Rapid Abiotic Dechlorination of Chlorinated Solvents by Remediation Emplacement of Zero Valent Iron (ZVI)

GeoTactical Remediation

Battelle 2024
Session: G2. Innovative and Optimized Amendment Delivery and Monitoring Methods

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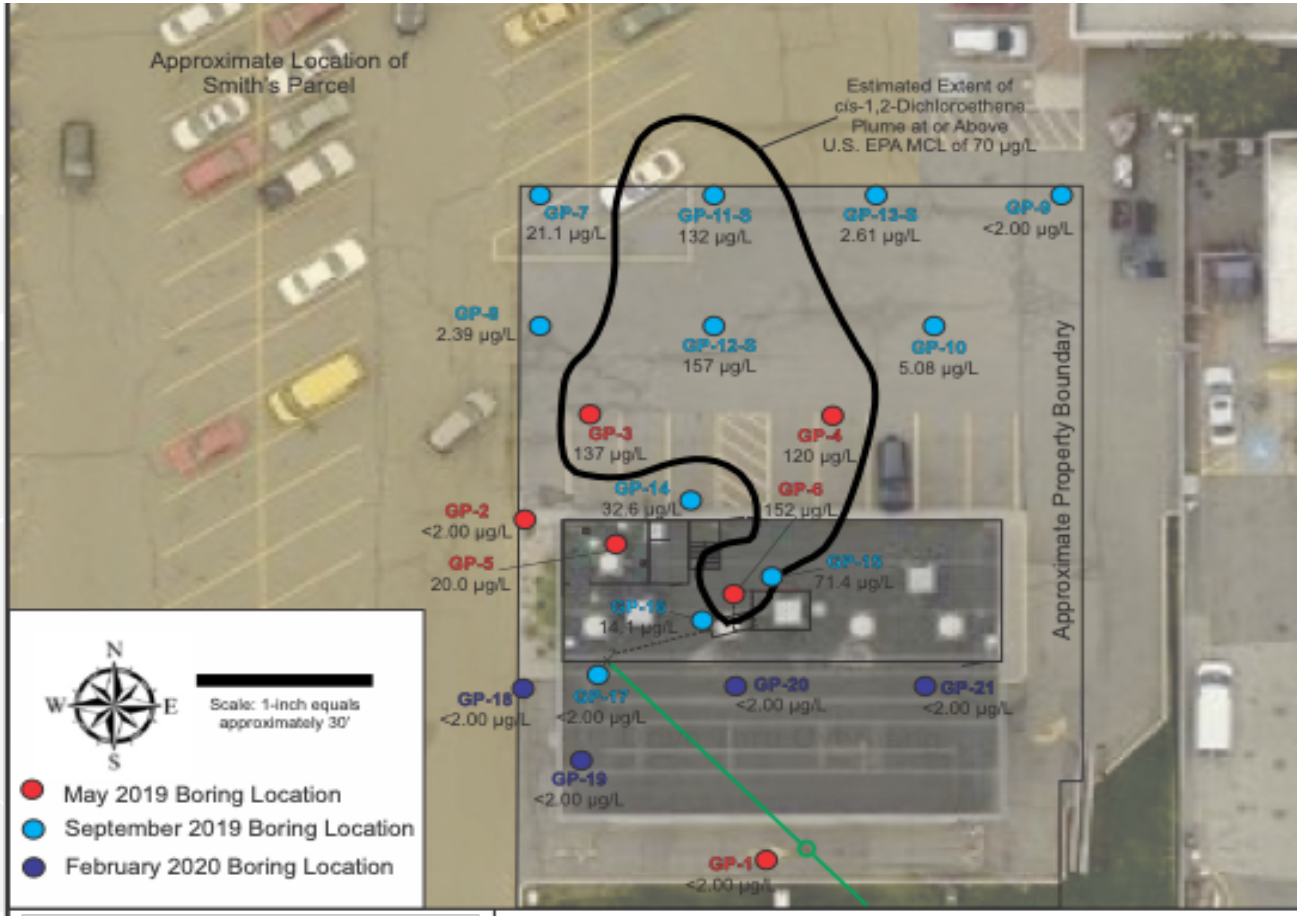
Introduction

- Site (Millcreek, Utah)
  - Drycleaner since 1987 (various drycleaning lessees)
  - Owned by a Trust looking to re-develop for new businesses
- Contaminant of concern (COC)
  - Chlorinated solvents above US EPA Maximum Contaminant Level (MCL) in groundwater (GW)
- Remedial approach
  - Emplace Zero Valent Iron (ZVI)

Site Background

- Previous consultant had performed Phase I and II
  - Identified tetrachloroethene (PCE) impacts- concluded not significant
- 2018 Wasatch Environmental engaged
  - Phase I Environmental Assessment showed PCE was used as drycleaning solvent from 1987 through 2011
  - Phase II Limited Subsurface Investigation in May 2019- Chlorinated solvents exceeding EPA MCL in GW
- Phase II GW data showed chlorinated solvent in groundwater under facility and migrating north.
  - Release reported to the Utah Division of Waste Management and Radiation Control (DWRMC), November 2019.

