

# Emulsified Oil Bioremediation Case Studies

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Evaluation of In Situ Bioremediation of  
Chlorinated Organic Solvents in Ground Water

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# Acknowledgements

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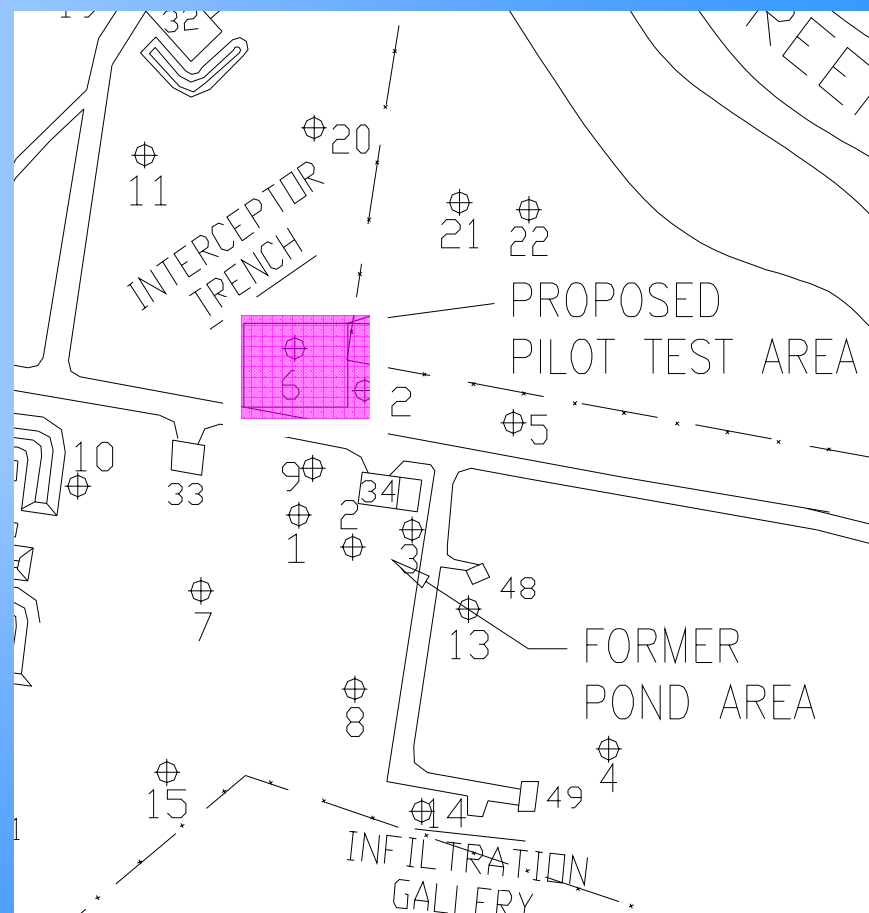
# Case Study Overview

- **Permeable Reactive Biobarrier**
  - Rocket manufacturing facility
  - ClO<sub>4</sub> / Chlorinated Solvents
  - Shallow / easy drilling
- **Source Area Treatment**
  - Tarheel Army Missile Plant
  - TCE source area
  - Weathered rock
  - Site access / utility issues

# ClO<sub>4</sub> / TCA Biobarrier

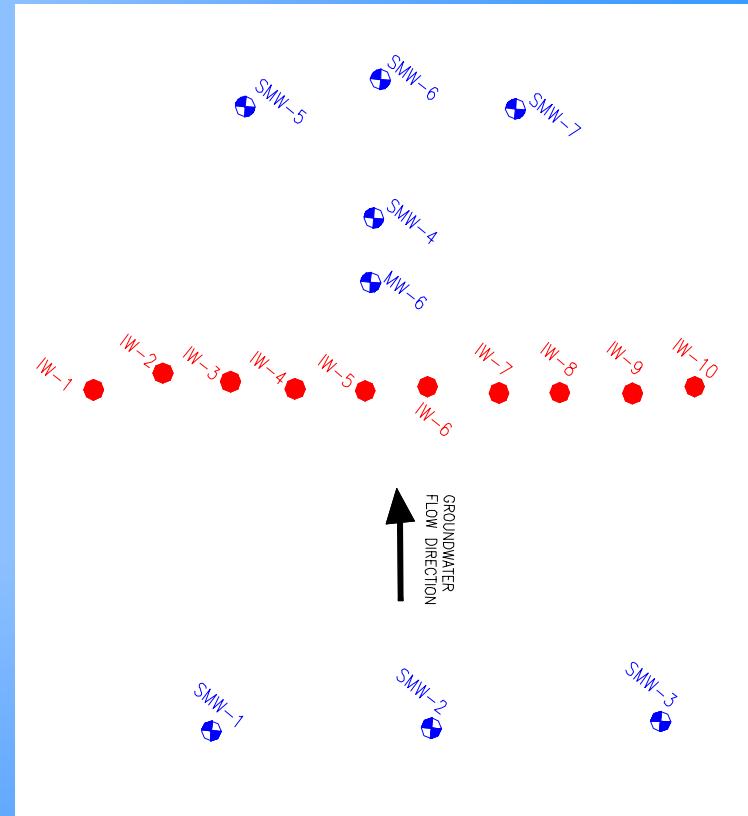


- **Former leaking surface impoundment**
- **Groundwater concentrations**
  - 5 to 150 mg/L Perchlorate
  - 5 to 20 mg/L 1,1,1-TCA
  - 0.1 to 0.3 mg/L TCE
- **Existing Pump and Treat System**
  - **Interceptor trench**
  - **Air stripper**
  - **Infiltration gallery**



