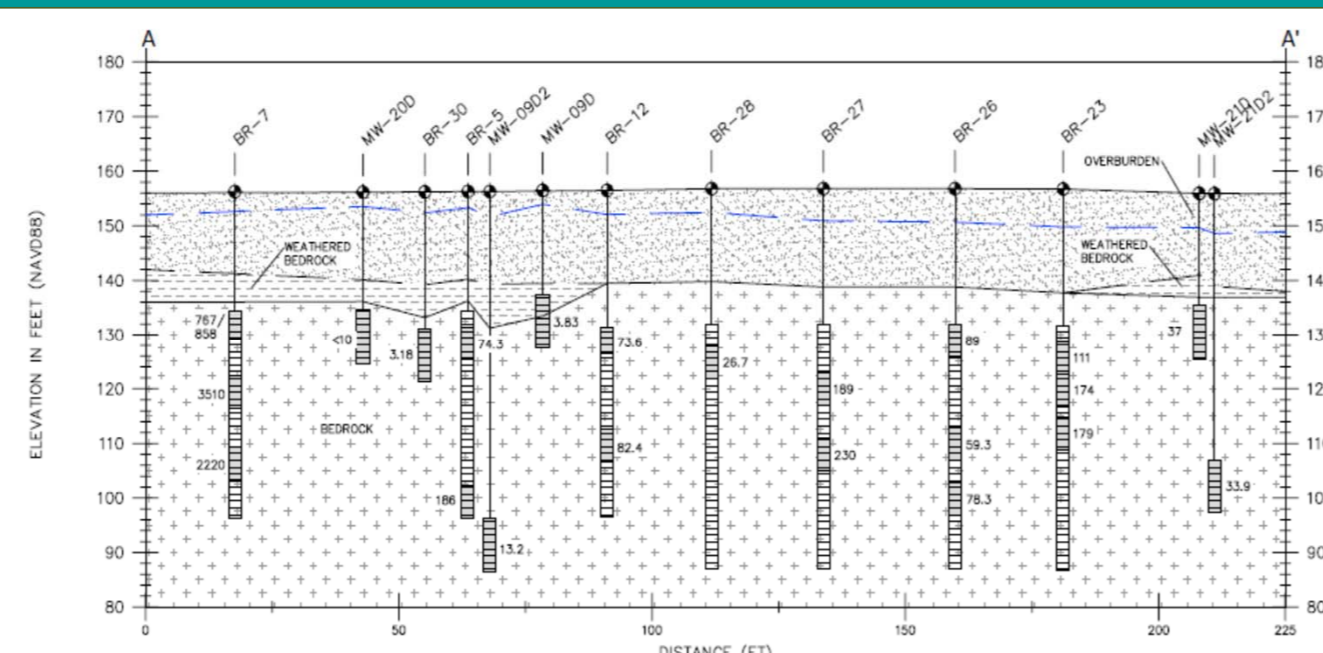


# Integrating Geologic Investigations into Remedial Design to Enhance Amendment Delivery to Solvents in Bedrock

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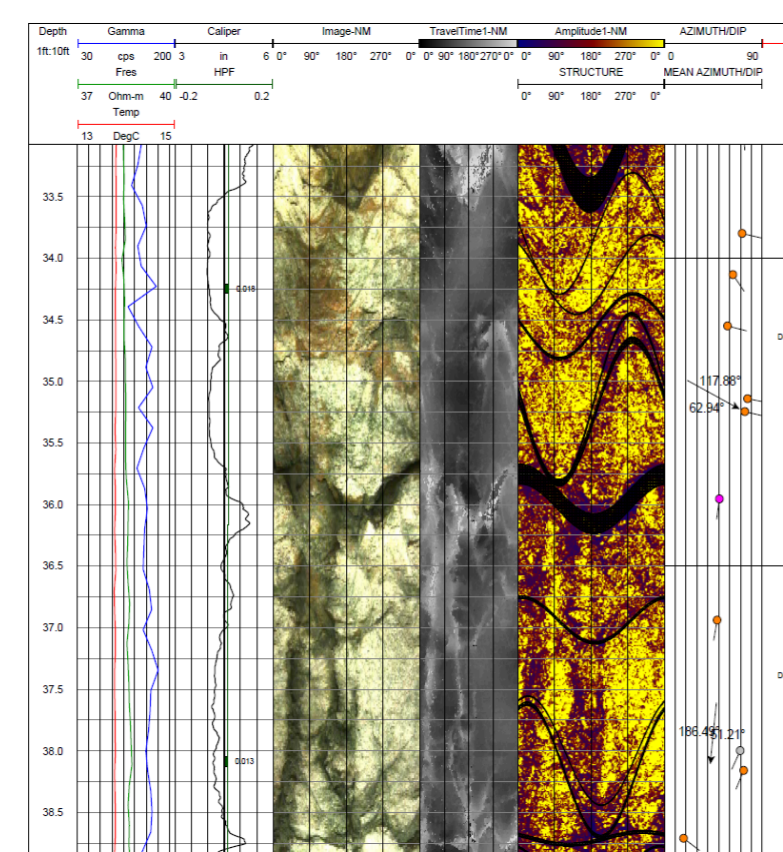
## Site 1

