



Best Practices for Environmental Site Management

A Practical Guide for Applying
Environmental Sequence Stratigraphy
to Improve Site Models

Mike Shultz, PhD

April 2018

ACKNOWLEDGEMENTS

EPA/600/R-17/293
September 2017



Groundwater Issue

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

Michael R. Shultz¹, Richard S. Cramer¹, Colin Plank¹, Herb Levine², Kenneth D. Ehman³

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AAPG (*American Assoc. of Petroleum Geologists*)

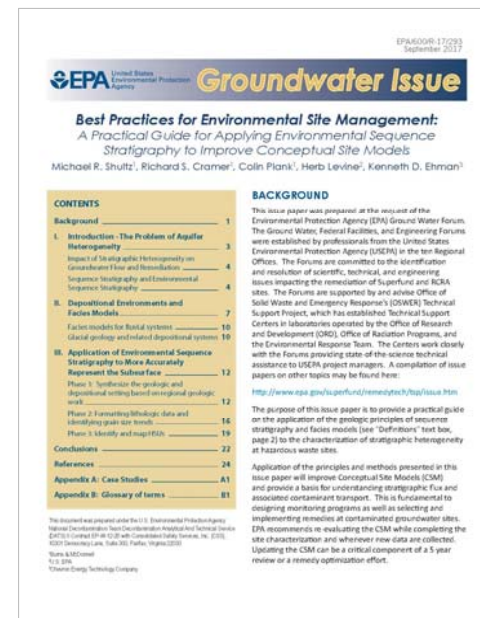
SEPM (*Society for Sedimentary Geology*)

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 Consolidated Safety Services, Inc. (CSS), 10301 Democracy Lane, Suite 300, Fairfax, Virginia 22030

¹Burns & McDonnell

²U.S. EPA

³Chevron Energy Technology Company



U.S. EPA GEOLOGY INITIATIVE

- ▶ 90% of mass flux contaminant transport at superfund sites has been shown to be through 10% of aquifer material
- ▶ A site conceptual model that accurately reflects the geologic plumbing is essential for successful remedy selection and implementation
- ▶ ESS reduces uncertainty, time to remedy complete, and cost

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 United States Environmental Protection Agency

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CONTENTS	
Background	1
I. Introduction - The Problem of Aquifer Heterogeneity	3
Impact of Stratigraphic Heterogeneity on Groundwater Flow and Remediation	4
Sequence Stratigraphy and Environmental Sequence Stratigraphy	4
II. Depositional Environments and Facies Models	7
Facies models for fluvial systems	10
Glacial geology and related depositional systems	10
III. Application of Environmental Sequence Stratigraphy to More Accurately Represent the Subsurface	12
Phase 1: Synthesize the geologic and depositional setting based on regional geologic work	12
Phase 2: Formatting lithologic data and identifying grain size trends	16
Phase 3: Identify and map HSUs	19
Conclusions	22
References	24
Appendix A: Case Studies	A1
Appendix B: Glossary of terms	B1

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 on the application of the geologic principles of sequence stratigraphy and facies models (see "Definitions" text box, page 2) to the characterization of stratigraphic heterogeneity at hazardous waste sites.

Application of the principles and methods presented in this issue paper will improve Conceptual Site Models (CSM) and provide a basis for understanding stratigraphic flux and associated contaminant transport. This is fundamental to designing monitoring programs as well as selecting and implementing remedies at contaminated groundwater sites. EPA recommends re-evaluating the CSM while completing the site characterization and whenever new data are collected. Updating the CSM can be a critical component of a 5 year review or a remedy optimization effort.

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²U.S. EPA
³Chevron Energy Technology Company

U.S. EPA GEOLOGY INITIATIVE: BEST PRACTICES FOR ENVIRONMENTAL SITE MANAGEMENT

- ▶ A practical guide for applying Environmental Sequence Stratigraphy to Improve Conceptual Site Models*
- ▶ Contents of a groundwater monitoring report*
- ▶ A framework for characterizing groundwater/surface water interaction
- ▶ Geologic characterization of hazardous waste sites
- ▶ Groundwater sampling methods

*currently published

EPA/600/R-17/293
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 United States Environmental Protection Agency **Groundwater Issue**

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Presentation Outline

- ▶ Introduction to ESS
- ▶ Depositional Environments and Facies Models
- ▶ ESS Process Overview, Stratigraphic “rules of thumb”
- ▶ Case Study: Silicon Valley Commingled Plume

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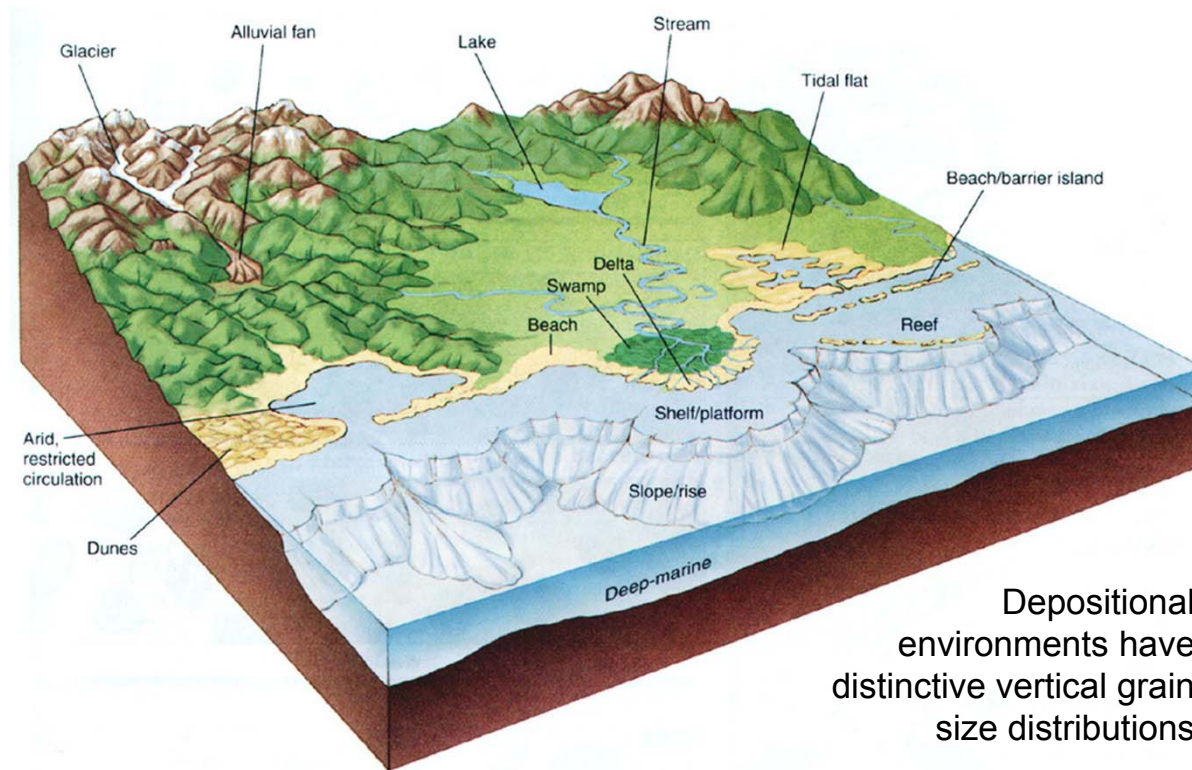
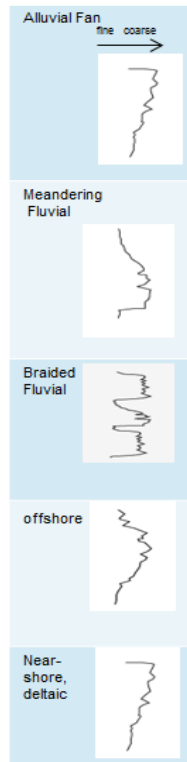
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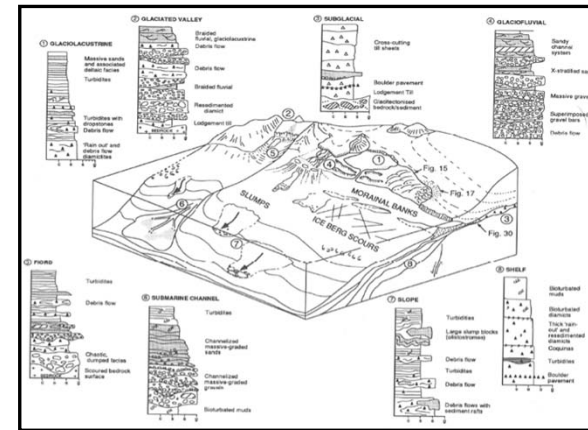


Depositional environments have distinctive vertical grain size distributions

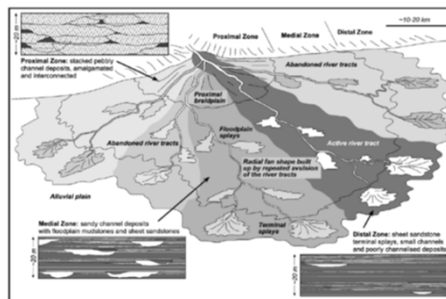
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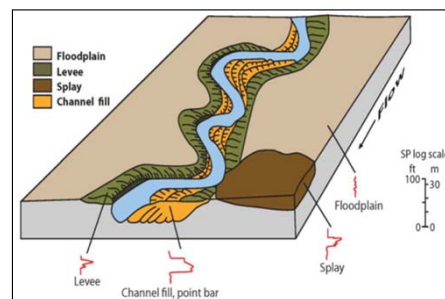
Glacial depositional systems



