

# BIOREMEDIATION USING EMULSIFIED VEGETABLE OIL – HOW LONG DOES IT REALLY LAST?

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Jefferson County GIS



**JRW** *BIOREMEDIATION* LLC

**Cleaned by  
Nature**

# PROJECT SETTING

- Drycleaner site in mountain valley in Central Colorado
- Groundwater Velocity  $<10'$ /yr
- PCE contamination with unconfirmed source
- Operating shopping center with multiple tenants
- Private small owner
- Limited access to presumed source area.



# Positive Aspects of the Project

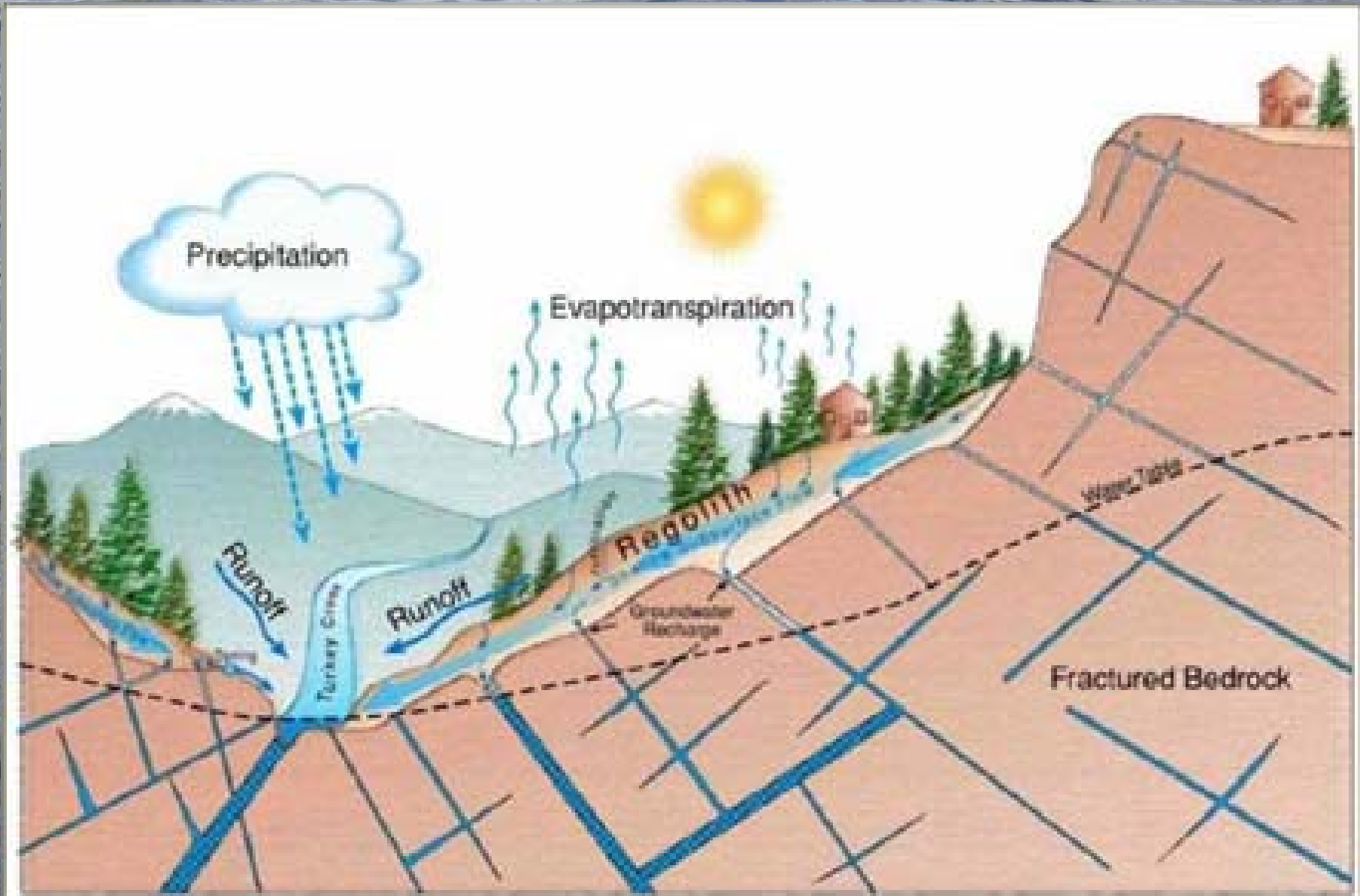
- Consultant has a good relationship with the property owner
- Consultant very attuned to concepts of added value and expectations management (Don't let your ego write checks that your boss won't let you cash!)
- Consultant understands “connections” and “cause and effect”.



# A MULTIPLE TECHNOLOGY SOLUTION?

- ISCO originally attempted BUT residual contamination remained in both source and plume areas
- Intent to use anaerobic bioremediation to address remaining CHCs in both the source and the dilute plume
- Both readily soluble (plume) and slowly soluble (source) substrates proposed
- Original case study presented at 2013 Battelle Conference, Jacksonville, FL.





Hirsch-Gibney 2013, USGS, Jefferson County, CO 2001





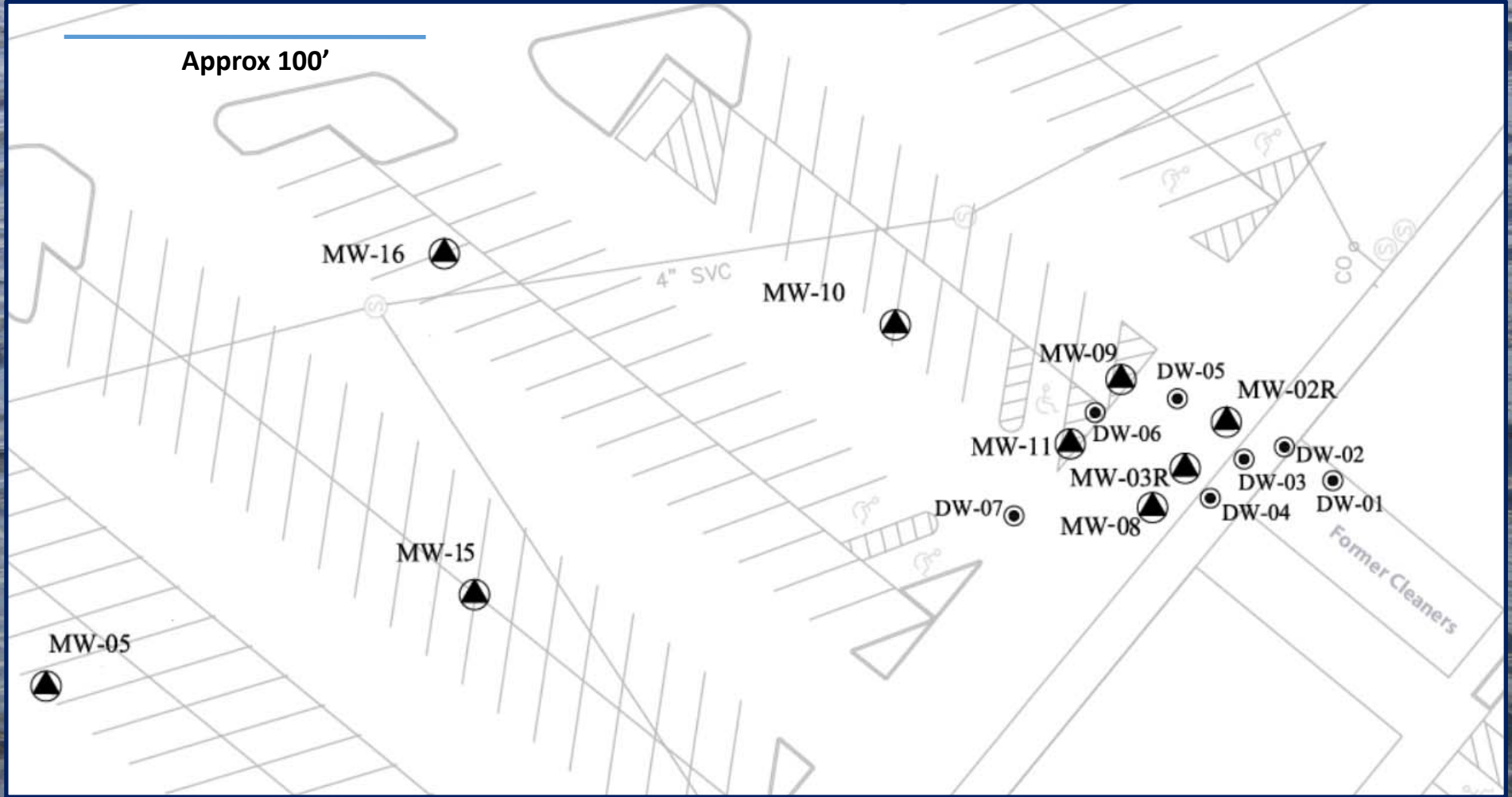
Snowmass Village, CO 2018

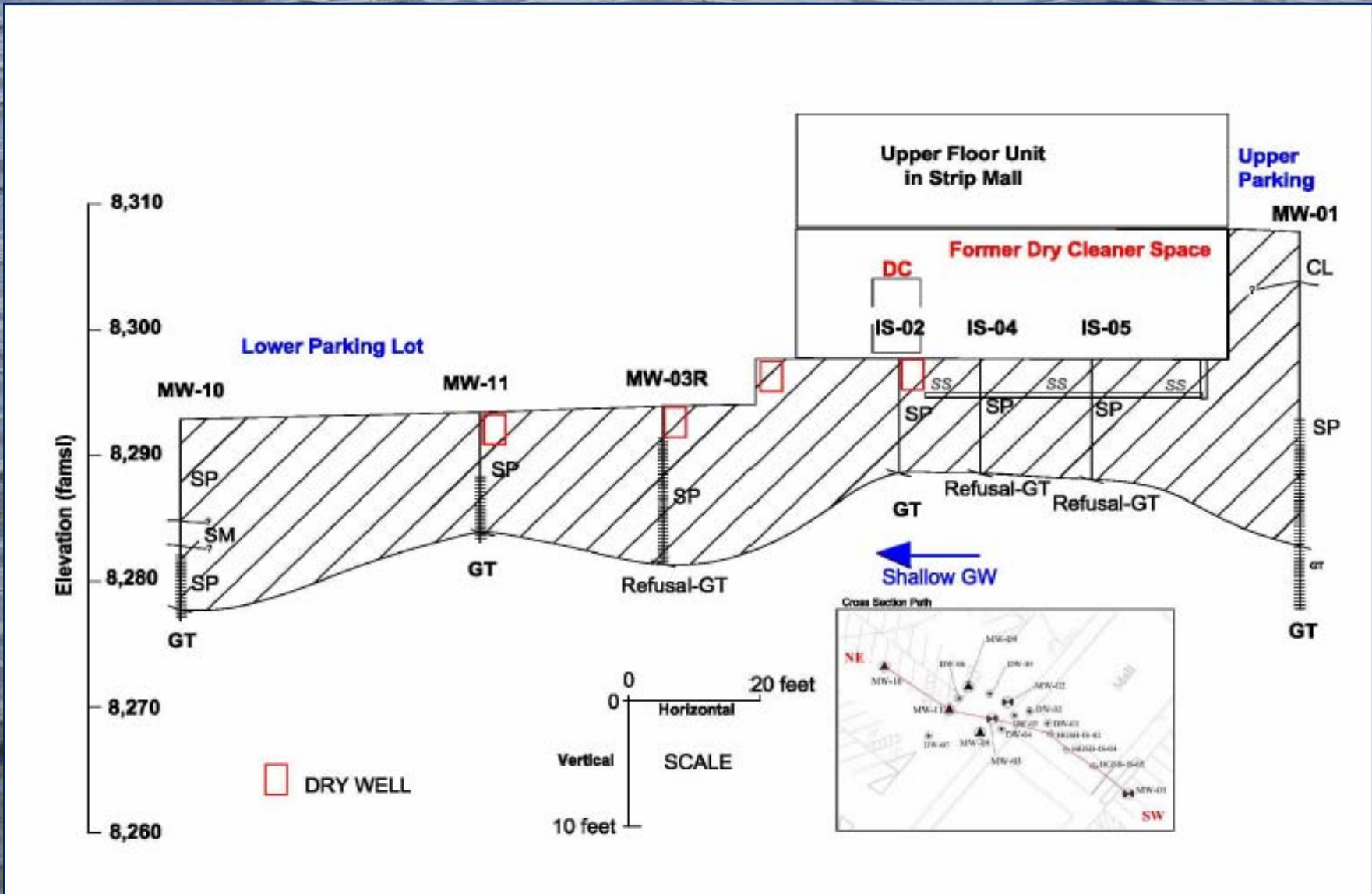


Google Earth 2018



Approx 100'





