

Lessons from DNAPL Remediation in Bedrock by Chemical Oxidation: Concentrations Had to Go Up to Come Down

Paul M. Dombrowski, P.E. and Prasad Kakarla, P.E.

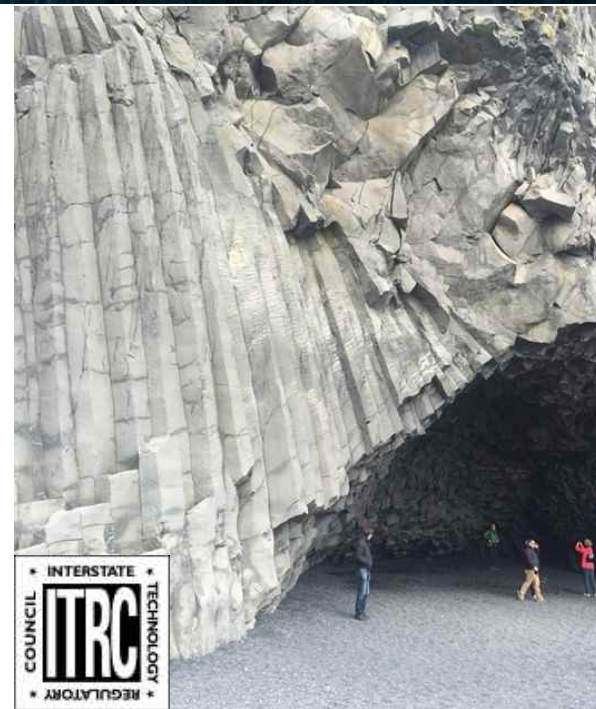
2024 Chlorinated Conference – Denver, CO

June 2024



Bedrock Remediation Challenges

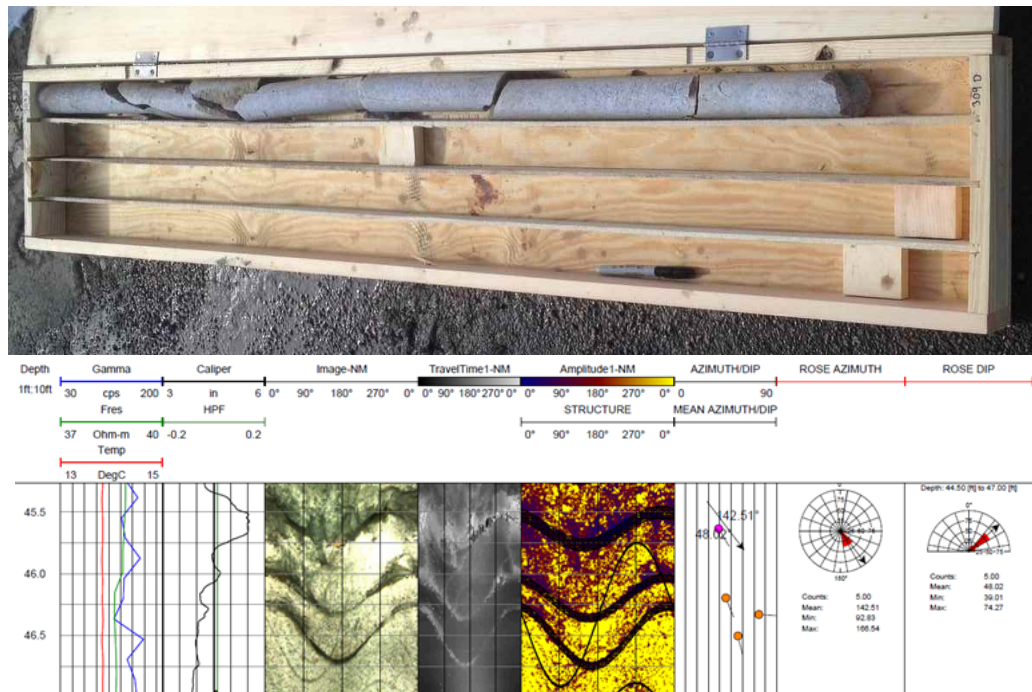
- Incomplete understanding of groundwater flow and contaminant transport
- Difficulties in site characterization
- Cost of investigation / remediation
- Unrealistic remedial objectives



