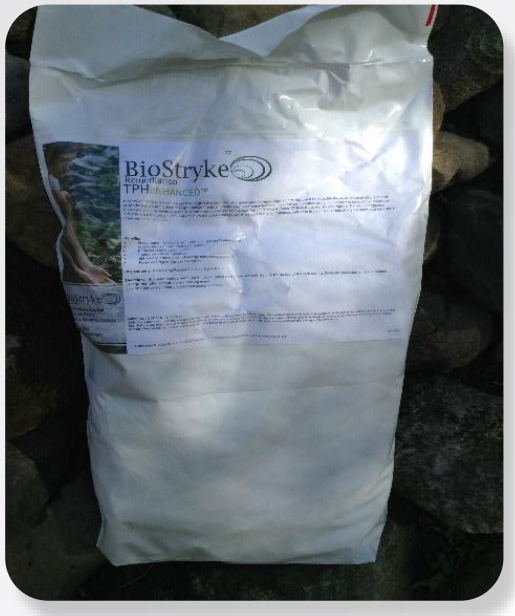
Cost-Effective In-Situ Remediation

Biostimulation as a Residual Source Mass Remediation Strategy



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October 11-13, 2017 Banff Alberta, Canada

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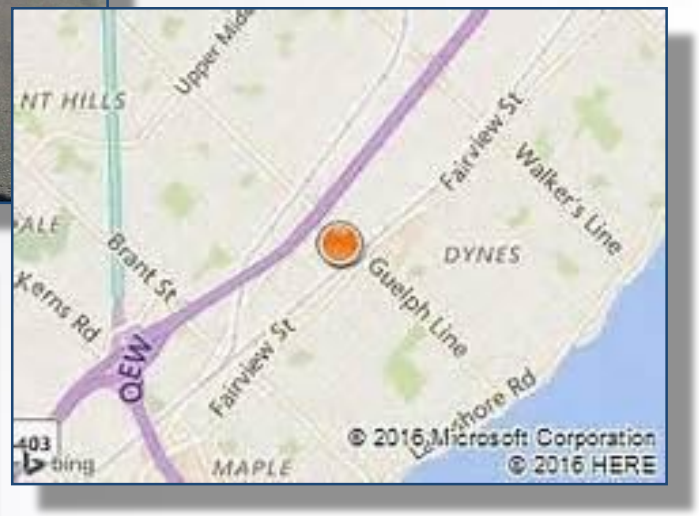
Summary of Site Conditions



Former Dry Cleaner

[PCE] in saturated soil/groundwater above MOECC Table 3 SCS

Concentrations above solubility indicative of residual source mass in saturated soils

Site Conditions

Generally Coarse Textured Soils

Silty Sand w/ Silt Generally moist

0.5m – 4.9m bgs, elevated PID readings

Weathered Shale 5-8m bgs

Bedrock below at ≈8m bgs

Property Value

Property attained by current Owner through bankruptcy

2011 Appraised Value $680,000.^{00}

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Site Conditions (cont.)

Groundwater Conditions

Flows generally southeast towards Lake Ontario

[PCE] in saturated soils and groundwater

Total [cVOC] ranged 15,000 – 130,000 ug/L

Parent:Parent/Daughter Molar Ratio ≈100%

Initial Consultants Recommendation

12-15 Year Pump-and-Treat Program

Indicated Bioremediation *not* Appropriate

Geochemistry not supportive of Enhanced Reductive Dechlorination (ERD)

Residual Source Mass Inhibitive

Cost Estimates in Excess of $650,000

Cost of Remediation Negated Property Value

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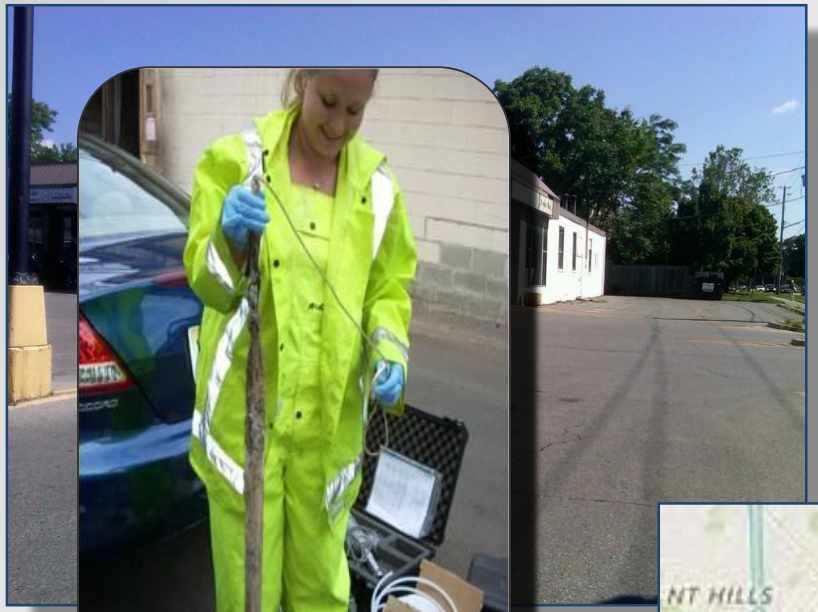
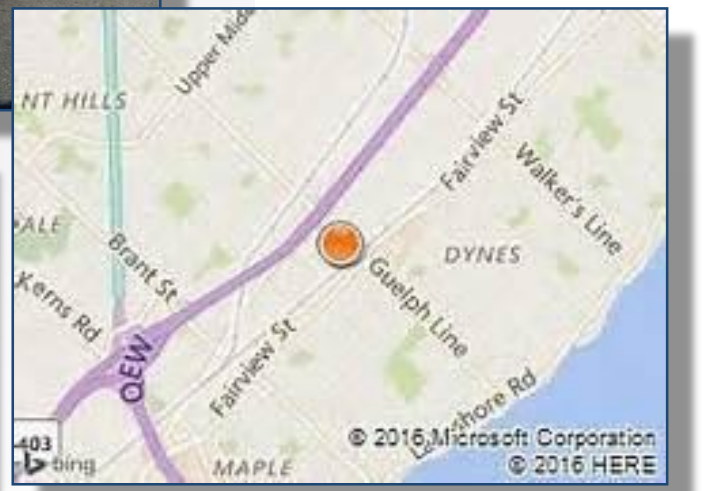
Summary of Remediation Activities





G2S Consultants Recommendation

Perform on-Site Pilot Study ≤$5,000

Evaluate additive efficacy under actual Site biogeochemical conditions

Assist further understanding of subsurface conditions:

- presence/absence residual source mass
- rates of dechlorination

Remove source zone contaminants

Excavate subslab source soils

Full-Scale In-situ biostimulation strategy to address residual source mass & dissolve phase contaminants

Estimated Remediation Cost ≈$100,000.^{00} - $200,000.^{00}

Retained Property Value ≈500,000.^{00}

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Enhanced Reductive Dechlorination

ERDENHANCED™

Patented (US/Canada)

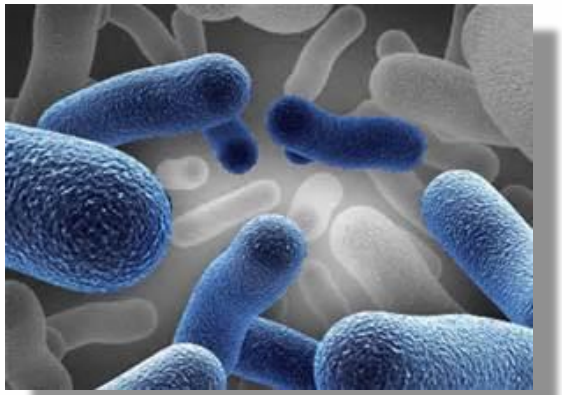
Carbon-Carbohydrate formulated with proprietary blend of macro-micro nutrients

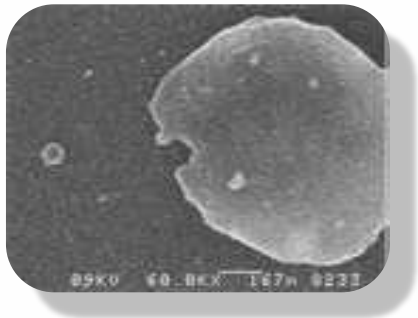
- ✓ Nourish native microbial populations
- ✓ Expedite electron scavenging, attaining methanogenic conditions faster
- ✓ Enhance solubilization of residual (DNAPL) *co-solvent effect*
- ✓ Realize superior kinetics
- ✓ Greater longevity
- ✓ Safe, Sustainable, Effective

Attain methanogenic conditions faster to favour ERD

Increase contaminant bioavailability & dissolve phase destruction

Minimize site activities while maximizing performance





Leverage Mother Nature's Momentum

Safely - Sustainably - Cost-Effectively

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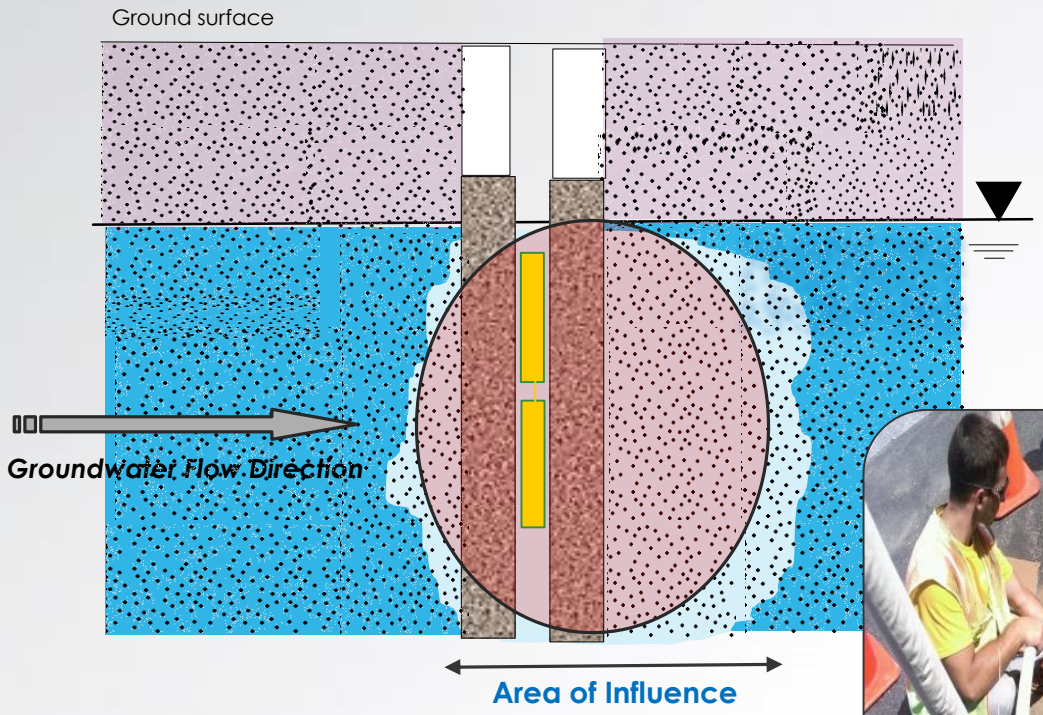
PRS Pilot Study
Schematic



