Persistence of Separate Phase, Dissolved, and Sorbed Chlorinated Solvents in Fractured-Rock Aquifers

Daniel J Goode and
Thomas E Imbrigiotta,
and others!

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Challenges to Characterizing and Remediating Contamination in Fractured Rocks

- Extreme heterogeneities...
  - Physical Heterogeneity
  - **Contaminant Distribution Heterogeneity**
  - Biogeochemical Heterogeneity
- ...Coupled with complex fate and transport processes

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Persistence of Chlorinated Solvents in Fractured-Rock Aquifers

- DNAPL screening during drilling
- VOC's in Rock Core
- Insitu Diffusion Test

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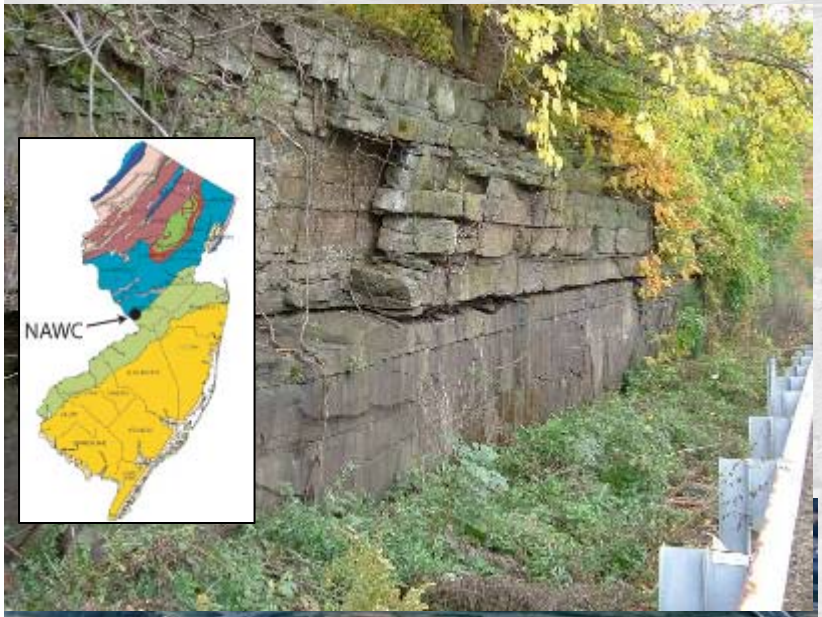
Naval Air Warfare Center (NAWC), West Trenton, New Jersey

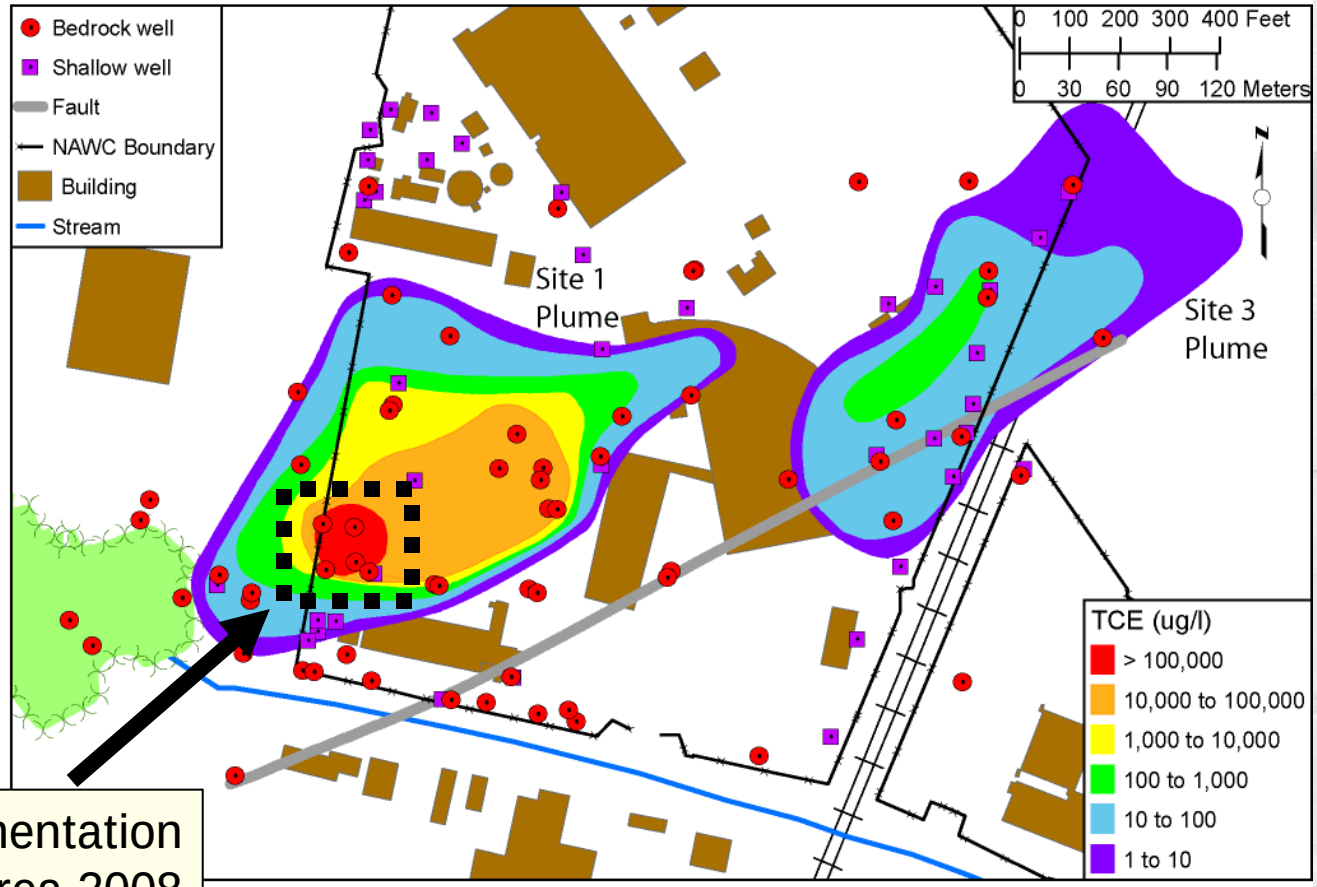


- **Current focus site** for Toxics Program research on fractured-rock contamination.
- **Sedimentary rocks** of the Newark Basin.
- **Extensive TCE, DCE, VC contamination**.
- Area of focused study: 0.5 x 0.5 km.

