


OBG PRESENTS:

EVO / Bioaugmentation for Treatment of Trichloroethene by Biobarrier and Source Injection Approach

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Emulsified Vegetable Oil (EVO) and Bioaugmentation for Treatment of Trichloroethene (TCE) by “Biobarrier” and Source Injection Approach

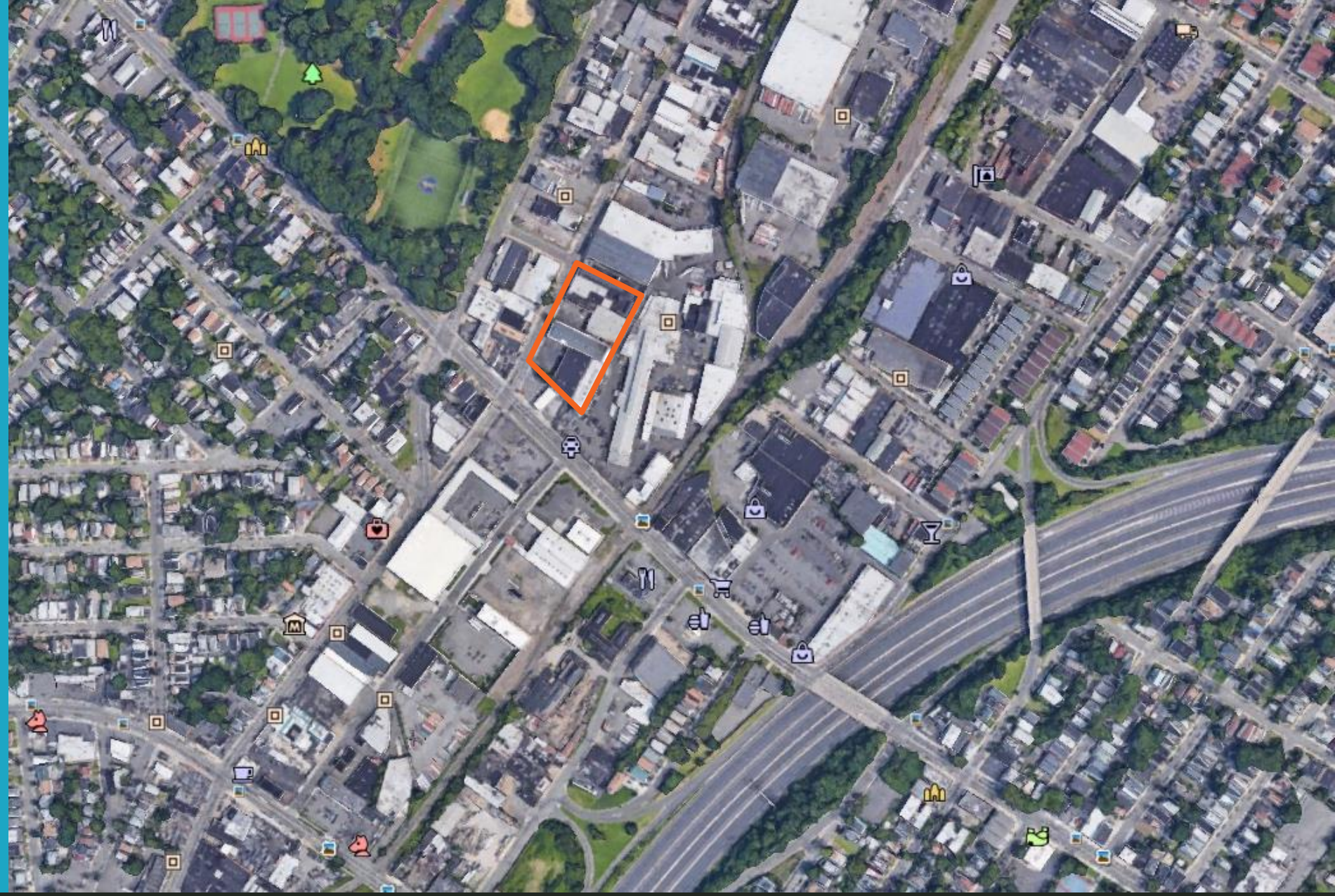
Background

Implementation

Performance Monitoring

Background

Site Setting




25 / 43.99
MW-26
70 / 80.5
MW-28
MW-9
MW-10
MW-17
100
MW-18
MW-8
MW-20
MW-1
MW-15
5,000
1,000
MW-14
MW-2
58 / 125.72
MW-19BR
MW-19
MW-21
MW-16
MW-6
MW-3
MW-7
MW-7D
670 / 1,183.2
MW-24
MW-24BR
MW-11
7,100 / 7,446
MW-29
MW-4
MW-13
MW-22
MW-23
MW-12
MW-25
850 / 1,519
MW-25BR
MW-27BR
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Remedial Objectives

Remediate source / reduce CVOC mass flux

Enhance monitored natural attenuation (MNA) downgradient

Meet New Jersey Groundwater Quality Standards (GWQS) – **TCE = 1 ppb; 1,1,1-TCA = 30 ppb**

