Case Study: Longevity of Multiple Amendments Used in Treatment of Chlorinated Solvents in Groundwater

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Problem Statement

- In situ treatment of solvent plume (TCE and 1,1-DCE) at Superfund site in NJ, using biological reductive dechlorination (RDC) technique
- Low pH of surficial groundwater aquifer requires pH adjustment to optimal conditions for RDC

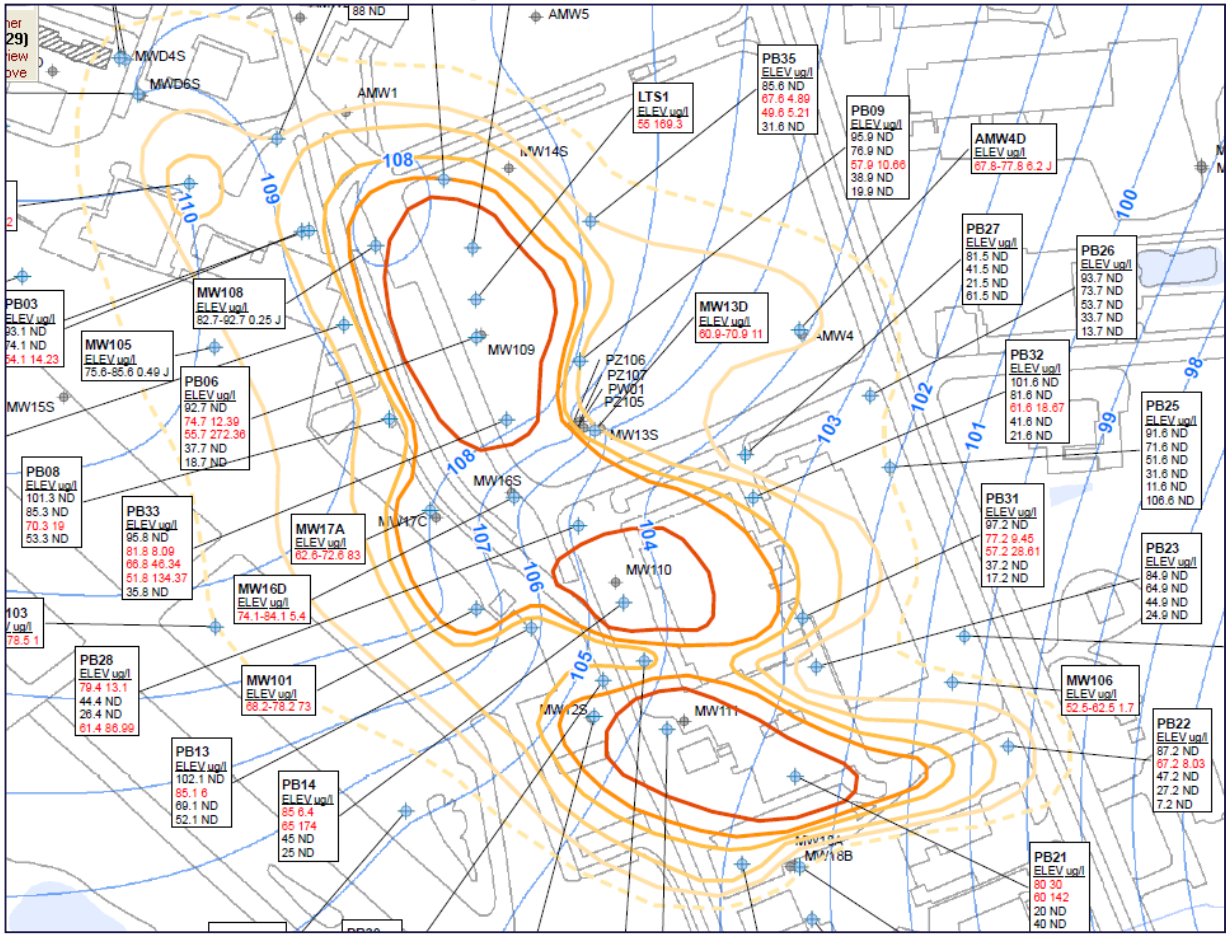
Objective

- Quantify amendment efficacy in situ through monitoring, to establish GW conditions when amendment re-application may be needed

