

Maximizing Insight and Data Capture from Borehole Logs: The Graphical Approach to Geologic Logging and Its Benefits

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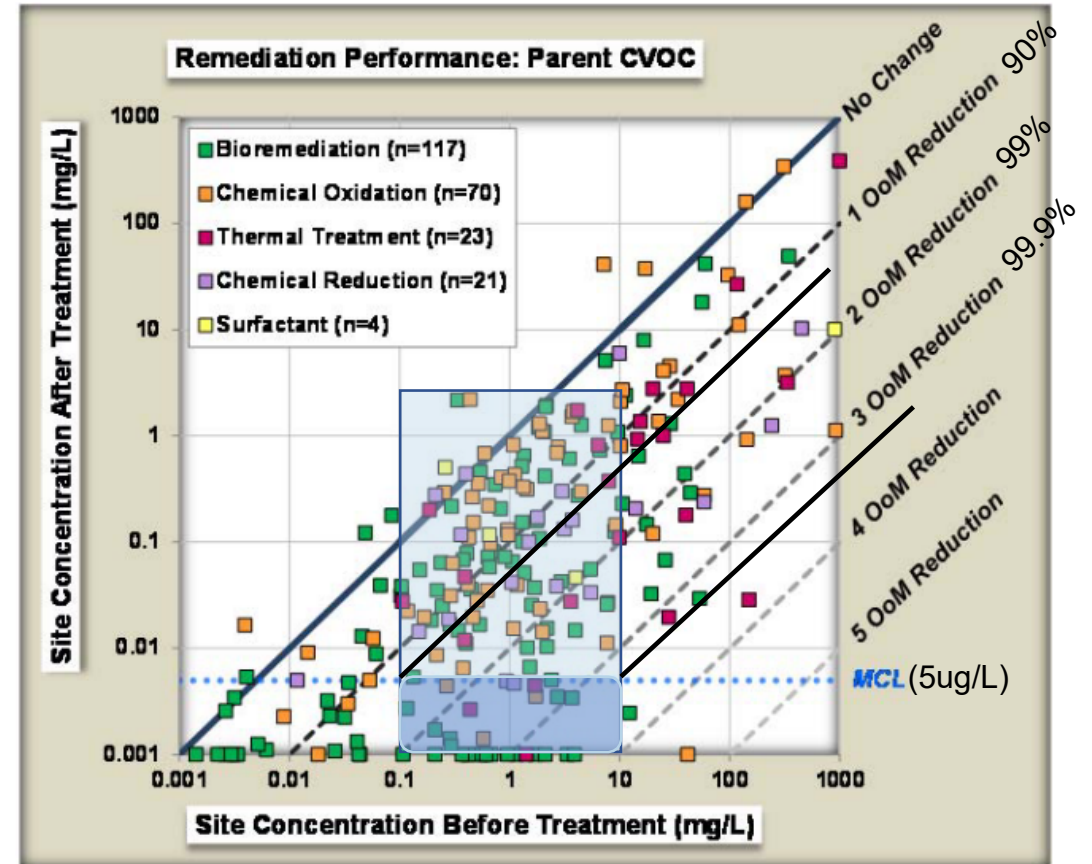
IOWA

 **GSI**
ENVIRONMENTAL

May 09, 2023

The Problem: Remediation Performance Often Does Not Meet Remediation Expectations

- Remediation success often requires destruction/removal of ~95-99.9% of the mass
- The actual median reduction in concentration achieved by applied technologies is closer to 90%



McGuire et al. 2016, ESTCP project ER-201120

A Major Obstacle For Performance : The Inherent Complexity of the Subsurface

Complexity Consists of:

