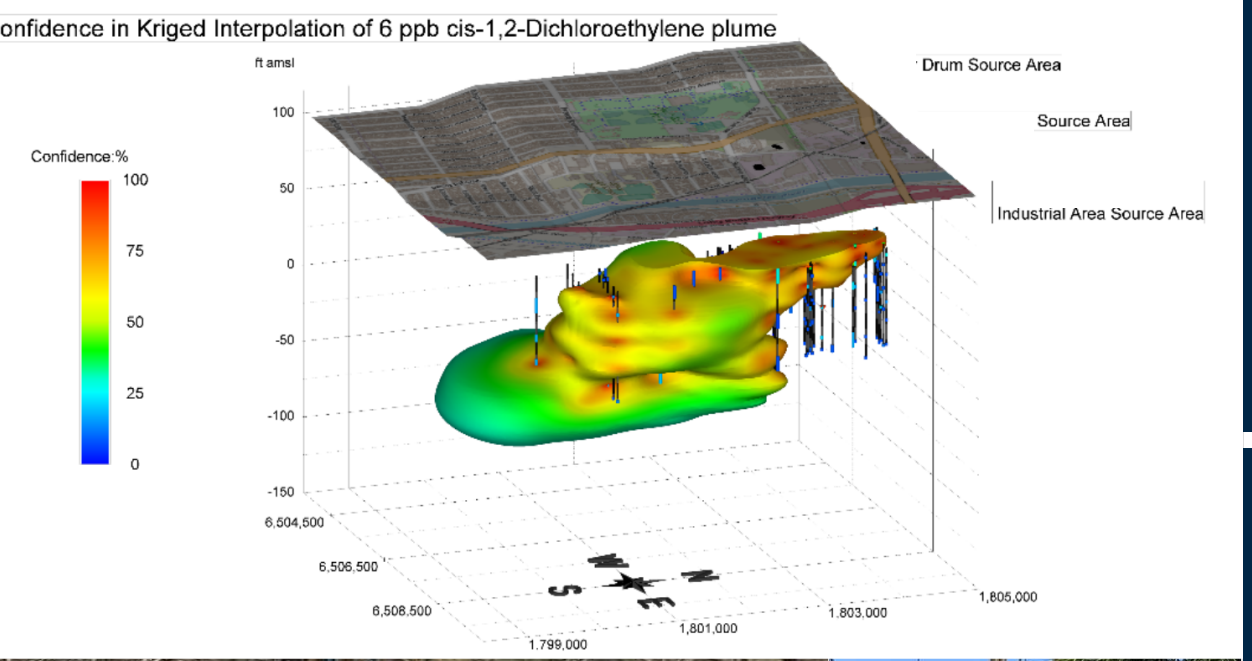

Immediate Benefits from HRSC Techniques for Three PFAS Investigations

Prepared for:

Sixth International Symposium on Bioremediation and Sustainable Environment Technologies

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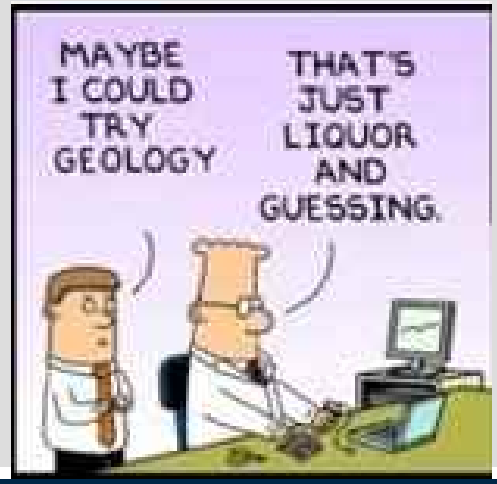
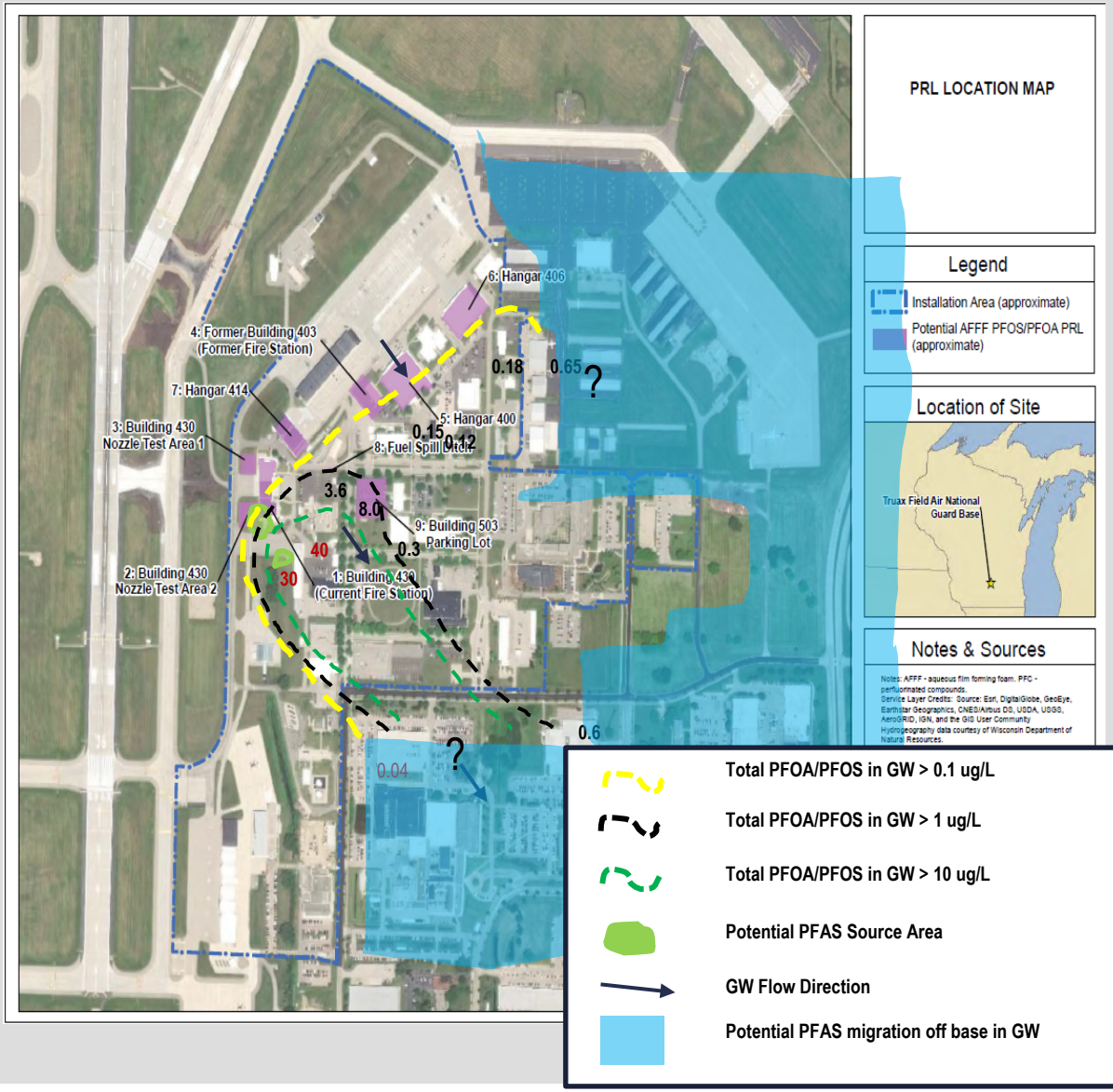
Introduction/Agenda

- Prior to 2020, HRSC generally used for recalcitrant sites
  - 80 percent of the mass transports through 20 percent of the aquifer
  - Matching investigations with the variability of the subsurface
- Contract types (FFP, PBC) have had limited use of HRSC
- PFAS has driven the need for HRSC to better understand plume sources, pathways, and geometry
- Three case studies where adaptive investigation phasing utilizing HRSC has been incorporated at active PFAS RI sites
  - Upper Midwest US site in glacial terrain
  - Central US site in a major river floodplain
  - Western US site in a semi-arid environment

