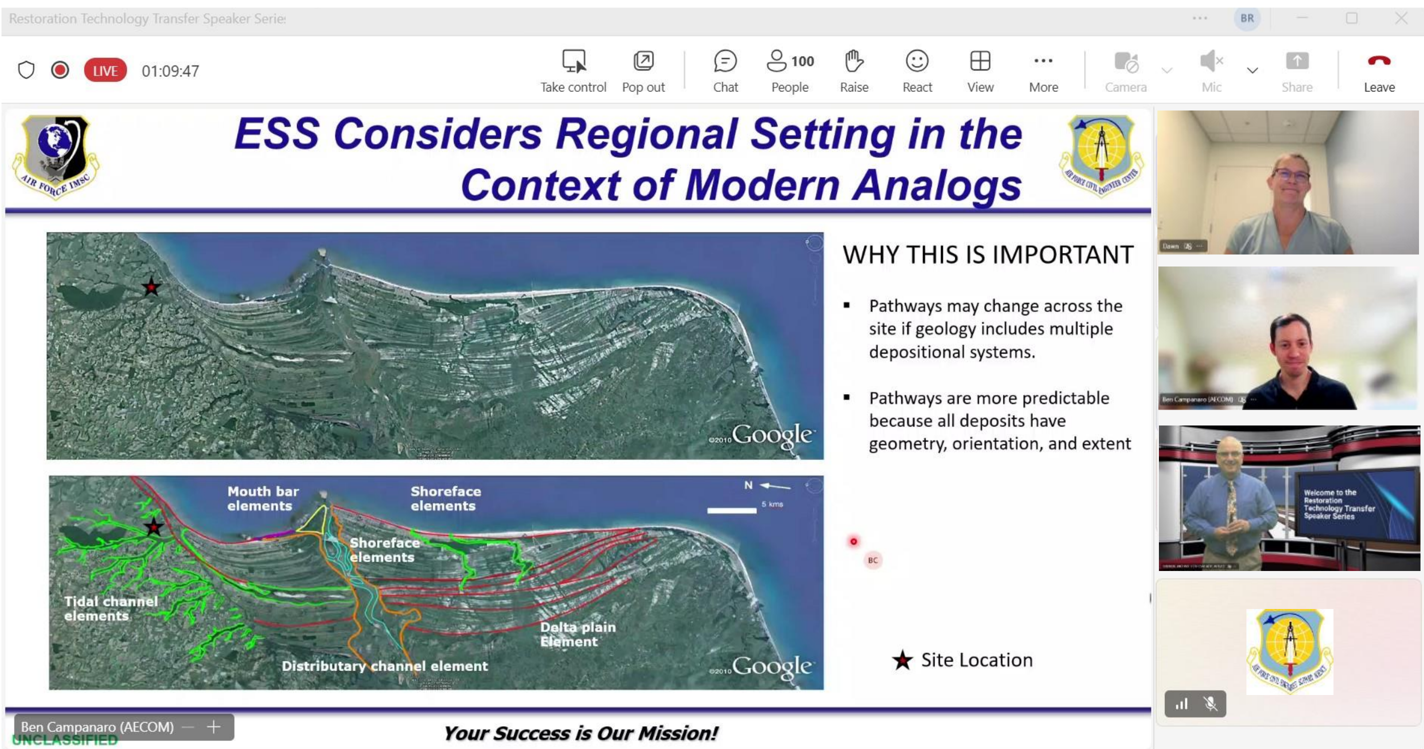
Air Force Civil Engineer Center

Restoration Technology Transfer Speakers Series
July 2026

Hydrogeologic Conceptual Site Models (CSM): The Foundation of Remediation Decisions

Presenters: Dawn Stock & Ben Campanaro (AECOM)

This webinar highlighted the essential elements of a quality Conceptual Site Model (CSM), its critical role in the remediation process, and how it enables more efficient and targeted remedy selection. The presentation offered a primer on sequence stratigraphy, highlighting its importance in understanding relative hydraulic conductivity and subsurface pathways. It also covered refining hydrostratigraphic units to align with stratigraphy, as well as integrating and visualizing other site characteristics that influence pathways—such as topography, groundwater-surface water interactions, bedrock elevation, and anthropogenic factors. Relevant case studies were shared to demonstrate these concepts in practice.



Dawn Stock and Ben Campanaro explain how hydrogeologic models inform remediation decisions using current regional analogs.

This event and future events are updated and posted on the AFIT website at: https://www.afit.edu/CE/index.cfm.

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Webinar Structure

	[Restoration Technology Transfer Webinar Series – eDASH Archive]()
5 min	Welcome and Administrative Business
45 min	Main Presentation – *Hydrogeologic Conceptual Site Models (CSM): The Foundation of Remediation Decisions*
10 min	Questions and Answers
5 min	Final Thoughts

Hydrogeologic Conceptual Site Models (CSM)

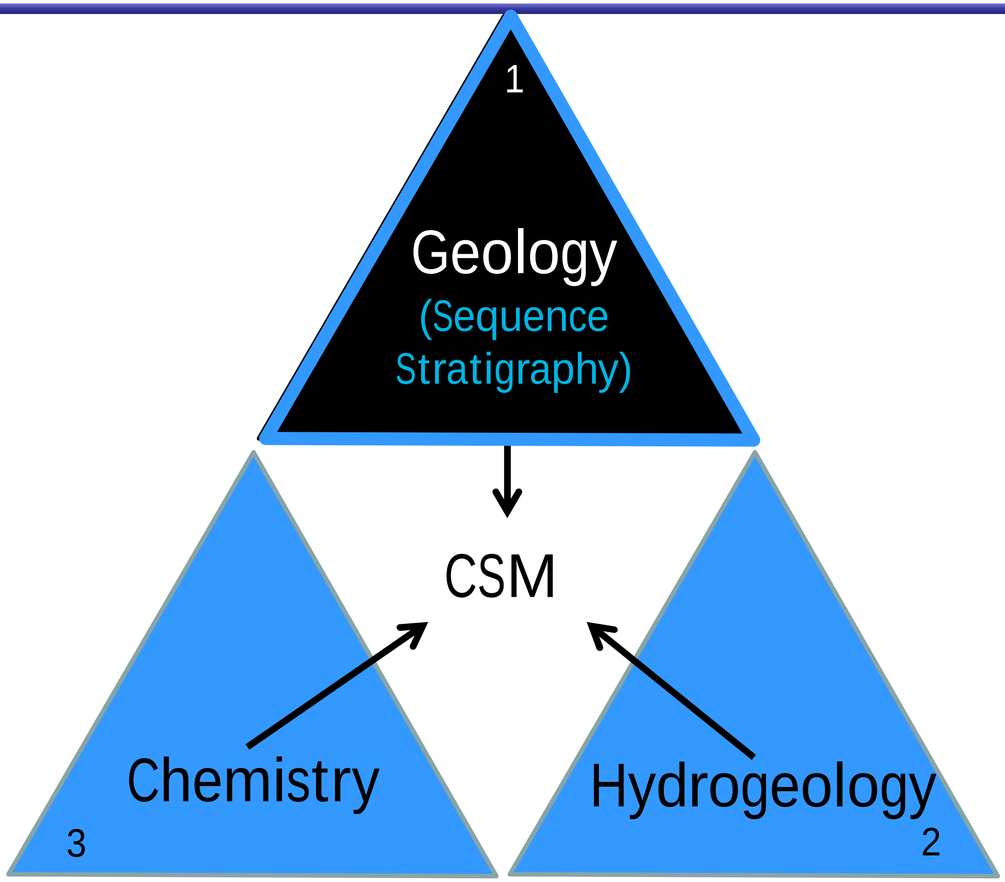
The Foundation of Remediation Decisions

Dawn Stock and Ben Campanaro
AECOM – on behalf of AFCEC | CZPR
JULY 8 2026

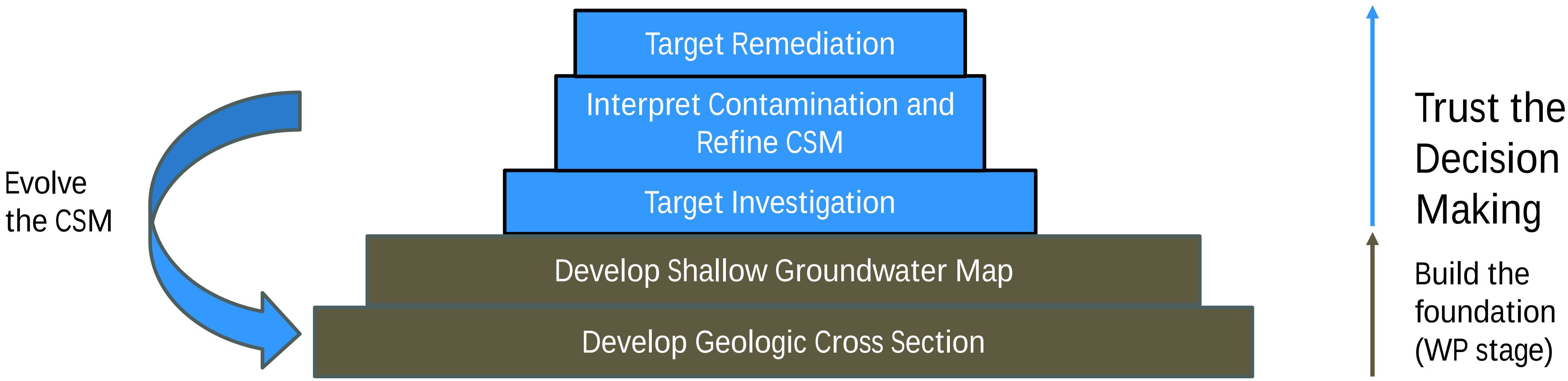
Overview

- Fundamentals and benefits of a high quality hydrogeologic CSM for sites regardless of complexity
- Scoping to support high quality CSM
- Evolution of the CSM – what am I looking for?
- Case Studies of fundamentals application and evolution of CSM throughout investigation phase

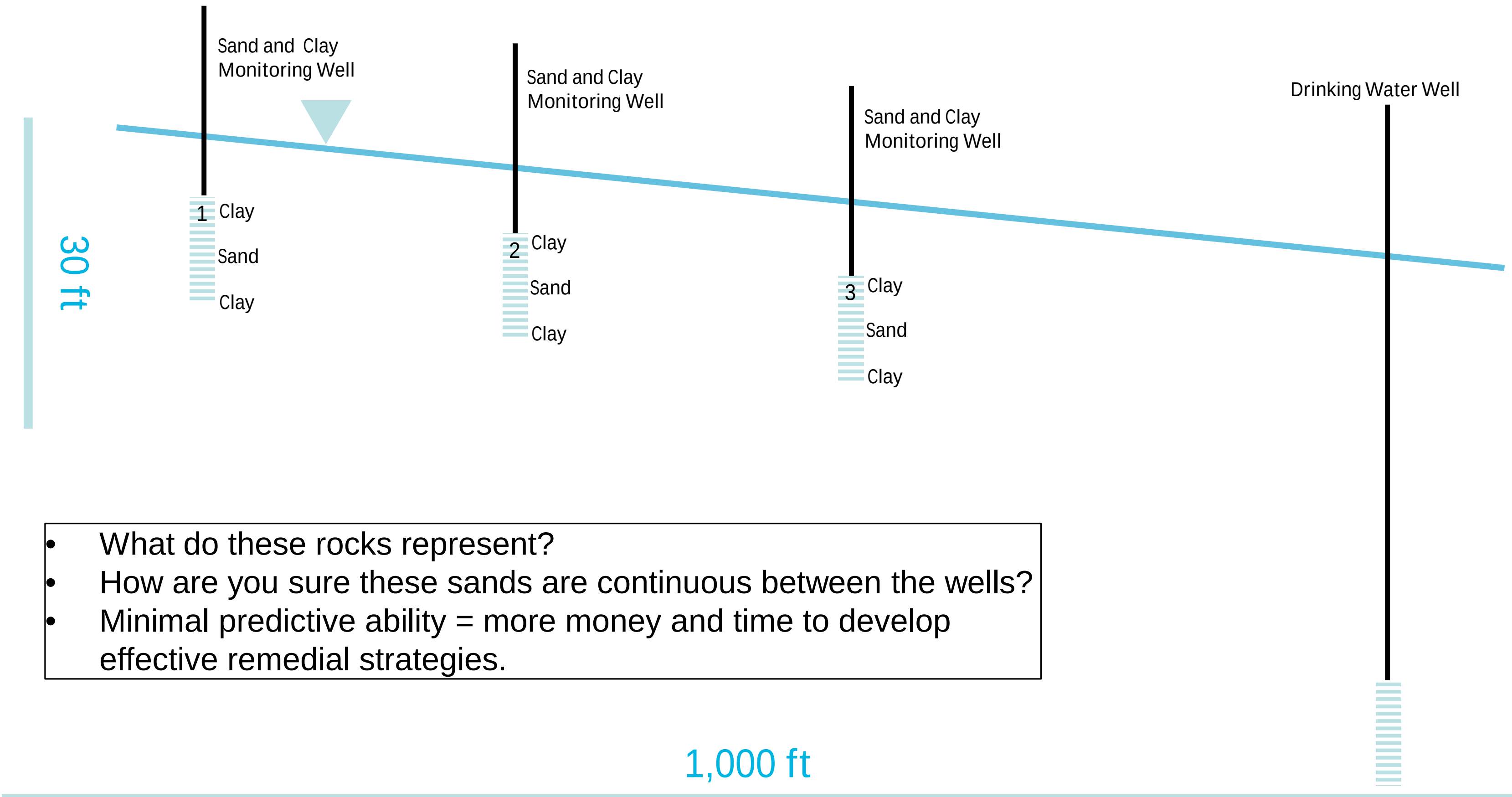
Hydrogeologic CSM to Support Fate and Transport



All Remediation Phases Rely on Strong CSM Foundation

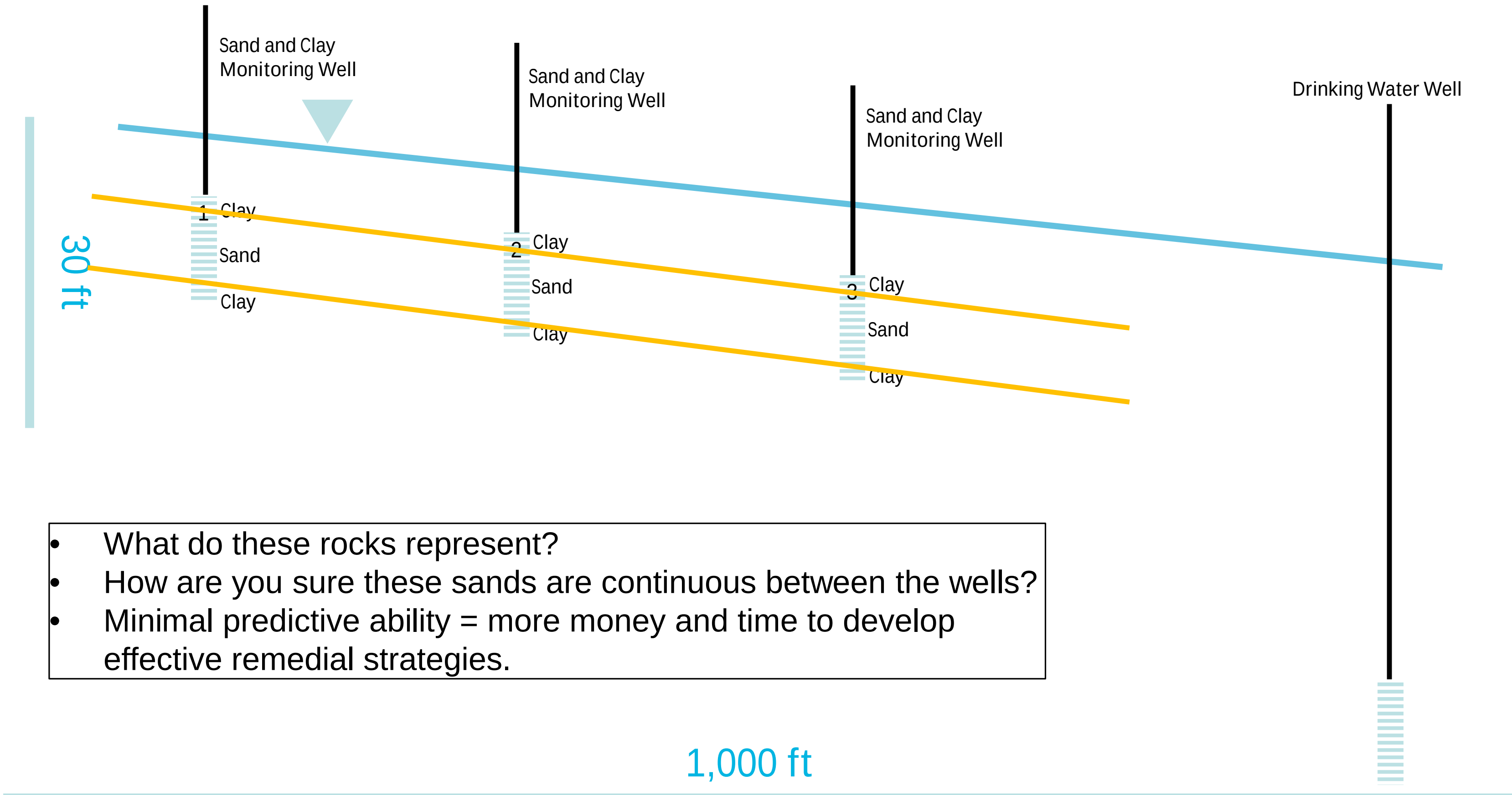


Why ESS is Foundational to Predicting Migration Pathways



- What do these rocks represent?
- How are you sure these sands are continuous between the wells?
- Minimal predictive ability = more money and time to develop effective remedial strategies.