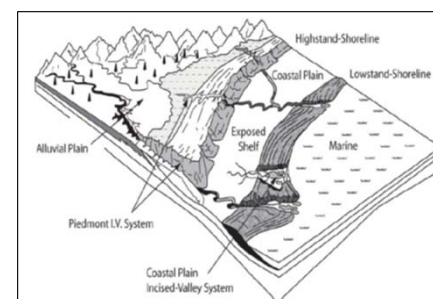
Alluvial fan facies model



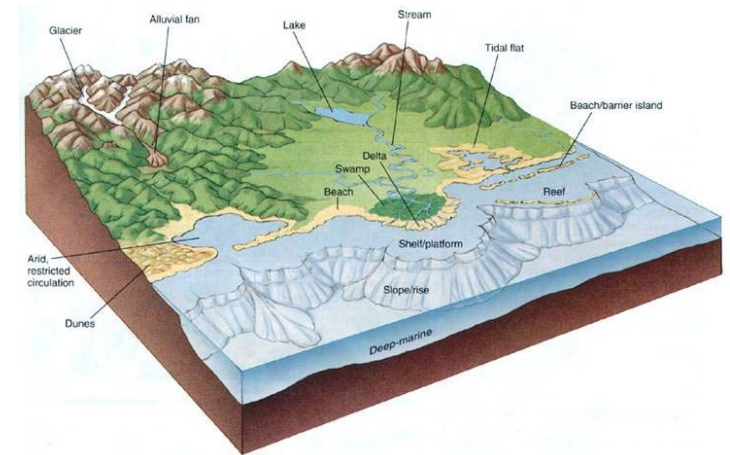
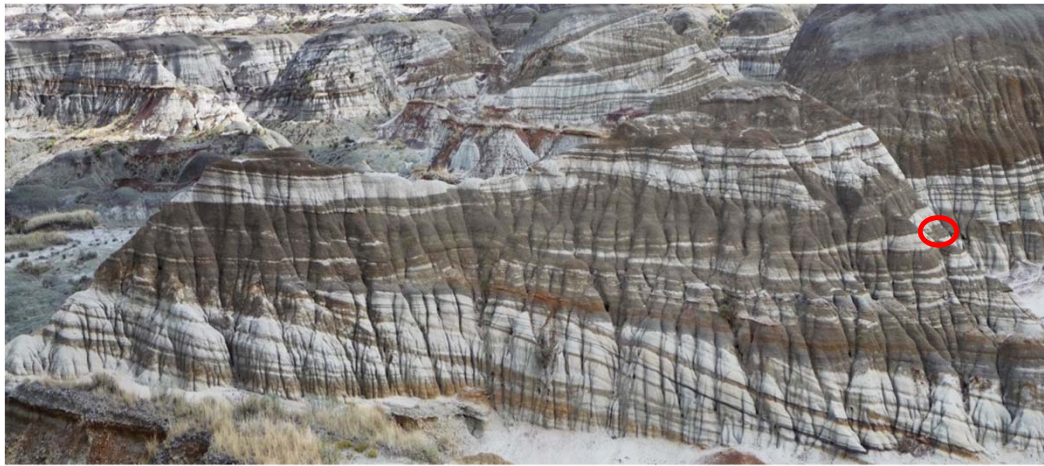
Meandering river facies model



Coastal depositional systems



THE PROBLEM OF AQUIFER HETEROGENEITY

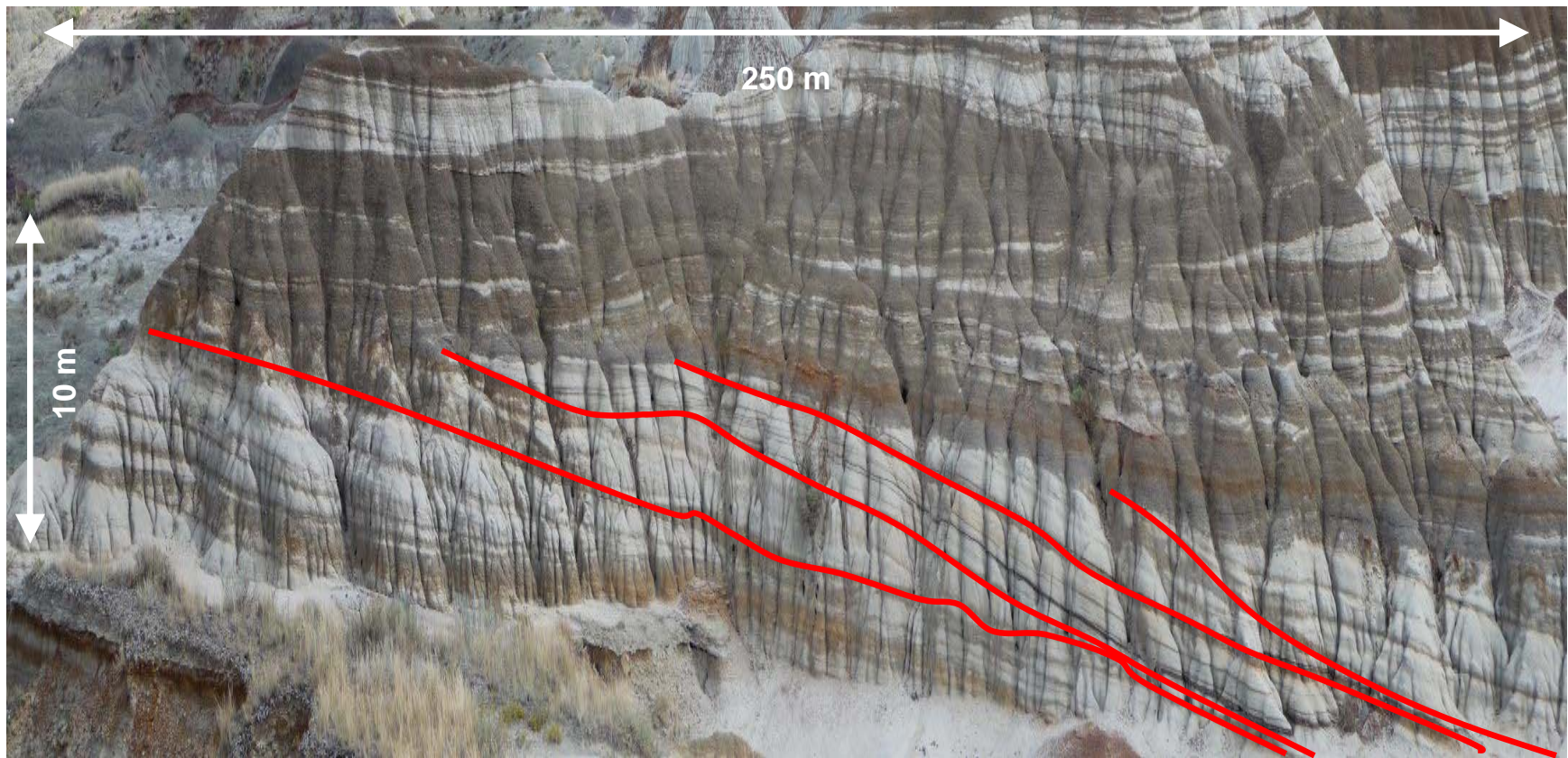


- ▶ Outcrop analog of meandering fluvial deposits (Upper Cretaceous Horseshoe Canyon Formation, Alberta, Canada)
- ▶ At aquifer remediation site scale
- ▶ Ability to map sand channels in three dimensions
- ▶ Facies models provide predictive tool for characterization based on depositional environments

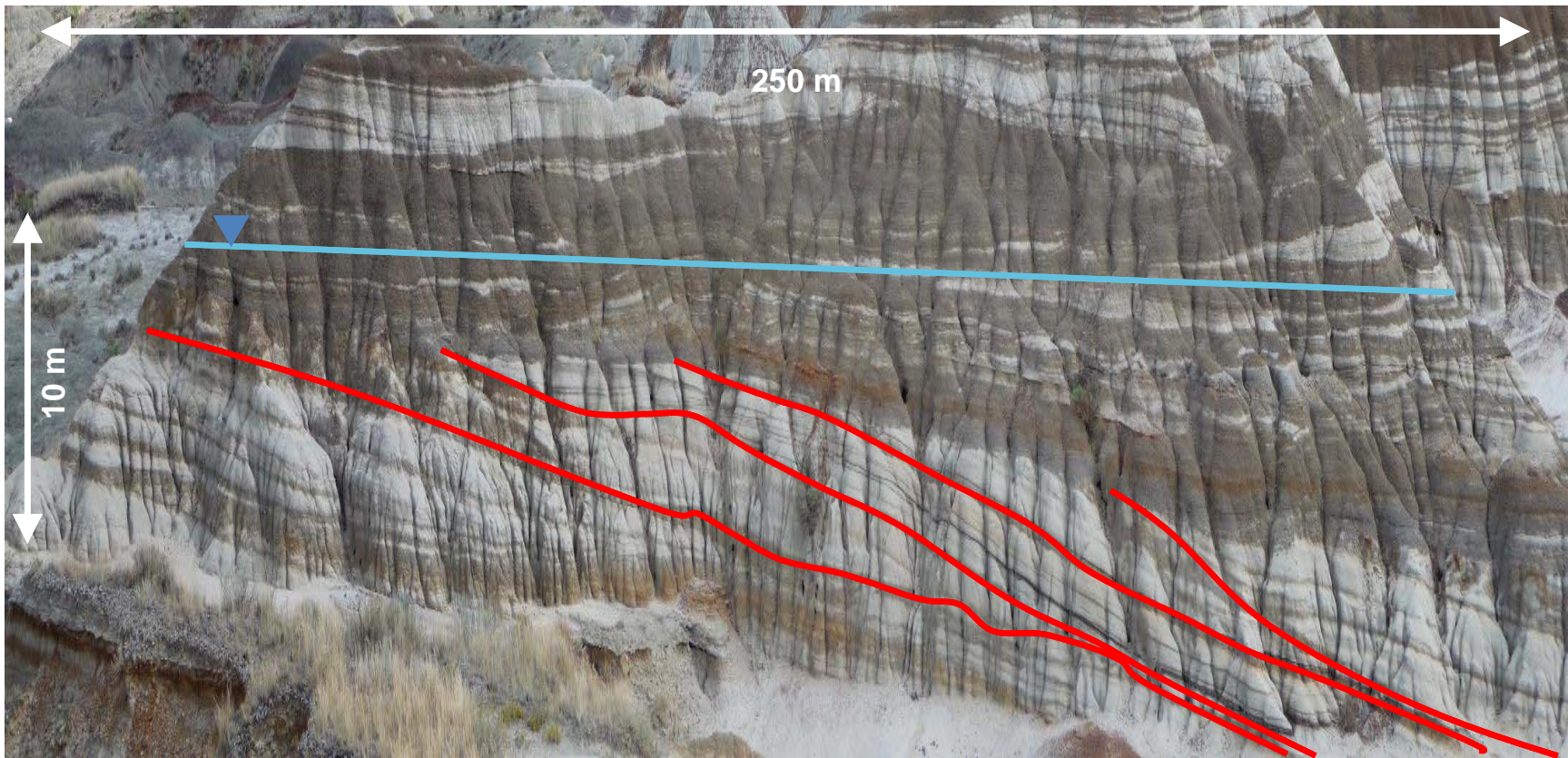
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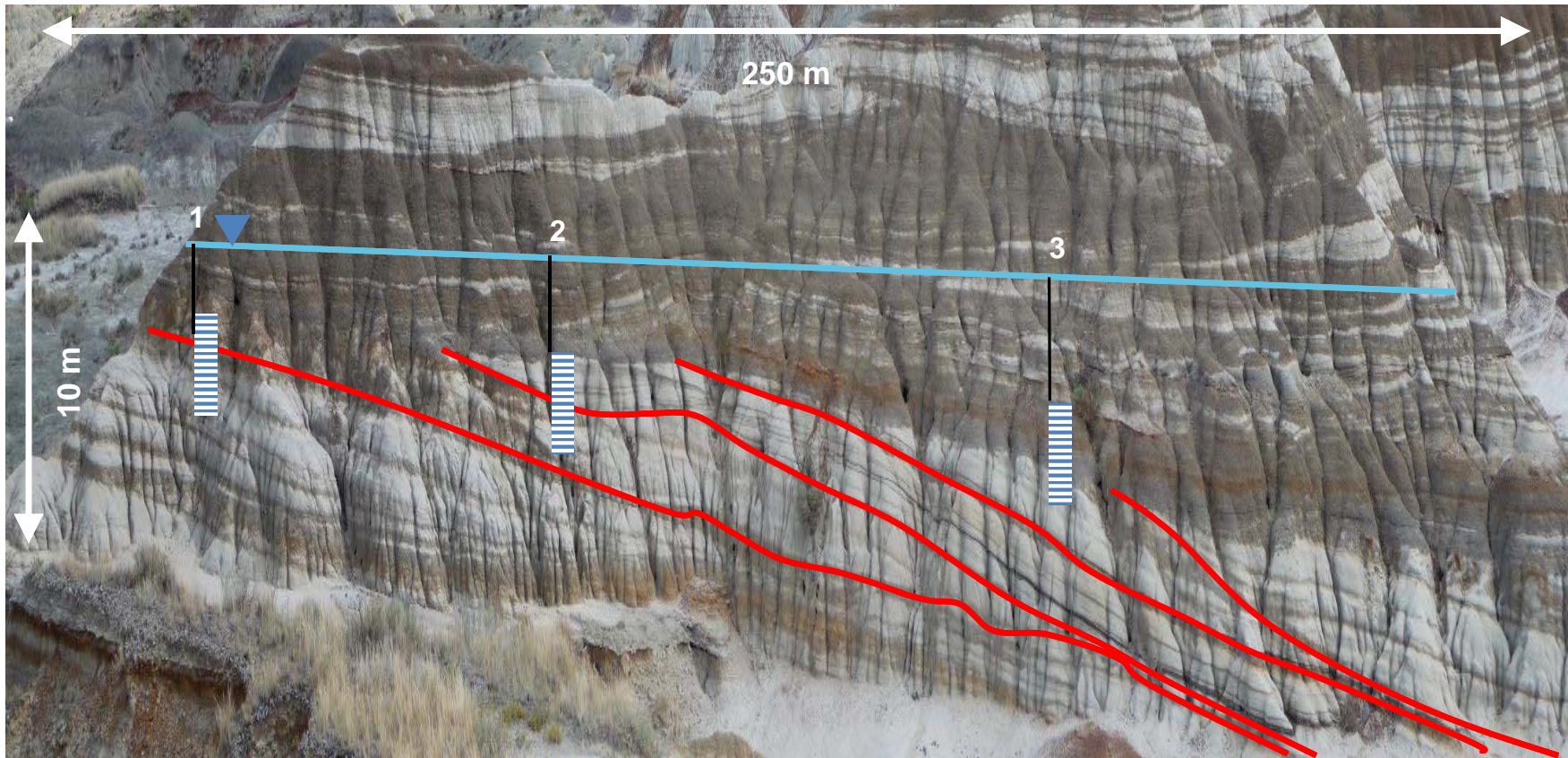
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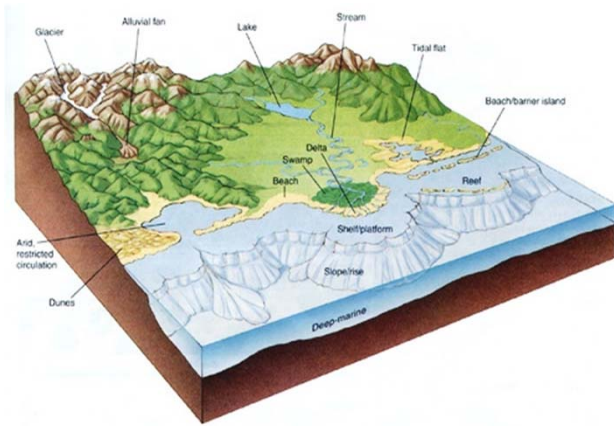
GEOLOGIC HETEROGENEITY MATTERS

