

Enhanced Bioremediation for Treatment of Chlorinated Solvent Residual Source Areas – Case Study and Implications



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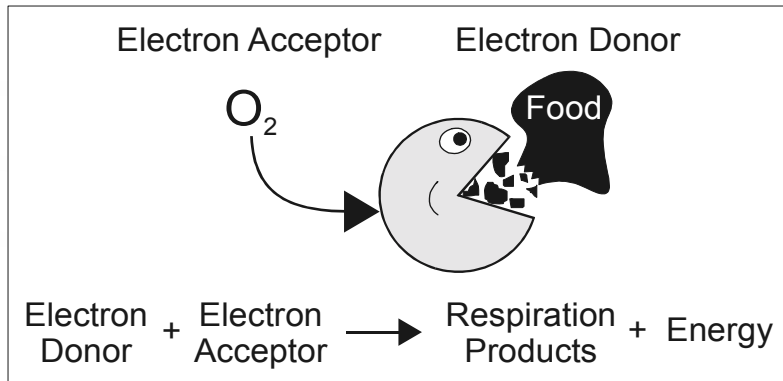
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Bioremediation Background

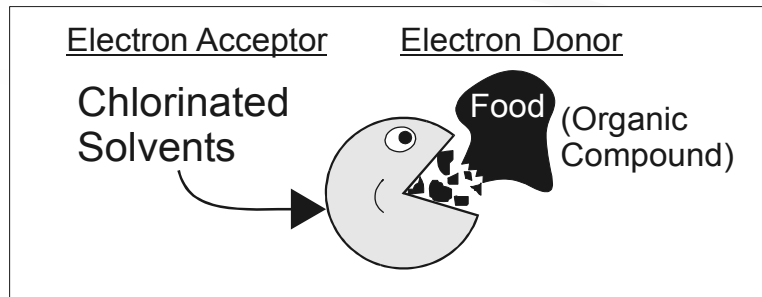
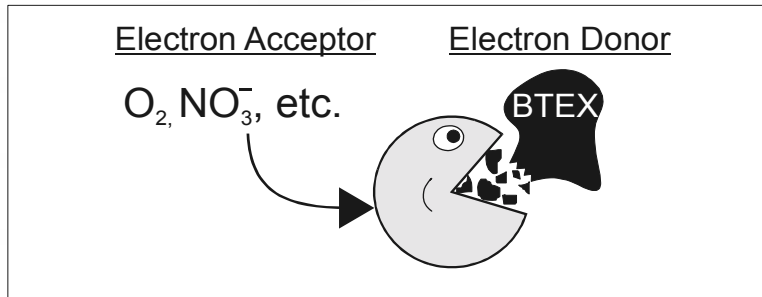
- In Situ Bioremediation of chlorinated solvents:
 - Solvents utilized as electron acceptors by indigenous microorganisms
 - Chlorine atoms sequentially replaced with hydrogen through “reductive dechlorination”

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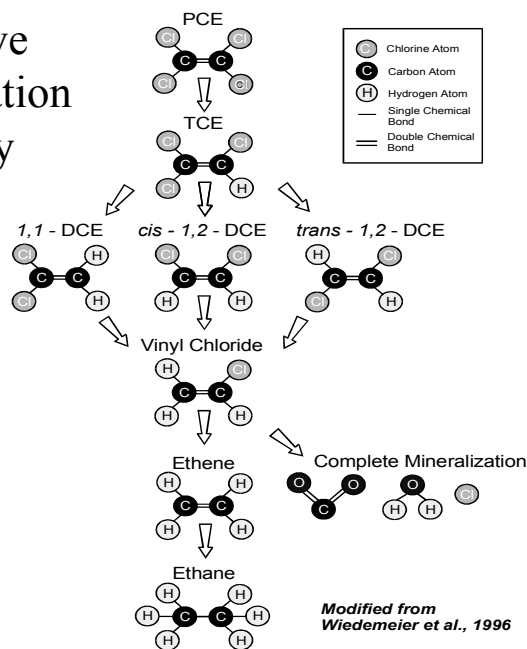
Microbial Metabolism



Bioremediation Metabolism



Reductive Dechlorination Pathway



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A Paradigm Shift?

- Conventional applications for in situ bioremediation limited to dissolved phase for two primary reasons:
 - Concerns about toxicity
 - Impact on nonaqueous sources thought to be no better than pump and treat
- New research reveals that in situ bioremediation may be extremely effective for chlorinated solvent source areas

Enhanced Mass Transfer

- In situ bioremediation can enhance mass transfer, addressing the concerns previously thought to limit bioremediation applications:
 - Many investigators have shown that dechlorinating bacteria actually have an ecological niche in high concentration areas
 - Several studies have shown that in situ bioremediation enhances mass transfer of contaminants through at least three mechanisms

Mechanisms of Enhanced Mass Transfer

- Mechanisms for enhanced mass transfer
 - Bioremediation removes contaminants from the aqueous phase, thereby increasing the driving force for mass transfer = $k(C_s - C)$
 - Increasing solubility of reductive dechlorination degradation products greatly increases the maximum aqueous contaminant loading
 - The electron donor solution can be used to decrease interfacial tension, thereby increasing the effective solubility

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Enhanced Mass Transfer: Mechanisms 1 and 2

- Enhanced mass transfer of chlorinated solvent NAPLs due to reductive dechlorination has been demonstrated in at least two laboratory batch studies:
 - Yang and McCarty (2000) showed enhanced PCE dissolution up to a factor of 5 higher than without reductive dechlorination
 - Carr et al. (2000) showed reductions in NAPL longevity of 83% due to reductive dechlorination in continuously stirred tank reactors

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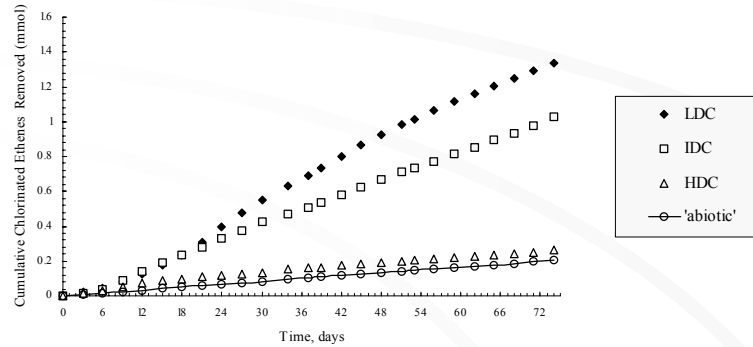
Enhanced Mass Transfer: Mechanisms 1 and 2

- Enhanced mass transfer of chlorinated solvent NAPLs due to reductive dechlorination has been demonstrated in at least one laboratory column study:
 - Cope and Hughes (2001) demonstrated total chlorinated ethene removal was 5 to 6 times higher with reductive dechlorination as compared to abiotic washout

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Enhanced Mass Transfer: Mechanisms 1 and 2

- Enhanced chlorinated ethene removal due to reductive dechlorination in columns with PCE DNAPL (*Courtesy of Joe Hughes*)