Site History

- Navy jet engine testing facility, 1950's to 1990's
- TCE & jet fuel leaked into subsurface
- Closed in 1998
- Pump & treat since mid-1990's

TCE in Ground Water (2-D Map View)



Bioaugmentation Area 2008

after Lacombe, 2000, WRIR 98-4167

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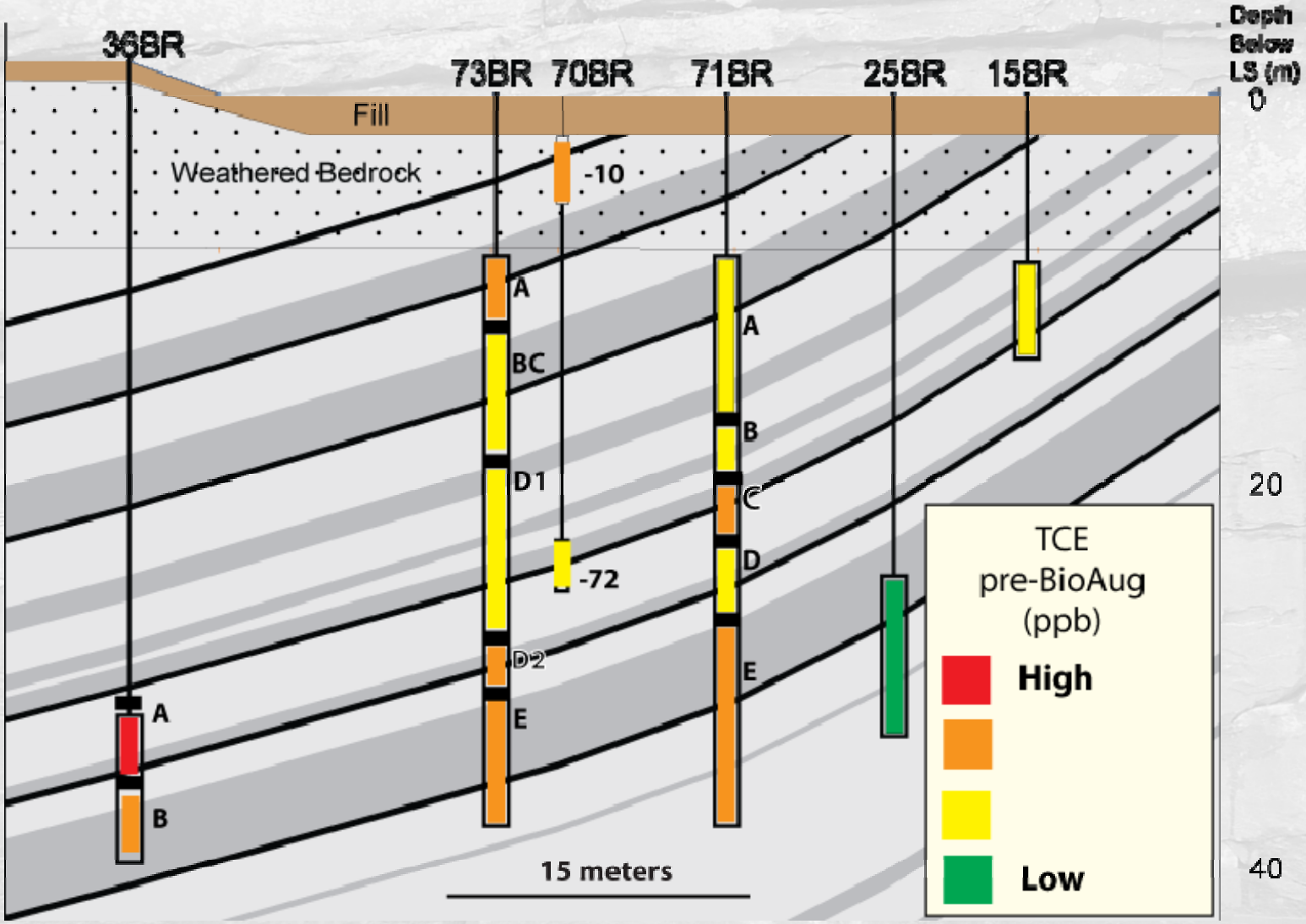
TCE in the other Dimension



