Case Study: When In-Situ Technologies Fail

Kevin French
Vertex Environmental Inc.

SMART Remediation
Edmonton, AB | March 11, 2020
Calgary, AB| March 12, 2020

SMART is Powered by: VERTEX Environmental Inc.

www.vertexenvironmental.ca

Vertex Environmental Inc.

Case Study:
When In-Situ Techniques Fail

March 2020

Kevin French, B.A.Sc., P.Eng.

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Outline

- Introduction
- How Can In-Situ Fail?
- Site Background
- Remediation
  - Colloidal Activated Carbon
  - Chemical Oxidation
  - Powdered Activated Carbon
- Lessons Learned
- Questions

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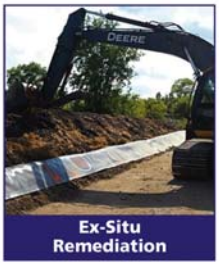
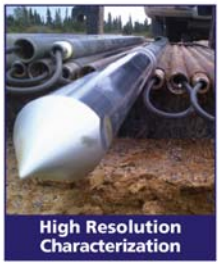
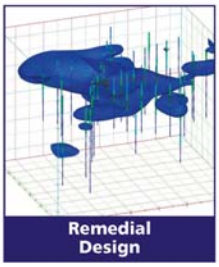
Vertex Environmental Inc.

Specialized Contractors







- Kevin French, P.Eng.
  - University of Waterloo
  - 30+ Years Environmental Consulting & Contracting
- Vertex founded in 2003
  - Specialized Environmental Remediation Contracting Firm
  - In-Situ & Ex-Site Remediation
  - High Resolution Site Characterization (HRSC)
  - Vapour & Water Treatment Systems

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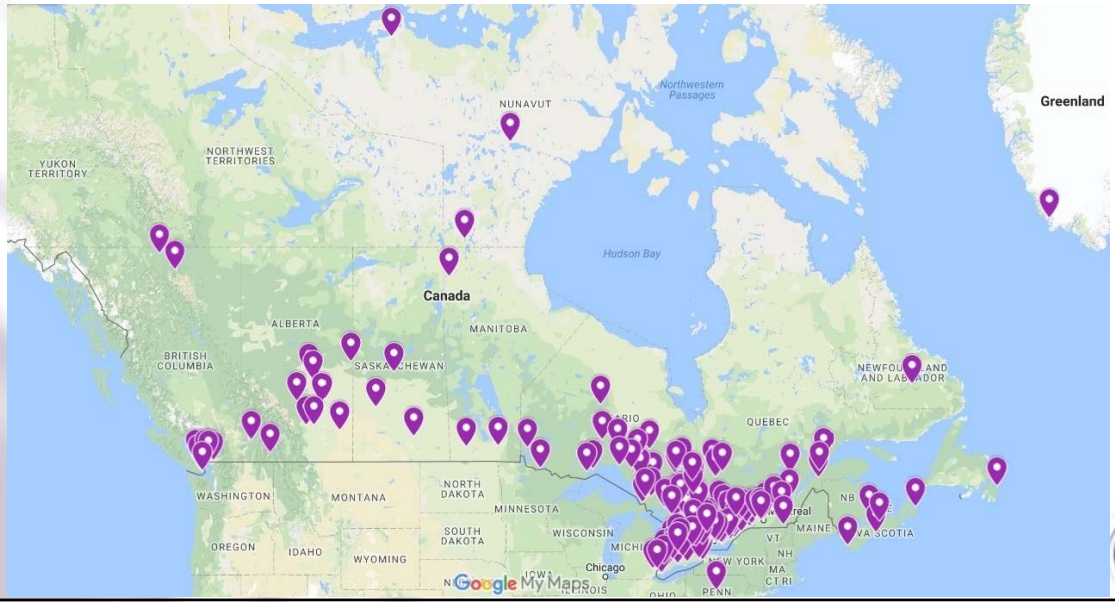
Vertex Environmental Inc.

Specialized Contractors



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How Can In-Situ Fail?

There are many ways that in-situ remediation technologies can fail:

- Contaminant Concentration / Distribution (LNAPL, etc.)
- Wrong Technology / Order of Application
- Under-Dosing the Amendment
- Poor Contact / Distribution in the Subsurface
- Baseline Geochemistry
- Age of Contamination
- Soil / Bedrock Characteristics
- Groundwater Flow Velocity
- Seasonal Water Table Fluctuations
- Etc.

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Background – The Situation

- Confidential Site
- Large REIT (real estate investment trust) purchasing portions of a block in large Canadian city. This Site was the key corner lot.
- Former gas station:
  - Operating 50+ years (1930s to 1980s)
  - At least 3 former USTs noted on Fire Insurance Plans
  - Late 1960s due to road widening, USTs and pump island relocated on Site
- Petroleum Hydrocarbon (PHC) contamination
- Full remediation in future (redevelopment of whole block)
- Short term:
  - Coffee chain set to lease existing building
  - **Lease contract detailed no contamination to migrate off-site during lease timeframe**

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Background – The Situation

Large high rise condos are becoming common on major intersections in some Canadian cities.

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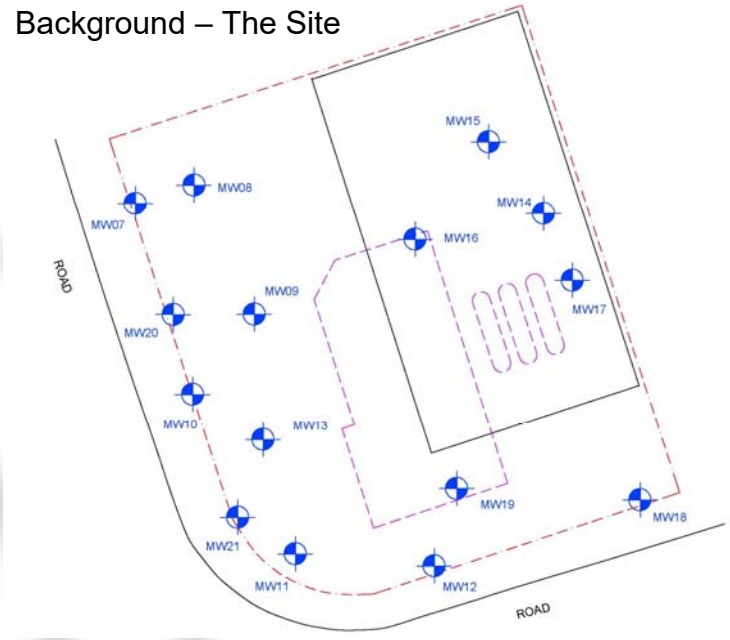
Background – The Site



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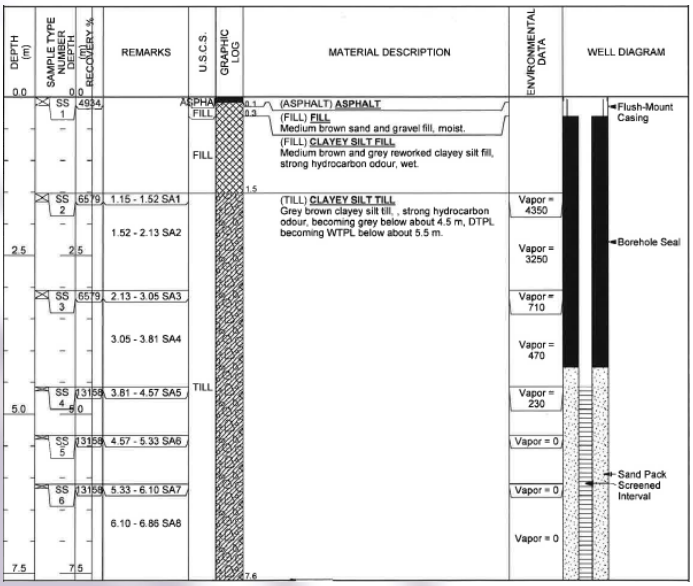
Background – The Subsurface



- Soil:
  - Fill
  - Hard silty-clay till
  - Classified as fine grained
- Groundwater:
  - 5.2 to 5.9 m below grade
  - Flowing W, SW direction
- Contamination:
  - Mostly BTEX and F1 PHCs
  - Minor 12DCA
- Geochemistry:
  - Likely anaerobic

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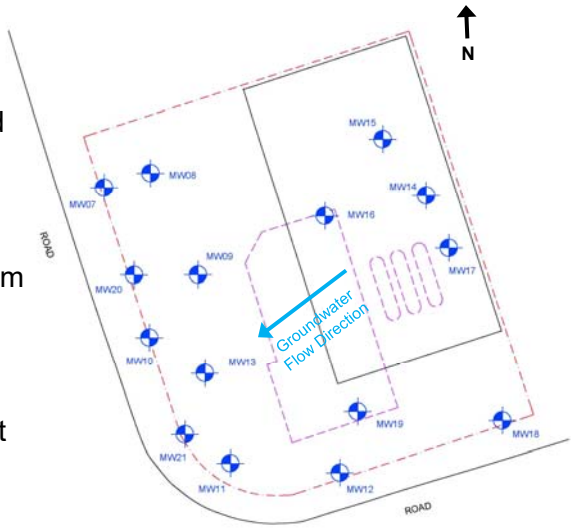
Background – The Subsurface

Comments in Phase II ESA (2017)

"On-site contamination appears to be located downgradient of the building" (no vapour intrusion issue)

"It is likely that soil and groundwater petroleum hydrocarbon impacts have moved off-Site to the west… and….southwest"

"Barrier options can be considered to prevent potential off-site movement of impacted groundwater."



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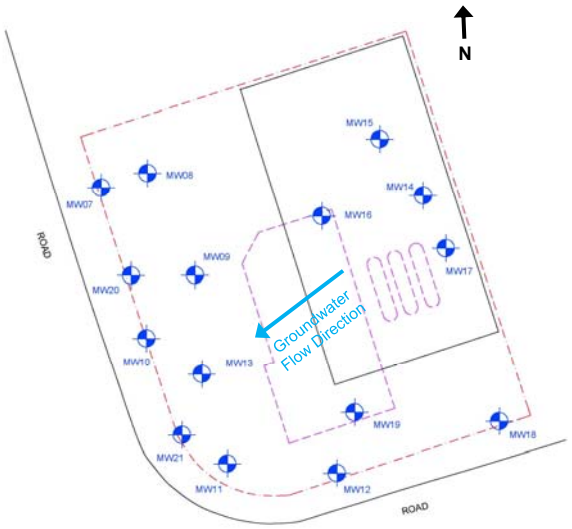
Background – Remedial Recommendation

"Barrier options can be considered to prevent potential off-site movement of impacted groundwater."



VERTEX

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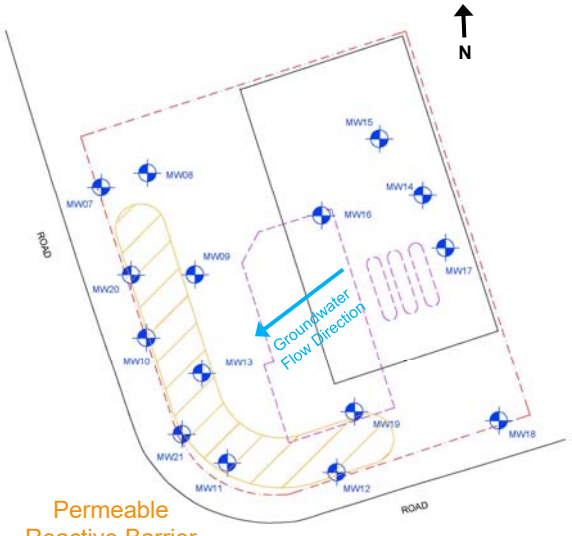
Background – Remedial Recommendation

"Barrier options can be considered to prevent potential off-site movement of impacted groundwater."



