Department of Environment & Conservation

High Resolution Site Characterization in Fractured Bedrock

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TN Department of Environment & Conservation

Case Study: Washburn Market

Background

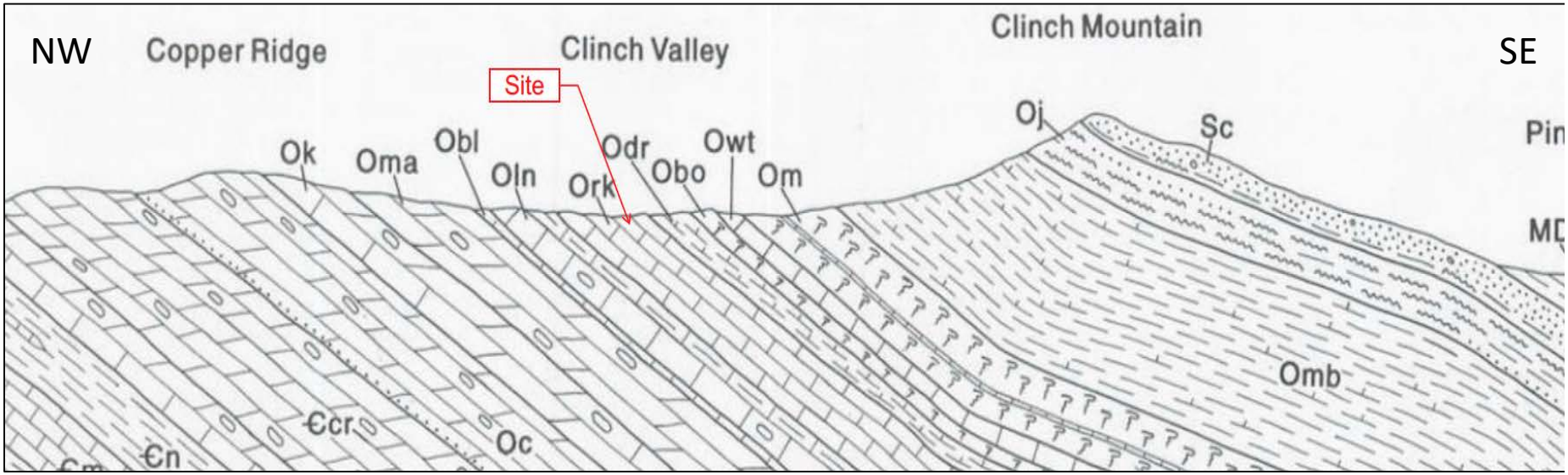
Small grocery store in rural East Tennessee

- 4 USTs installed in 1980 / Removed 2006
- Release reported August 9, 1996
- Receptors: Multiple drinking water wells
  - 4 DWWs impacted / connected to public water

Background (continued)

