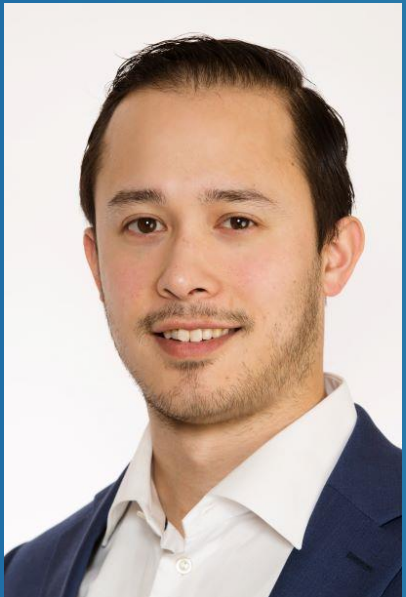




Performance of a New Activated Carbon Amendment for Bioremediating Petroleum-Impacted Sites



Andrew Punsoni
Northwest Technical Manager
apunsoni@Regenesis.com



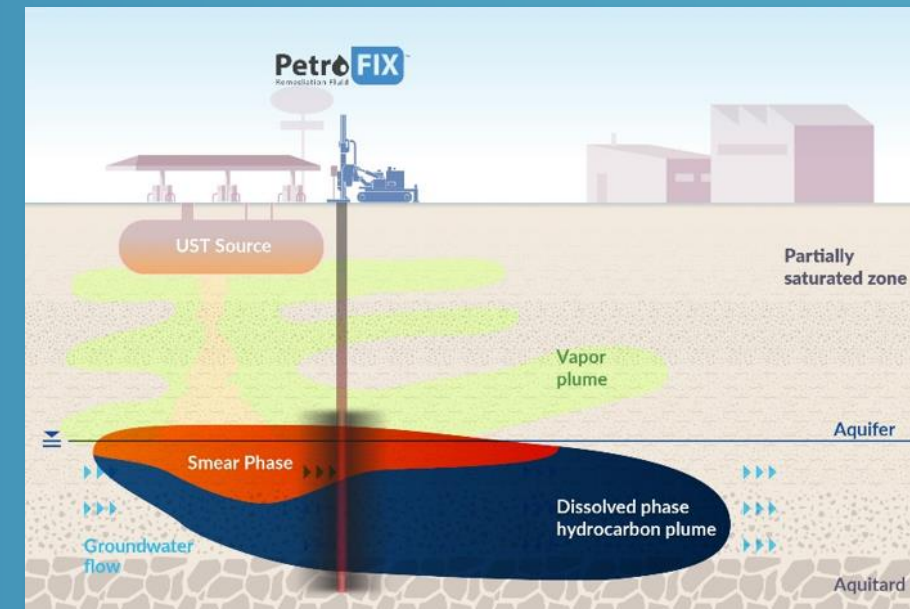
REGENESIS[®]

YOUR EXPERT SOURCE FOR COMPLETE SOIL AND
GROUNDWATER REMEDIATION



Outline

- Our Company
- Technology Overview
- UST/Service Station Case Studies
- PetroFix Resources
- Design Assistant Walkthrough (time and interest permitting)



WHAT WE DO

We develop cutting-edge technologies to clean up soil and groundwater *in-situ*.

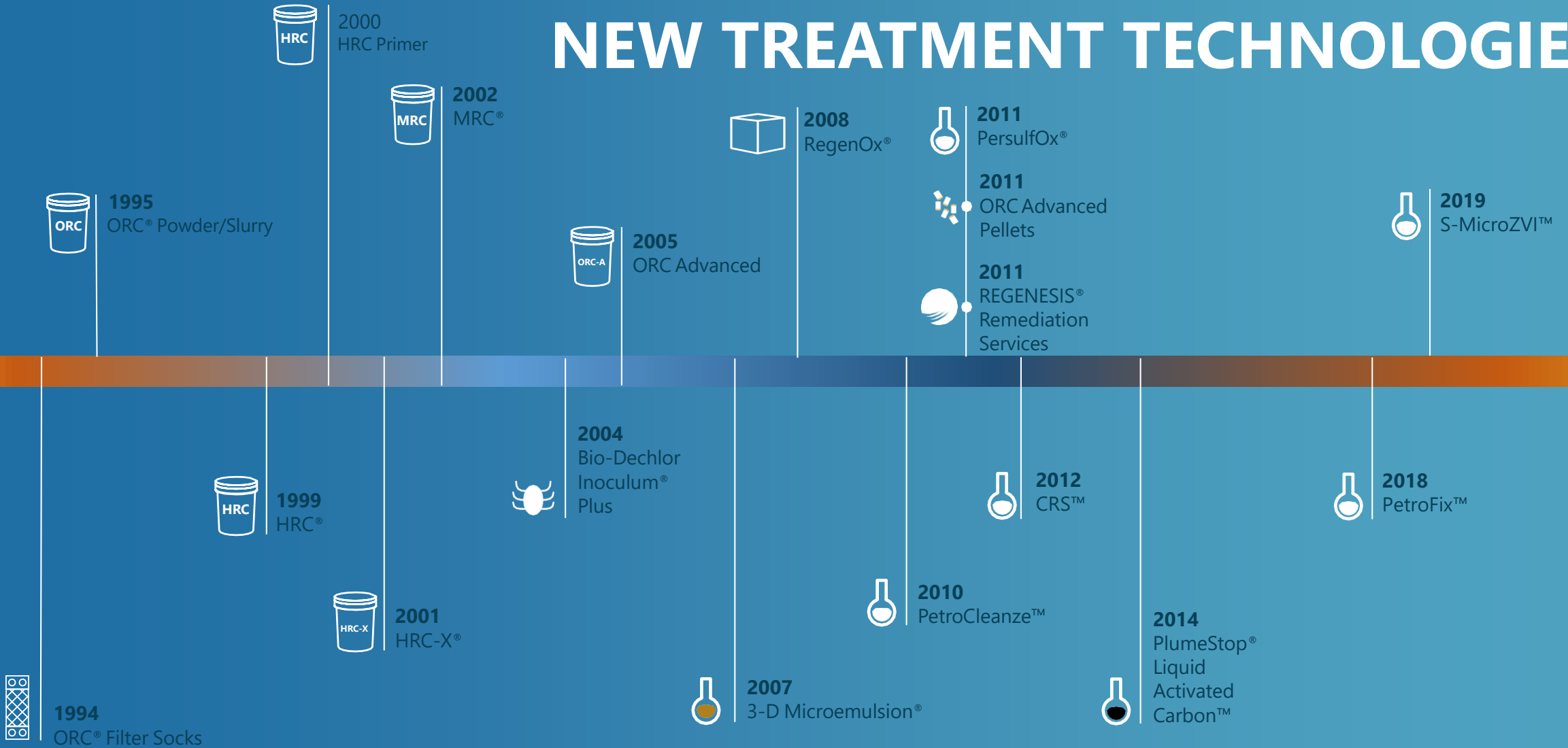


TECHNOLOGY CLASSES:

- Enhanced Aerobic Biodegradation
- Enhanced Anaerobic Biodegradation
- *In Situ* Chemical Oxidation (ISCO)
- *In Situ* Chemical Reduction (ISCR)
- Bioaugmentation
- Metals Immobilization
- *In Situ* Sorption and Biodegradation

25 Years in Business

CONTINUOUS DEVELOPMENT OF NEW TREATMENT TECHNOLOGIES



Technology Overview

Petro  **FIX**™
Remediation Fluid

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)



