Case Study: New Delivery Method to Inject Remedial Amendments into a Difficult Aquifer

RemTech Presentation

October 17, 2019

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Gerren Feeney, B.Sc. - Premier

Introduction – Agenda

- **Introduction**
  - What is a Difficult Aquifer?
- **Site Background**
  - Data Review & Gap Analysis
  - Bench-scale Treatability Testing
  - Historical Remediation Activities
- **Delivery Approach for Difficult Aquifer**
  - Pilot-Test Results
  - Full-Scale In-situ Program
  - Performance Monitoring
- **Conclusions / Lessons Learned**

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Introduction – Presenters

- **Nathan Lichti, B.A.Sc., P.Eng.**
  - Environmental Engineer at Vertex
  - University of Waterloo, Ontario
  - 12+ years experience as remedial contractor

- **Gerren Feeney, B.Sc.**
  - Project Manager at Premier
  - University of Guelph, Ontario
  - 11+ years experience as environmental consultant

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What is a Difficult Aquifer for Injection?

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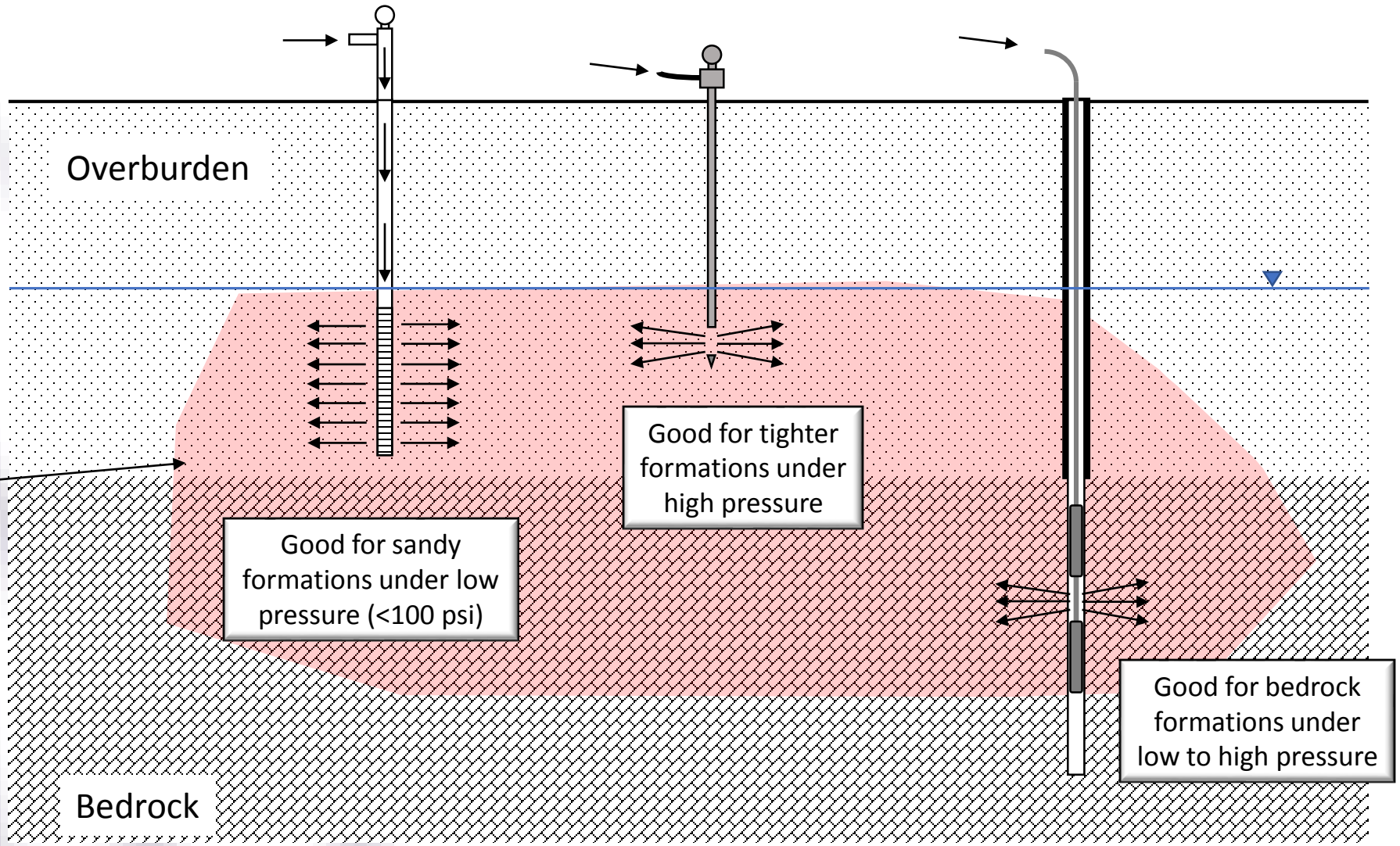
What is a Difficult Aquifer for Injection?

Three Standard Injection Methods:

1) Permanent Injection Well

2) Direct Push Injection Point

3) Open Borehole Packer Injection



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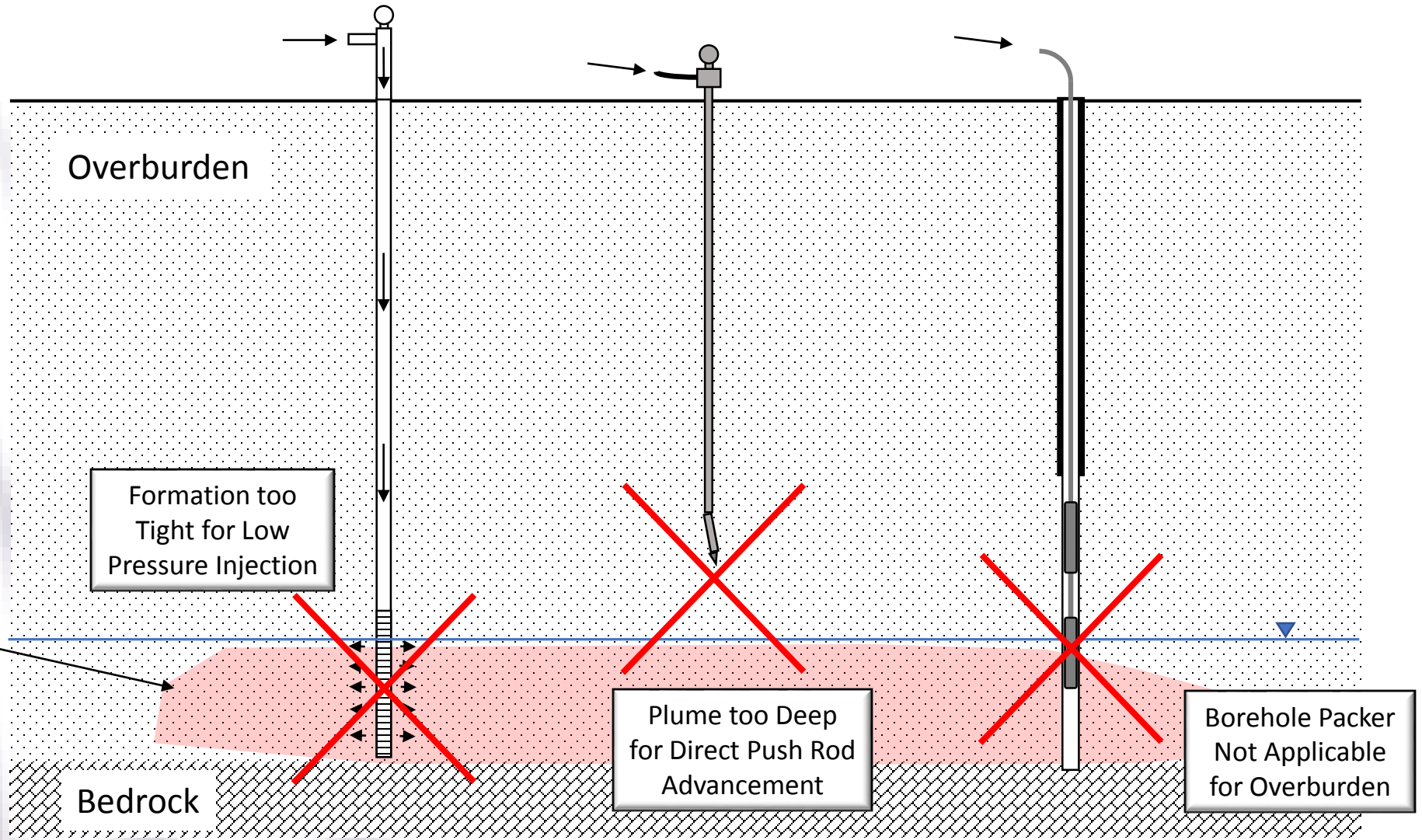

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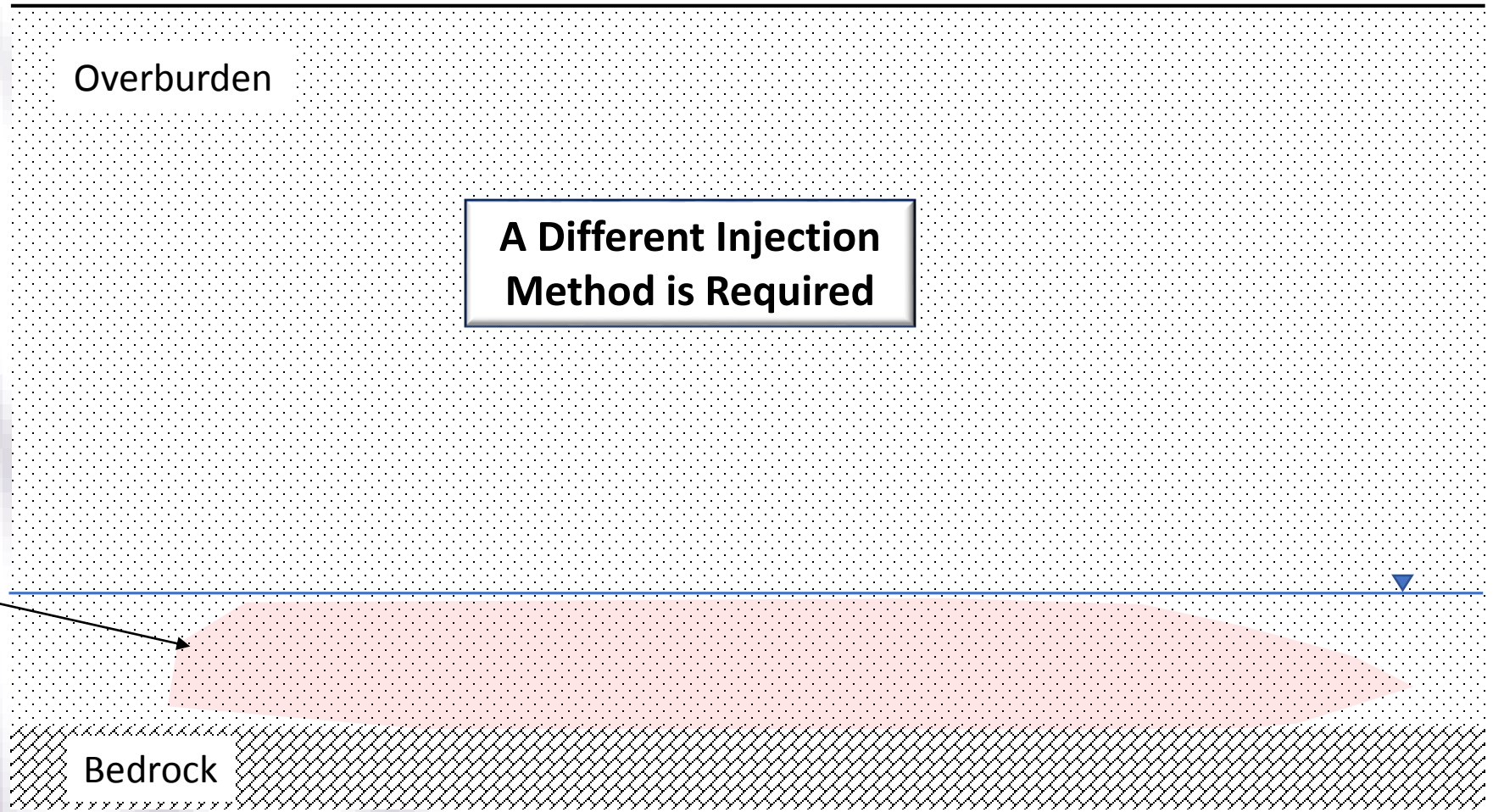

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Case Study

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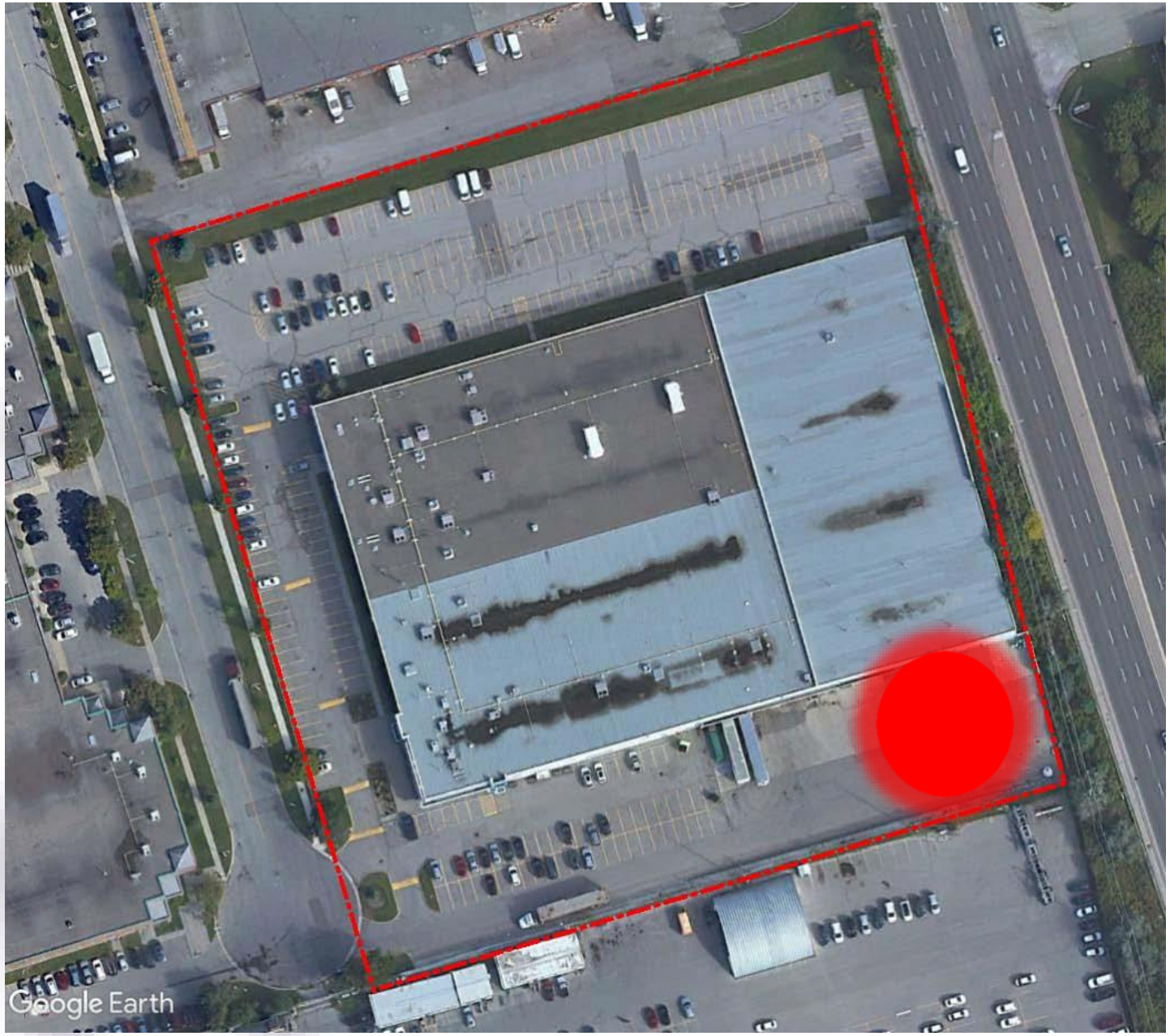
Site Background – Site Location



