In-situ Chemical Injection

to Treat Chlorinated Solvents in Groundwater

RemTech East | June 2022

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Outline

- **Site Description**
- **Background**
- **Objectives**
- **In-Situ Chemical Injection – Pilot-test & Large Scale**
  - Approach
  - Activities
  - Challenges and Solutions
- **Results & Next Steps**

Site Description

Site Description

- Site is an **active shopping centre** in Metro Vancouver, BC (commercial)
- **Dry cleaner** operated on the northwest corner of the site between early 1960s and late 1980s
- Adjacent surrounding properties: **commercial, residential, school**
- **Major river** ~2 km north of the site and **smaller tributaries** and **creeks** to ~600 m north, ~900 m northwest and ~850 m southeast
  - groundwater flow divide


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Background

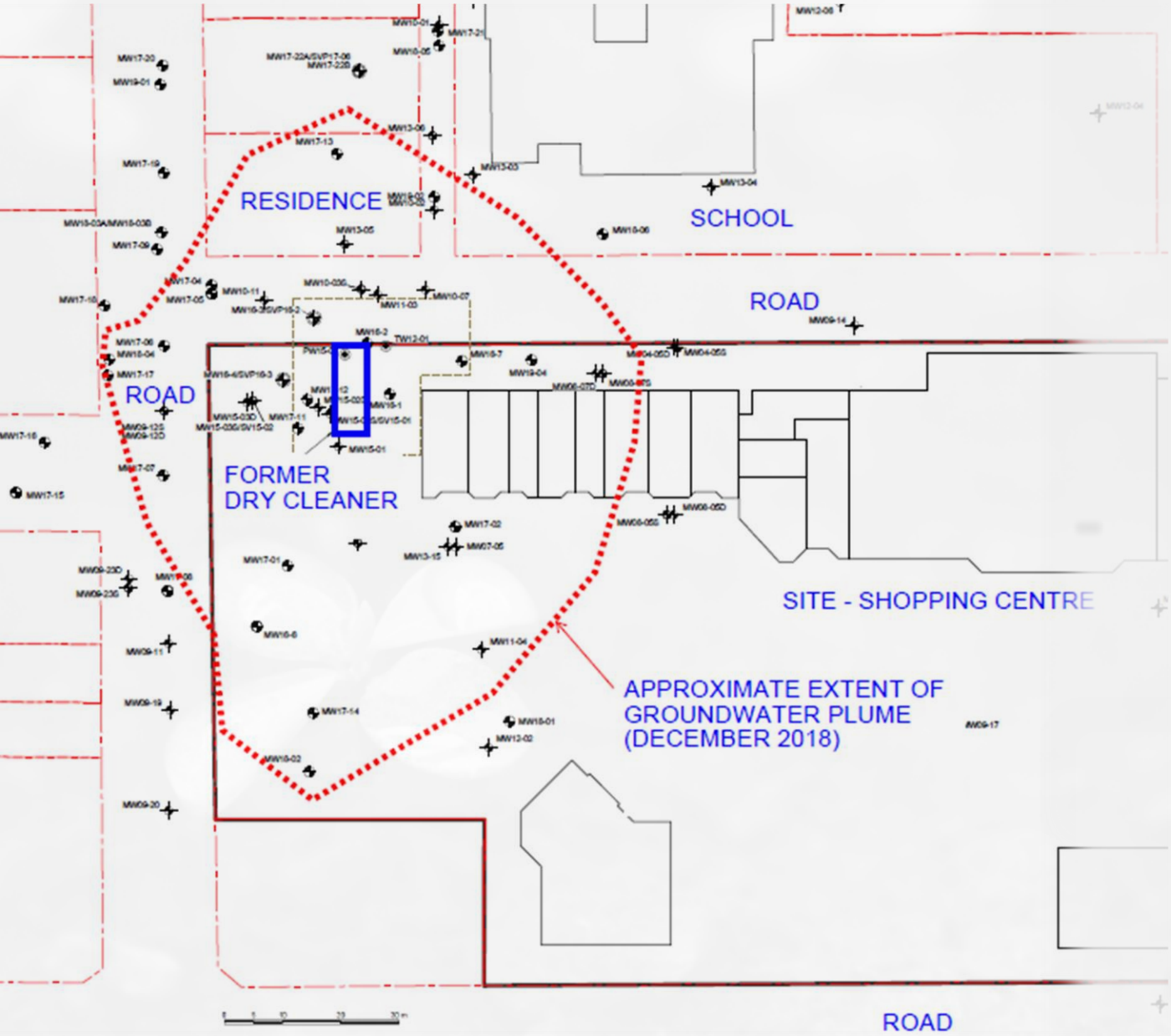
Background

Environmental investigation and remediation activities at site since 1988 by various consultants, **SLR since 2015.**

Applicable BC CSR standards:

Soil	Groundwater	Vapour
CL*	AWF & DW	RLv & CLv

*based on current land use



PCE and **degradation products** in soil, groundwater and vapour at concentrations above applicable BC CSR standards on-site and off-site to north and west beneath roads, a residence and a school.

