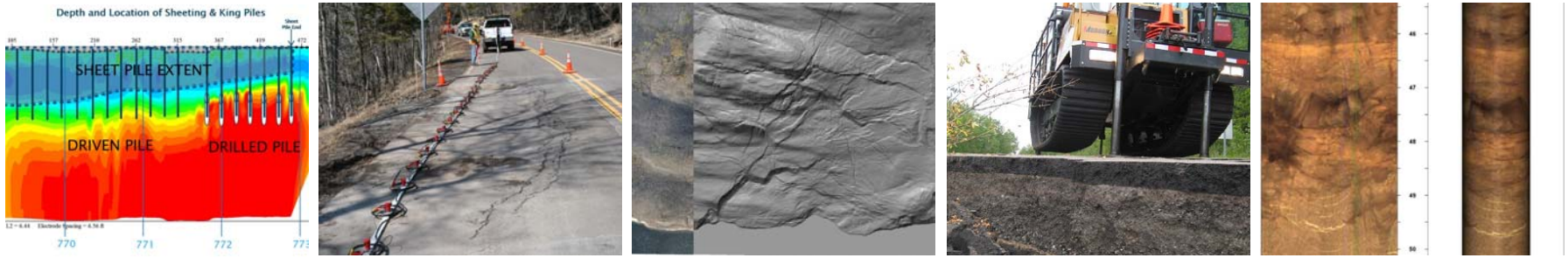
Center for Accelerating Innovation

U.S. Department of Transportation
Federal Highway Administration

On-Ramp to Innovation
every day counts



Advanced Geotechnical Methods in Exploration (The A-GaME)

Tools for Enhanced, Effective Site Characterization

Topics

- Every Day Counts (EDC)
- The A-GaME – Overview
- Featured Methods
- Summary of Benefits

What is *"Every Day Counts"*(EDC)?

State-based model to identify and rapidly deploy proven but underutilized innovations to:

- ✓shorten the project delivery process
- ✓enhance roadway safety
- ✓reduce congestion
- ✓improve environmental sustainability

- EDC Rounds: two year cycles
- Initiating 5th Round (2019-2020) - 10 innovations
- To date: 4 Rounds, over 40 innovations

For more information: https://www.fhwa.dot.gov/innovation/

FAST Act, Sec.1444

Implementation Planning Team

Practitioners | Geotechnical | Construction | Design | Risk | Geophysics | Site Variability | Public and Private Sectors | Industry Representation – ADSC, AEG, DFI, EEGS, GI and AASHTO COBS, COC, COMP

Brian Collins – FHWA-WFL
Derrick Dasenbrock – MNDOT
Mohammed Elias – FHWA-EFL
Vaughan Griffiths – Mines
Peggy Haggerty Duffy – ADSC
Khamis Haramy – FHWA-CFL
David Horhota – FLDOT
Jim Hussin – Keller Foundations
Mary Ellen Large – DFI
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Mike McVay – Univ. of Florida
Silas Nichols – FHWA HQ
Mary Nodine – GEI Consultants
Bill Owen – Caltrans
Krystle Pelham – NHDOT
Jeff Reid – Hager-Richter
Ben Rivers – FHWA-RC
Brent Rosenblad – Univ. of Missouri
Phil Sirles – Olson Engineering

