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Technology-Based Solutions for the Environment

Estimation of Sorbed-Phase Biodegradation Rate in Activated Carbon Barriers

Microbial Diagnostics – CSIA – *in situ* Microcosms

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mi microbialinsights

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Contents

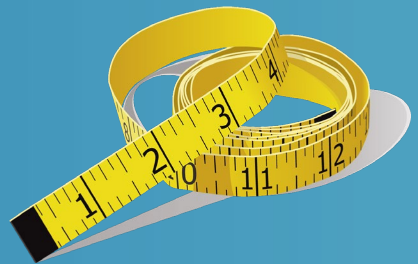
- Injectable Activated Carbon Barriers
  - plume management without pumping
- Coupling Sorption with Biodegradation
  - bioregeneration of capture capacity
- Field Validation and Rate Measurement
  - calibration for engineering control

The Challenge

In situ remediation performance is typically tracked using groundwater samples

So what to do when concentrations are non-detect within a colloidal carbon barrier?

How can we *quantify* net destruction rate to improve engineering control?



This talk

Estimation of post-sorption degradation rates using ***in situ* microcosms** (ISMs)

Injectable activated carbon – fundamentals

PLUME STOP™
Liquid Activated Carbon

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Booth # 134/6

Fundamentals

Plume Management – Barrier Configuration

Keeping it simple…

Bioregeneration of sorption sites extends barrier longevity

Fundamentals

- **The carbon quantity is tiny**
  - Groundwater flow is not affected
- **The capture efficiency is high**
  - Contaminant advection is slowed significantly
- **The groundwater may flow through the barrier in days**
  - The contaminants may take years to pass through
- **Biodegradation in the barrier extends its performance**
  - If the rate is fast enough the extension is indefinite

Key parameters

Barrier performance is the interplay of two modelling parameters:

- **Contaminant Retardation Factors**
- **Contaminant Degradation Rates**

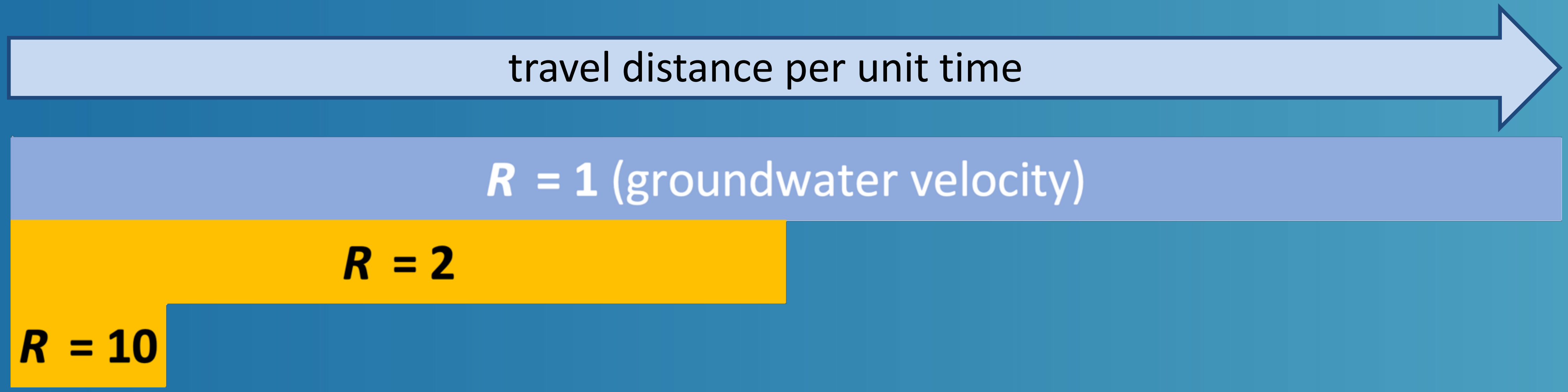
Retardation splices more treatment time into a shorter distance

Degradation rate determines if breakthrough will ever occur

Retardation-Factors

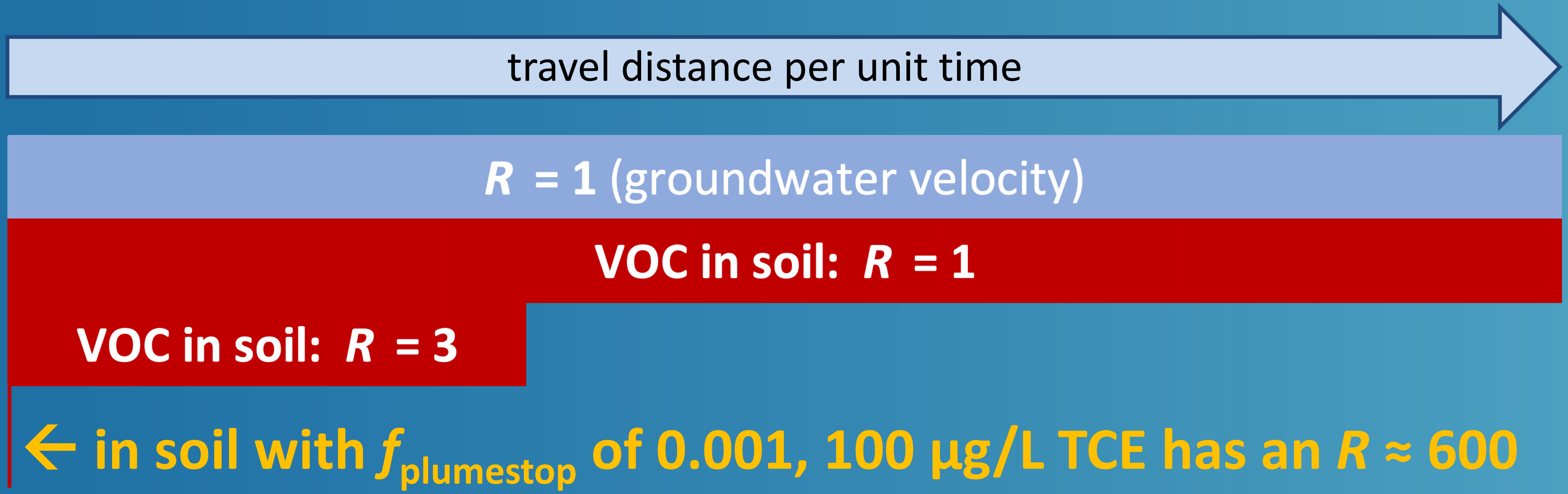
Managing plumes via the retardation factor *R*

- The Retardation Factor (*R*) determines how fast a contaminant moves relative to the groundwater.