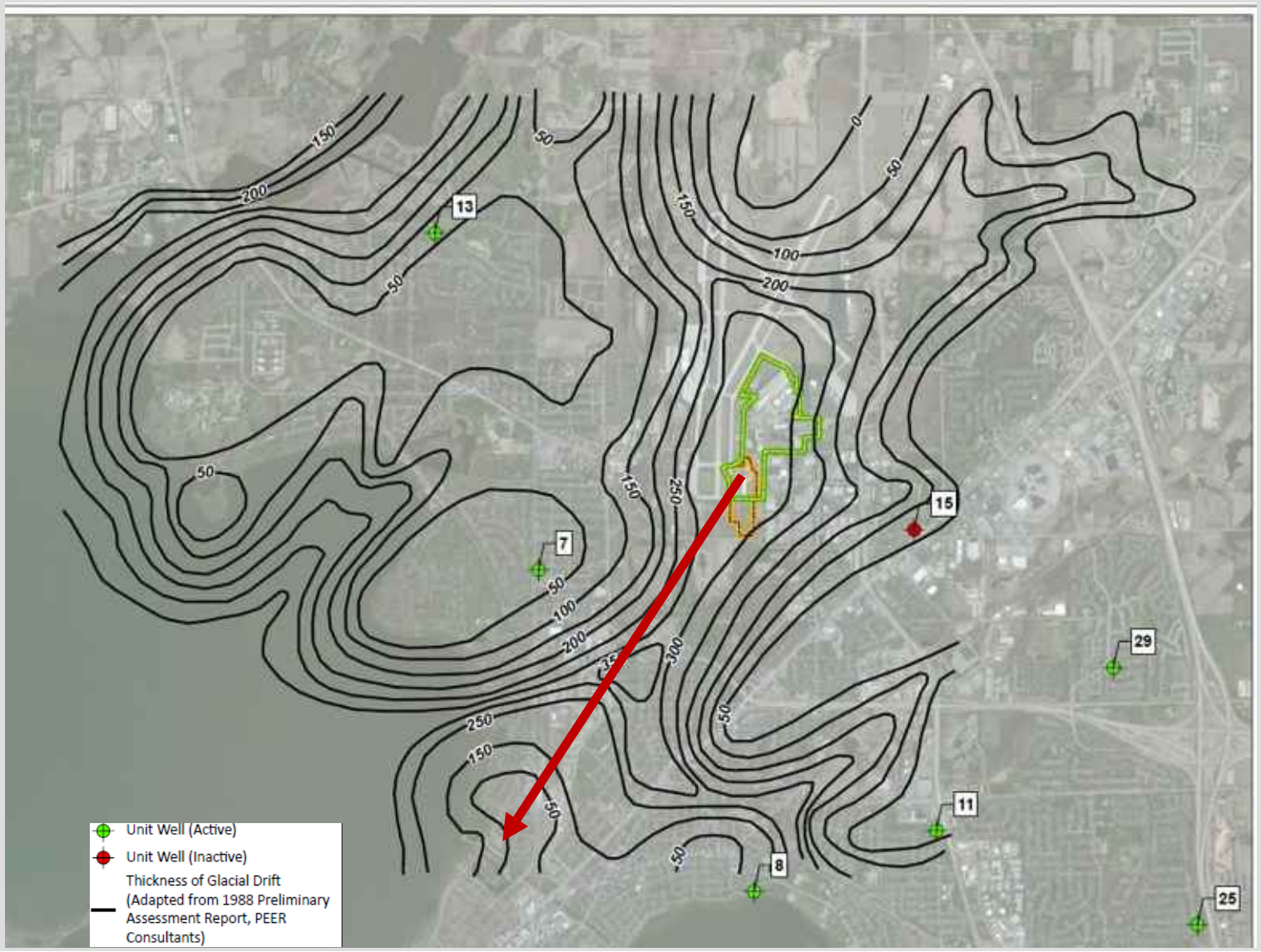


Case Study No. 1 – Upper Midwest Site

- DoD airfield in unconsolidated glacial and lacustrine sediments
- Regional groundwater pumping has/does affect groundwater flow direction
- Contracted under a FFP contract for a PFAS Phase I Remedial Investigation
- 9 identified PFAS release areas
- Limited historical investigation information available (PFAS SI was the last environmental investigation)



Case Study No. 1 – Upper Midwest Site



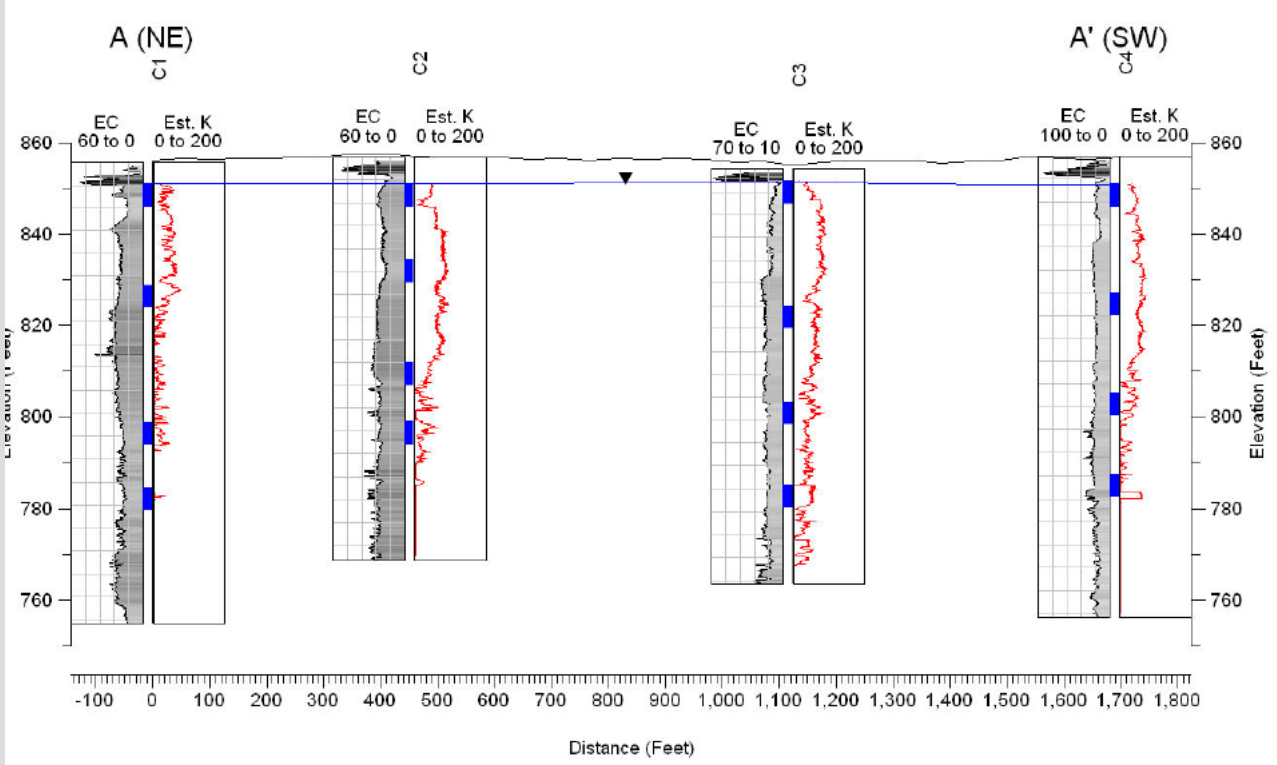
ESS analysis during proposal phase

- Glacial valley oriented southwest versus previously assumed groundwater flow direction
- Unclear direction of GW flow/PFAS migration
- Flexibility added to the design of sampling program

Case Study No. 1 – Upper Midwest Site

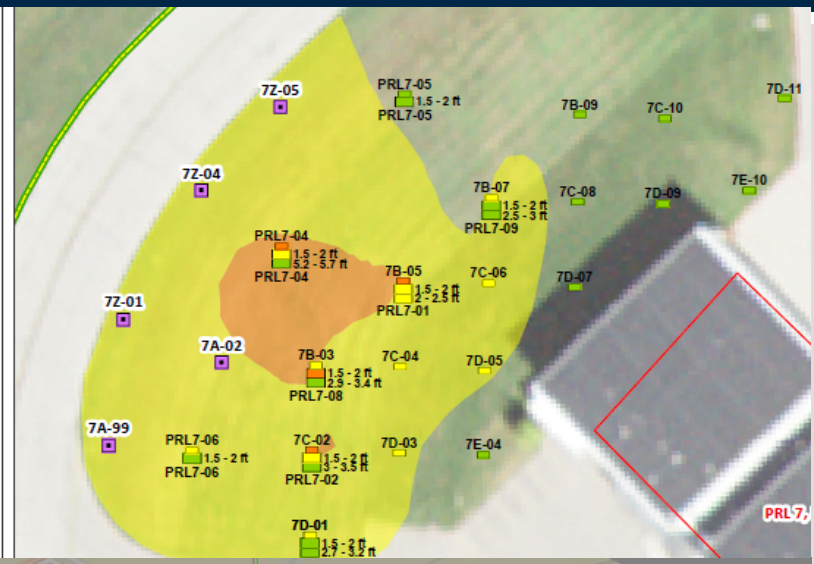
Adaptive Sampling Strategy Design

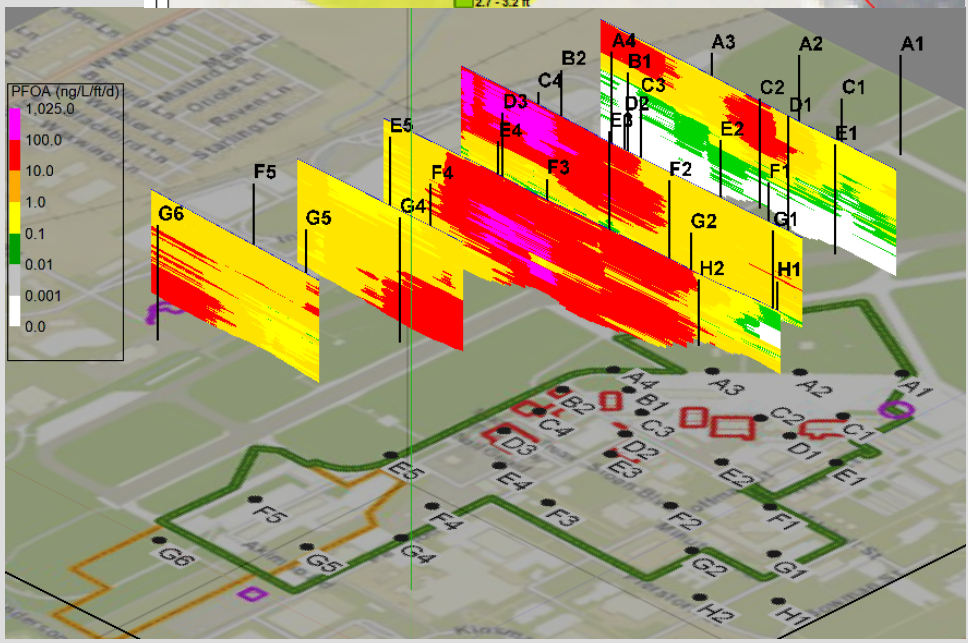
Media	Sampling Method	Analysis	Total Samples	Other Notes
Surface Soil	Grid approach	Definitive	229	PRL saturation sampling
Subsurface Soil	DPT Borings	Definitive	82	Selected based on surface soil sample results
Aquifer	DPT Borings	HPT/EC	65	
	Aquifer Profiling	Screening Level	251	~4 samples/VAP (PFOA/PFOS/PFBS)



