A TECHNOLOGY PLATFORM TO HARNESS SPEED AND CERTAINTY IN GROUNDWATER REMEDIATION:

RAPID RISK REDUCTION AND ACCELERATED BIOREMEDIATION FACILITATED BY A COLLODIAL BIOMATRIX

Ashley Cedzo, Northwest District Technical Manager

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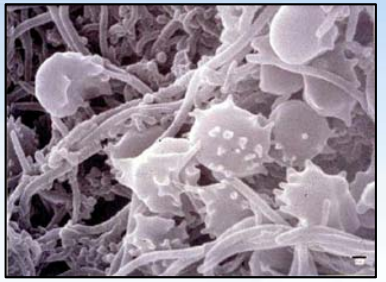
Technology-Based Solutions for the Environment

Biodegradation Principles



- **Bacteria live on surfaces –** biofilms
  - Think slime not Pac-Man

- **They have to wait for their growth sub** **t hunt**

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Question to our R&D group: “How do we increase microbial efficiency rates.”

R&D Efforts

2007: Began to focus on use of particulate sorbents to bind dissolved contaminants *in situ.*

- Surfactant modified zeolites
- Organo-clays
- Activated carbons

Findings

Activated carbon and other sorbent particulates do not disperse in the aquifer waters.

- Granular Activated Carbon particles: > 1000 µm
- Powdered Activated Carbon particles:
  - 40 to 100 micrometers diameter
  - Agglomerate to >1000 µm in water
- Soil Pore Throat Diameter Silts/Sands
  Est. Range: 3- 30 µm

Challenge to REGENESIS

PLUME STOP™
Liquid Activated Carbon

Development of:

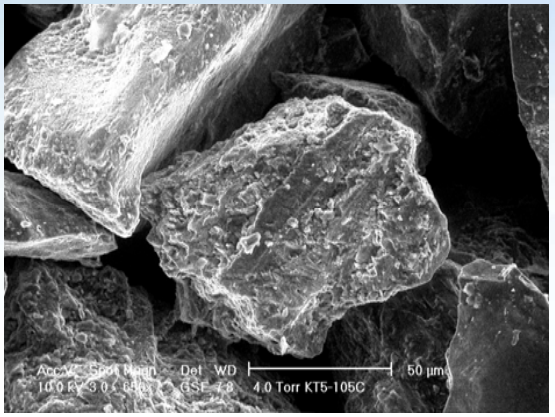
- Flow-able and dispersible sorbent
- Stimulates rapid sorption of contaminant
- Permanently biodegrades contaminants

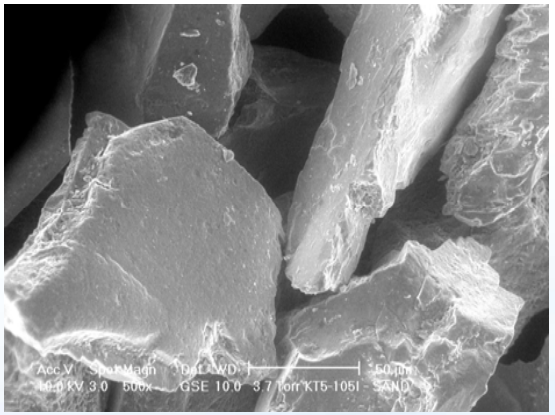
PlumeStop® is a Technology Platform

PlumeStop BioMatrix (PlumeStop) was specifically designed to eliminate rebound, mitigate matrix back diffusion and meet stringent groundwater standards.

PlumeStop provides the first ever colloidal biomatrix for contaminated sites that rapidly reduces contaminant concentrations while enhancing bioremediation of a wide range of contaminants.

It reduces risk by being the first wide-area distribution, high-volume, sorptive media to be applied directly into groundwater.





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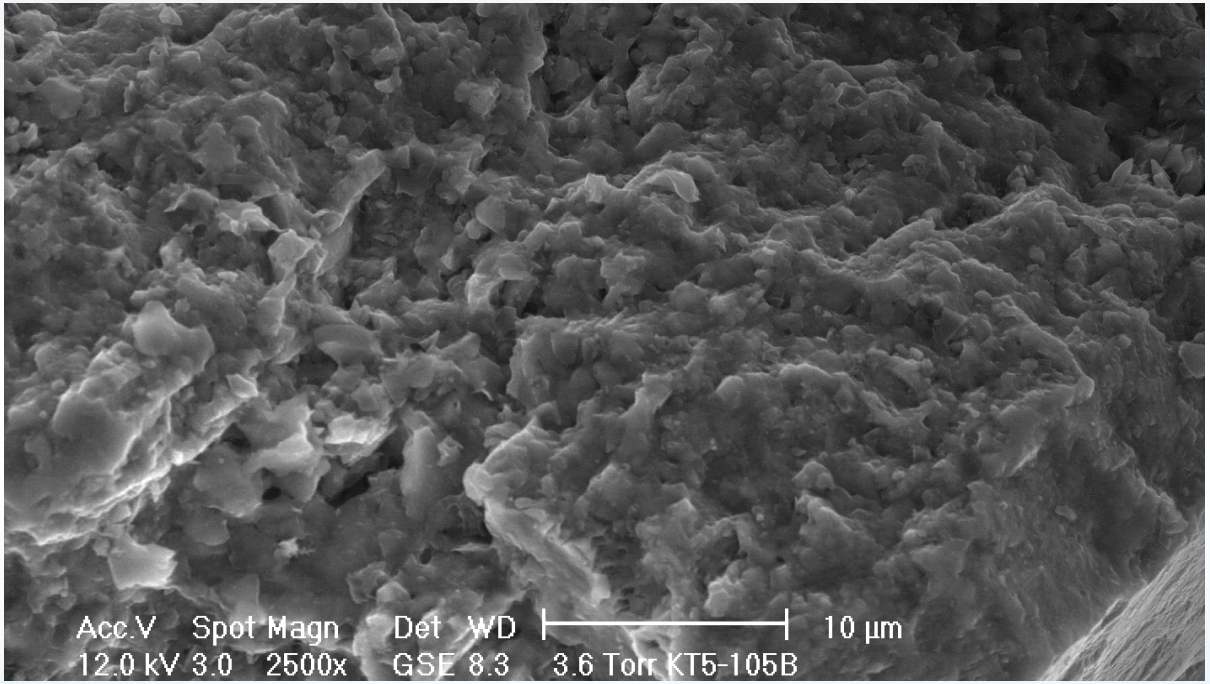
PlumeStop Coating on Soil Particle



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What the Reagent is

PLUME STOP™
Liquid Activated Carbon

- Colloidal activated carbon (1 – 2 µm)
  - Size of a bacterium – suspends as ‘liquid’
  - Huge surface area – extremely fast sorption
- Proprietary anti-clumping / distribution supporting surface treatment (patent applied for)
  - Core innovation
  - Enables wide-area, low-pressure distribution through the soil matrix without clogging
- Low-solubility / controlled availability matrix nutrients
  - Support in-matrix contaminant biodegradation
  - Does not impact groundwater / eutrophication

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Liquid Activated Carbon

What it Treats

- CVOCs including ethenes and ethanes
- Petroleum Hydrocarbons (TPH, BTEX, etc.)
- MTBE, pesticides, and more

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Contaminants Sorbed, Now What?

3 Primary Methods of Contaminant Destruction

- Aerobic Treatment
  - Electron Acceptor Addition, Sparging…
- Anaerobic Treatment
  - Slow release electron donors
  - Lactate, recirculation systems
- Monitored Natural Attenuation/Intrinsic Remediation

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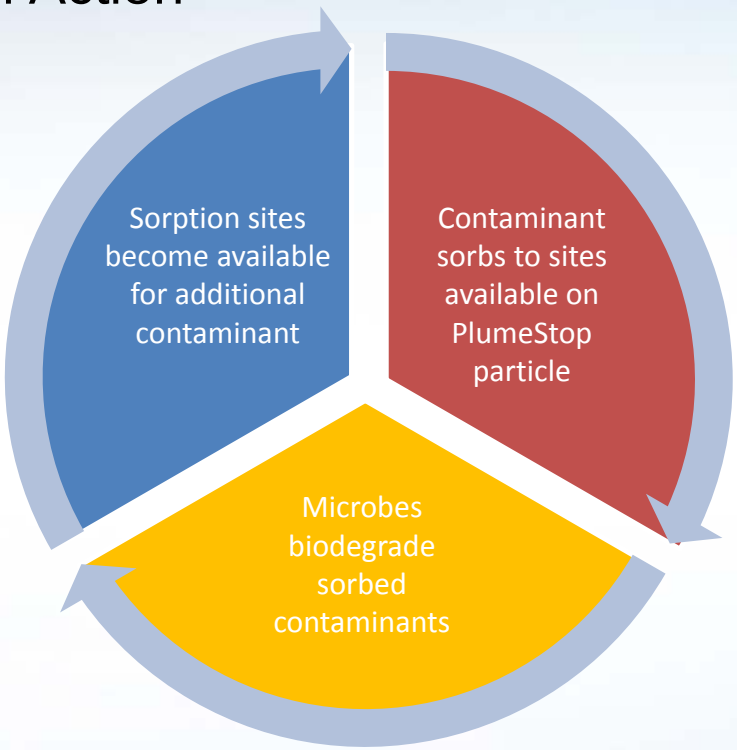
PlumeStop Mode of Action



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When/Where to Use

1. When time is critical
2. As a long-term barrier
3. To achieve stringent cleanup standards
4. To address matrix back diffusion

Pitfalls – Things to Avoid

- High mass/high concentration zones
  - NAPL – too much to sorb, too much to bio
- Low resolution sites
  - Design Verification – “Infeasability Testing”

How are we Different than other Carbon Approaches?

Injecting granular or powder activated carbon requires fracturing of aquifer formation (grain displacement) due to large particle size and agglomeration.

Results in:

- Inefficient placement
- Only partial treatment of subsurface
- Can compromise monitoring wells

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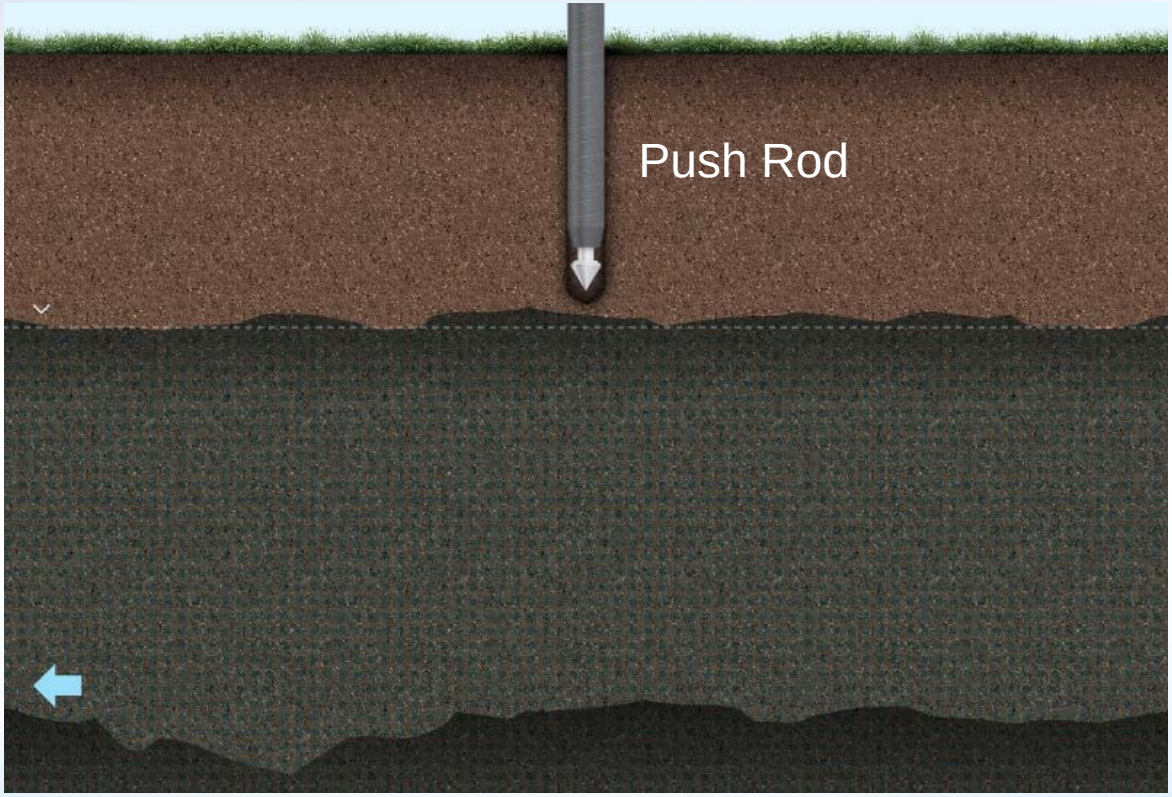
Fracturing Carbon: Only Partial Treatment of Subsurface



