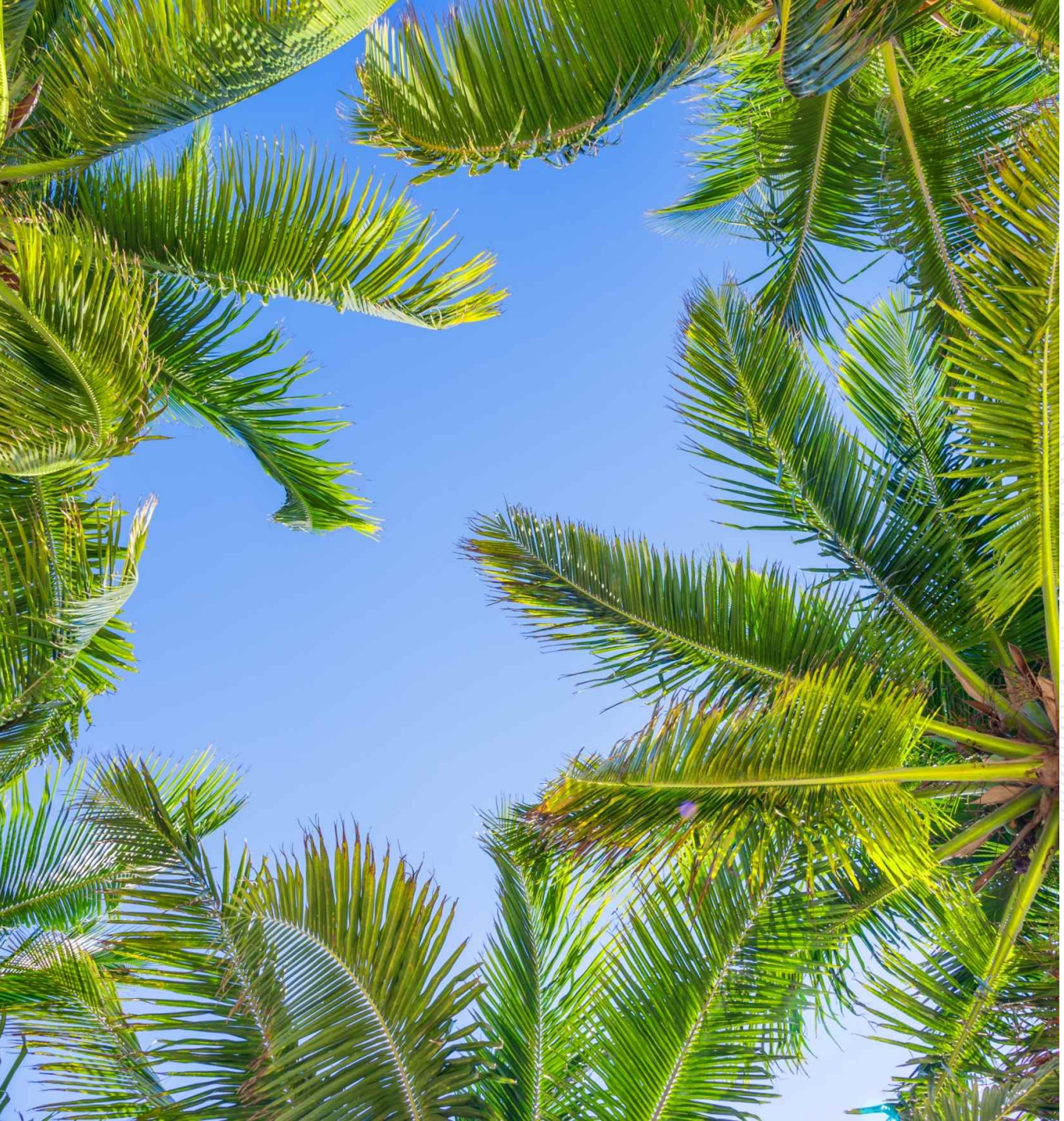

Case Study: Pilot Test to Evaluate 1,2-DCA Bioremediation Effectiveness in Saline Groundwater

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Sixth International Symposium on Bioremediation and Sustainable Environment Technologies
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The business of sustainability

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Introduction

Presentation will discuss:

- How can elevated salinity in groundwater impact in situ biological reduction (ISBR) of VOCs?
- How was our field pilot study designed to evaluate if salinity effects ISBR of 1,2-dichloroethane (1,2-DCA)?
- What were the pilot study results?
- What lessons learned can be applied to other sites with elevated salinity?

Agenda

01

- Site Conditions
- Salinity and ISBR

Background

02

- Pilot Study Design, Setup, Implementation, and Monitoring

Approach

03

- Pilot Study Results

Results

04

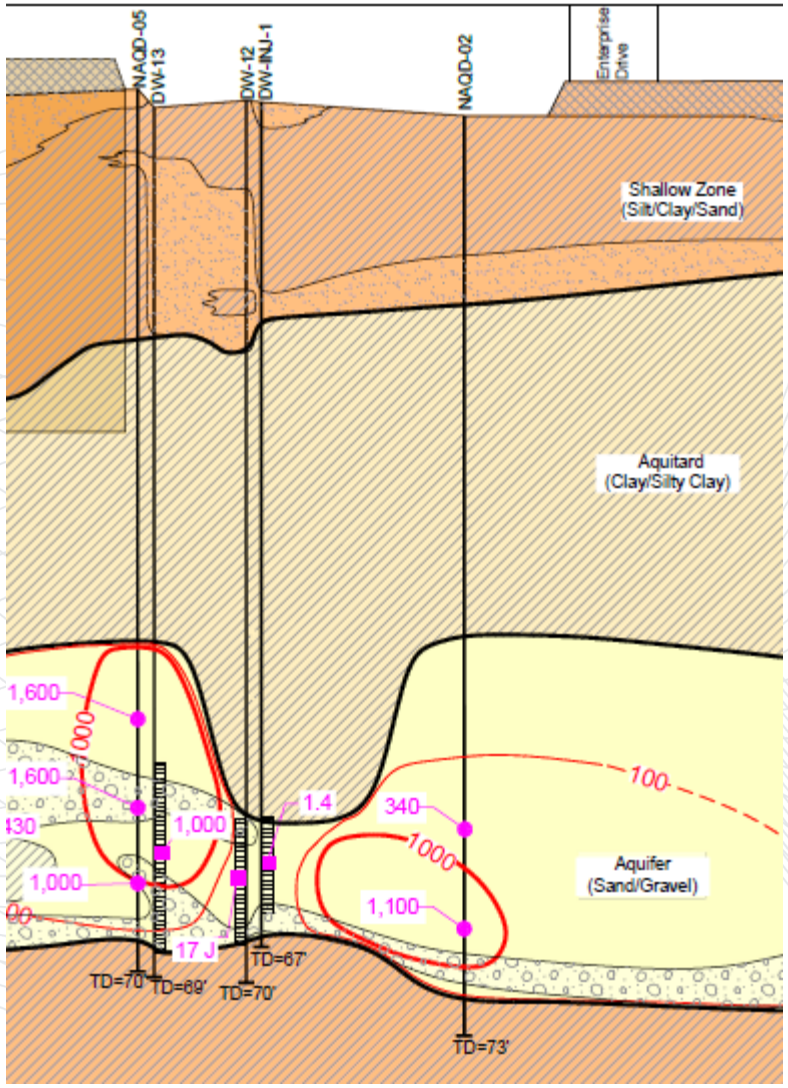
- Conclusions
- Lessons Learned
- Next Steps

