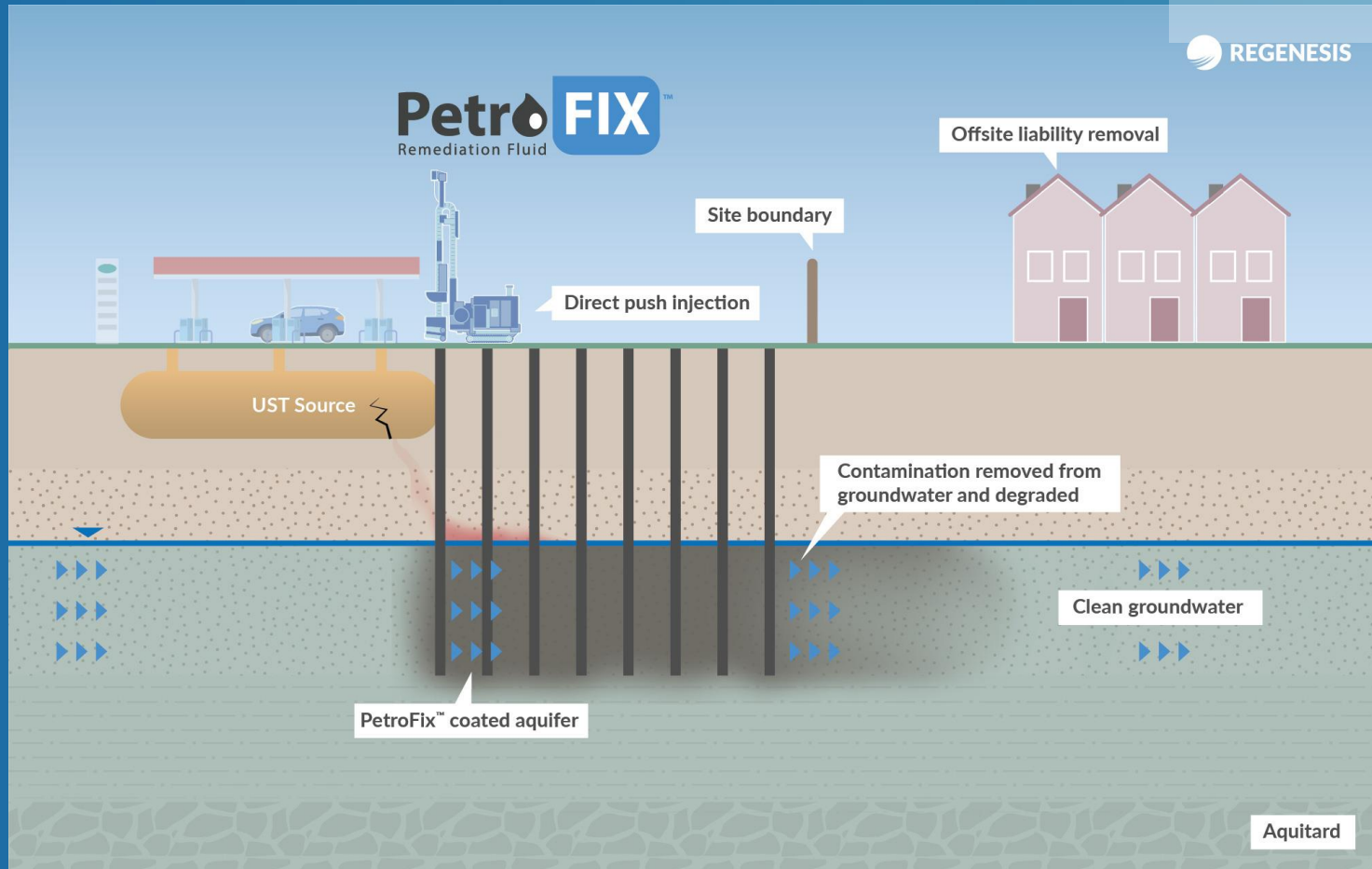


Performance of a New Activated Carbon Amendment for Bioremediating Petroleum-Impacted Sites

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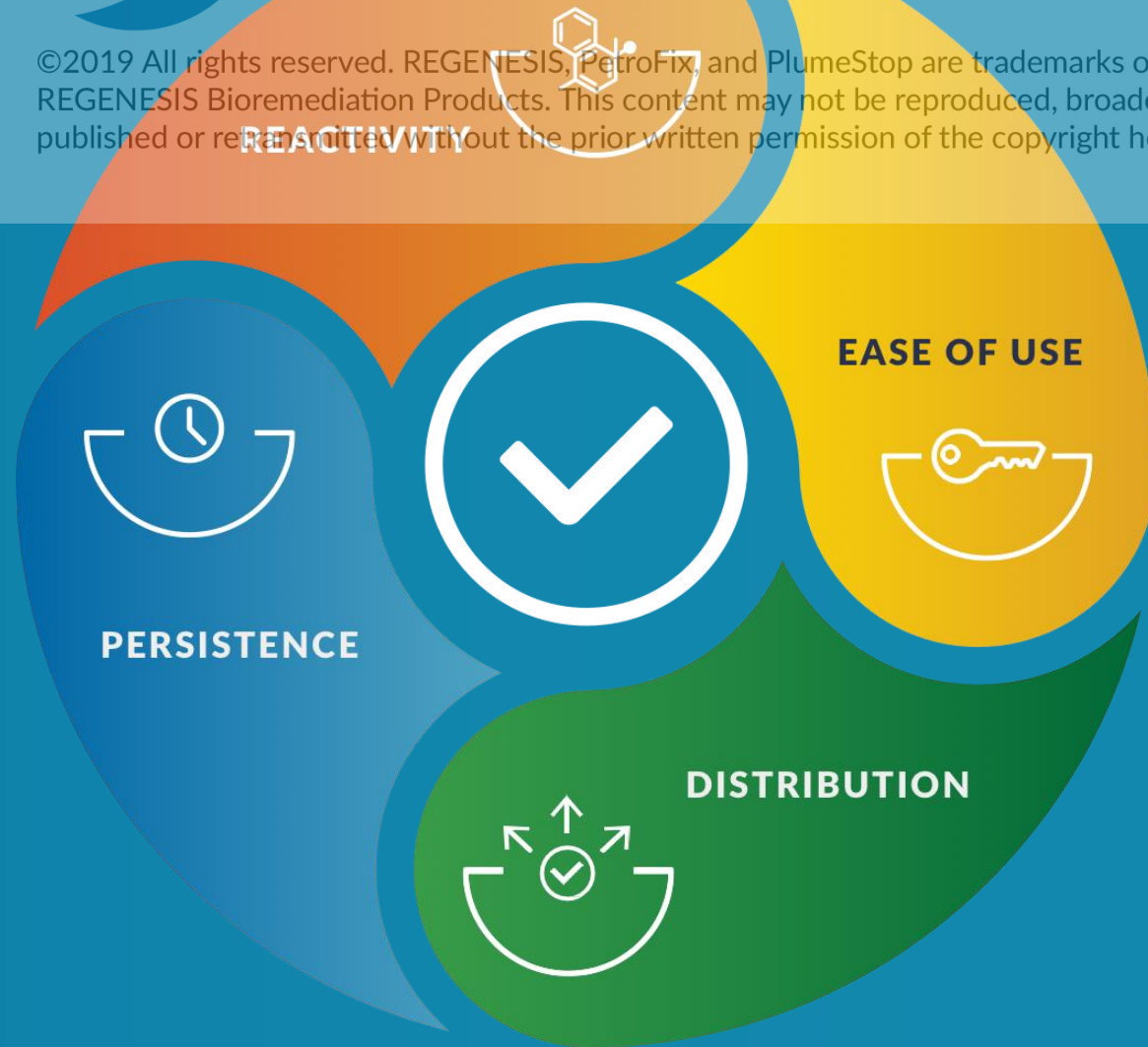
IPEC 2019



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REQUIREMENTS FOR SUCCESSFUL *IN SITU* REMEDIATION



PetroFix Resulted From PlumeStop Research

PLUMESTOP® LIQUID ACTIVATED CARBON™ LAUNCHED IN 2013

- Applied on 300+ sites
- Industry leading product for solvents, PFAS, hydrocarbons

IDENTIFIED AN OPPORTUNITY TO EVOLVE THE FORMULATION FOR PETROLEUM SITES - PETROFIX™

- Fast results for petroleum sites
- Persistent treatment
- Higher treatment range
- Promotes biodegradation after sorption
- Easy and safe to apply
- Do it yourself process (versus turn-key)

