OBG PRESENTS:

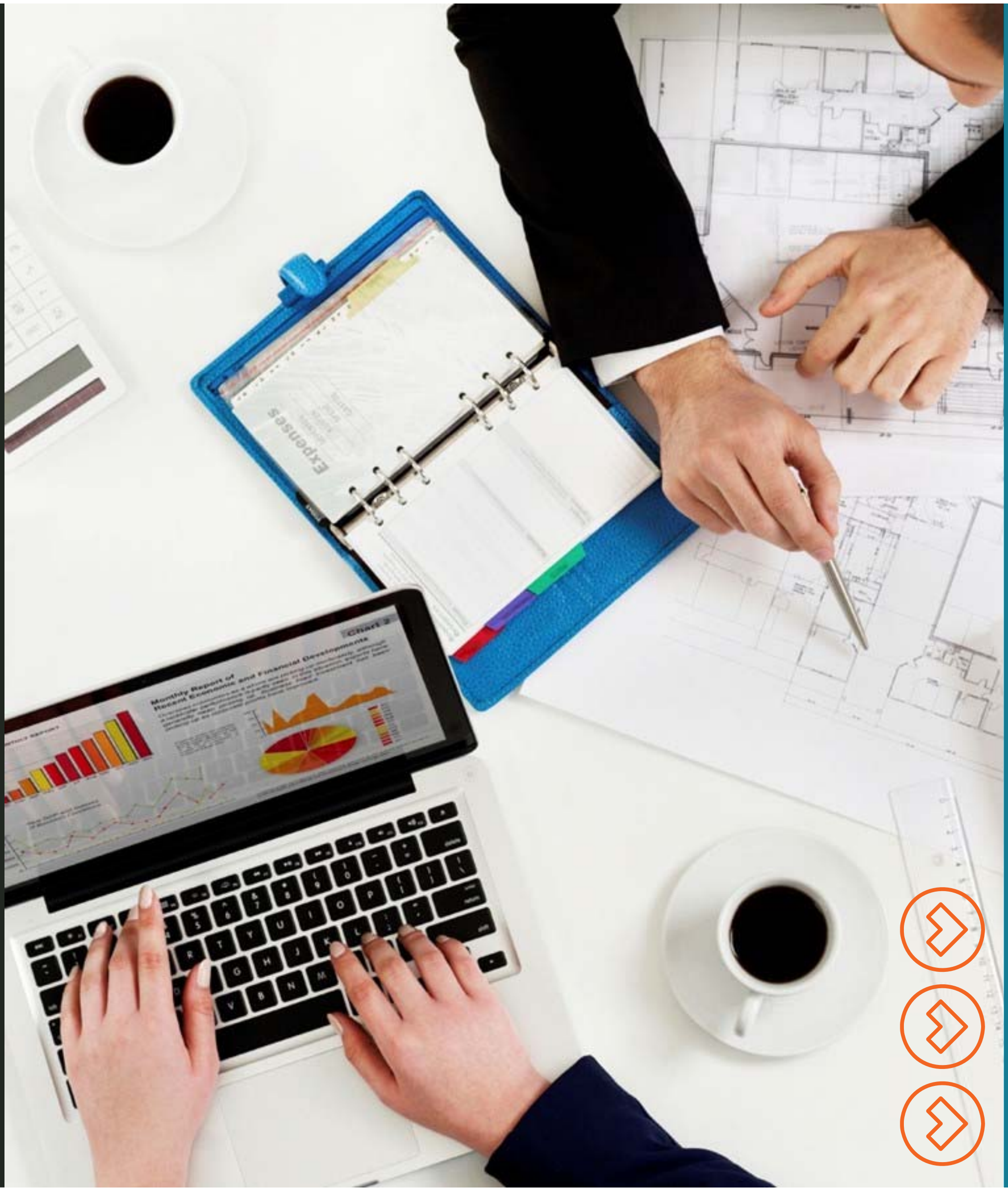
Lessons Learned Over 20 Years of Designing and Implementing Enhanced *In Situ* Bioremediation Remedies

Mark Harkness (OBG Engineers)

Lessons Learned

“We know a thing or two because we’ve seen a thing or two.”

– Farmer’s Insurance Company



AGENDA

Remedy Selection

Treatability Studies

Pre-design Investigation

Injection Management

REMEDY SELECTION

FS Considerations

DR. STEPHEN R. COVEY
“Seven Habits of Highly Effective People”

What is the Endpoint?

Rare for remedial sites to reach MCLs

Best intermediate option is to get site to MNA

If natural assimilative capacity of aquifer > rate of release of VOCs into the groundwater, the net result is no plume expansion

Often requires combination of source reduction, plume treatment, and protection of sensitive receptors

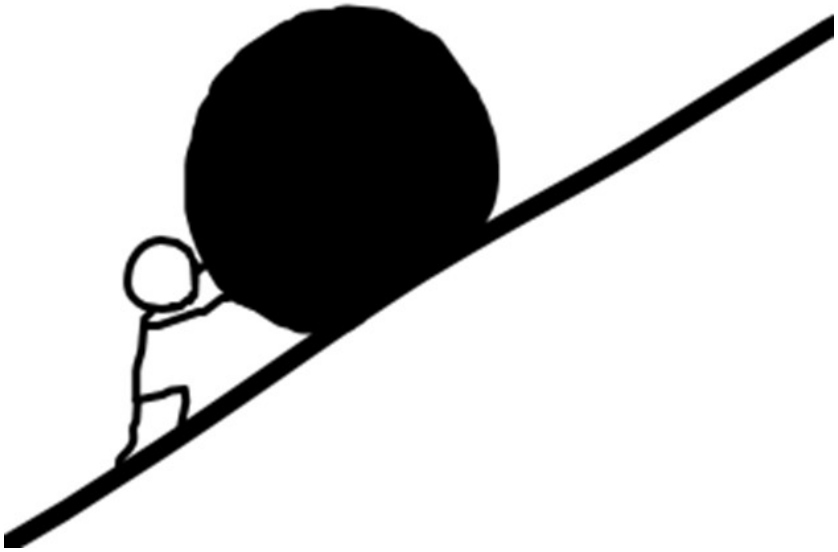
Treatment Train Approach

Source Reduction → Plume treatment → MNA
Excavation → EISB → MNA
EISB → EISB → MNA
ISCO → EISB → MNA
Thermal → EISB → MNA

When we try to fight mother nature, we usually lose...

Match the remedy to the natural environment
Anaerobic aquifers → EISB or ISCR (not ISCO)
Aerobic aquifers → more options (but avoid EISB in high-flow situations)
Low permeability soils → modify injection method and use solid amendments

When we try to fight mother nature, we usually lose...