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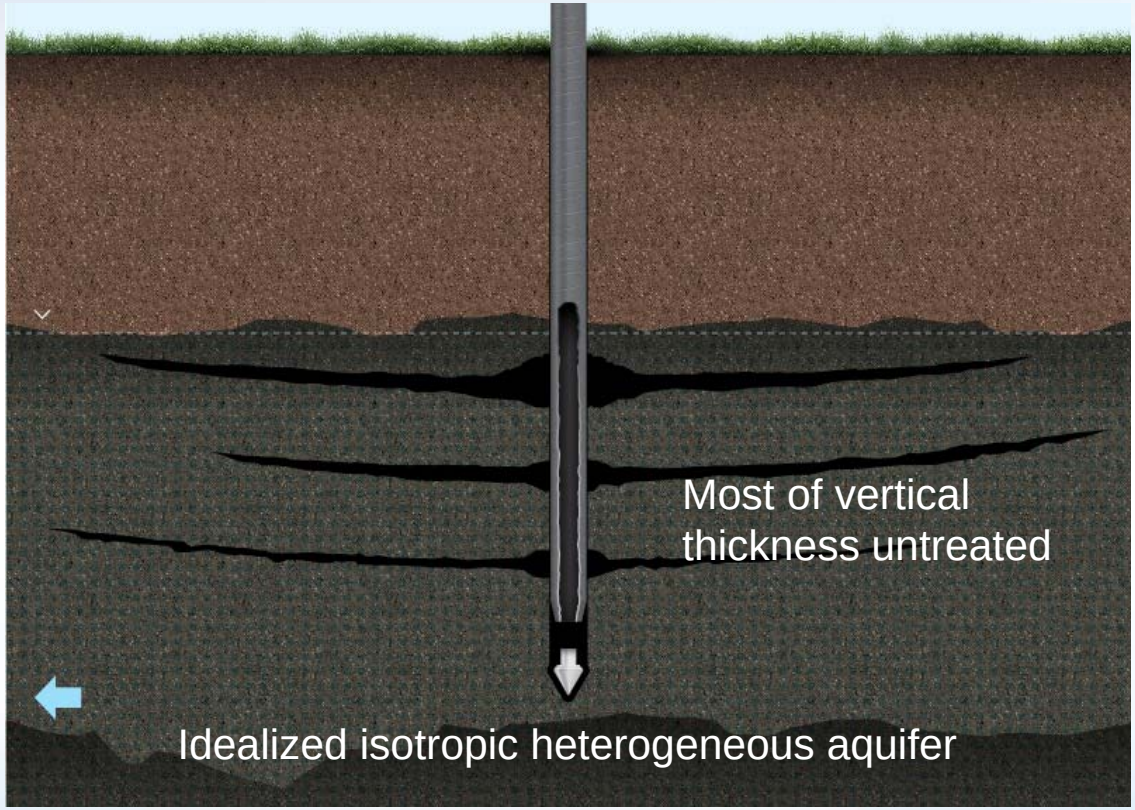
Fracturing Carbon: Only Partial Treatment of Subsurface



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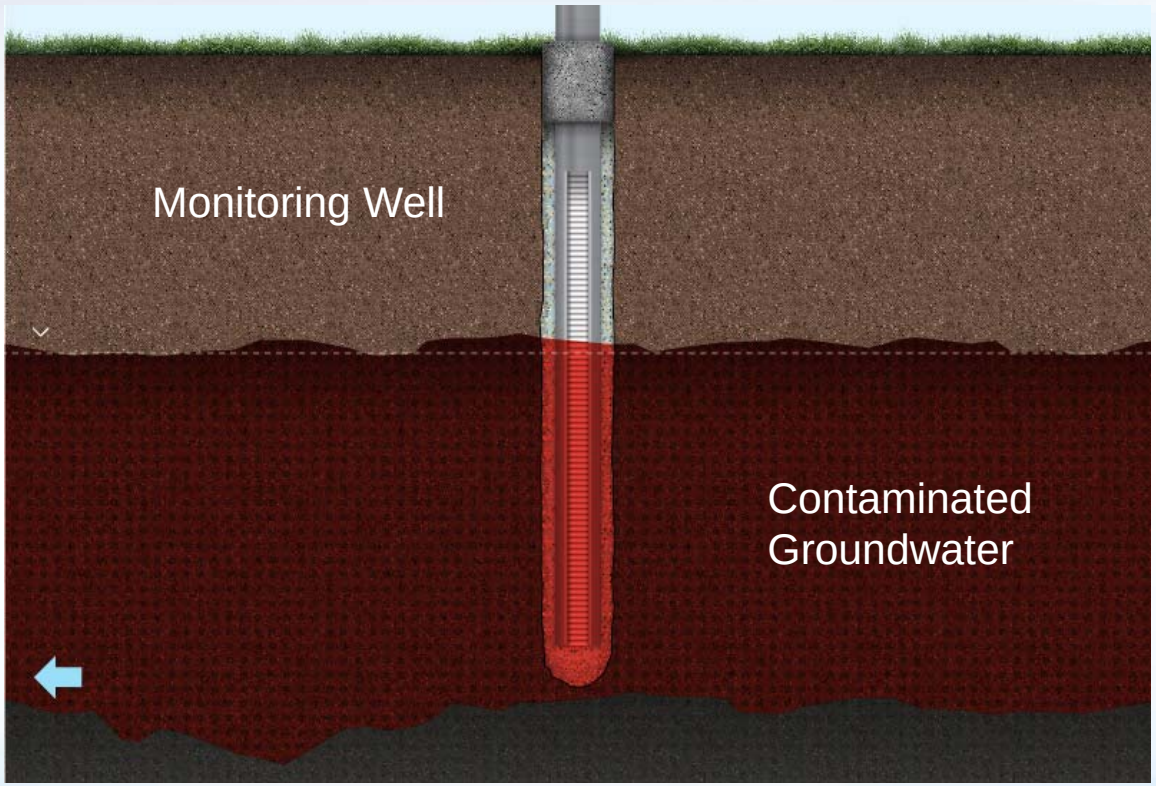
Fracturing Carbon: Compromises Monitoring Wells



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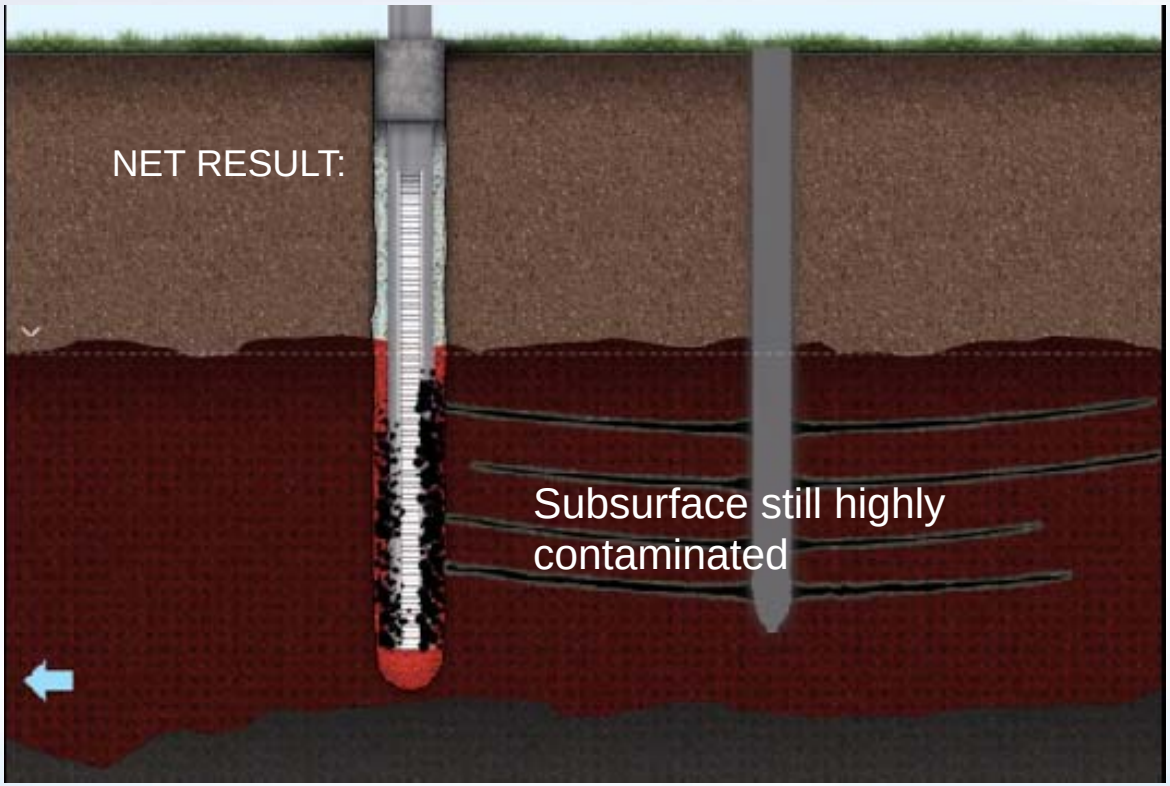
Fracturing Carbon: Can Effect Monitoring Wells



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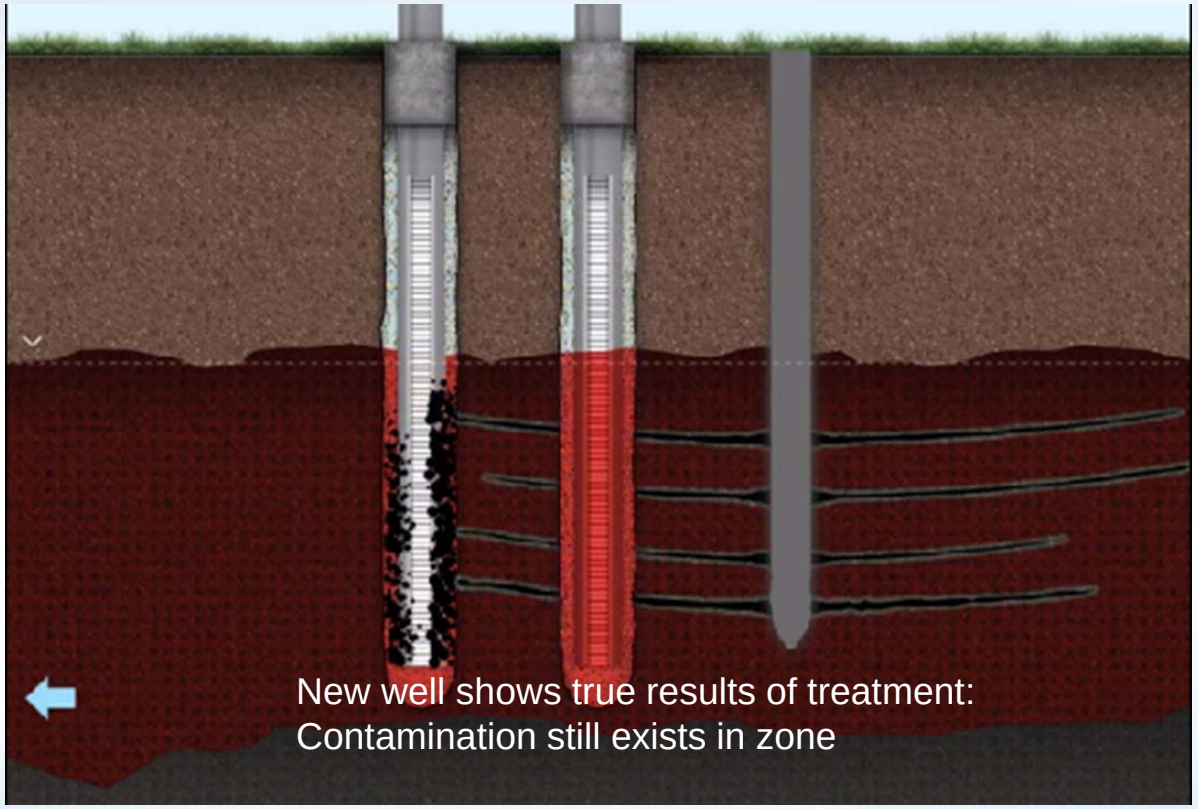
Post-Fracture Monitoring Requires New Well



