

Optimizing Remediation in Fractured and Weathered Bedrock: Lessons from Successful Injection Projects

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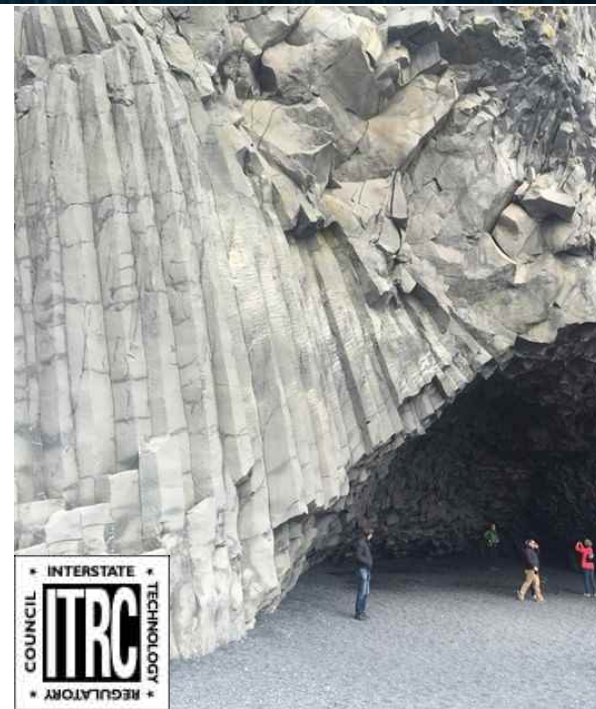
Acknowledgements

- Scott Pittenger (ISOTEC)
- Curt Weeden, PG (AECOM)
- Paul Trudell (WSP)



Bedrock Remediation Challenges

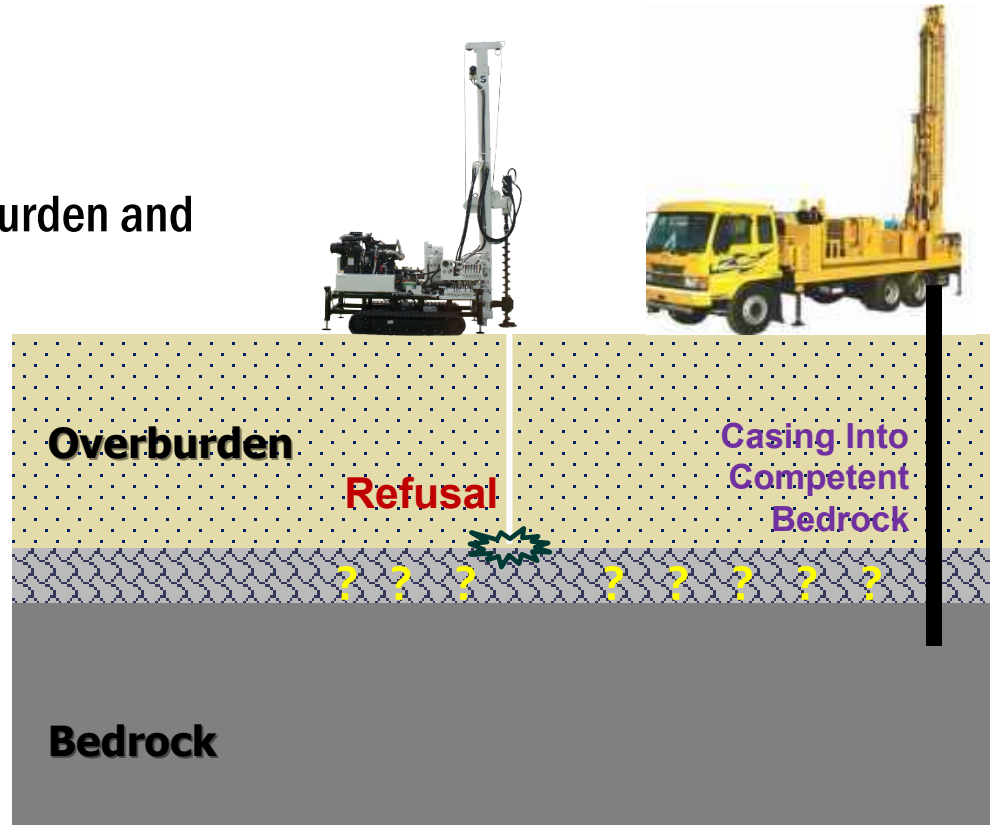
- Incomplete understanding of groundwater flow and contaminant transport
- Difficult to inject
- Cost of investigation / remediation
- Unrealistic remedial objectives