Choosing the wrong remedy is like trying to push a big rock up a hill

When we try to fight mother nature, we usually lose...

Match the remedy to the natural environment
Anaerobic aquifers → EISB or ISCR (not ISCO)
Aerobic aquifers → more options (but avoid EISB in high-flow situations)
Low permeability soils → modify injection method and use solid amendments

Treatment Train Approach

Source Reduction → Plume treatment → MNA
Excavation → EISB → MNA
EISB → EISB → MNA
ISCO → EISB → MNA
Thermal → EISB → MNA

Application of EISB to Source Areas

Outdated thinking based on early application of EISB to plumes

Bacteria activity will be inhibited in presence of DNAPL

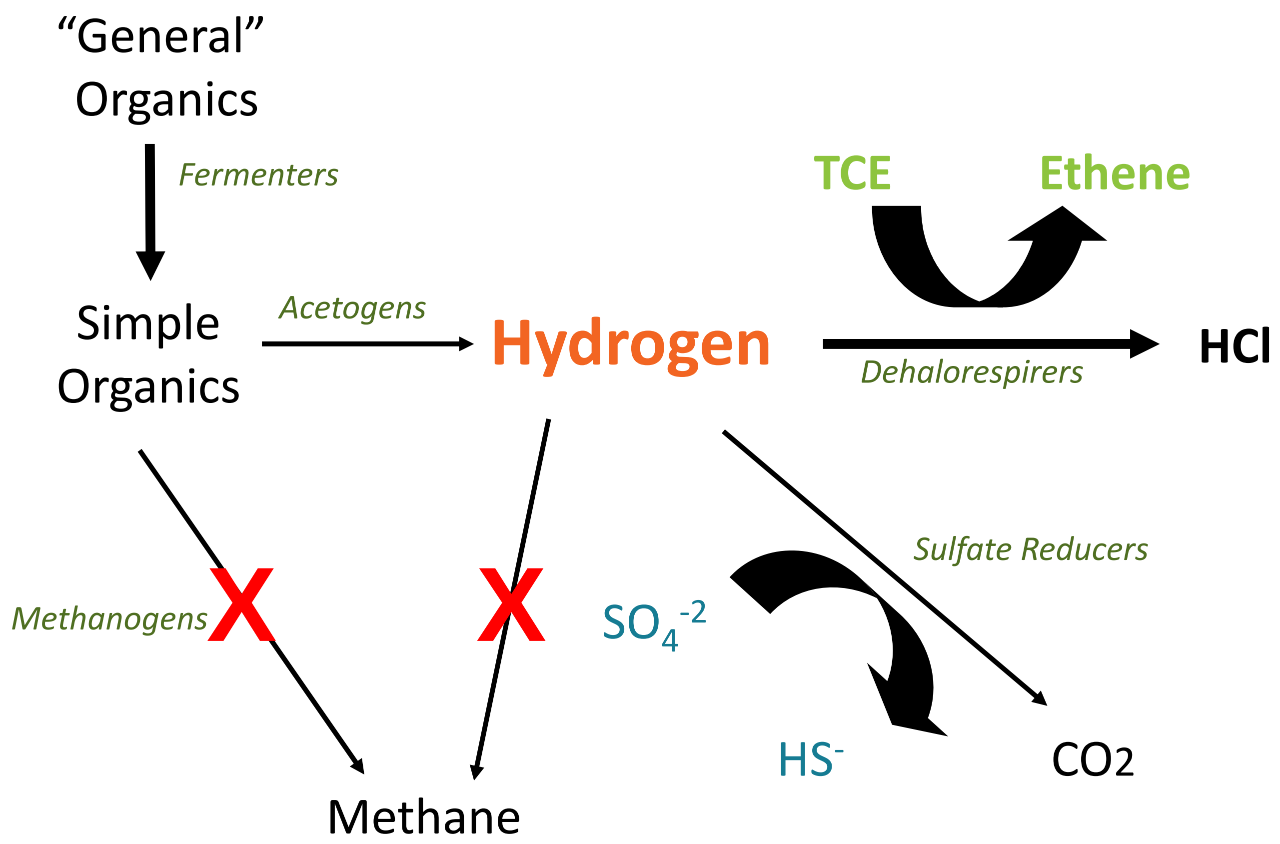
Can We Treat DNAPL Source Areas Using EISB?

SourceAreaBioREmediation

Key Question: Can EISB result in effective and quantifiable treatment of chlorinated solvent DNAPL source areas?

