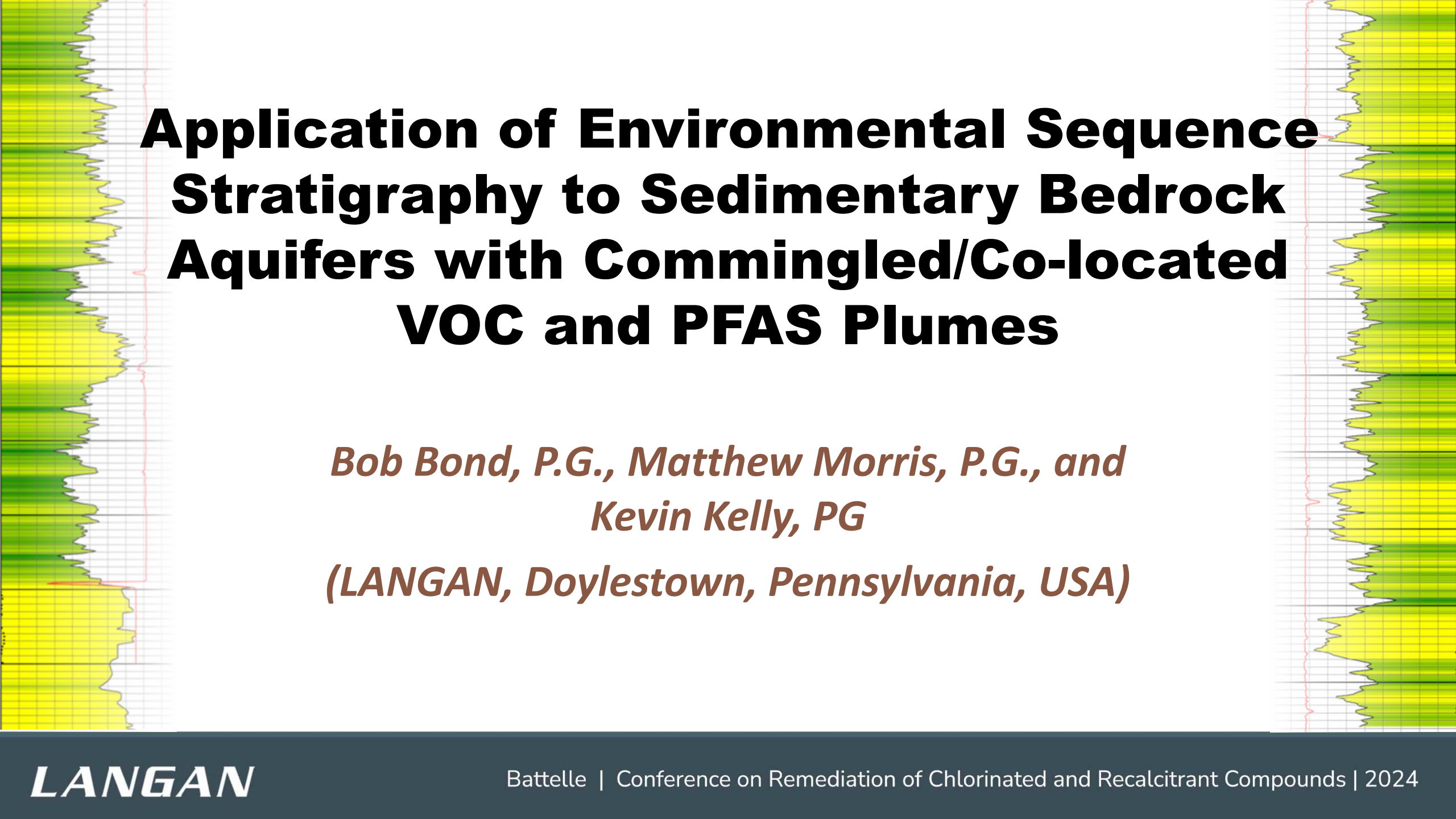




# **Application of Environmental Sequence Stratigraphy to Sedimentary Bedrock Aquifers with Commingled/Co-located VOC and PFAS Plumes**

*Bob Bond, P.G., Matthew Morris, P.G., and  
Kevin Kelly, PG*

*(LANGAN, Doylestown, Pennsylvania, USA)*

# AGENDA

1. Introduction to ESS and why it is important to our community
2. The Newark Basin in Connecticut, New York, New Jersey, and Pennsylvania:
  - Beautifully complex cyclically-sequenced sedimentary bedrock
  - Monoclinally-dipping bedding imparts first-order control on groundwater flow, contaminant migration, and amendment distribution
  - Significant number of contaminated bedrock sites and commingling of groundwater plumes
3. Bedrock case studies and methods where ESS has improved CSMs (from easy to challenging)

# Environmental Sequence Stratigraphy (ESS)

## 10 ESS Presentations at Battelle 2022

Presentations/Posters in 6 different session tracks

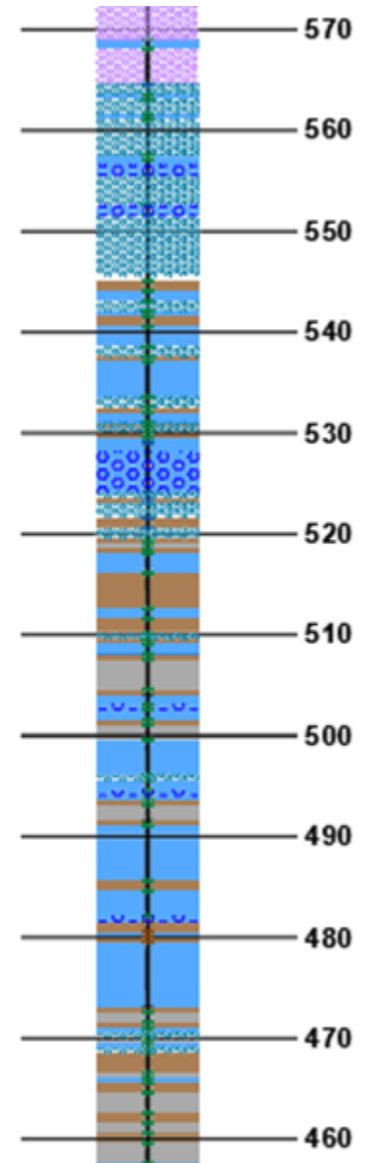
## 20 ESS Presentations at Battelle 2024

- Depositional Environments & Stratigraphic Considerations for Remediation (6)
- Conceptual Site Models: Improvements in Development and Application (2)
- Advances in the Application of Geologic Interpretation to Remediation (2)
- Process-Based Conceptual Site Models for Informing Remediation (2)
- PFAS Conceptual Site Model Approaches (2)
- High-Resolution Site Characterization (2)
- Geology Revolution Cont'd ... What the Well Will Tell You Before You Drill (1)
- Addressing Subsurface Heterogeneity throughout the Project Lifecycle (1)
- Innovative and Optimized Amendment Delivery and Monitoring Methods (1)
- Advanced Data Analytics and Forensics Framework for PFAS RIs (1)



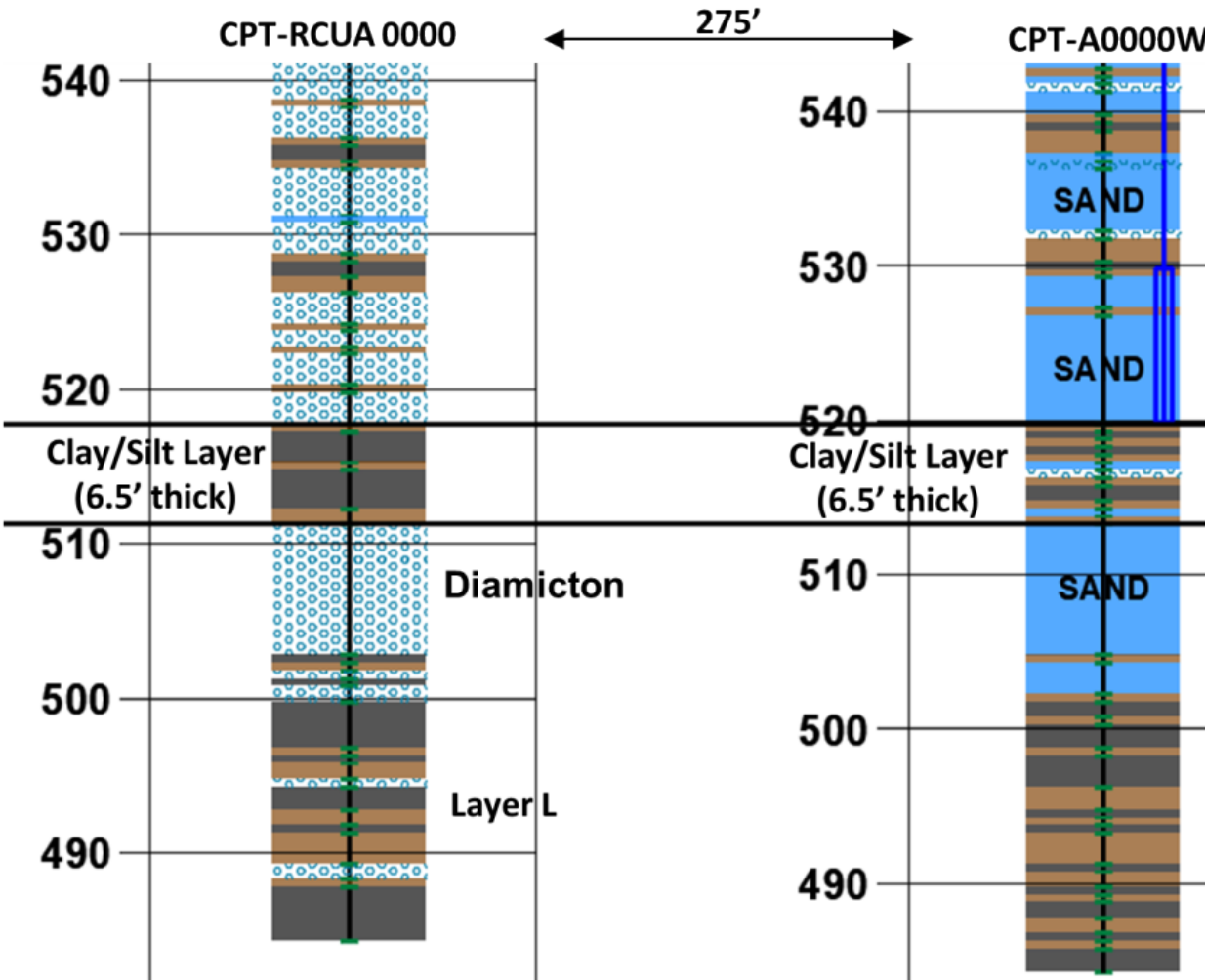
# Sequence Stratigraphy Method

- Expert geologic interpretation – in depth, e.g. petroleum exploration geologist expertise is ideal
- Recognition of stacking patterns of strata, key surfaces, breaks, and cycles
- Identification of facies, sequences, and depositional environments
- Understanding of the scales of the component depositional elements





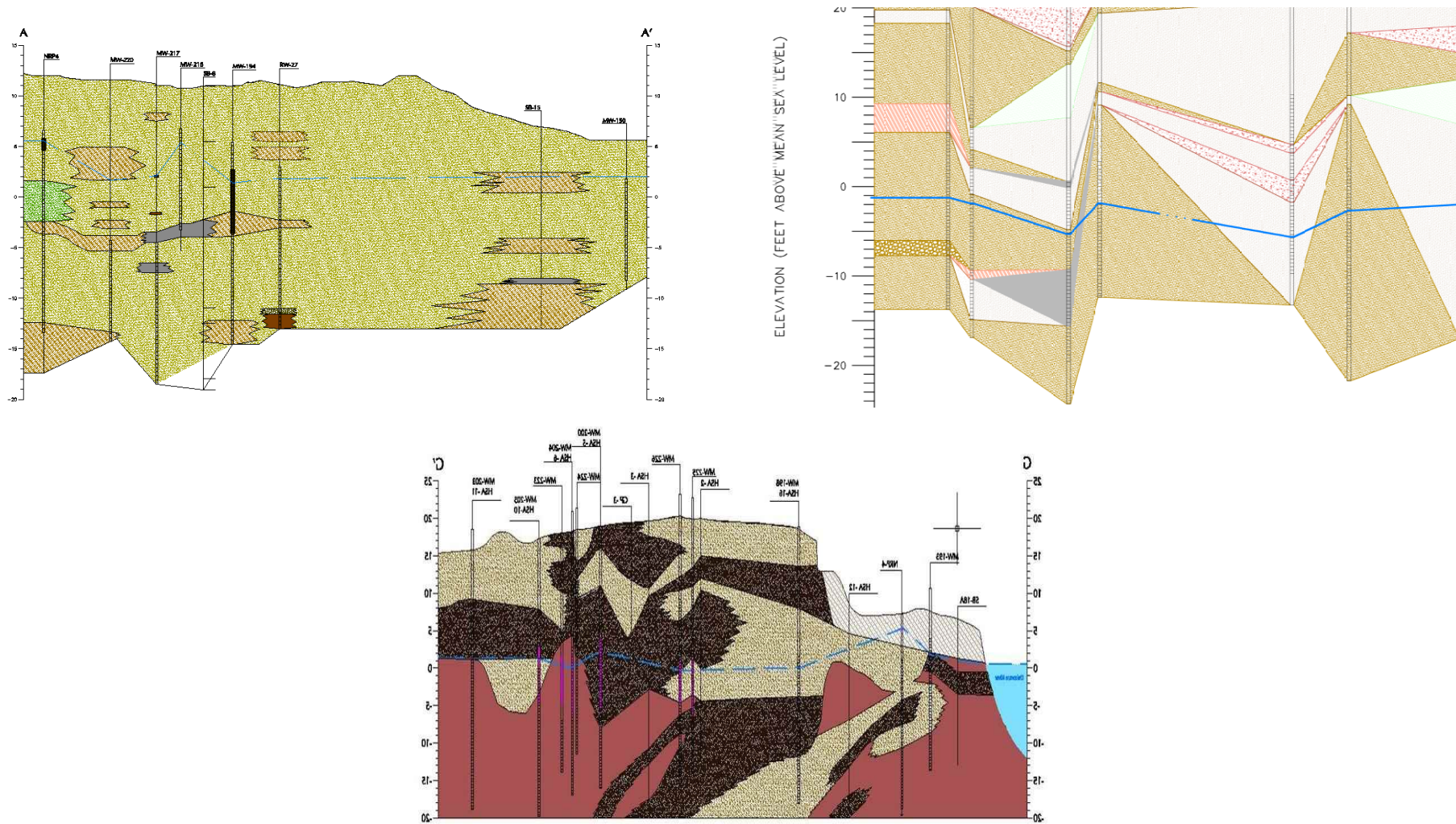
# Common Challenge – Multiple Geologists with Varying (or No) ESS Skills Leads to Multiple Interpretations