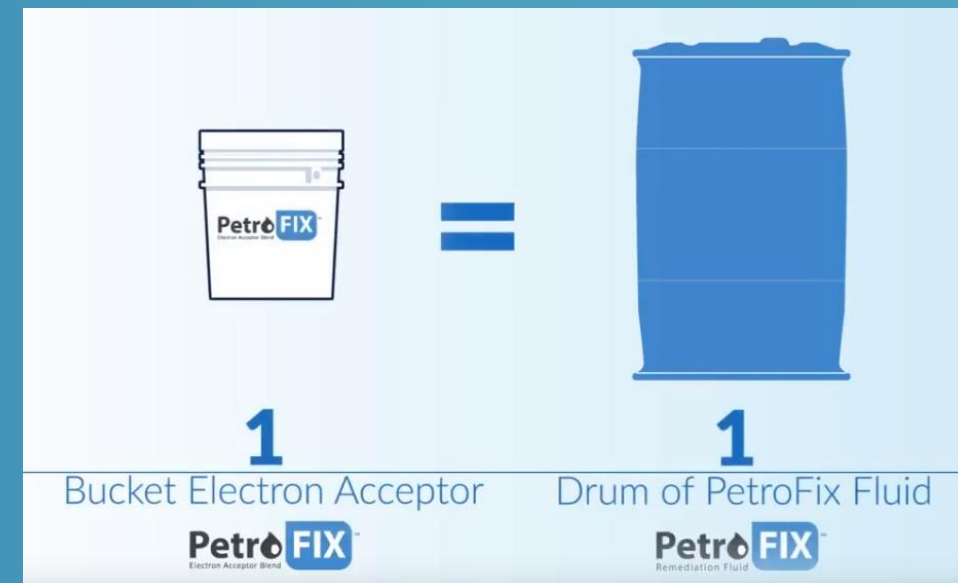
Features

- 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



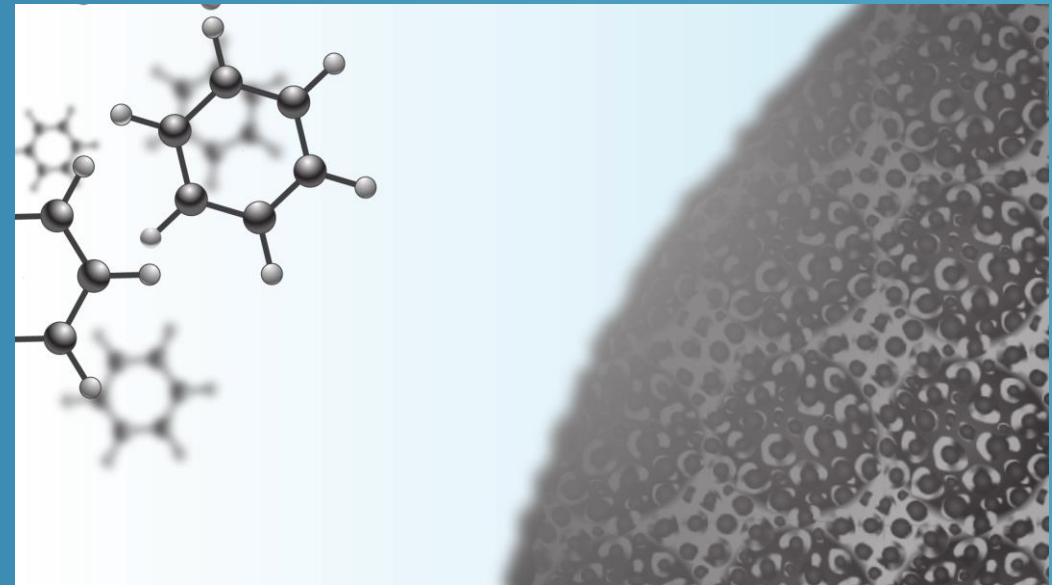
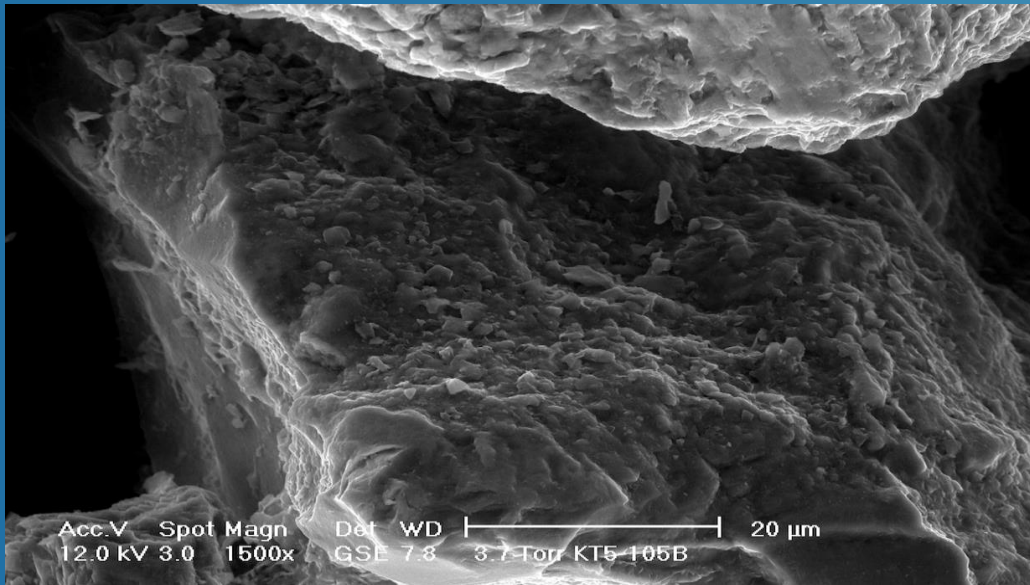
Formulation