Site Geology

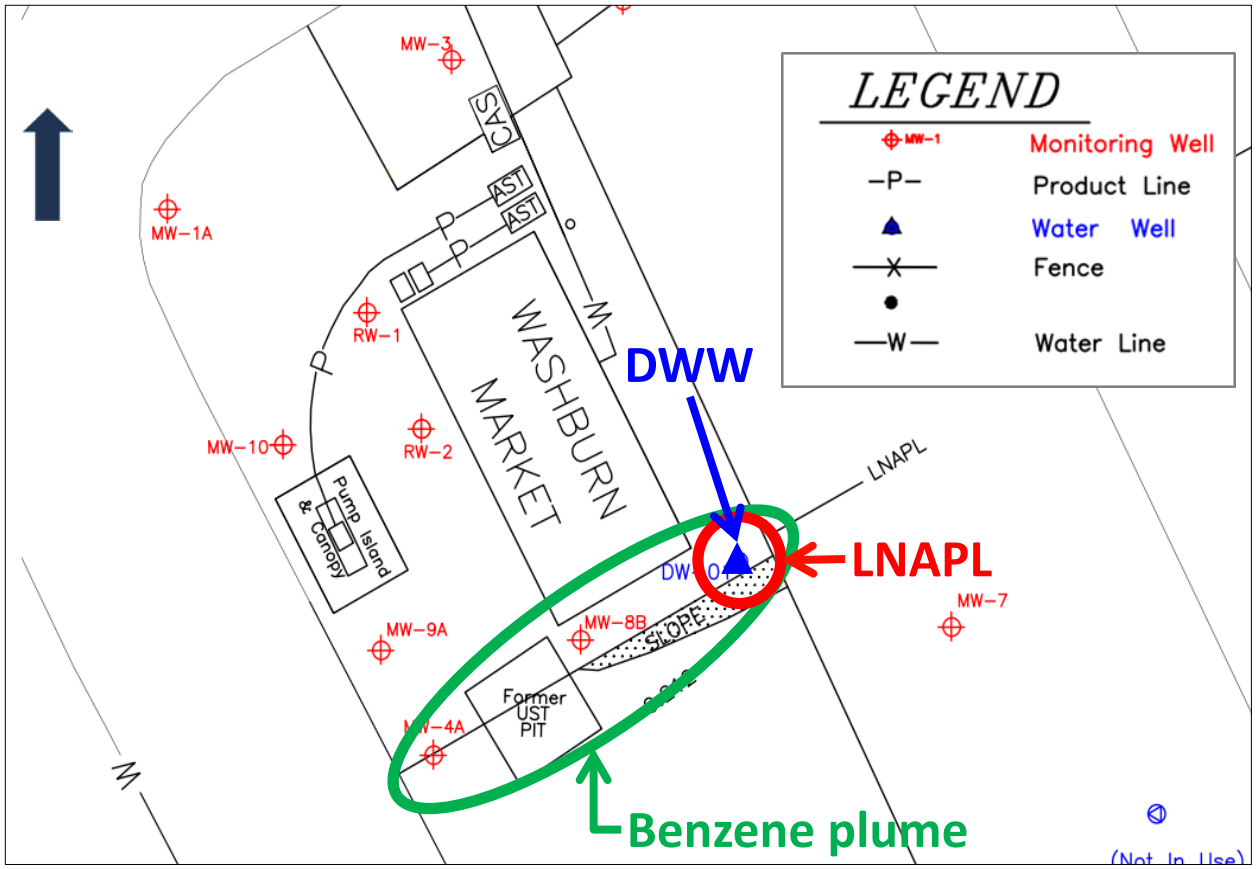
- Valley and Ridge Physiographic Province
- Plastic silt and clay (10’ to 29’ thick) overlying limestone
- Groundwater (12’ to 27’) in fractured limestone



Background (continued)

Remedial Efforts To-Date

- FPR/MEME followed by Pump and Treat: 1996-2008
- Dual Phase Extraction (LRP/High Vac): 2009-2017
- LNAPL and contaminant rebound when CAS turned off



- Dissolved Benzene Plume

  SSCL = 0.212 mg/L

- LNAPL persistence in on-site DWW

Change of Course 2017

- In 2016-2017, the Division began investigating non-traditional remedial technologies to push cases to closure
  - Focus on legacy cases which have been lingering in and out of active remediation more than 2 years

- Remedial Objectives
  - Mitigate LNAPL in the onsite DWW
  - Prevent migration to nearby DWWs
  - Reduce COCs to < SSCLs quickly

Many Options…No Guarantees!

How do we decrease the uncertainty?

Remedial Technology Selected

- Trap and Treat® BOS200®
  - Activated carbon with blend of bacteria
  - Quick (immediate reduction of COCs)
  - Long term biodegradation

Trap & Treat® BOS 200®

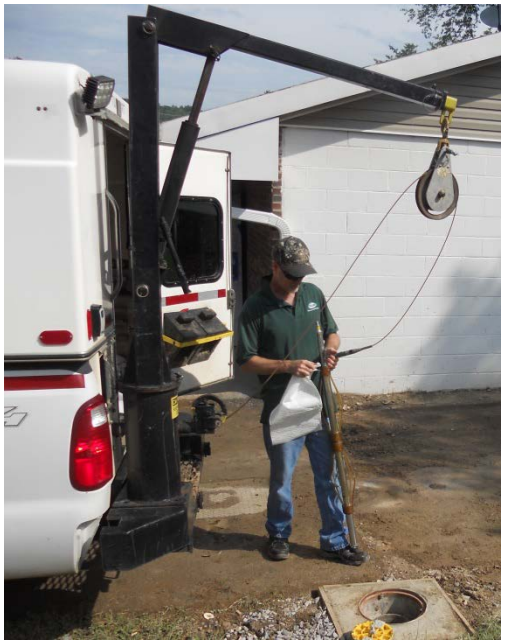
- Keys to Effective Remediation
  - Contaminant Mass
  - Distribution
  - Contact

- Issues / Data Gaps
  - Limited soil sampling
  - Lack of detailed boring logs
  - Cased MW's with long screened intervals
  - Soil cleanup levels contribute to GW > SSCLs

TN

Remedial Design Characterization (RDC)

