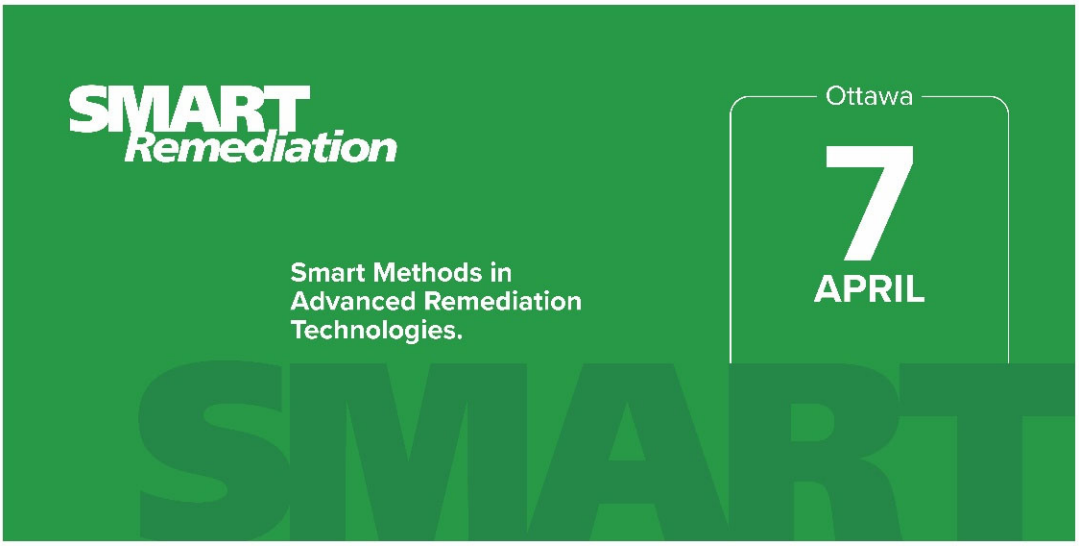

Lessons learned from one of the largest "Traditional" ZVI PRBs installed in North America

Ben Sweet
QM Environmental

SMART Remediation
Ottawa, ON | April 7, 2022

SMART is Powered by: VERTEX Environmental Inc.

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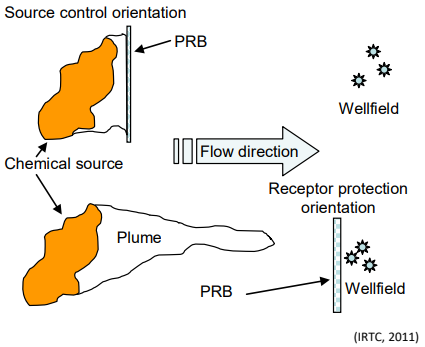
ZVI PRBs

- **Permeable Reactive Barriers (PRBs) – passive (*In-situ)* groundwater treatment zone.**
- **Zero Valent Iron (ZVI) - the first reactive material used for groundwater treatment via PRB installation.**



(IRTC, 2011)

COCs	ZVI	Biobarriers	Apatite	Zeolite	Slag	ZVI-carbon combinations	Organophilic clay
Chlorinated ethenes, ethanes	F[a]	F			L	F	
Chlorinated methanes, propanes						F	
Chlorinated pesticides						P	
Freons						L	
Nitrobenzene	P						
Benzene, toluene, ethylbenzene, and xylenes (BTEX)		F					
Polycyclic aromatic hydrocarbons (PAHs)							L
Energetics	P	F				P	
Perchlorate		F	F	L		L	
NAPL							F
Creosote							F
Cationic metals (e.g., Cu, Ni, Zn)	L	F	F		L	F	
Arsenic	F			L	F	F	
Chromium(VI)	F			L	L	F	
Uranium	F	P	F			T	
Strontium-90			F	F			
Selenium	L					L	
Phosphate					P		
Nitrate		F	F			F	
Ammonium				L			
Sulfate		F				L	
Methyl tertiary butyl ether (MTBE)		F					

[a] F = full-scale application, L = laboratory evaluation, P = pilot-scale application.

