# “Unconventional Remediation” The Paradox of Hydraulic Fracturing for Restoring Contaminated Sediments and Groundwater


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# Outline

- Background: What is Hydraulic Fracturing and what are its applications?
- Evolution of Fracturing in Oil and Gas Extraction and in Environmental remediation
- Contrast and Comparison:

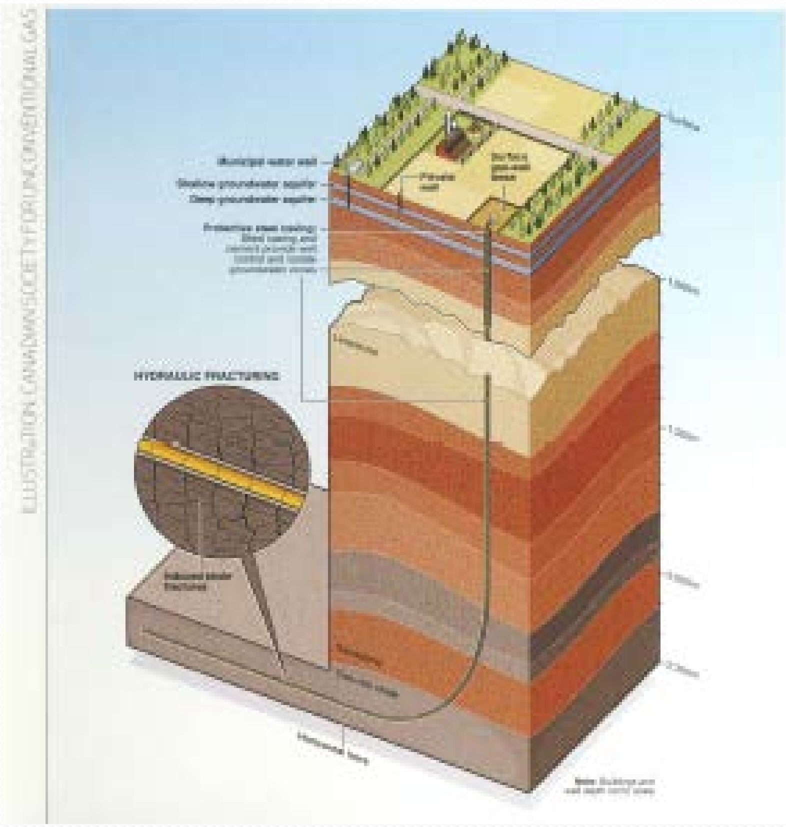
  O&G Fracing vs. Environmental Fracing-

  - Environmental Footprint
  - Regulatory Perspectives
  - Potential Environmental Impacts
  - Examples of Use
  - Common misperceptions
- Summary and Food for Thought

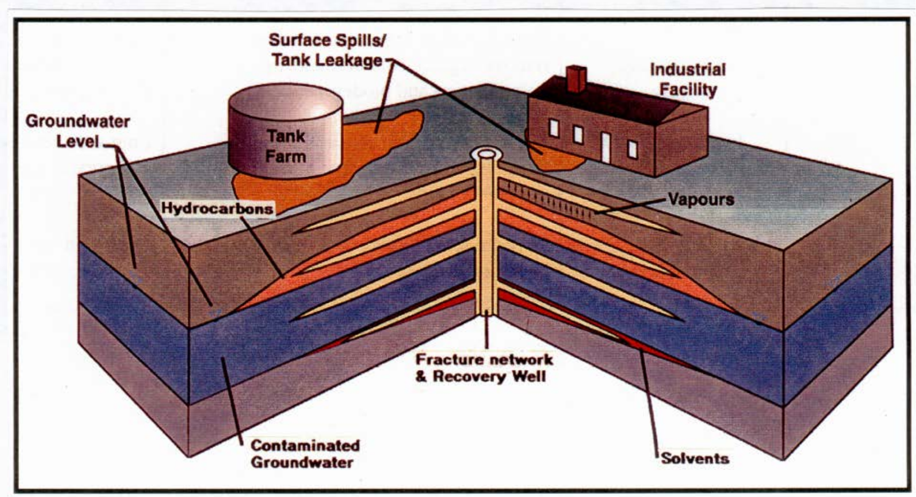
# What is Hydraulic Fracturing?

Hydraulic Fracturing is the process of transmitting pressure by fluid or gas to create cracks, or to open existing cracks in hydrocarbon bearing rocks, thousands of feet (Petroleum Industry Definition).

## OIL AND GAS




## ENVIRONMENTAL

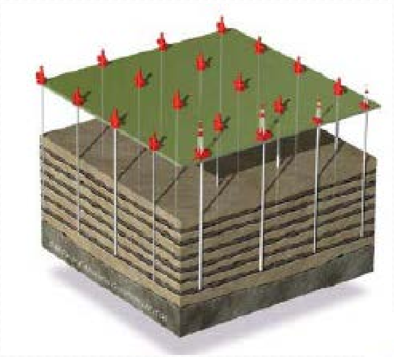



### WHY DO IT?

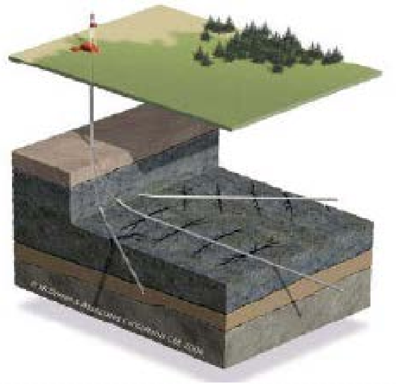
- to increase production of oil and gas (petroleum industry application)
- to facilitate the in- place treatment or extraction of subsurface contaminants (environmental application)

# Evolution of Oil and Gas Fracturing


- First commercial fracturing application in oil and gas industry by Halliburton in Texas, 1949.
- 60+ year old practice
- During 1980s and 1990s hydraulic fracturing "came of age", and became accepted practice for tight (i.e. low permeability) formations – est. 2 million wells fractured.



- Fracturing now coupled with Horizontal Drilling, multi-stage fracturing events, and micro-seismic acoustic mapping.
- Combined technologies now in widespread use for developing "unconventional" resources such as CBM, tight oil and gas, shale gas, shale oil, etc.



