FARALLON

Bioremediation of Former Industrial Chemical Plant Using Multiple Injectates: Enhanced Reductive Dechlorination, Chemical Reduction, and Bioaugmentation

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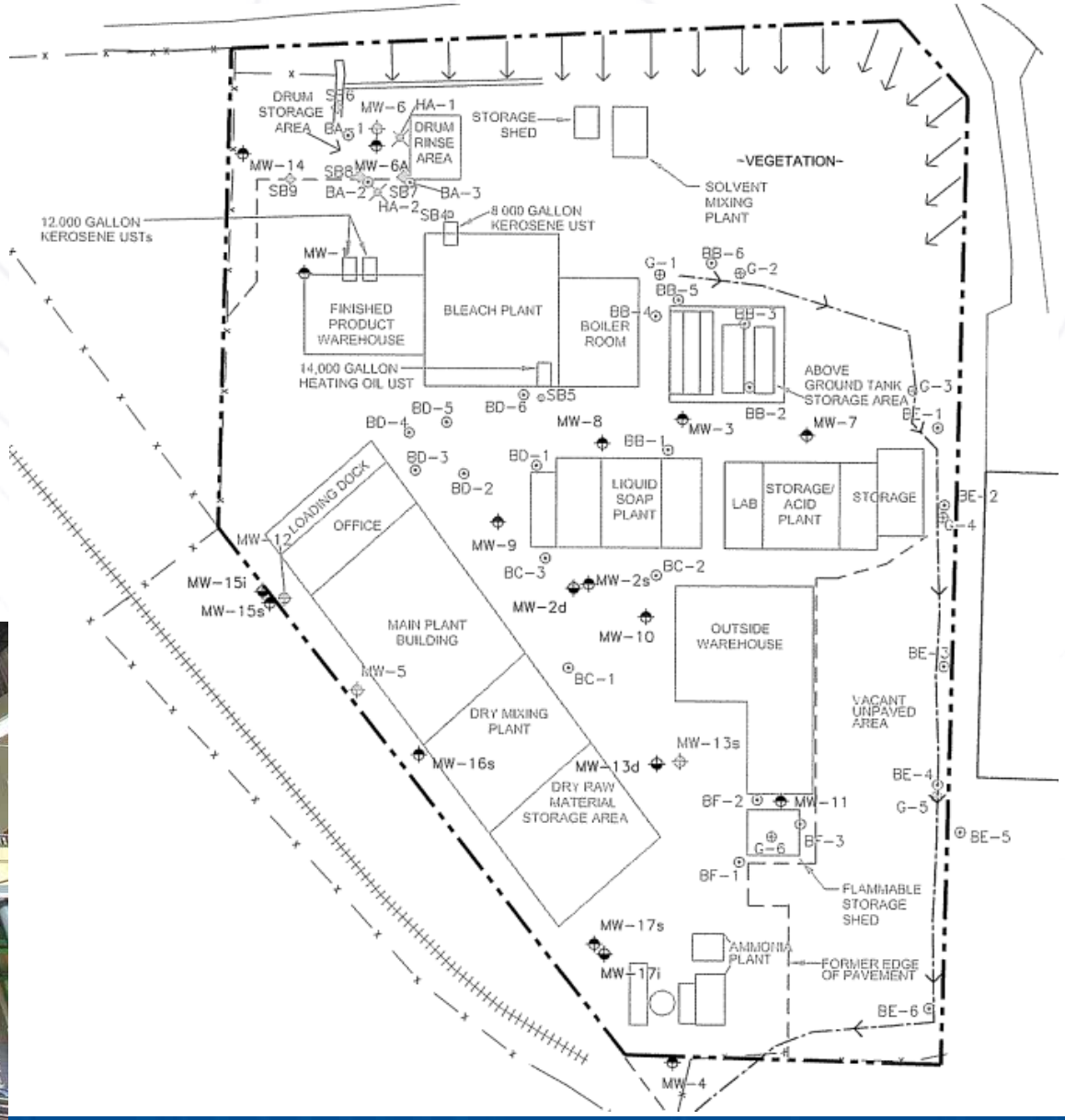
Historical Land Use

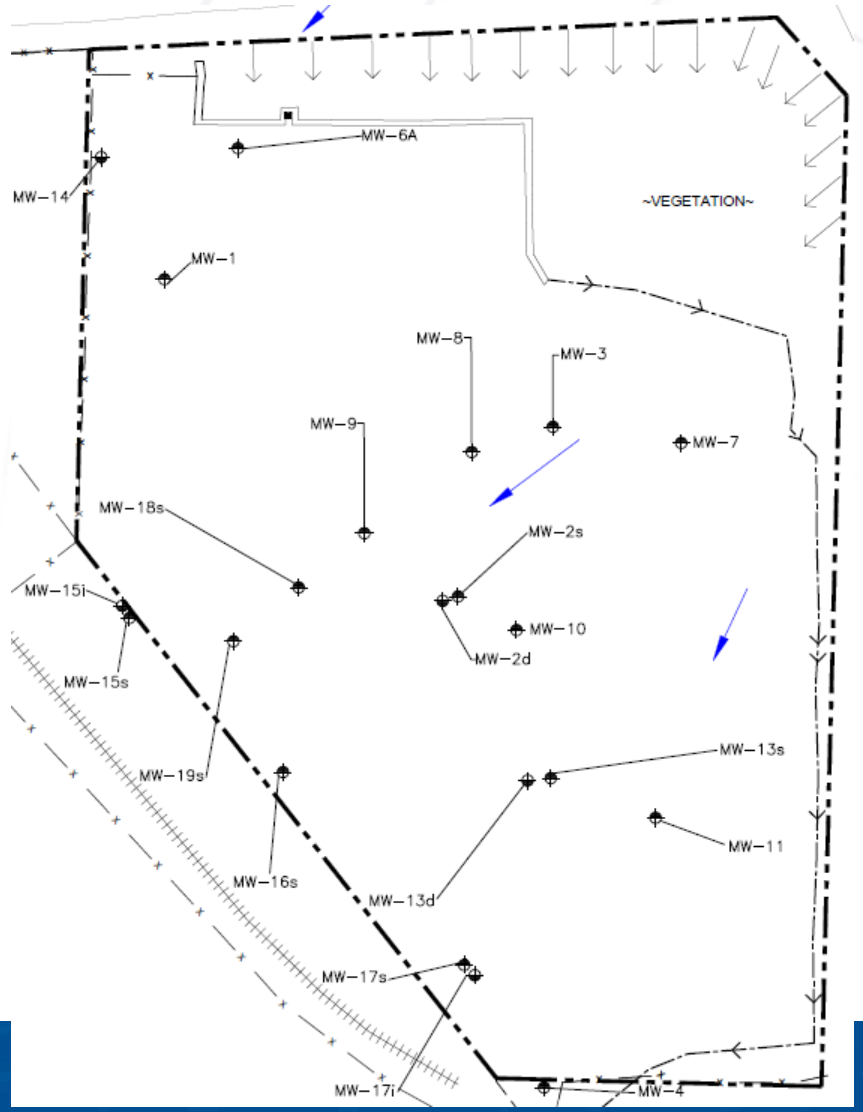
- Prior to 1919 – Undeveloped
- 1920 to 1990 – Chemical manufacturing facility
- Historical land use resulted in release of hazardous substances to the environment



Current Facility Operations

- From 2000 to Current – Manufacturer of concrete ecology blocks

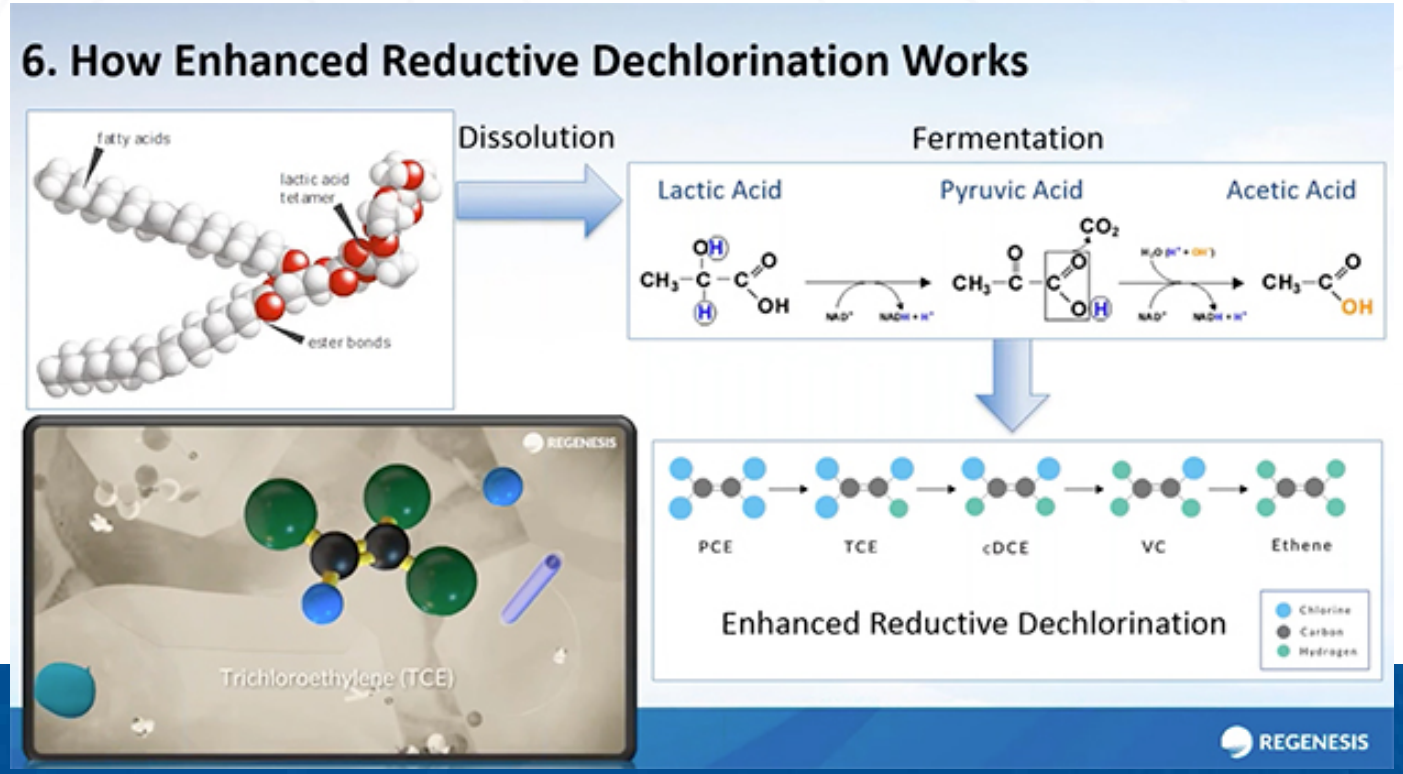
Groundwater Characteristics



- Silty sand, sandy silt
- Shallow groundwater, ½ to 7 feet below ground surface (bgs), seasonally dependent
- Site located approximately 1 mile from a river
- Groundwater flow direction west/southwest

