Remediation of Petroleum Hydrocarbons, Case Studies Using the Trap and Treat Technique

Kevin French
Vertex Environmental Inc.

SMART Remediation
Calgary, AB| March 19, 2019
Edmonton, AB| March 20, 2019

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Case Studies Using the Trap & Treat® Technique

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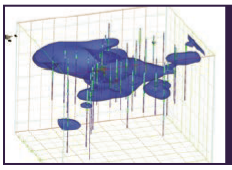
Specialized Contracting Company

In-Situ Remediation

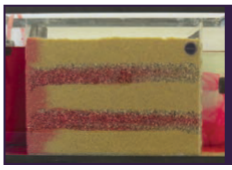
Ex-Situ Remediation

High Resolution Characterization

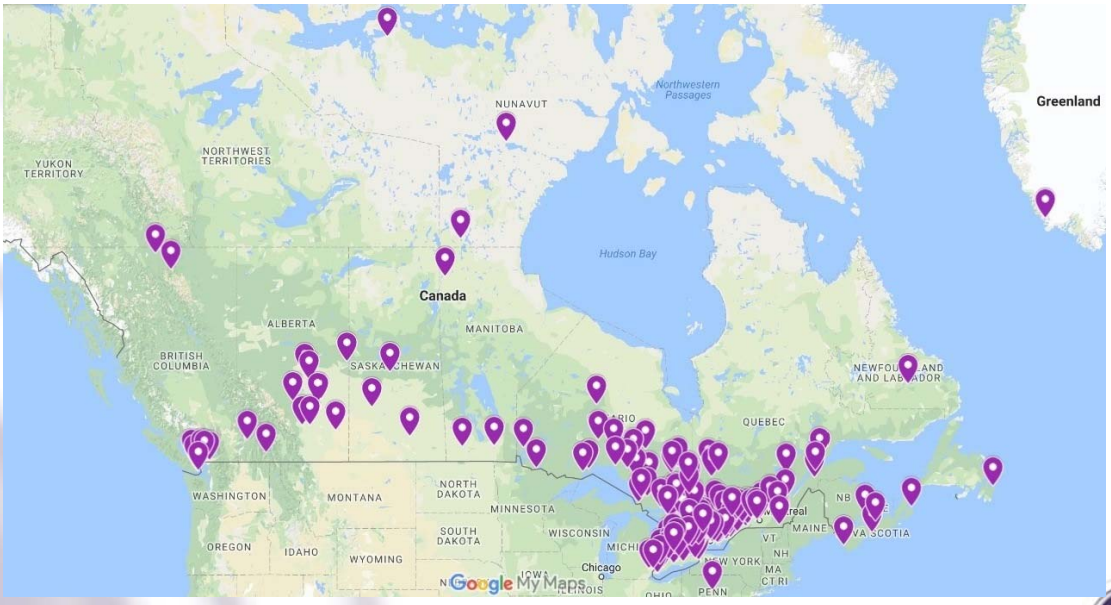
Treatment Systems



Remedial Design



Bench-Scale Testing



Presentation Overview

- Petroleum Hydrocarbons
  - What They Are and How to Find Them
  - Why Are They a Problem?
  - Common Approaches to Remediation
  - Trap & Treat® Technology
- Case Studies
  - Former Underground Storage Tank
  - Permeable Reactive Barrier for PHCs
  - Former on-Site RFO “Quickie”
- Closing Thoughts
- Questions

Petroleum Hydrocarbons
What They Are
and How to Find Them

Petroleum Hydrocarbons

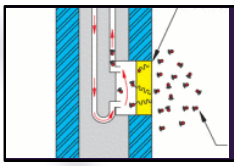
LNAPL

Gasoline
0.75 g/cm^3

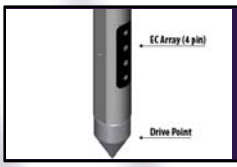
- One of the most common organic contaminants (if not the most common)
- Gasoline, diesel, motor oil, fuel oil, etc.
- Lighter than water ("floater", LNAPL)
- Many sources of potential contamination including spills, leaking tanks, accidents, etc.

High Resolution Methods to Find PHCs

LIF



MIP



HPT

Laser Induced Fluorescence (LIF)

- Free Phase PHCs / LNAPL

Membrane Interface Probe (MIP)

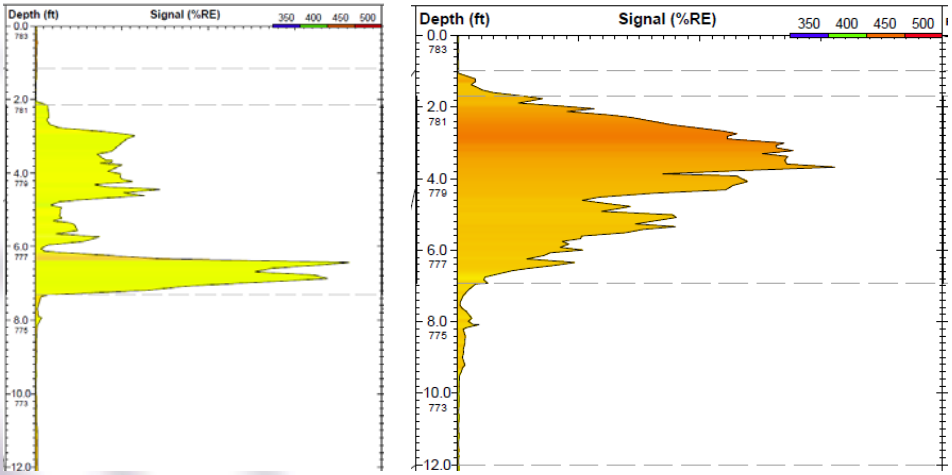
- Dissolved Phase PHCs and VOCs

Hydraulic Profiling Tool (HPT)

- Subsurface Permeability and Conductivity Est.