Characterization and Remediation of Fractured Rock (FracRx-1) <http://fracturedRX-1.itrcweb.org>

Site Investigation

- Weathered Bedrock
- Rarely a sharp transition between overburden and competent bedrock

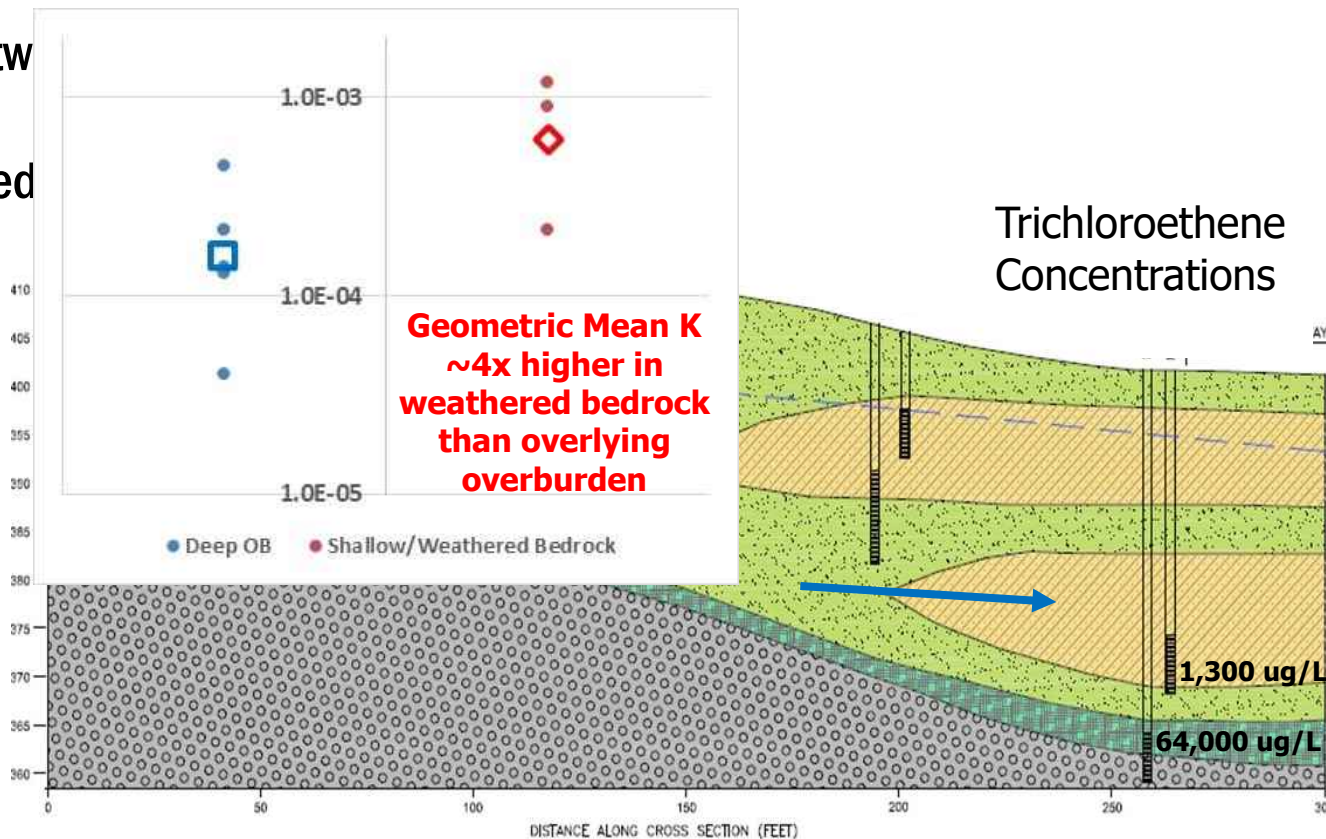


Weathered Bedrock

- Hydrogeology differs between overburden, weathered bedrock, & bedrock

- porosity
- hydraulic conductivity
- contaminant concentrations

- Contaminant Flux



ISOTEC
REMEDIATION
TECHNOLOGIES

-
- A photograph of an open wooden crate. Inside, a rolled-up rug with a grey and blue pattern is visible on the right side. Several long, thin wooden planks are laid out horizontally across the crate. A small black object, possibly a pen or a small tool, is lying on one of the planks on the left side. The crate is made of light-colored wood and is placed on a dark, textured surface.