# Evolution of Environmental Fracturing

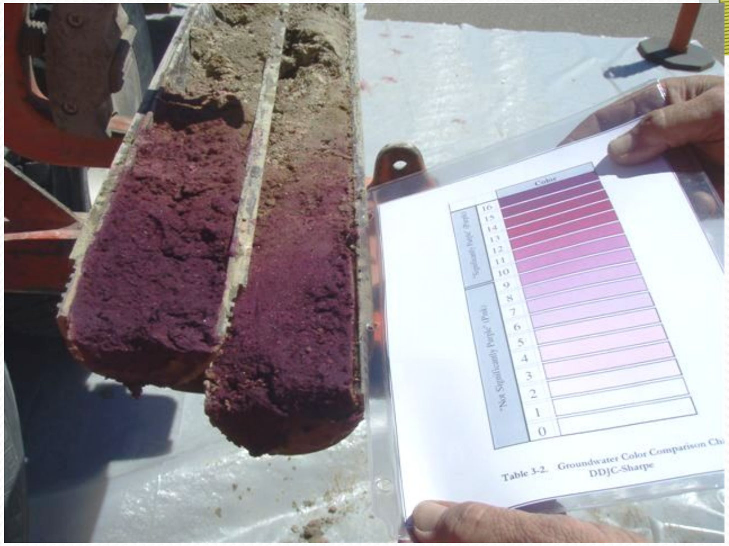
*In Canada* – adapted and modified from research into fracturing of oil sands (Golder Associates) in late 1980s

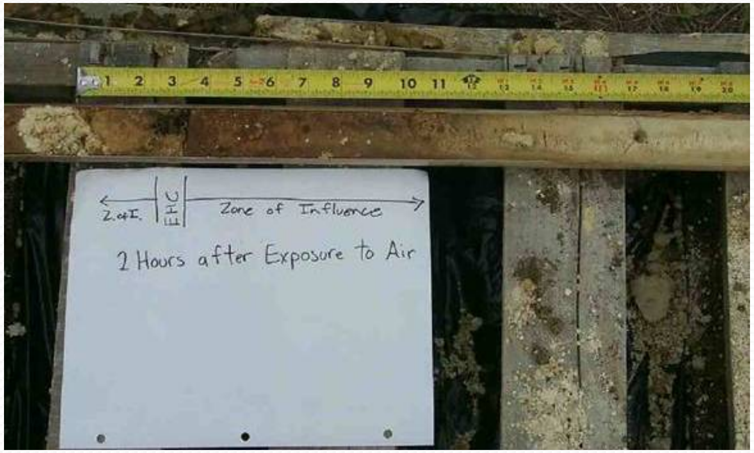
*In the U.S.A.* – from research into environmental applications for hydraulic fracturing at University of Cincinnati and New Jersey Institute of Technology in late 1980s

Commercial “environmental” fracturing services for in situ remediation of contaminated sites available since 1993:

- Refineries and Tank Farms
- Gas Plants and Battery Sites
- Pipeline ROWs
- Bulk Fuel Plants
- Former Flare Pit sites
- Retail Gasoline Stations
- Dry cleaner sites
- Grain Terminals
- Landfills
- Industrial Manufacturing Sites
- Brownfield redevelopment properties

