REGENESIS®

Eliminating Risk of PFAS in Groundwater

Alana Miller – Northeast District Manager

AGENDA

- PlumeStop – Groundbreaking Technology Development
- Manipulating Retardation Factor and Environmental Risk
- Treatment Strategies
- Case Studies
- Other Services We Provide

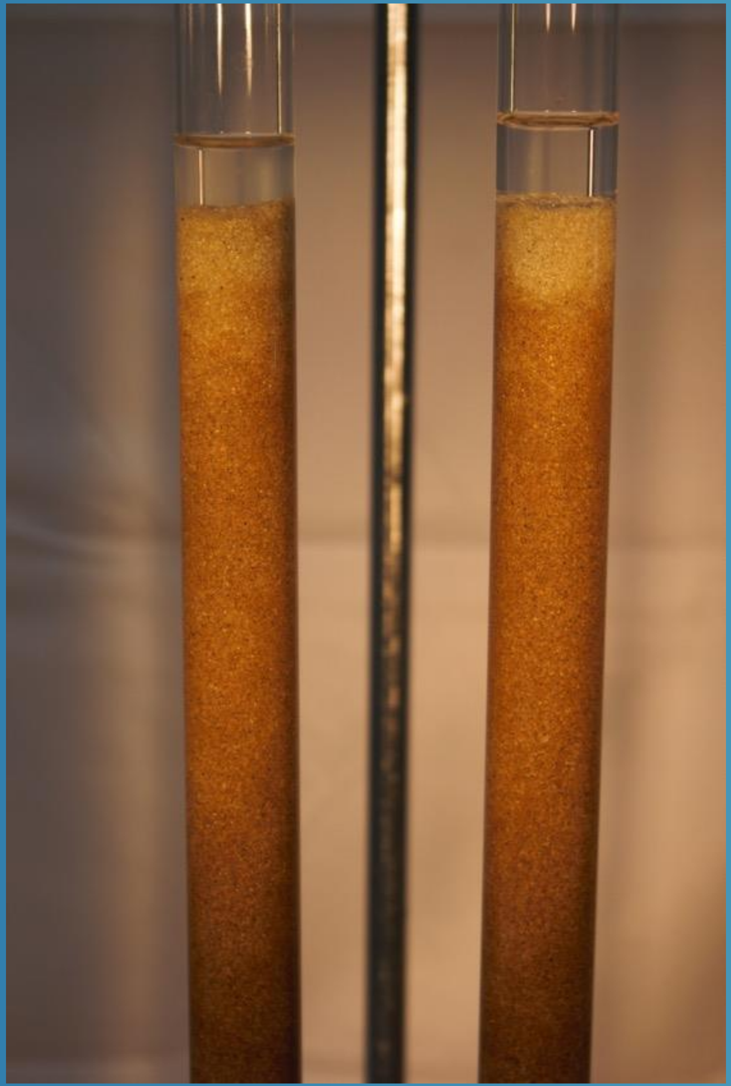
COLLOIDAL ACTIVATED CARBON

- Size (1–2 µm)
  - 2-3 OoMs smaller than GAC (500-1,000 µm)
  - Size of a red blood cell
  - Suspended in water
  - Huge surface area
  - Extremely fast sorption

COLLOIDAL ACTIVATED CARBON

- Additives
  - Allow for suspension without clumping
  - Enable wide-area, low-pressure distribution
  - Particles coat the surface of aquifer matrix
  - No impedance of groundwater flow
  - Converts polluted aquifer into purifying filter

PLUMESTOP – REAGENT DISTRIBUTION



PLUMESTOP – REAGENT DISTRIBUTION

PLUME STOP
Liquid Activated Carbon

Powdered
Activated Carbon

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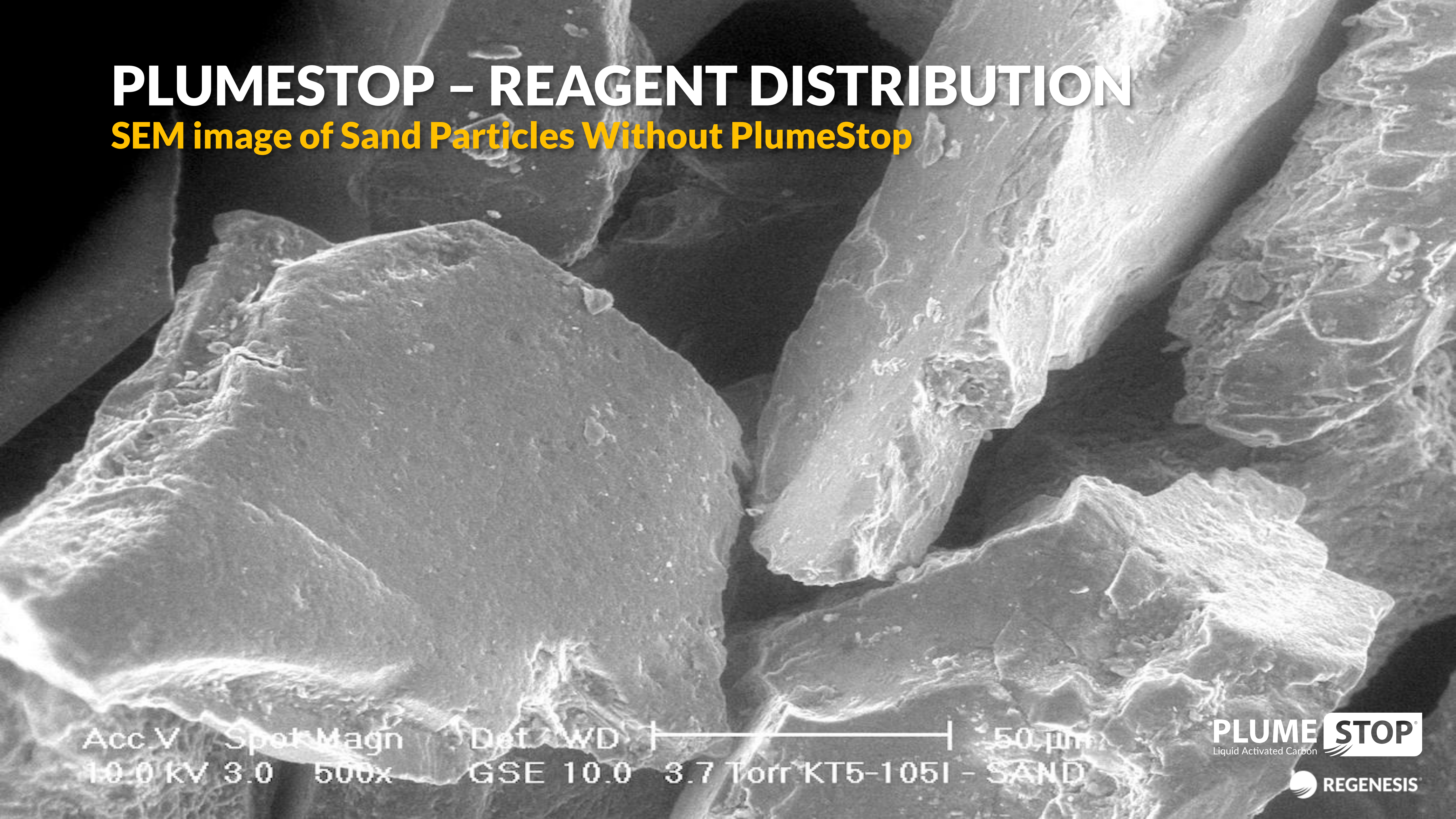
PLUMESTOP – REAGENT DISTRIBUTION

SEM image of Sand Particles Without PlumeStop



PLUME STOP
Liquid Activated Carbon
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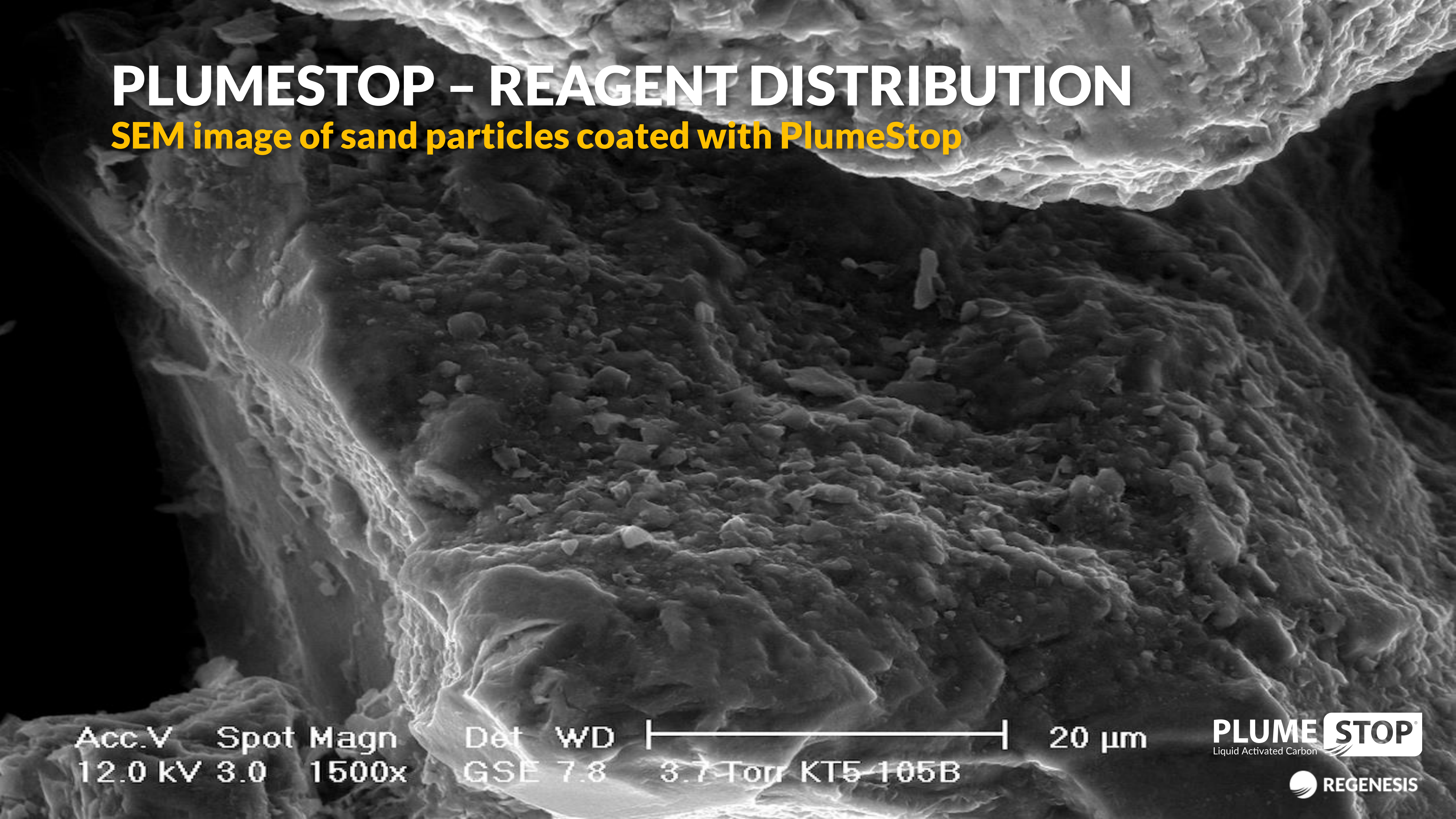
PLUMESTOP – REAGENT DISTRIBUTION

SEM image of sand particles coated with PlumeStop



PLUME STOP
Liquid Activated Carbon

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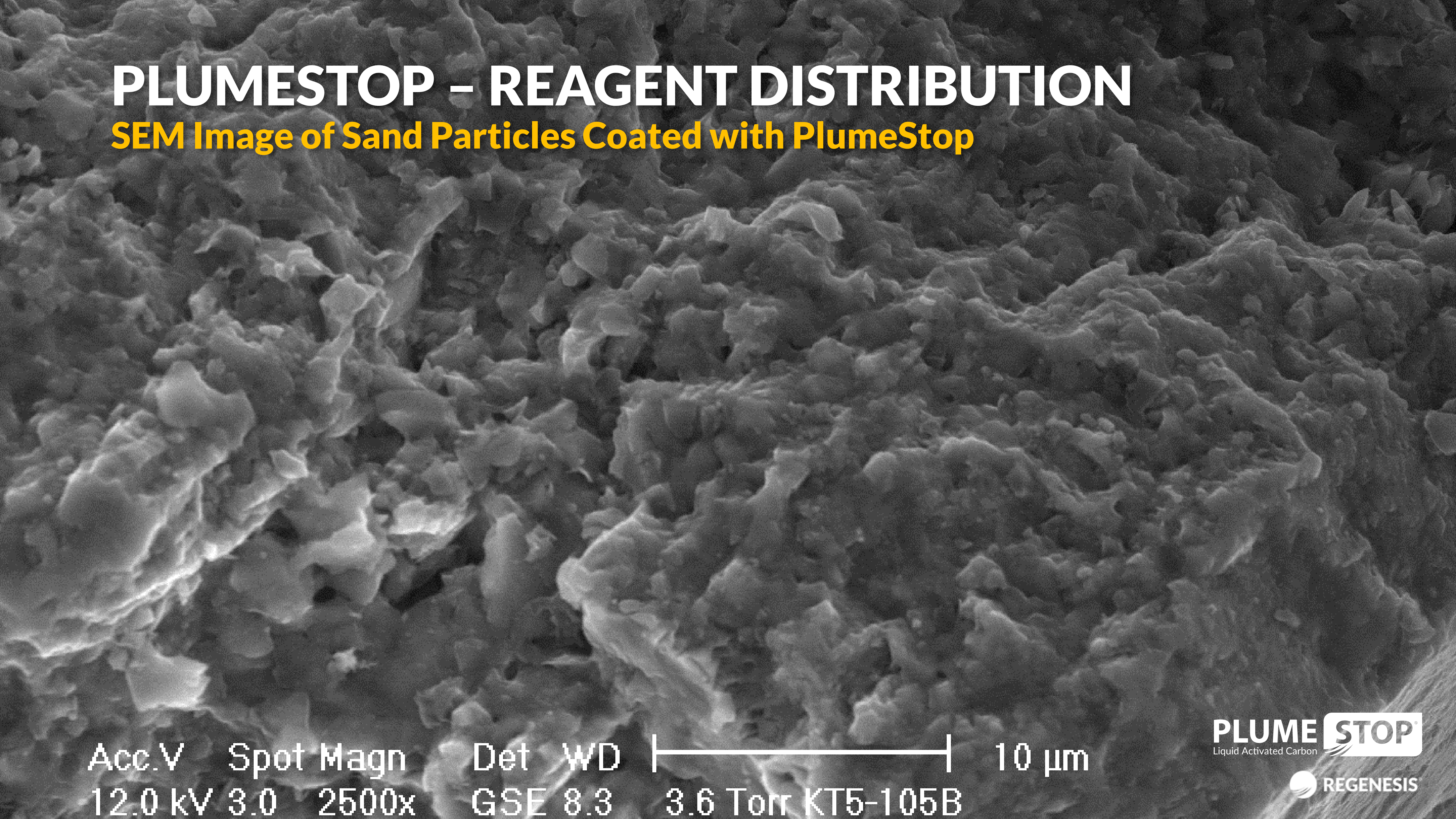
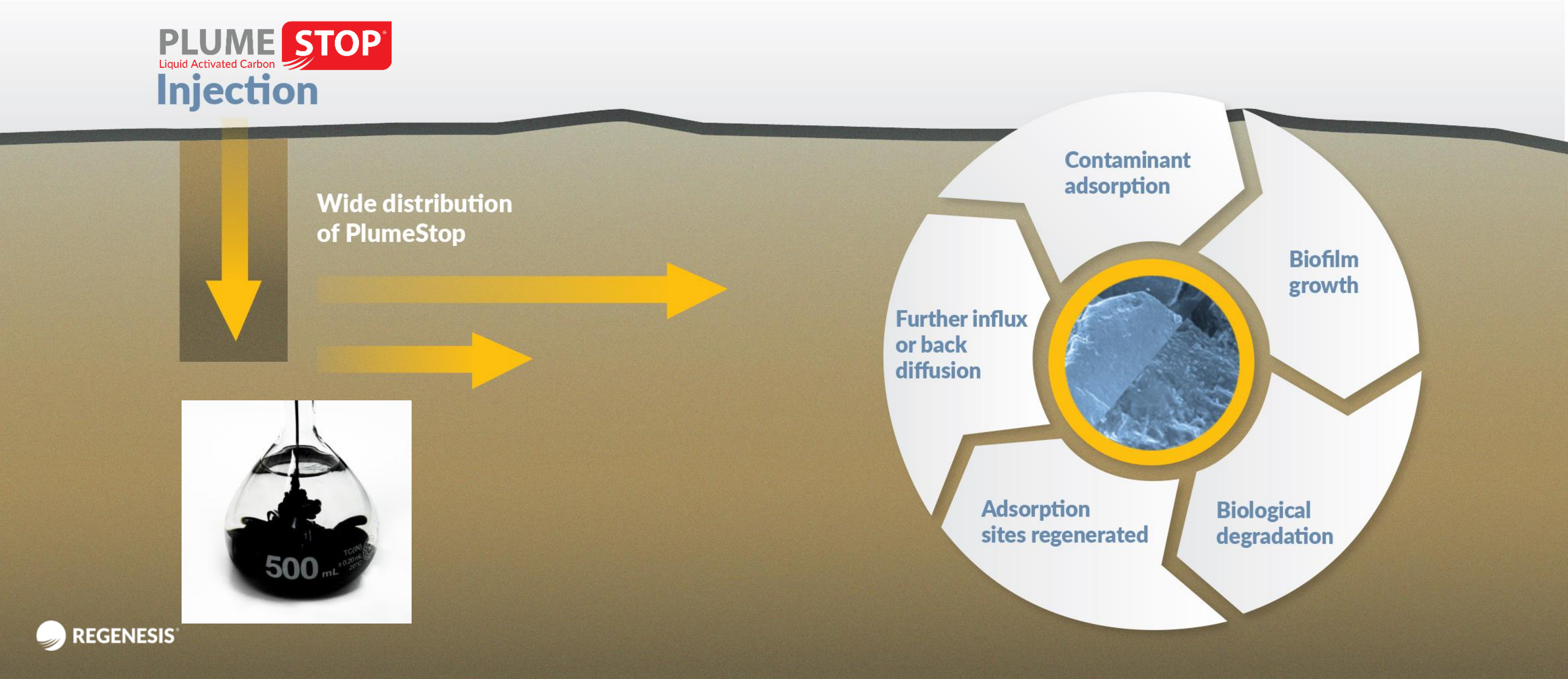
PLUMESTOP – REAGENT DISTRIBUTION