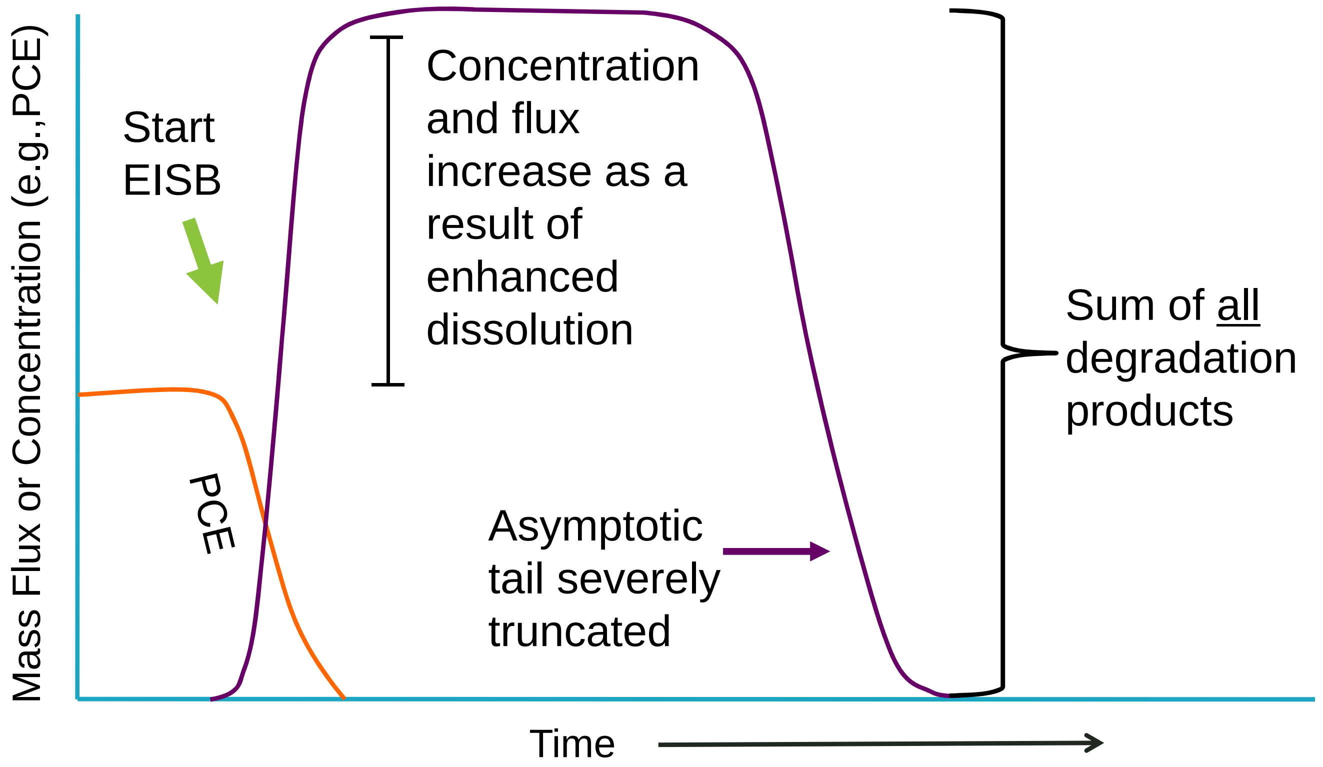
BENEFIT 1

Methane Inhibition in the Presence of DNAPL



BENEFIT 2

DNAPL Dissolution Enhancement



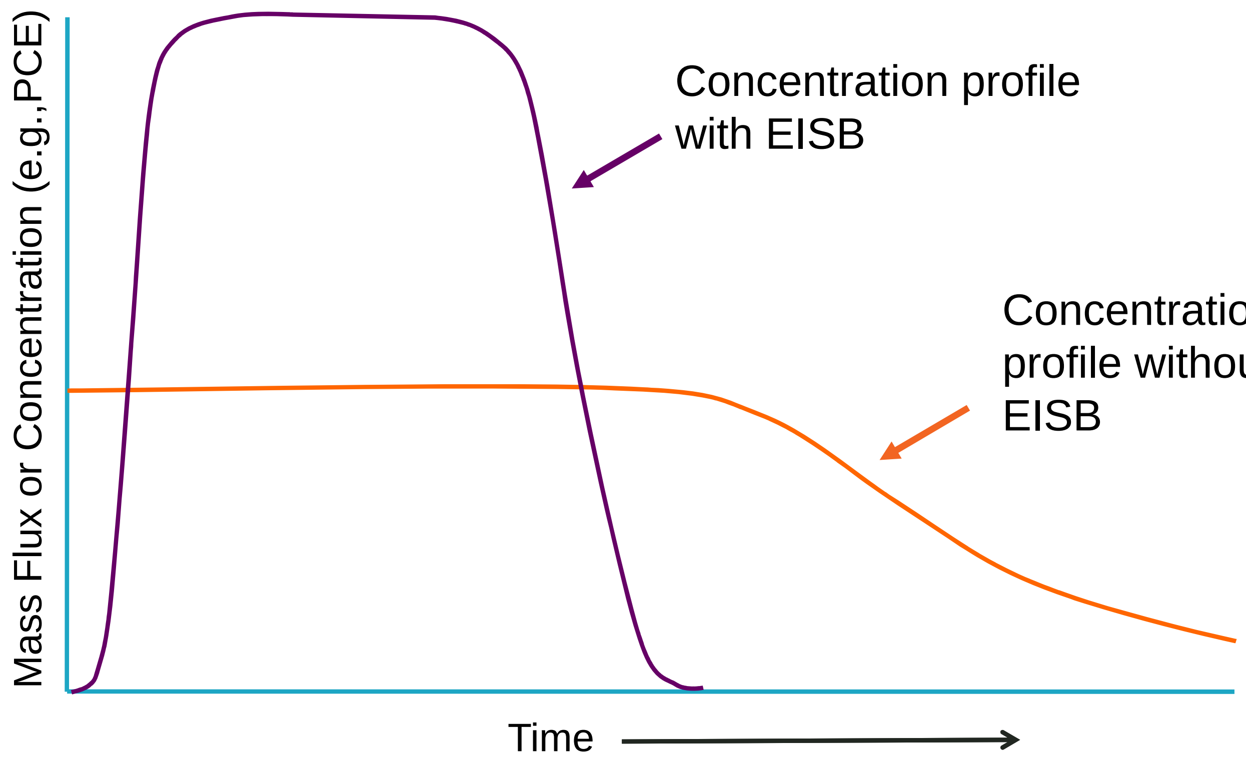
ITRC, In Situ Bioremediation of Chlorinated Ethene: DNAPL Source Zones. June 2008.

BENEFIT 2

DNAPL
Dissolution
Enhancement

How much should we expect?		
	Compound	
	PCE	TCE
Solubility (mg/L)	150	1,100
Enhancement in Lab	5-15	~2
Enhancement in Field	3-5	~1.5

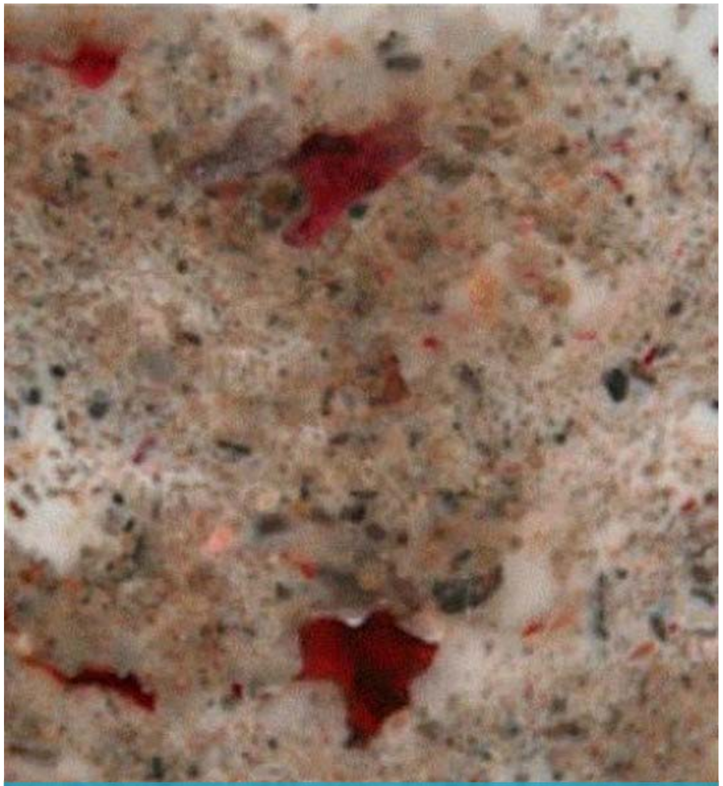
Comparison of Mass Removal over Time



BENEFIT 3

Partitioning Donor Behavior (EVO)