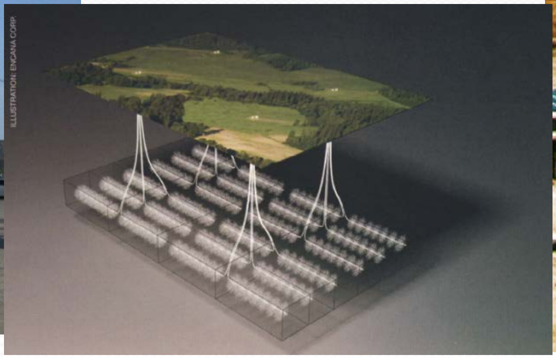
# Remedial Fracturing Exposed



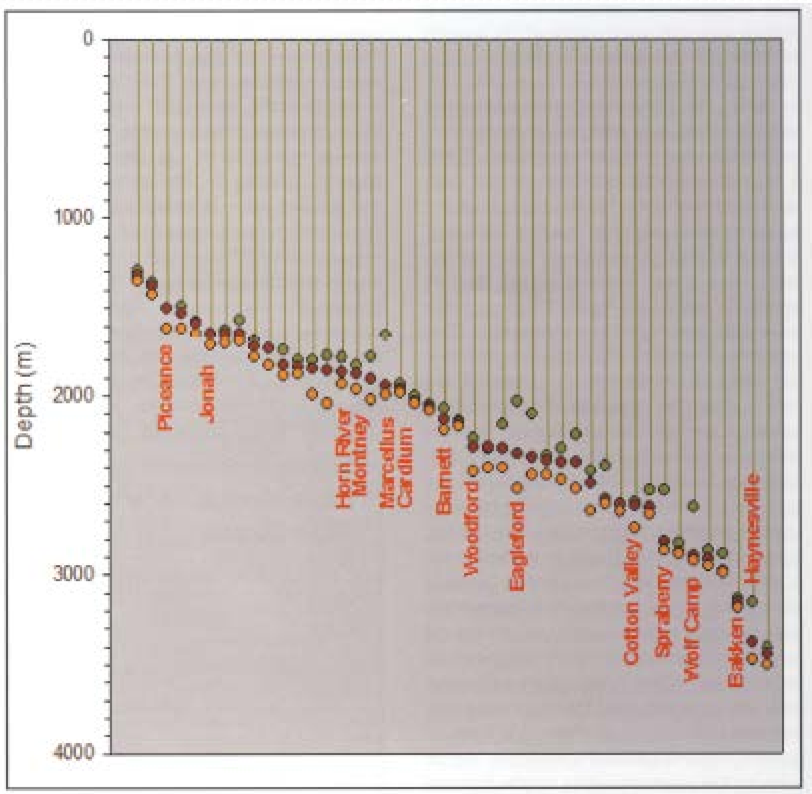
# Comparison: Environmental Footprint

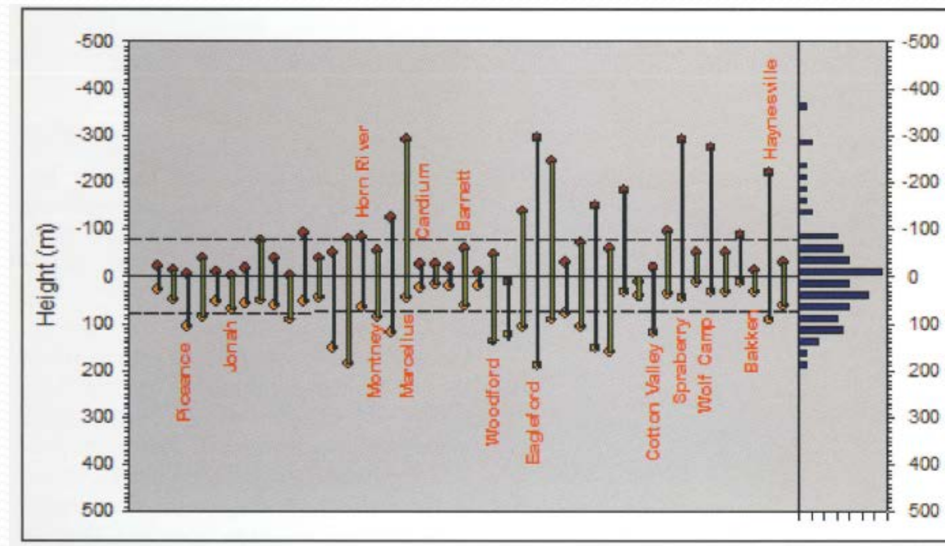
| Parameter | Environmental | Oil and Gas |
|---|---|---|
| No. of wells fraced | 1,000 – 2,000 | > 2 million (M.J. Economides) |
| Drilling Depth | < 100 m (vertical) | 1,200 to 3,500 m (vertical) in AB<br>up to 2,500 m (horizontal) in AB |
| Frac Volume (water) | 0.5 to 10 $m^3$ per frac;<br>3 to 50 $m^3$ per well | 100 to 3,600 $m^3$ per frac;<br>10,000 to 70,000 $m^3$ per well |
| Fracs per Well | 5 to 10 | 30 to 50 per HDMSF well |
| Frac Dimensions | 3 to 30 m (horizontal) | 20 to 300 m in height (vertical) |
| Areal Footprint | Typically < 1,000 $m^2$<br>No site preparation required | Acres to hectares;<br>clearing and pad construction req'd |



# Oilfield Fracture Height Statistics

## (based on micro-seismic data)




| | UPWARD GROWTH | DOWNWARD GROWTH |
|---|---|---|
| Mean +/- stand dev | 80 m +/- 87 m | 73 m +/- 48 m |
| Maximum | 295 m | 190 m |
| Minimum | 12 m | 10 m |

S. Maxwell, CSPG “Reservoir”, 2012

# Classification of ZVI/C Fractures at Atlas 12

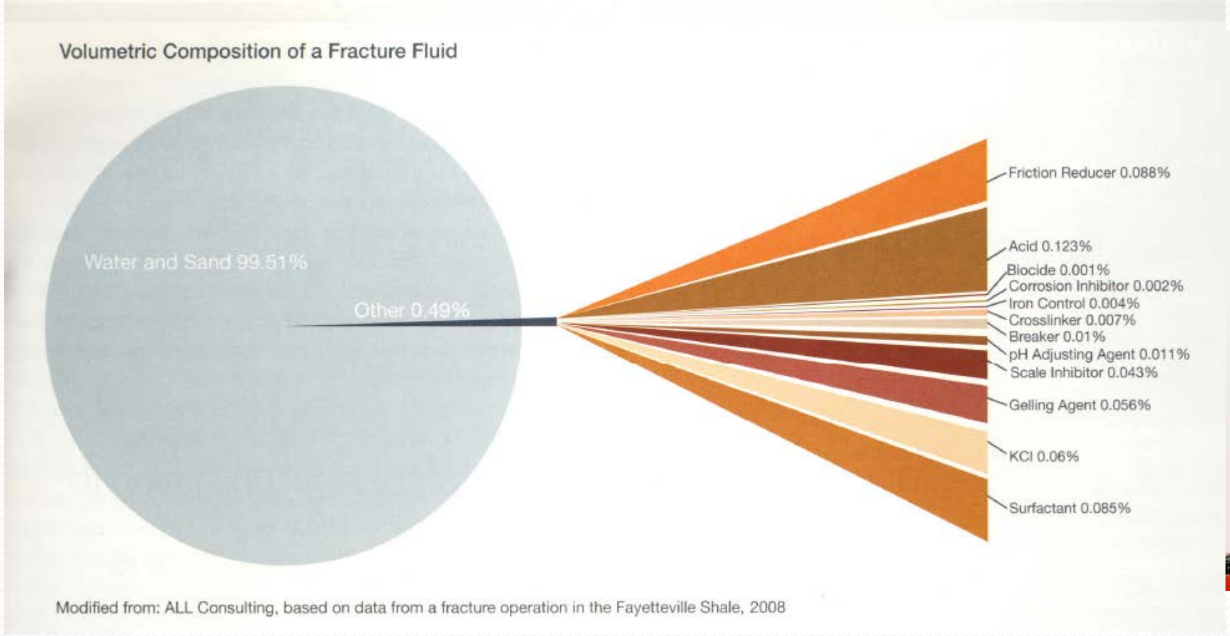
| No. of Fractures | FRACTURE CLASSIFICATION | % of Total Fracs |
|---|---|---|
| 3 | Near-Horizontal ($\leq$ 10º) | 6 |
| 6 | Slightly Ascending (11 to 20º) | 12 |
| 29 | Moderately Ascending (21 to 45º) | 57 |
| 13 | Strongly Ascending (46 to 79º) | 25 |
| 0 | Near-Vertical ($\geq$ 80º) | 0 |

**51 Fractures initiated in depth interval of 45 to 80 ft. in sandstone bedrock: 75% of ZVI/C Fractures were near-horizontal to moderately ascending.**

# Potential Environmental Impacts

| Parameter | Environmental | Oil and Gas |
|---|---|---|
| Frac Chemicals | Food grade chemicals (GRAS rated) biodegradable polysaccharides and surfactants. Passes microtox. | Industrial or saline quality water ; Often hydrocarbon based; Additives may include biocides (toxic) |
| Creation of Contaminant Pathways to Aquifers | Fractures are created in already contaminated sediments to act as pathways for injecting treatment amendments to remediate contamination in soil and GW | Indirectly through poorly completed boreholes and poorly cemented wellcasings, or intersection of fracs with operational wells. |
| Water use | Potable water quality, minor volumes | Potentially large demand on local water sources |
| Frac Blowback | Minor, usually less than 5%, recylce | Can be significant – 25% to 40% Containerize, recycle or deep well inject |
| Ground Disturbance | Can be significant at shallow frac depths (< 3 m bgs) | Oil and gas fracs have been cited as a possible trigger for earthquakes (!?) |

# Chemical Composition: Water based Fracs




- But … many fracs in oil and gas based on other fluids: diesel, propane, CO2, liquid N, saline water, foam, etc.