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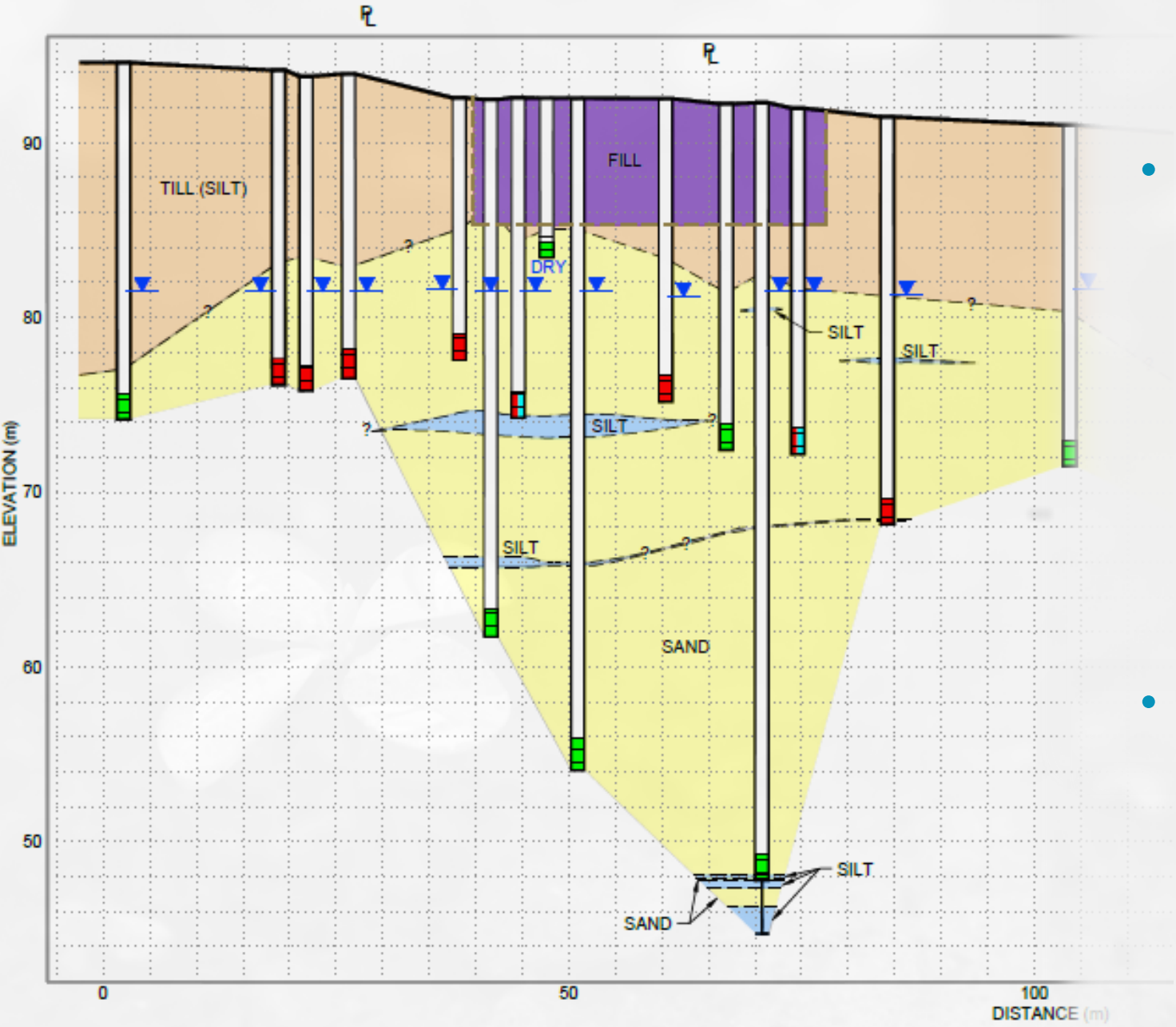


- Soil profile in area of plume approximately:
  - **till (silt) to 8 mbg**
    (hard - difficult to drill)
  - **sand to 45 mbg**
    (heaving – difficult to drill)
  - lower silt

- Main groundwater plume in sand between approximately **11 and 21 mbg** (delineated horizontally and vertically)

Remediation Activities

1990s & 2010s

Remedial excavations removed 6,000 m^3 of PCE-impacted soil in source area on-site and off-site to north, focussed on the till.