- ▶ More than **126,000** sites across the U.S. require remediation
- ▶ More than **12,000** of these sites are considered "complex"
- ▶ "...due to **inherent geologic complexities**, restoration within the next 50-100 years is likely not achievable."
- ▶ USEPA Geology Initiative addresses historic underperformance of remedies



THE ESS PROCESS

1



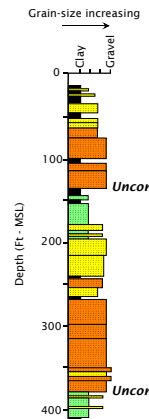
Determine depositional environment, which is the foundation of the ESS evaluation

2

100 or well no. 371 K sheet 1

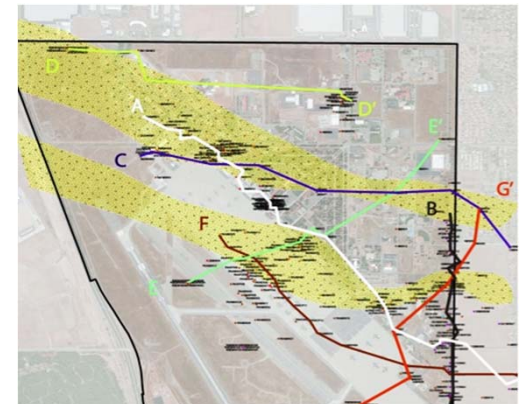
Well	Interval (feet)	Description
10	0 to 10	to 10' to 15'
15	15	Clay, gray, with interbedded fine sand, rounded shells
20	20	Clay, gray, -
25	25	Clay, fine to silty, gray, uniform
30	30	Clay, gray, silty, plastic, with a 1" gray, fine, sand bed @ 30' - 32'
35	35	Sand, coarsest, gray
40	40	Sand, fine to medium, gray
45	45	Sand, medium gray with 1/4" gravel to 1/2", and a trace of shells
50	50	Sand, medium to coarse, gray, with pebbles and a few small cobbles to 3/4" some clay balls @ 50' to 55'
55	55	Clay, gray
60	60	Sand, medium to coarse, with gravel and a few cobbles to 1" diameter
65	65	Sand, medium to fine, coarse, with cobbles to 1/2" dia, and up to 100 grains
70	70	Clay, gray with shells
75	75	Silt, fine sandy, gray
80	80	Clay, gray
85	85	Silt, fine sandy, gray silt sh above becoming sandier with shells from 80' to 85'
90	90	Silt, fine sandy, gray silt sh above becoming sandier with shells from 85' to 90'

Notes:
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Leverage existing lithology data: format to emphasize vertical grainsize distribution

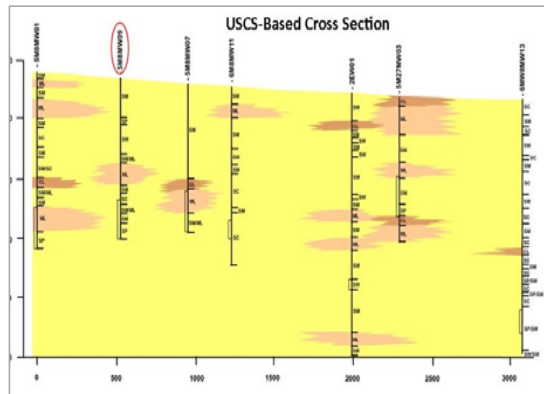
3



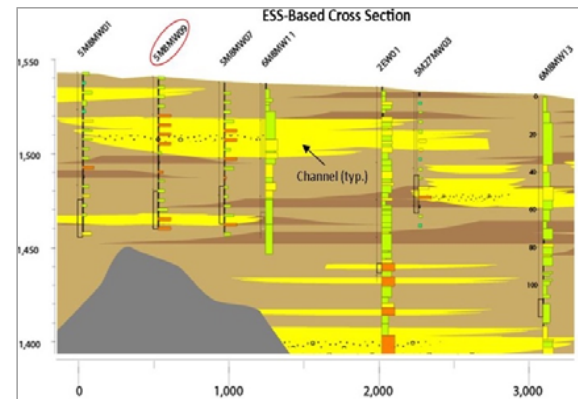
Map and predict in 3-D the subsurface conditions away from the data points

MAPPED BURIED SAND CHANNELS

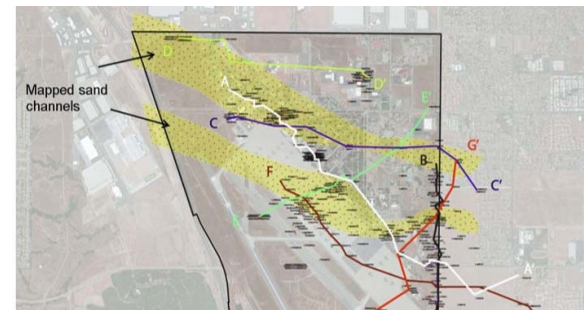
USCS-Based Cross Section



ESS-Based Cross Section



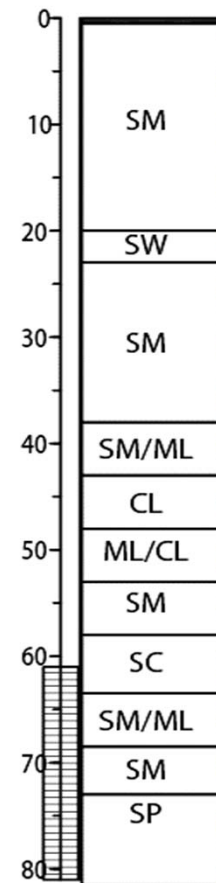
VS



GETTING MORE FROM EXISTING SITE DATA

- ▶ “All we have are these lousy USCS boring logs”
- ▶ USCS is not a geologic description of the lithology
- ▶ Different geologists
- ▶ Different drilling methods
- ▶ Different sampling intervals

5M8MW09

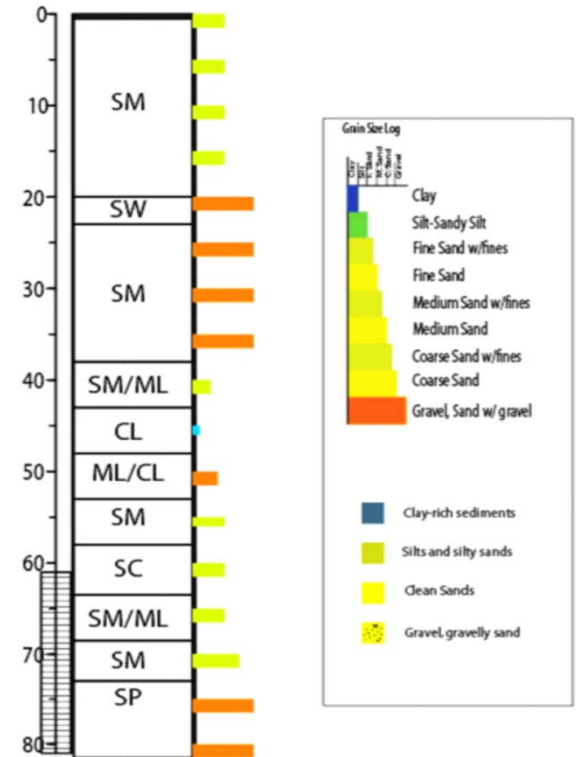


ESS PROCESS

Graphic Grain-Size Logs (GSLs)