- +30% 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



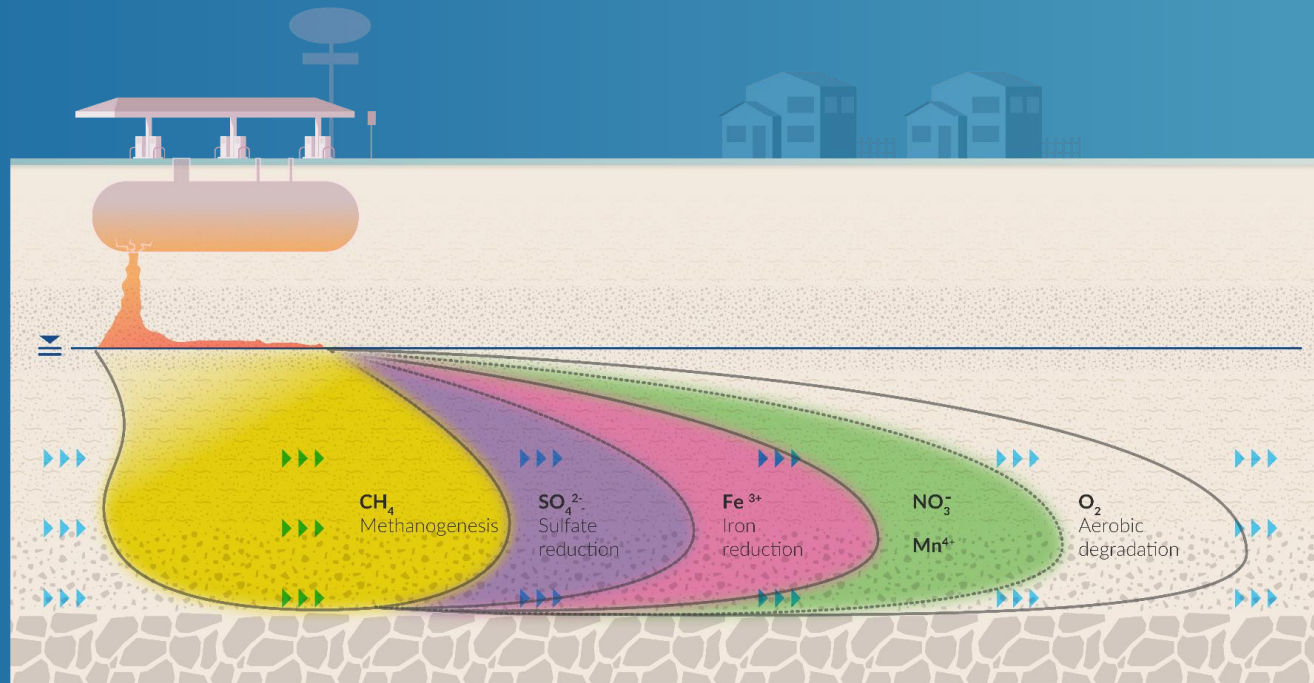
Modes of Action

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



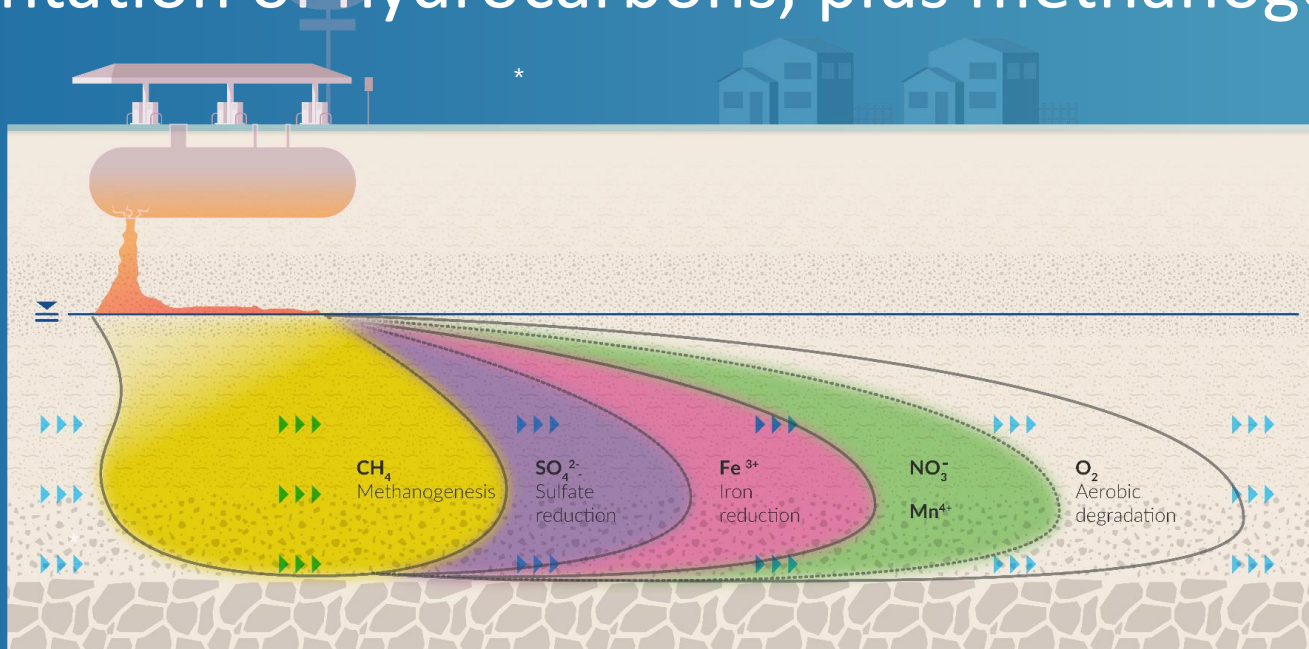
Modes of Action

- 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



$\text{NO}_3 + \text{SO}_4$ Promote Syntrophic Bioremediation

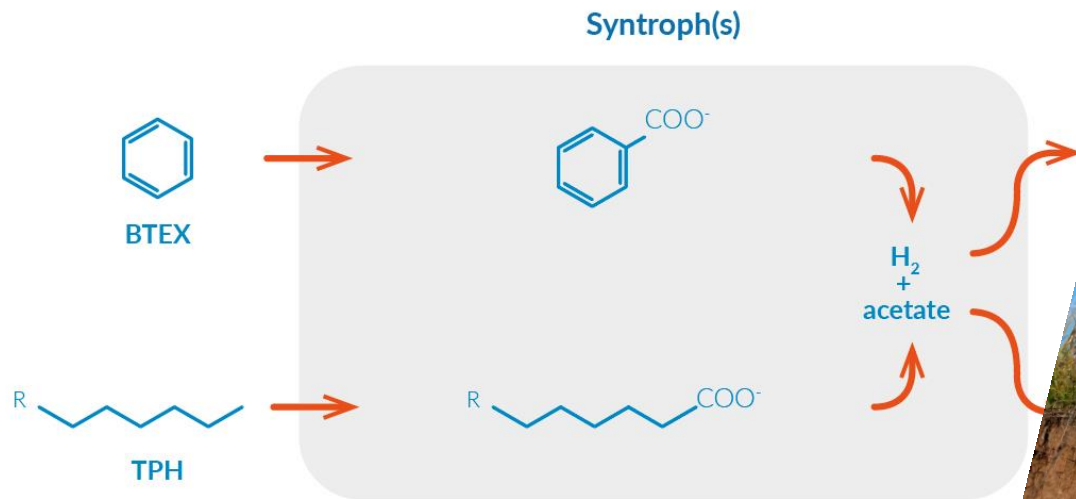
- Improved outcomes when $\text{NO}_3 + \text{SO}_4$ used together – microbes “feed” together and have ecological partnership.
- Nitrate better for benzene. Sulfate reducers are versatile, co-exist with methanogens
- Fermentation of hydrocarbons, plus methanogenesis improved



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).

Once Kickstarted, Methanogens can Finish the Job

Benefits of adding sulfate/nitrate continue after their exhaustion



characterized by higher redox potentials [8]. Some bacteria, such as sulfate-reducing *Desulfovibrio* spp., are metabolically versatile in that they respire sulfate when it is available, but switch to syntrophic metabolism in its absence [9]. Other syntrophs are obligate in that they can

Metha

rk



ELSEVIER

Curr. Opin. Biotechnol. 27,

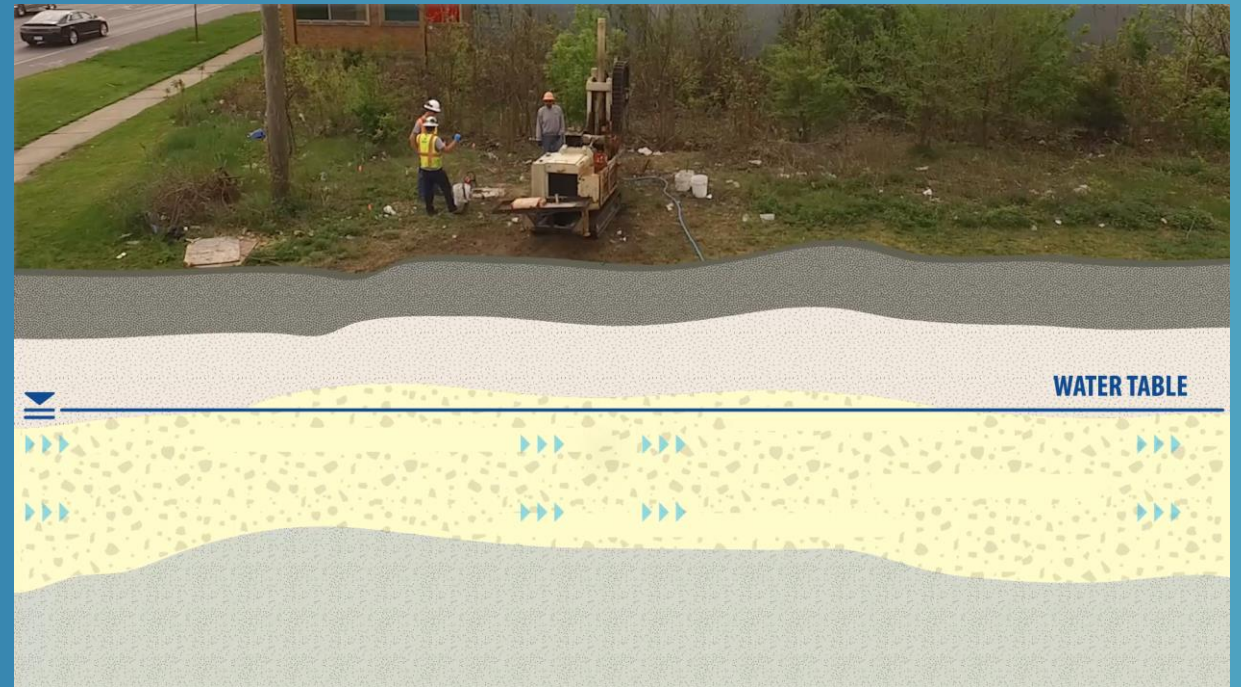
Syntrophic biodegradation of hydrocarbon
Lisa M Gieg, S Jane Fowler and Carolina Berdugo-Clavijo



Colloidal Suspension Is “Flooded” vs “Fractured” = Total Coverage of Migration Pathways and Excellent for Back Diffusion



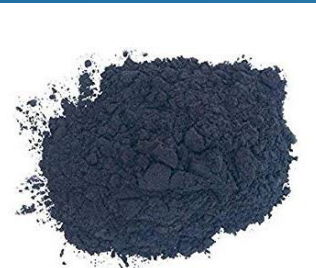
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PetroFix Compared To Injectable Carbon



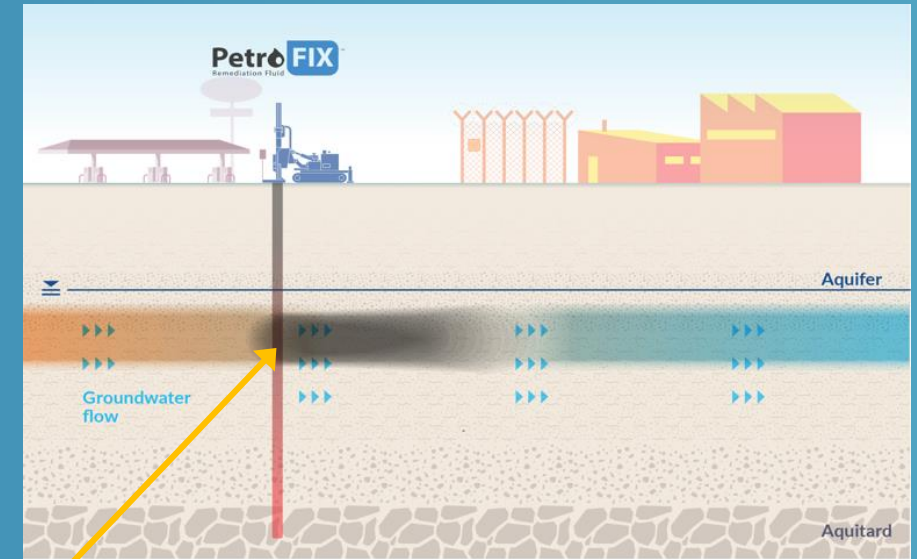
Picture of Granular Activated Carbon (GAC)
Particle size: 400 to 1,000 microns
High Pressure Needed (>60 psi)
Results in Aquifer Fracturing? YES



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.