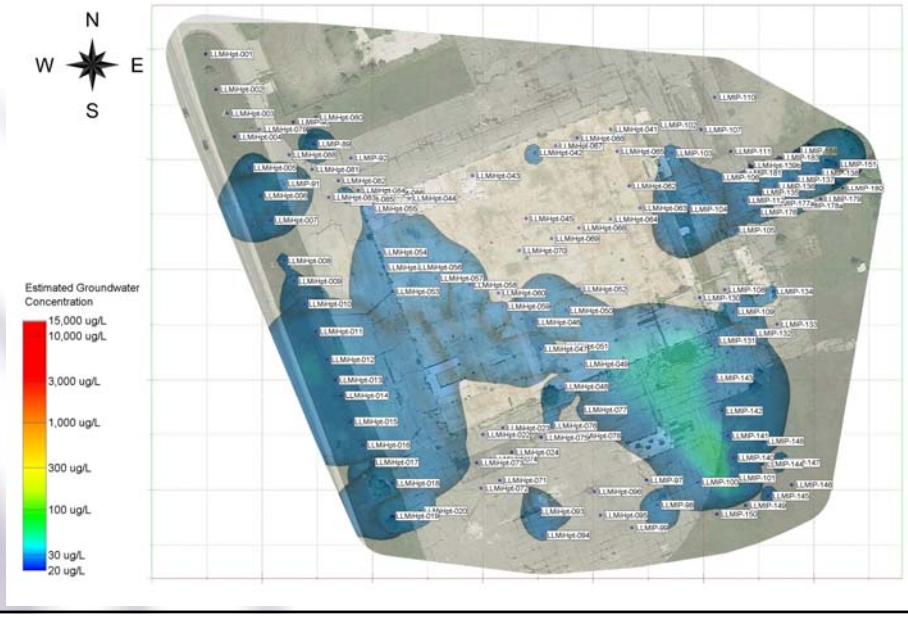
High Resolution Methods to Find PHCs

High Resolution Methods to Find PHCs

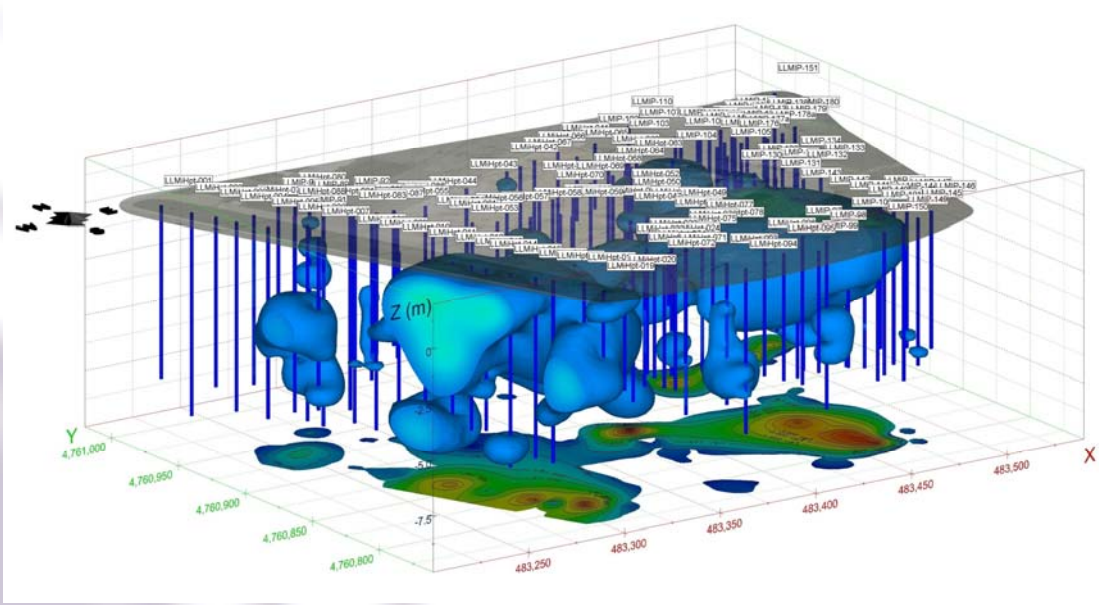


Example LIF Plots – same site, different fuels

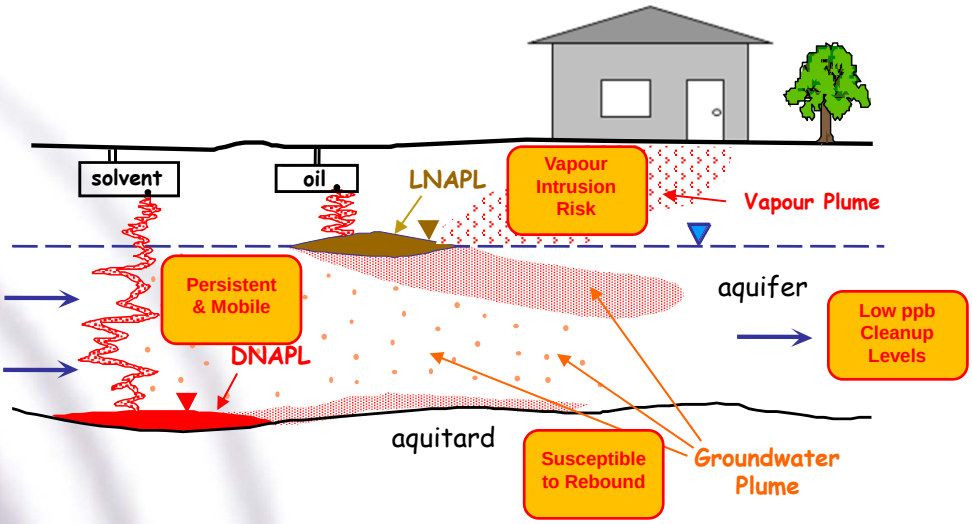
High Resolution Methods to Find PHCs



High Resolution Methods to Find PHCs



Why PHCs Can be so Problematic



Source - Dr. Jim Barker, UW

Common Remediation Approaches

- "Do Nothing" / Monitored Natural Attenuation (MNA)
- Excavation and Off-Site Disposal
- Enhanced Bioremediation (aerobic & anaerobic)
- Chemical Oxidation & Reduction
- Stabilization (physical & chemical)
- Adsorption-based (Trap & Treat®)
- Permeable Reactive Barriers (PRBs)
- Enhanced Delivery & Recovery (injection, extraction, recirculation)
- Systems Technologies & Phase Separation (P&T, MPE)
- Sub-Slab Depressurization (vapour intrusion mitigation)
- Risk Assessment / Risk Management
- Combinations of the above

Trap & Treat® Technology

Remedial Amendments

- Trap & Treat® BOS 100® - for cVOCs
- Trap & Treat® BOS 200® - for PHCs
- Trap & Treat® CAT 100® - for DNAPL
- Application using temporary points or by direct soil mixing
- Plume remediation or PRB applications

Mechanisms of Trap & Treat®

- **"Trap"** the contamination within the activated carbon matrix
- **"Treat"** within the matrix using amendment

Benefits

- Usually Single Application
- Long-Term Solution
- **Back Diffusion Control = Prevents "Rebound"**

Trap & Treat® Technology

Activated Carbon-Based Technology for In Situ Remediation

EPA 542-F-18-001 | April 2018

EPA
United States Environmental Protection Agency

Remedial Technology Fact Sheet – Activated Carbon-Based Technology for In Situ Remediation

Introduction

At a Glance

- An emerging remedial technology combining adsorption by activated carbon (AC) and degradation by reactive amendments.

