

An aerial photograph of a city skyline, likely Boston, featuring a river, a bridge, and several skyscrapers. The image is partially obscured by a light blue geometric overlay on the left side.

Identification of Actionable Data for Maintenance Permeable Reactive Bio-Barrier

Session A10, Biobarrier
installation and management

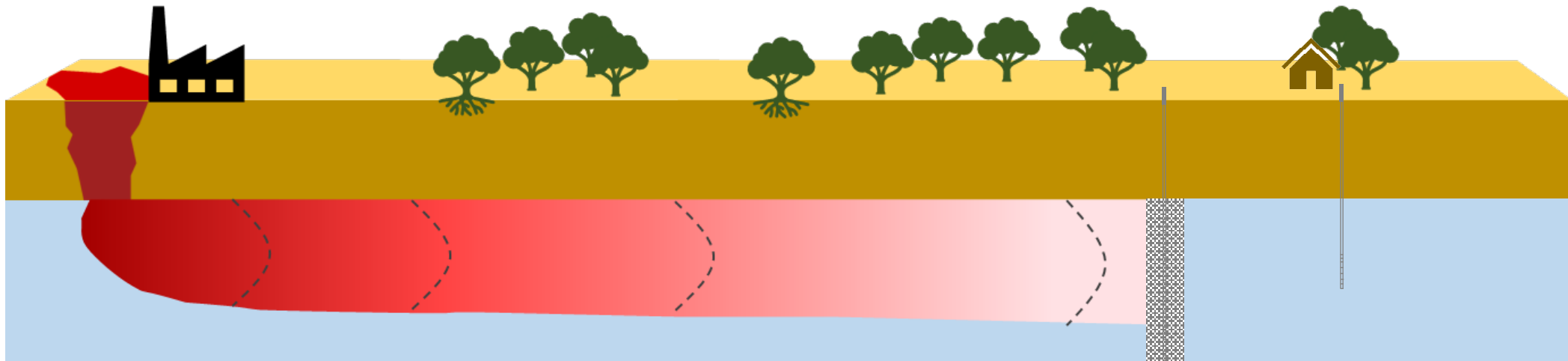
Matt Burns / matt.burns@wsp.com / Boston, MA, USA

Mike Brown / michael.j.brown@wsp.com / Boston, MA, USA

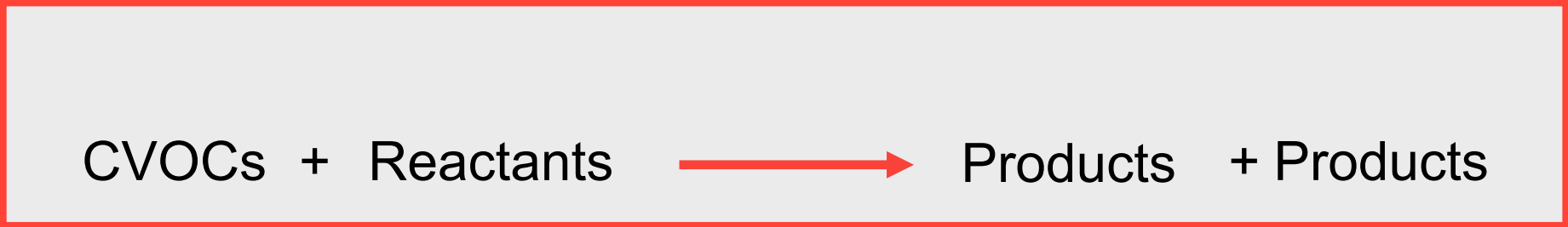
May 11, 2023

Factors influencing bioremediation configuration: whole plume vs passive treatment barrier

- Accessibility restrictions
- Delivery inefficiencies (e.g., low-k zones)
- Receptor proximity
- Response urgency
- Costs/cashflow



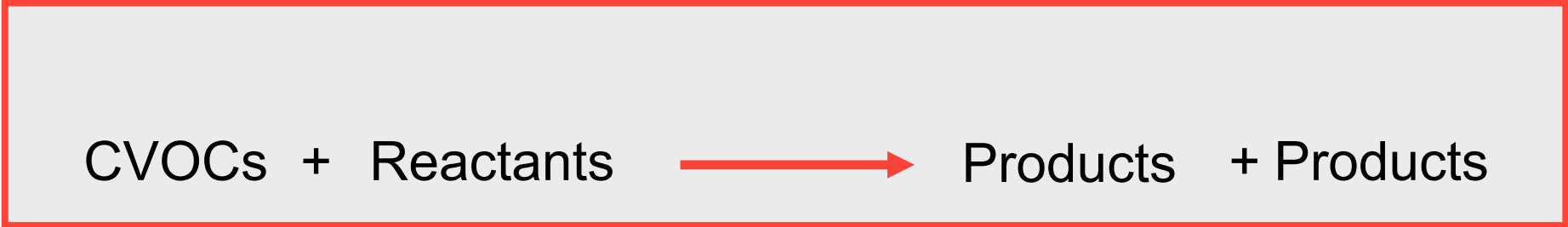
Degradation pathway



— The degradation equation/pathway is the **remediation roadmap**



Degradation pathways



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- Reactants must be present or introduced to maintain ideal conditions **throughout the duration of the remedy**



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 - *macro-nutrients*
 - *micro-nutrients*
 - *ideal “conditions”*



Degradation pathways

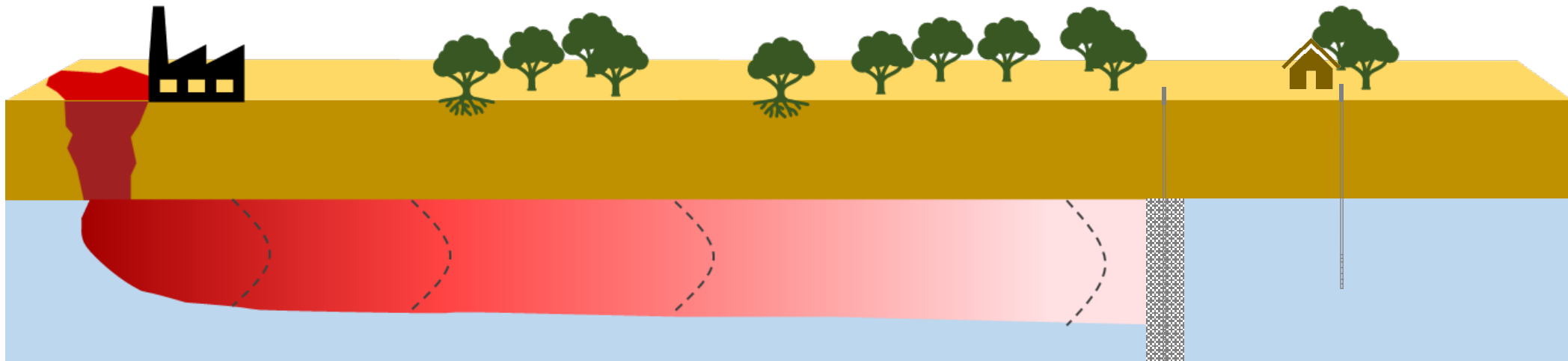


- The degradation equation/pathway is the **remediation roadmap**
- Reactants must be present or introduced to maintain ideal conditions **throughout the duration of the remedy**
 - *macro-nutrients*
 - *micro-nutrients*
 - *ideal “conditions”*
- Reaction won't proceed if “ingredient” is missing
- *In situ* longevity of many amendments is not consistent with a single application achieving remedial goals



Factors influencing maintenance injection frequency

- In barrier attenuation rate must be greater than the mass loading rate
- CVOC concentration
- Naturally occurring “reactants”
- Nature and quantity of amendments previously applied
- Activated carbon slows contaminant transport and provides flexibility with maintenance injections (among other benefits)