Mission

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

Risk

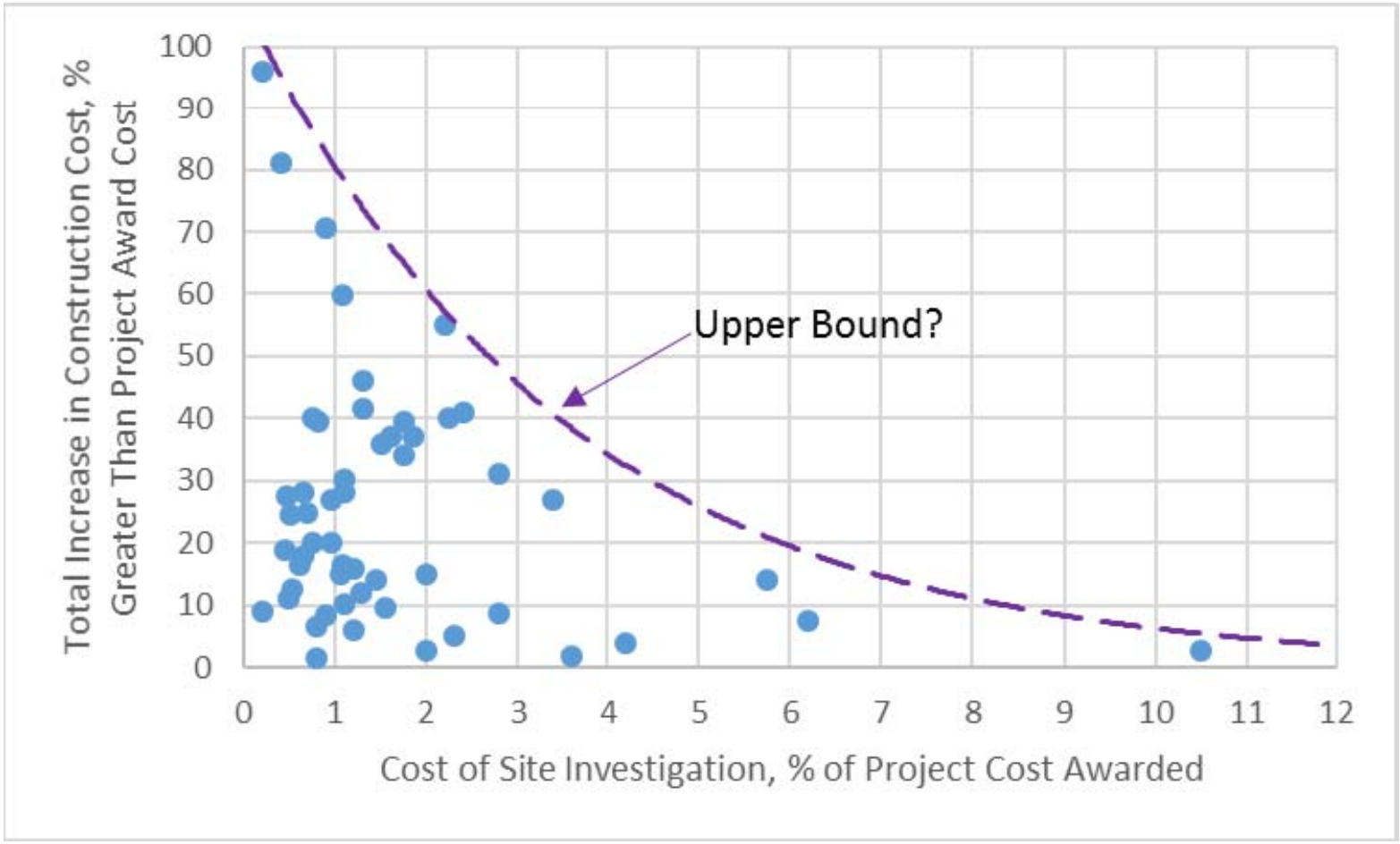
Source: FHWA

Risk

Source: Florida DOT

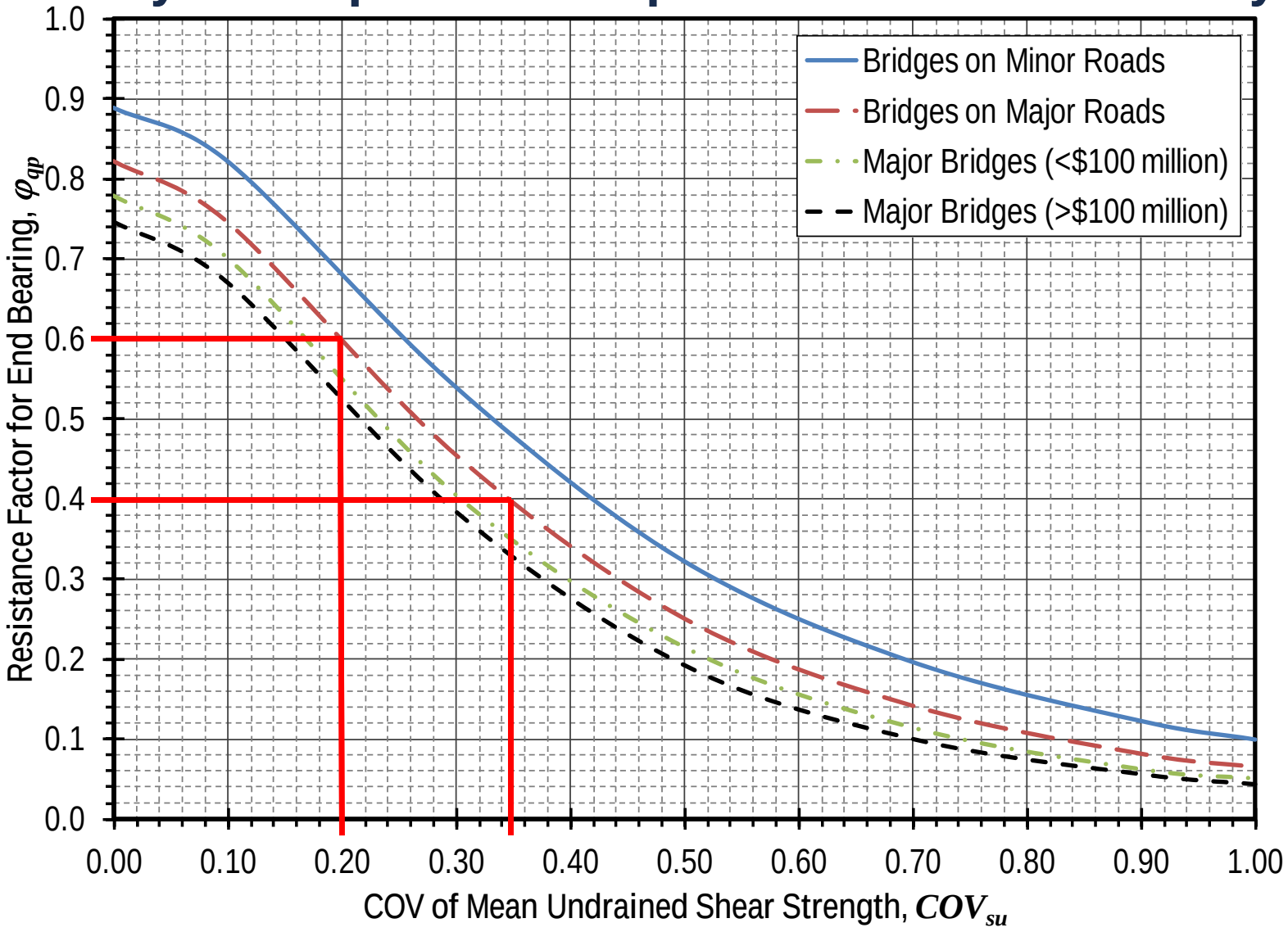
Source: Florida DOT

Benefit of Upfront Investment in Site Investigation



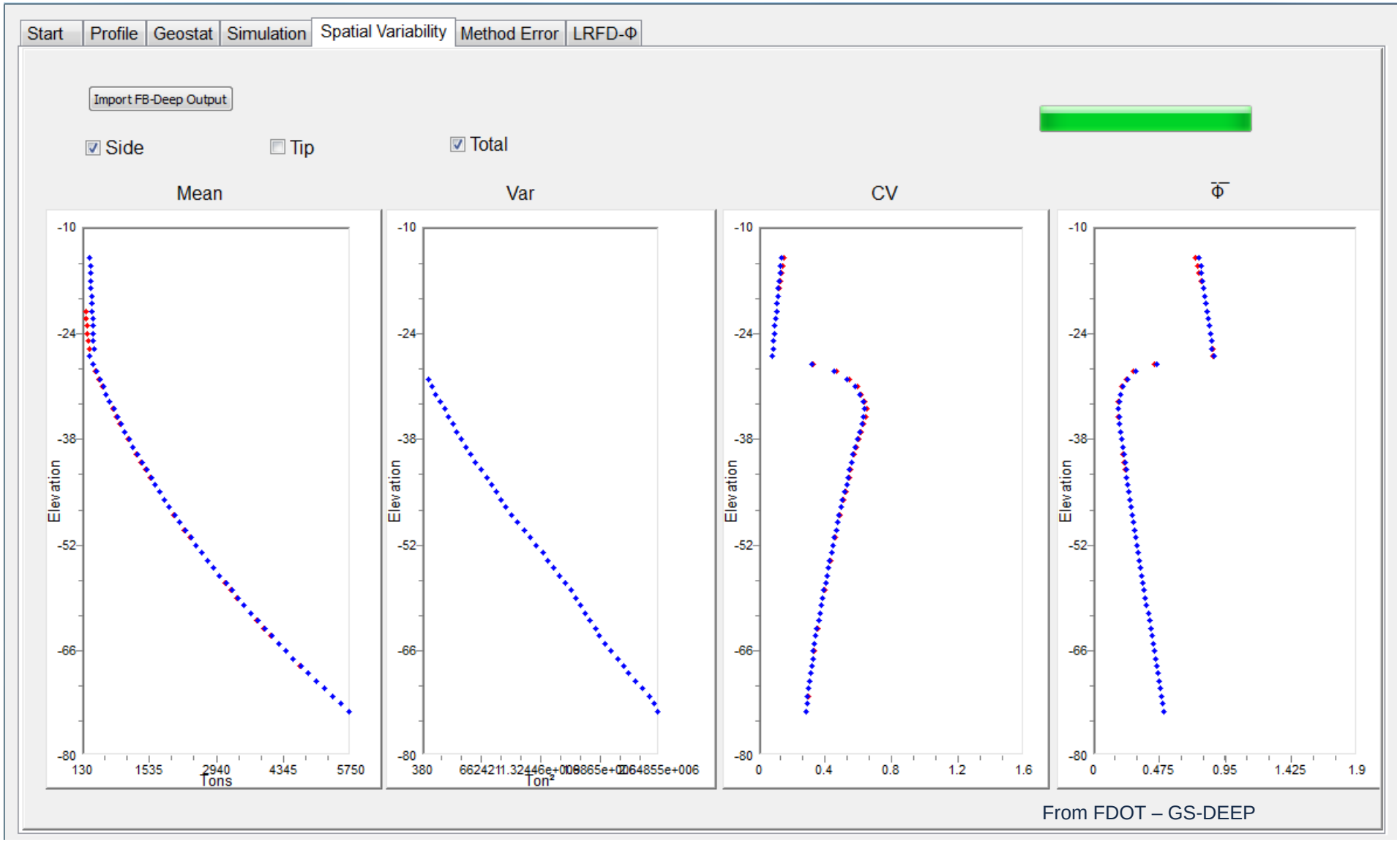
Source: NCHRP Synthesis 484 - Influence of Geotechnical Investigation and Subsurface Conditions on Claims, Change Orders, and Overruns (After Figure 1)

MODOT Approach for Relating Design Reliability to Variability. Example Shown: Tip resistance – shafts in clay



Source: Missouri DOT

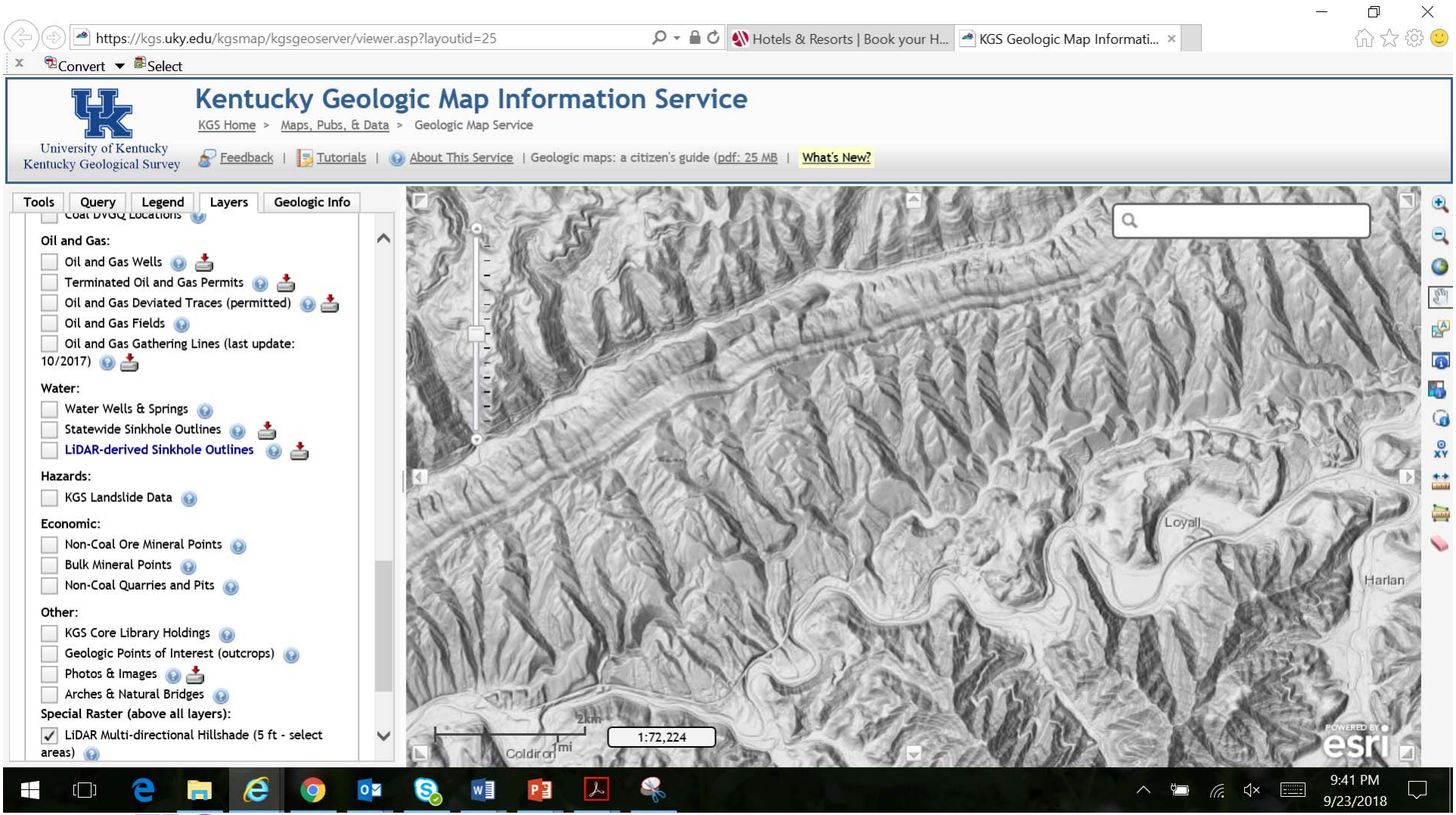
Spatial Variability and Design Reliability