Optimal Tooling To Inject PetroFix

- Top Down or Bottom Up Tooling Usually Recommended
- 2' to 3' vertical multi-port tooling work great in most aquifers and straddle inject product easily
- Helps keep pressures down and injection volumes up



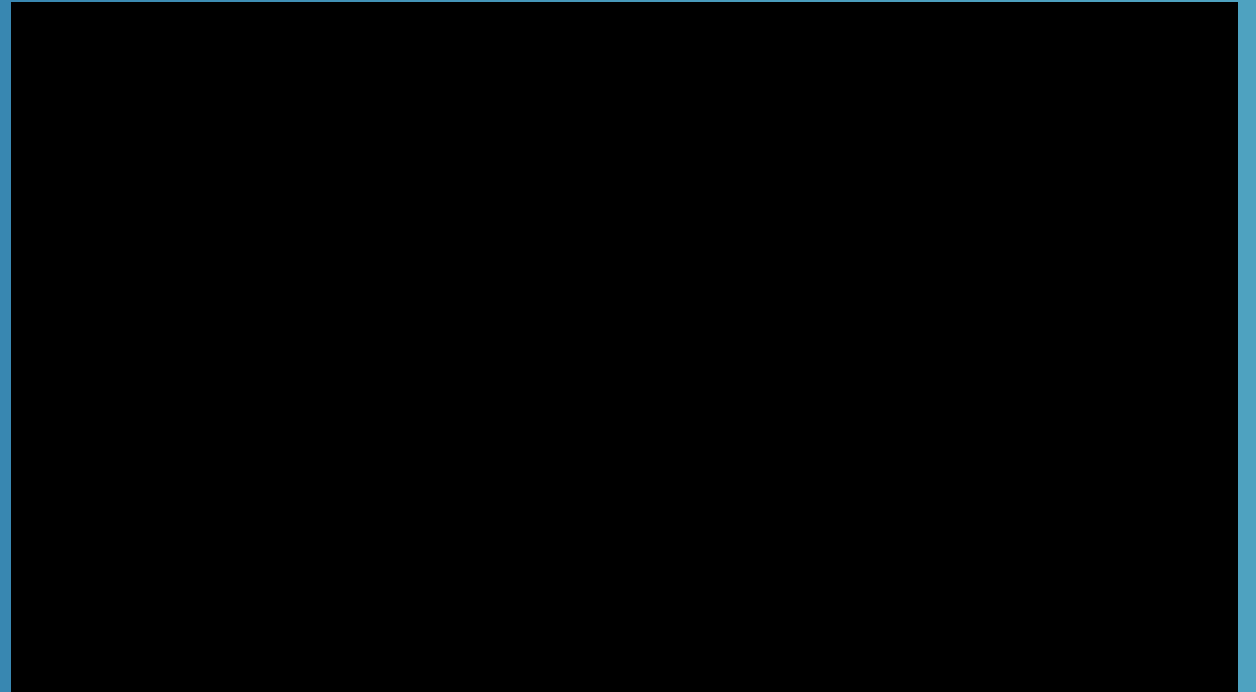
Ease of Mixing PetroFix



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



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



VERIFICATION OF PRODUCT PLACEMENT (observance in wells or soil cores)



PetroFix in wells can be flushed out using a clean-water flush. Instructions at www.petrofix.com

Before PetroFix Injection



After PetroFix Injection



Most Common Applications



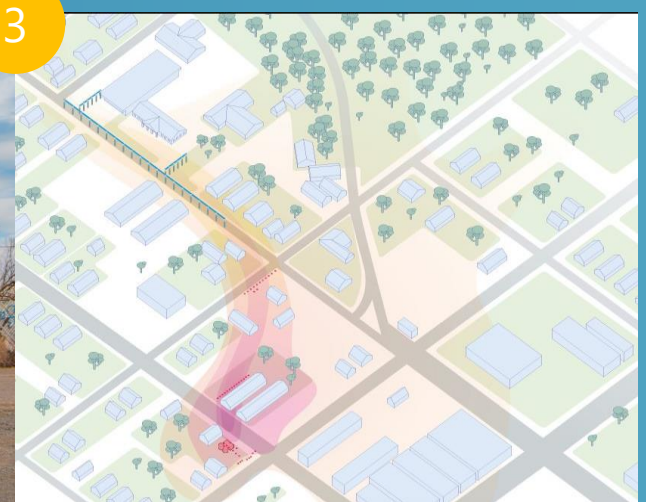
Tank Removal/Upgrade

Excavation application
addressing residual mass



Contaminated Source Areas

- Grid Approach
- Smear Zone



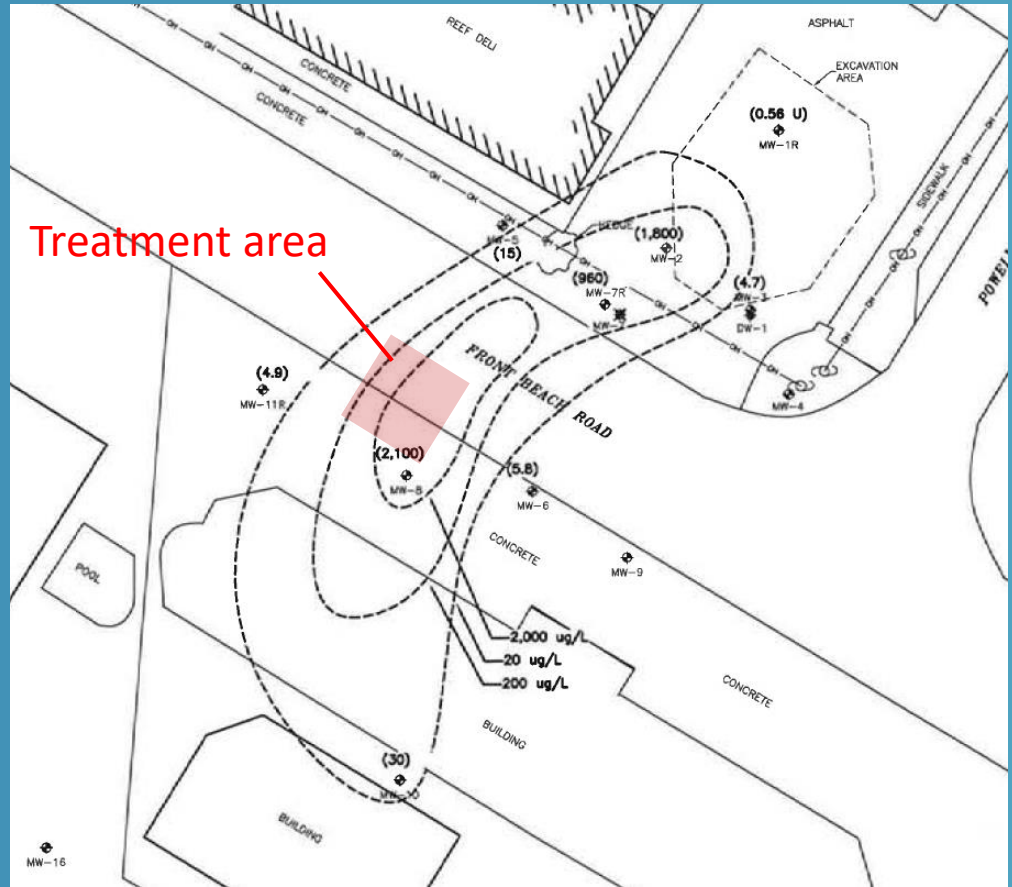
Dilute Plume

- Use of Barriers
- Eliminate off-site migration & reduce liability



Site 1: Panama City Beach, FL - BACKGROUND

- Former gasoline service station
- 1,000 Gal gasoline release 2007
- Excavation completed 2007 (~300 tons)
- Several remedial technologies have been implemented with limited success
- BTEX + Naph – 1,300 to 14,300 ug/l,
- TPHg 4,300-15,000 ug/l





