

LESSONS LEARNED PERFORMING AMENDMENT INJECTIONS INTO LOW-PERMEABILITY MEDIA



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LESSONS LEARNED

“We know a thing or two because we’ve seen a thing or two.”

– *Farmer’s Insurance Company*



INJECTION MATRIX

Low pressure fluid injection is not appropriate for low permeability soils

Table 4-4. Site-Specific Impacts on Reagent Distribution Technique

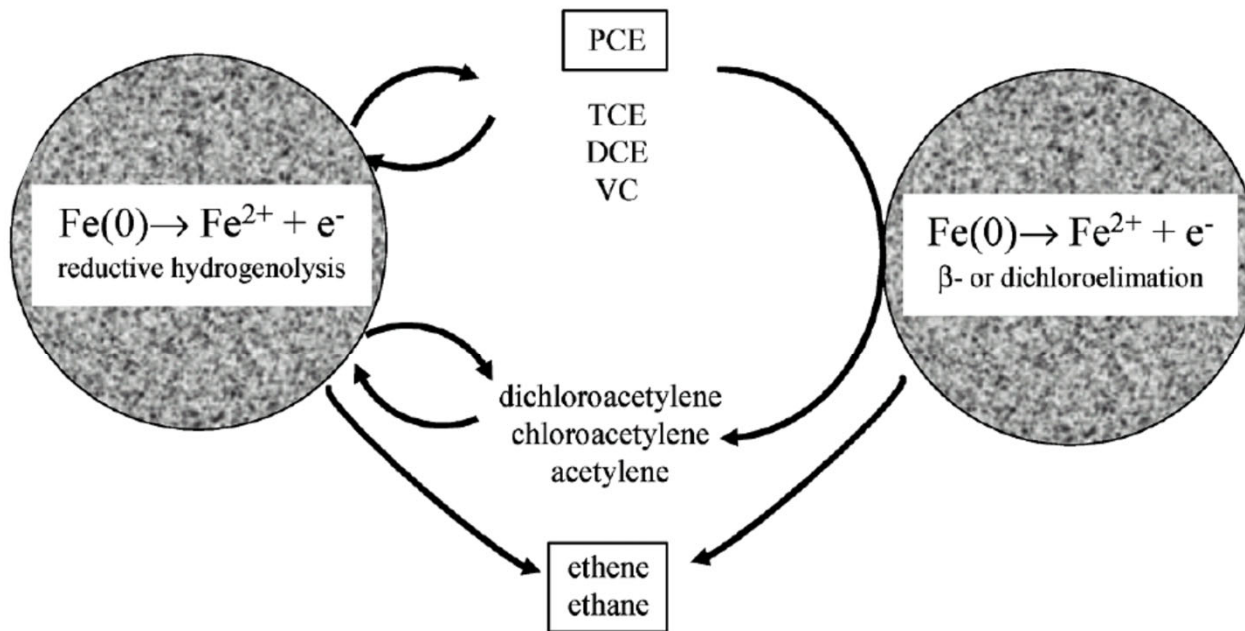
Parameter	Vertical Injection Wells	Vertical Recirculation Wells	Horizontal Wells	Direct-push Technology Injection	Hydraulic Fracture	Pneumatic Fracture
Amenability to Media Type						
Unconsolidated media	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
Consolidated media	Excellent	Good	Excellent	Not recommended	Excellent	Excellent
Fracture Continuity						
Good fracture continuity	Good	Good	Fair	Not recommended	Good	Good
Poor fracture continuity	Fair	Poor	Poor	Not recommended	Good	Good
Hydraulic Conductivity						
$>10^{-3}$ cm/sec	Excellent	Excellent	Excellent	Excellent	Poor	Poor
$<10^{-3}$ but $>10^{-4}$ cm/sec	Good	Fair	Fair	Excellent	Fair	Fair
$<10^{-4}$ but $>10^{-5}$ cm/sec	Fair	Poor	Poor	Good	Good	Good
$<10^{-5}$ but $>10^{-6}$ cm/sec	Poor	Not recommended	Not recommended	Fair	Excellent	Excellent
$<10^{-6}$ cm/sec	Not recommended	Not recommended	Not recommended	Not recommended	Excellent	Excellent
Lithology						
Homogeneous ($K_{max}/K_{min} < 1,000$)	Excellent	Excellent	Excellent	Excellent	Excellent	Fair
Heterogeneous ($K_{max}/K_{min} > 1,000$)	Fair	Fair	poor	Good	Fair	Fair

Source: Best Practices for Injection and Distribution of Amendments, Technical Report TR-NAVFAC-EXWC-EX-1303, March 2013