2015

Groundwater treatment system installed on-site to extract and treat groundwater and prevent further migration of groundwater plume off-site in the sand.

2019

Pilot-test injection program of BOS 100® was implemented in “hot spot” on-site to treat PCE in groundwater.

2021

Based on success of pilot-test, large scale injection program implemented on-site and off-site.

Objectives

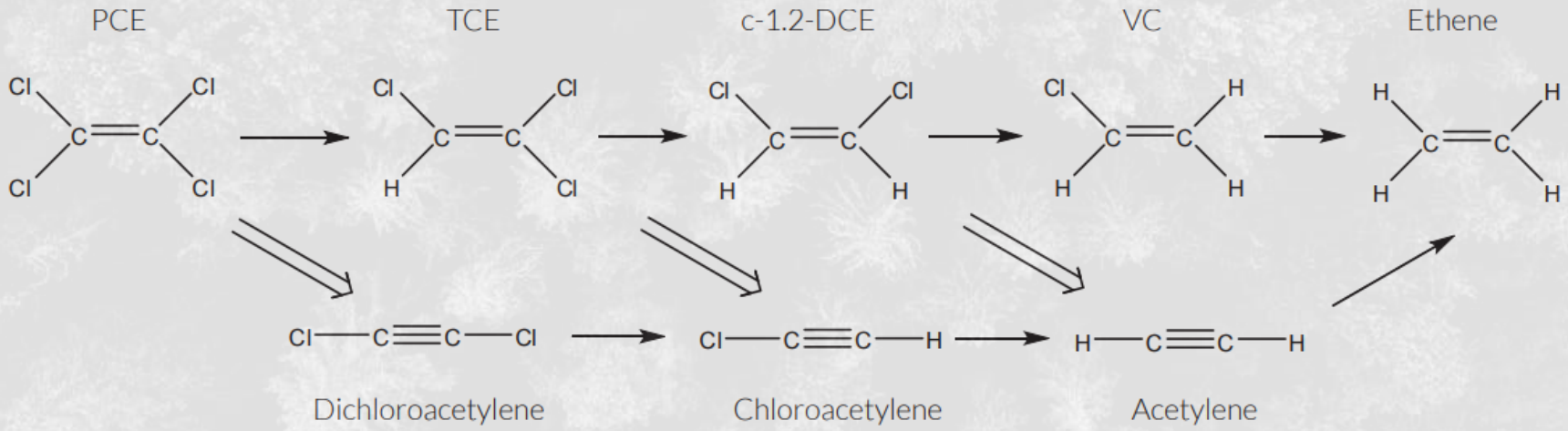
Objective of Remediation by Chemical Injection

Objective: To reduce high PCE concentrations

- To eliminate need for groundwater treatment system.
- To facilitate a human health and ecological risk assessment for the site.
- To obtain risk-based Certificates of Compliance from the BC ENV for the site and off-site affected areas.

Remedial Amendment Trap & Treat BOS 100®

- Designed for in-situ chlorinated solvent remediation
- Activated carbon impregnated with elemental iron
- Contaminants are “trapped” (i.e. adsorbed) by the carbon then “treated” by the elemental iron
- Abiotic process avoids formation of daughter products (double arrows)



