Open Environmental Restoration Resources (OER2) Webinar #23

Environmental Sequence Stratigraphy (ESS) as a Remedy Optimization Tool

Rick Cramer, PG
Burns & McDonnell

JD Spalding, PG
NAVFAC SE

Dave Collins, PG
NAVFAC Washington

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Today's Speakers

Rick Cramer, PG
Burns & McDonnell

JD Spalding
NAVFAC SE

Dave Collins, PG
NAVFAC Washington

OER2 Webinar Series

- **Why Attend?**
  - Obtain and hear about the latest DOD and DON's policies/guidance, tools, technologies and practices to improve the ERP's efficiency
  - Promote innovation and share lessons learned
  - FEEDBACK to the ERP Leadership
- **Who Should Attend?**
  - ERP Community Members: RPMs, RTMs, Contractors, and other remediation practitioners who support and execute the ERP
  - Voluntary participation
- **Schedule and Registration:**
  - Offered quarterly
  - Registration link for each topic (announced via ER T2 email)
- **Topics and Presenters:**
  - ERP community members to submit topics (non-marketing and DON ERP-relevant) to POCs (Gunarti Coghlan – gunarti.coghlan@navy.mil or Amy Hawkins – amy.hawkins@navy.mil)
  - Selected topic will be assigned Champion to work with presenter

Why is new approach to Complex Sites necessary?

- Despite nearly 40 years of intensive efforts, groundwater remediation is required at more than 126,000 sites across the U.S.
- Reasons for protracted remediation efforts include:
  - Ineffective subsurface investigations
  - Highly heterogeneous subsurface conditions
  - Insufficient remedial technologies
- Of the nation's remaining groundwater remediation sites, more than 12,000 are considered "complex"; this estimate is almost certainly biased low, particularly when emerging contaminants, including PFAS, are considered.

National Academy of Sciences Committee on Future Options for Management in the Nation's Subsurface Remediation Effort, 2013

RITS 2018

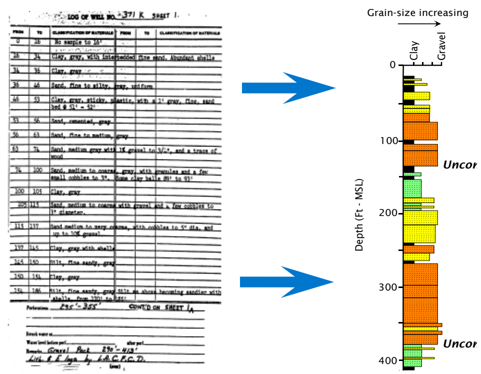
Naval Facilities Engineering Command

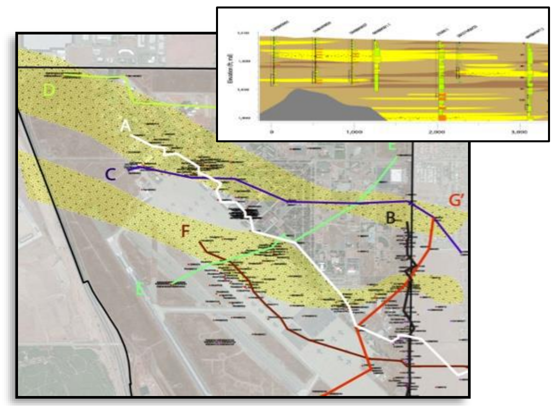
ENGINEERING AND EXPEDITIONARY WARFARE CENTER

Applying Environmental Sequence Stratigraphy to Unlock the Clues Beneath Your Site and Improve the Conceptual Site Model

Rick Cramer, PG
Burns & McDonnell

The Environmental Sequence Stratigraphy (ESS) Process



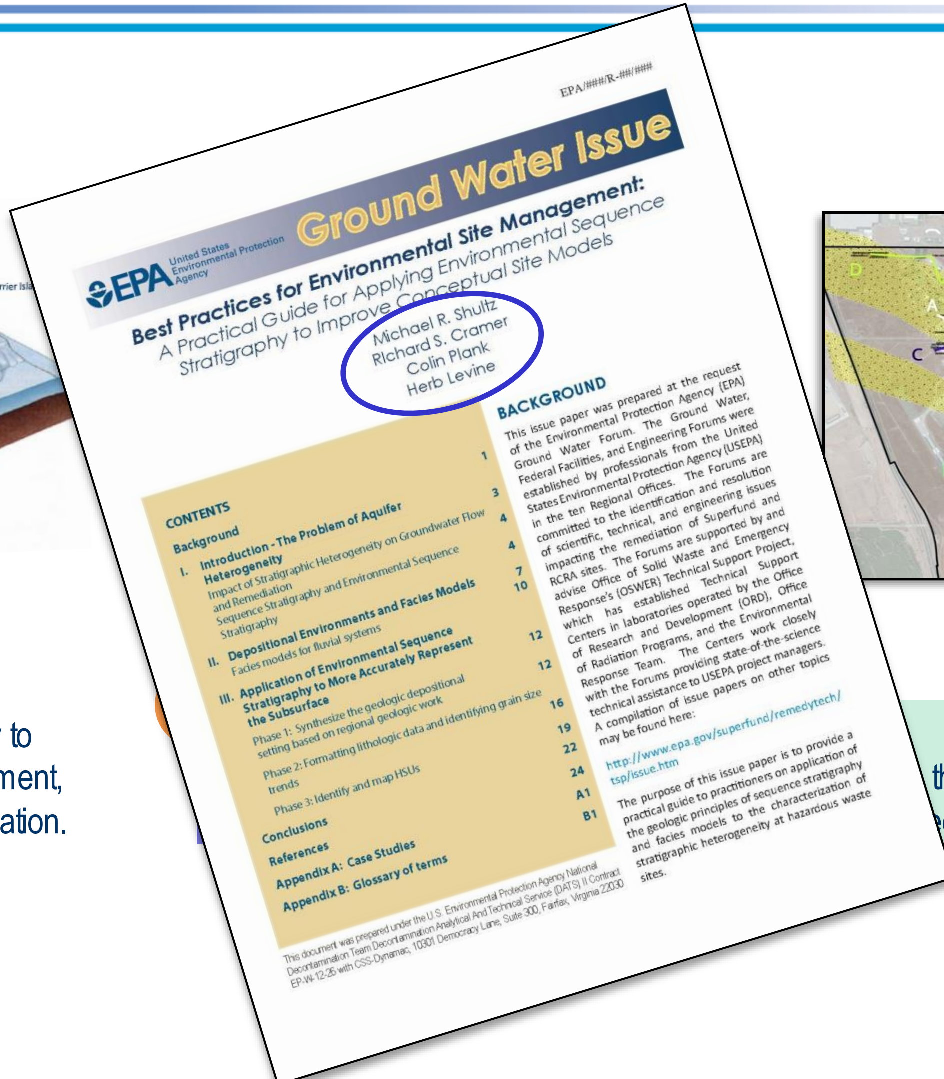


1 **Research regional geology** to determine depositional environment, the foundation of the ESS evaluation.

2 **Leverage existing lithology data:** vertical grain size patterns indicative of genetic relationships.

3 **Map and predict** the subsurface permeability architecture away from the data points.

The Environmental Sequence Stratigraphy (ESS) Process



EPA/###/R-##/###

EPA United States Environmental Protection Agency

Ground Water Issue

Best Practices for Environmental Site Management:
A Practical Guide for Applying Environmental Sequence Stratigraphy to Improve Conceptual Site Models

Michael R. Shultz
Richard S. Cramer
Colin Plank
Herb Levine

CONTENTS

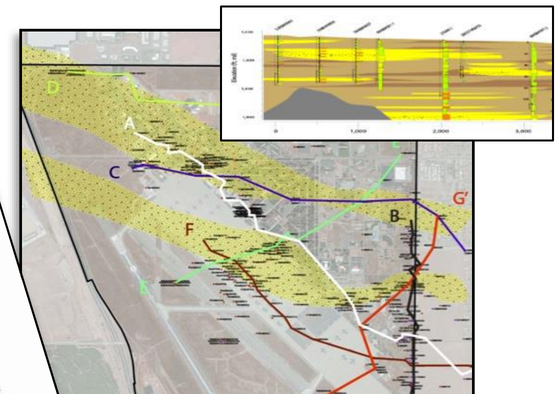
BACKGROUND

This issue paper was prepared at the request of the Environmental Protection Agency (EPA) Ground Water Forum. The Ground Water, Federal Facilities, and Engineering Forums were established by professionals from the United States Environmental Protection Agency (USEPA) in the ten Regional Offices. The Forums are committed to the identification and resolution of scientific, technical, and engineering issues impacting the remediation of Superfund and RCRA sites. The Forums are supported by and advise Office of Solid Waste and Emergency Response's (OSWER) Technical Support Project, which has established Technical Support Centers in laboratories operated by the Office of Research and Development (ORD), Office of Radiation Programs, and the Environmental Response Team. The Centers work closely with the Forums providing state-of-the-science technical assistance to USEPA project managers. A compilation of issue papers on other topics may be found here:

http://www.epa.gov/superfund/remedytech/tsp/issue.htm

The purpose of this issue paper is to provide a practical guide to practitioners on application of the geologic principles of sequence stratigraphy and facies models to the characterization of stratigraphic heterogeneity at hazardous waste sites.

This document was prepared under the U.S. Environmental Protection Agency National Decontamination Team Decontamination Analytical And Technical Service (DATS) II Contract EP-W-12-26 with CSS-Dynamac, 10301 Democracy Lane, Suite 300, Fairfax, Virginia 22030



1

Research regional geology to determine depositional environment, the foundation of the ESS evaluation.

Map and predict the subsurface permeability …ecture away from the data points.

U.S. EPA Contaminated Site Cleanup Information (CLU-IN)

Environmental Sequence Stratigraphy and the new EPA Remediation Geology Paradigm

Sponsored by: U.S. EPA Technical Support Project

Archived: Tuesday, April 3, 2018

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Description | Presenters | Webinar Slides | Related Links

Link to US EPA Technical Issue Paper

https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=341373&Lab=NRMRL

Link to US EPA CLU-IN Webinar

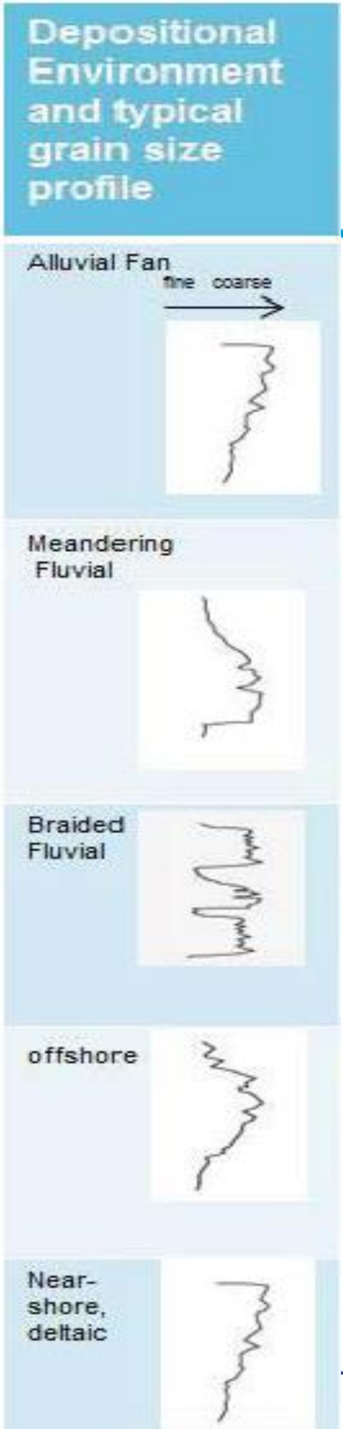
http://www.clu-in.org/conf/tio/EnvSeqStrat_040318/

Stratigraphy, Sub-discipline of Geology

Geology

- mineralogy
- economic geology
- geophysics
- stratigraphy
- marine geology
- volcanology
- geochemistry
- structural geology
- sedimentology
- paleontology
- seismology
- hydrogeology
- petroleum geology
- tectonics
- engineering geology
- geomorphology
- igneous petrology
- metamorphic petrology

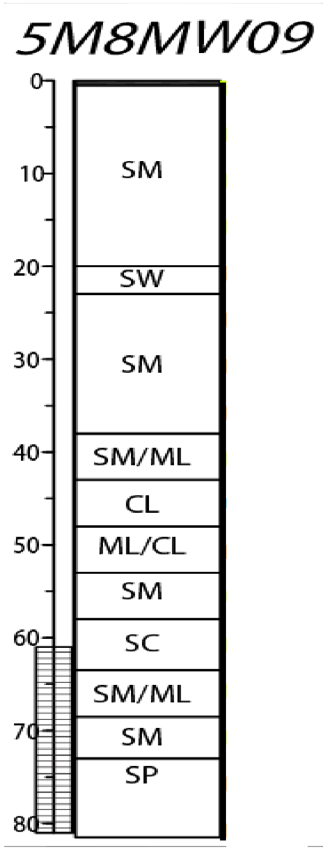
Depositional environments = distinctive vertical grain size distributions



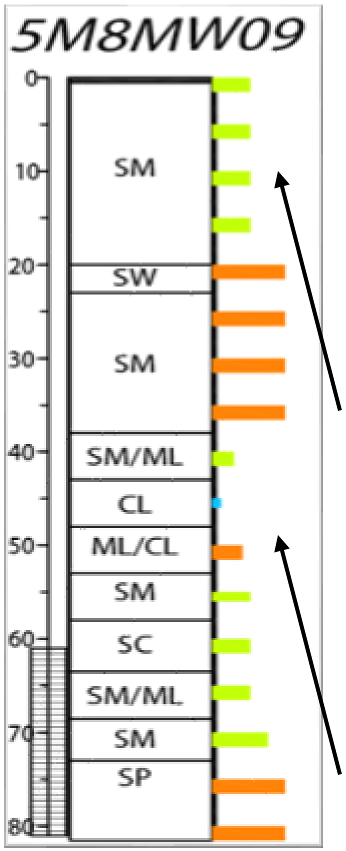
ITRC Integrated DNAPL Site Characterization document

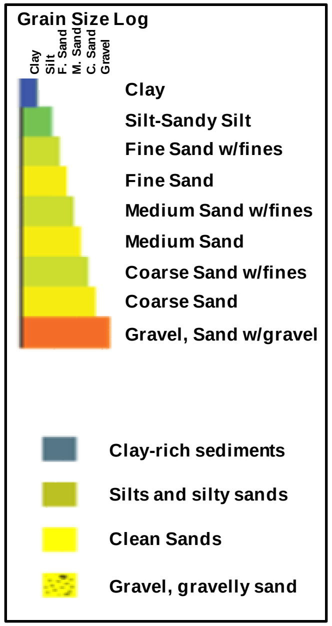
http://www.itrcweb.org/DNAPL-ISC_tools-selection

How to Find Buried Channels with Existing Data – March AFB



How to Find Buried Channels with Existing Data – March AFB



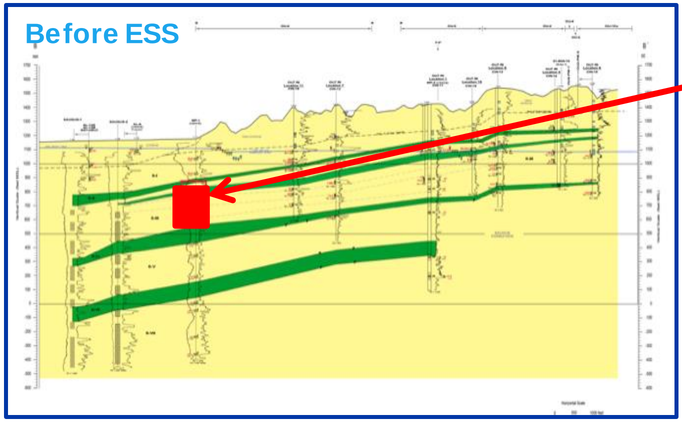


Graphic Grain-Size Logs (GSLs)

- Alternative to the standard of posting USCS symbols
- Existing data is formatted for stratigraphic interpretation

Key Point: Reveals the “hidden” stratigraphic information available with existing lithology data

Cost Savings: Optimize Plume Containment Remedy

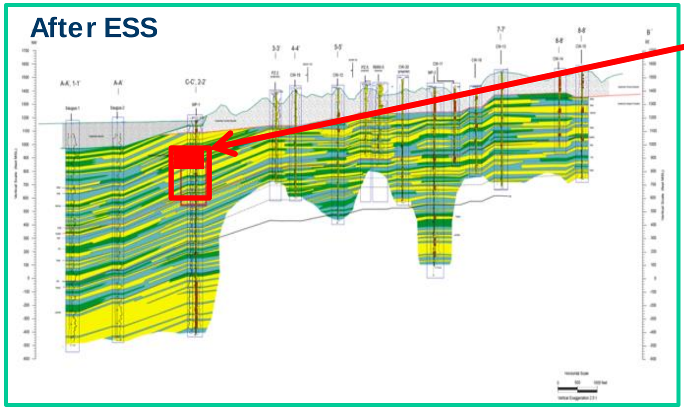


125' extraction interval (includes non-impacted strata)