Hirsch-Gibney 2013

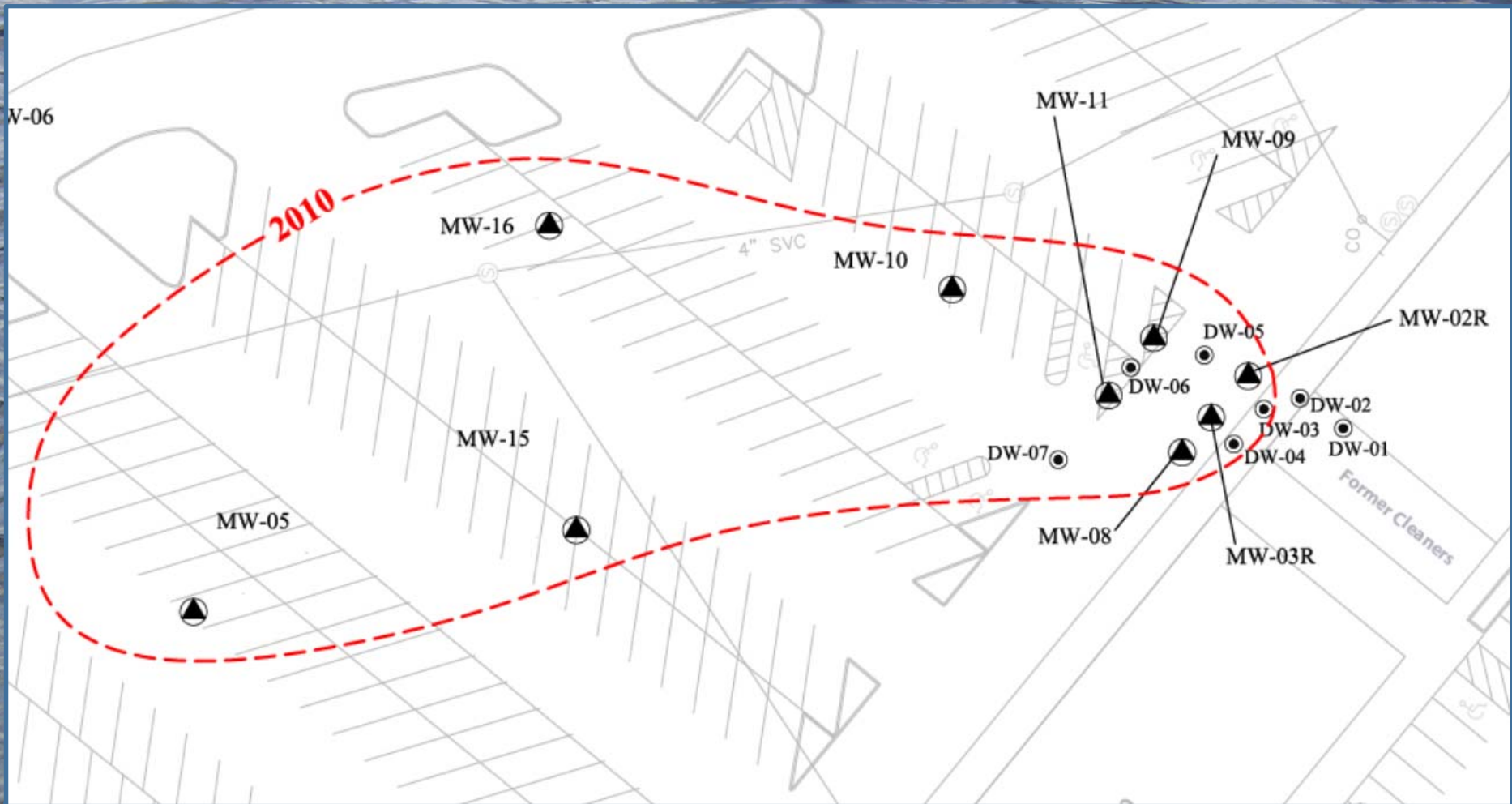


# MULTIPLE ISCO APPLICATIONS TRIED

- ISCO – 2 doses of  $\text{KMnO}_4$  – April 2007 and December 2007 – Source and Plume
- ISCO – 2 doses  $\text{NaMnO}_4$  – December 2008 and December 2009 – Source

PCE in source area still 100-5,000  $\mu\text{g}/\text{L}$ .  
Plume not addressed.