Site Map



WASATCH ENVIRONMENTAL

Environmental Science and Engineering

***cis*-1,2-Dichloroethene in Shallow Groundwater**

877 East 4500 South
Millcreek, Utah

PROJECT NO.: 2336-001C	DATE: 3/5/2020	FIGURE 4

WASATCH ENVIRONMENTAL

GEOTACTICAL REMEDIATION

Site Geology and Contamination

- Geology
  - Gravely sand with high hydraulic conductivity, underlain by sands and silts with reduced hydraulic conductivity
- GW plume extent
  - Lateral treatment area 4,600 ft^2
- COCs treat to [MCL]
  - Tetrachloroethene (PCE): [5 µg/L]
  - Trichloroethene (TCE): [5 µg/L]
  - cis 1,2-dichloroethene (DCE): [70 µg/L]

Site Options

- Dig- expensive
- Bioremediation (biotic)
  - Cost effective
  - Time intensive
  - Environmental condition sensitive
- ZVI (abiotic) - ***Selected***
  - Cost effective
  - Rapid and passive management

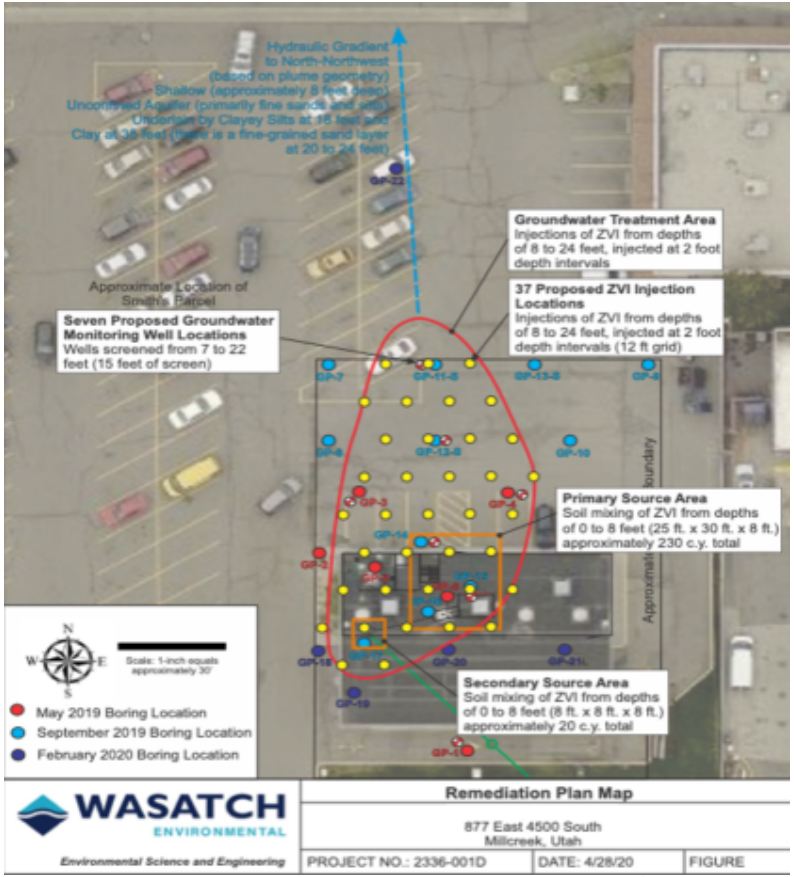
Site Approach

- GW and Soil plume fully delineated
  - Lateral treatment area 4,600 ft^2
- Corrective Action Plan (CAP) submitted to DWRMC and approved March 2021
- Zero Valent Iron amendment- C.E.R.E.S Corporation
  - C.E.R.E.S provided dosing

- Engaged local soil mixing contractor and in situ injection services
  - Geo Tactical Remediation (fracture injection)

