The National Academies of
SCIENCES · ENGINEERING · MEDICINE

TRANSPORTATION RESEARCH BOARD

Rock On - The Impacts of the Mischaracterization of Rock

February 3, 2021

@NASEMTRB
#TRBwebinar

PDH Certification Information:

- 1.5 Professional Development Hour (PDH) – see follow-up email for instructions
- You must attend the entire webinar to be eligible to receive PDH credits
- Questions? Contact Reggie Gillum at RGillum@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

#TRBwebinar

Learning Objectives

1. Identify risks related to soil and rock identification

2. Identify how to alleviate these risks

#TRBwebinar

Is It Soil or Is It Rock? How Project Outcomes Depend on the Properties and Word Choices

Technical Webinar

Impact of the Mischaracterization of Rock (on Construction Projects)

Wednesday, 3 February 2021, 1:00 to 2:30

Robert Bachus – Geosyntec Consultants

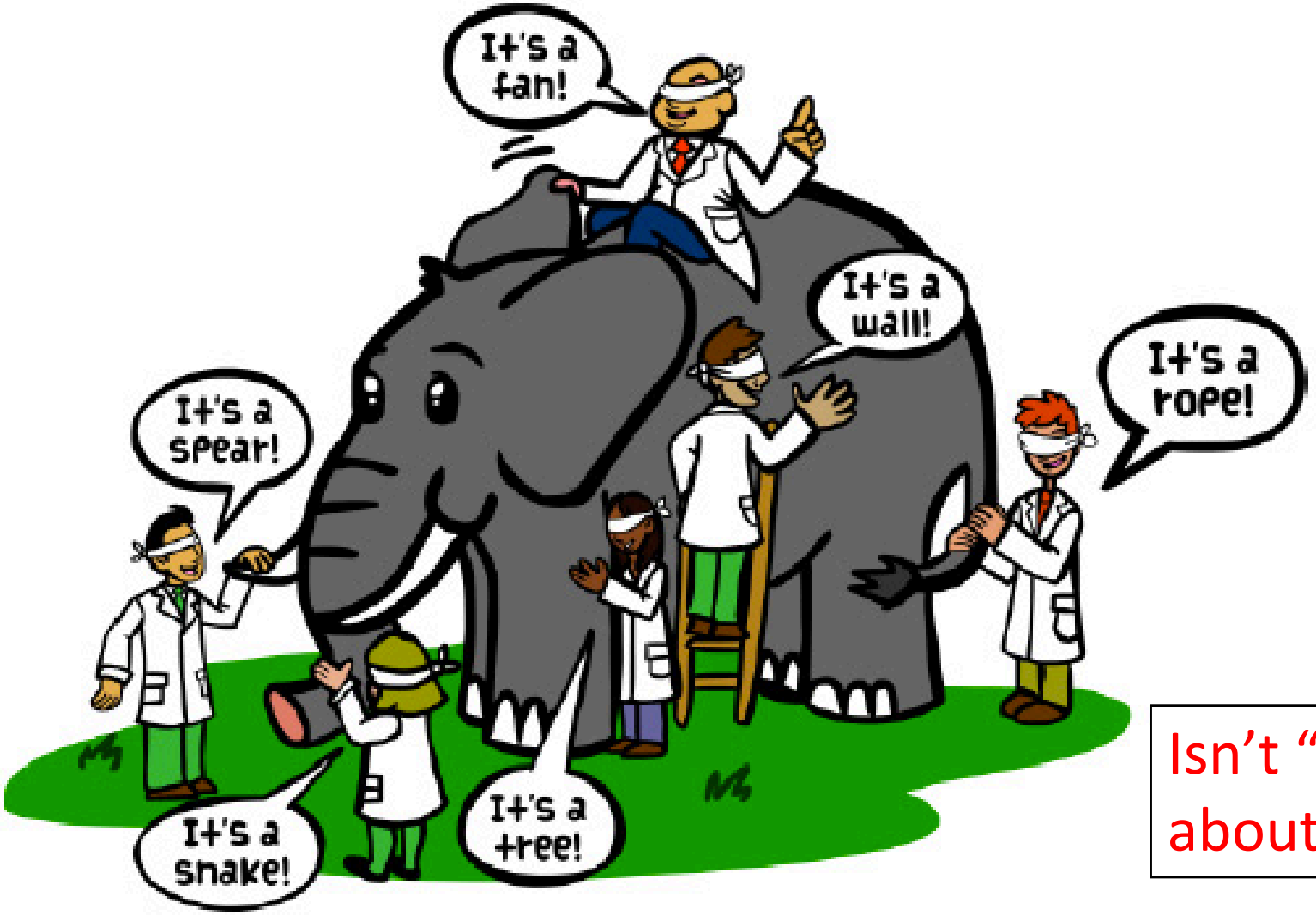
Is It Soil or Is It Rock?

- Rock: Rock is a relatively hard, naturally formed solid mass consisting of various minerals and whose formation is due to any number of physical and chemical processes. The rock mass is generally so large and so hard that relatively great effort (e.g., blasting or heavy crushing forces) is required to break it down into smaller particles.
- Soil: Soil is defined as a conglomeration consisting of a wide range of relatively smaller particles derived from a parent rock through mechanical weathering processes that include air and/or water abrasion, freeze/thaw cycles, temperature changes, plant and animal activity, and chemical weathering processes that include oxidation and carbonation.

(after FHWA, 2006)

Why is it Easy to Mischaracterize?
Why this Webinar?

Let’s Pick Something Easy to Characterize…



Isn’t “characterization” all about your perspective?

https://tekrighter.wordpress.com/2014/03/13/metabolomics-elephants-and-blind-men/

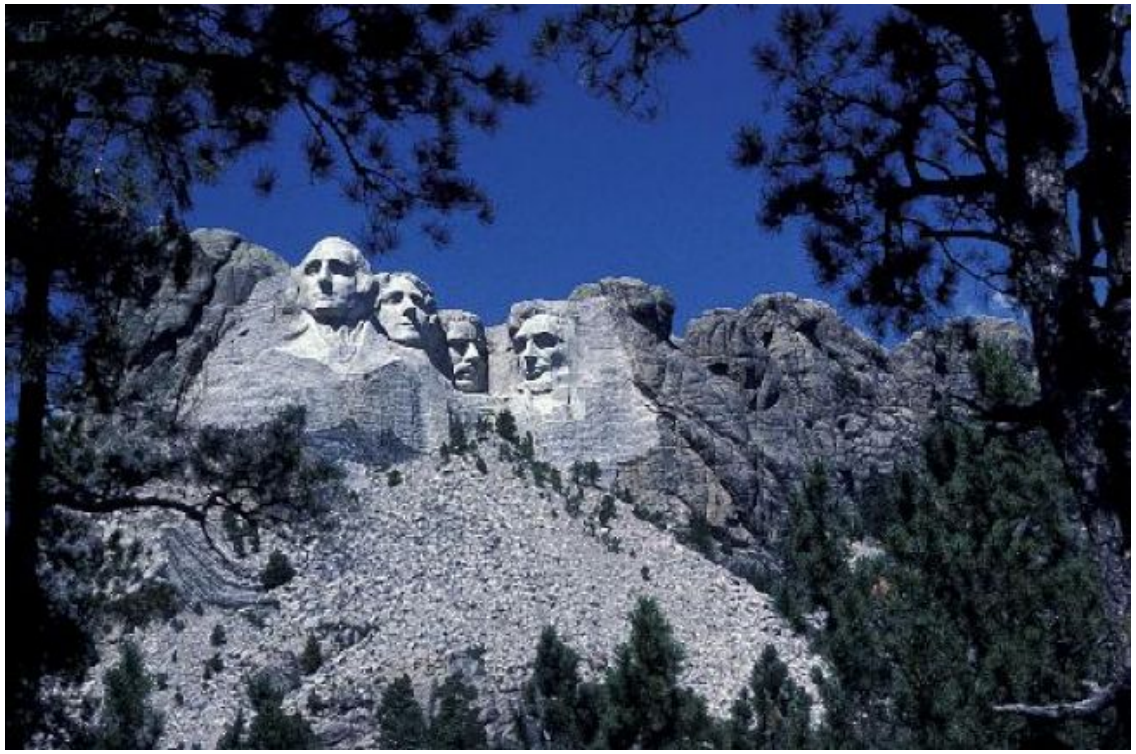
Is It Soil or Is It Rock…. What is Your Perspective?

- Geologist
- Excavation Contractor
- Foundation Contractor
- Tunneller
- Construction Manager
- Mining/Miner
- Quarry
- Engineer

Who Wants to Know?