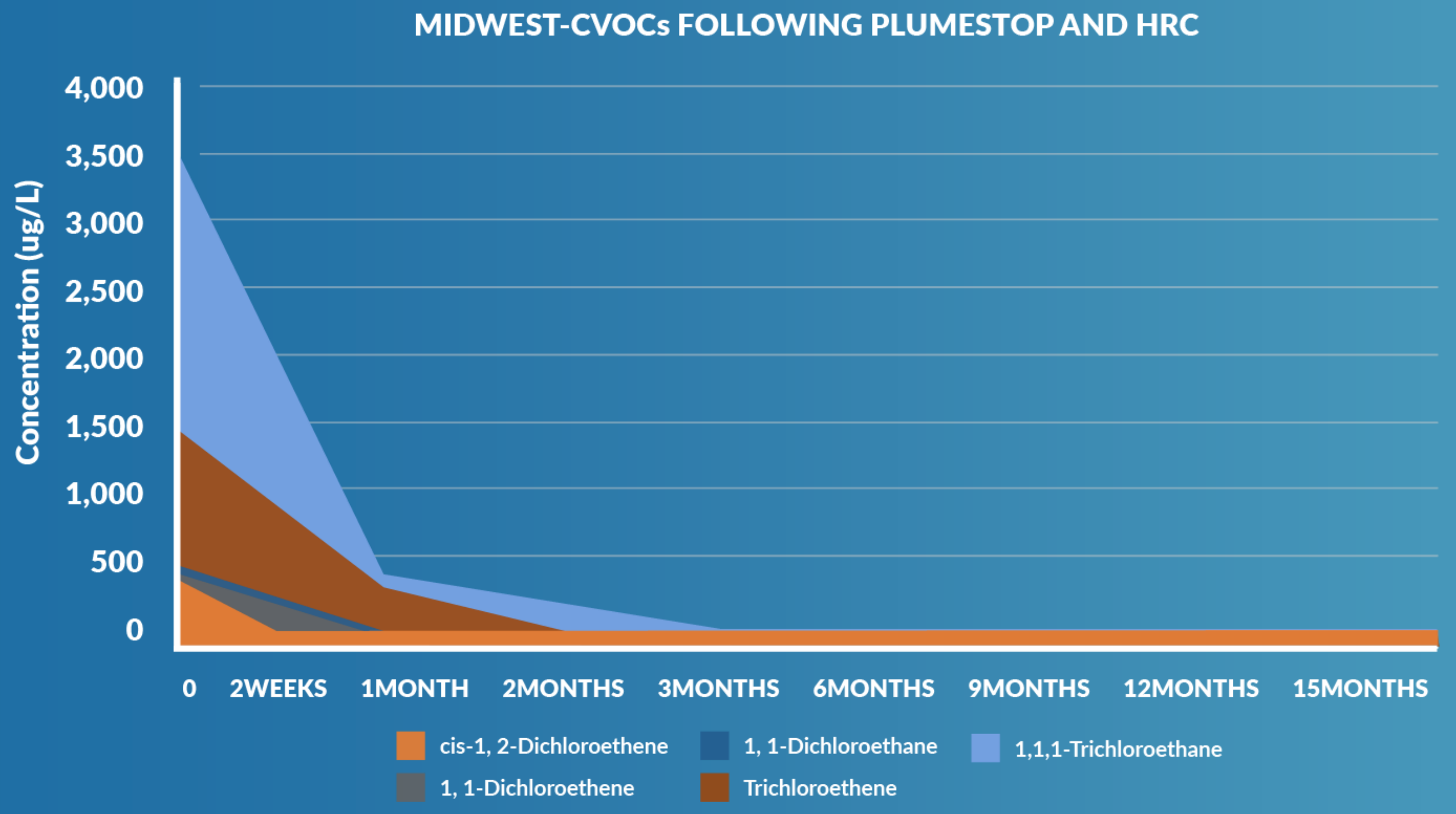
SEM Image of Sand Particles Coated with PlumeStop



PLUMESTOP LIQUID ACTIVATED CARBON



TYPICAL PERFORMANCE OF PLUMESTOP



- 98% reduction in 1 month
- Minimal CVOC daughter products observed
- Sustained reductions over time

PLUME STOP®
Liquid Activated Carbon

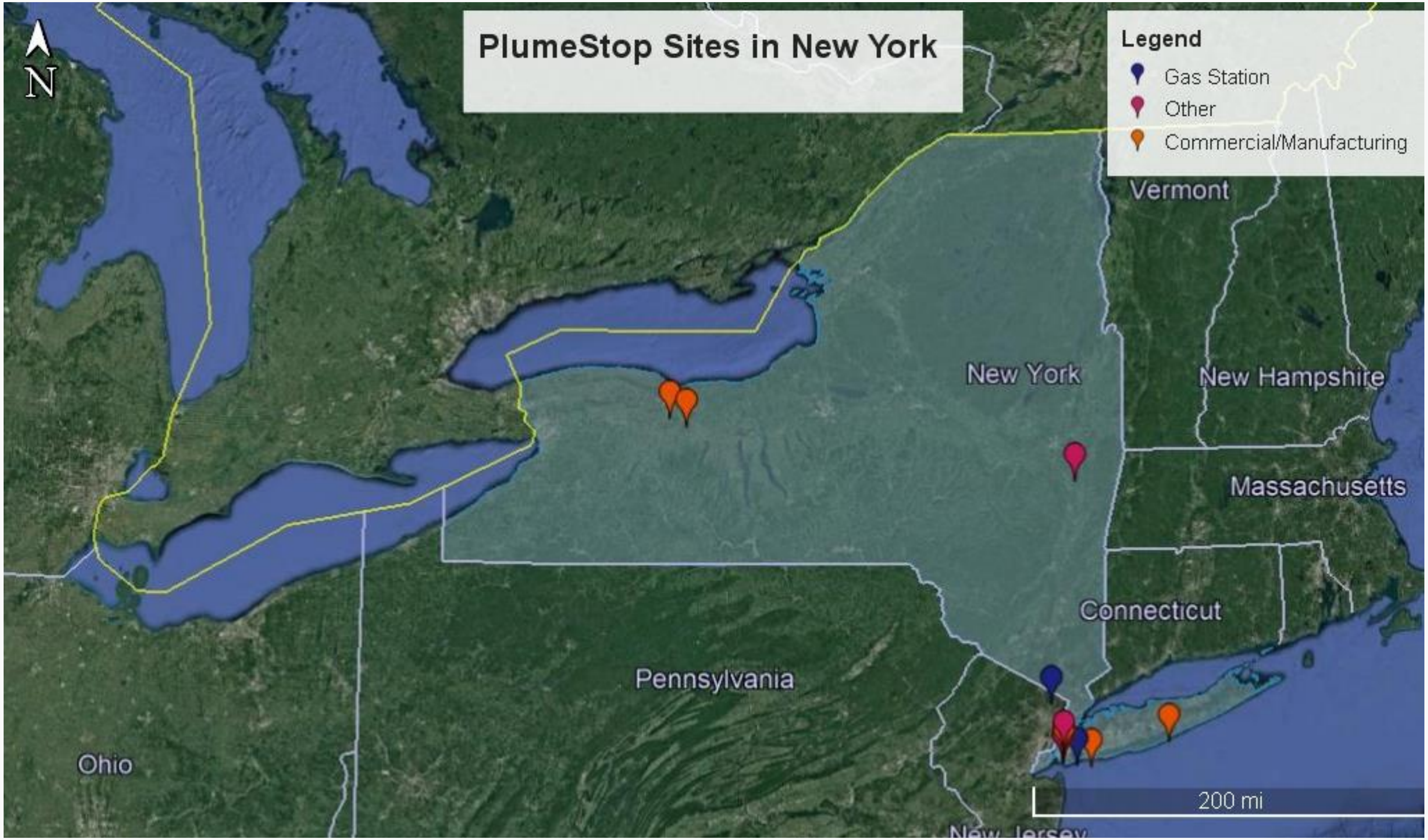
Remediation Projects

200+

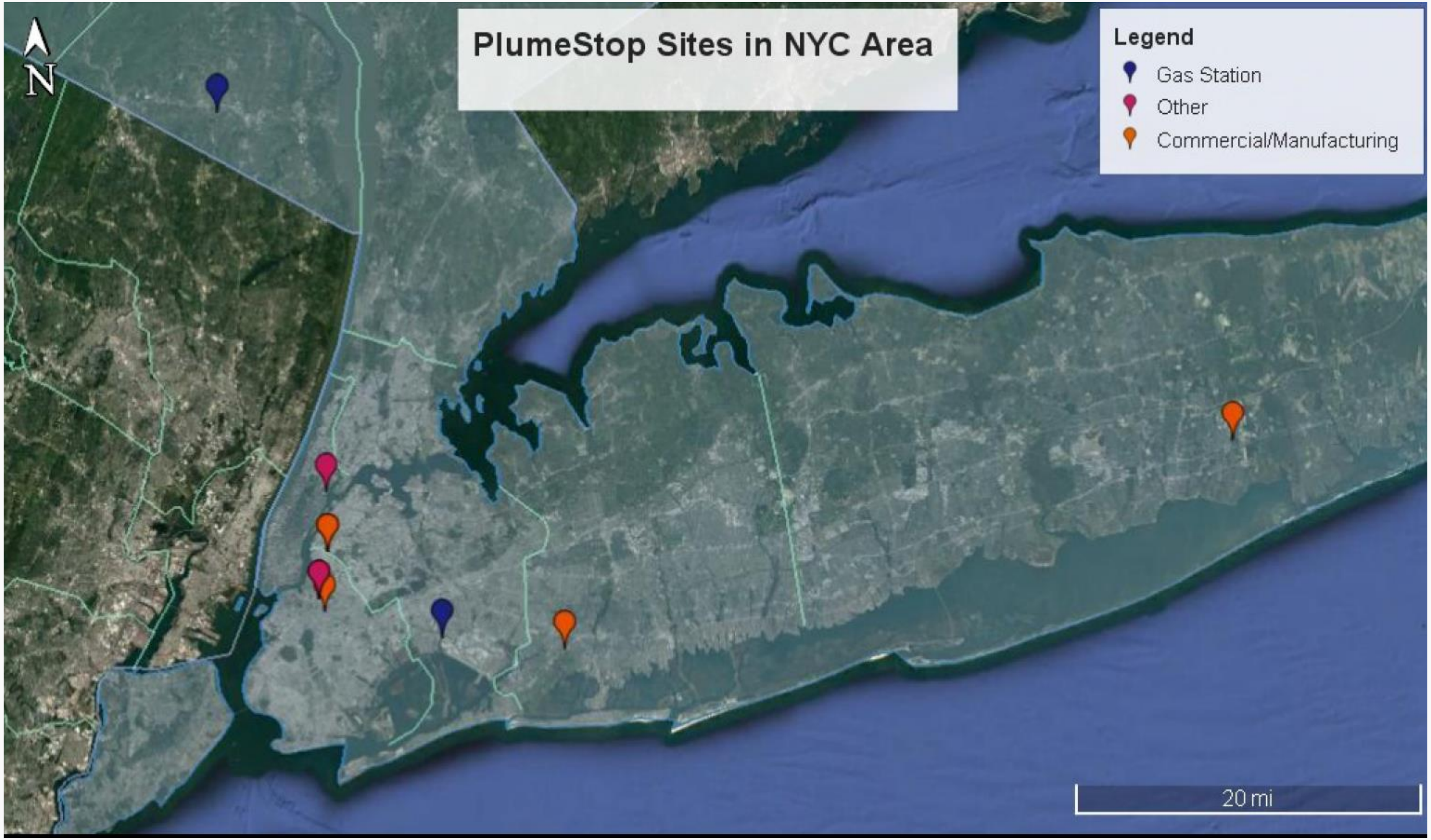
Successful Projects Worldwide

PLUME STOP Liquid Activated Carbon

Remediation Projects



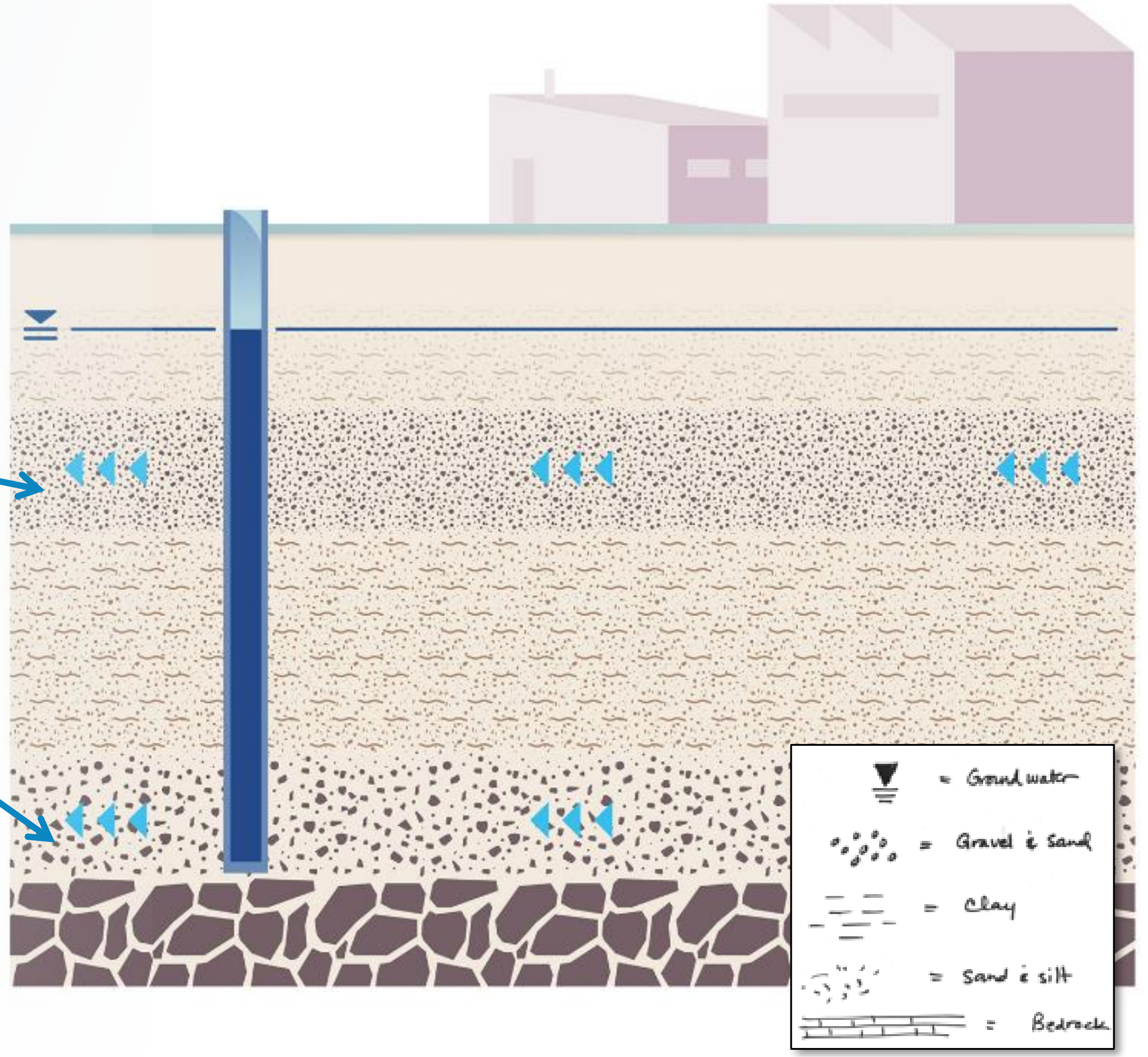
Remediation Projects



Back Diffusion Management

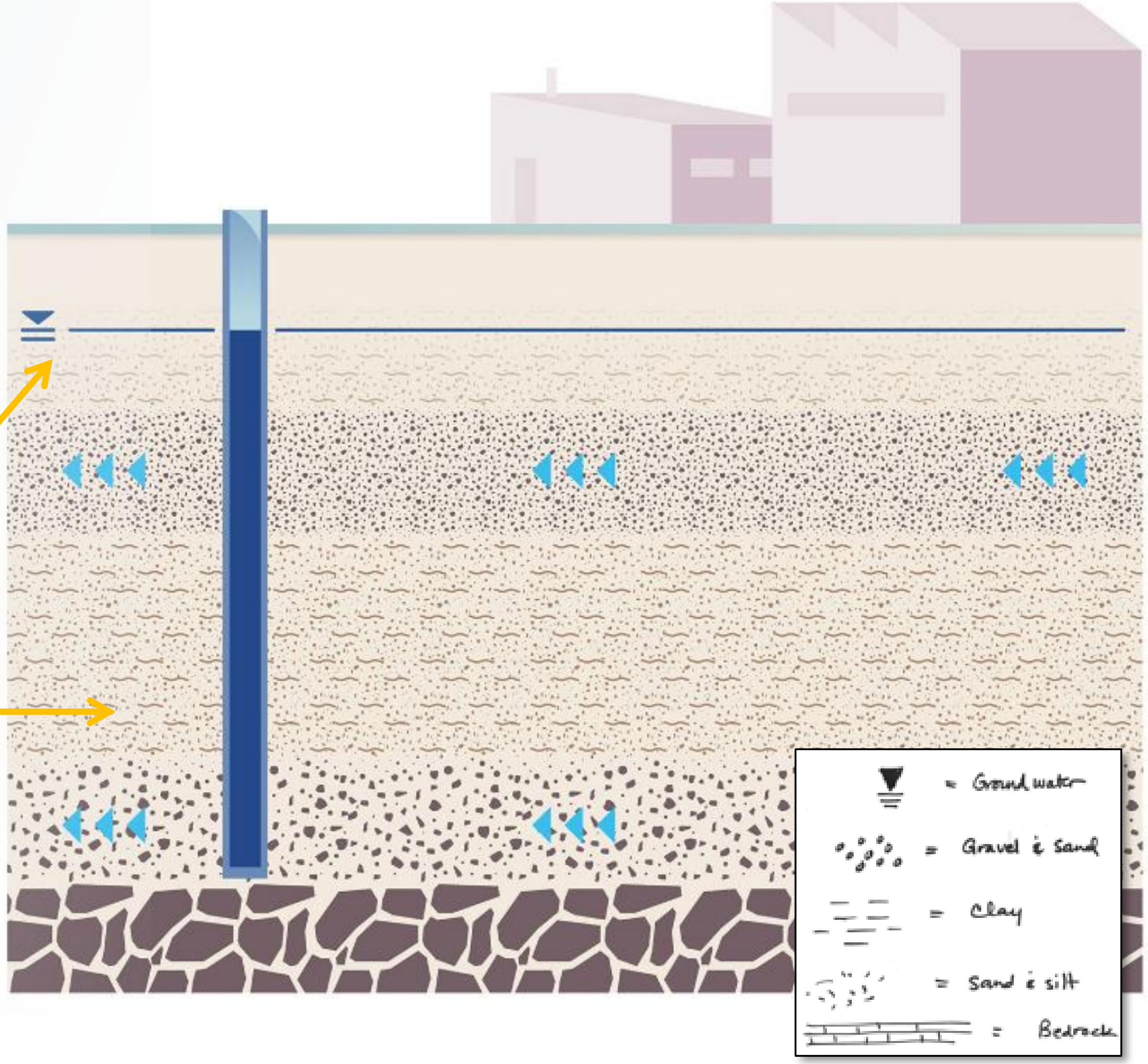
AQUIFER FLUX ZONES

Higher Permeability Zones
“Freeways”



