Implementation of a Nanoscale Zero Valent Iron Remediation Demonstration

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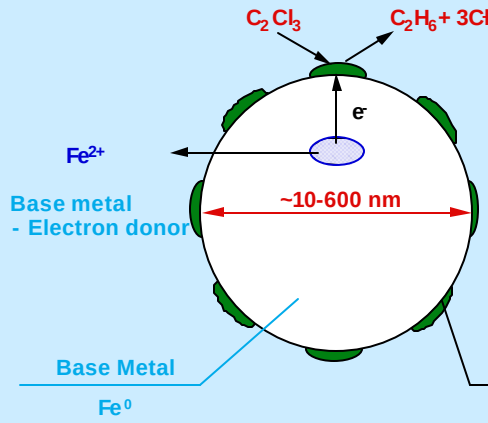
Overview of presentation

- Overview of Nanoscale Iron
- Full Scale Pilot Study, NAS Jacksonville
- Summary and Conclusions

Nanoscale Zero Valent Iron

Dehalogenation Schematic



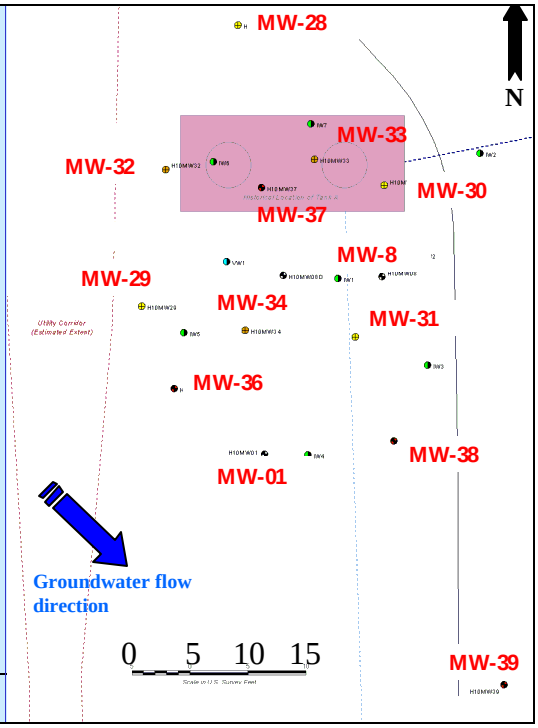
Other Contaminants
- Chlorinated VOCs
- Nitrates
- Metals (e.g, Cr, As)
- Chlorinated Pesticides

Noble Metals:
- forms galvanic cells
- catalyze hydrogenation

Source: modified after Lehigh University

Site Background

- Small area (1050 sq ft)
- Utility corridor
- Geology
  - Silty to fine sand from 0 to 24 feet bgs
  - Dense clay from 24 to 54 ft bgs
- Hydrogeology
  - Flow toward southeast
  - Water table at 7 feet bgs
  - Hyd. Conduct. ~2 ft/day

