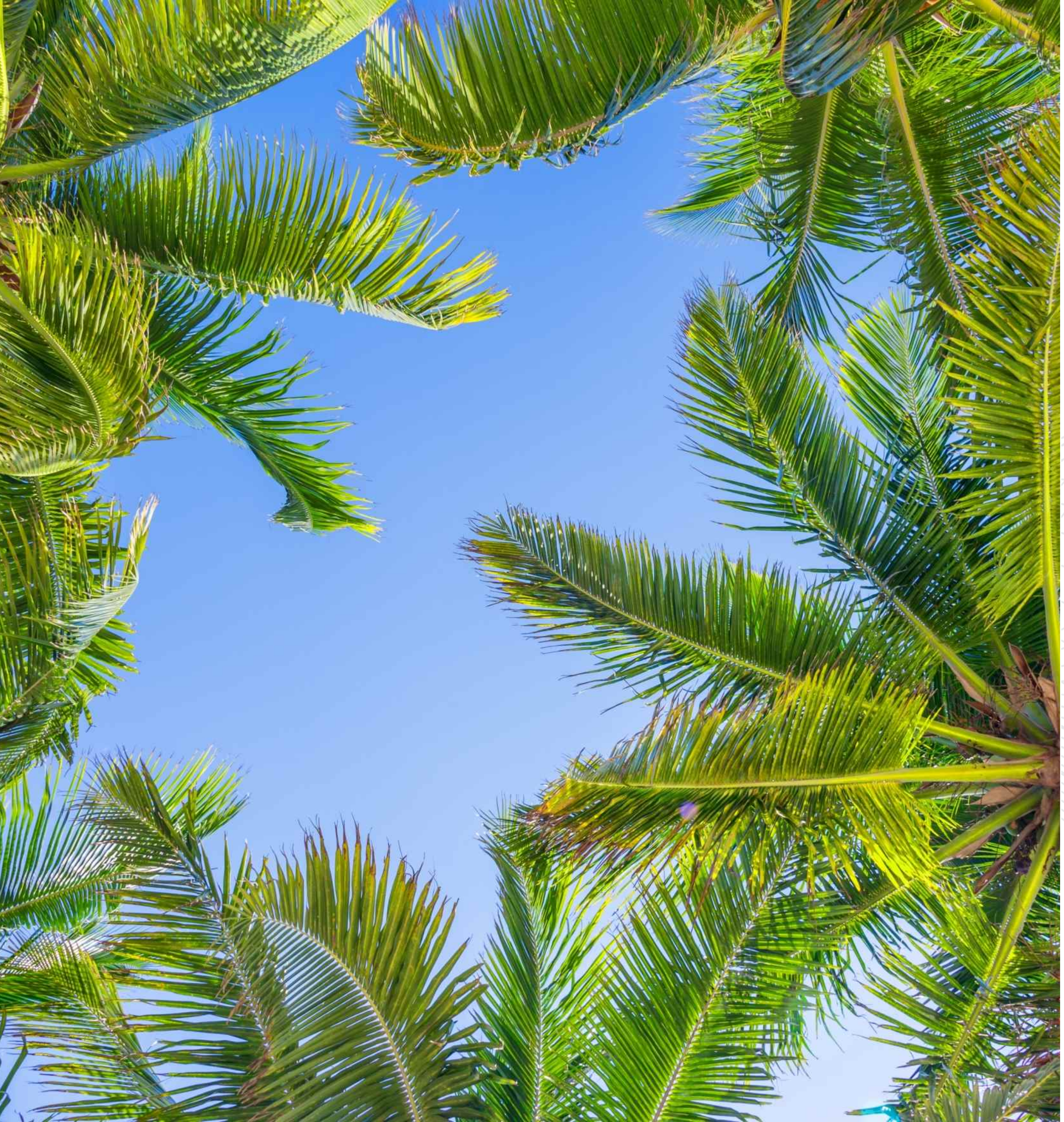


Using High Resolution Site Characterization and Chemical Fingerprinting and Forensics to Develop Three-Dimensional & Four-Dimensional Conceptual Site Models

Presented by: Larry Mastera

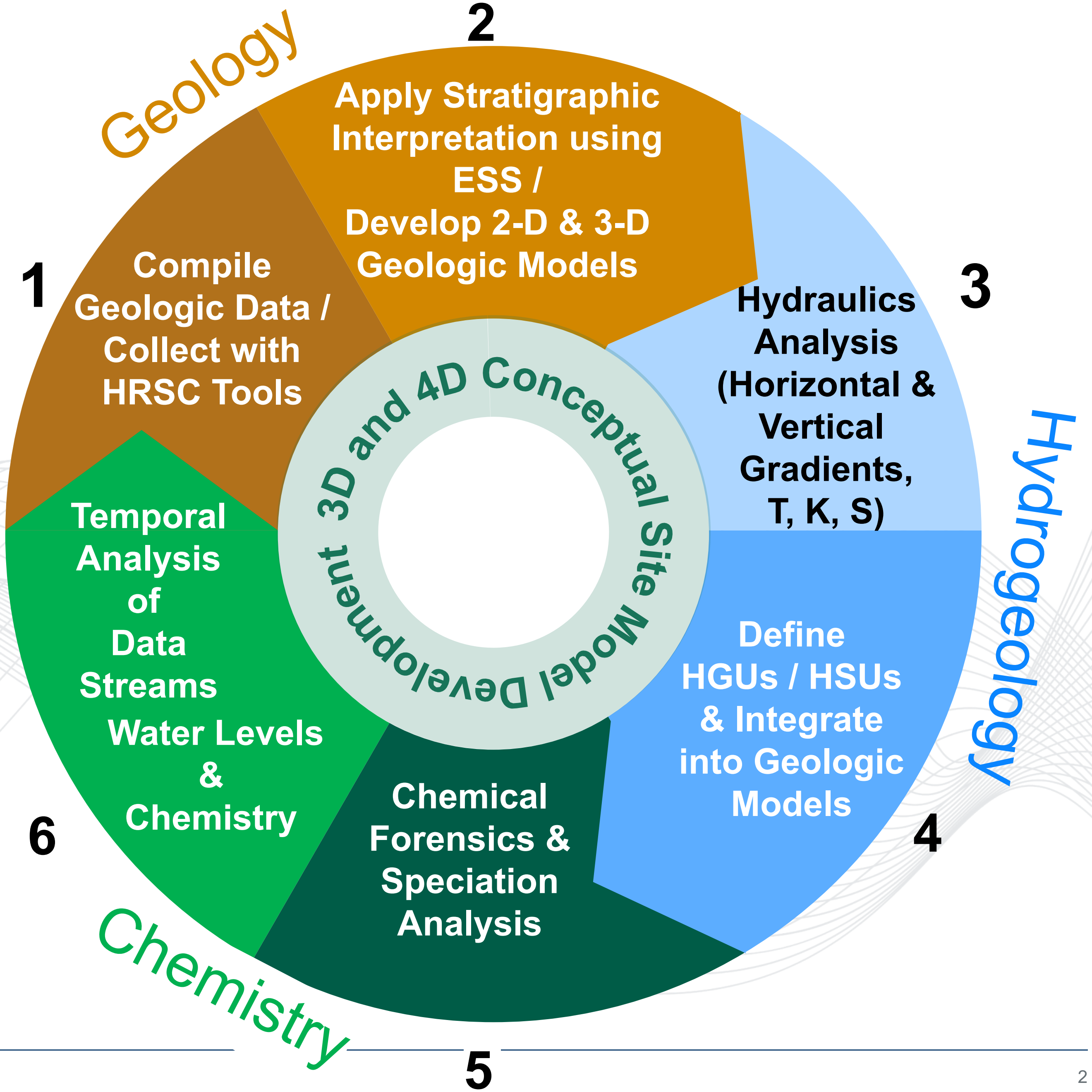
Battelle Bioremediation Symposium
May 10th, 2023
Austin, Texas

The business of sustainability

ERM

Talk Objectives

1. Develop rigorous CSMs with HRSC tools & Environmental Sequence Stratigraphy (ESS) to facilitate site closure strategy.
2. Show evidence of biodegradation with chemical speciation and forensics to NOT have to perform bioremediation.



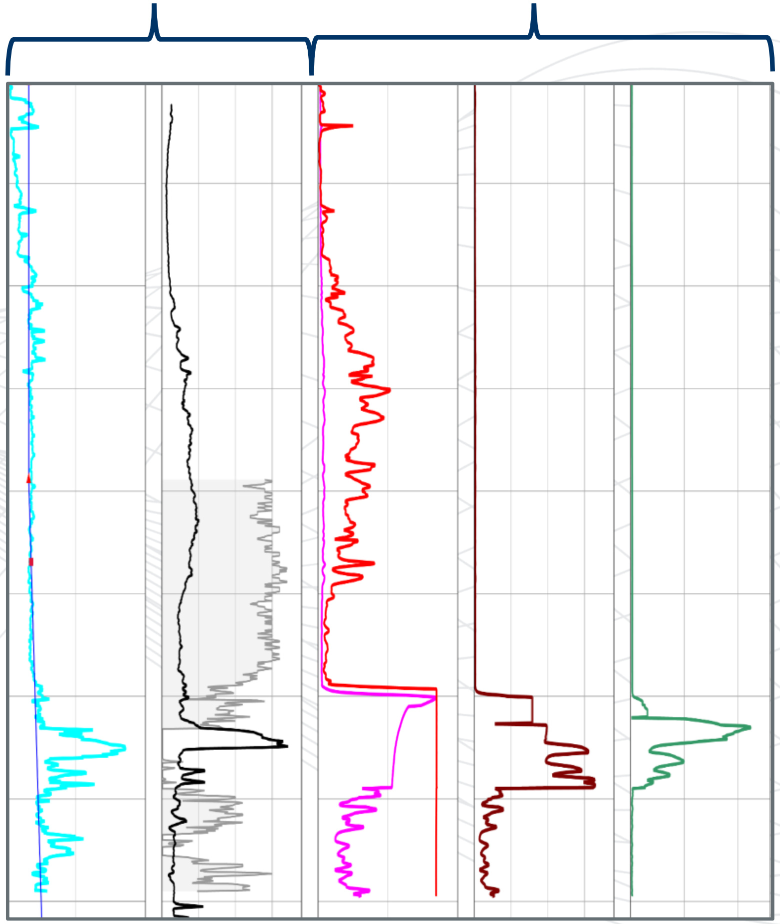
HRSC Tool Overview - MIHPT

The MIHPT includes the following detectors:

Hydrogeology
- Hydraulic Profiling Tool (HPT)
- Hydraulic Conductivity (K)
- Electrical Conductivity (EC)

Chemistry
- Electron Capture (ECD)
- Halogen Specific (XSD)
- Photoionization (PID)
- Flame Ionization (FID)

Hydrogeology Chemistry



Example MIHPT Combined Log

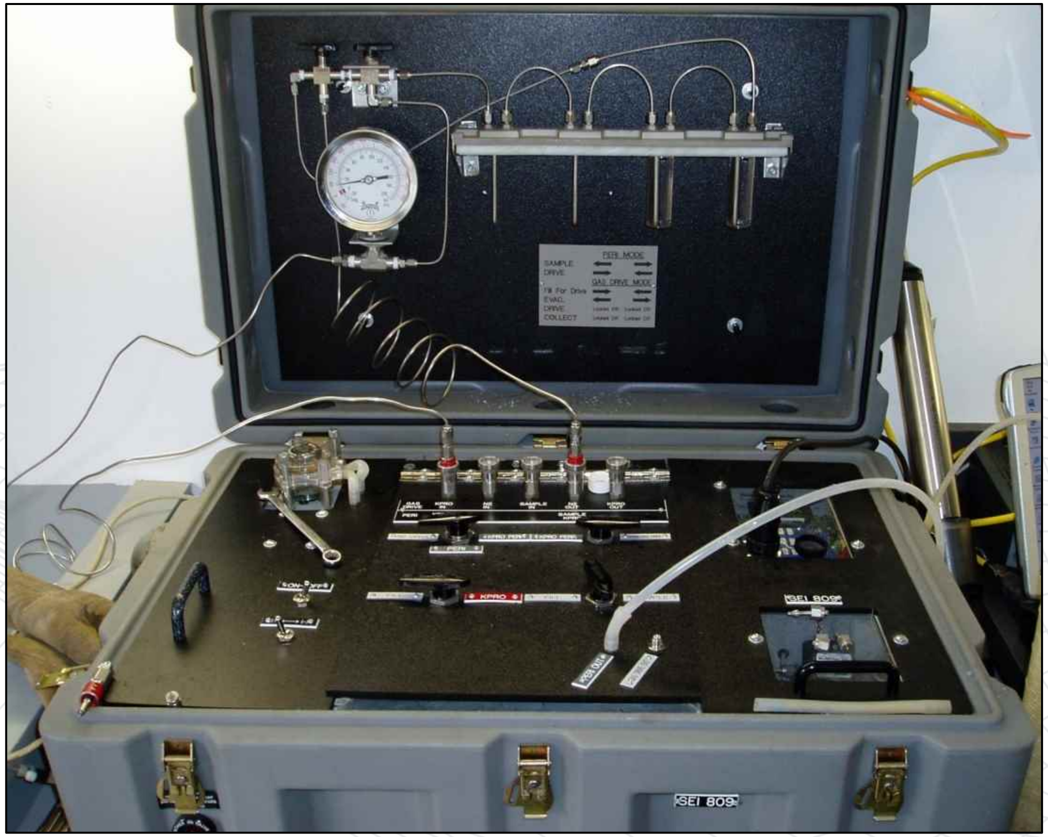
MIHPT probe

DPT Drill Rig

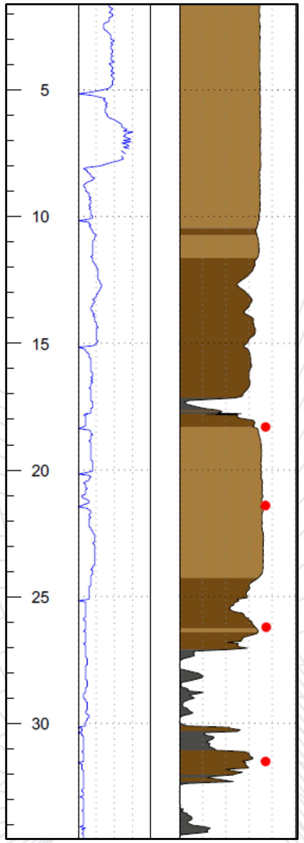
HRSC Tool Overview - Waterloo$^{APS™}$ Tool (Groundwater Profiling)

The Waterloo$^{APS™}$(APS) is a direct-push groundwater sampling tool that generates a continuous log of soil permeability and can collect multiple discrete-interval groundwater samples during a single push of the drill string.

APS Probe



APS Sampling Kit



IK Log & GW Sample Locations

ESS with MIHPT and Waterloo^{APS}™ Considerations

Depositional Environment:

- Contrasting grain sizes (i.e., silt and sand sequences) = 
- Saprolite & glacial till = 

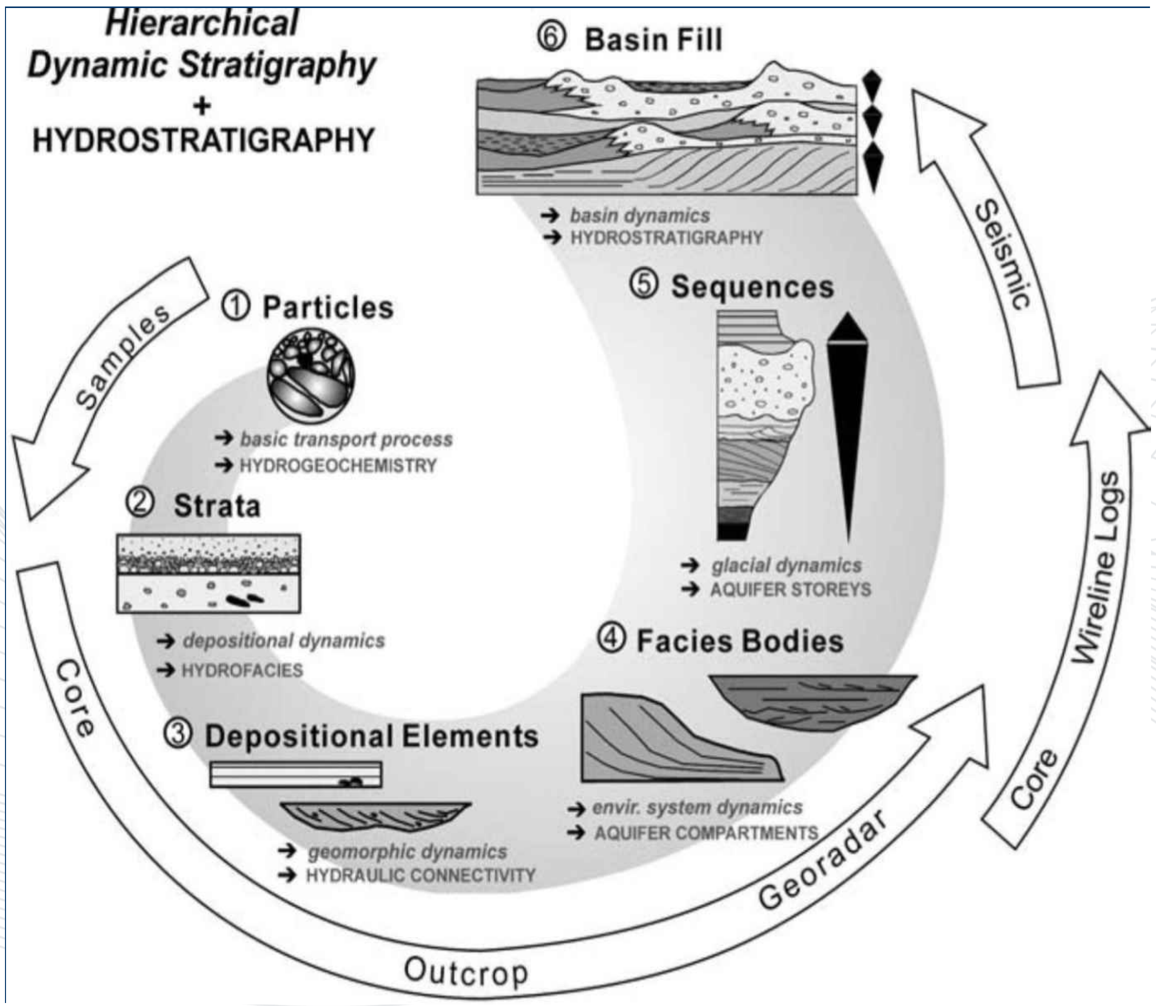
Instrument Sensitivity:

- HPT and Index of Hydraulic Conductivity (IK) is challenged in gravels
- Site specific calibration and verification

Scale of Investigation Interval:

- ~ ≤100 feet below ground surface (bgs.)
- Need for high Horizontal and vertical resolution

Sequence Stratigraphy Principles and Terms



Adapted from Remediation Hydraulics, Payne et al. 2008

Facies & Sub-facies:

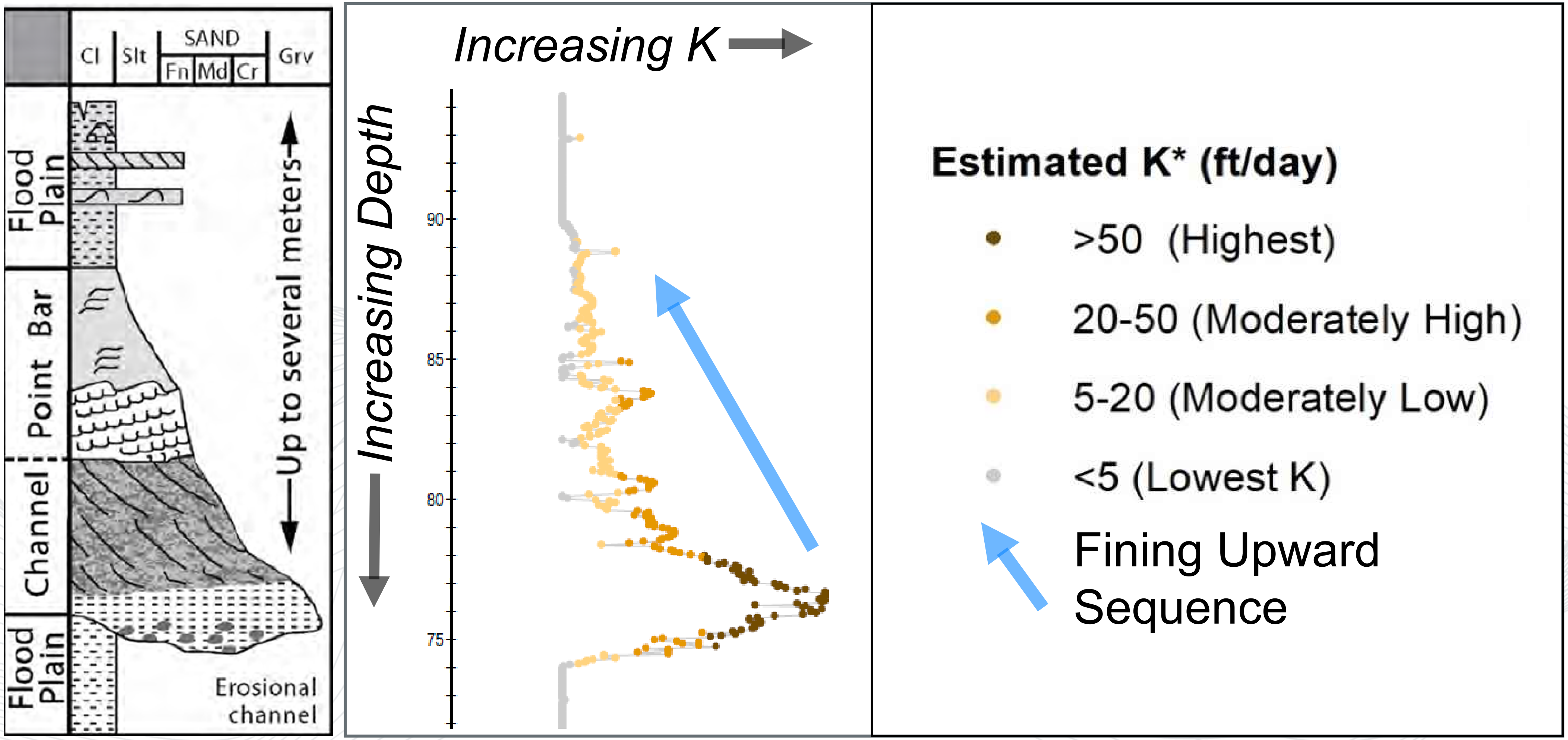
- A body of sediments with specified characteristics defined on the basis of composition, texture, sedimentary structures, and morphology.

Facies Associations, Assemblages, & Sequences:

- Groups of facies that occur together and are considered to be genetically or environmentally related.

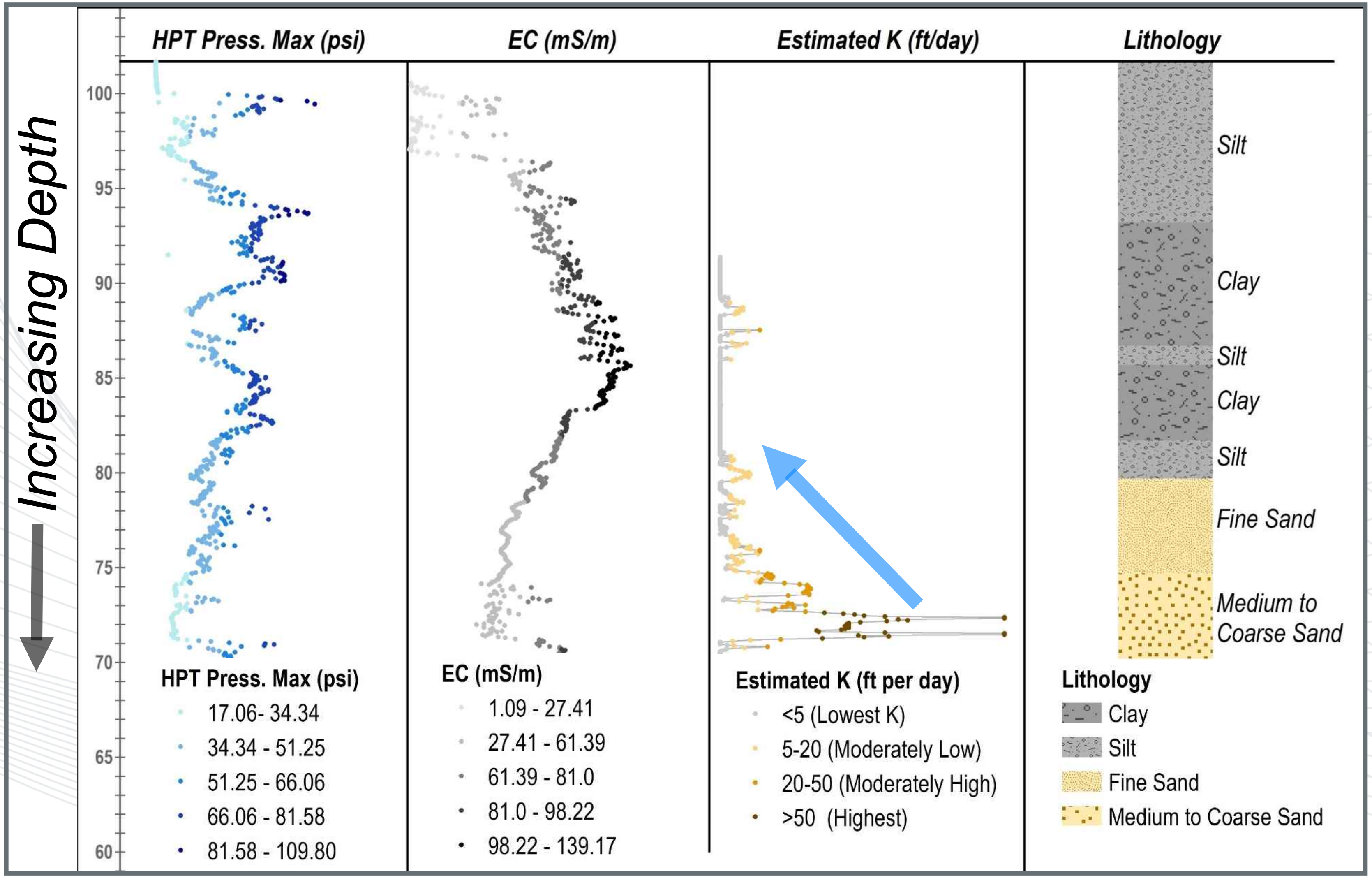
MIHPT and Waterloo$^{APS™}$ HRSC tools can collect data between hierarchy 2 through 5.

ESS Using HRSC – Depositional Environments & HPT Logs



Adapted from Shultz et al. 2017

ESS Using HRSC – HRSC and Traditional Log Integration



Traditional geologic datasets can be educated with HRSC data sets.

Knowledge of facies architecture from HRSC data can be used to inform ESS at sites with only traditional data sets.

Fining Upward Sequence

Recommended Soil Logging Practices

Groundwater Monitoring&Remediation

Meyer et al. 2022

Graphical Shading Logs: An Improved Approach for Collecting High Resolution Sedimentological Data at Contaminated Sites

by Jessica Meyer, Jonathan Munn, Emmanuelle Arnaud, Jonathan Kennel and Beth Parker

Abstract

Predicting contaminant transport in groundwater requires an accurate representation of the subsurface geology controlling the spatial distribution of hydrogeologic parameters. Developing accurate geological models for sedimentary systems relies on quality sedimentological data collected from cores. Standard logging forms used to collect data from cores create a persistent data gap in hydrogeology because they hinder efficient collection of high-quality sedimentological data. These logging forms require time-consuming text descriptions of sedimentological characteristics and often result in inconsistent, poorly resolved data insufficient to support realistic geological models. We describe a graphical approach to core logging, the graphical shading log, that facilitates rapid, accurate capture of sedimentological data and a complementary database to store the raw data and interpretations. The visual format of the graphical shading log provides a roadmap of the parameters to log and their possible values, helping to ensure accurate and consistent data collection by loggers with a range of experience. Examples from sites with contaminated groundwater in glaciogenic sediments and siliciclastic and carbonate bedrock show how data from the graphical shading logs improved geological interpretations, supported the design of high-resolution multilevel systems needed to collect minimally blended hydrogeologic data, and helped to more accurately delineate hydrogeologic units. The format of the graphical shading log and complementary database are designed to be customizable and transferable between hydrogeologic settings providing a new tool to advance geological data collection and management. Improved sedimentological data and insight are critical inputs for process-based conceptual site models needed to effectively manage contaminant plumes in the subsurface.

Introduction

Over four decades ago attention was drawn to diffusion as a key process controlling contaminant transport in heterogenous unconsolidated sediments (Gillham and Cherry 1982) and fractured rock (Foster 1975). However, the importance of diffusion as a dominant contaminant transport process was not fully appreciated until the impact of mass storage and re-release of chlorinated solvents from lower permeability zones on plume persistence and ineffective remediation was demonstrated and understood widely (Mutch Jr. et al. 1993; Parker et al. 1994; Parker and McWhorter 1994). Mackay and Cherry (1989) used simplified examples and illustrations to argue diffusion of contaminants from low permeability materials into advective pathways was responsible for the failure of many pump and treat systems to reach remediation objectives and Mutch Jr. et al. (1993) demonstrated the impacts of diffusion from the rock matrix back to the fractures on plume persistence in fractured rock using a numerical model. Early field evidence for diffusion controlled release of contaminants stored in low permeability zones in sandy aquifers was provided by detailed sampling of cores for the contaminants of concern combined with analytical and numerical modeling, and in some cases, regular sampling of conventional wells and multilevel systems (e.g., Ball et al. 1997; Liu and Ball 2002; Parker et al. 2004; Chapman and Parker 2005; Parker et al. 2008). Similarly, field evidence for diffusion of contaminants from the low permeability rock matrix to the fractures in sedimentary rock was provided by contaminant distributions derived from cores combined with synoptic sampling of a multilevel system (e.g., Sterling et al. 2005). Later, a visual sand tank experiment (Doner 2008) complemented by numerical modeling (Chapman et al. 2012) helped to make the impacts of diffusion driven release of contaminants stored in low permeability zones more intuitive and widely appreciated. These studies, and others, combined with broadly disseminated publications identifying the limitations of remediation due to diffusion (e.g., US EPA 2003; National Research Council 2004; Sale et al. 2008; Stroo et al. 2012; National Research

Article impact statement: Graphical shading logs facilitate efficient, accurate, and consistent core sedimentological logging to support contaminated site investigations.

doi: 10.1111/gwmr.12521

NGWA.org
Groundwater Monitoring & Remediation 1

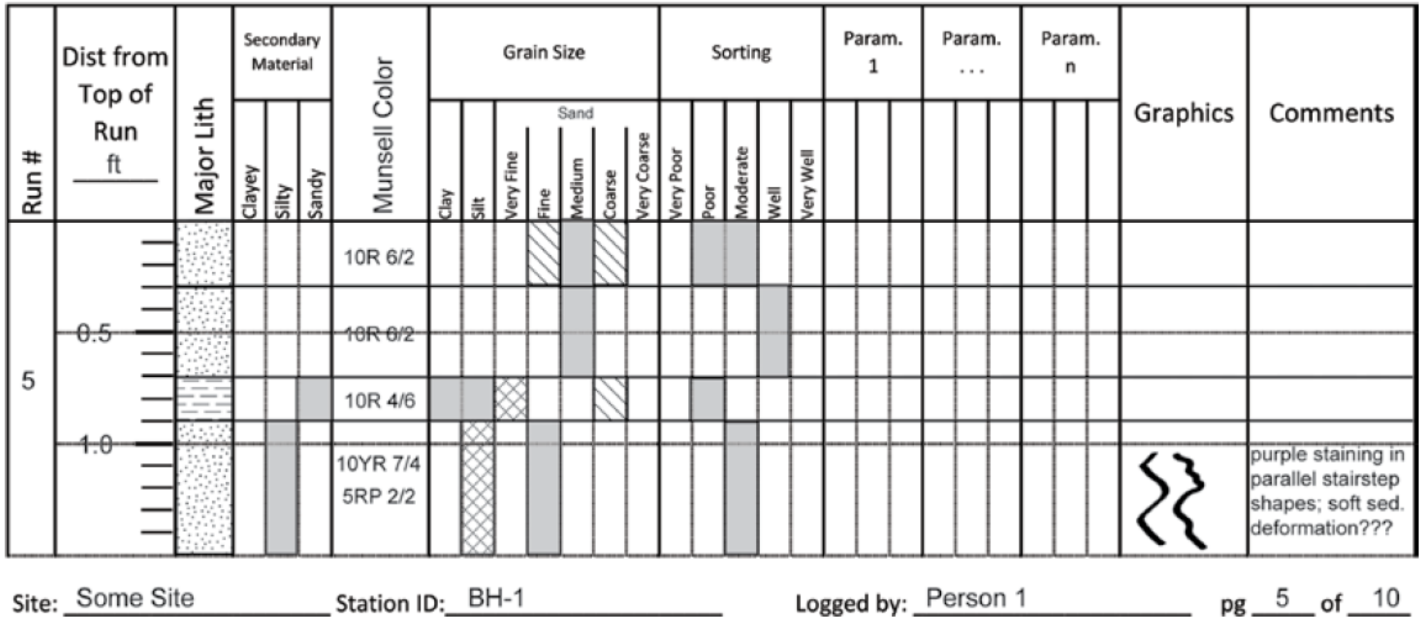
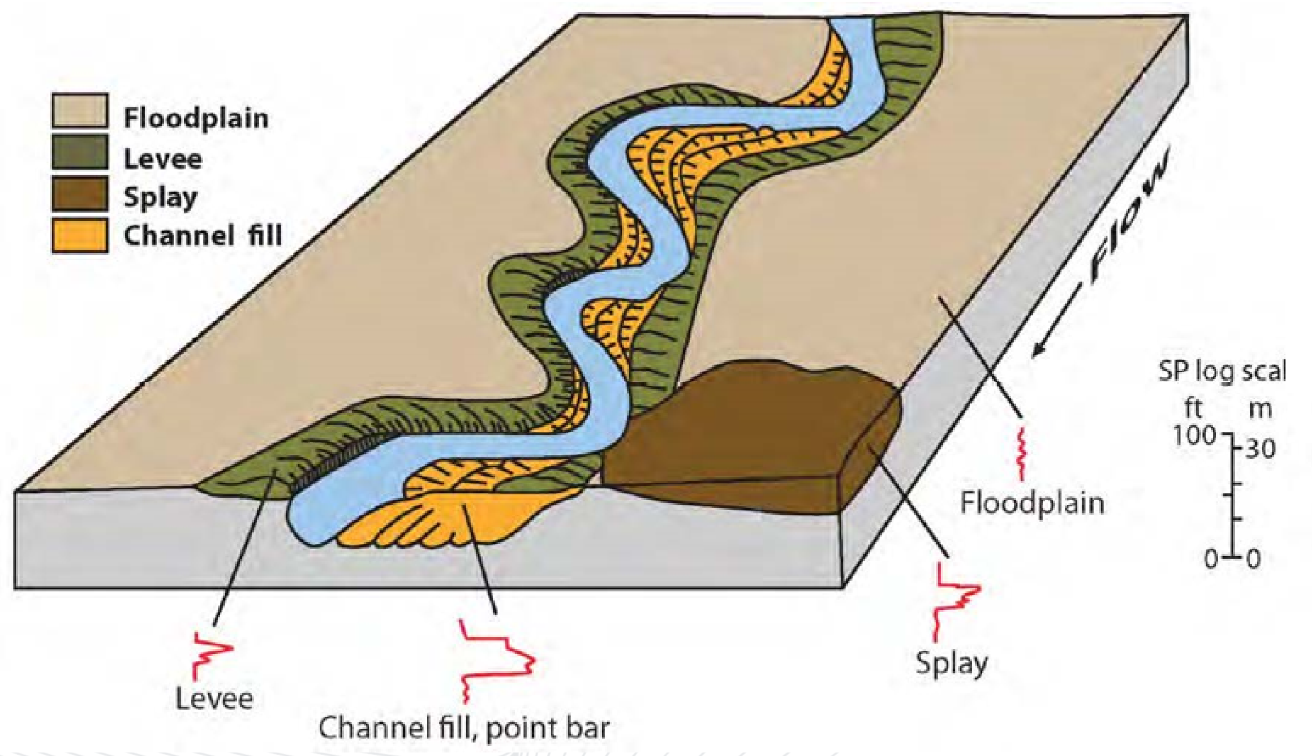


Figure 1. Generic elements of a graphical shading log designed for siliciclastic rock. Lithology, color, grain size, sorting (a.k.a. "graded" in USCS scheme), contact relationships, and bedding thickness are relevant parameters for most sedimentary environments. Additional parameters included on the log depend on the specific geological setting but commonly include particle rounding, gravel/clast descriptors, indicators of diagenesis, and/or fossil content.

