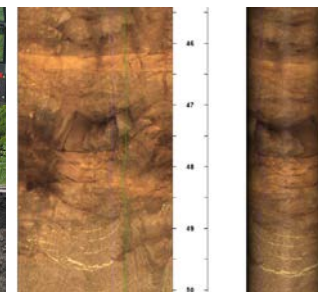
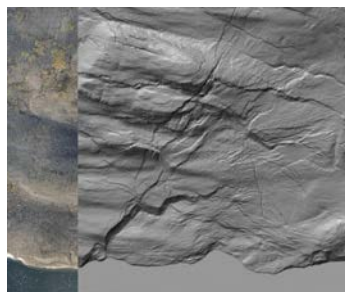
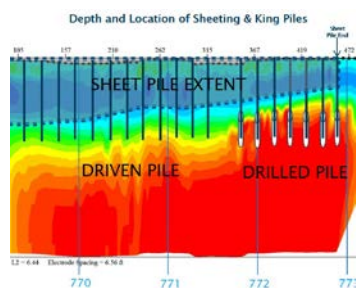


## Center for Accelerating Innovation



# Advanced Geotechnical Methods in Exploration (A-GaME)

Tools for Enhanced, Effective Site  
Characterization

# What are the Advanced Geotechnical Methods in Exploration?

The A-GaME is a toolbox of underutilized subsurface exploration tools that will assist with:

- Assessing risk and variability in site characterization
- Optimizing subsurface exploration programs
- Maximizing return on investment in project delivery

# Why do you need to bring your A-GaME?

- Because, in up to 50% of major infrastructure projects, schedule or costs will be significantly impacted by geotechnical issues!!
- The majority of these issues will be directly or indirectly related to the scope and quality of subsurface investigation and site characterization work.

# Presenters



Silas Nichols  
Principal Bridge  
Engineer –  
Geotechnical  
FHWA HQ



Derrick Dasenbrock  
Geomechanics/LRFD  
Engineer  
Minnesota DOT



Ben Rivers  
Geotechnical  
Engineer  
FHWA RC



# 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 5<sup>th</sup> 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

**Brian Lawrence** – FHWA-ME Div.

**Erik Loehr** – Univ. of Missouri

**Michelle Mann** – NMDOT

**Marc Mastronardi** - GDOT

**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



# Topics

- Overview of The A-GaME
  - Mission
  - Motivation, Benefits
  - Contrast Current Practice and The A-GaME
  - Featured Technologies in The A-GaME Toolbox
- State Experience
  - MNDOT Experience, Applications, Case-Examples
- Implementation
  - Vision
  - Discussion
    - What you want to see
    - How to maximize value to you

# Mission

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

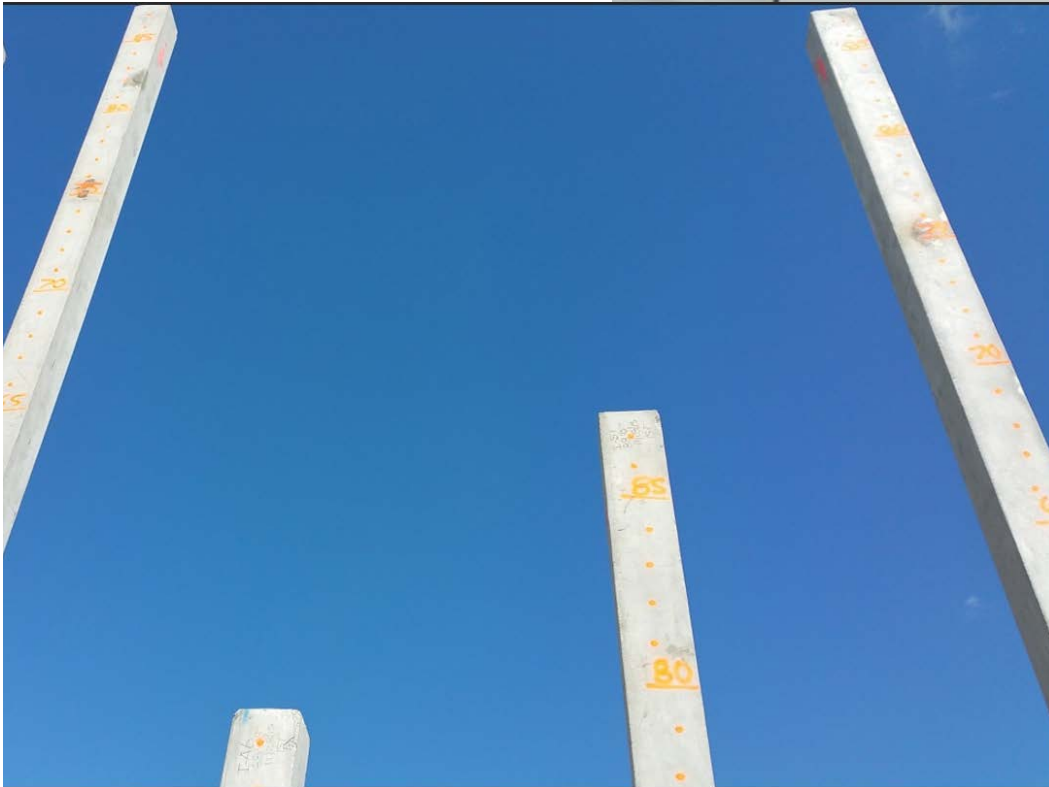
# Risk



Source: FHWA



# Risk



Source: Florida DOT



Source: Florida DOT



# Benefits of Bringing Your A-GaME

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

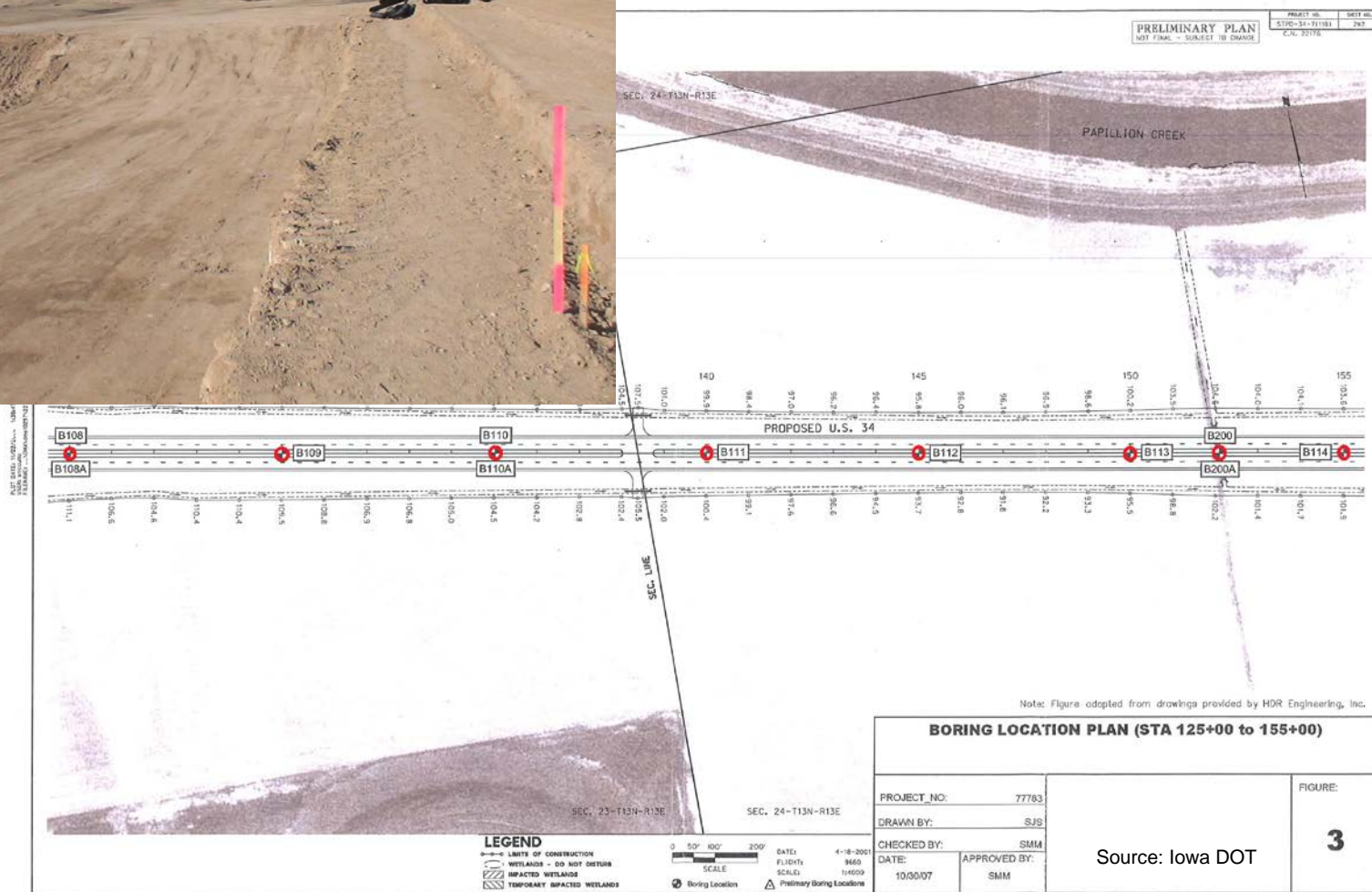
**Improved Quality.** Improving confidence in the geotechnical characterization reduces unnecessary conservatism in design and establishes a more reliable basis for design and construction of foundations and other geotechnical features impacting the highway system.

