

# Implementation of a Nanoscale Zero Valent Iron Remediation Demonstration

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Tetra Tech NUS, Inc.



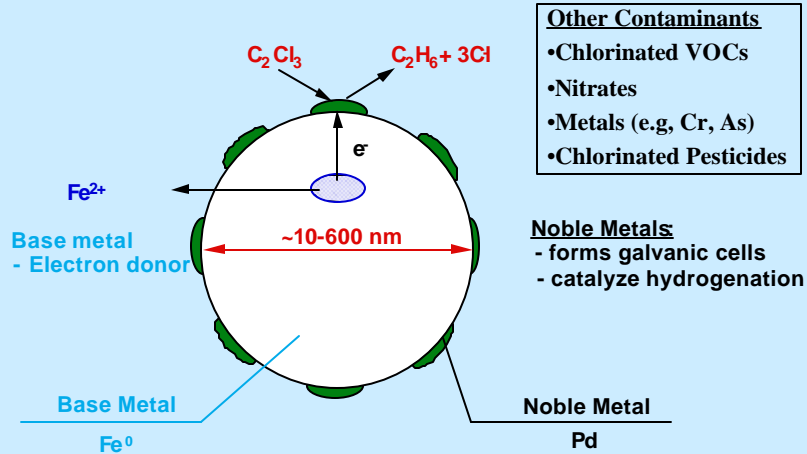
## Overview of presentation

- [Overview of Nanoscale Iron](#)
- Full Scale Pilot Study, NAS Jacksonville
- Summary and Conclusions

# Nanoscale Zero Valent Iron



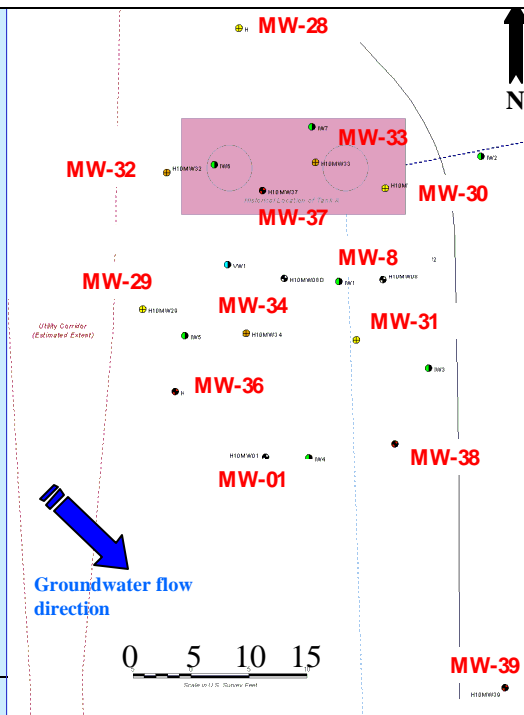
## Dehalogenation Schematic



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.  $\sim 2 \text{ ft/day}$



## Site Contamination Summary

Hangar 1000, NAS Jacksonville

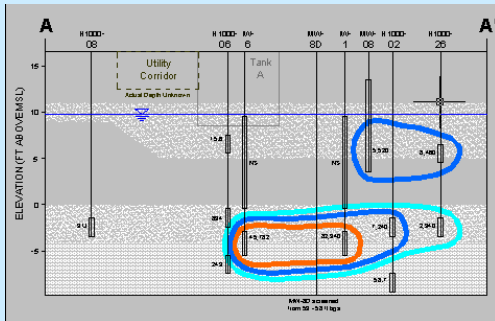
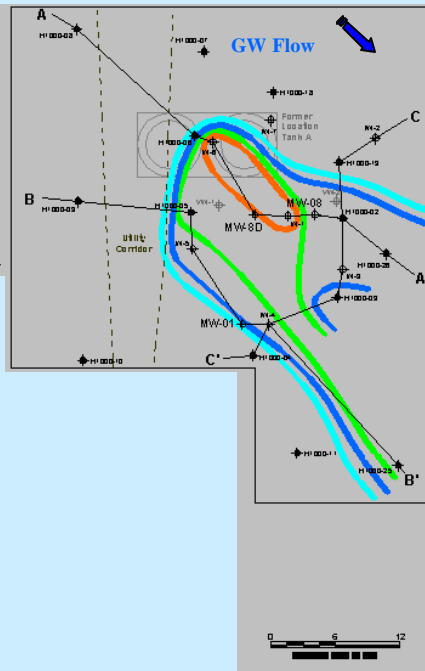
Maximum Total VOC  
550 mg/kg in soil  
80 mg/L in groundwater