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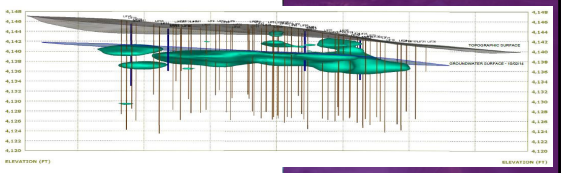
Successful PRB Delivery

- **Key Elements:**
  - **Site Conditions & Screening**
  - **Conceptual Design**
  - **Final Design**
  - **Construction**
  - **Performance Monitoring**
- **Key Functional Requirements:**
  - **Hydraulic Performance**
  - **Contaminant Treatment Performance**



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Case Study

- Major Infrastructure Project – Brownfield Redevelopment
  - RSC via RA lead to CPU.
  - Target potential offsite migration of TCE and cVOCs.
- Barrier System required as part of CPU.
  - 2018 – Full-Scale Barrier System Conceptual Design and Tender
    - Full thickness ZVI barrier – 400+ m Length
- Vertex & QM:
  - Data Gaps & Design Optimization
  - Final Design
  - Installation (2018- hiatus - 2021)

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PRB Installation

- ZVI PRB construction balancing act:
  - Retain key functional requirements.
  - Optimize mass loading based on variable plume flux and treatment requirements.
  - Costs
  - Feasibility
- Available construction techniques?

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PRB Installation:

Method	Relative Mobilization Cost	Approx. Max. Depth (m)	Relative Cost	Notes
Direct Placement	Low	6*	Very low	Wide (>1.3 m), dewatering issues, safety, very depth limited
Trench Box	Low	6*	Low	Wide (>1.3 m), dewatering issues, very depth limited
Sheet & Shore	Medium	12	High	Slow, possible dewatering issues, smearing, vibrocompaction
Caissons	Medium	>12**	High	Slow, wastage in overlapping columns, smearing, vibrocompaction
Continuous Trencher	High	12*	Moderate	Limited soil types (refusal common), limited width, difficult to verify key.
Biopolymer Trench	Medium	>25	Moderate	Slurry requires expert contractor, slower than trencher in shallow (<12 m) sandy soil.
Injection	Low/Medium	>40	Low to Moderate	Gaps in coverage, repeated applications (Includes fracturing, passive wells, direct push)
Jetting/jet grouting	Low/Medium	30	Very High	Potential gaps in coverage
Soil Mixing	Very High	30	High	High cost. Stuck with native soil (grain size, etc.)
Mandrels, Vibrating Beams	Medium	30	Low to Moderate	Gaps in coverage, extremely thin (0.15 m!), QA/QC difficult. Smearing, vibrocompaction. No spoils, though.

* Benching (digging down to create a work platform) extends depth

**Hypothetically, very large caissons and very large depths are possible. Most experience, however, is with caissons <2.5 m in diameter to depths < 12 m