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Features

- Patented use of **micro-scale activated carbon (1-2 μm – size of red blood cell)**
- Contains **Nitrate and Sulfate** electron acceptors
- Treats BTEX, TPH-G, TPH-D, MTBE, naphthalene, etc.
- Easily injected with direct push using low pressure for uniform distribution
- Not recommended for free-phase LNAPL

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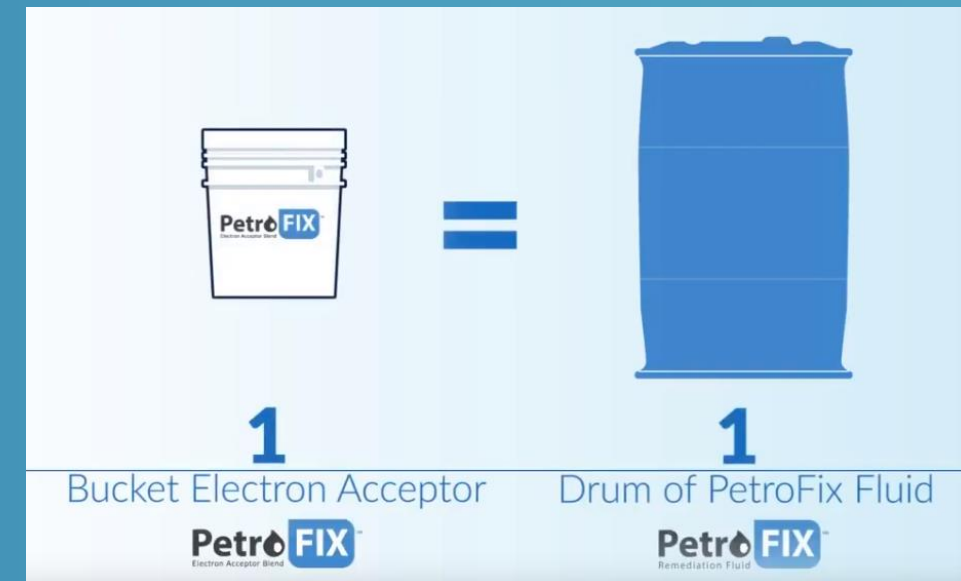


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Formulation

- +25% 1-2 μm carbon as shipped in 55-gallon poly drums
- Sulfate pre-blended in drum with carbon in form of calcium sulfate dihydrate = <10%
- Each drum of PetroFix also given:
 - **20 lb EA Blend, sulfate + nitrate (preferred)**
 - 40 to 60% Ammonium Sulfate
 - 40 to 60% Sodium Nitrate
 - **Or, 20 lb EA Blend NF, sulfate (nitrate free)**
 - 40 to 60% Ammonium Sulfate
 - 40 to 60% Potassium Sulfate

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PetroFix vs PlumeStop – What’s Different?

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Parameter	PlumeStop	PetroFix	Impact
1-2 µm carbon	Yes	Yes	Both liquid, low-pressure injection, non-fractured placement.
Shipped carbon	>4%	+25%	PetroFix has significantly more carbon than PlumeStop.
Polymer coating	Yes	No	PetroFix adsorbs thicker on surface of soil particle, typical spacing 5' to 6.5'-on-center (more injection points needed).
Specially formulated for hydrocarbons	No	Yes	Pre-blended with calcium sulfate dihydrate plus additional nitrate/sulfate before injection. Promotes syntrophic biodegradation.
Polymer bio demand	Yes	No	Electron acceptor can be wasted toward biodegradation of polymer coating. Not an issue with PetroFix since it doesn't have coating.
Self Apply?	No	Yes	PetroFix can be self-applied as compared to PlumeStop or other carbon injectates on market

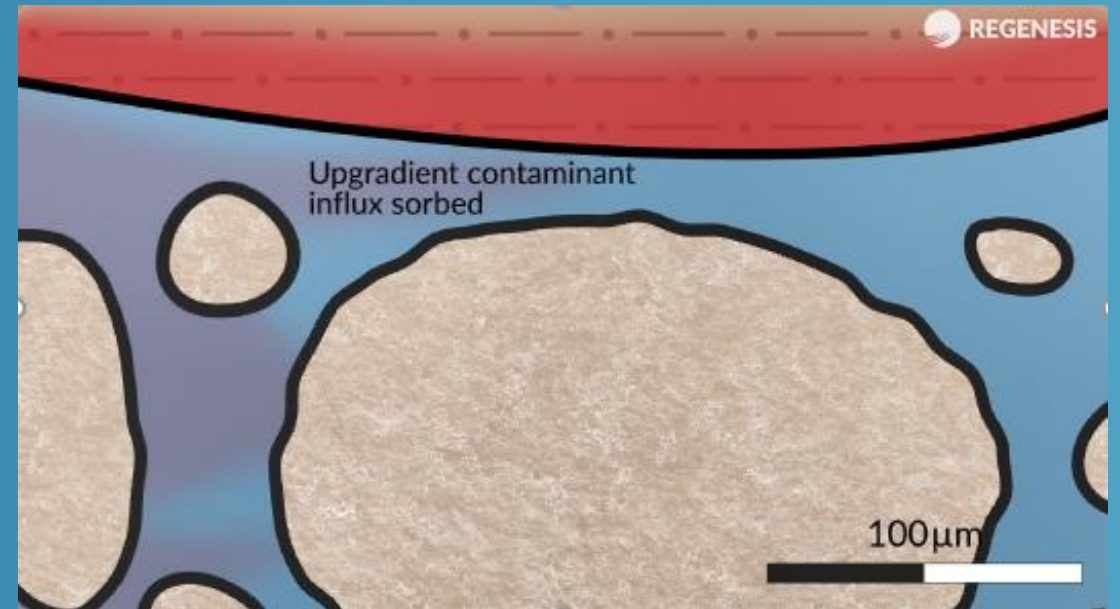
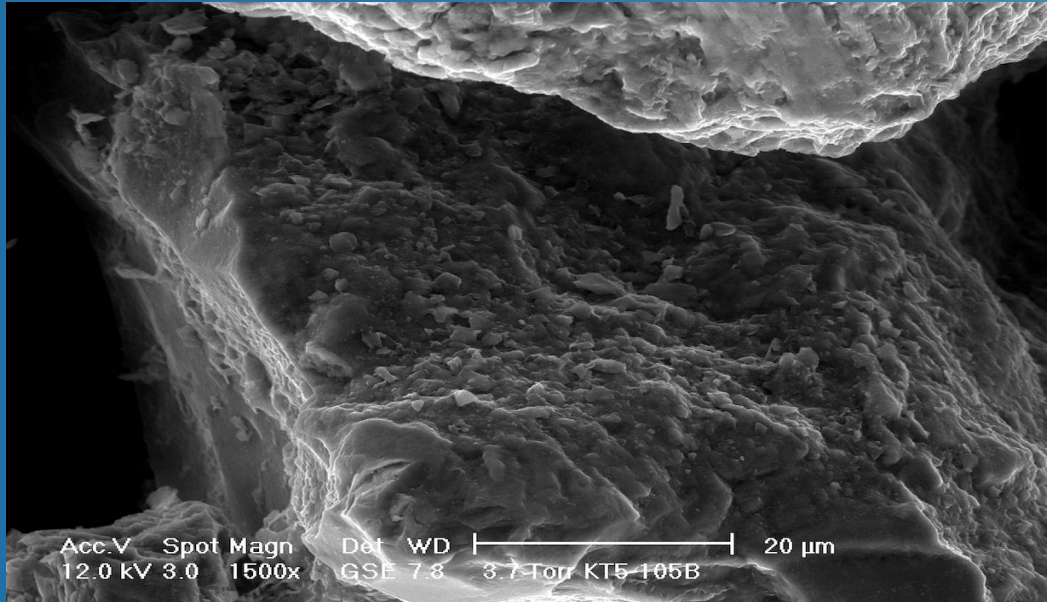
Modes of Action



REGENESIS[®]