- Environmental Fracture Fluid:

Potable water and biodegradable polysaccharide (i.e .sugar based) guar polymer (non toxic)

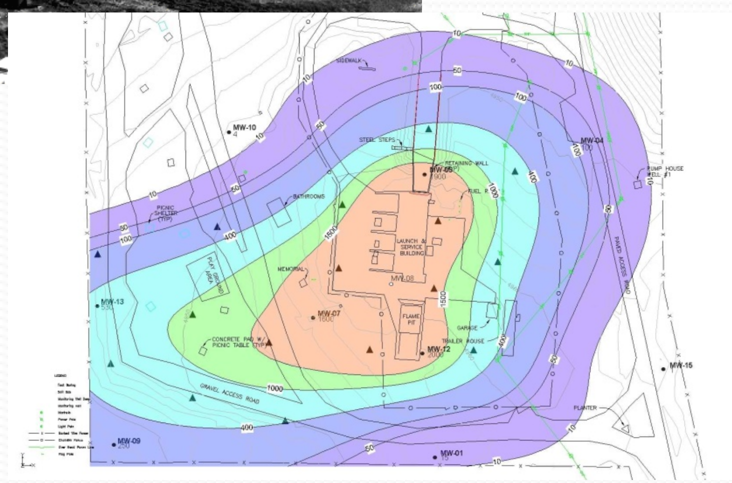
# Regulatory Perspective

| Parameter | Environmental | Oil and Gas |
|---|---|---|
| Frac Chemicals | Food grade chemicals (GRAS rated) scrutinized by provincial, state, and water board environmental authorities – e.g. used for remediation in California aquifers. | Disclosure has not been provided in past due to propriety of fluid formulations; call for transparency has resulted in industry deciding on voluntary disclosure |
| Groundwater Protection | Fracturing confined to delineated areas of contamination in aquicludes, aquitards , and aquifers to remediate carcinogenic compounds in GW | 3 U.S. EPA studies since 2004; ERCB Directive 27 for fracture offsets with respect to shallow gas fracturing; Fracfocus – U.S. and Canada |
| Moratoriums on Fracturing | None in place – fracturing has resulted in remediation of 100s of contaminated sites in North America; U.S. EPA has acknowledged fracturing for environmental remediation applications since 2001; European countries researching environmental fracturing for remediation & considering pilot projects – want to first see demonstrated success. | Quebec, New York, France; other jurisdictions considering moratorium (e.g. New Jersey) |

# Common Misperceptions

- Fractures can be steered – Nope. Stress regime, fabric
- Oil and Gas fractures are proximal to GW zone – usually not
- Fracturing directly impacts aquifers – indirectly maybe
- All fracs are vertical:  oil and gas fracs (except at shallow depth of a few 100 metres) are generally vertical, but environmental fracs are generally near – horizontal
- Fracturing is an explosive process – incorrect. It is a gradual tensile splitting of the rock or soil with pressure.

# Validating the Fracture-emplacement of 140 tons of Zero Valent micro-iron for TCE remediation in bedrock



- Former USAF "Atlas 12" Missile Site, Colorado
- Operational disposals of TCE (1960-1965) resulted in impacts in underlying sandstone aquifer to 60 ft. depth
- Widespread TCE concentrations in groundwater upwards to 4,000 ug/L

# Atlas 12 Pilot Test EHC-G Distribution

Source Area:
7 Fracture Boreholes

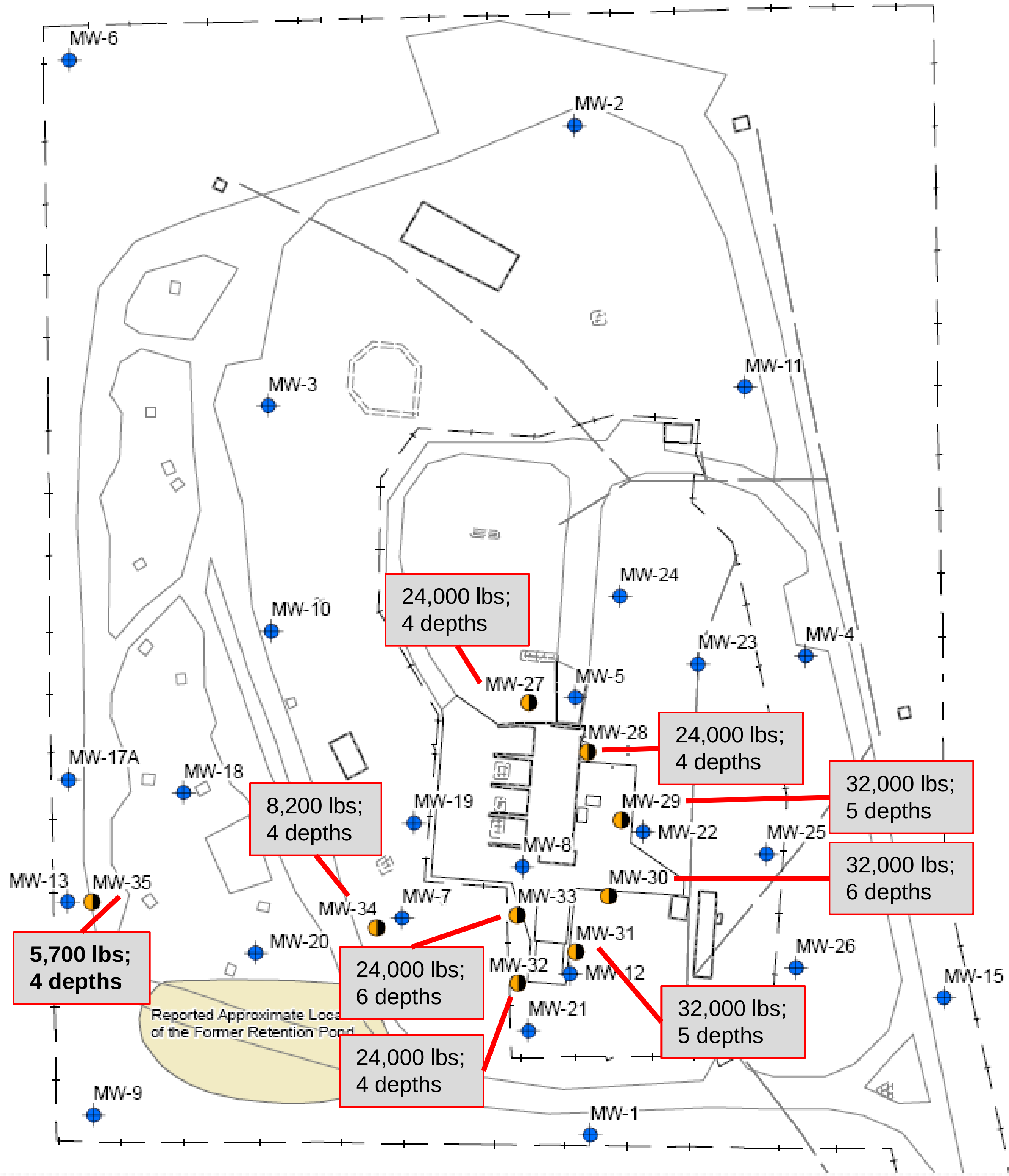
Dissolved Phase Plume:
2 Fracture Boreholes