**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.

# Site Characterization – Current Practice



Source: FHWA



# Site Characterization – Current Practice

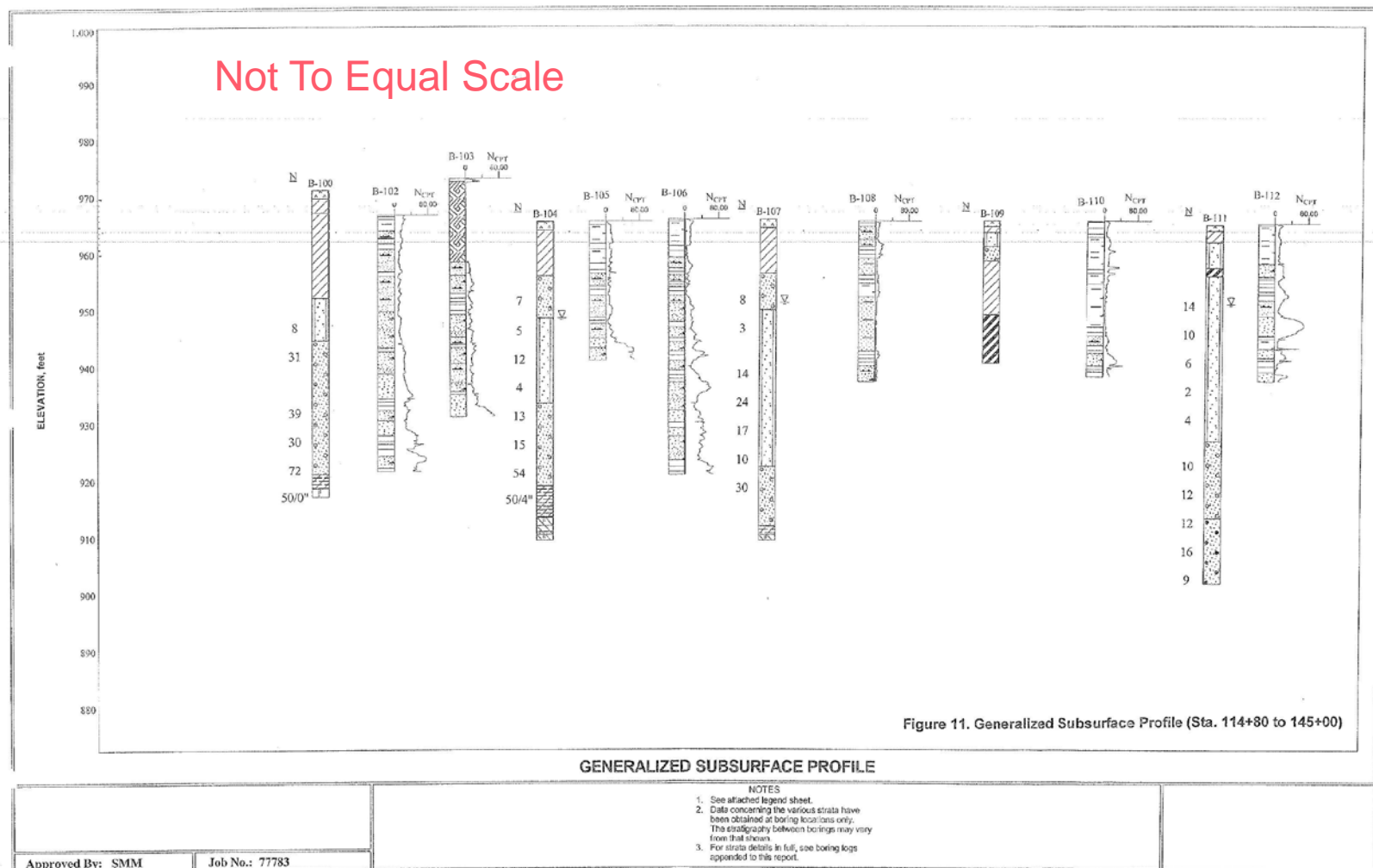
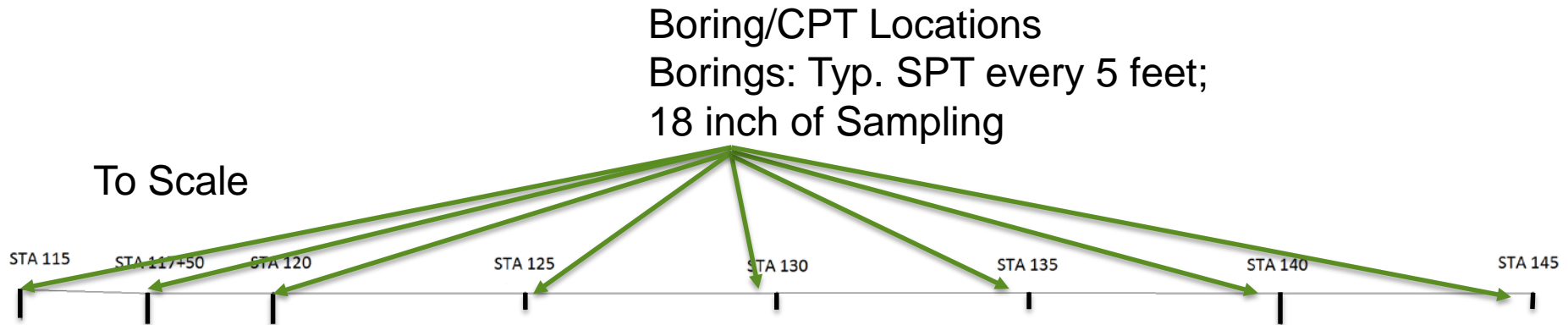


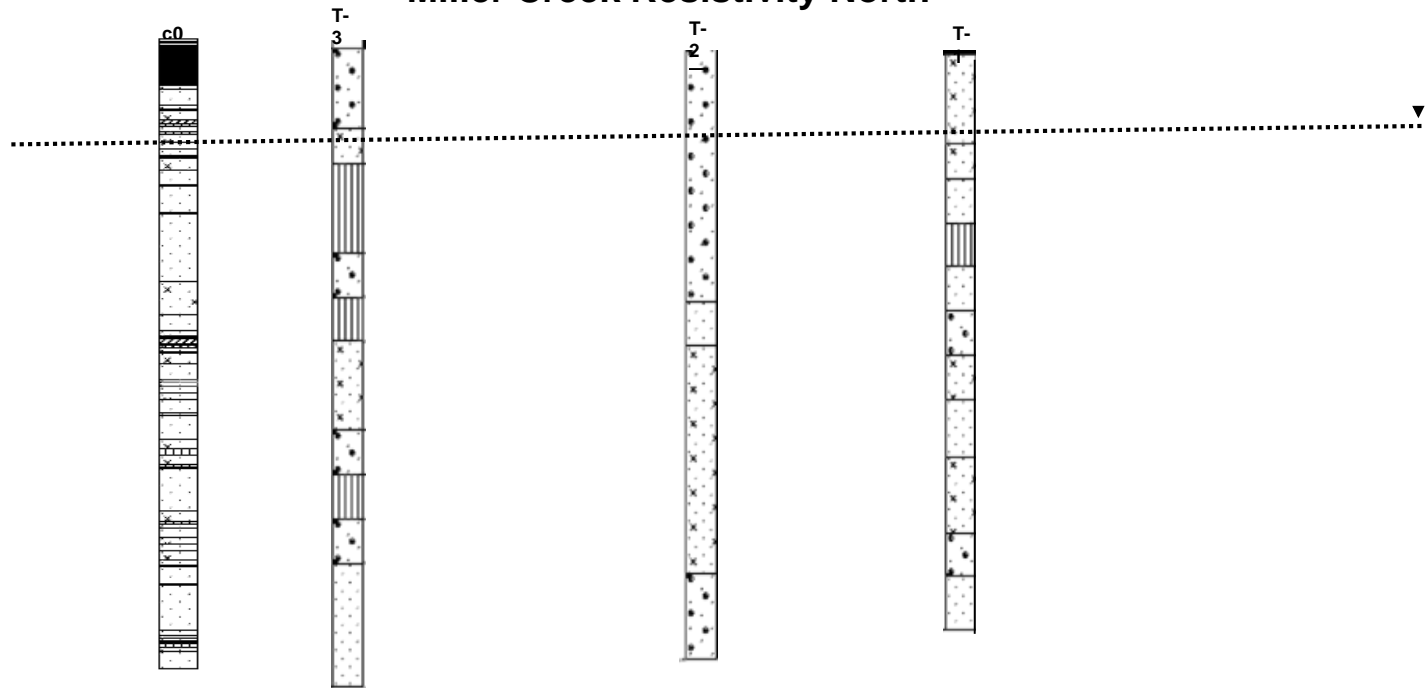
Figure 11. Generalized Subsurface Profile (Sta. 114+80 to 145+00)

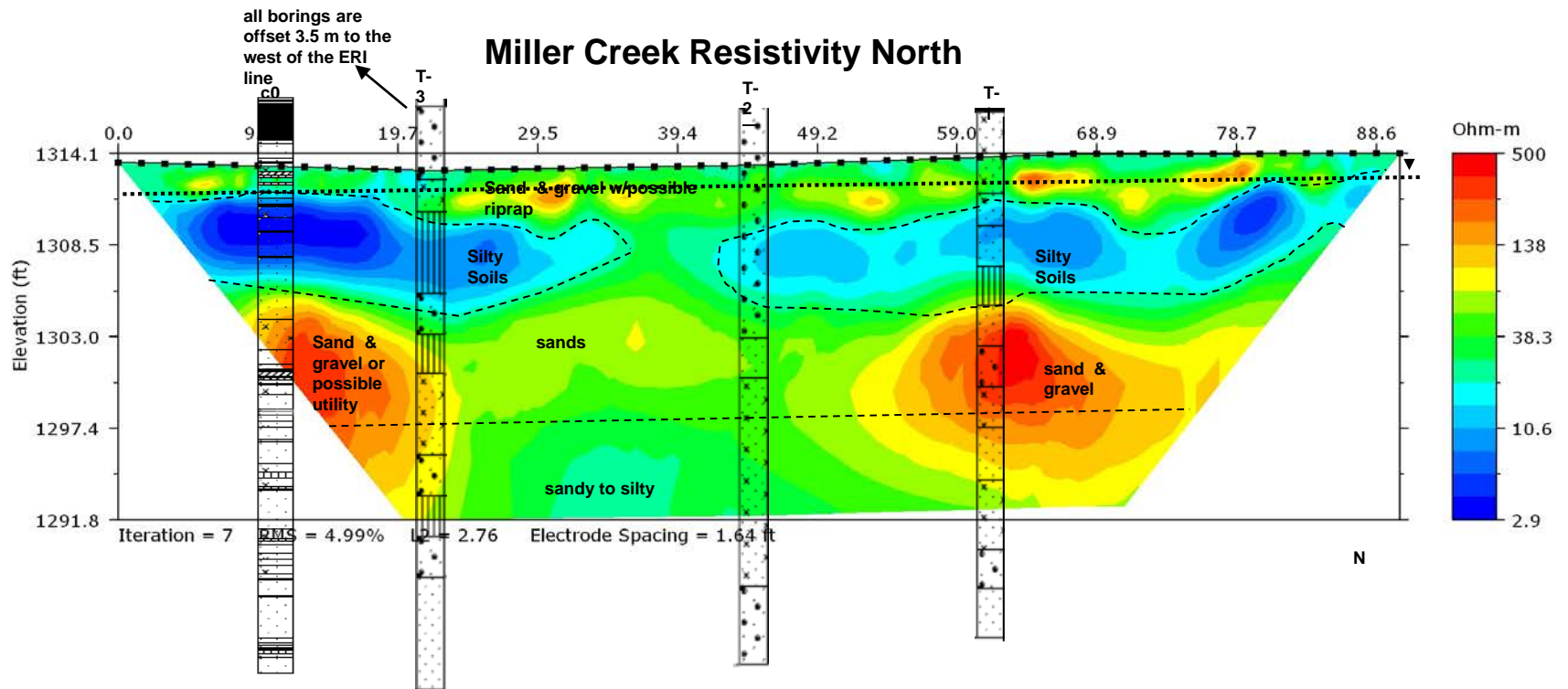
# Site Characterization – Current Practice