Not for compliance testing

Reproducible, not scalable

‘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

PRS Pilot Study
Groundwater Monitoring Metrics

- **Indicator Metrics**

Field Parameters
ORP, DO, pH, Temperature

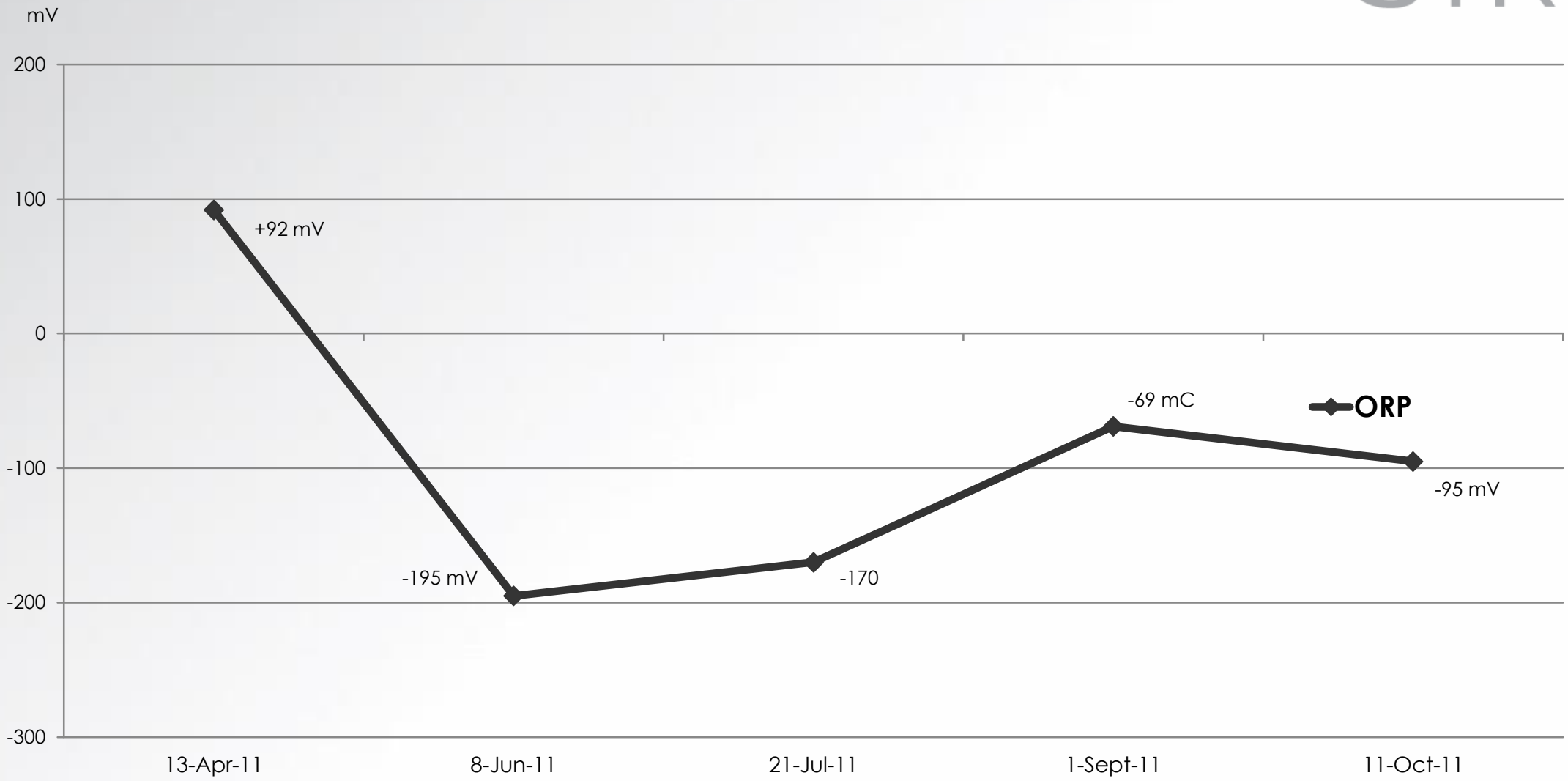
Geochemistry
Nitrates (NO3)
Diss. Iron/Manganese (Fe/Mn)
Sulphates (SO_4)
Ethane/Methane/Ethene (MEE)
Chloride (Cl^-)

Analytical
Contaminant of Concern (EPA 8260)

- Comparison of baseline data to performance data is basis for efficacy determination