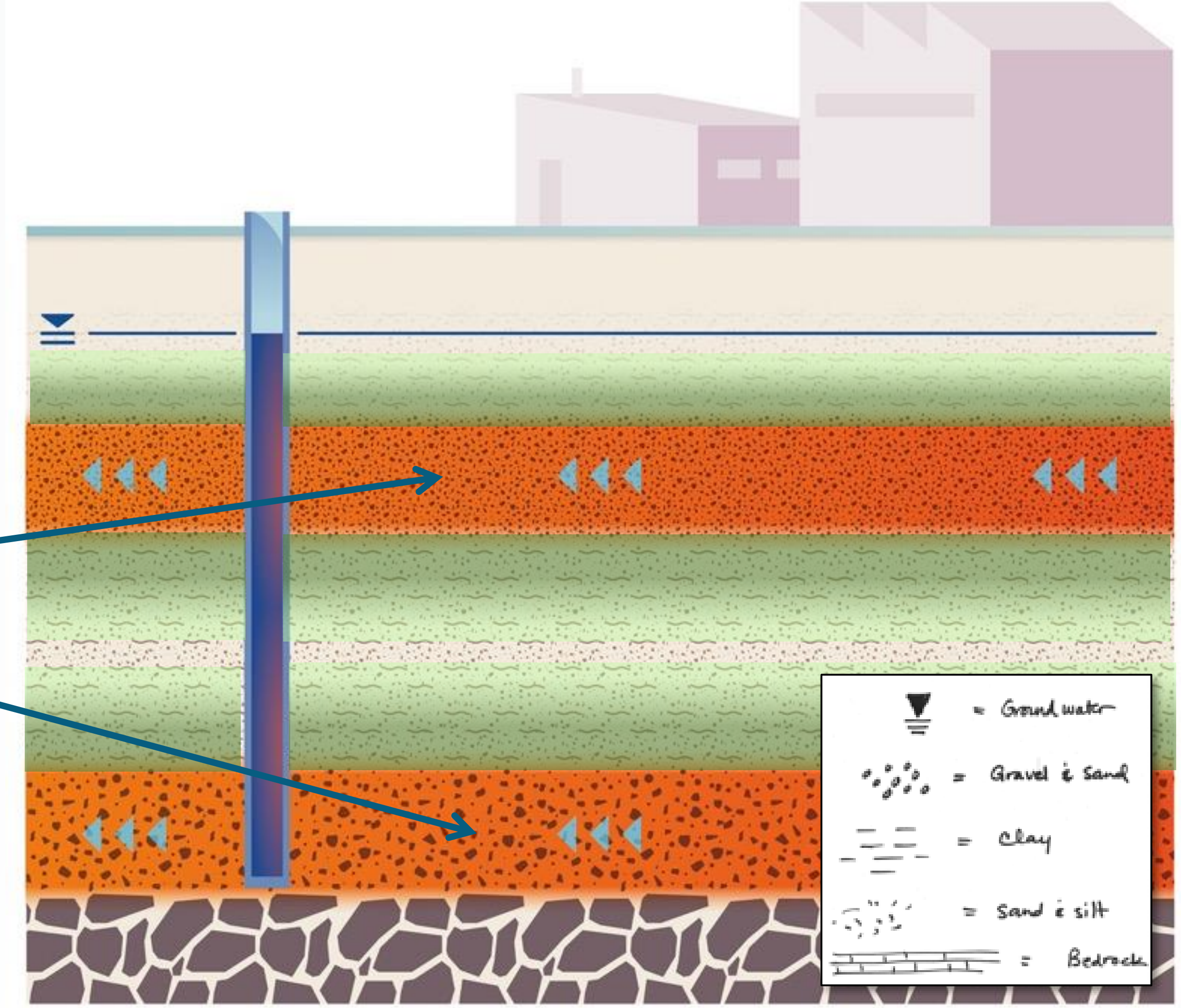
AQUIFER FLUX ZONES

Lower Permeability Zones
“Parking Lots”

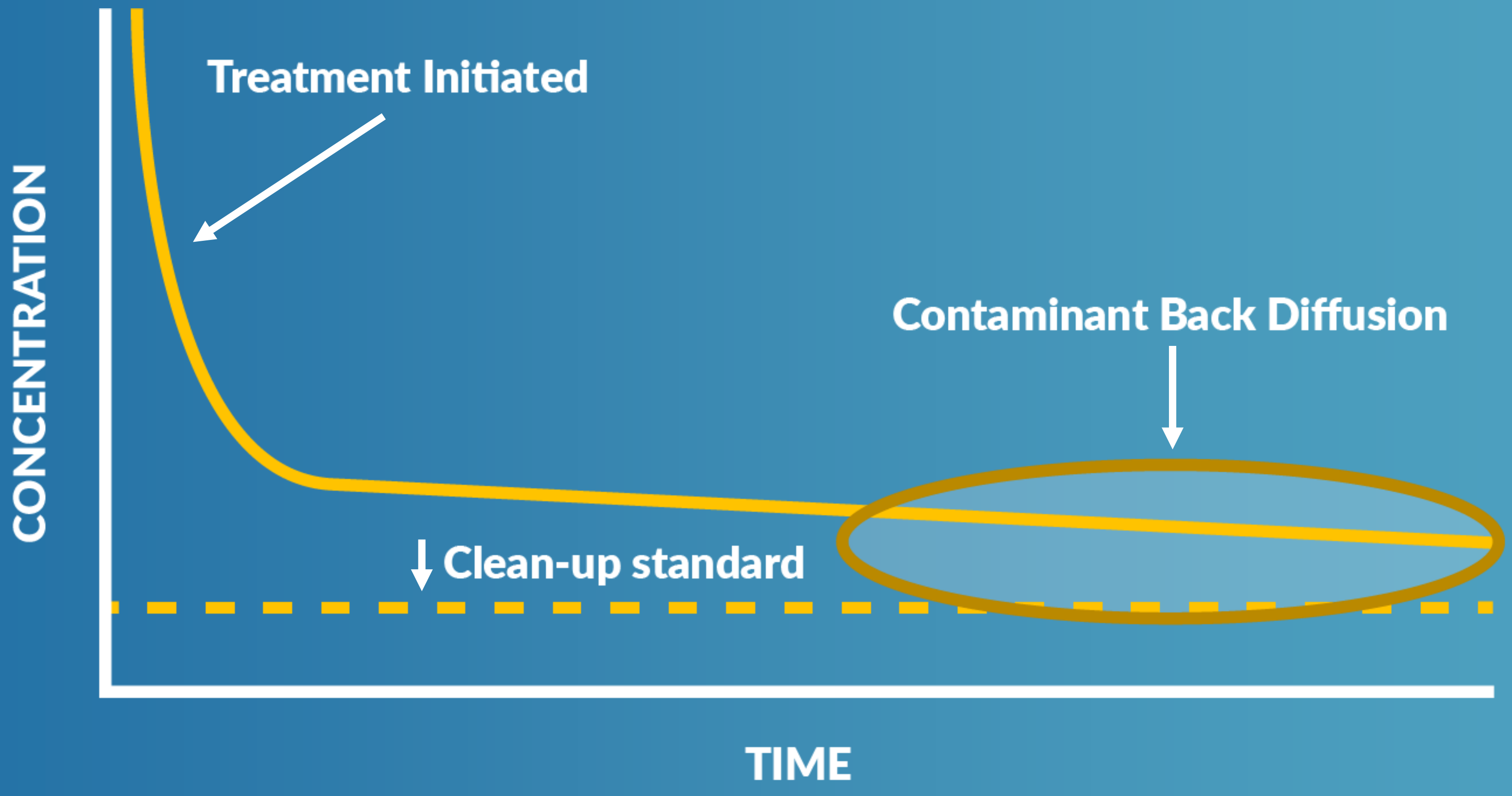


BACK DIFFUSION

Relatively Easy to Remediate Contaminants in the Freeways



IMPACT OF BACK DIFFUSION



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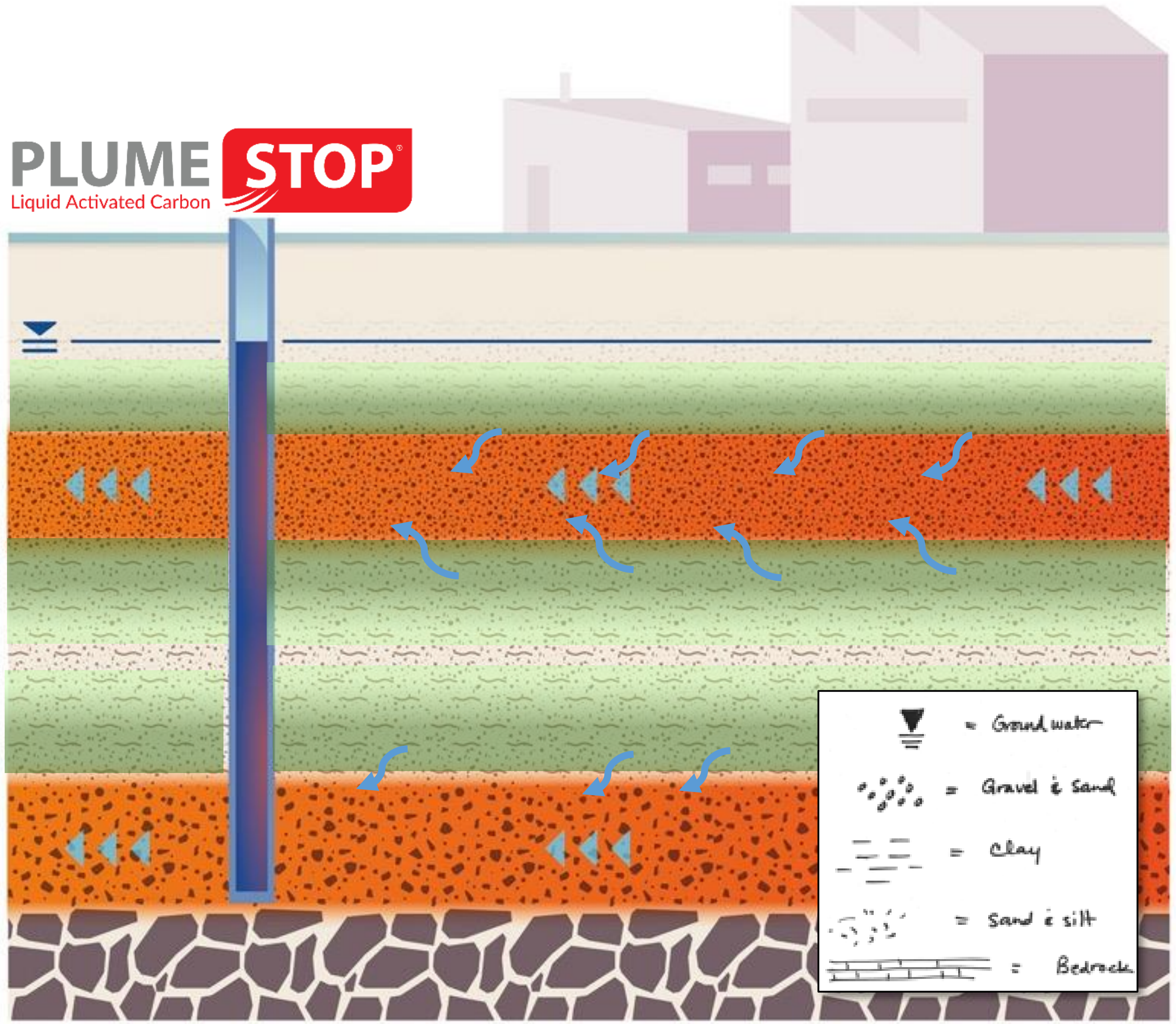
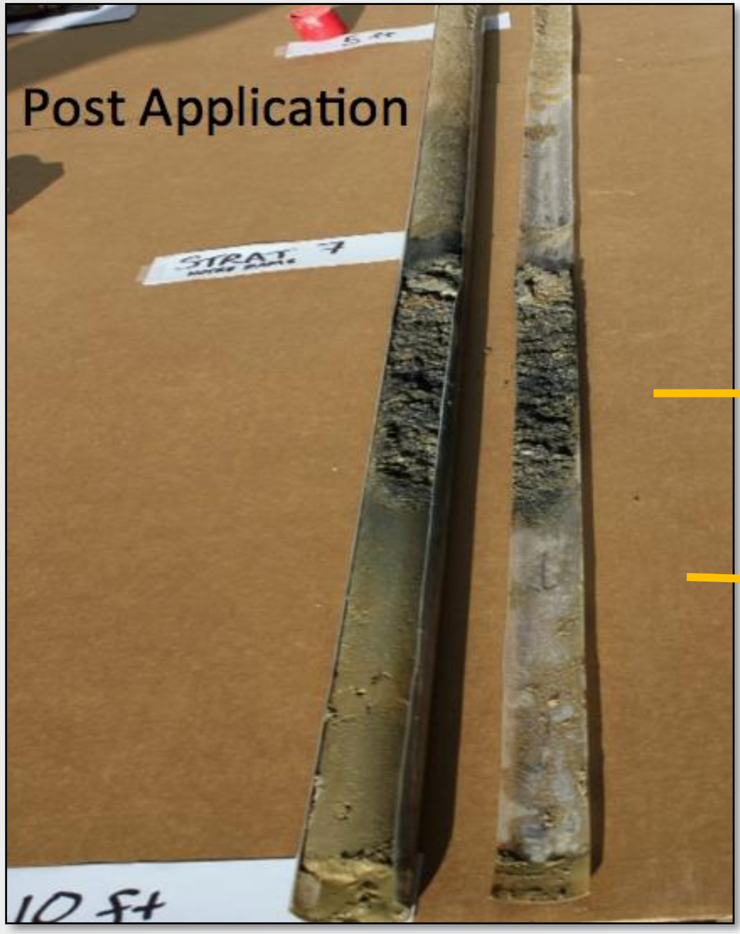
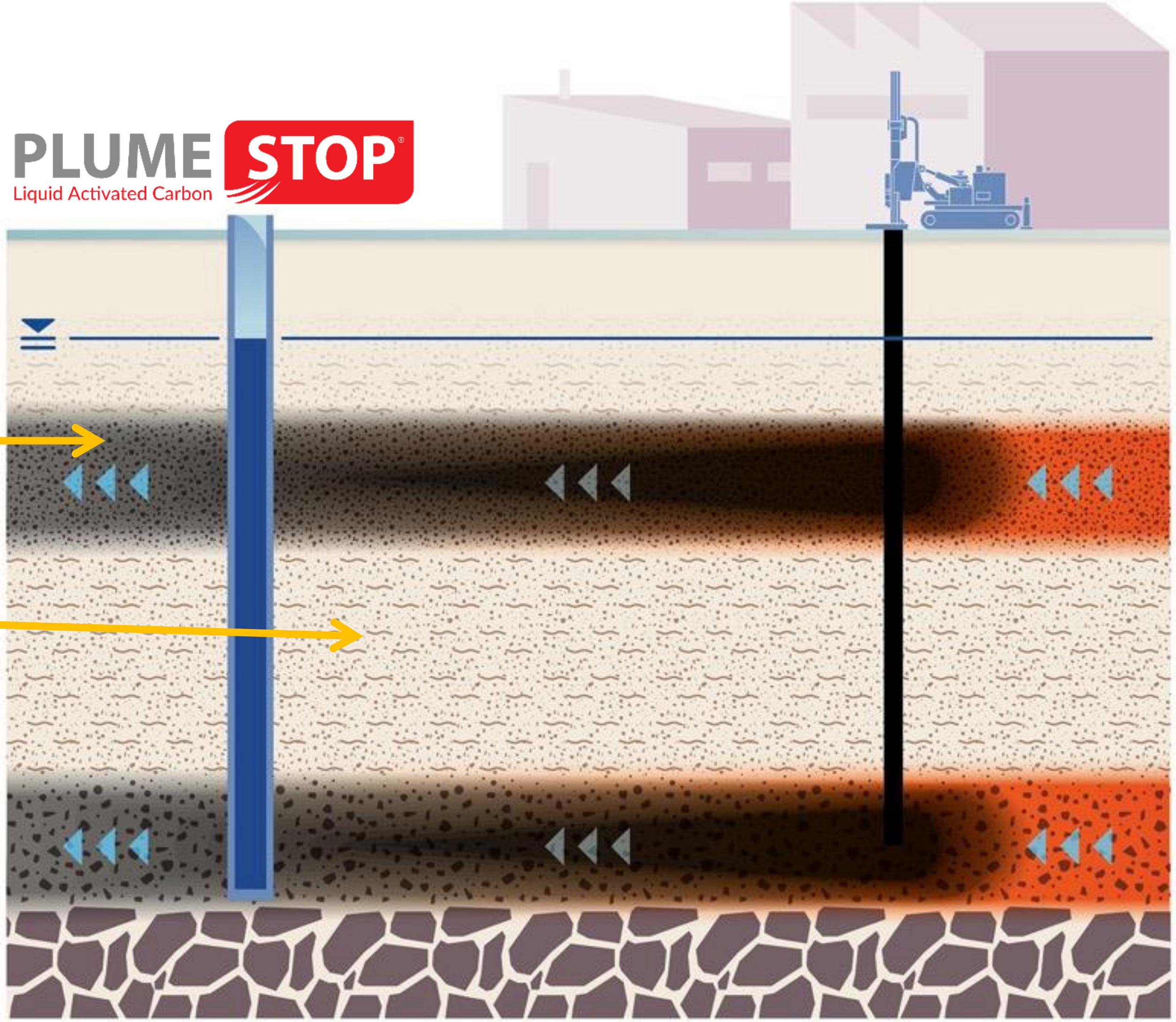
PLUMESTOP TREATMENT

