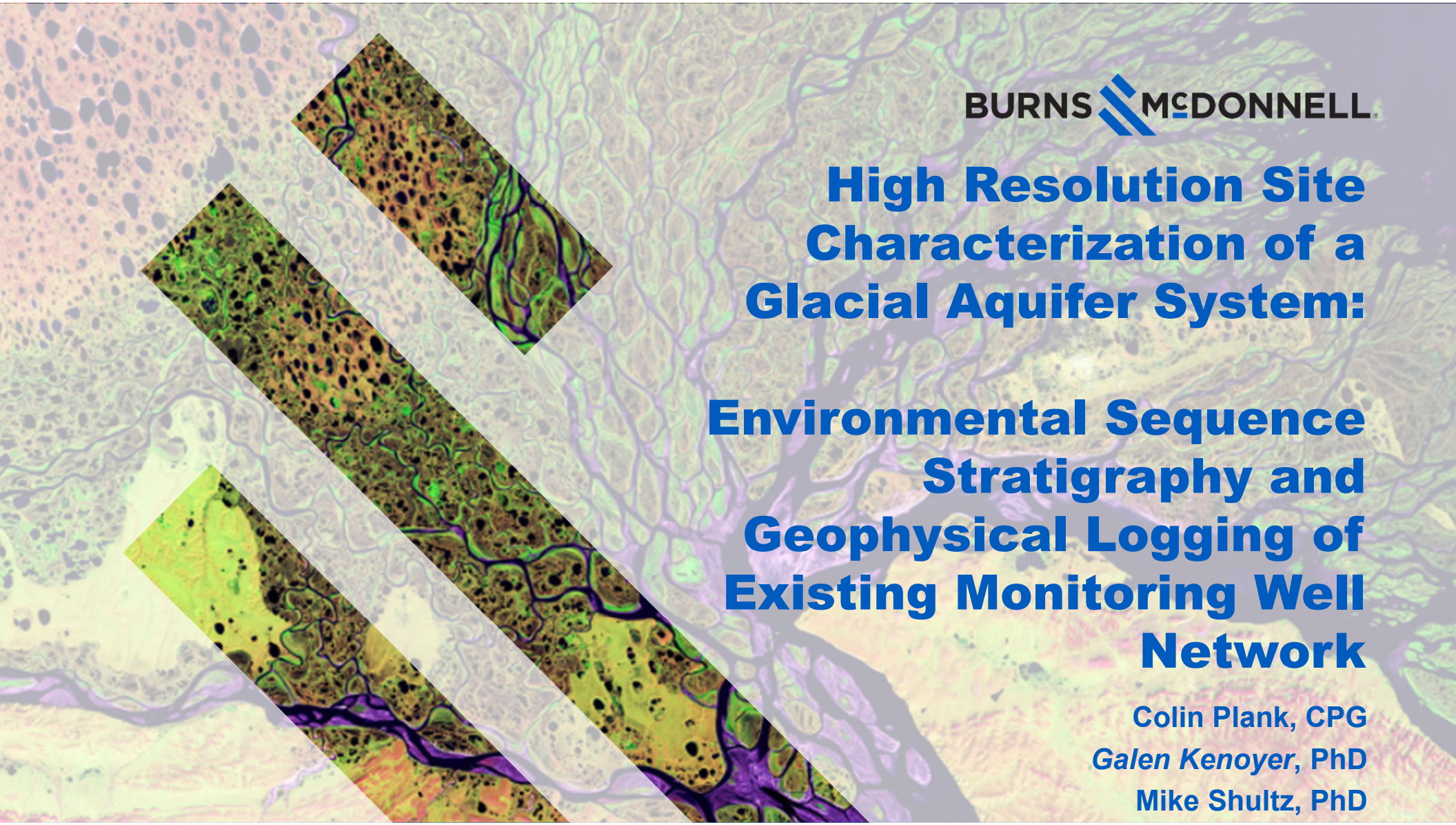

BURNS McDONNELL

High Resolution Site Characterization of a Glacial Aquifer System:

Environmental Sequence Stratigraphy and Geophysical Logging of Existing Monitoring Well Network

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Galen Kenoyer, PhD
Mike Shultz, PhD

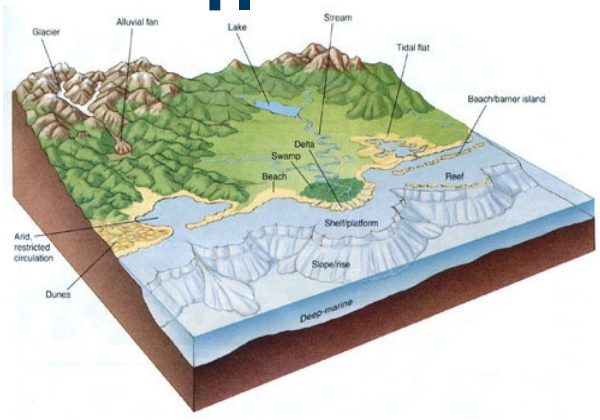
Agenda

- Glacial Geology
- Approaches used
  - ESS
  - Gamma Logging
  - Colloidal Borescope
- Results: Updated Conceptual Site Model (CSM)

Soller, D.R. and M.C. Reheis, 2004, Surficial Materials In The Conterminous United States. U.S. Geological Survey Open-File Report OFR-03-275

The Environmental Sequence Stratigraphy (ESS) Process

1.



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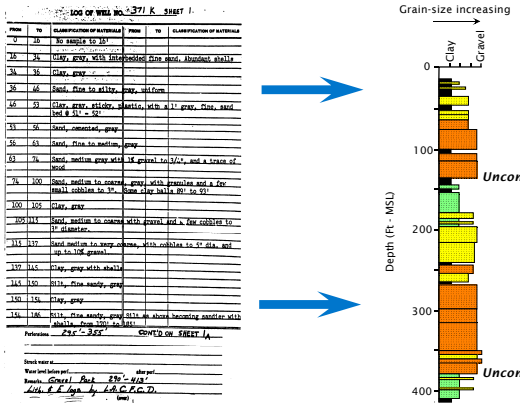
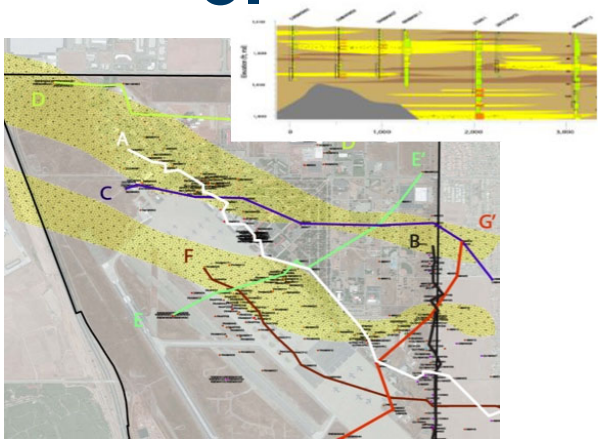


3.

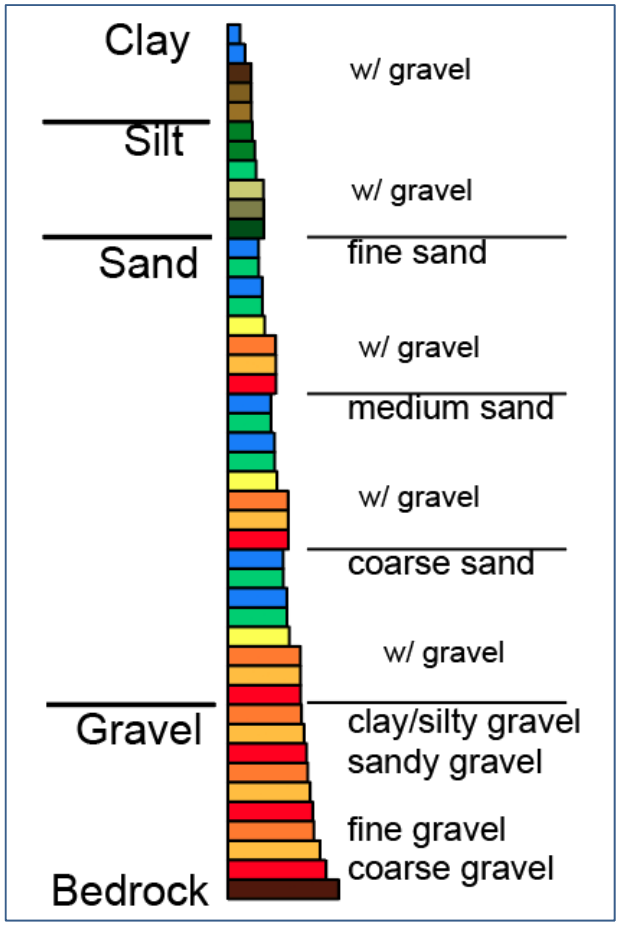


Determine depositional environment, which is the foundation of the ESS evaluation

Leverage existing lithology data: format to emphasize vertical grainsize patterns

Map and predict the subsurface permeability architecture and HSUs **away from the data points**