Characterization and Remediation of Fractured Rock (FracRx-1) <http://fracturedRX-1.itrcweb.org>

Focus on Geology / Hydrogeology

- How does site geology impact the answers to these questions?
 - Where is the contamination?
 - Where is it traveling?
 - How did it get there?
 - What amendment is being delivered?
- Injected amendments likely to follow path similar to groundwater flow



Site Setting

- Paper mill, textile manufacturing, dry cleaning
- PCE primary contaminant: >120 mg/L
 - DNAPL – likely
- Superfund-lead site
 - ROD: demolition, soil excavation, ISCO in groundwater and fractured rock
 - 50-ppb is GW remediation target
- Groundwater flows south towards river
 - GW depth 5-35' bgs

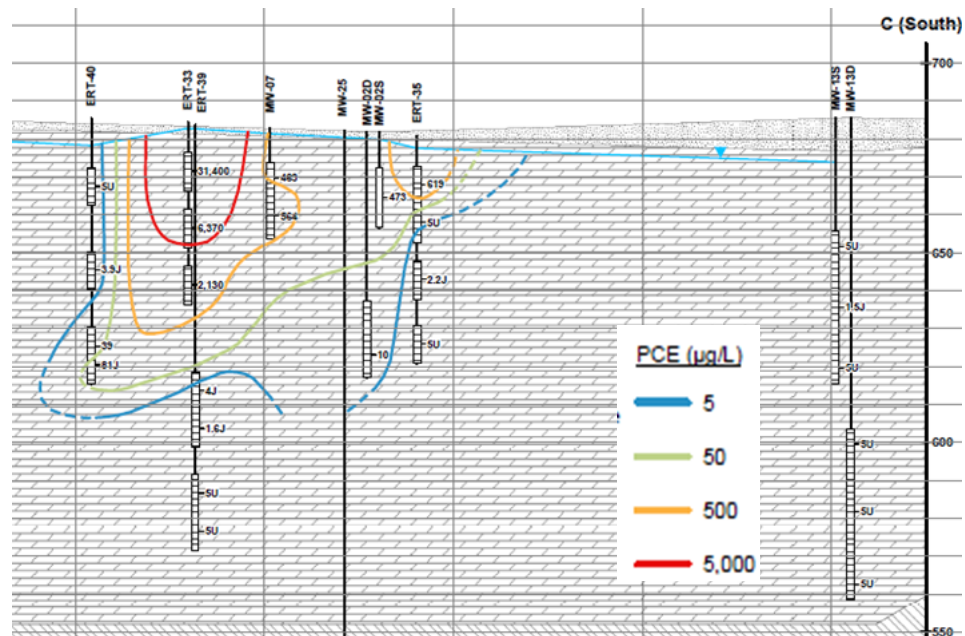
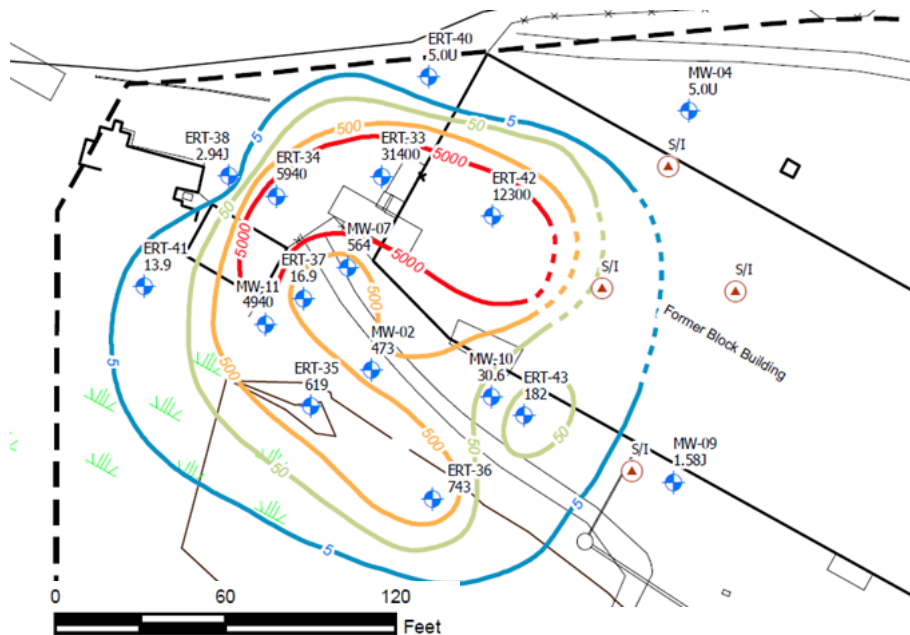