Contaminant Mass Back-Diffusing From the Low-Perm Zones is Captured

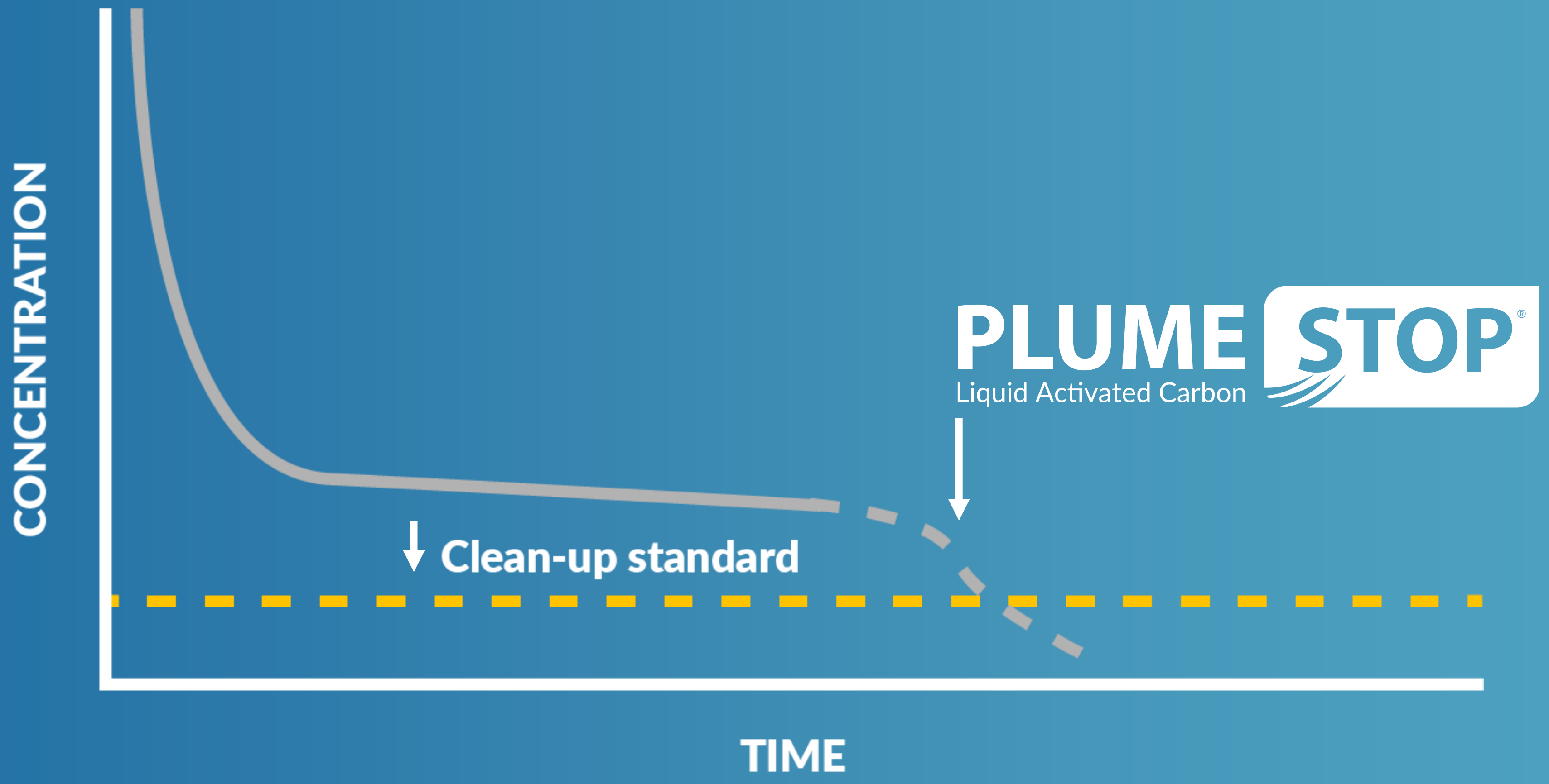


PLUMESTOP INJECTION





PLUMESTOP ELIMINATES BACK-DIFFUSION IMPACT



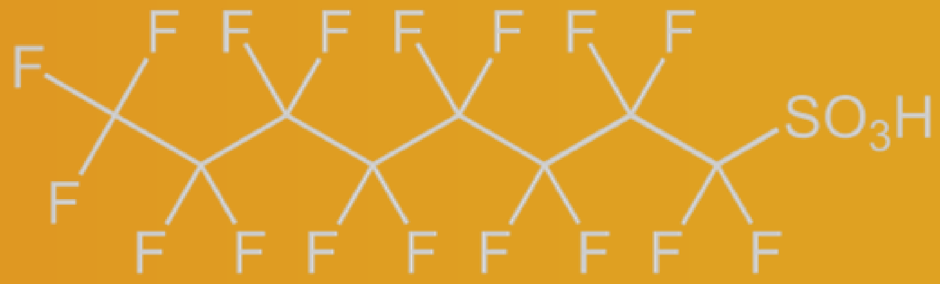
REGENESIS

PASSIVE MANAGEMENT OF GROUNDWATER PLUMES LONG-TERM

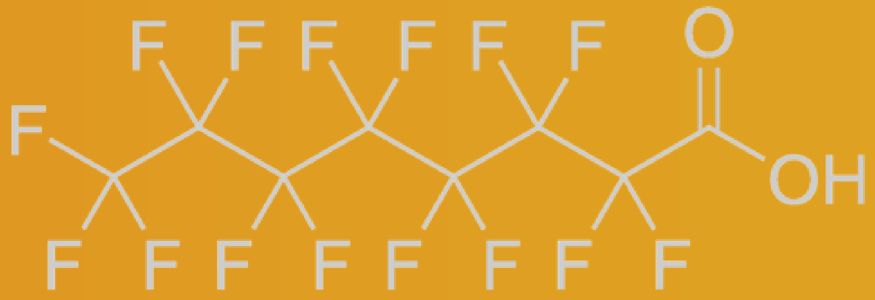
WHICH BRINGS US TO...

PLUME STOP®

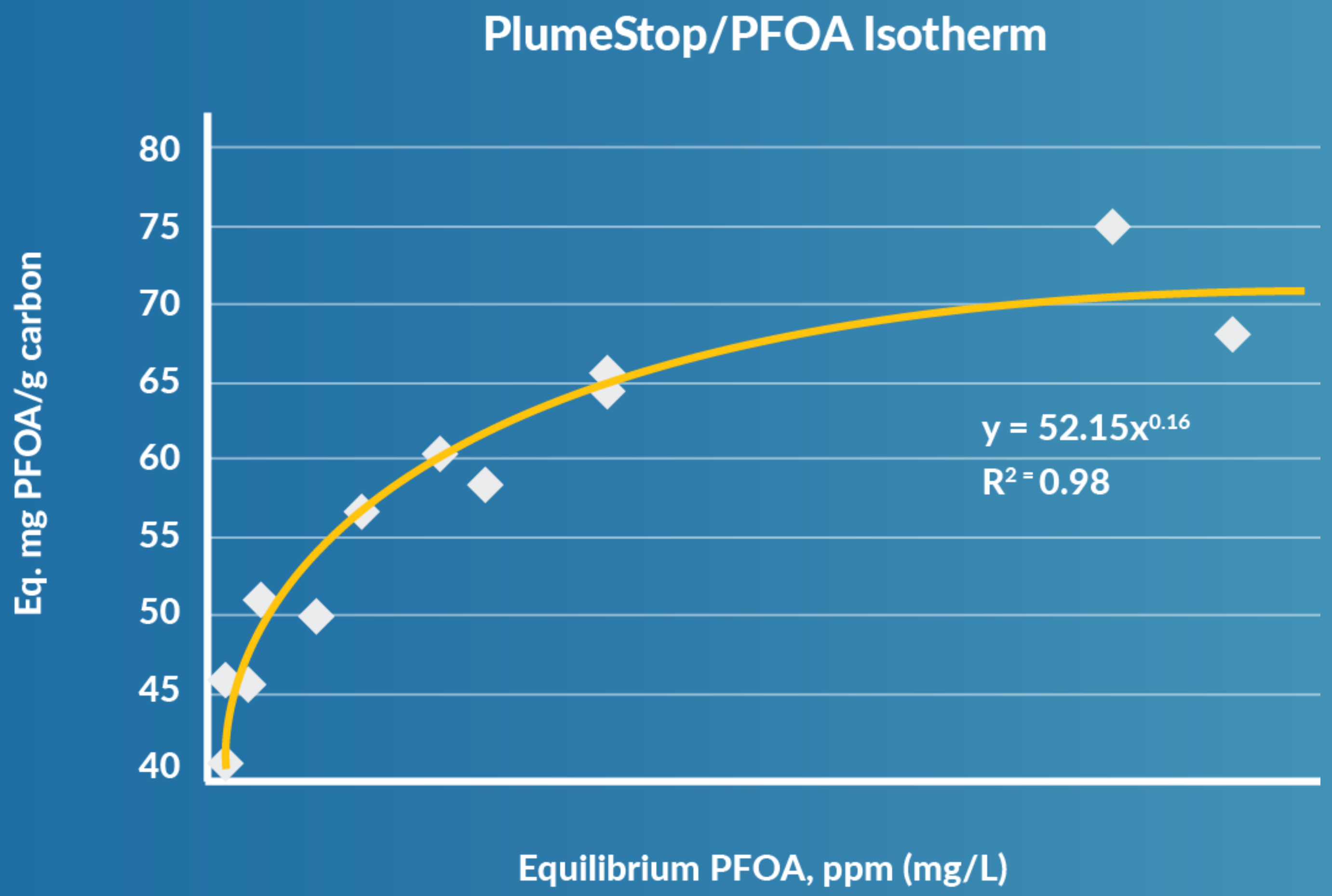
Liquid Activated Carbon



Perfluorinated Compounds



PLUMESTOP + PFOA/PFOS



	Kf	1/n	PS dose, mg/L: 5 ppm -> .005 ppm
PFOA	52	0.16	**224**
PFOS	135	0.28	**163**
PCE	105	0.42	**445**

Sorption only

(currently no validated destruction methods are available)

PLUMESTOP + PFOA/PFOS: CAPTURE EFFICIENCY

So what happens over time?

- Won’t the barrier eventually fill up and breakthrough?
- As PFAS do not degrade, the answer is yes
- What’s important is how long this will take

PLUMESTOP + PFAS: RETARDATION FACTOR

For a PlumeStop Barrier at a Mid-Range Dose:

PFOA

- The R of a 1,000 µg/L plume is 80
- The R of a 100 µg/L plume is 570
- The R of a 10 µg/L plume is 4,000

PFOS

- The R of a 1,000 µg/L plume is 375
- The R of a 100 µg/L plume is 2,000
- The R of a 10 µg/L plume is 10,000

*based on individual components

PLUMESTOP + PFAS: RETARDATION FACTOR

Example:

- PlumeStop barrier width 16’ (single application at mid-range dose)
- 160’ per year seepage velocity
- 100 µg/L influent concentration

This is at 100 µg/L

At lower influent concentrations, the retardation quickly becomes much greater.

- Groundwater transit time 36.5 days
- PFOA transit time* = 20,800 days (57 years)
- PFOS transit time* = 73,000 days (200 years)

* transit time peak based on individual components

ELIMINATE THE RISK FROM PFAS

Environmental RISK = (**PFAS**) X (Exposure)

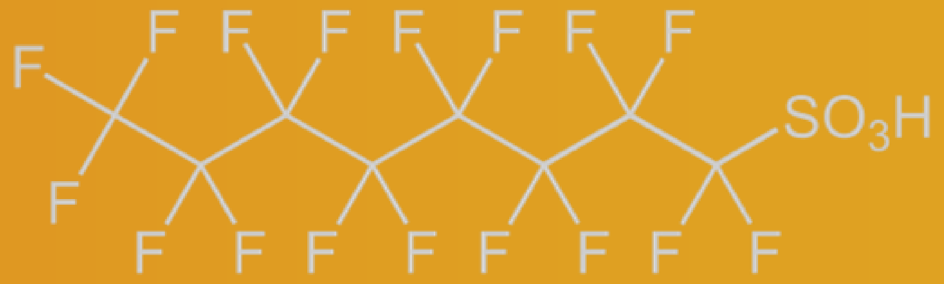
ELIMINATE THE RISK FROM PFAS

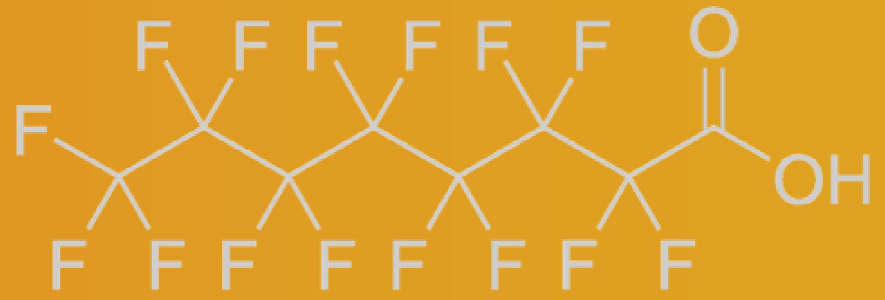
- “Risk-Based Corrective Action” is commonplace throughout world since 1990’s
- “No Further Action” granted if plume not expanding and no receptor impacted (water well or surface water)

PLUME STOP®

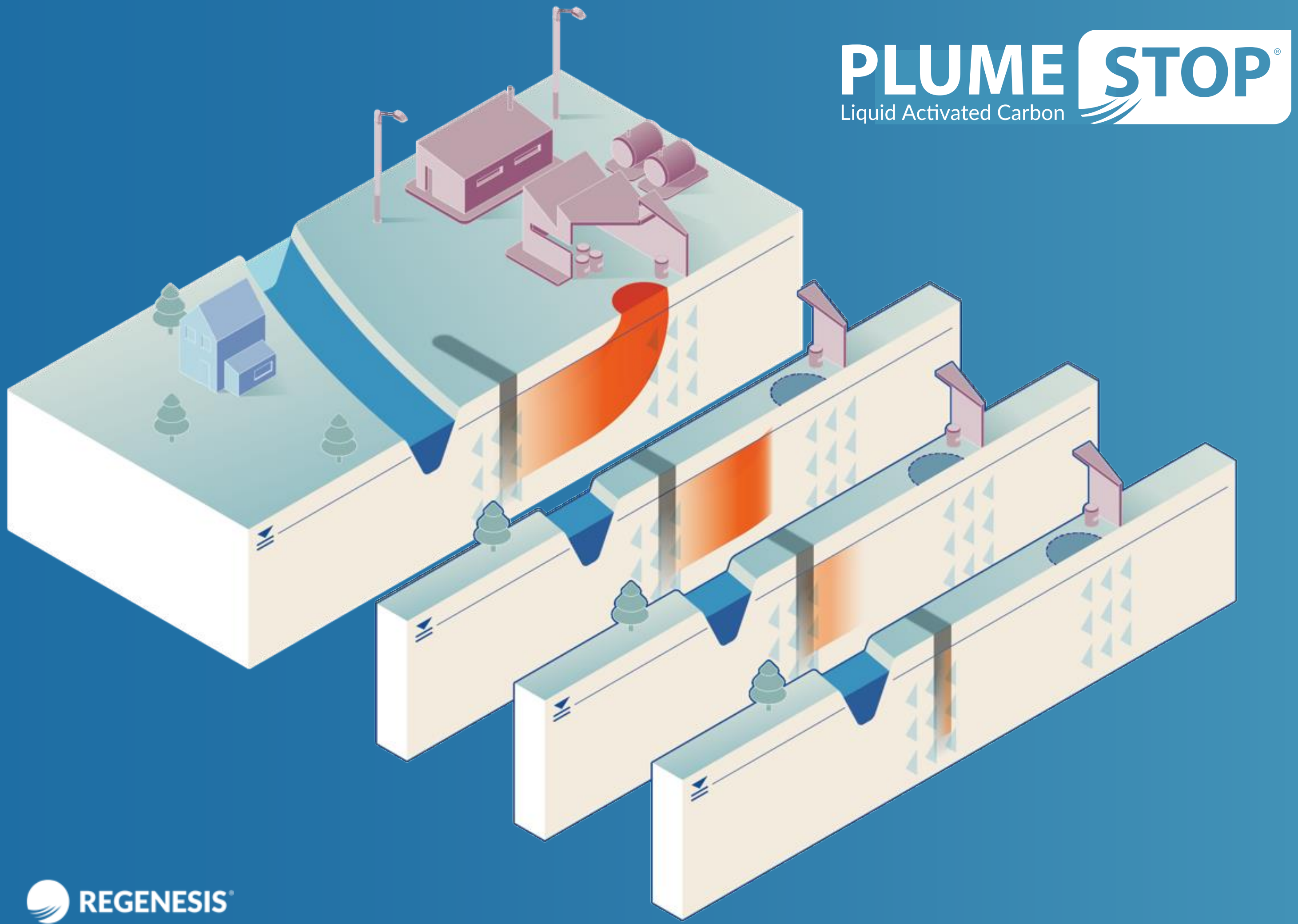
Liquid Activated Carbon

Application Strategies





STRATEGY #1 – SIMPLE PLUME CUT-OFF BARRIER



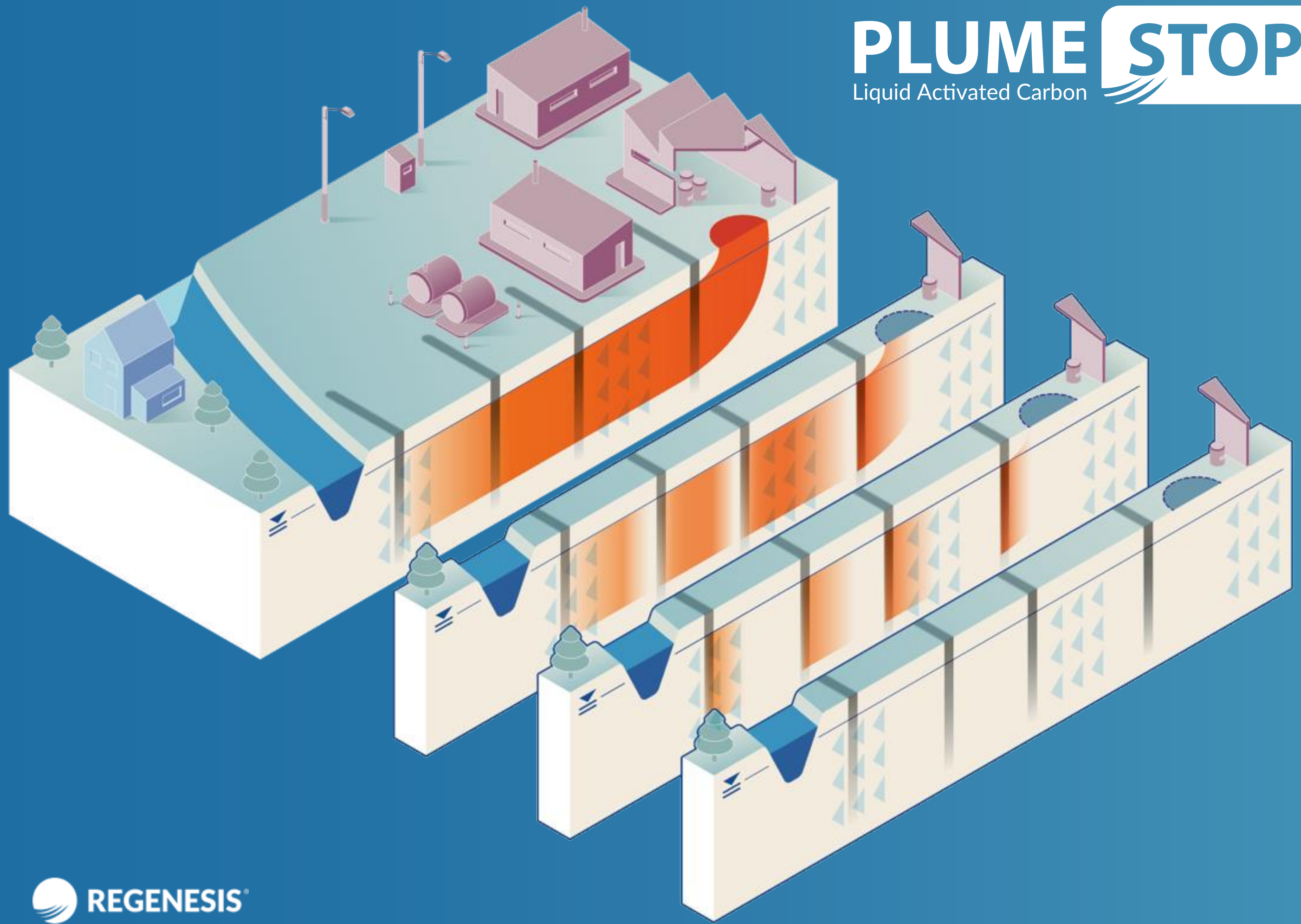
Description

- Single barrier of PlumeStop®
- Limits plume expansion

Application

- Protection of property boundary
  - (entering site or exiting site)
- Protection of receptor (shown)
  - (e.g. water body; well)
- Plume minimization
  - Liability containment
  - (possible) regulatory compliance