EHC-G Injections:
April 20 to May 19, 2009

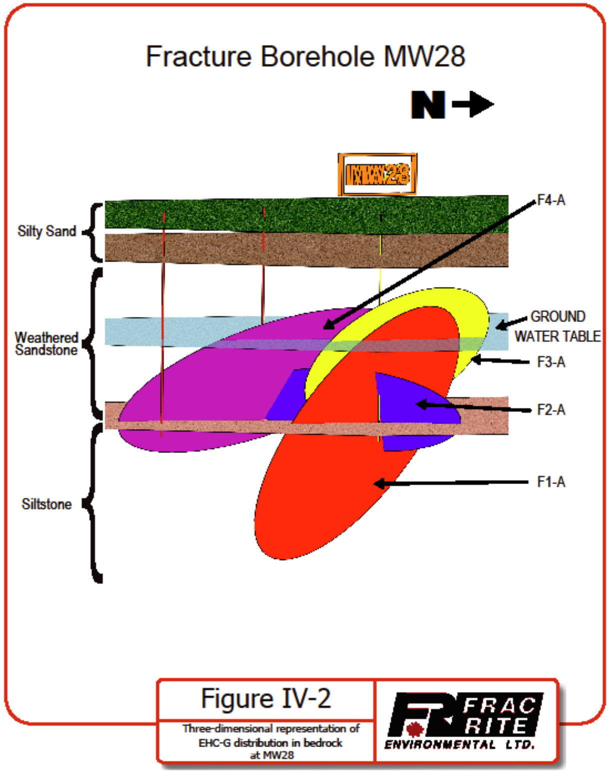
**Mass of EHC-G per Borehole; Number of Fracture Depths**

**Legend**

- Monitoring Well Fox Hill Sandstone
- Pilot Test Fracture Borehole/Monitoring Well Fox Hill Sandstone
- Buildings
- Fence
- Former Retention Pond



