



**ERD**ENHANCED

TCE Biotransformation Evaluation

Biostimulation alone vs. Modified  
Inorganic/Organic Formulation

TerraStryke Learning Program 23

ESAA EnviroTech 2022

# Bacteria - History



Antoni van Leeuwenhoek 1632-1723



Founding Father of Microbiology



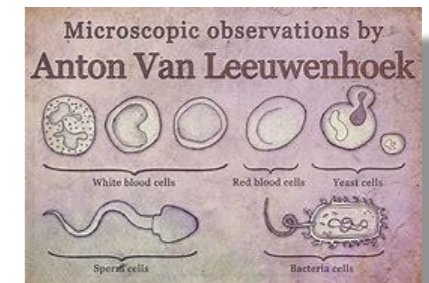
Identified planktonic bacteria – called them ‘Animalcules’ –



What he observed were protozoa, or ‘little animals’.

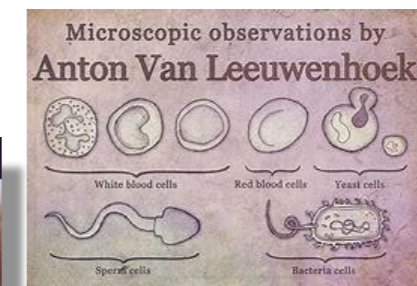


Also observed, after time, test tube solution gelled.



## Bacteria - History

- ✓ Late 1600's Leeuwenhoek noted biofilm bound bacteria.
- ✓ Conveniently harvested from the plaque on his teeth.
- ✓ Weren't aware of the complexity and prevalence of biofilm until the 1970s.



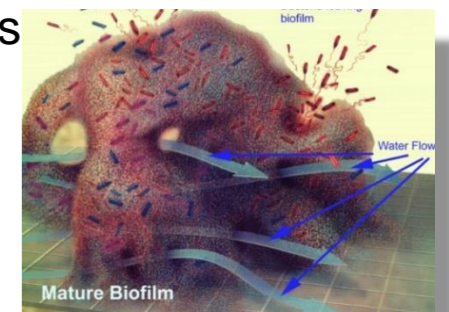
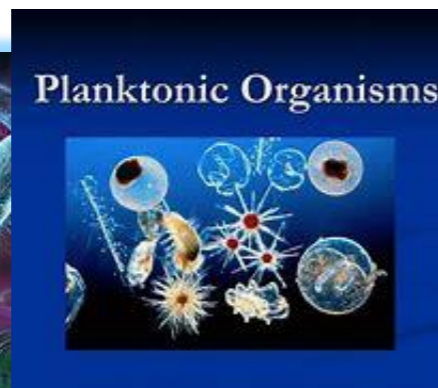
# The Power of the Unicellular

## Historically believed






- ✓ Solitary
- ✓ Capable of little.
- ✓ Swimmers key

## We now have a completely different perspective

- ✓ < 1% of bacteria exist in planktonic form
- ✓ >99% of microbial populations live in biofilm
- ✓ Communicate ('talk'), share information, and recruit.
- ✓ Determine what benefits the population.
- ✓ Abandon individual roles for specific roles
- ✓ Establish structures like multi-cellular organism.



# *Quorum Sensing & Signaling (QSS)*

-  Initiated with adequate nutritive capacity of microbial ecosystem
-  Requires bulk water planktonic densities to achieve 'quorum levels'
-  Allows signaling molecule (AI-2) to reach 'quorum' concentrations.
-  'Instructs' community of planktonic bacteria to phenotypically change.
-  Collectively become sessile and begin to establish a multi-specie biofilm.



# What is a Biostimulation Strategy

At TerraStryke, we wholeheartedly believe that the **TREATMENT ZONE** needs to be viewed as an ecosystem that, **WHEN CONTAMINATED, IS UNDER DURESS** and can not support healthy microbes or QSS.

 **TERRA STRYKE** #bioremediation4point0

- ✓ Enhance geochemistry and growth capacity of treatment zone.
- ✓ Support indigenous populations
- ✓ Restores nutritive capacity of ecosystem.
- ✓ Maximizes microbial information sharing
- ✓ Establishes greater bulk fraction of contaminant degraders

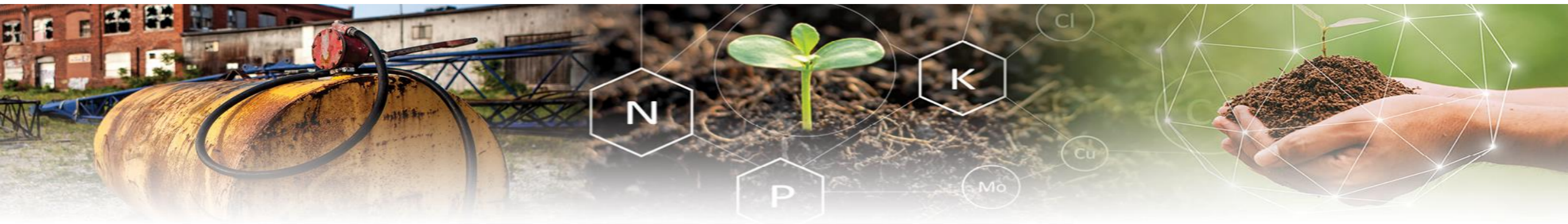




**What is *not* Biostimulation**



BRINGING THE GROUND TO LIFE. [TERRASTRYKE.COM](http://TERRASTRYKE.COM)



## What *is* Biostimulation





# Evaluation Amendments

## ERDenhanced™

Supports reducing  
conditions for decades after  
single injection program

### APPLICATIONS:

Dry cleaner, manufacturing, tool-dye

ERDenhanced™

## SUSTAINABLE

cVOC remediation with complete  
destruction, without rebound,

- with **NO** multiple deployments
- with **NO** secondary contaminants
- with **NO** adverse affects

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STRYKE

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# Case Study

## Burlington, Ontario Site Former Dry Cleaner



### Former Dry Cleaner

- [PCE] in saturated soil/groundwater
- Residual source mass in saturated soils



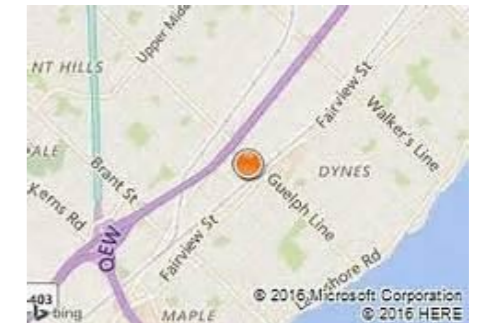
### Site Conditions

- Highly weathered Shale with Silty-Sand
- Silt Generally moist
- 1-25ft bgs elevated PID readings



### Property Value

- 2011 Appraised Value \$680,000





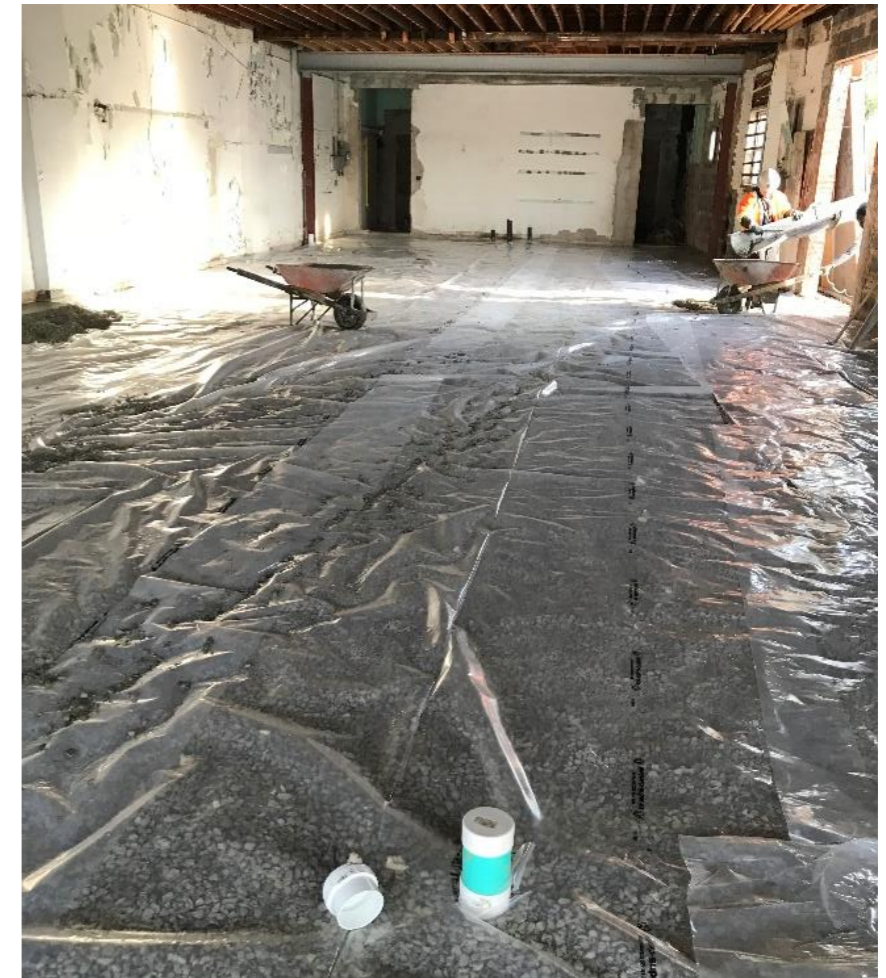
### Excavation – Source Removal

- Excavated 250c.y. contaminated soils
- Infiltration gallery installed w/in footprint
- Clear stone, 6-inch slotted PVC, 6-9ft bgs



### Additive Deployment

- Gravity fed 9% additive slurry
- 1,056 lbs to 1,100 gallons chase water  
March and again June 2014



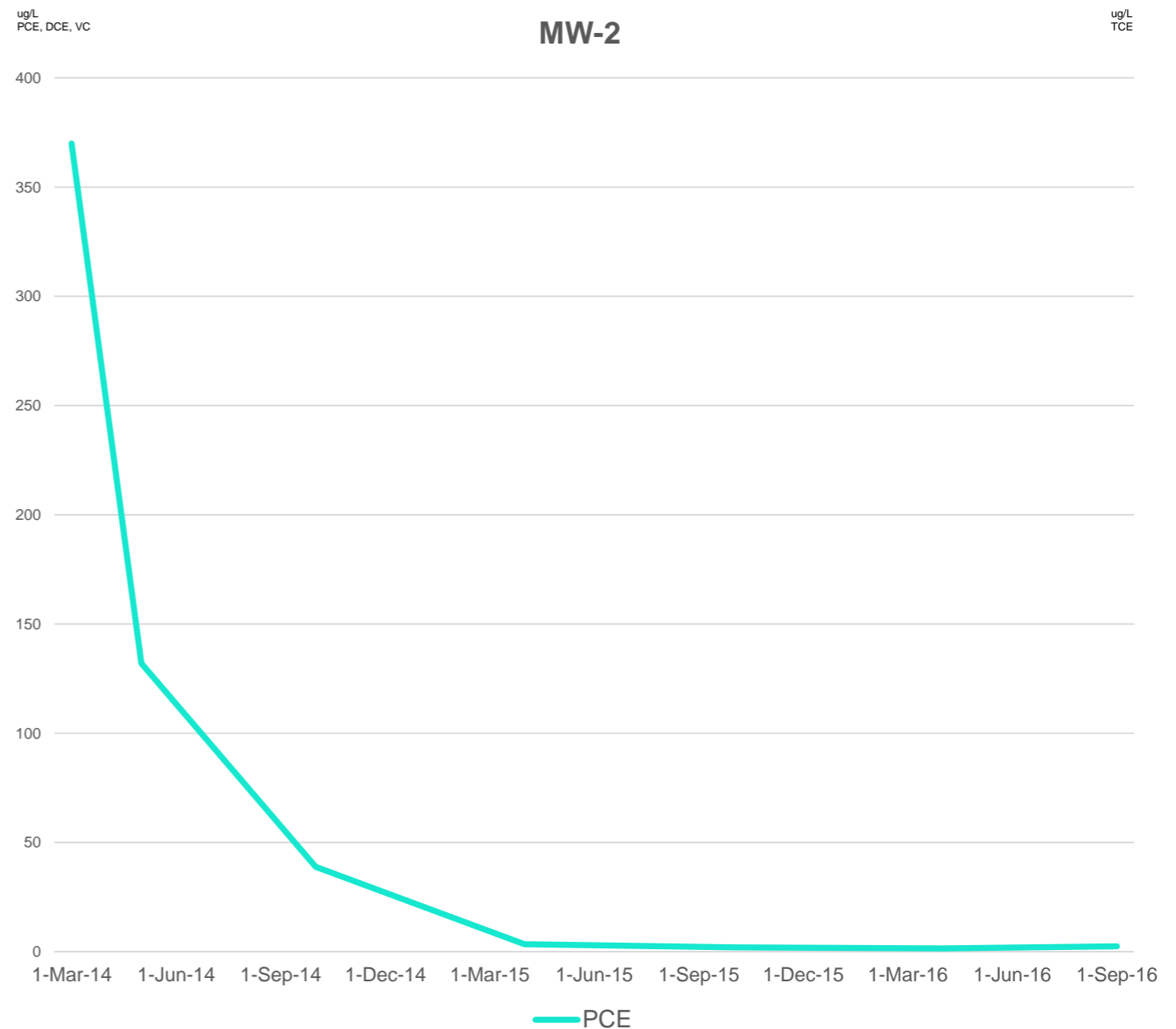
# Case Study

## Burlington, Ontario Site Former Dry Cleaner

### Results T=2 Years

#### MW-2 50-60ft downgradient

- 99.4% reduction [PCE]



