Applications of Environmental Sequence Stratigraphy (ESS) to Remediation Design and Optimization

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Agenda

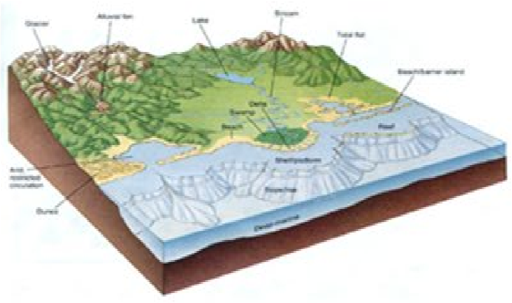
- **Environmental Sequence Stratigraphy (ESS) Model Benefits to Groundwater Remediation**
- **AFCEC ESS – Conceptual Site Model (CSM) Library**
- **Case Studies**
  - Cannon Air Force Base (AFB), Multiple Aqueous Film Forming Foam (AFFF) Release Areas and Landfill-005
  - Kirtland AFB, Bulk Fuels Facility (BFF)
  - Eglin AFB, Duke Field, Site ST-69
- **Lessons Learned**

Environmental Sequence Stratigraphy (ESS) Education To Date

"Science can amuse and fascinate us all,

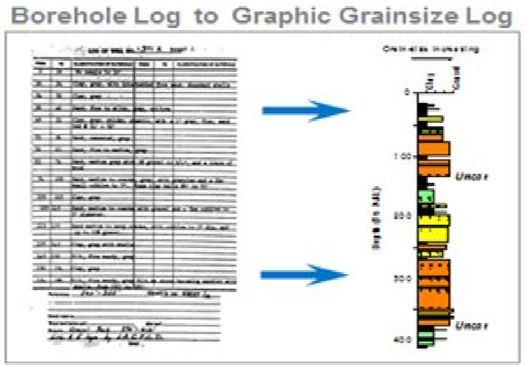
but it is engineering that changes the world"

- *Isaac Asimov*



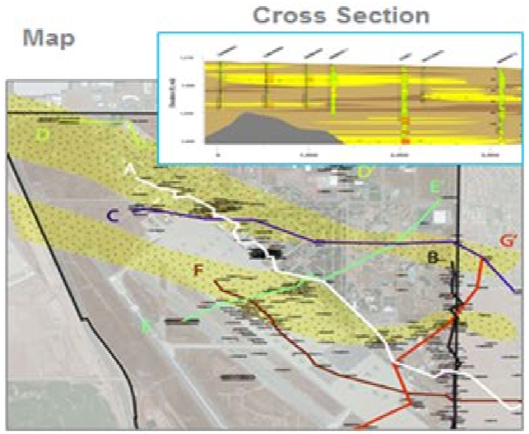
1

Determine depositional environment which is the foundation to the ESS evaluation



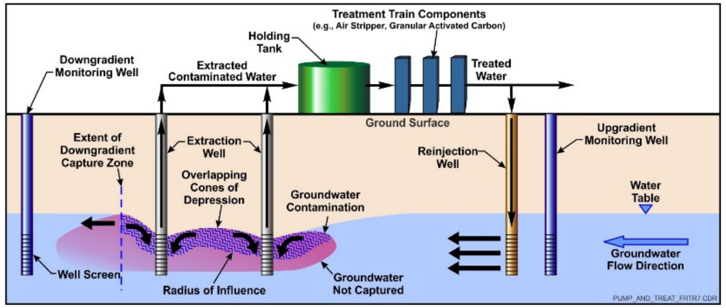
2

Leverage existing lithology data to identify vertical grain size trends and correlate between boreholes



3

Map the permeability architecture to predict contaminant migration

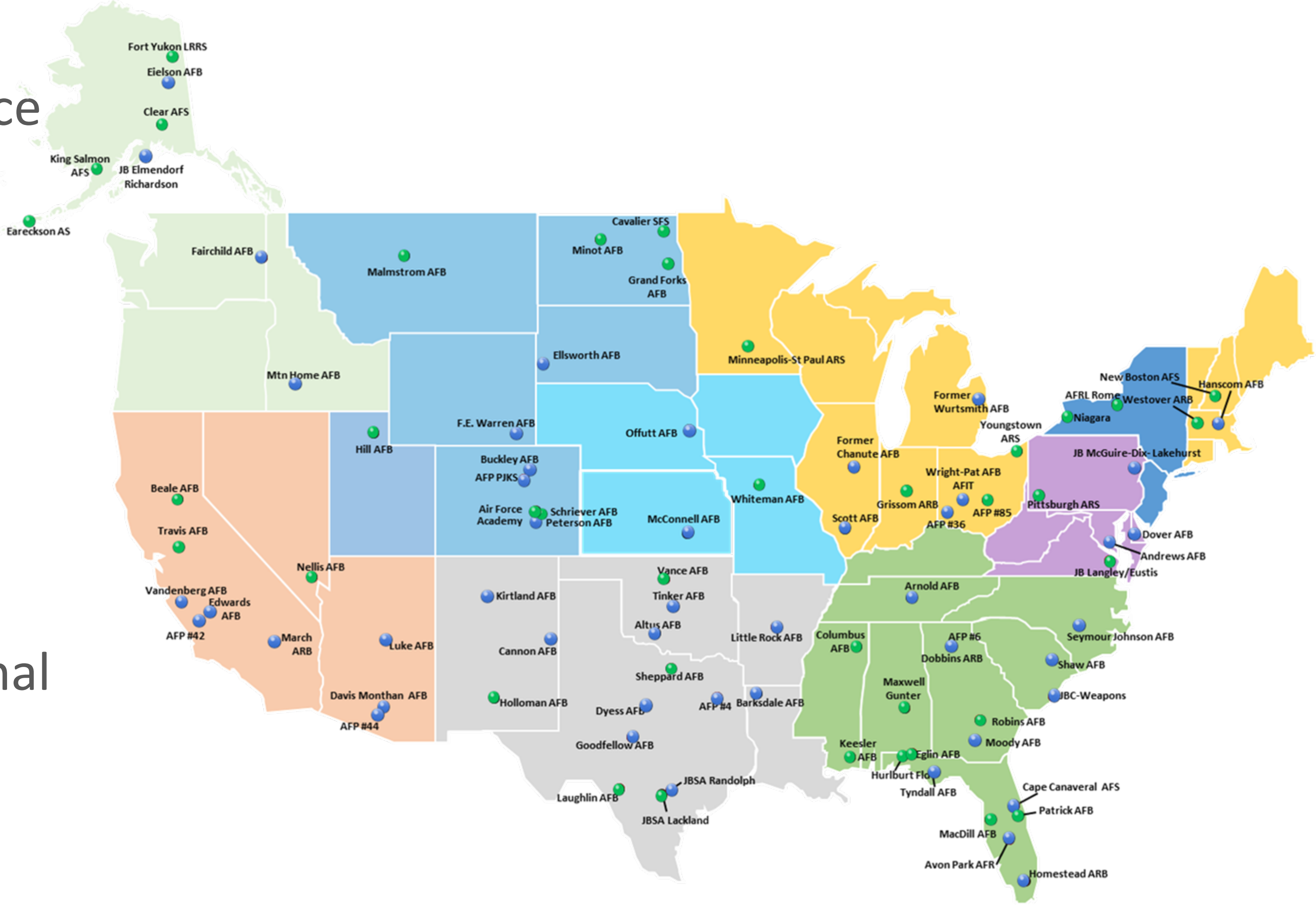


4

Benefits to Remedial System Design and Operations

ESS Library

- AFCEC conducted an enterprise-wide study to capture performance and lessons learned information related to application of ESS principles to inform site remedial approaches.
- 58 ESS reports at active Installations in the library
- Reports range from regional, basewide to site-specific; additional reports in development
- Over the next 4 years, AFCEC will be conducting 43 additional installation level studies



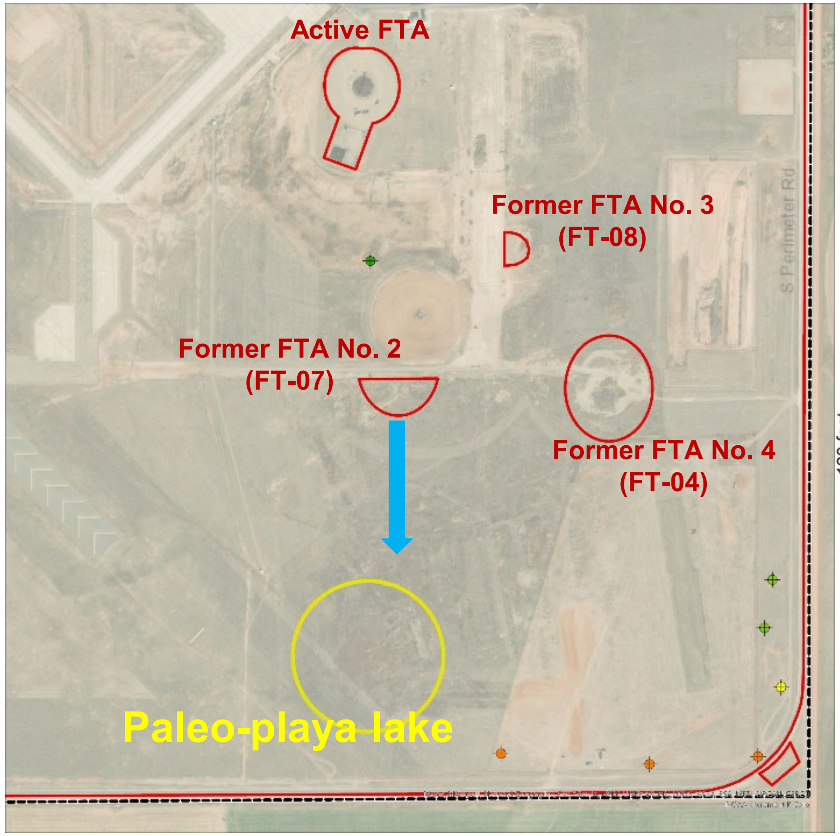
Cannon AFB Case Study, Multiple AFFF Release Areas and Landfill-005

Cannon AFB, Multiple AFFF Release Areas and Landfill-005

- Preliminary Assessment (PA) - Completed in 2015
- Site Inspection Report (SI) - Completed August 2018
- Identified Sites with Impacted with Emerging Contaminants
- Remedial Investigation (RI) awarded August 2020
- Anticipated Completion Date Summer 2025
- Environmental Sequence Stratigraphy – Completed September 2020
- Design Team engaged February 2021.
- Awarded the May 2021
- Initial Design Completed February 2022
- Optimized the Design July 2022 – Cannon AFB Workshop
- Construction Begins May 2023
- System Commissioning March 2024

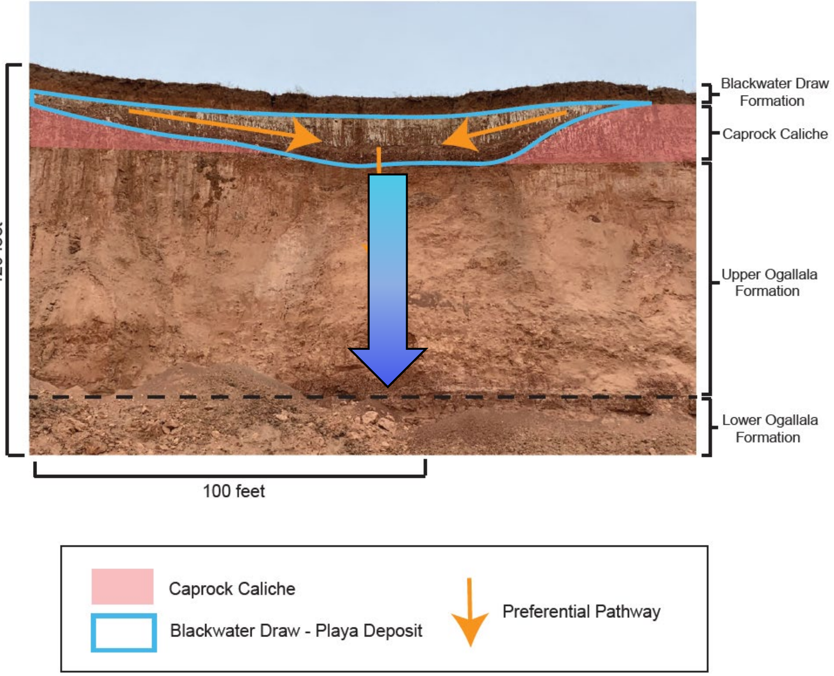
Cannon AFB Case Study
General Contaminant Transport Pathway