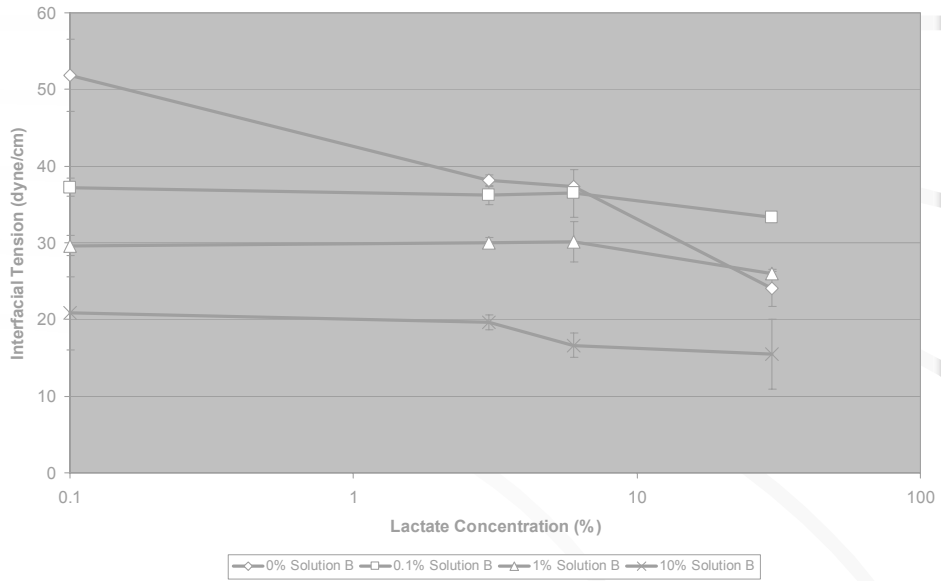


Enhanced Mass Transfer: Mechanism 3

- The impact of sodium lactate and other electron donor solutions on water-TCE interfacial tension was investigated in unpublished laboratory studies
- The results supported a pending patent for the Idaho National Engineering and Environmental Laboratory
- The process is referred to as Bioavailability Enhancement Technology™ (B.E.T.™)

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Impact of Electron Donor Solutions on Interfacial Tension

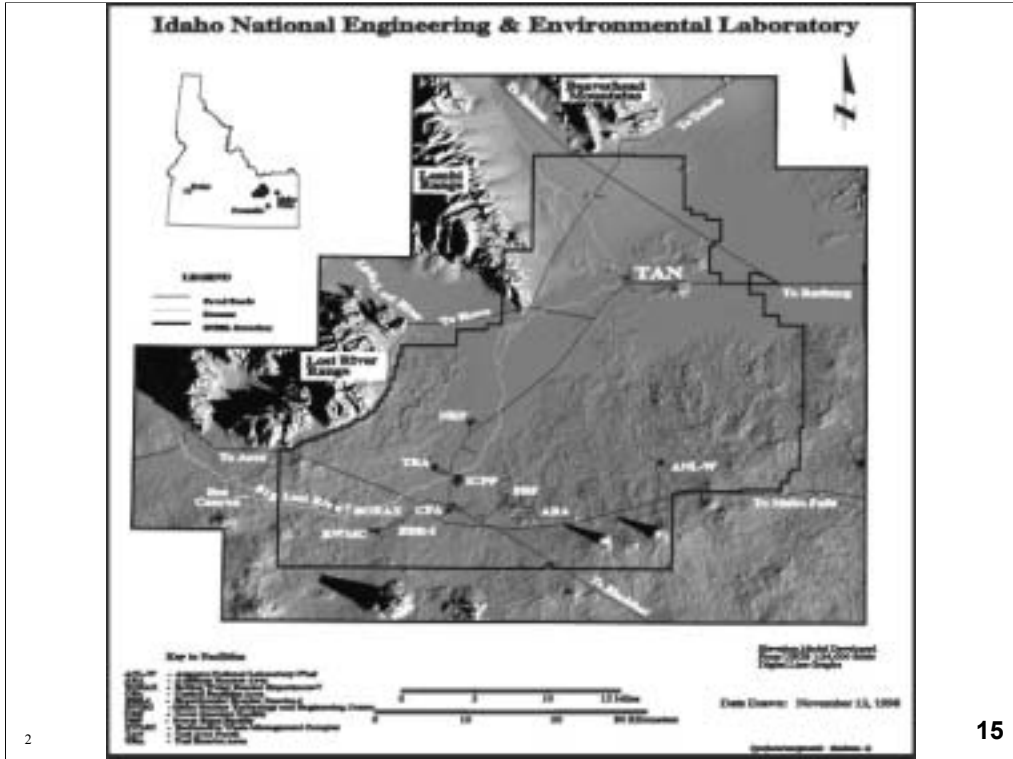


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Enhanced Mass Transfer: Mechanism 3

- Enhanced mass transfer due to electron donor solution interaction with nonaqueous TCE, followed by complete reductive dechlorination has been observed in at least one field study:
 - Sorenson (2000, in press) showed that TCE concentrations were greatly enhanced due to facilitated transport associated with the electron donor solution (high concentration sodium lactate)
 - This work will serve as our case study

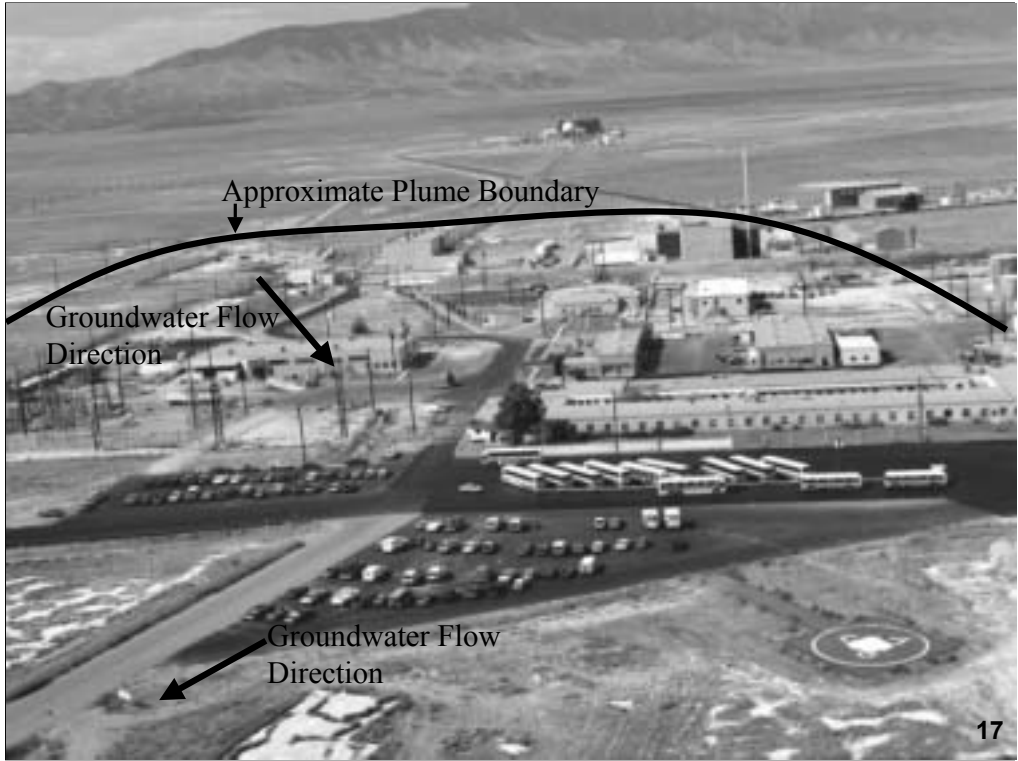
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Test Area North (TAN) Background