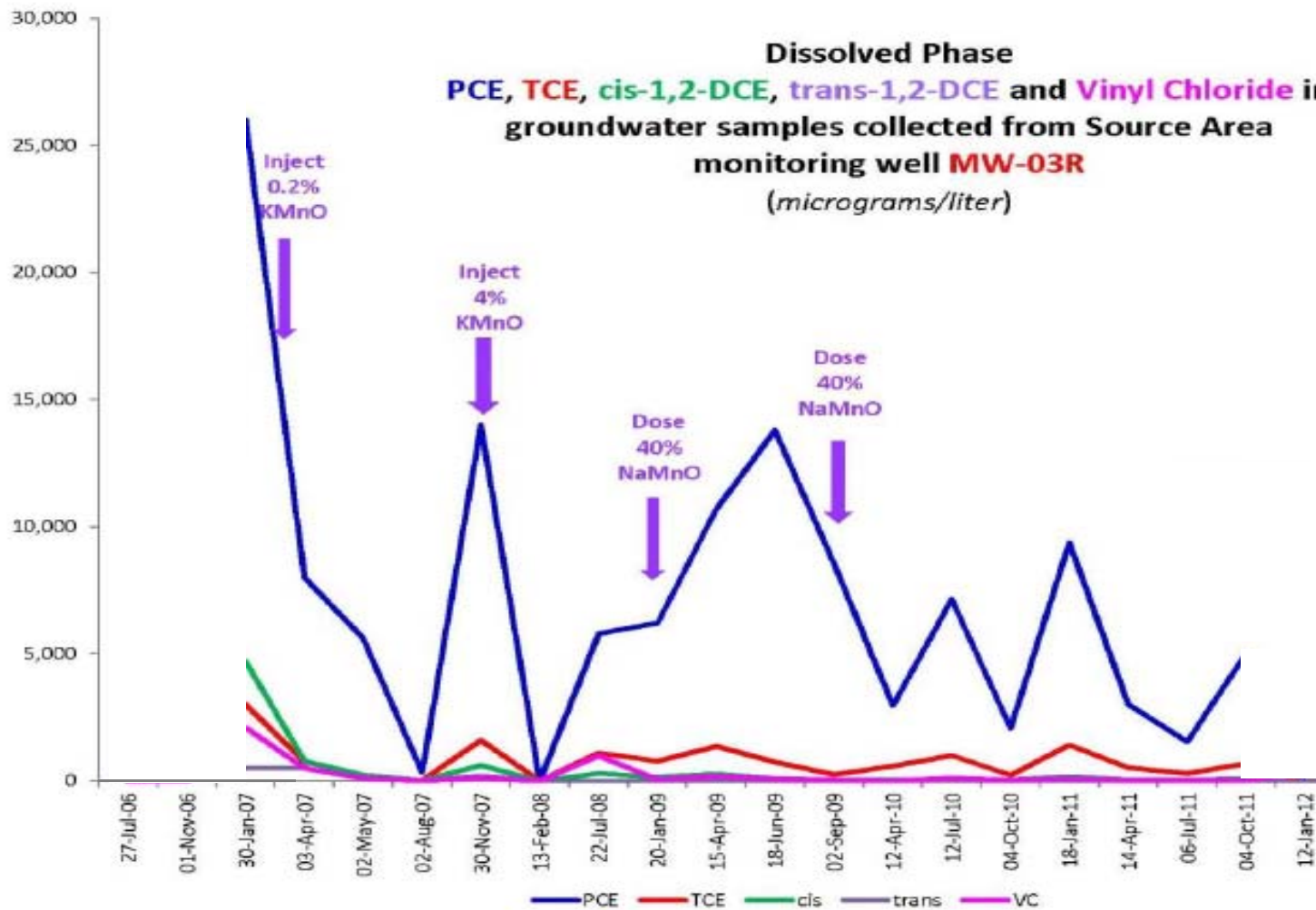




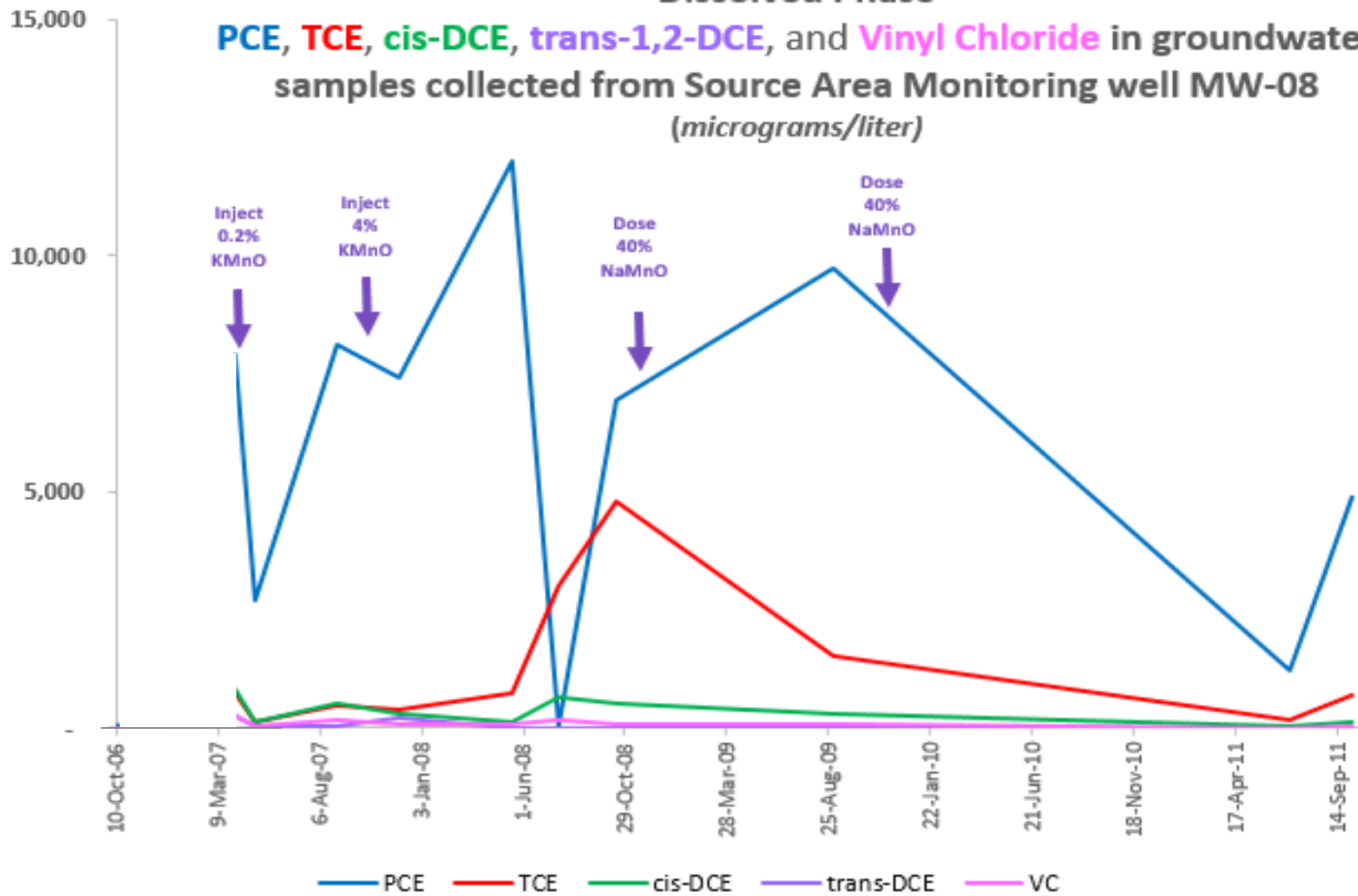
**PRE-BIOREMEDIATION ESTIMATED EXTENT OF PCE GREATER THAN 5 µg/L  
2010**



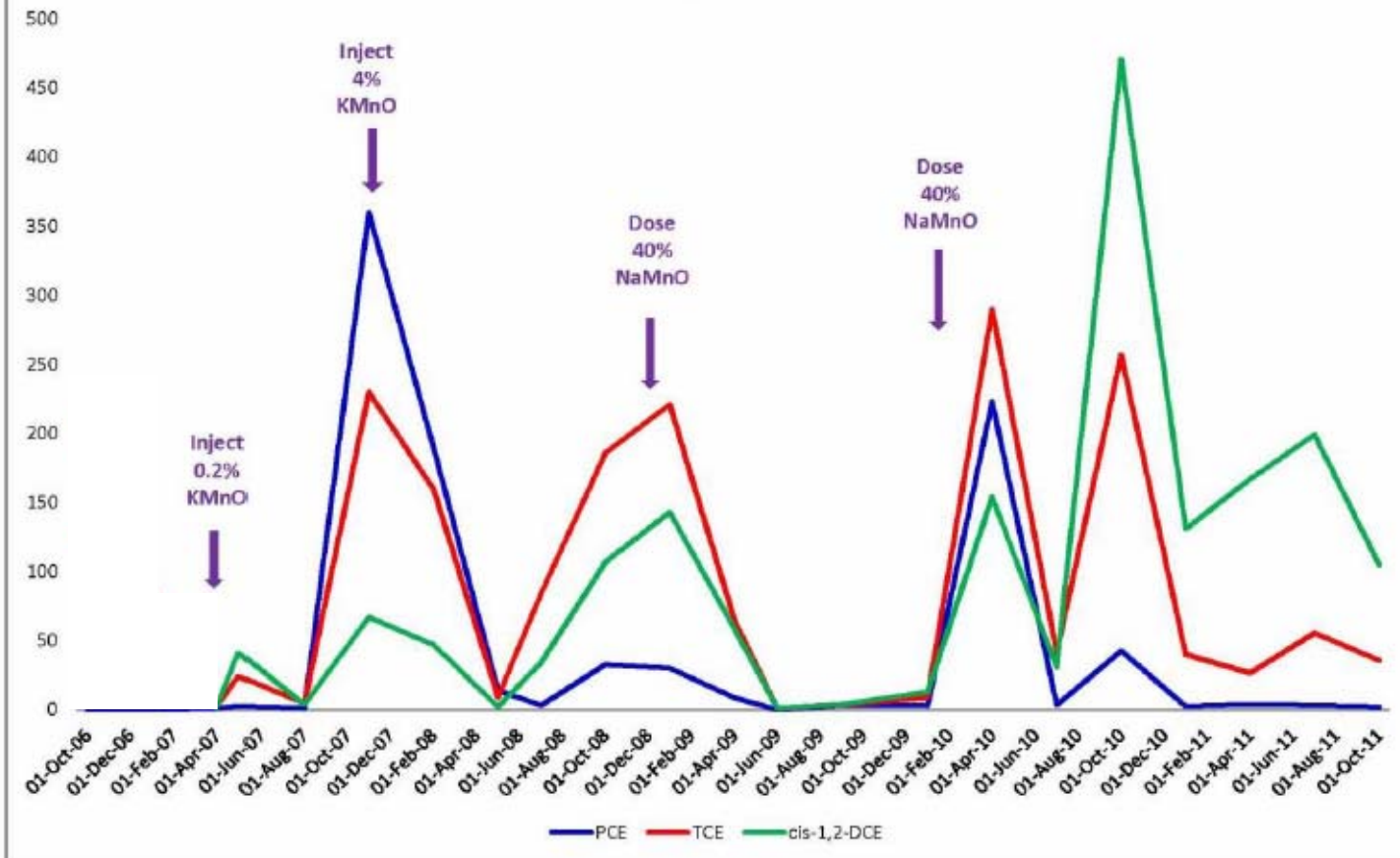
**Dissolved Phase  
PCE, TCE, cis-1,2-DCE, trans-1,2-DCE and Vinyl Chloride in  
groundwater samples collected from Source Area  
monitoring well MW-03R  
(micrograms/liter)**



### Dissolved Phase PCE, TCE, cis-DCE, trans-1,2-DCE, and Vinyl Chloride in groundwater samples collected from Source Area Monitoring well MW-08 (micrograms/liter)



Dissolved Phase PCE, TCE and cis-1,2-DCE in groundwater samples collected from downgradient monitoring well MW-10  
(micrograms/liter)



# SWITCH TO ENHANCED BIOREMEDIATION

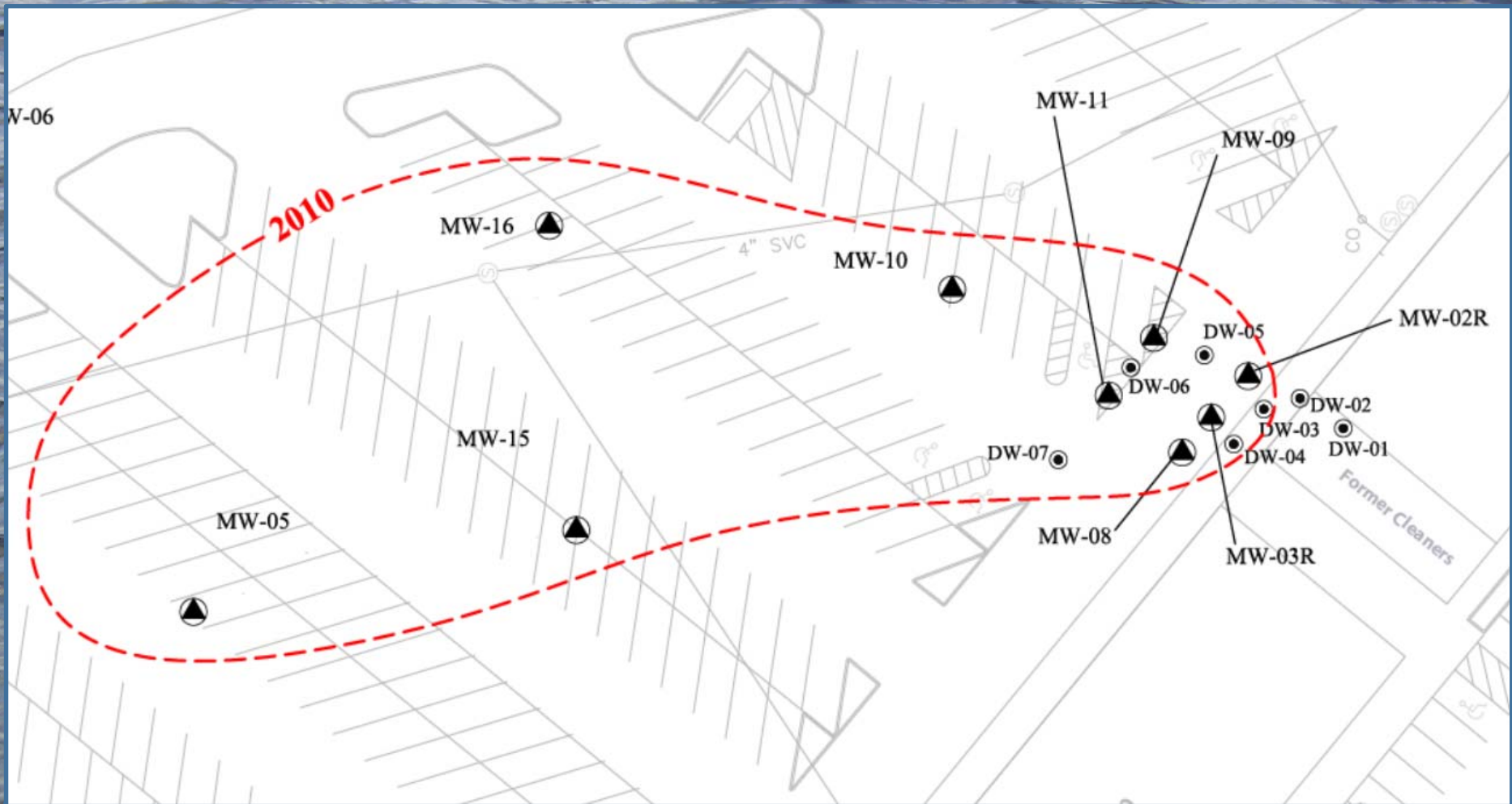
- Pilot test in source area to prove concept
- Source area treatment
- Plume treatment and follow up source area treatment if needed.



