Remediation of a TCE Groundwater Plume using Hydraulic Fracturing to Emplace ZVI/Carbon Amendment

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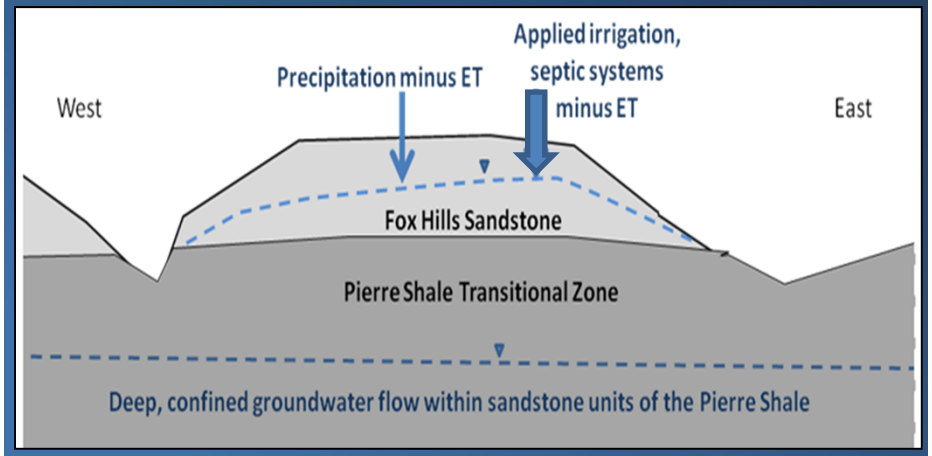
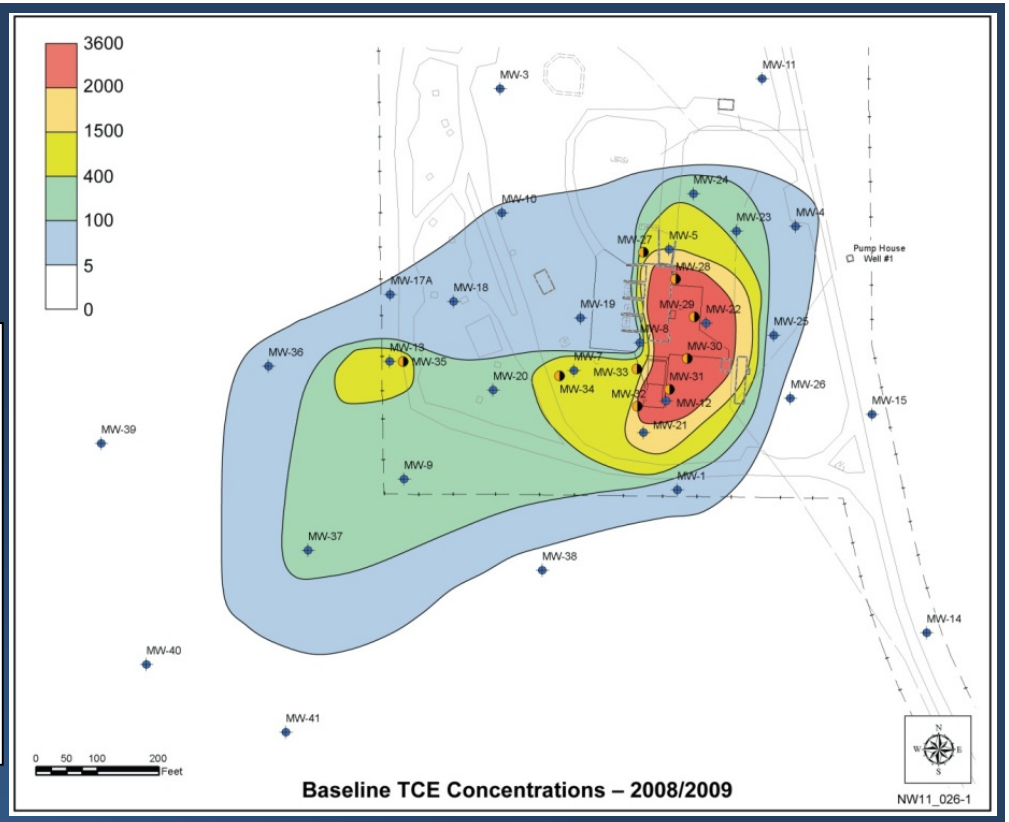
Site History

- Operational disposals of TCE-contaminated wastewater (1960-1965)
- UST Closures (1994), Site Investigation (1996), Remedial Investigation (1999), Feasibility Study (2003), Continued Site Characterization (2003-2008), Pilot Test (2009), Interim Action (2011)

Conceptual Site Model





Remedial Actions and Activities

Site Characterization Oct-Dec 2008

Pilot Test Apr-May 2009

Interim Action Planning Jan-May 2011

Interim Action Jul-Aug 2011

Initial CSM Development Oct 2008

CSM Update Apr 2009

CSM Update Dec 2010

CSM Update Jun 2011

CSM Development and Refinement

Hydraulic Fracturing for Remediation

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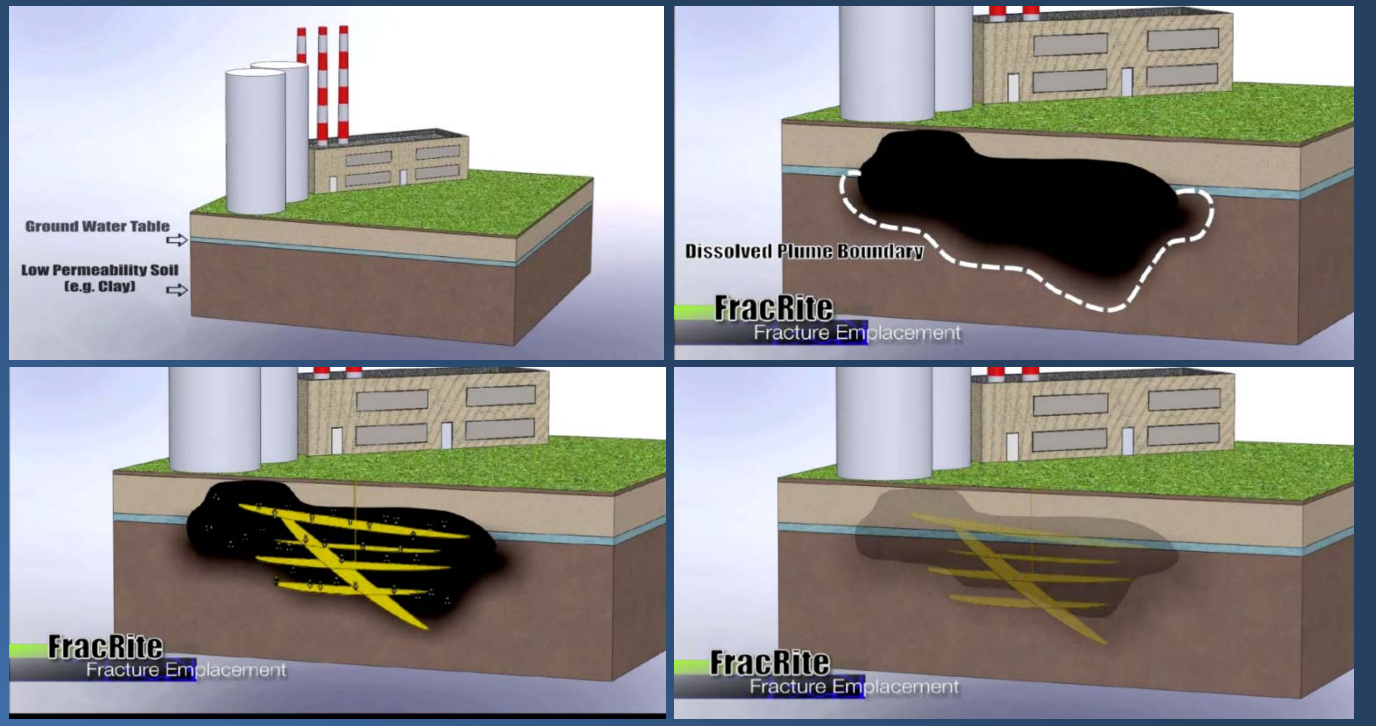
Create treatment pathways to increase:

- permeability
- treatment area
- contact with contaminants



YouTube: Frac Rite FRAC RITE ENVIRONMENTAL LTD.