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Effective Distribution

- To get more details on this topic read Technical Bulletin 1.1 Distribution through a Permeable Medium
- Long Column Study
  - 16 foot length (5m) (ID 2”; 5 cm)
  - Fine to medium silica sand (210 – 420 µm)
  - 20% porosity (est.) (pore volume 0.5 gal; 2 L)

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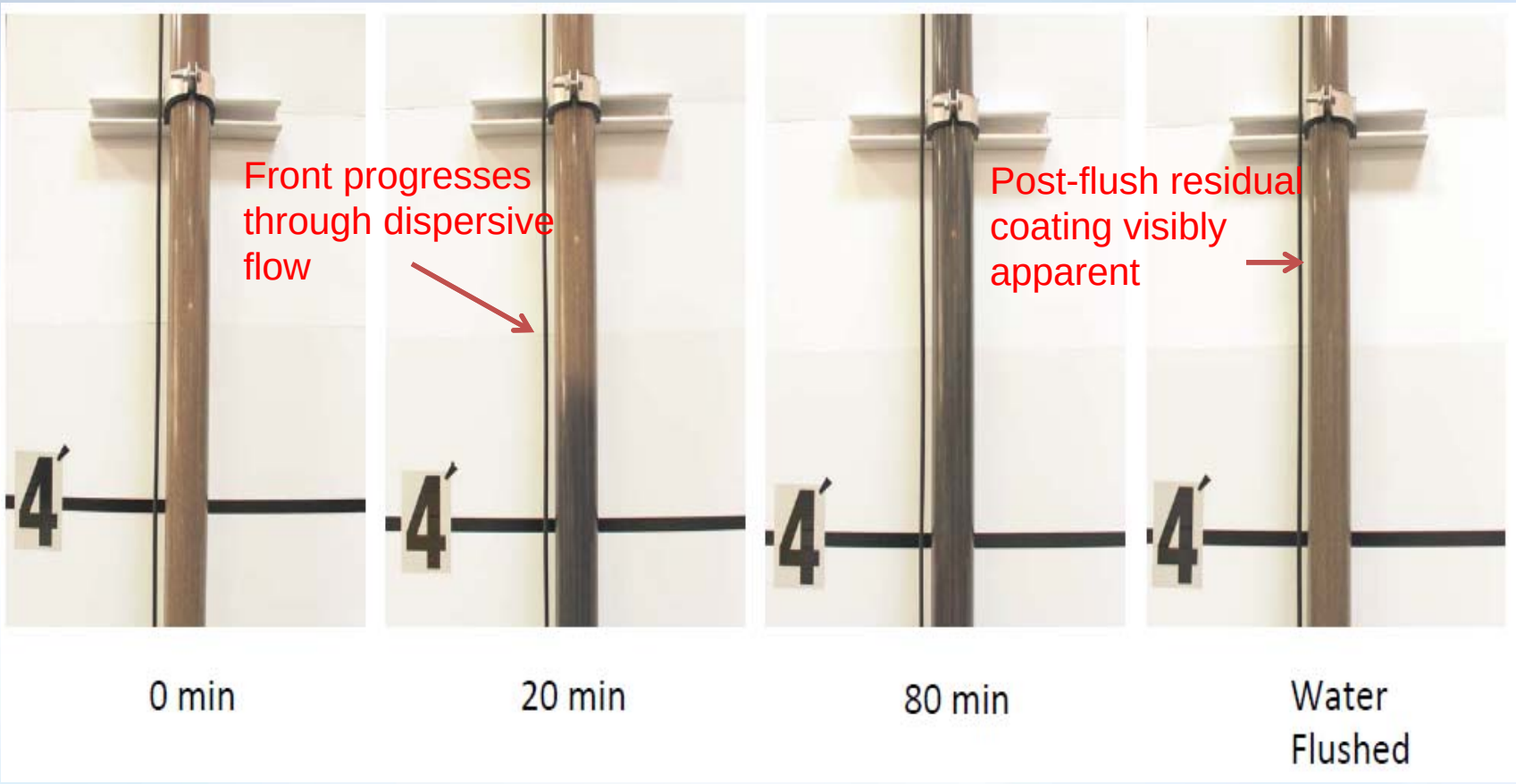

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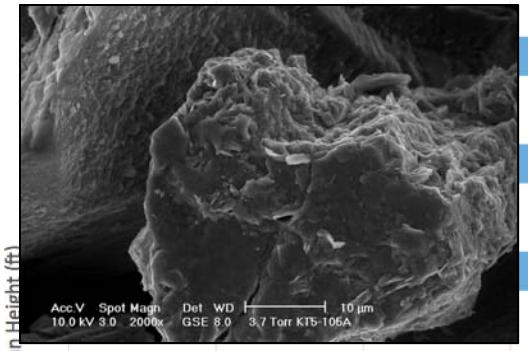
Elemental Carbon Analysis (from column-dissection post-application)



Total mass retained within column ca. 0.1% of pore volume

1-2 µm coating on sand particles

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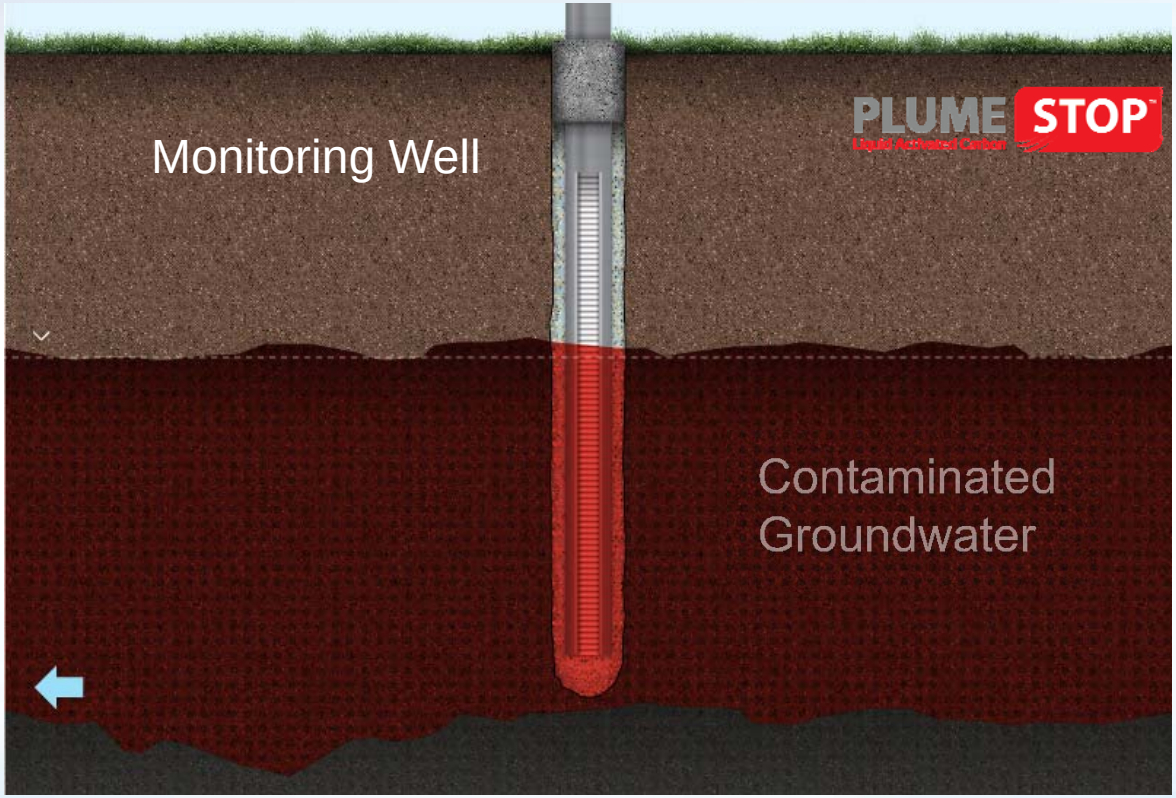
PlumeStop Flows into Subsurface



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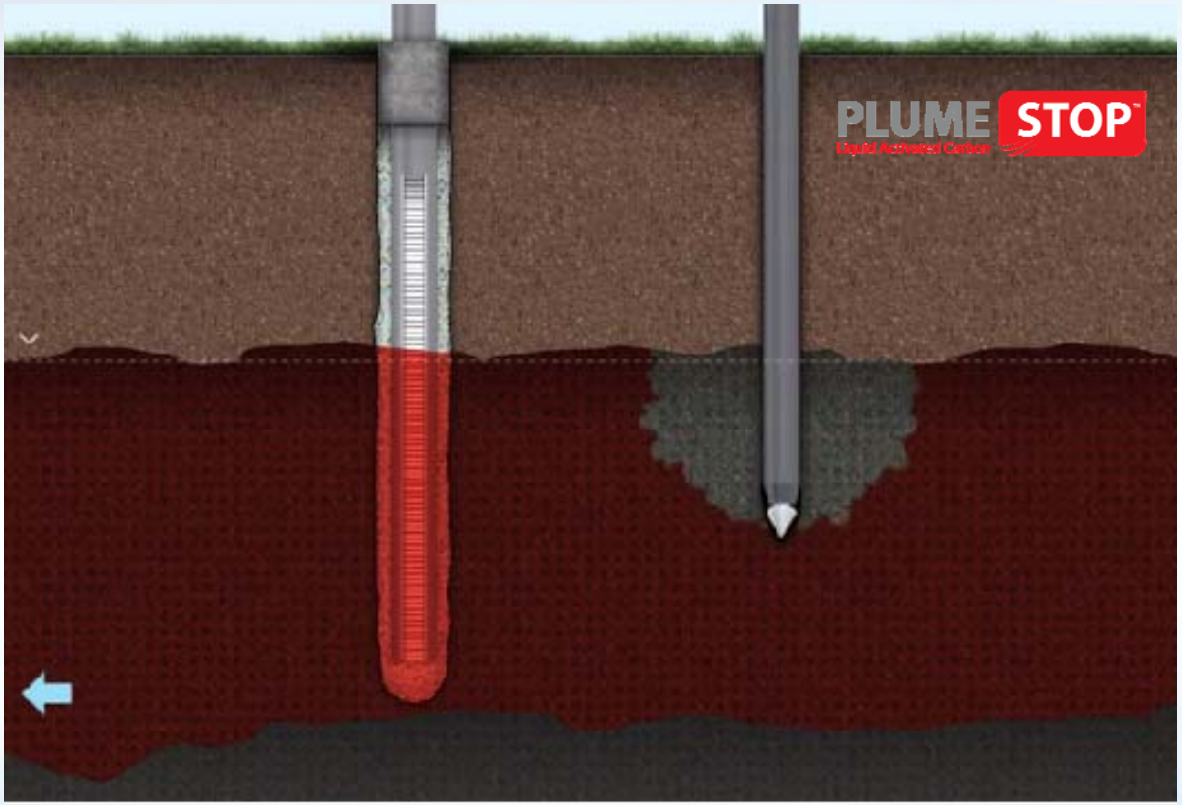
PlumeStop Flows into Subsurface