Lithologic Heterogeneity

- Scale of detection vs. reality

Stratigraphic Geometry

- Real vs. Interpreted Hydro stratigraphic unit continuity

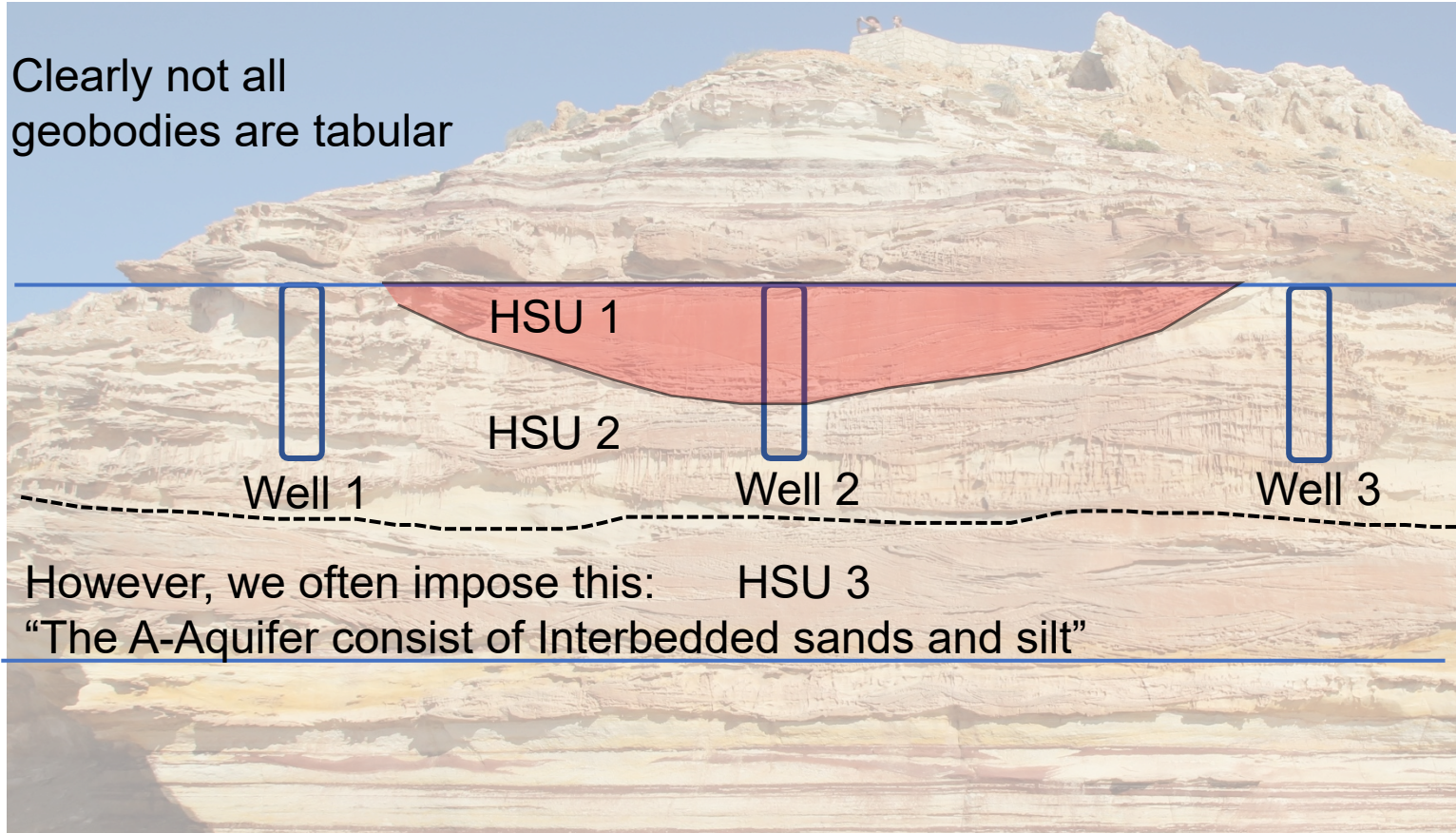


Van Etten Creek, Oscoda, MI

Impacts of Geometry and Heterogeneity

Geometry

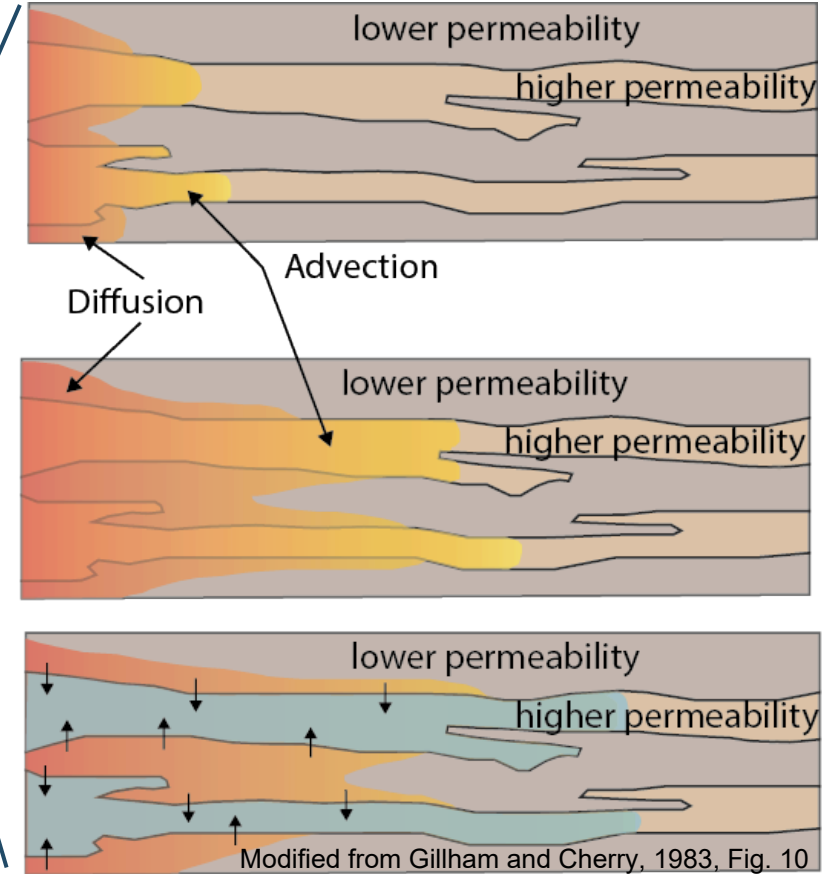
Clearly not all geobodies are tabular



However, we often impose this: HSU 3
"The A-Aquifer consist of Interbedded sands and silt"

Depositional geometry of HSU's can significantly impact hydraulic connectivity, well performance, and/or amendment efficacy and so must be addressed.

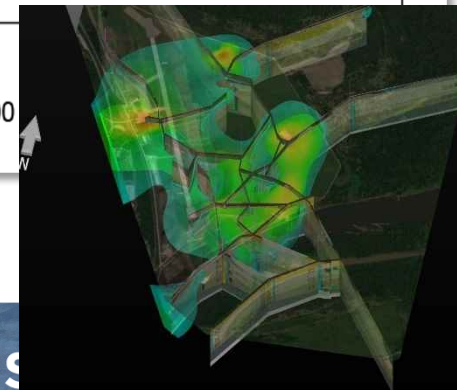
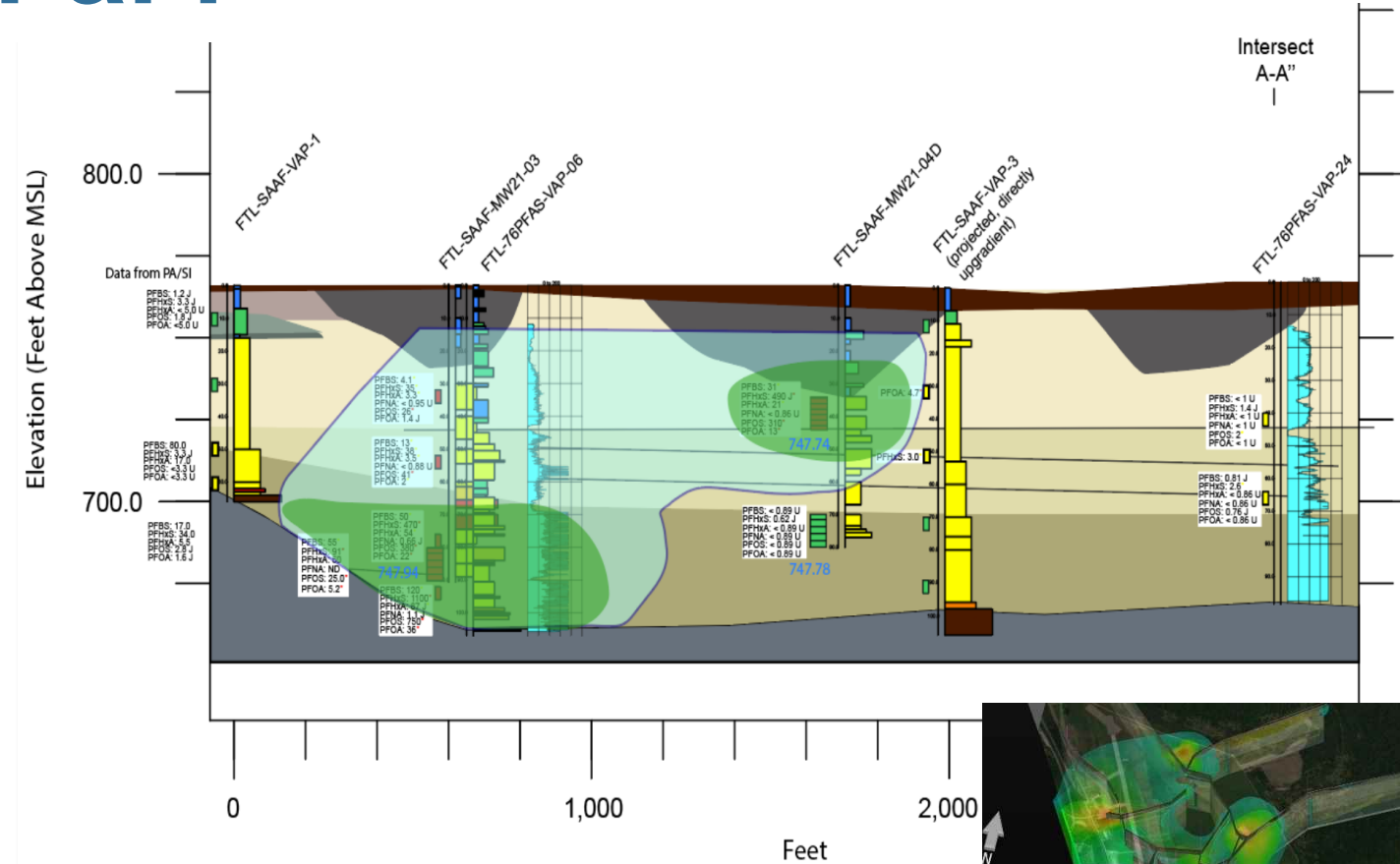
Heterogeneity



Diffusion of mass into fine-grained storage zones can lead to back diffusion and prolonged remediation time frames

How Have We Tackled These Aspects of Complexity So Far?