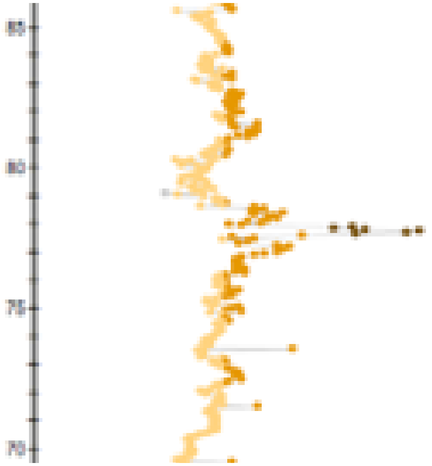
A paradigm shift is coming….

ESS Using HRSC - Relative Grain Size Profiles from HPT Logs to Identify Facies Structures

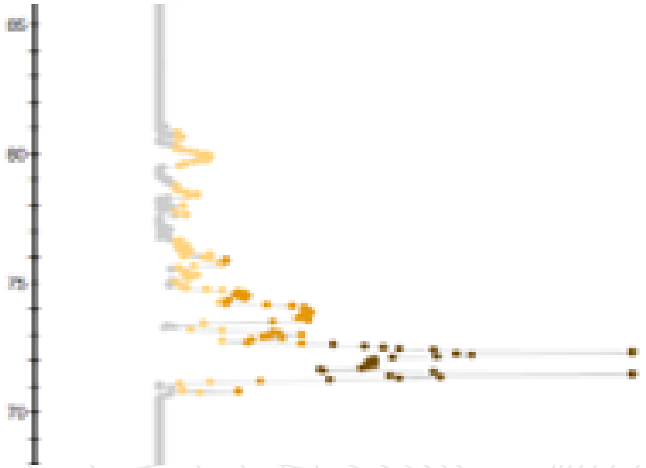


Adapted from Shultz et al. 2017

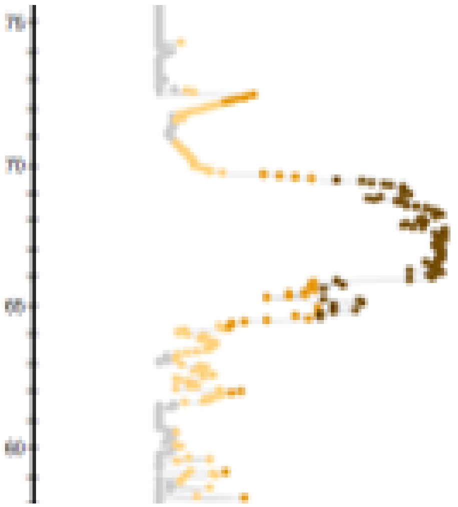
Levee



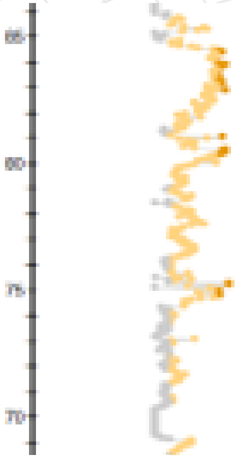
Channel



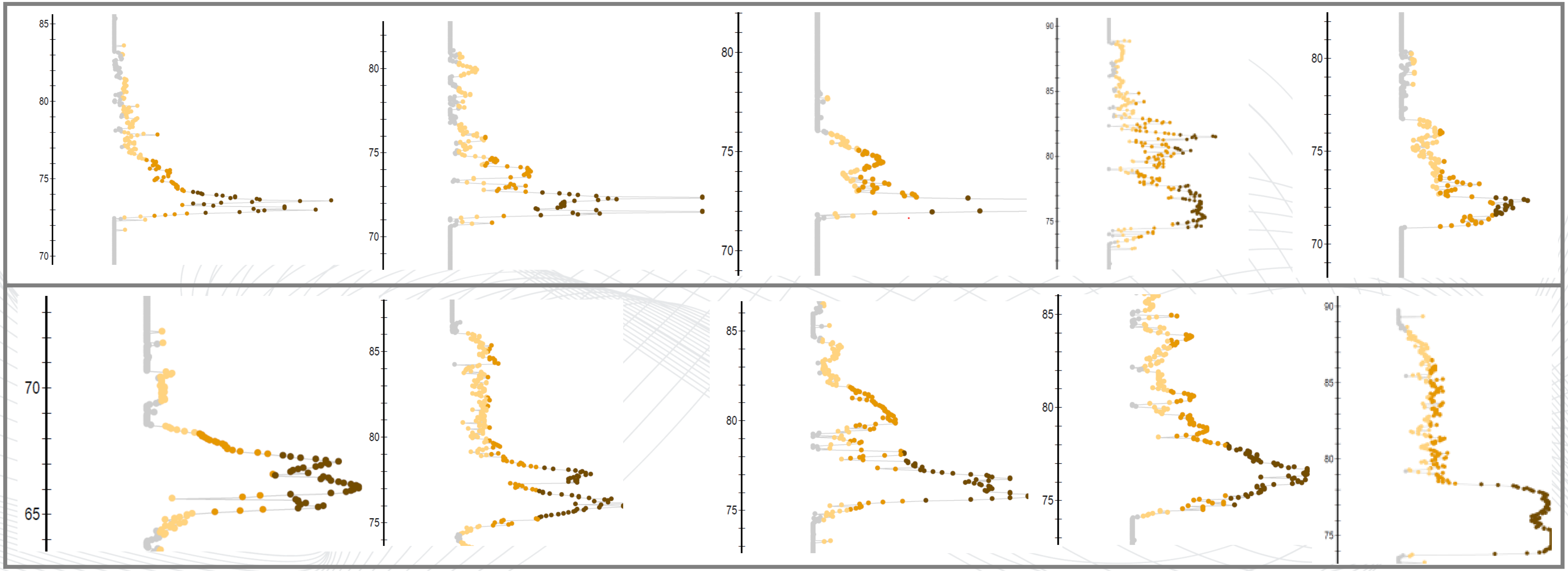
Channel or Splay



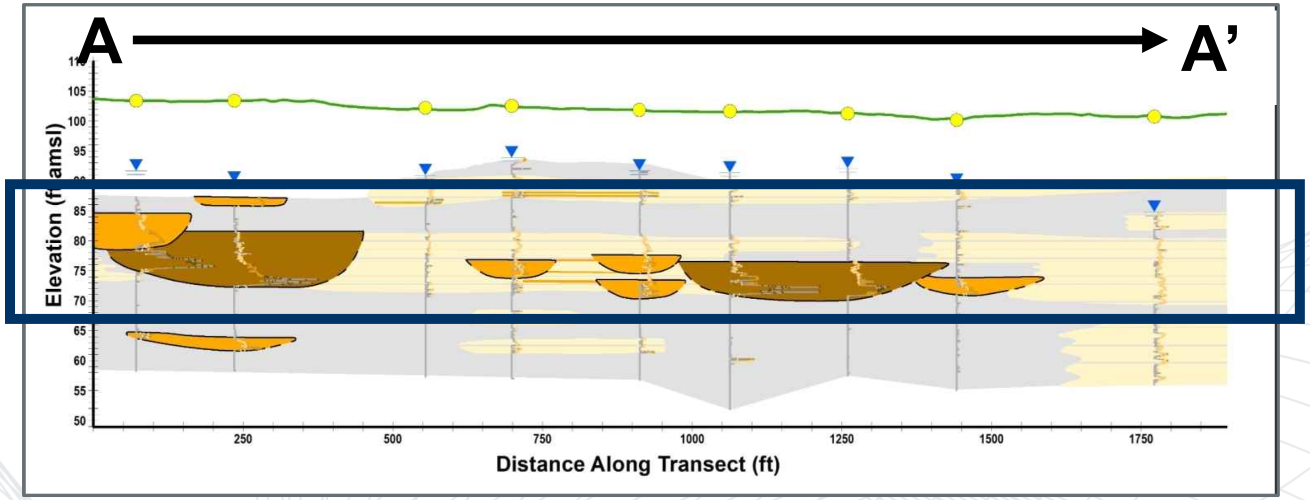
Channel Margin

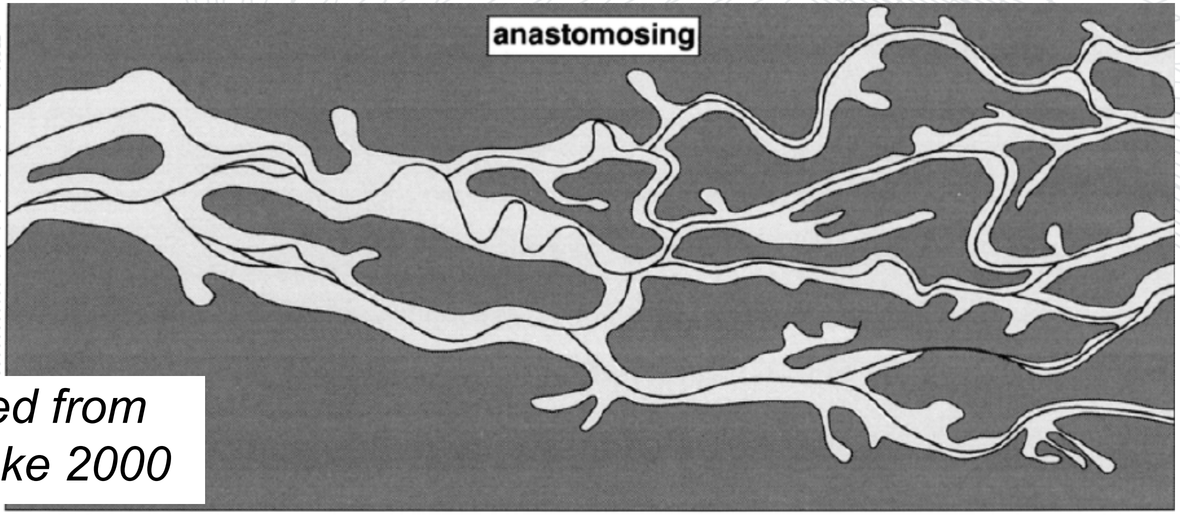


ESS Using HRSC - Channel Signatures from HPT Logs



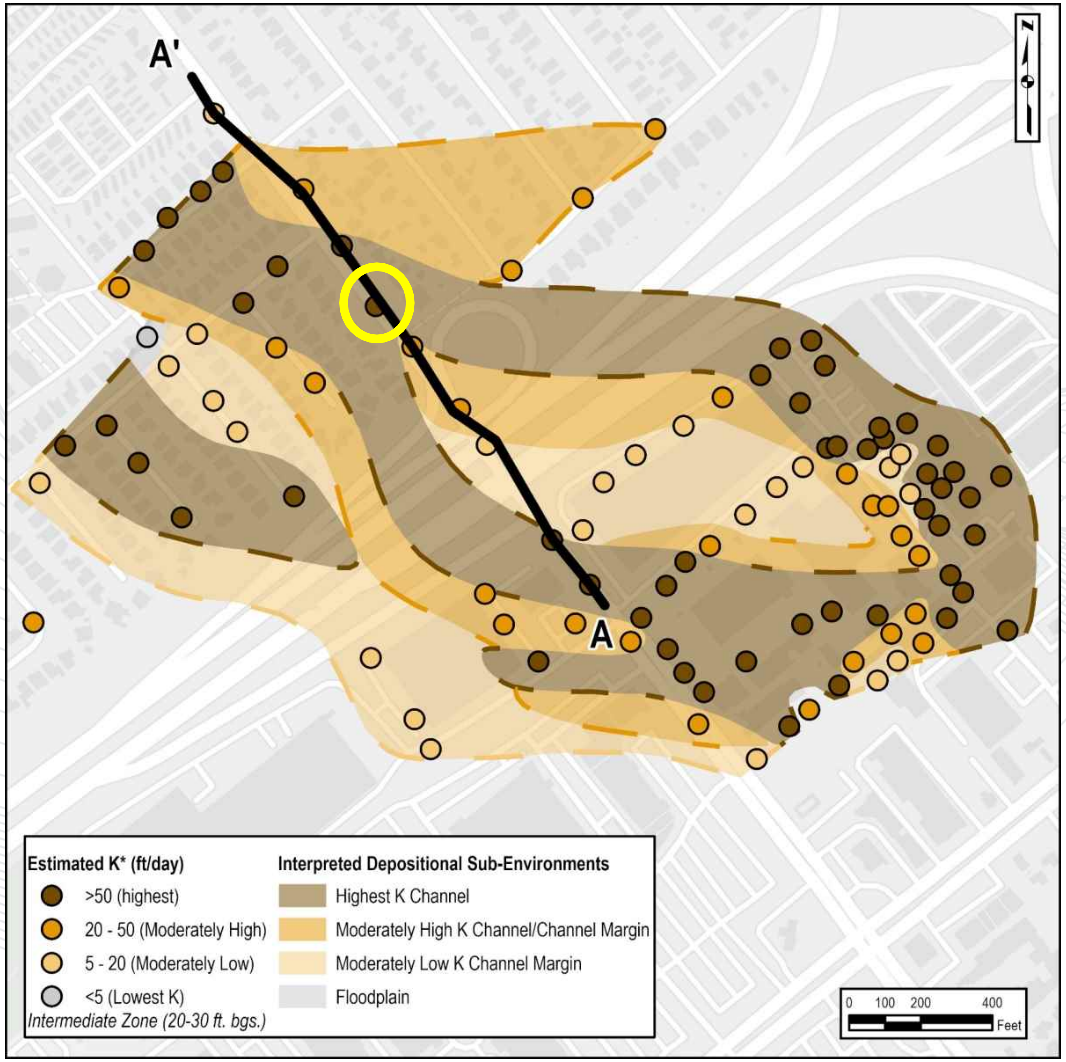
ESS Using HRSC – Quasi 3-D Geologic Model