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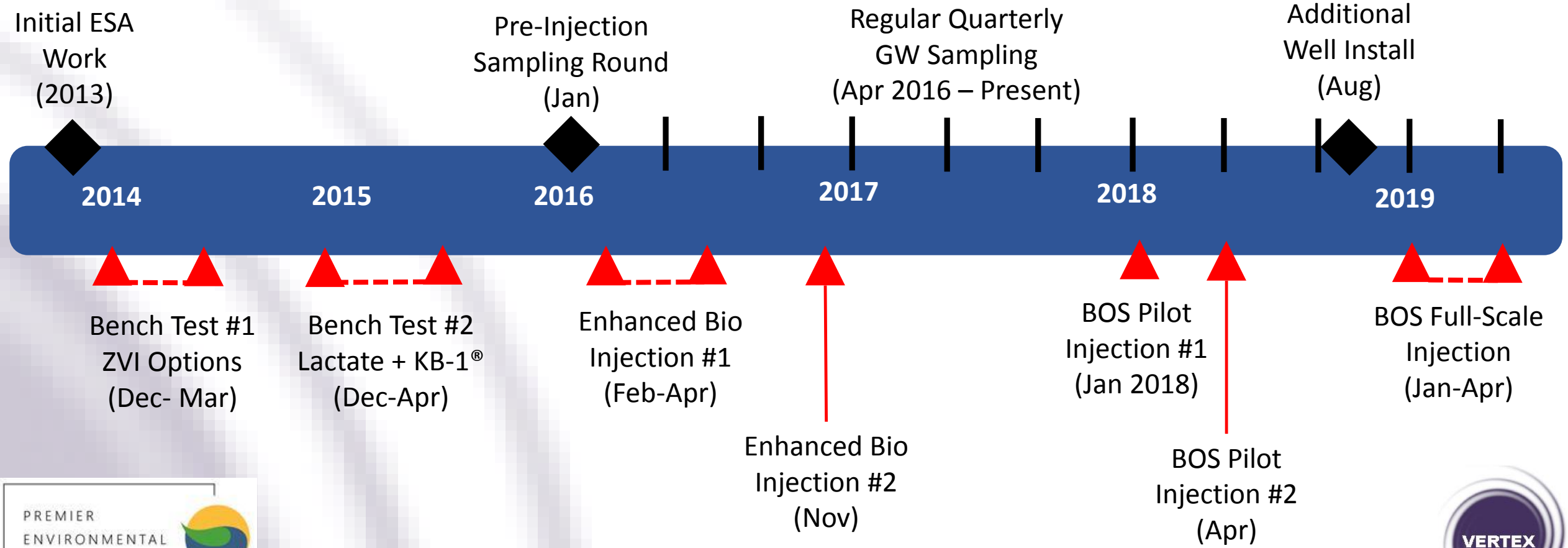
Timeline



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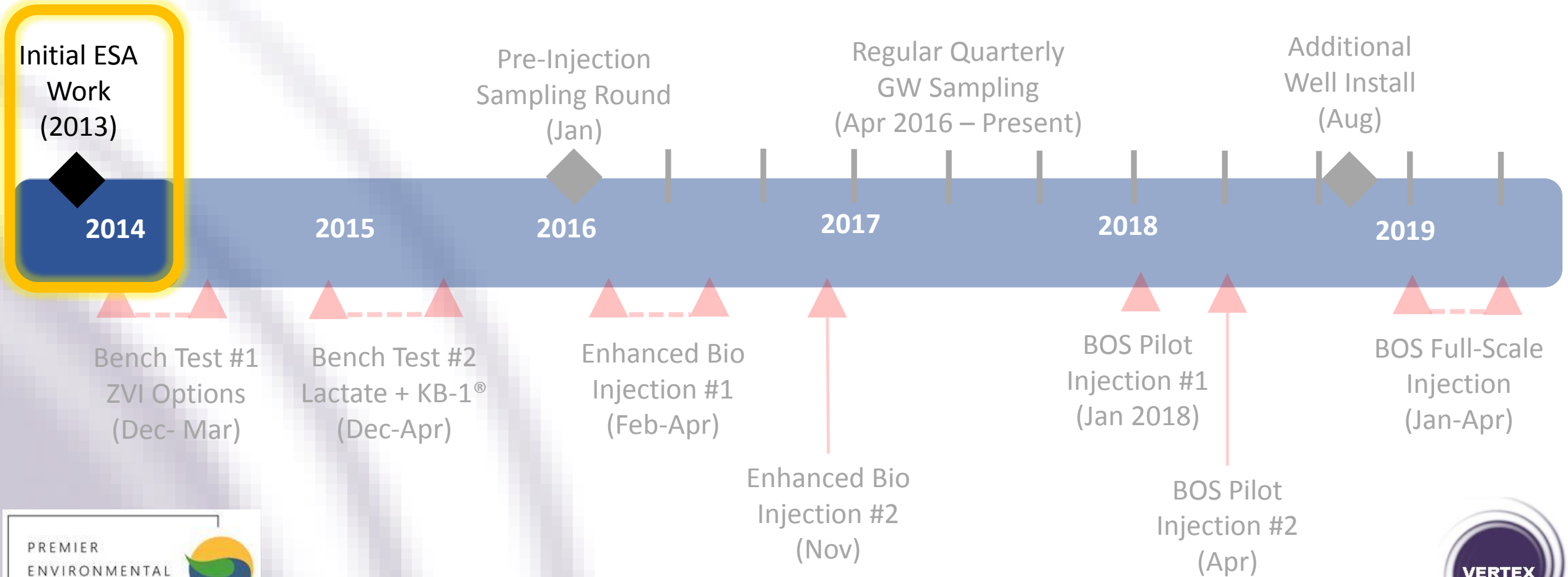

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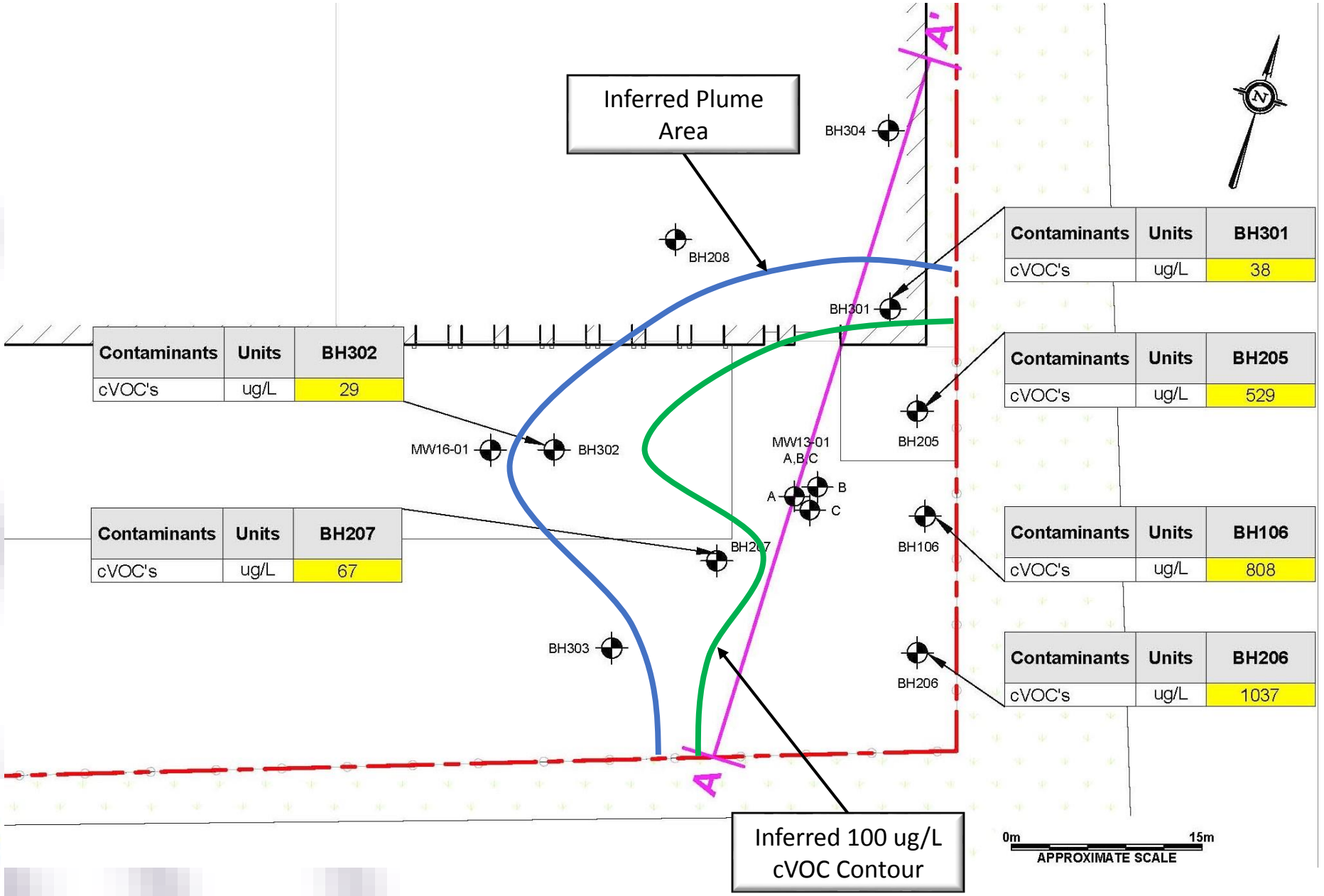
Site Background – ESA Approach - Site Characterization & Delineation

- Industrial manufacturing facility located in the GTA
- ESA site characterization work completed in 2013/2014
  - No soil concentrations > applicable Table 3 SCS limits
  - cVOC impacted groundwater in southeast corner
    - Laterally and vertically delineated
    - Unknown source!

Site Background – ESA Approach - Site Characterization & Delineation



Contaminants	Units	BH301
cVOC's	ug/L	38

Contaminants	Units	BH205
cVOC's	ug/L	529

Contaminants	Units	BH106
cVOC's	ug/L	808

Contaminants	Units	BH206
cVOC's	ug/L	1037

Contaminants	Units	BH302
cVOC's	ug/L	29

Contaminants	Units	BH207
cVOC's	ug/L	67

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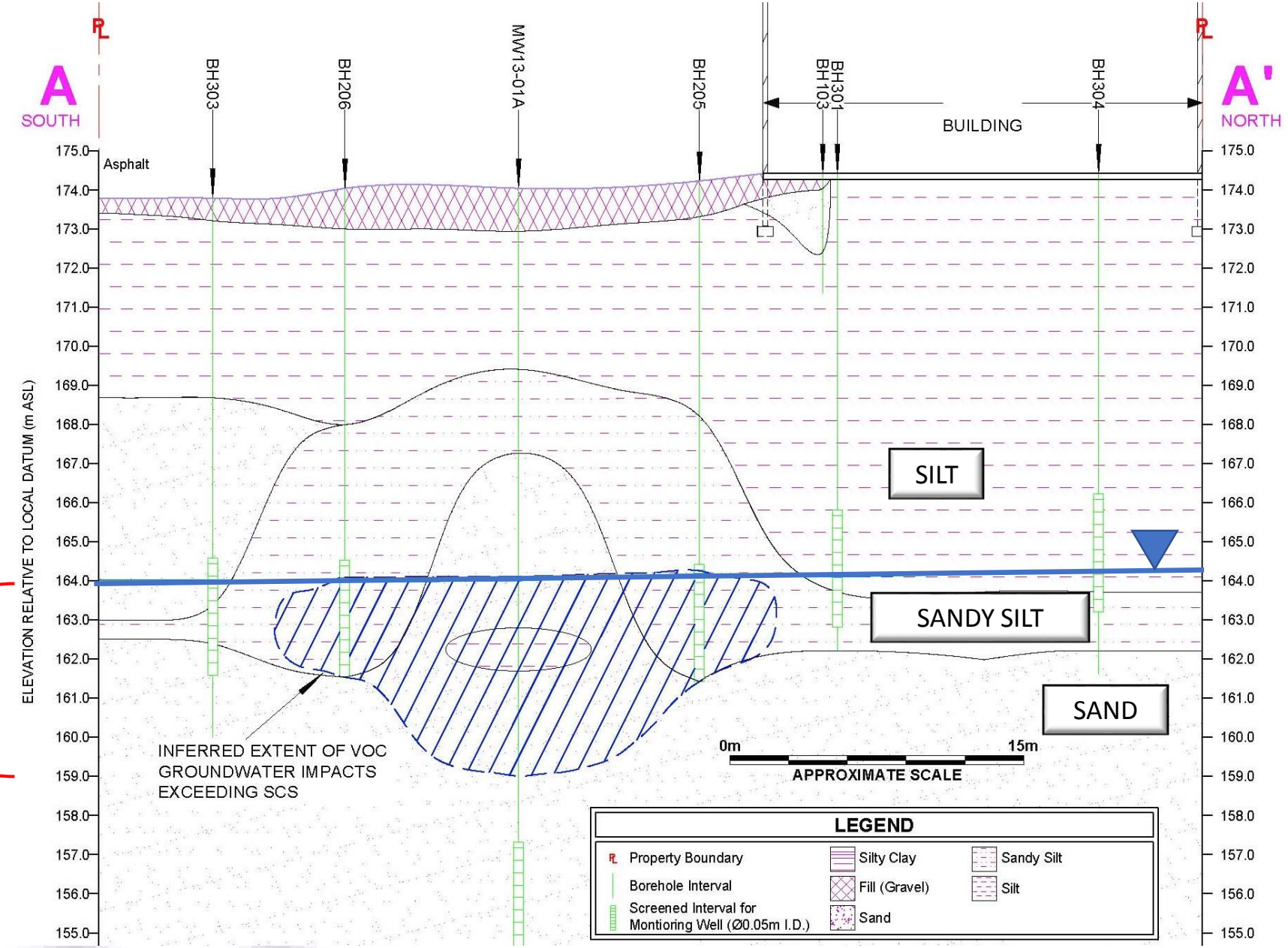
Site Background – ESA Approach - Site Characterization & Delineation



Target Treatment Zone

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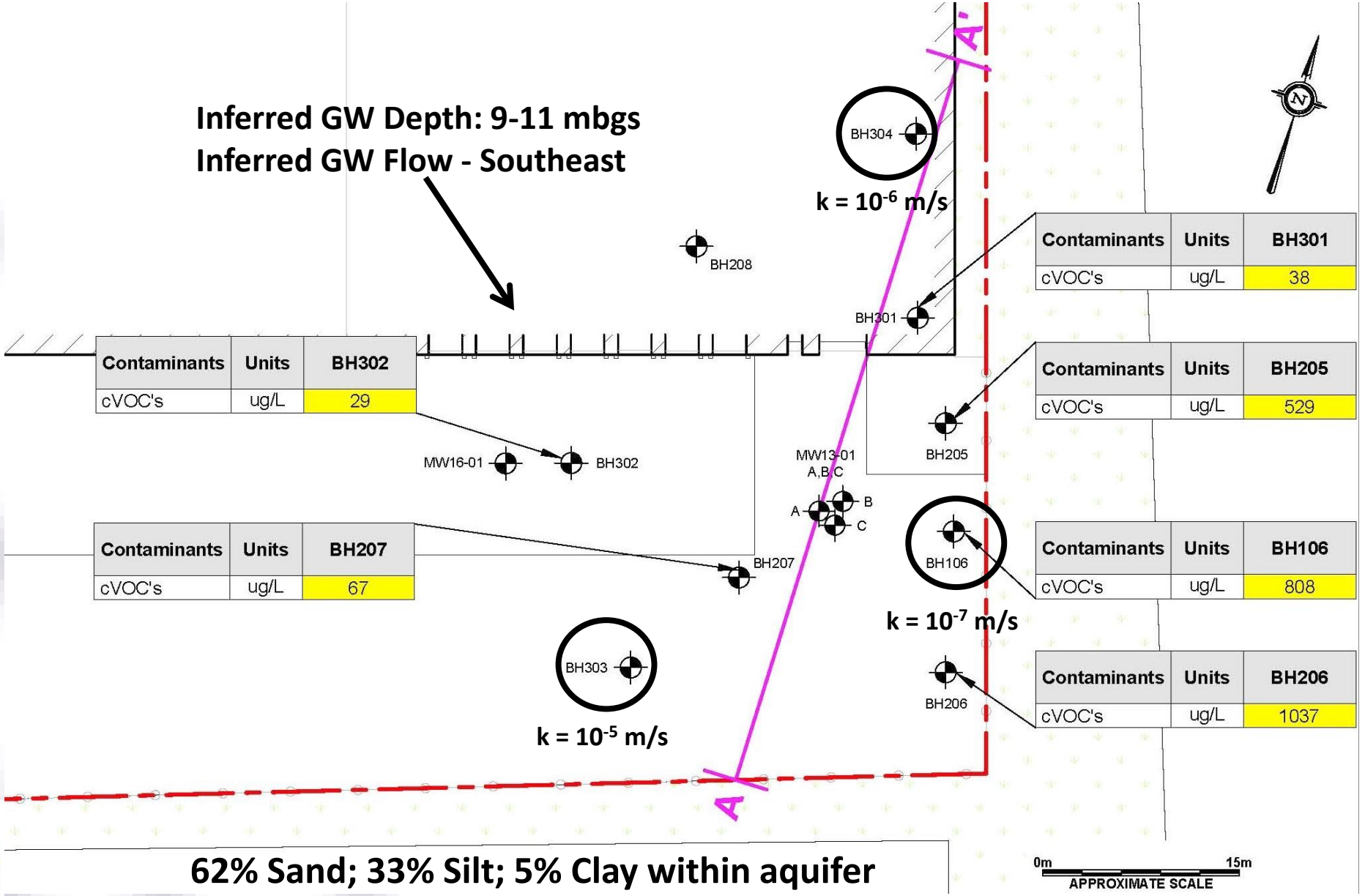