- High-resolution site characterization (HRSC):
 - High-resolution in Z-dimension
 - Insight into heterogeneity and mass at a range of scales
 - Proxy data requires calibration to high-quality lithologic logs
- Advanced methods in stratigraphic correlation
 - Environmental Sequence Strat. and facies-based interpretations of HSU continuity
 - Leveraging HRSC and other new and legacy site data



Environmental Sequence Stratigraphy (ESS) and Facies-Based Correlations

Facies Analysis: Characterization of geo bodies according to unique Lithological, Physical, and Biological Attributes

Facies Model (Modern Analogue):
Distributive Fluvial System
(outwash fan)

Predictable Successions of Grainsize and Environment

Boring Logs

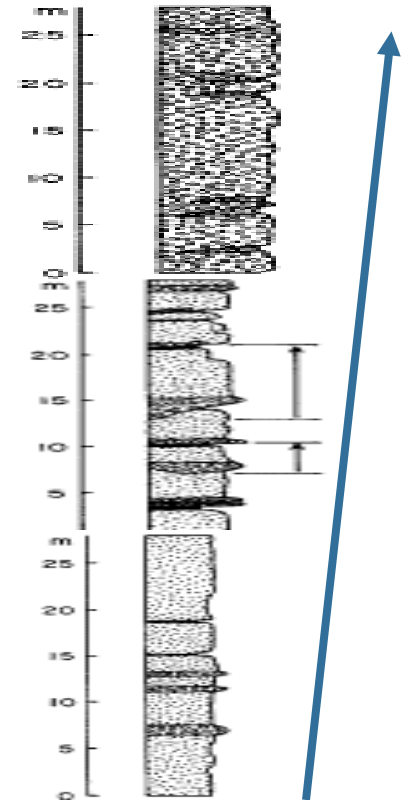
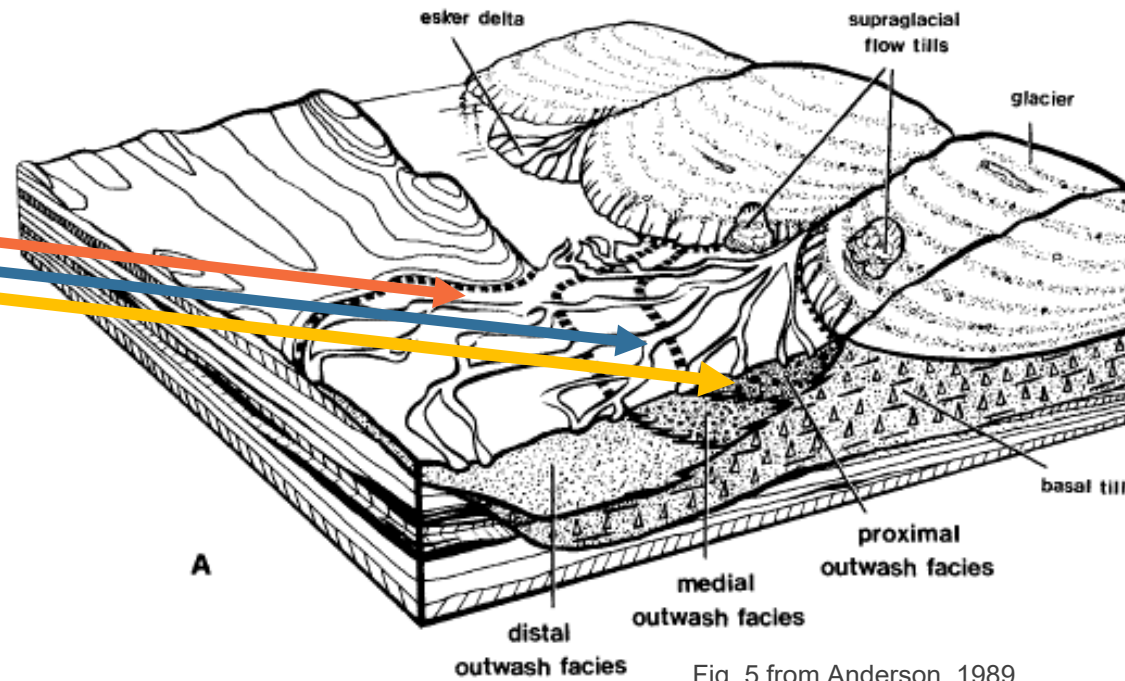
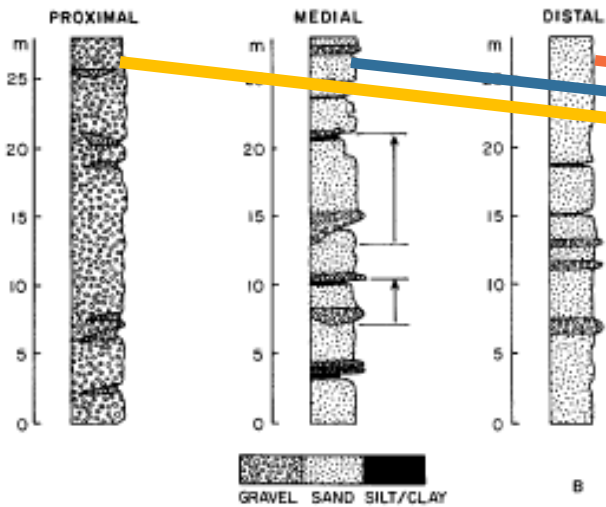
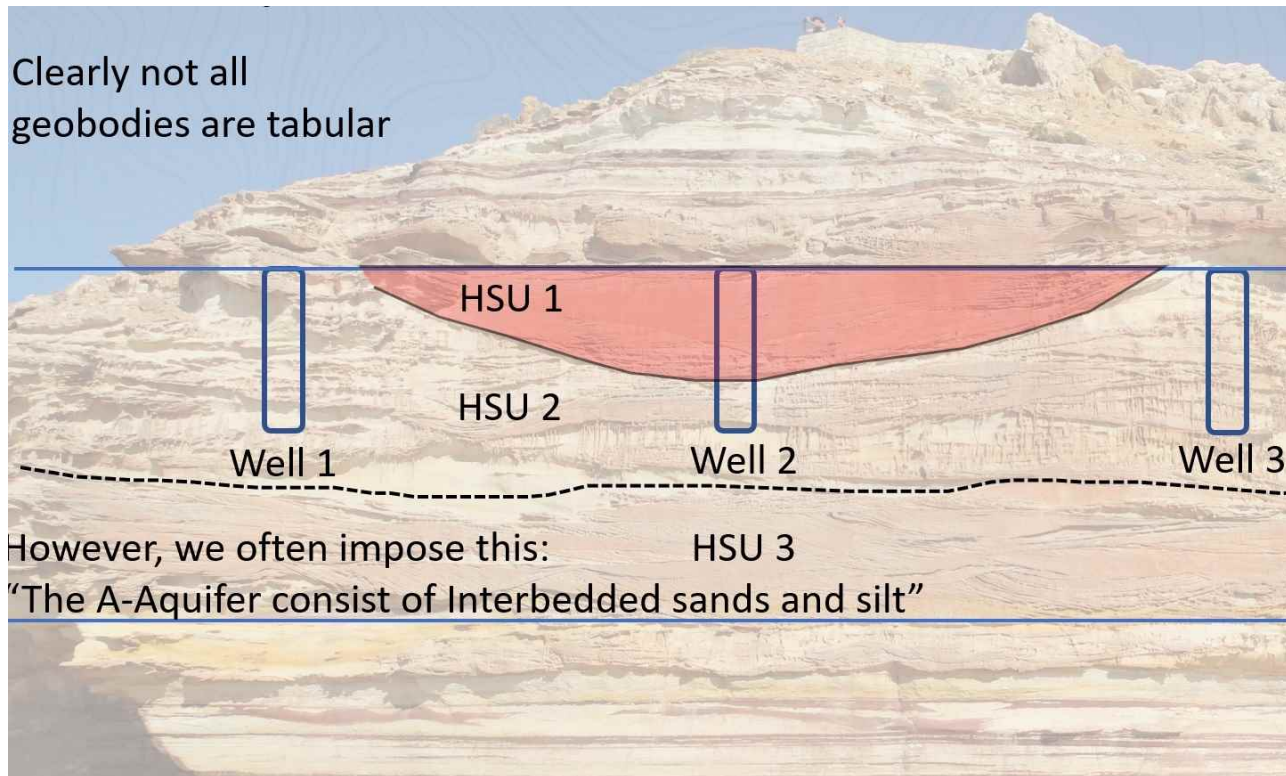