Chemical oxidation  
conducted in 2001

### Legend:

- ~ TCE > 1,000 ug/L
- ~ TCE > 5,000 ug/L
- ~ TCE > 10,000 ug/L
- ~ VOCs > 40,000 ug/L

- Sand
- Silty Sand
- Silty Sand / Sandy Clay



## 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 Capacity (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**



7

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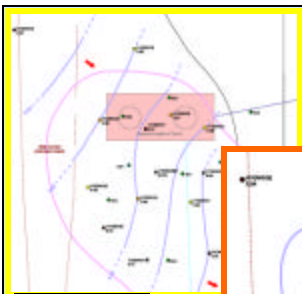
**Nanoscale Iron**

- Polymer Supported w/Palladium Catalyst
- No carbon substrate

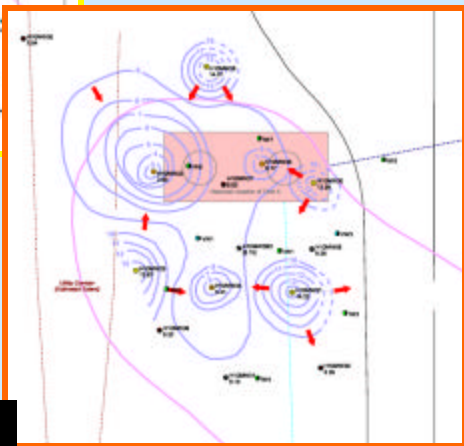
8

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# Recirculation: Hydraulic Results



Before  
(Dec 29<sup>th</sup>)



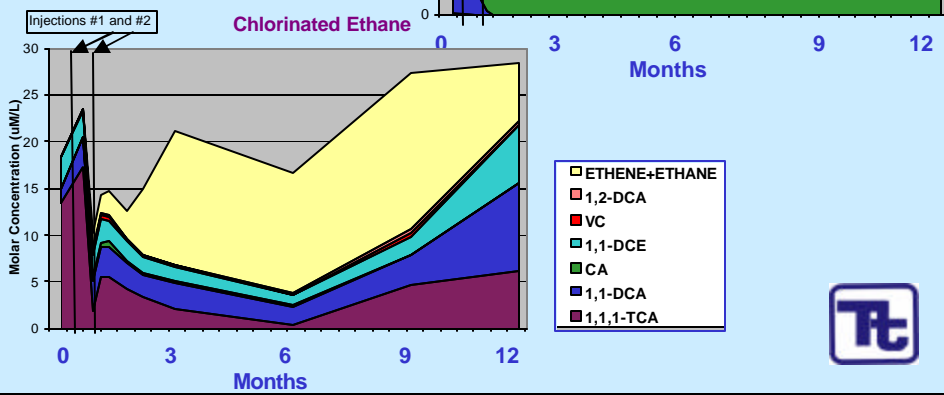
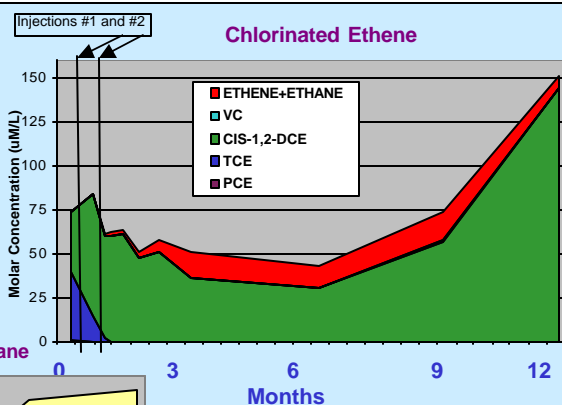
During  
(Jan 21<sup>st</sup>)