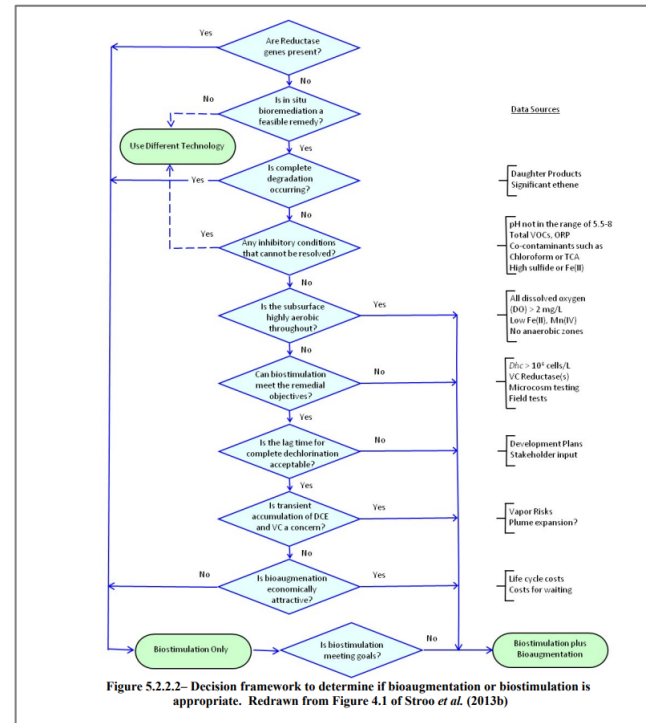
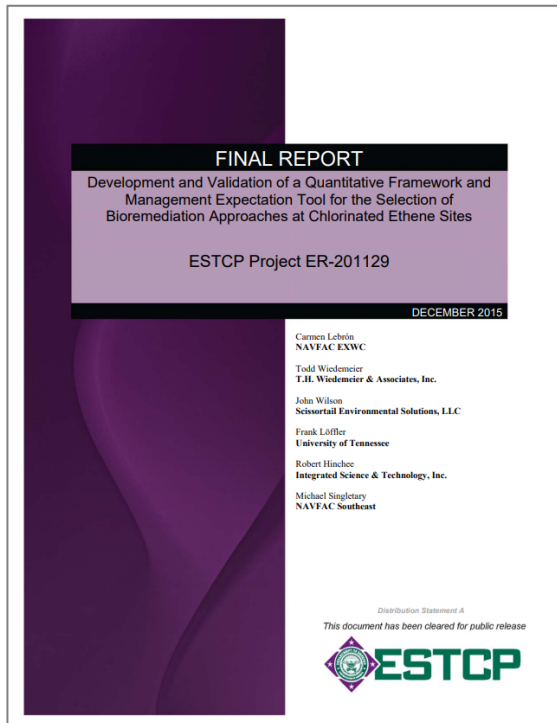


Timing of maintenance injections is important

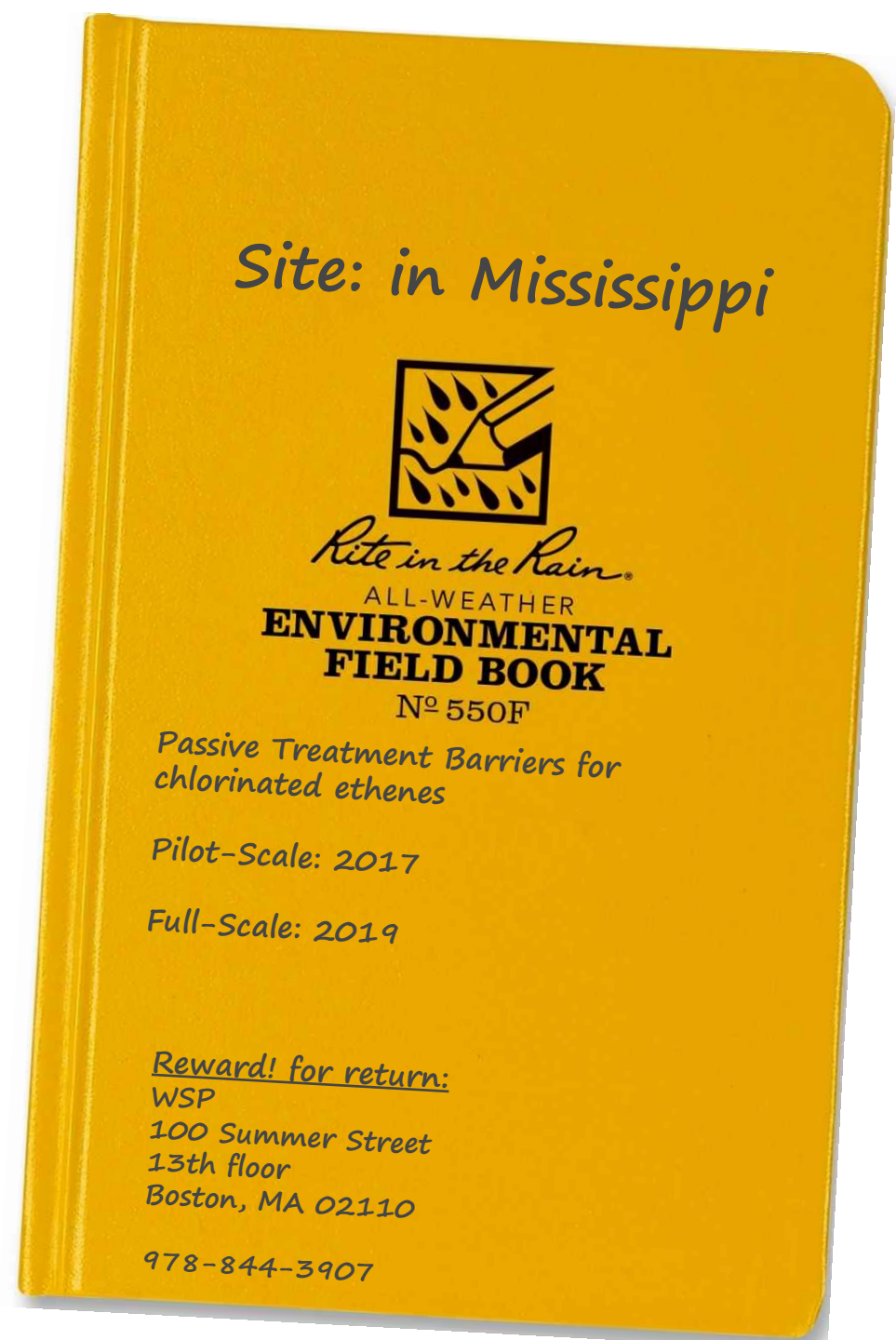
Collecting analytical data that indicate amendment deficiencies is also very important