1. Hydrocarbon Sorption: Once injected, PetroFix coats soil surface with thin layer of carbon, then sorbs hydrocarbons

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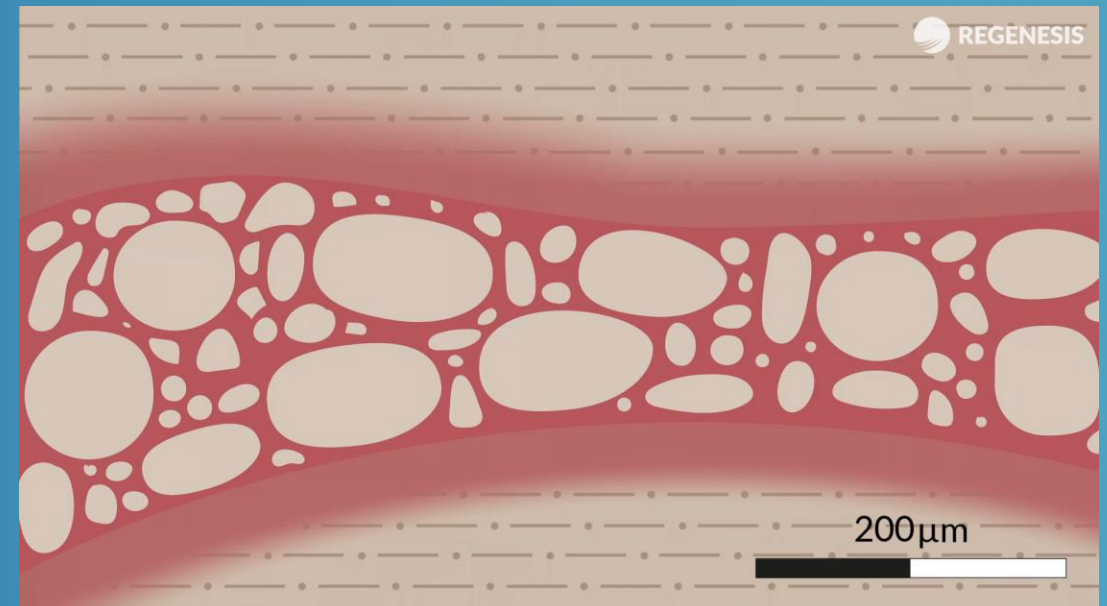
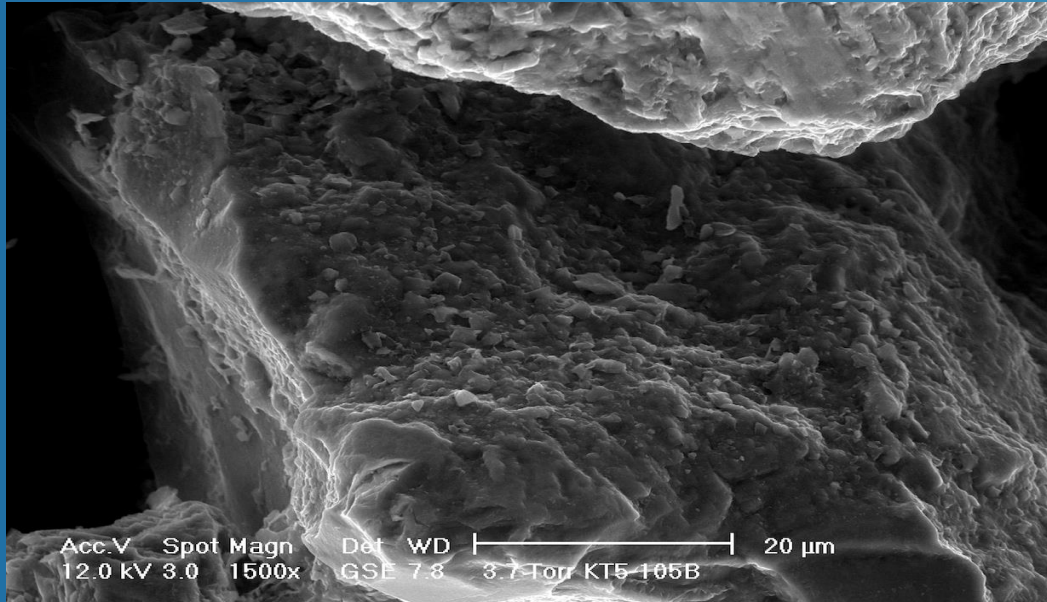
Modes of Action

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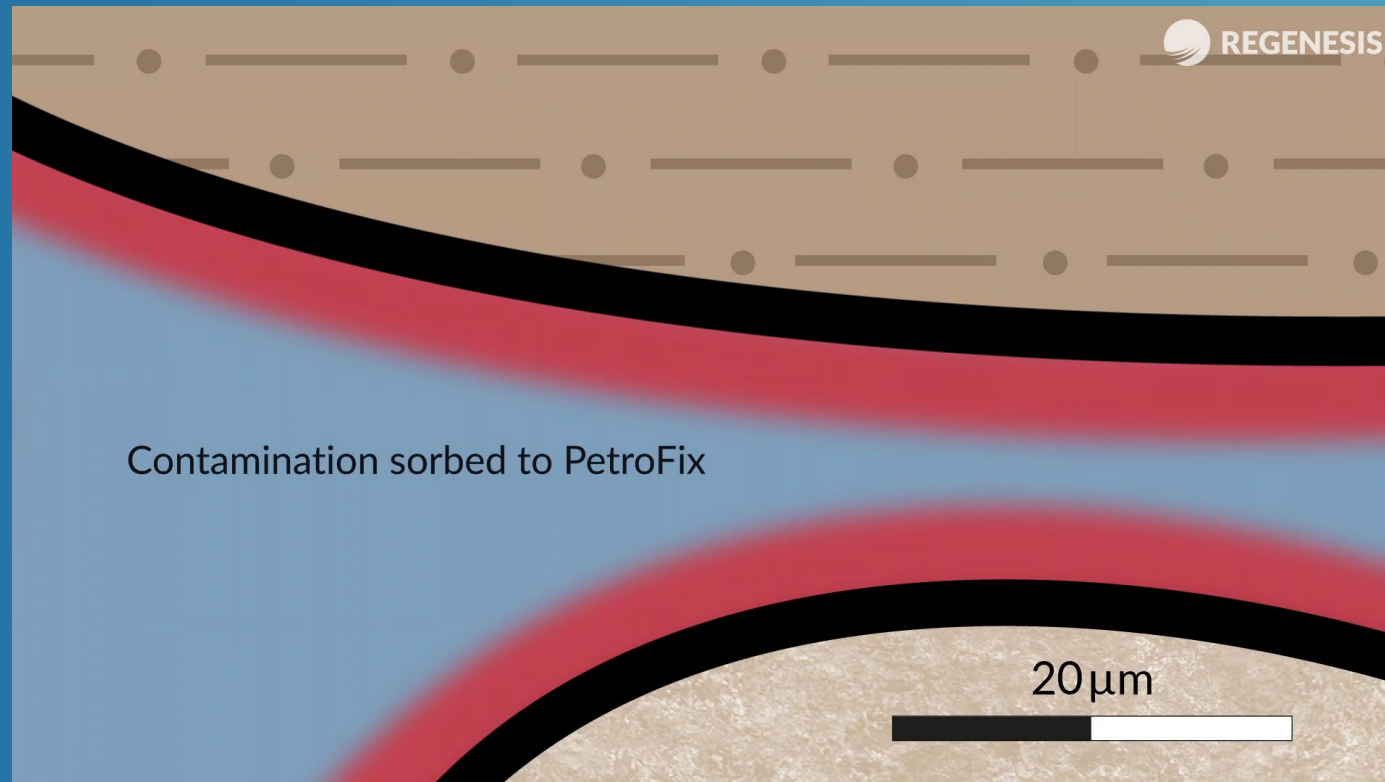
Modes of Action