Why ESS is Foundational to Predicting Migration Pathways



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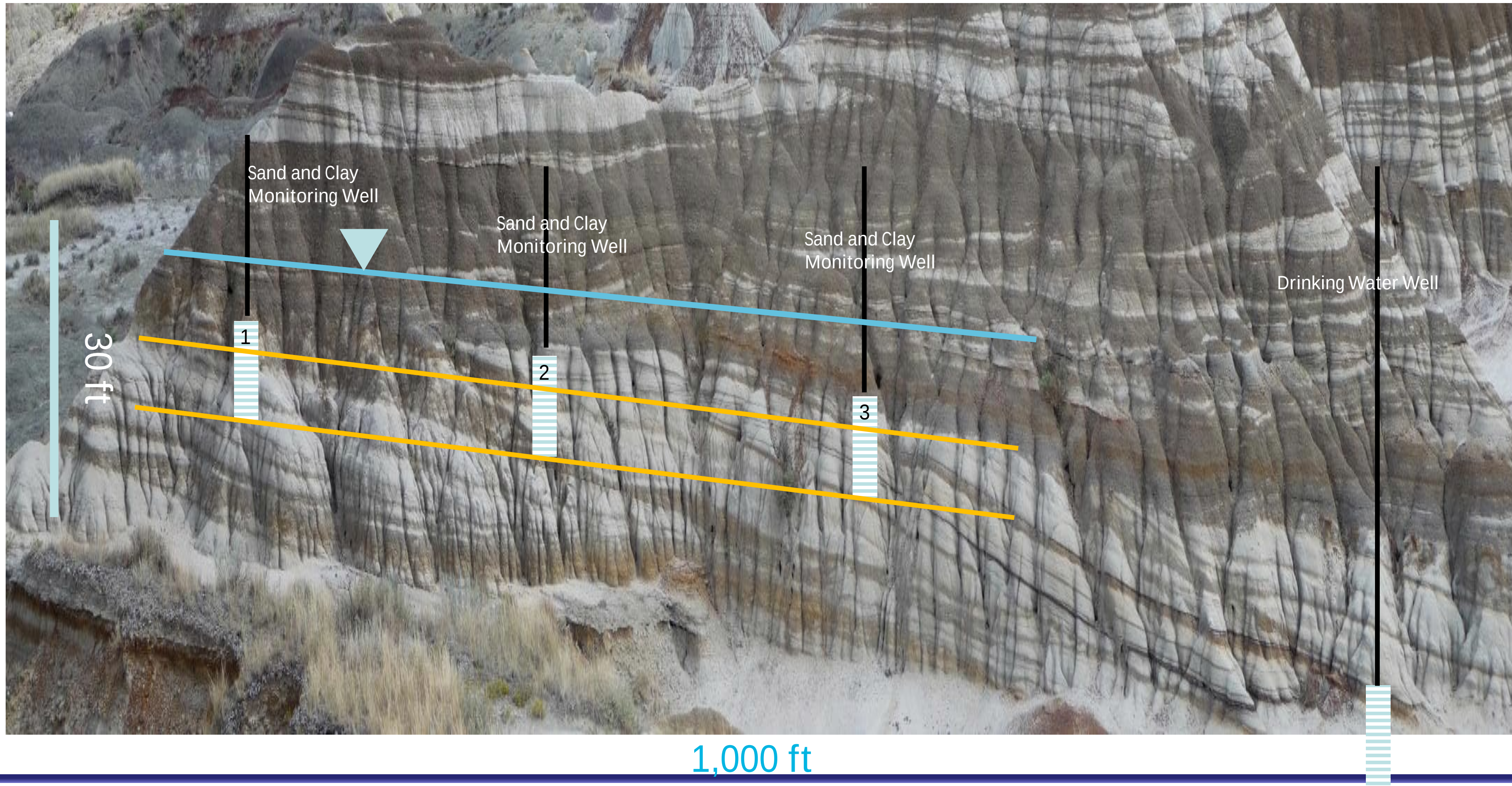

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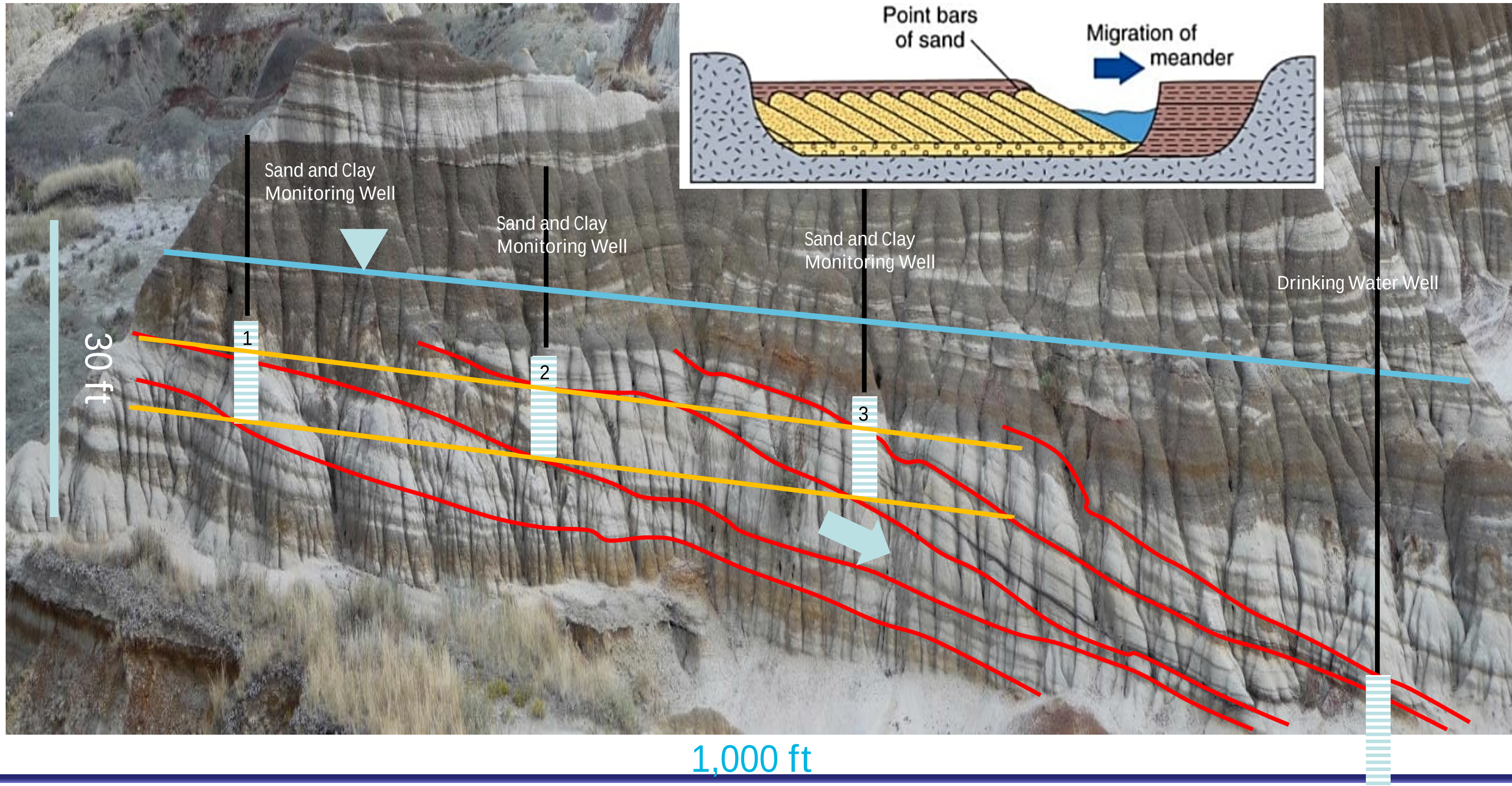

Best Practice: Develop/Maintain Comprehensive Well Inventory

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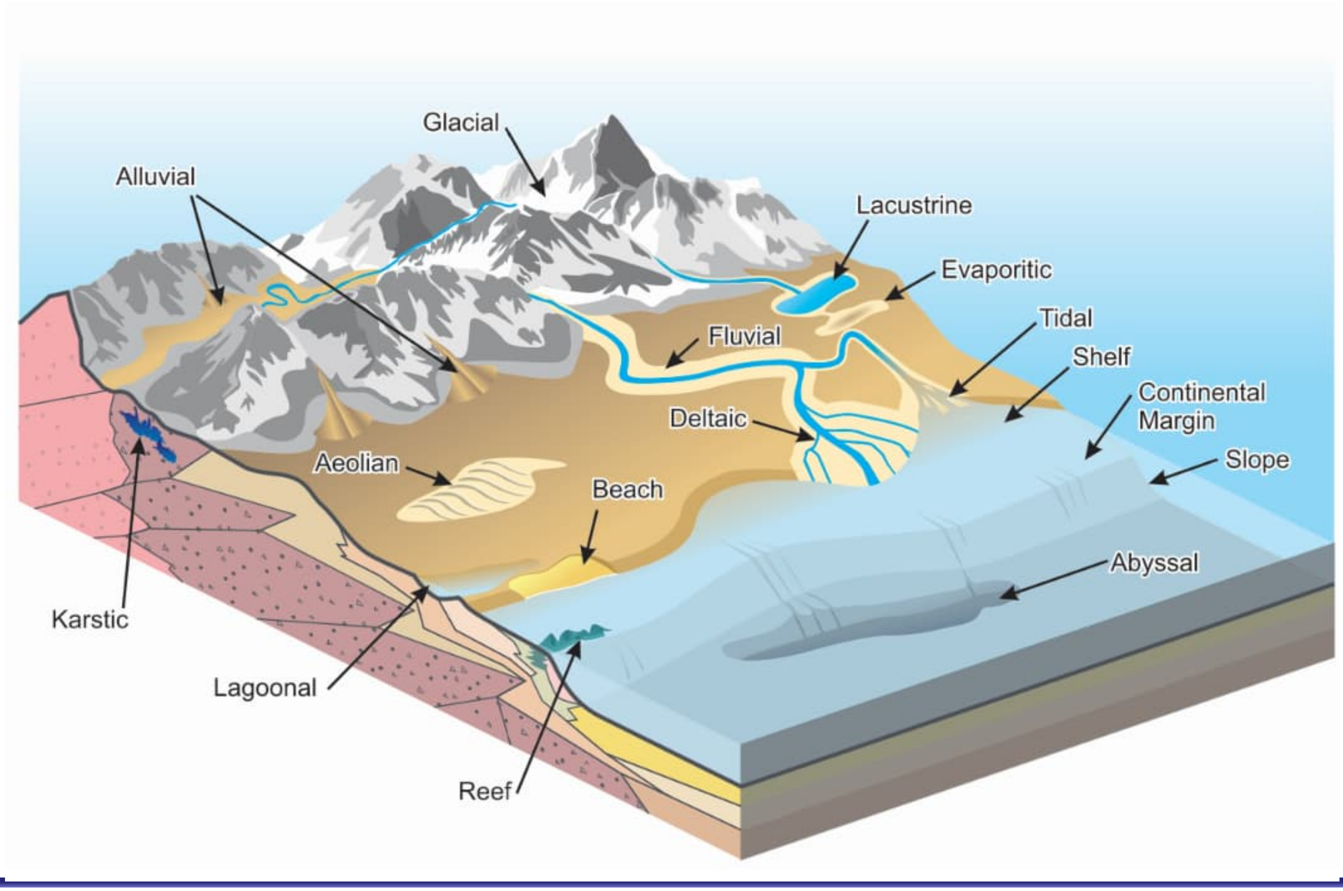
86MW-8		2308412.15	587201.35	103.3649979	105.09	25	20	85.09	25	80.09	19.98	85.11	
86TW-1		2308444.33	587251.03	102.5149994	102.75	25	20	82.75	24.75	78	NM	NM	not found
86TW-2		2308404.11	587258.52	101.3669968	102.75	25	20	82.75	24.75	78	NM	NM	not found
AOC32-TW1		2303566.54	580876.04	70.7018967	72.57	15	5	67.57	14.45	58.12	NM	NM	not found
AOC32-TW2		2303576.25	580778.99	71.5675964	73.86	19	9	64.86	18.45	55.41	NM	NM	not found
AOC32-TW3		2303433.79	580706.4	72.240097	74.24	20	10	64.24	19.45	54.79	NM	NM	not found
AOC32-													not found
AOC33-DF													not found

Abandoned Locations can be relevant

Easily integrates into GIS and 3D programs to visualize

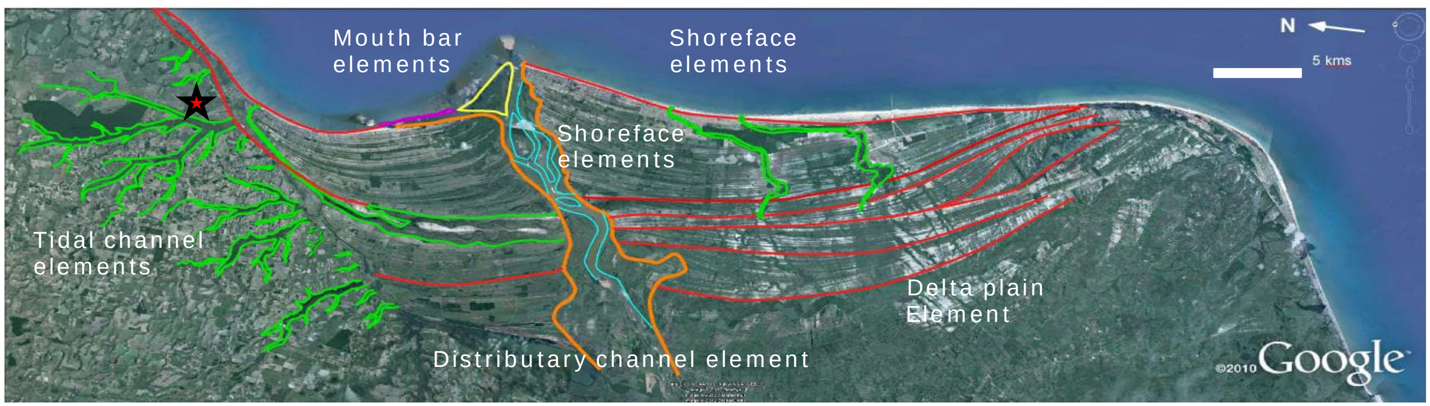
Sequence Stratigraphy: Understanding Geology Within the Context of Deposition



Range of depositional environments where ESS is applicable.
Note: Carbonate environments are outside of the scope of this training.

Samuels and Sadeque, 2021

ESS Considers Regional Setting in the Context of Modern Analogs

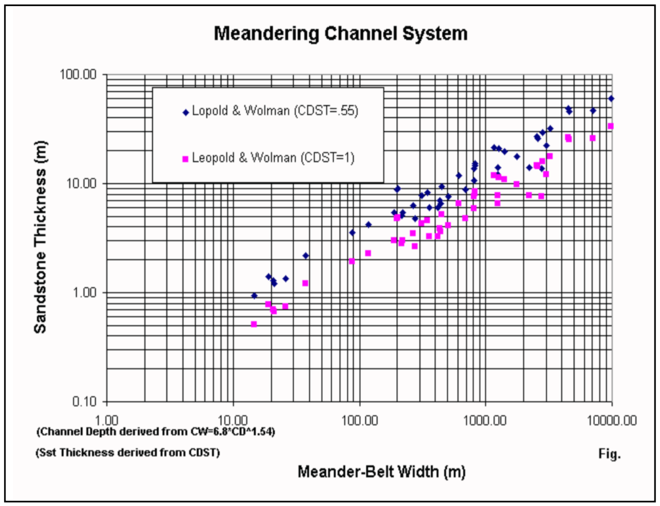


WHY THIS IS IMPORTANT

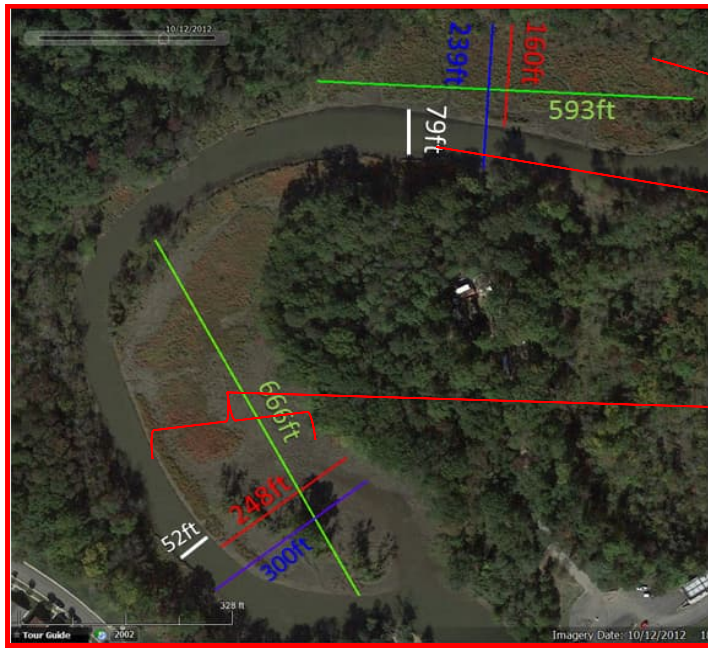
- Pathways may change across the site if geology includes multiple depositional systems.
- Pathways are more predictable because all deposits have geometry, orientation, and extent

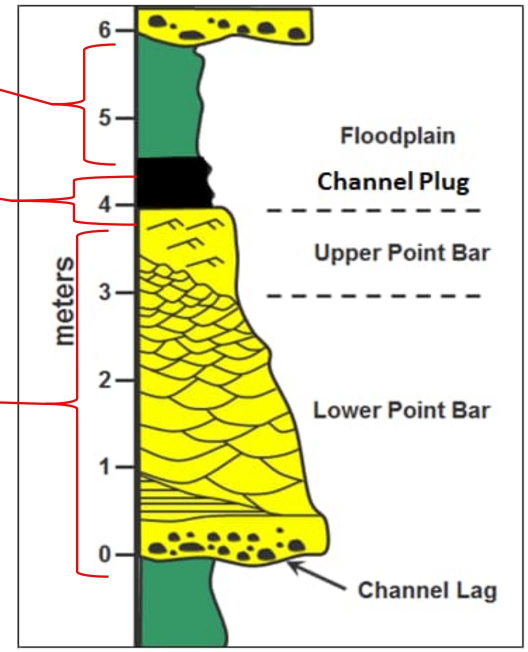
★ Site Location

ESS is Not Guesswork: Depositional Systems have known Geometries and Trends



Width/Thickness ratios of ancient and modern fluvial environment (Fielding and Crane, 1987).

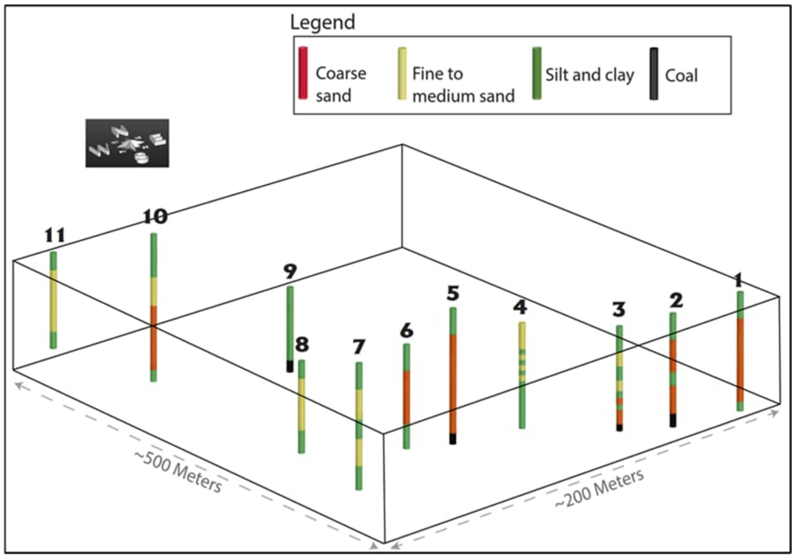


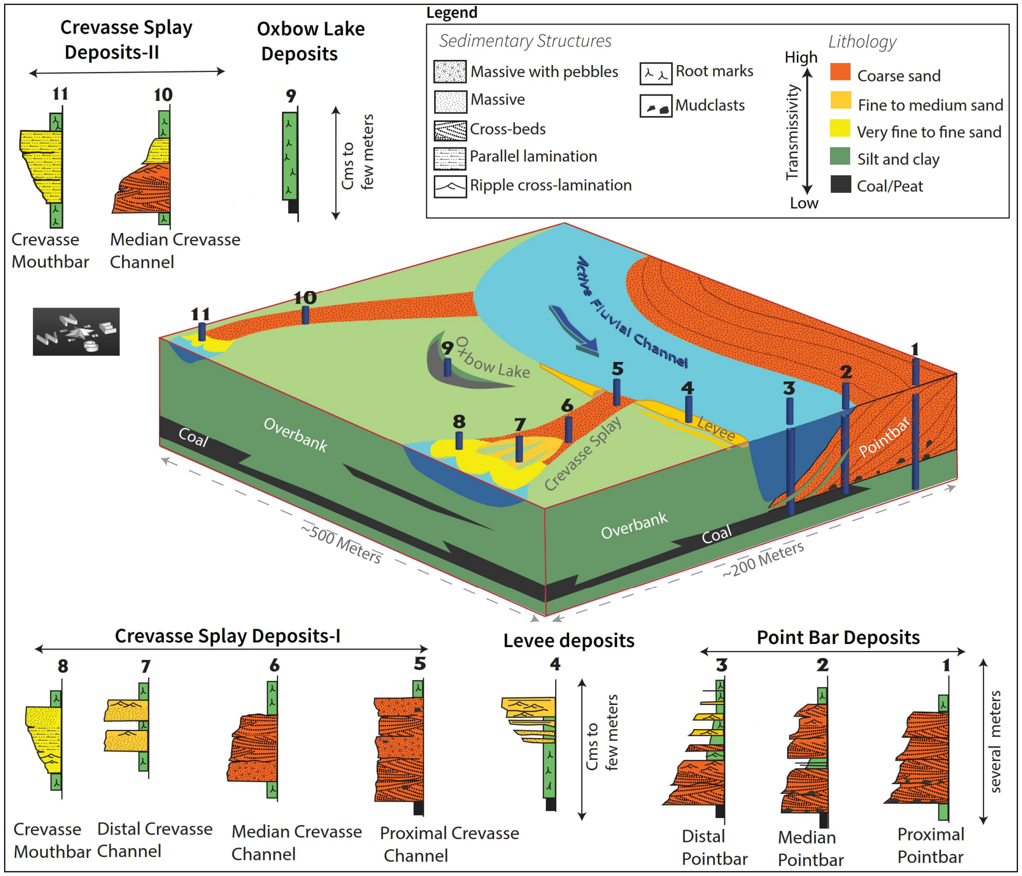


Relationship of measured length/width of modern fluvial system to estimated vertical thickness of sediments.