## Interpretations from CPT Logs

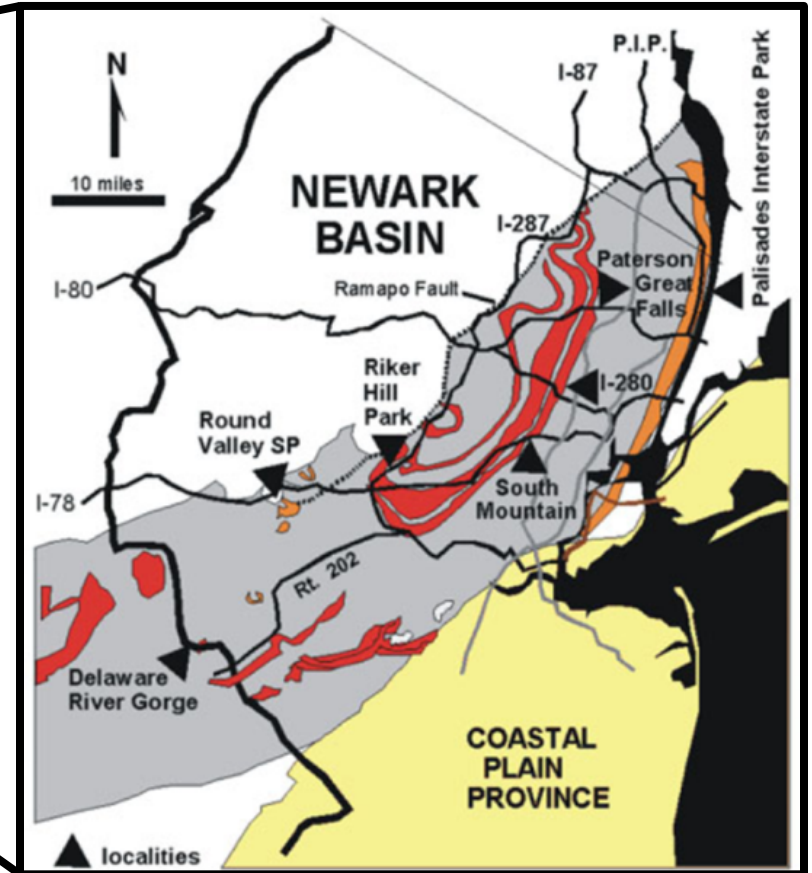
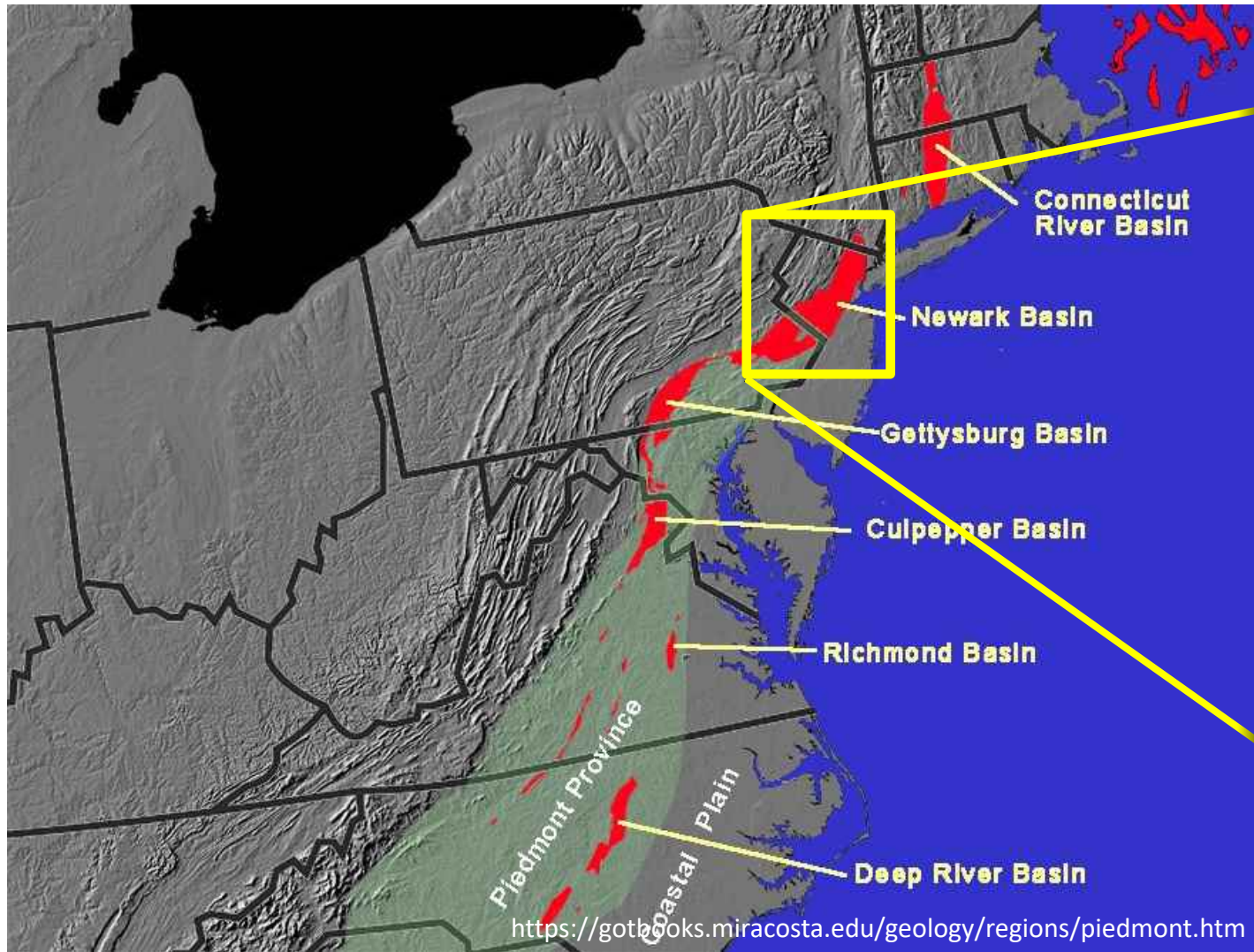
- Strat column on left interpreted as layers of “diamicton”, which is unsorted glacial till in Michigan.
- Column on right updated to actual mapped formations in area (no diamicton), actually sand layers – a huge difference
- Important to recognize & understand depositional environment and cycles

# Unrealistic Models without ESS Expertise





# Mesozoic Rift Basins of the East Coast



<https://www.usgs.gov/media/images/nyc-region-map-field-localities-newark-basin-ny-nj-pa>



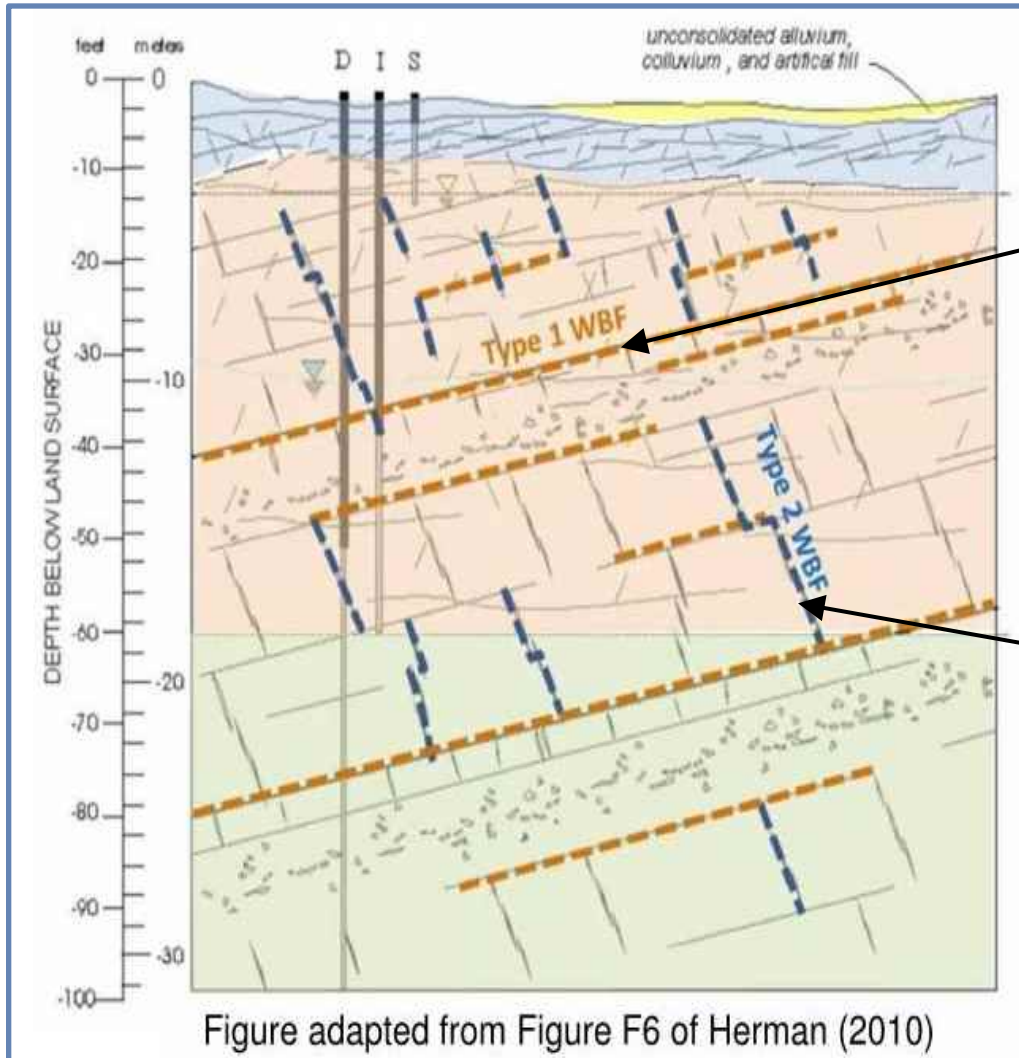
Prepared in cooperation with the  
NEW JERSEY GEOLOGICAL SURVEY



CROSS SECTIONS OF THE VALLEY AND RIDGE, HIGHLANDS,  
AND PIEDMONT GEOLOGIC PROVINCES, NORTHERN AND  
CENTRAL BEDROCK SHEETS, NEW JERSEY

By G.C. Herman, D.H. Monteverde, R.A. Volkert, H.F. Houghton,  
R.A. Parker, A.A. Drake, Jr., and R.F. Dalton

# Dipping Water-Bearing Fractures (WBF)



- **Type 1 WBF**

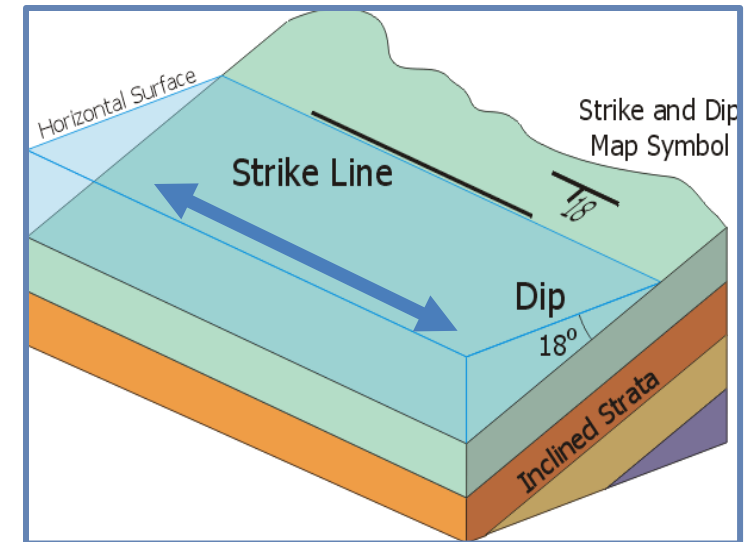
- Bedding Plane Partings
- Primary Pathway
- **Multi-Aquifer**

- **Type 2 WBF**

- Steeply-Dipping Fractures
- **Leaky**

## LMAS Model

### Leaky Multi-Aquifer System



Dipping Type 1 WBFs impart first-order control on groundwater flow  
– Flow along strike (generally)

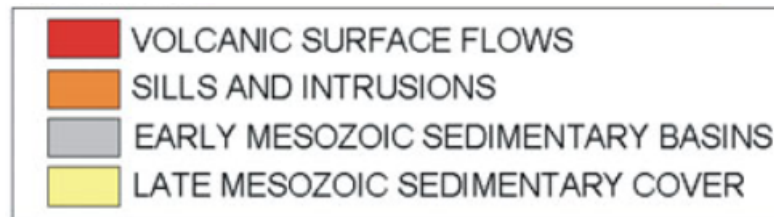
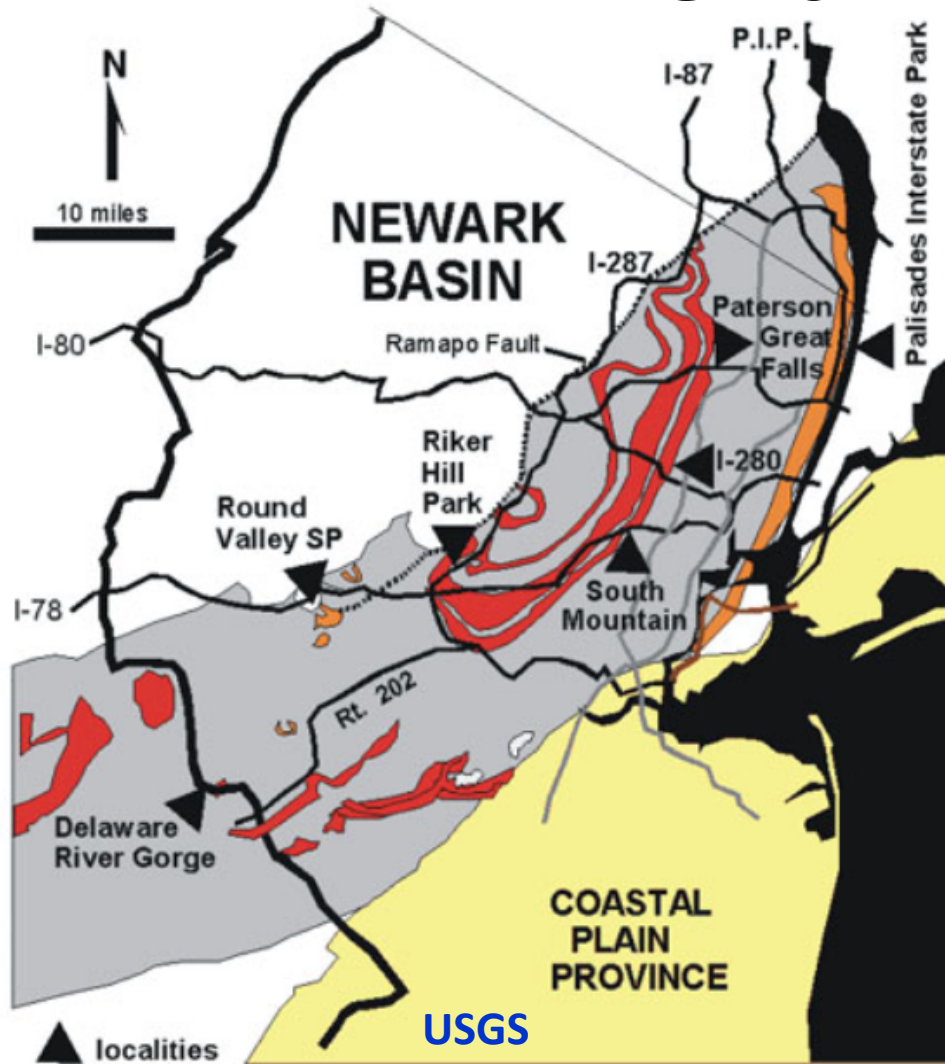


