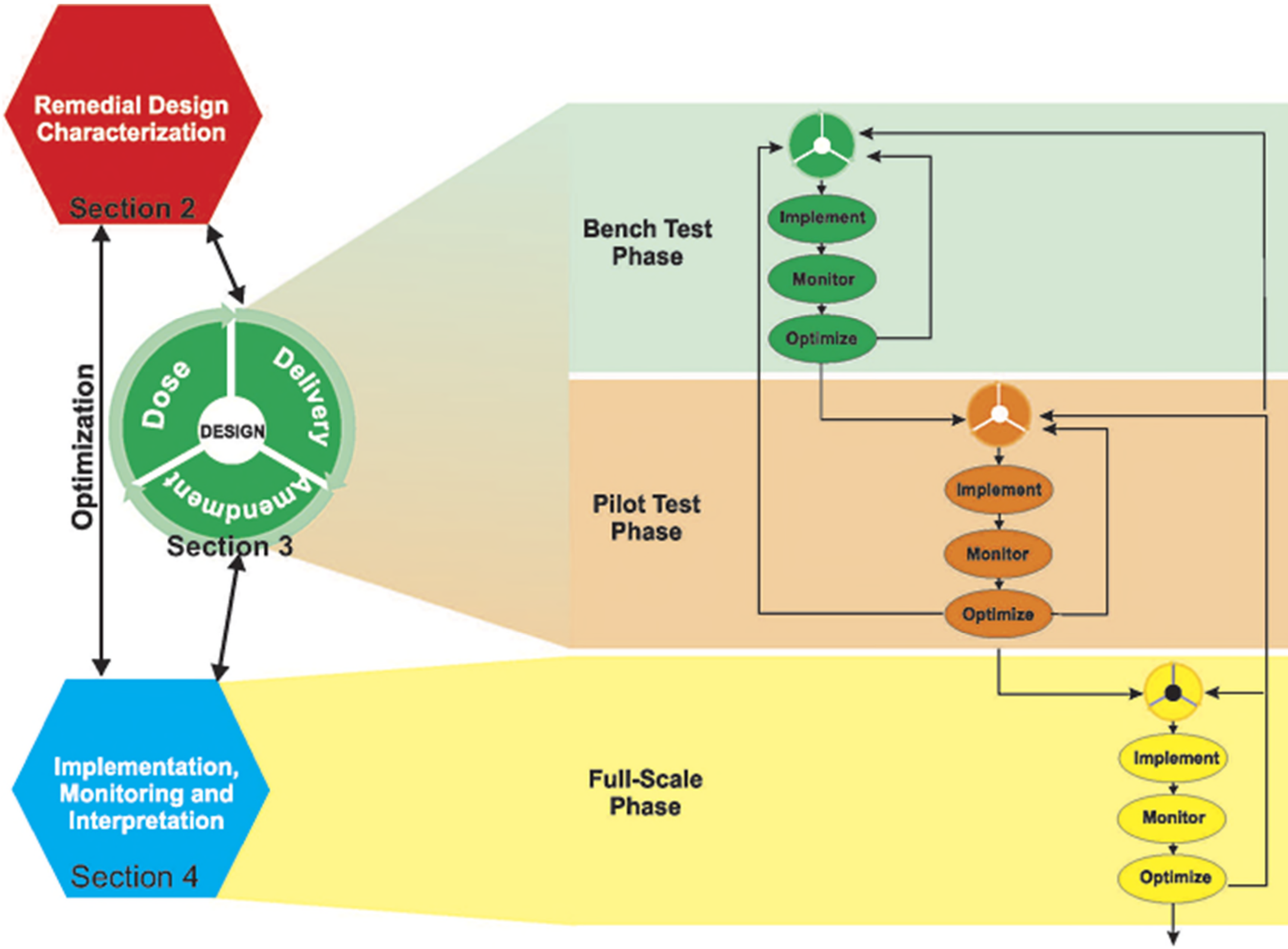
Commonly Encountered Challenges

Amendment Factsheets

Delivery / Injection Screening Matrix & Factsheets

Bench / Pilot Testing Considerations for Design

Iterative Approach to Optimization



ITRC OIS-ISRP-1 Figure 3-1

Remedial Design Characterization (RDC)

WHAT DO WE NEED TO KNOW?

Geology

properties that define flow regimes

Hydrogeology

properties that influence flow and transport

Geochemistry

electron acceptors, competitors, metal mobilization

Microbiology

degradation potential

What Do We Need To Know? The RDC TABLE (2-2)

Parameters	In Situ Approach		Remediation Phase/Step		
	Abiotic	Biotic	Alternatives Screening	Remedial Design	Performance Monitoring
Physical Properties					
Provenance and Mineralogy	M	M	HIGH	MEDIUM	LOW
Stratigraphy	M	M	MEDIUM	HIGH	LOW
Degree of Weathering of Geologic Formation	M	M	MEDIUM	HIGH	LOW
Fracture Representative Aperture and Length	M	M	MEDIUM	HIGH	LOW
Fracture Connectivity / Rock Quality Designation	M	M	MEDIUM	HIGH	LOW
Fracture Orientation	M	M	MEDIUM	HIGH	LOW
Grain Size Distribution	M	M	LOW	HIGH	LOW
Bulk Density	M	M	LOW	HIGH	LOW
Fraction of Organic Carbon	M	M	MEDIUM	HIGH	LOW
Primary and Secondary Porosity	M	M	MEDIUM	HIGH	LOW

ITRC OIS-ISRP-1 Table 2-2

THE "HOVER" TABLE (2-2)

Provenance and mineralogy of a rock or soil matrix are the properties of its physicochemical formation - geologic structure, chemical composition, distribution, and occurrence. They are the governing factors for the physical, flow, and geochemical properties, discussed in Table 2-2, that are necessary to understand and quantify in order to design an optimal in-situ approach.

			Phase/Step		
				lial gn	Performance Monitoring
Physical Properties					
Provenance and Mineralogy	M	M	HIGH	MEDIUM	LOW
Stratigraphy	M	M	MEDIUM	HIGH	LOW
Degree of Weathering of Geologic Formation	M	M	MEDIUM	HIGH	LOW
Fracture Representative Aperture and Length	M	M	MEDIUM	HIGH	LOW
Fracture Connectivity / Rock Quality Designation	M	M	MEDIUM	HIGH	LOW
Fracture Orientation	M	M	MEDIUM	HIGH	LOW
Grain Size Distribution	M	M	LOW	HIGH	LOW
Bulk Density	M	M	LOW	HIGH	LOW
Fraction of Organic Carbon	M	M	MEDIUM	HIGH	LOW
Primary and Secondary Porosity	M	M	MEDIUM	HIGH	LOW

ITRC OIS-ISRP-1 Table 2-2

Flow Properties

Parameters	In Situ Approach		Remediation Phase/Step		
	Abiotic	Biotic	Alternatives Screening	Remedial Design	Performance Monitoring
Flow Properties					
				HIGH	HIGH
				HIGH	HIGH
				HIGH	LOW
De[illegible]	M	M	HIGH	HIGH	LOW
Anisotropy	M	M	HIGH	HIGH	LOW
Effective Porosity	M	M	HIGH	HIGH	LOW
Velocity/Flux	M	M	HIGH	HIGH	HIGH

Anisotropy refers to the directionality of physical aquifer properties. Layered units are generally anisotropic, with continuity of properties and flow in the lateral direction, limited in the vertical direction by low permeability layers.

ITRC OIS-ISRP-1 Table 2-2

Aqueous Geochemistry

ITRC OIS-ISRP-1 Table 2-2

Sulfate is naturally present in many ground waters as a product of geologic formations and their naturally occurring minerals and is often elevated in saline waters. It can also be a manufacturing or agricultural contaminant and a byproduct of persulfate used in some ISCO treatments. Sulfate needs to be carefully considered when selecting a remedial approach, as it can be beneficial and impeding, depending on the technology selected. Natural or pre-remediation sulfate at elevated concentrations can inhibit reductive processes such as reductive dechlorination, because sulfate, at elevated concentrations, is a powerful competitor for electrons. Typically, approximately 400 mg/L or greater sulfate at pre-remediation conditions can be a potential cause for concern (for reductive dechlorination) and special consideration for dosing. On the other hand, sulfate can react in situ with iron to form iron sulfides, which can provide long-term anaerobic chemical reduction. Sulfate reduction is yet another process, where sulfate is used as the primary electron acceptor, that can degrade specific contaminants (i.e., petroleum hydrocarbons).

Parameters	In Situ Approach		Remediation Phase/Step		
	Abiotic	Biotic	Alternatives Screening	Remedial Design	Performance Monitoring
Aqueous Geochemistry					
					HIGH
					HIGH
					HIGH
					MEDIUM
					HIGH
					HIGH
					MEDIUM
					MEDIUM
					MEDIUM
					MEDIUM
					HIGH
	M	M	MEDIUM	HIGH	HIGH
Sulfate (SO_4^{2-})	M	M	HIGH	HIGH	HIGH
	M	M	LOW	MEDIUM	HIGH
Chloride (Cl^-)	L	M	MEDIUM	LOW	MEDIUM
COD (chemical oxygen demand)	L	L	LOW	LOW	LOW
SOD (soil oxidant demand)	M	L	MEDIUM	HIGH	LOW
TOD (total oxidant demand)	M	L	MEDIUM	HIGH	LOW
NOI (natural oxidant interaction)	M	L	MEDIUM	HIGH	LOW
TOC (total organic carbon)	M	M	MEDIUM	HIGH	MEDIUM
Anions, cations	*Individually listed*				
Arsenite (As^{+3})	M	L	LOW	MEDIUM	HIGH
Arsenate (As^{+5})	M	M	MEDIUM	HIGH	MEDIUM
Chromium (Cr^{+3})	M	M	MEDIUM	HIGH	MEDIUM
Chromium (Cr^{+6})	M	L	LOW	MEDIUM	HIGH
Other Heavy Metals (e.g., lead, copper, selenium)	L	L	LOW	MEDIUM	MEDIUM

Commonly Encountered Issues

Commonly Encountered Issues Associated with Remedial Design Characterization – Section 2			
Lithology	**Contaminant**	**Challenges, Lessons Learned, and/or Best Practices**	**Discussion, Document Section, Links**
Bedrock		The amount of contaminant mass sorbed into bedrock secondary porosity.	(ITRC 2017a)
Soil		Lack of understanding of contaminant mass sorbed onto finer grained soils.	Application of MiHPT, MiHPT-CPT coupled with high density soil sampling to determine extent and distribution of contaminant mass (ITRC 2015).
		Limitations of solvent extraction in quantifying mass sorbed into soil.	See Discrete fracture network approach for studying contamination in fractured rock
Groundwater		Variability of K and calculated seepage velocity in contaminated intervals is needed to estimate ROI delivery approaches and residence time within ROI.	Higher resolution slug testing, tracer testing, or pilot testing with monitoring to determine amendment distribution in effective pore space.
		Mischaracterization of mass flux to be targeted in a mass flux reduction strategy.	Higher resolution sampling to identify transmissive zones for injection based on defined targeted K values, contaminant mass, and heterogeneity within the TTZ.
	NAPL or DNAPL	Mischaracterization resulting in not identifying the presence of LNAPL or DNAPL that overwhelms efficacy of in situ treatment.	Evaluate vertical extent of TTZ for presence of LNAPL or DNAPL (ITRC 2015) (ITRC 2018).

ITRC OIS-ISRP-1 Table 1-1 (See Additional Information, Appendix B)
Commonly Encountered Issues with In Situ Remediation

Delivery Methods (Table 3-4)

"Widely used = ●", "Site-specific = ▣", and "Not applicable = NA"

Delivery Technique / Hydrogeologic Characteristics Unified Soil Classification System	Direct Push Injection (DPI) [D1]	Injection Through Wells & Boreholes [D2]	Electrokinetics This is injection through wells. [D3]	Solid Injection [D4]: Hydraulic Delivery Through Wells & Boreholes [D5]	Solid Injection [D4]: Pneumatic Delivery Through Open Boreholes [D6]	Permeable Reactive Barriers (PRBs) [D7]
Gravels	● (Sonic)	●	NA	NA	NA	●
Cobbles	● (Sonic)	●	NA	NA	NA	●
Sandy Soils (Sm, Sc, Sp, Sw)	●	●	NA	▣	▣	●
Silty Soils (Ml, Mh)	●	▣	●	●	●	●
Clayey Soils (Cl, Ch, Oh)	●	▣	●	●	●	●
Weathered Bedrock	●	●	▣	●	●	▣
Competent/Fractured Bedrock	NA	●	NA	▣	▣	▣
K ≤ 10^{-3} to 10^{-4} (Low Perm Soils)	●	▣	●	●	●	●
K ≥ 10^{-3} (High Perm Soils)	●	●	▣	▣	▣	●
Depth > Direct Push Capabilities	NA	●	▣	▣	▣	▣

Appendix D. Injection Fact Sheets

Table of Contents

D1 Direct Push Delivery Methods
D1.1 Types of Equipment
D1.2 Types of Delivery
D1.3 Advantages
D1.4 Limitations

D2 Injection Through Wells & Boreholes
D2.1 Types of Equipment
D2.2 Types of Delivery
D2.3 Advantages
D2.4 Limitations

D3 Electrokinetics Delivery Methods
D3.1 Types of Equipment
D3.2 Types of Delivery/Electrodes
D3.3 Advantages
D3.4 Limitations

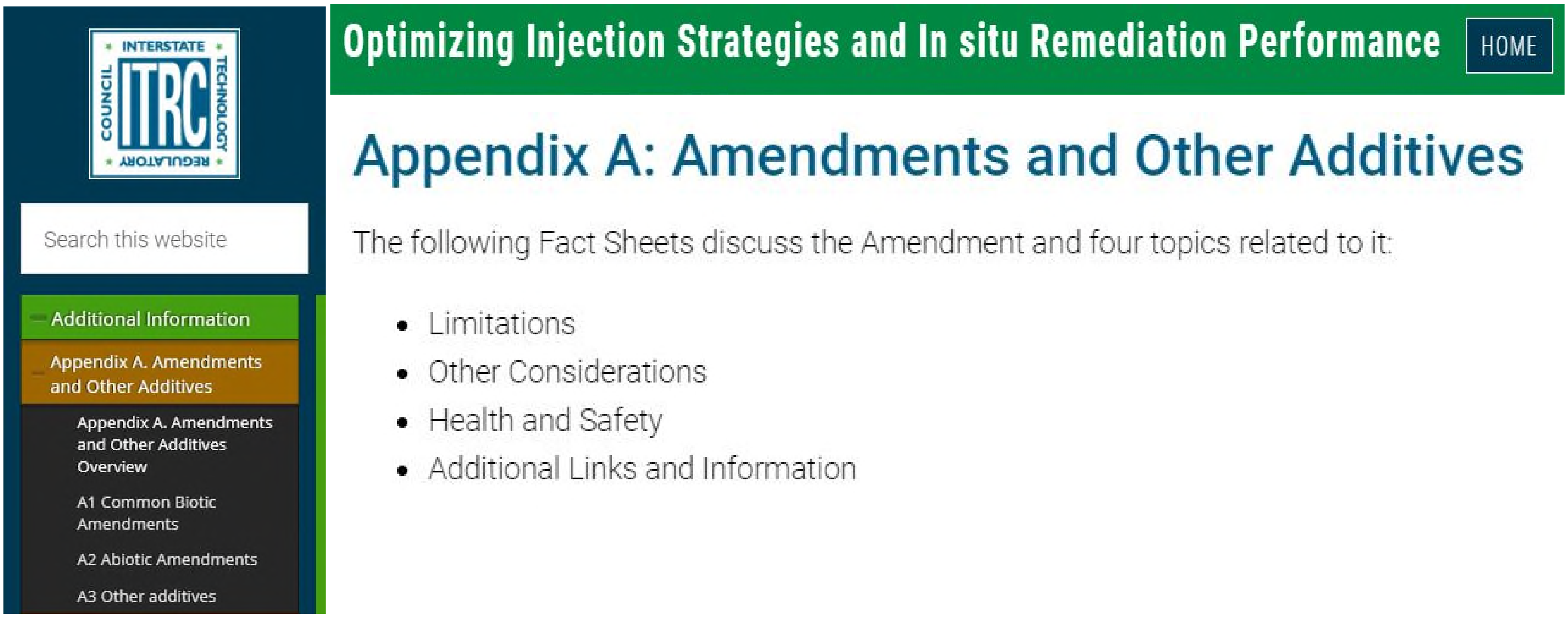
D4 Solid Injection Principles
D4.1 Fracture-Based Delivery
D4.2 Governing Principles
D4.3 Differences between Hydraulic and Pneumatic Fracturing

