

# Combining Biotic and Abiotic Treatment Processes to Overcome Challenges of a Mixed Chlorinated Solvent Plume

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# Agenda Slide

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**01** Introduction

**03** Results

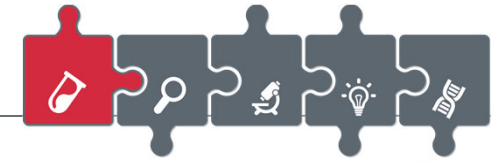
**05** Conclusion



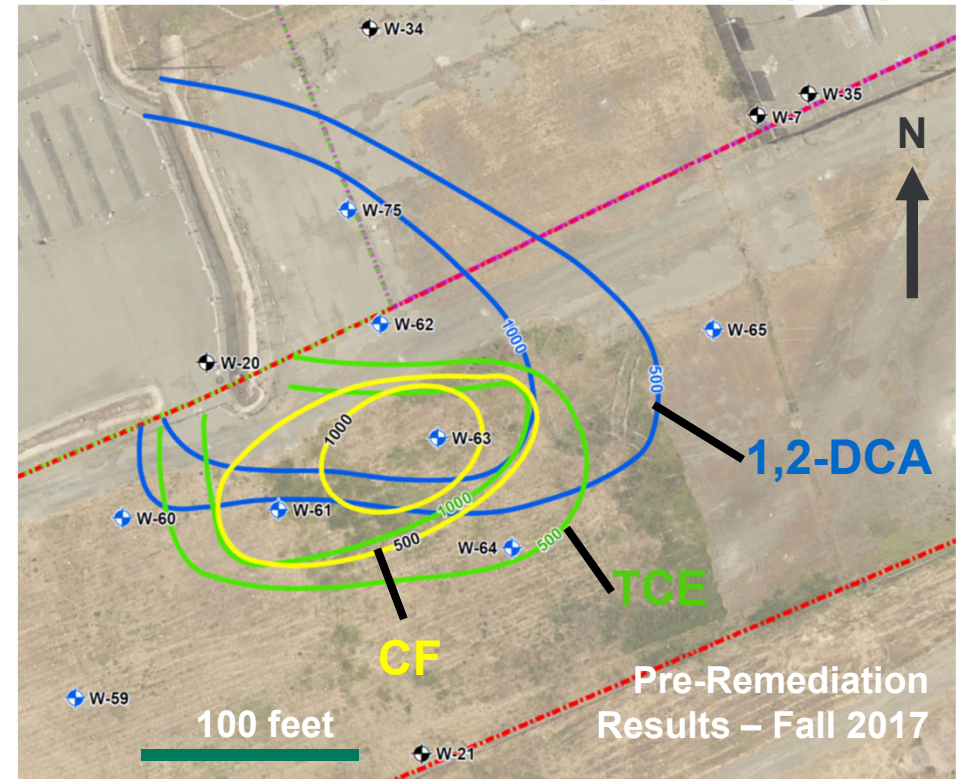
**02** Approach

**04** Lessons  
Learned

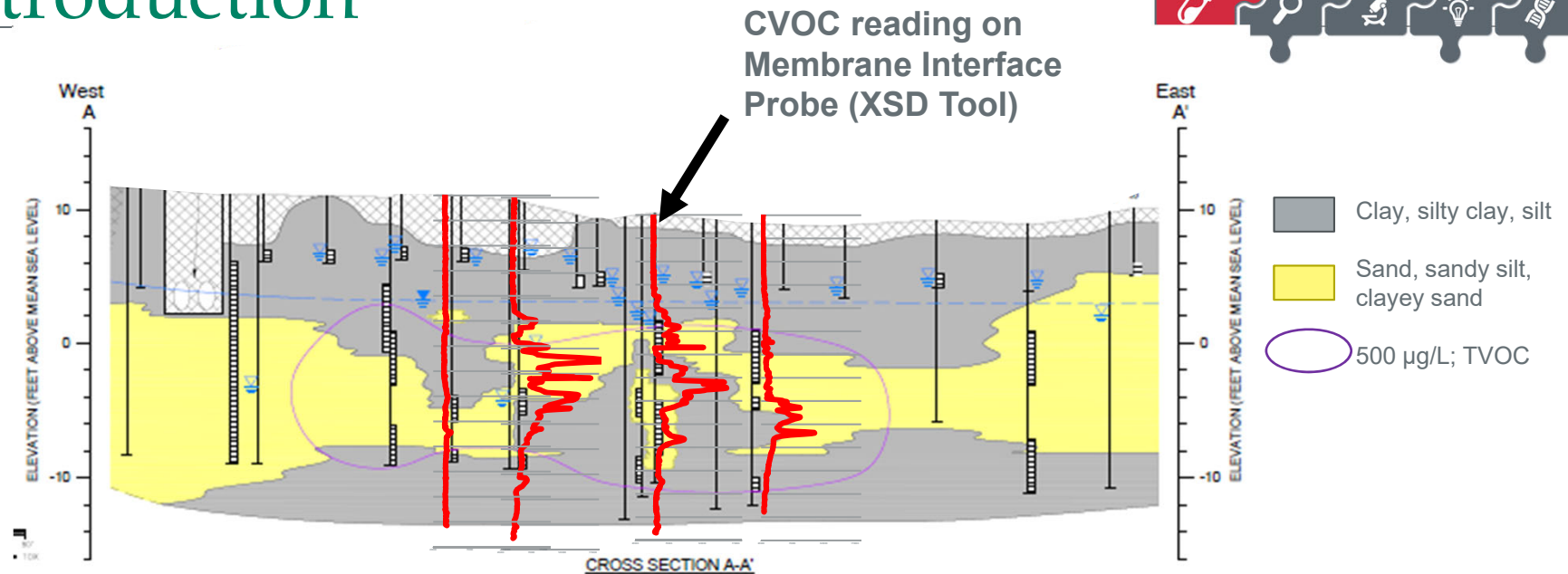
# Introduction



- Former chemical manufacturer plant planned for redevelopment
- Comingled plume of CVOCs under future homes (1.5 yr clean-up time-frame)
- Derived residential vapor intrusion risk-based clean-up goals
  - Trichloroethene (TCE):
    - 3,600 initial / 466 goal ( $\mu\text{g/L}$ )
  - 1,2-Dichloroethane (1,2-DCA)
    - 2,600 initial / 1,070 goal ( $\mu\text{g/L}$ )
  - Chloroform (CF)
    - 1,100 initial / 550 goal ( $\mu\text{g/L}$ )



# Introduction



- CVOC plume located ~ 10 – 20 ft bgs
- Interbedded layers of silt/clay with sand lenses; K: 0.1-10 ft/day
- Slow groundwater velocity



# Approach



- Chemical Properties & Remedial Approach
  - In Situ Chemical/Biological Reduction (ISCR/ISBR) remedy selected based on contaminants, cleanup timeline, and geology