Overview

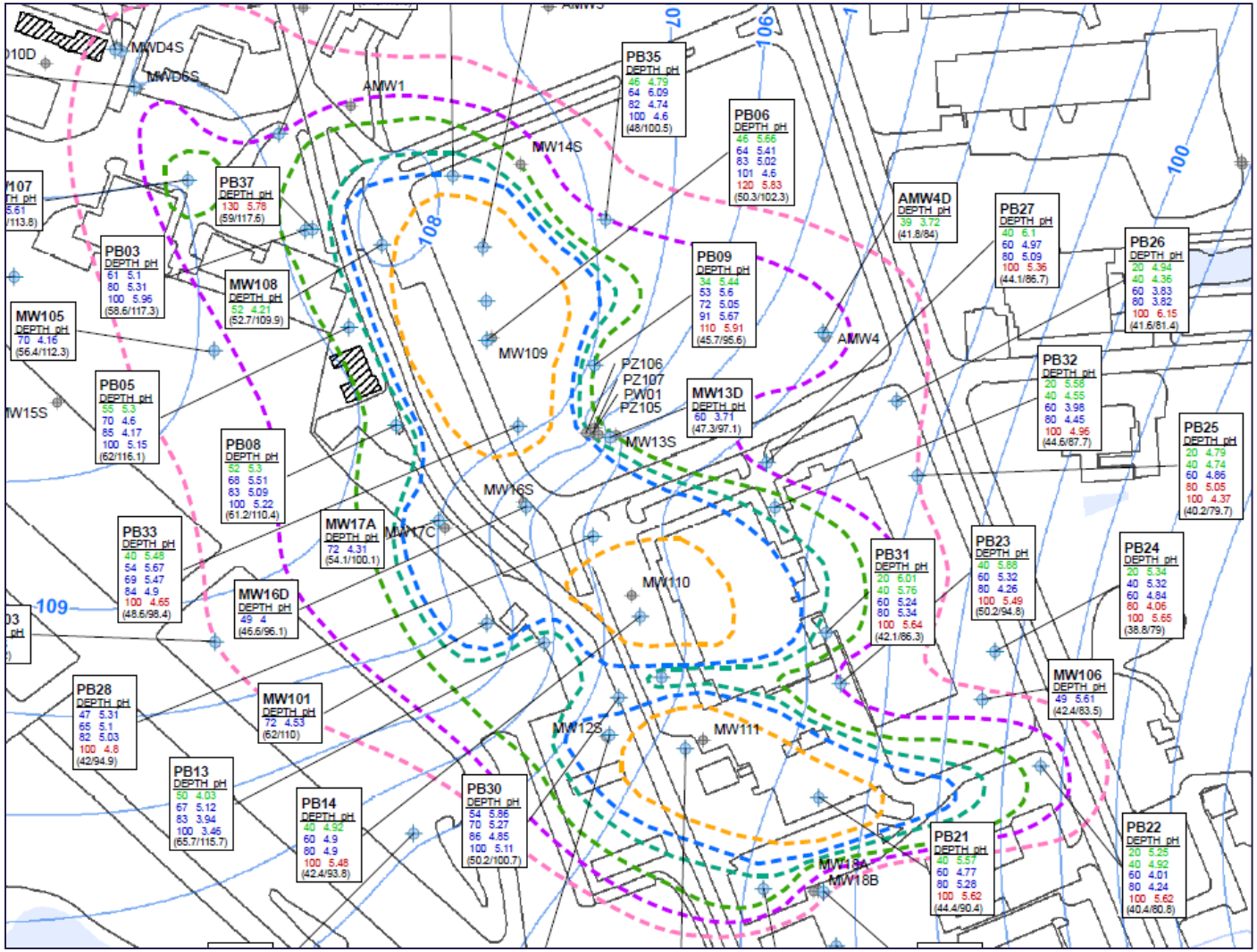
- Site Background
- Treatment Description
- Achieving In situ Conditions for Treatment
- Summary and Conclusions

Site and TCE Plume Map 2010



1,1-DCE is also a principal site contaminant, having originated from released 1,1,1-TCA