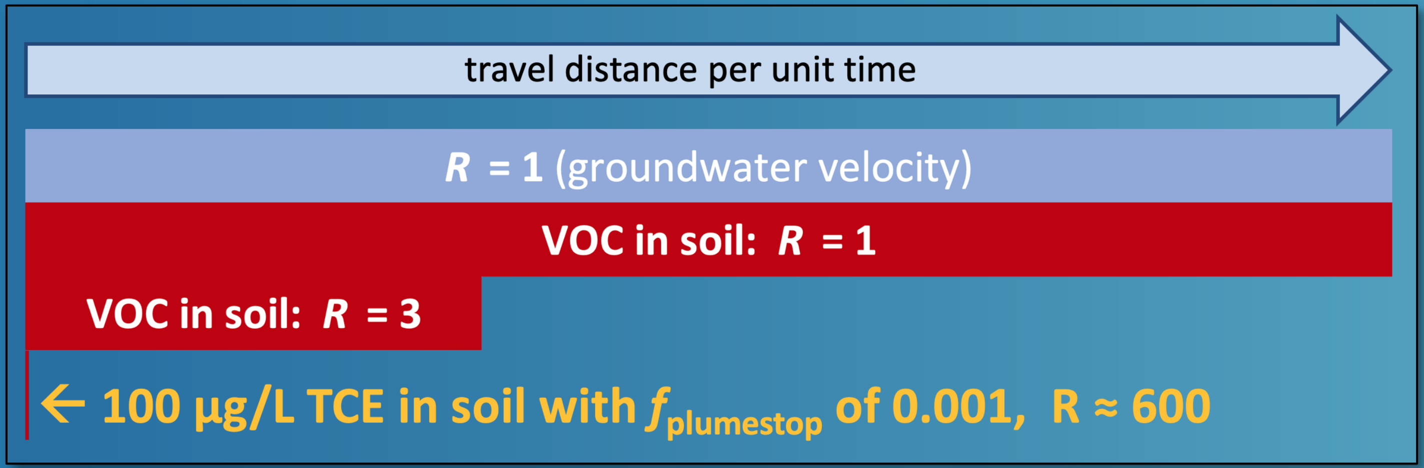
Managing plumes via the retardation factor *R*

- The Retardation Factor (*R*) determines how fast a contaminant moves relative to the groundwater.



Managing plumes via the retardation factor *R*

- The TCE may therefore have **one month** to degrade in a bio-only barrier
- But it will have **16 years** to degrade over the same distance if PlumeStop® is added
- This translates to better performance and greater security



Field Validation and Rate Measurement

- *R* as installed can be validated through soil cores or tracer tests

Challenge:

- But how to determine bio rates if the dissolved phase is non-detect?
- Solution – *in situ* microcosms (ISMs)
- Key – data resolution sufficient for purpose

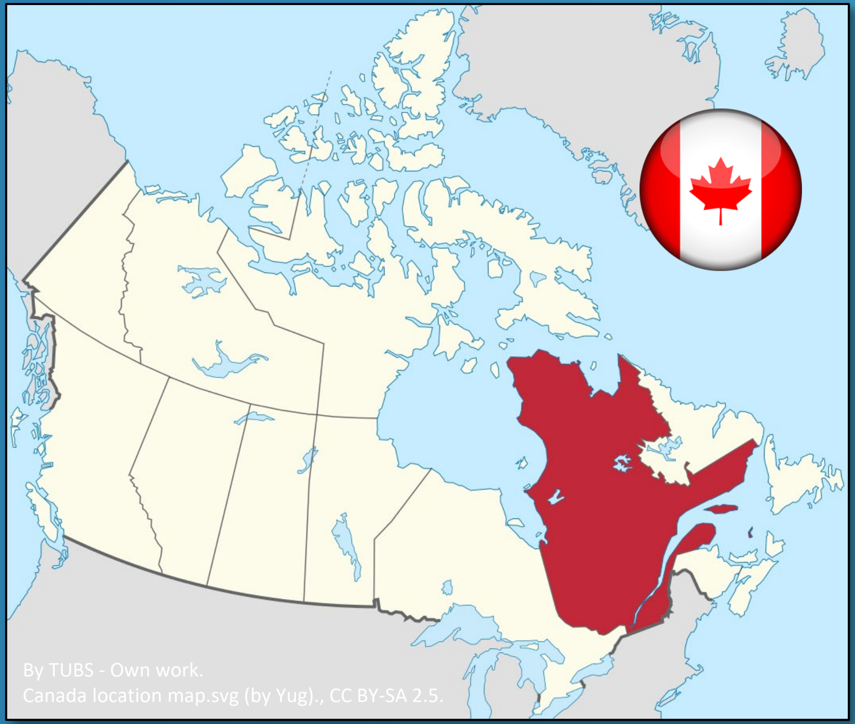
In Situ Microcosms

collect and dry saturated soils

place soil into screened housings

deploy before amendment application

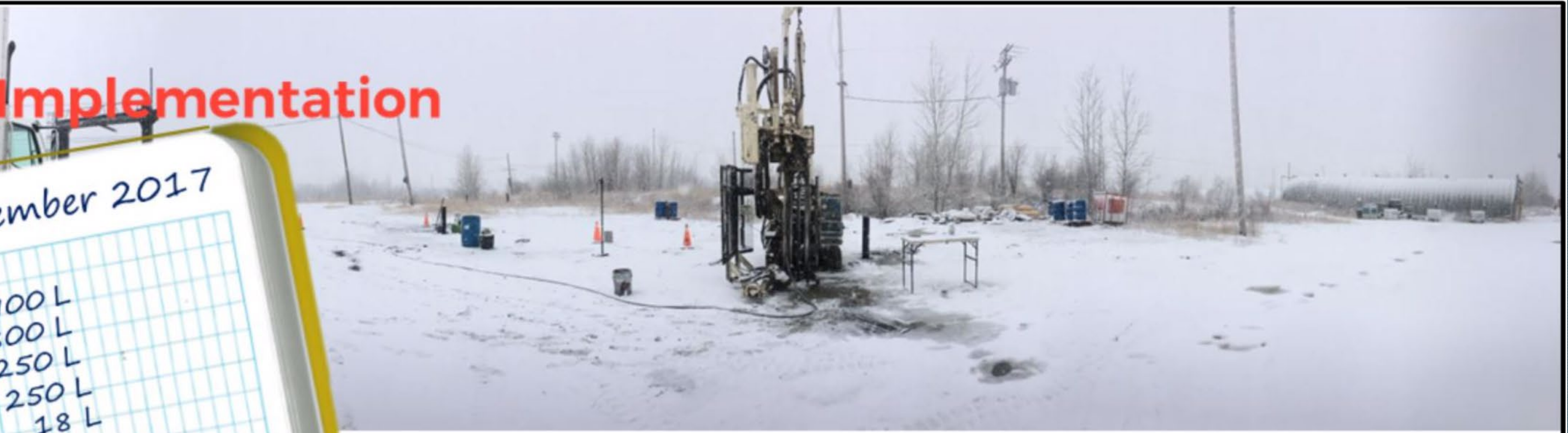
ISM Usage Example



Quebec, Canada
Rail Yard, VOCs

Matt Burns

Implementation



November 2017

Amendments
- PlumeStop: 1,900 L
- AquaZVI: 800 L
- HRC Pimer: 250 L
- HRC: 250 L
- Augment: 18 L

Dilution/Chase Water
- Potable Water: 25,000L

Total Fluids:
- Wast + Amendment: 28,000
- Aproximately 10% of mobile porosity within treatment zone

Observations
- Pressure: 20 to 40 psi
- Some back pressure
- Amendment observed and some geochemical shifts in wells within treatment area