Fig. 5 from Anderson, 1989

Facies Models Are Key: Geology Controls the Distribution of Permeability Contrasts



Facies Model:
Distributive Fluvial System
(outwash fan)

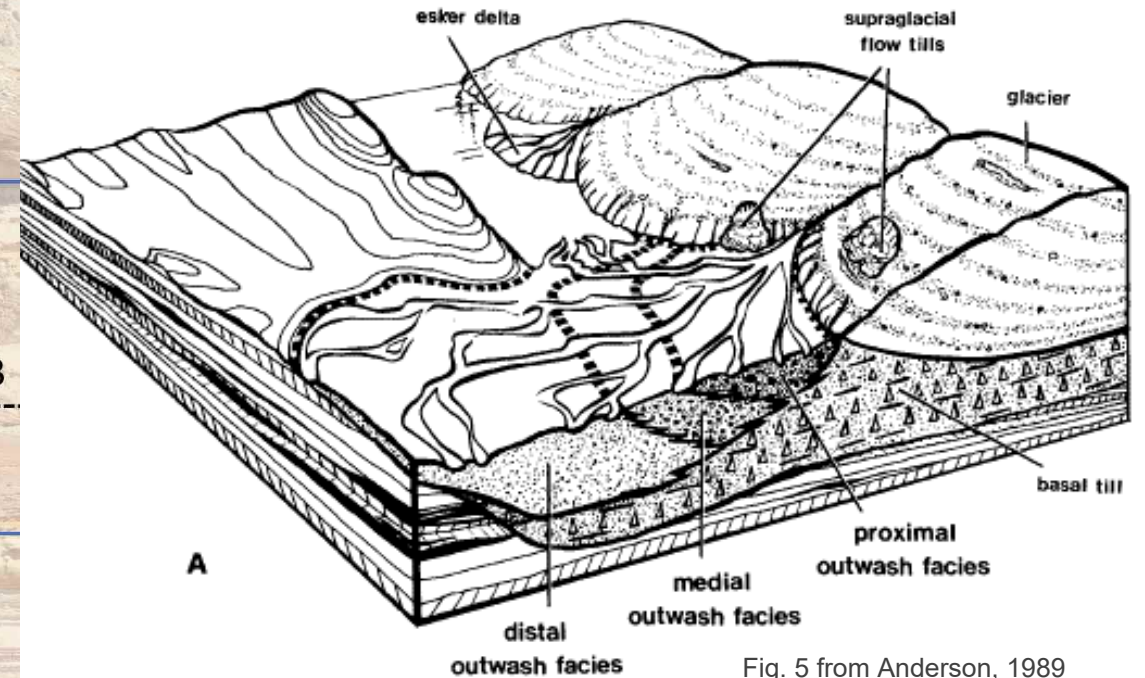


Fig. 5 from Anderson, 1989

Accurate Facies Analysis Depends on High Quality Observations From Borings

Data Types (After Catuneanu, 2006; Reineck & Singh, 1975)		Common	Uncommon	Never
	Facies Model/Modern Analogue	■		
	Sedimentary Lithology (Core)	■		
Improved Log Quality is Key	Grainsize description and/or visual % estimate	■	■	
	Vertical Grading Trends	■		
	Paleocurrent Indicators/Physical Sediment Structures		■	
	Pedologic data (Soil indicators: color, organics, mineralogy, cementation)		■	■
	Ichnology (biologic trace fossils), biostratigraphy			■
	Outcrops/Exposures		■	
	Well Log (Gamma log motifs)		■	
	Direct Push Data (CPT, HPT, EC)	■		
	Clay Minerology			■

Facies Analyses in Environmental Industry are frequently conducted using practitioner's best judgement at a 50% Data Deficit

Improving Log Quality: Tools We Use to Collect Geologic Data From Borings



- Hand lens
- Grain size charts
- Munsell color charts
- Acid
- Soil knife
- Reference documents
- ***Logging Form***