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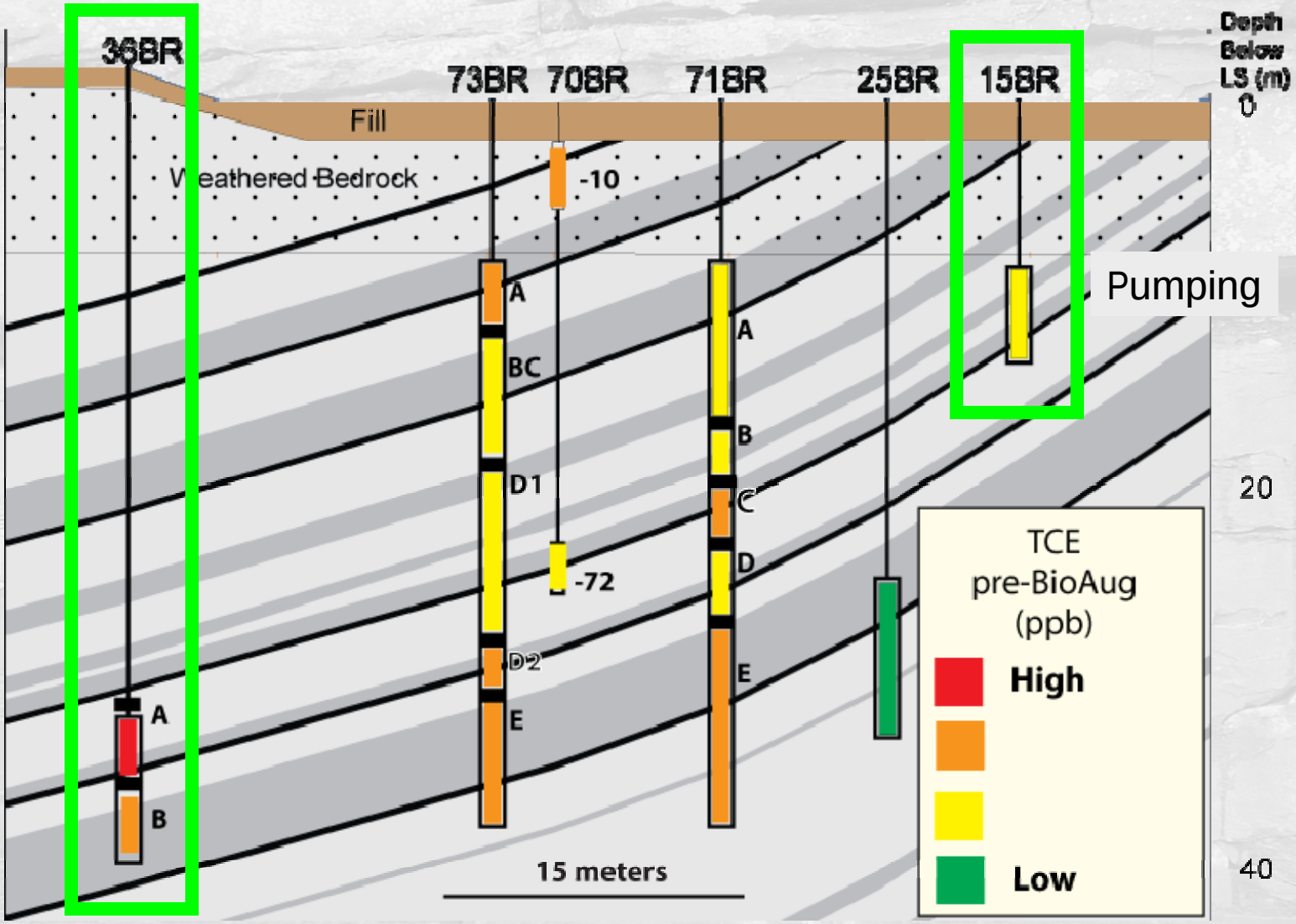
Persistent High Concentrations