# REMEDIAL APPROACH

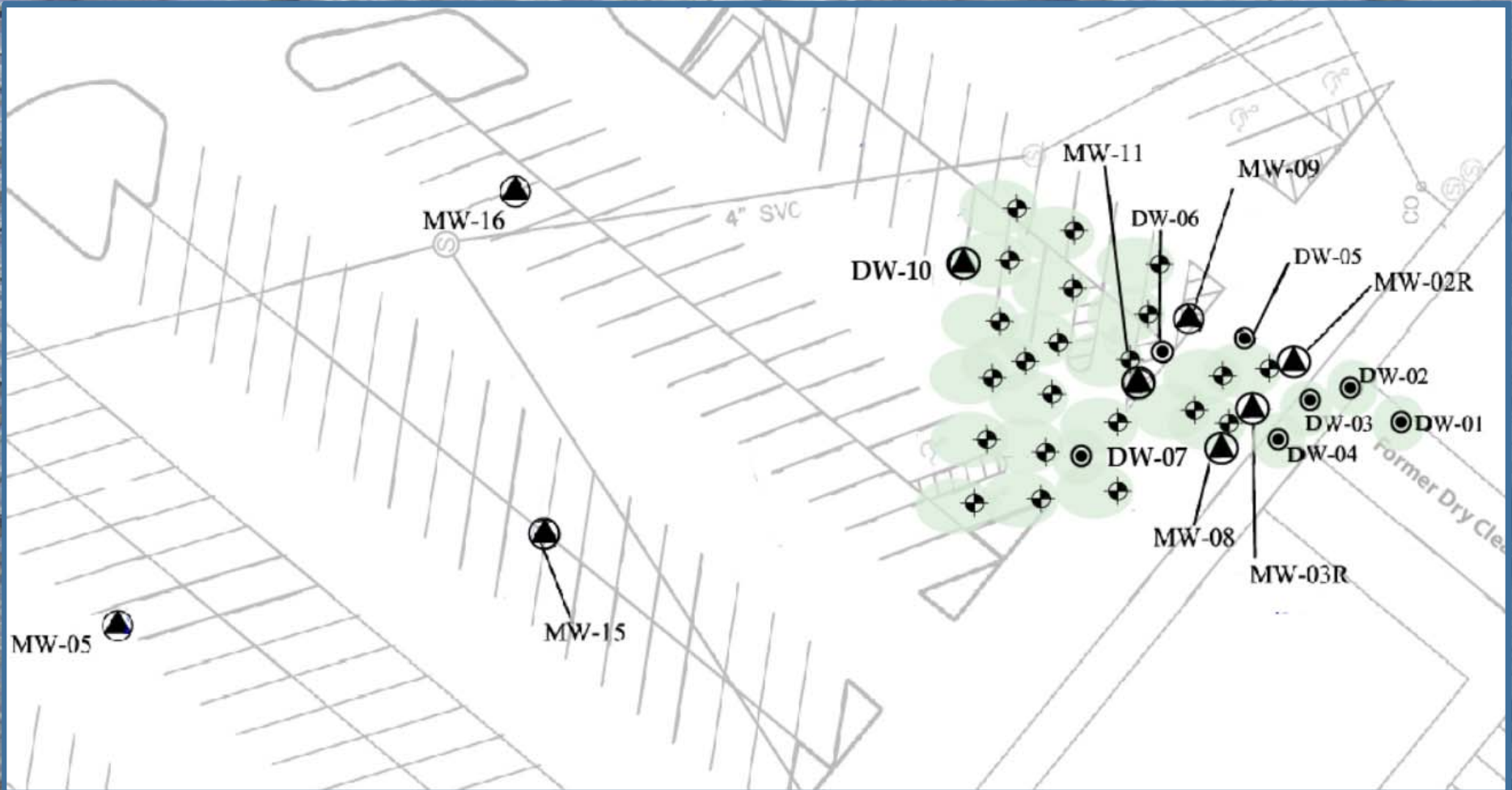
- Emulsified vegetable oil in source along with highly soluble substrate in plume
- Field application mixed both substrates and applied them across entire treatment area at a dosage of 1,800 mg/L
- Apparent effective ROI, treatment longevity, and CHC removal prompted substrates to be mixed for subsequent applications.