↑
Low-pressure injection through Geoprobe rod

EHC[®] DESCRIPTION



From *In Situ* Chemical Reduction (ISCR) Technologies: Significance of Low Eh Reactions, Dolfig, J., et al. *Soils & Sediment Contamination*, 17: 63-74, 2008

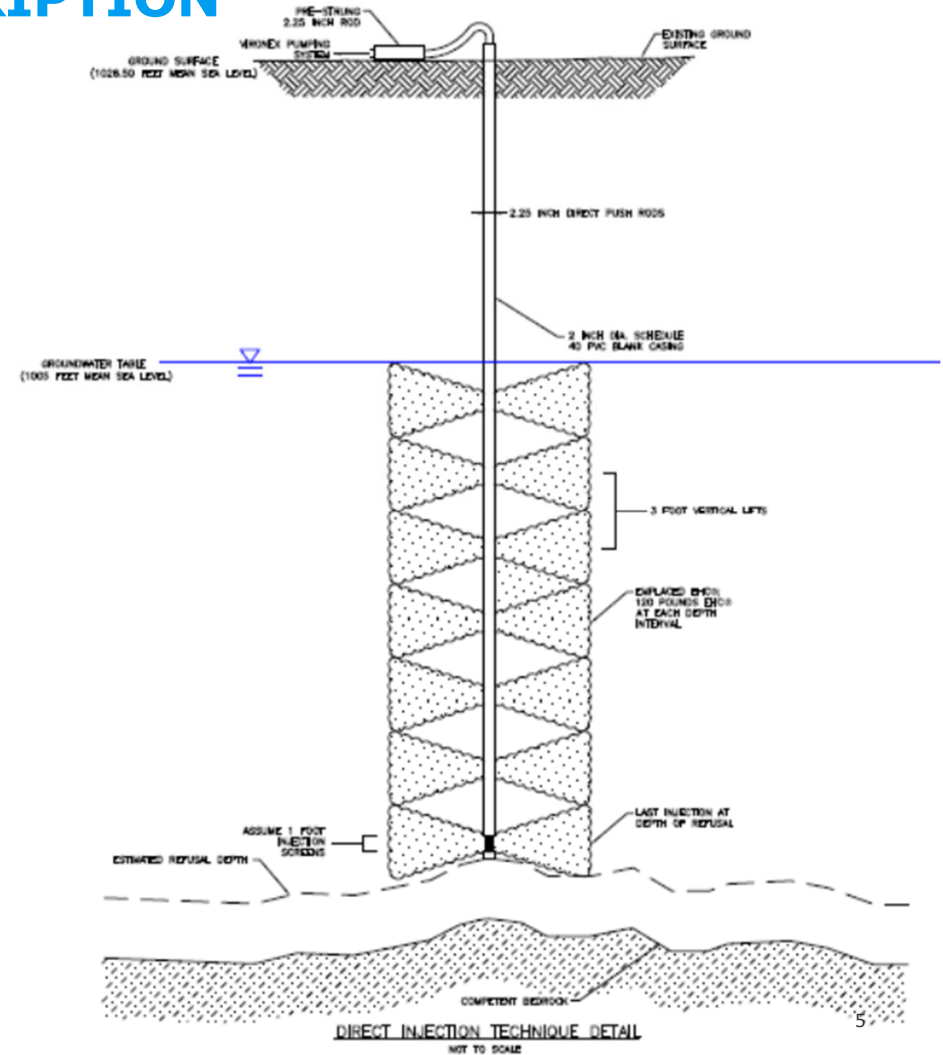
EHC[®] combines long lasting plant-based carbon source (electron donor) and zero-valent iron (ZVI)

Vendor claims EHC[®] promotes both biotic (reductive dechlorination) and abiotic (beta elimination) degradation pathways

Addition of ZVI known to lower ORP and increase pH

DIRECT INJECTION PROCESS DESCRIPTION

- Injection occurs at high pressure (150-250 psi) using a Geoprobe
- EHC® slurry injected at discrete intervals (every 3 feet) from top down
- Typically add 100 lbs of EHC® per injection interval to produce an ROI of ~5 feet
- Slurry concentration is 20-30% EHC® in water
- EHC® target loading for treatment zone is 0.5%, based on soil weight



EHC® Emplacement by Direct Injection



REMEDY APPLICATIONS

- Open fields, near buildings, inside buildings, through concrete slab or asphalt
- Sand, silts, plastic clay, Saprolite
- Injection depths from 6-50 feet below ground surface