- Former Industrial Site where UST leaked resulting in PCE in overburden and bedrock groundwater
- Granite bedrock
- ISCO (Fenton's Reagent) performed in 2001-2002 (31 open boreholes) with mixed results
- Record of Decision selected Enhanced Reductive Dechlorination for overburden and bedrock



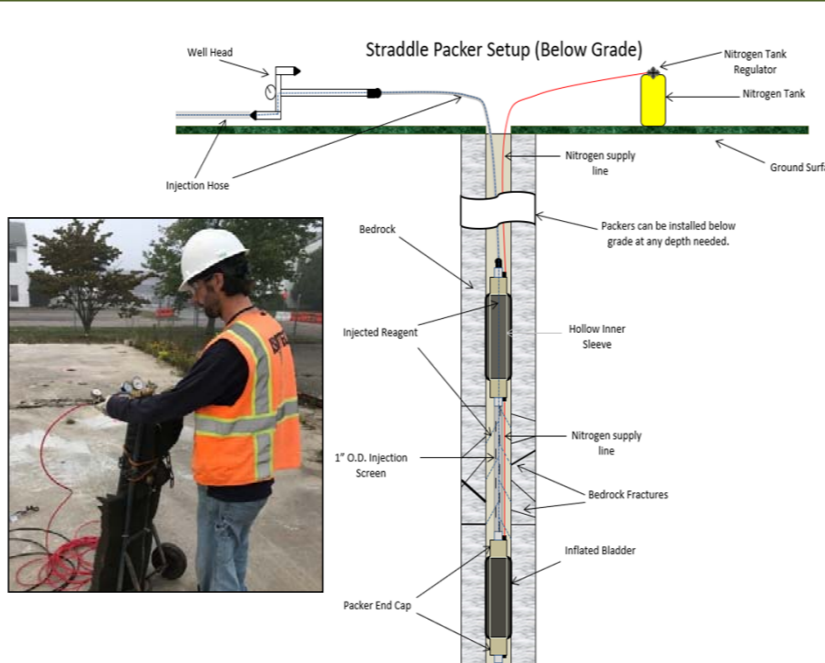
## Remedial Design Bedrock Investigations

- Previously only 9 of 31 open boreholes had geophysical logs
- Remedial Design Investigation conducted borehole geophysics at all boreholes
  - Caliper, fluid temperature, fluid resistivity, natural gamma, optical and acoustic televiwer, and heat pulse flow meter
- Identified water bearing fracture zones
- Performed packer sampling to measure PCE in fractures
- Performed low flow pump tests for 6-8 hours at boreholes to assess interconnectivity