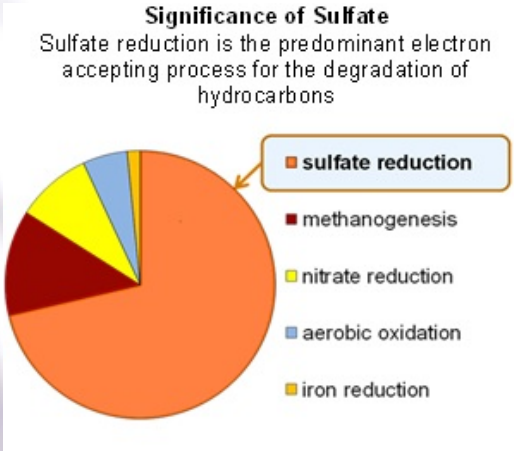
This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Office of Superfund Remediation and Technology Innovation, concerns an emerging remedial technology that applies a combination of activated carbon (AC) and chemical and/or biological amendments for in situ remediation of soil and groundwater contaminated by organic contaminants, primarily petroleum hydrocarbons and chlorinated solvents. The technology typically is designed to carry out two contaminant removal

Trap & Treat® Technology

AC is produced from carbonaceous source materials
(coconut husk, wood, coal, etc)

VERTEX

Trap & Treat® Technology

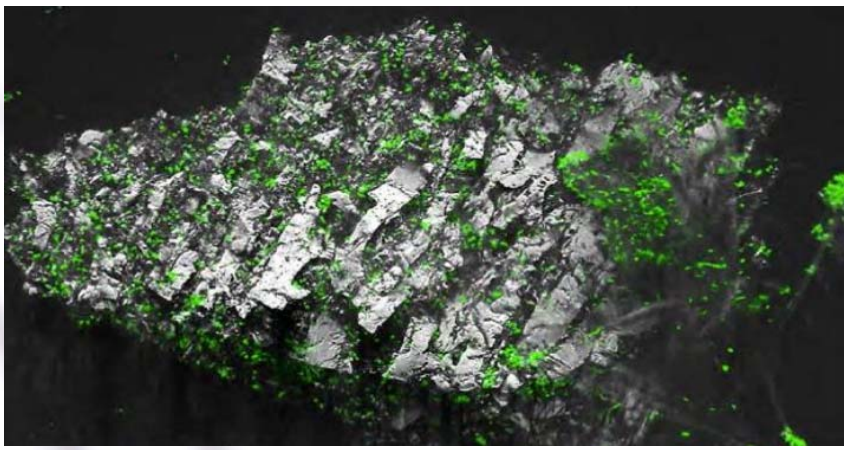


BOS200®

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

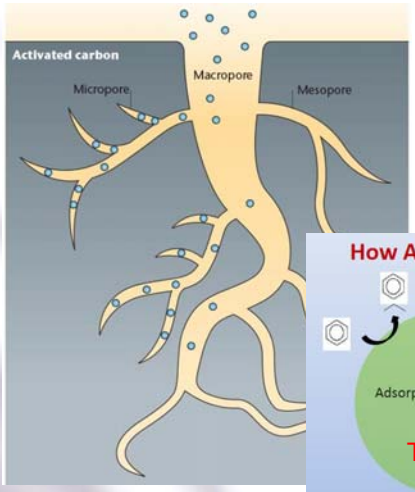
Oxygen : Benzene bio = 3.1 : 1
Sulfate : Benzene bio = 4.6 : 1

Trap & Treat® Technology

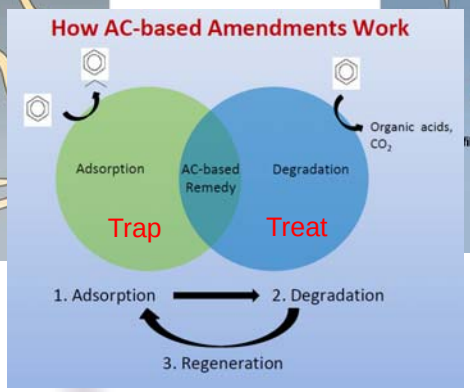


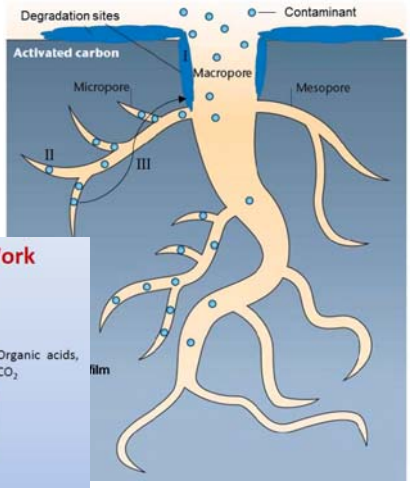
Application of Biofilm Covered Activated Carbon Particles as a Microbial Inoculum Delivery System for Enhanced Bioaugmentation of PCBs in Contaminated Sediments, Birthe Kjellerup and Sarah Edwards, SERDP Project ER-2135

Trap & Treat® Technology



Trap





Treat

Case Studies

Case Study #1
Former Underground Storage Tank (UST)

Case Study #1: Former UST

Site Background

- Tenant occupied light industrial site for over 25 years
- Former diesel fuel UST for truck fleet removed and soil / groundwater remediated in 1998
- **Lease expiring** and tenant vacating property

Contaminant Situation

- PHC impacts in soil and groundwater (vs current standards)
- Soils a mixture of granular fill, clayey silt, silty clay, silty sand, silt, sand

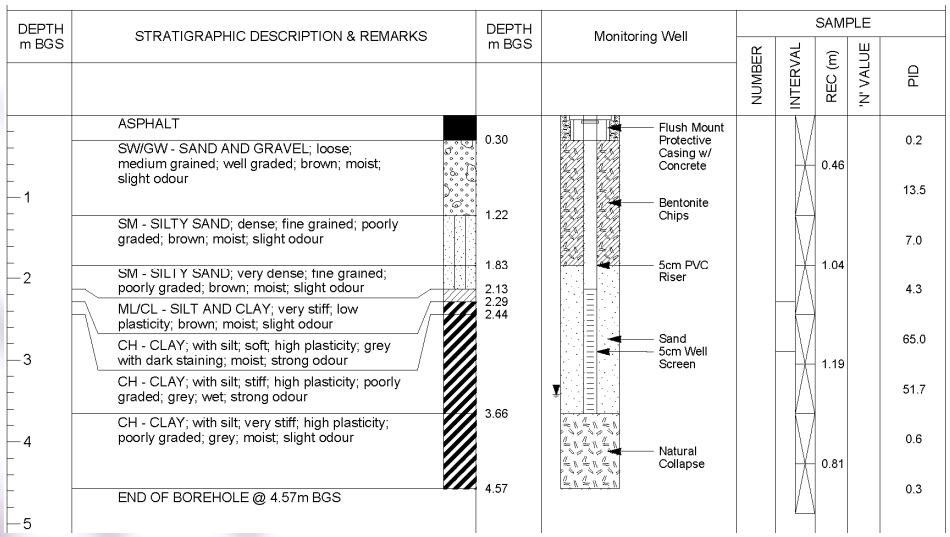
Remedial Objective

- Complete remediation of site prior to lease expiry
- Allow for “four quarters clean” verification sampling (therefore prevent “rebound”)
- **Generic regulatory standards**

Case Study #1: Former UST

Case Study #1: Former UST

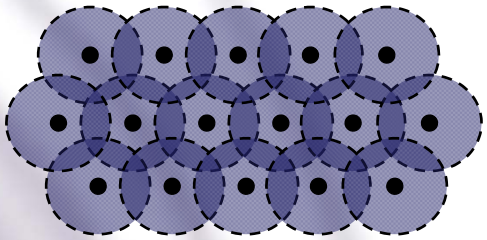
Mixed geology of sands, gravels, silts and clays