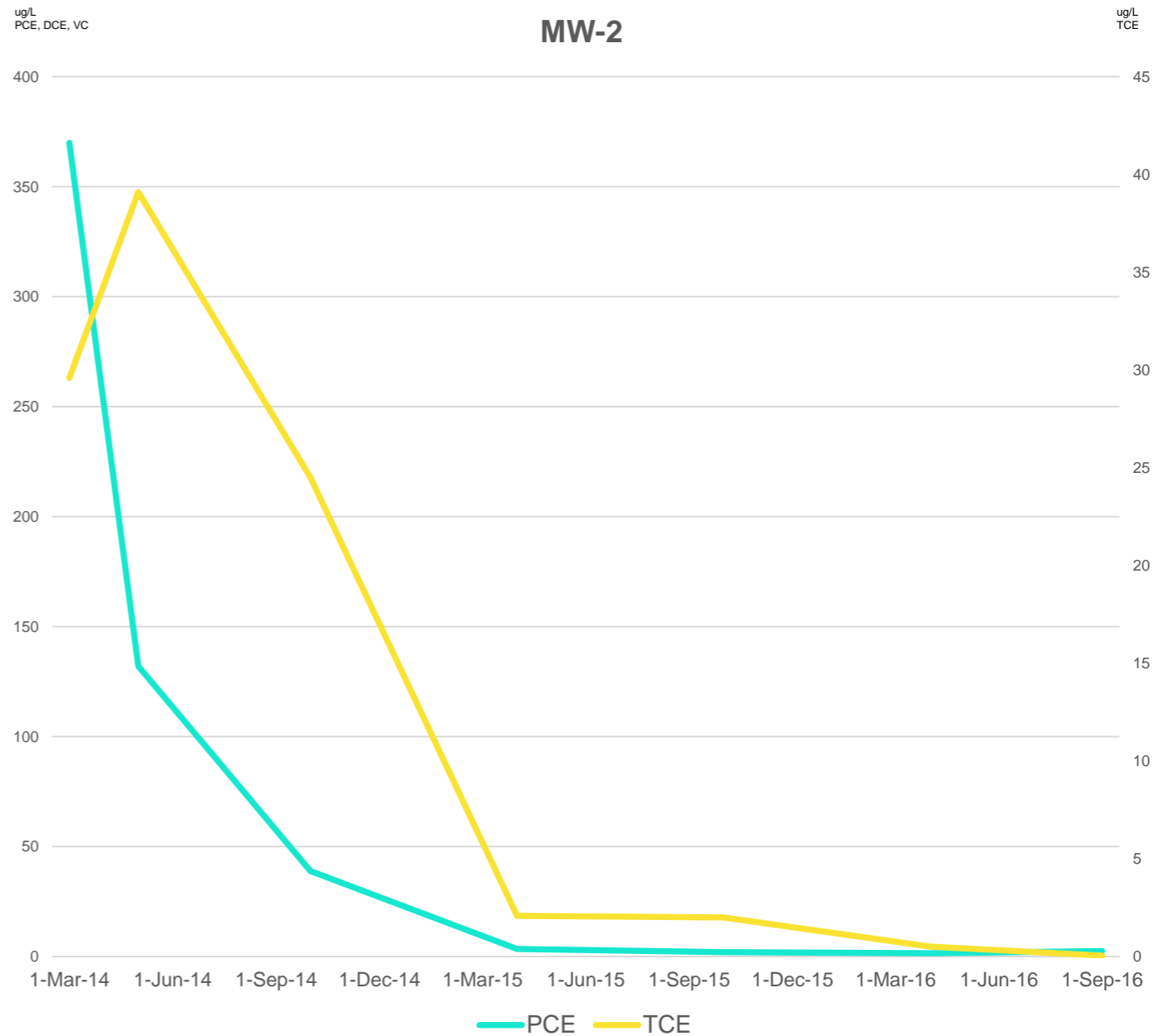
# Case Study

## Burlington, Ontario Site Former Dry Cleaner

### Results T=2 Years

#### MW-2 50ft downgradient

- 99.4% reduction [PCE]
- After initial 32.1% increase
- 99.9% reduction [TCE] from peak.



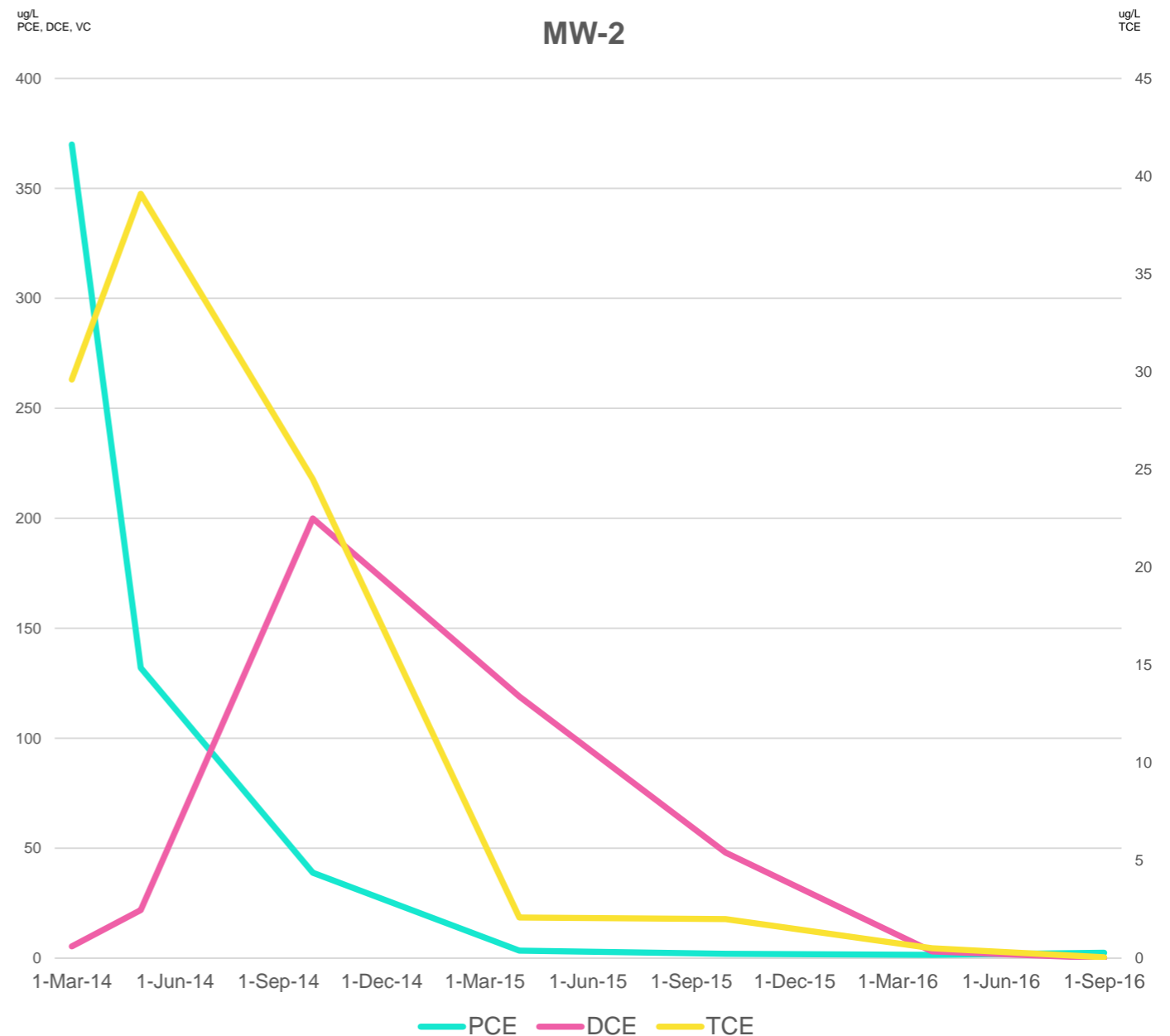
# Case Study

## Burlington, Ontario Site Former Dry Cleaner

### Results T=2 Years

#### MW-2 50ft downgradient

- 99.4% reduction [PCE]
- 99.9% reduction [TCE]
- After 3,600% increase
- >99.99% reduction [cis-DCE] from peak



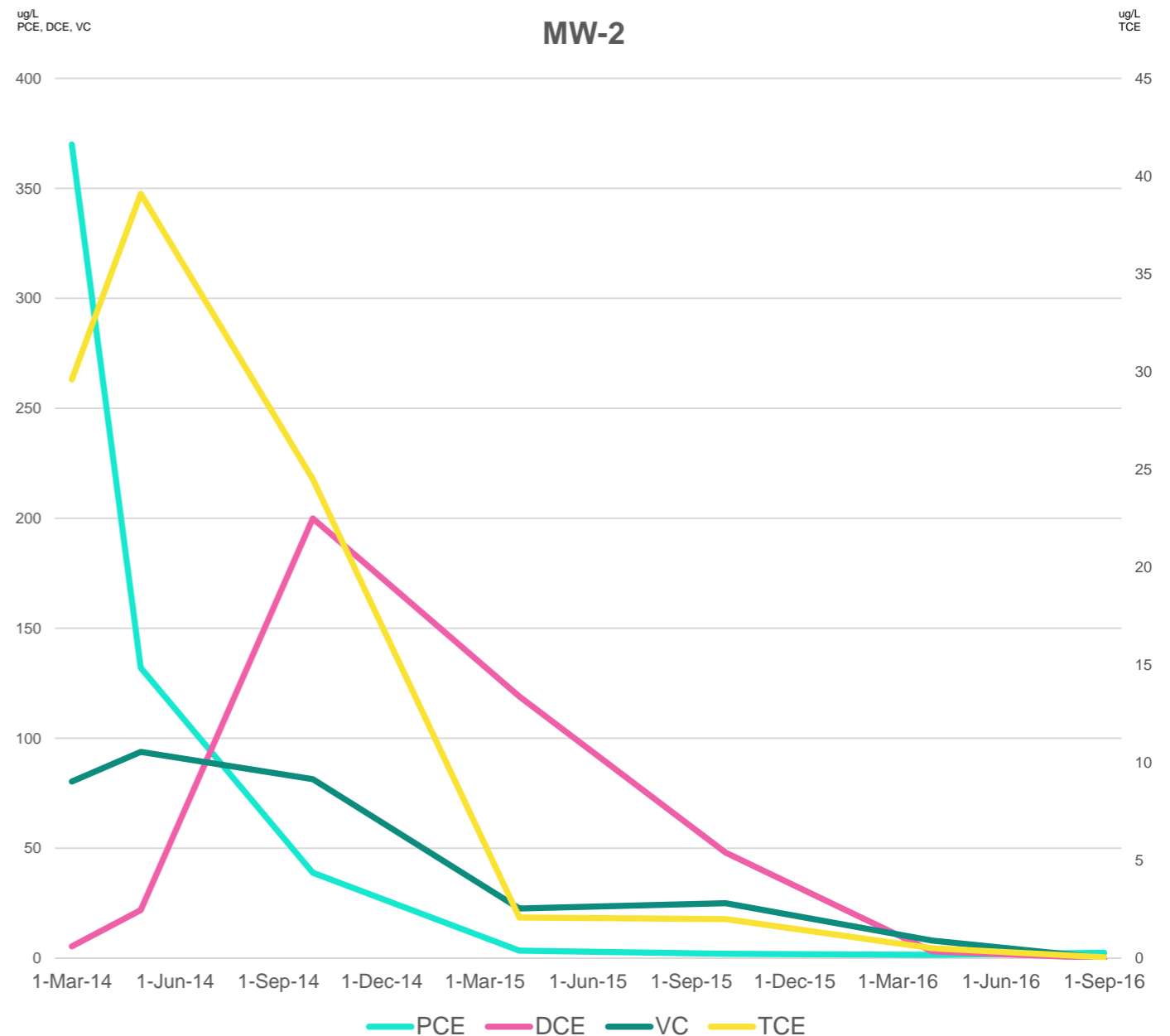
# Case Study

## Burlington, Ontario Site Former Dry Cleaner

### Results T=2 Years

#### MW-2 50ft downgradient

- 99.4% reduction [PCE]
- 99.9% reduction [TCE]
- ≈100% reduction [cis-DCE]
- 99.9% reduction [VC] after 16.8%↑
- 99.5% reduction in [cVOCtotal]
- [Ethene] generated throughout program = complete biotransformation



# Case Study

Burlington, Ontario Site  
Former Dry Cleaner

**2018 Property  
Value Assessed  
at MORE THAN  
\$2.5  
million**



Contaminated, property value \$680,000  
P&T Estimated \$750,000 over 12-15 years  
Effective Property Value for 15-years \$0.00



## Biostimulation Strategy

Total project Costs

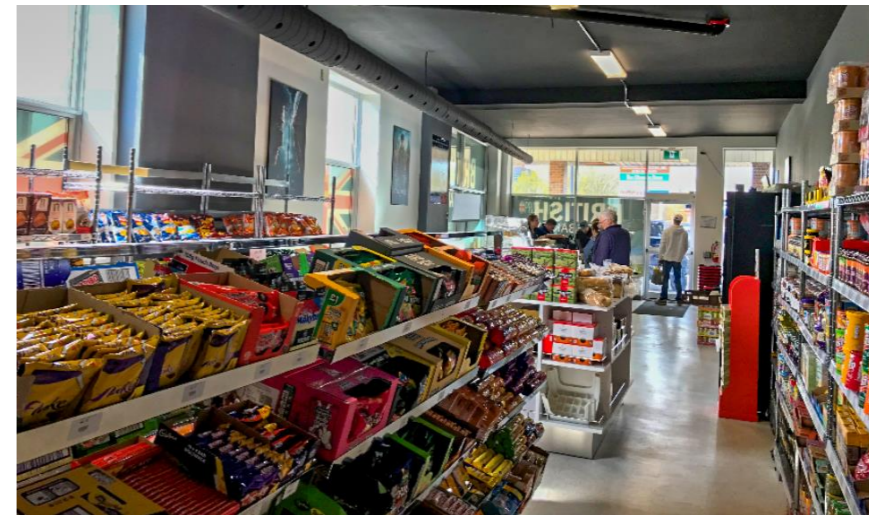
Soil removal/gallery install	\$38,000
Pilot and Full-Scale Additive	\$35,000
Consulting and Analytical	\$150,000
	<hr/>
	\$223,000



During 4<sup>th</sup> year of remediation Site redeveloped



Property Manager attributes \$1 million of property value increase to remediation strategy