… and facilitate

- emplacement or injection of treatment amendments.

Hydraulic fracturing provides an opportunity to ***remediate low permeability formations that would not otherwise be amenable to in situ treatment***.

Pilot Test Design

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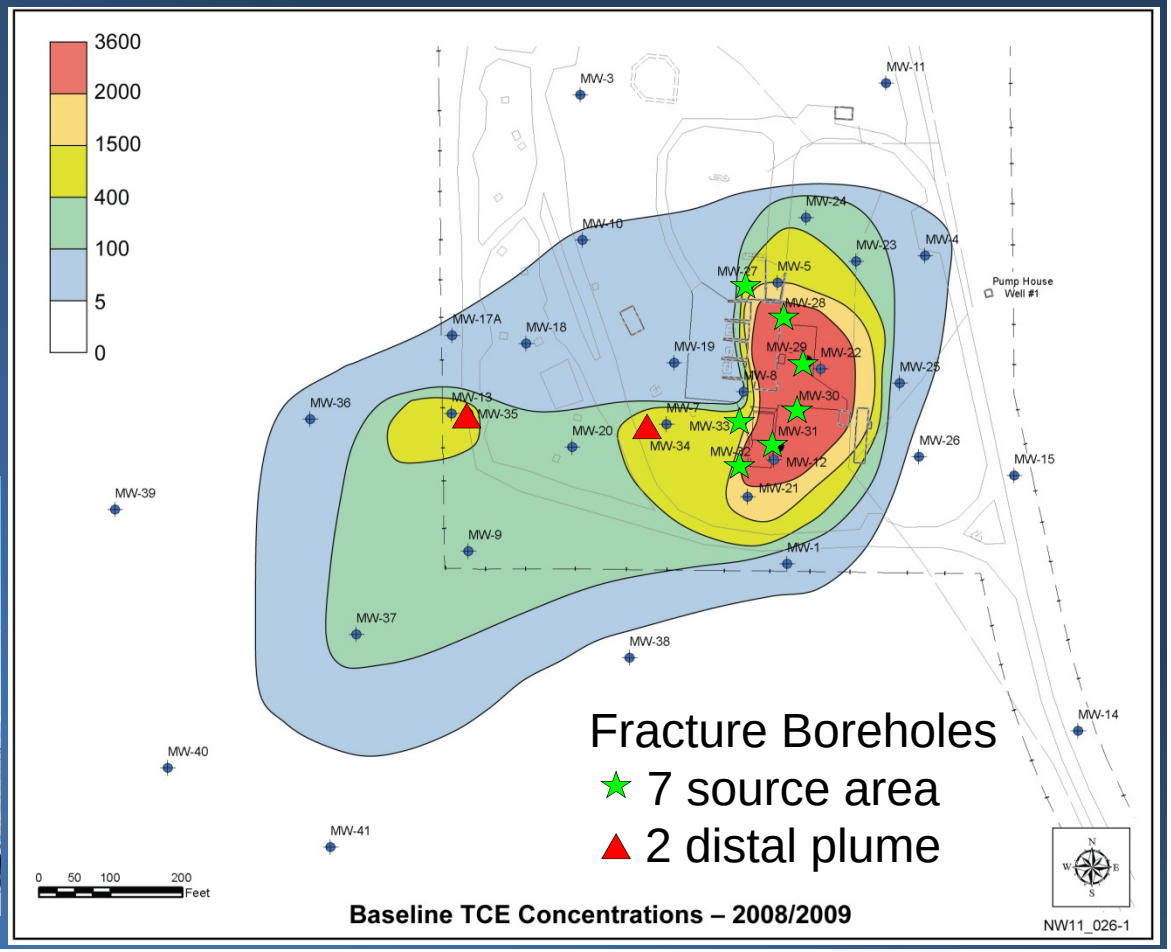
- Hydraulic fracturing to emplace EHC-G®
- EHC-G® is zero valent iron (ZVI) and complex carbon
- Fracture mapping using tiltmeters



Pilot Test Amendment Distribution

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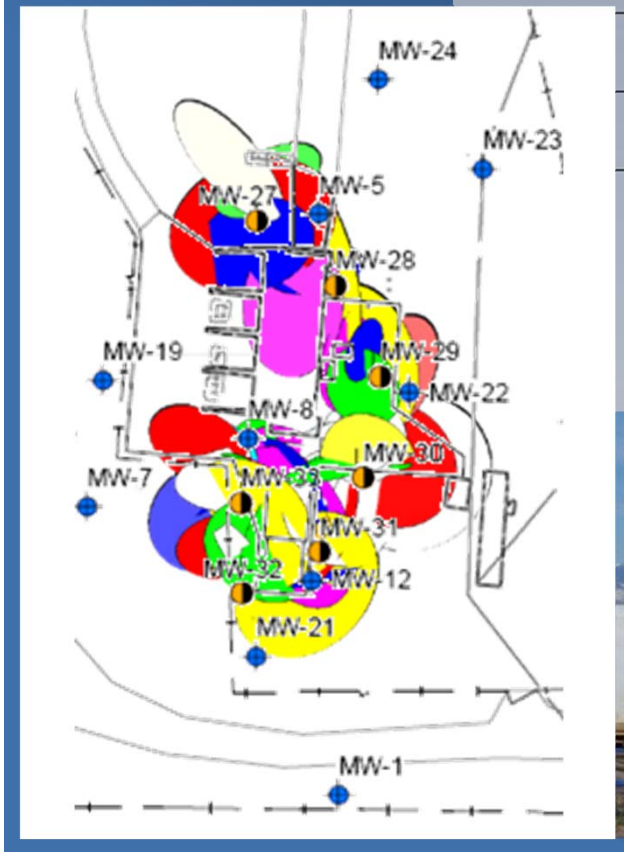
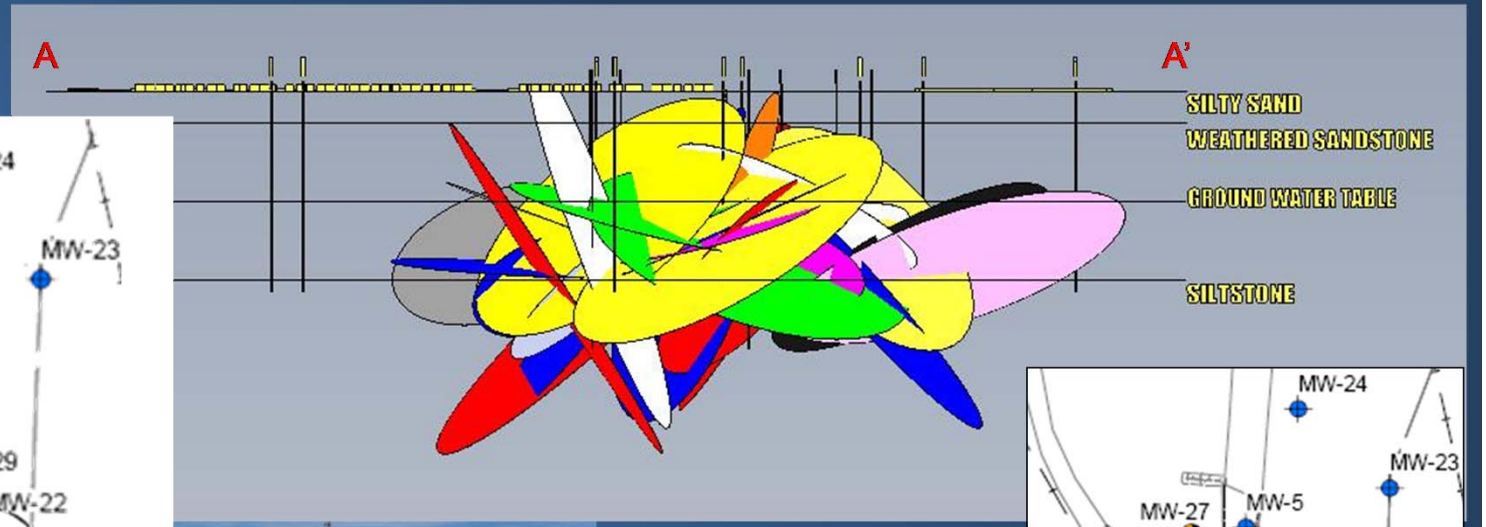
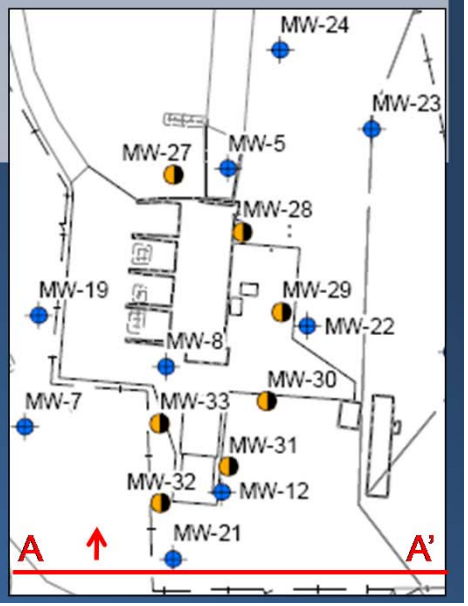
- Vertical coverage across entire saturated zone (every ~6 ft)
- Amendment distribution radius ~65 to ~80 ft
- Extensive, overlapping fracture network in source area