Three days



Six days

Treatment Train Approach

Source Reduction → Plume treatment → MNA
Excavation → EISB → MNA
EISB → EISB → MNA
ISCO → EISB → MNA
Thermal → EISB → MNA

There are issues with ISCO & EISB due to residuals left in soil

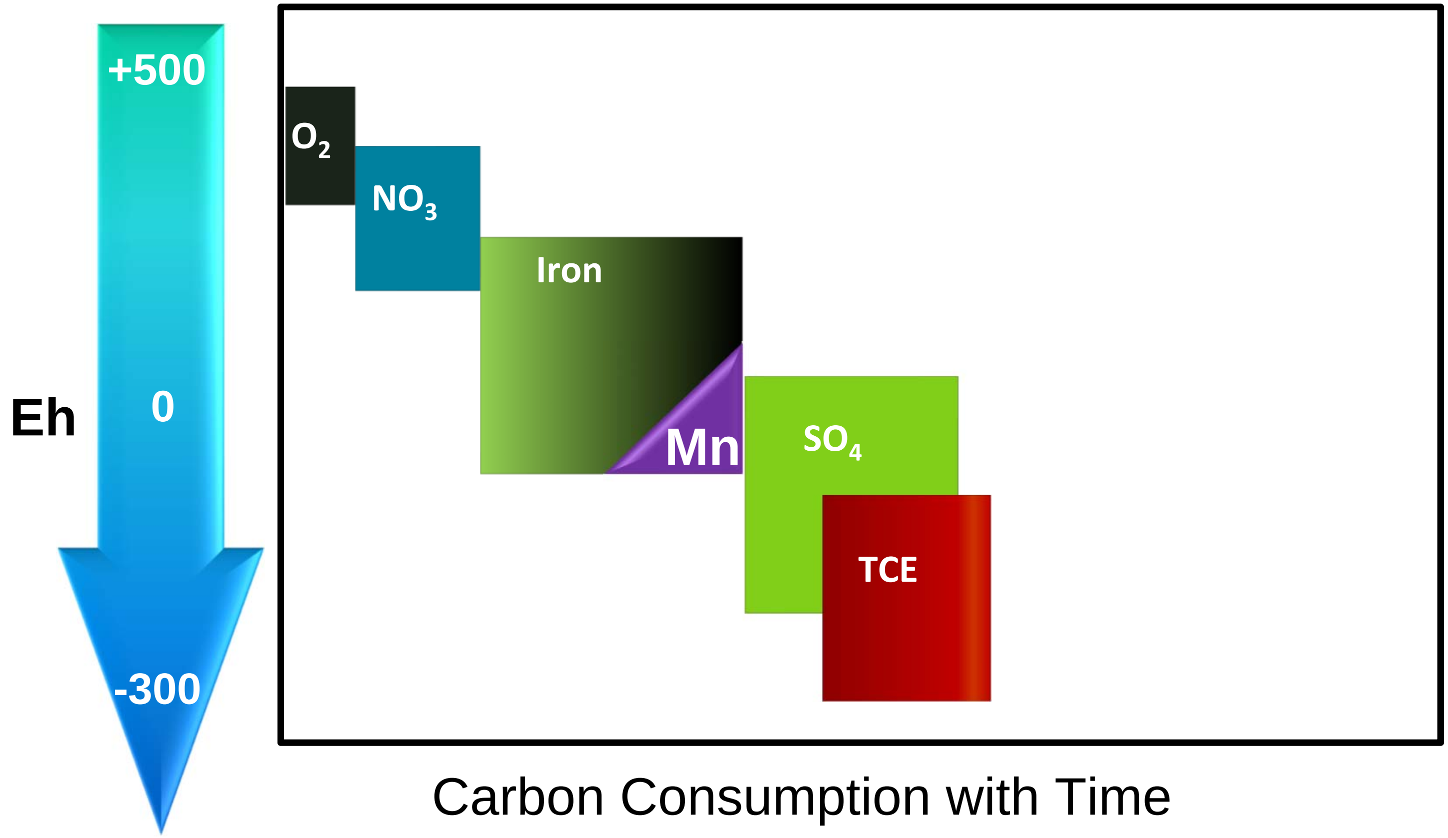
Impact of ISCO on EISB

Permanganate oxidation forms MnO_2 by-product

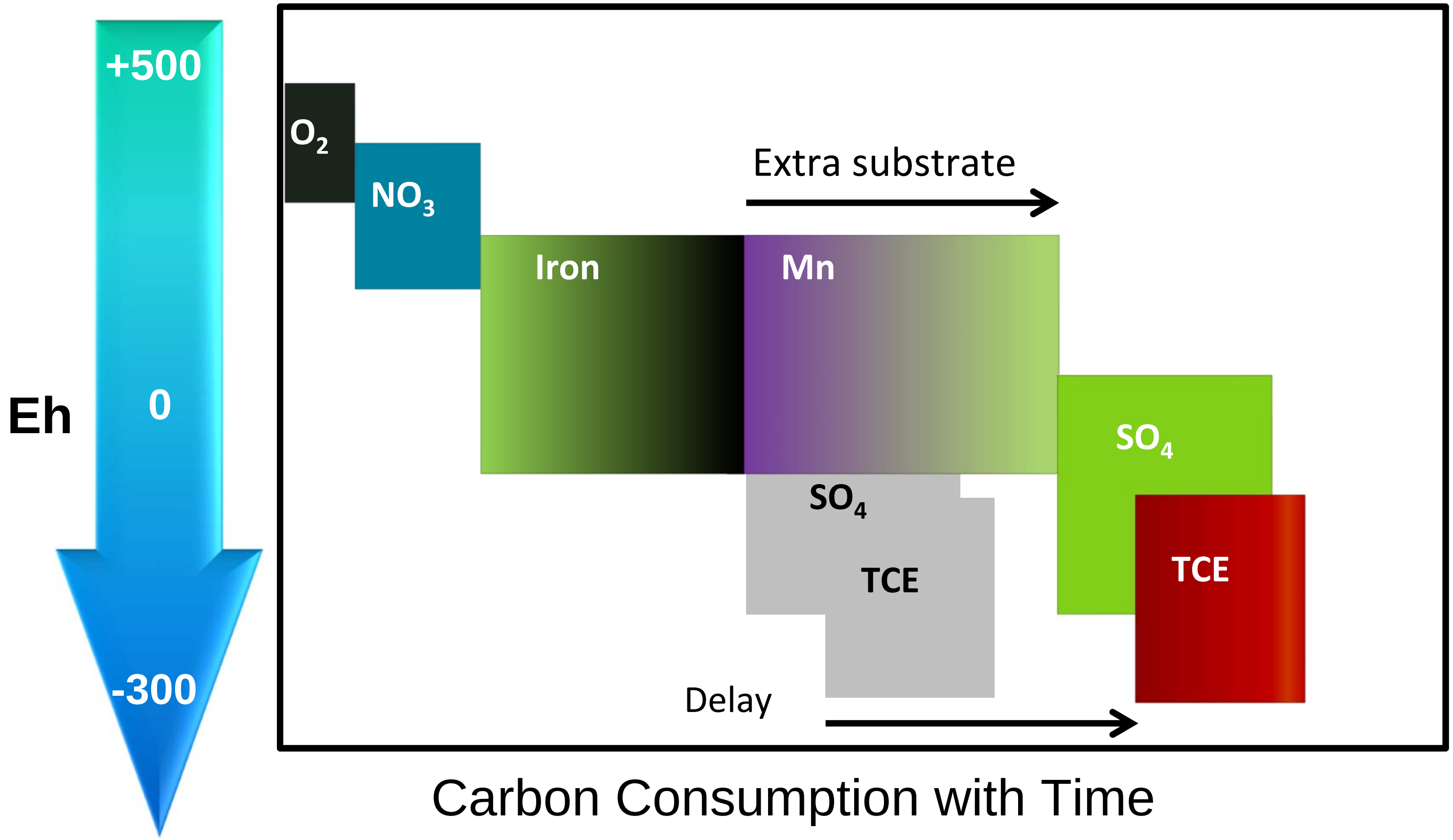
$$2MnO_4^- + TCE \rightarrow \mathbf{2MnO_2(s)} + 2CO_2 + 3Cl^- + H^+$$