Long term costs are important too

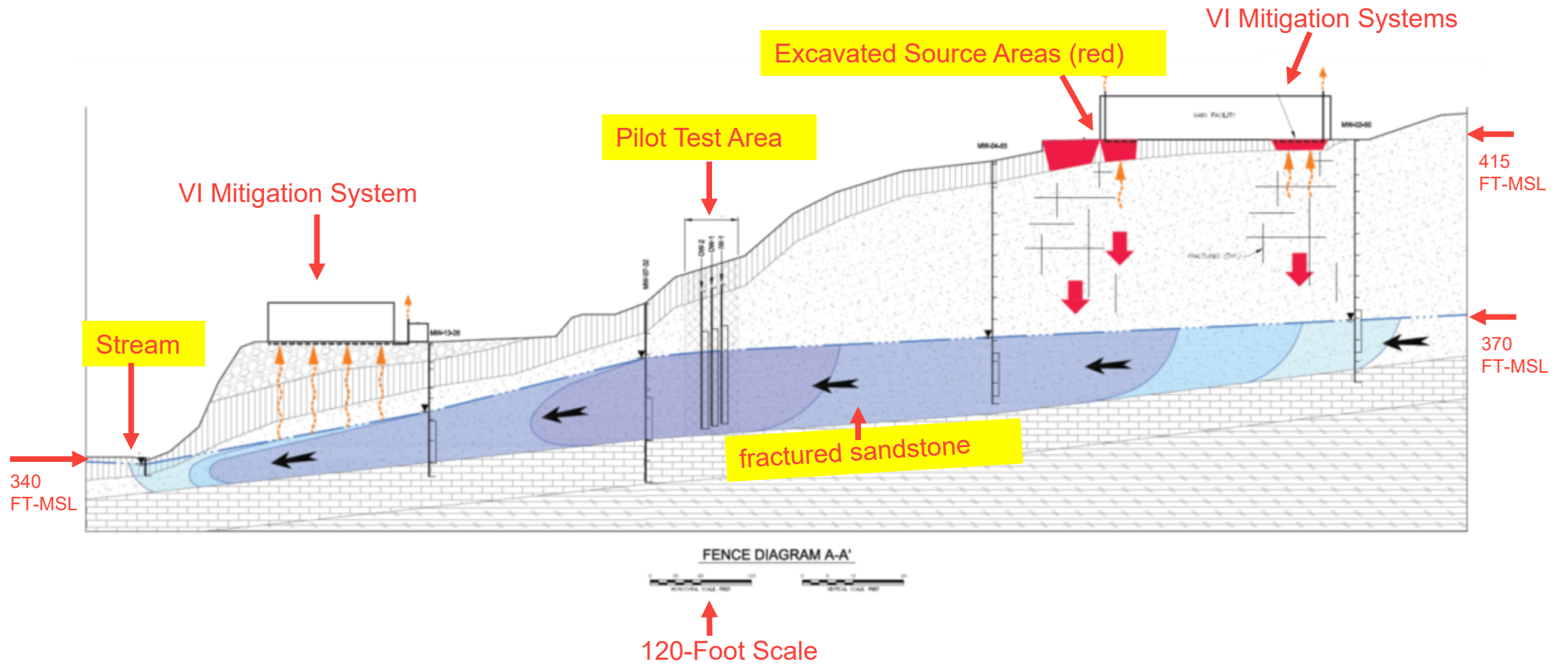
- Analytical suites that efficiently inform on degradation pathway specifics are imperative
 - *Do conventional diagnostics alone provide enough information?*
 - *Do MBT “pay for themselves”?*