Augers grinding significantly – loud chatter at 14'. Stopped advance – possibly top of rock at 14' bgs or shallower (10' - 14')

Site 1 – (MIS) Interpretation of Data

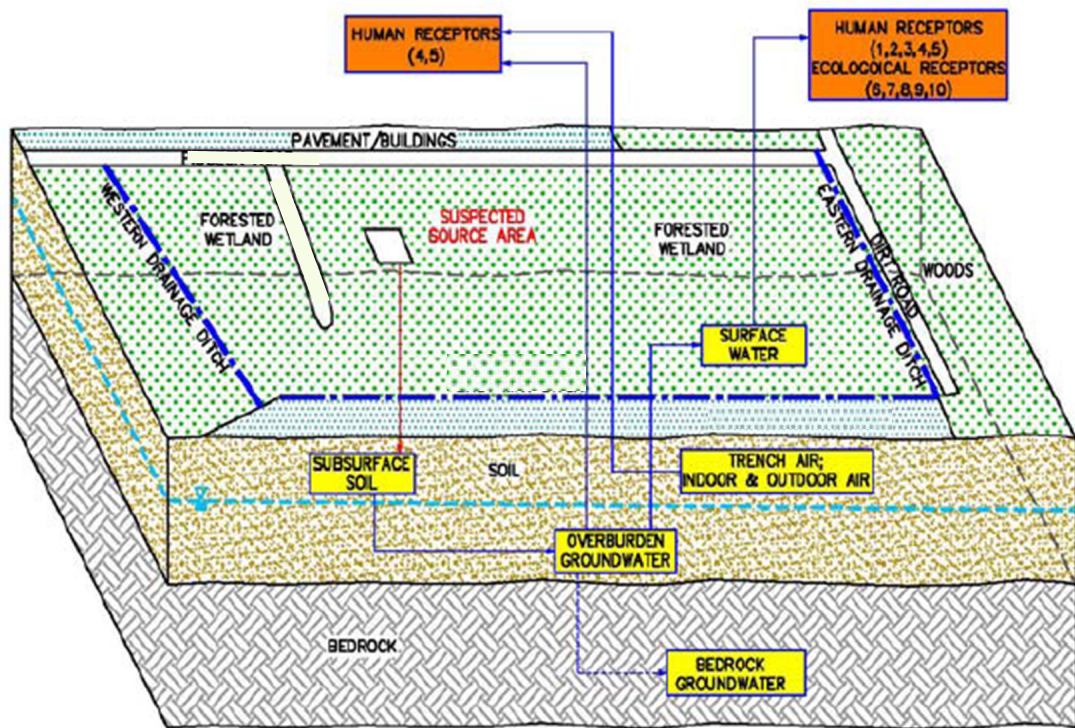
- RI evaluated the bedrock/overburden interface
 - Upper bedrock transmissivity closer to unconsolidated deposits than bedrock
 - Thickness of the weathered bedrock zone ranges from 0 to 6 feet
- “the very shallow bedrock does not have higher K values than the deeper shallow bedrock leads to the conclusion that preferred groundwater flow along a highly weathered/ fractured zone on the bedrock surface is not a significant transport mechanism at the Site.”
 - Most monitoring wells are 10-foot screens
 - Average shallow bedrock K “skewed slightly on the low side” and average deeper bedrock K “skewed on the high side”
- Borehole Geophysics
 - likely transmissive fracture zone just below the well casing, at a depth of between 12 and 16 feet
 - likely transmissive fractures encountered at 19 feet

Weathered Bedrock?

- Feasibility Study evaluated alternatives for Overburden and Bedrock
- Record of Decision

TTZ	Targeted Depth Interval
Overburden	2 – 17 feet bgs
Bedrock	17 – 37 feet bgs

- Overburden Source Area Enhanced Bioremediation
- Bedrock Source Area Enhanced Bioremediation
- Two Mulch PRBs



POTENTIAL RECEPTORS
 POTENTIALLY AFFECTED MEDIA

RED TEXT/ARROWS = CONTAMINANT SOURCE/DISCHARGE ROUTE
 BLUE ARROWS = FATE AND TRANSPORT ROUTE

SURFACE WATER FEATURE (DRAINAGE DITCH)
 GROUNDWATER ELEVATION

Site 1 – Remedial Design

- Recognition that overburden and bedrock not fully delineated for VOCs
- Sonic drilling utilized as part of characterization
- Observed significant difference in depth between previous refusal (auger or direct push) and top of competent bedrock
 - 3 – 10+ feet