Case Study No. 1 – Upper Midwest Site

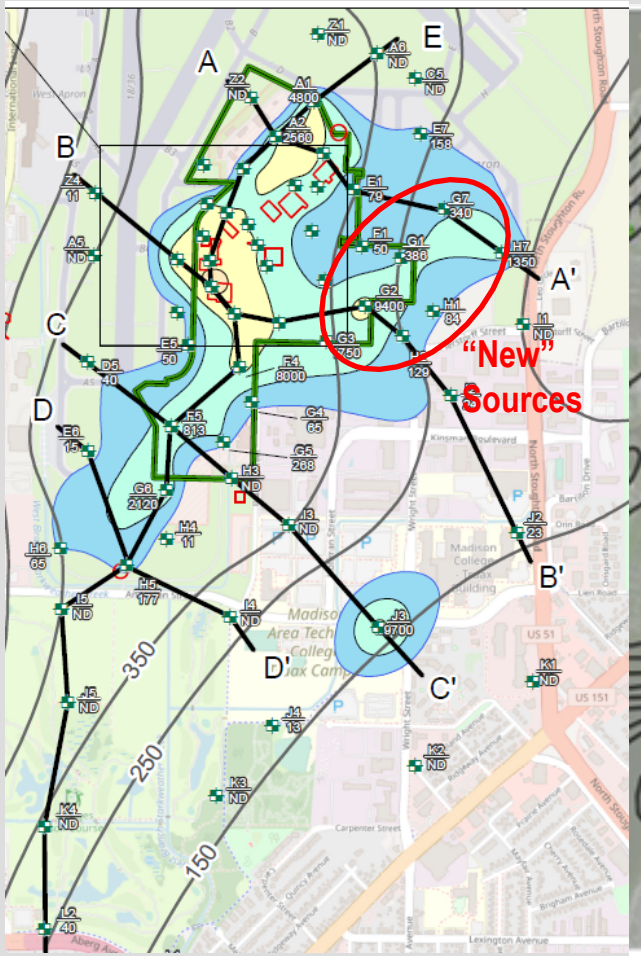
- Dense/grid approach soil sampling performed to identify PFAS actual release points
- Groundwater sampling design flexible to move in either direction (SE or SW)
- HPT/EC used to identify potential preferential flow paths for downgradient sampling
- Frequent data presentations to project team

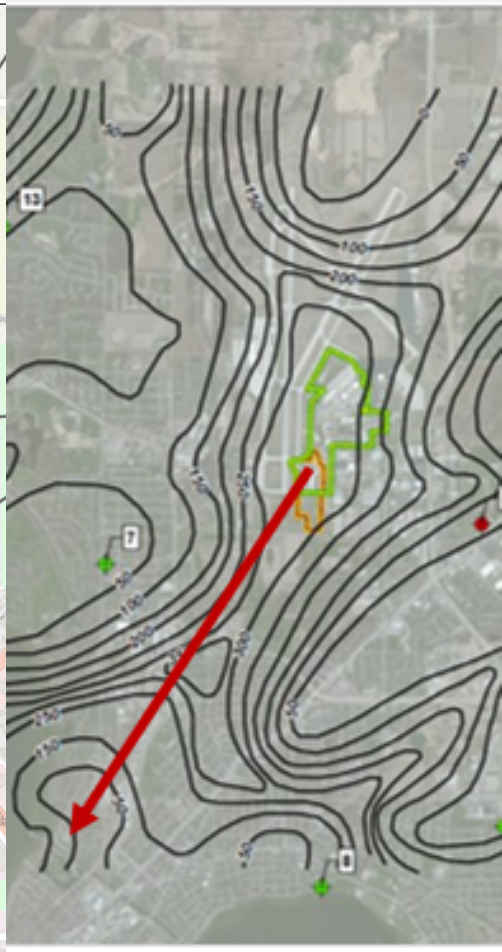




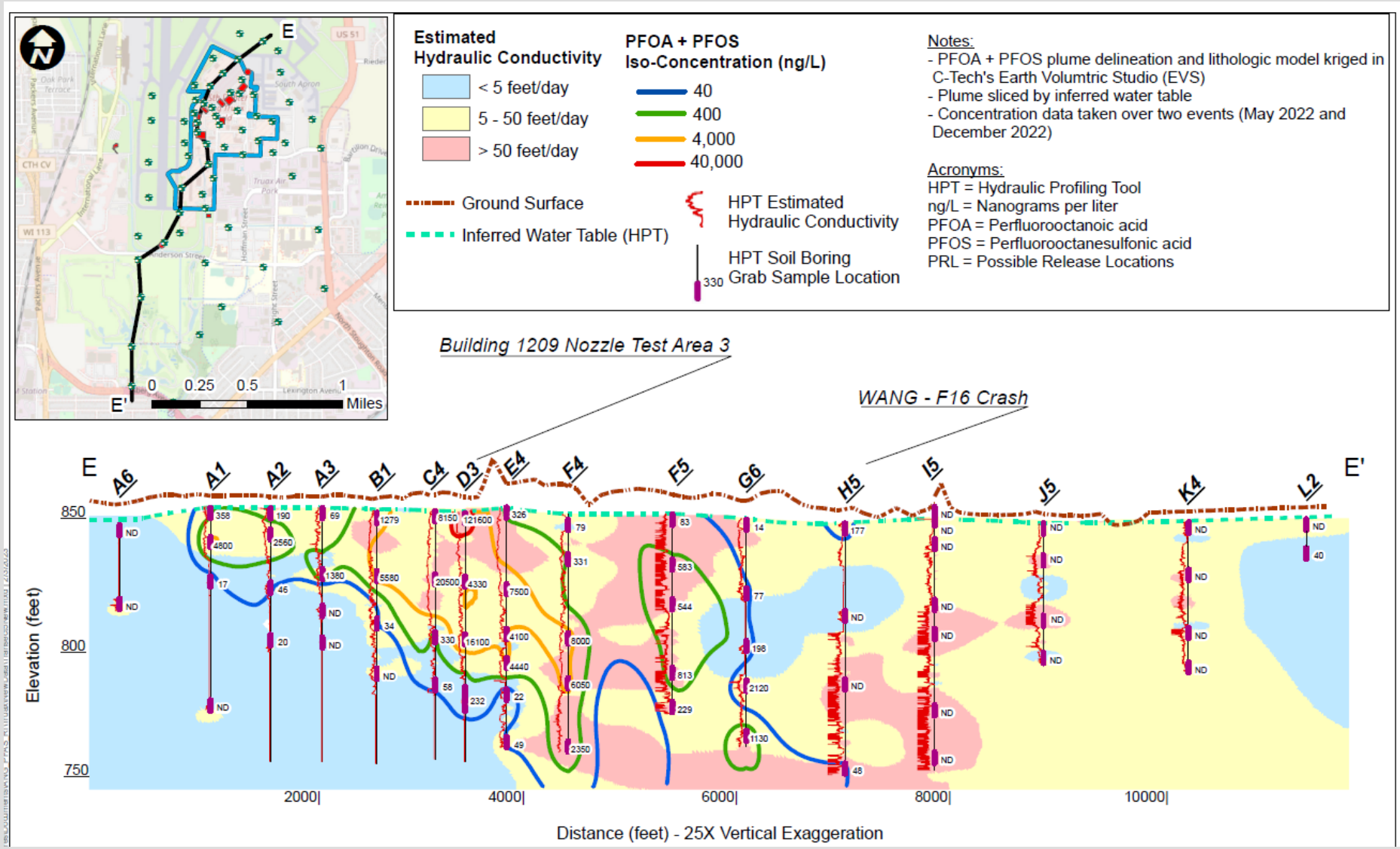
Case Study No. 1 – Upper Midwest Site

- Groundwater flow direction – used DEMs and HPT/EC results to determine groundwater elevation and water table
  - PFAS follows the glacial channel
  - Former active production well likely modified natural groundwater gradient to southeast seen in the SI
- Transect sampling approach identified two additional sources of PFAS
  - Former operational testing areas
- Vertical migration of PFAS significant
  - > 100 ft bgs