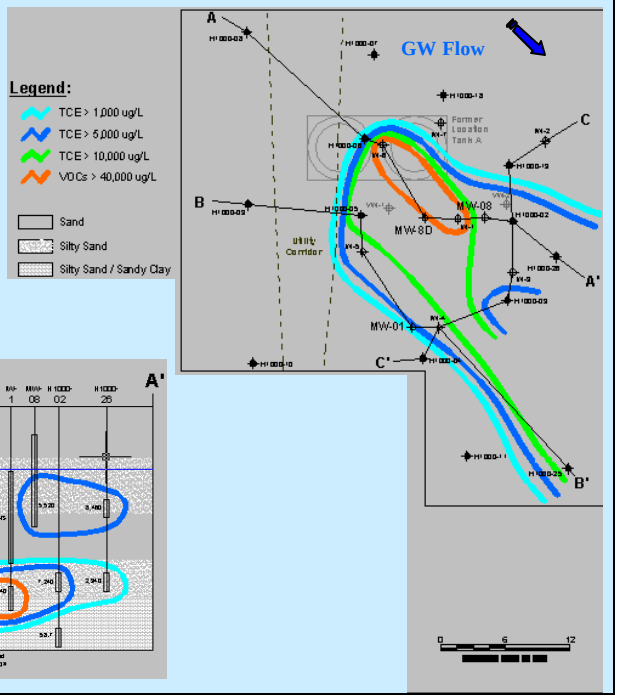


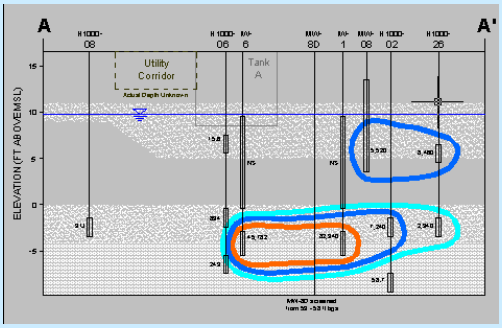
Site Contamination Summary

Hangar 1000, NAS Jacksonville

Maximum Total VOC
550 mg/kg in soil
80 mg/L in groundwater

Chemical oxidation conducted in 2001





Full Scale Pilot Study Design

- Remedial Goal as defined in the Work Plan
  - Reduce contaminant mass **40 to 50%**
  - Not expected to reach groundwater MCLs
  - MNA anticipated as next step
- How much iron is needed?
  - Reaction Capactity (VOCs : Nano Fe) = ~1:5-10 by wt.
  - CVOC mass estimated: 42 to 125 lbs
  - Need an estimated 210 to 1250 lbs
  - Injected 300 lbs
- Two injection methods:
  - Strategic DPT injections
  - Recirculation Process