Measured width/thickness ratios of modern analog can enhance correlation between boreholes.

Depositional Facies Models Make Sense out of the Subsurface

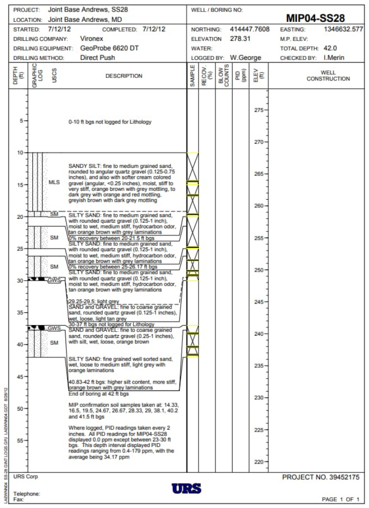




Depositional environments provide a predictable geologic framework for better understanding spatial relationship between boreholes.

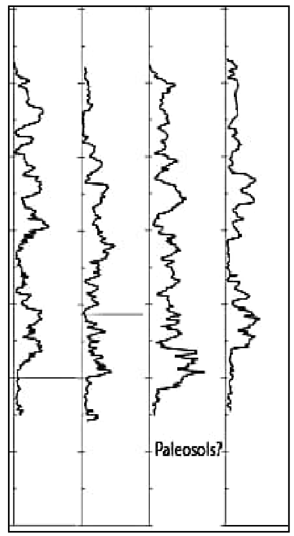
Geologic Data Inputs to Support ESS: Consider in Project Scope

Borehole information



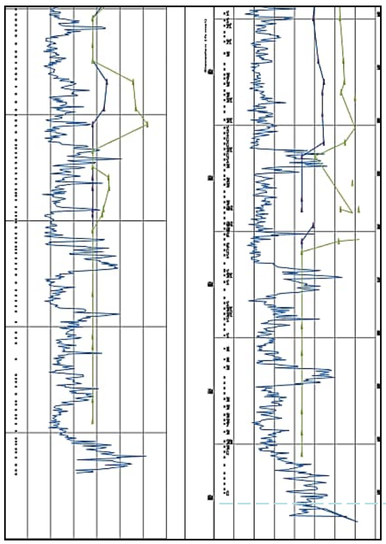
Grain-size, Composition %, Change in lithology

HPT/CPT log



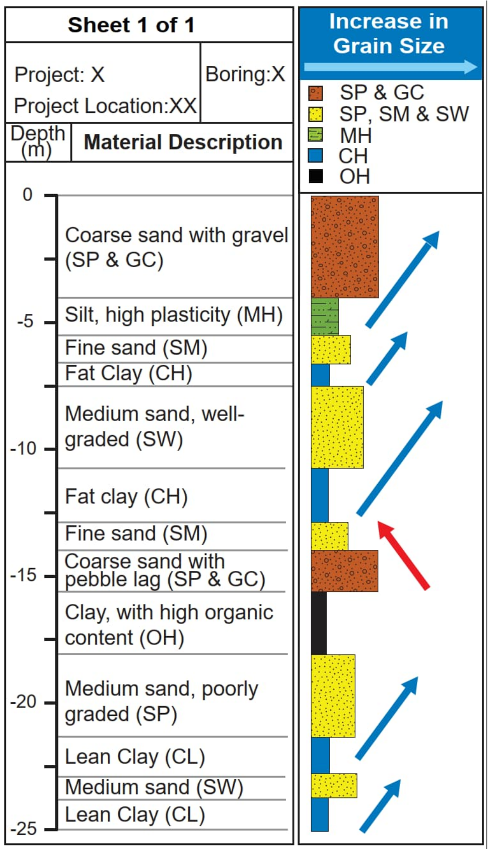
Response Indicative of sand, clay, flow zones

Downhole geophysical log (gamma/resistivity)

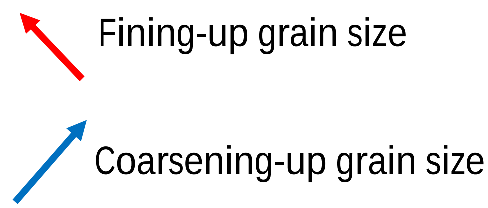


- Lithology, grain-size, porosity
- Can be available from USGS
- Unbiased lithologic record
- Best for ESS interpretation
- Highest value on deeper borings

ESS Methodology: Conversion of Logs to Graphical Grain-Size Logs (GSLs)

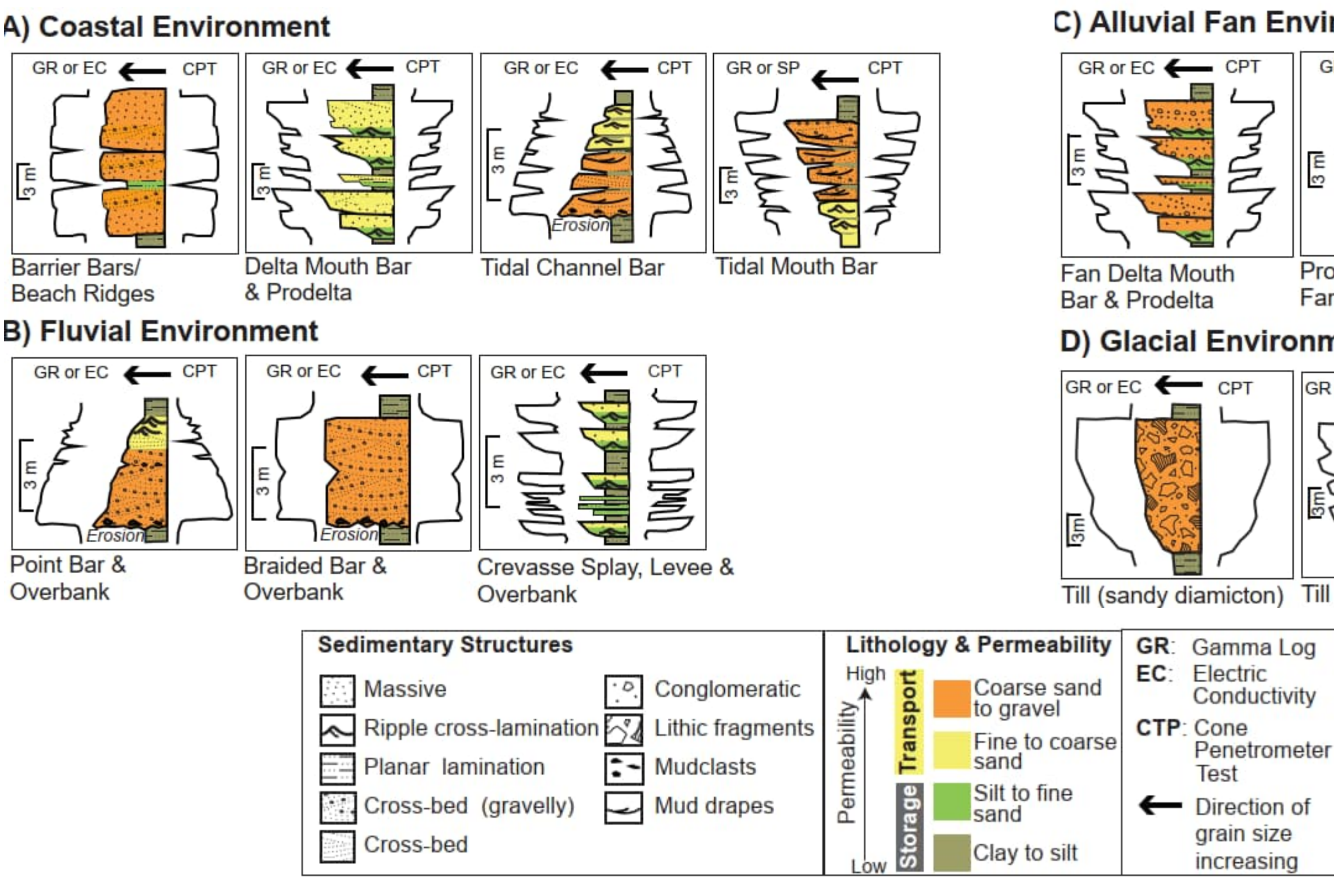


- Width of the box represents grain size (wider the box, coarser the sediments)
- Color of the box represents composition (soil type based on BS5930)



Note: Example based on US classification scheme, but any scheme (such as UK BS5930) can be used.

ESS Methodology: Associate Vertical Grain-Size Trends to Depositional Environment

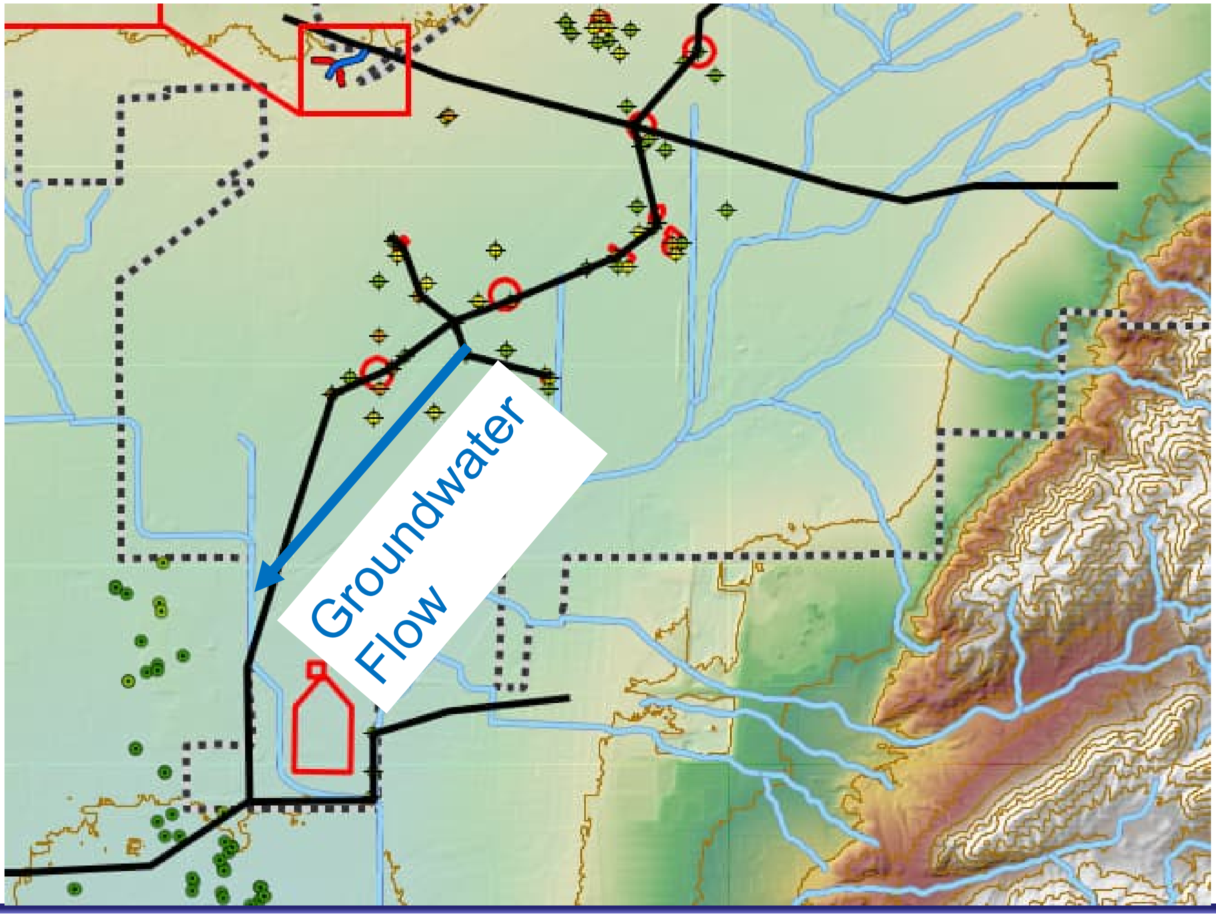


From Sadeque and Samuels, 2023

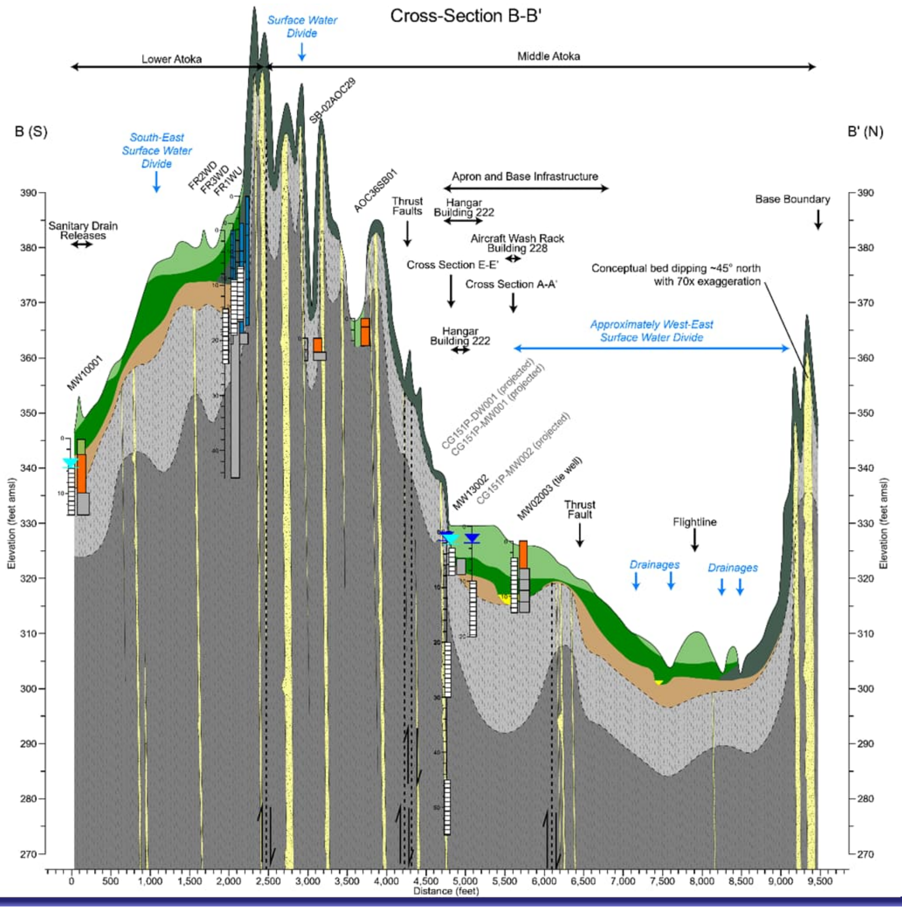
The Application of Sequence Stratigraphy to the Investigation and Remediation of LNAPL-Contaminated Sites | SpringerLink

Cross Section Development

- Boring depth
- Log quality and detail
- Depositional orientation
- Orientation relative to groundwater flow
- Target areas (e.g., sites and boundaries)
- Intersection with surface water



Case Study Example: Vertical Exaggeration for Depositional Scales



VERTICAL EXAGGERATION

$$V.E. = \frac{\text{HORIZONTAL SCALE}}{\text{VERTICAL SCALE}}$$

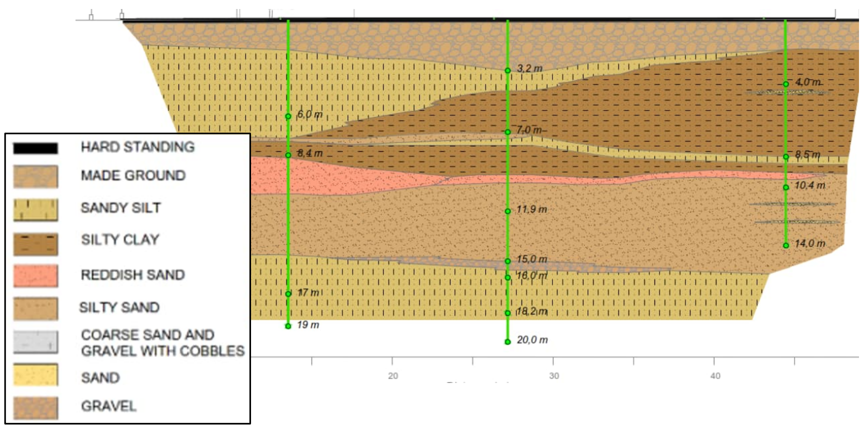
$$V.E. = \frac{HS}{VS}$$ both scales have to be in the same units

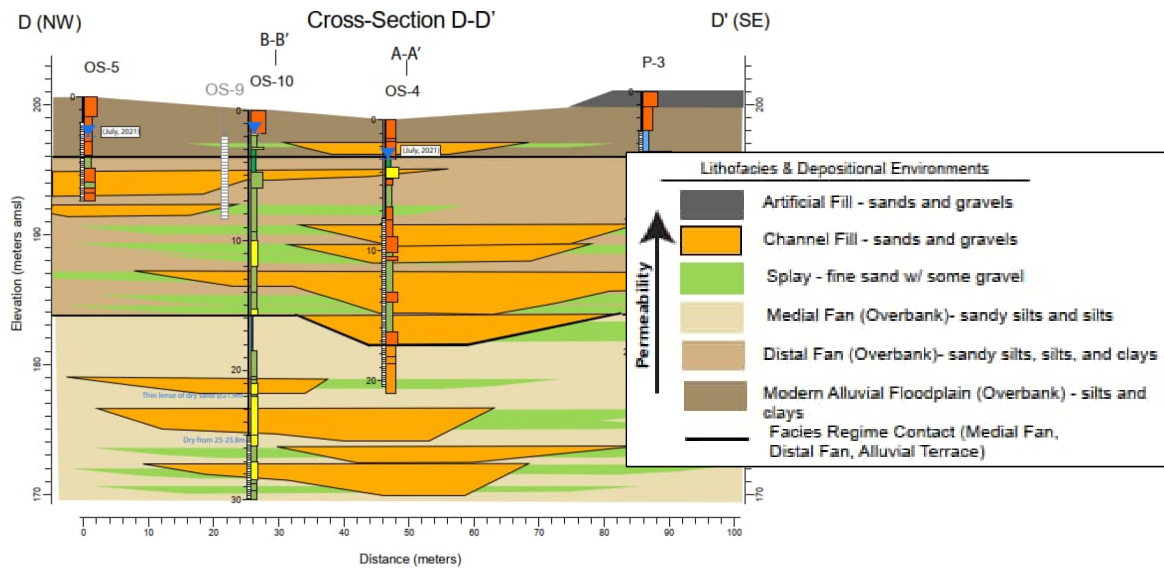
HS = 1" = 12,000" = 1,000'