West

East





Represents direction of cross section view

Performance Monitoring

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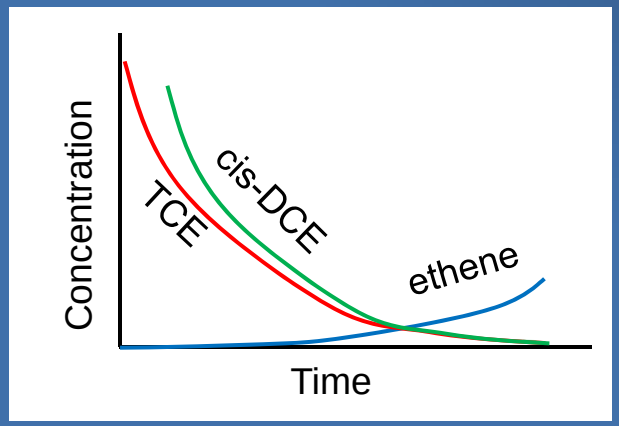
Abiotic TCE Degradation

- ZVI
- Chemical Dechlorination Pathways

TCE → { cis-DCE, vinyl chloride, chloroacetylene, acetylene } → ethene + chloride

short lived intermediates



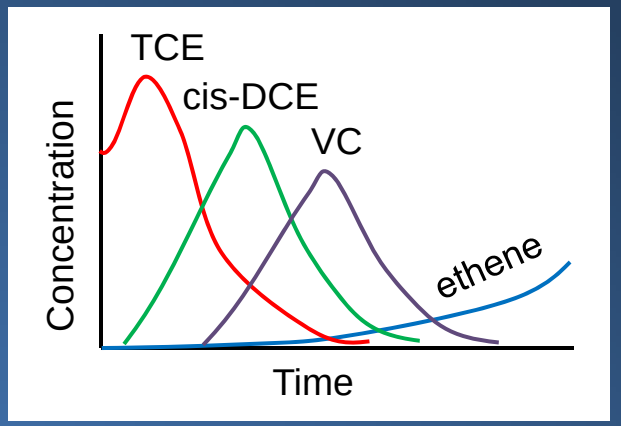
Biotic TCE Degradation

- Carbon Amendment
- Anaerobic Reductive Dechlorination (ARD) Pathways

TCE → cis-DCE → vinyl chloride → ethene

TCE → chloride; cis-DCE → chloride; vinyl chloride → chloride