1. Surface Water Flow

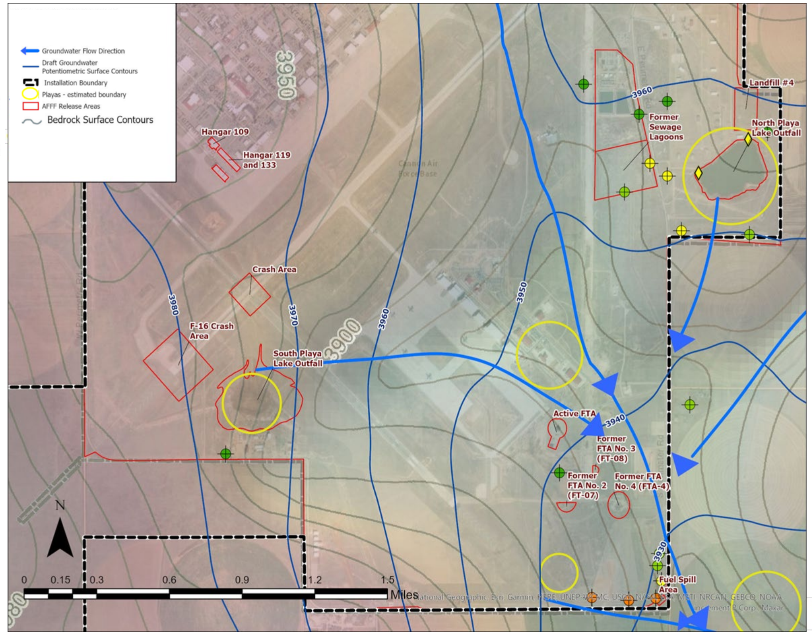


2. Infiltration into Groundwater

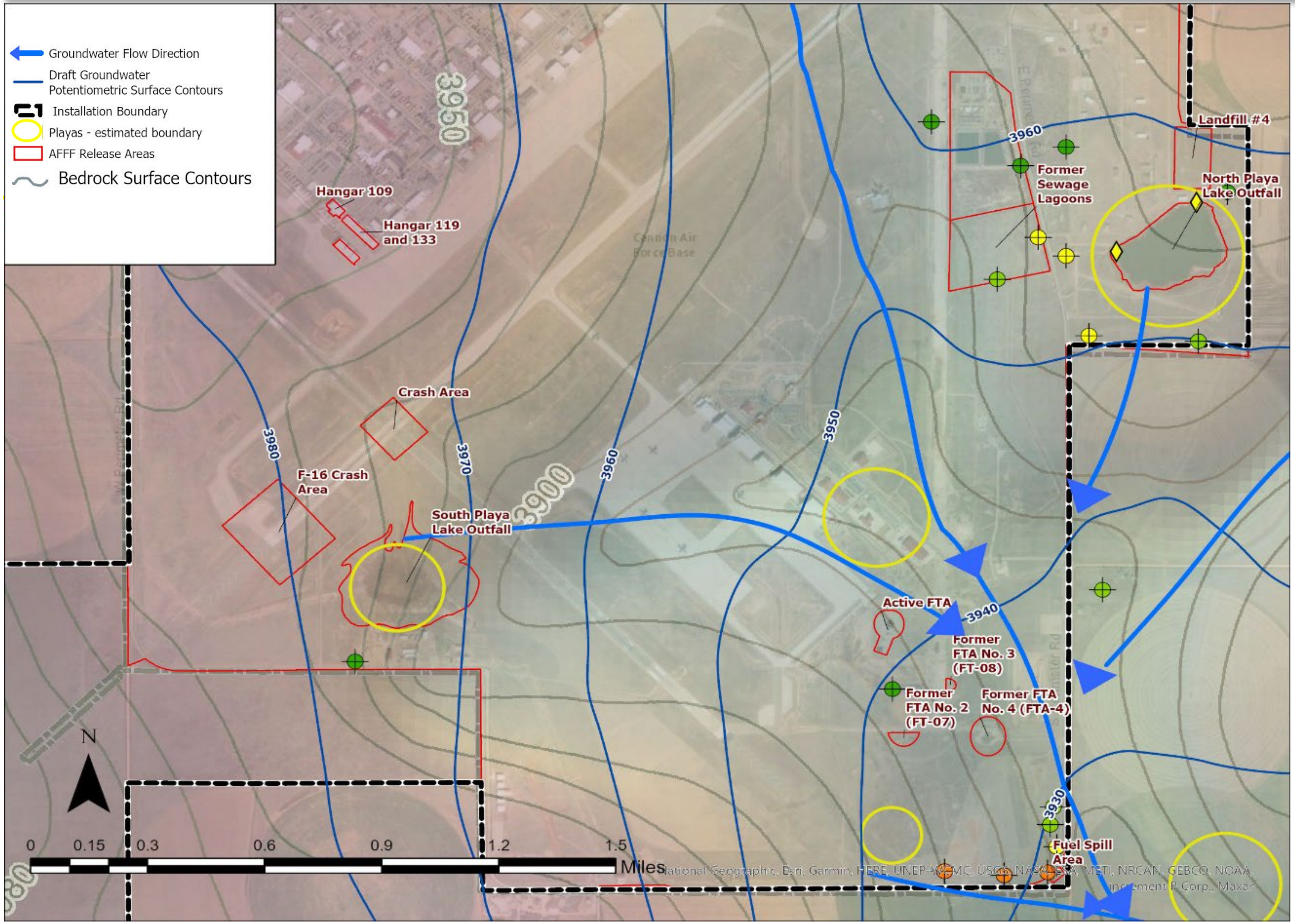
Annotated Quarry Cut



3. Groundwater Flow

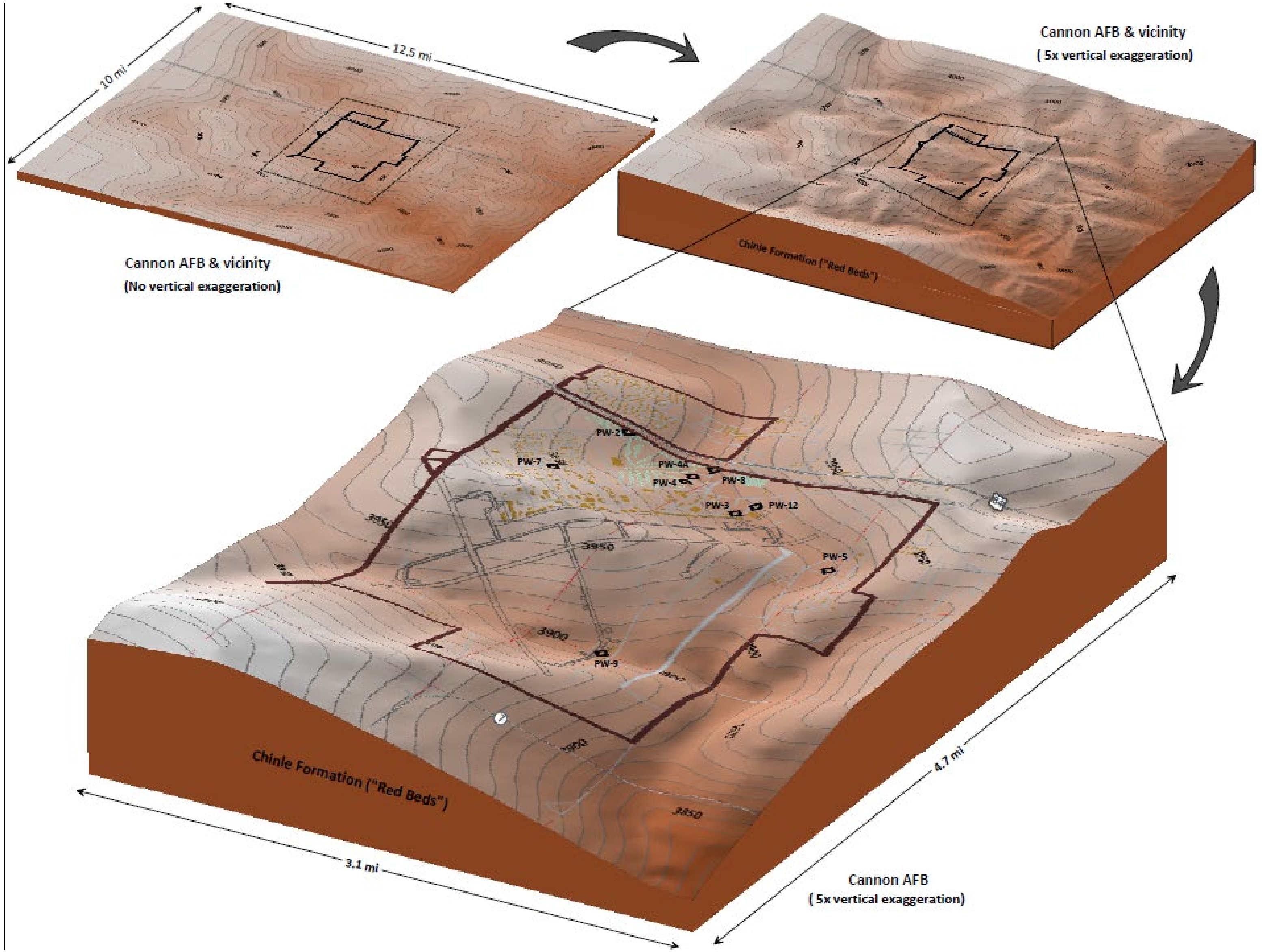


Cannon AFB Case Study
Groundwater Moves Into and Through Channel

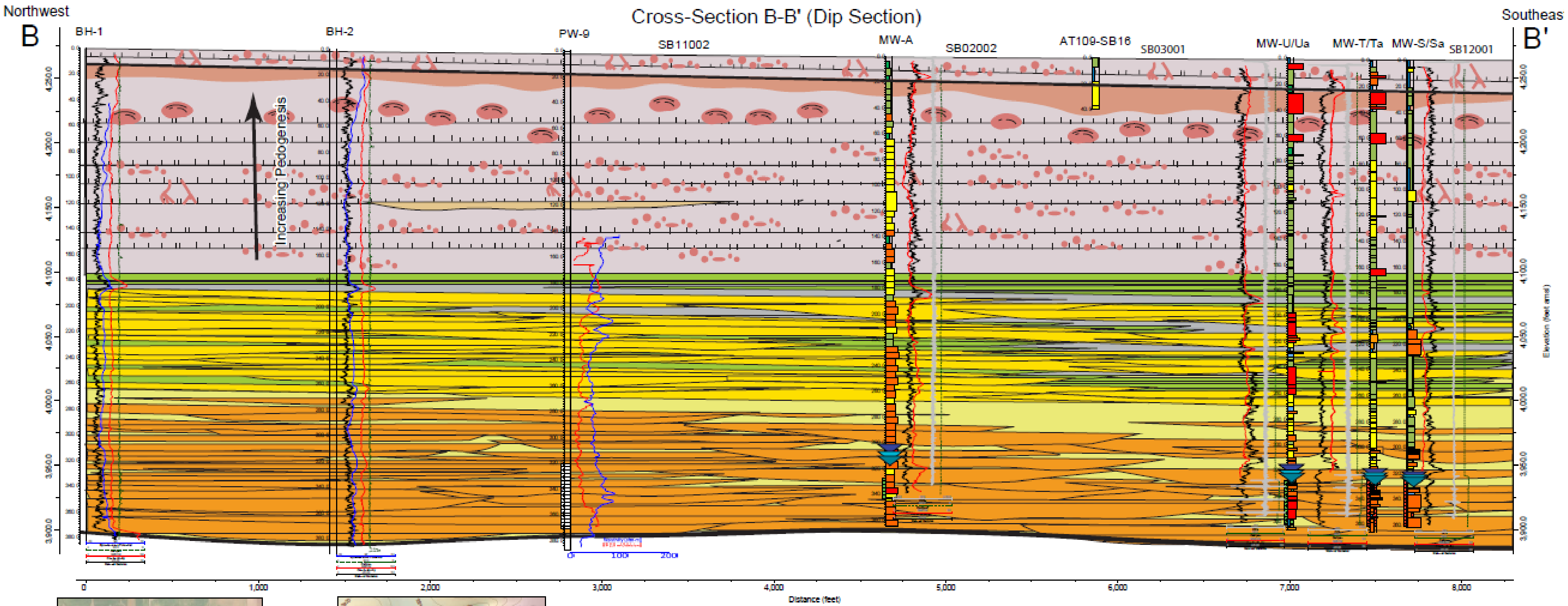


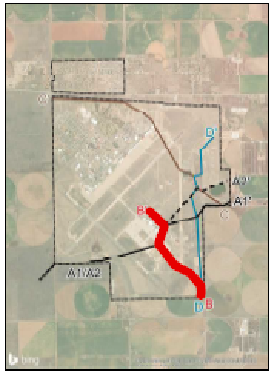
- Narrow window to intercept contaminants crossing installation boundary
- Top of bedrock was mapped during CSM
- Paleovalleys!
- ‘Choke point’ controlling groundwater flow