How to optimize analytical suite



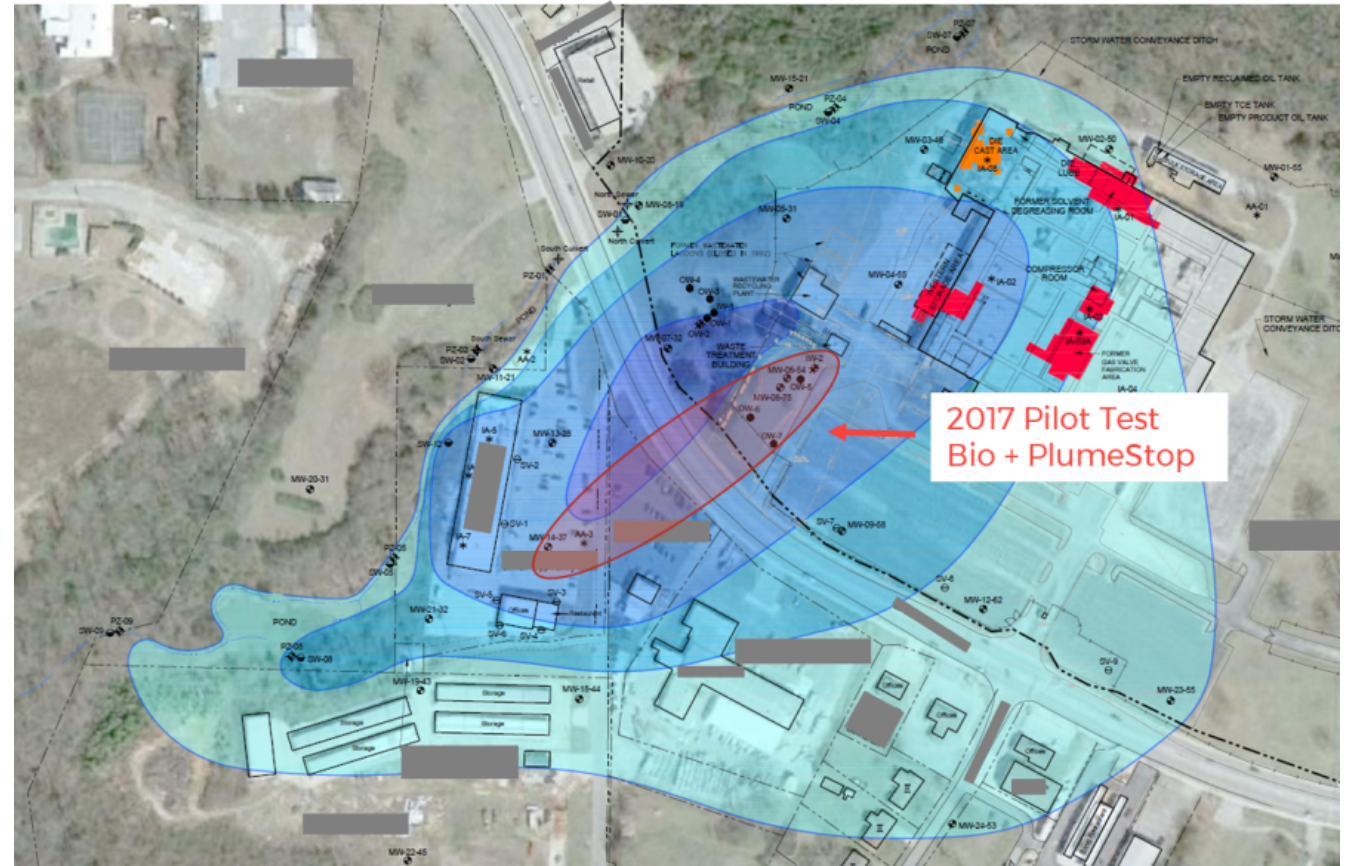
Site background



Site background

Remedial Strategy

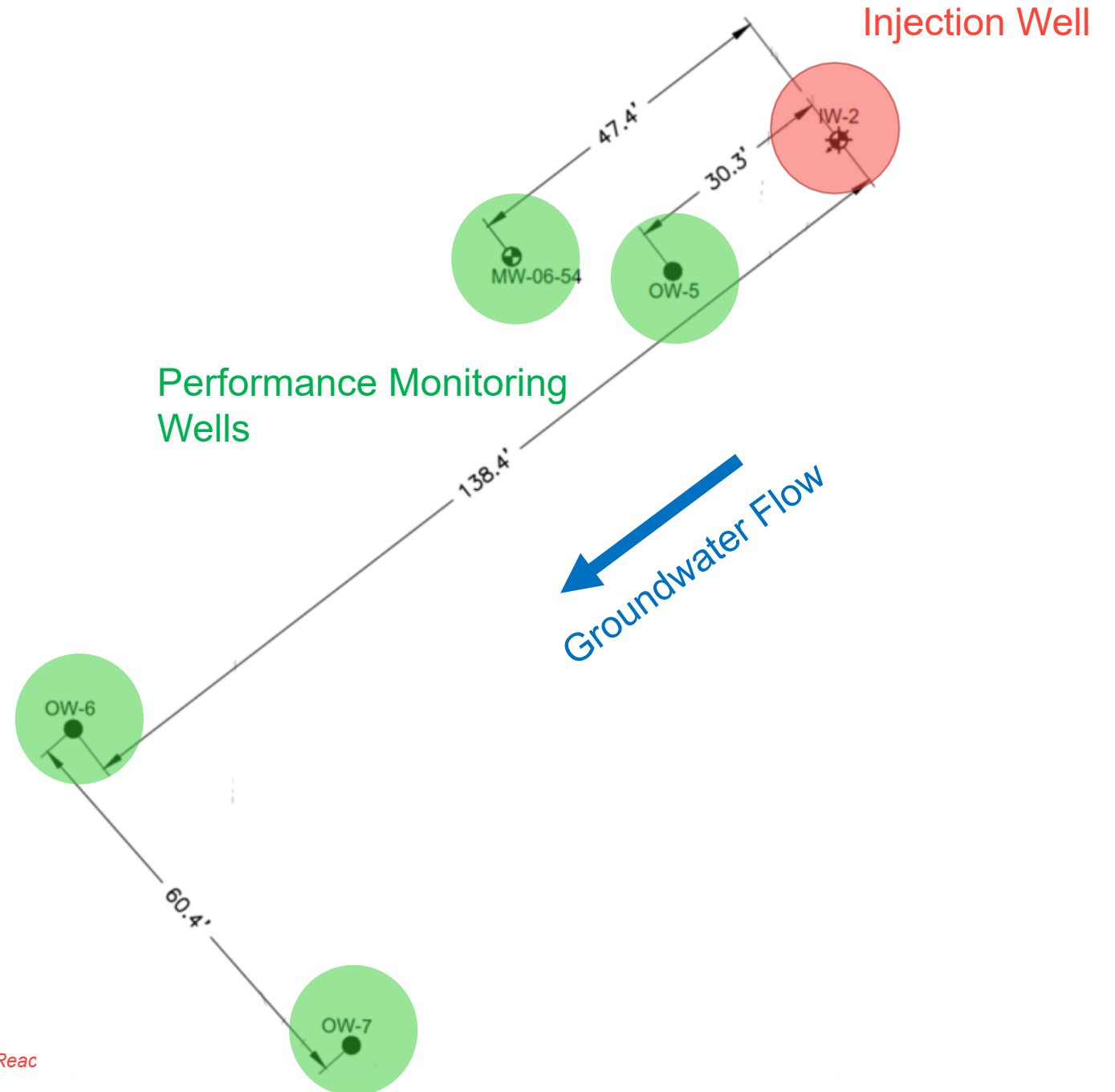
- Back diffusion necessitates long-term management strategy
- Permeable reactive bio-barriers
Vs
Hydraulic control (P&T)
- Cost model showed bio-barrier to be favorable (similar capital costs but O&M less for the bio-barrier)
- Pilot bio-barrier



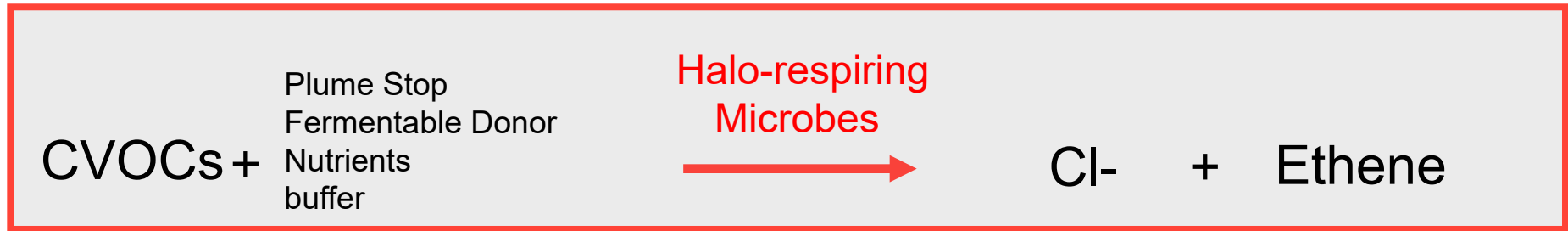
Pilot test well layout

Amendments

- PlumeStop
- Sodium lactate
- HRC
- Microbial Augment
- Ammonium Sulfate
- Diammonium Phosphate
- Sodium Bicarbonate



Pilot test analytical suite



Data Type	Diagnostic	Aqueous	Sorbed/ISM
Empirical	Macronutrients	√	-
	Geochemical shifts	√	-
Direct	VOCs	√	√
	End Products	√	-
	CSIA	√	-
Mechanistic	Microbial Diagnostics	√	-

Delivery confirmation

Legend

OW-5		
Parameter	1	2
VFA	Strong	Limited
pH	Strong	Strong
Specific Conductance	Strong	Strong
DO	Strong	None
ORP	Strong	Strong

← Sampling period
1 = 5/17
2 = 8/17

Evidence of Delivery

- Strong
- Limited
- None

MW-6		
Parameter	1	2
VFA	Strong	Strong
pH	Strong	Strong
Specific Conductance	Strong	Strong
DO	Strong	Strong
ORP	Strong	Strong