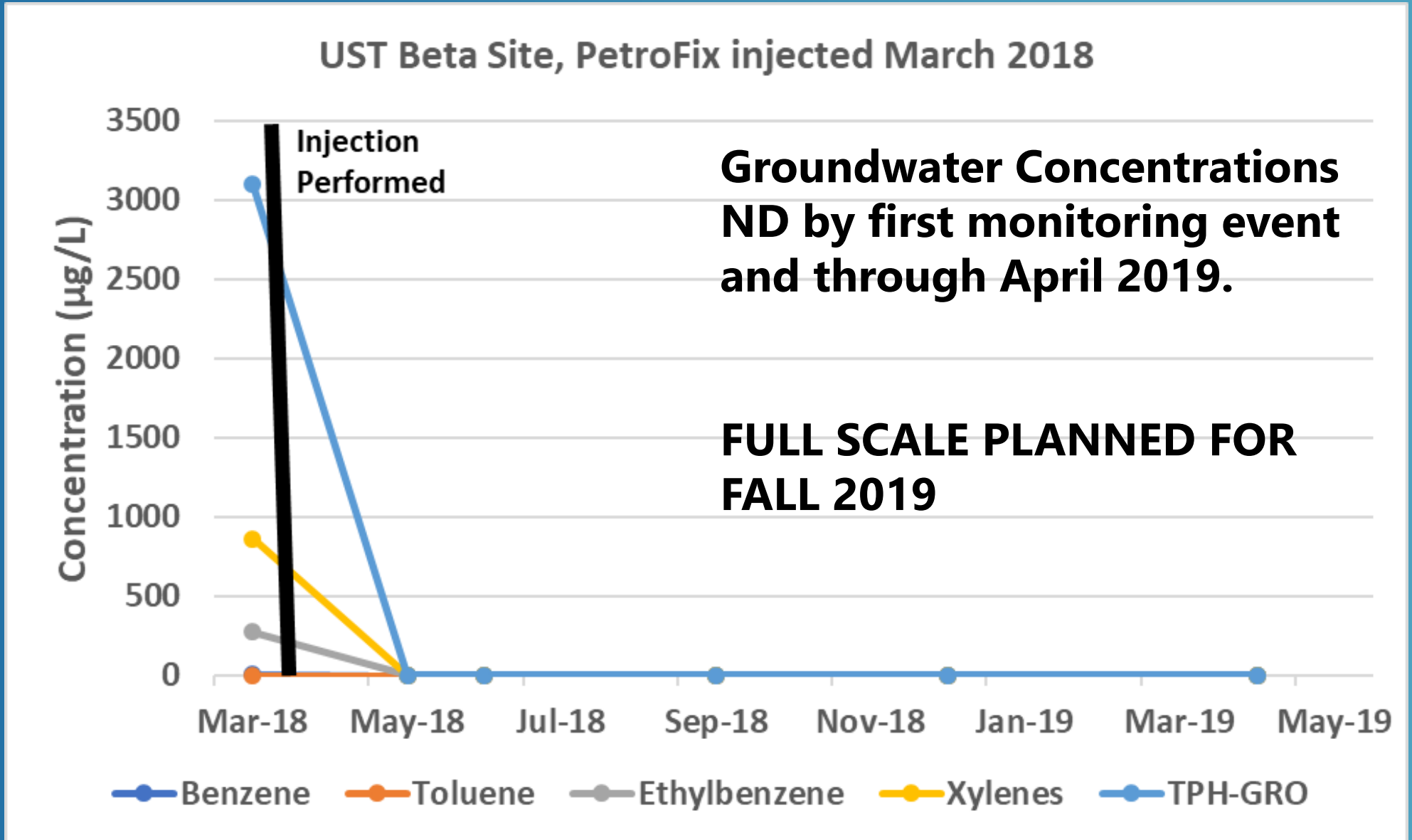
Site 1: Panama City Beach, FL

- 1,700 lbs of PetroFix injected w/ sulfate + nitrate EA Blend
- 10 direct push points, 20'x20' test area
- Target zone: 5-15' bgs
- Homogenous beach sand
- Excellent distribution across target treatment zone
- Confirmed 5-6 ft spacing was optimal





Site 1: Panama City Beach, FL - RESULTS



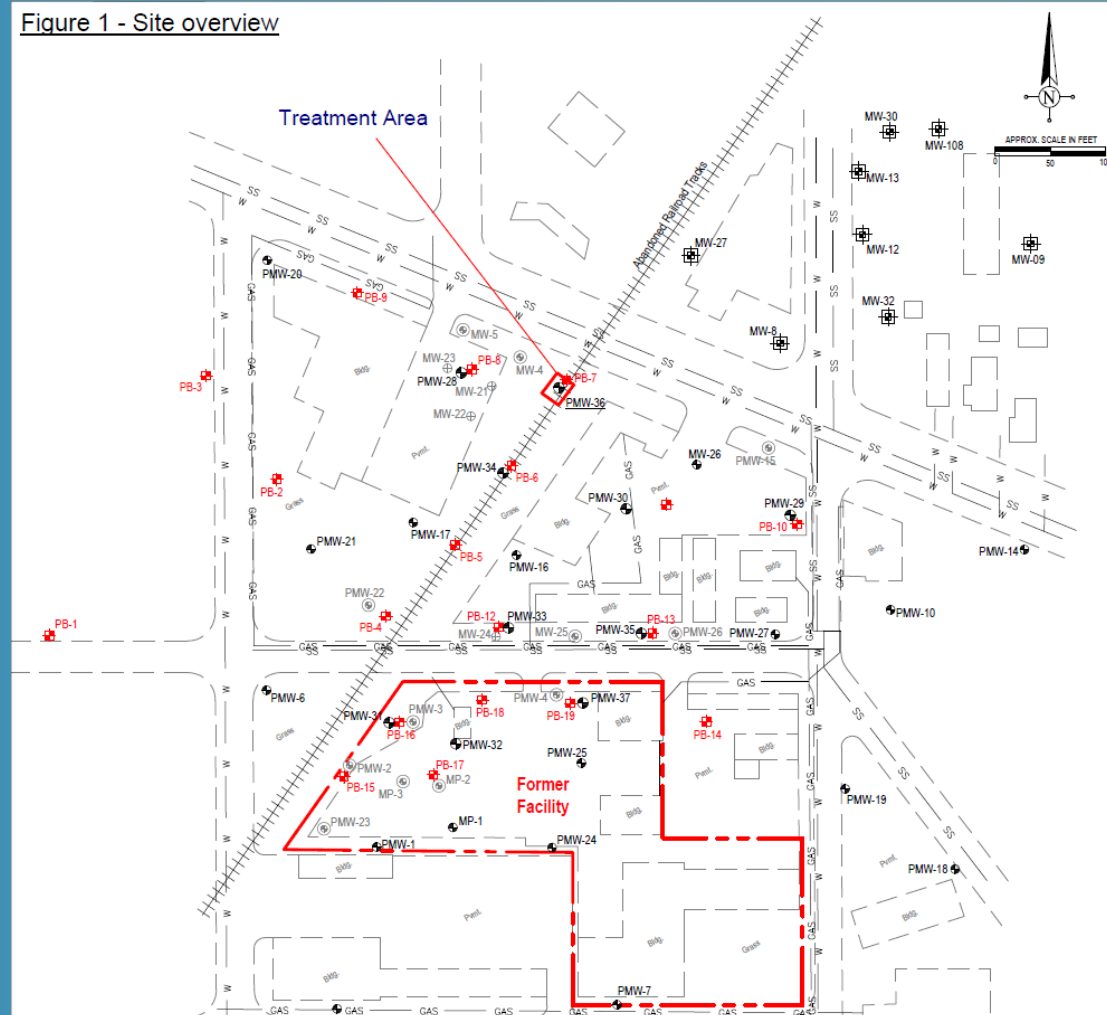


Site 2: Northern IN- BACKGROUND

- Historical Bulk Petroleum Storage Facility
- LNAPL Recovery – 2006,
- AS/SVE – 2007-2009
- **BTEX – 3,500 $\mu\text{g}/\text{l}$**
- **TPH-G –38,800 $\mu\text{g}/\text{l}$**
- **TPH-D –17,800 $\mu\text{g}/\text{l}$**