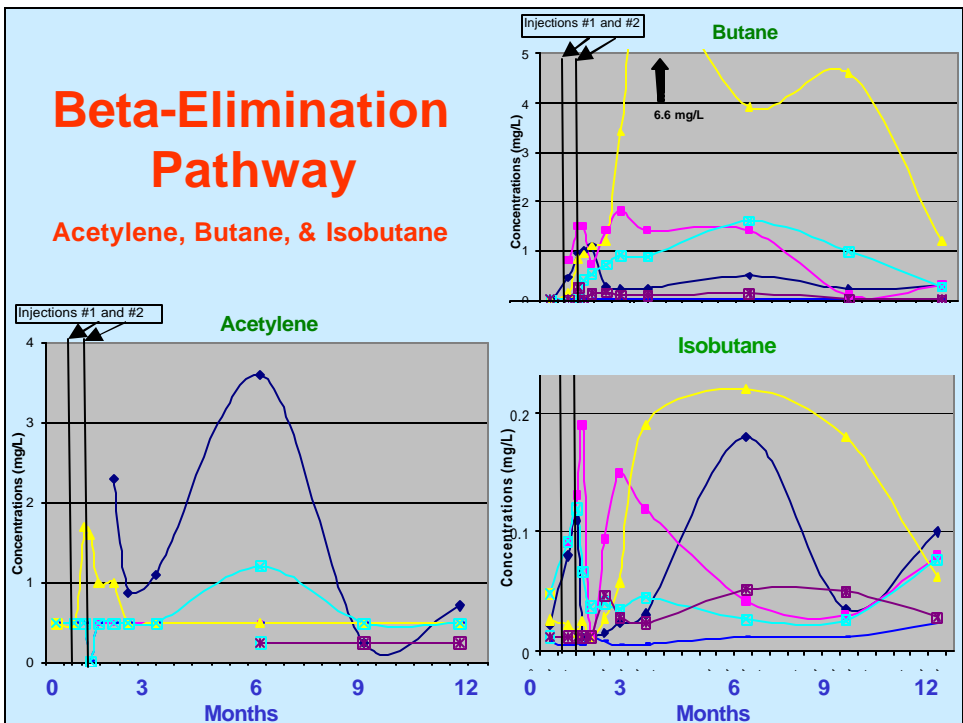
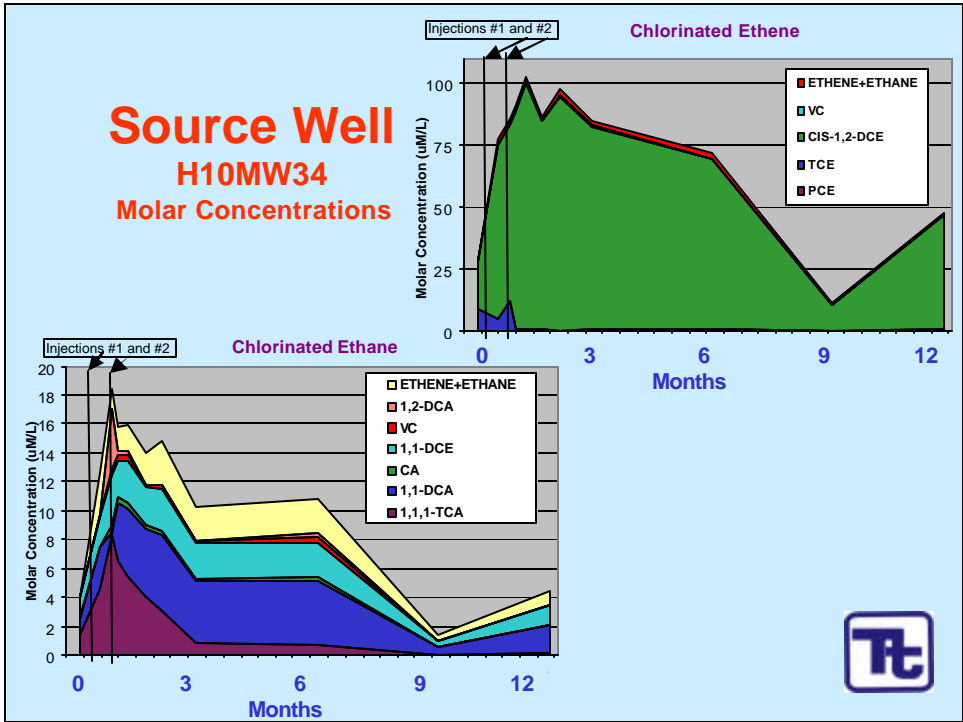
- Keep iron in source
- Good mixing
- Good iron distribution