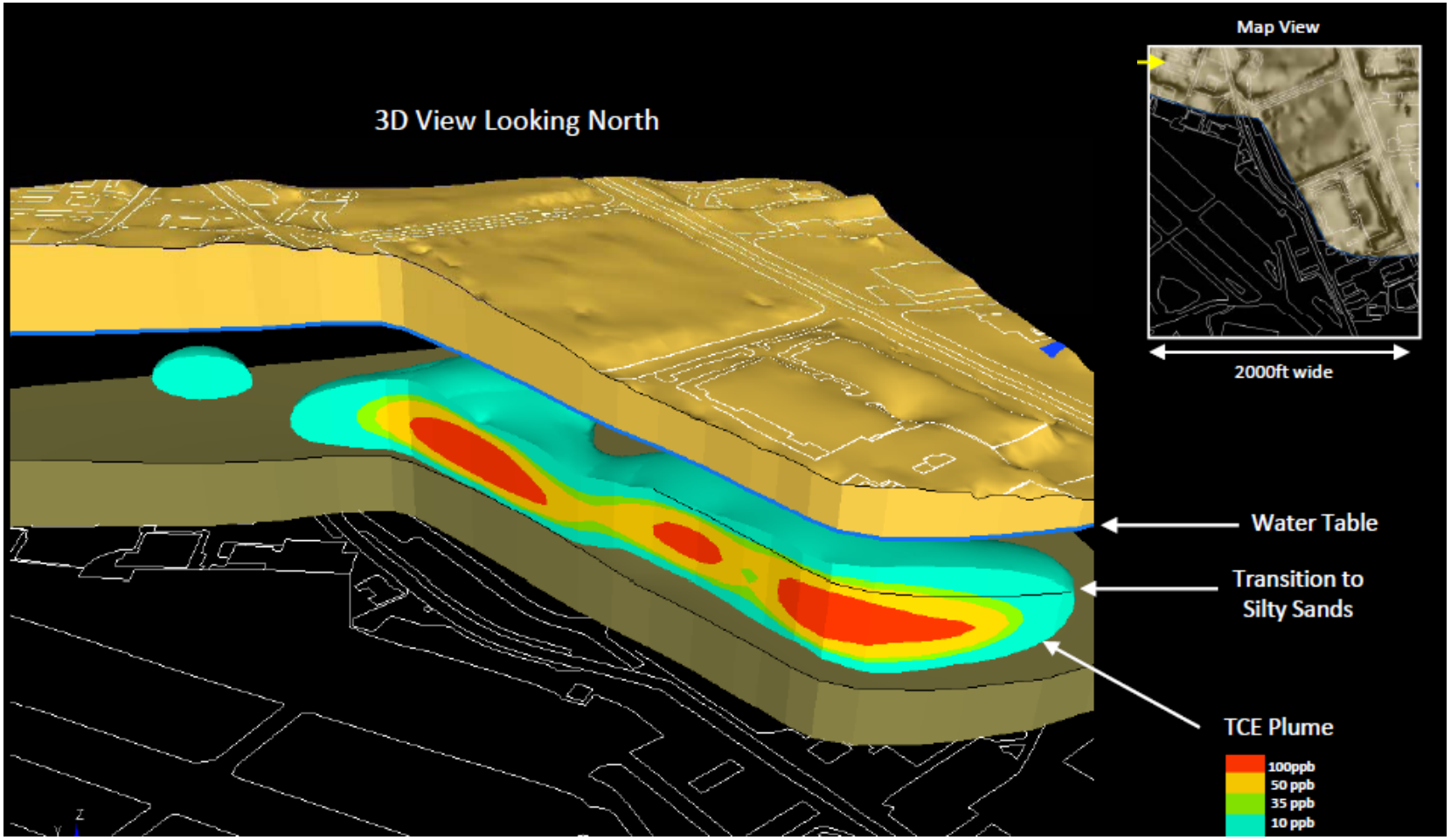
Aquifer pH Baseline Sampling 2010



Site Hydrogeology

- Upper surficial aquifer:
- Medium to coarse sands—Cohansey formation
- Sands with alternating and discontinuous layers of silt and clay—Kirkwood formation
- Kirkwood-Cohansey is 100-150 ft thick at site
- Clayey sand and clayey silt—Manasquan formation, serves as regional aquitard

Site Cross-section



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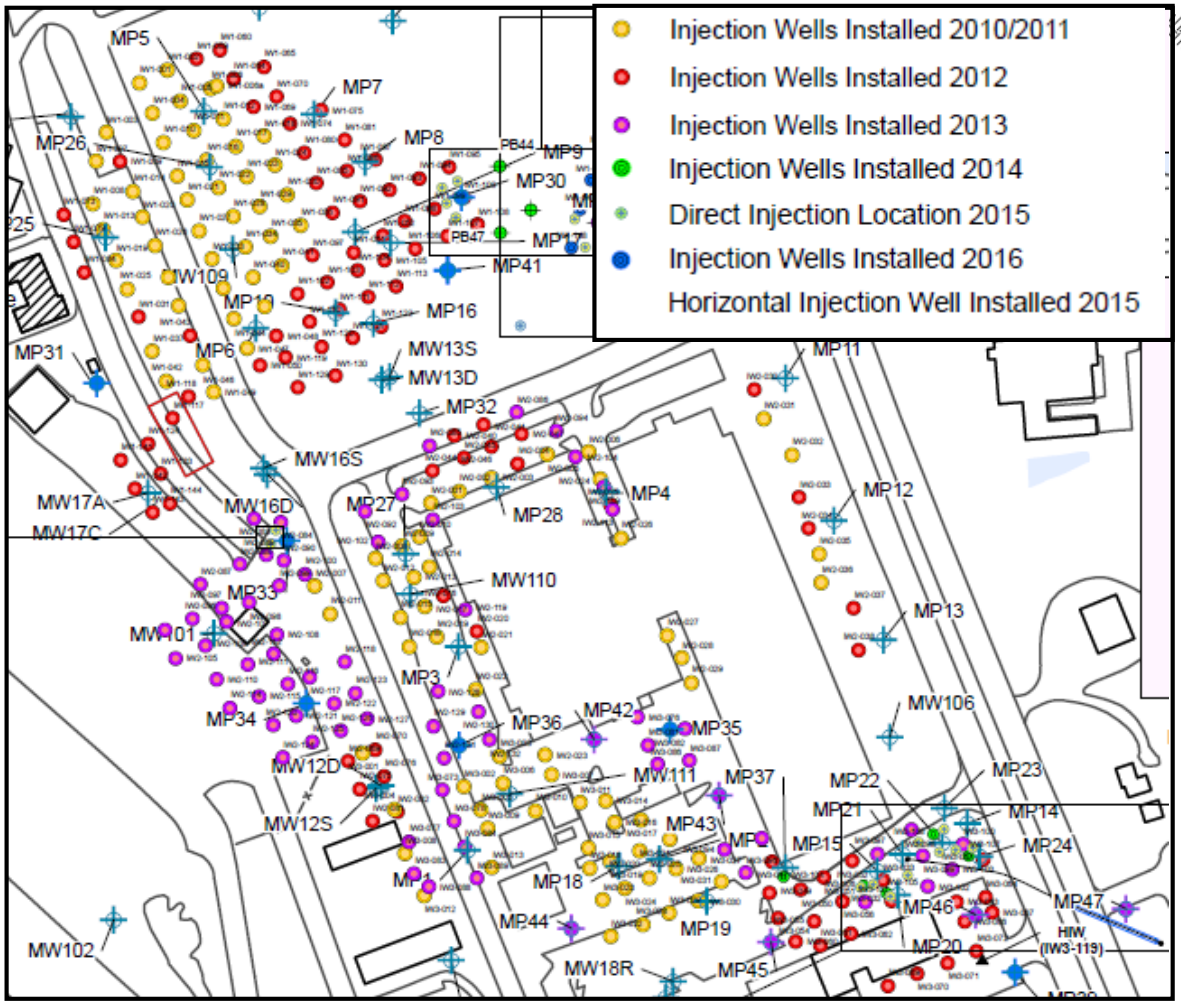
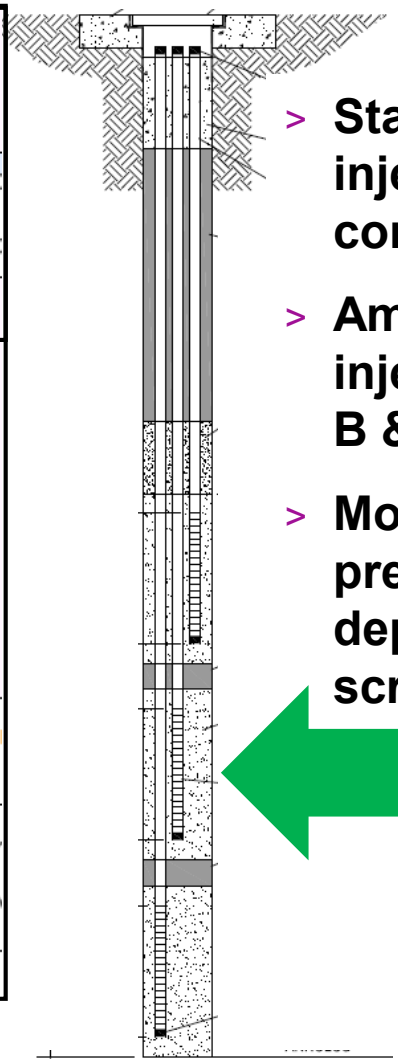
In situ Treatment for 100 ppb Hot Spot Areas