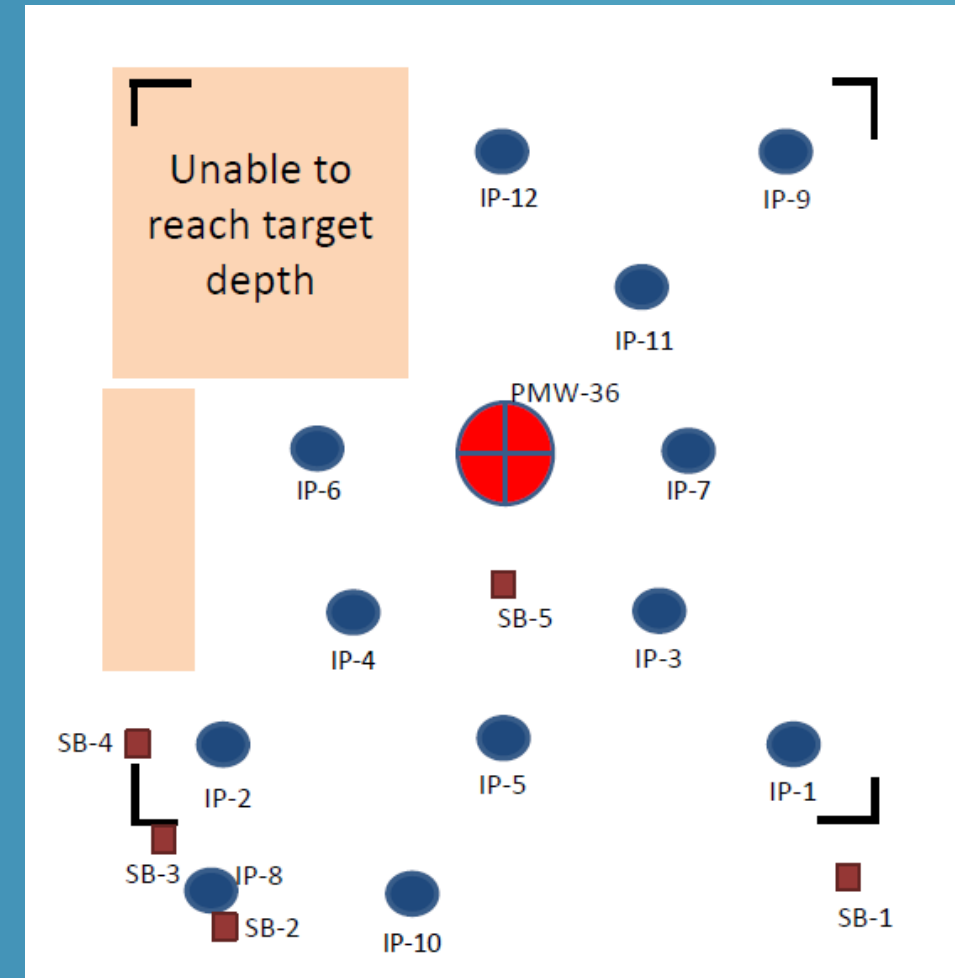
Figure 1 - Site overview





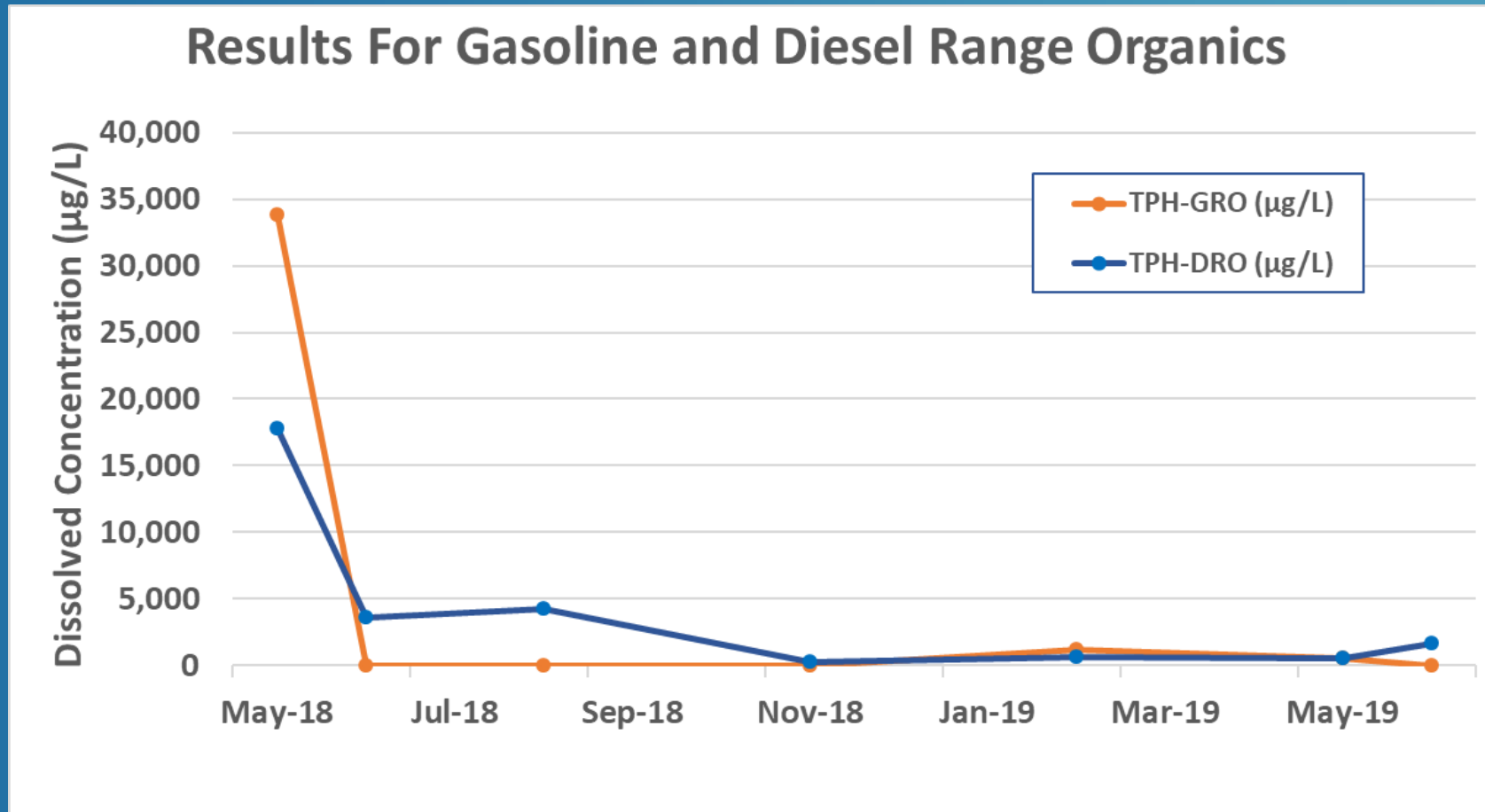
Site 2: Northern IN

- 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





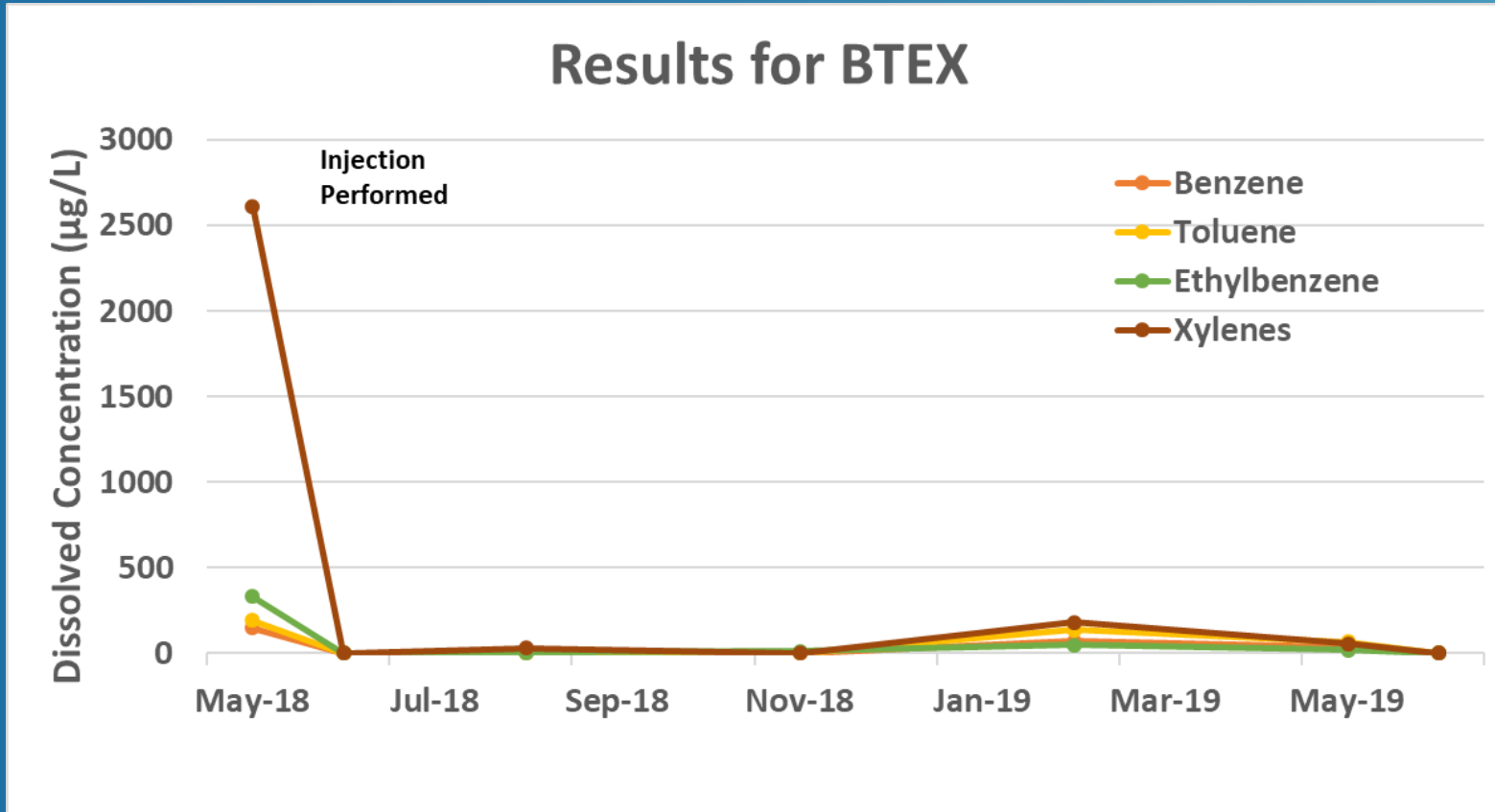
Site 2: Northern IN – Results for Gas and Diesel