ISM Usage Example – Quebec Rail Yard

Chlorinated ethenes / ethanes

- ∑ Tri – 4,500 µg/L
- ∑ Di – 13,000 µg/L

Soil type

- Heterogeneous silt and sand

Treatment

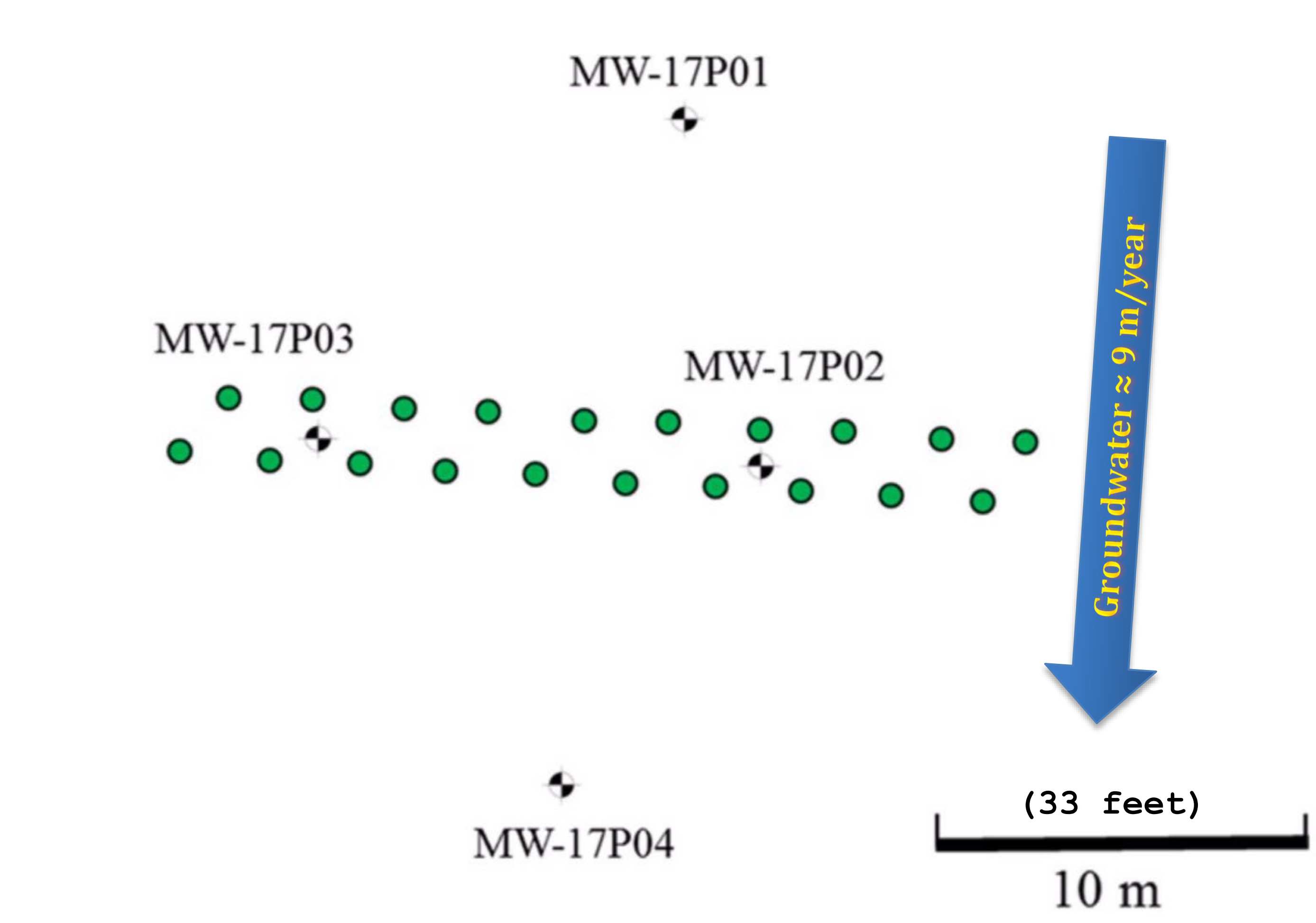
- 26' – 46' bgl (8 – 14 m)

Seepage velocity

- 30 ft/year (9 m/year)

Barrier

- 16' x 100' x 20' d
- 5 m x 30 m x 6 m d



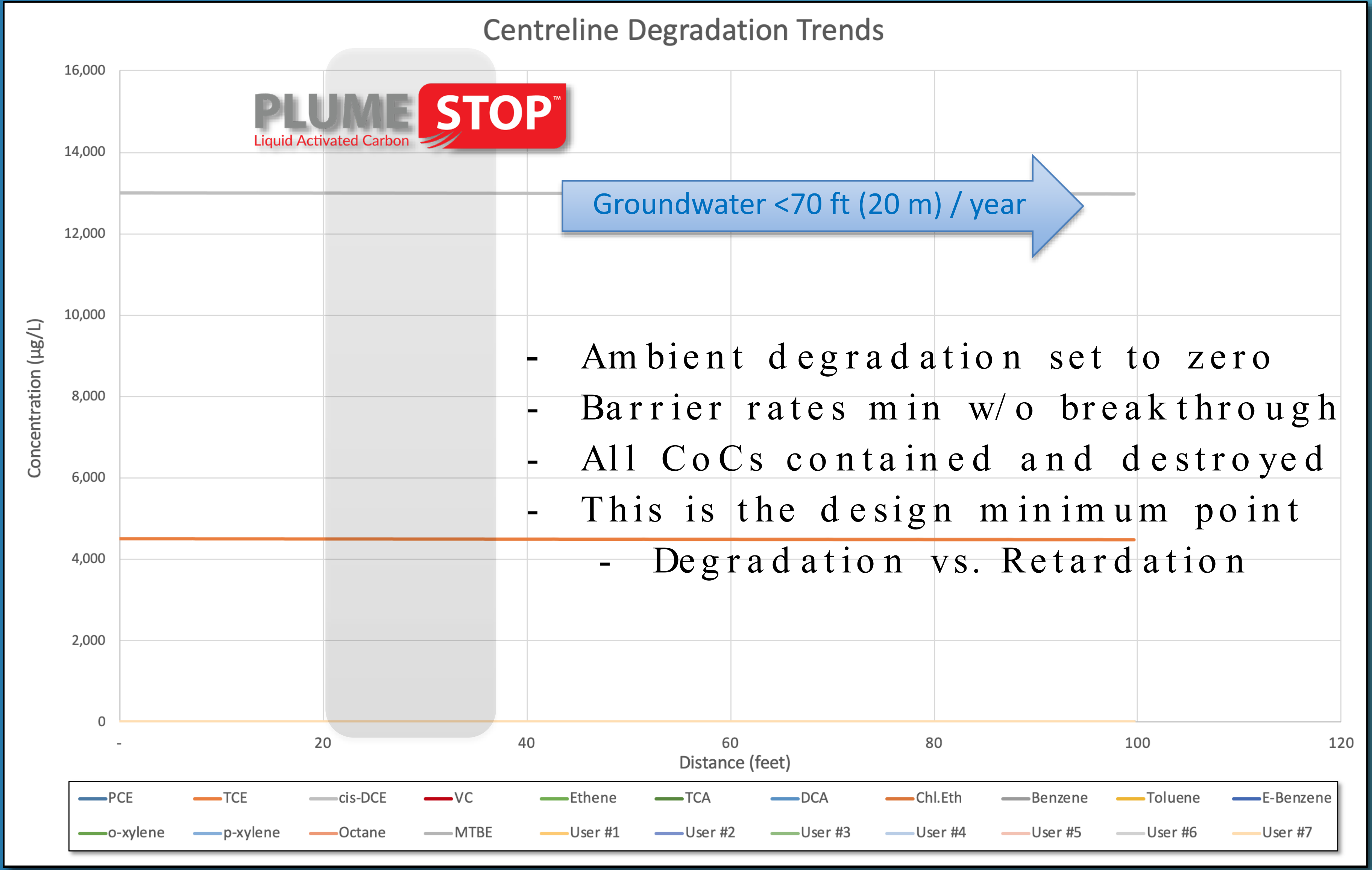
Design Model - Quebec Rail Yard
(Post LAC™ Application)

