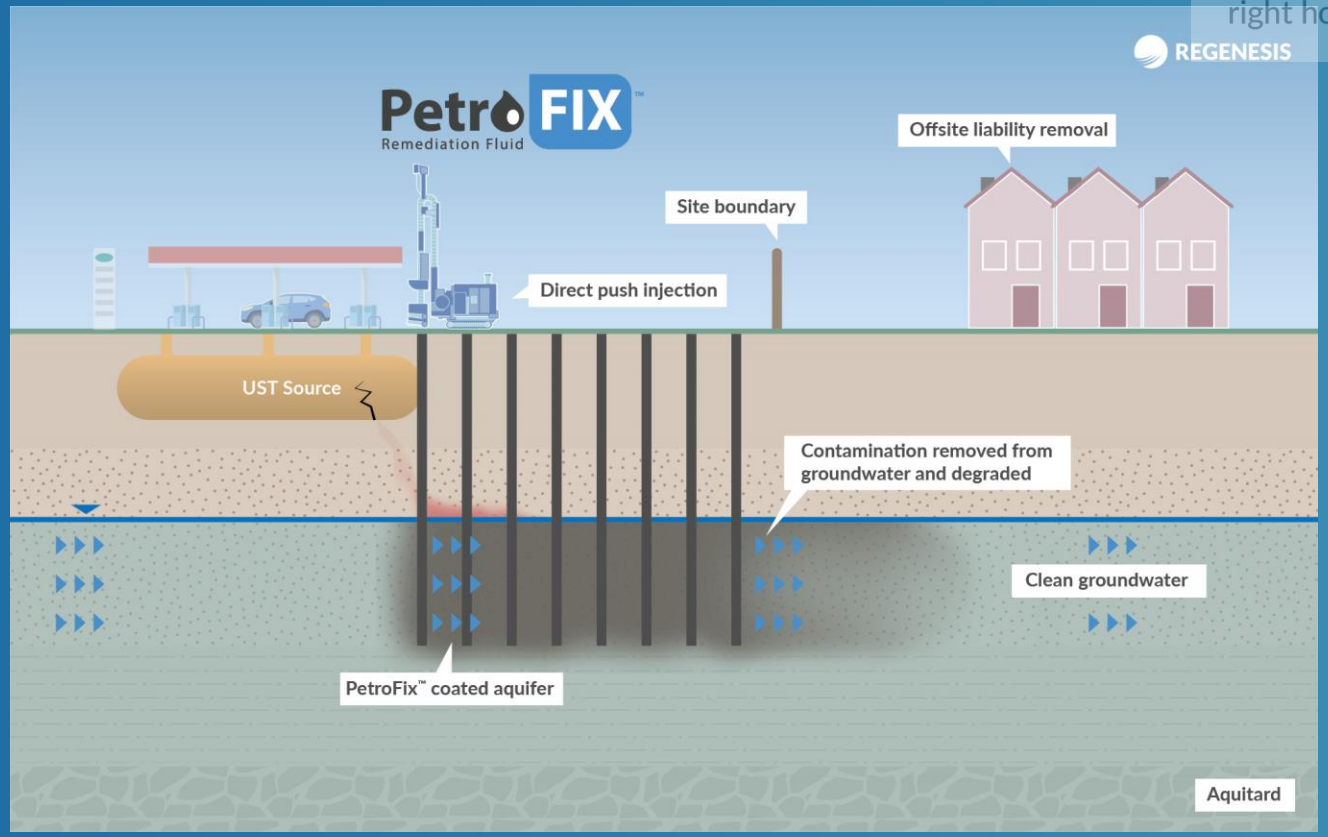
Recent Trends in In-Situ Hydrocarbon Remediation – Treatment With Activated Carbon Remedial Fluid



Todd Herrington, REGENESIS
Global PetroFix Product Manager
Presenting on PetroFix™

Andrew Punsoni, REGENESIS
Northwest District Manager
Technical Point of Contact

ESAA Weekly Webinar Series - May 19th, 2020

WHAT WE DO

REGENESIS®

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

26 Years in Business

REQUIREMENTS FOR SUCCESSFUL *IN SITU* REMEDIATION

MICRON-SCALE REAGENTS

REGENESIS®

PLUME STOP® Liquid Activated Carbon

PetroFix® Remediation Fluid

S-MicroZVI™ Sulfidated Zero-Valent Iron

Colloidal Solid Sorbent Suspended in Aqueous Liquid

***In Situ* Sorption**
In Situ Enhanced Bioremediation

- Secures rapid GW concentration reduction coupled with accelerated bio
- Composed of micron-scale activated carbon (1-2 µm)
- Organic polymer dispersion chemistry
- Designed & applied by REGENESIS

Solid Sorbent Suspended in Aqueous Liquid

***In Situ* Sorption**
In Situ Enhanced Bioremediation

- Secures rapid GW concentration reduction coupled with accelerated bio
- Composed of micron-scale activated carbon (1-2 µm)
- No organic polymer dispersion chemistry
- Self-applied and designed by user
- Designed specifically for petroleum hydrocarbon sites

Engineered Glycerol-Based ZVI Amendment

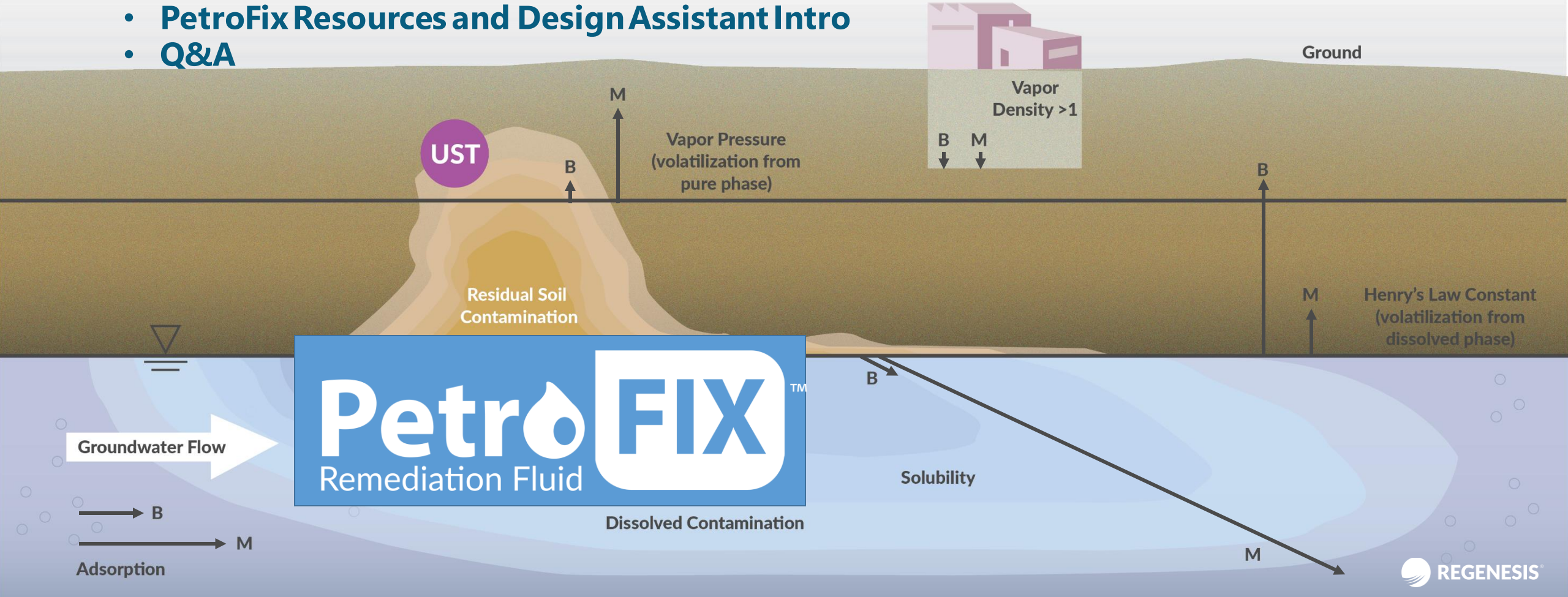
***In Situ* Chemical Reduction**
***In Situ Enhanced* Anaerobic Bioremediation**

- Contains 40% sulfidated ZVI (2-3 µm)
- Can be co-applied with organic amendments, dechlorinating microbes, and PlumeStop

OUTLINE

- **Brief Intro**
- **PetroFix core-technology overview**
- **PetroFix injection Practices**
- **UST/AST Case Studies**
- **PetroFix Resources and Design Assistant Intro**
- **Q&A**

REGENESIS®



PetroFix Resulted From PlumeStop Research

PLUMESTOP® LIQUID ACTIVATED CARBON™ LAUNCHED IN 2013

- Applied on 500+ sites
- Industry leading product for solvents, PFAS, hydrocarbons

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

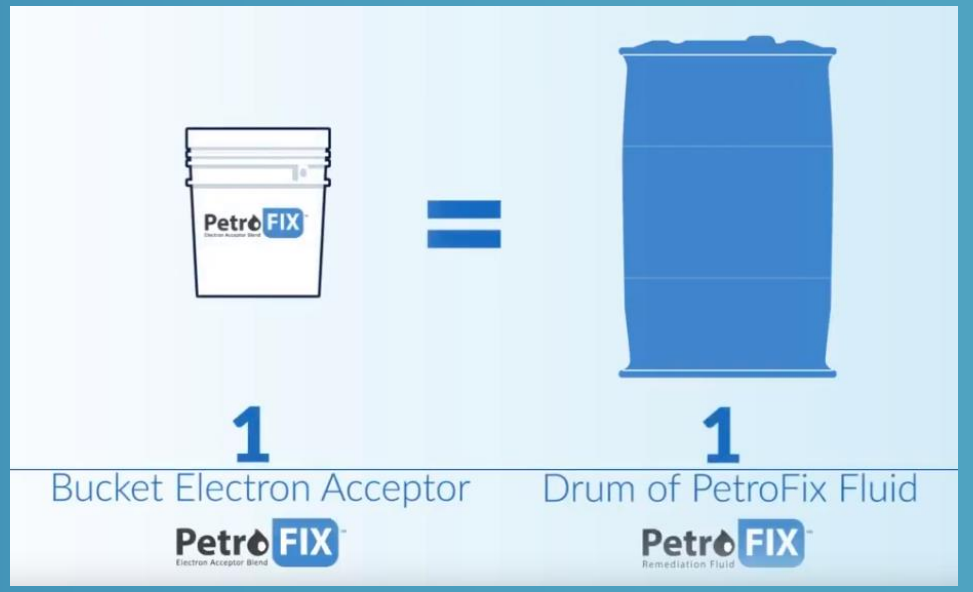
- Fast results for petroleum sites
- Persistent treatment
- Higher treatment range
- Promotes biodegradation after sorption
- Easy and safe to apply
- Do it yourself process (versus turn-key)

PetroFix 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

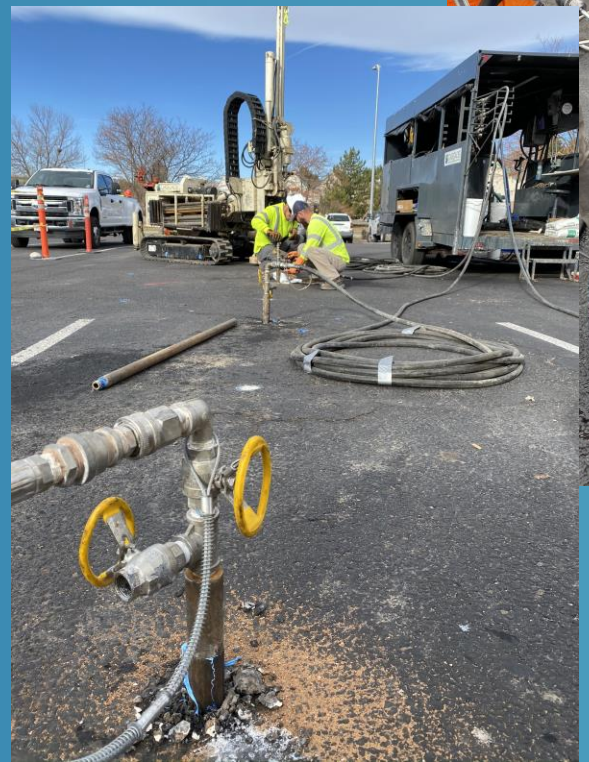
PetroFix Formulation

- +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



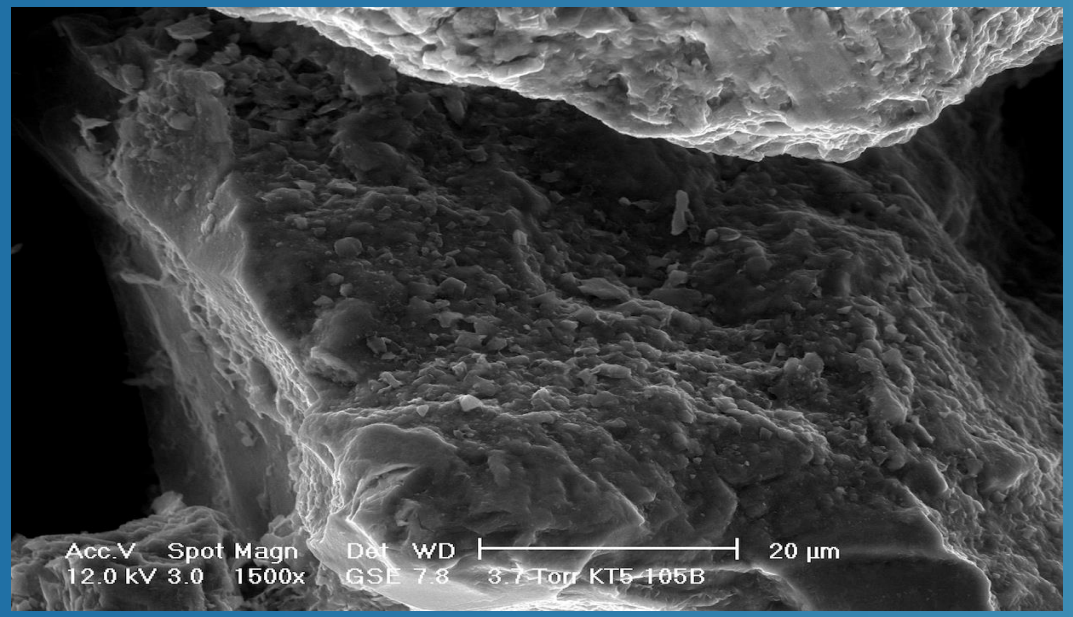
PETROFIX ADOPTION TO DATE:

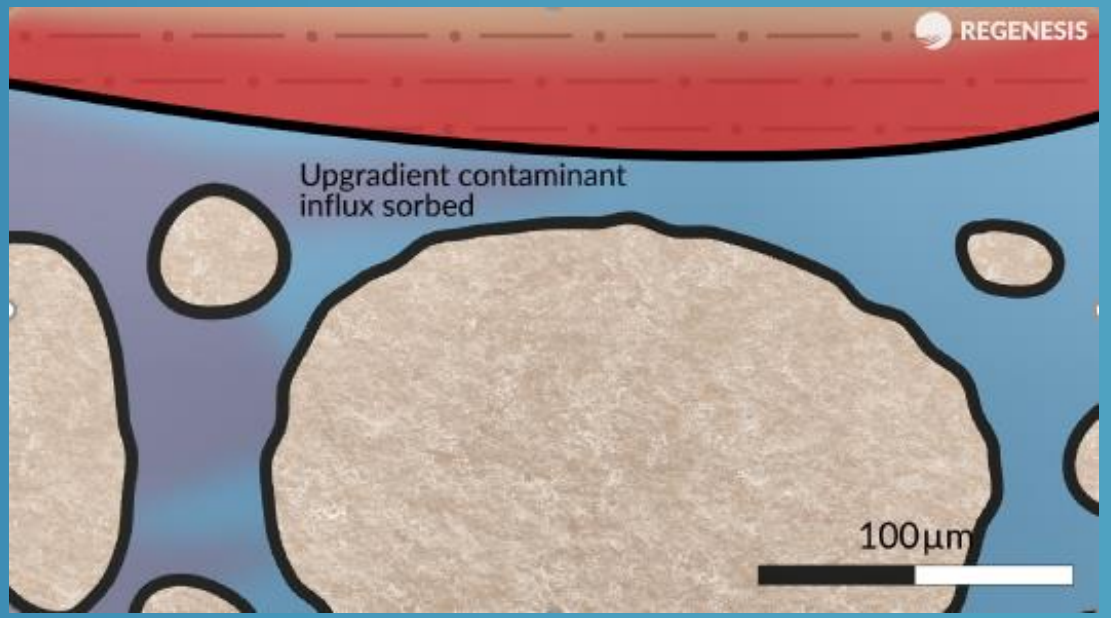
- Released September 2018
- +129 sites world wide
- +6 projects in Canada
- Simple UIC process



Modes of Action

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





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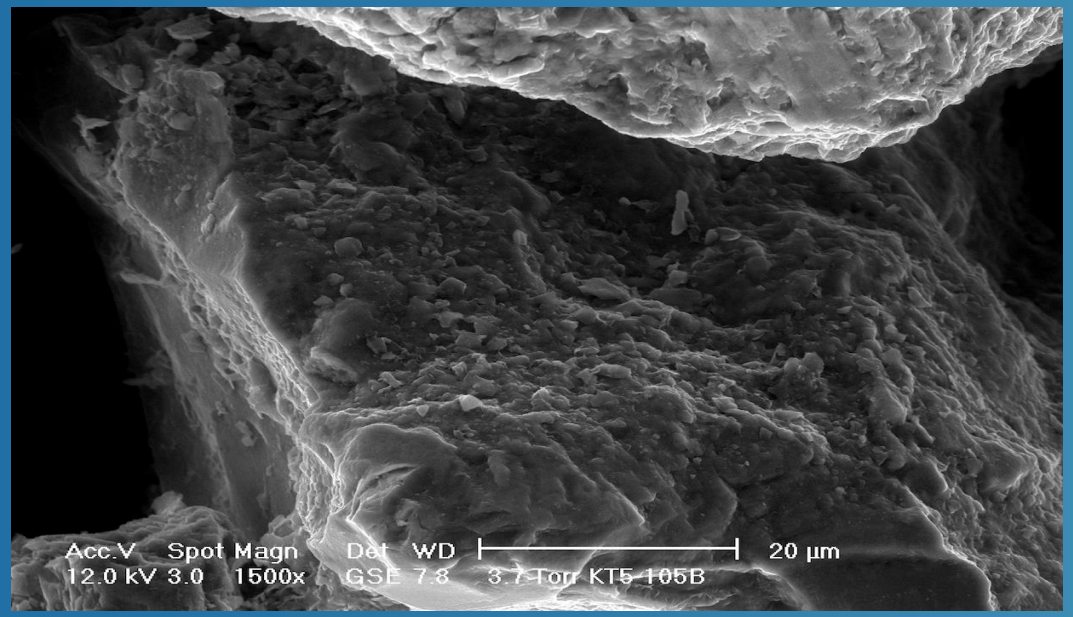
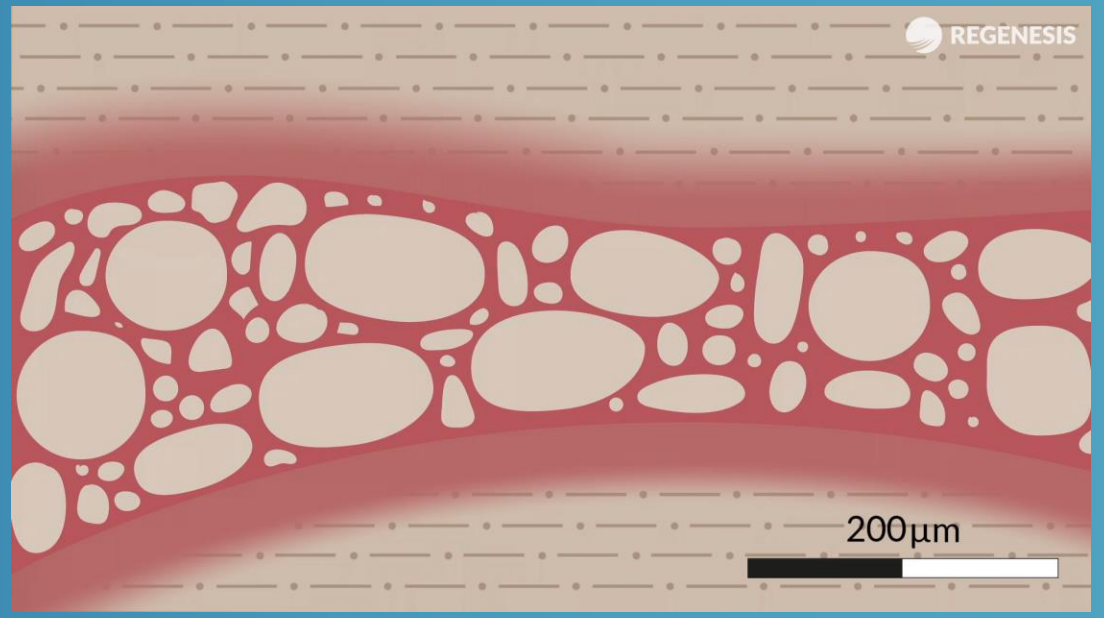
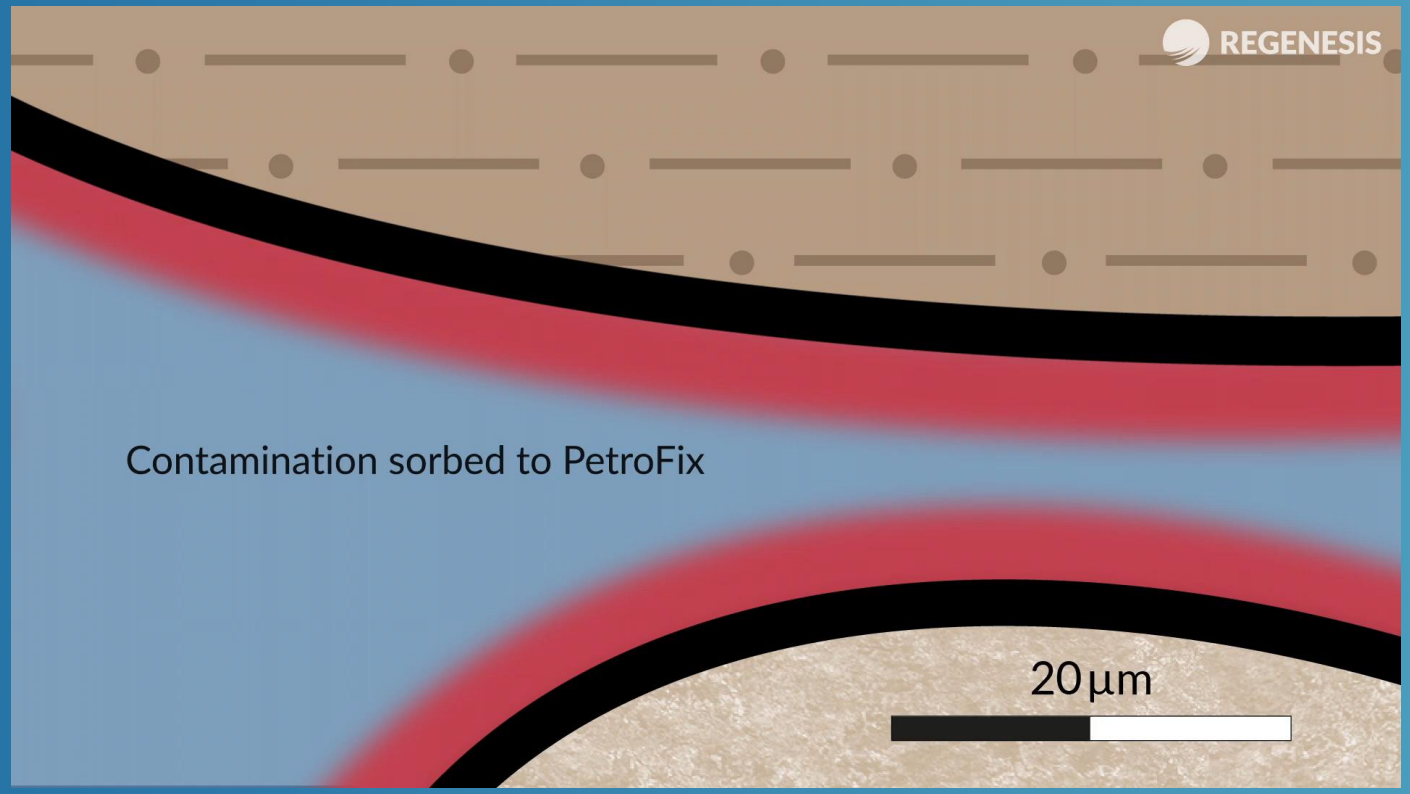