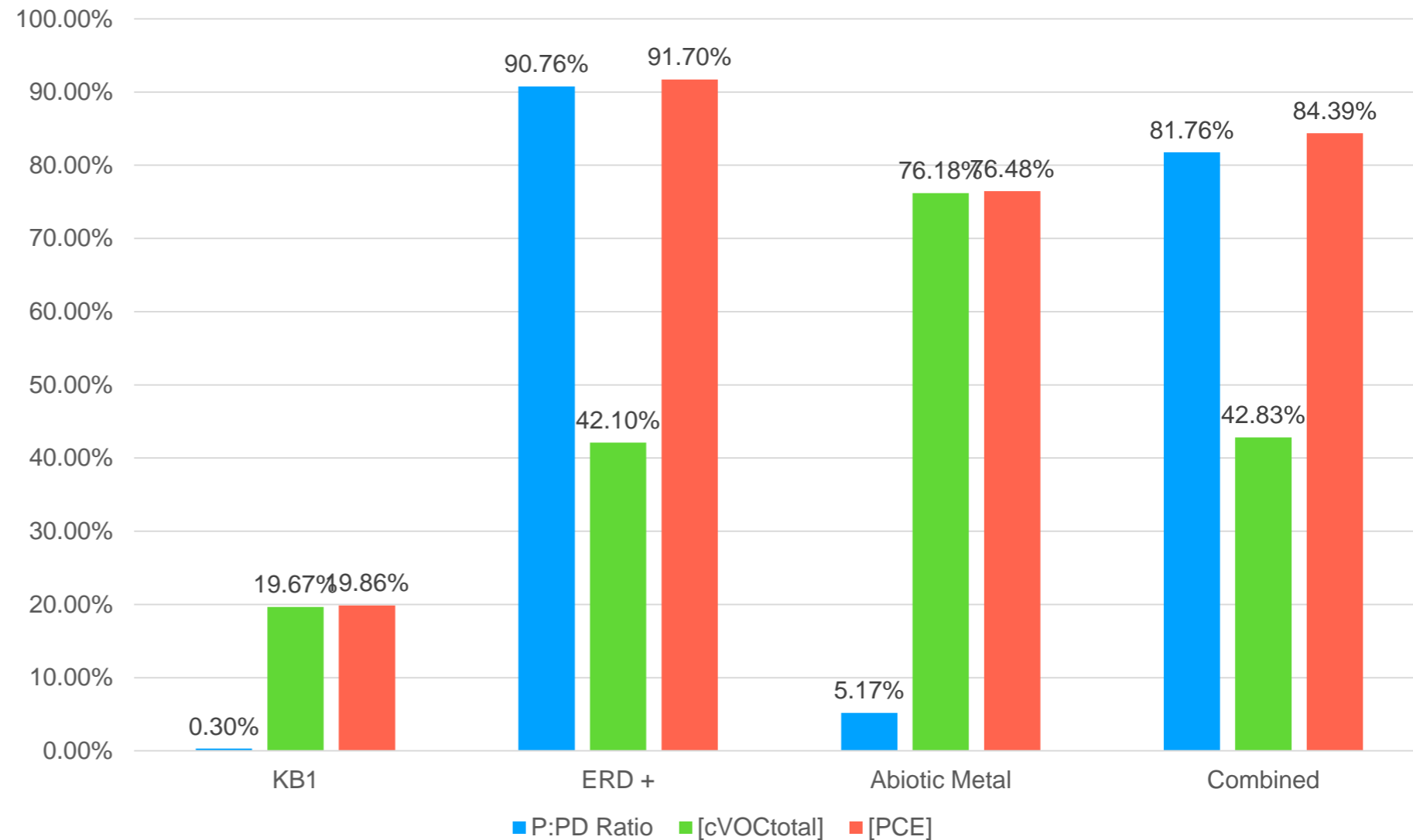
# Microcosm Study

## Independent Comparative Evaluation

### 28-day microcosm study

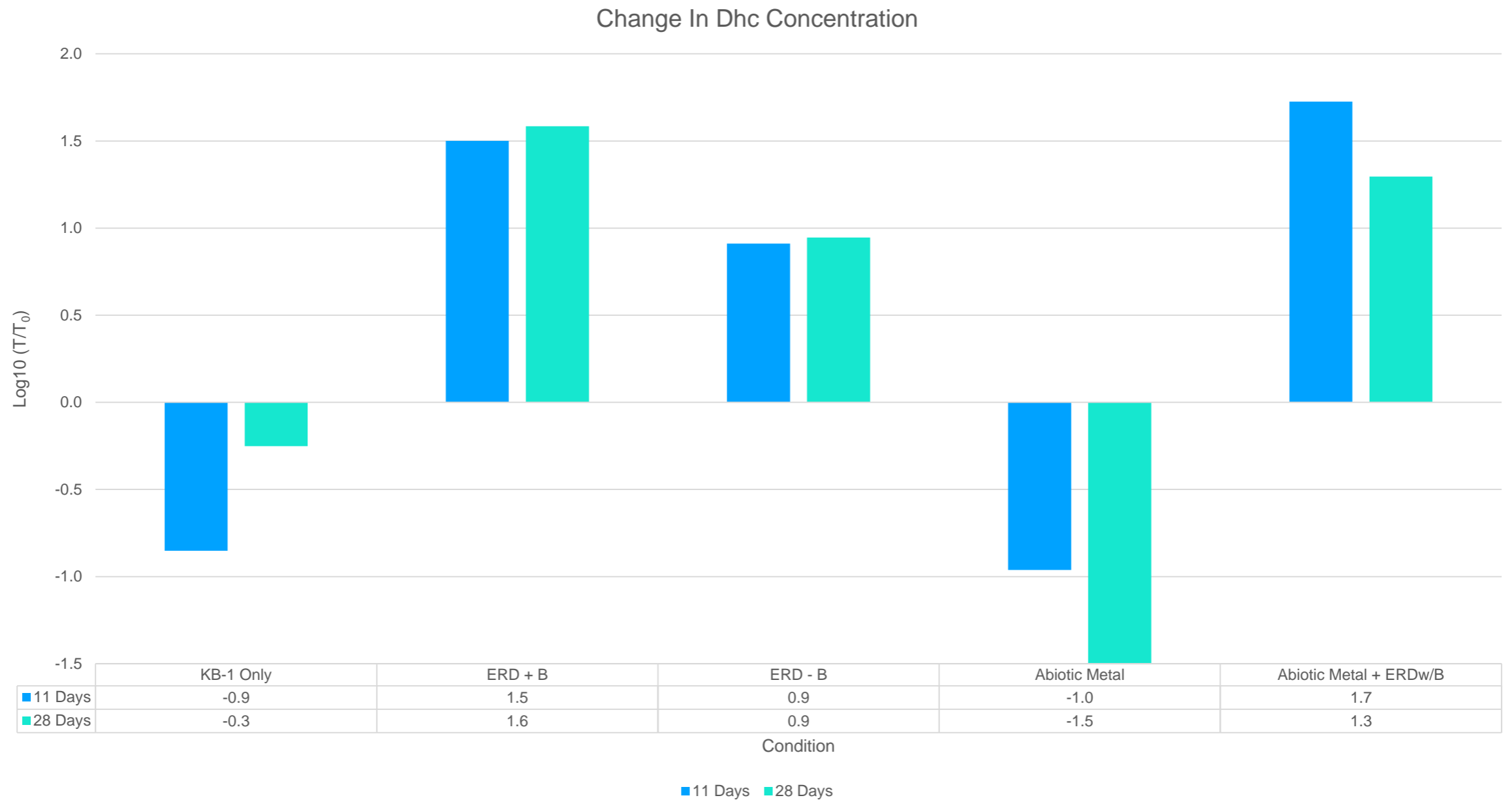
- Baseline [PCE] 50,000 ug/L
- ERD enhanced alone best
- Biology outperformed abiotic

Percent Decreases cVOCs Day 28



# Microcosm Study

## Independent Comparative Evaluation



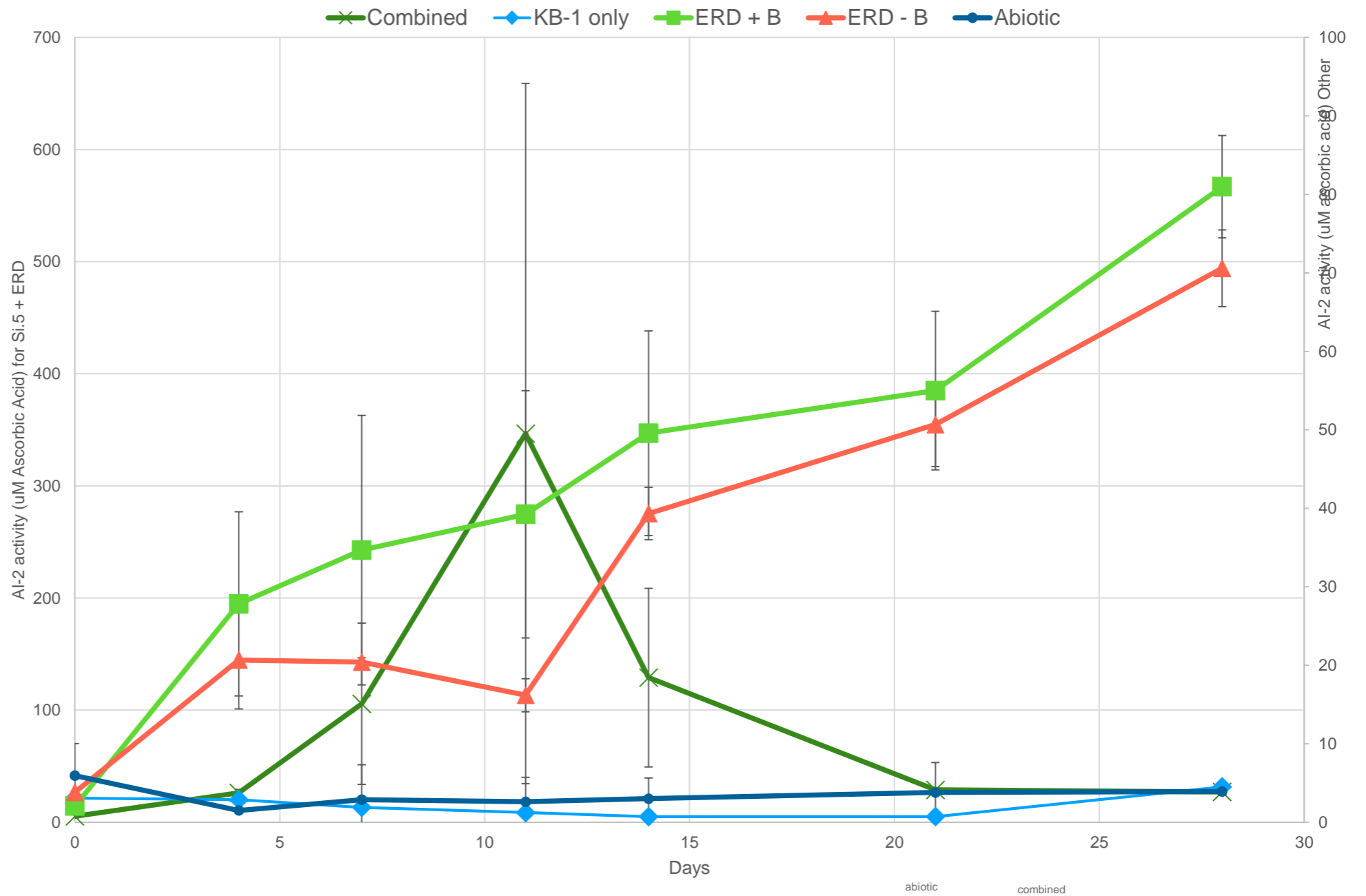
# Case Study

# Independent Comparative Evaluation

## 28-day microcosm study

Autoinducer-2 (AI-2) signal realized quorum levels in combined formulae

## AI-2 Activity

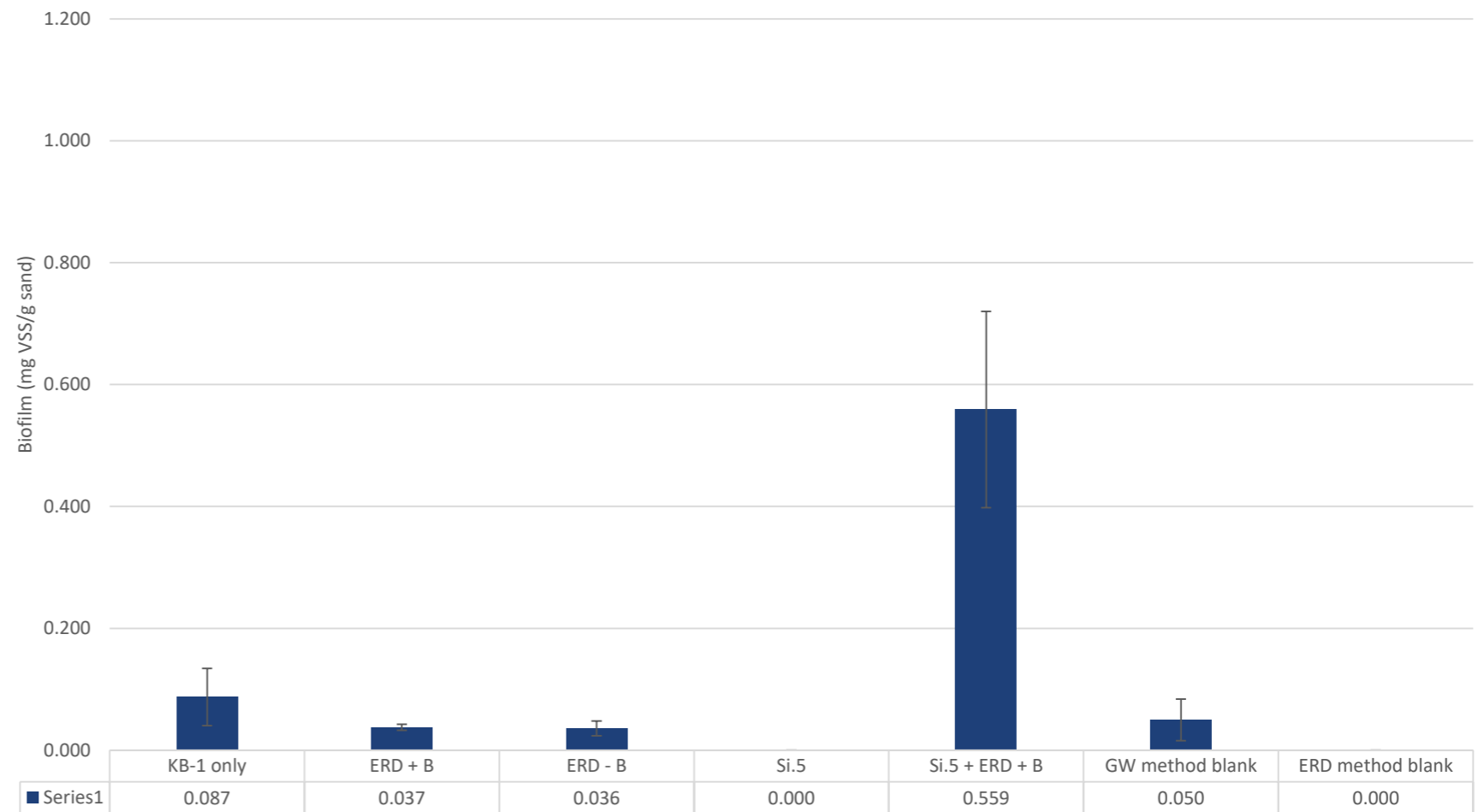


## 28-day microcosm study

Autoinducer-2 (AI-2) signal realized quorum levels in combined formulae

Also realized greatest biofilm growth

Biofilm Quantity



# Field Evaluation Study

## Bridgeport Ohio

### Former Electronics Manufacturing Facility



#### Site

- [TCE] in saturated shallow bedrock
- 15-20ft alluvial silty clay/gravelly sand atop bedrock
- Bedrock highly fractured sandstone
- Residual DNAPL in 1<sup>0</sup>/2<sup>0</sup> pore space of bedrock



