GREAT LAKES
ENVIRONMENTAL REMEDIATION
& REDEVELOPMENT CONFERENCE

OCTOBER 16-18, 2019 // LANSING CENTER, LANSING

ARCADIS Design & Consultancy for natural and built assets

PFAS: NEXT GENERATION CHARACTERIZATION FOR AN EMERGING CONTAMINANT

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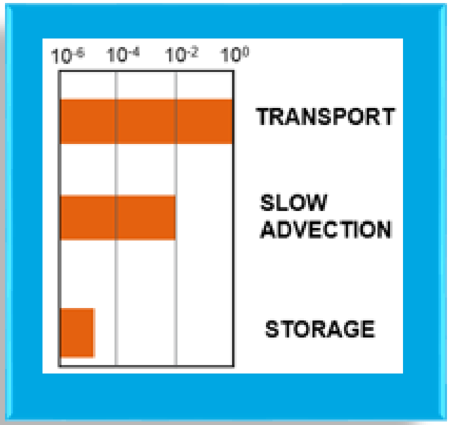
Outline

- Smart Characterization & Mass Flux Framework
- Case Study: PFAS Mass Discharge
- Adaptive Investigations
- PFAS Mobile Laboratory
- Case Study: Adaptive PFAS Site Characterization

Smart Characterization

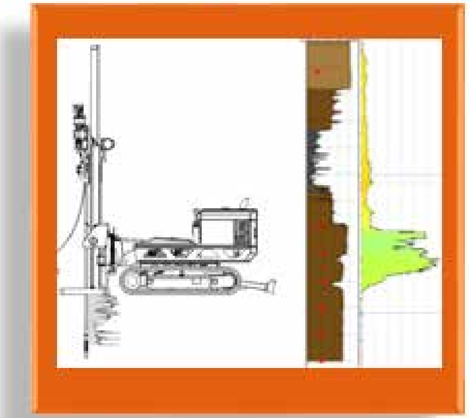
Its not just about more data, its what you do with the data that counts:

Flux-Based CSM



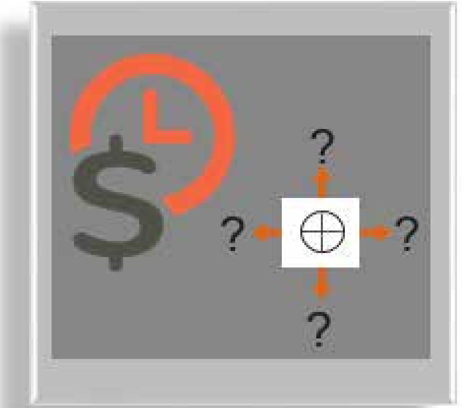
- *Majority of Flux in Permeable Zones*

Right Tools to Map Flux



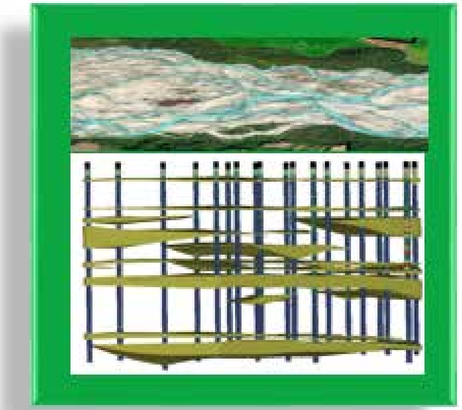
- *Quantitative*
- *High-Resolution*

Real-Time & Adaptive



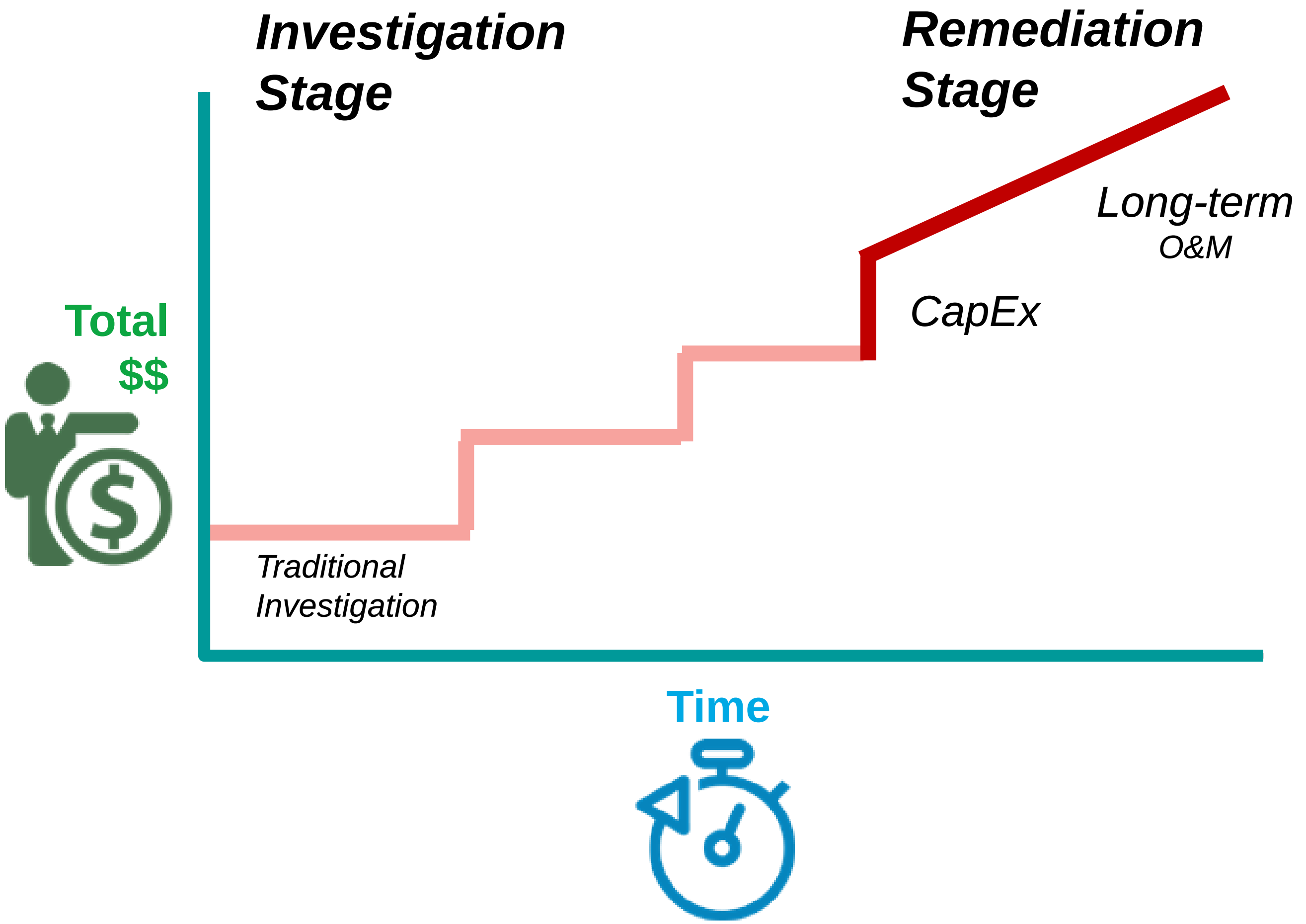
- *Lower Investigation Costs*

Interpretation

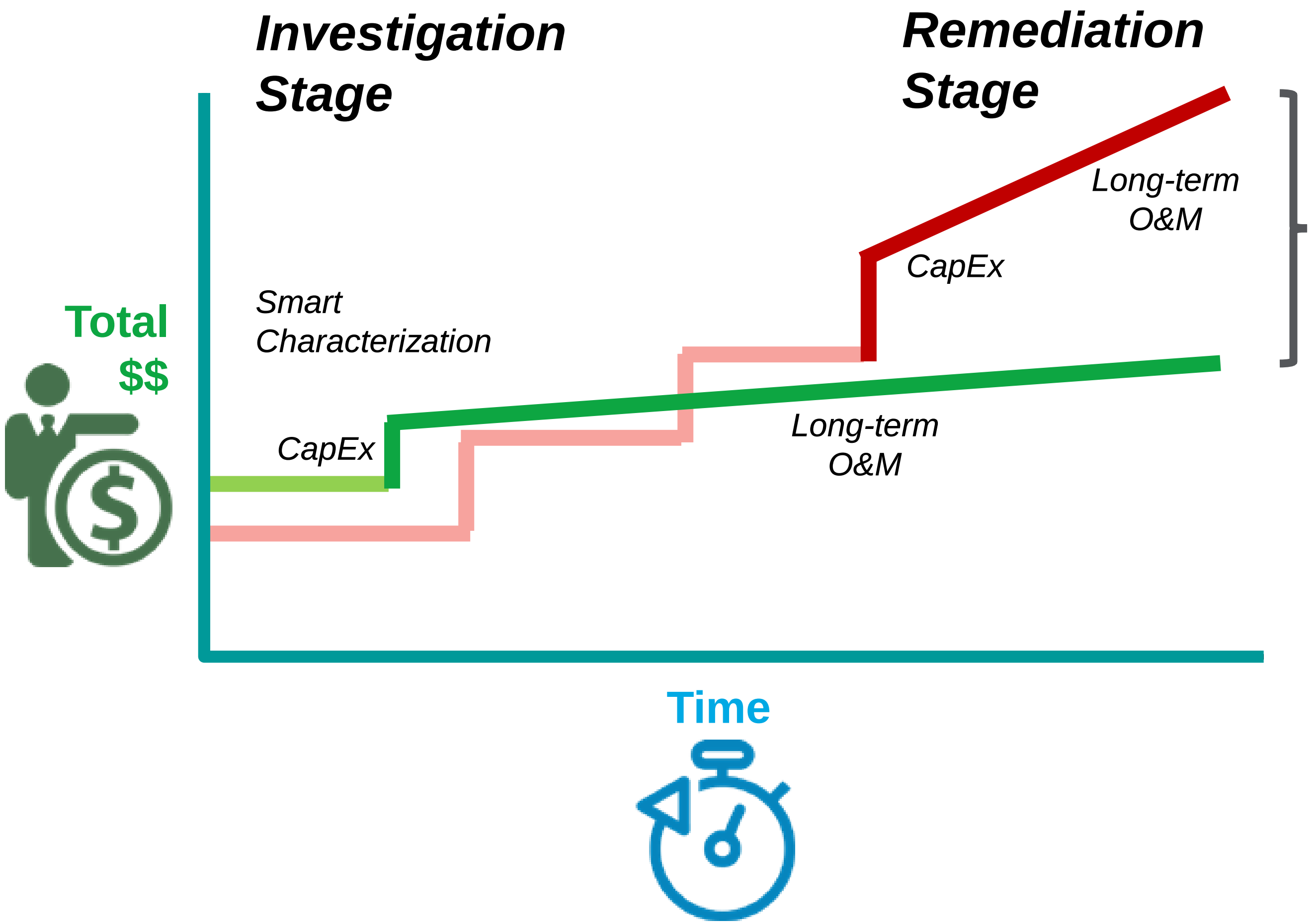


- *3D Analysis*
- *Classical Geologic Approach*

Return on Investigation



Return on Investigation

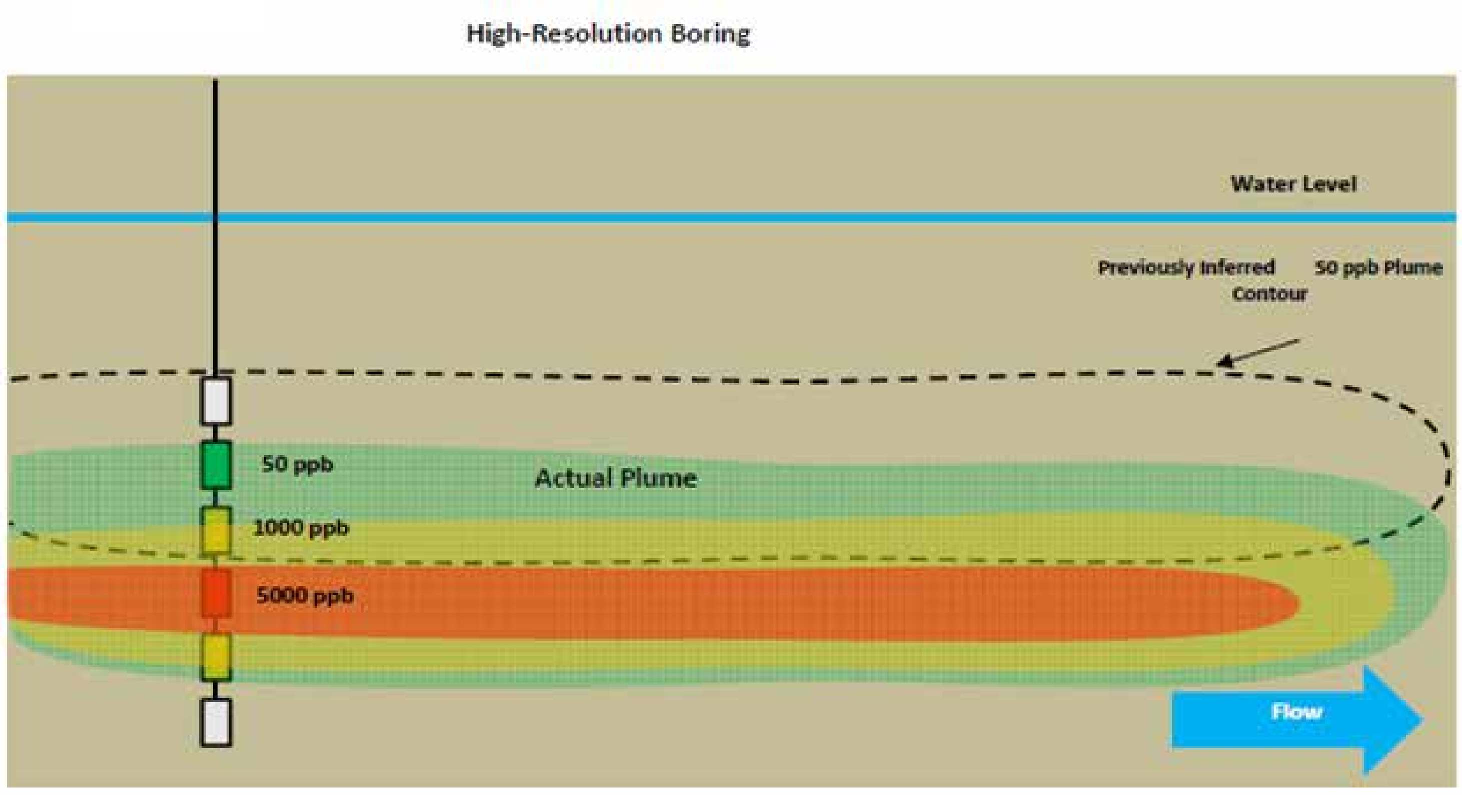


ROI - Reduced total life-cycle costs

Monitoring Wells vs. High Res

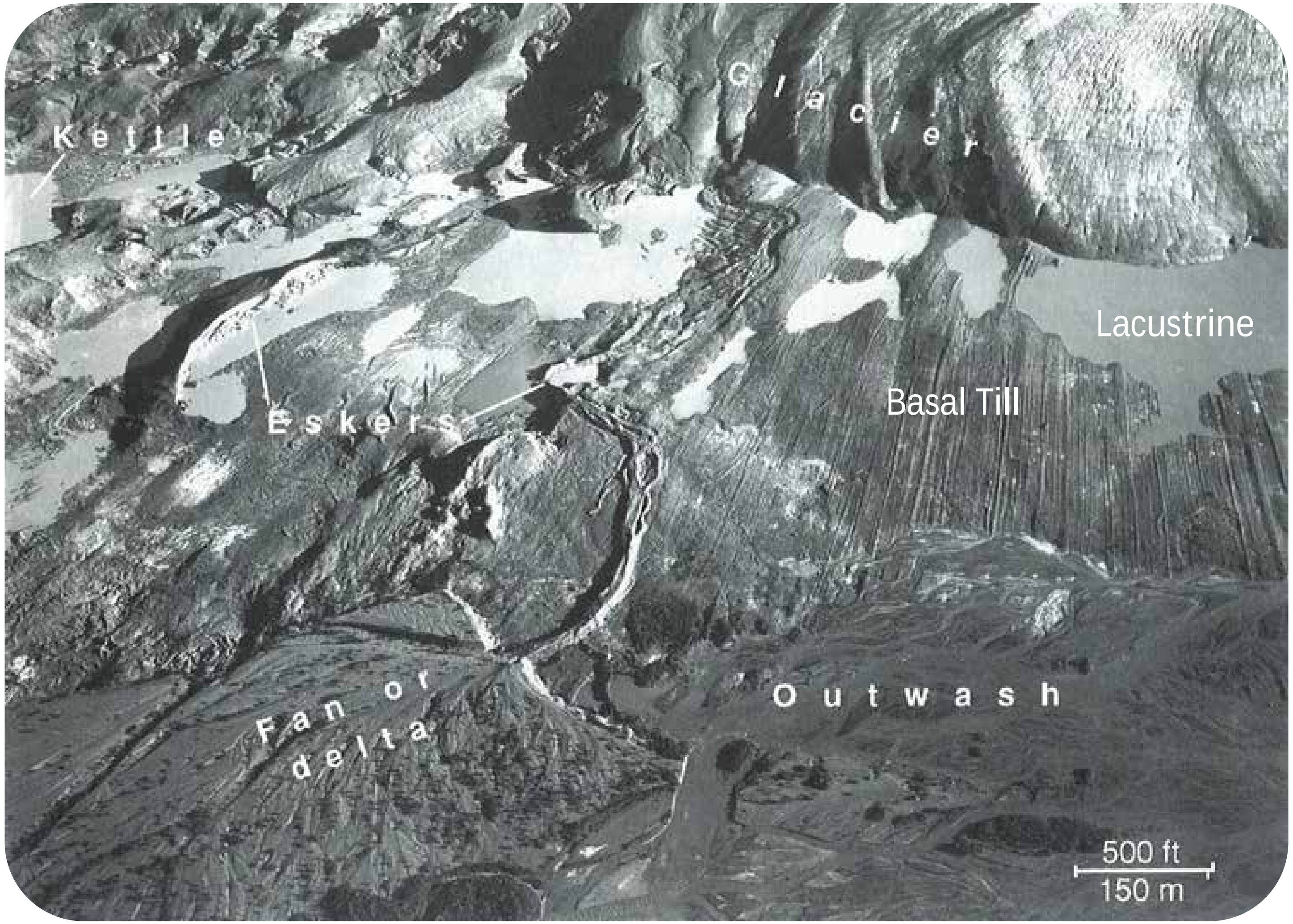
Monitoring wells are for monitoring, not site characterization:

- Provide
  - Average permeability
  - Average concentration
- Can miss mass
  - Accuracy vs Precision
- End up with more wells than needed
  - Expensive to sample