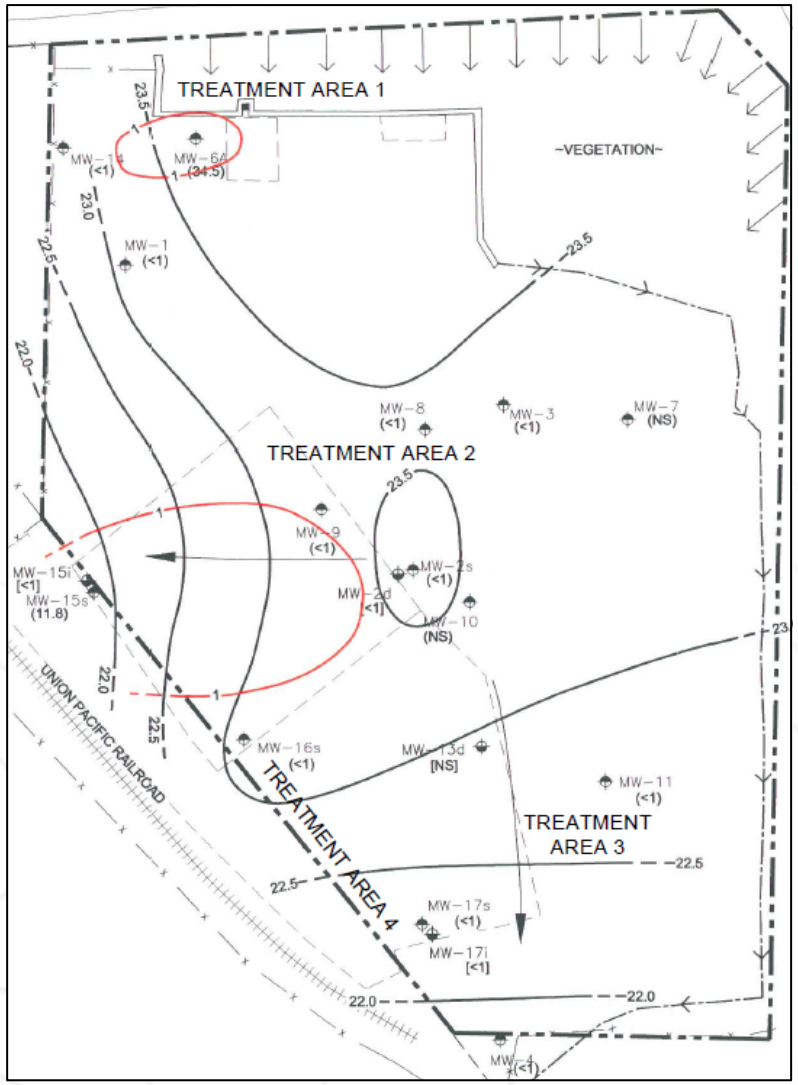
Design Considerations for Enhanced Reductive Dechlorination

- Anaerobic
- Sulfate-reducing and methanogenic conditions
- Oxidation-reduction potential

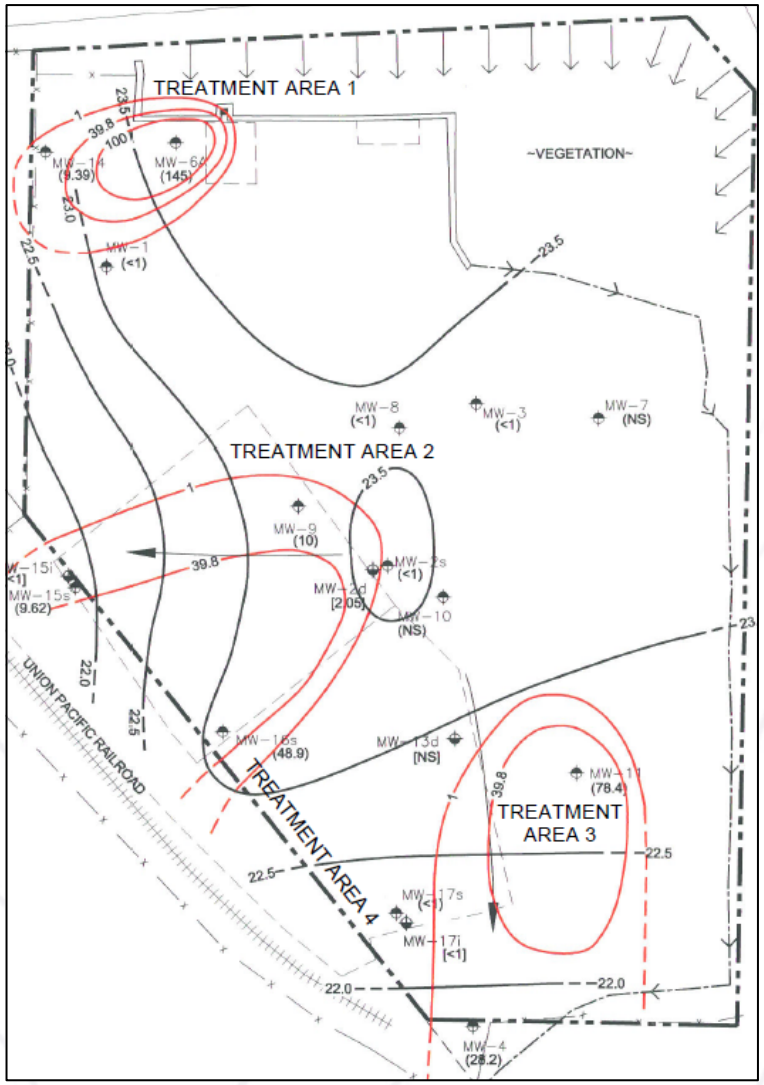


Conceptual Site Model, Isoconcentration Maps

PCE (September 2004)

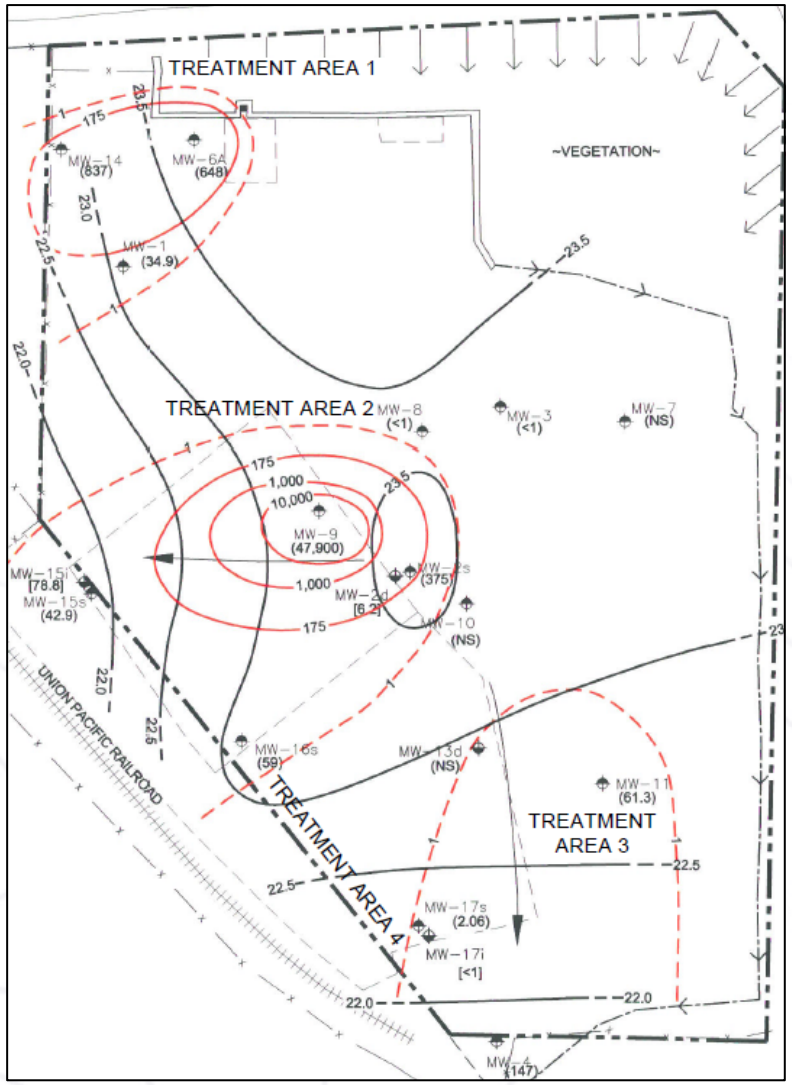


TCE (September 2004)