Cannon AFB Case Study
Groundwater Moves Into & Through Channel

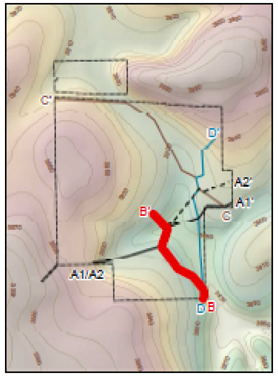


Cannon AFB Case Study
Transect B to B', Southeast Corner

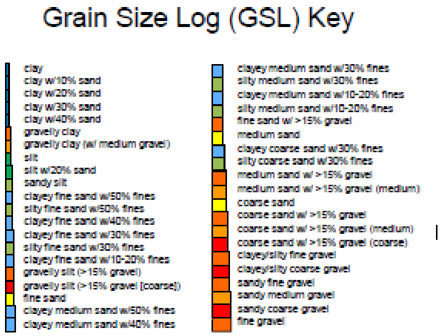


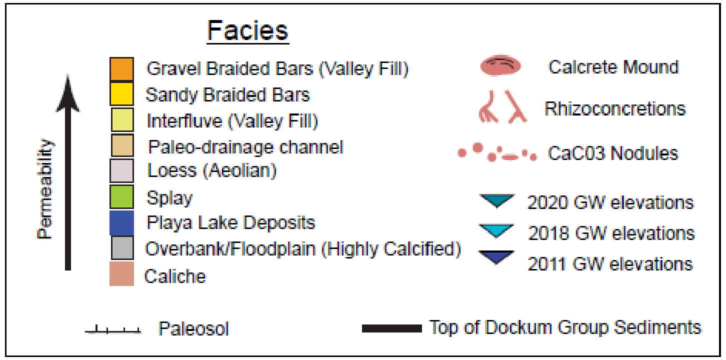


Cross Section Locations on Aerial Imagery

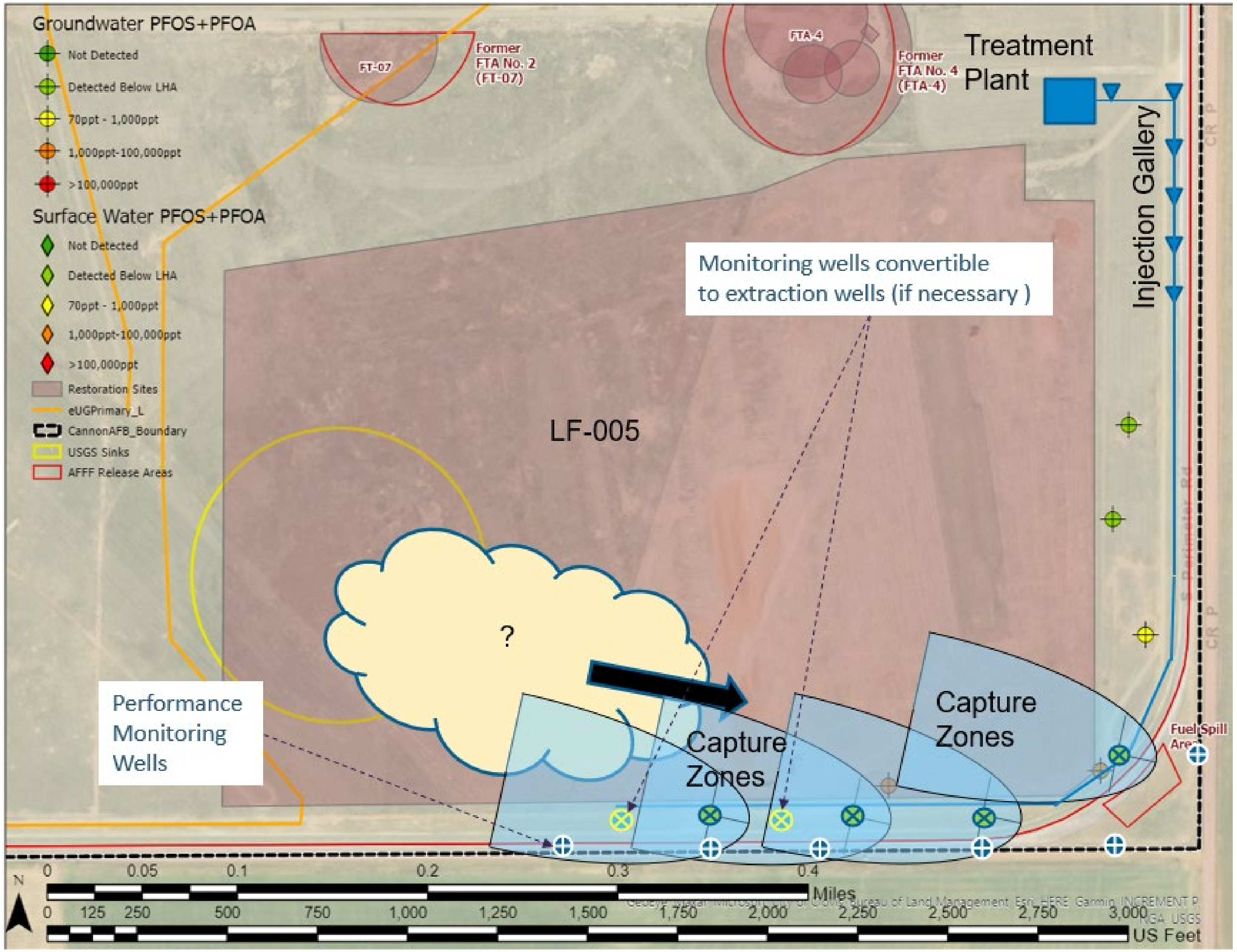


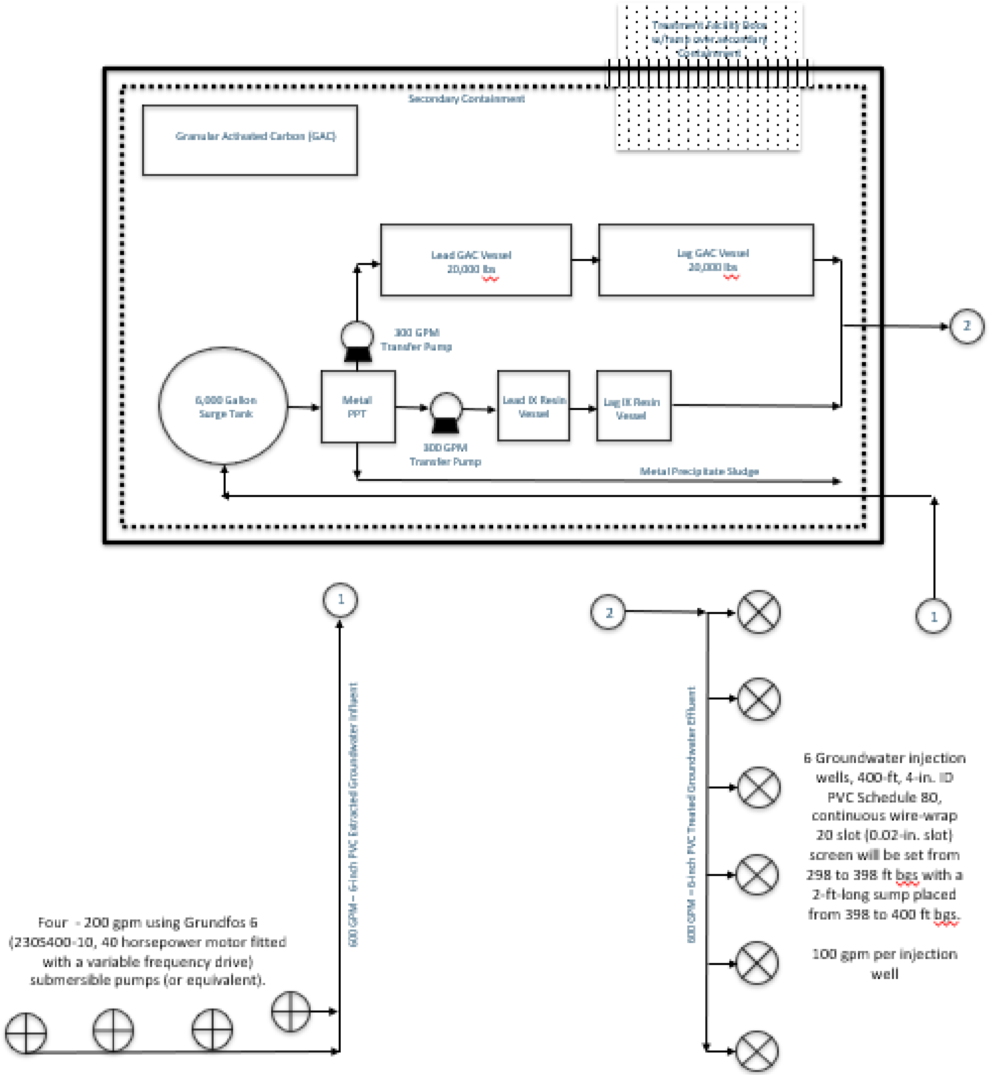
Cross Section Locations on Top of Dockum Formation