Geologist

https://www.thoughtco.com/sedimentary-rock-classification-diagrams-4123127



https://www.americangeosciences.org/education/k5geosource/content/rocks/what-are-igneous-rocks

Rock Description:
Limestone, light gray, very fine-grained, thinly bedded, unweathered, strong

Rock Type
Color
Grain Size and Shape
Texture

Mineral Composition
Weathering/Alteration
Strength
Strike/Dip

Excavation Contractor

https://www.britannica.com/technology/blasting

https://www.911metallurgist.com/blog/rock-blasting

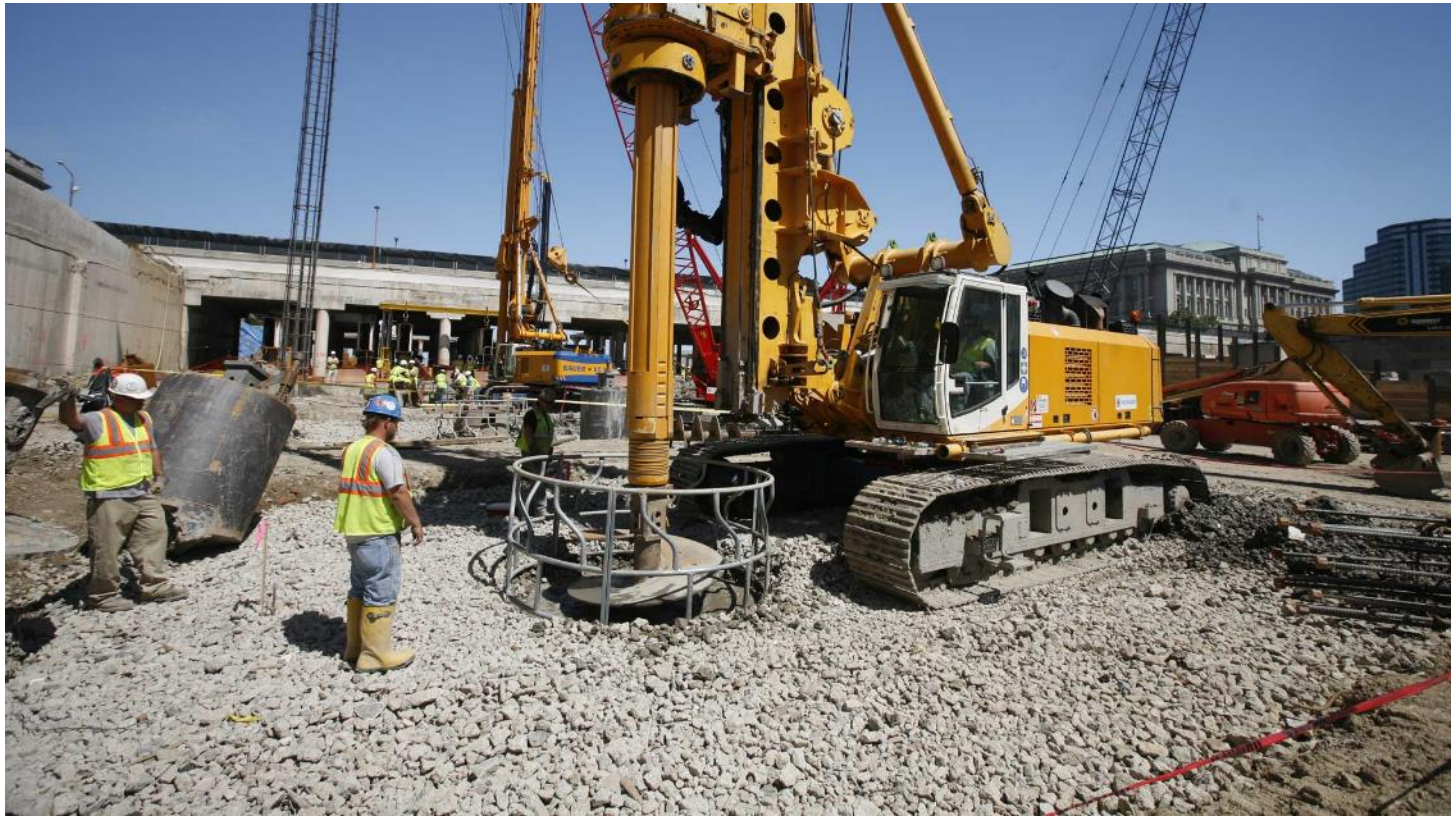
https://www.youtube.com/watch?v=cKwkr3Ed14g

Tensile Strength
Joint spacing
Hardness

https://rockworkinc.com/blasting/

Foundation Contractor

https://www.morrisshea.com/portfolio-item/drilled-shaft_caisson/

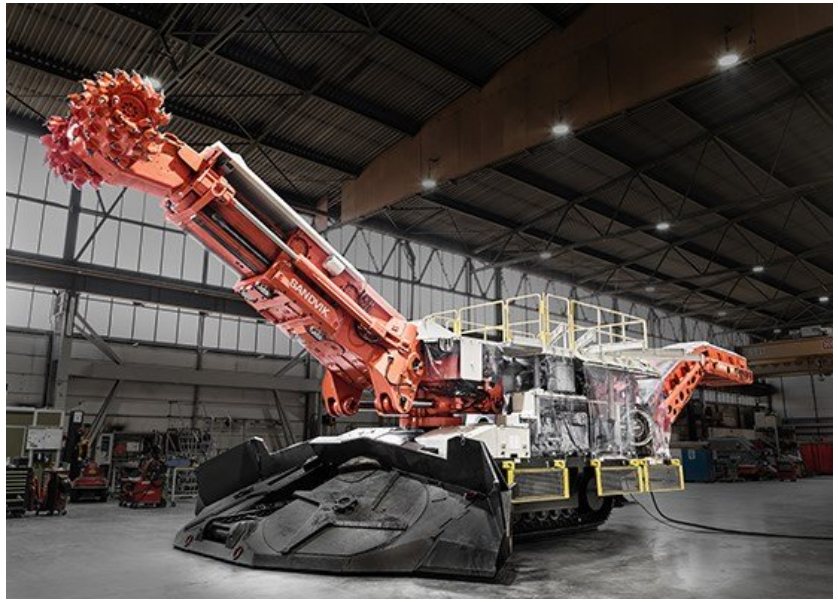


https://www.nicholsonconstruction.com/geotechnical-solutions/deep-foundations/drilled-shafts

Tensile Strength
Discontinuities
Harness
Stratigraphy
Degradation
Water

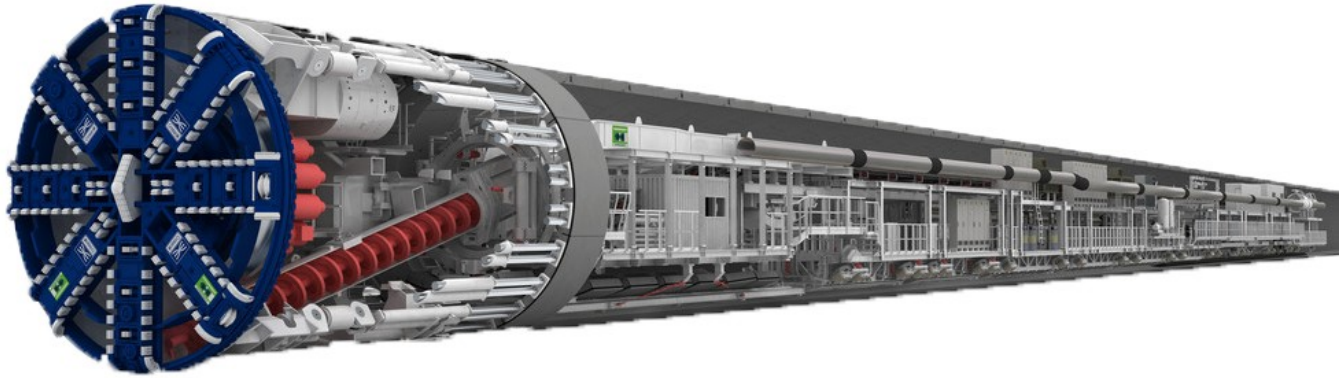
Tunneller

https://www.autostemtechnology.com/autostem-tunneling/



https://www.rocktechnology.sandvik/en/products/mechanical-cutting-equipment/roadheaders-for-tunneling/

Discontinuities
Continuity of Face
Strength
Hardness
Processing



http://www.crossrail.co.uk/construction/tunnelling/meet-our-giant-tunnelling-machines/

Mining/Miner

https://en.wikipedia.org/wiki/Mining

Quality/Purity
Overburden
Stability
Handling
Water

https://3d-p.com/performance-of-lte-in-mining-in-2019-what-to-expect/

https://www.newsbtc.com/2016/07/21/bitcoin-miners-in-washington-state-to-pay-more-for-electricity/