CHEMGROUT PUMPS

- Provides robust operational performance
- Easy to maintain and change seals
- Allows slurry injection at high pressures (> 400 psi)
- Higher injection pressures and flowrates provide better EHC® distribution



How NOT to Perform EHC® Injections



SLURRY SURFACING – PART 1

Surfacing can occur through old boreholes or other open conduits to the surface

To prevent surfacing:

- Plug old boreholes and conduits
- Reduce injection volumes or use thicker slurry

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SLURRY SURFACING – PART 2

Surfacing can occur due to poor soil seal with Geoprobe rod

To prevent surfacing:

- Exercise care when performing hand clearance of injection locations
- Leave injection tooling in the ground overnight to allow subsurface pressure to dissipate before pulling rods

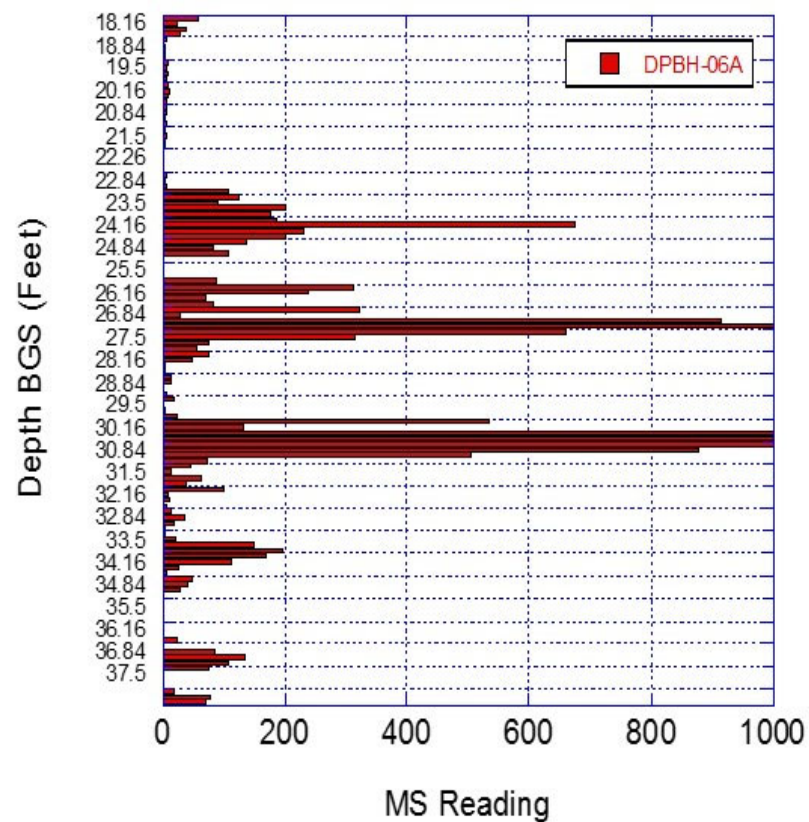
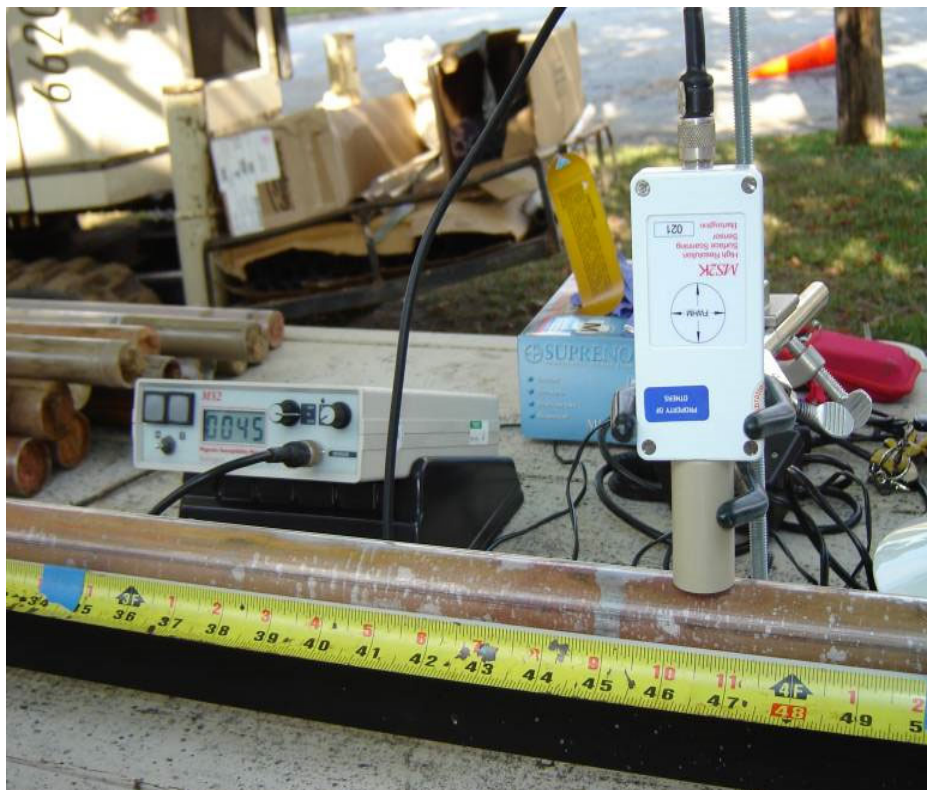
RAMBOLL