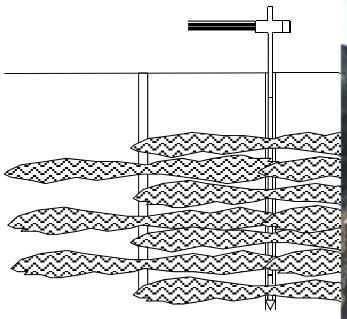
Case Study #1: Former UST

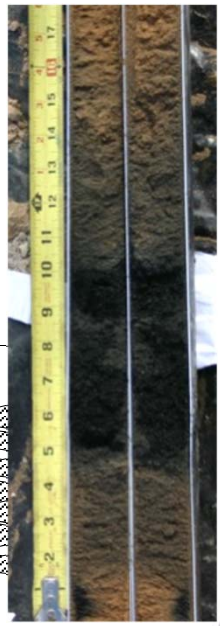
The Goal:

- Uniform Distribution
- Intimate contact between remedial amendment and contaminants



Plan View





Profile View

Case Study #1: Former UST

Locations	Date	Soil								
		Depth	B	T	E	X	F1	F2	F3	F4
MW07-2	07/2007	2.71-3.05	<0.02	<0.02	0.31	0.34	21	330	170	<10
		3.05-3.23	<0.02	<0.02	0.12	0.07	<10	220	89	<10
BH3	11/2012	2.5-3.6	<0.02	<0.05	0.45	<0.05	61	800	350	<50
BH4	11/2012	3.7-4.8	<0.02	<0.05	1.9	<0.05	72	530	160	<50
MW01-16	10/2016	2.29-2.90	<0.0068	<0.08	0.040	<0.05	6.9	1120	454	<50
MW02-16	10/2016	3.66-4.27	<0.0068	<0.08	0.203	0.297	101	66	56	<50
MOECC Standards (Table 3)		-	**0.32**	**68**	**9.5**	**26**	**55**	**230**	**1700**	**3300**

Locations	Date	Groundwater							
		B	T	E	X	F1	F2	F3	F4
MW07-2	08/2007	83	4.5	90	51	550	530	<100	<100
	11/2012	-	-	-	-	190	<100	<100	<100
	12/2016	5.49	<0.50	2.20	2.90	98	310	<250	<250
MW01-16	12/2016	1.39	<0.50	2.76	4.36	83	210	<250	<250
MW02-16	12/2016	1.60	<0.50	3.33	5.71	97	180	<250	<250
MOECC Standards (Table 3)		**44**	**18000**	**2300**	**4200**	**750**	**150**	**500**	**500**

Main Concern

Case Study #1: Former UST

Remedial Approach

- Full-scale **BOS 200® injection** program
  - Combined carbon adsorption and anaerobic biodegradation for PHCs

Obstacles

- **Excavation** approach ("cut & fill") would require **shoring & dewatering**
- Relatively small work area with **lots of truck traffic**
- Limited disruption allowed = **no multiple injection events**
  - ISCO or bio alone would have required at least 2 to 3 injection events
- Client anxious to ensure site is remediated before end of lease
  - Therefore, **certainty in approach was a priority**

Case Study #1: Former UST

Case Study #1: Former UST

Work Completed

- Impacted area 100 m^2 by 2 m thick with soil and groundwater impacts
- 2,000 kg of BOS 200® , 800 kg gypsum & microbes in 10,000 L of slurry injected
- Approx. 40 temporary injection points advanced via Geoprobe
  - 1.5 m lateral spacing for points
  - Vertical injection intervals from 2.1 to 4.5 mbgs
- Completed over 3 working days on-Site

Case Study #1: Former UST

Locations	Date	Groundwater							
		B	T	E	X	F1	F2	F3	F4
MW07-2	08/2007	83	4.5	90	51	550	530	<100	<100
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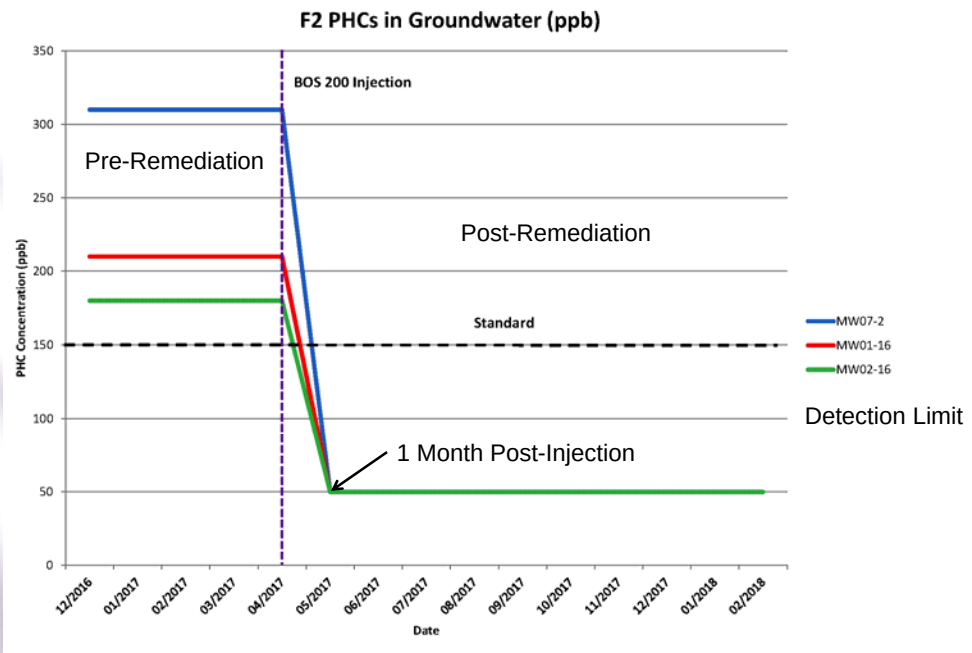
	12/2016	5.49	<0.50	2.20	2.90	98	310	<250	<250
MW01-16	12/2016	1.39	<0.50	2.76	4.36	83	210	<250	<250
MW02-16	12/2016	1.60	<0.50	3.33	5.71	97	180	<250	<250
N/A	04/2017	BOS 200® Injection Event							
MW07-2	05/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	08/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	11/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	02/2018	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
MW01-16	05/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	08/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	11/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	02/2018	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
MW02-16	05/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	08/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	11/2017	<0.50	<0.50	<0.50	<0.50	44	<100	<250	<250
	02/2018	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
MW03-17	05/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	08/2017	1.13	<0.50	<0.50	<0.50	<25	<100	<250	<250
	11/2017	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
	02/2018	<0.50	<0.50	<0.50	<0.50	<25	<100	<250	<250
MOECC Standards (Table 3)		44	18000	2300	4200	750	150	500	500

Pre-injection groundwater analytical data

Four rounds of post-remediation groundwater analytical data



Case Study #1: Former UST

Project Summary:

- Client **required certainty** prior to end of lease
- Trap & Treat® BOS 200® approach selected
- **Design work was essential**
  - Calculation of carbon and sulphate demand
  - Designed lateral and vertical injection spacing to ensure uniform distribution in the subsurface
- Full-scale application completed as planned
- Remedial objective achieved – **below Generic Standard**
- **PHCs remain low (mostly ND) one year after injection event!**

Case Study #2
Permeable Reactive Barrier (PRB) for PHCs

Case Study #2: PRB for PHCs

Site Background

- Site was a commercial property with **former on-site auto servicing and RFO**
- Previous remediation activities completed included excavation, ISCO injections and installation of a Waterloo Barrier®

Contaminant Situation

- Plume of PHCs in groundwater migrating towards property line

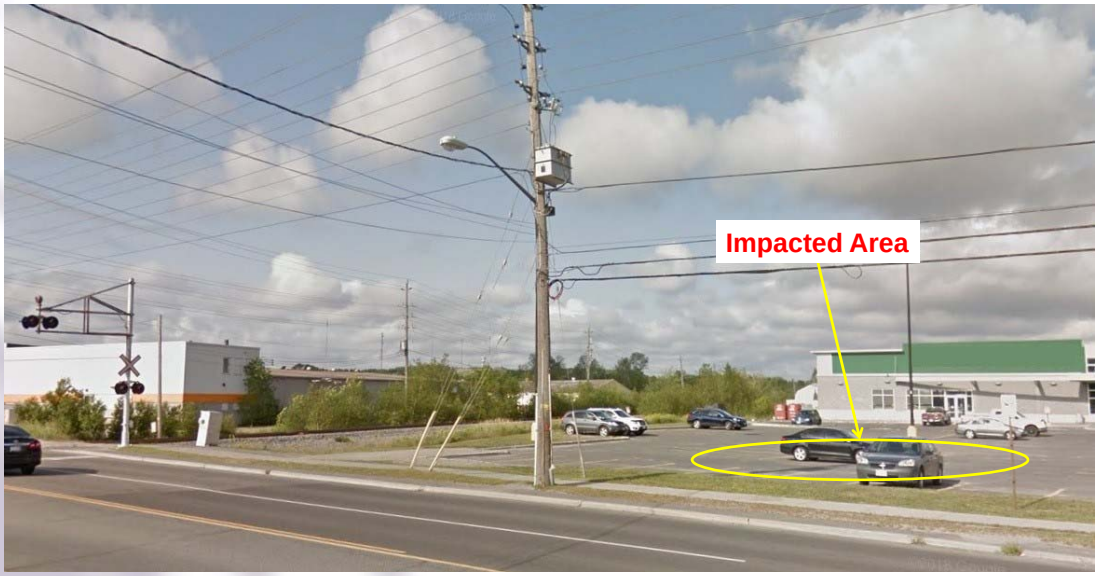
Remedial Objective

- Groundwater leaving the site to **meet generic** groundwater standards

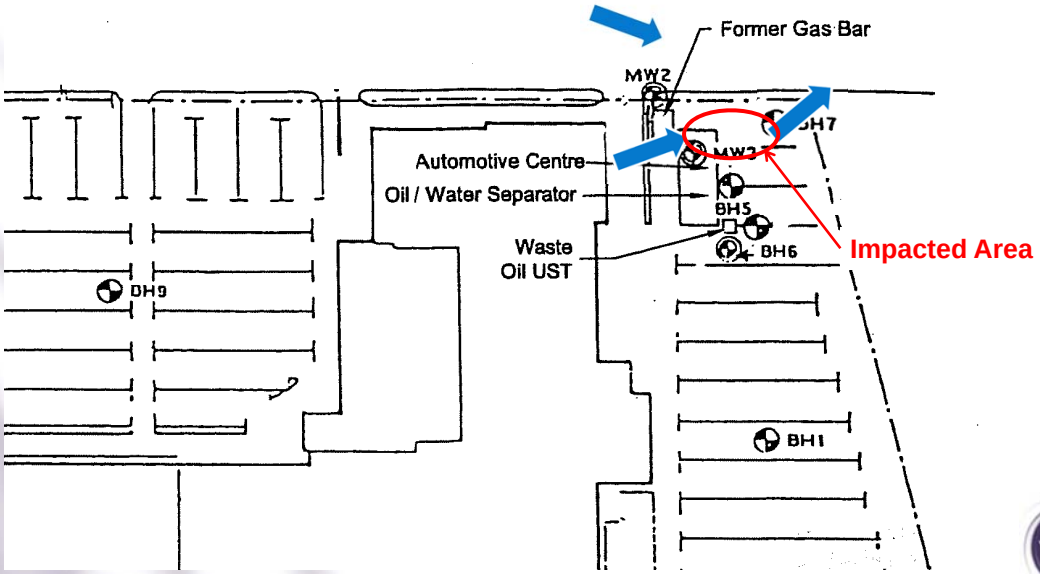
Obstacles

- Lots of **underground services** passing through work area (electrical, gas, etc.)
- **Long term**, yet **passive solution** required