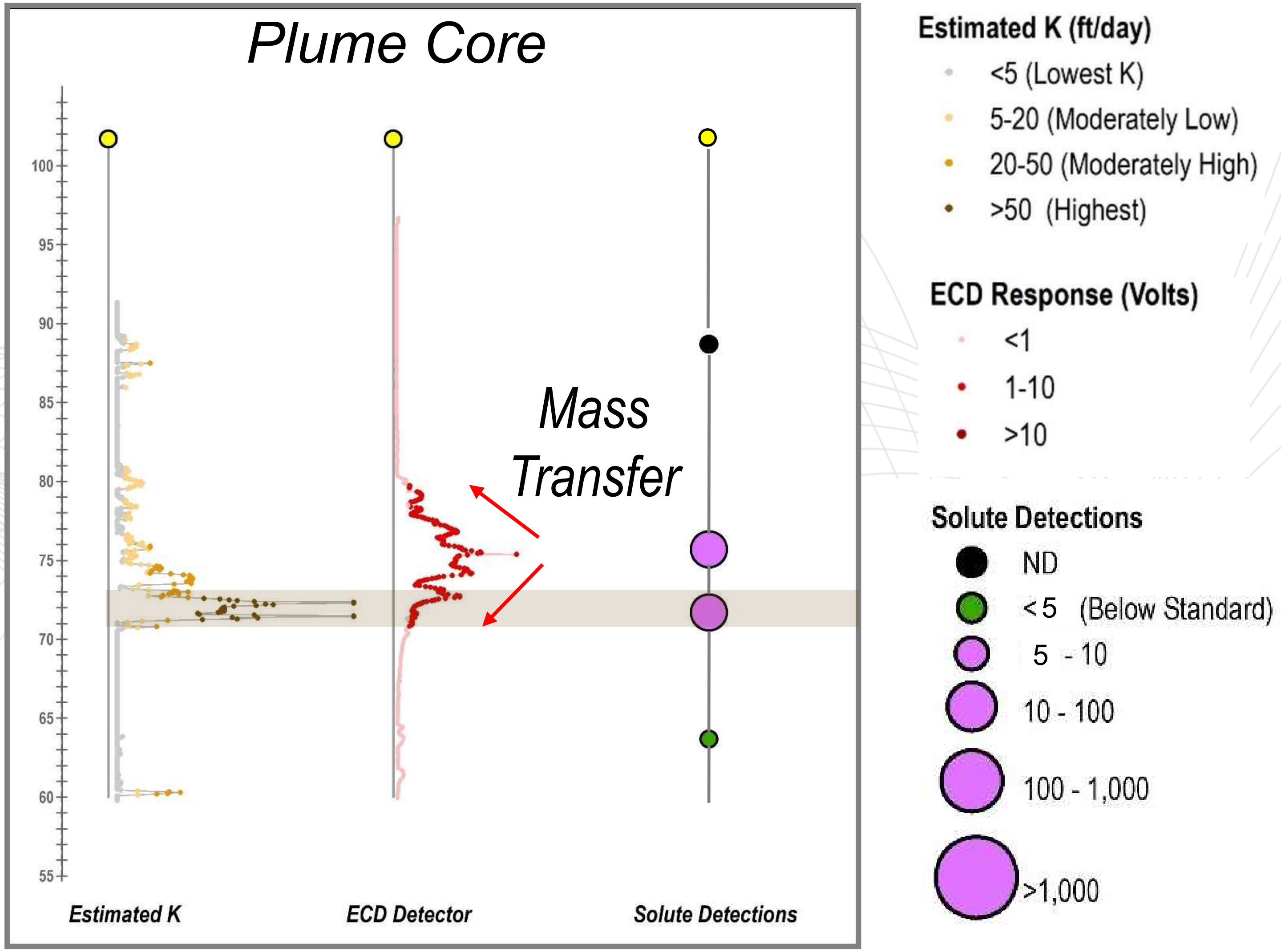




Adapted from Makaske 2000

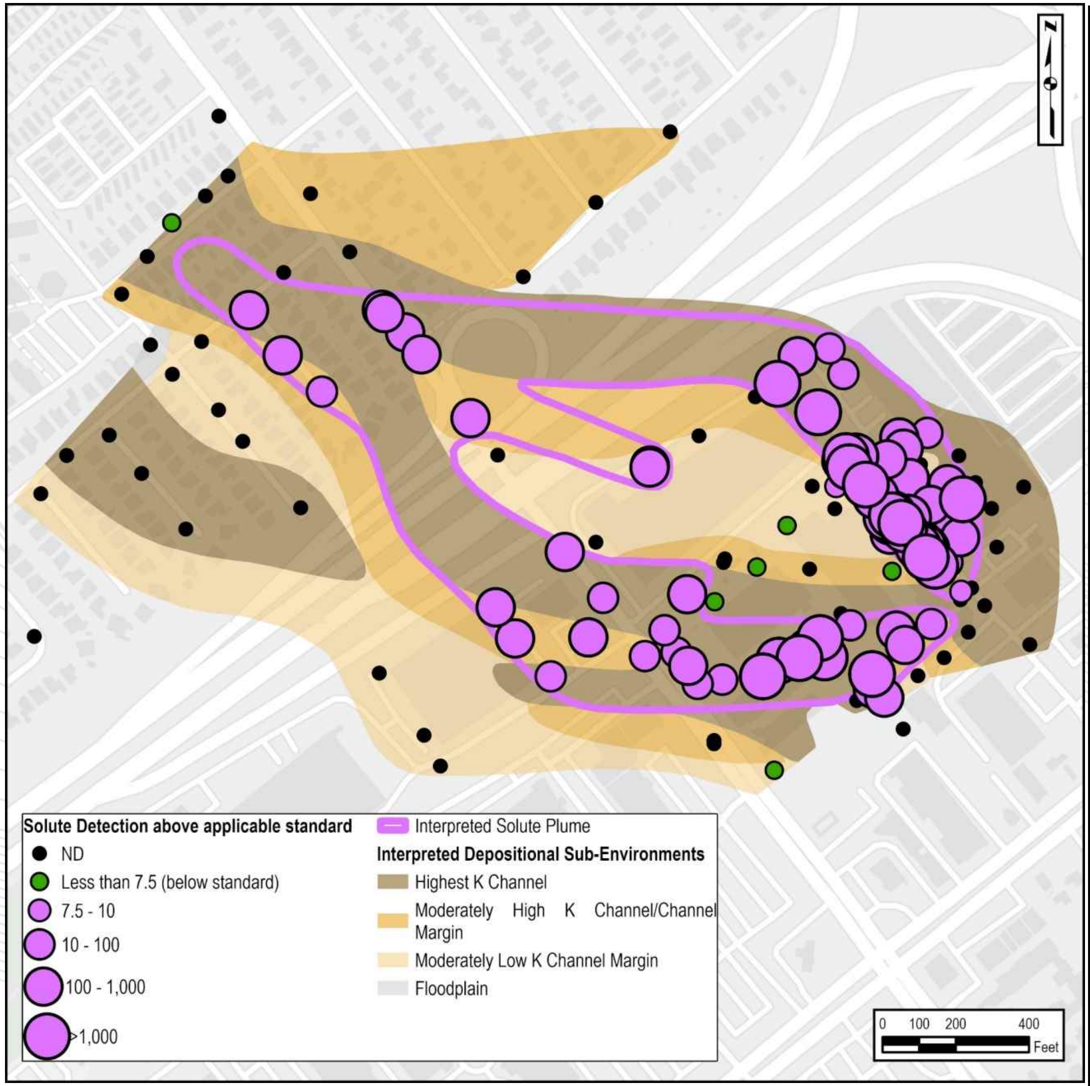
ESS Using HRSC - MIP & CVOC Solute Mapping



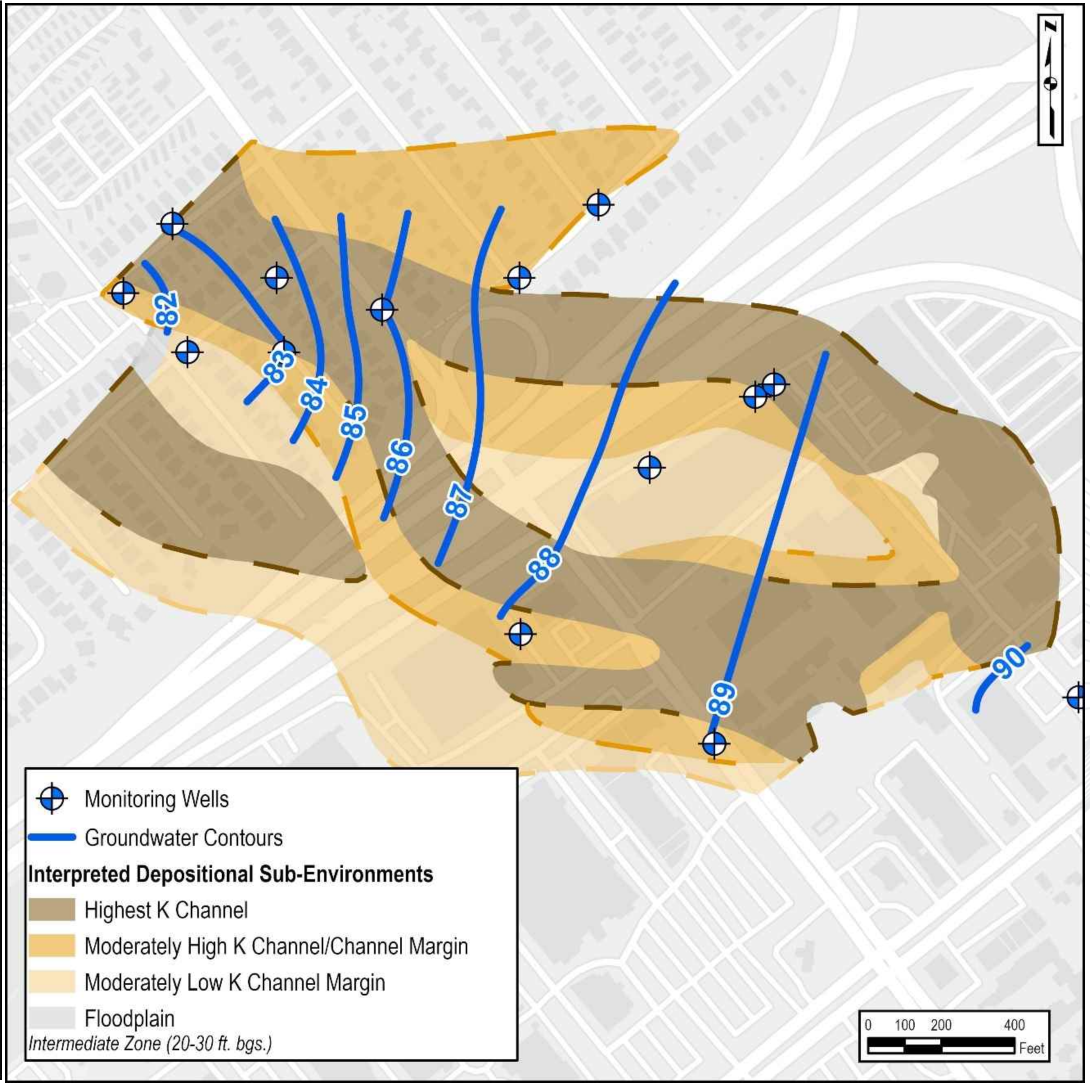


ESS Using HRSC: Chemistry and Water level Integration

Solute Distribution

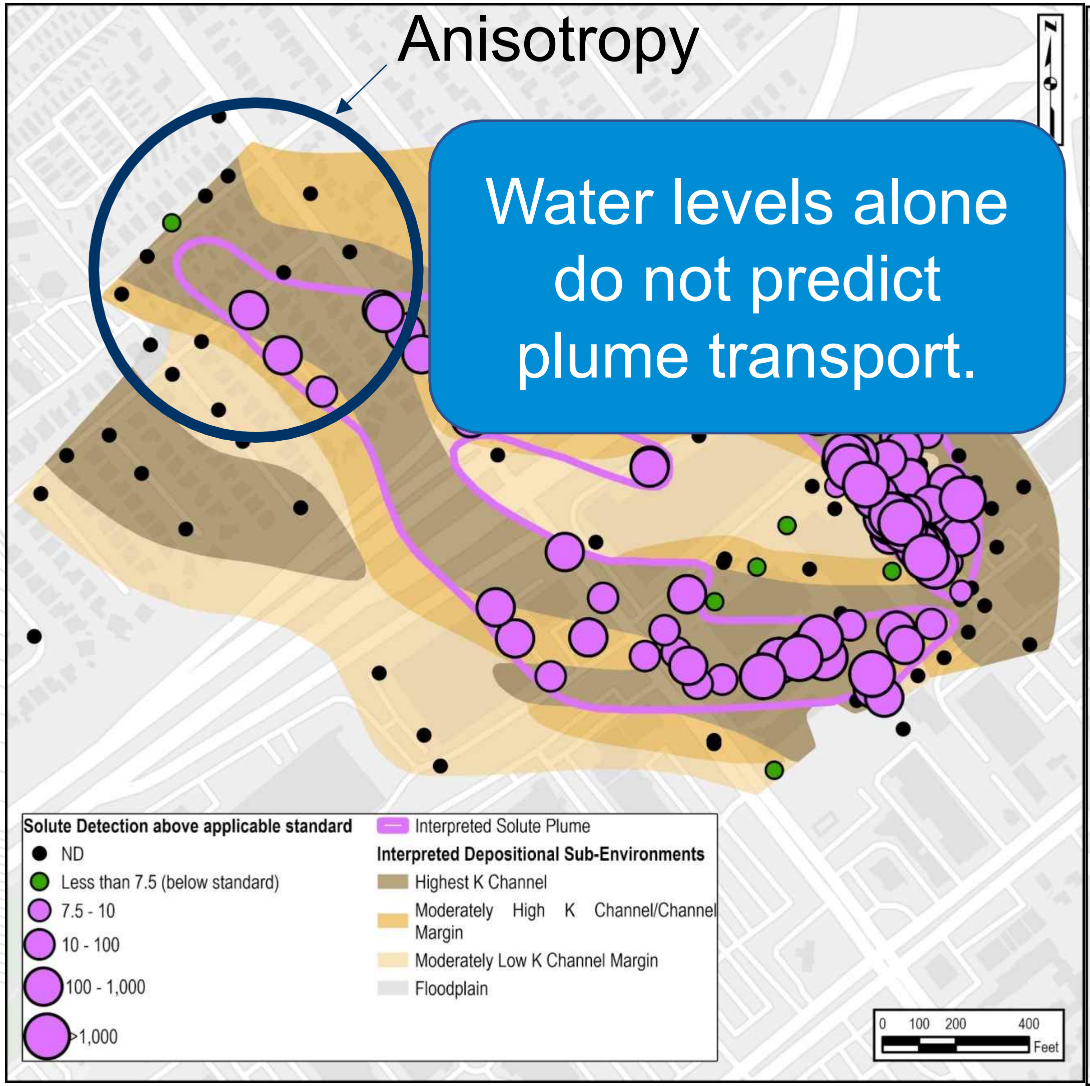


Potentiometric Surface

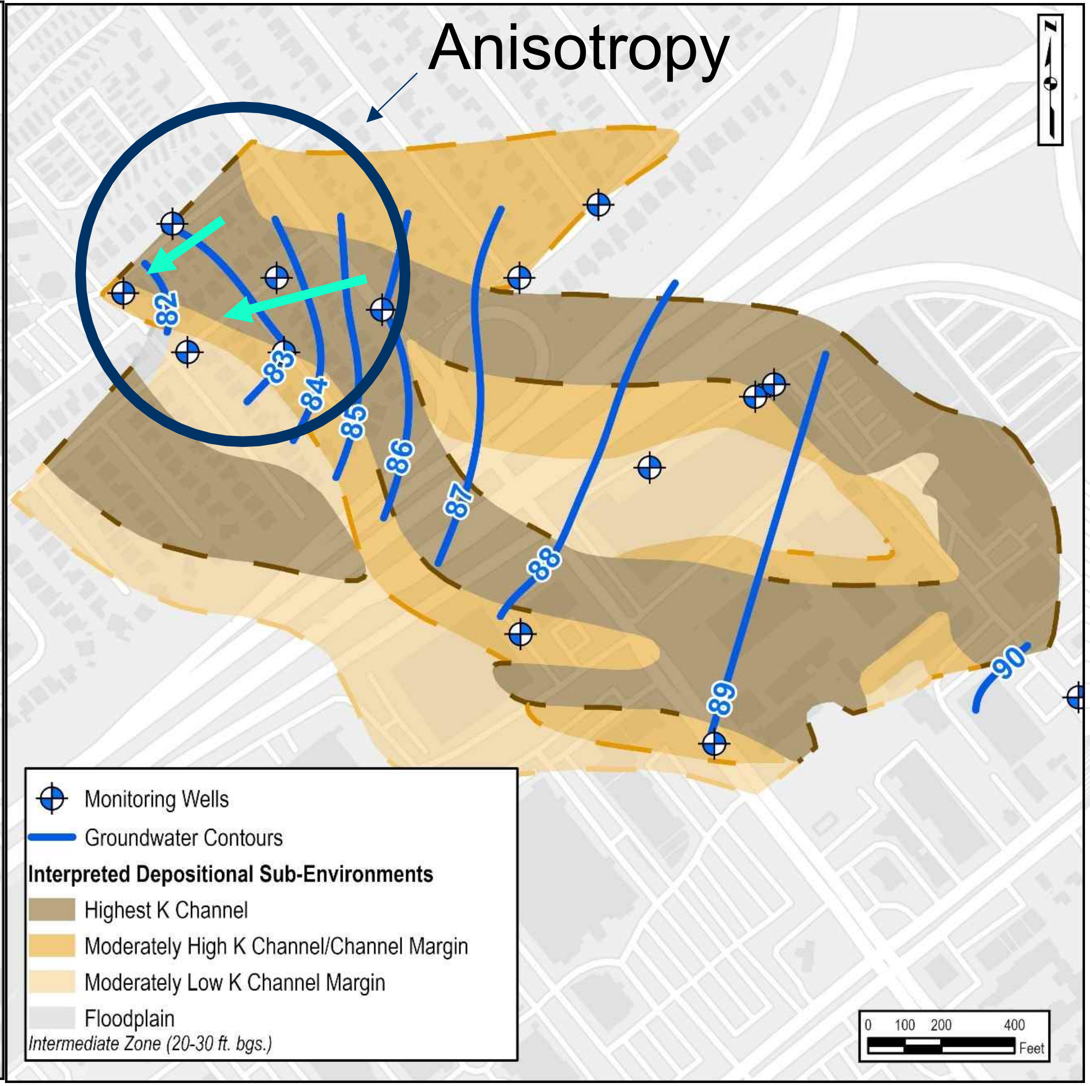


ESS Using HRSC: Chemistry and Water level Integration

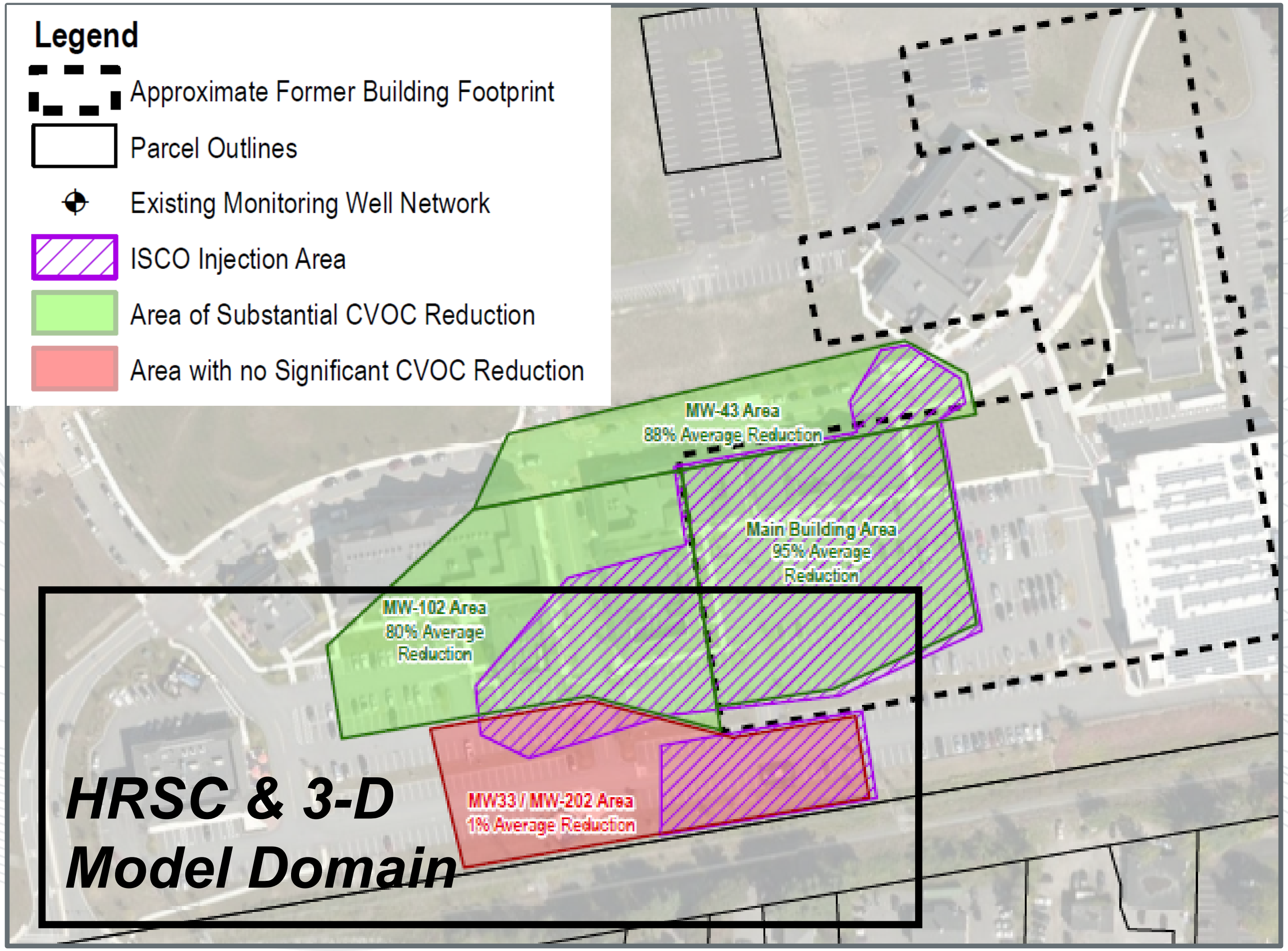
Solute Distribution



Potentiometric Surface



Site 1: Background



Site Location:

- Eastern Massachusetts

Depositional Environment:

- Glacio-fluvial (proglacial lake bottom deposits)

Multiple Sources of CVOCs (i.e., TCE) and resultant plumes

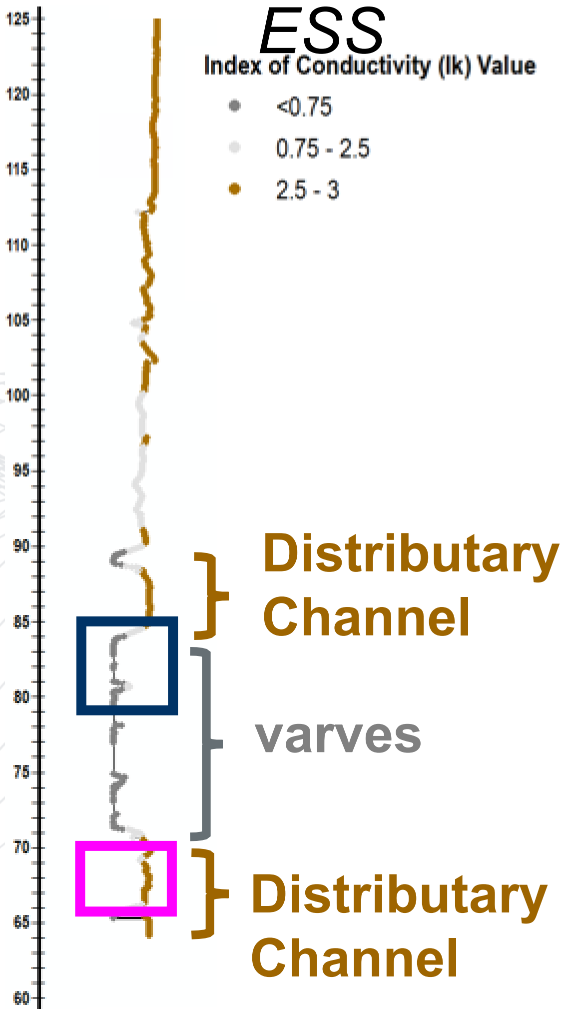
ISCO Treatment:

- Why is the southern boundary source area rebounding post ISCO?
- Completed over 100 HRSC borings within focus area

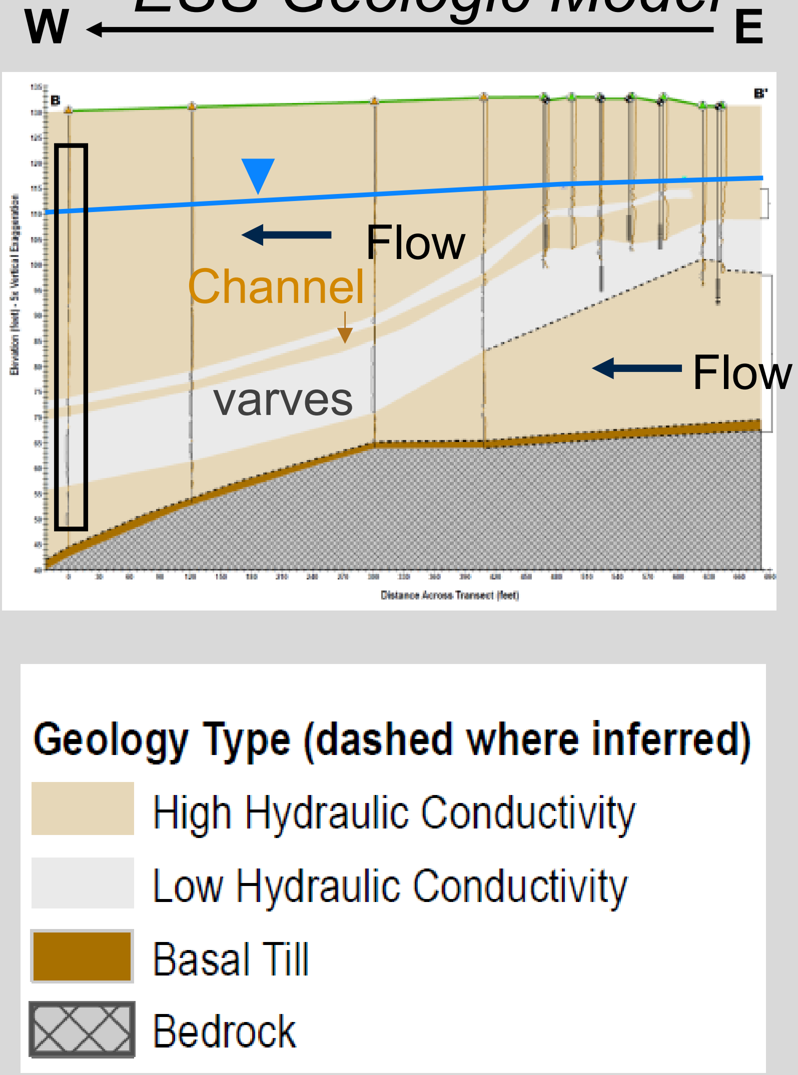
Site 1: Waterloo$^{APS™}$ IK Logs Educated with Detailed Core Logs

Detailed Core

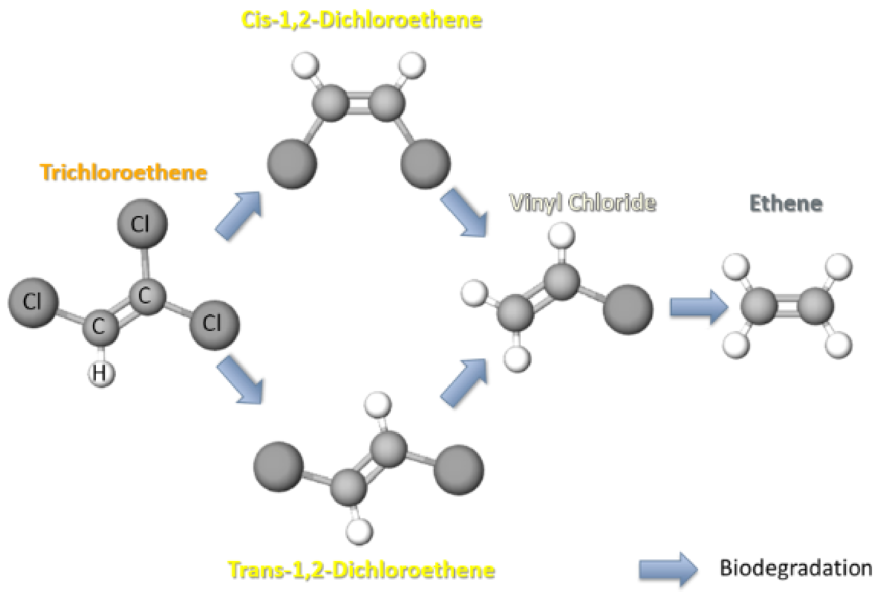
APS-01 *HRSC Log & ESS*



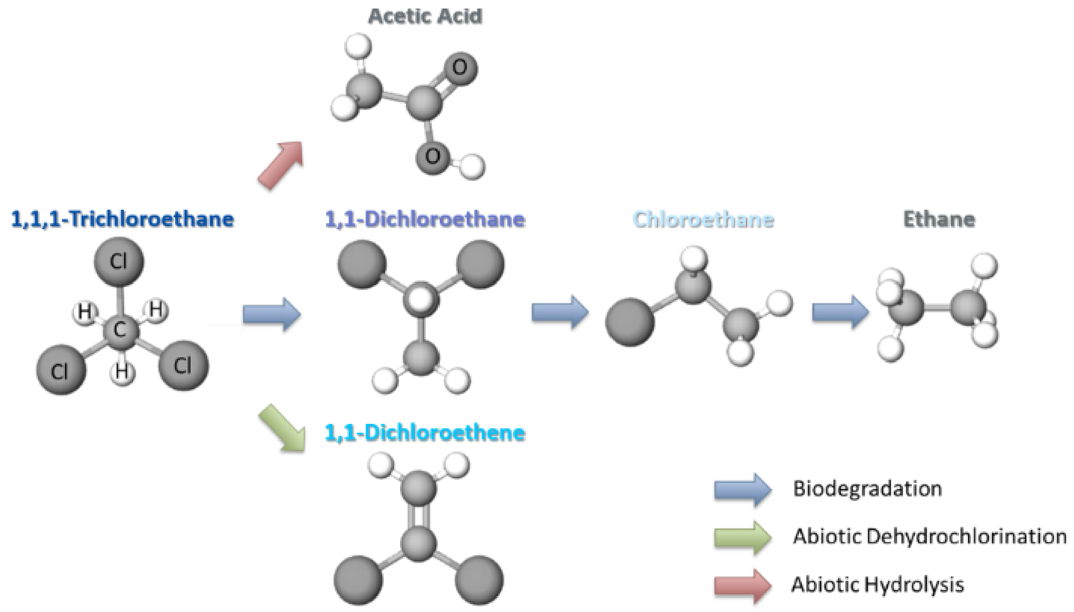
ESS Geologic Model

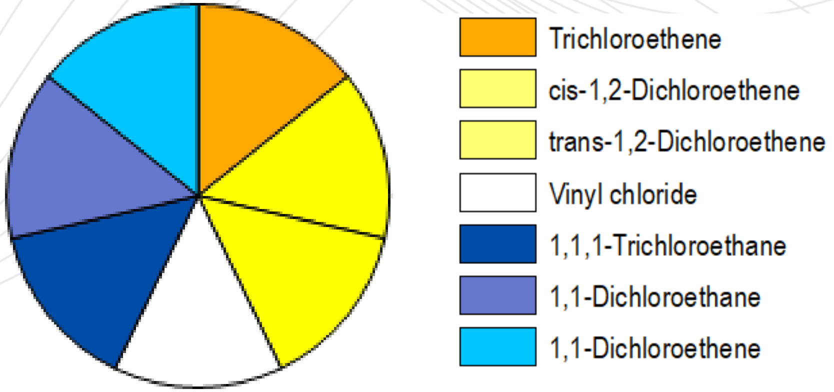


Site 1: Chemical Fingerprinting Analysis – Approach



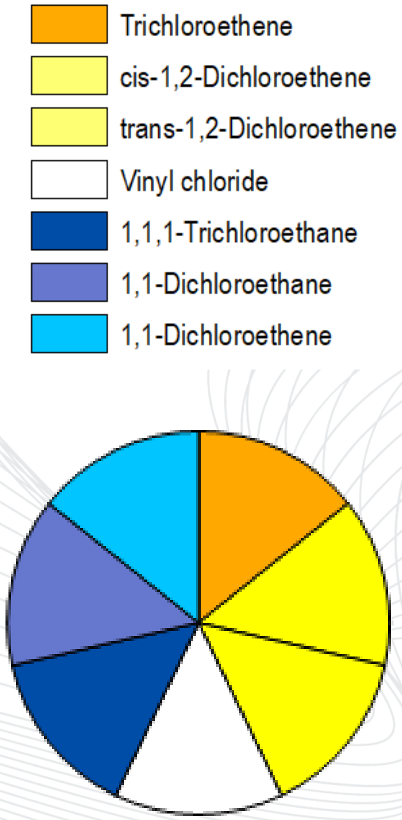
Lawrence, 2006

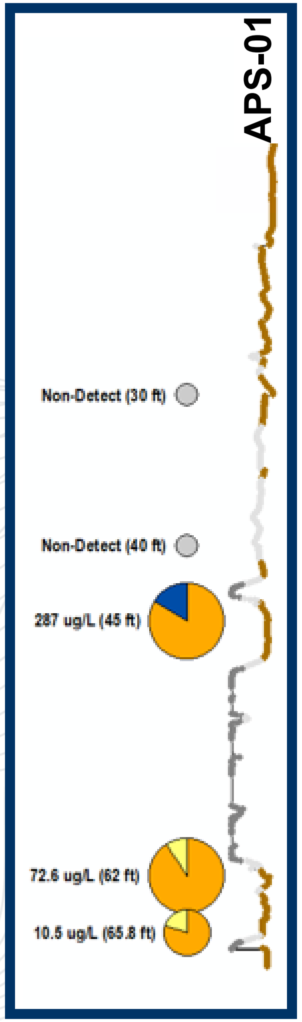


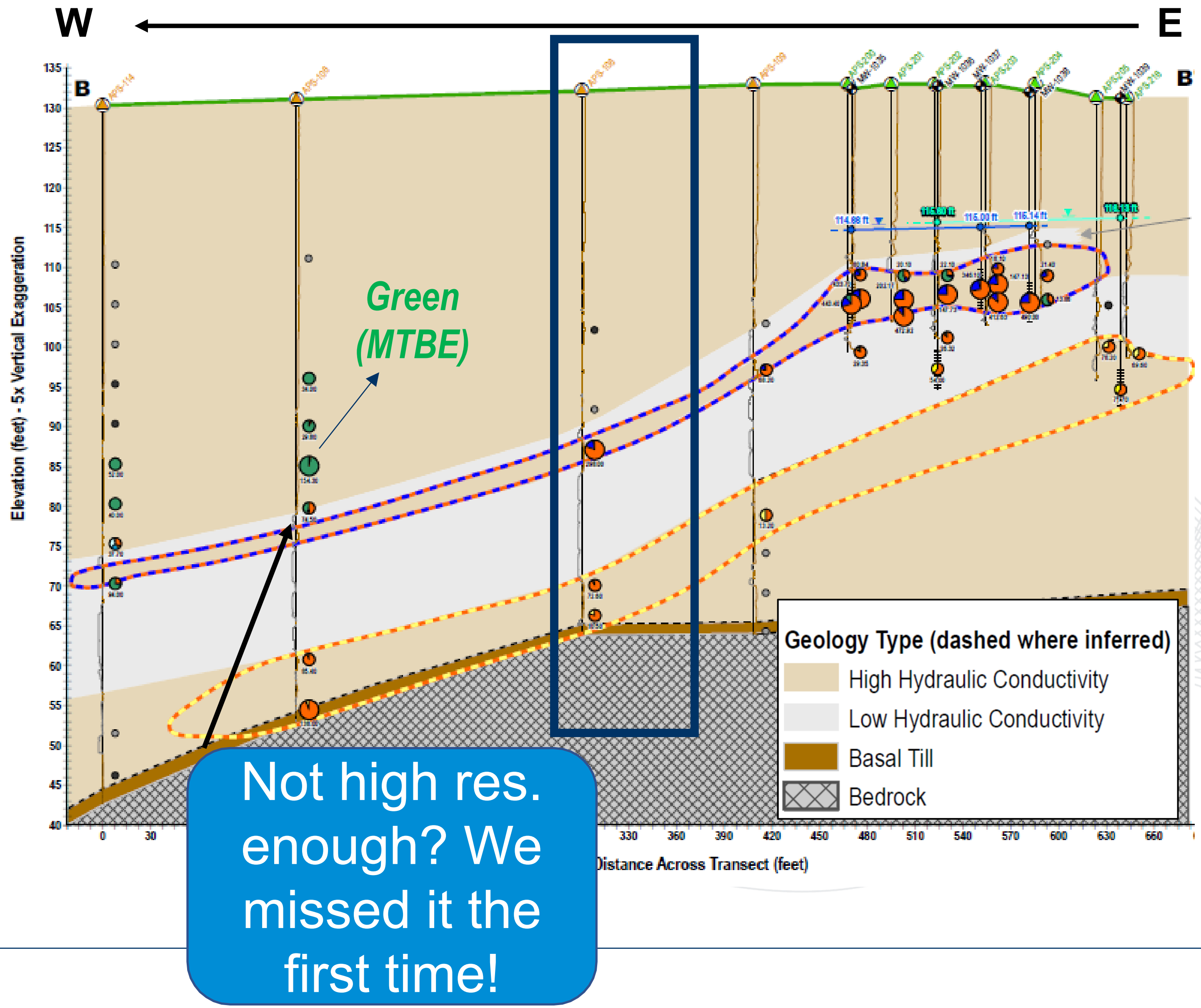


For the stratigraphers pretending to be chemists!