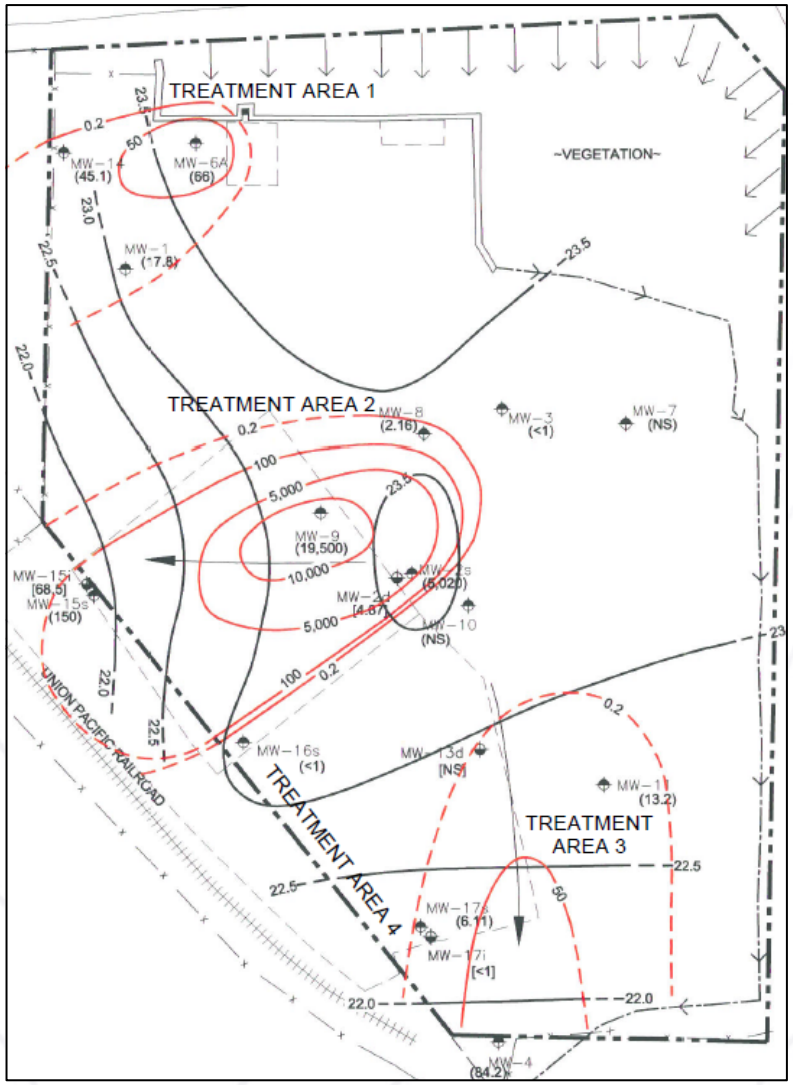


Conceptual Site Model, Isoconcentration Maps

Cis-1,2-DCE (September 2004)



Vinyl Chloride (September 2004)



Remedial Actions

2005 and 2010 Injections

- 2005 – Hydrogen Release Compound (HRC®) in Treatment Area 2
  - 40 injections (6,300 pounds)
- 2010 – HRC and HRC-X across the Site
  - 116 injections (9,000 pounds)
- Intended to accelerate biodegradation rates in areas with the highest chlorinated volatile organic compound (CVOC) concentrations and/or areas with potential for migration off-Site

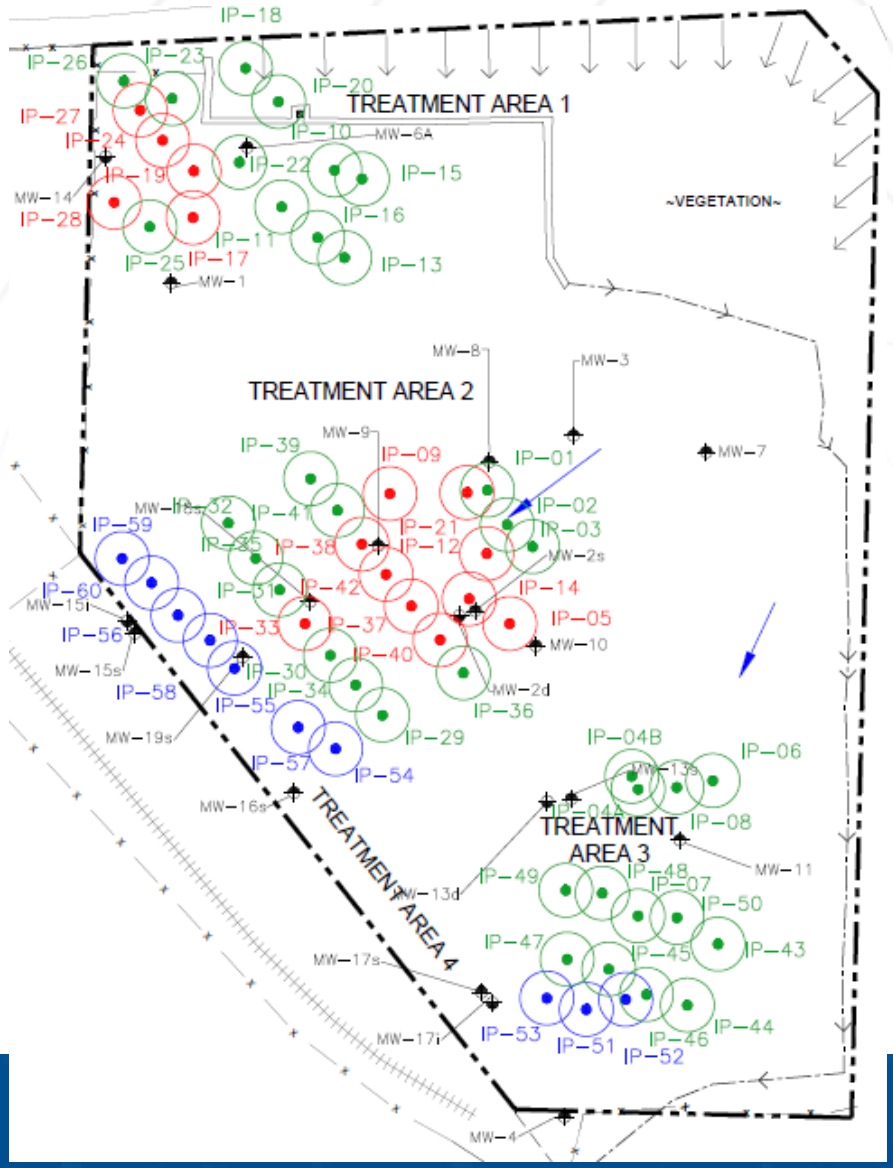
REGENESIS®

Remedial Actions

2015 Injections

- Pilot test to evaluate if *Dehalococcoides* (*Dhc*) bacteria culture could accelerate reductive chlorination without injection of an electron donor
  - 12 injections
- Results indicated injecting only *Dhc* did not sufficiently increase microbial population

2021 Injections



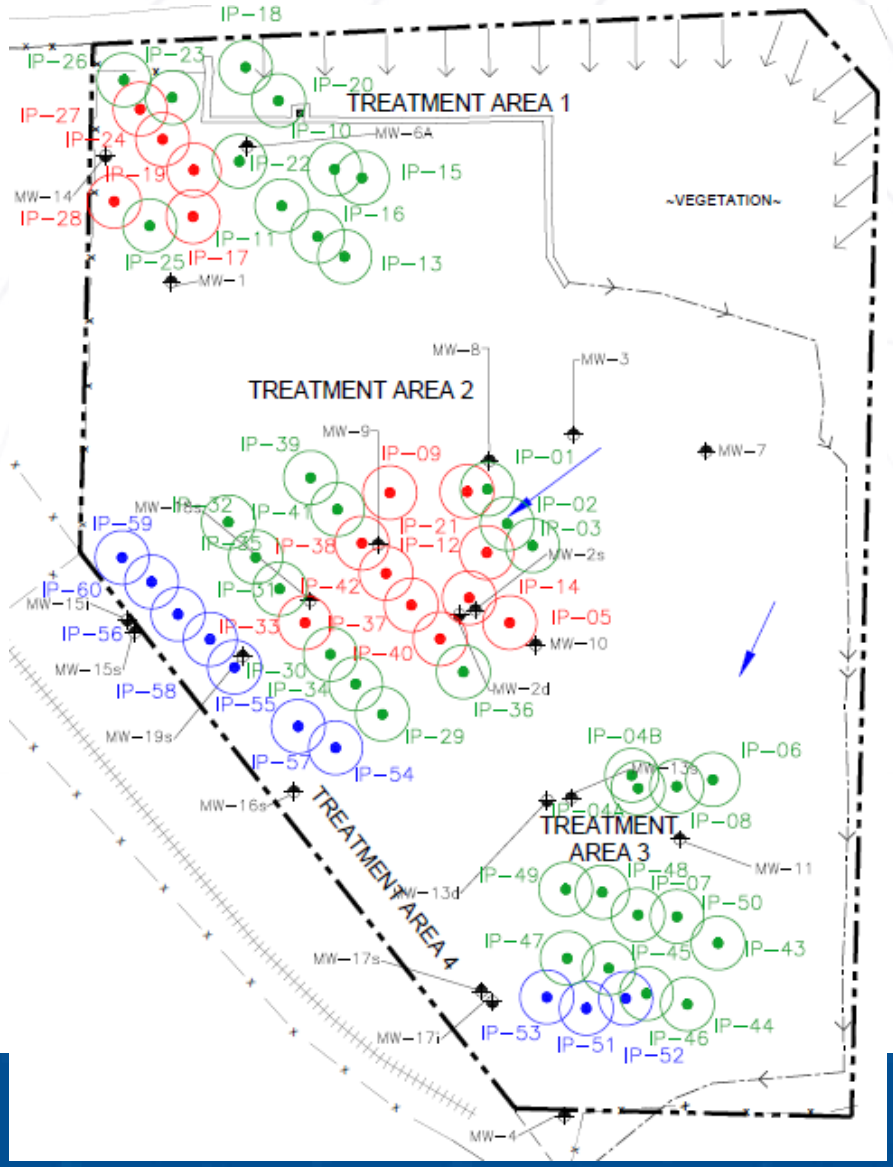
- 60 injections
- 3 to 30 feet bgs, varying
- 4,500 gallons EOS®PRO (emulsified vegetable oil)
- 440 gallons Wilclear Plus® (lactate)
- 14.7 liters KB-1® Plus (*Dhc*)
- 3,300 pounds zero valent iron (ZVI)