Case Study No. 1 – Upper Midwest Site

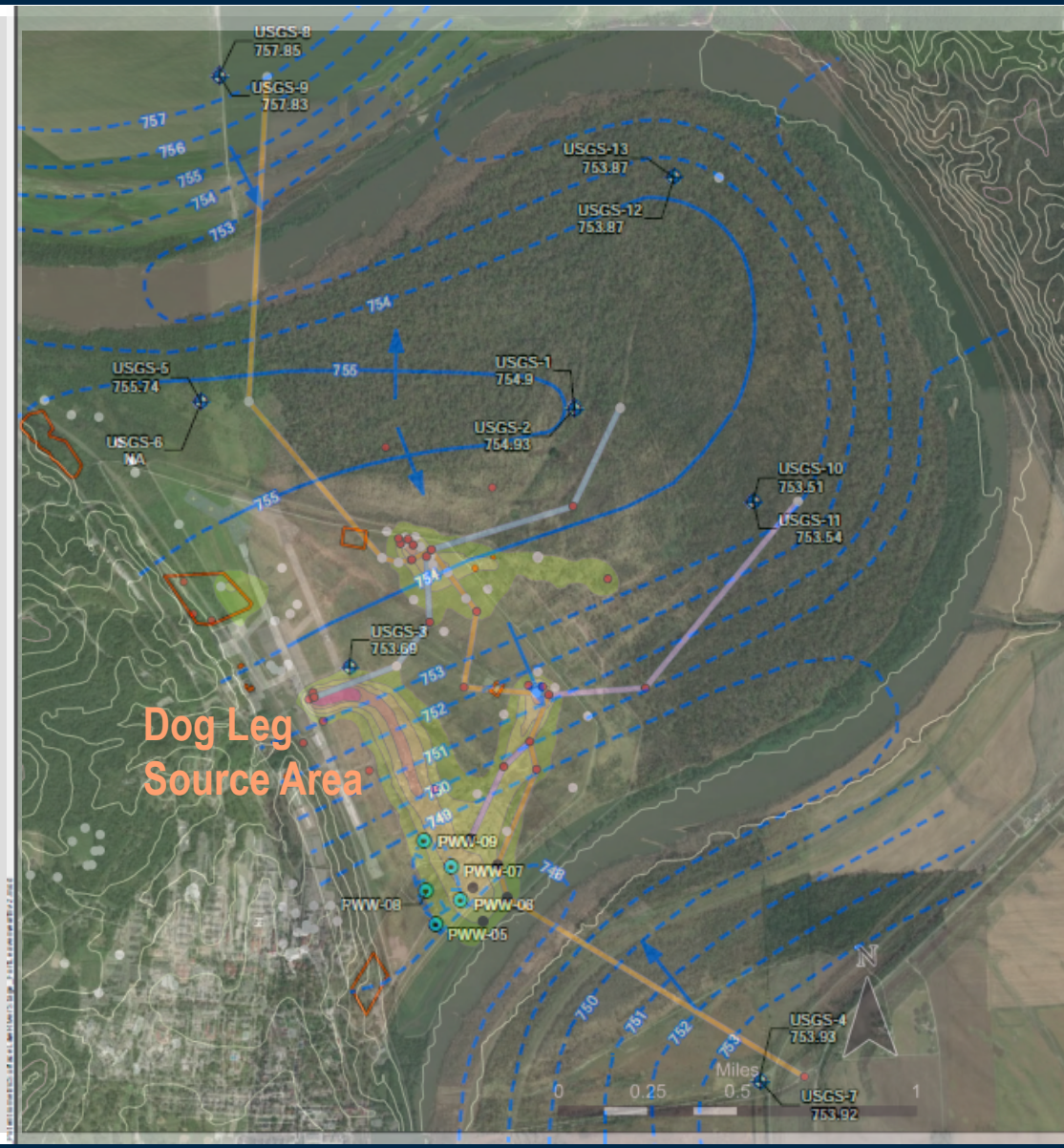


Advantages:

- Quickly modified the main characterization axis
- New source areas identified
- Reduces need for delineation wells – focus on monitoring locations
  - 26 MWs versus 50-100 MWs for pre-HRSC plumes

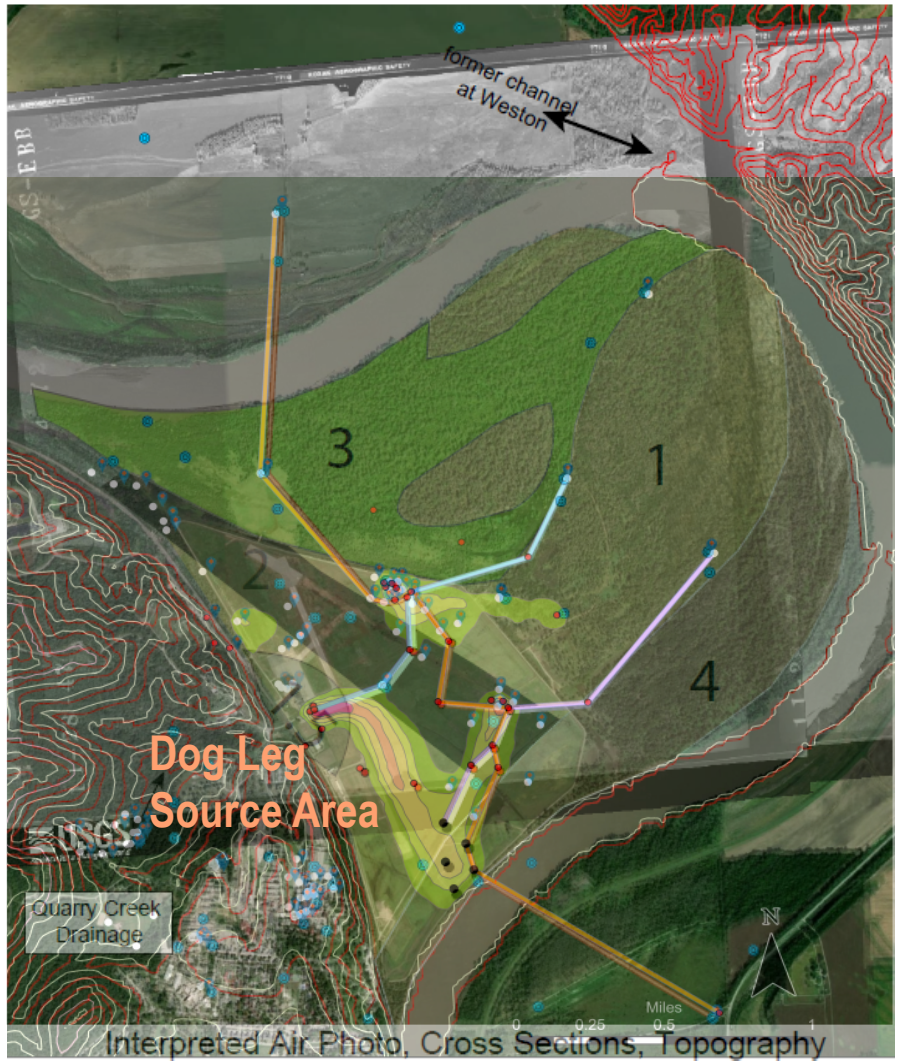
Case Study No. 2 – Floodplain Site

- DoD installation in floodplain of major central US river
- PFAS investigations performed prior to RI were significant (VAPs/wells)
- PFAS deep (100 ft bgs) – production wells
- Plume(s) shape/direction did not match the historical groundwater potentiometric surface
- Approach included ESS analysis (BMcD) and HRSC to enhance the CSM



Case Study No. 2 – Floodplain Site

- Groundwater pumping a sink for groundwater flow/plume migration
- ESS analysis to understand why plume doesn't match contours
  - Dog-leg right question – chute plug effect?
  - With pumping off, migration pathways altered?
  - Identify HRSC sampling locations to confirm and/or update the hydrostratagraphic model and delineate PFAS impacts