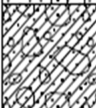
Site 1 – Remediation

**Till = low permeability
(K~10-5 cm/s)**

Weathered Bedrock

- Sand seam
- Driller observed change
- ~3 feet thick

**Observed change to
fractured bedrock**

8	10	0.2 / 3.7 / 0		SP-SM	sand, and silt with 10% fine gravel, SP-SM, loose, moist to wet, poorly graded, Grayish light brown, slightly cohesive, angular gravel with a couple of cobbles.
			8.50		
10				TILL	TILL, Well graded till, slightly cohesive. Clay to cobble. Light brownish gray.
			9.60		
12	1	0		BEDROCK	IGNEOUS, Weathered bedrock. Possible sand seam. Driller reports change in density at 11 feet. Ran core barrel dry to 11 feet then used water to core 11-15 feet.
					12.50
14	2.5	NS		BEDROCK	IGNEOUS, Highly fractured Dedham Granite; black, white, and pink. Few to little stained surfaces on angular rock fragments.
Remarks: Boring Terminated (ft): 15 Weathered Bedrock 9.6' Competent 12.5?					

Site 1 – Remedial Design – Mulch PRBs

- ROD Remedy – Mulch PRB to ~15' bgs
- Monitoring wells installed with screens in overburden & weathered bedrock
- Depth to bedrock
 - 3 – 6 ft on west side
 - 8 – 12 ft on east side
- Depth to groundwater
 - 5.5 – 7 ft in summer
 - 3 – 4 ft in spring

MW10-601S	3.0 - 6.0
Date:	5/17/2016
PCE	145
TCE	0.500U
VC	0.500U
cis-DCE	0.500U
TOC	4
MW10-601BR	8.5 - 13.5
Date:	5/17/2016
PCE	454
TCE	2.50U
VC	2.50U
cis-DCE	2.50U
TOC	0.67J