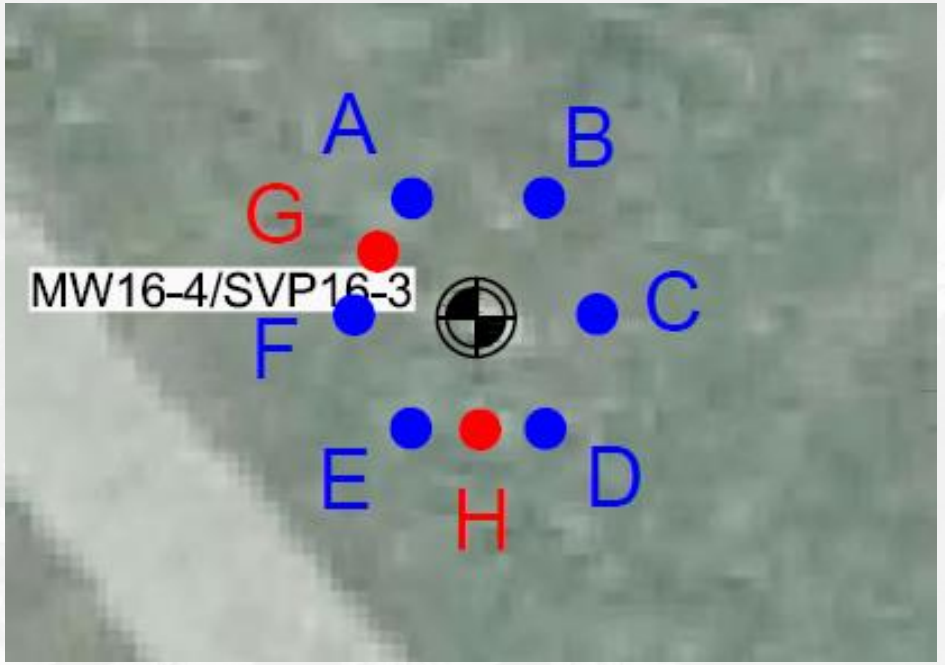
In-Situ Chemical Injection

Pilot-test & Large Scale

Pilot-test

Approach & Activities

- Health & Safety
- Selected “hotspot” of groundwater plume in the source area on-site (MW16-4)
- 6 temporary IPs completed in 2 steps:
  - used sonic rig to pre-drill to 19 mbg (difficult drilling), ~1.5 m step-outs
  - Direct push (Geoprobe®) inject 12%wt suspension (BOS 100® and water)
    (total 650 kg BOS 100®, 5,500 L suspension)

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Geoprobe 7822DT
Geoprobe
VERTEX
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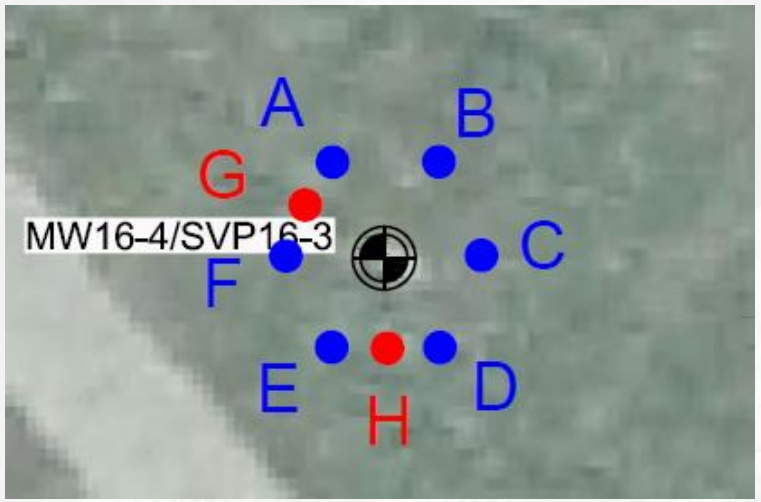


Verification

- Vertex monitored **injection flow rates**, **pressures** and **volumes** during injection and monitored adjacent wells for influence from injections
- Drilled **two post injection verification boreholes** midway between injection points with sonic rig for continuous soil sampling at target depths and **completed visual inspection** of soil cores for distribution of BOS 100®

Pilot-Test - Conclusions & Observations

- Sonic pre-drilling for IPs followed by direct push to inject at target depth intervals feasible
- Injection volumes, flow rates and pressures observed during pilot-test considered feasible for large scale injection program
- Based on visual inspection of post injection verification boreholes, BOS 100® amendment well distributed within targeted injection depth ranges
- Average ROI approximately 1.2 m and 1.5 m