Total Volume Tested or Sampled < 0.01% (typically)

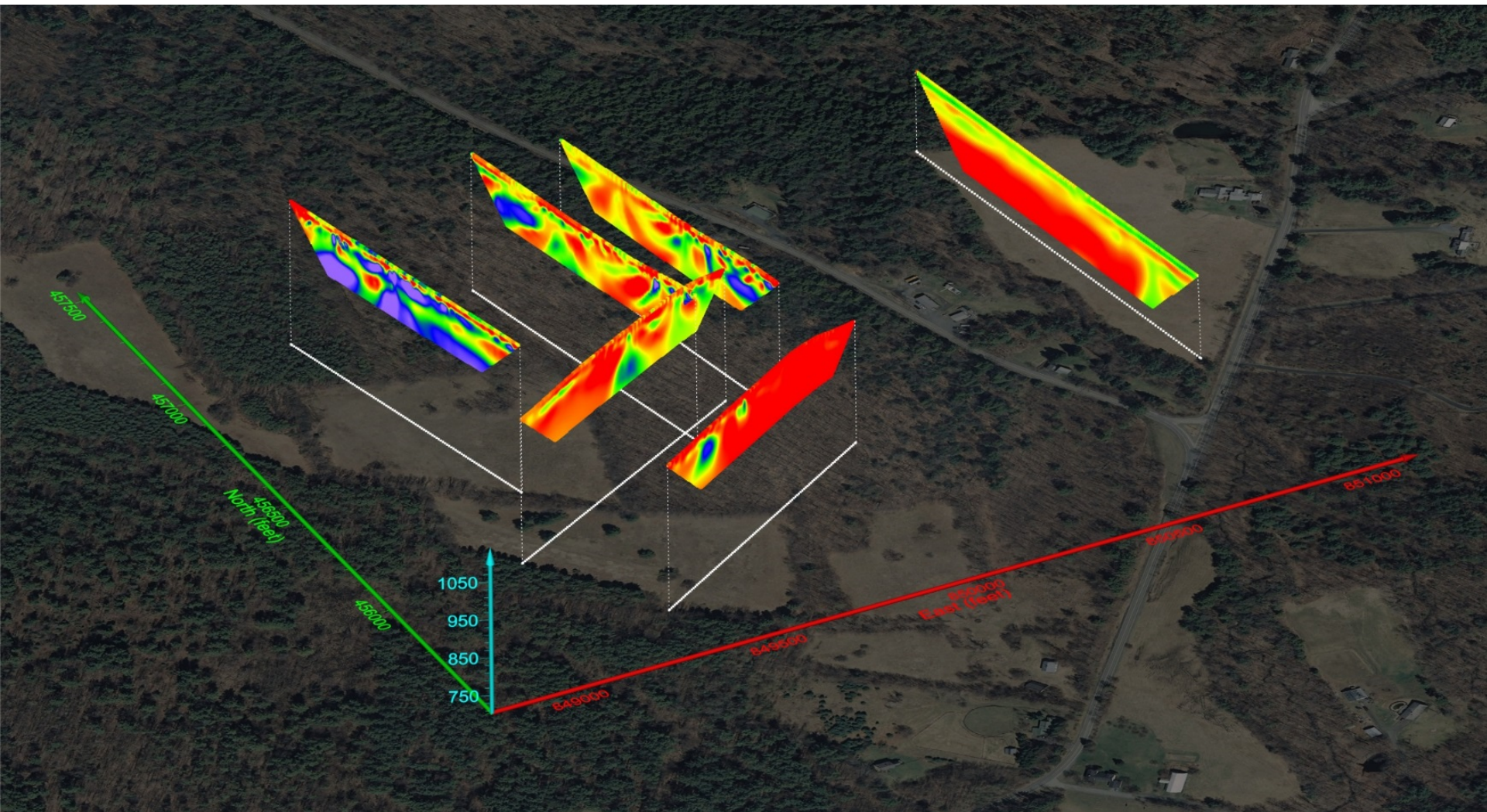
## Miller Creek Resistivity North







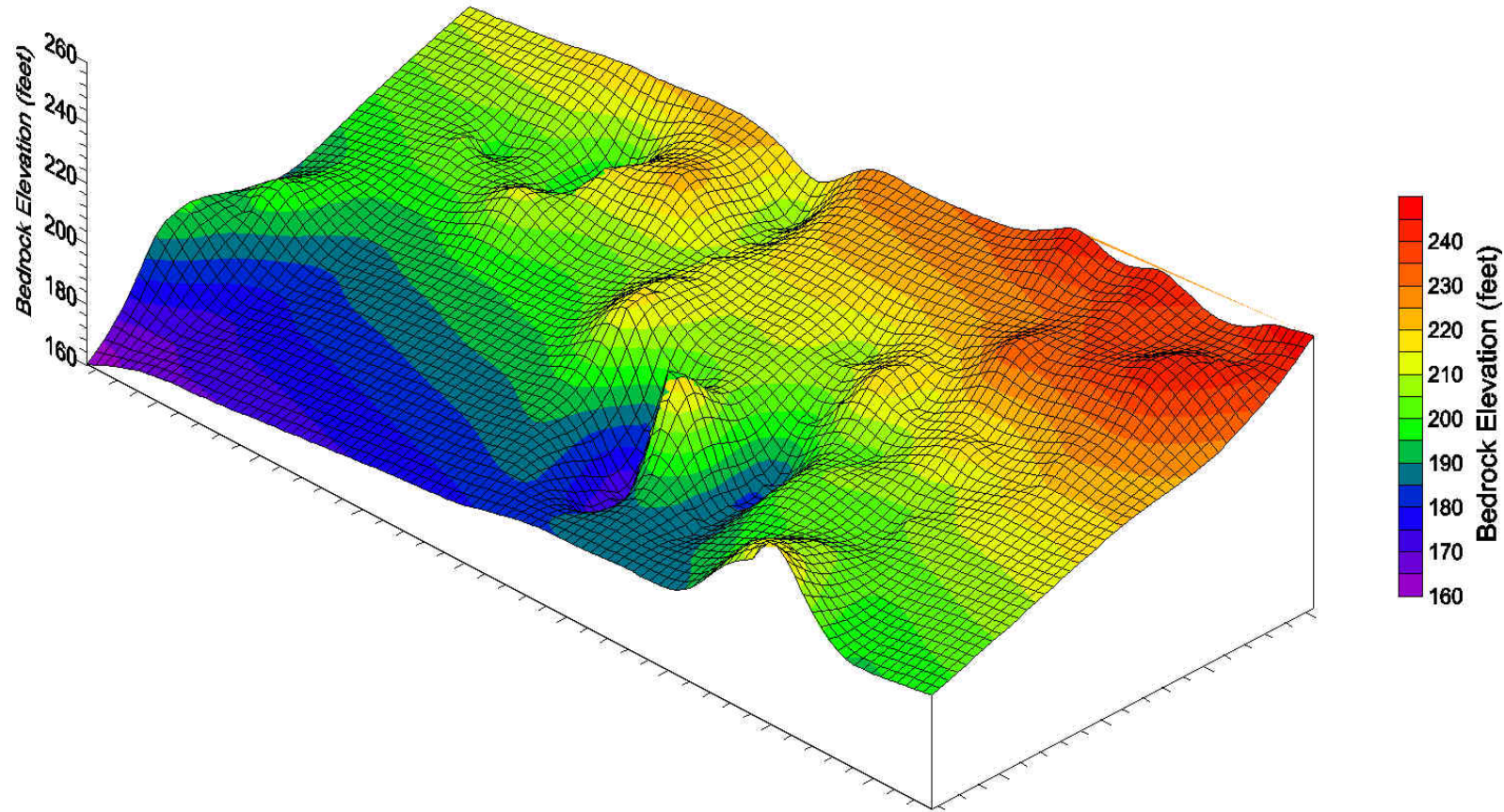
# Site Characterization – Bringing your A-GaME