Permeable Reactive Barrier (PRB)

VERTEX

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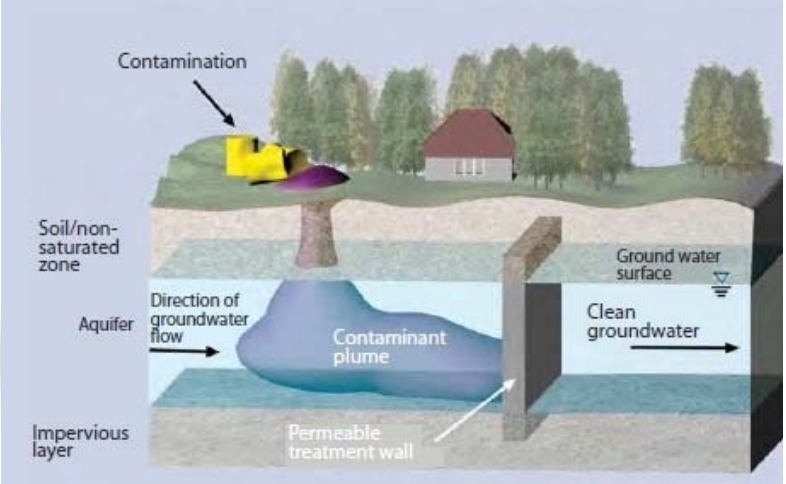
Permeable Reactive Barrier (PRB)



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MW07 (ug/L)	Conc.	Standard
PHC(F1)	57	750
BTEX	14	-
1,2-DCA	<0.5	12

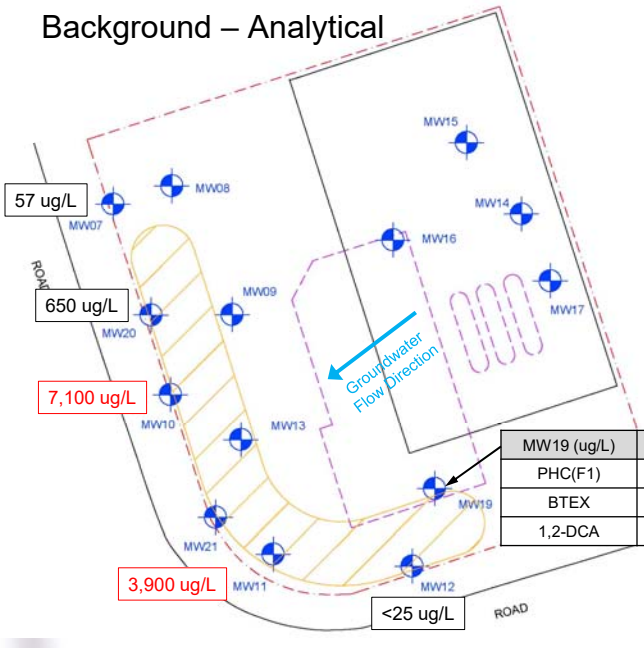
MW20 (ug/L)	Conc.	Standard
PHC(F1)	650	750
BTEX	650	-
1,2-DCA	<0.5	12

MW10 (ug/L)	Conc.	Standard
PHC(F1)	7,100	750
BTEX	4,100	-
1,2-DCA	15	12

MW11 (ug/L)	Conc.	Standard
PHC(F1)	3,900	750
BTEX	3,900	-
1,2-DCA	<4	12

MW12 (ug/L)	Conc.	Standard
PHC(F1)	<25	750
BTEX	<25	-
1,2-DCA	<0.5	12

Background – Analytical



MW19 (ug/L)	Conc.	Standard
PHC(F1)	130,000	750
BTEX	38,700	-
1,2-DCA	<0.5	12

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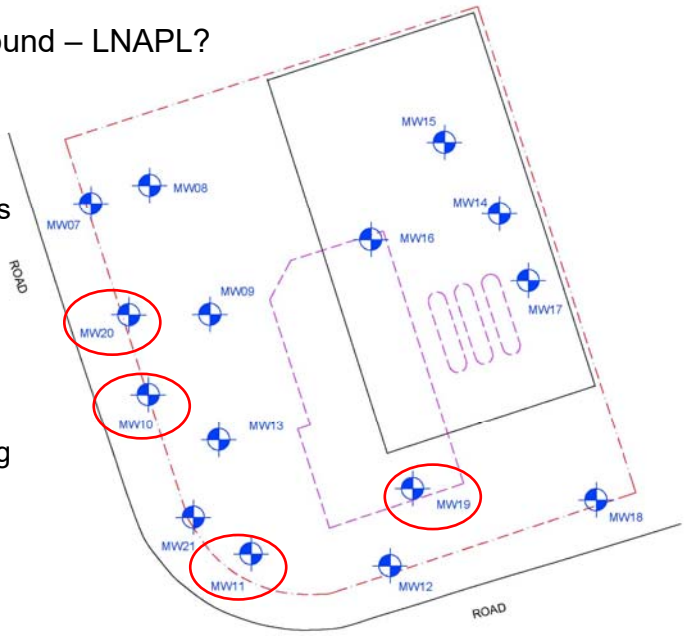
Background – LNAPL?

Comment in Phase II ESA (2017)

"There was no measureable non-aqueous phase liquid detected in any of the groundwater monitoring wells, however, evidence of liquid phase gasoline was observed during the drilling in boreholes MW10, MW11, MW19 and MW20."

"It should be noted that during the purging of location MW19, hydrocarbon product was observed in the purge water and on the sample tubing."



VERTEX

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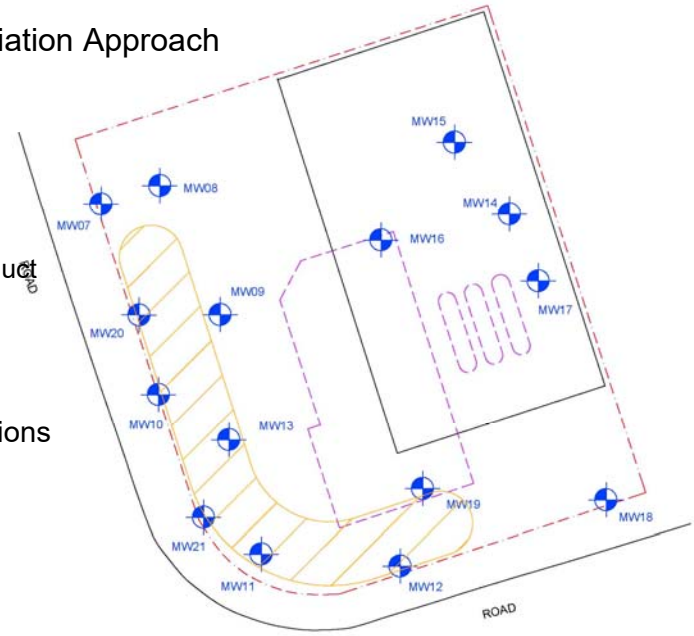
Remediation Approach

- Injected PRB
- Remedial Amendments:
  - Colloidal Activated Carbon (AC) Product
  - Oxygen Releasing Material (ORM)
- Design to treat to Generic Standards
- 24 m long by 3 m wide
- Twenty-four (24) Injection Point locations
  - Single line on a 1 m spacing
  - 3 discrete vertical intervals



VERTEX

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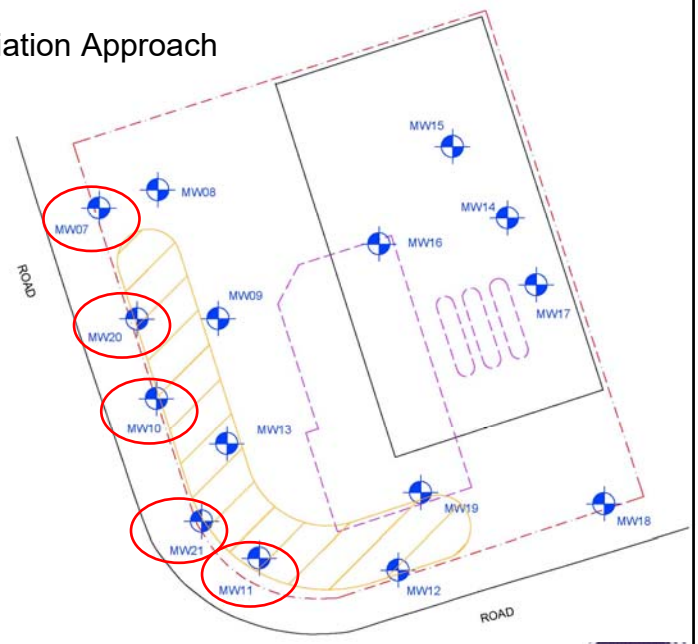
Remediation Approach

- Analytical to Review



VERTEX

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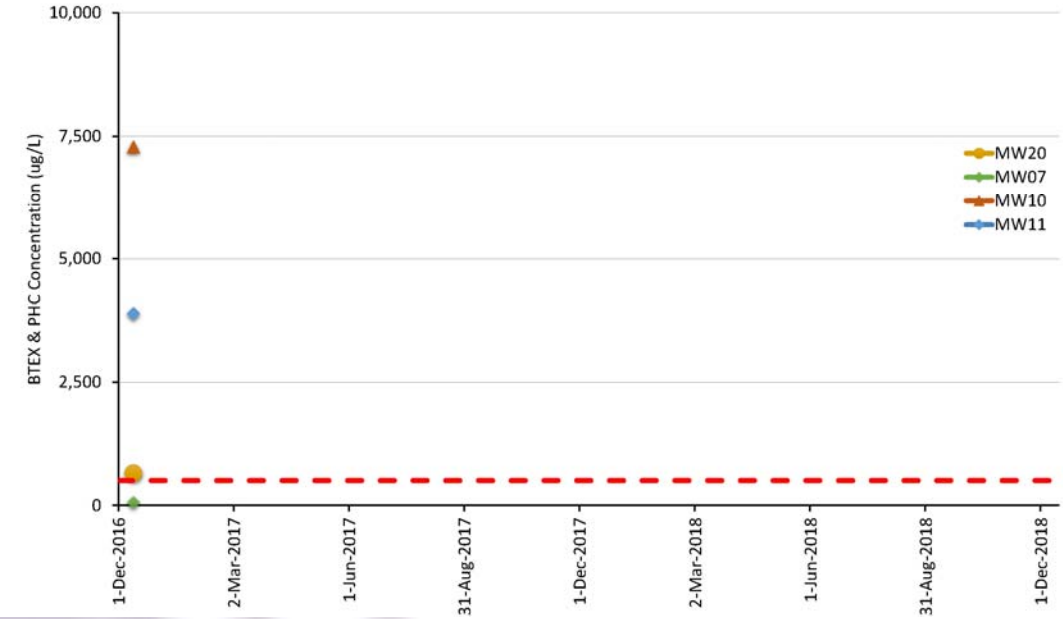
Total PHCs in Groundwater