Conclusion

Background

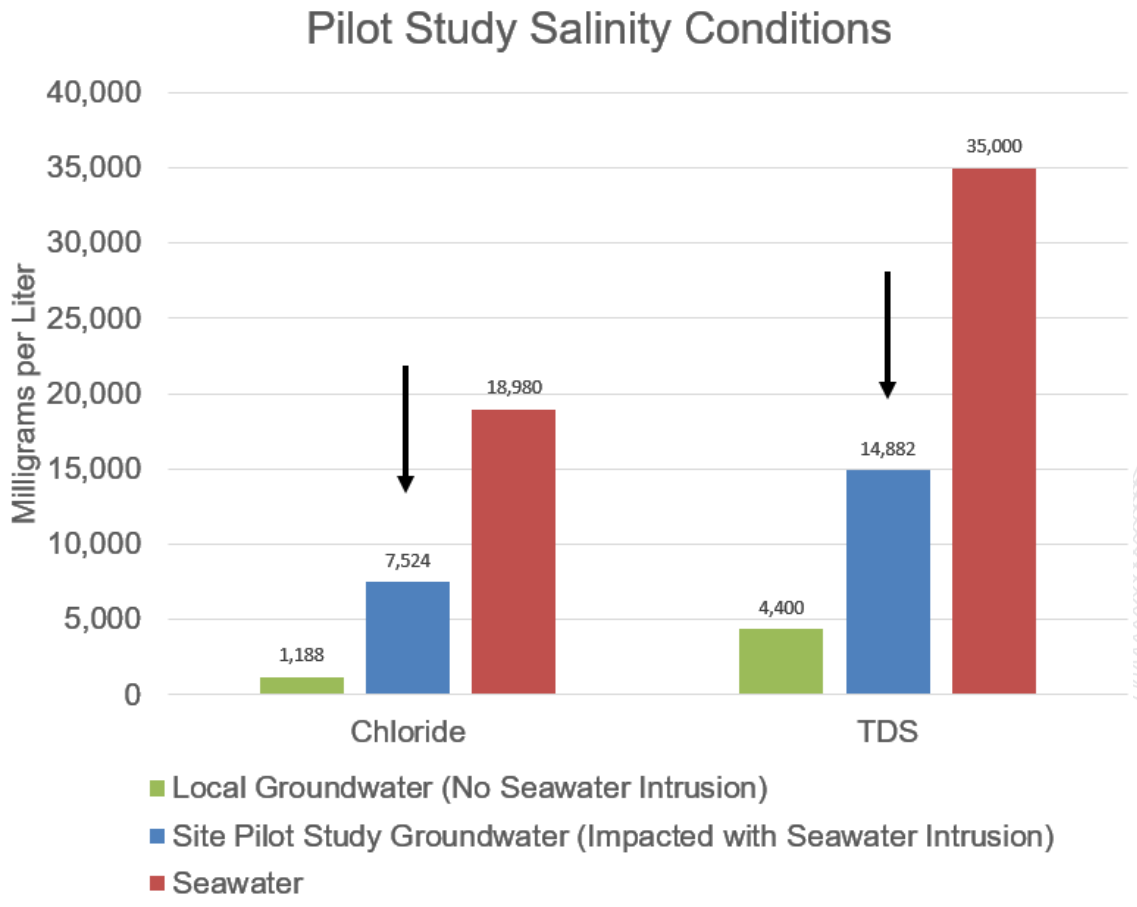
Site Background

- Former chemical plant undergoing cleanup and redevelopment
- Long term pump & treat system operating to address VOC plume in deeper groundwater zone (55-65 feet bgs)
- Evaluating ISBR as alternative to pump & treat



Pilot Test Background

- Coastal cleanup site impacted with 1,2-DCA and seawater intrusion
  - 1,000 µg/L 1,2-DCA
  - 1 to 5 µg/L TCE, EDB, and chloroform
  - 15,000 mg/L Total Dissolved Solids (TDS)
  - 7,500 mg/L chloride
  - 600 mg/L sulfate
  - Neutral pH



Salinity Effect on Reductive Dechlorination

- Elevated salinity in groundwater can significantly slow microbial activity or kill microbes.
- Salinity toxicity to microbes caused by the ionic gradient across microbial cell walls. Extreme ionic conditions can cause cell destruction or lysis
- Most inhibition data is limited to lab bench studies evaluating TCE treatment using only one microbial degrader (dehalococcoides [DHC])
- At high salinity sites, bench or pilot testing is recommended to determine if salinity is an inhibitory factor for microbial activity.

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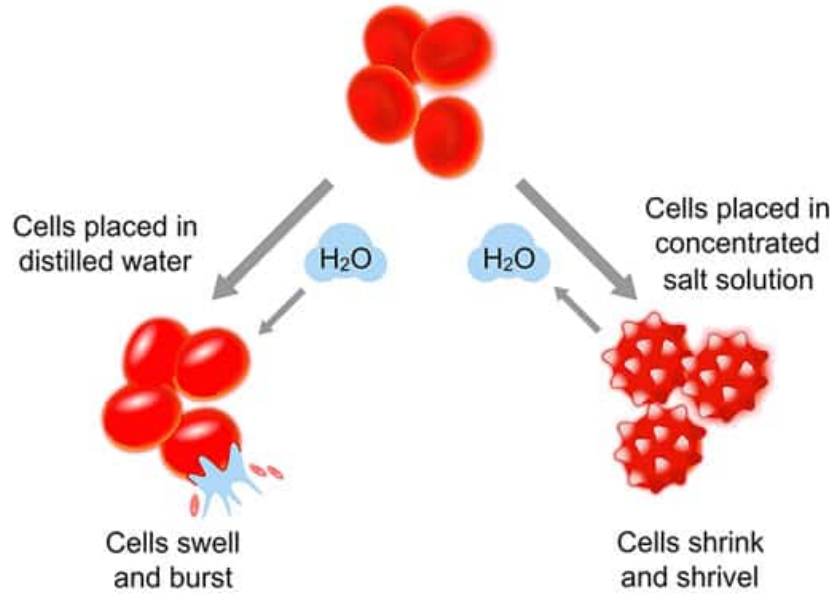

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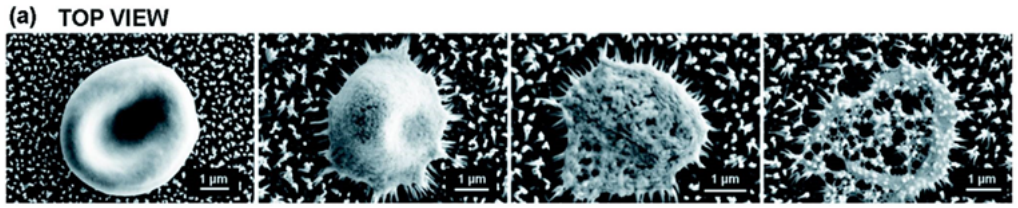