EOS PRO INJECTION BORING WITH INJECTION INTERVAL FROM 3 TO 30 FEET BGS, VARIABLE

EOS PRO AND ZVI INJECTION BORING WITH INJECTION INTERVAL FROM 6 TO 30 FEET BGS, VARIABLE

LACTATE INJECTION BORING WITH INJECTION INTERVAL FROM 10 TO 20 FEET BGS

2021 Injections, Bioremediation

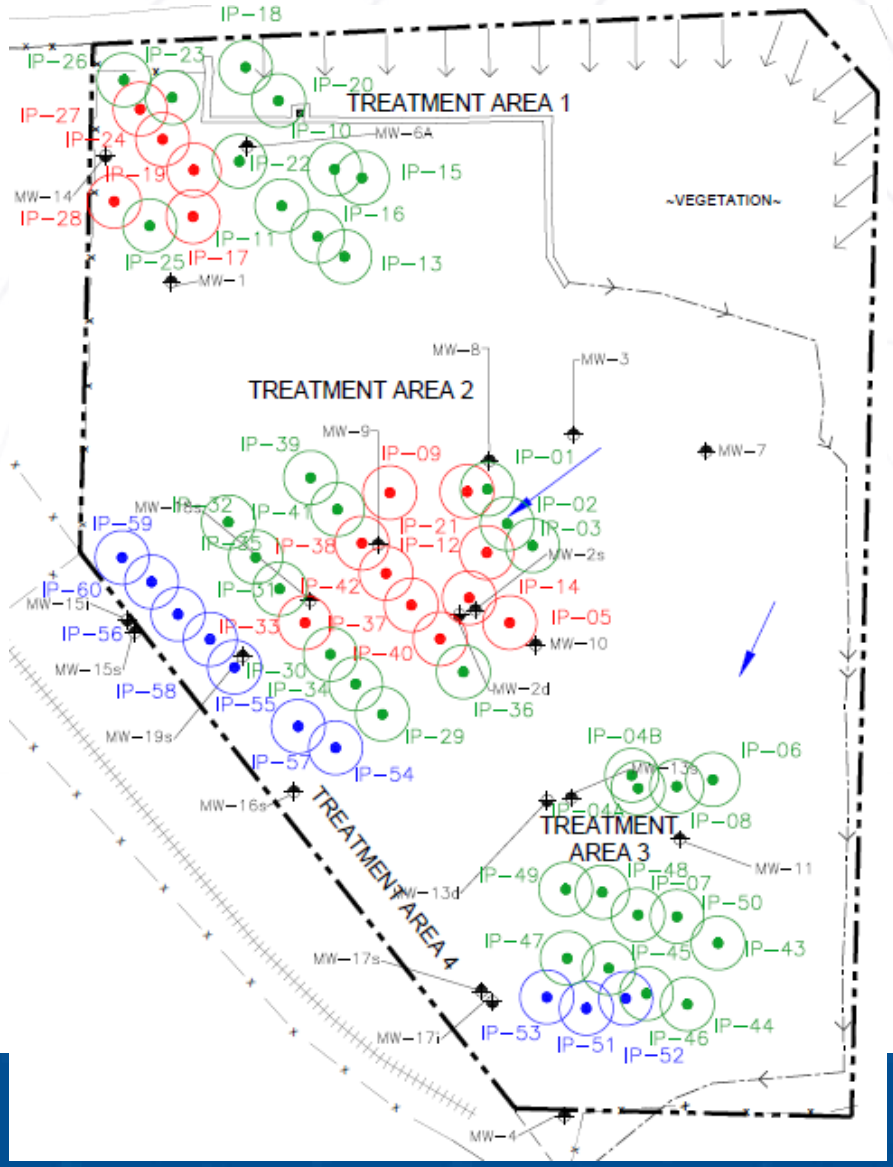


- EOSPRO, an emulsified vegetable oil substrate (electron donor) with micronutrients and vitamin B-12, injected in the areas with higher CVOC mass
- Wilclear Plus®, a lactate product, injected along property boundary to provide soluble electron donor to treat lower CVOC mass

EOS a REDOX TECH company

JRW BIOREMEDIATION

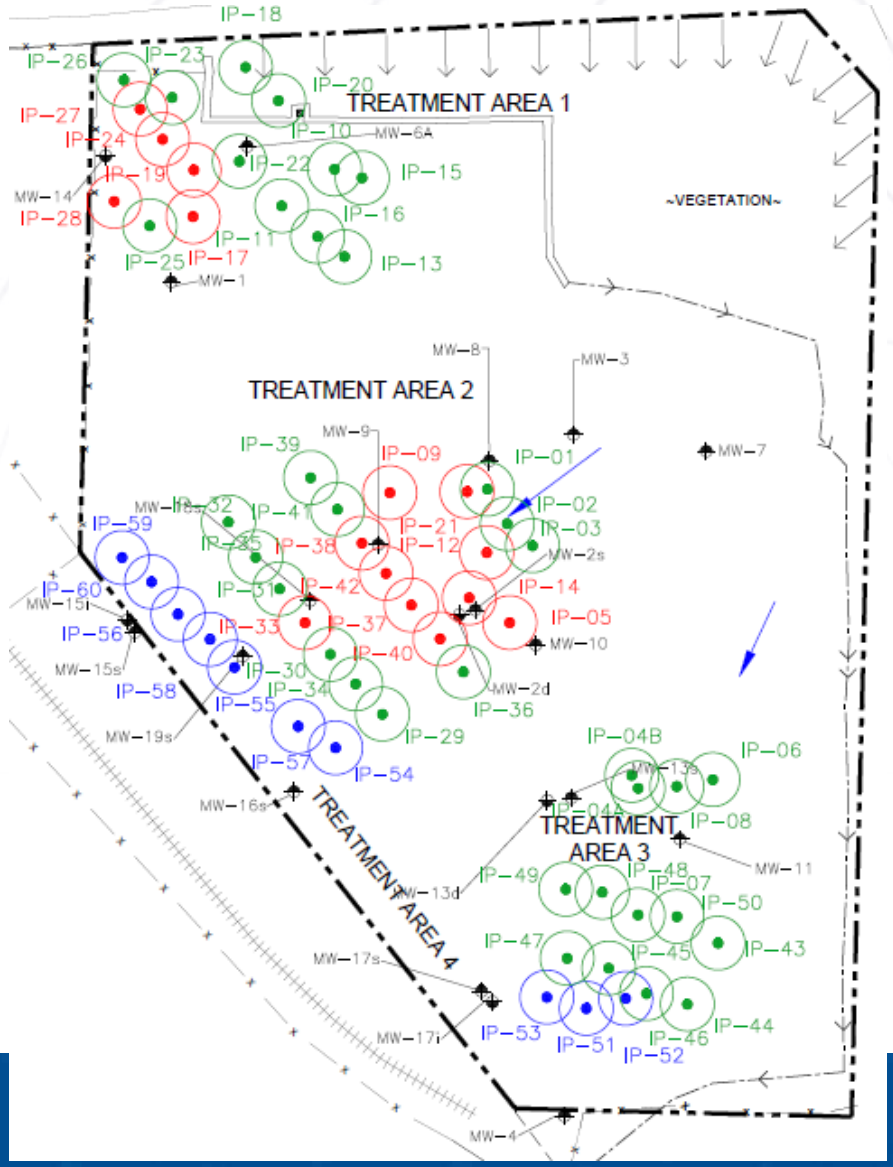
2021 Injections, Bioaugmentation



- KB-1®, provided by SiREM, is a consortium of *Dhc* that includes vinyl chloride degrading bacteria
- Injected in each treatment area concurrently with electron donor
- Primer of anaerobic water injected before and after KB-1® culture

SiREM
Leading Science · Lasting Solutions

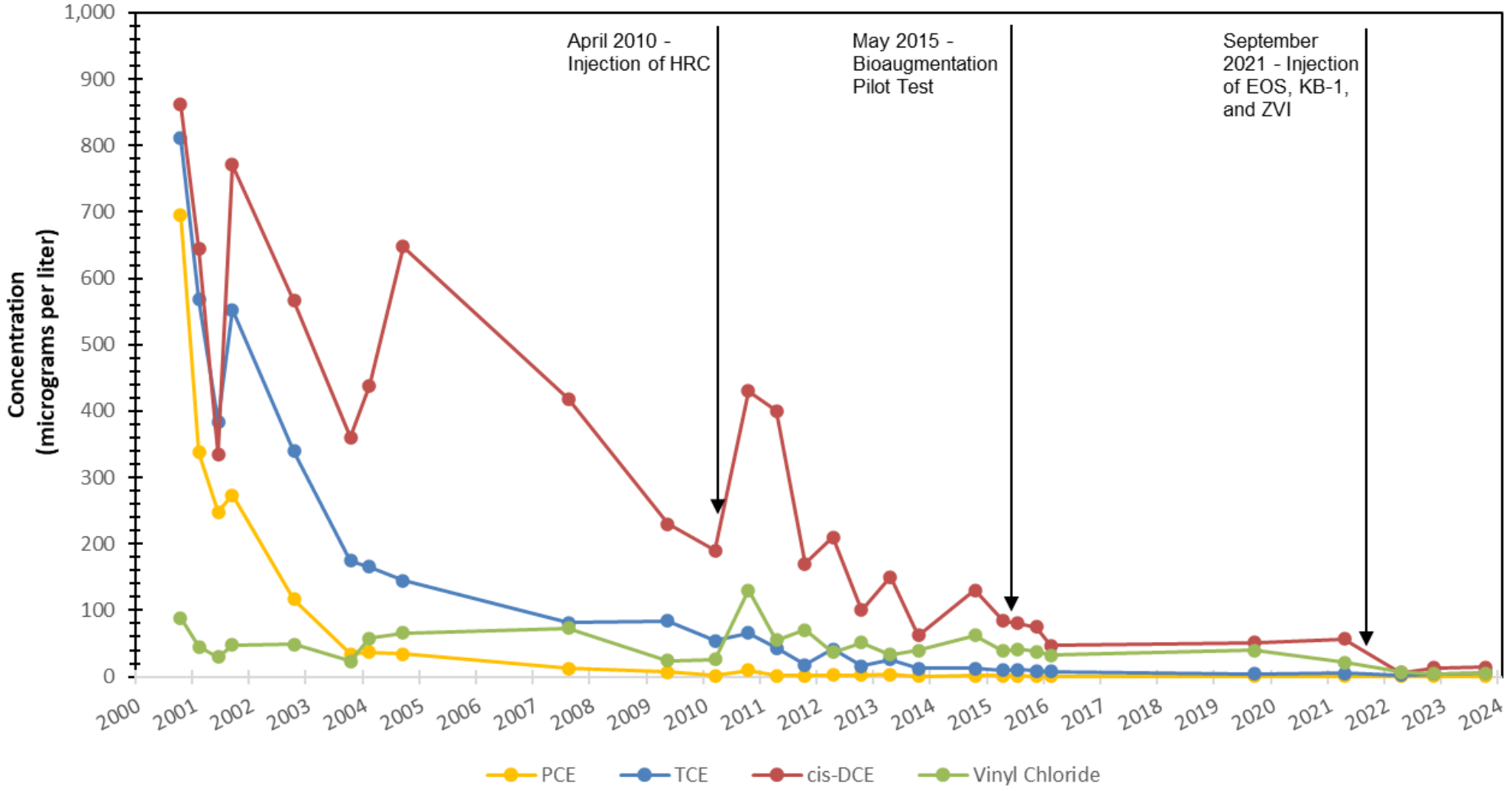
2021 Injections, In Situ Chemical Reduction