VERTEX

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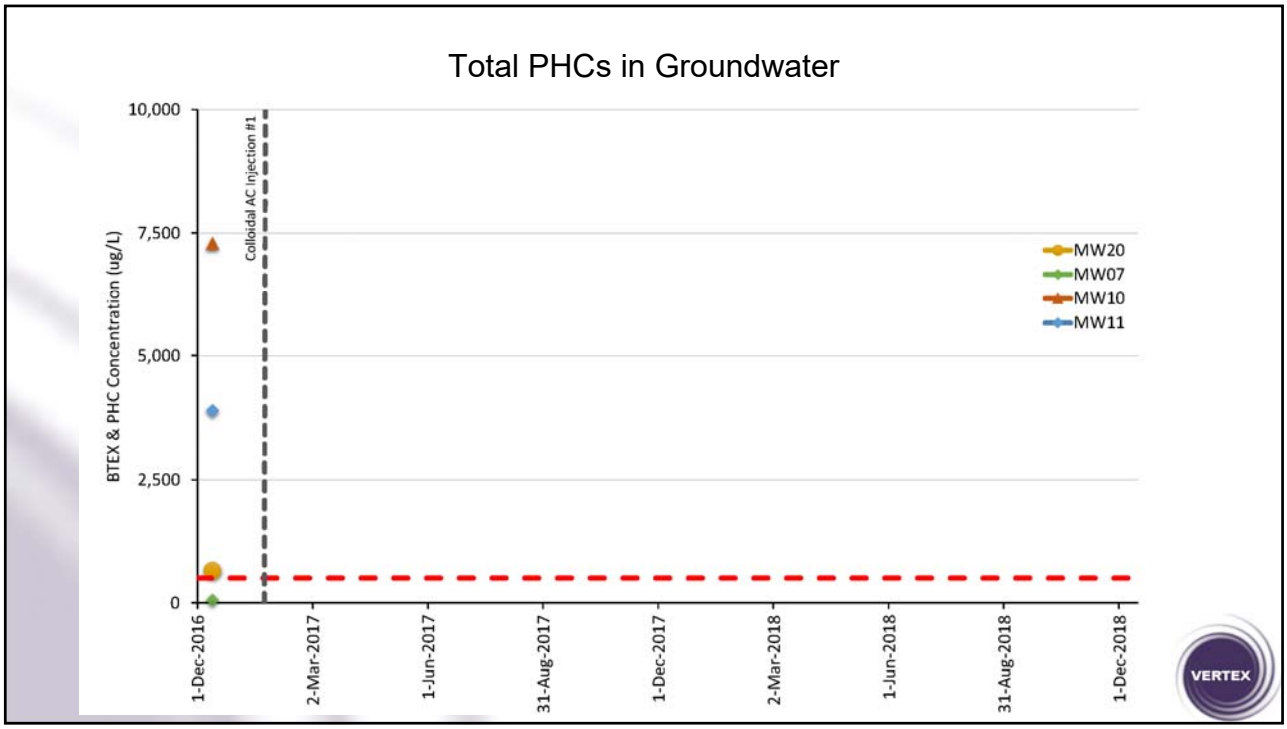
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
10,000
7,500
5,000
2,500
0
Colloidal AC injection #1
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
MW20
MW07
MW10
MW11
VERTEX

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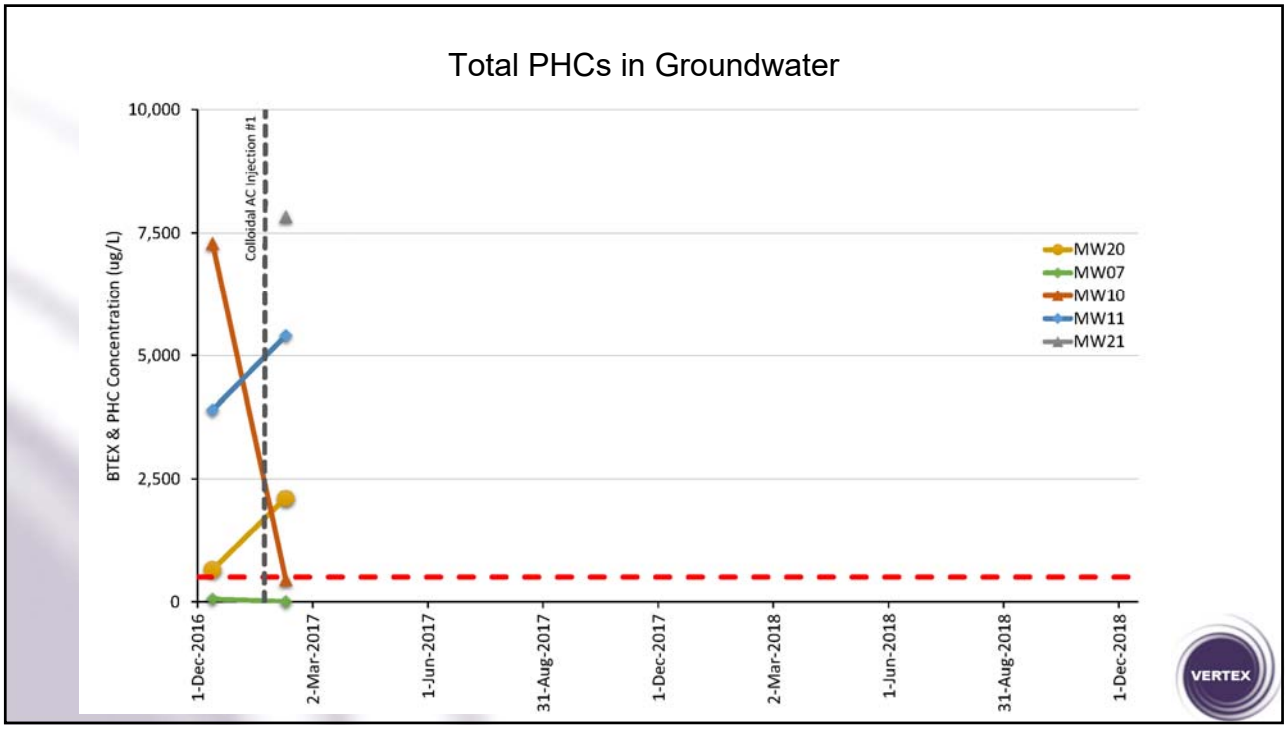
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
10,000
7,500
5,000
2,500
0
Colloidal AC injection #1
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
MW20
MW07
MW10
MW11
MW21
VERTEX

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Remediation Approach

- Colloidal AC PRB Injection #1
- 24 m long by 3 m wide
- Twenty-four (24) Injection Point locations
  - Single line
  - 1 m spacing
  - 3 discrete vertical intervals
- Colloidal AC Product
  - Dilute Colloidal AC solution injected
  - Some ORM

- Colloidal AC PRB Injection #2
- 24 m long by 3 m wide
- Seventeen (17) Injection Point locations
  - Single line
  - 1.5 m spacing
  - 1 to 2 discrete vertical intervals
- Colloidal AC Product
  - Dilute Colloidal AC solution injected
  - Some ORM

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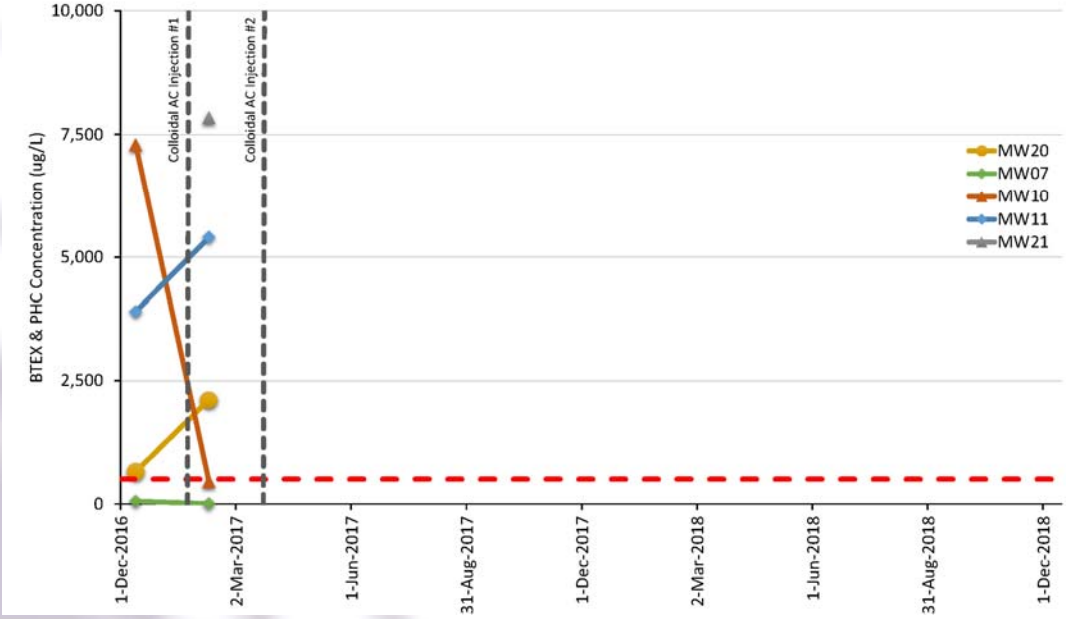
Total PHCs in Groundwater



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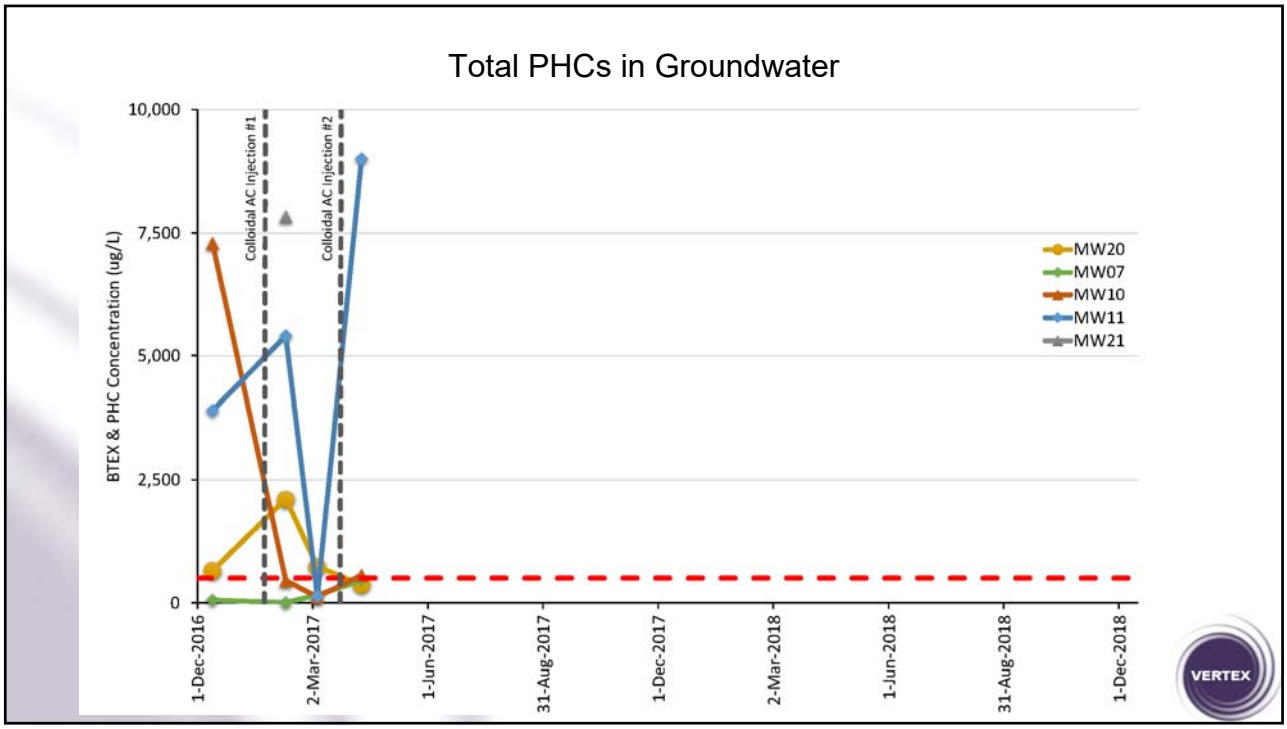
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
10,000
7,500
5,000
2,500
0
Colloidal AC Injection #1
Colloidal AC Injection #2
MW20
MW07
MW10
MW11
MW21
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
VERTEX