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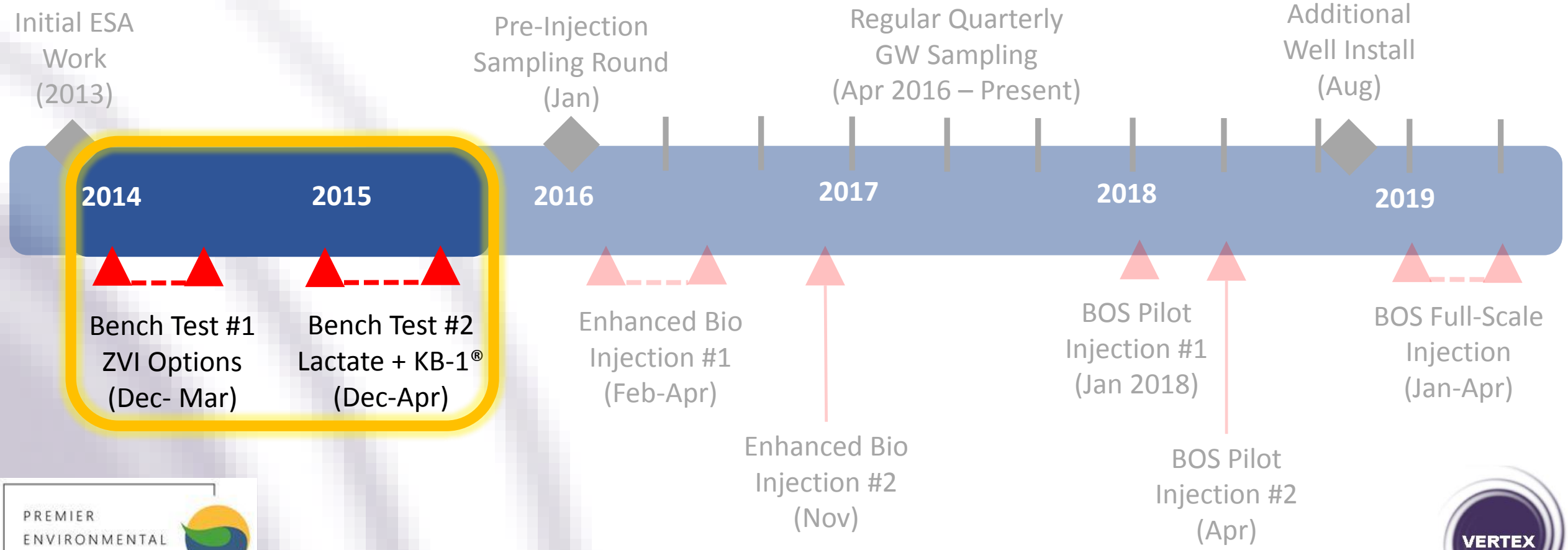

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Site Background – Bench Test

Bench Test:

Vertex retained to conduct Bench Testing using soil and groundwater from the site to evaluate:

- Plume Treatment via Enhanced Bio
- Permeable Reactive Barrier with ZVI

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Site Background – Bench Test

Bench Test Results:

- Biostimulation (0.2% or 1.0% sodium lactate) was **not successful** in reducing cVOCs below the applicable SCS
- Biostimulation with bioaugmentation (KB-1®) **was successful** in reducing cVOCs below the SCS
- 1.0% by weight ZVI mixture was **not successful** in reducing cVOC below the SCS
- 30% by weight ZVI mixture **was successful** in reducing cVOC conc. below the applicable SCS

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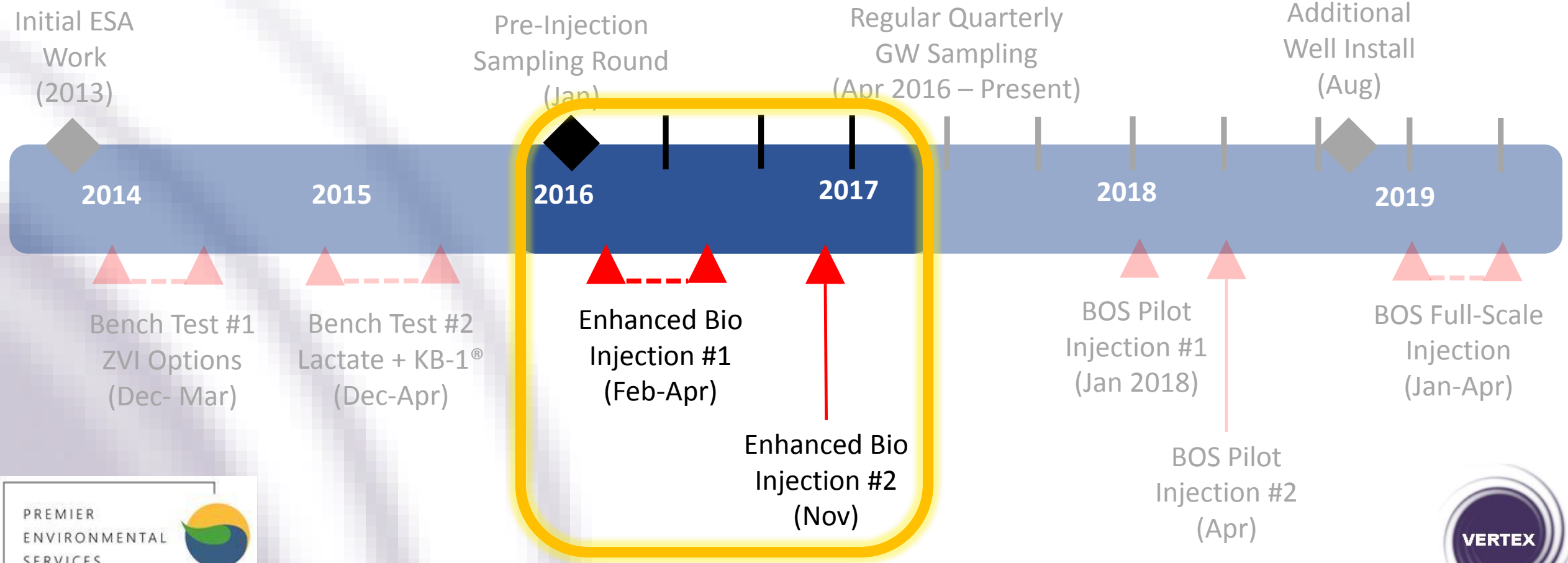
Timeline



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2016 Injection Summary

Selected Approach: In-situ injection of sodium lactate biostimulant with KB-1® bioaugmentation

- Primary goal to reduce mass of contaminants
- Sodium lactate – electron donor
- KB-1® - metabolize contaminants

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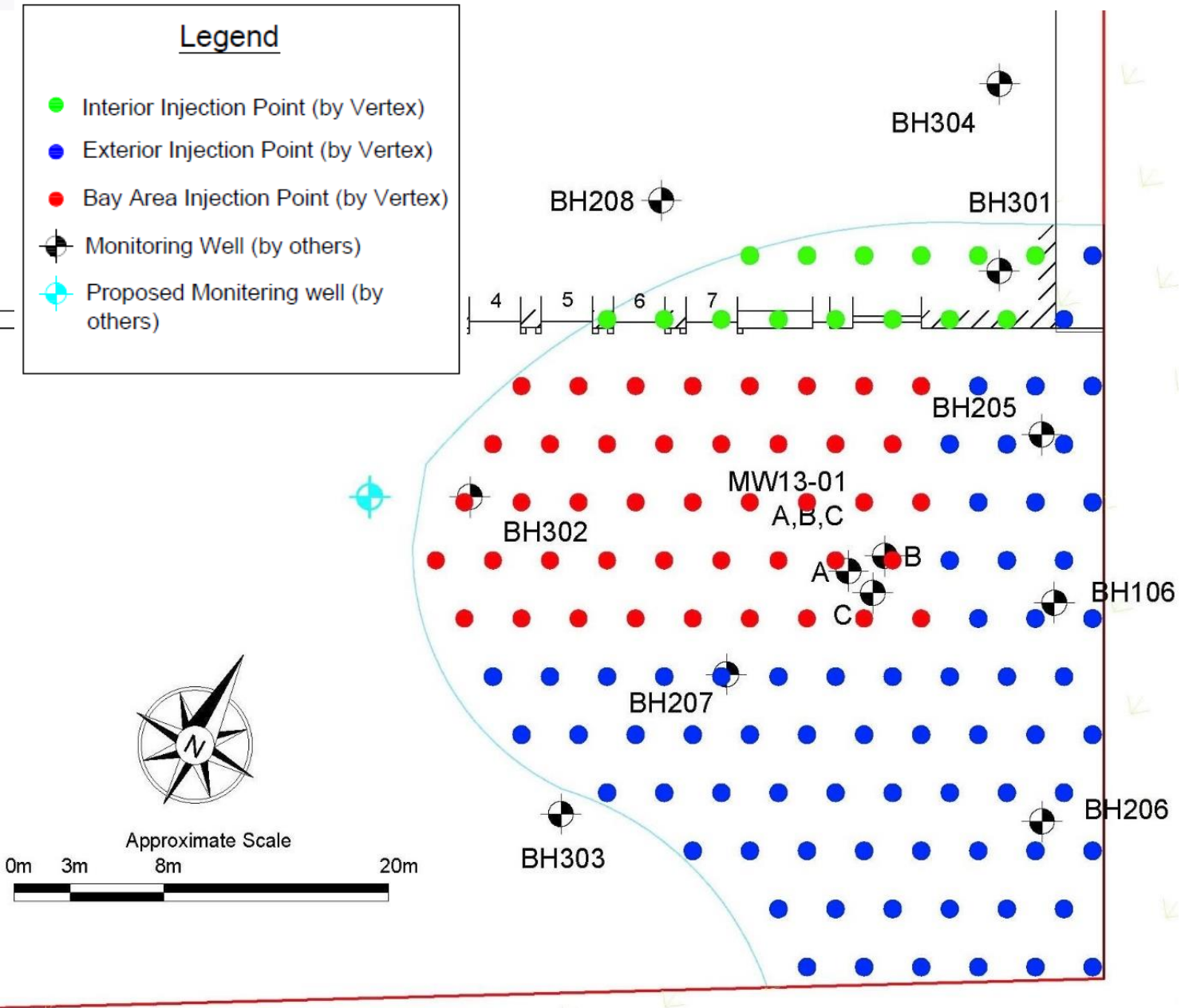
2016 Injection Summary



Injection Plan:

- Grid of 150 temporary injection points (over ~1,025 m^2 plume)
- Advance Injection Rods with Geoprobe to depth
- Inject Shallow Interval (10-13 m bgs) and Deep Interval (13-16.5 m bgs)

Injection delivery approach did not work

2016 Injection Summary – Delivery Issues

Delivery Issues

- Shallow Interval (10-13 m bgs):
  - Geoprobe could advance injection rods to depths
  - Rod breakage at 4 of 12 locations
  - The male thread snapped off inside the female thread due to extended hammering – stress on the rods

Decent Injection ROI but breakage at 1/3 of locations

- Deep Interval (13 – 16.5 m bgs):
  - Geoprobe could not advance rods to depth

Direct Push not Viable for deep

- Switched to Hollow Stem Augers (HSA) for Deep
  - HSA were able to advance to target depths
  - Attempted injection thru HSA didn't work
  - HSA very slow – Schedule Restraints

Temporary Point Injection not going to work

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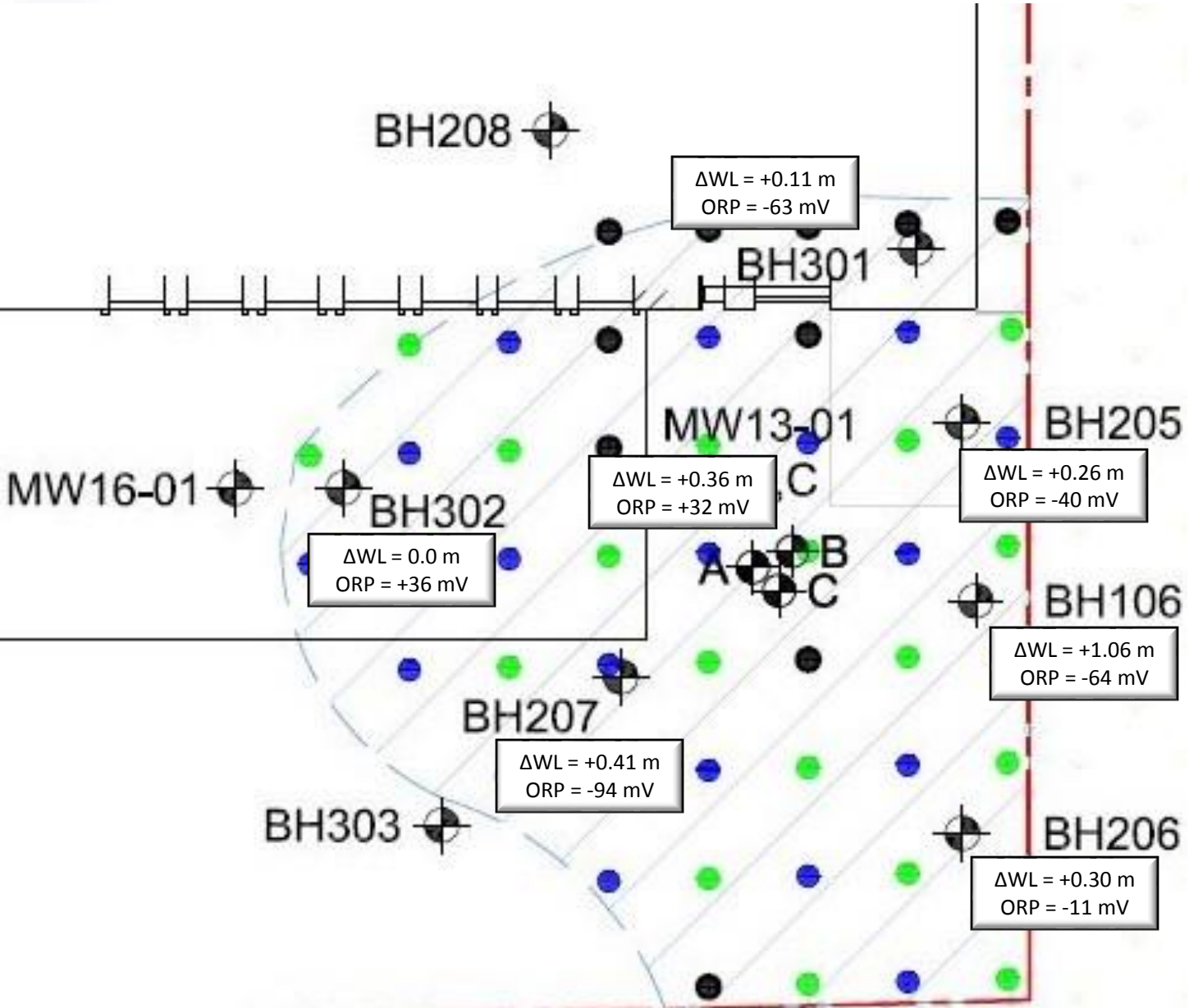
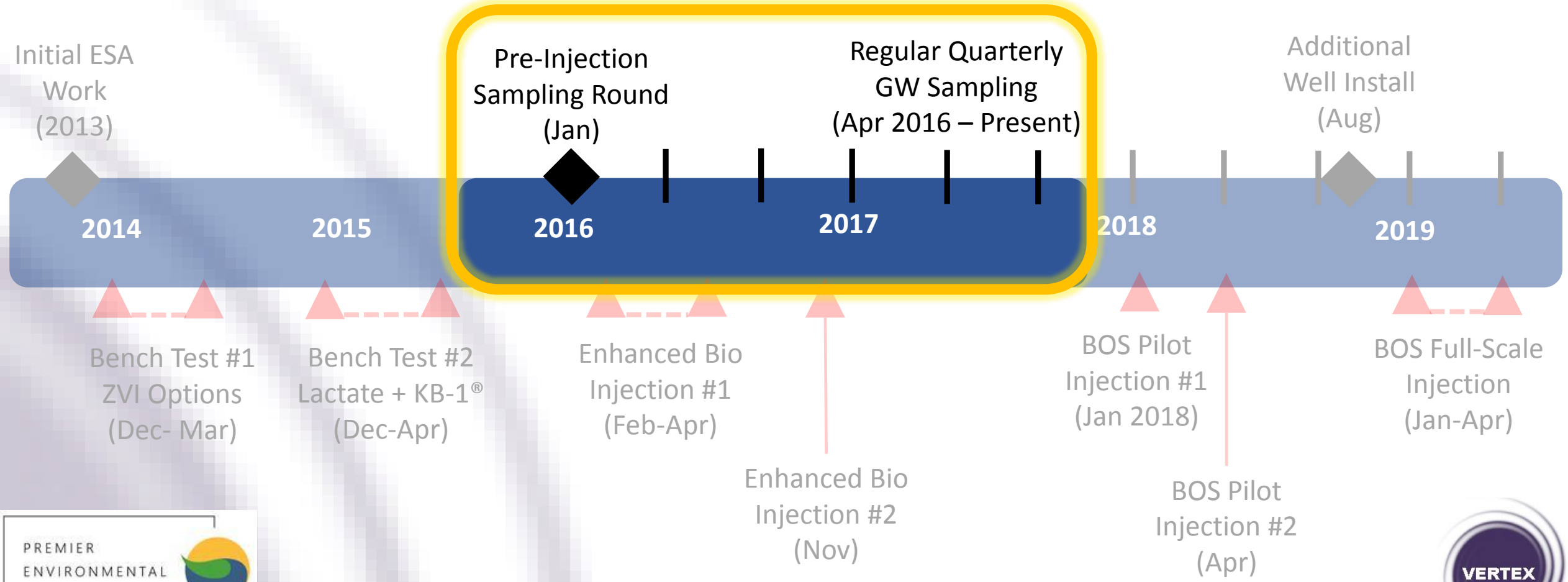
2016 Injection Summary – Delivery Issues