Source: QM/QM Staff Experience, also referencing Day 1999, ETI 2003 & USACE 1997

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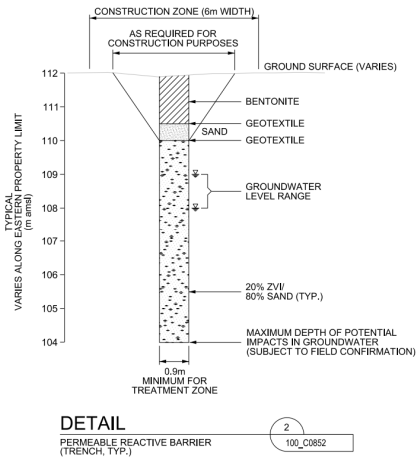
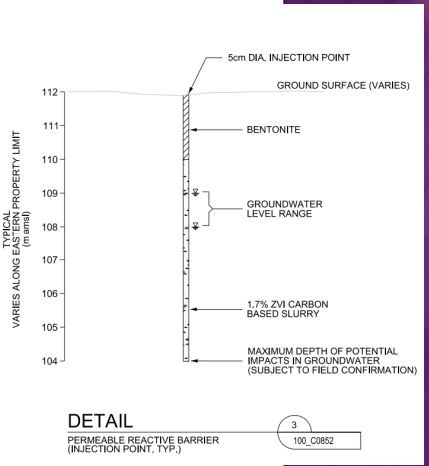
PRB Installation

- **Injection & Trench based installation - Optimization!**





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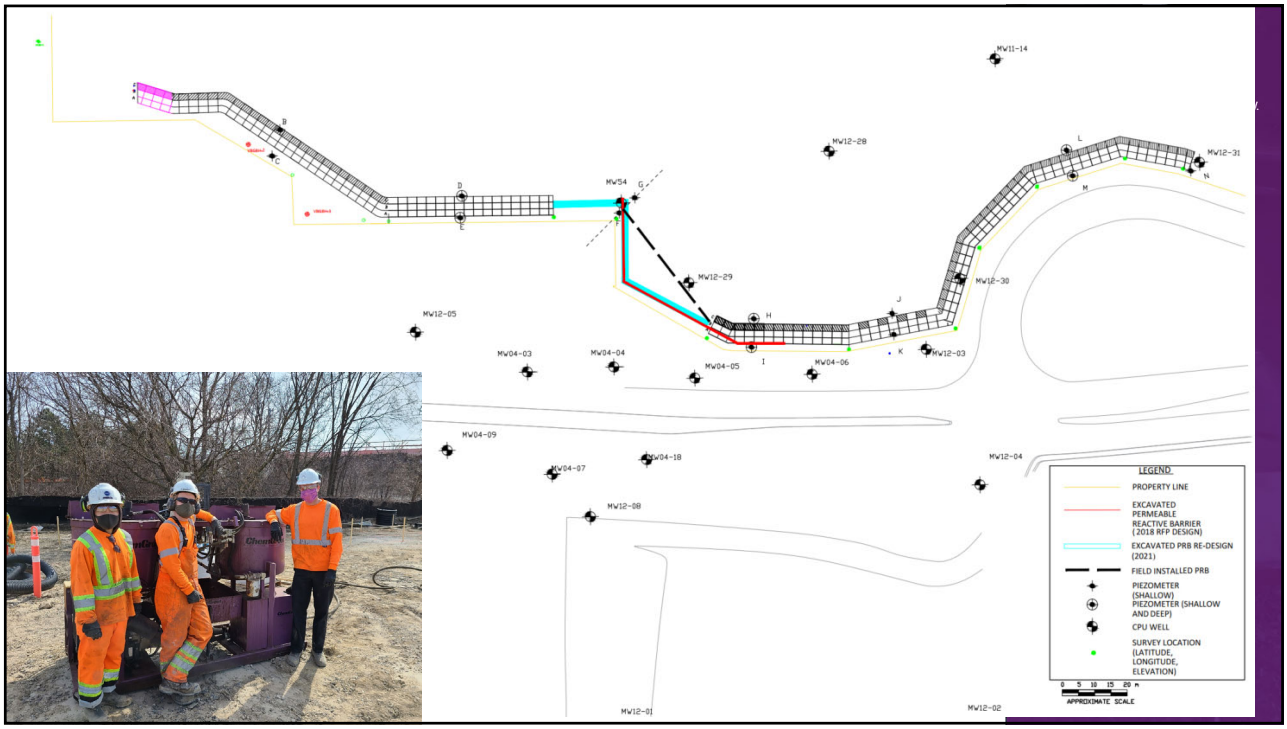

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PRB Installation - Trench

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- Original concept – Standard Approach:
  - Guar Slurry - good fit but limitations.
- Innovative approach:
  - Target – effective placement of a shallow PRB in an incompetent soil system.
    - Low cost of direct placement/trench box.
    - Precision, control, and stability of caissons.
  - QM designed and delivered a novel modular hybrid system for PRB installation.