# Site Characterization – Bringing your A-GaME

## Seismic Refraction – Top of Bedrock



# Site Characterization – Bringing your A-GaME

- 6-Mile Section
- 1-day Field Testing
- ½-day Processing

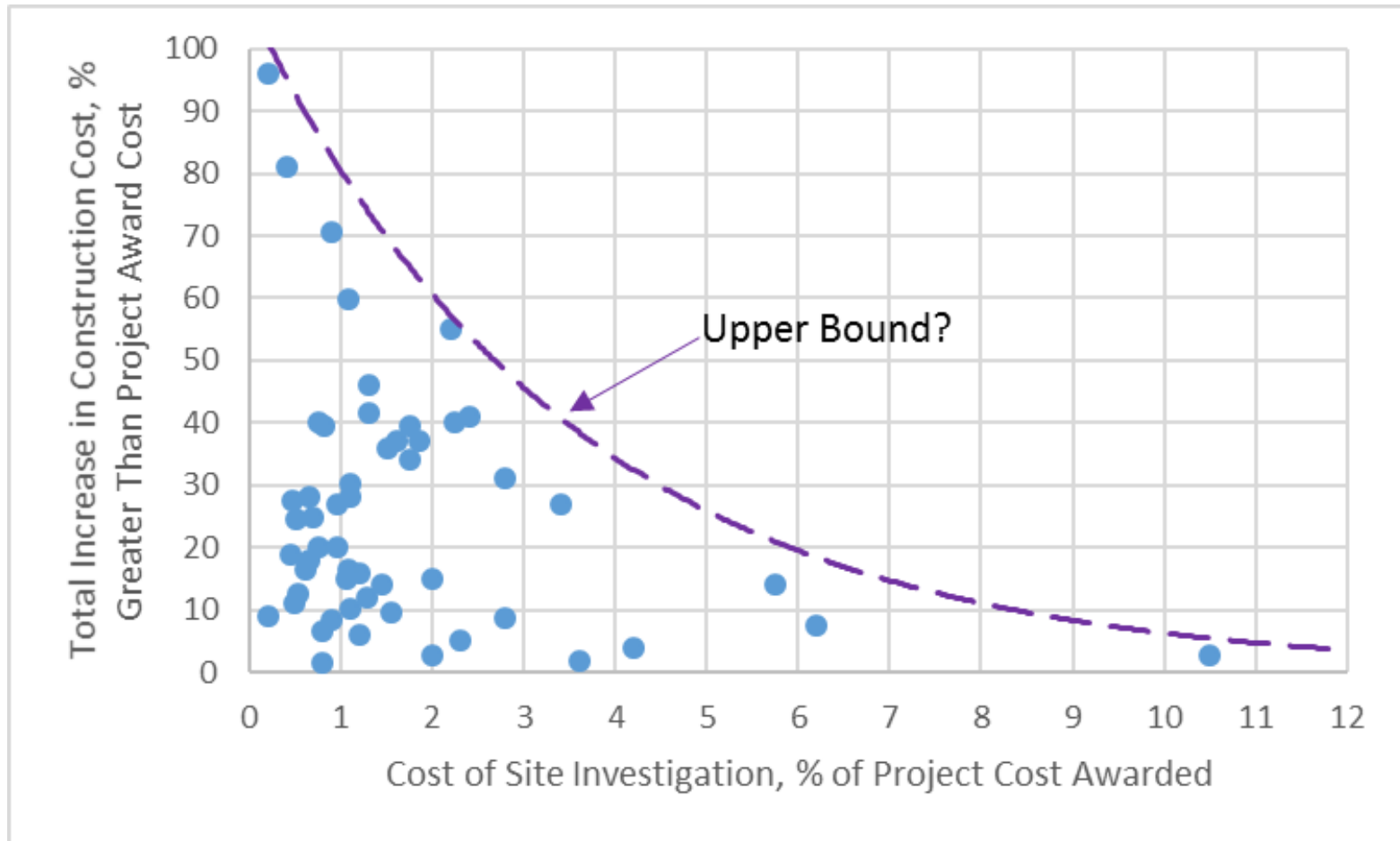
Confirm conditions

Concentrate additional investigation where most valuable



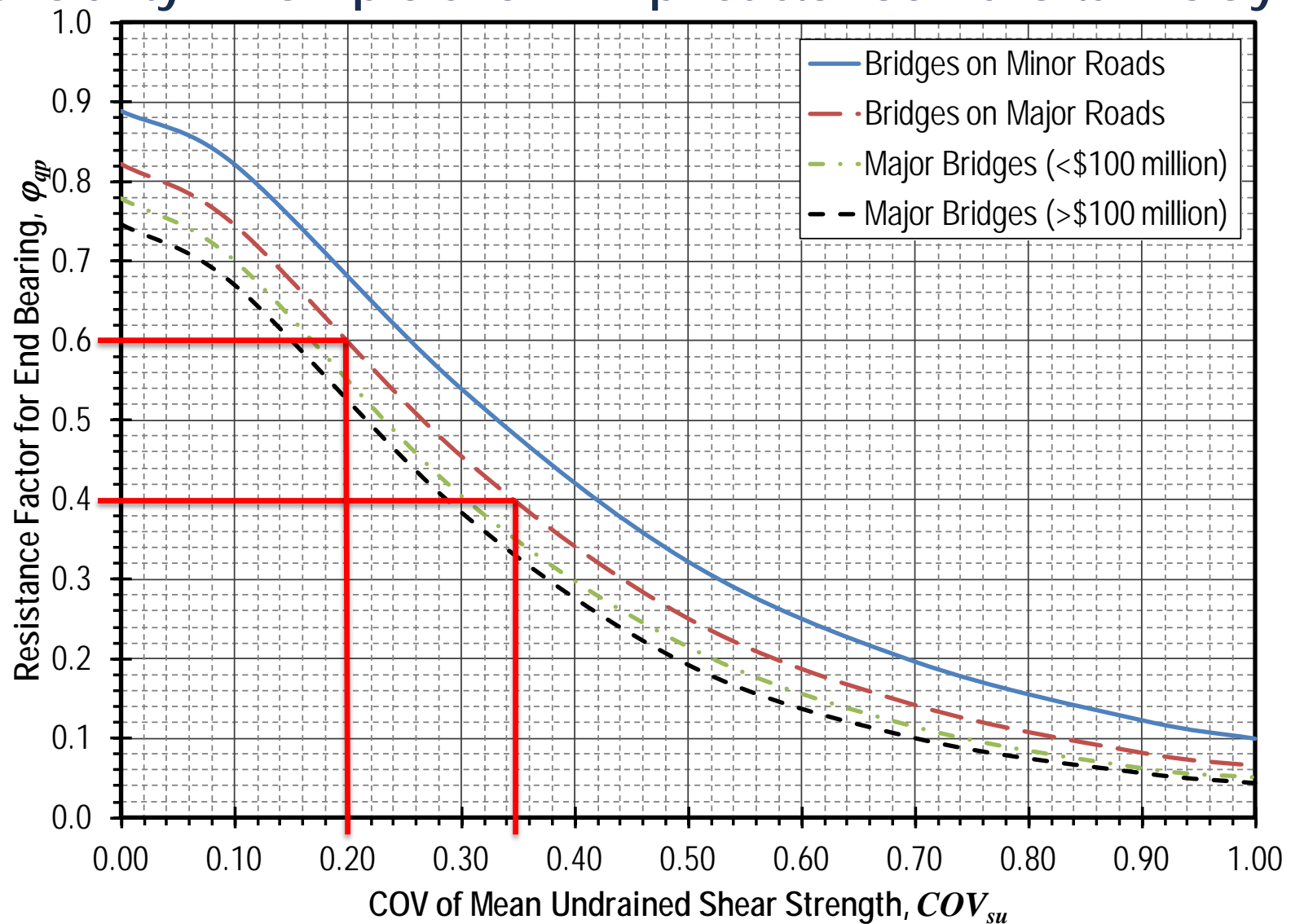
Source: Florida DOT

# 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





# Preliminary Planning – Site Investigation



# Featured Geotechnical Exploration Methods

Cone Penetration Test (CPT/SCPT)

Electrical Methods (ER, IP, SP)

Measurement While Drilling (MWD)

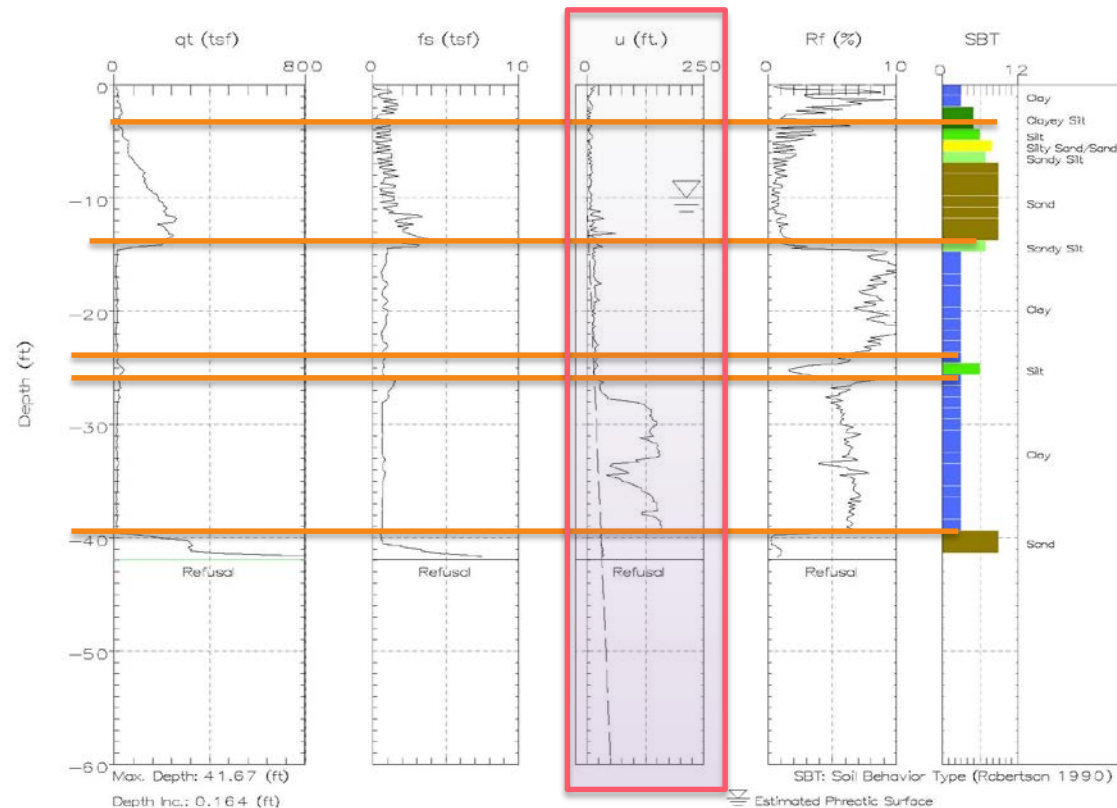
Seismic Methods (Refraction, Surface Waves, FWI, Tomography, Reflection)

