Outline

- Challenges to in situ bioremediation
- Hydraulic soil fracturing – an enabling technology
- Fracture-enhanced in situ bioremediation case study
- Conclusions

Challenges

- In situ bioremediation constrained by:
  - Unfavourable geology (i.e. low permeability soils)
  - Inadequate presence or distribution of required electron acceptors, nutrients and microbial substrates
  - Incomplete understanding of in situ biochemical processes
  - Few demonstrated successes in the field

Important Factors

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- Nature of contaminant
- Subsurface geology
- Substrate delivery and distribution
- Biochemical processes

What is Soil Fracturing?

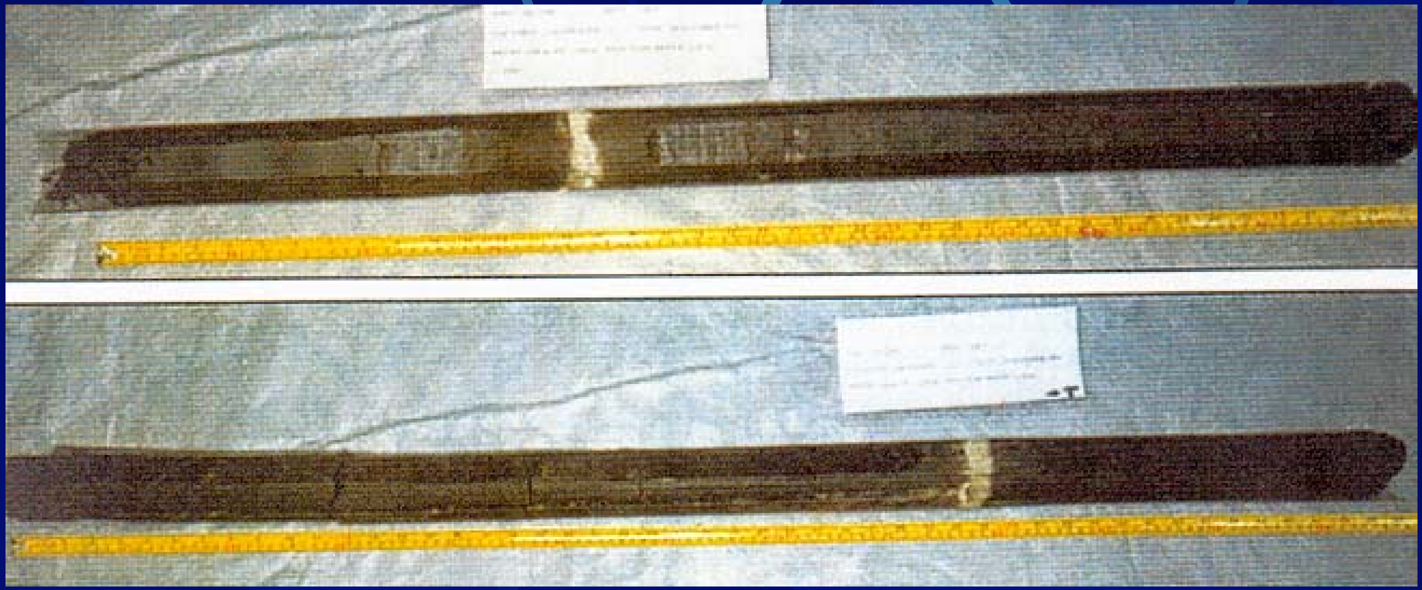
- A unique adaptation of hydraulic fracturing technology (like that used in the petroleum industry) to enhance the in situ remediation of contaminated media.
- Fracturing in soils is achieved using the FRAC RITE™ process and specialized fracturing equipment.

How is Soil Fracturing Effective?

- It creates a network of highly permeable sand fractures in the contaminated soil mass which function as conduits for the expeditious removal or in-place treatment of subsurface contamination.
- Fractures serve as pathways for the delivery of reagents (e.g. nutrients, surfactants, oxygen, biological amendments) to enhance the in situ remediation of contaminants.

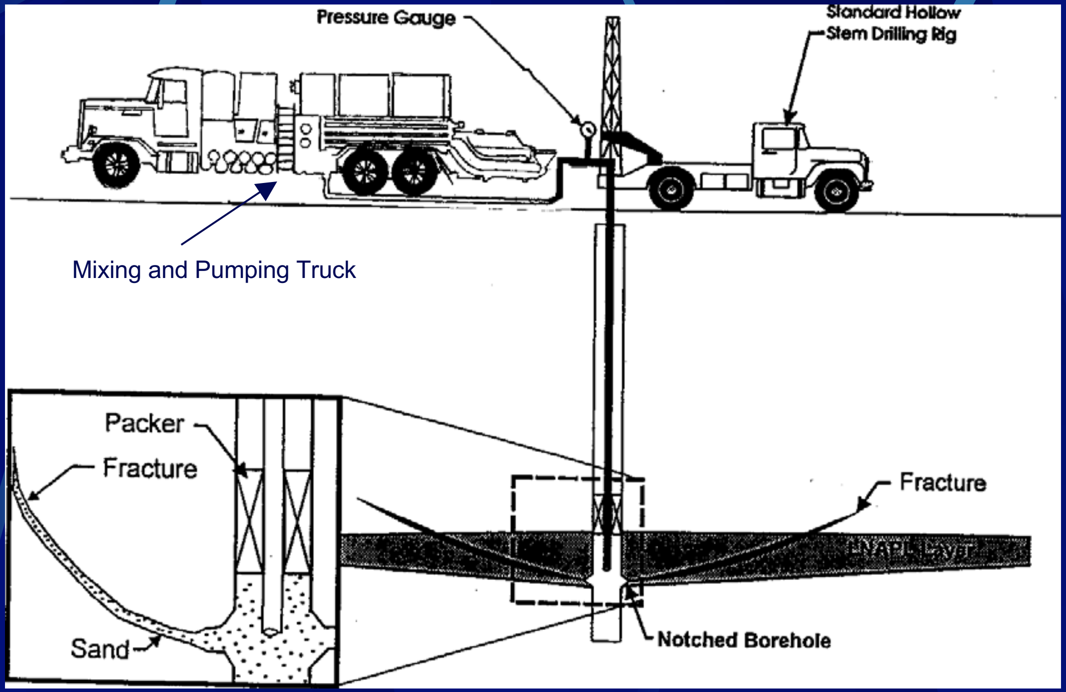
Excavation of Fractures Placed in Clay Till