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PRB Installation - Trench

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PRB Installation - Trench

- Ground conditions and humbling lessons in the art of pivoting.
  - Binding & production challenges BUT require the form for quality.
  - Options?
- A new, new technique is born:
  - Rectangular caissons and sheet piles used to maintain form and enable modular PRB install.
  - Trench box system to manage unstable soils.
  - “Open Form - Modified Caisson – Trench Box – Sheet Pile Installation System”? (OFMCTBSPIS)

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PRB Installation - Trench

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PRB Installation – Field QA/QC

- Quality Control & Assurance:
  - Precision field measurements.
  - Materials management process.
  - Sampling – mix ratio; % m/m installed.
  - Bore log and sample collection.
- Key to project success.
  - Translate design parameters to the field.

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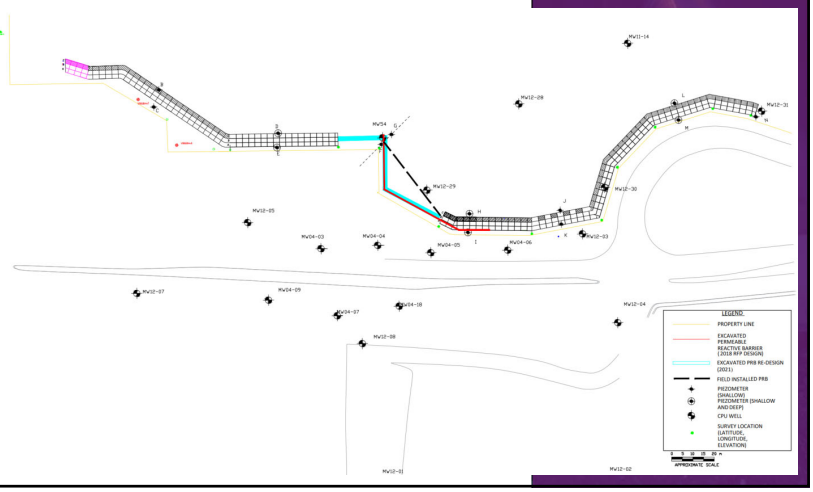
PRB Installation - Totals

- Injection:
  - Approx. 350 m
  - 315 locations
  - 277,000 Kg of ZVI
- Trenching:
  - Approx. 65m
  - 160,000 kg of ZVI



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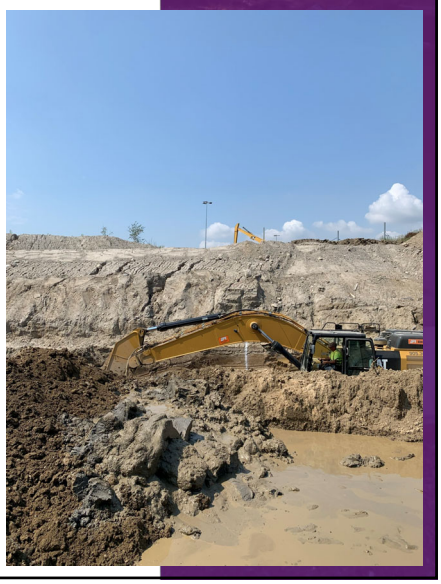
Keys to PRB Success

- Construction is a key element!
  - Innovate strategically – manage the scale and scope of risks.
  - Be prepared to pivot.
    - Plan A, B, C…
  - Focus on functional requirements.
    - Design & Delivery - QA/QC
  - Teamwork makes the dreamwork.
  - Experience matters.



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Thank you
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