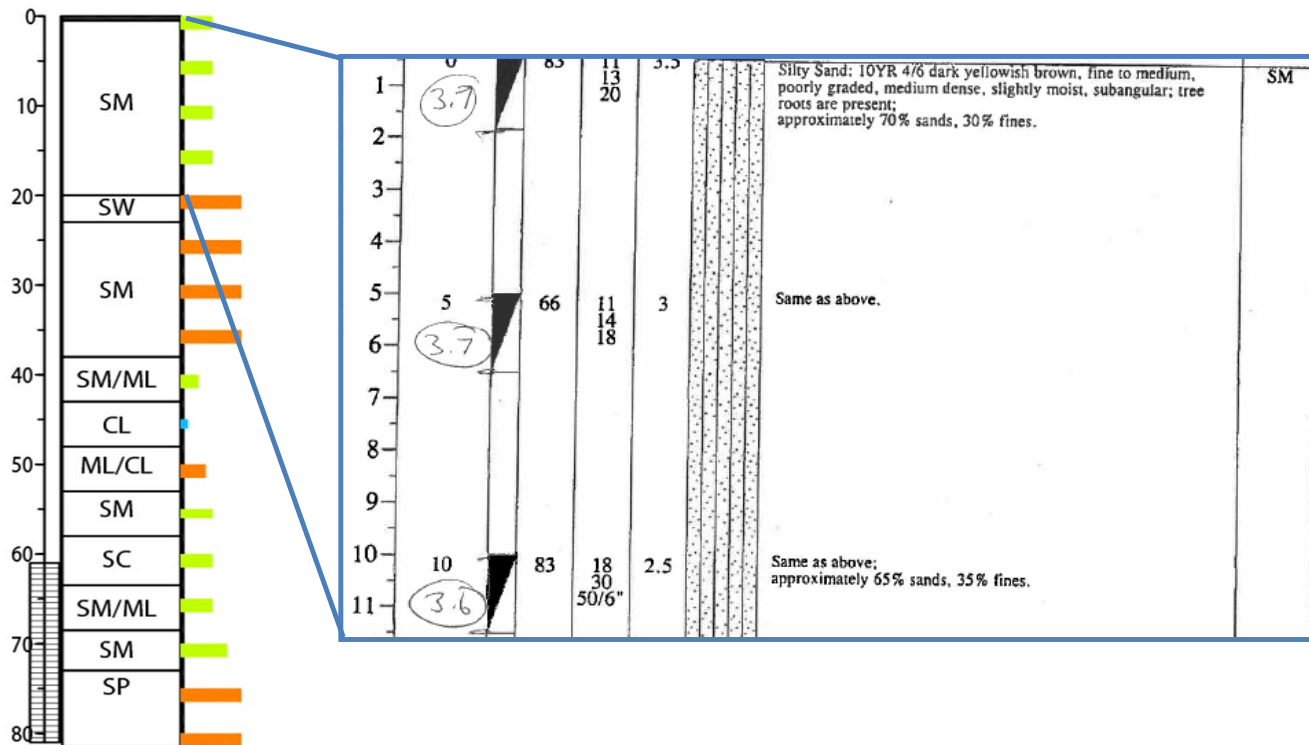
- ▶ Existing data is formatted for stratigraphic interpretation
- ▶ Reveals the “hidden” stratigraphic information available with existing lithology data

5M8MW09



ESS PROCESS

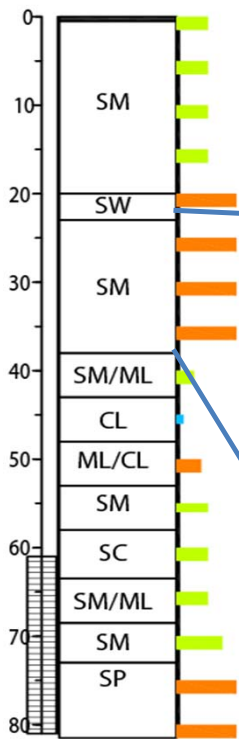
5M8MW09



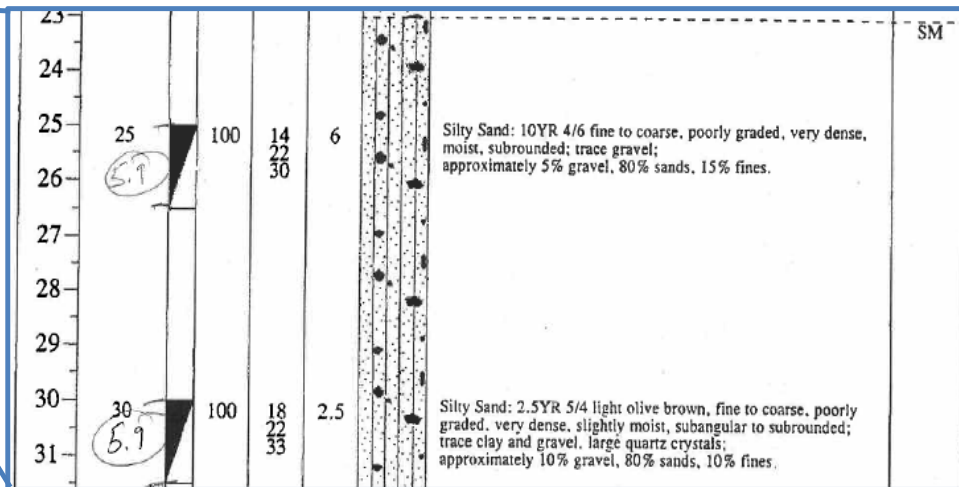
This SM interval is a fine to medium-grained silty sand

ESS PROCESS

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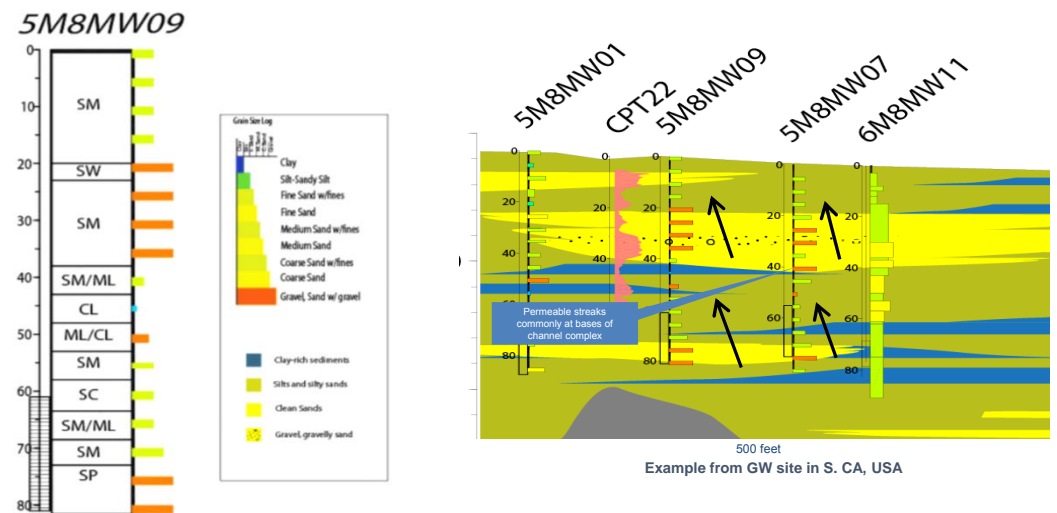


This SM interval is a fine- to coarse-grained silty sand with gravel, representative of a channel deposit

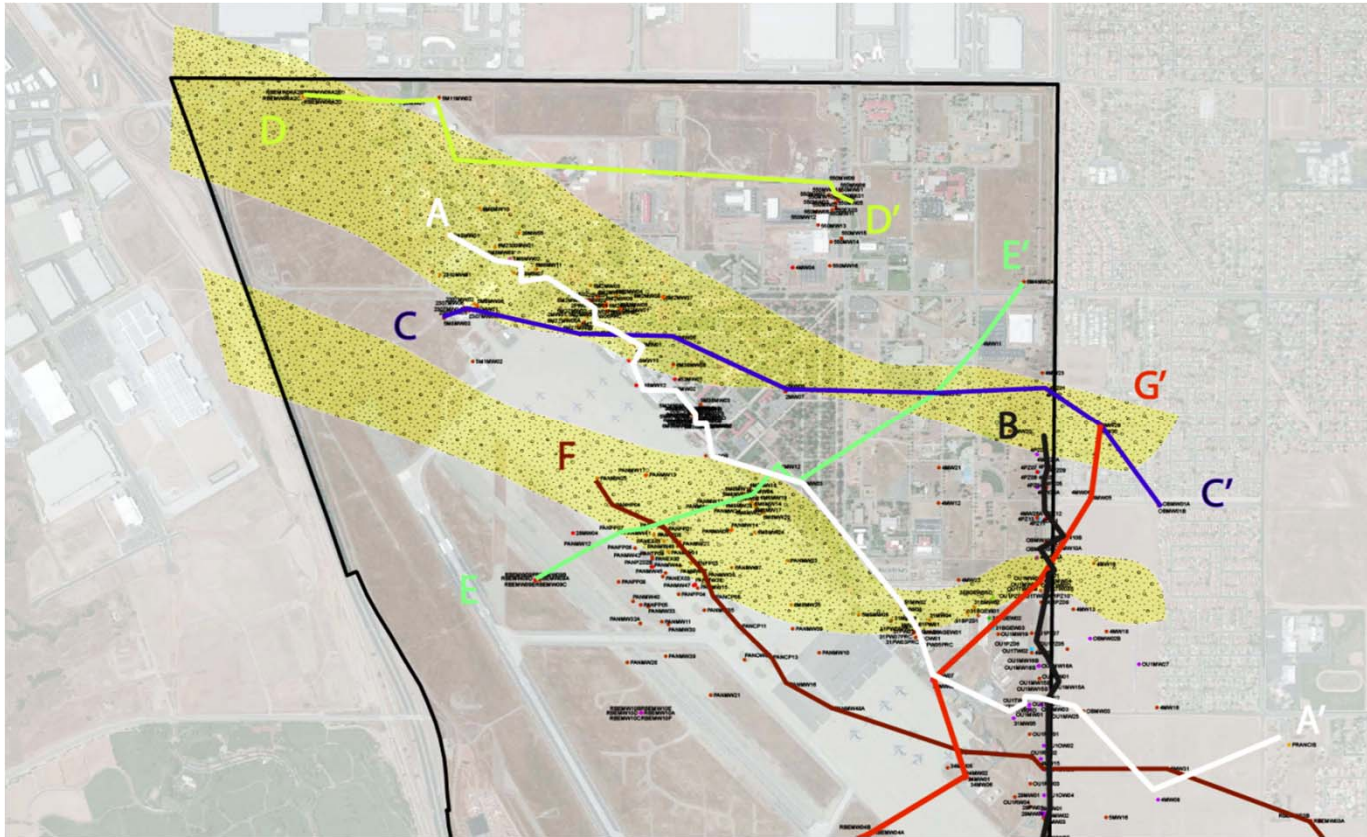


ESS PROCESS

- ▶ Reformat existing data to identify sequences
- ▶ Apply facies models, stratigraphic “rules of thumb” to correlate and map the subsurface, predict character of heterogeneity present