# Geologic Setting for Bedrock Case Studies – Newark Basin of NJ

## Passaic Formation

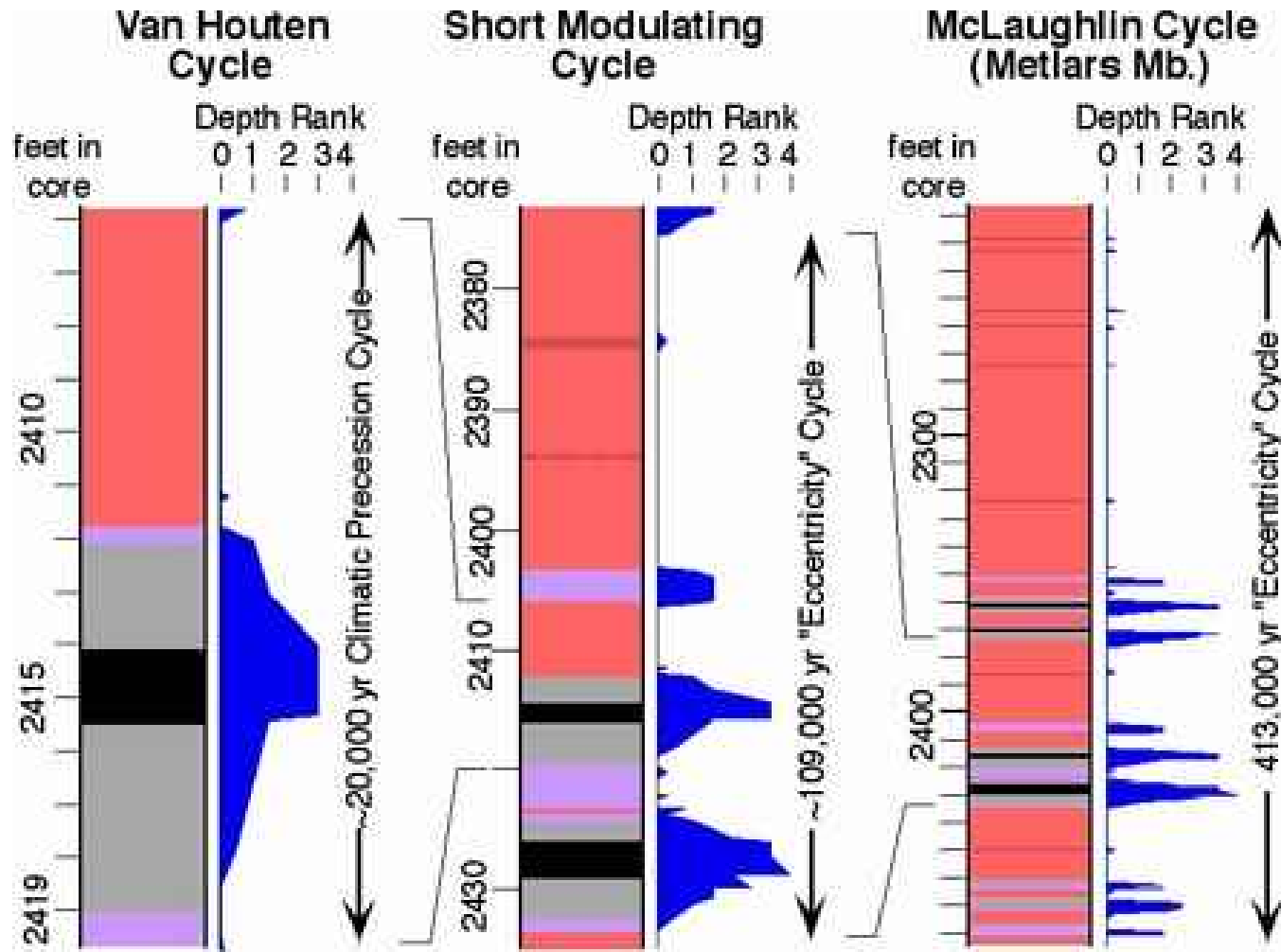
(USGS) Predominantly **red beds** consisting of argillaceous **siltstone**; silty **mudstone**; argillaceous, very fine-grained **sandstone**; and **shale**

**ESS - Individual lacustrine cycles can be traced basin-wide**



<https://www.usgs.gov/media/images/nyc-region-map-field-localities-newark-basin-ny-nj-pa>

# Lockatong Fm and Passaic Fm Deeply Cyclical at Several Scales



- Van Houten Cycle (20K years)
- Short Modulating Cycle (109K years)
- **McLaughlin Cycle (413K years)**  
Strongest Expression – Most Appropriate for **Map-Scale Member Subdivision**
- Long Modulating Cycle (1.6-2.0 MM-years) weakest cycle (not shown)

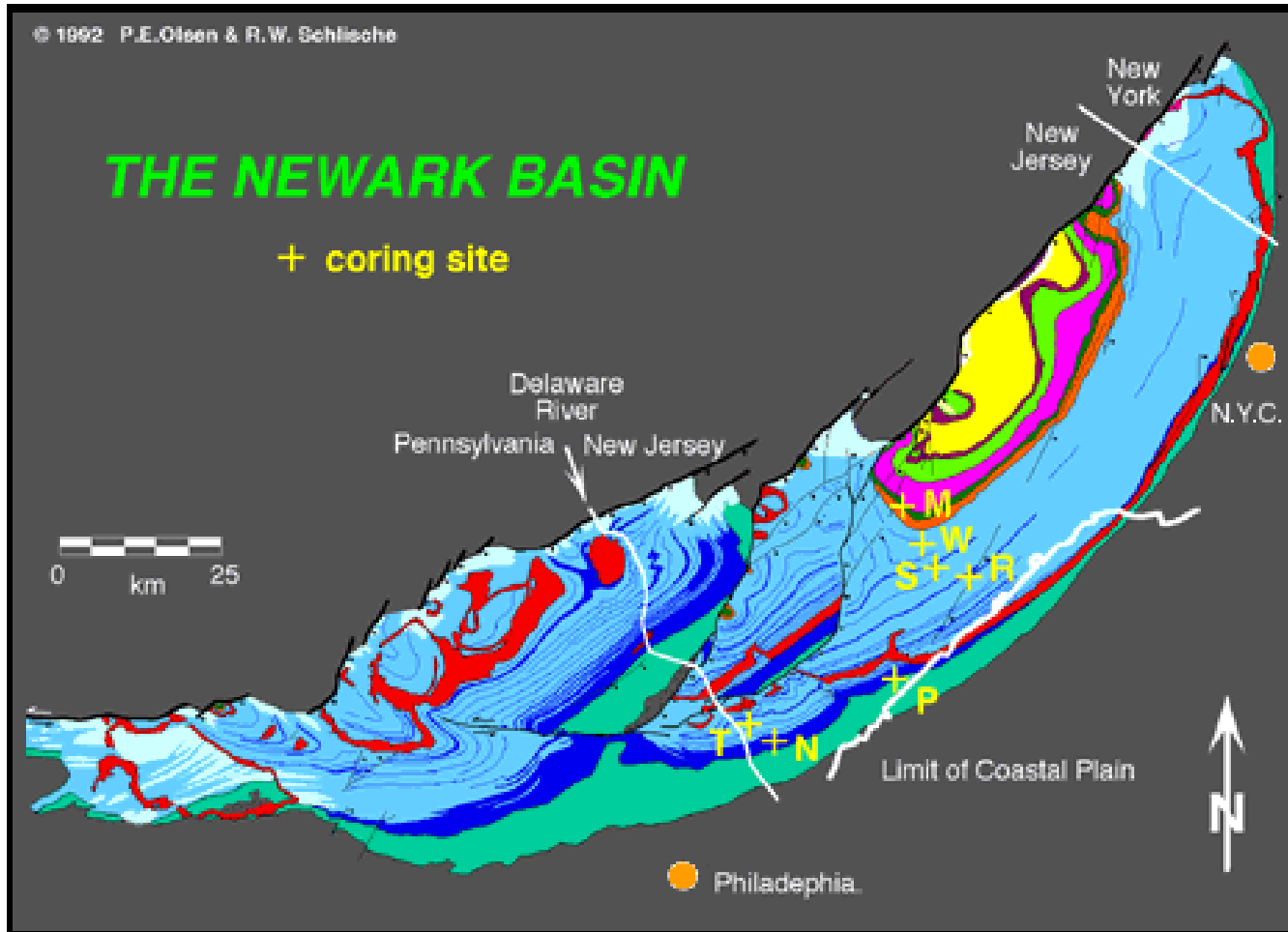
## REFERENCE:

High-resolution stratigraphy of the Newark rift basin (early Mesozoic, eastern North America)

Paul E. Olsen, Dennis V. Kent, Bruce Cornet, William K. Witte, Roy W. Schlische

GSA Bulletin, January 1996, v.108, no.1

# Newark Basin Coring Project (NBCP) 1989-1994



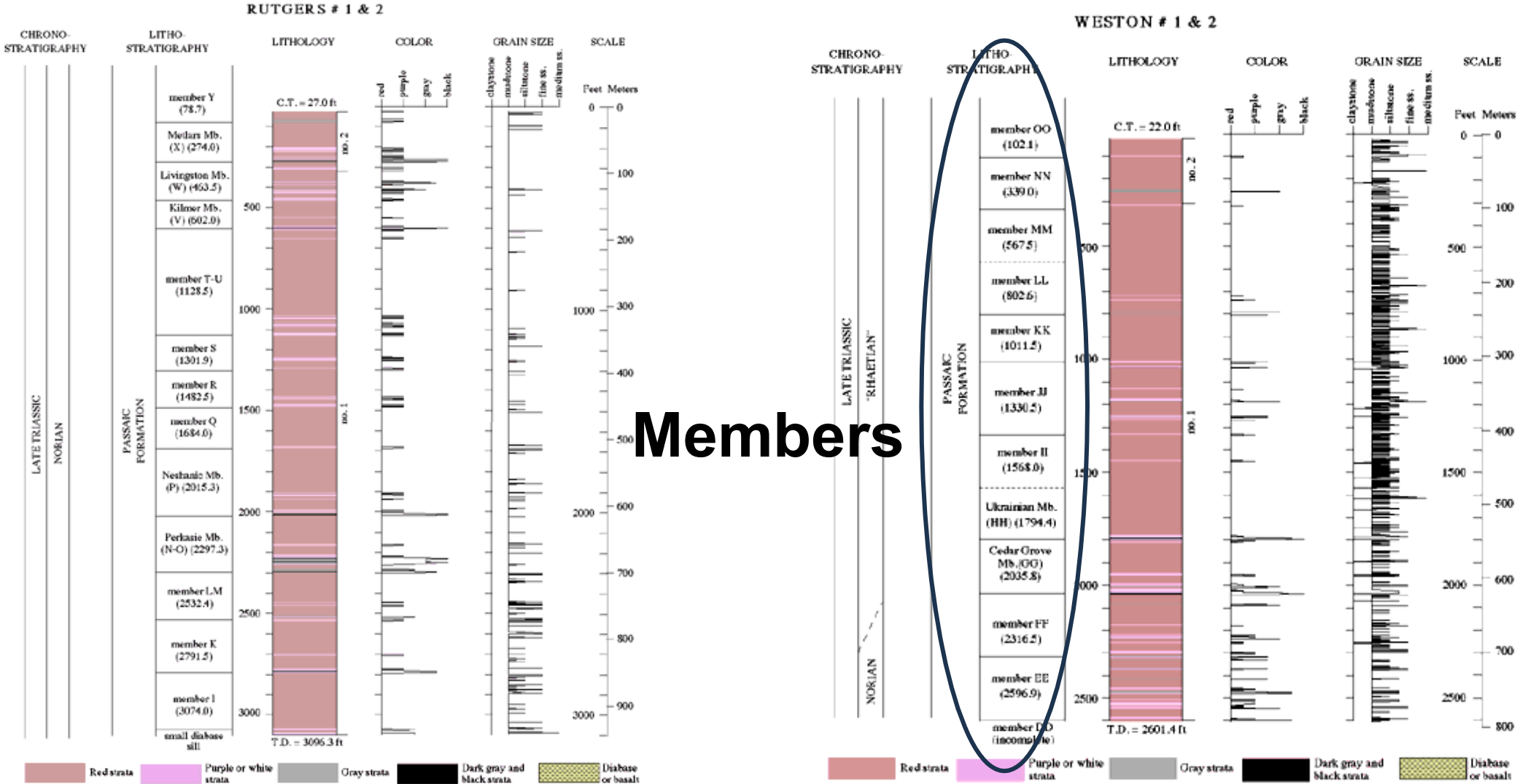
- The Newark Basin Coring Project (NBCP) was a scientific drilling project funded by the National Science Foundation from 1989 to 1994.
- Seven Drilling Locations, overlapping cores, entire sequence

M) [Martinsville](#); W) [Weston](#); S) [Somerset](#); R) [Rutgers](#); T) [Titusville](#); N) [Nursery](#); and P) [Princeton](#)

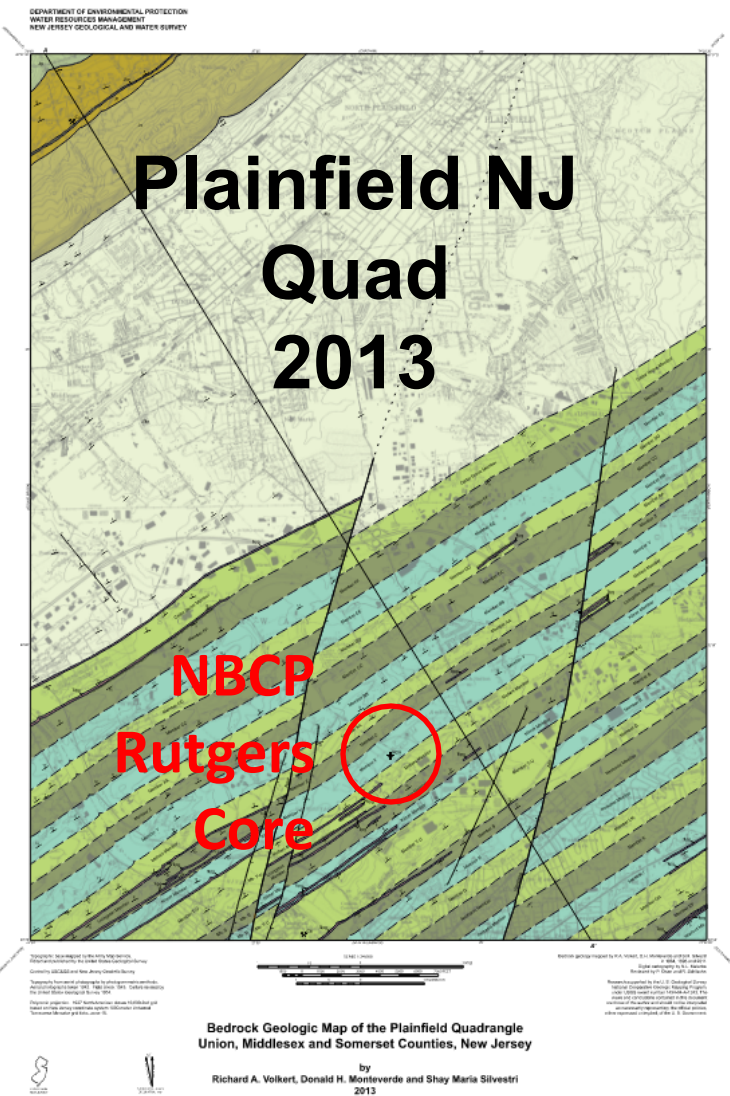
<https://www.ldeo.columbia.edu/~polsen/nbcp/projectdescription.htm>