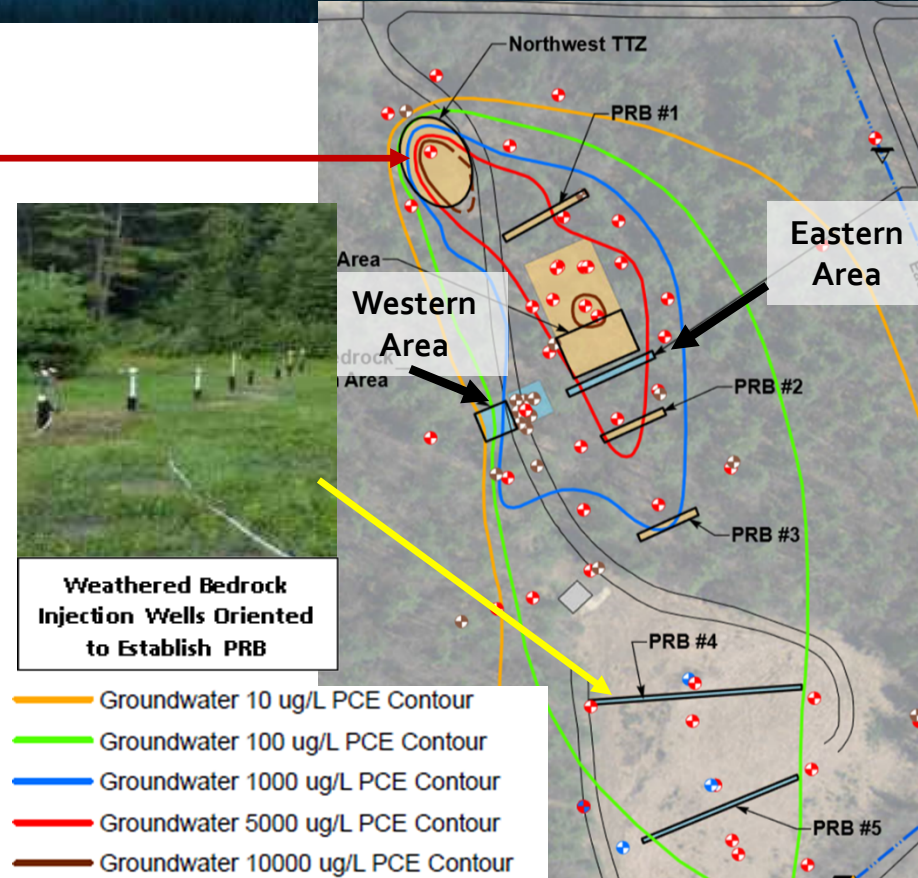
Overburden Well
Screen 3-6 ft bgs

Weathered Bedrock Well
Screen 8.5-13.5 ft bgs

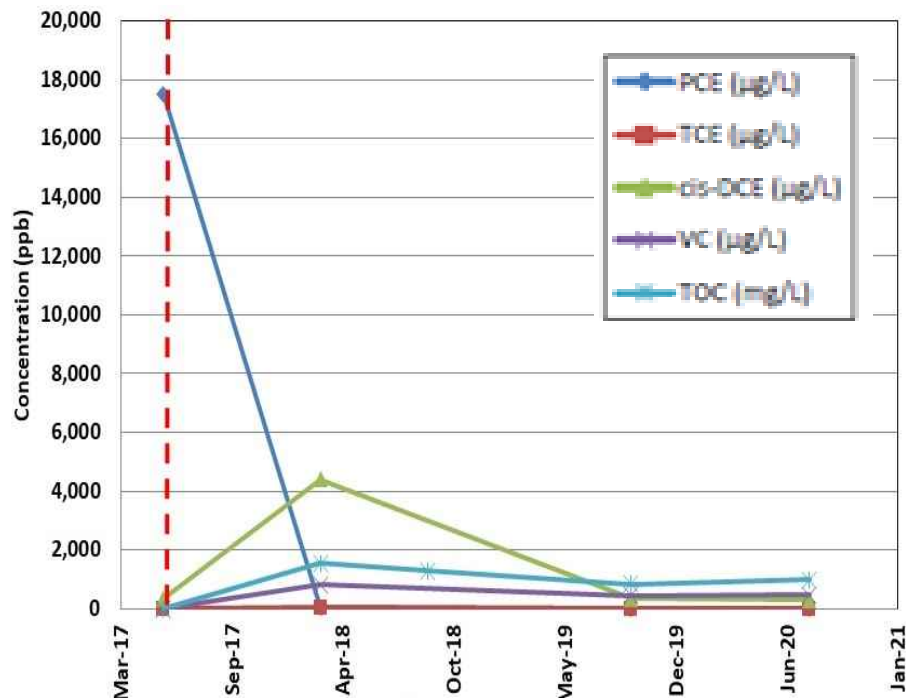
PCE RG 370 ppb

Site 1 – RemedY

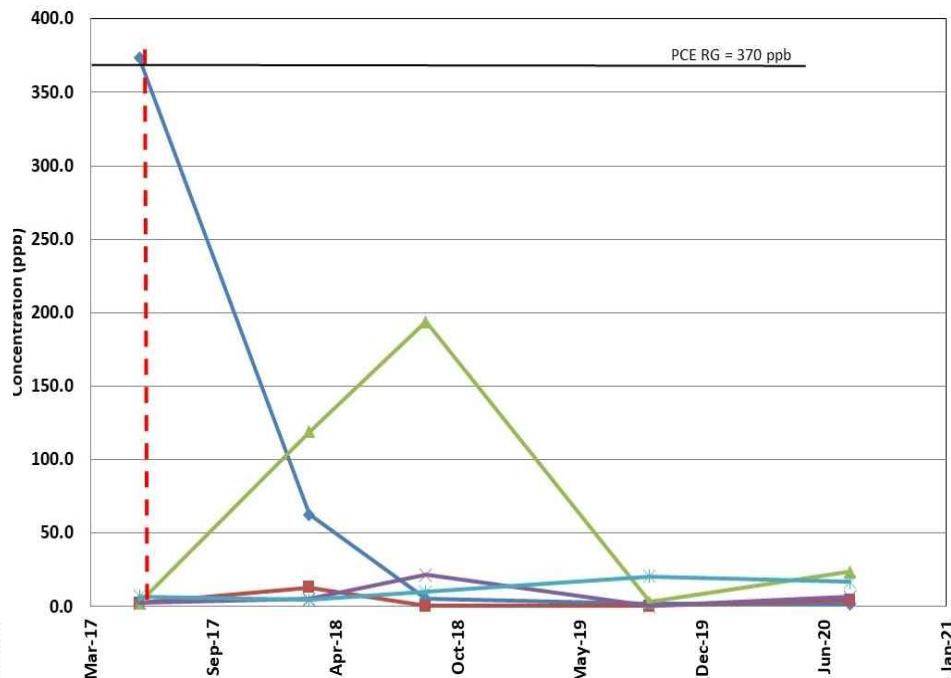
- **Source Area: injection point grids**
 - Northwest TTZ not included in RI/FS/ROD
- **2 overburden PRBs**
- **3 weathered bedrock PRBs**
- **Overburden: 74 DPT injection points**
 - Small droplet EVO for silt and till
- **Weathered Bedrock: 51 injection wells**
 - Installed by Sonic drilling
 - Large droplet EVO