# Fracture Mapping using Tiltmeter Geophysics

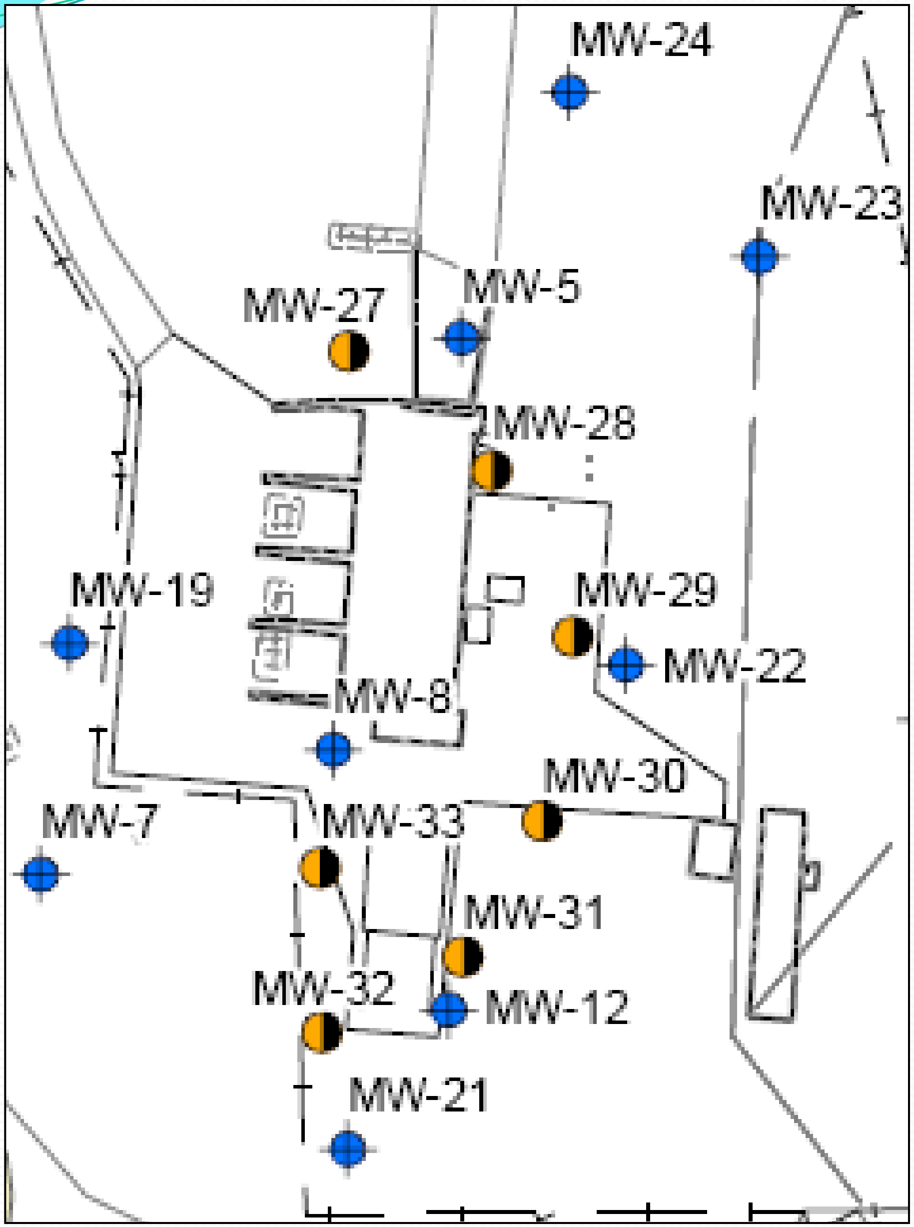


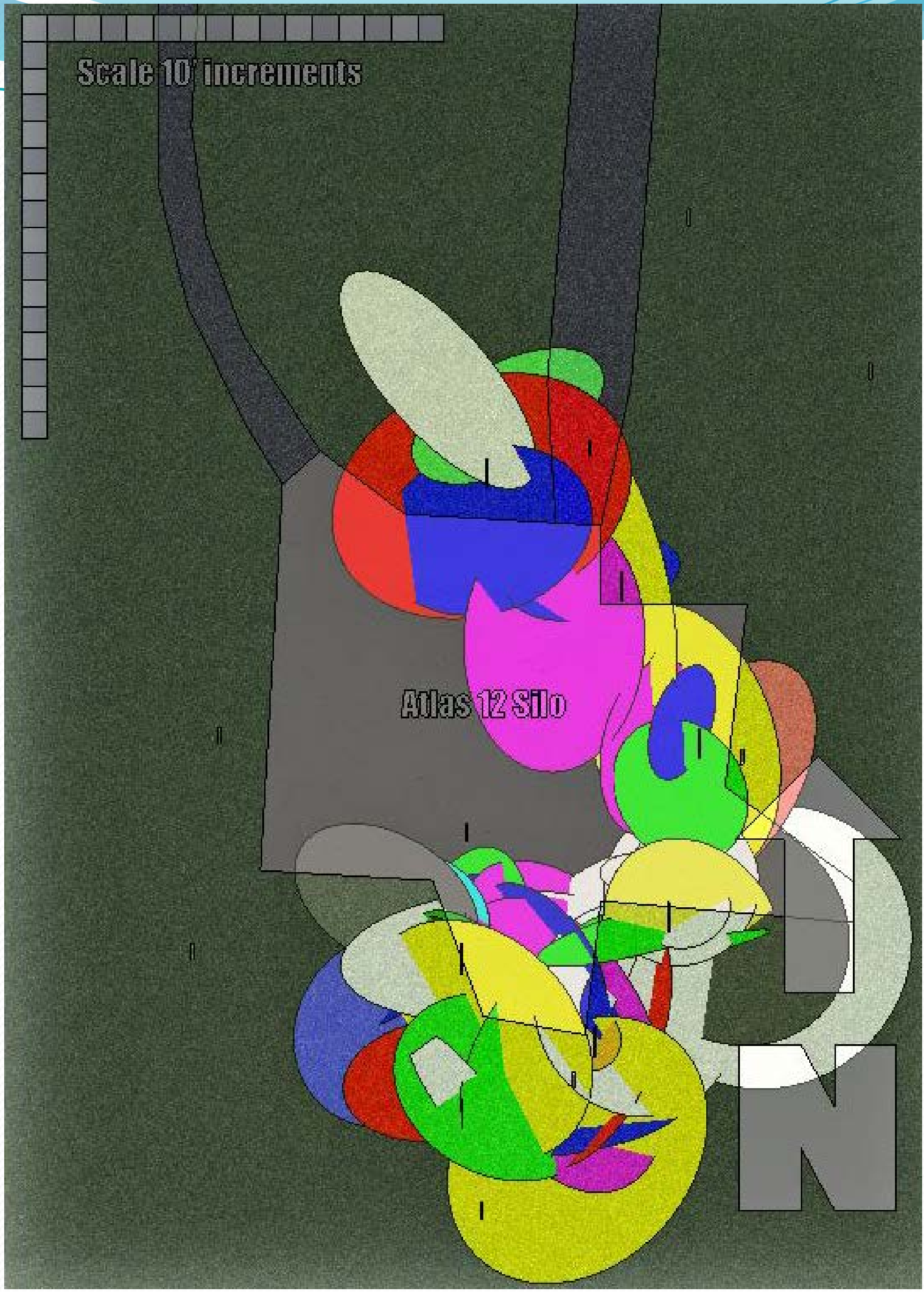


- Tiltmeters are ground surface sensors that detect tilt angle and tilt direction in response to a fracturing or injection event in the subsurface