- Industrial wastewater (including solvents), low-level radioactive wastes, and sanitary sewage were injected directly to the Snake River Plain Aquifer from the late 1950s to 1972
- TCE plume is nearly 2 miles long
- Residual source area is about 100 ft in diameter
- Contaminated aquifer is about 200-400 ft deep
- Aquifer is comprised of fractured basalt

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Record of Decision (1995)

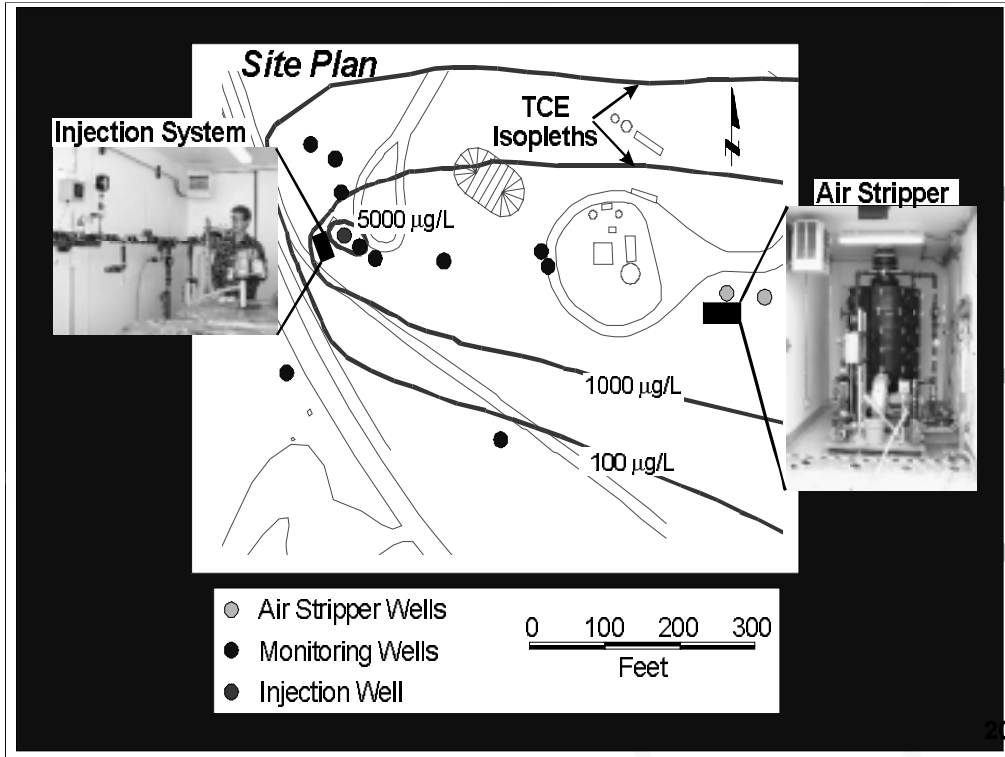
- Pump and treat selected as default remedy
- Treatability studies established for alternative technologies:
 - zero-valent iron
 - monolithic confinement
 - in situ chemical oxidation
 - **in situ bioremediation**
 - natural attenuation
- 100-year remedial time frame

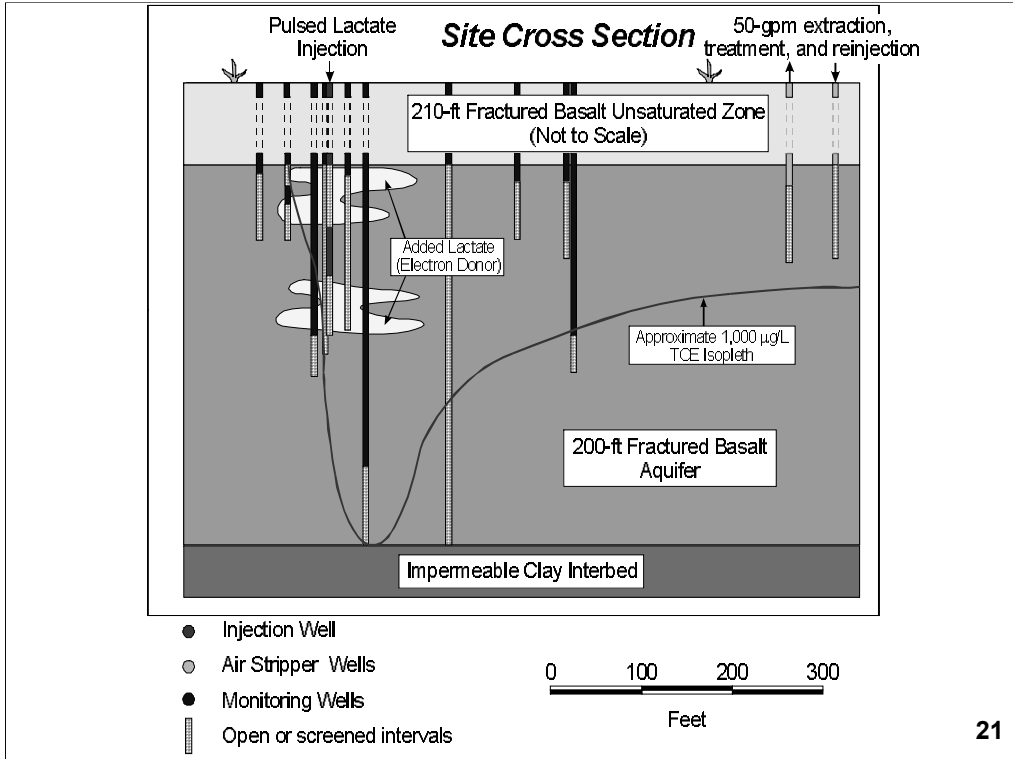
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Objectives for the 1-year In Situ Bioremediation Field Evaluation