VS = 1" = 200'

$$V.E. = \frac{HS}{VS} = \frac{1{,}000'}{200'} = 5$$

Case Study Example: ESS is Better at Predicting Pathways





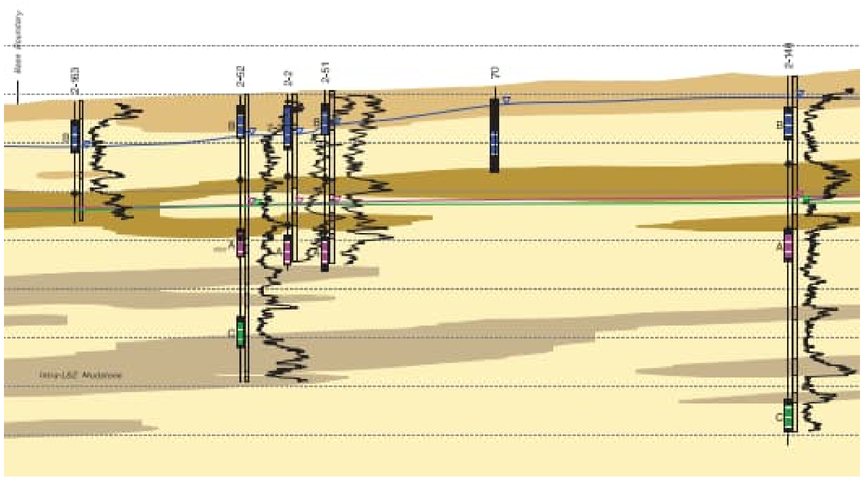
<u>Lithostratigraphic Interpretation</u>

- Fine vs coarse-grained deposits not visualized
- Migration pathways not clear

<u>ESS Interpretation</u>

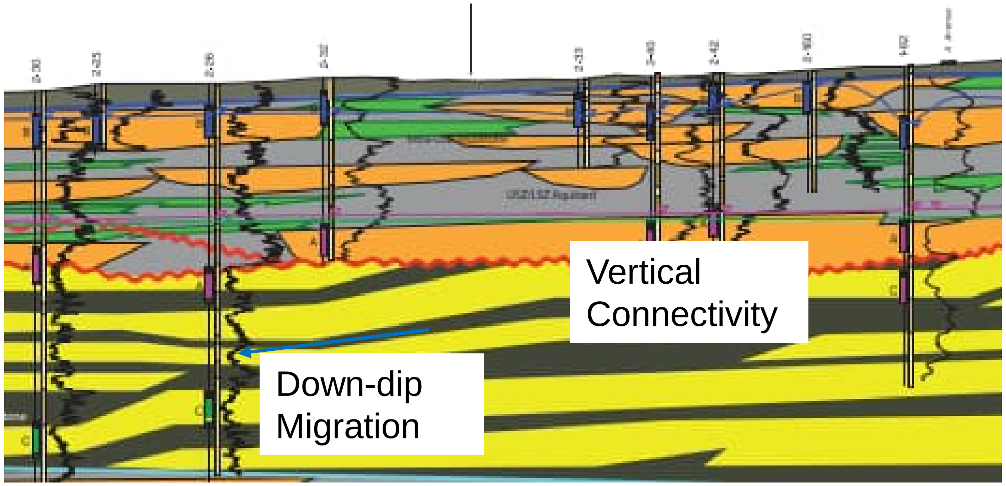
- Illustrates permeability
- Shows vertically and laterally connected channel deposits (pathways)

Case Study Example: ESS is a Better Illustration of Heterogeneity and Connectivity



Lithostratigraphic Interpretation

- Relatively homogenous
- Does not consider deposit geometry
- Shows higher transmissivity of deeper deposits
- Minimizes fine grained units that may dictate migration and flow

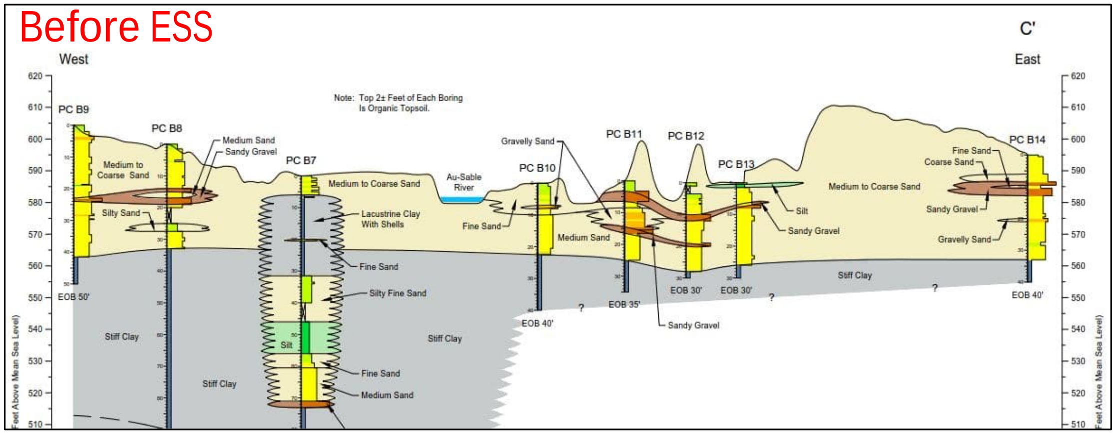


ESS Interpretation

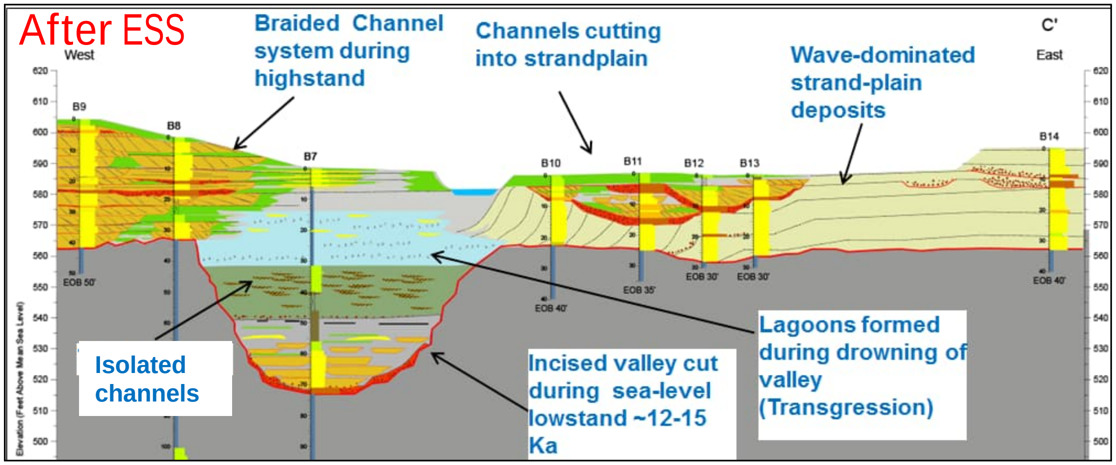
- Illustrates more heterogeneity between shallow and deeper deposits
- Illustrates geometry of coarse grained deposits (pathways)
- Shows relatively higher transmissivity of deeper deposits
- Shows dip of sediments that may facilitate downward migration

Benefits of ESS: Considers How Flow Can Change with Geology

Before ESS



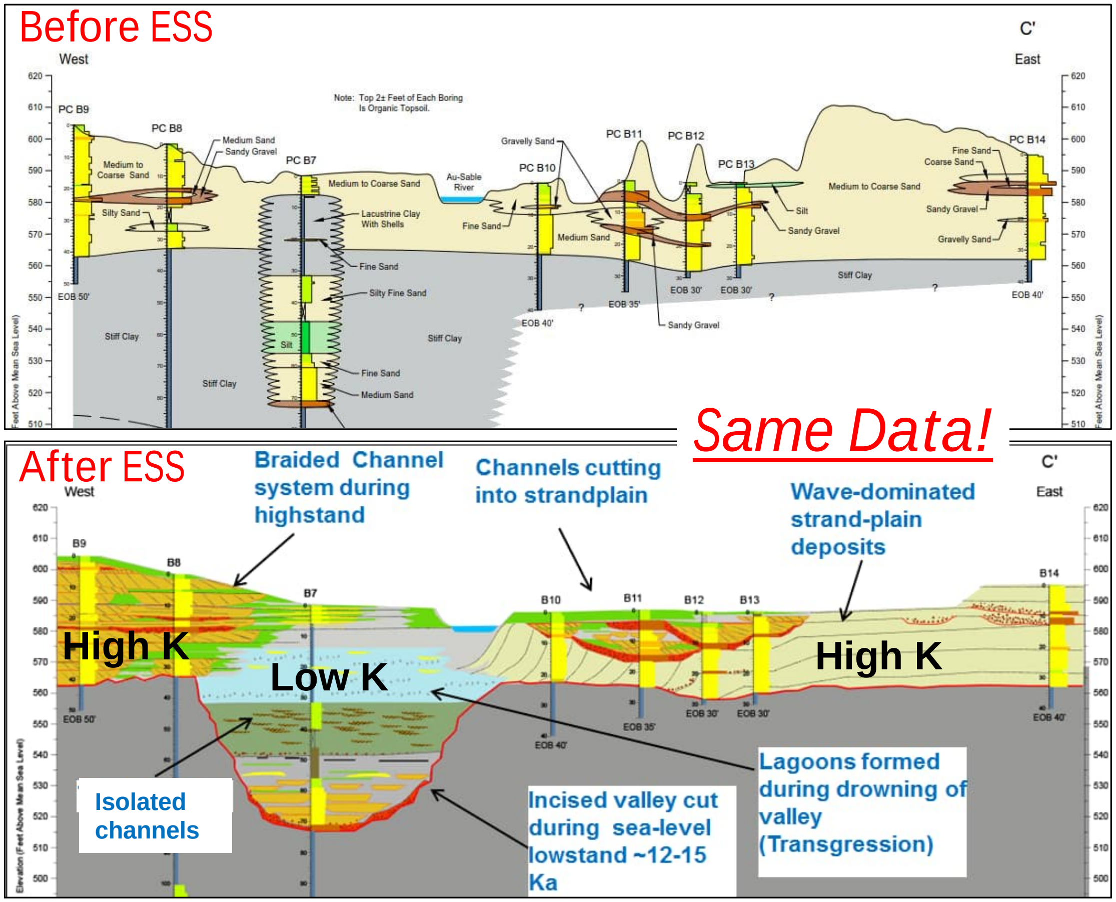
After ESS



ESS cross sections help us understand where the transport my be occurring between data points.

Same Data!

Case Study Example: ESS Solves CSM Mysteries



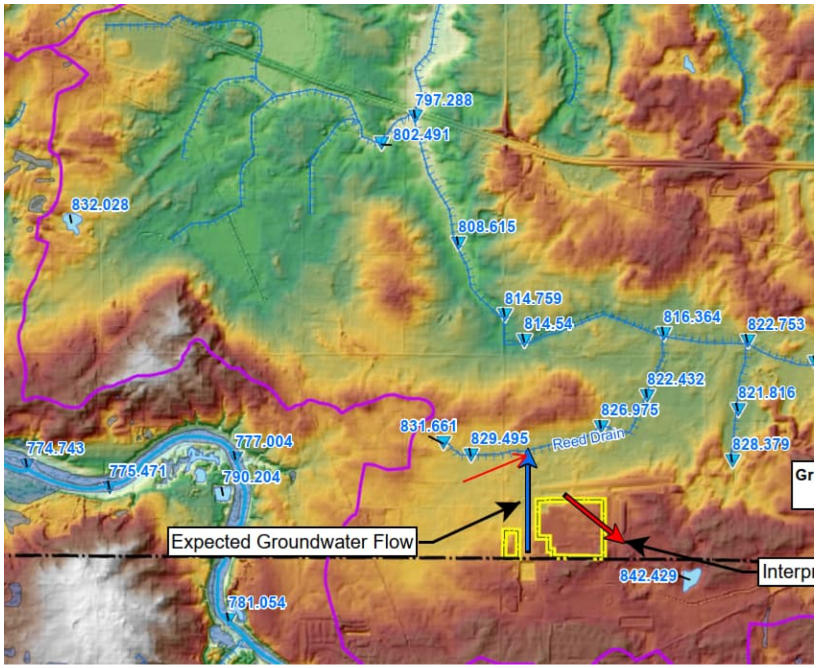
Lithostratigraphic Interpretation

- Connects sand with sand and clay with clay
- Two regionally-extensive hydrostratigraphic layers (brown and gray)

ESS Interpretation

- Clearly illustrates 3 hydrogeologically distinct zones
- Better illustrates the need to characterize flow and transport between data points.

Build a Hydrogeologic Foundation through Publicly Available Resources



Topographic digital elevation model with Surface Water and Watersheds

- Informs shallow groundwater flow
- Can extract surface water elevations to inform gaining/losing streams

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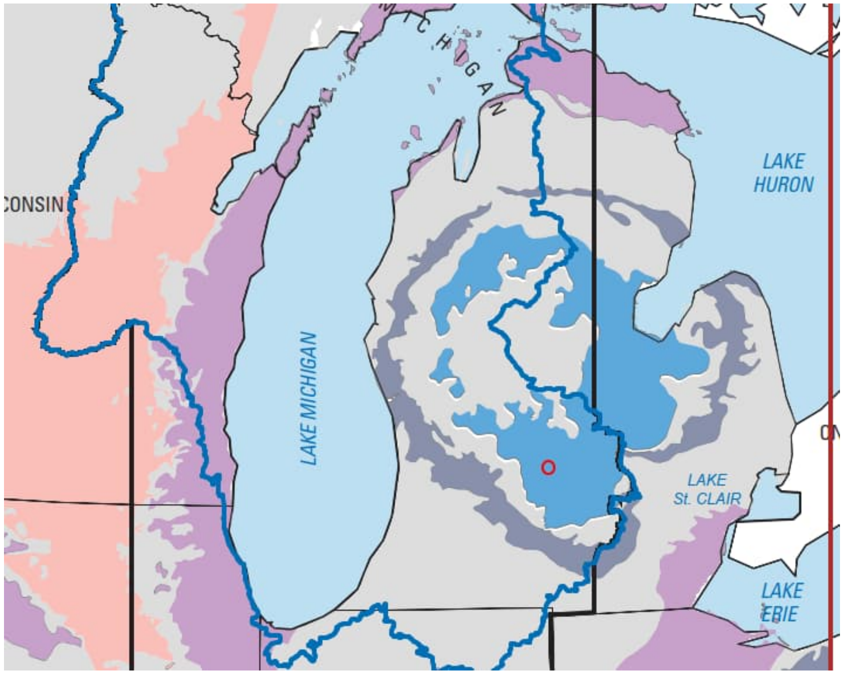

Aquifer Presence

Verify:

- What aquifers are expected
- What depths they occupy
- Whether they are connected to other aquifers

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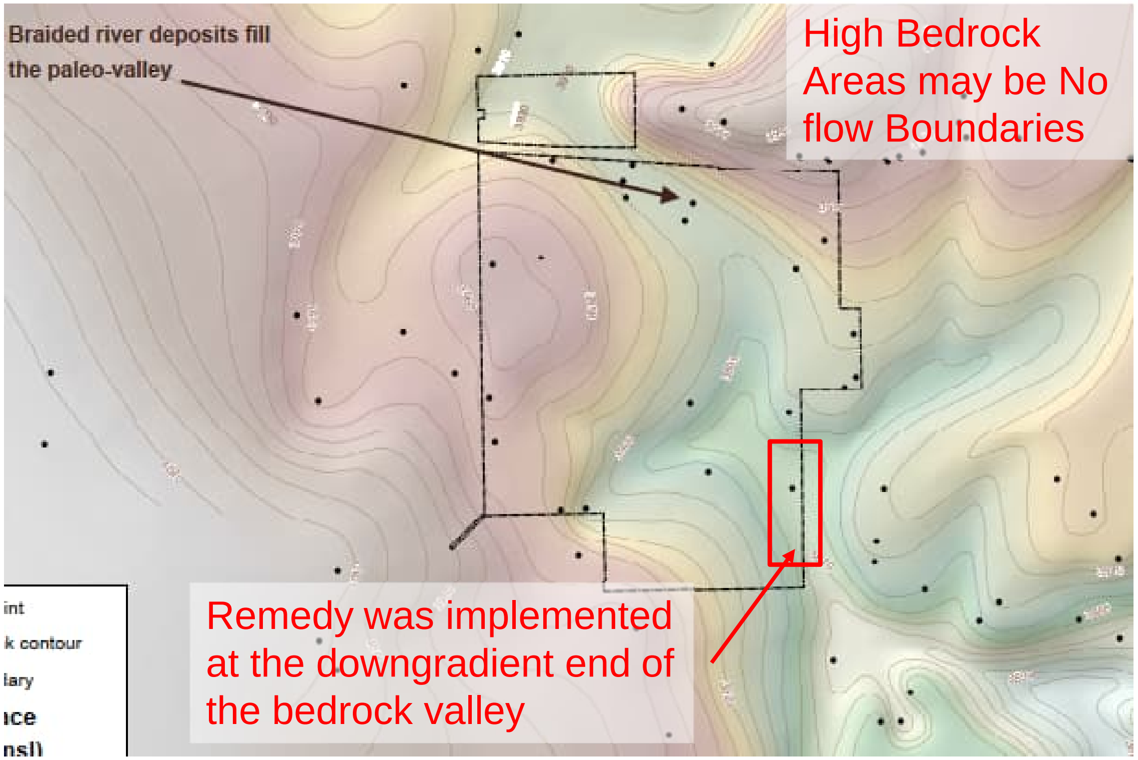

Top of Bedrock

- May be a confining unit
- Incised paleovalleys may dictate groundwater flow
- Can develop color flood raster from contours for visualization