- ZVI injected in select areas with higher residual CVOC concentrations in groundwater
- Result in extreme anaerobic conditions to eliminate sulfate-degrading bacteria compete for electron donors
- Abiotically treat CVOCs
- Slower reaction rate versus bioremediation amendments

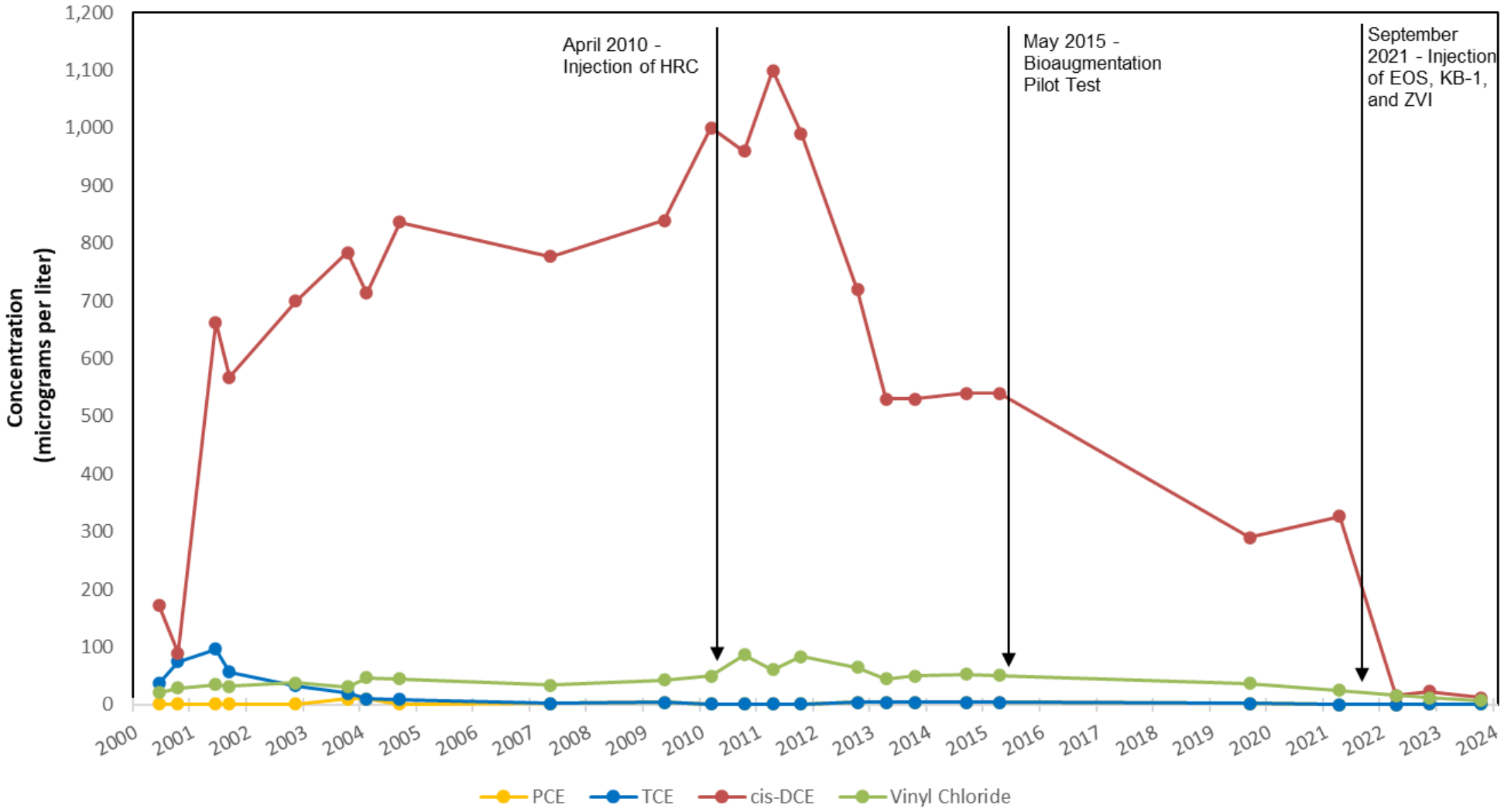
Remedial Action Progress

Chart 1
CVOCs in Groundwater