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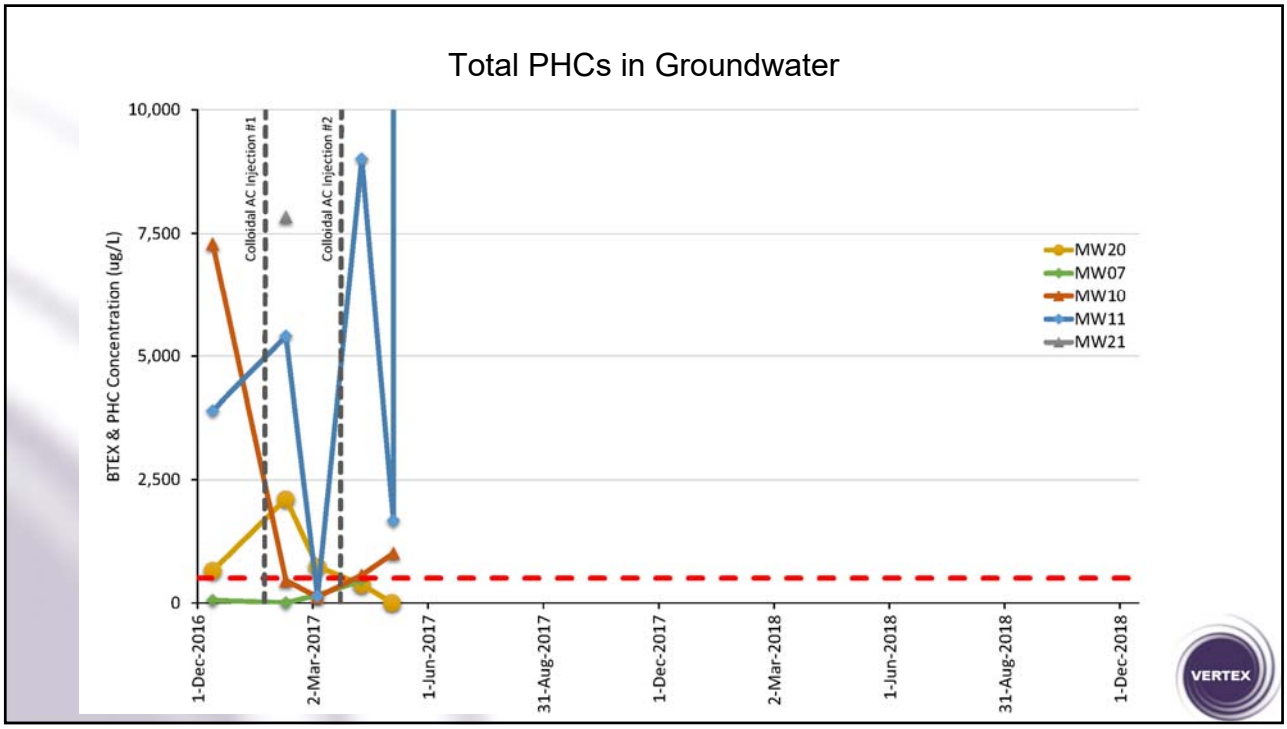
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
10,000
7,500
5,000
2,500
0
Colloidal AC Injection #1
Colloidal AC Injection #2
MW20
MW07
MW10
MW11
MW21
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
VERTEX

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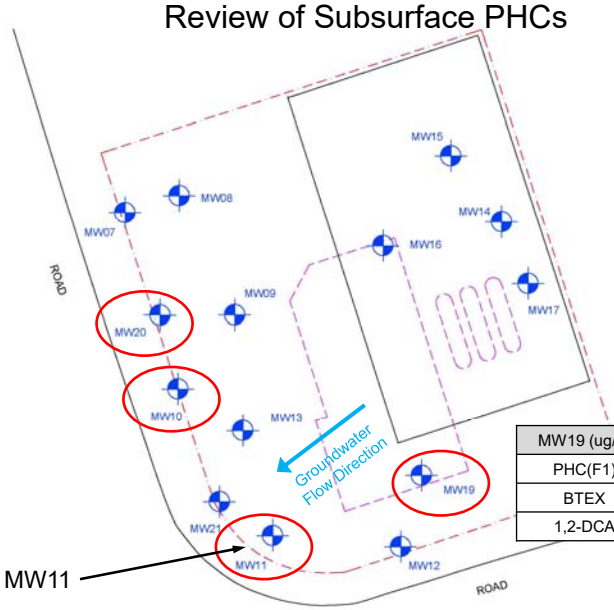
Review of Subsurface PHCs

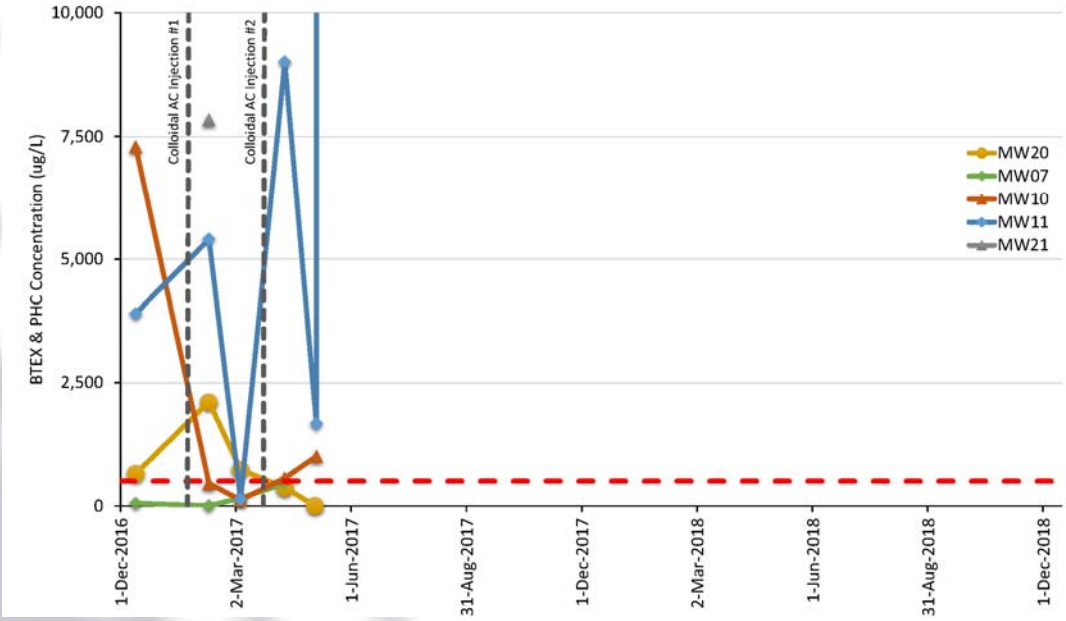
Evidence of LNAPL noted in soil during drilling



MW19 (ug/L)	Conc.	Standard
PHC(F1)	130,000	750
BTEX	38,700	-
1,2-DCA	<0.5	12

25

Total PHCs in Groundwater



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Remediation Approach

- Colloidal AC PRB Injection #1
- 24 m long by 3 m wide
- 24 Injection Points
  - Single line
  - 1 m spacing
  - 3 discrete vertical intervals
- Colloidal AC Product
  - Dilute Colloidal AC solution
  - Some ORM

- Colloidal AC PRB Injection #2
- 24 m long by 3 m wide
- 17 Injection Points
  - Single line
  - 1.5 m spacing
  - 1 to 2 discrete vertical intervals
- Colloidal AC Product
  - Dilute Colloidal AC solution
  - Some ORM

- Oxidant Injection
- Targeted (MW10, MW11)
- 8 Injection Points
  - Single line
  - random spacing
  - 2 discrete vertical intervals
- Sodium persulfate product
  - Oxidant solution
  - Some ORM

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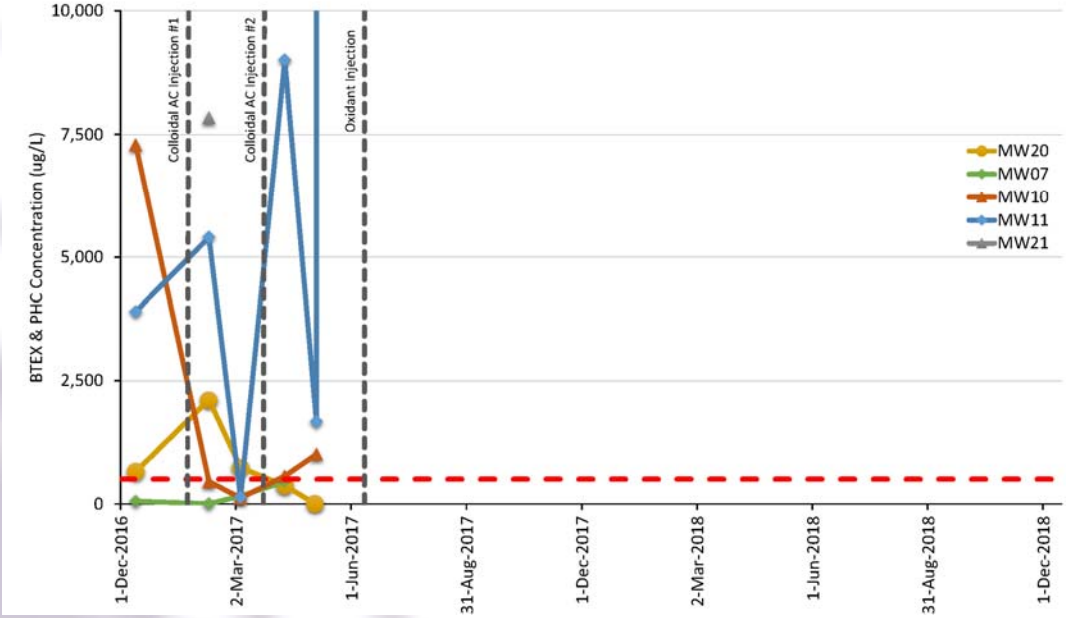
Total PHCs in Groundwater



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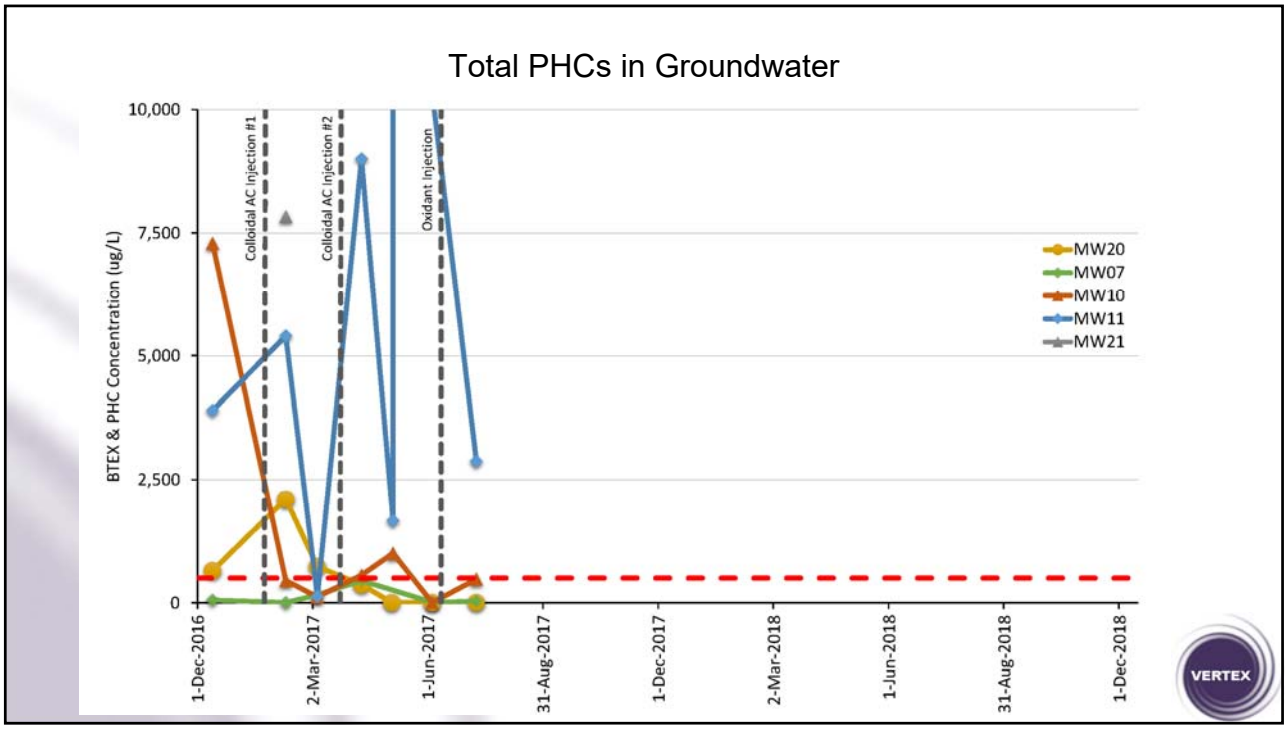
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
10,000
7,500
5,000
2,500
0
Colloidal AC injection #1
Colloidal AC injection #2
Oxidant injection
MW20
MW07
MW10
MW11
MW21
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
VERTEX