Pilot-Test - Analytical Results

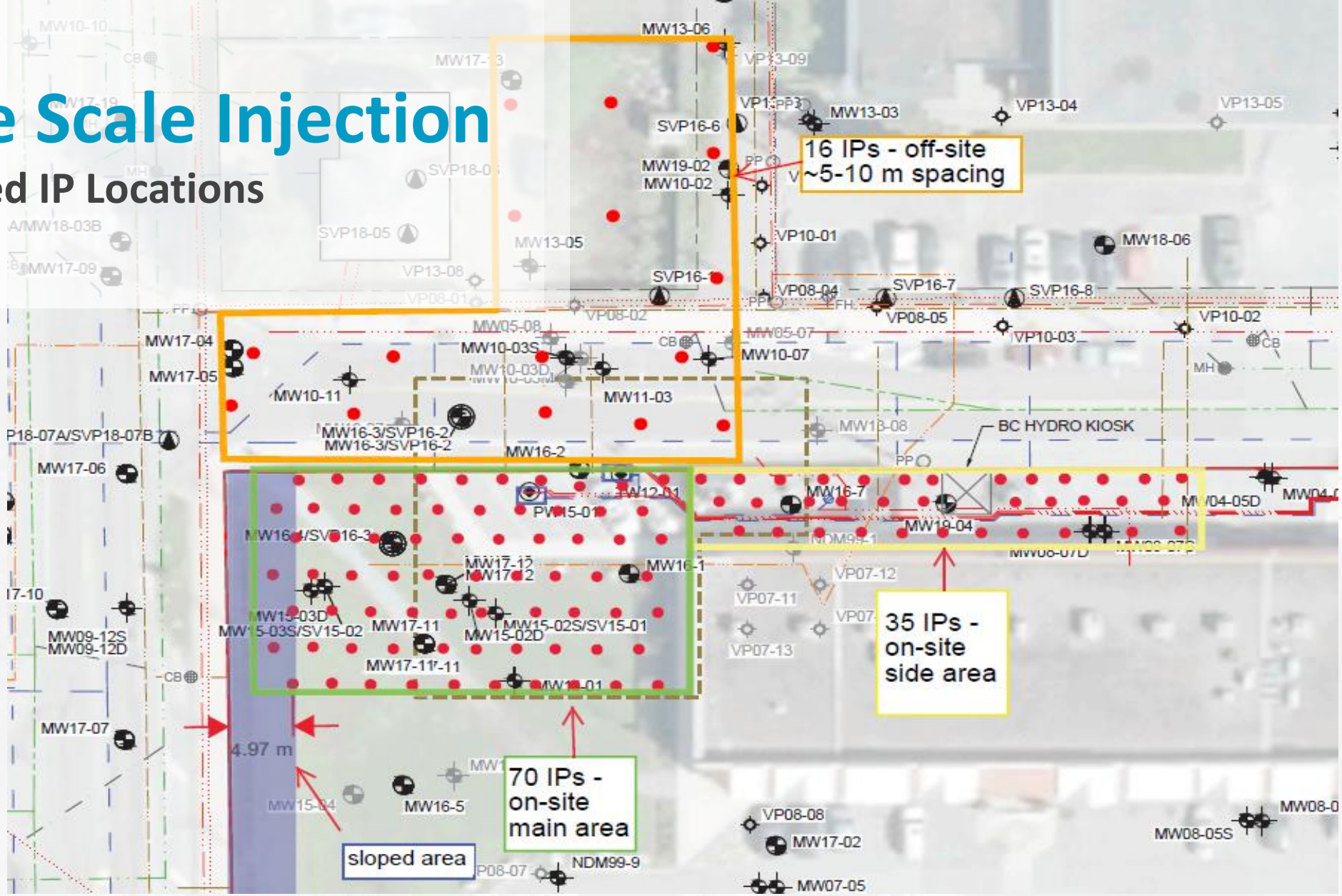
MW16-4

Sample Date	PCE (µg/L)	TCE (µg/L)	1,2-cis-DCE (µg/L)	VC (µg/L)
CSR DW Standards	30	5	8	2
CSR AWF Standards	1,100	200		
20-Jun-2018	22,700	56.5	23.9	1.75
3-Oct-2018	25,500	60	28.4	0.49
4-Dec-2018	26,900	74.7	33.6	2.19
15-May-2019	17,200	64.8	44.4	1.12
2-Jul-2019	14,400	71.8	97.1	3.34
25-Jul-2019	9,890	60	214	19.2
8-Aug-2019	12,600	76.7	93.5	13.2
29-Aug-2019	11,200	43.6	37.8	2.98
4-Oct-2019	5,140	55.6	36.2	3
31-Jan-2020	2,760	40.8	24	0.55
25-Mar-2021	658	21.5	4.51	<0.4

pilot-test
Jun 2019

Large Scale Injection

Proposed IP Locations



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Proposed IP Locations

121 IPs

105 IPs on-site

- 3m off-set grid
- Injection interval 8.8-18.9 mbg
- 0.6 m vertical intervals
- 6% wt. BOS 100® (21,000 kg BOS 100®, 330,000 L)

16 IPs off-site

- 5-10m spacing
- Injection interval 14.9-21.3 mbg
- 0.6 m vertical intervals
- 4.2% wt. BOS 100® (2,500 kg BOS 100®, 60,000 L)

Large Scale Injection

Planning & Preparation

- Health & Safety
- Access requests (city and residence)
- Utility clearance and grid layout (reviewing plans, physical locates & marking, hydrovac each location)
- Mobilization of equipment/supplies to site (fencing, sea-cans, BOS 100®, trailer, rigs, vac trucks, water tanks, skid steer etc.)
- Removal of garbage enclosure
- Waste management and disposal
- Traffic control/management
- Overnight security