# Site Conditions / Barrier Design

- **Hydrology / Geology**
  - Water table at 5 to 10 ft
  - Silty clay confining layer at ~20 ft
  - ~10 ft of saturated sand
- **Hydraulic Conductivity**
  - Initial data indicated low K (~ 1 ft/d)
  - Additional characterization showed K = 20 – 50 Ft/d
  - V = 300 to 800 Ft/yr (high V due to P&T system)
- **Barrier Design**
  - Install 10 direct push wells – 5 Ft OC
  - Provide enough oil to support biodegradation for 18 months



# Injection System

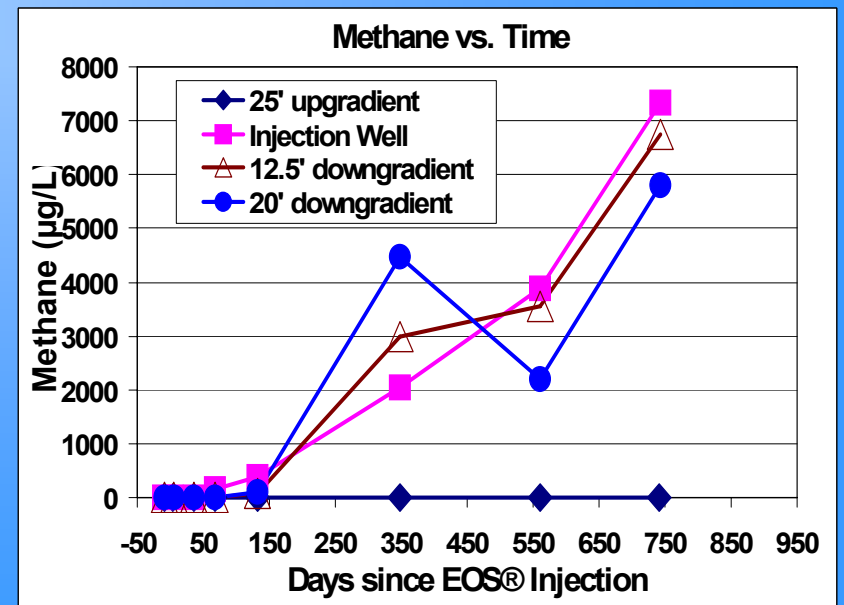
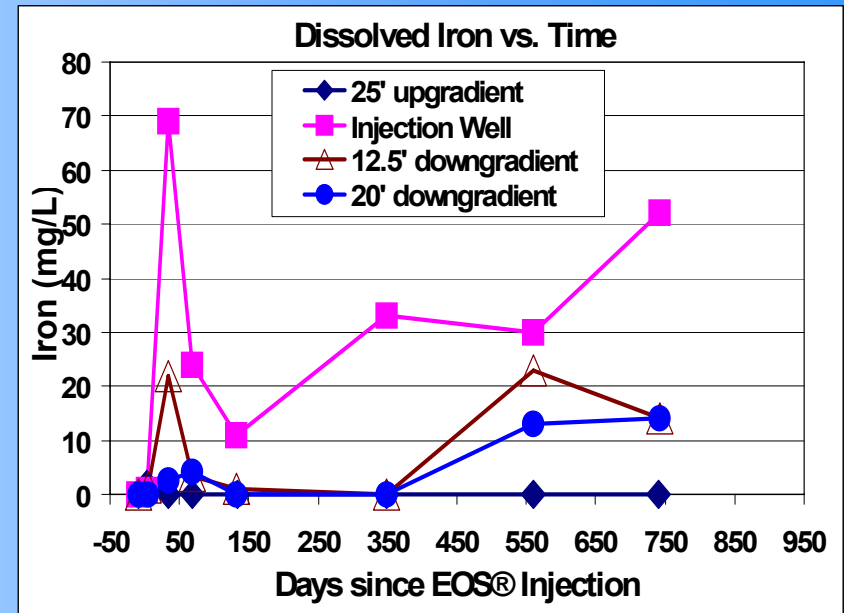
- **Injection Volumes**
  - 55 gal. diluted emulsion per well
    - 11 gal. EOS<sup>®</sup> concentrate
    - 44 gal. water)
  - 165 gallons chase water per well
- **Injection Procedure**
  - Injected every other wells at one time using manifold system
  - Rest over night, they inject other half
- **Completed by two people in two days**