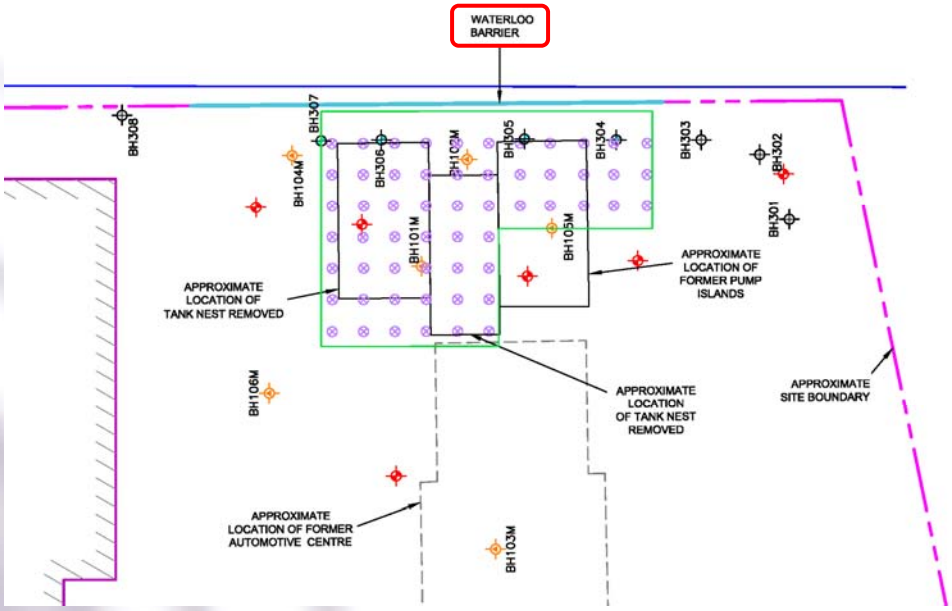
Case Study #2: PRB for PHCs



Case Study #2: PRB for PHCs



Case Study #2: PRB for PHCs



Case Study #2: PRB for PHCs

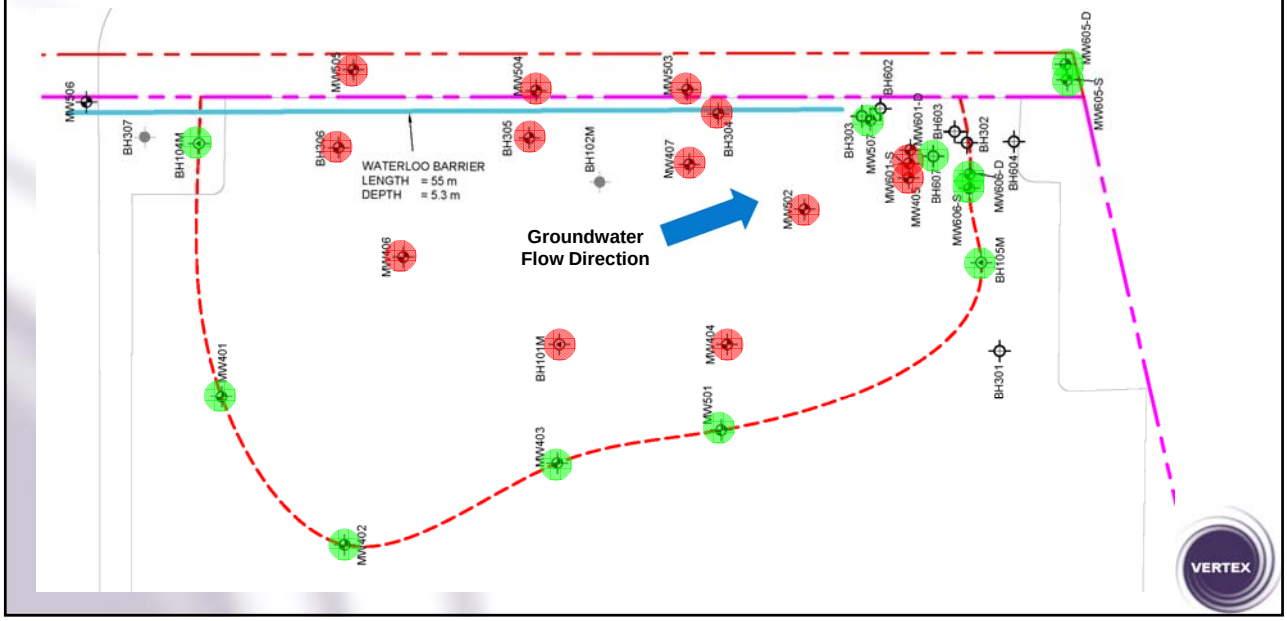
Remedial Approach

- Full-scale **BOS 200®** "cut & fill" PRB

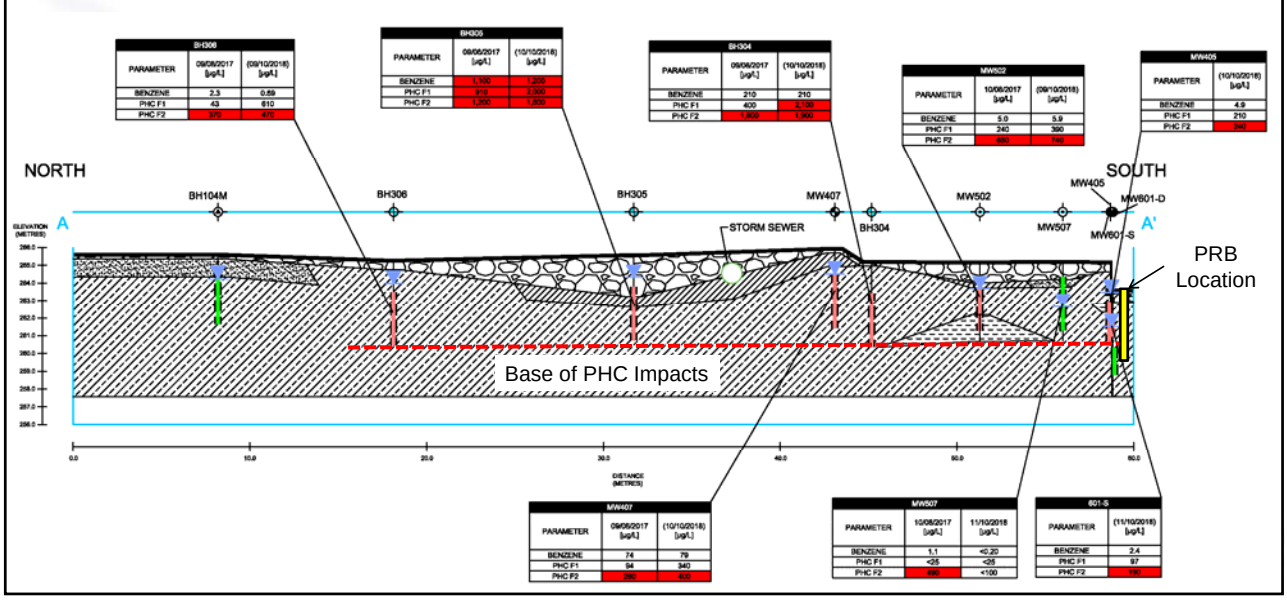
Work Completed To Date:

- Preliminary design and data gap analysis
- Detailed **Remedial Design Characterization (RDC)**
  - Additional soil and groundwater sample analyses completed (6 BHs, 8 MWs, 32 soil samples & 6 water samples)
  - Hydraulic conductivity testing on wells
- Contaminant migration modeling and flux calculations
- **Re-design of full-scale PRB**