- MnO_2 can act as an electron acceptor at higher ORP/Eh than chlorinated ethenes
- Reduction of MnO_2 consumes carbon substrate
- Reductive dechlorination will be delayed by residual MnO_2

Sequential Consumption of Electron Acceptors



MnO_2 – Delay in Redox Reduction and Increase in Substrate Demand



Carbon Consumption with Time

LAB TREATABILITY TESTING

What is a treatability test?

- Laboratory based "bench-scale" testing
- Uses site soil, sediment or rock and groundwater, typically in batch bottles
- Used to assess biodegradation potential under site-specific conditions
- Typically 6 -12 months long
- Column studies can also be performed, but are much less common

Why do Treatability Studies?

- Relatively low cost
- Test multiple variables at the same time – narrows potential options prior to going to the field
- Identify potential complications and address them before they cause problems in the field
- Obtain regulator or client buy-in prior to investing in field-scale tests

TYPICAL COST

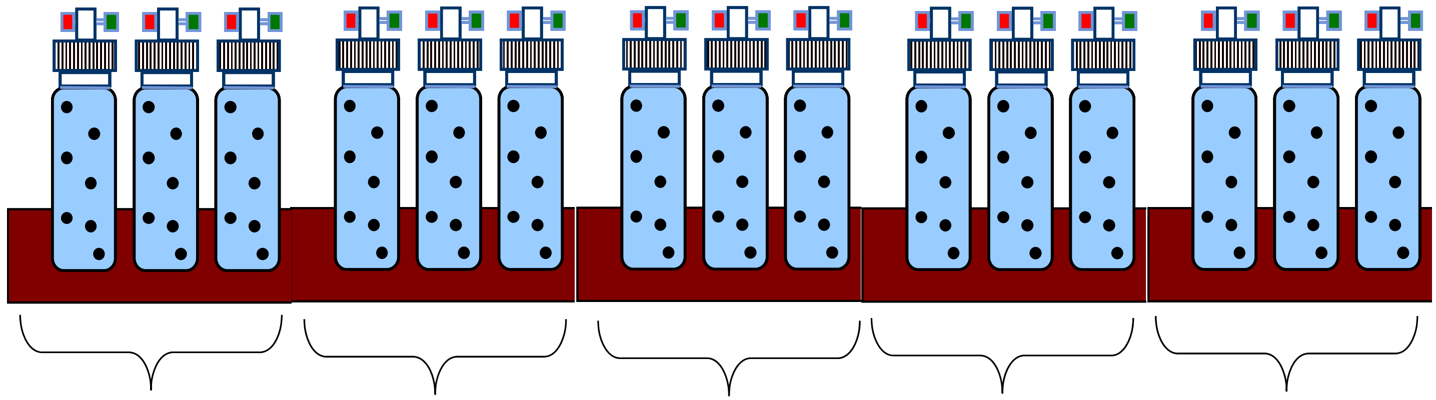
Lab treatability study - $10-30 K

Field pilot test - $100-300 K

Specific Objectives of Biotreatability Studies

- Verify overall performance
- Test various electron donors
- Identify inhibitory factors and evaluate solutions
- Evaluate benefits of bioaugmentation
- Evaluate benefits of nutrients
- Confirm reaction end products

Biotreatability Study Design



Sterile Control

autoclaved and poisoned

Active Control

unamended

Biostimulation

addition of electron donors

Bioaugmentation

addition of known degrading DHC populations

Nutrients

addition of YE, DAP

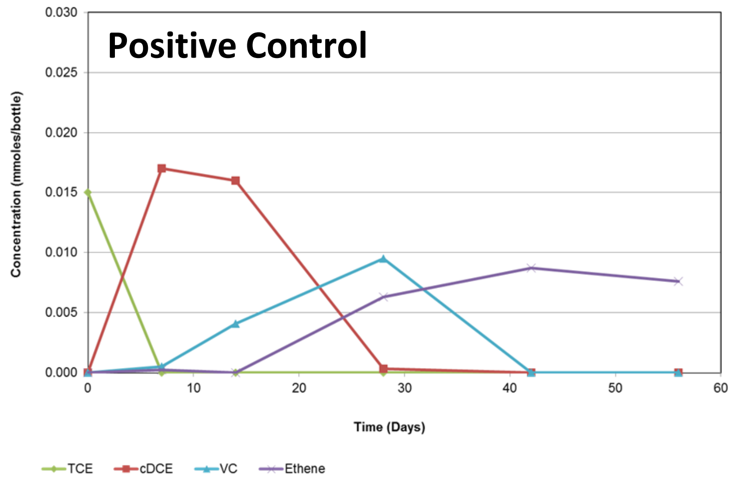
Design of Experiment (DoE) approach reduces the number of bottles and provides best way to do statistical analysis