Treatment Area 1, MW-6A

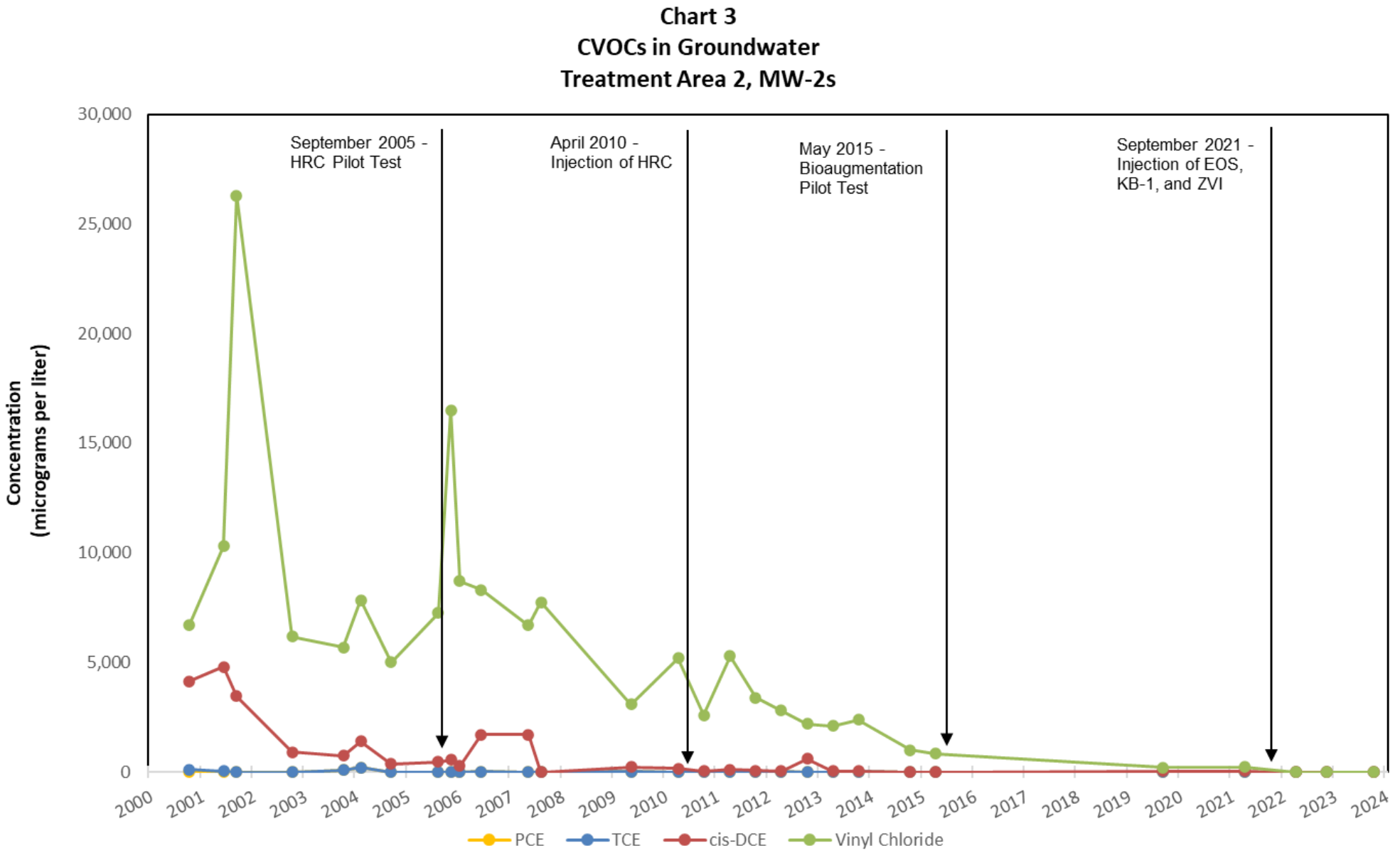


Remedial Action Progress

Chart 2
CVOCs in Groundwater
Treatment Area 1, MW-14



Remedial Action Progress



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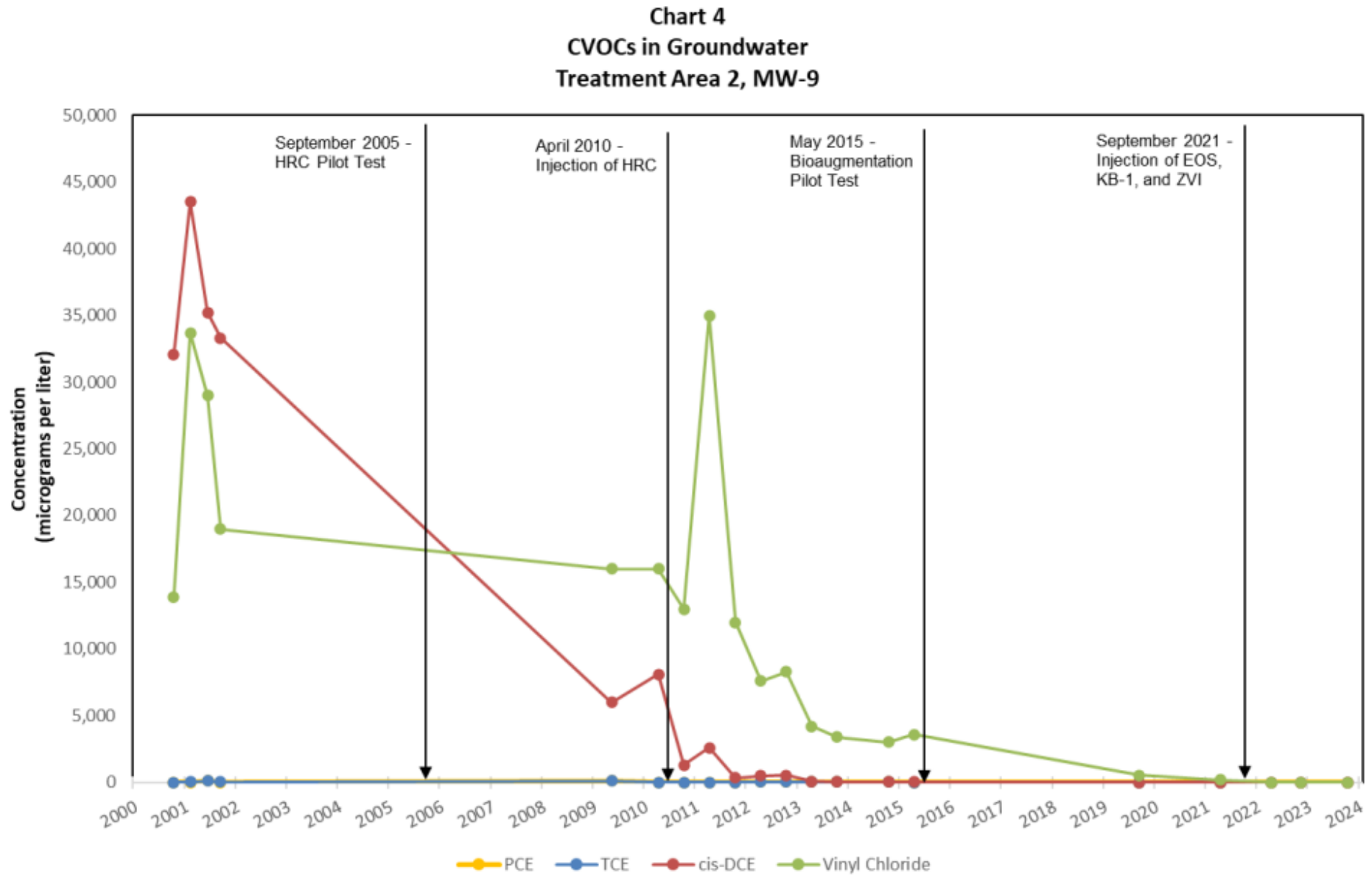

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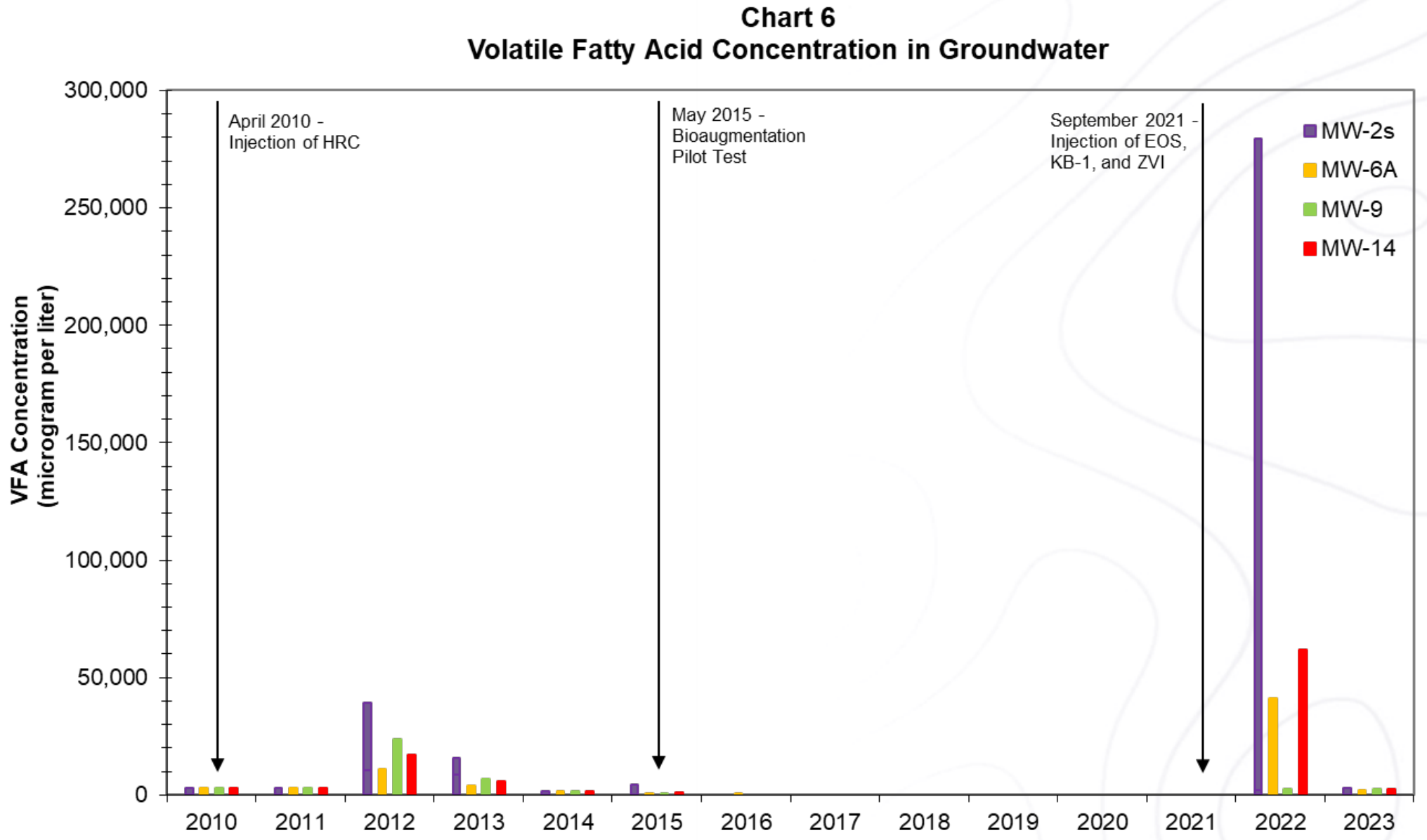