Remediation System Design (Before ESS)

- 12 extraction wells
- ~200 gpm per well
- 1,261 million gallons per year

Total cost = $82 million



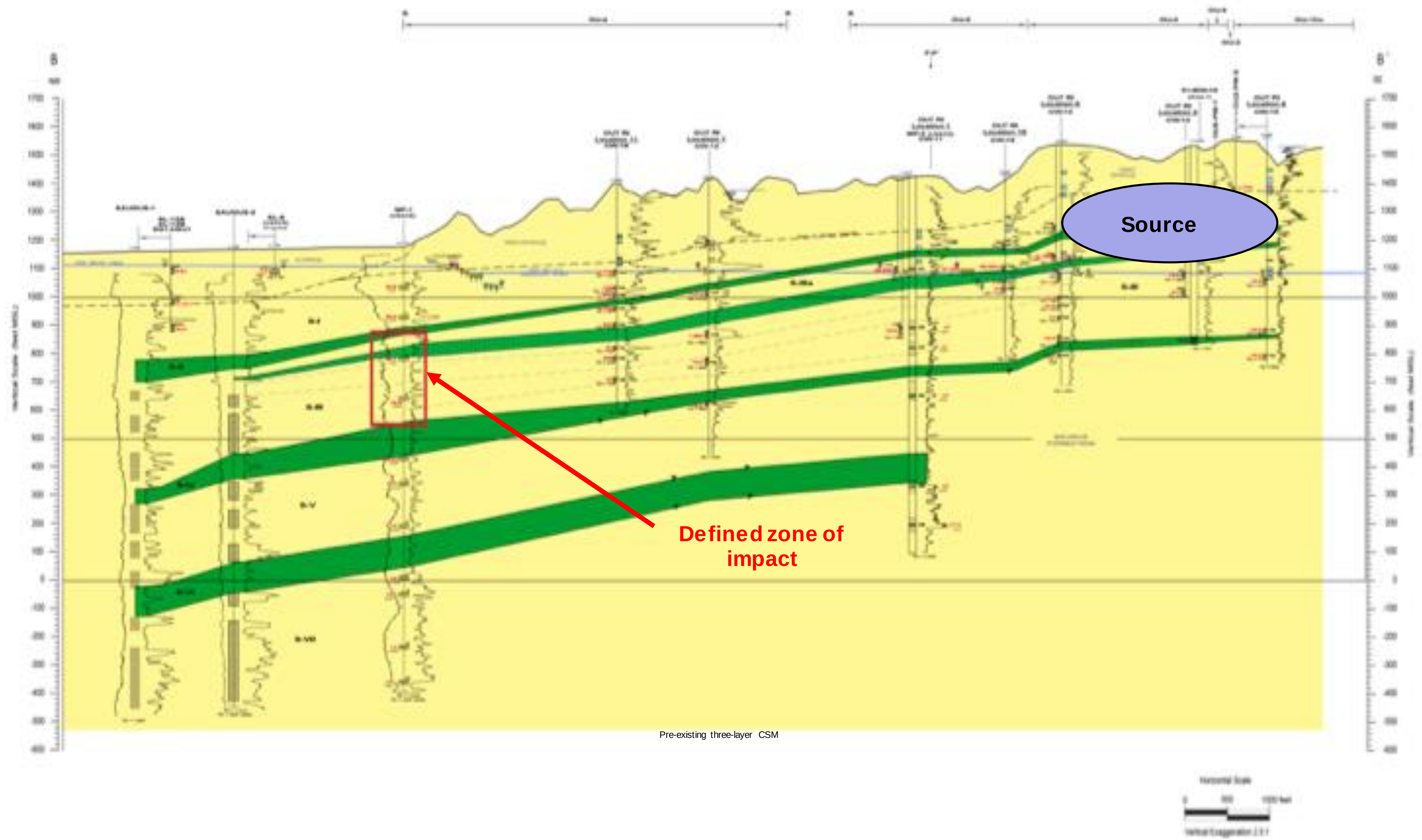
35' extraction interval (impacted strata only)

Estimated Remediation System Cost (After ESS)

- 13 extraction wells
- 46 gpm per well
- 314 million gallons per year

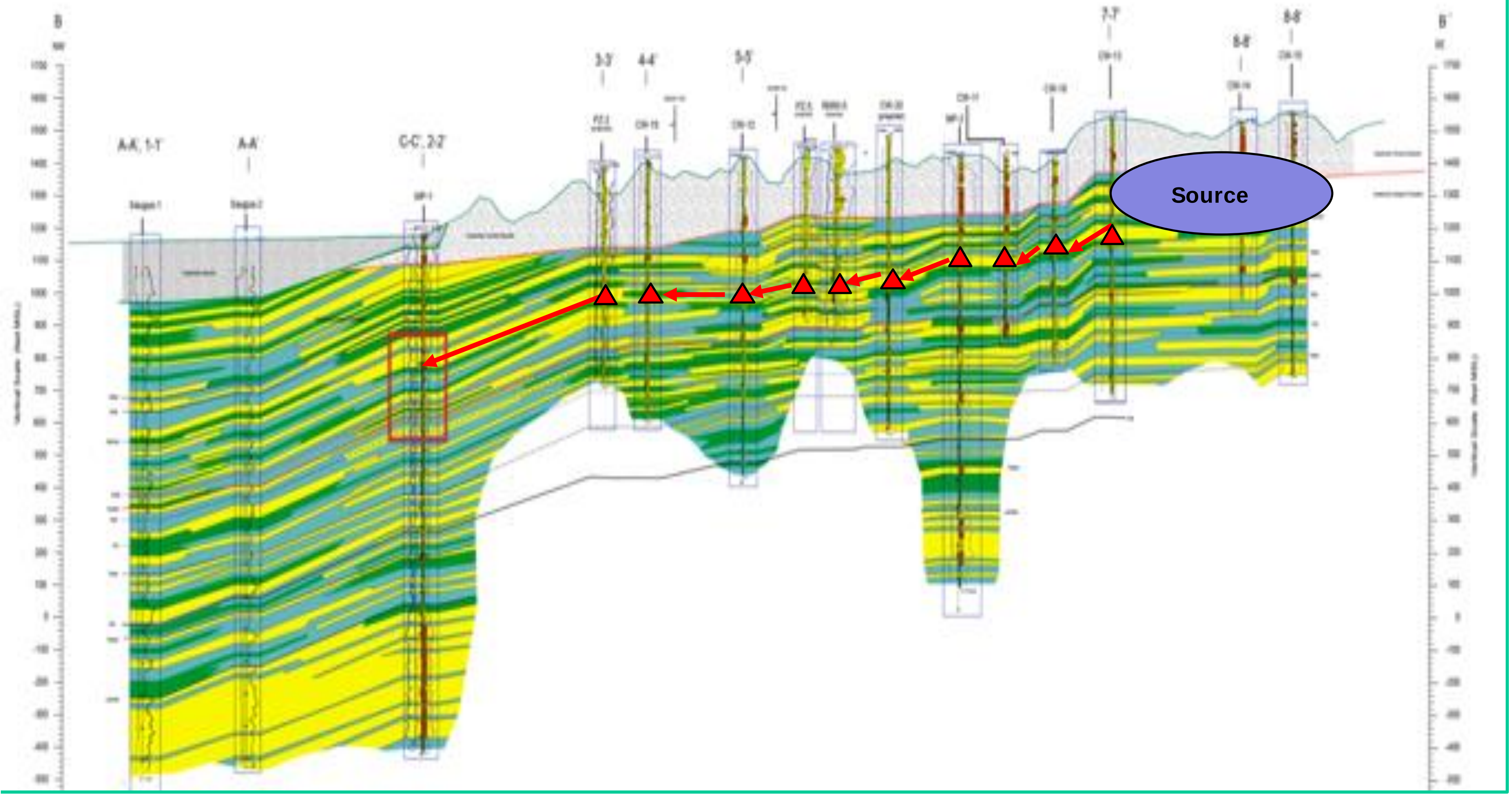
Total cost = $26.5 million

Before ESS: "Lumping" Heterogeneity

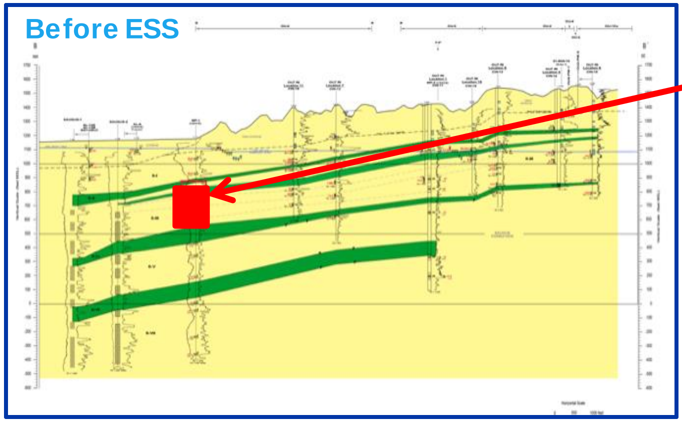


Pre-existing three-layer CSM

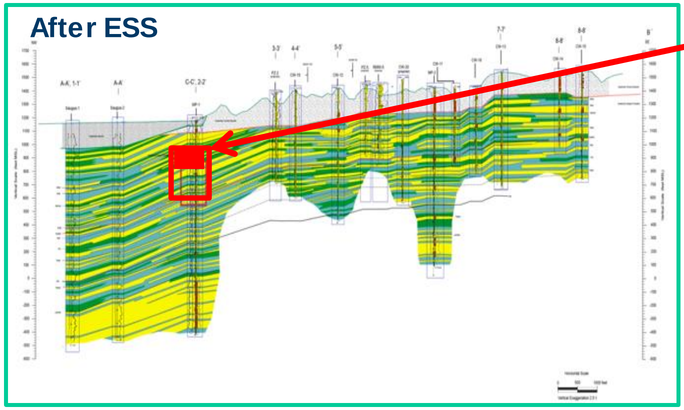
After ESS: Define Hydrostratigraphic Units



Cost Savings: Optimize Plume Containment Remedy

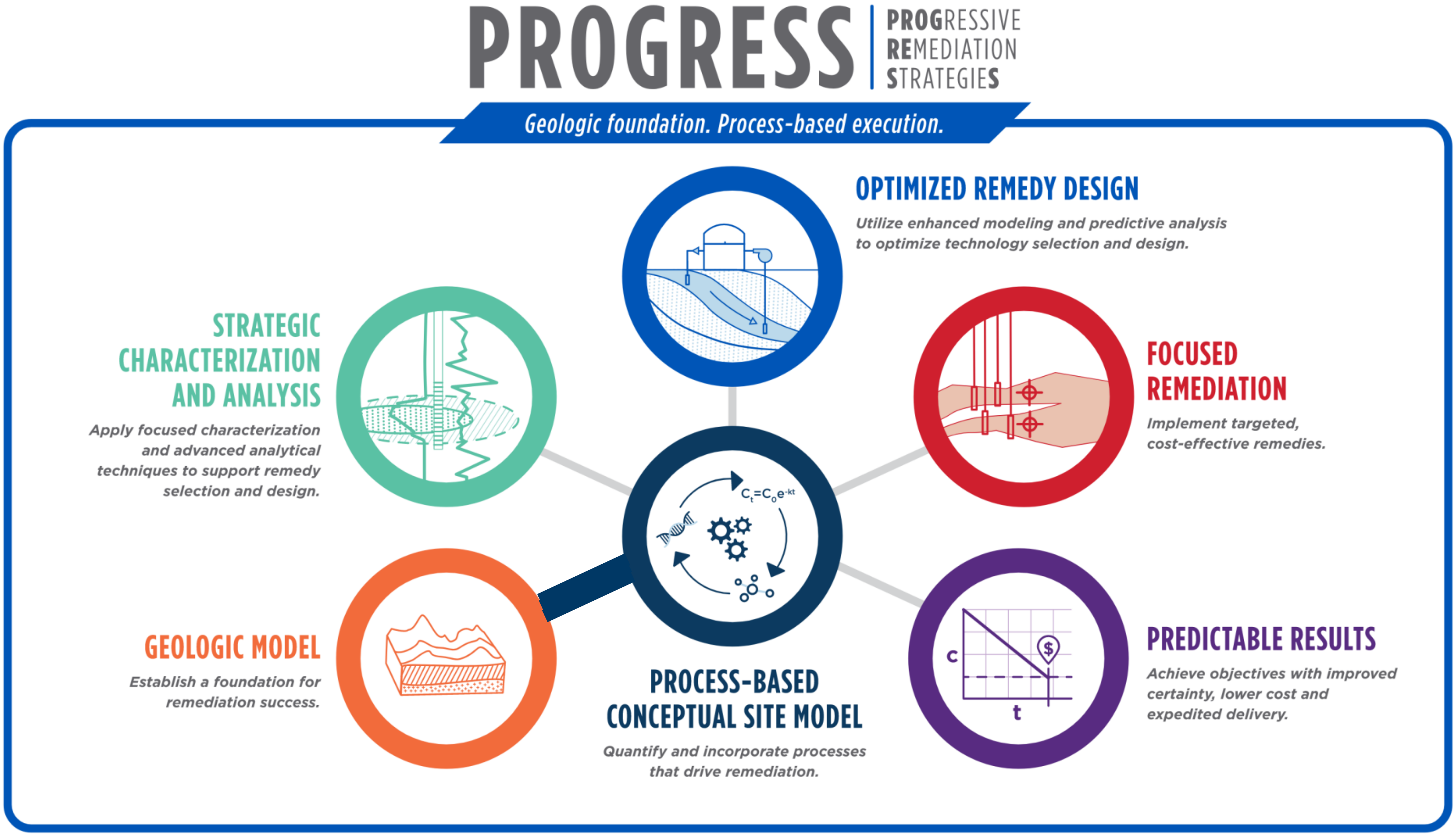


125' extraction interval (includes non-impacted strata)



35' extraction interval (impacted strata only)

- **Significantly reduced quantity of extracted groundwater (by >70%)**
- **Significantly reduced cost of remediation (by >$50 million)**


PROGRESS
PROGRESSIVE REMEDIATION STRATEGIES
Geologic foundation. Process-based execution.
OPTIMIZED REMEDY DESIGN
Utilize enhanced modeling and predictive analysis to optimize technology selection and design.
STRATEGIC CHARACTERIZATION AND ANALYSIS
Apply focused characterization and advanced analytical techniques to support remedy selection and design.
FOCUSED REMEDIATION
Implement targeted, cost-effective remedies.
$C_t=C_0e^{-kt}$
GEOLOGIC MODEL
Establish a foundation for remediation success.
PROCESS-BASED CONCEPTUAL SITE MODEL
Quantify and incorporate processes that drive remediation.
PREDICTABLE RESULTS
Achieve objectives with improved certainty, lower cost and expedited delivery.
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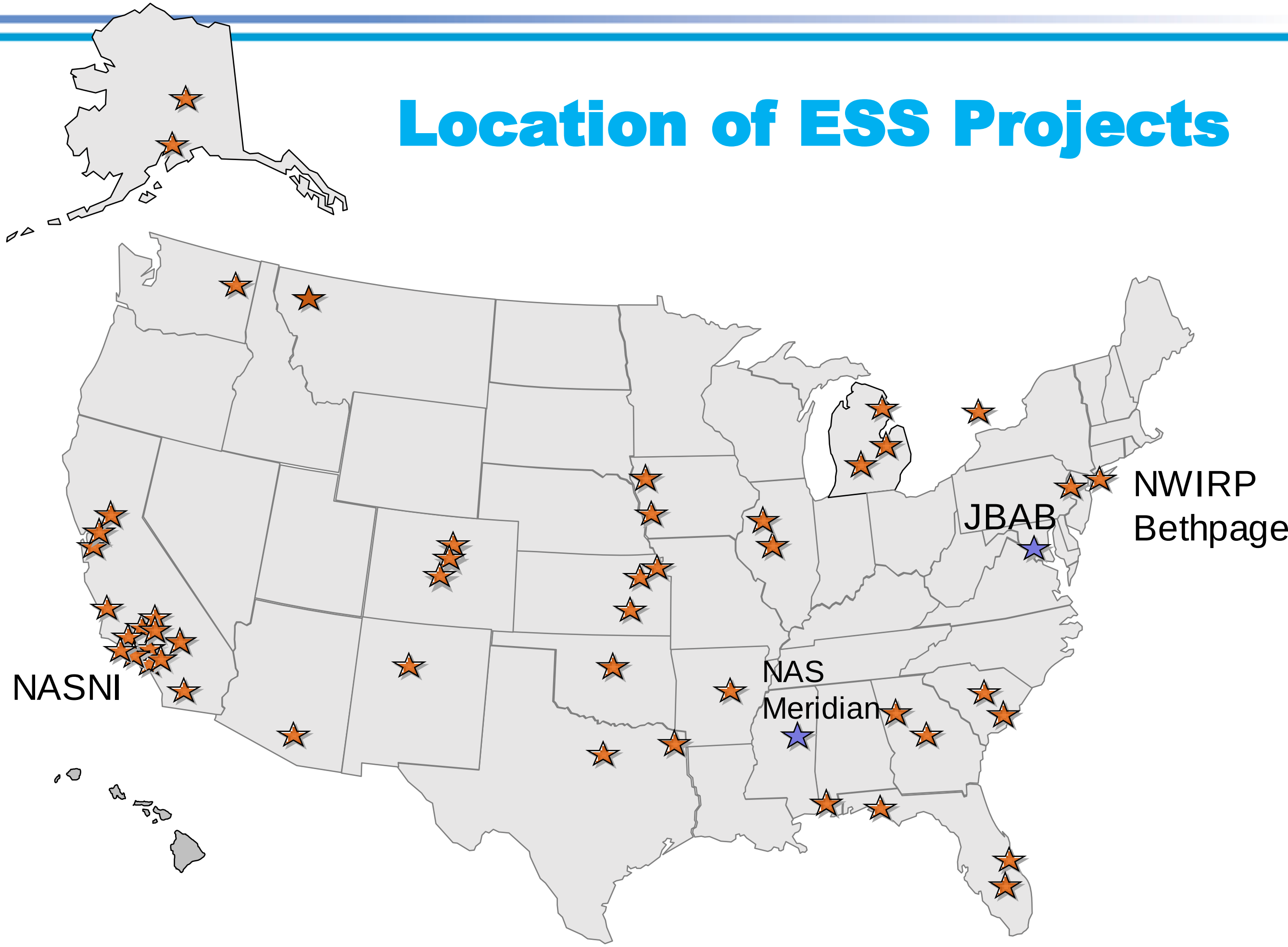
Location of ESS Projects



KEYS TO APPLY ESS

- A trained & experienced stratigrapher to apply ESS per EPA Guidance
- Format lithology as Graphic Grainsize Logs (NOT Unified Soil Classification System)
- Apply stratigraphic principles to correlate lithology logs, make valid geologic interpretations.
- Goal is to define detailed subsurface plumbing that controls groundwater flow and contaminant migration.