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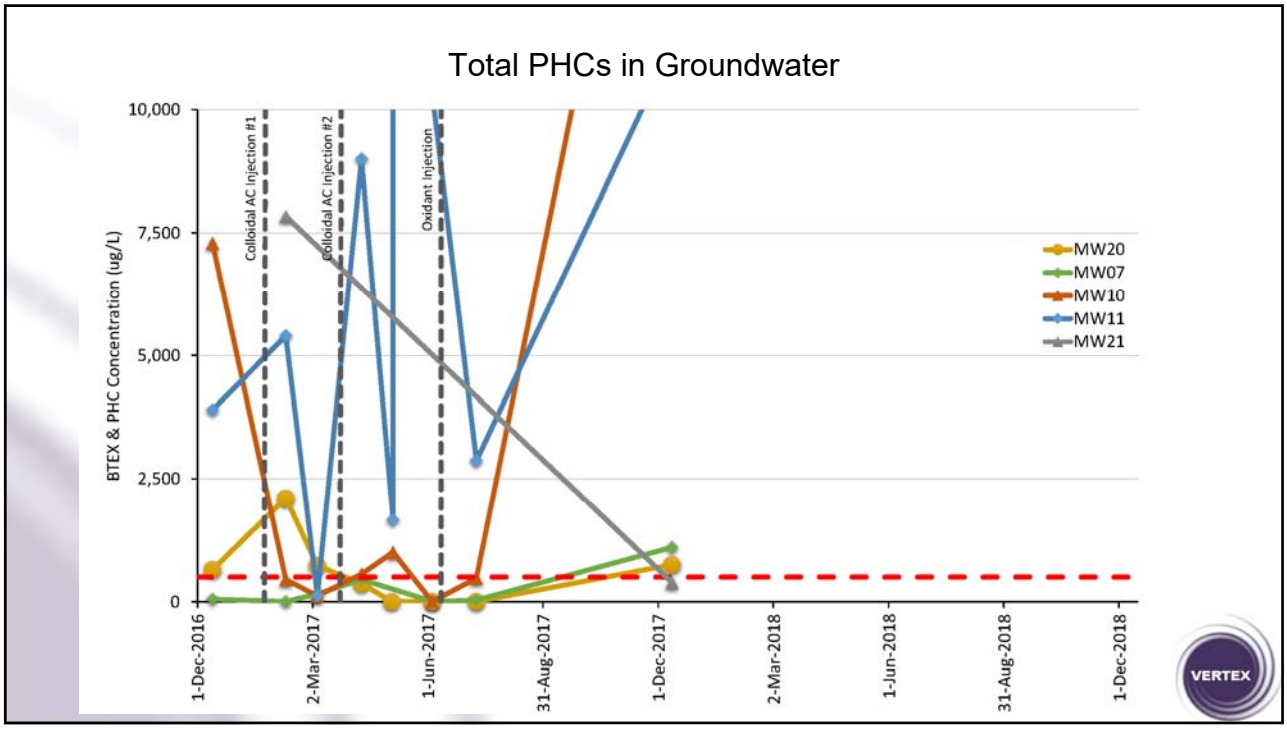
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Colloidal AC injection #1
Colloidal AC injection #2
Oxidant injection
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1-Jun-2018
31-Aug-2018
1-Dec-2018
VERTEX

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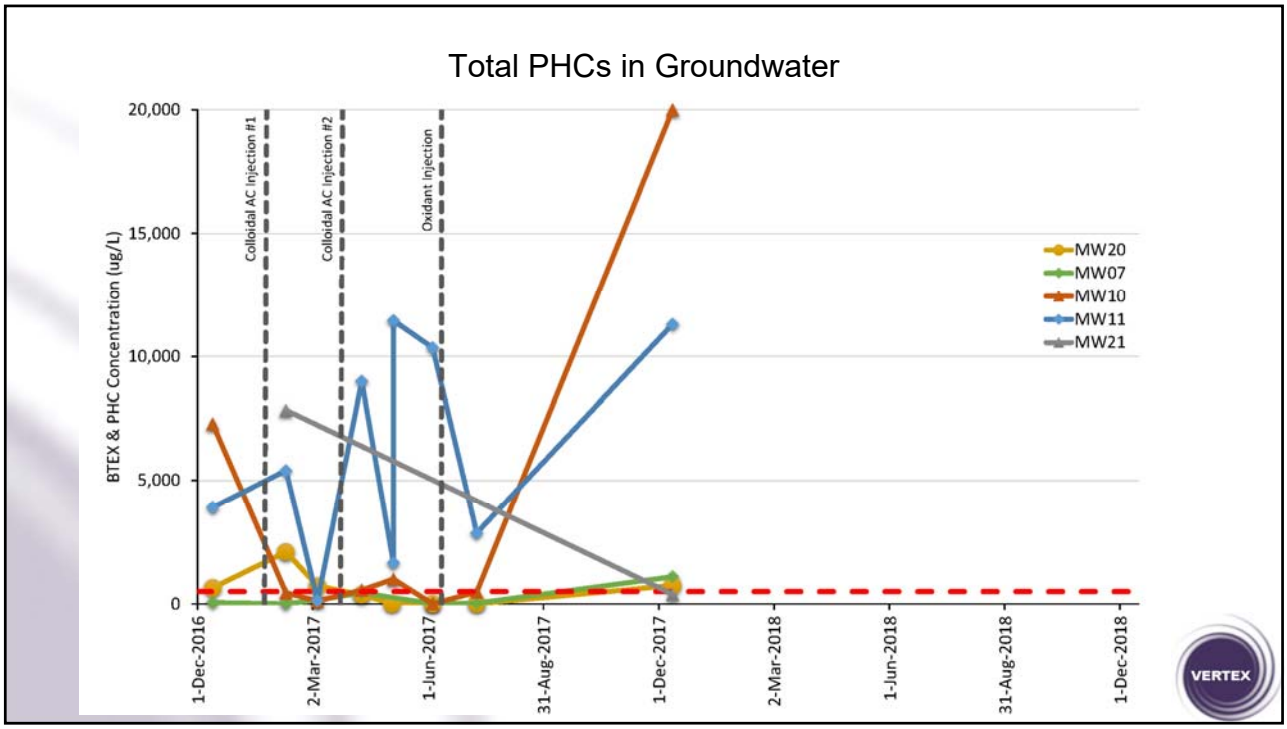
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
20,000
15,000
10,000
5,000
0
Colloidal AC injection #1
Colloidal AC injection #2
Oxidant injection
MW20
MW07
MW10
MW11
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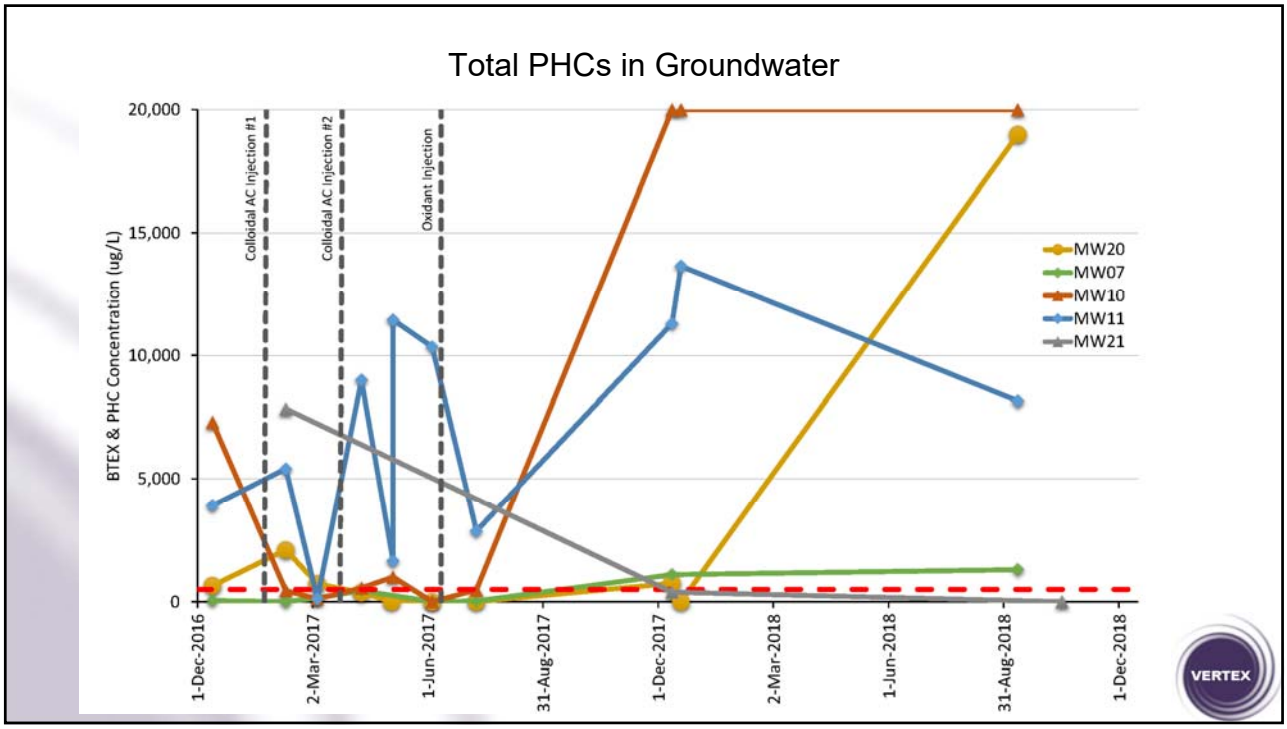
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
VERTEX

31


Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
20,000
15,000
10,000
5,000
0
Colloidal AC injection #1
Colloidal AC injection #2
Oxidant injection
MW20
MW07
MW10
MW11
MW21
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
VERTEX

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How Can In-Situ Fail?

There are many ways that in-situ remediation technologies can fail:

- **Contaminant Concentration** / Distribution (**LNAPL**, etc.)
- Wrong Technology / **Order of Application**
- **Under-Dosing the Amendment**
- **Poor Contact / Distribution in the Subsurface**
- **Baseline Geochemistry**
- Age of Contamination
- Soil / Bedrock Characteristics
- Groundwater Flow Velocity
- Seasonal Water Table Fluctuations
- Etc.