STRATEGY #2 – SEQUENCE OF BARRIERS



PLUME STOP®
Liquid Activated Carbon

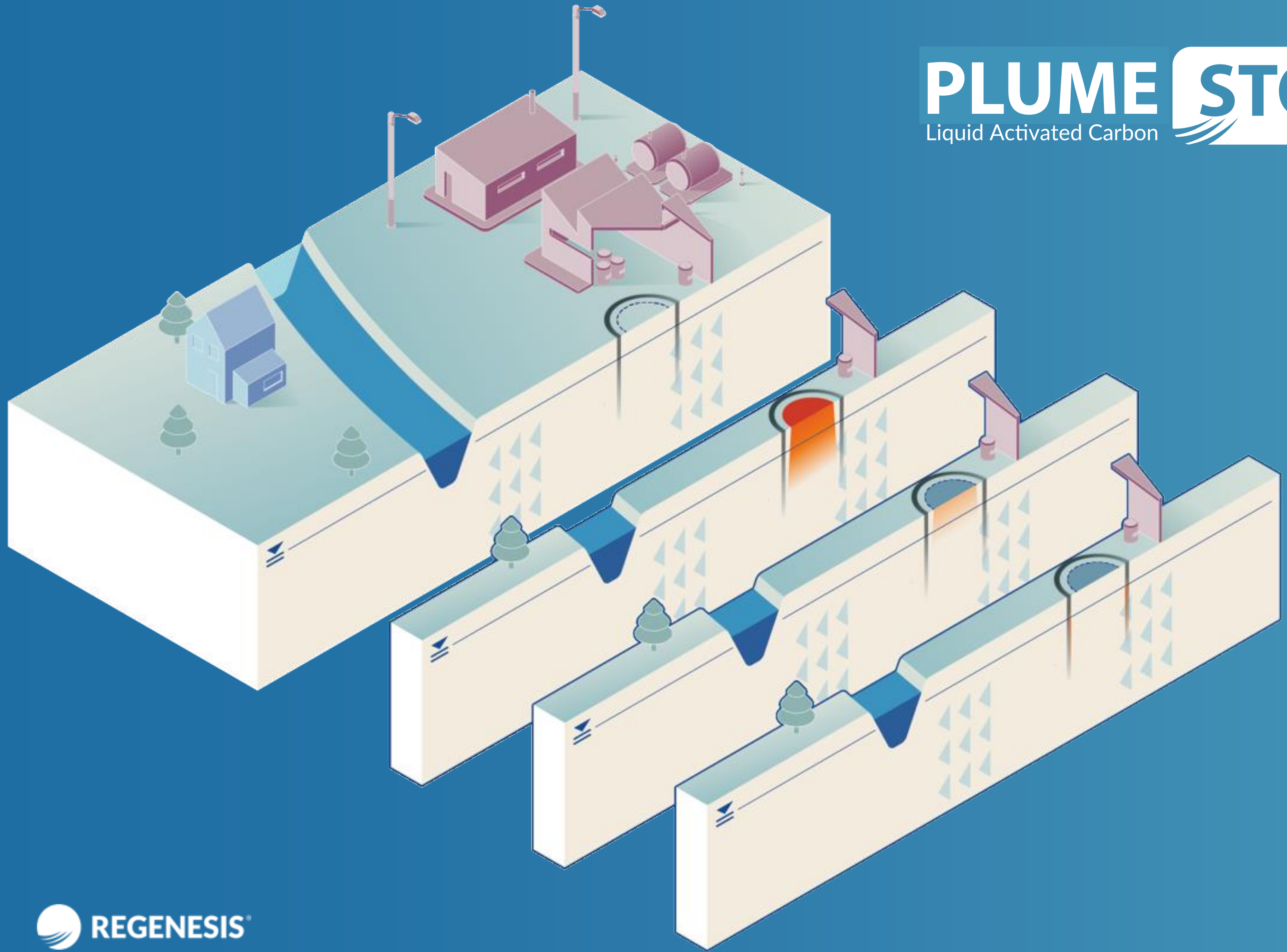
Description

– Multiple barriers of PlumeStop®
– Progressive elimination of plume

Application

– Addresses entire plume
– Utilizes advection for efficiency
– Particularly suited for:
  - Large plumes (compare cost of grid injection)
  - Built-up areas / restricted access
    – Barriers in access corridors / roadways

STRATEGY #3 – POTENTIAL SOURCE CONTAINMENT



PLUME STOP®
Liquid Activated Carbon

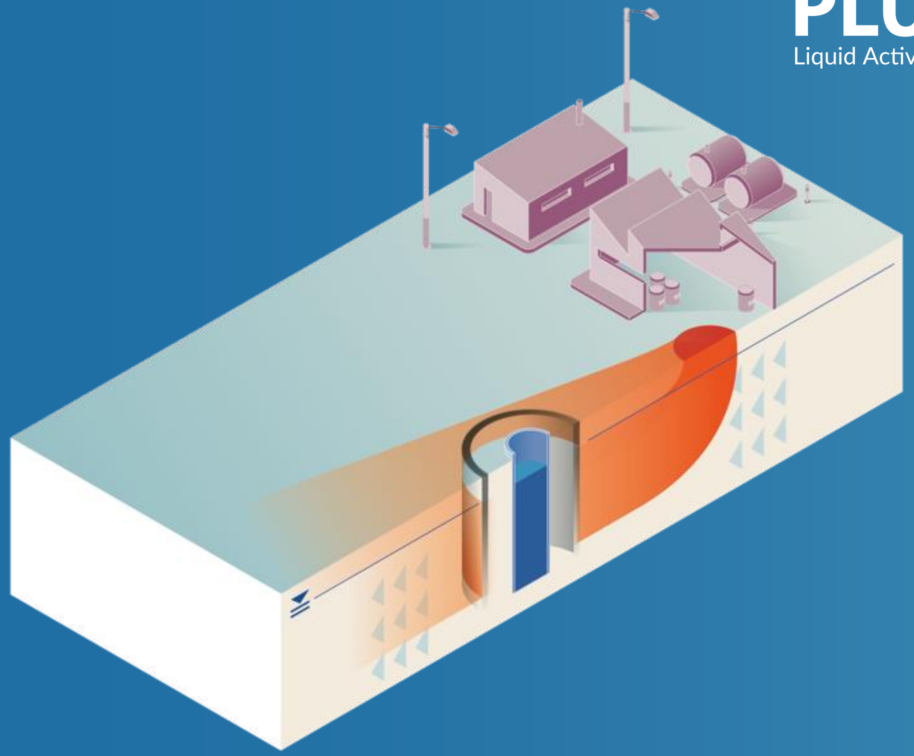
Description

- Pre-emptive source control
- PlumeStop® *in situ* ‘berm’

Application

- Ring-fence known ***potential*** source
- Avoidance of plume generation
- Provide extra time for emergency response

STRATEGY #4 – LOCALIZED RECEPTOR PROTECTION



PLUME STOP®
Liquid Activated Carbon

Description

- Individual receptor protection
- ‘Brita®’ filter in-ground

Application

- Protection of abstraction wells
  - (e.g. agricultural)
- Interim measure where plume is large
- Amenable to push-pull application
  - Fast response
  - Minimally intrusive
  - Eliminates requirement for additional borings
  - Ability to treat deep wells

CASE STUDY
PFAS – FORMER FURNITURE FACILITY

ONTARIO, CANADA

INSITU
REMEDIATION SERVICES

REGENESIS®

BACKGROUND

Initial Driver: Hydrocarbons

- Mixed chain lengths, 100 – 5,000 µg/L

Formation

- Silty sand – till based with sand seams
- Water at 3 – 5' below grade

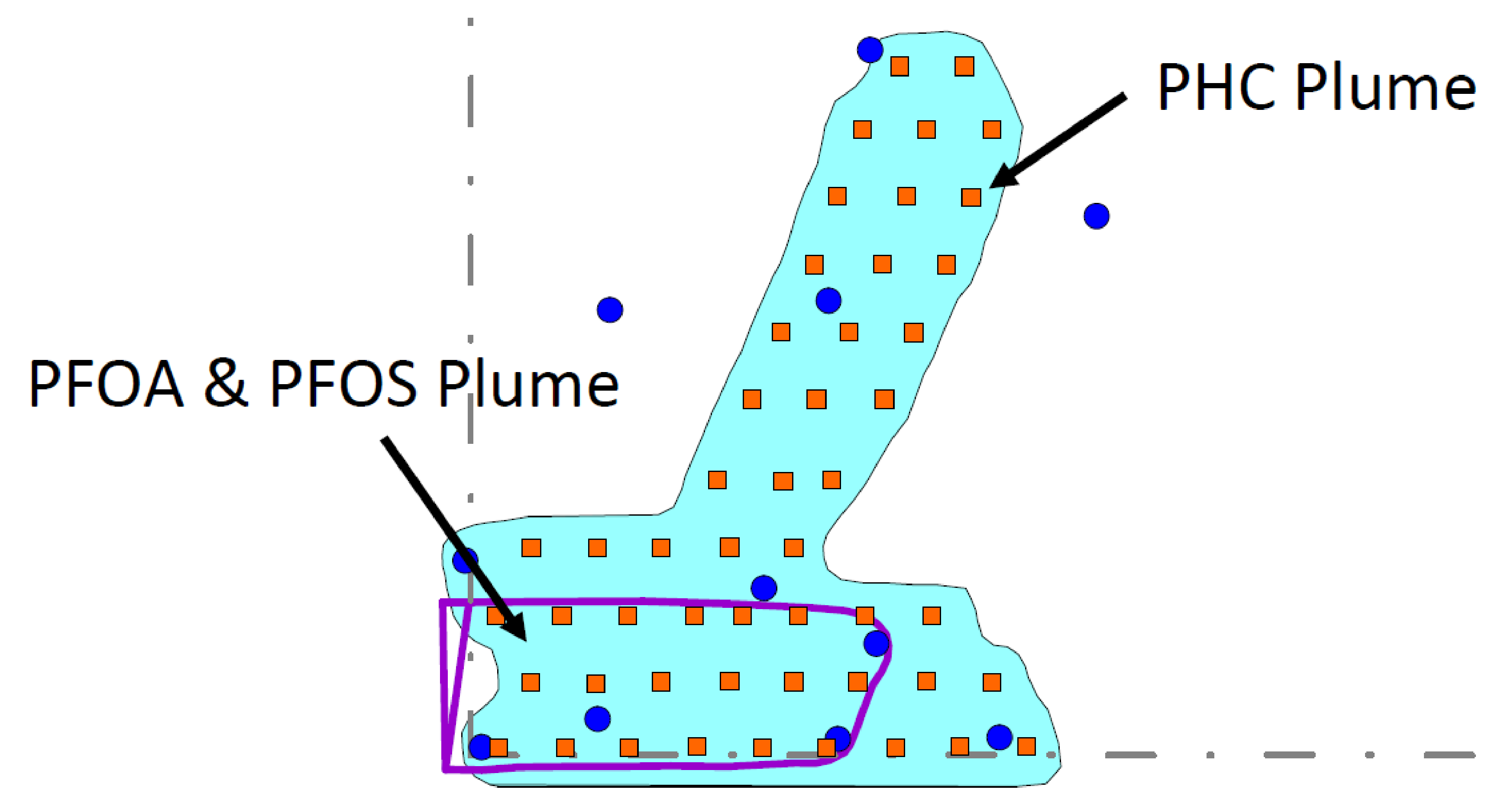
Former Fire Training Area

- History of furniture manufacturing
- PFAS tested for just in case and found!