#### Concern

- [TCE] 25-250 milligrams per Litre (mg/L)
- Minimal daughter product present
- Current P&T System manages plume migration



#### Goal

- Owner desires sustainable low-impact, low-cost strategy to target the destruction of dissolved phase and residual source mass contaminants.



# Field Evaluation Study

## Bridgeport Ohio

### Former Electronics Manufacturing Facility



#### Strategy

- On-Site proof-of-concept evaluation
- Performed under actual biogeochemical conditions
- Compared ERDenhanced standard formulation
- to modified version containing a minimal % of electron generating metal



#### Process

- Amend monitoring/test wells using Passive Release Sock (PRS)
- One with original, one with modified ERDenhanced
- Monitor/sample test wells over 12-month evaluation



#### Goal

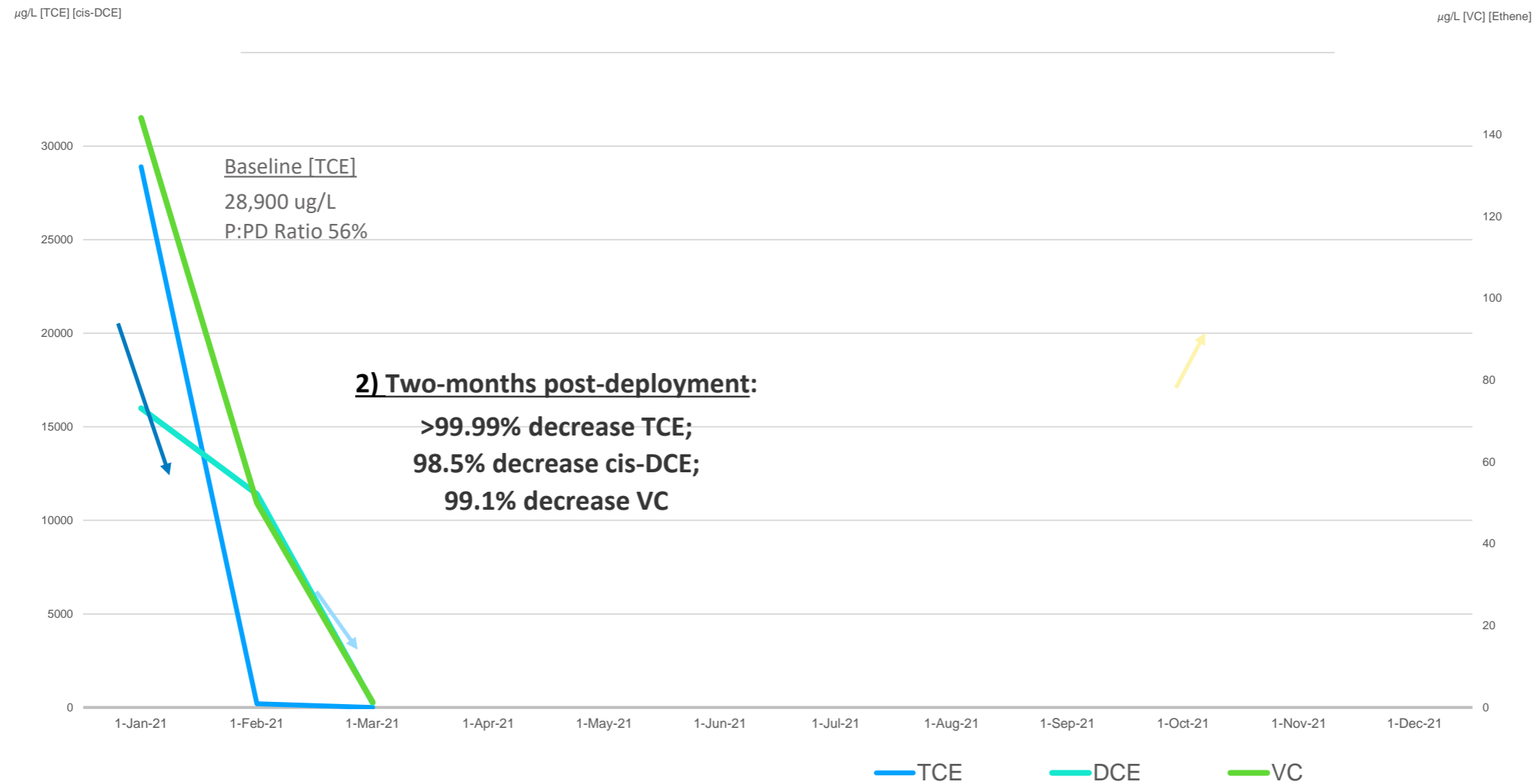
- Realize increased densities of indigenous microbials
- Expedited residual mass solubilization
- Enhanced and complete dissolved phase cVOC destruction