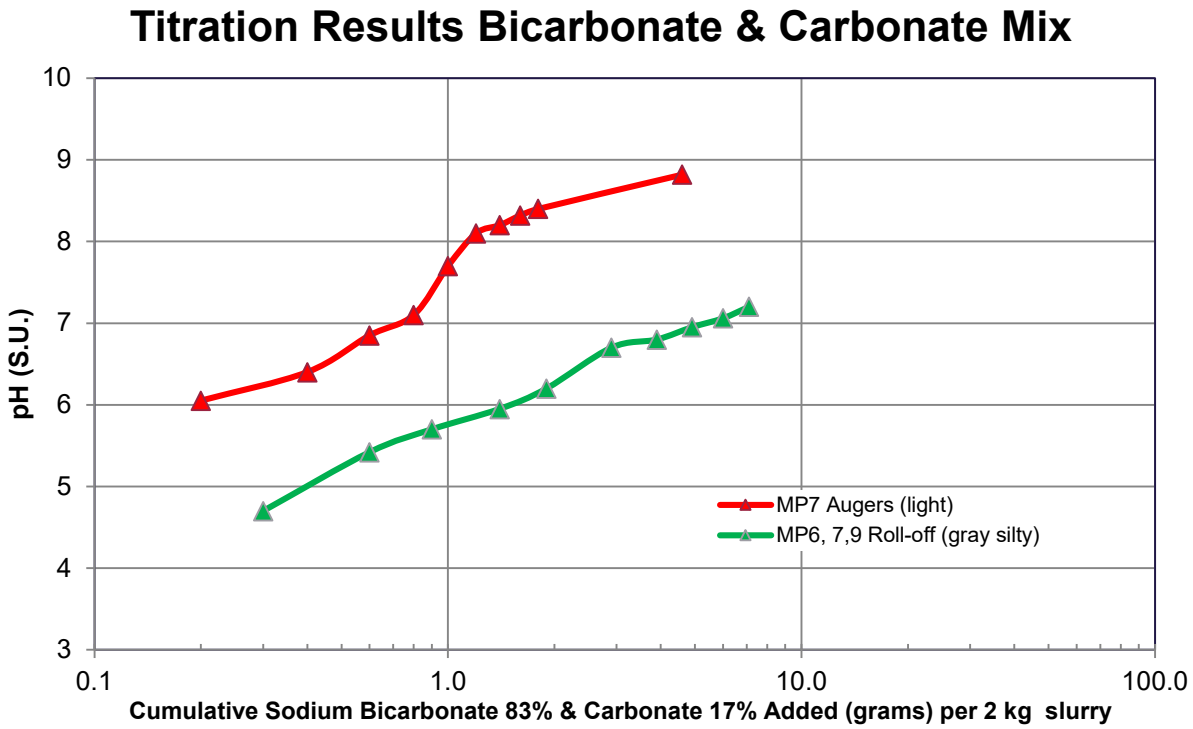
- **Stacked injection well construction**
- **Amendment injected to A, B & C screens**
- **Most all TCE present at depth of B screen**

Neutralization Requirements

- Considered Neutralization--
  - Sodium Hydroxide—strong base, hazardous chemical, likely overshoot of target aquifer pH
  - Sodium Carbonate—moderately weak base, equilibrium pH ~11, possible overshoot of target aquifer pH
  - Sodium Bicarbonate--weaker base, equilibrium pH ~8.5, low possibility to overshoot target aquifer pH

- Conclusion: Lab test neutralization demand using sodium carbonate, bicarbonate, and carbonate/bicarbonate mix

Neutralization Requirements—lab titration test



- Red data represents upper aquifer material, less acidic (A)
- Green data represents lower aquifer material, more acidic (B & C)
- Basis of 2 kg due to soil slurry 1 kg soil & 1 kg groundwater

Amendment Components and Formulation

- Emulsified vegetable oil (EVO) as carbon source to drive biological reductive dechlorination
- Buffering agent (e.g. sodium bicarbonate) to increase pH of aquifer to optimal pH range (6.5 – 8.5) for reductive dechlorination

- Detailed amendment formulation injected per 10-ft IW screen
  - 1,000 lbs veg oil (emulsified) [EVO]
  - 4,000 lbs sodium bicarbonate [SBC]
  - 5,800 gallons water
  - SBC is 8.3 wt%, near solubility limit