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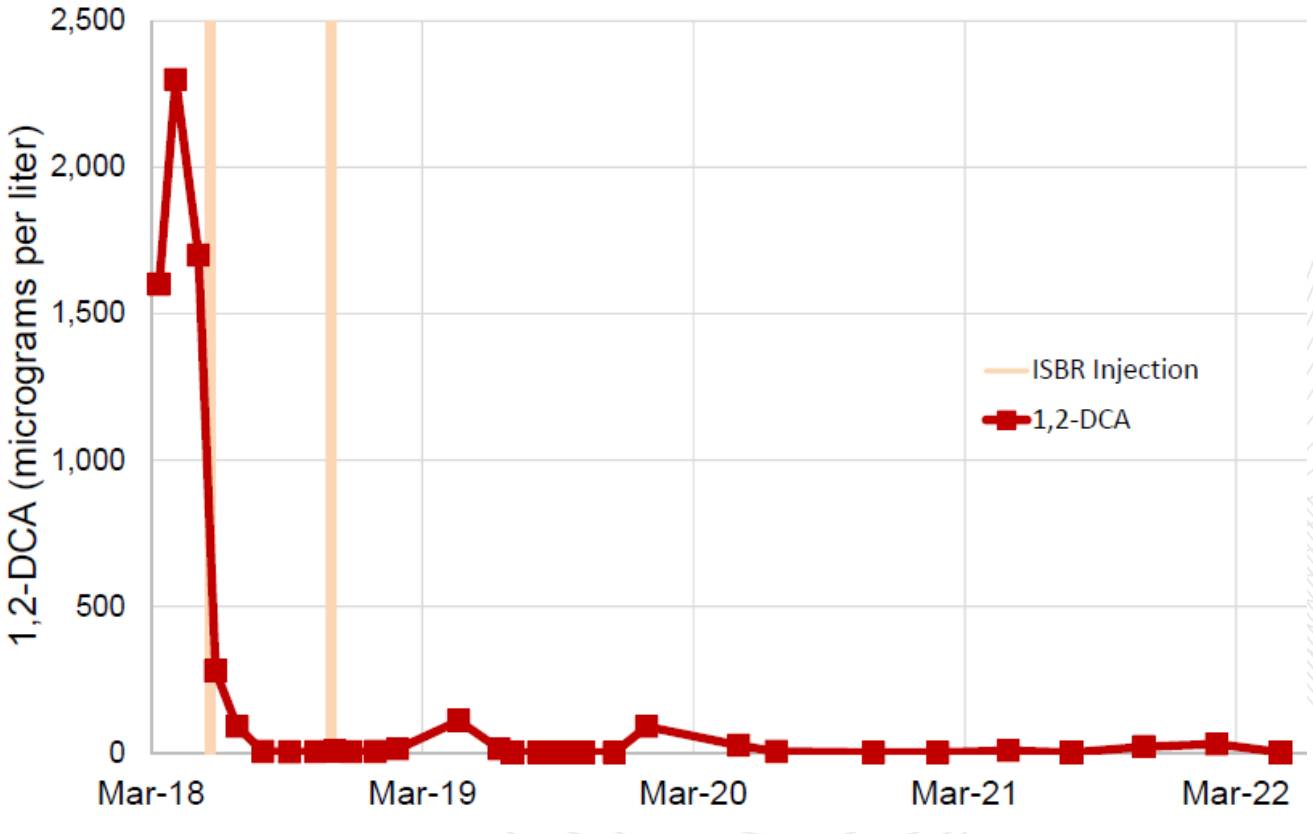
ISBR Effectiveness for 1,2-DCA

At this site, ISBR successfully remediated 1,2-DCA in shallow (non saline) groundwater, therefore ISBR is being evaluated for remediating deeper (saline) groundwater.

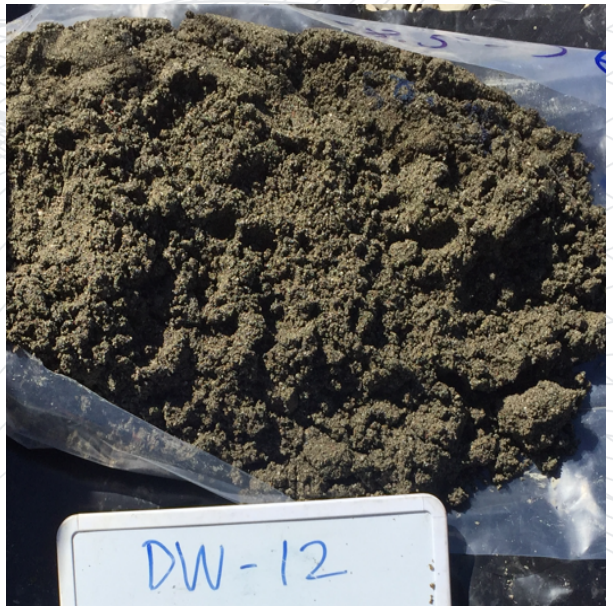
Shallow Groundwater ISBR Results

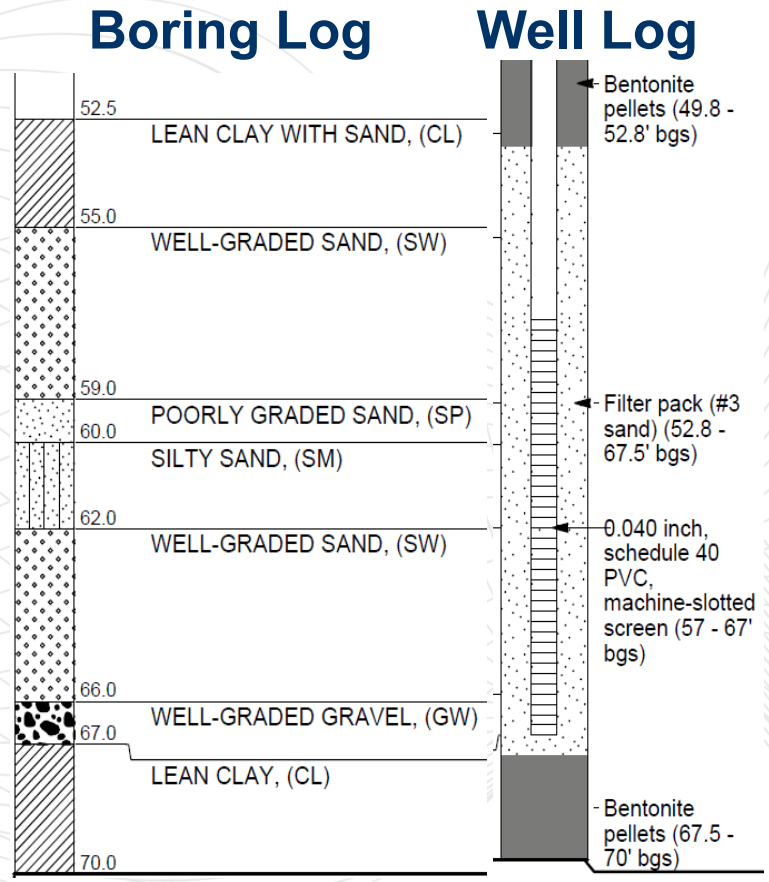


Treatment Zone Conditions

- Sandy soil from 55 to 65 feet below ground surface (bgs)
- Treatment zone bounded by fine-grained aquitards above and below.
- Excellent conditions for injection based remedy