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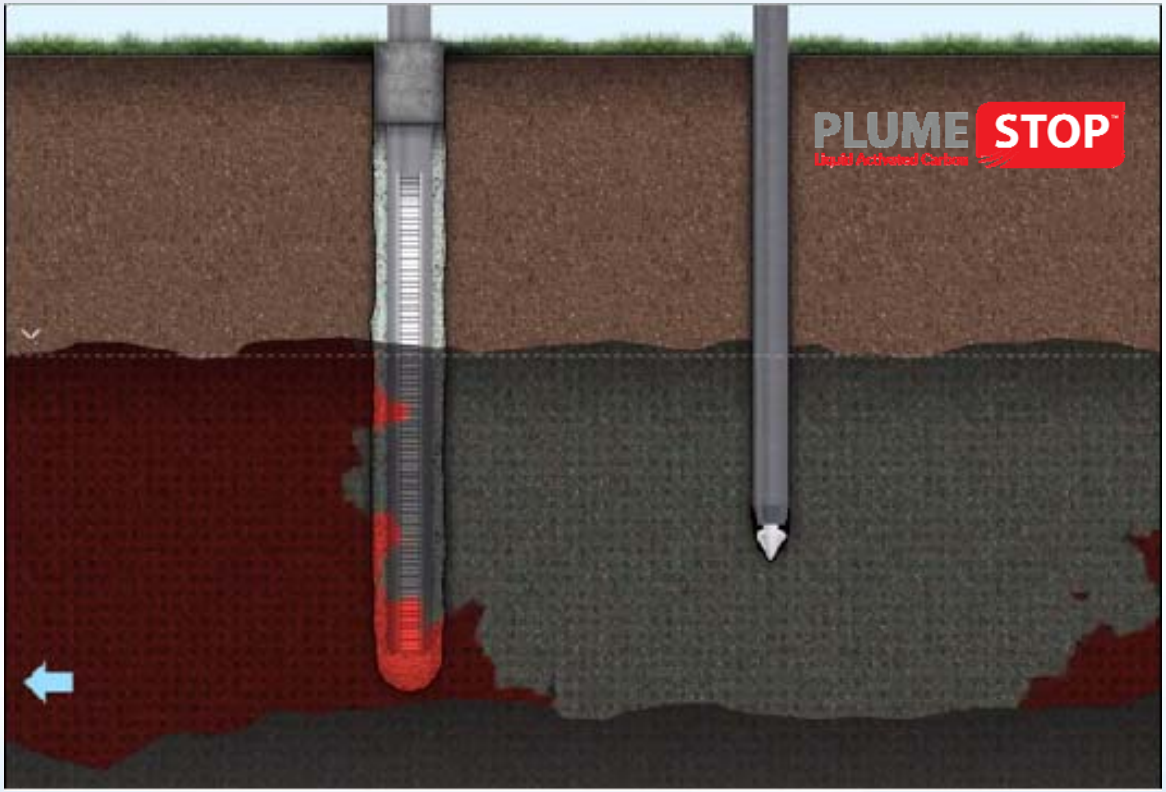
Low Pressure Injection- Flows into Subsurface



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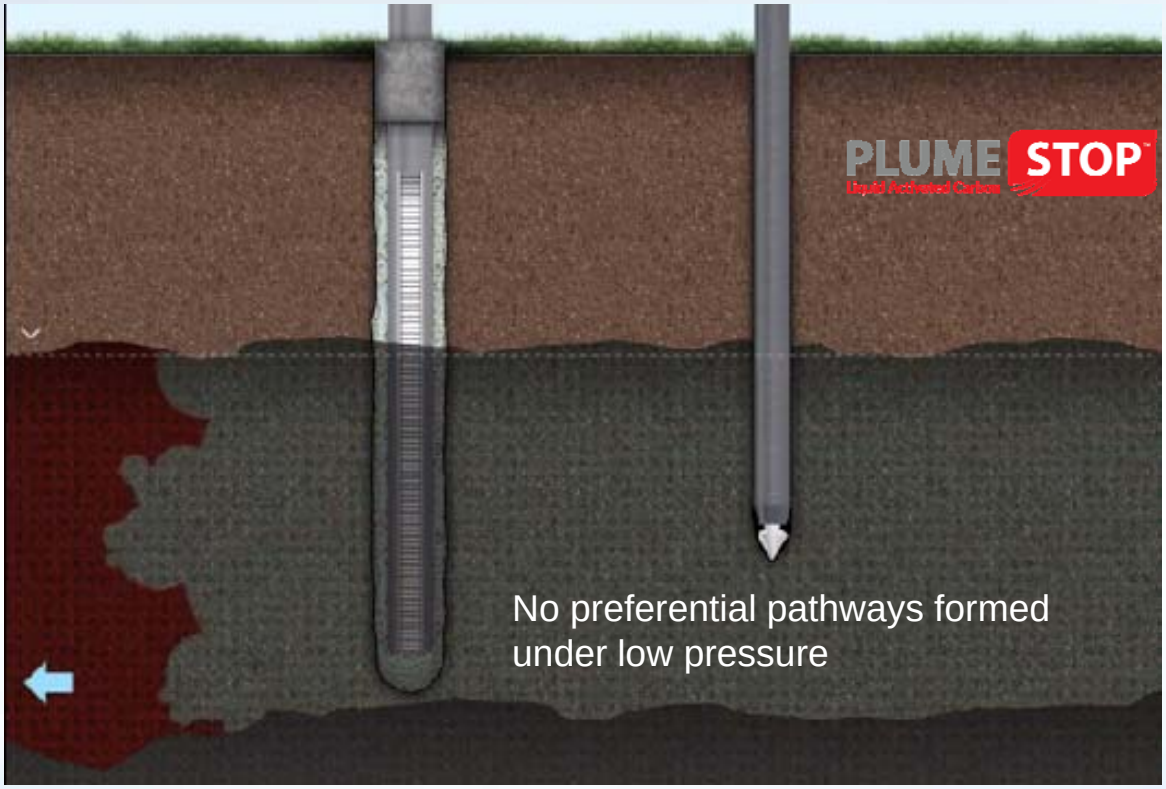

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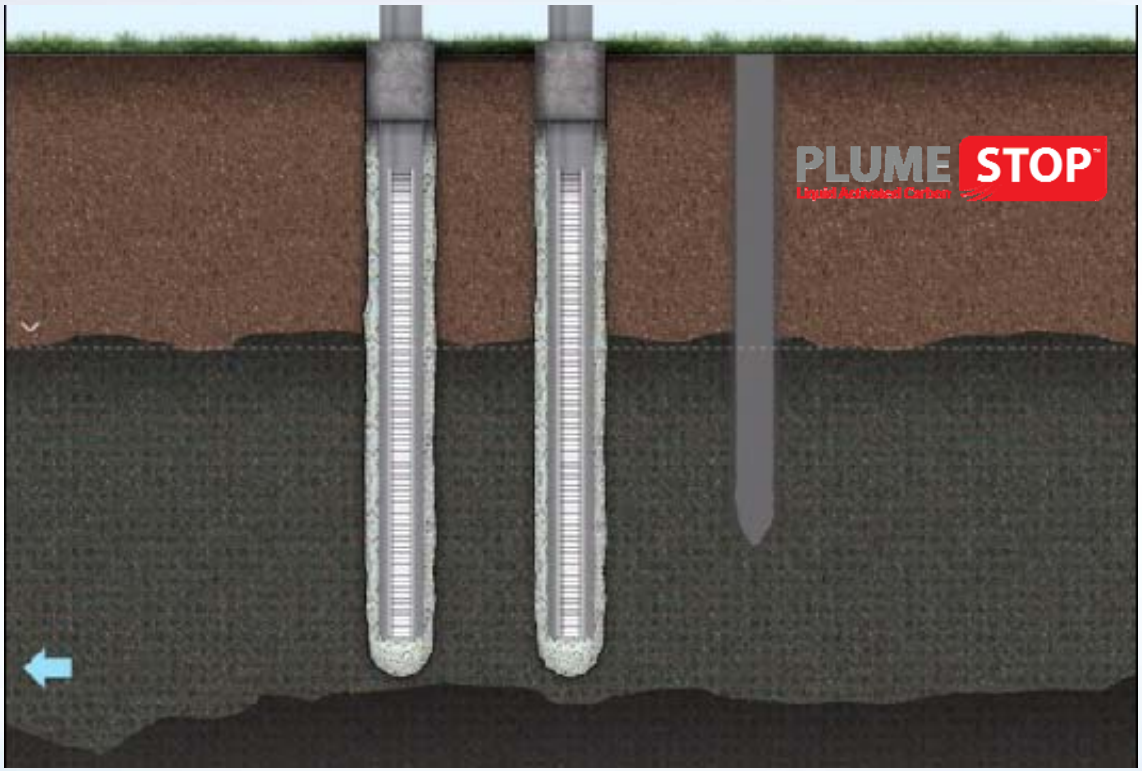
Low Pressure Injection Does Not Compromise Monitoring Wells



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Evidence of Dispersive Flow (low pressure application)

Pre-app

Post-app

- Distribution of PlumeStop through target zone visually apparent
- Even dispersion evident through permeable strata

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Field Performance

How fast does it work?
How long does it last?
Is biodegradation occurring?