  - Diversified approach selected to overcome inhibitory effects of comingled CVOC plume
    - ISCR via ZVI (abiotic, rapid destruction of TCE/CF, no daughter products) and
    - ISBR via carbon substrate + bioaugmentation (biotic, required for 1,2-DCA degradation)
      - Bioaugmented with SDC-9 (DHC) and MDB-1 (CF/CM degrading microbes)
    - Geoform ER combines abiotic, biotic and biogeochemical degradation mechanisms

# Approach



## ■ Degradation Mechanisms

	ZVI	ELS/ bio-augment	Geoform ER	CVOC/ Primary Pathway
abiotic	X		X	TCE- $\beta$ -elimination CF- reductive dechlorination
biotic		X	X	TCE- hydrogenolysis CF- cometabolism 1,2-DCA- dihaloelimination
BGC			X	TCE- $\beta$ -elimination CF- reductive dechlorination

BGC = Biogeochemical: Processes where contaminants are degraded by abiotic reactions with naturally occurring and biogenically-formed minerals in the subsurface.

# Approach

- 3 rounds of in-situ Direct-Push injections
  - Phase 1: Injections (Winter 2017)
    - ELS at 1,000 mg/l (220 pts) (with SDC-9)
    - ZVI at 0.18% w/w (173 pts)
  - Phase 2: Injections (Spring 2018)
    - ELS at 3,000 mg/L (253 pts) (with SDC-9 and MDB-1)
    - ZVI at 0.19% w/w (33 pts)
  - Phase 3: Injections (Fall 2018)
    - ELS at 5,000 mg/L (185 pts) (with SDC-9 and MDB-1)
    - GeoForm (65 pts)