Our Data Collection Tool is *Flawed*

Project Name		Boring Number										
AMEREN - LITCHFIELD M&P		TEST BORING #1										
Project Number		Page										
101498		2 of 4										
Date		PID (spans) ppb										
2/22/2018												
Depth (feet)	Description	Class	Blow Count	Sample Number and Type	Length Att. & Recovered (in)	Blow Counts	Depth in Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	FID
15	CLAY, trace silt 10YR 4/5 brown, very moist, very stiff, highly plastic no odor (shaly clay)	CH	4				0.0	0.0 - 0.9' GRAVEL: angular up to 1/2", mostly 1/4", some very coarse sand, little silt, loose, moist, no odor, very pale brown (10YR 7/4)	GW			235
16	CLAY 10YR 4/1 light brownish grey, some silt, very soft, moist, shaly, plastic, no odor, trace brownish yellow silt from angular to sub rounded rock fragments from 1 cm - 2 cm	CH	4				1.0	0.9 - 1.4' FILL: slag, vesicular, little coarse sand, loose, moist, no odor, black (10YR 2/1)	FILL	x x x x		
17	becomes 3/3 dark brown						2.0	1.4 - 2.7' CLAY: some silt, trace very fine sand, trace 1/8-1/4" slag pieces, low plasticity, very stiff (HP=3-3.5), moist, slight odor, orange mottling, very dark brown (10YR 2/2)	CL			
18	CLAY SAND 10YR 5/6 yellowish brown, soft, moist, fine plastic, wet no odor, trace fine gravel	SC	4				3.0	2.7 - 3.6' SAND: very fine to fine, trace gravel up to 1/2", subround, trace silt, loose, moist, no odor, brown (10YR 5/3)	SW			425
19	SAND 10YR 5/6 yellowish brown, wet, naturally well sorted, loose, fine, and grainy, some angular to rounded gravel	SM	4				4.0	3.6 - 5.0' CLAY: some silt, trace very fine sand, trace gravel up to 1/2", angular, low plasticity, moist, slight odor, black mottling from 2.3-2.8", dark yellowish brown (10YR 4/4)	CL			
20	SAND 10YR 5/6 light brownish grey, wet medium gravel with fine gravel	GC	4				5.0	5.0 - 8.4' CLAY: little silt, trace very fine sand, very stiff (HP=3), medium plasticity, moist, no odor, orange and grey mottling, dark yellowish brown (10YR 4/4)	CL			38.78
21	SAND 5Y 6/1 grey, wet, medium coarse, some silt and gravel, trace clay, no odor					38.4	6.0					
22							7.0					57.22
23	CLAY 5Y 6/1 grey, wet, medium coarse, some silt and gravel, trace clay, no odor						8.0					
24	CLAY 4/1 dark grey, moist, hard, high plasticity, some silt, trace gravel, no odor, massive bedding	ML	4				9.0					62.19
25							10.0					
26												
27												
28	becomes hard											
29	CLAY 4/1 dark grey, moist, hard, high plasticity, some silt, trace gravel, no odor, massive bedding	CH	4									
30												
31												
32						52.8						
								8.4 - 9.4' SAND: very fine to fine, trace silt, trace gravel up to 1", mostly 1/4", subangular to subround, loose, poorly sorted, moist, no odor, yellowish brown (10YR 5/6)	SW			
								9.4 - 10.0' CLAY: some silt, trace very fine sand, stiff (HP=1-1.5), low plasticity, moist, no odor, yellowish brown (10YR 5/4)	CL			
									SW			

- Inconsistent data capture
 - Often missing critical data for geologic interpretation
- Long logging times (or incomplete logs)
- Loss of data for thin intervals
- Text format inhibits comparison with HRSC data & real time decision making
- Digitization is inefficient

Geologic data/insight are never fully utilized

Graphical Approaches to Logging

Promote High-Quality Data Capture

An Example Form

- Introduced in ~2017
- ### A step in the right direction:

- Lots of data cues
- High-quality data
- Captured nature of contacts

Drawbacks:

- Form was intimidating
- Difficult to make “report ready”
- Still relies on some paragraph-style input