Naval Facilities Engineering Systems Command

Application of Environmental Sequence Stratigraphy (ESS) to Improve the Per- and Polyfluoroalkyl Substances (PFAS) Conceptual Site Model

NAS Meridian, Meridian, MS

July 2021

Preface

A Site Inspection (SI) for PFAS was initiated in 2017 at NAS Meridian. As part of the SI process, a desktop ESS study was conducted in 2018. The study identified buried sand channel features at the Base and additional data needs to support the SI. Following a 2020 SI field investigation, the ESS study was updated. This presentation provides an overview of the ESS study for NAS Meridian and the updated conceptual site model (CSM).

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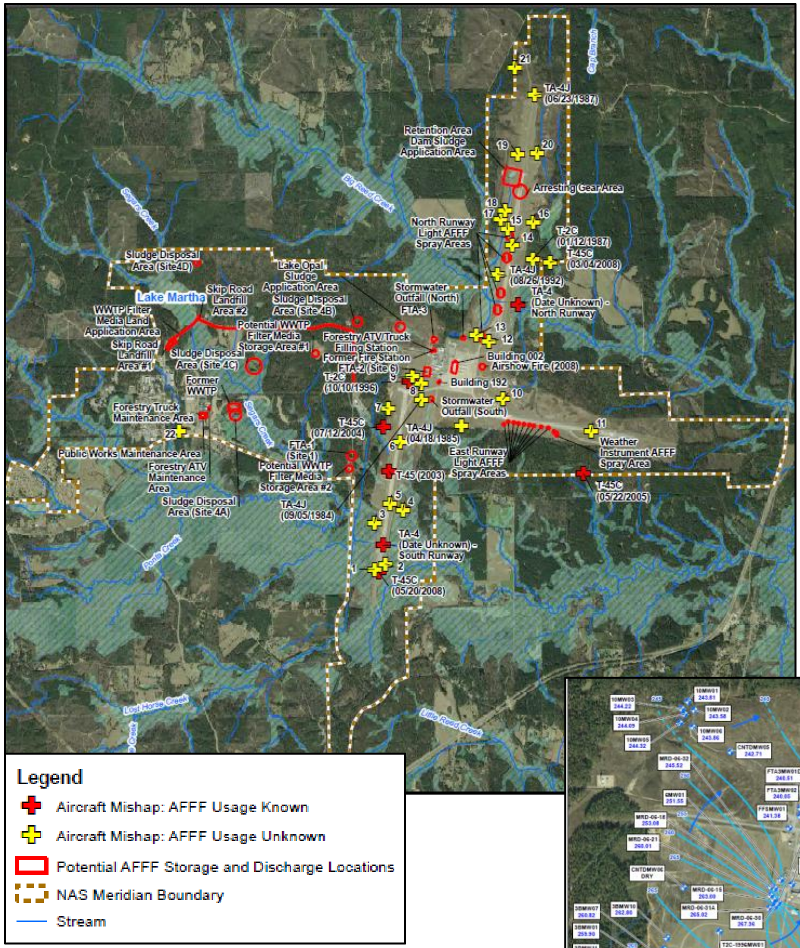
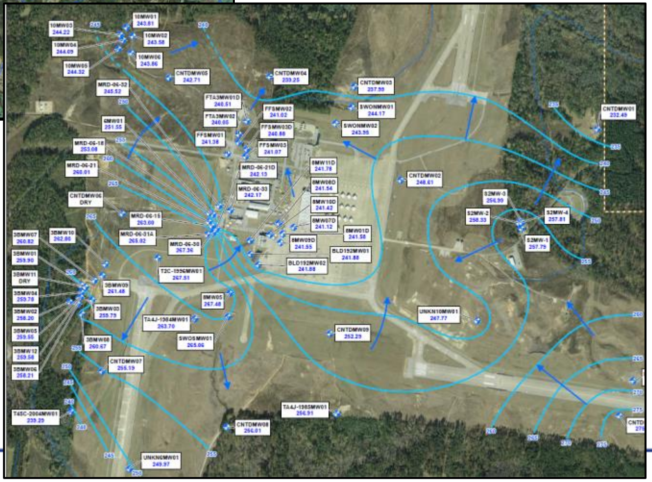
Outline

- Introduction
- ESS Study Methodology
- ESS Interpretation and CSM Updates
- Conclusions

Introduction

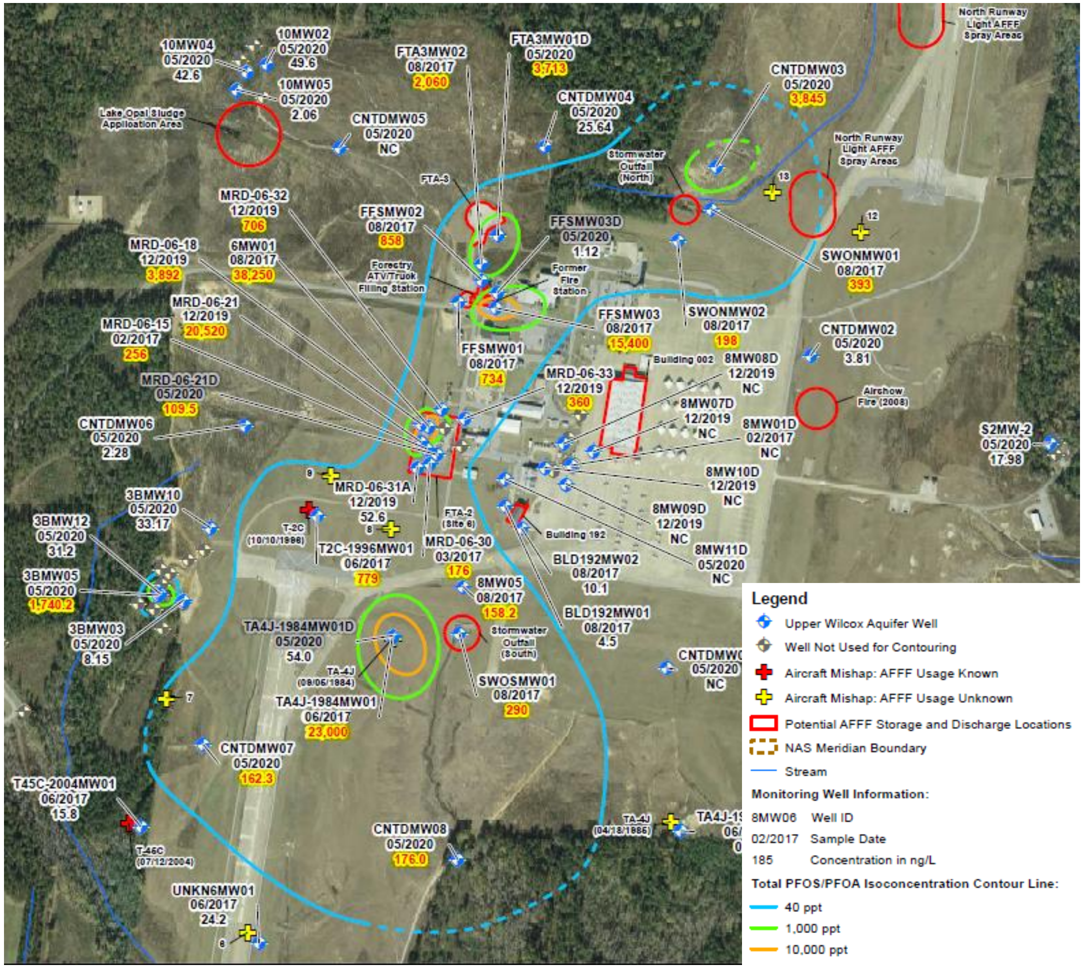


- Over 30 potential PFAS sources have been identified for SI at NAS Meridian
- Due to the geologic depositional history and the placement of fill material, the Base has complex groundwater flow patterns
- During the SI planning process, an ESS study was proposed to assess if the site stratigraphy indicated the presence of buried sand channels that could serve as preferential pathways for PFAS, particularly in the off-Base directions



Study Objective

<u>Study Objective</u>: Apply ESS to refine the understanding of hydrogeology at NAS Meridian and assess if buried sand channels may be present that could serve as preferential pathways for PFAS migration.



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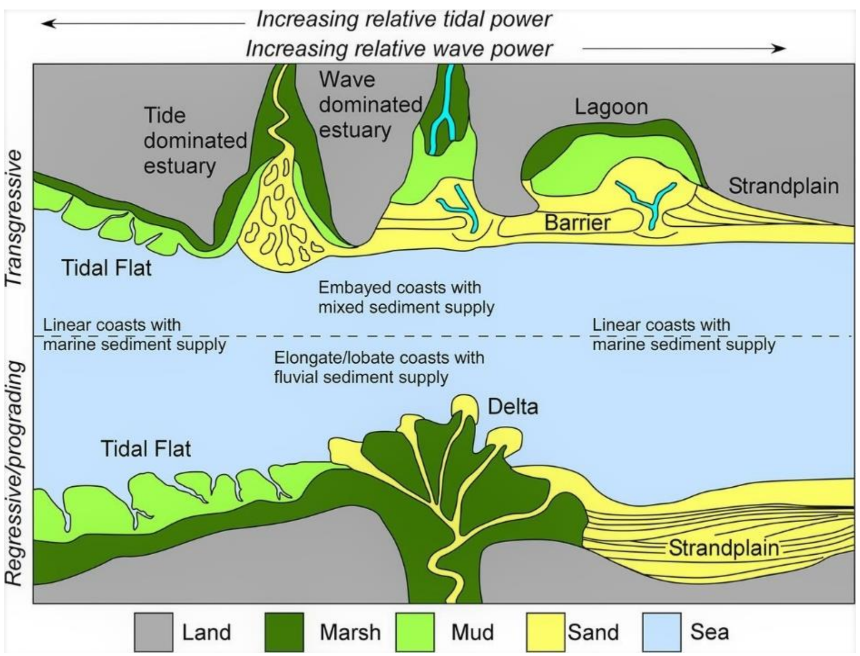
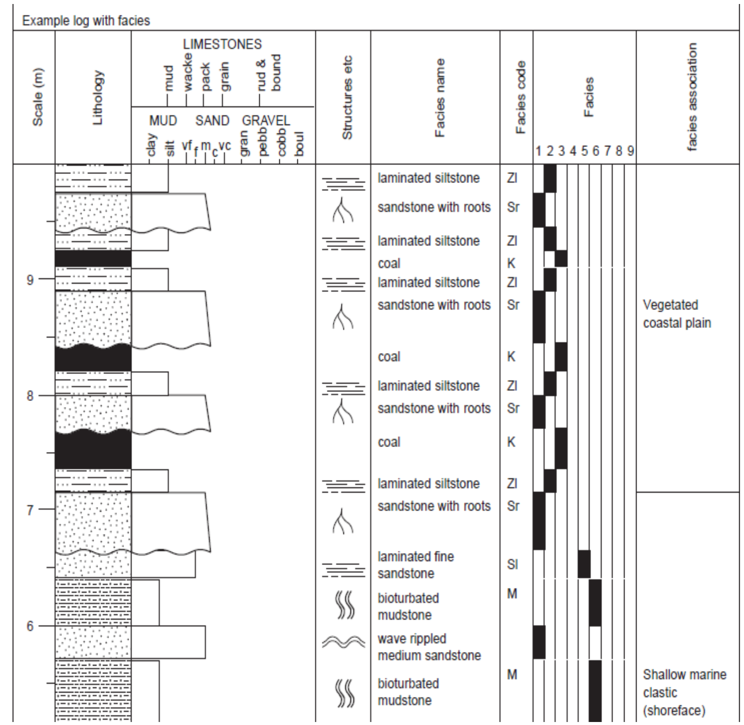
ESS Study Methodology

1. Identify Depositional Environment

- NAS Meridian is located in the Coastal Plain of Mississippi and is part of the Mississippi Embayment
- Geology is a mix of marine and alluvial/deltaic deposits from cyclical transgressing and regressing seas



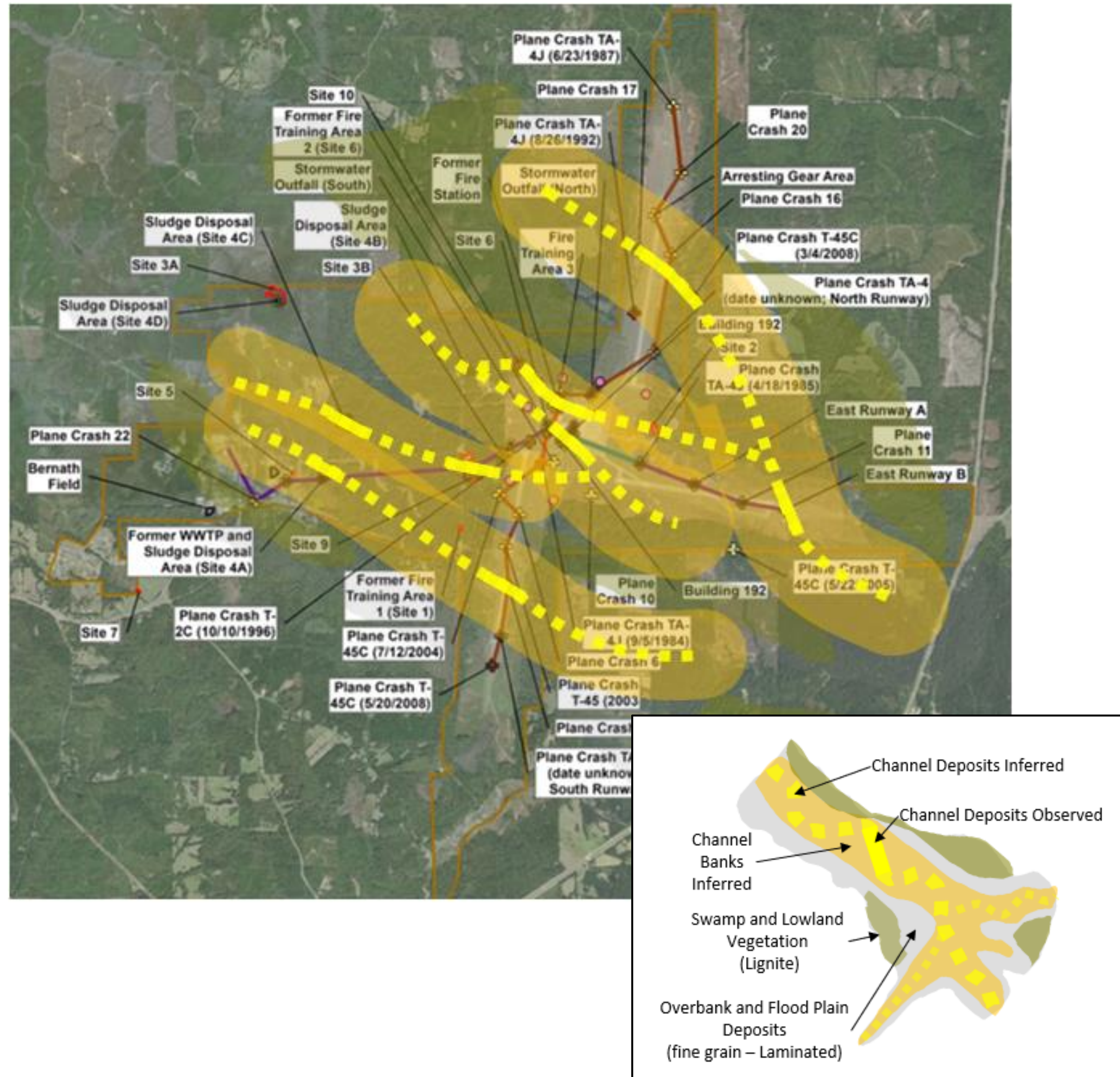


River-dominated deltas selected as depositional environment for ESS study

ch2m

2. Review Existing Soil Logs and Identify Additional Data Needs

- Desktop ESS study was conducted as a preliminary step in 2018
  - Soil boring logs from historical investigations and 2017 SI activities were reviewed
  - Preliminary sand channels mapped
  - Areas were identified where additional stratigraphic information would be beneficial