# Geochemistry

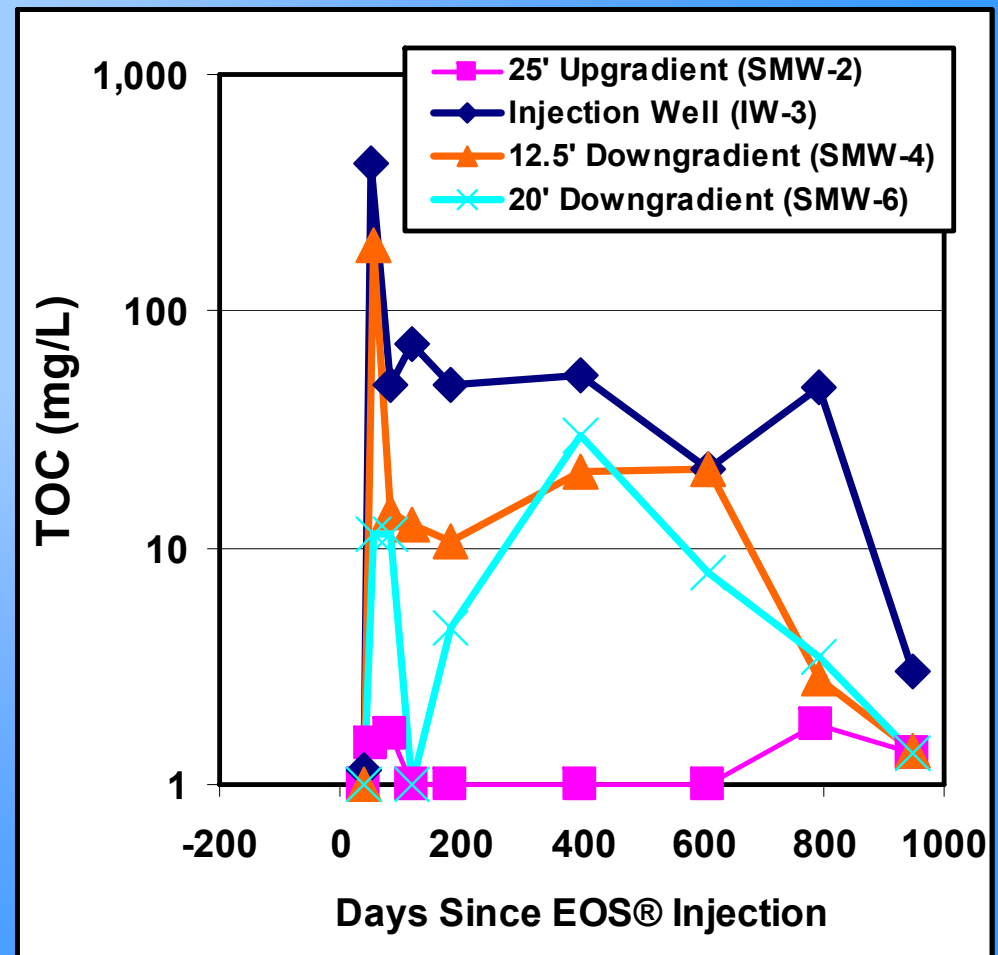
- **Iron**
  - Large initial increase in injection wells
  - Some migrated downgradient
- **Methane**
  - Steady increase with time
  - Up to 7 mg/L in downgradient wells

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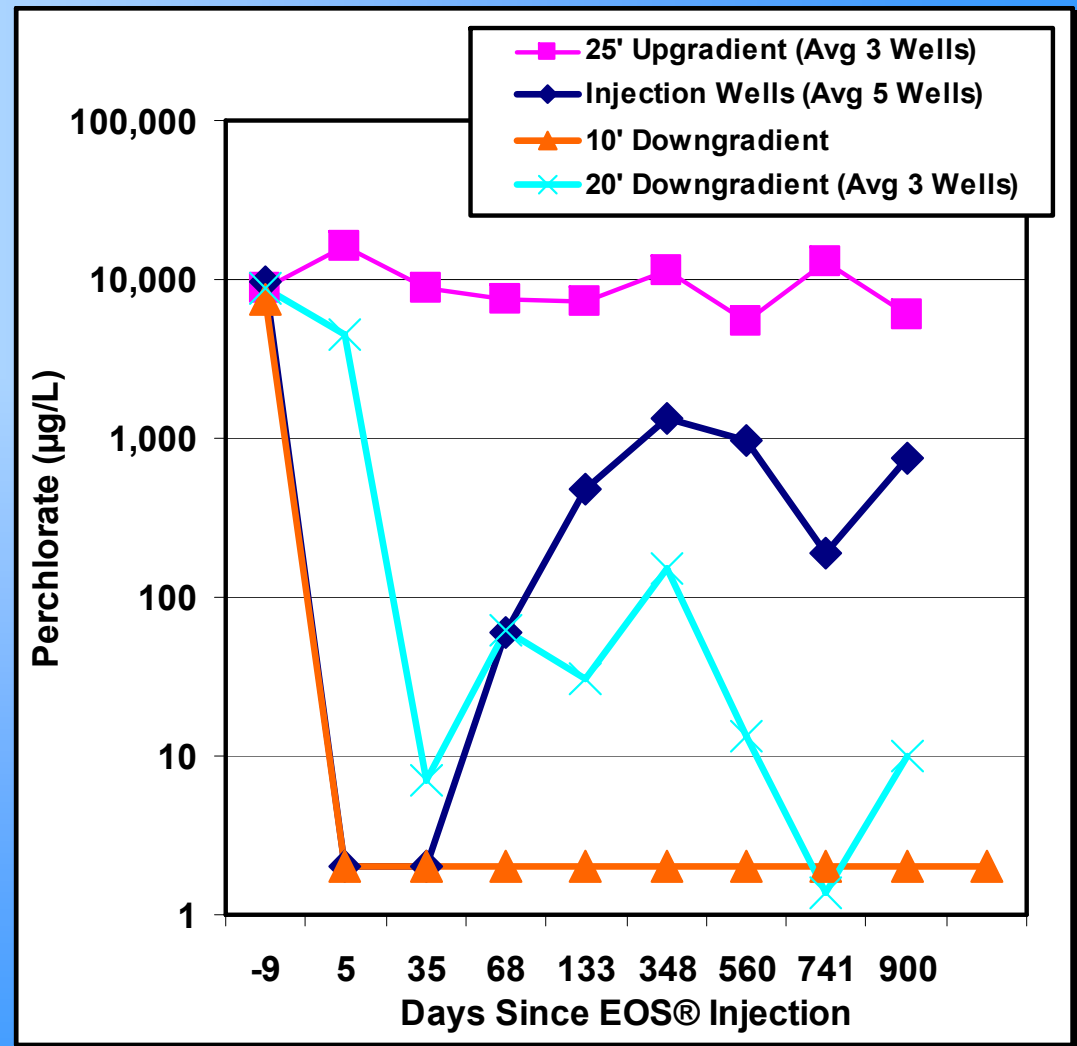
# Monitoring Results - TOC