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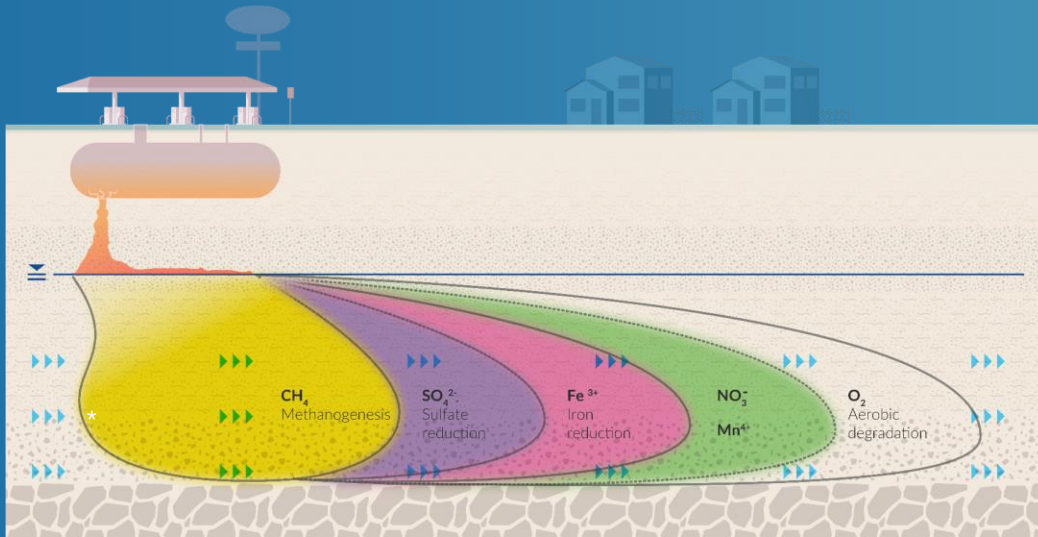
- 1. Hydrocarbon Sorption:** Once injected, PetroFix coats soil surface with thin layer of carbon, then sorbs hydrocarbons.
- 2. Stimulated Anaerobic Bioremediation:** Nitrate and sulfate kickstart bioremediation and enhance syntrophic remediation



NO₃ + SO₄ Promote Syntrophic Bioremediation

- Water soluble forms of NO₃ + SO₄ to go with PetroFix.
- Improved outcomes when NO₃ + SO₄ used together (Research of this from Cunningham et al.). Nitrate better for benzene. Sulfate reducers are versatile, co-exist with methanogens
- Fermentation of hydrocarbons, plus methanogenesis improved – Improved long-term methanogenesis after NO₃ + SO₄ depletion

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Cunningham, J. A., Rahme, H., Hopkins, G. D., Lebron, C. & Reinhard, M. Enhanced In Situ Bioremediation of BTEX-Contaminated Groundwater by Combined Injection of Nitrate and Sulfate. *Environ. Sci. Technol.* 35, 1663–1670 (2001).



PetroFix Compared To Injectable Carbon

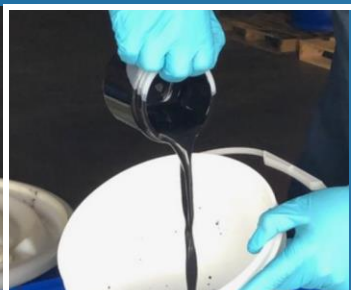
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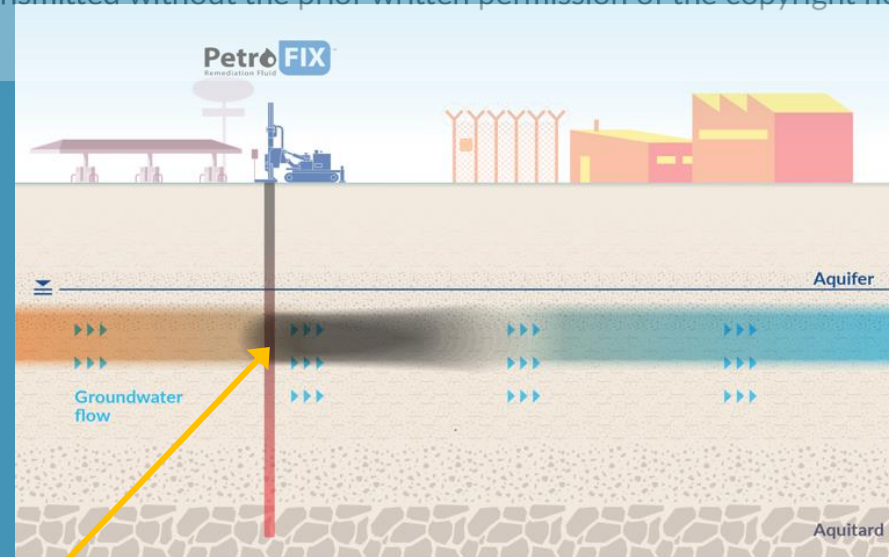
Picture of Granular Activated Carbon (GAC)
Particle size: 400 to 1,000 microns
High Pressure Needed (>60 psi)
Results in Aquifer Fracturing? YES



Picture of Powdered Activated Carbon (PAC)
Particle size: 50 to 250 microns
High Pressure Needed (>60 psi)
Results in Aquifer Fracturing? YES



Picture of Liquid Carbon Suspension (PetroFix)
Particle size: 1 to 2 microns
Low Pressure Needed (<60 psi)
Results in Aquifer Fracturing? NO



Grain Size	Pore Throat Diameter (micrometers)*
Medium Sand	8-50
Fine Sand	5-20
Silt	3-8

*Note: Only LAC has a diameter below the typical pore throat diameter for silty soils.

Ease of Mixing PetroFix



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Unlike bulk phase solids, suspensions like PetroFix can be **pumped or poured into mix tank**



Water-like suspension like PetroFix requires **only gentle agitation**



Multiport Tips “Straddle” Conductive Zones To Force PetroFix Into Those Zones

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PETROFIX APPLICATION – KEY POINTS

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Multi-Port Tooling DOES work at most sites

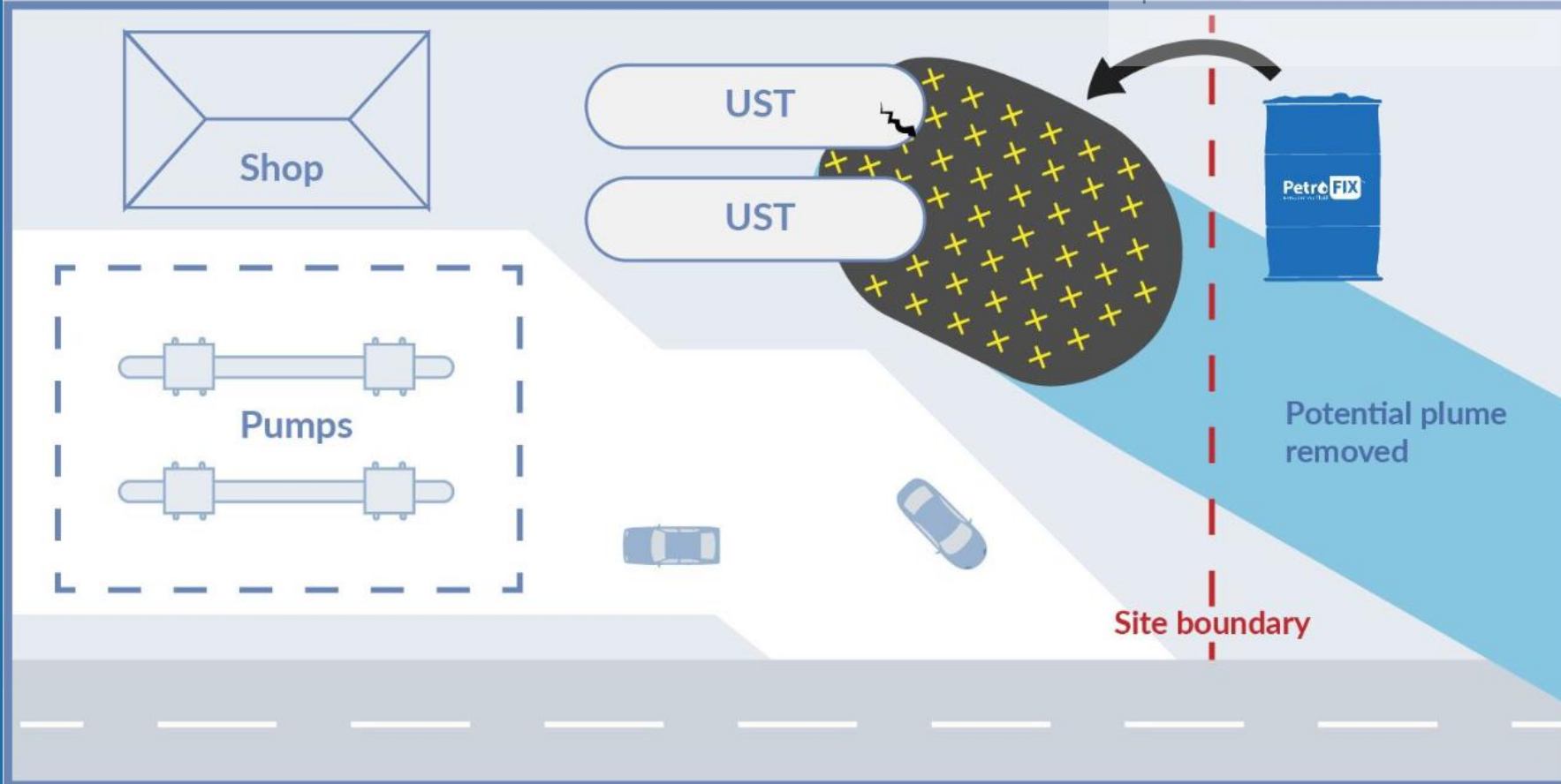
- Lower pressures (20 to 60 psi typical)
- 2 to 8 gpm per point
- Less surfacing/fracturing