**ROI
DETERMINATION
FOR EHC[®]
INJECTION
PROGRAMS**

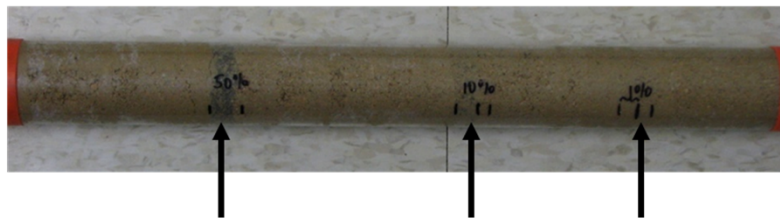
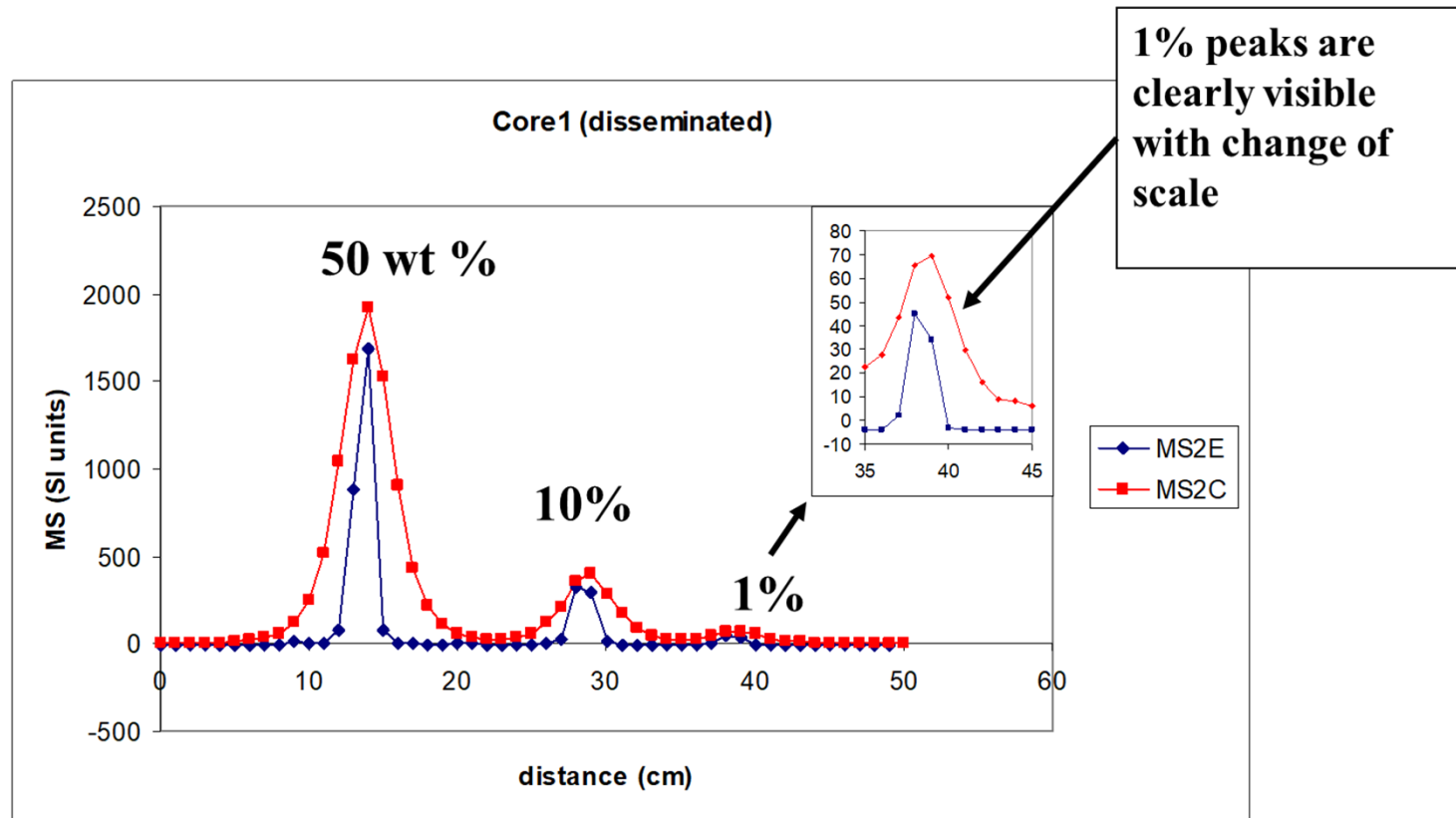