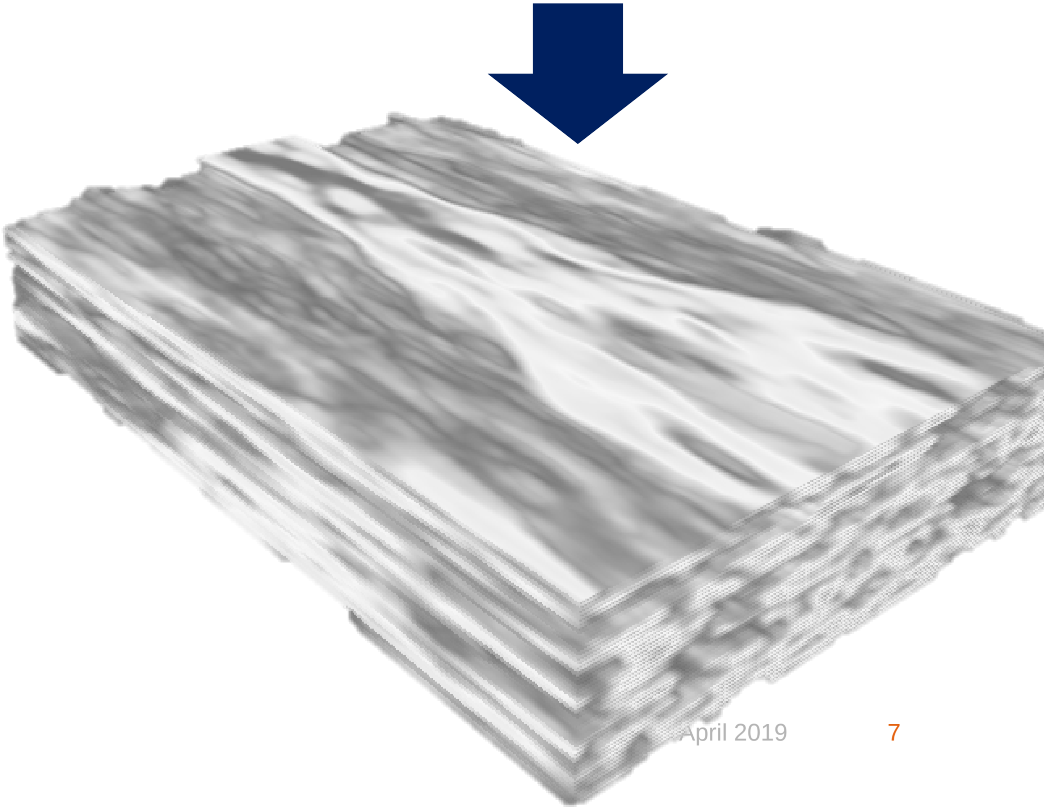


1. Characterize 2. Focused MW Install

Starts with Depositional Environment…



Source: D.F. Ritter et. al., Process Geomorphology, 3rd Edition

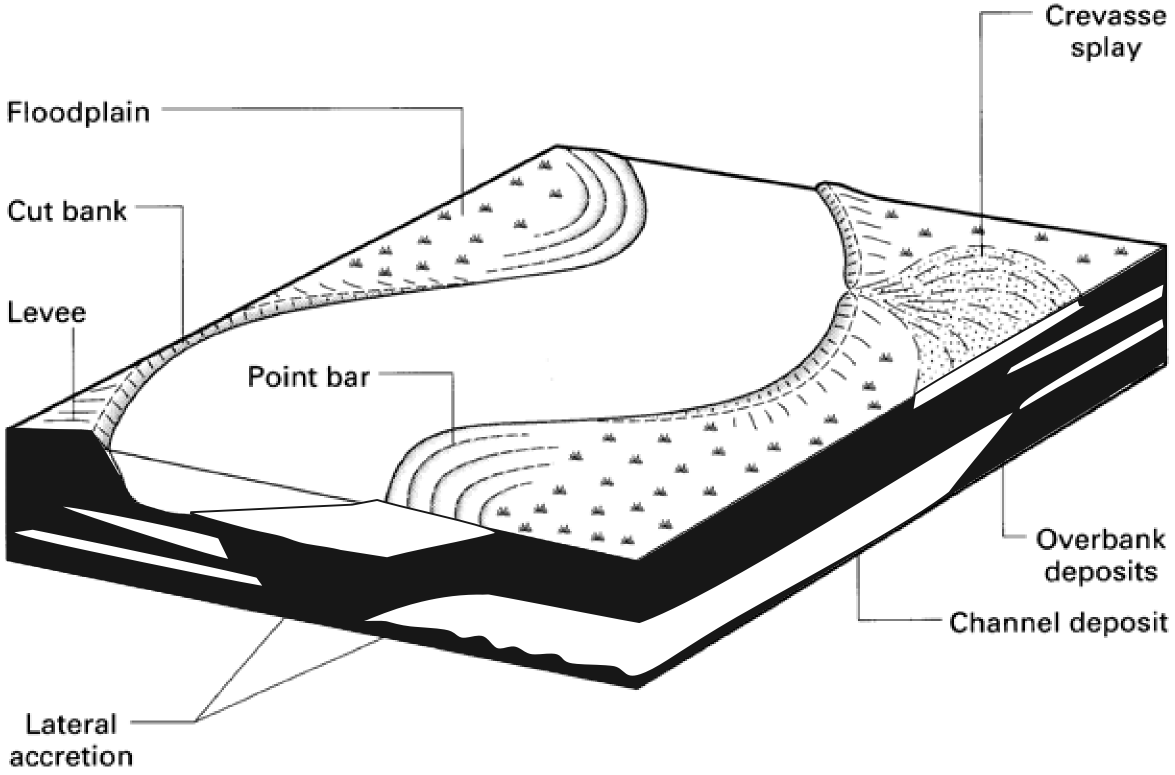


Flux-Based Conceptual Site Models

Link mass flux analysis with geological interpretation

- Describe the 3-D aquifer architecture
- Focus evaluation on zones that matter

Meandering Channel



Transport zones

Storage zones

Mass Flux Framework for Transport

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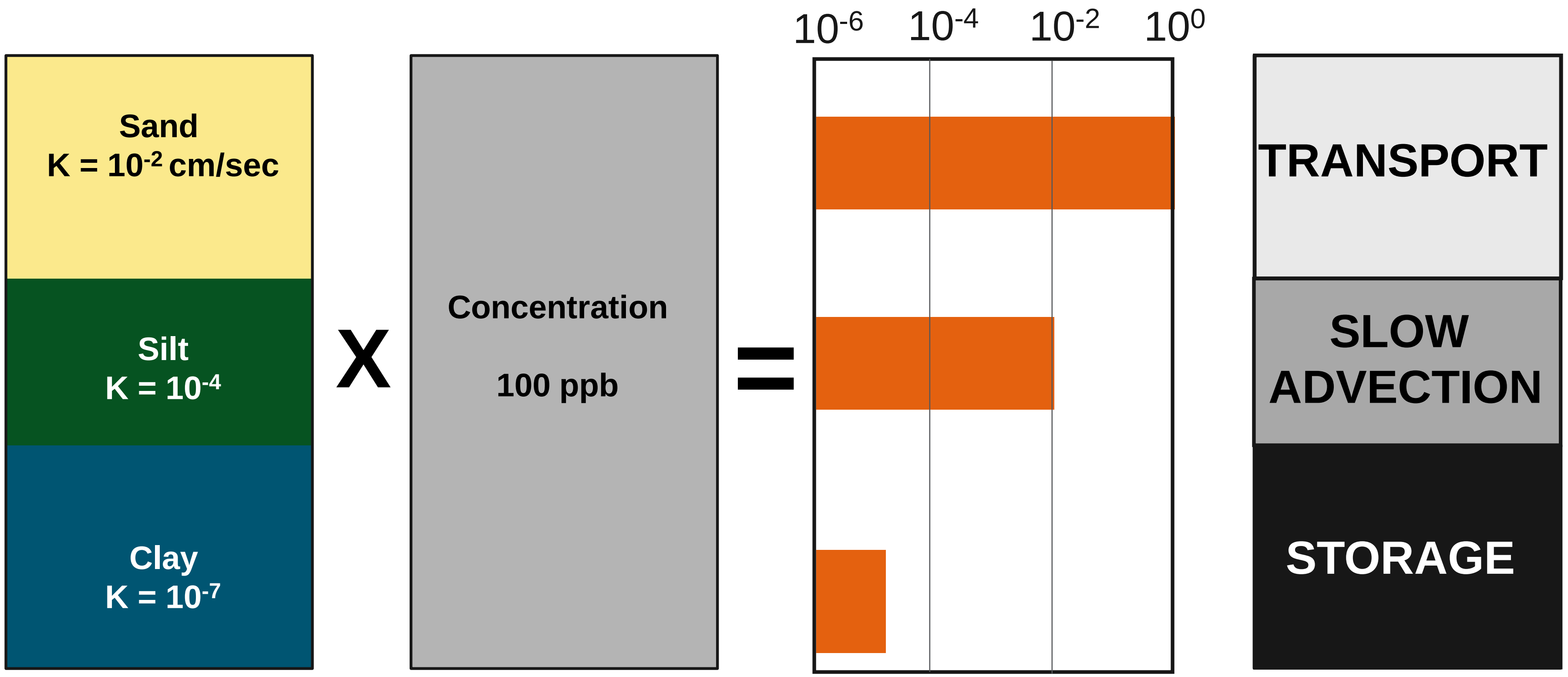
Mass Flux = J = K i C

Relative Mass Flux

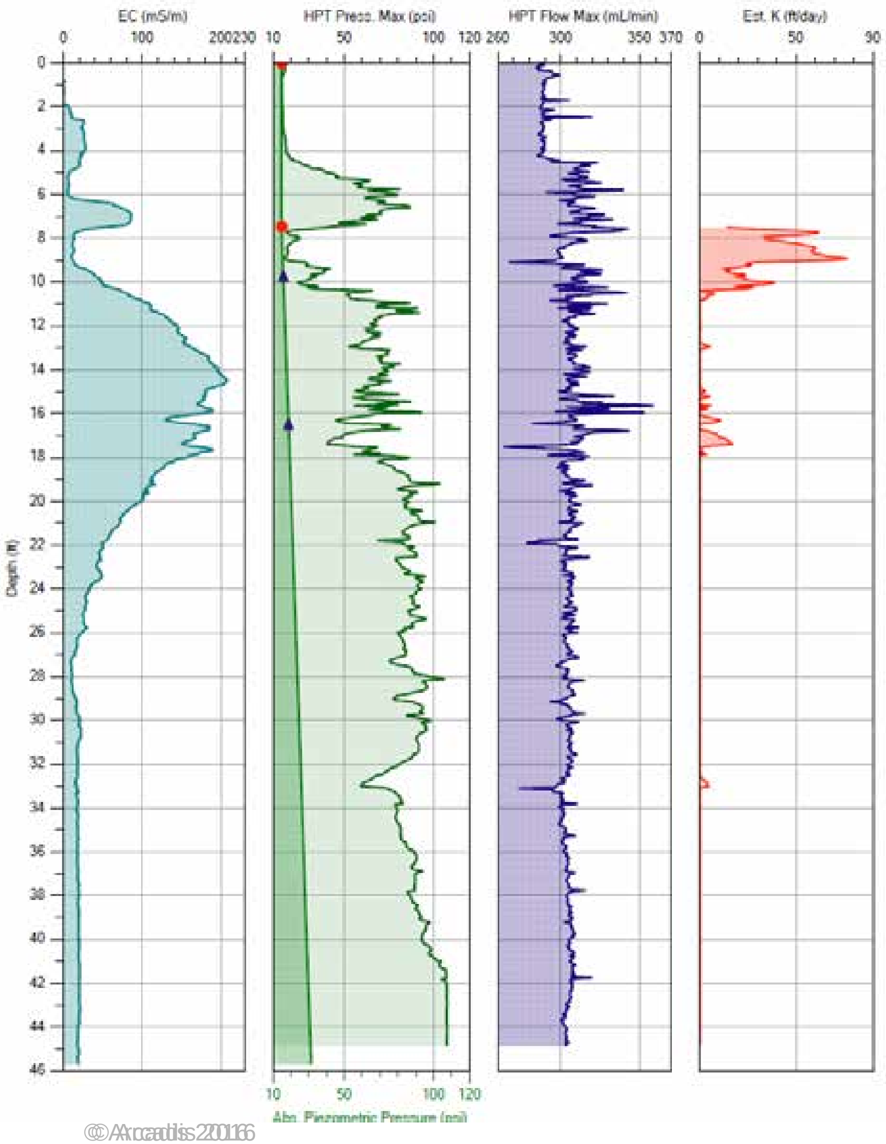
$J_r = K * C$

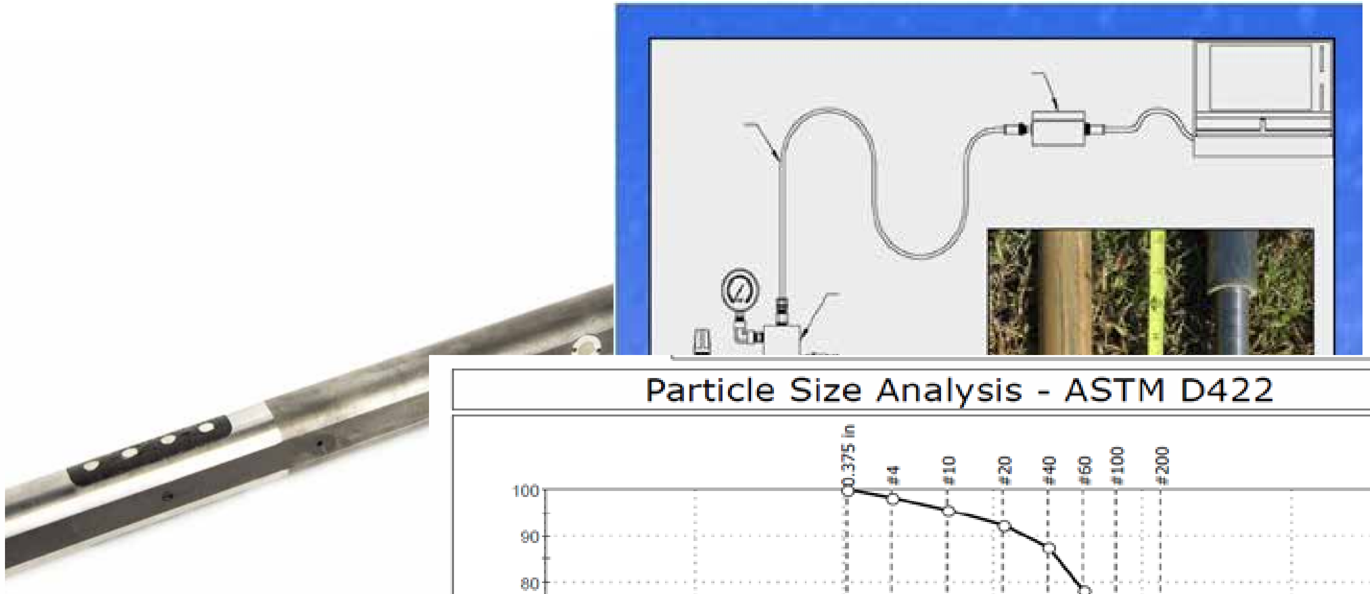


Relative Mass Flux

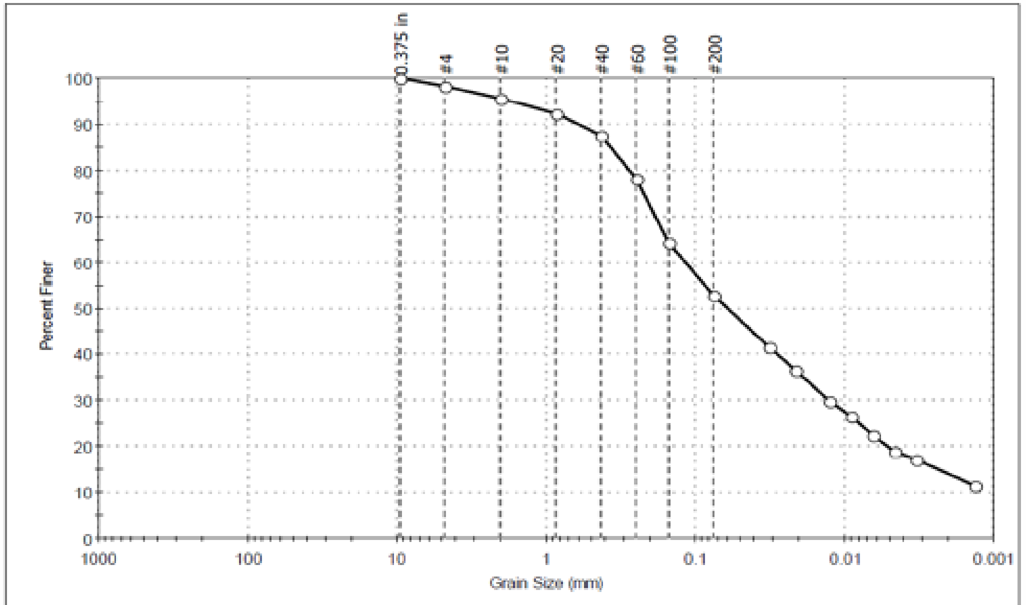
Hydrofacies Class

Permeability & Aquifer Profiling





Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	1.9	45.4	52.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	98		
#10	2.00	96		
#20	0.85	92		
#40	0.42	88		
#60	0.25	78		
#100	0.15	64		
#200	0.075	53		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies

Coefficients

D_{85} =0.3654 mm　D_{30} =0.0125 mm
D_{60} =0.1162 mm　D_{15} =0.0023 mm
D_{50} =0.0611 mm　D_{10} =N/A
C_u =N/A　C_c =N/A

Classification

ASTM N/A

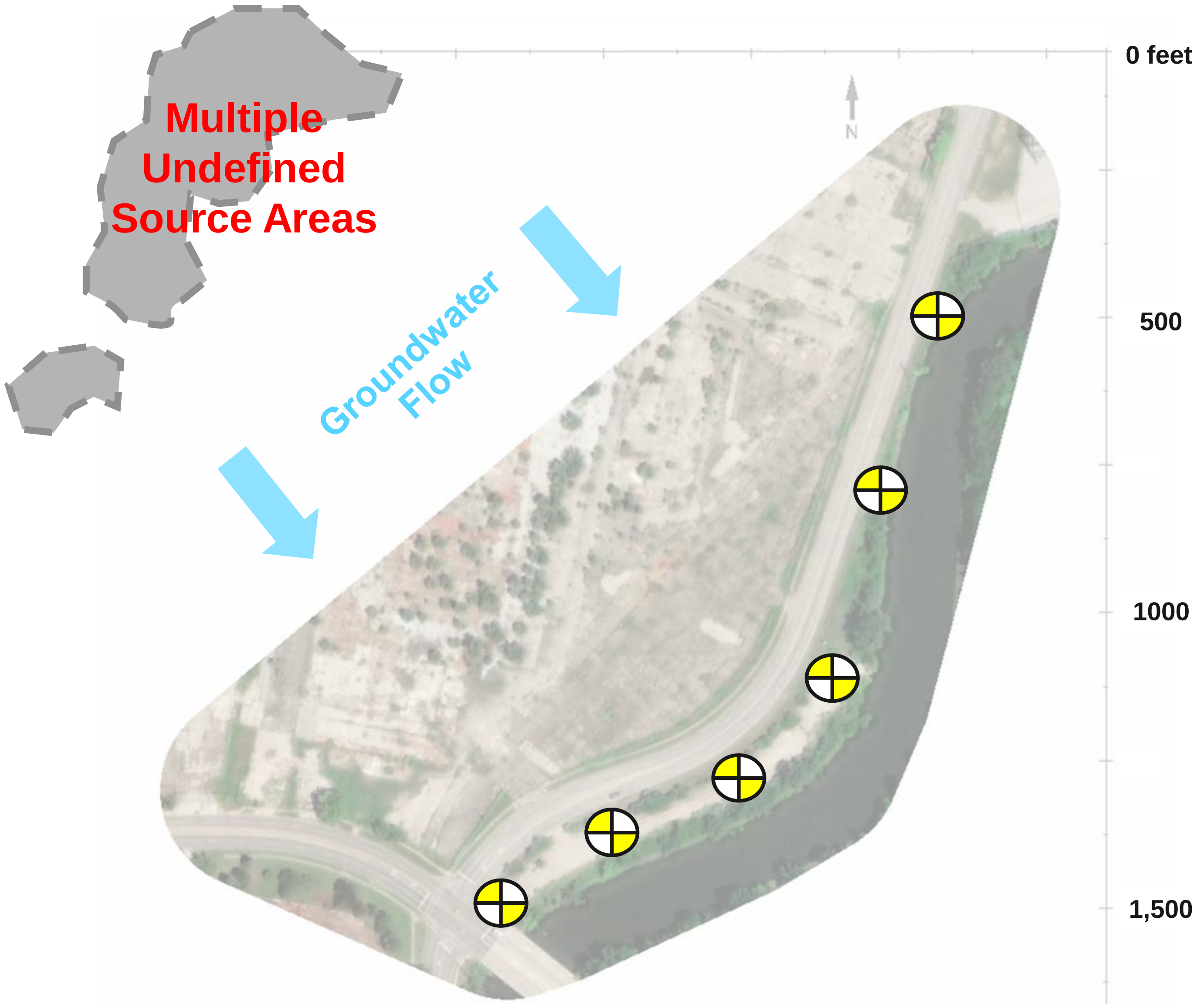
AASHTO Silty Soils (A-4 (0))

PFAS Mass Flux/Mass Discharge

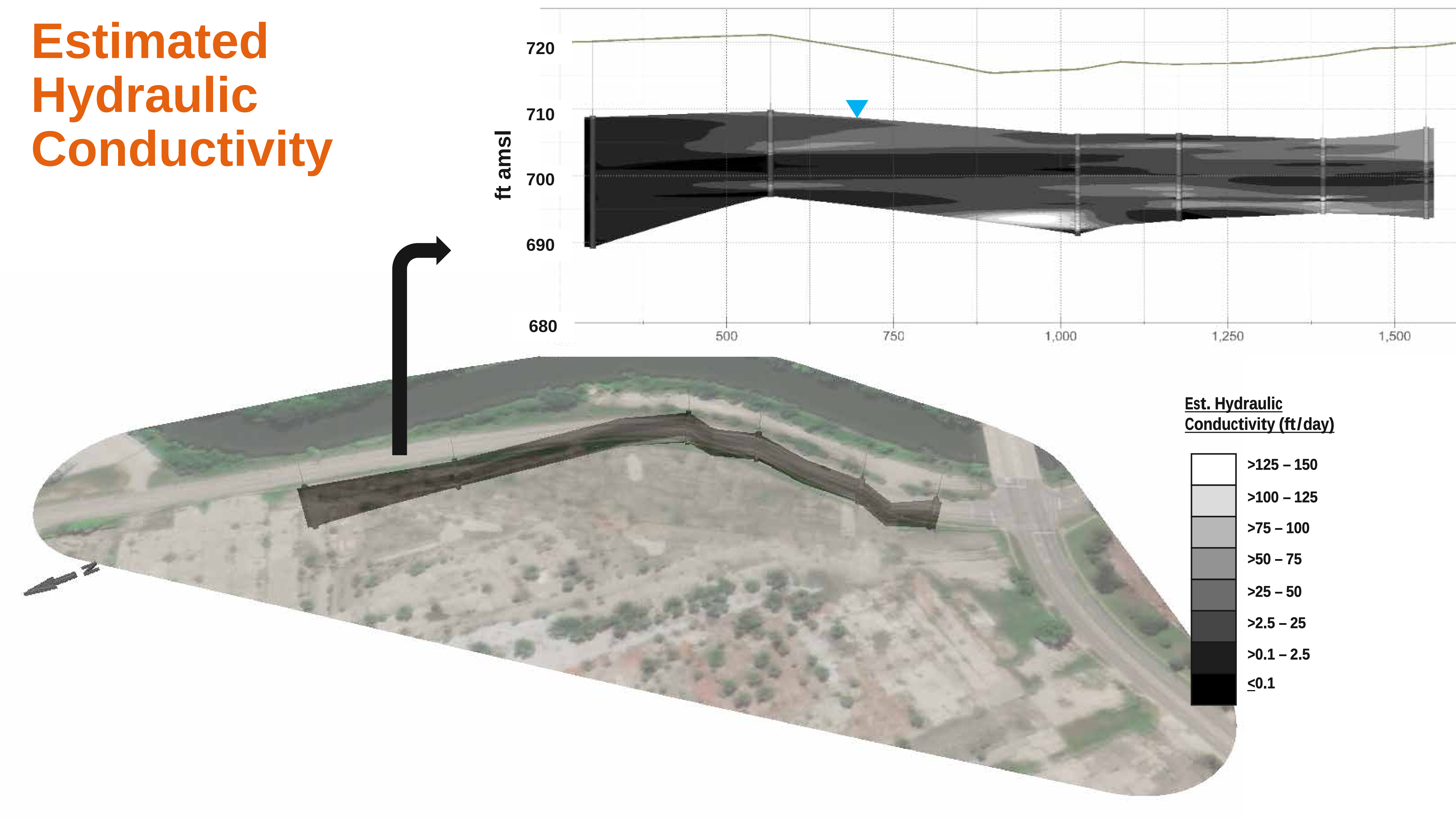
Objective:

Quantify impact to river

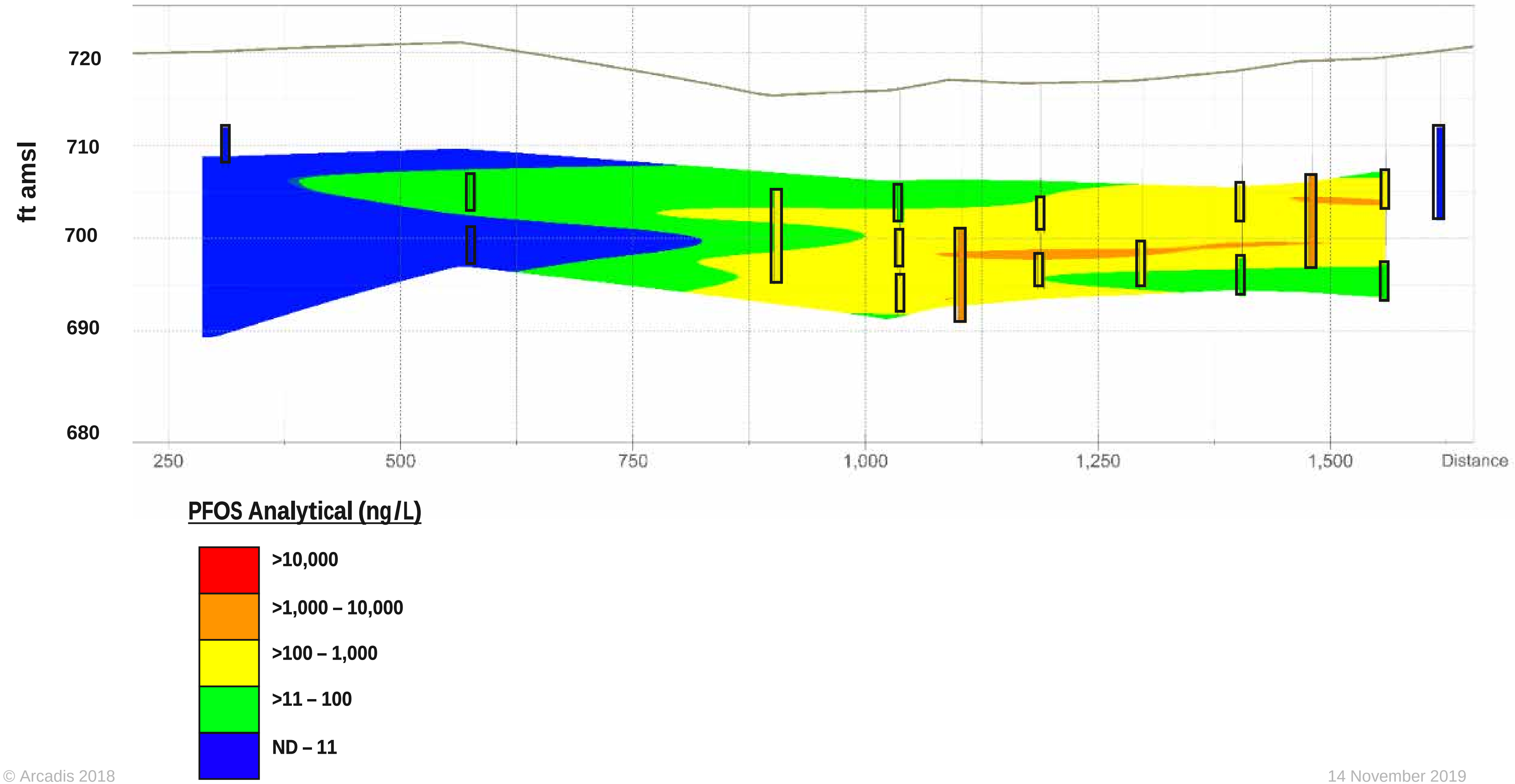
- Rank and prioritize remediation



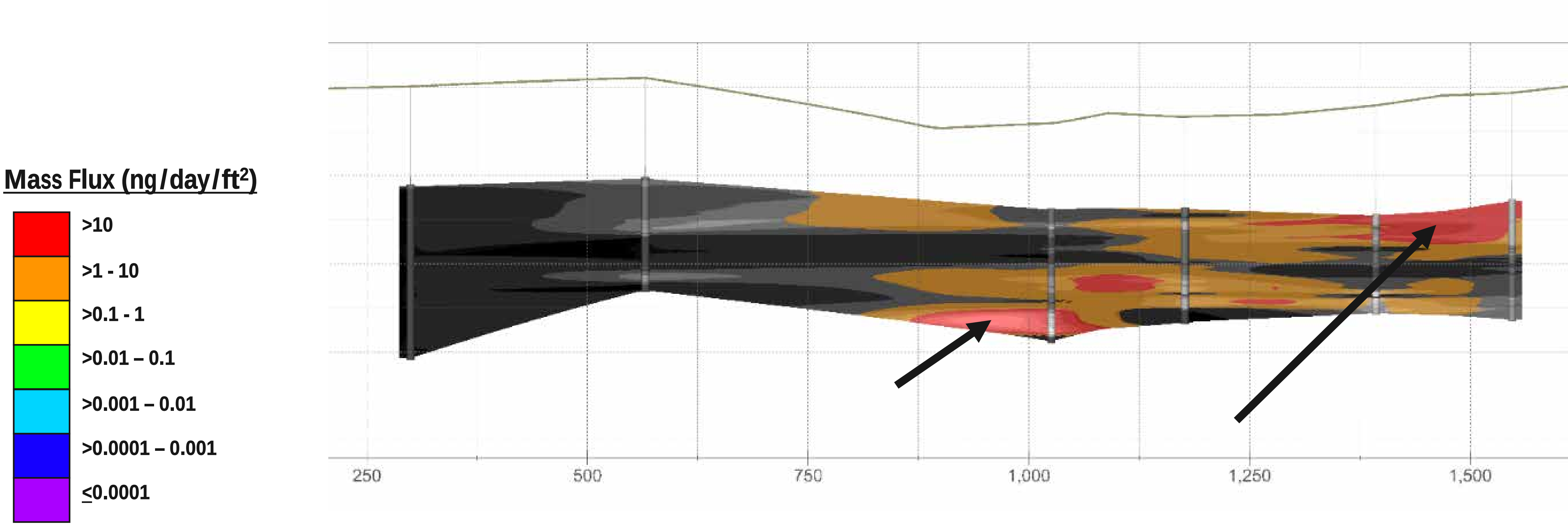
Estimated Hydraulic Conductivity



Concentration



Mass Flux: PFOS



$J = K\,i\,C$

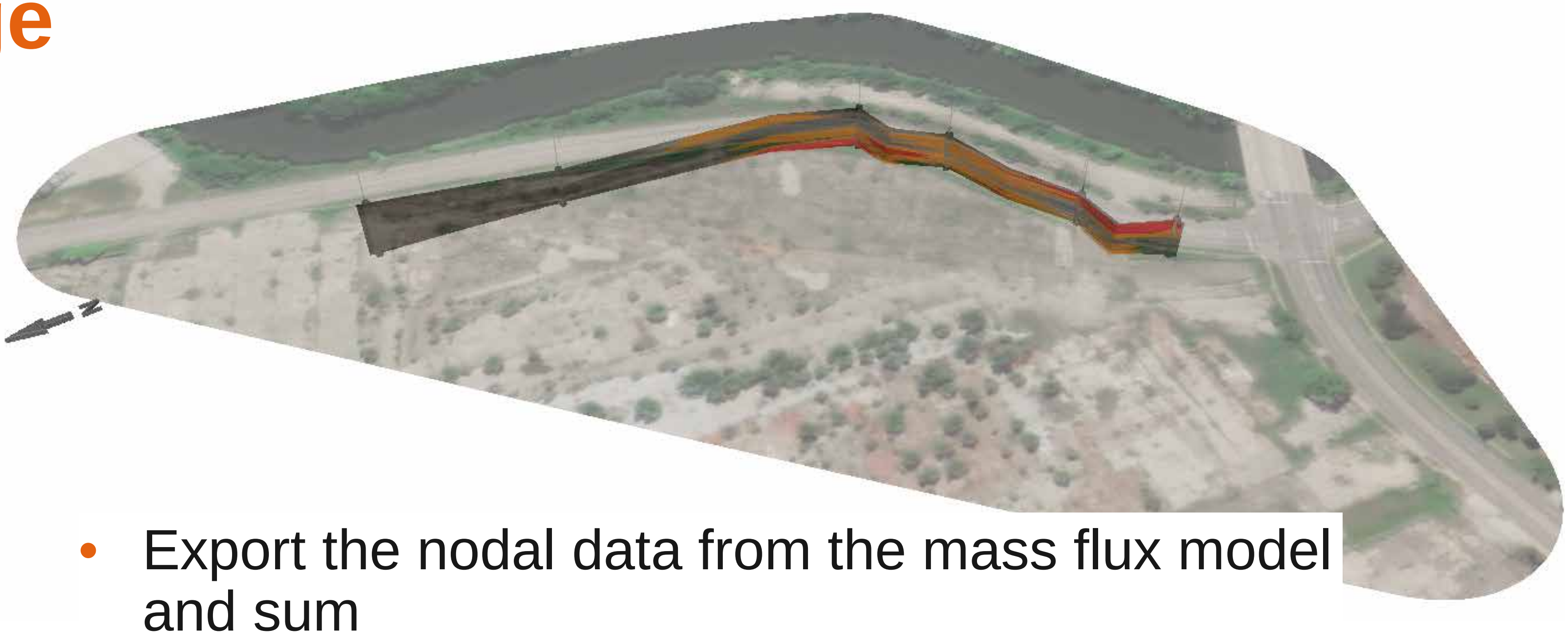
- Incorporate hydraulic gradient to estimate mass flux

Majority of mass flux occurs in two discrete zones

Mass Discharge

$$M_d = \int_A J\, A$$

(mass/time)



J = Mass Flux
(mass/time/area)

A = Total area

- Export the nodal data from the mass flux model and sum
- Groundwater Discharge: 24 gpm
- PFOS Mass Discharge: 0.05 mg/day

Background Loading in River: 10,000 mg/day

PFAS Special Considerations

Organic Carbon Partitioning

- Inhibits migration, particularly for longer chain PFASs

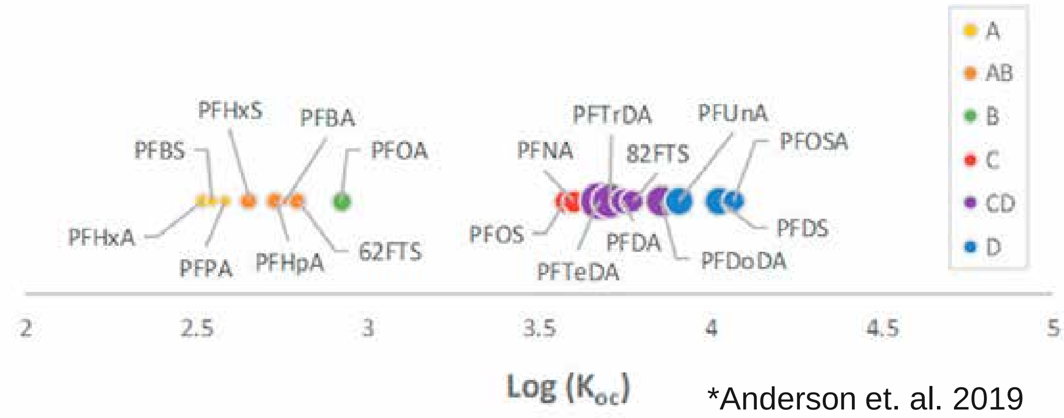
Electrostatic Interaction

- Partitioning in vadose zone due to electrostatic interaction

Air-Water Interface

- Mass storage in phreatic zone - unconfined aquifers,
  - dry or deep environments with limited flushing

Apparent Log(K_{oc})

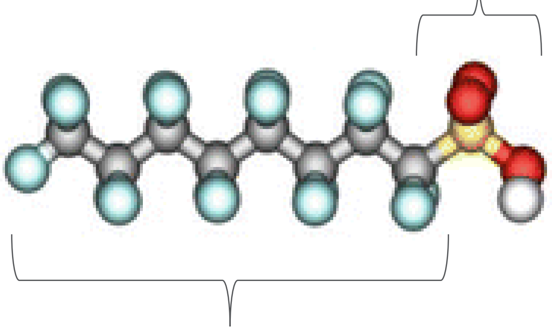


*Anderson et. al. 2019

PFOS

Hydrophilic

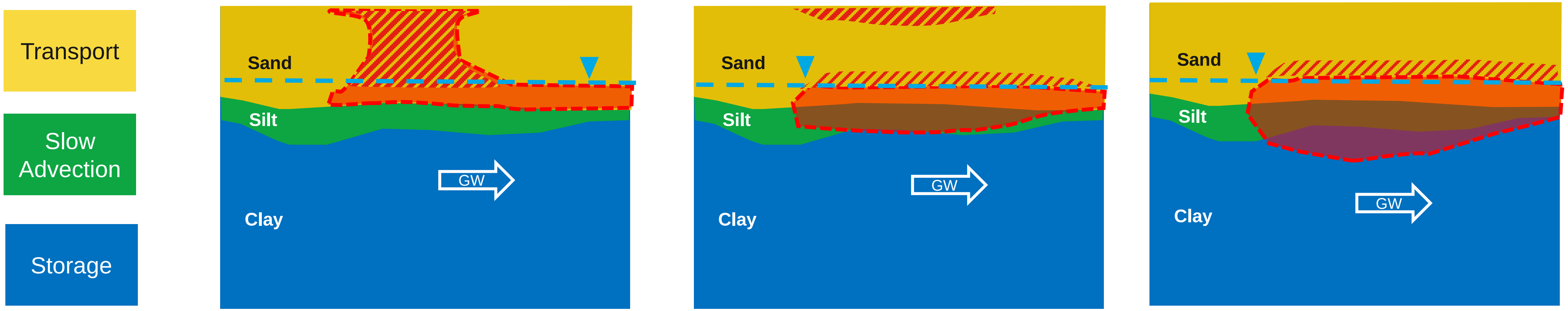
(-)



Hydrophobic

Understanding Mass Distribution

Source Age: New | Moderate | Mature



Remediation: Hard | Harder | Hardest

Hard

Flux in transport zones:

- Vadose Zone
- Phreatic Zone
- Minimal back-diffusion
- Source Removal/Capture & Treat/Stabilize

Harder

Flux in transport /slow advection:

- Mass flux in slow advection potentially significant
- Back diffusion from silt ongoing issue