**PRE-BIOREMEDIATION ESTIMATED EXTENT OF PCE GREATER THAN 5 µg/L  
2010**

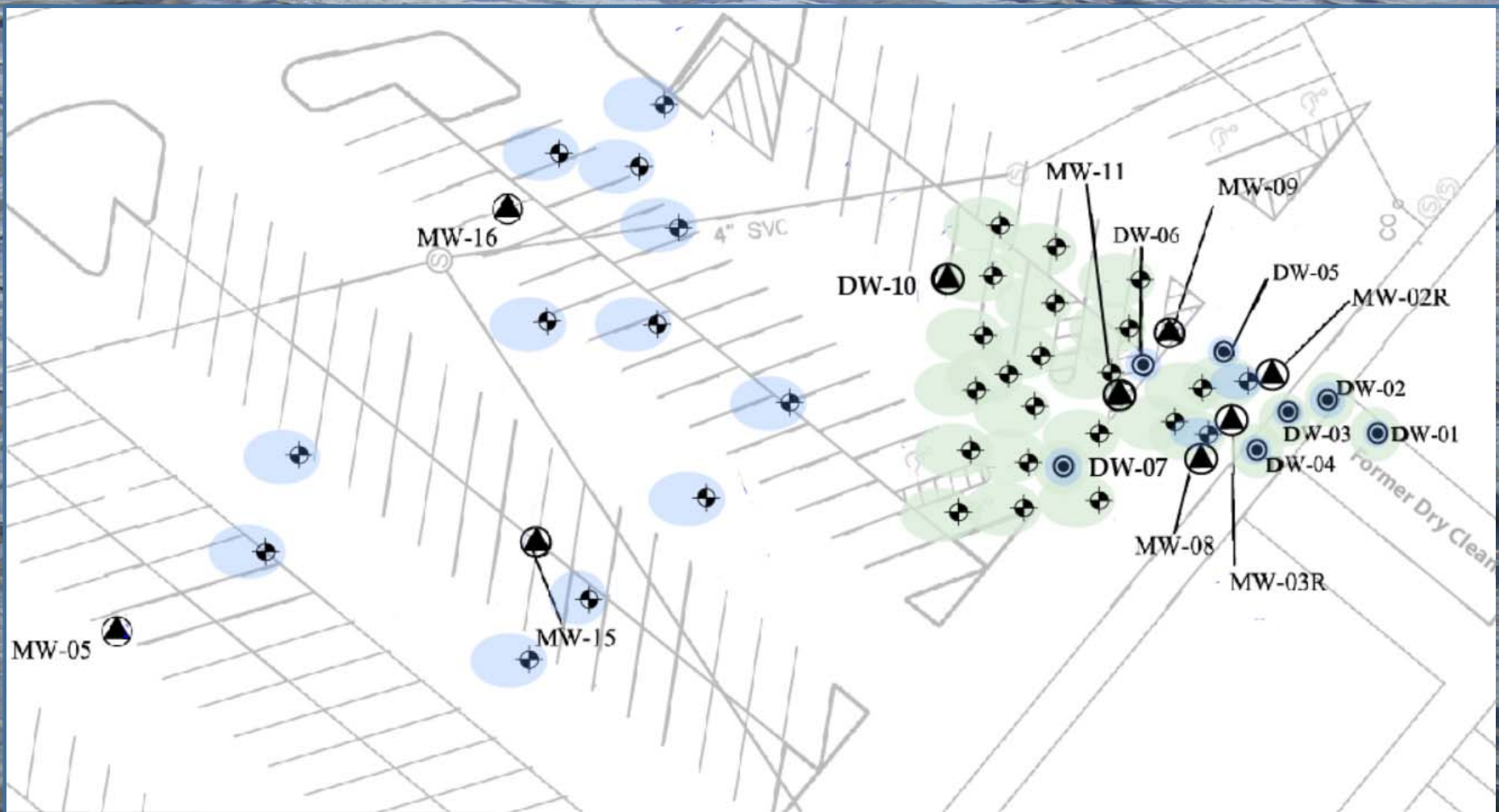




● 2011 Injection Locations

### APPLICATION LOCATIONS Oct 2011

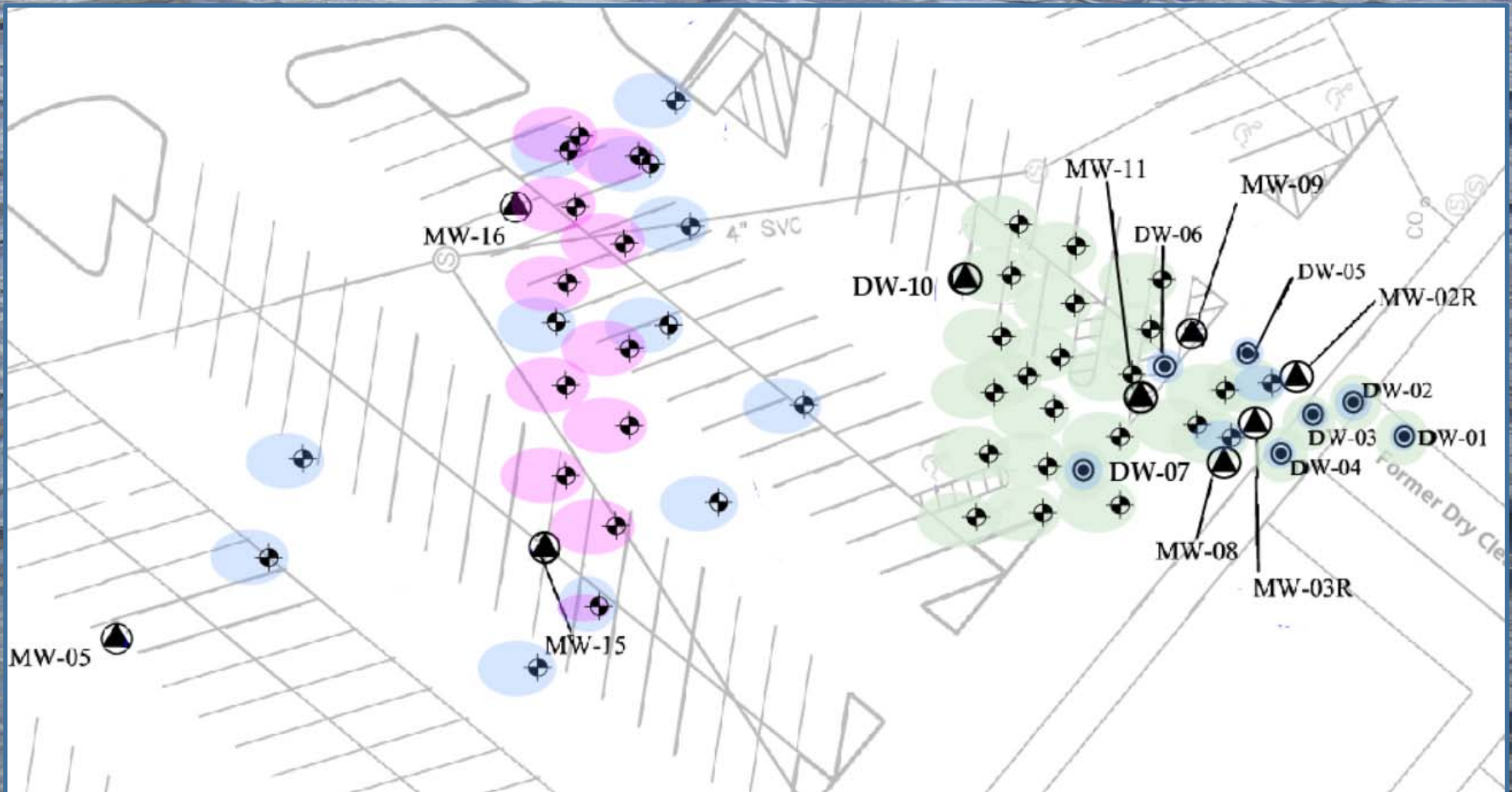




- 2011 Injection Locations
- 2012 Injection Locations

### APPLICATION LOCATIONS Oct 2011- Nov 2012

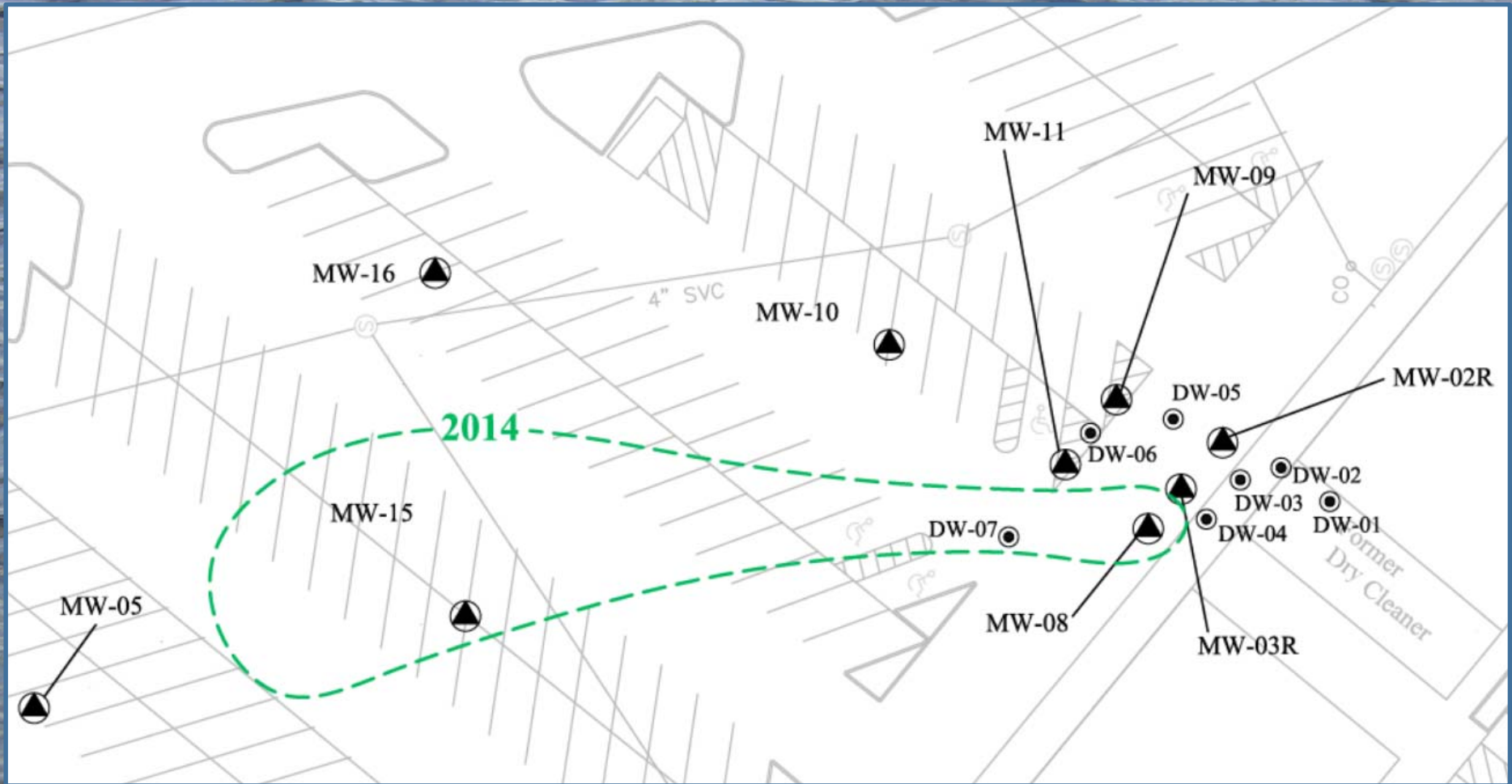




- 2011 Injection Locations
- 2012 Injection Locations
- 2013 Injection Locations

### SITE MAP WITH APPLICATION LOCATIONS Oct 2011-Dec 2013





**ESTIMATED EXTENT OF PCE GREATER THAN 5 µg/L 2014**



# HOW DO YOU EVALUATE IF YOU HAVE SUFFICIENT SUBSTRATE TO SUPPORT REDUCTIVE DECHLORINATION?

AFCEE Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, 2004

USEPA (1998a) looking at: DO, nitrate, sulfate, and total organic carbon with iron and methane possible additions.

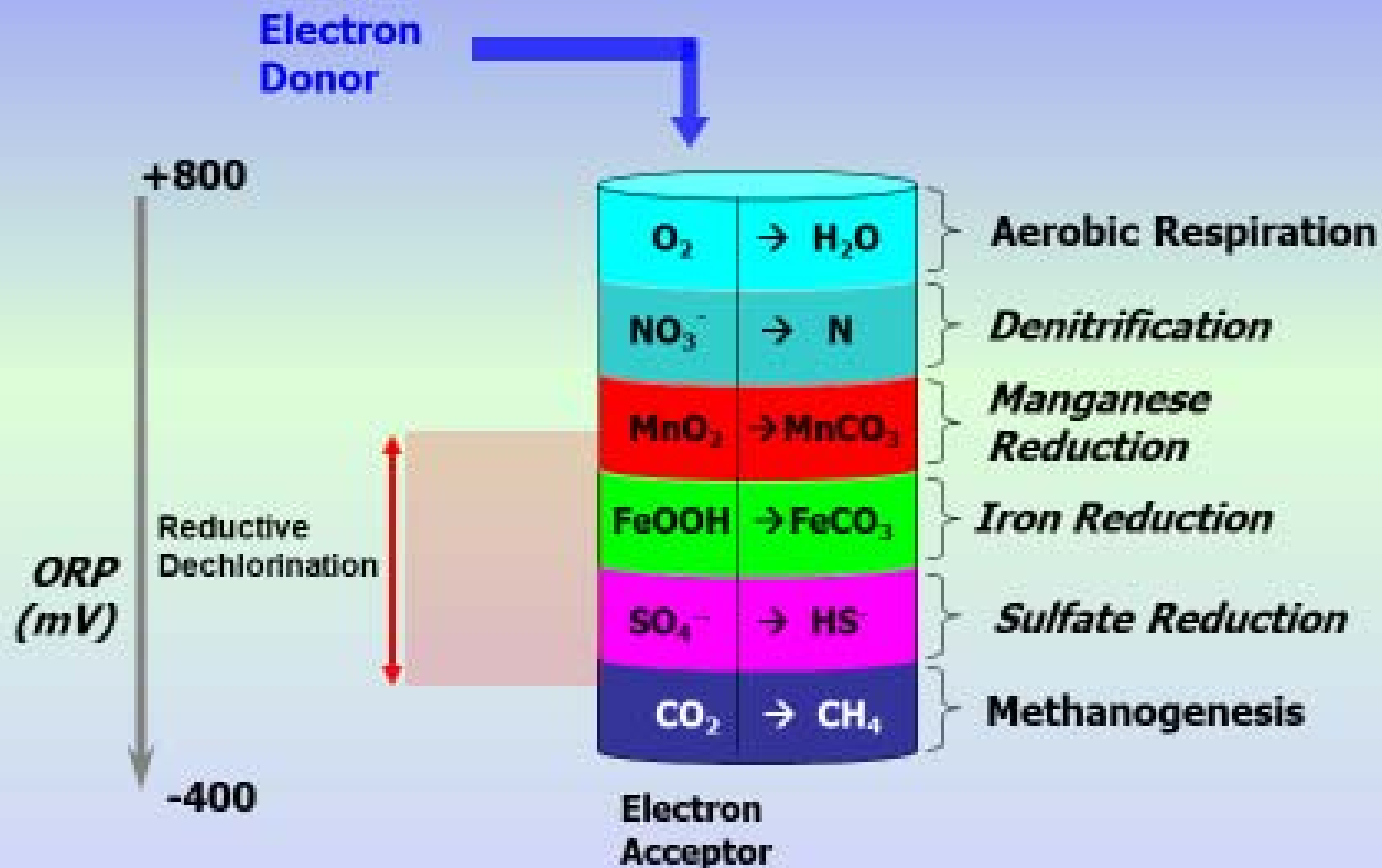


# HOW DO YOU EVALUATE IF YOU HAVE SUFFICIENT SUBSTRATE TO SUPPORT REDUCTIVE DECHLORINATION?

- REDOX? – Can be difficult to measure
- Dissolved Oxygen? – Can be difficult to measure
- Nitrate? – Not always high enough to spot trends
- Sulfate? – Don't need to completely convert it
- Methane? – Can be difficult to collect
- TOC? – Difficult to determine accurately.



# Geochemistry and ORP Hierarchy



Adapted from Wiedemeier, et al., 1999



# HOW DO YOU EVALUATE IF YOU HAVE SUFFICIENT SUBSTRATE TO SUPPORT REDUCTIVE DECHLORINATION?

- Continued contaminant degradation supported by geochemistry!

But, you have to convince the critics with numbers! So pick your poison.