- **Total Organic Carbon (TOC)**
  - Initial spike
  - Stabilized at relatively constant value
  - Rapid decrease with distance downgradient
  - TOC dropped during last sampling indicating substrate is starting to be exhausted



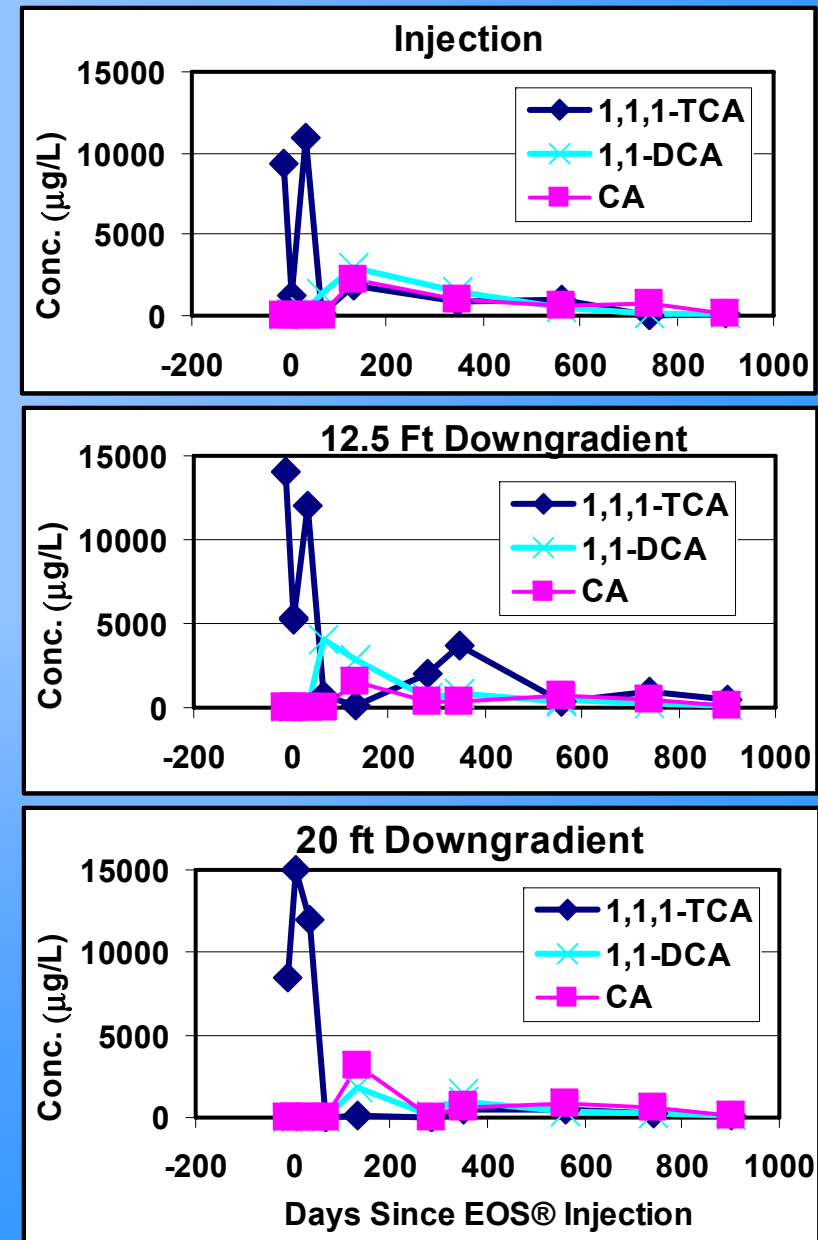
# Monitoring Results - Perchlorate

- **Perchlorate**
  - Rapid decrease in injection and downgradient wells
  - 90% to >99% removal in injection wells
  - 99% to >99.99% removal in downgradient wells