The Graphic Grain Size Log



- Can use existing boring logs
- Width of box = greater for larger dominant grain size
- Color – corresponds to the grain size of the primary accessory grain size
  (e.g., fine sand with silt is green, fine sand with gravel is red)
- Stratigrapher can recognize vertical trends and patterns characteristic for different types of deposits in the appropriate geologic setting
- E.g., basal till, braided stream outwash

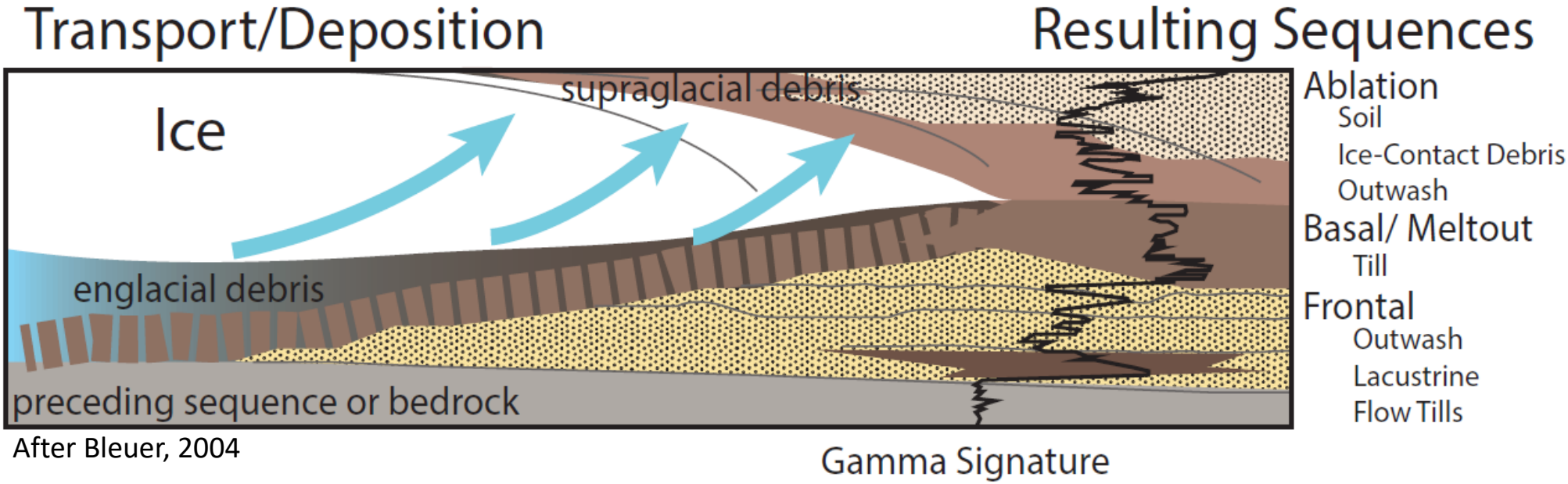
Natural Gamma Logging

- Natural Gamma Emissions from Clay and Feldspathic Minerals
- Continuous Log of Geology with ~1 ft. Resolution
  - Logs ~relative grainsize
- Logging speed-
  - 5 to 10 ft/min
- Works in Cased Wells


Inserting gamma probe into well

Decontamination after every log

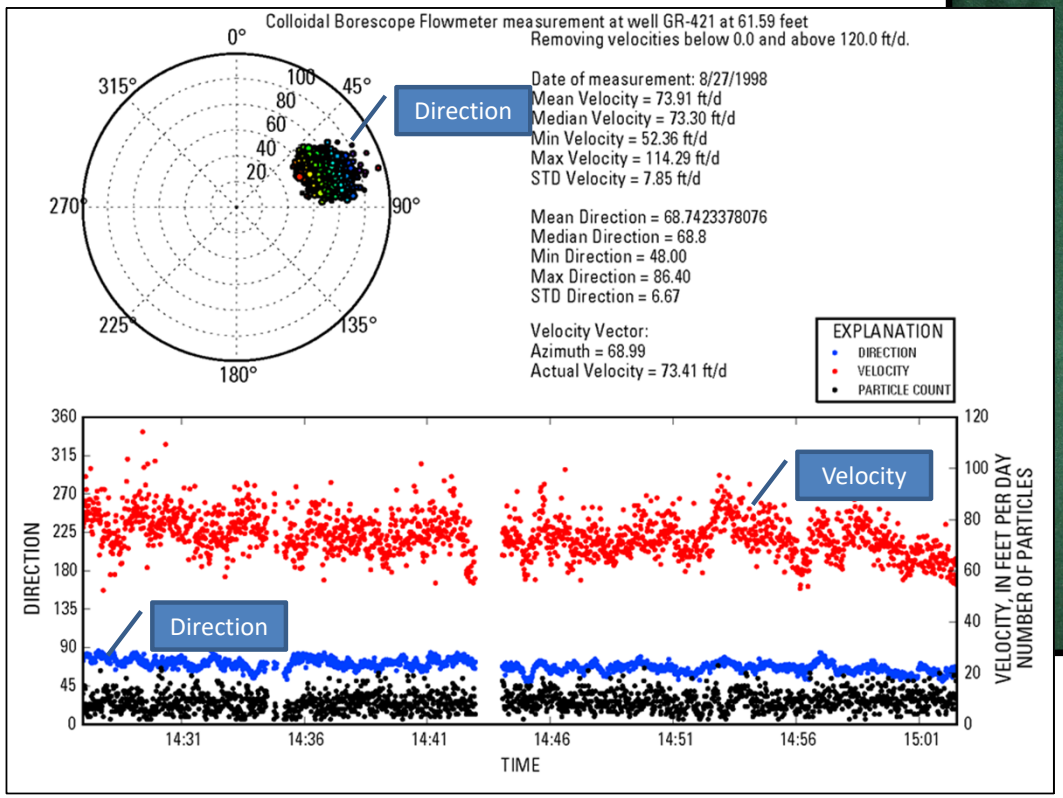
The Gamma Log Signature of A Glacial Cycle



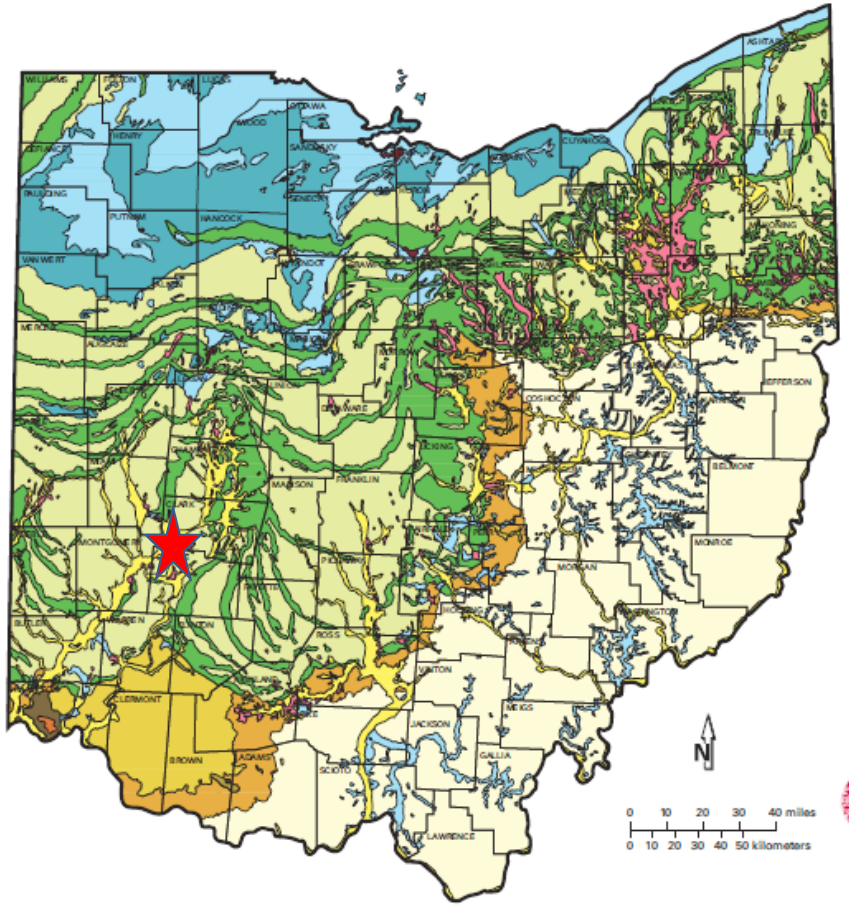
After Bleuer, 2004

Bleuer, N.K., 2004. Slow Logging Subtle Sequences The Gamma-Ray Log Character of Glacigenic and other Unconsolidated Sedimentary Sequences. *Indiana Geological Survey Report 65*