Revised Approach

- Finished Injection program with Permanent Injection Wells
  - 19x shallow wells (10-13 m bgs)
  - 18x deep wells (13-16.5 m)
- Injected 20% Sodium Lactate Solution + KB-1®:
  - 18,550 L via temporary points
  - 106,400 L via permanent wells
- Field Monitoring:
  - Average hydraulic influence of +0.36 m
  - Partial Geochem Shift
    - ORP_{AVG} = +38 mV (Pre-Inj)
    - ORP_{AVG} = -39 mV (Post-Inj)
    - KB-1 should have < -75 mV

Timeline



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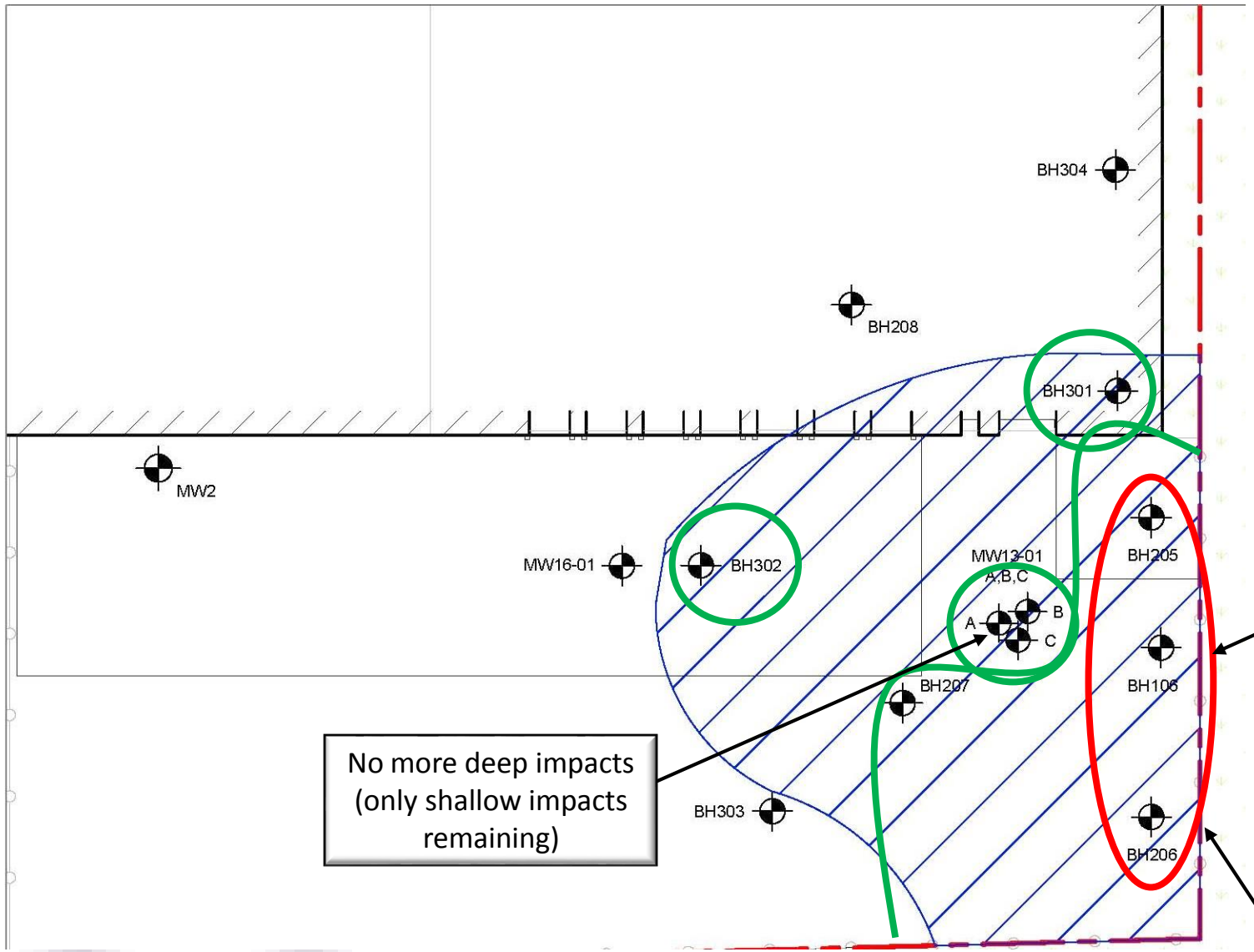
Site Background – Performance Monitoring



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Next Steps

Next Steps?

- Collected 2+ years of analytical and geochemistry data
- Completed additional Enhanced Bio injection, and well cleaning event
  - Enhanced Bio just not working for wells along property boundary

	Pros	Cons
Enhanced Bio (Sodium Lactate + KB-1)	Lab proof of concept Some success at site	Delivery issues Cannot maintaining ORP < -75 mV KB-1® not thriving
Trap and Treat BOS 100®	Does not depend on geochemistry Persistence No maintenance or re-application	How to deliver a slurry?

Decided to undertake BOS 100® Pilot-Test to see if delivery was feasible

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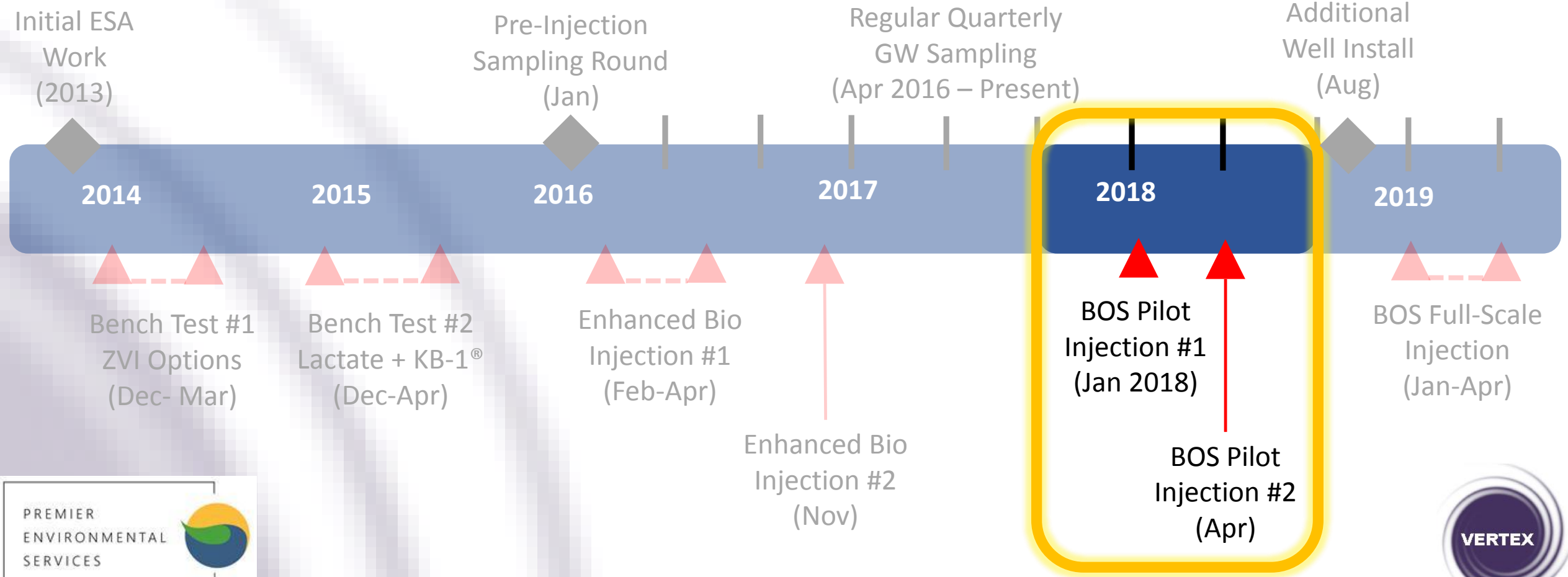
Timeline



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BOS 100® Pilot-Test – Delivery Attempt #1

What is BOS 100®?

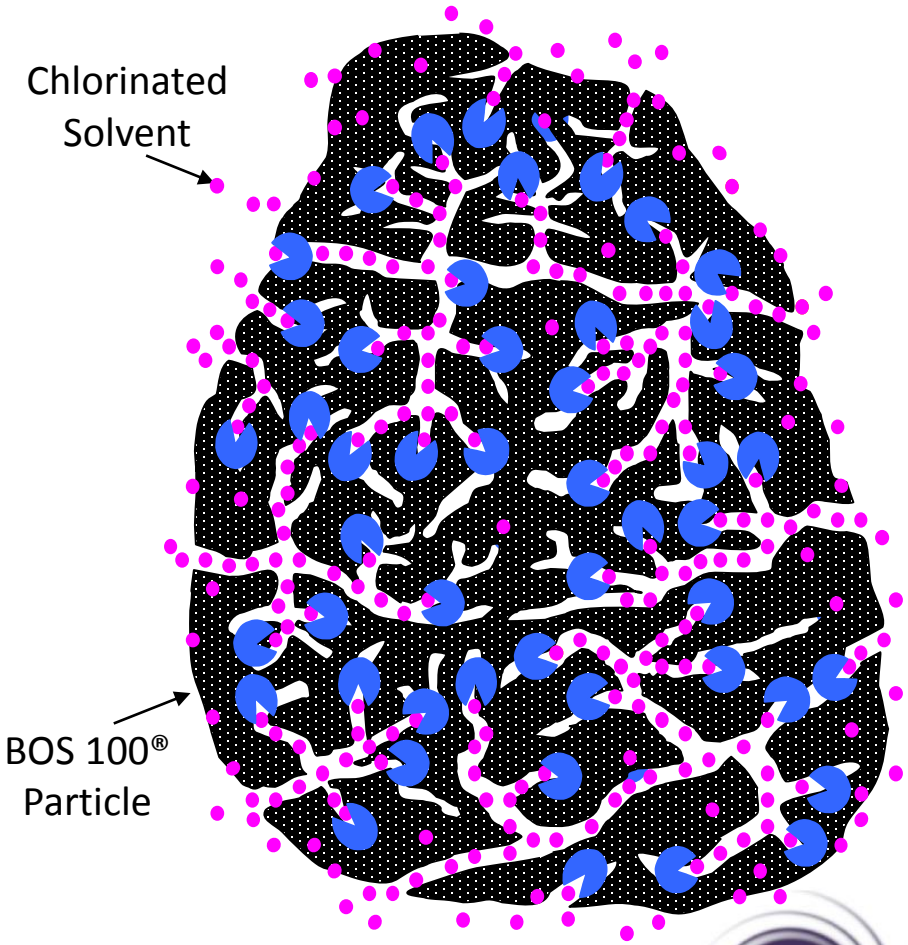
- Consists of GAC impregnated with iron

Mechanisms:

- **"Trap"** the contamination within the GAC matrix
- **"Treat"** the contamination via reductive dechlorination within the GAC matrix

Injection Delivery:

- Mixed as a slurry
- Injected under high pressure
- Typically use Direct-Push rig with pre-strung 2.25" rods
- Slurry will not pass through well screen



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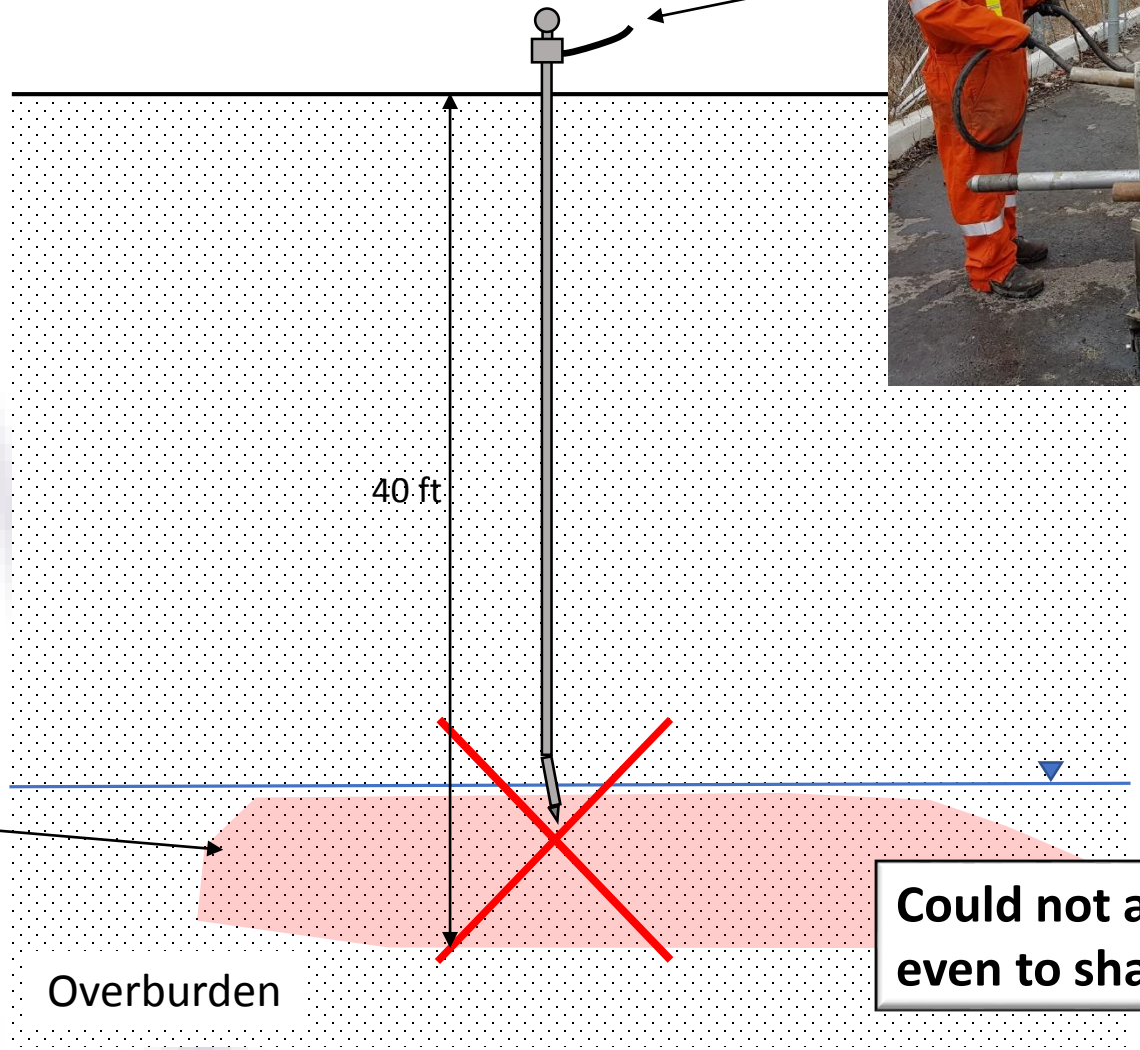
BOS 100® Pilot-Test – Delivery Attempt #1