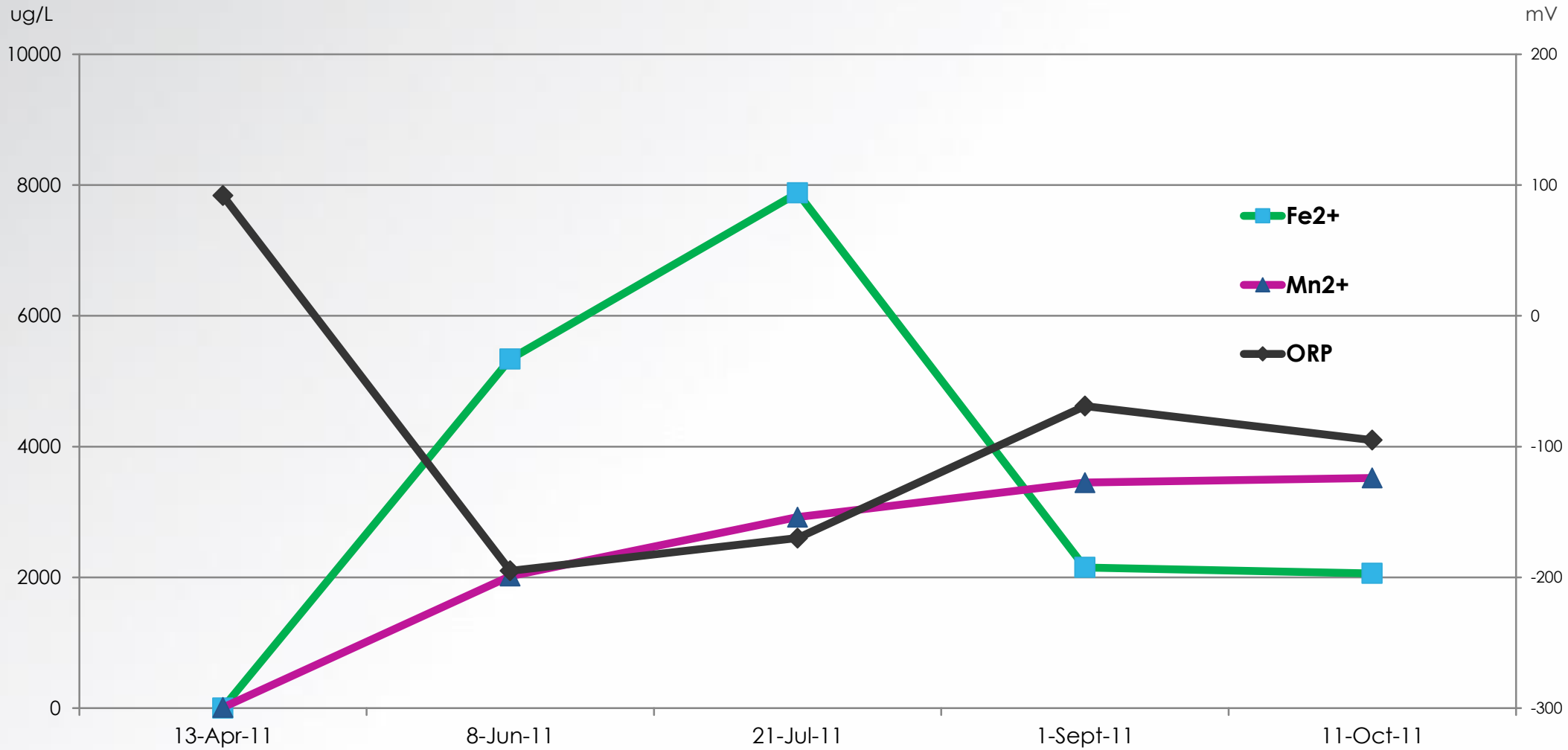
PRS Pilot Study

Geochemical Metrics



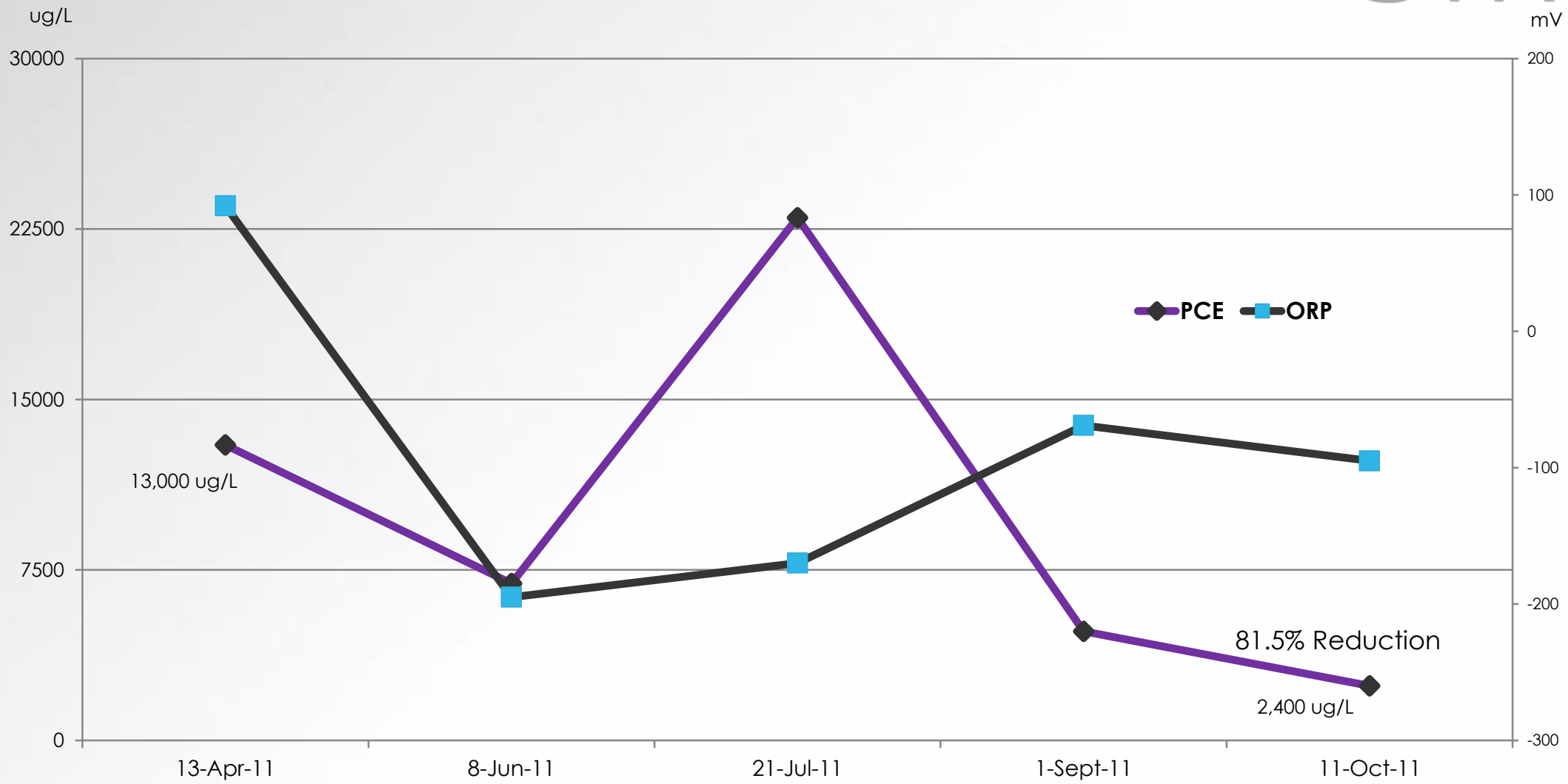
PRS Pilot Study

Geochemical Metrics



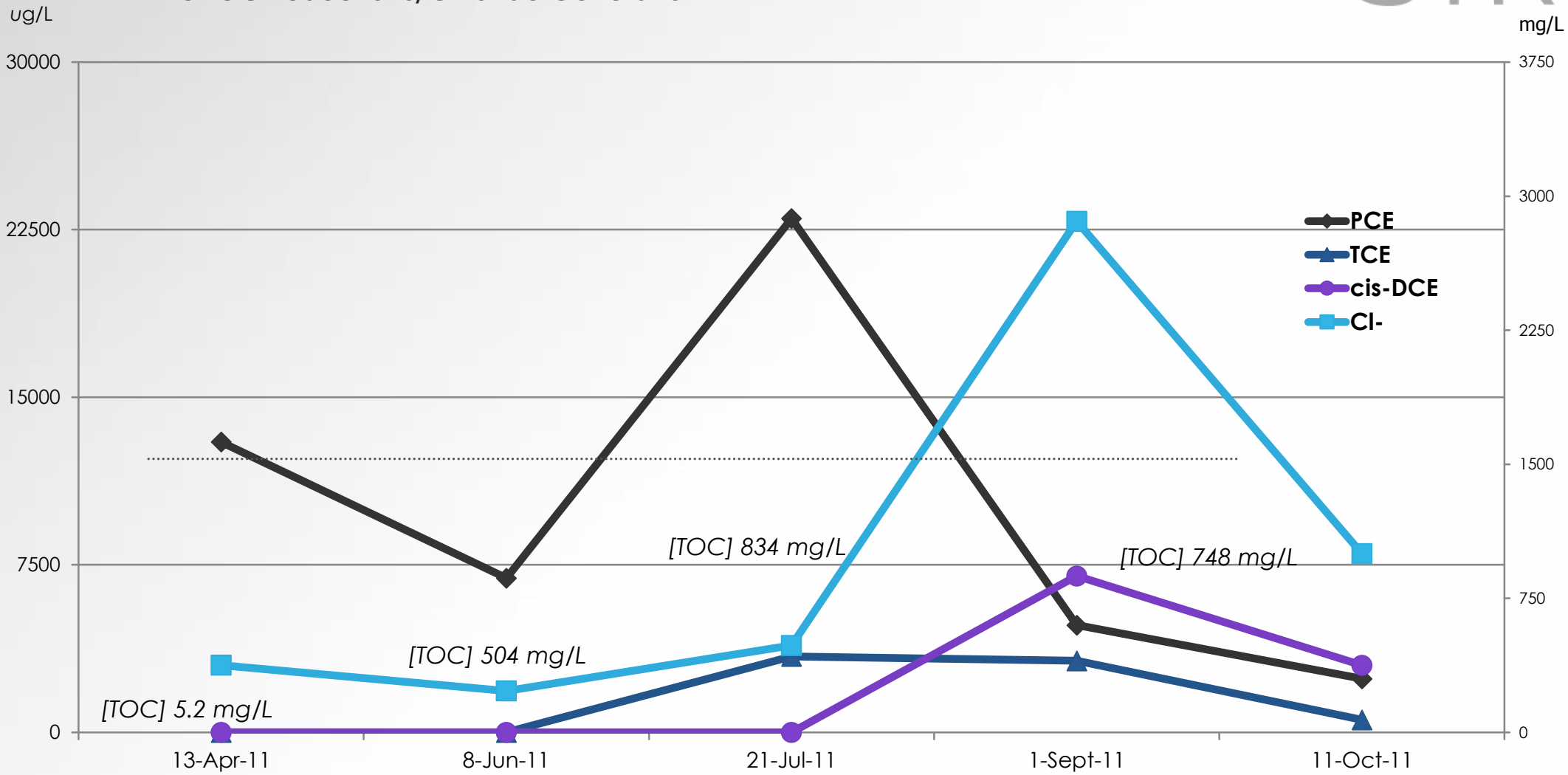
PRS Pilot Study

cVOC Reductions



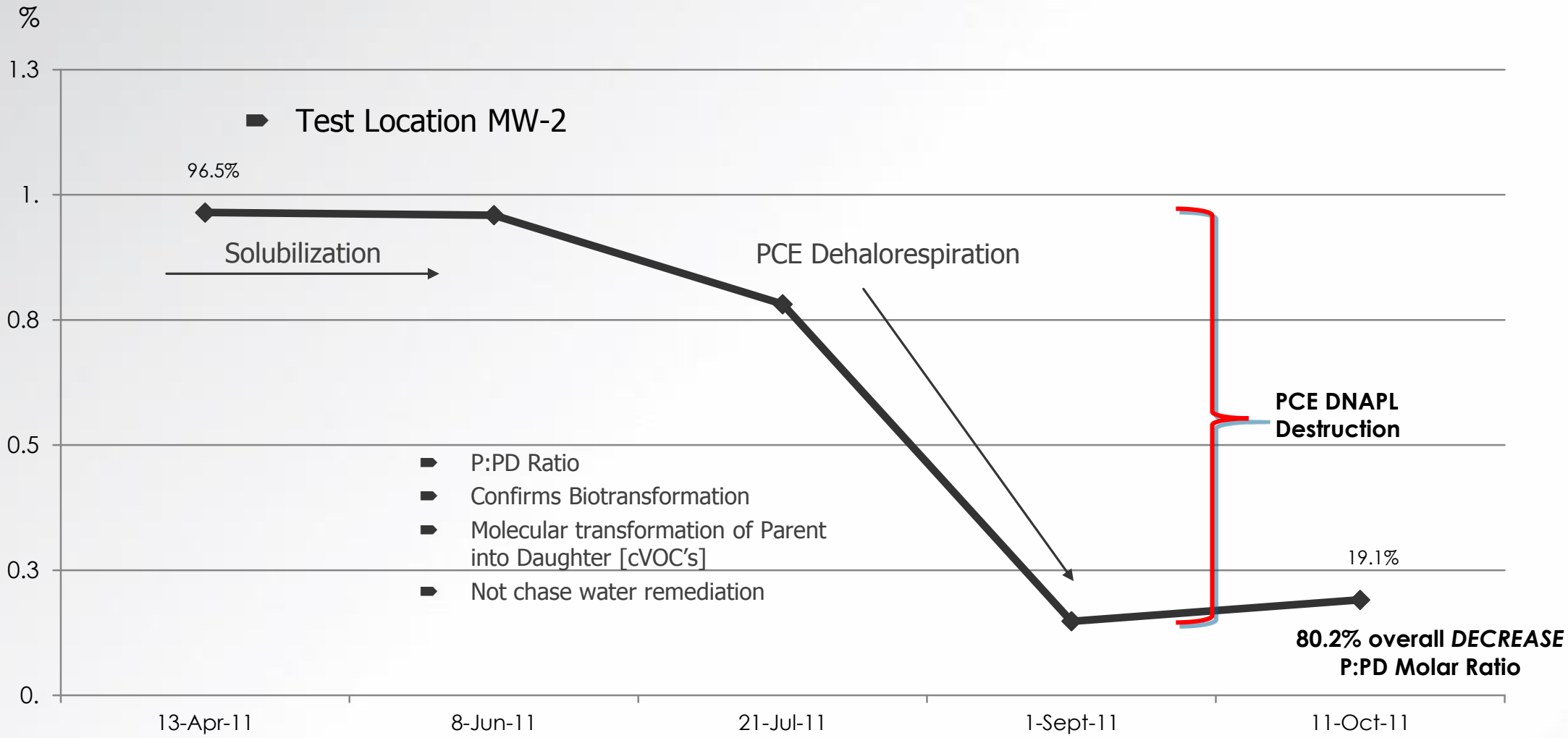
PRS Pilot Study

cVOC Reductions/Chloride Generation

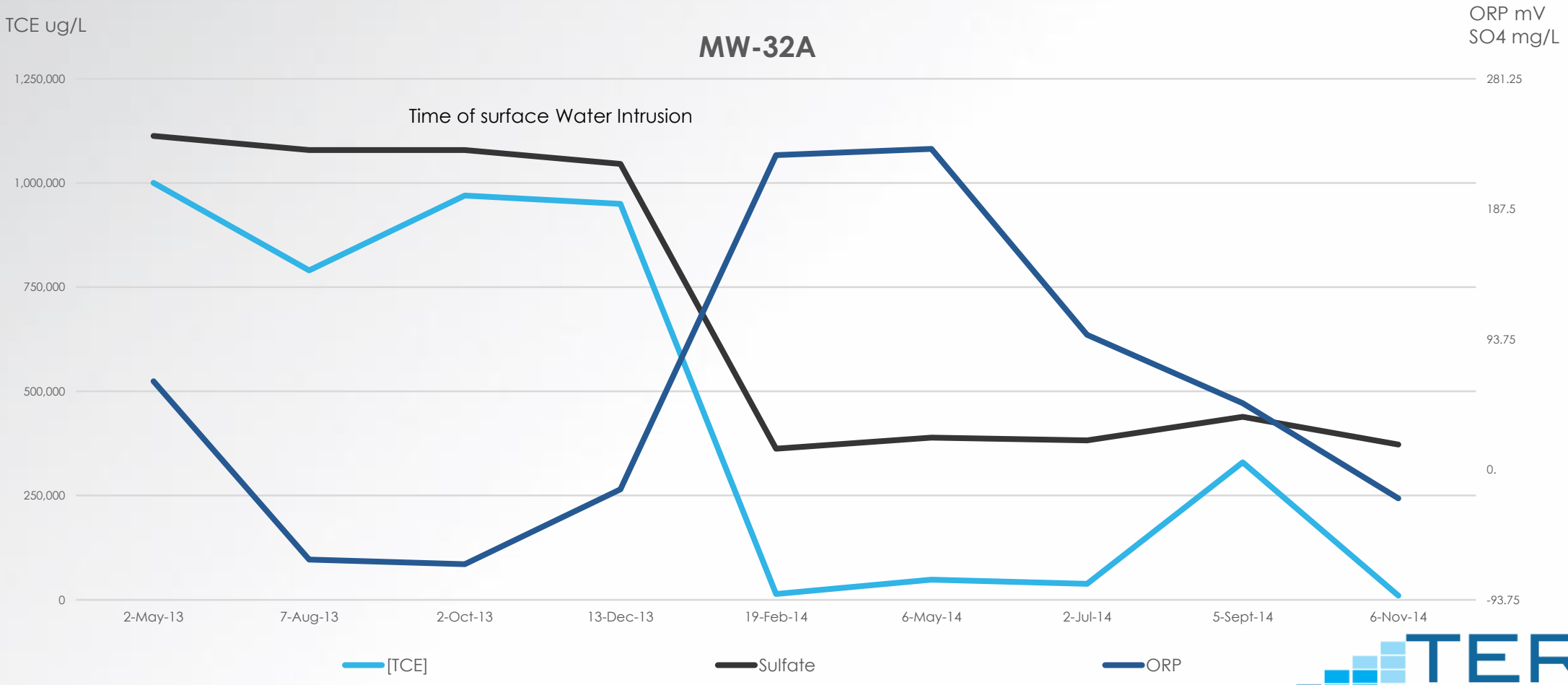


PRS Pilot Study

Parent:Parent-Daughter Molar Ratio



Importance of P:PD Molar Ratio
Contaminant Reduction?



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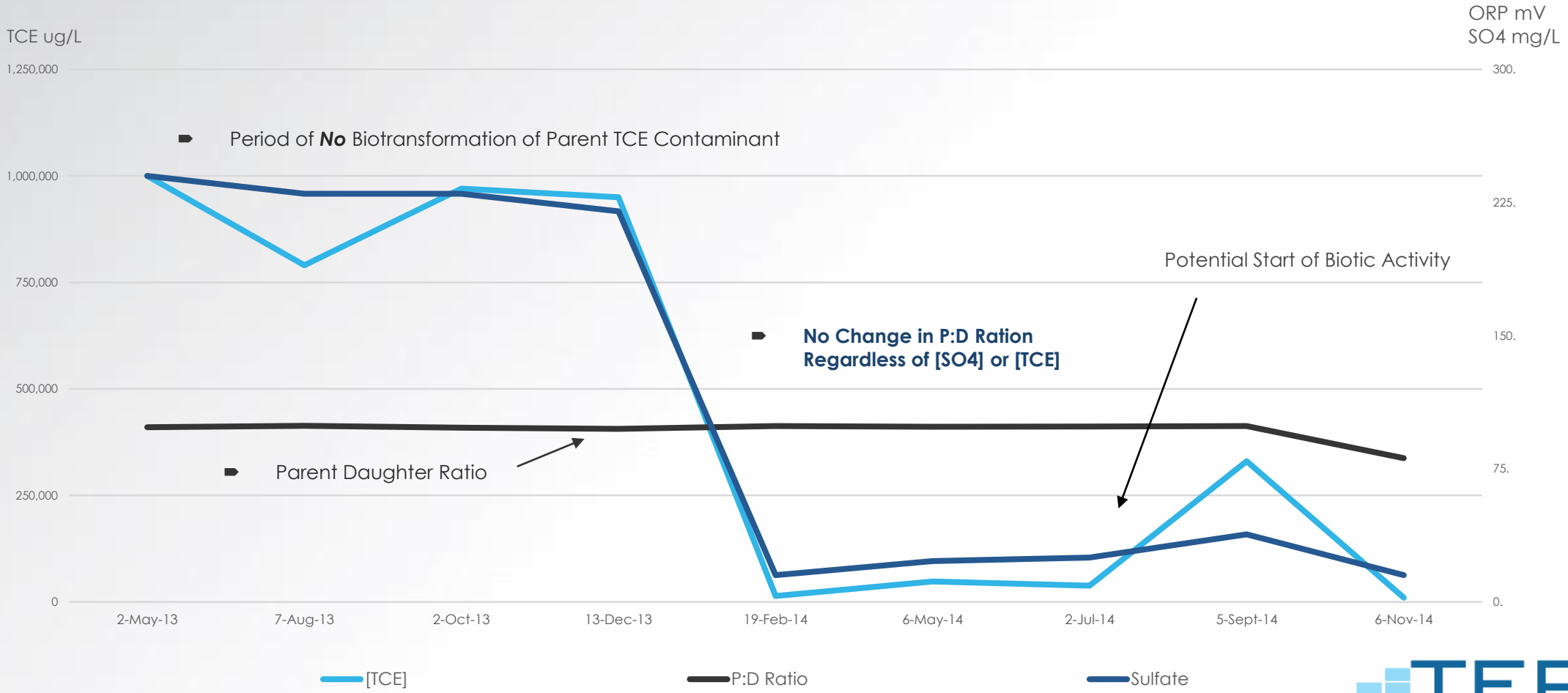
Solution to Pollution….Biotransformation! not dillution!



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Full Scale Remediation

Source Area Removal Fall 2013

Contaminant Location

Subslab soils