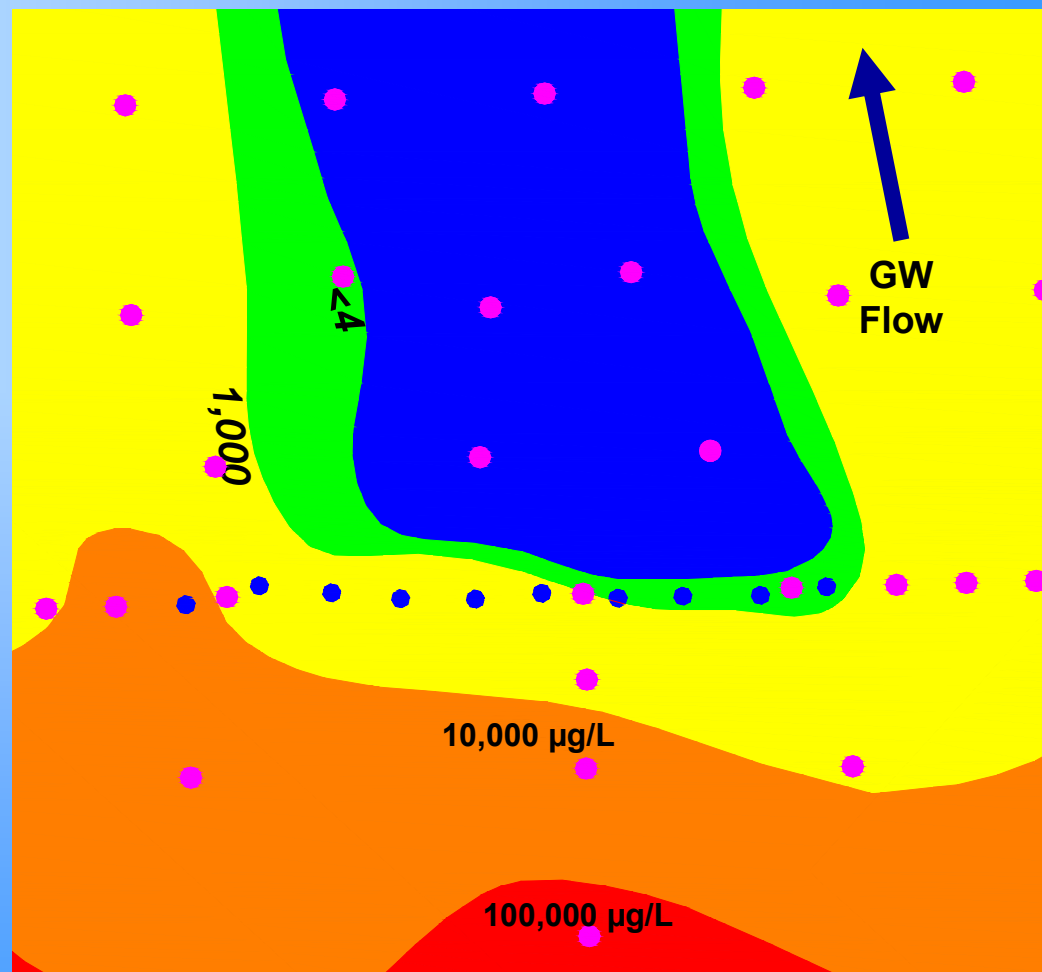
# Monitoring Results - TCA

- **1,1,1-TCA**
  - Reduced by > 95%
  - 1,1-DCA and CA accumulated then declined
  - However, TCA is NOT BDL in downgradient wells
  - High V resulted in 1-3 week contact time in oil treated zone
  - Additional contact time required for complete treatment



# Perchlorate Results

- Perchlorate
  - Geoprobe used to map distribution at 6 months post-injection
  - $<4 \mu\text{g/L}$  in wide area downgradient of barrier
  - No evidence of flow bypassing



# **ClO<sub>4</sub> / TCA Biobarrier Summary**

- **EOS<sup>®</sup> easily injected with good distribution**
- **Geochemical parameters suitable for anaerobic biodegradation**
- **Complete perchlorate removal observed up to 35 feet downgradient of barrier**
- **>95% reduction in 1,1,1-TCA observed 20 feet downgradient of barrier**
- **Single EOS<sup>®</sup> injection lasted over three years**
- **Barrier performance has not been adversely impacted by changes in hydraulic conductivity**
- **Anaerobic degradation did release dissolved Fe and Mn**
  - **Operational problems with P&T system located 35 ft away**