intermediates persist in biotic pathway



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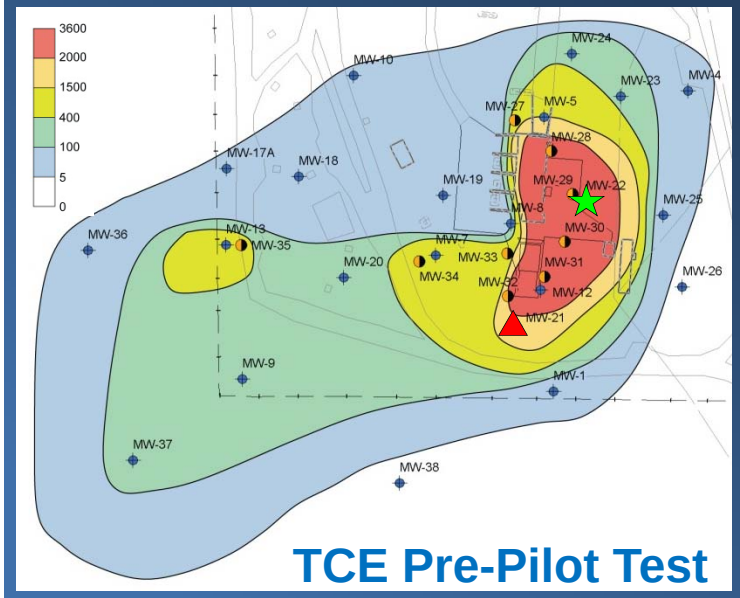
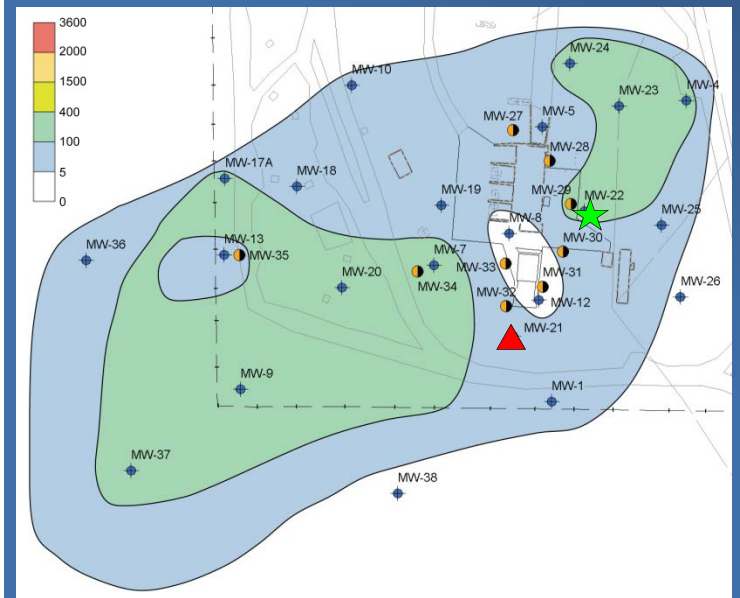
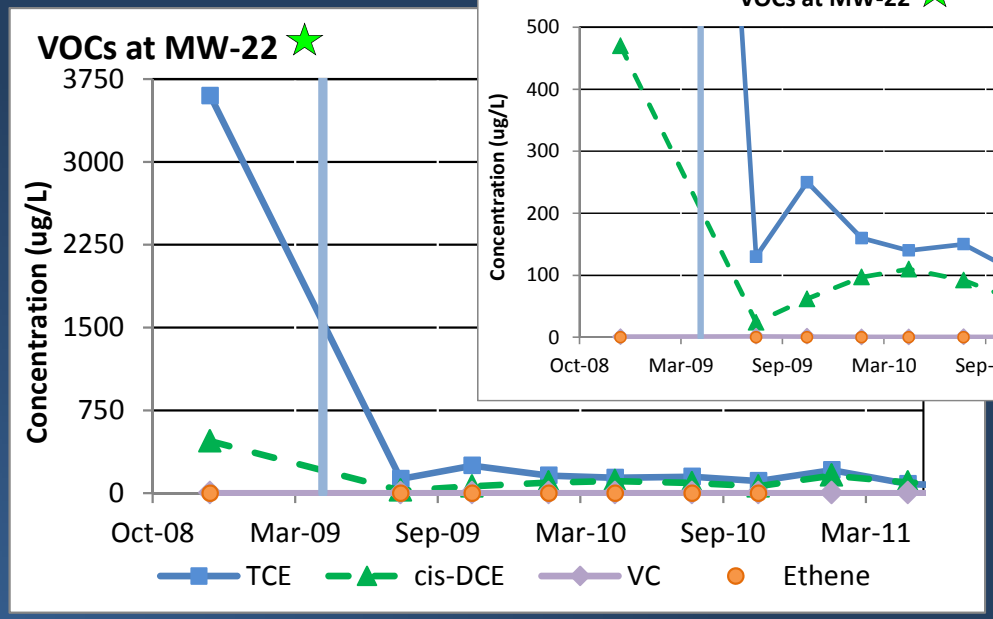
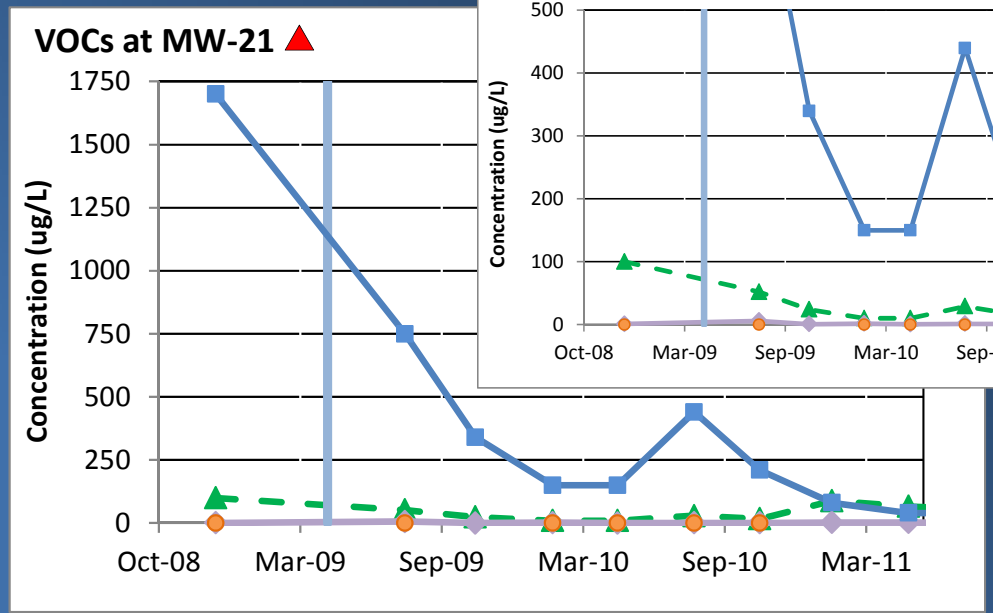


TCE Pre-Pilot Test



TCE 21 Months Post-Pilot Test





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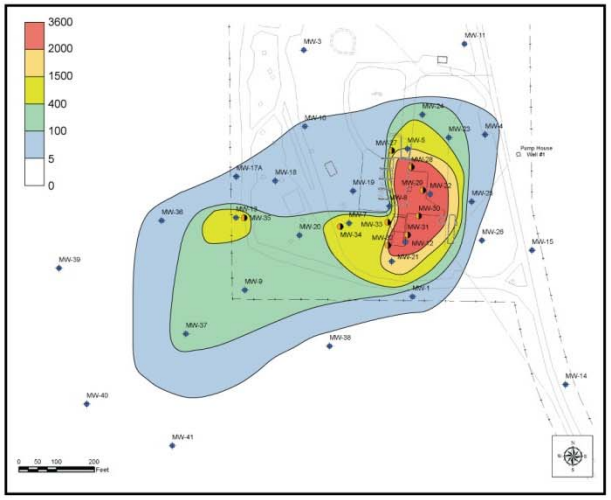
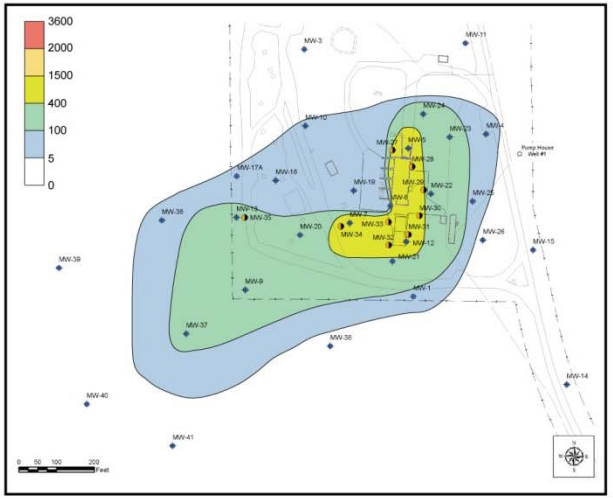
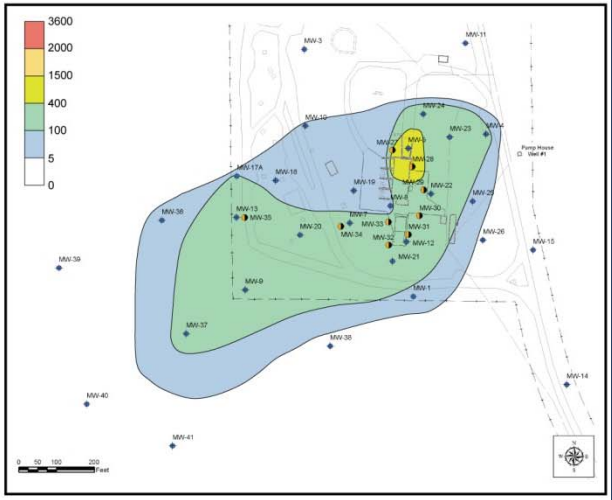
Post-Pilot Test TCE Concentration Changes