Site Bedrock

- Glacial till & floodplain deposits – 4-5 feet thick
- Bedrock
 - interbedded & fractured limestone
 - dolomitic limestone
 - dolomitic sandstone
 - granitic gneiss at ~140 feet bgs
- Geophysics
 - bedding plane fractures slightly dip away river
 - vertical fractures strike toward river



PCE in Site Bedrock



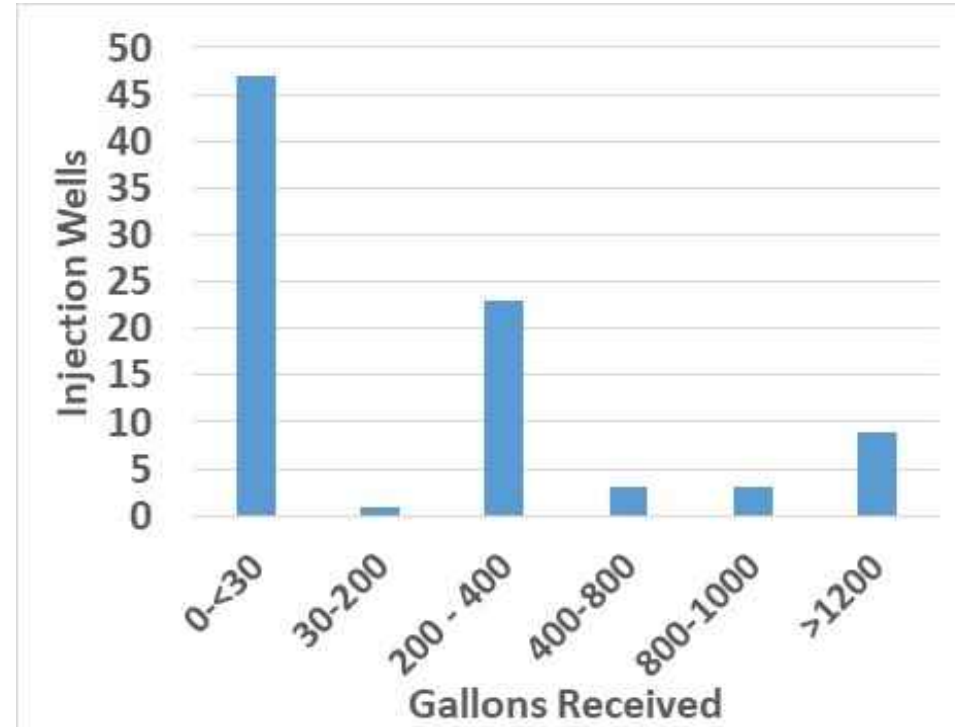
Bedrock Groundwater Remediation

- Air hammer drill rigs installed injection wells
 - 43 IWs: 30-ft bgs, 2", 20-ft screens
 - 19 nested IWs: 2", 20-ft screens (@ 30 & 75-ft bgs)
 - 4 nested IWs: 2", 20-ft screens (@ 30 & 55-ft bgs)
- Injection wells for ISCO injections
 - Sodium persulfate selected as oxidant