D5 Hydraulic Fracturing-Based Delivery Methods
D5.1 Types of Equipment
D5.2 Types of Delivery
D5.3 Advantages
D5.4 Limitations

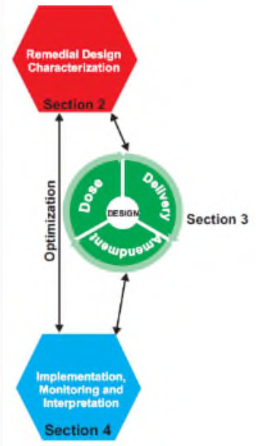
D6 Pneumatic Fracturing-Based Delivery Methods
D6.1 Types of Equipment
D6.2 Types of Delivery
D6.3 Advantages
D6.4 Limitations

D7 Permeable Reactive Barrier Construction
D7.1 Types of Equipment
D7.2 Types of Delivery
D7.3 Advantages
D7.4 Limitations

Amendment Factsheets



Overall Course Summary – Call to Action



- RDC is key to developing detailed Conceptual Site Model
- Design of amendment, dose and delivery is an iterative process with multiple feedback loops
- Monitoring and data analysis inform adaptive implementation and feedback optimization

Appendix F Checklist

Performance Evaluation & Optimization of In situ Remediation

Predictable and Optimized Outcome for In Situ Remedies using sound science and engineering

ITRC's TPH Risk Evaluation at Petroleum-Contaminated Sites

Free Online Access at: https://tphrisk-1.itrcweb.org/

The Use of Geophysics to Determine Placement of 5 Bedrock Monitoring Wells to Eliminate Data Gaps

Vicki Voisard

Commonwealth of Kentucky
Department for Environmental Protection
Division of Waste Management
Underground Storage Tank (UST) Branch

USTB
KENTUCKY UNDERGROUND STORAGE TANK BRANCH

Kentucky UNBRIDLED SPIRIT

KENTUCKY ENERGY & ENVIRONMENT CABINET

A CASE STUDY IN BOYLE COUNTY, KY

Many underground storage tank (UST) sites in KY are located in karst areas with nearby creeks and springs and this site has all 3.

Site map courtesy by Shield Environmental

Site History

- On March 20, 2014 two USTs were removed at this site and it was noted there was visible soil staining on the pit walls and notable petroleum odor.
- Depth of pit was 5.5’ and bedrock was encountered at 3’.
- In August 2015 twelve soil borings were advanced to refusal at the top of bedrock, which ranged from 3.70 to 6.0 feet below ground surface (ft bgs).
- In February 2018, it was determined that data gaps related to the subsurface conditions at this site needed to be identified. It was decided a Geophysical Investigation was needed to place bedrock wells.

SITE GEOLOGY

The unconsolidated material beneath the site is predominately clayey-silty soil. The first bedrock unit encountered is the middle Devonian-aged New Albany Shale, which is underlain by the Boyle Formation. The Boyle formation is described as dolomite conglomerate, dolomite/dolomitic limestone and limestone.

Why Surface & Borehole Geophysics?

Several items were consider when making decisions on a path forward for this particular site.

- Size of the lot (165’ x 105’)
- Thickness of the New Albany Shale
- Depth to the Limestone/Dolomite Contact
- Mitchell’s Spring to the North

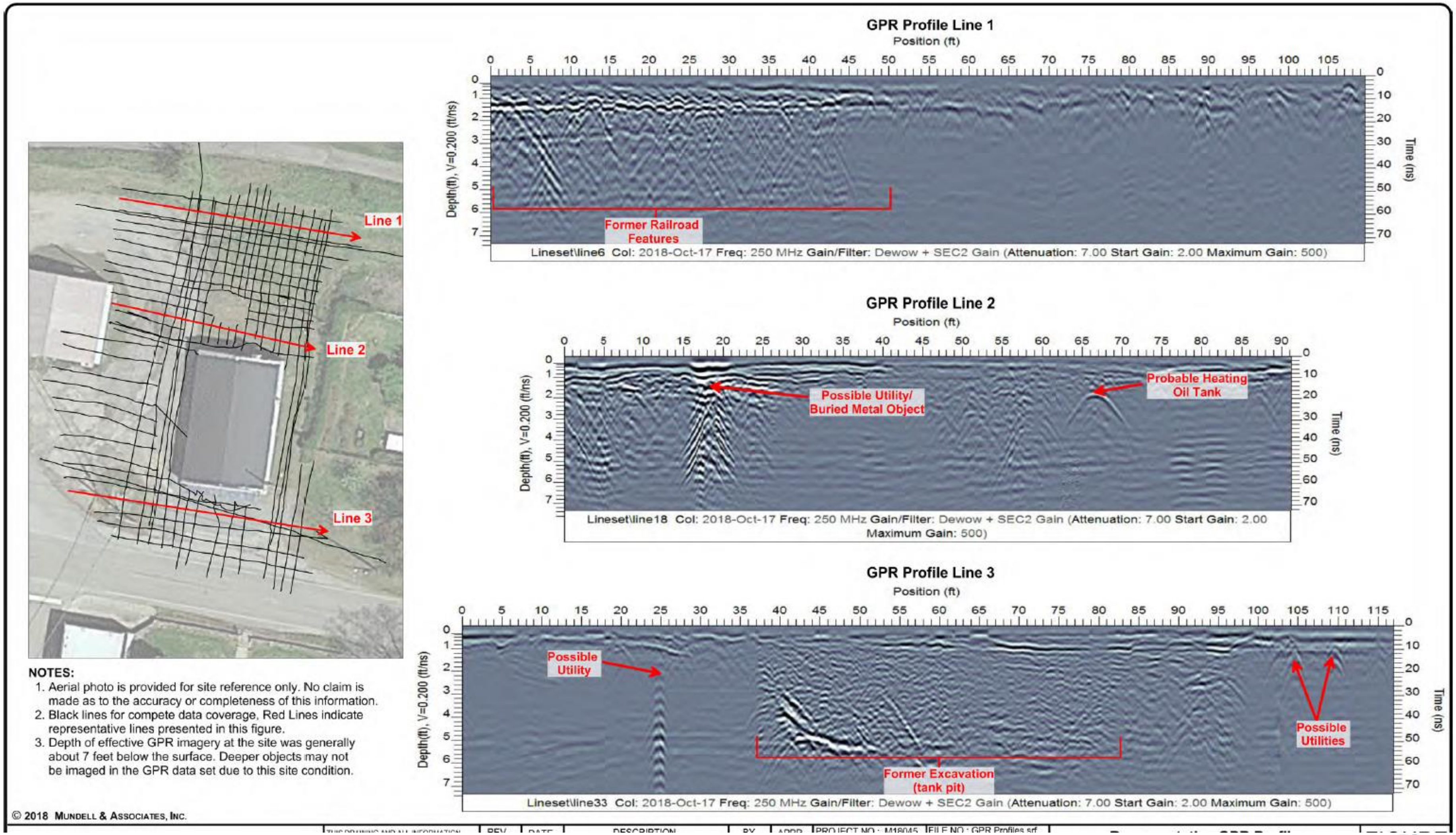
Using Surface Geophysics we would be able to determine the best locations for the 5 bedrock monitoring wells and with the Borehole Geophysics we would be able to properly screen the wells at the appropriate depths.

SURFACE GEOPHYSICS

The following Technologies and instruments were used for the surface geophysics investigation in order to determine buried items.

- Terrain conductivity with localized ground penetrating radar (GPR).
- CDM Explorer is a hand-held, digital, multi-antenna sensor.

GPR Imagery about 7' bgs



Graphical data representations courtesy of Mundell & Associates

Surface Geophysics

➢Seismic Refraction Profiling

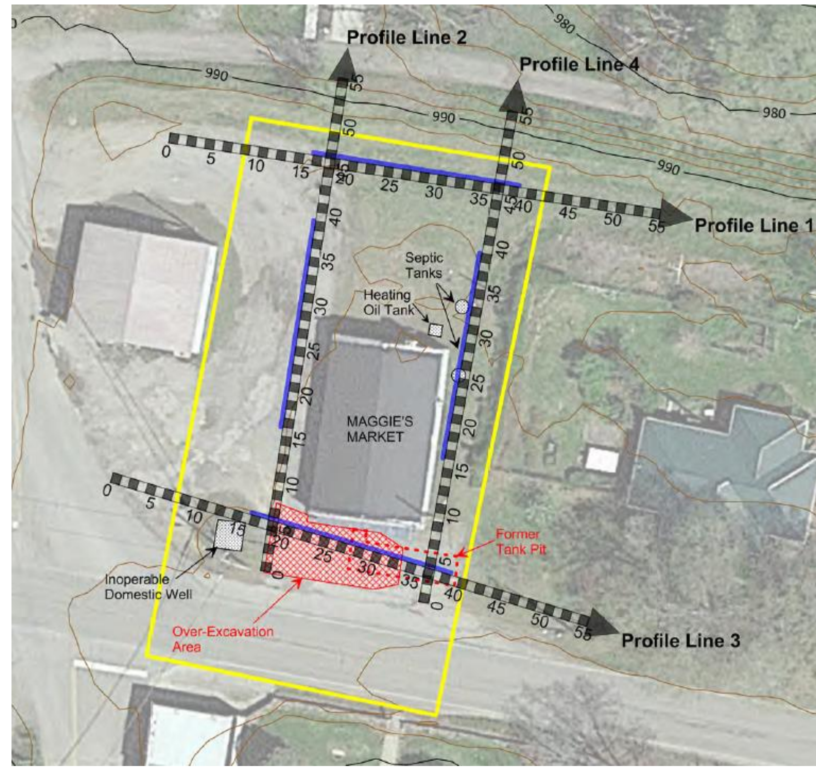
In order to determine geologic layers a seismic line with geophones (3’ spacing) and a sledgehammer used to hit onto a metal plate sending shockwaves down to refract along the boundaries between geologic layers and return to the surface.

Kentucky
UNBRIDLED SPIRIT

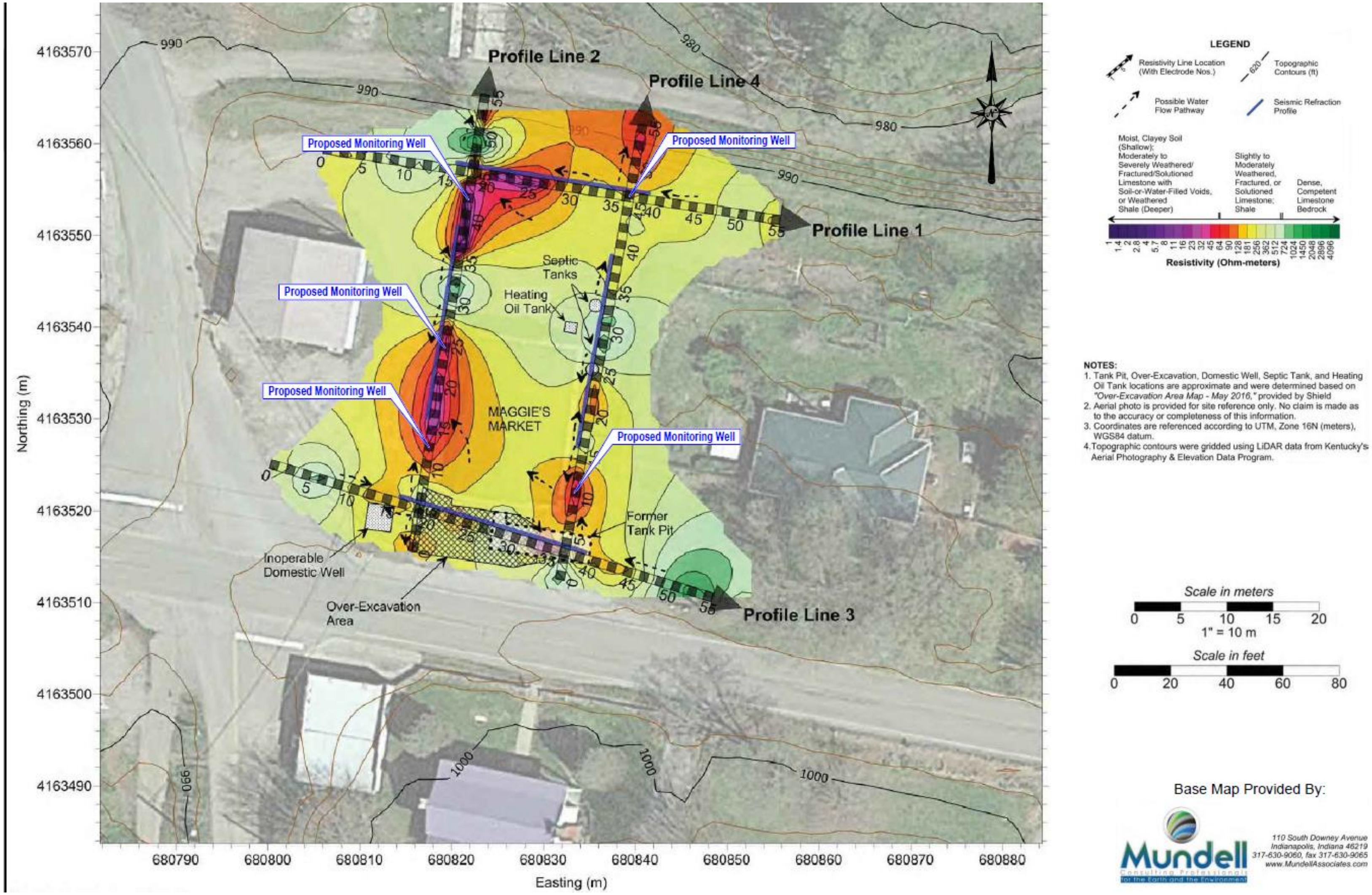
Surface Geophysics

- 2-Dimensional resistivity

Profile Line 1



Proposed Monitoring Well Locations



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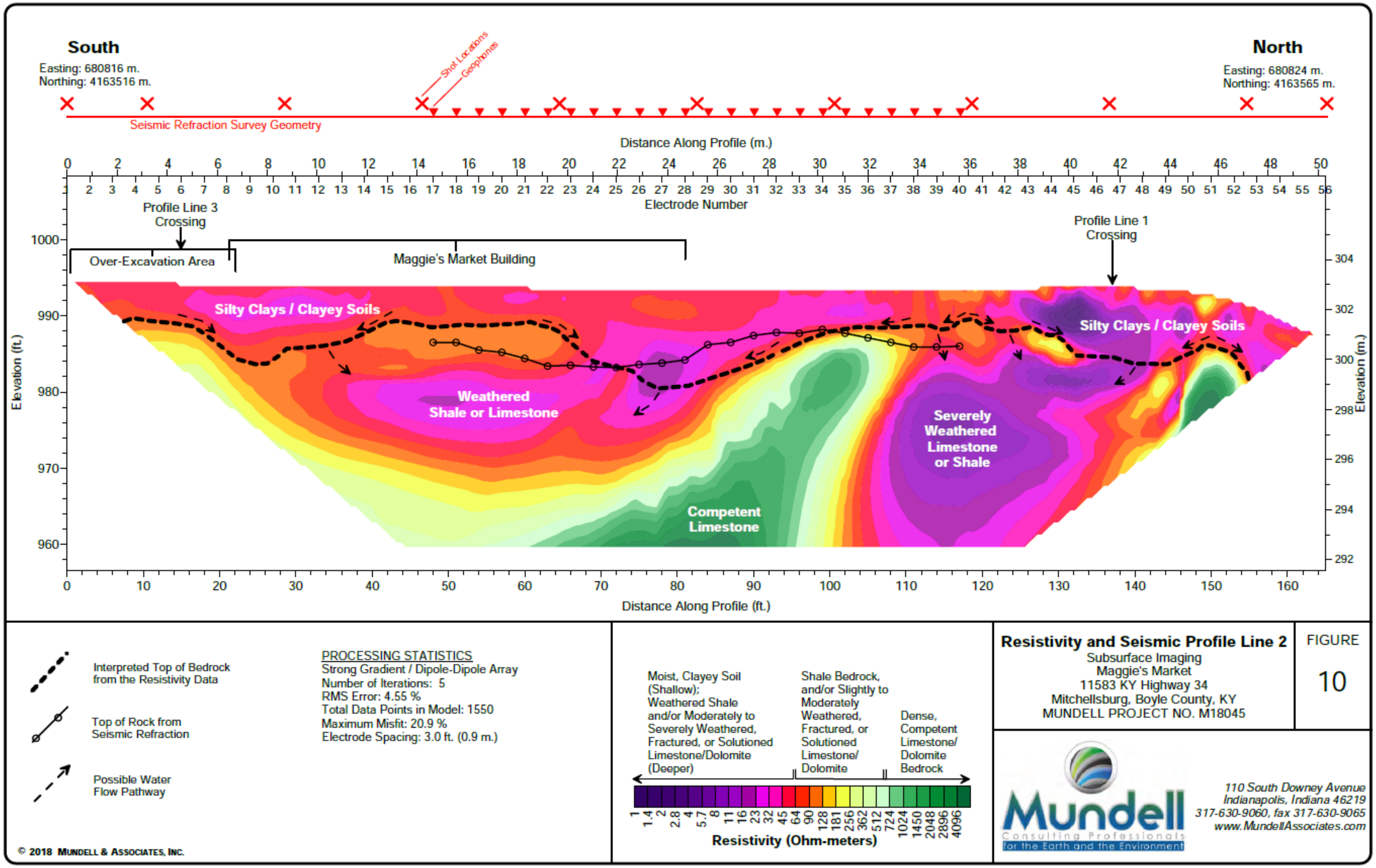
Resistivity and Seismic Profile Line 2