Colloidal Borescope Flowmeter

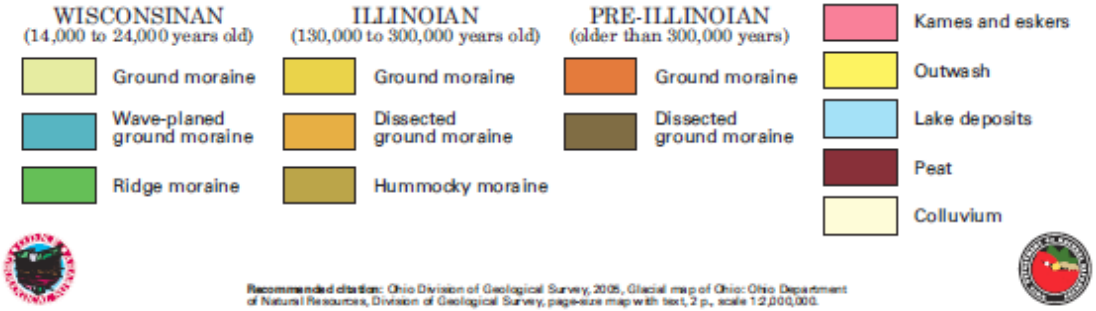


Site Setting- The Glacial Landscape of Ohio

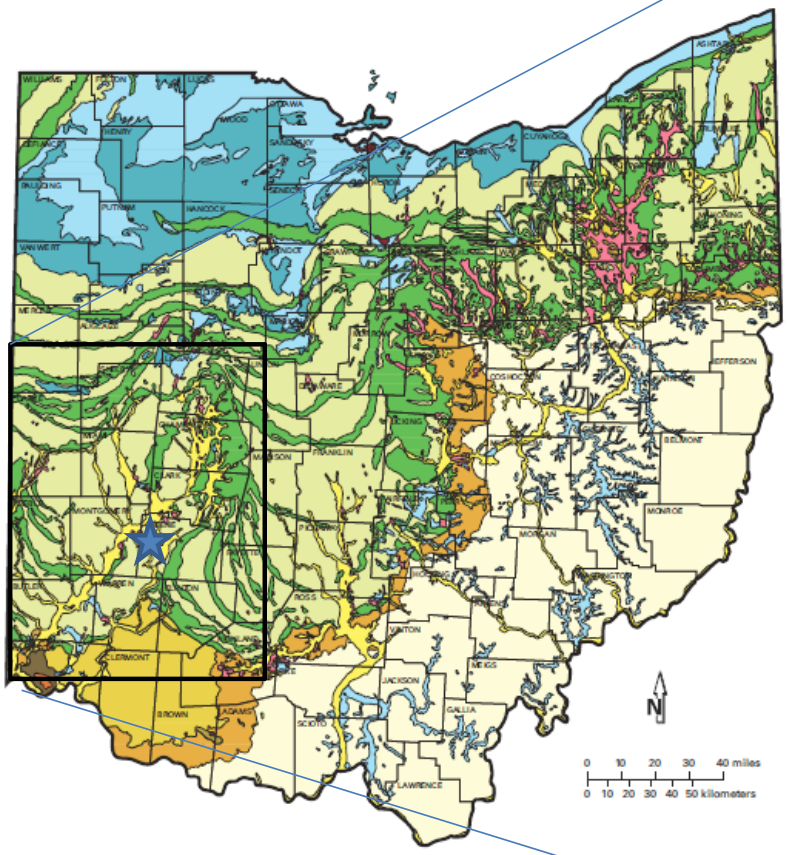


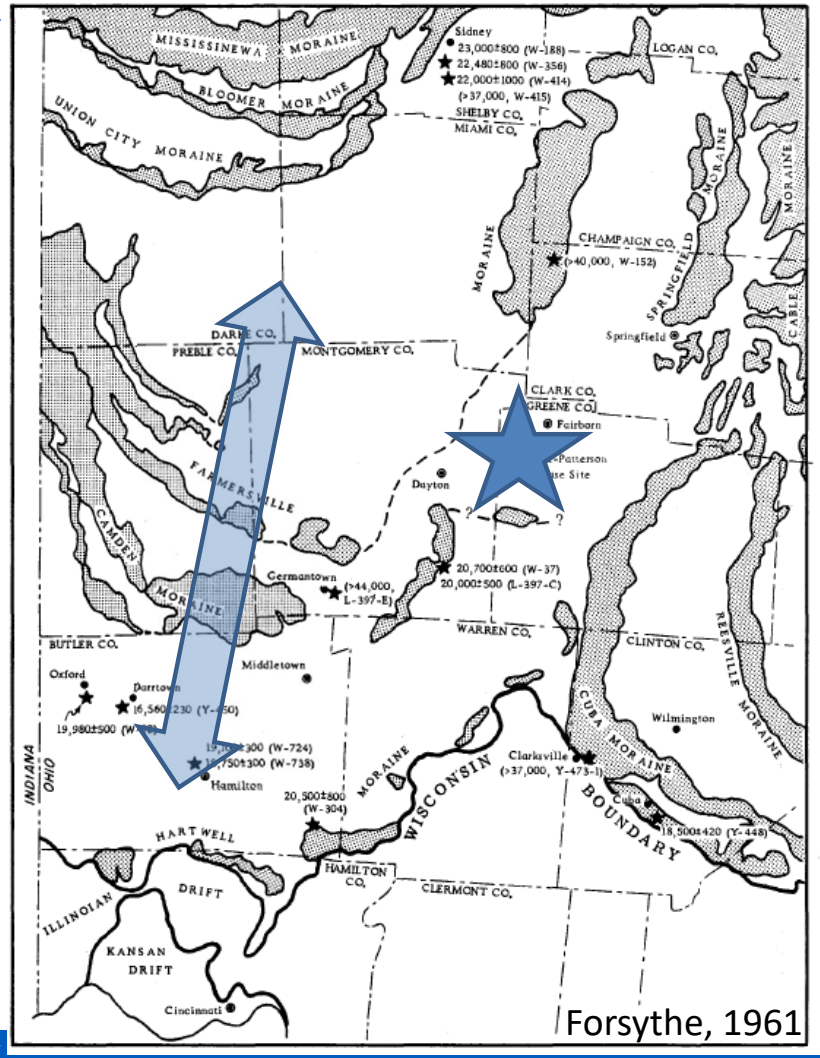
Site Located in Interlobate Area Between Miami and Scioto Lobes