2. Review Existing Soil Logs and Identify Additional Data Needs

- Originally, 9 monitoring wells were proposed for the 2020 SI
- After preliminary ESS study, two well locations were modified, and three additional wells were proposed

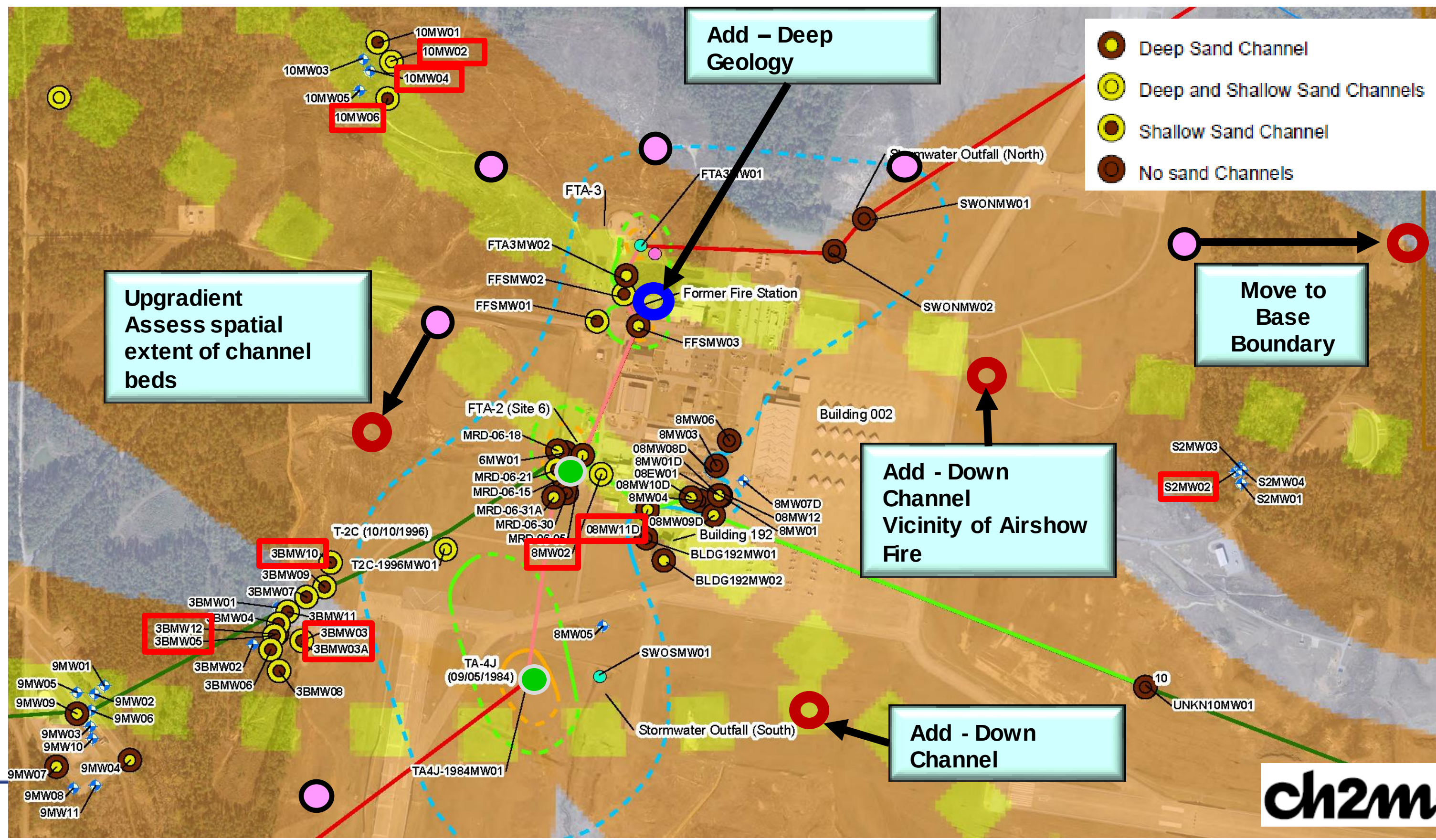
Previously Proposed Single-Cased Well

Revised or Additional Single-Cased Well

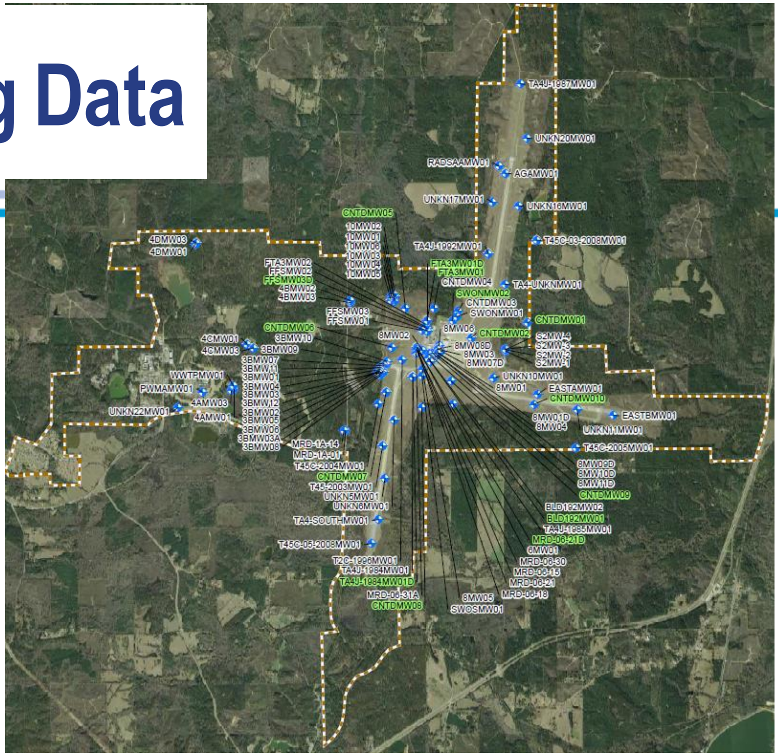
Previously Proposed Double-Cased Well

Additional Double Cased Well

Existing Well Proposed for Sampling

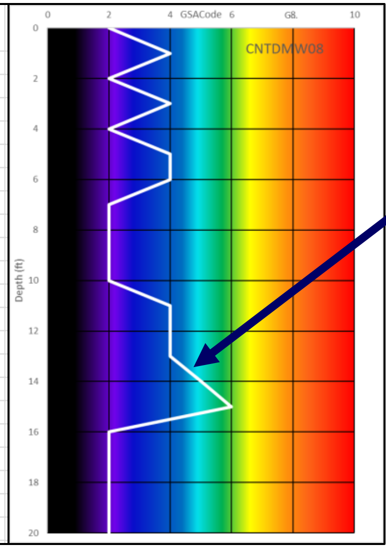


3. Re-Categorize Soil Boring Data



- Re-classified soil boring USCS descriptions based on grain size
- Depositional setting added for cross-section development
- EC data from membrane interface probe (MIP) investigations also considered

ID	Depth (ft)	GSACode	Description	Max Grain Size	Depositional Setting	Depositional Code
CNTDMW08	0	2	Clay	Fine Sand	Delta	6
CNTDMW08	1	4	Silty Sand	Fine Sand	Delta	6
CNTDMW08	2	2	Clay	Fine Sand	Delta	6
CNTDMW08	3	4	Silty Sand	Fine Sand	Delta	6
CNTDMW08	4	2	Clay	Fine Sand	Delta	6
CNTDMW08	5	4	Silty Sand	Fine Sand	Delta	6
CNTDMW08	6	4	Silty Sand	Fine Sand	Delta	6
CNTDMW08	7	2	Clay	Fine Sand	Delta	6
CNTDMW08	8	2	Clay	Fine Sand	Delta	6
CNTDMW08	9	2	Clay	Fine Sand	Delta	6
CNTDMW08	10	2	Clay	Fine Sand	Delta	6
CNTDMW08	11	4	Fine Sand	Fine Sand	Delta	6
CNTDMW08	12	4	Fine Sand	Fine Sand	Delta	6
CNTDMW08	13	4	Silty Sand	Fine Sand	Delta	6
CNTDMW08	14	5	Fine Sand	Fine Sand	Delta	6
CNTDMW08	15	6	Med. Sand w/ clay	Med Sand	Delta	6
CNTDMW08	16	2	Clay	Clay	lagoon	2
CNTDMW08	17	2	Clay	Clay	lagoon	2
CNTDMW08	18	2	Clay	Clay	lagoon	2
CNTDMW08	19	2	Clay	Clay	lagoon	2
CNTDMW08	20	2	Clay	Clay	lagoon	2

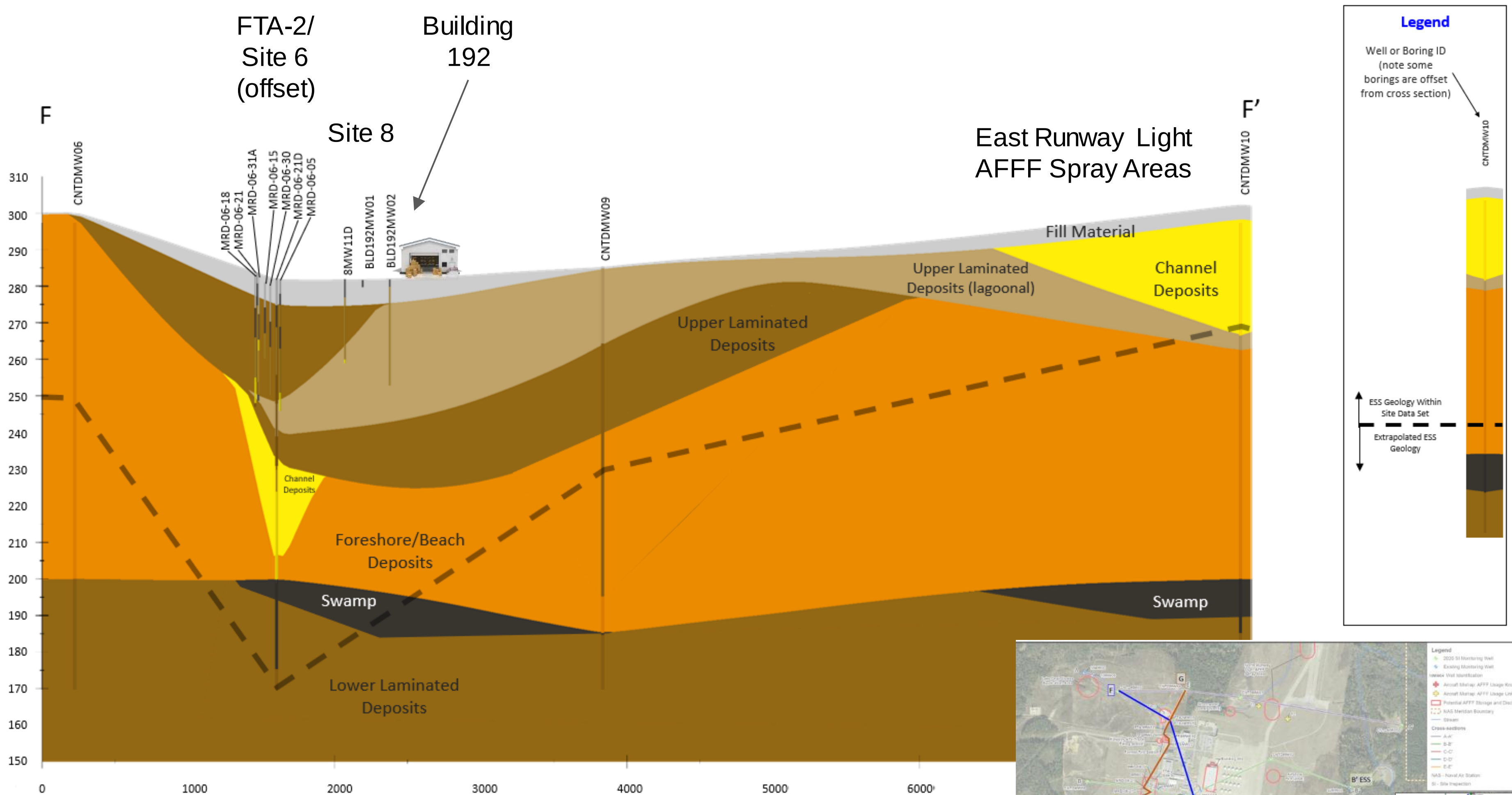


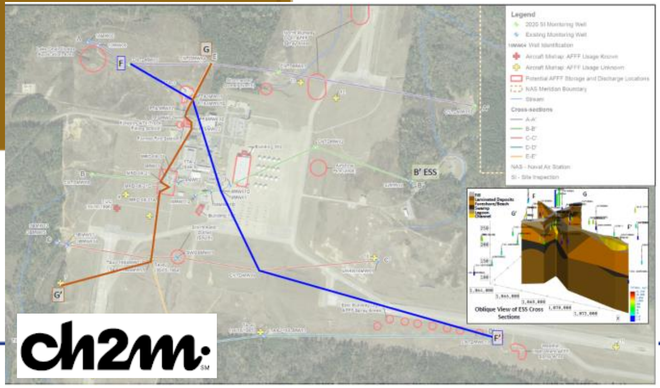
Channel cutting through lagoonal and swamp deposits

Depositio	Code		Color	SoilName
swamp	1			Lignite
lagoon	2			Clay
laminated	3			Silt
fill	4			Silty/Clayey Sand
channel	5			Fine Sand
delta	6			Med. Sand with Silt/Clay
foreshore	7			Med. Sand
				Coarse Sand
				Gravel
				Cobbles