ZONE
ONLY


ENTRANCE

Large Scale Injection

Approach & Activities

- 121 IPs
  - 105 IPs on-site, 6 IPs off-site (utility locates & hydrovac each IP)
  - Two steps: 1) pre-drill with sonic, 2) injection with direct push
  - Approximately 3 pre-drills/day, 1.5 injections/day
  - Logistical planning
    - pre-drills completed in batches to stay ahead of injections
    - keep sonic and direct push rigs in separate areas to avoid over crowding
    - work within permit hours and one lane at time for off-site
- Duration of field program May to September 2021


SLEU 2906475
25G1


BADGER
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BRILLWELL


800-UR-RENTS
GENERAC
United Rentals
800-UR-RENTS
United Rentals
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Photo credit: Vertex

Photo credit: Vertex

Large Scale Injection

Challenges

Challenge:
Refusal of direct push in pre-drilled boreholes

Solution:
Increasing diameter of pre-drilled holes from 3.5 to 6 inches

Challenge:

Injection tooling/rods clogging, lost rods

Solutions:

- Removing rods/tooling, cleaning and reattempting
- Injecting from top down (instead of from bottom up)
- Adjusting injection pressures (150-1,350 psi)
- Disconnected rods that could not be removed, left in place, cut hose and backfilled

Challenge:

Daylighting of suspension through the top of pre-drilled boreholes and/or interconnecting boreholes (instead of going into the formation)

Solutions:

- Changing backfill material of pre-drilled boreholes from bentonite grout to hydrated bentonite for a better seal
- Increasing concentration of BOS 100® slurry to reduce volume (6%-12% on-site, 4.2%-8.4% off-site)
- Adjusting injection pressures (150-1,350 psi)
- Relocating to adjacent IPs

In total, 23,500 kg BOS 100® injected, 250,525 L suspension

Large Scale Injection

Wrap up

- Demobilization of equipment
- Restoration of residence driveway and garden
- Restoration on-site – new lawn and repaving

Large Scale Injection

Restoration

Photo credit: Vertex


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Large Scale Injection

Post Injection

- Injections completed **September 2021**
- Groundwater treatment system shut down **September 2021**
- Completed 3 rounds of groundwater sampling **October 2021, January 2022** and **April 2022**

  Approximately 40 wells each round for analysis of chlorinated solvents

Results & Next steps

Large Scale Injection

Large Scale Injection

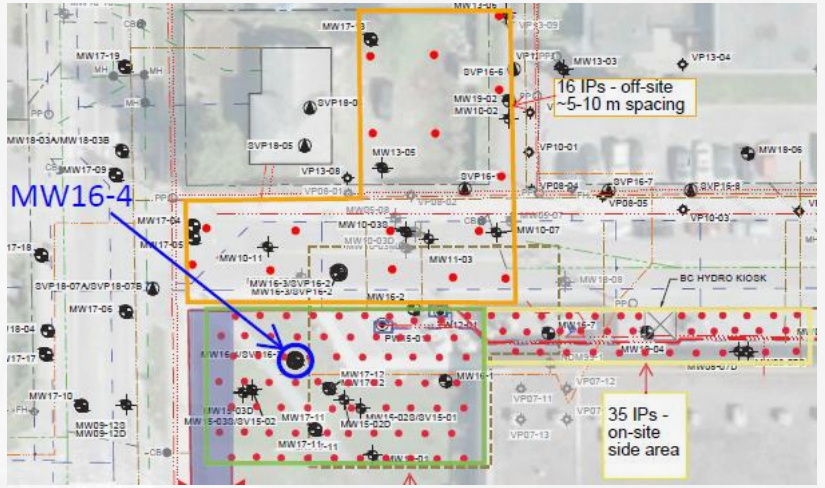
MW16-4 - on-site within injection area

Sample Date	PCE (µg/L)	TCE (µg/L)	1,2-cis-DCE (µg/L)	VC (µg/L)
CSR DW Standards	30	5	8	2
CSR AWF Standards	1,100	200		
25-Mar-2021	658	21.5	4.51	<0.4
5-Oct-2021	451	34.8	12.1	1.61
25-Jan-2022	7.41	0.52	<0.5	<0.4
27-Apr-2022	1.46	2.8	5.57	<0.4