## ERDENHANCED MW-23A 12-month evaluation

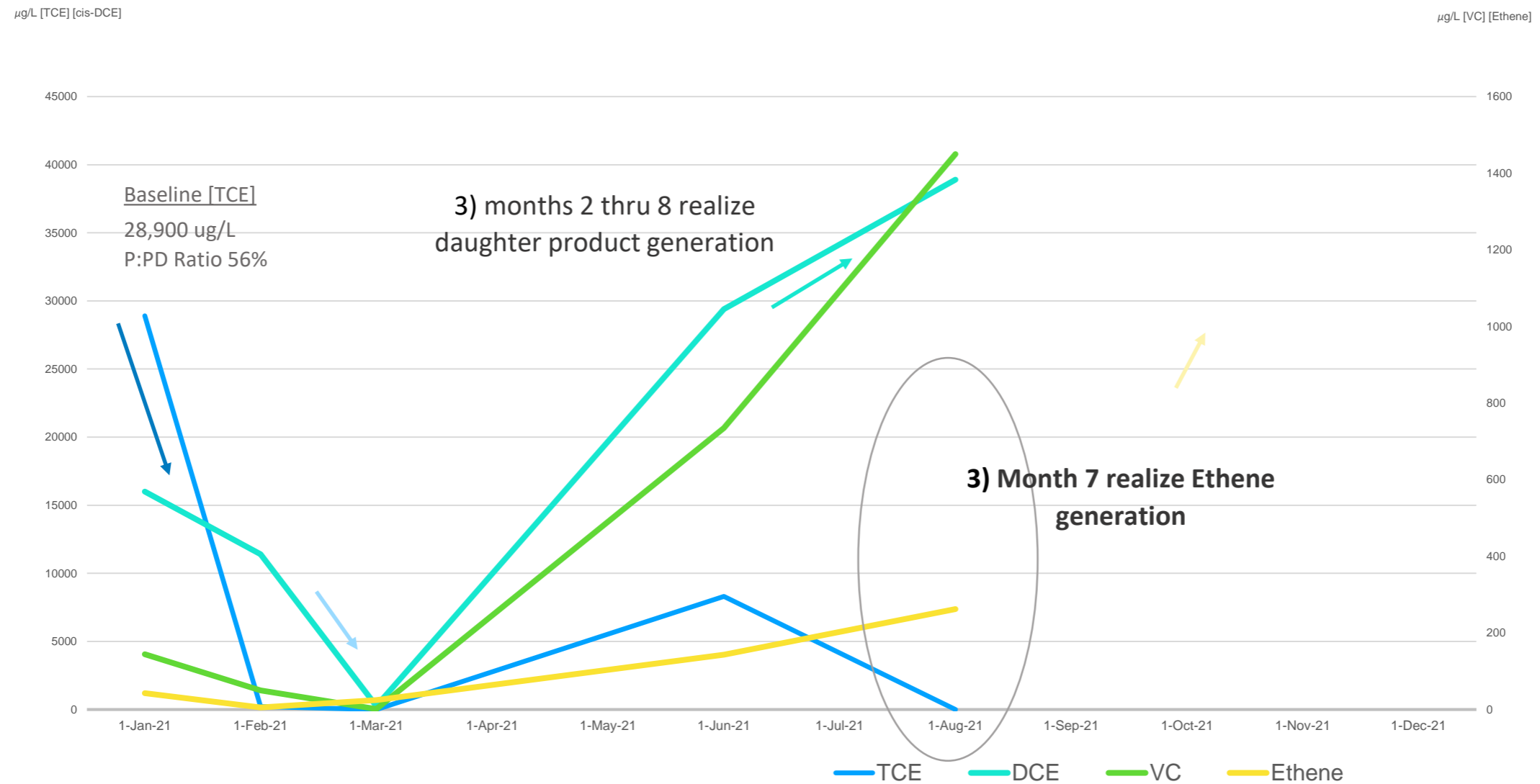


## ERDENHANCED MW-23A 12-month evaluation

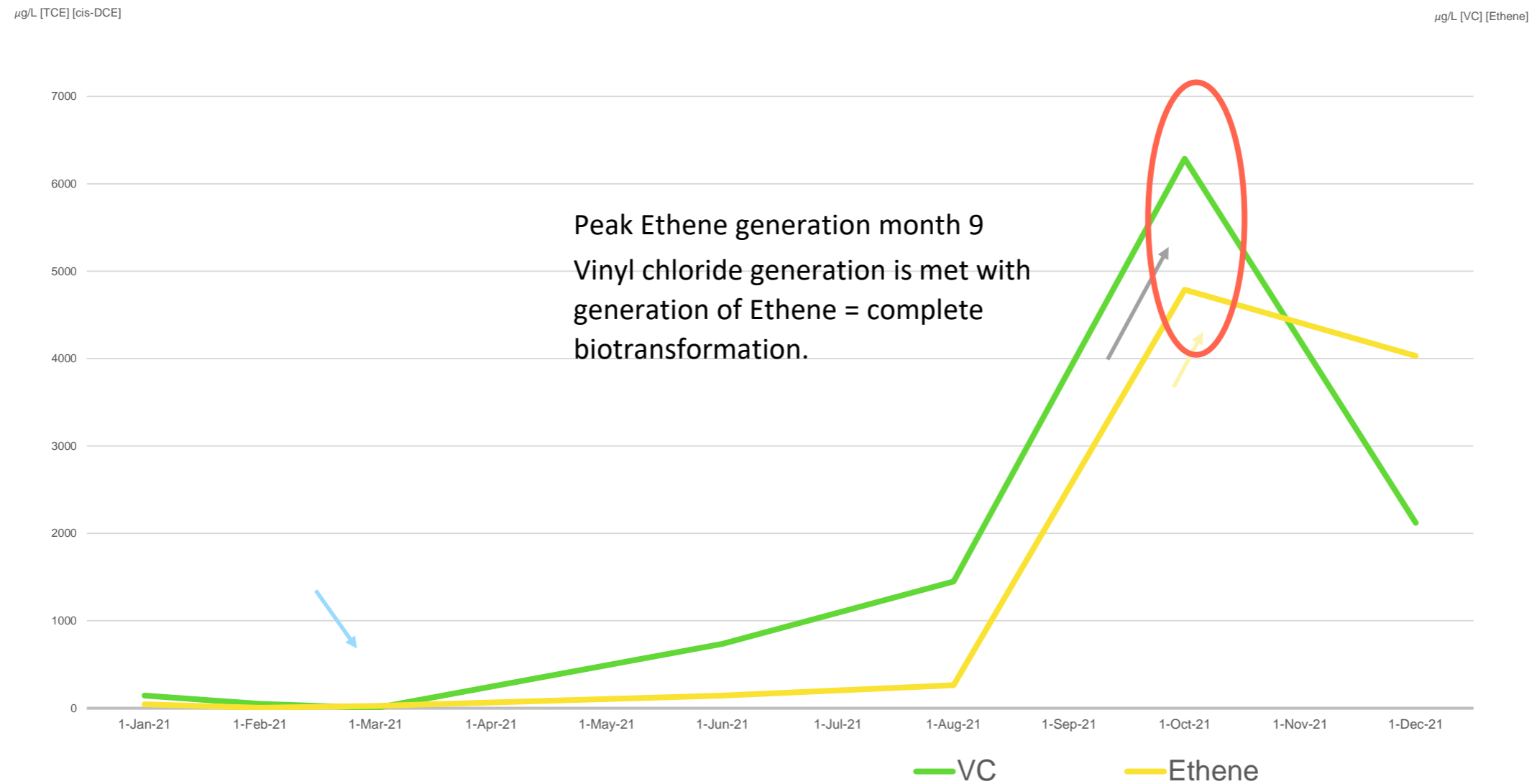




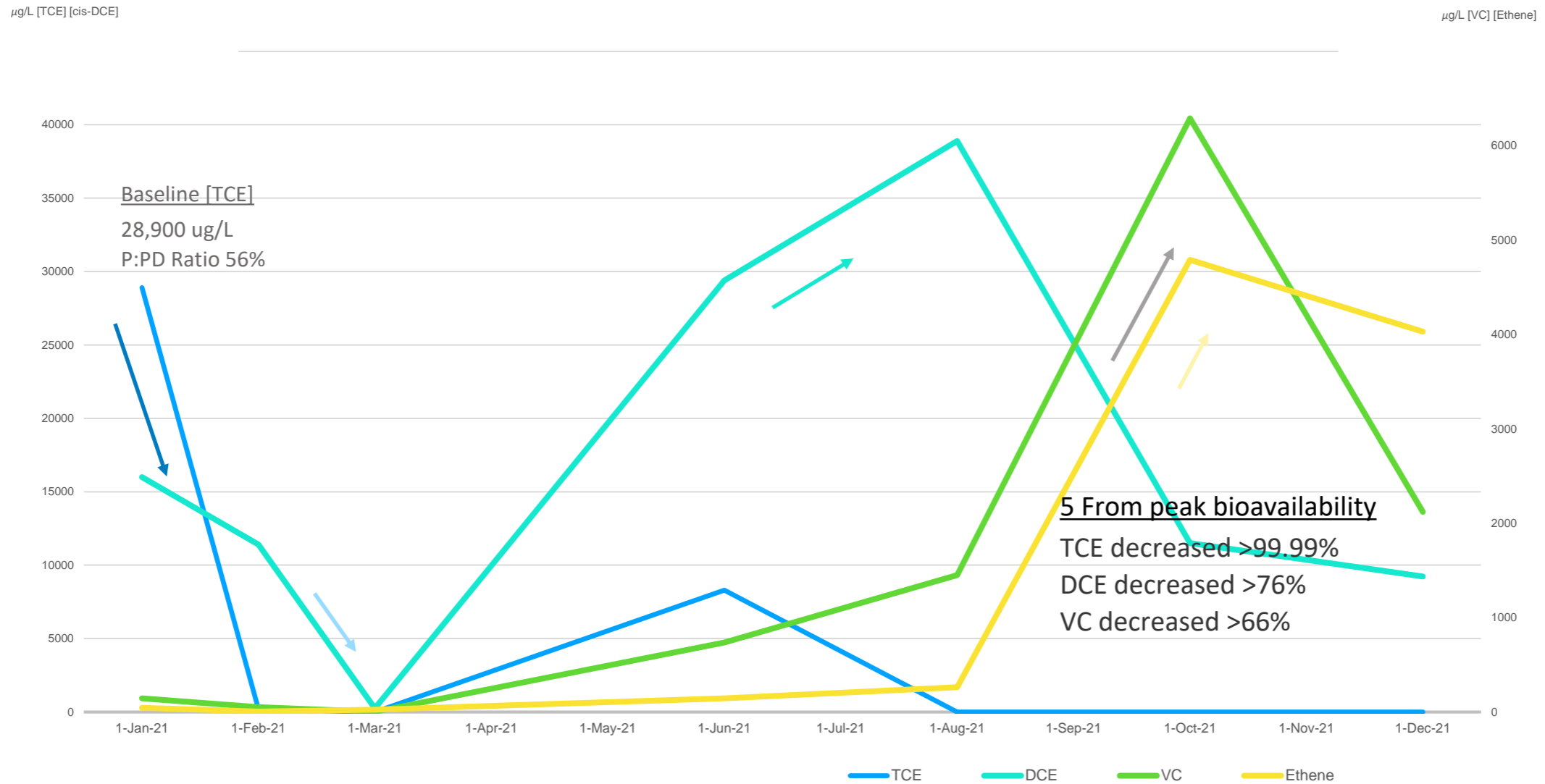
## ERDENHANCED MW-23A 12-month evaluation



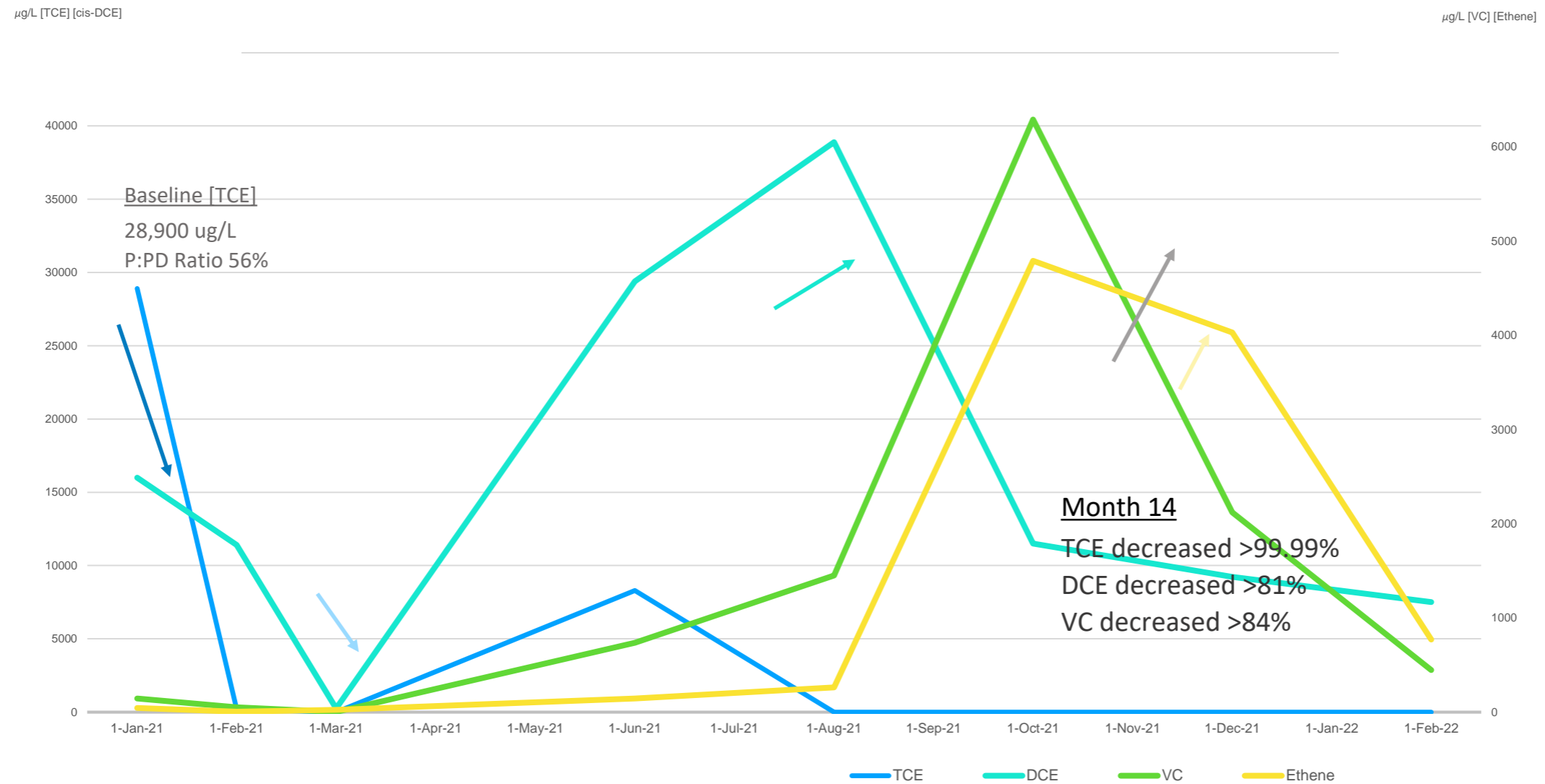
## ERDENHANCED MW-23A 12-month evaluation



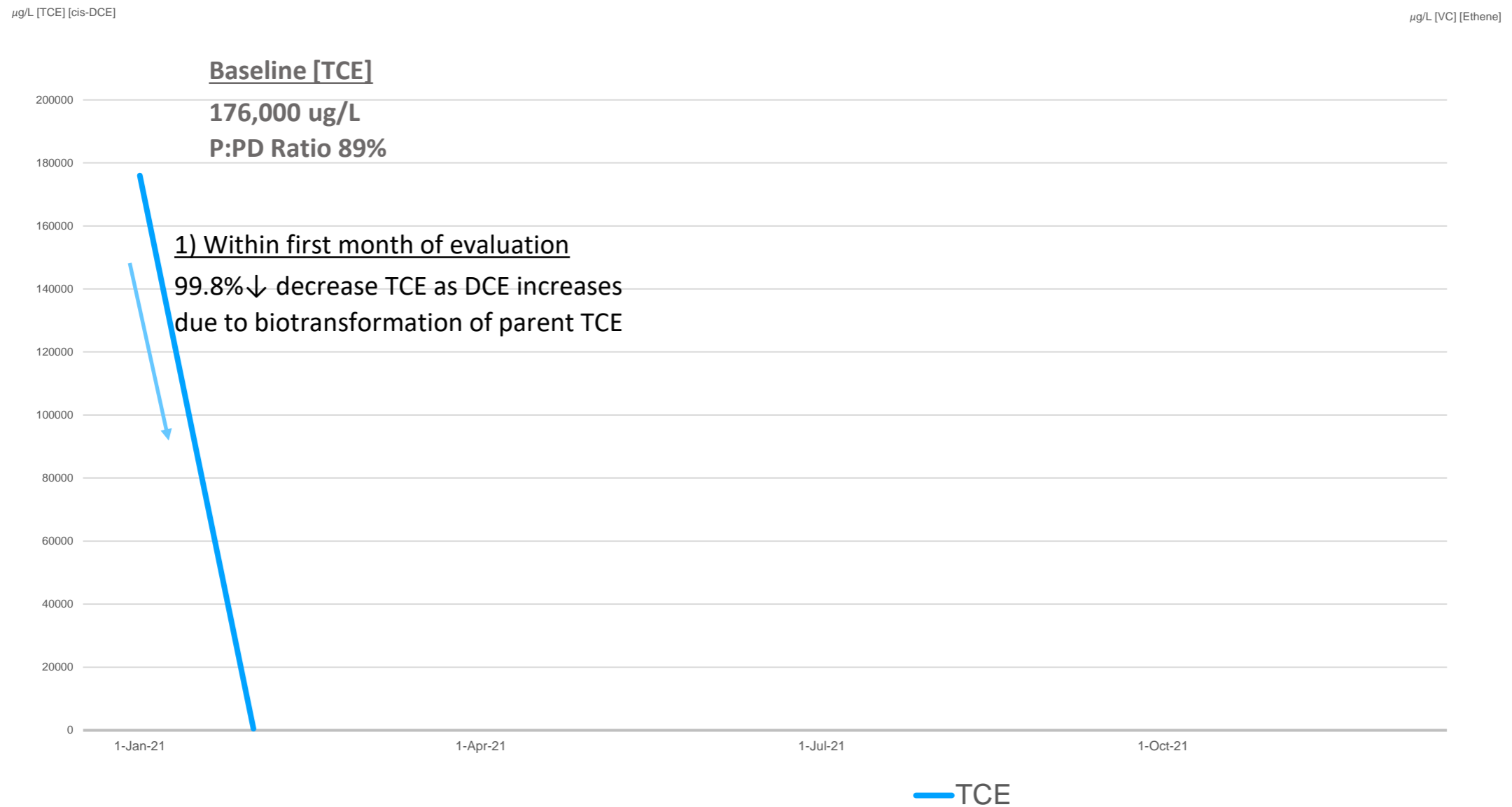
## ERDENHANCED MW-23A 12-month evaluation



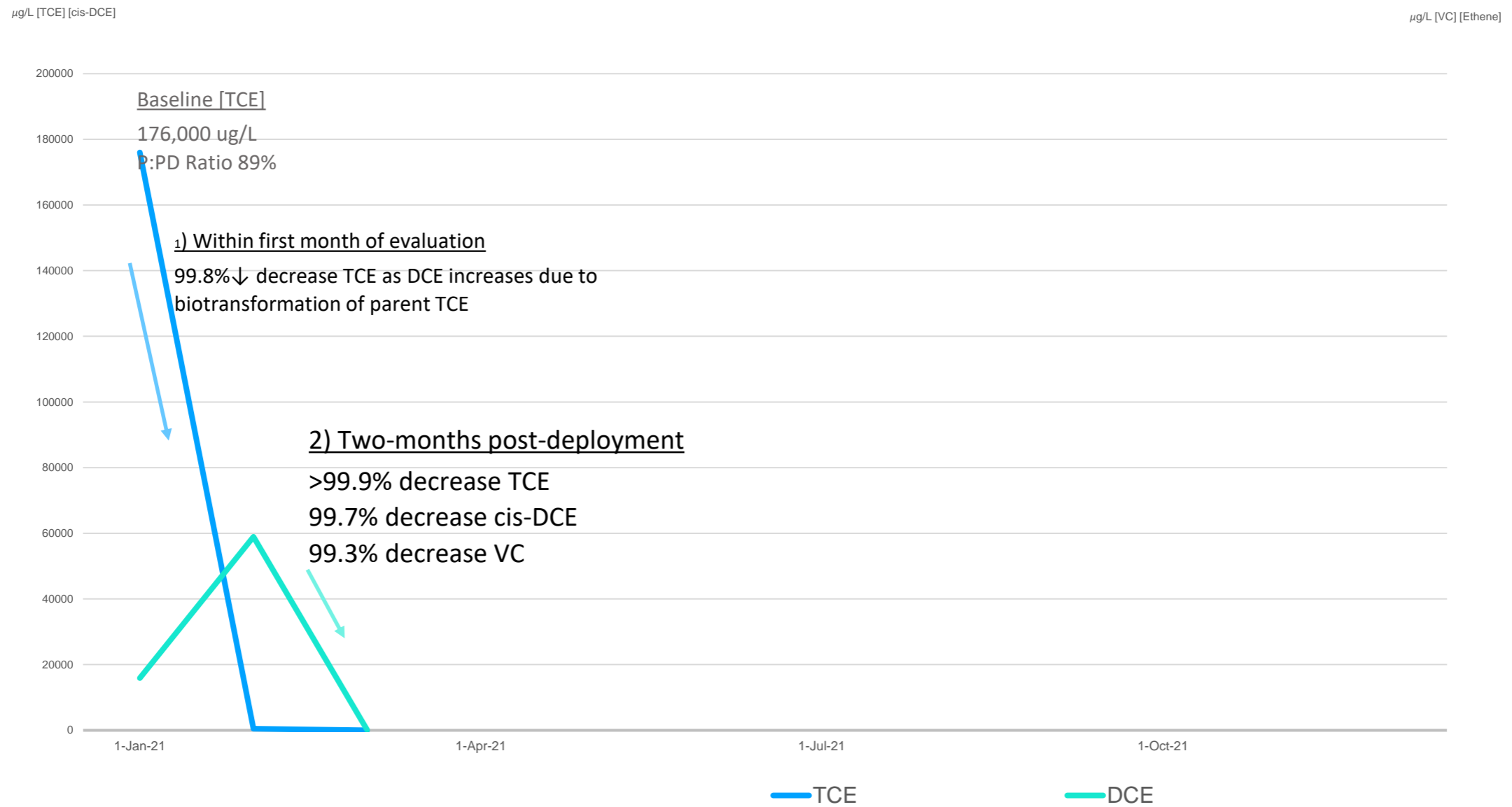
## ERDENHANCED MW-23A 12-month evaluation