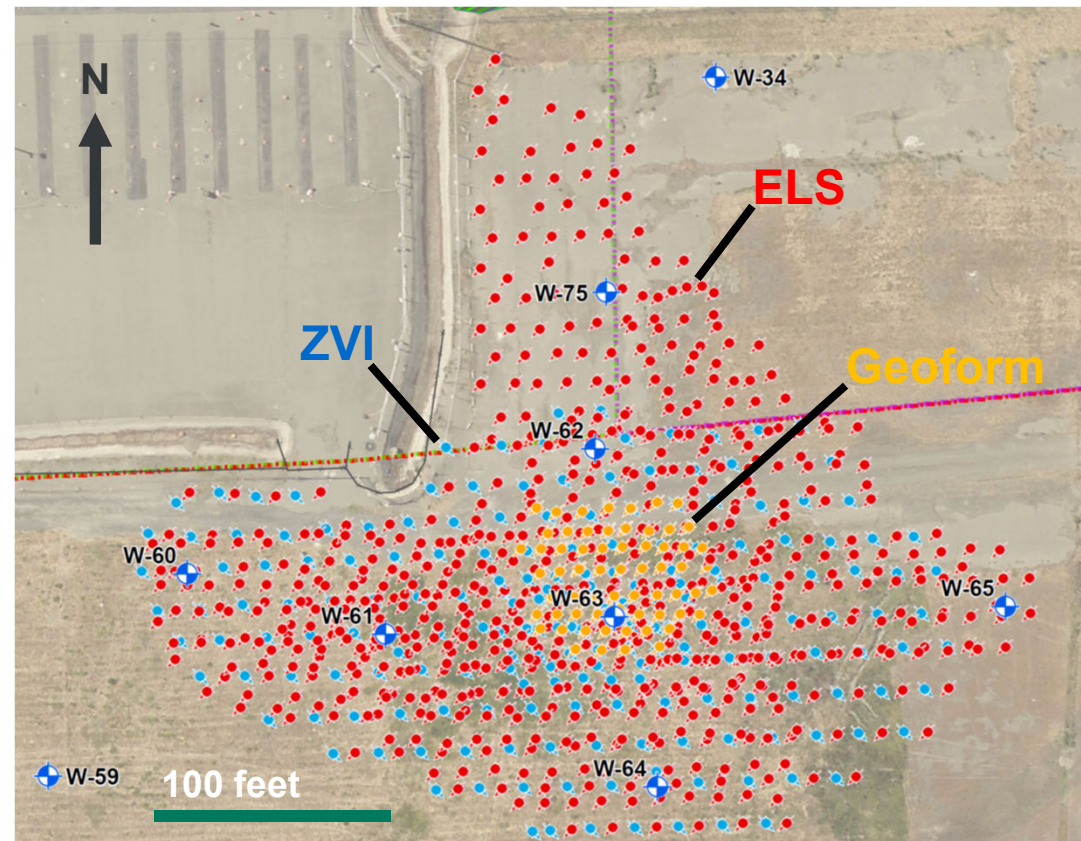


\*ELS concentrations were in situ targets based on 10% total pore volume replacement.

# Approach

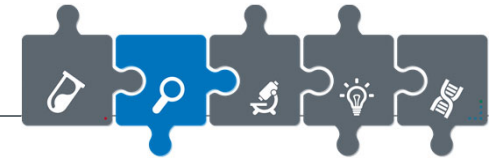


- Point spacing ranged from 7.5 to 15 feet
- Spacing after three events ~3 to 10 feet total
- 919 injection points total
- Delivered:
  - 43,000 lbs ELS
  - 40,000 lbs ZVI
  - 5,000 lbs Geoform ER





# Approach - Challenges



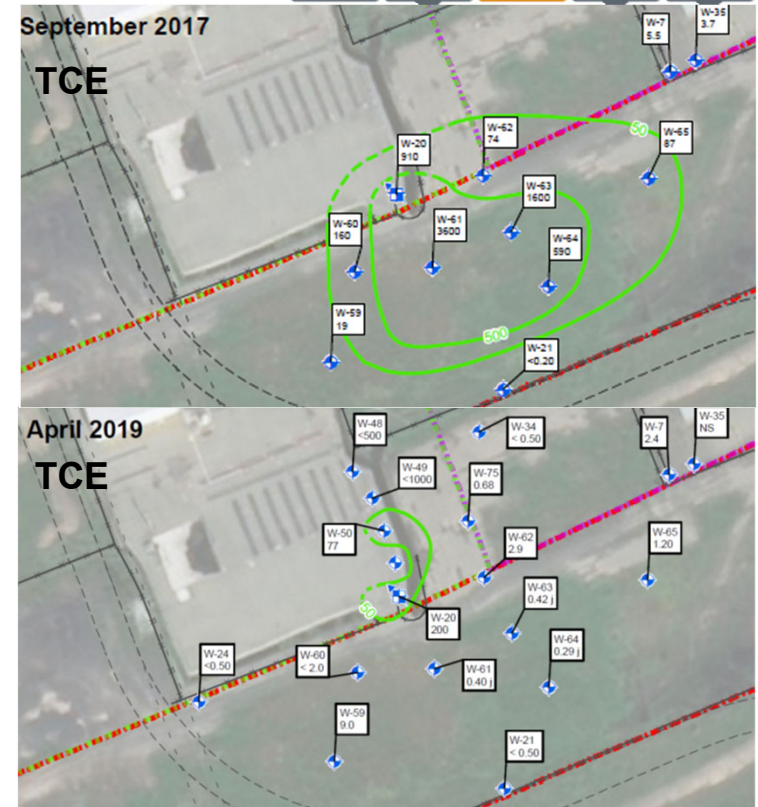
- There was surfacing (no way!)
- Soil heterogeneity led to uneven reagent distribution
- ELS/TOC initially too low
- Inhibition of commingled CVOCs (CF, TCE, 1,2-DCA)