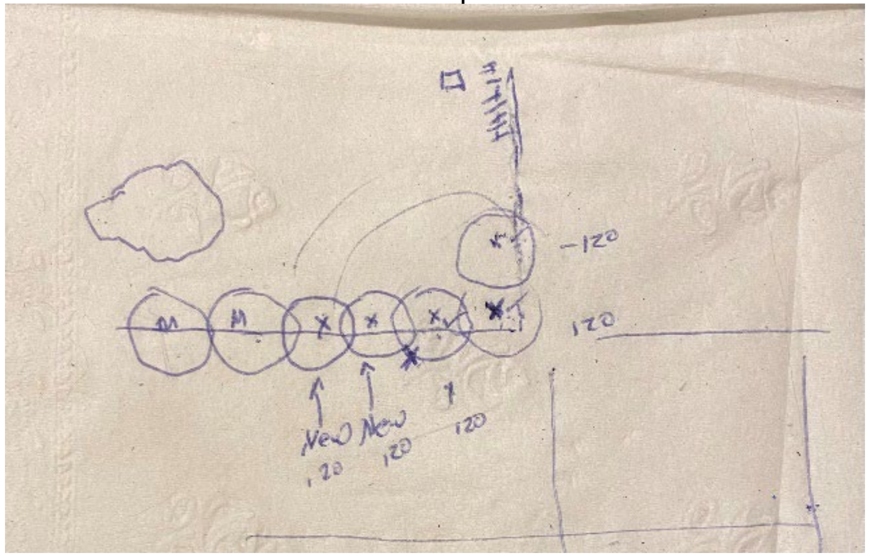


Cannon AFB Case Study
Groundwater Extraction System Layout

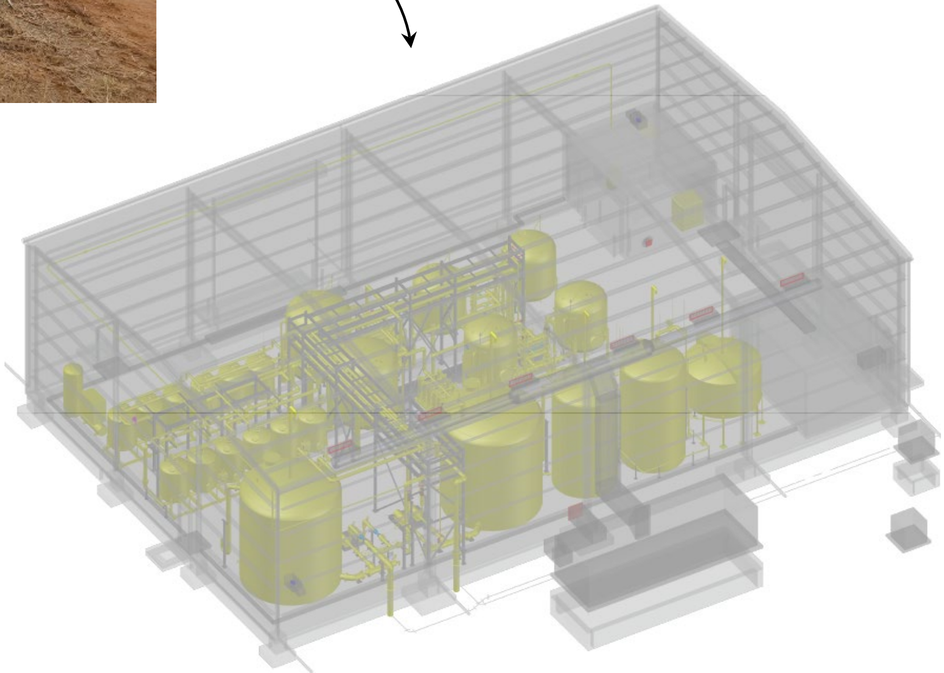




Cannon AFB Case Study
Concept to Design



4 Months



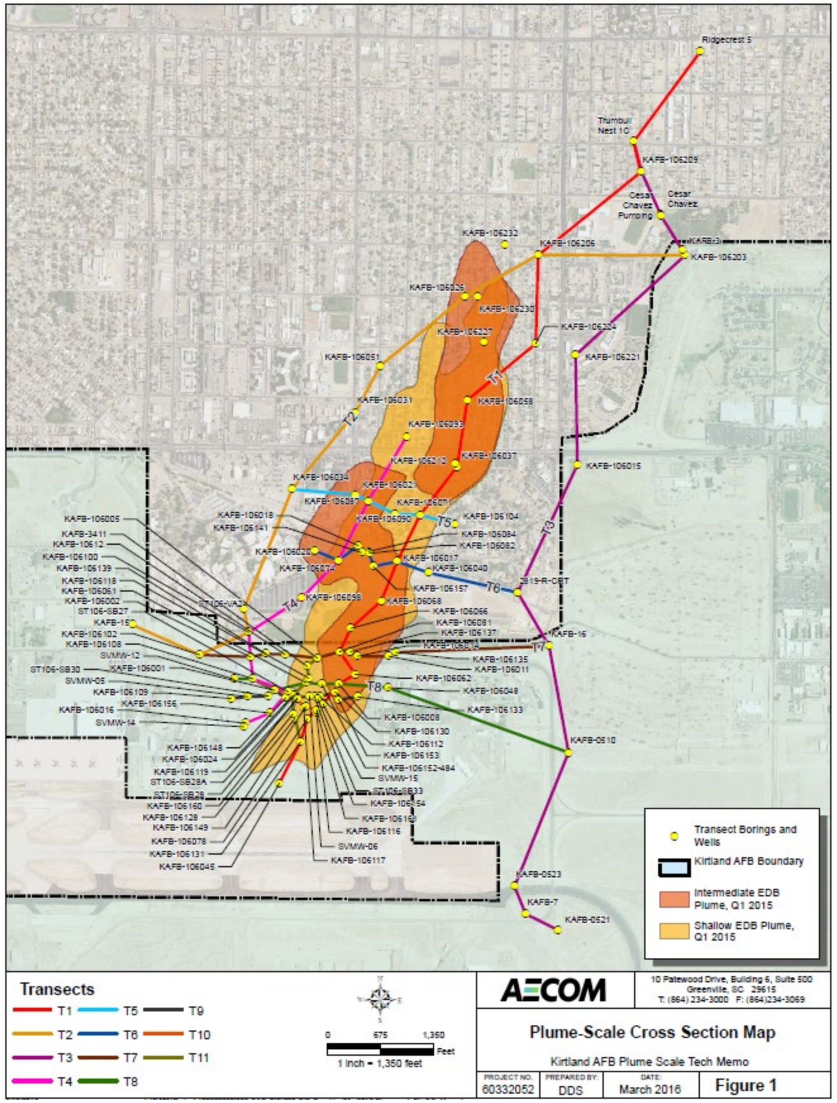
Cannon AFB Case Study Summary

- Rapid deployment from the drawing board to field implementation was achieved within one year utilizing the Non-Time-Critical Removal Actions (NTCRA) process under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).
- Combination of ESS, synoptic groundwater measurements, and contaminant data accelerated the remedial approach.
- Beneficial impacts to off-base receptors should be realized within the first five years of treatment system operations.
- Treatment system will not exacerbate decreasing groundwater elevations at Cannon AFB.

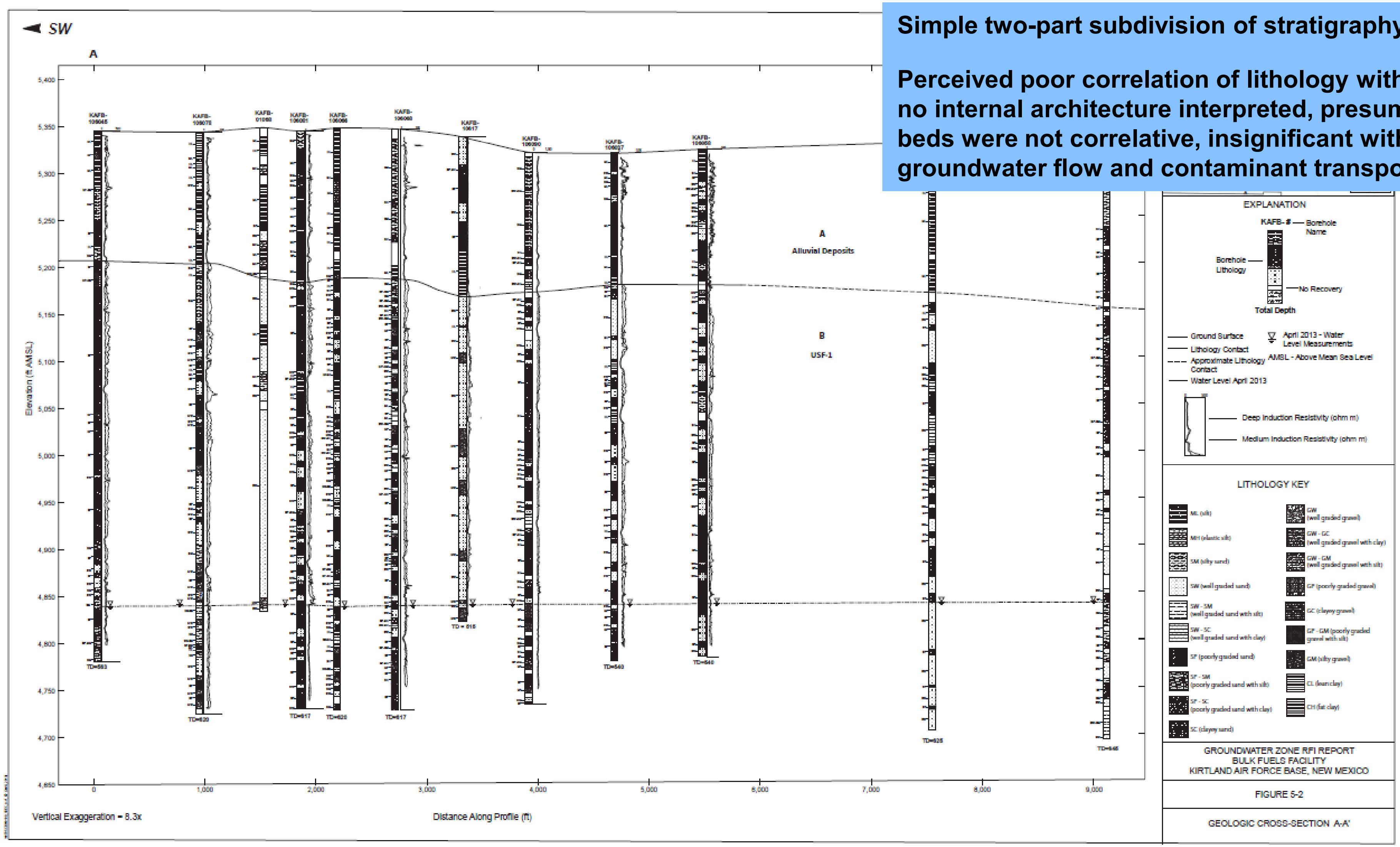
Kirtland AFB Case Study - Bulk Fuels Facility (BFF)

Kirtland AFB Case Study
Bulk Fuels Facility (BFF)

- 1953 to late-1975, the primary fuel stored and used at the BFF was AvGas.
- Ethylene dibromide (EDB) use as a fuel additive was discontinued in 1975.
- Fuel release discovered on 11 November 1999.
- Soil Vapor Extraction (SVE) systems operated at the site from 2003 through 2015.
- 2014 Air Force committed to installing 8 extraction wells to contain the EDB plumes.
- January 2015, New Mexico Environment Department (NMED) issued Notice of Violation (NOV) ~$900,000.
- Air Force turned to ESS.