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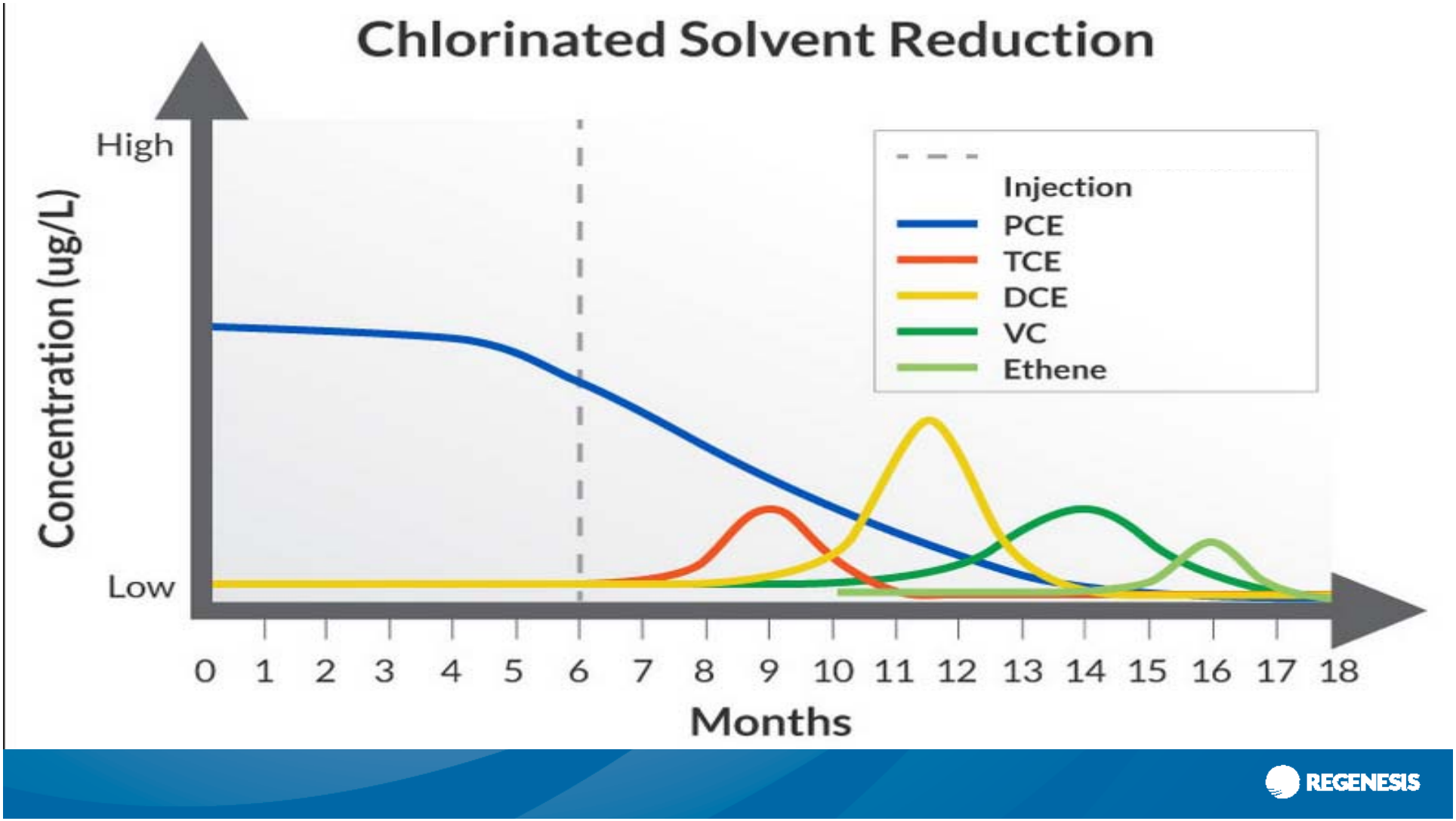
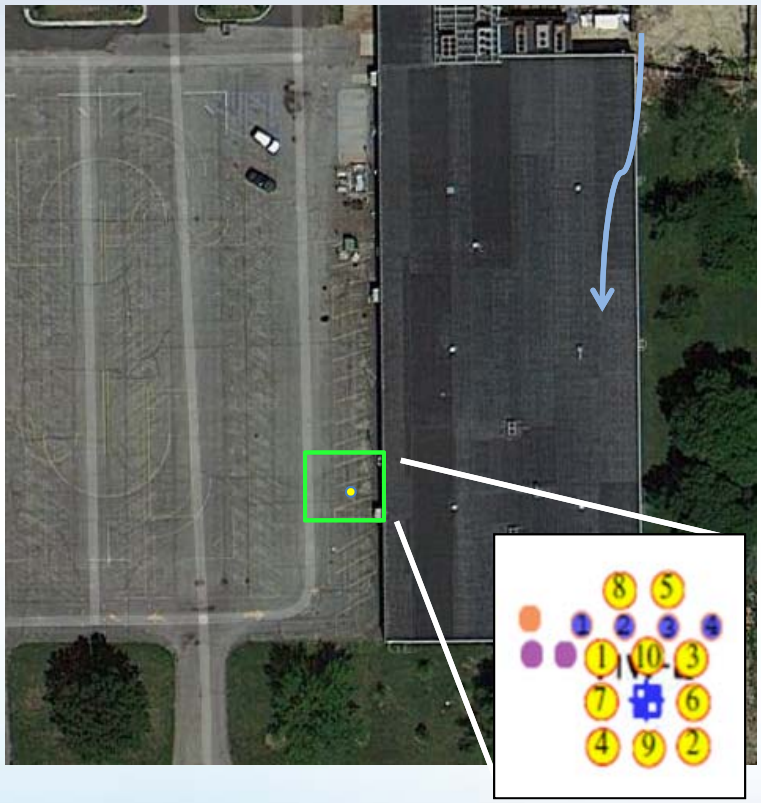

Chlorinated Solvent Reduction
High
Low
Concentration (ug/L)
Injection
PCE
TCE
DCE
VC
Ethene
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Months

Midwest Chlorinated VOC Site



- Former electronics facility
- Contaminants: TCA, TCE, etc.
  - TCE 1,390 µg/L
  - TCA 3,550 µg/L
- Treatment Area
  - Plume area only, no NAPL
  - PlumeStop: 10-pt low pressure injection grid around MW-6
  - HRC electron donor applied up-gradient

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PlumeStop - Parameters at Midwest Project

- Sand to silty-sand
- Depth to groundwater 3 – 4 m (10 – 13 feet)
- Seepage velocity 3.7 m/yr (12 ft/yr) to the southwest

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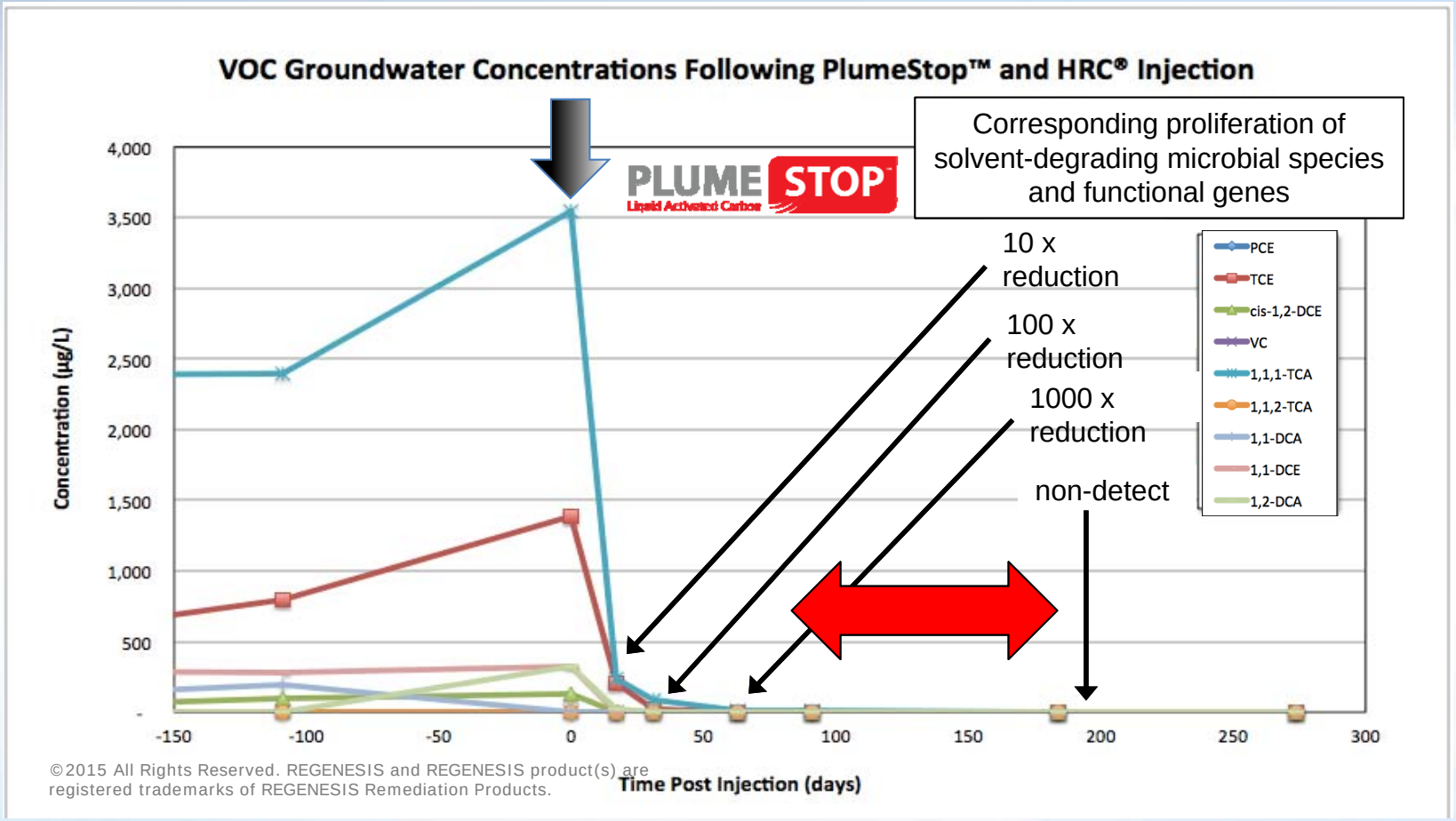

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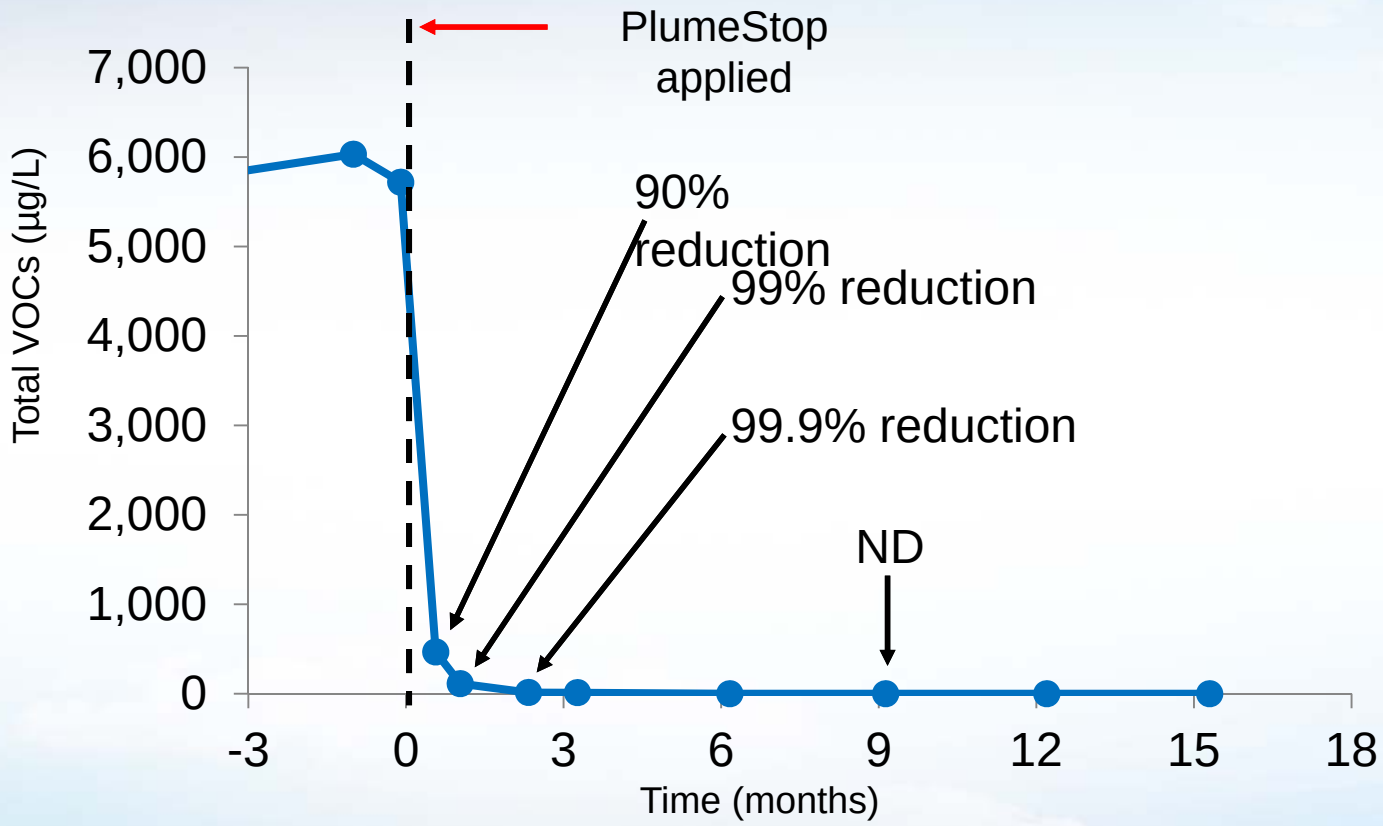
Groundwater Data: CVOC site