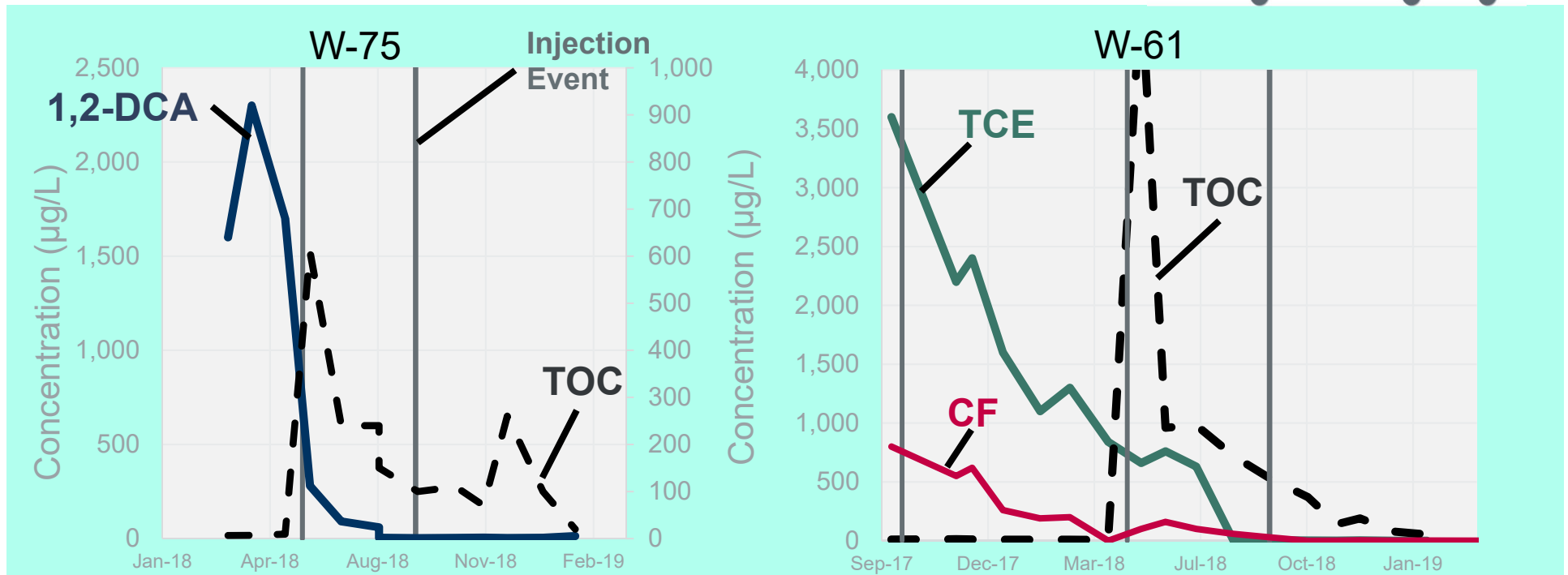
# Results



- 99% decrease of total CVOC concentrations in 1.5 yrs
- 1,2-DCA, TCE, and CF below clean-up goals (TCE below MCL)
- No significant stalling at vinyl chloride
- Met goals in time for property redevelopment