# Tarheel Army Missile Plant

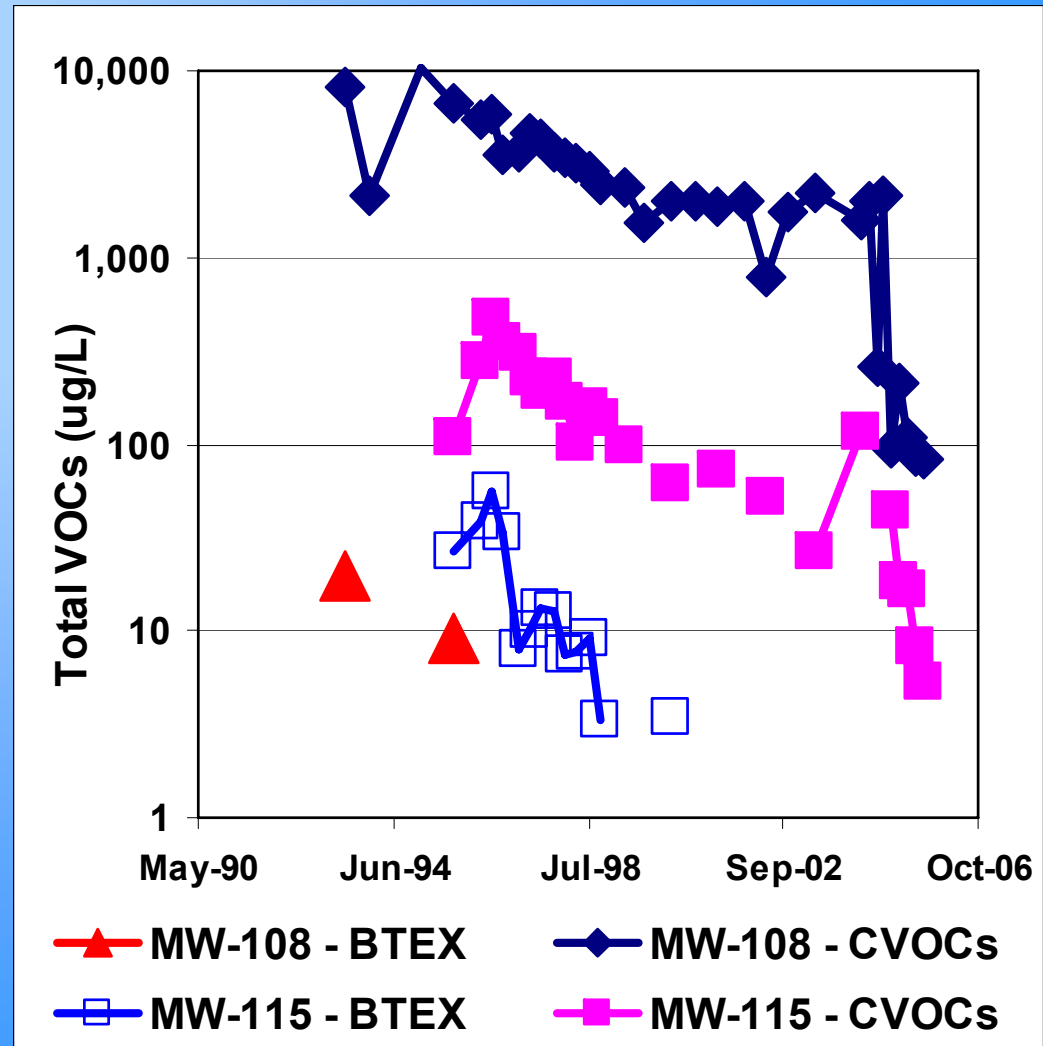


- **Site Conditions**
  - 100 ft by 100 ft source area
  - Existing AS/SVE system
    - Oxidative conditions
  - Chlorinated solvents at 2 to 4 mg/L
- **Challenges**
  - Low permeability = low injection rates
  - Existing AS/SVE system
  - Tunnel
  - Expensive wells (air rotary drilling, lots of thick concrete)
  - UIC permit required that extracted water could not be reinjected



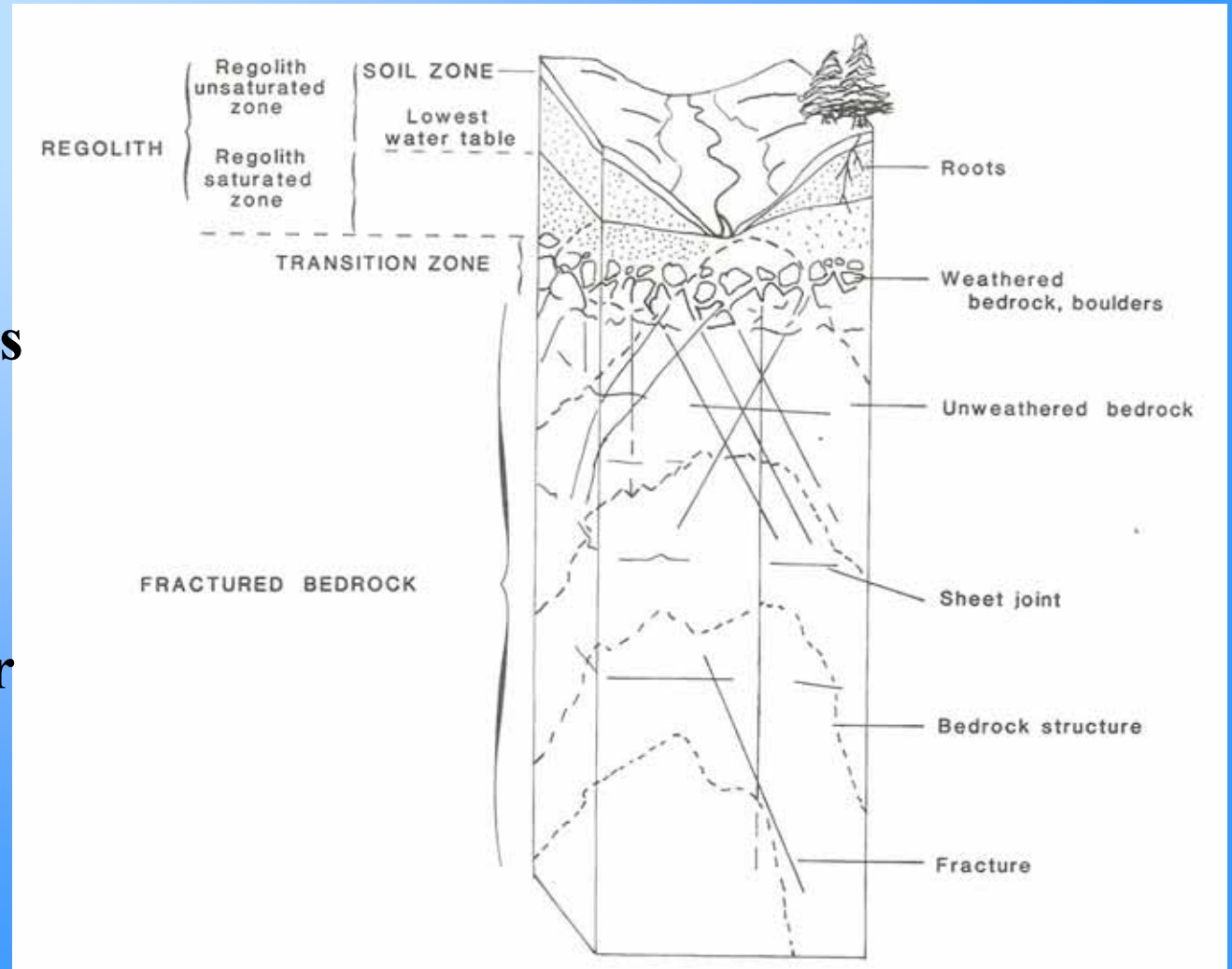
# VOCs in Groundwater

- AS/SVE system installed in 1995
- BTEX reduced to BDL
- Some initial reduction in CVOCs
- CVOCs plateau in 1999
- EOS<sup>®</sup> injection in July 2004