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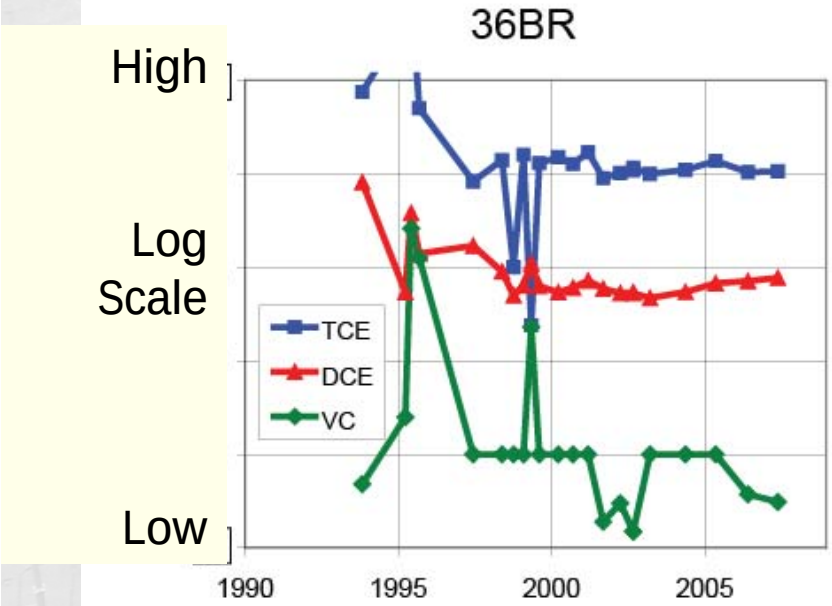
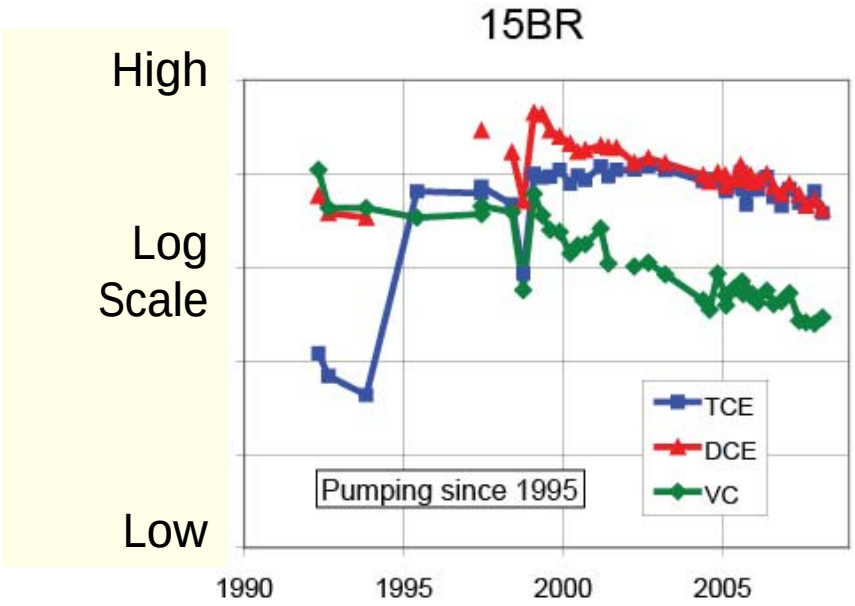
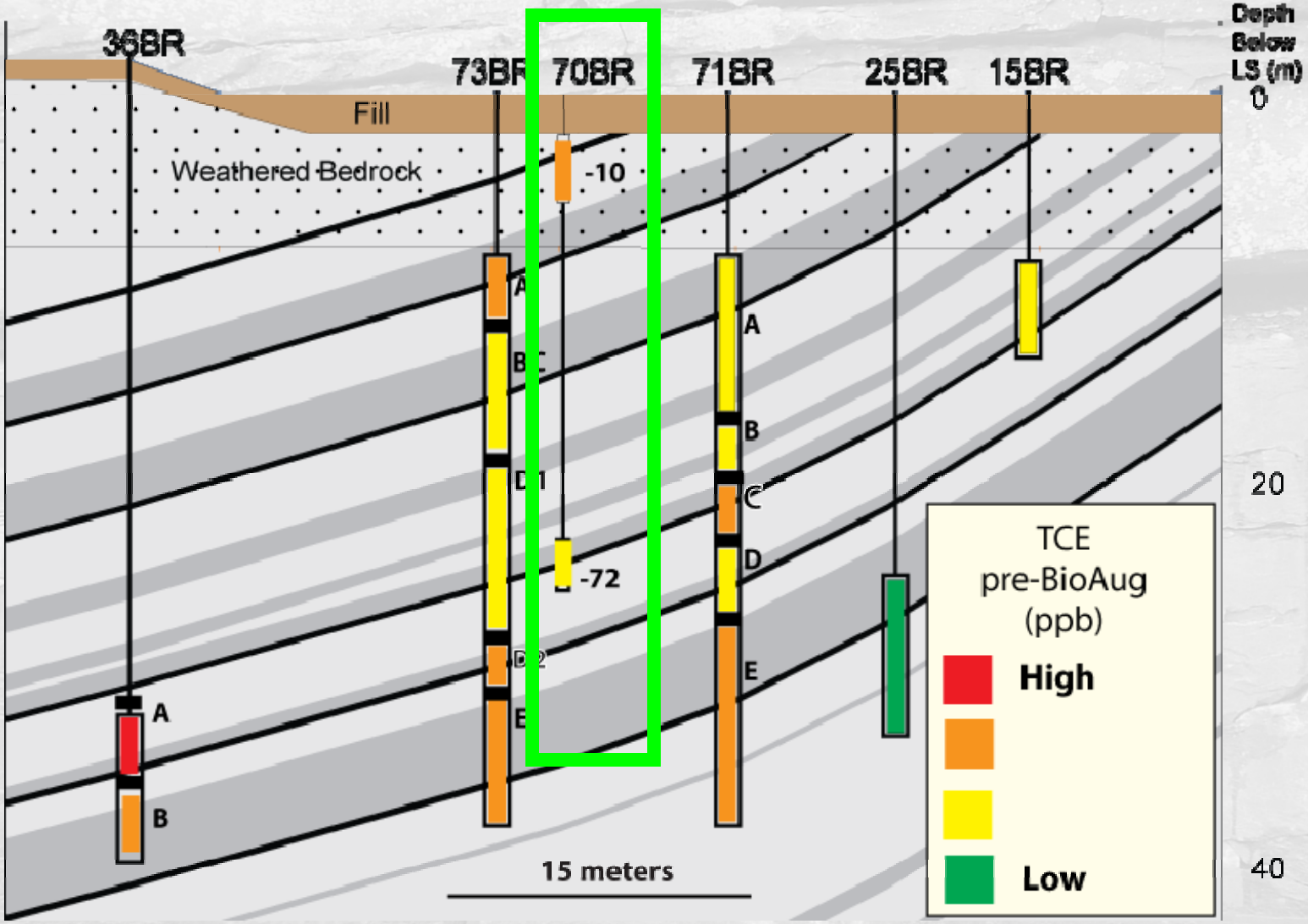




DNAPL Screening



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DNAPL Screening during Coring 70BR