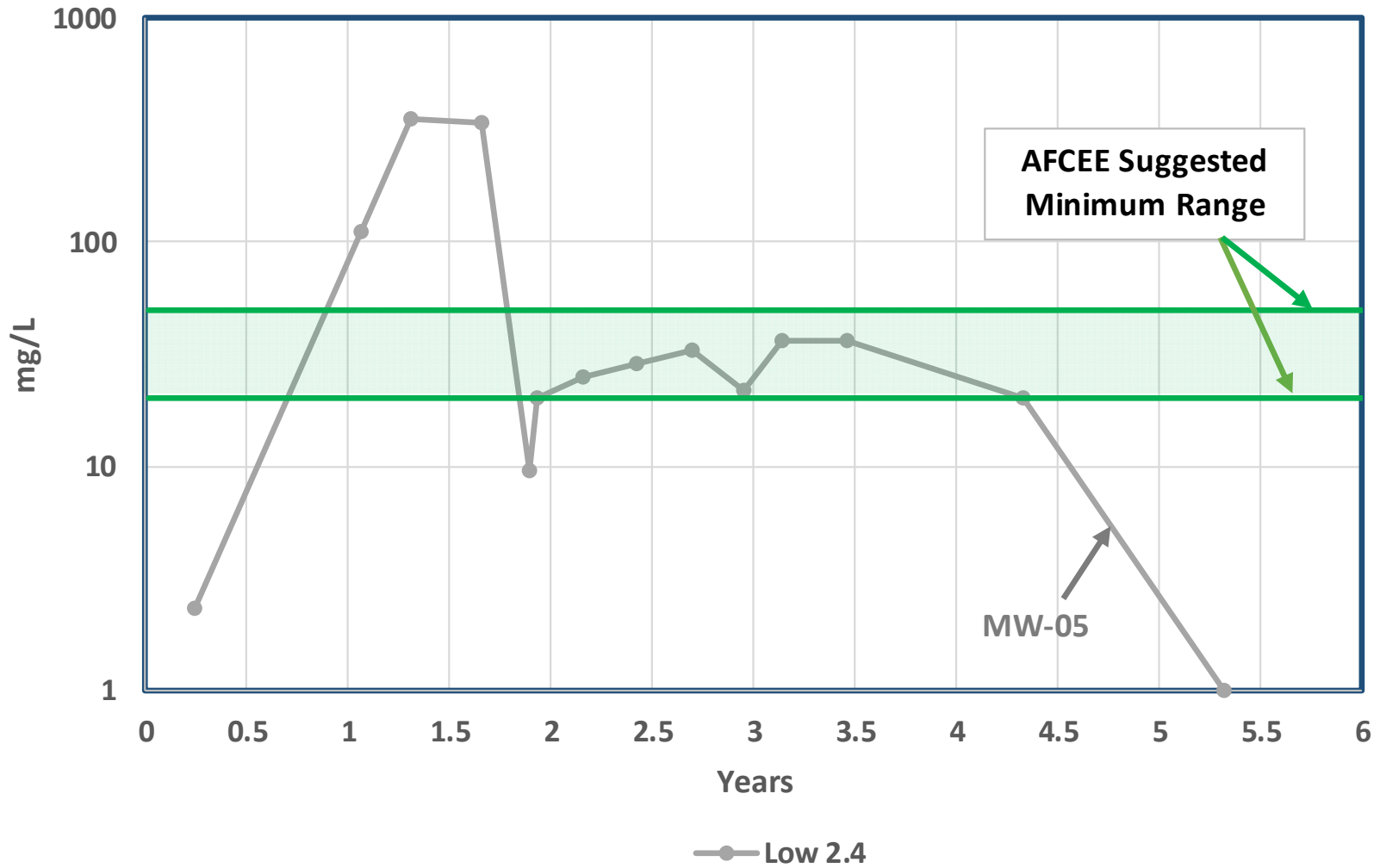


# AFCEE Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, 2004

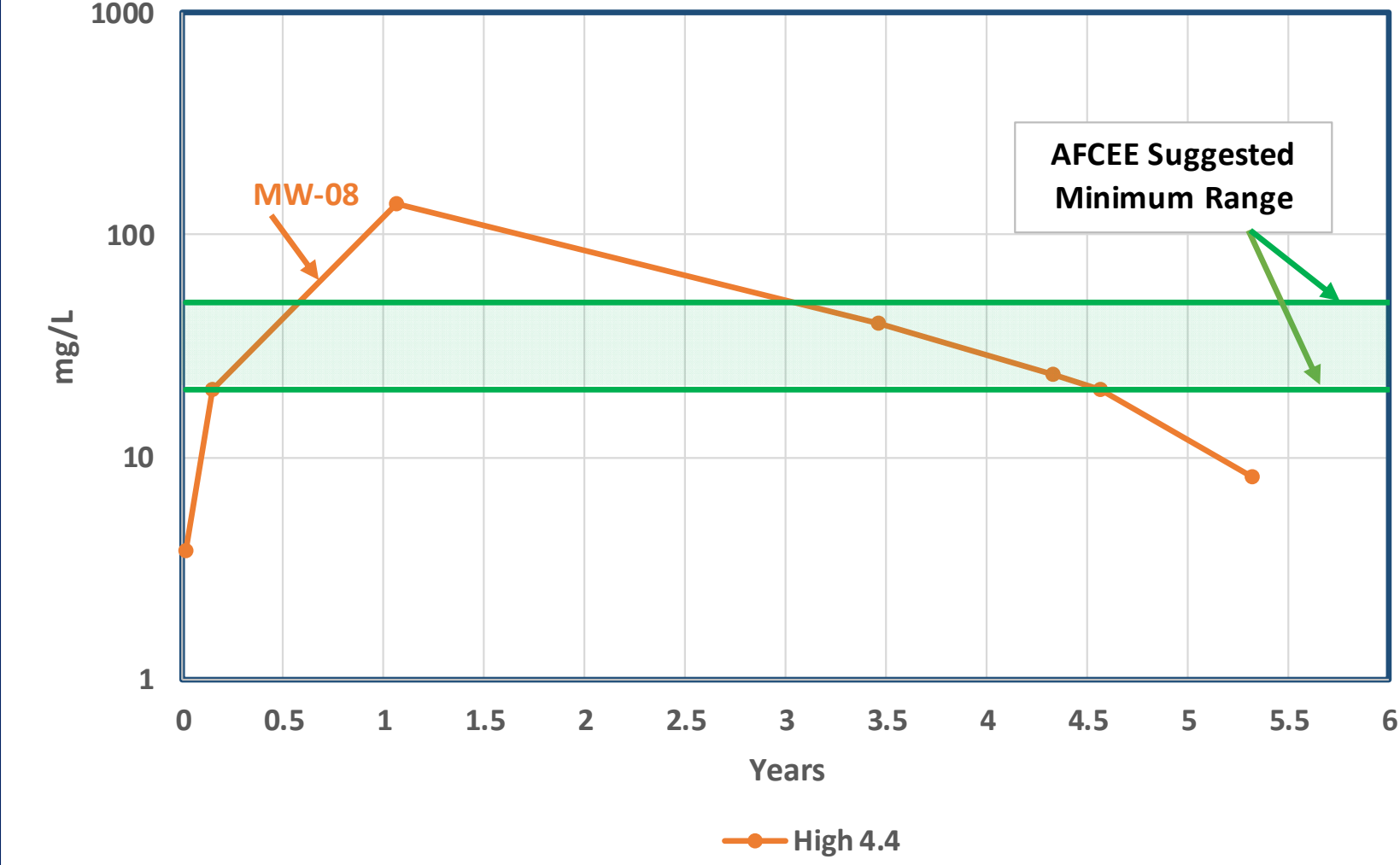
“Total Organic Carbon (TOC) or Dissolved Organic Carbon (DOC) SW9060, EPA Method 415.1 (laboratory) Indicator of natural organic carbon present at site during baseline characterization and as an indicator of substrate distribution during performance monitoring. TOC/DOC concentrations greater than 20 to 50 mg/L are desired in the anaerobic treatment zone. Stable or declining TOC/DOC levels less than 20 mg/L in conjunction with elevated levels of VOCs and alternate electron acceptors indicate additional substrate is required to sustain the treatment zone.”

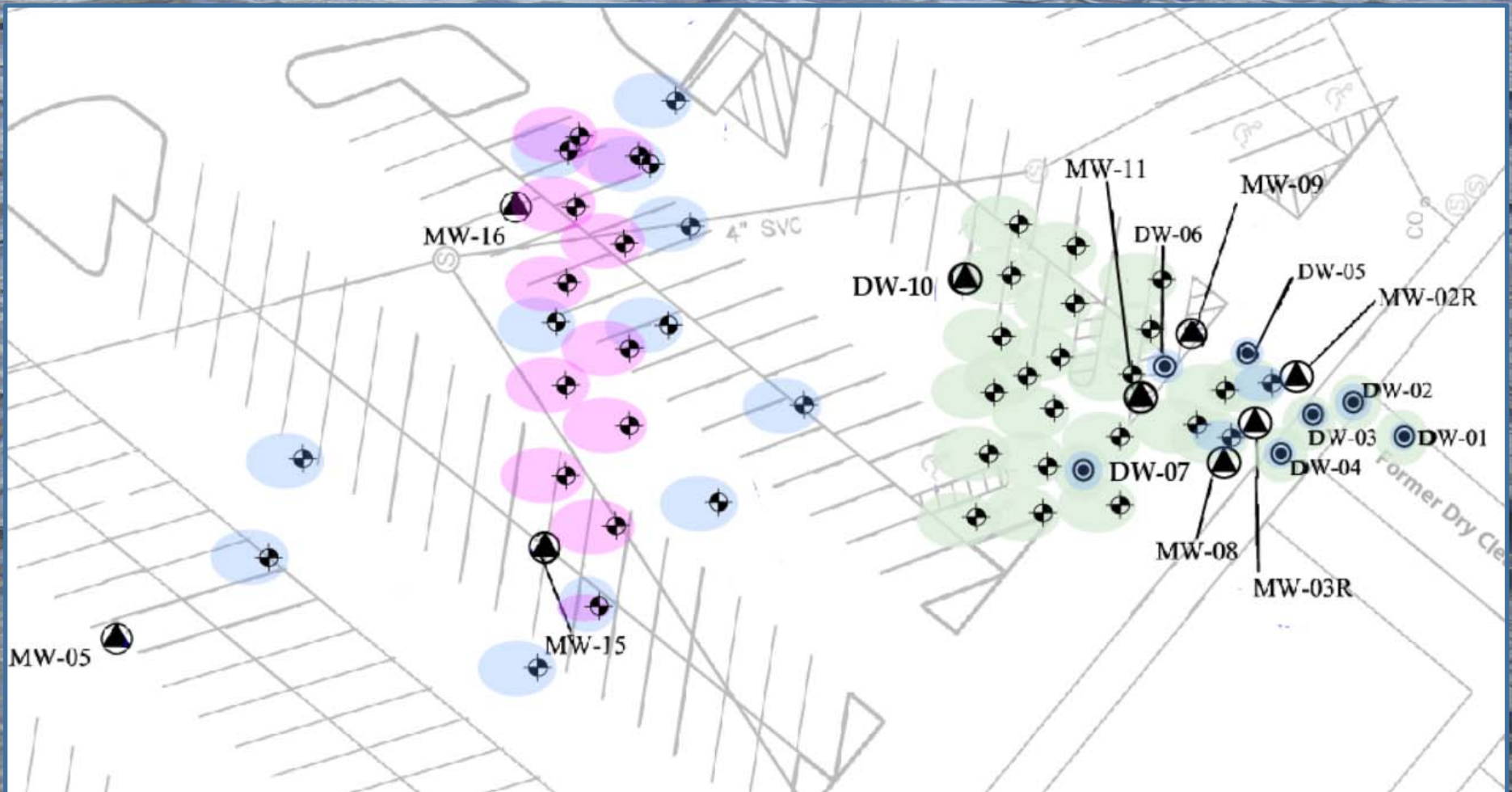


# Low DOC MW-05



# High DOC MW-08





- 2011 Injection Locations
- 2012 Injection Locations
- 2013 Injection Locations

### SITE MAP WITH APPLICATION LOCATIONS Oct 2011-Dec 2013



# DOC CONCLUSION

- DOC increase consistent with application events
- DOC increase a minimum of about one order of magnitude above background
- DOC above AFCEE/EPA suggested levels for at least 3 ¼ years and possibly in excess of 4 years, more than twice expected with low dosage of emulsified vegetable oil.