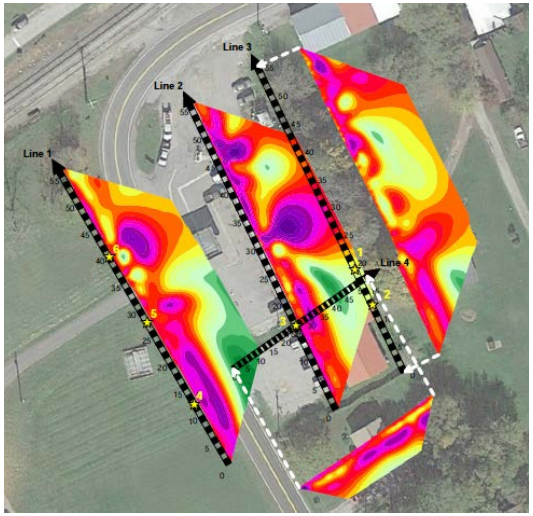
- Surface Geophysics
- Confirmatory Soil Sampling
- Aquifer Characterization
  - Sonic Drilling / Rock Coring
  - New Well Installation
  - Downhole Geophysics/Imaging
  - Groundwater Characterization

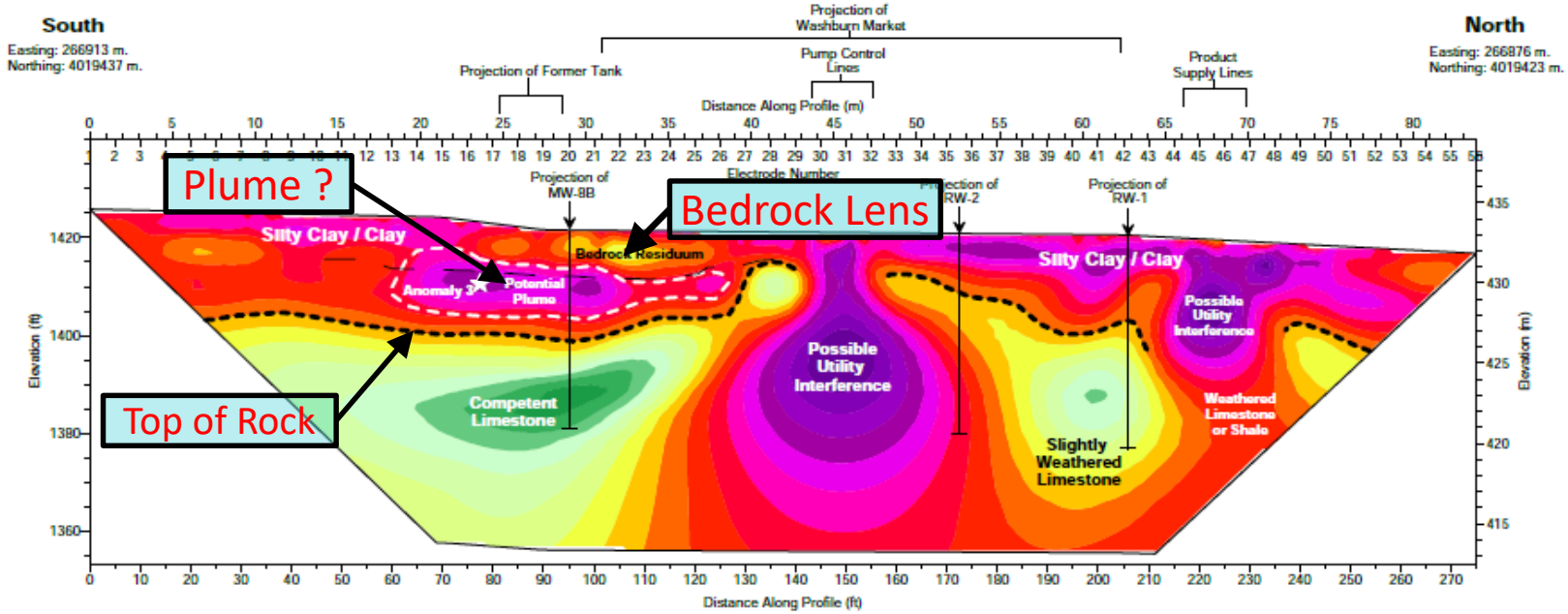


RDC: 2D Electrical Resistivity Imaging

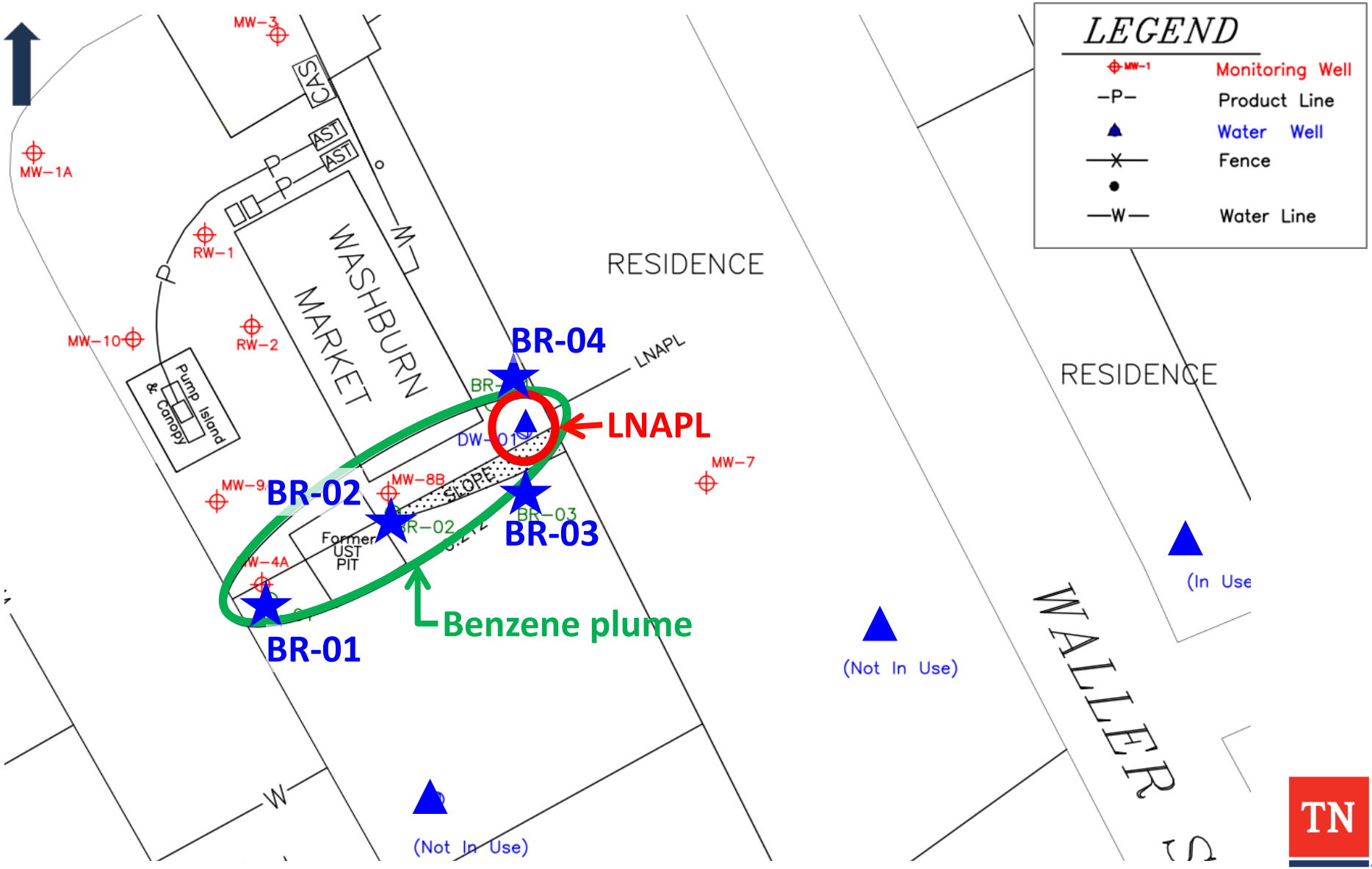
Identify fracture and weathering zones

- 4 ERI lines/profiles
- Identified shallow, thin discontinuous rock layer and bedrock profile
- 4 low resistivity anomalies to investigate





Site Map / Boring Locations



RDC: Confirmatory Soil Sampling

- Investigate potential contaminant mass in soil identified by 2D ERI
  - 4 Soil Borings (Sonic Drilling)
  - Detailed Logging
  - Minimum 1 sample to lab per 5-ft interval

  - Soil thickness: 10-29 ft
  - Xylenes > SSCLs
  - No risk of leaching to groundwater due to low ppm and isolation of impacted zone by rock lenses

RDC: Rock Coring (NQ)

- **Detailed lithologic log with RQD and visual identification of weathered and fractured zones and evidence of hydrocarbon impacts**
  - **Identified several key fracture zones with evidence of contaminant migration**