After  
(Jan 23<sup>rd</sup>)

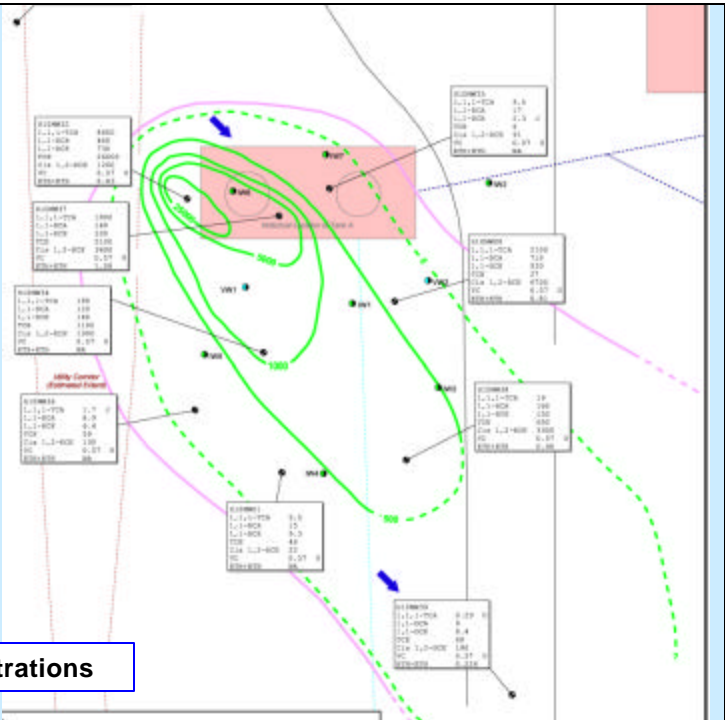


## Source Well H10MW37 Molar Concentrations

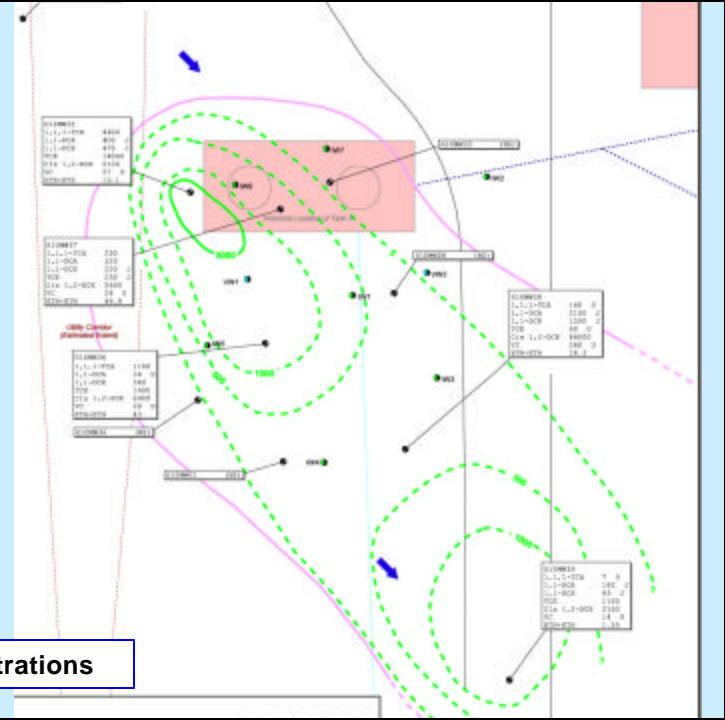




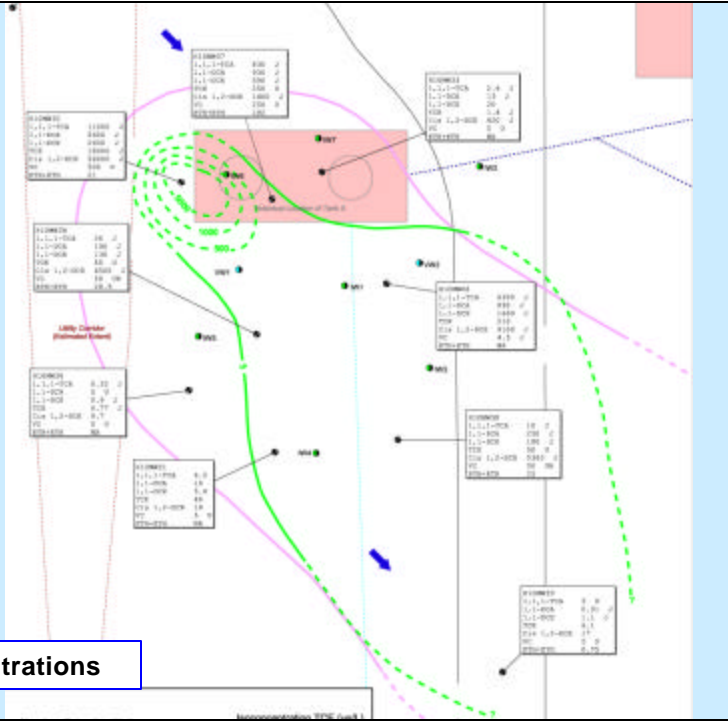
**Round 1  
(baseline)**



**Round 3  
(after inject)**

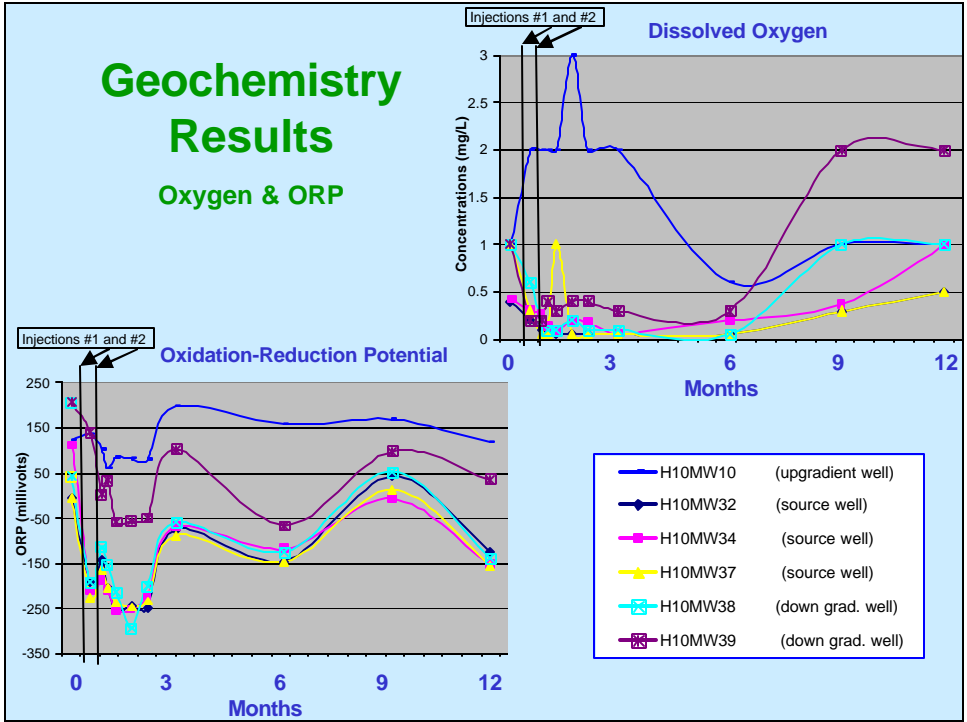


**Round 11  
(after inject)**



**TCE isoconcentrations**

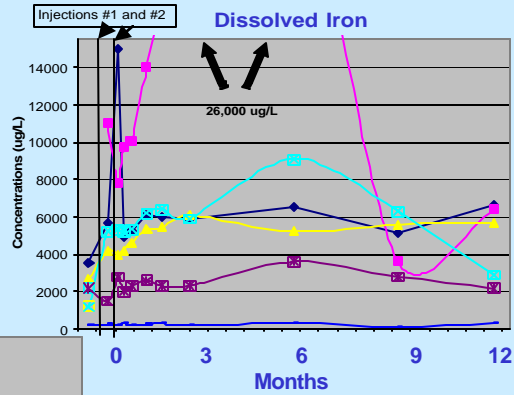
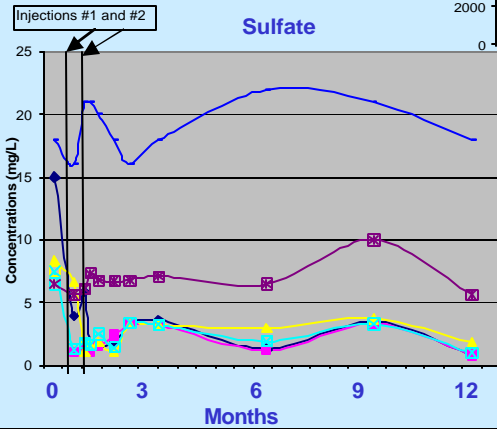
**Geochemistry  
Results  
Oxygen & ORP**





# Geochemistry Results

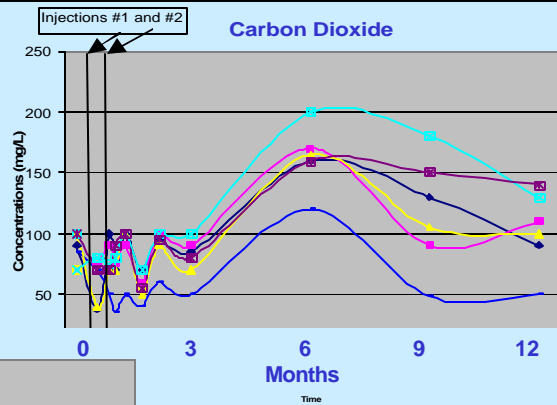
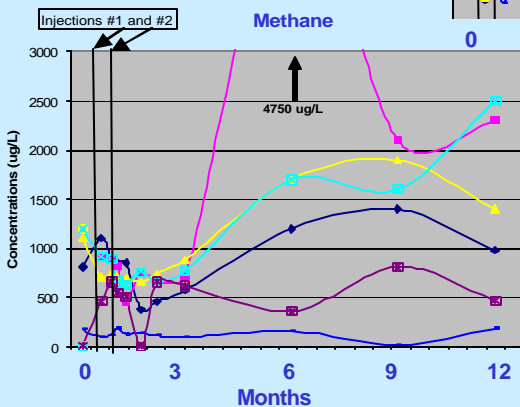
## Dissolved Iron & Sulfate



- H10MW10 (upgradient well)
- H10MW32 (source well)
- H10MW34 (source well)
- H10MW37 (source well)
- H10MW38 (down grad. well)
- H10MW39 (down grad. well)

# Geochemistry Results

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



- H10MW10 (upgradient well)
- H10MW32 (source well)
- H10MW34 (source well)
- H10MW37 (source well)
- H10MW38 (down grad. well)
- H10MW39 (down grad. well)



## 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

19

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## 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

20

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## 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
<b>Maximum</b>	<b>125 lbs</b>	<b>47 lbs</b>	<b>78</b>	<b>62%</b>
<b>Most Likely</b>	<b>61 lbs</b>	<b>47 lbs</b>	<b>14</b>	<b>23%</b>
<b>Minimum</b>	<b>42 lbs</b>	<b>35 lbs</b>	<b>7</b>	<b>16%</b>

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 concentrations 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 concentrations 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'



Tetra Tech NUS, Inc.

**Thanks for attending**

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