TCE Isoconcentration Maps

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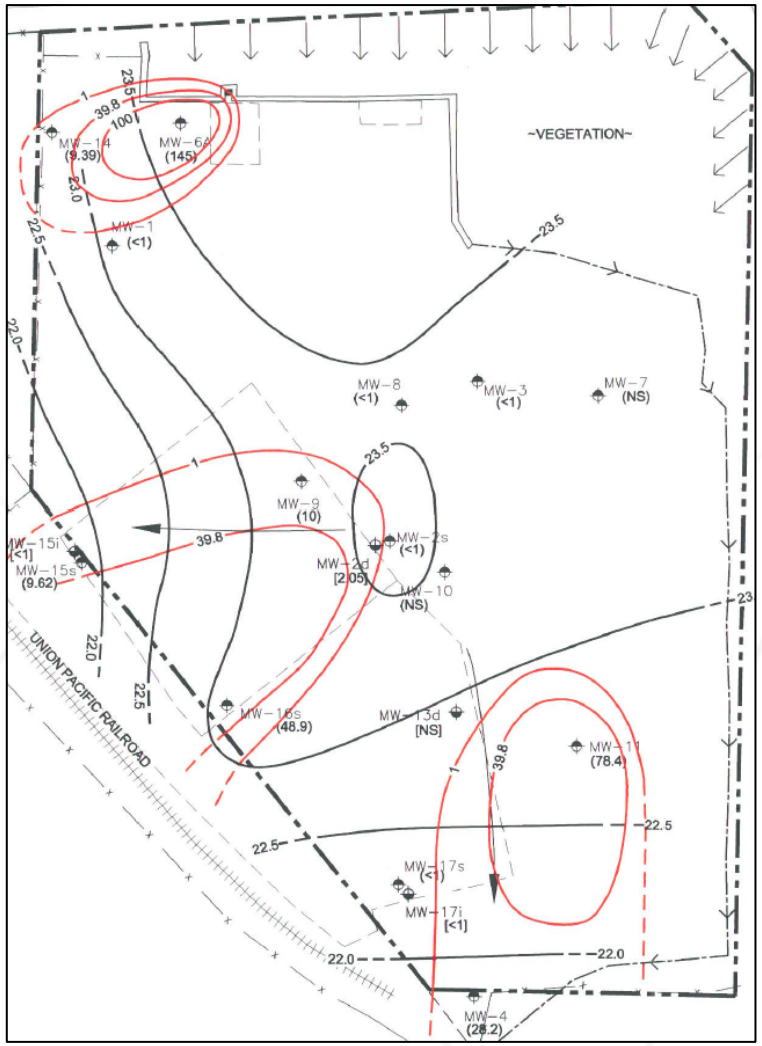
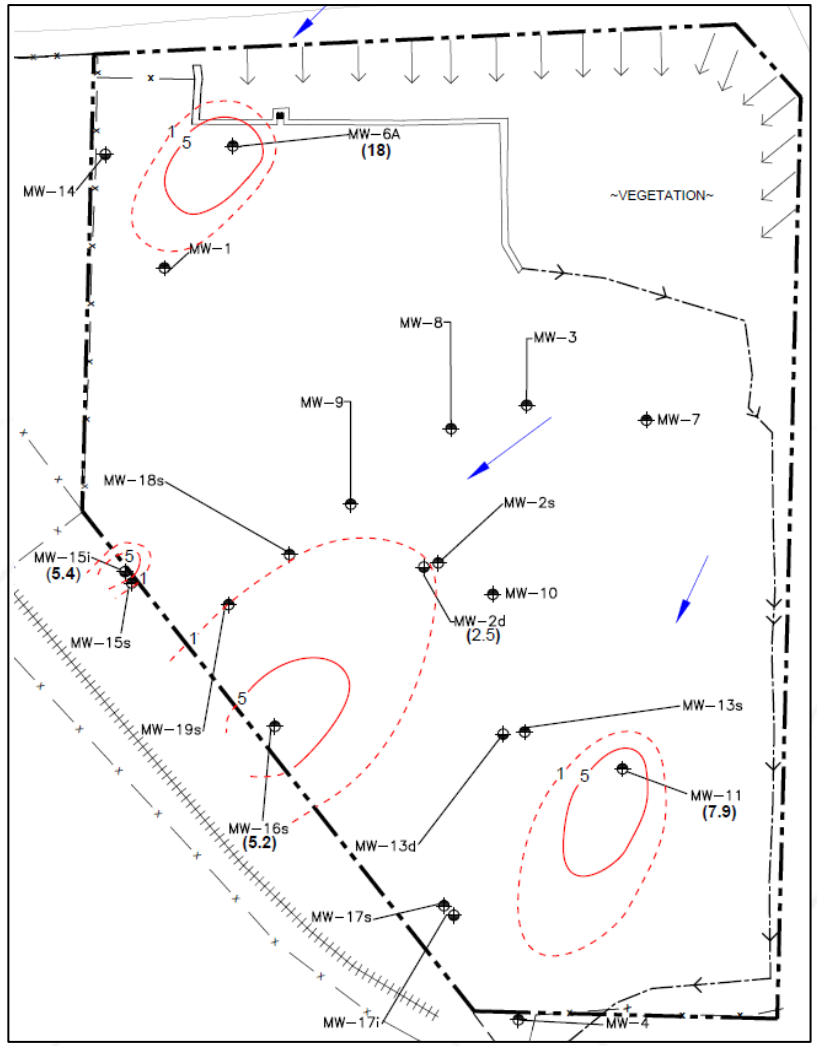
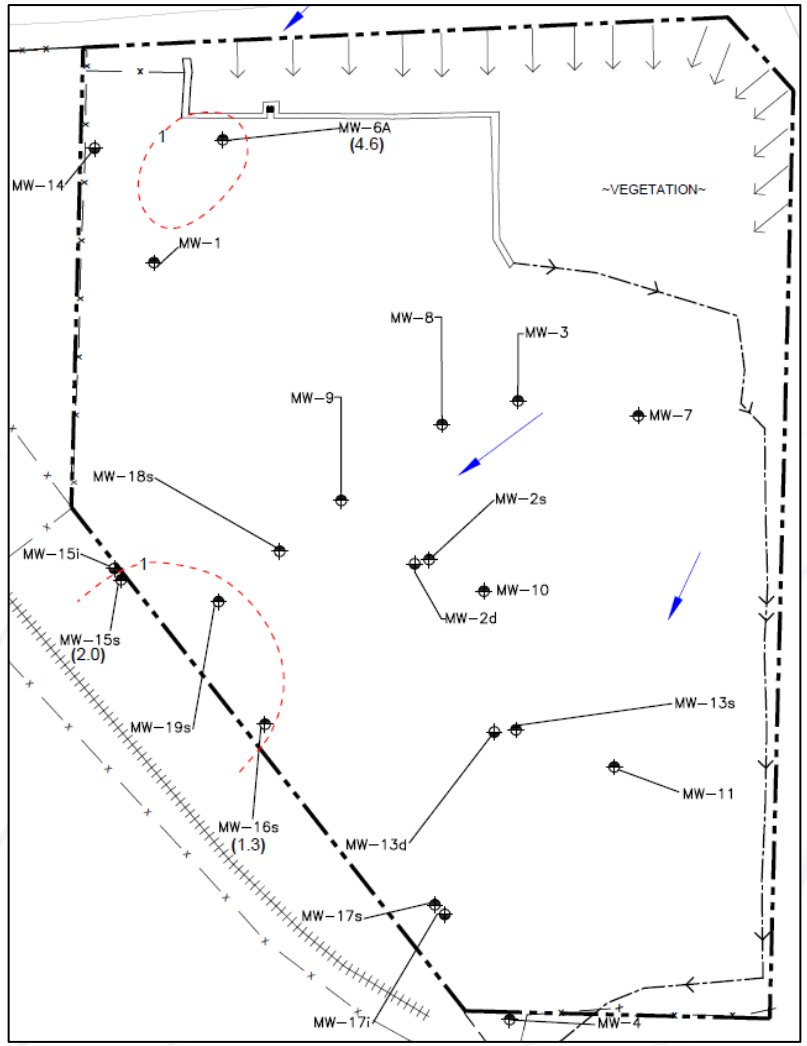


October 2011



November 2022



Cis-DCE Isoconcentration Maps

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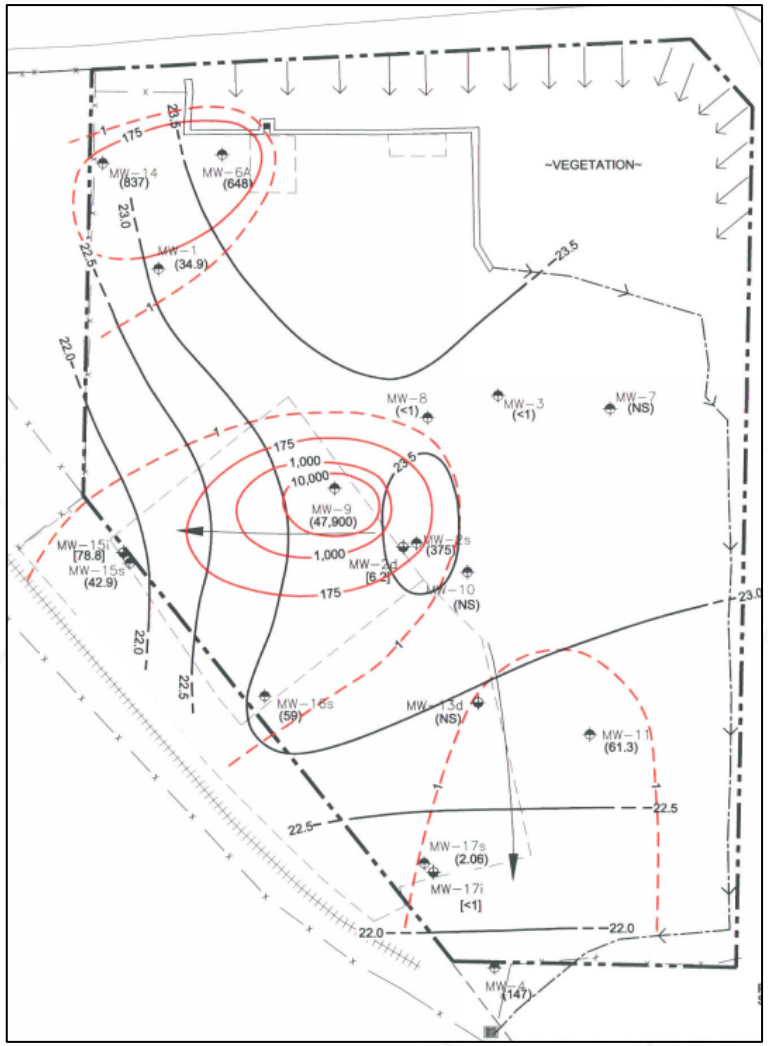

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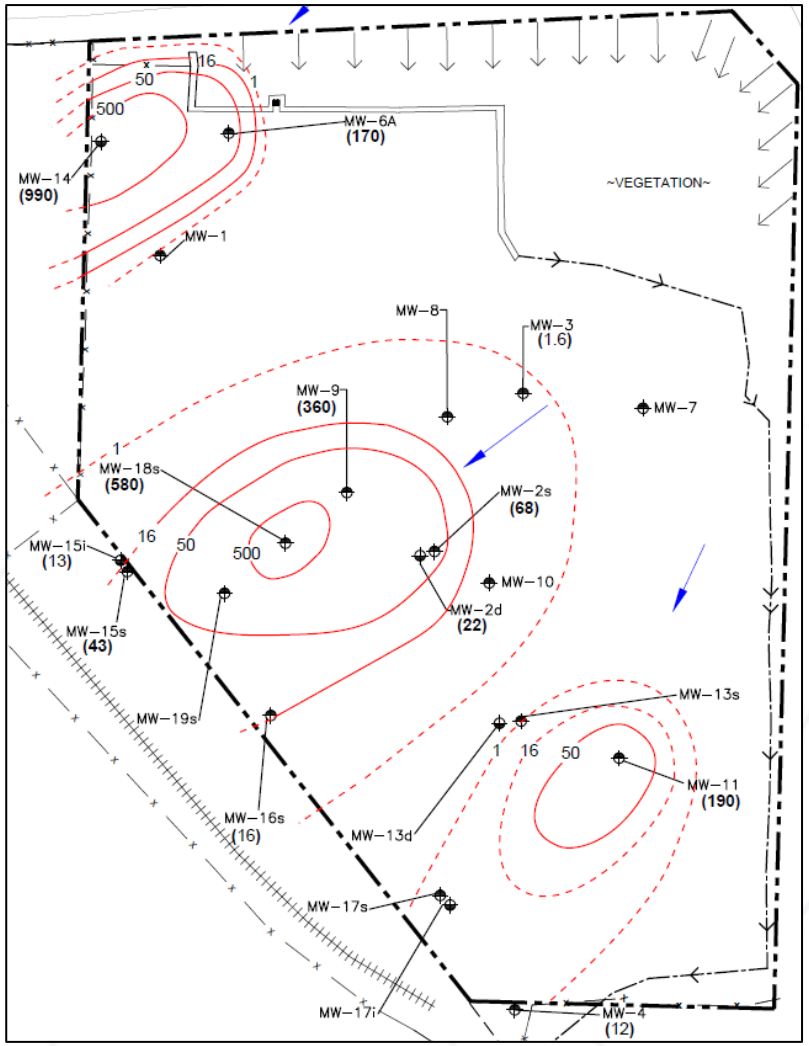

