DNAPL Remediation at Camp Lejeune Using ZVI-Clay Soil Mixing

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Presentation Outline

- Background discussion
- Technology description
- Implementation
- Results
- Summary
Camp Lejeune Background

- Camp Lejeune was established near the city of Jacksonville, N.C, in 1941.
- Base covers 236 square miles
- 44,000 Active Duty Military
- Maintains over 50 Live-Fire Ranges
- NPL site since 1989
- Signed FFA in 1991
Camp Lejeune Background

- Environmental Restoration Sites
  - 43 Installation Restoration (IR) Sites, 22 Operable Units (OUs); 15 Active Sites
  - 159 Solid Waste Management Unit (SWMU) Sites; 28 Active Sites
  - 221 Underground Storage Tank (UST) Sites; 32 Active Sites
  - 25 Military Munitions Response Program (MMRP) Sites
Building 25 used as dry cleaner since 1940’s
Operations ceased in 2004 and building demolished to slab
Located in congested portion of base
Source was solvent poured down floor drains plus tanks located behind building
IR Site 88, Former Dry Cleaners

- Source - Chlorinated Solvents
- Source Area Less Than ¼ acre
- Dissolved Plume Approx. 20 Acres
- Plume Heading Toward River
Historic Investigations/Actions

- 1997: Phase I/II Focused Remedial Investigation
- 1999: Surfactant Enhanced Aquifer Remediation (SEAR)
- 2002 – 2003: Supplemental Site Investigation
  - Summary of 6 years of RI and Pilot Study
- 2004: Membrane Interface Probe Investigation
  - Delineation of DNAPL area
- 1998 – 2004: DNAPL removal using vacuum truck with extraction wells
Site Conditions

- Tetrachloroethene (PCE) primary contaminant
- Observable DNAPL Present
- Highest groundwater concentrations in non-DNAPL areas:
  - PCE = 64,000 µg/L
  - TCE = 37,000 µg/L
  - cDCE = 84,000 µg/L
  - VC = 45,000 µg/L
- Source area delineated with MIP
  - Source Area is 10,000 ft² and 20 ft deep (7,000 yd³)
  - Estimate of 2,100 gallons of PCE (14 tons) present
- Site has silty-clay layer 20 ft bgs
Horizontal Source Zone View

Approximately 10,000 ft²

results of MIP investigation
Vertical Source Zone View

results of MIP investigation
Soil Mixing with Clay-ZVI Addition

- In-Situ Technology using large auger system equipped with nozzles to inject zero valent iron and clay mixture into the soil while mixing the soil

- Pros
  - relatively fast treatment (< 2 months in field)
  - robust, able to treat entire area (no dead zones)
  - reduces treated area permeability

- Cons
  - Safety due to large equipment
  - messy
  - utility removal/relocation
  - required excavation to account for volume expansion
Patented technology held by Colorado State University
Column Layout

red – 2,500 lb ZVI
blue – 2,250 lb ZVI

SEAR Test Area
DNAPL Observed

146 total columns
2% ZVI (200 tons)
1% bentonite (100 tons)
Project Timeline

- Preparation (August 2004 – January 2005)
  - bench-scale study
  - utility removal
- Mixing (February 2005)
  - 17 days to mix 7,000 yd$^3$ of soil
- Restoration (May – September 2005)
  - stabilization
  - parking lot
- Monitoring (February 2005 – February 2006)
  - soil and groundwater monitoring
Building 25 Before Work
Soil Mixing Auger (10 ft diameter)
Soil Mixing
Soil Mixing
Collecting QC Samples
Before and After

Site 88 Prior to Treatment

Site 88 After Treatment
Overall Treatment Area
Weighted Average Soil Concentrations
(78% outside SEAR area, 22% SEAR area)

91% Reduction
Overall Treatment Area
Average Soil Concentrations

Concentration (mg/kg)

Feb-05 May-05 Aug-05 Nov-05 Feb-06

TCE PCE

82% Reduction
Outside SEAR Area
Average Soil Concentrations

Concentration (mg/kg)

Feb-05 May-05 Aug-05 Nov-05 Feb-06

>99% Reduction

TCE PCE
SEAR Area
Average Soil Concentrations

61% Reduction

Concentration (mg/kg)

Feb-05 May-05 Aug-05 Nov-05 Feb-06

TCE PCE
PCE Soil Vapor Results (mg/m³)

- Col. 28: >99 % Removal
- Col. 70: 95 % Removal
- Col. 127: 83 % Removal

Legend:
- Pretreatment
- Post-Treatment
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<td>200 U</td>
<td>200 U</td>
<td>13 U</td>
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<tr>
<td>TCE</td>
<td>200 U</td>
<td>200 U</td>
<td>13 U</td>
</tr>
<tr>
<td>cDCE</td>
<td>1,500</td>
<td>1,600</td>
<td>520 B</td>
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<tr>
<td>Vinyl Chloride</td>
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<tr>
<td>Acetone</td>
<td>460</td>
<td>110 J</td>
<td>410 B</td>
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# MW-31 – Treatment Area (μg/L)

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<tr>
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<td>160,000</td>
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<td>7,300 J</td>
<td>5,000 J</td>
<td>24,000 J</td>
<td>27,000 J</td>
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MW-31 (treatment area)

PCE reduction = 93%

Concentration (mg/L)

Aug-05 Nov-05 Feb-06 May-06 Aug-06

cDCE PCE TCE
MW-27 (Downgradient)

- PCE reduction = >90%
- PCE non-detect since June 2005, half detection limit plotted

Concentration (mg/L)

- cDCE
- PCE
- TCE
Summary

- Seeing excellent contaminant reduction across site (>90%)
- The remnants of the SEAR test may be interfering with the ZVI.
  - Elevated concentrations are isolated (about 25 ft apart)
  - These areas should continue to degrade
  - Bentonite will significantly reduce contaminant mobility
- ZVI still present in treatment area (0.8 and 1.3%) after 9 months
- Hydraulic conductivity reduced by 400 times
Summary

- New 38,000 ft² parking lot with 65 spaces
- Total project cost = $1.96 Million
- Only about 60% of the project cost was for treatment, rest was for restoration and infrastructure