Deg. Rates k (as $t_{\frac{1}{2}}$)
100 days (TCE, DCE)
30 days (VC, ethene)

Retardation Factors (R)
- dynamically variable
  - convex isotherms
  - competitive sorption
  - **range 10's to 1000's**

f_{oc} = 0.001
$f_{PlumeStop}$ = **0.0003**

LAC™ Emplaceable Range:
~0.0001 – 0.02 (∴0.0003 ≈ 1.5%)



Design Model - Quebec Rail Yard

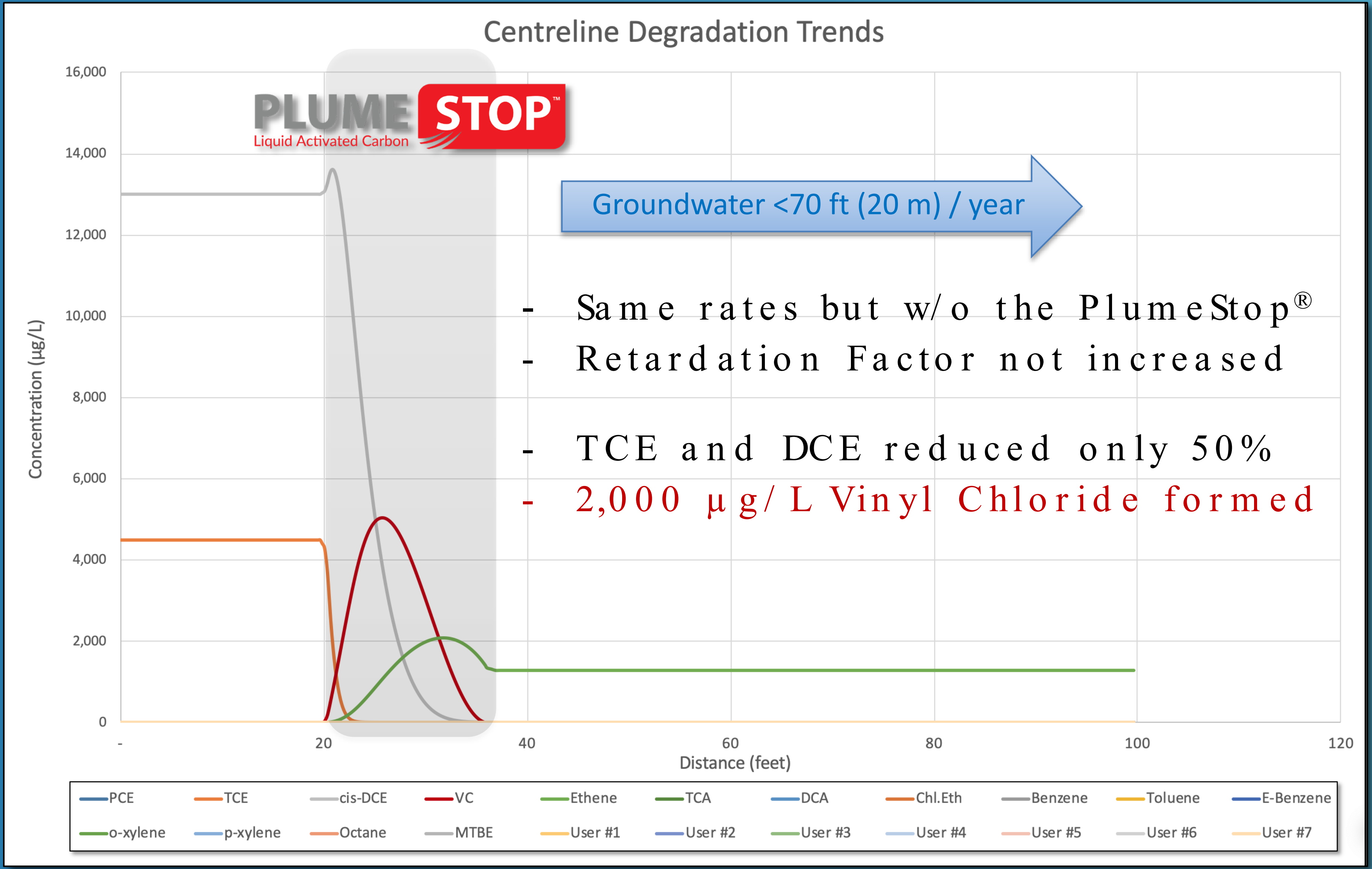
(*No* LAC™ Application)

Deg. Rates *k* (as $t_{\frac{1}{2}}$)
100 days (TCE, DCE)
30 days (VC, ethene)
- (all unchanged)

Retardation Factors (*R*)
- TCE = 1.81
- DCE = 1.53
- VC = 1.02

f_{oc} = 0.001
$f_{PlumeStop}$ = **zero**

Bio rates would have to be
<10 days (TCE, DCE)
< 3 days (VC)
for compliance w/o retardation
(in the Quebec winter)



Design Model - Quebec Rail Yard

(i.e. Post LAC™ Application)

Deg. Rates k (as $t_{\frac{1}{2}}$)
100 days (PCE, TCE, DCE)
30 days (VC, ethene)

Retardation Factors (R)
- dynamically variable
  - convex isotherms
  - competitive sorption
  - range 10's to 1000's