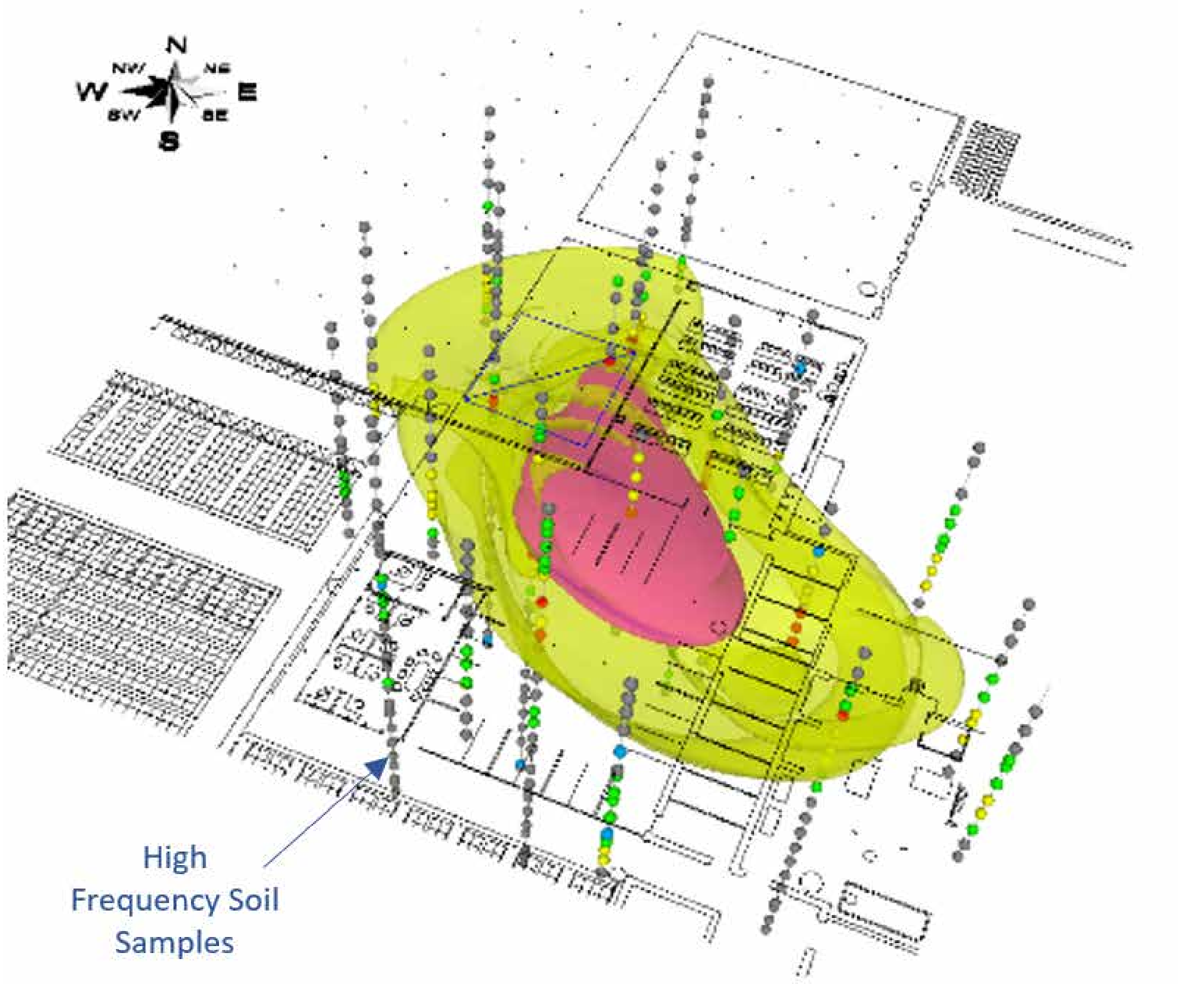
Hardest

Mass distributed across all hydrofacies:

- Significant mass in storage zones and along plume
- Options for source removal limited

Adaptive Approach

- Adaptive grids & transects
- High resolution soil and groundwater sampling
- *Mobile Laboratories* for real-time decision making



TCE in Soil

> 3 ppm

> 100 ppm

An adaptive approach reduces cost by eliminating unnecessary borings and reducing mob/reporting cycles

PFAS Mobile Lab

Pace Analytical Services

- DoD ELAP accreditation
- Soil and groundwater
- Modified USEPA 537
- DoD QSM 5.1 Compliant
- Single digit ppt detection limits
- 20 to 30-minute turnaround times
- 20 to 30 samples per day throughput

PFAS Mobile Lab - Exterior

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PFAS Mobile Lab - Interior

Shimadzu Model 8050 LC/MS/MS

Gerstel Robotic Multi Purpose Sampling DI/SPE

Equipment refitted to eliminate fluoropolymers (blanks free of contamination)

Nitrogen Generator

20kW diesel Generator

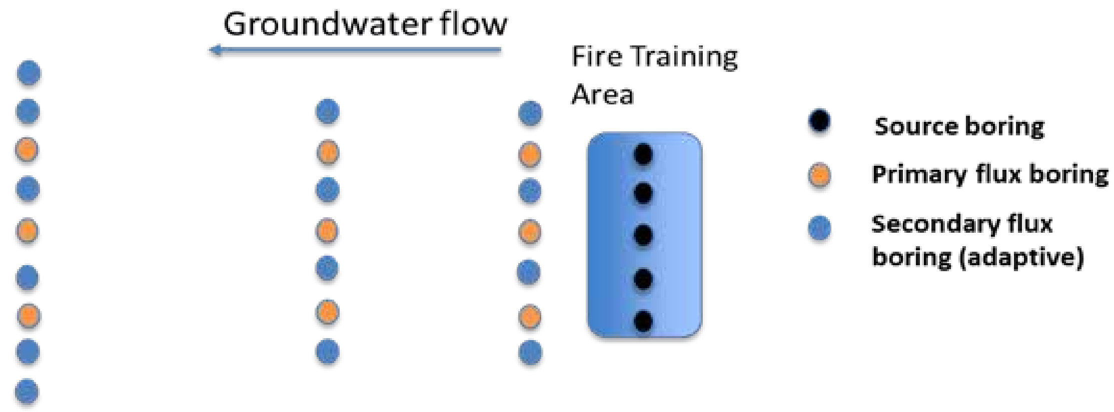
Completely self-contained lab

ESTCP Project –

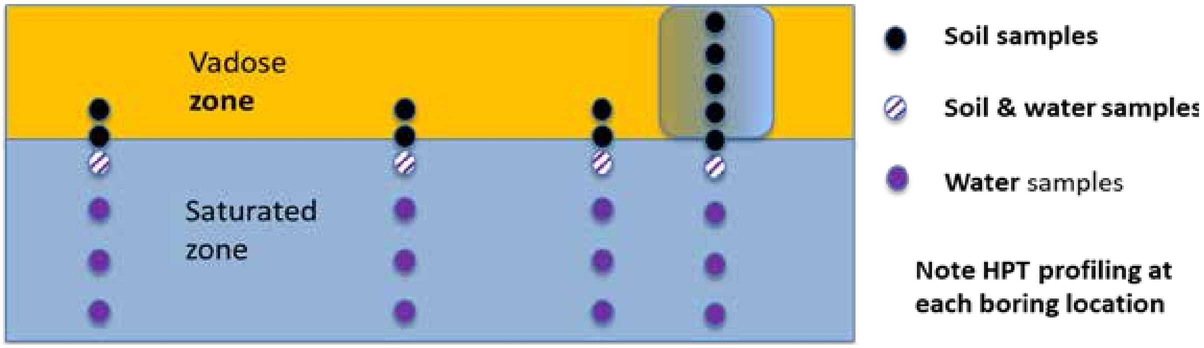
Validation of Streamlined Mobile Lab Methods for Real-time PFAS Characterization

- **Hydrostratigraphic Profiling**
  - Identify storage versus transport zones via HPT
  - Mass flux analysis
- **High-Frequency Sampling**
  - Vadose/Phreatic zone - soil/lysimeter
  - Low permeability – soils
  - High permeability – groundwater
- **Adaptive**
  - Primary locations to bound plume
  - Adaptive locations to “zoom in”

Plan View



X-Sec



ESTCP Analytical Validation

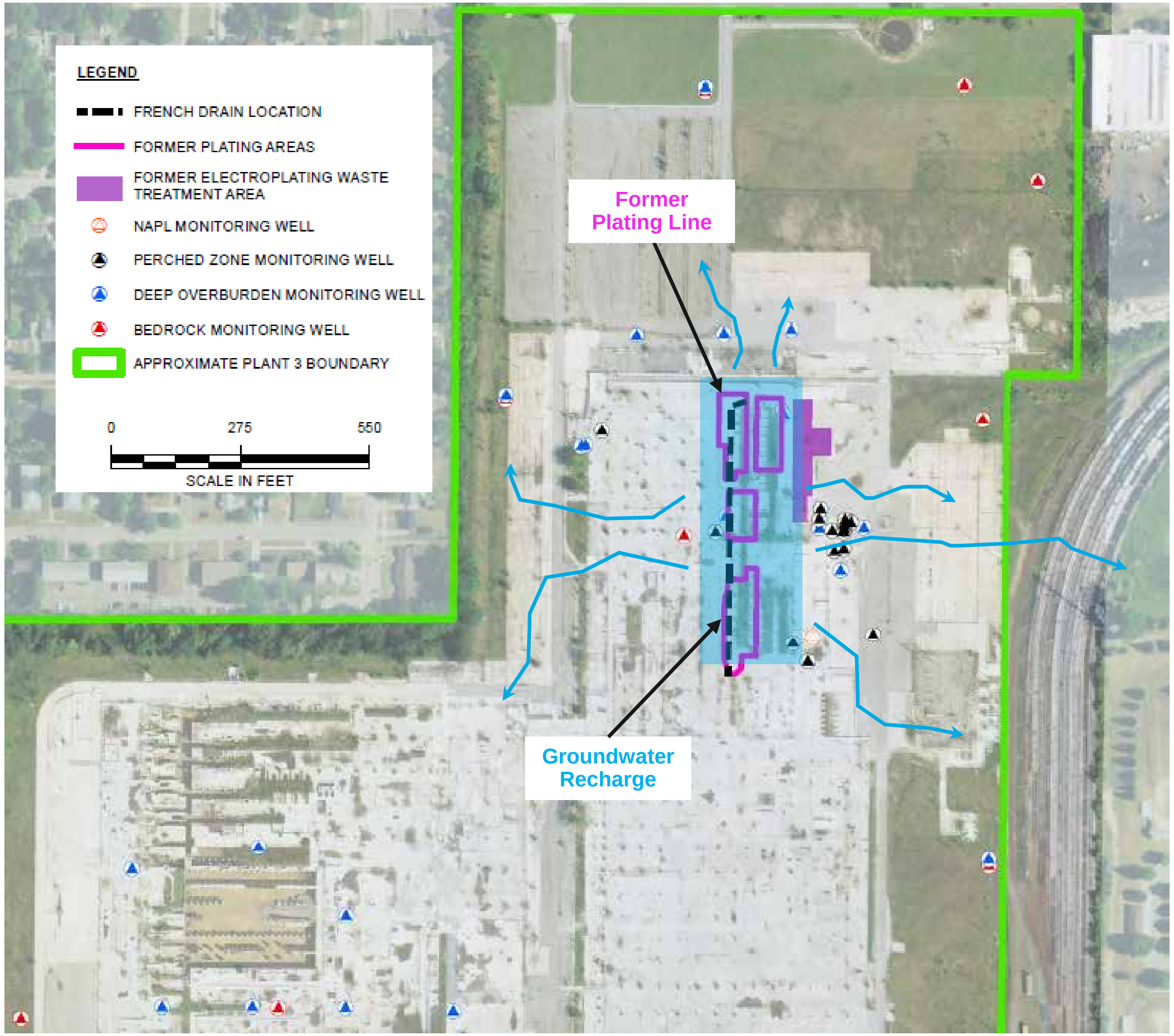
- **Quantitative**
  - Standard Method 537 DoD QSM 5.1 for 24 PFAS via mobile lab
- **Semi-Quantitative**
  - Accelerated on-site PFAS analyses using in-line SPE LC/MS/MS for limited site-specific analytes
- **Qualitative**
  - Screening PFAS Analyses using Methylene Blue Active Substances (MBAS)