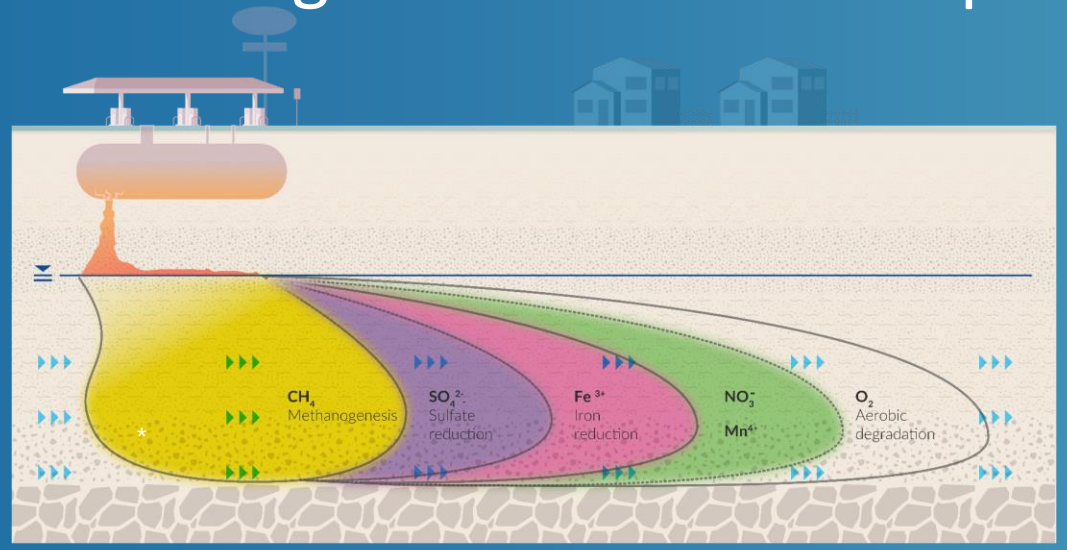
Modes of Action

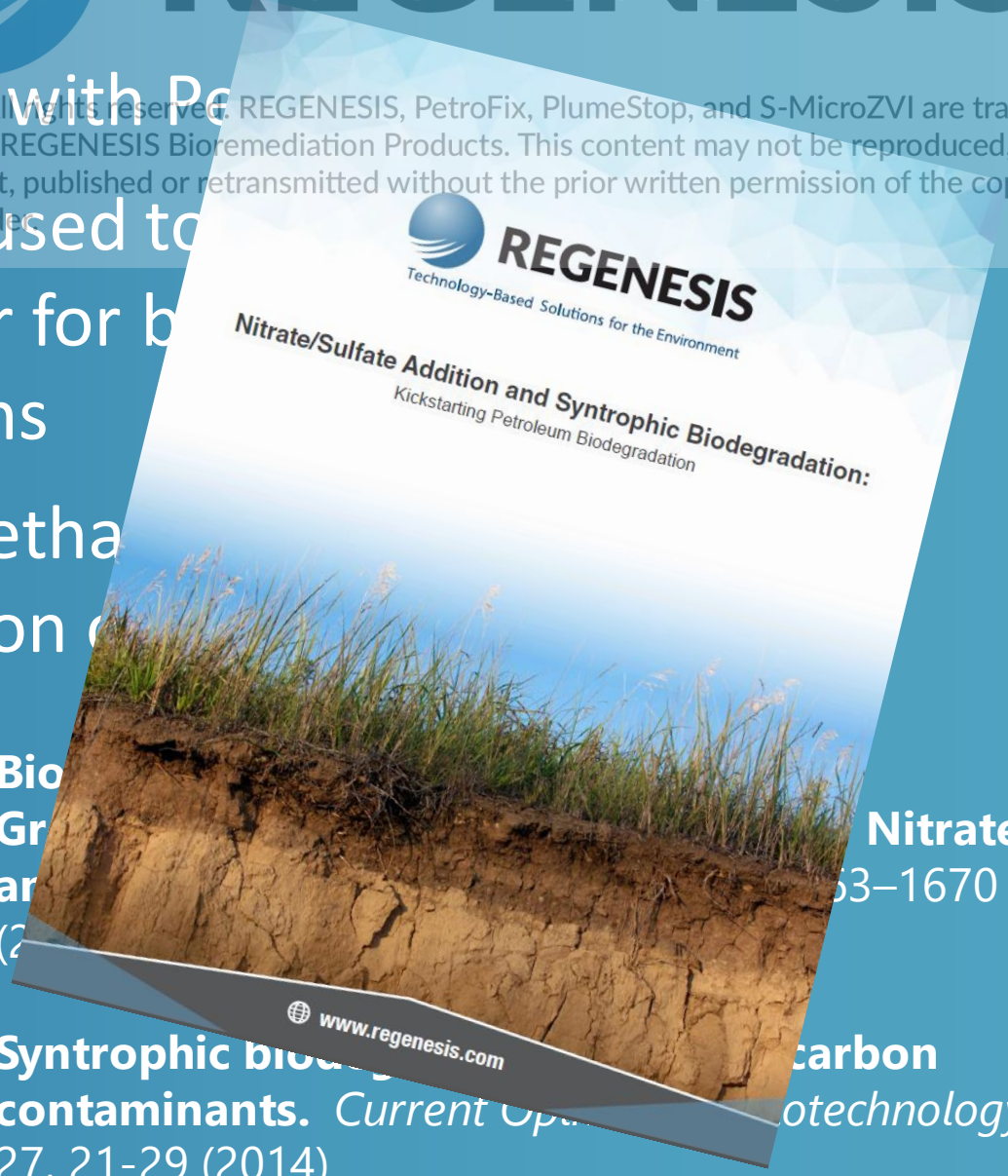
1. **Hydrocarbon Sorption**: Once injected, PetroFix coats soil surface with thin layer of carbon, then sorbs hydrocarbons.
2. **Stimulated Anaerobic Bioremediation**: Nitrate and sulfate kickstart bioremediation and enhance syntrophic remediation



NO_3 + SO_4 Promote Syntrophic Bioremediation

- Water soluble forms of NO_3 + SO_4 to go with Pe
- Improved outcomes when NO_3 + SO_4 used to
  from Cunningham et al.). Nitrate better for b
  are versatile, co-exist with methanogens
- Fermentation of hydrocarbons, plus metha
  Improved long-term even after depletion





Bio
Gr **Nitrate**
ar 53–1670
(2

Syntrophic bio **carbon**
contaminants. *Current Opi* *otechnology.* 27, 21-29 (2014)

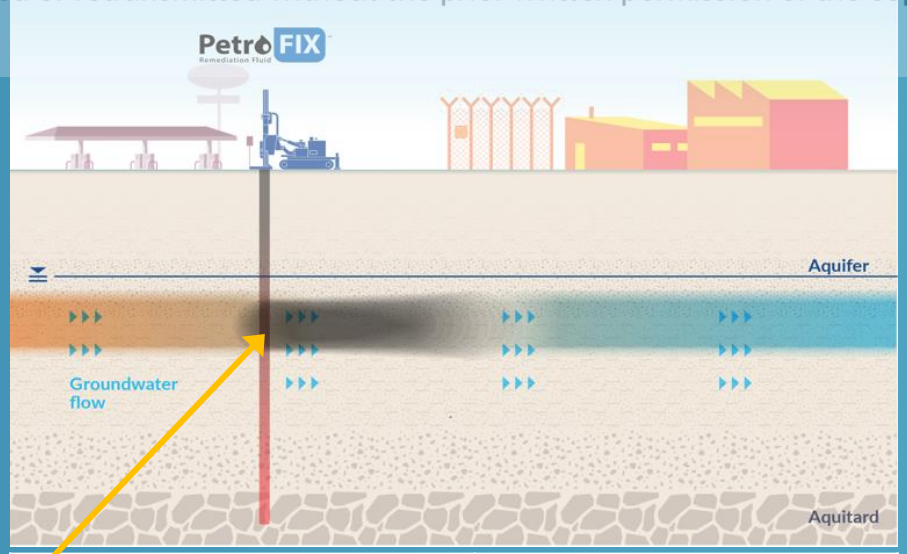
REGENESIS

1 to 2 Micrometer Carbon Diameter Provides Advantage for Aquifer Injection

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

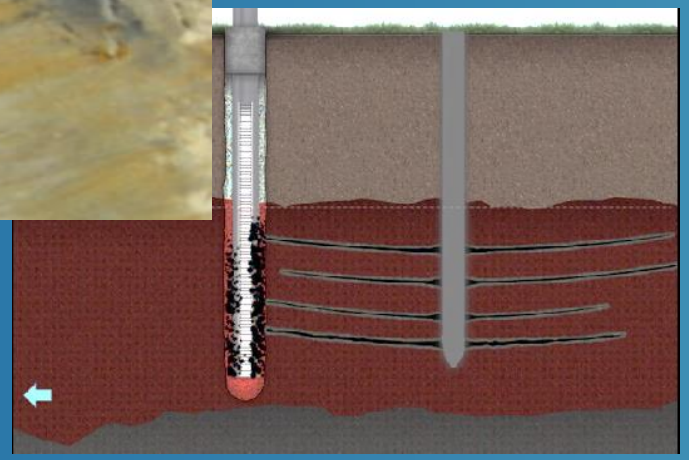
*Note: Only 1-2 micron carbon has a diameter below the typical pore throat diameter for silty soils.

Aquifer Seam Fractures vs Aquifer Flooding

FRACTURE PLACMENT OF CARBON

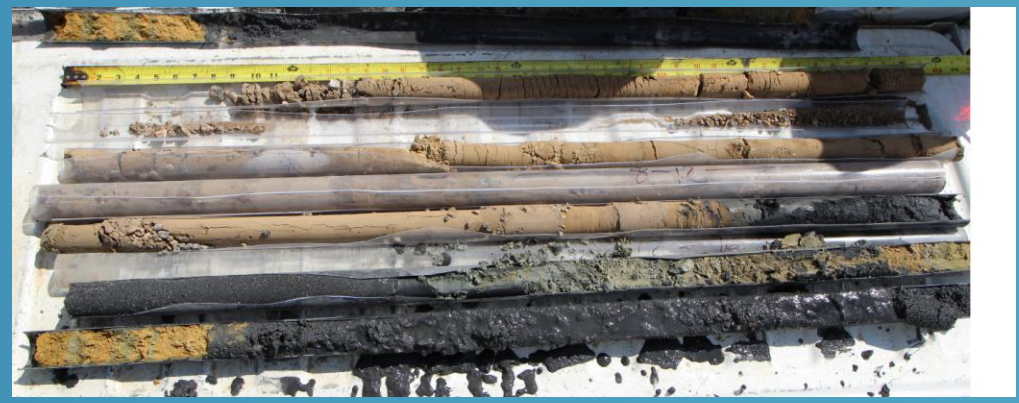
- Random Fractures
- Only partial treatment of conductive zones
- Can compromise monitoring wells