Recommend you VERIFY distribution

- PetroFix is its own tracer
- Inject...take a core(s)...evaluate ROI
- Make volume, pressure, tip adjustments for ROI increase as needed



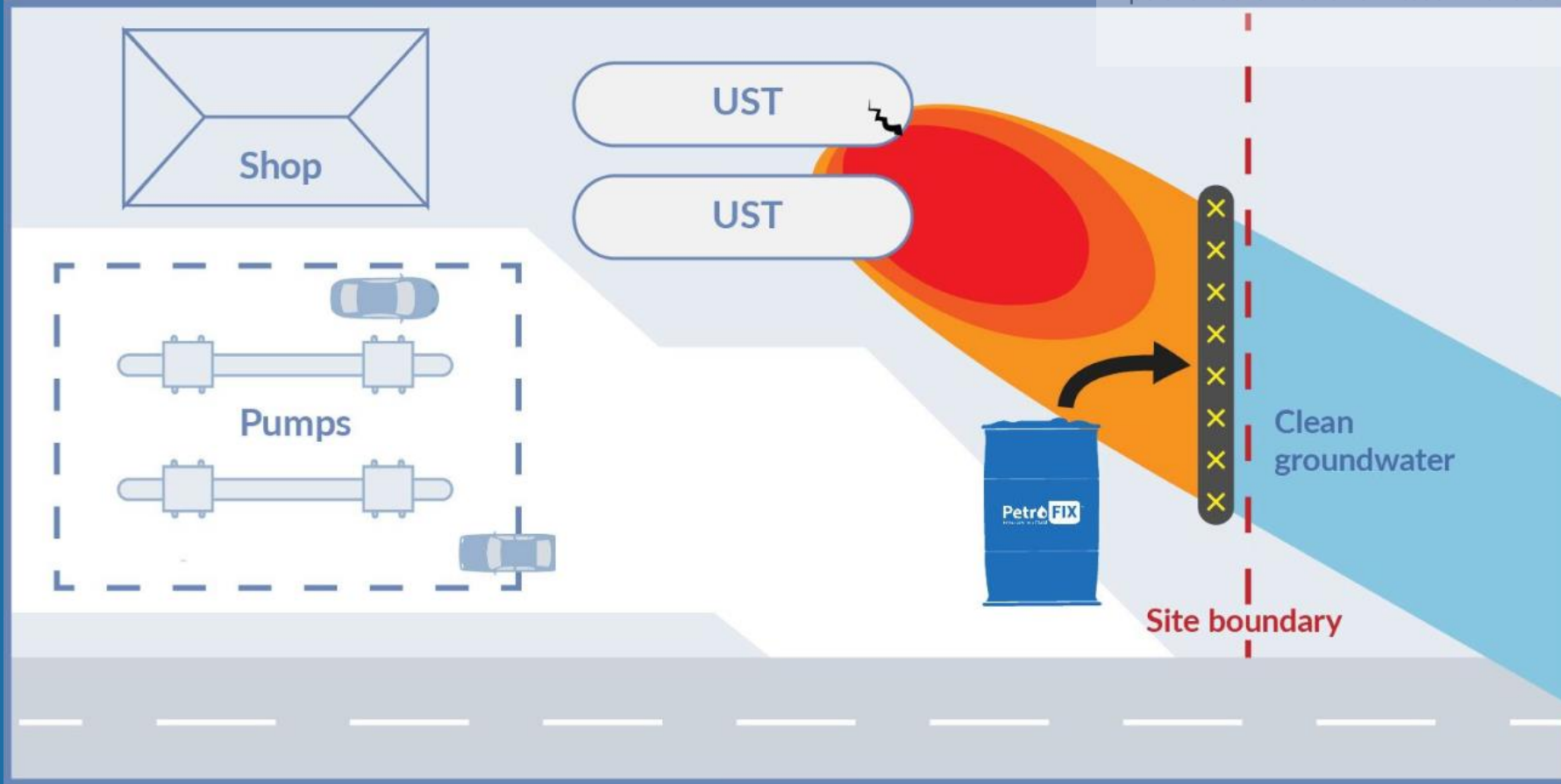
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SOURCE AREA TREATMENT

- Grid Approach
- Smear Zone

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BARRIERS

Eliminate Off-Site Migration and Reduce Liability



Most Common Applications



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EXCAVATIONS

Insurance against residual mass





Northern IN- BACKGROUND



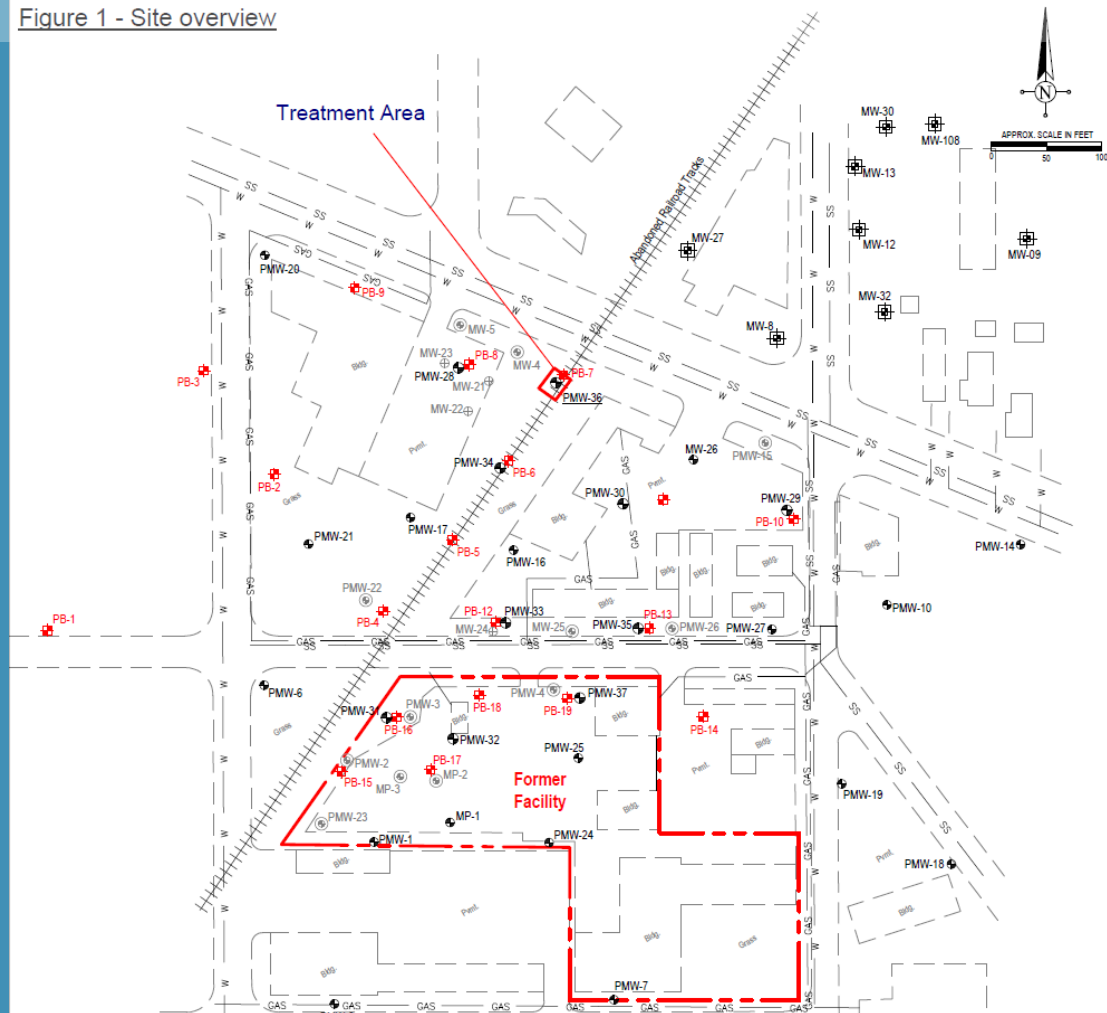
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- Historical Bulk Petroleum Storage Facility
- LNAPL Recovery – 2006,
- AS/SVE – 2007-2009
- **BTEX – 3,500 µg/l**
- **TPH-G –38,800 µg/l**
- **TPH-D –17,800 µg/l**