# Newark Basin Coring Project (NBCP)

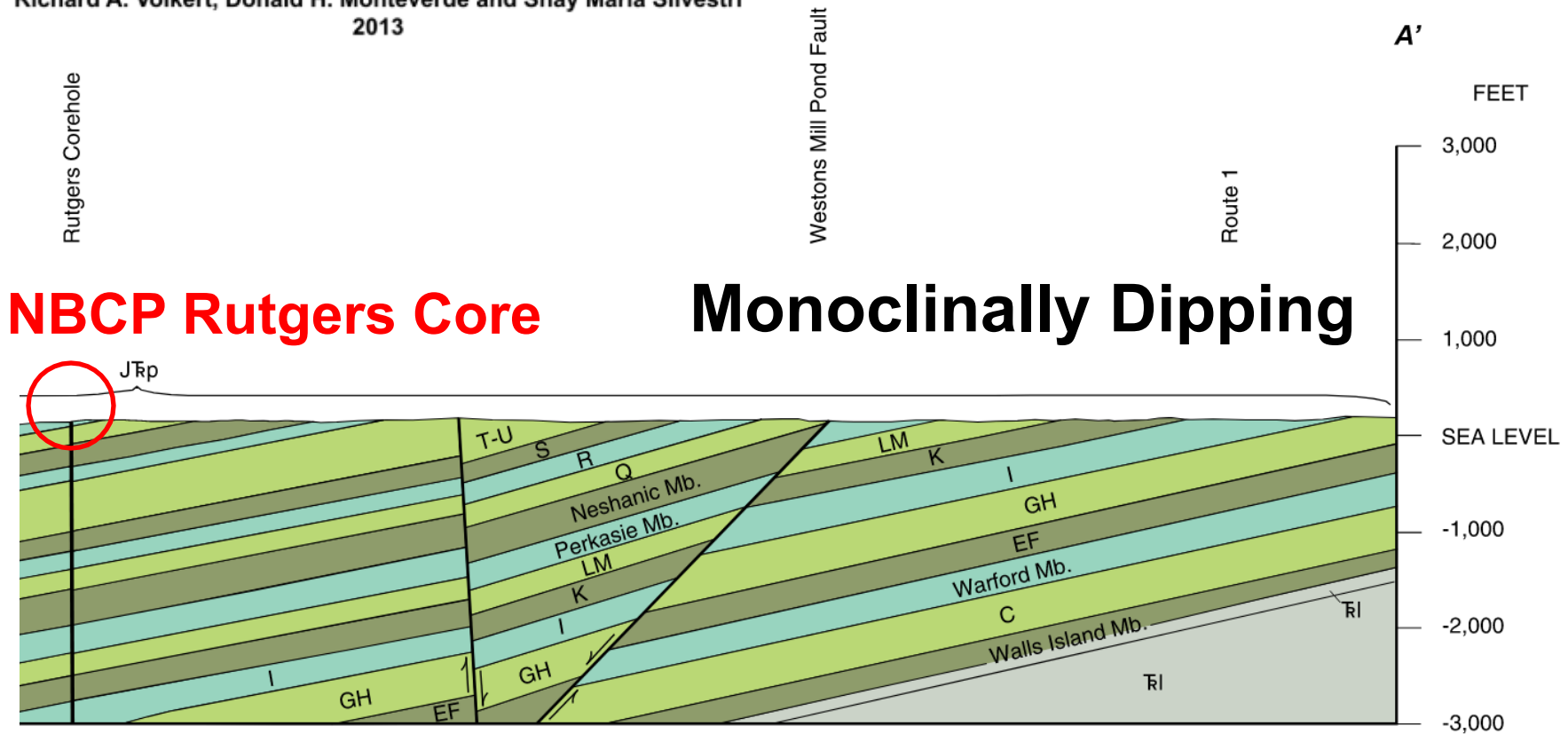


# Bedrock Quads have Members (McLaughlin Cycles) Mapped



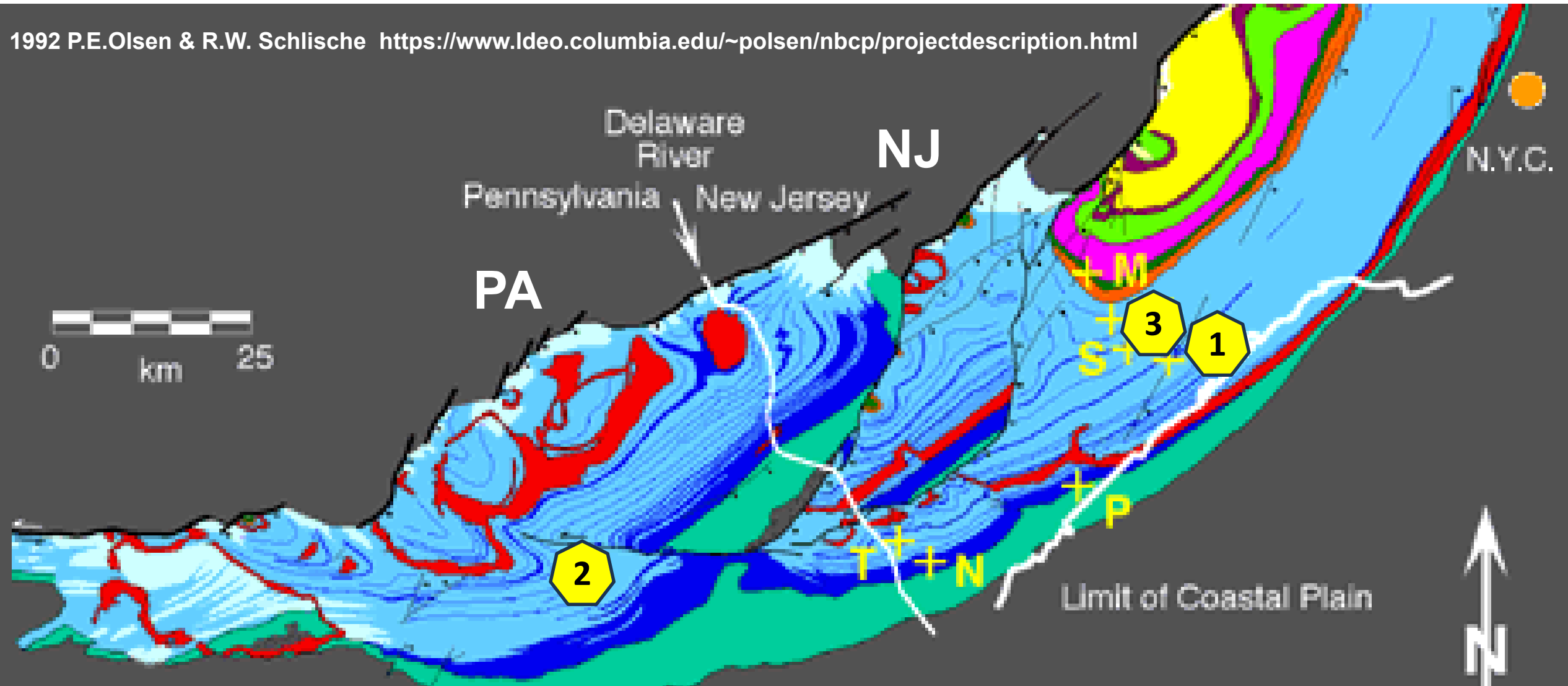
Bedrock Geologic Map of the Plainfield Quadrangle  
Union, Middlesex and Somerset Counties, New Jersey