Courtesy T. Fox, Colorado Division of Oil and Public Safety



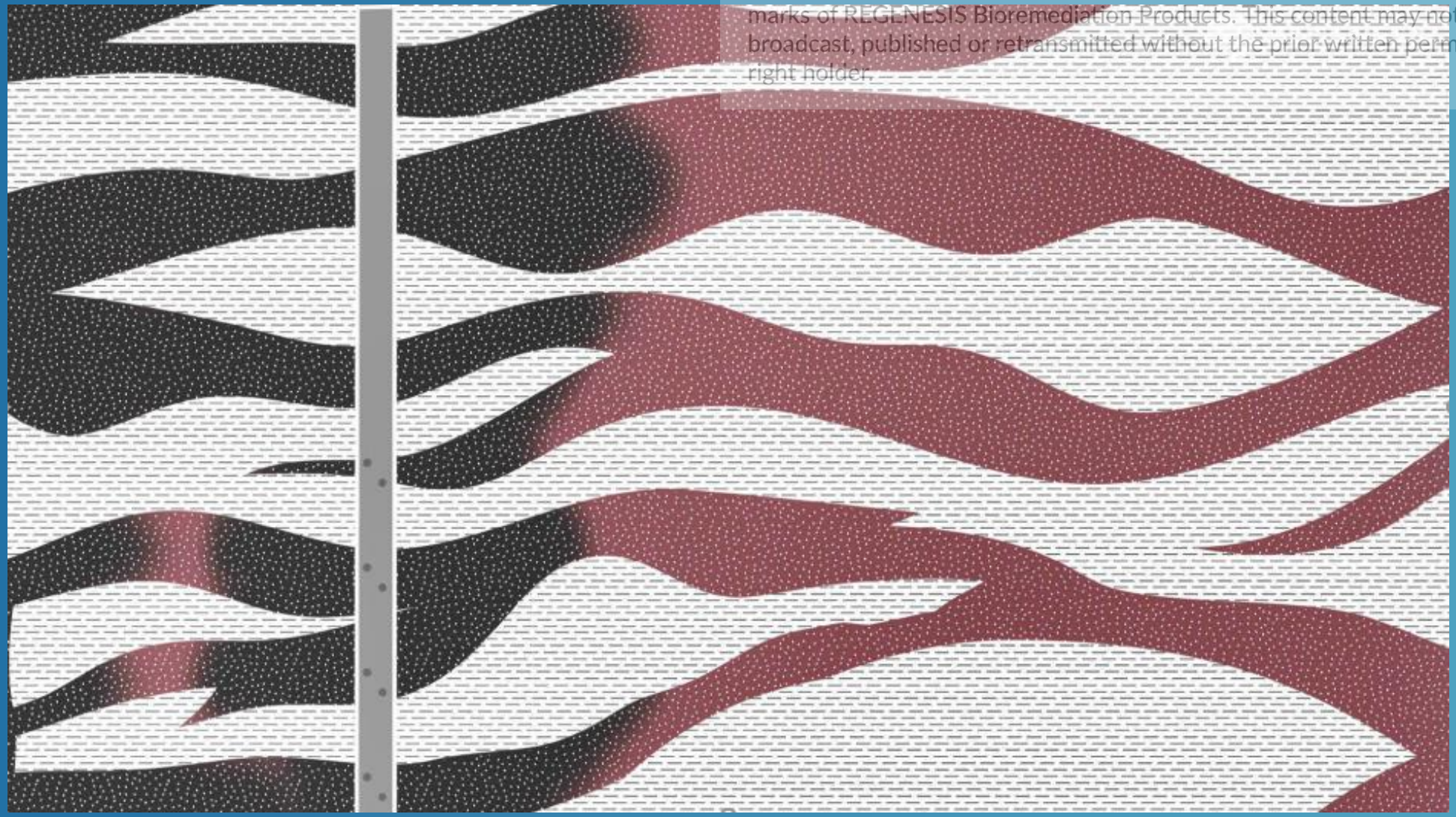
LOW-PRESSURE PLACEMENT OF CARBON

- Flood coverage of entire conductive zone
- Clean water flush out wells



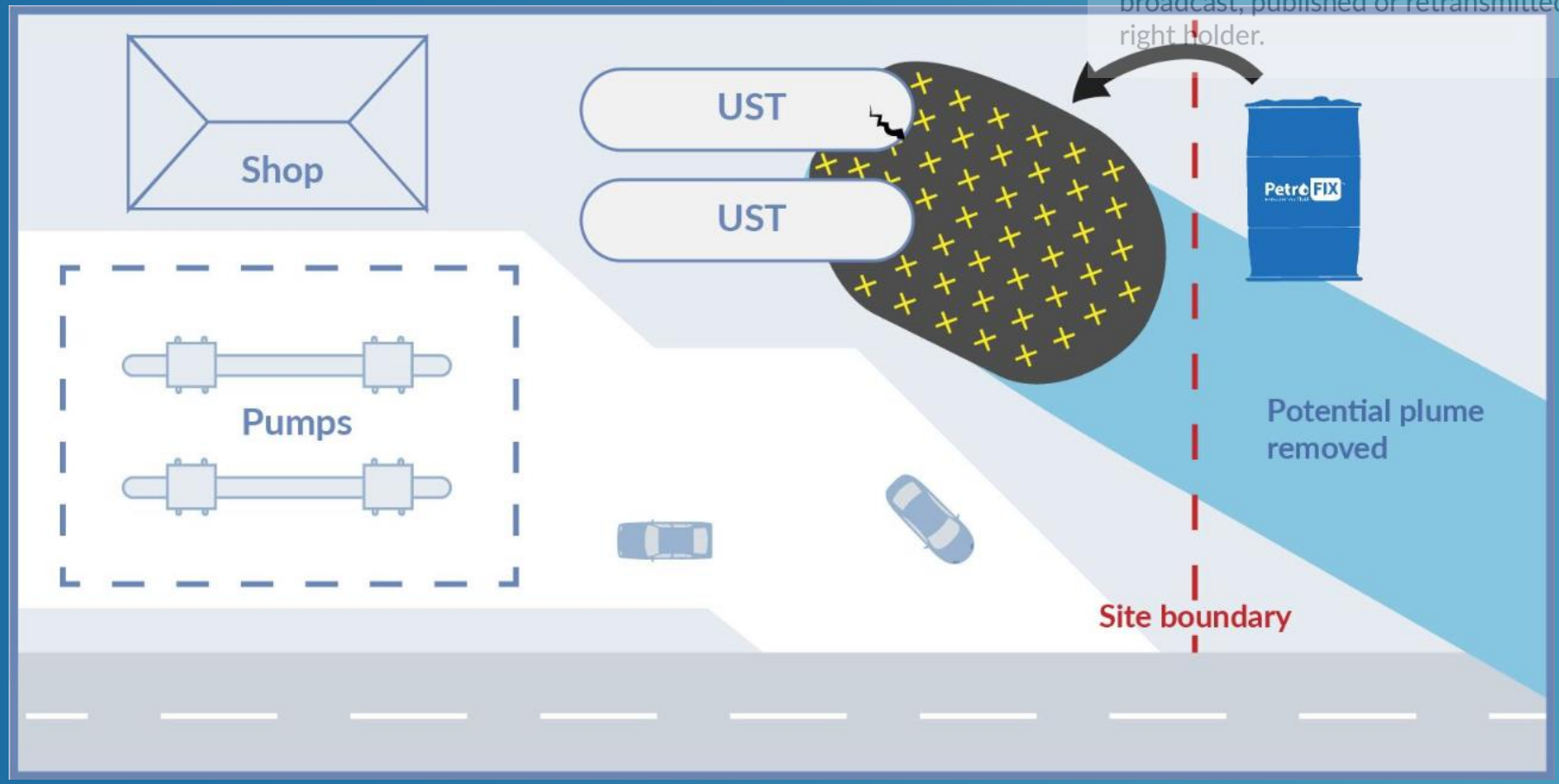
REGENESIS

TIP: Use Long, Multiport Tips To "Straddle" Conductive Zones And Low-Pressure To Flood Into Them