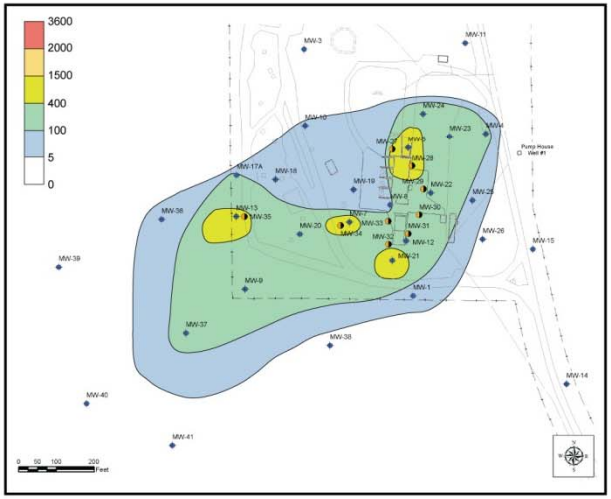
Baseline



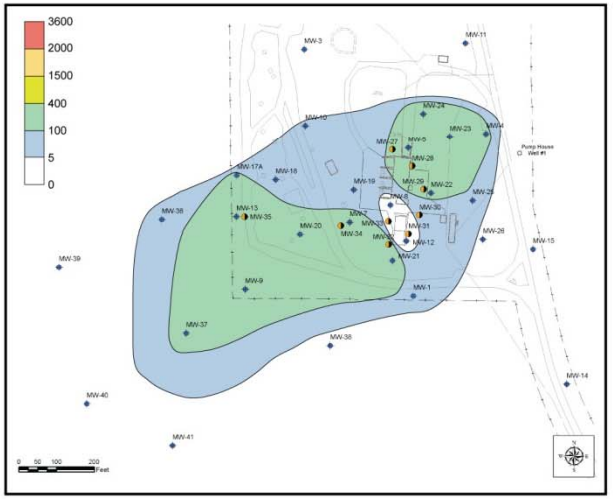
6 months



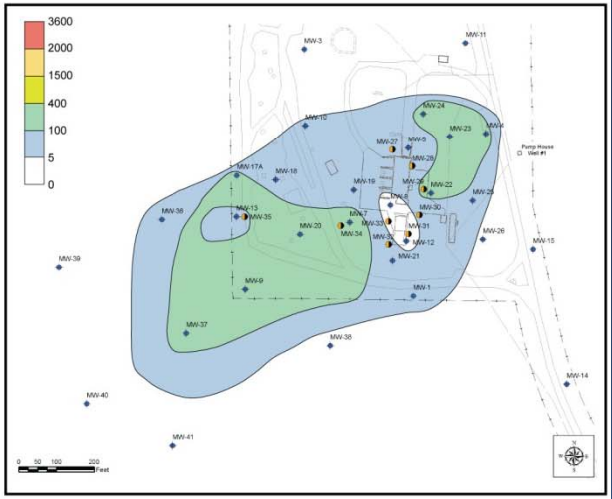
12 months



15 months



18 months



21 months

NW11_026-7

Pilot Test Lessons Learned

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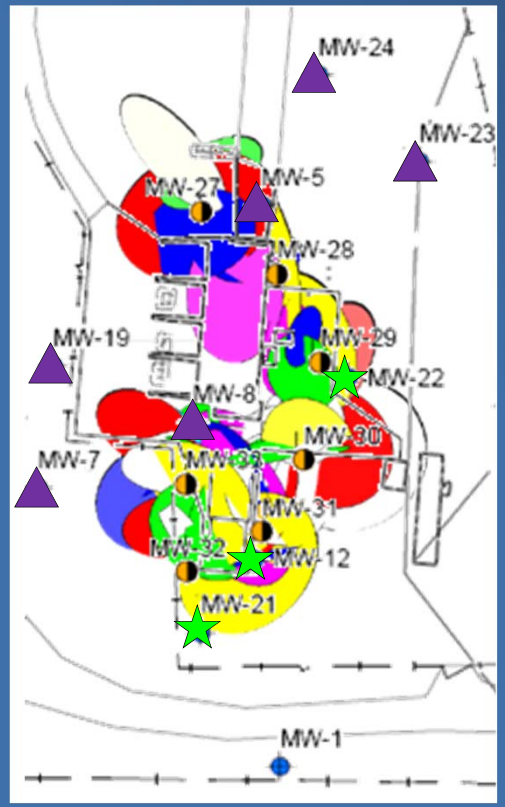
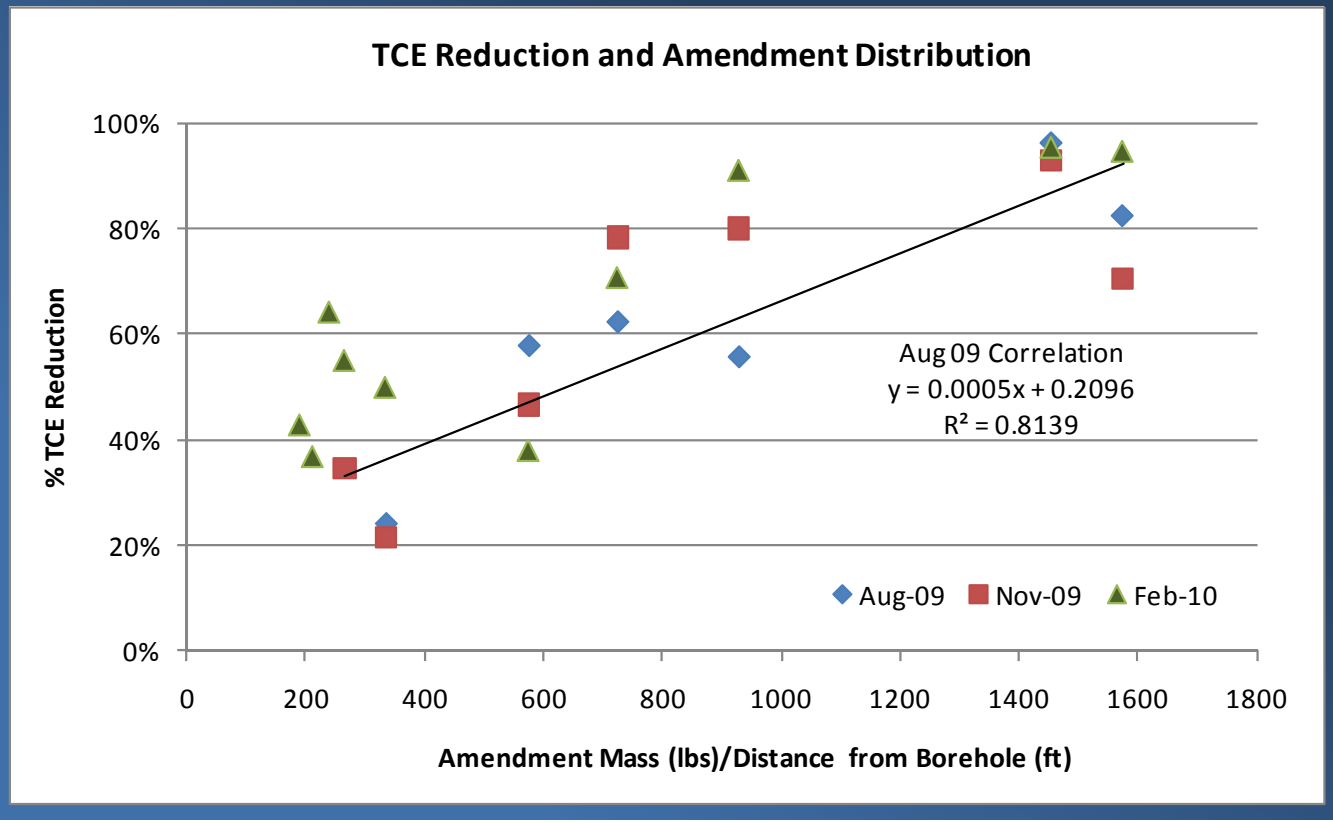
#1 TCE mass reduction correlates with amendment distribution.