Figure 1 - Site overview





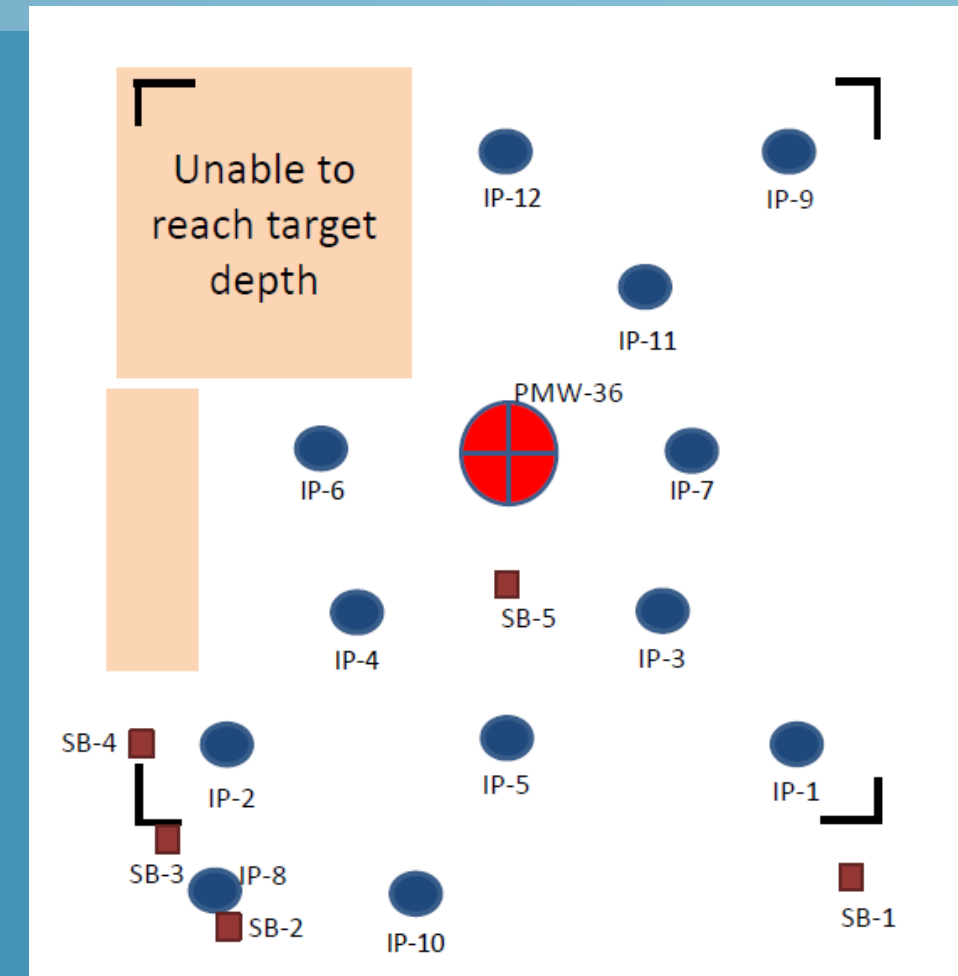
Northern IN- PILOT

- 2,000 lbs of PetroFix injected w/ sulfate + nitrate EA Blend
- 12 direct push points
- Target treatment zone: 15-22' bgs
- Heterogeneous soils
- 5-7' spacing optimal



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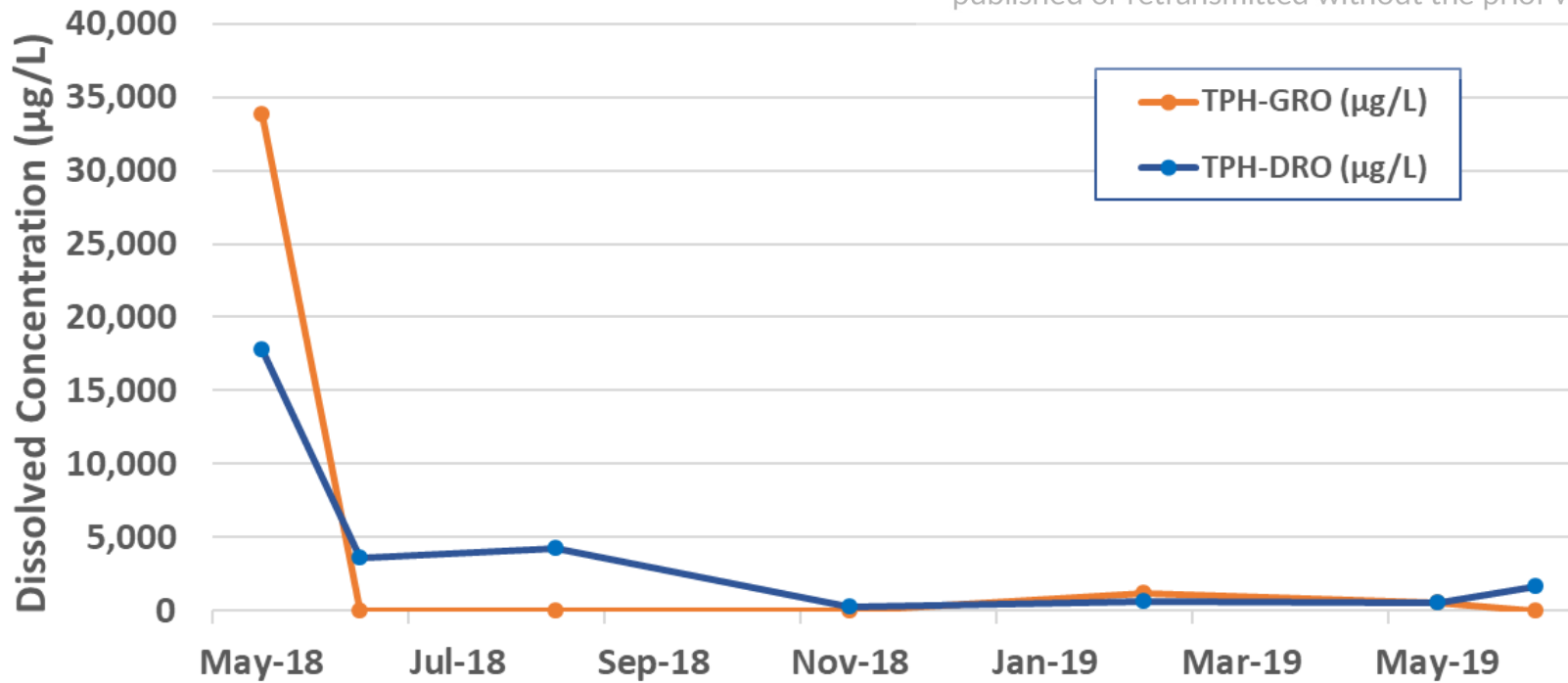