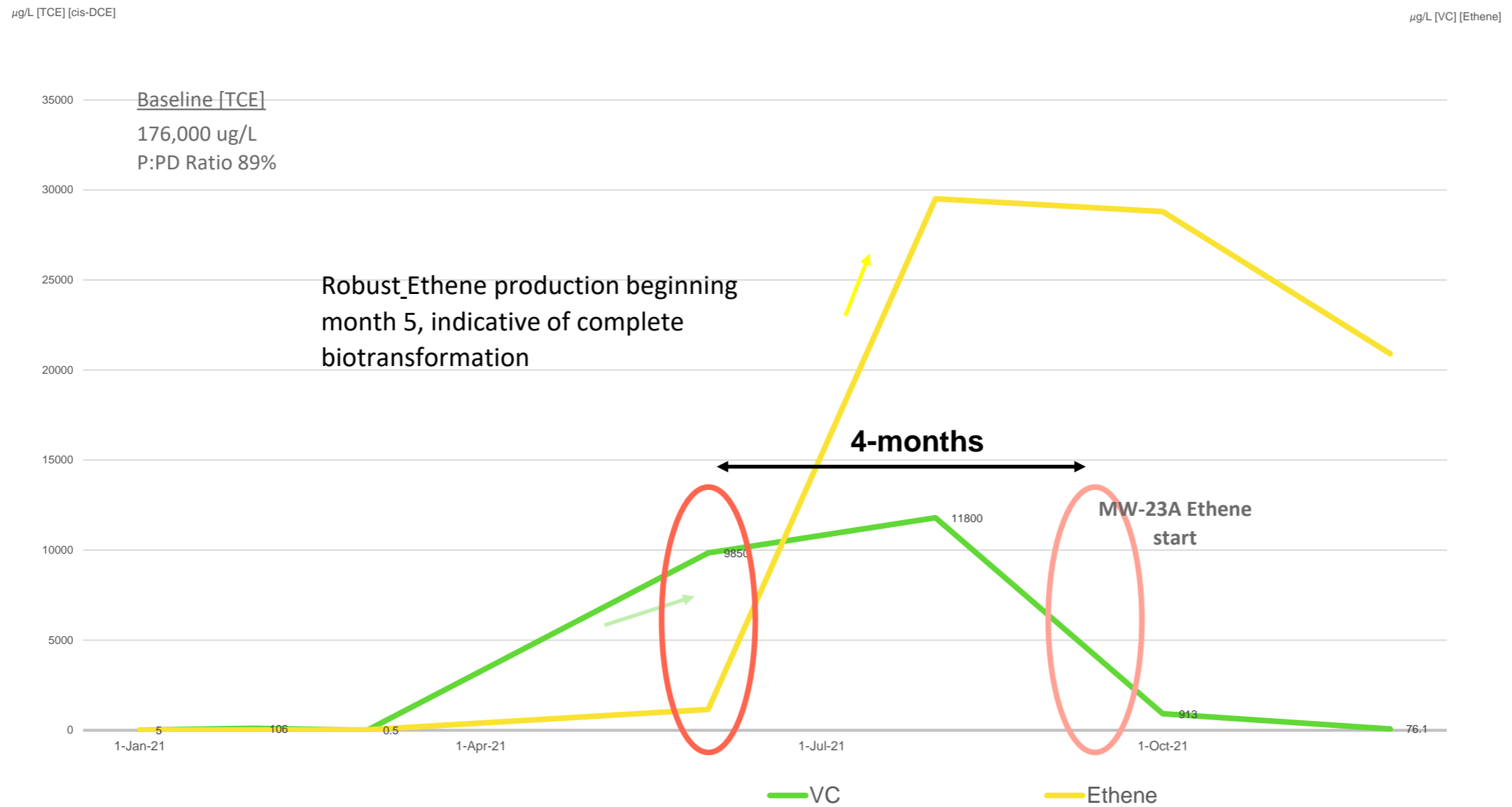
## Modified ERD ENHANCED MW-24A



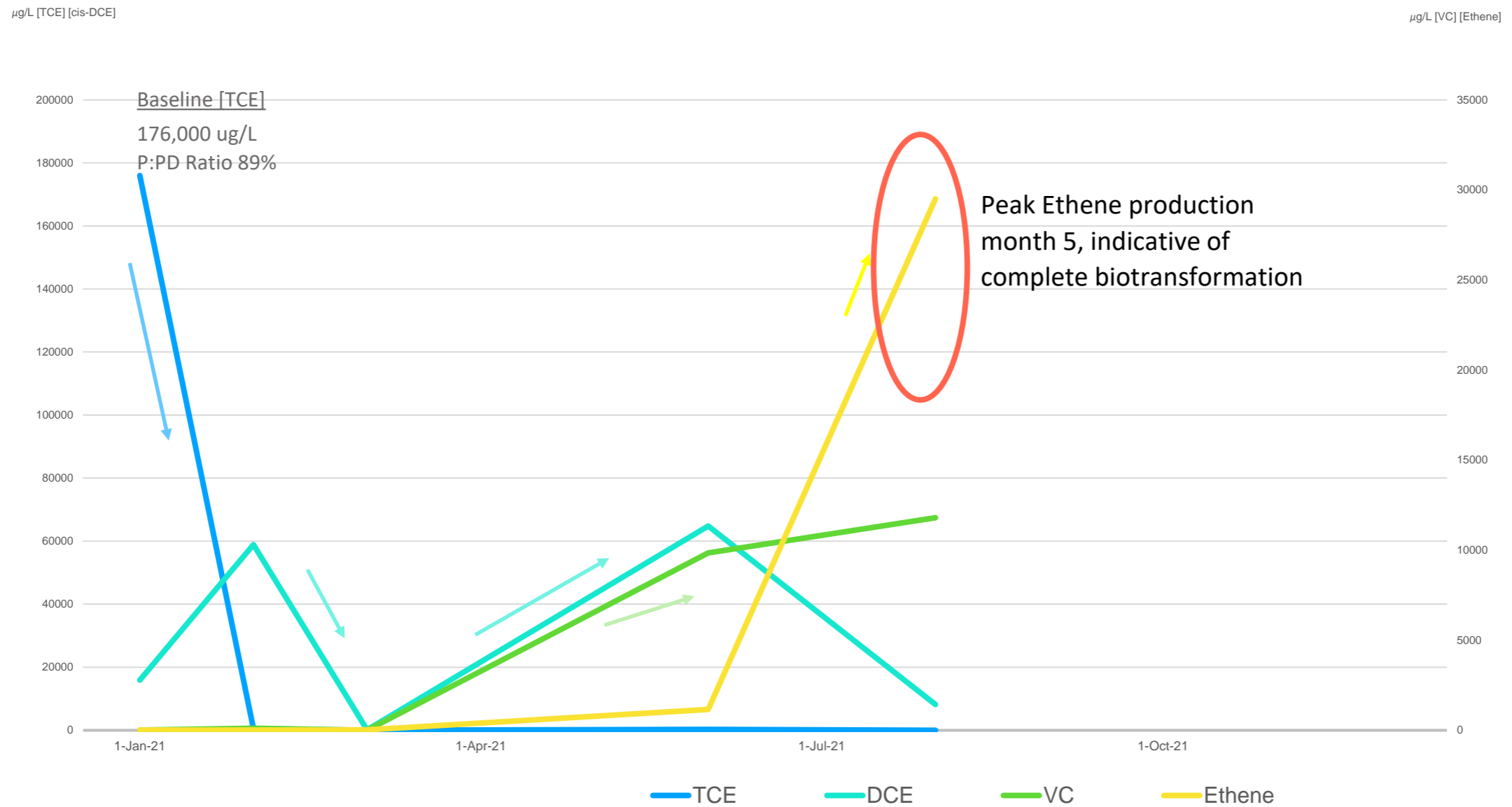
## Modified ERD ENHANCED MW-24A



## ERDENHANCED W/ ZVI MW-24A

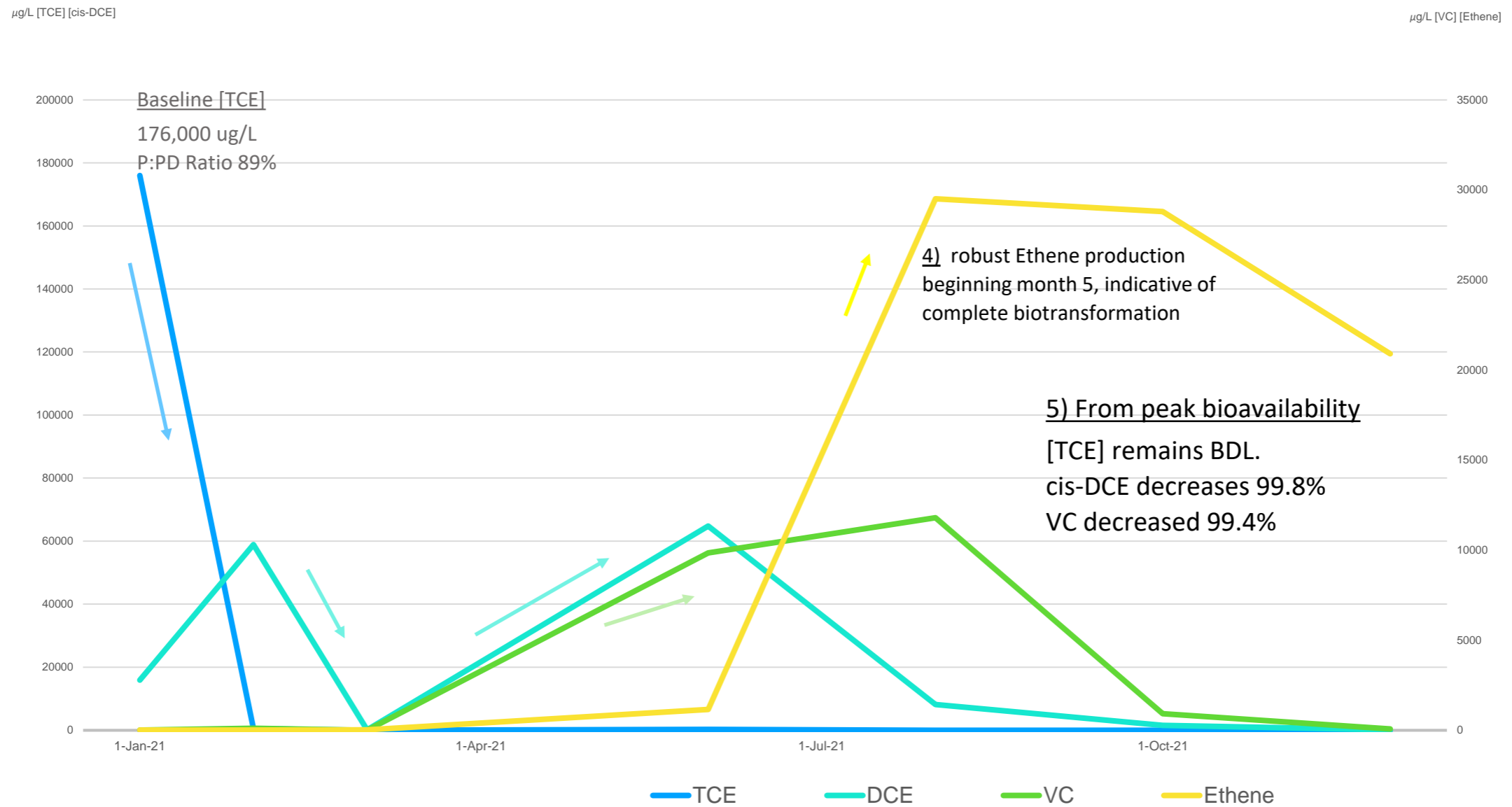


## Modified ERDENHANCED MW-24A

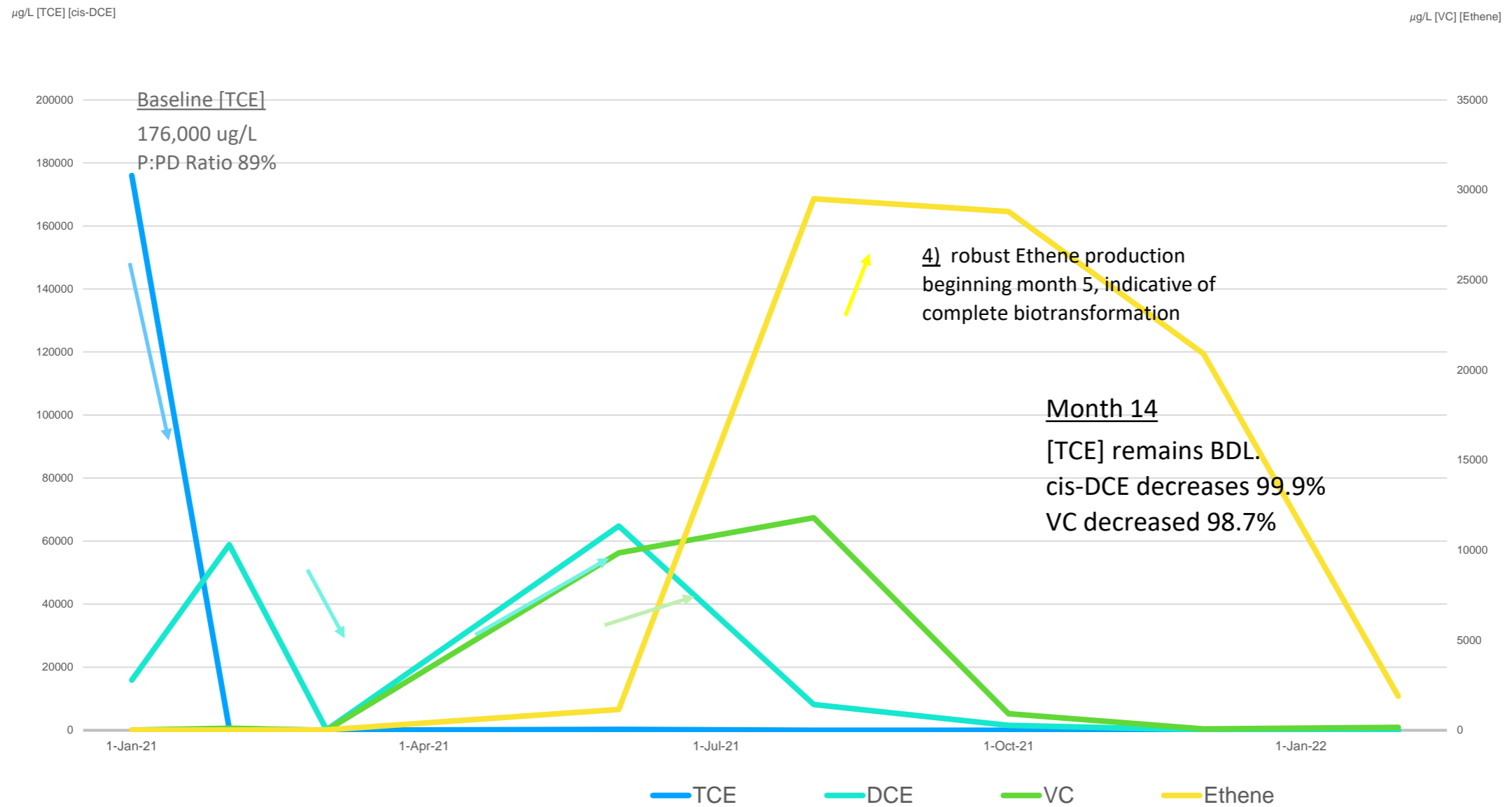




## Modified ERDENHANCED MW-24A



## Modified ERDENHANCED MW-24A



# Field Evaluation Study

## Summary

### Former Electronics Manufacturing Facility



#### Alternative electron utilization

- Addition of electron/Hydrogen generating expedites biological activity



#### ERDenhanced alone

- Achieved robust and complete DNAPL destruction in dehalorespiration
- Without 'cis-stall', realizing 76% reduction from peak; 66% reduction VC



#### Modified Formulation

- Expedites diss.phase contaminant reductions; while,
- Realizing complete and long-term dehalorespiration of DNAPL and diss.phase contaminants realizing 99.8% reduction DCE, 99.4% reduction VC



# Conclusions

## TerraStryke biostimulation additives support the subsurface ecosystem and microbes to expedite:

- ✓ LNAPL/DNAPL solubilization.
- ✓ Dissolved-phase contaminant utilization/destruction.