Kentucky UNBRIDLED SPIRIT

Surface Geophysics Results

- Miscellaneous metallic debris may be present in the shallow subsurface on the western side of the building.
- Indication of undulating bedrock surface (between about 4 to 18 ft bgs).
- The topographic high of the bedrock surface is in the southern portion of the site.
- A potential preferential groundwater/contaminant mass pathways exist at depth in the vicinity of the former tank pit.

Drill 5 MWs into Bedrock

- Overburden was drilled through to bedrock and 6" PVC outer casings installed
- An Air Rotary Rig was used in the bedrock to advance the hole to 25' bgs

MW-3 located on the NW corner of the property

MW-5 located near the SE corner of the building

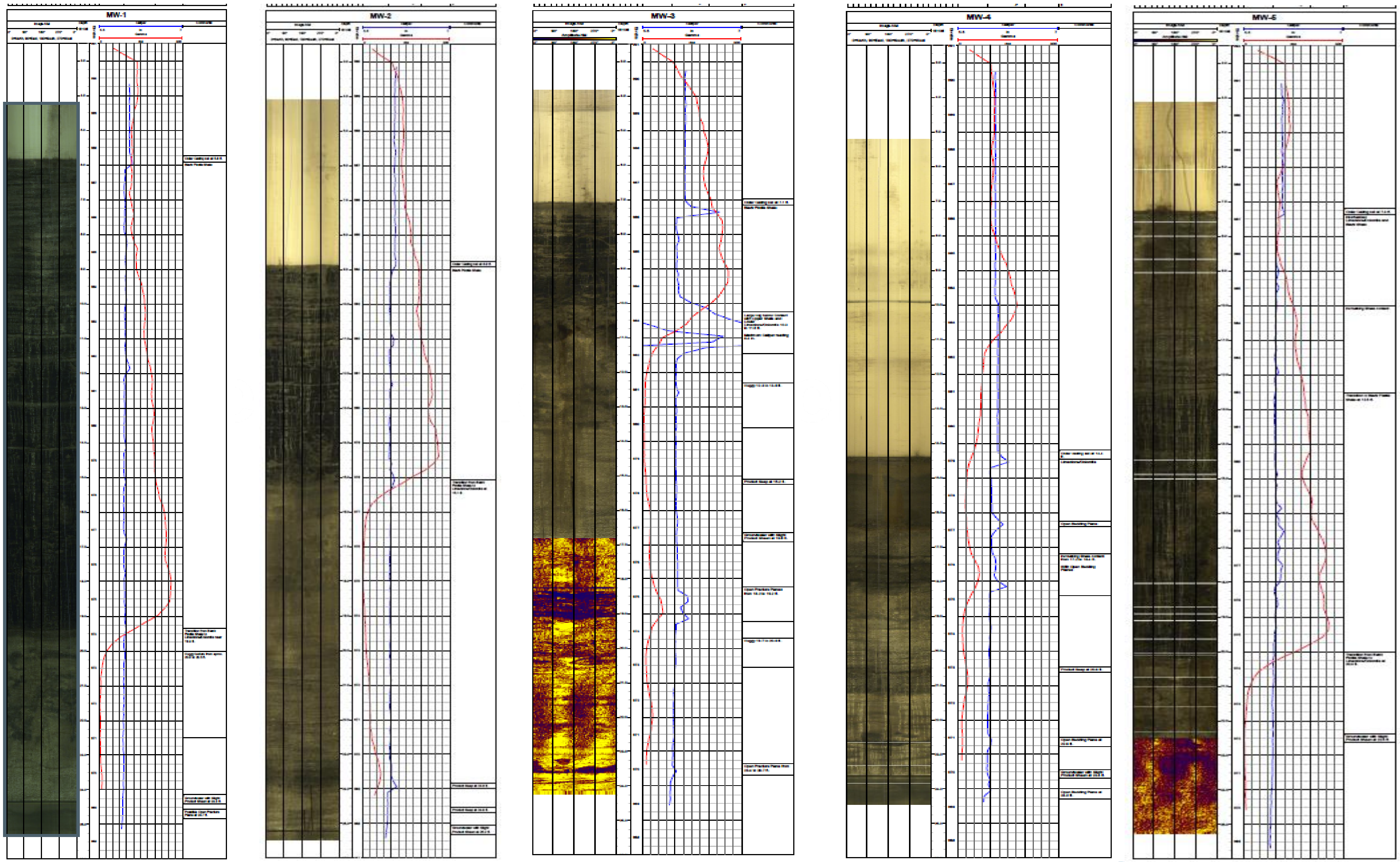
Borehole Geophysics

- The following Borehole Geophysical Methods were used in the investigation:
- **Three-Arm Caliper** – Establishes diameter changes along the borehole profile. Locations of fracture zones can be interpreted.
- **Natural Gamma** – uses a natural gamma probe to provide information about the geologic layers. Clay minerals are the most commonly observed natural gamma emitters.

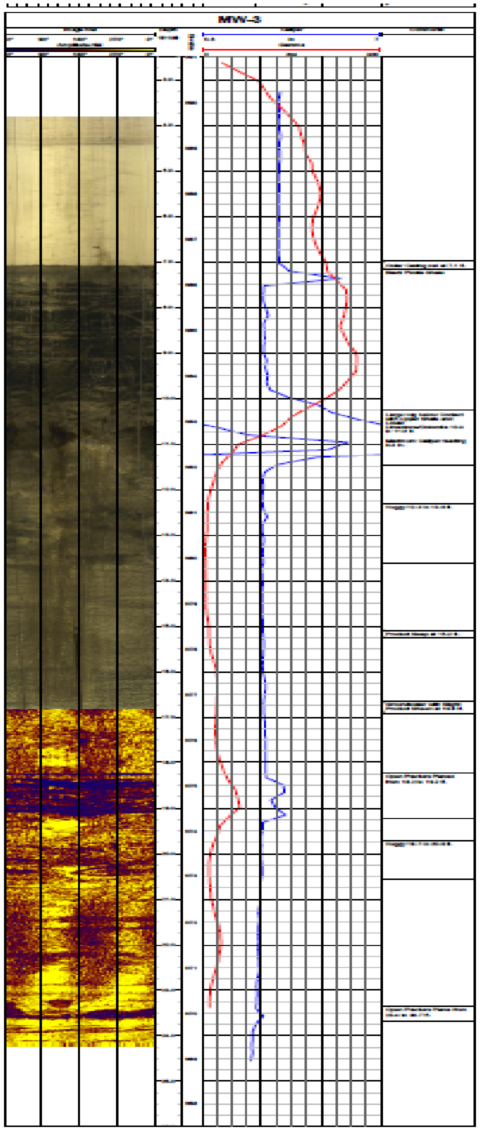
cont. Borehole Geophysics

- **Acoustic Televiewer** – Used to image the bedrock fractures within the borehole.
- **Optical Televiewer** – Provide detailed, oriented, structural and geological information for the dry sections in each borehole.

Geophysical Borehole Logs



Geophysical Borehole Log MW-3

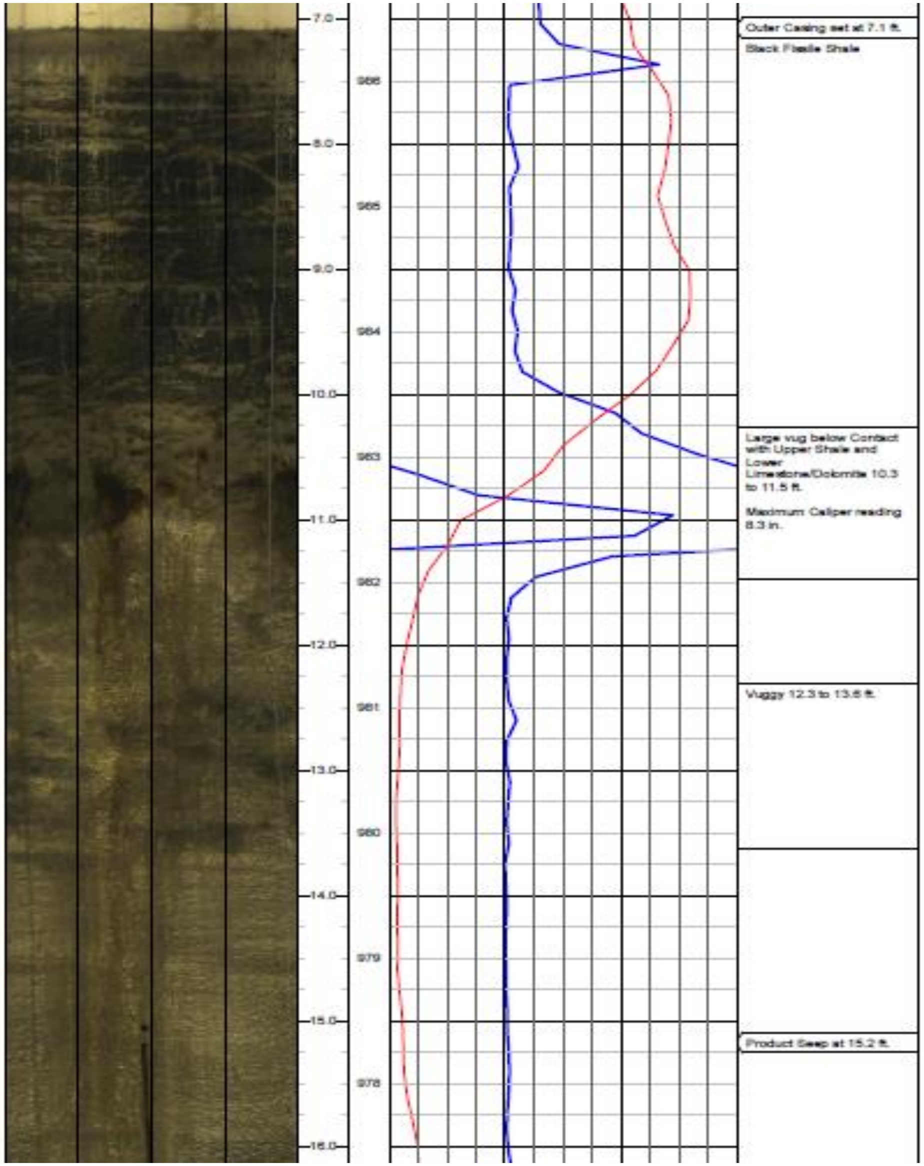


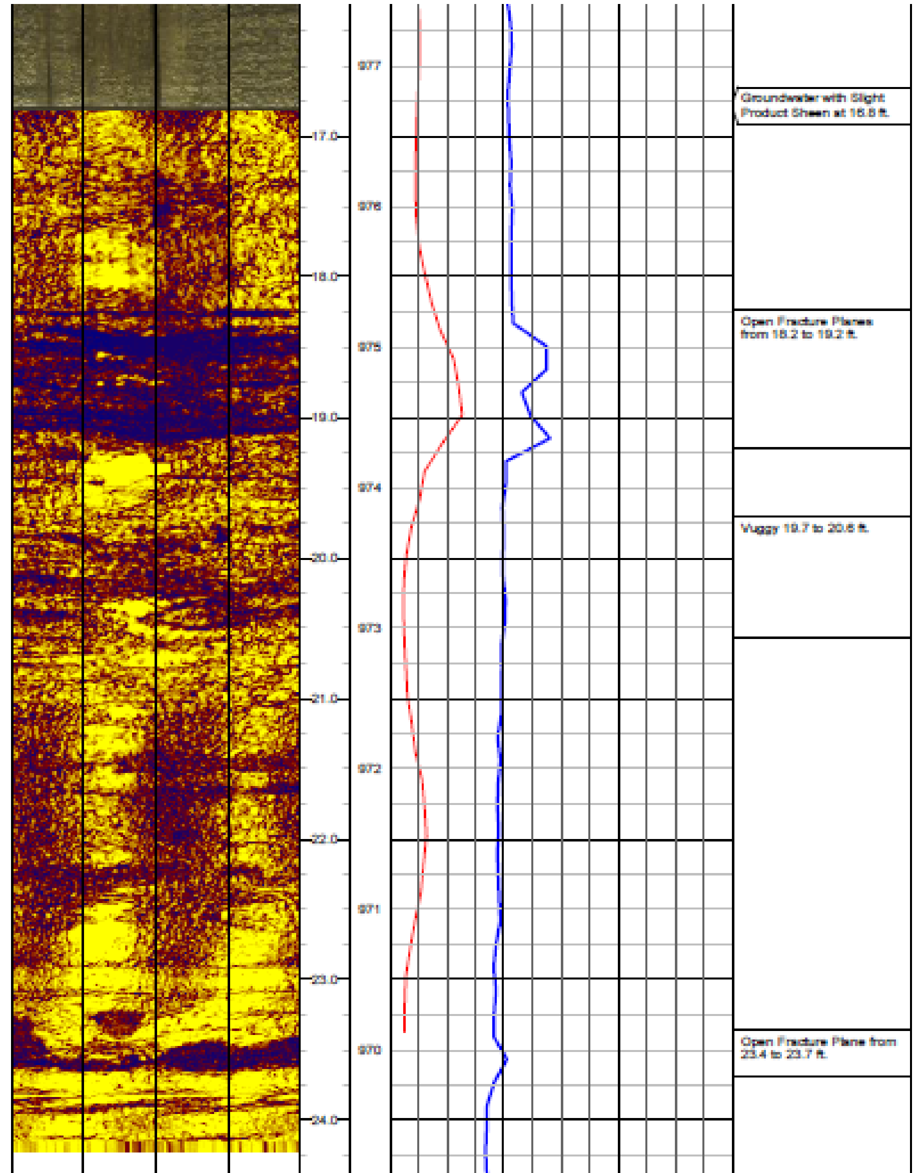
MW-3

- Outer Casing set at 7.1'
- Black Fissile Shale (7.1'-10.3'),
- Large vug below Contact with upper Shale and Lower Limestone/Dolomite (10.3'-11.5'),
- Maximum Caliper reading 8.3 in.
- Vuggy (12.3-13.6),
- Product Seep at 15.2',
- Groundwater with Slight Product Sheen at 16.8',
- Open Fracture Planes from 18.2'-19.2'
- Vuggy (19.7'-20.6'),
- Open Fracture Planes from 23.4' to 23.7'
- Blue Line - 3 Arm Caliper – 5.5 to 7 inches
- Red Line – Gamma – 0 to 300 cps

Borehole log courtesy of Mundell & Associates

Geophysical Borehole Log MW-3





Borehole Information

- Once the borehole logs were generated from the information collected a clear picture was formed on how to design the bedrock monitoring wells to maximize sampling of water bearing fractures and smear zones that were encountered in the investigation.