Sand-filled Fractures in Clay Soil Core Samples



Sand Fracture (Red) in Clay Till

Equipment Required for Soil Fracturing



- Mobile mixing tank and pumps
- Drilling equipment
- Fracturing tools
- Instrumentation
- Fracture mapping equipment

Case Study- Background

- Former Brickyard site near Ohio River, KY
- Dissolved chlorinated contaminants TCE and cis 1,2 DCE in groundwater
- Low hydraulic conductivity (1x10E-7 m/s) in clayey and silty soils
- Zone of contamination variably saturated

Approach

- Soil hydraulic fracturing to increase bulk soil permeability in contaminated zone
- Simultaneous injection of “chitin”, a natural polymeric organic material consisting of shrimp and crab shells
- Objective: to enhance anaerobic reductive chlorination (ARD) of chlorinated solvents.

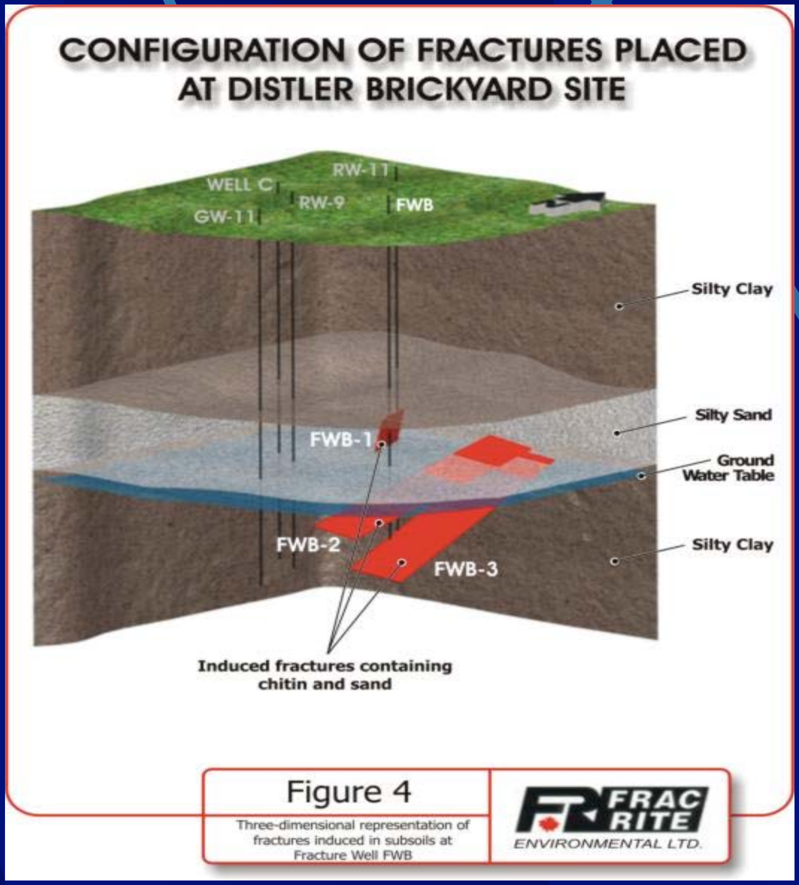
Field Pilot

- Consisted of:
  - Soil fracturing and simultaneous injection of sand-chitin slurry
  - Three fractures containing chitin induced in contaminant source area
  - Fracture placement and geometry mapped remotely using tiltmeter geophysics and correlated with soil coring
  - Pump testing and groundwater monitoring

Fracturing Operations at Distler Brickyard site

Chitin Bioamendment

Fracture Mapping



Chitin filled Fracture

Chitin Fracture in Soil Core

Evaluation

- Performance evaluation over 4 months:
  - Increase in hydraulic conductivity by one order of magnitude
  - Hydraulic connectivity and chitin distribution to surrounding MWs
  - Increase in Volatile Fatty Acids
  - Decrease in DCE and VC by 78% and 60% respectively, within 6 weeks

Conclusions

- Soil fracturing and injection of chitin bioamendment was successful in field
- Soil fracturing resulted in hydraulic connectivity and increased permeability
- Distribution of chitin was mapped using tiltmeter geophysics and soil coring
- Where distributed, chitin was effective in enhancing anaerobic biodegradation of chlorinated contaminants