Cloth with hydrophobic dye -- staining where dye dissolves in NAPL

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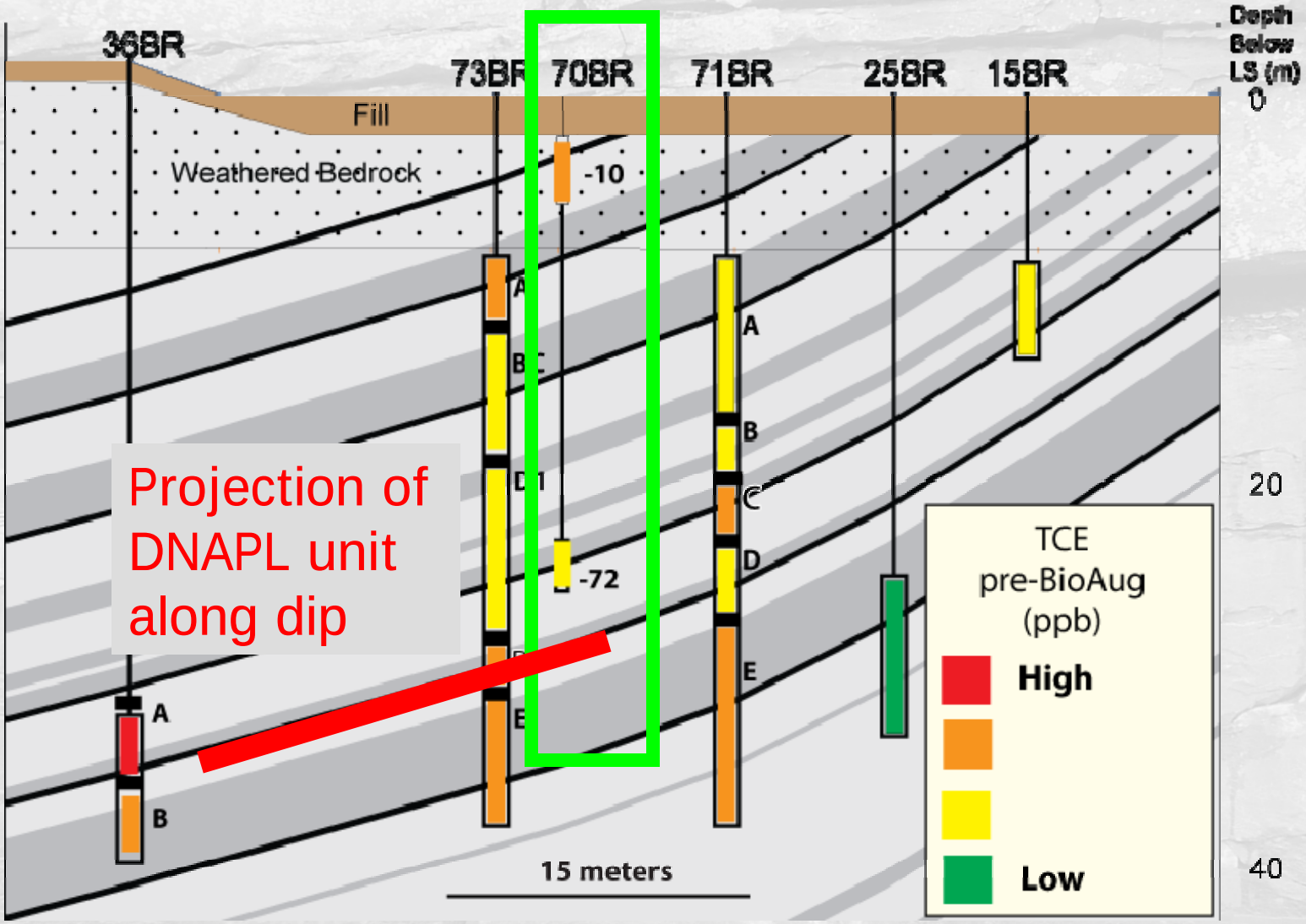
DNAPL Screening



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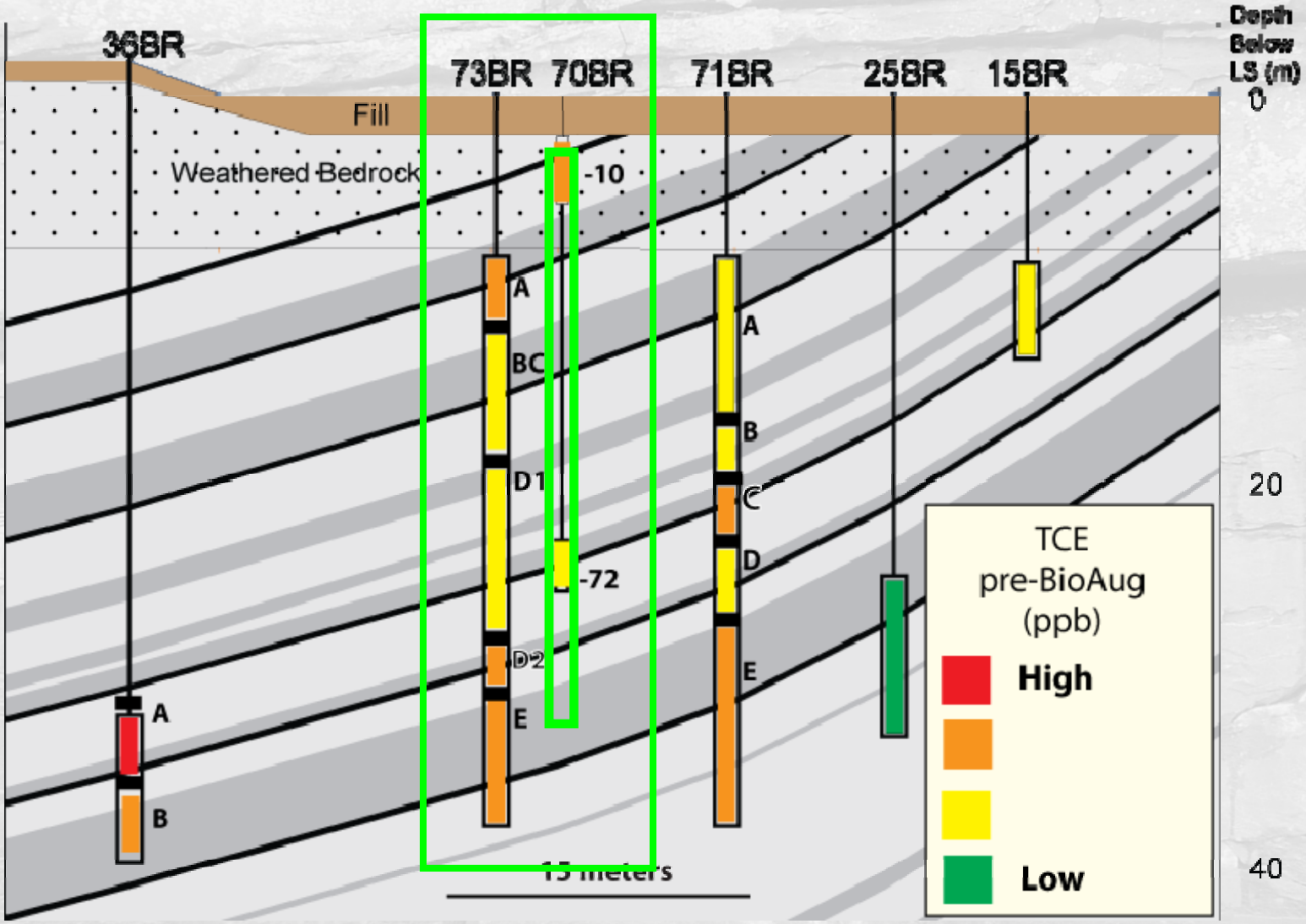
TCE in Bulk Rock Core