BOS 100® is a slurry of granular carbon & iron

Cannot Inject Through Well Screen

Attempted Injection via Pre-Strung Rods



Could not advance rods even to shallow interval

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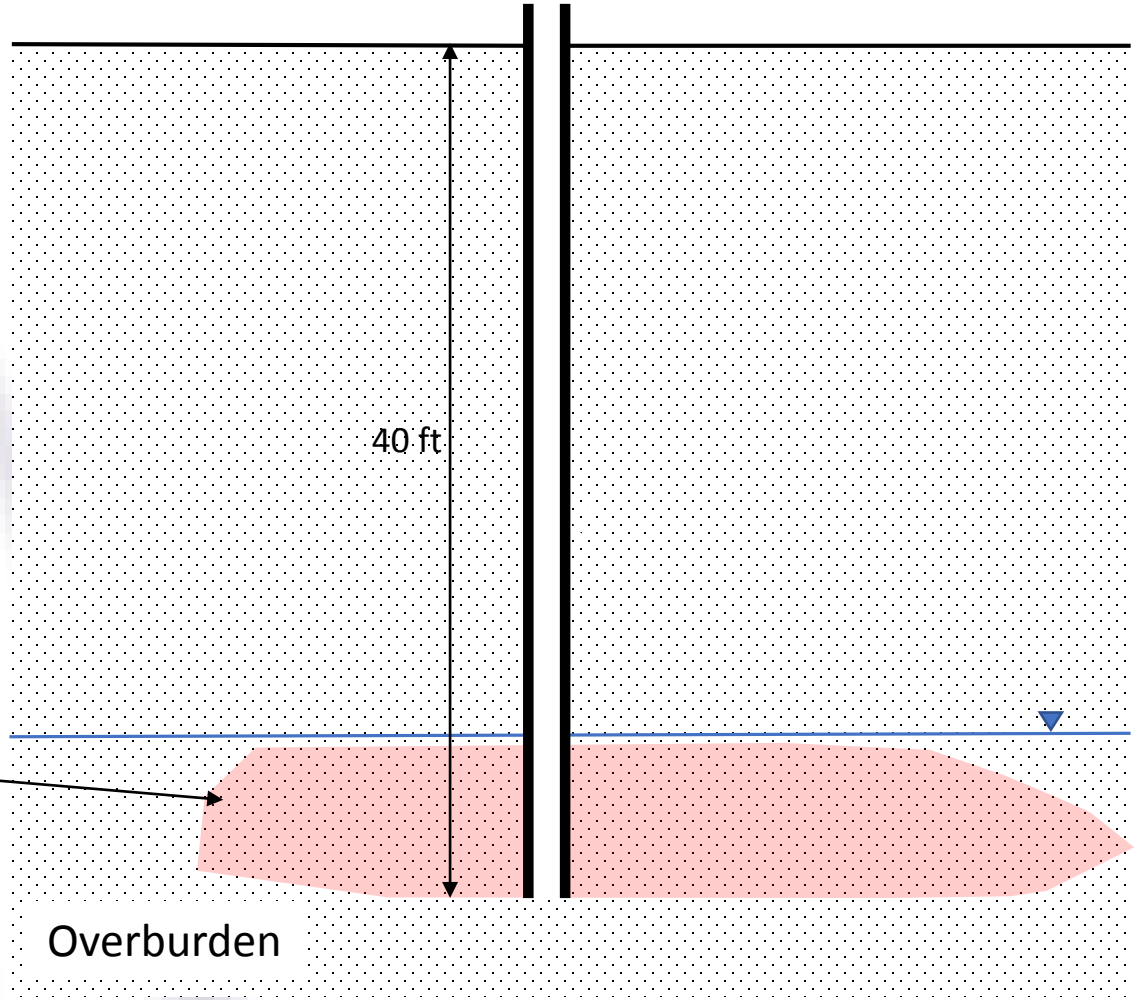
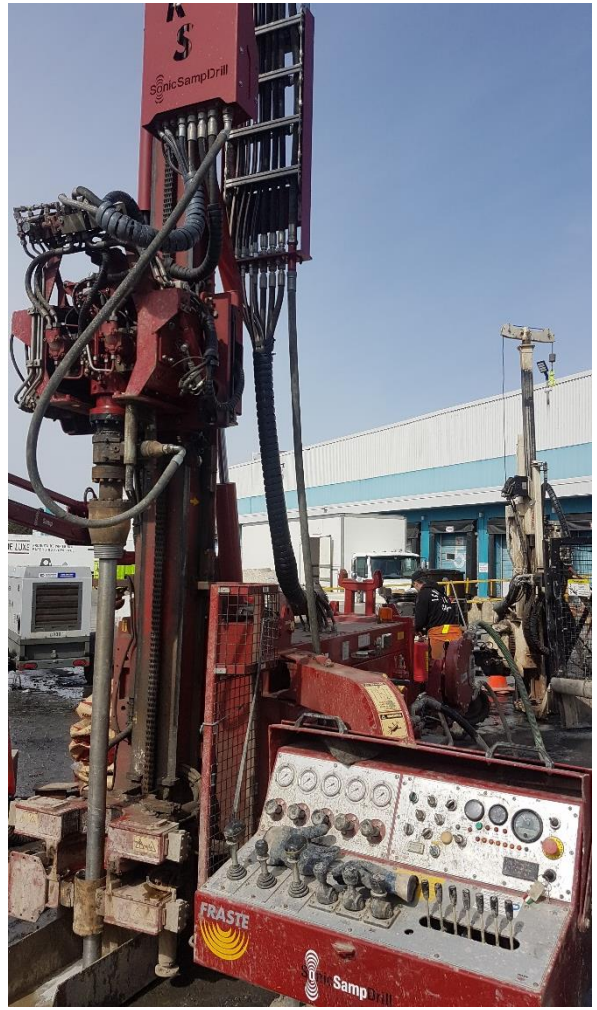
BOS 100® Pilot-Test – Delivery Attempt #2

Mobilize Sonic Drill Rig

- Needed rig that could quickly pre-drill BHs

Step #1
Borehole Pre-Drill





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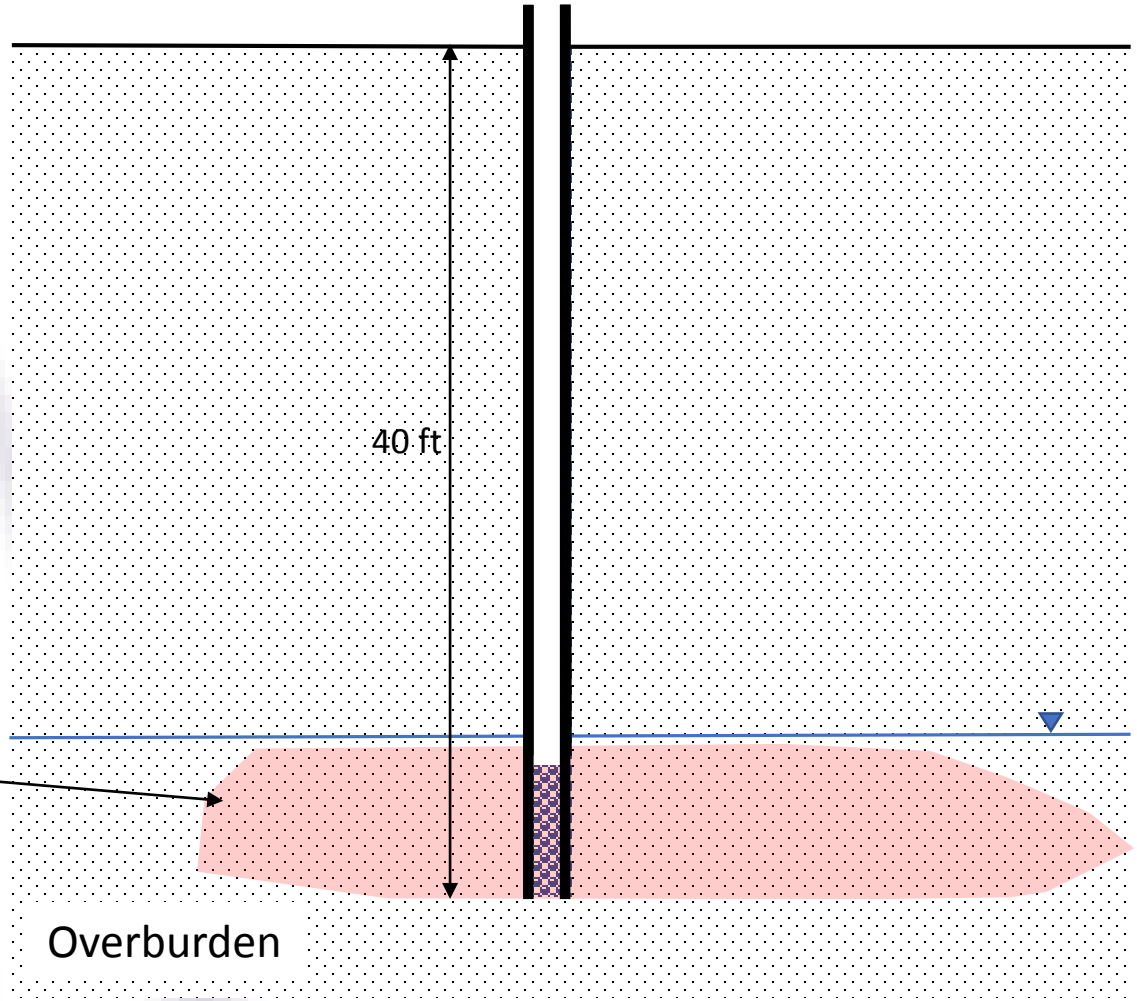
BOS 100® Pilot-Test – Delivery Attempt #2

Backfill Process:

- Add backfill in lifts

Step #2
Bentonite/Grout Backfill



Needed backfill material that can be drilled through while providing sufficient injection resistance?

Tested a variety of materials

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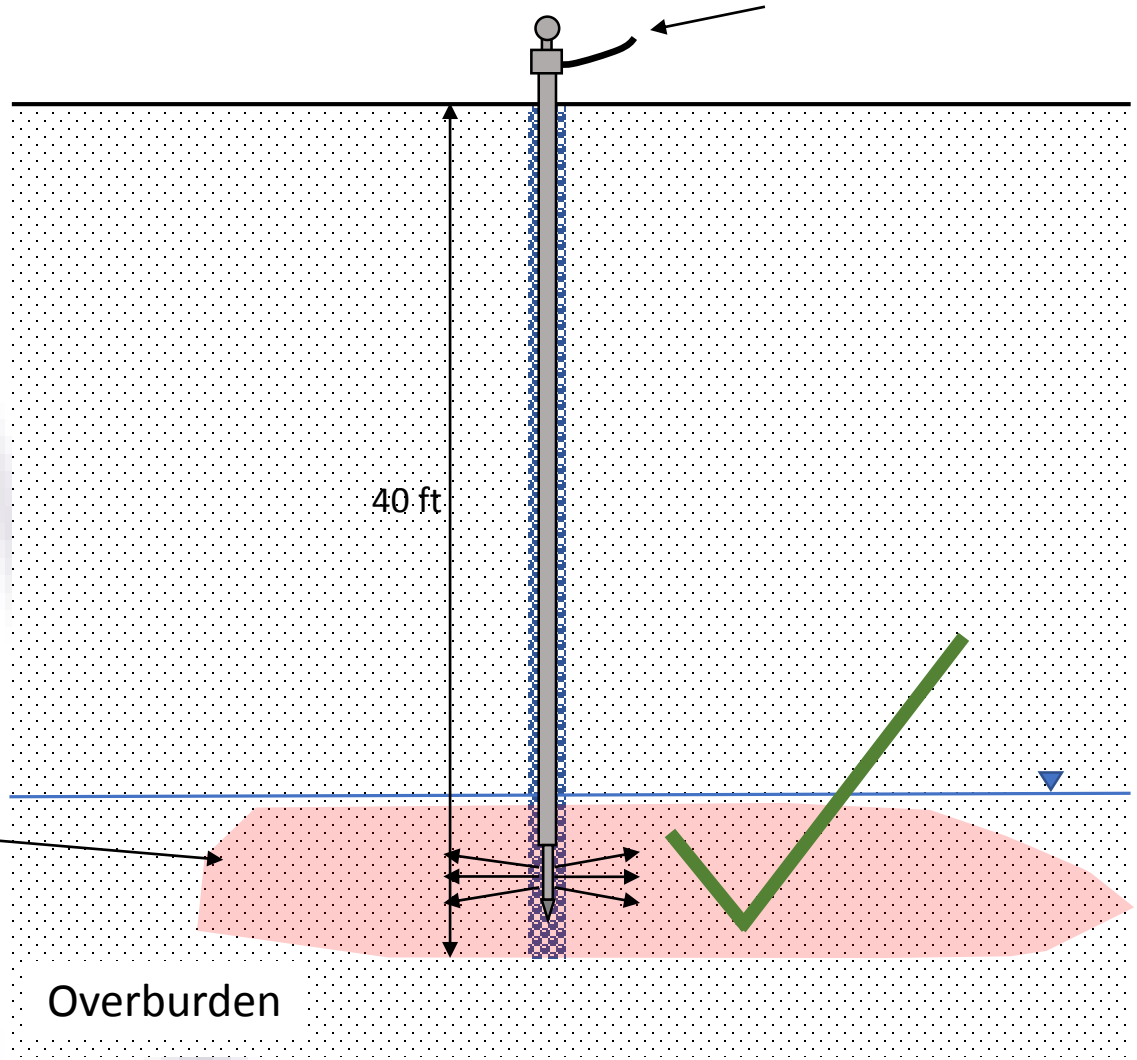
BOS 100® Pilot-Test – Delivery Attempt #2

Injection Process:

- Mobilize direct push rig
- Advance 2.25” pre-strung rods down pre-drilled BH to top of injection interval