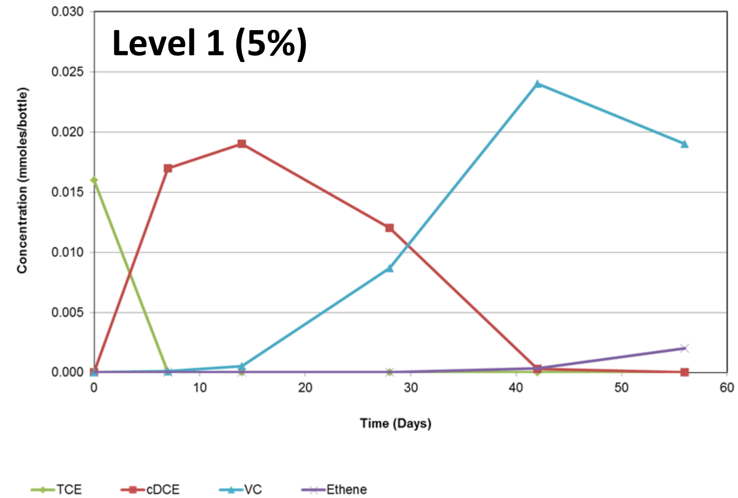
Ode to Lab Treatability Studies

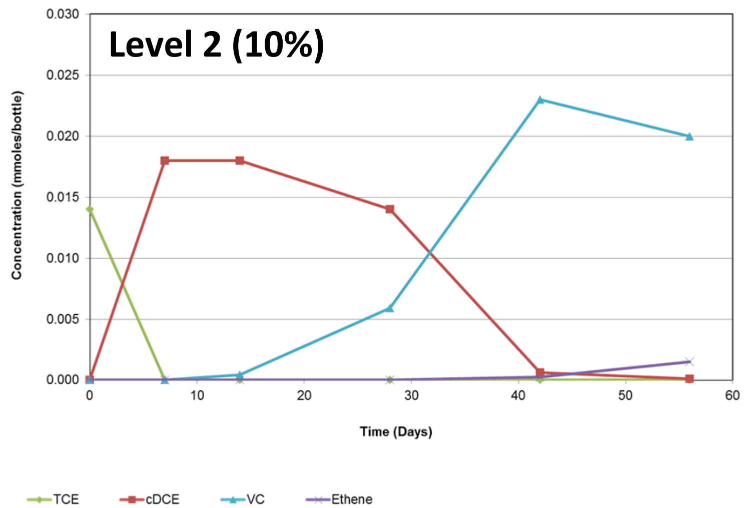
TABLE 1: OVERALL STUDY DESIGN

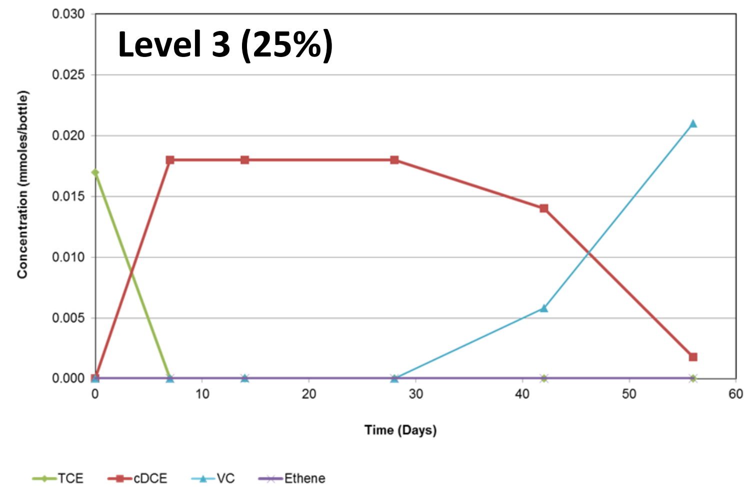
Treatment	Mineral Media	Bioaug	Nutrients
Control	X	X	Standard N&P
Slow Release 1 Level 1	X	X	Slow-release
Slow Release 2 Level 2	X	X	Slow-release
Slow Release 3 Level 3	X	X	Slow-release