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Bulk Rock Core TCE in 70BR

- Following methods of Parker, Cherry and others
- Sample core as removed from barrel
- Crush to < 1-inch by hand, if necessary
- Place in pre-weighed glass jar w/ 50 mL methanol
- Extract in cold storage for several months
- Dilute methanol aliquot in 50 mL distilled water
- Analyze VOC's in water

Below Analytical Detection Limit

Above Saturation: Due to Desorption or DNAPL Dissolution

Bulk Rock Core TCE in 70BR

- BULK values, VOCs extracted include dissolved, sorbed, and DNAPL
- Convert to “pore water concentration” by assuming 5 percent porosity
- High detection limit, due to dilution of methanol in water for analysis
- Some loss due to volatilization during sampling

Below Analytical Detection Limit

Above Saturation: Due to Desorption or DNAPL Dissolution

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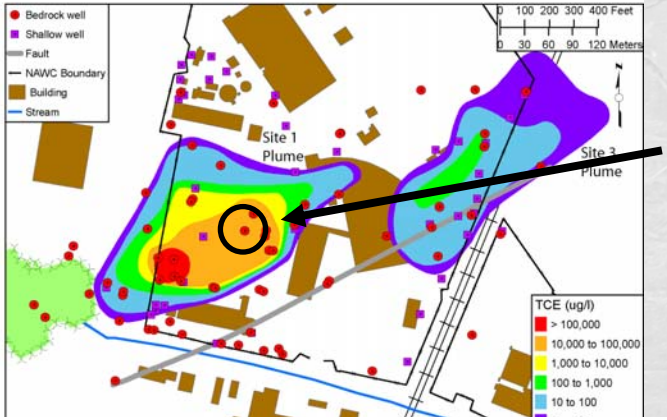
Bulk Rock Core TCE in 68BR

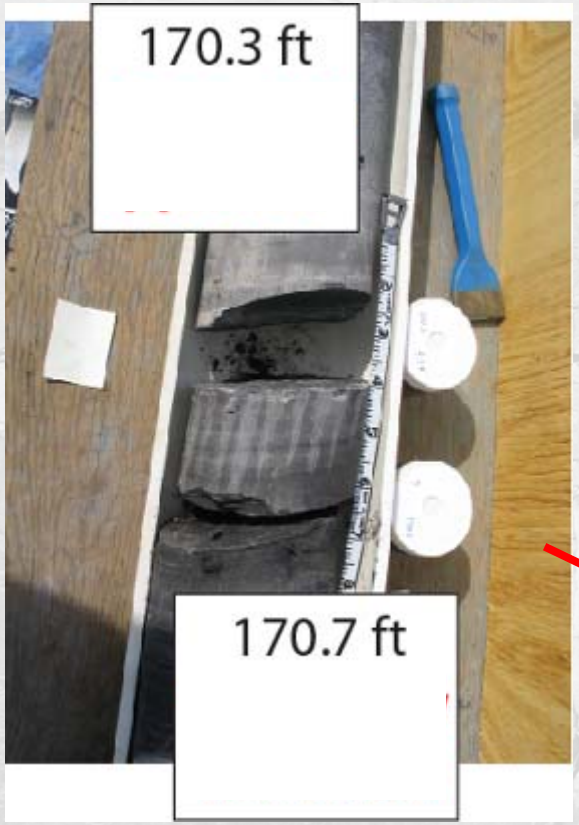


68BR

Below Analytical Detection Limit

Above Saturation: Due to Desorption or DNAPL Dissolution

Bulk Rock Core TCE in 68BR



Below Analytical Detection Limit

Above Saturation: Due to Desorption or DNAPL Dissolution

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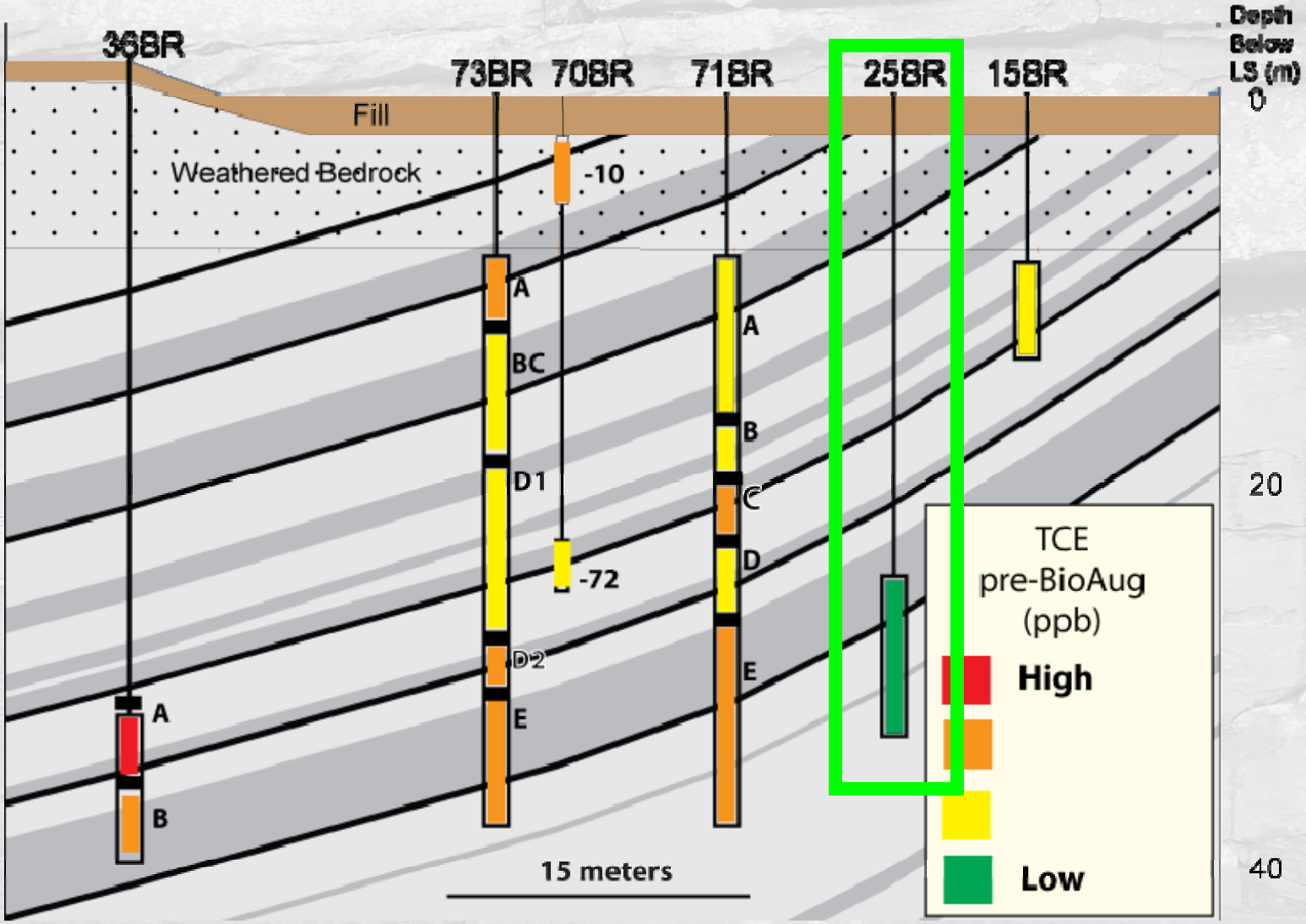
Insitu Diffusion Test