Sandy Soil in the Treatment Zone

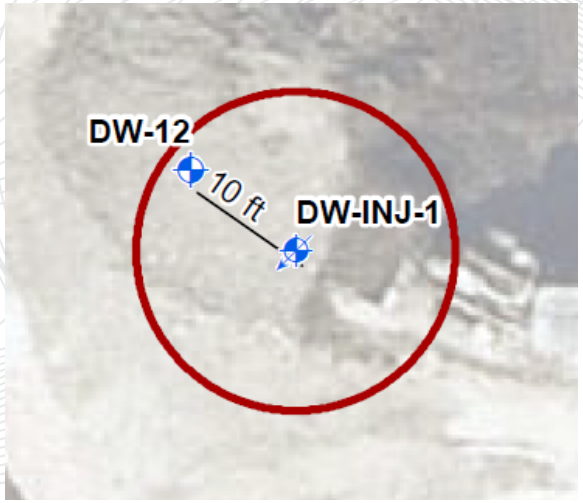




Pilot Study - Approach

Pilot Test Setup

- Considered bench test; ultimately selected pilot test
- Installed Injection well and monitoring well 10 feet apart
- Made sure test area was representative of overall plume conditions
- Design isolated other variables to test effectiveness



Injection Well **Monitoring Well**

Reagent Details

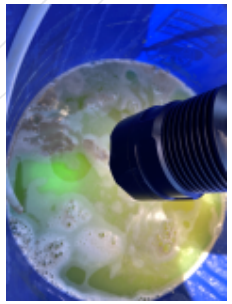
- Reagent designed using site geochemistry and successful shallow groundwater injections. Reagent consisted of:
  - Newman Zone OS™ to condition potable feed water
  - Emulsified Lecithin Substrate (ELS®; a carbon substrate)
  - EHC-liquid® (containing iron salts)
  - Bioaugmentation using DHC (KB-1 Plus®) and a culture containing chloroform-degrading microbes (MDB-1®).
  - pH Buffer
  - Fluorescein tracer dye

Injection Details

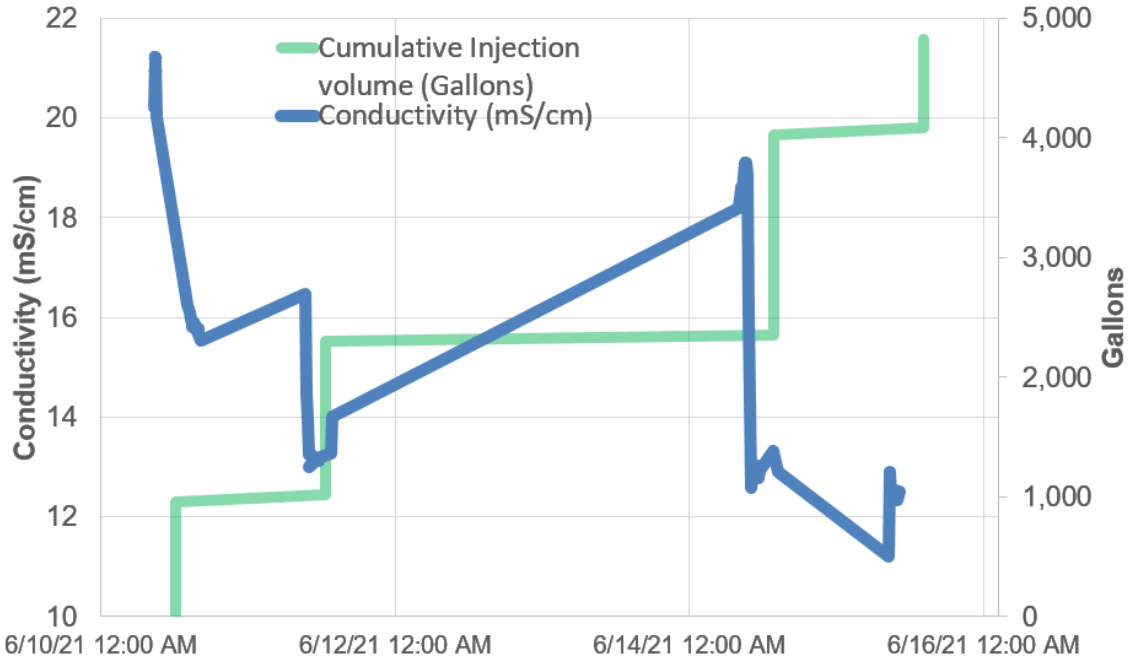
- Injected approximately 4,900 gallons of reagent mixture into the injection well.
  - Equates to 18% mobile porosity treatment for a 12 foot ROI.
- Injected 920 lbs of ELS (~2.25% W/W of water)
- Injected at 4 gallons per minute at average 6 psi pressure
- Maintained low pressure to reduce risk of creating preferential pathways.

Groundwater Monitoring

- Sampled groundwater in nearby monitoring well (10 feet away) during the injection to track reagent migration
- Reagent migration into monitoring well confirmed by conductivity drop, negative oxidation-reduction potential, tracer dye, and TOC results.
- Monthly groundwater monitoring performed before and after the injection