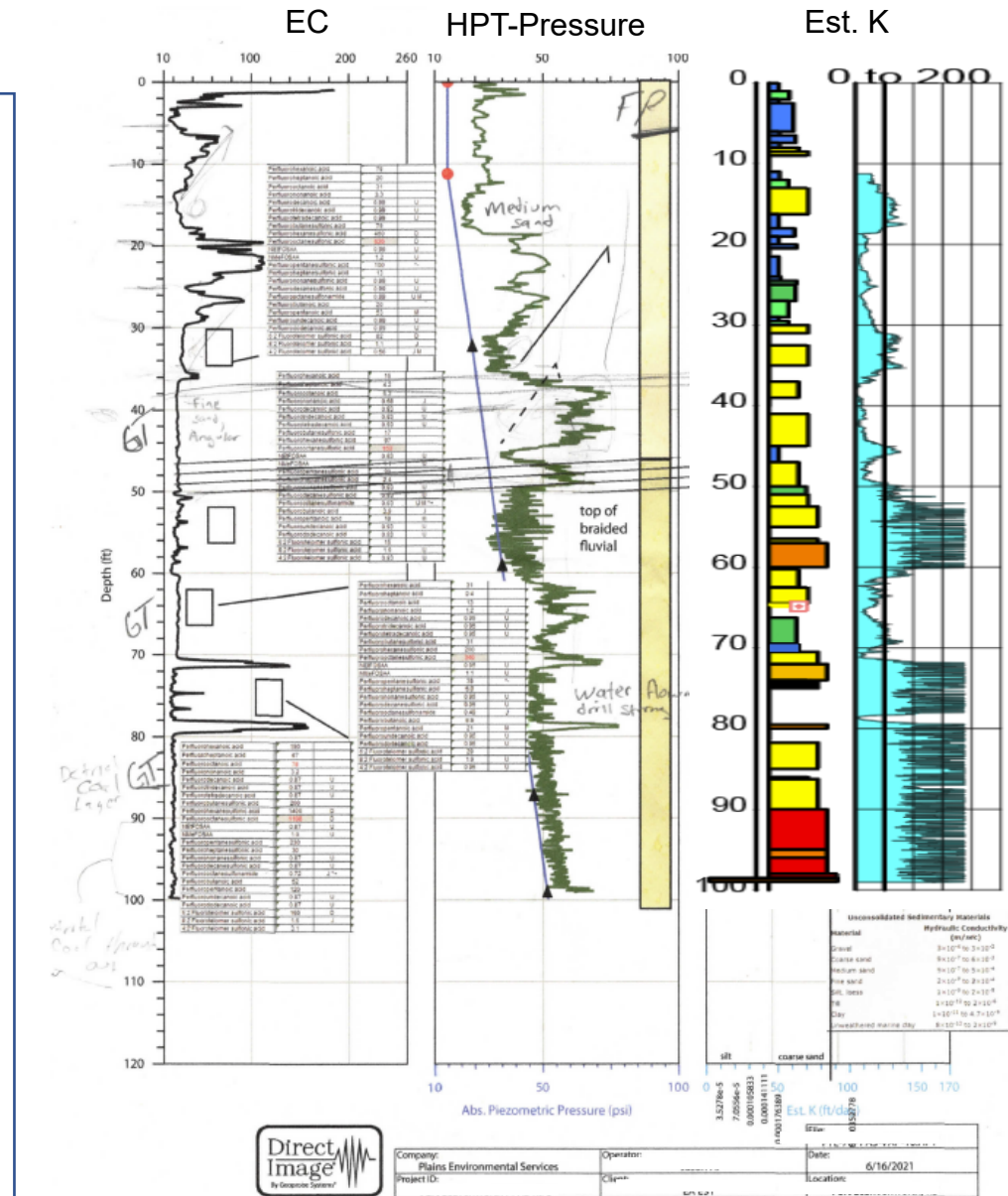
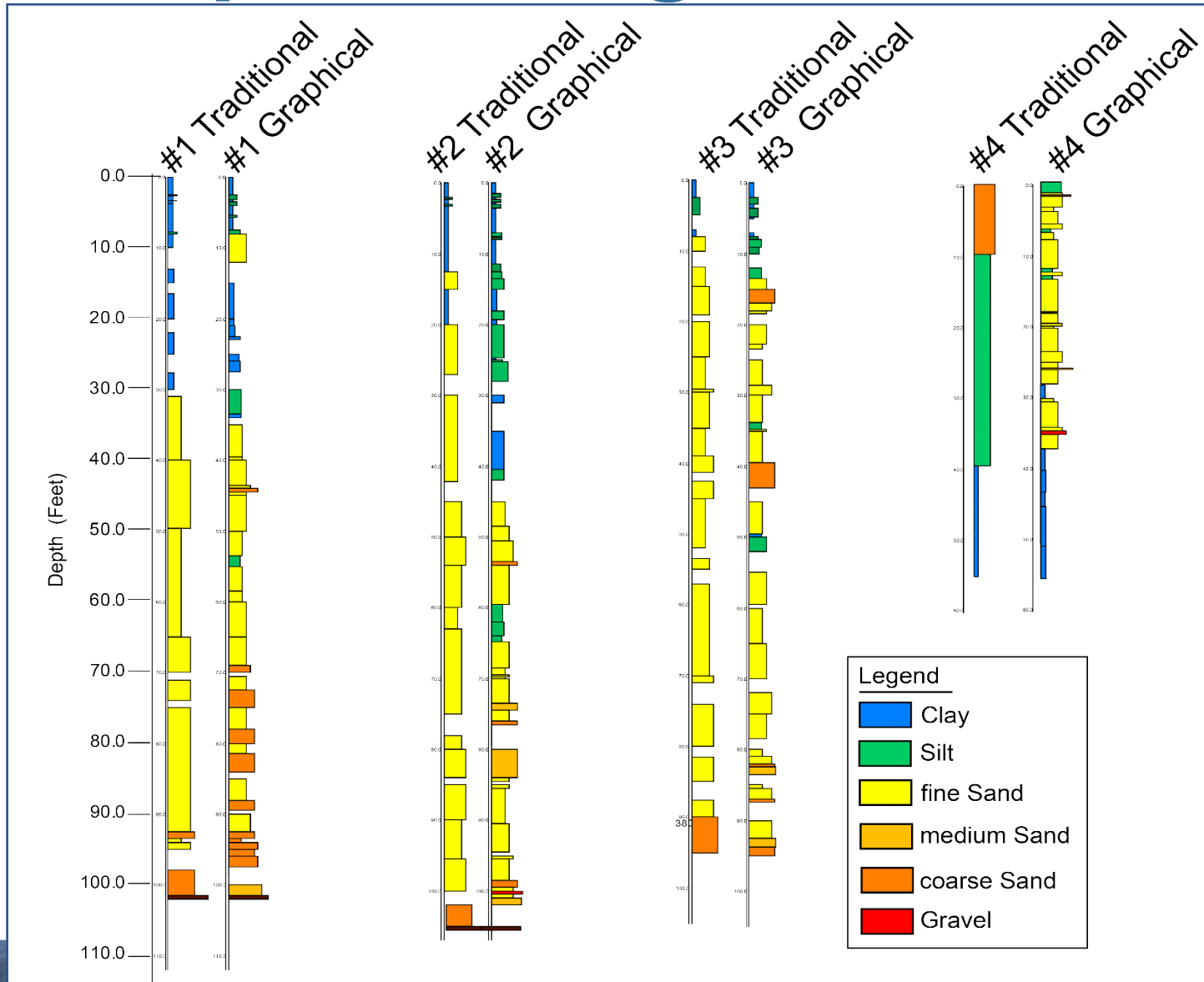
Drilling Progress												Geologic Description														Strat Log Sketch	Comments	Log of Exploratory Boring																	
Depth	Time	FIDPID at surface casing (gpm)	Penetration rate/ drilling observations	Rig Motion	Sample recovery, type	Sample Interval	Munsell Color Code	% Clay	% Silt	Plasticity of fines	% Fine Sand	% Medium Sand	% Coarse Sand	Roundness of Sand	% Fine Gravel	% Coarse Gravel	Roundness of Gravel	Degree of sorting	Sand Composition	Calcium / HCl reaction	Mineral staining/Redox	USCS Code (if required)	LIMESTONES <small>mi, ve, mt, gh, ml, ls</small>														Texture Grain size and other notes (structures, palaeocuments, fossils, color)	Notes	Well No.	Page of					
1					95% recovery (vibracore)						60	40		R				W	2																				Massive, fine to medium sand sparse bioturbation	Switch Bar, or Beach Face (sands sorted by wave energy)					
											50	50		R				1																											
												40	60		R																														
												10	50	40	R					2	Q, D																								
2					% recovery (vibracore)						20	50	30					MW	2	Q, D																			sparse bioturbation grainsize grades to medium/coarse						
											10	40	50	SR					1																										
												95	5	H																											sharp contact clay, massive irregular contact bioturbation and flaser bedding	Sheltered Tidal Flat, (possible flood-tidal flat)			
										20	10	L	10	60				2	Q, D																										
										30	30	40																																	
3					% recovery (vibracore)						20	10	L	10	60				2	Q, D																			potentially cross bedded here sparse flasers irregular contact						
											50	40	L	10						2	Q, D																								
4											10	10	80						1	Q, D																			Lenticular sands in silty clay matrix, possible bioturbation medium sand						

Geologic Description																						Strat Log Sketch														Texture			
% Clay	% Silt	Plasticity of fines	% Fine Sand	% Medium Sand	% Coarse Sand	Roundness of Sand	% Fine Gravel	% Coarse Gravel	Roundness of Gravel	Degree of sorting	Sand Composition	Calcium / HCl reaction	Mineral staining/Redox	USCS Code (if required)	LIMESTONES <small>mi, ve, mt, gh, ml, ls</small>														Texture Grain size and other notes (structures, palaeocuments, fossils, color)										