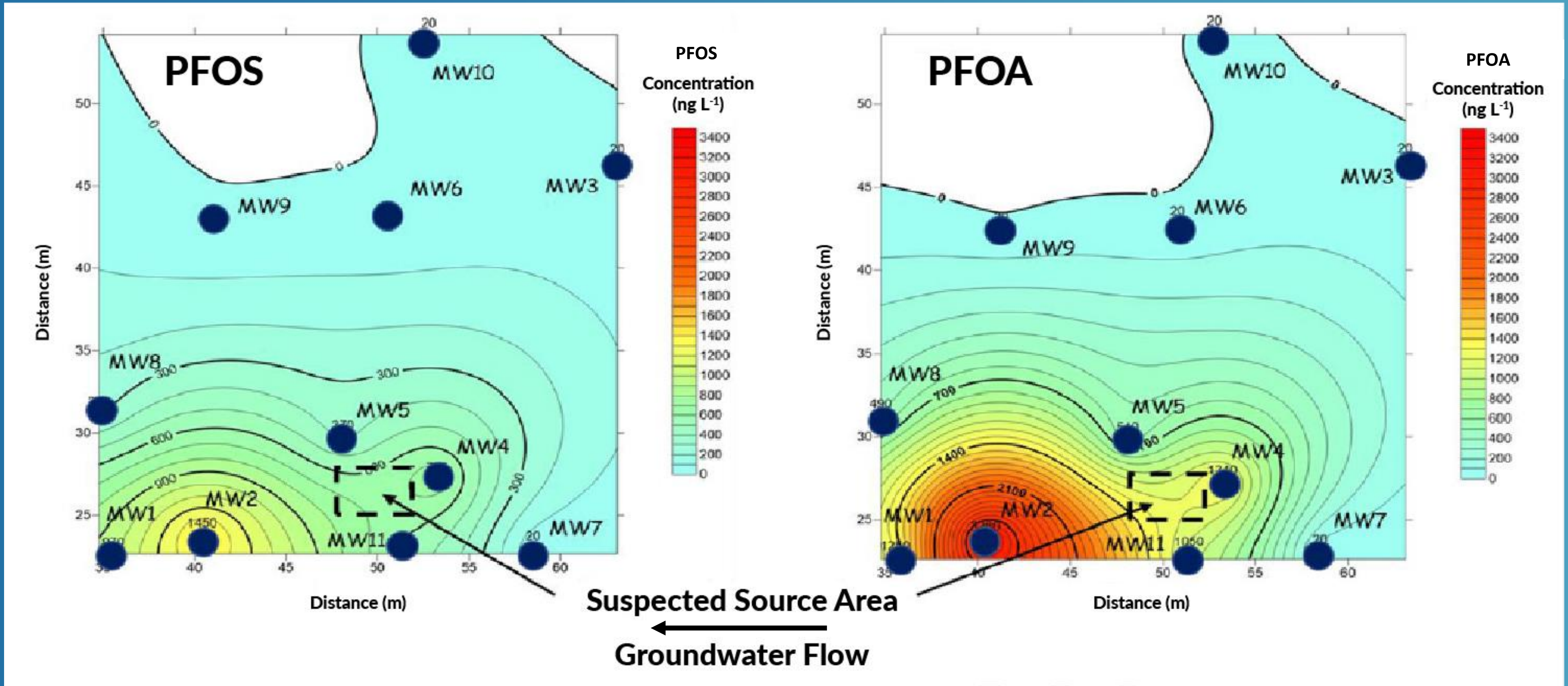
Rick McGregor

INSITU REMEDIATION SERVICES

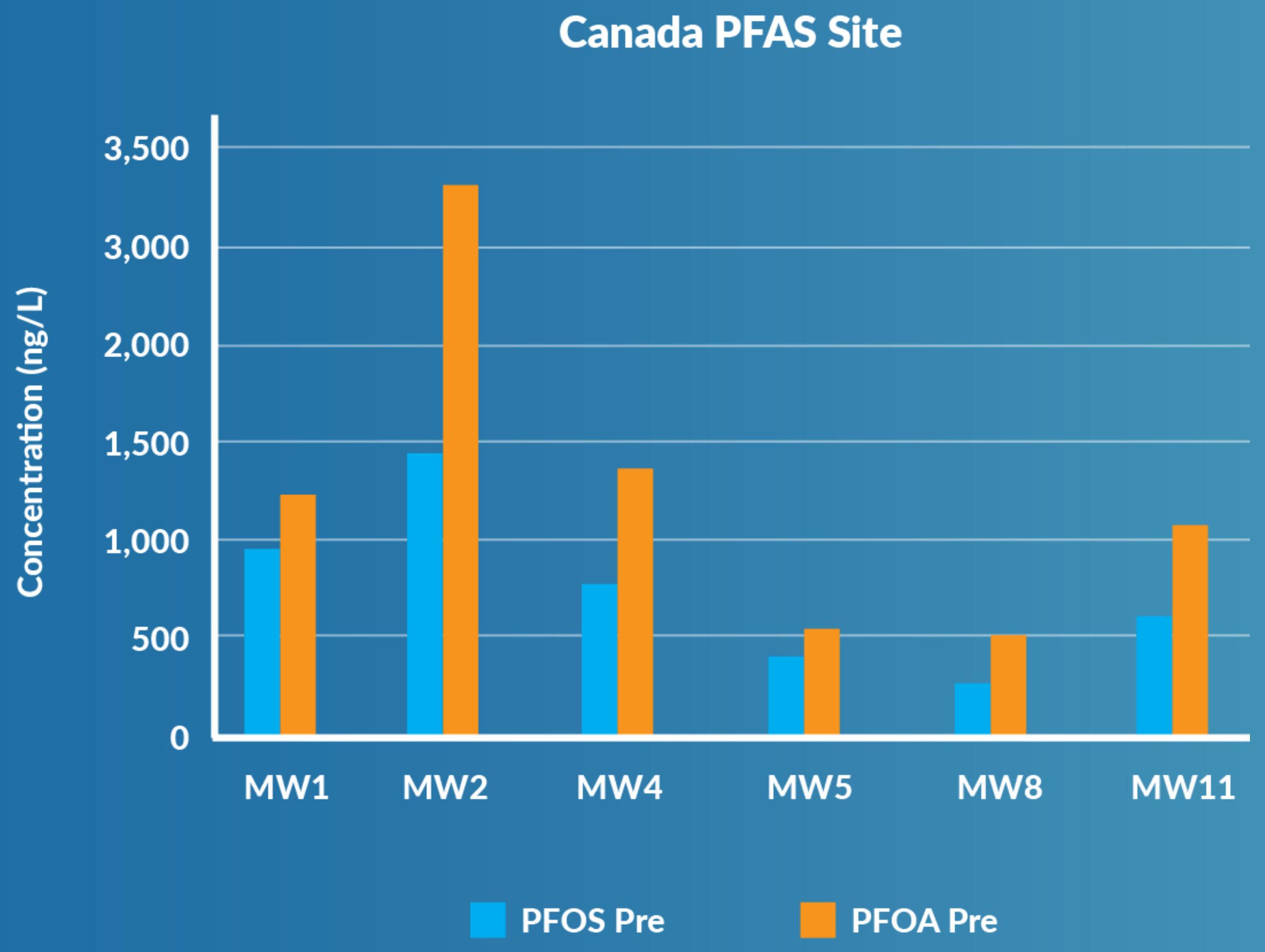
PLUME AREA DIAGRAM



EXTENT OF PFAS AND PFOA CONTAMINATION PRE-TREATMENT



PFAS FORMER FURNITURE SITE



Site Location:
Ontario, Canada

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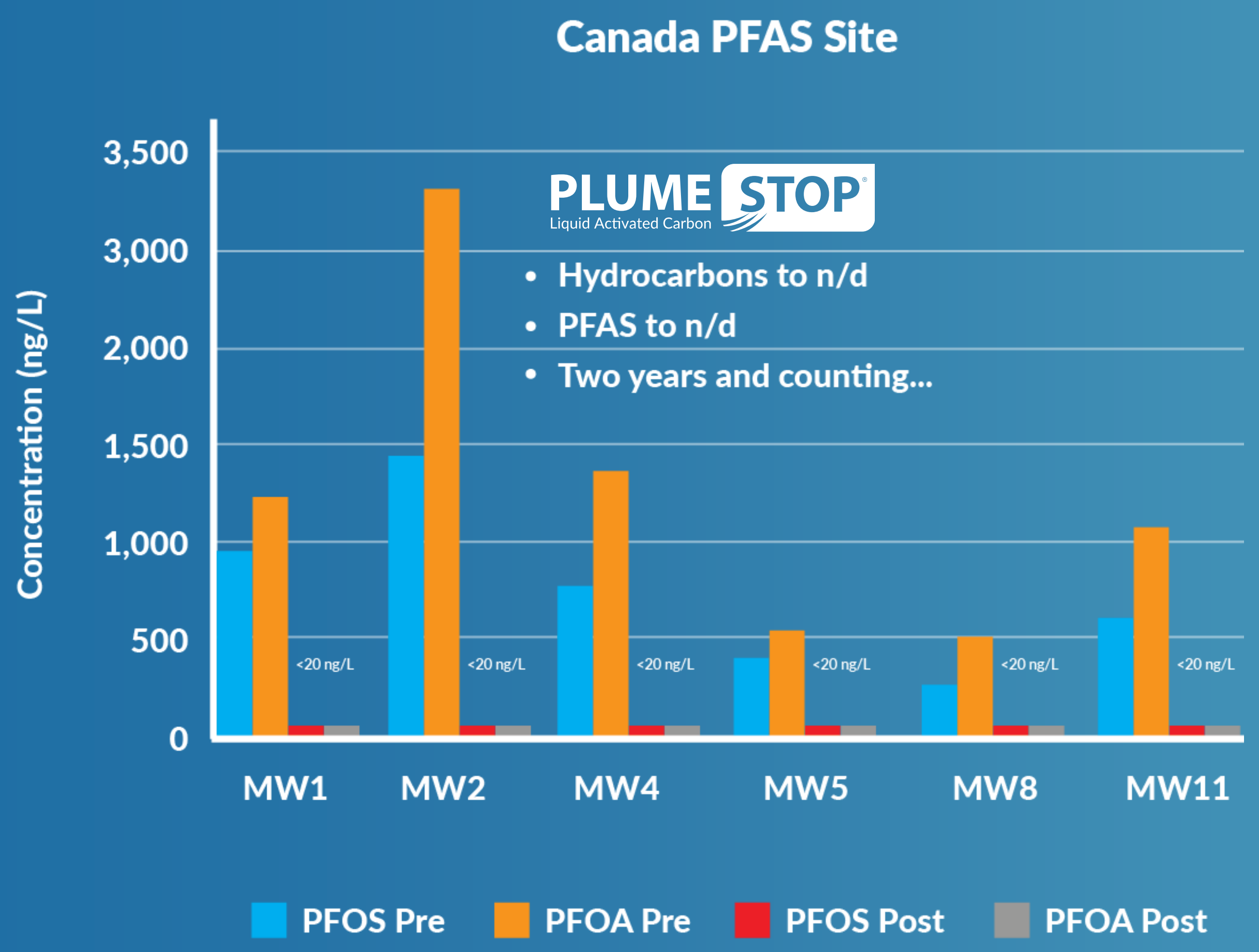
PFAS FORMER FURNITURE SITE



Site Location:
Ontario, Canada

REGENESIS

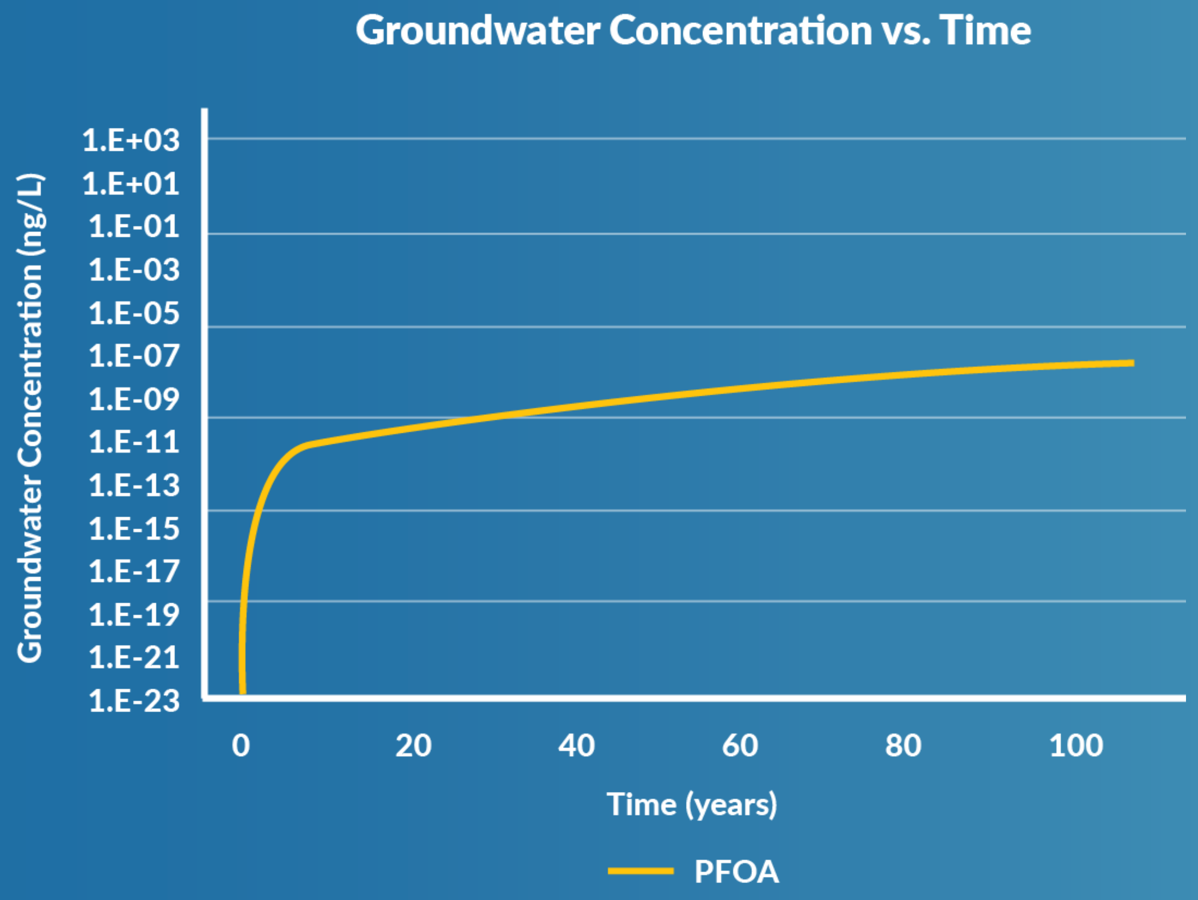
INDEPENDENT RESEARCH AND CALBIBRATION ONGOING

- Involved in independent PFAS research
- Modeled contaminant hydrogeology at project site
- Performed sensitivity analysis under a range of K_f values to estimate the longevity of capture

Grant Carey, PhD

Porewater Solutions
Expertise • Experience • Innovation

RESULTS



Long Term Results

- Modeled (Grant Carey, PhD)
  - Conservative Analytical Solution
    - Mass flux 161 ug/m²/day
    - Source half life 30 years
  - Source Zone PFOA
    - Strongly adsorbed
    - ~100 years 1×10^{-6} ng/L
  - Source Zone PFOS
    - Not as strongly adsorbed
    - ~100 years ~24 ng/L

COST COMPARISON

Actual Cost of PlumeStop Treatment

• Design, product and application (total)	$73,000
• Ongoing system O & M (ex. monitoring)	$0
	$73,000

Estimated Cost of Pumping & Treating (Most Efficient GAC)

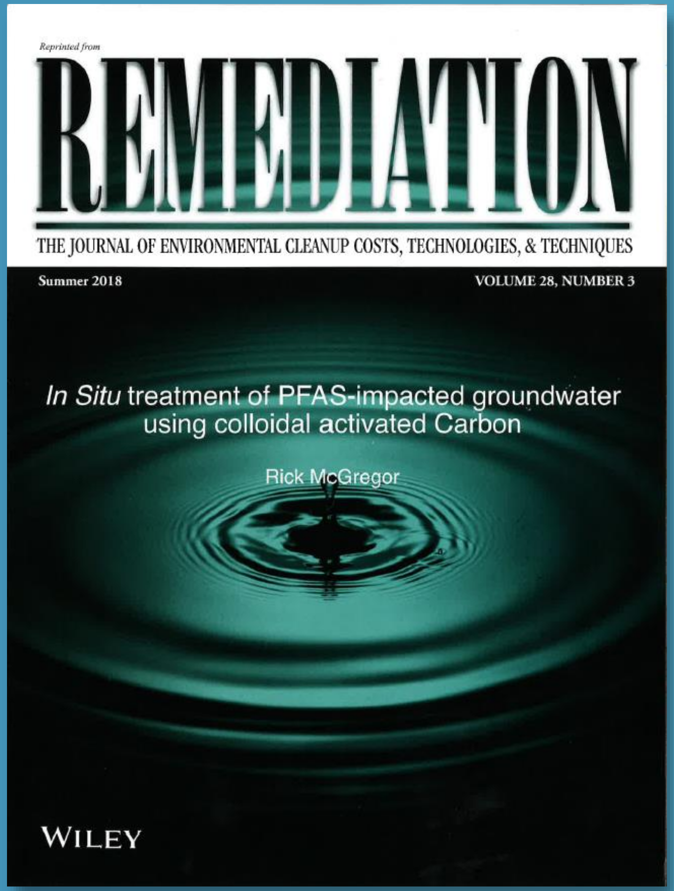
• Design, permitting, construction, startup	$150,000
• Ongoing system O&M	$1,200,000
• (ex. monitoring @ $60k/yr X 20 yrs)	
	$1,350,000

REMEDIATION MAGAZINE

Case Published:

REMEDIATION Journal

Volume 28, No. 2
Summer 2018
Wiley Press



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CASE STUDY

PFAS – SOLVENT RECOVERY FACILITY

CONNECTICUT

de maximis, inc.

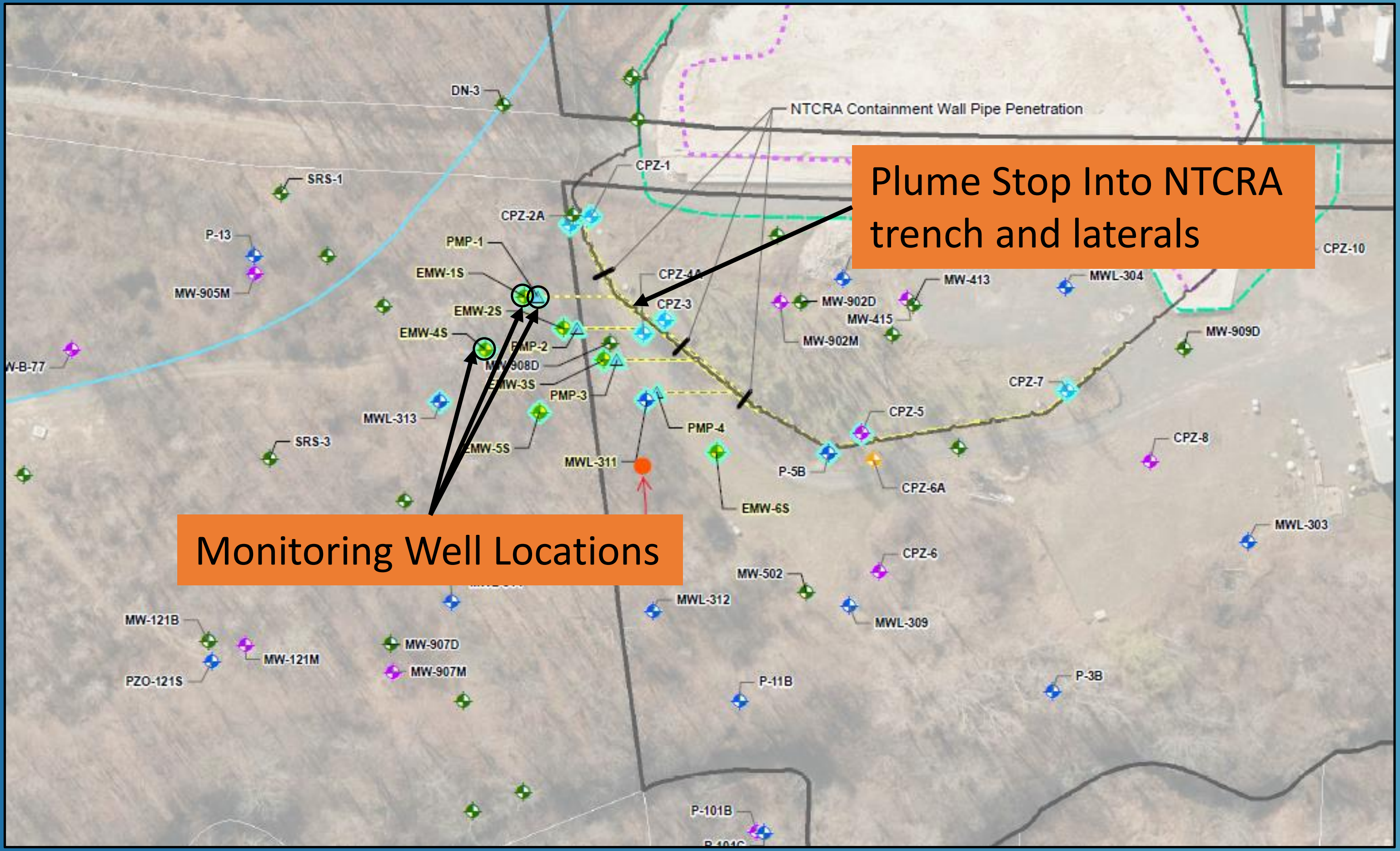
GEI Consultants

REGENESIS

Solvent Recovery Services of New England Superfund Site in CT

- Plume Stop and Aqua ZVI Application to address cVOC and PFAS contamination
- Target combined 5 compounds 70 ppt: PFOA, PFOS, PFNA, PFHxS, PFHpA
- Starting concentration: max 148ppt
- Applied Reagents in Trench and laterals
- Application July 23-25, 2018
- Aqua ZVI: 4,000 lbs
  Plume Stop: 21,600 lbs

Solvent Recovery Services of New England Superfund Site in CT

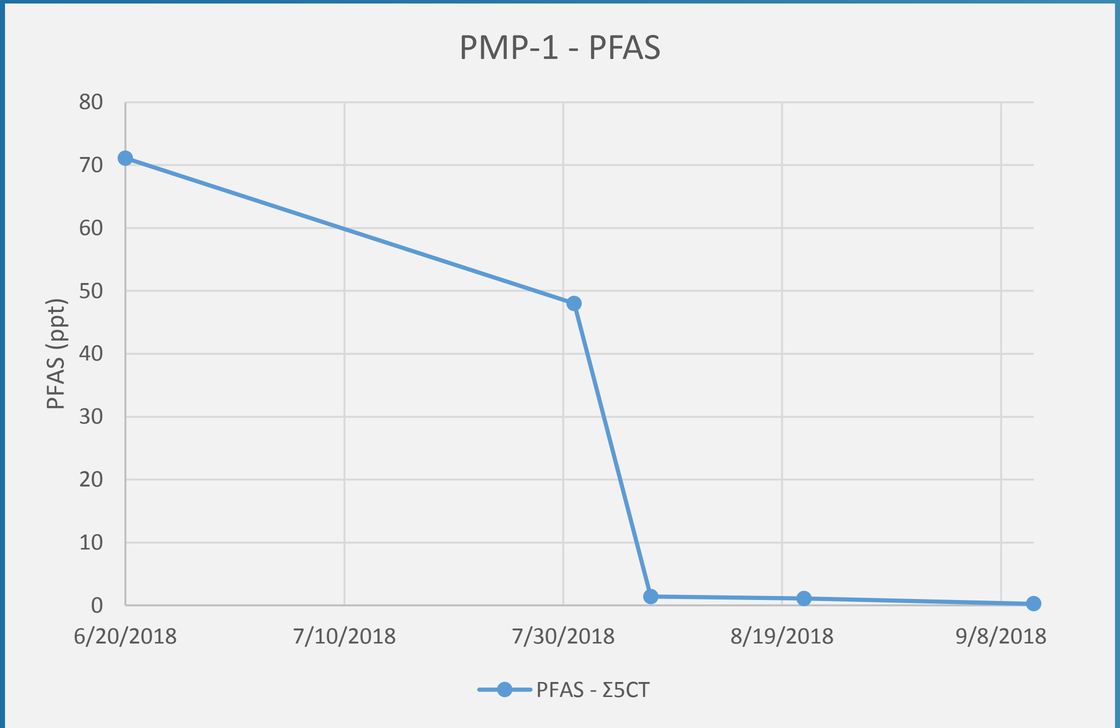


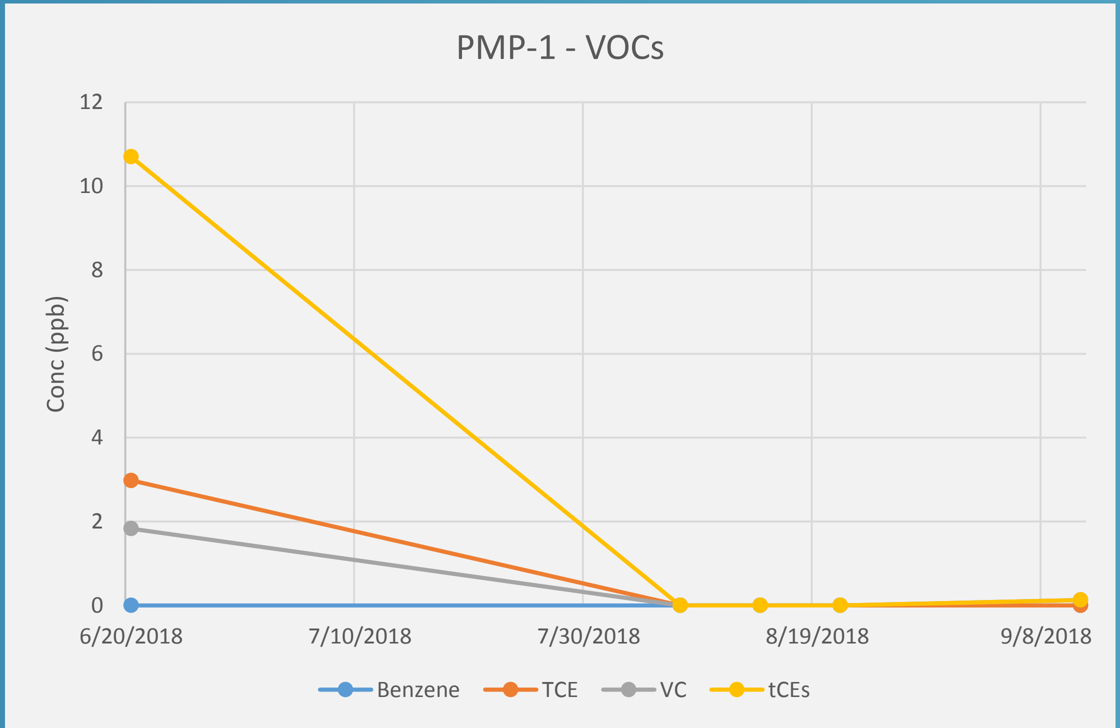
- 8,800 lbs of PlumeStop and 4,000 lbs of ZVI into the upgradient trench
- 12,800 lbs of PlumeStop into the downgradient trench (including four 50’ distribution trenches)