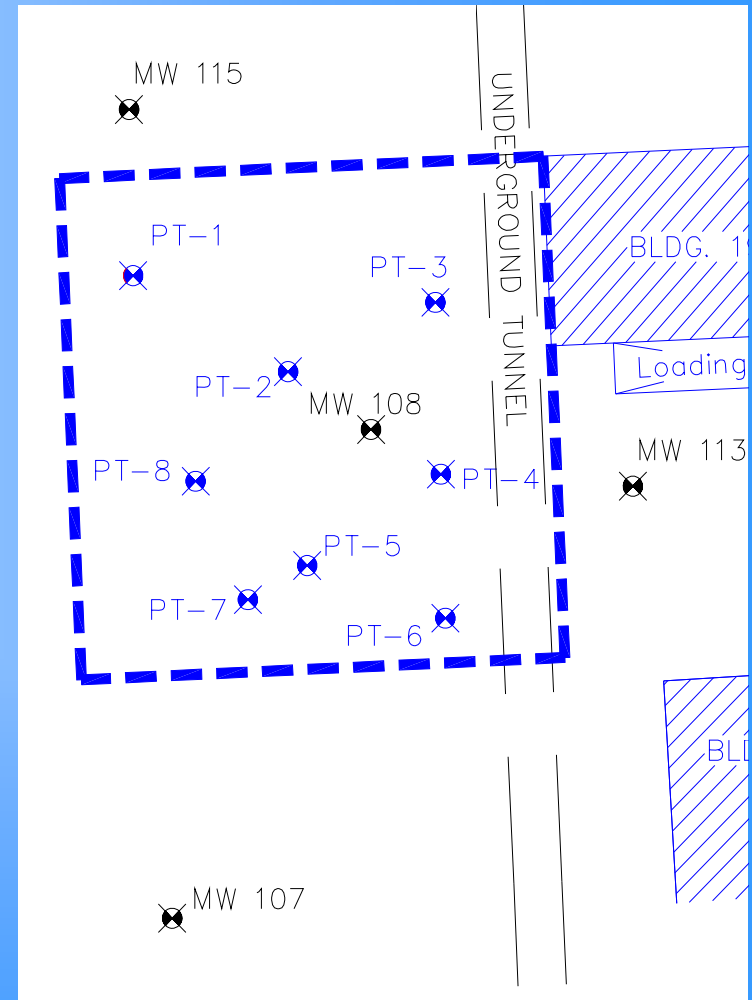
# Piedmont Hydrogeology

- **Clayey residual soils**
- **Bedrock 12 to 30 ft bgs**
- **Depth to groundwater ~ 6-12 ft bgs**
- **Groundwater velocity ~ 24 ft/yr**



# Technical Approach

- **Engineering Approach**
  - Inject EOS<sup>®</sup> to stimulate reductive dechlorination
  - Short-term groundwater recirculation to distribute substrate through fractures
- **Treatment Approach**
  - TCE in high K zones will be rapidly degraded
  - As TCE diffuses out of low K zones, contacts substrate and will be degraded
  - Future bioaugmentation if required



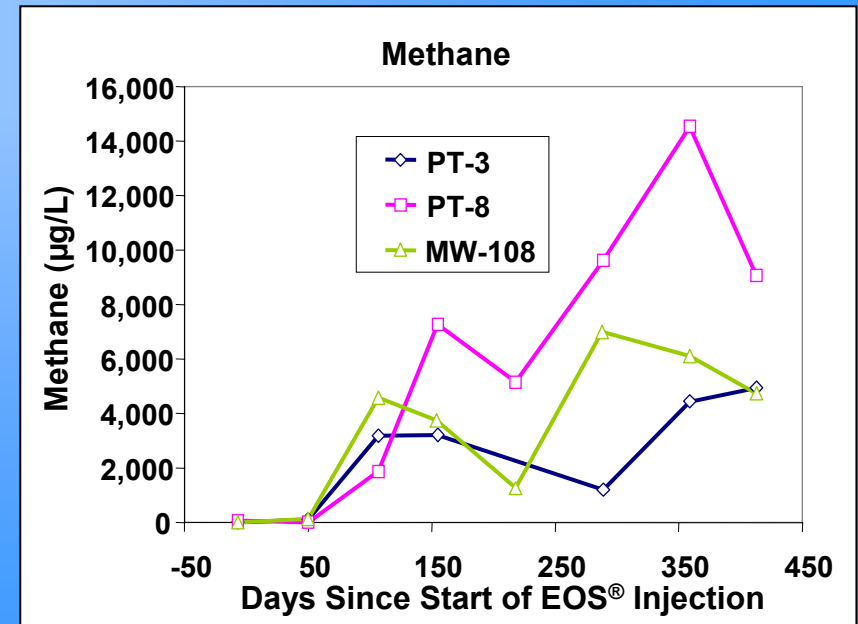
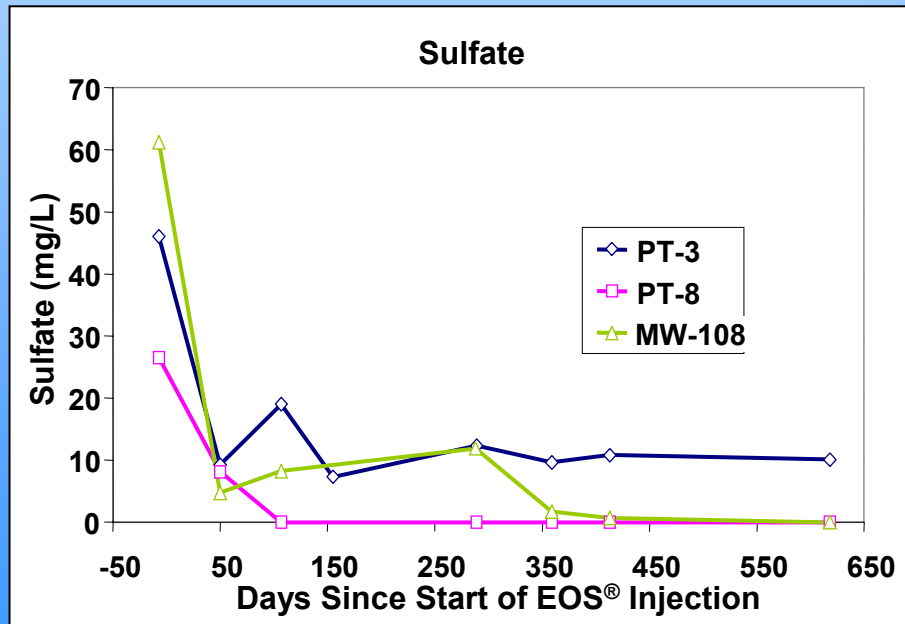
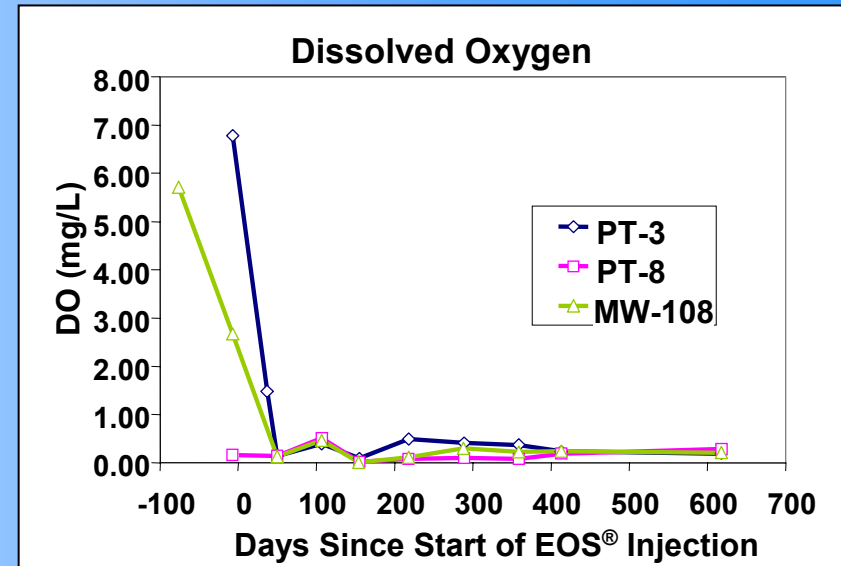
# Injection System