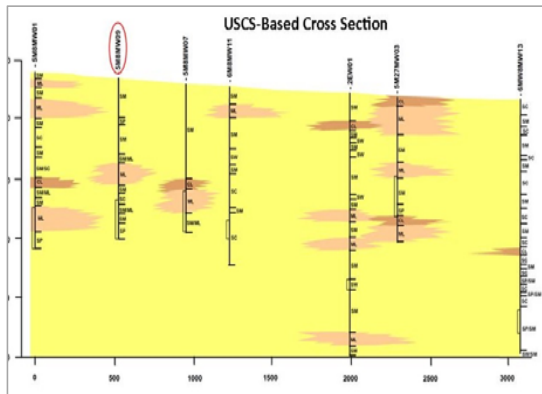


MAPPED BURIED SAND CHANNELS

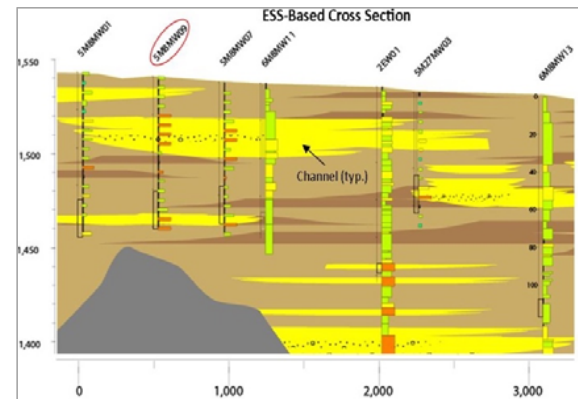


GRAIN SIZE TRENDS USED TO MAP PATHWAYS

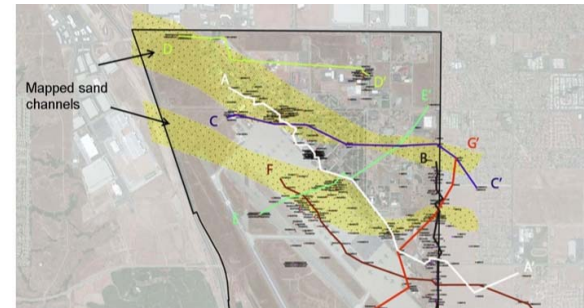
USCS-Based Cross Section



ESS-Based Cross Section



VS



STRATIGRAPHIC “RULES OF THUMB” FOR LOG CORRELATION

- ▶ Generalized guidelines for stratigraphic correlation of log data
 - ▶ Intended to facilitate “reality check” by non-stratigraphers
 - ▶ Some global guidance (e.g., 7, 8)
 - ▶ Some specific cautions (e.g., 10, 11)
- 1) Interpretation must consider depositional environment, facies model
 - 2) Patterns, not “tops”
 - 3) Consider erosional events
 - 4) Correlate clays first instead of sands
 - 5) Look for paleosols
 - 6) Channels have erosive bases, flat tops
 - 7) Increasing heterogeneity with clay content in fluvial systems
 - 8) Vertical heterogeneity is an indicator of lateral heterogeneity (fluvial systems)
 - 9) Look for Maximum Flooding Surfaces (coastal settings)
 - 10) Avoid the “mounded clay”
 - 11) Avoid “Pillars” of facies

PILLAR FACIES

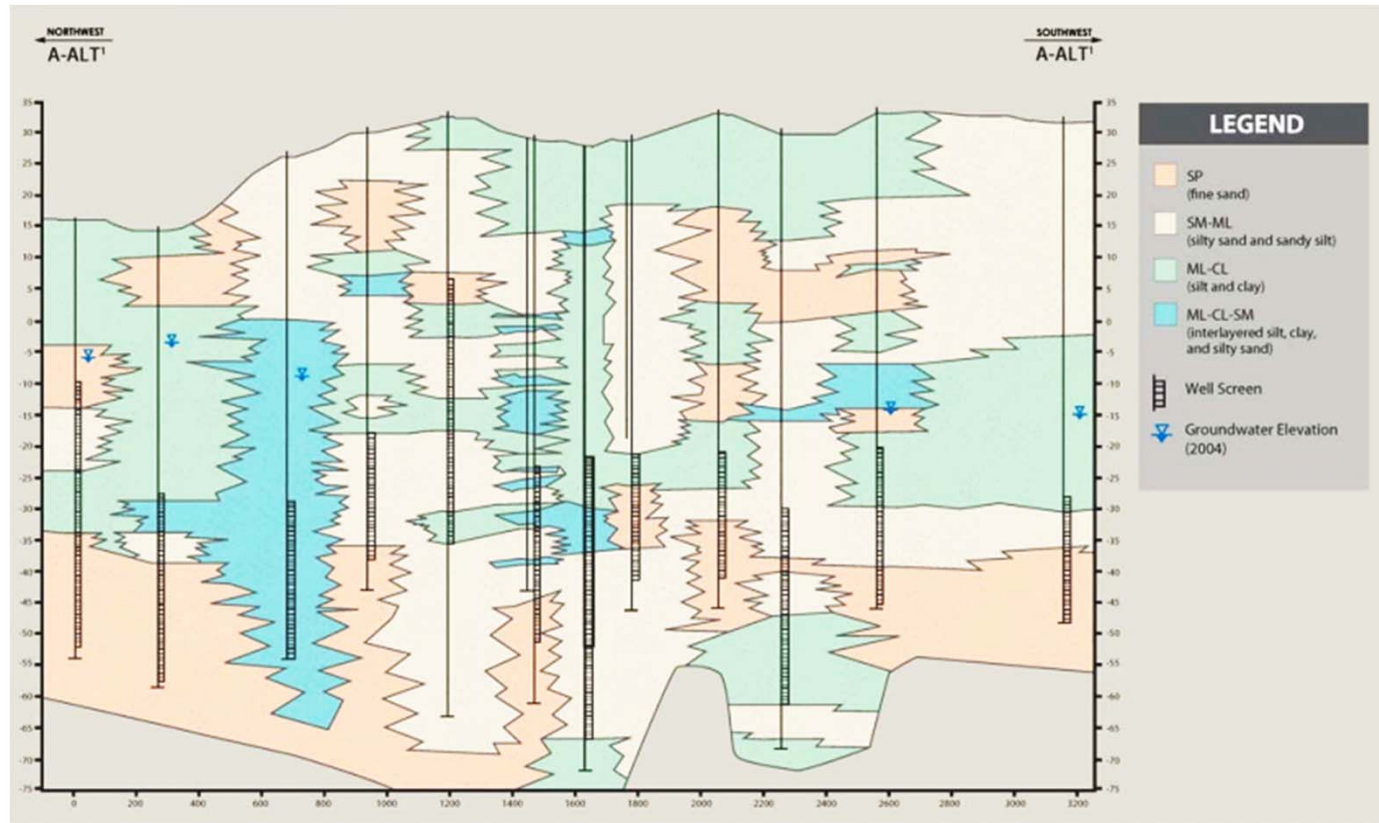


Figure 10. Cross section showing a common mistake in correlating subsurface data. Interpreted vertical facies patterns ("pillars") corresponding to individual borehole locations with interfingering facies changes laterally. This cross section reflects biases in USCS classification between different geologists or vintages of data collection, is not geologically defensible, and is of extremely limited utility in understanding subsurface conditions.

THE "MOUNDED CLAY"

- How different can two interpretations of the same data be?
- Does it matter?
- Is there a "right answer"?
- Sometimes, there are equiprobable interpretations
- But not this one...