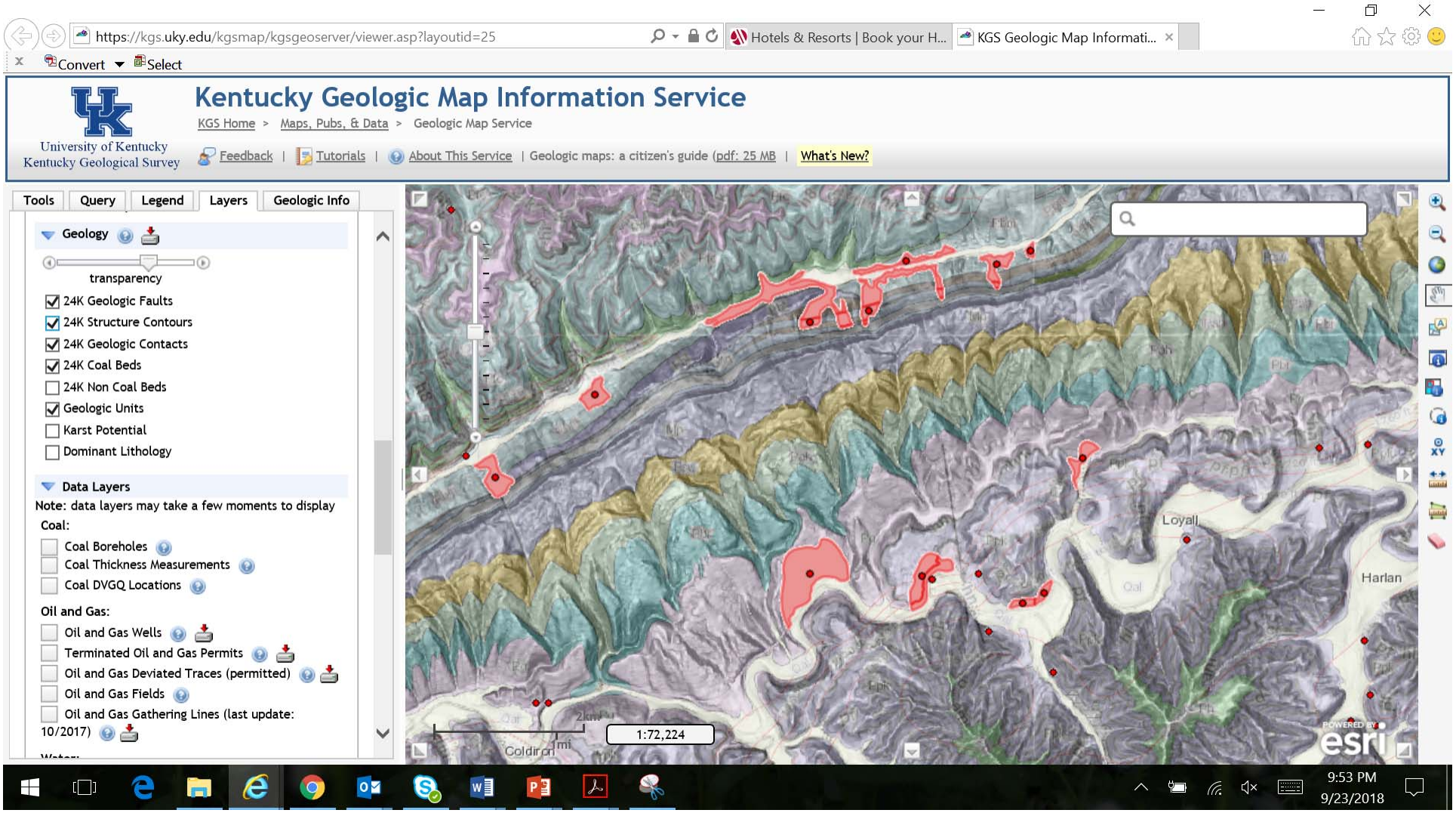
Preliminary Planning – LiDAR

Courtesy of BGC Engineering
and BC Hydro

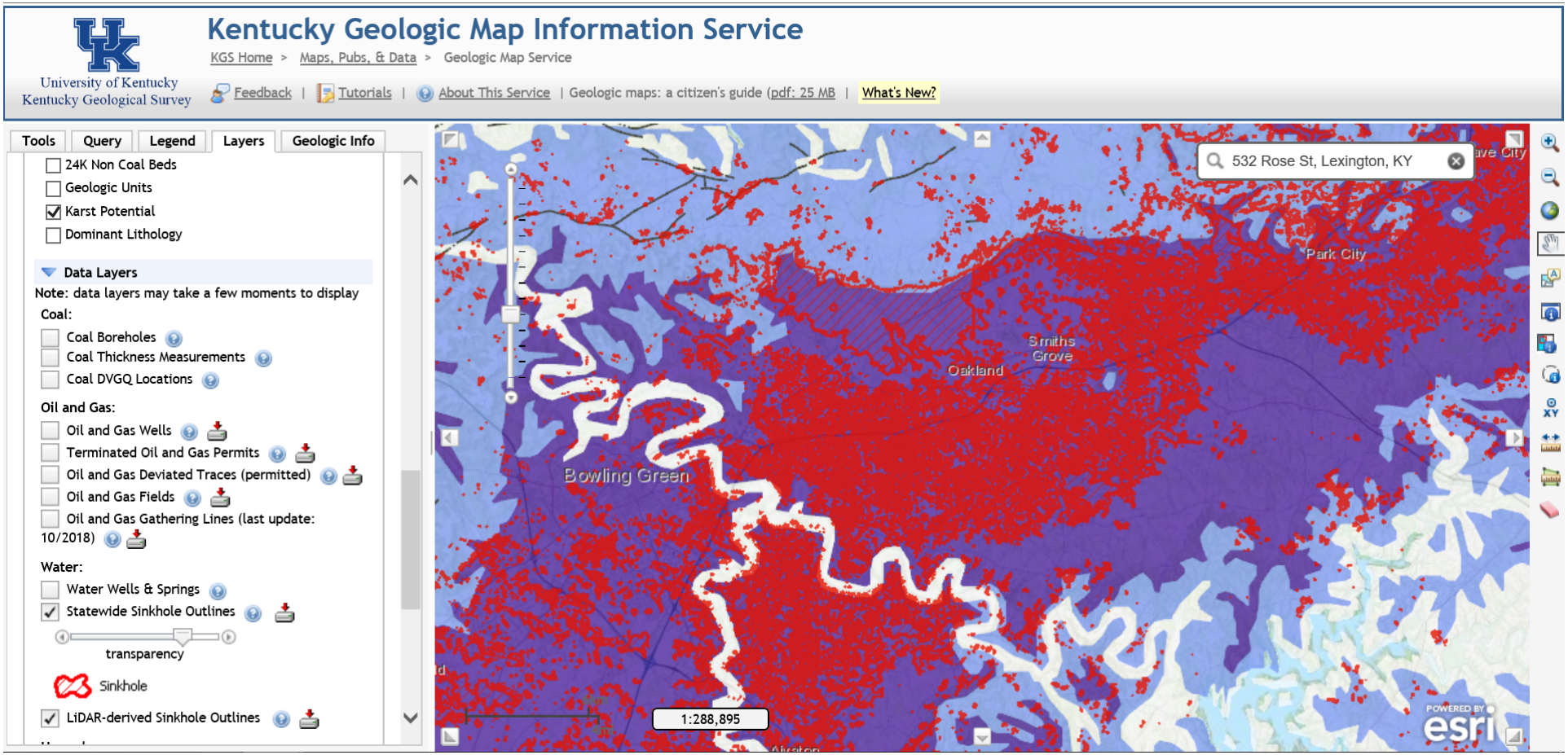
LiDAR Overlay - Kentucky



LiDAR, Mapped Landslides, Geologic Units - Kentucky



Karst Potential, Mapped Features - Kentucky



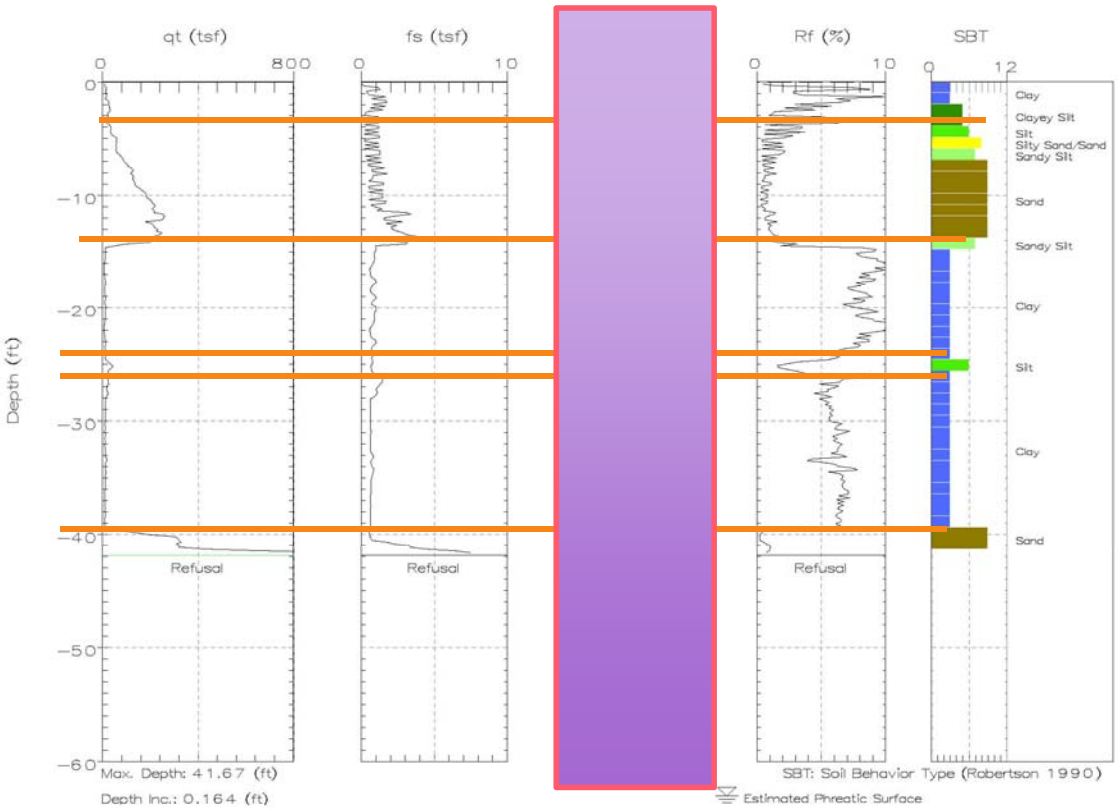
Featured Geotechnical Exploration Methods

- Cone Penetration Test (CPT/SCPT)
- Electrical Methods (ER, IP, SP)
- Seismic Methods (Refraction, Surface Waves, FWI, Tomography, Reflection)
- Measurement While Drilling (MWD)
- Optical and Acoustic Televiewers (OTV/ATV)

Mainstream Effective Underutilized Methods

Cone Penetration Testing (CPTu/SCPTu)

- More reliable parameters than from conventional SPT
- Small strata changes easily discernable
- Pore-water pressure measurements
- Shear-wave measurements with SCPTu
- 3-10 times faster than conventional drilling