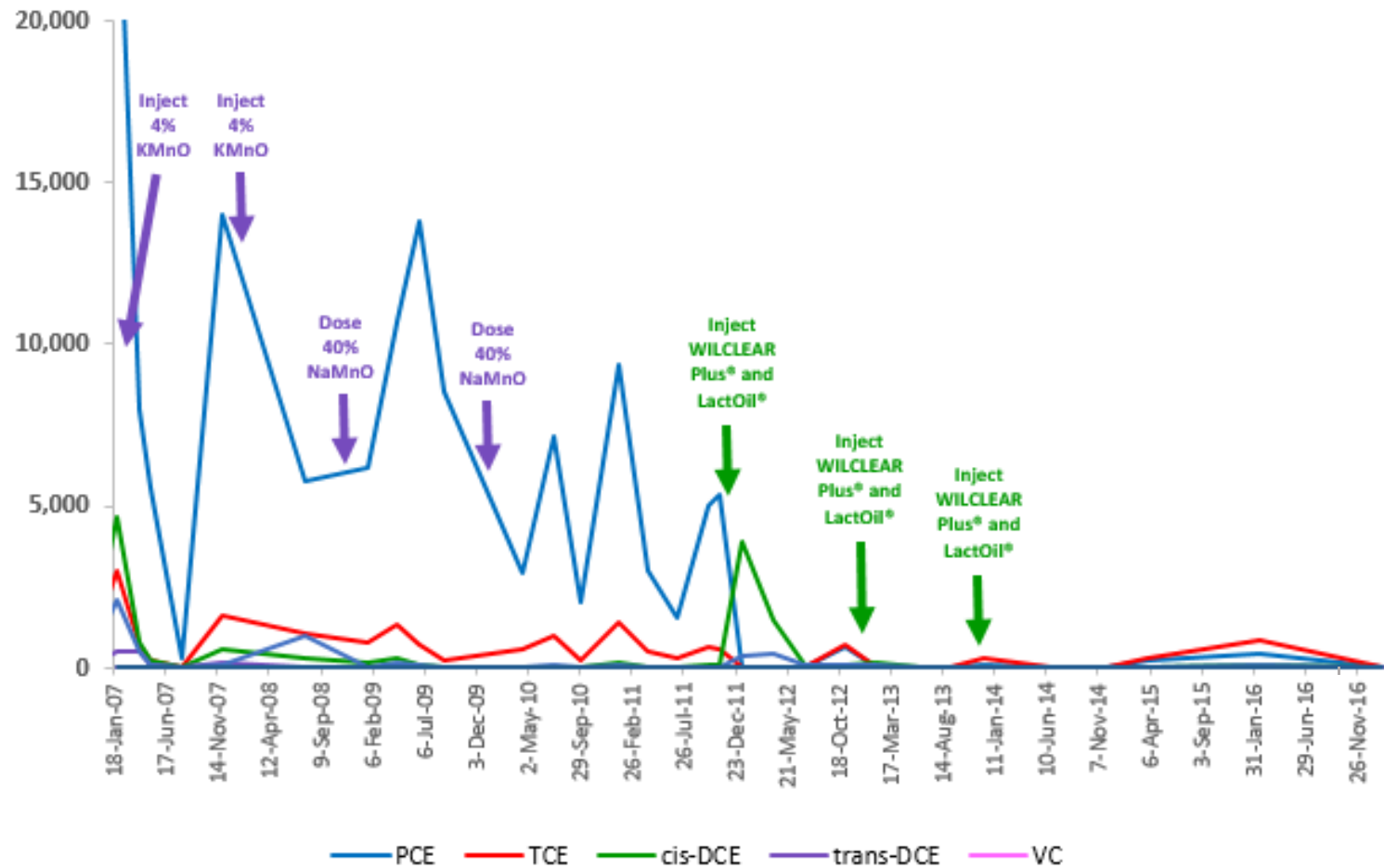


# THE CASE FOR PERFORMANCE BASED LONGEVITY

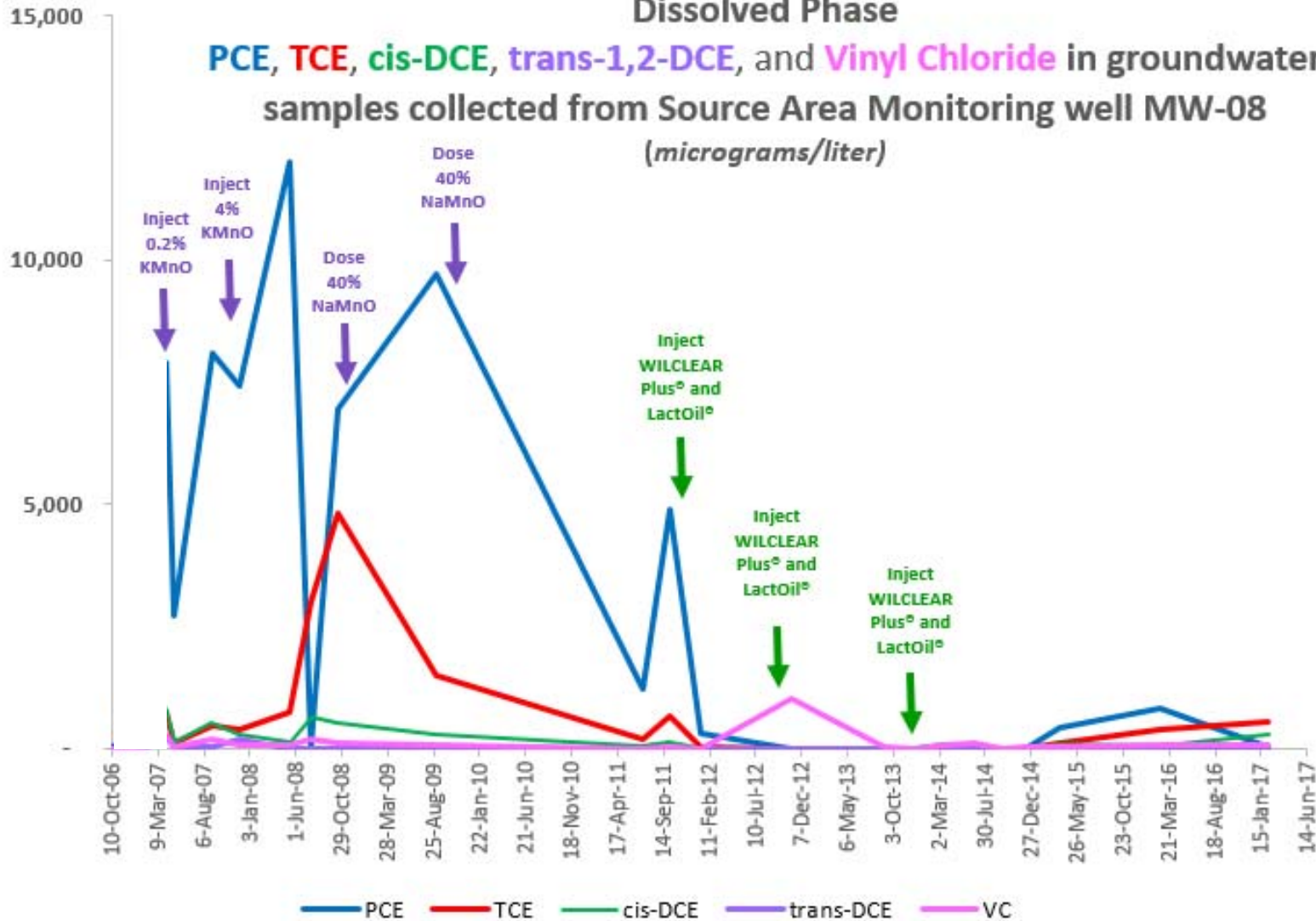
- How long does the system support reductive dechlorination?



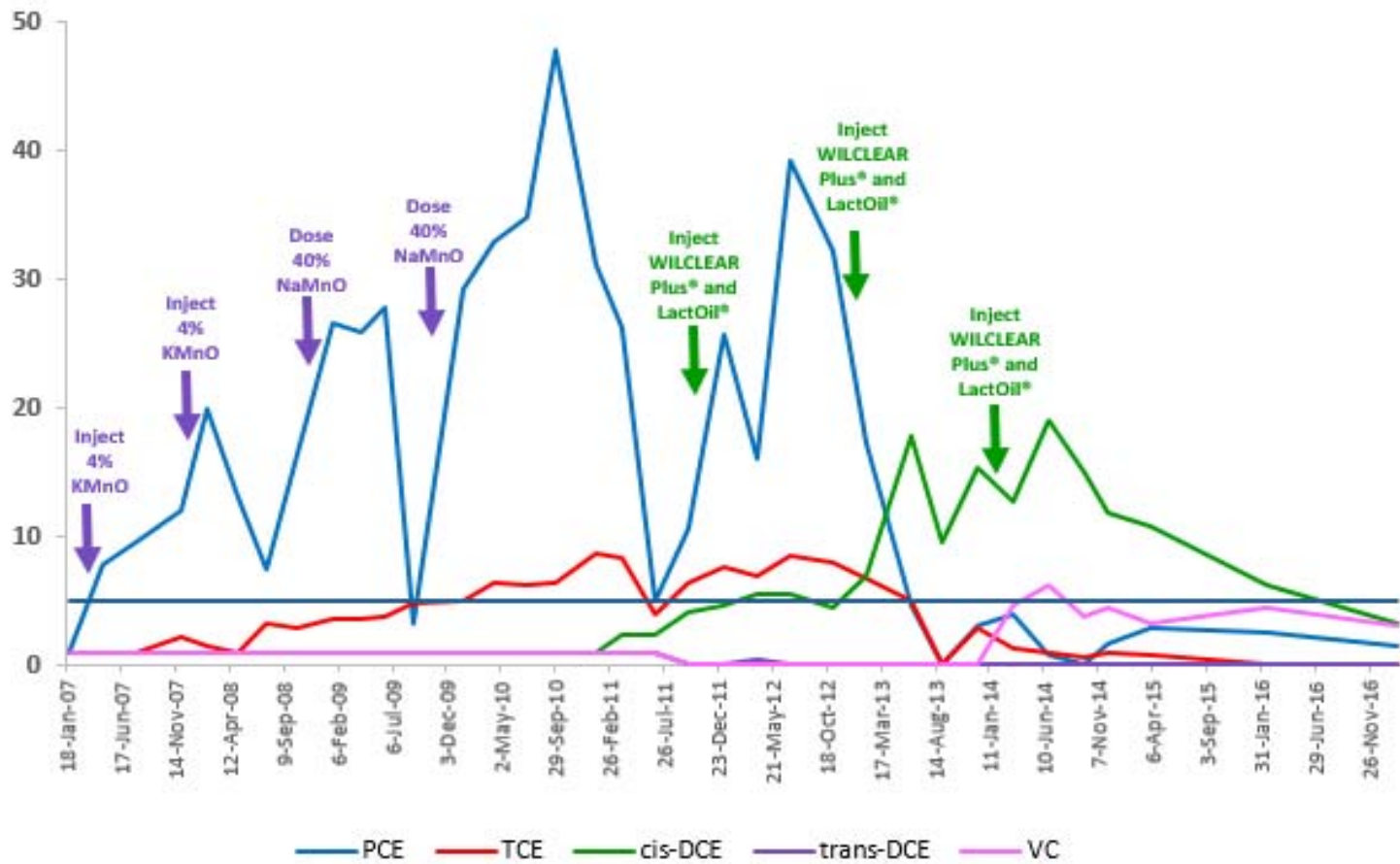
**Dissolved Phase**  
**PCE, TCE, cis-DCE, trans-1,2-DCE, and Vinyl Chloride** in groundwater  
 samples collected from Source Area Monitoring well MW-03  
 (micrograms/liter)