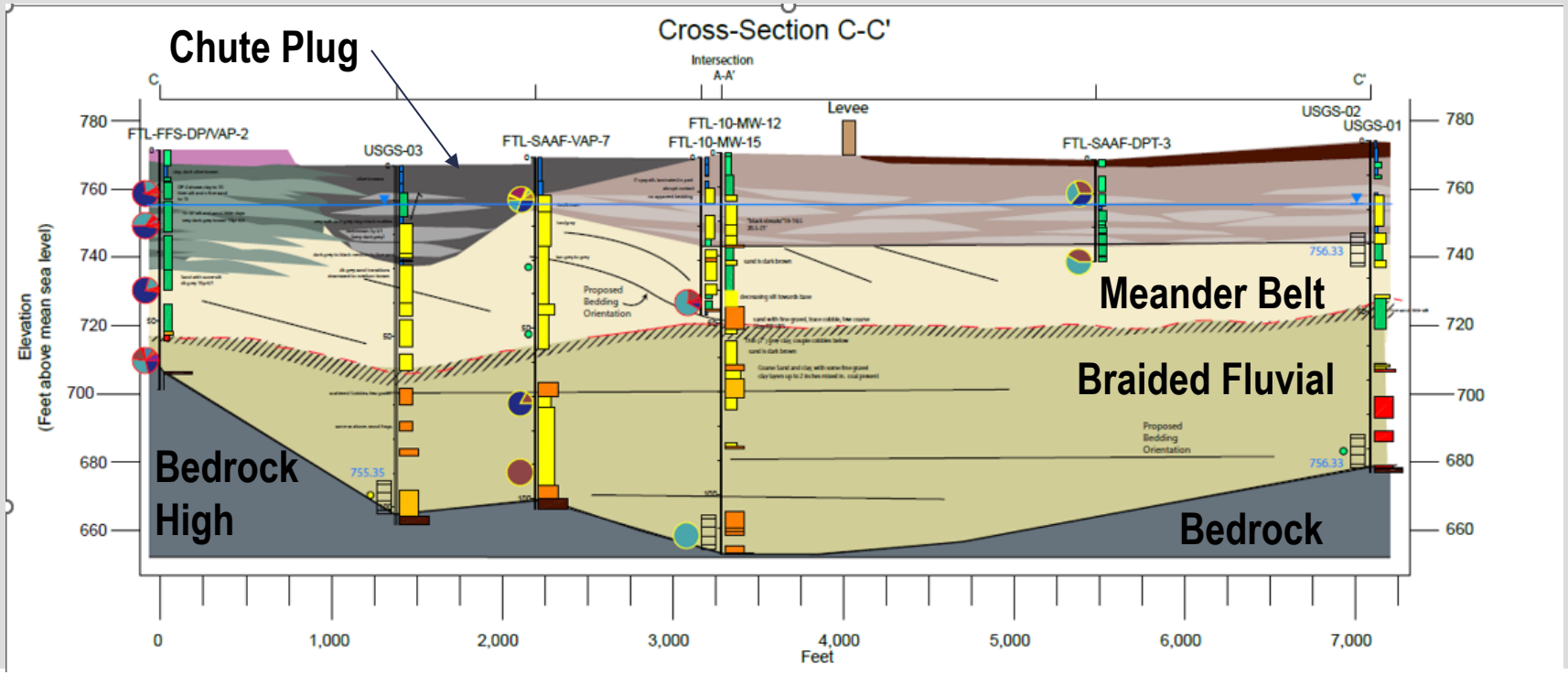


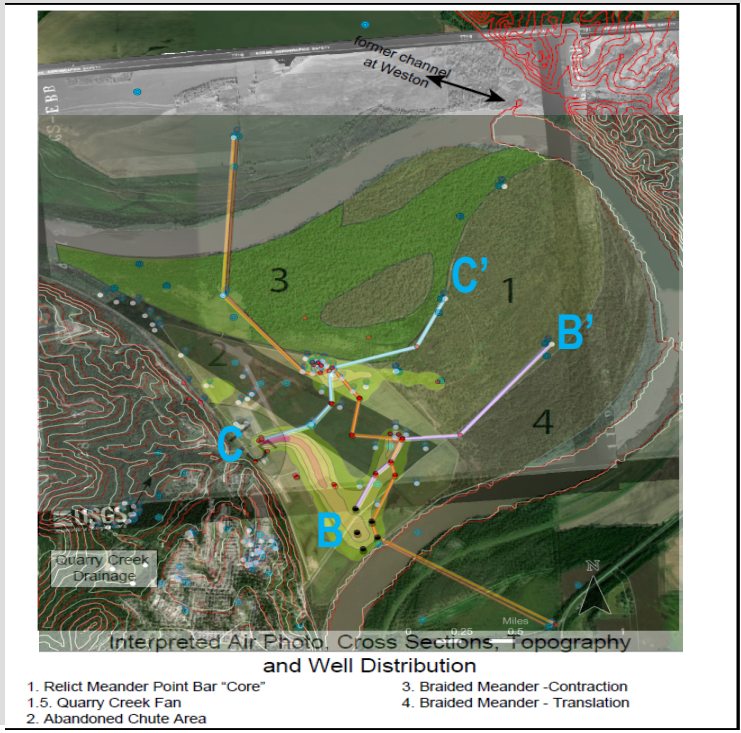
Interpreted Air Photo, Cross Sections, Topography and Well Distribution

1. Relict Meander Point Bar "Core"
1.5. Quarry Creek Fan
2. Abandoned Chute Area
3. Braided Meander -Contraction
4. Braided Meander - Translation

Case Study No. 2 – Floodplain Site

- Cross-section based on previous data (reinterpreted)
- Dog leg source is on a bedrock high – local groundwater to east
- Channel plug could deflect groundwater from dog leg source to the regional flow to SE