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How to Help In-Situ Succeed

A good approach to maximize the chances that in-situ remediation will succeed:

- Review all characterization data available for the Site
  - Soil and groundwater contaminant chemistry and distribution, subsurface geology, hydrogeology, geochemistry, etc.
- Identify data gaps (physical / chemical)
- Complete additional, targeted data collection (e.g. RDC)
- Prepare a remedial approach focusing on selecting the correct technology, applying it properly, in adequate amounts, and in appropriate locations
- Interim QA/QC monitoring
- Plan for contingencies

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Background – Analytical (2017 Phase II ESA)

Soil

(mg/kg)	Maximum Concentration	Standard
PHC(F1)	3,900	65
PHC(F2)	770	250
Benzene	150	0.4
Toluene	970	78
Ethylbenzene	250	19
Xylenes	1,100	30
1,2-DCA	0.50	0.05

Dec 2016 Data

Groundwater

(ug/L)	Maximum Concentration	Standard
PHC(F1)	130,000	750
PHC(F2)	18,000	150
Benzene	6,500	430
Toluene	12,000	18,000
Ethylbenzene	5,500	2,300
Xylenes	25,000	4,200
1,2-DCA	15	12

Dec 2016 Data

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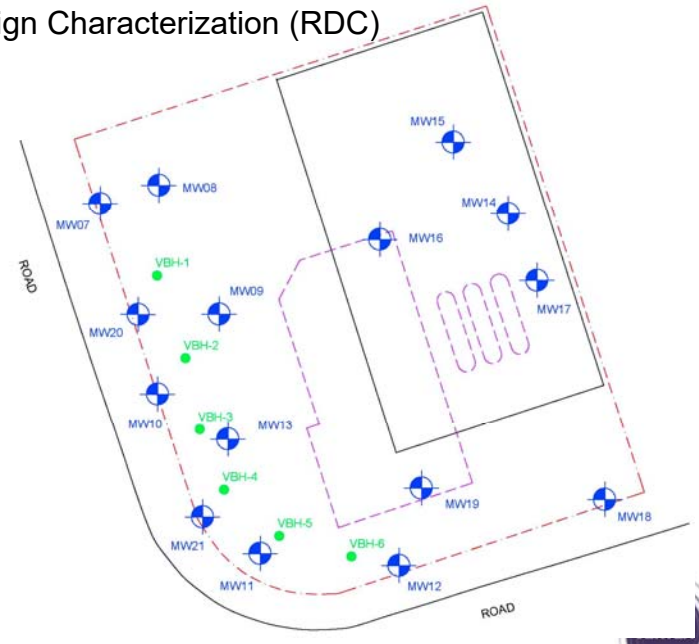
Remedial Design Characterization (RDC)

- Six (6) boreholes
- 1 day of work
  - Sept 2018
- 27 soil samples
  - Detailed analysis of PHCs with depth
- 12 groundwater samples
- Allowed for detailed understanding of PHC contaminated zones



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Remediation Approach – Updated

- Colloidal AC PRB Injection #1
- 24 m long by 3 m wide
- 24 Injection Points
  - Single line
  - 1 m spacing
  - 3 discrete vertical intervals
- Colloidal carbon
  - Dilute Colloidal AC solution
  - Some ORM
    - Aerobic bio

- Powdered AC Injection
- 25 m long by 3 m wide
- 81 Injection Points
  - 3 Rows forming Triangular Grid
  - 1 m spacing
  - 9 discrete vertical intervals
- Powdered carbon
  - Concentrated powdered AC product
  - Sulphate added
    - Anaerobic bio

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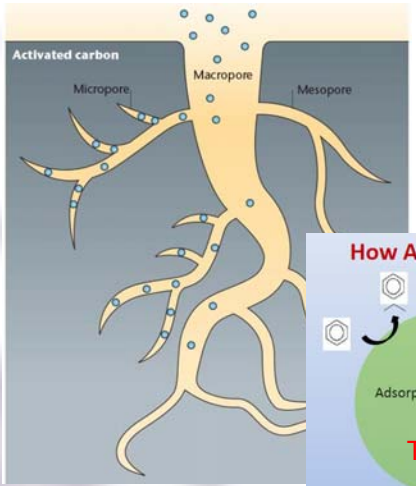
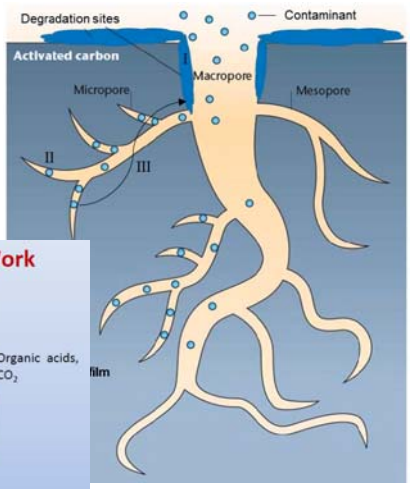
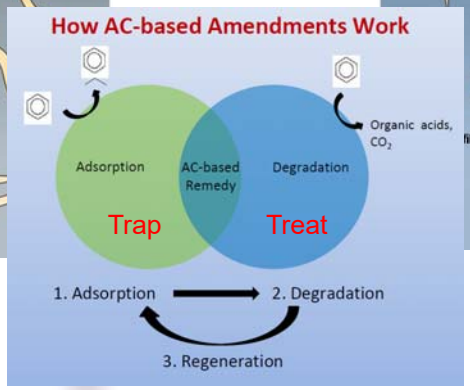
Activated Carbon-Based Remedial Amendments



Trap



Treat



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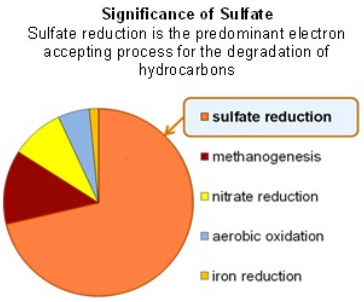
PHC Treatment & Geochemistry – What is Best for PRBs?

Trap and Treat BOS200®



Oxygen Solubility = 12 mg/L
Sulfate Solubility = 10,000 mg/L

Oxygen : Benzene bio = 3.1 : 1
Sulfate : Benzene bio = 4.6 : 1

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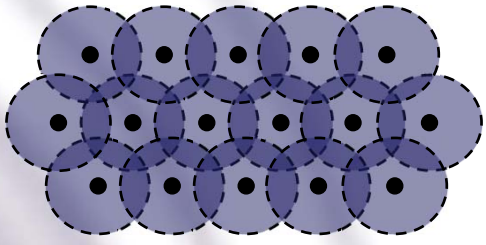
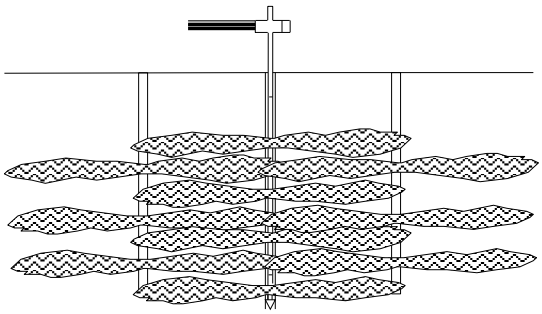
Injected PRB – Planning the IP Layout

The Goal:

- Uniform Distribution
- Intimate contact between remedial amendment and contaminants



Plan View



Profile View

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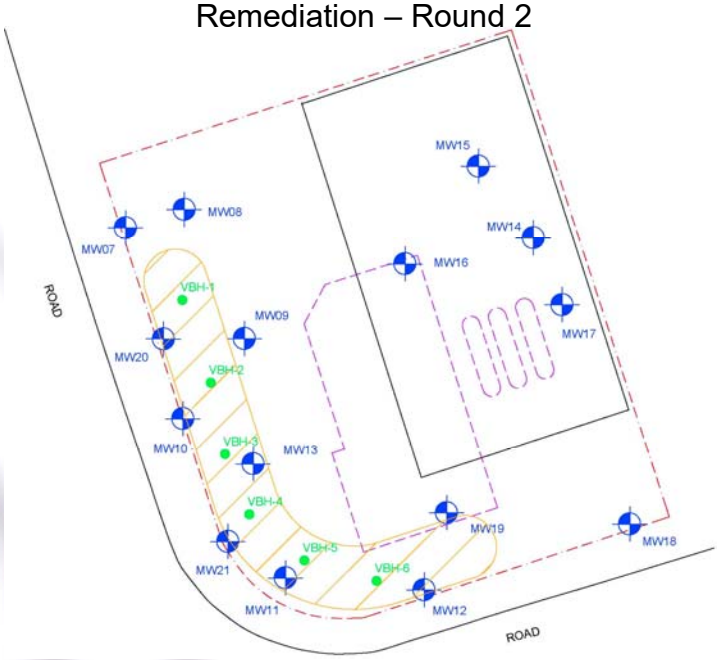
Remediation – Round 2



VERTEX

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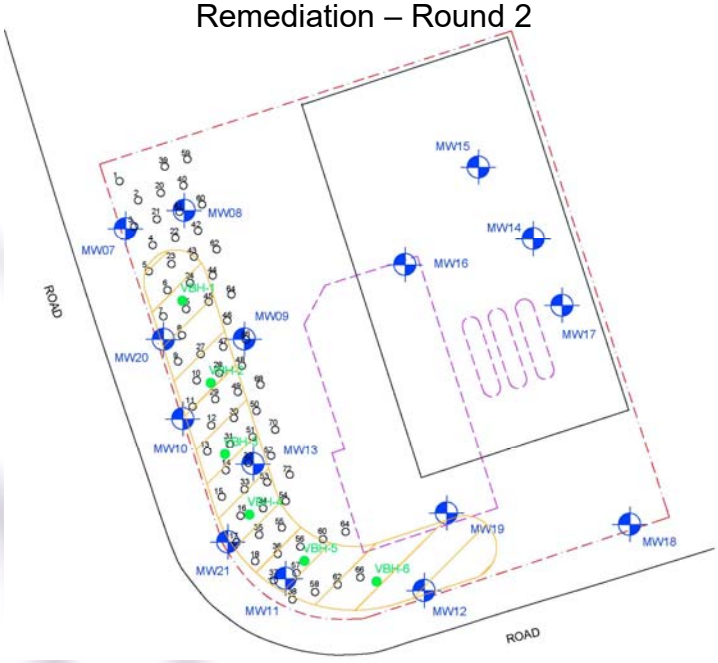
Remediation – Round 2



VERTEX

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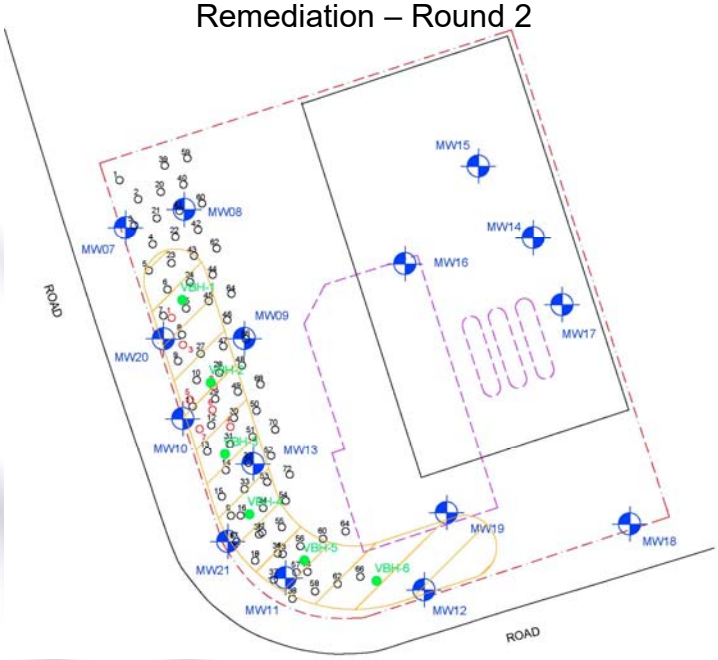
Remediation – Round 2