Quarry

https://waypoint.sensefly.com/quarry-survey-drone/

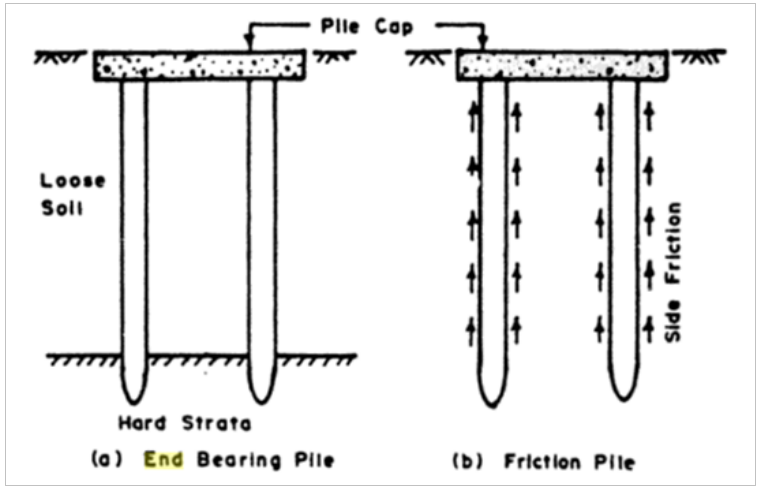
https://en.wikipedia.org/wiki/Statham%27s_Quarry

https://bhamnow.com/2018/12/03/vulcan-materials-company-food-drive/

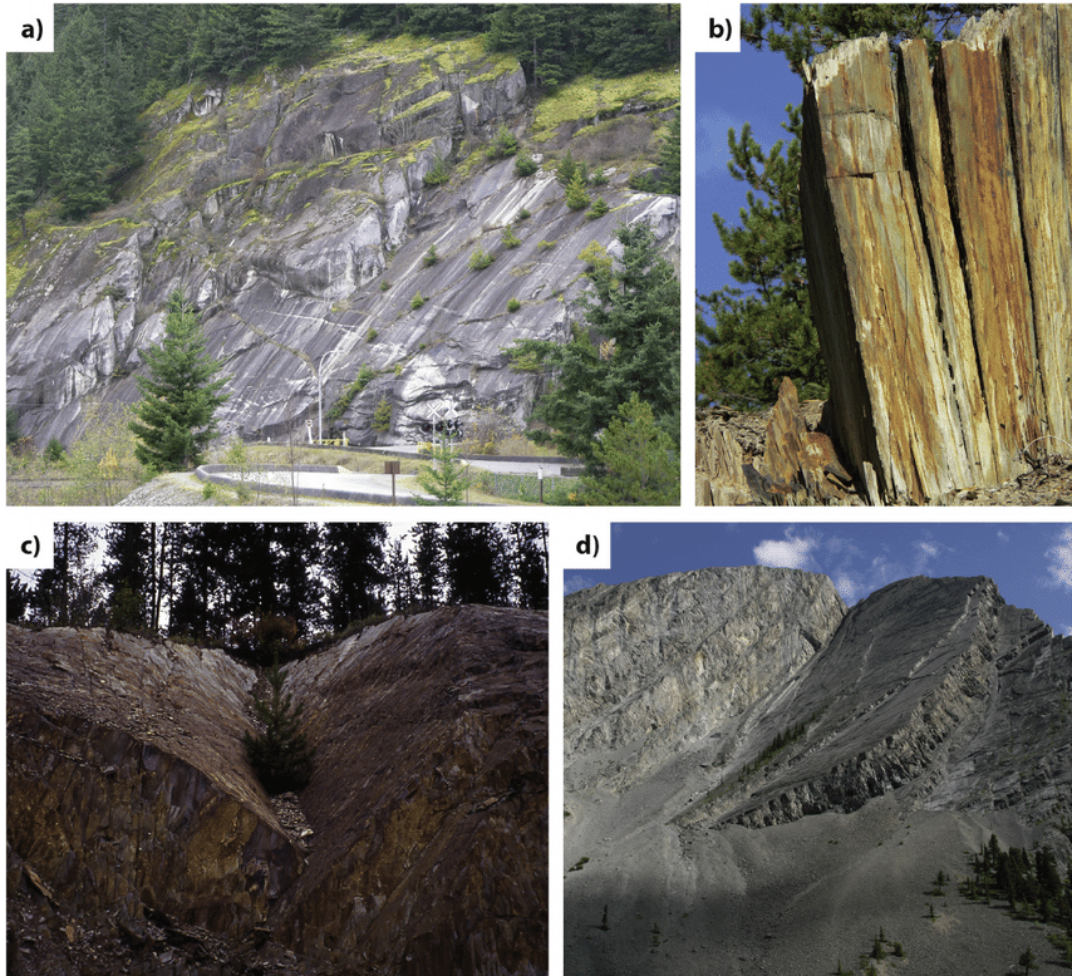
Quality
Consistency
Hardness
Stability
Water
Operations

Engineer

https://civildigital.com/failure-modes-in-rock-and-soil-slopes-slope-failure/



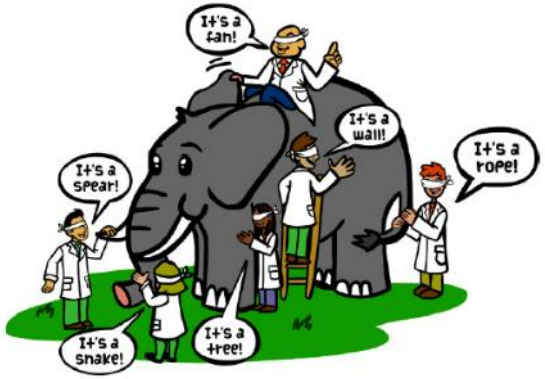
https://www.iamcivilengineer.com/difference-between-end-bearing-piles/



https://www.researchgate.net/figure/Key-rock-failure-modes-considered-in-slope-stability-analysis-a-planar-translational_fig1_259330495

Hopefully, conscious of all of the factors presented previously

Is It Rock or Is It Soil?



How Project Outcomes Depend on the Properties and Word Choices

- Rock means different thing to different people/organizations
- It would be easy to mischaracterize rock…"good" vs. "bad"???
- The challenge is to understand the context and perspective of the user
- The goal is to properly convey the characterization to each user

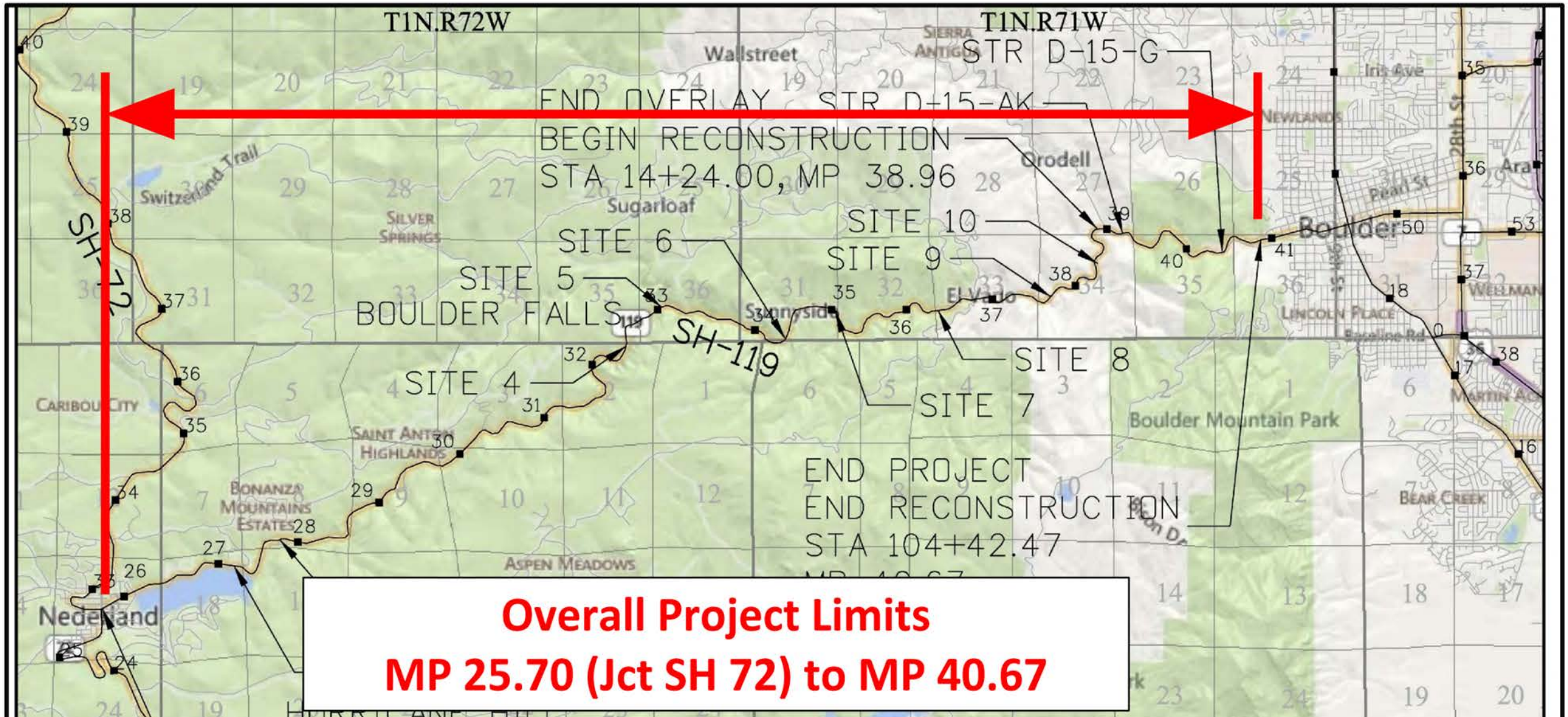
Rock Excavation: Current State of Practice and Potential Improvements to Reduce Risk