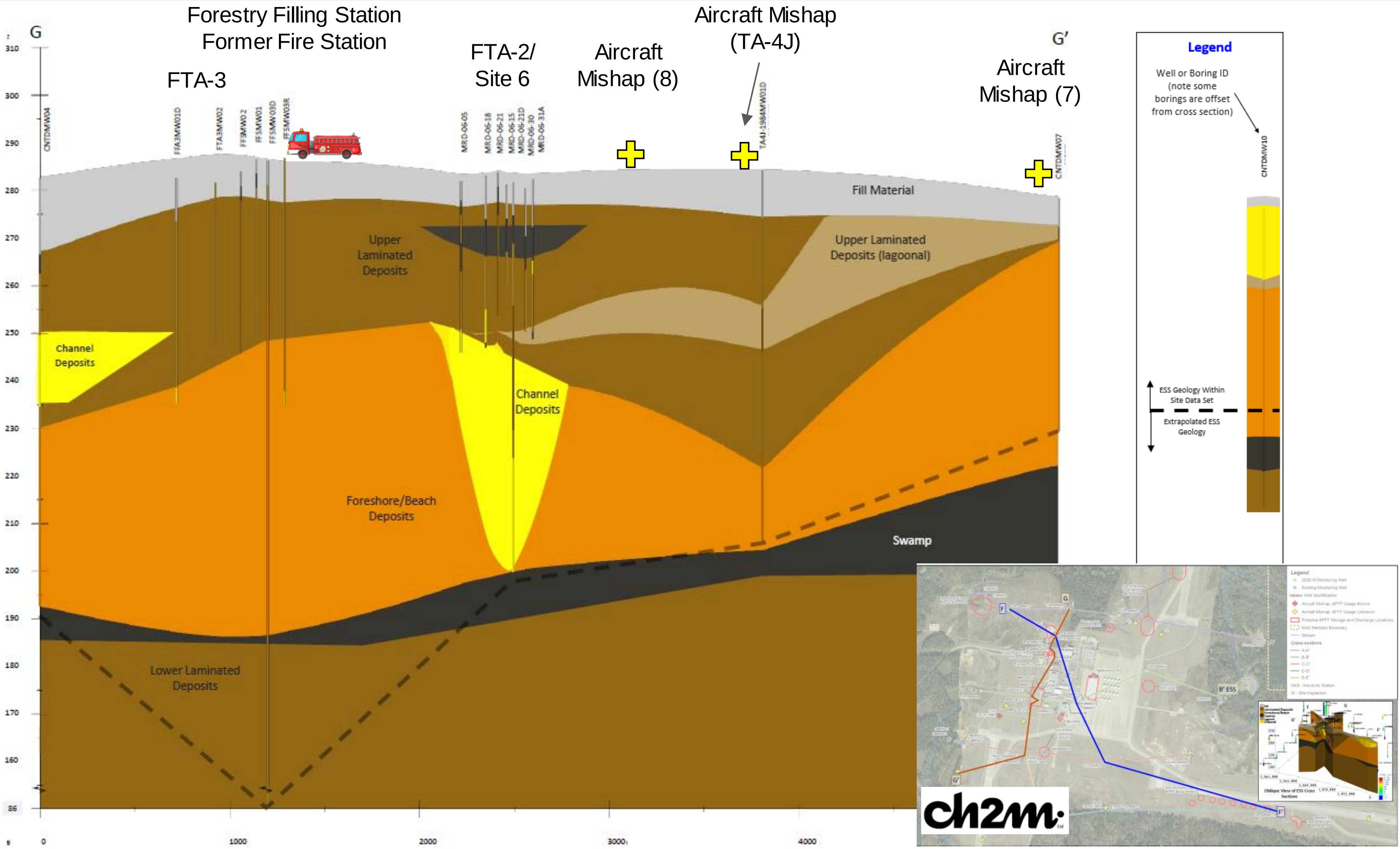
ch2m

4. Identify and Model Key Hydrostratigraphic Units
ESS Hydrostratigraphic Section F-F’





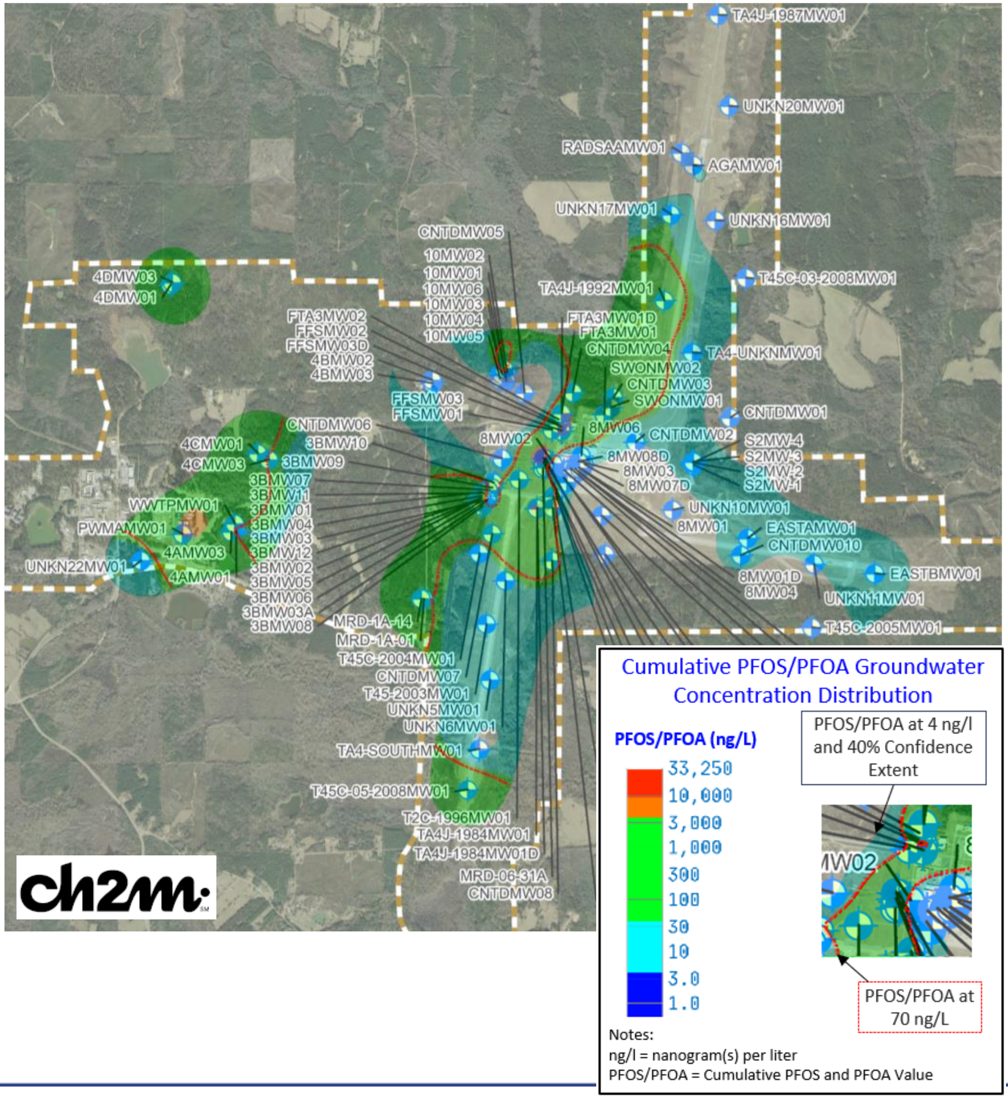
4. Identify and Model Key Hydrostratigraphic Units
ESS Hydrostratigraphic Section G-G'



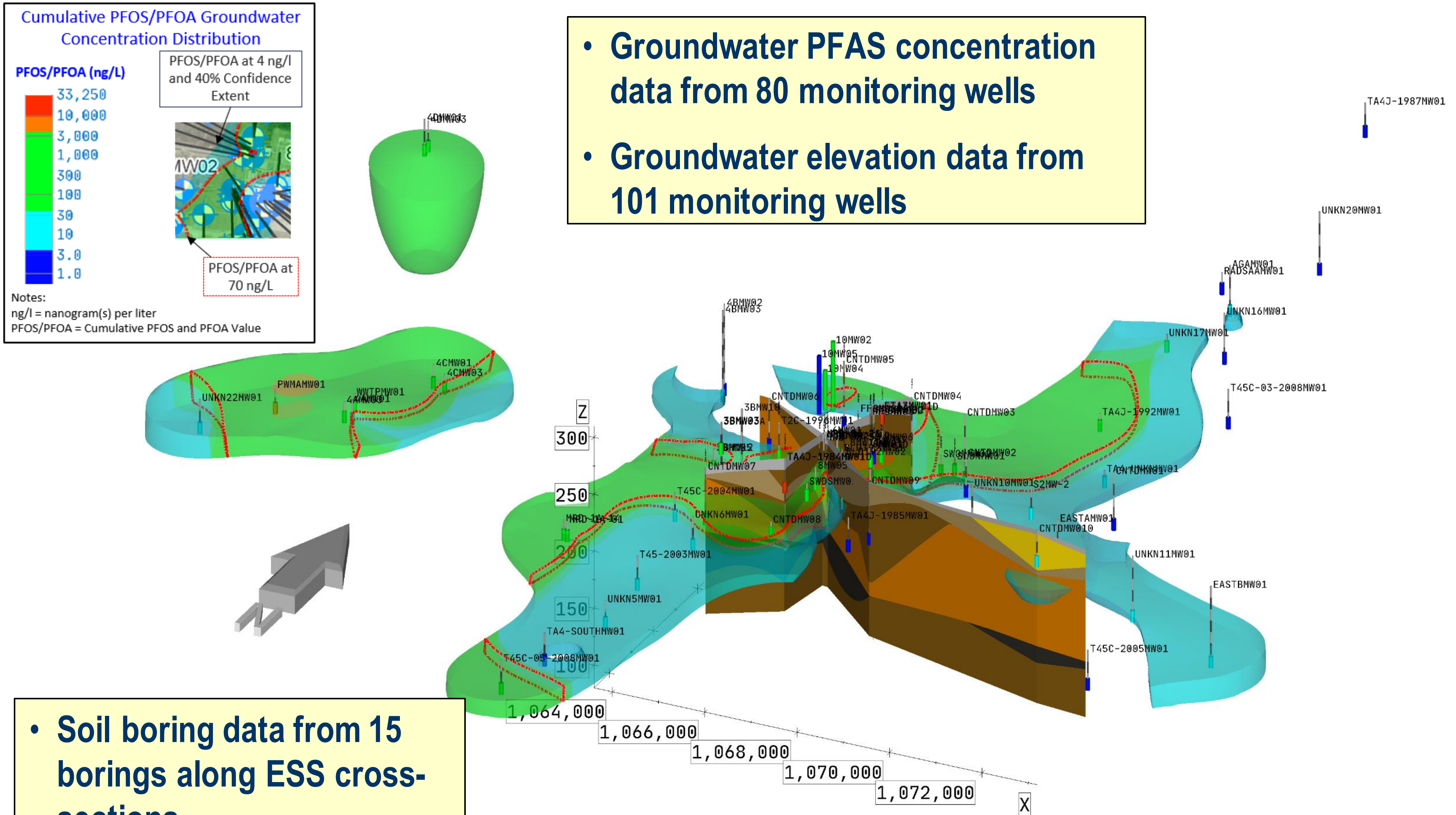
ESS Interpretation and PFAS

ESS Interpretation and CSM Update

- **Contaminant Transport**
  - **The most recent PFAS groundwater data was added to the 3-D model for each monitoring well with data**
  - **In order to observe patterns in contaminant distribution, the cumulative PFOS/PFOA value was interpolated down to 4 ng/L**
  - **Due to the large size of the study area, the data was interpolated within a "confidence boundary"**
    - The interpolation was bound within an area defined by approximately 2,000 feet from the nearest monitoring point
    - The arbitrary boundary was used to help focus the model output on areas that had the most certainty; that is, the farther away from the sample point, the greater the uncertainty in the interpolation.



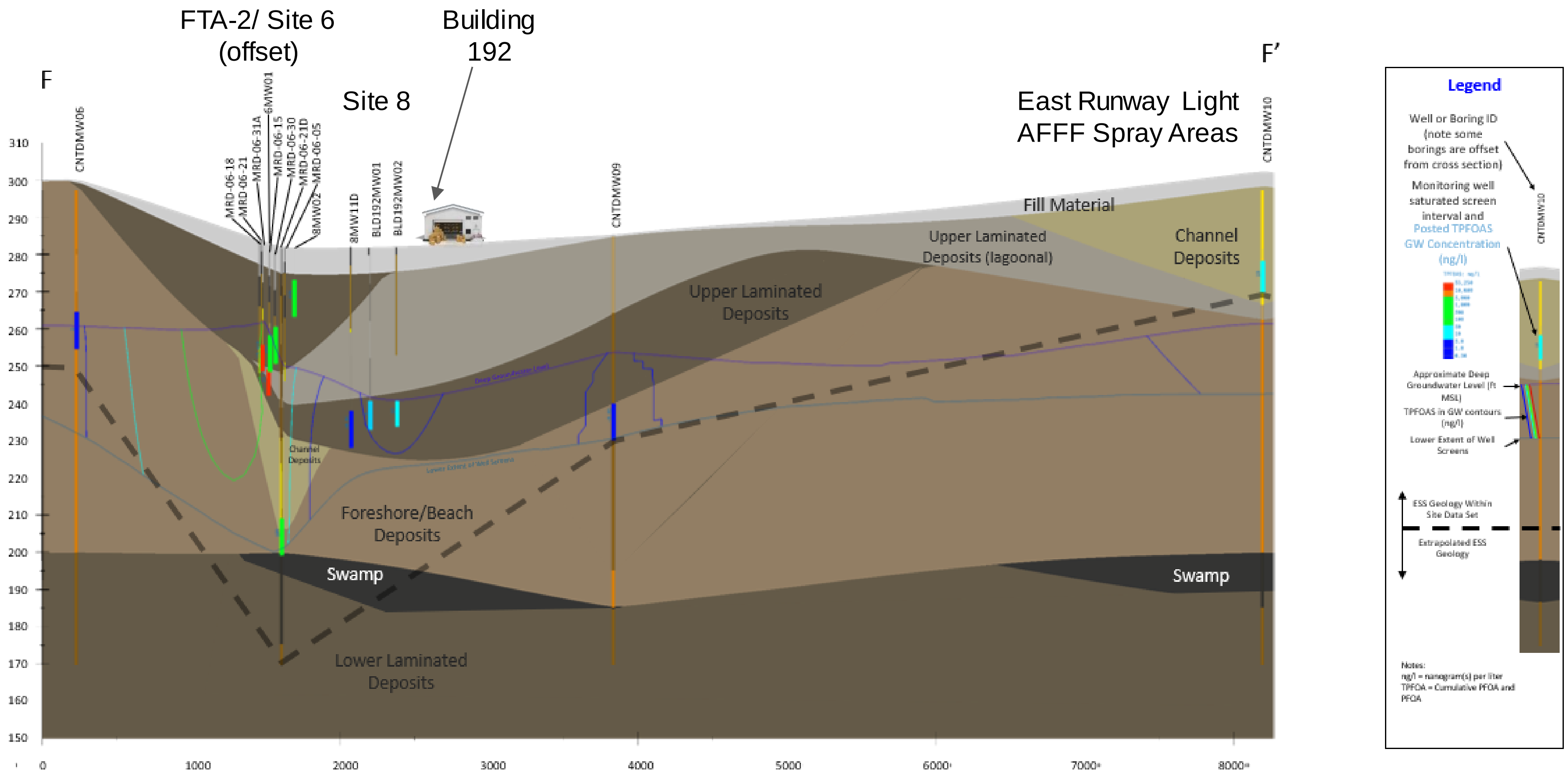
3-D Model Input and CSM Update



- Groundwater PFAS concentration data from 80 monitoring wells
- Groundwater elevation data from 101 monitoring wells

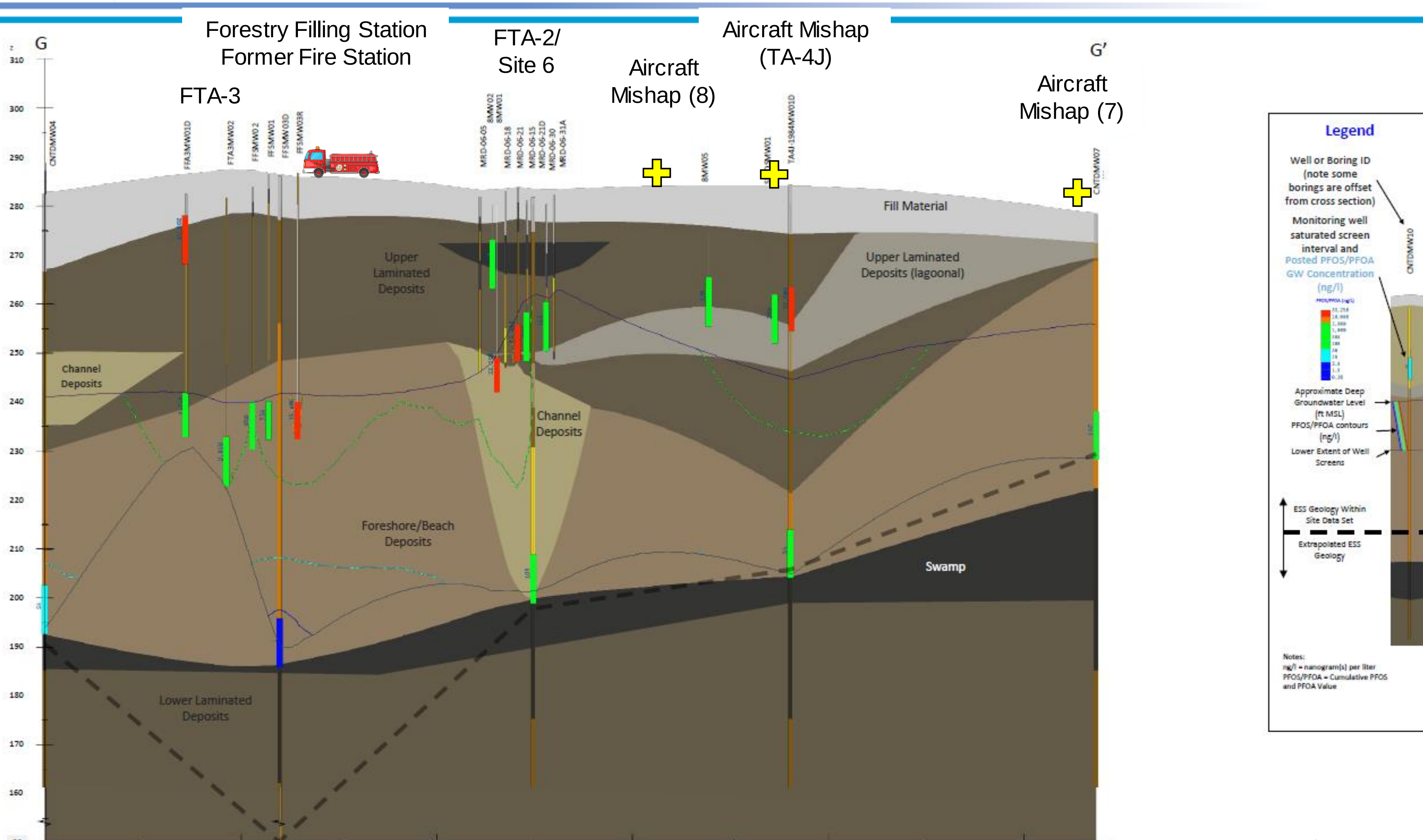
- Soil boring data from 15 borings along ESS cross-sections

ESS Hydrostratigraphic Section F-F'



Note: The hydrostratigraphic layers are presented in neutral colors on this slide so that the color-coded PFAS concentration data can be visualized easier.