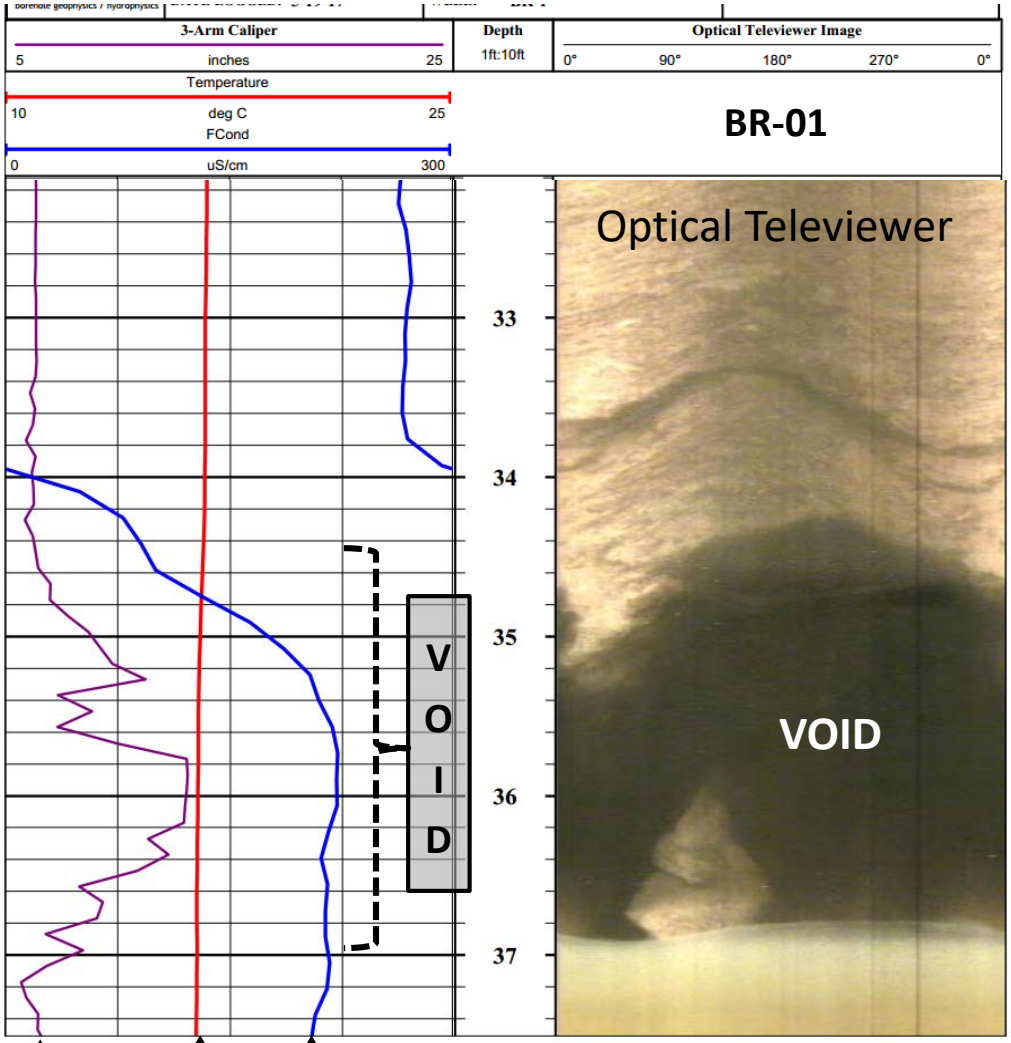
RDC: Downhole Geophysics

- Map the distribution/location of fractures and weathered bedding planes
  - Resistivity/Conductivity (porosity/pore fluid)
  - 3-Arm Caliper (borehole dimensions)
  - Natural Gamma (shale/clay vs non-shale/clay)
- Identify vertical flow patterns and orientation/dip direction of fractures
  - Acoustic Televiewer (ultrasound)
  - Optical Televiewer (camera)
  - Fluid Temperature and Conductivity

RDC: Downhole Geophysics - Results

- **Notable fractures and voids recorded during logging of rock core were compared to the geophysical logs to identify zones for further investigation**

- **Multiple fractures, voids, and potential flow zones were identified/defined**