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



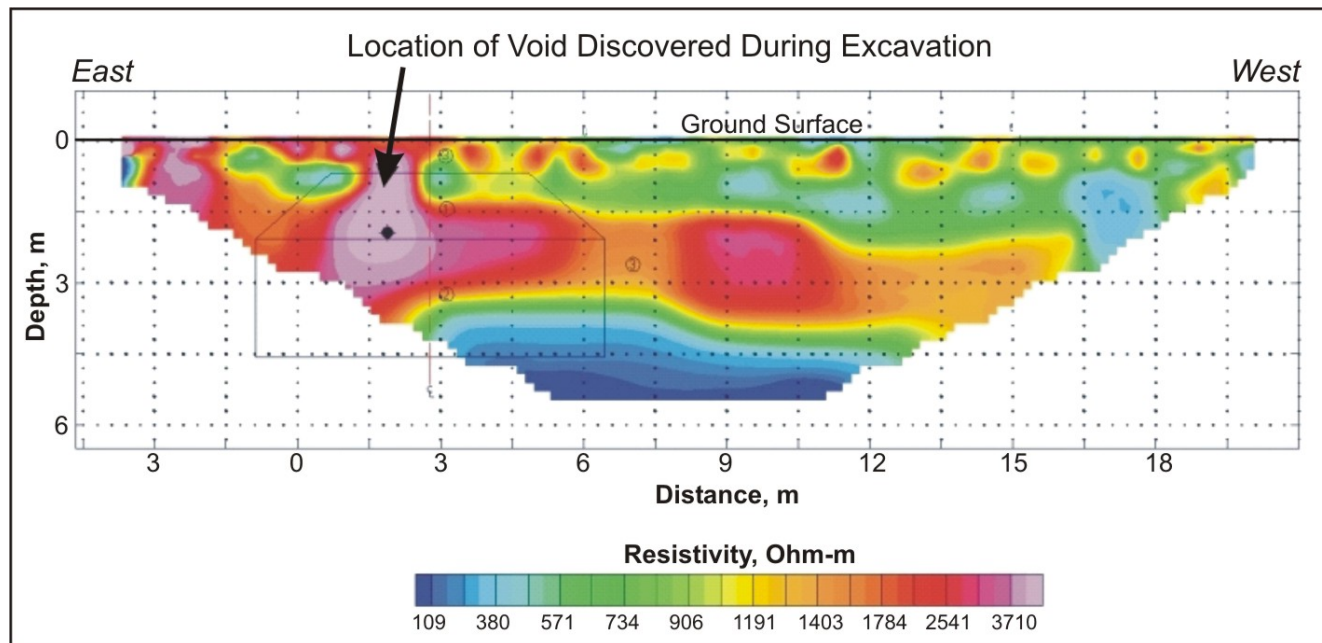
Source: FHWA



# 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

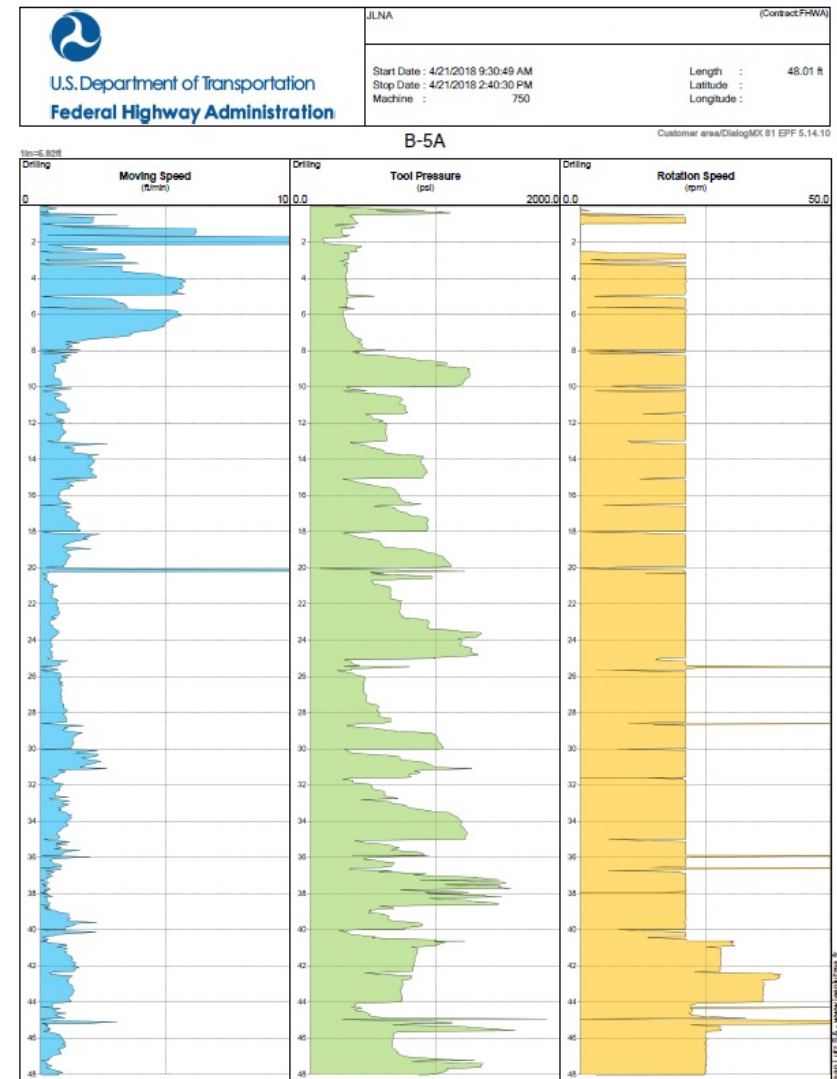


Source: FHWA-CFL

# Mainstream Effective Underutilized Methods

## Measurement While Drilling (MWD)

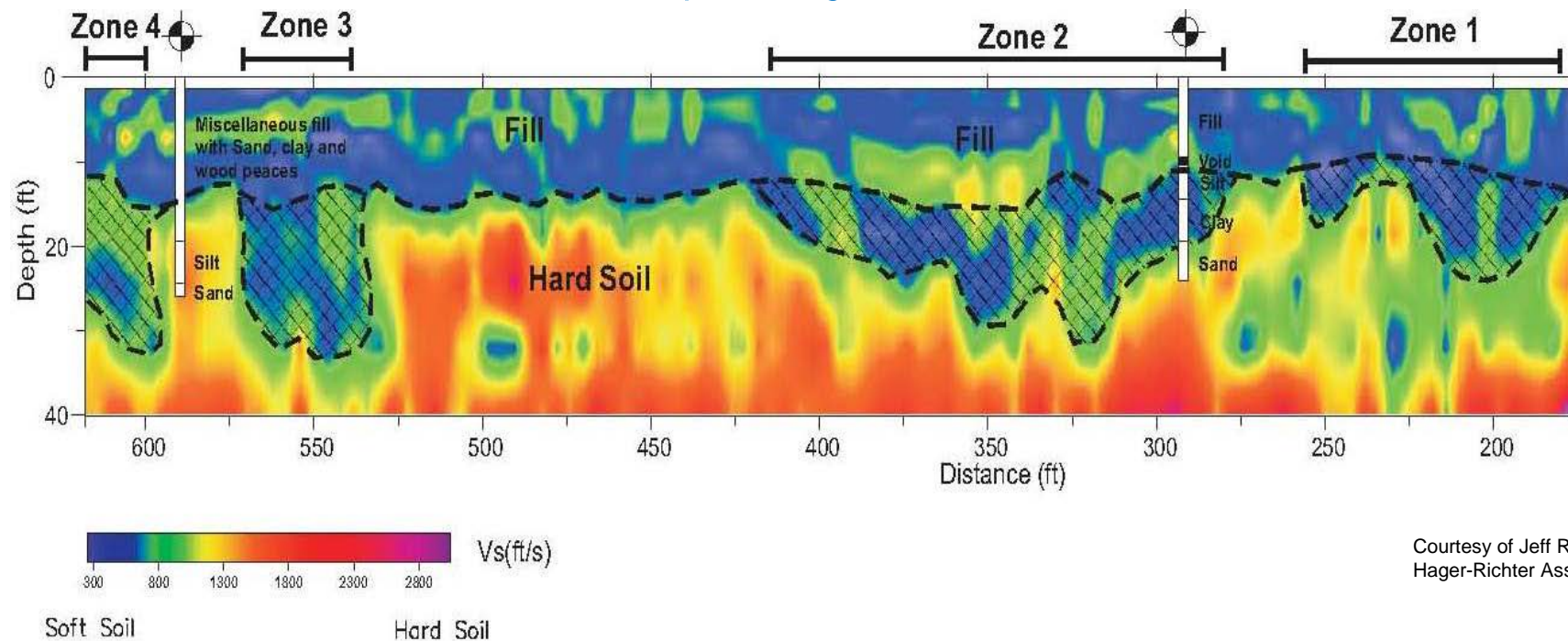
- Continuous profile
- Discernable stratigraphic and material changes
- Rock or Soil
- Standardized in Europe ISO 22476-15



# 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

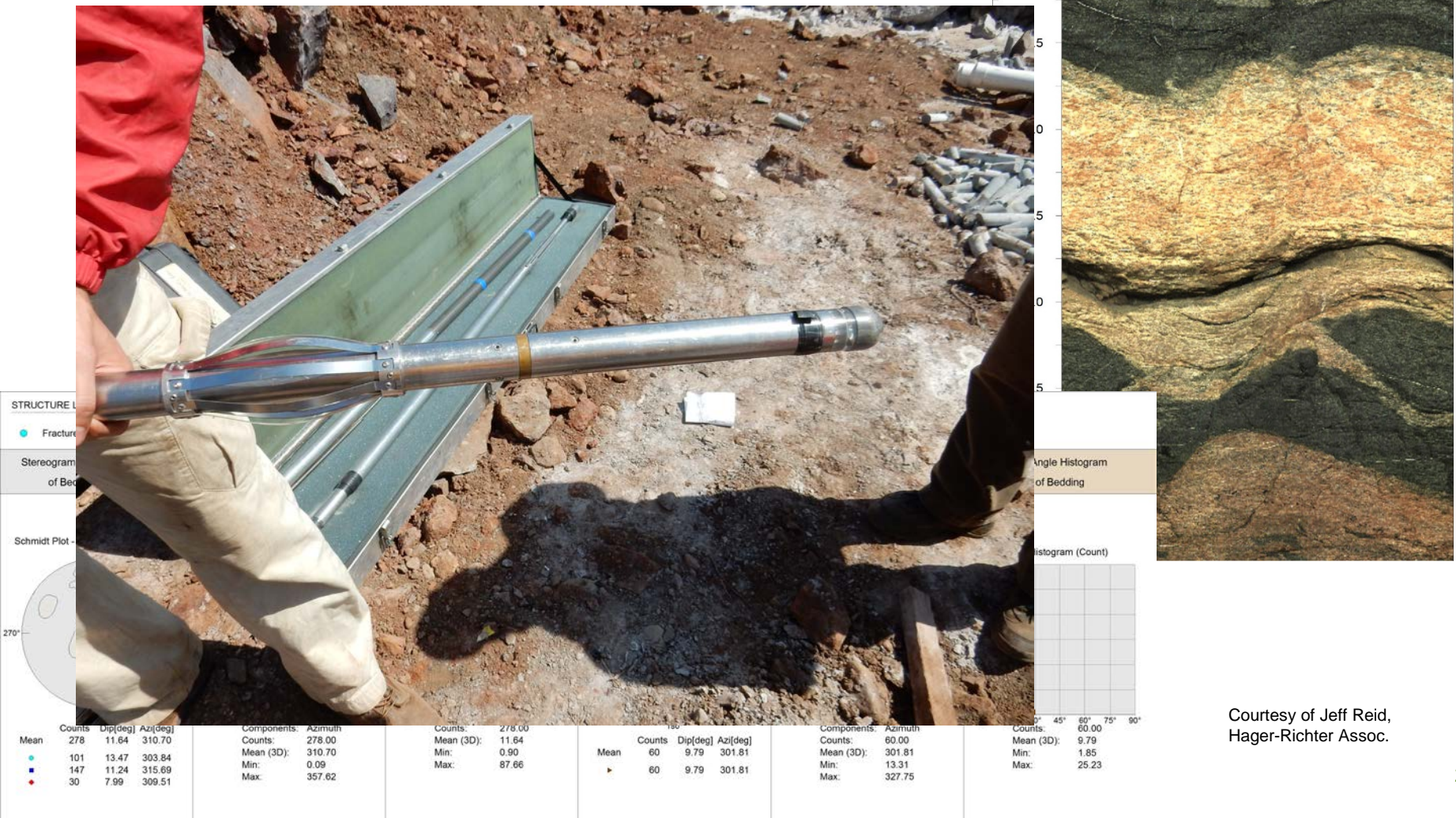


Courtesy of Jeff Reid,  
Hager-Richter Assoc.



# Mainstream Effective Underutilized Methods

## Televiewers – Optical and Acoustic (OTV/ATV)



Courtesy of Jeff Reid,  
Hager-Richter Assoc.