## Bioremediation Injections

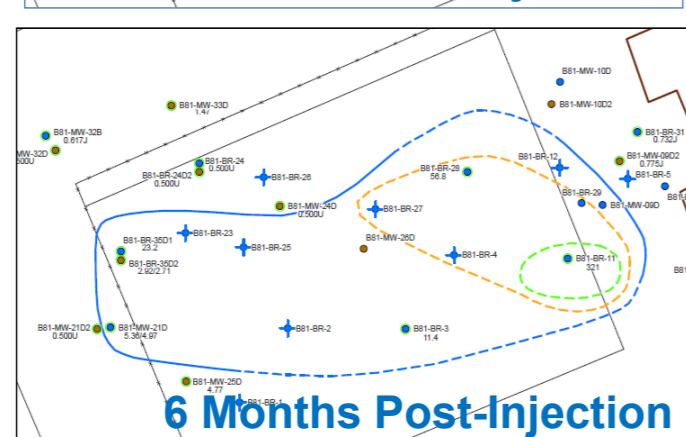
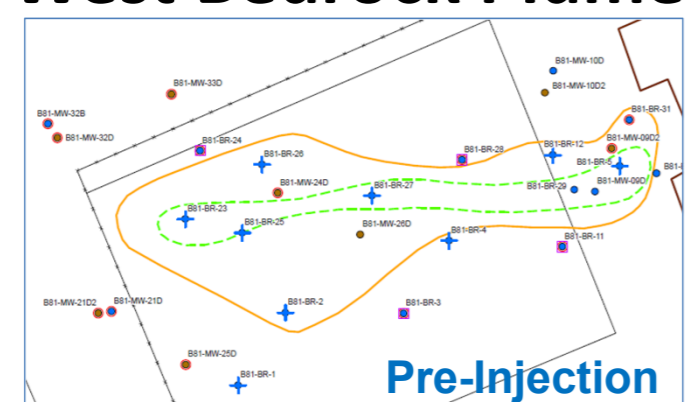
- Inflatable packers used to target fractures 21 to 120 feet bgs
- 7,170 gallons of EVO-lactate, 1,560 gallons of anaerobic water and 37 liters of DHC (same total volume as 2 ISCO events)
- Large droplet EVO (SRS®-FRL) selected for bedrock
- Inject into 4 boreholes simultaneously and each injection point received design volume



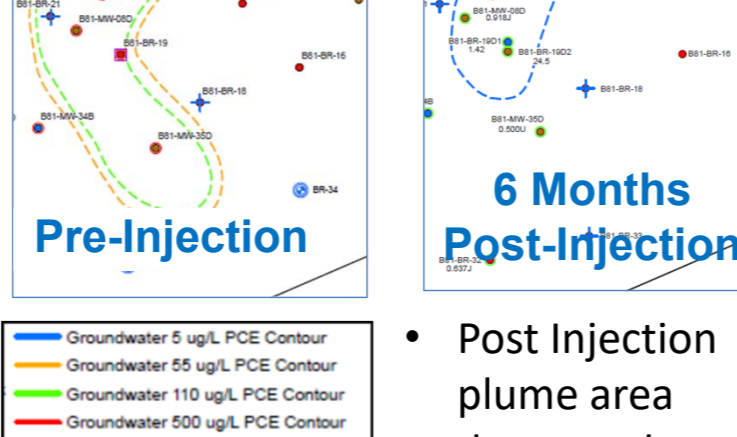
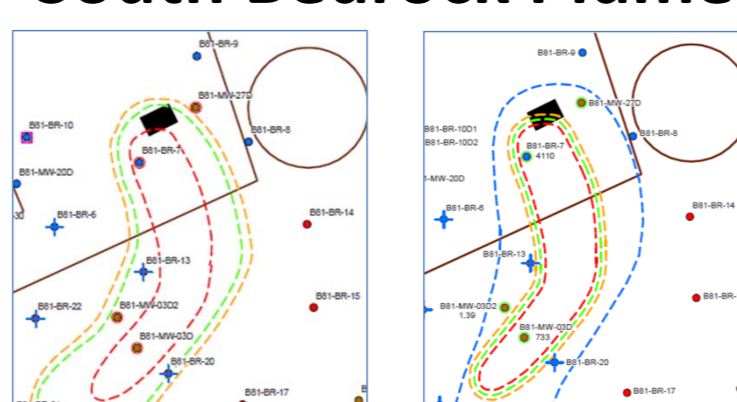
## Remedial Design

- Enhanced Reductive Dechlorination
- Emulsified Vegetable Oil with added Sodium Lactate for fast-release and slow-release substrates and Bioaugmentation
- Added and moved treatment zones based on orientation of revised plumes
  - Record of Decision missed South Plume entirely
- 17 Open Boreholes for Injection
- Injection volumes specified for each injection borehole and each fracture zone