Caliper

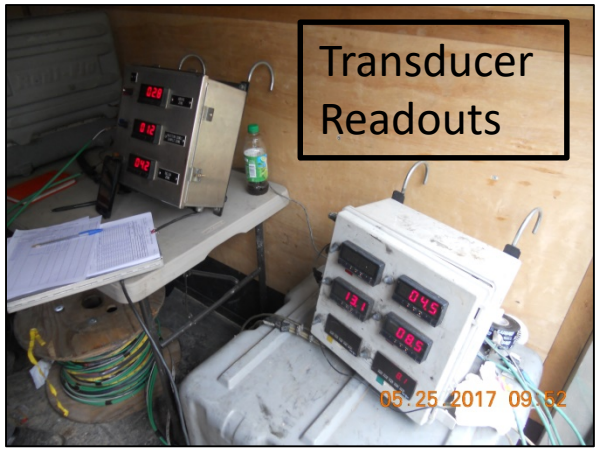
Temperature

Conductivity

RDC: Groundwater Characterization

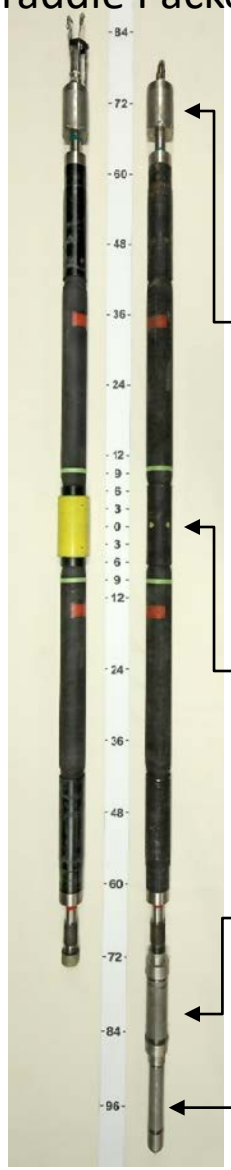
Evaluate connectivity, influence, and water chemistry

- Pump Testing (straddle packer)
- Discrete Groundwater Sampling



RDC: Groundwater Characterization - Results

Straddle Packers



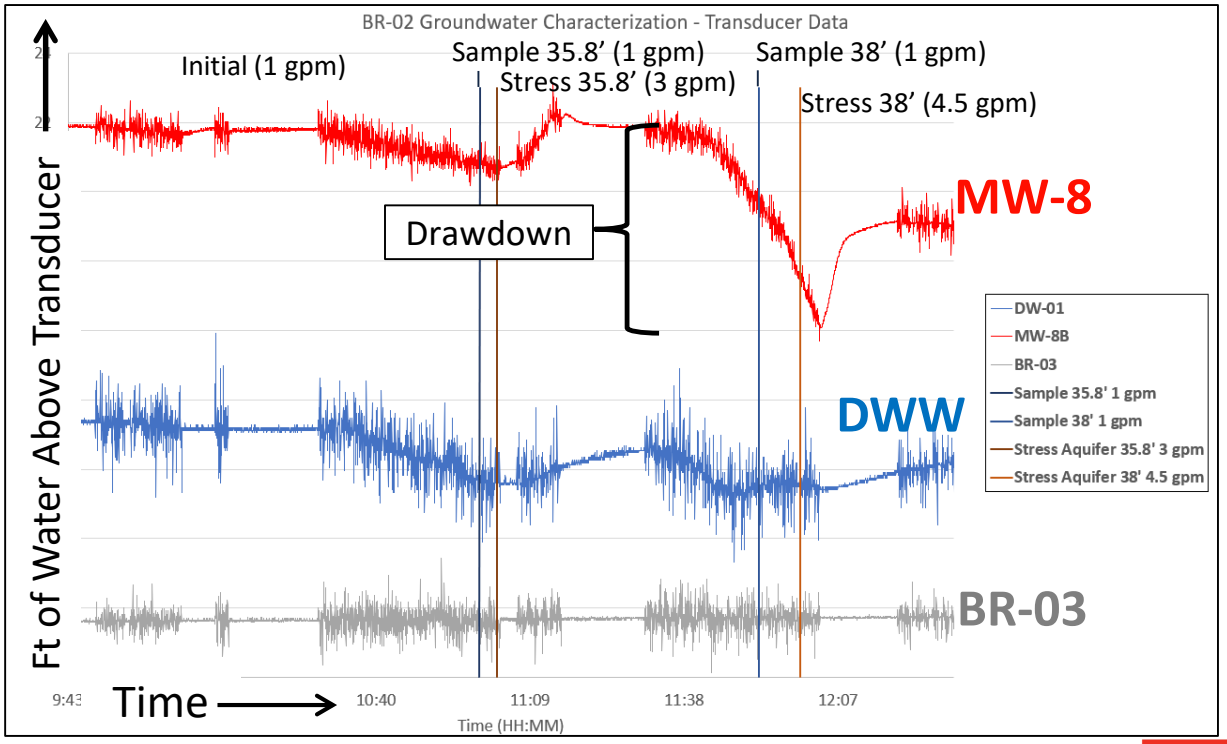
Pressure Transducer

Pressure Transducer in Discrete Interval

Grundfos RediFlo2

Pressure Transducer

- **PUMP TESTING**
  - **All monitored wells/borings with exception of BR-03 demonstrated response/connectivity during both sampling and stress pumping rates**