Ode to Lab Treatability Studies









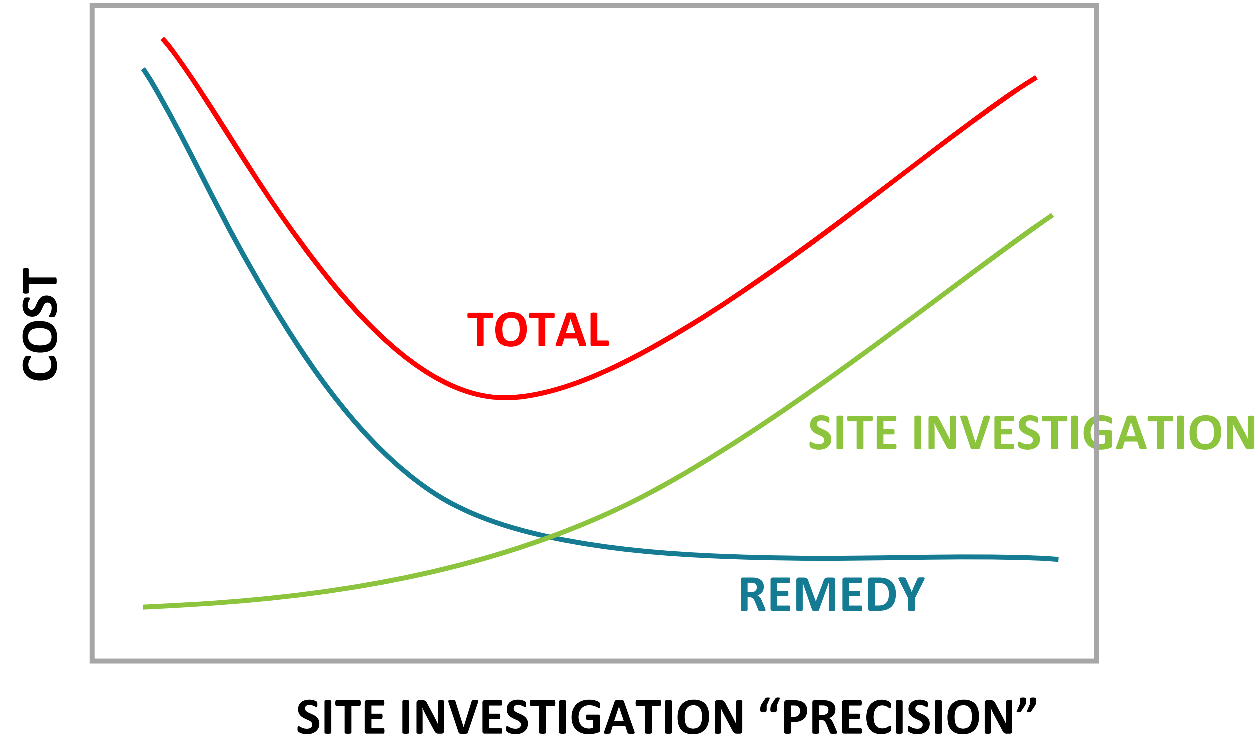
Importance of Sample Collection

- The sample is “alive”
- Collect using core tube
- Minimize field disturbance
- Cap and seal ends, store on ice
- Ship to lab quickly
- Lab should transfer soil to glass container and store under anaerobic conditions
- Set up study quickly
- Understand that soil has a “shelf life”

PRE-DESIGN SITE INVESTIGATION

PRE-DESIGN SITE INVESTIGATION

Example



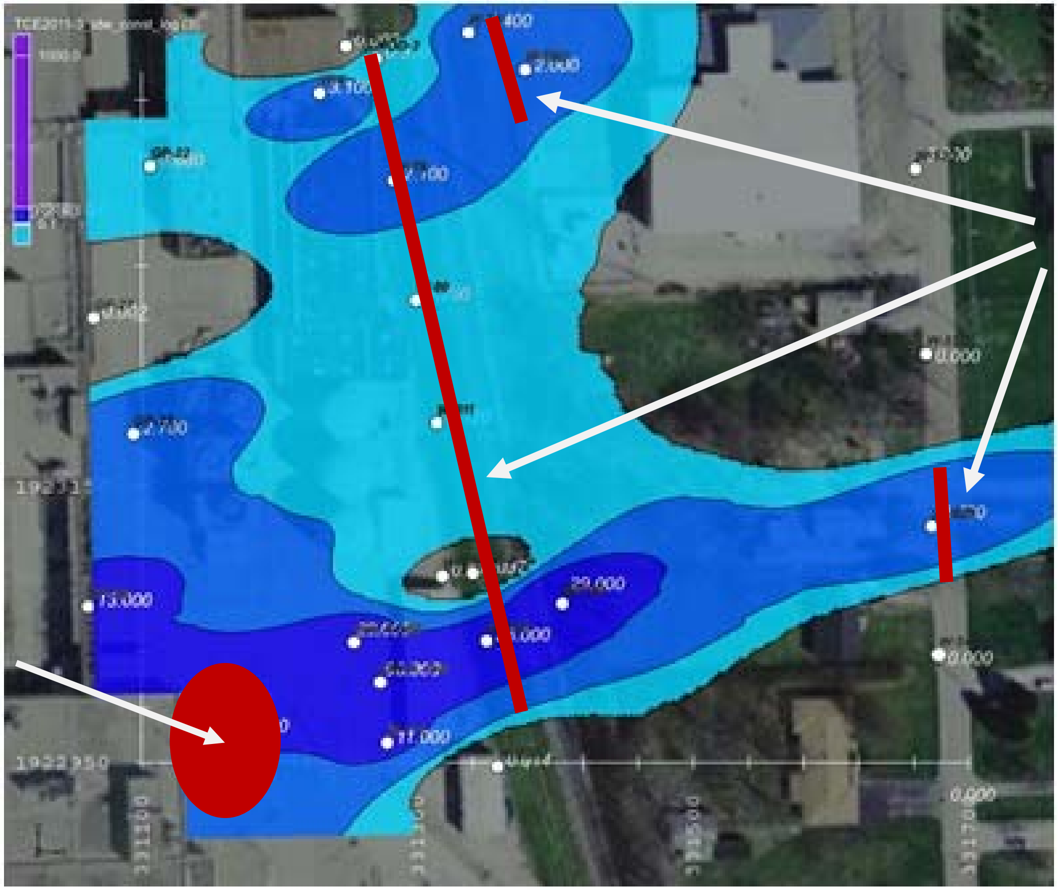
Investments in site investigation can support remedy savings, to a point.