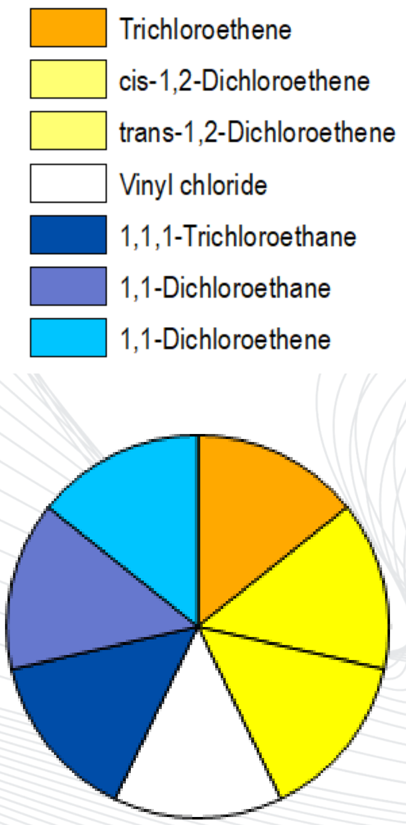
Site 1: ESS & Chemical Fingerprinting Analysis Integration in 2-D

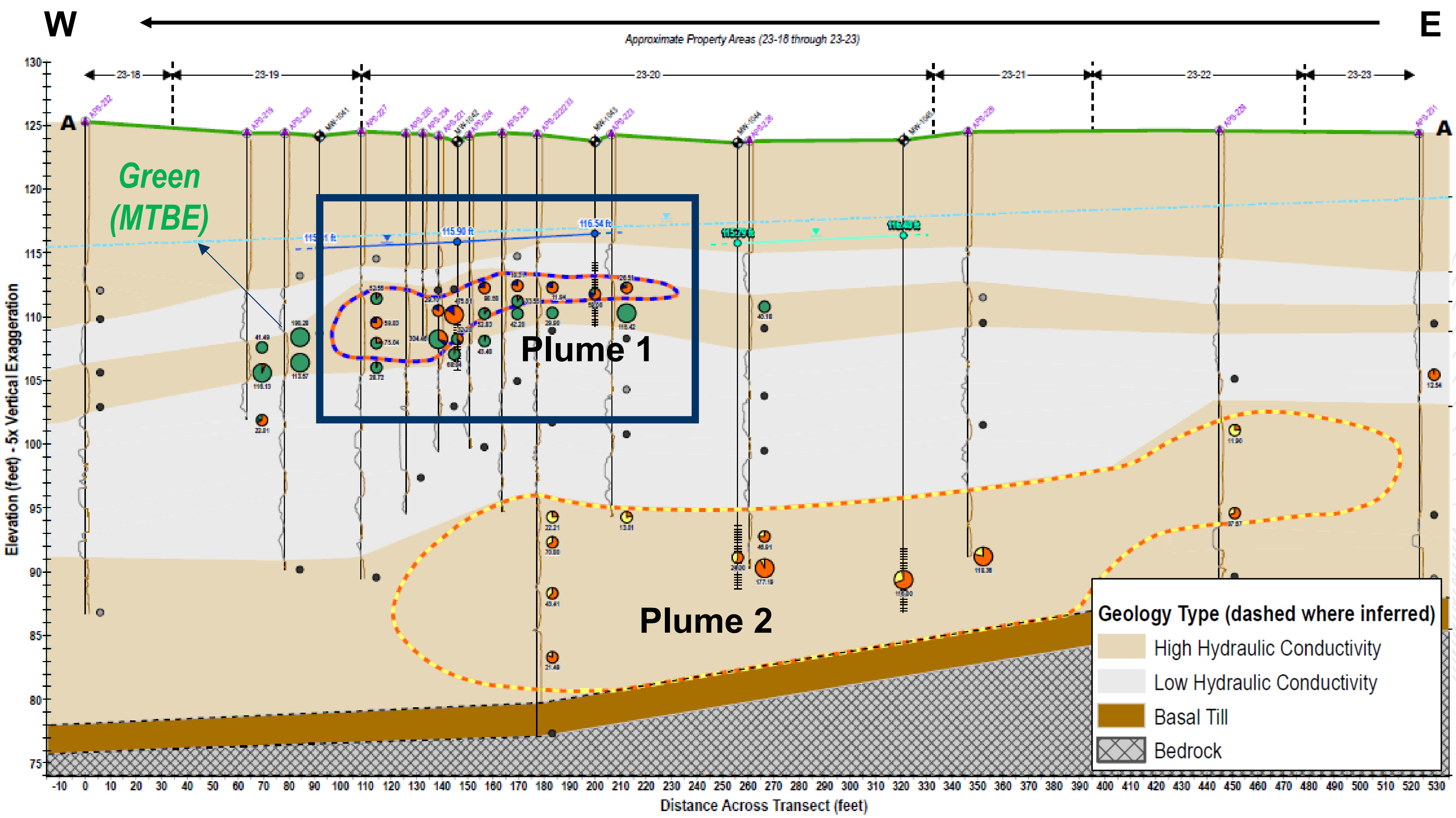




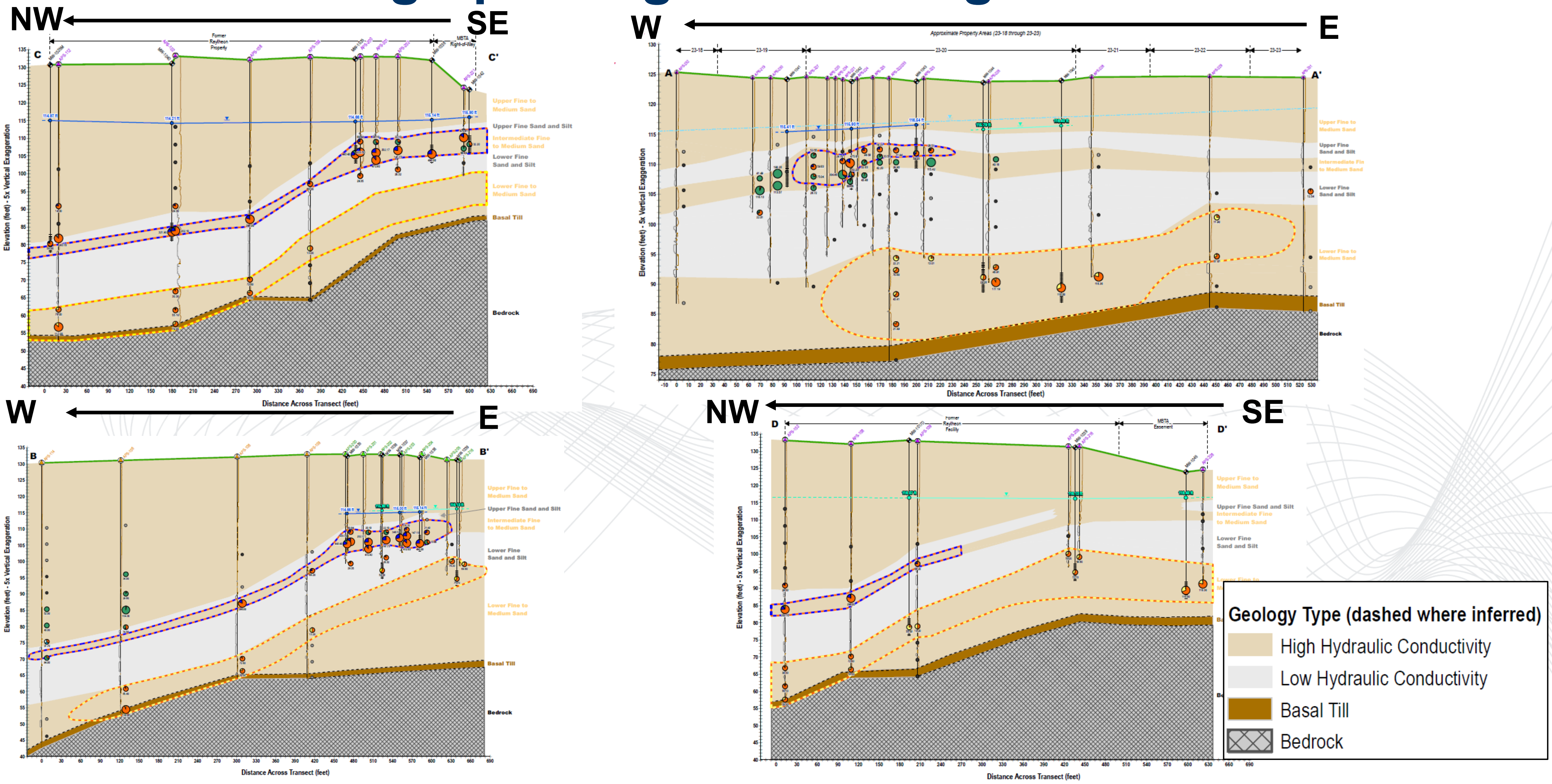


Site 1: ESS & Chemical Fingerprinting Analysis Integration in 2-D



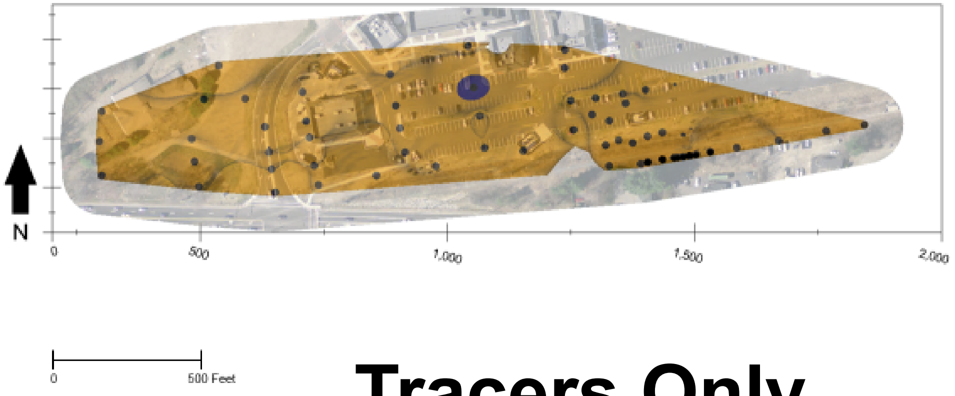


Site 1: Chemical Fingerprinting & ESS Integration in 3-D

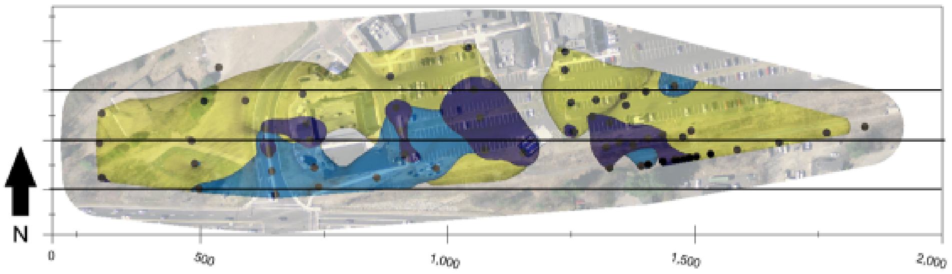


Site 1: Environmental Visualization System (EVS) 3-D Modeling

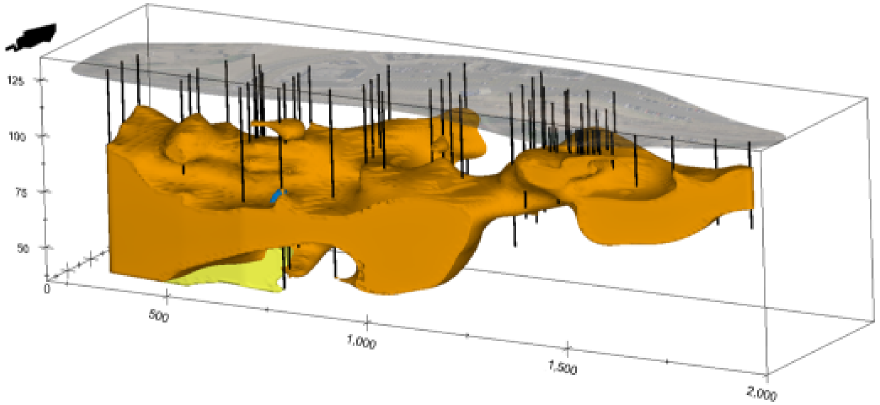
TCE (Overlay)



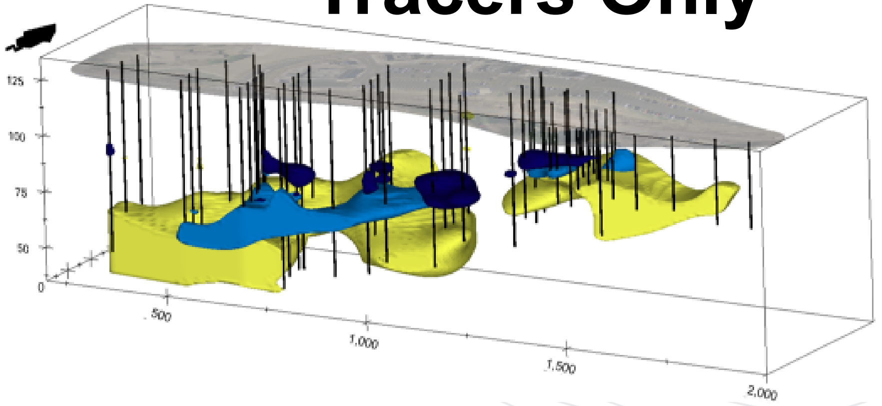
Tracers Only



TCE (Overlay)



Tracers Only

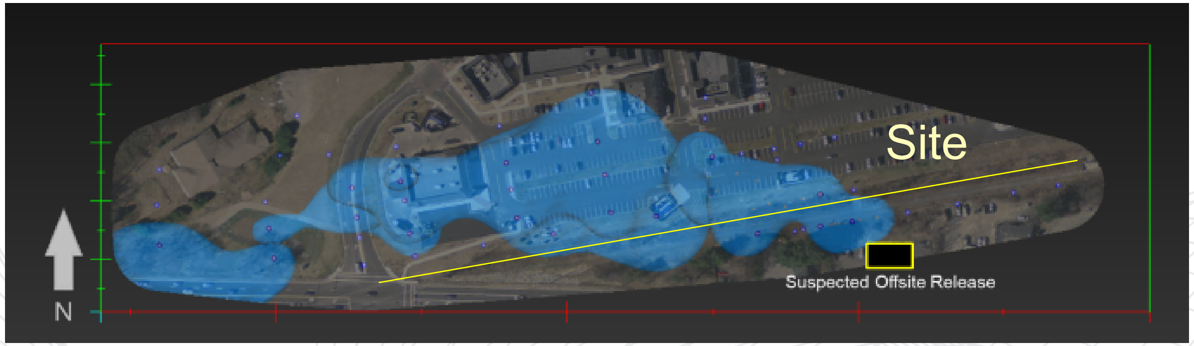


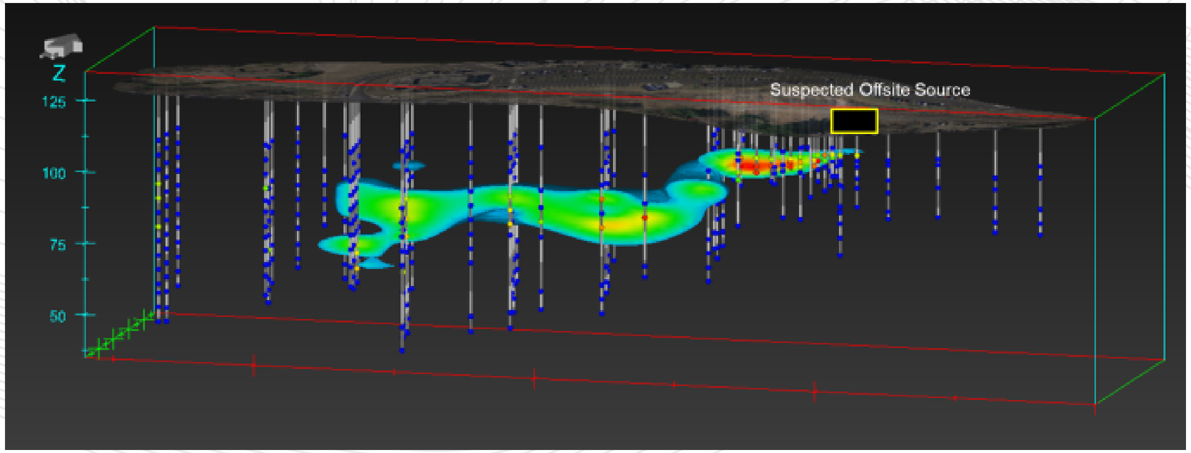
- Trichloroethene
- cis-1,2-Dichloroethene
- trans-1,2-Dichloroethene
- Vinyl chloride
- 1,1,1-Trichloroethane
- 1,1-Dichloroethane
- 1,1-Dichloroethene