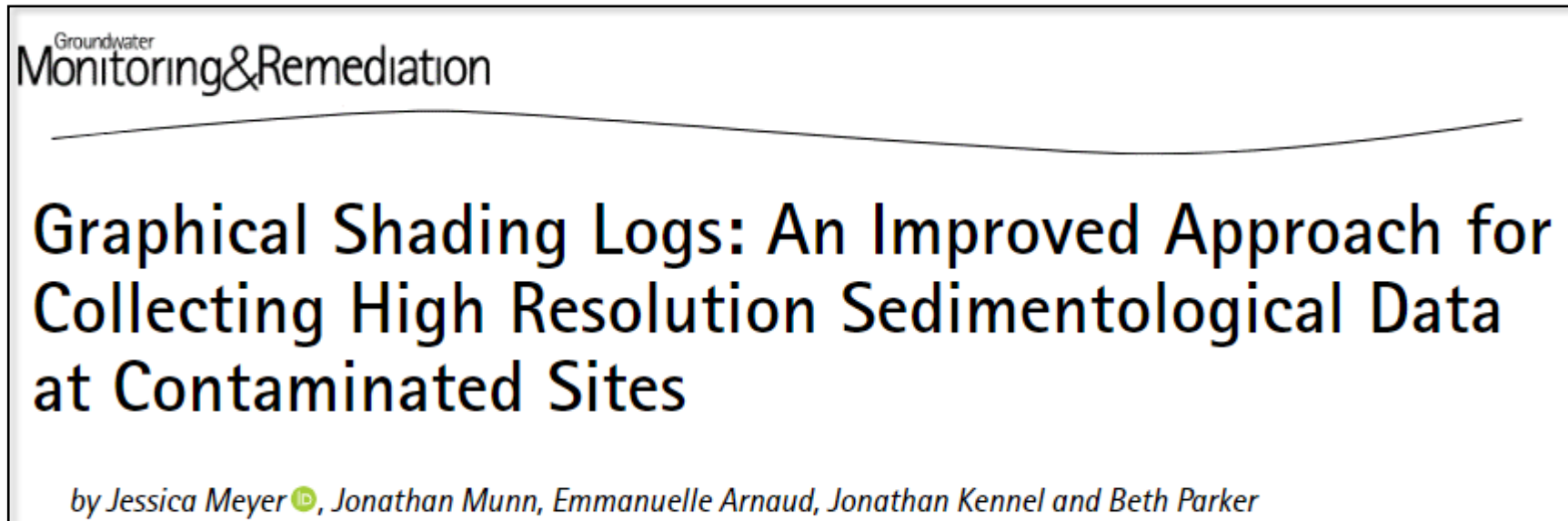
Date		F/Min or F/Hr	Smooth, Coarse, Heavy, Chatter, Loss of Circulation	Gas, Discrete					Max. High, Med. Low	0.0025" to 0.017" No 40-200	0.017" to 0.075" No 10-40	0.075" to 0.15" No 4-10	U.S.A. 5A, 5R, 1, R, VR	0.15" to 0.25" 20mm to No. 4	0.25" to 3"	U.S.A. 5A, 5R, 1, R, VR	0.1, 2, 3, 4	No. High, Quartz, Feldspar, Dark matrix	None, Slight, High	Yellow, Orange, Red, Gray, Black																
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Client:	Coasta
Project No.:	
Site:	
Surface geologic unit:	
Logged by:	
Drilling Co.:	
Driller:	
Drilling Method:	
Drill Rig Model:	

Graphical Logs in Use














Published Approach to be Further Developed in 2023-2025 Time Frame



GWMR, 2022, <https://doi.org/10.1111/gwmr.12521>

Graphical Shading Logs Provide a Next Step Solution

Run #	Dist from Top of Run ft	Major Lith	Secondary Material			Munsell Color	Grain Size							Sorting					Param. 1	Param. ...	Param. n	Graphics	Comments													
			Clayey	Silty	Sandy		Clay	Silt	Very Fine	Fine	Medium	Coarse	Very Coarse	Very Poor	Poor	Moderate	Well	Very Well																		
5						10R 6/2																														
	0.5					10R 6/2																														
							10R 4/6																													
	1.0					10YR 7/4 5RP 2/2																							purple staining in parallel stairstep shapes; soft sed. deformation???							