- Lobes migrated around the Bellefontaine Outlier

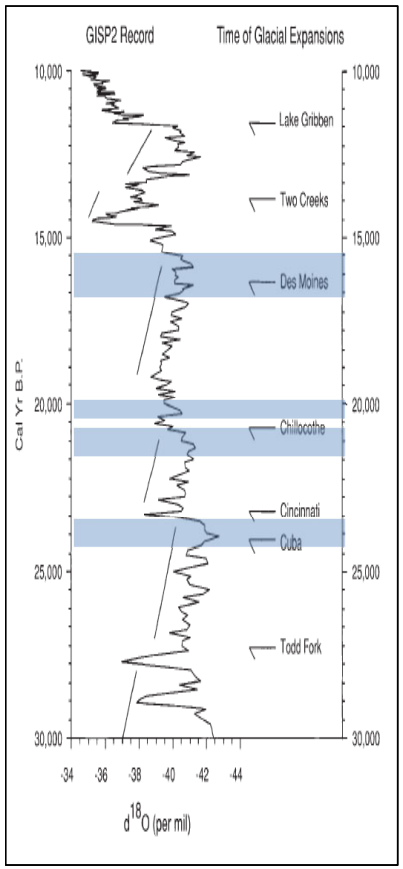


Dynamic Ice Margin



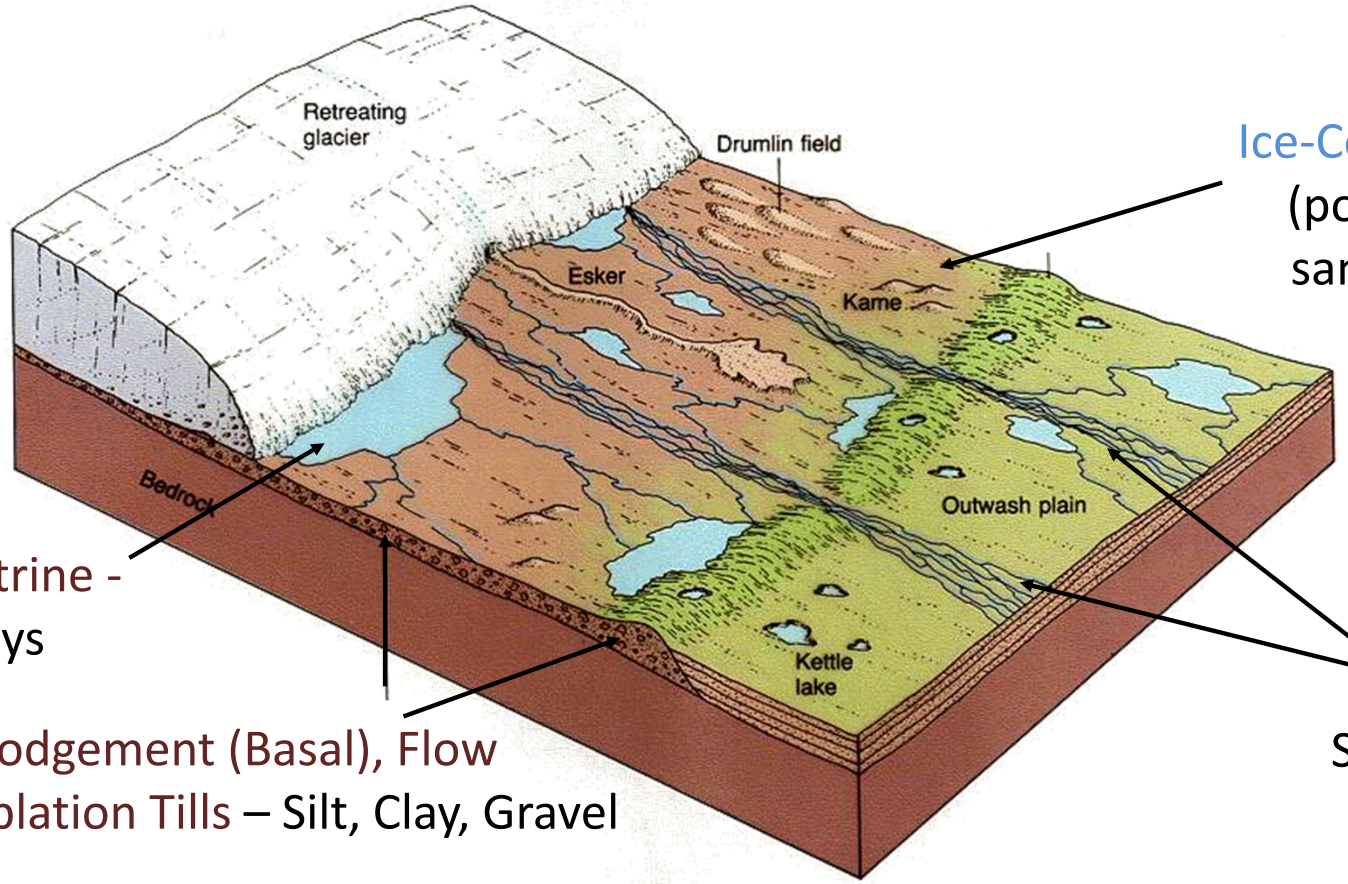


Forsythe, 1961



Lowell et al., 1999

Glacial Facies: Aquifers vs. Aquitards



Aquifers

Ice-Contact Deposits- (poorly stratified sand and gravel)

Aquitards

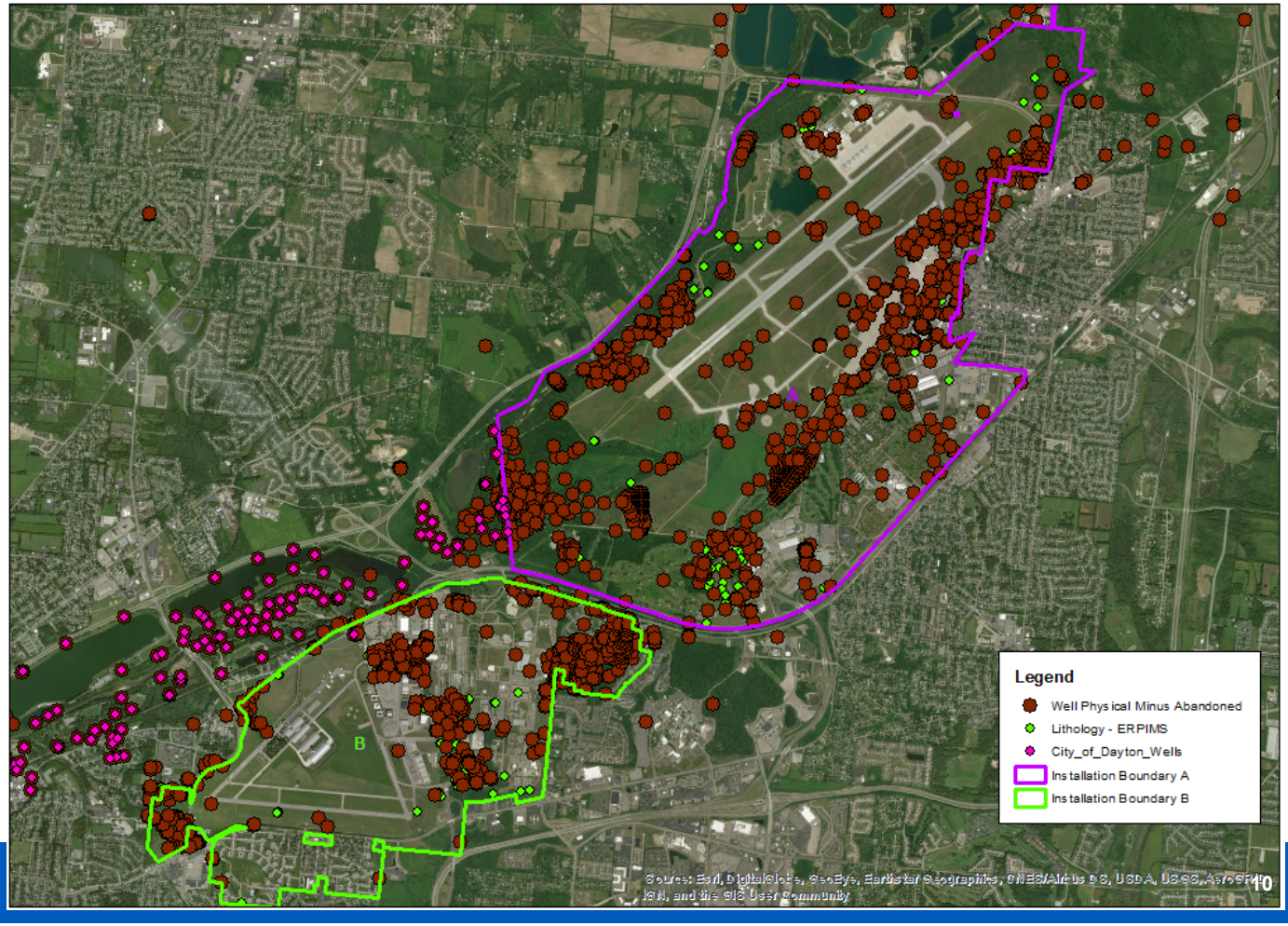
Proglacial Lacustrine - Silts and Clays

Lodgement (Basal), Flow and Ablation Tills – Silt, Clay, Gravel

Outwash- Stratified Sand and gravel

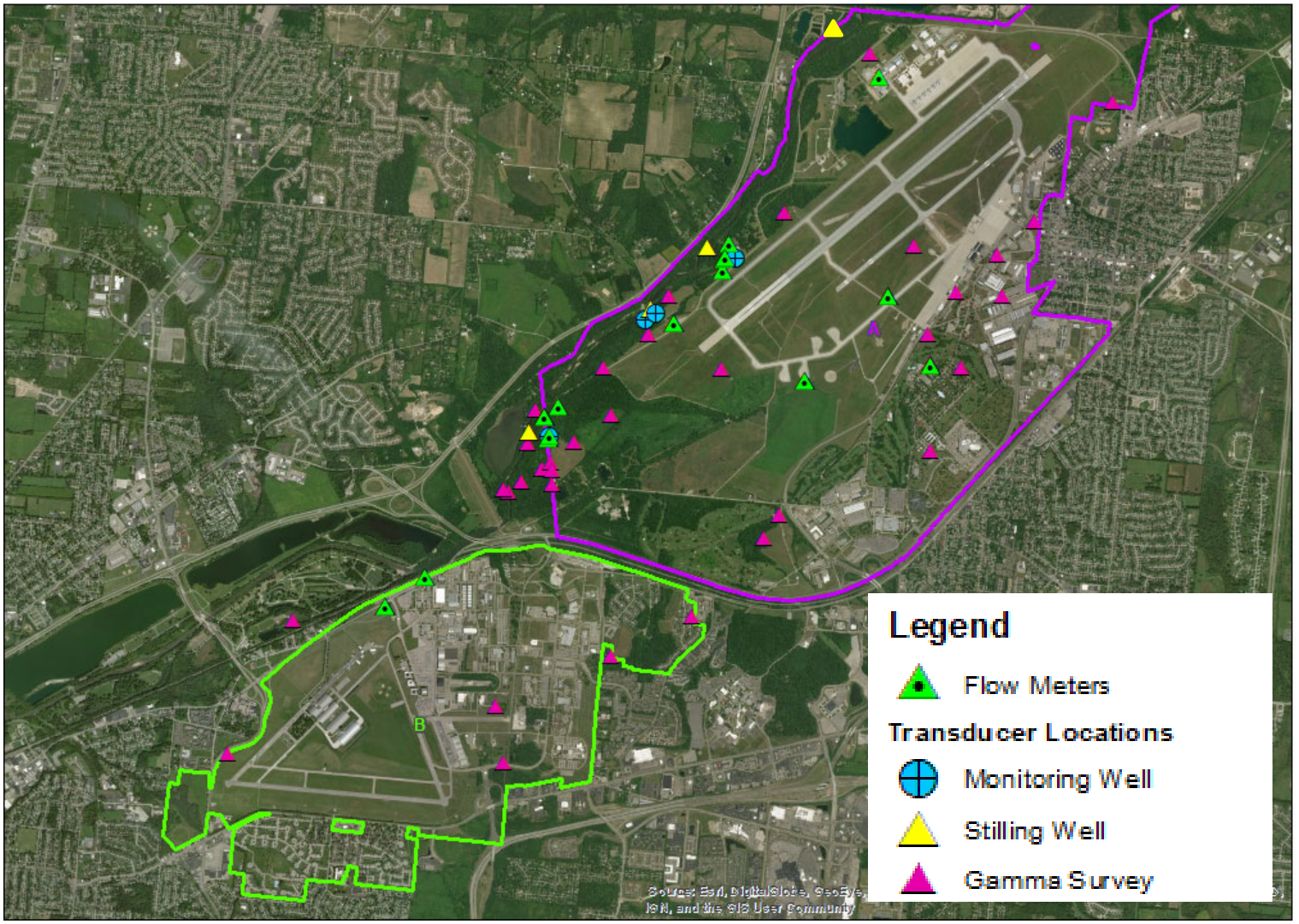
Spatial Coverage of Existing Data

- Active and inactive wells, and borings of all depths shown
- Extensive Legacy Dataset
- Tackled initially with ESS
- Strategic Data Points Added