f_{oc} = 0.001
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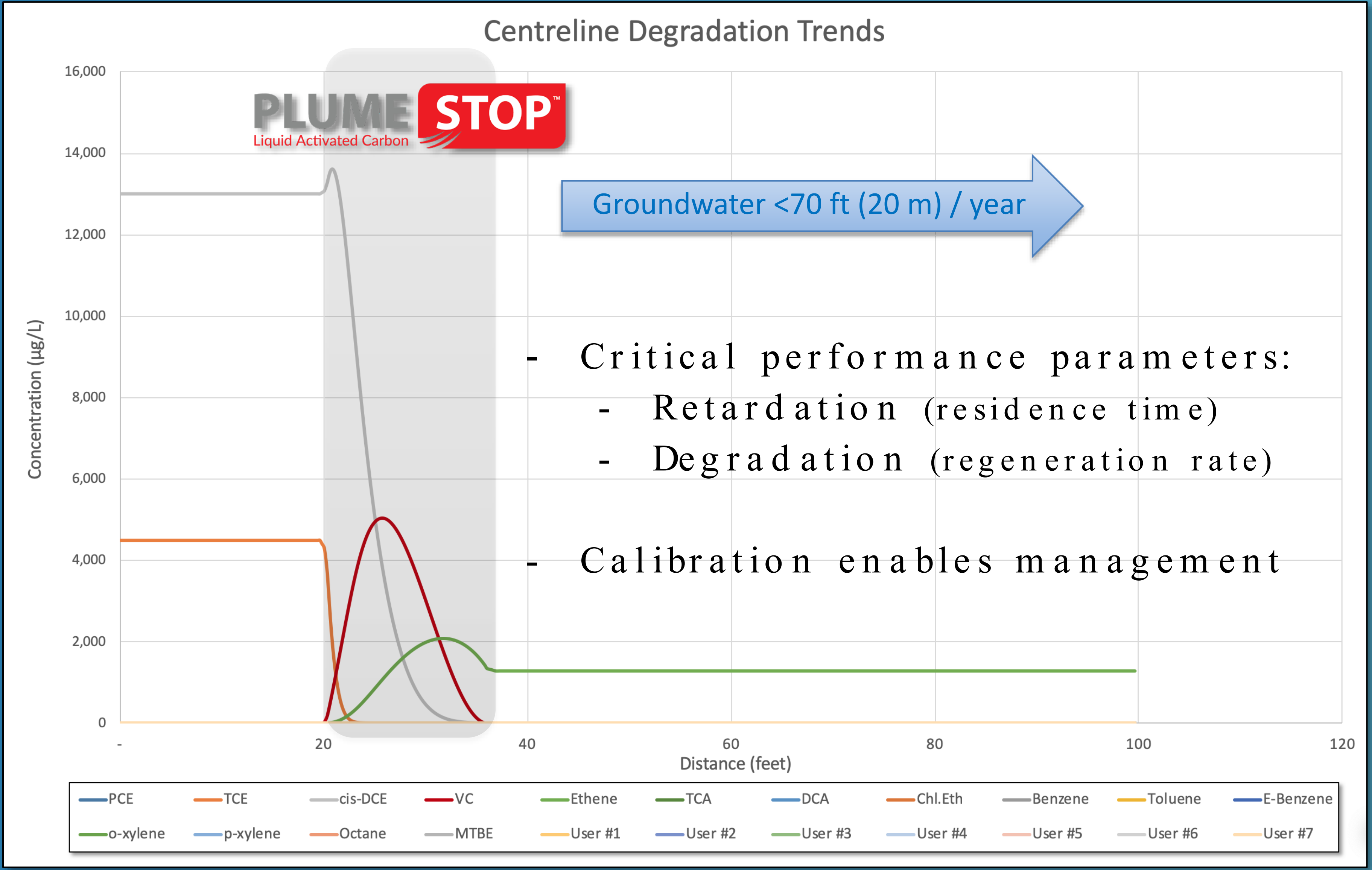
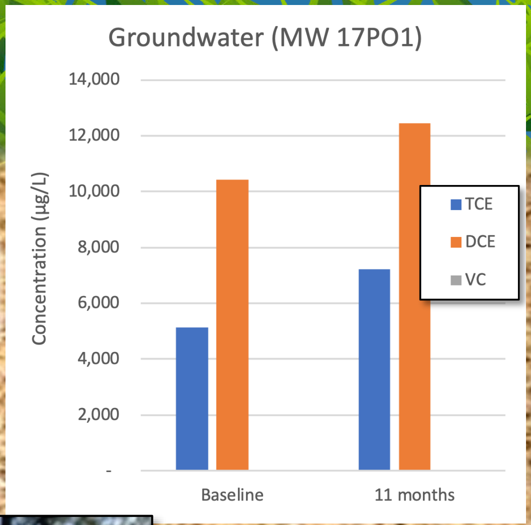
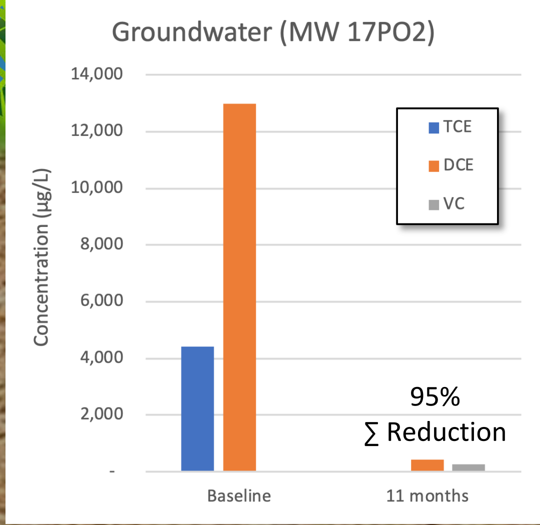
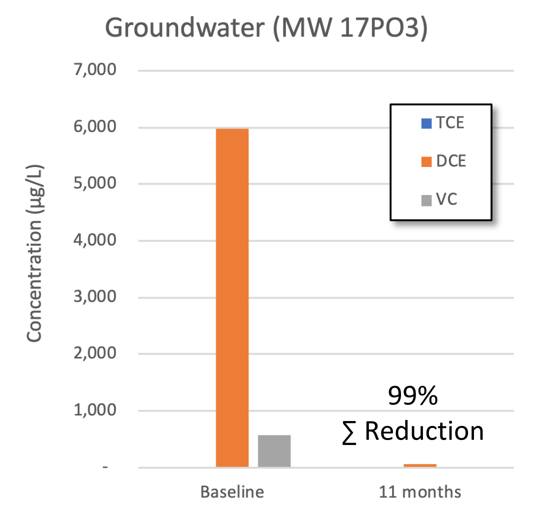


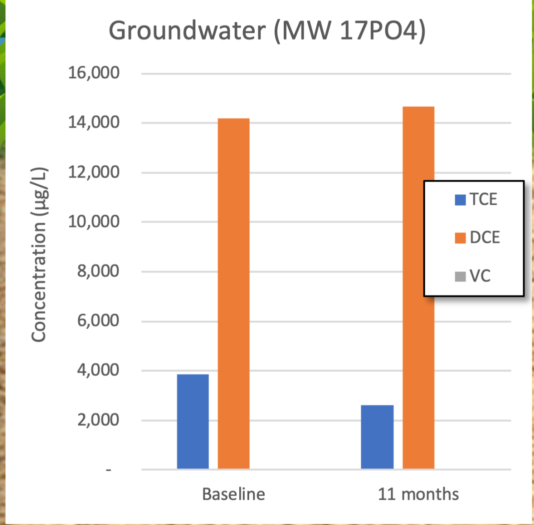
Contaminant Destruction (11 months)