PetroFIX™ Remediation Fluid

Most Common Applications

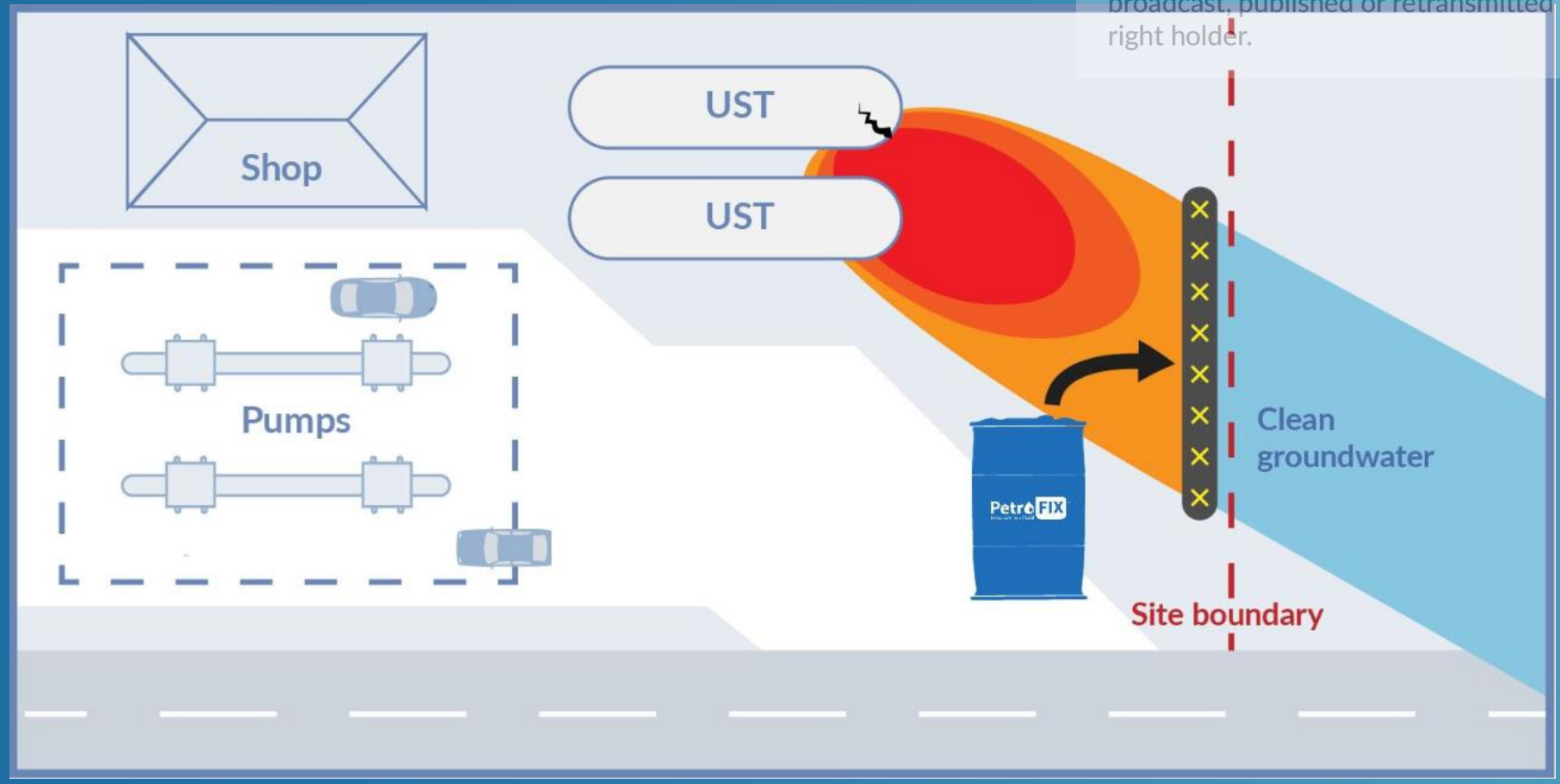


SOURCE AREA TREATMENT

- Grid Approach
- Smear Zone

PetroFIX™ Remediation Fluid

Most Common Applications

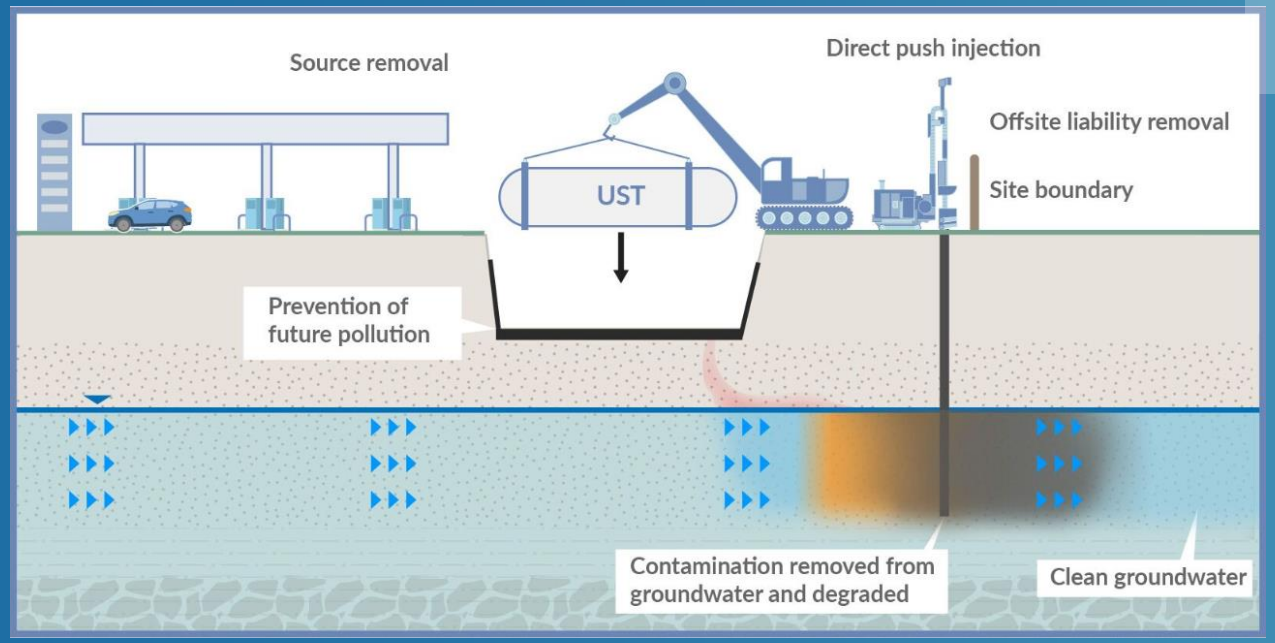


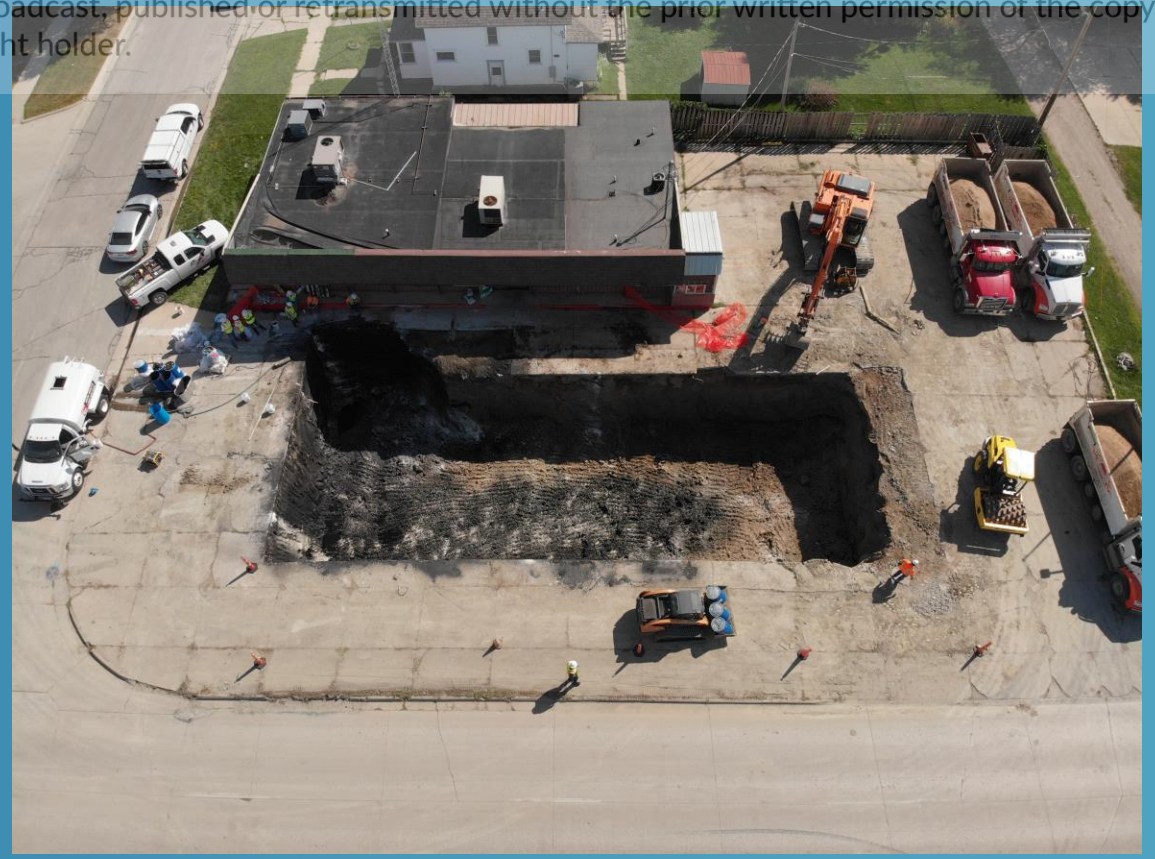
BARRIERS

Eliminate Off-Site Migration and Reduce Liability

PetroFIX™ Remediation Fluid

Most Common Applications





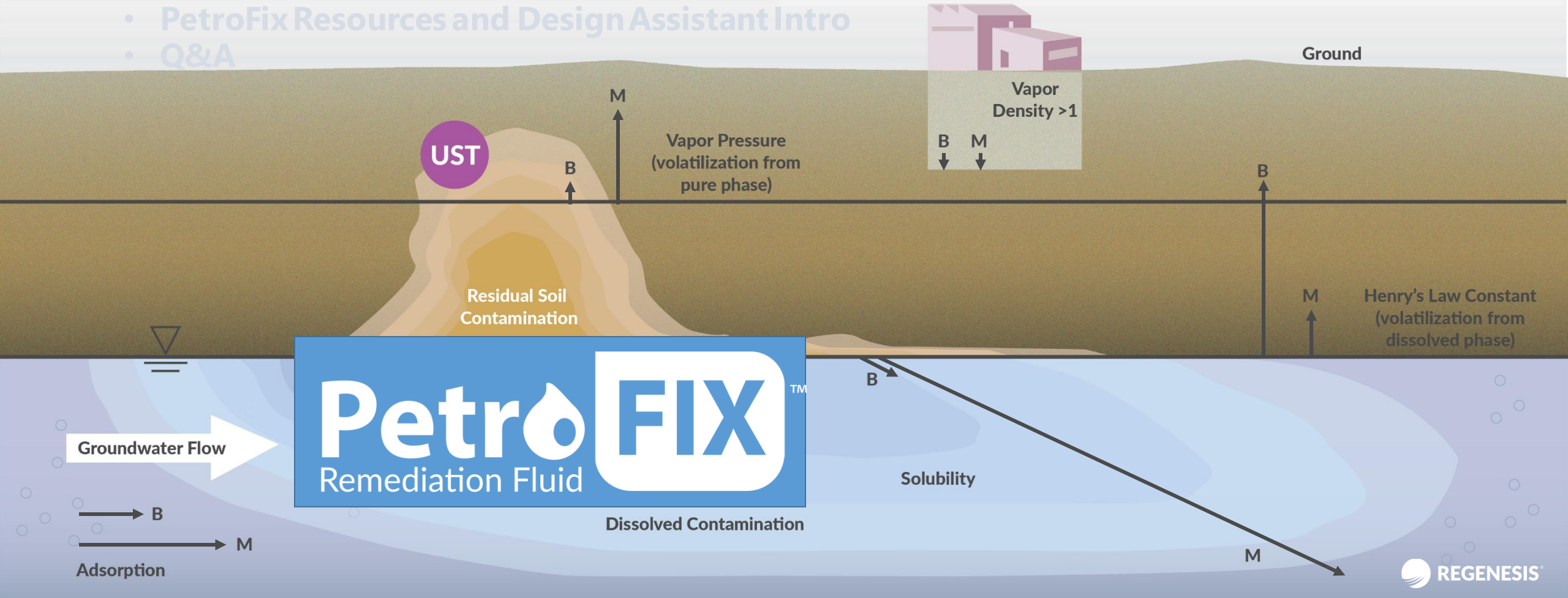
EXCAVATIONS

Insurance against residual mass

OUTLINE

- Brief Intro
- PetroFix core-technology overview
- **PetroFix injection Practices**
- UST/AST Case Studies
- PetroFix Resources and Design Assistant Intro
- Q&A

REGENESIS®



PETROFIX APPLICATION – KEY POINTS

Multi-Port Tooling DOES work at most sites

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

PETROFIX APPLICATION – KEY POINTS

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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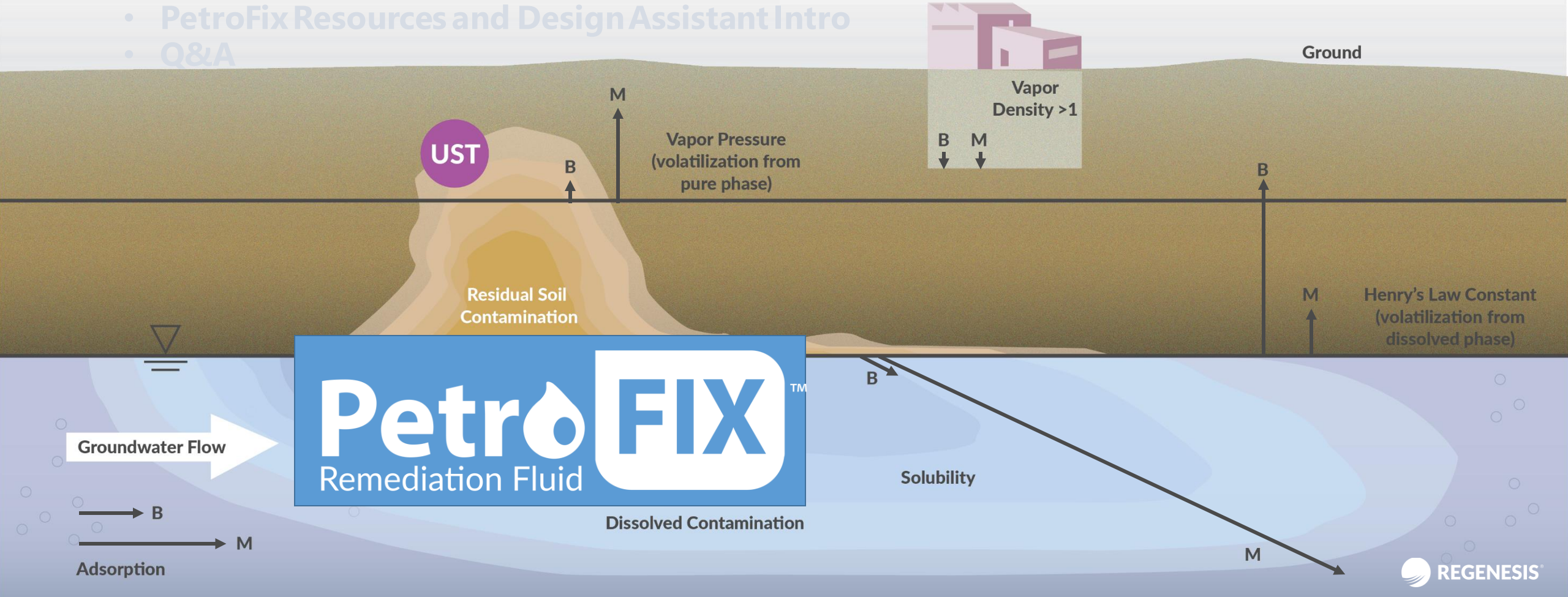


REGENESIS®

PERFORMANCE-BASED OBJECTIVES ACHIEVED AT SCOTT AFB

CASE STUDY:
PetroFix Reduces Benzene Levels to Non-Detect

OVERVIEW

- A large airforce base in southwestern Illinois had soil impacted by a plume of petroleum hydrocarbons and BTEX
- Contamination occured as a result of leaking underground storage tanks located on site
- Combined remedy utilized RegenOx, ORC-Advanced and PetroFix to achieve groundwater remediation objectives

TREATMENT

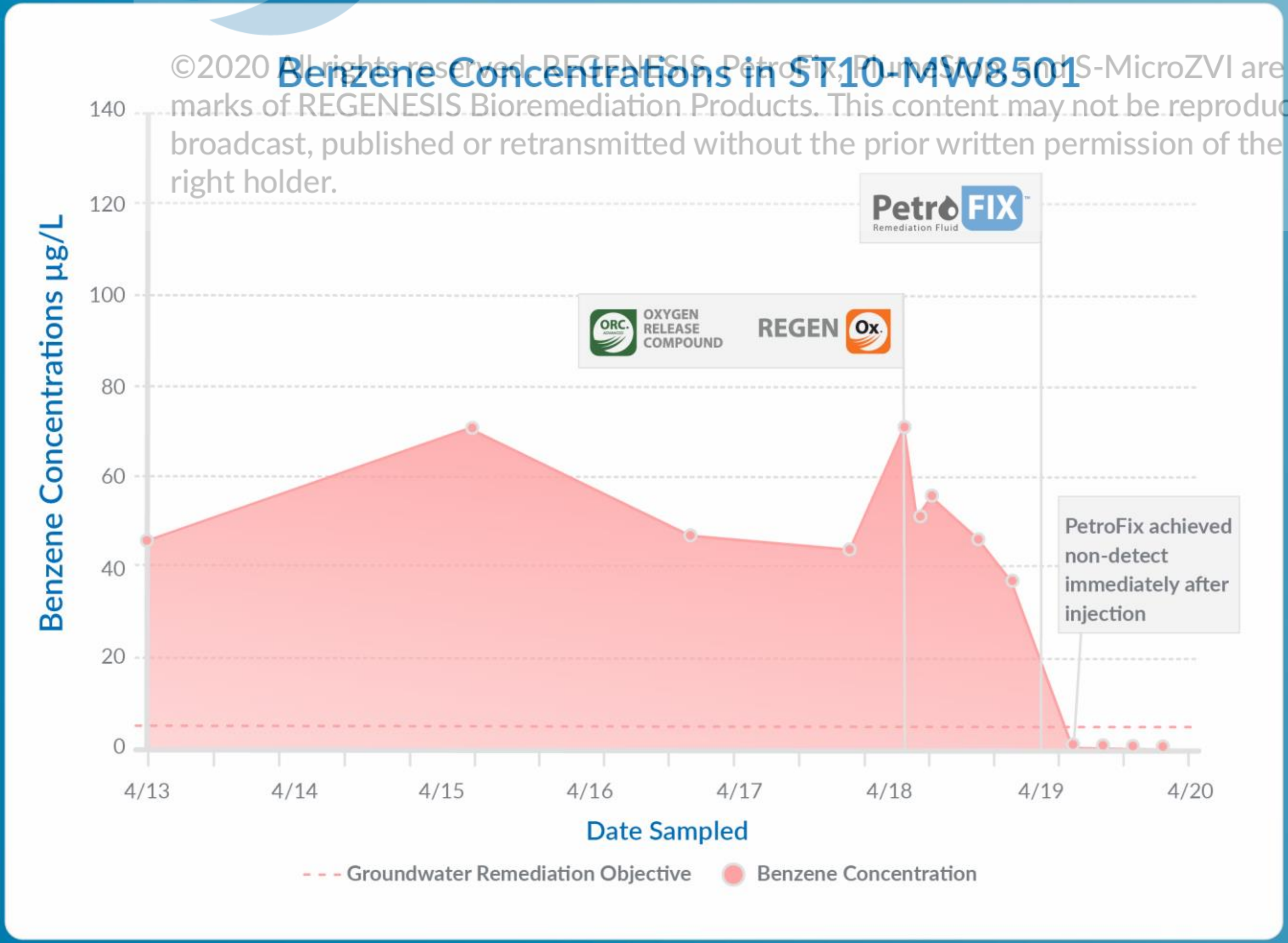
- Initial injections of RegenOx and ORC-Advanced occurred from February-March 2018
- PetroFix was applied at a second injection event which occured in March 2019