# Fracture Mapping

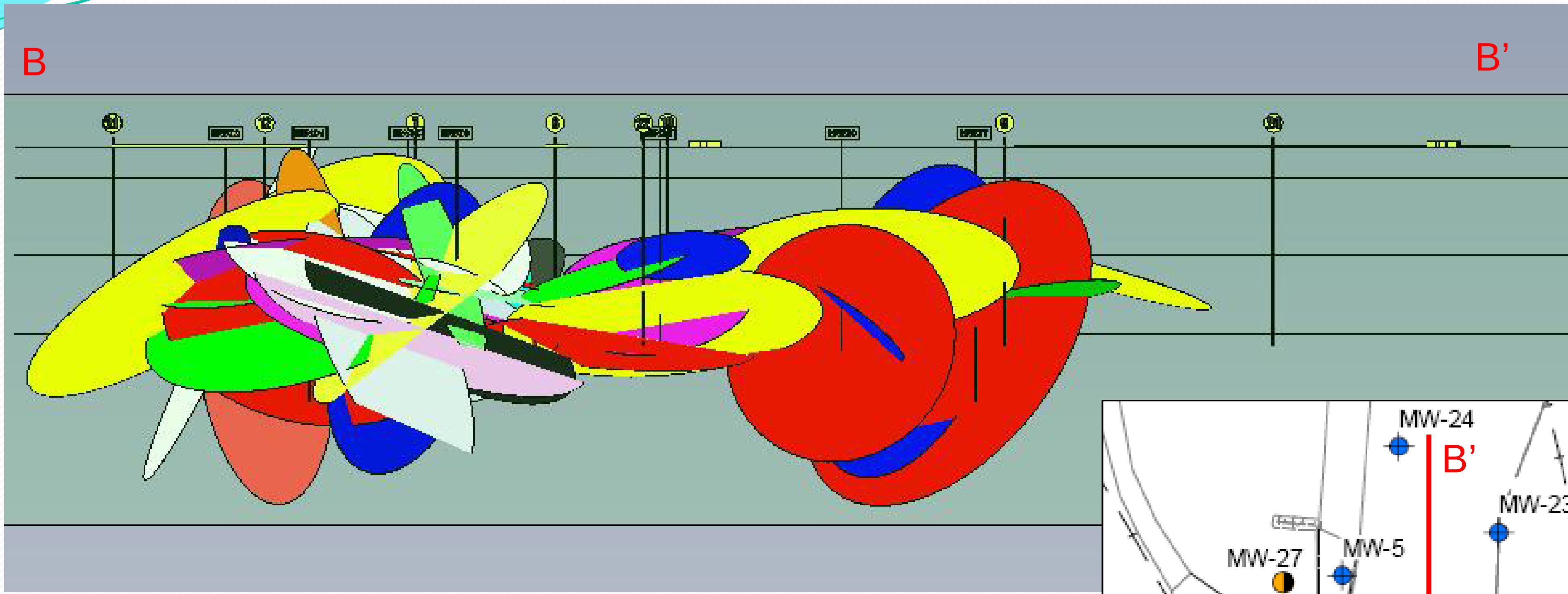
Conducted for 7 boreholes in source area

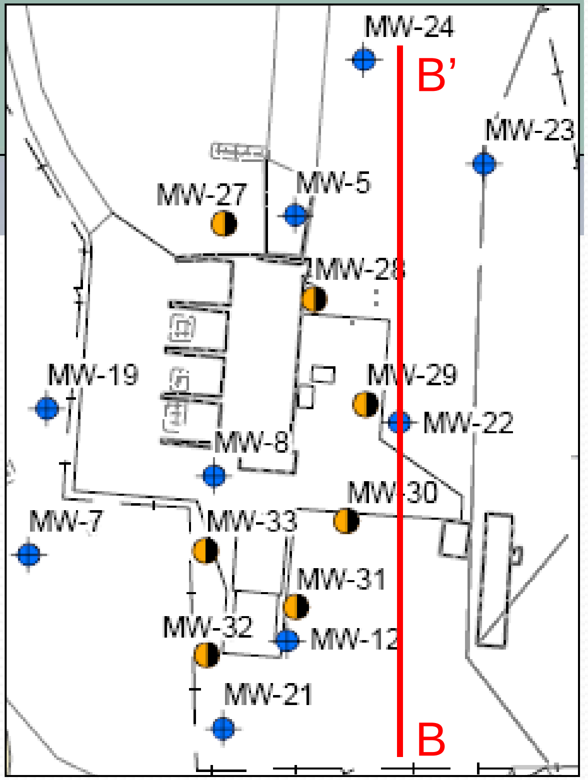


# Fracture Mapping

From MW-22 looking west




**North-South extent of continuous ZVI/C coverage is approximately 450 ft, effectively comprising a treatment barrier**

# TCE Treatment Perfomance after 21 months

- **<u>Source Area</u>**:

Pre-treatment TCE levels - >2000 to 4,000 ug/L

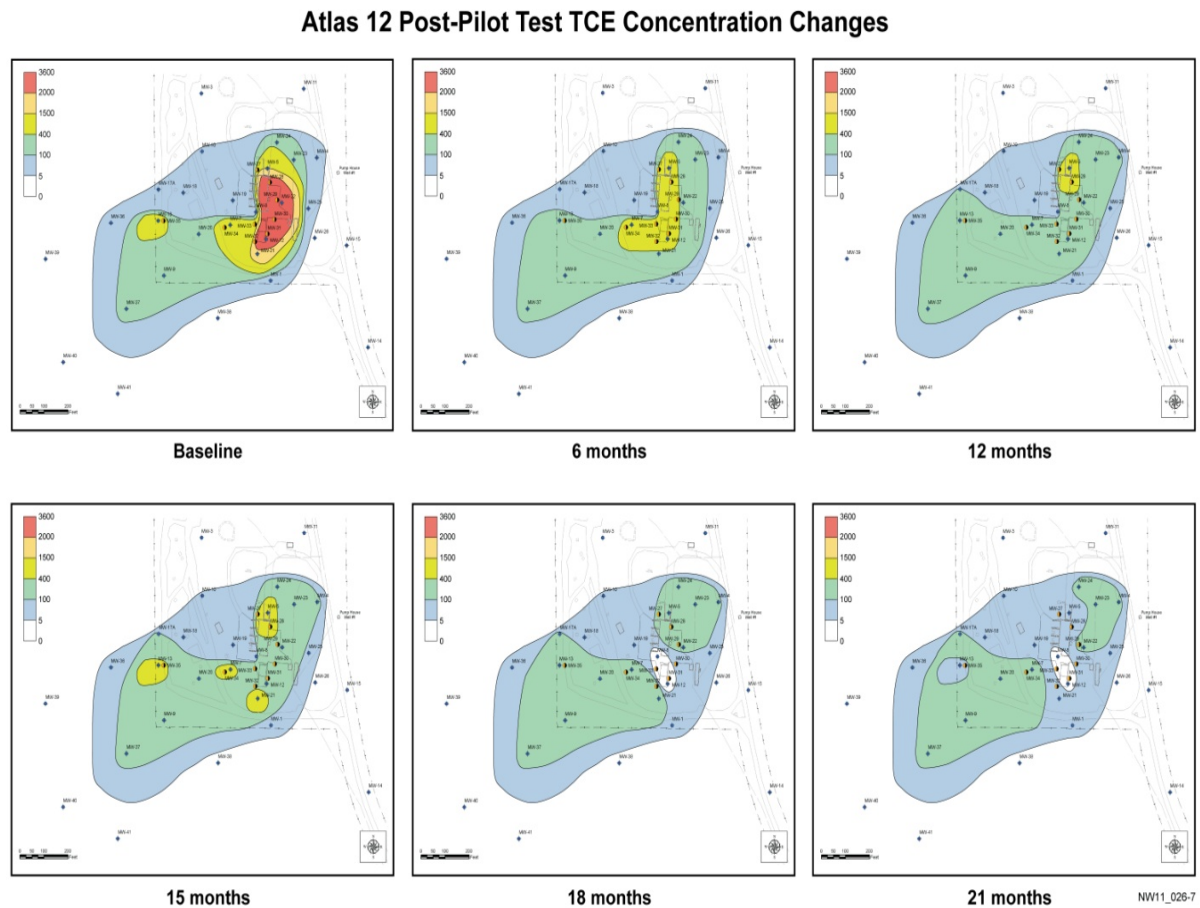
After 12 months – less than 400 ug/L except at 2 wells