Remediation Design

- ZVI fracture injections
  - Source Area 1 and 2
  - Soil mixing and injections with ZVI
- GW Plume Treatment
  - Fracture injections
- Completed from Aug 2021- Jan 2022
  - 68,418 lbs. of CERES ZVI injected
  - 8,713 lbs. of CERES ZVI soil mixing



C.E.R.E.S. Remediation Products

WASATCH ENVIRONMENTAL

GeoTactical Remediation

ZVI Treatment Emplacement

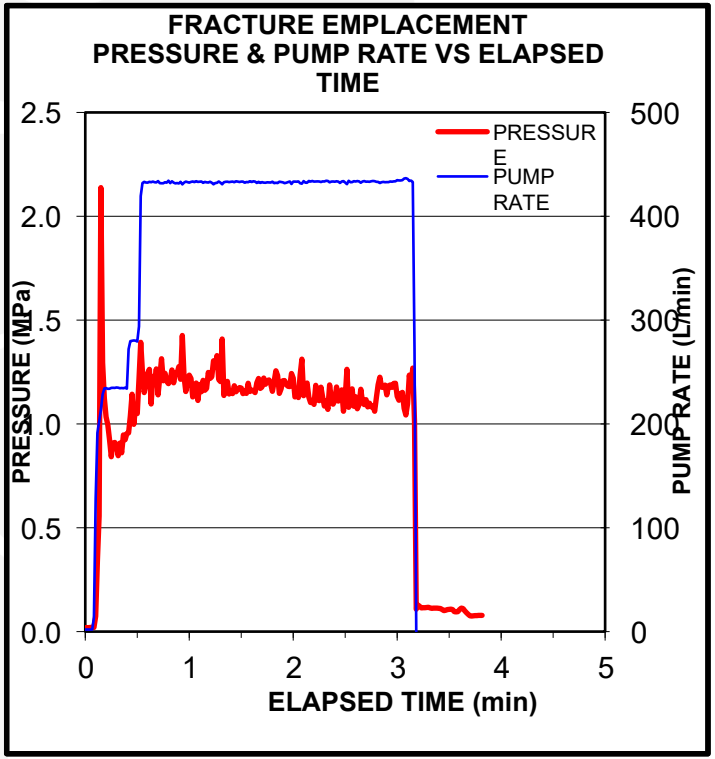
- Local Contractor
  - Soil mixing- shallow
    - Vadose zone 0-8 ft below ground surface (bgs)

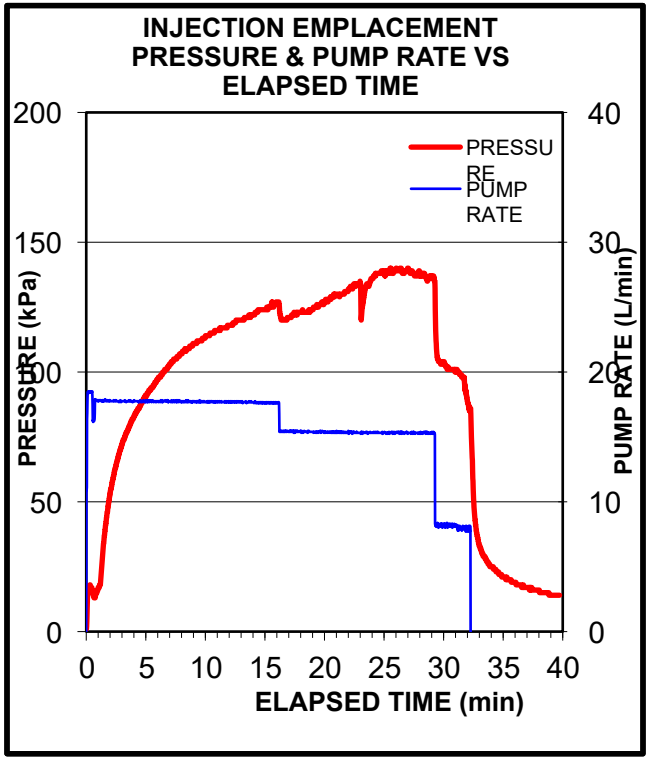
- Geo Tactical Remediation Ltd. (this presentation)
  - Fracture injection emplacement- deep
    - Groundwater plume zone 8-24 ft bgs

Fracture Injection

- Fracture- pressure induced tensile parting
- ZVI emplacement
- EF 9300 skid mounted mixing and pumping unit