Real-Time Conductivity Monitoring

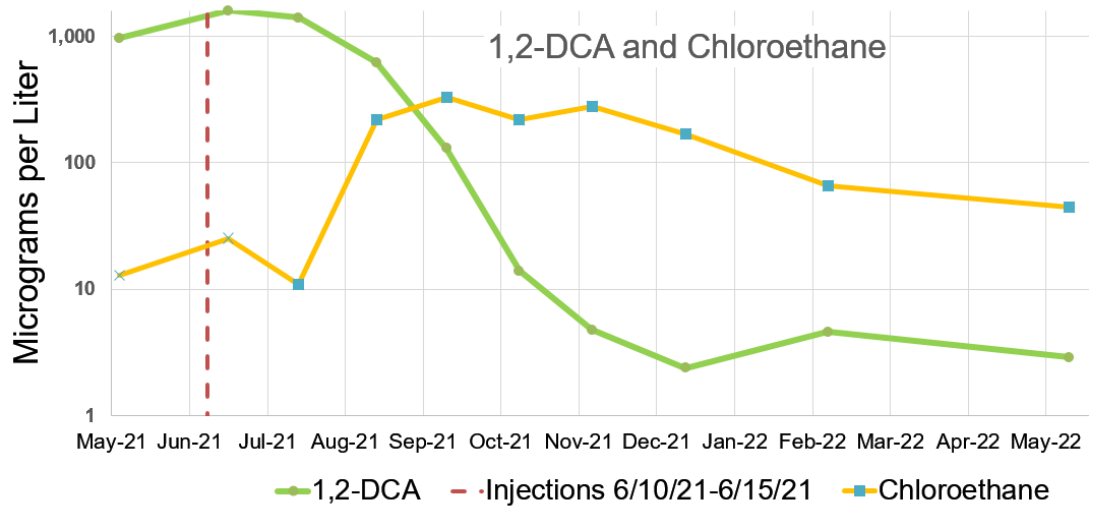


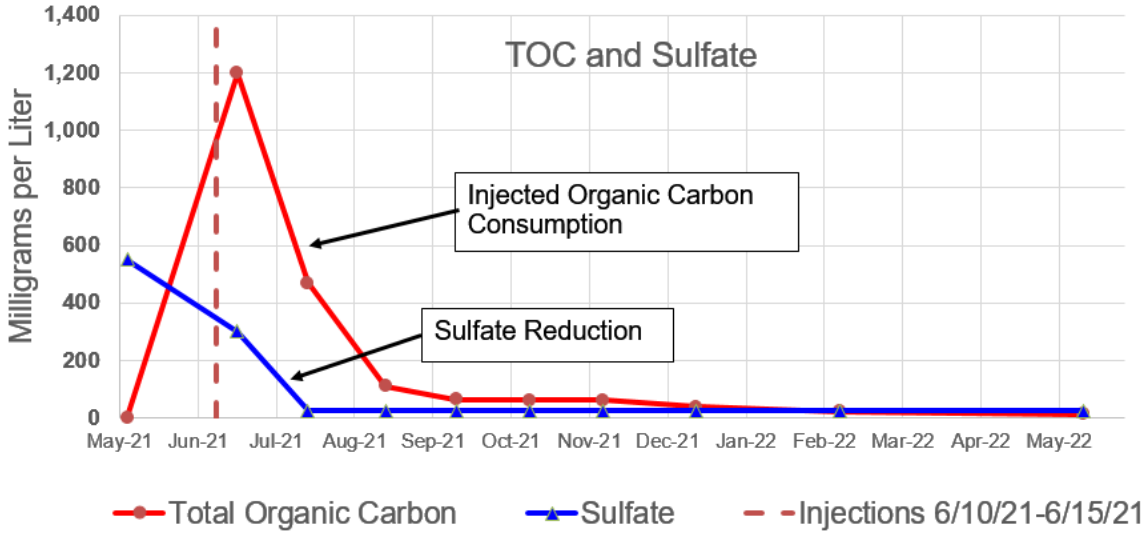
Pilot Study - Results

Results Overview

- Achieved more than 99 percent reduction of 1,2-DCA. Also effective for reducing EDB, TCE, and chloroform
- No rebound through 11+ months after the injection
- Rapid onset of sulfate-reducing conditions (1 month after the injection)
- Generated chloroethane (CA) (1,2-DCA breakdown product)
- No generation of vinyl chloride (VC)

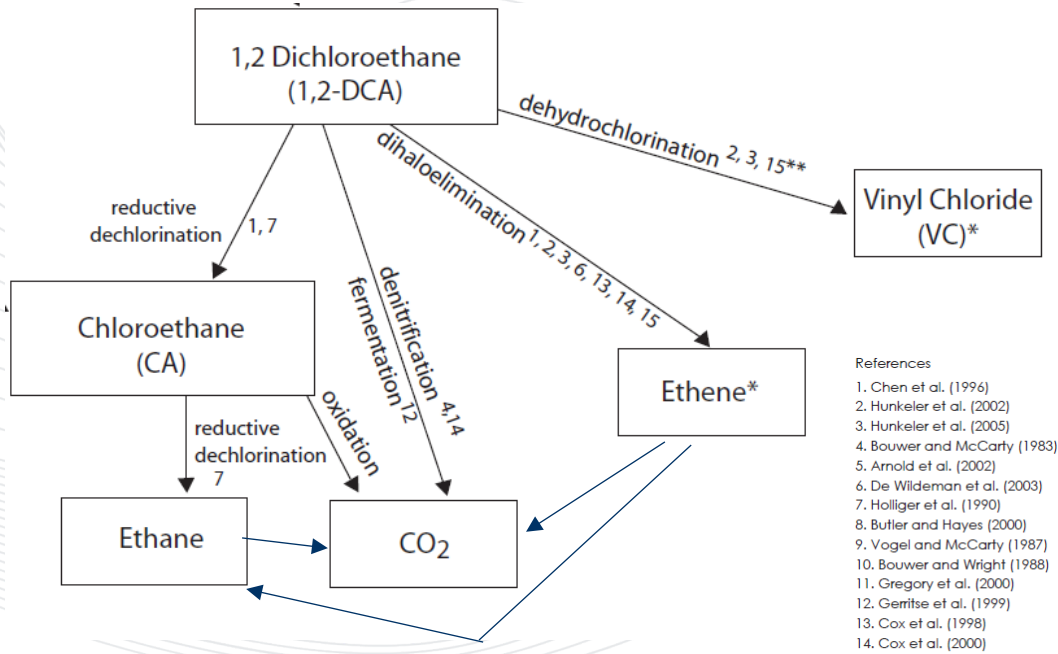
	1,2-DCA (µg/L)	EDB (µg/L)	TCE (µg/L)	Chloroform (µg/L)	CA (µg/L)	VC (µg/L)
Pre-Injection	970	0.38	4.6 J	4.1 J	<25	<13
11 Months Post-Injection	2.9 J	<0.0048	2.6 J	<1.2	39	<1.8





1,2-DCA Degradation

- Approximately one-third of 1,2-DCA was converted to chloroethane
- Remainder likely skipped through to ethene/ethane then CO_2/methane (see later slide) or to ethanol!