After 21 months – less than 100 ug/L generally

- **<u>Dissolved Plume Area</u>**:

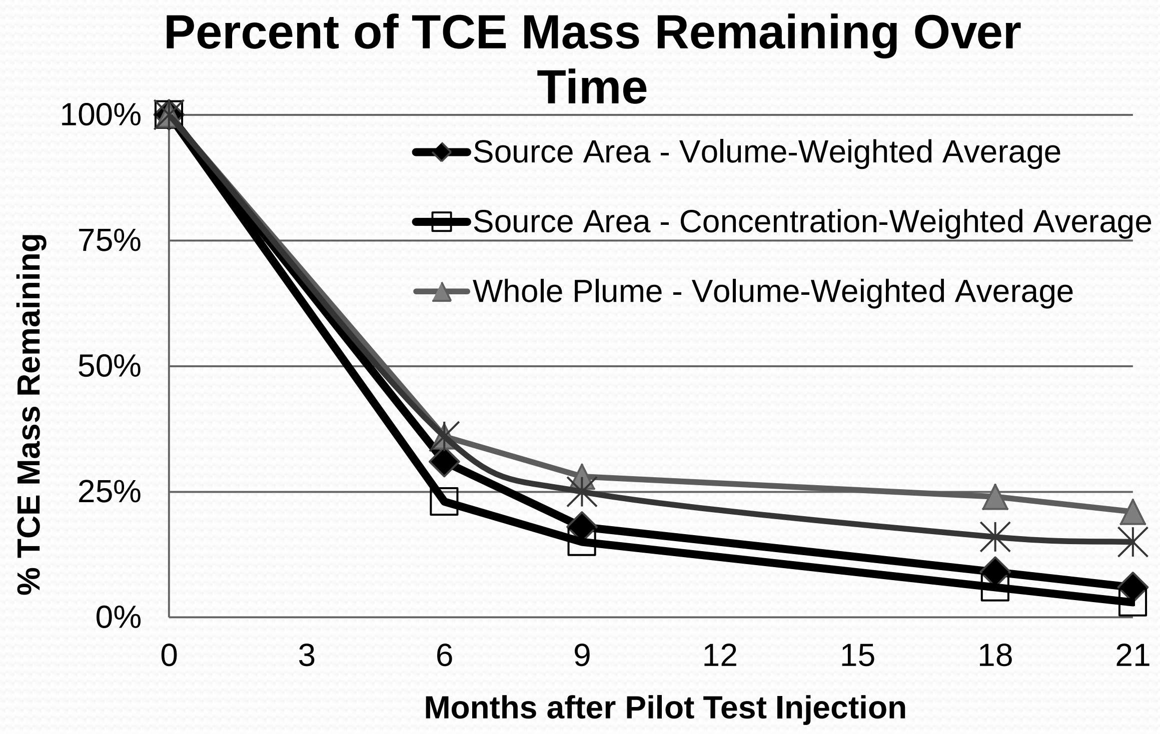
Pre-treatment TCE levels - 500 to 700 ug/L

- After 21 months – 200 to 400 ug/L



# 21 Month Performance Evaluation

- 94% of Source Area below RMC of 100 ppb TCE
- 82% of Dissolved Plume Area below TCE RMCs
- Phase 2 ZVI Injection of another 40 tons ZVI completed in August 2011, TCE is ND to 100 ug/L
- Treatment cost equivalent: $8 per ton
- Approach in now the model for addn. USACE missile site clean-ups (Journal of Remediation, Spring, 2012).



# How is Environmental Fracturing different from Oil and Gas fracturing?

## Environmental Fracturing

- **Uses potable water, sand, and food grade polysaccharides (sugar) to formulate fracture slurry**
- **Is used for cleaning up ground-water to drinking water quality in contaminated aquifers**
- **Has been acknowledged by the US Environmental Protection Agency as a proven remedial technology**
- **Small scale, shallow fractures (approx. 1,000 litres and 10 m wide)**
- **Passes Microtox test criteria**
- **Proven use in Canada and U.S. for site remediation since 1993.**

## Oil and Gas Fracturing

- Uses industrial water quality, or brine water, diesel oil or propane, often containing biocides, to formulate fracture slurry
- Is suspected of causing ground-water contamination in some instances (e.g. Wyoming, Pennsylvannia)
- Is being required to set up a data base inventory to disclose frac chemicals used (B.C., AB, U.S.)
- Massive in size, and deep (300,000+ litres and 300 m wide)
- Improved practices being considered or implemented

# Food for Thought

Hydraulic Fracturing for oil and gas extraction is a mature technology used for over 60 years in millions of wells. Could it be responsibe for contributing to groundwater aquifer contamination, as has recently been suggested?

- Evidence for direct contact of fractures with aquifers resulting in contamination of groundwater is scarce (U.S. EPA), however –
- There has been isolated evidence of indirect contact of fractures with aquifers through poorly abandoned wells or poorly cemented or cased wells that has negatively affected groundwater quality.

The rapid development of Horizontal Drilling with multi-stage fracturing, is resulting in increasing fracture size and intensity, which could potentially evolve into a *"crisis of water, space and pace".* Recommendations from NGWA (& others) include:

- improved monitoring and further study of potential for GW contamination – baseline water quality studies
- proper construction and regular maintenance of oil and gas wells
- proper abandonment and sealing of non producing wells
- disclosure of all chemicals used in oil and gas hydraulic fracturing operations (Fracfocus.org)
- recycle/reuse water in fracturing operations
- fracture mapping using microseismic

# Thank you !!

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