AEHS Poster 2018 Thompson et.al

REGENESIS de maximis, inc. GEI Consultants

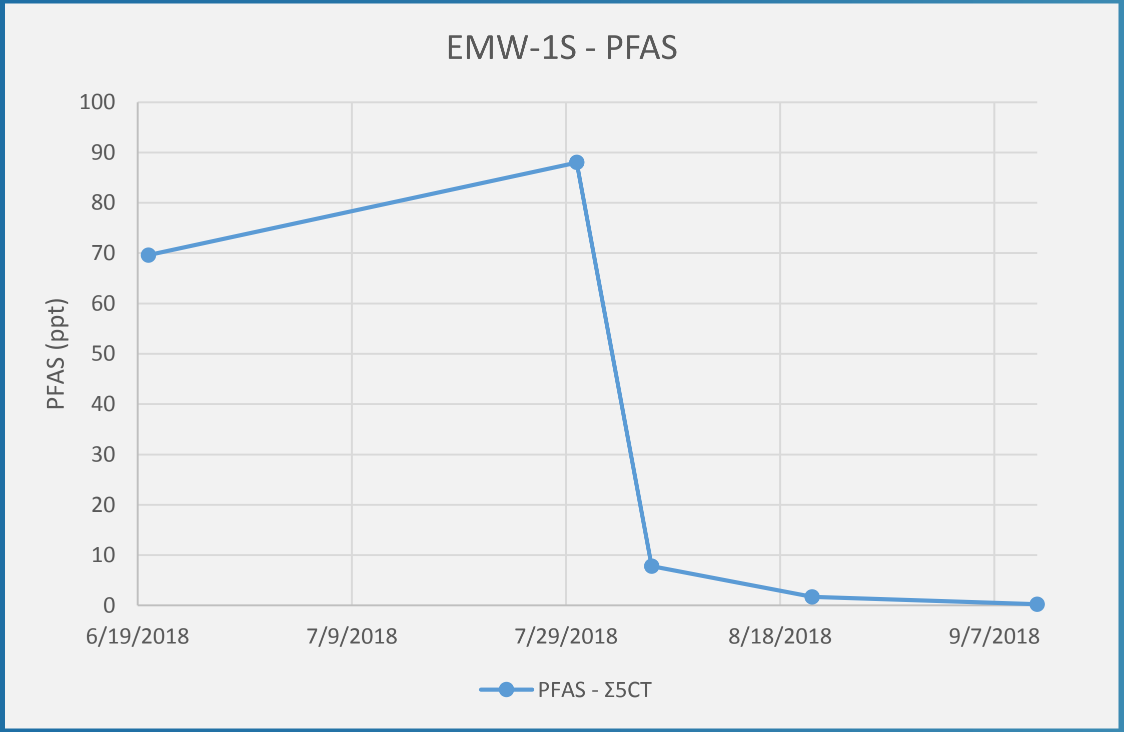
Results from PMP-1 (within trench)

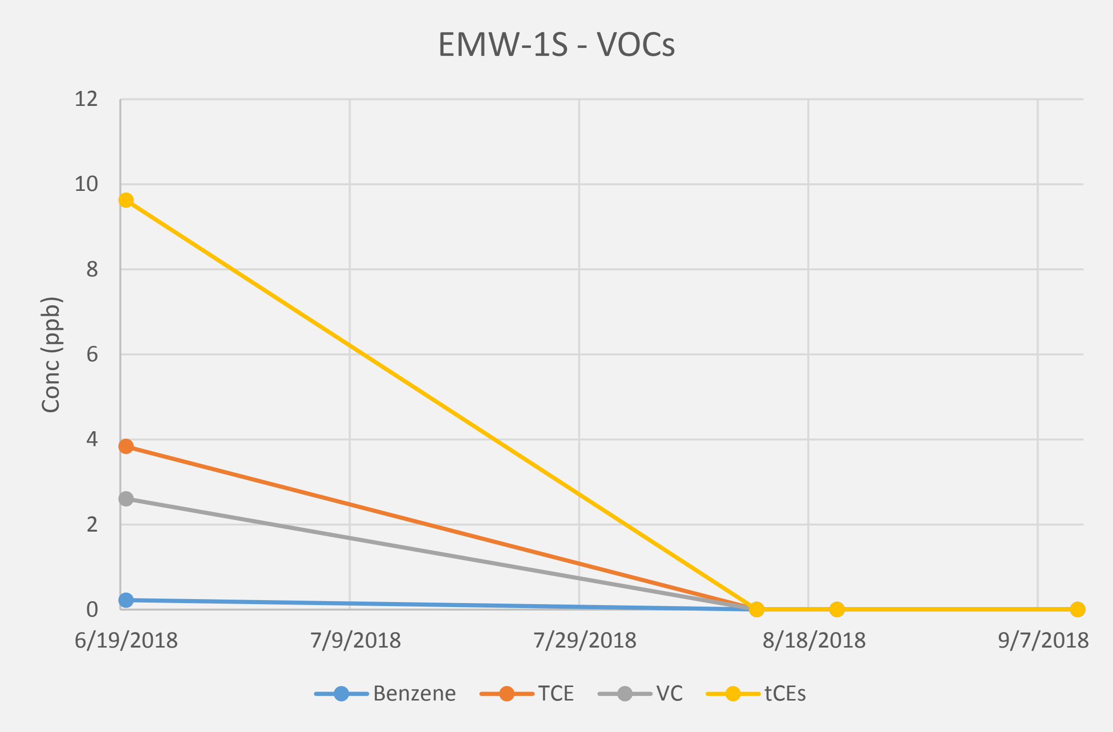




Σ5CT is sum of 5 PFAS compounds (PFOA, PFOS, PFNA, PFHpA, and PFHxS)

Results from EMW-1S (10 ft downgradient of trench)





Σ5CT is sum of 5 PFAS compounds (PFOA, PFOS, PFNA, PFHpA, and PFHxS)

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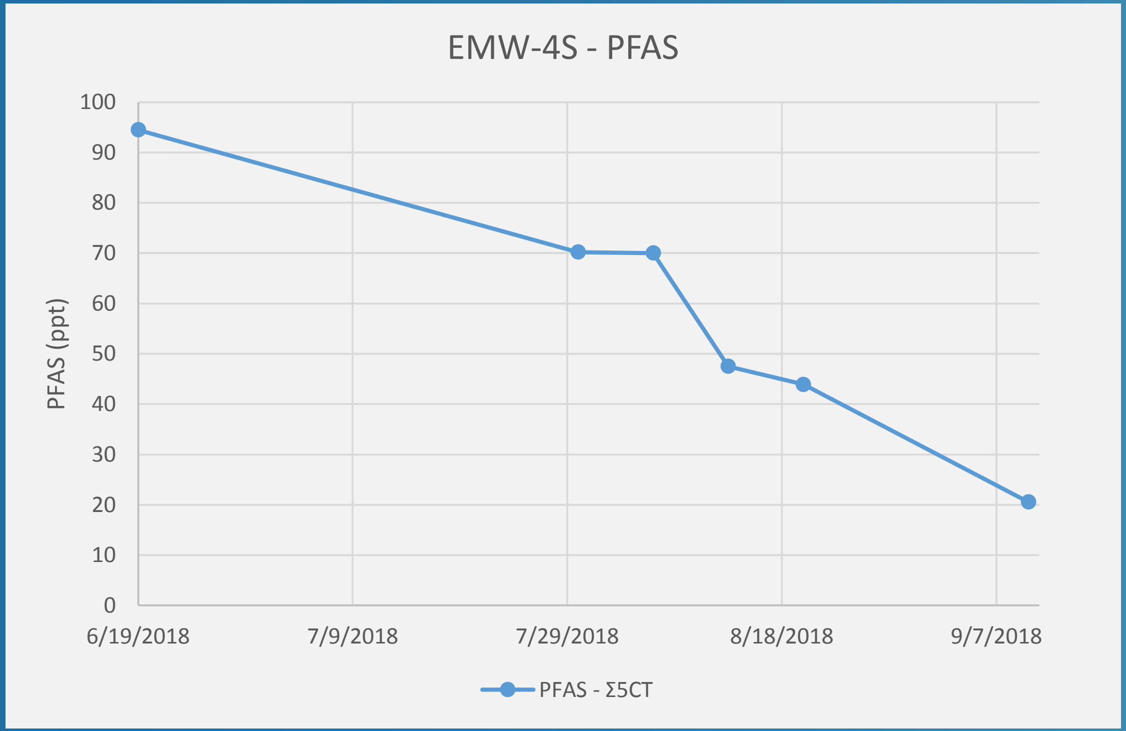
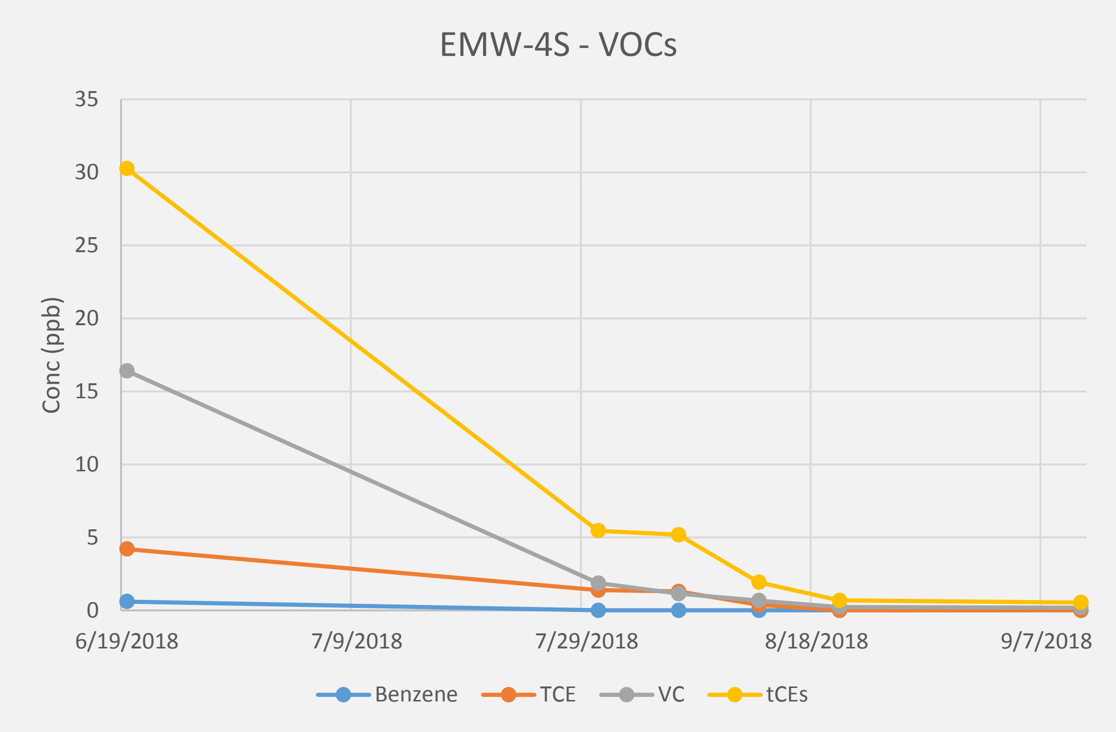
Results from EMW-4S (about 50 ft downgradient of trench)





Σ5CT is sum of 5 PFAS compounds (PFOA, PFOS, PFNA, PFHpA, and PFHxS)

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REGENESIS R&D LAB

Should we expect GAC and PlumeStop to work the same?

What about the shorter chain PFAS species, will they adsorb to PlumeStop?

- Lab studies
- Bench test with groundwater from an Italian site

REGENESIS

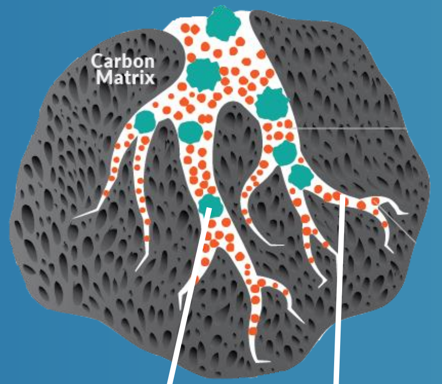
ACTIVATED CARBON PARTICLE SIZE AND ADSORPTION EFFICACY

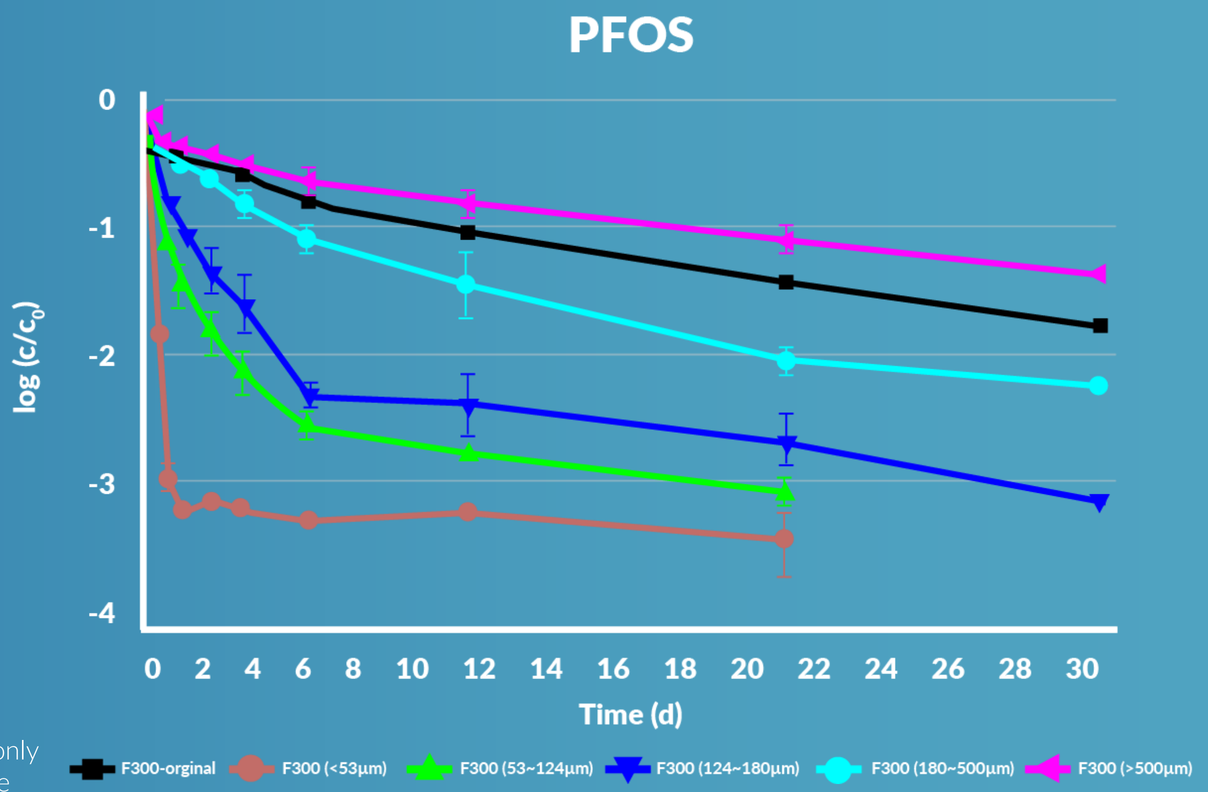
- Recent study demonstrated 2 OoM improved removal with smaller activated carbon particles
  - 180–500 mm AC removed 90% PFOS
  - <53 mm AC removed 99.9+% PFOS
- *GAC particles are less efficient at adsorbing PFAS than PlumeStop because of their size

Xiao, Ulrich, Chen & Higgins. Environ. Sci. Technol. 2017, 51, 6342-6351.

PFAS ADSORPTON KINETICS & PARTICLE SIZE

- The reason can be attributed to kinetics: intraparticle diffusion
- Smaller particles provide better access to all the sorption sites that activated carbon provides.