ISCO Event 1

- **Sodium Persulfate**
 - Molar ratio of base:persulfate < 0.5:1
 - Overburden and Bedrock
 - 24,300 gallons injected in bedrock
- **High injection rates (5-10 gpm)**
 - Significant daylighting
- **Many wells did not receive oxidant**
 - 60% of volume into 12 wells (of 89)
- **PCE results mixed**
 - Decreased some / increased many
 - Sulfate, chloride, and CO₂ in many wells



Optimizations

- ISCO primarily treats aqueous phase contaminants
- Can non-aqueous phase made more treatment?
- Modified Fenton's Reagent
 - Bubble agitation
 - Free radicals
 - $O_2 \bullet^-$ surfactant-like effect
 - Globule breakdown

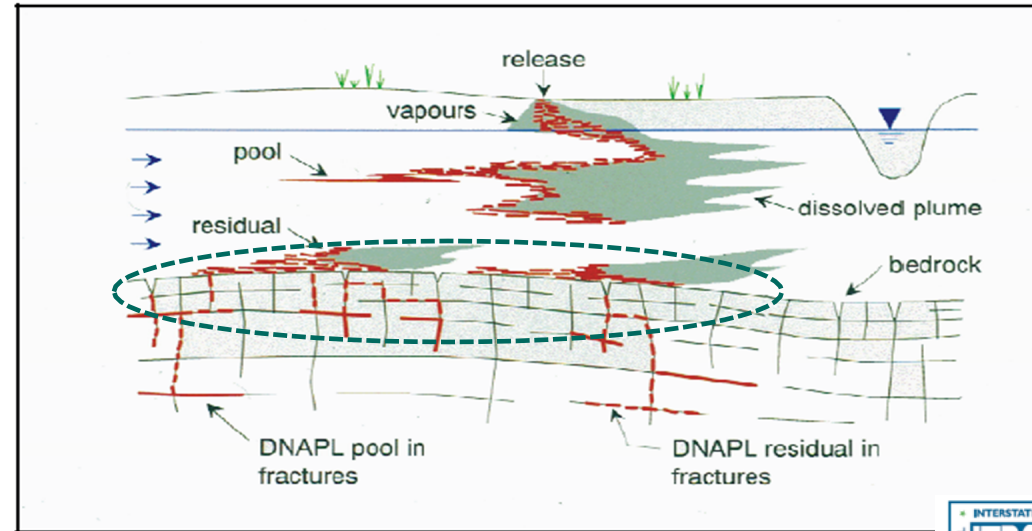
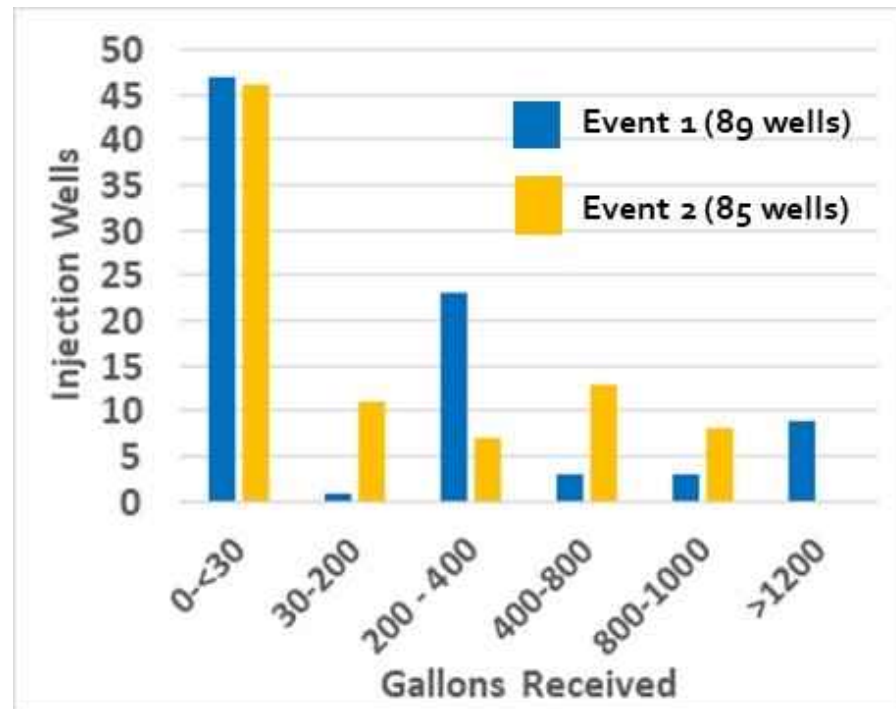