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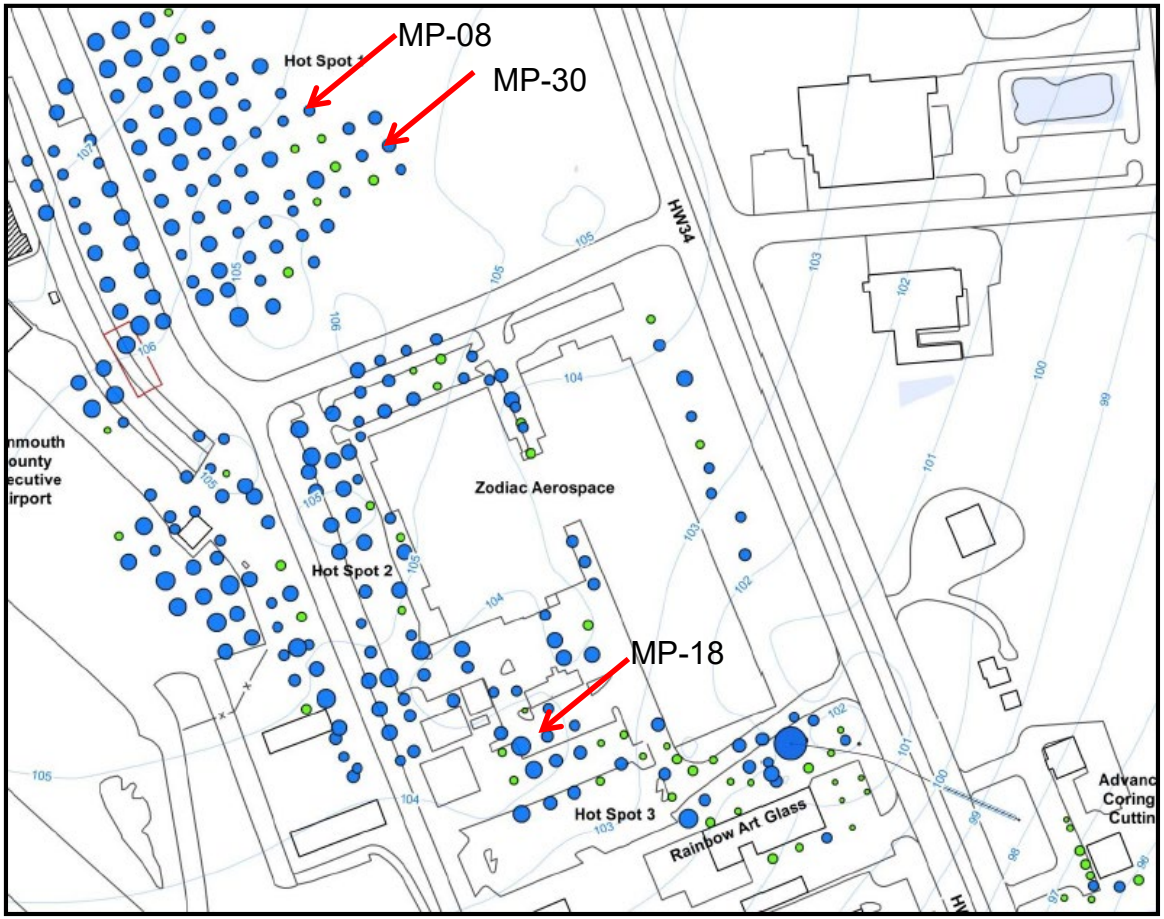
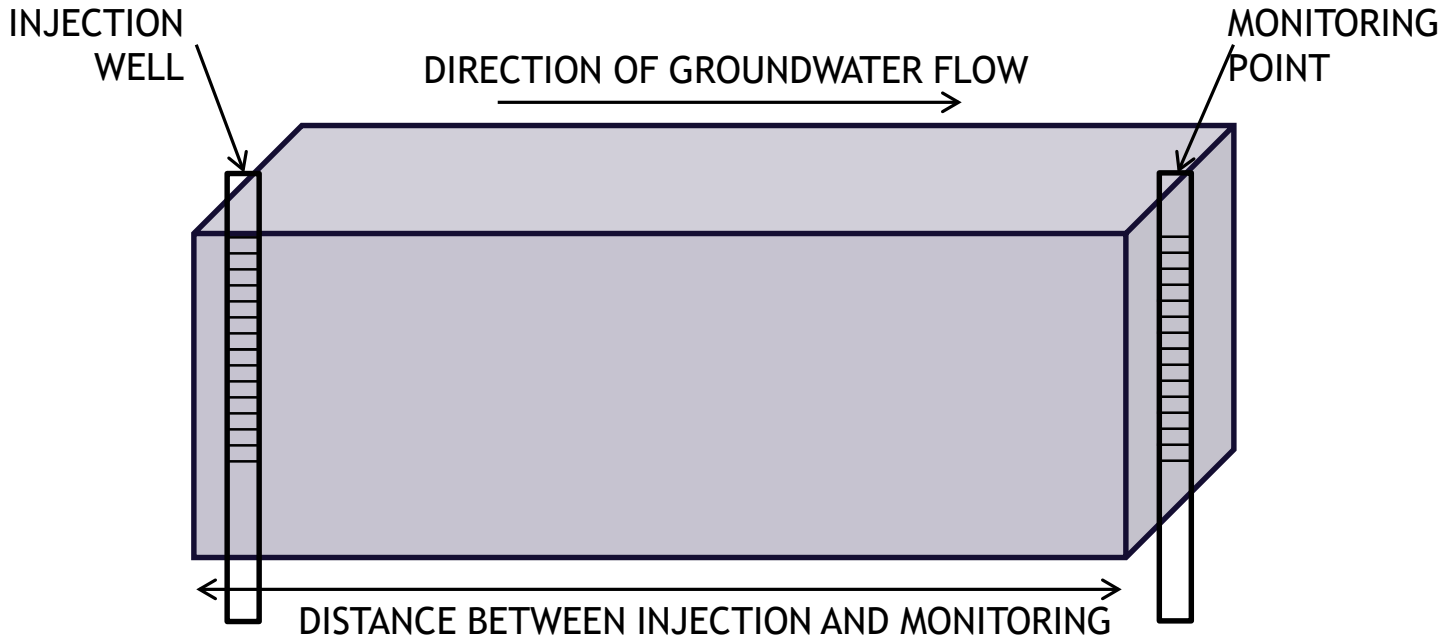
Analysis of Aquifer Volume Treated by Amendment Injection