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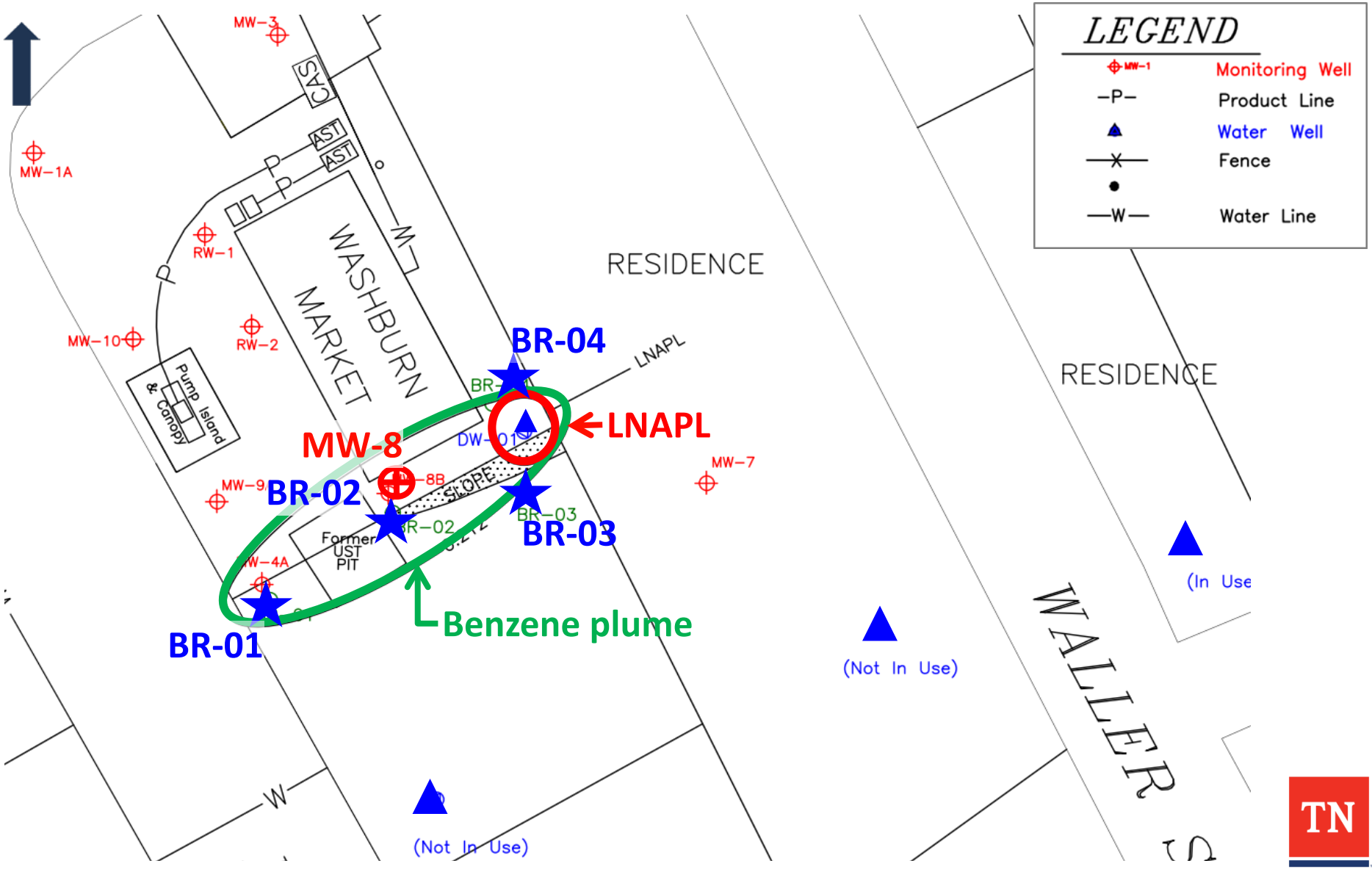
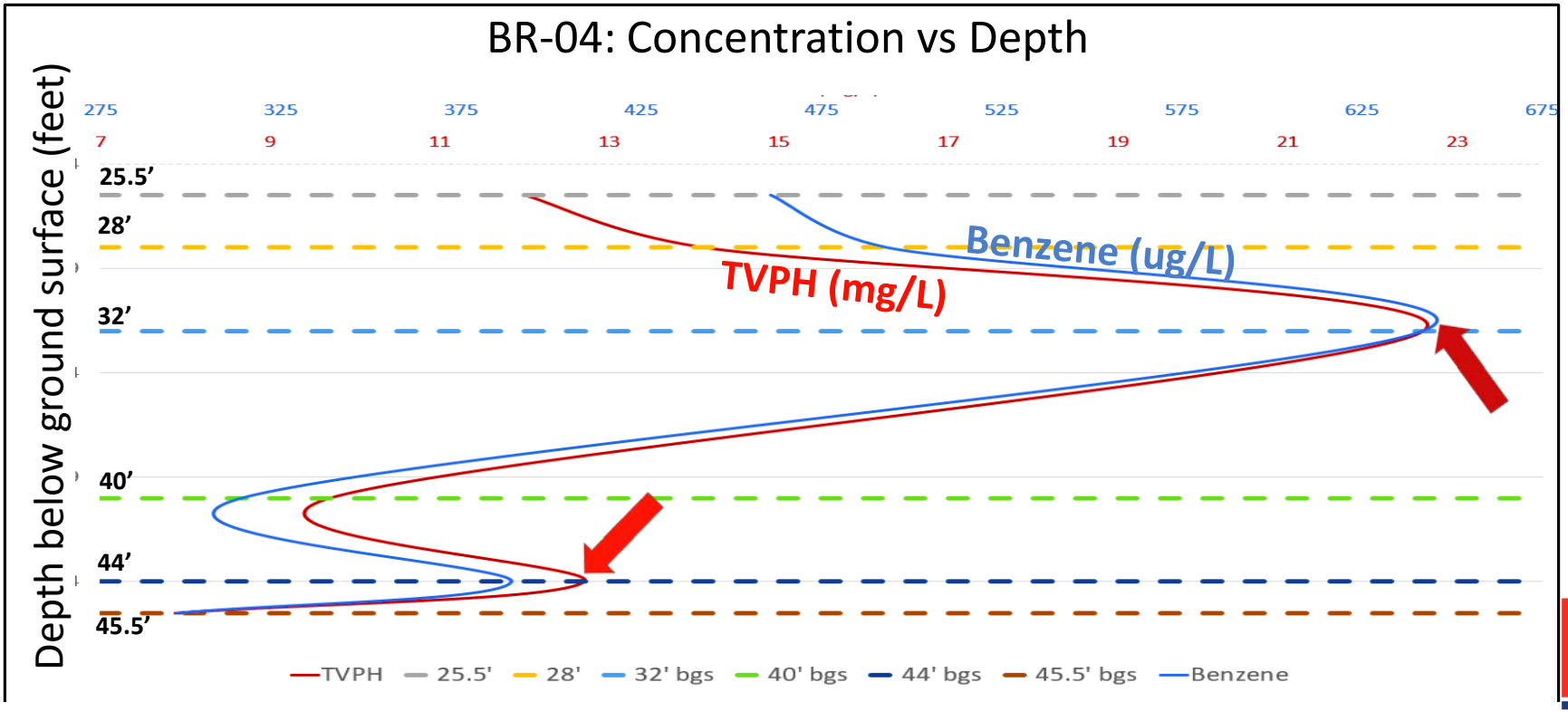