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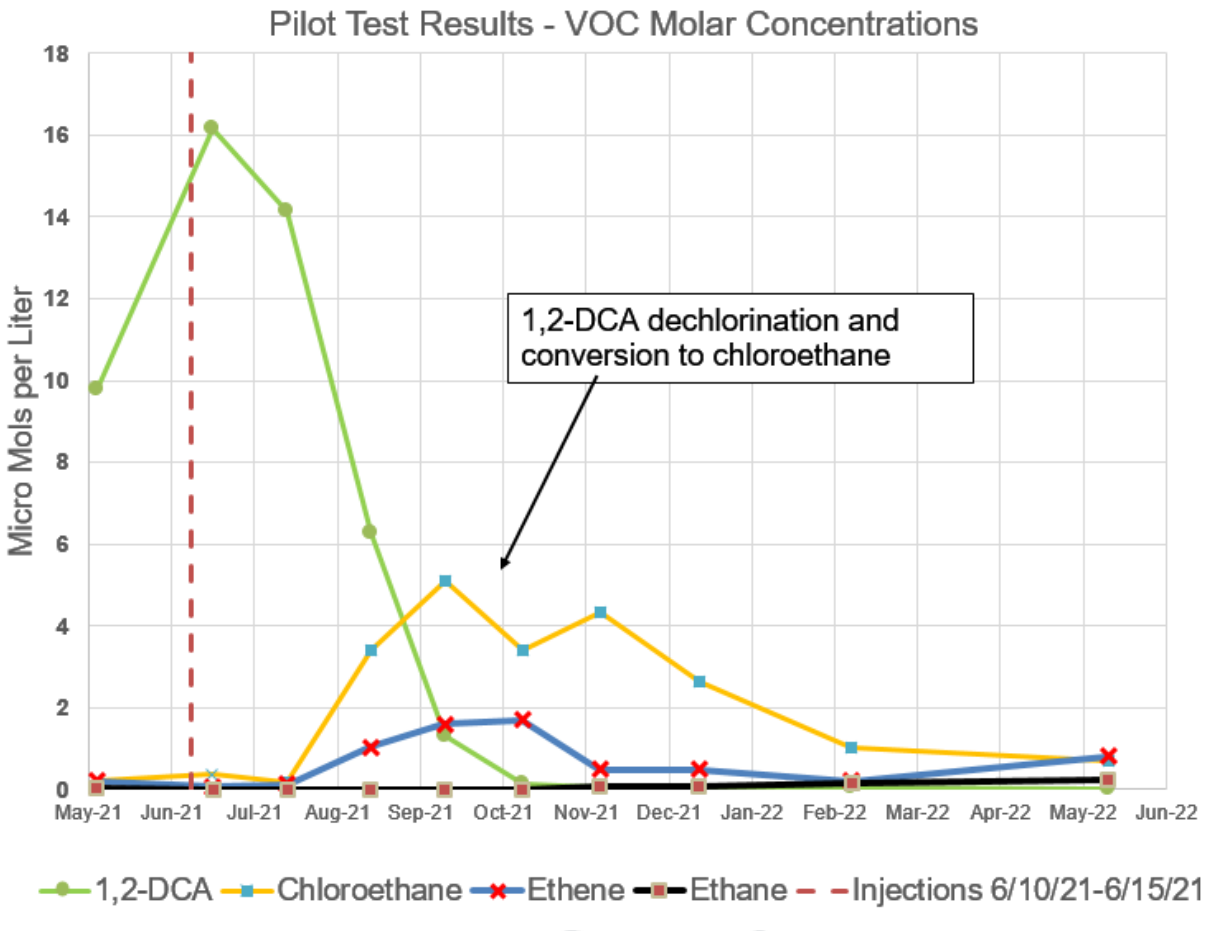
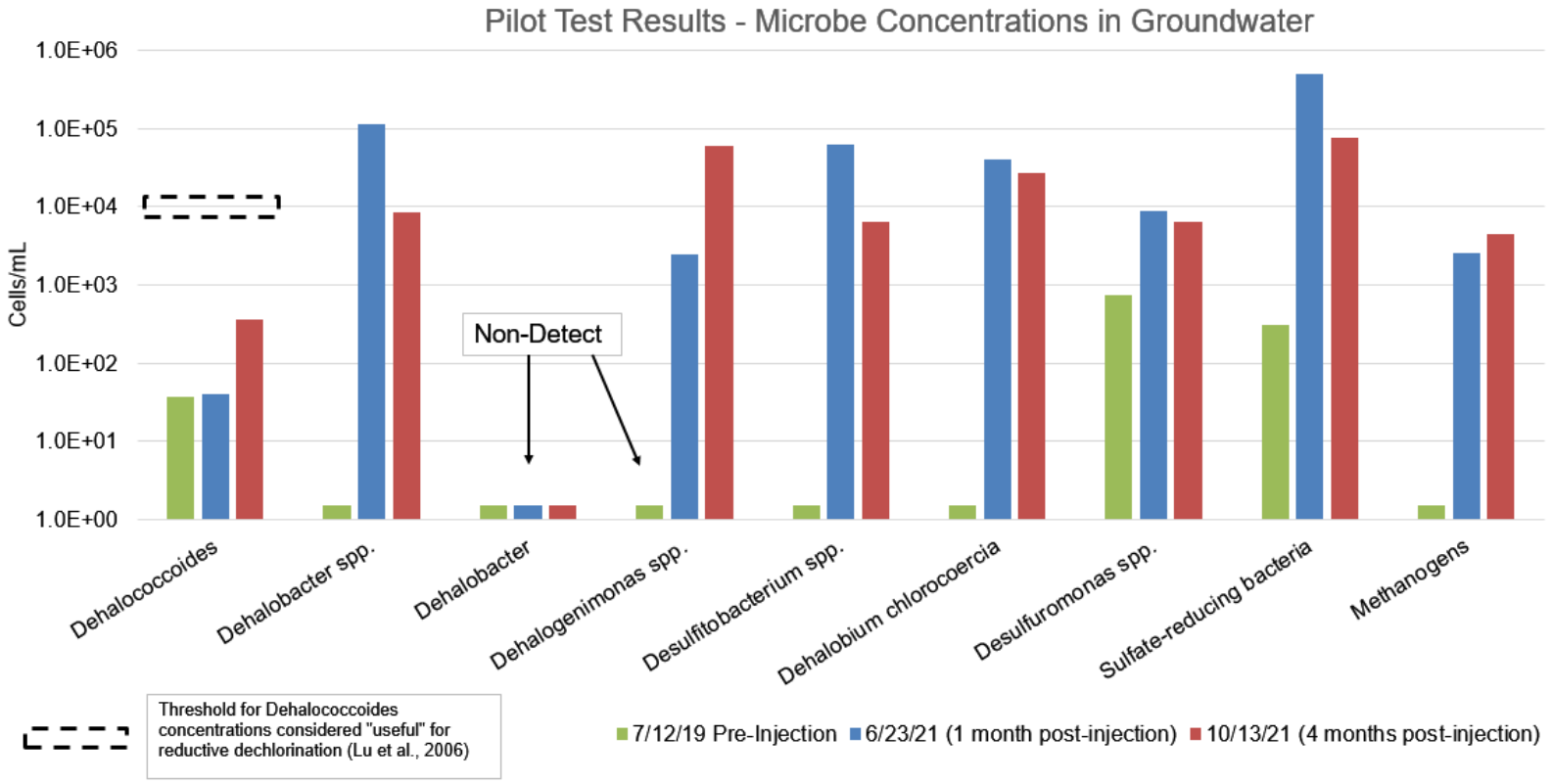