by  
Richard A. Volkert, Donald H. Monteverde and Shay Maria Silvestri  
2013



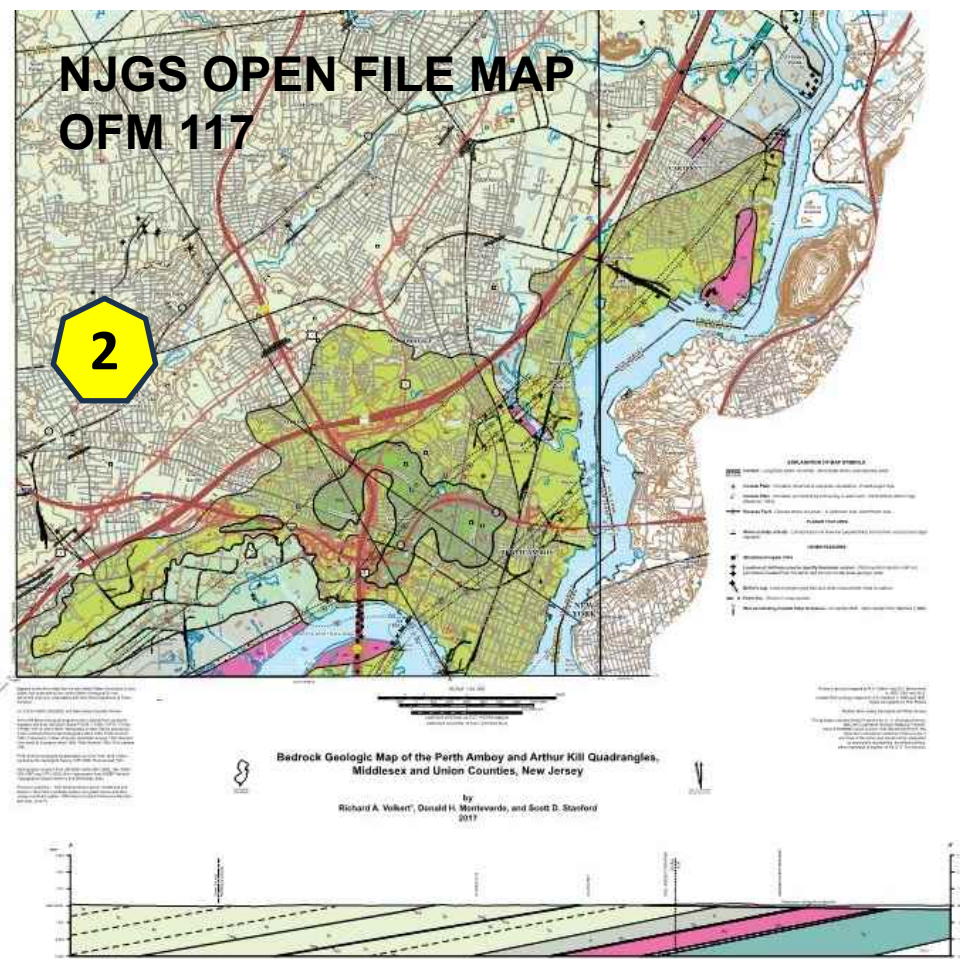
# CASE STUDY LOCATIONS

1992 P.E.Olsen & R.W. Schlische <https://www.ideo.columbia.edu/~polen/nbcp/projectdescription.html>

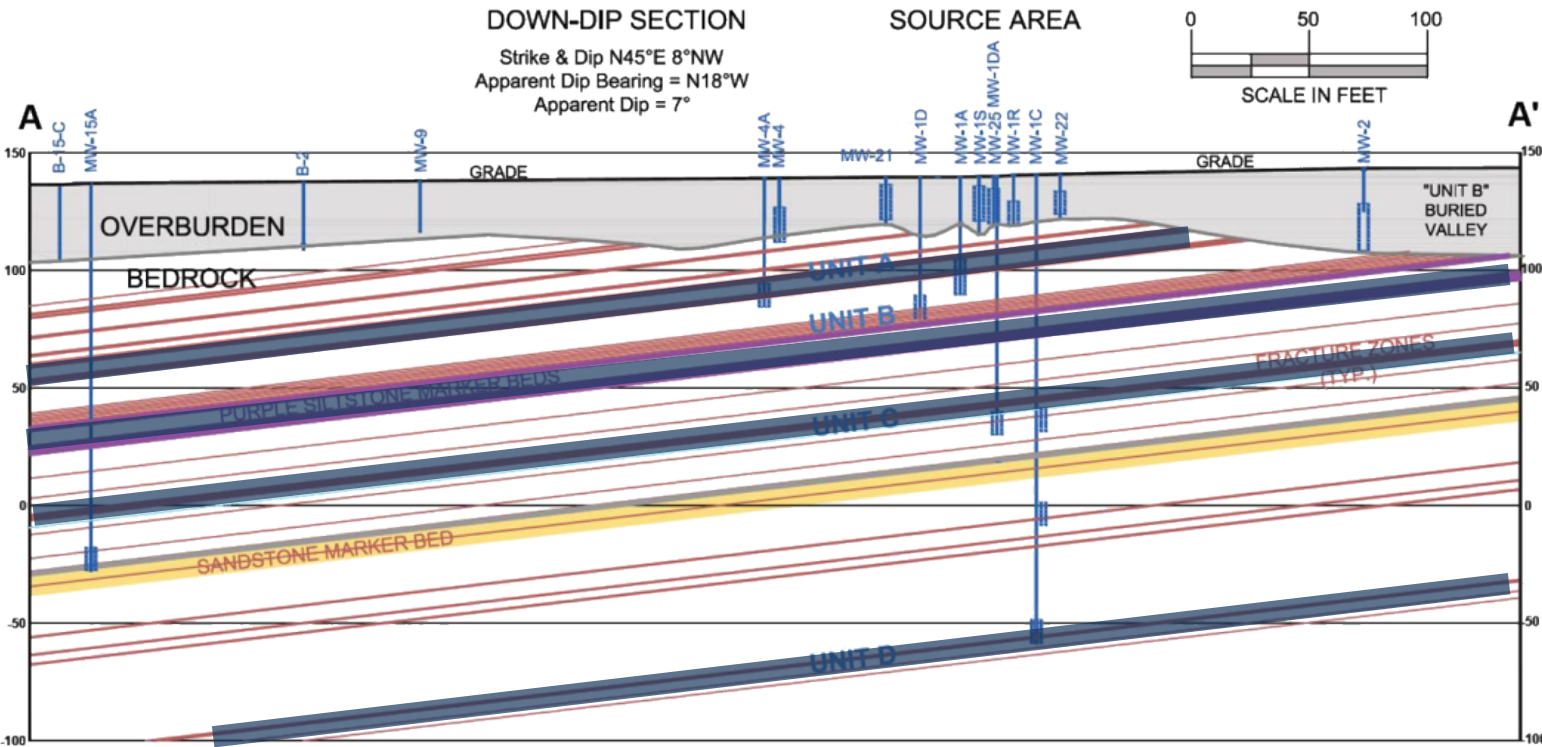




# Case Study 1 – Laminated Purple Lake Deposit Marker Beds

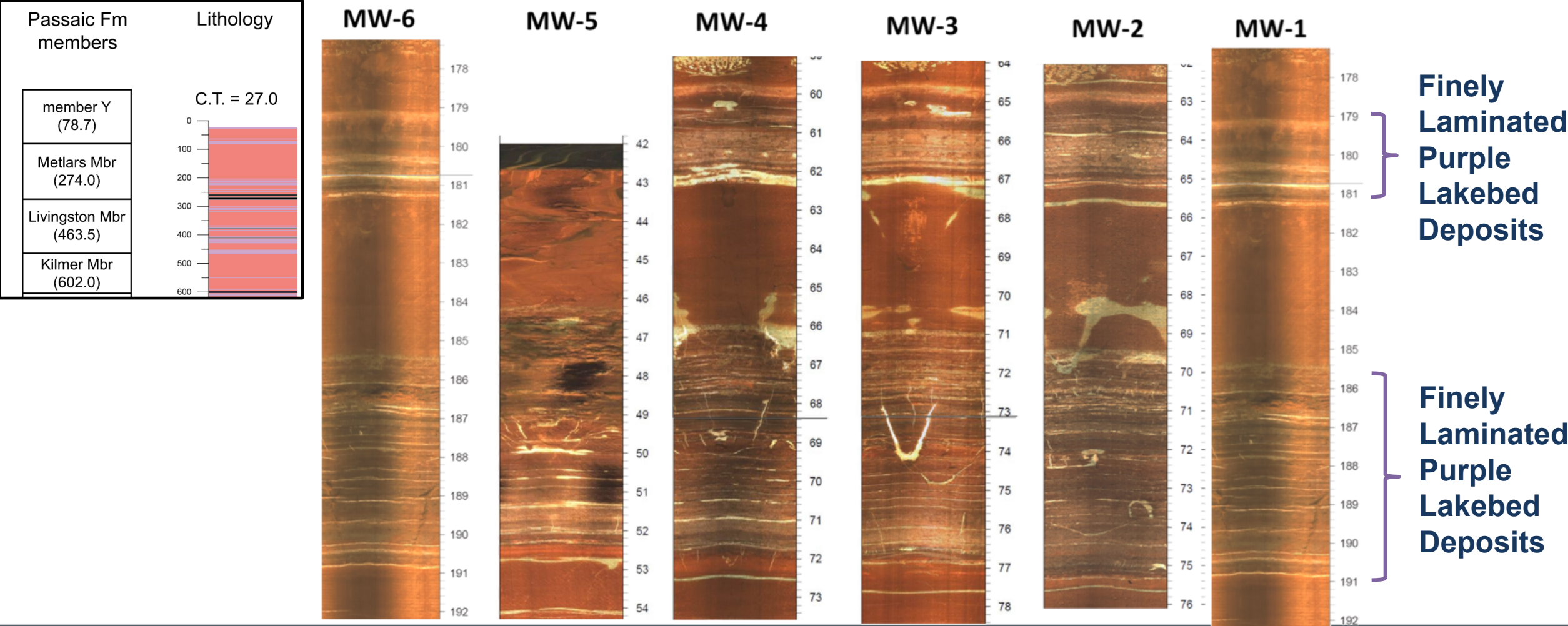


Richard A. Volkert<sup>1</sup>, Donald H. Monteverde, and Scott D. Stanford  
2017



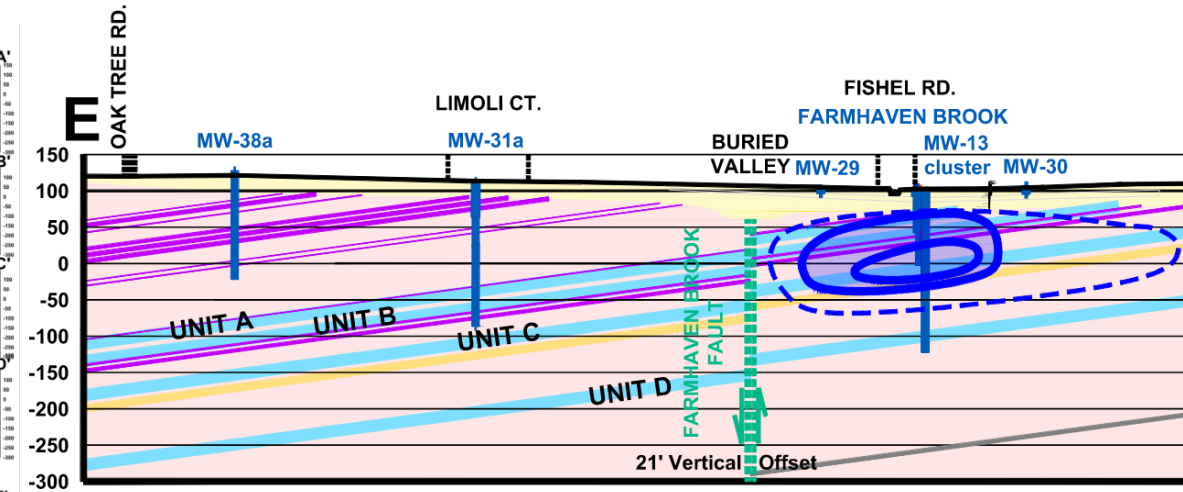
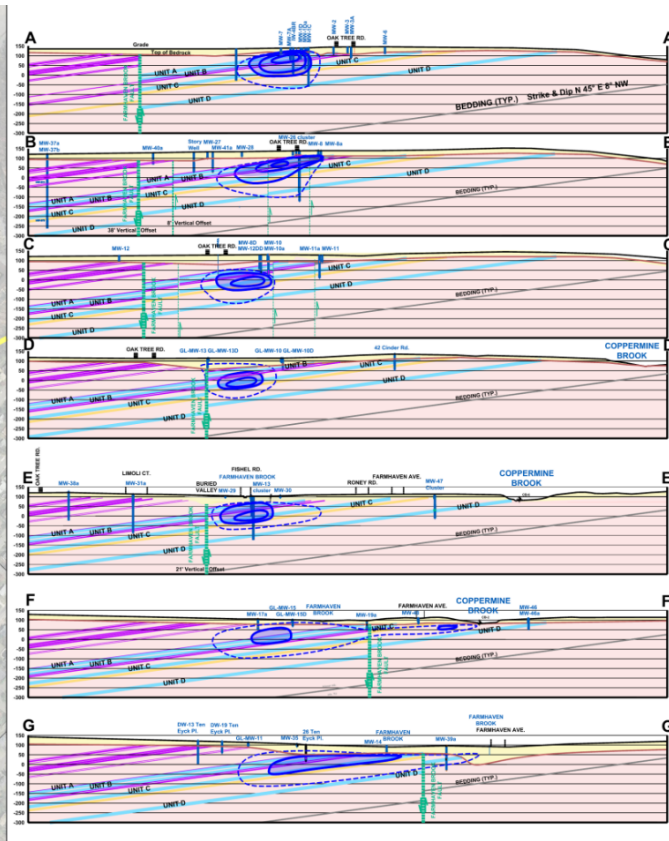
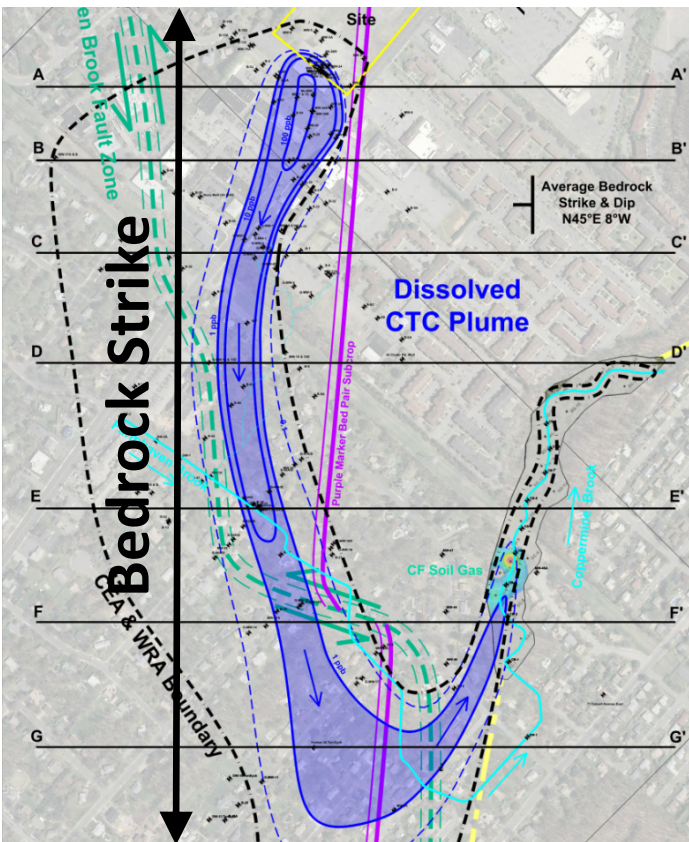
Four Major Type 1 WBZs

# Correlation of Marker Beds with Optical Televiewer Logs for > One Mile





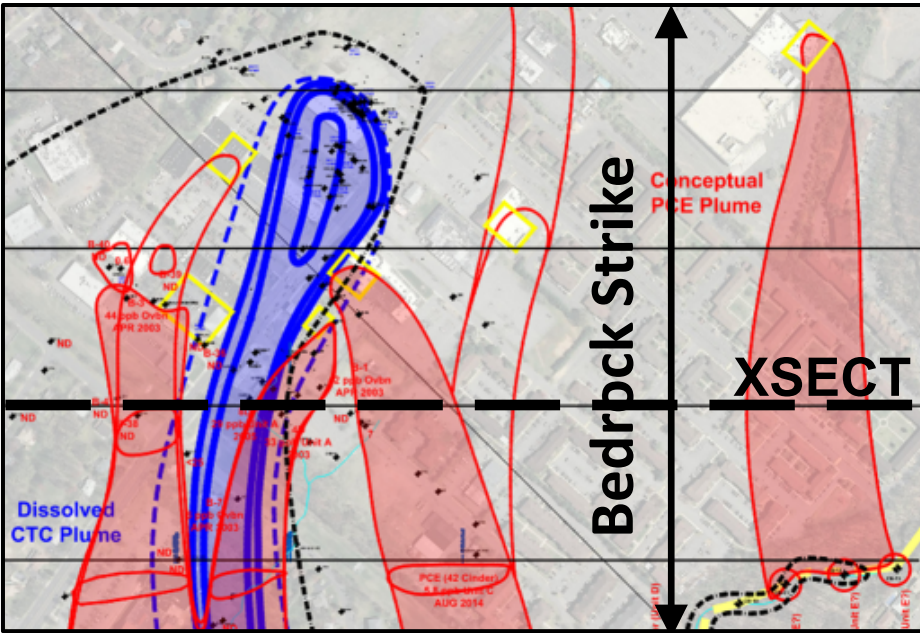
# CTC Plume Traceable along Specific Bedding Planes for > One Mile with Complete ESS Correlations



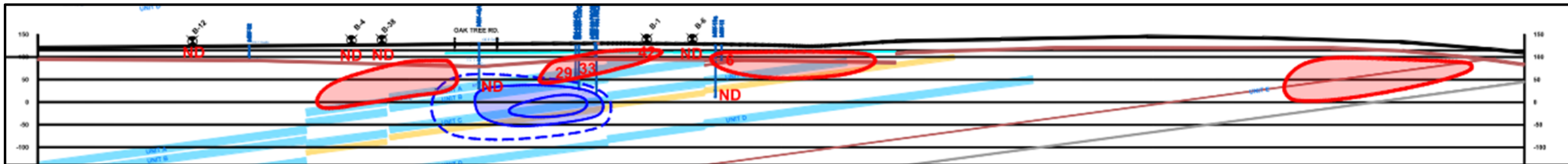
- Network of 85 Monitoring Wells
- Carbon tetrachloride (CTC) plume traceable for over one mile within specific water-bearing fractures
- Plume Discharges to Surface Water



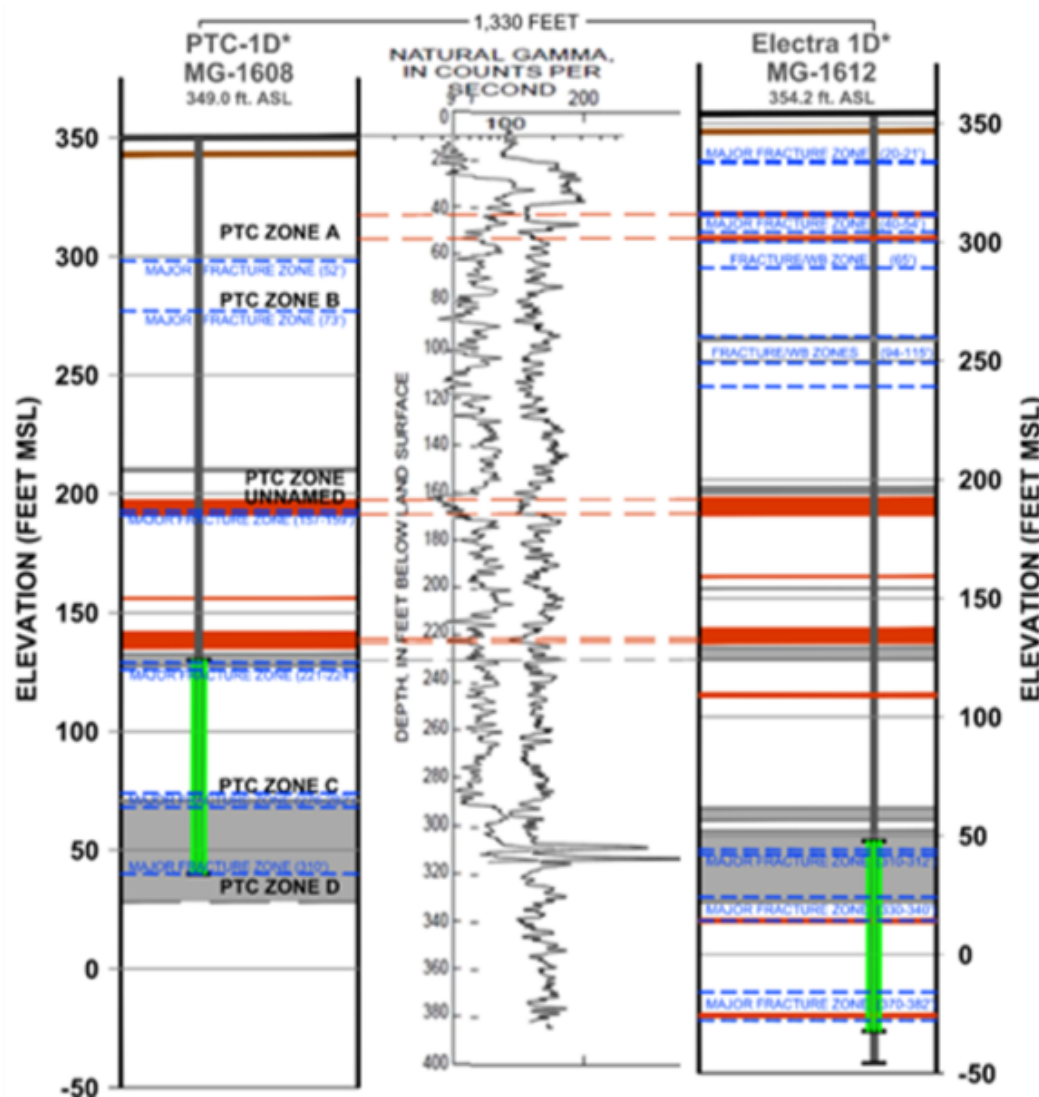
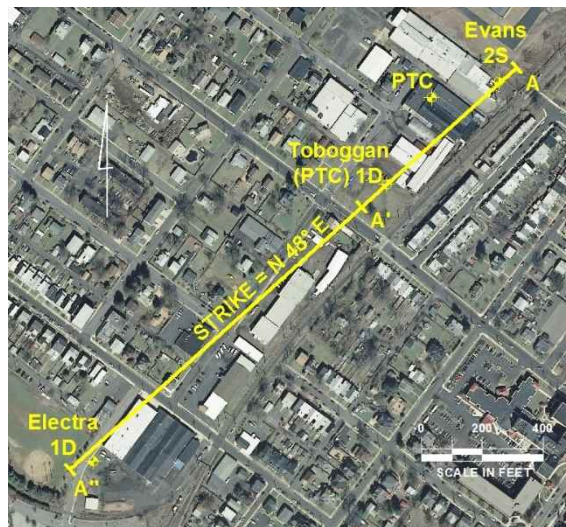
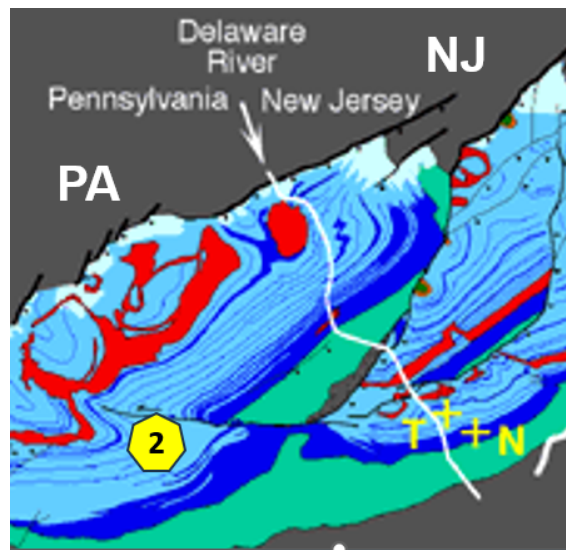
# CTC Plume Commingled with PCE Plumes from Multiple Offsite Sources