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PLUMESTOP PERFORMANCE SITE WATER BATCH TEST

Analyte (ng/L)	Units	Baseline		Control		Treated	
		Baseline 1	Baseline 2	Control 1	Control 2	Treated 1	Treated 2
4:2 fluorotelomersulfonate	ng/l	210	230	280	260	< 0.96	< 0.95
6:2 fluorotelomersulfonate	ng/l	6,900	7,600	7,800	7,800	< 2.9	< 2.9
8:2 fluorotelomersulfonate	ng/l	200	190	240	210	< 1.9	< 1.9
Perfluoro-octanesulfonate	ng/l	8,300	8,300	9,300	8,700	< 0.39	< 0.38
Perfluorobutanesulfonate	ng/l	78	75	89	85	< 0.29	< 0.29
Perfluorobutanoic acid	ng/l	920	930	950	880	34	34
Perfluorodecanoic acid	ng/l	< 10	< 9	9.4	< 8.8	< 0.96	< 0.95
Perfluoroheptanesulfonate	ng/l	94	99	93	94	< 0.39	< 0.38
Perfluoroheptanoic acid	ng/l	1,200	1,200	1,500	1,300	< 0.29	< 0.29
Perfluorohexanesulfonate	ng/l	1,700	1,800	2,000	2,100	< 0.39	< 0.38
Perfluorohexanoic acid	ng/l	4,500	4,600	5,200	5,000	< 0.39	< 0.38
Perfluorononanoic acid	ng/l	570	590	610	620	< 0.39	< 0.38
Perfluorooctanoic acid	ng/l	990	1,000	1,100	1,100	< 0.29	< 0.29
Perfluoropentanesulfonate	ng/l	110	100	110	110	< 0.39	< 0.38
Perfluoropentanoic acid	ng/l	7,800	7,700	9,000	8,000	< 1.9	< 1.9
Perfluoroundecanoic acid	ng/l	5	5	4.8	3.9	< 0.39	< 0.38
Total PFAS		**33,577**	**34,419**	**38,286**	**36,263**	**34**	**34**

SUMMARY

- PlumeStop is a Proven Technology
  - Treatment of CVOCS, Petroleum Hydrocarbons, and PFAS
- Eliminates the RISK of PFAS in groundwater
- Passive Plume Management
- Cost Effective!
  - Low Cap-Ex
  - Low Op-Ex

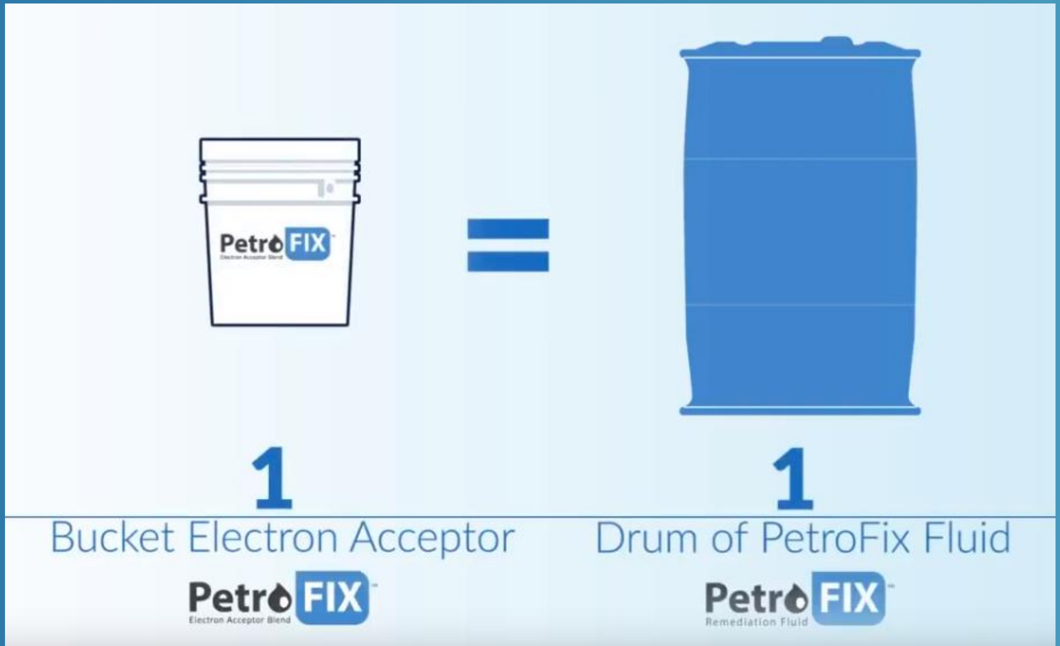
PETROFIX REMEDIATION FLUID

PetroFIX™ Remediation Fluid

REGENESIS®

COMPOSITION

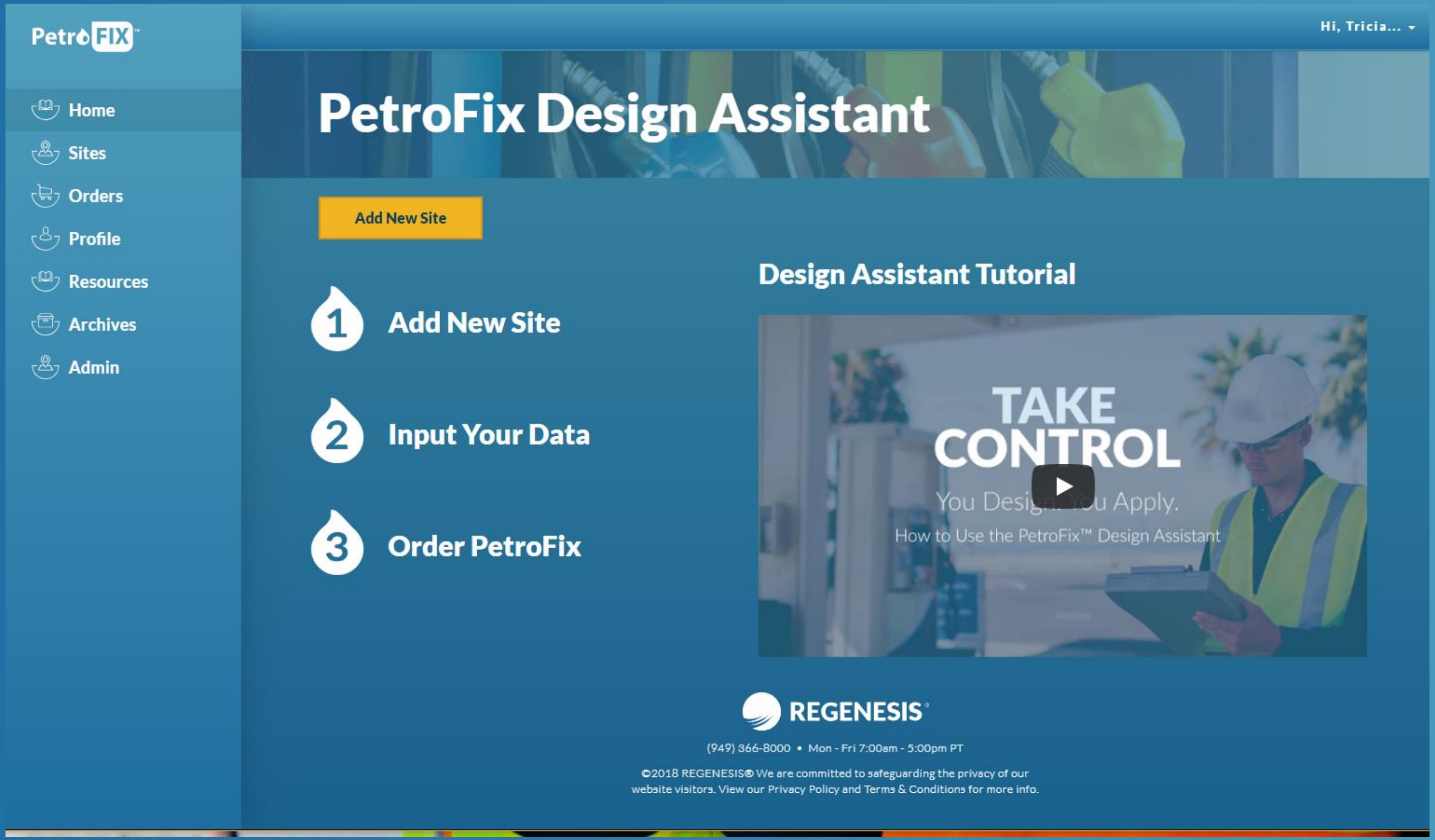
- Fluid, 400 lbs: 32 % activated carbon + slow-release sulfate
  - No transport polymers
- EA Blend, 20 lbs: nitrate/sulfate mix or sulfate salts only
  - Tech bulletin explaining PetroFix treatment approach



PetroFIX™ Remediation Fluid

REGENESIS®

PETROFIX DESIGN ASSISTANT

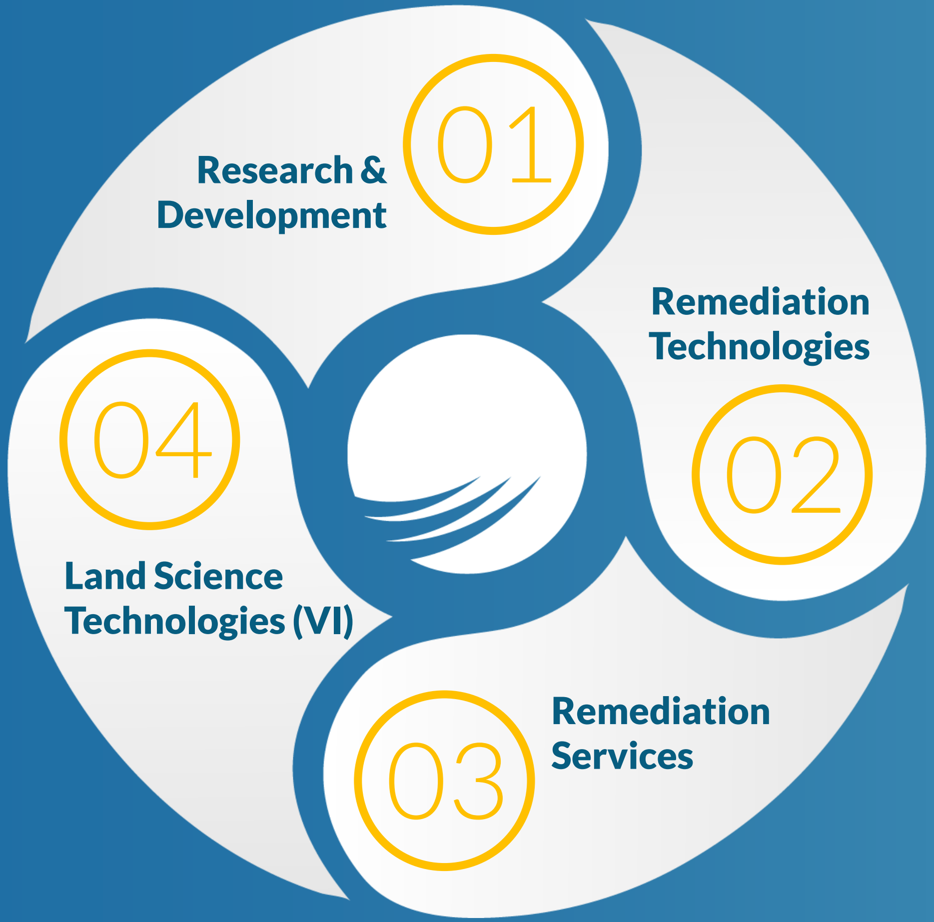


Design Assistant Lets You:

- Track Your Orders
- Manage Your Sites
- Recommends Designs
- Access Helpful Resources
- Archive Your Sites

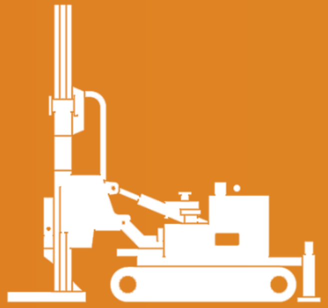
PetroFIX™ Remediation Fluid

REMEDIATION TECHNOLOGY CLASSES:



- Enhanced Aerobic Biodegradation
  - ORC-Advanced
- Enhanced Anaerobic Biodegradation
  - 3-D Microemulsion
- *In Situ* Chemical Oxidation (ISCO)
  - RegenOx
  - PersulfOx
- *In Situ* Chemical Reduction (ISCR)
  - Chemical Reducing Solution
  - AquaZVI
  - MicroZVI
- Bioaugmentation
  - BDI Plus
- *In Situ* Sorption and Biodegradation
  - PlumeStop
  - PetroFix
- Metals Immobilization
  - Metals Remediation Compounds (MRC)

REMEDIAL APPROACHES OFFERED:



DIRECT PUSH INJECTION

- In-Situ Chemical Oxidation (ISCO)
- In-Situ Chemical Reduction (ISCR)
- Bioaugmentation
- In Situ Sorption & Biodegradation
- Enhanced Aerobic Bioremediation
- Enhanced Anaerobic Bioremediation

HORIZONTAL DRILL:

- ISCO
- ISCR
- Bioaugmentation
- In Situ Sorption & Biodegradation
- Enhanced Aerobic Bioremediation
- Enhanced Anaerobic Bioremediation

WELLS

- ISCO
- ISCR
- Sorption
- Enhanced Anaerobic Bioremediation

EXCAVATION

- Soil Mixing & Handling

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Three core Technologies

federal and state regulatory approved

Geo-Seal®
Vapor Intrusion Barrier

Vapor-Vent™
Vapor Collection System

Retro-Coat™
Vapor Intrusion Coating

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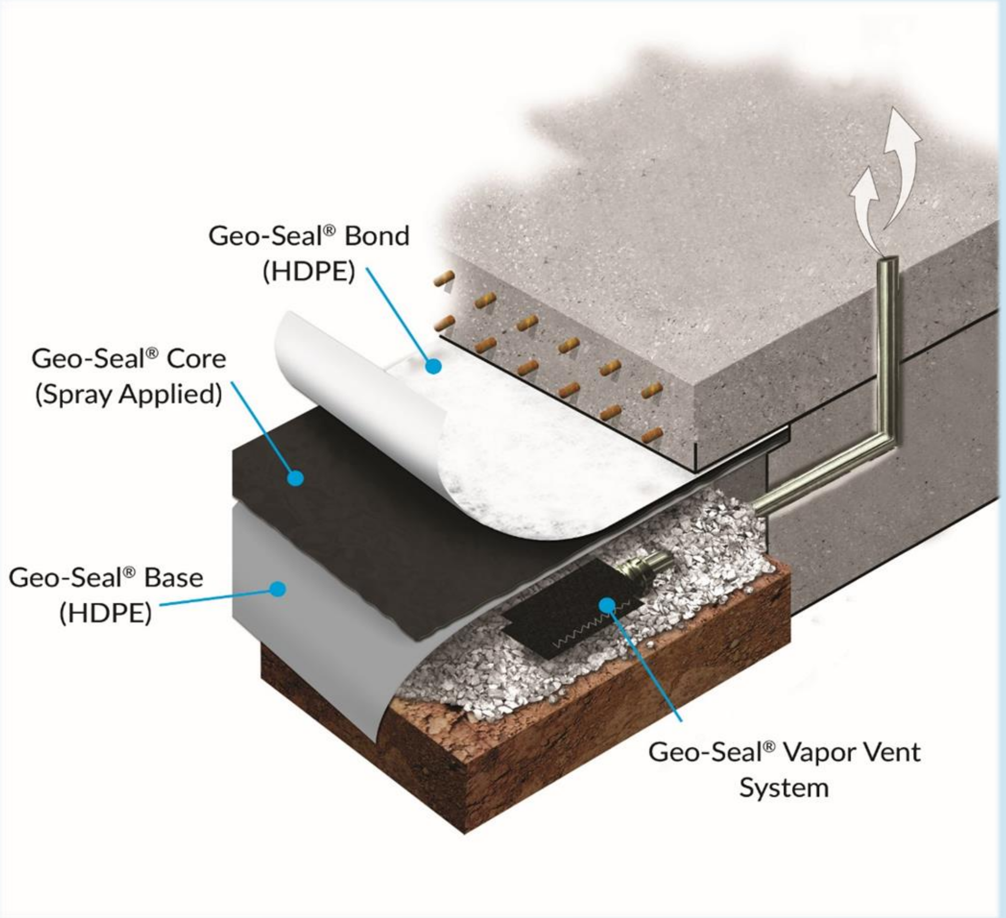
Geo-Seal®
Vapor Intrusion Barrier



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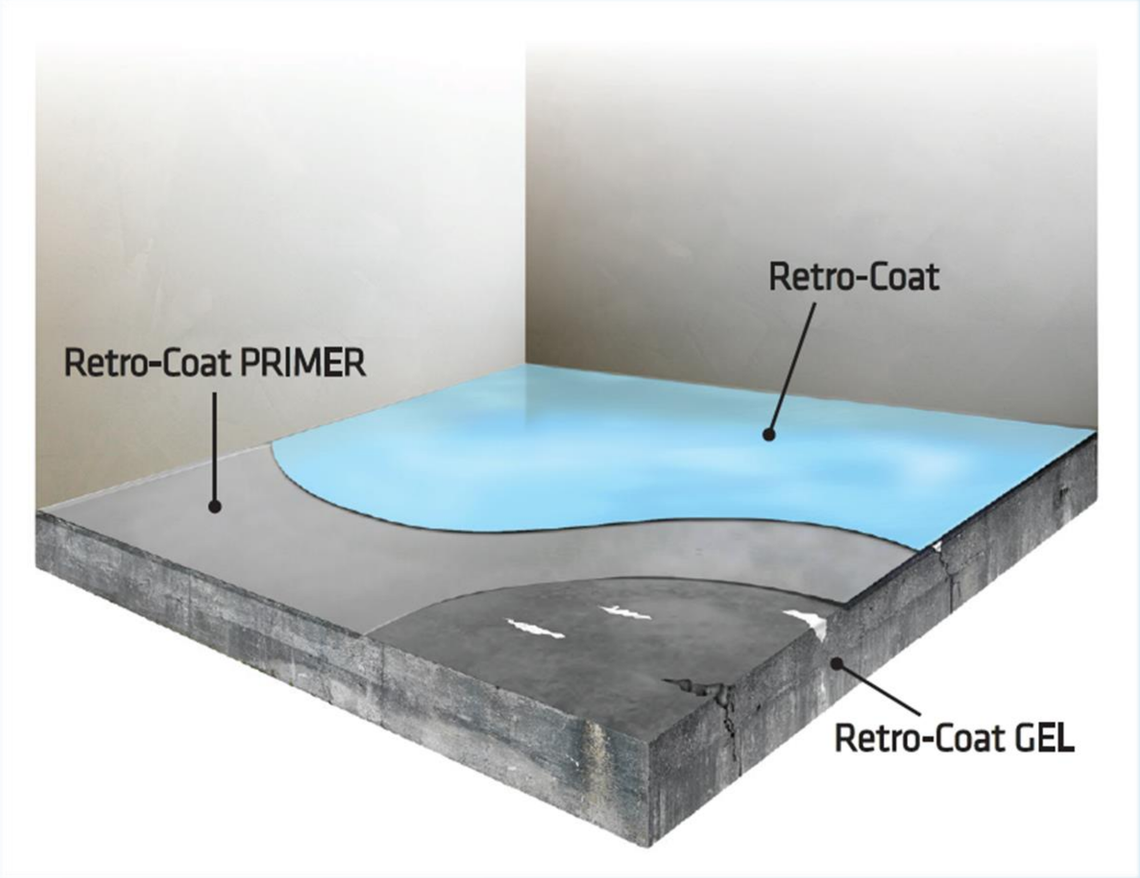
Retro-Coat™

Vapor Intrusion Coating



Thank You!

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REGENESIS® REMEDIATION SERVICES
Technology-Based Solutions for the Environment

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