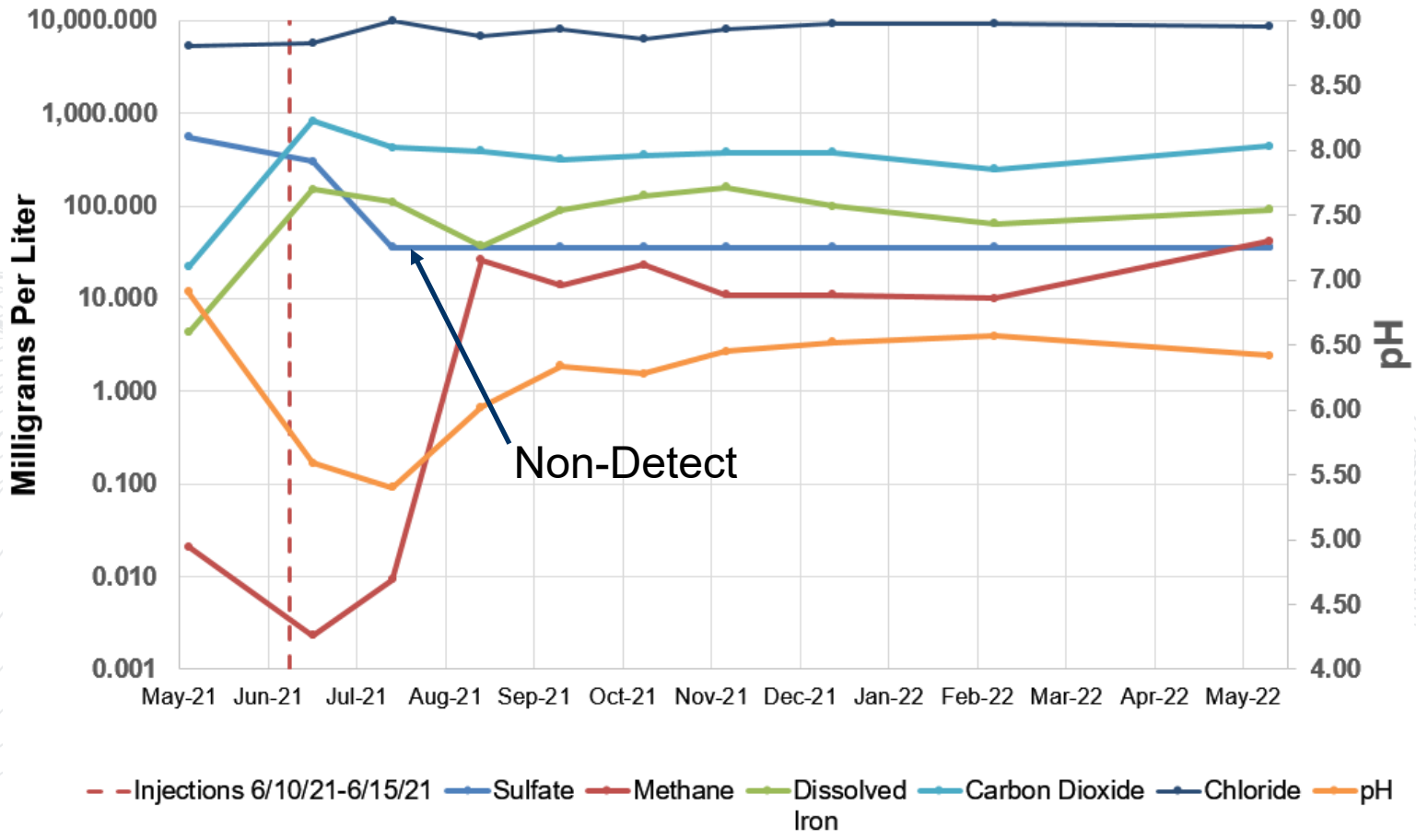
Microbial Results (QuantArray® Chlor)

- Numerous microbes are known to dechlorinate 1,2-DCA, including DHB, dehalogeninomas (DHG), deslfitobacterium (DSB), and DHC.
- Microbes in MDB-1® (DHB spp., DHC, DSB, dehalobium chlorocercia) increased 3-5 orders of magnitude after the injection.
- DHC populations were never observed at “useful” concentrations.



Other Geochemistry

- Chloride remained consistent over time
- CO_2 and iron increased immediately after injections
- Sulfate declined to non-detect 1 month after injections
- Methane increased to 26 mg/L 2 months after injections
- Temporary pH drop to 5.40

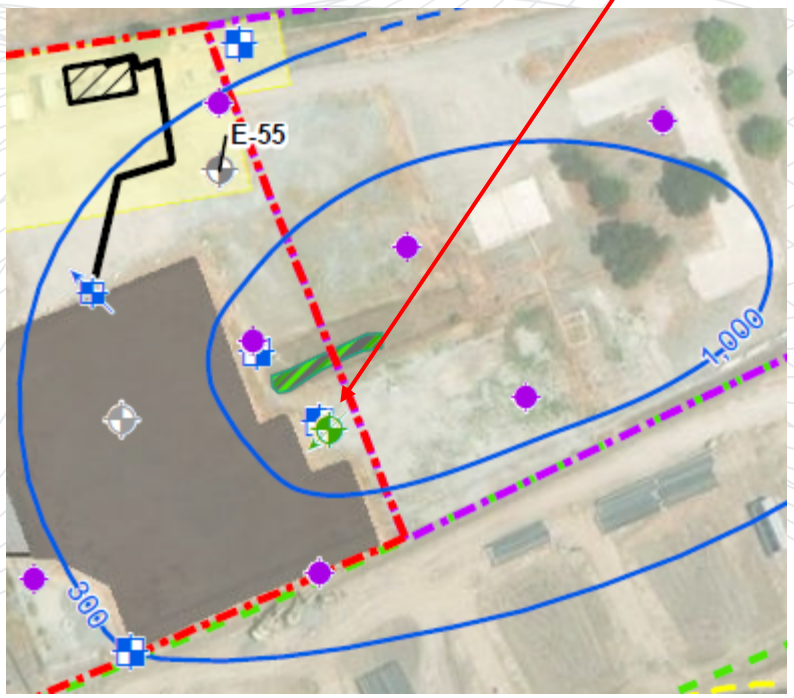


Post-Remediation 1,2-DCA Results

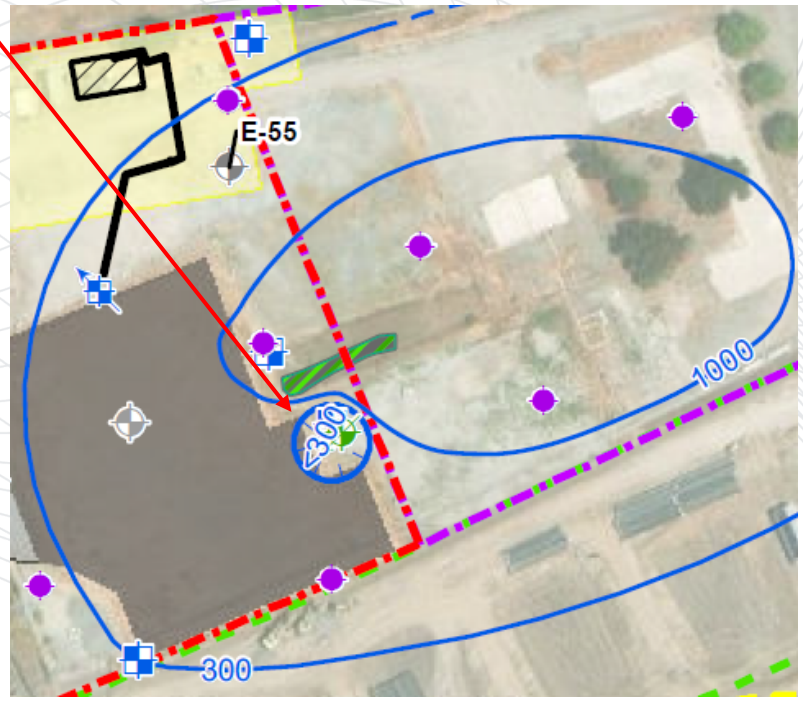
- Post-remediation 1,2-DCA Concentrations (µg/L)
- Progress!