Figure 1-1. Conceptual site model of a DNAPL source zone.
(Source: U.K. Environmental Agency 2004)

ISCO Event 2

- **Optimized Chemical Oxidation**
 - Base buffer capacity test
 - 2:1 molar ratio of base:persulfate
 - Bedrock: BASP
 - Overburden: MFR + BASP (1:1 v/v)
- **Lower injection rates + more pumps**
 - 0.5 – 1.5 gpm (less daylighting)
 - Multiple attempts into wells



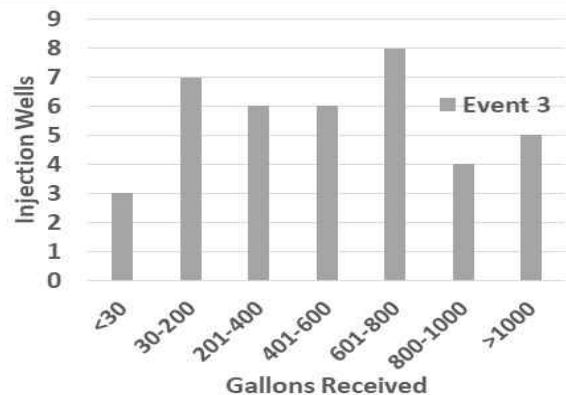
ISCO Event 3

■ Bedrock Well Modifications

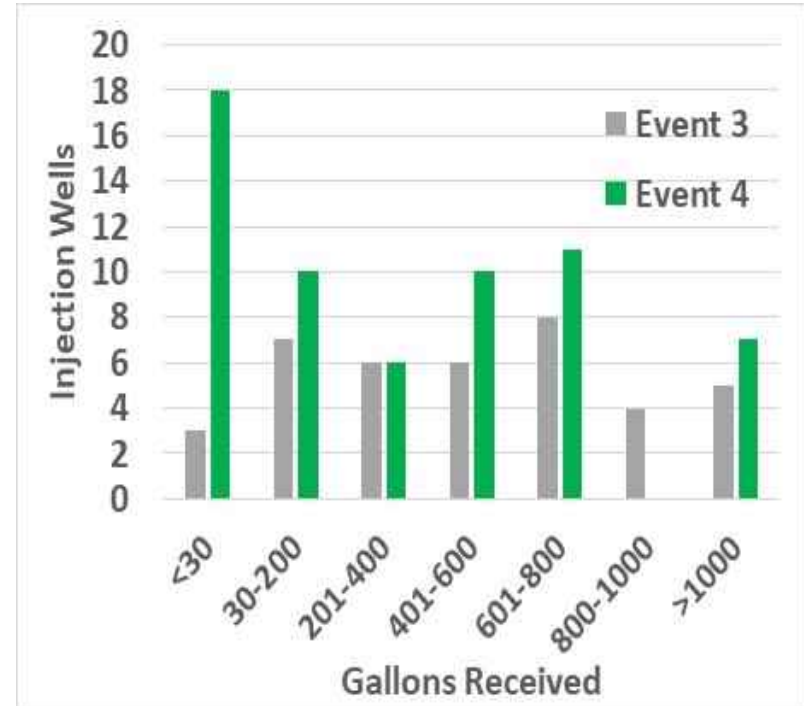
- Removed casings and screens
- Re-install casings keyed into bedrock
- Open boreholes for injection