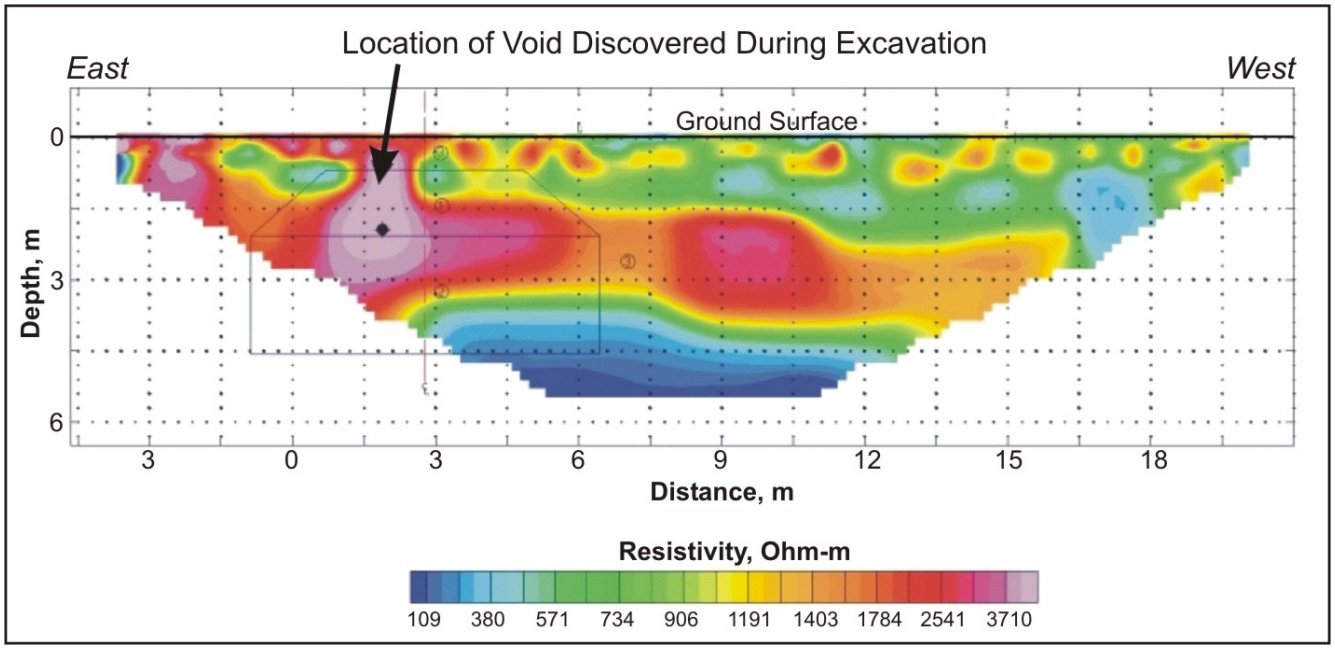


Source: FHWA

Mainstream Effective Underutilized Methods

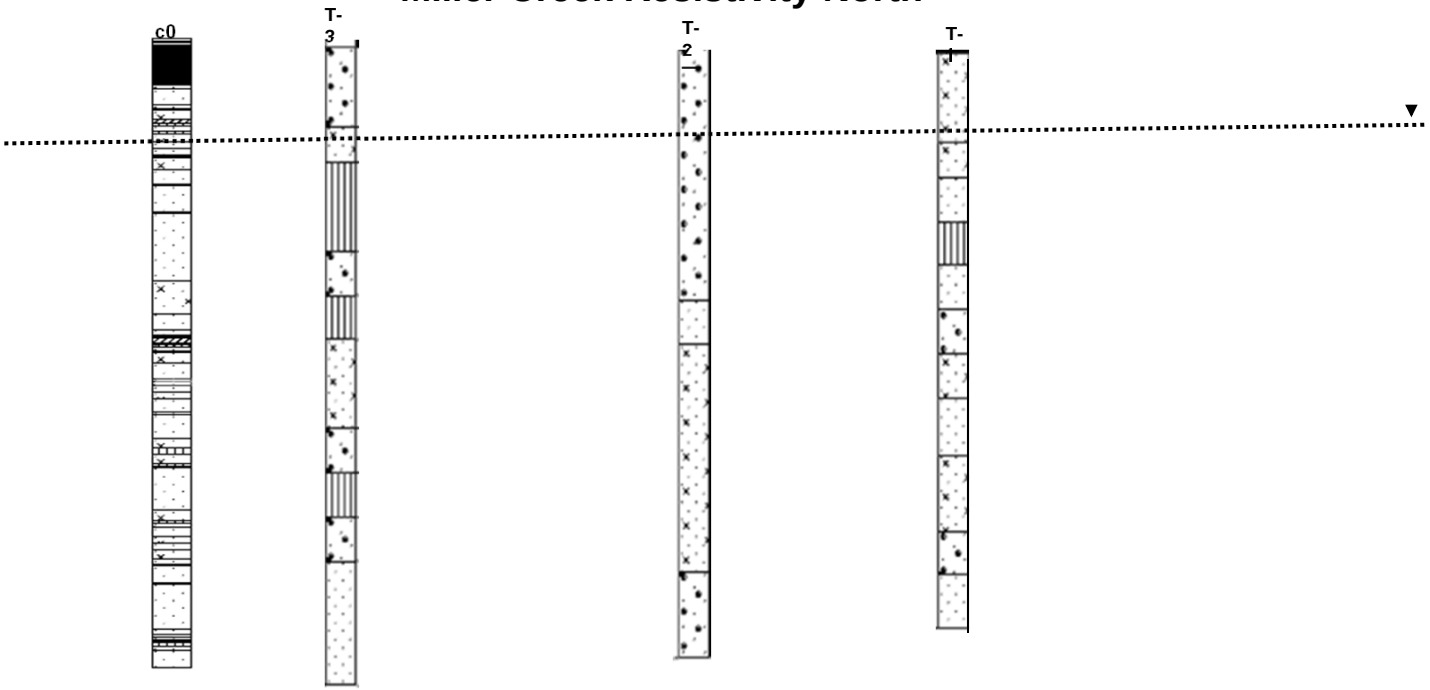
Electrical Methods (ER, IP, SP)

- Discern contrasting materials and groundwater conditions over large areas
  - Clay, Silts, Sands/Gravel, Voids, Groundwater, geologic features