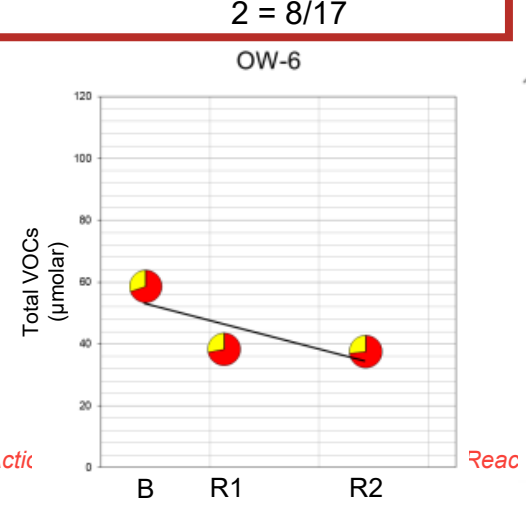
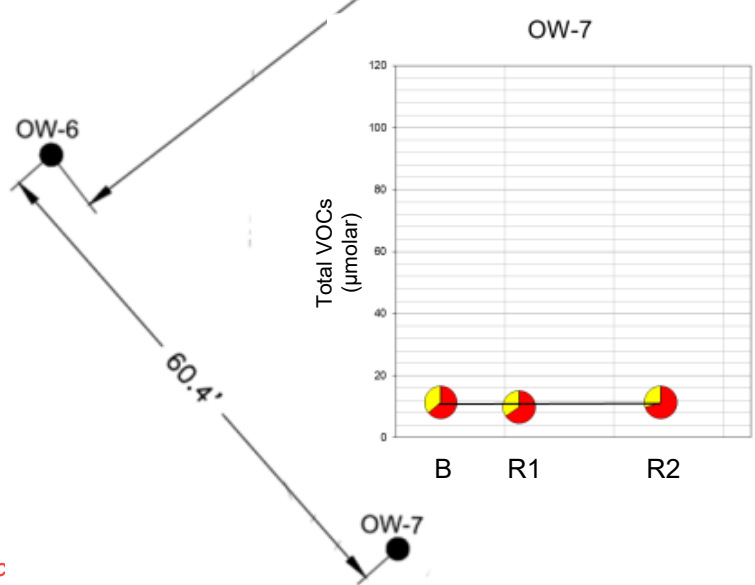
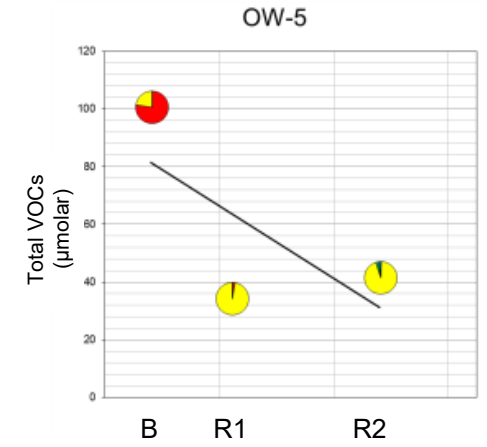
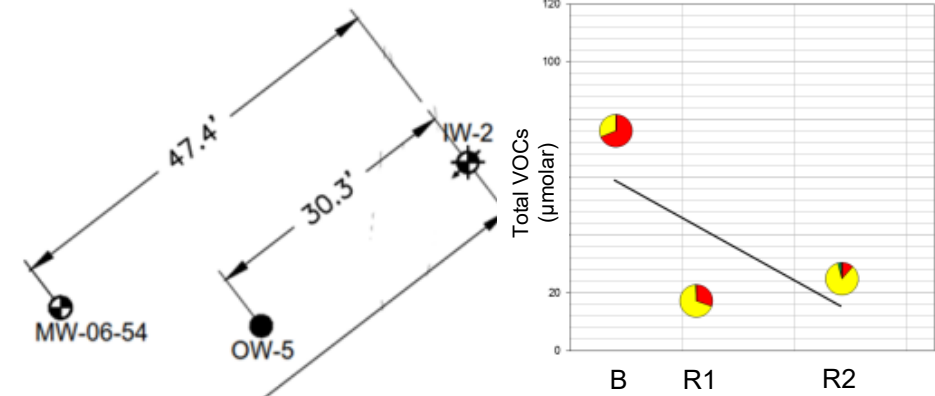
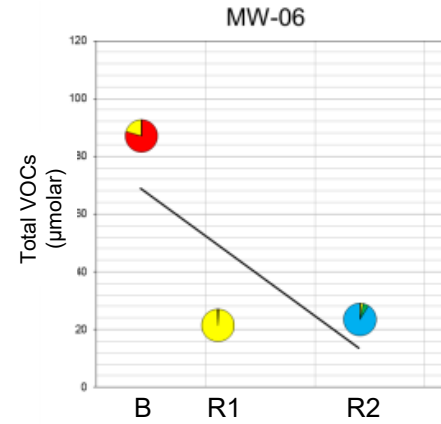
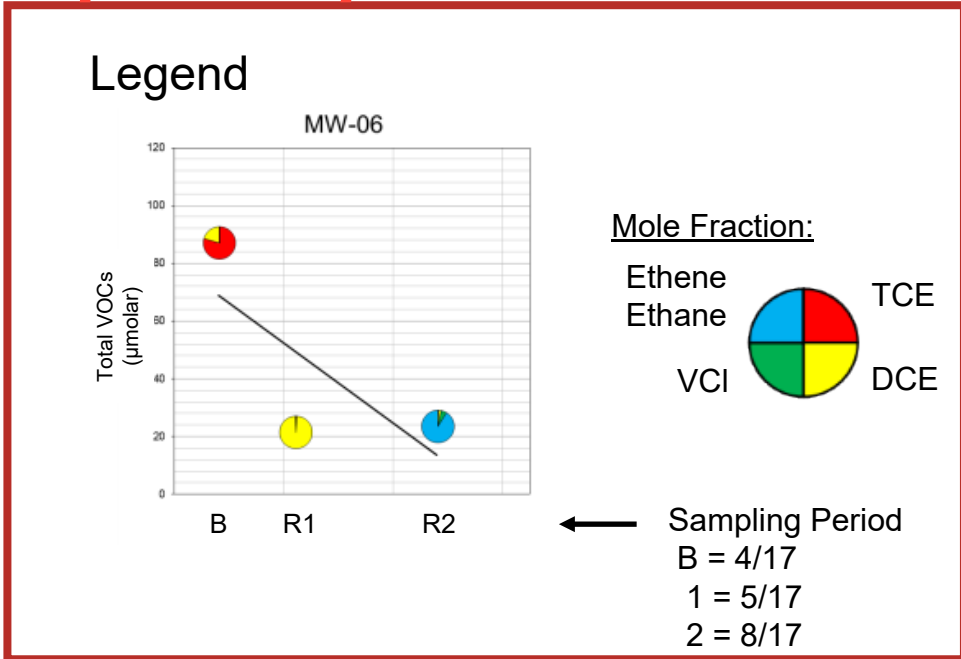
IW-2		
Parameter	1	2
VFA	Strong	Limited
pH	Strong	Strong
Specific Conductance	Strong	Strong
DO	Strong	None
ORP	Strong	Strong

OW-5		
Parameter	1	2
VFA	Strong	Limited
pH	Strong	Strong
Specific Conductance	Strong	Strong
DO	Strong	None
ORP	Strong	Strong

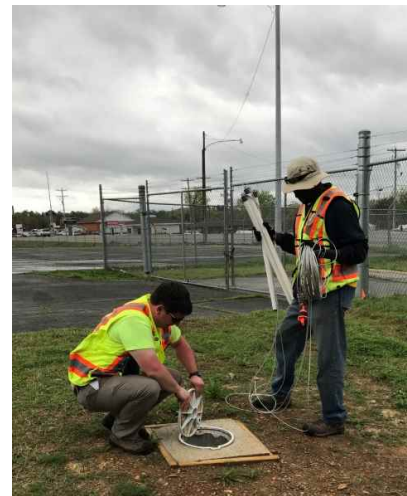
OW-6		
Parameter	1	2
VFA	None	None
pH	None	None
Specific Conductance	None	None
DO	Strong	Limited
ORP	Limited	None

OW-7		
Parameter	1	2
VFA	None	None
pH	None	None
Specific Conductance	Limited	Limited
DO	Limited	Limited
ORP	None	None