HIGHLIGHTS

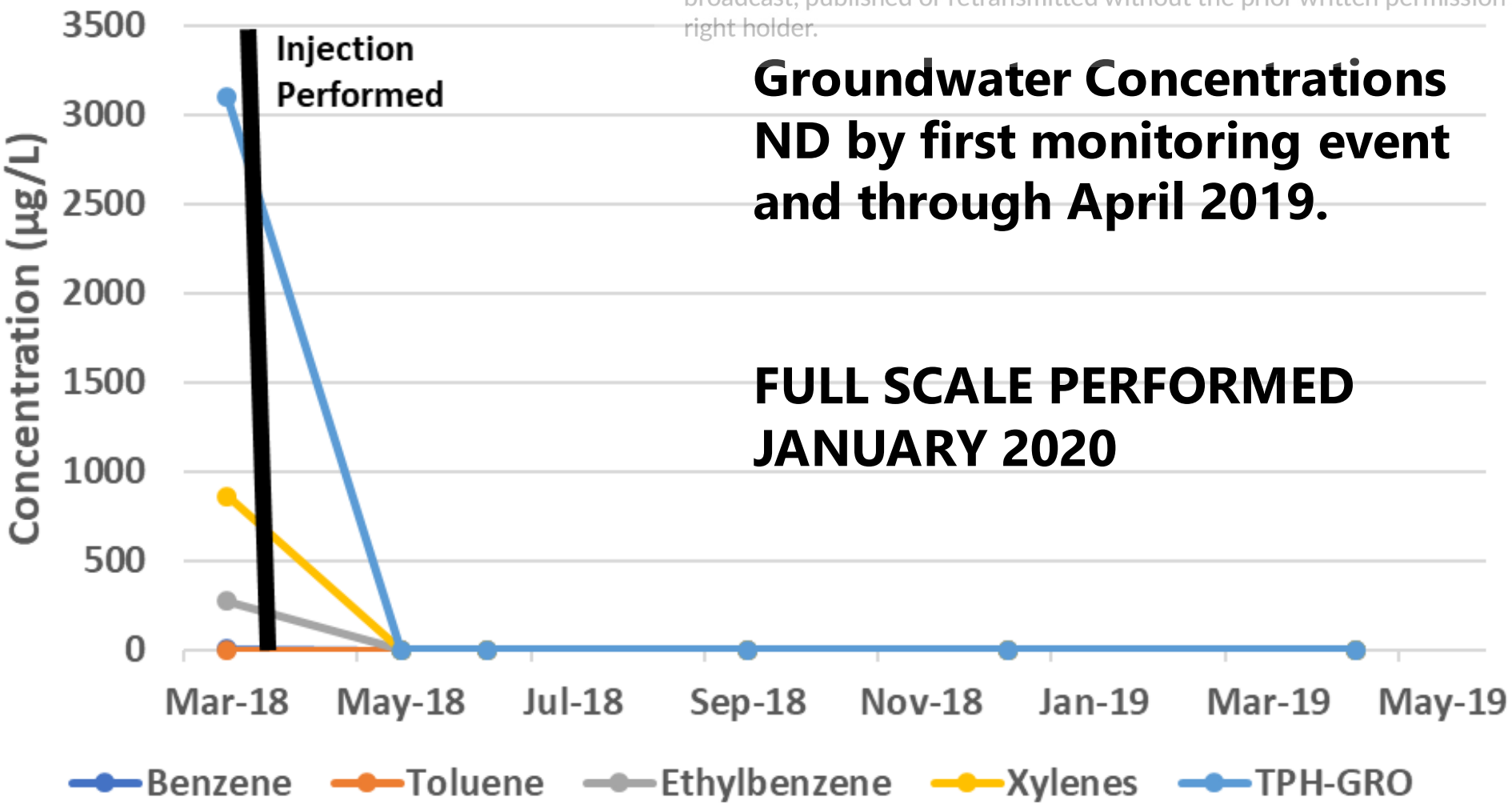
- Impacted soil was caused by leaking underground piping and removal of two large UST's
- Second round of direct push injection included PetroFix to treat lingering BTEX
- One month following application of PetroFix, BTEX levels were at non-detect and have continued to remain at that level for 5 sampling events

RESULTS

- The remedial approach successfully treated the lingering contamination.
- The initial combination of RegenOx and ORC Advanced, coupled with the secondary measure of PetroFix has provided the contaminant mass reduction needed.
- The site is currently in place to receive a 'No Further Action' status following 5 sampling events at non-detect.



Panama City Beach, FL - RESULTS



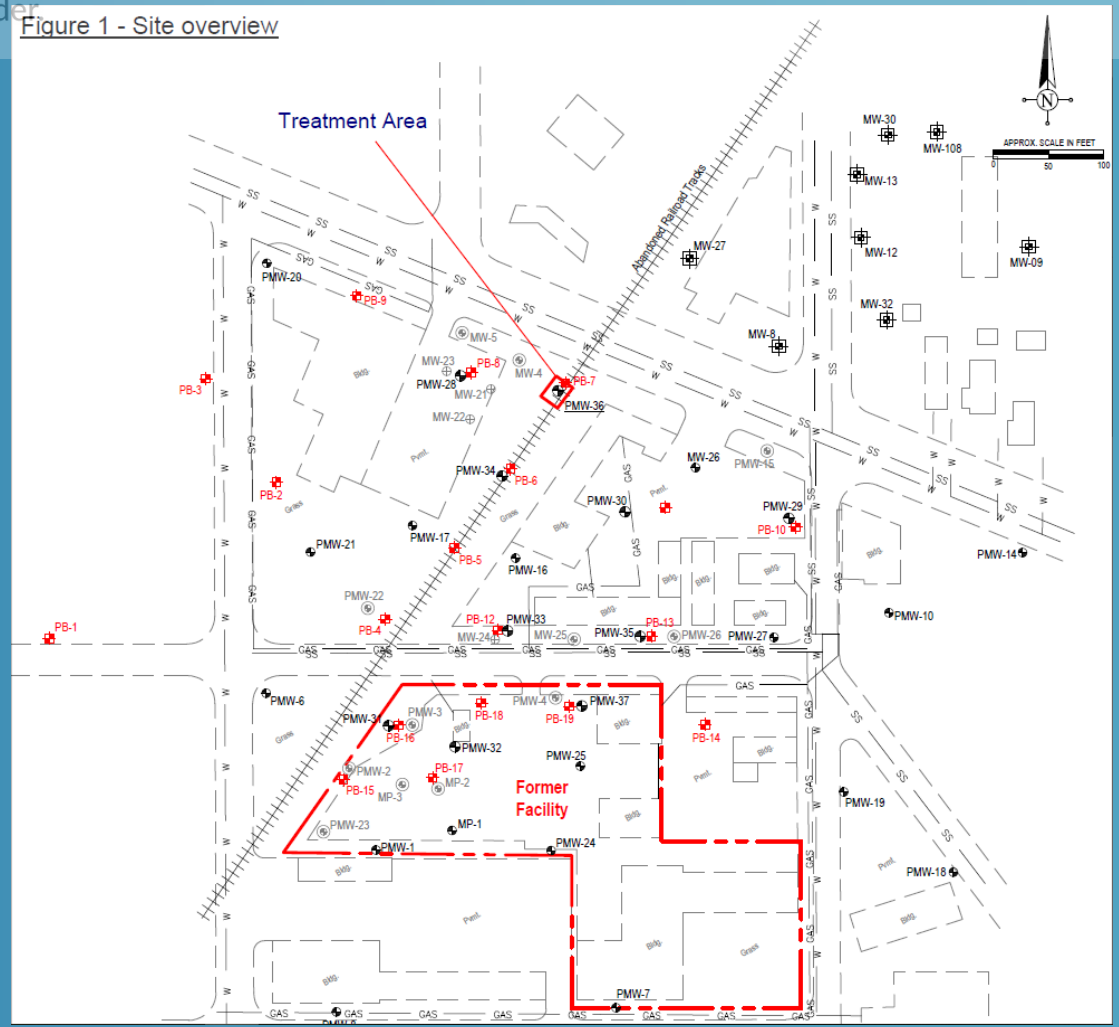
Groundwater Concentrations ND by first monitoring event and through April 2019.