Learning Objectives:

1. Identify risk sources related to rock mischaracterization
   - Alignment/constructability
   - Geologic/geotechnical characterization and design
   - Construction means and methods
   - Project complexity and communication
2. Identify tools for minimizing or mitigating sources of risk

Case History: Roadway widening and improvements in mountain corridor

Project Limits: 15 Miles of Improvements – 5 Rock Cuts

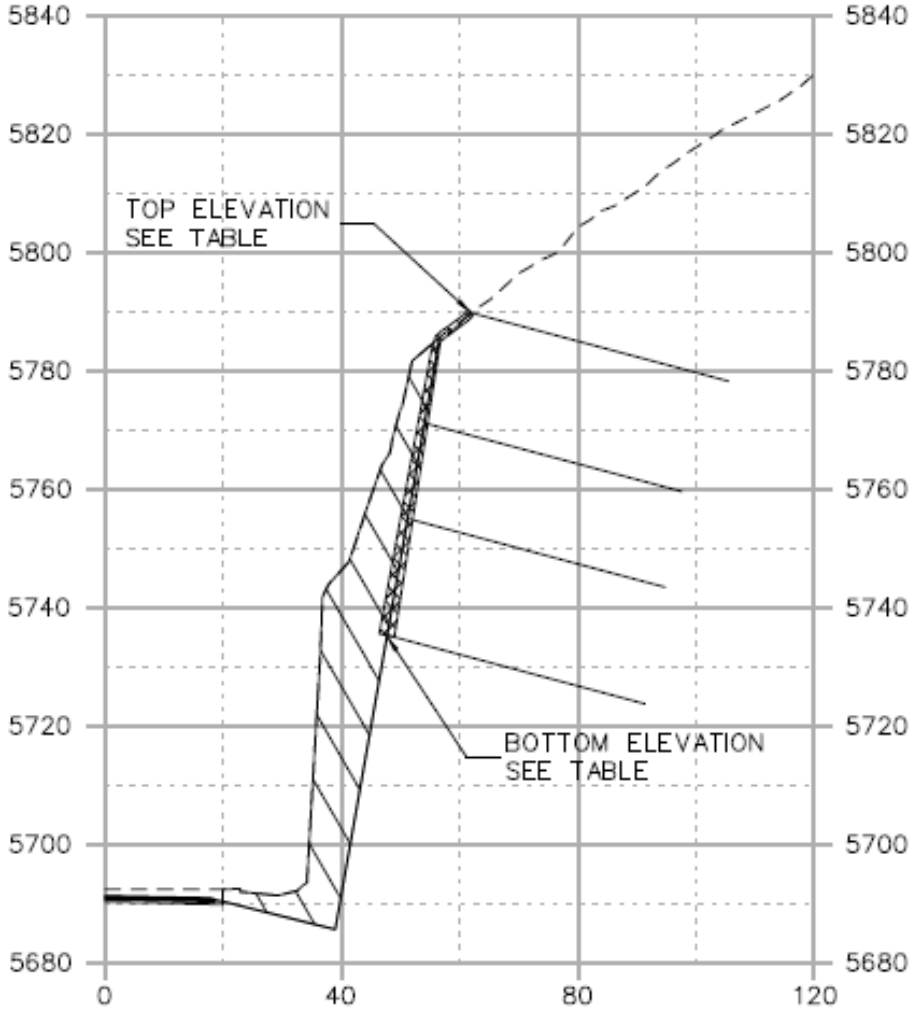


Project Scope

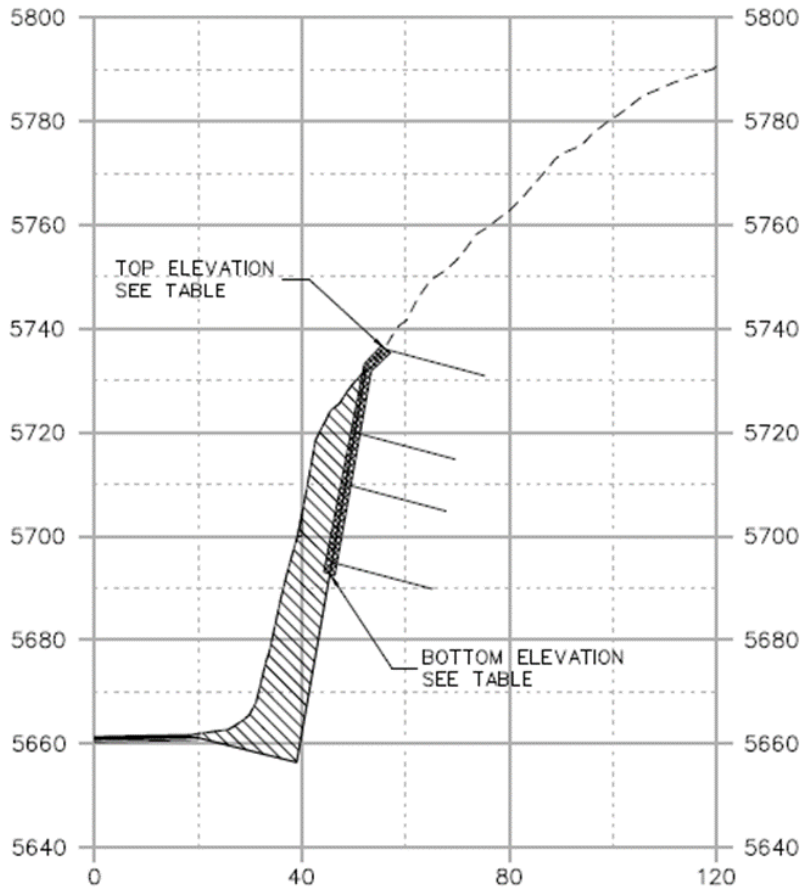
Project # 20258 Key Work Elements

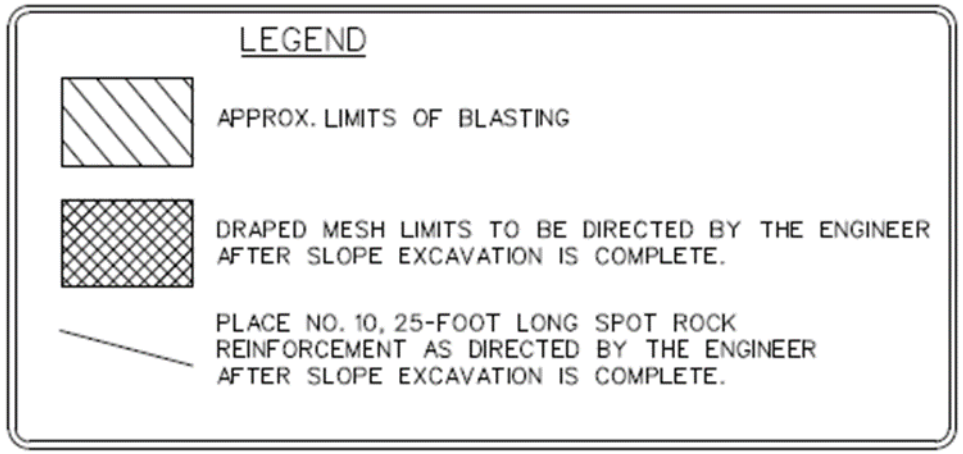
- Reconstruction – MP 38.96 (Fourmile Canyon Drive) To MP 40.67
  - Full depth pavement reconstruction
  - Shoulder widening
  - Rock excavation, rock scaling, rock reinforcement & draped wire mesh installation
  - Water control / dewatering
  - Bridge repairs, scour mitigation (Structure D-15-AK, d_{50}=36” rock obtained from embankment repairs at Site 5, MP 39.6, and MP 40.1)
  - Embankment repairs, scour mitigation
  - Pedestrian box culvert extension and wingwalls
  - Stacked rock walls
  - Soil nail wall
  - Trail reconstruction
  - Cross culvert replacement / cleaning
  - Type C and D Inlets
  - Guardrail / barrier replacement
  - Temporary traffic signals – 4 areas

Rock Excavation Cross-sections: Alignment and Constructability



Rock Excavation Cross-sections: Site Characterization and Design





Construction: Means and Methods

Construction: Means and Methods

Construction

Boulder Canyon closed up to 3 days

Blasting brought down 8,000 cubic feet of rock on Wednesday

By Charlie Brennan
and Kelsey Hammon
Staff Writers

A massive rockslide that brought down 20 times more rock than expected during scheduled blasting Wednesday has prompted a two- to possibly three-day closure of Boulder Canyon Drive, according to Colorado Department of Transportation officials.