Site Selection - Grayling Army Airfield

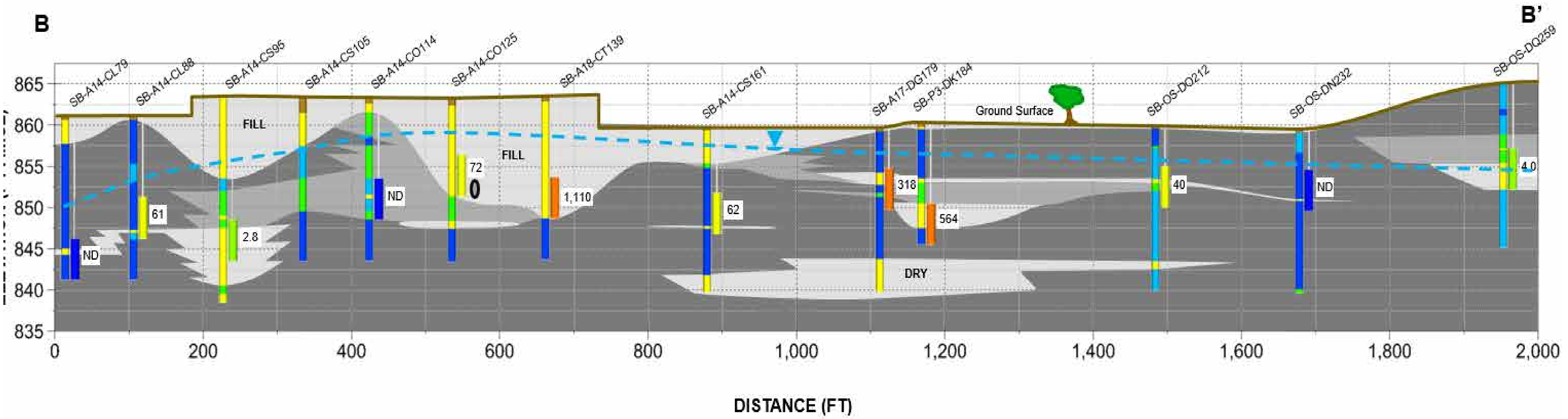
RACER Trust
Lansing, Michigan

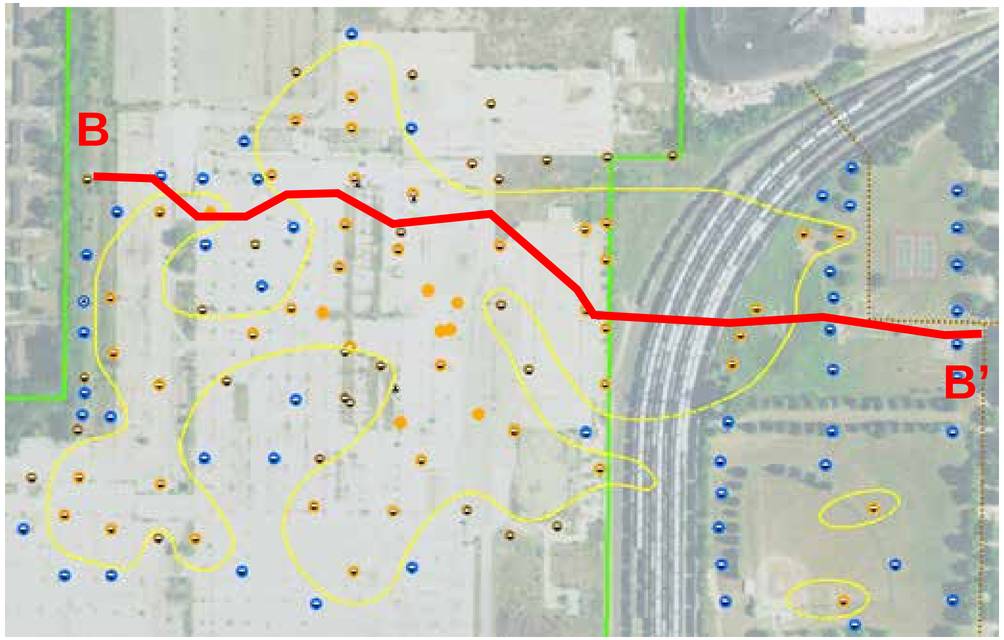
Former Automotive Plating Line:

- PFAS used as part of plating mist suppressant system
- Detections of PFAS in existing wells in 2017
- PFAS Mobile Lab for Adaptive Delineation



Site Geology





Generalized Hydrostratigraphy

- Transport (Sand/Gravel)
- Slow Advection (Silt/Sandy Silt)
- Storage (Clay/Glacial Till)
- Approximate Water Table
- Groundwater Sample

PFOS

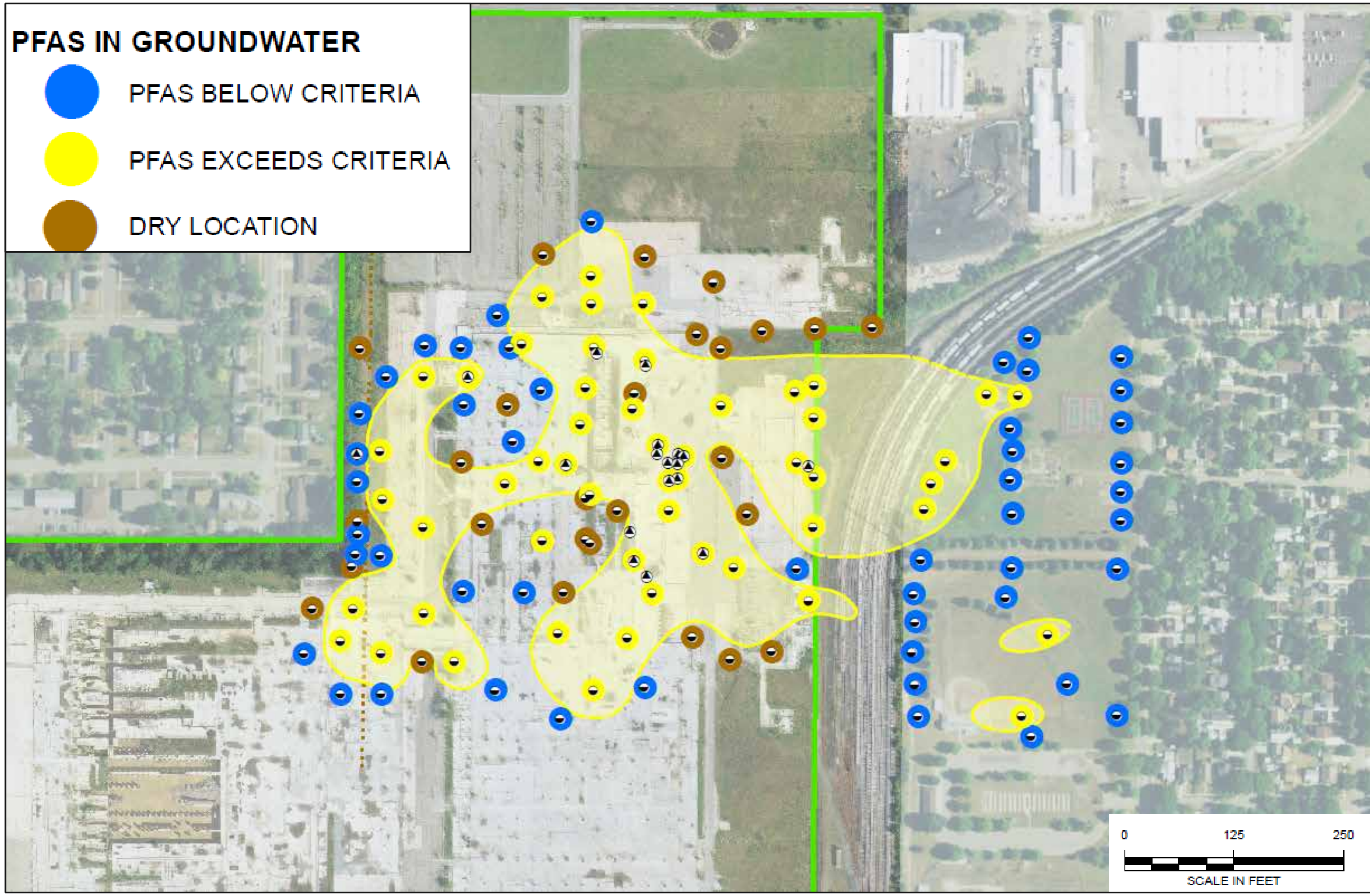
- >14000
- 10,000
- 1,000
- 100
- 10
- <1

PFAS Delineation

Used an adaptive grid and PFAS Mobile Lab

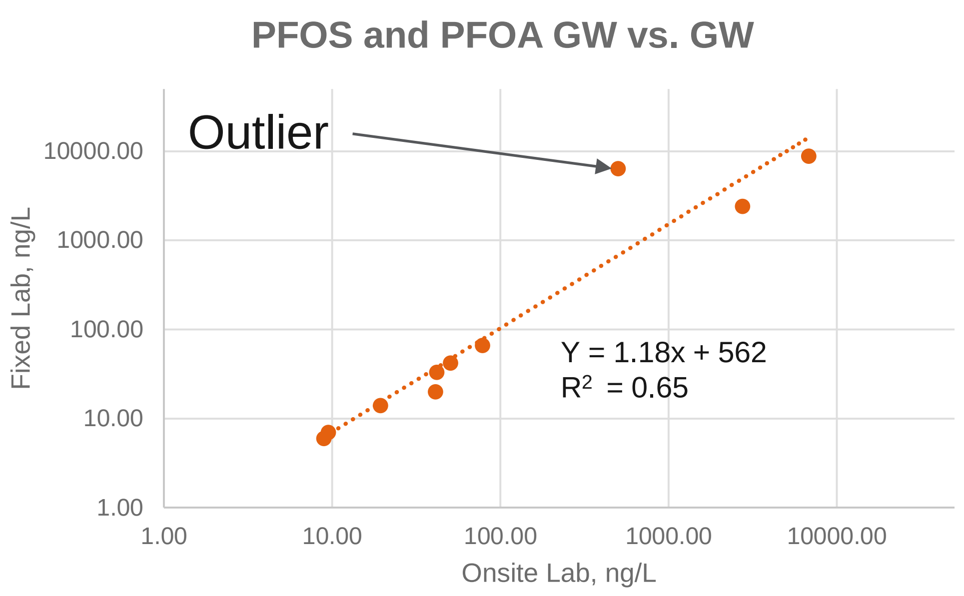
Two mobilizations; on-site, off-site

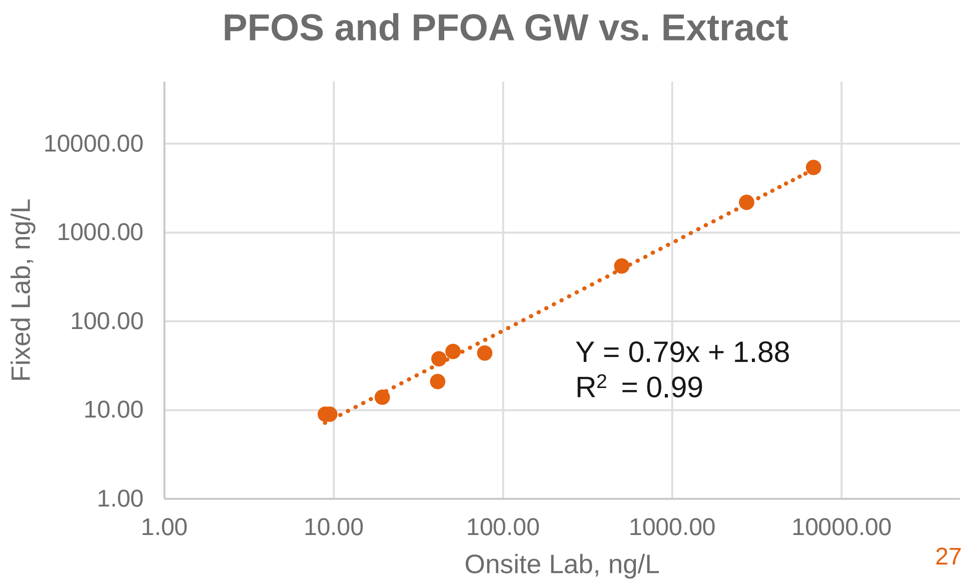
- >100 Groundwater Samples
- Total field time of 3-4 weeks



