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

GeoTactical Remediation

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Gord Guest, P.Geol.
Principal

Outline

- Zero Valent Iron abiotic dechlorination
- Emplacement method
  - Fracture injection
- Case studies

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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)
    - $C_2Cl_4 + Fe^0 + H^+ \rightarrow C_2HCl_3 + Fe^+ + Cl^-$
  - Process continues to Ethene
    - PCE $\xrightarrow{e^-}$ TCE $\xrightarrow{e^-}$ DCE $\xrightarrow{e^-}$ Vinyl Chloride (VC) $\xrightarrow{e^-}$ Ethene (C2H4)
  - Overall reaction: $C_2Cl_4 + 4H^+ + 4e^- \rightarrow C_2H_4 + 4Cl^-$

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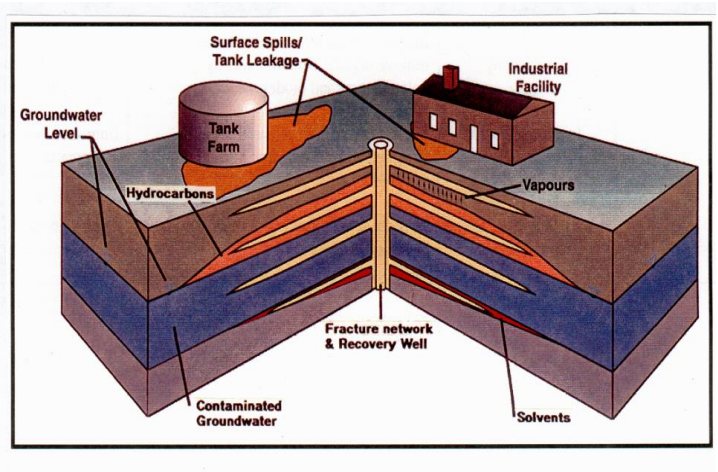
Abiotic – Excess Amendment Mass

- 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)
  - E.g., cis or trans-1,2- DCE → VC (stall)
- 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

Fracture Injection

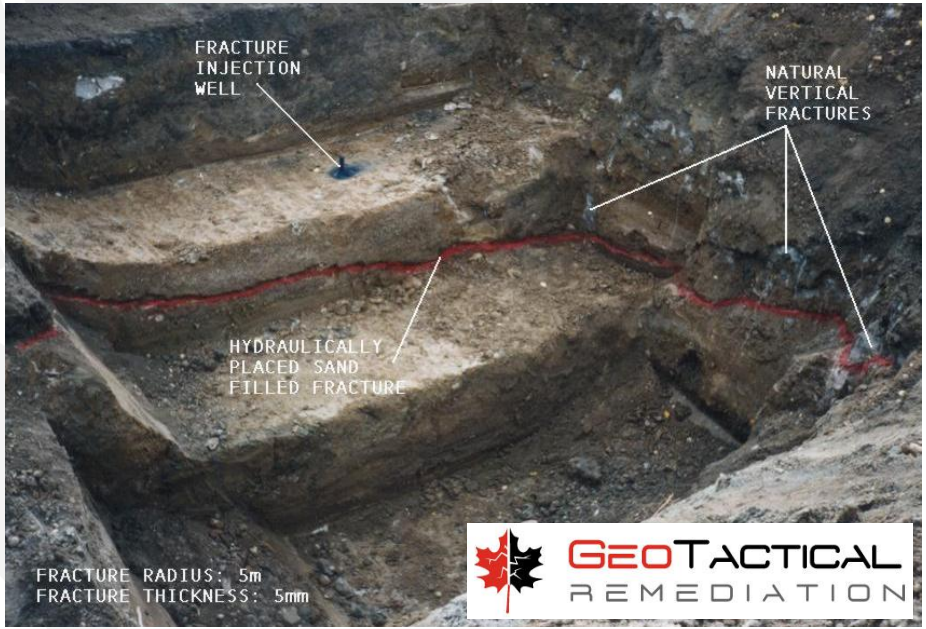
- *Fracture Injection* is a process in which a fluid is applied to a soil or rock mass until failure of the soil or rock occurs, resulting in a tensile parting (fracture)