MAGNETIC SUSCEPTIBILITY MEASUREMENT

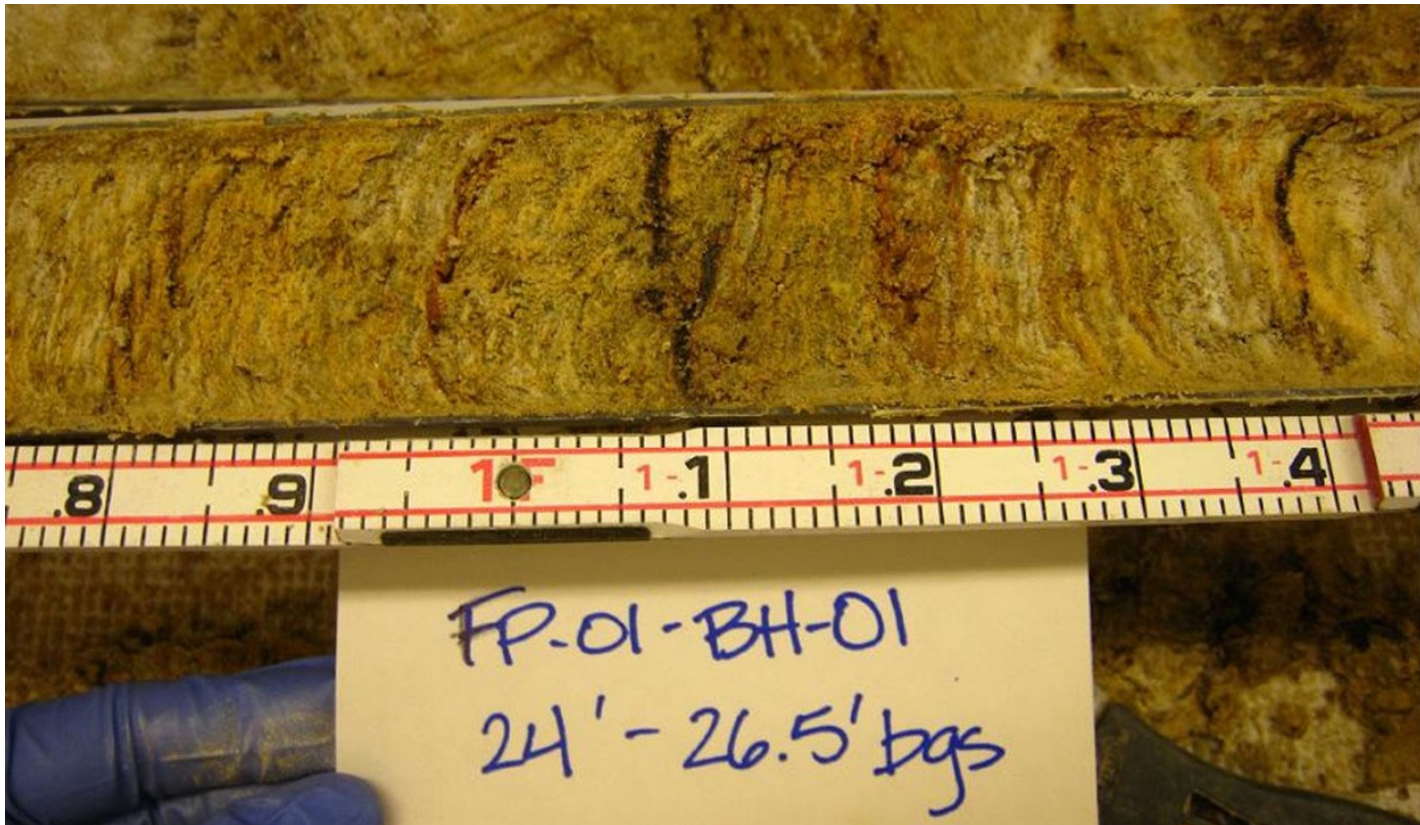


Arnason, J.G., Harkness, M., Butler-Veytia, B., Evaluating the Subsurface Distribution of Zero-Valent Iron Using Magnetic Susceptibility, Groundwater Monitoring & Remediation 34, no. 2/ Spring 2014/pages 96-106.