- ★ High TCE reductions (>90%) = extensive fracture network, high amendment mass distributed
- ▲ Moderate TCE reductions (~40-80%) = increased distance from fractures, lower amendment mass distributed





Pilot Test Lessons Learned

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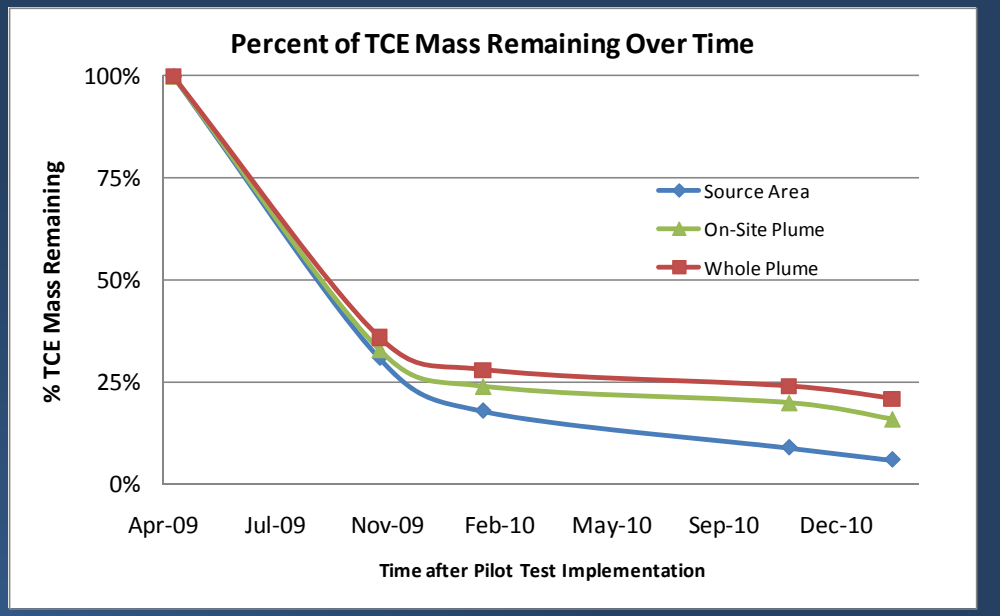
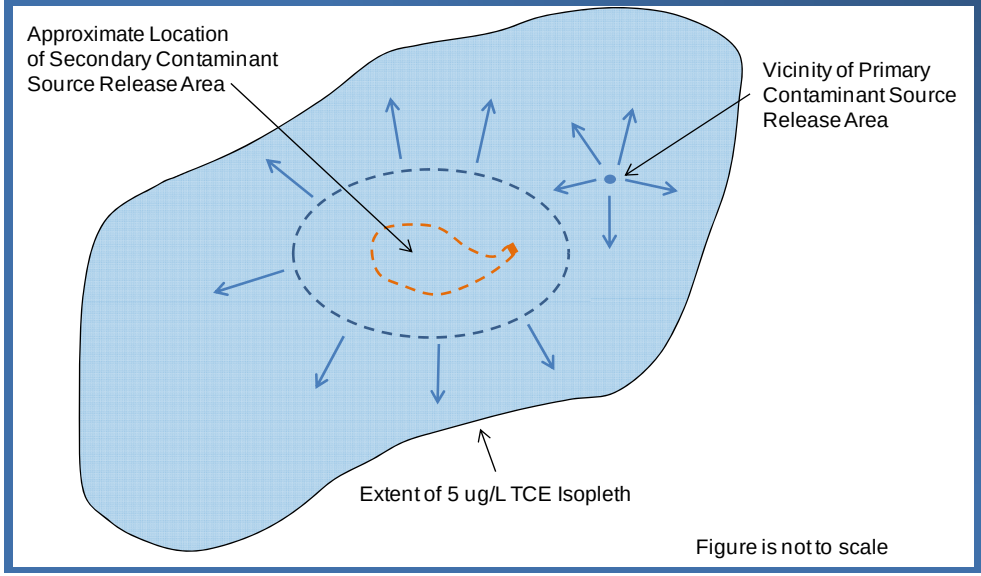
#2 The emplaced amendment resulted in significant TCE degradation.

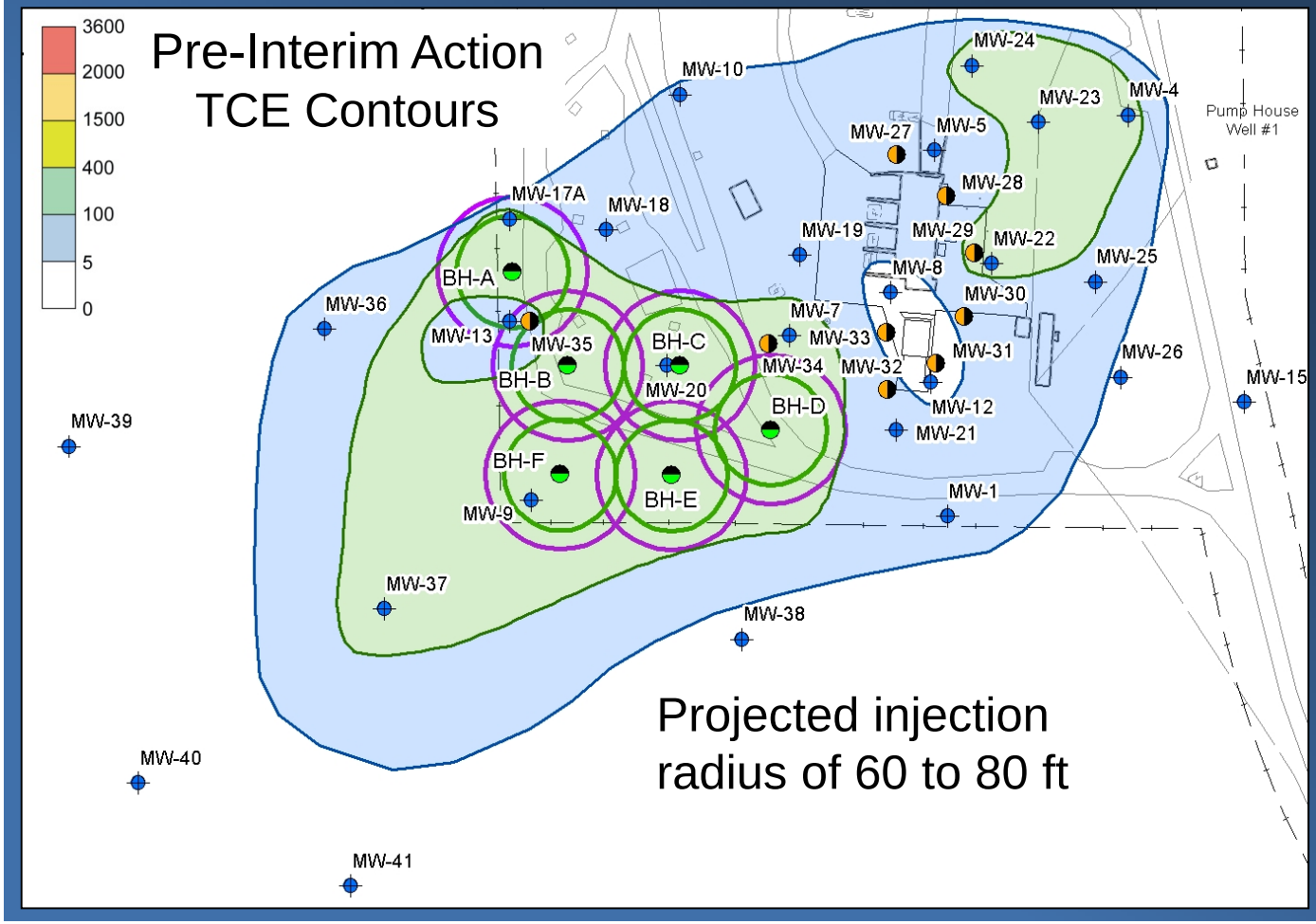




#3 Plume configuration is not always a good indication of contaminant fate and transport.