cDCE / tDCE / 111TCA / 11DCE

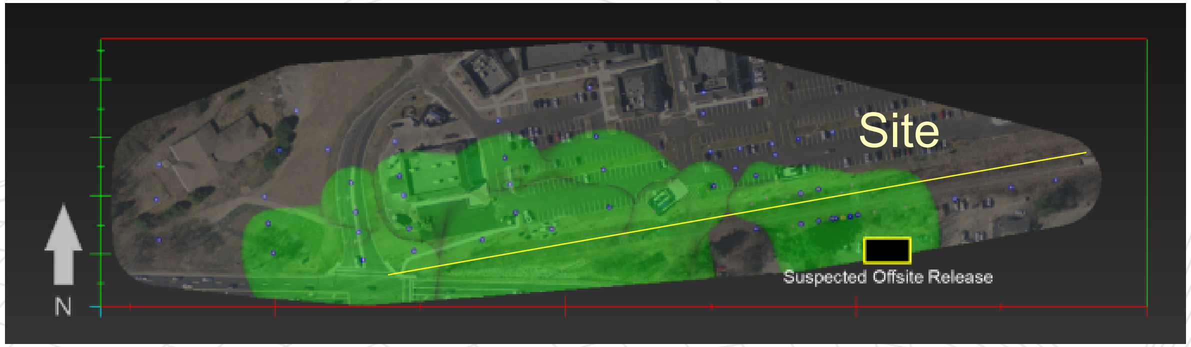
Site 1: EVS 3-D Modeling

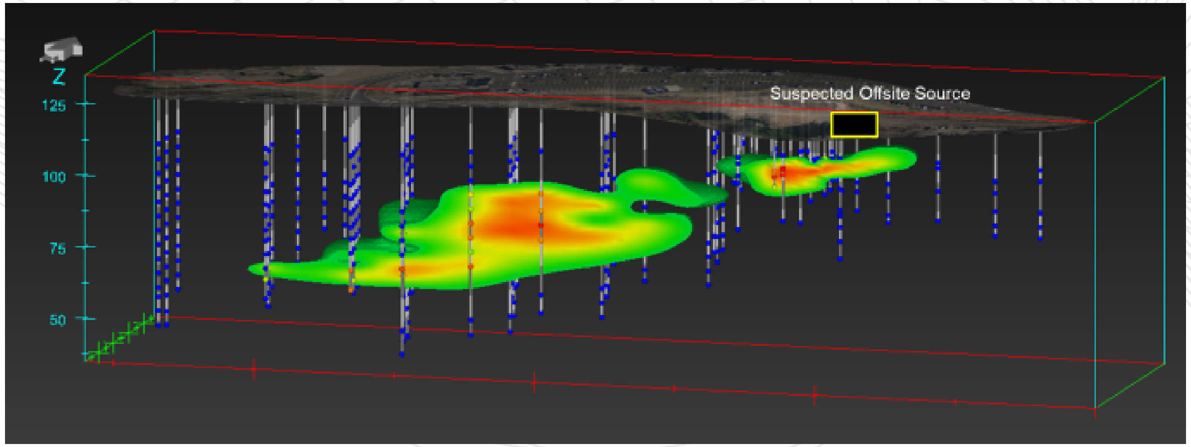
1,1,1-TCA Tracer





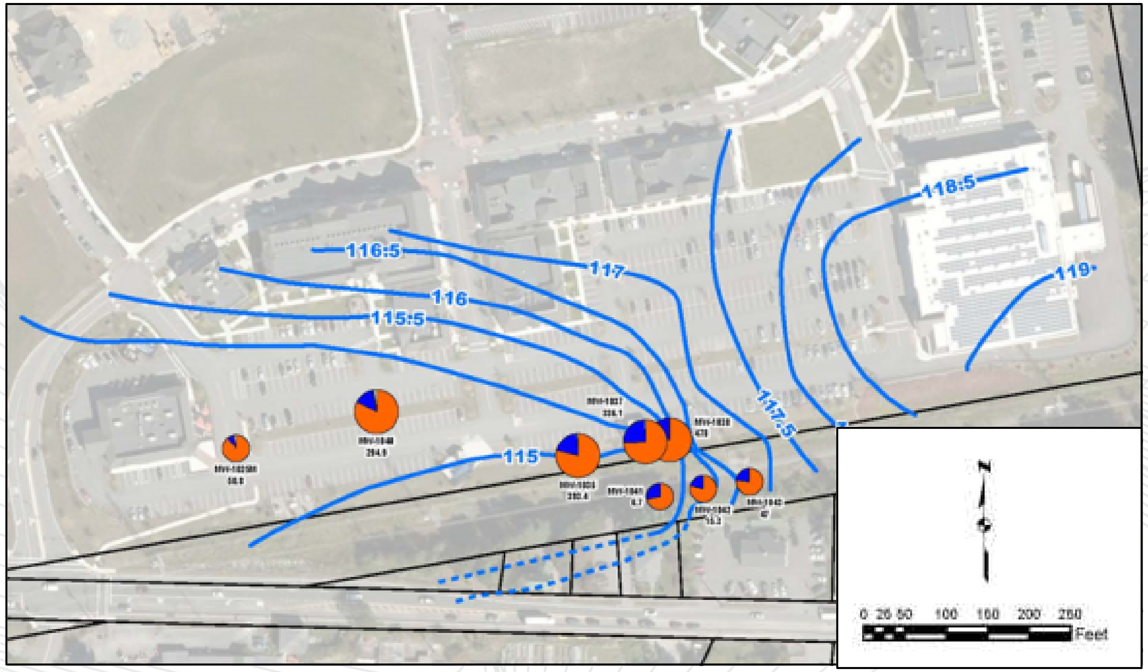
MTBE Tracer



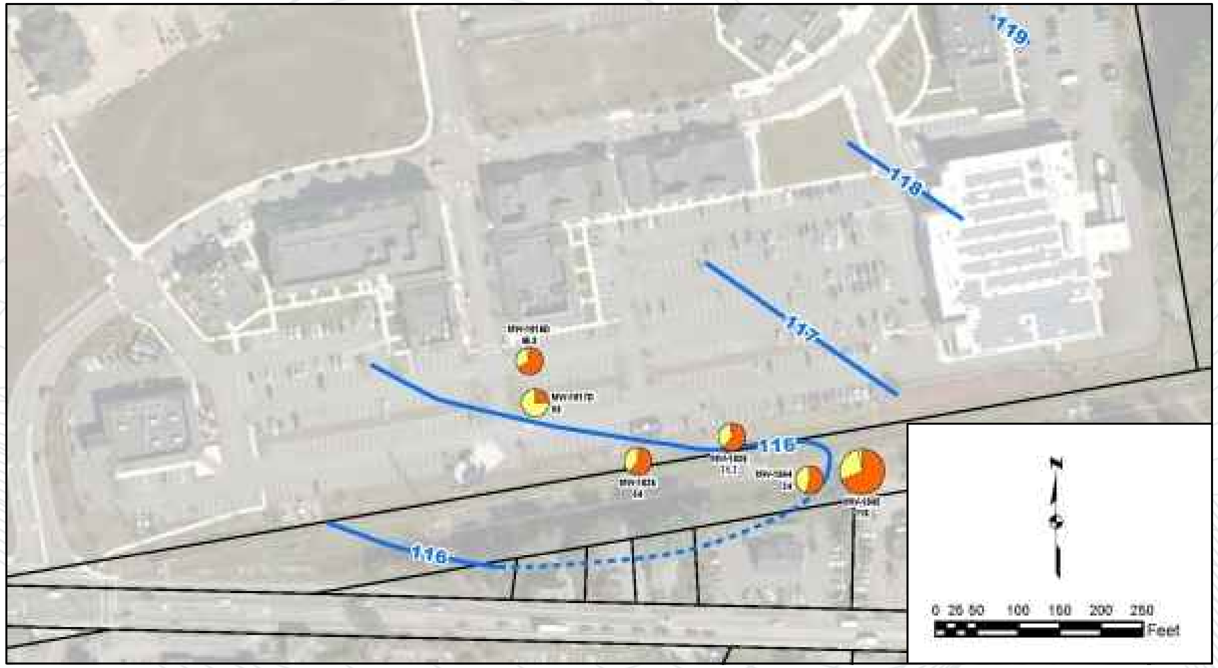


Site 1: Chemistry and Water Level Integration (Well Data)

Plume 1



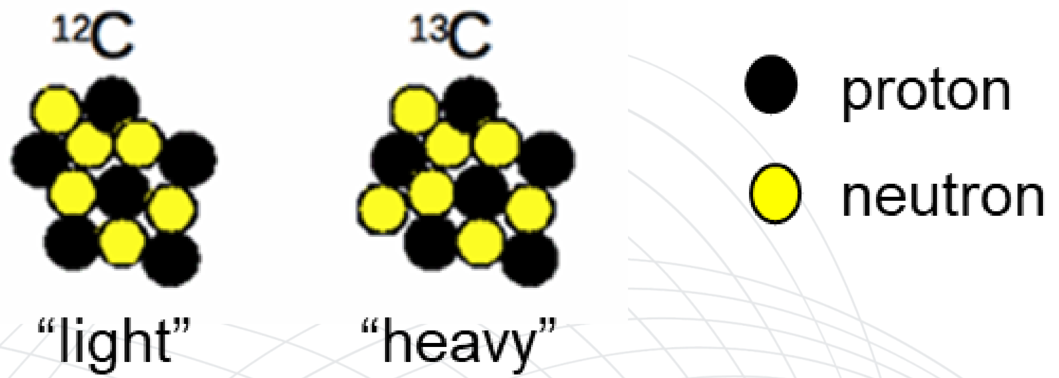
Plume 2



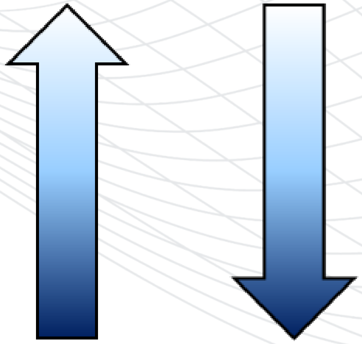
Strategic well placement in plume cores

Site 1: Chemical Fingerprinting Informed Compound Specific Isotope Analysis (CSIA)

C^{12} is preferentially degraded, so if you measure the ratio of C^{13}/C^{12} in a compound, the ratio will increase as the compound degrades (becomes less negative)



"lighter"



"heavier"

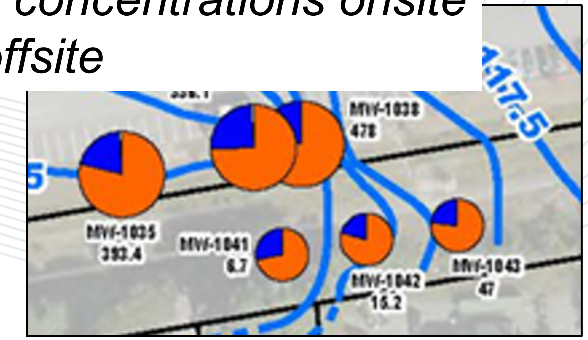
Increasing Ratio

- Degradation of the compound

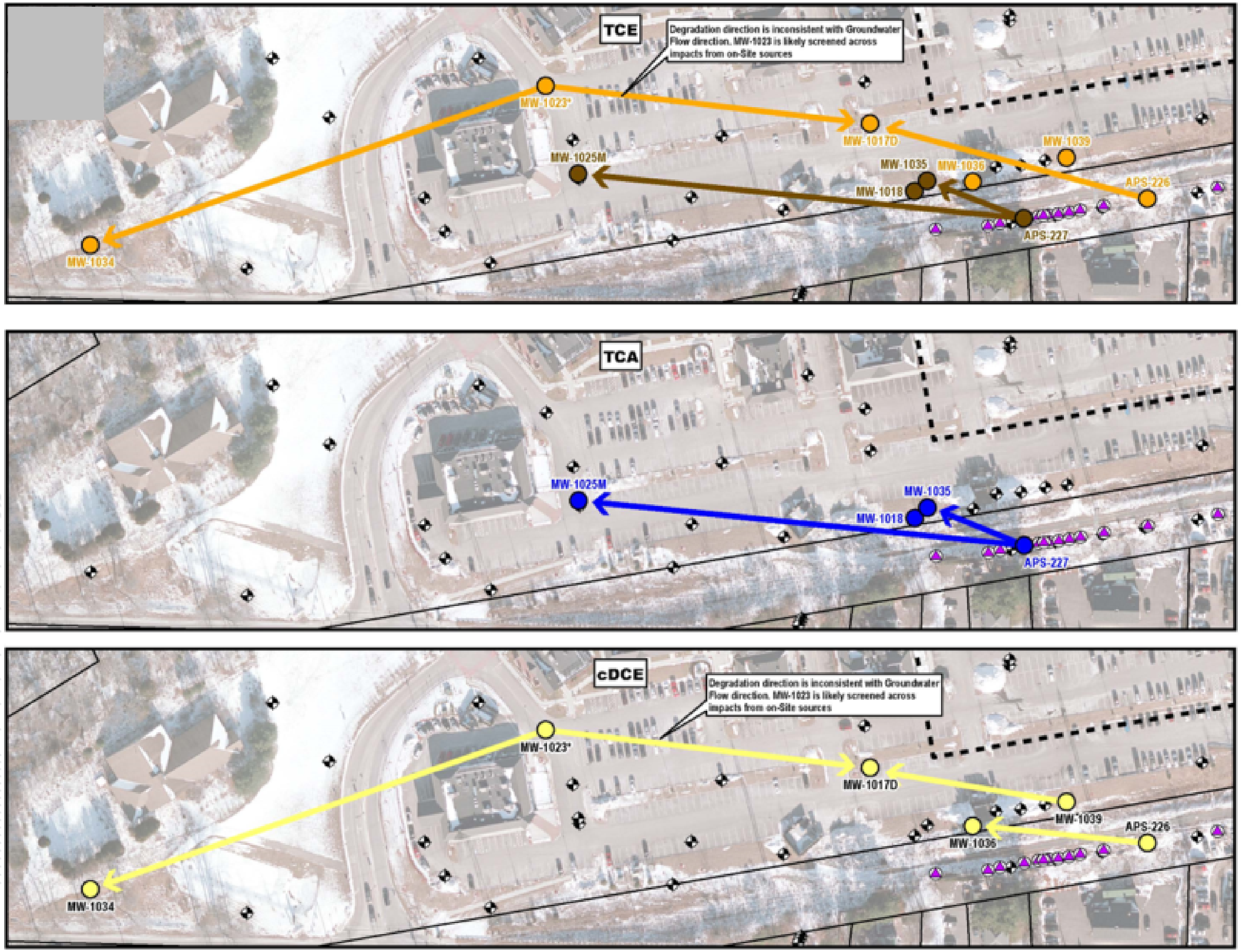
Decreasing Ratio

- production by degradation of parent
- Dissolution from NAPL
- Desorption from soil
- Release from the source

Lower concentrations onsite than offsite

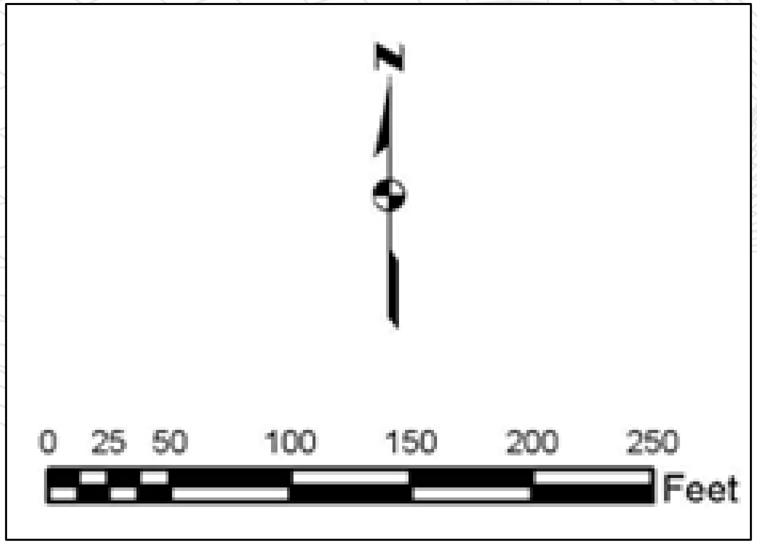


Site 1: CSIA Results



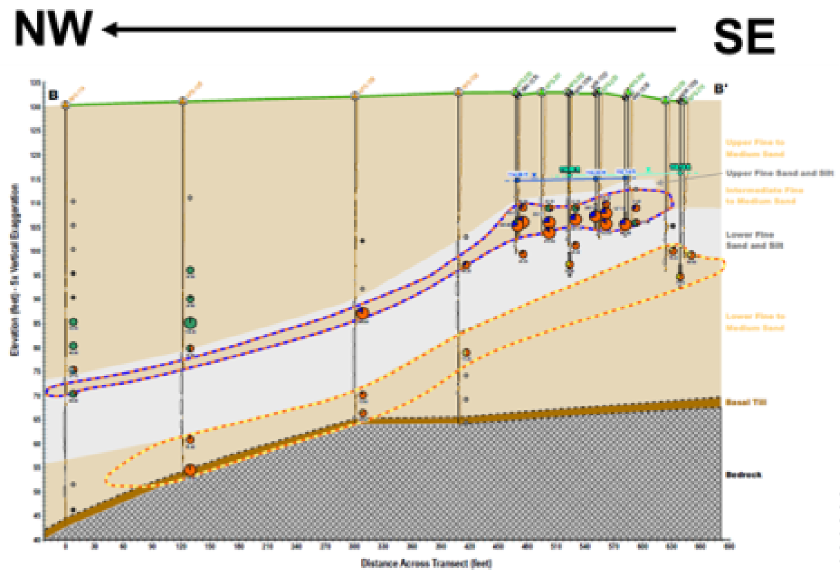
Locations for δ¹³C Analysis:

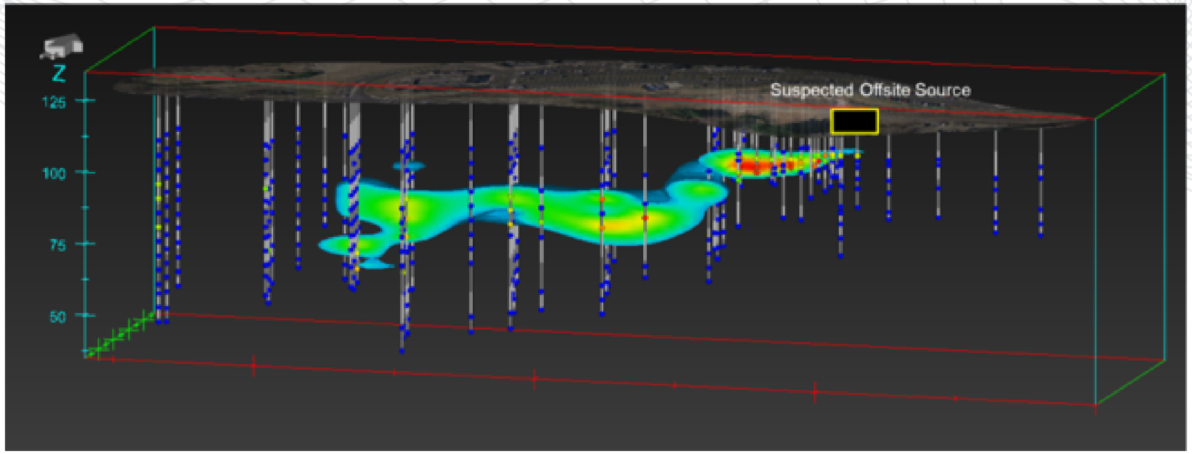
- TCE Plume 1 (-24.56 to -26.18)
- TCE Plume 2 (-12.20 to -19.53)
- TCA (signature 1 only)
- cDCE (signature 2 only)
- Degradation Direction (increasing)