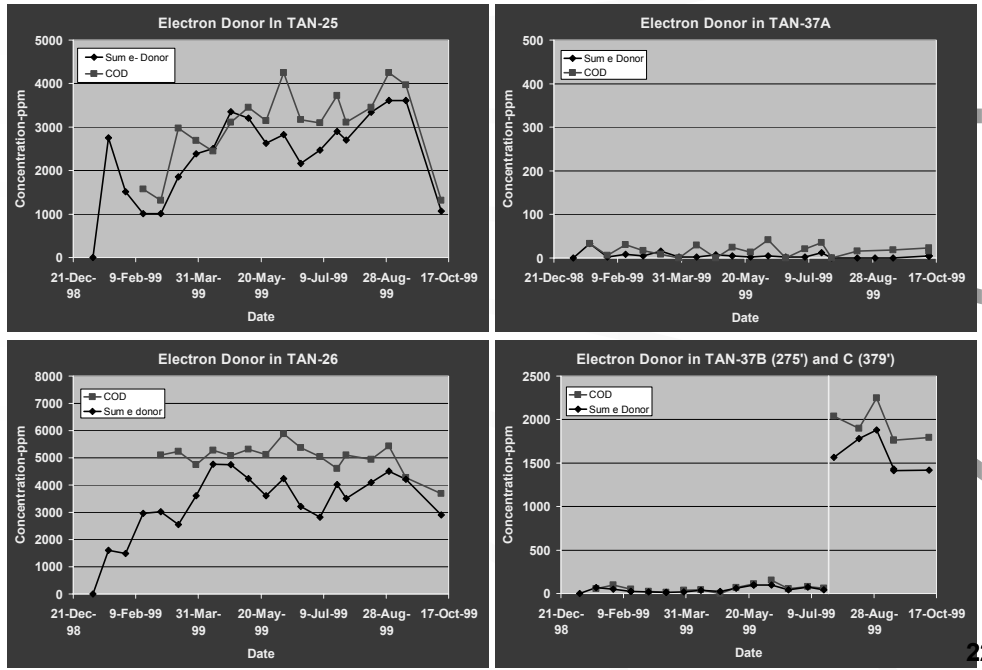
- Primary Objective: Demonstrate that biodegradation of TCE can be significantly enhanced through electron donor addition
- Create hydraulic “treatment cell” to maintain hydraulic containment of the source area and control residence time
- Determine controls on process efficiency through extensive monitoring

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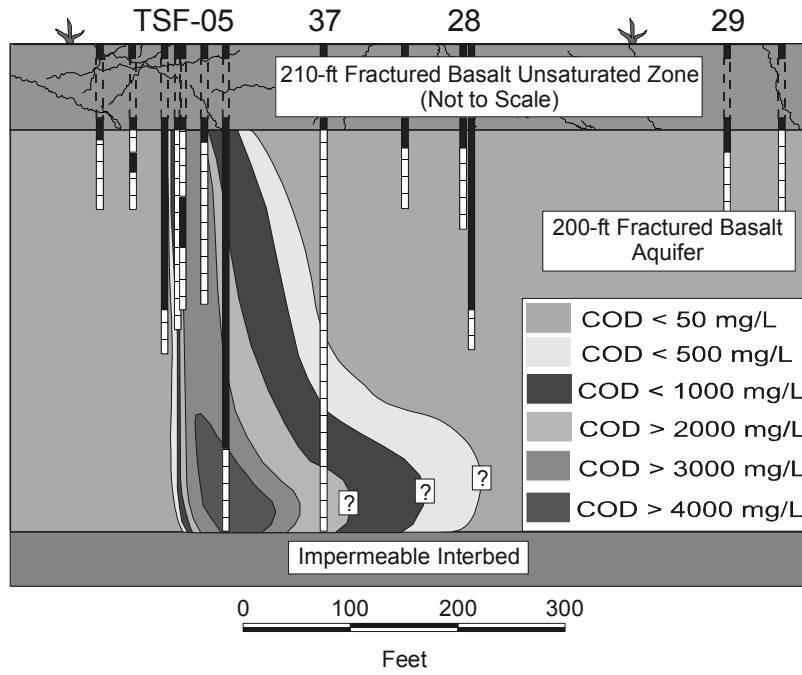