■ Bedrock ISCO

- Straddle Packers to target intervals
- 39 wells
- MFR (5% H_2O_2) in 13 BR boreholes (pilot)

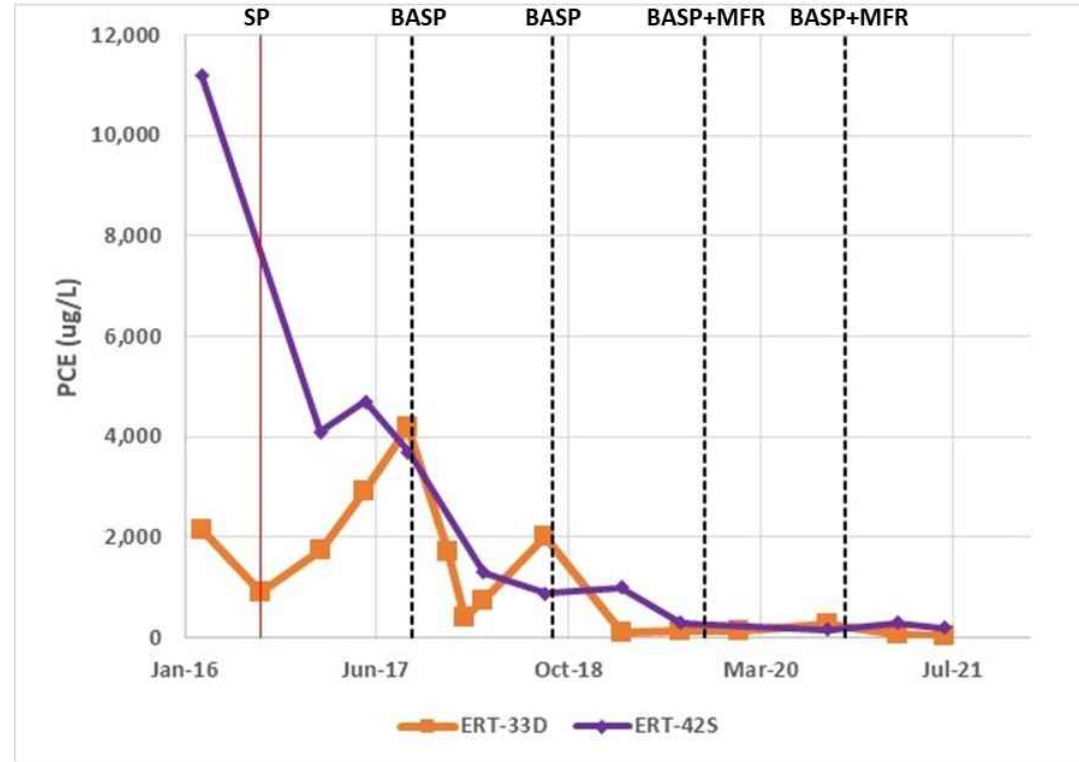
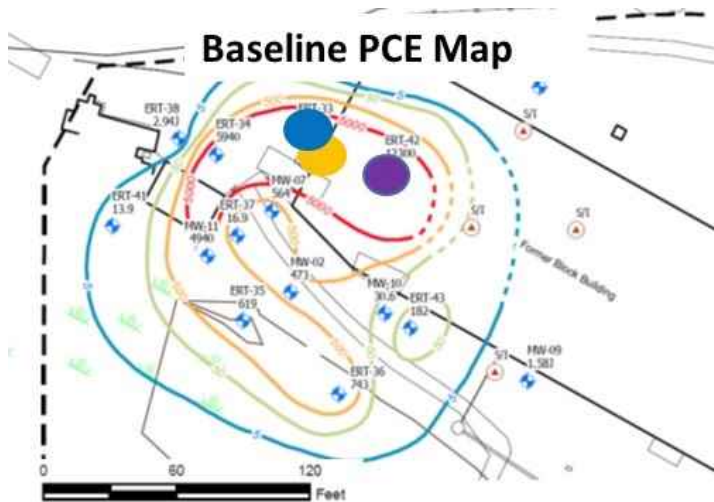