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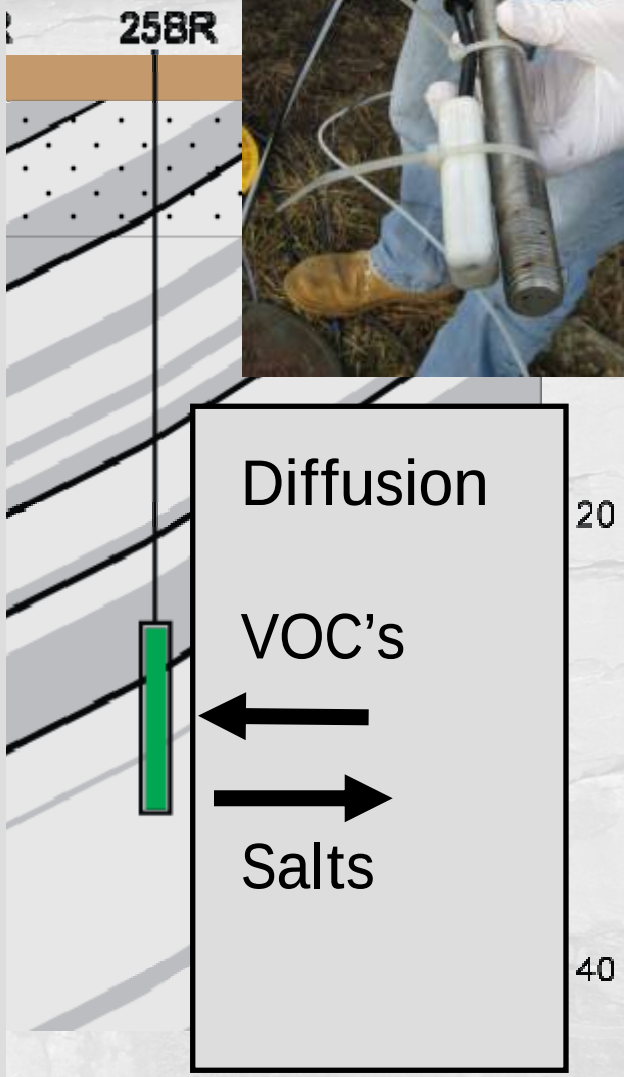
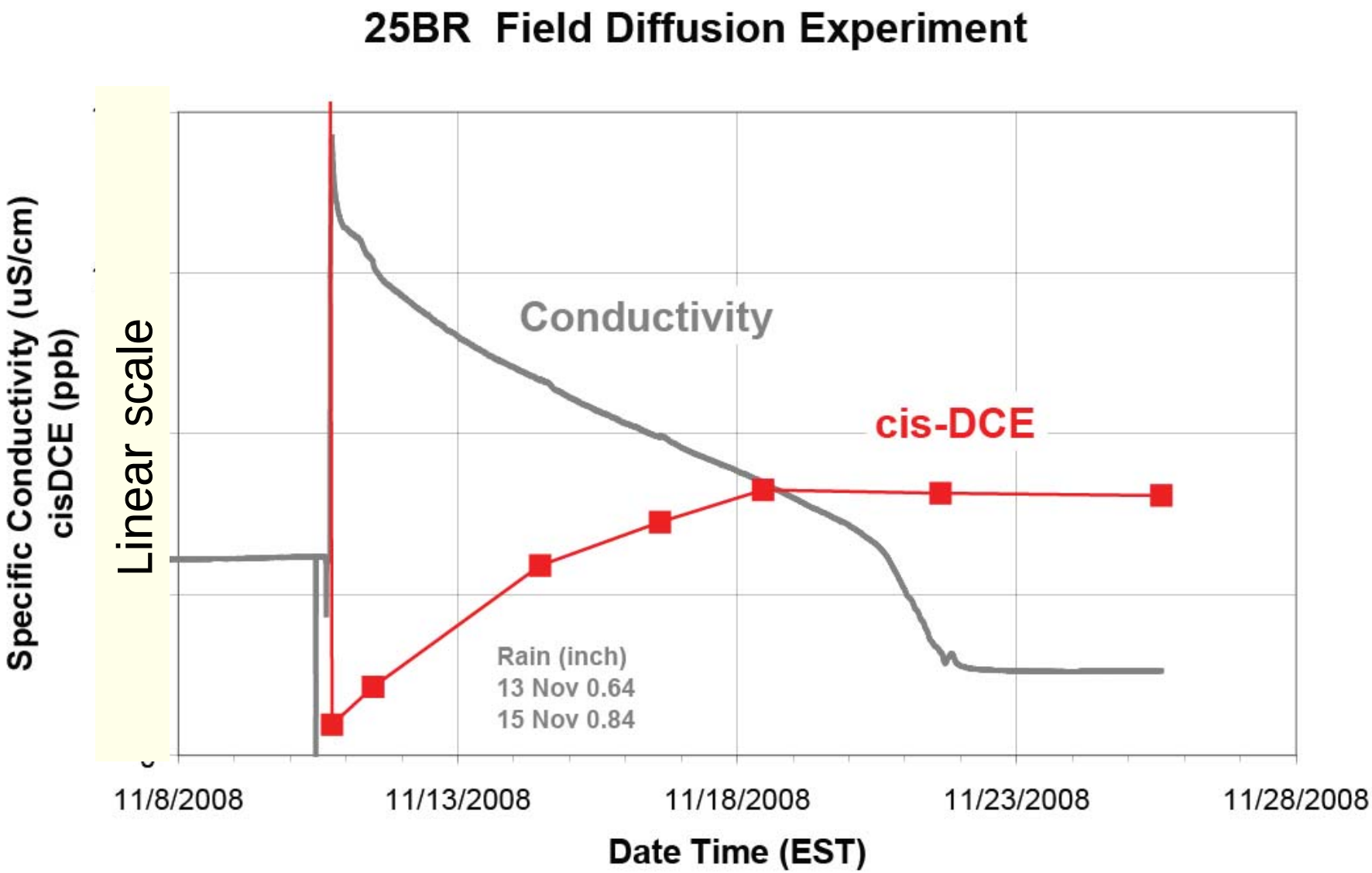
Insitu Diffusion Te