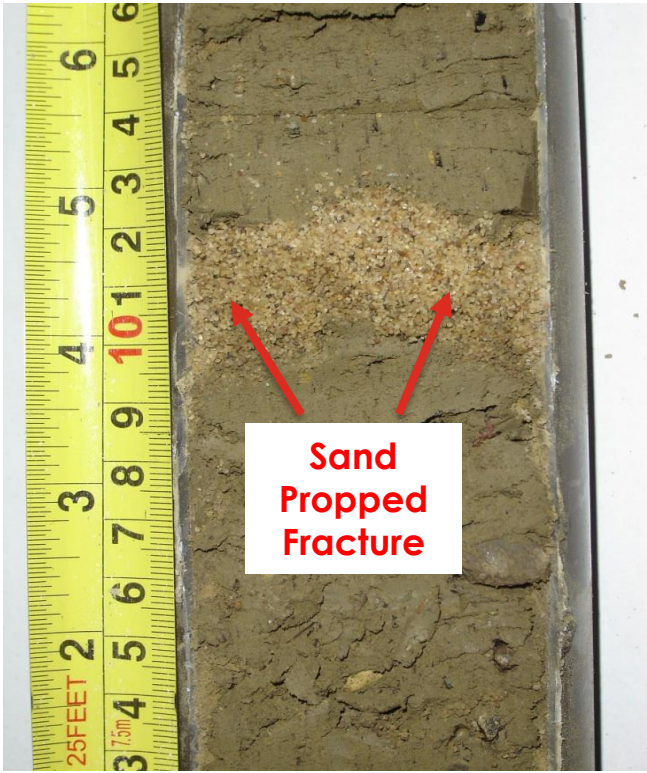
- Used for:
  - Greater treatment area per well
  - Better contact with contaminants in matrices with secondary porosity
  - Increasing bulk permeability
  - Solid phase amendments



Fracture Injection

Particle emplacement using fracture pressure induced tensile parting





Site 1

- 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 1- 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 425 m^2
  - Vertical treatment depth (Source) 0-7.3 mbgs
  - Vertical treatment depth (Distal) 2.4-7.3 mbgs
- COCs treat to [MCL]
  - Tetrachloroethene (PCE): [5 µg/L]
  - Trichloroethene (TCE): [5 µg/L]
  - cis 1,2-dichloroethene (DCE): [70 µg/L]

Site 1- Options

- Dig- expensive

- Bioremediation (biotic)
  - Cost effective
  - Time requirement
  - Environmental condition sensitive

- ZVI (abiotic) - ***Selected***
  - Cost effective
  - Rapid and passive management

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Site 1- Approach

- Corrective Action Plan (CAP) submitted to DWMRC and approved
- 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)

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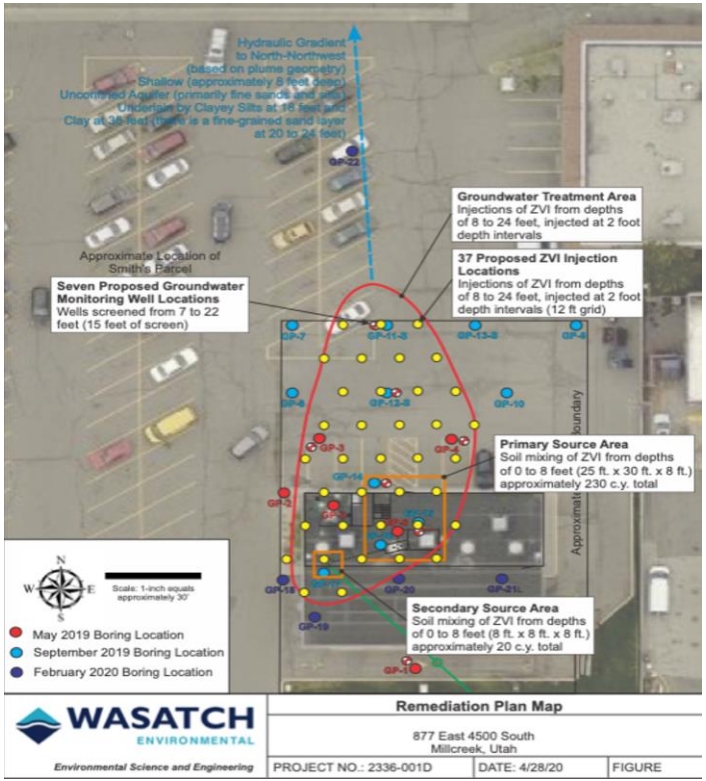
Site 1- Remediation Plan