Full soil source removal unfeasible

Residual Mass Remains

Excavation – Source Removal

Excavation removed 250m^3 contaminated soils

Infiltration gallery installed w/in footprint

Clear stone, 6-inch slotted PVC, 2-3m bgs

Groundwater Conditions

Residual mass likely in saturated soils not excavated

Post-excavation [PCE] in area 5,000-30,000 ug/L

Daughter products remain absent

ORP Values

MW2 -278

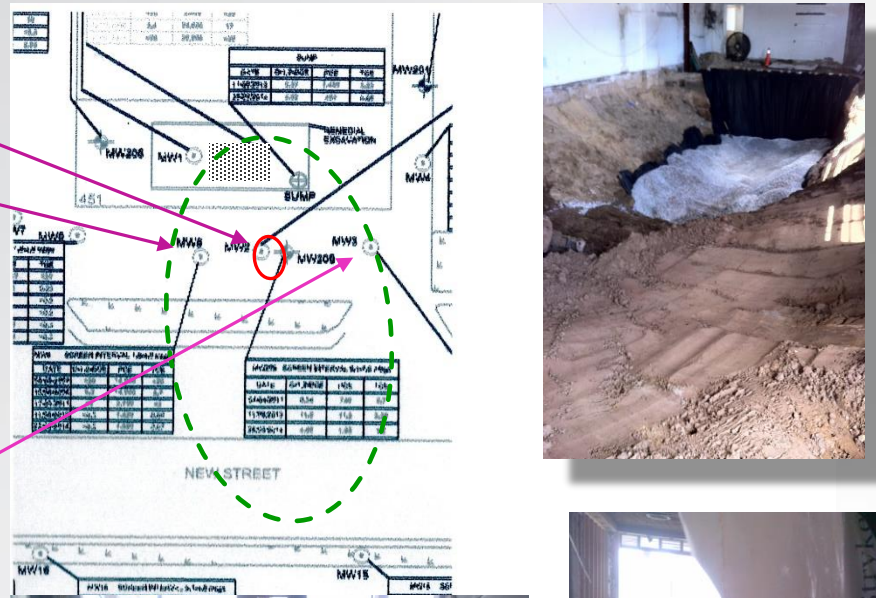
MW3 -187

MW5 -156

MW6 -199

Full Scale Remediation 2.0

Biostimulation



Additive Deployment

- Additive deployed 2-times passively
- Used infiltration gallery
- Limited matrix ability to receive slurry
- 9% additive slurry
- 990kg to 1,100 gallons chase water (March 2014)
- 840kg to 1,100 gallons chase water (July 2014)