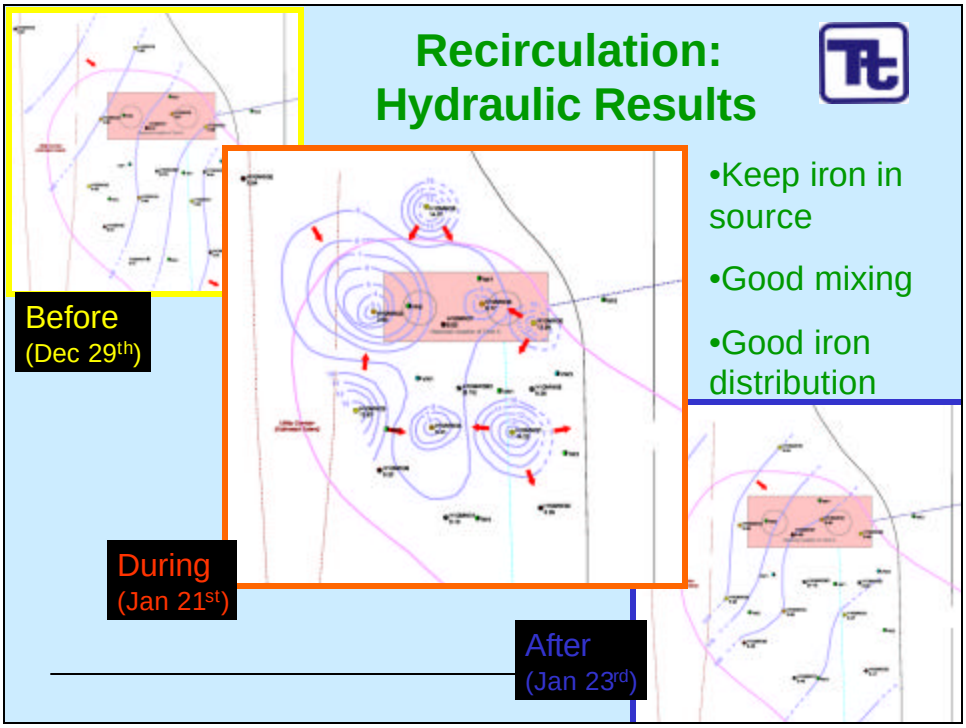
Source: U.S. Navy

Recirculation Setup

Nanoscale Iron

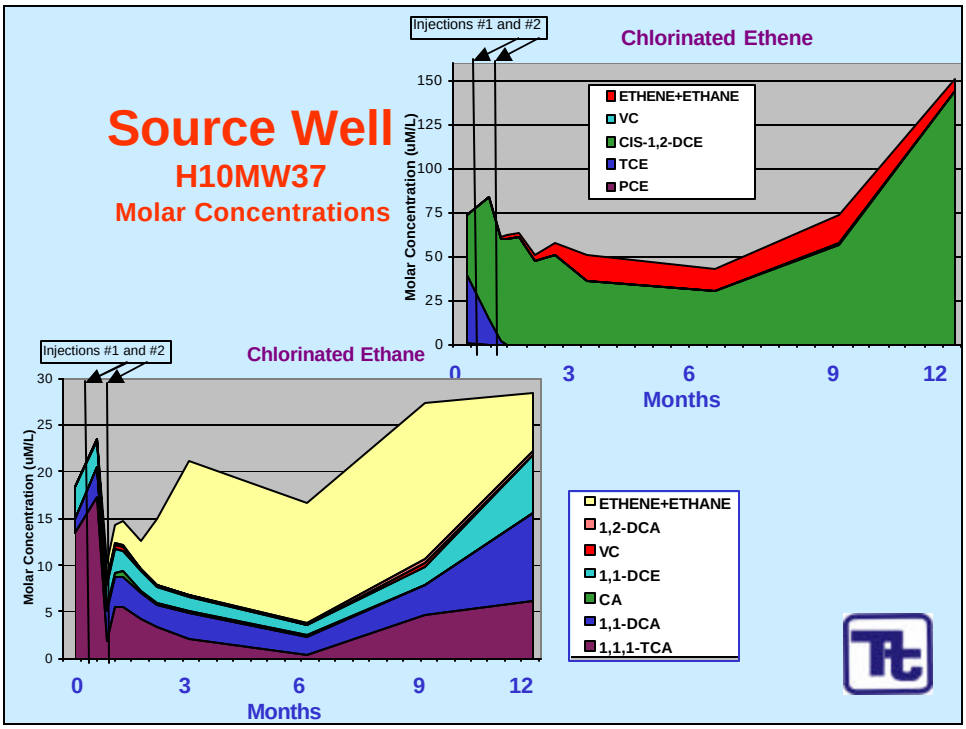
- Polymer Supported w/Palladium Catalyst
- No carbon substrate

Recirculation: Hydraulic Results



- Keep iron in source
- Good mixing
- Good iron distribution

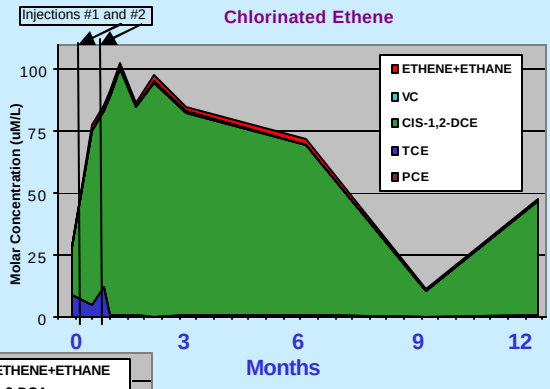
Source Well
H10MW37
Molar Concentrations