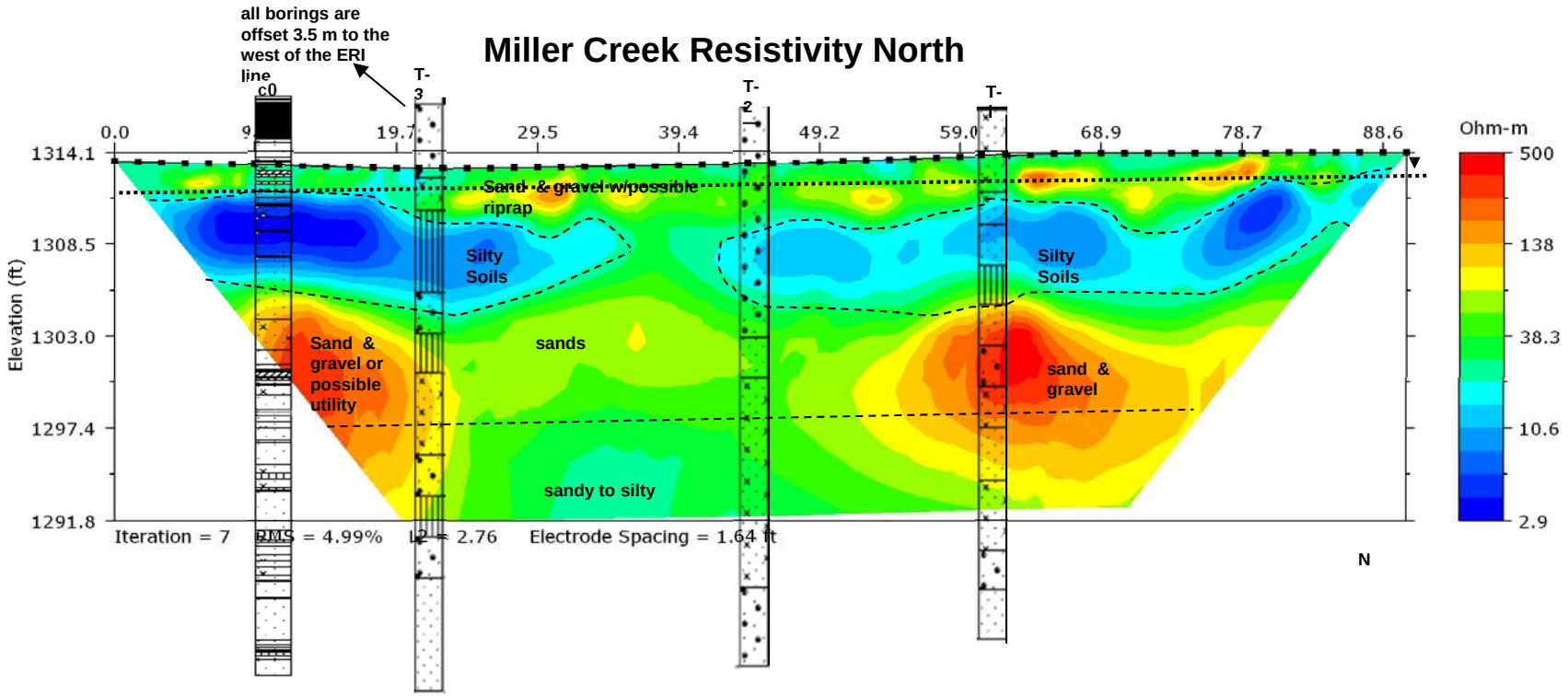


Source: FHWA-CFL

Miller Creek Resistivity North

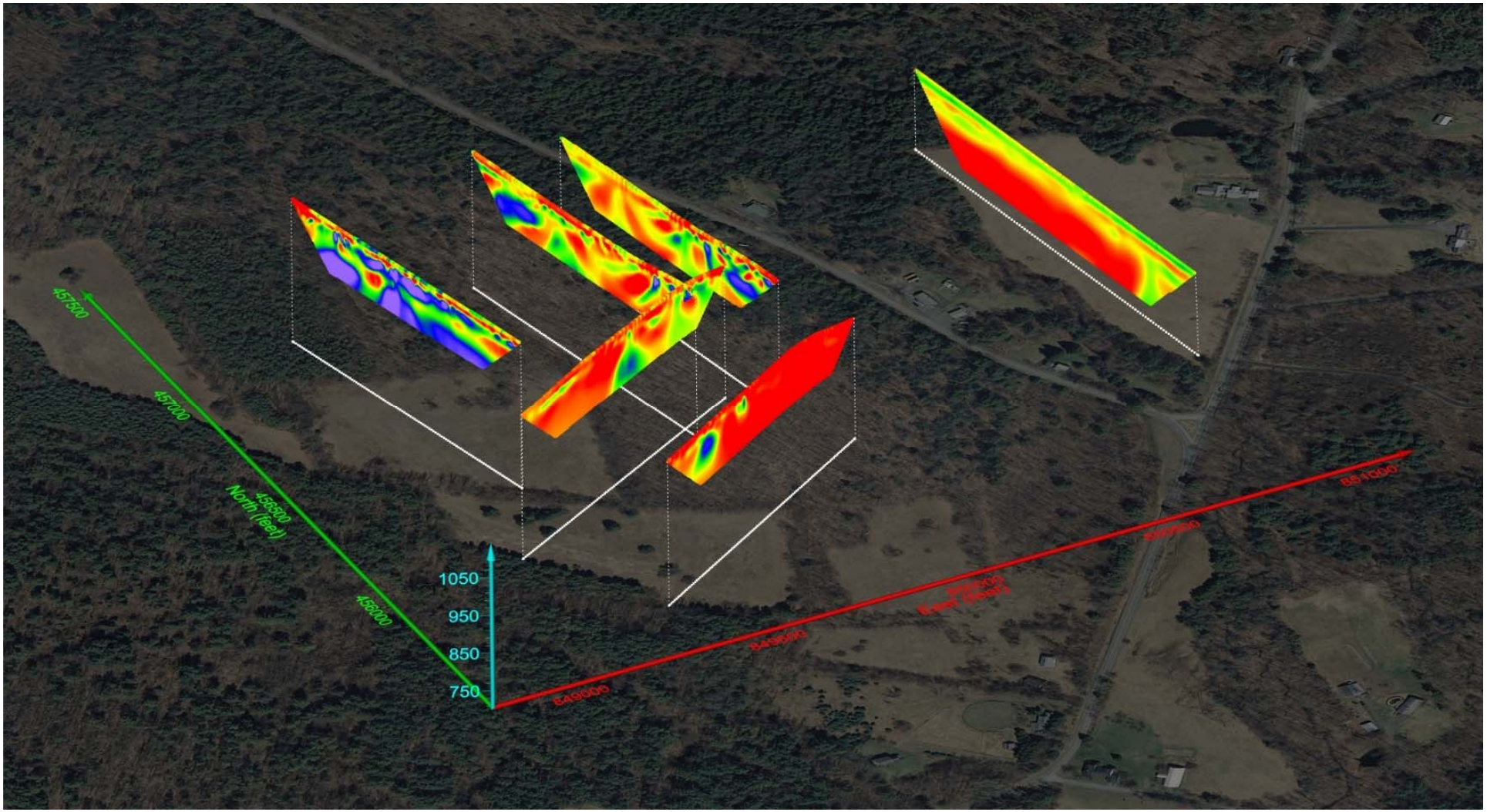


Source: Minnesota DOT



Source: Minnesota DOT

Electrical Resistivity – 2D Profiles in 3D Space

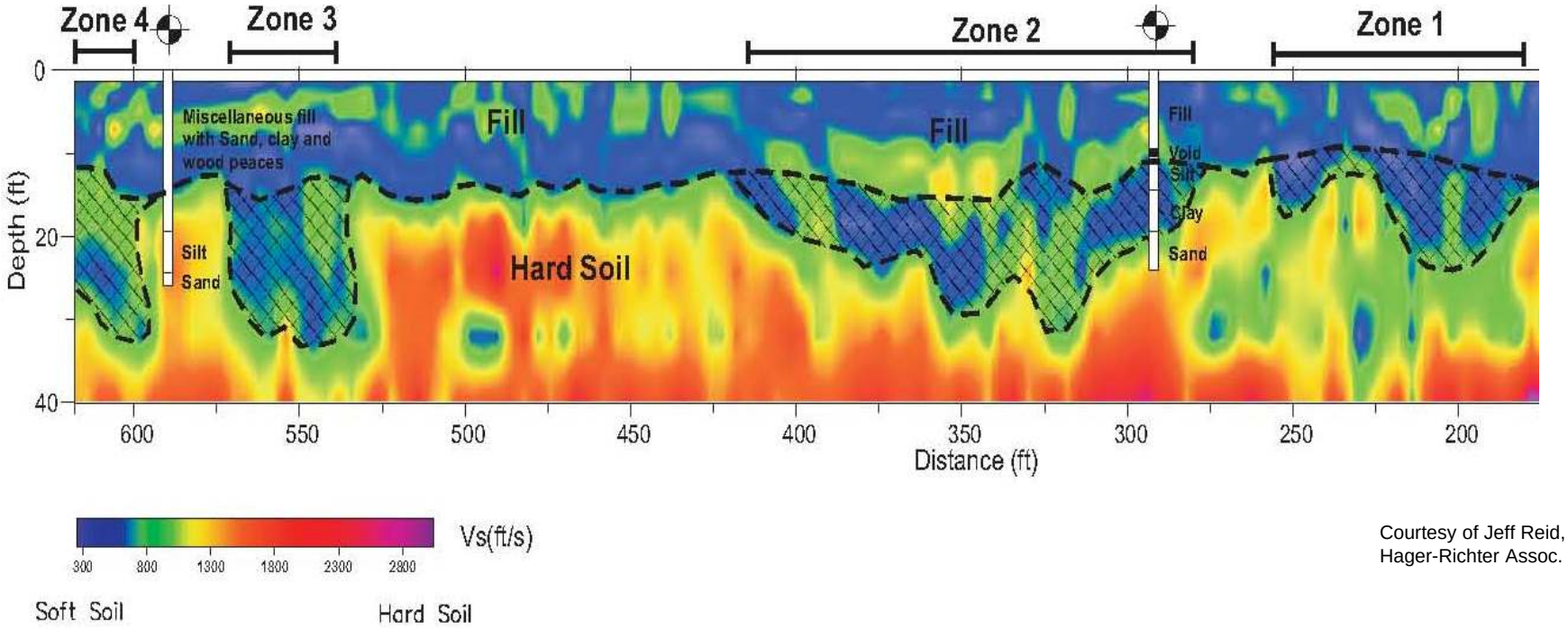


Courtesy of Jeff Reid,
Hager-Richter Assoc.

Mainstream Effective Underutilized Methods

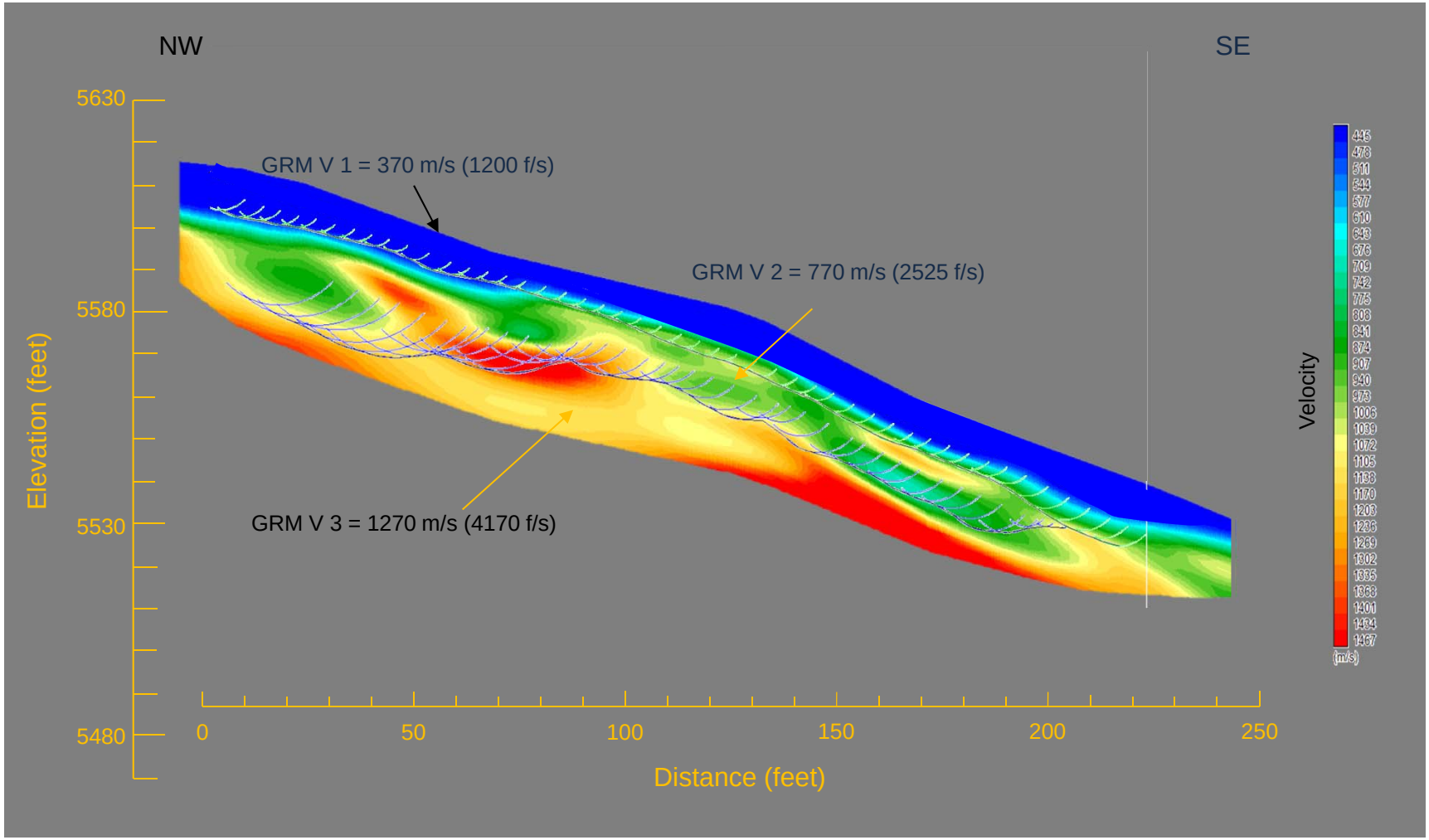
Seismic Methods (Surface Waves, Refraction, FWI, Downhole, Reflection)

- Indicates stratigraphic changes and boundaries over large areas
- Load-displacement behavior
- Seismic hazard susceptibility