ACKNOWLEDGEMENTS

Shield Environmental Associates
948 Floyd Drive
Lexington, Kentucky 40505

Strata Group
648 Blue Sky Parkway
Lexington, Kentucky 40509

Mundell Associates
110 South Downey Avenue
Indianapolis, Indiana 46219

Thank You!

COMMONWEALTH OF KENTUCKY

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Department for Environmental Protection

Division of Waste Management

UST Branch

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Frankfort, Kentucky 40601

Vicki Voisard

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KENTUCKY UNDERGROUND STORAGE TANK BRANCH

LESSONS LEARNED AND THE EVOLUTION OF HIGH-DENSITY QUANTITATIVE CHARACTERIZATION AND SURGICAL HIGH-PRESSURE IN-SITU INJECTION

Bill Brab, PG, CPG

Senior Remediation Geologist

AST ENVIRONMENTAL, INC.

RPI GROUP

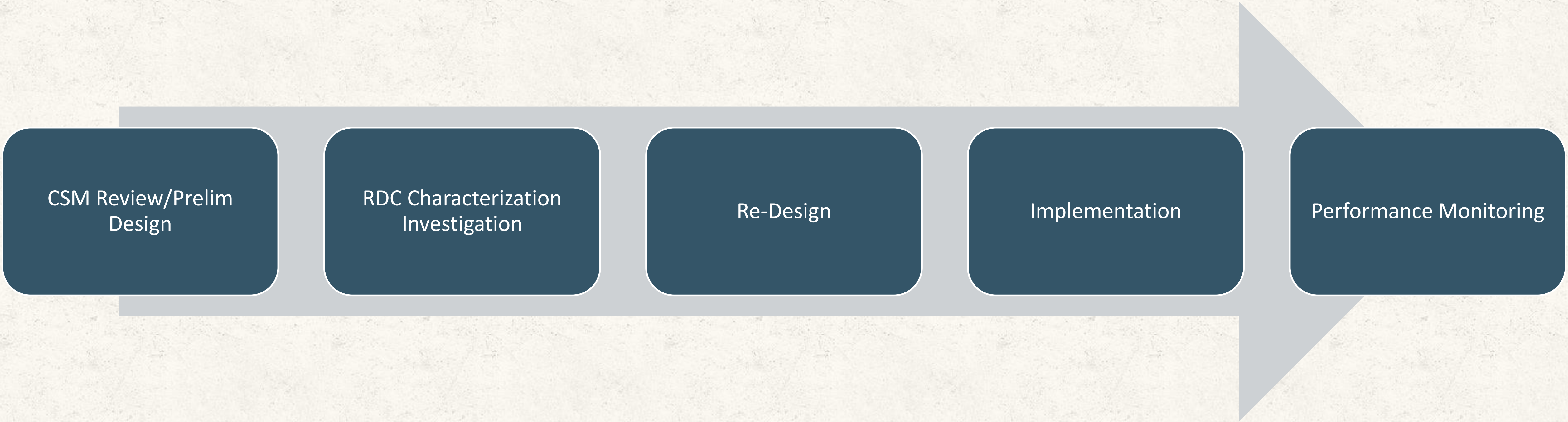
A Few Comments Before We Begin

Most remediation chemistries work in a beaker/column – so what causes failures?

- Inaccurate Loading/Dosing
  - Contaminant mass distribution is complex and scales with the heterogeneity of the lithology
  - Soil mass contribution is typically underestimated

- Contact
  - We all know contact is critical to success
  - Assess distribution to confirm design spacing/injection volumes

Trap & Treat® Remediation Process (The Approach)



High Density Qualitative Characterization

Goal is to develop a surgical remediation plan and evaluate combined remedies or approaches

First step is a thorough data review

- Geology (age and quality of logs)
- Groundwater levels
- Groundwater flow direction
- Groundwater concentrations
- Geochemistry
- Soil concentrations
- Prior remedial efforts

High Density QC Development

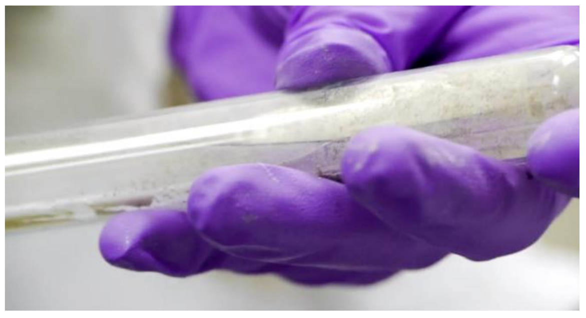
Detailed understanding of vertical and horizontal distribution of total mass

The Remedial Design Characterization (RDC) is a critical step to fine tune the CSM and optimize the remedial design

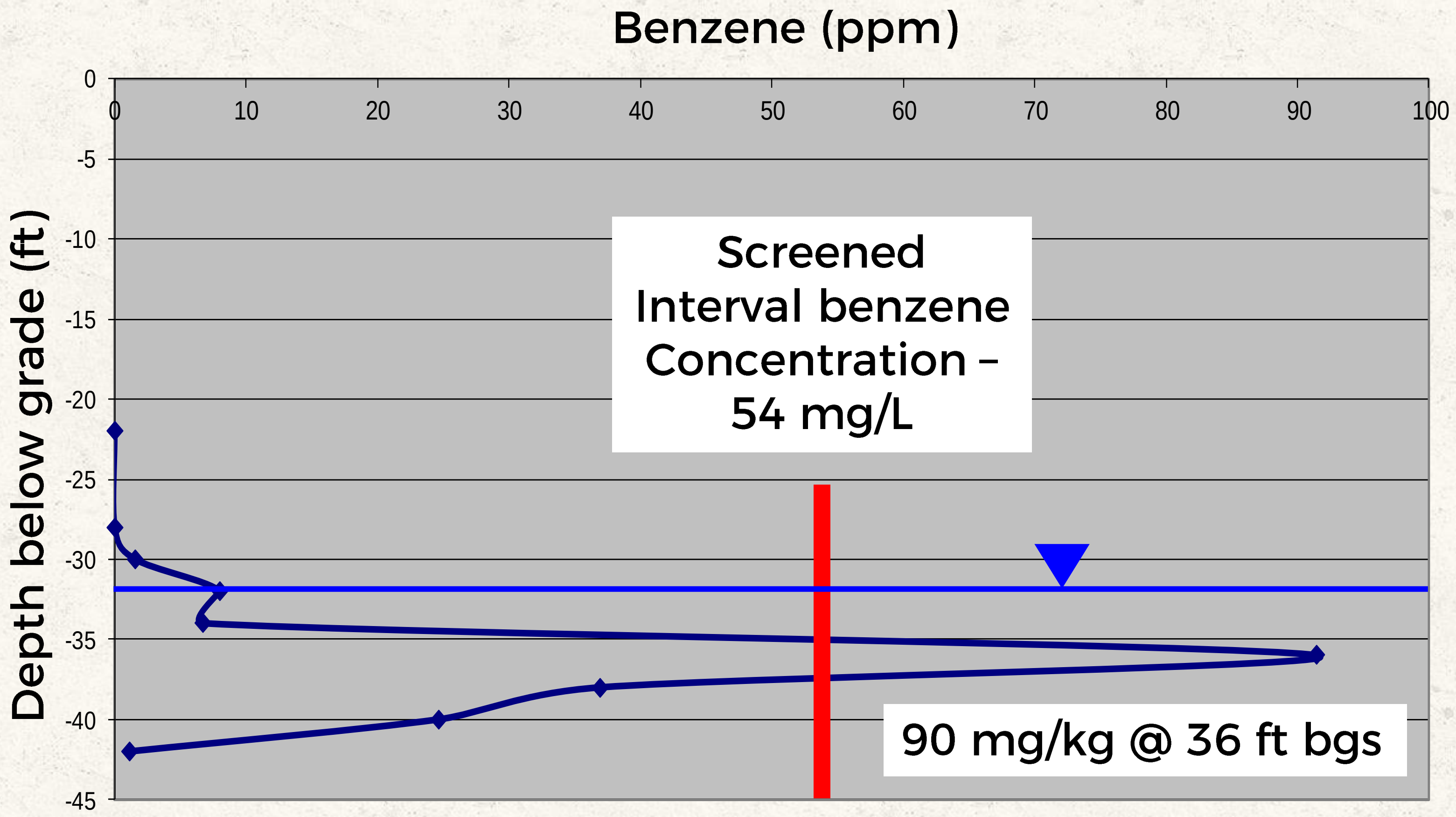
- Dense soil vertical profiles (e.g. 1-2 ft)
- Hydropunch or nested temporary wells to define horizontal and vertical distribution of groundwater impacts
  - Assist in distribution assessment during implementation phase
- Integrate High Resolution Site Characterization tools when applicable (e.g. HPT, UVOST)
- Mass discharge calculation necessary if designing a barrier
  - May need to install nested wells to assess K vertically
- Geophysics and packer testing necessary if working in competent bedrock

Laboratory Methods

- Volatiles - GC/MS Method 8260b/c
- Total Fraction TPH-GRO and TPH-DRO - GC FID/PID Method 8015
- Anions and VFAs - Ion Chromatography Method 300.1
- Dissolved Gases - Method RSK-175



Why Saturated Soil Contaminant Data Is So Important



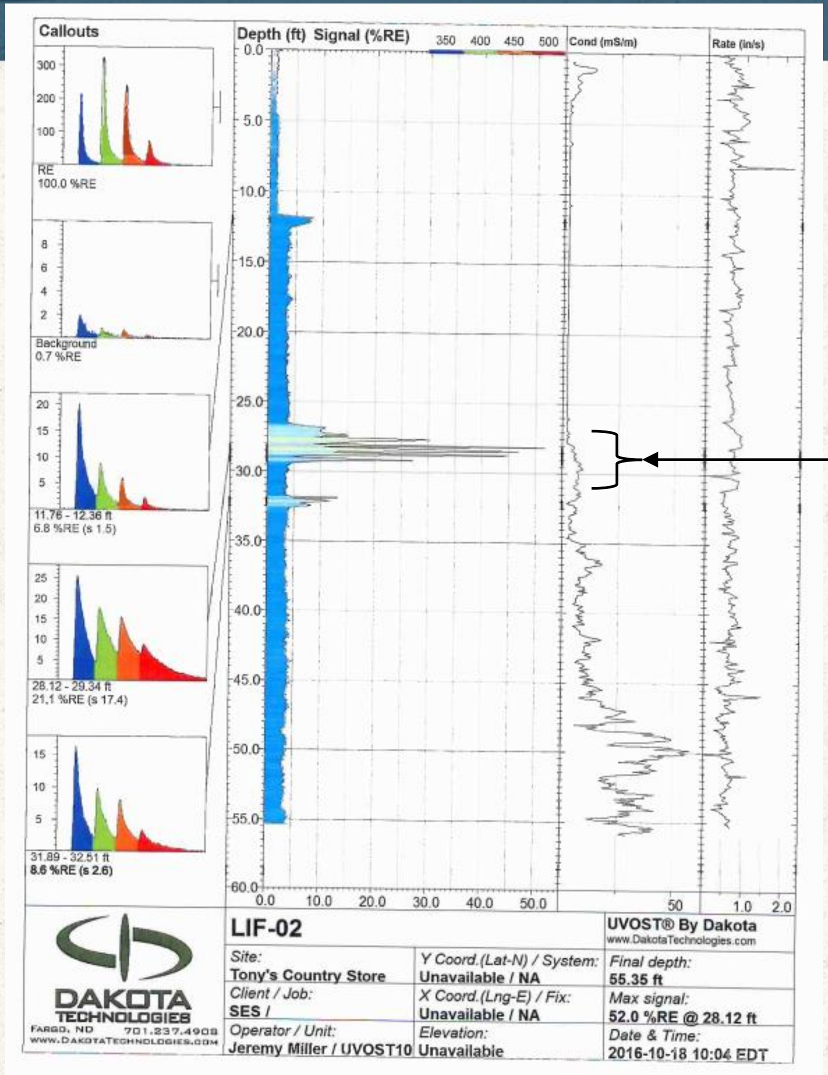
- GW @ 54 mg/L = 454 mg/ft^3
- Soil @ 90 mg/kg = 4,500 mg/ft^3
- *In Saturated Conditions: The Soil Contains as much as 10 times the Contaminant Mass As Does The Groundwater*

Soil Data from Diesel LNAPL Site

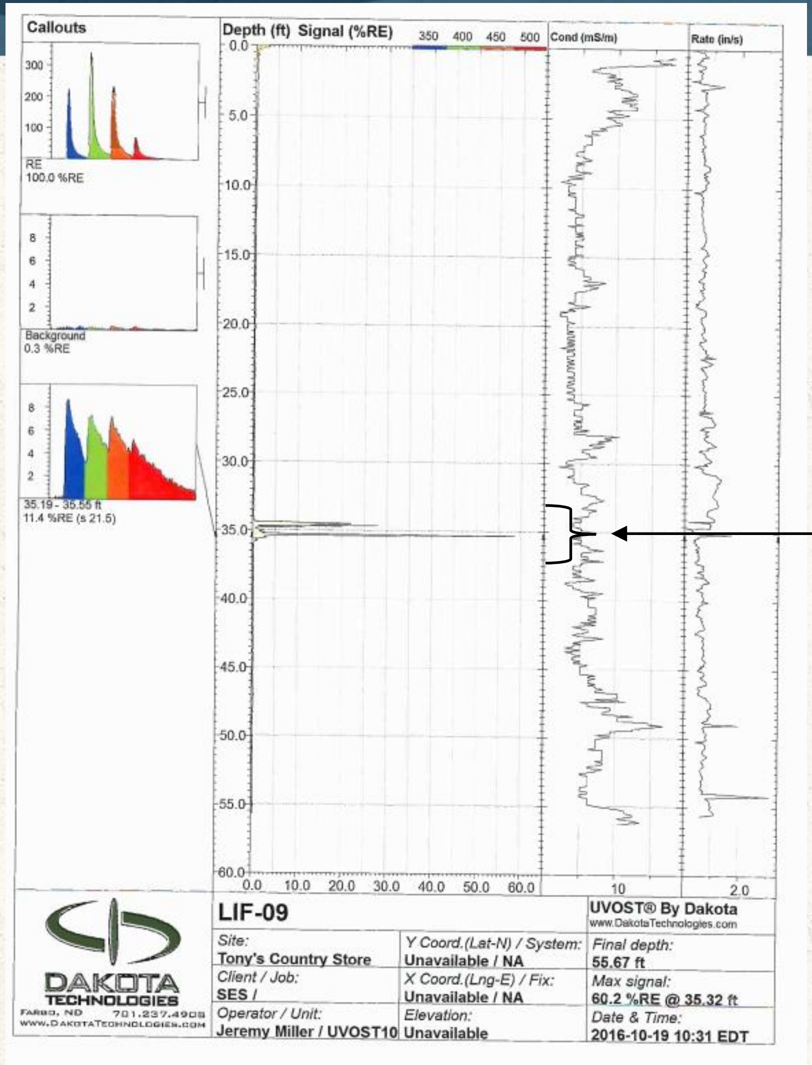
Depth	SB-19	SB-20	SB-21	SB-23	SB-24	SB-26	SB-27	SB-28	SB-30	SB-31	SB-32	SB-33	SB-34	SB-35	SB-36	SB-39	
23			3,370			14,000			3,420								
24	219		ND	1,650		ND						5,760			258		
25		ND	7,180				9,390	214	17,000	4,500	7,050		643	789		4,650	
26	ND		32,200	6,770	5,460	4,030	62,100					15,000					GW High
27		13,900						ND	6,440	ND	7,720	28,200	13,700	14,300	218	ND	
28	5,830	ND	2,370	1,480	473	ND	111	ND		28,600					1,610	1,510	GW Avg
29	153			ND				137	165	12,600	6,500	753	9,330	82		ND	
30		2,910	258			104							ND			3,170	GW Low
31				25,900	ND		412				248	ND	3,060	ND	ND	306	
32		94								ND				5,590		498	
33				270			82						ND				
34				137	729						ND			333		ND	
35																	
36					118									ND			