Initially, CDOT officials on Wednesday afternoon predicted the highway would be closed for at least 24 hours. By evening, they said a multiple-day closure was necessary to clear fallen rock.

Wednesday's scheduled blast sent 8,000 cubic yards of rockfall crashing down the side of the mountain and onto the

Courtesy photo / Colorado Department of Transportation
A rockslide in Boulder Canyon on Wednesday has closed Colo. 119 until further notice.

Construction

Current State of Practice: Risk Sources

Alignment

- Drives initial excavation layout and volumes
- Constructability not always thoroughly considered

Site characterization and design

- Investigation – funding, scope, execution
- Plans & specs - accuracy, consistency, clarity

Construction means/methods and contract administration

- Balancing expectations, flexibility, authority, and risk ownership between contractor and owner

Project complexity and communication

- Conveying geologic knowledge, risk considerations, and consequences to project staff at all phases and in all disciplines is a challenge

Areas for Improvement: Risk Mitigation Tools

Alignment

- Early involvement of geotechnical staff
  - Clarify project needs vs. geotechnical needs
  - Set realistic expectations for time and budget
  - Identify/mitigate potential high risk areas before they are baked into the design
- Value engineering workshops

Areas for Improvement: Risk Mitigation Tools

Site characterization and design

- Investigation
- Plans & specs – accuracy, consistency, clarity
  - Inconsistent or conflicting plans and specifications are a common source of problems
  - Specify and enforce experience requirements for complex projects
  - Photos in plan sets to illustrate areas of concern
  - If plans include risk mitigation elements, be sure specs give project manager clear authority to implement them

Areas for Improvement: Risk Mitigation Tools

Construction means/methods and contract administration

- Pre-bid and pre-construction meetings to convey specific areas of concern to contractors
- Consider performance requirements vs. prescriptive requirements
- Contractor risk vs. owner risk

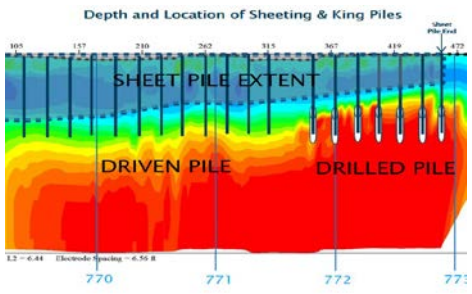
Areas for Improvement: Risk Mitigation Tools

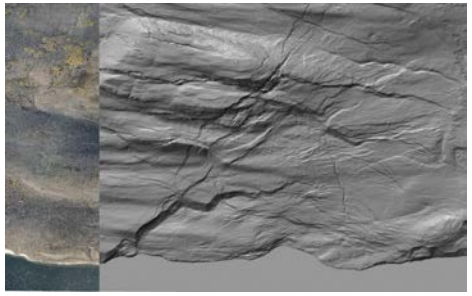
Project complexity and communication

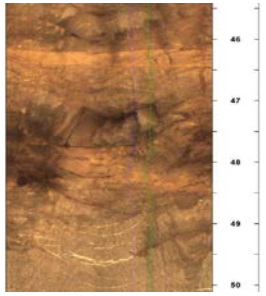
- Conveying geologic knowledge, risk considerations, and consequences to project staff through all phases and in all disciplines is a challenge
  - Make sure geotech isn't an afterthought until problems arise
- Risk identification and ownership discussion with decision makers
- Specify check-in points and parties for critical geotechnical issues
  - Assume no one has read the geotechnical report
  - Design to construction management hand-off for owner/agency
  - Include both prime and sub-contractors at check-ins
- Risk mitigation tools are important and helpful but only if project personnel are aware of and know how to use them

Center for Accelerating Innovation

On-Ramp to Innovation
every day counts





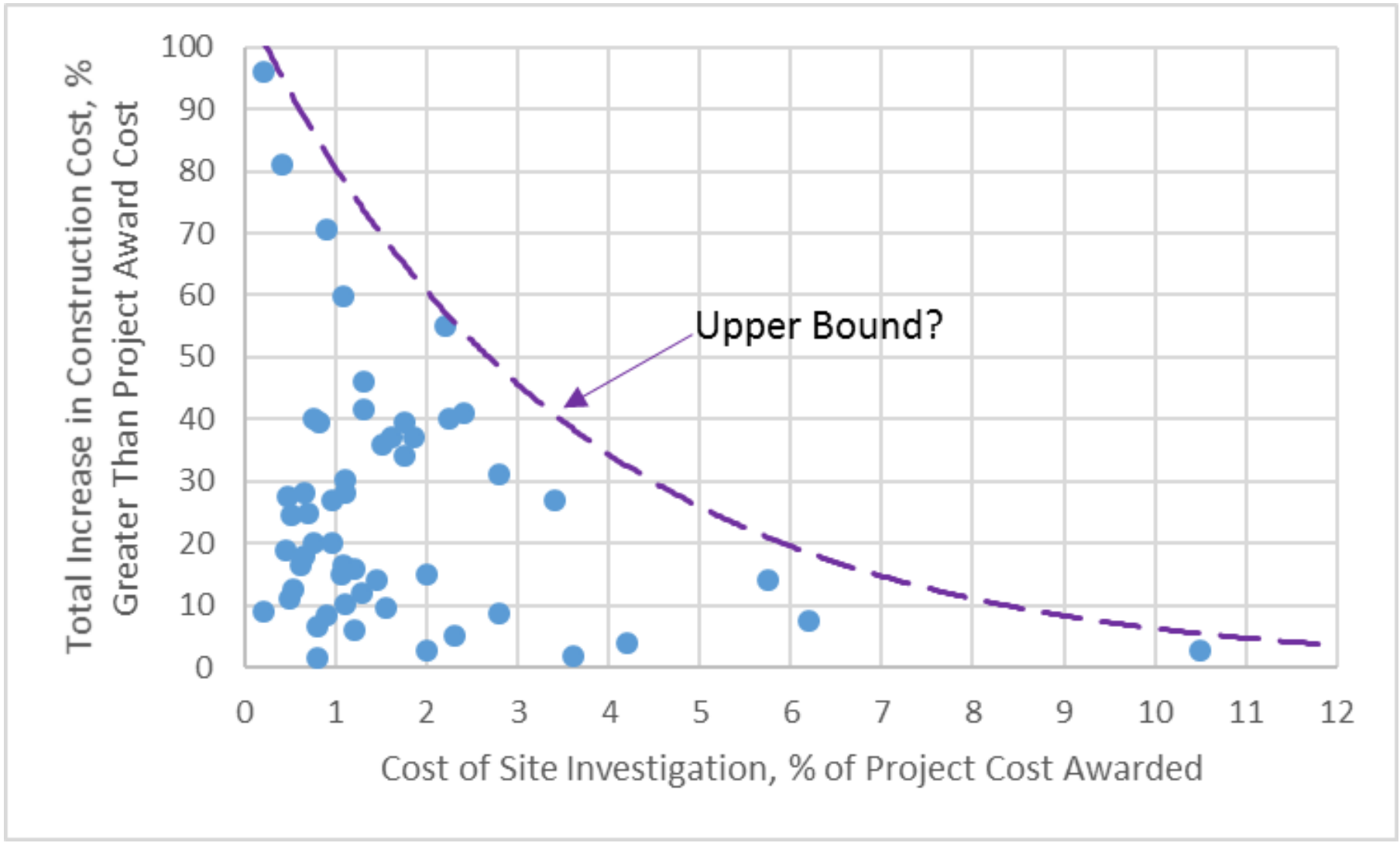

Advanced Geotechnical Methods in Exploration (A-GaME)

Bring your A-GaME – Reduce Uncertainty, Risk and Mischaracterization of Rock

The A-GaME's Mission

Mitigate risks to project schedule and budget, and improve reliability by optimizing geotechnical site characterization using proven, effective exploration methods and practices.