- ZVI fracture injections
  - Source Area 1 and 2
  - Soil mixing and injections with ZVI
- GW Plume Treatment
  - Fracture injections
- ZVI Emplaced
  - 31,000 kg of ZVI injected
  - 3,950 kg of ZVI soil mixed



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Site 1- ZVI Treatment Emplacement

- Local Contractor
  - Soil mixing- shallow
    - Vadose zone 0-2.4 m below ground surface (bgs)
- Geo Tactical Remediation Ltd. (this presentation)
  - Fracture injection emplacement- deep
    - Groundwater plume zone 2.4-7.3 m bgs

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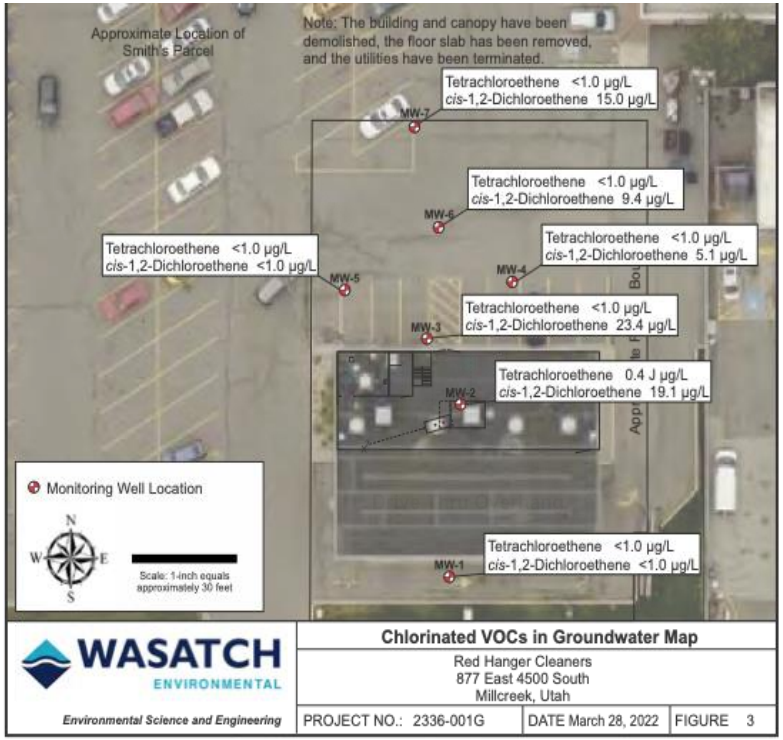
Site 1- Application

- Injection
  - 31,000 kg of ZVI by fracture injection
  - 5 days of fracture injection
- 27 Emplacement Boreholes (EH) at approximately 4.2 m spacing
  - 110 discrete emplacement intervals (EI)
  - Create overlap and interconnectivity for GW plume treatment
- ZVI injected using high viscosity slurry system
- Frac tool advanced with direct push drill rod (direct injection) top down

Site 1- Results 7 Months Post Remediation

MW	PCE µg/L		cis1,2 DCE µg/L	
	Pre Injection	Post Injection	Pre Injection	Post Injection
MW-2	**8.76**	<0.4	**71.4**	19.1
MW-3	**64.2**	ND	32.6	23.4
MW-4	ND	ND	**120**	5.1
MW-5	2.33	ND	**137**	ND
MW-6	ND	ND	**157**	9.4
MW-7	ND	ND	**132**	15.0
U.S. EPA MCL	5		70	



Courtesy of Wasatch Environmental

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Site 1- Summary

- 6 Operational days on site, 5 days of injection
- 7 months of passive treatment to reach remediation goal
- 100% reduction of all COCs below US EPA MCL
  - PCE, TCE, trans-1,2 DCE and VC non-detect all sampling locations
  - cis-1,2 DCE detected in four monitoring wells - below U.S EPA MCL

Site 2

- Bountiful/Woods Cross Superfund site (Woods Cross, Utah)
  - Former trucking facility, currently Utah Transit Authority parking lot
- Contaminant of concern (COC)
  - Chlorinated solvents above US EPA Maximum Contaminant Level (MCL) in groundwater (GW)
- Previous work included injections of EVO, lactate and EIR
- Remedial approach
  - Emplace Zero Valent Iron (ZVI) and sand proppant