# ...So, Get Your A-GaME On and Consider the UNDERGROUND ROC<sub>3</sub>KED!

This toolbox will assist you with:

Reducing Risks, Uncertainties and Unknowns

Optimizing Characterization

Enhancing Design Reliability and Decisions

Knocking-Out Geo-Construction Delays and Cost Escalations





# Advanced Geotechnical Methods in Exploration: Enhanced, Effective, Site Characterization



**Highlights of how MnDOT adds project value through high quality site characterization: Geophysical methods and CPT**

Derrick Dasenbrock, P.E., F. ASCE  
Geomechanics/LRFD Engineer  
Minnesota DOT Office of Materials and Road Research





# MnDOT Geotechnical Section

- Subsurface Investigation
- In-Situ/Lab Testing
- Geotechnical Design/Analysis
- Geotechnical Data Reports and Design Recommendations
- Construction Assistance/Verification
- Standards + Specifications
- Performance Monitoring
- Geo-technology & Innovation Implementation

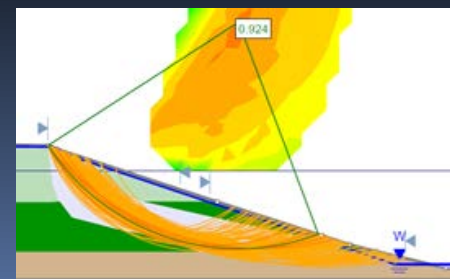
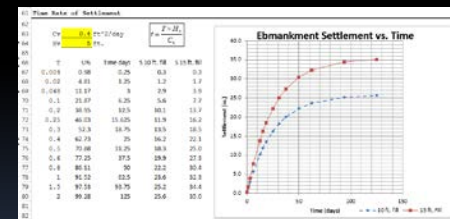
MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION  
LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 57448  
U.S. Customary Units

Date Project: 2/24/09 Bridge No. or Job Desc.: Statewide Road Highway: ST, State Route: 74  
Location: Goodhue County (4410217) N42E85W 19.1  
Latitude (NAD83): 45°57'34"N Longitude (NAD83): 94°17'07"W  
Sheet No.: 57448-1 of 1

Depth (ft)	Soil Description	Classification	SPF No.	AC No.	COH No.	Y No.	Formation or Member
0.0	Top of Road						
0.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 1: 1000 ft. to 1000 ft.
1.0	Gravelly sand, 10% to 20% gravel	SP-1	1				
1.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 2: 1000 ft. to 1000 ft.
2.0	Gravelly sand, 10% to 20% gravel	SP-1	1				
2.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 3: 1000 ft. to 1000 ft.
3.0	Gravelly sand, 10% to 20% gravel	SP-1	1				
3.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 4: 1000 ft. to 1000 ft.
4.0	Gravelly sand, 10% to 20% gravel	SP-1	1				
4.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 5: 1000 ft. to 1000 ft.
5.0	Gravelly sand, 10% to 20% gravel	SP-1	1				
5.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 6: 1000 ft. to 1000 ft.
6.0	Gravelly sand, 10% to 20% gravel	SP-1	1				
6.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 7: 1000 ft. to 1000 ft.
7.0	Gravelly sand, 10% to 20% gravel	SP-1	1				
7.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 8: 1000 ft. to 1000 ft.
8.0	Gravelly sand, 10% to 20% gravel	SP-1	1				
8.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 9: 1000 ft. to 1000 ft.
9.0	Gravelly sand, 10% to 20% gravel	SP-1	1				
9.5	Gravelly sand, 10% to 20% gravel	SP-1	1				Formation 10: 1000 ft. to 1000 ft.
10.0	Gravelly sand, 10% to 20% gravel	SP-1	1				

Index Sheet Code: 2



# Geotechnical Design Purpose

- Life Cycle Performance
  - Meet the design requirements
    - Strength + Serviceability
    - Settlement + Deformation/stability
    - Reliability and extreme events
- Typical DOT Assets
  - Bridges, tunnels, walls
  - Culverts and channels
  - Embankments and slopes
  - Buildings, signs, and towers



# Geotechnical Timelines

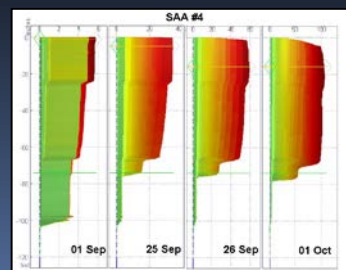
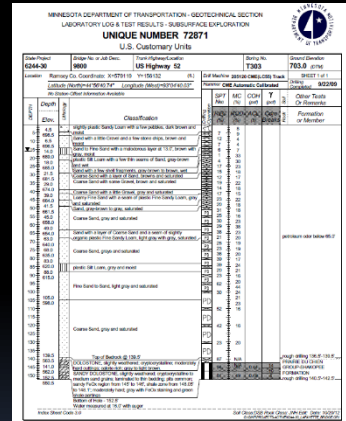
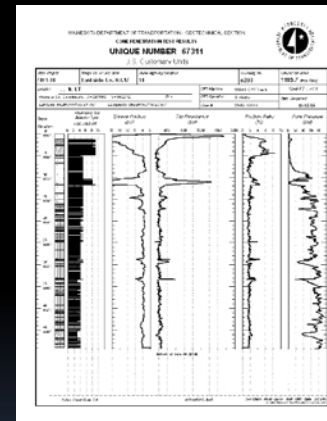
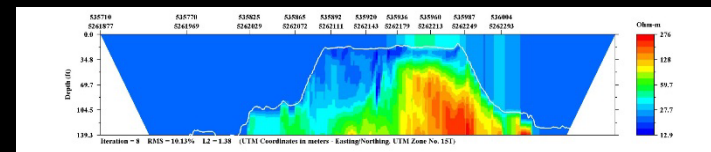
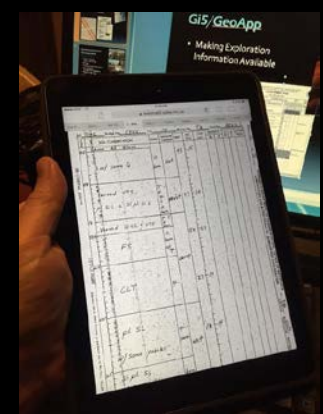
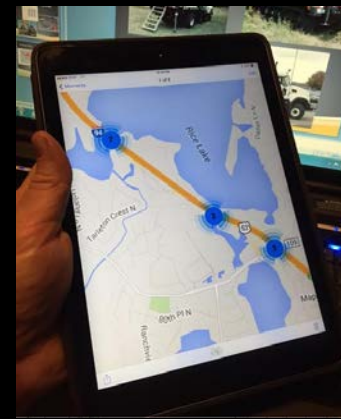
- Scoping
- Pre-Design
- Final-Design
- Pre-Bid
- Pre-Construction
- Construction
- Post-Construction
- In Service
- Forensic/Litigation





# Site Investigation

- Existing Information
- Exploration Geophysics
- Cone Penetration Testing
- SPT (Rotary Drilling, In-situ testing, and Sampling)
- Quality Lab Testing
- Remote Sensing
- Performance Monitoring



# Site Investigation

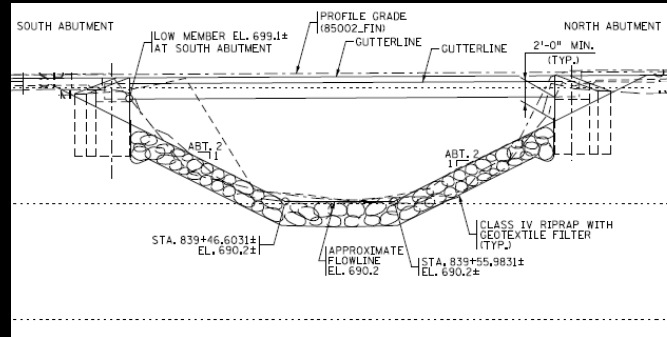
- Purpose
  - Solve the Site Challenges
    - Performance
    - Cost + Cost Estimates
    - Risk + Reliability
  - Develop Requirements and Specifications
    - Means and Methods
    - Performance Specifications
    - Traditional and Alternative Procurement