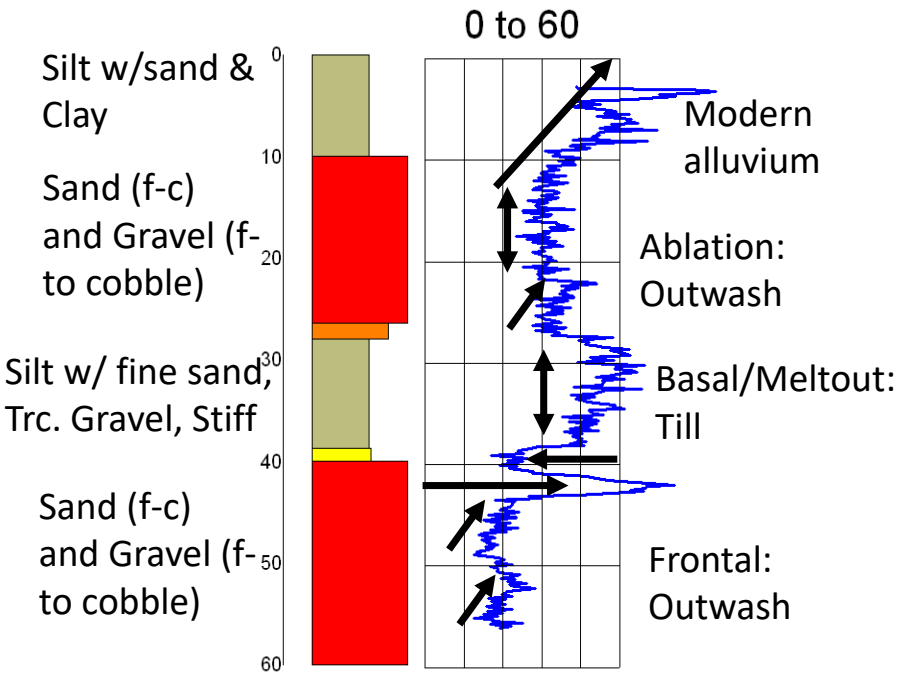


New Data Acquired

- USGS Support
- 45 Wells Gamma Logged
- Groundwater Flowmeter deployed at 17 Well Locations
- Seasonal Synoptic Groundwater Levels

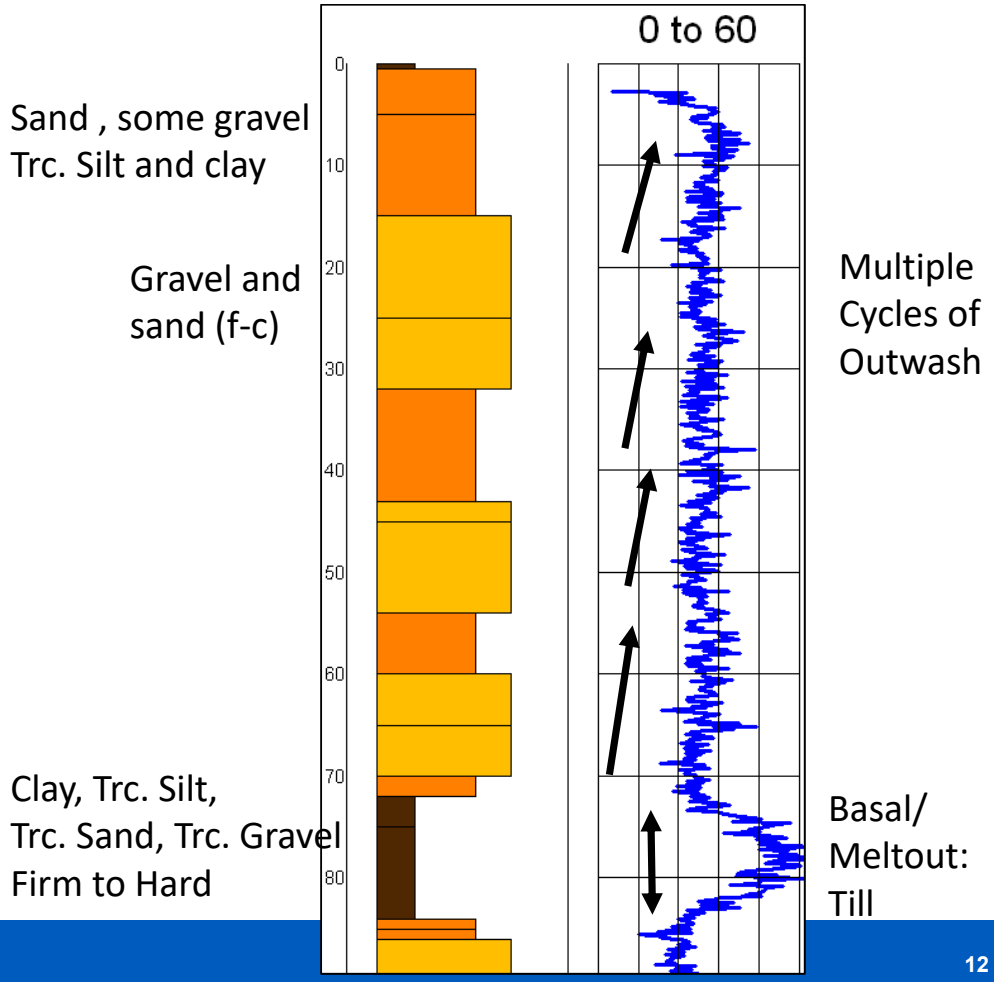


Example Gamma Log Interpretation

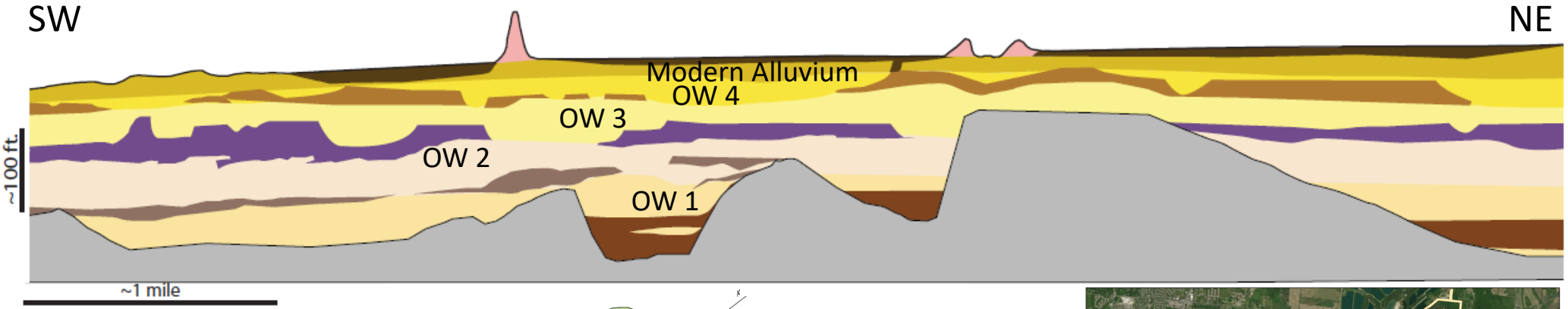


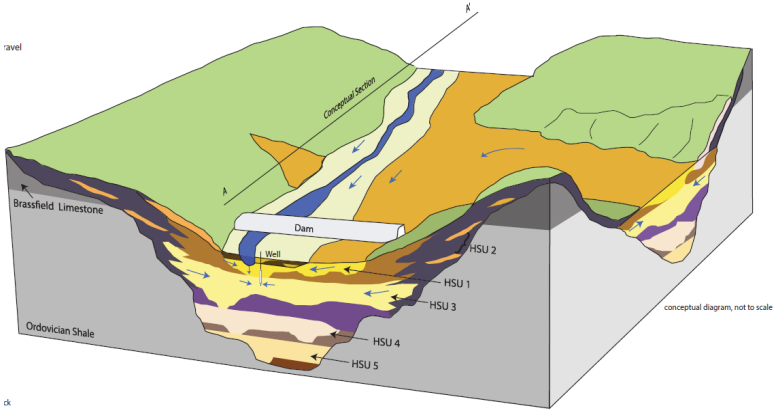
Paleo Valley Margin:
Full Cycles Preserved