- Well 25BR has very low specific yield
- Replace well 25BR water with water pumped from well 23BR
  - 23BR has higher specific conductivity and lower VOC's
- Downhole continuous (15-min) monitoring for specific conductivity & temperature
- Ultra-low volume sampling for VOC's
  - Purge water discharged to top of water column in well
  - Replace sample volume with distilled water at top of water column
- Fit model of diffusion from formation into monitoring well to estimate field-scale diffusion parameters





Insitu Diffusion Test

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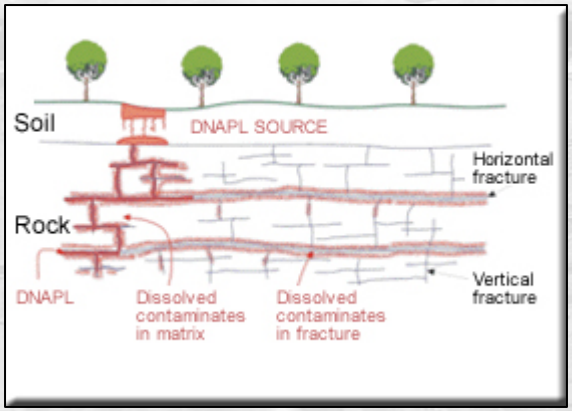
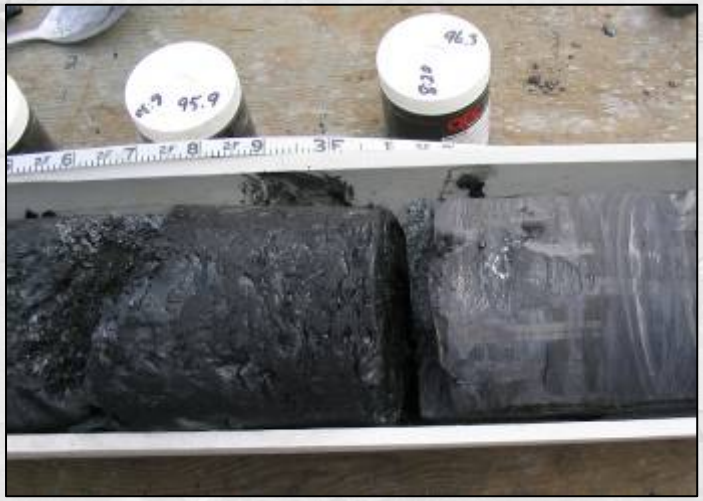
Fractured-Rock Heterogeneity

Complex spatial and temporal history of aqueous-phase and NAPL contaminant spills

Primary (rock matrix) and secondary (fractures) porosities with greatly different flow and transport properties



Spatially variable Sorption due to heterogeneity of Lithology



Persistence of Chlorinated Solvents in Fractured-Rock Aquifers

Remediation focused on high-K fractures **inefficient**

- **DNAPL** remains isolated from flow system
- Slow back-diffusion from **rock matrix**
- **Sorption** likely in high-carbon sedimentary rocks

Monitoring focused on high-K fractures misleading

- Long-term contamination levels controlled by **residual VOC's**
- Complex **spatial variability** not captured by pumped samples
- **Large dilution** between low-K contaminated zones and high-K flowpaths

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Persistence of Chlorinated Solvents in Fractured-Rock Aquifers

Cost-effective field methods available

- Shake kit & vapor monitoring during drilling
- In situ **NAPL detection** – hydrophobic-dye cloth
- **Rock core** sampling for VOC's
- Insitu **Diffusion** Test

Improved **understanding** of processes helps design remediation and monitoring

- If not time critical, design low-cost **SLOW remediation**
- Limit migration away from **source areas**
- Monitor low-yield wells to track **residual reduction**

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Toxic Substances Hydrology Program
New Jersey Water Science Center
National Research Program
Office of Ground Water

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