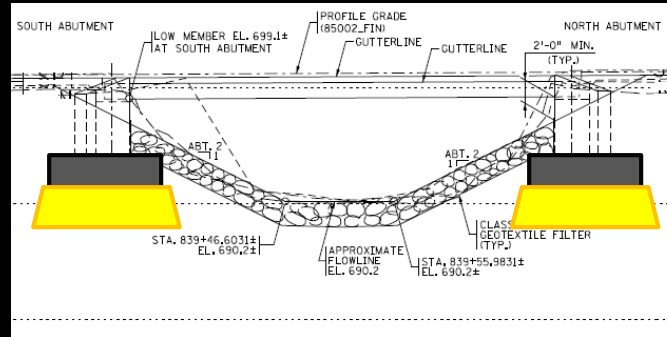
# Adding Project Value

## The Project (Preliminary Design):



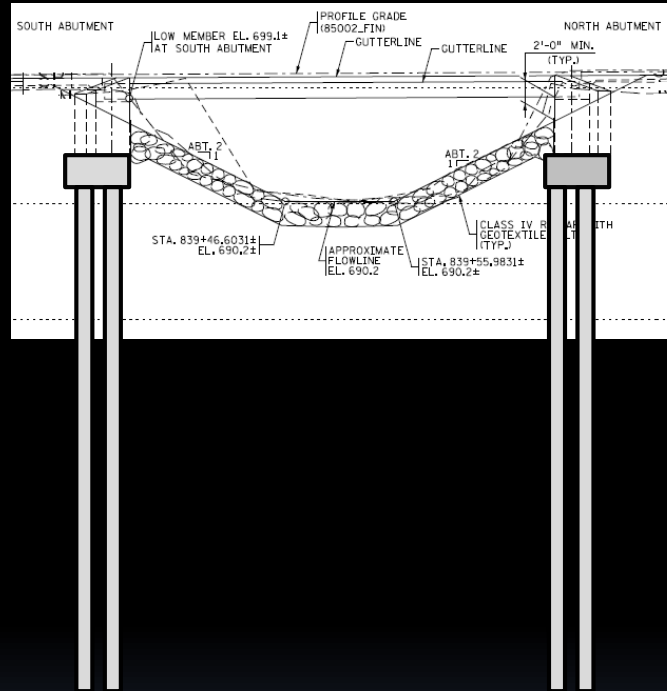
# Adding Project Value

## Site Characterization: Foundation Selection



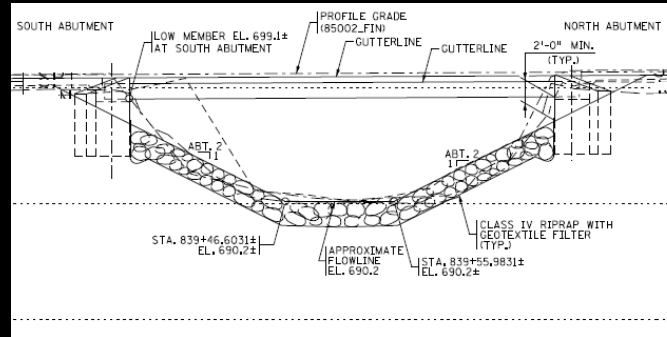
# Adding Project Value

## Site Characterization: Foundation Selection



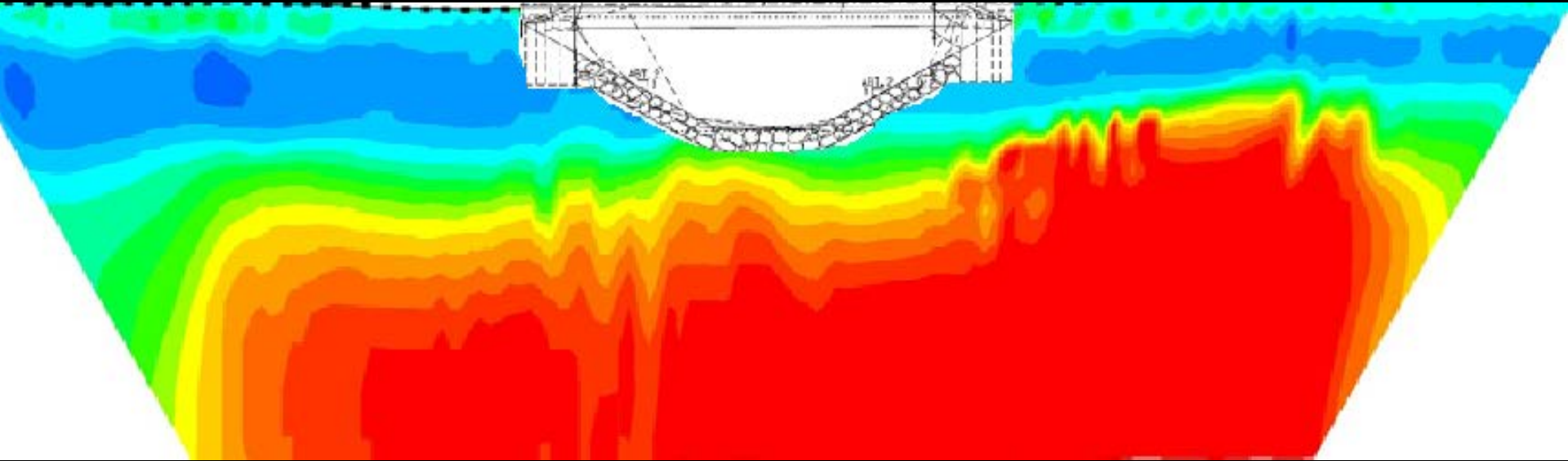
# Adding Project Value: Geophysics

Foundation Selection: Information is needed for efficient + reliable design



# Adding Project Value

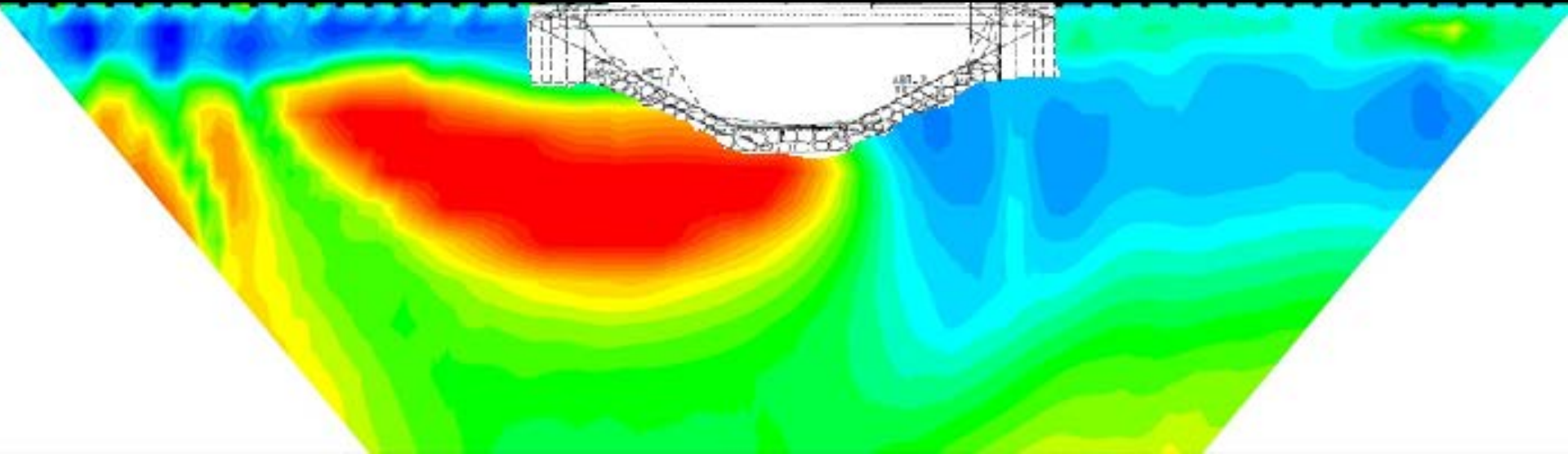
Exploration Geophysics: Assessing site variability