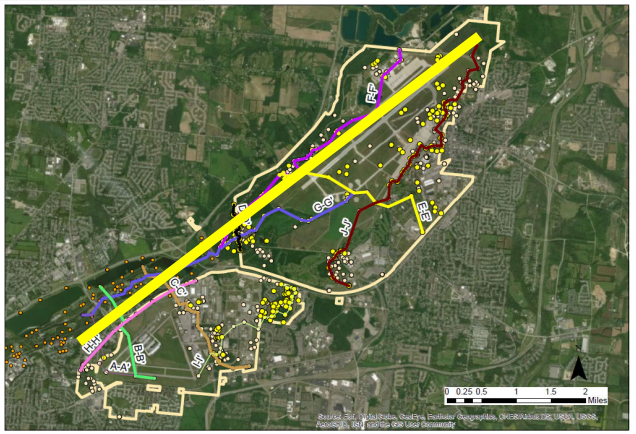
Paleo Valley Axis:
Braided Fluvial Record Dominant



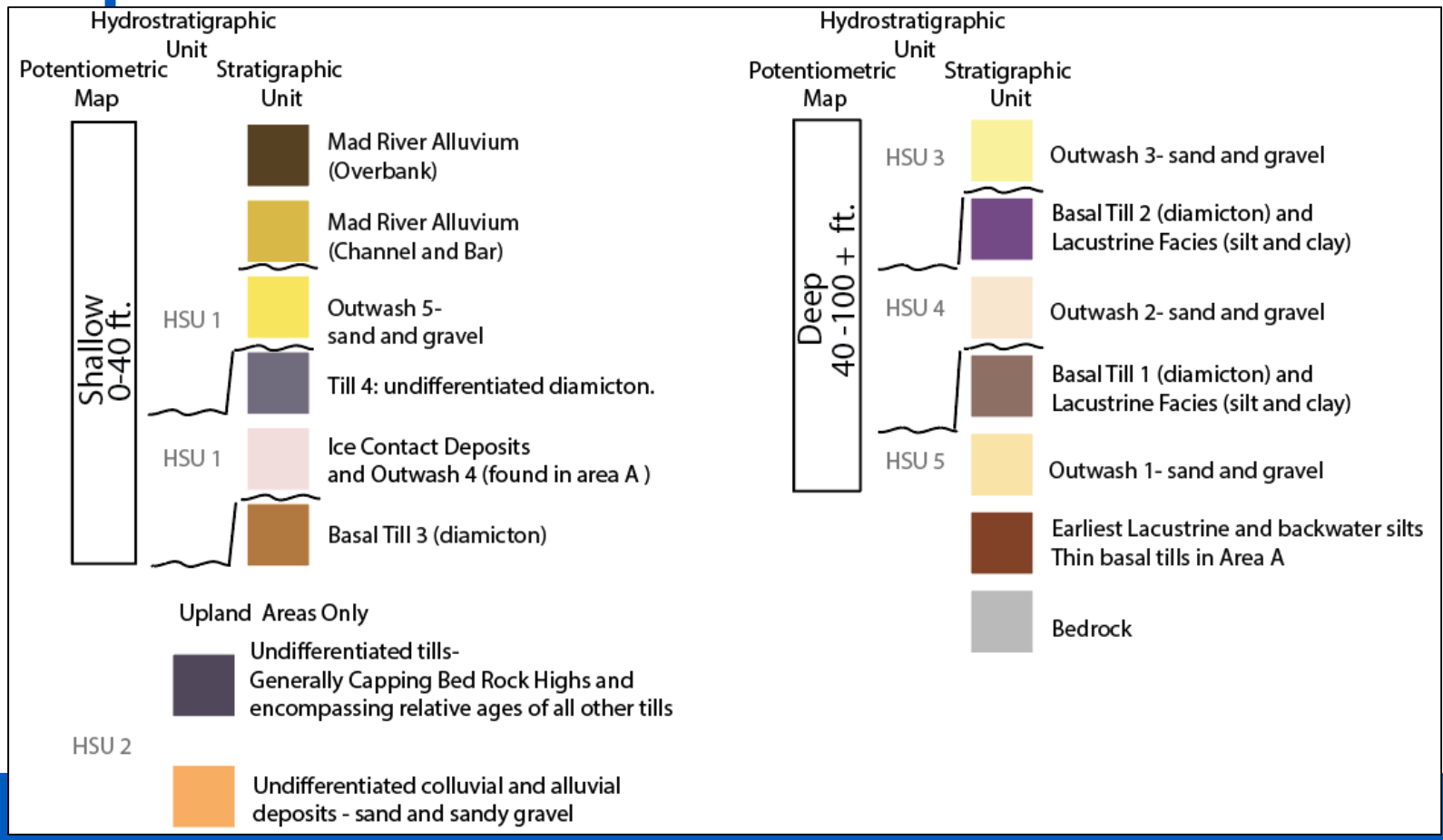
Continuity of Aquifers and Aquitards Understood Three-Dimensionally







The ESS Approach, Augmented By Gamma Log Data Improved CSM Resolution

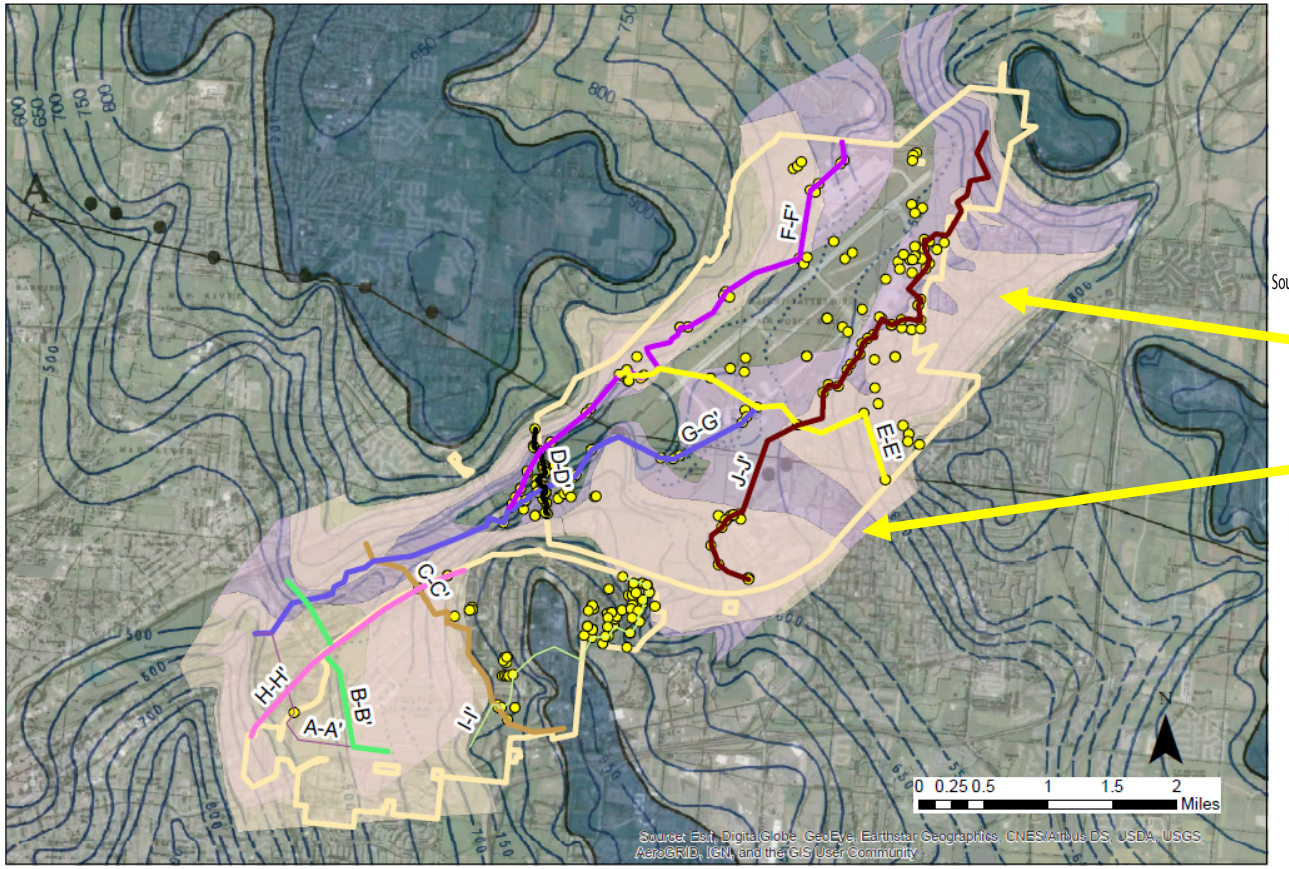


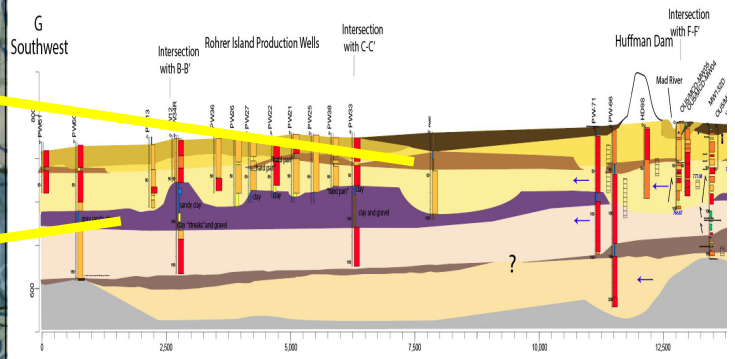
K (cm/s)