injection May-Sep 2021

Analytical Results

- Concentrations decreasing



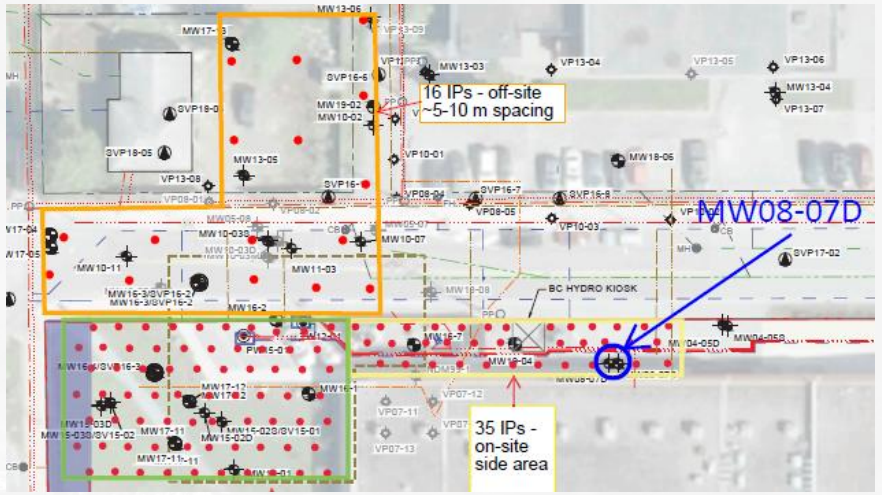
MW08-07D - on-site within injection area

Sample Date	PCE (µg/L)	TCE (µg/L)	1,2-cis-DCE (µg/L)	VC (µg/L)
CSR DW Standards	30	5	8	2
CSR AWF Standards	1,100	200		
22-Mar-2021	33.7	11.6	28.1	<0.4
5-Oct-2021	4.82	2.77	12.2	<0.4
27-Jan-2022	29.1	4.57	8.48	<0.4
26-Apr-2022	4.64	3.78	8.87	<0.4

injection
May-Sep 2021

Analytical Results

- Concentrations decreasing



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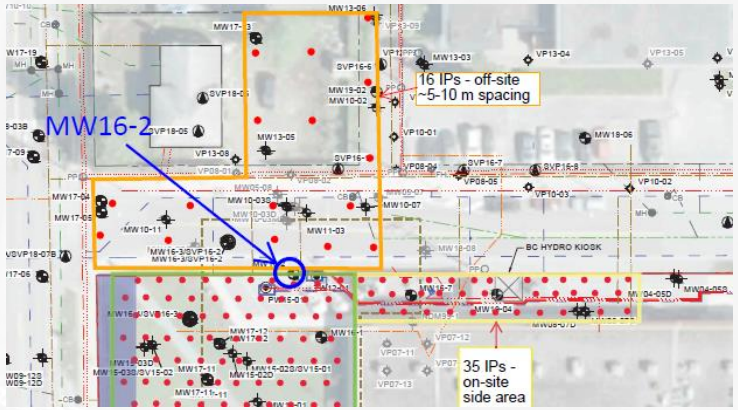
MW16-2 - on-site within injection area (between extraction wells)

Sample Date	PCE (µg/L)	TCE (µg/L)	1,2-cis-DCE (µg/L)	VC (µg/L)
CSR DW Standards	30	5	8	2
CSR AWF Standards	1,100	200		
2-Jul-2019	77.2	5.4	3	<0.4
29-Aug-2019	121	6.6	3.3	<0.4
9-Dec-2019	40.4	1.4	<1	<0.4
22-Mar-2021	48.7	1.02	<0.5	<0.4
5-Oct-2021	61.7	1.92	<0.5	<0.4
25-Apr-2022	90.4	3.47	1.09	<0.4

injection May-Sep 2021

Analytical Results

- concentrations increasing
- near extraction wells (system off)
- expect to see decrease over time



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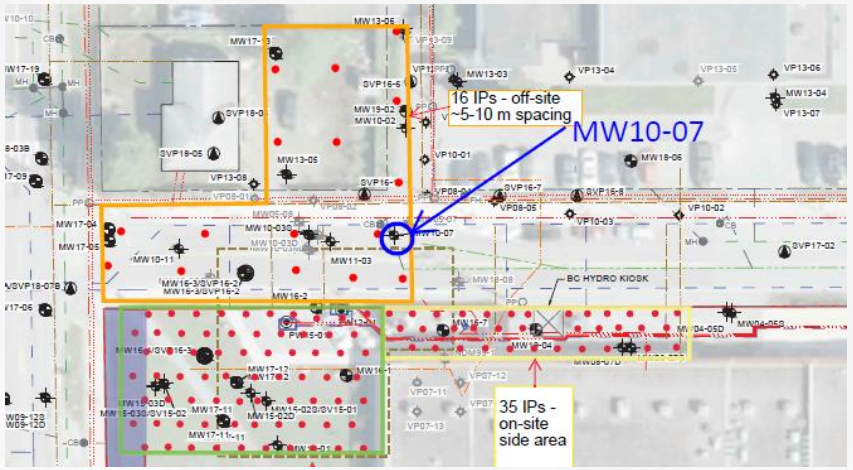
MW10-07 - off-site within injection area