Key Considerations

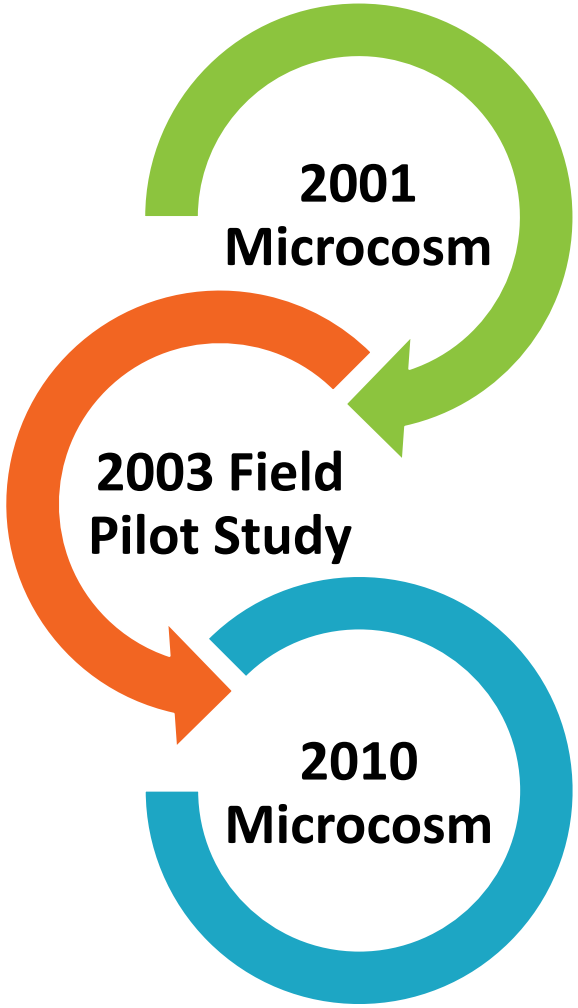
Difficult urban setting

Treatment needed off-Site

Long-term solution / low maintenance

No aboveground equipment

Enhanced In Situ Bioremediation (EISB) Proof of Concept

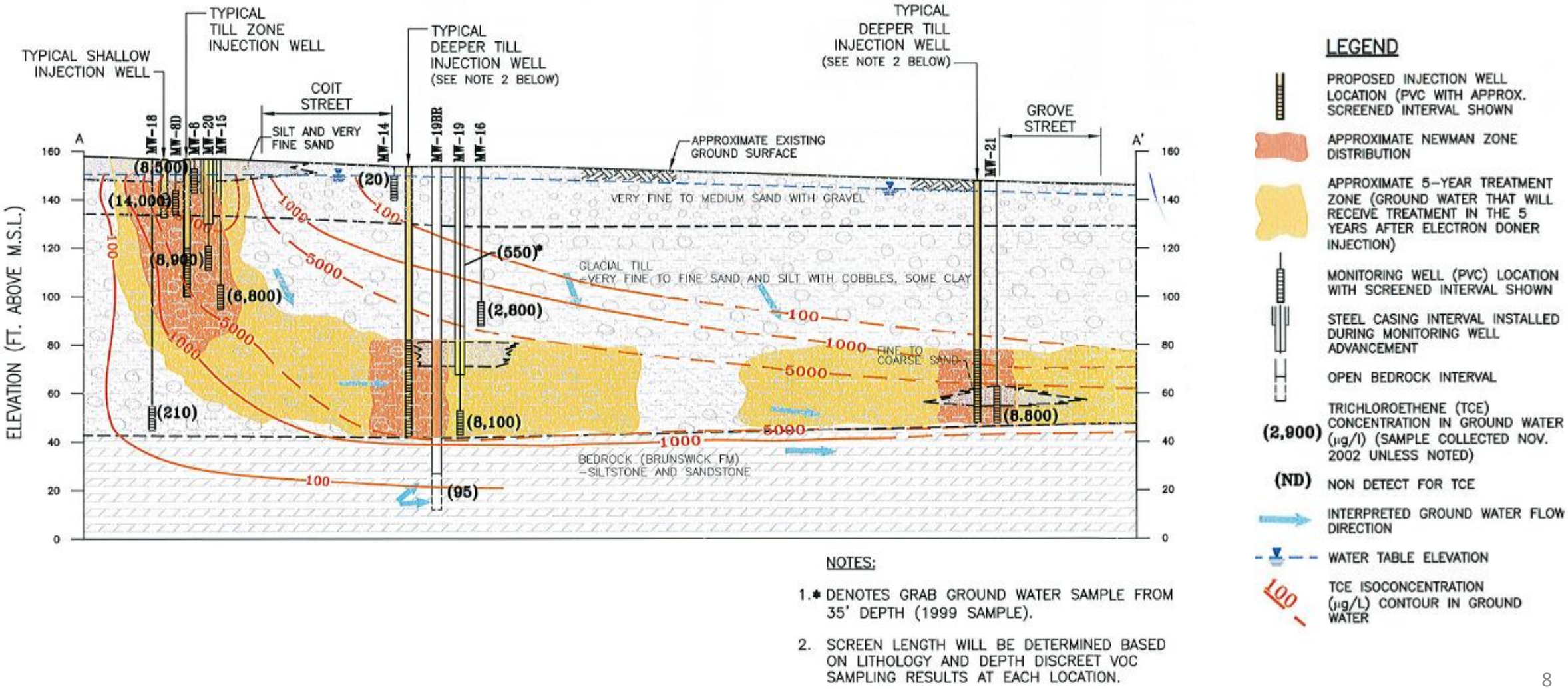


- Showed TCE degradation, but accumulation of cDCE with electron donor only (MEAL)
- Showed complete dechlorination to ethene with Dhc addition (KB-1)

- Conducted at a “hot-spot” in shallow source area
- 1st Injection = 65 lbs sodium lactate; 2nd Injection = 600 lbs sodium lactate
- Bioaugmentation with Dhc

- Used groundwater from off-site monitoring well where “biobarrier” was planned
- Tested new commercially available electron donors and buffers

Cross Sectional View of Site

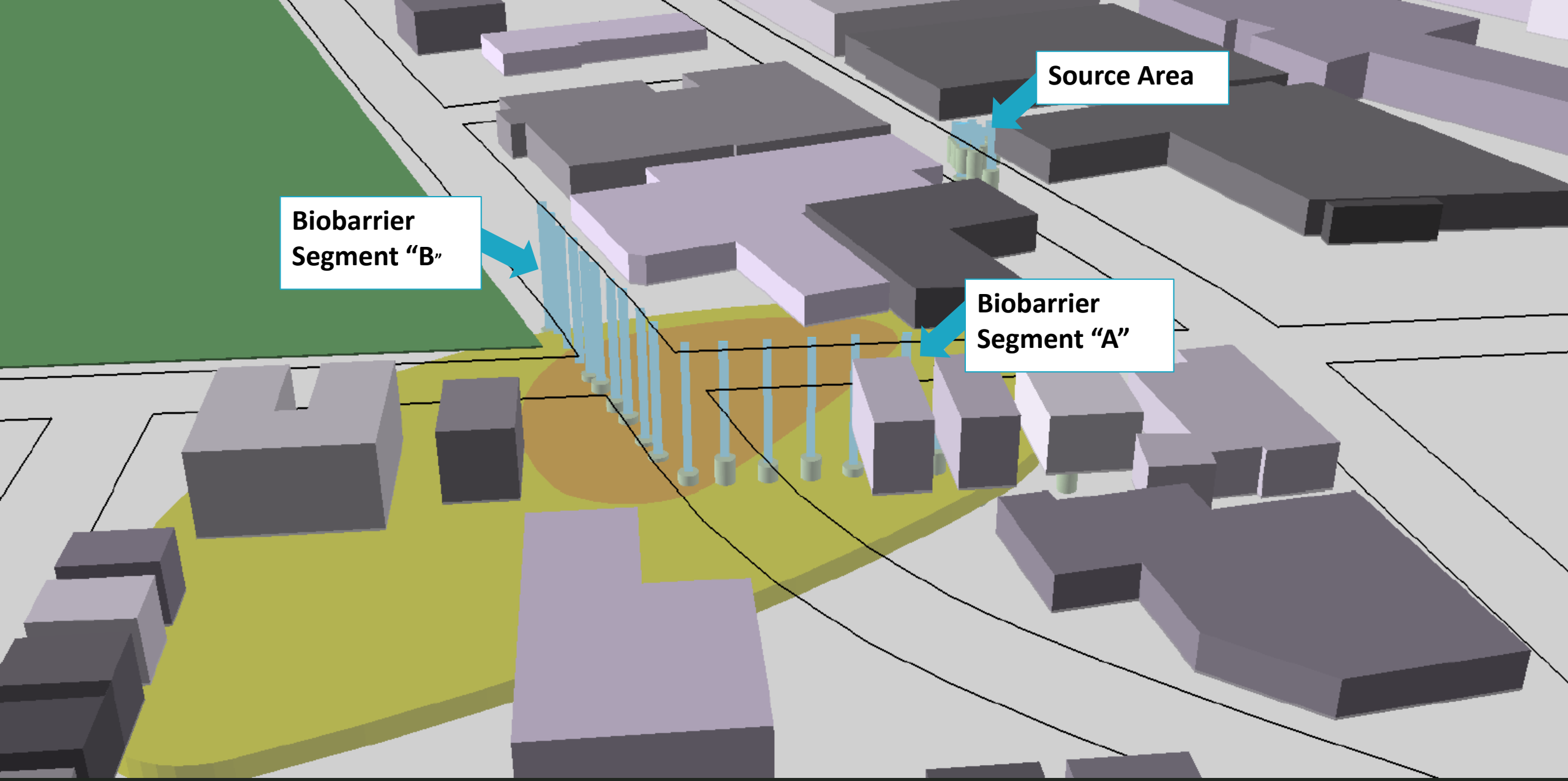


NOTES:

1. * DENOTES GRAB GROUND WATER SAMPLE FROM 35' DEPTH (1999 SAMPLE).
2. SCREEN LENGTH WILL BE DETERMINED BASED ON LITHOLOGY AND DEPTH DISCREET VOC SAMPLING RESULTS AT EACH LOCATION.

LEGEND

- PROPOSED INJECTION WELL LOCATION (PVC WITH APPROX. SCREENED INTERVAL SHOWN
- APPROXIMATE NEWMAN ZONE DISTRIBUTION
- APPROXIMATE 5-YEAR TREATMENT ZONE (GROUND WATER THAT WILL RECEIVE TREATMENT IN THE 5 YEARS AFTER ELECTRON DONER INJECTION)
- MONITORING WELL (PVC) LOCATION WITH SCREENED INTERVAL SHOWN
- STEEL CASING INTERVAL INSTALLED DURING MONITORING WELL ADVANCEMENT
- OPEN BEDROCK INTERVAL
- (2,900) TRICHLOROETHENE (TCE) CONCENTRATION IN GROUND WATER (µg/l) (SAMPLE COLLECTED NOV. 2002 UNLESS NOTED)
- (ND) NON DETECT FOR TCE
- INTERPRETED GROUND WATER FLOW DIRECTION
- WATER TABLE ELEVATION
- 100 TCE ISOCONCENTRATION (µg/L) CONTOUR IN GROUND WATER


Source Area
Biobarrier Segment “B”
Biobarrier Segment “A”

Implementation

Overview / Chronology

Injection Well Install

- Initial (8) injection wells for EISB pilot test in source area installed June 2003
- Additional (25) injection wells installed January – March 2014

EVO Injection

- Newman Zone® Standard Emulsified Vegetable Oil (EVO) was selected
- EVO injection completed over a period of 14 days (September 2014 – October 2014)

Bioaugment

- Bioaugmentation conducted May 2015
- TSI-DC *Dehalococcoides mccartyii* Bioaugmentation Culture® supplied by Terra Systems, Inc.