Benefit of Upfront Site Investigation Investment



Source: NCHRP Synthesis 484 - Influence of Geotechnical Investigation and Subsurface Conditions on Claims, Change Orders, and Overruns (After Figure 1)

Advanced Geotechnical Methods in Exploration

CPT - Cone Penetration Test

SCPT - Seismic Cone Penetration Test

ER - Electrical Resistivity

IP - Induced Polarization

SP - Self Potential

MWD - Measurement While Drilling

Seismic: Refraction

Seismic: Reflection

Seismic: FWI - Full Waveform Inversion

Seismic: SASW - Spectral Analysis of Surface Waves

Seismic: Tomography

Seismic: Downhole

Seismic: Crosshole Shear

TDEM - Time-Domain Electromagnetic

FDEM - Frequency-Domain Electromagnetic

VLFEM - Very Low Frequency Electromagnetic

OTV - Optical Televiewers

ATV - Acoustic Televiewers

GPR - Ground Penetrating Radar

MicroGravity

PMT - Pressuremeter Test

DMT - Flat Plate Dilatometer Test

Rock Discontinuities from Photogrammetry

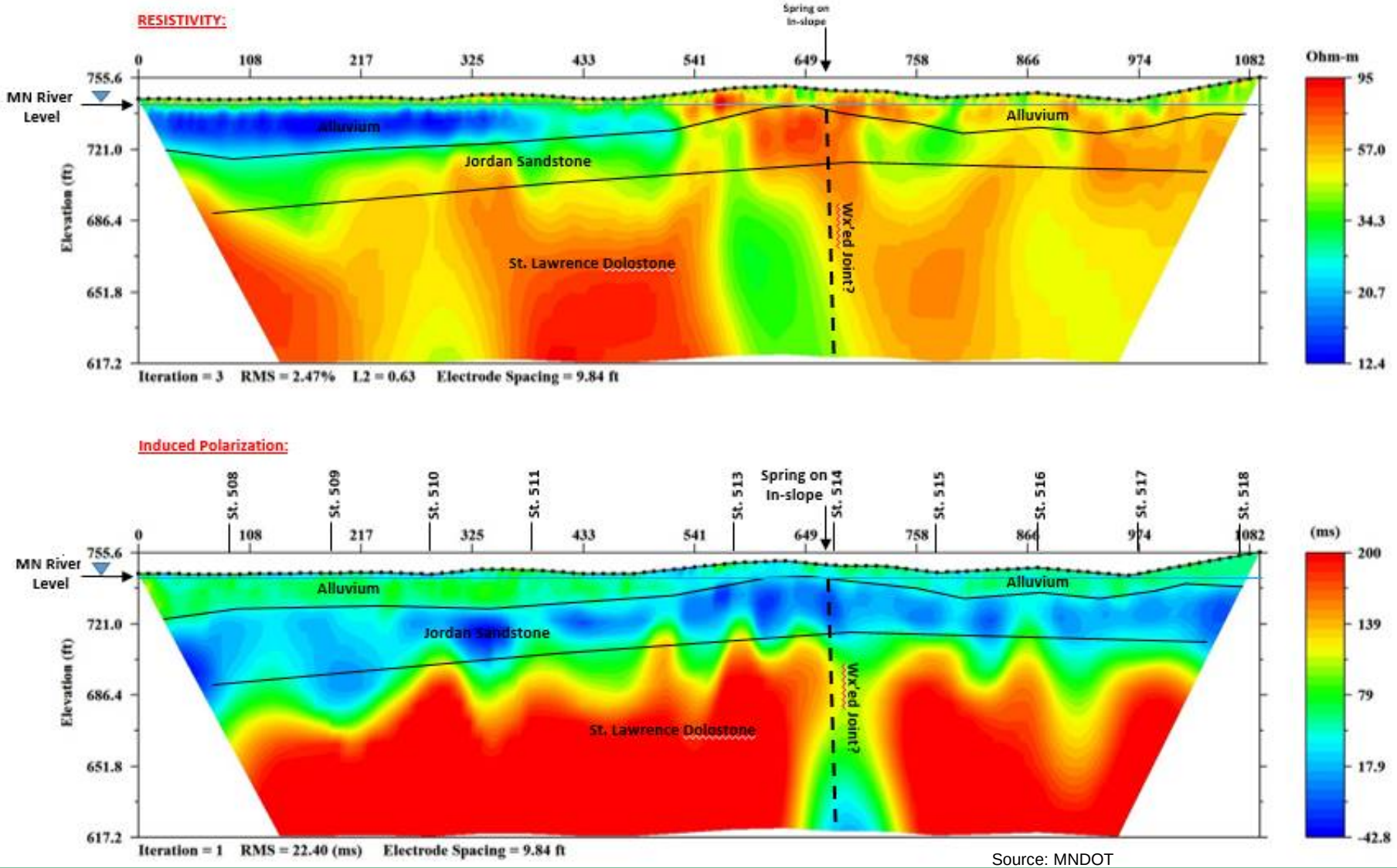
Pore-water pressure from Field Piezometers

Suspension Logging

Vane Shear Test (VST)

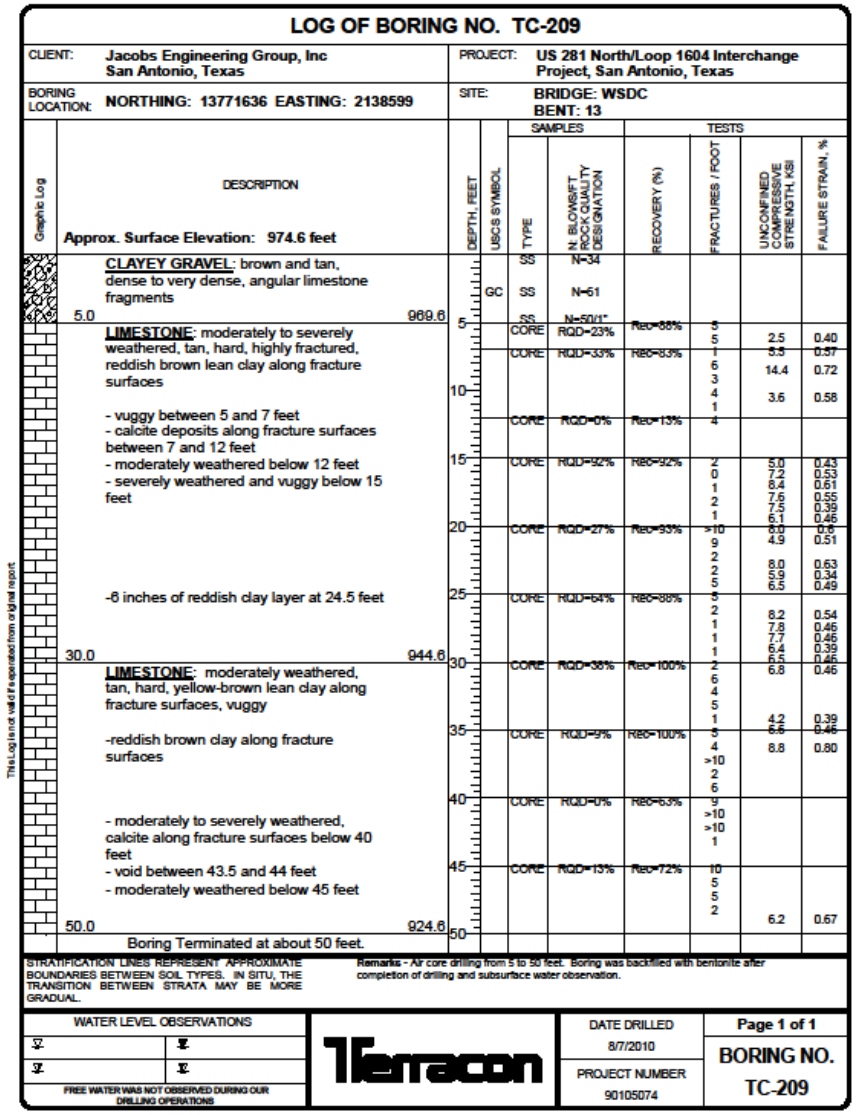
Downhole Full Waveform Sonic Logging

Electrical Resistivity and Induced Polarization



Source: MNDOT

Measurement While Drilling (MWD)