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Performance

- Chlorinated solvents
- Post-sorption degradation
- Lines of evidence

Closed

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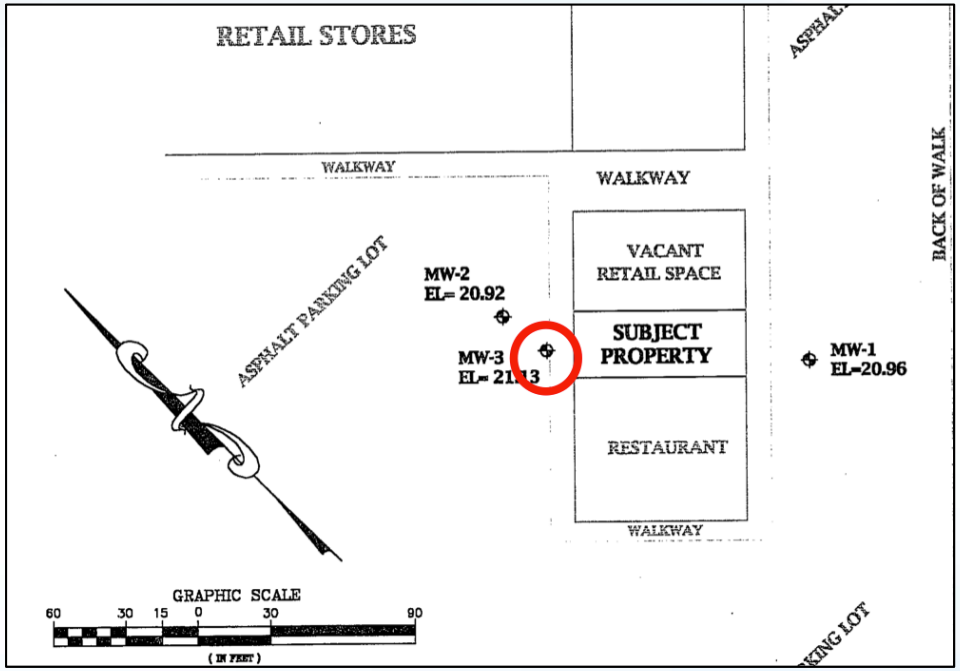
California Site

- ‘Dune Sand’ formation
- 10 m/year groundwater flow
- High redox conditions (aerobic)
- No attenuation evident
- PCE 550 µg/L
- No daughter products
- PlumeStop
- Electron donor and bacteria



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Historic Data

MW-3 (ppb)

Year	PCE	TCE	VC	1,2 Cis	VC
2001	156	0	0	0	0
2002	94	0	0	0	0
2002.5	242	0	0	0	0
2003	174	0	0	0	
2004	147	0	0	0	
2005	122	0	0	0	
2006	203	0	0	0	
2007	584	0	0	0	
2008	310	0	0	0	
2009	587	0	0	0	
2010	330	0	0	0	
2011	501	0	0	0	0
2012	499	0	0	0	0

Steadily increasing PCE

No daughter products

(aerobic conditions)

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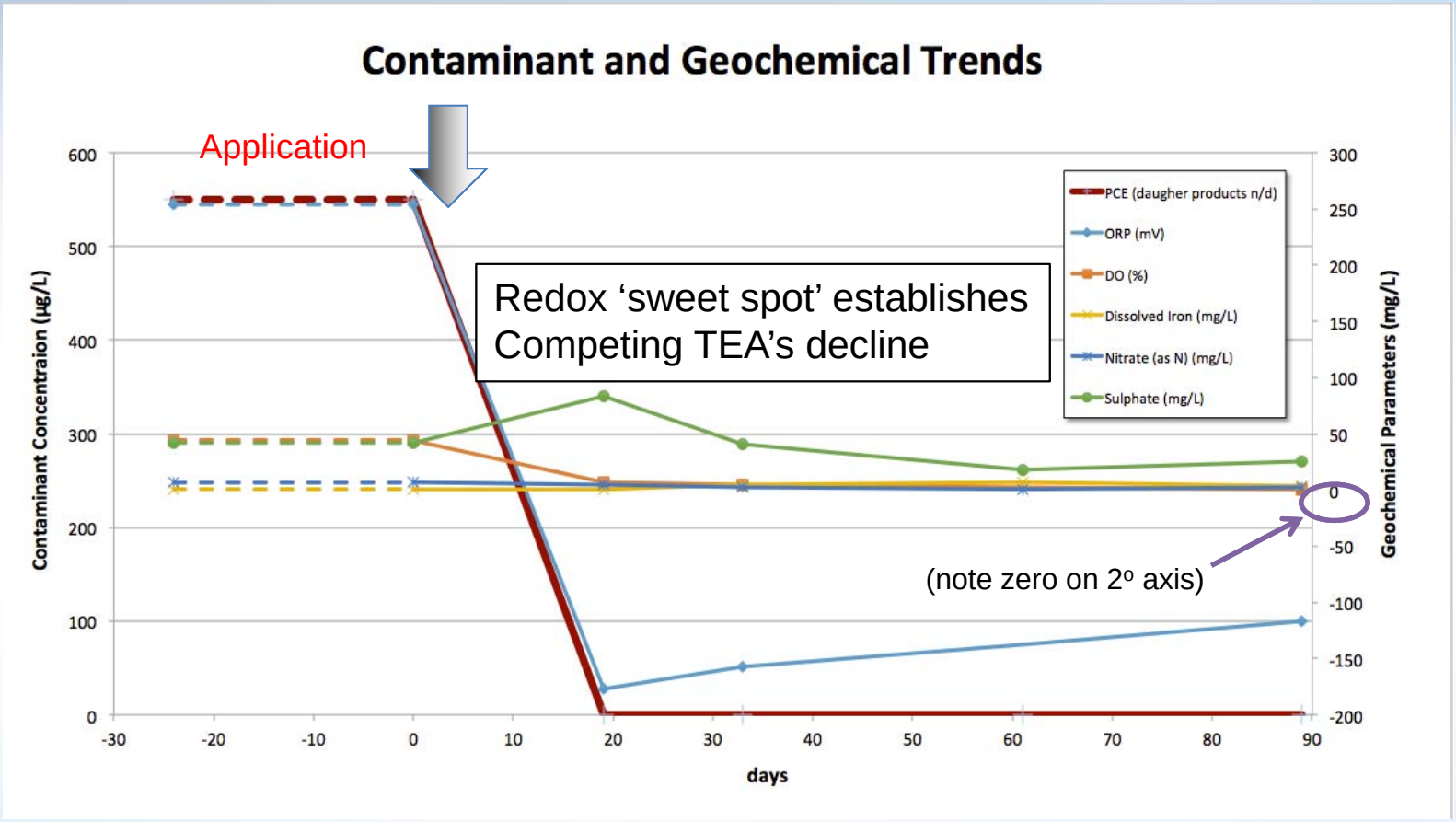

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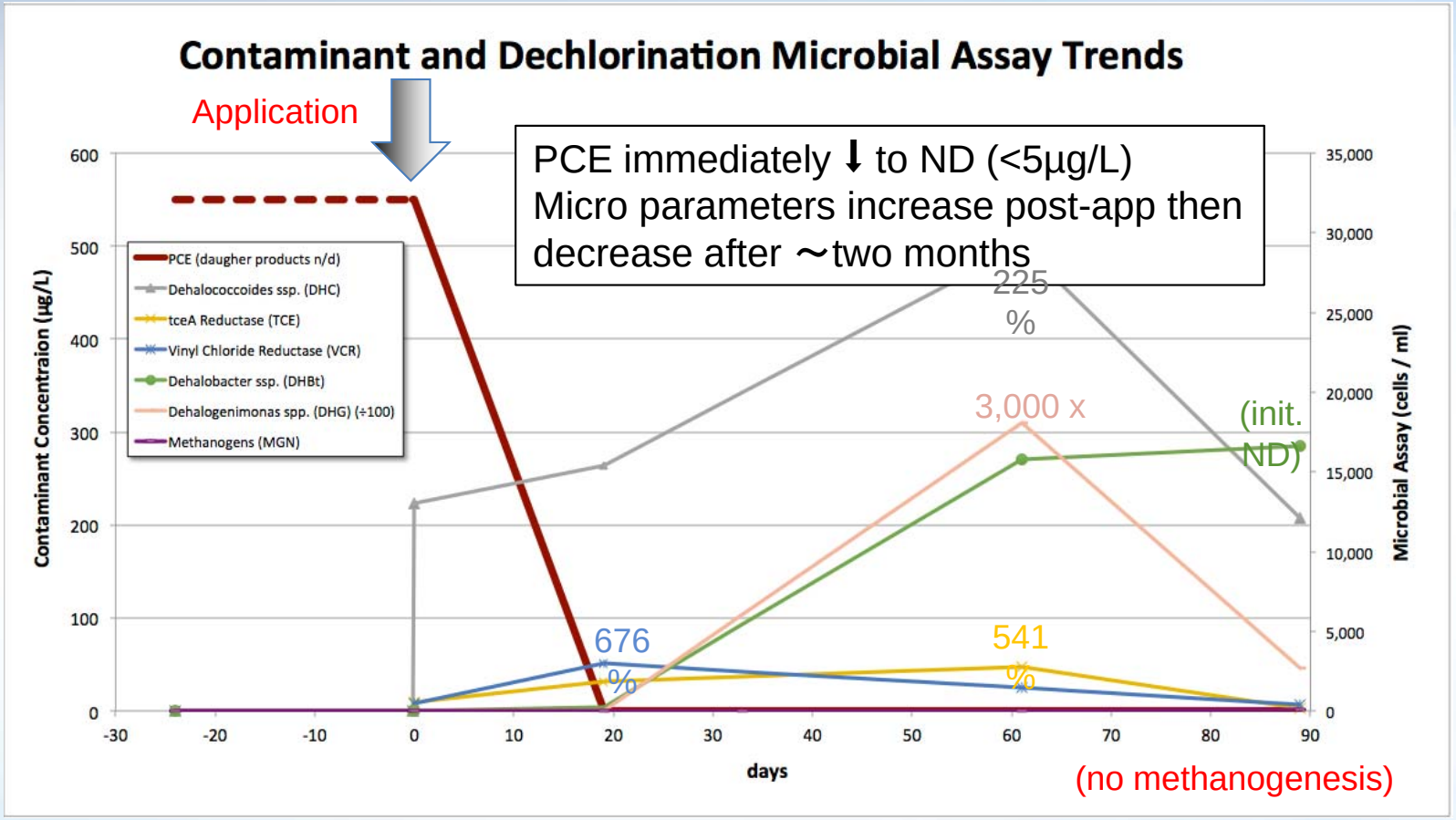

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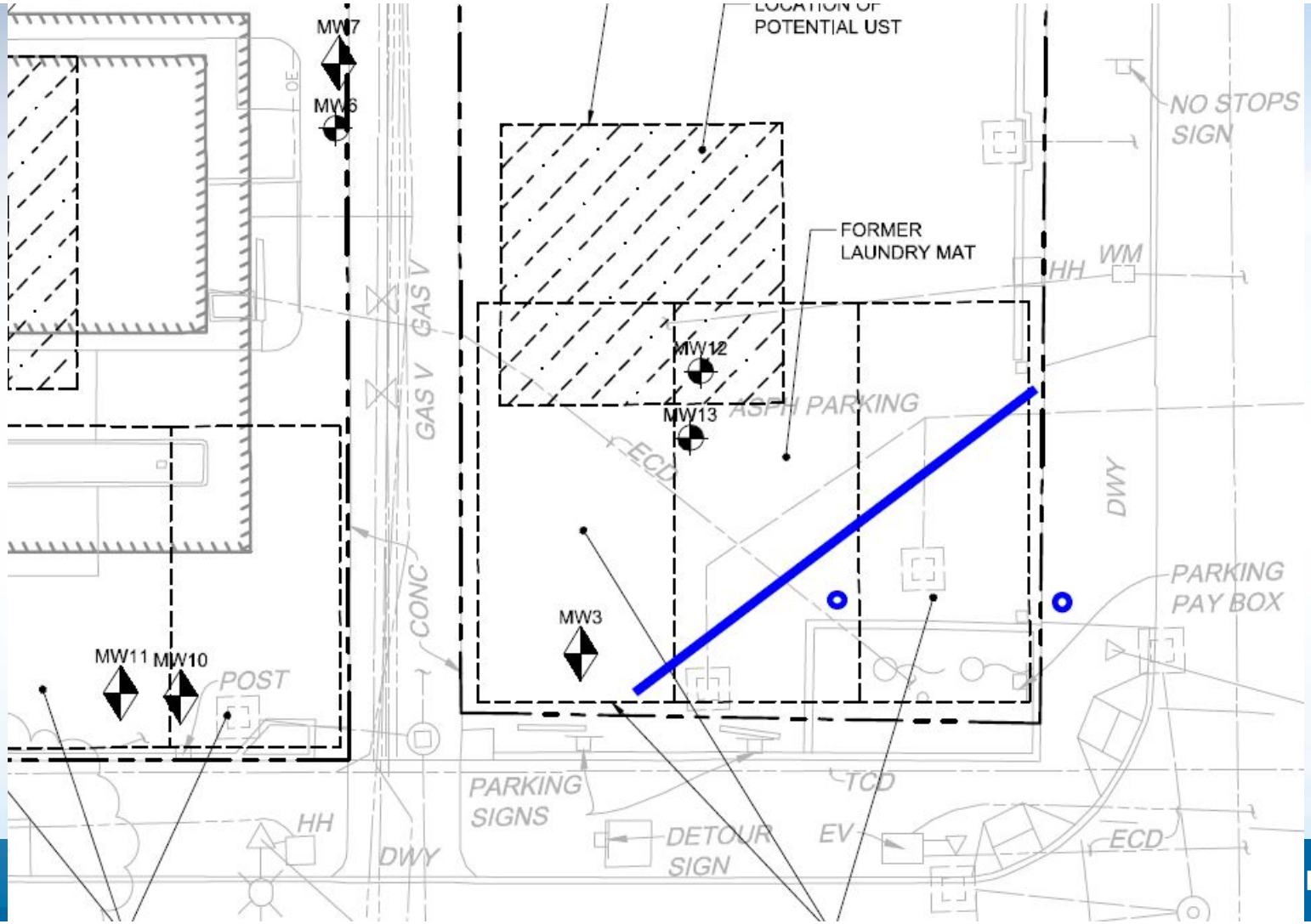
Northwest Case Studies:

1) Mixed Plumes- Former dry cleaner and service station
2) Active gas station


MW7
MW6
POTENTIAL UST
NO STOPS SIGN
FORMER LAUNDRY MAT
HH
WM
MW12
MW13
ASPH PARKING
ECD
DWY
GAS V
CONC
MW3
PARKING PAY BOX
MW11
MW10
POST
PARKING SIGNS
TCD
HH
DWY
DETOUR SIGN
EV
ECD

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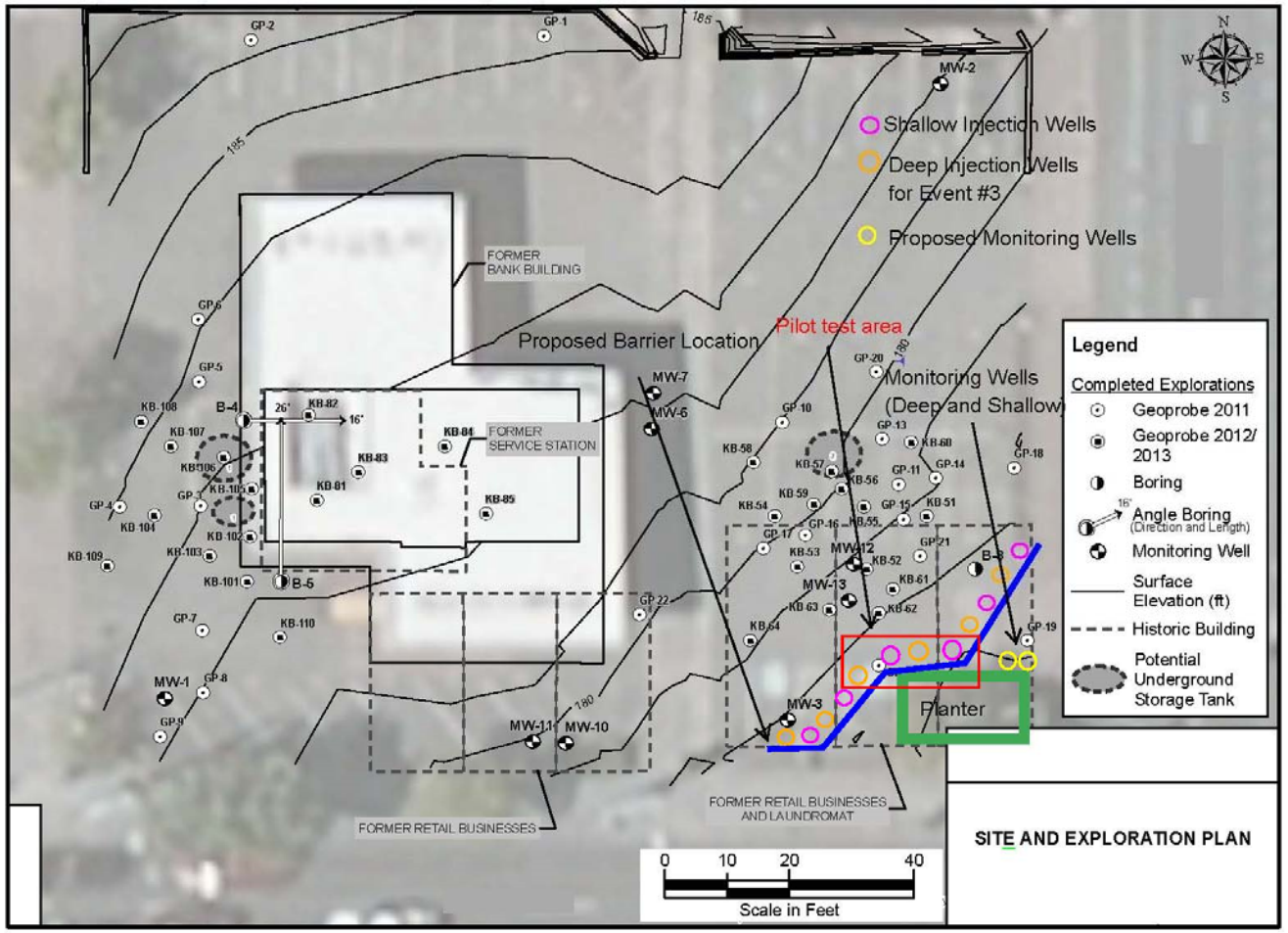
Shallow Injection Wells
Deep Injection Wells for Event #3
Proposed Monitoring Wells
Proposed Barrier Location
Pilot test area
Monitoring Wells (Deep and Shallow)
FORMER BANK BUILDING
FORMER SERVICE STATION
FORMER RETAIL BUSINESSES
FORMER RETAIL BUSINESSES AND LAUNDROMAT
Planter
Legend
Completed Explorations
Geoprobe 2011
Geoprobe 2012/ 2013
Boring
Angle Boring (Direction and Length)
Monitoring Well
Surface Elevation (ft)
Historic Building
Potential Underground Storage Tank
0 10 20 40
Scale in Feet
SITE AND EXPLORATION PLAN

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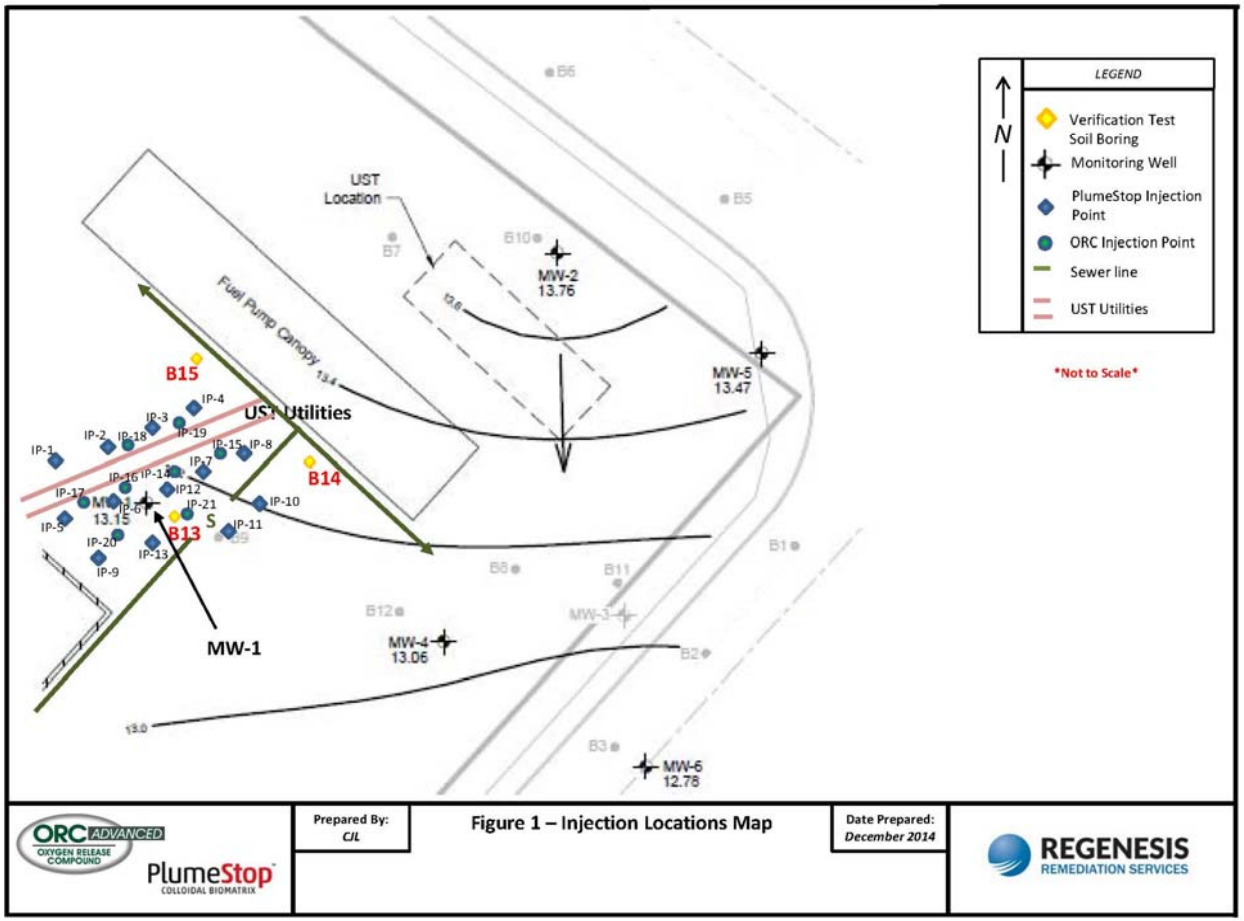
LEGEND
Verification Test Soil Boring
Monitoring Well
PlumeStop Injection Point
ORC Injection Point
Sewer line
UST Utilities
N
Not to Scale
UST Location
Fuel Pump Canopy
UST Utilities
B15
B14
B13
MW-1
MW-2
13.76
MW-3
MW-4
13.06
MW-5
13.47
MW-6
12.78
IP-1
IP-2
IP-3
IP-4
IP-5
IP-7
IP-8
IP-9
IP-10
IP-11
IP-12
IP-13
IP-14
IP-15
IP-16
IP-17
IP-18
IP-19
IP-20
IP-21
13.15
13.8
13.4
13.0
B1
B2
B3
B5
B6
B7
B8
B10
B11
B12
ORC ADVANCED
OXYGEN RELEASE COMPOUND
PlumeStop
COLLOIDAL BIOMATRIX
Prepared By:
CJL
Figure 1 – Injection Locations Map
Date Prepared:
December 2014
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REMEDIATION SERVICES