Northern IN – Results for Gas and Diesel

Results For Gasoline and Diesel Range Organics

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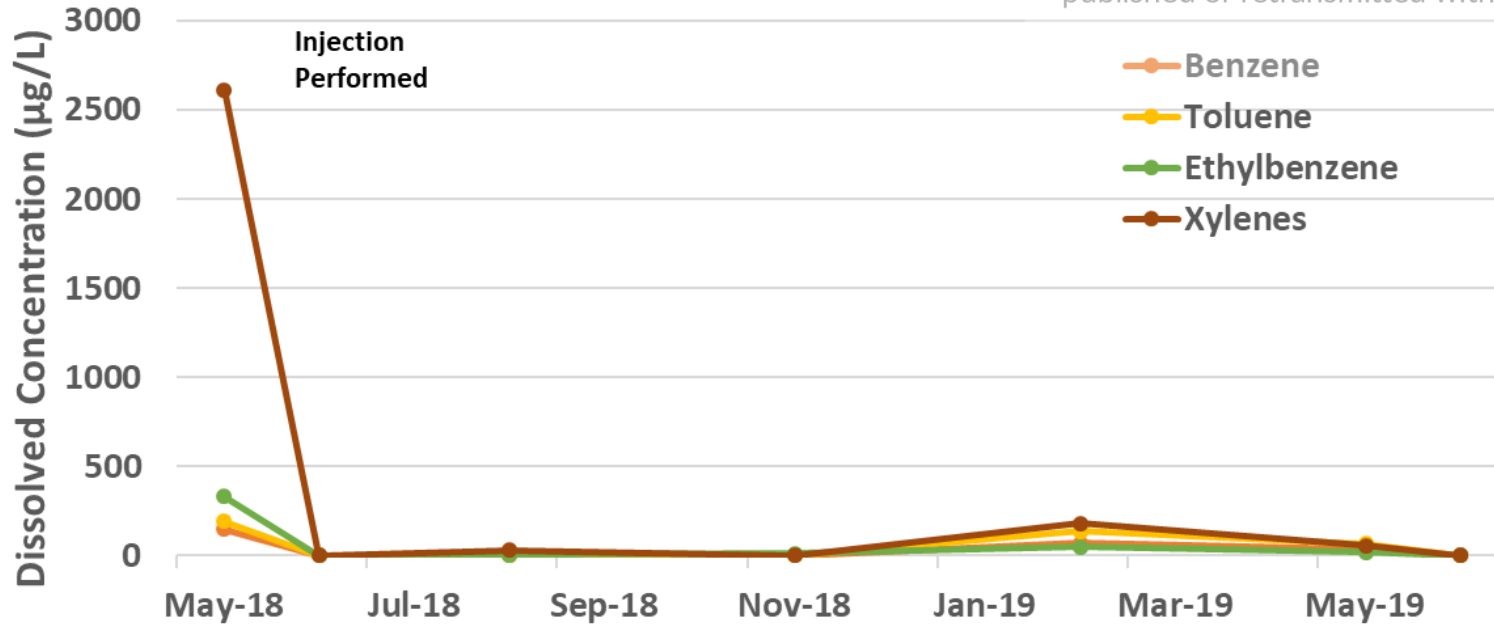
Analyte	May-18	Jun-18	Aug-18	Nov-18	Feb-19	May-19	Jun-19
TPH-GRO (µg/L)	33,800	0	0	0	1,170	506	0
TPH-DRO (µg/L)	17,800	3,600	4,200	250	596	538	1,680



Northern IN – Results for BTEX

Results for BTEX

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- Client suspected some rebound. Beta in center of plume and being recharged with upgradient contamination
- 94.5% reduction to date
- Full-Scale initiated upgradient in March-April 2019

Analyte	May-18	Jun-18	Aug-18	Nov-18	Feb-19	May-19	Jun-19
Benzene	149	0	0	0	69.9	36.8	3.04
Toluene	191	0	5.7	0	139	68.2	2.05
Ethylbenzene	330	0	5.6	14	49.1	19.2	0
Xylenes	2,610	0	30	0	181	56.6	0



Northern IN – BIO RESULTS

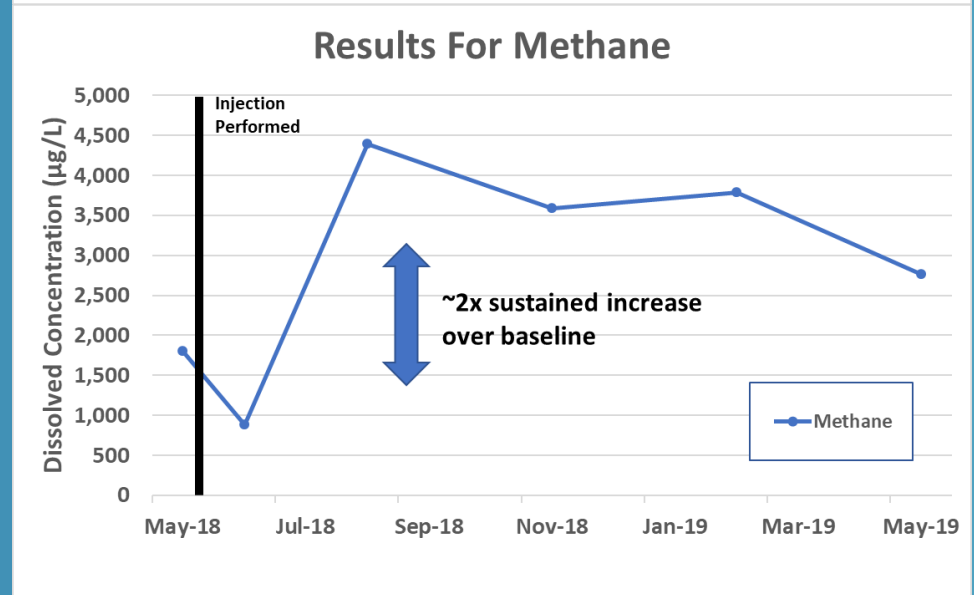
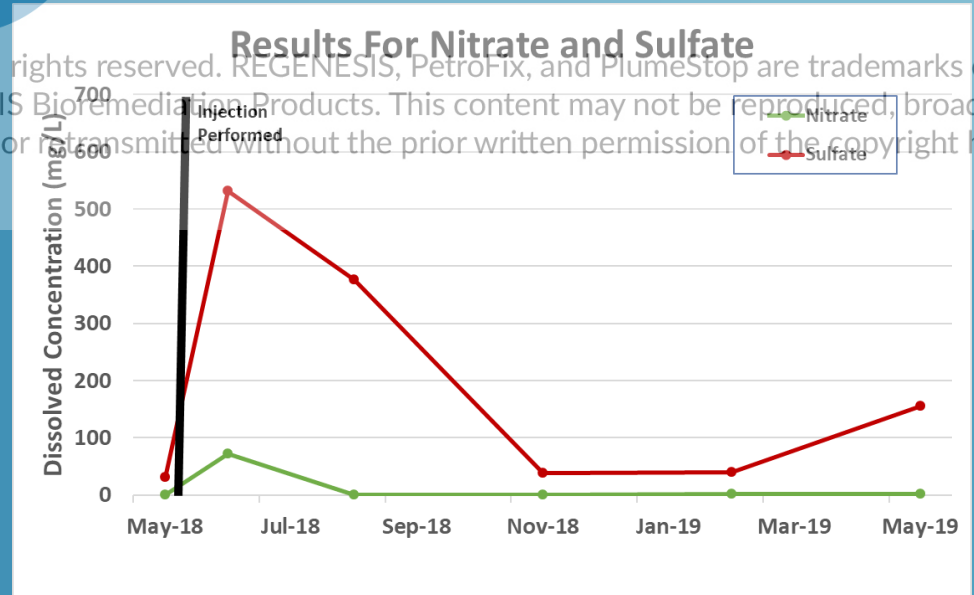


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Lines of Evidence for biodegradation

1. Electron Acceptors Deplete over time
 - Nitrate consumption > sulfate
2. Products of reaction
 - Sustained methane production (from hydrocarbon biodegradation) lasting after nitrate, sulfate consumed
 - Contaminants bioavailable
 - Attributed to syntrophic biodegradation