Step #3
Injection Via Pre-Strung Rods



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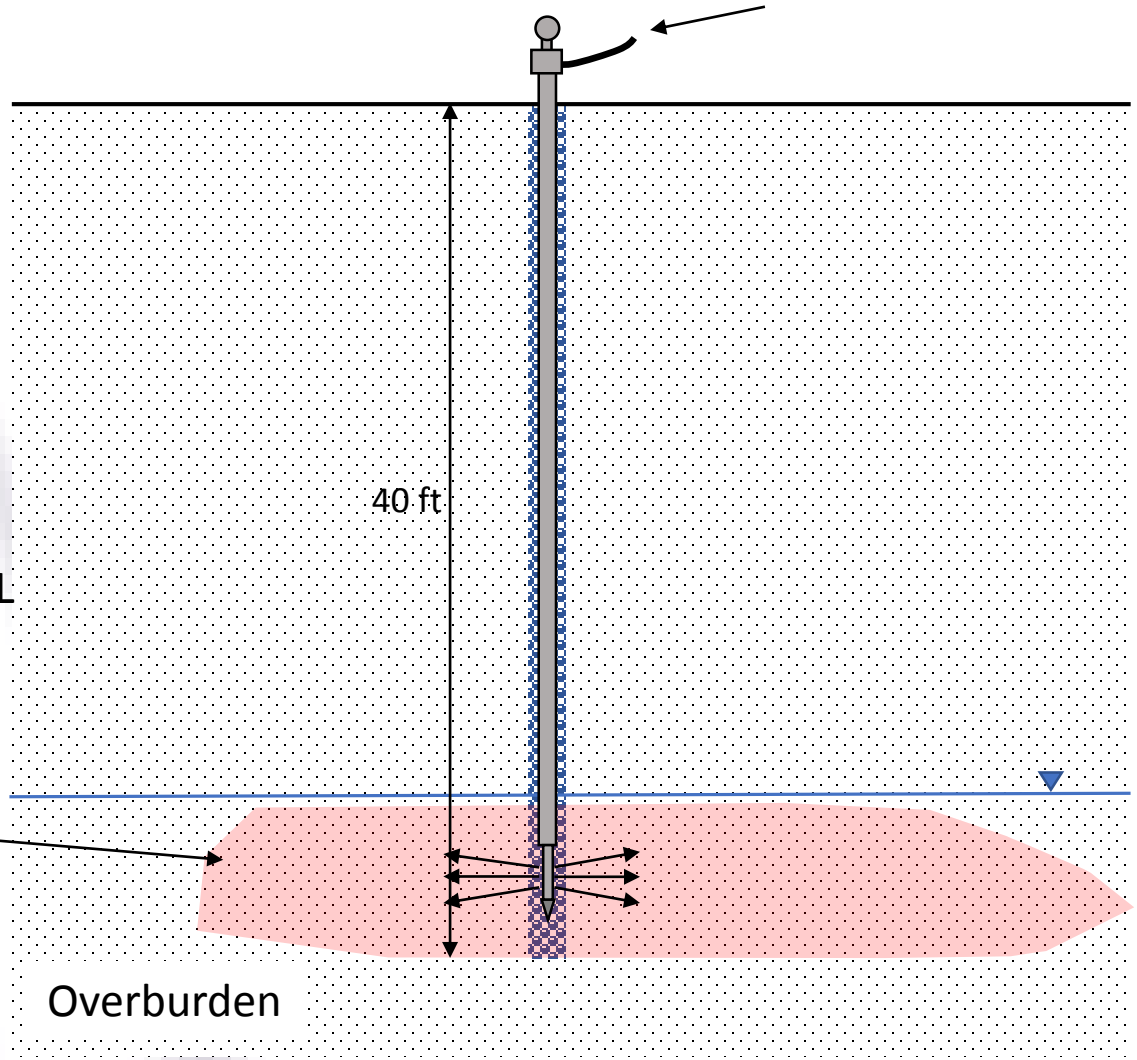
BOS 100® Pilot-Test – Delivery Attempt #2

Results:

- Injected up to 500 L per IP
  - 100 L/depth interval
- Injection pump pressure ranged from 300-1,000 psi
- Observed Radius of Influence of 1.2 to 1.5 m
- Average analytical results at BH206 as follows:
- 1,1-DCE: 47 ug/L to 0.7 ug/L
- 1,1,1-TCA: 625 ug/L to 5.0 ug/L

Step #3
Injection Via Pre-Strung Rods



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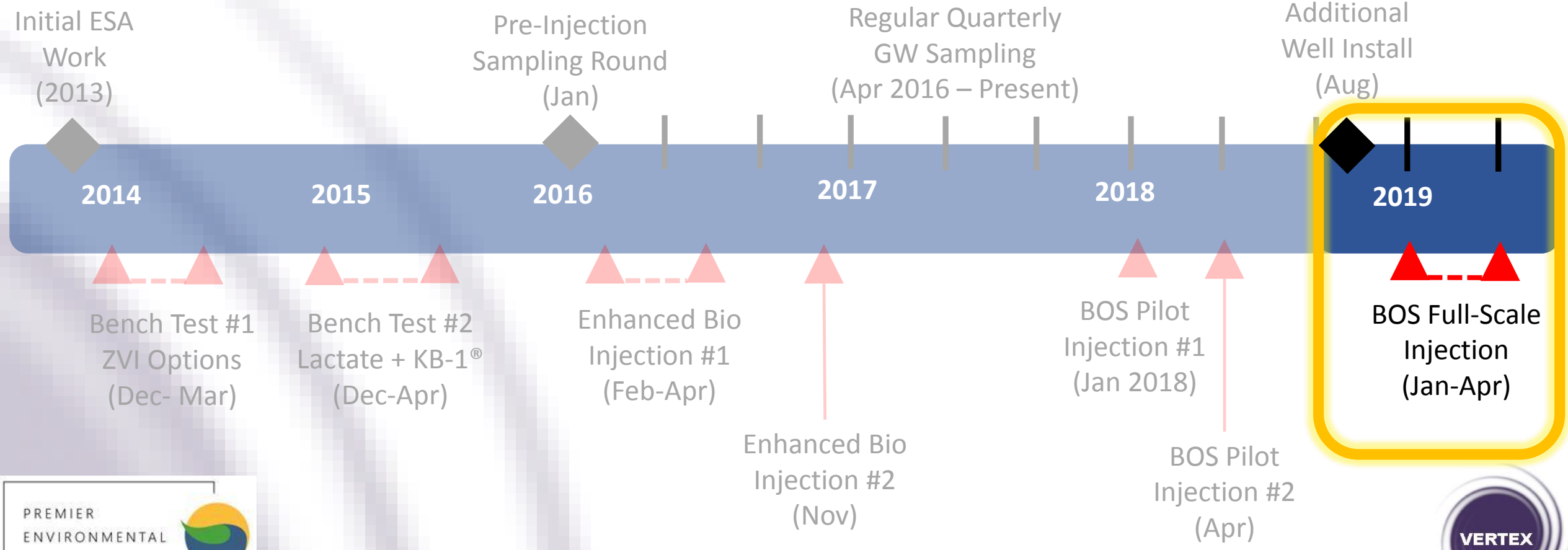
Timeline



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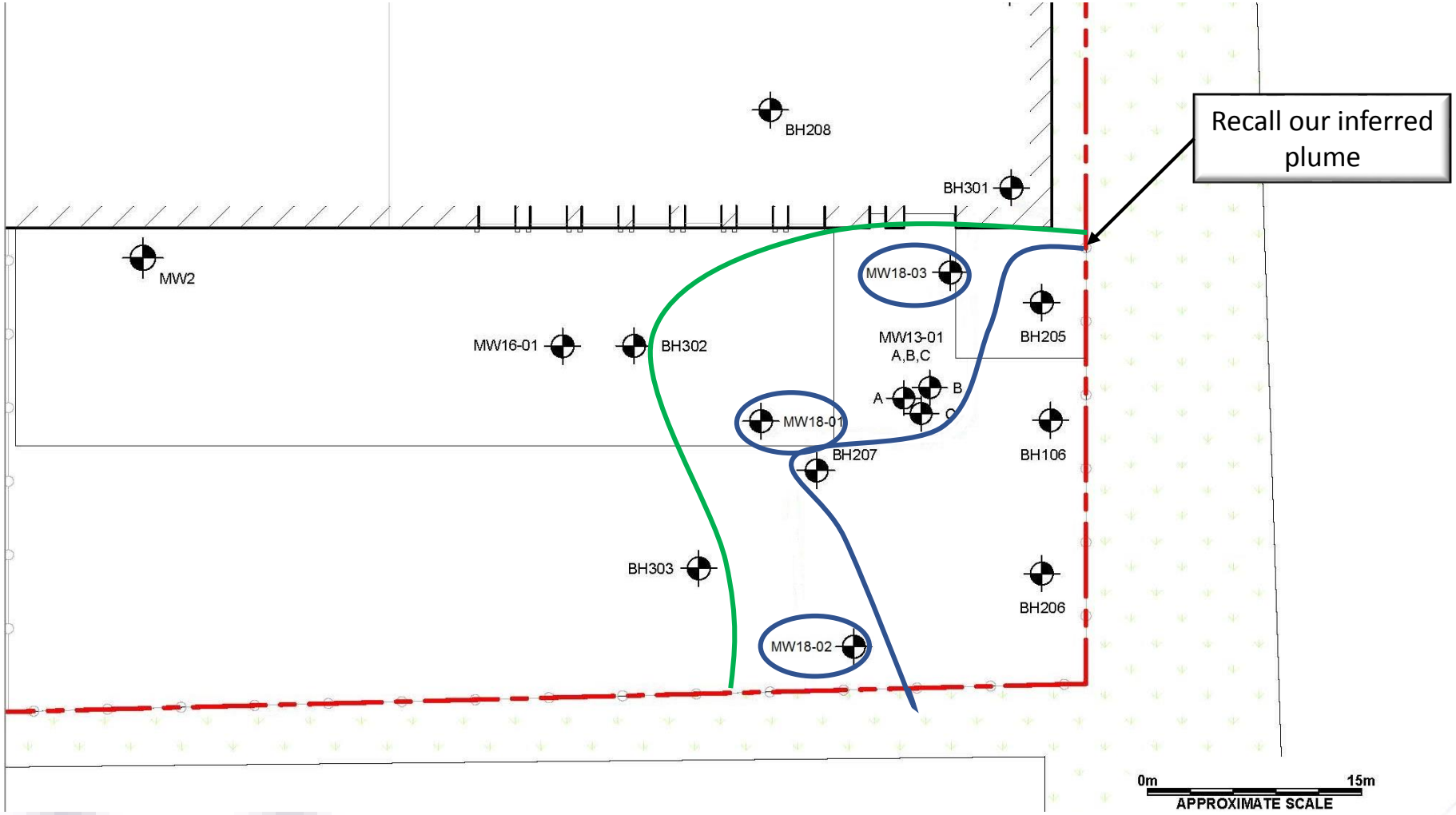
Additional Delineation



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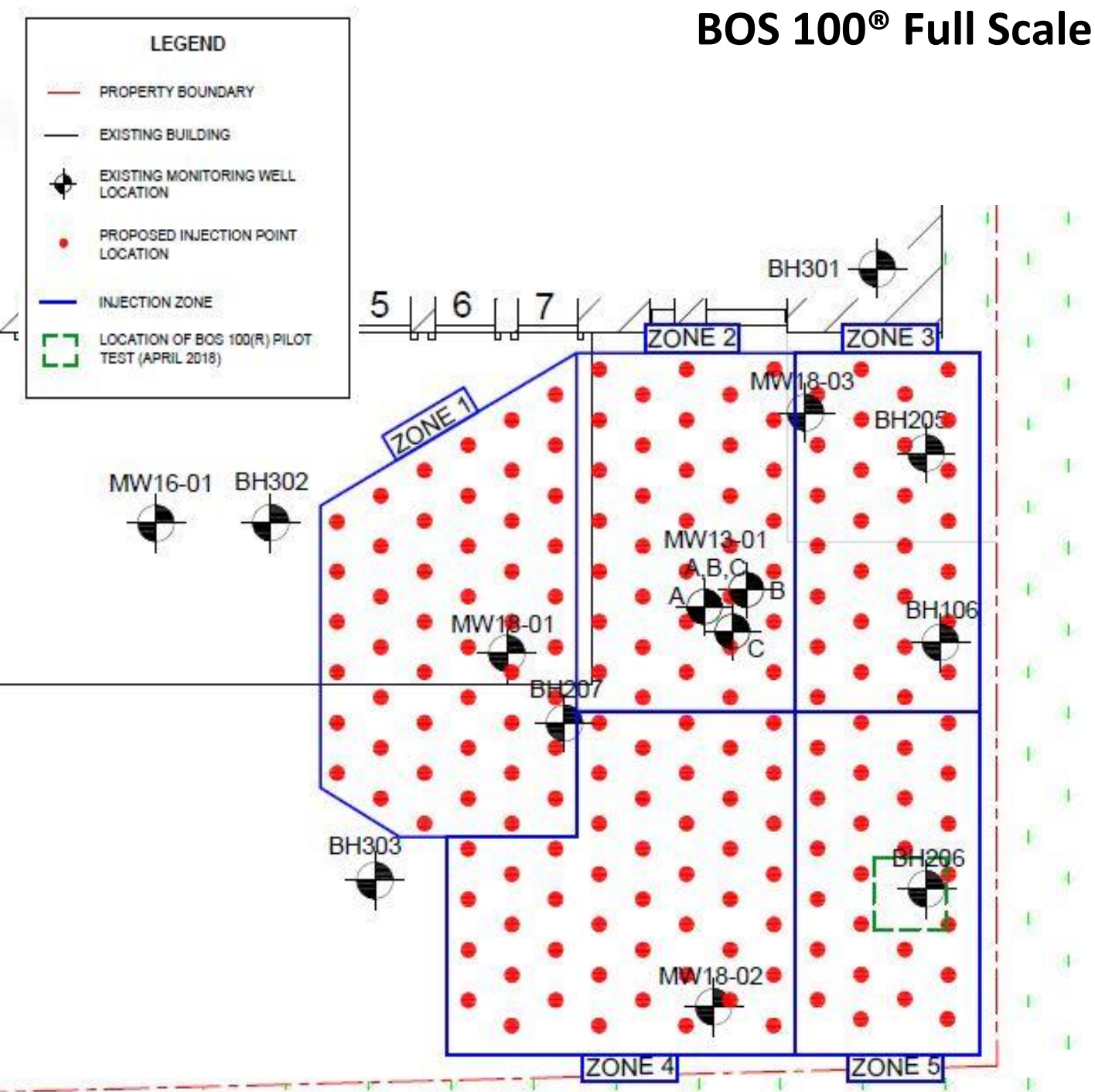
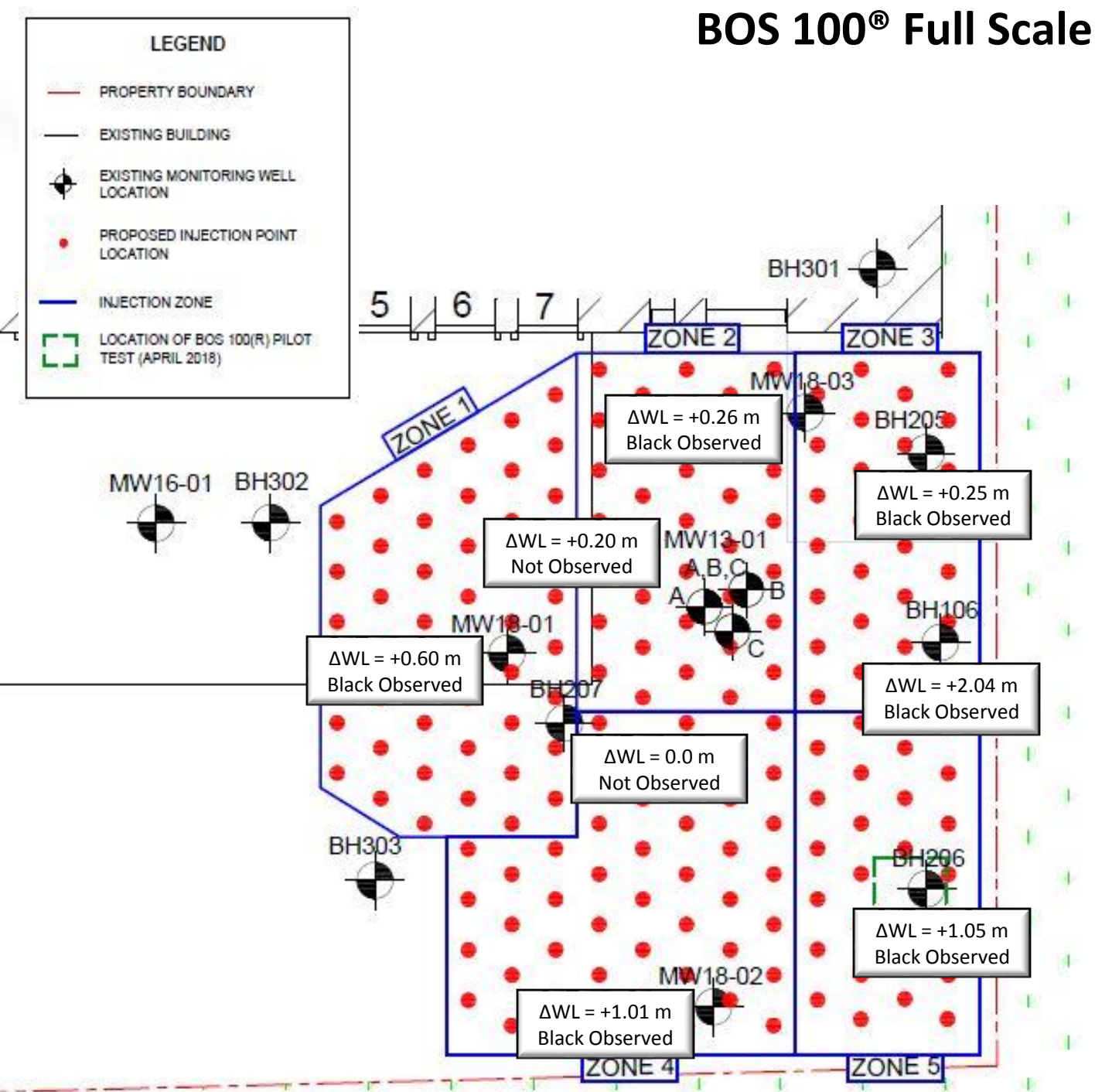
BOS 100® Full Scale Injection