TPH-DRO in soil (mg/kg) – performed by RPI Project Support Laboratory

UVOST/LIF

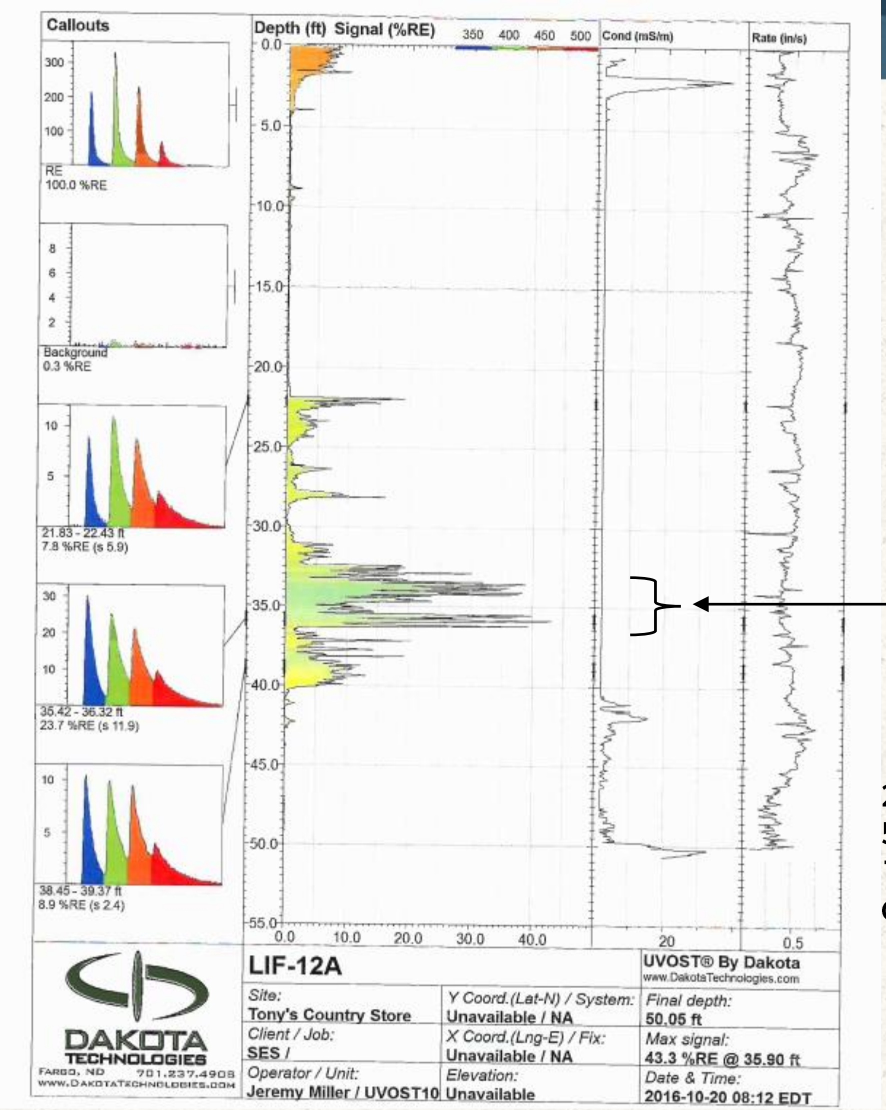


21% RE
2.15 mg/kg benzene
1,260 mg/kg TPH-GRO

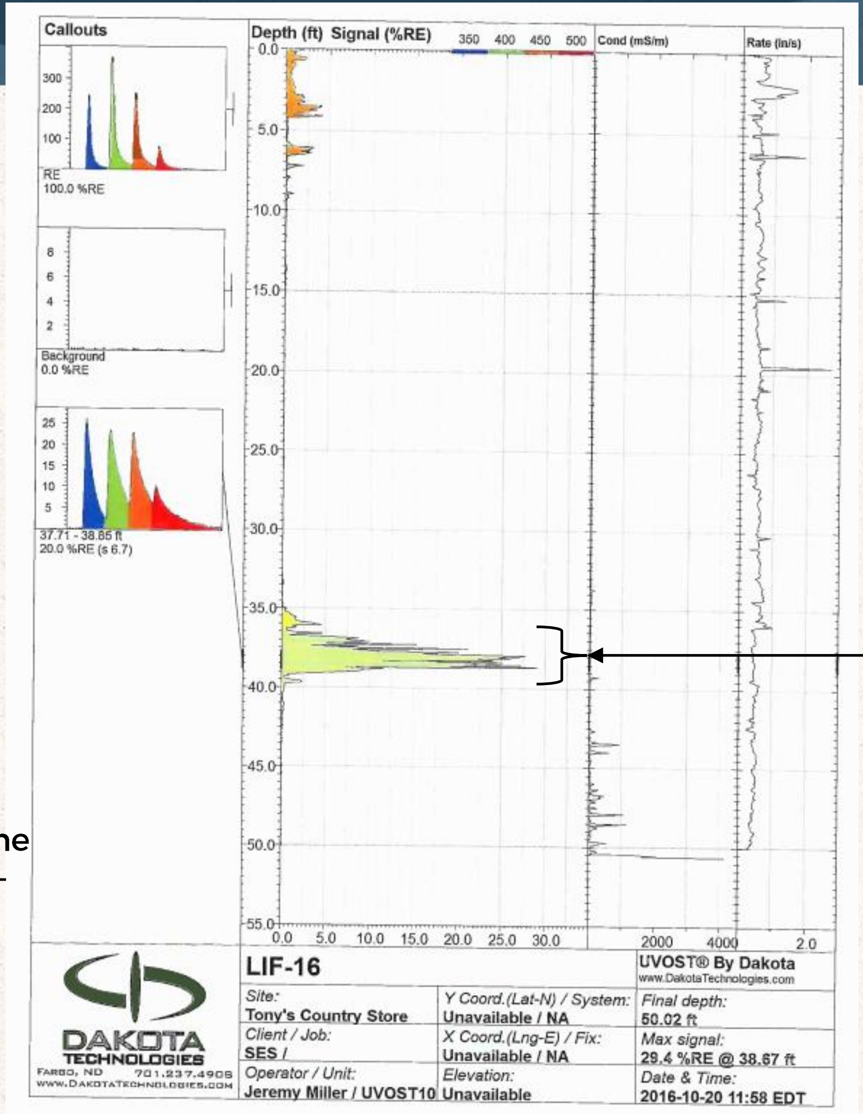


11.4% RE
55.7 mg/kg benzene
10,300 mg/kg TPH-GRO

UVOST/LIF (cont.)

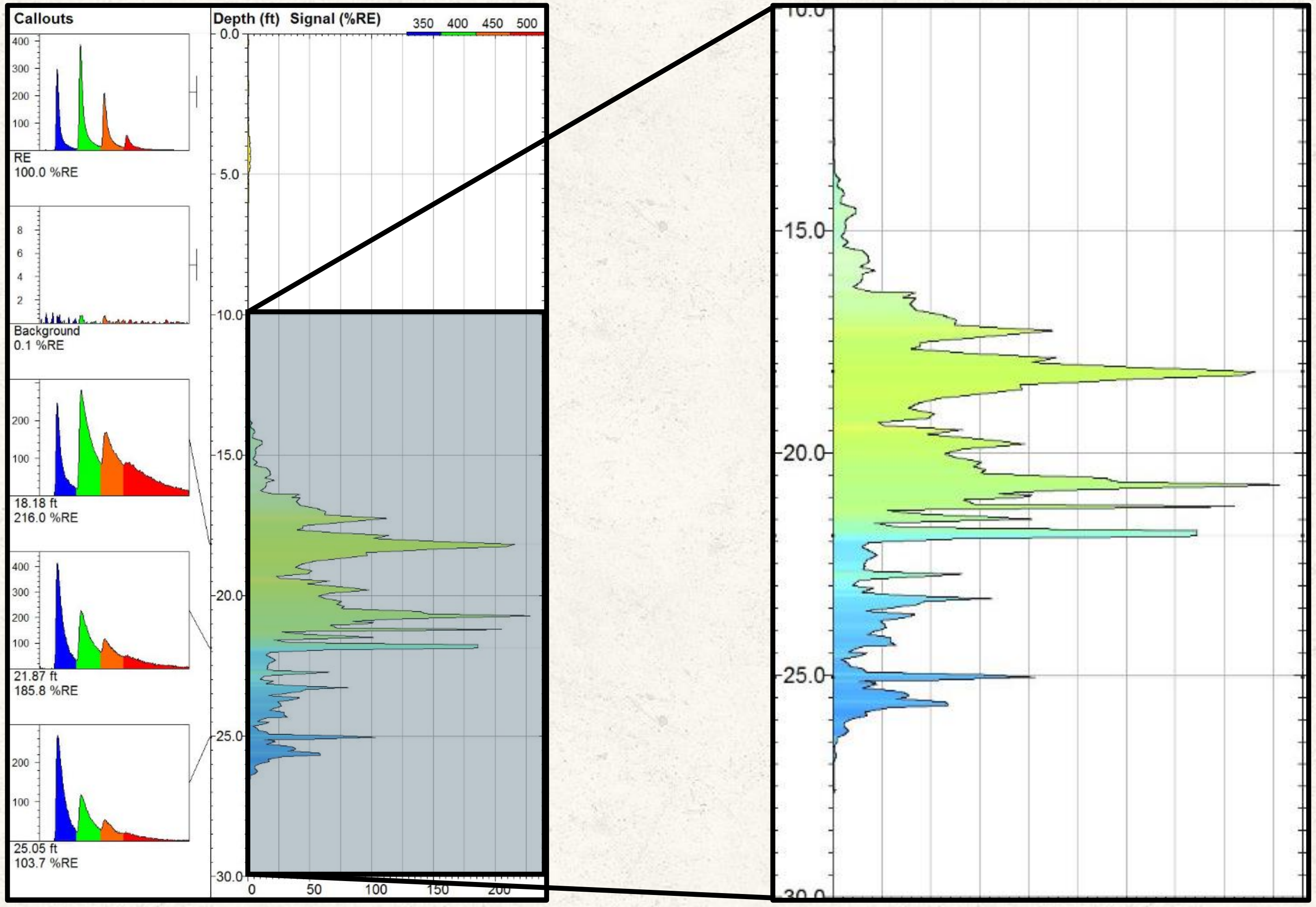


23.7% RE
5.94 mg/kg benzene
11,800 mg/kg TPH-GRO



20% RE
4.96 mg/kg benzene
1,960 mg/kg TPH-GRO

HDCSM and High-Resolution Site Characterization Integration



Depth (ft bgs)	DRO (mg/kg)
15	593
17	1,870
19	3,470
20	1,130
22	2,970
24	303
26	5,340
28	667

Courtesy of Cascade Technical Services

Bedrock Considerations

Data Gaps and Holes in the Prelim CSM

- Long well screens that span an extended heterogeneous matrix
- Cased wells cannot be used for downhole geophysics or slurry injection
- No discrete groundwater characterization data
- Matrix characterization:
  - Little to no sorbed mass data → soil filled permeable zones?
  - Lithology logged from chips expelled during air rotary → need rock cores

Preliminary Designs and Estimates Based Upon:

- Thick saturated profiles with no indication of Hi-conc vs. Low-conc intervals
- Published or estimated porosities and hydraulic gradients
- Homogeneous stratigraphy
- Groundwater mass only

Bedrock RDC

Surface Geophysics

- 2D Electrical Resistivity (2D-ERI) and Induced Potential (IP)
- Multichannel Analysis of Surface Waves (MASW) or seismic-energy analysis

Characterization → Injection Wells

- Open Borehole with surface casing
- Rock Cores – logging and sampling of matrix

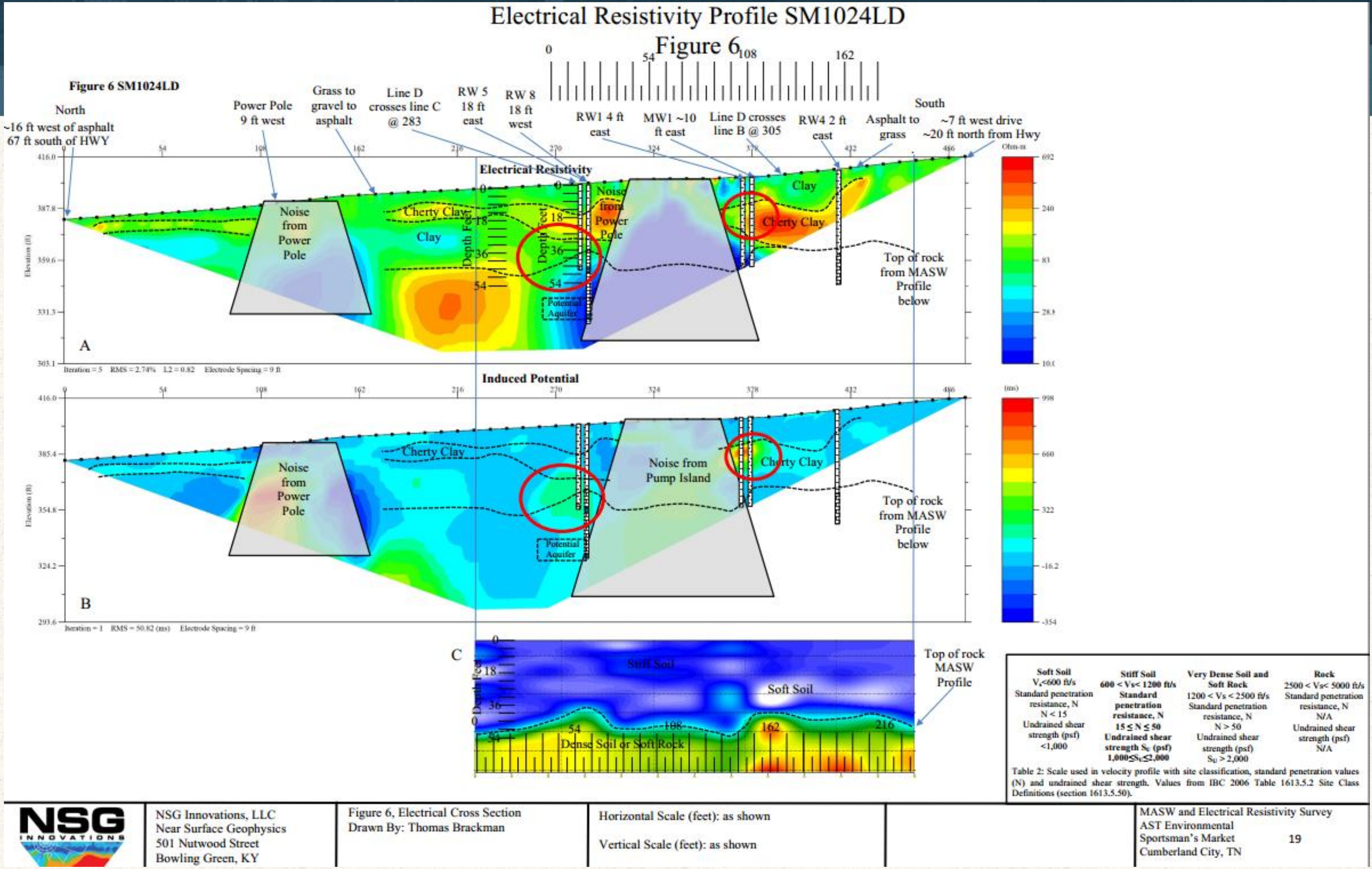
Downhole (wireline) Geophysics

- Caliper, Acoustic/Optical Televiewer, Downhole Camera, etc.