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	1680



Site 2: Northern IN – Results for BTEX



- 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

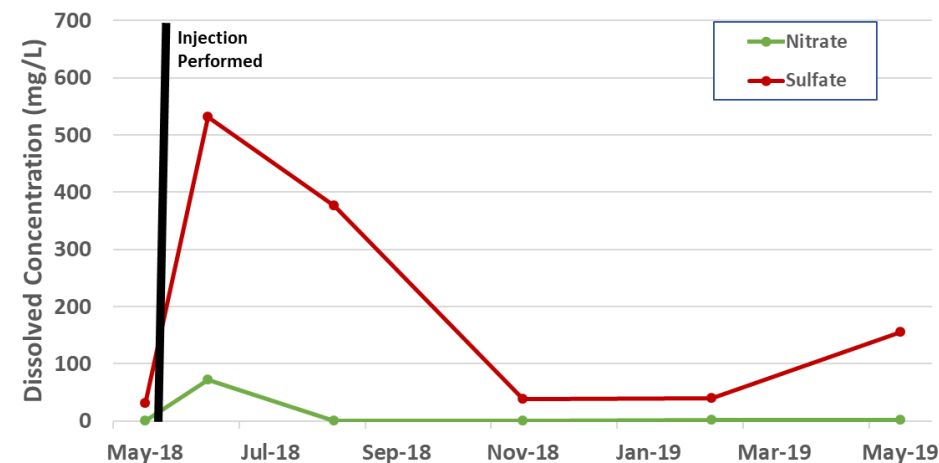


Site 2: Northern IN – BIO RESULTS

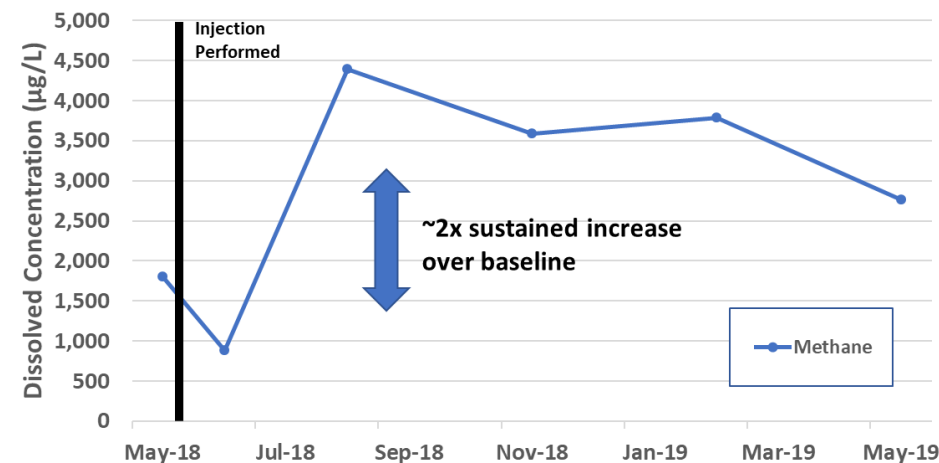
Lines of Evidence for biodegradation

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

Results For Nitrate and Sulfate

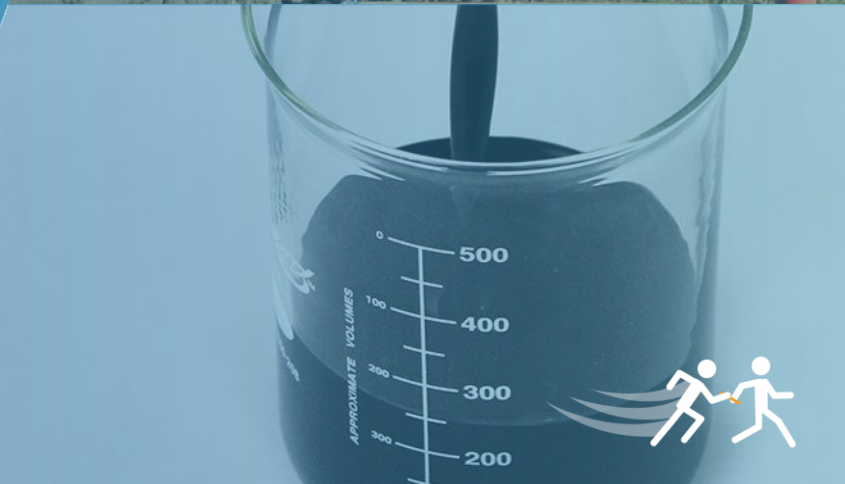


Results For Methane

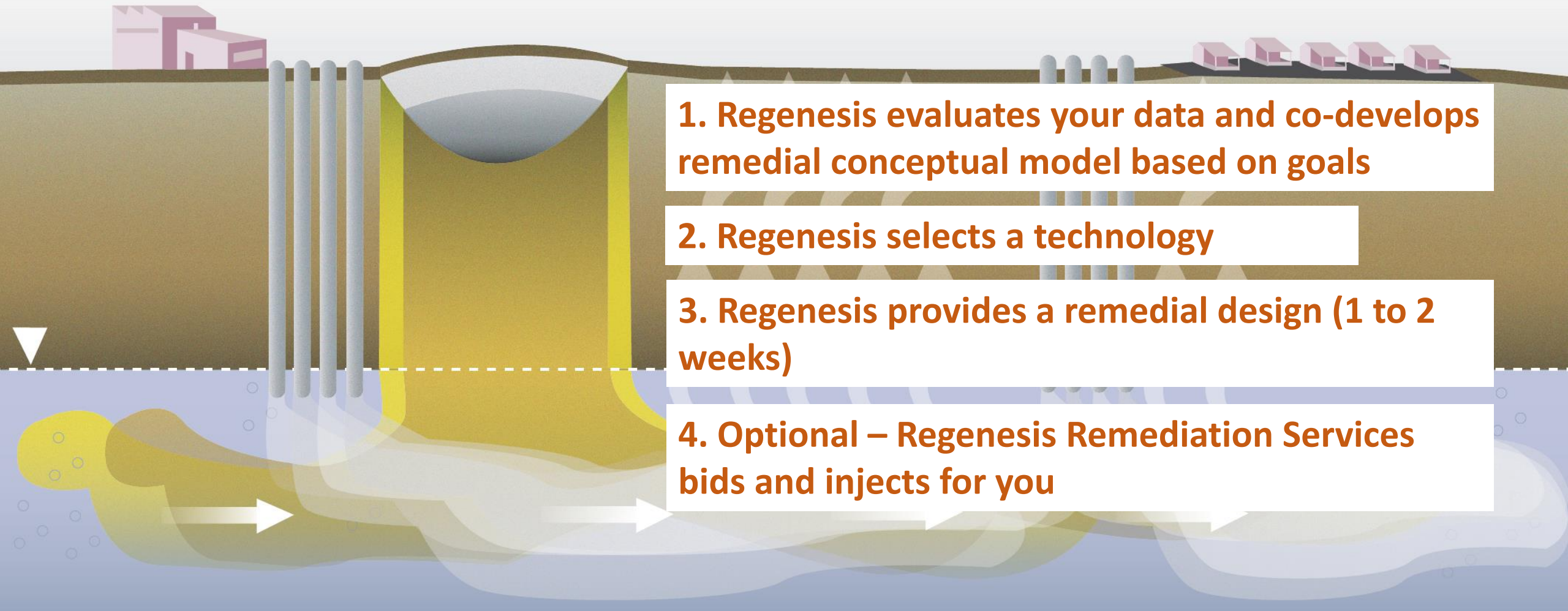




PetroFix Resources



TRADITIONAL REMEDIATION DESIGN APPROACH – WE PROVIDE DESIGN



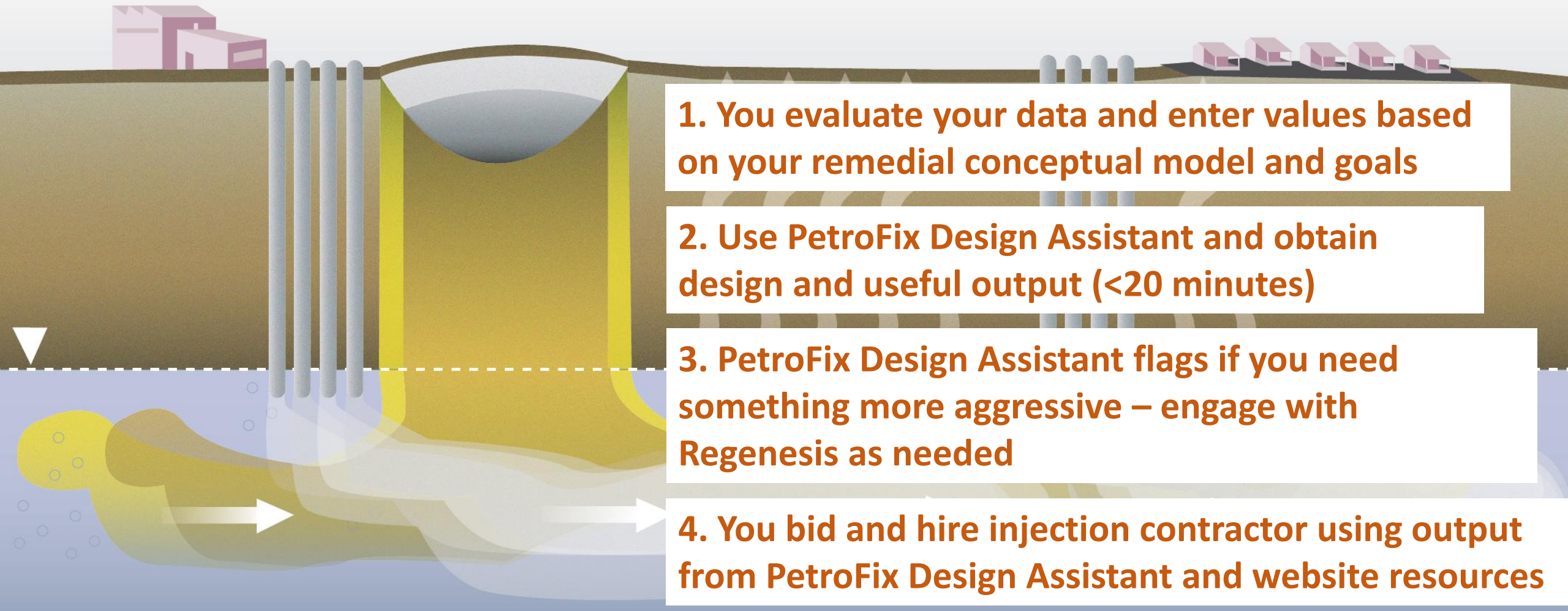
1. Regenesi s evaluates your data and co-develops remedial conceptual model based on goals

2. Regenesi s selects a technology

3. Regenesi s provides a remedial design (1 to 2 weeks)

4. Optional – Regenesi s Remediation Services bids and injects for you

NEW PETROFIX DESIGN – ONLINE DESIGN ASSISTANT PROVIDES DESIGN, WE SUPPORT



1. You evaluate your data and enter values based on your remedial conceptual model and goals

2. Use PetroFix Design Assistant and obtain design and useful output (<20 minutes)

3. PetroFix Design Assistant flags if you need something more aggressive – engage with Regeneration as needed

4. You bid and hire injection contractor using output from PetroFix Design Assistant and website resources

PETROFIX DESIGN ASSISTANT

- ✓ YouTube Training Video Available (9m 19s)
- ✓ Rapid designs provides dosage, volume and spacing and other variables
- ✓ Send output to local driller for bid
- ✓ www.petrofix.com/design

12.07.18

Pilot Test

SOURCE AREA
Application Summary

PetroFix Amount	1,200 lbs	Total Volume	1,842 gal
Treatment Surface Area	400.0 ft ²	Product Volume	123 gal
Delivery Points	16	Water Volume	1,720 gal
Point Spacing	5.0 ft	Injection Volume/Point	115 gal
Top of Treatment Interval	17.0 ft bgs	Inject Volume/Vertical ft	14 gal
Bottom of Treatment Interval	25.0 ft bgs	Product/Point	7.7 gal
Vertical Treatment Interval Thickness	8.0 ft	Water/Point	107.5 gal