- Locations selected for analysis:
  - Injection rate > 1 gpm;
  - Full target volume of 5,800 gallons readily achieved;
  - No apparent injection hindrance due to lithology

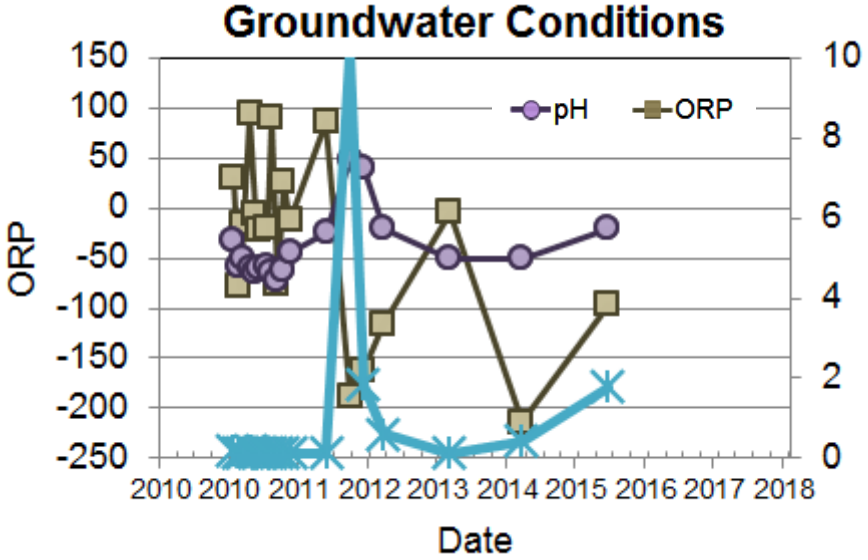
Analysis of Aquifer Volume Treated by Amendment Injection

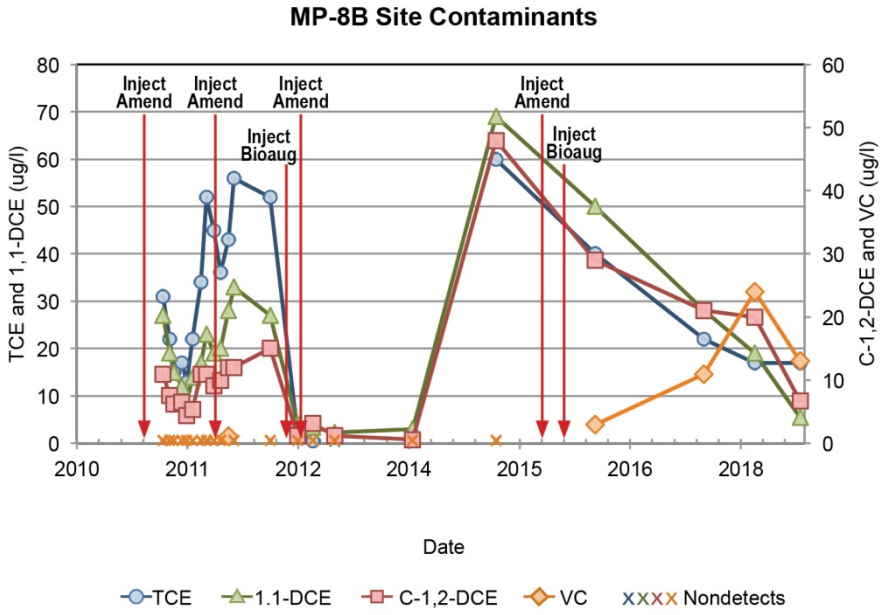


- Control volume dimensions for analysis:
  - Width = 30 ft (IW spacing 40 ft on square grid
  - Height = 15 ft (10-ft screen plus ½ distance to next screen above & below
  - Length = distance varies in each case (see below)

Analysis of Aquifer Volume Treated by Amendment Injection

MP well	Distance [IW→MP] (ft)	Pre-treat pH (SU)	Date injections	Cumulative gr SBC/ kg soil	Date effective treatment
MP-08	40	4.5	9/2012	2.05	2013-Rbnd
			9/2015	4.1	2016