LOG OF BORING NO. TC-209

CLIENT: Jacobs Engineering Group, Inc San Antonio, Texas

PROJECT: US 281 North/Loop 1604 Interchange Project, San Antonio, Texas

BORING LOCATION: NORTHING: 13771636 EASTING: 2138599

SITE: BRIDGE: WSDC BENT: 13

Graphic Log	DESCRIPTION	DEPTH, FEET	USCS SYMBOL	SAMPLES TYPE	SAMPLES N, BLOWS/FT ROCK QUALITY DESIGNATION	TESTS RECOVERY (%)	TESTS FRACTURES / FOOT	TESTS UNCONFINED COMPRESSIVE STRENGTH, KSI	TESTS FAILURE STRAIN, %
	Approx. Surface Elevation: 974.6 feet								
	CLAYEY GRAVEL: brown and tan, dense to very dense, angular limestone fragments		GC	SS	N=34				
			GC	SS	N=61				
	5.0 969.6	5		SS	N=50/1"				
	LIMESTONE: moderately to severely weathered, tan, hard, highly fractured, reddish brown lean clay along fracture surfaces			CORE	RQD=23%	Rec=88%	5 5	2.5	0.40
				CORE	RQD=33%	Rec=83%	1 6 3 4 1	8.5 14.4 3.6	0.57 0.72 0.58
	- vuggy between 5 and 7 feet - calcite deposits along fracture surfaces between 7 and 12 feet - moderately weathered below 12 feet - severely weathered and vuggy below 15 feet	10		CORE	RQD=0%	Rec=13%	4		
		15		CORE	RQD=92%	Rec=92%	2 0 1 2 1	5.0 7.2 8.4 7.6 7.5	0.43 0.53 0.61 0.55 0.59
				CORE	RQD=27%	Rec=93%	>10 9 2 2 5	6.1 8.0 4.9 8.0 6.9	0.45 0.6 0.51 0.63 0.34
	-6 inches of reddish clay layer at 24.5 feet	20						6.5	0.49
	30.0 944.6	25		CORE	RQD=64%	Rec=88%	5 2 1 1 1	8.2 7.8 7.7 6.4 6.5	0.54 0.46 0.46 0.36 0.46
	LIMESTONE: moderately weathered, tan, hard, yellow-brown lean clay along fracture surfaces, vuggy	30		CORE	RQD=38%	Rec=100%	2 6 4 5 1	6.8 4.2	0.46 0.39
	-reddish brown clay along fracture surfaces	35		CORE	RQD=9%	Rec=100%	5 4 >10 2 6	6.6 8.8	0.46 0.80
	- moderately to severely weathered, calcite along fracture surfaces below 40 feet - void between 43.5 and 44 feet - moderately weathered below 45 feet	40		CORE	RQD=0%	Rec=63%	9 >10 >10 1		
		45		CORE	RQD=13%	Rec=72%	10 5 5 2		
	50.0 924.6	50						6.2	0.67
	Boring Terminated at about 50 feet.								

This Log is not valid if separated from original report

STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION BETWEEN STRATA MAY BE MORE GRADUAL.

Remarks - Air core drilling from 5 to 50 feet. Boring was backfilled with bentonite after completion of drilling and subsurface water observation.