ESS Hydrostratigraphic Section G-G'



Note: The hydrostratigraphic layers are presented in neutral colors on this slide so that the color-coded concentration data can be visualized easier.

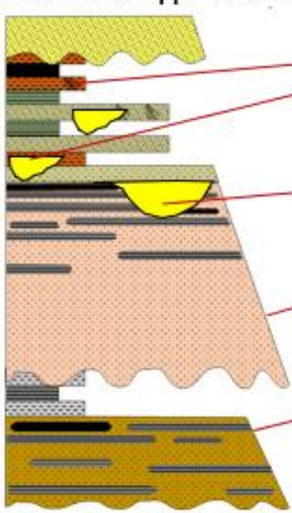
ch2m

Conclusions

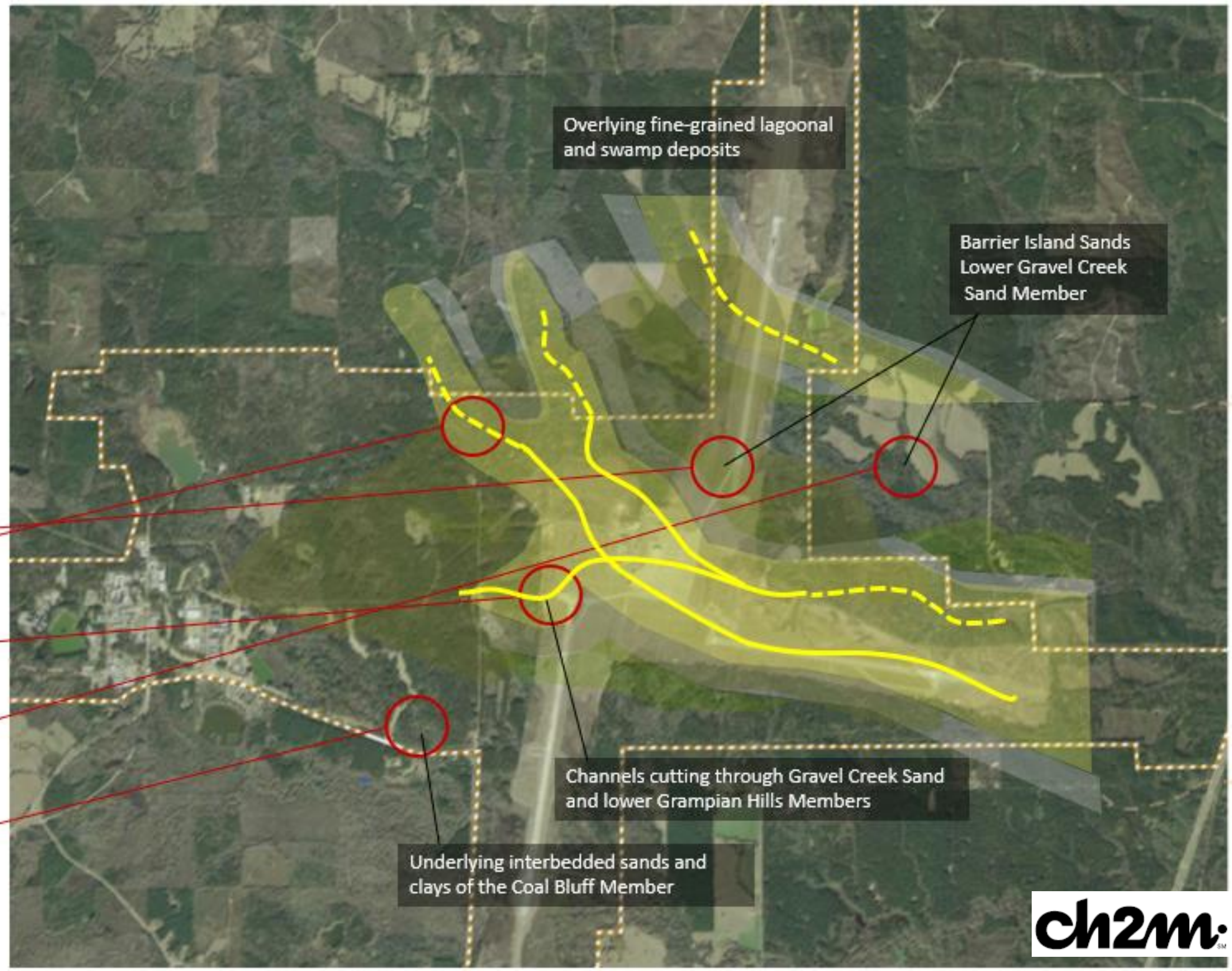
ESS Study CSM Overview

Used a combination of cross-sections, hydrostratigraphic units, site groundwater levels, and contaminant distribution data to identify likely contaminant transport pathways

Typical Sediment-Dominated Delta (Bird Foot)
e.g., Current Mississippi Delta in Louisiana

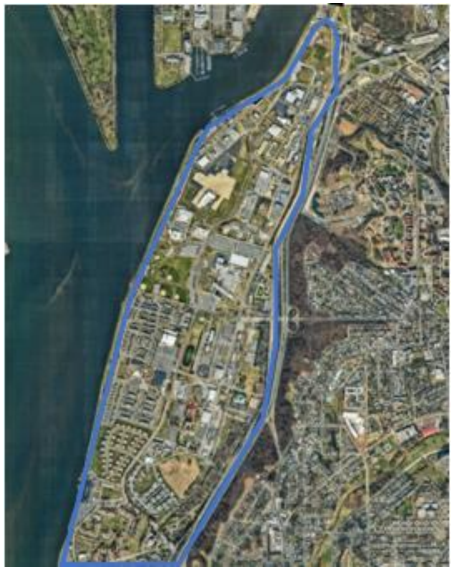


Generalized Site Stratigraphic Column



Conclusions and Path Forward

- ESS was used to improve the understanding of potential PFAS migration in groundwater within the Operational Airfield Area at NAS Meridian
  - The 2018 desktop study extracted additional value from existing site data and identified locations for new monitoring wells and soil borings
  - The 2020 SI data improved the identification of depositional units at NAS Meridian and interpretation of transport pathways
- ESS Study Results
  - Supported MDEQ's concurrence to reduce the frequency of LTM sampling for Site 6
  - Helped define the PFAS Remedial Investigation (RI) site boundaries at the Base
    - Three buried sand channels were identified within the Operational Airfield Area, which can serve as preferential pathways for contamination, and provide the basis for a standalone PFAS RI site
    - Other potential PFAS RI sites at the Base could be located to the north, west, and east of the Operational Airfield Area



Joint Base Anacostia-Bolling

APPLICATION OF ENVIRONMENTAL SEQUENCE STRATIGRAPHY (ESS) AT JOINT BASE ANACOSTIA-BOLLING (JBAB)

PRESETATION OVERVIEW

Objective

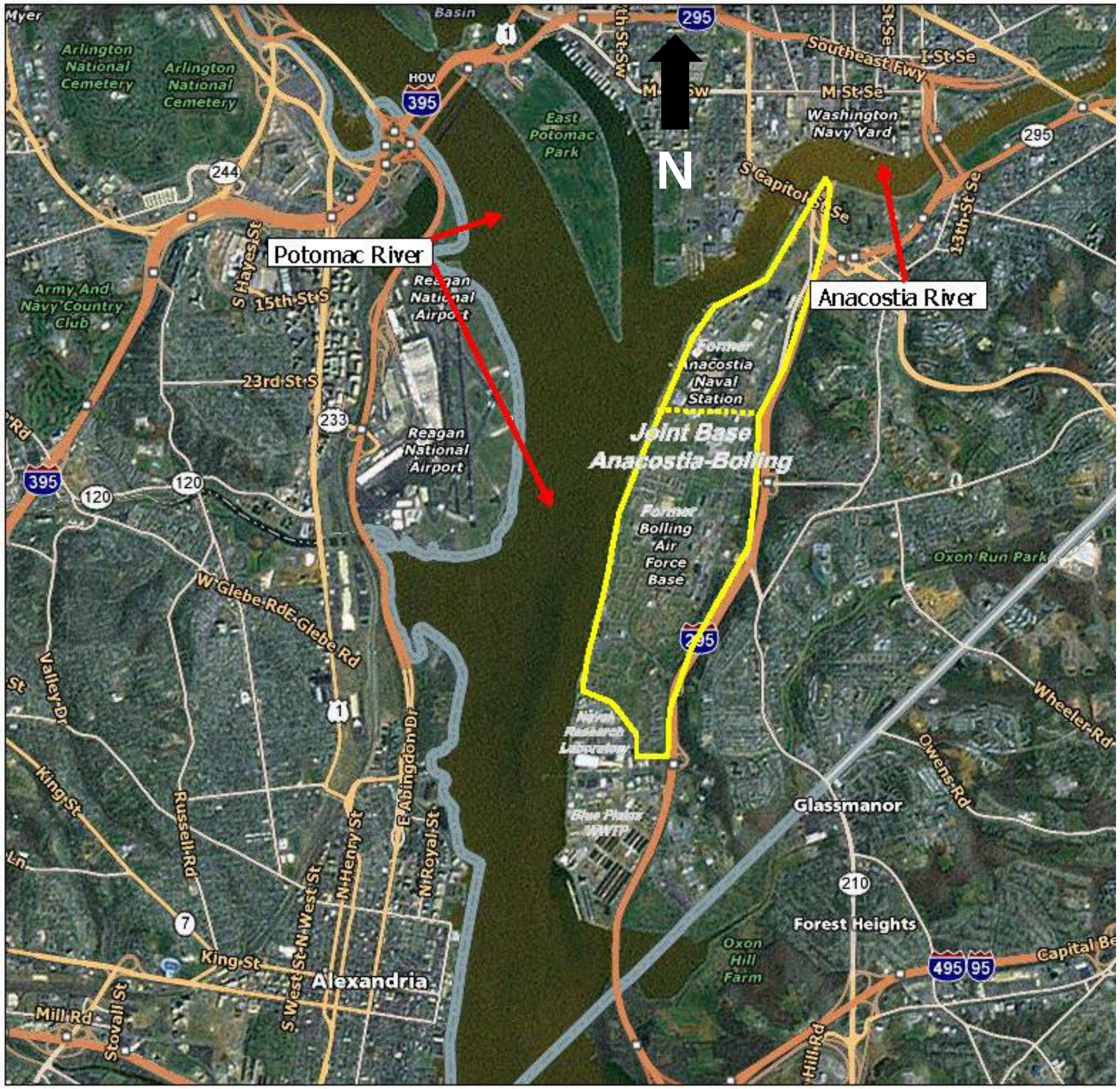
To illustrate the benefit of applying the Environmental Sequence Stratigraphy (ESS) approach for JBAB

Key Questions

- Why Use ESS?
- How Did ESS Add Value for JBAB?
- Takeaways
- The Next Question Is….

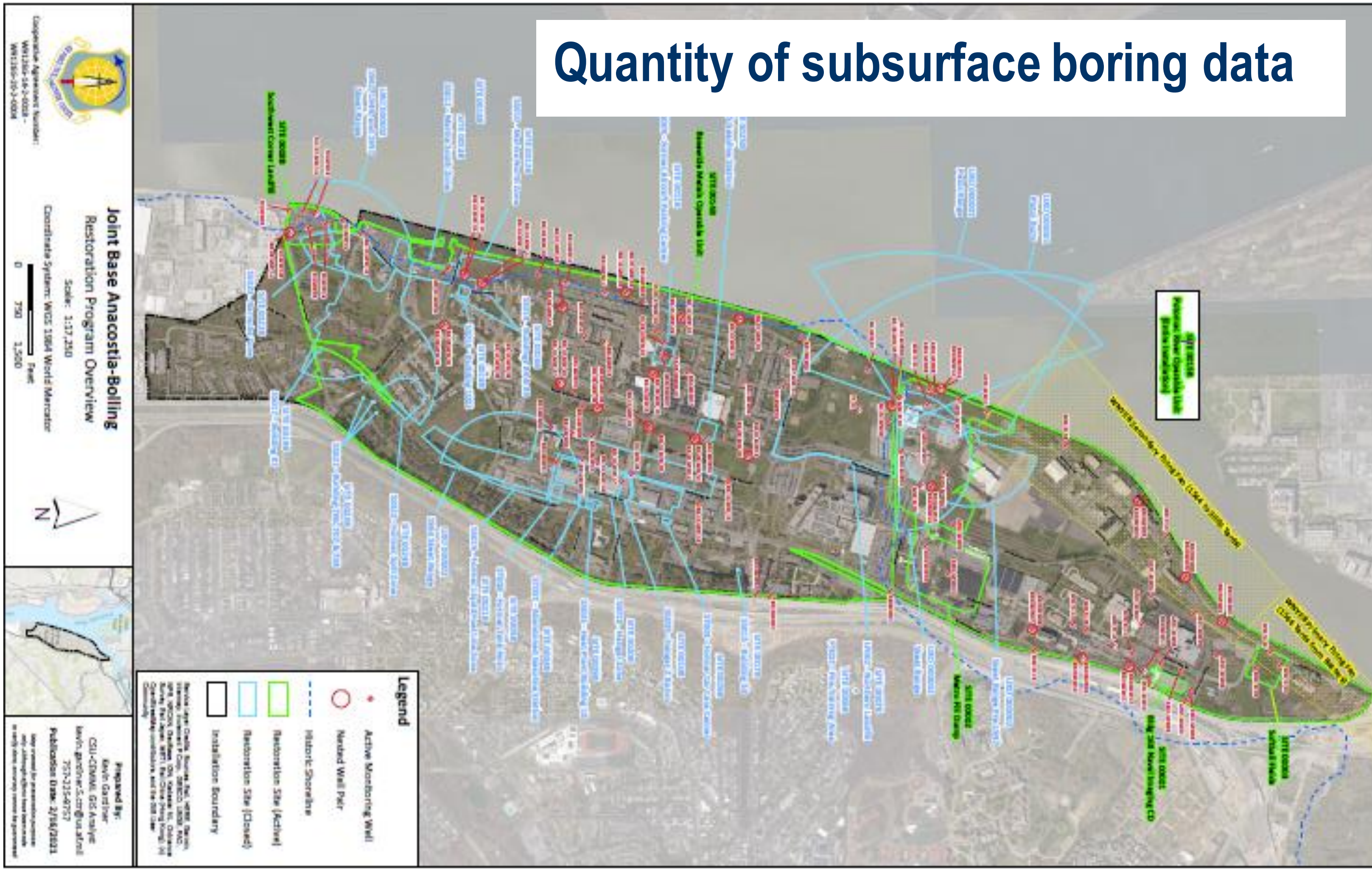
WHY USE ESS?

It's a BIG site…



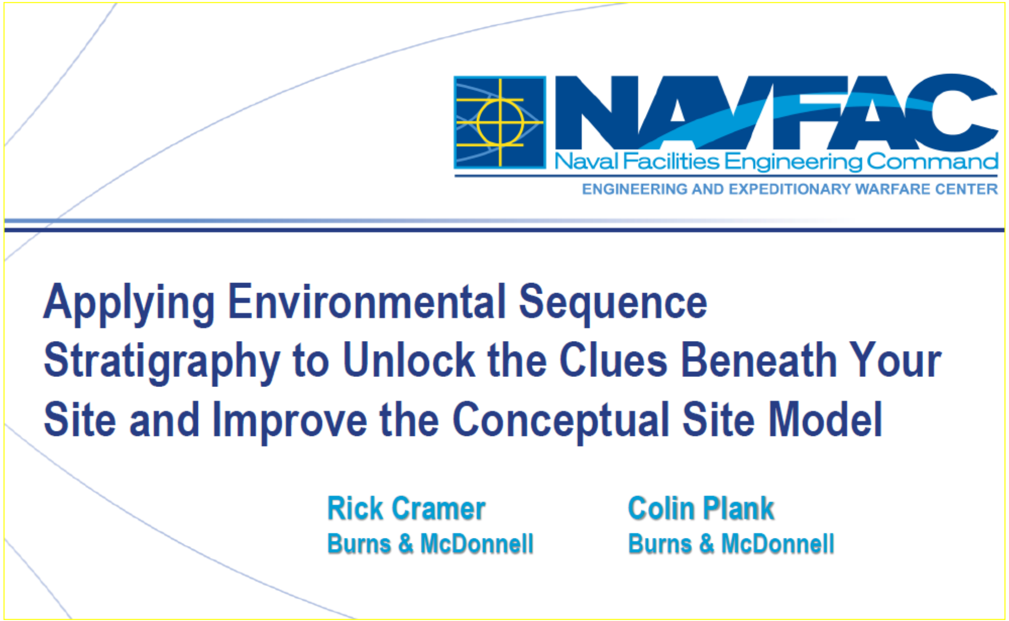
WHY USE ESS?