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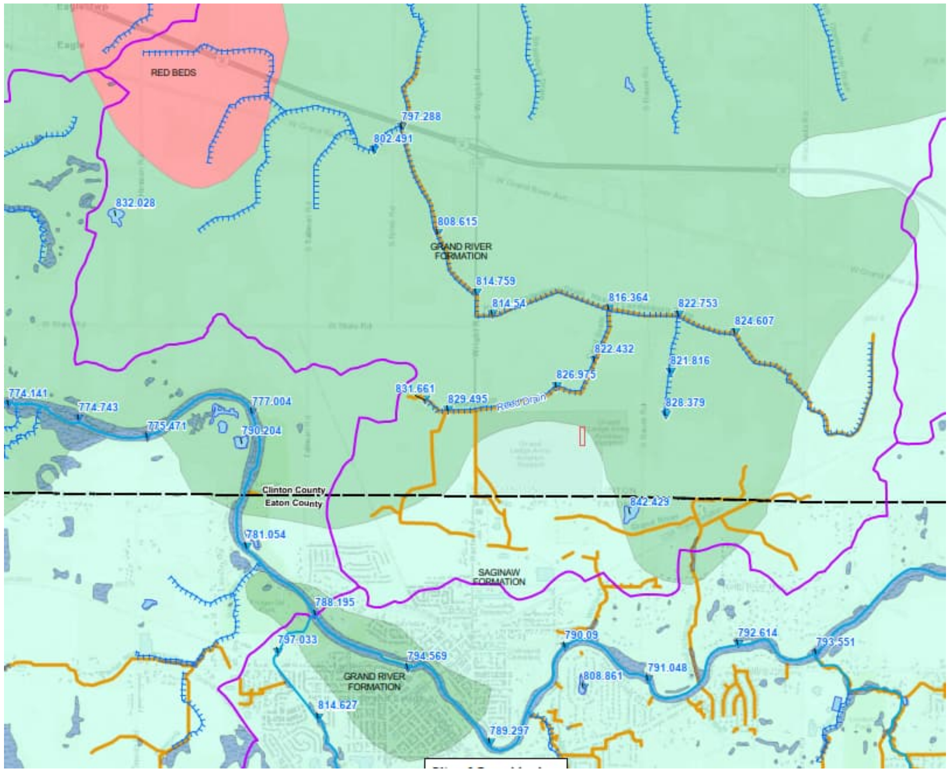
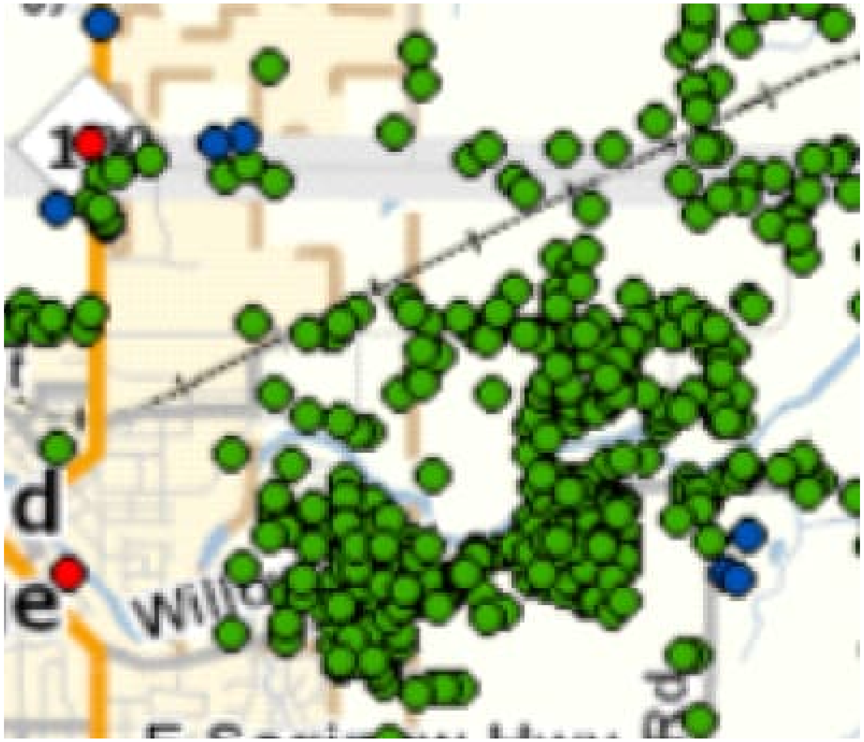


Bedrock Geology and Confining Units

Informs:

- Areas where overburden may be connected to bedrock
- Where confining units are present separating aquifer zones

Build a Hydrogeologic Foundation through Publicly Available Resources



Pumping Wells

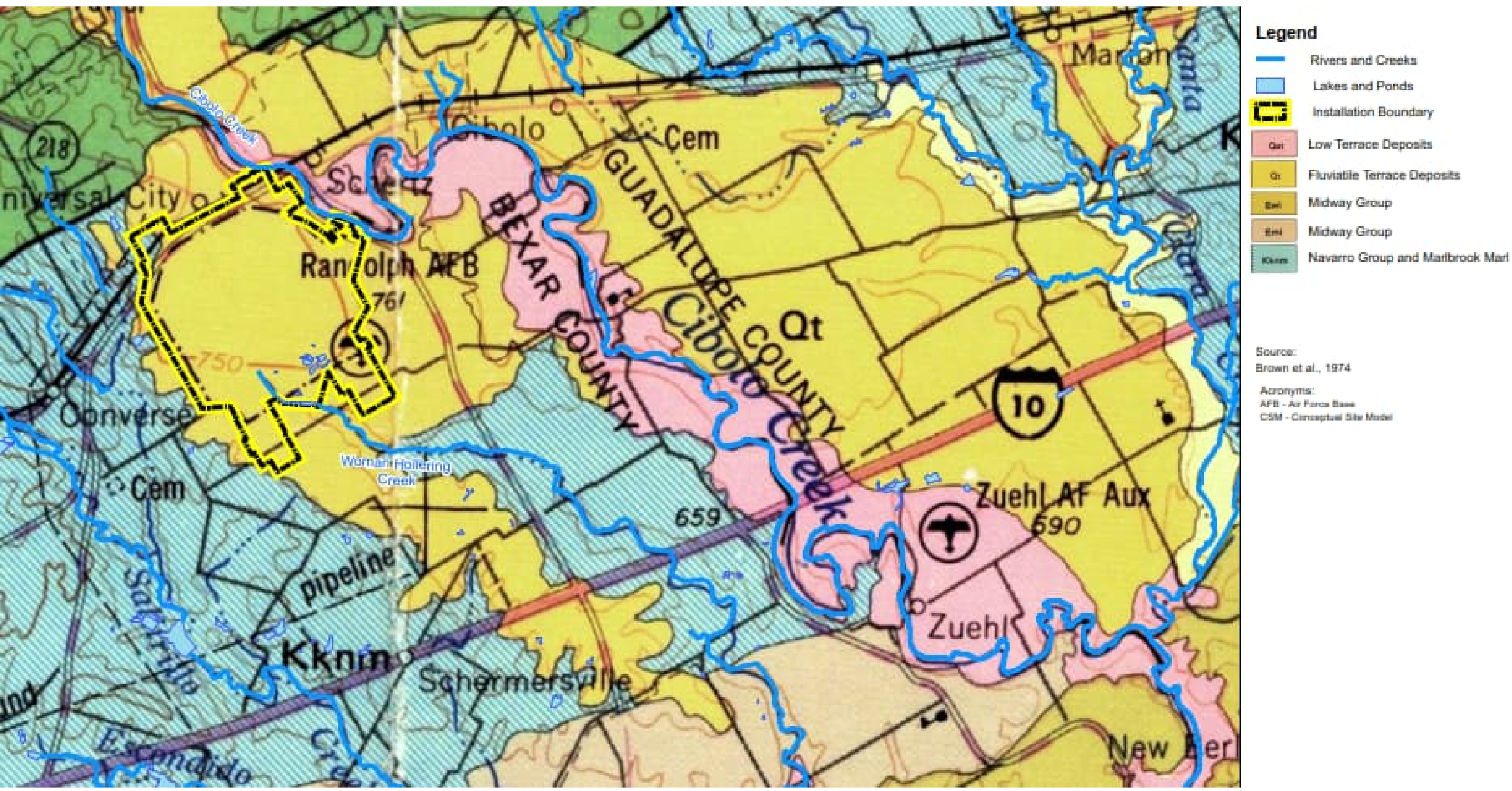
- May influence flow and contaminant migration direction locally or regionally
- Often screened across aquifer zones

Build a Hydrogeologic Foundation through Publicly Available Resources

Regional Groundwater Maps

- •Compare to flow interpreted for site
- •If flow doesn’t match, need to determine why
  - •Different aquifer zone?
  - •Regional map scale too large to reflect local variations

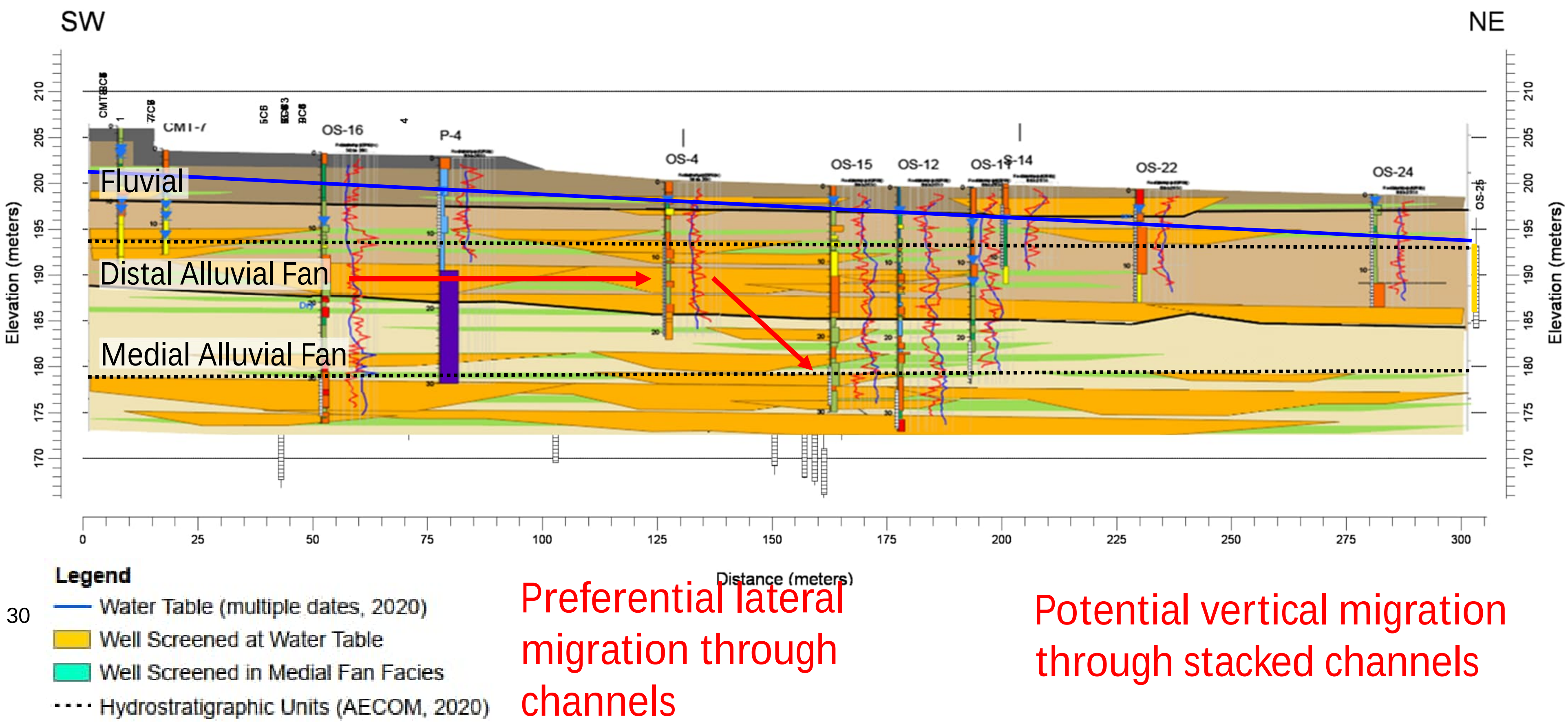
Build a Hydrogeologic Foundation through Publicly Available Resources



May inform amount of infiltration to groundwater

- Less in fine grained geology
- More in coarse grained geology

Use Sequence Stratigraphy to Classify Well Network by Hydrostratigraphic Unit (HSU), not depth



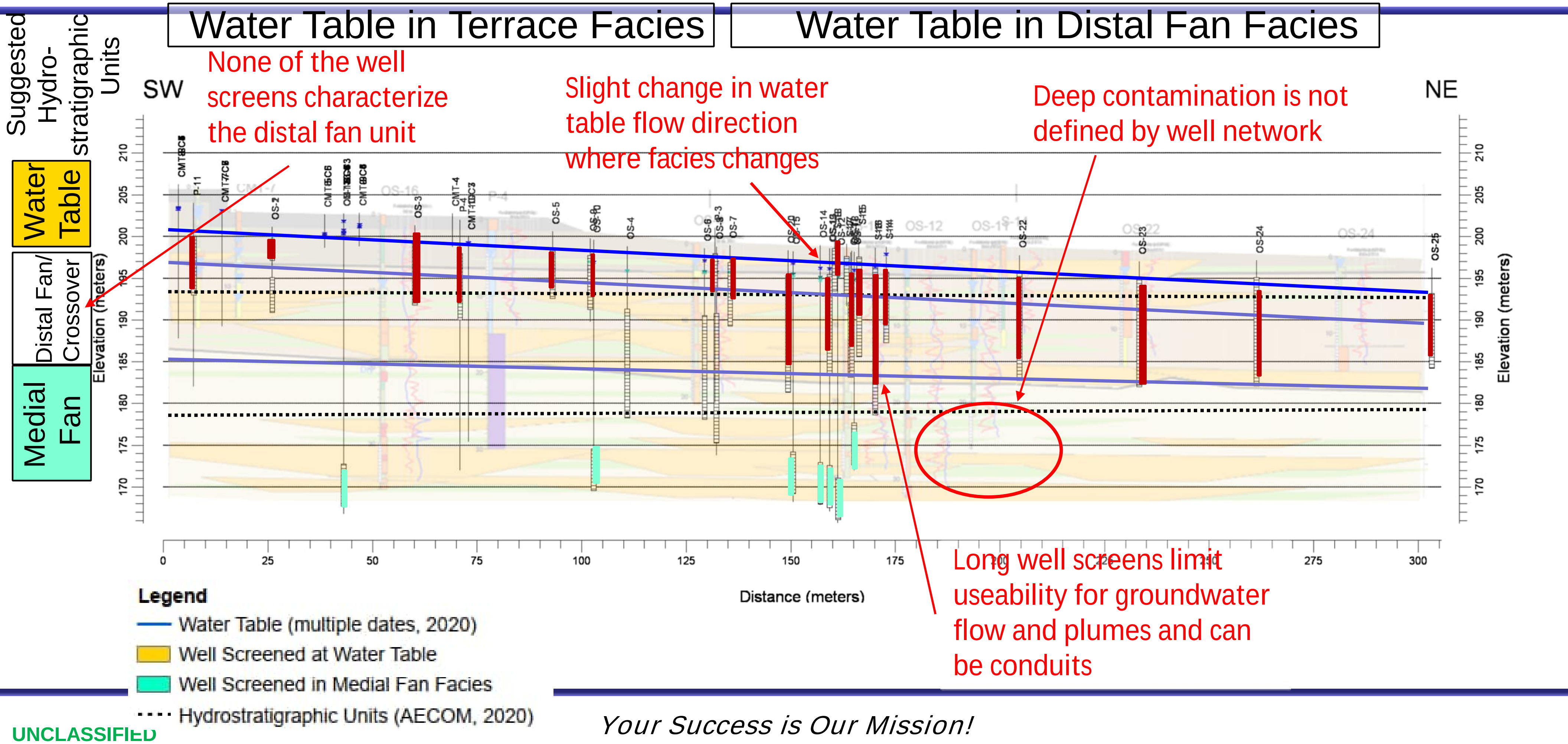
Preferential lateral migration through channels

Potential vertical migration through stacked channels

Use Sequence Stratigraphy to Classify Well Network by Hydrostratigraphic Unit (HSU), not depth

Water Table in Terrace Facies

Water Table in Distal Fan Facies



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86MW-6		2308378.61	587134.76	104.1149979	103.87	25	20	83.87	25	78.87	18.75	85.12	
86MW-7		2308480.68	587242.54	104.1429977	104.02	25	20	84.02	25	79.02	NM	NM	not found
86MW-8		2308412.15	587201.35	103.3649979	105.09	25	20	85.09	25	80.09	19.98	85.11	
86TW-1		2308444.33	587251.03	102.5149994	102.75	25	20	82.75	24.75	78	NM	NM	not found
86TW-2		2308404.11	587258.52	101.3669968	102.75	25	20	82.75	24.75	78	NM	NM	not found
AOC32-TW1		2303566.54	580876.04	70.7018967	72.57	15	5	67.57	14.45	58.12	NM	NM	not found
AOC32-TW2		2303576.25	580778.99	71.5675964	73.86	19	9	64.86	18.45	55.41	NM	NM	not found
AOC32-TW3		2303433.79	580706.4	72.240097	74.24	20	10	64.24	19.45	54.79	NM	NM	not found
AOC32-													not found
AOC33-DF													not found

Abandoned Locations can be relevant

Easily integrates into GIS and 3D programs to visualize

Drawing a Shallow Groundwater Map

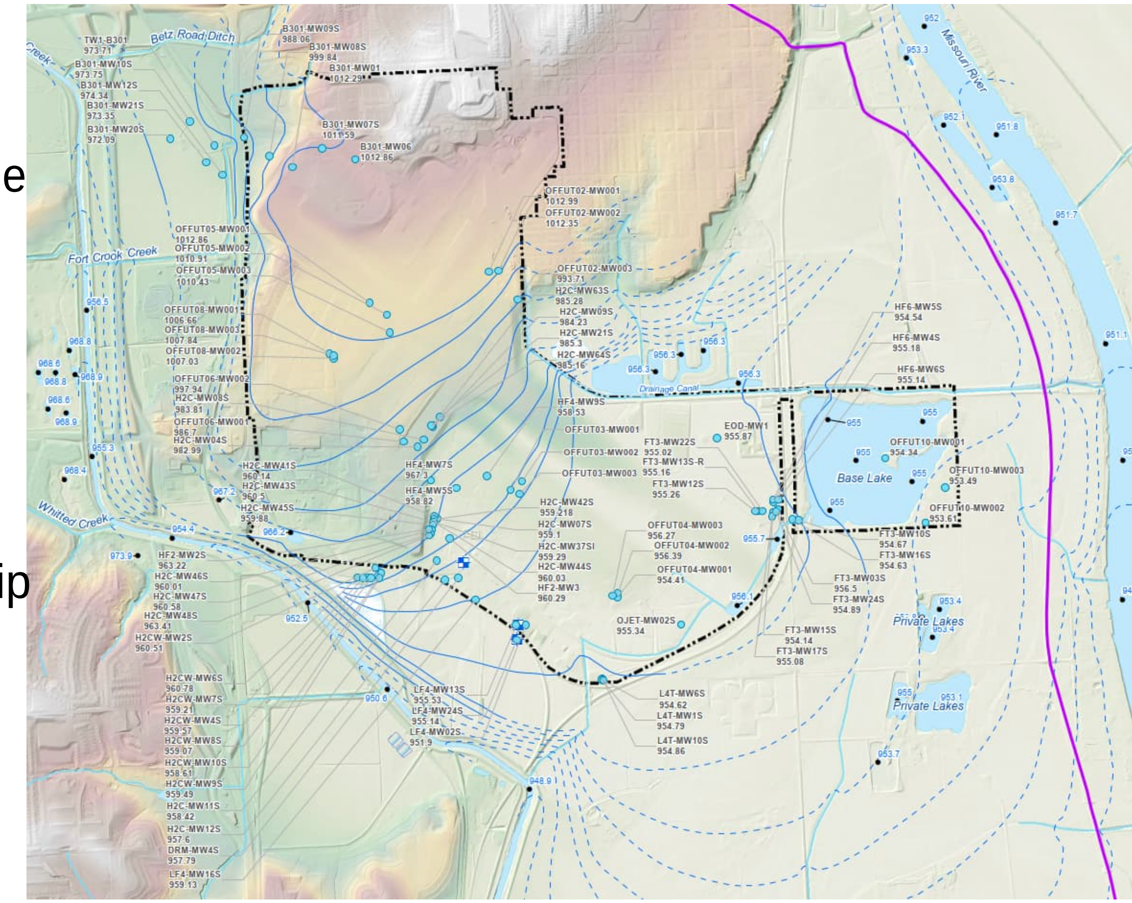
1. Scoping Consideration: Synoptic Event