Case Study #2: PRB for PHCs



Case Study #2: PRB for PHCs



BH306		
PARAMETER	09/06/2017 [µg/L]	(09/10/2018) [µg/L]
BENZENE	3.3	0.59
PHC F1	43	610
PHC F2	370	470

BH305		
PARAMETER	09/06/2017 [µg/L]	(10/10/2018) [µg/L]
BENZENE	1,100	1,200
PHC F1	910	2,000
PHC F2	1,200	1,600

BH304		
PARAMETER	09/06/2017 [µg/L]	(10/10/2018) [µg/L]
BENZENE	210	210
PHC F1	400	2,100
PHC F2	1,800	1,900

MW502		
PARAMETER	10/08/2017 [µg/L]	(09/10/2018) [µg/L]
BENZENE	5.0	5.9
PHC F1	240	390
PHC F2	650	740

MW405	
PARAMETER	(10/10/2018) [µg/L]
BENZENE	4.9
PHC F1	210
PHC F2	240

MW407		
PARAMETER	09/06/2017 [µg/L]	(10/10/2018) [µg/L]
BENZENE	74	79
PHC F1	54	340
PHC F2	280	400

MW507		
PARAMETER	10/08/2017 [µg/L]	11/10/2018 [µg/L]
BENZENE	1.1	<0.20
PHC F1	<25	<25
PHC F2	490	<100

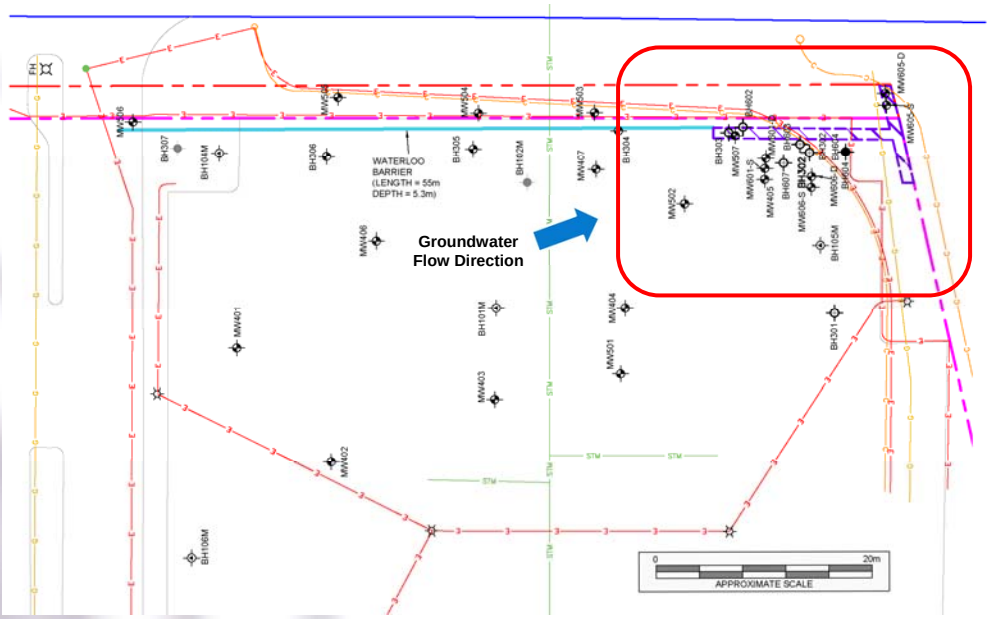
601-S	
PARAMETER	(11/10/2018) [µg/L]
BENZENE	2.4
PHC F1	97
PHC F2	190

Case Study #2: PRB for PHCs

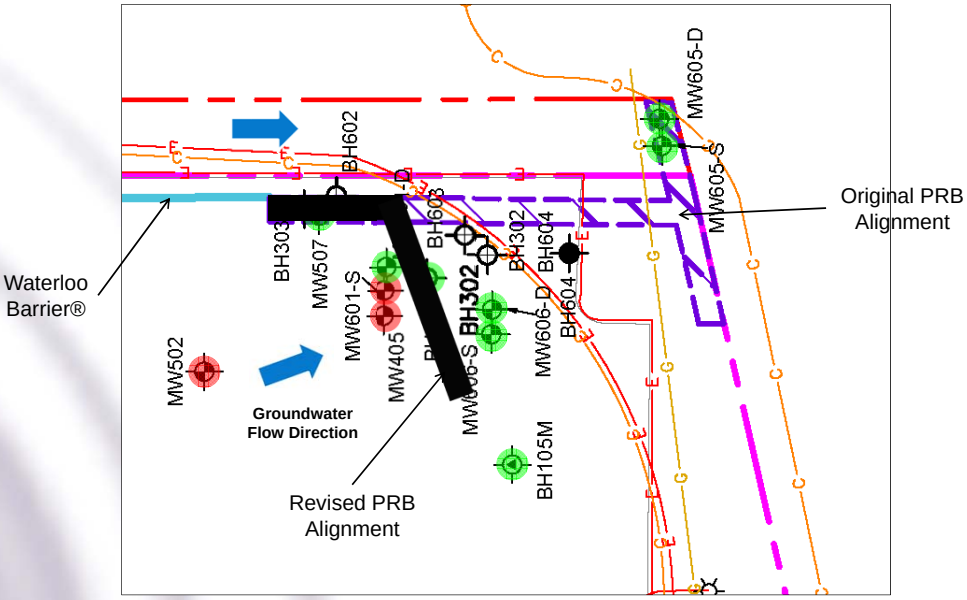
BOS 200® Placement Interval (0.5 – 4.5 m)

SUBSURFACE PROFILE					SAMPLE				
Depth (ft / m)	Symbol	Description	Measured Depth (m)	Monitoring Well Details	Sampler #	Recovery (%)	Sample ID	Soil Vapour Concentration (ppm) (HEX|3L)	Laboratory Analysis
0		Ground Surface	0.00	No Monitoring Well Installed					
1		*Asphalt*							
2		*Silty Sand and Gravel* Brown, dry to moist.	0.76		1	50	SS1	0 / 0	
3		*Sand and Silt* Grey, trace black, dry, trace organics. Light grey brown, wet.					SS2	0 / 0	BTEX, PHCs
6			1.83						
7		*Silty Sandy Clay* Light brown, wet.			2	100	SS3	0 / 0	BTEX, PHCs
9							SS4	0 / 0	
12					3	100	SS5	0 / 1	
14							SS6	0 / 0	BTEX, PHCs
17					4	100	SS7	0 / 0	
18			5.49						
19		Grey.					SS8	0 / 0	
20			6.10						
21		End of Borehole							

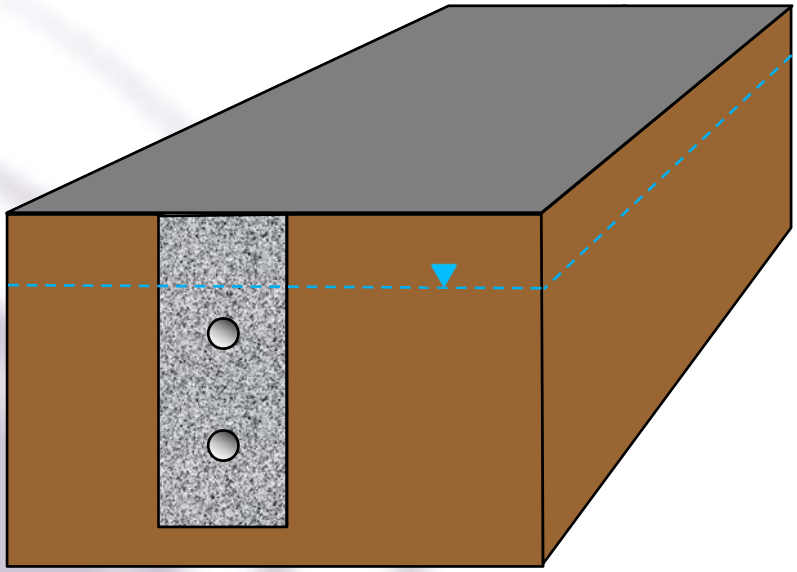
Case Study #2: PRB for PHCs



Case Study #2: PRB for PHCs



Case Study #2: PRB for PHCs



Installation Plan:

- Excavate trench using trench boxes, if needed
- Groundwater management, if needed
- Install perforated piping for injection infrastructure during backfill
- Backfill with BOS 200®, gypsum and microbes mixed with coarse sand
- Repave at grade
- Off-site soil disposal

Case Study #2: PRB for PHCs

Full-Scale Remediation Plan:

- Physical isolation of Site from off-Site source property by impermeable barrier (Waterloo Barrier® previously installed)
- **Trap & Treat® BOS 200®** approach selected for PRB
- Design work completed to calculate theoretical carbon and sulphate demands
- **RDC completed** for lateral and vertical delineation of PHCs in subsurface
- **Adjustments / refinements made** to full-scale BOS 200® PRB design and allowance incorporated for supplemental sulphate injections (if needed)
- Full-scale installation at the Site about to start

"Quickie" Case Study

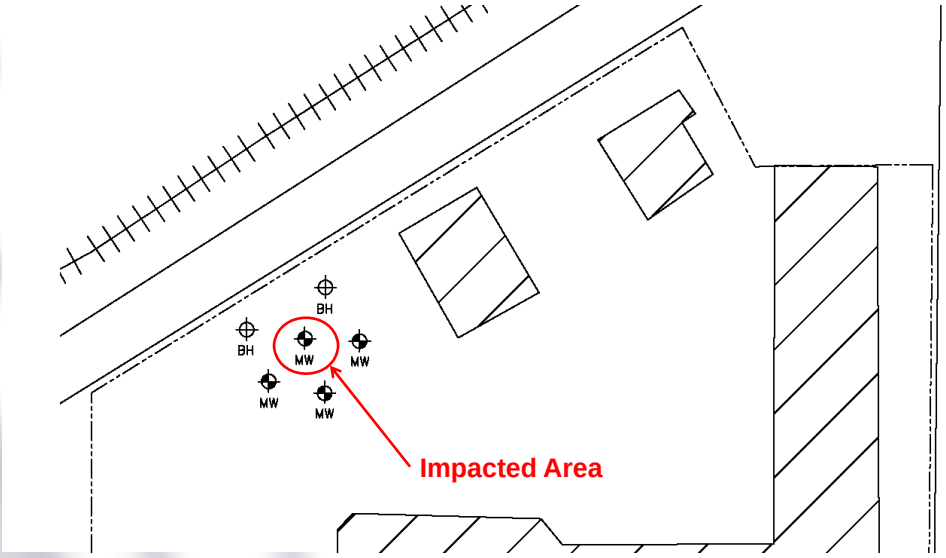
“Quickie” Case Study – Former On-Site RFO

“Quickie” Case Study – Former On-Site RFO

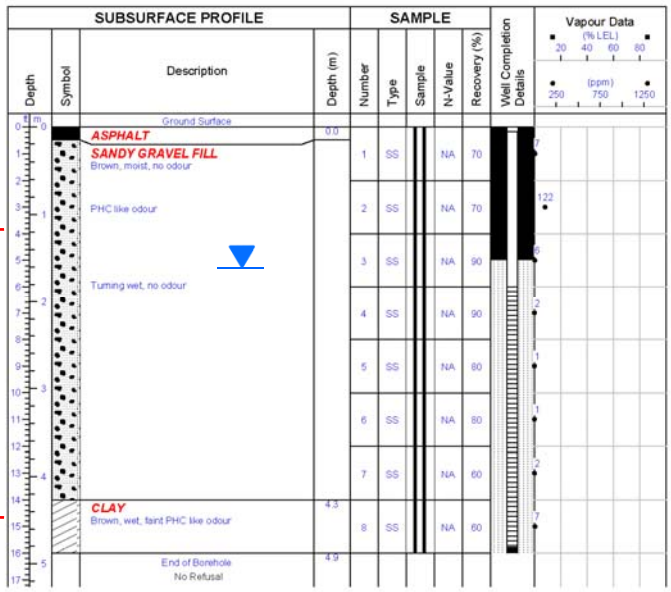
Project Summary:

- Commercial property with former on-Site RFO from 1970s-1990s
- Excavation completed in May 2018 to remove PHC impacted soils
- Backfilled soils were sand and gravel fill
- Post-remediation groundwater quality failed at 1 of 4 MWs in backfill
- Trap & Treat® BOS 200® approach selected for fast and sustained remediation and to prevent “rebound”
- One day injection completed in July 2018
  - 216 kg BOS 200® plus microbial amendment
  - 1,800 L over six temporary injection points

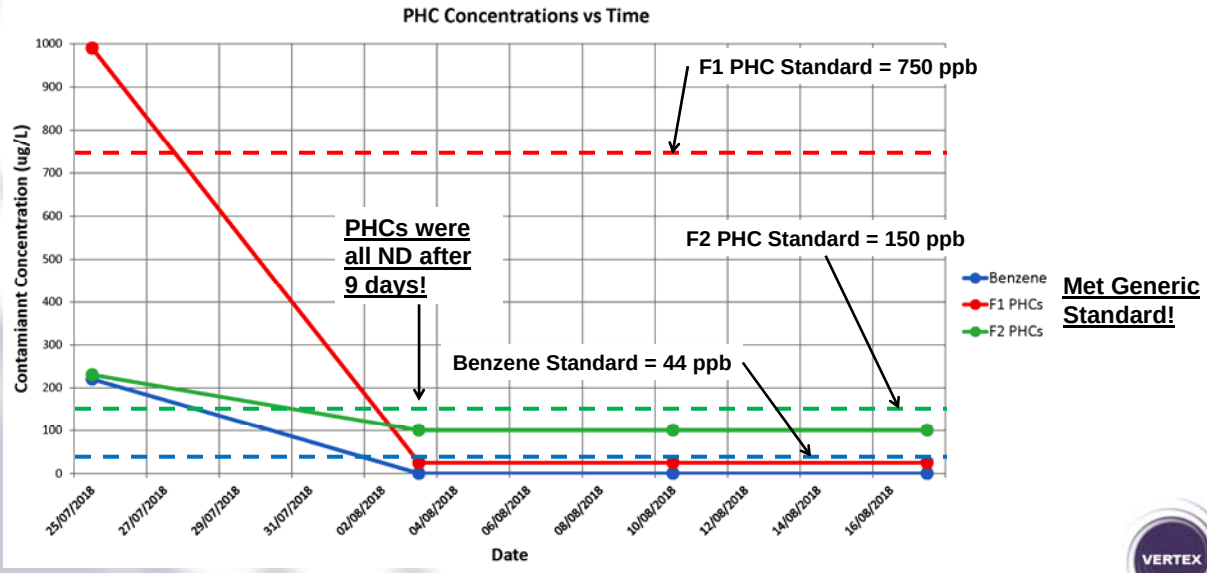
“Quickie” Case Study – Former On-Site RFO



“Quickie” Case Study – Former On-Site RFO



“Quickie” Case Study – Former On-Site RFO



Closing Thoughts

Remediation of PHCs Using the Trap & Treat® Technique

- Adequately understand Site conditions (the “problem”)
- Collect additional site characterization data, if needed
  - Traditional Phase II ESA, HRSC and/or RDC
- Select the right remedial amendment and apply it properly
  - BOS 200® for PHCs (or BOS 100® for CVOCs)
  - The right amounts in the right places to ensure contact for injection or cut & fill trench for complete intersection of plume
- Monitor and re-evaluate as remediation progresses
  - Interim QA/QC (groundwater sampling, forensic soil cores)
- Allow for future re-application of sulphate & microbes for long-term PRB applications

Questions?

Thank You for Your Time

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