PRS Pilot Test AOI

Extent of cVOC Plume

Source Removal Area

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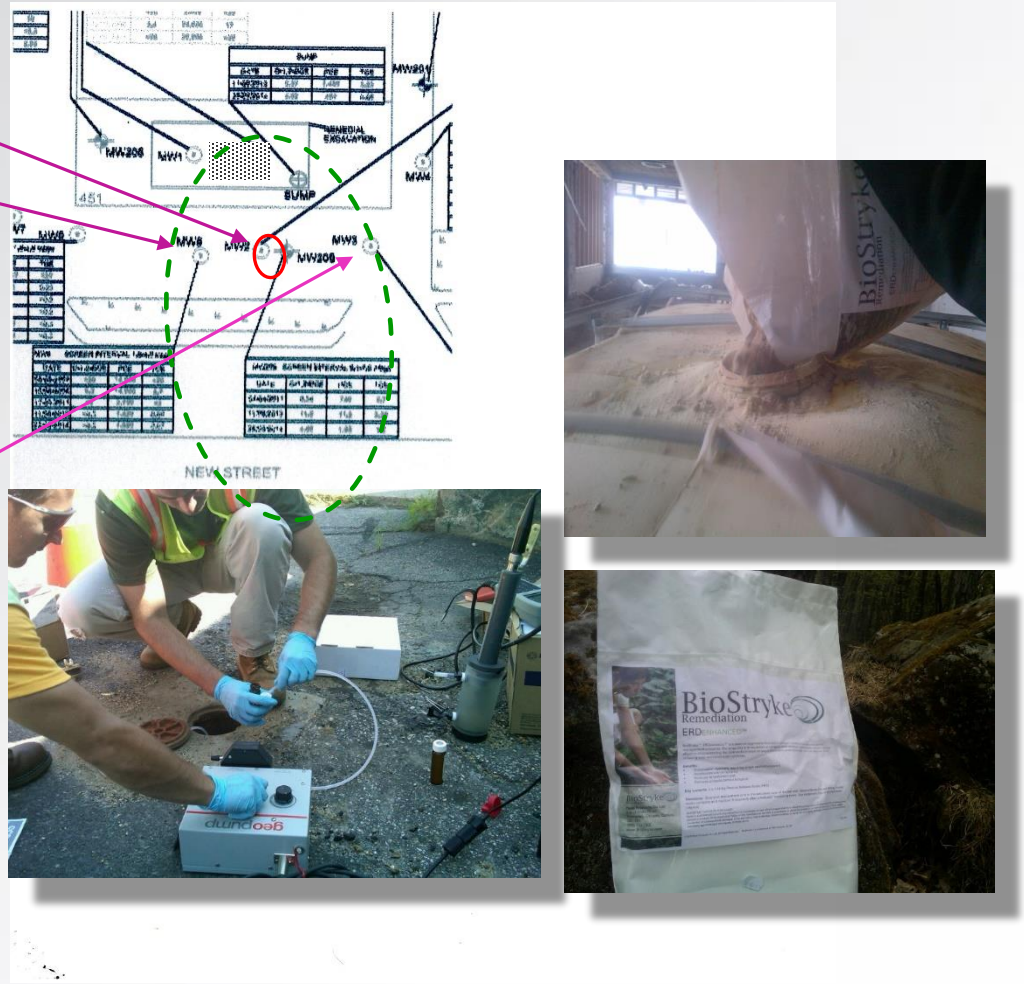
Full Scale Remediation 2.0

Biostimulation



Groundwater Monitoring Performed @ MW-2 over 6yrs

- 5 rounds March 2011 to October 2011 (PRS Pilot)
- 1 pre-excavation round September 2013
- 8 additional rounds March 2014 to May 30, 2017
- Other locations monitored Sept 2013 – May 2017
- MW-3, MW-5, MW-6 on-Site
- MW-15, MW-16 and MW-17 off-Site

PRS Pilot Test AOI

Extent of cVOC Plume

Source Removal Area

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Results

March 2014 pre Full-Scale deployment
≈2½ years after PRS Pilot Study

Location	[PCE]	[TCE]	[cis-DCE]	[VC]	P:PD Ratio	[TOC]*
MW-2*	370 ug/L	29.6 ug/L	5.4 ug/L	80.3	58.8%	434 mg/L
MW-3	1,030 ug/L	<0.05 ug/L	<0.05 ug/L	ND	99.9%	1.7 mg/L
MW-6	1,950 ug/L	0.67 ug/L	<0.05 ug/L	ND	99.9%	1.8 mg/L
MW-209	1.93 ug/L	1.2 ug/L	4.66 ug/L	ND	30.4%	1.3 mg/L

Pre-Pilot [PCE] 13,000 ug/L
[PCE] at MW-2 post-Pilot ≤84.6% (2,400 ug/L)
P:PD Molar Ratio 19.1%.

MW-2 former PRS location
MW-209 ≈abuts

MW-3 MW-6 not effected by PRS evaluation

Non-effected areas with >99% P:PD Ratio

Indicative of little to no biotic activity evident

*Total Organic Carbon (TOC) levels recorded August 19, 2014

ORP Values October 23, 2014

MW2 -32

MW3 +16

MW5 +20

MW6 +16

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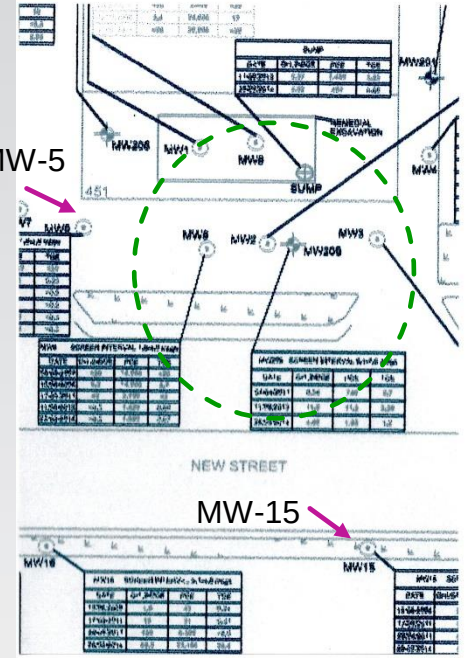
Results

October 2015
≈1½ years post Full-Scale deployment



Location	[PCE]	[TCE]	[cis-DCE]	[VC]	%Δ[cVOC$_{total}$]	P:PD Ratio	[TOC]*
MW-2	BDL	BDL	48 ug/L	BDL	84.1%$_{reduction}$	8.7%	211,110 mg/L
MW-3	51 ug/L	2.7 ug/L	170 ug/L	26 ug/L	78.3%$_{reduction}$	0.8%	700,000 mg/L
MW-6	41 ug/L	12 ug/L	130 ug/L	50 ug/L	88.0%$_{reduction}$	3.7%	239,000 mg/L
MW-209	NS	NS	NS	NS	-%$_{reduction}$	NS	NS
MW-15	10,000 ug/L	BDL	BDL	BDL	NA	100%	NR

Average 94.9% Reduction P:PD Ratio 17-months Post Deployment

Near 100% *REDUCTION* at MW-3

*** TOC readings recorded April 24, 2015**

Area of Amendment Influence

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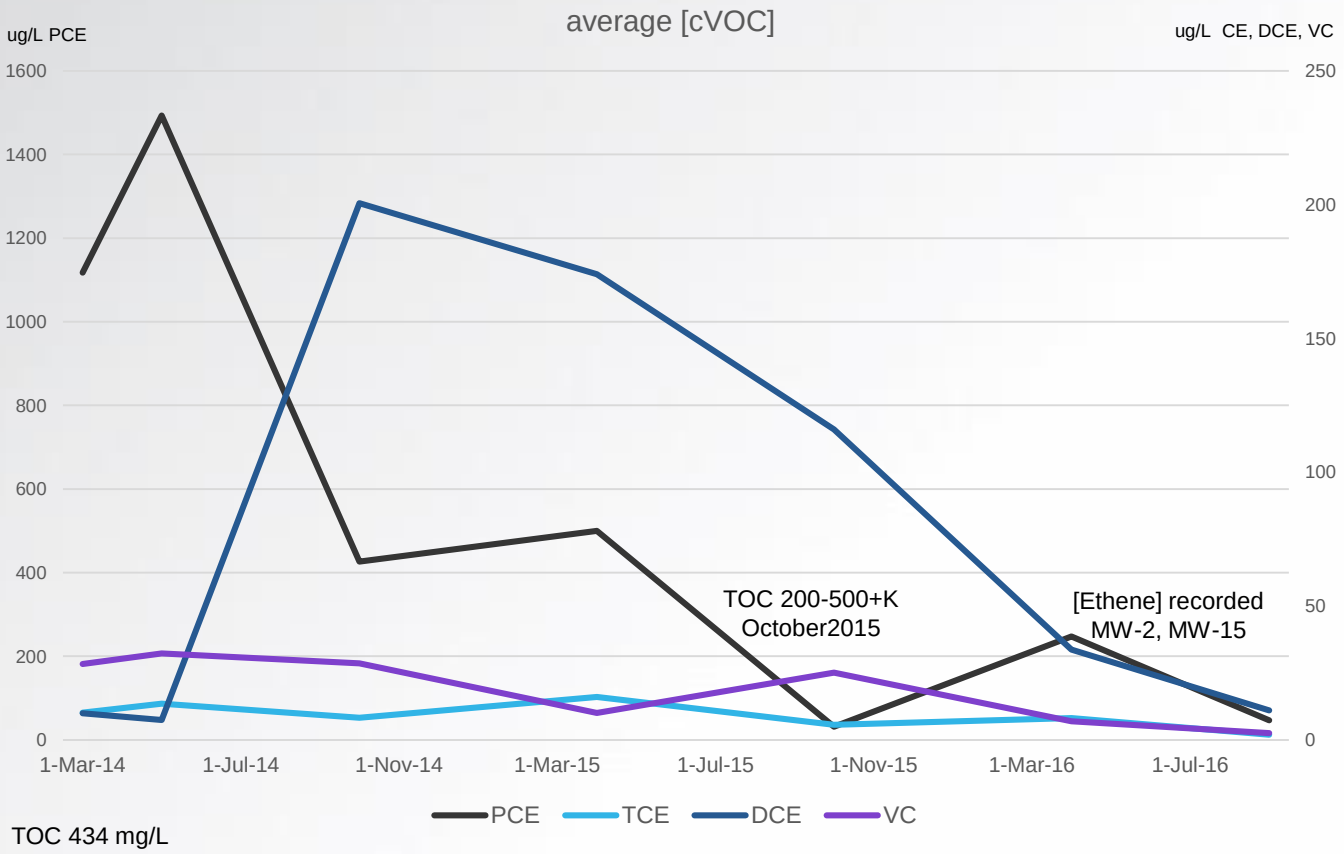
Results