- **Bedrock Well Modifications**
 - Install additional injection wells (not all boreholes connected)
- **Increased injection volume in bedrock**
 - 62 wells (vs. 39 during Event 3)
 - MFR + BASP in 24 wells (MFR:BASP ~ 1:1 v/v)
 - Straddle Packers
 - 26,000 gallons injected in bedrock



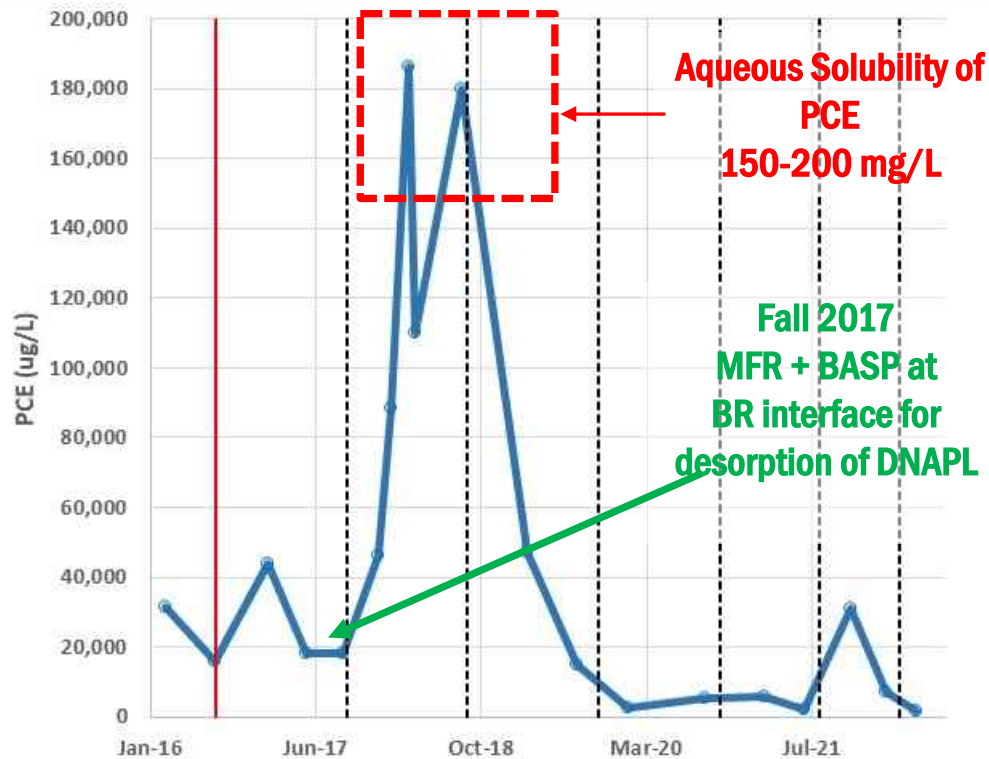
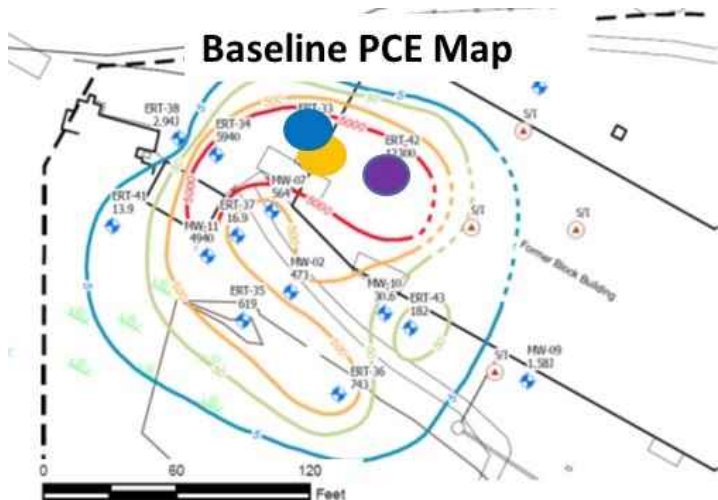
Performance results