PRE-DESIGN SITE INVESTIGATION

Example

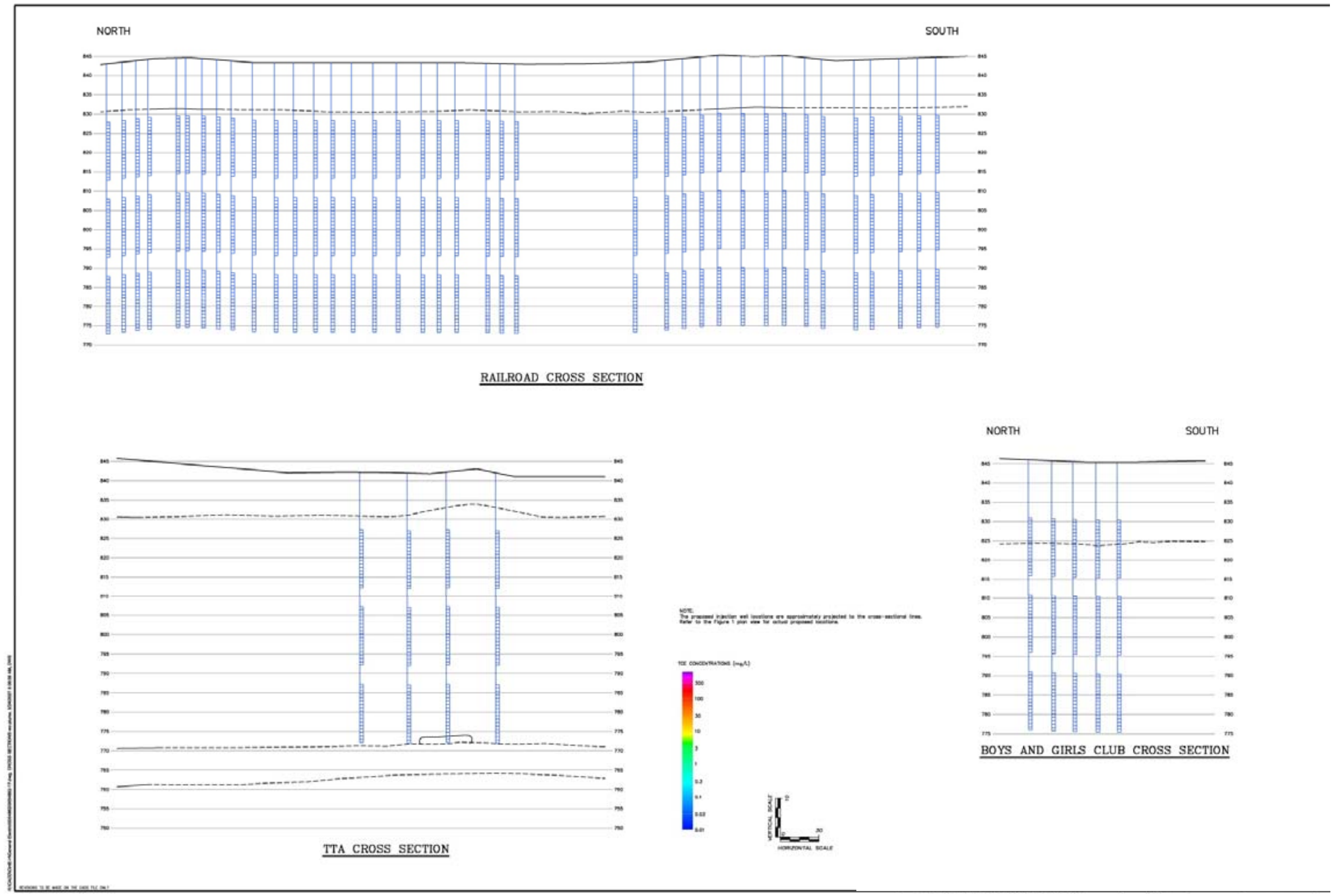
Source treatment area

Biobarriers



PRE-DESIGN SITE INVESTIGATION

Example



PRE-DESIGN SITE INVESTIGATION

Example

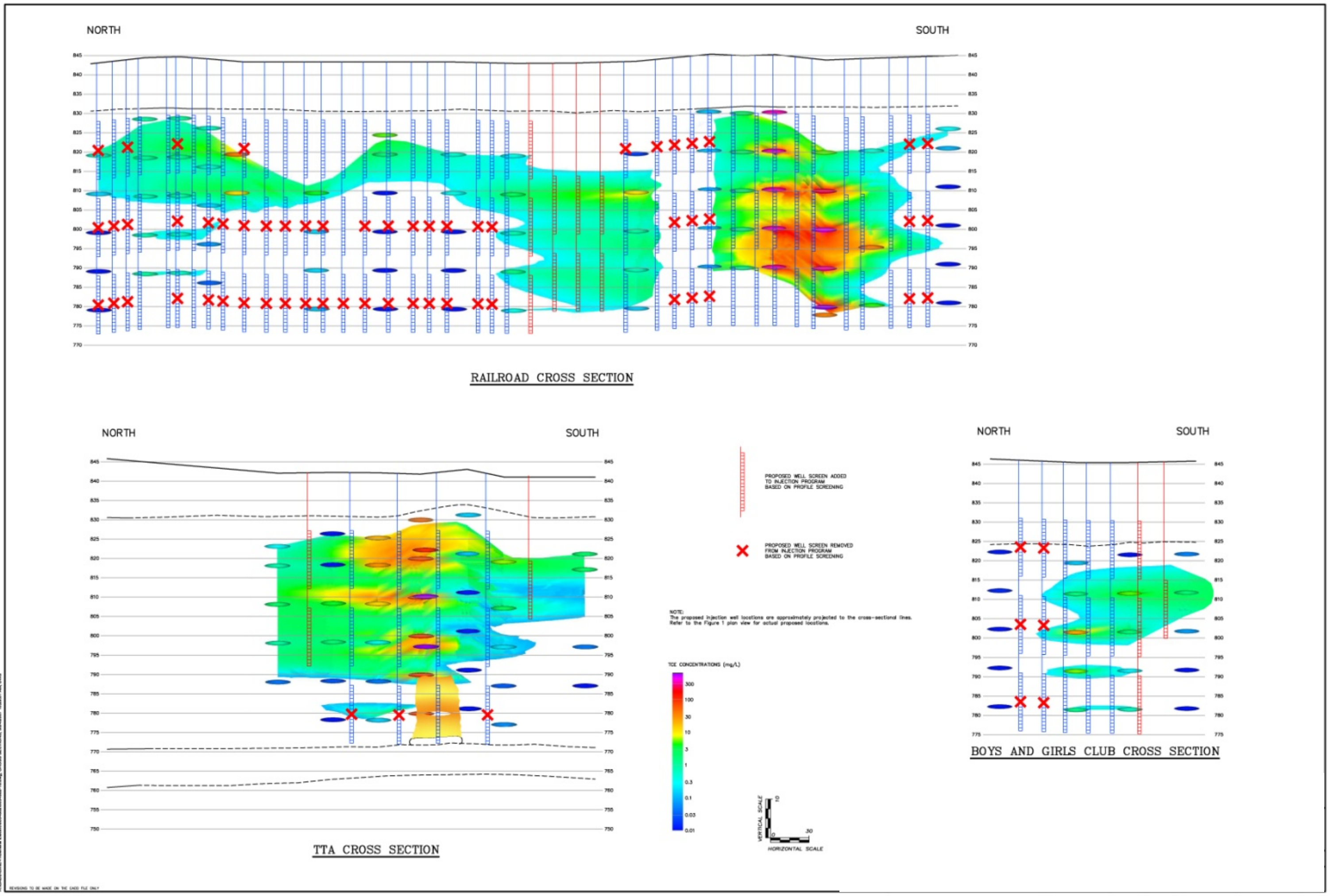
Site investigation program cost for 20 Geoprobe points to 65 feet with field GC and lab confirmations = $61,347

Unit cost savings by eliminating one injection location with 3 injection intervals and injection of treatment chemicals = $16,000

Elimination of 4 well locations results in positive cost benefit

PRE-DESIGN SITE INVESTIGATION

Example



PRE-DESIGN SITE INVESTIGATION

Example

- Pre-design investigation resulted in an improved, more focused treatment strategy
- Plume volume estimate shrunk by 35 to 40%
- Eliminated 56 of 183 well screens (30% reduction)
- Relocation of 15 well screens for better coverage

Cost reduction of $288,000 for investment of $61,300

INJECTION MANAGEMENT

INJECTION MANAGEMENT

Lessons Learned from Direct-Push Injection of In Situ Reagents

This Session - 9:40-10:05 am

M. McCaughey, R. Oesterreich, P. Jin, M. Gentile, A. Pennington, S. Burnell, M. Chalfant, and J. McDonough.
Ryan Oesterreich (Arcadis/USA)

OBG | THERE'S A WAY

Thank you!

Mark.Harkness@obg.com