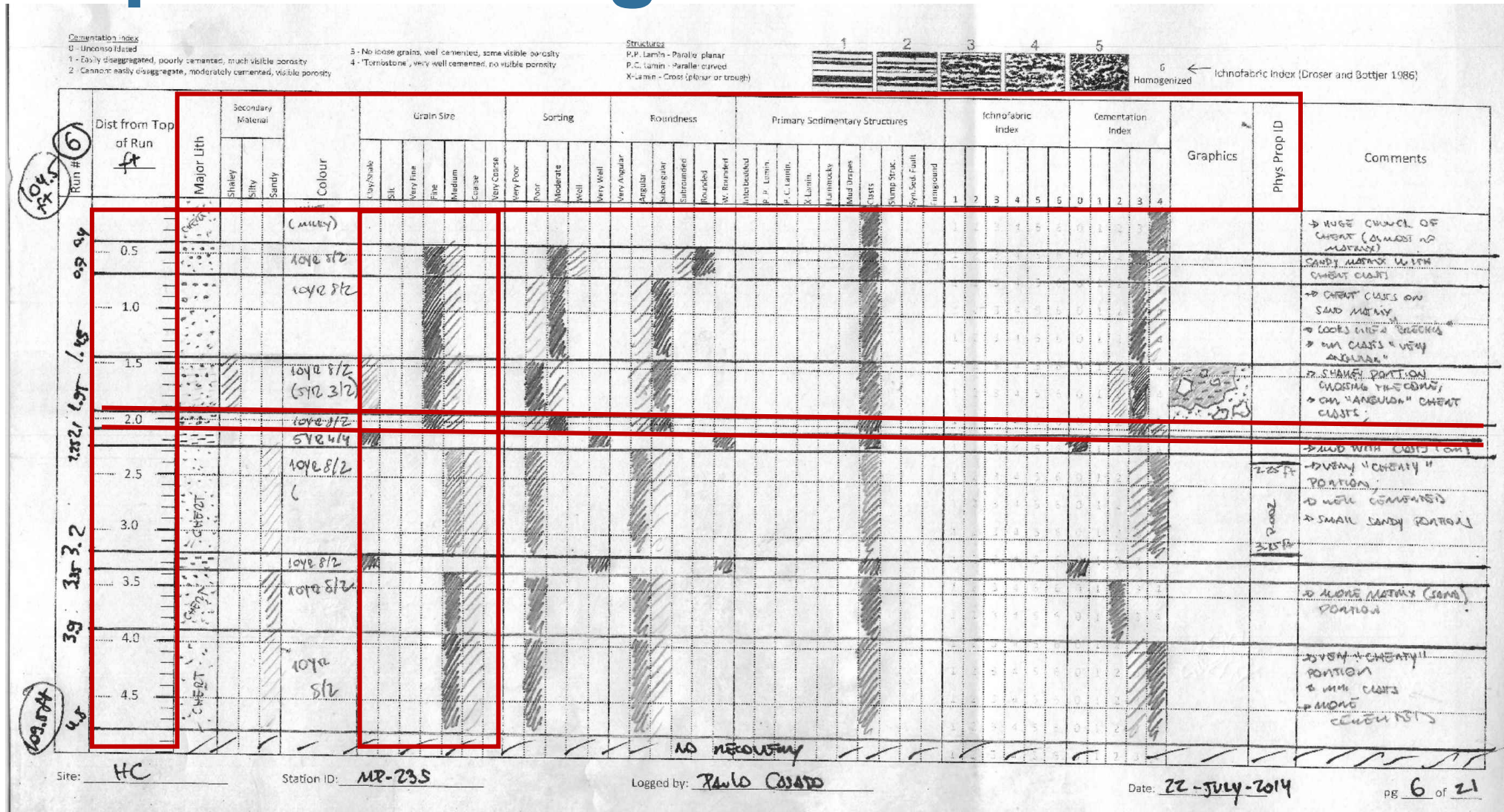
Site: Some Site

Station ID: BH-1

Logged by: Person 1

pg 5 of 10

Example Field Log



Easy Digitization, Storage, Retrieval and Presentation of Geologic Data

Depth ft bgs	Run #	Corect (ft)	Recovered (ft)	RQD (%) Very Poor Poor Fair Good Excellent	Dominant Grain Size/Lith/Color								Secondary Material	Grain Size Range								Sorting				Rounding				Cementation Index				Ichnofabric Index				Laminae	Structures	Minerals	Comments																						
					Clastic									Coarse								Fine				Very Poor				Poor				Moderate								Well				Very Well				Very Angular				Angular				Subangular				Subrounded	
					Clay	Silt	VF Sand	F Sand	M Sand	C Sand	VC Sand	Granule	Clay	Silt	VF Sand	F Sand	M Sand	C Sand	VC Sand	Granule	Clay	Silt	VF Sand	F Sand	M Sand	C Sand	VC Sand	Granule	Very Poor	Poor	Moderate	Well	Very Well	Very Angular	Angular	Subangular	Subrounded	Rounded	Well Rounded	0	1	2	3	4	1	2	3	4	5														
106.0	6	5	4.80	25																																															huge chunks of chert (almost no matrix) -sandy matrix with chert clasts "chert clasts on sand matrix; -looks like a "brechia"; - cm clasts, very angular;" "shalley portion crossing the core; - cm "angular" chert clasts;" -mud with clasts (cm) "very "cherty" portion; -well cemented; -small sandy portions" more matrix (sand) portions very cherty portion; -mm clasts; -more cemented "still readtown; -very dense chert clasts portion within a sandy matrix; -cm "angular" chert clasts"												
110.0																																																															

Graphical Shading Logs Provide a Solution

- Easily Learned
- Serves as a road map to guide loggers and ensure consistent collection of *all* important geologic parameters
- Facilitates efficient collection of geologic data
- Visual log immediately useful to support real-time decision making
- Data is amenable to quantitative analysis
- Is more efficient to digitize and/or make report ready

Geologic data can be used to its full potential

Proposal Number: *NA23-B1-7659*

Delivering a More Accurate, Representative, and Useful Geologic Log to the ESTCP Remediation Community

Task 1

Developing Revised Forms, Reference Sheets & Open Access Tutorial for Graphical Shading Logs; Content To Support Working Professionals

Task 2

Developing a Core Logging Laboratory Activity for Post-Secondary Courses;
Case Study Demonstration of Improved Remediation out comes

Task 3


Technology Transfer Assessment

Learn

- Home
- Announcements
- Discussions
- Files
- Quizzes
- Collaborations
- BigBlueButton
- Modules
- Rubrics
- Outcomes
- Syllabus
- Pages
- People
- Grades
- Assignments
- Settings

Welcome

Advances in Geologic Logging and Data Management Methods for Groundwater Remediation Investigations



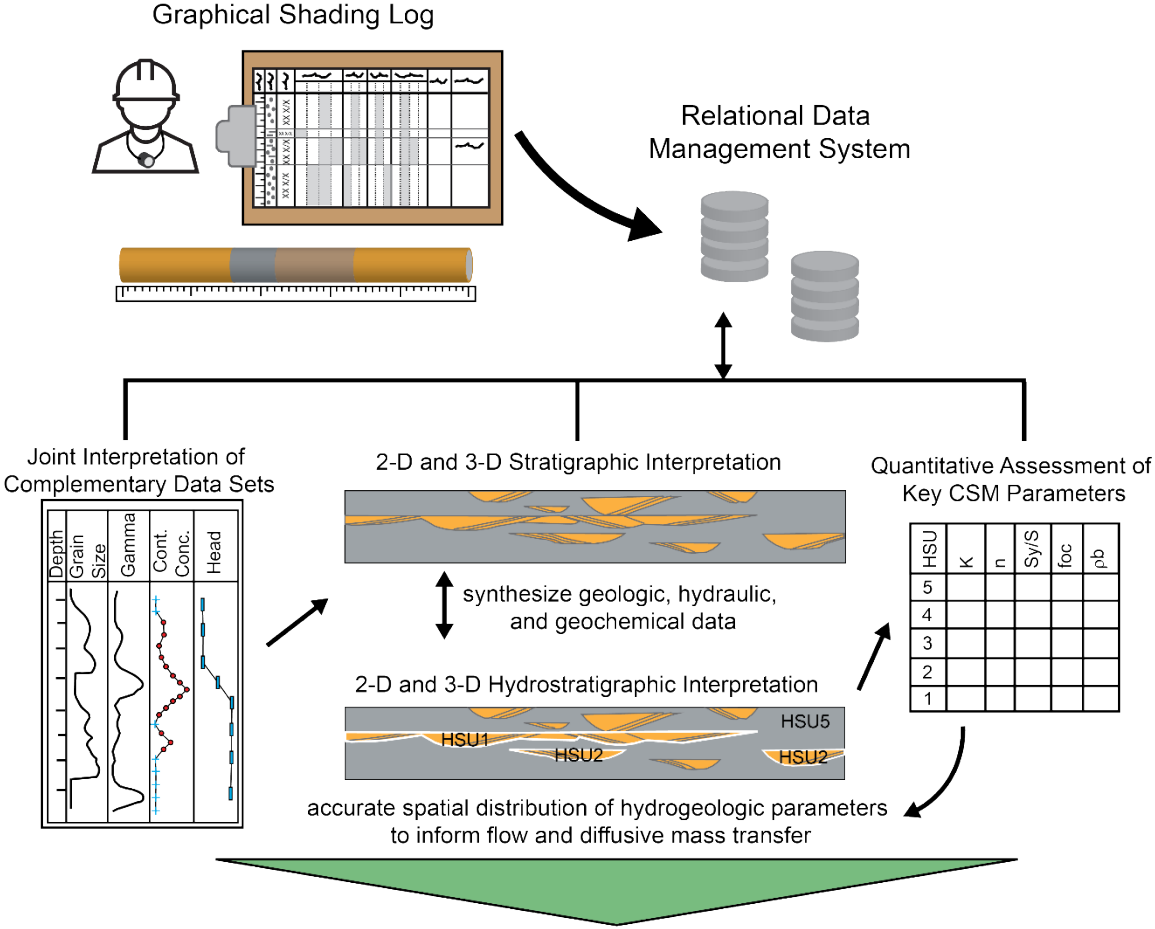
- The Problem Paragraph Logs
- A Solution Graphical Shading Logs
- Core Logging Demo
- Managing Geologic Data
- Graphical Logs and ESS to Generate Realistic Geologic Models
- Graphical Logs and REMChlor-MD to Assess Diffusion
- Graphical Shading Log and Database Templates



Industry conference demonstrations/panel discussions, social media, ESTCP flyer, Wikipedia article, explanation video



Graphical Geologic Logging: The Foundation for An Efficient CSM Workflow



Accurate CSMs to Drive Remediation Success

Thank you

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The Geologic Log: Your Link To Reality

Higher Efficiency Remediation Systems and Successful Site Closure Strategies

Geologically Focused Conceptual Site Models

Effective Data Capture and Efficient Database Construction

Core Logging and Lithological Characterization

Real Subsurface Heterogeneity: A Root Cause of Uncertainty