- ISCO effective for aqueous phase VOCs



Performance results

- Long view for DNAPL remediation in bedrock

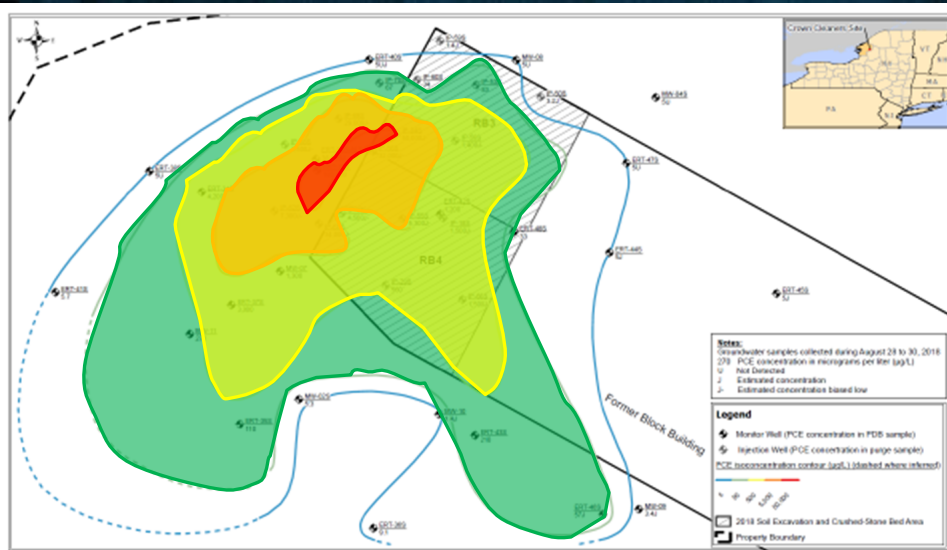


ISOTEC
REMEDIAL
TECHNOLOGIES

-  **BASP**
-  **BASP+MFR**



Performance Results



2018 August Baseline Sampling



2021 March Post-Injection

After 2nd ISCO injection
(add MFR to shallow OB)

After 5th ISCO injection

PCE isoconcentration contour (µg/L)



5 50 500 5,000 50,000

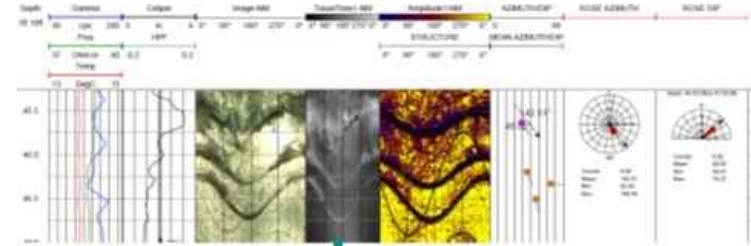
Next Steps

- **Additional ISCO injections**
 - Sodium permanganate (Fall 2023)
 - Persistence and migration
 - Reduced DNAPL mass
- **Methods to quantify PCE mass in bedrock fractures**



Summary

- If at first you don't succeed...
 - Re-evaluate Conceptual Site Model
 - Optimize Remedial Design
- ...Try again



Acknowledgements

ISOTEC

- Prasad Kakarla, P.E.
- Mike Temple
- Kevin O'Neal

KEMRON

- Dan Kowalski

USEPA Region 2

- Scott Grossman



Thank You



Paul M. Dombrowski, P.E.



pdombrowski@isotec-inc.com
(609) 275-8500 x202
www.isotec-inc.com



Bioremediation



Chemical Oxidation /
Chemical Reduction



Surfactant Remediation



Bedrock
Injections



Treatability
Laboratory



Activated Carbon Injectates
(BOS 100® & BOS 200®)



Soil Mixing



Locations Nationwide

Lawrenceville, NJ
(Headquarters)
Denver Area
Boston Area
Atlanta Area
San Diego
Connecticut