Injection Details:

- Injection Grid of 180 locations on a 2.25 m grid spacing, split out over 5 zones
  - Active facility receiving deliveries
- Completed Injection over 3 months
  - Sonic 5 days per week (3-6 BHs/day)
  - Injection 50% of time (6-9/day)
- Totals:
  - 5,600 kg of BOS 100®
  - 83,500 L of slurry injected
  - Average Pump Pressure of 430 psi

BOS 100® Full Scale Injection



Field Results:

- Field Monitoring:
  - Minimal daylighting
  - Good hydraulic influence ranging from +0.25 m to +2.04 m
  - Average hydraulic influence +0.70 m
- Visual Inspection
  - BOS 100® has black colour
  - Amendment can be visually observed as grey to black discolouration

BOS 100® Full Scale Injection

Injection Delivery Challenges:

- Winter Weather
  - Shut-down for 4 days (temp < -20 °C)
  - 3 partial injection days due to line freezing issues
- Injection Tip Clogging
  - Problems with Bentonite Grout clogging injection tip while pushing down
  - Developed method of pulsing water as injection tip is advanced

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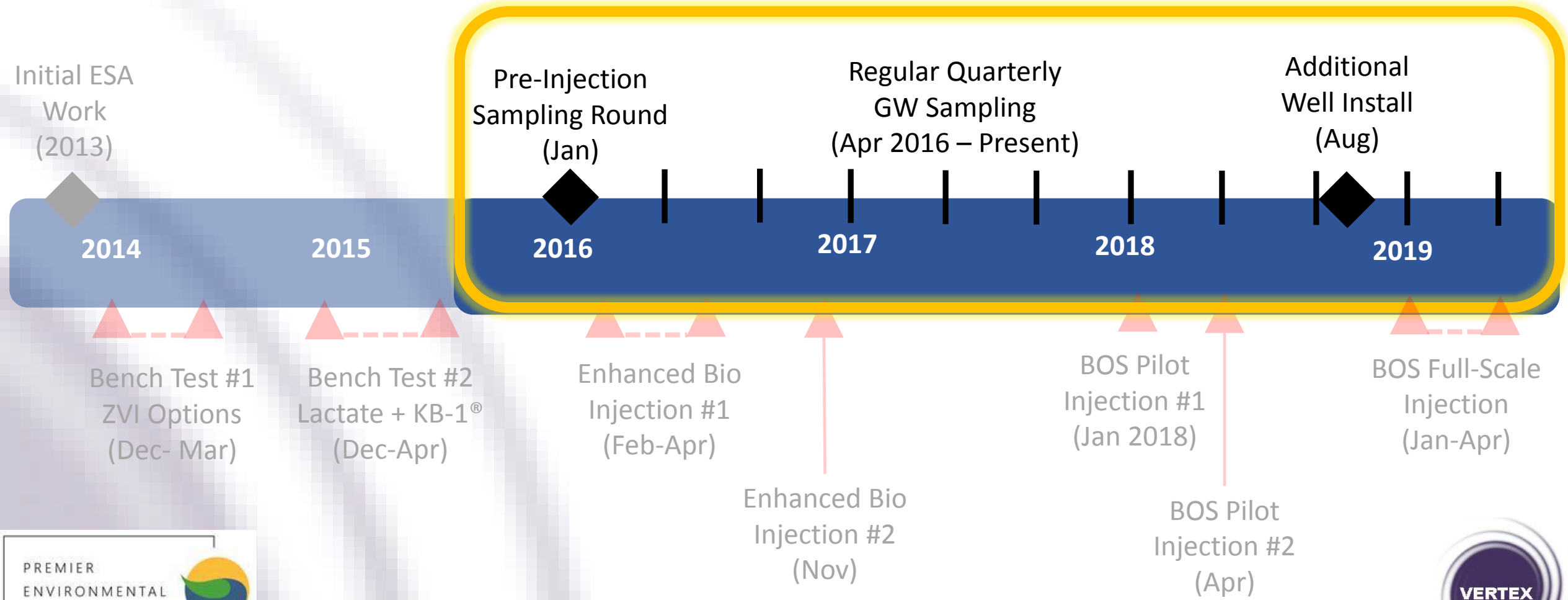
Timeline



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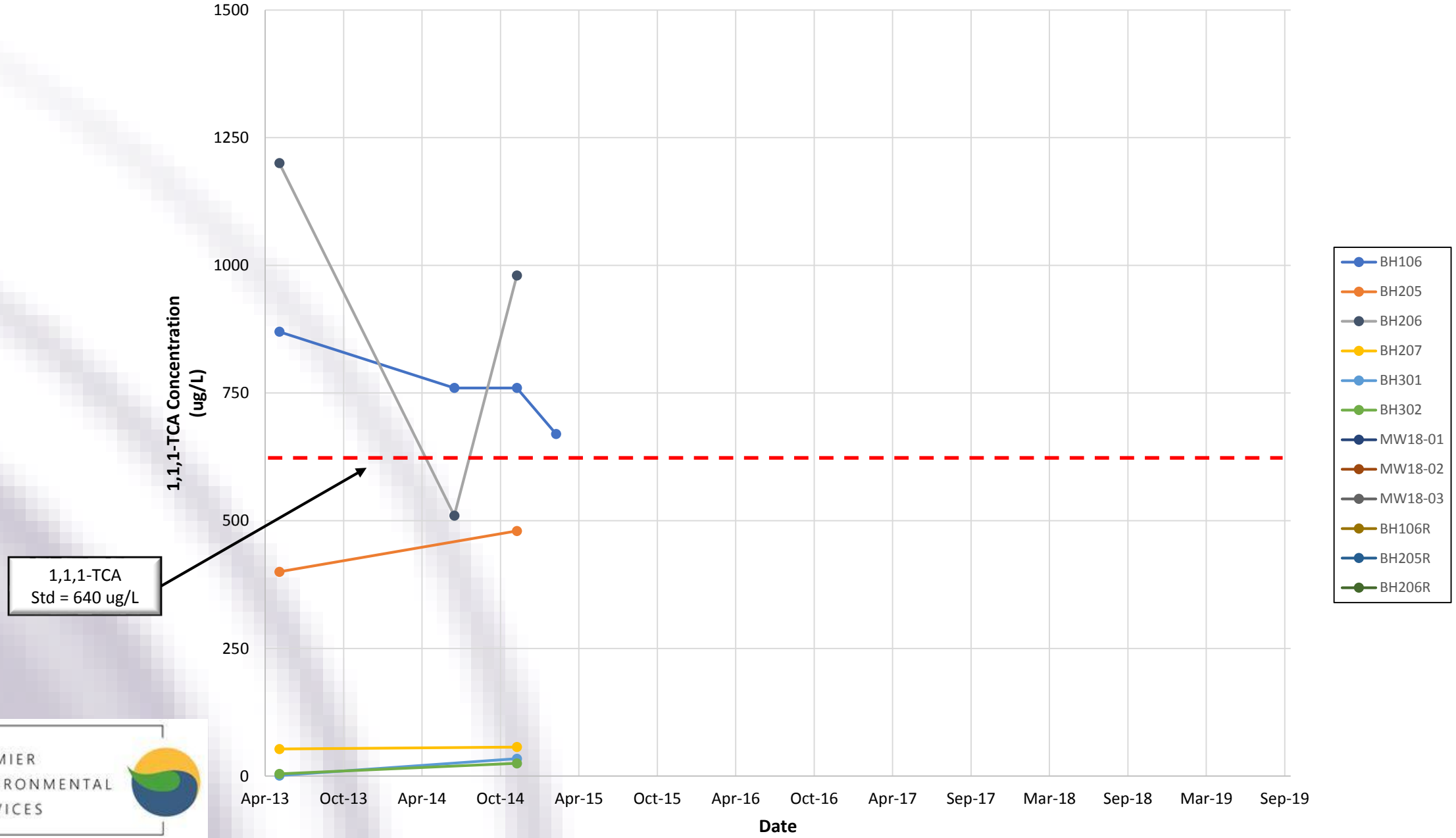
Analytical Results – 1,1,1-TCA



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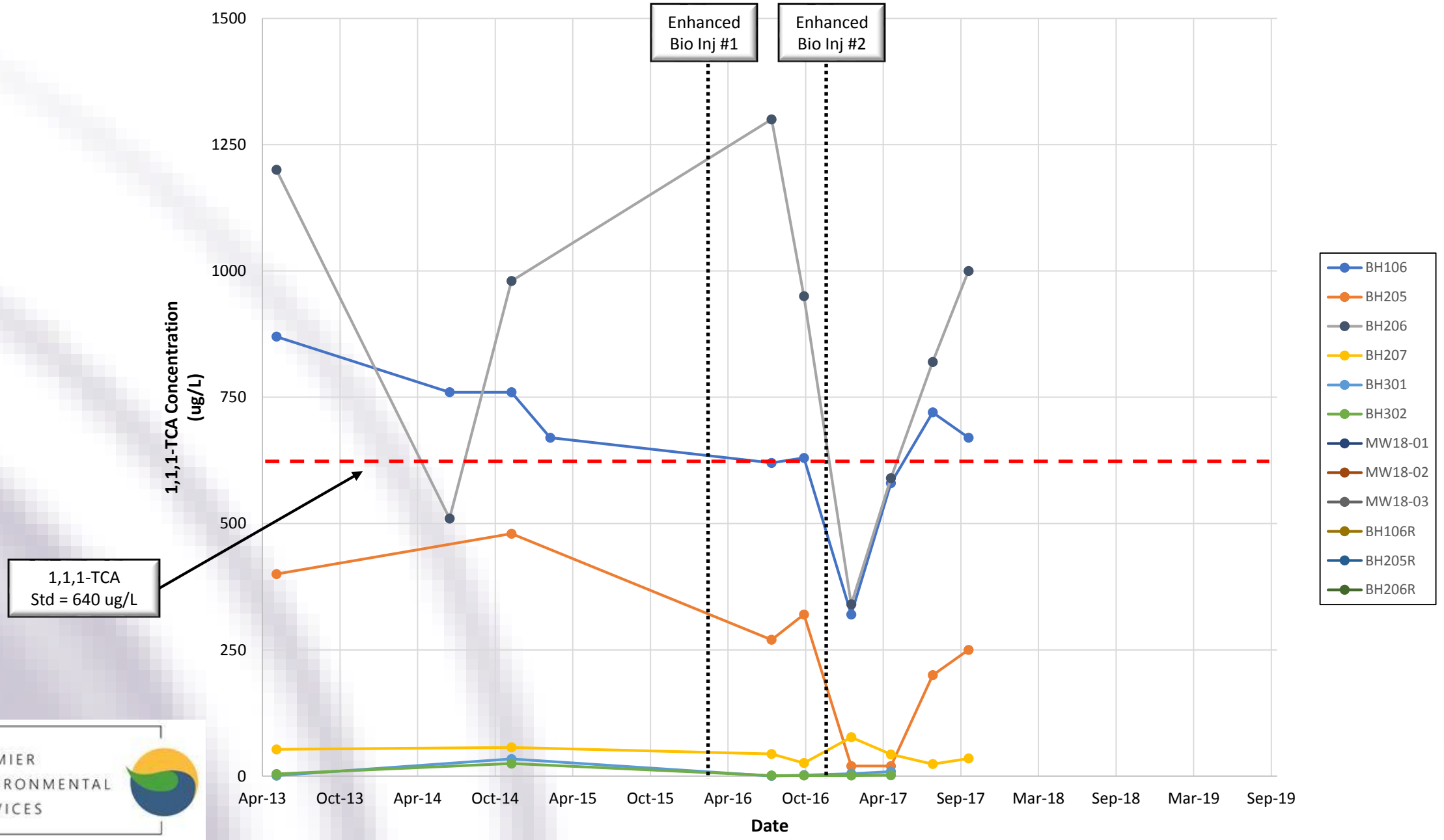
Analytical Results – 1,1,1-TCA



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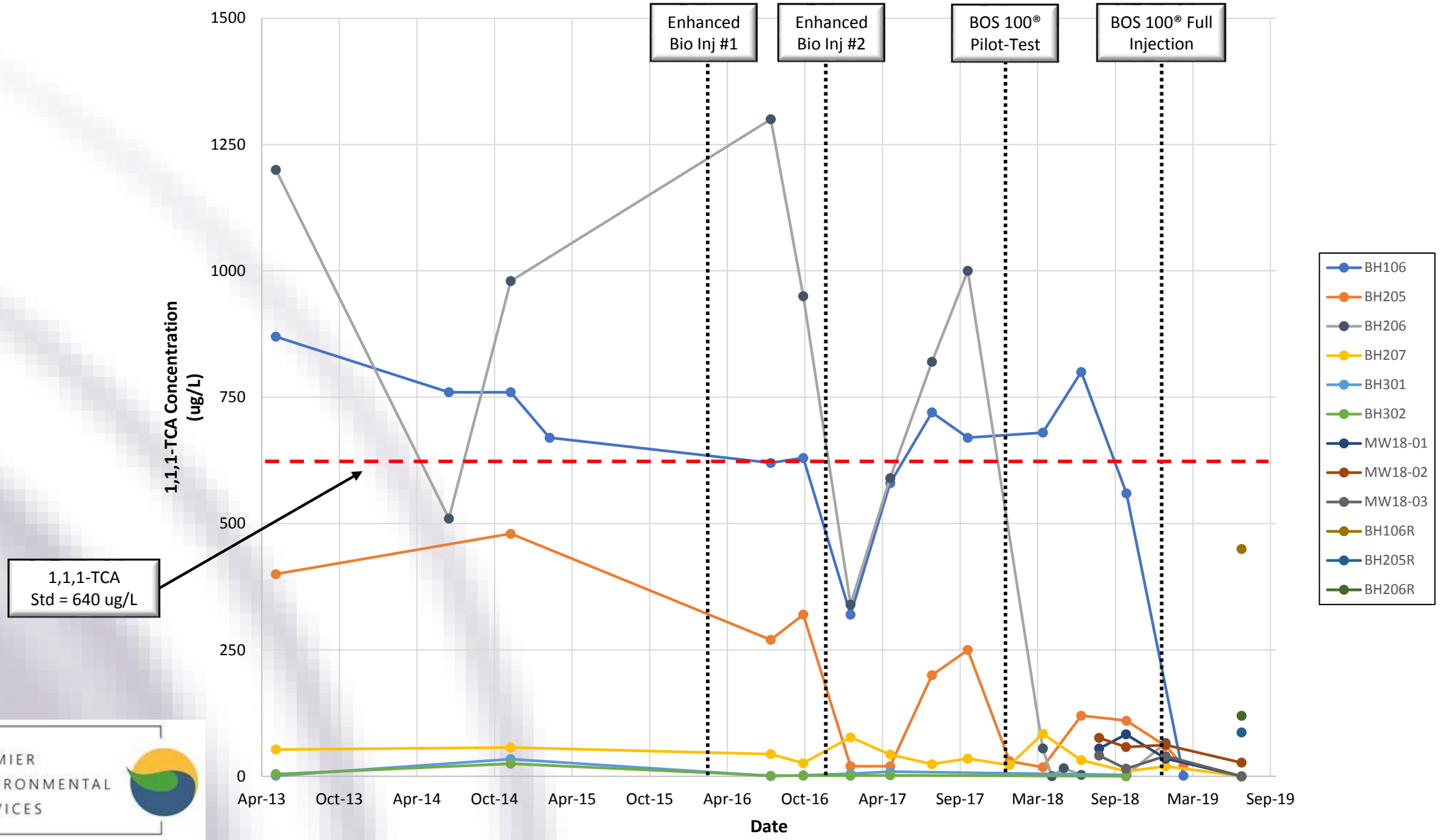
Analytical Results – 1,1,1-TCA