Performance Monitoring

- Groundwater (GW) sampling / monitoring events conducted:
  - Baseline (pre-EVO injection): May 2014
  - Months 1 through 6: November 2014 – April 2015 (pre-bioaugmentation)
  - Months 7 and beyond: August 2015 – April 2017 (post-bioaugmentation)

Injection Well Installation

Off-site barrier well installations

9-ft high pile of plow snow covering two planned drill locations

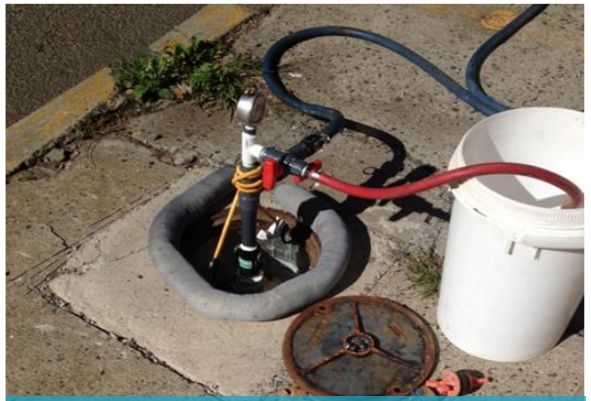
Compact Rotosonic drill rig

EVO Injections

Newman Zone® product tote

Mixing tanks

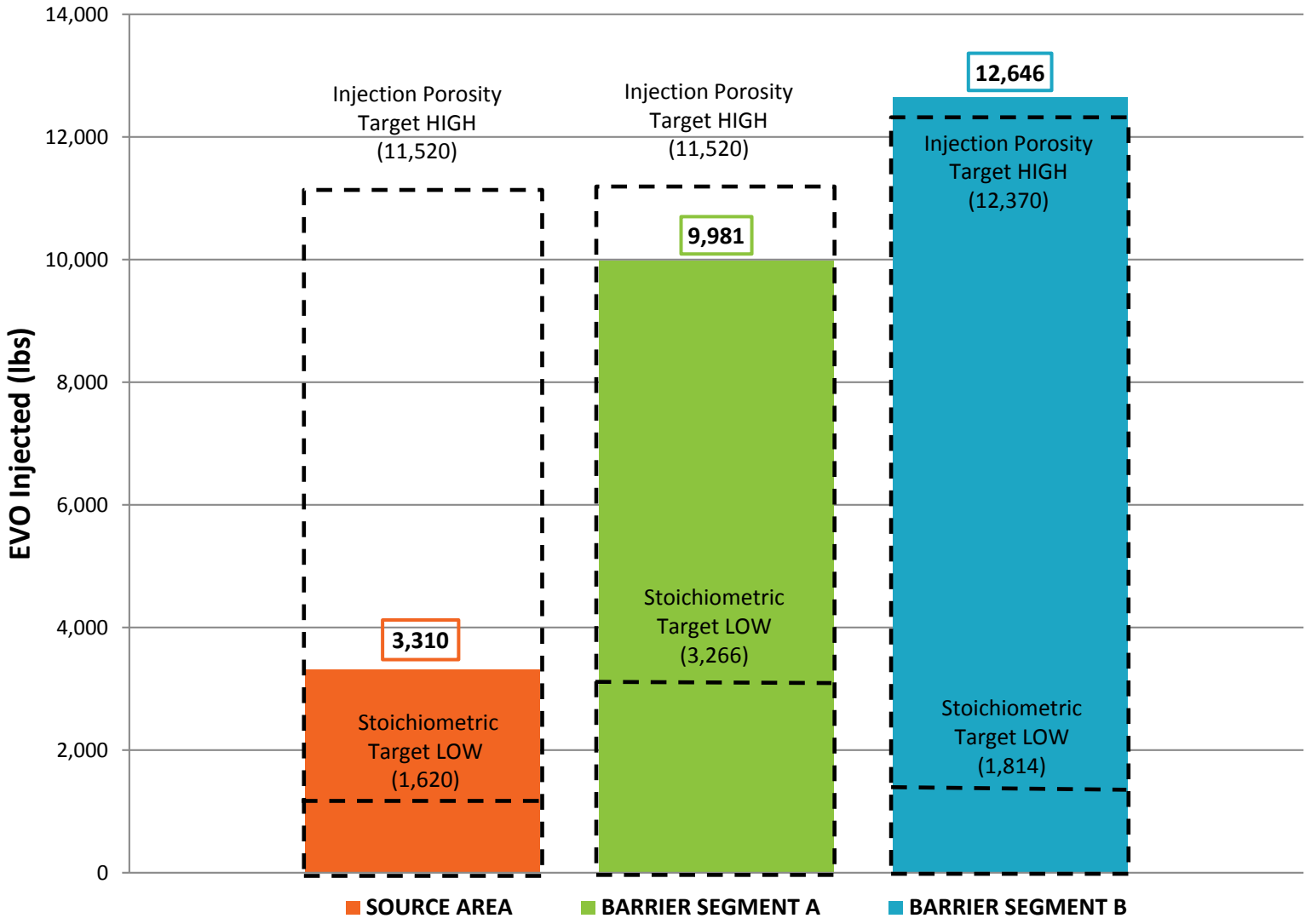
Biobarrier injections



Spill containment

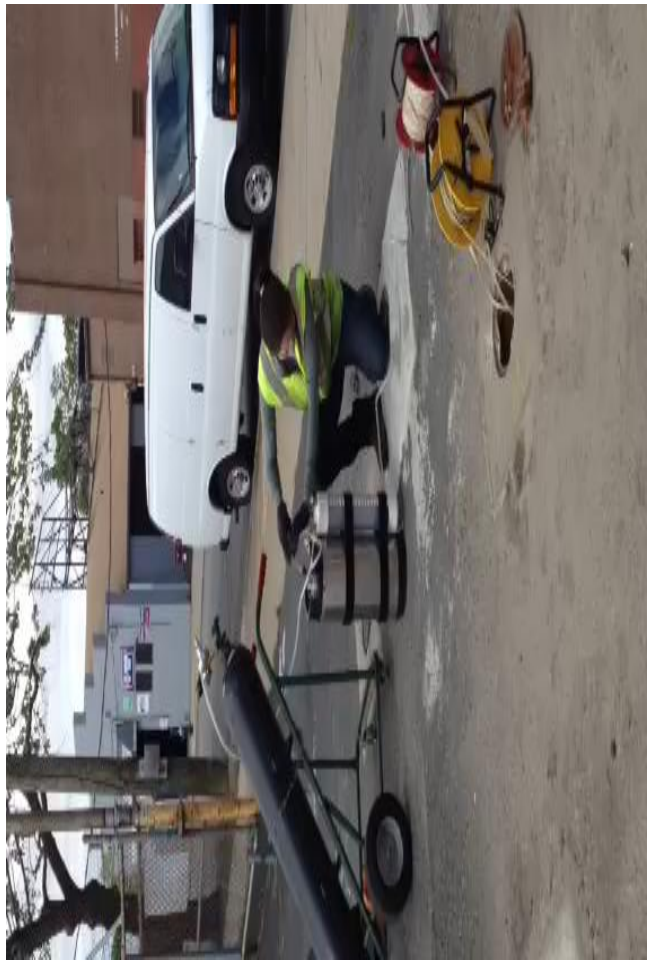
Gravity feed setup

Actual vs. Target EVO Injected in Pounds



A total of 25,937 lbs of Newman Zone® Standard EVO at 10% concentration (31,438 gallons in solution) was injected in the EISB treatment zones over a period of 14 days