VERTEX

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VERTEX

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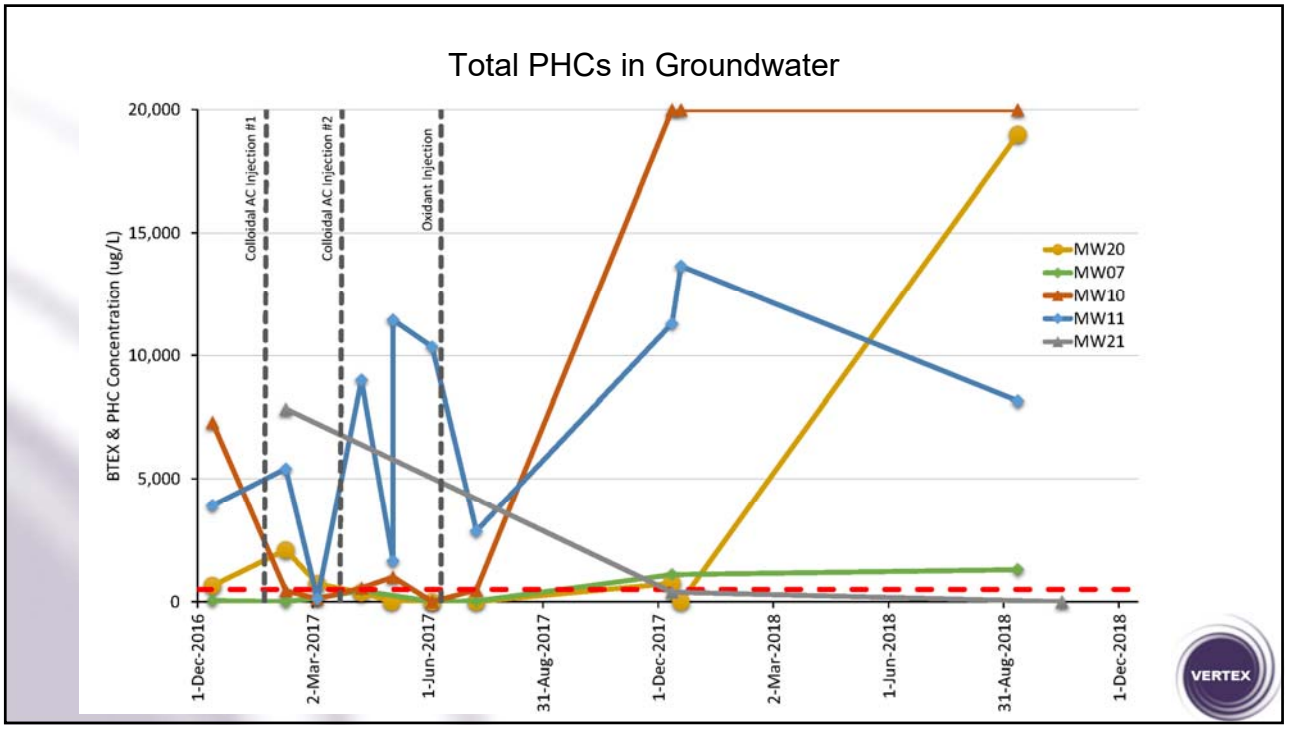
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
20,000
15,000
10,000
5,000
0
Colloidal AC injection #1
Colloidal AC injection #2
Oxidant injection
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
MW20
MW07
MW10
MW11
MW21

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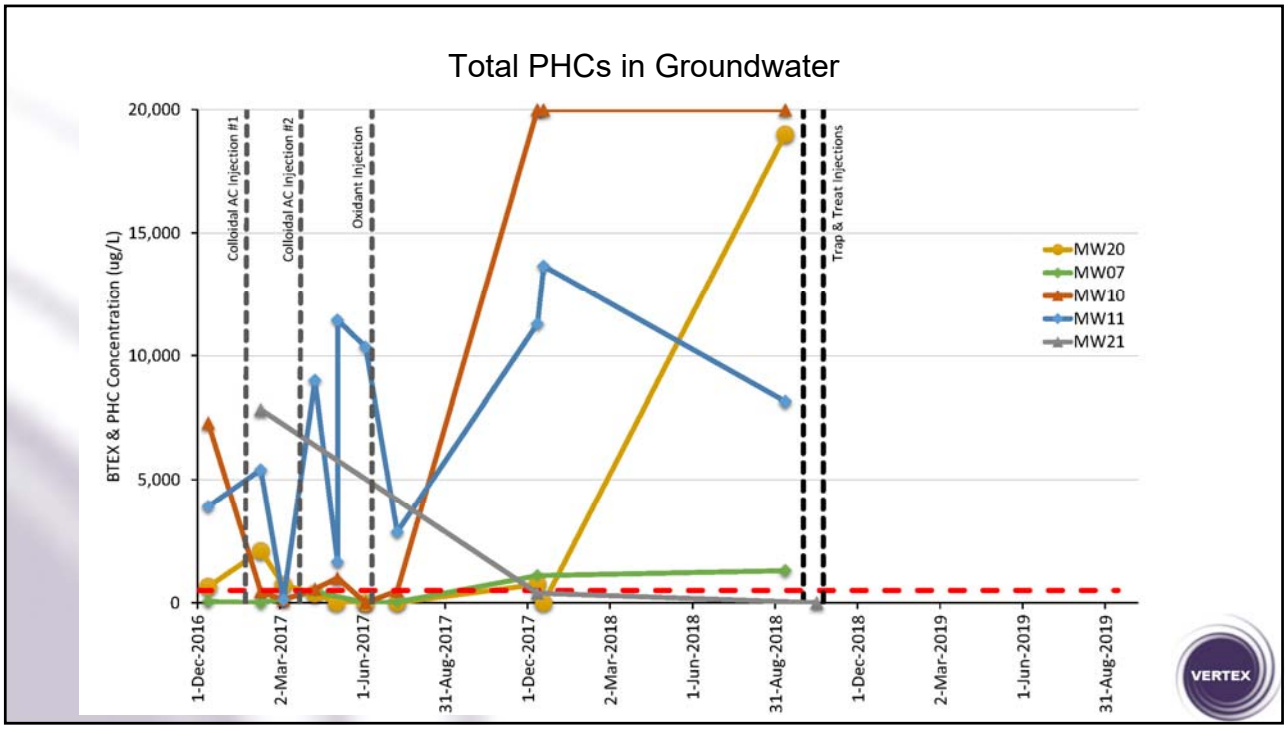
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
20,000
15,000
10,000
5,000
0
Colloidal AC injection #1
Colloidal AC injection #2
Oxidant Injection
Trap & Treat Injections
MW20
MW07
MW10
MW11
MW21
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
2-Mar-2019
1-Jun-2019
31-Aug-2019
VERTEX

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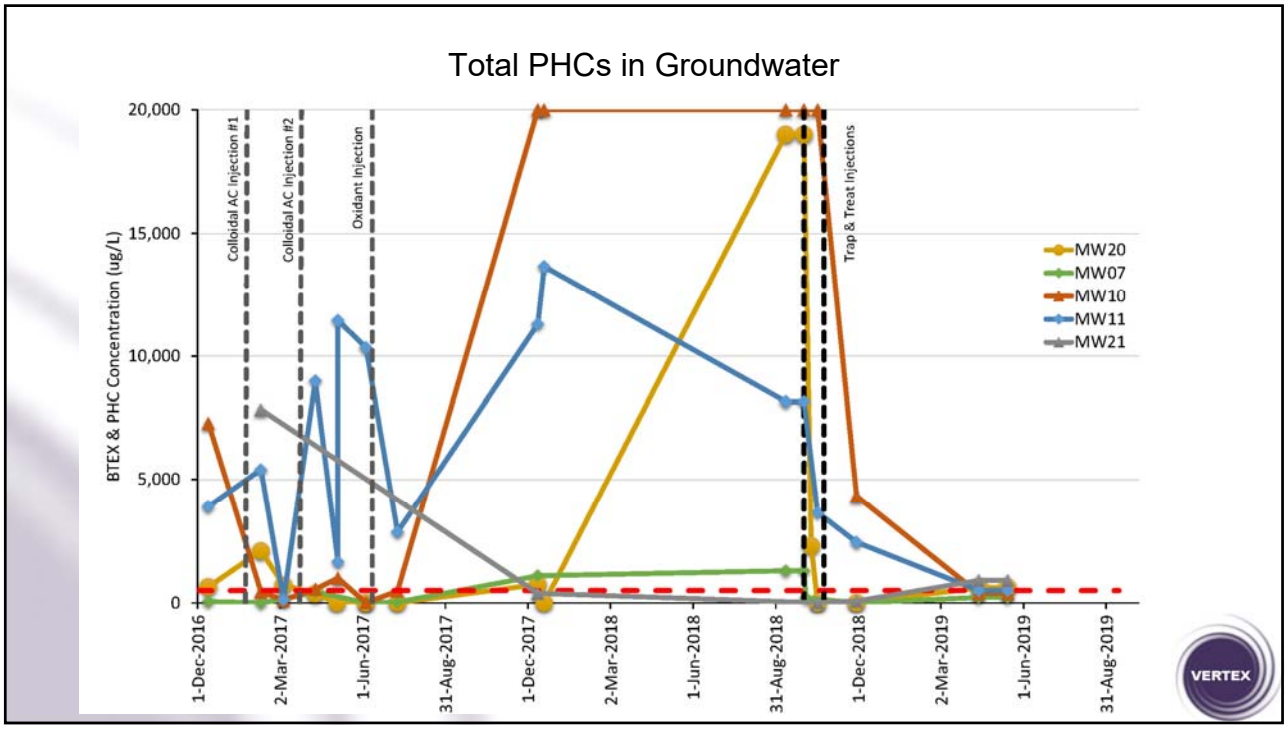
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
20,000
15,000
10,000
5,000
0
Colloidal AC injection #1
Colloidal AC injection #2
Oxidant Injection
Trap & Treat Injections
MW20
MW07
MW10
MW11
MW21
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
2-Mar-2019
1-Jun-2019
31-Aug-2019
VERTEX

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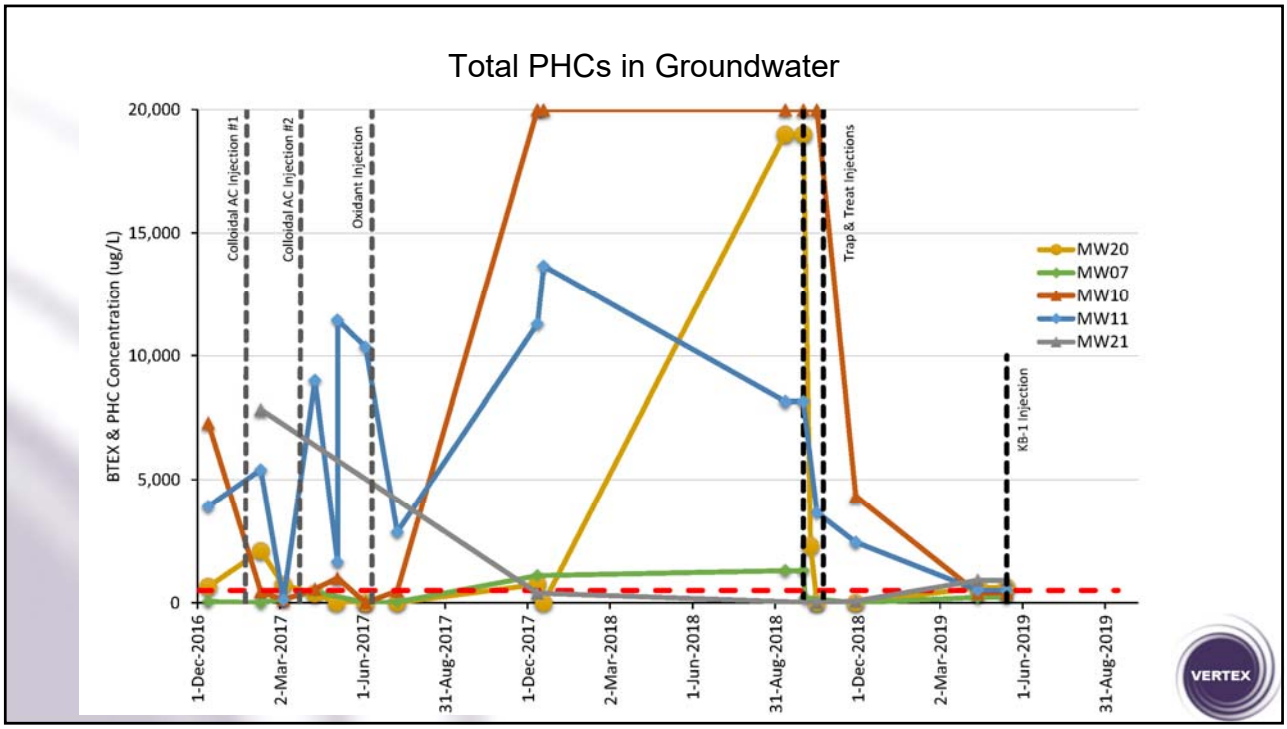
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
20,000
15,000
10,000
5,000
0
Colloidal AC injection #1
Colloidal AC injection #2
Oxidant Injection
Trap & Treat Injections
KB-1 injection
MW20
MW07
MW10
MW11
MW21
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
2-Mar-2019
1-Jun-2019
31-Aug-2019
VERTEX