Groundwater Characterization

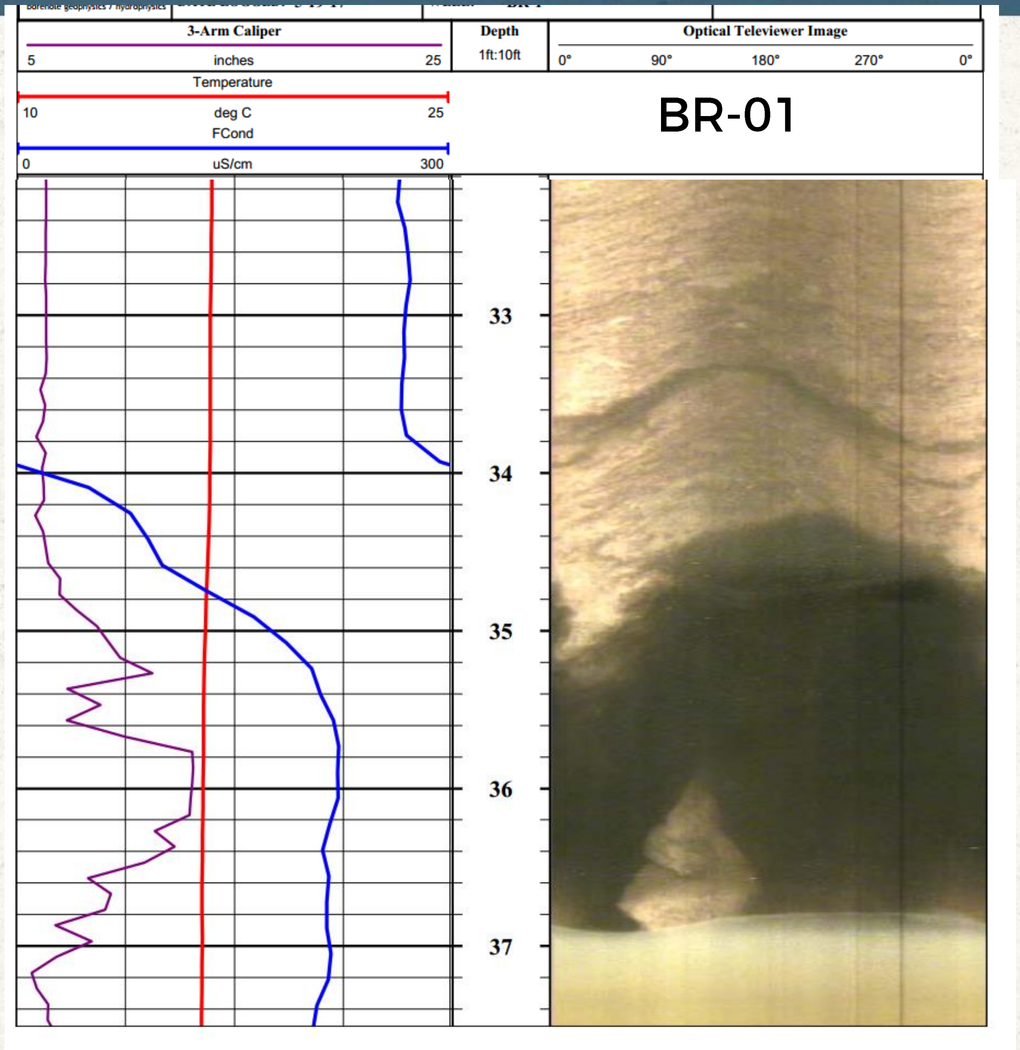
- Pumping Tests
- Discrete Interval Analytical Sampling
- Response Data - Transducers

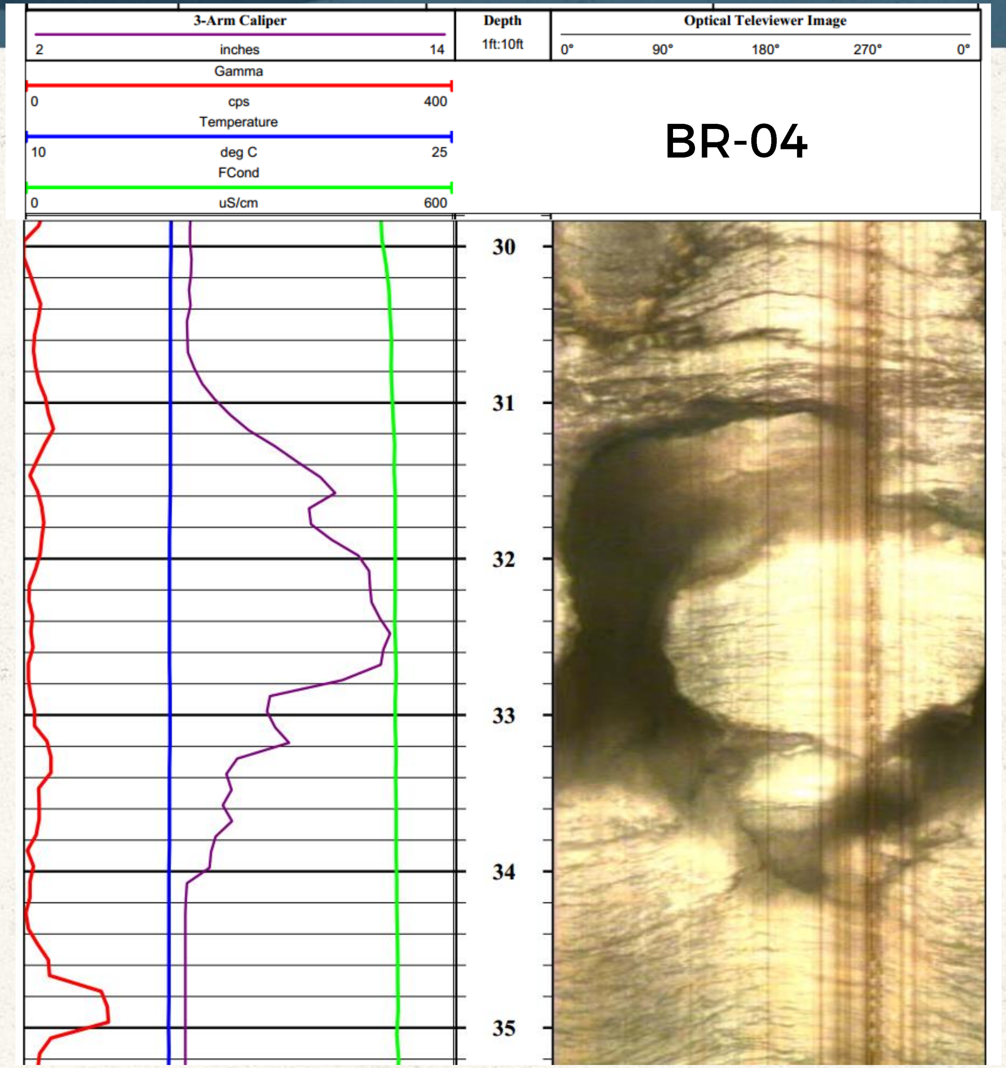
RDC – 2D-ERI, IP, and MASW



RDC – Sonic and Rock Coring

RDC – Downhole Geophysics





RDC – Aquifer Characterization

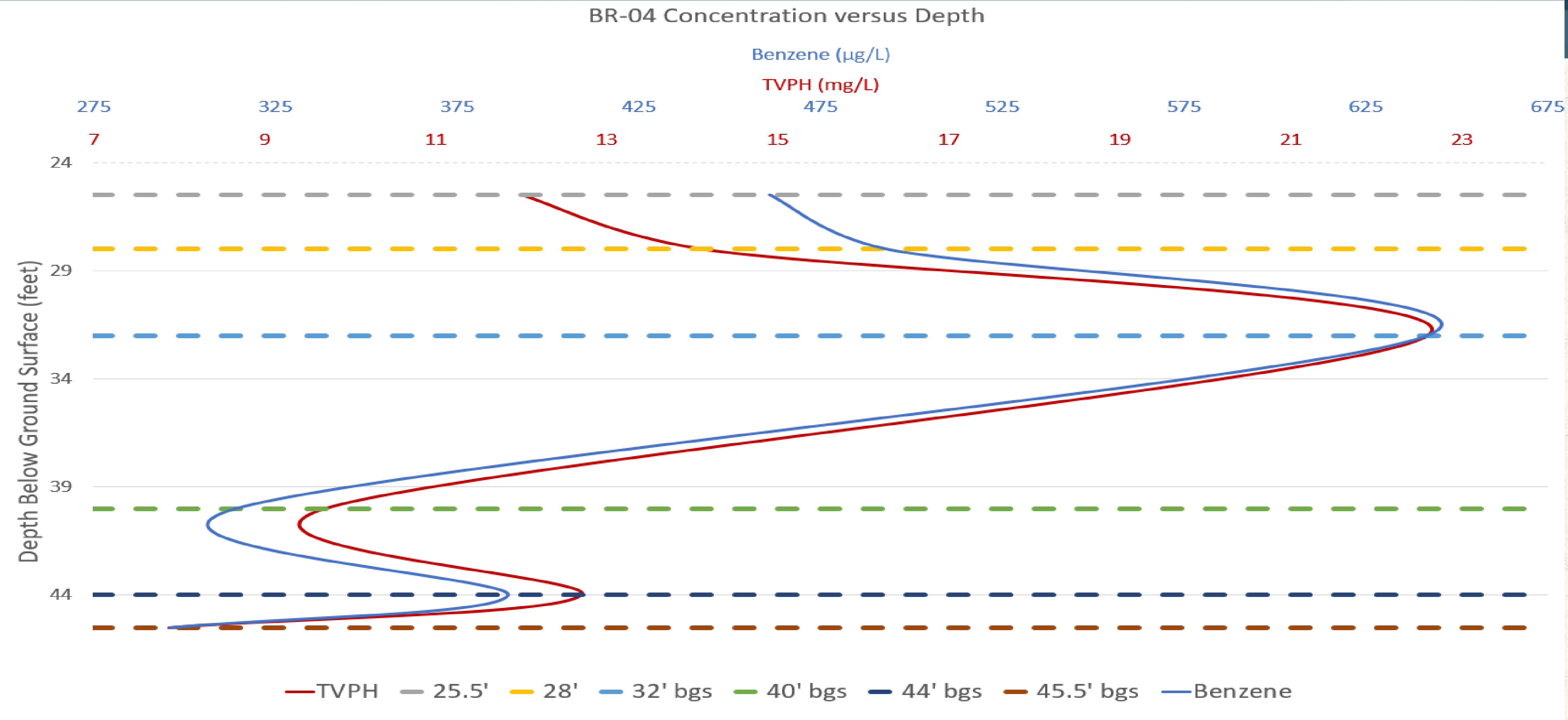
Pressure Transducer Above Discrete Interval

Pressure Transducer w/in Discrete Interval

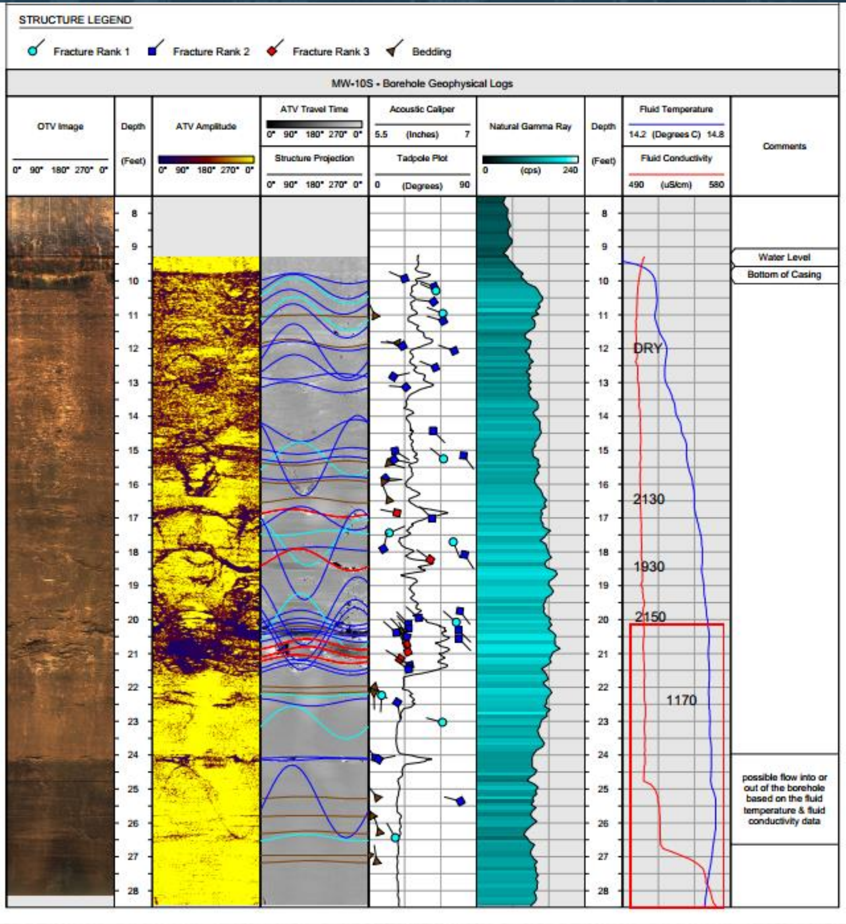
Grundfos Rediflo 2

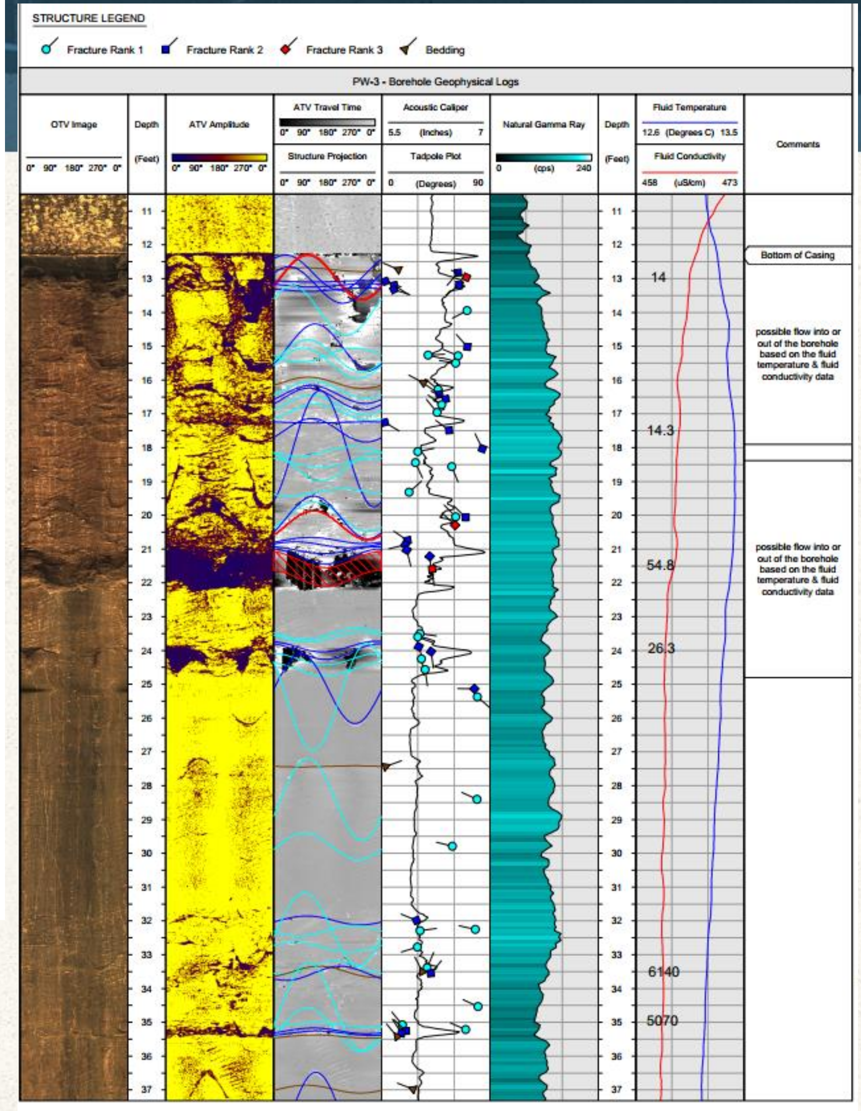
Pressure Transducer Below Discrete Interval