Outwash: 1e-0 – 1e-2

Till: 1e-5 – 1e-6

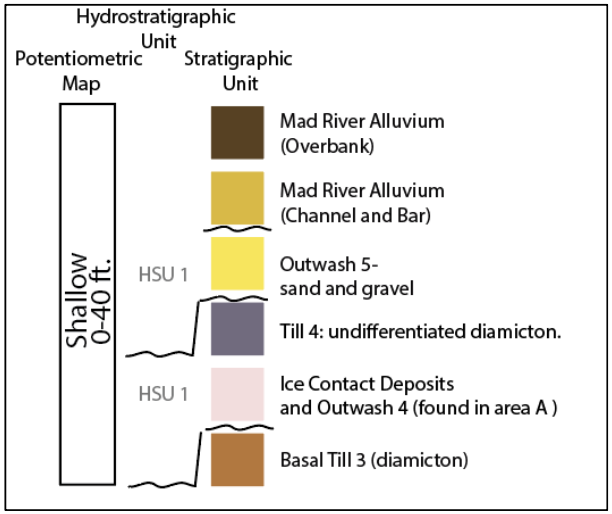
Extent of Regionally Significant Aquitards Mapped

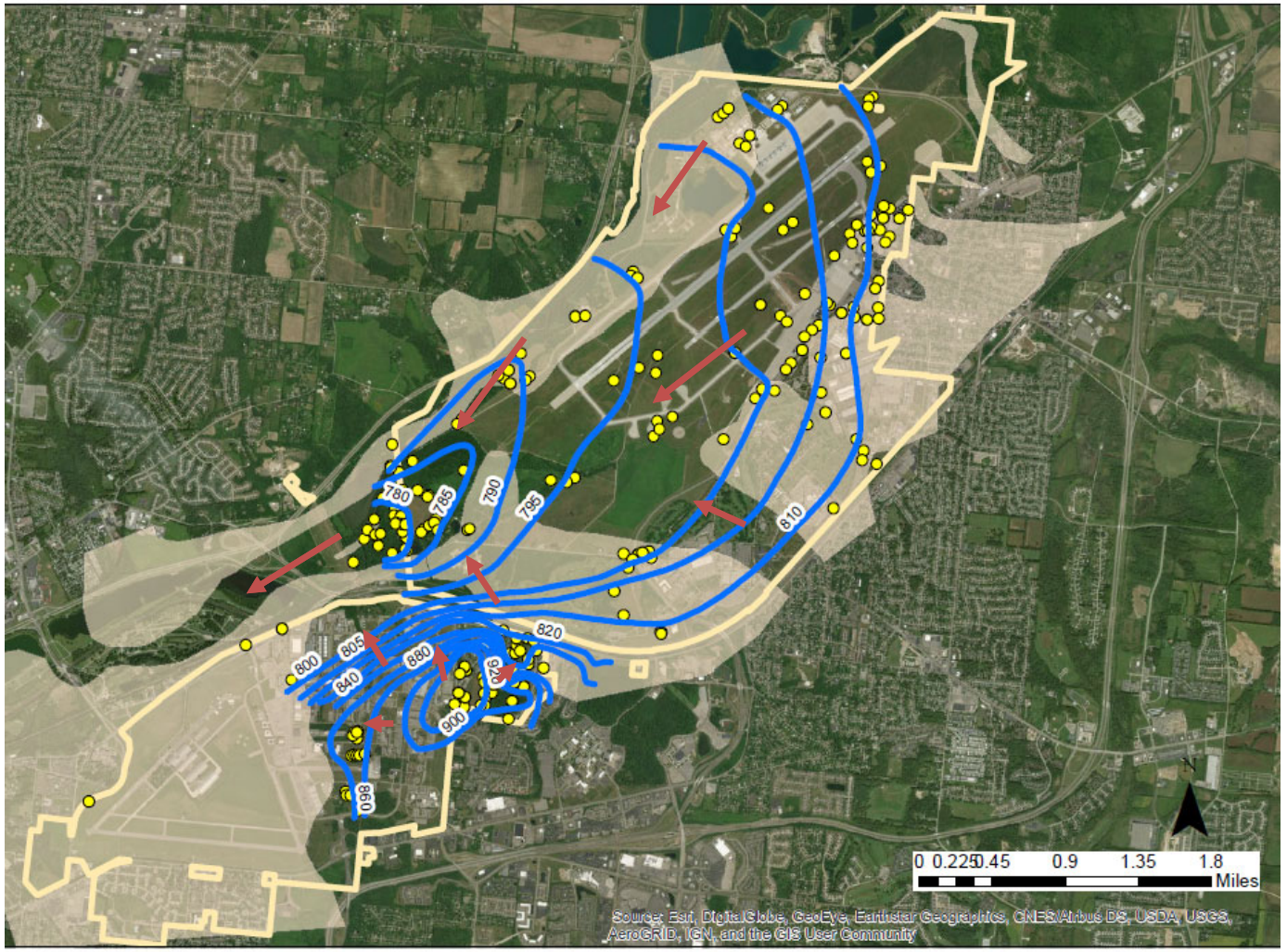




Preserved Till Distribution Impacted By Valley Geometry and Paleo-Drainage

Shallow Groundwater And Upper Till

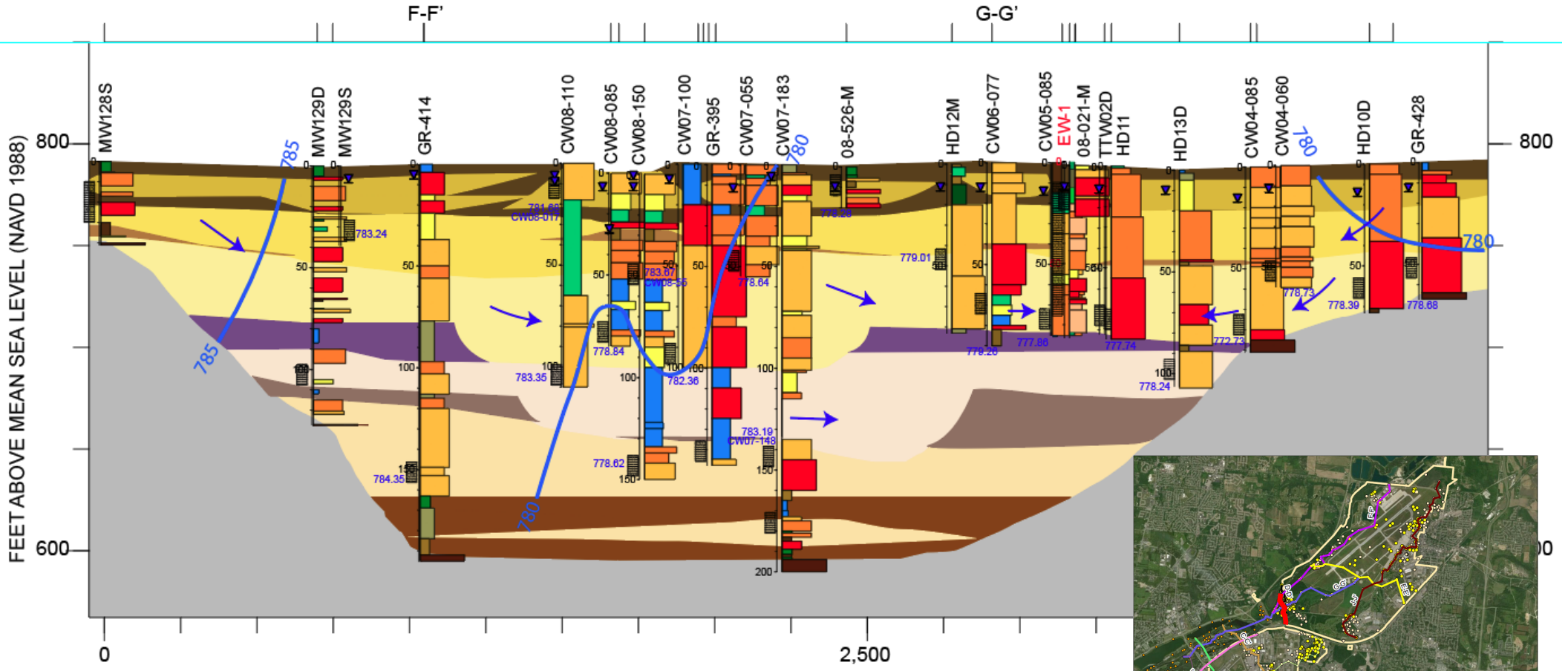




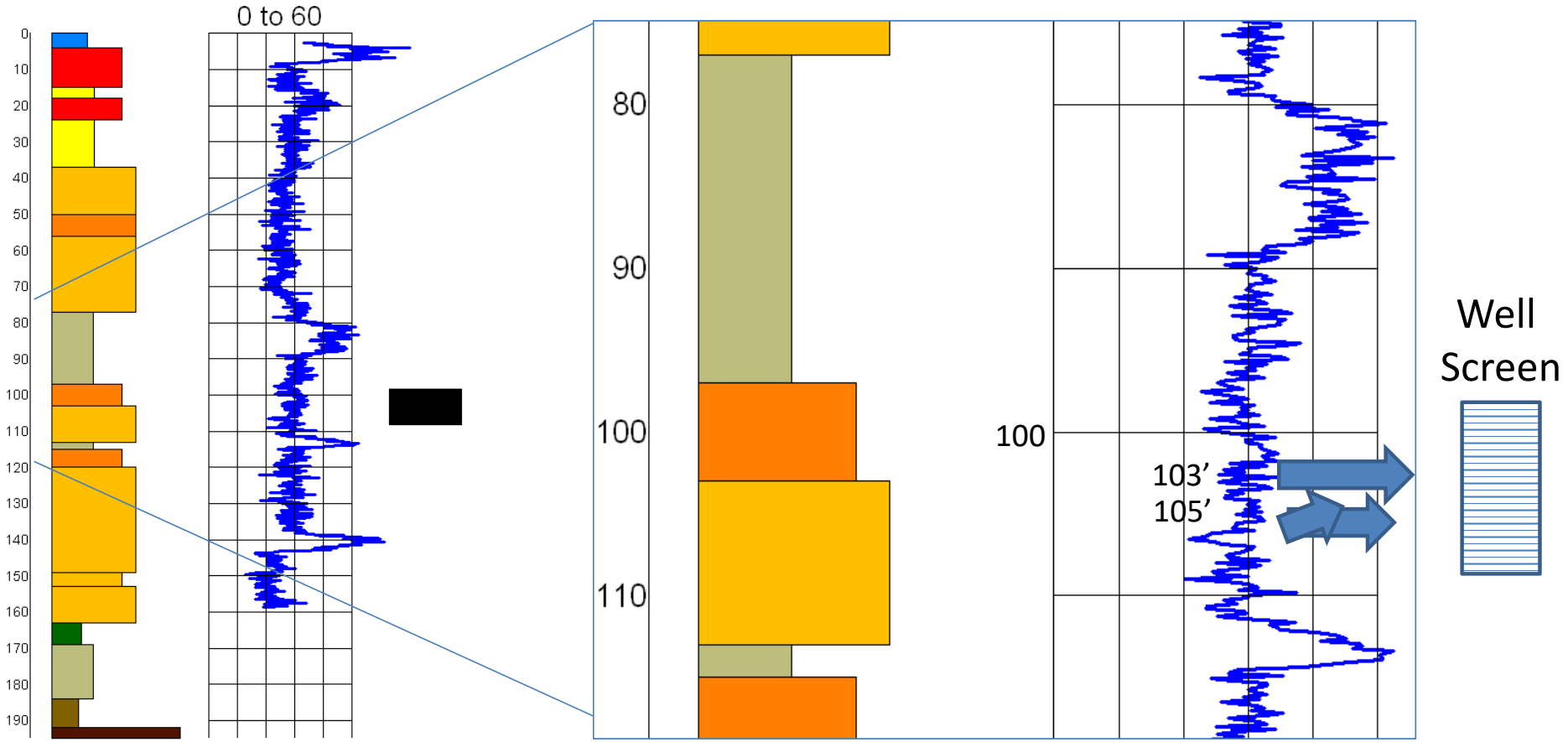
Cross-Section D-D'

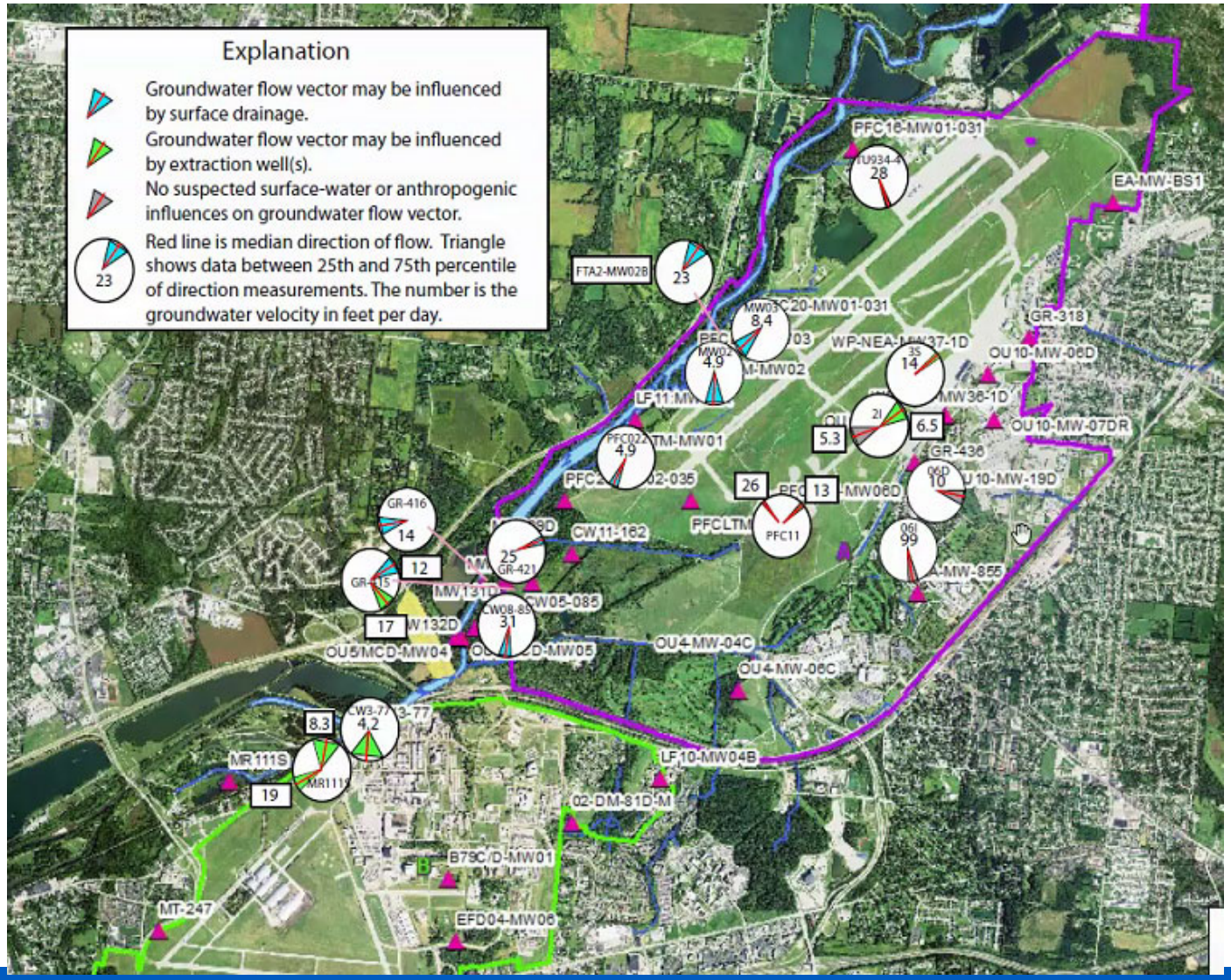
D
NORTHWEST

D'
SOUTHEAST



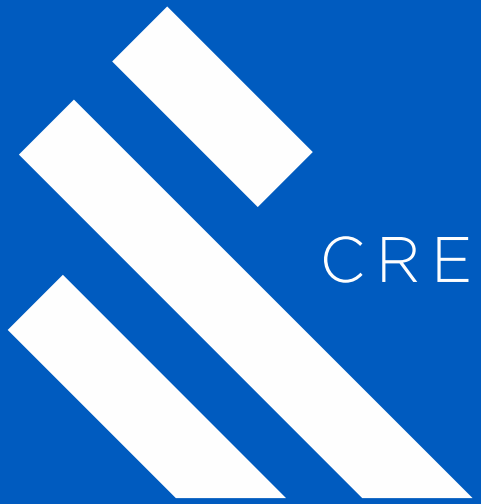
Relating Borescope Results to The Aquifer




Explanation
Groundwater flow vector may be influenced by surface drainage.
Groundwater flow vector may be influenced by extraction well(s).
No suspected surface-water or anthropogenic influences on groundwater flow vector.
Red line is median direction of flow. Triangle shows data between 25th and 75th percentile of direction measurements. The number is the groundwater velocity in feet per day.
23
PFC16-MW01-031
EA-MW-BS1
FTA2-MW02B
GR-318
OU10-MW-06D
MW36-1D
OU10-MW-07DR
GR-436
OU10-MW-19D
GR-416
CW11-162
PFC11
OU5MCD-MW04
OU4-MW-04C
OU4-MW-06C
LF10-MW04B
02-DM-81D-M
B79C/D-MW01
MT-247
EFD04-MW06

Conclusions

- Benefits of ESS and Gamma Logging
  - Uses existing monitoring well and borehole log data
  - ESS and Gamma logging brings geologic insight into the CSM
  - ESS informs our model on the shape, direction, and continuity of deposits
  - **Identifies the subsurface permeability architecture**
- Costs of Gamma/Flowmeter:
  - Efficient – 3 weeks for 45 wells gamma, and 17 wells flow metering, one person
- Upcoming Work:
  - Hydrologic Profiling Tool (BEST Technologies)
  - Additional Gamma Logging
  - Resistivity surveys in strategic locations
  - Pressure transducers in river and adjacent wells



CREATE AMAZING.