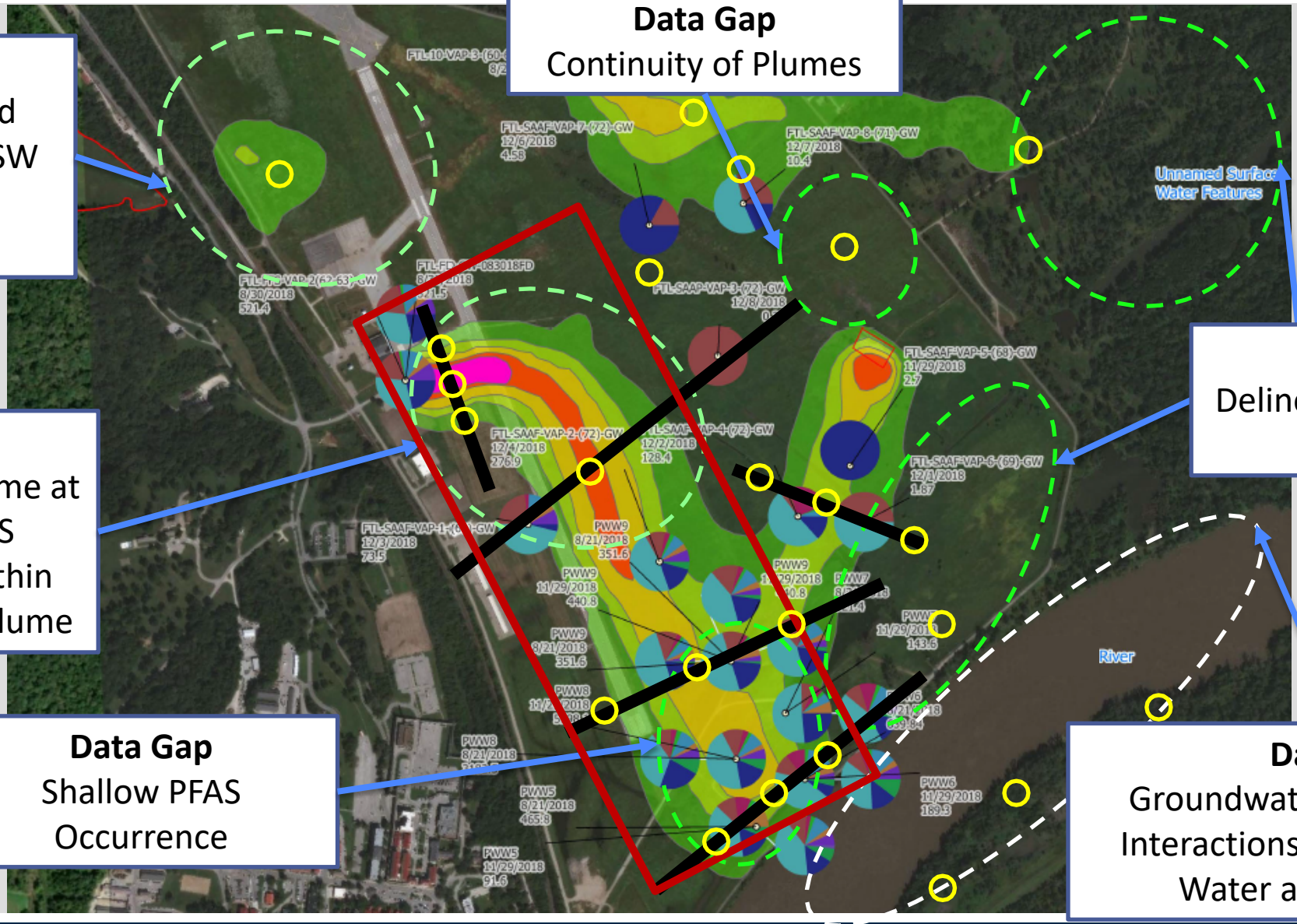




Case Study No. 2 – Floodplain Site

Data Gap
Plume Nature and Extent Related to SW Runoff and GW Contributions

Data Gap
Continuity of Plumes



Data Gap
Delineation Relative to the River

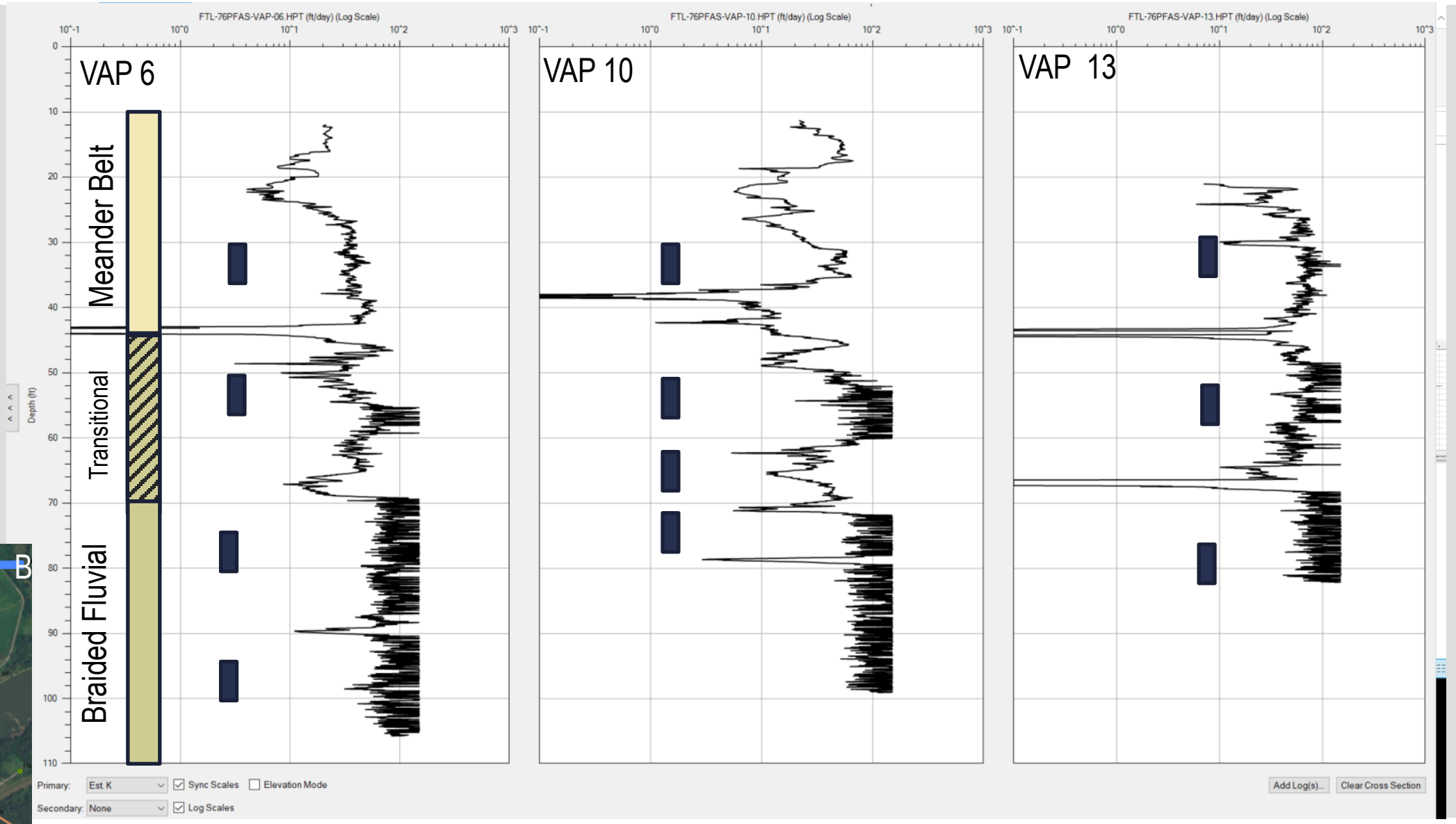
Data Gap
Delineation of Plume at Bend and PFAS Composition Within Core of Dog Leg Plume

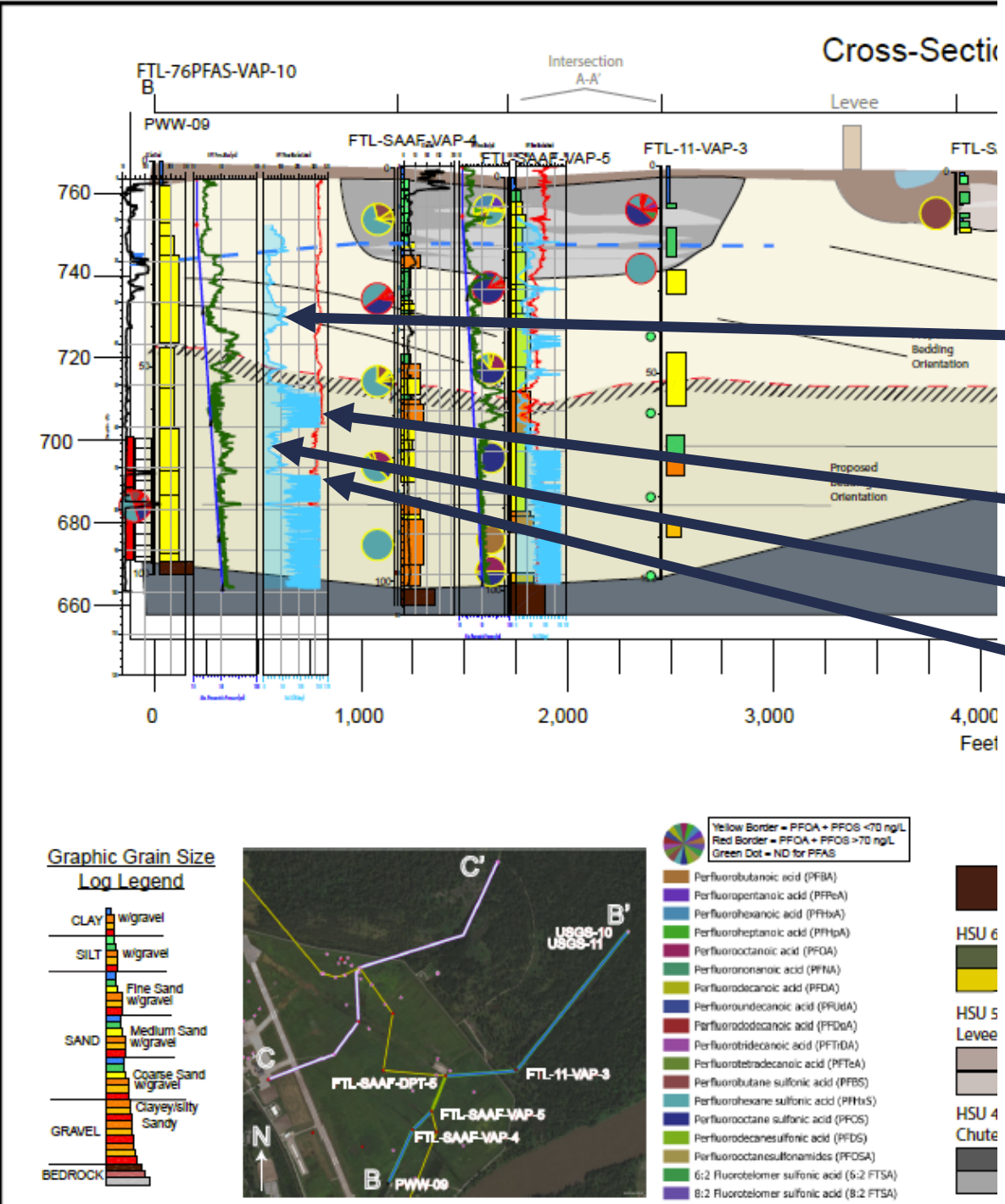
Data Gap
Shallow PFAS Occurrence

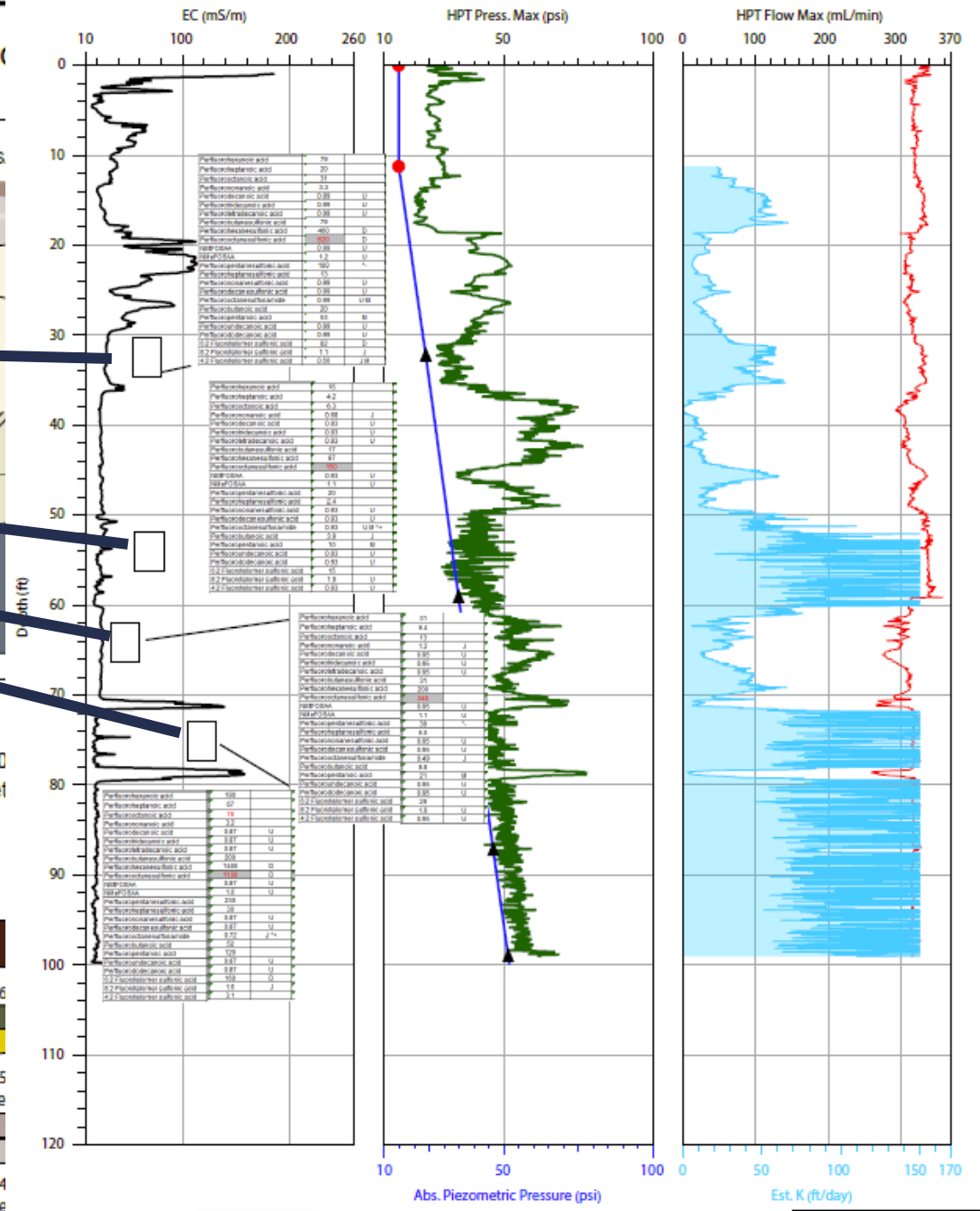
Data Gap
Groundwater Surface Water Interactions / PFAS in Surface Water and Sediments