PFAS Mobile Lab / Fixed Lab Data Comparison

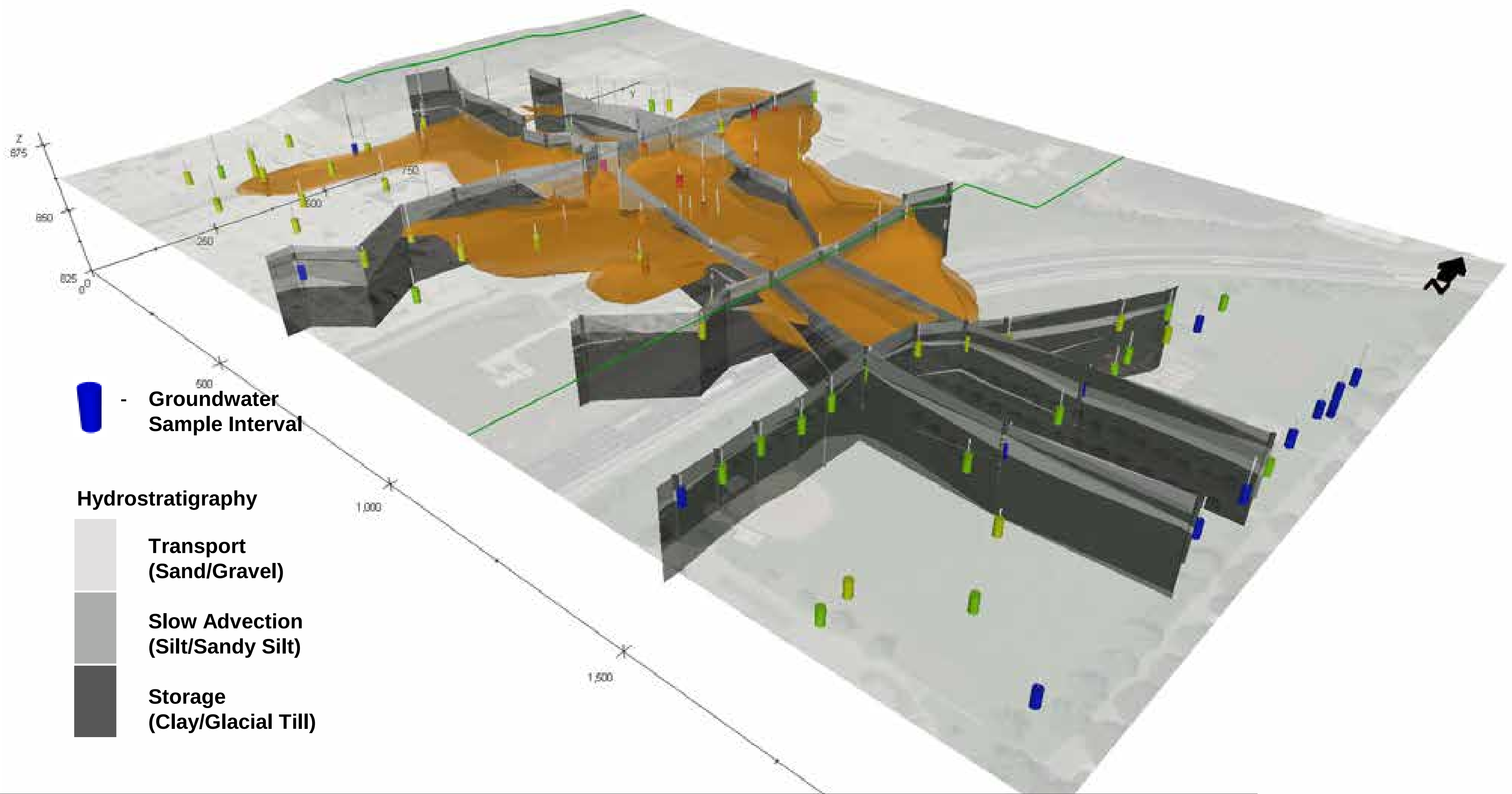
PFOS and PFOA				
Mobile Lab GW, ng/L	Fixed Lab GW, ng/L	Fixed Lab Extract, ng/L	RPD - GW vs. GW	RPD - GW vs. Extract
2740	**2400**	**2200**	13	22
6800	**8800**	**5400**	26	23
9	**7**	**9**	30	5
51	**42**	**46**	18	9
501	**6400**	**420**	171	18
42	**33**	**38**	24	10
41	**20**	**21**	69	65
9	**6**	**9**	39	1
19	**14**	**14**	32	32
78	**66**	**44**	17	56
		Averages	**36**	**33**





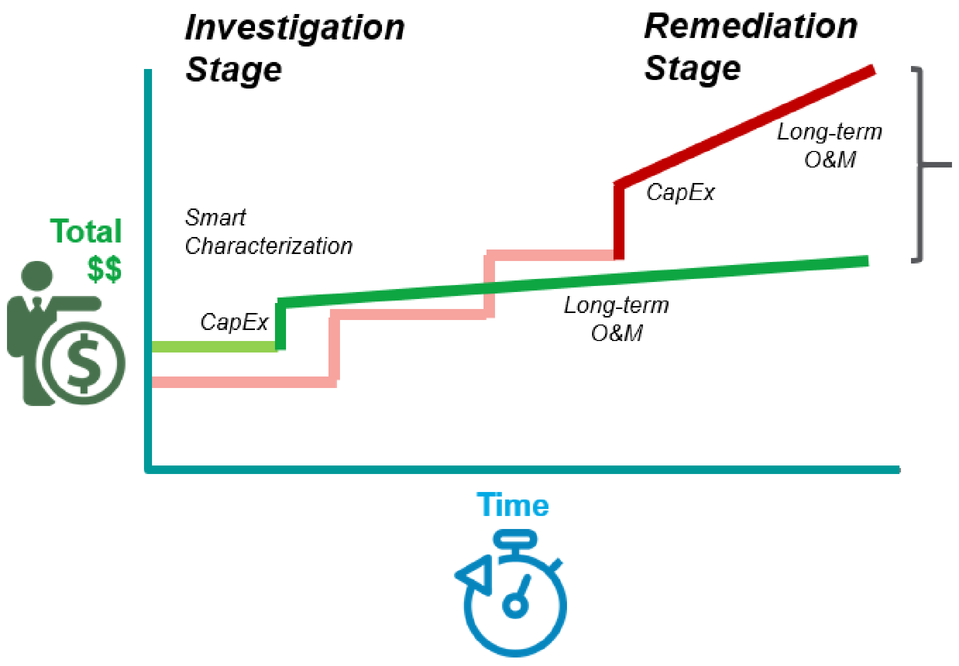
3D Hydrostratigraphic Model

Used data to installed 15 monitoring wells in key locations



Delineation Completed Efficiently with Long-term Reduction in Monitoring Costs

Key Takeaways



ROI - Reduced total life-cycle costs

Return on Investigation

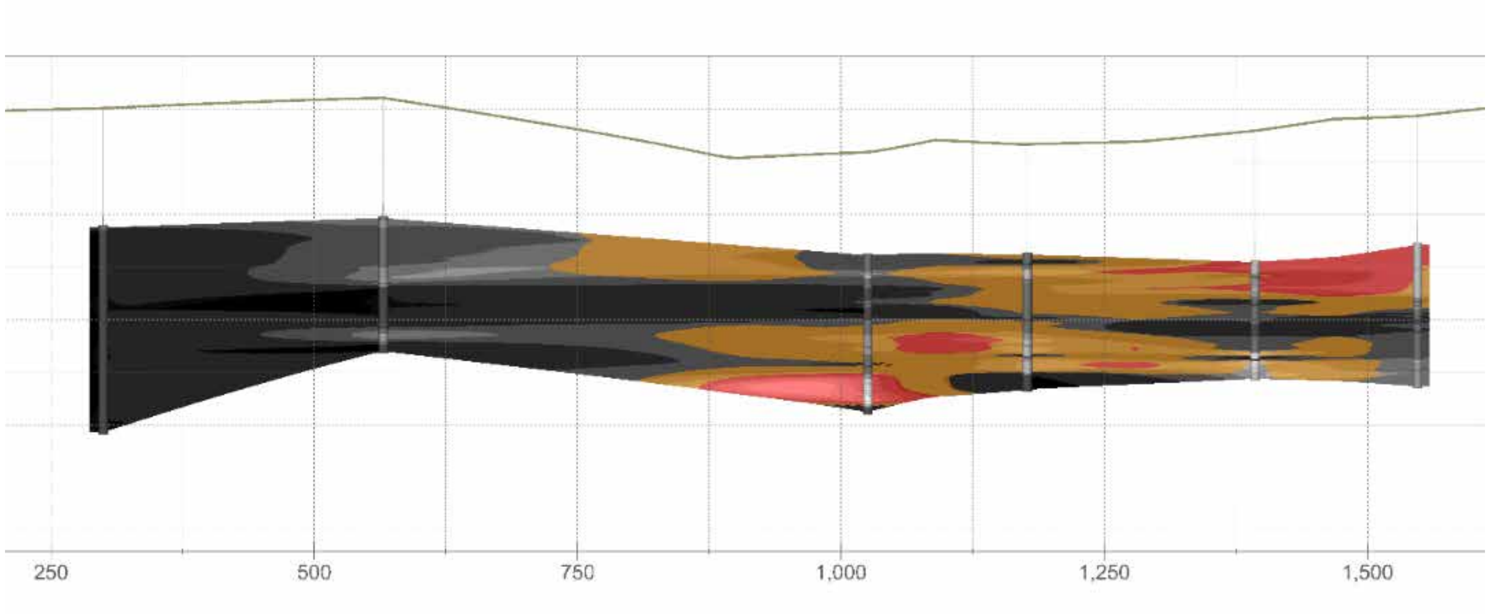
Cheaper, faster, better

Flux Based CSMs

Mass distribution

Better monitoring strategies

Informed remedies



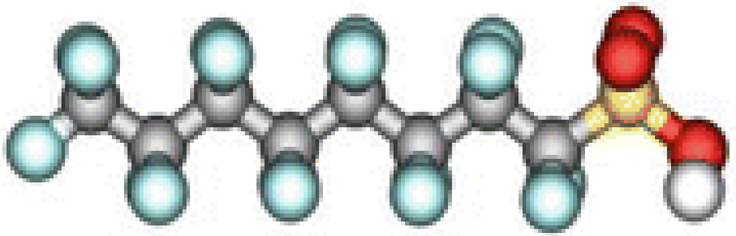
Key Takeaways

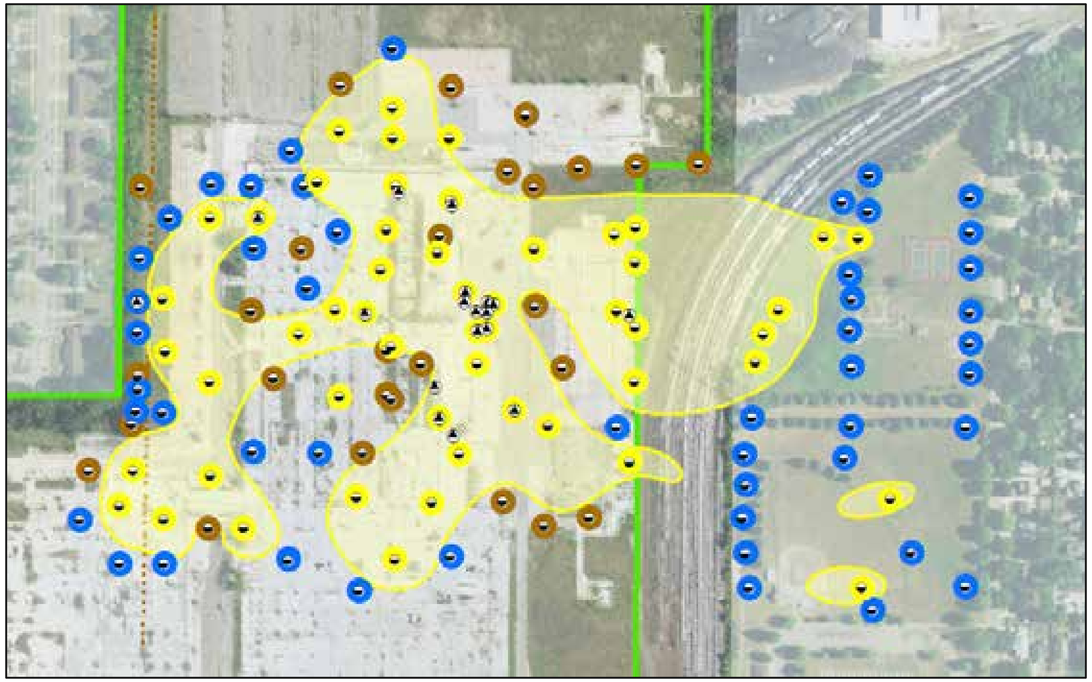
Adaptative Investigations

PFAS Mobile Lab = Real-time data

Focused data collection

Better CSM





Questions?

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