Interim Action Design

- Design targeted the plume area with TCE concentrations >100 ug/L
- Hydraulic fracturing to emplace EHC®; 6 distal plume boreholes
- Vertical coverage across saturated zone (every 3 to 6 ft)



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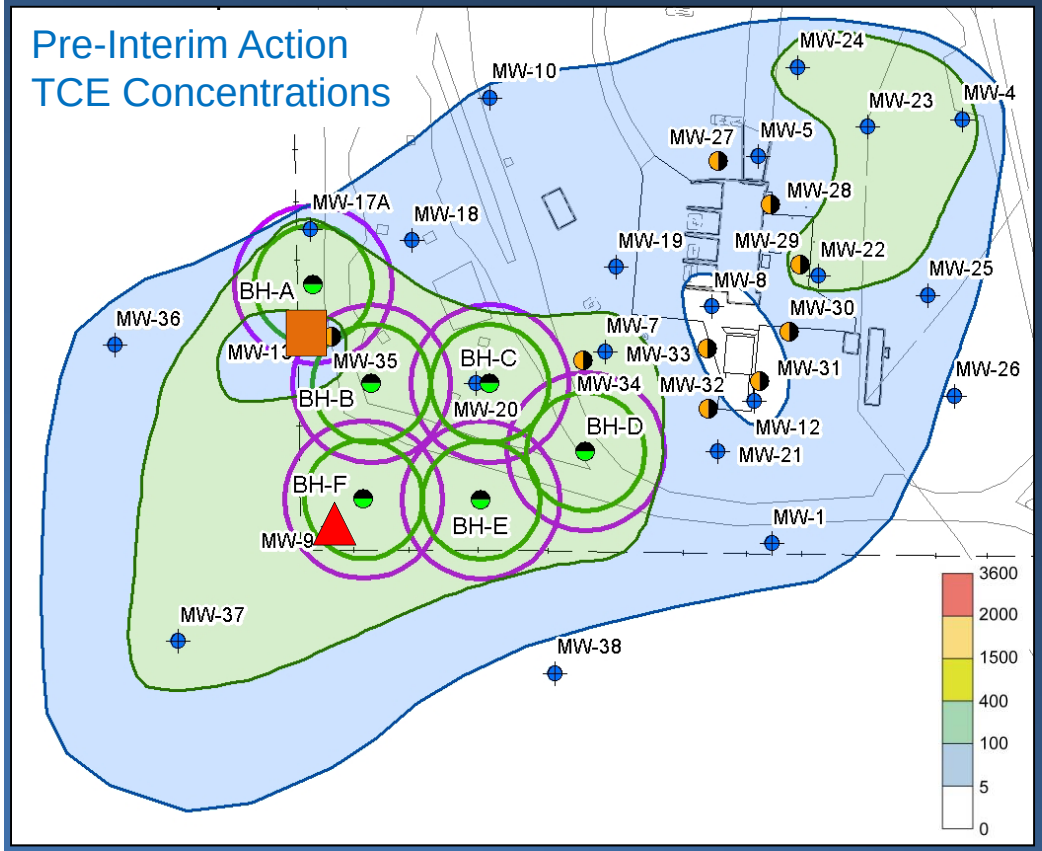
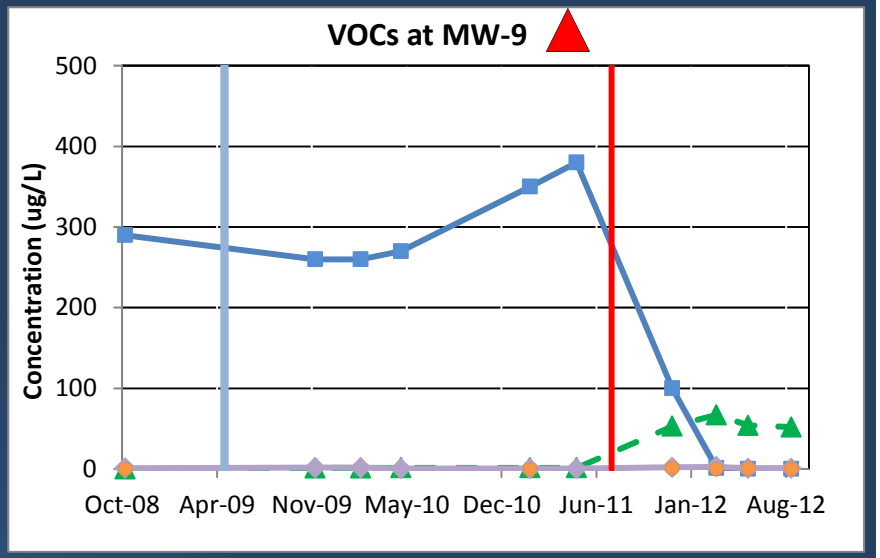
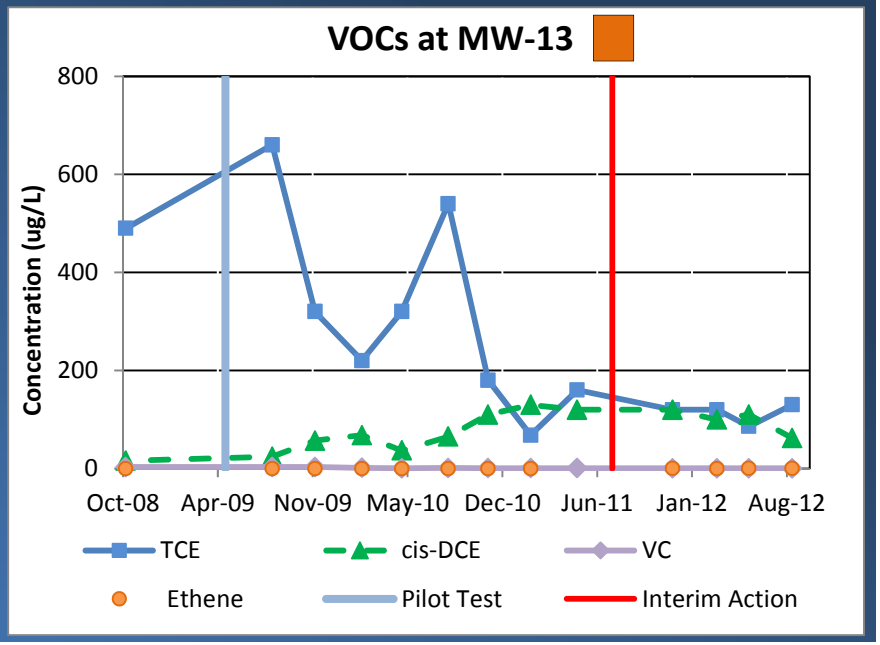
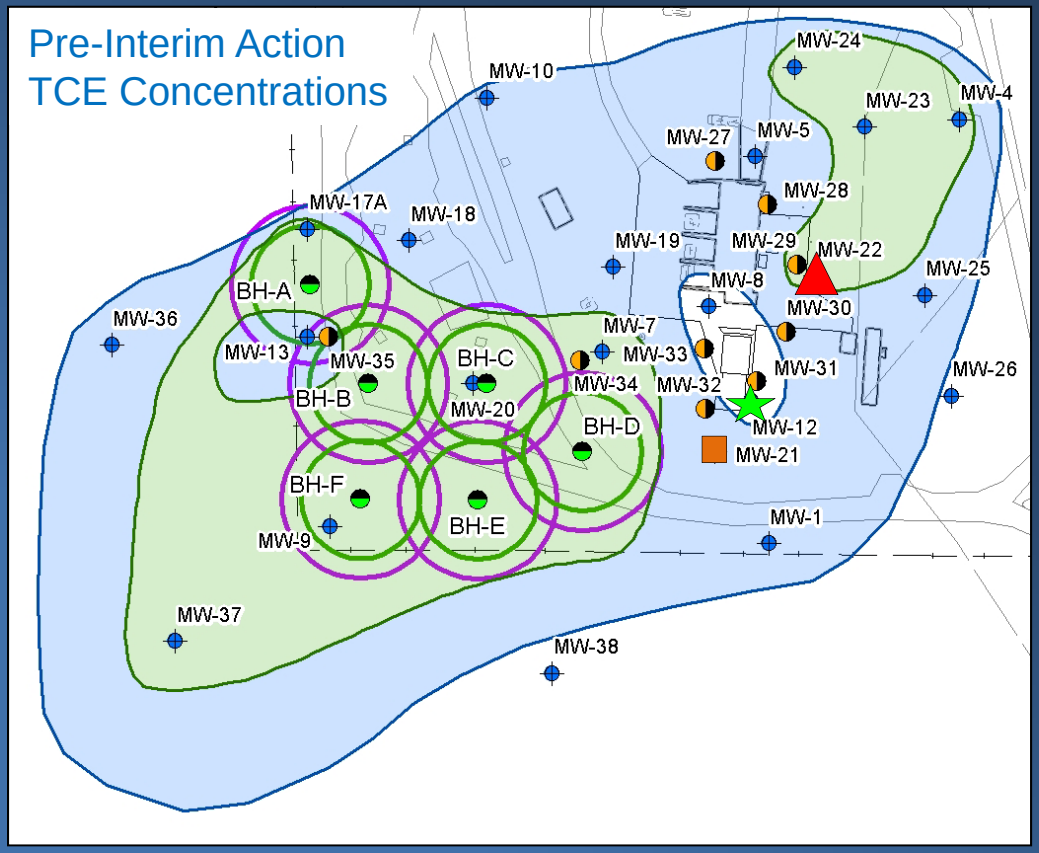