Site 1 – ReSULTS



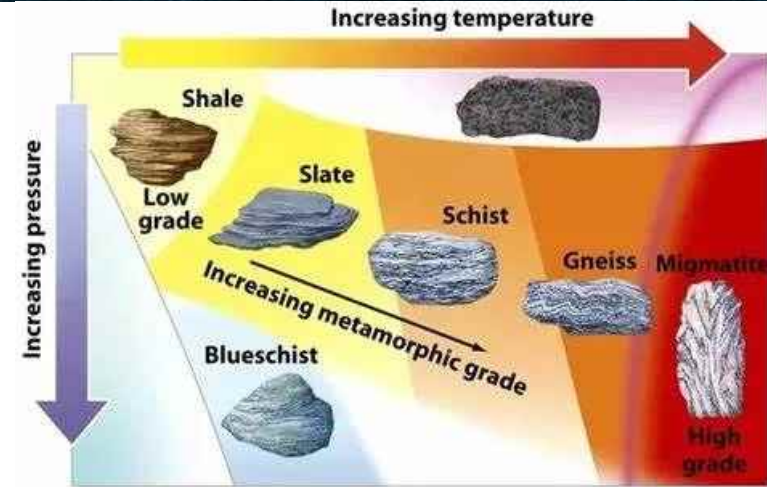
Eastern Area WBR Monitoring Well



Downgradient of WBR PRB

Site 2 – Site Setting

- TCE primary contaminant
 - 142,000 ug/L in 2018
 - Likely residual DNAPL
- Historic MPE system
 - Extracted from bedrock & weathered bedrock
- Pump & Treat operating (3 wells)
- Bedrock: schist (metamorphic)
 - Depth to competent bedrock varies from 13-22 ft bgs
- Objective: accelerate treatment to shorten pump and treat system lifetime