Treatment Volume	119 yd ³	Soil Type	Mix of coarse and fine
PetroFix Dose	10.12 lb/yd ³	Effective Pore Volume Fill %	38%

Mix Tank Volume	250 gal	AREA NOTES
Dilution Factor	15.0	
PetroFix per Mix Tank	17 gal	
Water per Mix Tank	233 gal	
Number of Batches Required	7.37	

REPORTED		NAPL Present?	No
Ground Water Concentrations (µg/L)			
Benzene	460	Isopropylbenzene	0
Toluene	5,500	Naphthalenes	0
Ethylbenzene	740	MTBE	0
Xylenes	3,600	TPH-GRO	0
Trimethylbenzenes	0	TPH-DRO	0
Butylbenzene	0	Total Contaminant Mass:	10,300

Self-Design and Application - Calculations

REVIEW OR ADJUST

Application Details

Injection volume and point spacings are critical to achieving good product coverage. We have provided recommended starting values, but you may edit the fields as needed. Warnings are displayed for concerns with edited values.

MIX TANK VOLUME

250 gal

INJECTION POINT SPACING

5 ft

DILUTION FACTOR

15.0

Saved

[REVERT TO RECOMMENDED VALUES](#)

PILOT TEST

Application Summary

DELIVERY POINTS	16
Product Volume	123 Gal
Water Volume	1,720 Gal
TOTAL VOLUME	1,842 Gal
Inject Volume/Point	115 Gal
Volume Per Vertical ft.	14 Gal
Soil Type	Mix of coarse and fine
EFFECTIVE PORE VOL. FILLED	38%
Mix Tank Fill Volume	250 Gal
Product to Add	17 Gal
Water to Add	233 Gal
Number of Batches Required	7.37

- Calculate treatment volume and effective porosity based on soil type
- Use PetroFix isotherms to calculate loading rate for dissolved mass.
- Estimated sorbed mass with text book values of Koc and Foc for contaminants and soil type
- Estimate dilution factors
- Estimate spacing based on soil type
- Round to nearest drum

PETROFIX INJECTION INSTRUCTIONS

PetroFix Application Instructional
YouTube Training Video Available
(4m 23s)

- ✓ Find under “You Apply”
- ✓ Installation equipment required
- ✓ Tools and supplies required
- ✓ Mixing and injection instructions
- ✓ Documenting distribution





Thank you!

For More Information Go To:
www.petrofix.com



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