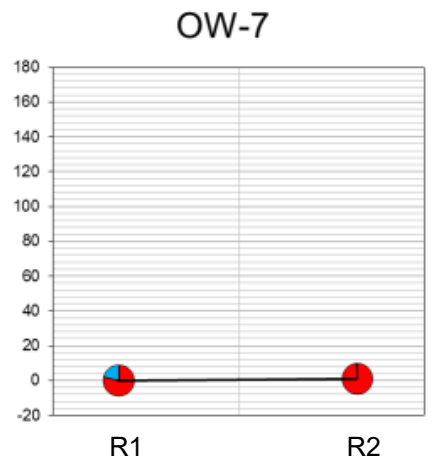
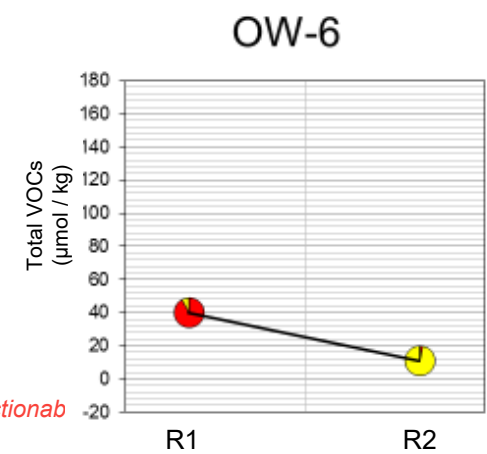
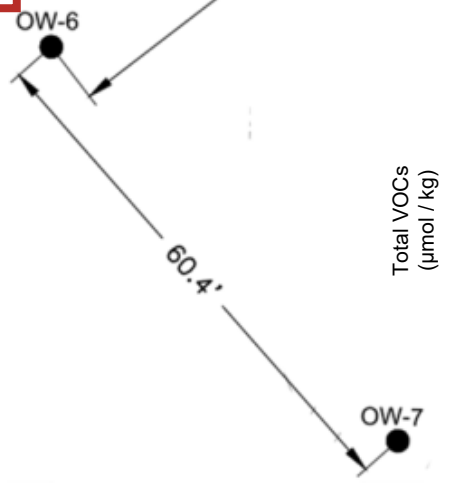
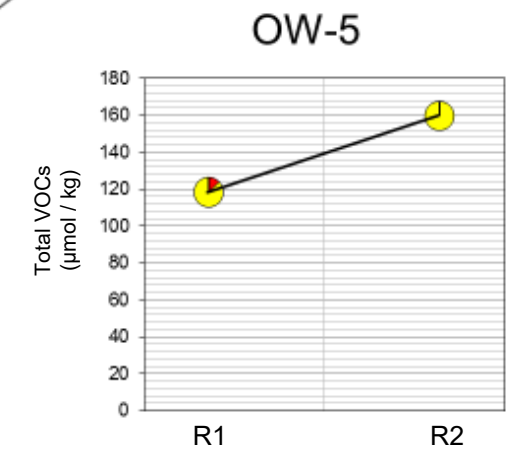
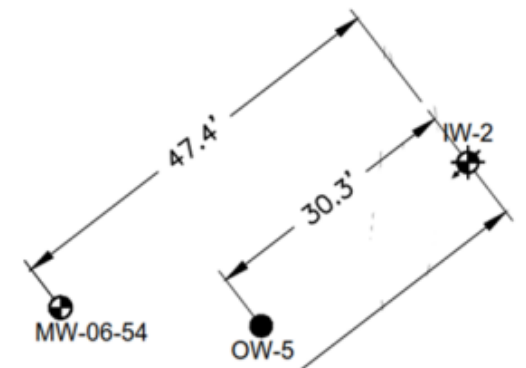
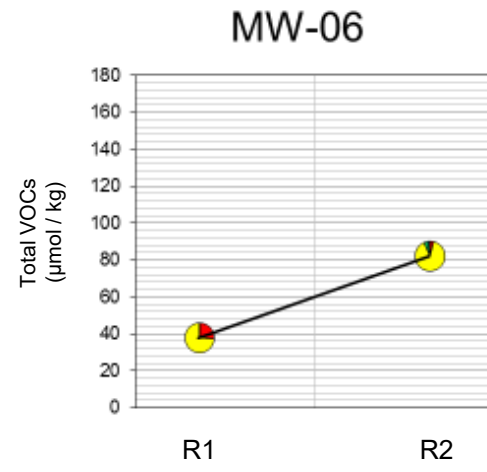
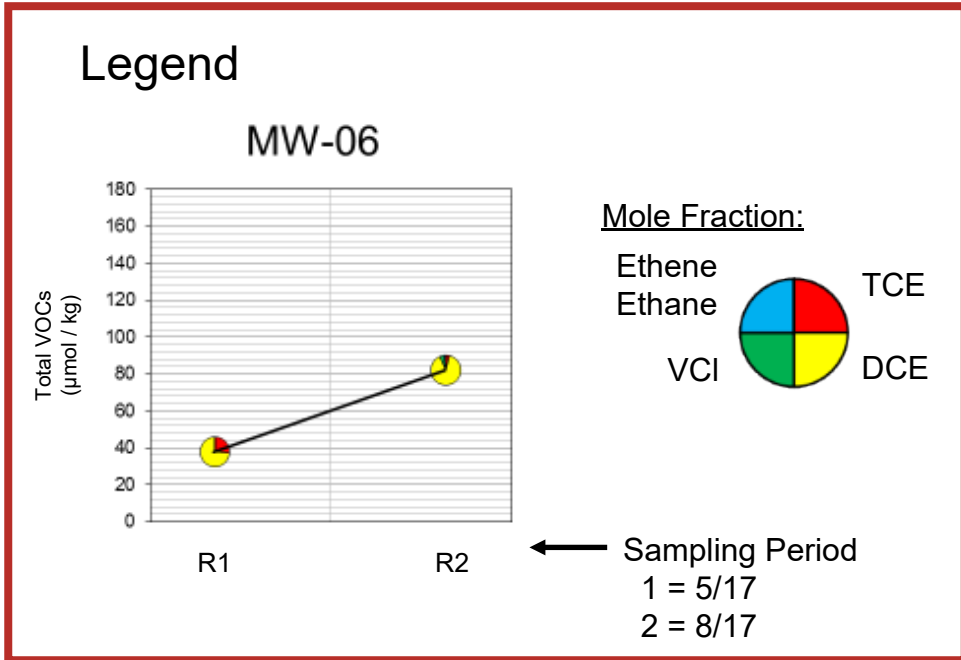
Daughter products aqueous phase