WATER LEVEL OBSERVATIONS

FREE WATER WAS NOT OBSERVED DURING OUR DRILLING OPERATIONS

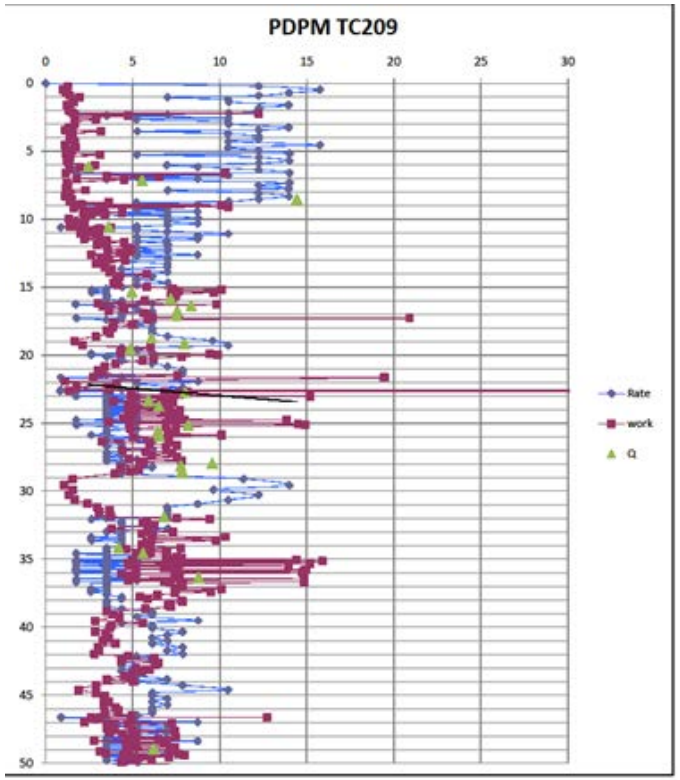
Terracon

DATE DRILLED 8/7/2010

PROJECT NUMBER 90105074

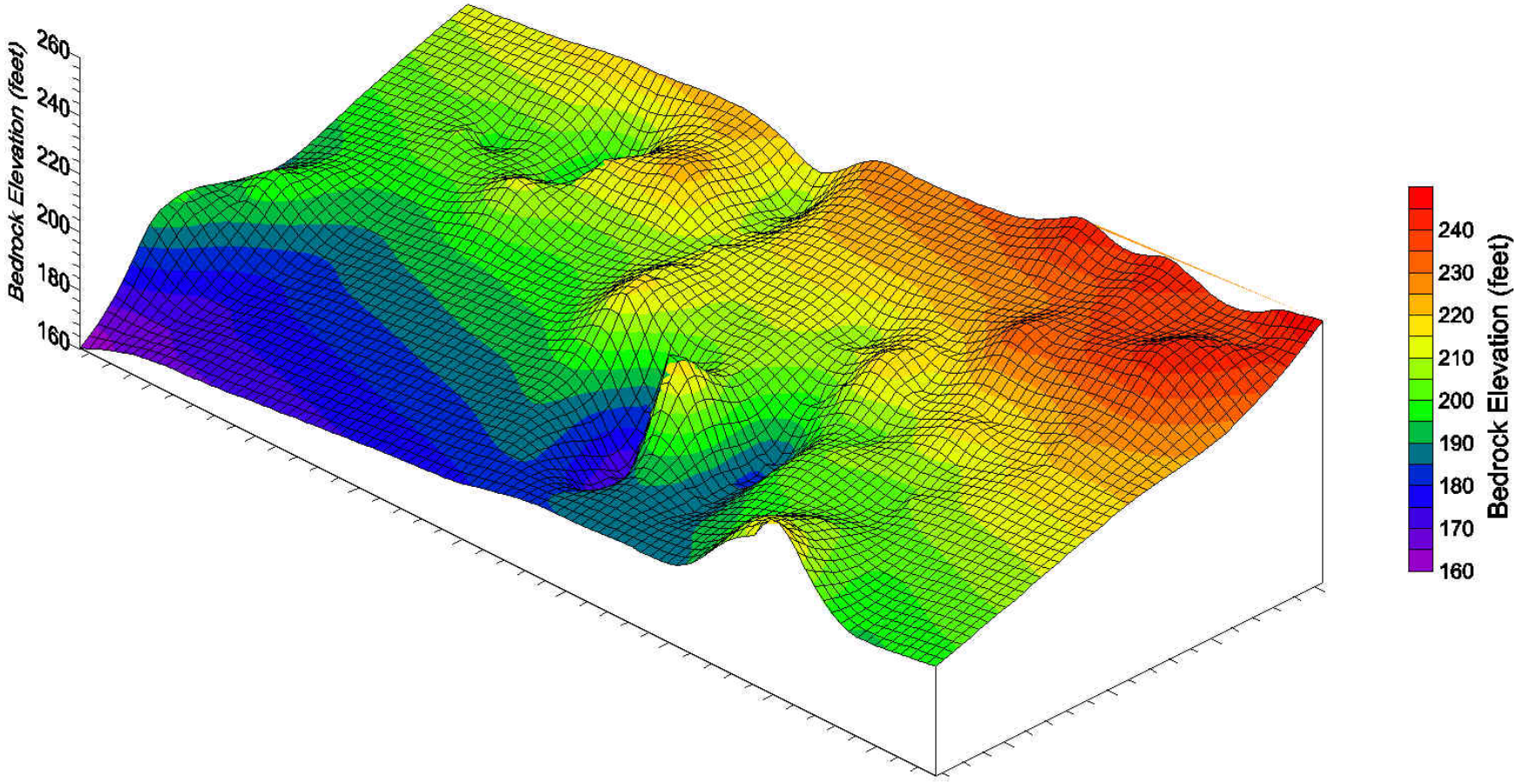
Page 1 of 1

BORING NO. TC-209



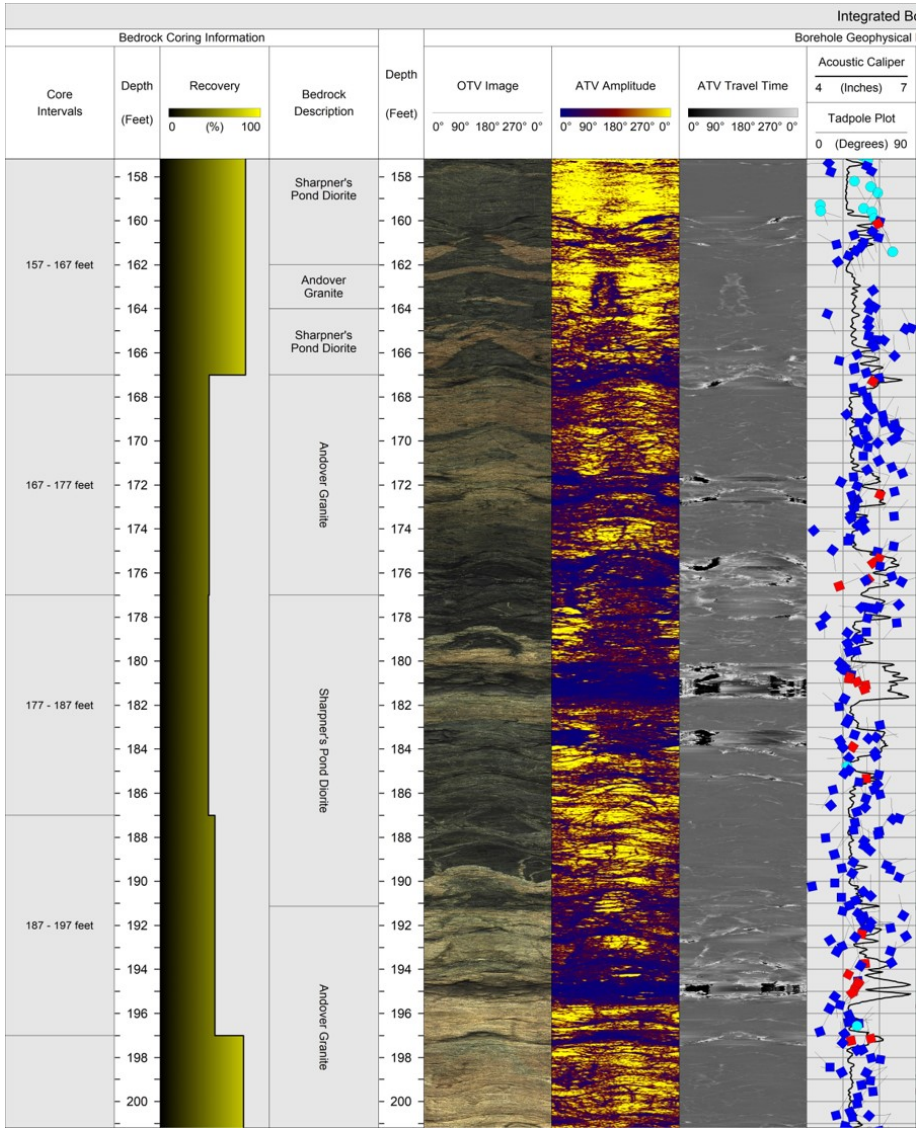
Source: Terracon

Seismic Refraction – Top of Bedrock



Source: Jeff Reid, Hager-Richter

Optical and Acoustic Televiewers (OTV/ATV)



Source: Rob Garfield, Hager-Richter

Issues & Observations from States

Issues with -

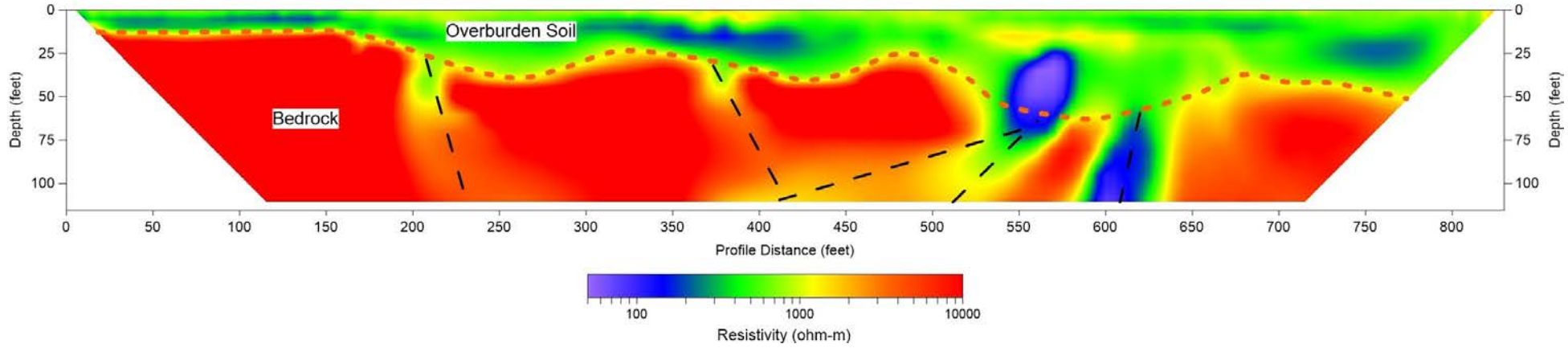
- Mischaracterized rock for drilled shaft construction – impacting equipment selection and construction schedule
- Certain types of soil and rock are difficult to characterize
- Unanticipated rock encountered during foundation construction
- Scourability of rock, depth to “unscourable” rock

Source: FHWA

Issues & Observations from States

Observations -

- Modest changes to subsurface investigation practices can produce significant reductions to problems
- Geophysical methods have helped characterize rock over large areas where traditionally not explored – like for sound-walls and secondary structures
- Televiewers have demonstrated great value for rock characterization for foundation design and construction
- Generate office-study and recon report & program stop-point. Lay-out risks and anticipated conditions for project requirements. Make case for enhanced investigations where warranted.

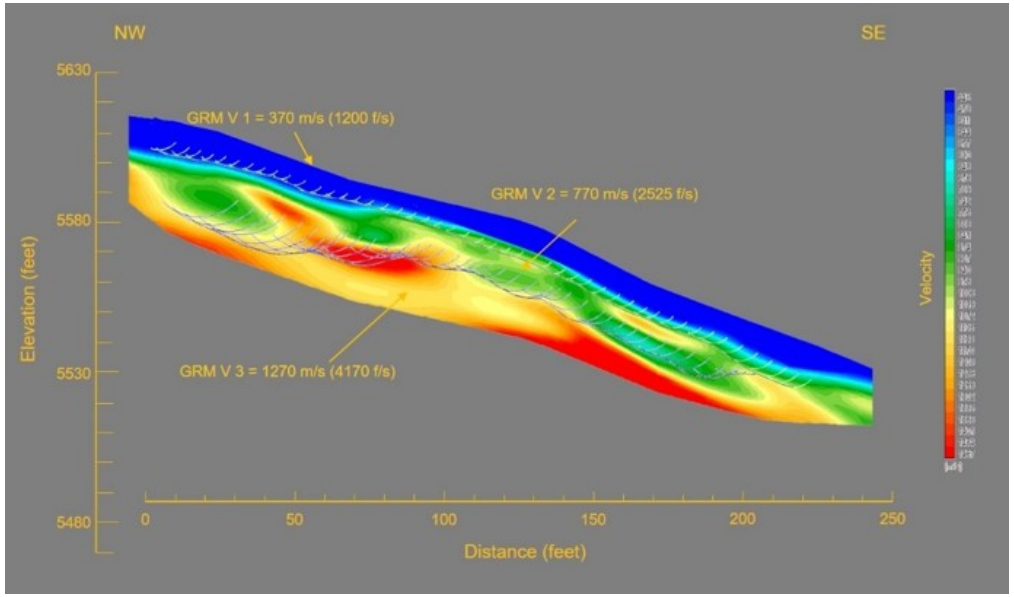


Source: Jeff Reid, Hager-Richter

Take-Aways from TRB Workshop Discussion

Change the standard of practice to allow innovation:

- Move away from prescriptive practice
- Allow phased investigations
- Allow observational approach where appropriate
- Allow time and effort for appropriate methods and lab testing
- GIS in preliminary phase
- Build site model before the project
- Aggregate existing information before doing anything



Source: CalTrans

Take-Aways from TRB Workshop Discussion

- Provide access to existing information
- Communicate with others on project
- Assure professionals get contacted to re-evaluate project location and plans
- Set expectations; phased investigations should be planned when project is complex
- Prevent misstep where phased or additional investigation is not allowed when plans change

Source: ALDOT

Questions

Benjamin S. Rivers, FHWA
Resource Center
benjamin.rivers@dot.gov
404-562-3926

Today's Panelists

- Bob Bachus, *Geosyntec Consultants*
- Bob Group, *Colorado Department of Transportation*
- Ben Rivers, *Federal Highway Administration*
- Moderated by Sharid Amiri, *California Department of Transportation*

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