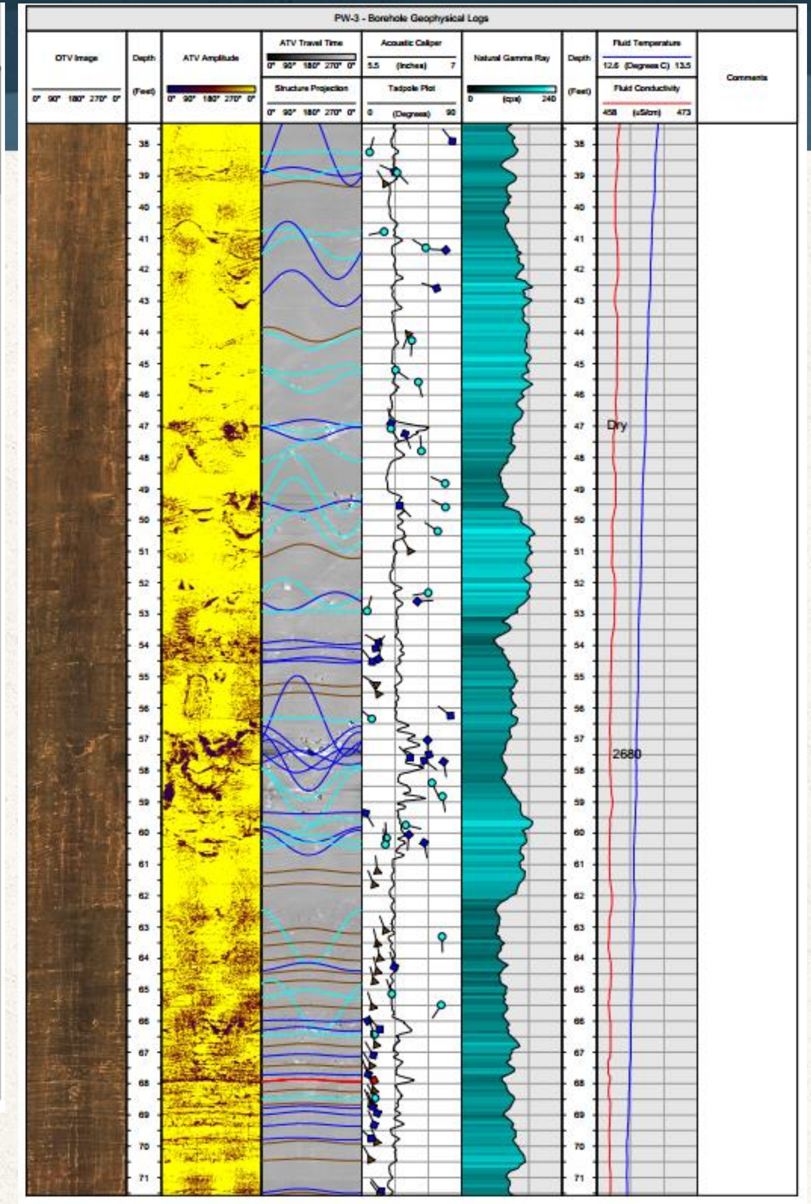
RDC – Aquifer Discrete Sampling



RDC – Aquifer Discrete Sampling



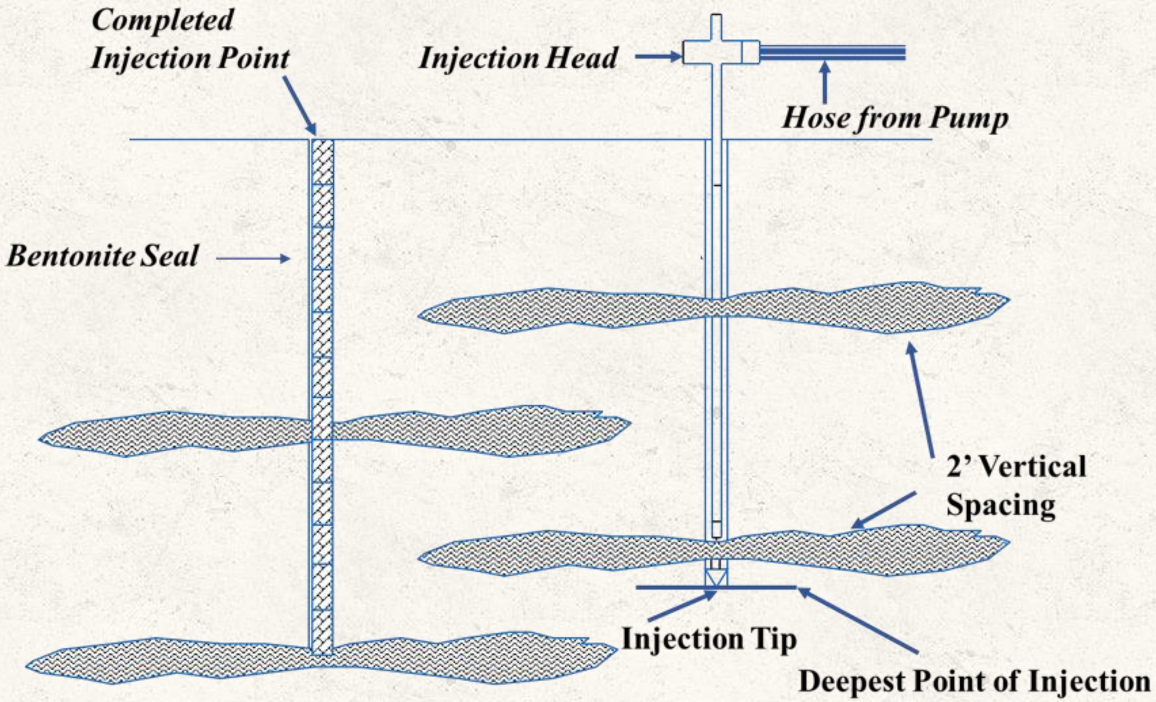




RDC – Aquifer Discrete Sampling

RW-4D Sample Intervals		
Sample Depth	**Benzene (ug/L)**	**Volume Pumped (g)**
41.2	184	5
42.5	300	10 (LNAPL)
43.5	355	10 (LNAPL)
45	371	5
47	443	5
49	619	10
52.5	425	10
53-open	259	10

Slurry Application Best Practices

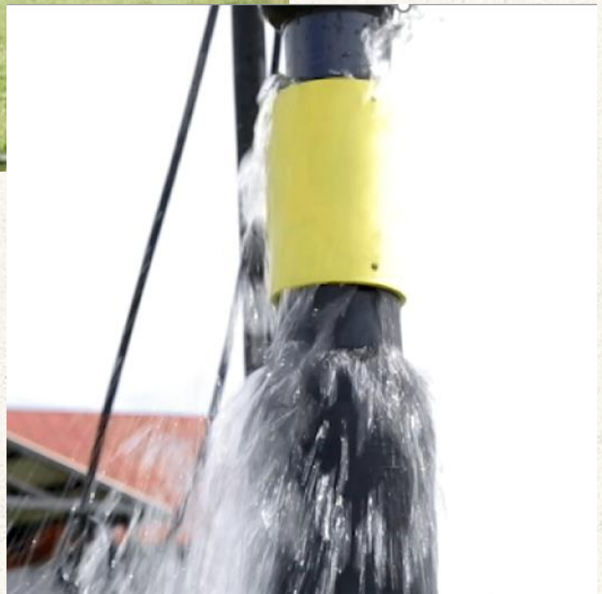


Typical "Top-Down" Injection

Proper method of installation depends on the product and delivery method

- Slurries = high flow rate and relatively small injection volumes
- Emplacement into formation
- Top-down = path of least resistance horizontal
- Dedicated temporary points