FULL SCALE PERFORMED JANUARY 2020

REGENESIS

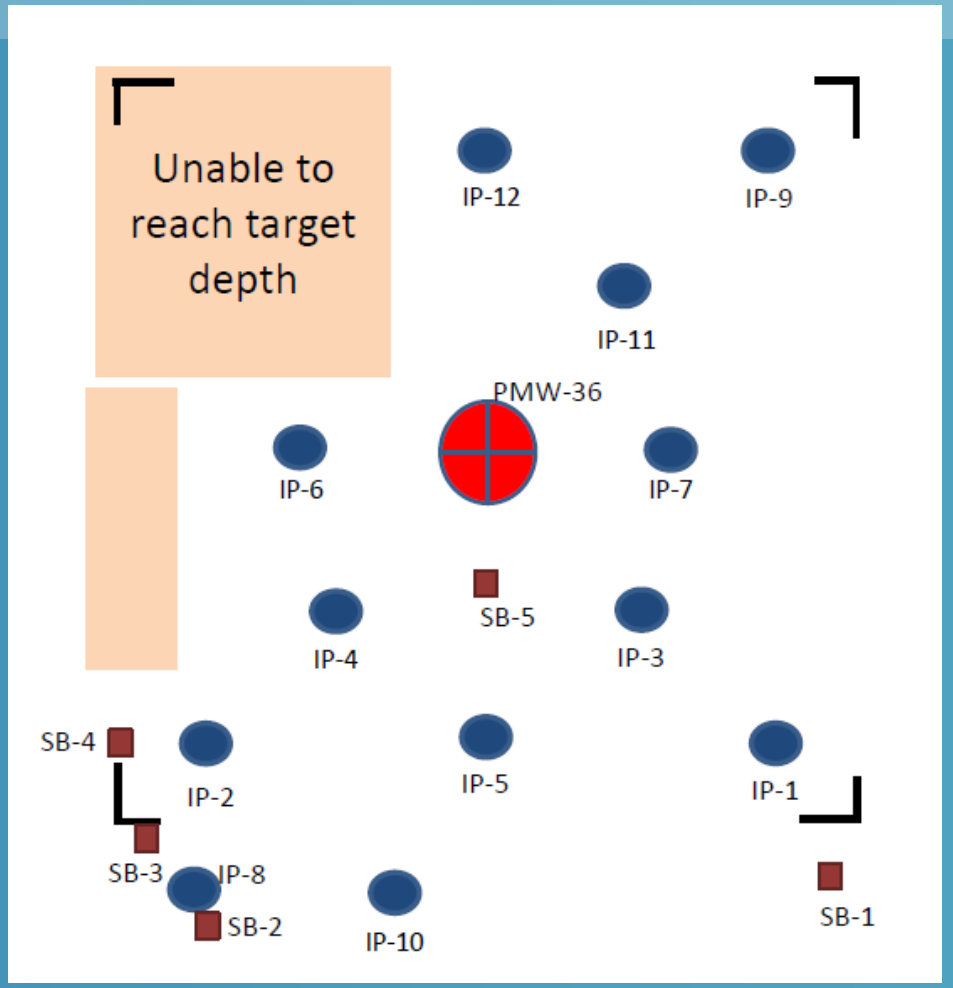
Northern IN- BACKGROUND

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

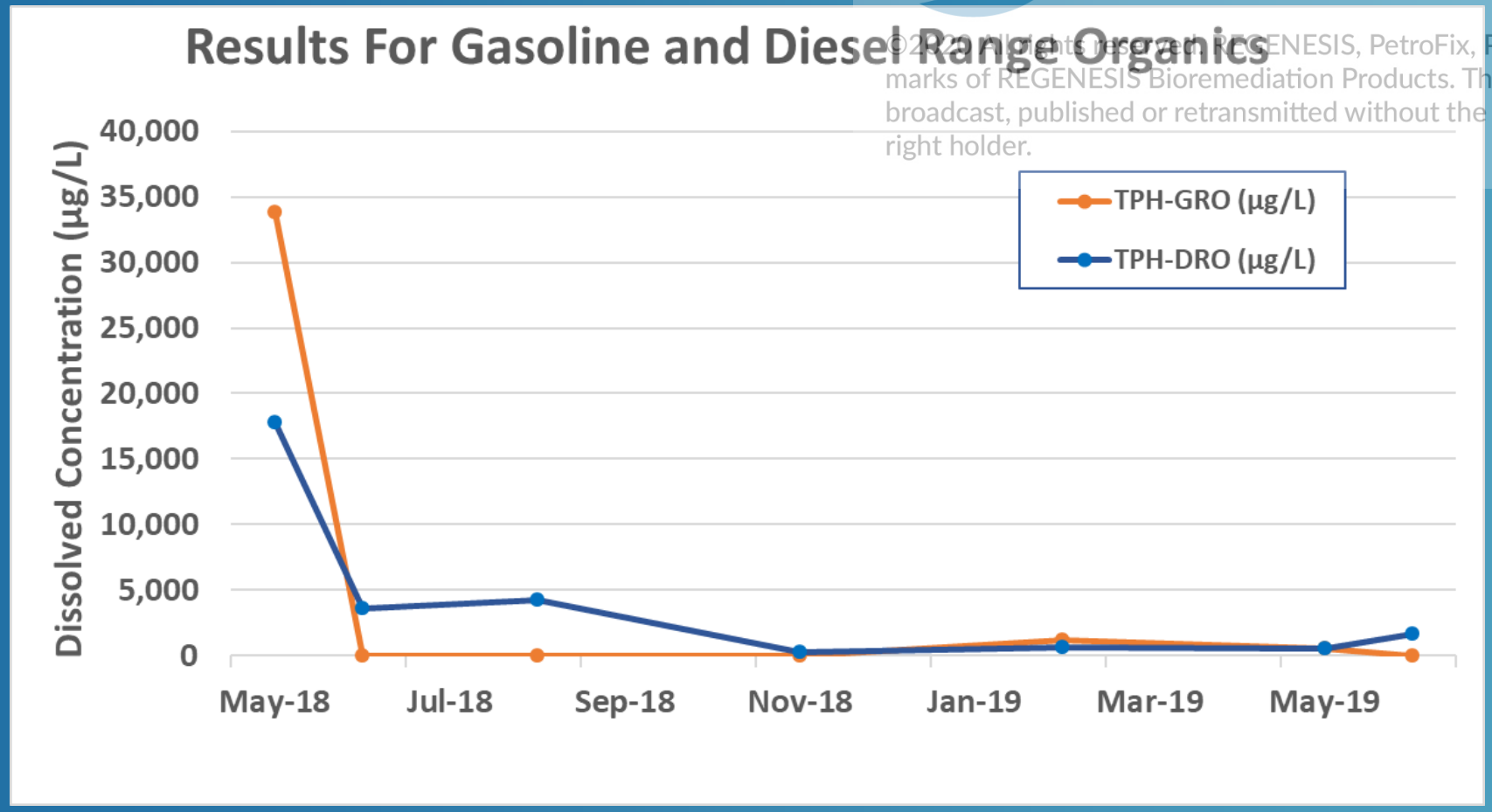


Northern IN- PILOT

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

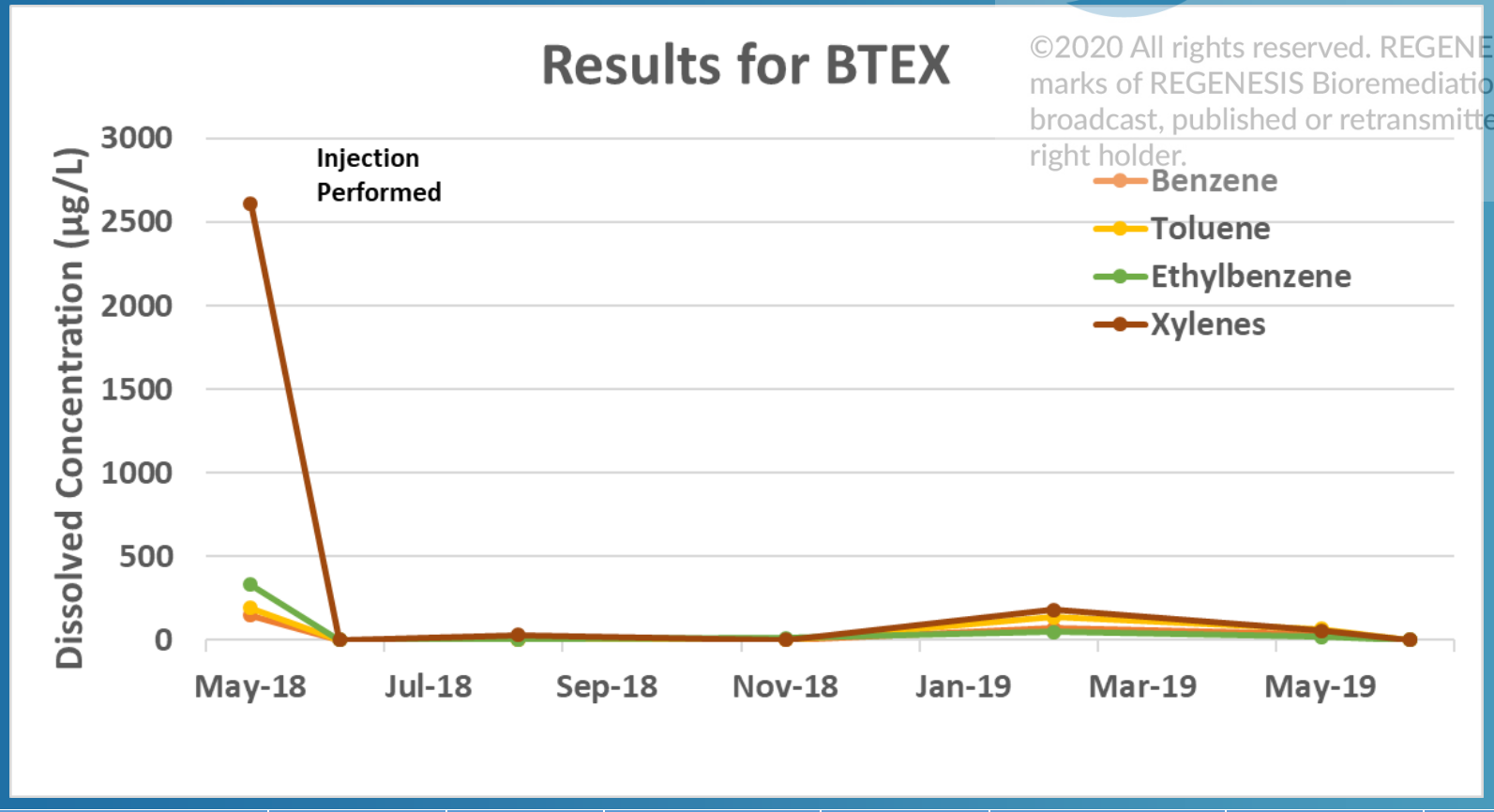


Northern IN – Results for Gas and Diesel



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**

Northern IN – Results for BTEX



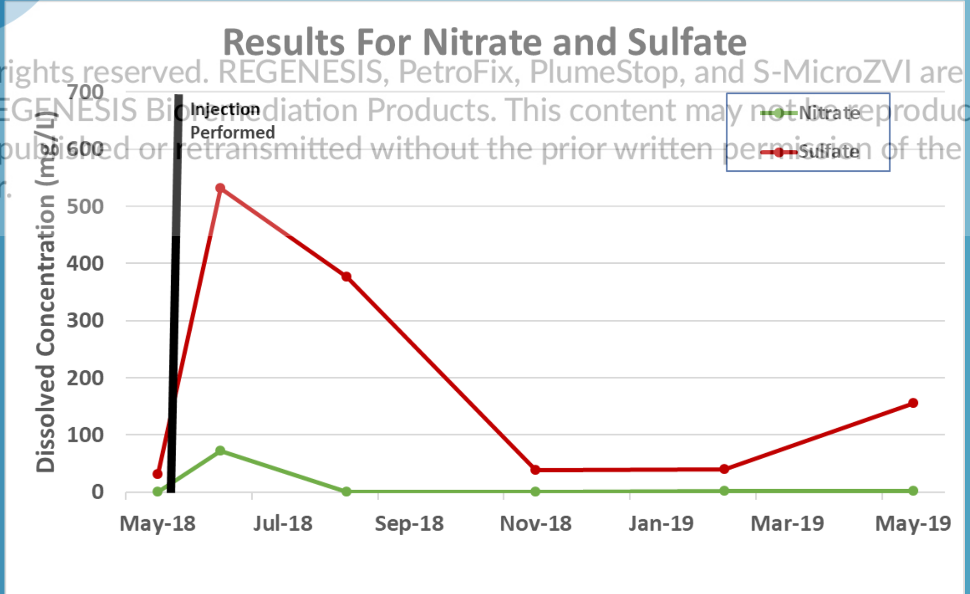
- Client suspected some rebound. Beta in center of plume and being recharged with upgradient contamination
- 94.5% reduction to date
- Full-Scale initiated upgradient in March-April 2019

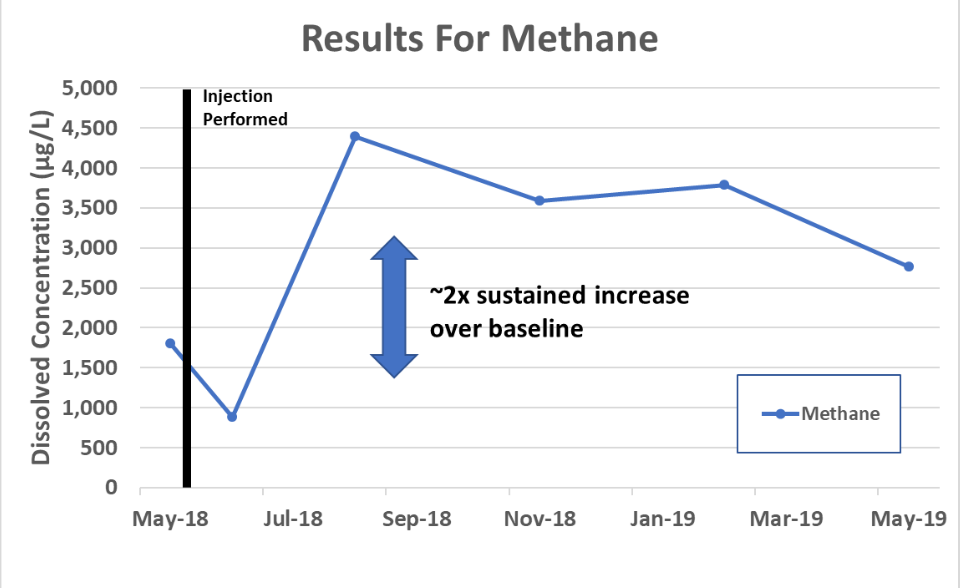
Analyte	May-18	Jun-18	Aug-18	Nov-18	Feb-19	May-19	Jun-19
Benzene	149	0	0	0	69.9	36.8	3.04
Toluene	191	0	5.7	0	139	68.2	2.05
Ethylbenzene	330	0	5.6	14	49.1	19.2	0
Xylenes	2,610	0	30	0	181	56.6	0