AMENDMENT MAPPING USING MS



FRACTURE MAPPING USING MS



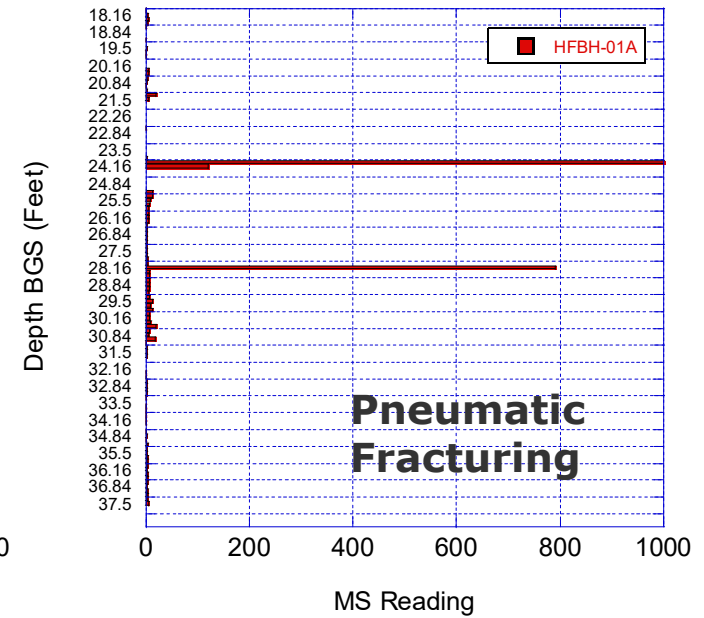
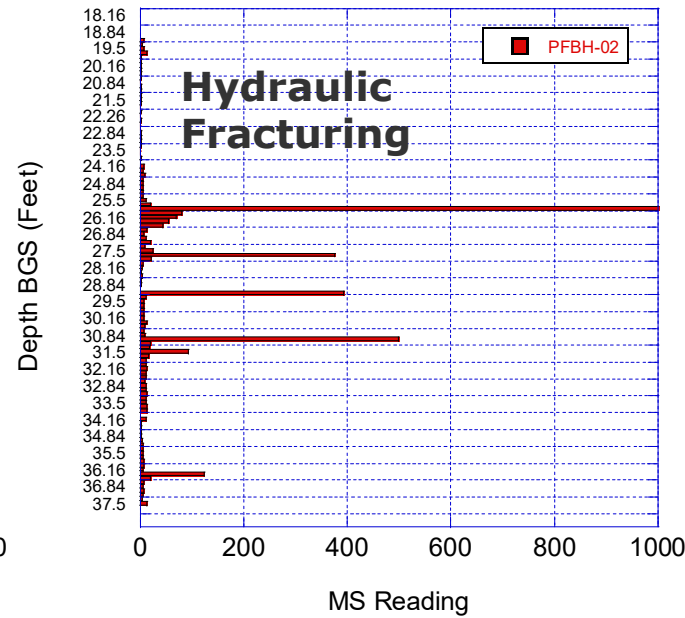
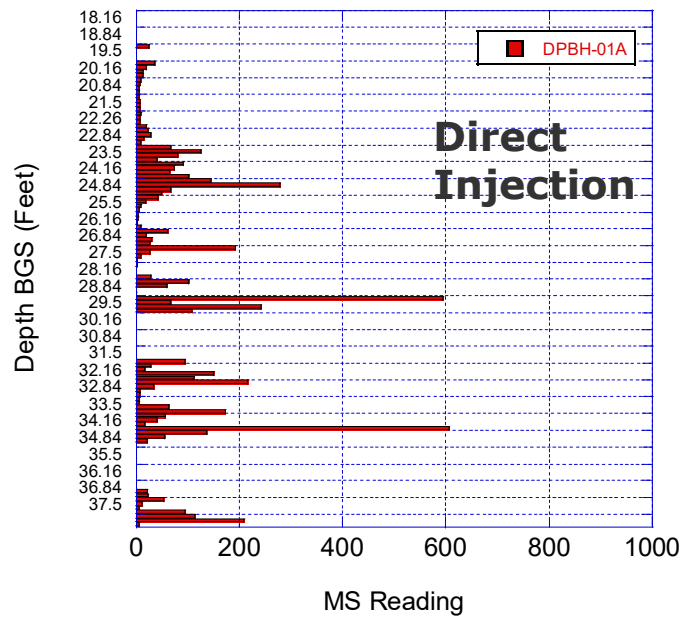
MS FIELD MEASUREMENTS