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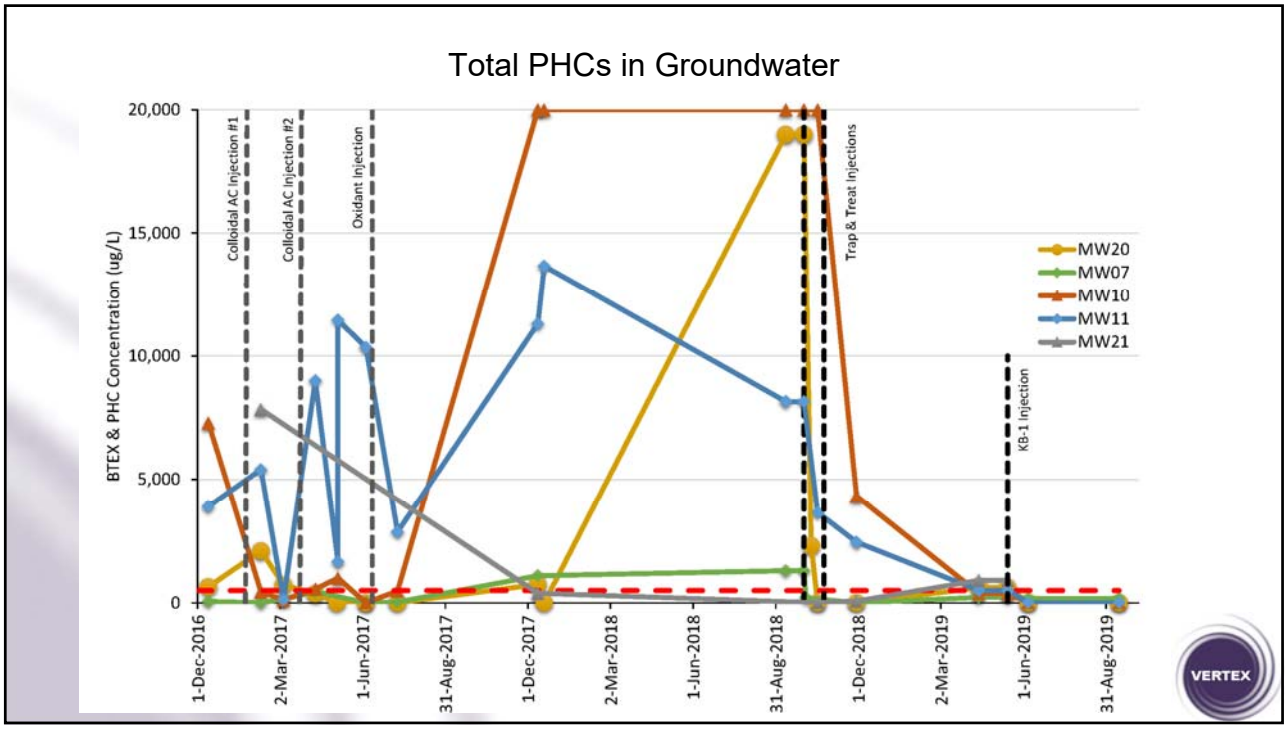
Total PHCs in Groundwater
BTEX & PHC Concentration (ug/L)
20,000
15,000
10,000
5,000
0
Colloidal AC injection #1
Colloidal AC injection #2
Oxidant Injection
Trap & Treat Injections
KB-1 injection
MW20
MW07
MW10
MW11
MW21
1-Dec-2016
2-Mar-2017
1-Jun-2017
31-Aug-2017
1-Dec-2017
2-Mar-2018
1-Jun-2018
31-Aug-2018
1-Dec-2018
2-Mar-2019
1-Jun-2019
31-Aug-2019
VERTEX

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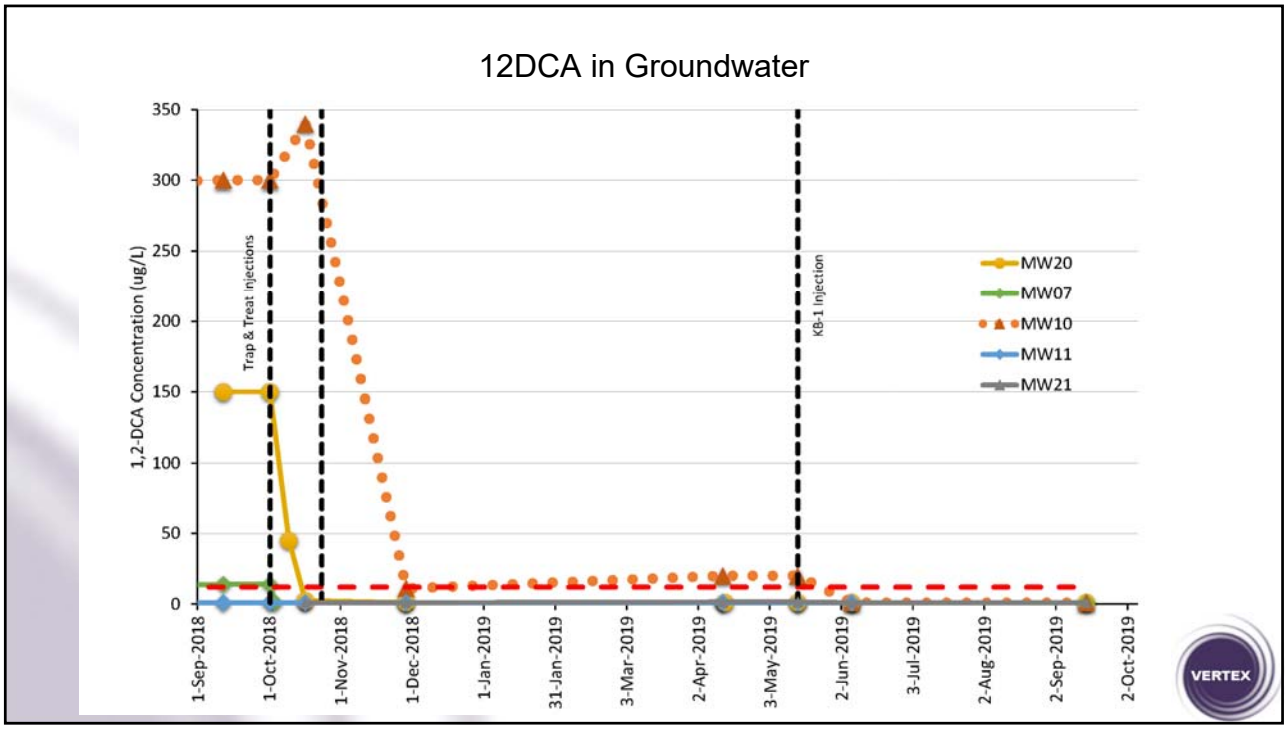
12DCA in Groundwater
1,2-DCA Concentration (ug/L)
350
300
250
200
150
100
50
0
Trap & Treat injections
KB-1 Injection
MW20
MW07
MW10
MW11
MW21
1-Sep-2018
1-Oct-2018
1-Nov-2018
1-Dec-2018
1-Jan-2019
31-Jan-2019
3-Mar-2019
2-Apr-2019
3-May-2019
2-Jun-2019
3-Jul-2019
2-Aug-2019
2-Sep-2019
2-Oct-2019
VERTEX

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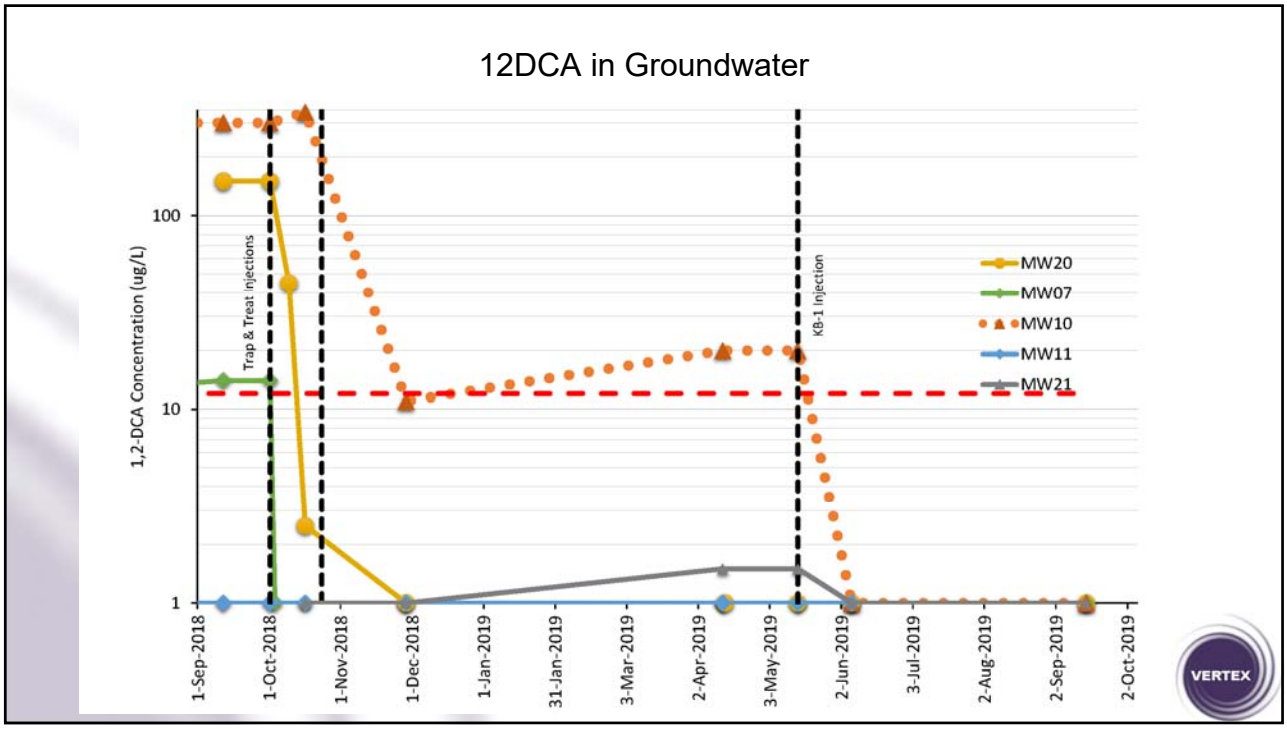
12DCA in Groundwater
1,2-DCA Concentration (ug/L)
100
10
1
Trap & Treat injections
KB-1 Injection
MW20
MW07
MW10
MW11
MW21
1-Sep-2018
1-Oct-2018
1-Nov-2018
1-Dec-2018
1-Jan-2019
31-Jan-2019
3-Mar-2019
2-Apr-2019
3-May-2019
2-Jun-2019
3-Jul-2019
2-Aug-2019
2-Sep-2019
2-Oct-2019
VERTEX

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Lessons Learned

There are many ways that in-situ remediation technologies can fail:

- Contaminant Concentration / Distribution (LNAPL, etc.)
  - Evidence of LNAPL possibly not taken into account during initial design
- Wrong Technology / Order of Application
  - ISCO completed after AC injection
- Under-Dosing the Amendment
  - Apparent low mass of AC and ORM injected relative to contaminant mass present
- Poor Contact / Distribution in the Subsurface
  - Insufficient number of IPs and vertical intervals for an injected PRB
- Baseline Geochemistry
  - Hard to try to maintain aerobic conditions over the long term

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Closing

Plume containment demonstrated.

Effective PRBs for PHCs are possible.

One just needs to design and install them properly.

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Questions?

Thank You for your Time!

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www.vertexenvironmental.ca

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