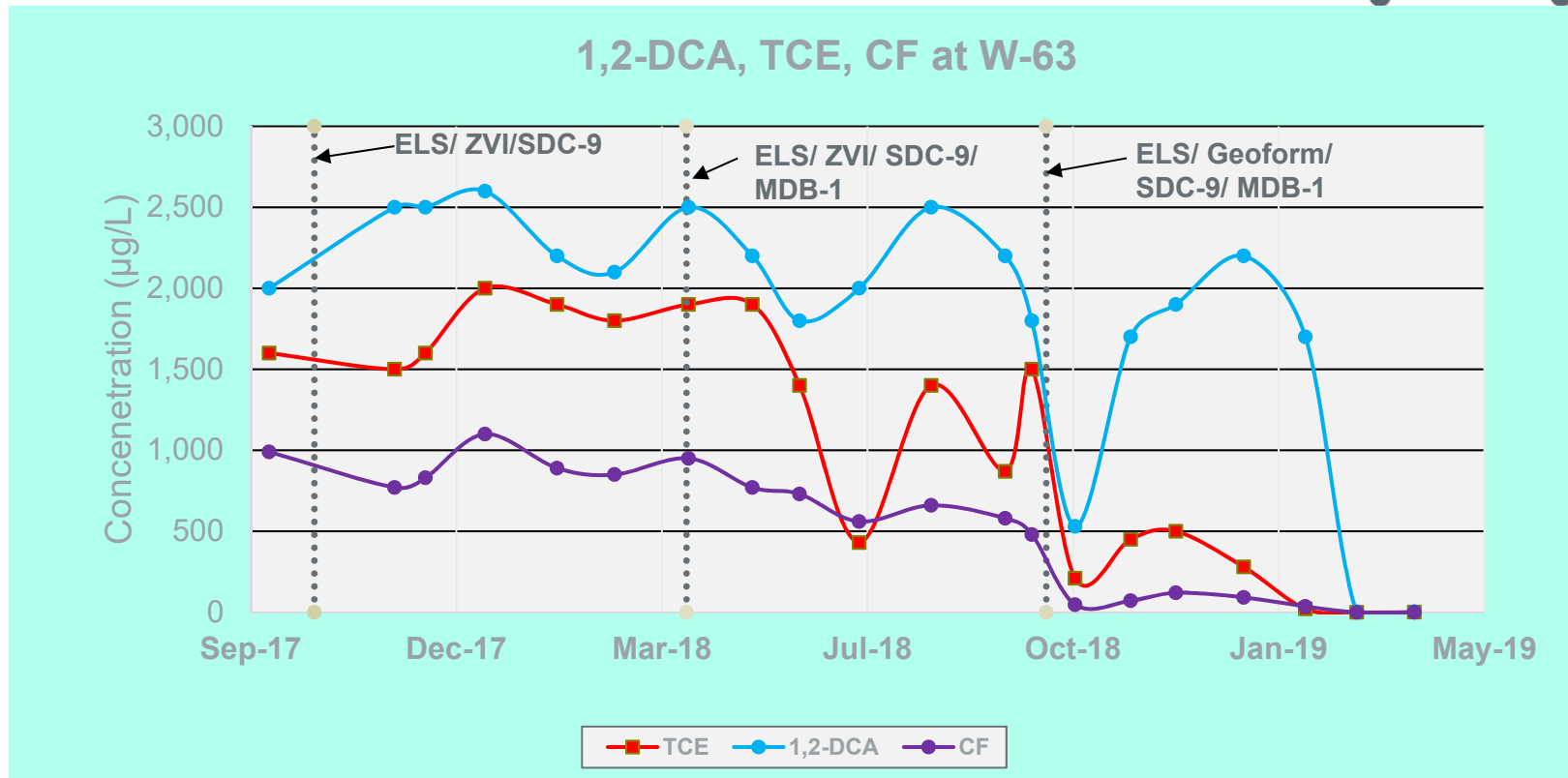


# Results - Non-commingled VOCs



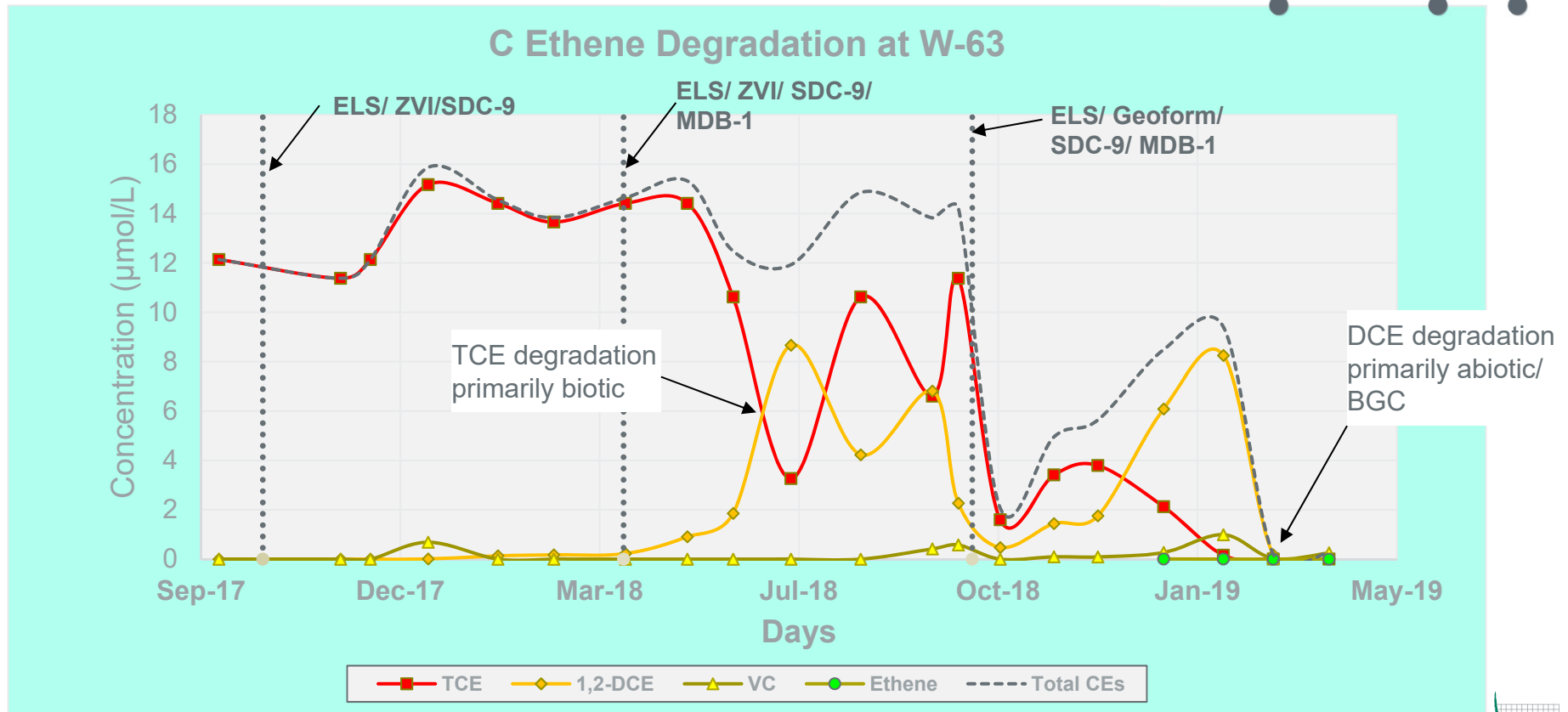
Where CVOCs are (mostly) not commingled, reductive dechlorination efficiently occurs (with sufficient TOC)