- Performed on confirmation soil cores collected in acetate sleeves
- Used hand-held MS meter (rental unit)
- Measured two sides of core at 2-inch increments
- Required 5-10 minutes per core (two people)



MS RESULTS

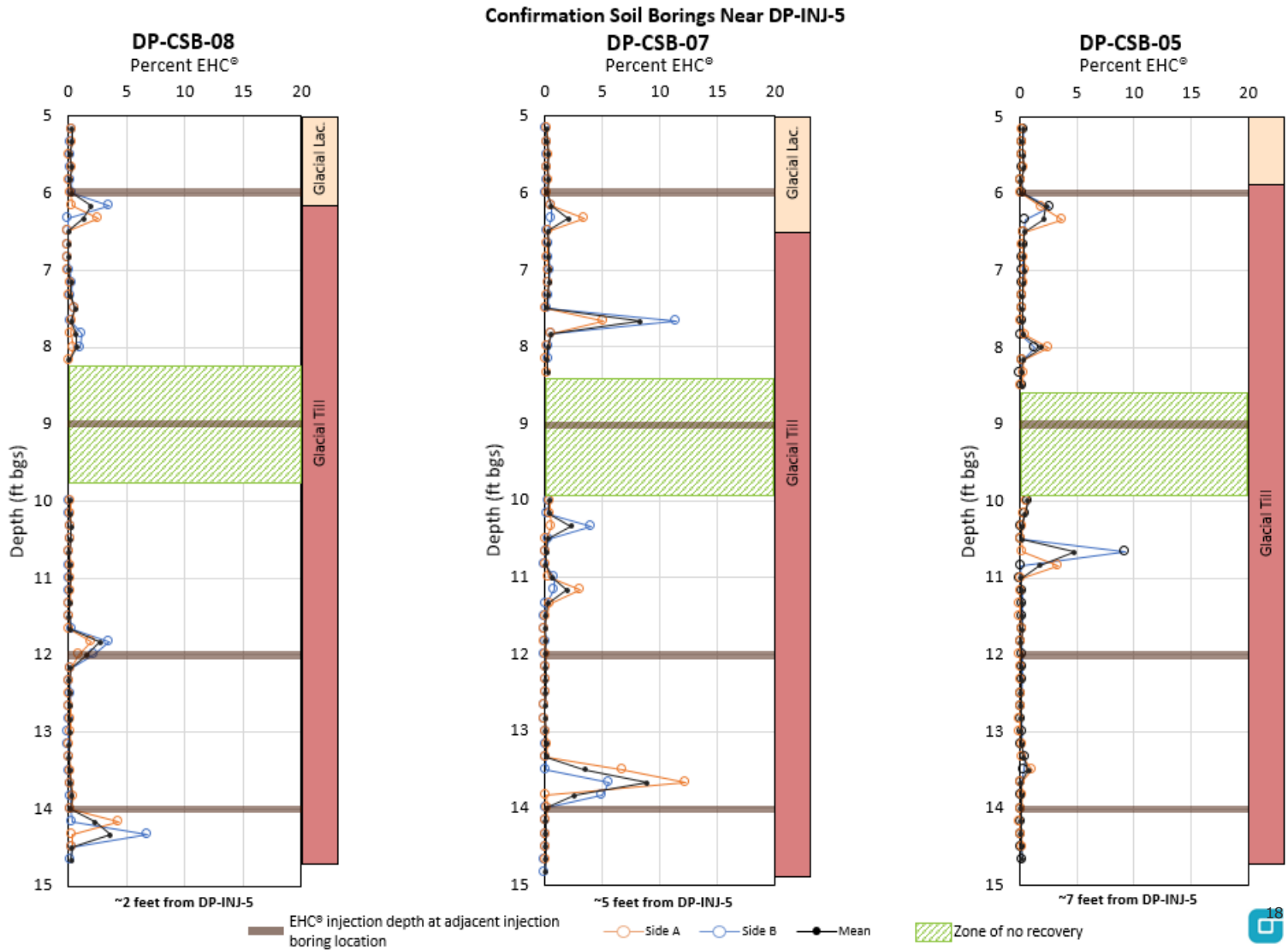
Pilot Program: Comparison between injection techniques



Harkness, M., Butler-Veytia, B., Antonoff, T., Nchako, F., Arnason, J., Comparison of Three Delivery Methods: Evaluation of ZVI Distribution using Magnetic Susceptibility, Battelle International Symposium on Bioremediation and Sustainable Environmental Technologies, Reno, Nevada, June 27-30, 2011.