Injection Tips – Geometry and Configuration Matter

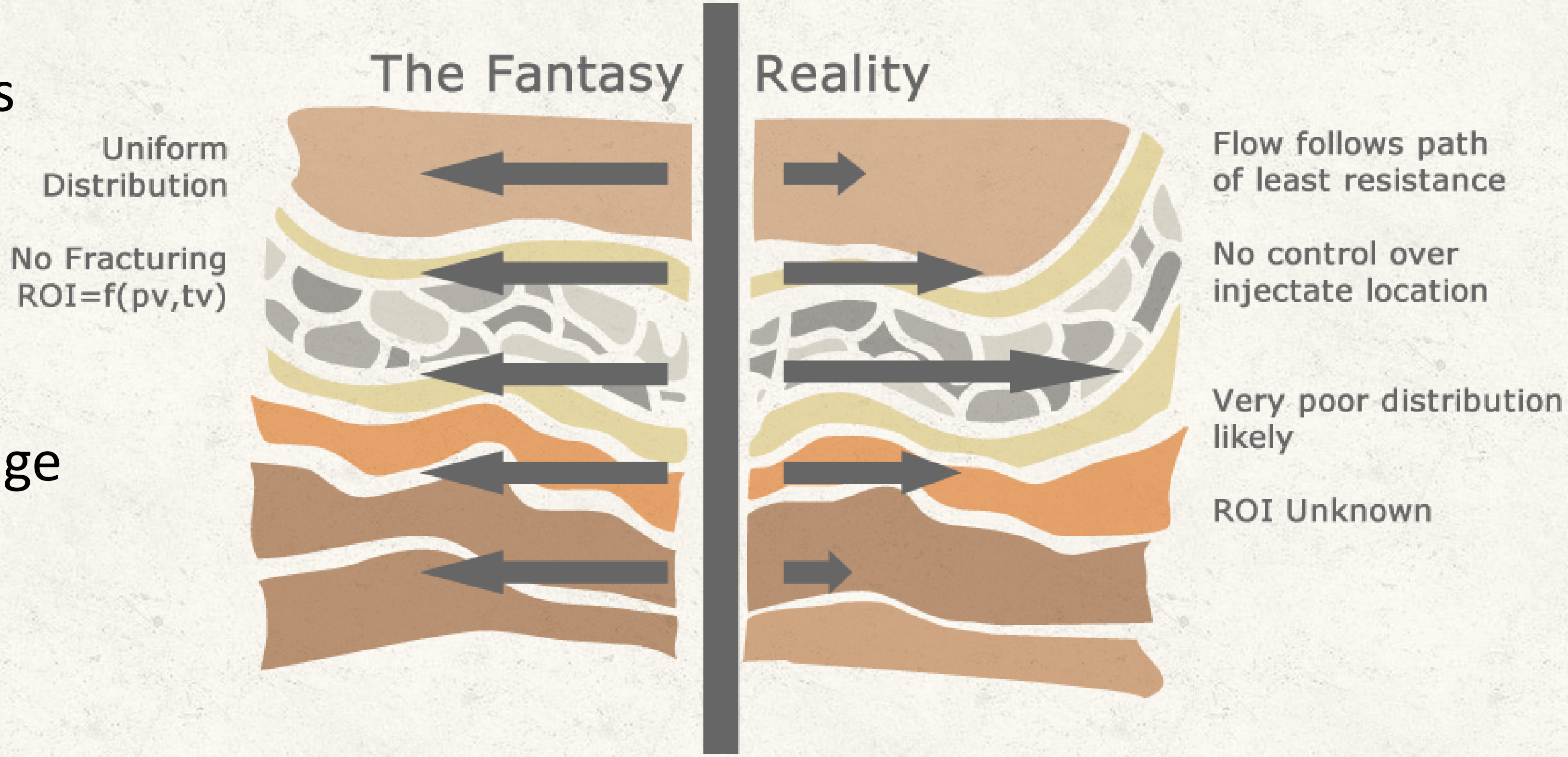


Low Flow, Low Pressure Injection

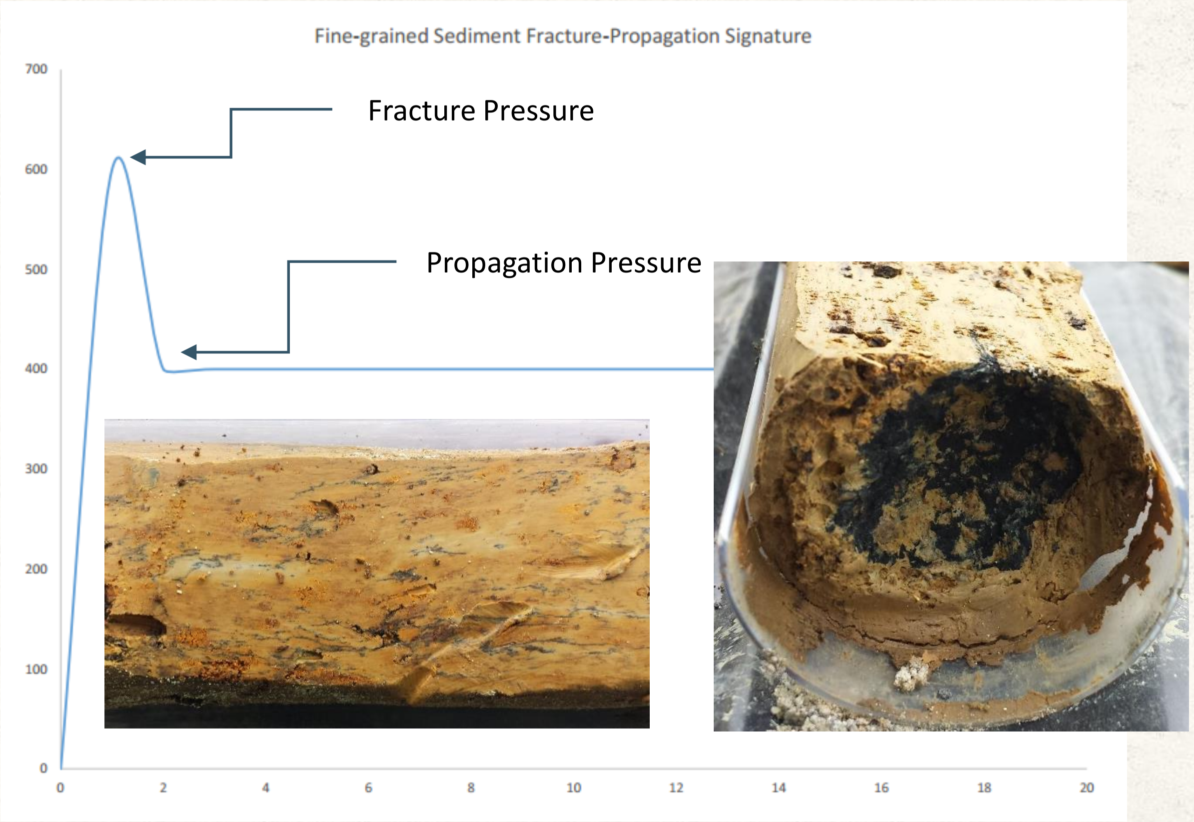
Doesn't account for low k zones

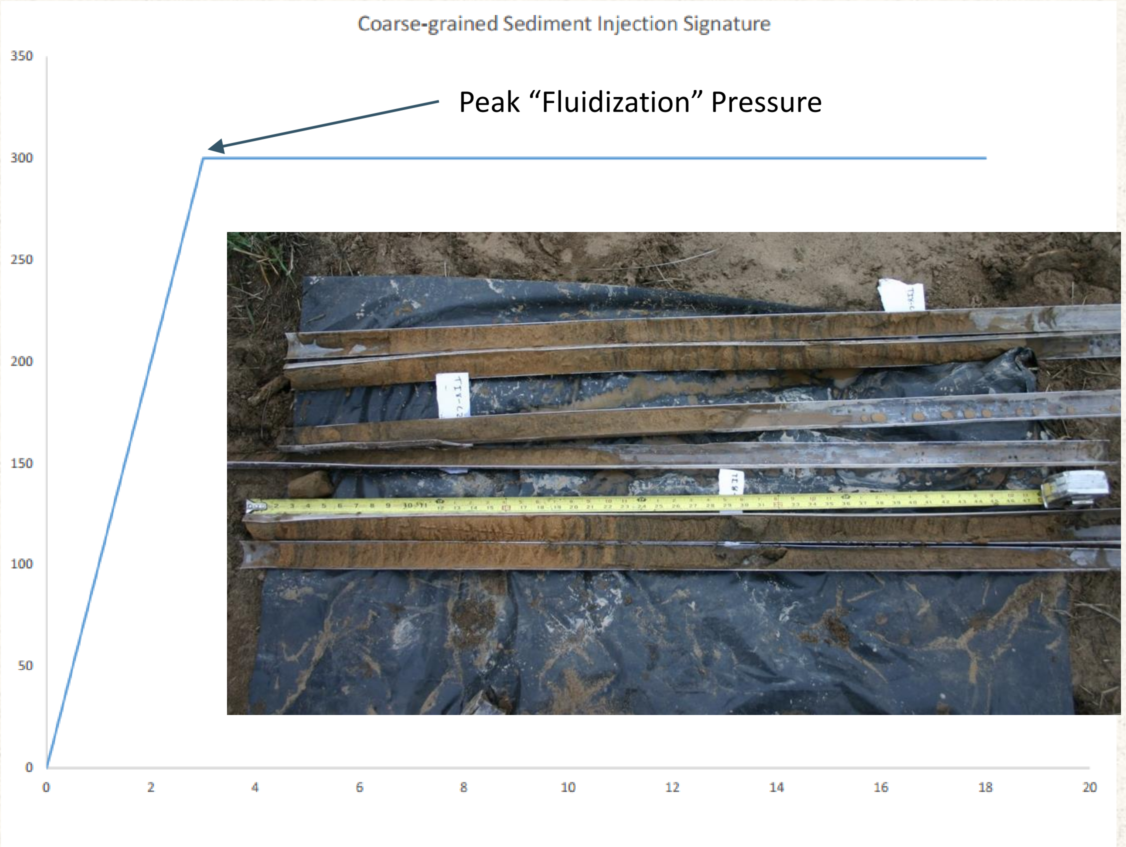
Preferential Flow

Injection Wells – limited coverage

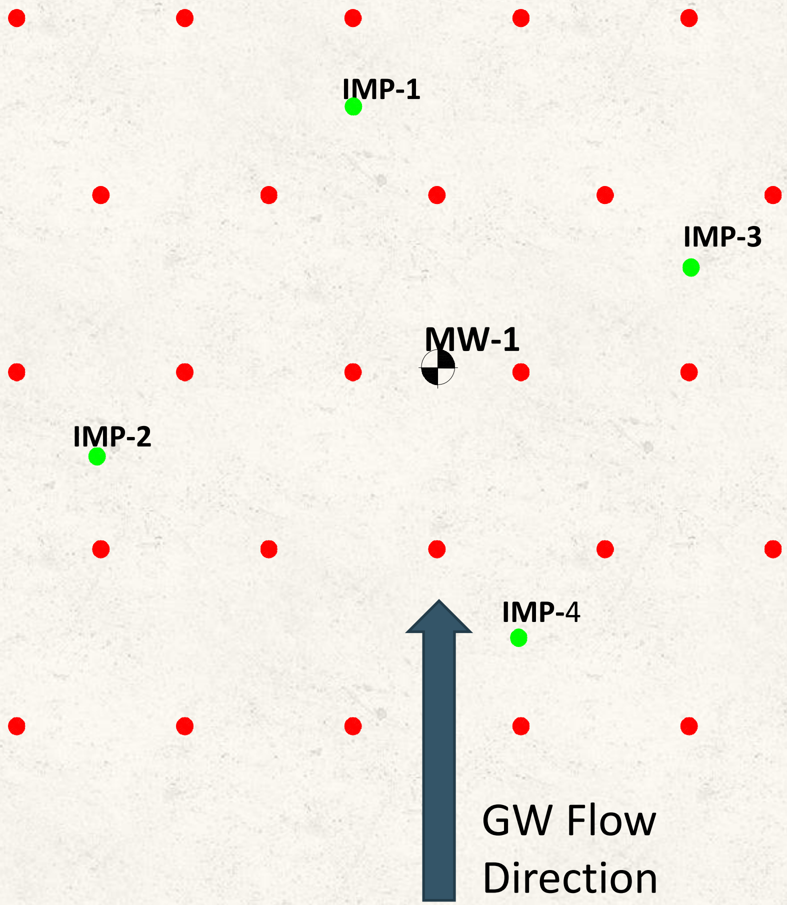


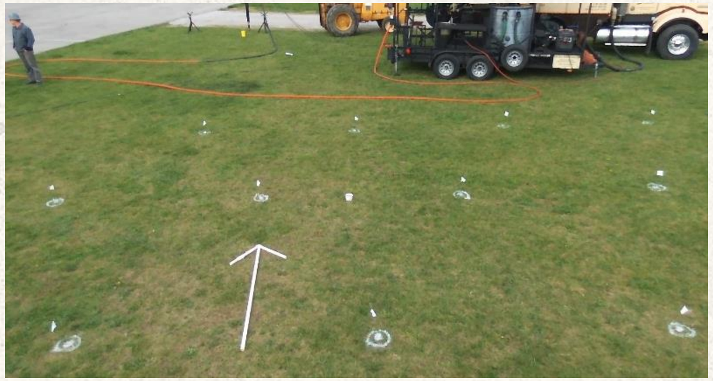
Pressure Signatures





Injection Grids





Permeable Reactive Barriers

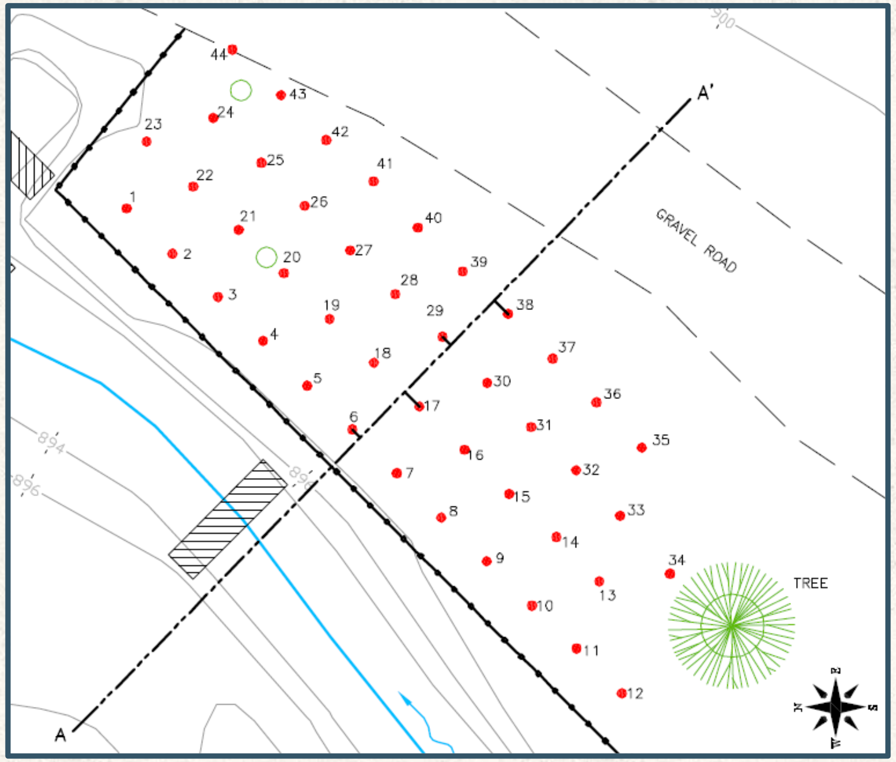
Injection approach

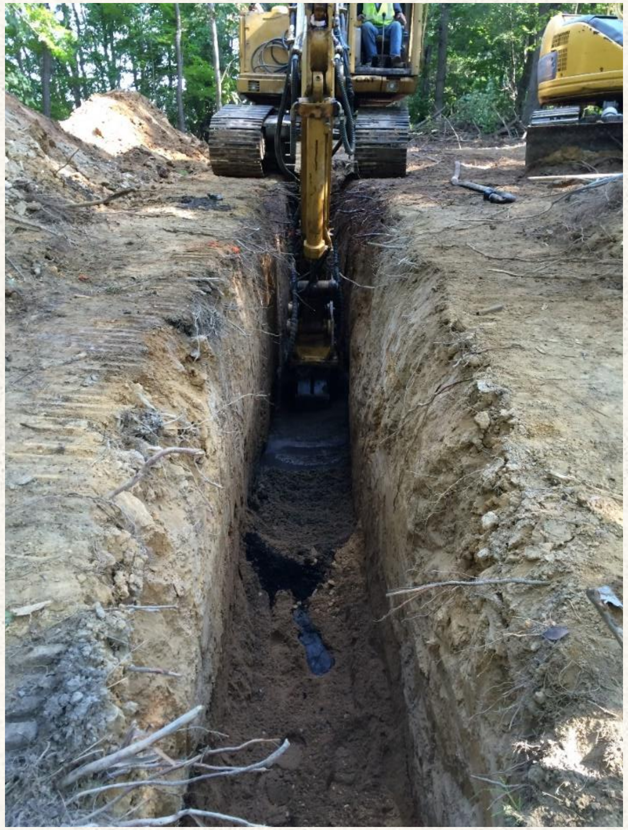
- Multiple tightly spaced rows (3-4)

Trench approach

- Great for shallow applications

Injection wells may need to be installed for future injection events (e.g. TEA addition)





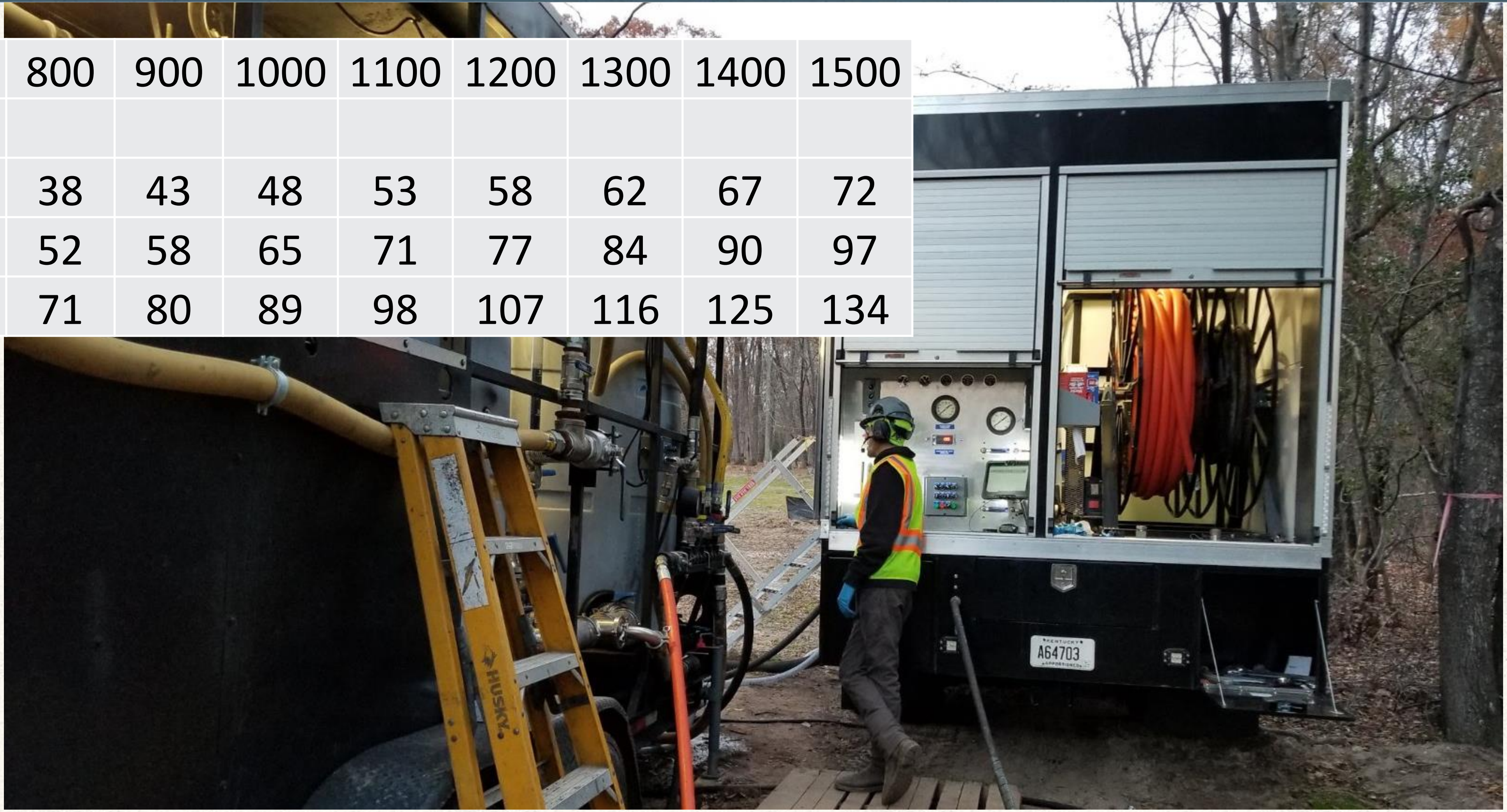
Bedrock Applications

- Portfolio of bedrock applications growing
- Characterization (geophysics and groundwater) critical to success
- Proper packer and pumping system selection will help minimize # of injection wells
- High flow/pressure systems necessary to drive ROI (higher than overburden)

Injection - The Custom Triplex

Injection - Triplex (Varied Flow Rates - GPM)

		RPM:	700	800	900	1000	1100	1200	1300	1400	1500
	GEAR										
	3		34	38	43	48	53	58	62	67	72
	4		45	52	58	65	71	77	84	90	97
	5		62	71	80	89	98	107	116	125	134



Injection - Triplex (Varied Flow Rates)

Various Flow Rates

20 gpm, 60 gpm
120 gpm, 250 gpm

Trap & Treat® Concept

- Contaminants sorb to activated carbon - “Trap”
  - Decreases groundwater mass and flux immediately
  - Disrupts groundwater/soil mass equilibrium to help drive desorption => Key to source area remediation
  - Concentrated mass accelerates degradation rates
- Degradation mechanism is used - “Treat”
  - Bioremediation (aerobic/anaerobic)
  - Chemical Reduction/Oxidation

BOS Technologies

BOS 100®

- Activated carbon impregnated with metallic iron
- Primarily used to treat chlorinated solvents (ethenes, ethanes, and methanes)

BOS 200®

- Primarily used to treat petroleum hydrocarbons
- Product consists of:
  - Activated Carbon
  - Terminal electron acceptors
  - Micro and macro nutrients
  - Consortium of facultative bacteria

CAT 100

- Activated Carbon Impregnated with Metallic Iron (BOS 100®)
- Complex Carbohydrate – Food Grade Starch
- One Set of Microorganisms Designed to Degrade COCs
- Second Set of Microorganisms Designed to Degrade the Carbohydrate
- Developed for High Concentration Scenarios (DNAPL) Where Fe Alone Would Limit Long-term Performance

Thank You For Joining Us

RPI Group Webinar Series: https://www.trapandtreat.com/video-library-2/

Bill Brab, PG, CPG

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Q&A

? ? ? ? ? ? ?

Please address all questions to a specific speaker or the panel

? ? ? ? ? ? ? ?

Thank you, speakers!

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Geologist Registered | *KY DEP*

Bill Brab, CPG, PG
Senior Remediation Geologist | *AST Environmental, Inc.*

UST Inspector Training Series: https://neiwpcc.org/our-programs/underground-storage-tanks/ust-training-resources-inspection-leak-prevention/webinar-archive-inspector-training/

LUST Corrective Action Series: https://neiwpcc.org/our-programs/underground-storage-tanks/lust-training-resources-corrective-action/webinar-archive-corrective-action/

LUST Line: https://neiwpcc.org/our-programs/underground-storage-tanks/l-u-s-t-line/

NE IW PCC

Thank you for your participation!

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10/14/2020