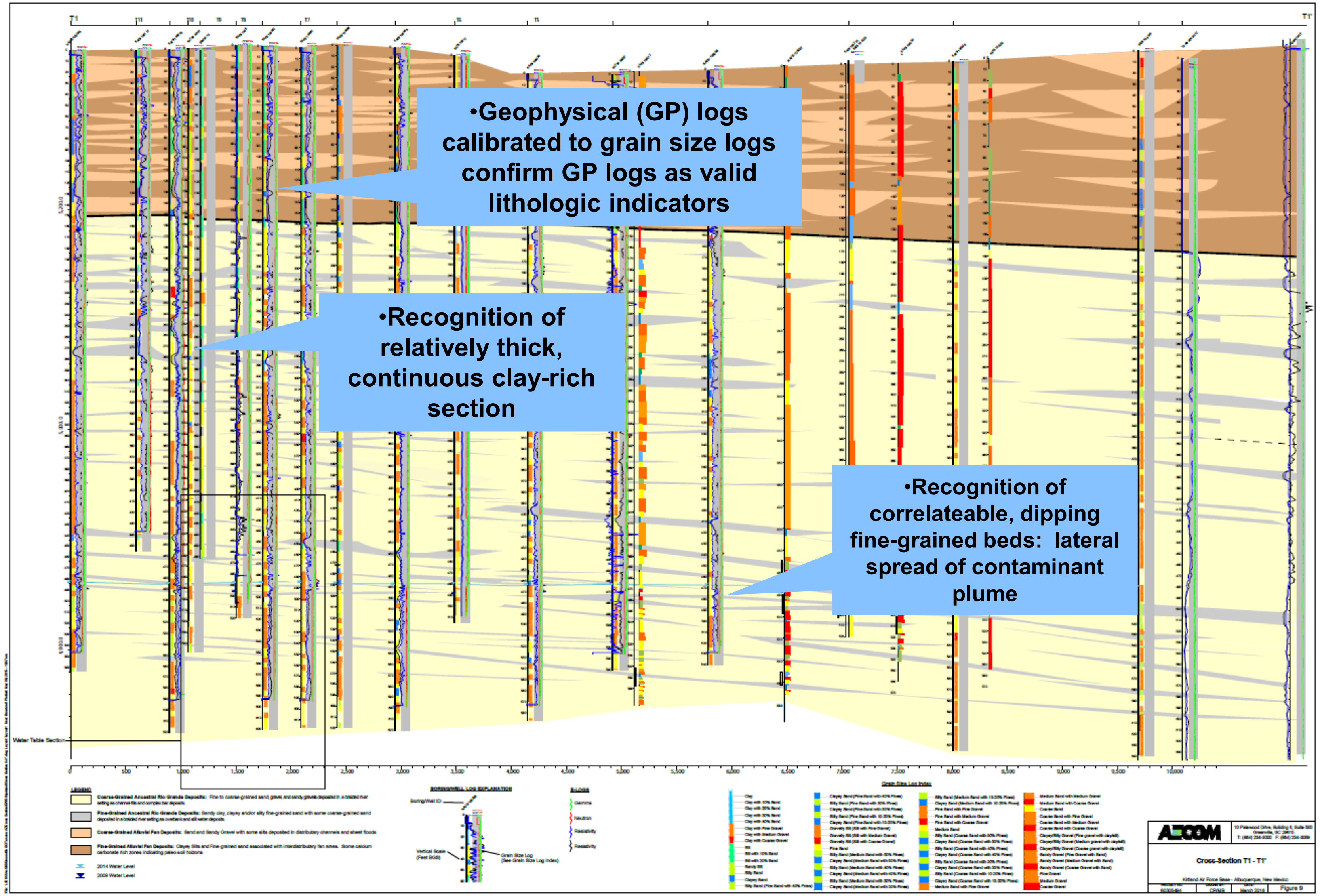
Pre-ESS Lithostratigraphic Correlation



Simple two-part subdivision of stratigraphy

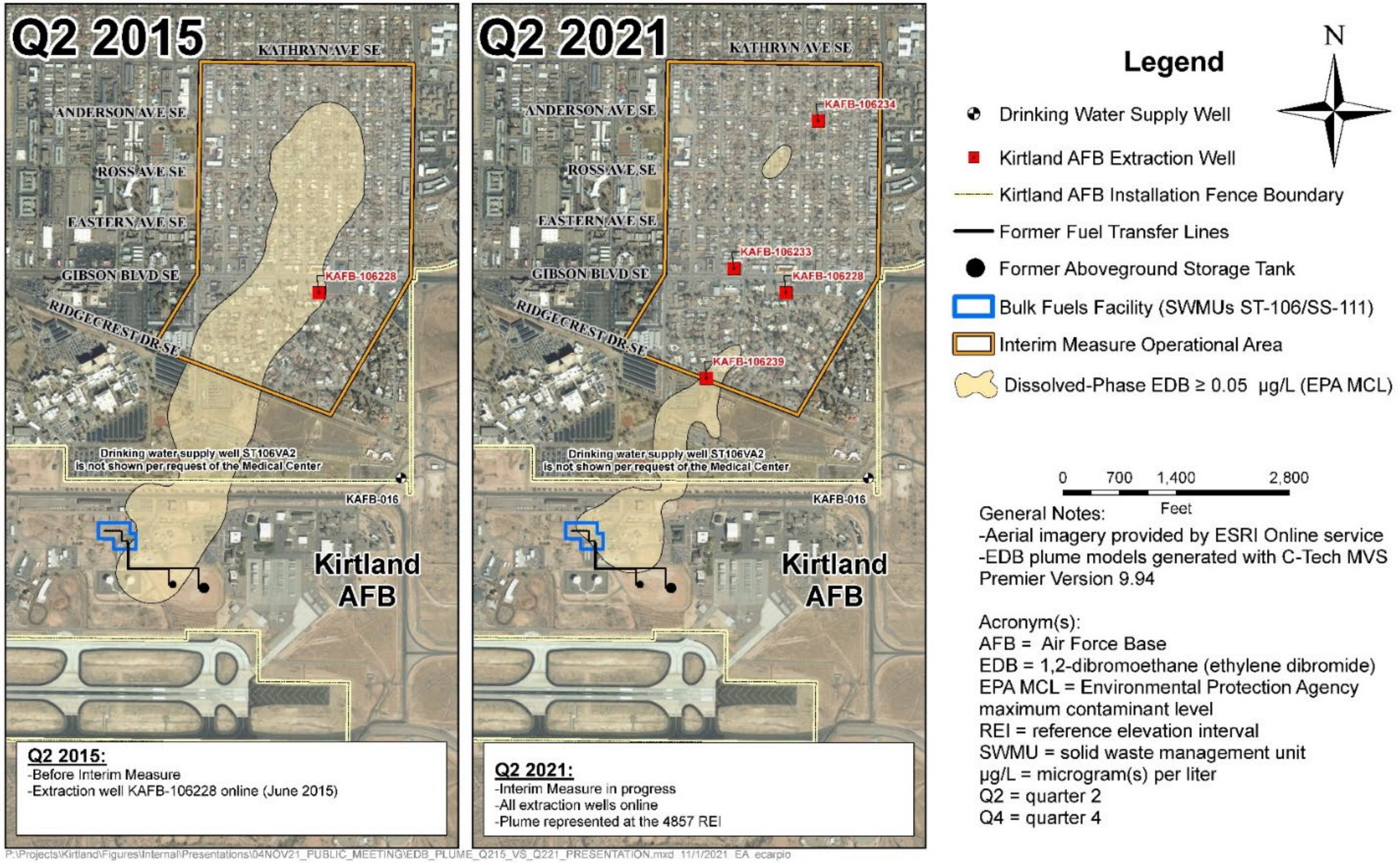
Perceived poor correlation of lithology with geophysical logs, no internal architecture interpreted, presumed that any clay beds were not correlative, insignificant with regard to groundwater flow and contaminant transport

ESS Correlation



EDB Plume – 2015 versus 2021

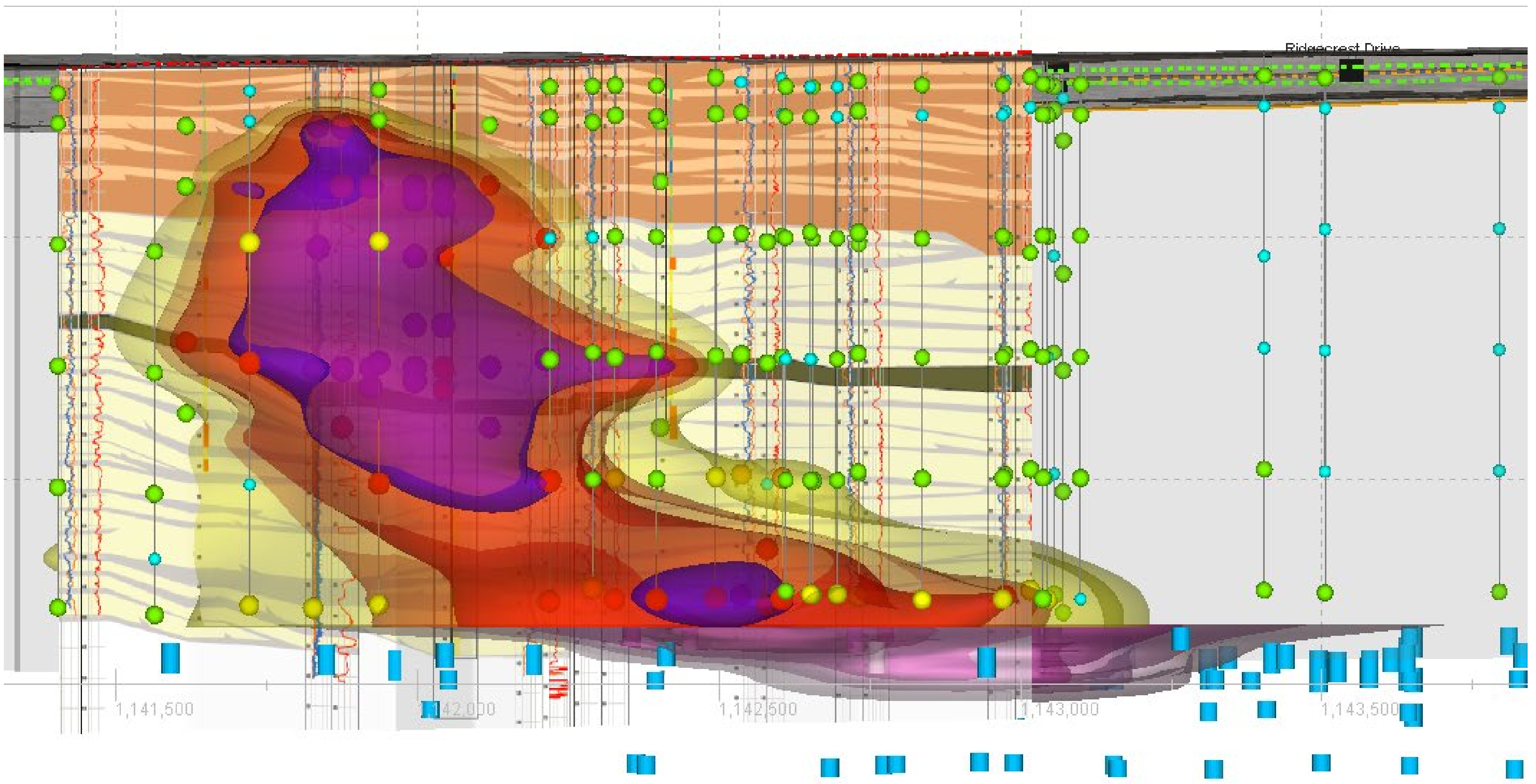
- Prior to 2014, Air Force committed to installing 8 extraction wells to contain the EDB plumes.
- Post-ESS refinements.
- Air Force used the Interim Remedial Action (IRA) process for rapid deployment.
- Only 3 wells were needed to collapse the plume initially; 4th well added in 2018
- On 31 December 2015, the switch was turned on and the NMED NOV was avoided.
- Plume asymptotic since 2019.



Plume maps are based on actual measurements and not simulations

3D Data Visualization Key to Success

- Vertical and lateral extent of impacted soil, soil vapors, and groundwater contamination is well defined.
- Sequence stratigraphy, soil vapor sampling, LNAPL detections, and groundwater sampling produce a highly refined CSM.
- On 23 July 2021, NMED announced the investigation phase was coming to an end.



Kirtland AFB Case Study Summary

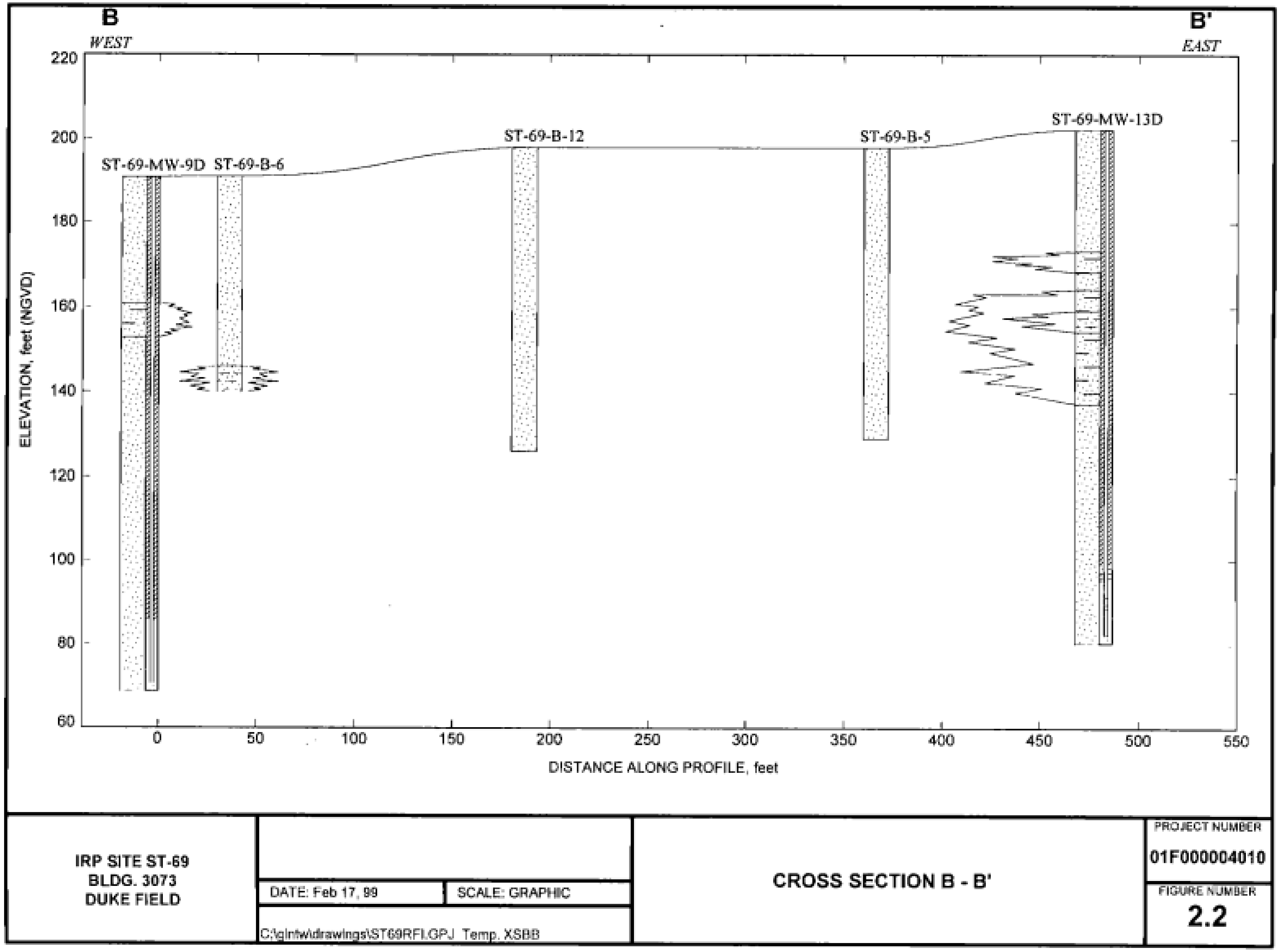
- Rapid deployment from the drawing board to field implementation was achieved in <1 year using the IRA process under CERCLA.
- Combination of ESS, recognition of dipping fine grain beds, and contaminant data accelerated the remedial approach avoiding the NOV.
- Air Force originally committed to installing 8 extraction wells but only needed 3 wells based on the ESS analysis – Cost savings.
- Plume collapse was achieved in 3 1/2 years.
- To date, 1,369,956,700 gallons of contaminated groundwater have been treated and reinjected or used for irrigation.
- Approximately 775,000 equivalent gallons of jet fuel have been removed to date.
- Combination ESS and 3D Data Visualization assisted in advance the site towards the Corrective Measures Evaluation.