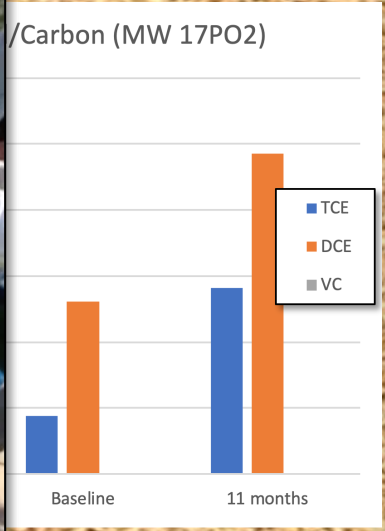
Water →

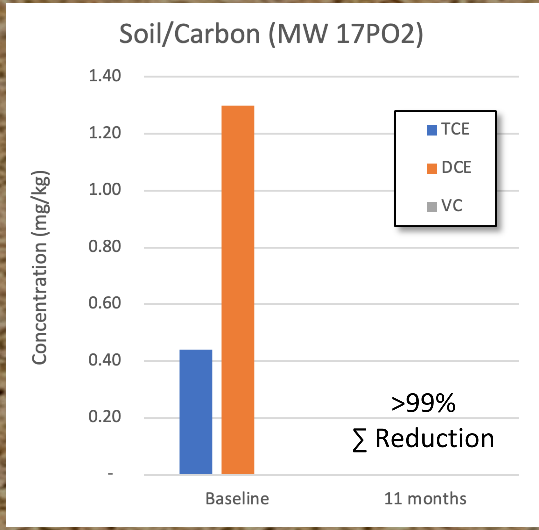


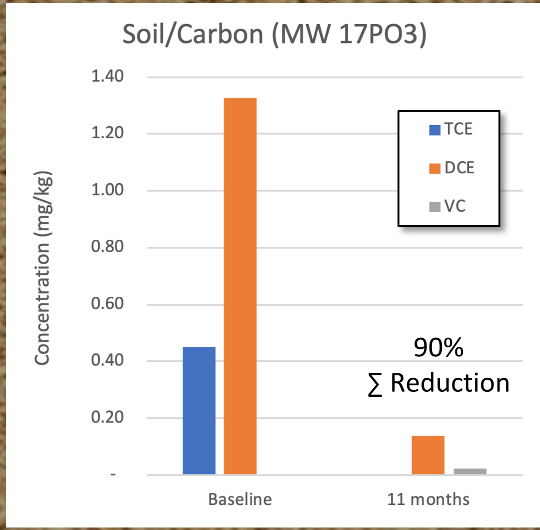


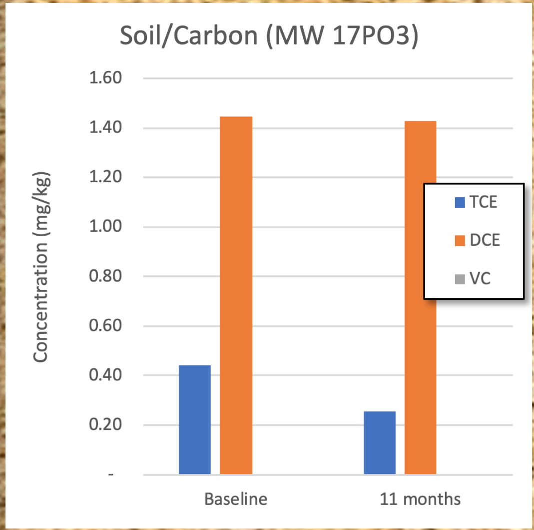








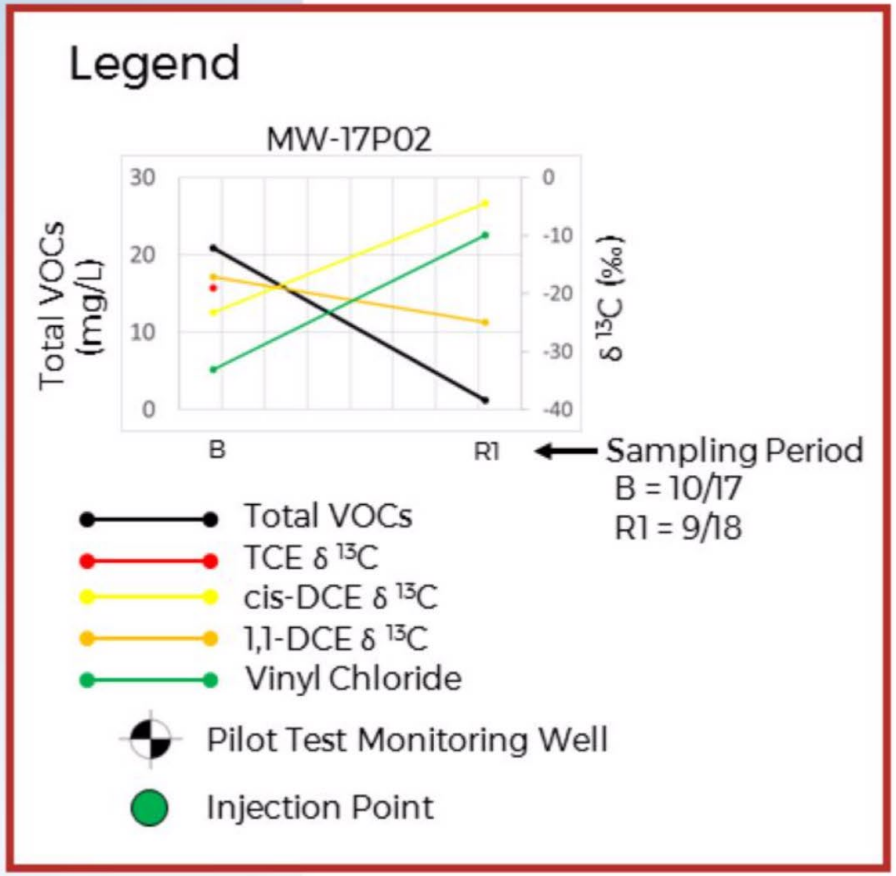


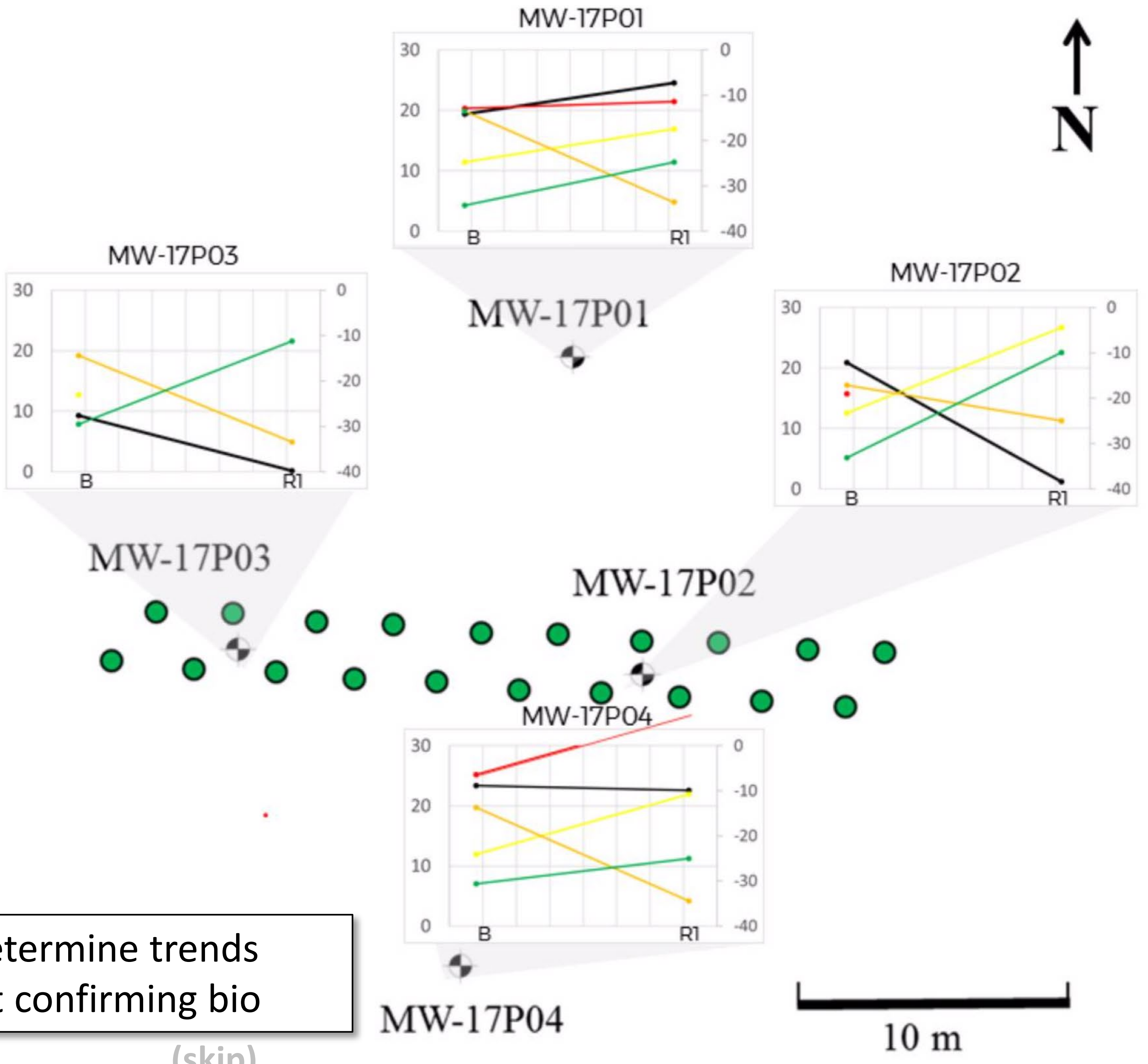


Treatment Zone

Results - CSIA

Sam Rosolina





- GW TCE reduced to n/d – nothing left to determine trends
- cis-DCE and VC show clear $\partial^{13}C$ enrichment confirming bio

(skip)

Estimation of Destruction Rate

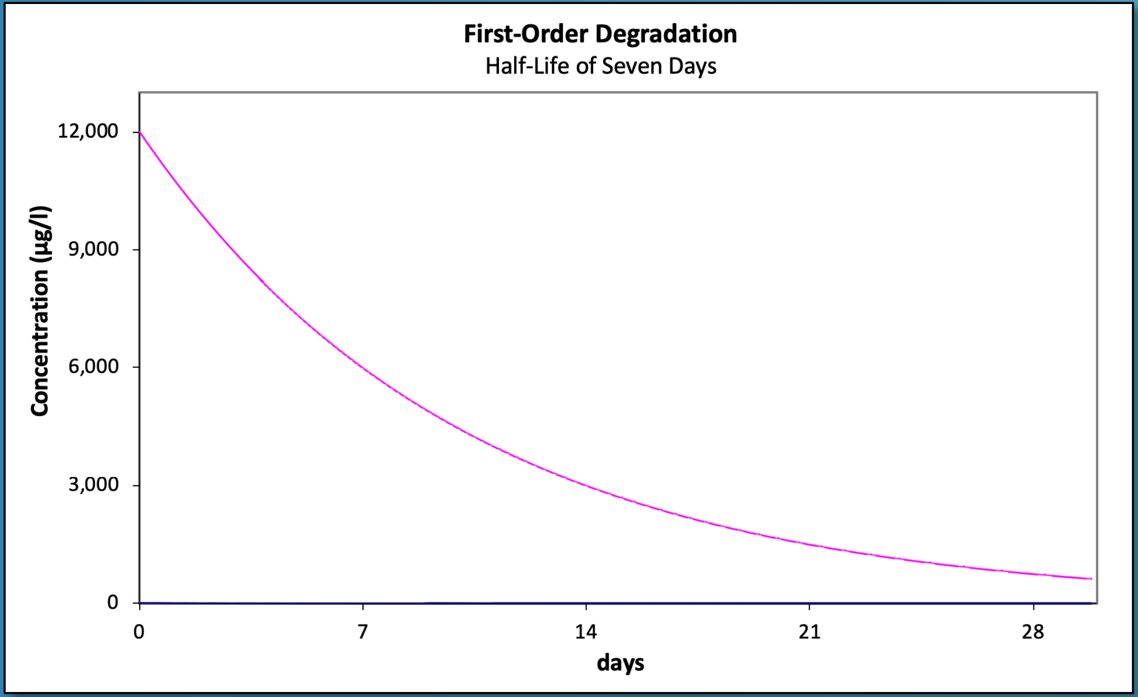
- Trendlines cannot be established from only two data points
  - But minimum rates can