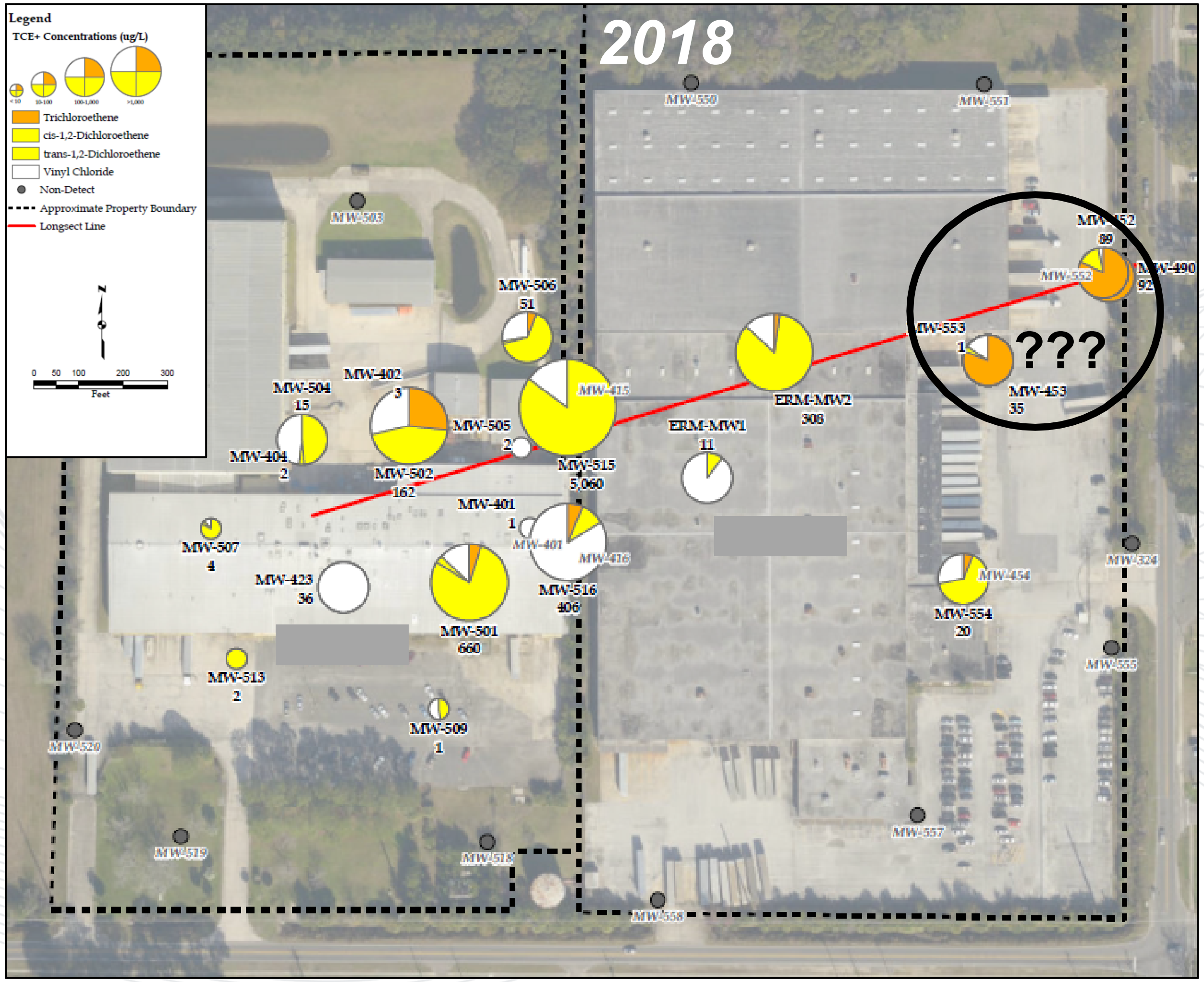
Site 1: Summary

- A successful Downgradient Property Status (DPS) (a form of site closure) was accepted by regulators. No additional onsite remediation required.
- The DPS document was recognized by regulators as a "go-to" example and shared during a Licensed Site Professional Association (LSPA) meeting.





Site 2: Background



Site Location:

- East Coast Florida

Depositional Environment:

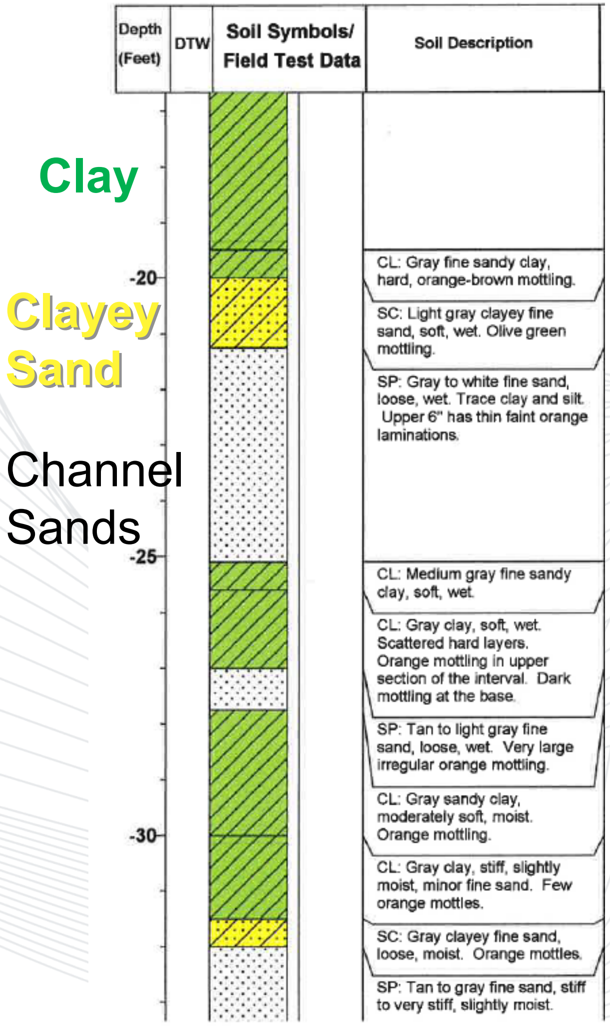
- Coastal Marine Deltaic

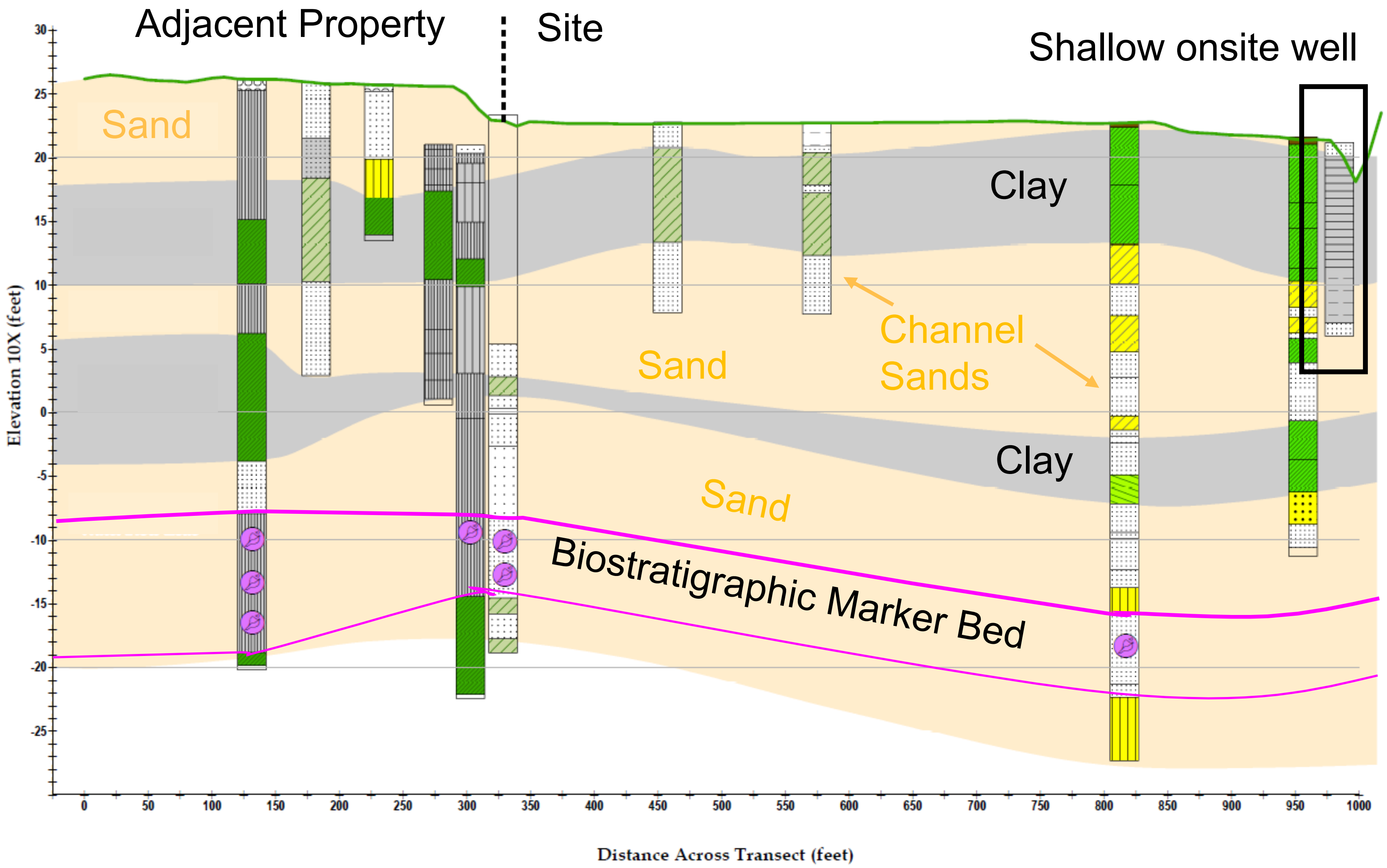
TCE in shallow groundwater but no historical use or suspected release.

Adjacent site with degraded TCE plume.

Temporal problem identified and 4-D analysis was required.

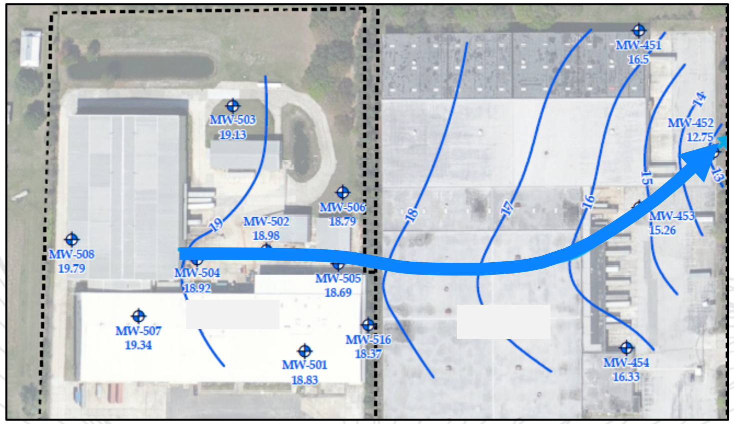
Site 2: Geologic Model

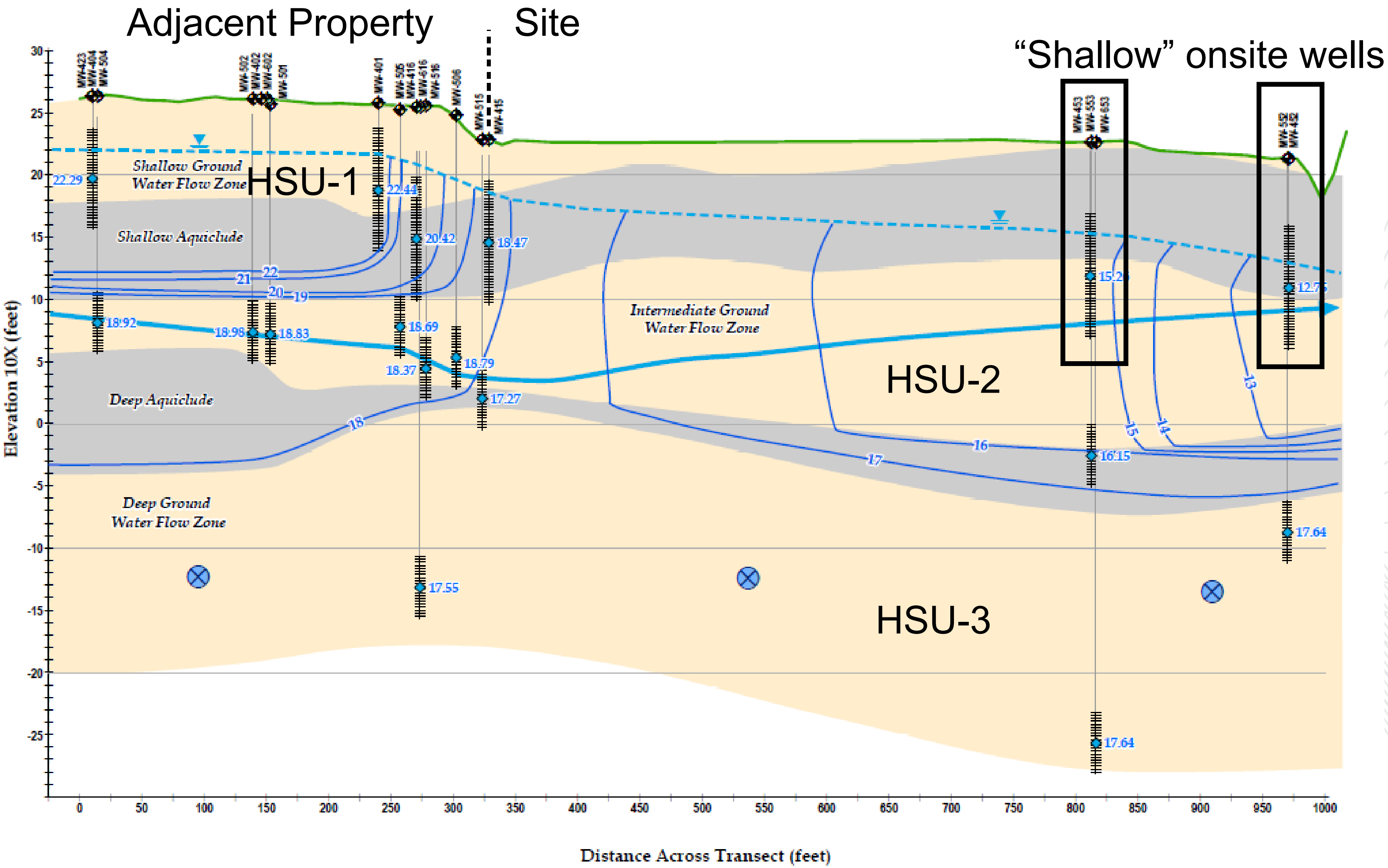




Site 2: Hydrogeologic Model (Flow Net and GW Contours)

HSU-2

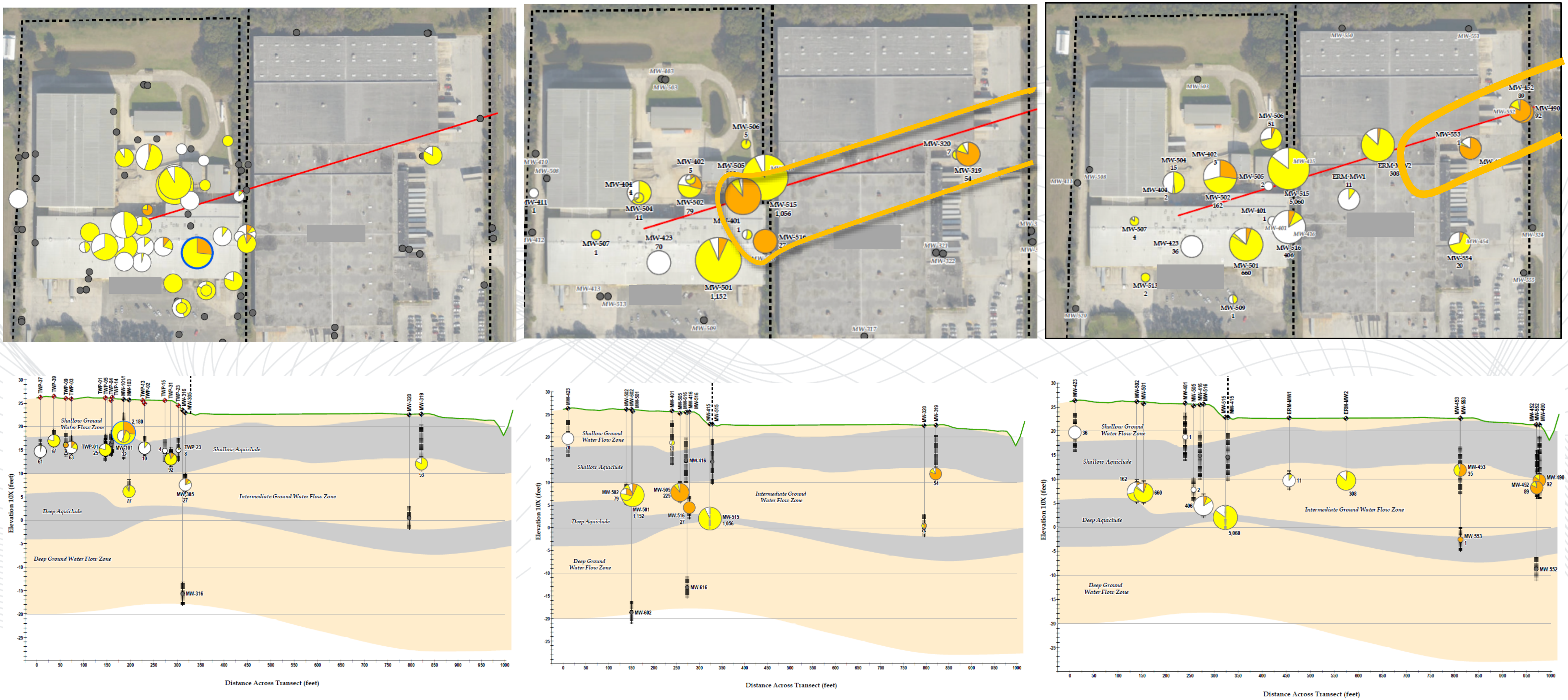




Shallow onsite wells were in the intermediate HSU-2

Site 2: CVOC Fate and Transport Through Time (Quasi-4D)

1999 | **2009 Offsite Remediation** | **2018**



Site 2: What happened after 2018?

Did the degraded plume arrive in “shallow” onsite wells downgradient of the offsite source?…..

Site 2: Summary

It didn't matter..

The revised CSM resulted in a no further action outcome.

So, we went to the beach…

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Thank you.

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