Electron Donor Distribution

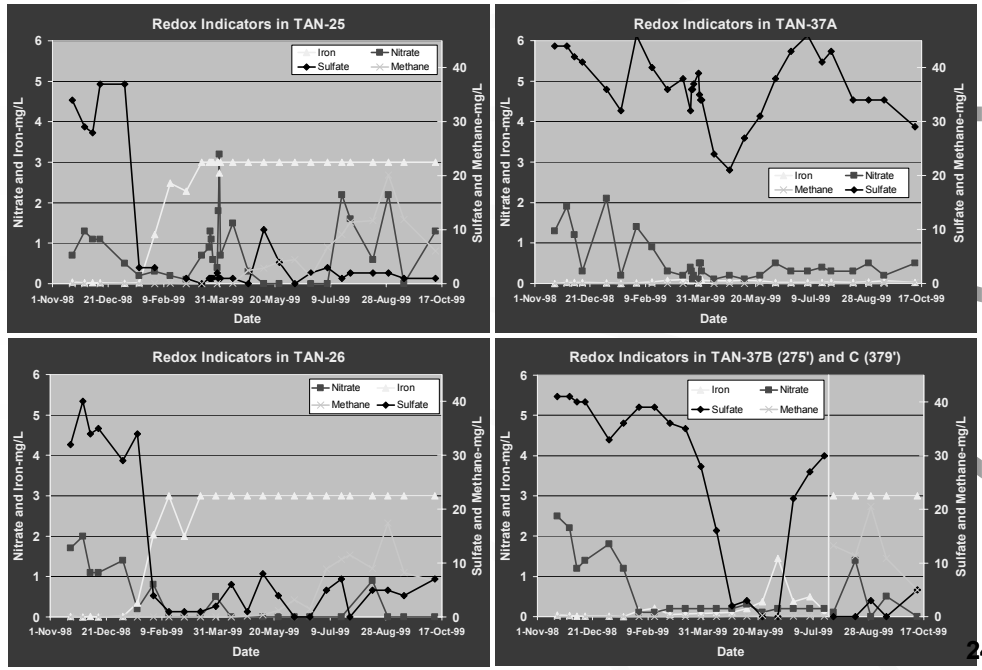


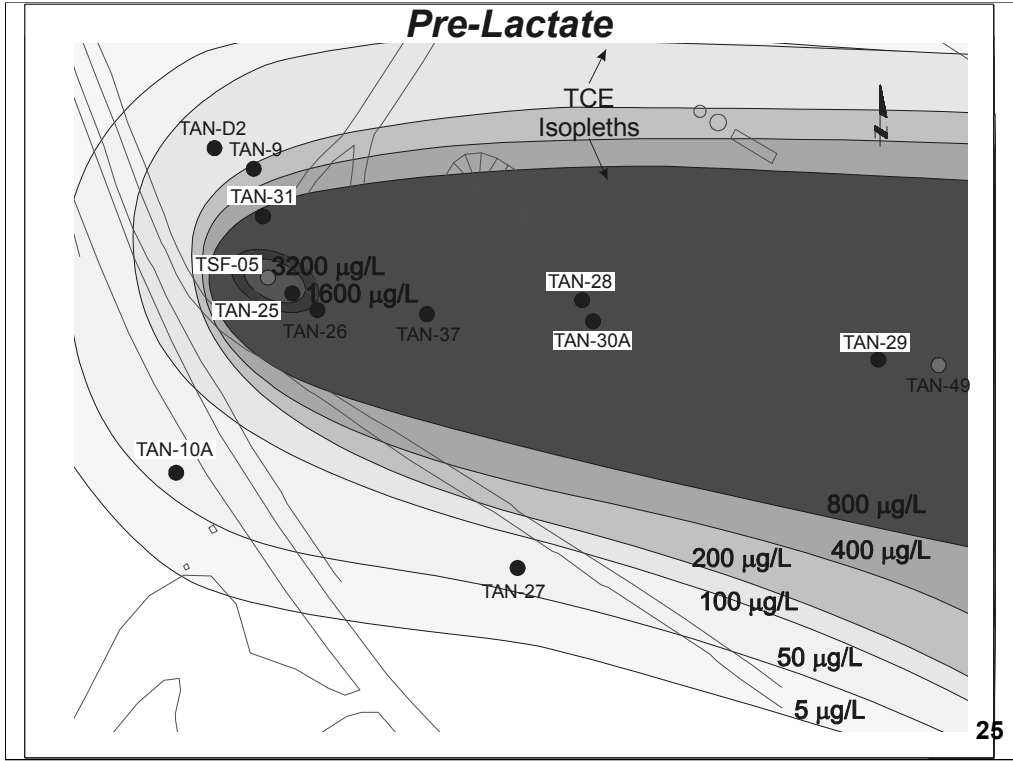
Chemical Oxygen Demand Sept. 13, 1999

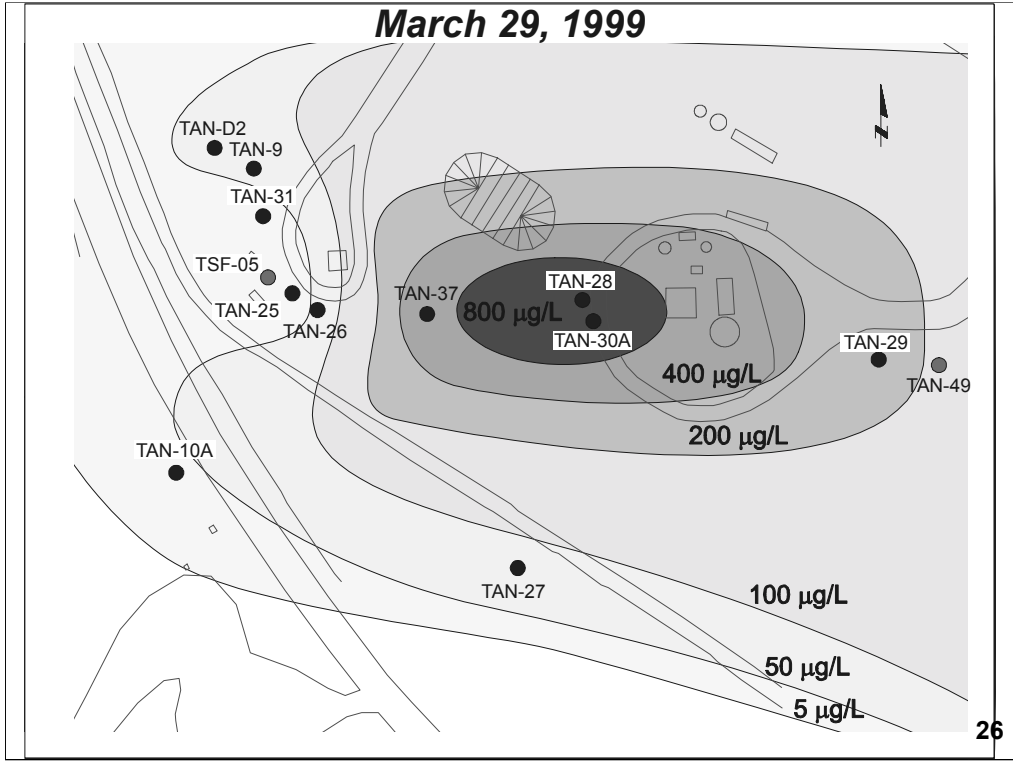