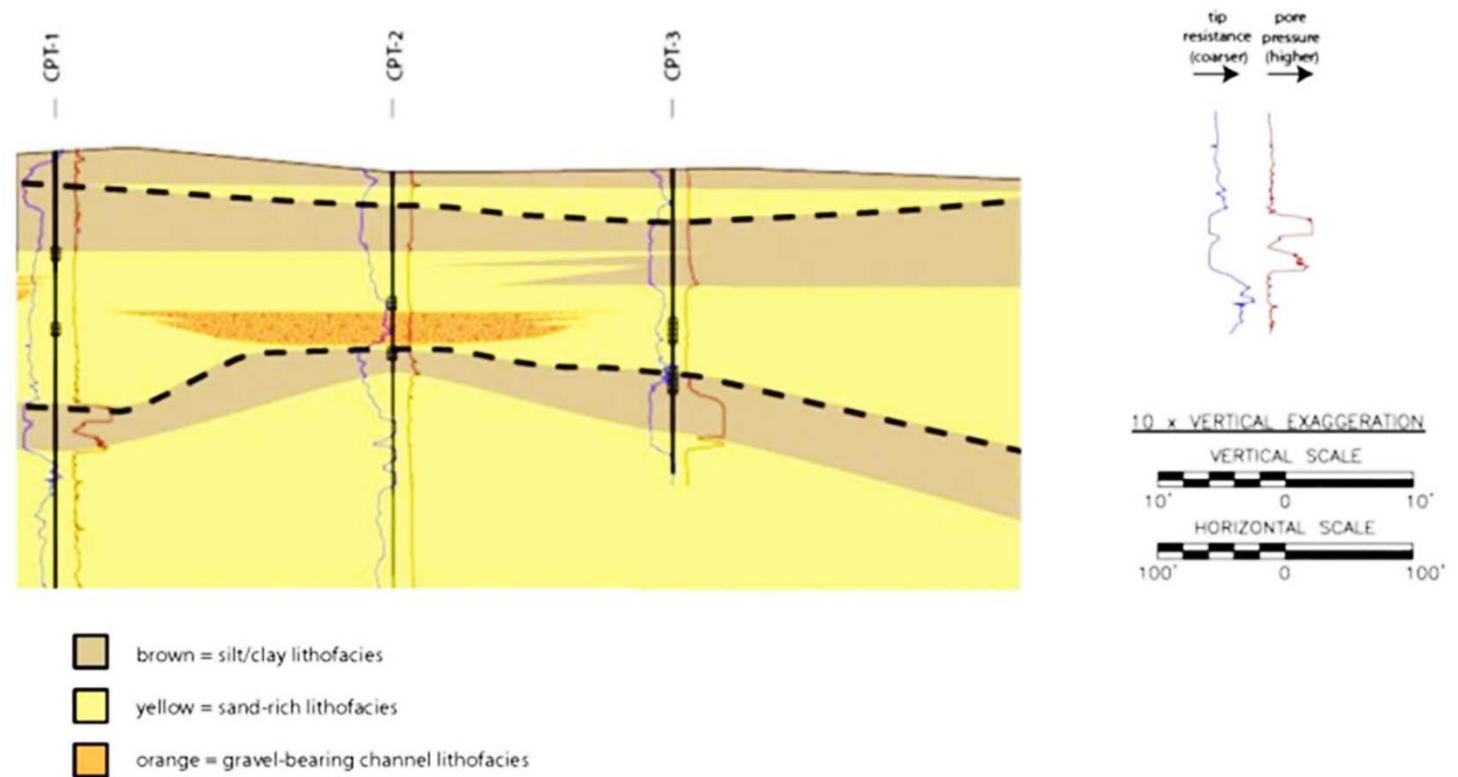
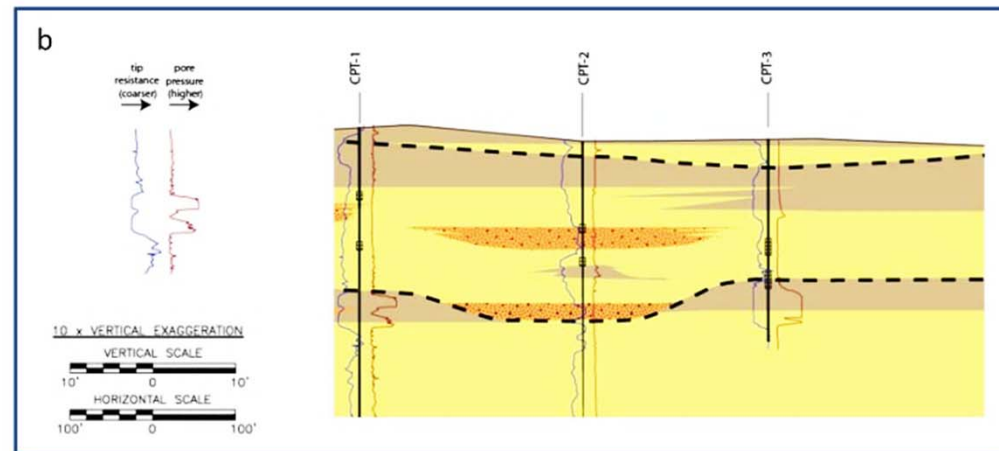
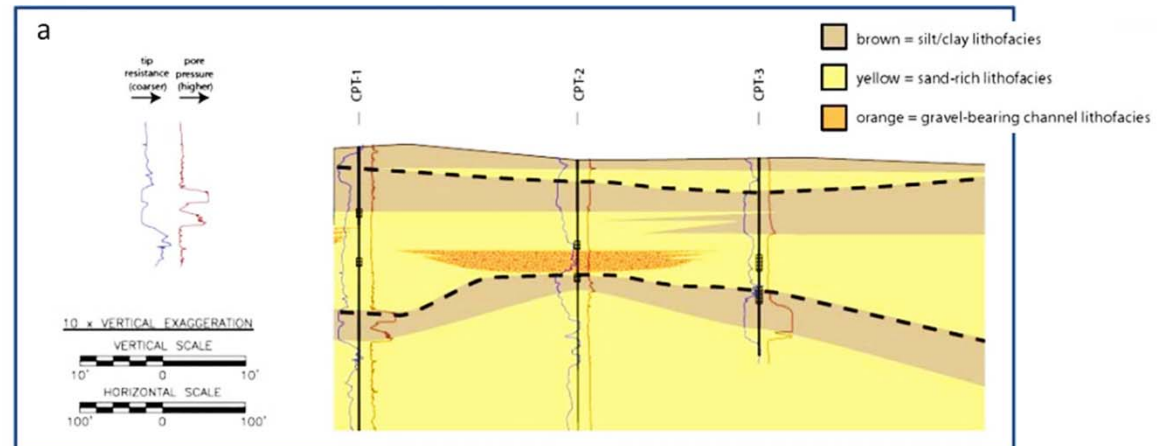


Figure A11. Existing CSM depicting three aquifer units (yellow) with gravel-bearing channel zone (orange) separated by aquitard units (brown). Lower aquitard unit shows convex-up morphology ("mounded").

KNOWLEDGE GAINED FROM ANALOG STUDIES AIDS IN INTERPRETATION OF SUBSURFACE DATA: OUTCROP OF CHANNEL DEPOSIT



THE "MOUNDED CLAY"



UPDATED CSM

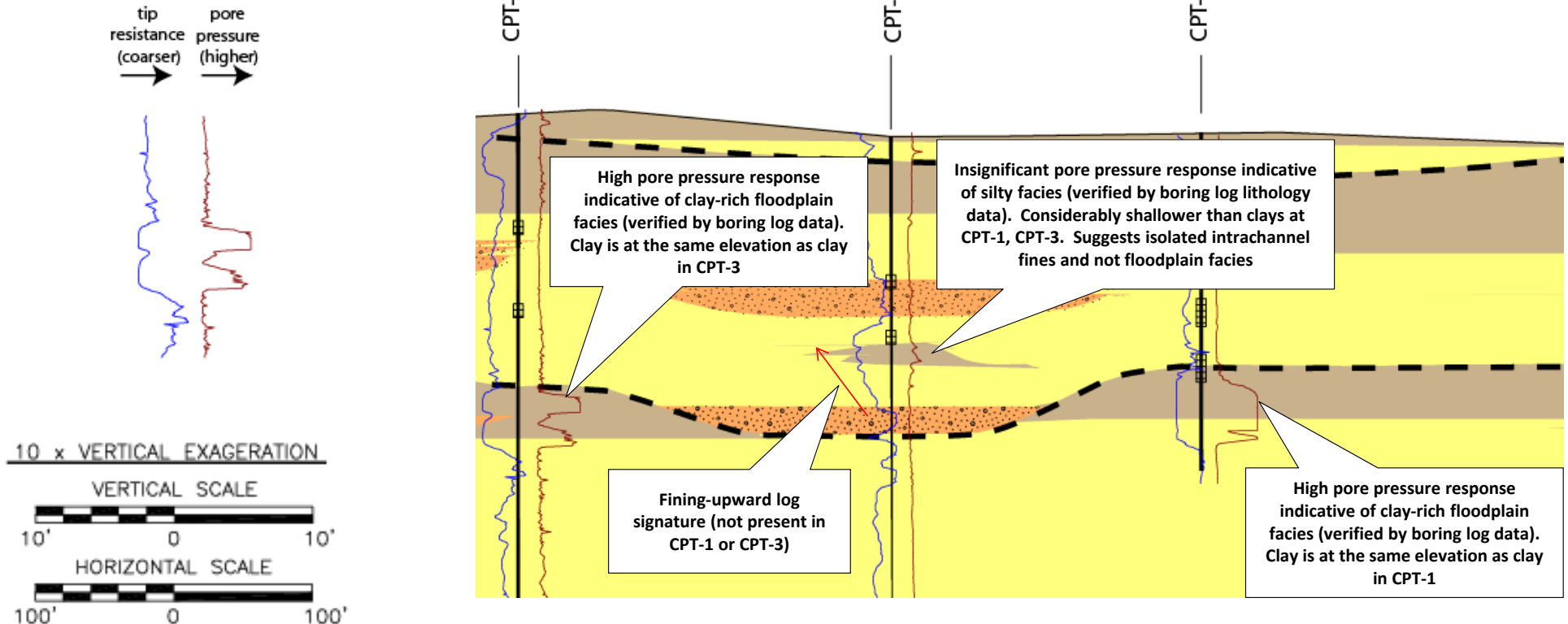


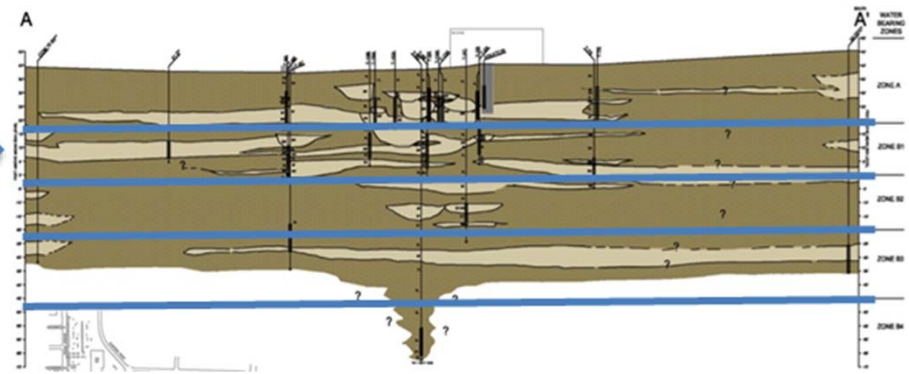
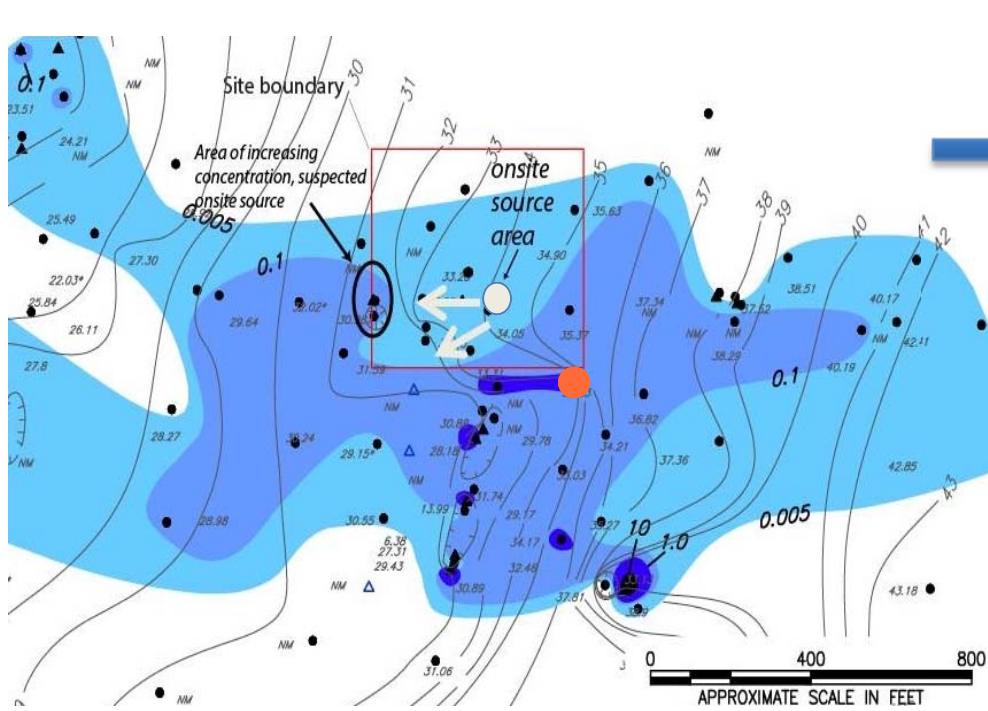
Figure A13. a) The original CSM. (b,c) ESS CSM stratigraphic interpretation of CPT data showing a channel deposit which has breached the principal aquitard unit through erosion. This interpretation is supported by the fining-upward nature of the channel deposit in CPT-2, the low pore pressure response of CPT-2 relative to CPT-1 and CPT-3, the similarity in elevation of the floodplain facies in CPT-1 and CPT-3, and the anomalous elevation of the silt unit in CPT-2.