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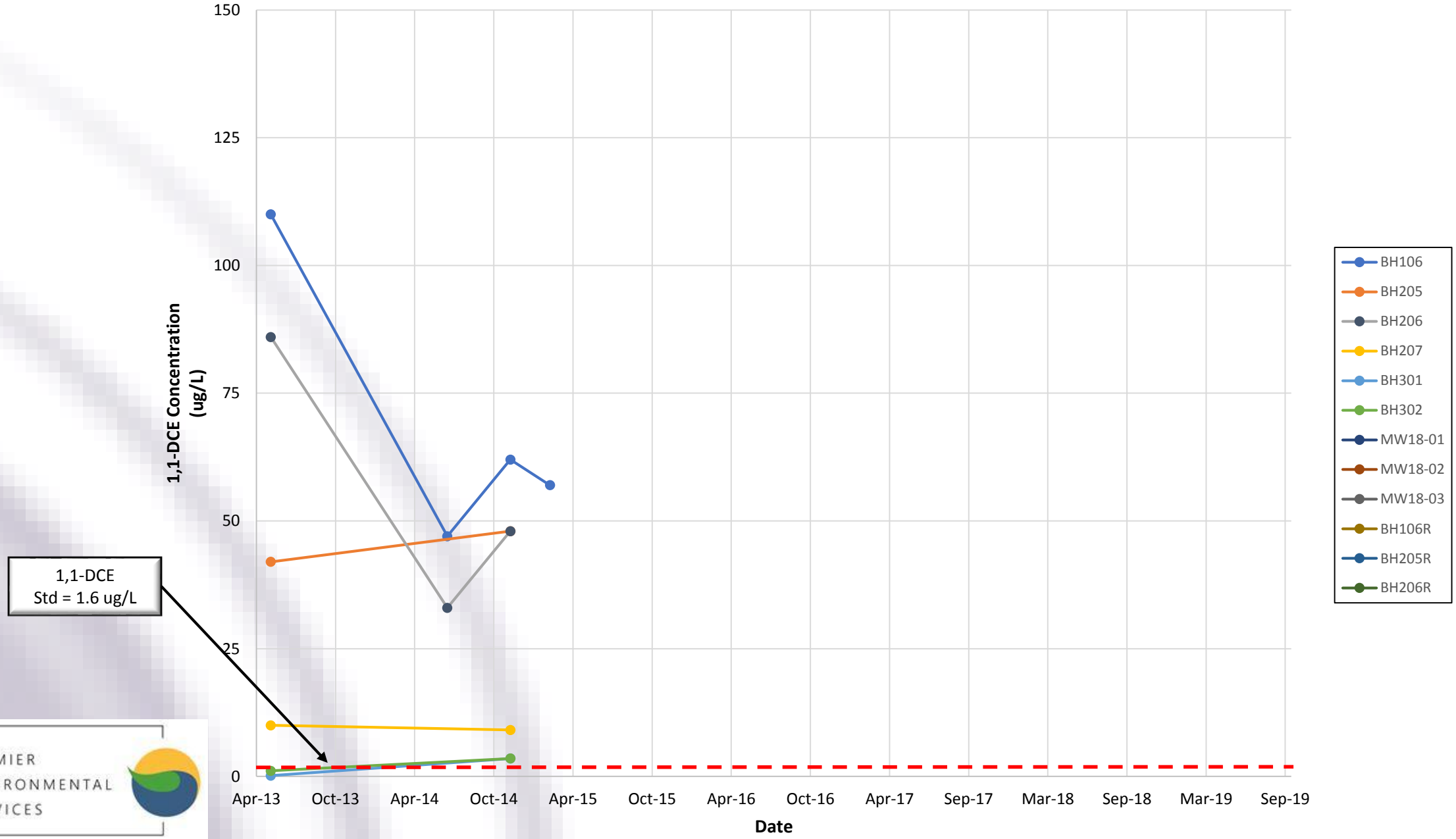
Analytical Results – 1,1-DCE



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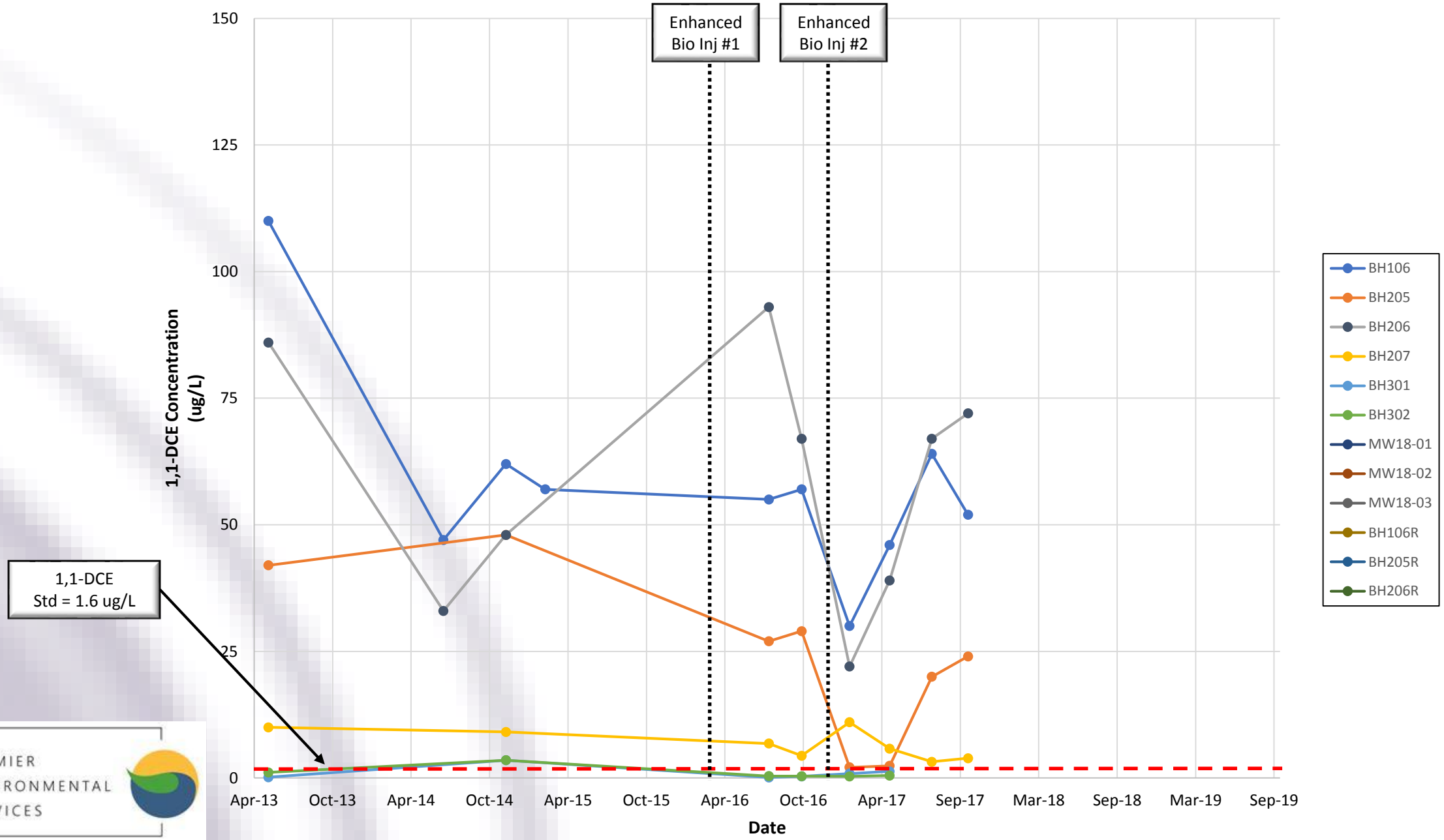
Analytical Results – 1,1-DCE



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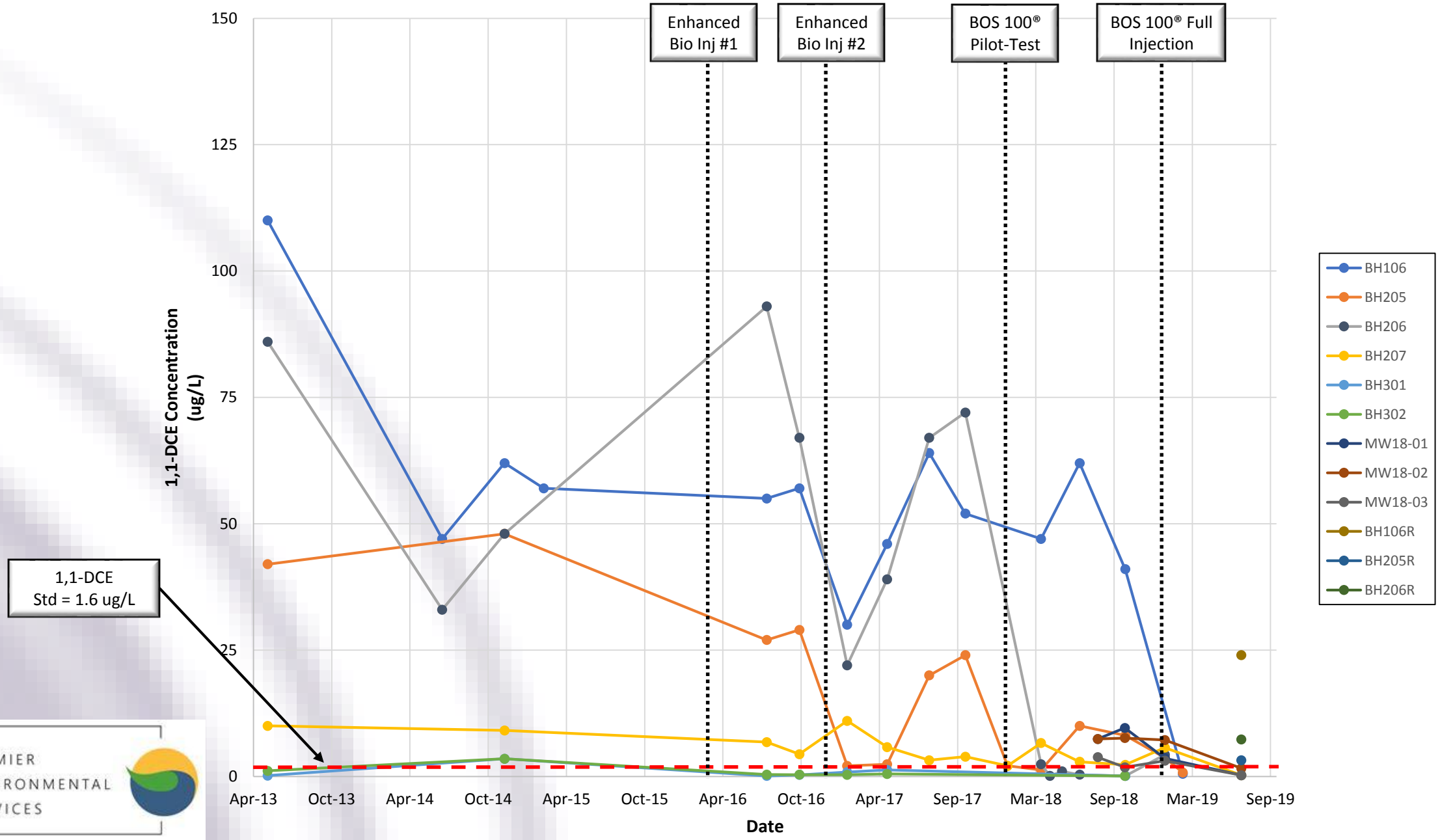
Analytical Results – 1,1-DCE



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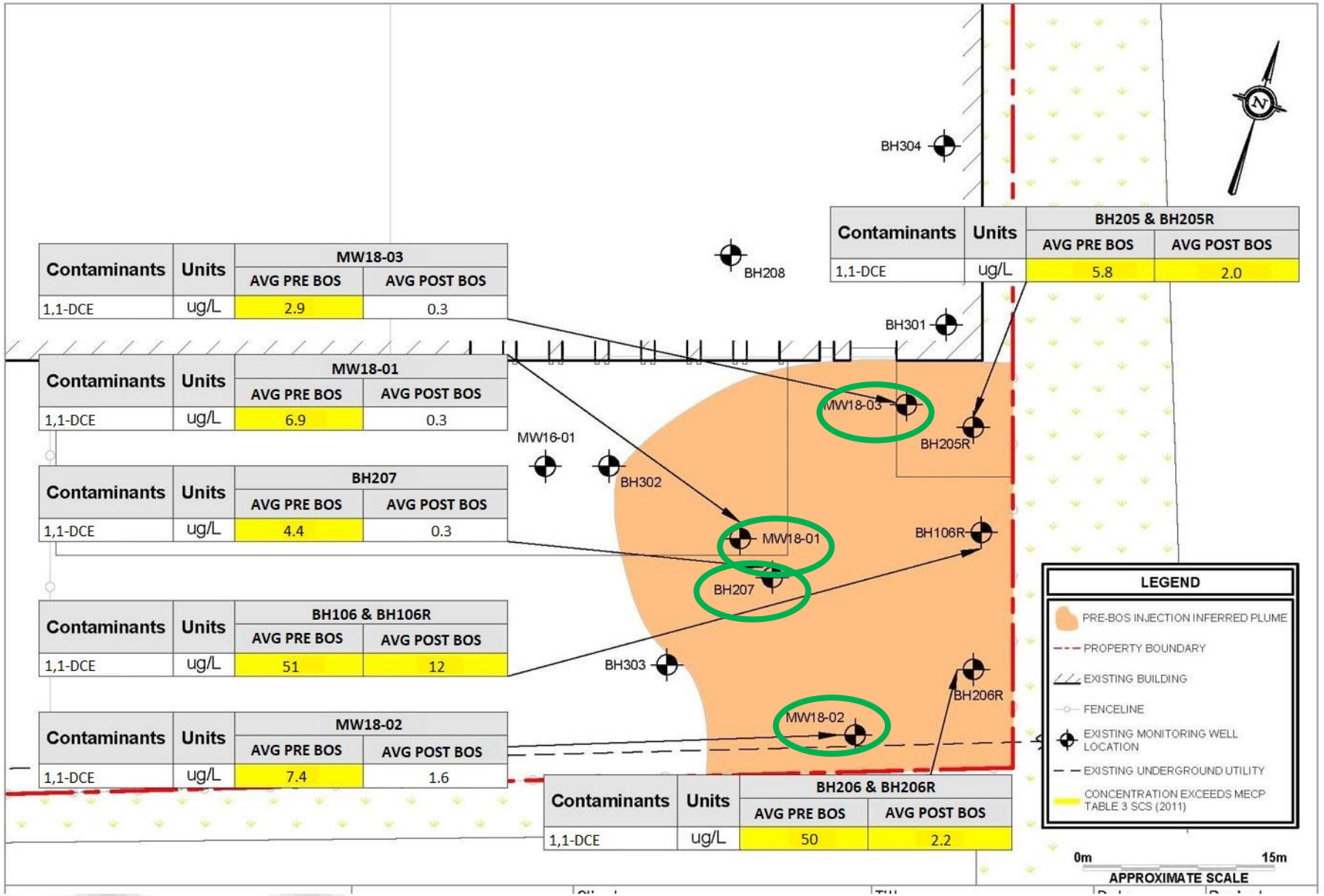
Analytical Results – Average 1,1-DCE Concentrations



Contaminants	Units	MW18-03	
		AVG PRE BOS	AVG POST BOS
1,1-DCE	ug/L	2.9	0.3

Contaminants	Units	MW18-01	
		AVG PRE BOS	AVG POST BOS
1,1-DCE	ug/L	6.9	0.3

Contaminants	Units	BH207	
		AVG PRE BOS	AVG POST BOS
1,1-DCE	ug/L	4.4	0.3

Contaminants	Units	BH106 & BH106R	
		AVG PRE BOS	AVG POST BOS
1,1-DCE	ug/L	51	12

Contaminants	Units	MW18-02	
		AVG PRE BOS	AVG POST BOS
1,1-DCE	ug/L	7.4	1.6

Contaminants	Units	BH205 & BH205R	
		AVG PRE BOS	AVG POST BOS
1,1-DCE	ug/L	5.8	2.0

Contaminants	Units	BH206 & BH206R	
		AVG PRE BOS	AVG POST BOS
1,1-DCE	ug/L	50	2.2

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Lessons Learned

Lessons Learned:

- Deep plumes in tight overburden soils are very “Difficult Aquifers” to treat via convention injection methods
- Bench & Pilot-Testing is critical!
- The Sonic Pre-Drilling Approach can provide a cost effective alternative
- The Sonic Pre-Drilling Approach can provide a delivery method for otherwise inaccessible “Difficult Aquifers”
- R&D for new Injection Methods should not be completed in the winter!

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Questions

Thank You for Your Time

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