- Carbon tetrachloride (CTC) plume **BLUE**
- Tetrachloroethene (PCE) plumes **RED**
- Same ESS/Down-Dip Sections as CTC
- Successfully demonstrated to regulators that PCE plumes were from offsite sources using ESS graphics and correlations



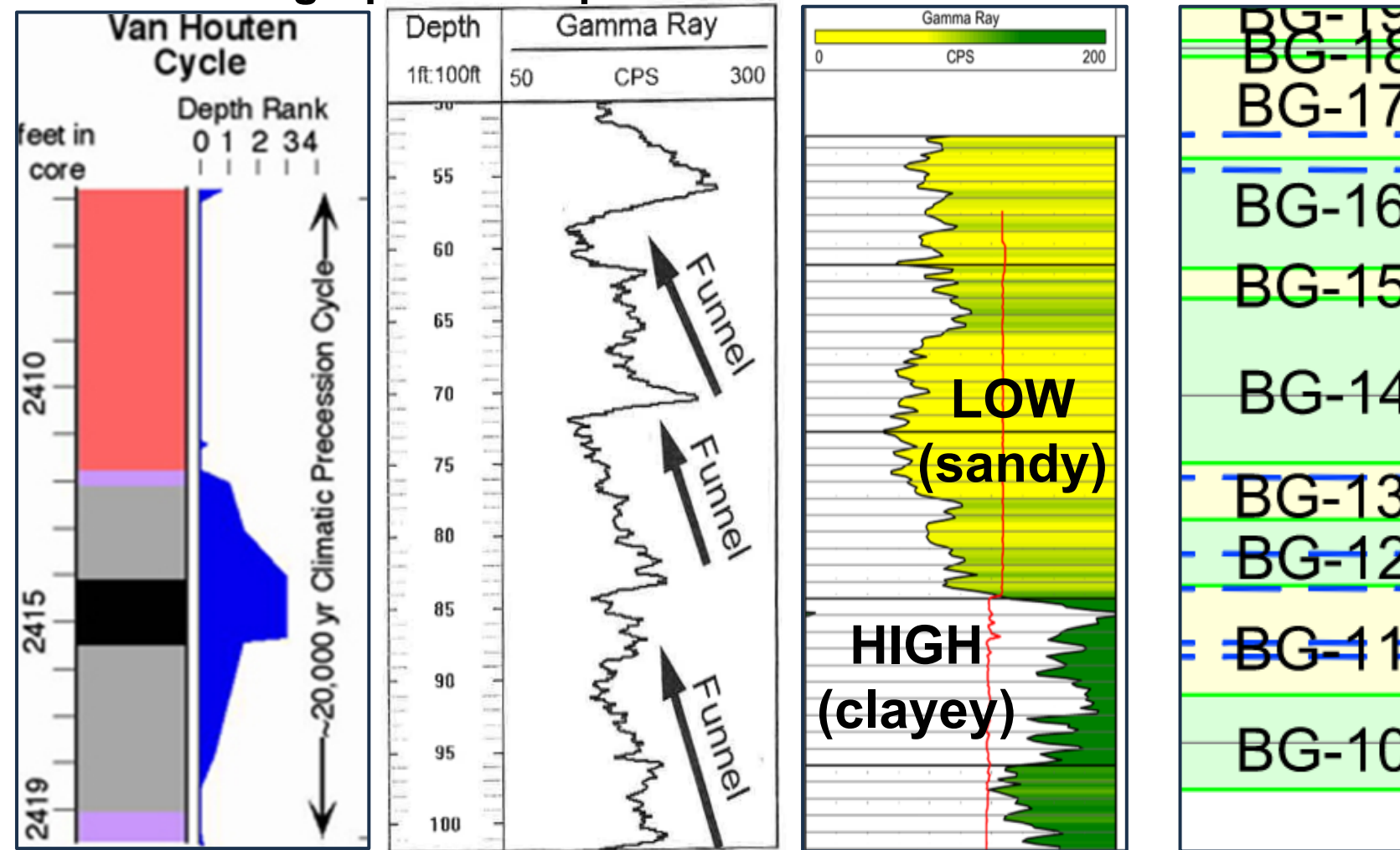
# Case Study 2 – Natural Gamma Log ESS



- Lack of Easily Discernable Bedding Units
- Natural Gamma log patterns, and associated ESS interpretations, correlated over 1,000's of feet

# New Fracture Nomenclature Based on ESS Analysis

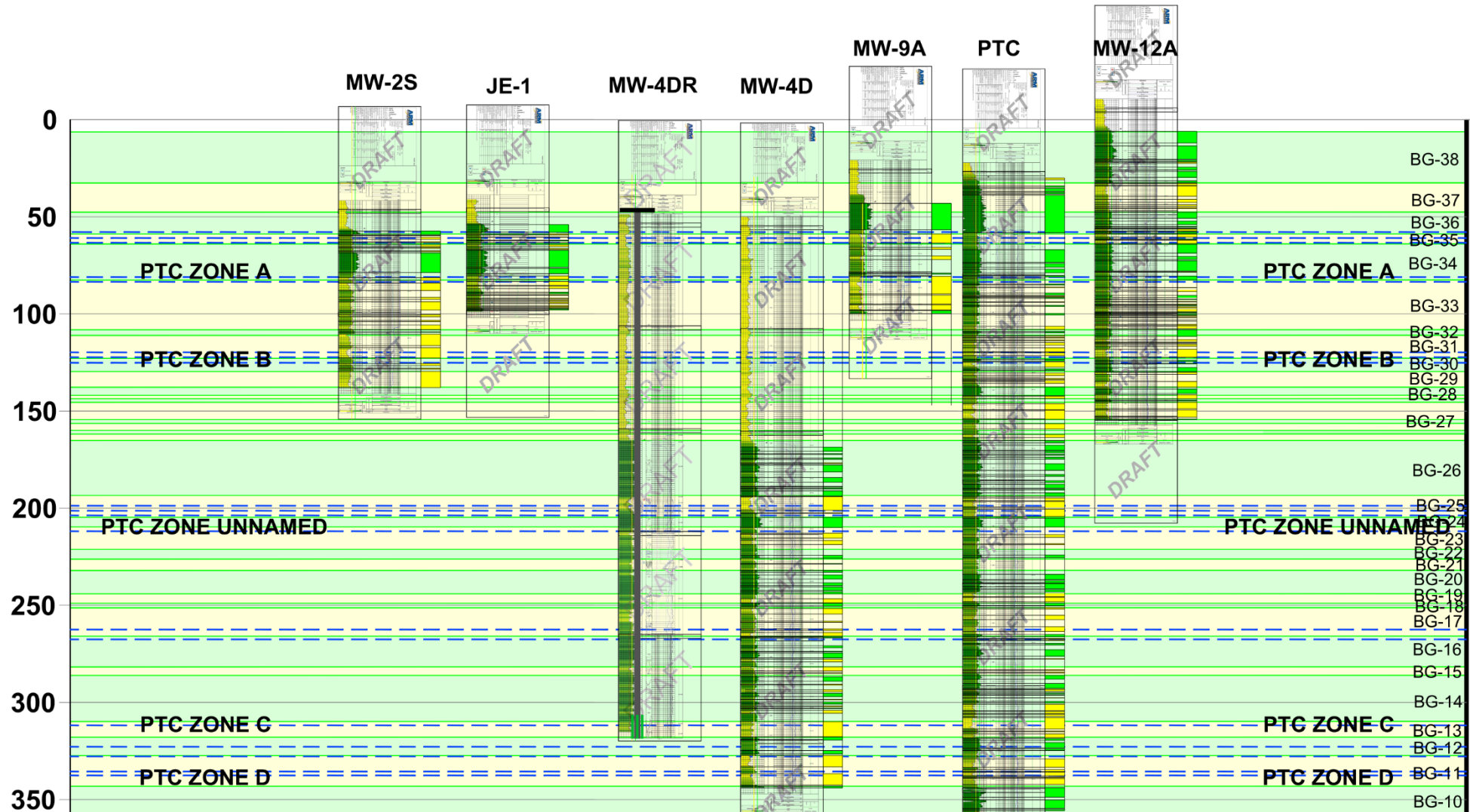
## Coarsening Upward Sequences



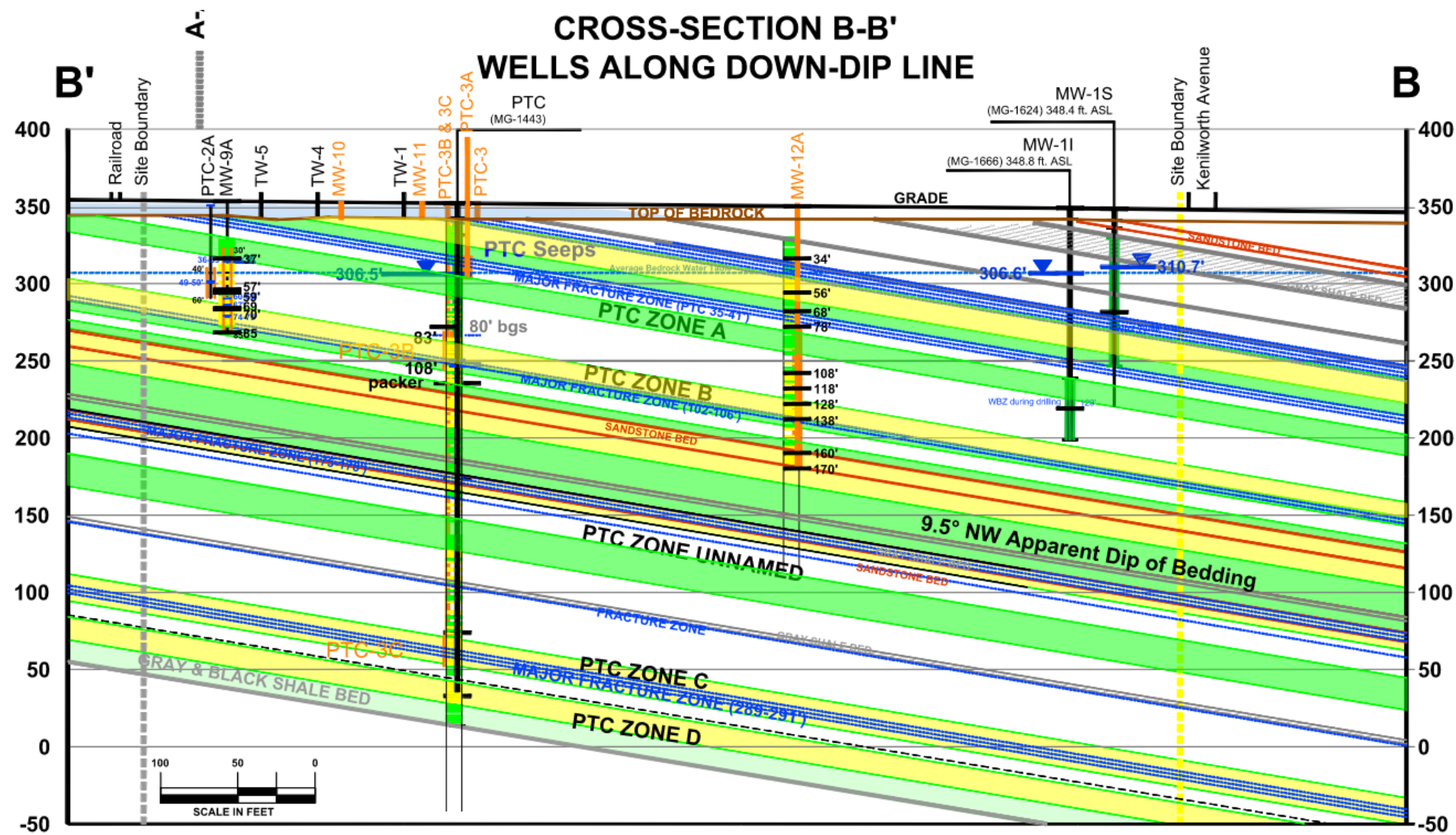
- Brunswick Group # (bedding unit)
- ESS and nomenclature based on rationale and process used by USGS at the Naval Air Warfare Center (NAWC) (USGS LaCombe 2000)
- Based primarily on natural gamma logs, with supporting data from driller logs and cores.