Bioaugmentation



Self-performed bioaugmentation

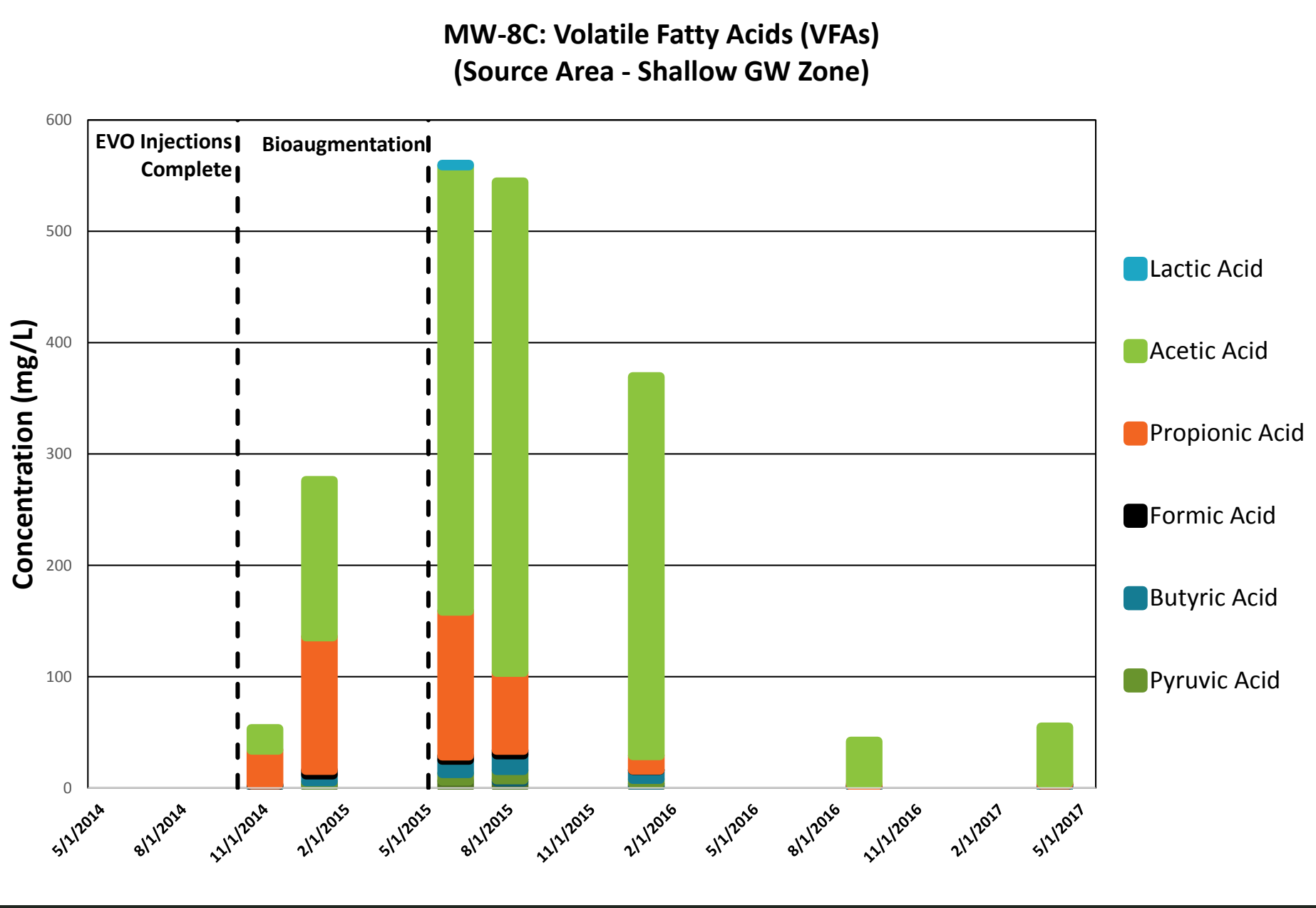
TSI-DC Bioaugmentation Culture® contains > 1 x 10^{11} cells/L of *Dehalococcoides mccartyii*

Total of 336 liters of culture injected over a period of 7 days to achieve target concentration of 1 x 10^{7} cells/L in groundwater

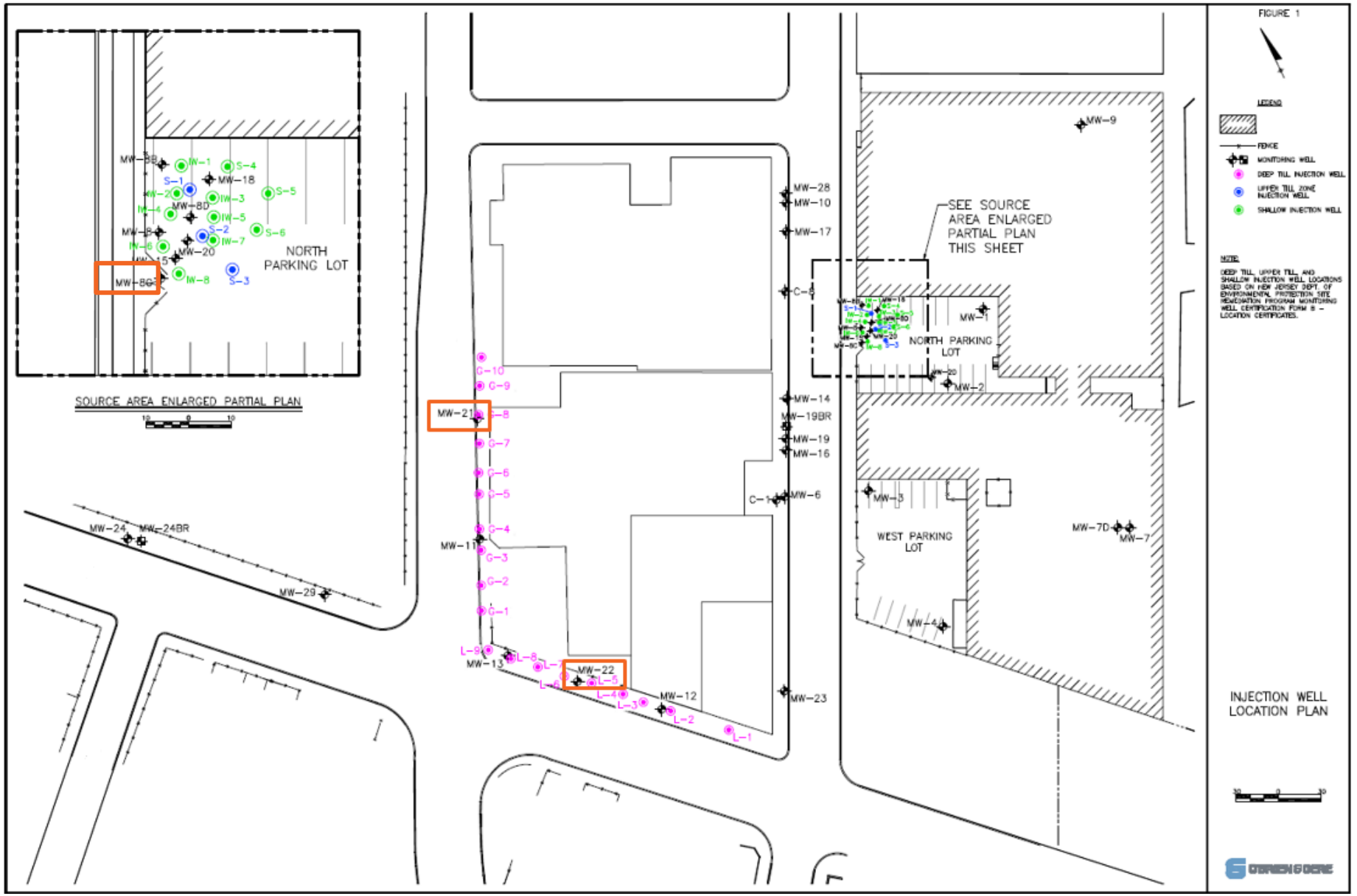
Fouling Slowed Progress

Performance Monitoring

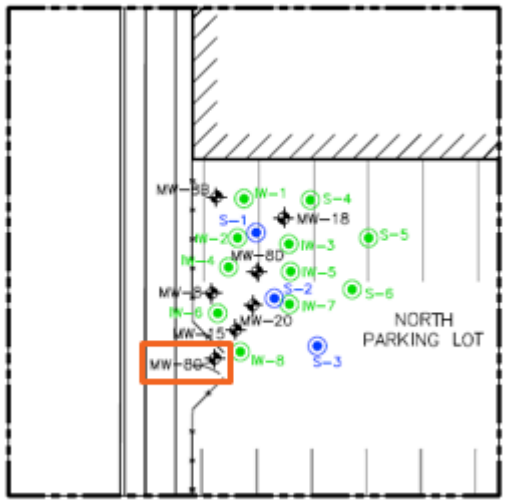
EVO is fermented to release volatile fatty acids (VFAs), which act as a carbon source for *Dhc* and other microbes