July 2016

2years 2months post Full-Scale deployment



TOC 434 mg/L

Average [cVOC]

- Plot averages [cVOC] at MW2, MW3, MW6
- **96.9%** overall reduction [PCE]
- **88.2%** reduction [TCE] from peak bioavailability
- **94.5%** reduction [cis-DCE] from peak bioavailability (after >1,600% increase)
- **92.3%** reduction [VC] after several occasional of increases/decreases
- **No** Indoor Ambient Methane/VC Issues
- Redevelopment planning is initiated

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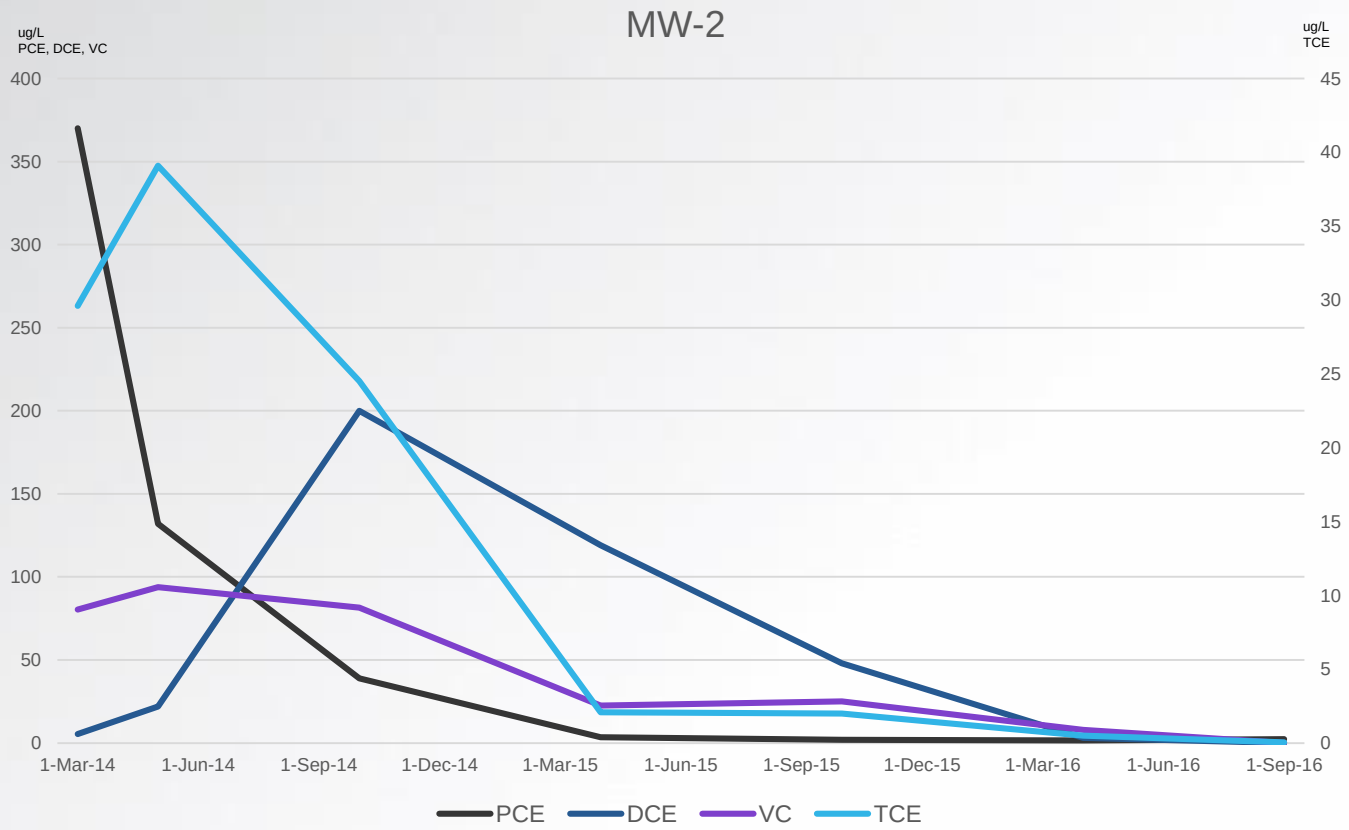
Results

September 2016
2½ years after Full-Scale deployment



MW-2

- **99.4%** reduction [PCE]
- **99.9%** reduction [TCE] *after* 32.1%↑
- **≈100%** reduction [cis-DCE] *after* 3,600%↑
- **99.9%** reduction [VC] *after* 16.8%↑
- **99.5%** reduction in [cVOCtotal]
- [Ethene] detected = *complete* biotransformation
- Demonstrated safe, sustainable and effective enhanced dehalorespiration
- All but [PCE] (2.4 ug/L) within MOE Criteria (1.6 ug/L)

TOC Levels
MW-2 13 mg/L
MW-15 130 mg/L
[Ethene] MW-2 and MW-15

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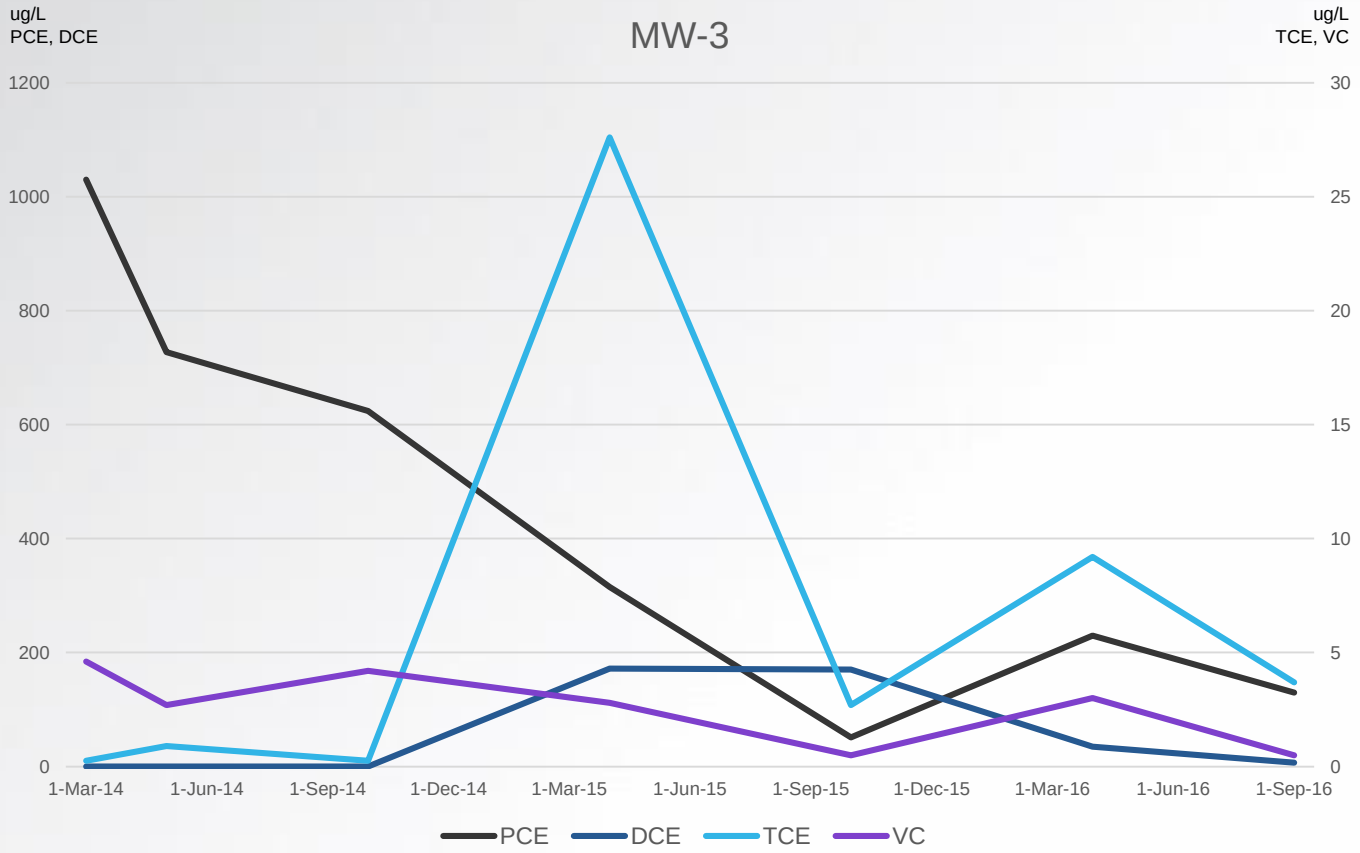
Results

September 2016
2½ years after Full-Scale deployment



MW-3

- **87.4%** overall reduction [PCE]
- Max. ↓ [PCE] >95% (T=18-months)
- **90.2%** reduction [TCE] first 6-months; then
- [TCE] increases Five Orders-of-Magnitude
- **86.6%** reduction [TCE] from peak
- **95.9%** reduction [DCE] from peak
- **89.1%** reduction [VC]; to <1.6 ug/L, from max. increase of ≈500%