Sample Date	PCE (µg/L)	TCE (µg/L)	1,2-cis-DCE (µg/L)	VC (µg/L)
CSR DW Standards	30	5	8	2
CSR AWF Standards	1,100	200		
22-Mar-2021	1510	32.1	8.27	<2
7-Oct-2021	1260	25.7	7.39	0.93
24-Jan-2022	1360	38.5	13.5	2.09
25-Apr-2022	1570	36	13.4	3.33

injection May-Sep 2021

Analytical Results

- concentrations increasing
- within injection area, IPs larger spacing and lower %wt BOS 100® injected
- near extraction wells (system off)
- expect to see decrease over time
- still delineated and within previous concentration ranges



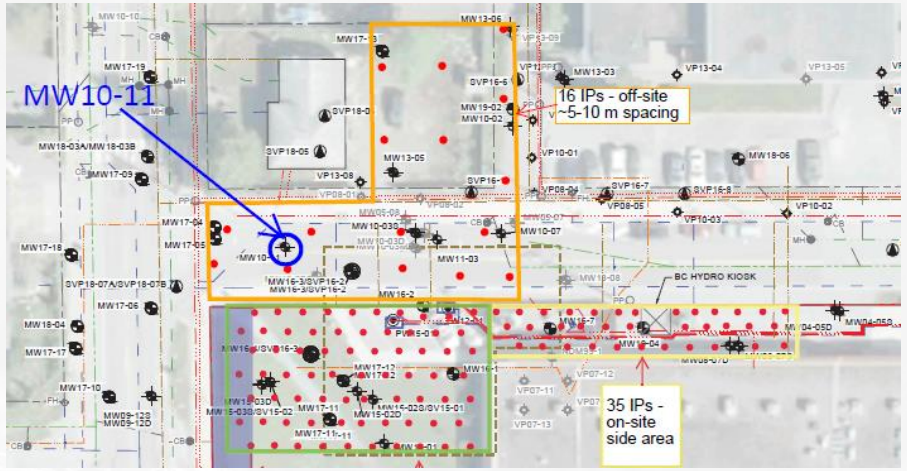
MW10-11 - off-site within injection area

Sample Date	PCE (µg/L)	TCE (µg/L)	1,2-cis-DCE (µg/L)	VC (µg/L)
CSR DW Standards	30	5	8	2
CSR AWF Standards	1,100	200		
22-Mar-2021	90.4	12.5	4.7	<0.4
7-Oct-2021	53.2	16.7	6.29	<0.4
24-Jan-2022	30.5	4.95	2.72	<0.4
25-Apr-2022	49.6	4.84	2.46	<0.4

injection
May-Sep 2021

Analytical Results

- concentrations fluctuating but decreasing



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Large Scale Injection

Analytical Results

- On-site injection area - PCE concentrations generally decreasing except in proximity to extraction wells for water treatment system (WTS shut off post injection, groundwater still delineated and PCE concentrations within previous range)
- Off-site injection area
  - PCE concentrations decreasing at some locations but slower than on-site
  - PCE concentrations fluctuating at some locations without much change compared to pre-injection
  - Larger IP spacing off-site, lower % wt BOS 100® suspension injected off-site and off-site wells are on leading edge of injection area
- No significant changes outside injection areas
- Based on analytical results following the pilot-test PCE concentrations continued to decrease over time

Large Scale Injection

Next Steps

one

Continue groundwater sampling on a quarterly basis until the groundwater plume is stable or shrinking.

two

Complete a risk assessment and apply for risk-based Certificates of Compliance for on-site and off-site.

- **SLR Consulting (Canada) Ltd.:**
  - Field staff: Jill Armstrong, Erica Moran, Lynsey Stone, Chad Choi, David Kinash, Stef Lee, Katelyn Ocampo, Allison Cranwell, Fiona Dobson, Natalia Fioretti
  - Technical support: Tim Whalen, Eva Gerencher, Cindy Ott, Ilya Biniowsky, Chris Taylor
- **Vertex Environmental Inc.**
- **Downrite Drilling Ltd. (pre-drilling)**
- **Drillwell Enterprises Ltd. (injections)**

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Thank you for your time!
Questions?
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