  - This is sufficient to validate design assumptions
  - There is design compliance if the rate is greater than the design minimum

Estimation of Destruction Rate

- Simple exponential (first-order) fits
- These may be also expressed as half-lives

$$k = -\frac{ln\left(\frac{C_1}{C_0}\right)}{t}$$

$$t_{1/2} = \frac{-ln(0.5)}{k}$$

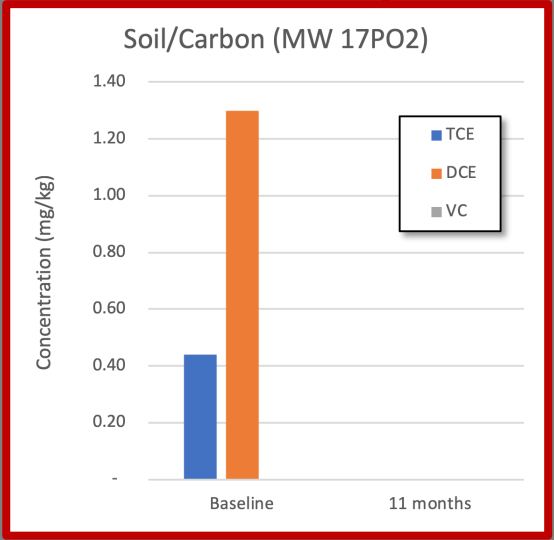


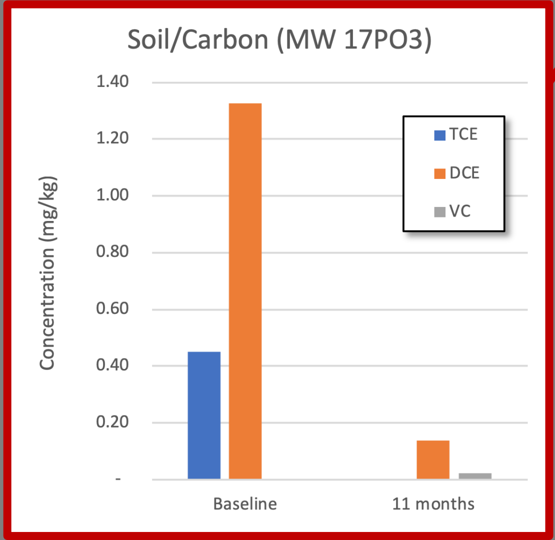
Estimation of Destruction Rate (bookending the minima)

TCE $t_{1/2}$ (days)	MW17P02	MW17P03
Soil / Carbon	38.1	37.6

DCE $t_{1/2}$ (days)	MW17P02	MW17P03
Soil / Carbon	24.5	154

Balance of loss and formation – very conservative as loss rate.