TOC Levels
MW-3 12 mg/L

No Ethene Detected

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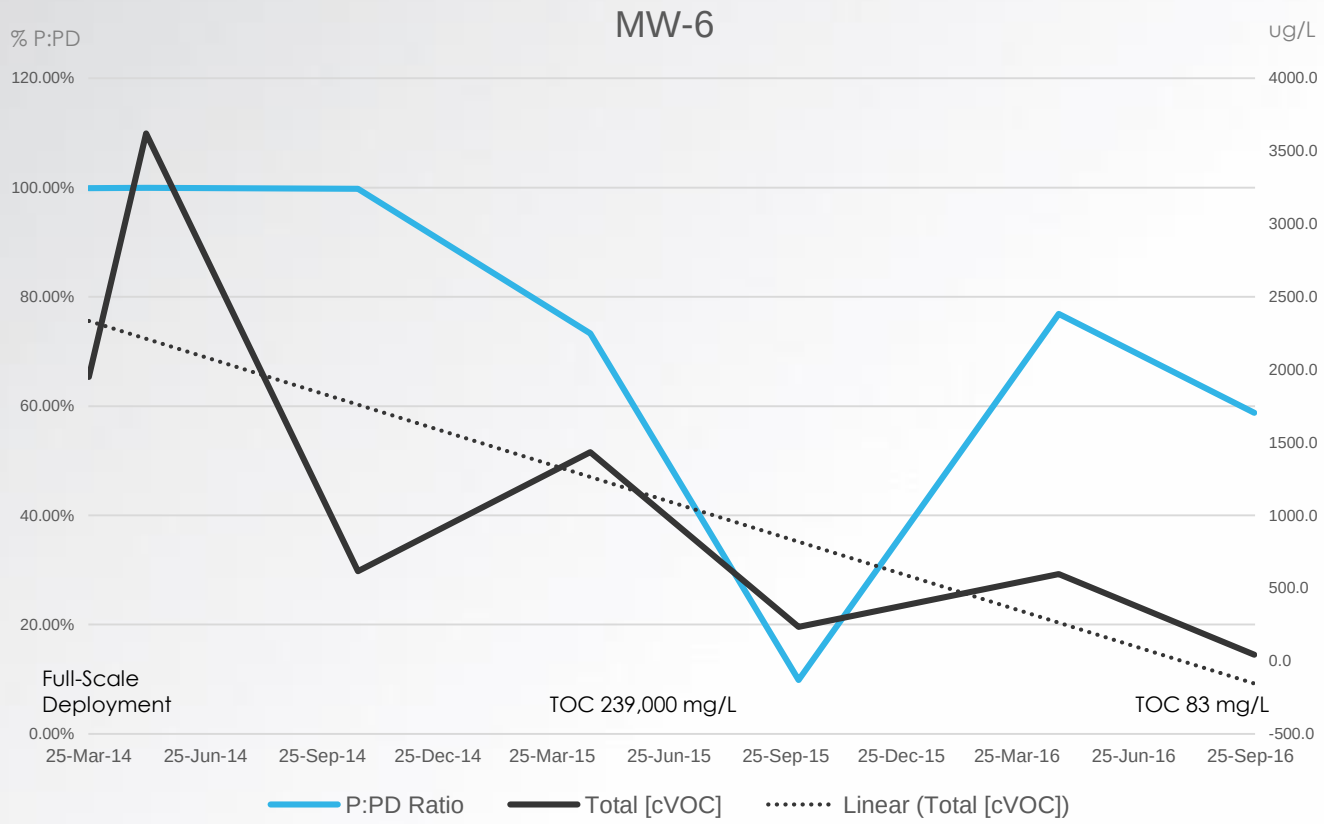
TOC 239,000 mg/L

Results

September 2016
2½ years after Full-Scale deployment



- **90.1%↓** P:PD Molar Ratio T=month18 (October 2015)
- 41.2%↓ overall reduction P:PD Molar Ratio
- P:PD Ratio confirms dehalorespiration molecular change of PCE
- **98.8%** reduction [$cVOC_{total}$] @ MW-6

TOC Levels
MW-6 83 mg/L

No Ethene Detected

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Results

May 26, 2017

3 years after Full-Scale deployment
6 years after PRS Pilot Study

Location	[PCE]	[TCE]	[cis-DCE]	[VC]	Change	[TOC]	ORP
MW-2	BDL	BDL	330 ug/L	210.0 ug/L	<0.01% P:PD	34 mg/L	-123 mV
MW-3*	130 ug/L	3.7 ug/L	BDL	BDL	87.0%reduction [$cVOC_{total}$]	12 mg/L	-50 mV*
MW-6	80 ug/L	BDL	BDL	BDL	95.9%reduction [$cVOC_{total}$]	13 mg/L	-79 mV
MW-15	4,300 ug/L	270 ug/L	1,200 ug/L	71 ug/L	≈50% Reduction P:PD Ratio	8.1 mg/L	-92 mV

- TOC Levels at MW-15 130 mg/L September 2016
- *MW-3 monitoring well destroyed after this round

MW-2

- >99.9% Reduction P:PPD
- 96.1% Reduction [$cVOC_{total}$]
- Compliant [PCE] & [TCE]

MW-3

- 87.0% Reduction [$cVOC_{total}$]
- Compliant [TCE], [cis-DCE], [VC]

MW-6

- 95.9% Reduction [$cVOC_{total}$]

MW-15 (off-Site)

- 50 meters downgradient gallery
- P:PD↓ dec. 99.97% to 50.81%
- 71.6%↓ dec. [$cVOC_{total}$] from peak bioavailability

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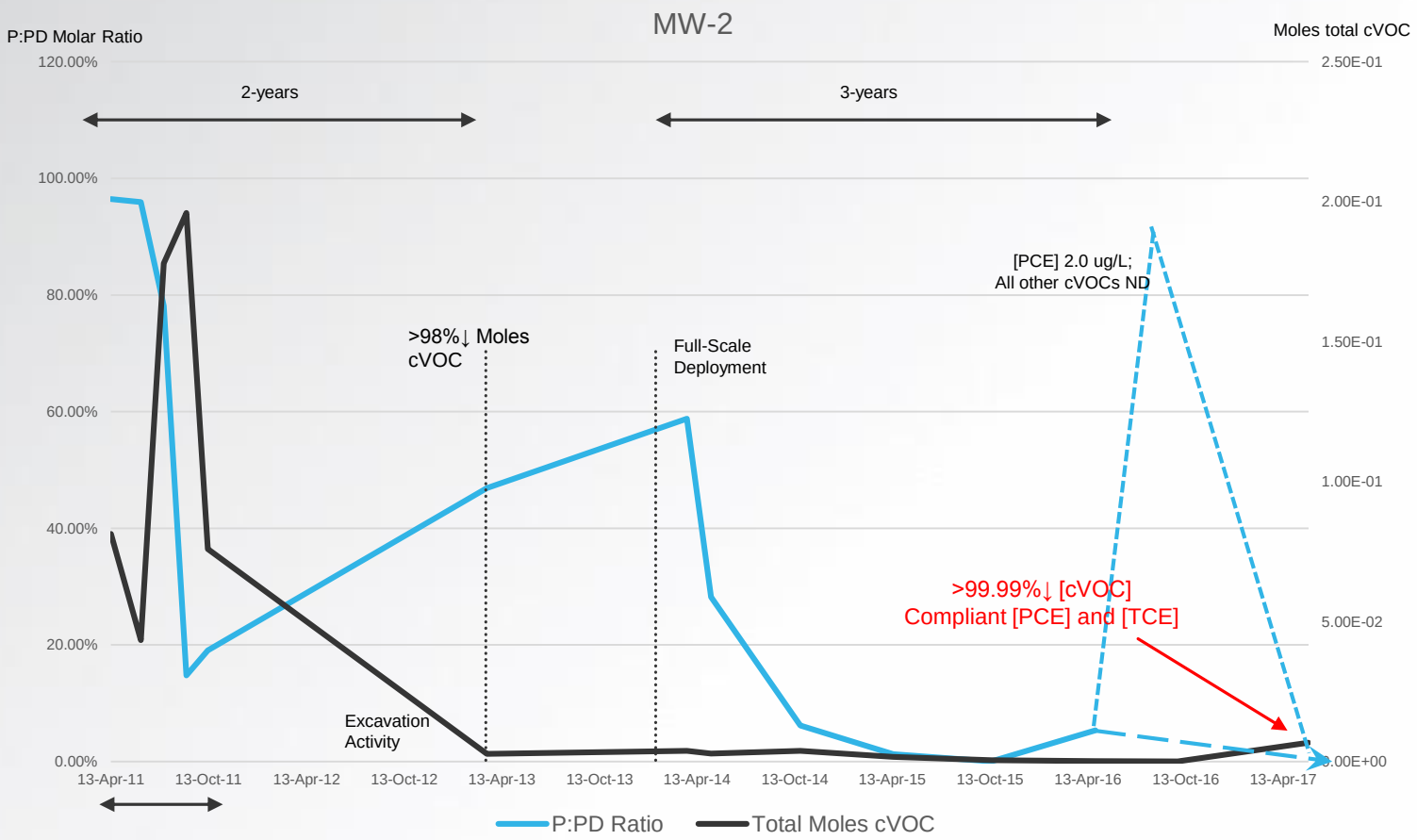
Results MW-2

May 2017
3 ½ years after Full-Scale deployment
6+ years post PRS evaluation



MW-2 over 6+ years

- 2-years after 24-lbs additive >98%↓ Moles cVOCs/P:PD
- PRS Pilot Study demonstrated solubilization/biotransformation
- 3-years post full-scale deployment
- >99.99%↓ P:PD Ratio/Moles cVOCs
- [PCE] & [TCE] below MOE Table 3 Criteria non-Potable groundwater
- Site currently undergoing redevelopment
- No Indoor Ambient Air issues recorded throughout 6+ years