# Correlated Newly Named Bedding Units Site-Wide

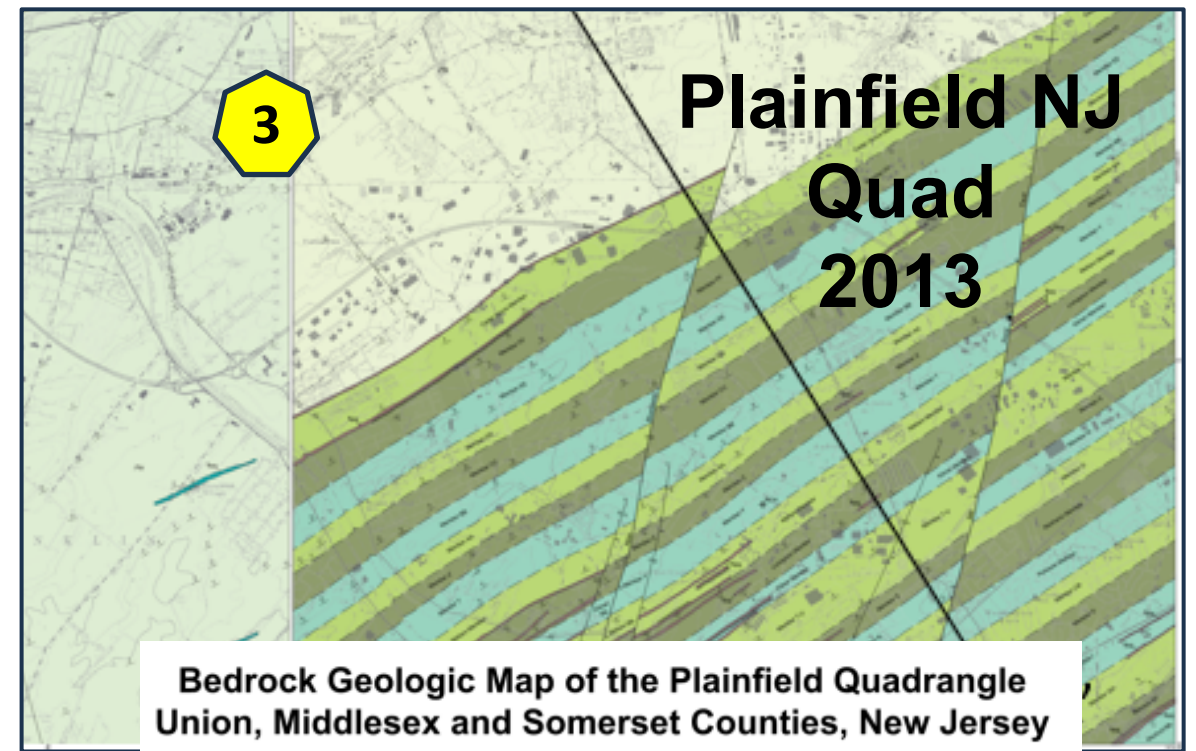
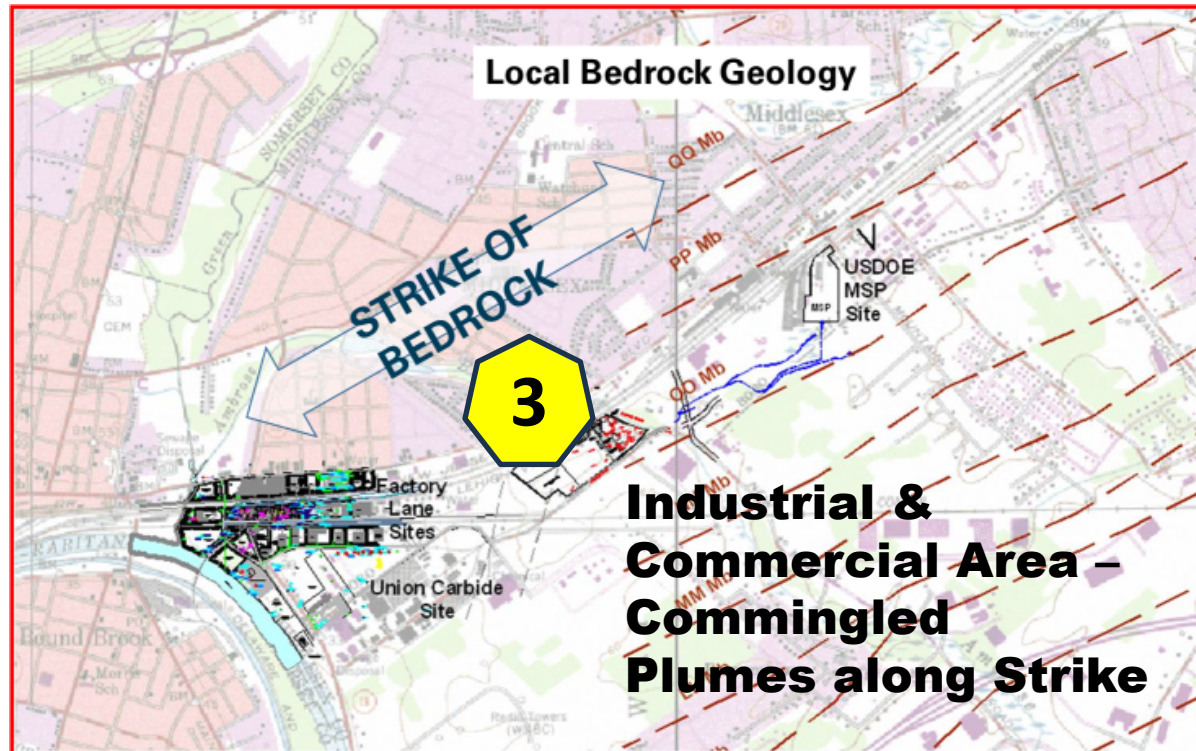


# Updated Conceptual Site Model used for Remedial Design





# Case Study 3 Brings Together Multiple ESS Methods

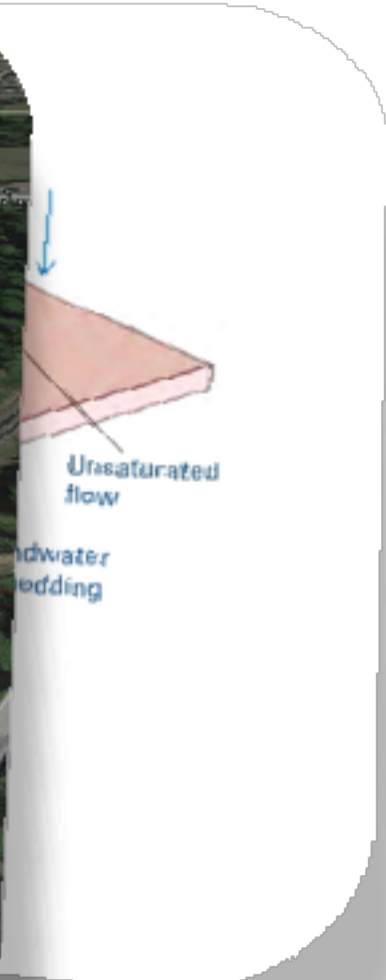


by  
Richard A. Volkert, Donald H. Monteverde and Shay Maria Silvestri  
2013





## An aerial photograph of an industrial area. A pink star in the center is labeled 'SITE' in large pink letters. A blue arrow labeled 'STREAM' points from the top left towards the site. The site itself is a large, cleared area with some buildings and equipment. To the right of the site is a large body of water. Roads are visible, including 'Barnes Rd' and 'Hickory St'. The surrounding area is a mix of industrial and natural landscape.





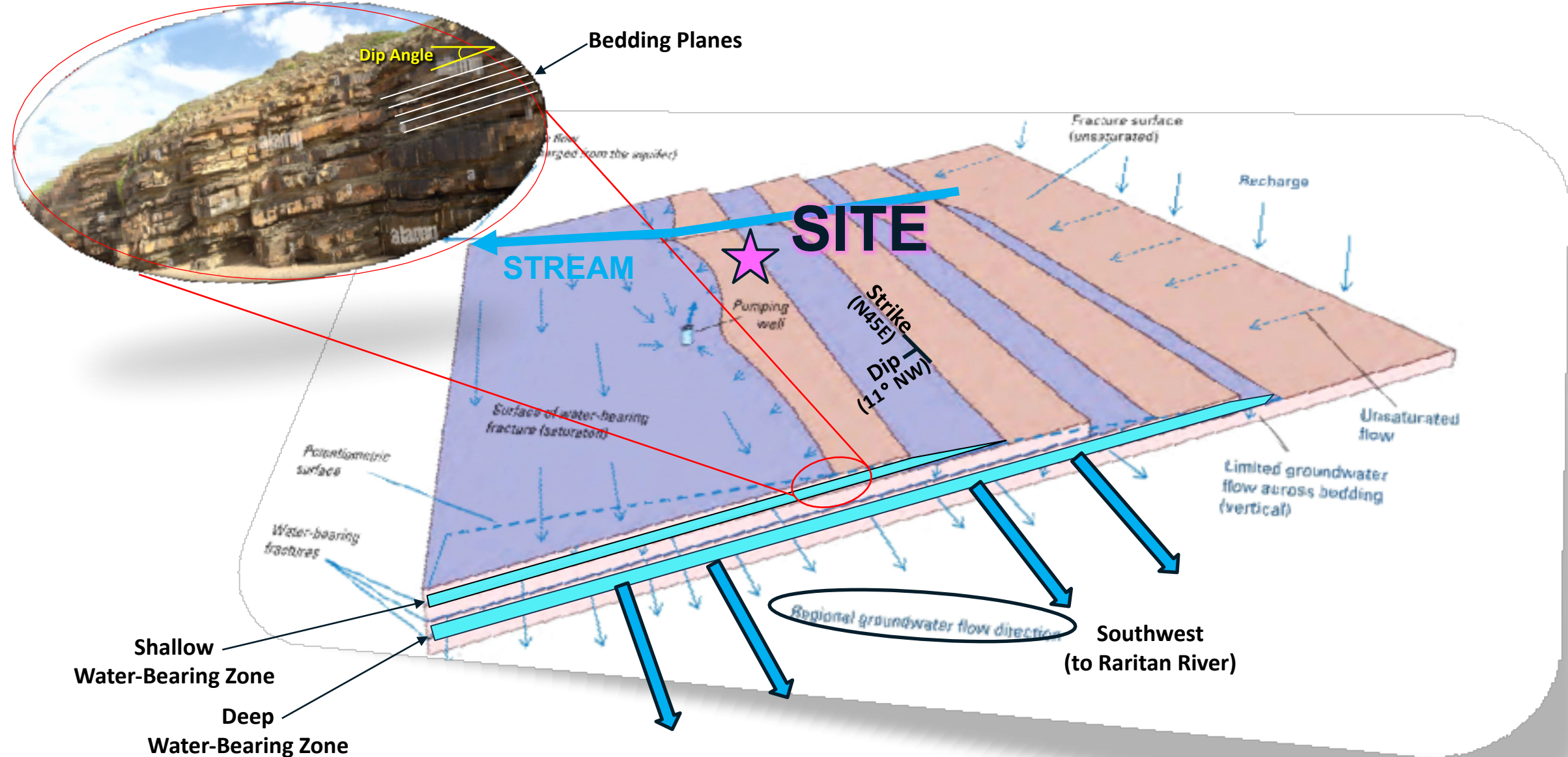
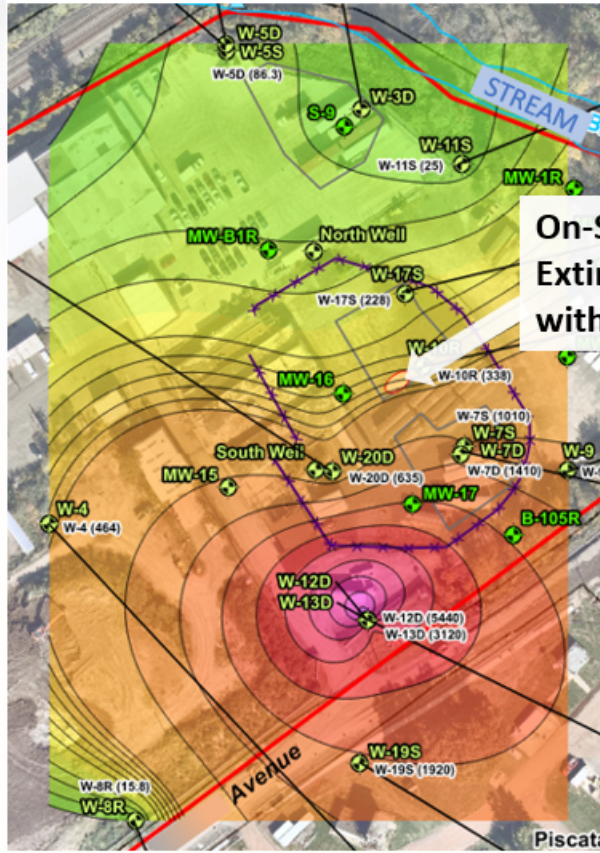


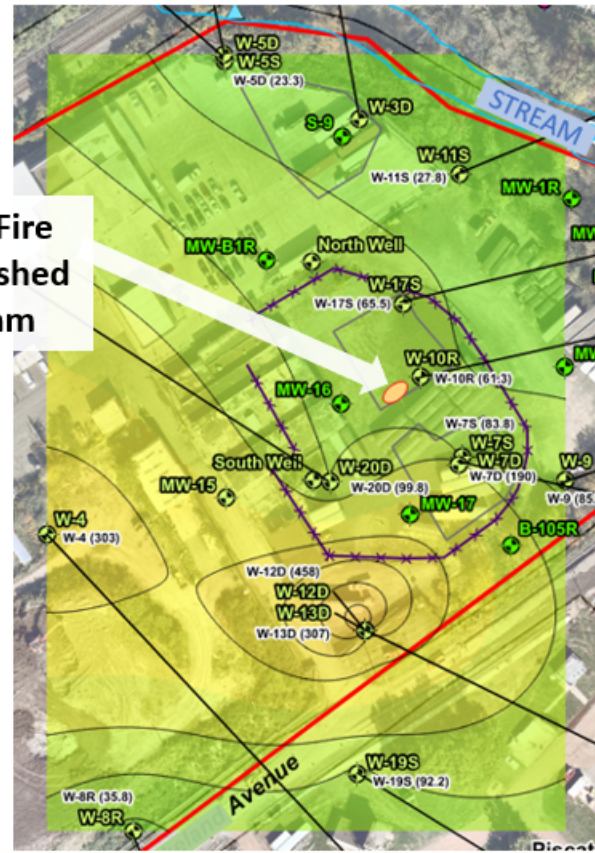
FIGURE REF: USGS 2010 Water Resources of Rockland County, NY, with Emphasis on Newark Basin Bedrock Aquifer