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Site 2- Geology and Contamination

- Geology
  - Highly variable – interbedded clay, sand and gravel
- GW plume extent
  - Lateral treatment area ~85 m^2
  - Shallow zone vertical treatment depth 11.5-14.5 mbgs
  - Deep zone vertical treatment depth 18.5-22.5 mbgs
- COC
  - PCE, TCE, DCE and VC

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Site 2- ZVI Treatment Emplacement

- Fracture injection emplacement of ZVI provided by C.E.R.E.S Corporation and sand proppant
- Create overlap and interconnectivity for GW plume treatment
- ZVI for abiotic reduction of the CoC
- Sand proppant for subsequent injections of lactate, if required
- Map fracture network with tiltmeters to confirm ZVI and sand distribution

Site 2- Application

- Fracture injection emplacement
  - ~8,600 kg of ZVI and ~8,600 kg sand proppant
- 9 Emplacement Boreholes (EH)
- 38 discrete emplacement intervals (EI)
- ZVI and sand emplacement using high viscosity slurry system
- Frac tool advanced with direct push drill rod (direct injection) top down
- Tiltmeter mapping of fracture network

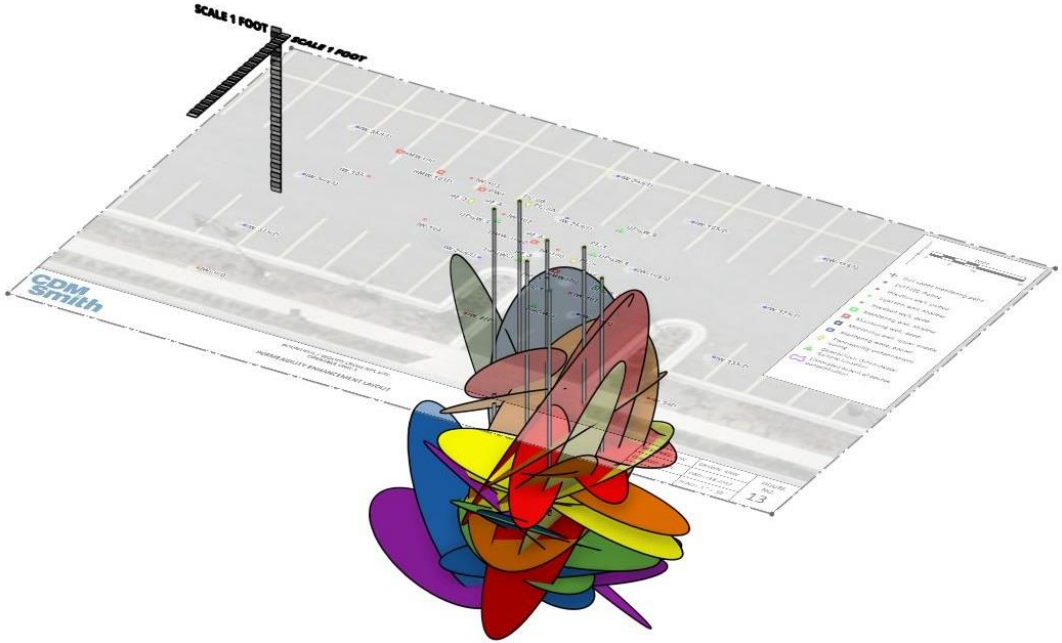
Site 2 – Results 9 Months After Remediation

- 99.5% reduction.
- TCE from 37 ppb to 1 ppb
- Total DCE from 35 ppm to ~115 ppb
- VC reduce from ~2,800 ppb to 6 ppb
- Bio injections not required to date.

Courtesy of CDM Smith

3D Tiltmeter Mapping

Tiltmeter data analysis confirms network of interconnected fractures.



Courtesy of CDM Smith

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Conclusion and Takeaways

- Abiotic process is effective for dechlorination
  - Appropriate approach based on site objectives
- ZVI injection effective when applied appropriately
  - High mass loading of ZVI
  - Fracture injection to distribute solid phase amendment
  - Fracture injection to create overlapping network
  - Can be very rapid, even with high concentrations

Service backed by Science

THANK YOU!

403.265.5533

geotactical.ca

Gord Guest- Principal
gguest@geotactical.ca

Danny Procter- Business Development Manager
dprocter@geotactical.ca

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