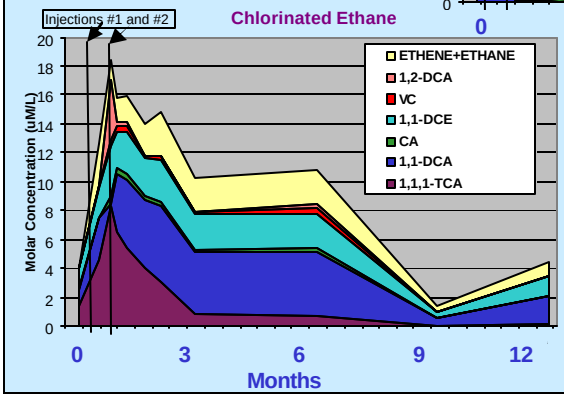


Source Well

H10MW34

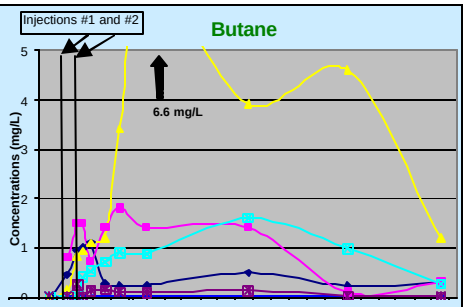
Molar Concentrations

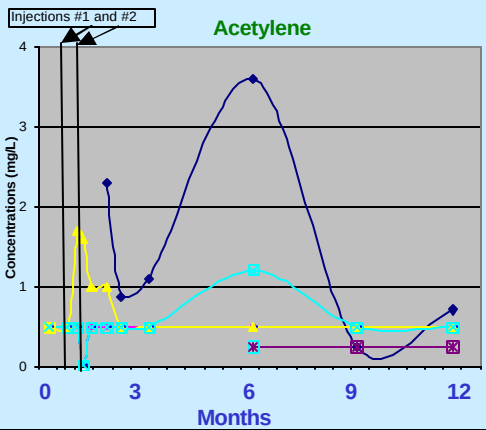


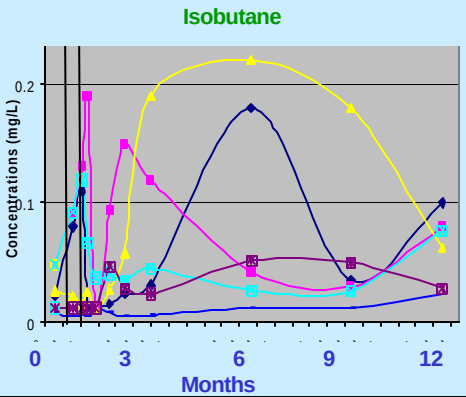


Beta-Elimination Pathway

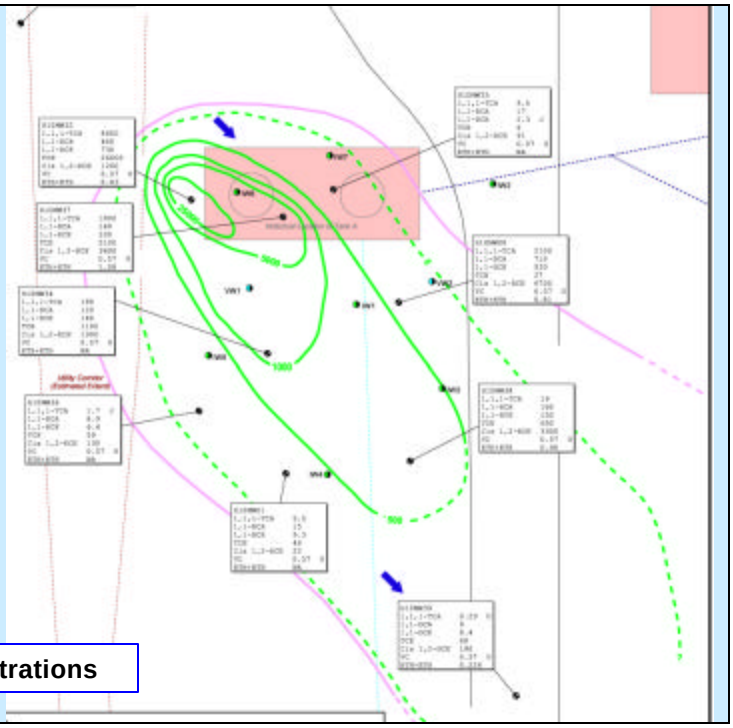
Acetylene, Butane, & Isobutane





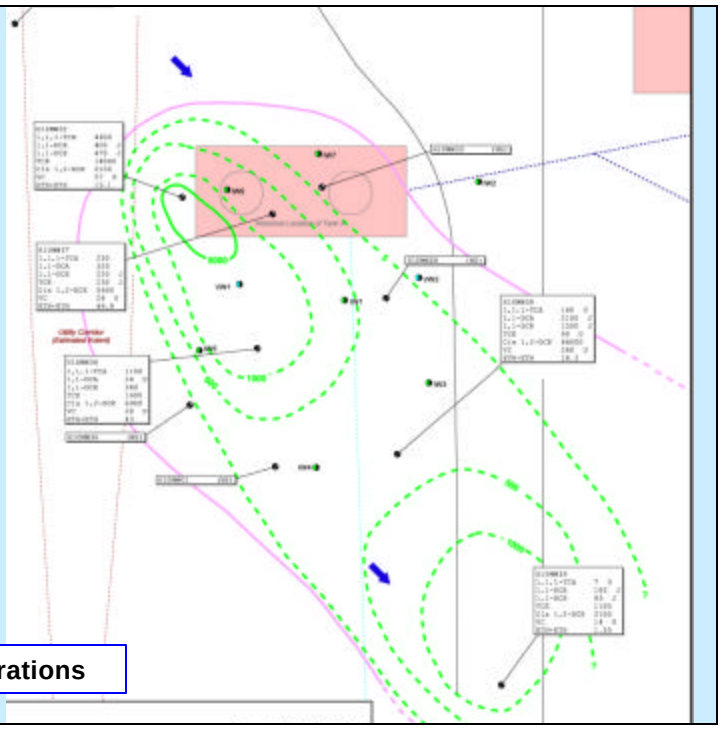


Round 1 (baseline)