- ✓ The use of organic contaminants as electron donors/acceptors.
- ✓ Achieve sustainable remediation without above ground equipment costs/permitting.
- ✓ Sequester Greenhouse Gasses.
- ✓ Realize Site Compliance with less impacts, less costs simply by letting Nature have it.



**WORKING TOGETHER,  
WE SUCCEED**

Did you know that prokaryotic bacteria under suitable anaerobic conditions **CHANGE PHENOTYPICALLY, COMMUNICATE/SIGNAL, BUILD, SHARE, AND WORK COLLECTIVELY?**

 **TERRA  
STRYKE** **#bioremediation4point0**

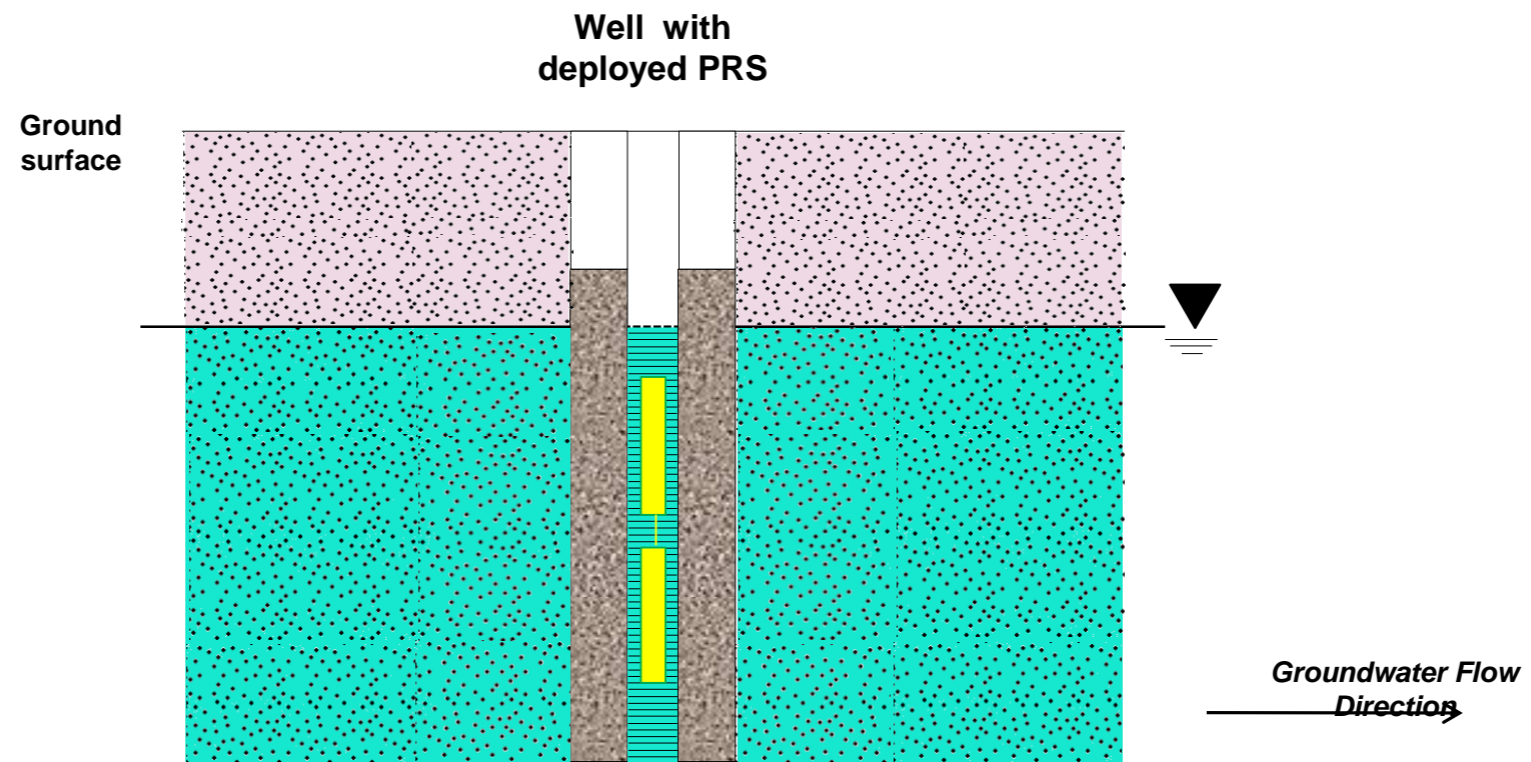


# Passive Release Sock (PRS Deployment Unit)

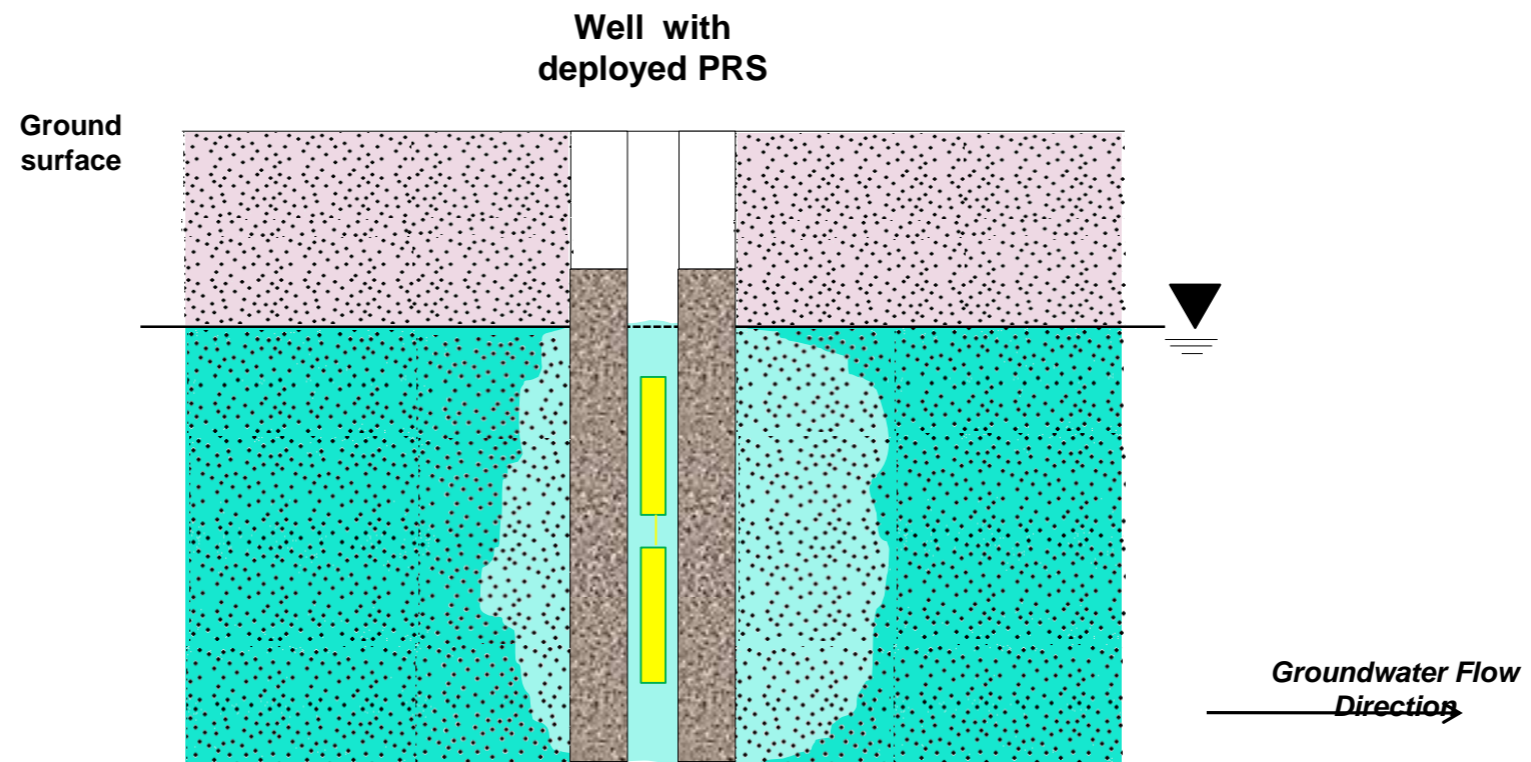
- **Low-Cost, Low-Risk On-site Evaluation process**
- **Fit directly into existing 2-inch GW monitoring well**
- **Provides Representative 'Go-no-Go' on-Site Evaluation**
- **Baseline & Performance Monitoring/Sampling**
- **Field Indicator Parameters Recorded Every Replacement Event**
- **ORP, DO, pH, Temp, Cond; NO<sub>3</sub>, SO<sub>4</sub>, dissolved Mn/Fe; Ethane, Methane, Ethene, and Contaminant of Concern**
- **Non-purge, low-flow sampling protocols**