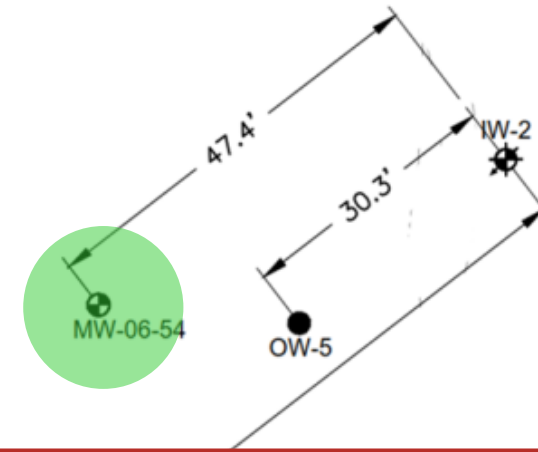
In Situ Microcosms



Daughter products sorbed/solid phase



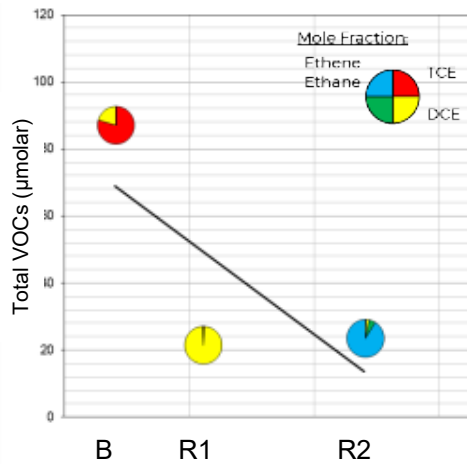
Advance diagnostics MW-6



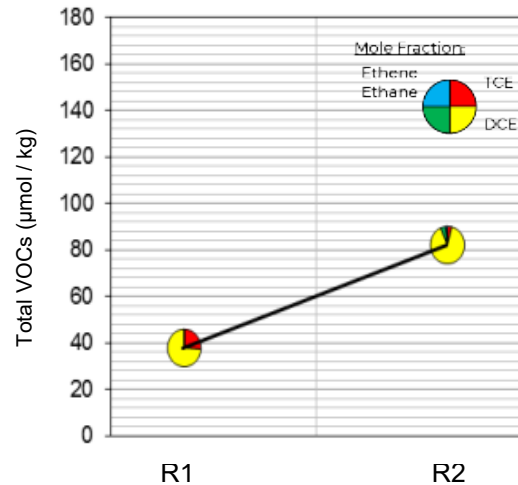
Mole Fraction

Ethene
Ethane

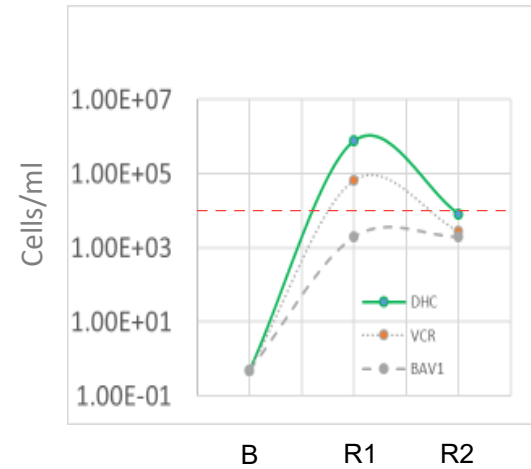
Dissolved Total VOCs & Mole Fraction



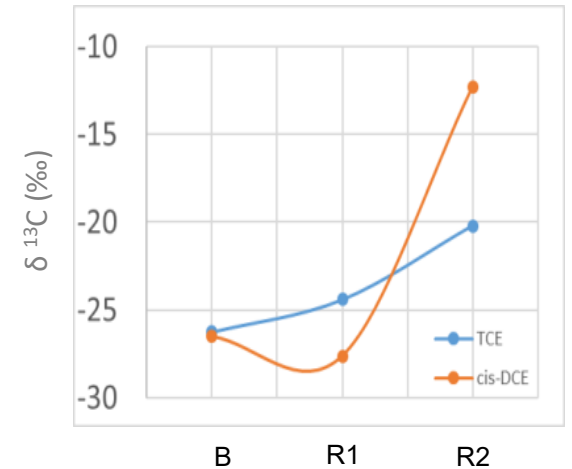
Sorbed Total VOCs & Mole Fraction



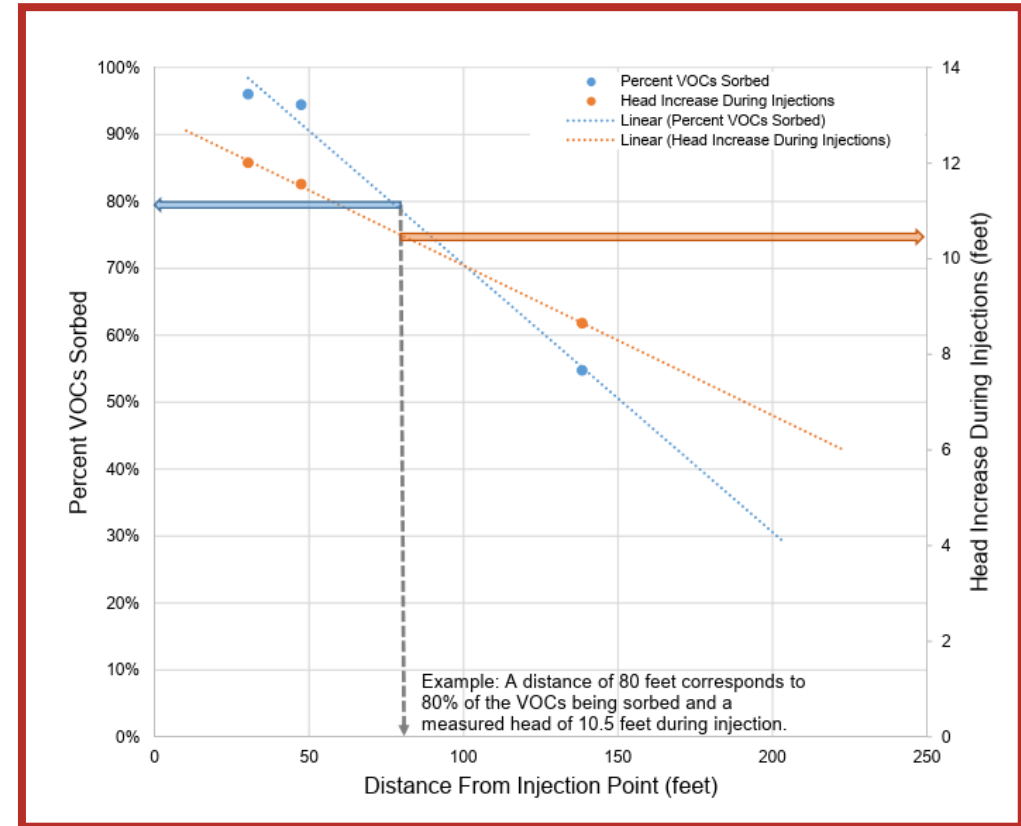
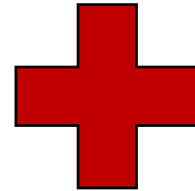
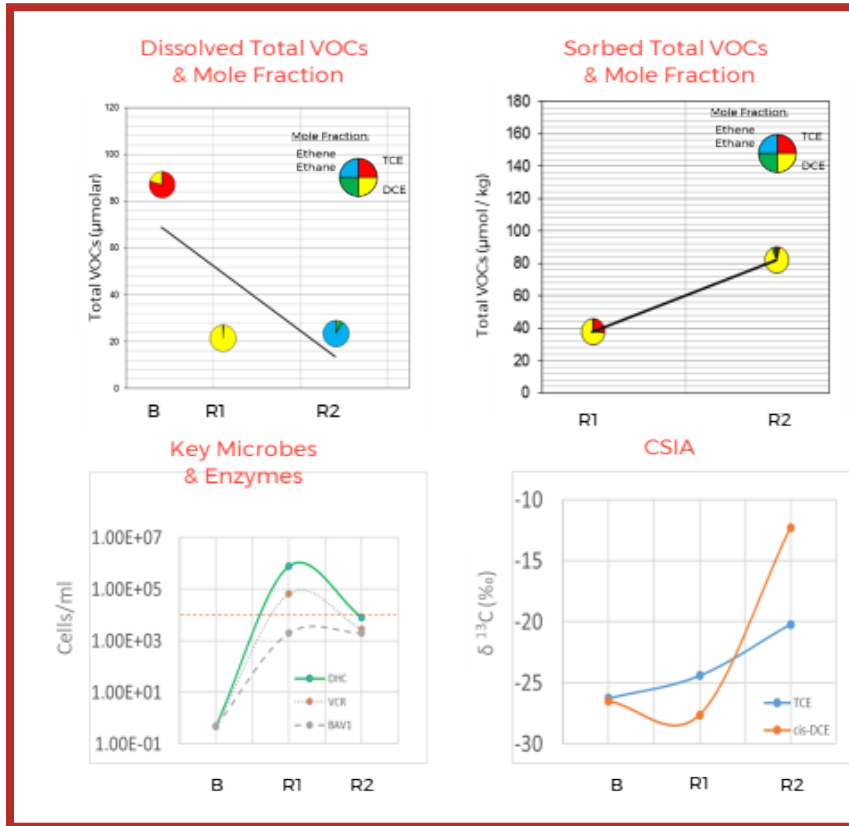
Key Microbes & Enzymes