2. Use classified well network. Map wells in same hydrostratigraphic unit.

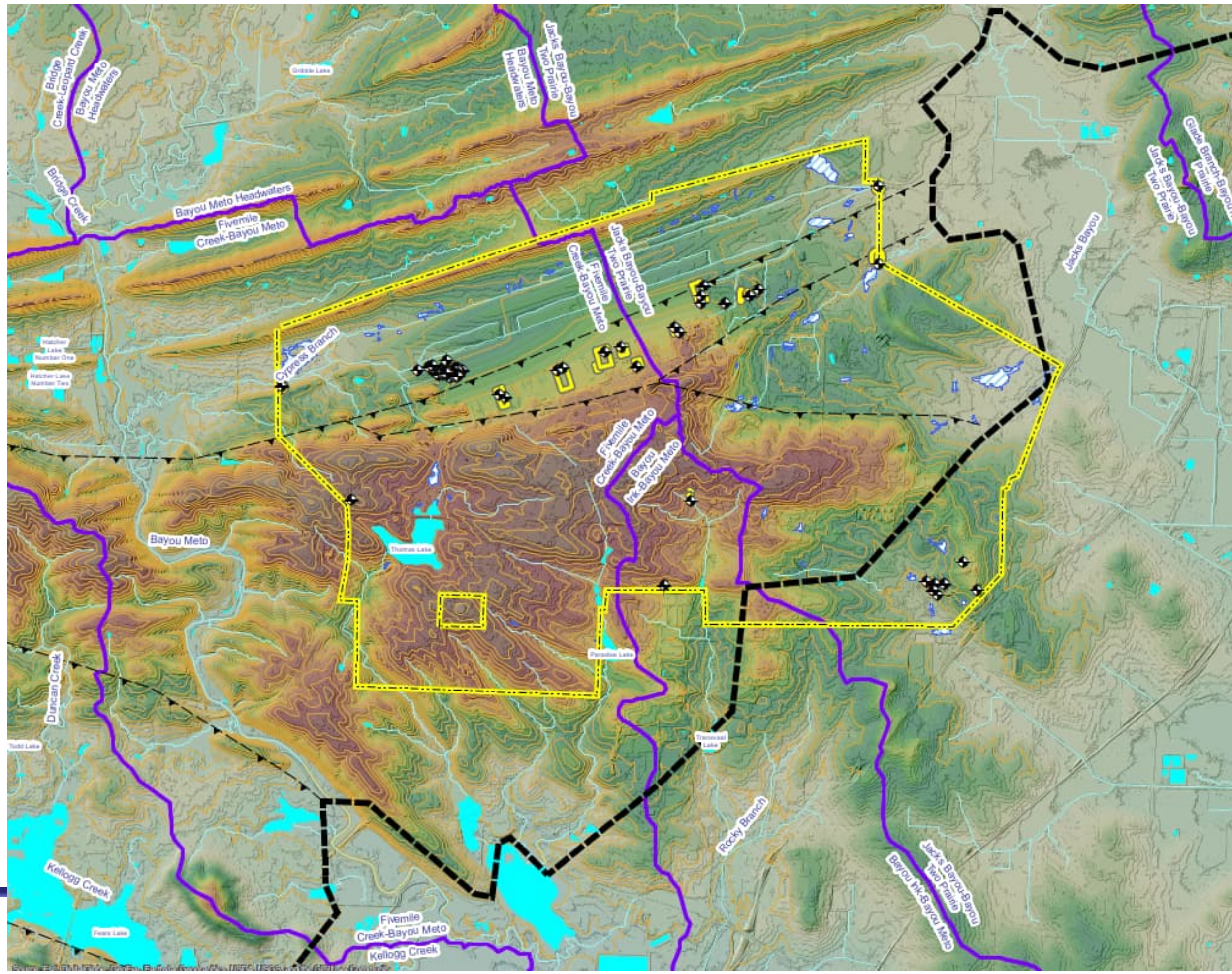
3. Use relevant, publicly available base maps!
   - Incorporate surface water/ watersheds
   - Topographic digital elevation model - extract surface water elevations
   - Consider gaining/losing stream relationship to groundwater

4. Develop concept outside data

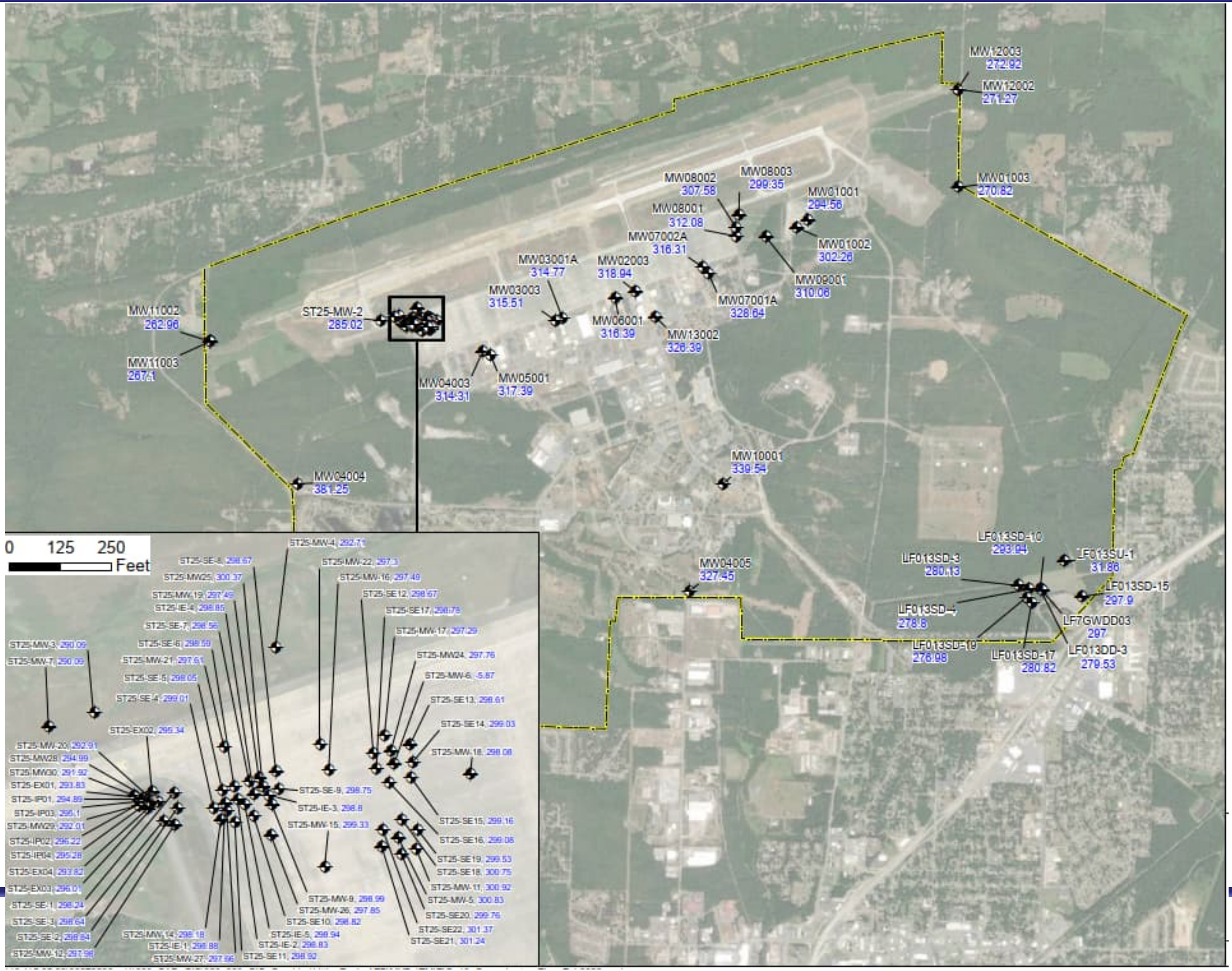
5. Use same network to interpret contamination



Case Study: Develop Conceptual Groundwater Map From Limited Data



Case Study: Develop Conceptual Groundwater Map From Limited Data



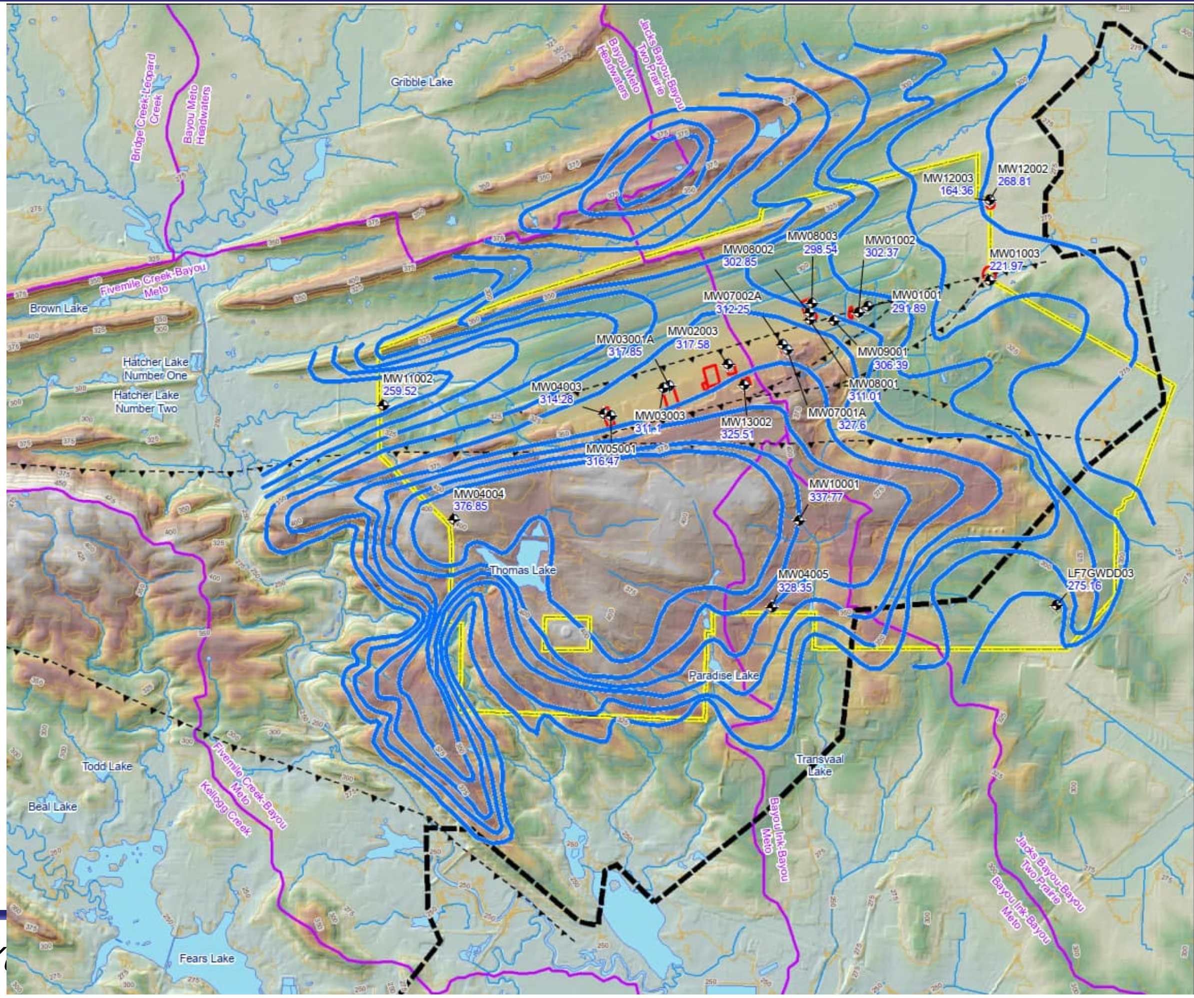
Case Study: Develop Conceptual Groundwater Map From Limited Data

May not have:

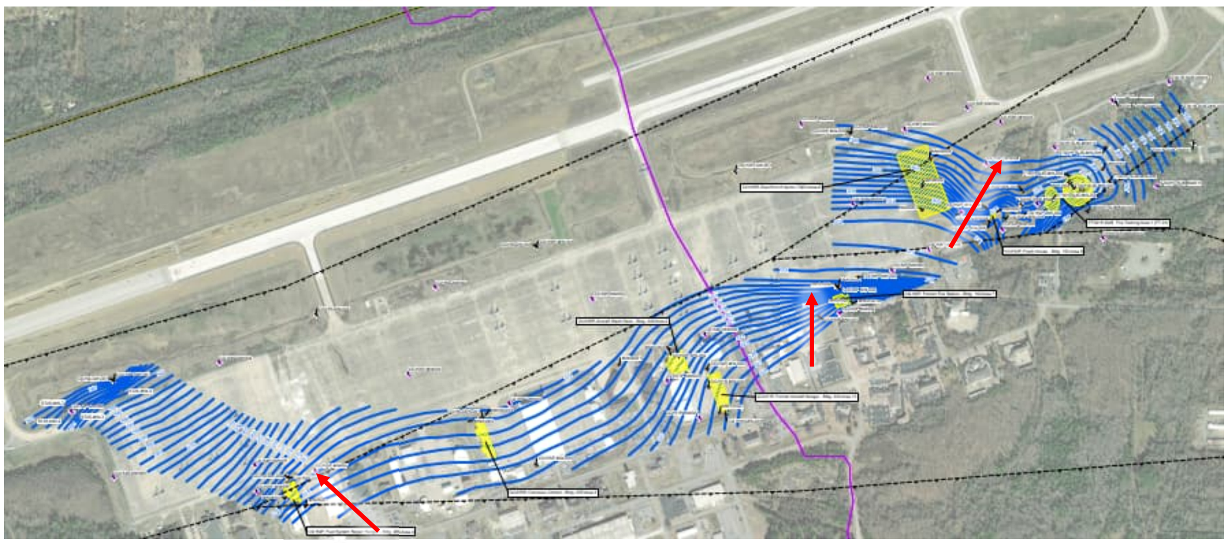
•Synoptic, Site-wide data

But you may have and consider:

- Regional aquifer data (USGS)
- Topography and watersheds
- Surface water data (extract from digital elevation model or USGS stream gauge)
- Historic groundwater elevation data
- Legacy plumes



Case Study: Confirm/Revise Concept with New Data



Before:

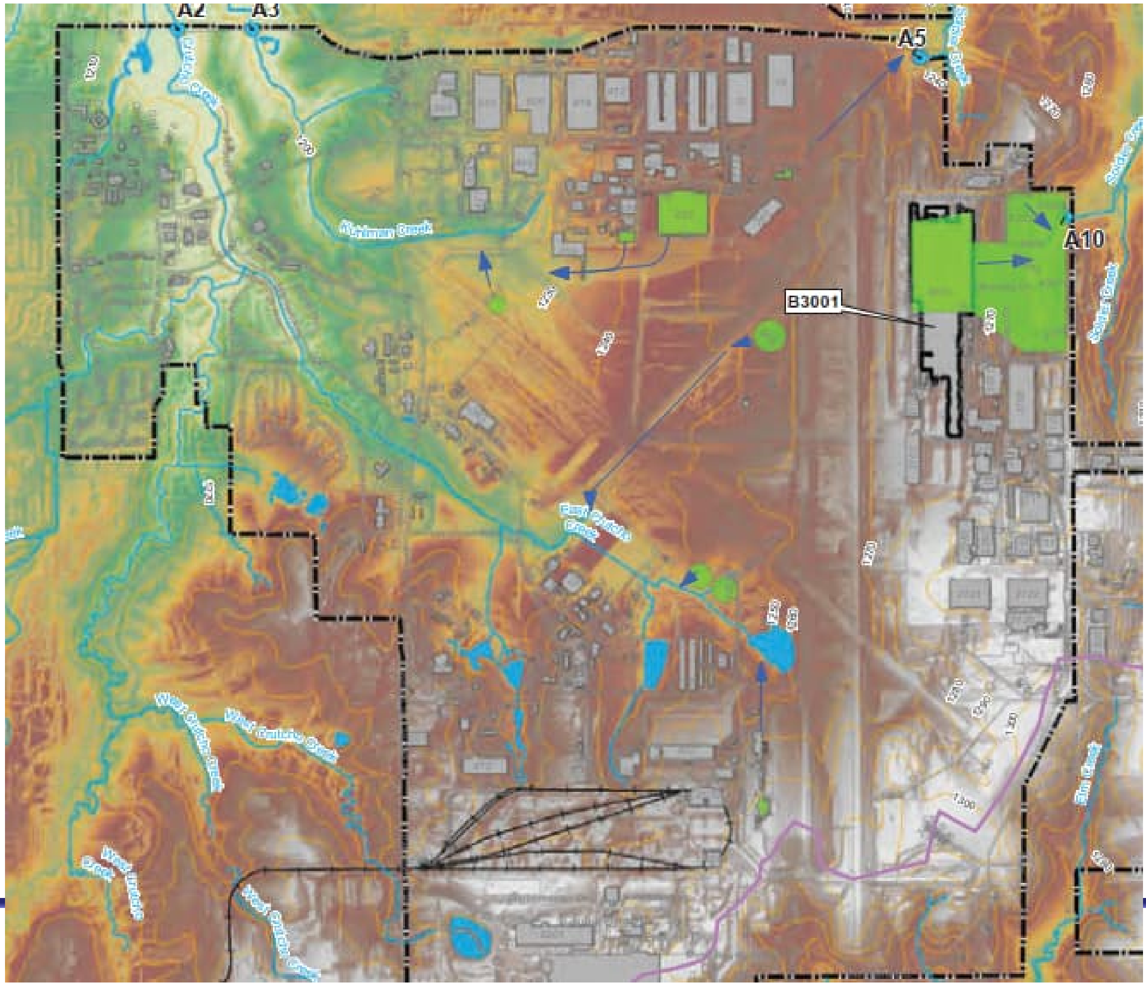
Concept developed using topography and surface water with less data (<20)

After:

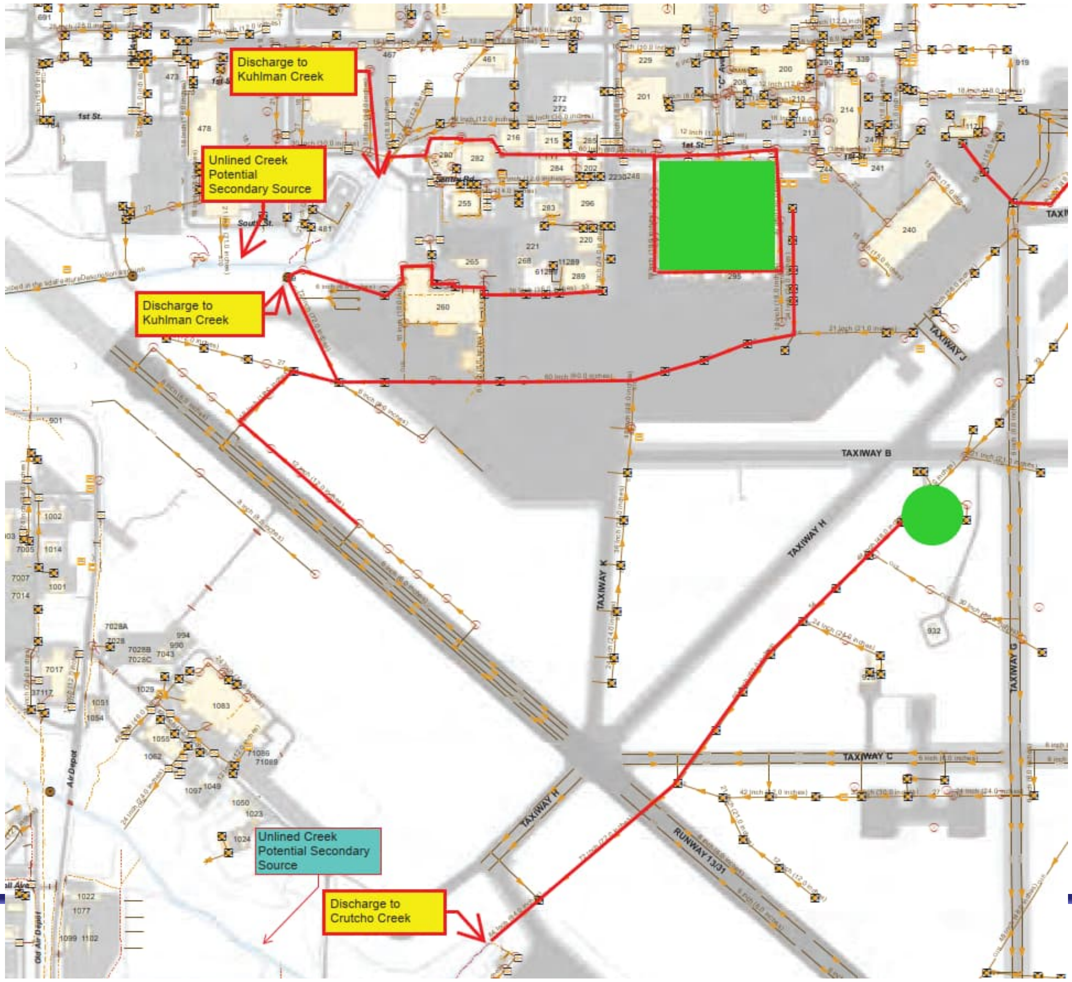
Concept confirmed with more data (>50)