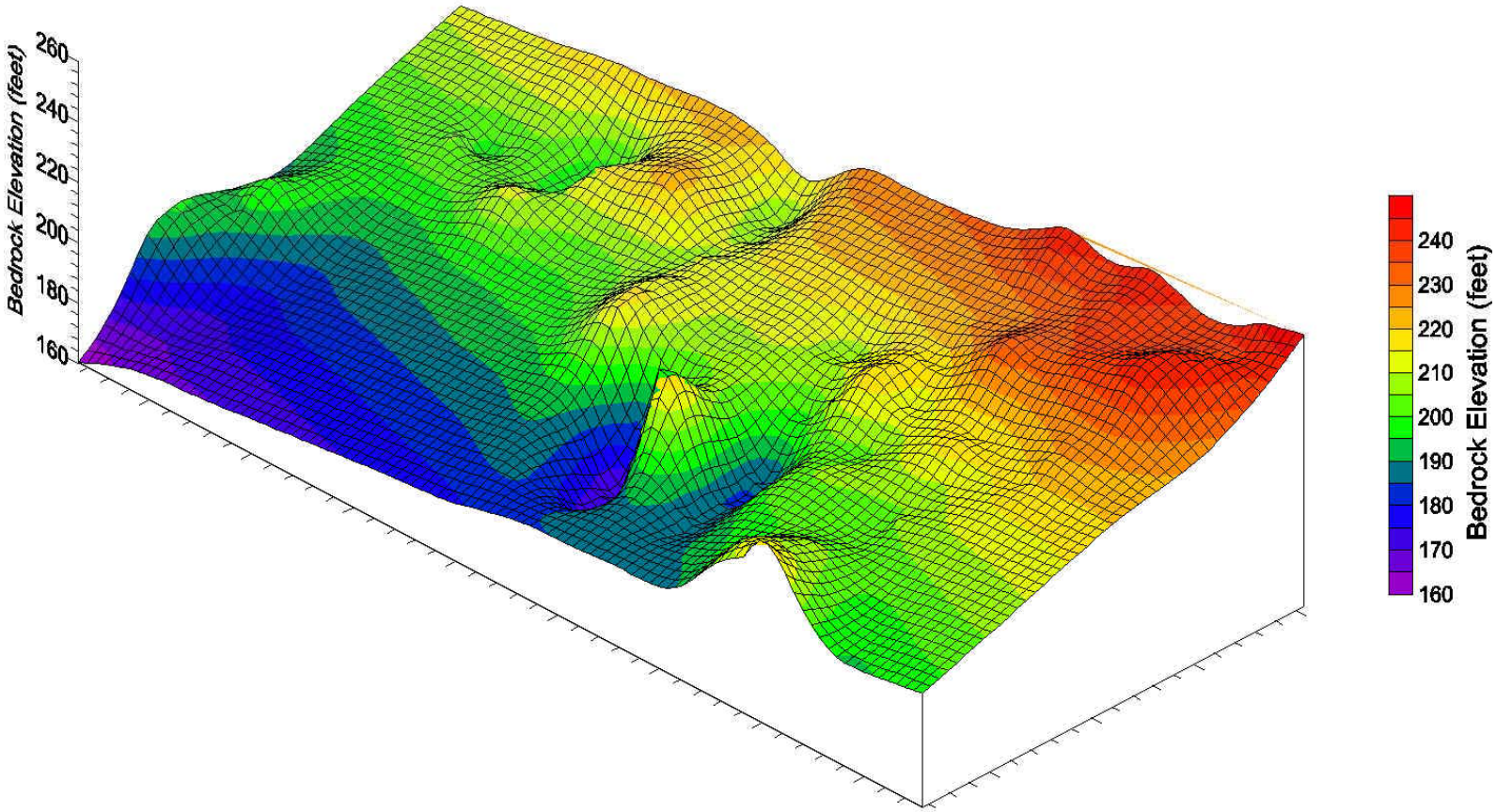
Courtesy of Jeff Reid, Hager-Richter Assoc.

GRM/Tomo Overlays - Seismic



Source: Owen, Caltrans, 2018

Seismic Refraction – Top of Bedrock



Courtesy of Jeff Reid,
Hager-Richter Assoc.

Measurement While Drilling (MWD) - Background

AKA – Diagraphy Drilling, Instrumented Drilling, Use of Drilling Parameters

Predominantly used with rotary-percussive, air-rotary and rotary-wash drilling

ACIP Piles - Use many of the same drilling measurements

Often used in conjunction with LWD – Logging While Drilling (down-hole geophysics) in the Oil/Gas/Mining Industries.

Background - Measurements

Measured and Recorded while Drilling:

- Fluid Pressure
- Torque
- Rotation Speed
- Thrust-on-bit (i.e. Down-thrust, Down-Pressure, Crowd)
- Hold-Back
- Penetration Depth
- Time
- Drilling-Speed (reciprocal of time)

Measurement While Drilling (MWD)

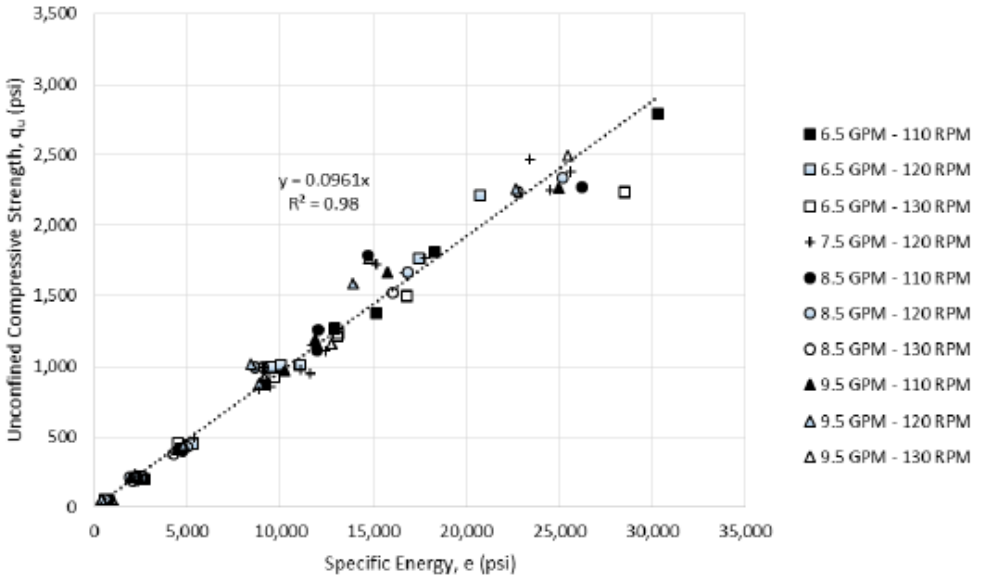
- Continuous profile
- Discernable stratigraphic and material changes
- Rock or Soil
- Standardized in Europe ISO 22476-15

Source: FHWA

From Rodgers et al. (Ongoing), McVay et al. 2016

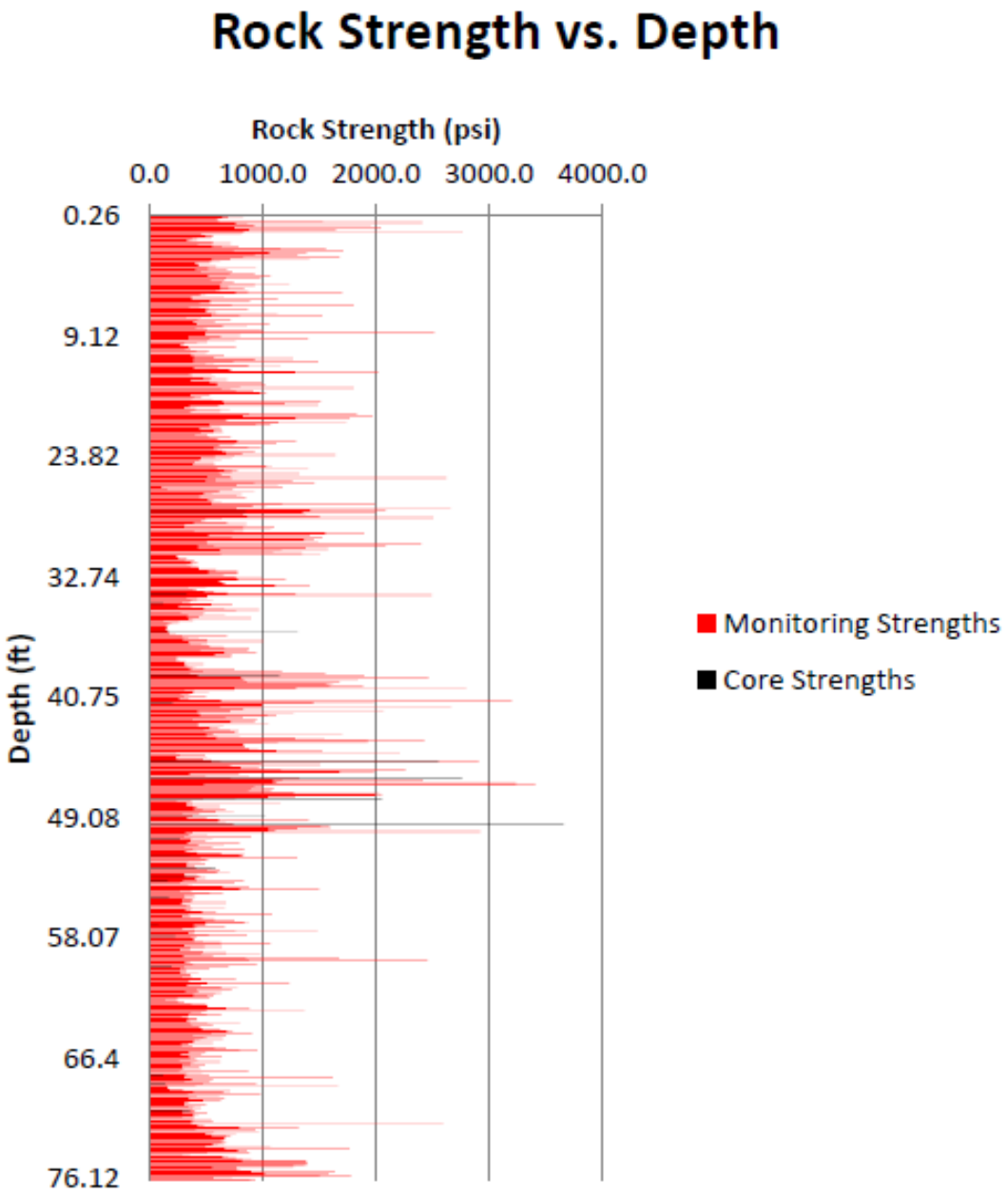
e vs. q_u Correlation

- Data grouped by combinations of variable flow rates and rotational speeds
  - 10 different combinations
- Excellent correlation was found using all 87 data points
  - Range of N and Q
- Nearly perfect RECs and RQDs for a q_u range of 183 psi to 2,788 psi
  - REC ≈ 100%
  - RQD ≈ 100%
- Lowest recovered strength
  - q_u = 24.7 psi