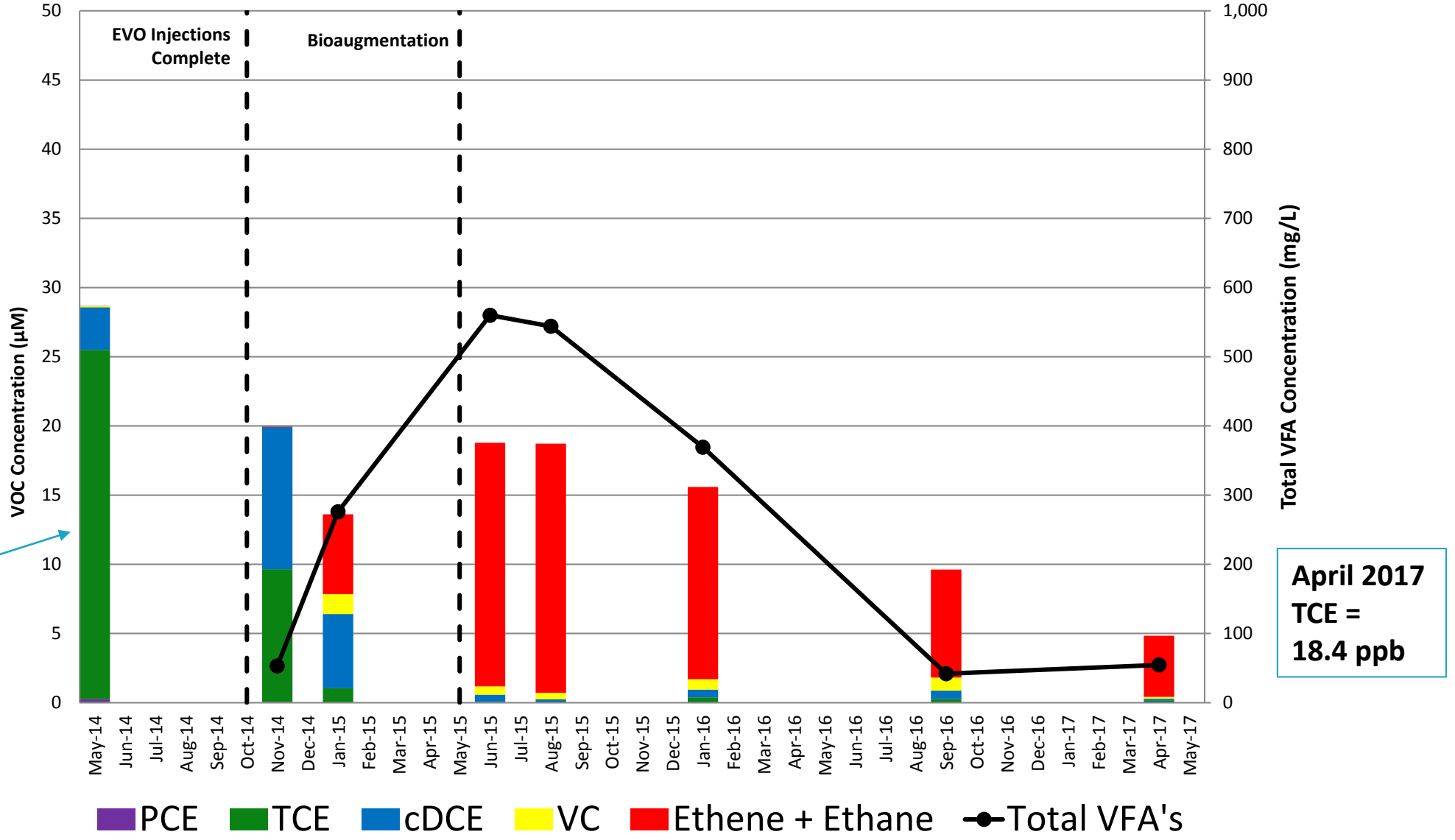


EISB Monitoring Wells



MW-8C: EISB Source Area - Shallow Overburden Zone





Baseline TCE = 3,320 ppb

NJ GWQS for TCE = 1 ppb

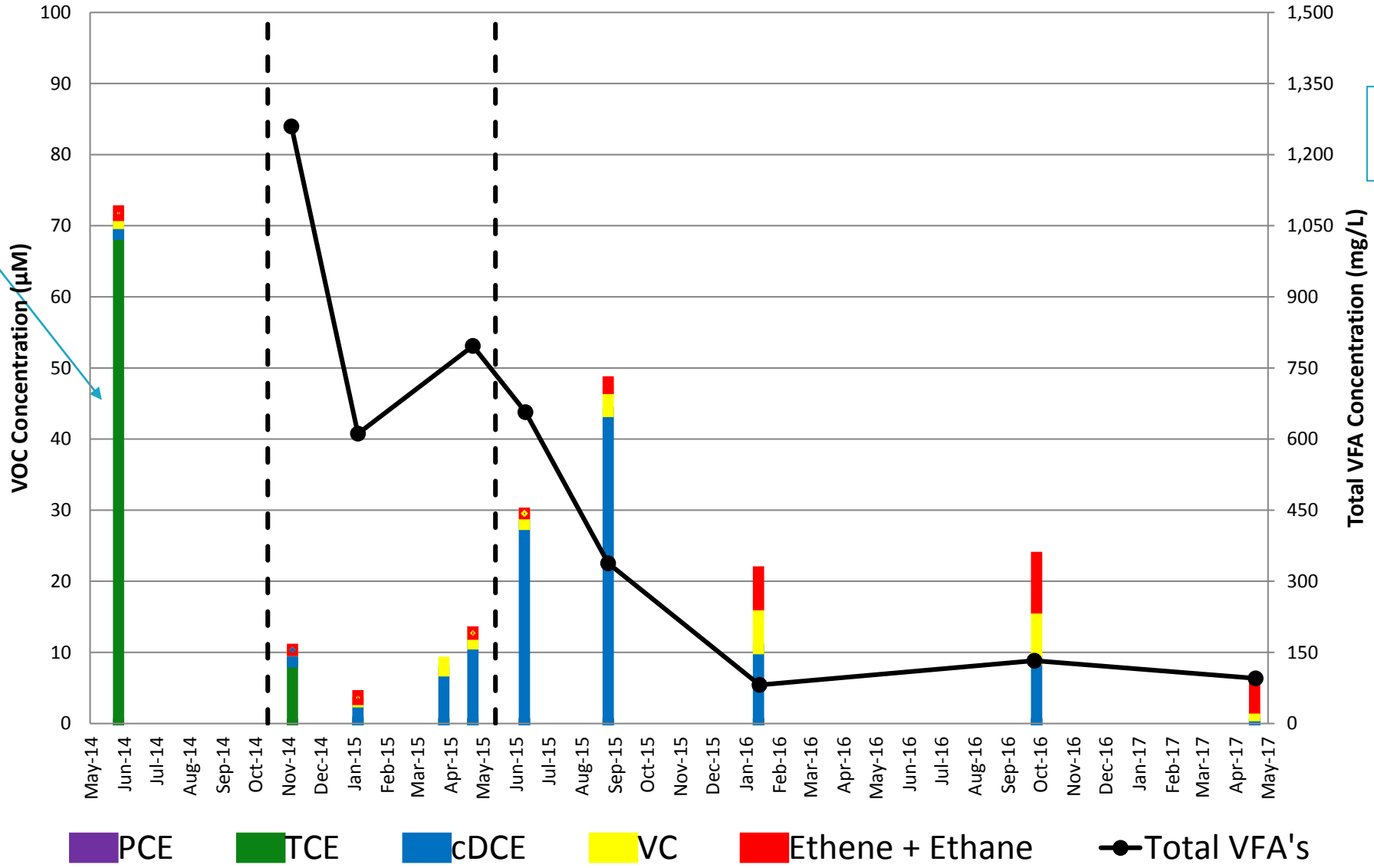
April 2017 TCE = 18.4 ppb

MW-21: EISB Biobarrier - Deep Till Zone

Baseline TCE = 9,030 ppb

NJ GWQS for TCE = 1 ppb

April 2017 TCE = < 0.26 ppb

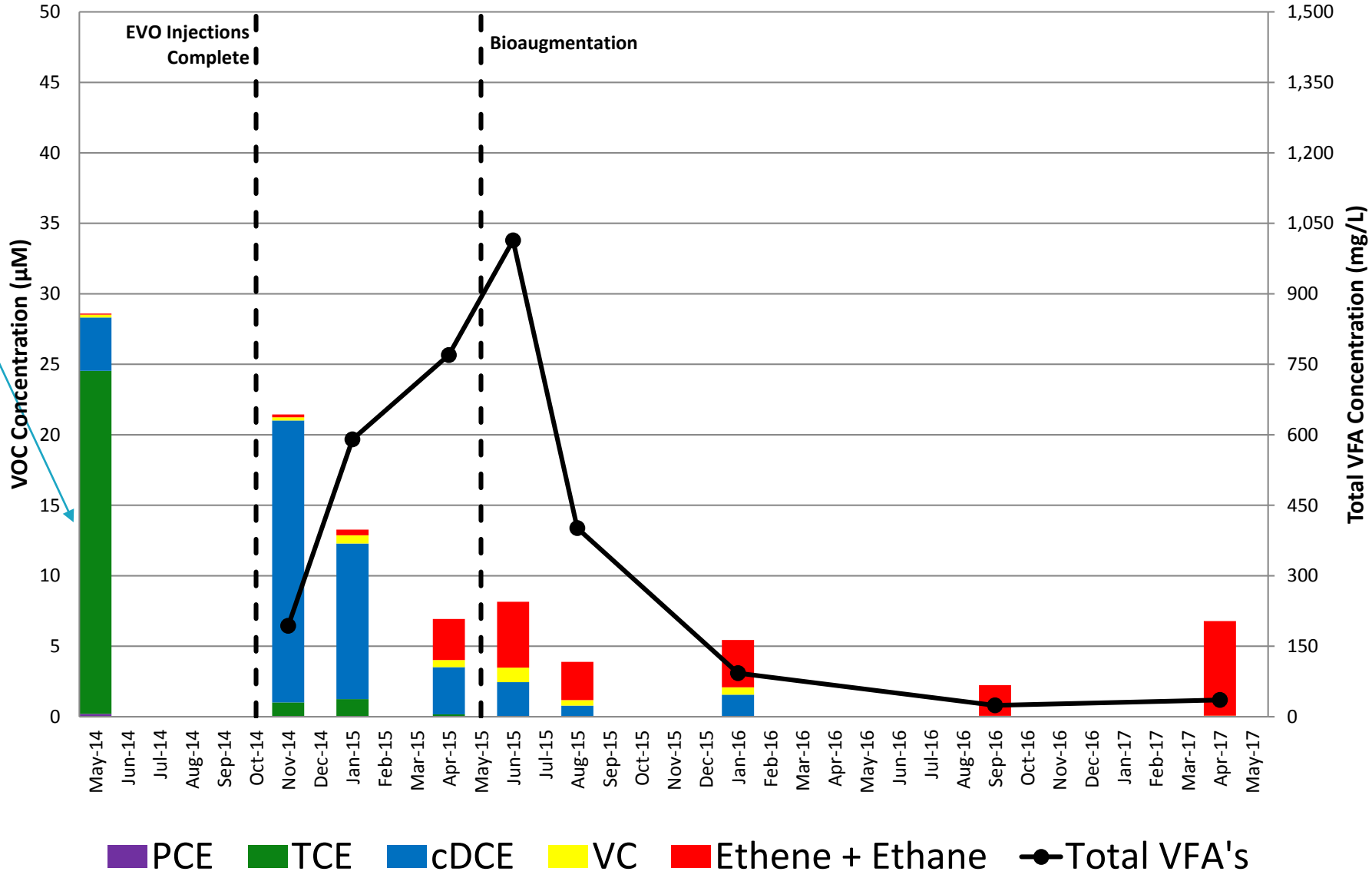


MW-22: EISB Biobarrier - Deep Till Zone

Baseline TCE = 3,200 ppb

NJ GWQS for TCE = 1 ppb

April 2017 TCE = 2.1 ppb



TCE Concentrations (ppb)

	Historic Range*	April 2017 Results
Source Area Monitoring Wells		
MW-8 *(shallow overburden)*[+]	110 – 3,300	< 0.26
MW-8B *(shallow overburden)*	54 - 760	5,270
MW-8C *(shallow overburden)*	130 - 6,100	18.4
MW-8D *(shallow overburden)*	42 - 17,000	< 0.26
MW-20 *(intermediate till)*	400 - 25,000	580
MW-18 *(deep till)*	130 - 340	148
Barrier Segment "B" Monitoring Well		
MW-21 *(deep till)*	5,500 - 16,000	< 0.26
Barrier Segment "A" Monitoring Well		
MW-22 *(deep till)*	580 - 9,000	2.1