CASE STUDY: SILICON VALLEY COMMINGLED PLUMES

- ▶ **Former semiconductor manufacturing site:** VOC groundwater plume commingled with neighboring plumes
- ▶ **Scale:** Less than 10 acres, approximately 100 feet depth of investigation
- ▶ **Geology:** Meandering/anastomosing stream (buried sand channels)
- ▶ **Lithology data:** Borehole logs
- ▶ **Approach:** In response to five-year review, use ESS to define contaminant migration pathways from off-site sources



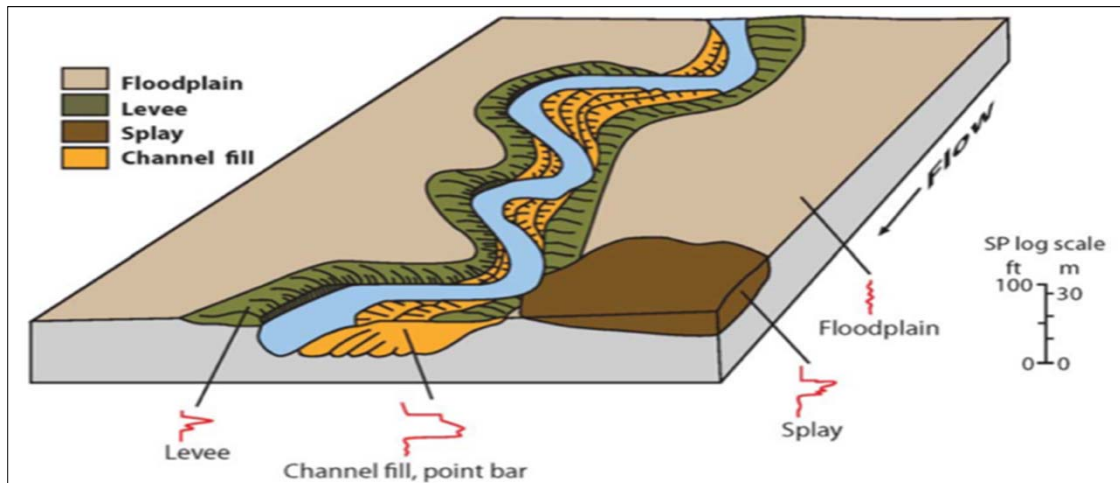
ORIGINAL CSM – B1 ZONE



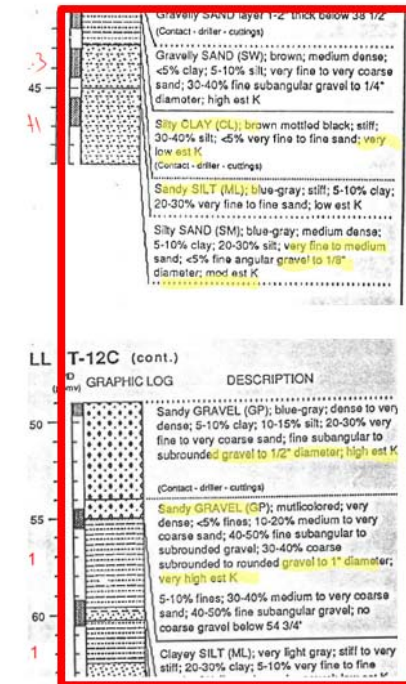
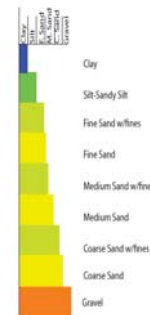
● Off site source area

GRAIN SIZE TRENDS AND GRAPHIC GRAIN SIZE LOGS

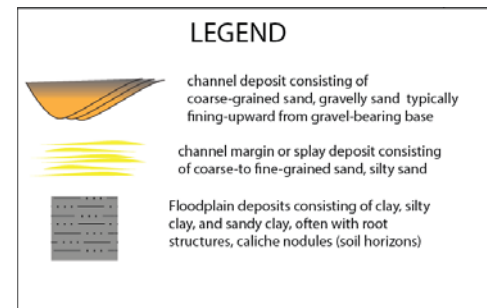
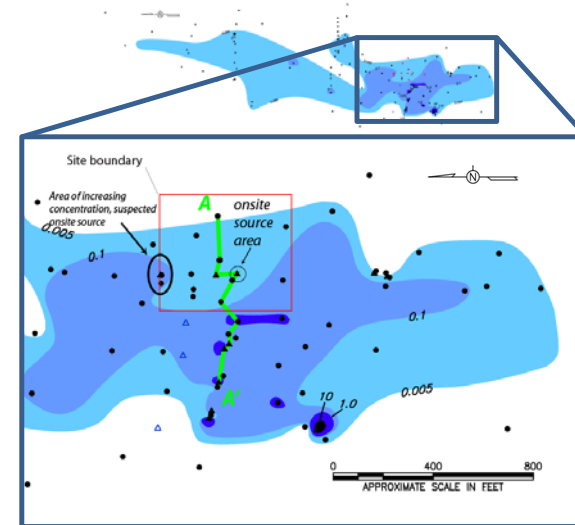
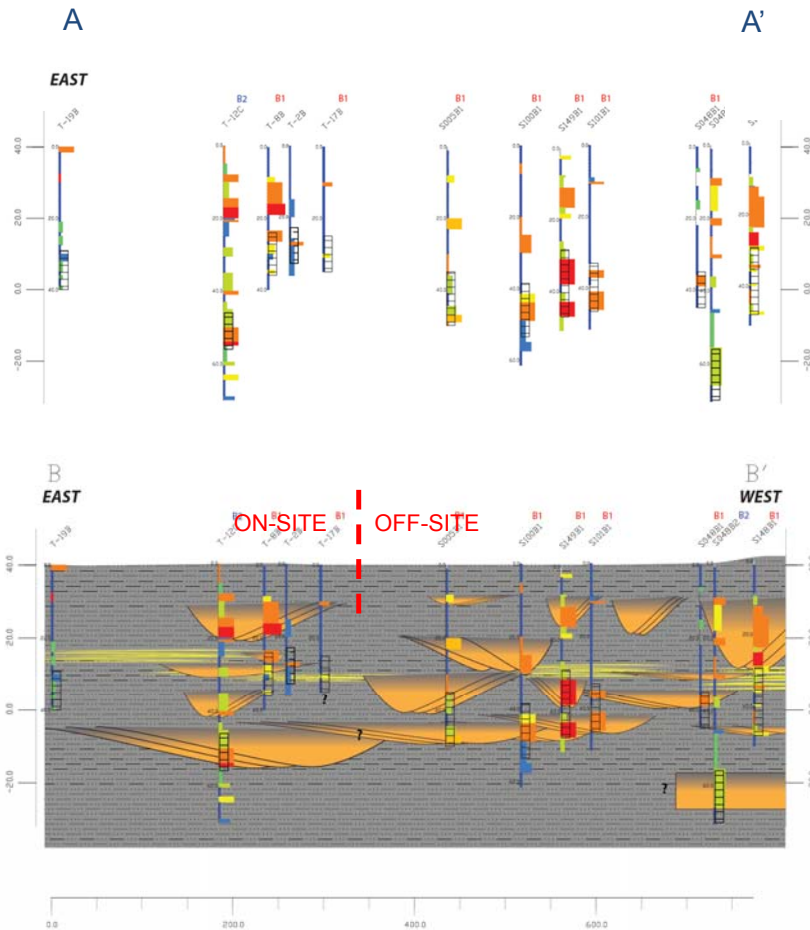
- ▶ Normalize different vintages of data collection, etc.
- ▶ Identify trends in maximum grain size (indicator of energy level in depositional processes)
- ▶ Provides “pseudo-elog”
- ▶ Example of fining upward channel deposit
- ▶ Channel “signature” provides basis for mapping



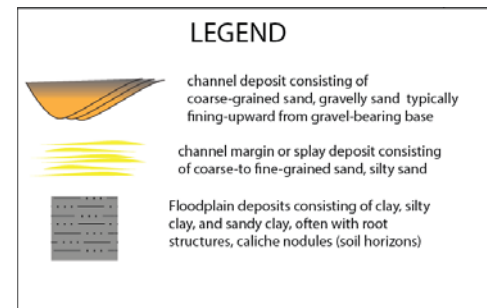
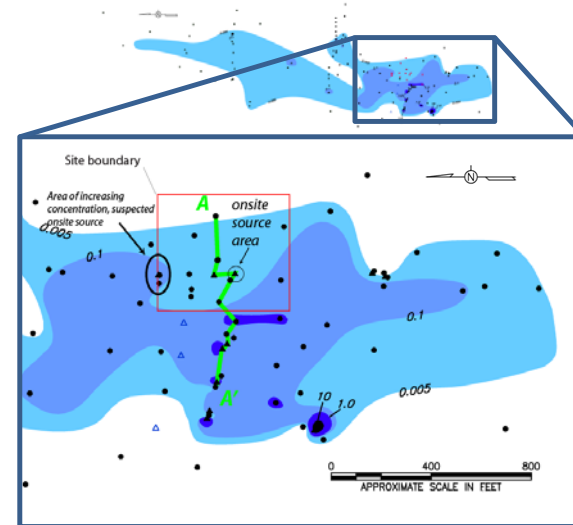
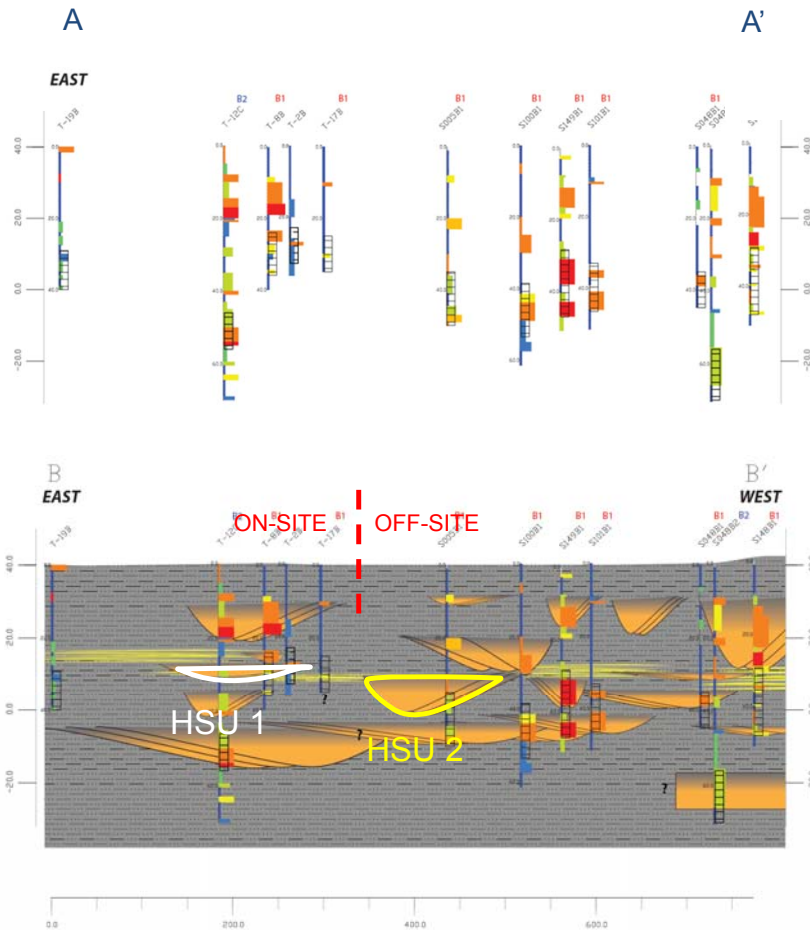
Grain Size Log