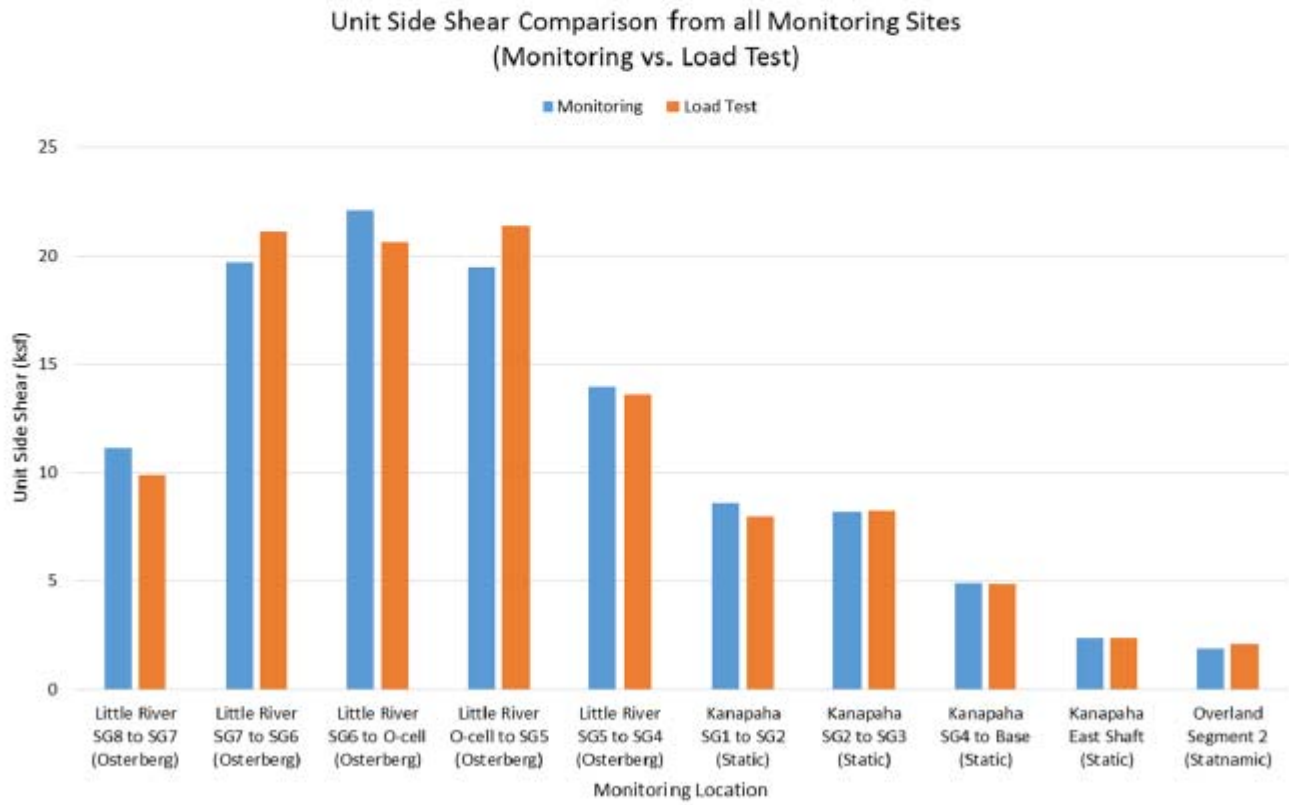
From McVay et al. – 2016

Estimated strengths from field MWD “Monitoring Strengths” and unconfined compressive strengths from core specimens.



From McVay et al. – 2016

Comparative Skin Friction Analysis



MWD - QA – Monitoring Drilling Efficiency

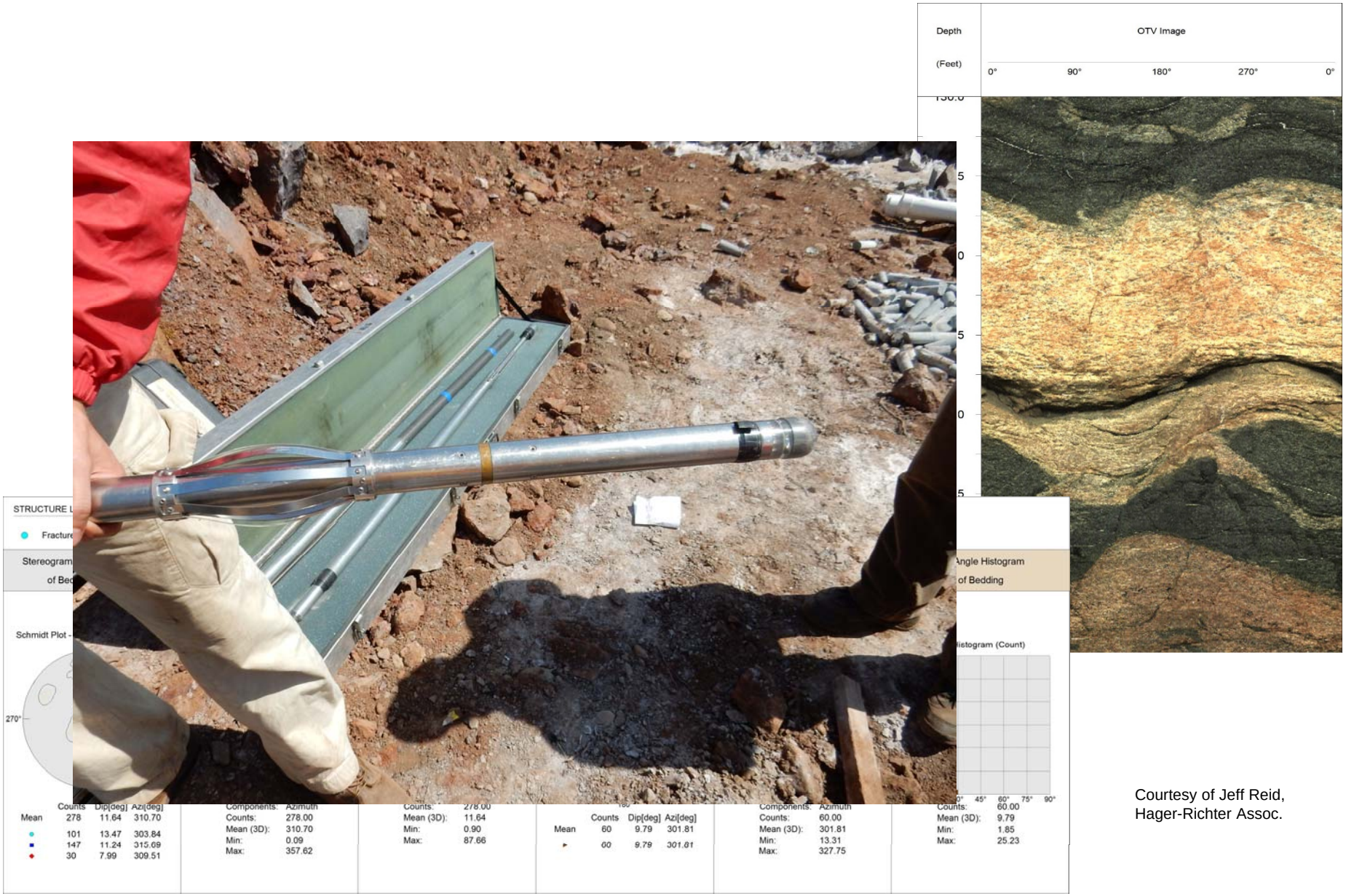
Effects of Overcrowding the Drill Bit

Drilling within the operational limits of the drill bit.
UCS ≈ 700 psi
REC = 100%
RQD = [redacted]

Drilling outside the operational limits. Fractured rock from overcrowding the drill bit.
UCS ≈ 700 psi
REC = 30%
RQD = 0%

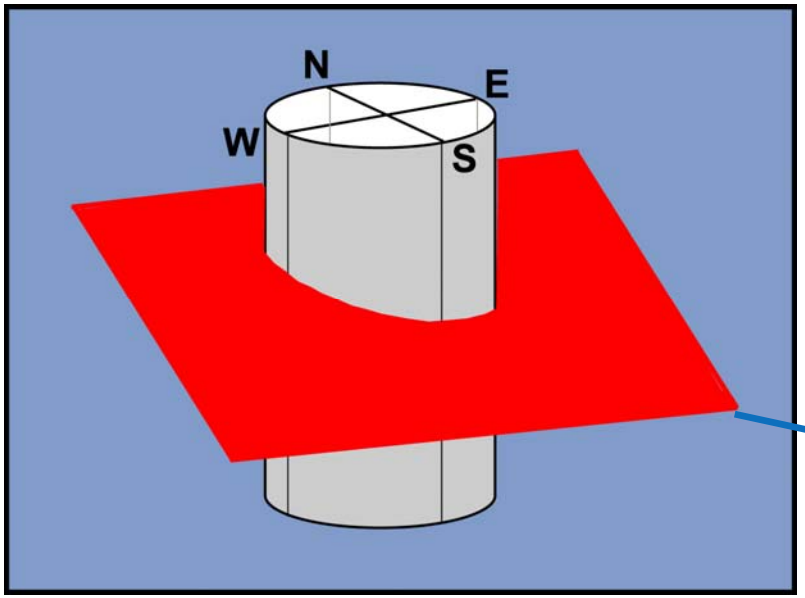
From Rodgers et al. (On-Going)

Downhole Televiewers

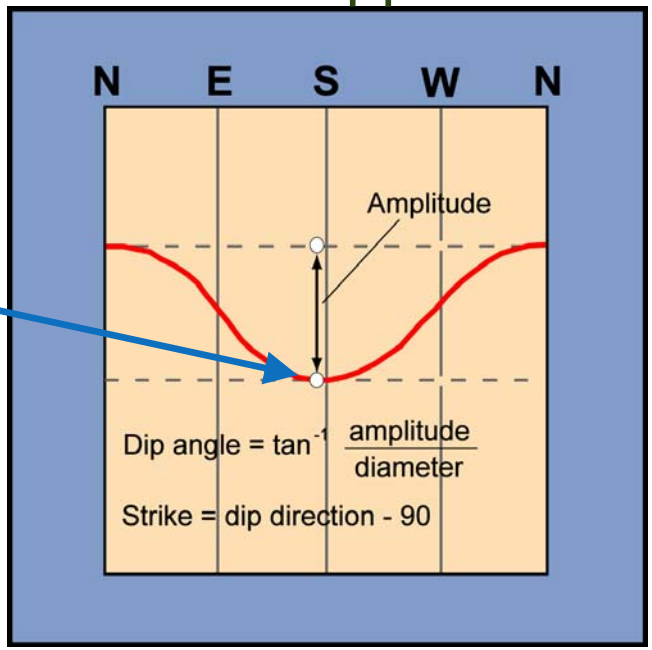


Courtesy of Jeff Reid,
Hager-Richter Assoc.