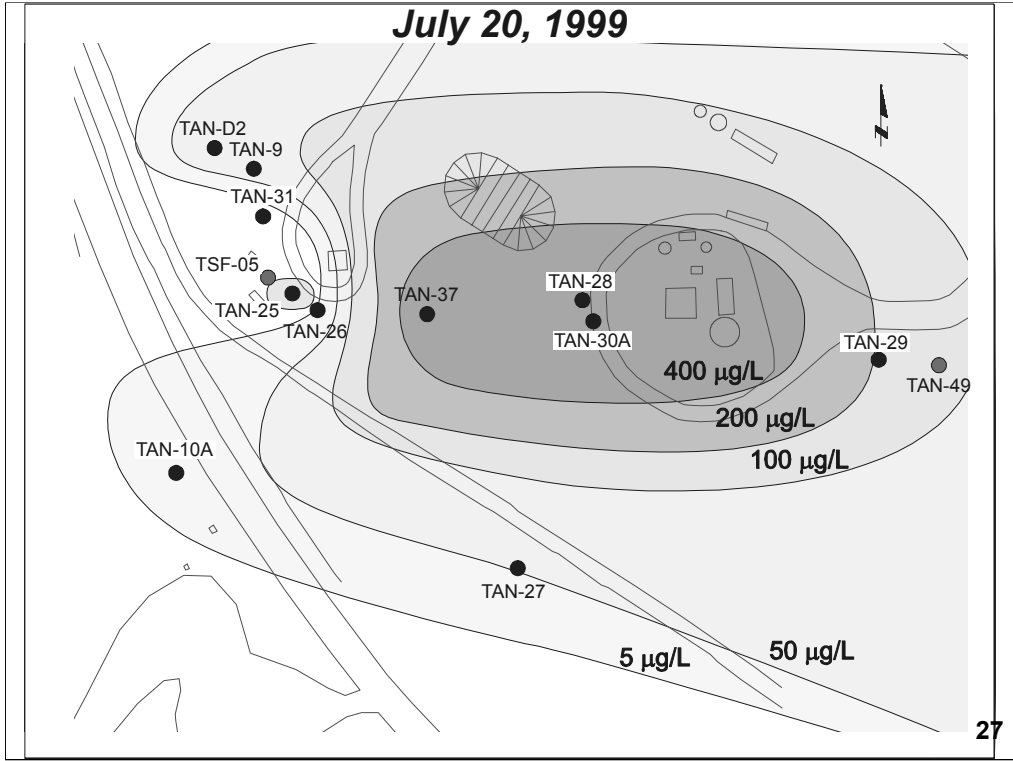
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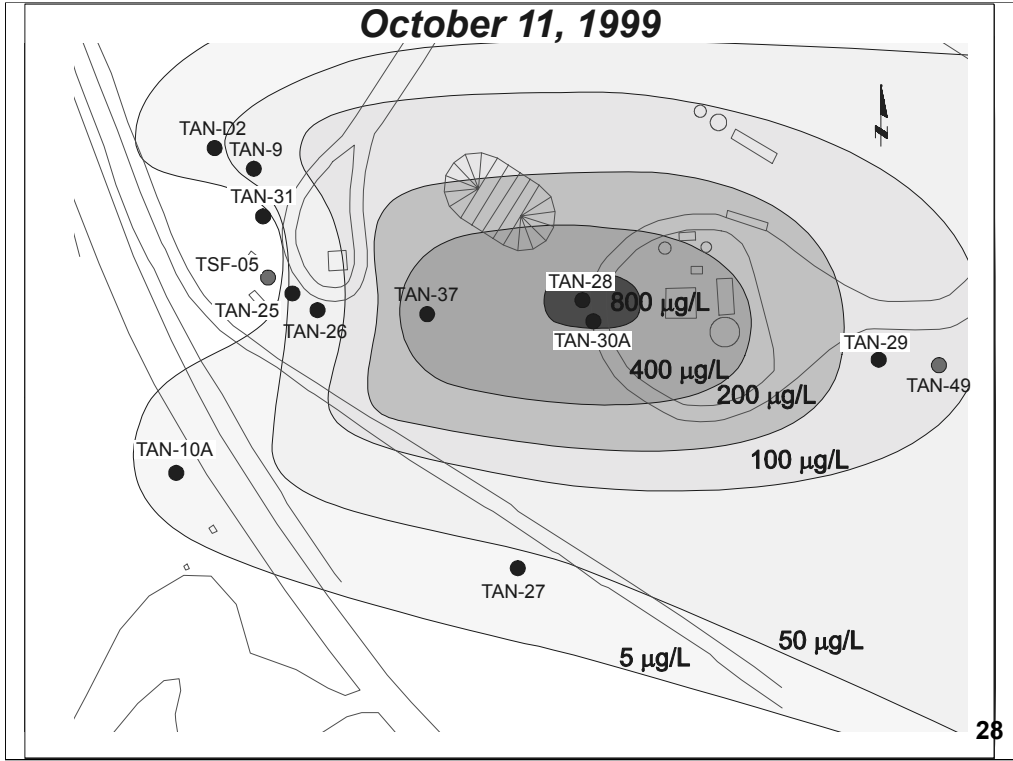
Redox Conditions