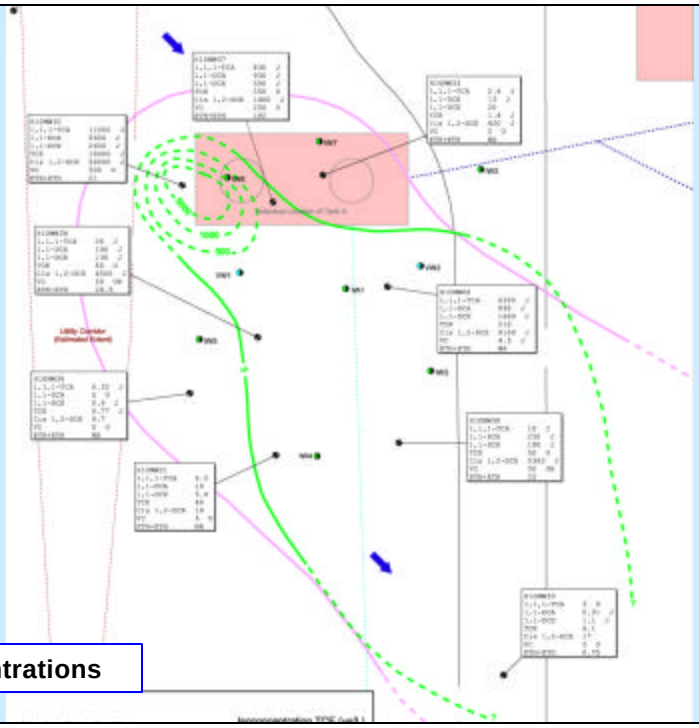
TCE isoconcentrations

Round 3 (after inject)



TCE isoconcentrations

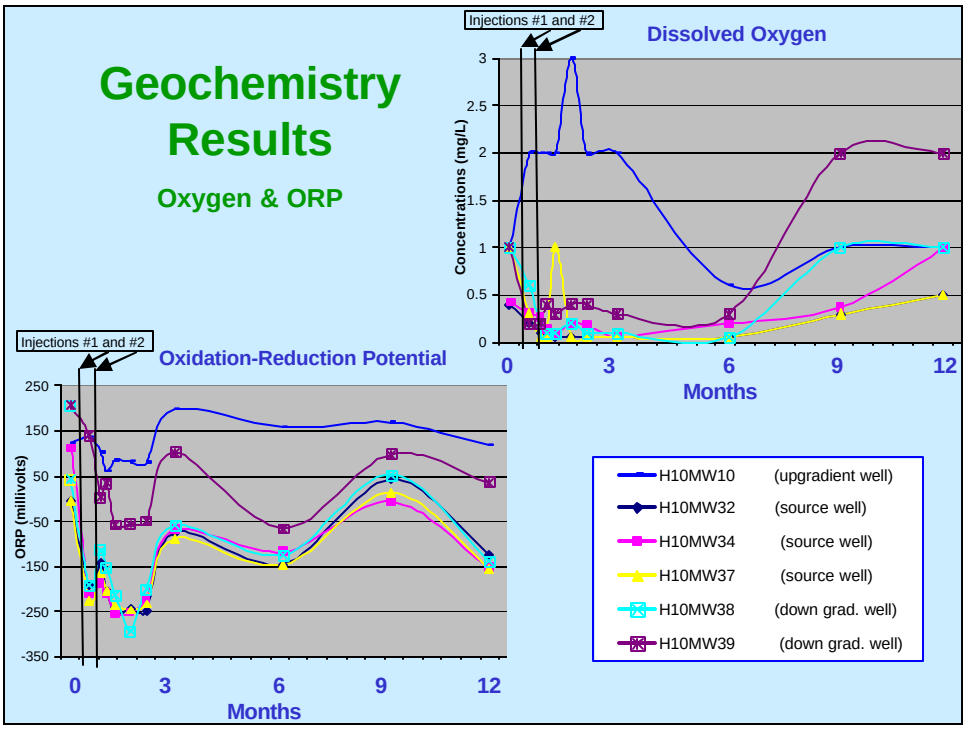
Round 11 (after inject)