MS RESULTS

Results demonstrate an ROI for EHC[®] injection of 5-7 feet achieved at this site

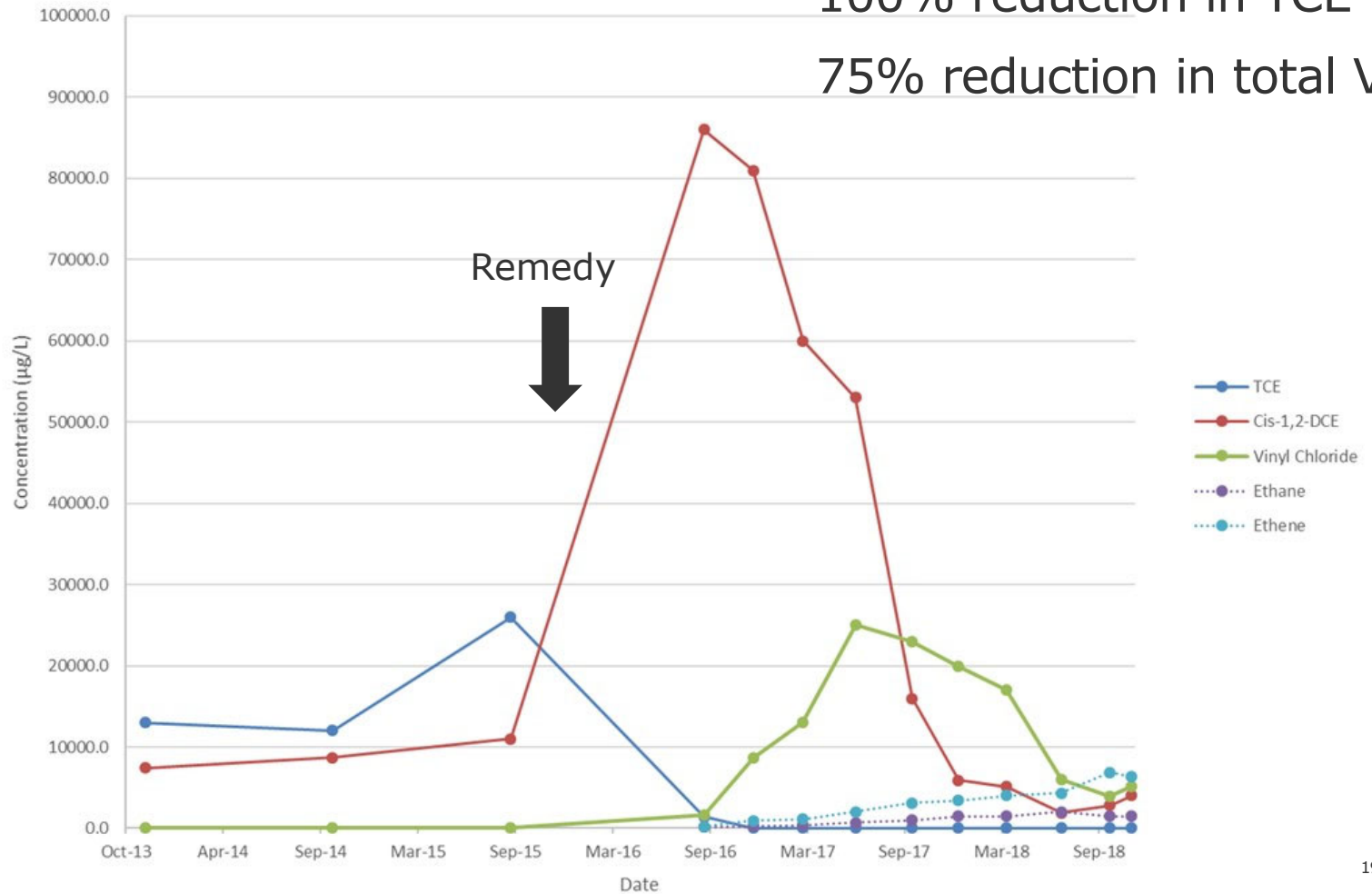


PERFORMANCE MONITORING

Former Wire Mill Area
DM-421-G

100% reduction in TCE

75% reduction in total VOCs



SUMMARY OF LESSONS LEARNED

Use solid amendments for low permeability formations

Use the proper equipment (ChemGrout pumps capable of high pressure injections)

Be aware of surfacing and how to prevent it

Measure the distribution of what you inject into the ground

THANK YOU

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