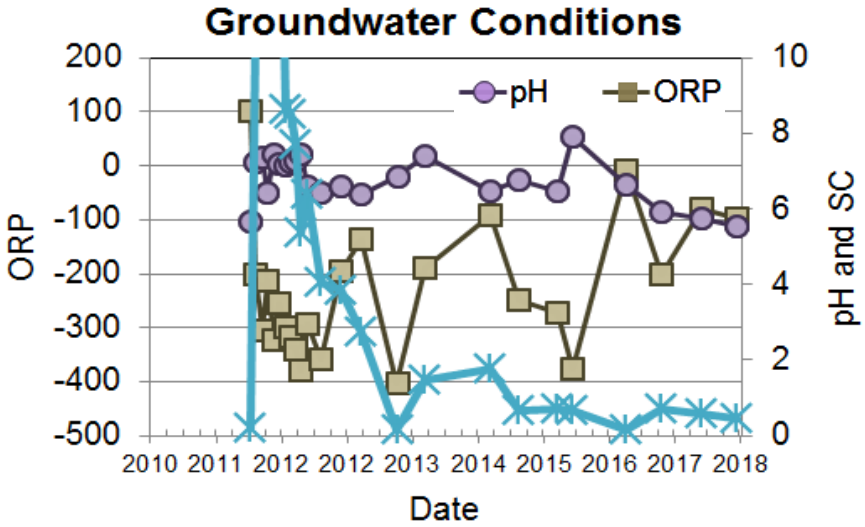


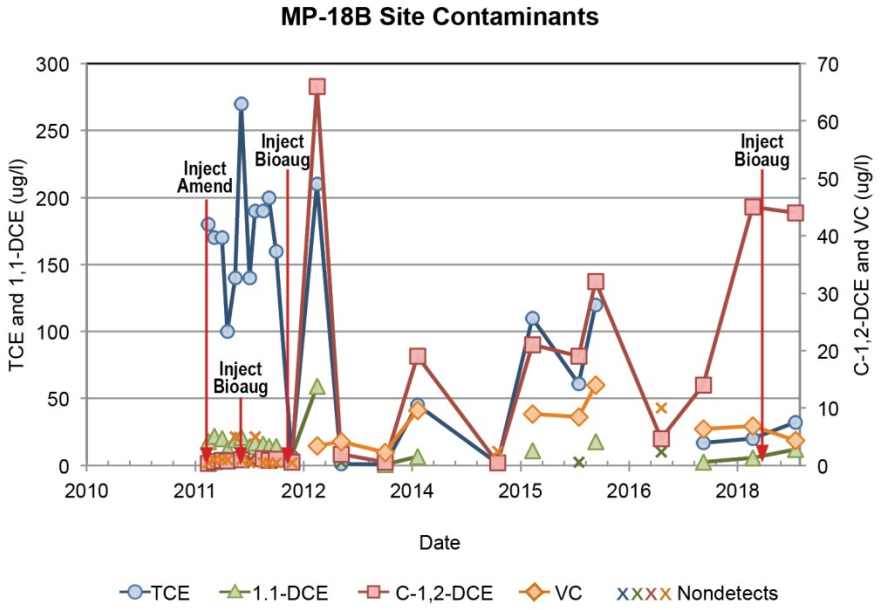


- Initial treatment in 2012, w/ rebound
- Injection 2015 re-set GW conditions, led to lasting treatment

Analysis of Aquifer Volume Treated by Amendment Injection

MP well	Distance [IW→MP] (ft)	Pre-treat pH (SU)	Date injections	gr SBC/ kg soil	Date effective treatment
MP-18	15	6.5	9/2011	5.4	2012

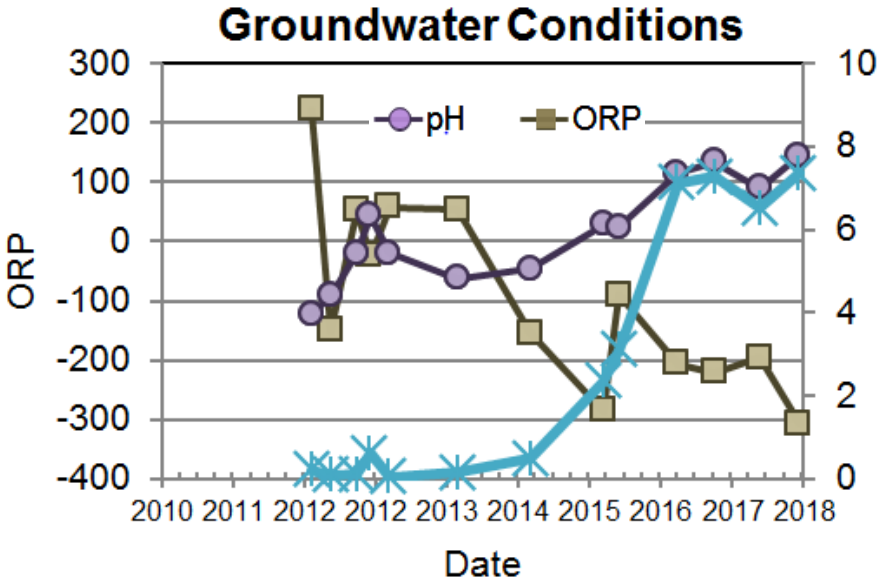


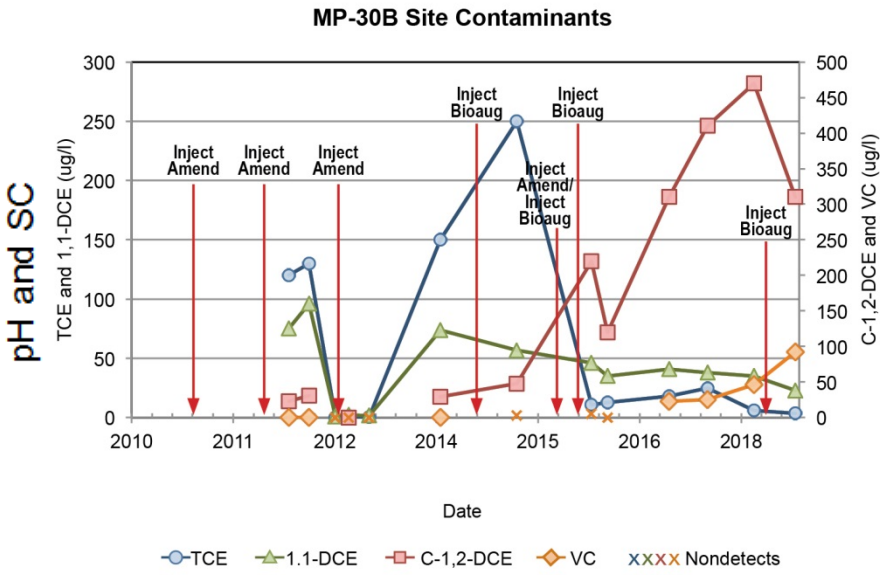


- Initial treatment in 2011, w/ rebound
- 2011 amendments persisted to 2016
- Moderate rebound cis-DCE, may require re-treatment