**Dissolved Phase**  
**PCE, TCE, cis-DCE, trans-1,2-DCE, and Vinyl Chloride** in groundwater  
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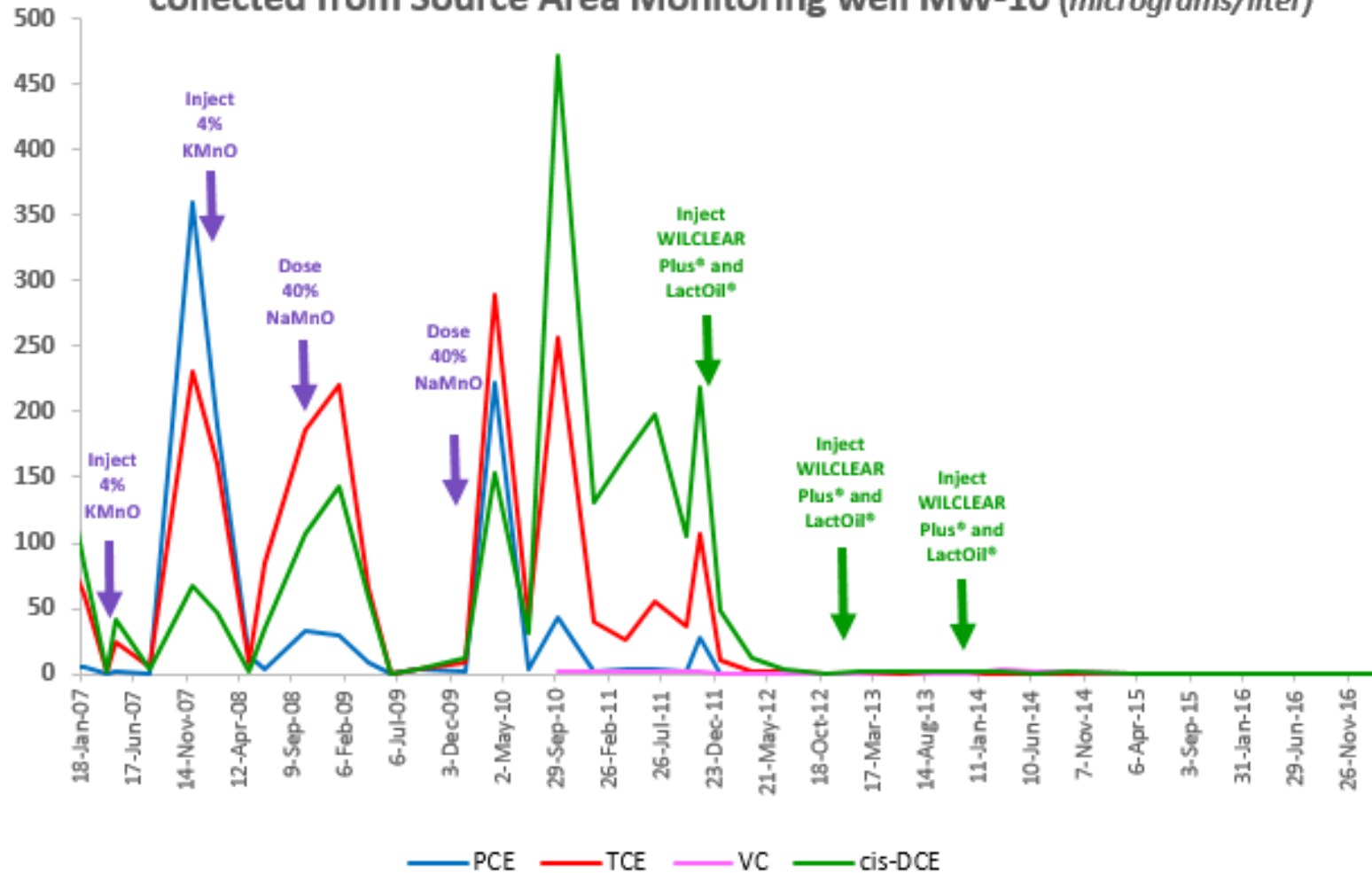


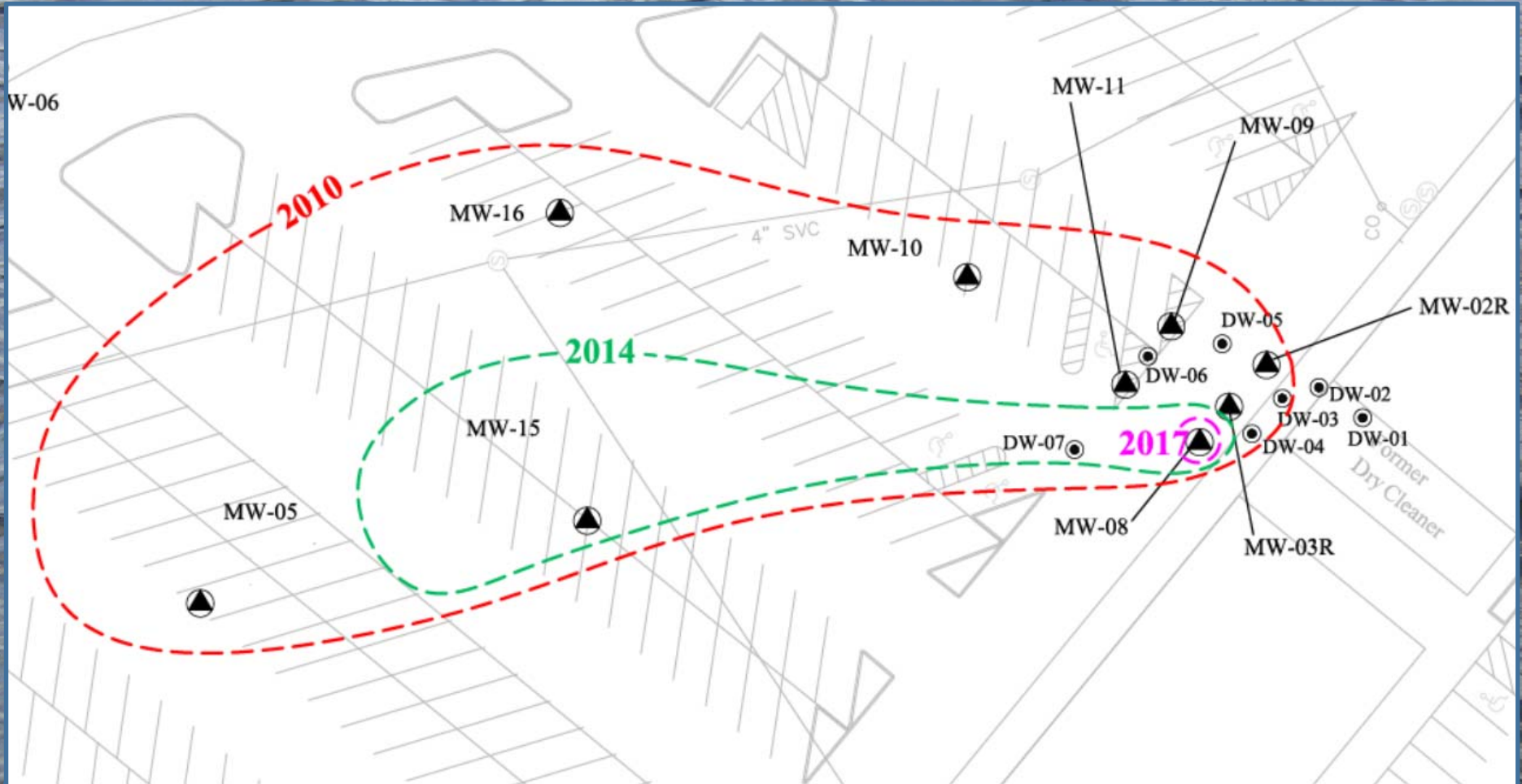
**Dissolved Phase**  
**PCE, TCE, cis-DCE, trans-1,2-DCE, and Vinyl Chloride** in groundwater  
 samples collected from Source Area Monitoring well MW-05  
 (micrograms/liter)



## Dissolved Phase

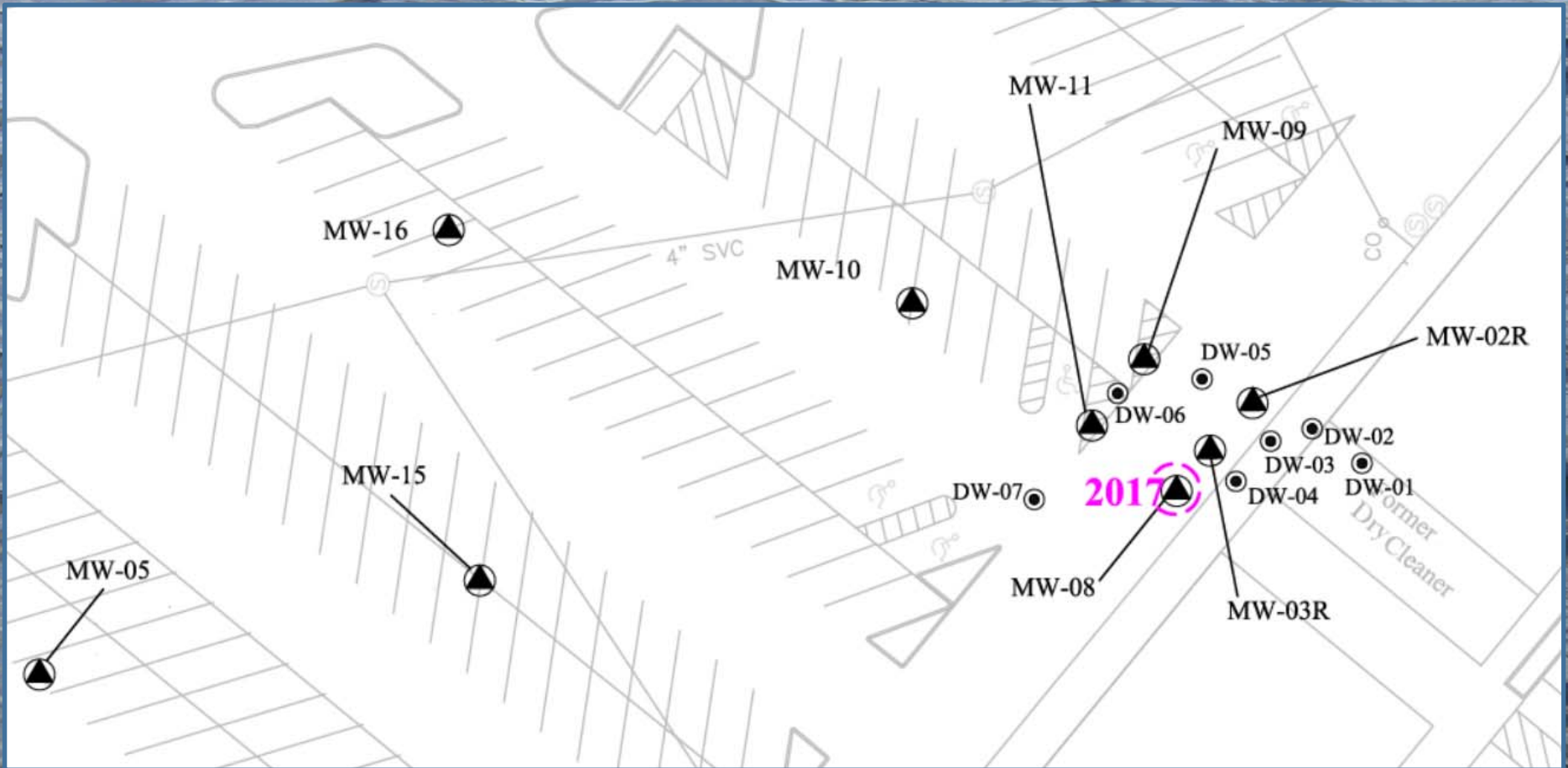
**PCE, TCE, cis-DCE, and Vinyl Chloride** in groundwater samples collected from Source Area Monitoring well MW-10 (*micrograms/liter*)





**ESTIMATED EXTENT OF PCE GREATER THAN 5 µg/L  
2010-2017**





**ESTIMATED EXTENT OF PCE GREATER THAN 5 µg/L  
2017**



# THE CASE FOR PERFORMANCE BASED LONGEVITY

- Source area still active
- Last substrate application in source area December 2012
- CHC reduction still likely occurring in source area for more than 5 years.



# PROJECT CONCLUSIONS

- Emulsified Vegetable Oil can maintain high DOC for at least 3 ¼ years and possibly in excess of 4 years
- Mix of soluble and semi-soluble substrate can lead to extended reductive dechlorinating activity within a system, possibly as long as 5 years
- Treatment train approach can be a viable option.



# QUESTIONS?

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Nature*