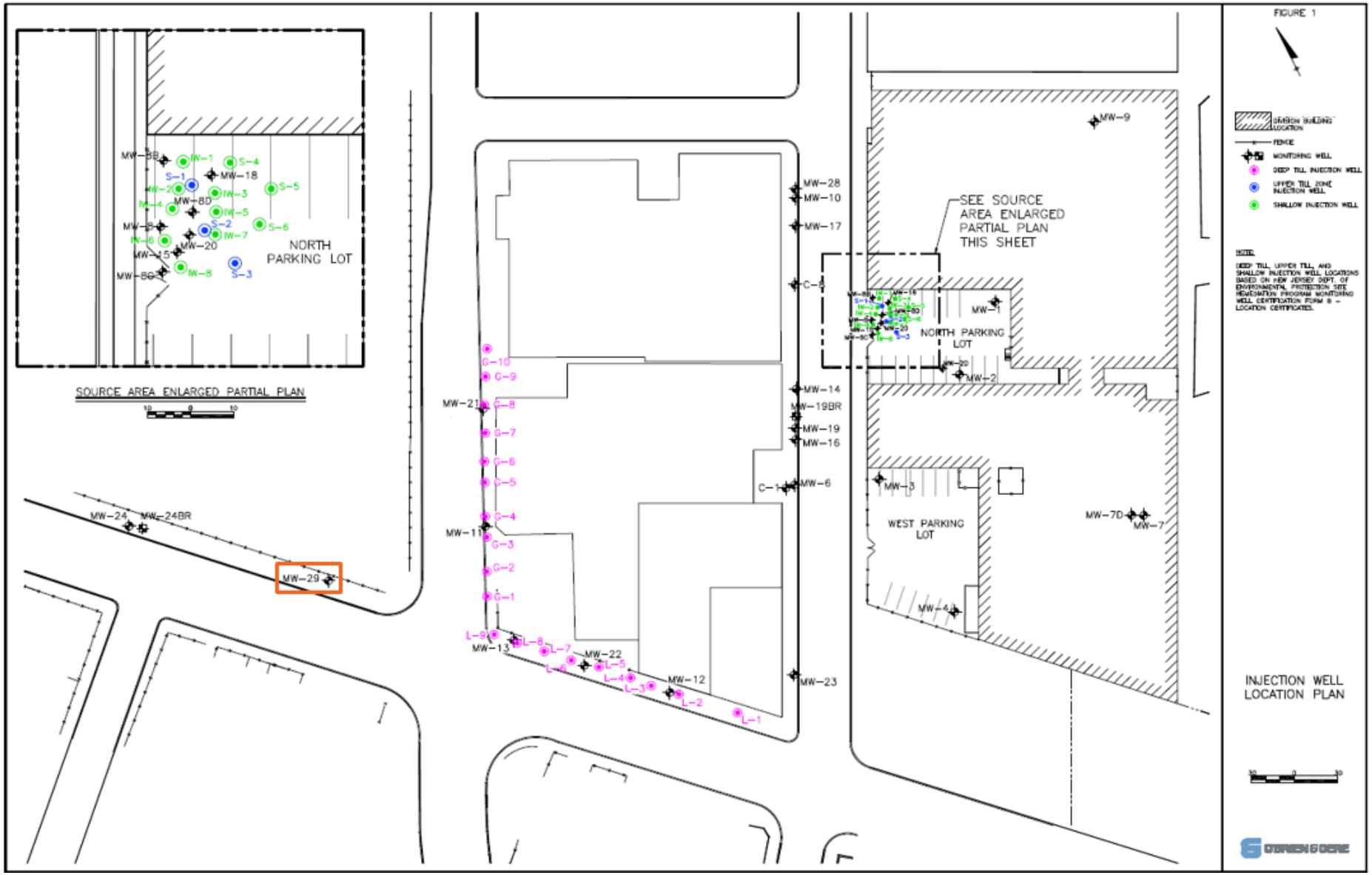
Notes:
NJ GWQS for TCE = 1 ppb, cDCE = 70 ppb
J = estimated value
* Excludes data from the EISB Pilot Test period (July 2003 – April 2004)
[+] cis-DCE concentrations shown for MW-8 (pilot test well)

1,1,1-TCA Concentrations (ppb)

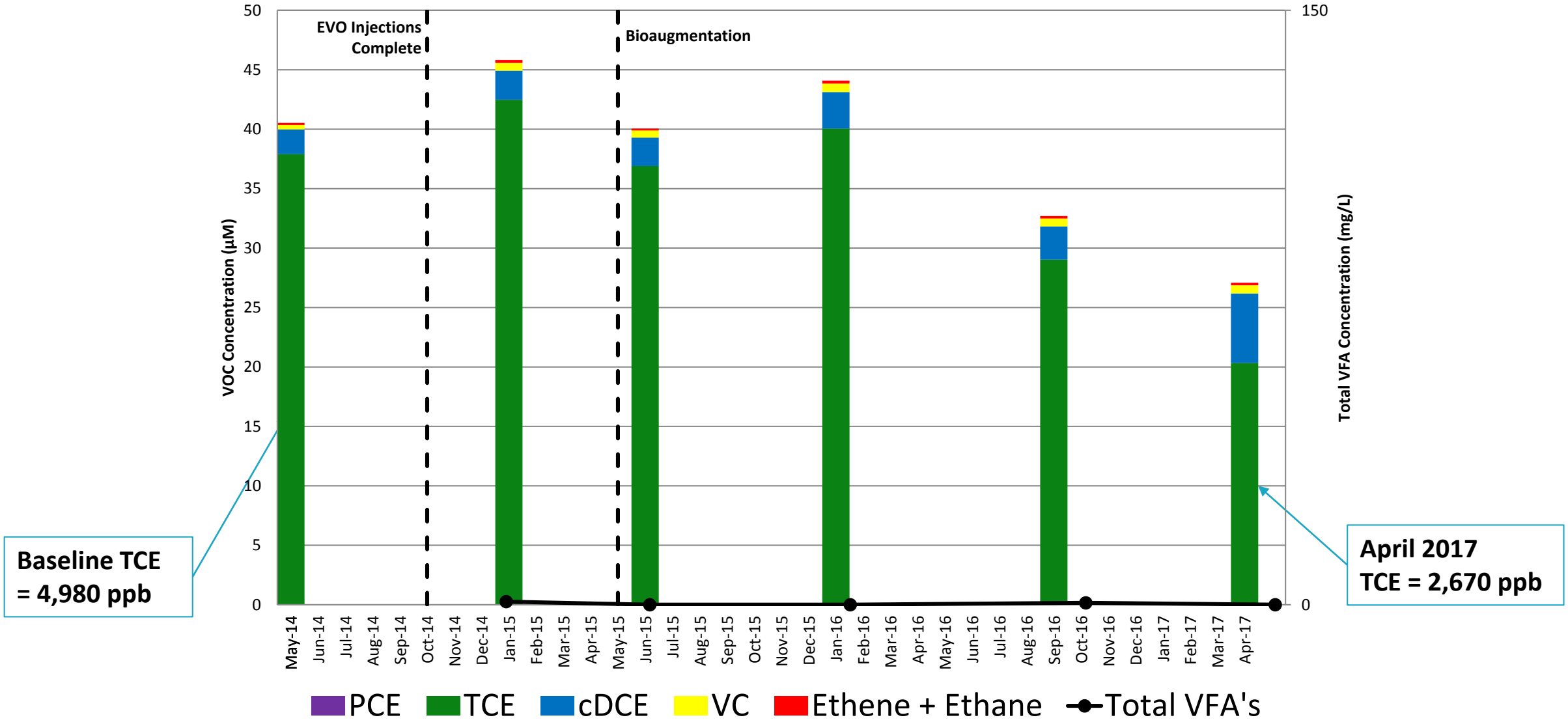
	Historic Range*	April 2017 Results
Source Area Monitoring Wells		
MW-8 *(shallow overburden)*	25 – 1,000	0.72 J
MW-8B *(shallow overburden)*	< 1 - 24	714
MW-8C *(shallow overburden)*	1.2 - 190	0.78 J
MW-8D *(shallow overburden)*	2.5 - 710	< 0.22
MW-20 *(intermediate till)*	2.7 – 1,100	25.6
MW-18 *(deep till)*	0.7 – 5.9	0.42 J
Barrier Segment "B" Monitoring Well		
MW-21 *(deep till)*	< 13 - 100	< 0.22
Barrier Segment "A" Monitoring Well		
MW-22 *(deep till)*	3.6 - 520	< 0.22

Notes:
NJ GWQS for TCA = 1 ppb
J = estimated value
*Excludes data from the EISB Pilot Test period (July 2003 – April 2004)