- Use widely spaced wells to reduce drilling costs
  - Six-inch air rotary
  - Wells 30 – 35 Ft OC
- All piping below grade
- Inject EOS<sup>®</sup> in two batches over two months
- $Q < 0.5$  gpm



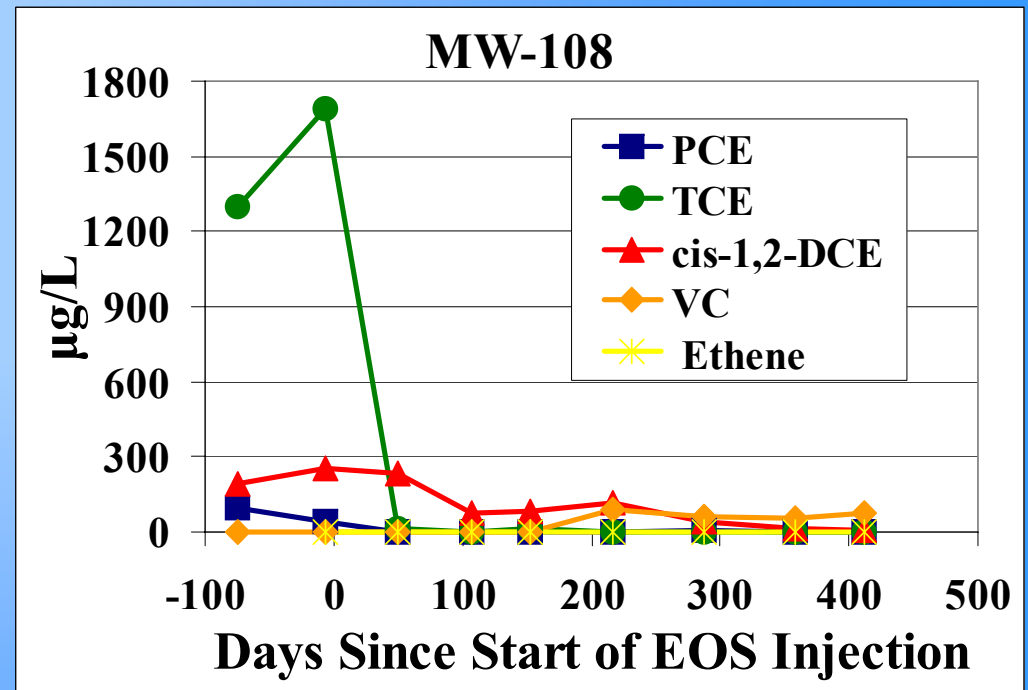
# Geochemistry

- Rapid depletion of oxygen
- Sulfate reduced
- Methane production
- Indicates strongly reducing conditions



# Chlorinated Solvent Results

- **Rapid reduction in TCE**
- **Production of cis-DCE and VC**
- **Bioaugmentation in Spring 06**
- **VC continues to slowly decline**



# TAMP Summary

- **EOS<sup>®</sup> effectively distributed throughout treatment area**
- **Quickly established favorable geochemistry for reductive dechlorination**
- **TCE reduced to below detection (<1.0 µg/L) in monitor wells**
- **Remedial goals met within 6 months of EOS<sup>®</sup> injection**
- **Dramatic improvements in groundwater conditions compared to prior technologies**

# Questions

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