Quantity of subsurface boring data



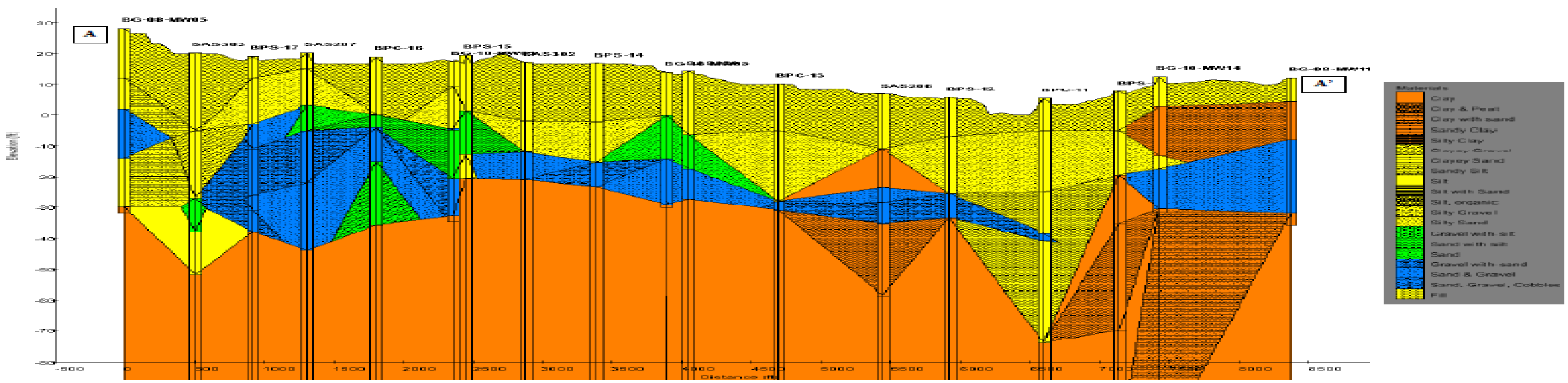
WHY USE ESS?

It all started with…



WHY USE ESS?

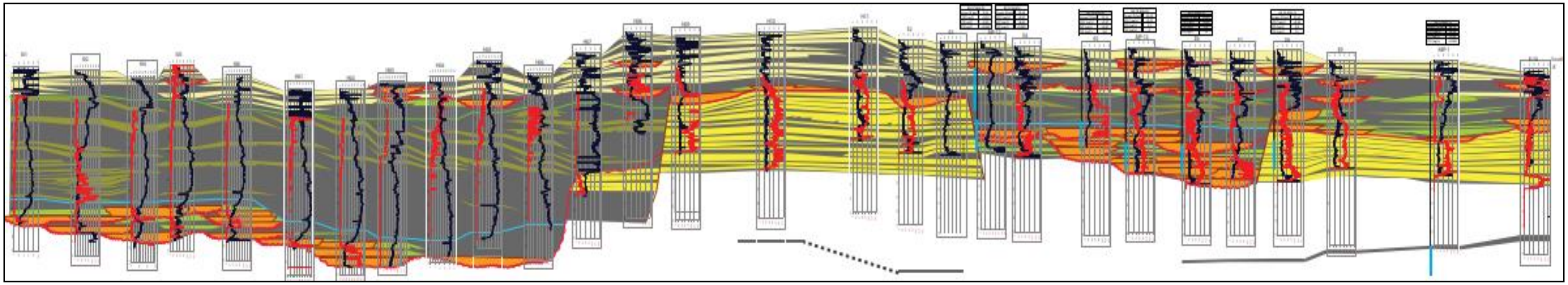
Before ESS



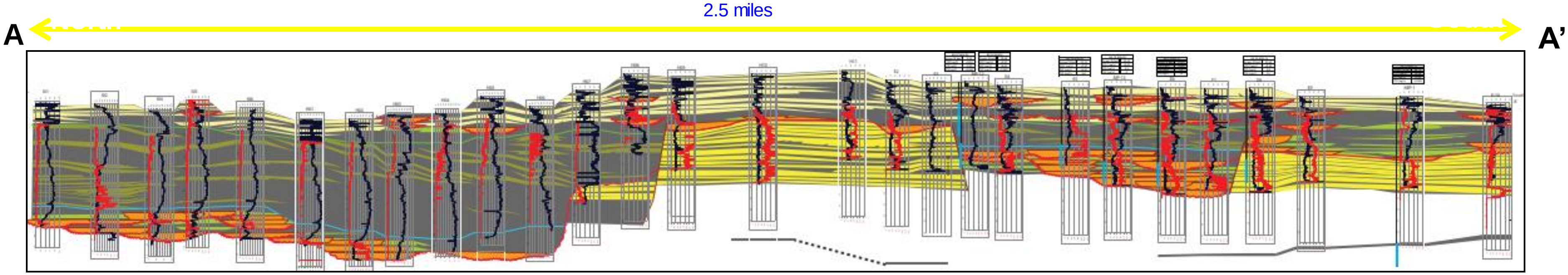
After ESS

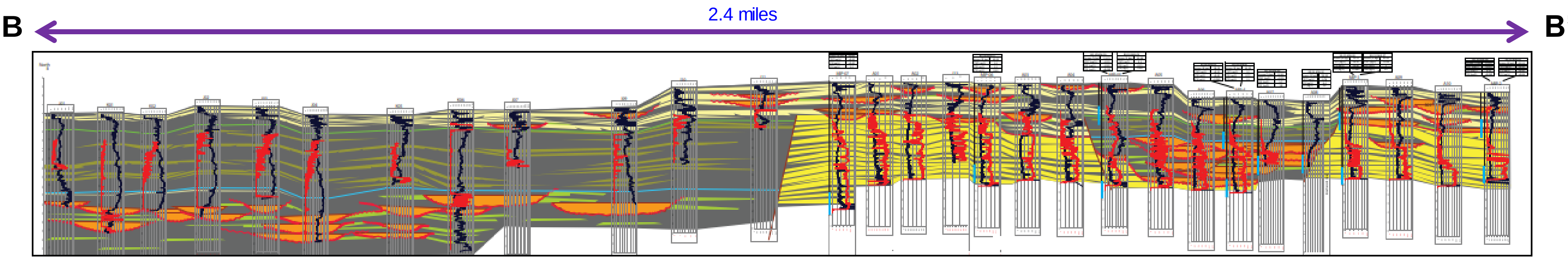
A

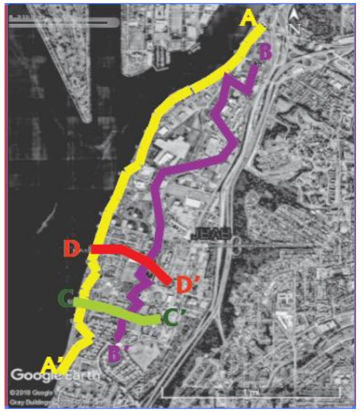
A’



WHY USE ESS FOR JBAB?

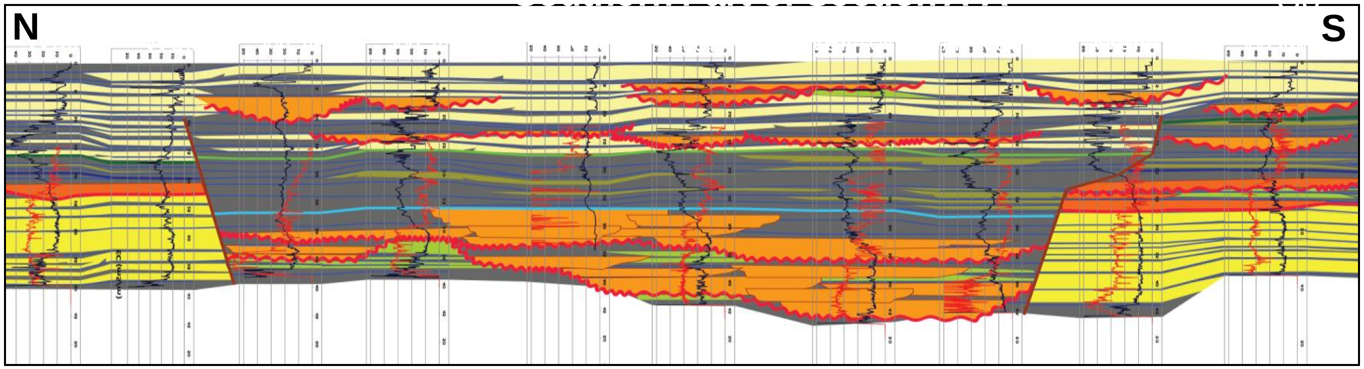






Yellow	**Fan Delta Deposits** (Coarse -fine sand with gravels)
Orange	**Channel Bars** (Coarse sand - silt)
Light yellow	**Bay-head Delta Mouthbars** (Medium-fine sand and silt)
Green	**Levee/Splay** (Very fine sand and silt)
Olive	**Tidal Bars** (Very fine sand, slit and clay)
Gray	**Overbank Fines**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

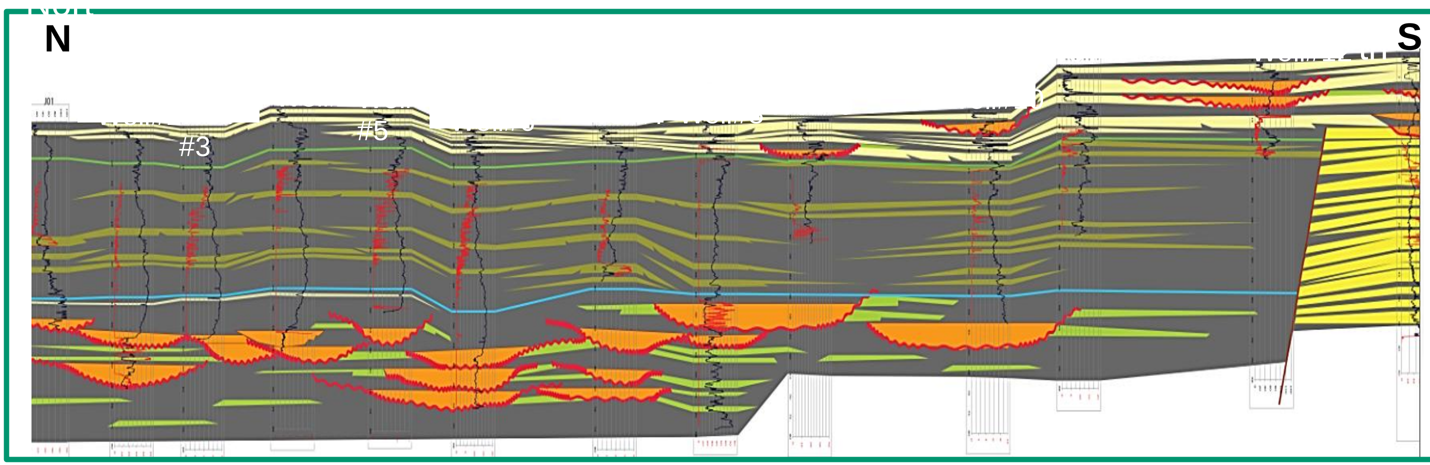
WHY USE ESS FOR JBAB?



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)

S

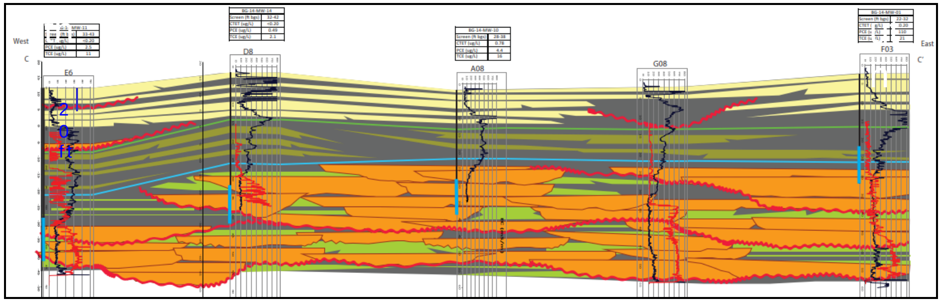
N S



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)

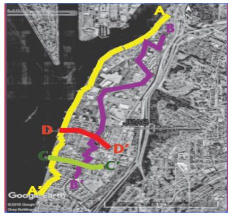
WHY USE ESS FOR JBAB?

C

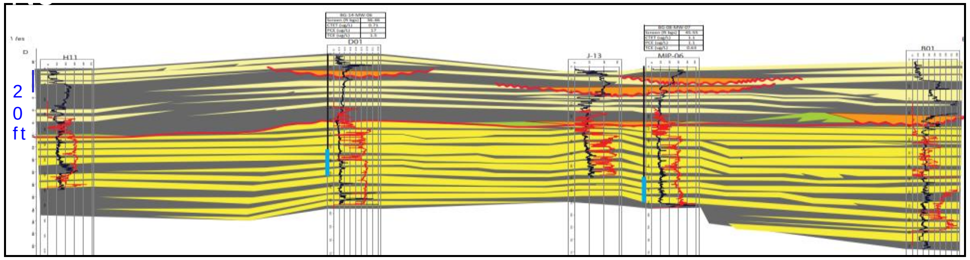


C'

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



D



D'

- Fan Delta Deposits (Coarse -fine sand with gravels)
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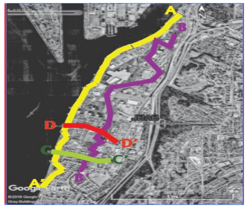
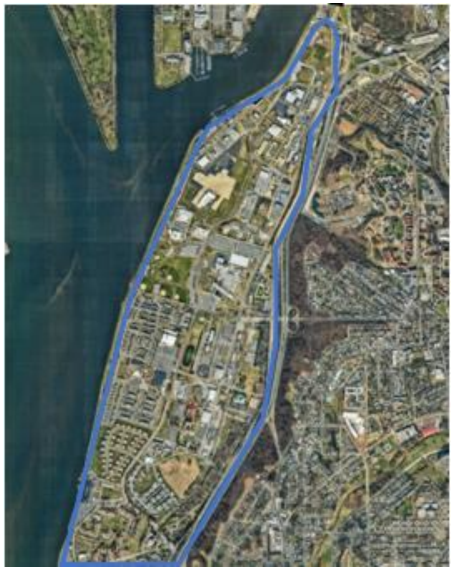
- Overbank Fines (Slit and clay)



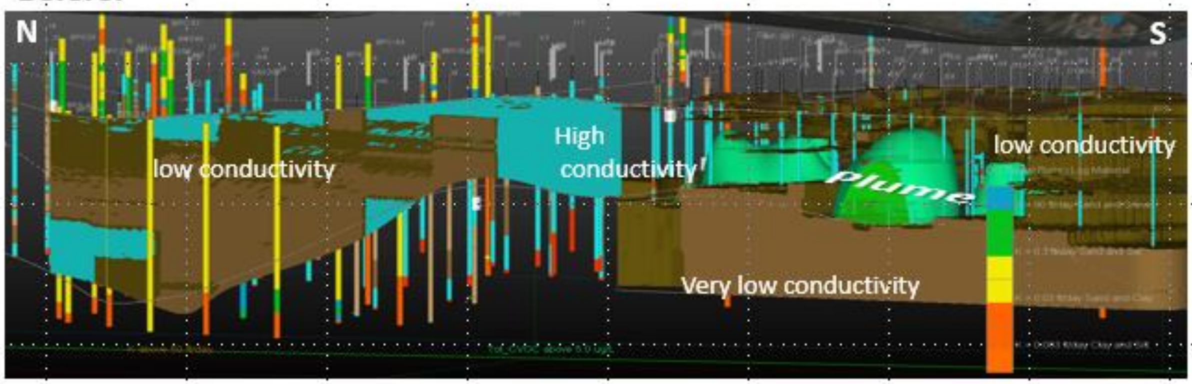


Joint Base Anacostia-Bolling

HOW DID ESS ADD VALUE FOR JBAB?

HOW DID ESS ADD VALUE FOR JBAB?