# Results – W-63, what gives?





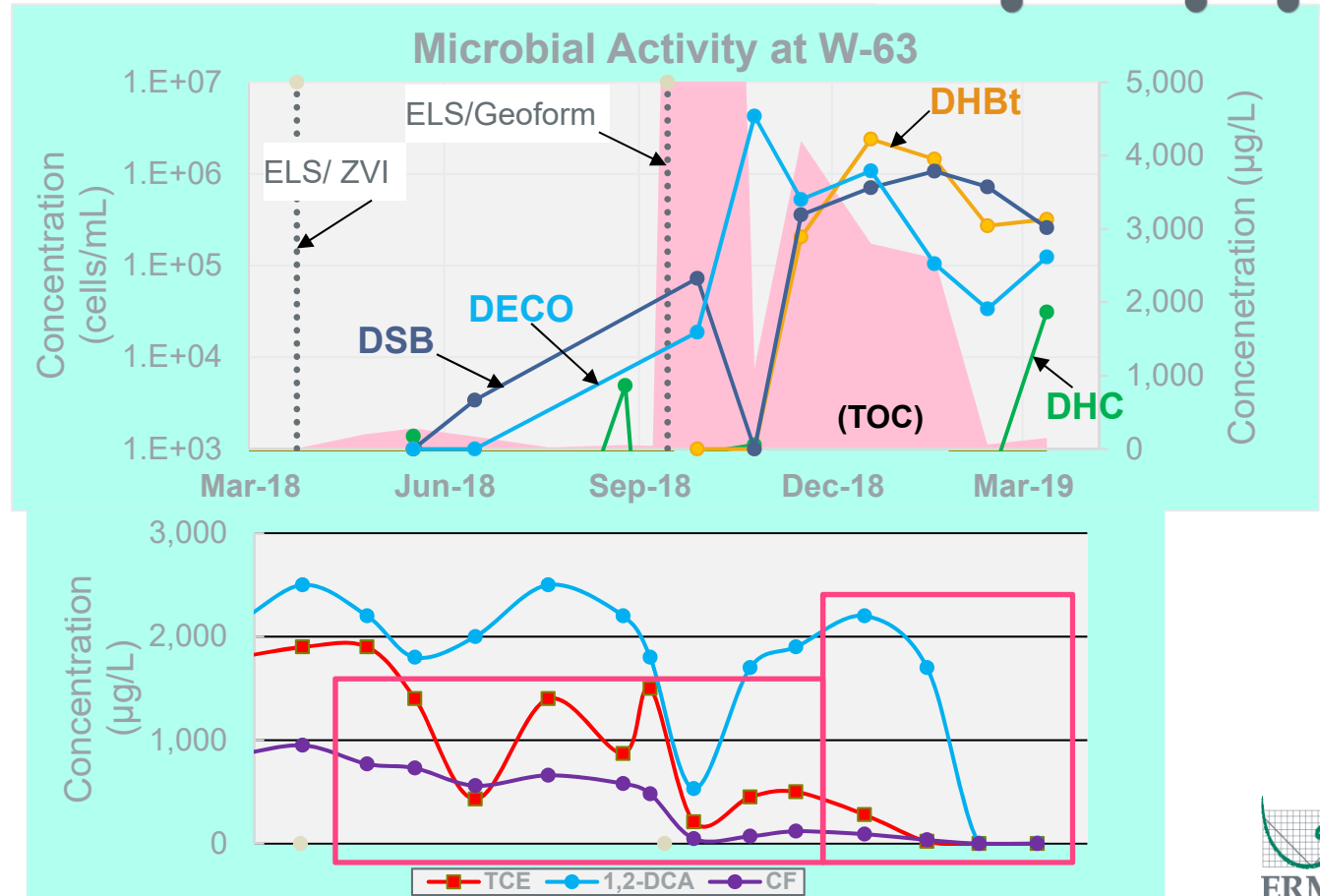
# Results – W-63, C Ethene Degradation



# Results – W-63, biotic



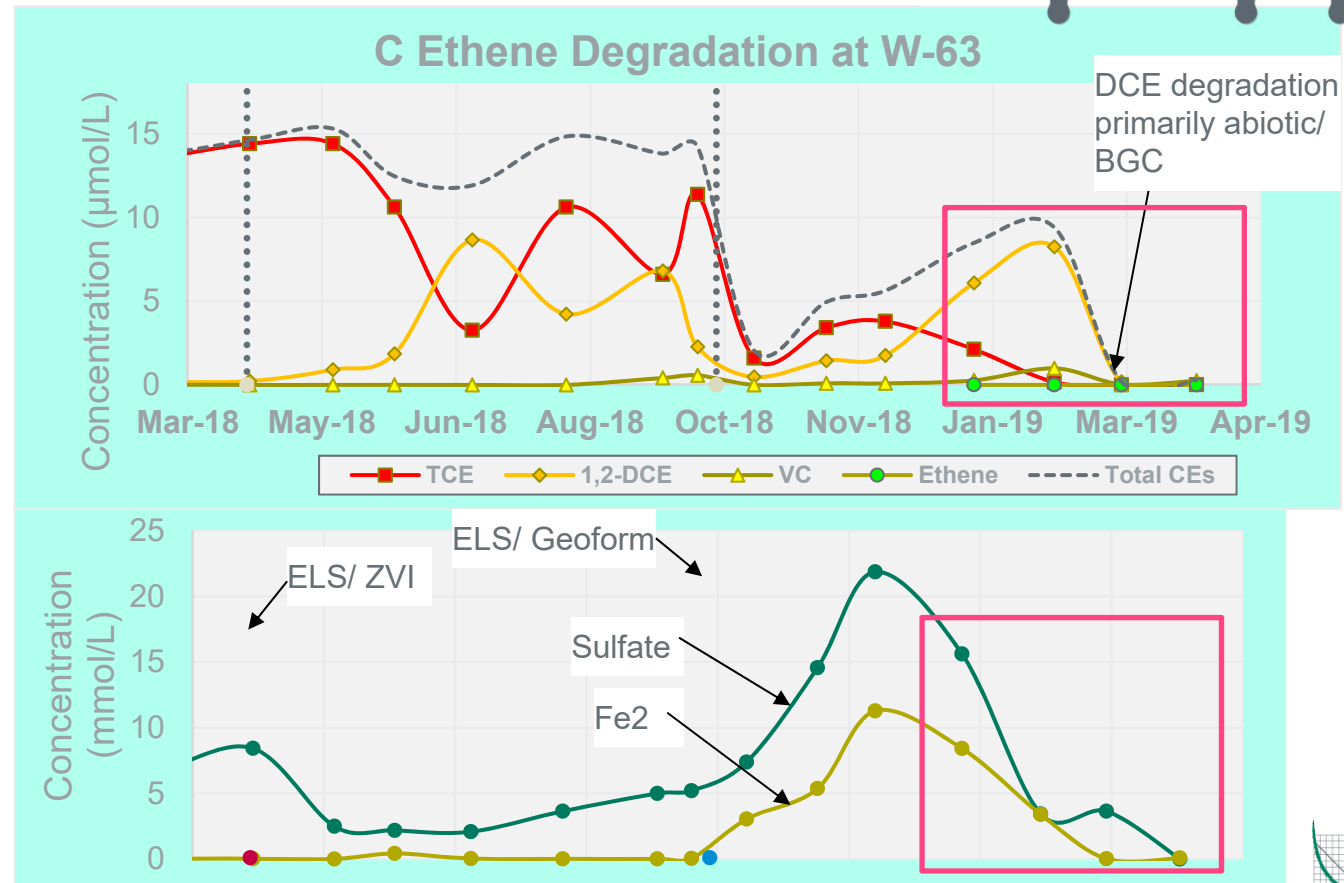
- Bioaugmented with SDC-9 and MDB-1 both events
- Biotic degradation by DHBt, DSB, DECO (same microbes in MDB-1)
- DHC not a key player (what happened to SDC-9?)
- 1,2-DCA last to go, degradation inhibited by TCE/CF