Sentinel Monitoring Well



MW-29: Sentinel A - Deep Till Zone



Baseline TCE = 4,980 ppb

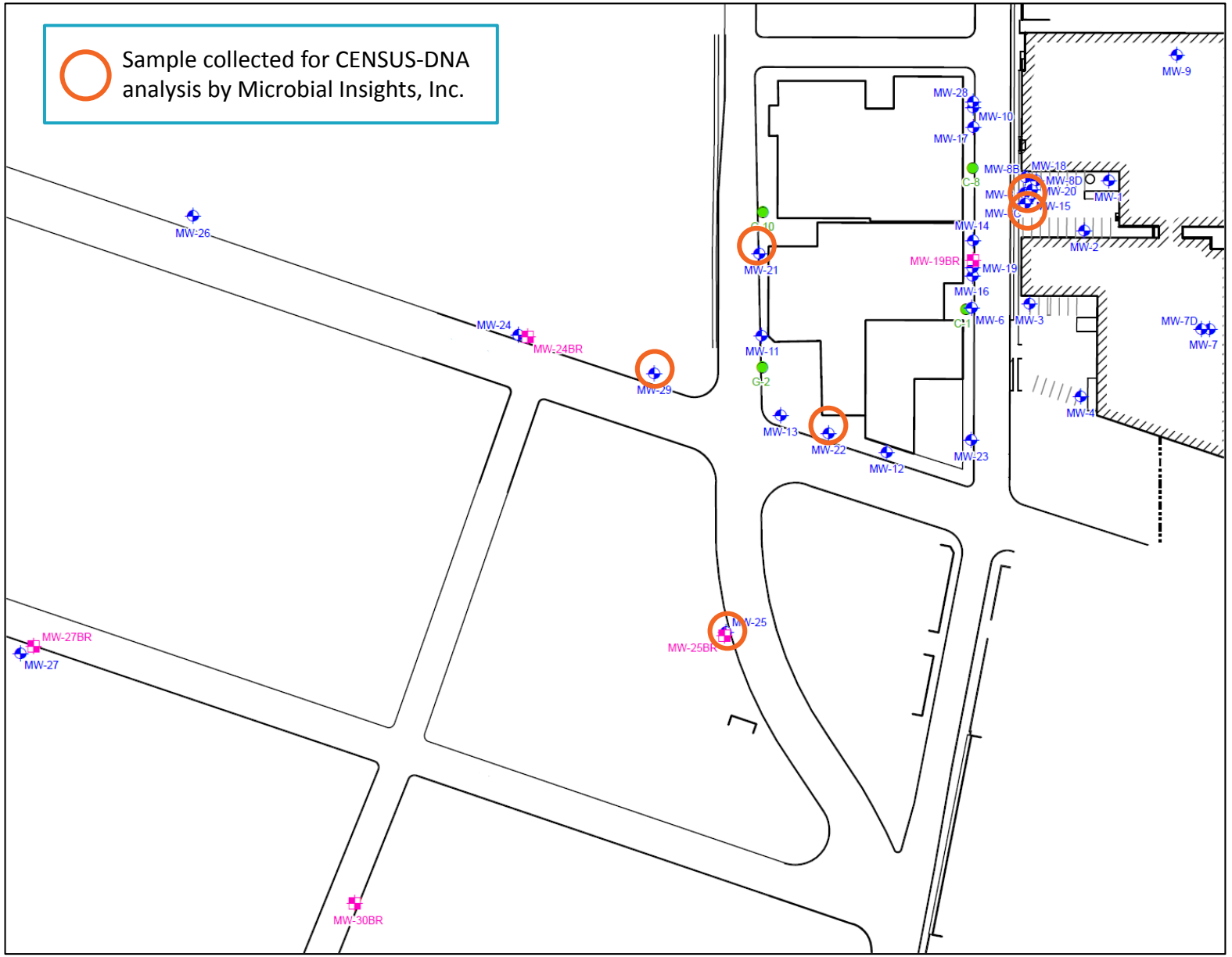
April 2017 TCE = 2,670 ppb

Post-Bioaugmentation

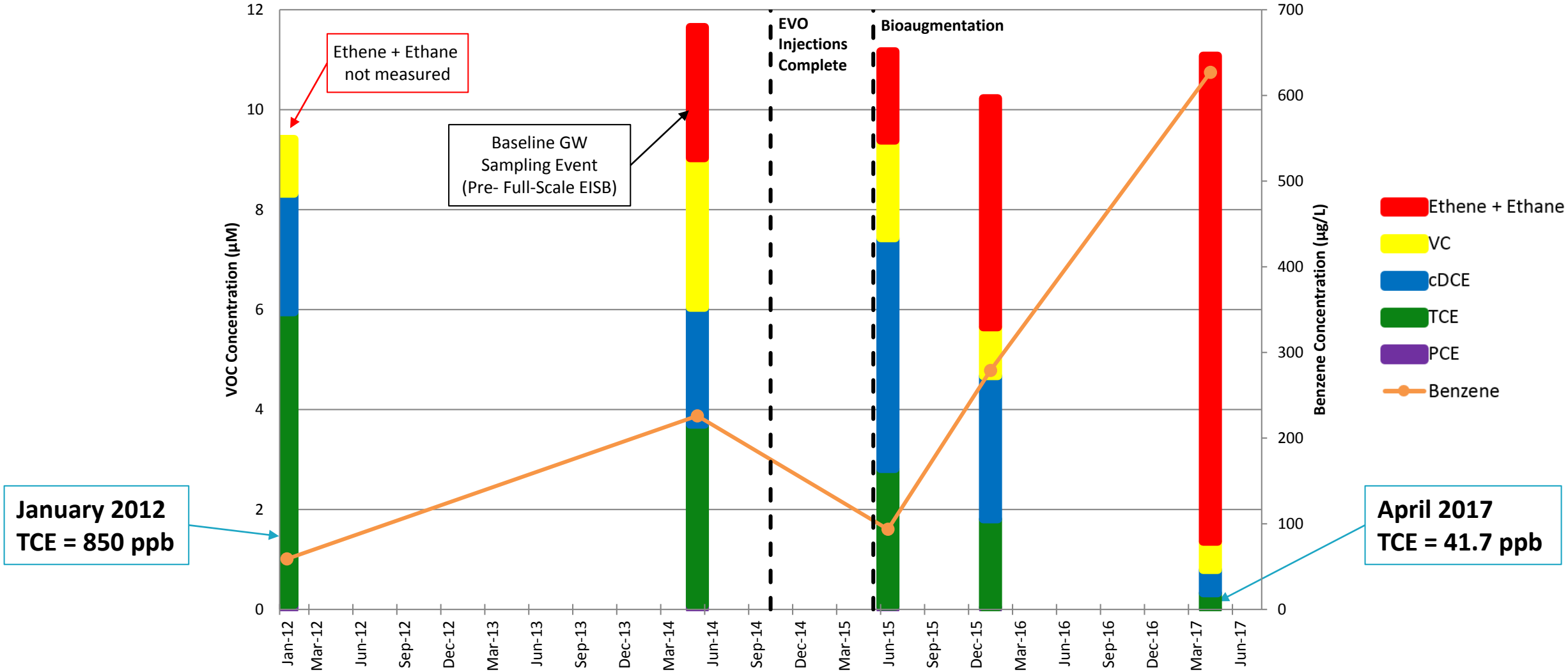
CENSUS-DNA: Dehalococcoides (Dhc) Results (cells/L)			
	June 2015	*Jan 2016*	*April 2017*
MW-8C	**1.90×10^{9}**	**N/A**	**N/A**
MW-20	**2.13×10^{7}**	**N/A**	**3.46×10^{6}**
MW-21	**2.84×10^{4}**	**3.28×10^{8}**	**N/A**
MW-22	**7.58×10^{8}**	**N/A**	**N/A**
MW-29	**4.80×10^{3}**	**N/A**	**1.90×10^{3}**
MW-25BR	**N/A**	**2.20×10^{8}**	**N/A**

Note:

Literature established **1×10^{7} cells/L** as a threshold for generally useful rates of dechlorination (Lu et. Al., 2006)



MW-25BR: Sentinel B - Bedrock Zone
Chlorinated Ethenes / Ethene + Ethane Concentrations vs. Benzene Concentration over Time



January 2012
TCE = 850 ppb

April 2017
TCE = 41.7 ppb

Methane production is expected as a result of EISB

Dissolved Methane in GW Results (ug/L)			
	MW-8C Shallow/Source	MW-20 Int/Source	MW-21 Deep/Biobarrier
5/28/2014	8.4	2.9	230
11/4/2014	12	19	35
1/5/2015	280	20	3,300
6/10/2015	1,900	120	13,000
8/26/2015	3,300	440	27,000
1/14/2016	9,700	--	26,000
9/26/2016	11,000	11,000	27,000
4/21/2017	15,000	6,300	17,000

Multigas meter used to check:

- Interior of Site building
- Basement spaces across street
- Nearby drainage inlets
- Shallow monitoring wells downgradient

No evidence of methane accumulation was found

Injection wells fitted with vented well caps to prevent methane gas buildup

Performance Monitoring Conclusions

- EVO + bioaugmentation injections were successful in establishing conditions for EISB in the source area and biobarrier treatment zones
- VFA depletion is not an immediate concern along the biobarriers and majority of source area
- Dhc population is thriving in EISB treatment zones, as well as in the downgradient bedrock zone
- Some of the VFAs are being utilized by methanogens, resulting in high levels of dissolved methane in groundwater

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Questions?

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