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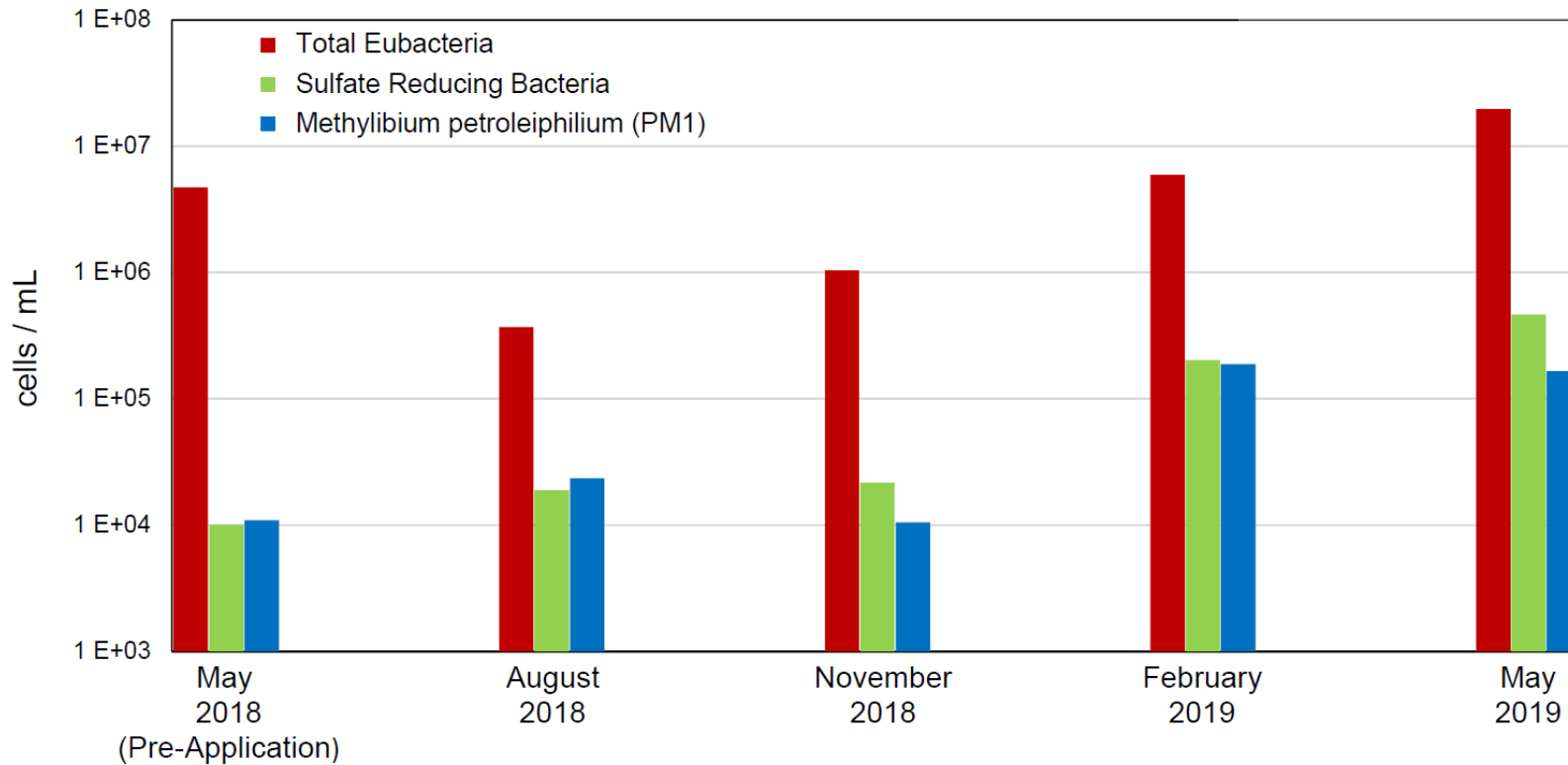
Northern IN - RESULTS



REGENESIS[®] microbial insights

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Site Microbial Activity



3. Microbial Analysis: Hydrocarbon concentration

reduced by +94.5%

- QuantArray[®] Petro data: Key petroleum degraders are still abundant
 - Diverse, healthy populations present
 - Supports on-going biodegradation even with adsorption to activated carbon
- mRNA data (Microbial Insights) indicates key populations are active and thriving

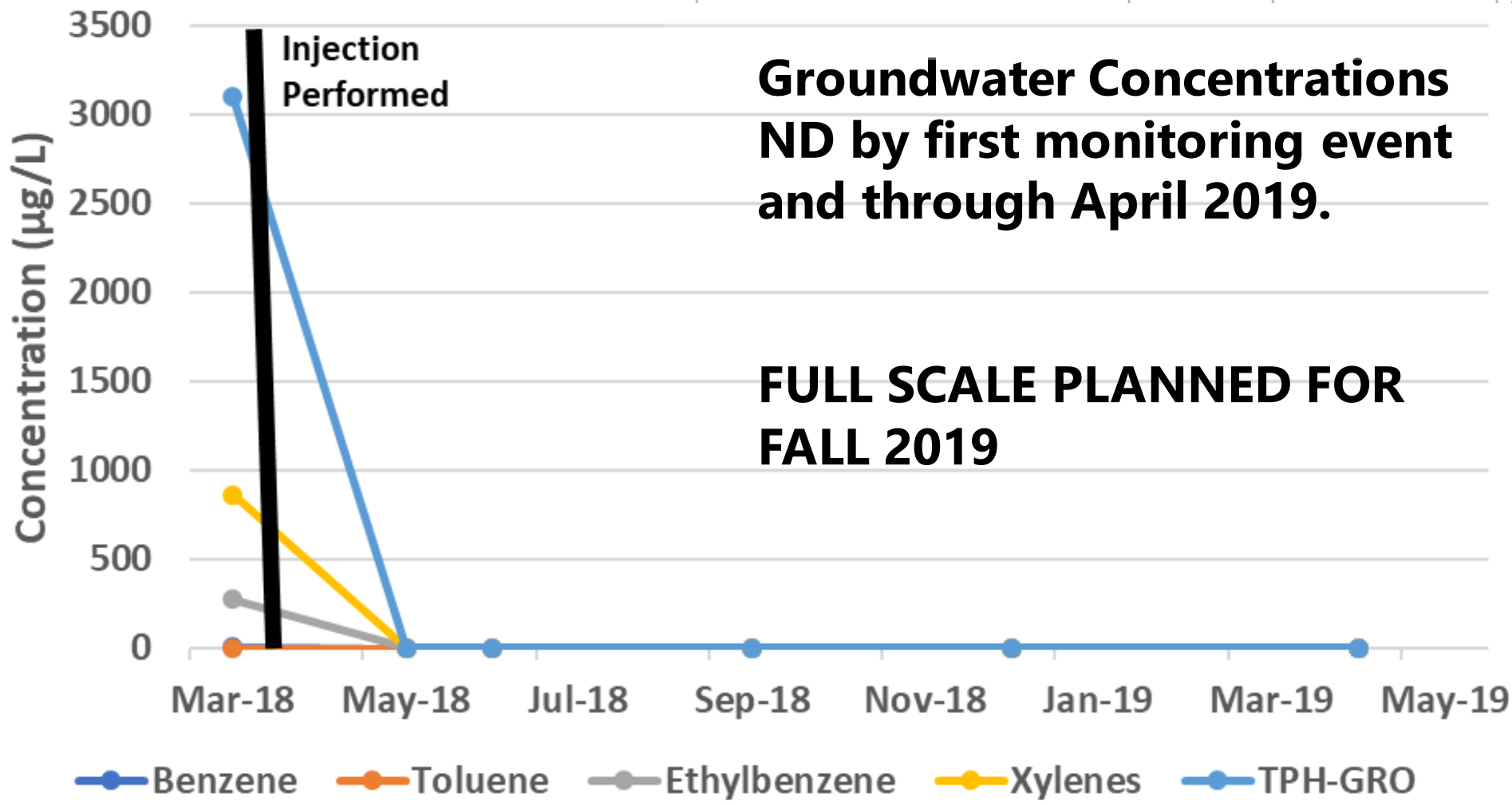


Site 1: Panama City Beach, FL - RESULTS



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UST Beta Site, PetroFix injected March 2018



**Groundwater Concentrations
ND by first monitoring event
and through April 2019.**

**FULL SCALE PLANNED FOR
FALL 2019**



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Questions?

Thank you!

www.petrofix.com



Todd Herrington
Global PetroFix Product Manager
therrington@RegenesiS.com

Benefits Recap:

BROADLY APPLICABLE – Source areas, excavations, barriers

SAFE TO APPLY – Safe around infrastructure, no carbon dust

LOW PRESSURE AND HIGH VOLUME – Excellent distribution with much less surfacing or entry into wells and utilities.

SIMPLE TO INJECT – Needs common application equipment

EASY TO VERIFY DISTRIBUTION – PetroFix is own tracer, can make field adjustments

EASY-TO-USE ONLINE TOOLS - Use the online PetroFix design assistant to create your own designs, generate output, and perform your own application.

EXTENSIVE SUPPORT - Design and application videos, written application guidance, technical bulletins, and phone support available.



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