Case Study No. 2 – Floodplain Site

- HPT used as surrogate for grain size analysis
- Guided sampling depth decisions







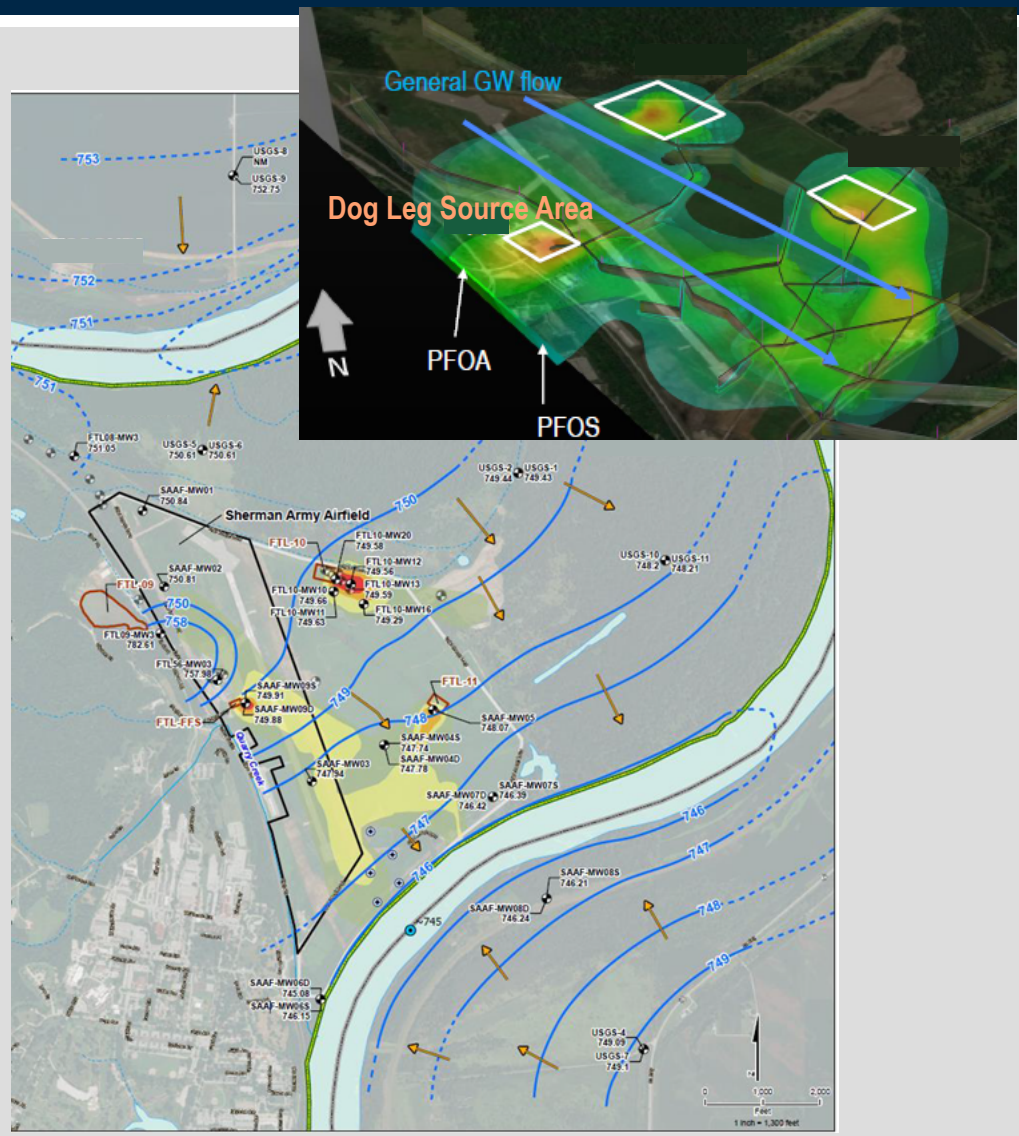
Direct Image

Company: Plains Environmental Services	Operator: Jason A.	File: FTL-76PFAS-VAP-10.HPT
Project ID: Fort Leavenworth PFAS RIFS	Client: EA EST	Date: 6/16/2021
		Location: Fort Leanvenworth, KS

EA 50 YEARS

Case Study No. 2 – Floodplain Site

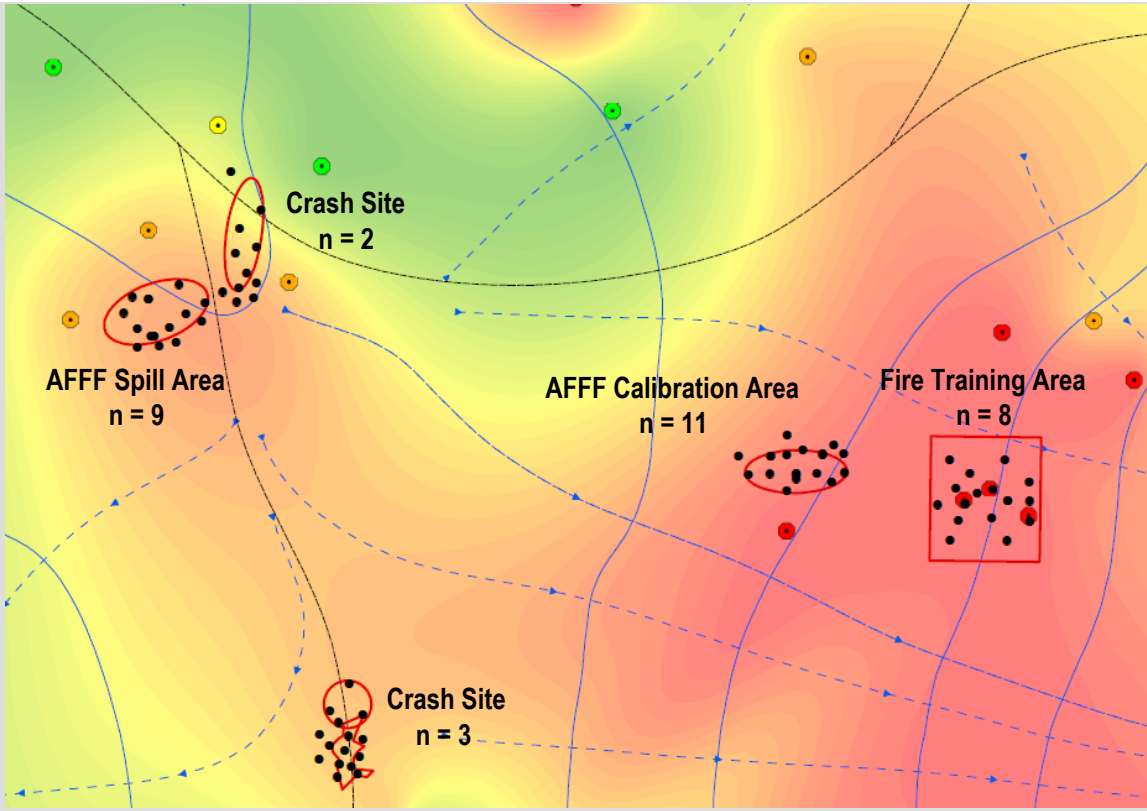
- Conclusions/Advantages:
  - HRSC used to confirm the ESS developed hydrostratigraphic model (26 VAPs)
  - Lithologic contacts did not vary more than a few feet vertically between projected and as observed – confidence in groundwater flow
  - Chute channel plug plays a role in site groundwater flow directions and plume migration
  - Stakeholder agreement for 14 additional wells + 21 existing wells
    - ~30 – 40 wells for 165 acres of plumes (to ~100 ft bgs)