TCE isoconcentrations

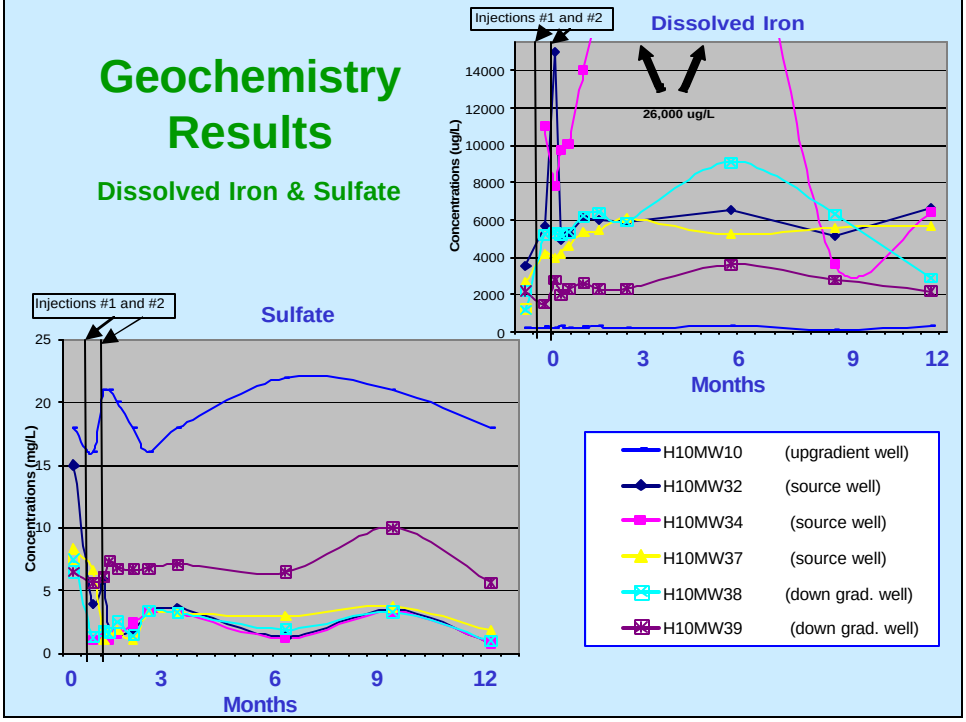
Geochemistry Results

Oxygen & ORP



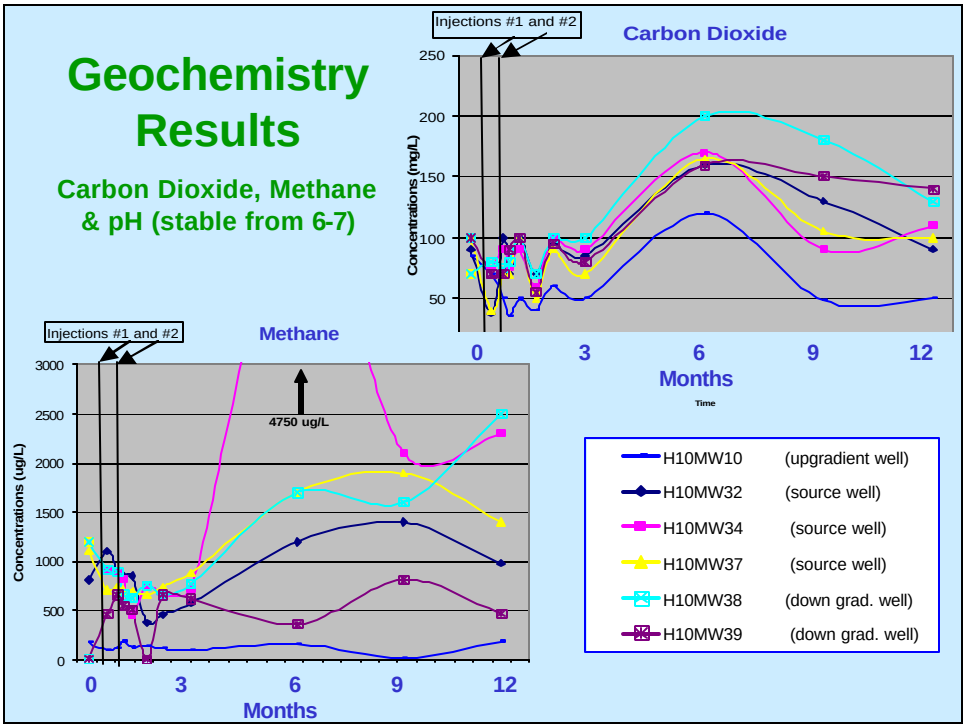
Geochemistry Results

Dissolved Iron & Sulfate



Geochemistry Results

Carbon Dioxide, Methane & pH (stable from 6-7)



Is there evidence for biological activity?