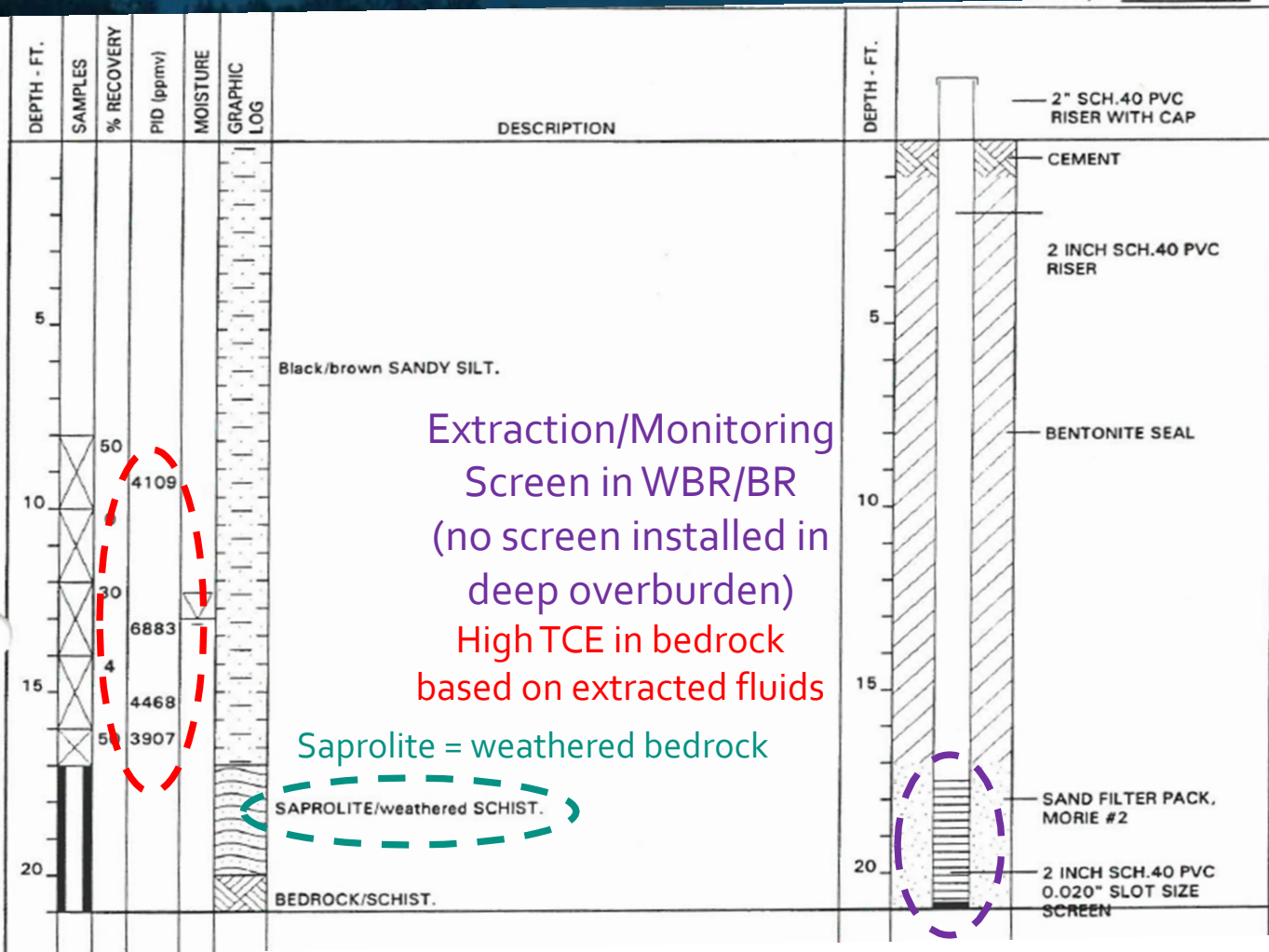


<https://geologyscience.com/rocks/metamorphic-rocks/schist/>

Site 2

Mid-1990s boring log
from DPE well
installation

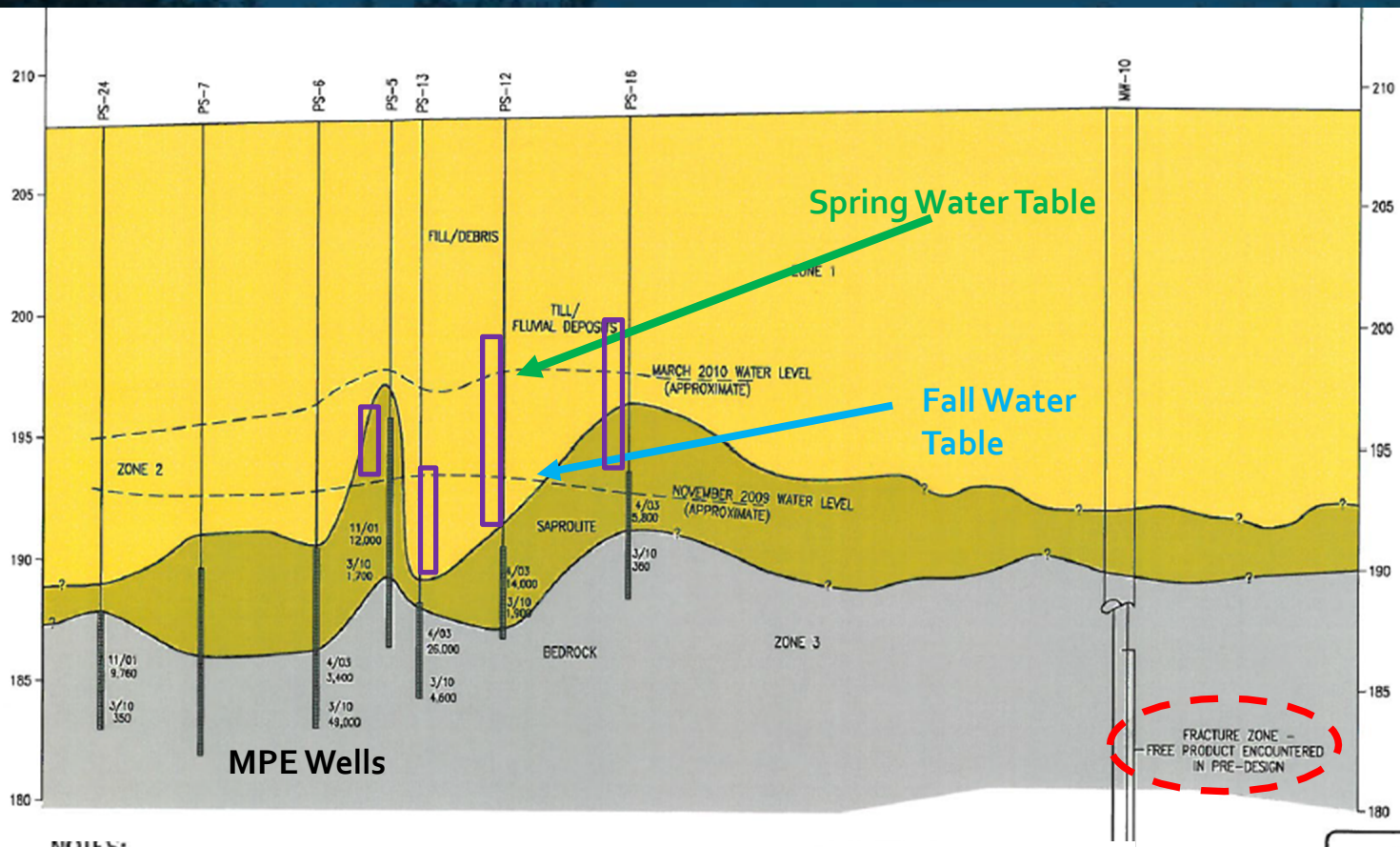
Very high PID readings
(overburden)



Site 2

WBR
~ 2- 7 ft
thick

PID
>1000 ppmv



NOTES:
SOFT BEDROCK, SCHIST, MICA, AND CLAYED SILT WAS CLASSIFIED AS SAPROLITE.
SAND AND SILTY-SAND WAS CLASSIFIED AS FILL.