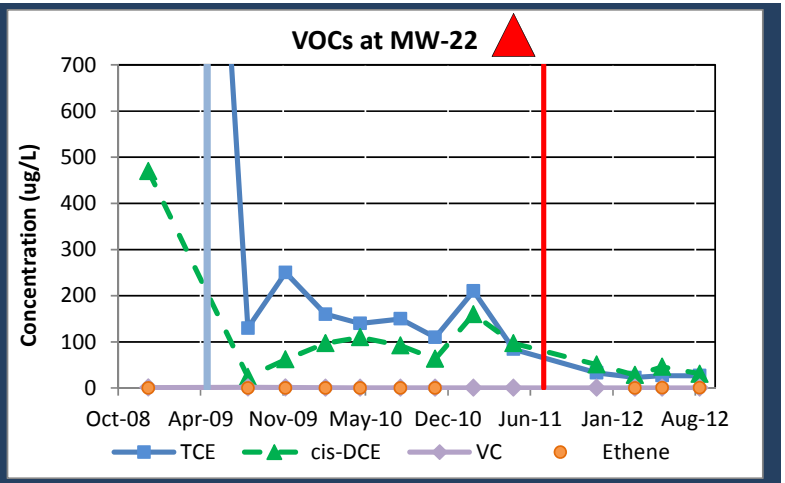


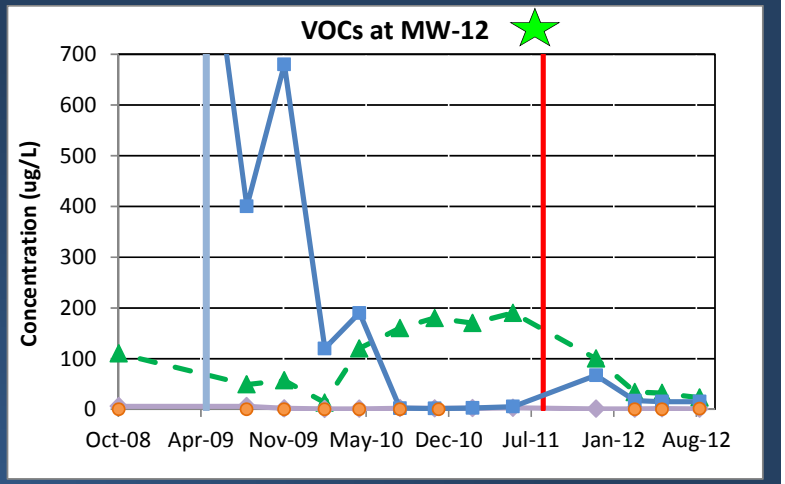
- Reduction to below the TCE MCL within 6 months where highest amendment distribution
- Minimal to no TCE reduction where amendment did not directly impact groundwater in vicinity of well

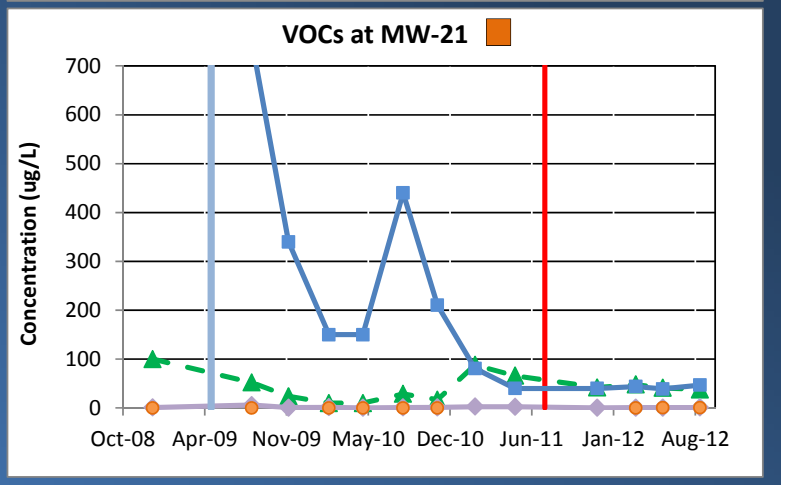
Performance Monitoring



- Continued TCE reduction 36 months post-Pilot Test
- Slight TCE rebound but overall declining trends







Conclusions

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The use of hydraulic fracturing to emplace ZVI/carbon amendment resulted in effective groundwater remediation of TCE.

Traditional groundwater remediation technologies would be difficult to implement at this site.

Future Actions

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- Site characterization activities prior to designing the full scale remedy:
  - Plume delineation
  - Investigate vertical contaminant distribution
  - Aquifer testing
- Full-scale design:
  - Hydraulic fracturing to treat remainder of plume
  - Long term remedy monitoring

Acknowledgments

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Omaha District

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