RDC: Groundwater Characterization - Results

- **Discrete Groundwater Sampling (VOCs + Anions)**
  - **Consistent COC concentrations across all intervals in BR-01 and BR-02, indicating a near uniform vertical distribution**
  - **COC concentrations in BR-04 exhibited spikes at two separate intervals, indicating a vertical connection**



Revised Injection Design

- Preliminary Design
  - Contingency for overburden treatment – soil contribution
  - Up to 12 injection intervals in rock – 15’ to 60’ bgs
  - Uniform distribution of reagent site-wide
- Revised Design (based on RDC)
  - No overburden treatment – soil contribution negligible
  - 4 to 6 injection intervals in rock
    - Based on permeability and mass present
  - Quantity of BOS200® customized for each interval based on mass present
- COST SAVINGS!
- IMPROVED OUTCOME!

Injection

- **Bedrock Injection**
  - **Custom Injection Unit on Kenworth T-800**
  - **National-Oilwell 165-hp triplex positive displacement pump**
    - **Capable of 2,200 psig**
  - **Custom Mixing Trailer**
  - **Product: 6,000 lbs Trap and Treat® BOS200®**

Final Outcome

- **LNAPL eliminated from onsite DWW immediately following injections**
- **COCs in all wells reduced to below SSCLs immediately**
- **Anion analyses showed progression of bioremediation**
- **Start to Finish: 8 months**
  - **Notice to Proceed: April 20, 2017**
  - **RDC through Injection: May 8 – June 2, 2017**
  - **No Further Action : December 29, 2017**

Questions?

Thank you for your attention!

Thank You!!!

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