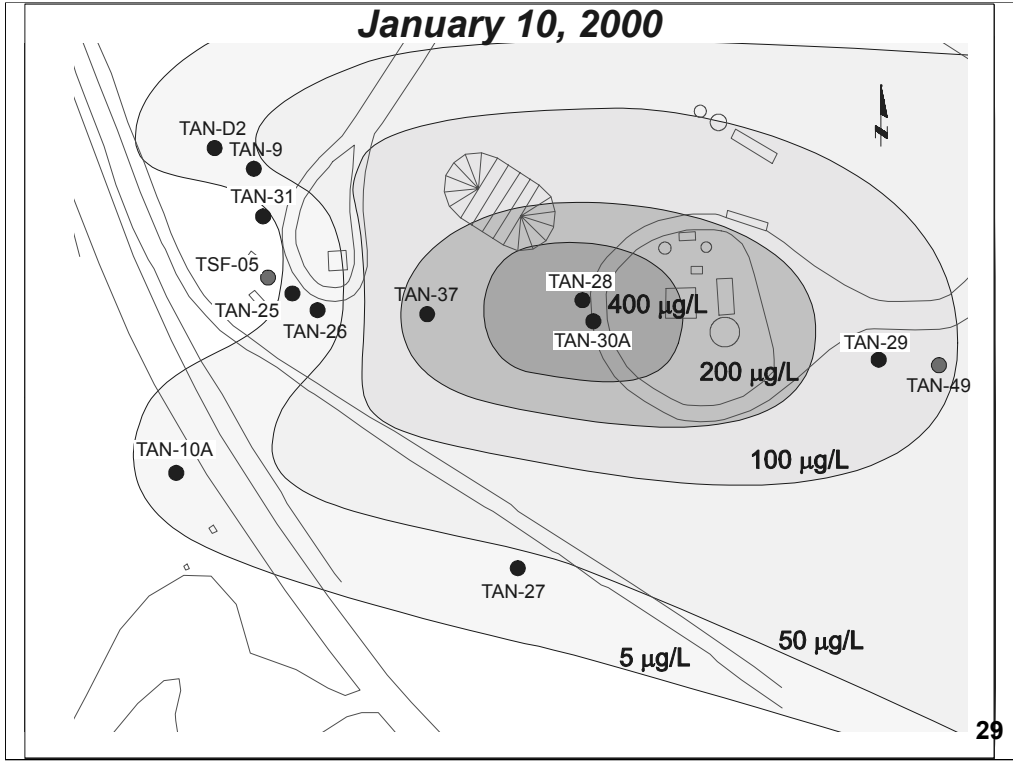


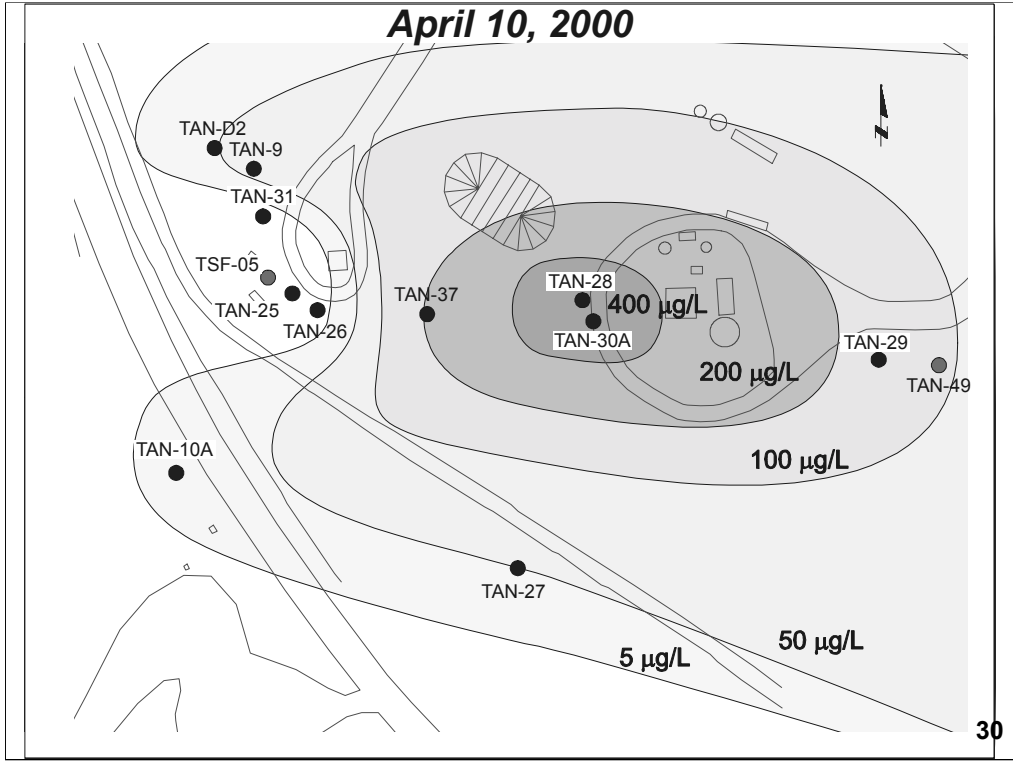


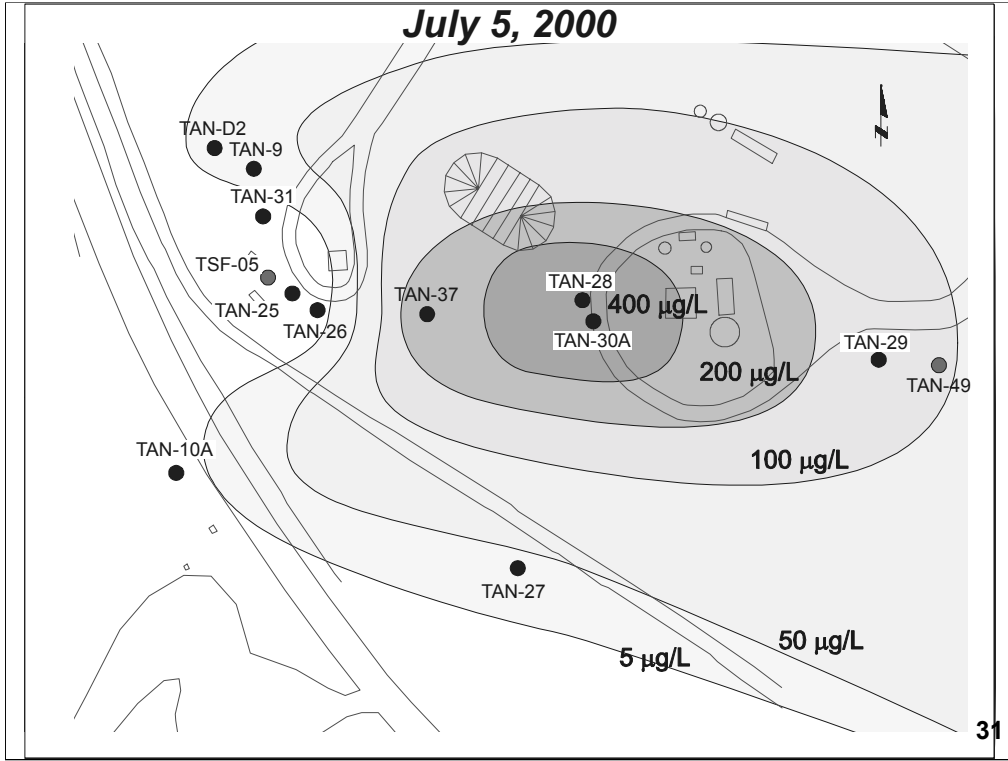


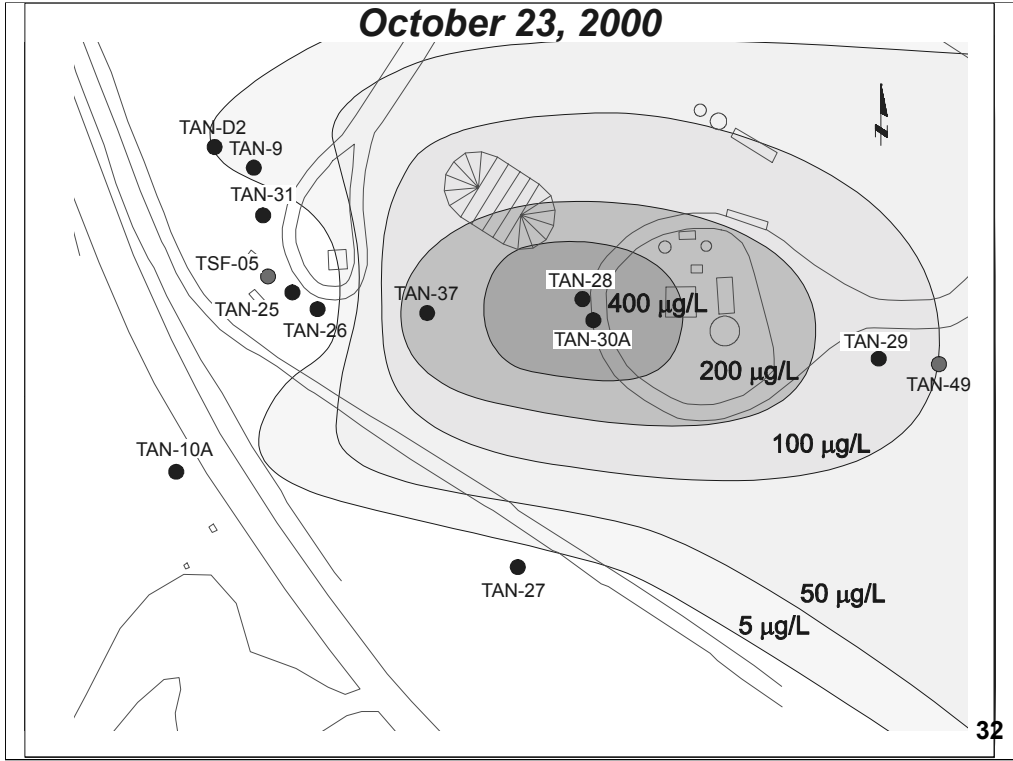




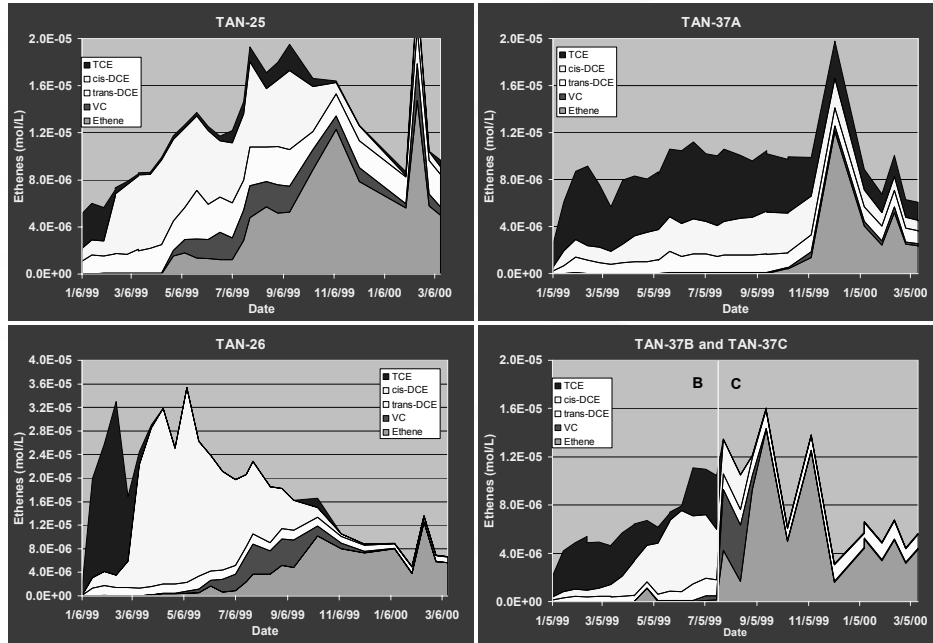






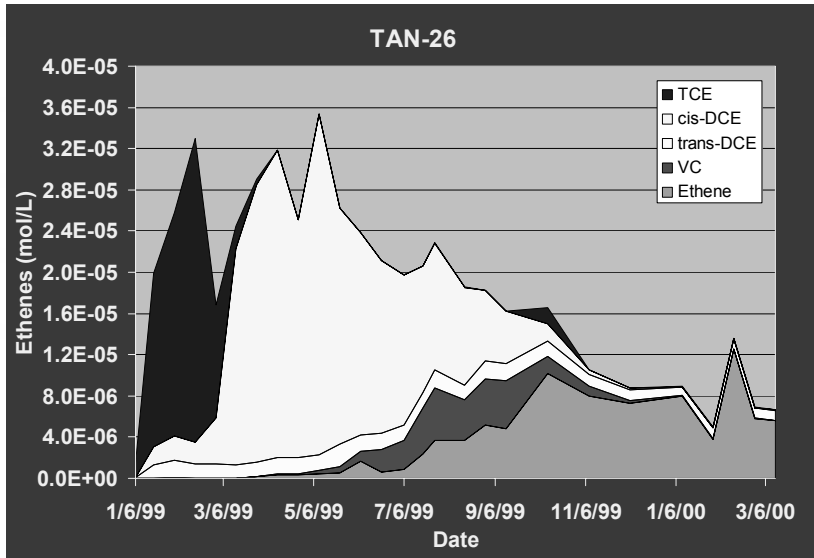


Long-Term Dechlorination

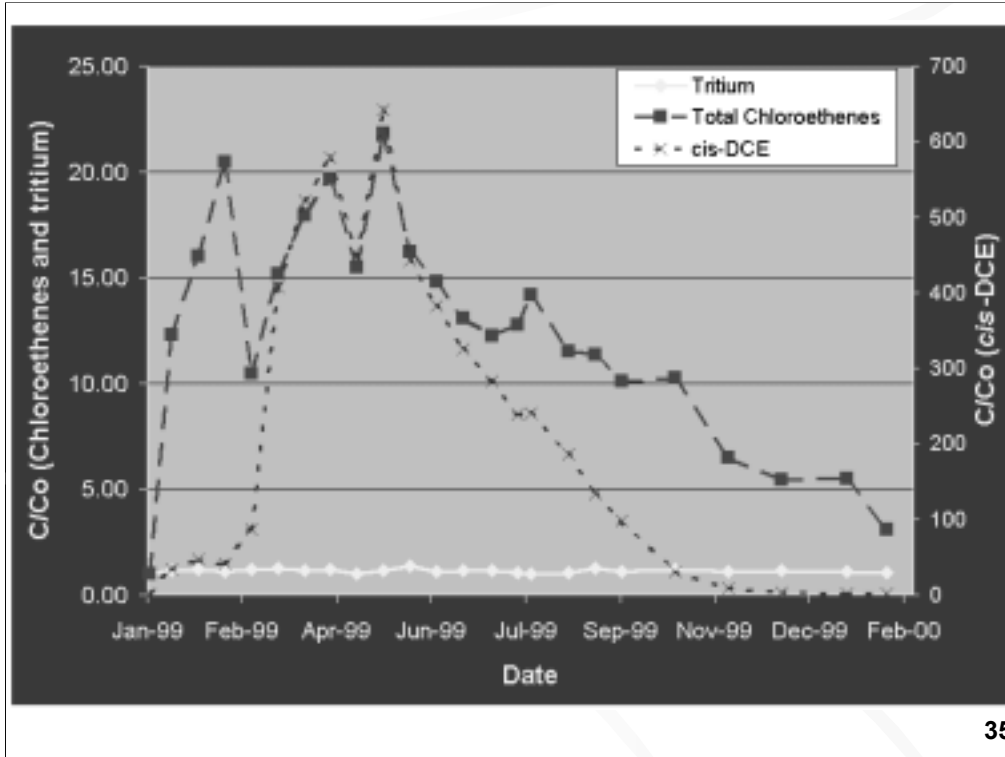


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Enhanced Mass Transfer from DNAPL Source Area

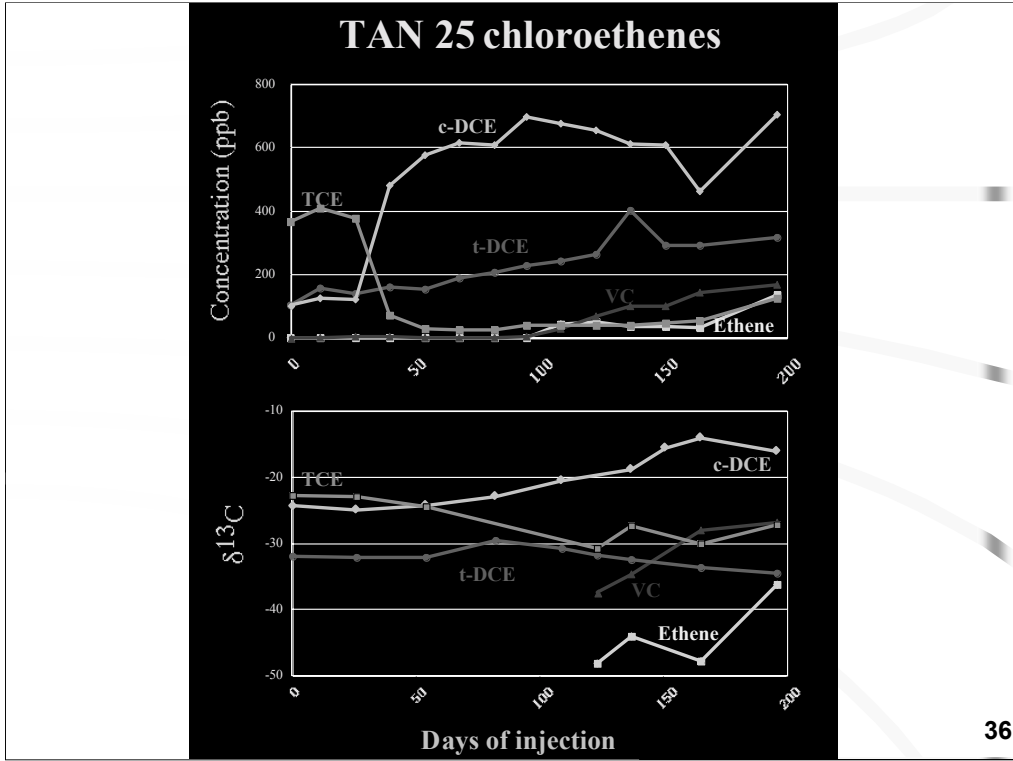


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Status of Enhanced In Situ Bioremediation at TAN

- Formal regulatory approval to implement bioremediation at the TAN DNAPL source area as a replacement for the default remedy has been granted. A ROD amendment was signed in 2001.

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Ft. Lewis ESTCP Demonstration

- The project will use two in situ treatment cells to quantitatively demonstrate the enhanced mass transfer and degradation that occurs due to in situ bioremediation in a chlorinated solvent source area
- One cell will be operated to test the first two mass transfer mechanisms, while the other will add the third mechanism
- Project planning is underway; field work is scheduled to begin in January 2003

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