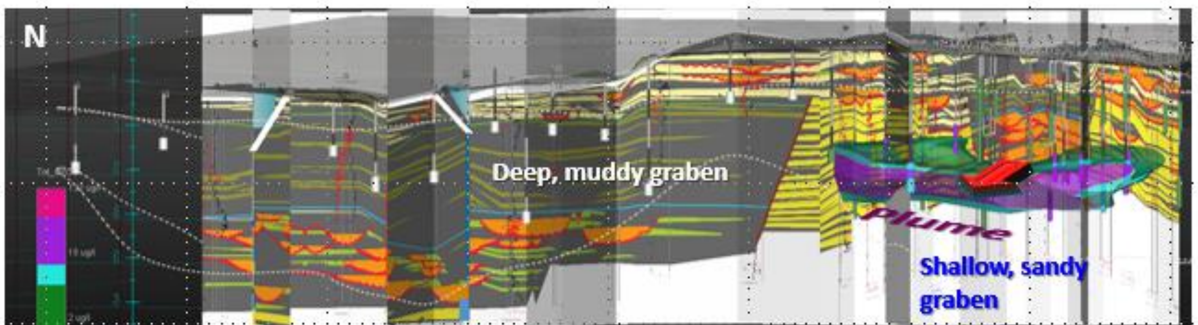
Before:



Typical EVS-generated CSM

- EVS model gives general ideas of plume migration based on HRSC data points
- Low predictive ability outside data points
- Kriged plume shape determined by statistics alone (high uncertainty)

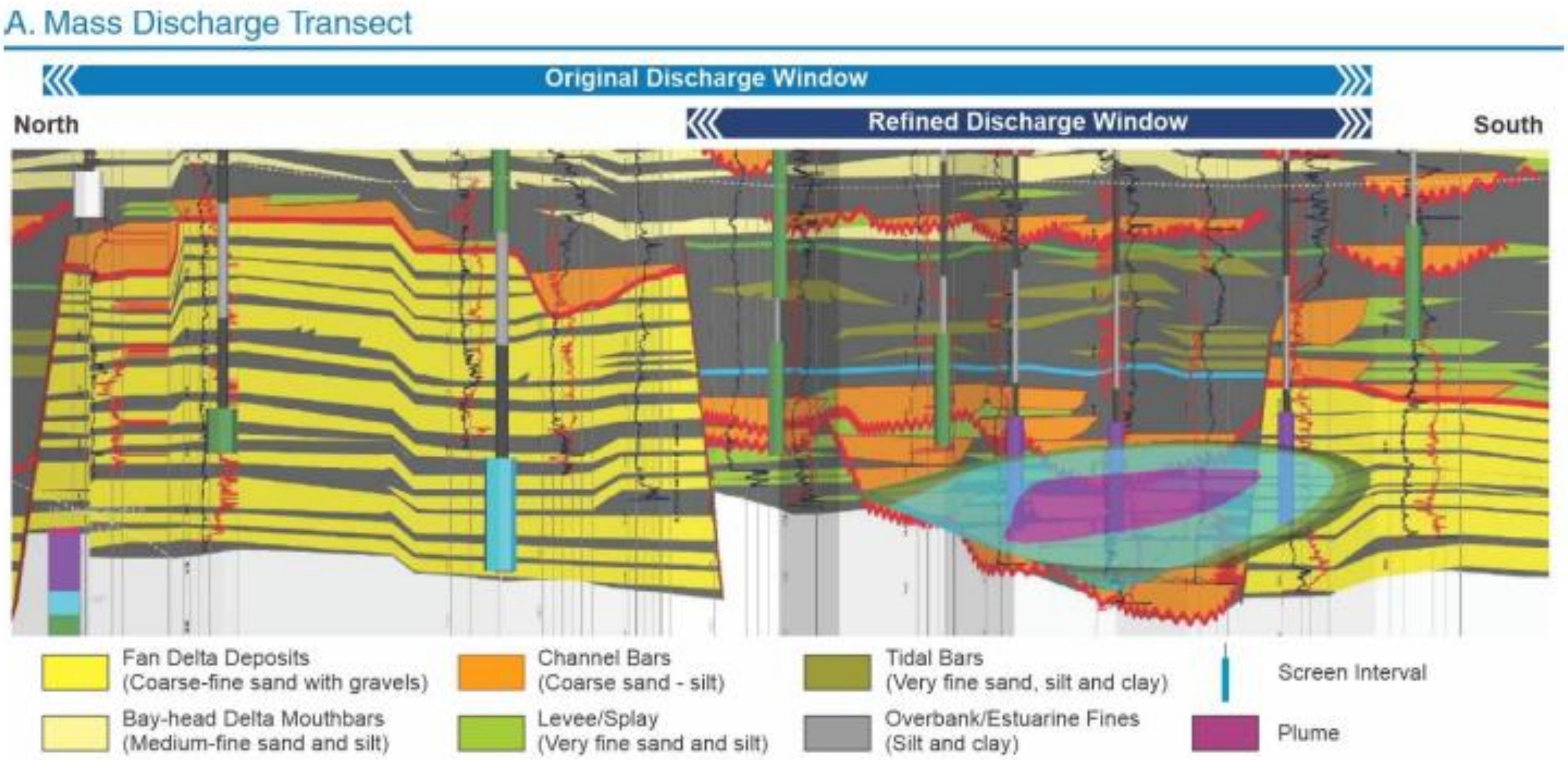
After:



- More specific understanding of plume migration
- High predictive ability outside data point through stratigraphy
- Kriged plume shape determined with the aid of geological constraints (low uncertainty)

HOW DID ESS ADD VALUE FOR JBAB?

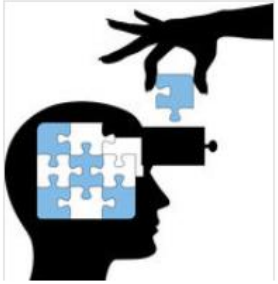
Example – Optimization/Cost Avoidance



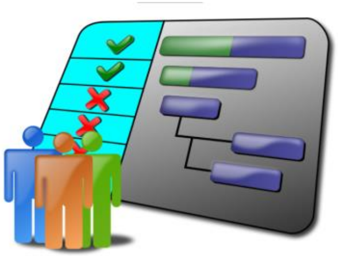
TAKEAWAYS

- ESS based on geologic science, therefore, improved interpretation of subsurface conditions
- Data integration and visualization
- Maximizes value of information obtained from soil boring and high resolution site characterization data
- Can reduce and/or avoid costs
- Using ESS requires a stratigrapher with specialized training and experience

THE NEXT QUESTION IS….



Can your project benefit from applying ESS?



Questions and Answers

NAVFAC Points of Contact

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  - david.g.collins1@navy.mil

- JD Spalding
  - (904) 542-6325
  - james.d.spalding@navy.mil

Wrap Up

Please complete the survey that you will be redirected to when you leave the webinar.

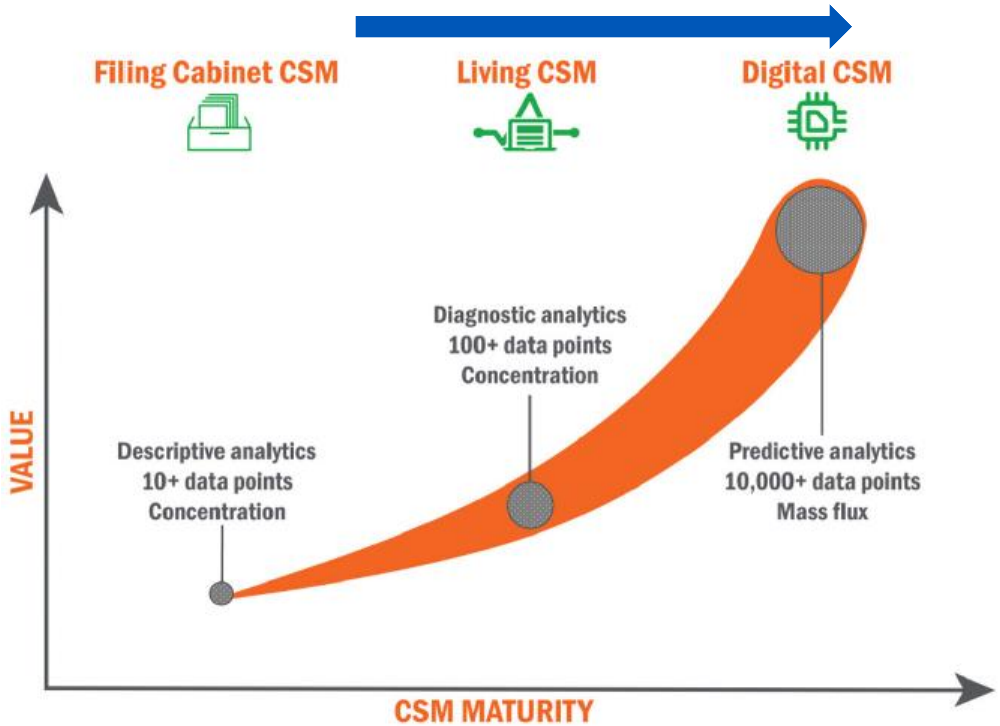
Next OER2:

Practical Examples of Bridging Remedy In Place to Response Complete

Coming Fall 2021

Thank you for participating!

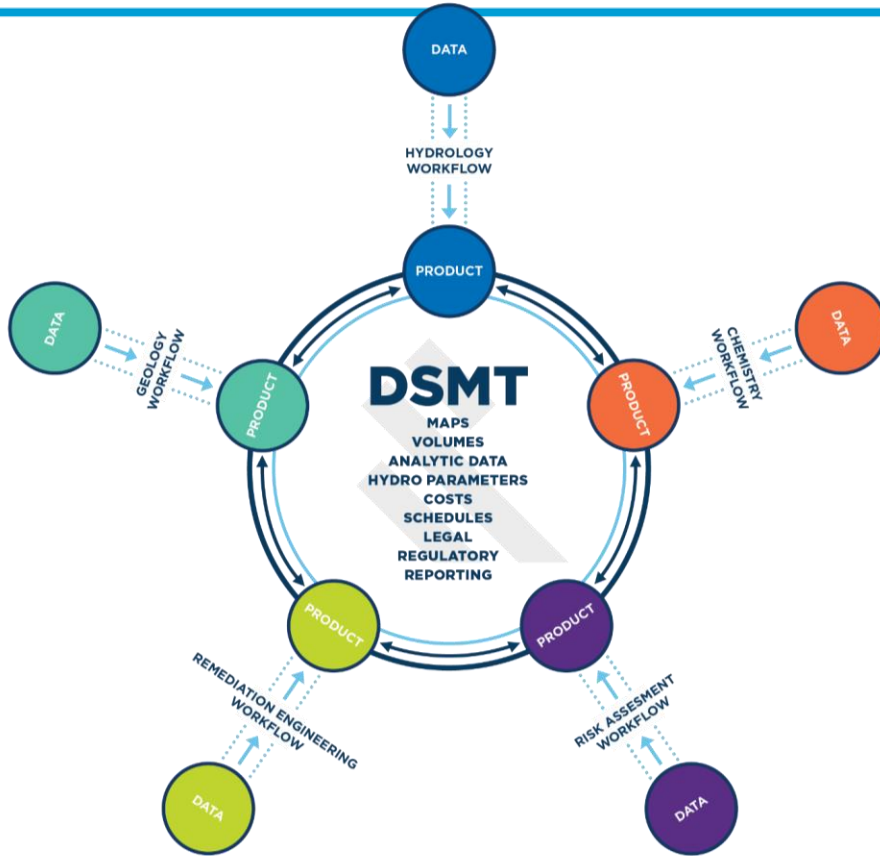
Evolution of The CSM: The Future is Now



J. Horst et al./ Groundwater Monitoring & Remediation 40, no. 3/ Summer 2020/pages 14–20

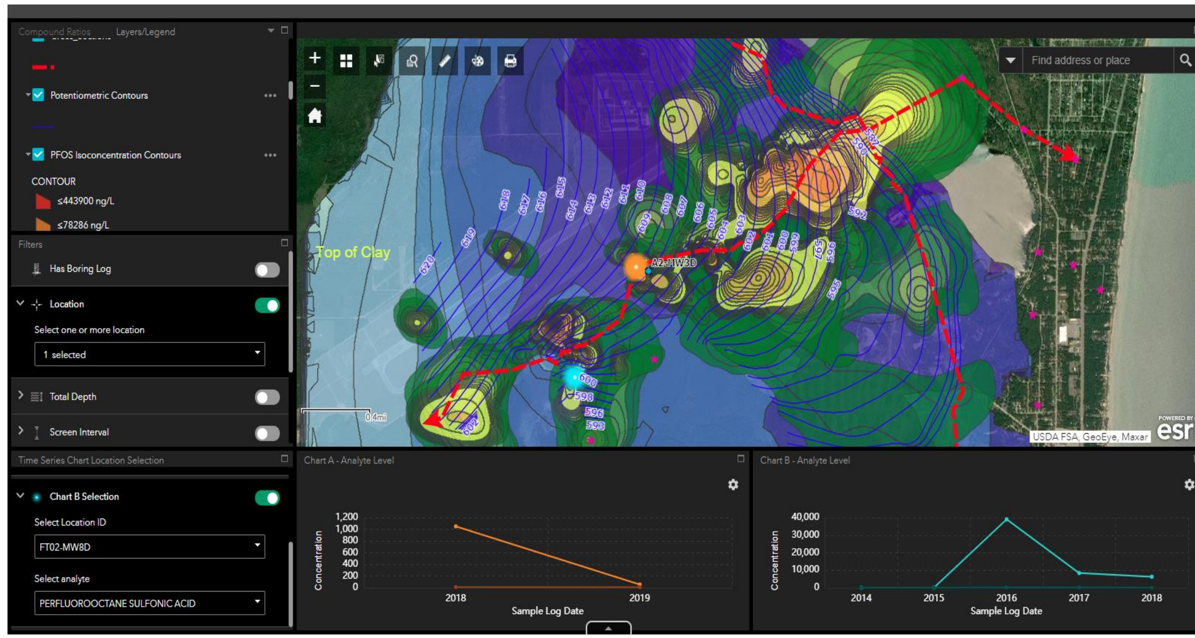
The Digital Site Management Tool (DSMT)

DATA | PRODUCT	GEOLOGY WORKFLOW
DATA | PRODUCT	HYDROLOGY WORKFLOW
DATA | PRODUCT	CHEMISTRY WORKFLOW
DATA | PRODUCT	REMEDIATION ENGINEERING WORKFLOW
DATA | PRODUCT	RISK ASSESMENT WORKFLOW



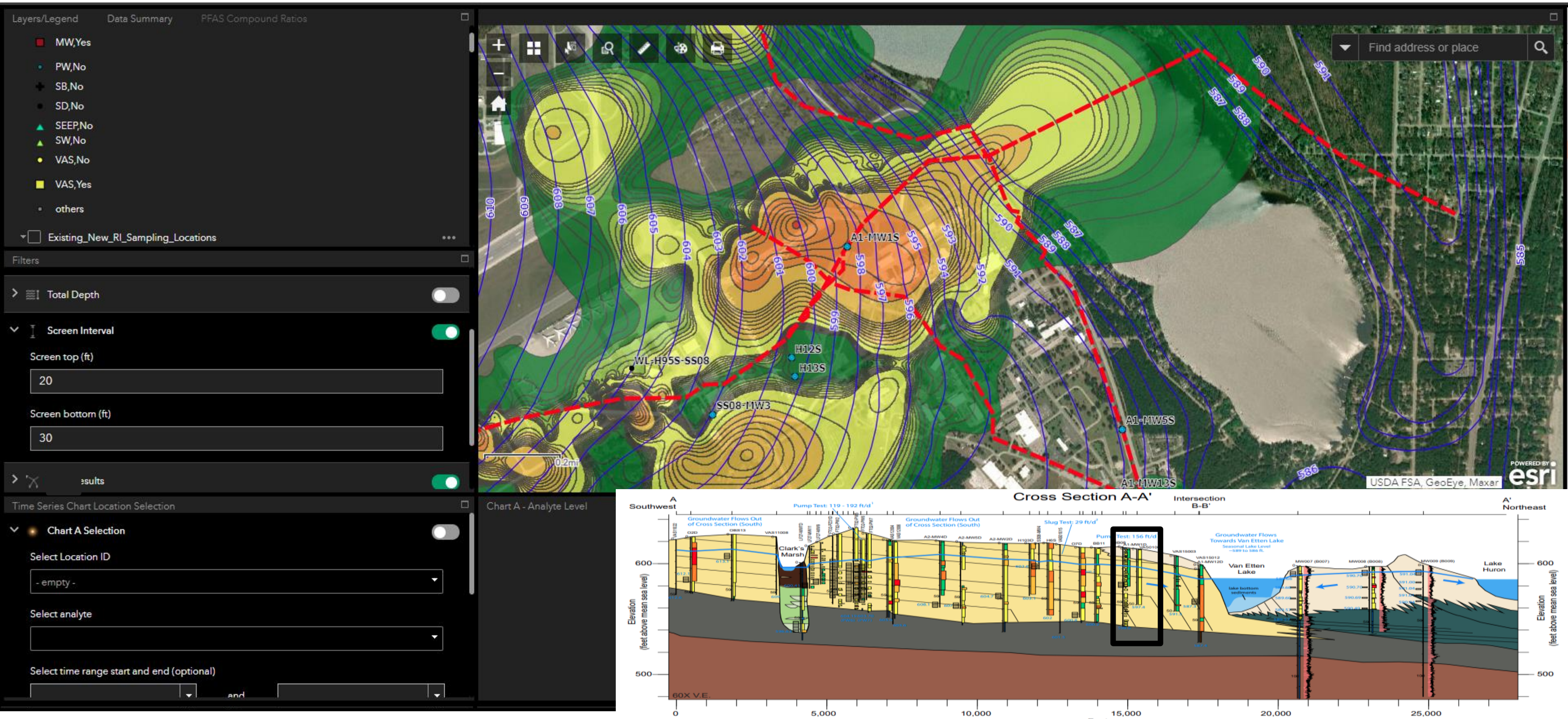
The DSMT: Overview and Demonstration

- “One-Stop-Shop” for project database and digital CSM data interrogation and presentation
- Developed to offer service to teams via existing ESRI licenses and software
- Provides your team a web-based platform for:
  - Sharing of data across disciplines: No GIS skills required
  - Accessing and growing a dynamic digital conceptual site model
  - Streamlined reporting and execution of work plans



- Increased Stake Holder Communications and Transparency

Using DSMT Web-Application To Integrate CSM Elements



Using DSMT Web-Application To Inform Strategic Site Characterization