Estimation of Destruction Rate

- Daughter loss rates can be refined using model-fits
  - Simple models are sufficient
  - The minimum is independently assignable rates and a parent-daughter molar cascade

- Model-unwrapped minimum half-lives from ISM data:
  - TCE = 38 days
  - DCE = 141 days
  - VC = 3 days

These can now be used in our design model for calibration

Design Model - Quebec Rail Yard

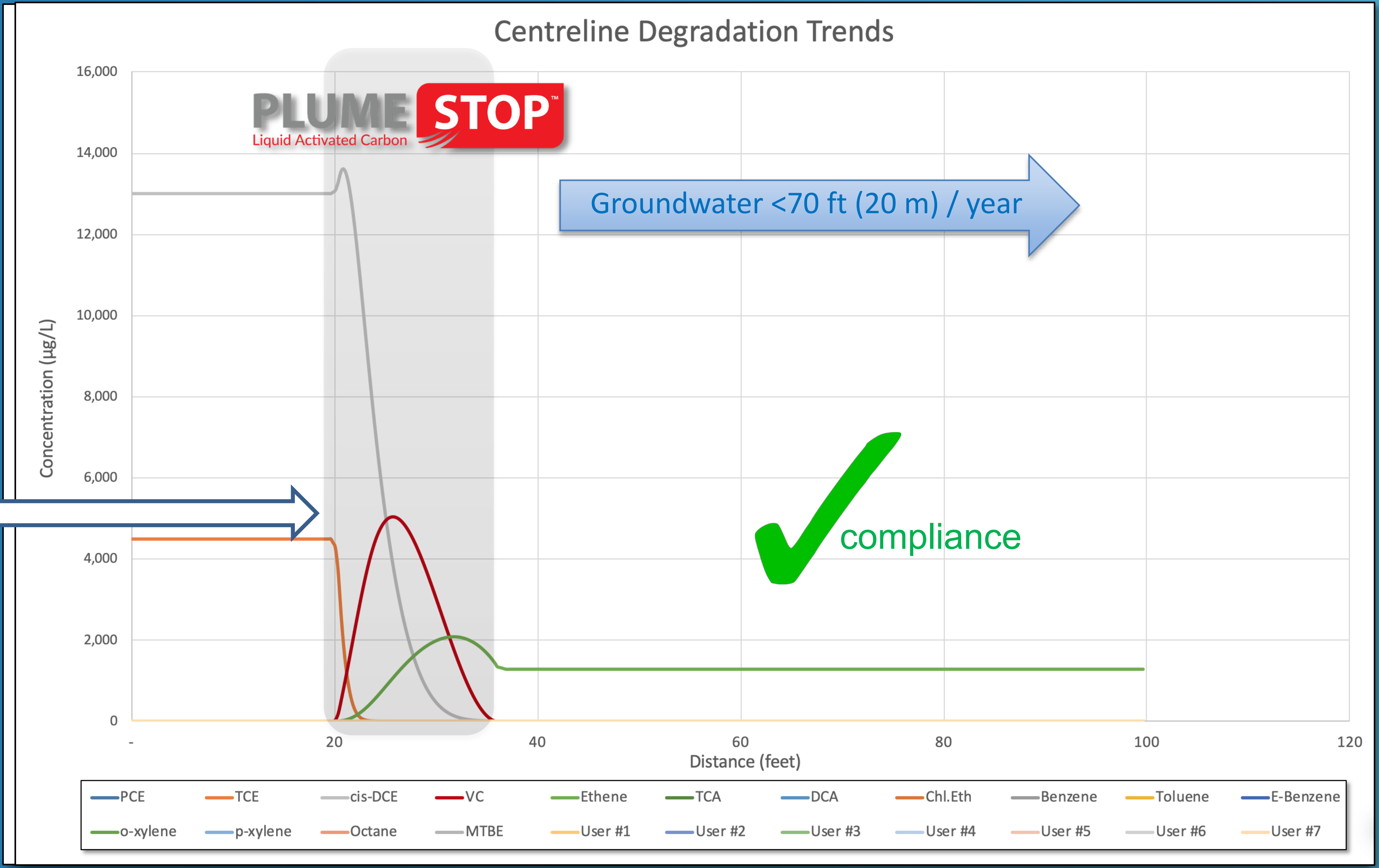
(i.e. Post LAC™ Application)

Design
Deg. Rates k (as $t_{\frac{1}{2}}$)
100 days (TCE, DCE)
30 days (VC, ethene)

Calibrated
Deg. Rates k (as $t_{\frac{1}{2}}$)
38 days (TCE)
141 days (DCE)
3 days (VC)
(3 days ethene)

f_{oc} = 0.001
$f_{PlumeStop}$ = **0.0003**

LAC™ Emplaceable Range:
~0.0001 – 0.02 (∴0.0003 ≈ 1.5%



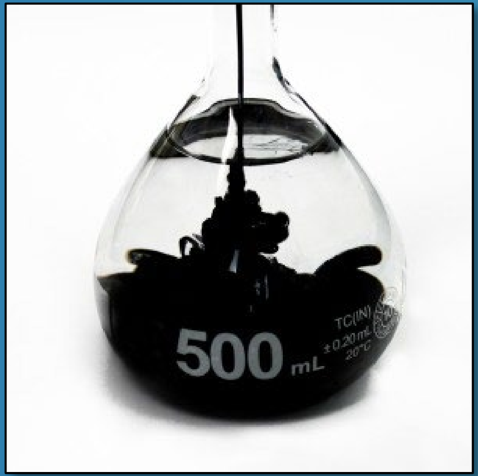
(close)

- Summary & Conclusions -

Summary and Conclusions

- **Injectable carbon – combined retardation and biodegradation**
  - More destruction in a shorter distance
  - Contained treatment without O&M costs

PLUME STOP™
Liquid Activated Carbon



Summary and Conclusions

- **ISMs – a management tool for engineers**
  - Validation of design assumptions
  - Longevity compliance prediction / early intervention alert
  - Ensure performance remains within design boundaries

A developing art!

Taking this forward

- Method refinements for <u>established</u> barriers
  - Identifying and quantifying new bias
    - E.g. acclimated barriers vs. non-acclimated ISMs
- Expanded use of microbial diagnostic tools
  - Attached community QuantArrays (ISMs ≈ BioTraps®)
  - Stable Isotope Probing (SIP) (aerobically degradable contaminants only)
- Combine with *in situ* retardation quantification
  - Full model calibration capability
  - Comprehensive management tool-kit for engineers

Thank You

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