Site 2 – Pilot TEST

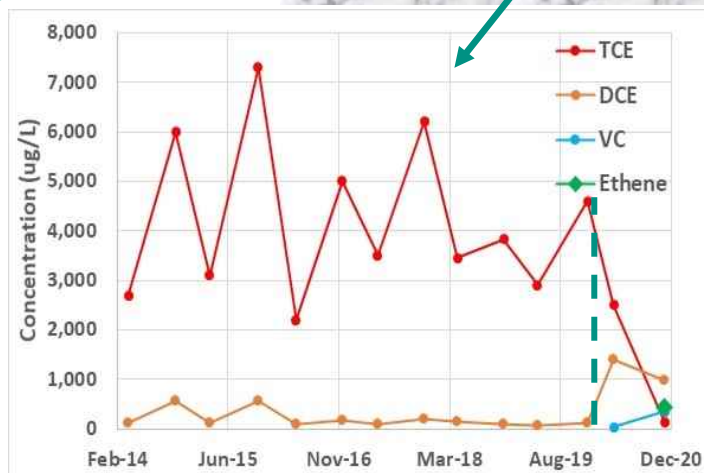
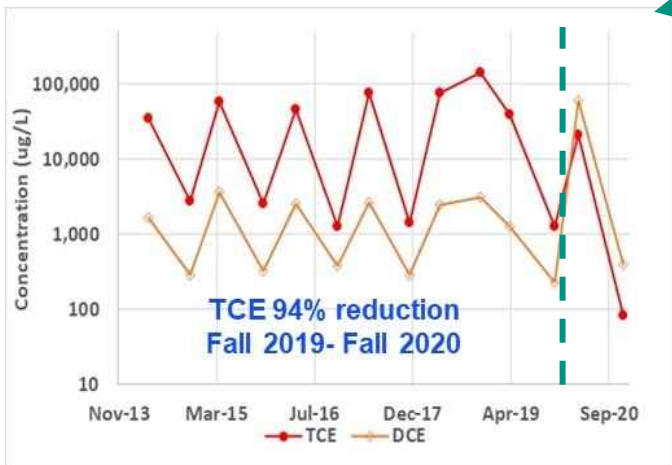
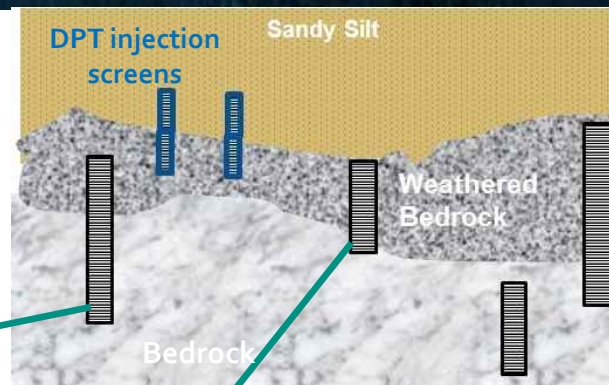
- **Objectives:**
 - Can DPT points be advanced into weathered bedrock?
 - Can remediation solutions be injected into weathered bedrock?
 - Will remediation of deep overburden improve bedrock groundwater?
 - Perform pilot test with limited budget

- **Pilot Test Details:**
 - 3 injection points
 - Advance to refusal (identify overburden-weathered bedrock interface)
 - SRS®-Z (EVO + ZVI) + bioaugmentation

Site 2 – Site Setting

- DPT advanced 0.5 to 2' into WBR

1. Expose 2' of screen to focus injection to weathered bedrock
2. Expose entire 5' of screen to injection at overburden-weathered bedrock interface



**98% reduction in
TCE 12 months
post-injection in
Extraction Well
(MW-10) ~60' away**

SUMMARY

- Remediation CAN be successful in bedrock
- Design remediation based on CSM
 - Where is the contamination? Where is it traveling?
 - What are proposed amendments?
 - How do geologic features impact above questions?
- Objective: maximize contact between contaminants and reagents
- Weathered bedrock is an important interval for contaminant transport
- Remediation can be targeted at weathered bedrock zone



Thank You



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