- qPCR analysis for Dehalococcoides (GC/ML) conducted in 3 wells:

Well	Baseline (GC/ML)	12 months after injection (GC/ML)
H10MW10	500 U	18
H10MW37	500 U	25 U
H10MW39	174	1.65

Soil Sampling Summary

Percent change: Soil data before & after study

Soil Boring Depth (feet-bgs)	H1K-03 19'	H1K-31 8'	H1K-31 20'	H1K-34 20'	H1K-35 22'	H1K-36 20'	H1K-38 20'	H1K-39 16'
1,1,1-TCA	-	-50%	-93%	-100%	-92%	-	-	-99%
1,1-DCA	5%	-	-	-84%	-43%	-	-91%	46%
1,1-DCE	-	-36%	-	-	-77%	-	-97%	-
Methylene chloride	-	-	-	-100%	-	-	-	-
PCE	-	-28%	-100%	-	-99%	-	-	-
TCE	-100%	141%	-96%	-100%	-100%	-100%	-100%	-
Vinyl chloride	-	-	-	-	-	-	-	-
cis-1,2-DCE	267%	-	1026%	174%	11%	-	-71%	18%
Total % Change	11%	8%	92%	92%	75%	94%	88%	25%

RED/Yellow - indicates DECREASE in concentration

BLUE/Gray - indicated INCREASE in concentration

Mass Reduction Summary

- Total Mass Reduction before & after study
  - Soil mass
  - Dissolved mass
  - Sorbed mass

	Pre-Injection (Baseline)	Post-Injection (after Round 11)	Pounds destroyed	Percent Difference
Maximum	**125 lbs**	**47 lbs**	**78**	**62%**
Most Likely	**61 lbs**	**47 lbs**	**14**	**23%**
Minimum	**42 lbs**	**35 lbs**	**7**	**16%**

RED/Yellow - indicates DECREASE in concentration
BLUE/Gray - indicated INCREASE in concentration

How much was it?

- Total Cost to Implement: $260K (2004)
  - Iron injection costs: $112K
  - Nanoscale iron: $37K (late 2003) *
    - Today this cost would have been $5 to 14K
  - Monitoring costs: $111K

- Comparable to other technologies today…
  - Nanoscale iron: $185K (2005)
  - Chemical Oxidation: $145K
  - Bioremediation $ 150K - $175K
  - Excavation: $385K – $485K

* Pound per pound is not a good comparison

Summary

- Data suggests favorable results
  - Significant TCE & 1,1,1-TCA reductions across the site
  - Generation of daughter products
    - cis-1,2 DCE, 1,1-DCE, 1,1-DCA
    - very little VC
  - Mass destruction evident
    - Good mass balance in some wells
    - Ethene & ethene conentrations increased up to 2 order (770%)
    - Acetylene and light hydrocarbons increased up to 2 order
  - Longevity of iron: 6 to 9 months

Summary (cont.)

- Data suggests favorable results (cont.)
  - Plume extent was reduced (MW-33 & MW-36)
  - At or below GCTLs levels in MW-39 (downgradient well)
    - Reduced mass flux from source
- Concentrations in the 'core' returned (expected)
  - Elevated concentations returned in source wells (MW-08, MW-32, MW-37)
- Mass reduced between 16 and 63 %
  - We met the 40-50% reduction goal (regulators)
  - To be included in the ROD for site
- **Further reductions could have been achieved** (not needed to meet project goals)

Is this the Silver Bullet ?

- It works…but not in all cases.
  - Quick…Not much to do (no nutrients, no pH issues)
  - Good for small sources…not for very large ones
  - Bioremediation may work better in some environments
  - An emerging science that is making strides
  - Treatment trains and 'combinations'

Thanks for attending

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