Eglin AFB Case Study - Duke Field, Site ST-69

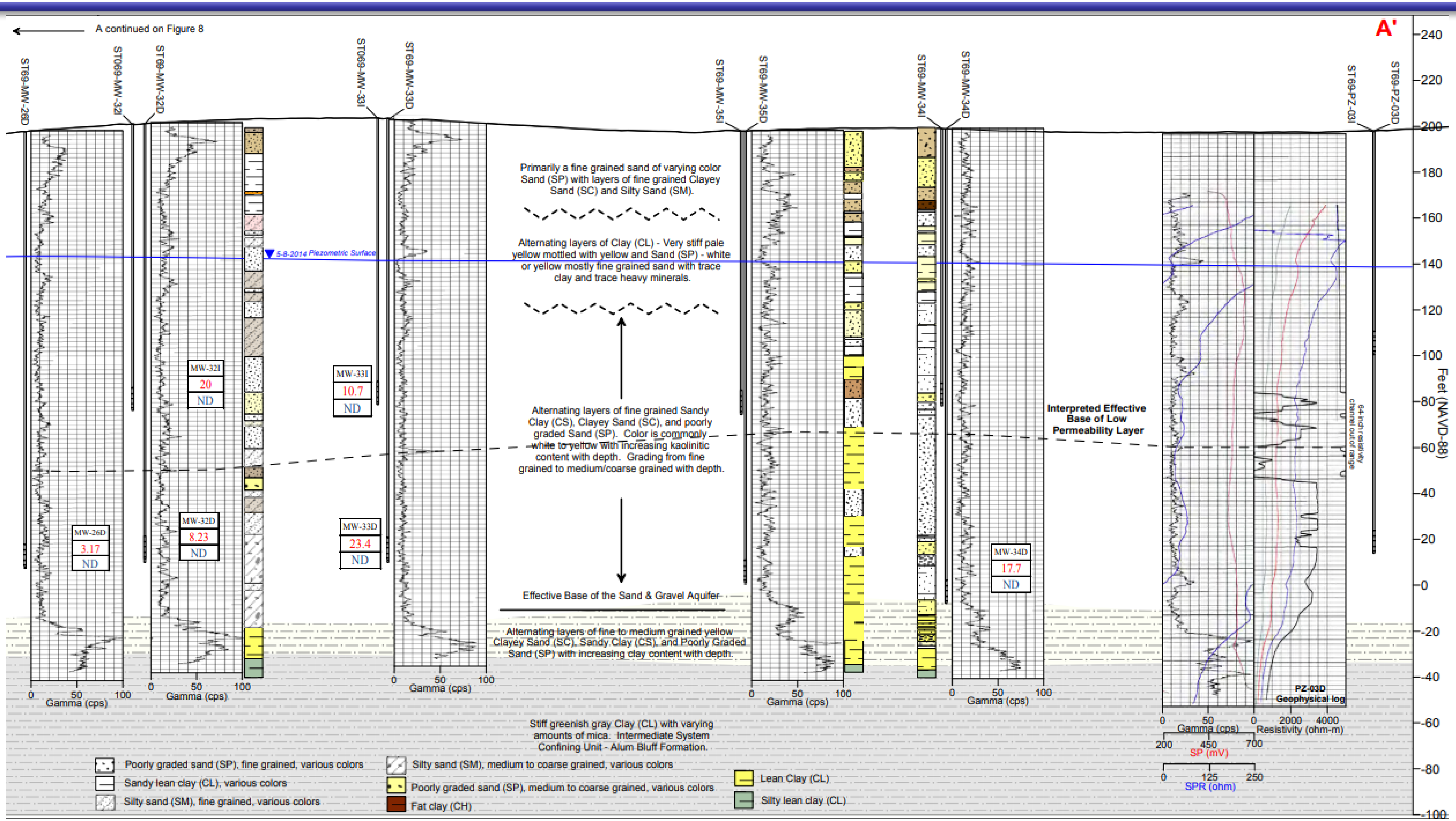
ST-69 – Former Waste Oil Tank, Building 3073 Duke Field Site Case Study

- A waste oil tank was the contamination source at Installation Restoration Program (IRP) Site No. ST-69. The fabricated waste oil tank had a 6-inch diameter hole in the bottom that drained south to a stone leach field.
- Roughly divided the Sand and Gravel Aquifer into three zones: the shallow zone (50–80 ft below land surface [bls]), the intermediate zone (100–150 ft bls), and the deep zone (175–276 ft bls).
- Source area remediation accomplished via excavation.
- Estimated extent of diffuse low-level perchloroethylene (PCE) contamination in the intermediate and deep zones exceeding Groundwater Cleanup Target Levels (GCTLs) is approximately 57 acres.
- Trichloroethylene (TCE), dichloroethane (DCE), and vinyl chloride (VC) have never been detected at the site.

Traditional Geologic Cross Section at ST-69



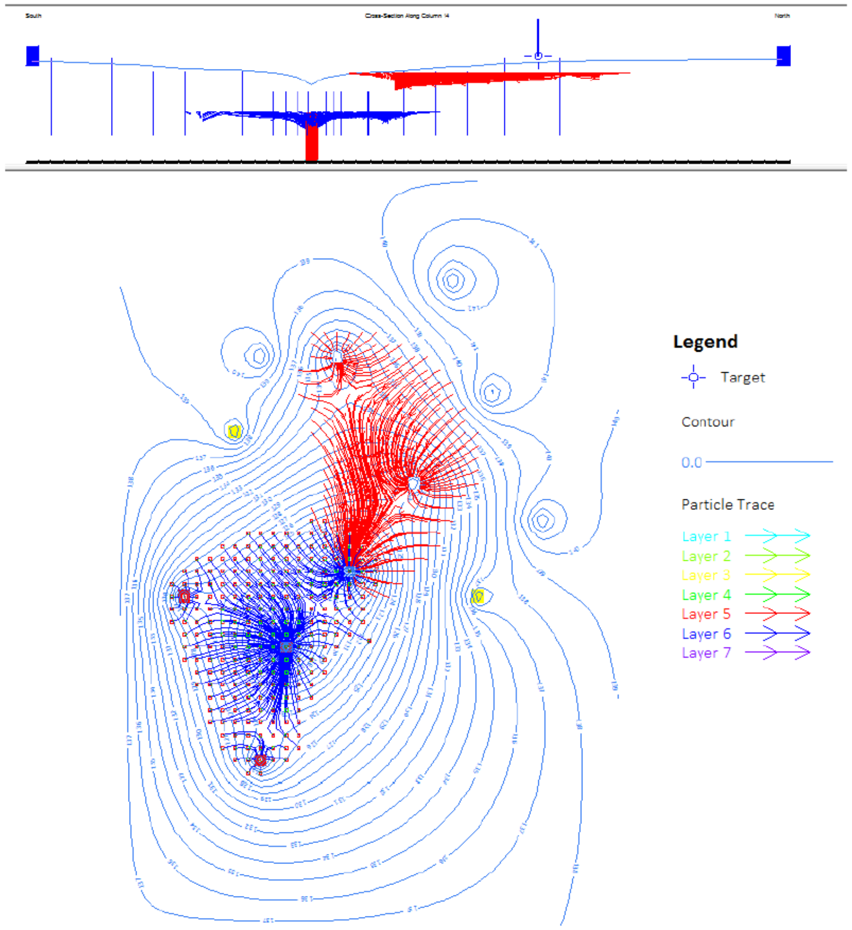
Pre-ESS Lithostratigraphic Cross Section

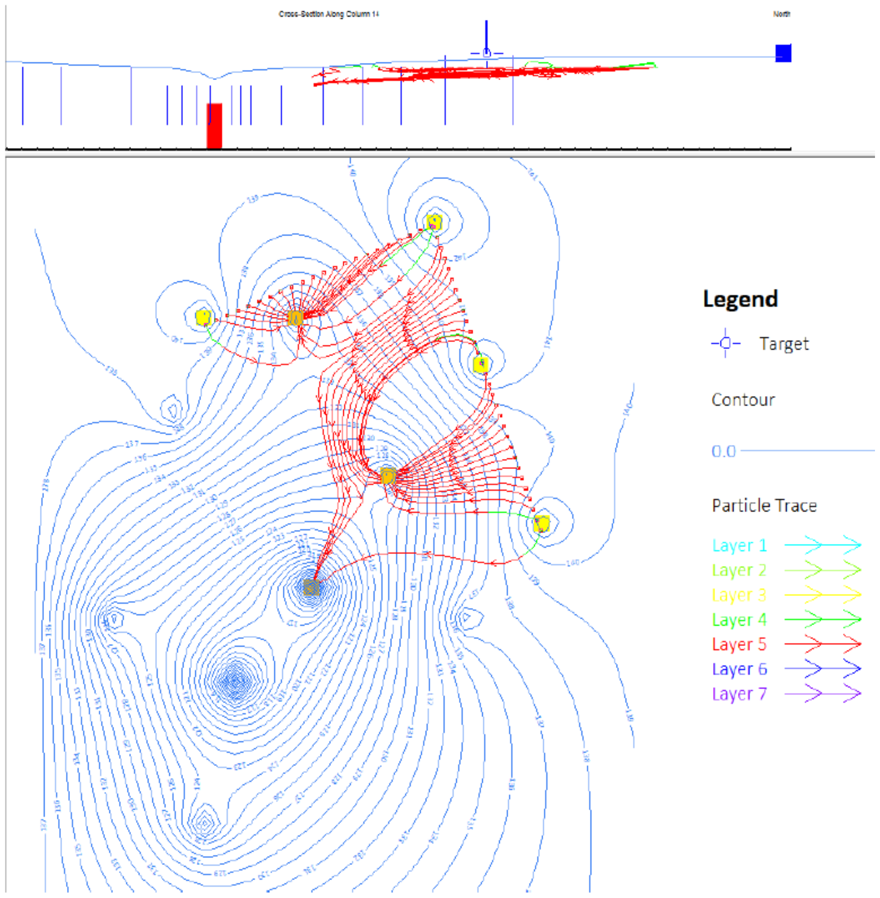


- From the traditional CSM, and the project geologist who characterized the site as **"a big ole' sandbox"**