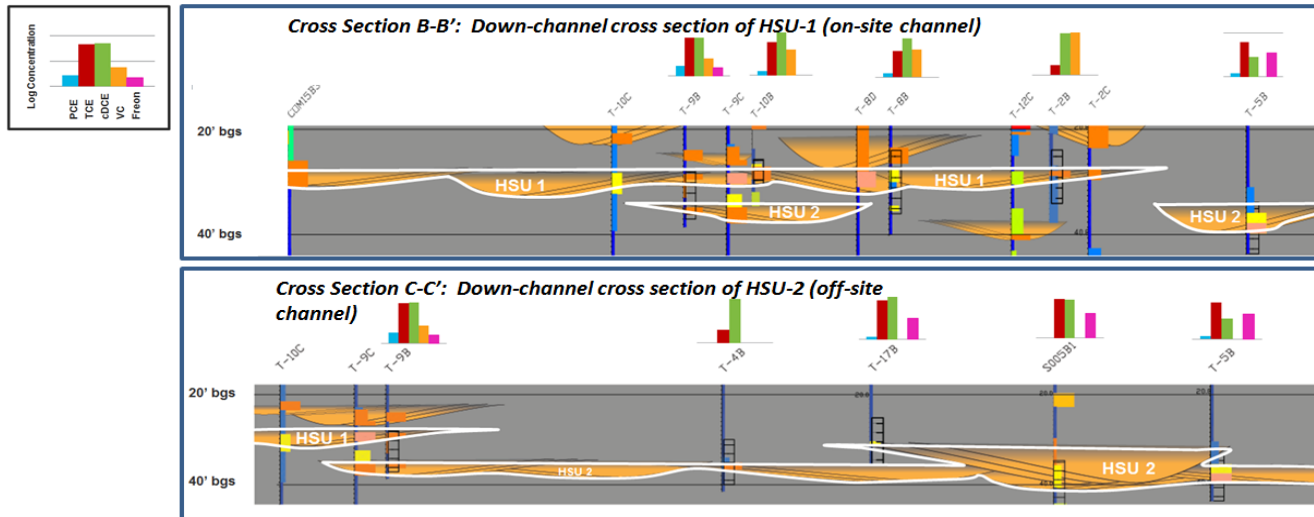
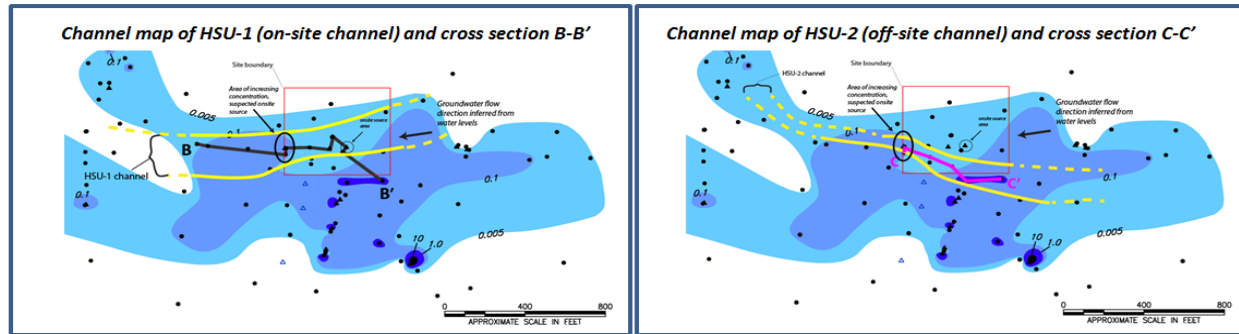
CHANNEL INTERPRETATION



CHANNEL INTERPRETATION



DOWNCHANNEL AXIAL PROFILE VIEWS WITH CONTAMINANT FINGERPRINT DATA

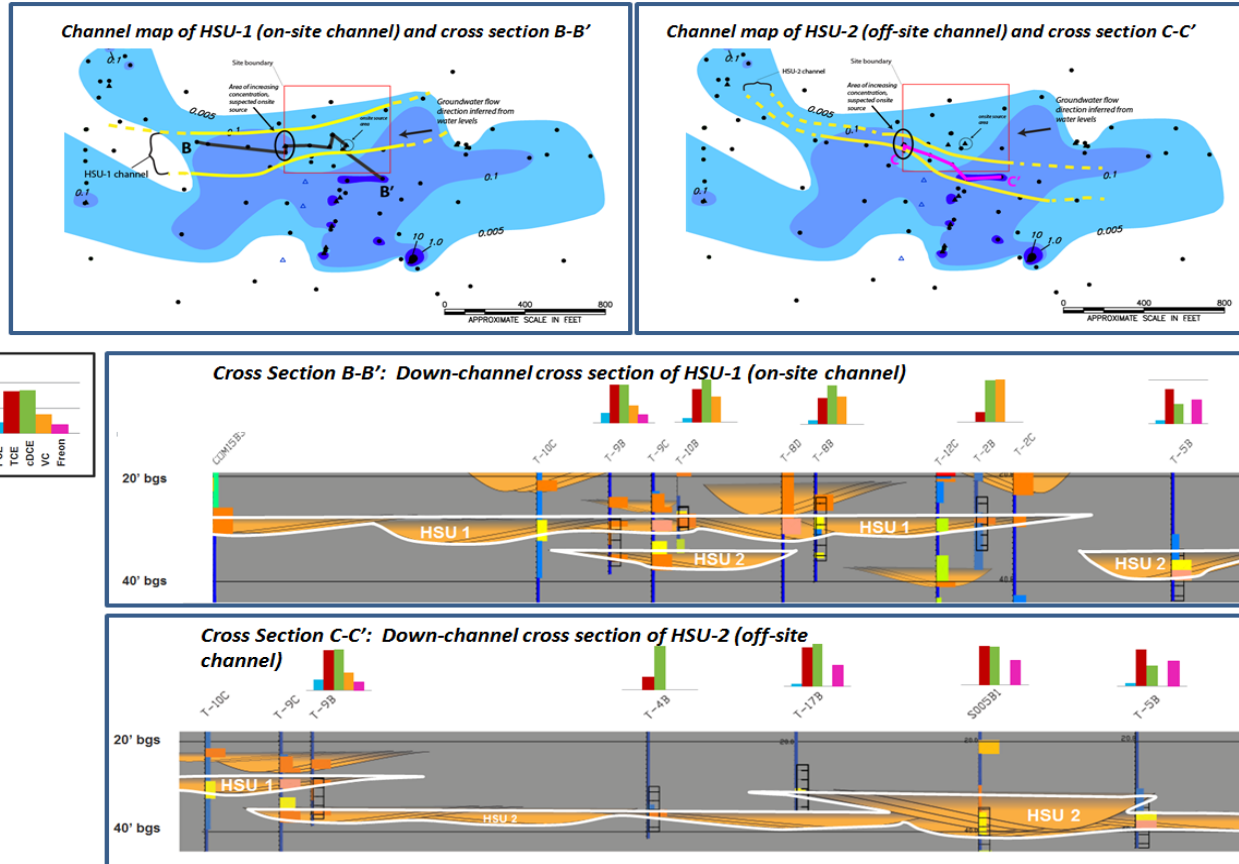


DOWNCHANNEL AXIAL PROFILE VIEWS WITH CONTAMINANT FINGERPRINT DATA

CSM reduced uncertainty and lead to resolution of a 5 year review issue.

provide rationale for monitoring well screen depth and monitoring objectives.

New CSM will result in clean up by parties responsible for each site related release.



CONCLUDING REMARKS

- ▶ Stratigraphy is complex, a critical control on contaminant flux
- ▶ While complex, stratigraphy is not “random”, facies models and sequence stratigraphy are tools to improve understanding of heterogeneity and groundwater CSMs
- ▶ ESS reduces uncertainty, time to remedy complete, and cost

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September 2017

 United States Environmental Protection Agency

Groundwater Issue

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

Michael R. Shultz¹, Richard S. Cramer¹, Colin Plank¹, Herb Levine², Kenneth D. Ehman³

CONTENTS	
Background	1
I. Introduction - The Problem of Aquifer Heterogeneity	3
Impact of Stratigraphic Heterogeneity on Groundwater Flow and Remediation	4
Sequence Stratigraphy and Environmental Sequence Stratigraphy	4
II. Depositional Environments and Facies Models	7
Facies models for fluvial systems	10
Glacial geology and related depositional systems	10
III. Application of Environmental Sequence Stratigraphy to More Accurately Represent the Subsurface	12
Phase 1: Synthesize the geologic and depositional setting based on regional geologic work	12
Phase 2: Formatting lithologic data and identifying grain size trends	16
Phase 3: Identify and map HSUs	19
Conclusions	22
References	24
Appendix A: Case Studies	A1
Appendix B: Glossary of terms	B1

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 on the application of the geologic principles of sequence stratigraphy and facies models (see "Definitions" text box, page 2) to the characterization of stratigraphic heterogeneity at hazardous waste sites.

Application of the principles and methods presented in this issue paper will improve Conceptual Site Models (CSM) and provide a basis for understanding stratigraphic flux and associated contaminant transport. This is fundamental to designing monitoring programs as well as selecting and implementing remedies at contaminated groundwater sites. EPA recommends re-evaluating the CSM while completing the site characterization and whenever new data are collected. Updating the CSM can be a critical component of a 5 year review or a remedy optimization effort.

The document was prepared under the U.S. Environmental Protection Agency National Decontamination Team Decontamination Analytical And Technical Service (DATS) II Contract EP-W-12-06 with Consolidated Safety Services, Inc. (CSS), 10301 Democracy Lane, Suite 300, Fairfax, Virginia 22030.
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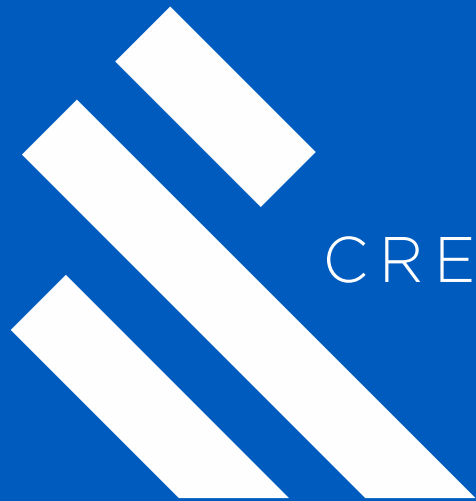
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