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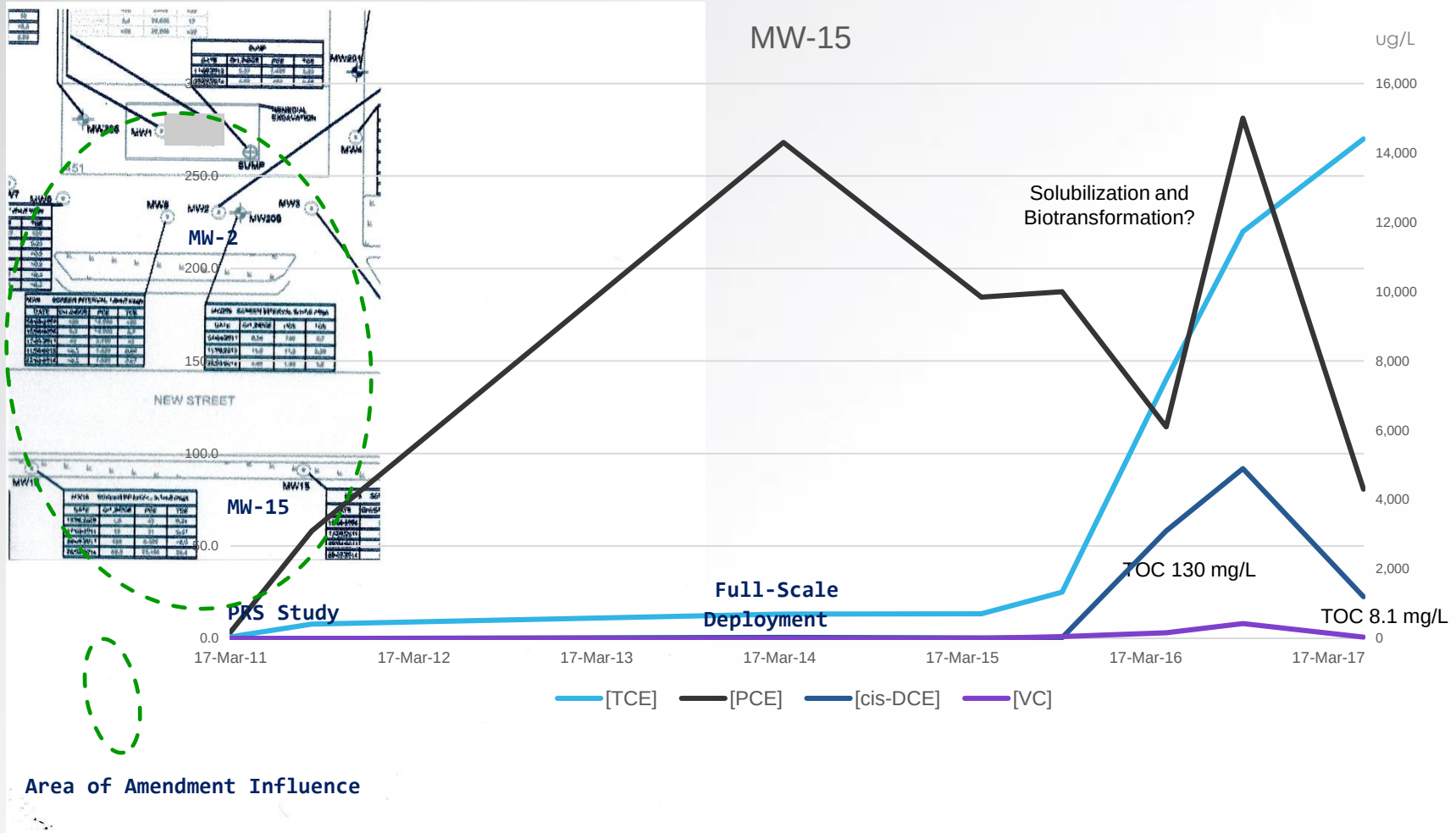
Results

May 26, 2016

2½ years after Full-Scale deployment



- MW15 ≈50 meters downgradient
- Monitored since 2011 Pilot Study
- [TOC] not recorded until Sept. ‘16
- [Ethene] detected since April ’16
- P:PD ratio >99% to <63%
  last 12-months of evaluation
- Max. reduction P:PD ≈50%
- Moles cVOCs 73%↓ since peak TOC
- Gallery influence extending beyond property boundary
- ORP Values -92 mV
- ORP MW16 -51 MW17 -15

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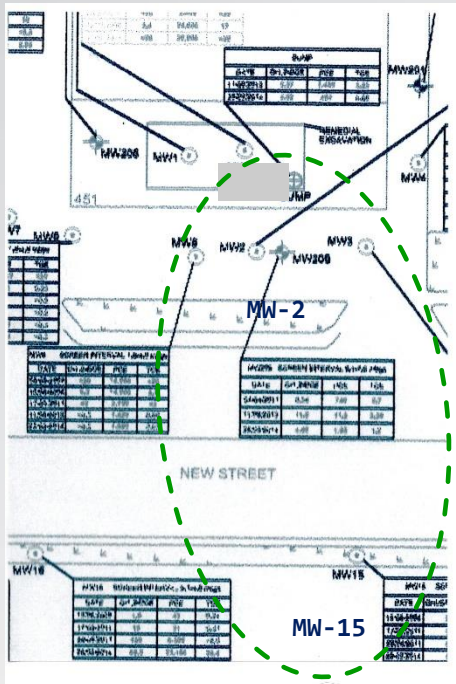
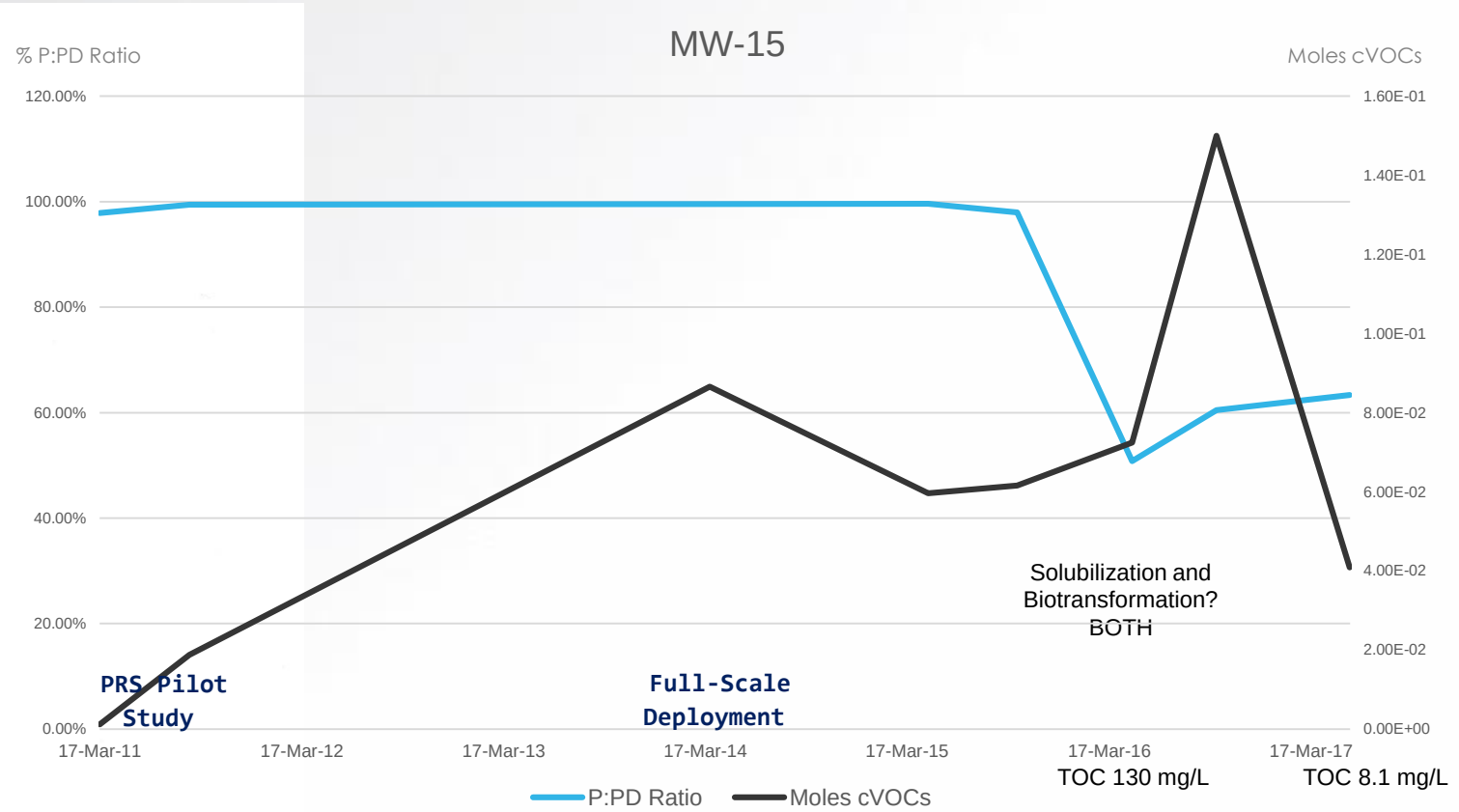
Results

May 26, 2016
2½ years after Full-Scale deployment



PRS Study



- P:PD Ratio Steady ≈100% Through 2015
- No amendment influence
- 2016 TOC levels increase
- P:PD Ratio ↓ 40%-50% 2016-2017
- Enhanced additive influenced ERD 3-years later

Area of Amendment Influence

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Conclusions ERD ENHANCED™

- **Safe Sustainable and Effective**
- **Enhance Native Microbial Populations to:**
  - Realize Superior rates of Dehalorespiration
  - Expedite Residual Mass Solubilization
    - 2^{O} Co-Solvent Effect
- **Sustainability**
  - Proprietary nutrient package vital to longevity
  - Extends/Recirculates Carbon/nutrient availability
  - Maintained reducing conditions for over six years
  - Minimize deployment efforts
  - Maximize remediation $dollars$ and project margins

G2S Environmental Consulting Inc.

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Conclusions The Real Story

Property Values

- Without contamination issues $680,000
- Initial P&T Costs Estimated @ $650,000 12-15 yrs (minimum)
- Property Value effectively $0.00
- Proved cost-prohibitive and Owner chose not to pursue

Biostimulation Remediation Strategy

- Total project Costs
  - $223,000
  - $85.00/yard

Soil removal/gallery install	$38,000
Pilot and Full-Scale Additive	$35,000
Consulting and Analytical	$150,000

- 6-years and Site under redevelopment

- Property Value Assessed 2017 @ 2.5 million dollars
- Property Manager attributes $1 million in increase to remediation strategy

G2S Environmental Consulting Inc.

TERRA STRYKE

Thank You

Carl Galli – Property Owner

Geoff Bell – G2S Environmental Consultants
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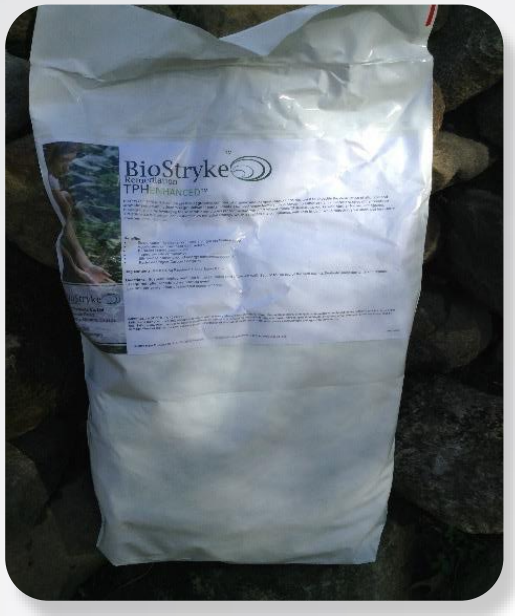
(905) 331-3735

Environmental Services Association of Alberta (ESSA) and all the RemTech Staff



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G2S Environmental Consulting Inc.

remediation technologies symposium

October 11-13, 2017 Banff Alberta, Canada