Site ST-69 Groundwater Model - Capture

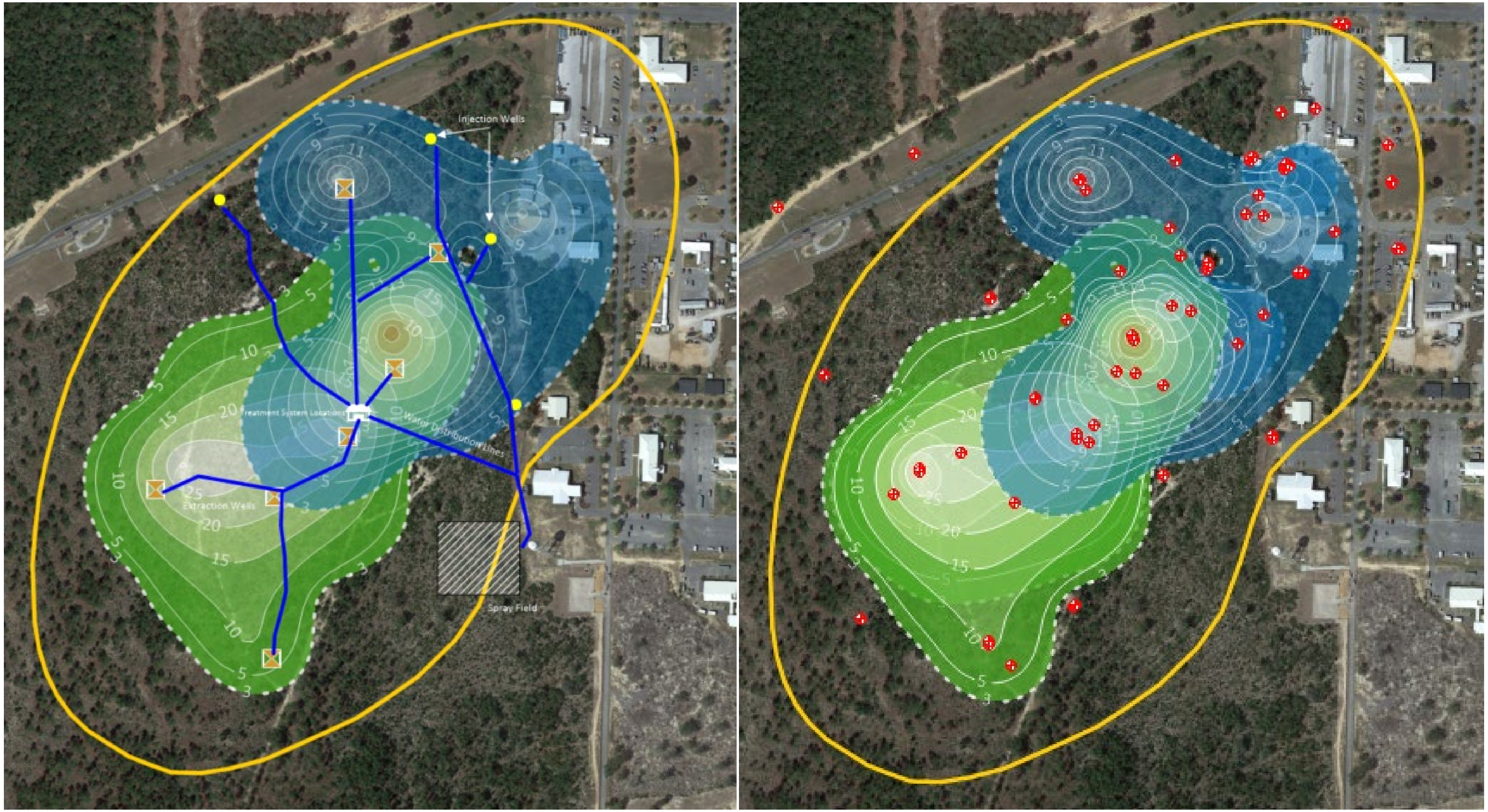
- Pump test data was used to generated a 3-dimensional steady state groundwater flow model
- Observed Heads - Calibration 9.5%. Less than 10% is considered “A Good Calibration”.
- Simulated pump and treat with recirculating groundwater remediation system and was able to demonstrate complete capture of PCE contamination and recirculated water.





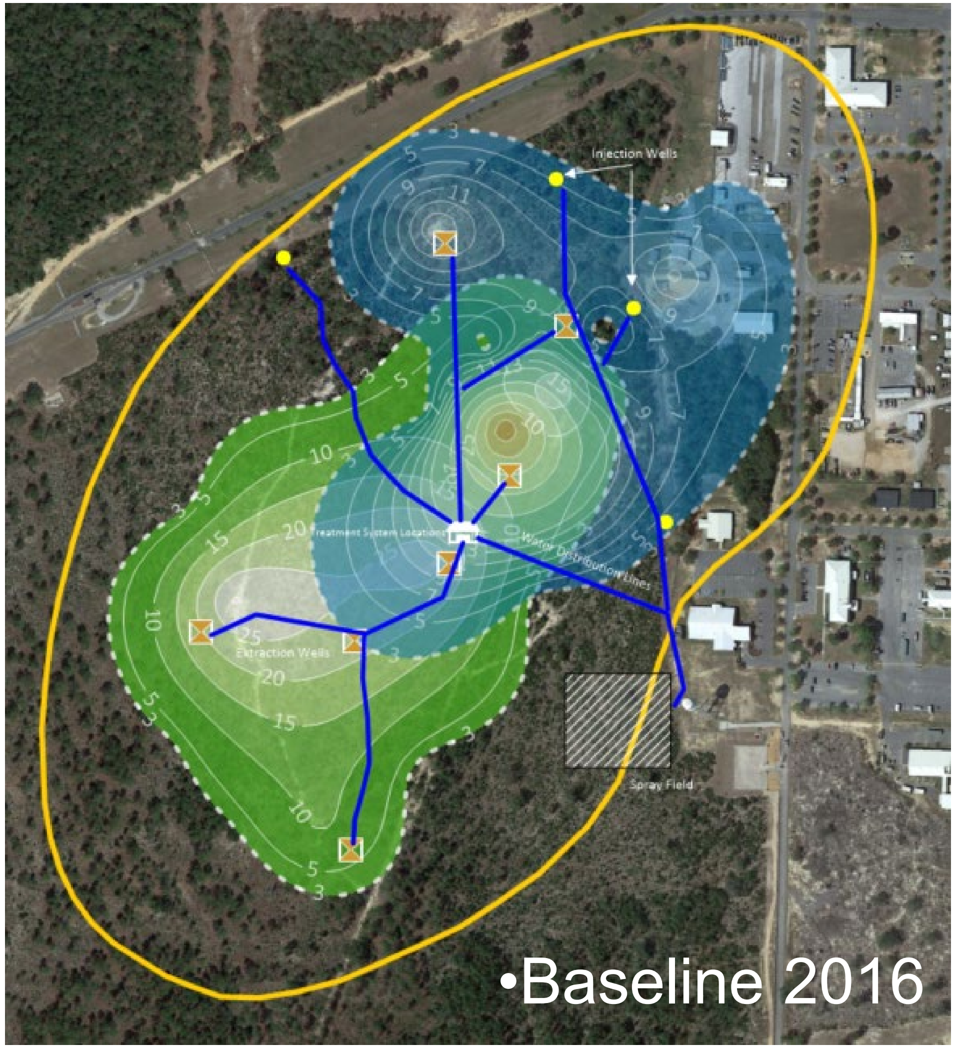
Site ST-69 Baseline Sampling Event

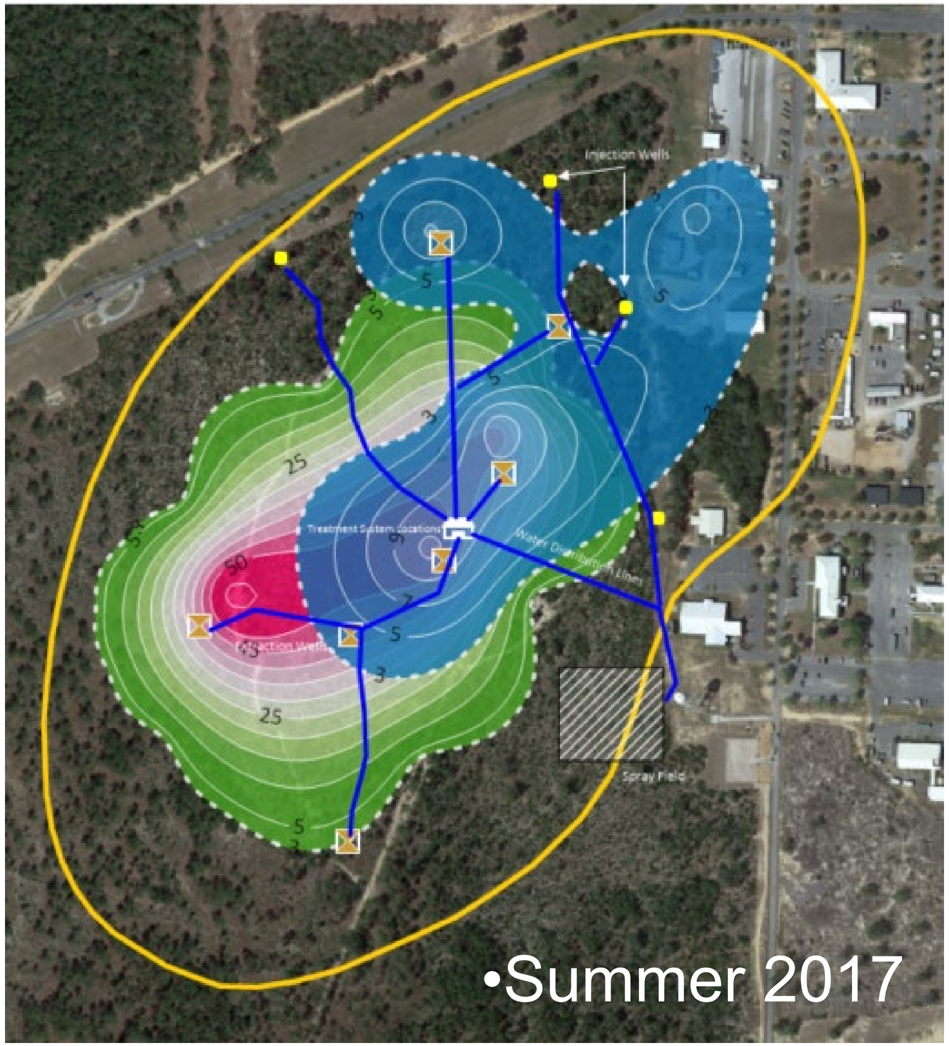
- Original design was a groundwater recirculation system composed of five extraction wells, four reinjection wells, and sprinkler irrigation.
- Extracted groundwater was treated using a 400 gallons per minute (gpm) air stripping column.
- **and on paper the system looked dynamite until...**