Analysis of Aquifer Volume Treated by Amendment Injection

MP well	Distance [IW→MP] (ft)	Pre-treat pH (SU)	Date injections	Cumulative gr SBC/ kg soil	Date effective treatment
MP-30	60	4.5	9/2012	1.35	2013 minimal
			9/2014	2.7	Insufficient data
			9/2015	4.1	2016





- Initial treatment in 2012, minimal treat effect
- Two more injections required to improve GW conditions, for lasting treatment

Overview

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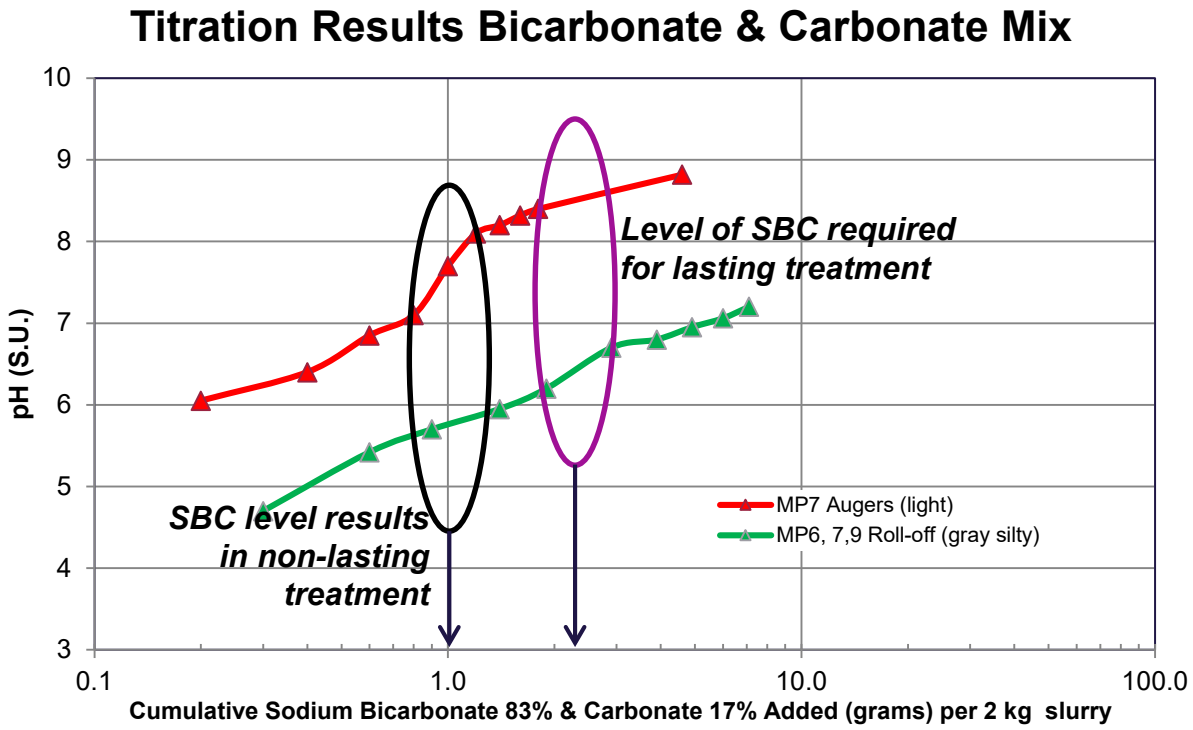
Summary of well treatments presented

MP Well	Distance [IW→MP] (ft)	No. amendment injections	Years to effective treatment after 1st injection	Cumulative SBC (gr SBC/kg soil)
MP-08	40	2	4	4.1
MP-18	15	1	1	5.4
MP-30	60	3	4	4.1

Neutralization level required for lasting treatment



Lower level of SBC application results in incomplete treatment (typically rebound)

Effective In Situ Treatment at Site

- Treatment requires
  - EVO as electron donor to promote reductive dechlorination
  - SBC to increase aquifer pH to minimum 6.0 SU
  - Bioaugment (*Dehalococcoides* species)—not discussed here
- Field monitoring data indicates treatment does not occur unless pH ~6.0 SU or greater, even if TOC and ORP are sufficient
- At least 4.0 gr SBC / kg aquifer soil is needed to raise pH adequate for treatment. This provides for lasting pH of 6.0 or greater.

Acronyms

DCE	1,1-dichloroethylene
EVO	emulsified vegetable oil
ft	feet
GW	groundwater
gr	grams
IW	injection well
kg	kilograms
MCL	maximum contaminant level
MP	monitoring point
ORP	oxidation reduction potential
pH	(-) log of aqueous hydrogen ion concentration
RDC	reductive dechlorination
SBC	sodium bicarbonate
SC	specific conductivity
SU	standard units for pH
TCE	trichloroethylene
TCA	trichloroethane
VC	vinyl chloride

Thank You

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