Results includes VAP and GW Well Data (40 ng/L)

Case Study No. 3 – Western Site

- Project consists of a DoD facility with documented AFFF releases
- Semi-arid environment (rainfall of 16 in./year)
- Five release areas identified for SPLP sampling
  - Previous soil sampling for PFAS confirmed releases
  - 33 SPLP samples (3 dups) collected across these release areas
- Goal to correlate leachate concentrations from SPLP analysis to soil concentrations that would impact groundwater above 40 ng/L
  - Updated our analyses considering Draft MCLs (4 ng/L)



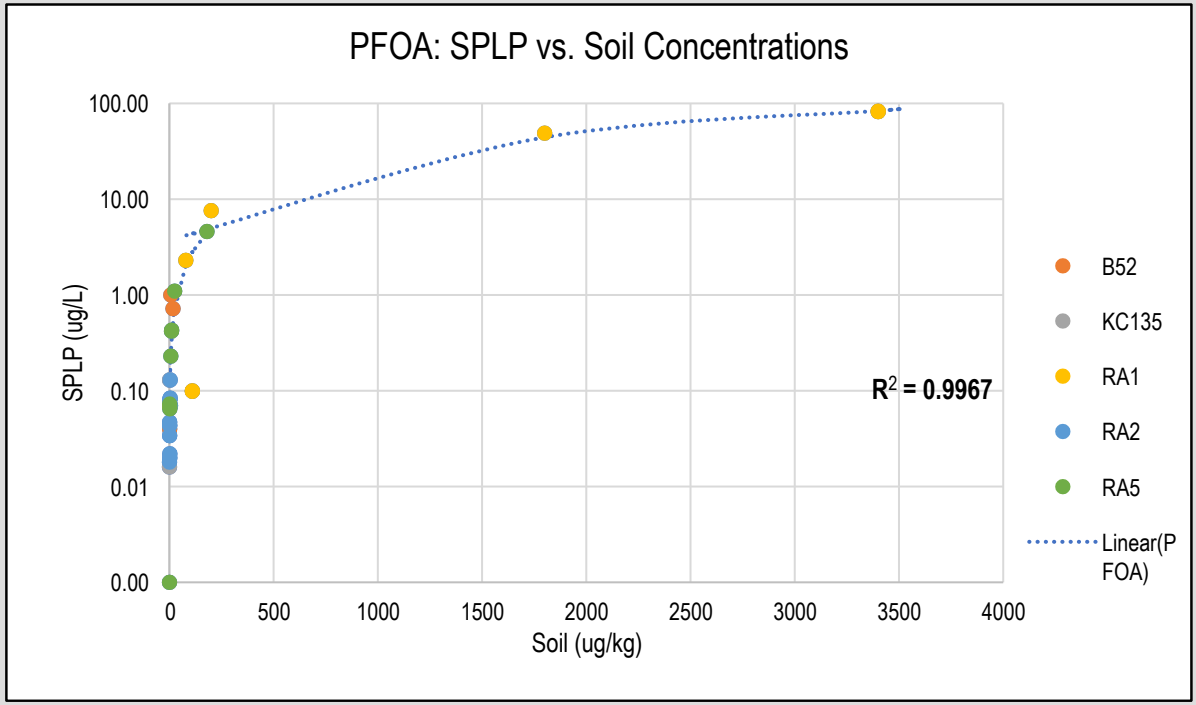
Case Study No. 3 – Western Site

- Previous soil sampling identified 0 – 1 ft bgs as the most impacted at the release areas
  - SPLP sampling from 0 – 1 ft bgs
  - Co-located soil samples for PFAS collected
  - Co-located groundwater grab water table sample for PFAS (21 of 30 locations)
  - One SPLP boring performed from surface to water table
    - 0-1, 2-3, 4-5, 9-10, and 14-15 ft bgs
- Samples analyzed via Modified 537
  - Analyses focuses PFOA, PFOS, PFBS, PFHxS, and PFNA (no Gen-X)
  - Focused on PFAS with screening criteria

	PFOS			PFOA		
	GW (µg/L)	Soil (µg/kg)	SPLP (µg/L)	GW (µg/L)	Soil (µg/kg)	SPLP (µg/L)
Average	27.2	3,837	74.5	4.02	239.6	6.08
Median	13.0	580	14.6	0.96	2.1	0.080
Maximum	73	28,000	350	23	3,400	83

Case Study No. 3 – Western Site

- Data Analyses Performed
  - Soil versus groundwater results
  - Groundwater versus SPLP results
  - Soil versus SPLP results
  - Modeling of soil concentrations based on draft MCL
  - EPA soil-to-groundwater equations
    - Soil-water partitioning
    - Mass limited
  - Reversed EPA SSL equation for estimating soil concentrations
  - Assessment of other soil parameters on leaching of PFAS

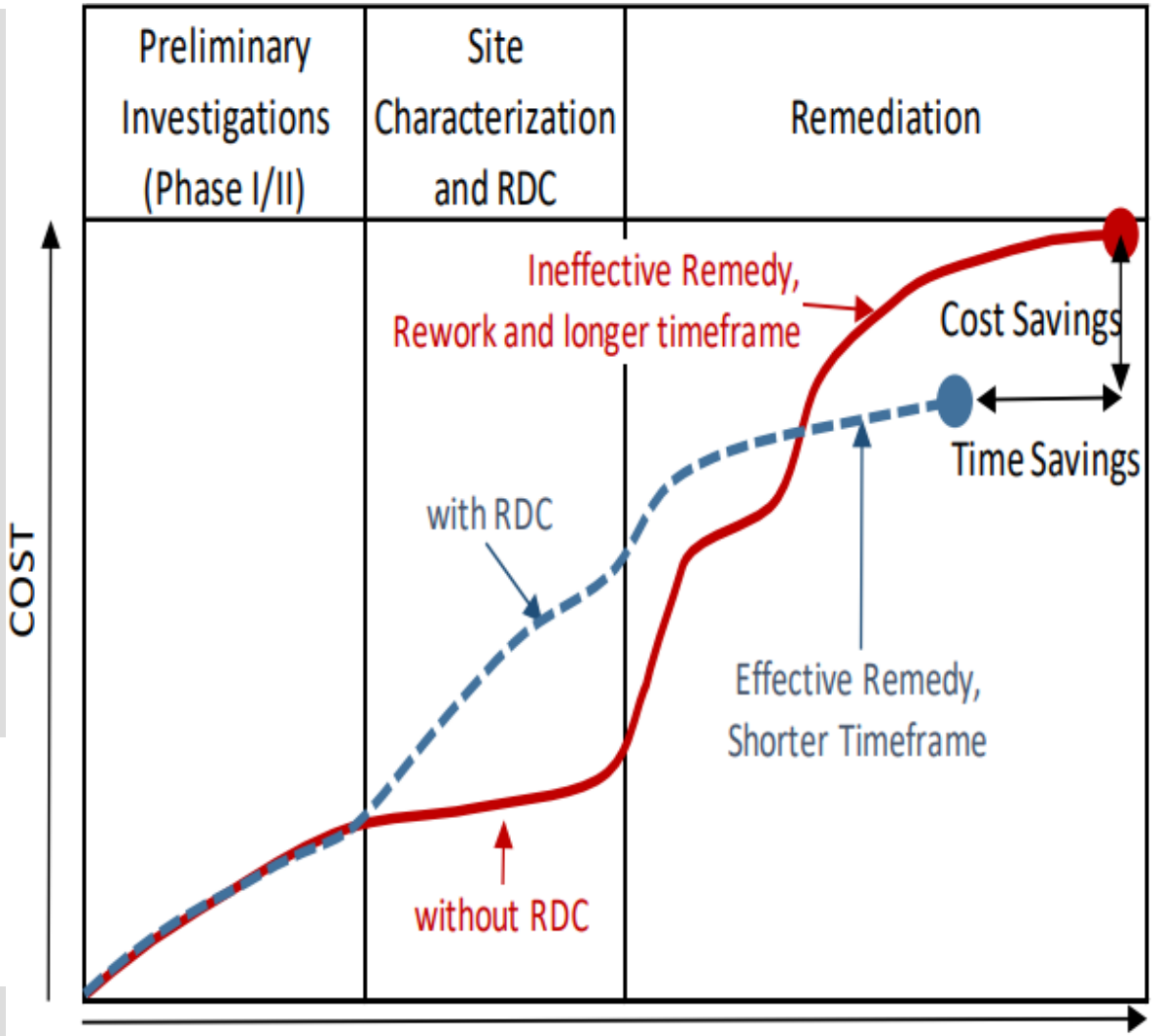


Case Study No. 3 – Western Site

- Findings/Conclusions
  - Addition of SPLP to soil/groundwater sampling borings provided data density
  - SPLP results do appear to account for soil variability (results biased high) BUT could be reasonable for estimating leachate concentrations to groundwater
  - Soil concentrations protective to groundwater are 2 to 4 orders of magnitude lower using the EPA soil to groundwater equations versus site specific data assessments

Conclusions

- Our industry is adapting and expects more and faster
- When does HRSC return on investment?
- Adaptive HRSC used to pivot direction of field investigation with Stakeholder rapid concurrence – faster investigation
- HRSC can lead to new source areas through constant CSM updates/evaluations



ITRC OIS-ISRP-1 Figure 2-1

Thank You!

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