# Results – W-63 abiotic/BGC



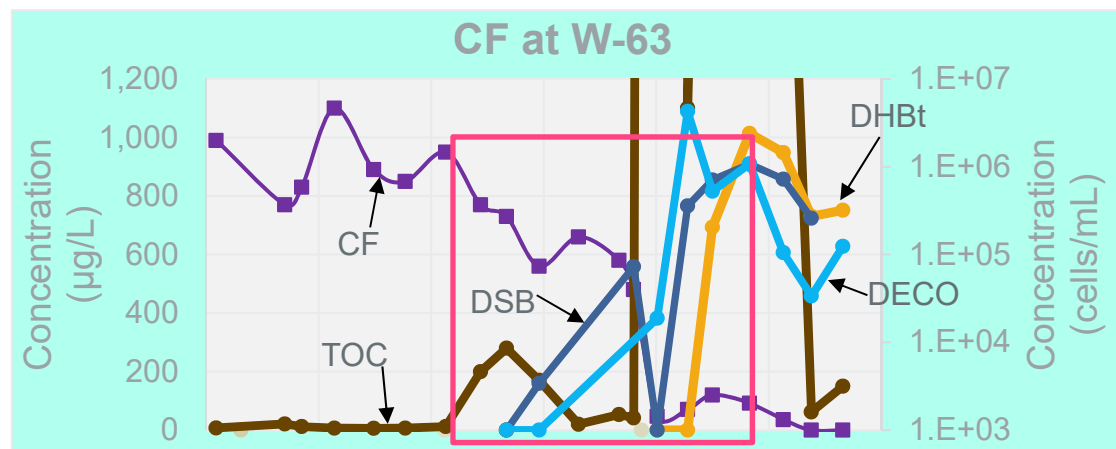
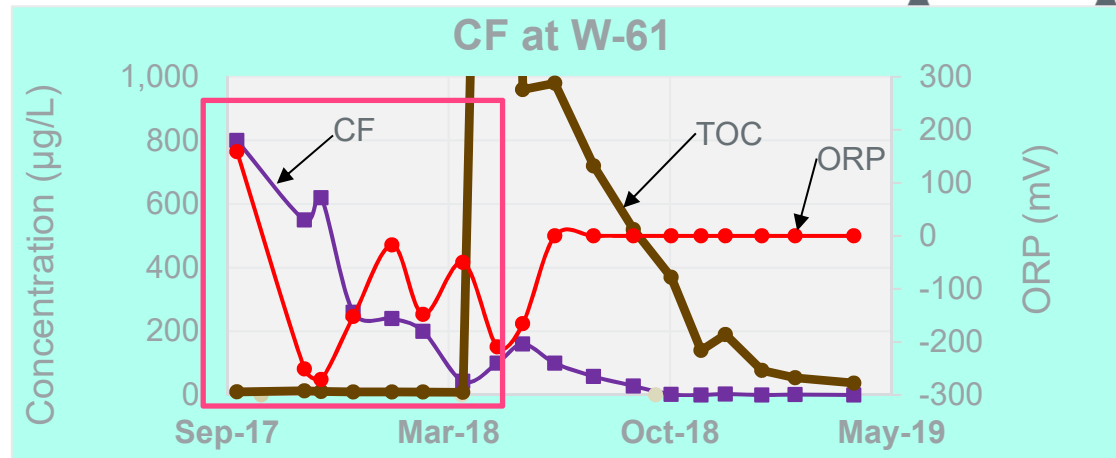
- Geoform added sulfate and Fe2
- Sulfate reduced to sulfide, react with Fe2 to form FeS minerals
- DCE β-elimination with FeS, complete dechlorination, skips VC



# Results – What happened to CF?



- CF degradation at W-61 primarily abiotic (ZVI) based on absence of TOC
- CF degradation at W-63 biotic and/or abiotic
- No generation of chloromethane (CF breakdown product); suggesting destruction either abiotic or also by MDB-1 microbes





# Conclusions

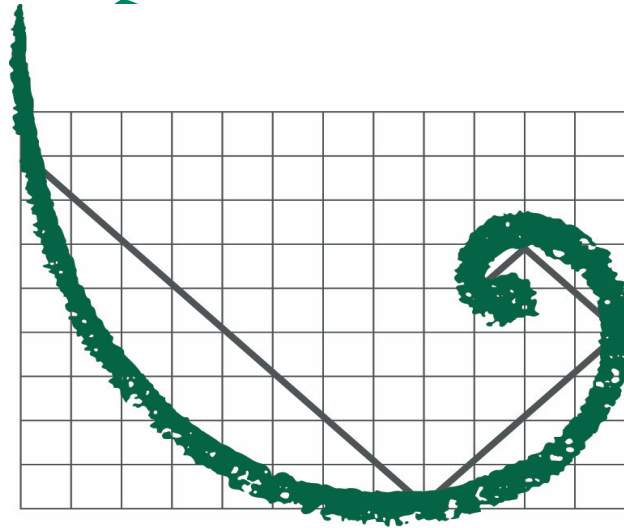


- Chloroform inhibition was confirmed; CVOC degradation occurs in series (1) CF, (2) C Ethenes, (3) 1,2-DCA
- CF degraded by abiotic (ZVI) and biotic (MDB-1) mechanisms
- Microbes in MDB-1 were successful in dechlorinating TCE, CF, and 1,2-DCA
  - No generation of chloromethane (CF breakdown product); likely also biotically dechlorinated by MDB-1
- DCE (cis) was completely dechlorinated (via  $\beta$ -elimination) by Geoform ER, preventing production of VC
- Further work needed to determine dominant pathways

# Thank You for Your Time

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## Questions?



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