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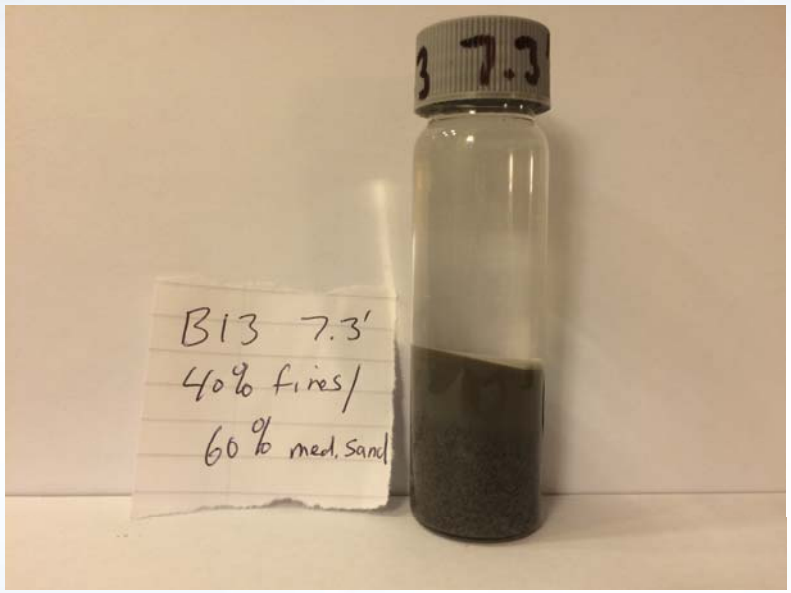
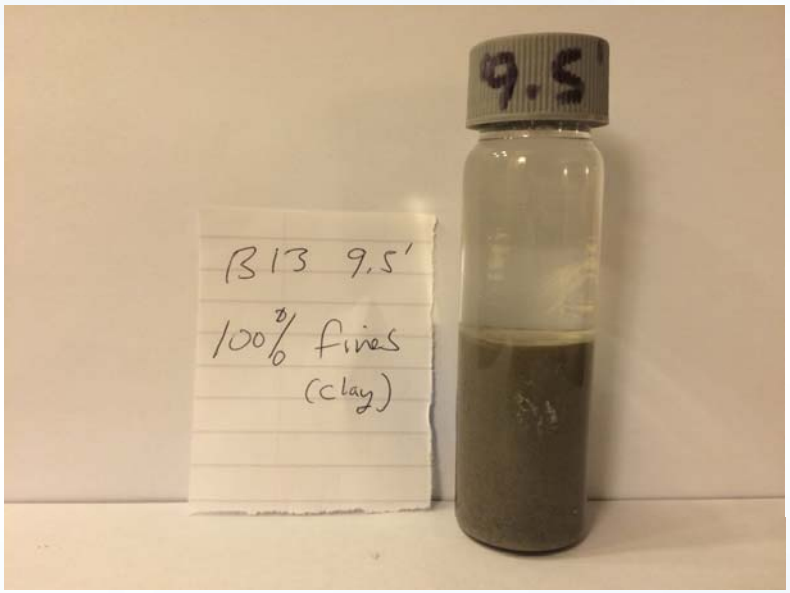
Soil Settling Tube Tests (aka Field Hydrometers)





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Case Study: Real Estate Development – Time Pressure

- Neighborhood of McCormick Place – Central Chicago
  - New Sports Stadium
  - New Hotel Complex

- Solvent residues
- Tight time window
- High cost implications of delay
- Key remediation requirement: FAST

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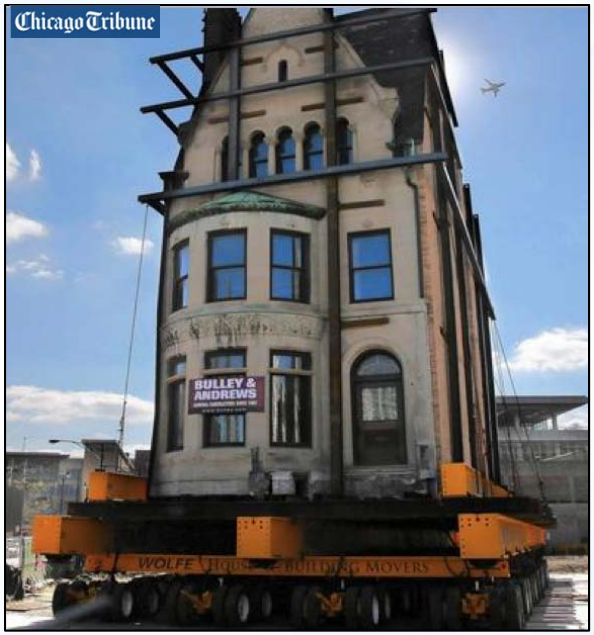
Case Study: Inner City Development – Time Pressure

- Why the tight time window?
  - Weren't the solvent residues known?
- Access restrictions – historic buildings
  - Precluded early start
- Problem was moved aside



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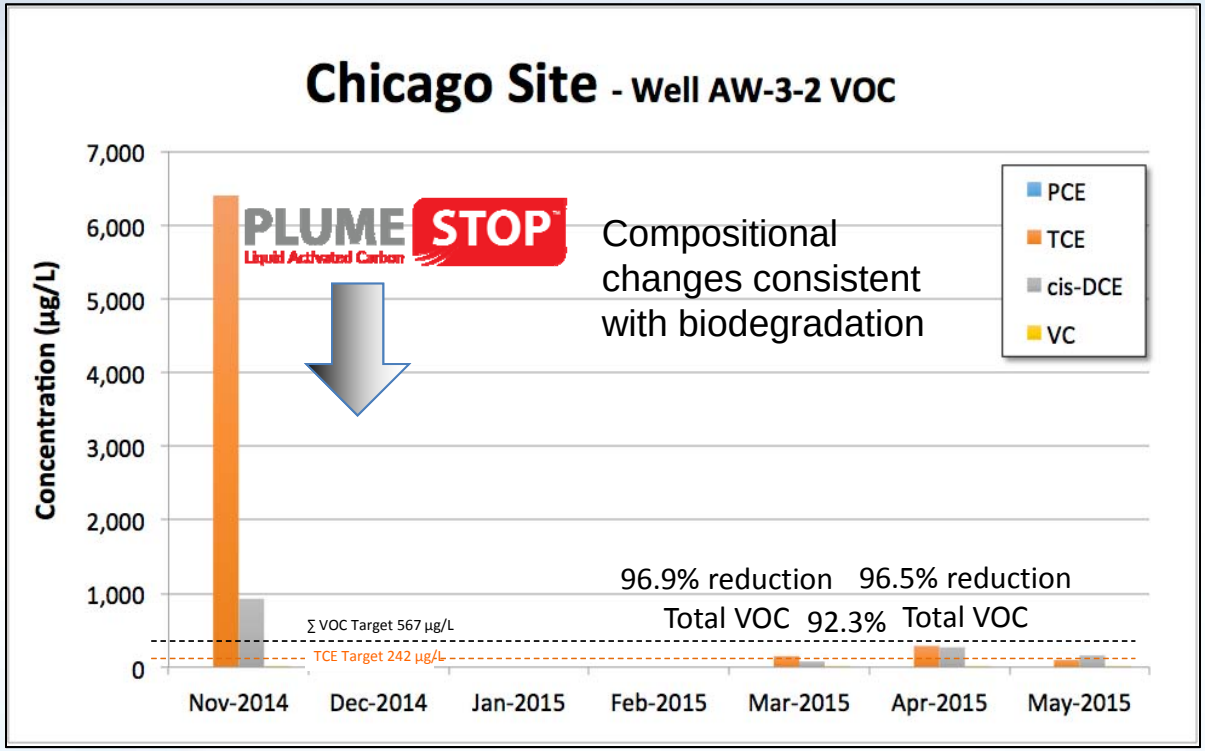
Site Details

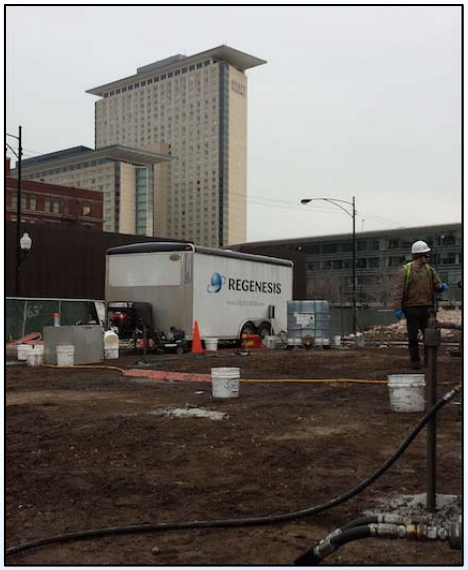
- PCE and TCE – up to 7,440 µg/L
- Sand formation over clay
  - Treatment area 300 m x 500 m – (1,000’ x 1,600’)
  - Treatment Zone 3 – 7 mbgl - (10’ – 22’)

Enhanced bio: HRC®, BDI®

  - Sufficient to address the contamination

- PlumeStop
  - Rapid risk reduction and bio process acceleration
  - Take the bio process out of the groundwater phase
- 17 days’ fieldwork on site (Chicago winter)
  - 138 direct-push injections – no resident equipment





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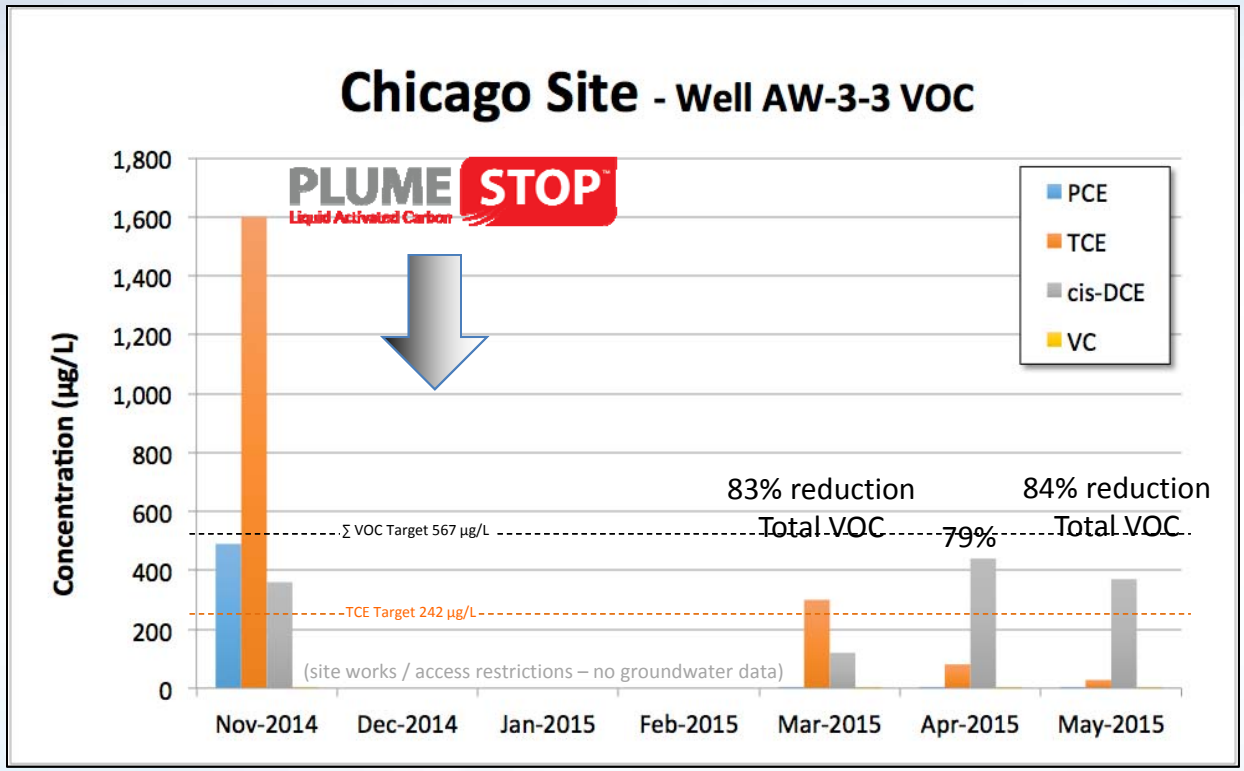

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Liquid Activated Carbon

How fast does it work?:

Generally > 90% reduction within 30 to 60 days.

How long does it last?

Indefinitely if electron donor/acceptors present.

Is biodegradation occurring?

Multiple lines of evidence indicate complete biodegradation.

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PlumeStop – When To Use?

1. When time is critical
2. For control of migrating contamination
3. To secure stringent clean-up targets
4. As a long–term means of addressing matrix back-diffusion
5. When remediation performance is flat-lining

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Ashley Cedzo, Northwest District Technical Manager

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Technology-Based Solutions for the Environment