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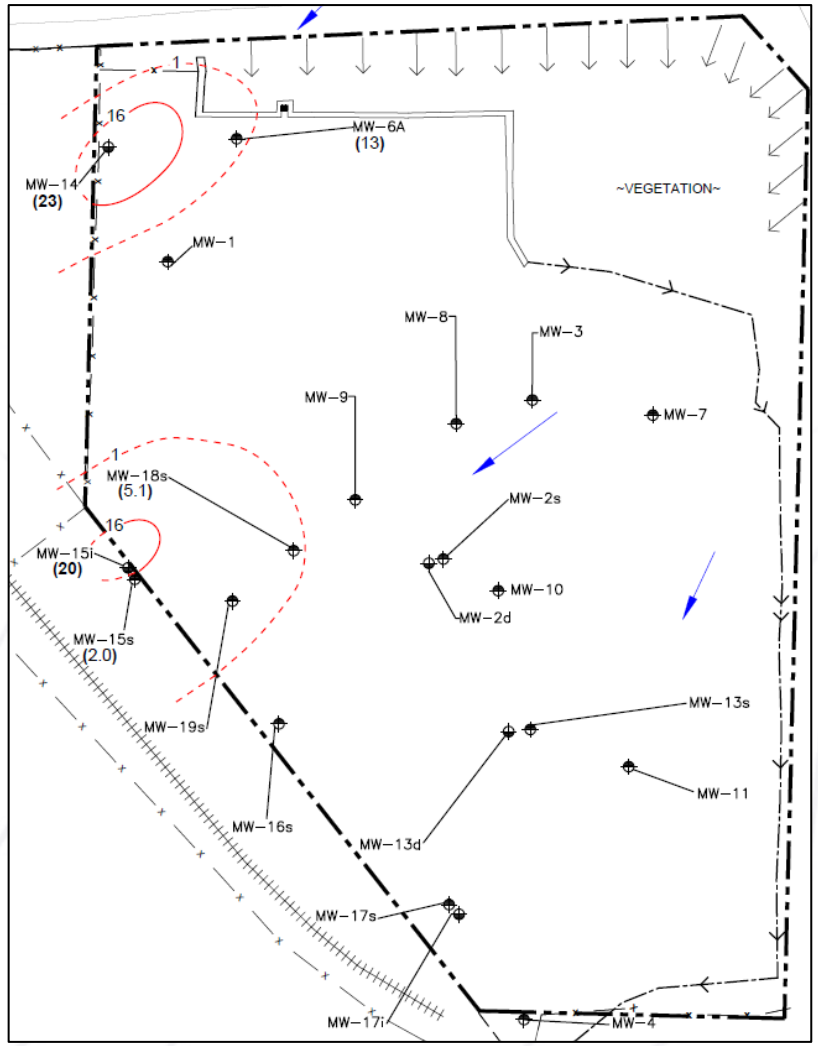

Vinyl Chloride Isoconcentration Maps

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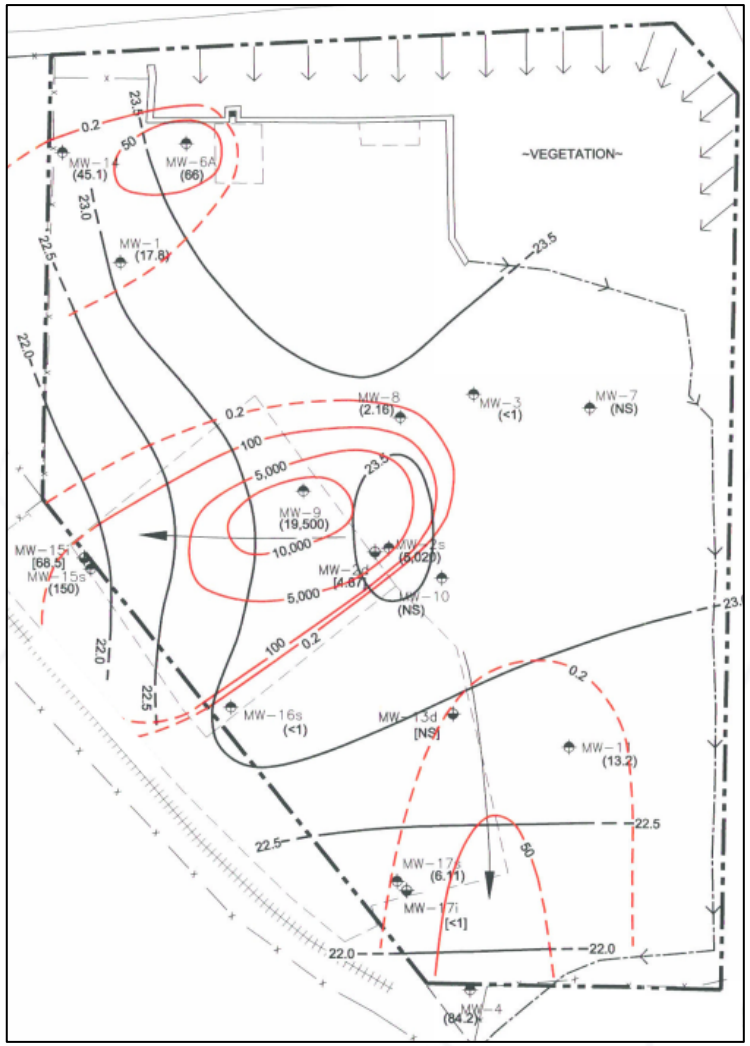

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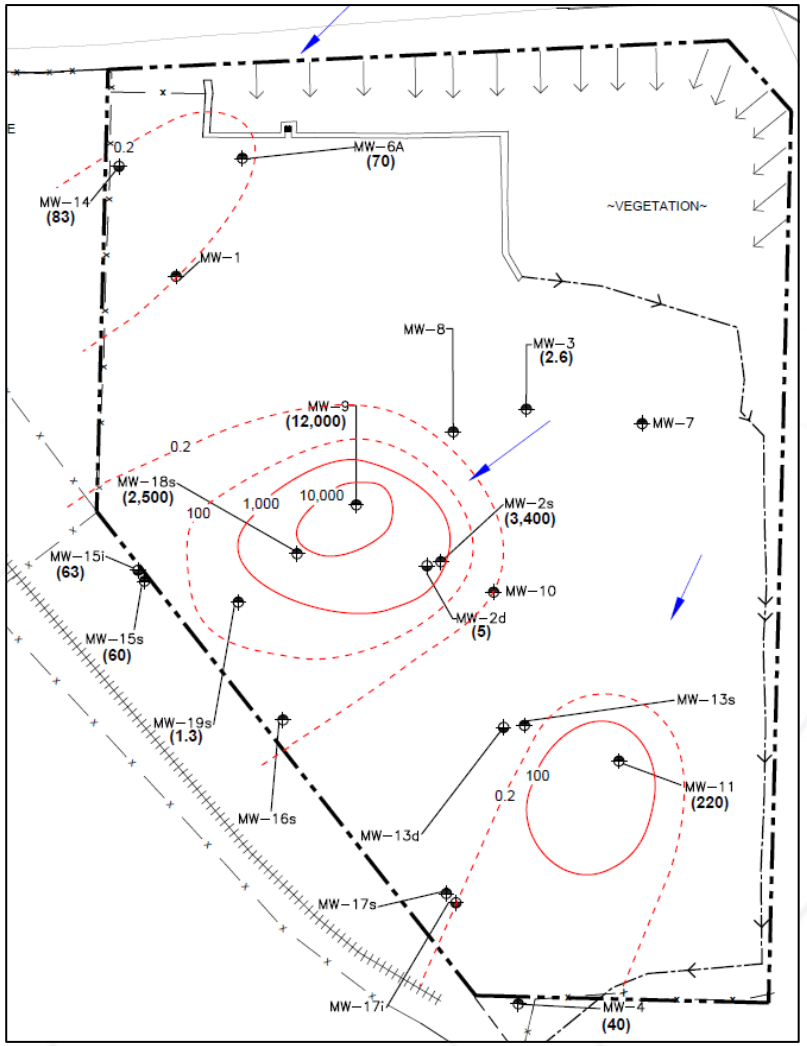

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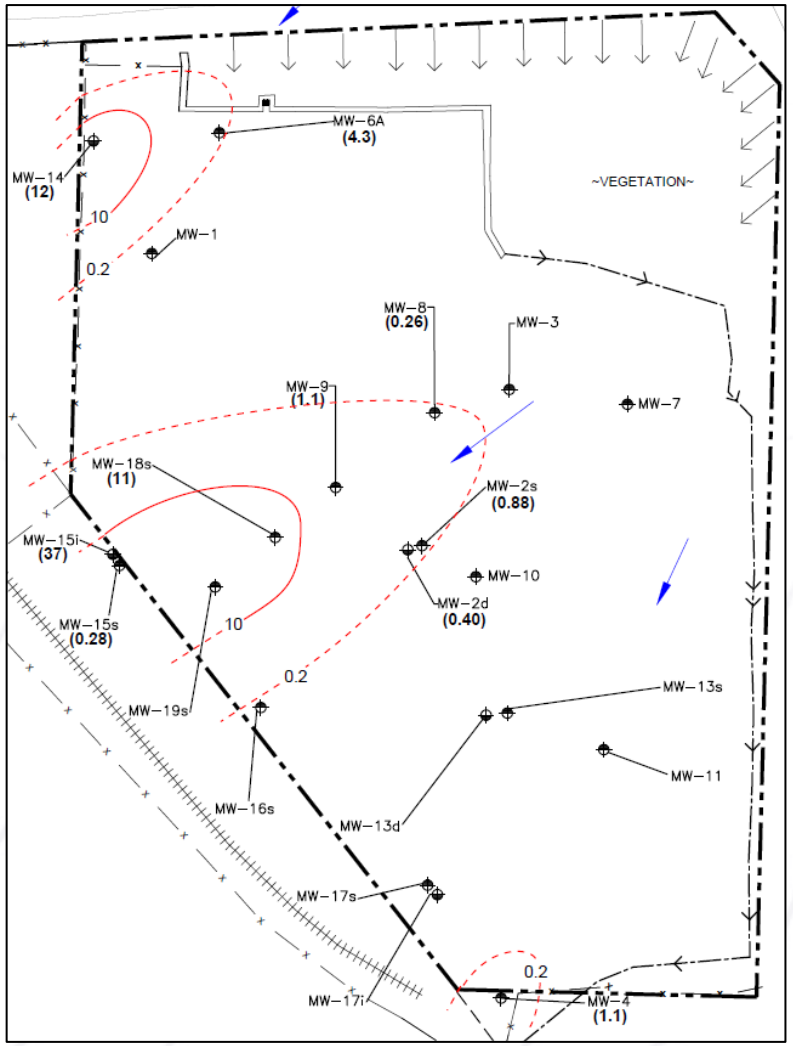

Current Status, Future Plans, Lessons Learned

- Geochemical parameters
- Effectiveness of different substrates
- Microbial populations
- Augment existing natural attenuation processes
- Shorten restoration timeframe
- Ongoing treatment and monitoring

Questions

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