Borehole Televiewer Explanation



Projected
"unwrapped"



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Borehole Televiewer Explanation

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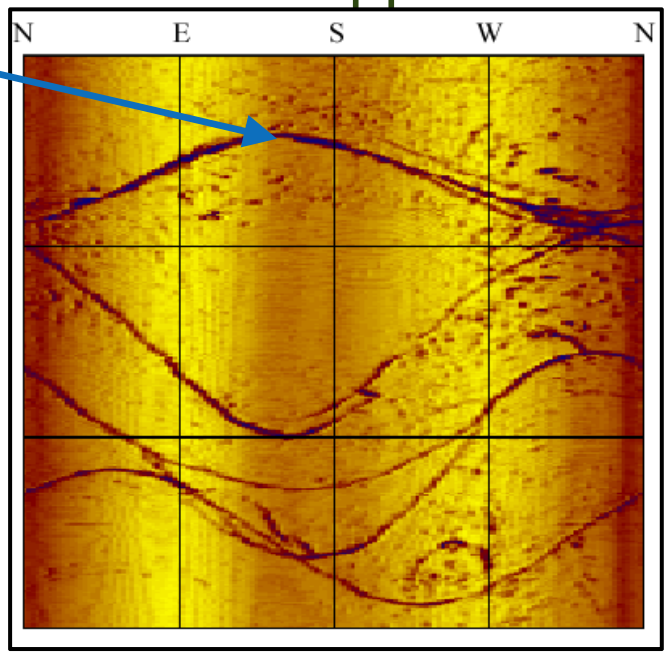
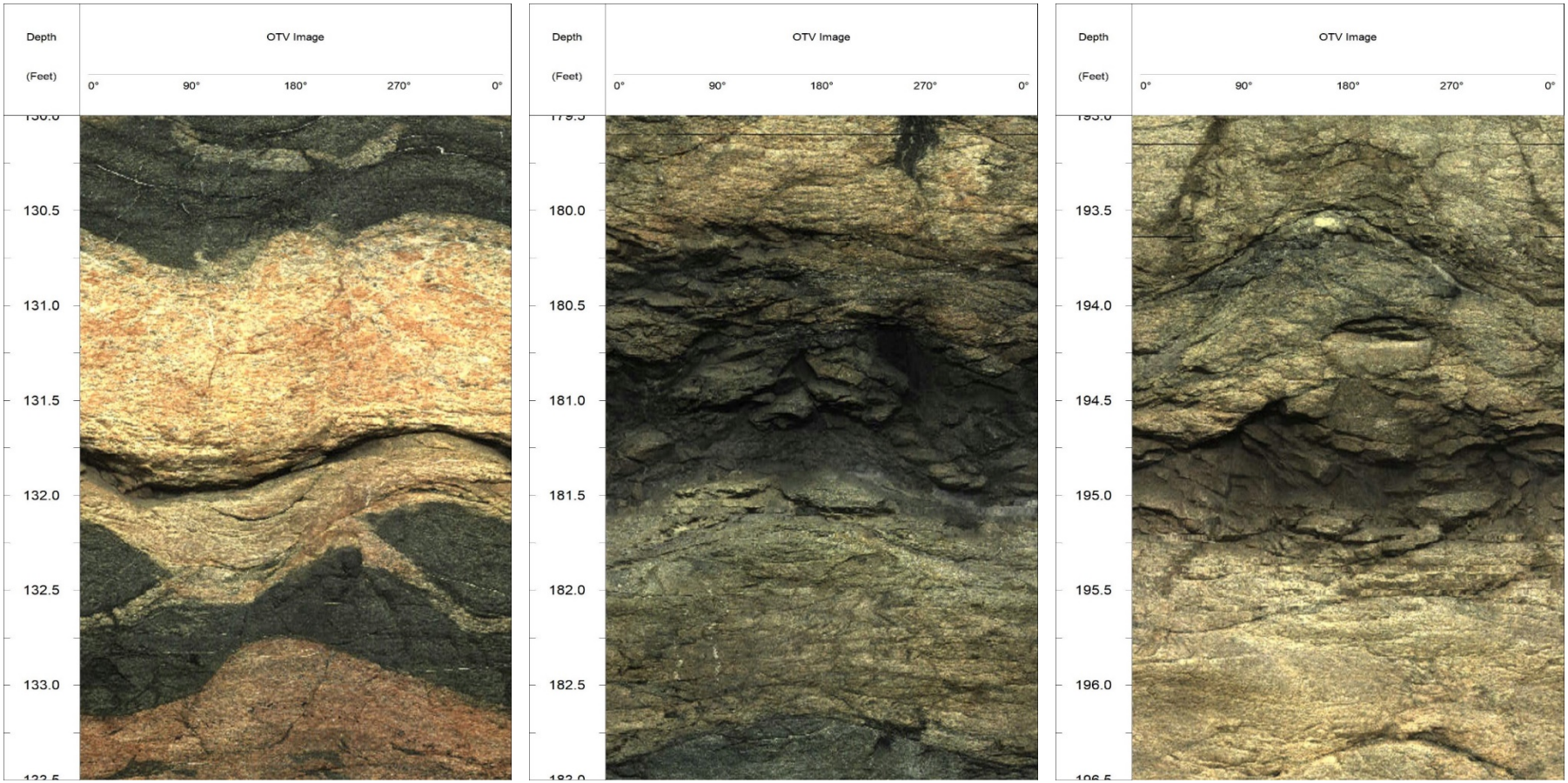


Courtesy of Jeff Reid,
Hager-Richter Assoc.

Optical Televiewer (OTV) Images



Courtesy of Jeff Reid,
Hager-Richter Assoc.

Benefits of Bringing Your A-GaME

Reduced Risk. Reducing uncertainties in subsurface conditions mitigates design and construction risks.

Improved Quality. Improving confidence in the geotechnical characterization reduces unnecessary conservatism in design and establishes a more reliable basis for design and construction of foundations and other geotechnical features impacting the highway system.

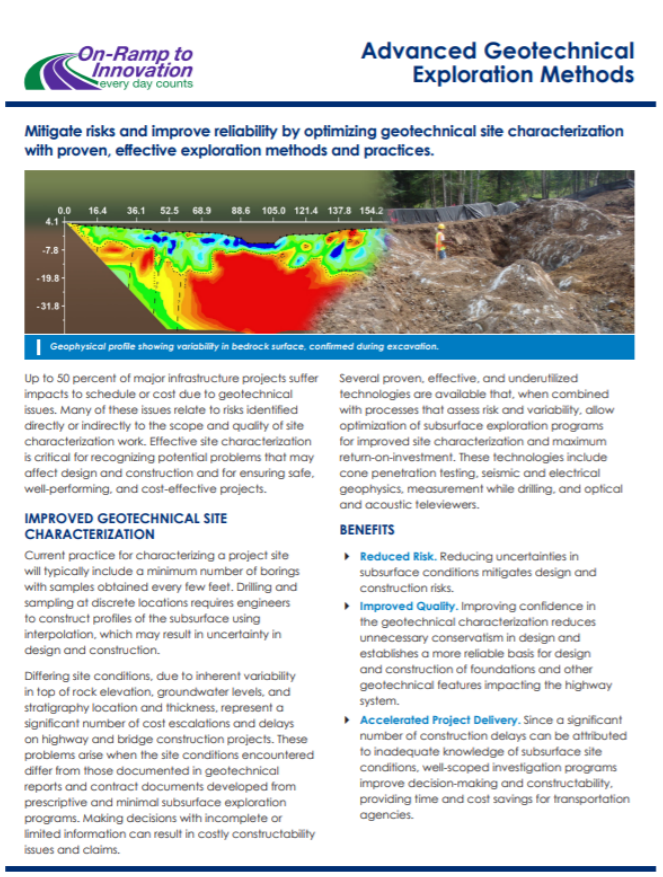
Accelerated Project Delivery. Since a significant number of construction delays can be attributed to inadequate knowledge of subsurface site conditions, well-scoped investigation programs improve decision-making and constructability, providing time and cost savings for transportation agencies.

Get Your A-GaME on!

https://www.fhwa.dot.gov/innovation/everydaycounts/edc_5/geotech_methods.cfm Or Search “FHWA EDC5”

benjamin.rivers@dot.gov

404-562-3926



On-Ramp to Innovation
every day counts

Advanced Geotechnical Exploration Methods

Mitigate risks and improve reliability by optimizing geotechnical site characterization with proven, effective exploration methods and practices.

Geophysical profile showing variability in bedrock surface, confirmed during excavation.

Up to 50 percent of major infrastructure projects suffer impacts to schedule or cost due to geotechnical issues. Many of these issues relate to risks identified directly or indirectly to the scope and quality of site characterization work. Effective site characterization is critical for recognizing potential problems that may affect design and construction and for ensuring safe, well-performing, and cost-effective projects.

IMPROVED GEOTECHNICAL SITE CHARACTERIZATION

Current practice for characterizing a project site will typically include a minimum number of borings with samples obtained every few feet. Drilling and sampling at discrete locations requires engineers to construct profiles of the subsurface using interpolation, which may result in uncertainty in design and construction.

Differing site conditions, due to inherent variability in top of rock elevation, groundwater levels, and stratigraphy location and thickness, represent a significant number of cost escalations and delays on highway and bridge construction projects. These problems arise when the site conditions encountered differ from those documented in geotechnical reports and contract documents developed from prescriptive and minimal subsurface exploration programs. Making decisions with incomplete or limited information can result in costly constructability issues and claims.

Several proven, effective, and underutilized technologies are available that, when combined with processes that assess risk and variability, allow optimization of subsurface exploration programs for improved site characterization and maximum return-on-investment. These technologies include cone penetration testing, seismic and electrical geophysics, measurement while drilling, and optical and acoustic televiewers.

BENEFITS

- **Reduced Risk.** Reducing uncertainties in subsurface conditions mitigates design and construction risks.
- **Improved Quality.** Improving confidence in the geotechnical characterization reduces unnecessary conservatism in design and establishes a more reliable basis for design and construction of foundations and other geotechnical features impacting the highway system.
- **Accelerated Project Delivery.** Since a significant number of construction delays can be attributed to inadequate knowledge of subsurface site conditions, well-scoped investigation programs improve decision-making and constructability, providing time and cost savings for transportation agencies.

EDC