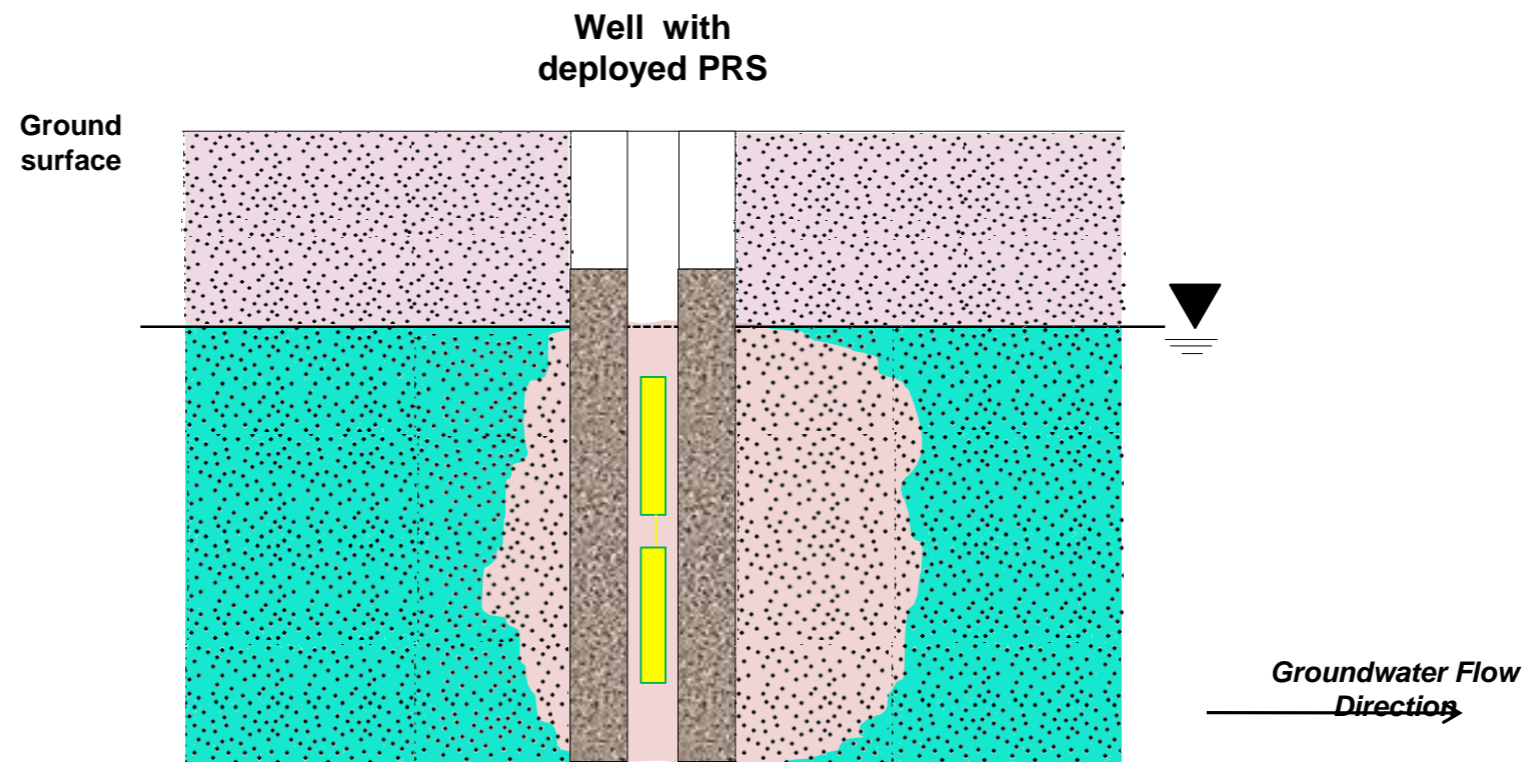
# PRS Proof of Concept Study



# PRS Proof of Concept Study

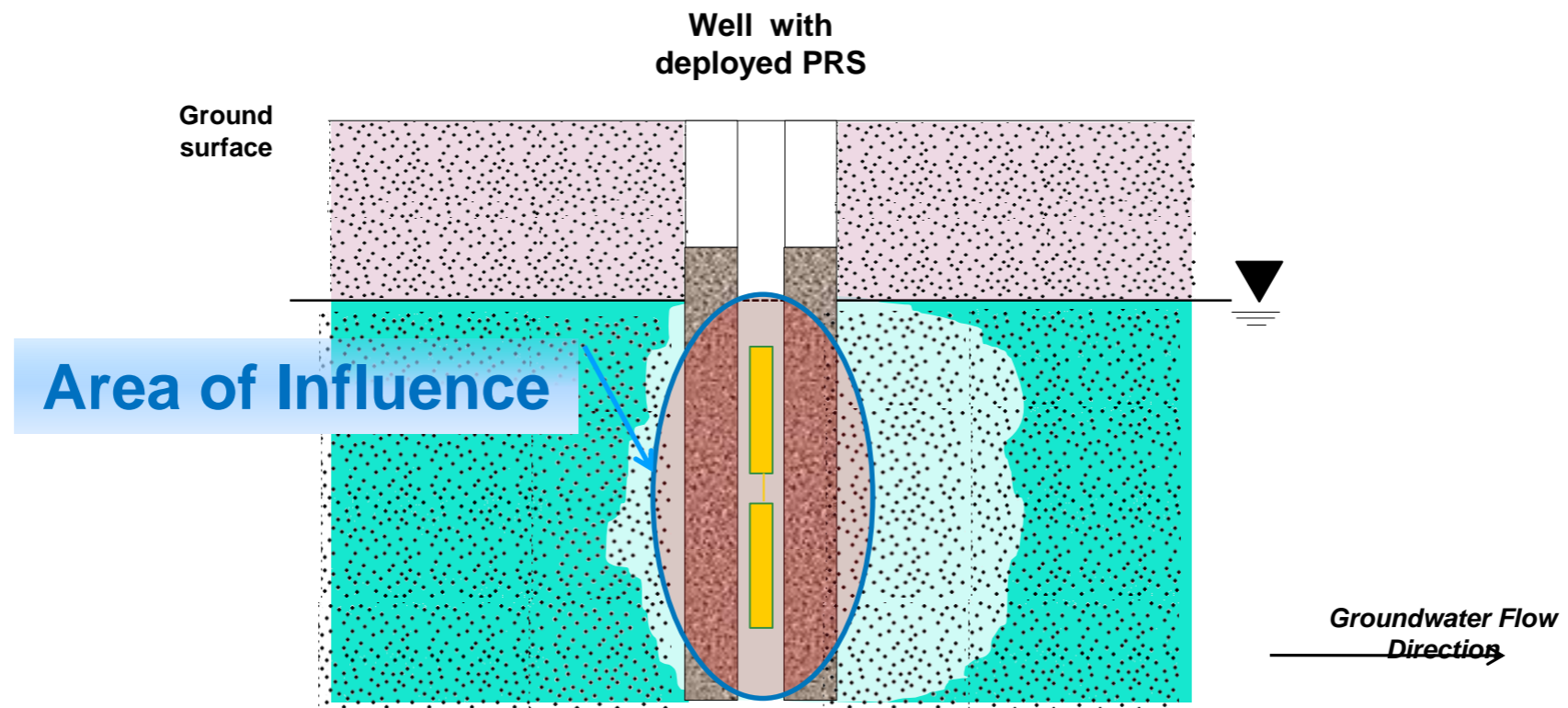


# PRS Proof of Concept Study



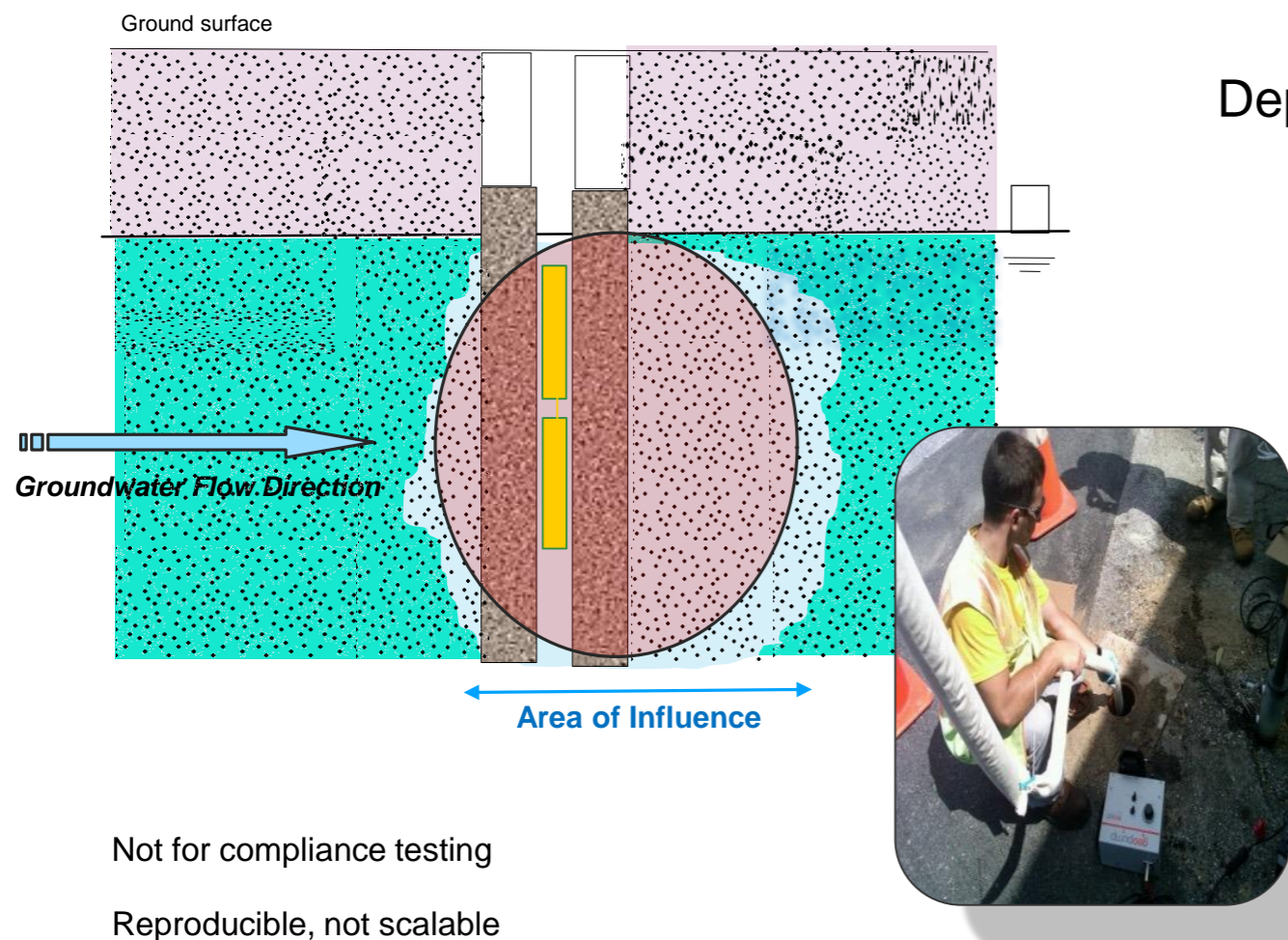


# PRS Proof of Concept Study



# PRS Proof of Concept Study

## PRS Pilot Study Schematic



'Go-no-Go' evaluation  
Additive filled Passive Release Sock (PRS)  
Deployed into existing 2-inch gw monitoring well

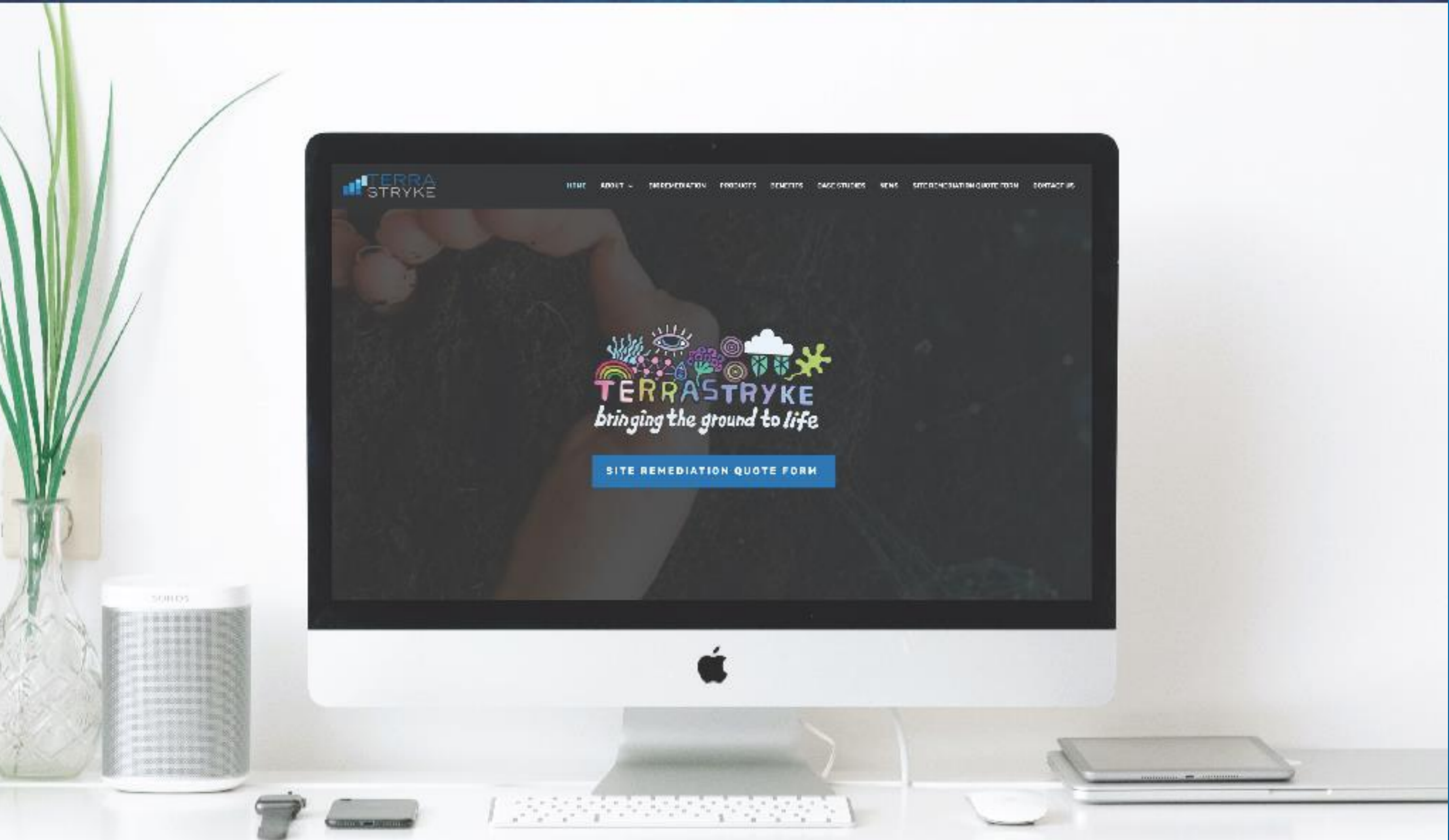
Passively amend saturated screened interval  
Create 1-2 meter area-of-influence  
Replace PRS units every 6-8 weeks

### ☐ Monitoring Program

Baseline  
Each replacement event  
Non-purge  
Low-flow  
6-8 replacement events typical



# Site Remediation Quote Form



# Conclusions

**There are lots of options out there**



# Contact Information

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**IF YOU HAVE A  
CONTAMINATED SITE THAT  
NEEDS CLEANING UP,  
REACH OUT TO US!**



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