Pressure – Time Response



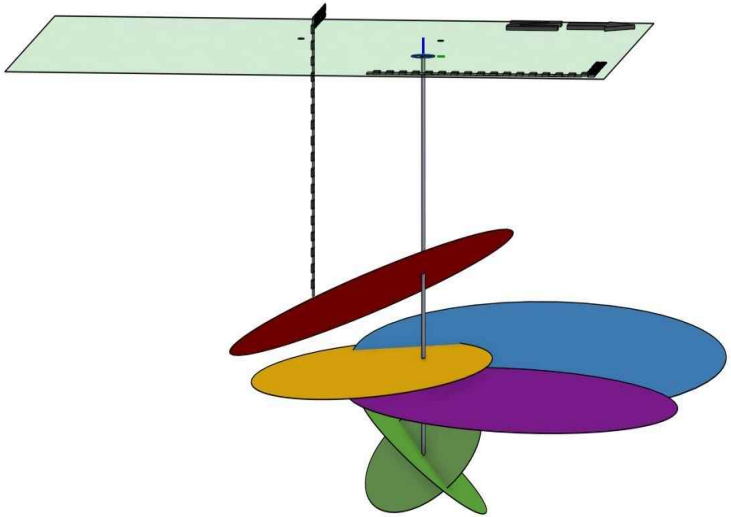


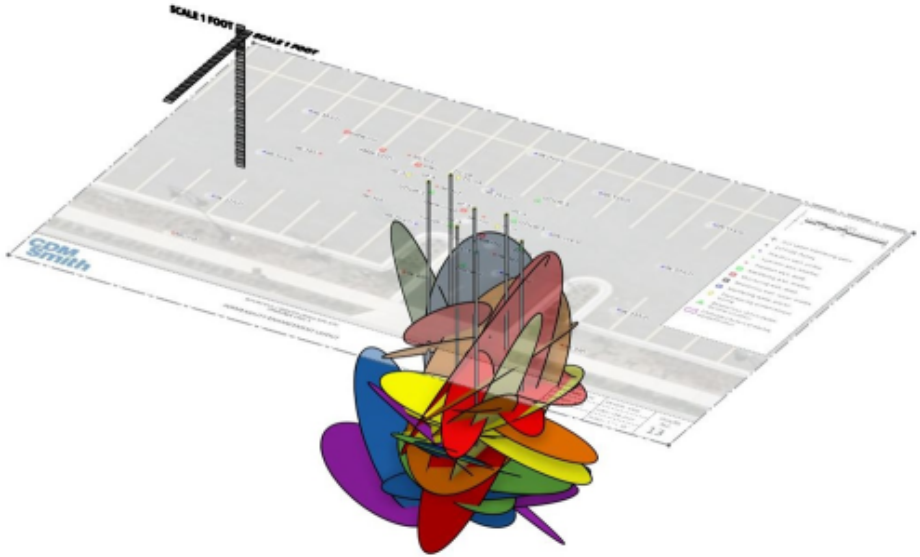
Site Operations

- Time
  - 6 days
- Emplaced
  - 68,418 lbs of ZVI by fracture injection
- 27 Emplacement Boreholes (EB)
  - 110 discrete emplacement intervals (EI)
  - Create overlap and interconnectivity for GW plume treatment
- ZVI emplacement
  - EF 9300 injection unit (see first slide)
  - Slurry system

3D Tiltmeter Mapping

(E.g., from a different site)





Courtesy of CDM Smith

Abiotic Dechlorination of Chlorinated Solvents

- ZVI acts as catalyst
  - PCE adsorbs to surface of ZVI (Fe^0)
  - Reduction of PCE (C_2Cl_4) to TCE (C_2HCl_3) (ZVI electron (e^-) transfer to PCE)
    - $C_2Cl_4 + Fe^0 + H^+ \rightarrow C_2HCl_3 + Fe^{2+} + Cl^-$
  - Rinse and repeat all the way to Ethene
    - PCE $\xrightarrow{e^-}$ TCE $\xrightarrow{e^-}$ DCE $\xrightarrow{e^-}$ Vinyl Chloride (VC) $\xrightarrow{e^-}$ Ethene (C2H4)
  - Overall reaction: $C_2Cl_4 + 4Fe^0 + 4H^+ + 4e^- \rightarrow C_2H_4 + 4Fe^{2+} + 4Cl^-$

Abiotic – Excess Amendment (Reagent)

- High mass loading **important** to ensure reaction proceeds to completion
  - Too many unknowns in subsurface to assume stoichiometric balance
  - Lab never quite captures the field ;)