# PFAS Investigated for Historic Chemical Fire Extinguished with AFFF

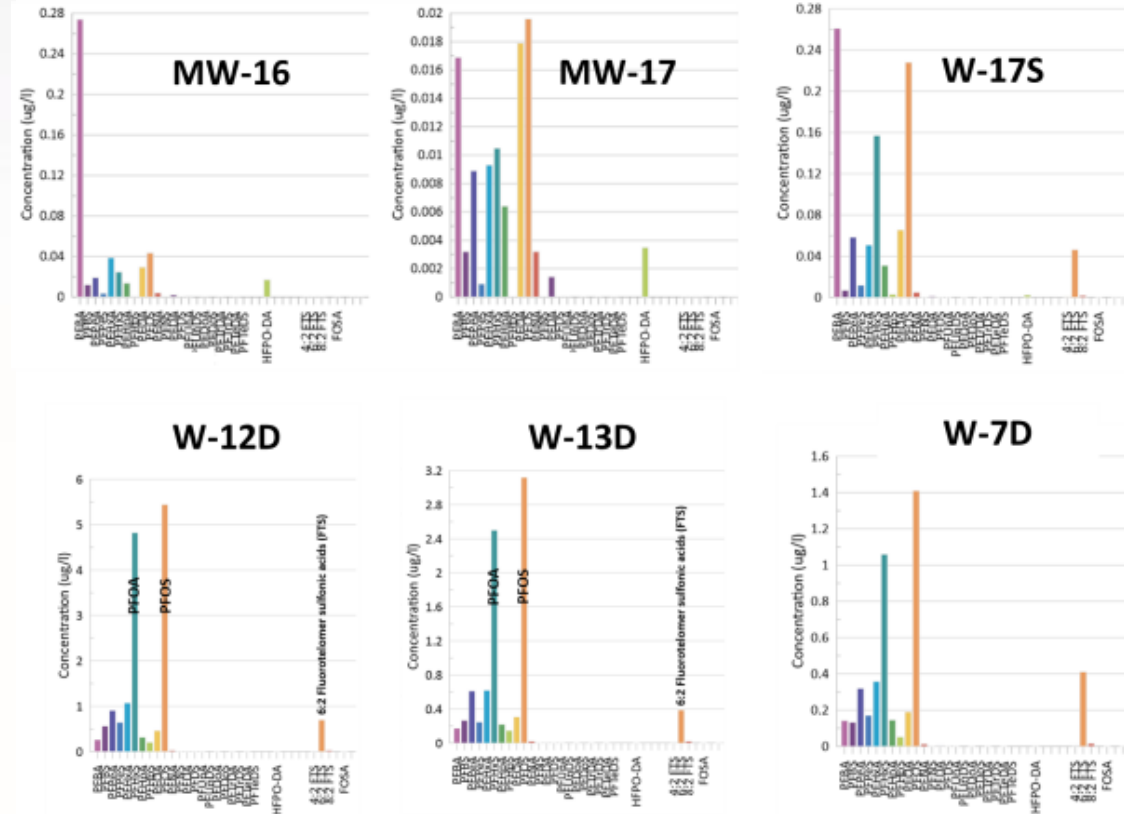
## PFOS



## PFOA



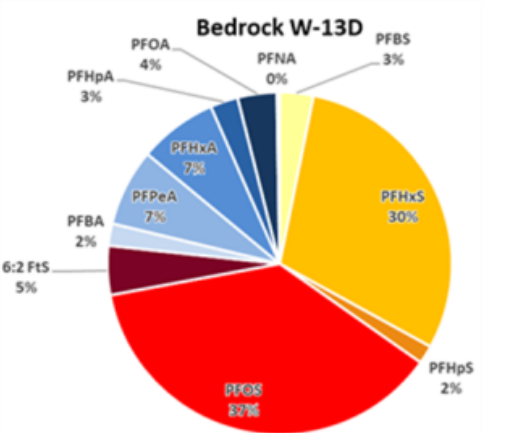
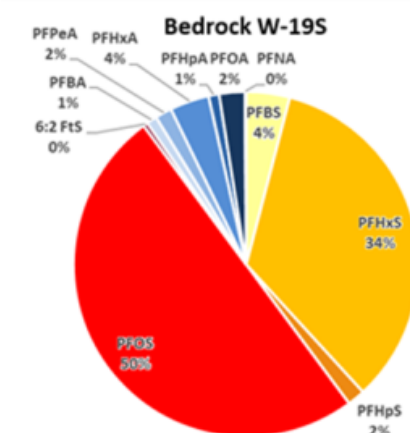
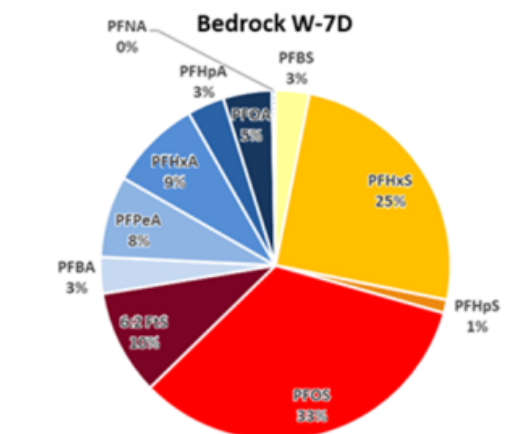
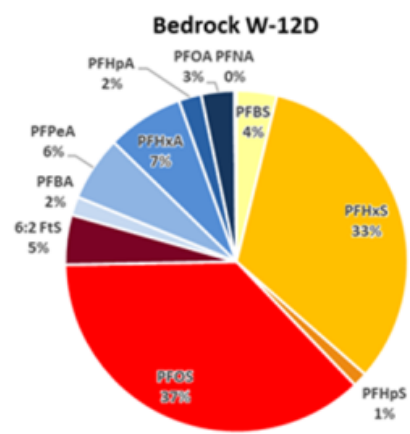
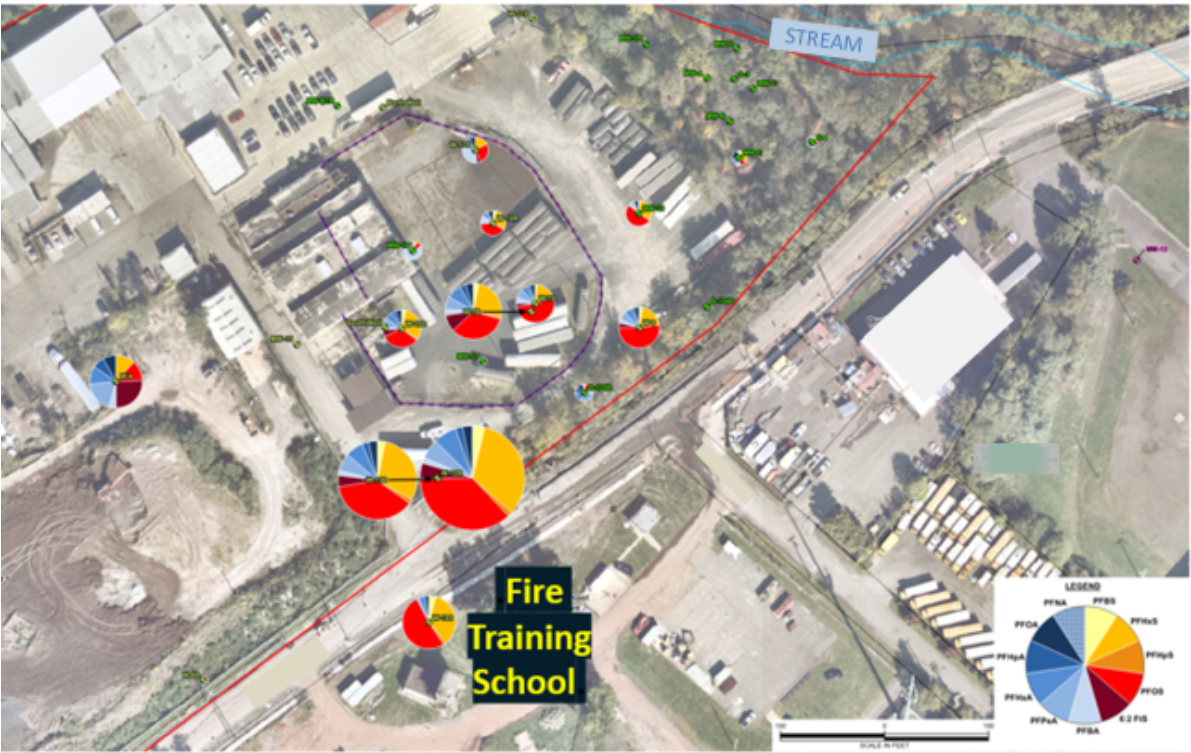
## PFAS Signatures Reflect Different Sources or Transport Scenarios



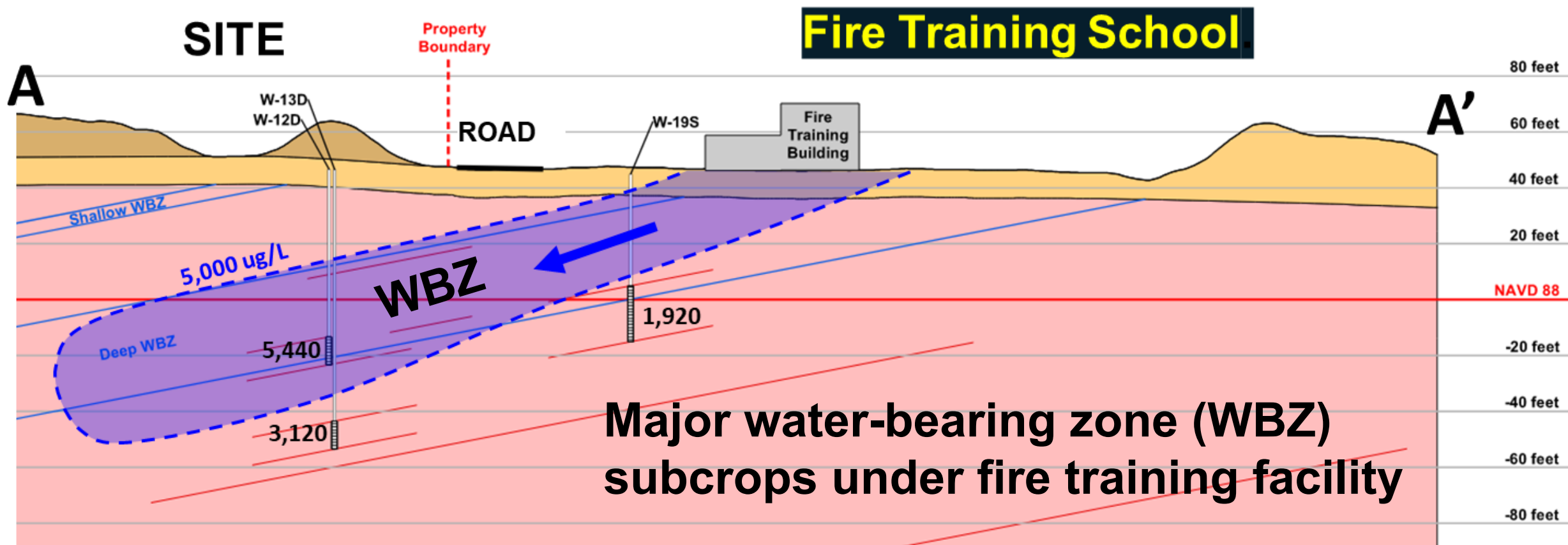


# Investigation Documented Updip Fire Training School

PFAS Ratios in Bedrock GW  
Scaled Based on Sum of Concentrations



# PFAS Migrating Down-Dip from Fire Training School

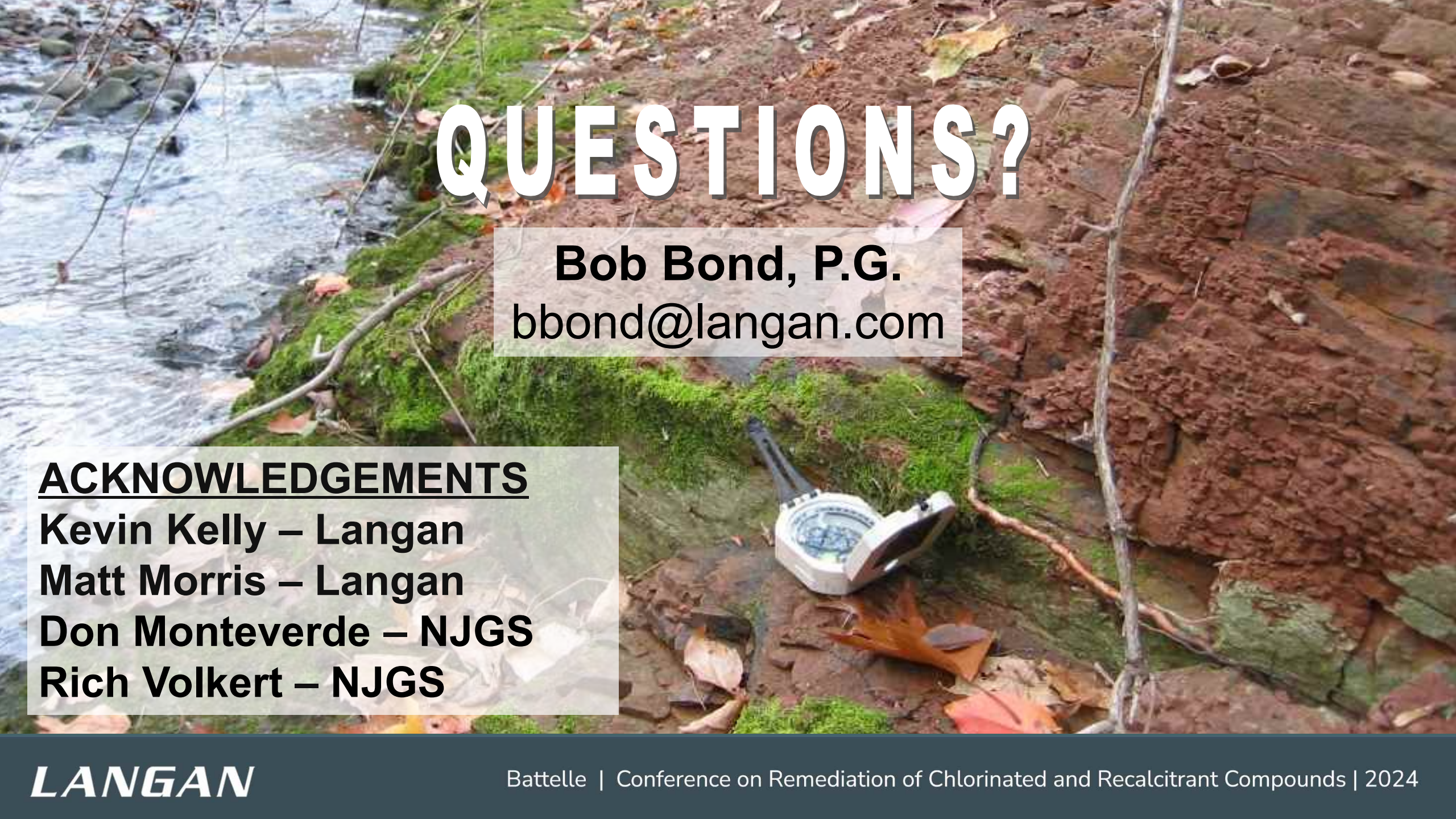




## 1,4-Dioxane (ug/L)





The background image shows a shallow stream with water flowing over rocks. The banks are covered in moss and fallen leaves. A white compass is lying on the mossy bank in the lower center of the frame.

# QUESTIONS?

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## ACKNOWLEDGEMENTS

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**Don Monteverde – NJGS**

**Rich Volkert – NJGS**