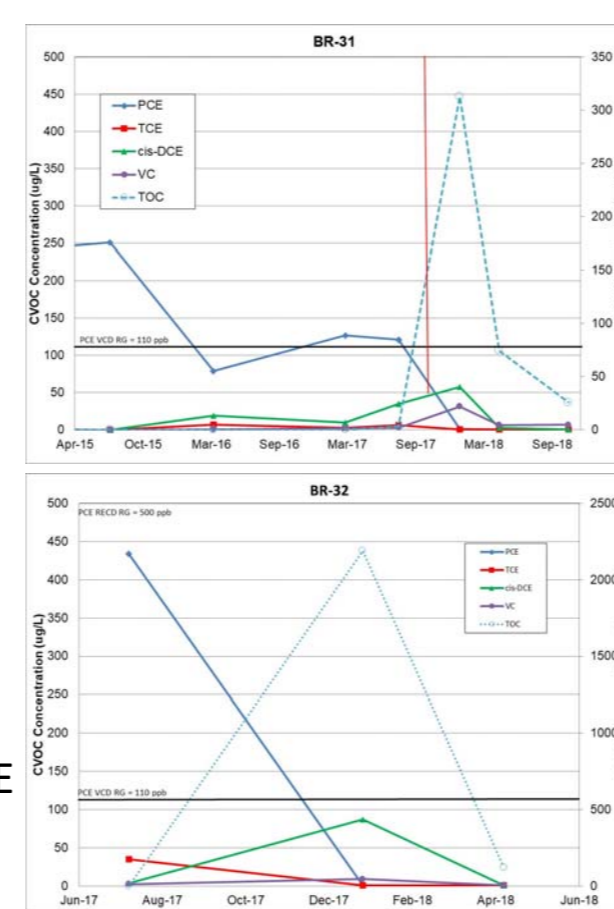
### West Bedrock Plume



### South Bedrock Plume

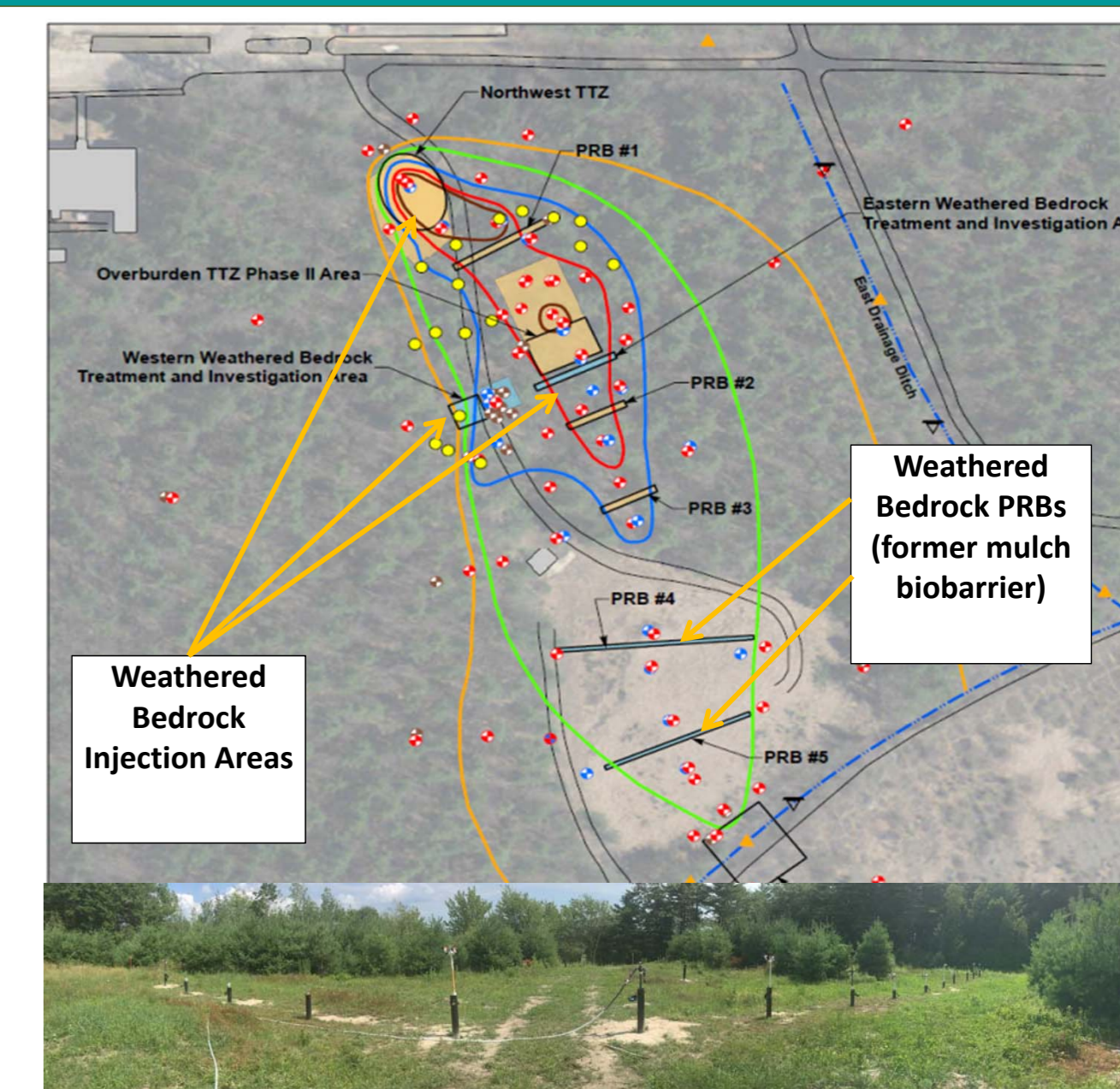


- Post Injection PCE plume area decreased



## Site 2

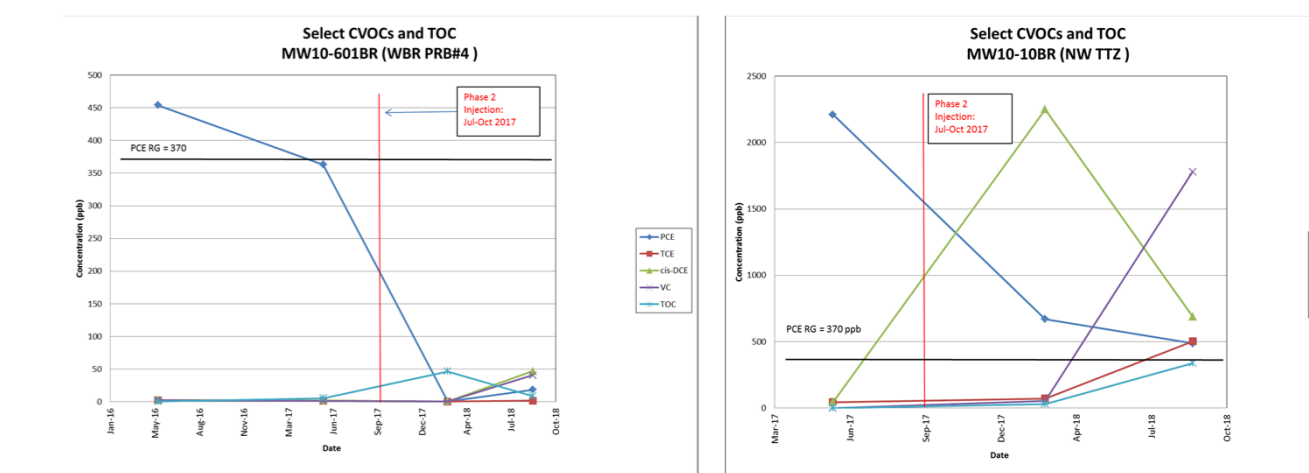
- Multi-acre PCE plume beneath heavily wooded area with unknown PCE release(s)
- ROD selected Enhanced Reductive Dechlorination for overburden and bedrock
- Site was not well characterized prior to Remedial Design
  - PCE source areas not identified or delineated
  - Geologic characterization
  - Thick weathered bedrock zone identified based on significant depth differential between direct push point refusal (bedrock) and top of competent bedrock (5-10+ ft)
- Mulch-based PRBs proposed in ROD were replaced with injection-based PRBs based on
  - Thin overburden with limited saturated thickness
  - Thick zone of weathered bedrock (5+ft)
  - PCE below Remedial Goals in overburden
  - PCE above Remedial Goals in weathered bedrock
- Change in biobarrier approach and differences between refusal prompted investigation of weathered bedrock
  - 15 weathered bedrock monitoring wells
  - 18 weathered bedrock injection wells in Target Treatment Areas
  - 33 weathered bedrock injection wells in the former mulch-based PRB area
  - Screen interval was selected based on geologic field observations



Downgradient PRB Injection Wells

## Bioremediation Injections

- 6,500 gallons of EVO-lactate, 1,200 gallons of anaerobic water and 30 liters of DHC
- Large droplet EVO (SRS®-FRL) selected for weathered bedrock
- Injection into 4-5 injection points simultaneously
- Injections performed from inside a mobile box truck to allow versatility across multi-acre plume area
- ISOTEC sequenced injections to cycle between different areas and between overburden and weathered bedrock injection points to minimize groundwater mounding
- State law required that groundwater was not to mound within 2 feet of ground surface



- Preliminary indications suggest ERD impacted deeper bedrock
- PCE concentration reductions reduced by >90% in weathered bedrock monitoring wells

## Overview

- Contamination in bedrock is one of the most challenging issues facing groundwater remediation practitioners.
- Bedrock characterization greatly improves remediation design and amendment delivery