Contaminant CSM Foundation: Surface Water Pathways

Map the surface water flow pathways from each PFAS site using topography

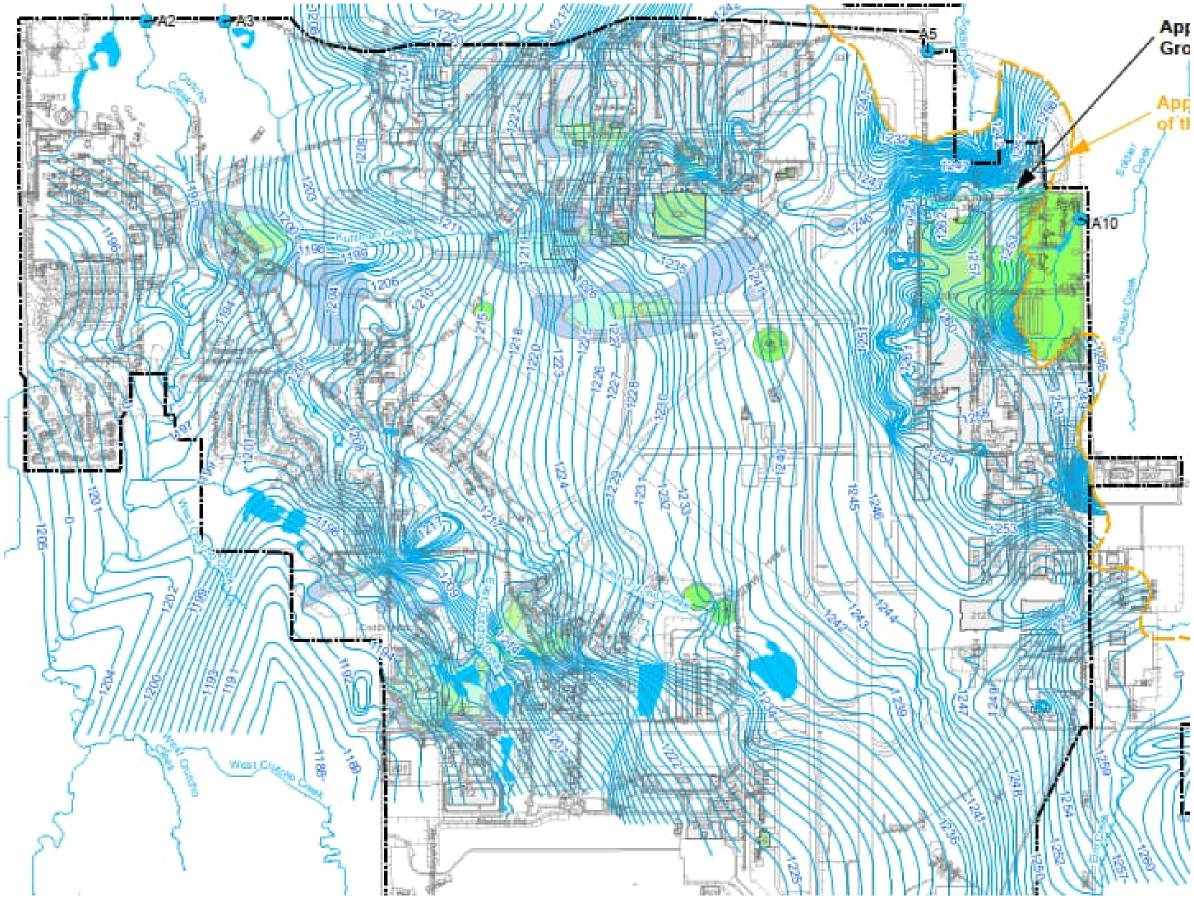


Contaminant CSM Foundation: Storm Water Pathways

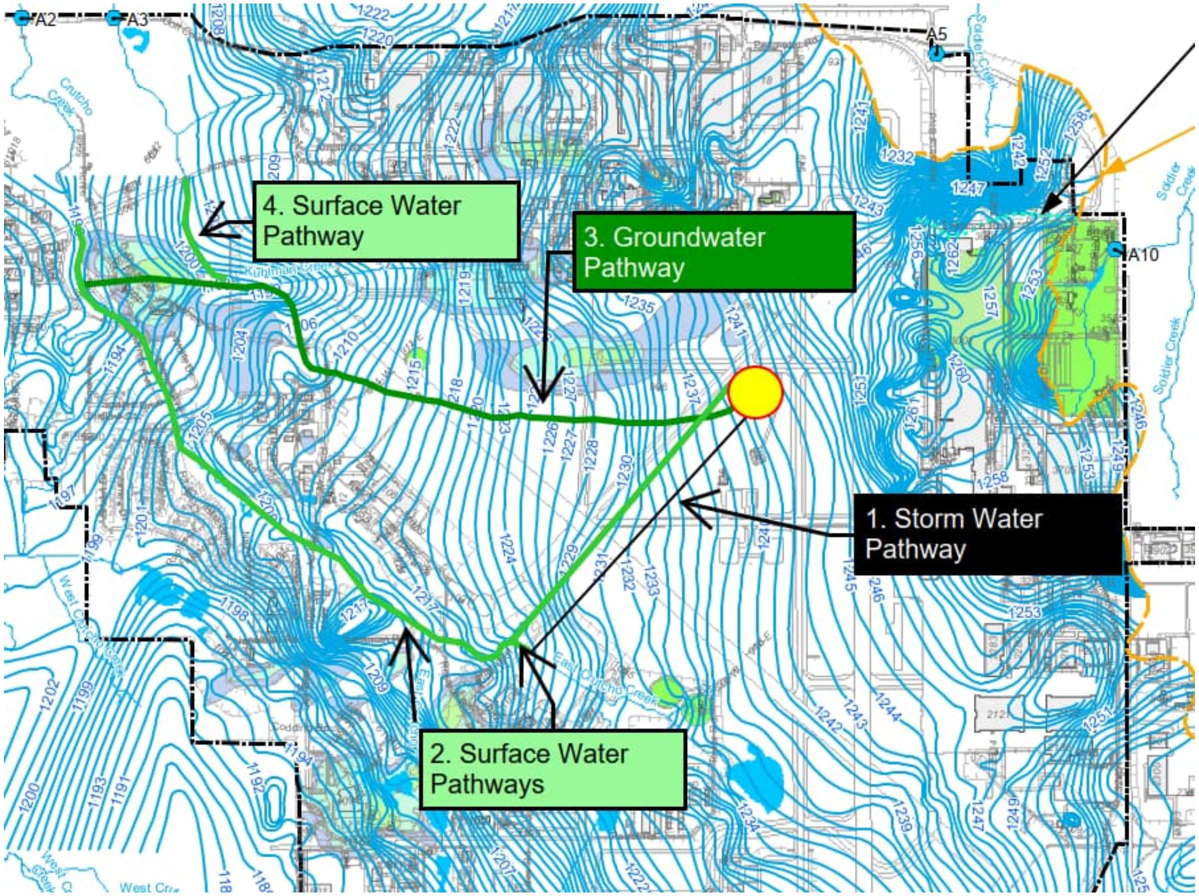


Contaminant CSM Foundation: Groundwater Pathways

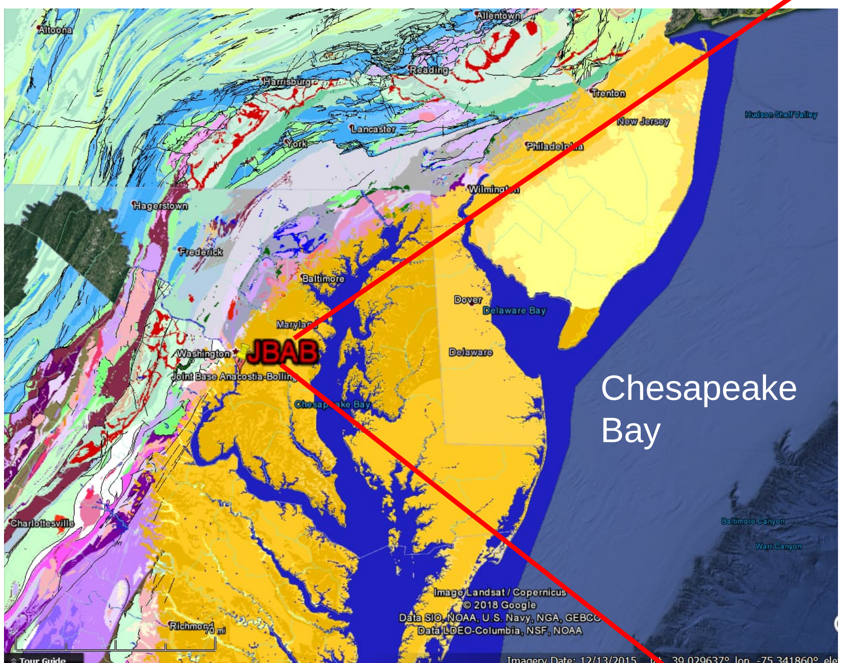
Map the groundwater flow pathways from each PFAS site using groundwater maps for each hydrogeologic zone and legacy plumes



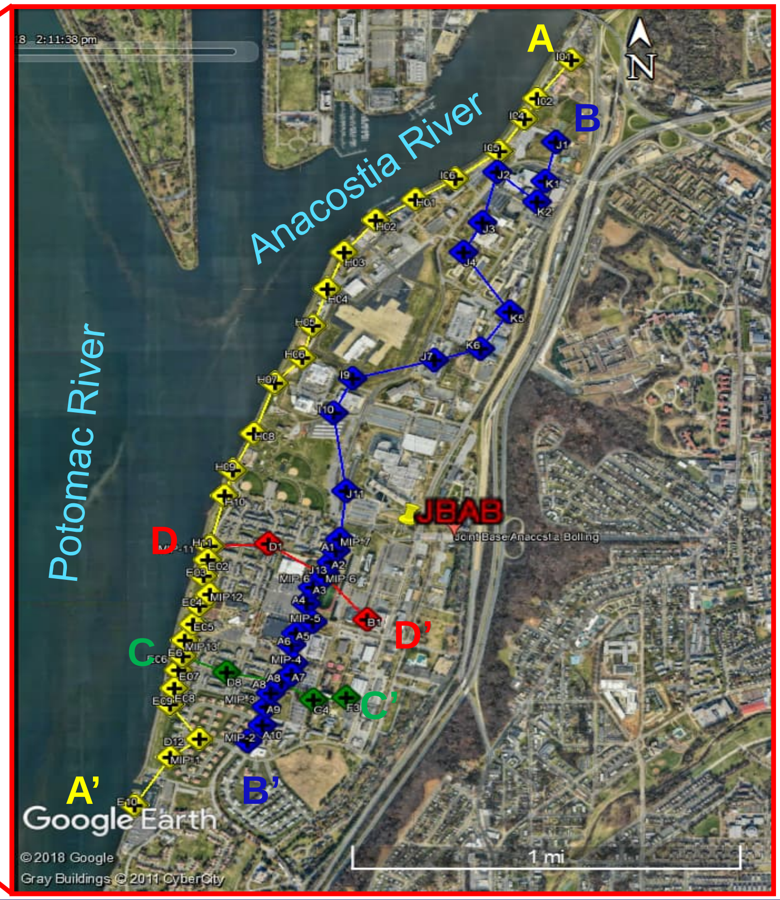
Contaminant CSM Foundation: Holistic and Complete Visualization



Case Study: Plume Reinterpretation



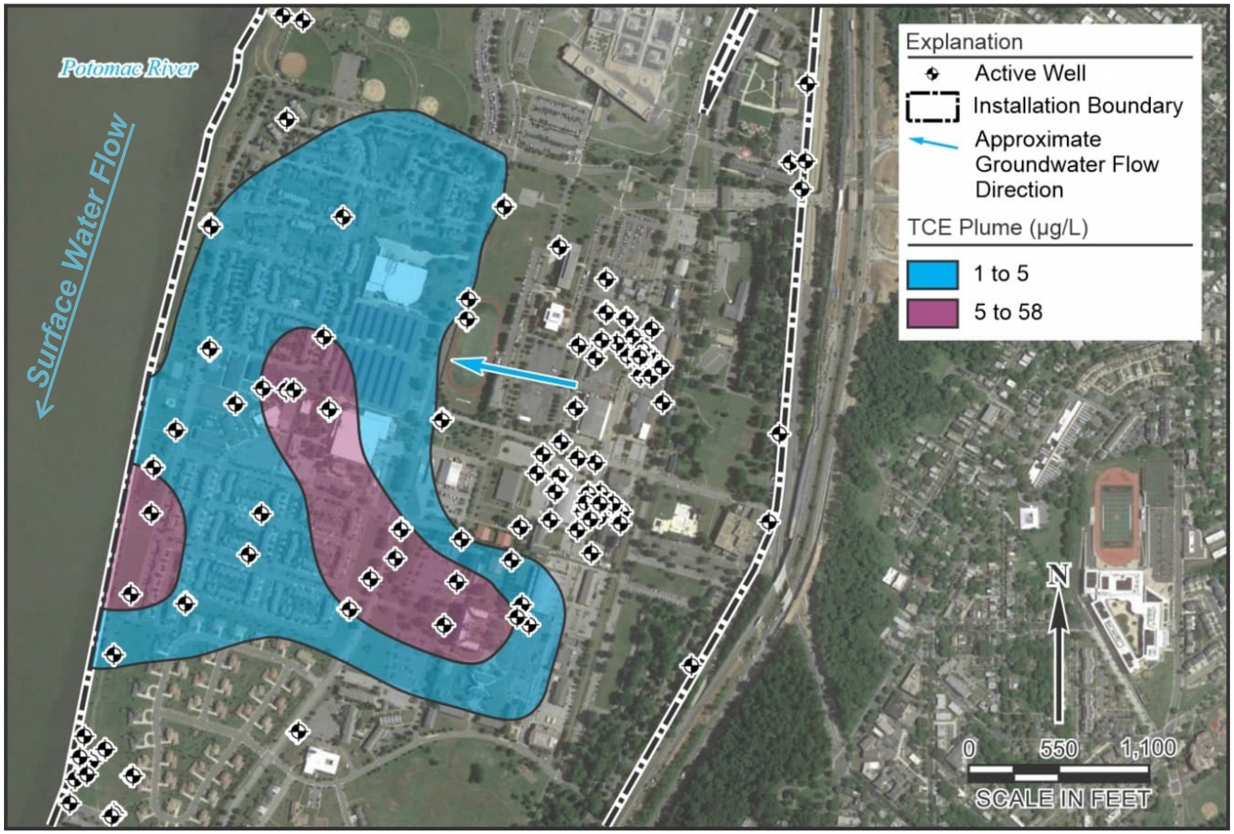
Purpose: To better understand and predict the contamination plume's flow-path at the site.



<u>Data use:</u>

- 60+ MIP/HPT/EC logs
- Boring logs from Water Division
- Chemical analysis from groundwater samples

Case Study: Plume Reinterpretation



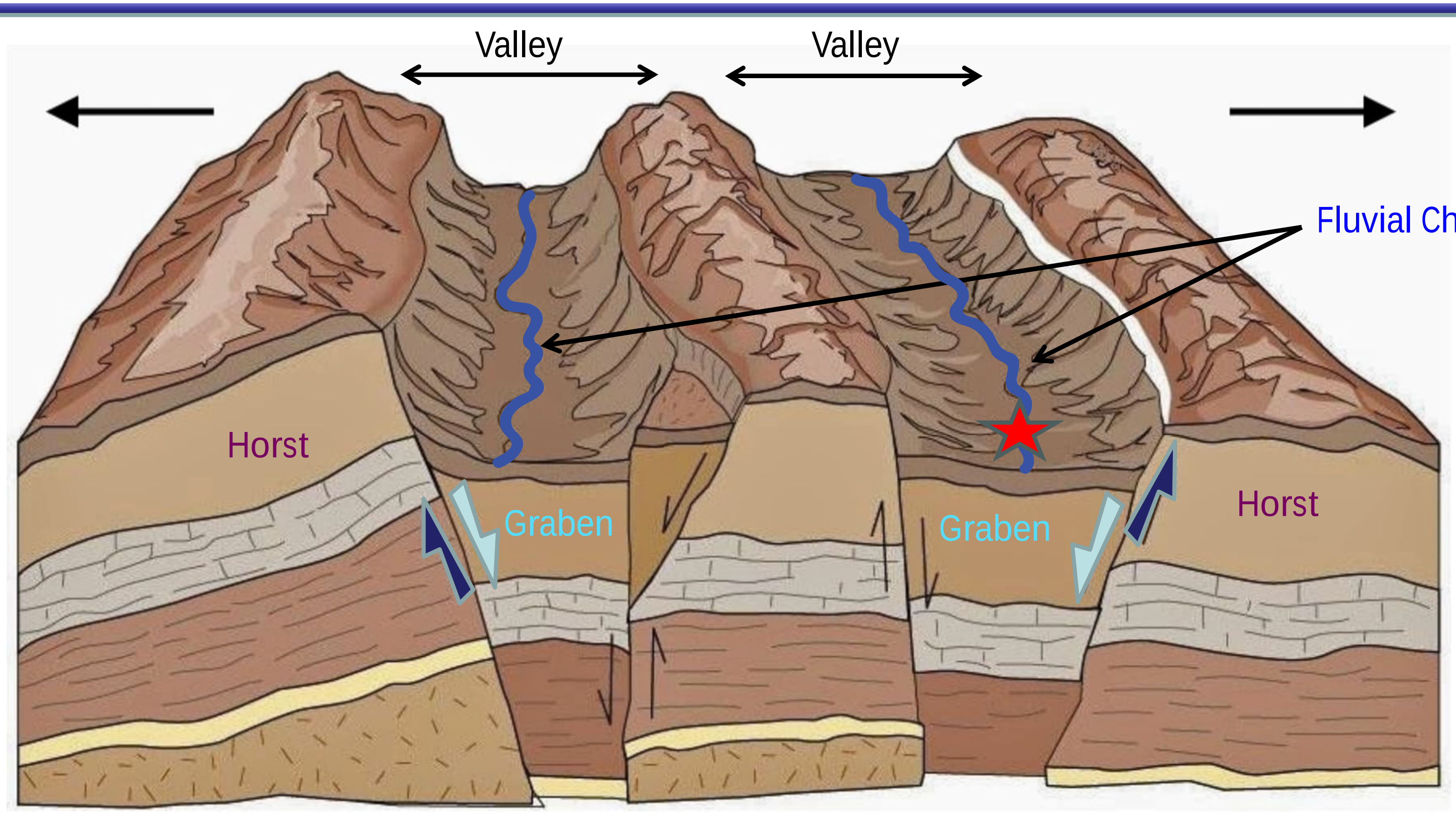
Problem

- How much contaminant mass is being discharged into the river?
- Plume migrating towards the north?