- Too little could stall (*concern with biotic process as well*)
  - E.g., TCE→ cis-1,2-DCE (stall)- ***Not good***
  - E.g., cis or trans-1,2- DCE → VC (stall)- ***Really not good***

- Effective to emplace a high mass loading
  - Drive to completion in one event and get passive ongoing treatment
  - Persistent and passive
  - Treat COC rebound from ongoing sources

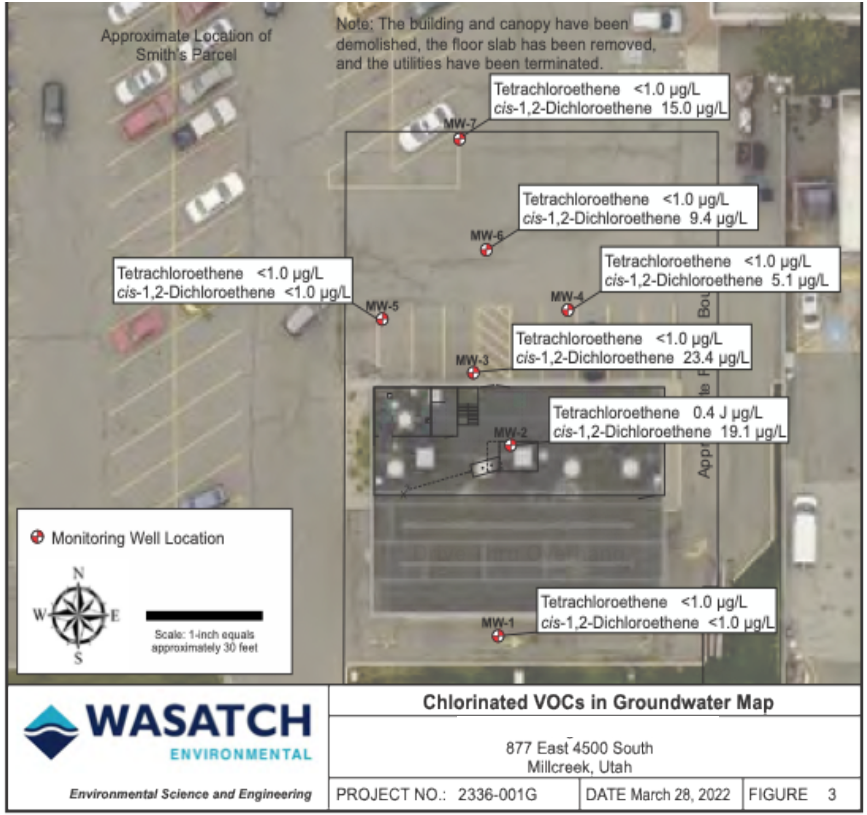
Biotic Dechlorination Process

- Bacterial degradation of chlorinated solvents
  - Dehalococcoides (anaerobic dehalogenation)
- Biotic processes require:
  - Carbon feedstock source e.g., emulsified vegetable oil (EVO)
  - pH, temperature, nutrients…
  - Lack of competing microbes
- ZVI is often used with EVO or other carbon source
- If anaerobic condition are not maintained; VC stall can occur
- If short on time, this can be difficult
  - With time a viable alternative

Performance Results March 2022
6 months post remediation

100% Reduction all COCs < US EPA MCL

COC	MW-3	US EPA MCL
PCE	<1.0 µg/L	5 µg/L
TCE	Non-detect	5 µg/L
cis-1,2-DCE	23.4 µg/L	70 µg/L
trans-1,2-DCE	Non-detect	100 µg/L
VC	Non-detect	2 µg/L



Site results

- Work completed March 2022
  - Site Corrective Action Plan approved March 2021
  - Work began August 2021
- Time to reach goal: ***6 months***
- COCs results: **100% reduction of all COCs below US EPA MCL**
  - TCE, trans-1,2 DCE and VC non-detect all sampling locations
  - cis-1,2 DCE detected in one monitoring well- below U.S EPA MCL
  - PCE detected in one well- below U.S EPA MCL

Conclusion and Takeaways

- Abiotic process is effective for dechlorination
  - Appropriate approach based on site objectives is important! (**Time**)
- In Situ injection effective when applied appropriately
  - High mass loading of ZVI to GW plume
  - Fracture injection to create overlapping network for GW treatment
  - Can be very rapid e.g., 6 months in this case
- Site meets unrestricted use criteria
  - Below U.S EPA MCL or detection limit
  - Client decision to speed up closure process
    - Regulatory closure with Corrective Action Plan with Controls status

Service backed by Science

THANK YOU!

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