Pilot Study Area

Before Pilot Study



After Pilot Study



Conclusions and Next Steps

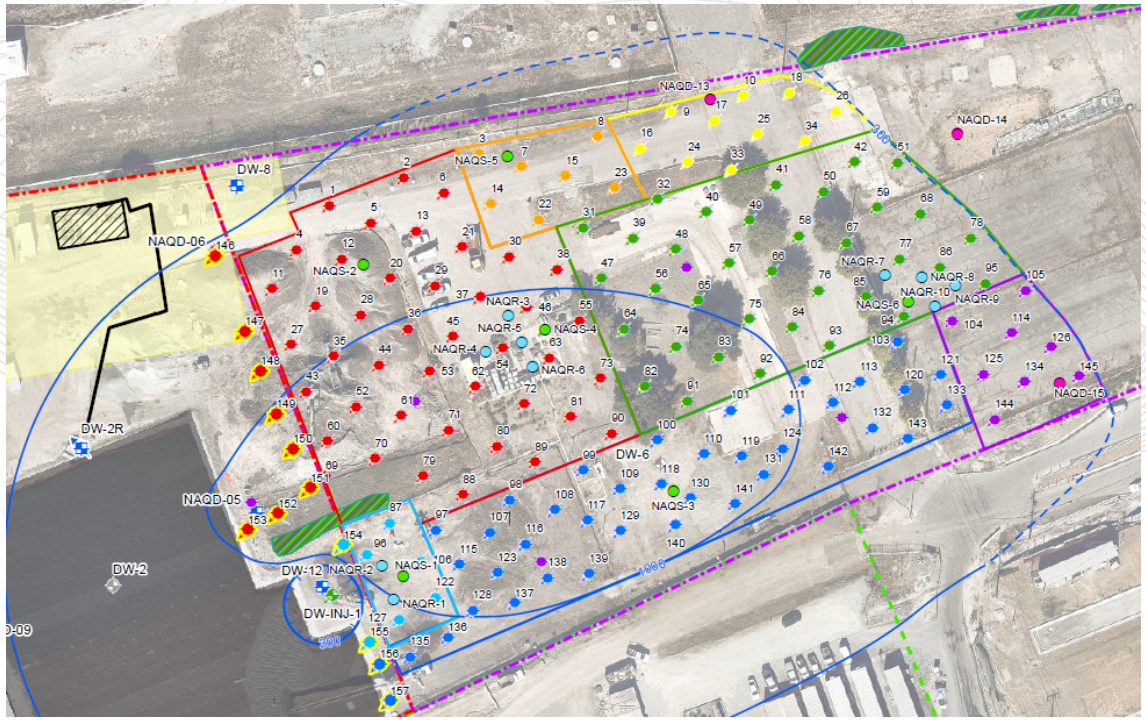
Conclusions

- The custom-designed pilot test created ideal conditions to test whether salinity would inhibit ISBR.
- 1,2-DCA was reduced from approx. 1,000 to <5 µg/L and no rebound was observed through 11+ months after the injection.
- ISBR remediation of 1,2-DCA was possible even under saline conditions (15,000 mg/L TDS and 7,500 mg/L chloride).
- The microbes in MDB-1® (e.g. DHB, DHG) may have played greater role in 1,2-DCA treatment than DHC. Using a diverse suite of microbes should be considered for remediation in difficult geochemical environments.

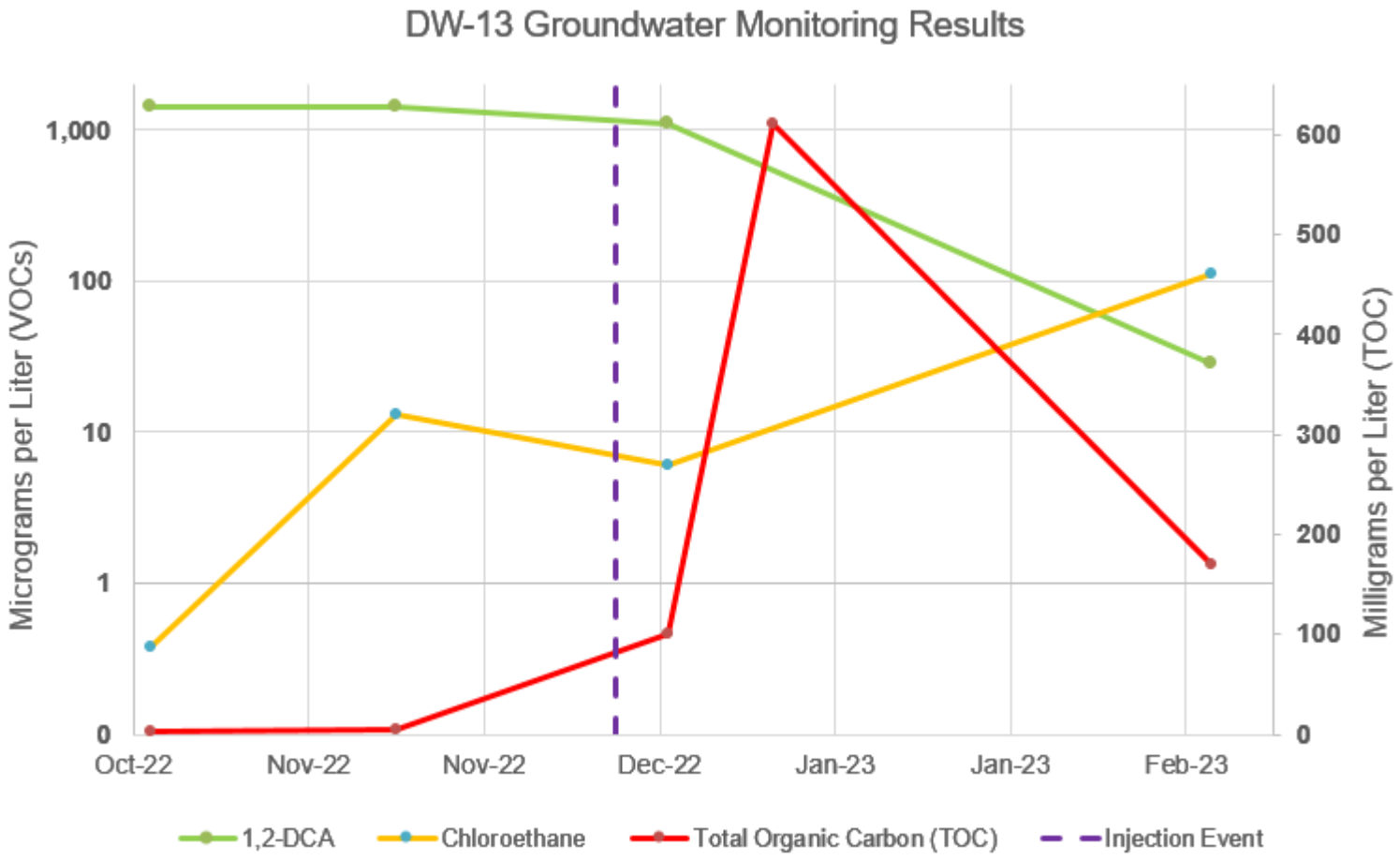
Remediation practitioners can apply these lessons to improve cleanup of chlorinated VOC plumes in challenging saline environments.

Planned Next Steps

- Completed Phase 2 pilot test to evaluate injection methods/scalability
- Implemented ISBR as interim action. Injected 2.3 million gallons of reagent over 2.5 months.
- Full scale injections in 2023



Bonus Results – ISBR Success at Another Well



Thank you!

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