Goals

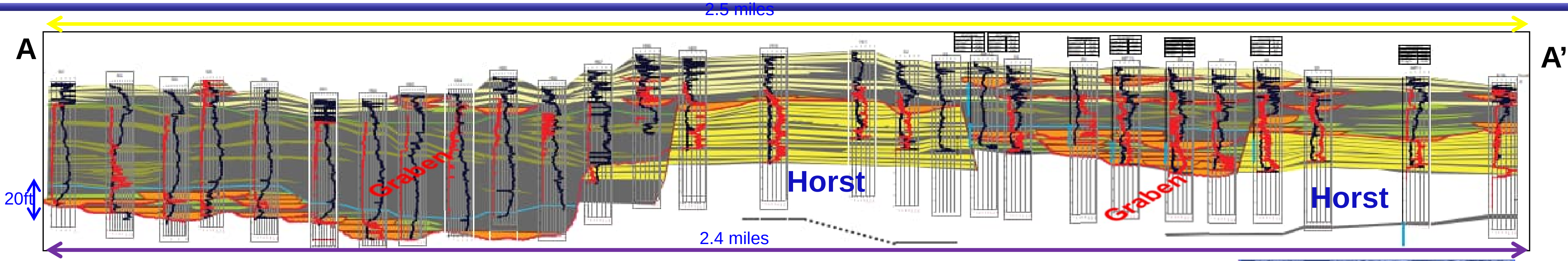
- Refine an existing EVS model to design a targeted remedy.

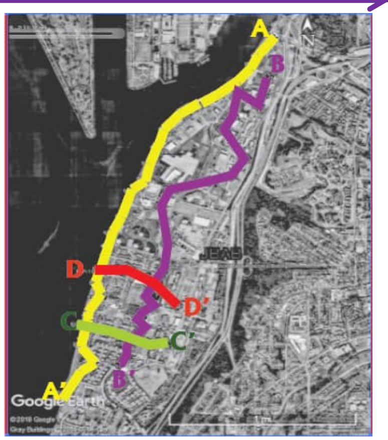
Case Study: ESS Evaluation

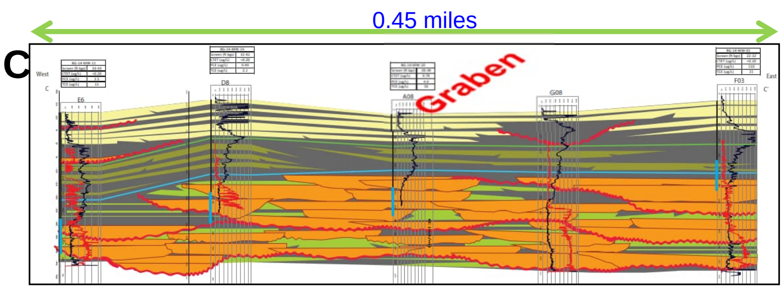


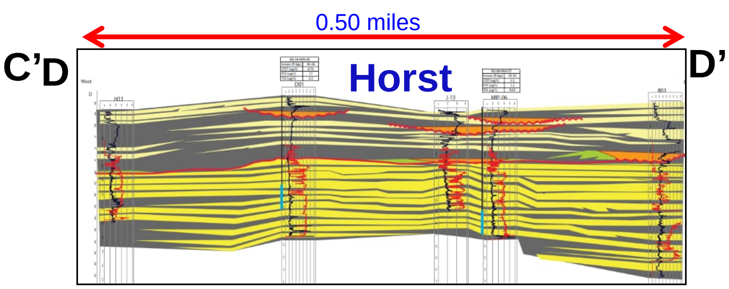
- Modified from geoscience.wisc.edu

Case Study: ESS Cross Sections



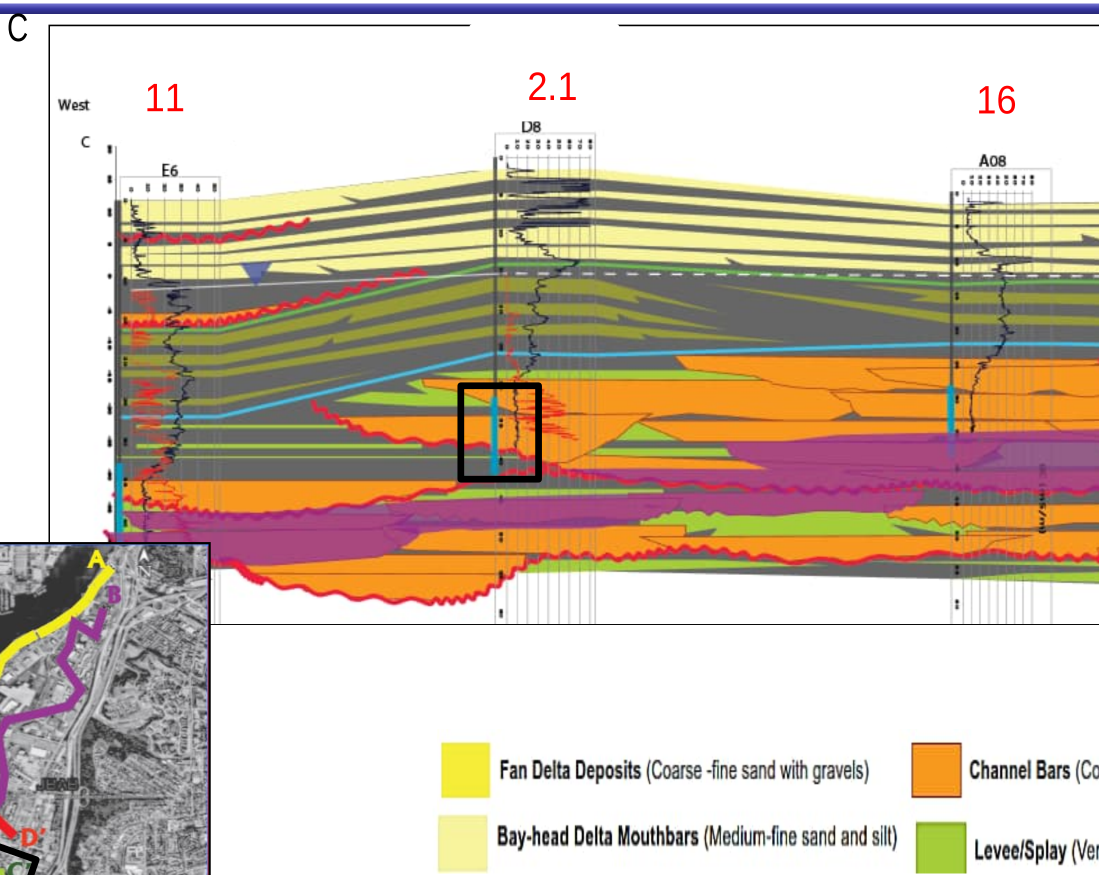


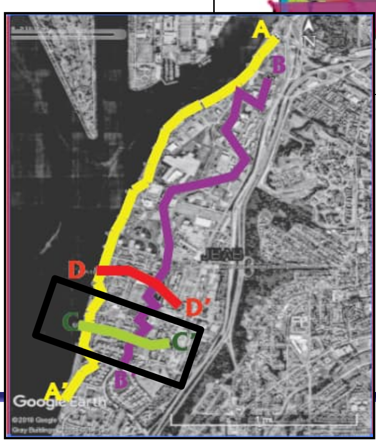


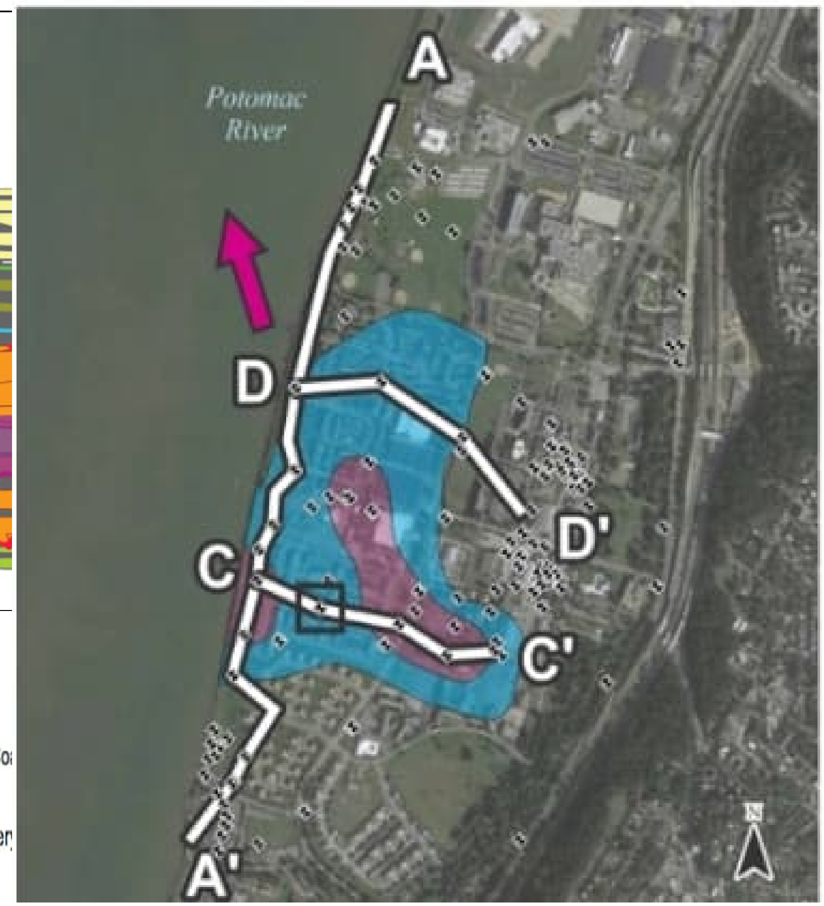


Fan Delta Deposits (Coarse -fine sand with gravels)	**Channel Bars** (Coarse sand - silt)	**Tidal Bars** (Very fine sand, slit and clay)
Bay-head Delta Mouthbars (Medium-fine sand and silt)	**Levee/Splay** (Very fine sand and silt)	**Overbank Fines** (Slit and clay)

Case Study: Well Screen Evaluation

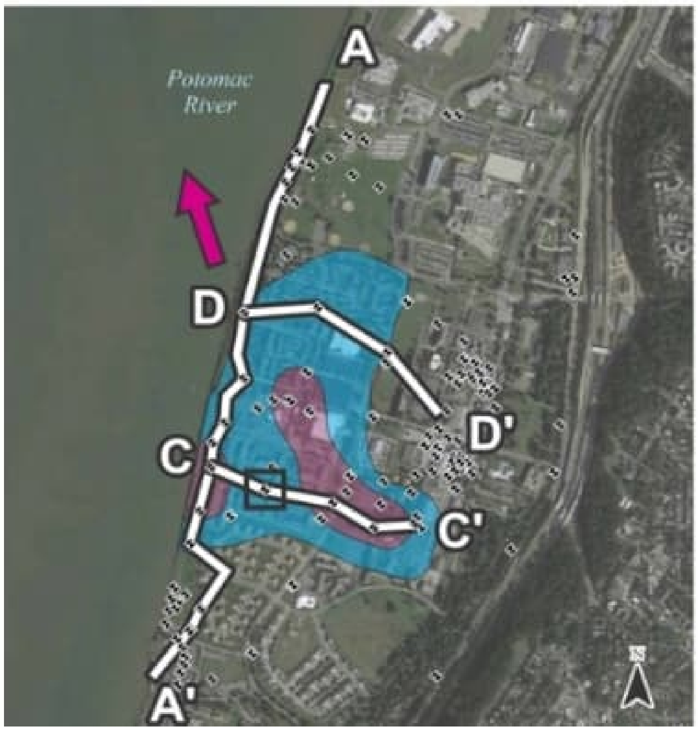




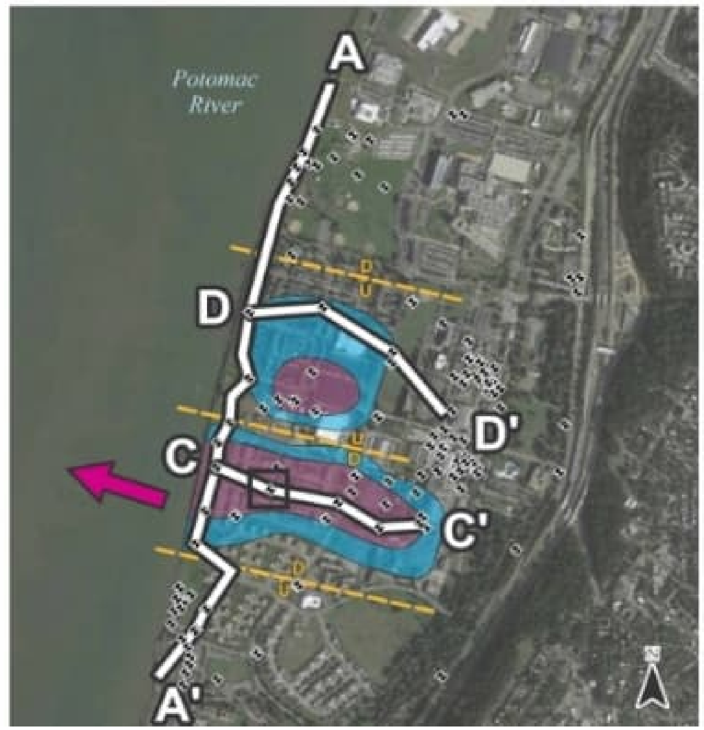


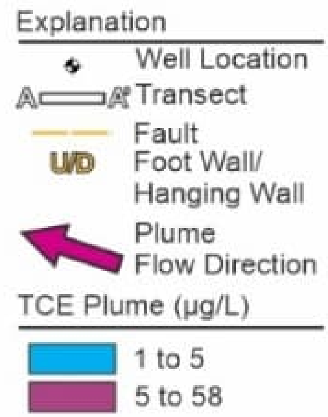
Case Study: Redefined Plume Shape and Extent

Before



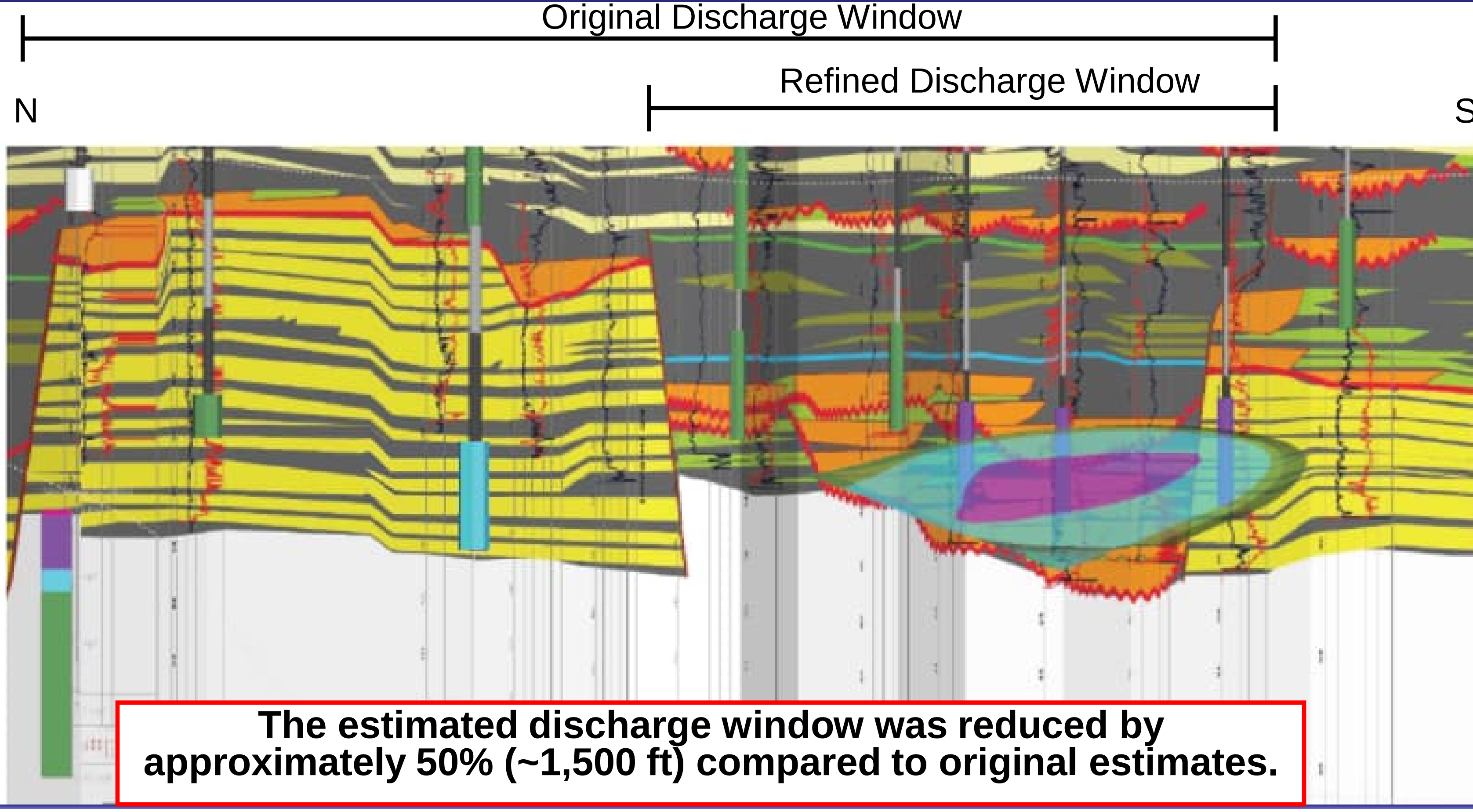
After



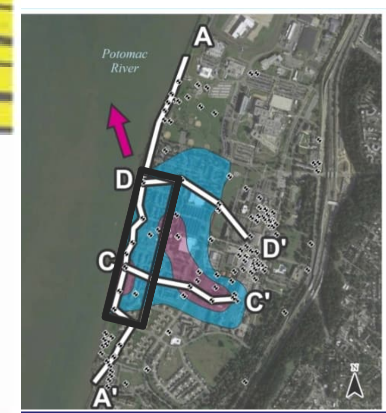


Discontinued the need to install 2-3 additional monitoring wells to the North

Case Study: Optimized Remedial Design



Original Discharge Window



CSMs: The Foundation of Remediation Decisions

QUESTIONS?

Free publication on
Sequence Stratigraphy

Chapter 4
The Application of Sequence Stratigraphy to the Investigation and Remediation of LNAPL-Contaminated Sites

Junaid Sadeque and Ryan C. Samuels

Abstract The heterogenous and complex nature of soil and groundwater systems leads to significant technical challenges in remediating Light Non-Aqueous Phase Liquid (LNAPL) contamination and achieving cleanup goals within reasonable timeframes. Therefore, implementing a correlation approach that adequately addresses subsurface heterogeneity between sampling locations is critical for effective management of LNAPL-contaminated sites. In traditional LNAPL remedial investigations in clastic environments, correlation has typically been conducted using 'lithostratigraphy', which connects like-lithologies without recognizing the heterogeneity of subsurface sediments between boreholes. The resulting 'layer cake' stratigraphy of the subsurface is often too simplistic and inadequate for developing effective remedial strategies. In contrast, the sequence stratigraphic approach (supported by facies analysis) provides a more realistic subsurface correlation based on the predictable distribution of sediments in different depositional environments. The three-dimensional geologic framework derived from sequence stratigraphy can be used to map the heterogeneity between coarse- and fine-grained units across multiple scales and beyond the existing site data set. Moreover, this framework can be integrated with site hydrologic and chemical data to identify sediments with high- and low-fluid

The original version of this chapter has been revised: The author's figures and text corrections have been updated. The correction to this chapter can be found at https://doi.org/10.1007/978-3-031-34447-3_19

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/978-3-031-34447-3_4.

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