Site ST-69 Plume Map 2017 Sampling Event

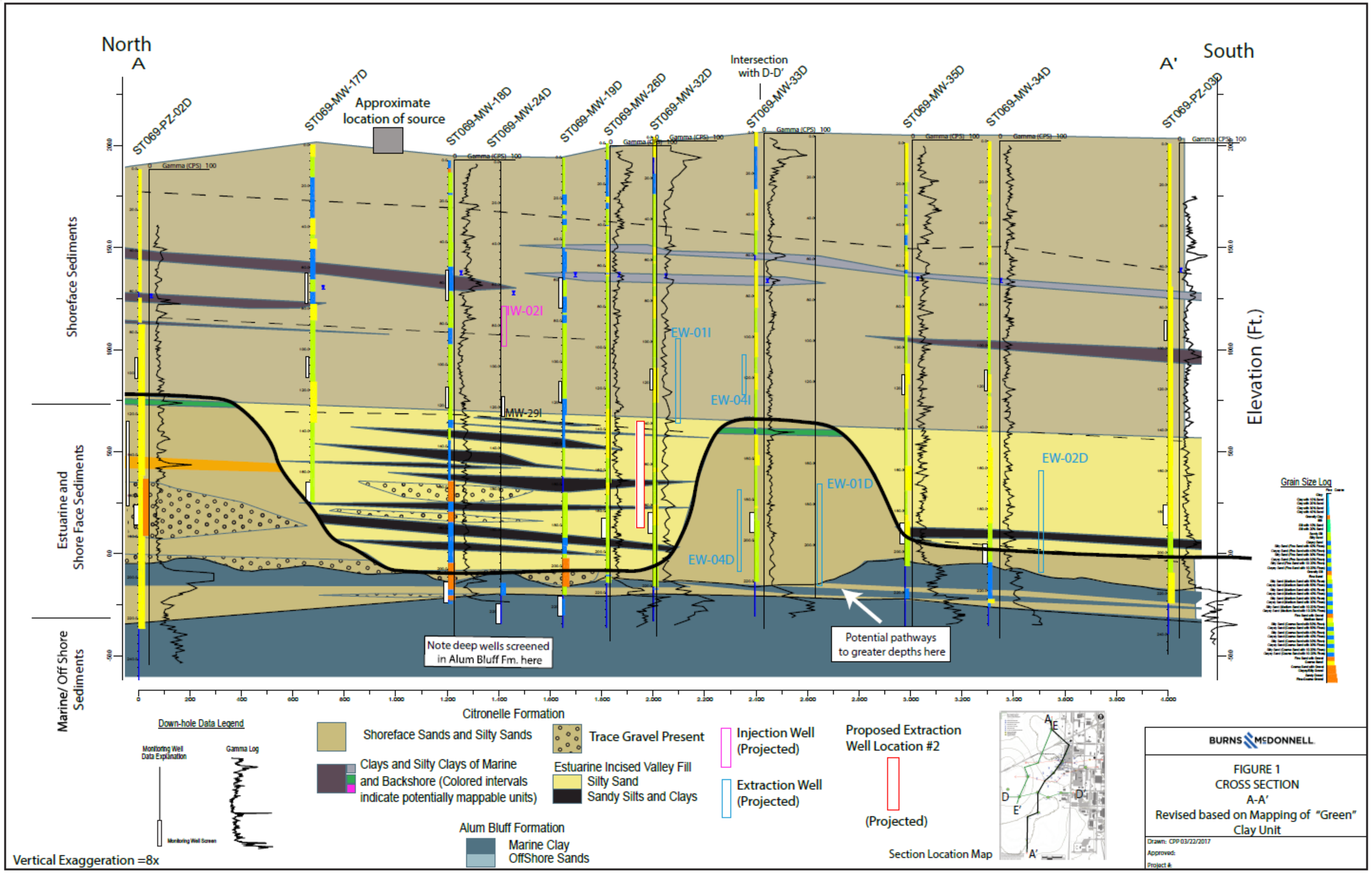
- Deep zone contamination increased significantly following system activation.
- Turned to ESS.





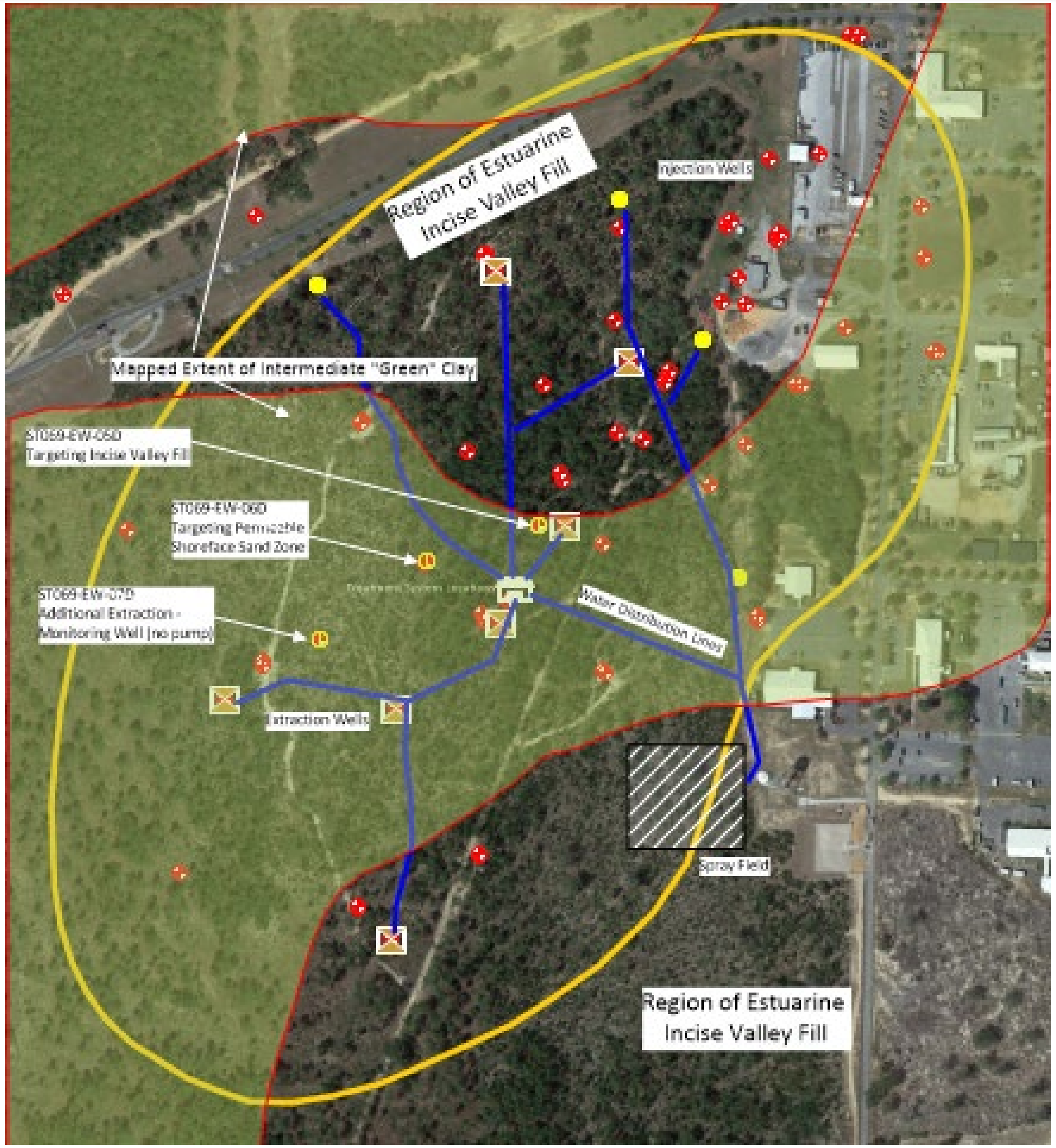
ST-69 ESS

- According to the ESS - CSM and an educated and experienced sequence stratigrapher **"its definitely not a big ole' sandbox."**
- Contaminant pathway suggested "stair stepping," which promotes vertical and lateral migration.
- Deep zone extraction well positively impacted intermediate level contamination.



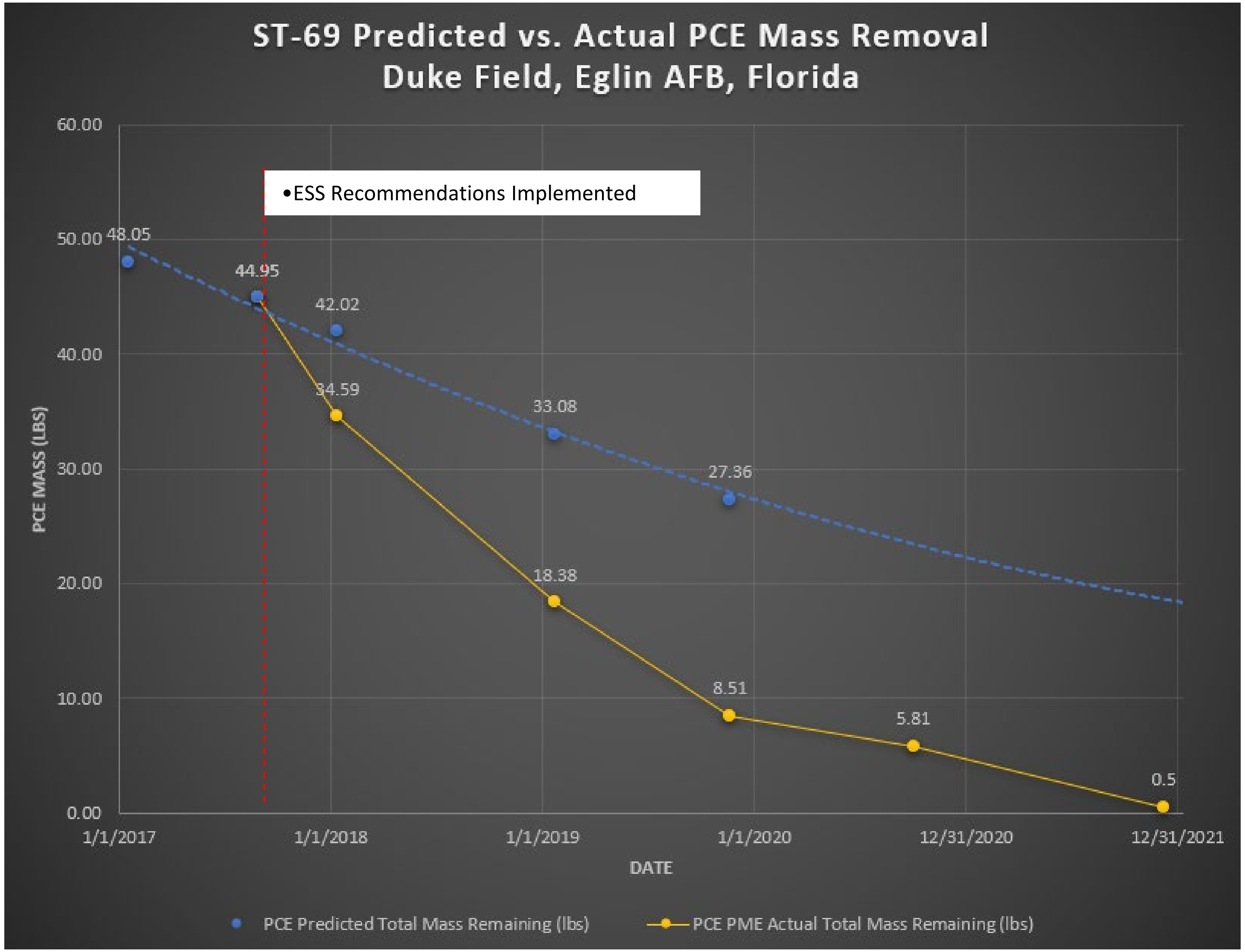
ESS - Planview

- Detection of Estuarine Incised Valley Fill
- Plank's Lightning Bolt!!
- Transmissivities were generally greater parallel to the shoreline than perpendicular
- Isotropy versus Anisotropy – Assumed Kx = Ky
- Impacts on groundwater modeling
- Two extraction wells were installed



Performance Model

- Prior to ESS, predicted Site Closure (SC) date is 2032 plus Post Active Remedial Monitoring (PARM).
- Post-ESS implementation 2022 plus PARM
- Implementation of ESS is reducing the time to achieve SC by 10 years.
- 87% PCE Mass Reduction in 3 years



•Sources: Updated from Eglin AR 31434, 31133, 32613

Duke Field Site Case Study Summary

- The reduction in treatment time by 10 years represents a $700,000 reduction in life cycle cost (LCC) based on annual recurring cost, operations and maintenance, sampling, Five-Year Review (FYR), PARM, and documentation.
- Implementation of the ESS process prior to the Performance-Based Remediation (PBR) handoff would have likely resulted in achieving the performance milestone of SC.
- Results of the ESS approach provided a better understanding of the site geology and a means of optimizing the remedial design.
- An experienced and educated sequence stratigrapher identified the significant differences between ESS and the traditional CSM.
- Regardless of a site status within the remediation process, ESS can produce significant project savings – Implementation early in the remedial process is preferred.
- Optimization of existing remedial systems at Duke Field Site was conducted in near real-time.

Lessons Learned

- In general, the ESS methodology provides a better understanding of the site geology and a more effective means of designing, installing, and optimizing a remedial system.
- Minimizing site uncertainties prevents overdesigning of remedial systems.
- Increasing site knowledge and identification of key hydrostratigraphic units is critical to achieving ever more stringent regulatory requirements.
- Regardless of site status, implementation of the ESS approach in the restoration/remediation flow train can result in significant cost avoidance and/or reduce LCC.
- Analysis has shown that ESS can accelerate the remedial process, on average 2–4 years.
- Experienced and formally educated sequence stratigraphers are essential.
- Conceptual remedial designs to field deployment was achieved in < 1 year.

Questions?

Your Success is Our Mission!