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





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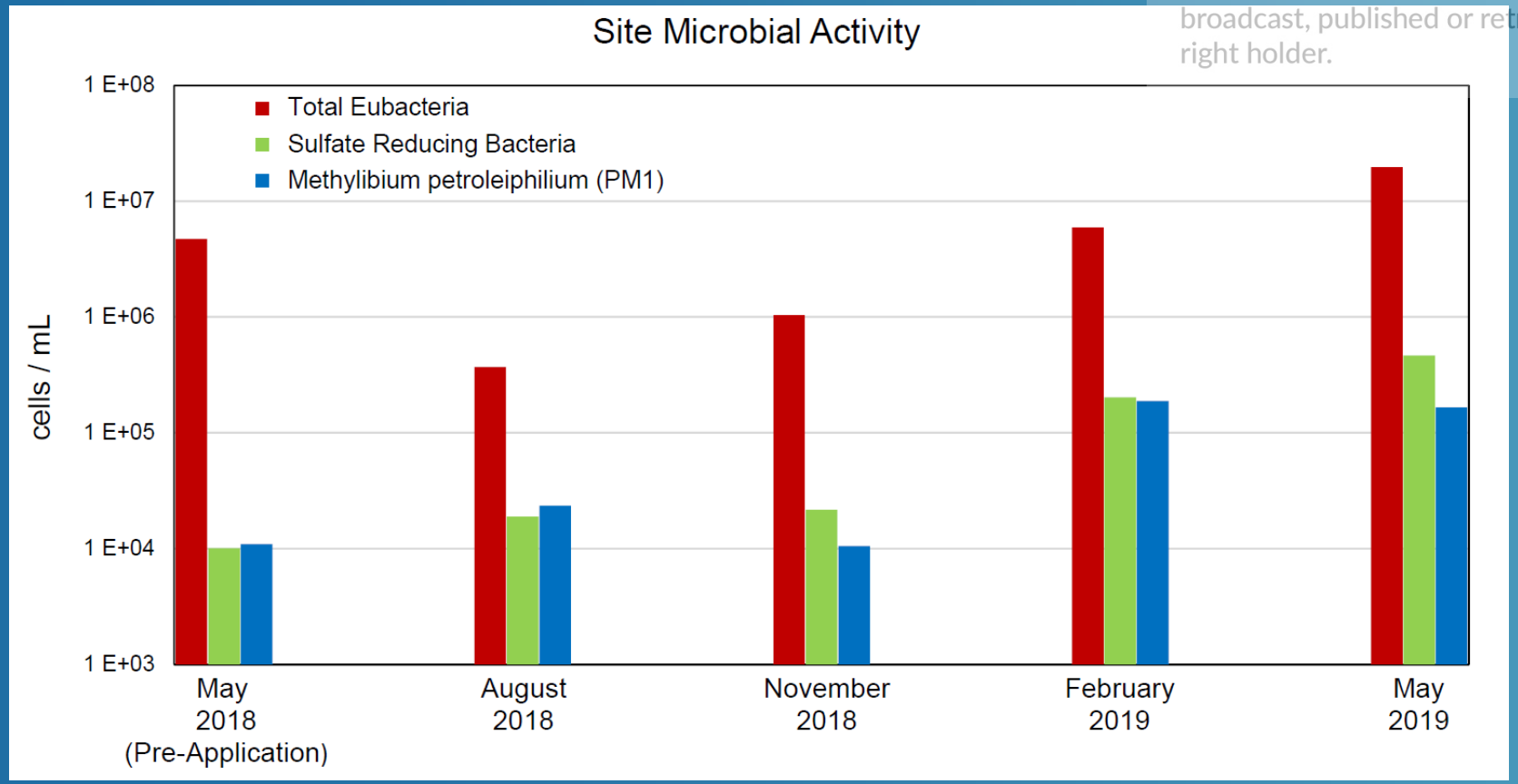
Northern IN - RESULTS



- 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

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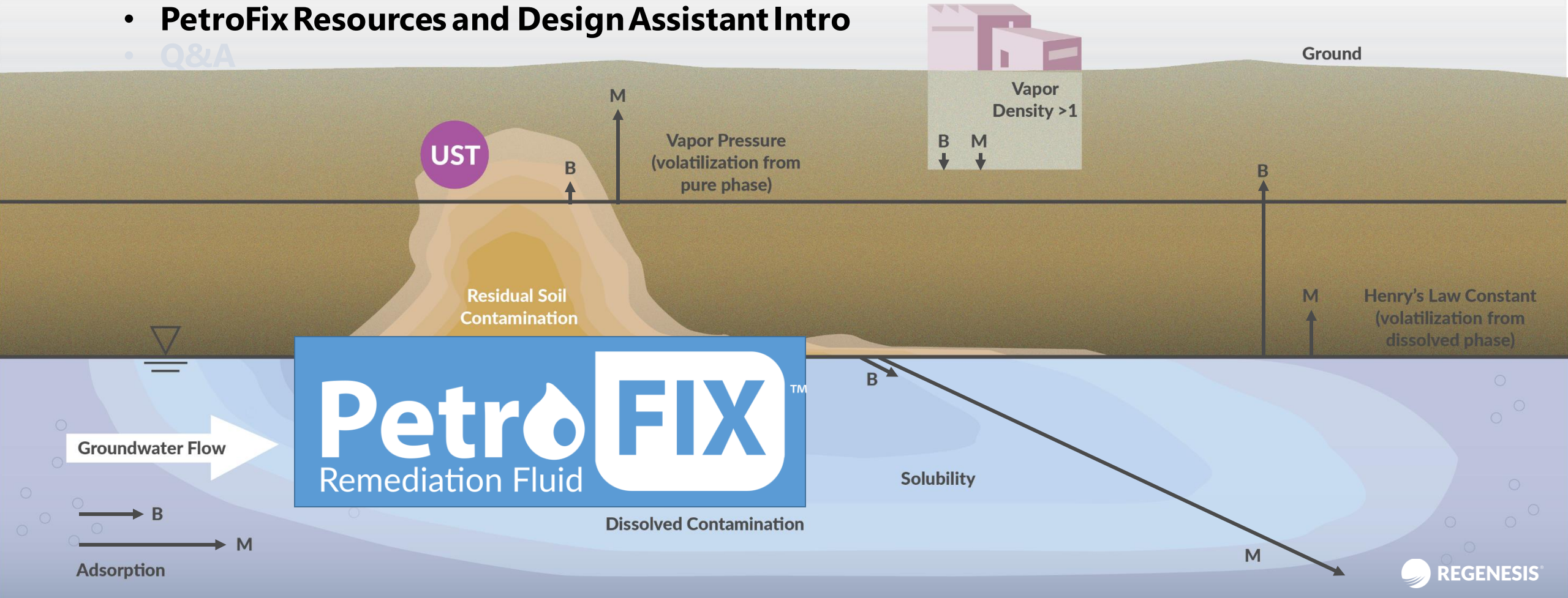
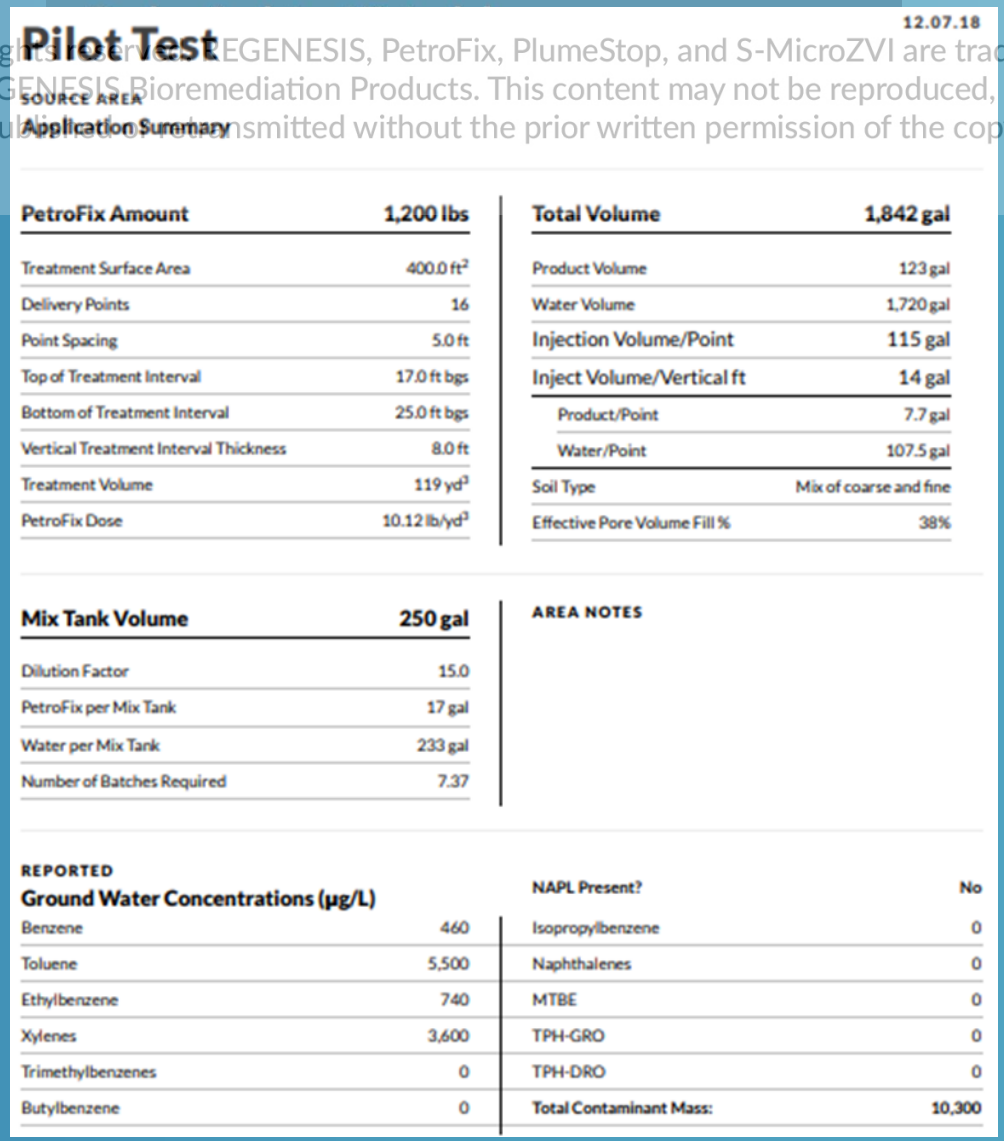


PETROFIX DESIGN ASSISTANT

- ✓ **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



Pilot Test 12.07.18

SOURCE AREA
Application Summary

PetroFix Amount	1,200 lbs
Treatment Surface Area	400.0 ft²
Delivery Points	16
Point Spacing	5.0 ft
Top of Treatment Interval	17.0 ft bgs
Bottom of Treatment Interval	25.0 ft bgs
Vertical Treatment Interval Thickness	8.0 ft
Treatment Volume	119 yd³
PetroFix Dose	10.12 lb/yd³

Total Volume	1,842 gal
Product Volume	123 gal
Water Volume	1,720 gal
Injection Volume/Point	115 gal
Inject Volume/Vertical ft	14 gal
Product/Point	7.7 gal
Water/Point	107.5 gal
Soil Type	Mix of coarse and fine
Effective Pore Volume Fill %	38%

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

AREA NOTES

REPORTED
Ground Water Concentrations (µg/L)

Benzene	460
Toluene	5,500
Ethylbenzene	740
Xylenes	3,600
Trimethylbenzenes	0
Butylbenzene	0

NAPL Present?	No
Isopropylbenzene	0
Naphthalenes	0
MTBE	0
TPH-GRO	0
TPH-DRO	0
Total Contaminant Mass:	**10,300**

REGENESIS

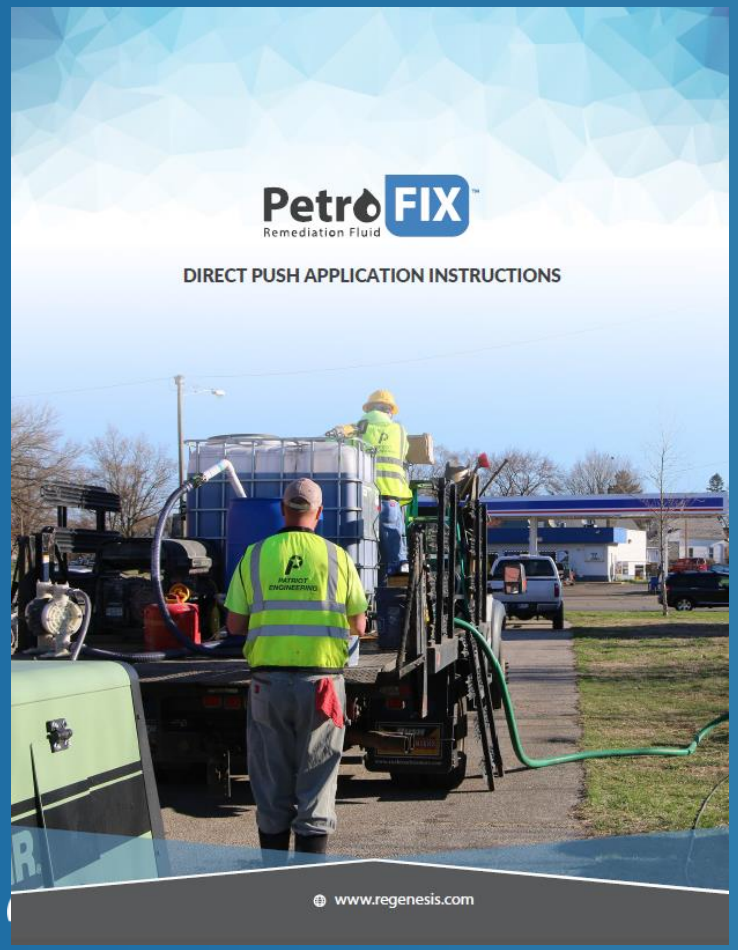
PETROFIX INJECTION INSTRUCTIONS

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

Current Written Instructions for PetroFix

Direct Push



Well Injection

Excavation

PetroFIX™
Remediation Fluid

REGENESIS®

Todd Herrington
Global PetroFix Product Manager
therrington@Regenesis.com

Questions?

Thank you!

Andrew Punsoni
Northwest District Technical Manager
apunsoni@Regenesis.com

REGENESIS

www.petrofix.com

Summary of Benefits

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.
MINIMIZE VAPOR EMISSIONS - Rapidly capturing and treating hydrocarbons from the dissolved phase will mitigate vapor plume formation.