CSIA



Pilot study diagnostics provided high level of confidence

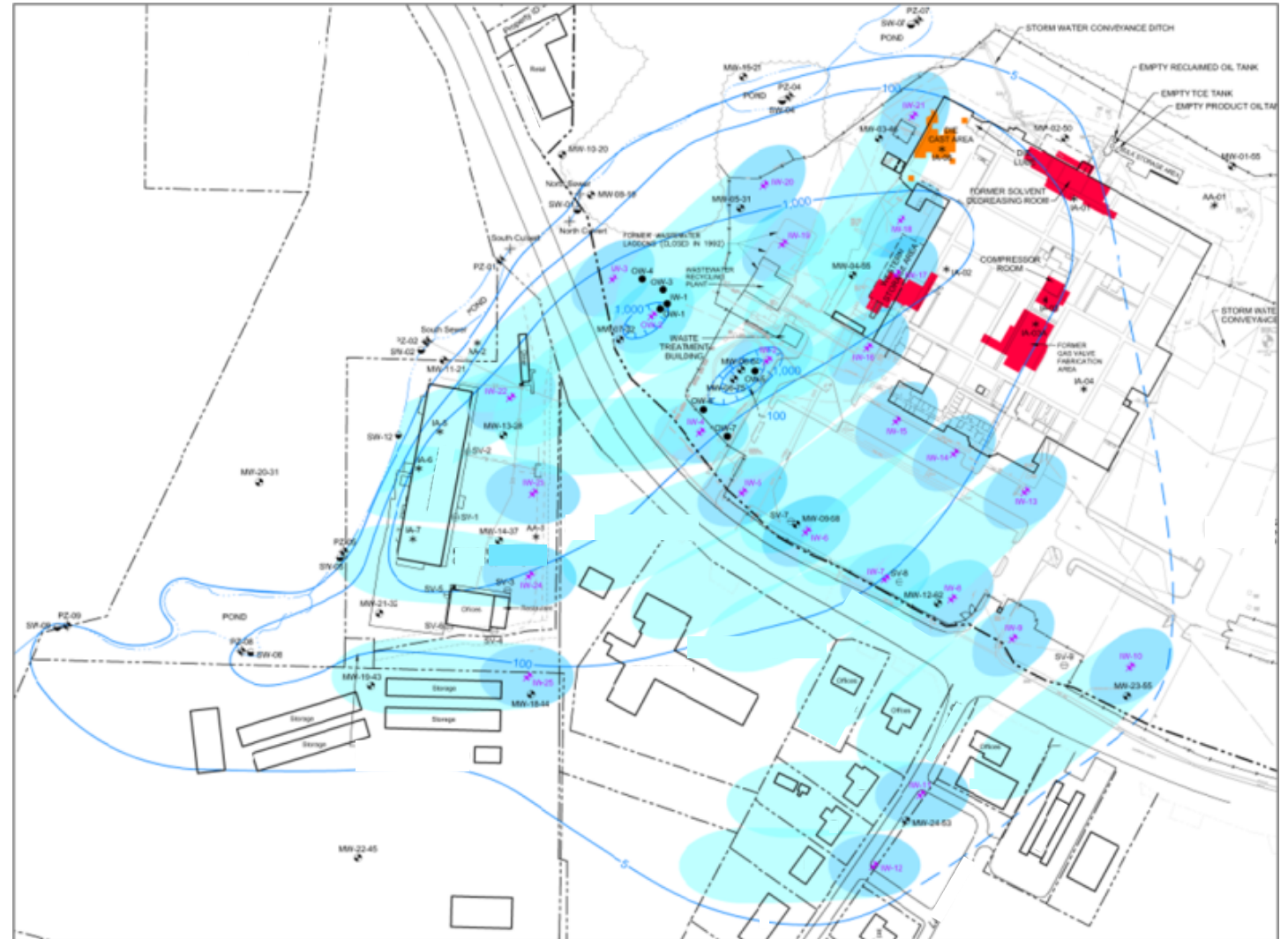


Pathway Stimulated

Area of Influence

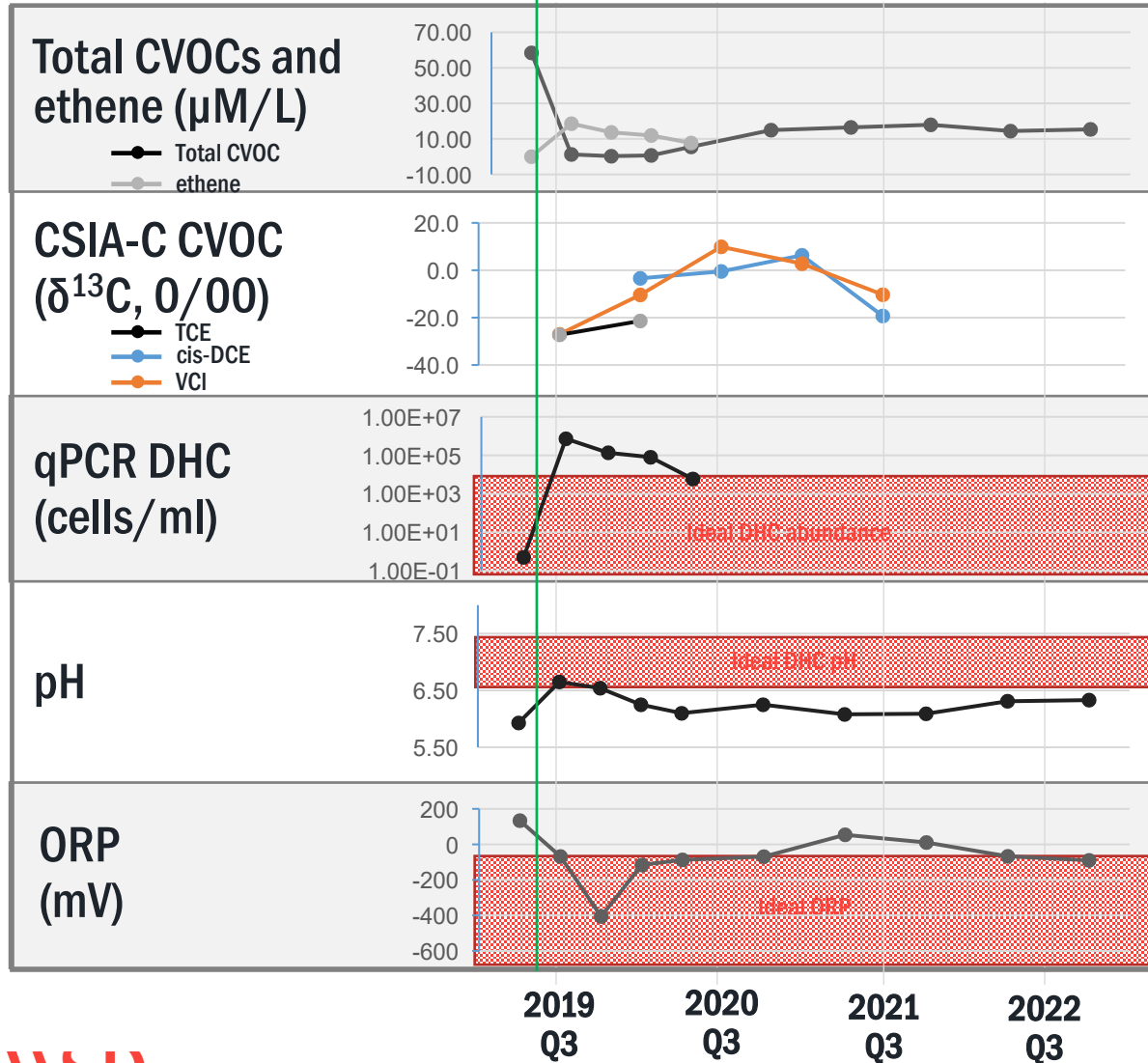
Full-scale application

- 26 injection wells
- ~ 3 transects
- 160,000 gallons of amendment
- Formulation consistent with pilot



Performance monitoring results (typical)

OW-6 (Typical)



- Substantial initial decrease in CVOC concentrations with increased ethene production
 - *Less efficient treatment evident about 1 year after application*
- Effects of treatment apparent in isotopic data too
 - *TCE enriched and non-detect soon after treatment*
 - *Daughter products both also significantly enriched initially with depletion trend after a year*
- DHC abundance shows same trend great initially then decreasing
- pH and ORP trends consistent with advanced diagnostics but at a much lower price point
- Can always supplement analytical with MBTs on an “as needed” basis

Conclusions



- At pilot test, a comprehensive analytical suite, including MBTs, are strongly recommended to demonstrate activity along degradation pathways
- A more efficient analytical suite can be used to identify that consumable amendments need replenishing (e.g., ORP, pH, ethene, etc.)
 - *Metabolomics will be even better after sentinel metabolites are identified*
- Regeneration recently announced availability of new colloidal electron donor (AquiFix™) designed to be used with PlumeStop® with up to a 10-year release profile
- Image to the left shows the site-specific cost justification for permeable reactive bio-barrier treatment at this site
 - *Capital costs between both alternatives similar*
 - *O&M of permeable reactive bio-barrier much less costly*
 - *Validated feasibility of cost-effective analytical suite*

Thank You

Corresponding Author Contact

Matt Burns

matt.burns@wsp.com

978-844-3907

<https://www.linkedin.com/in/mattburnswsp>