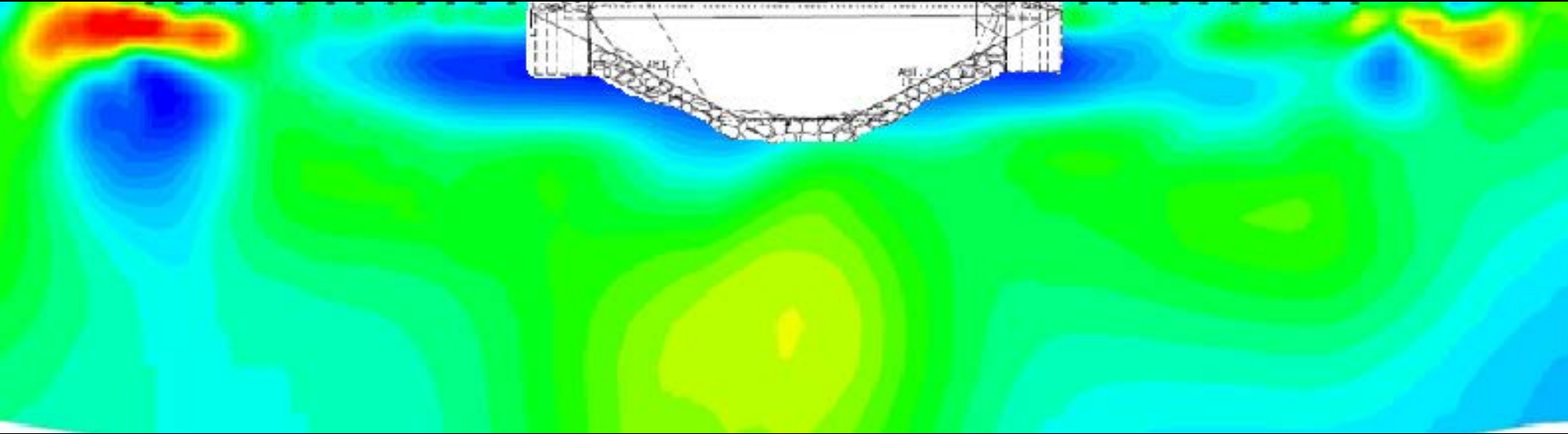
# Adding Project Value

Exploration Geophysics: Assessing site variability



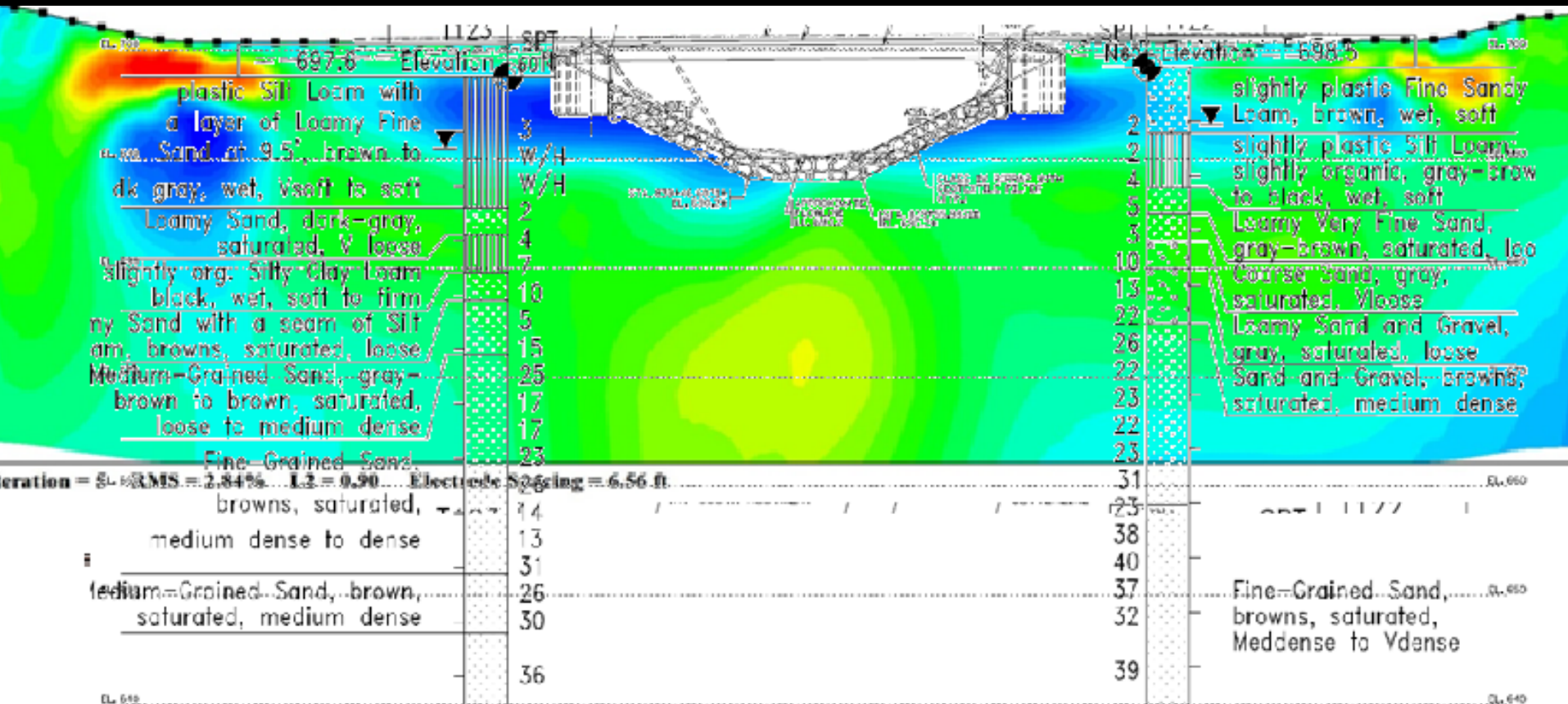
# Adding Project Value

Exploration Geophysics: Assessing site variability



# Adding Project Value

Using additional tools in the geotechnical toolbox





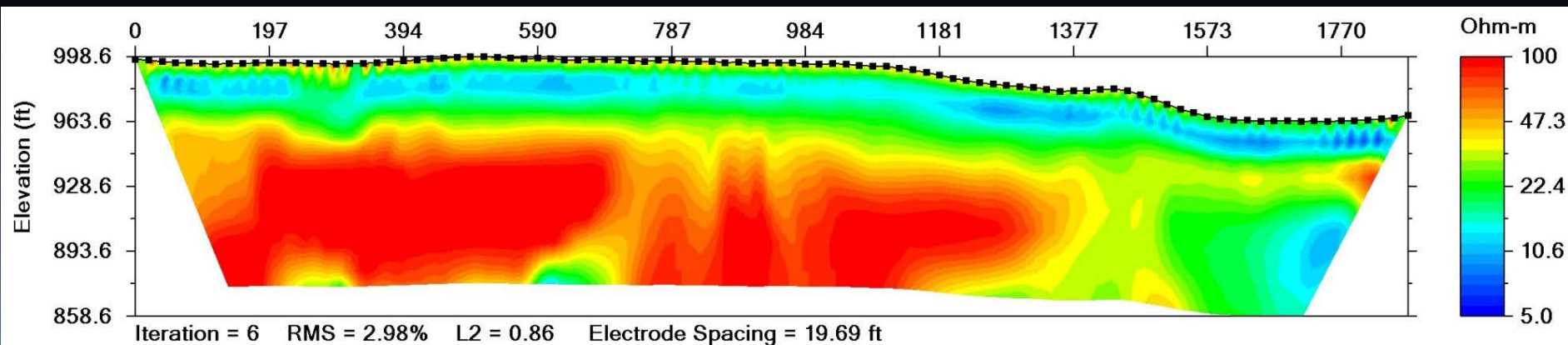
# Geophysics for preliminary design

- Project Scoping



# Geophysics for preliminary design

- Improves geospatial assessment of variability
  - Provides useful information to “target” or compliment soundings/drilling
  - Fast and comparatively inexpensive





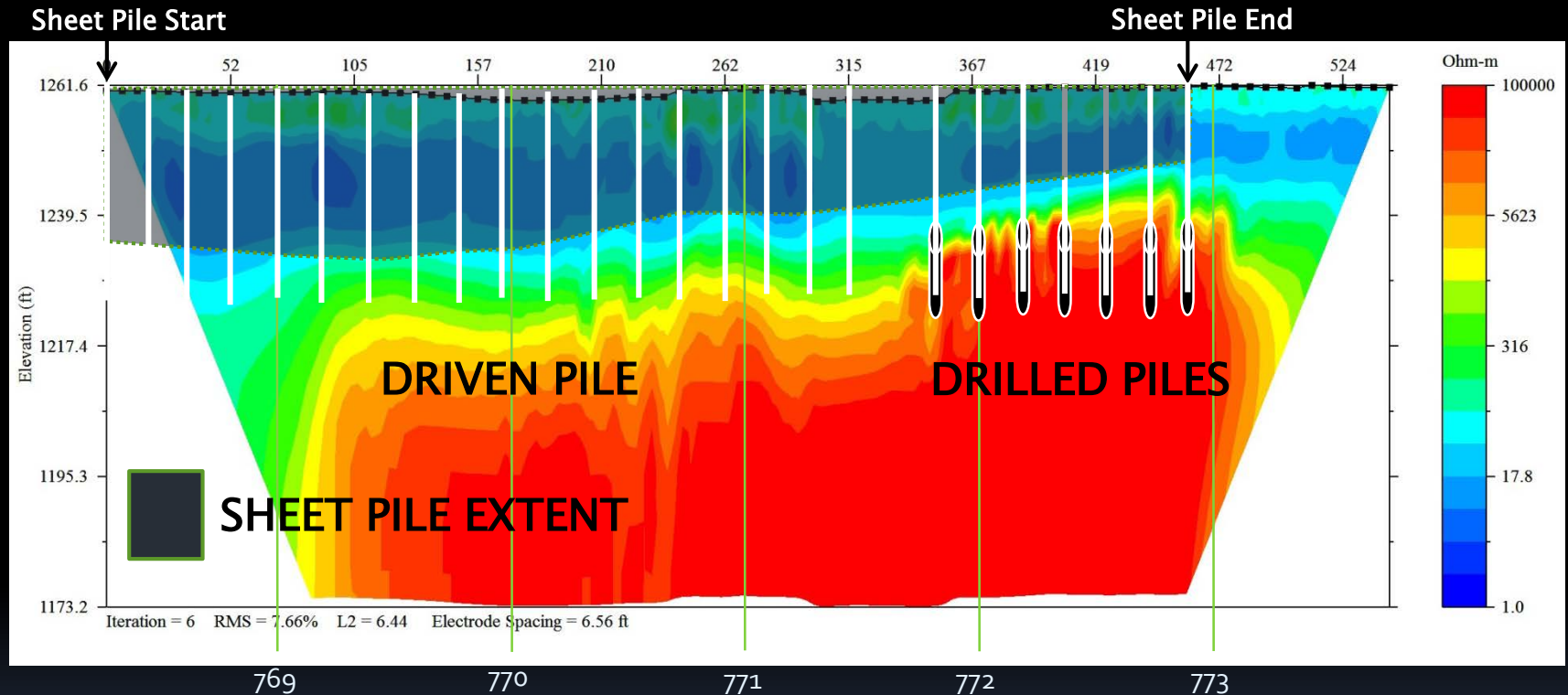
# Geophysics for final design

US 53 Slope Stability Solution, Ash Lake, MN



# Geophysics for final design

Applying geophysics to pile design/layout



Depth and location of sheeting & king piles



# Geophysics for final design

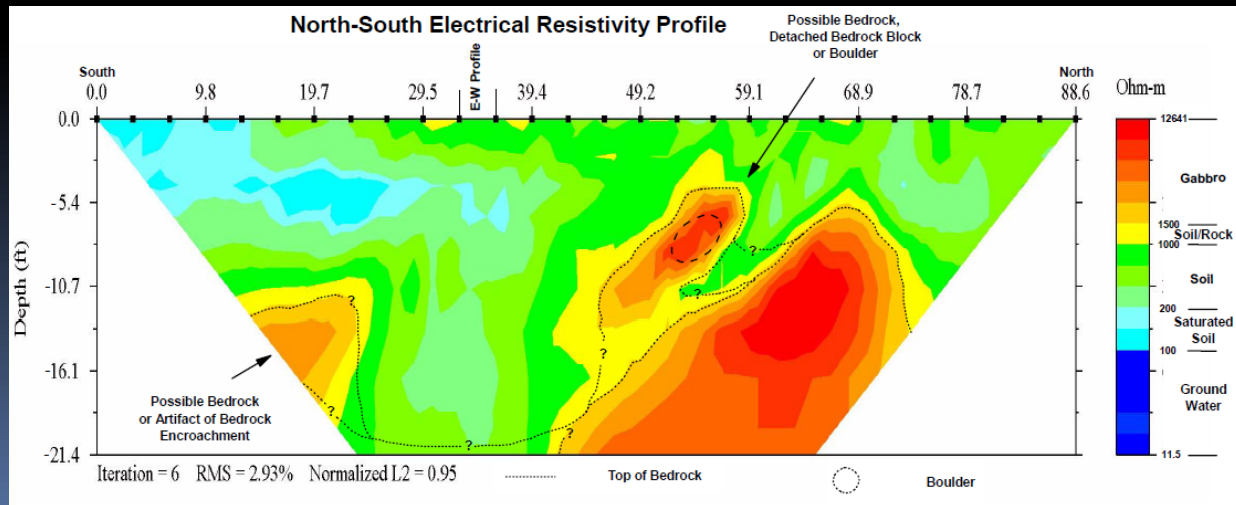
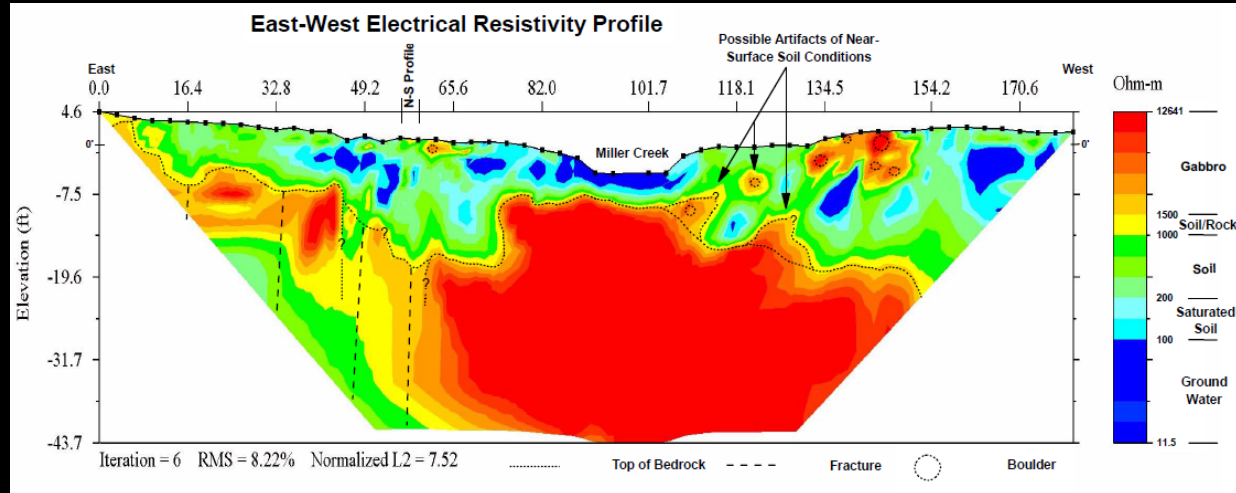
BR 69656, US 53 @ Kohl's, Duluth, MN





# Geophysics for final design

Clearly showed the near-surface bedrock location and variability. The designers and contractors knew what to expect; the spread footing foundation was specifically designed to accommodate variable bedrock.



# Geophysics for final design

Only electrical resistivity was used as the foundation investigation tool for this bridge

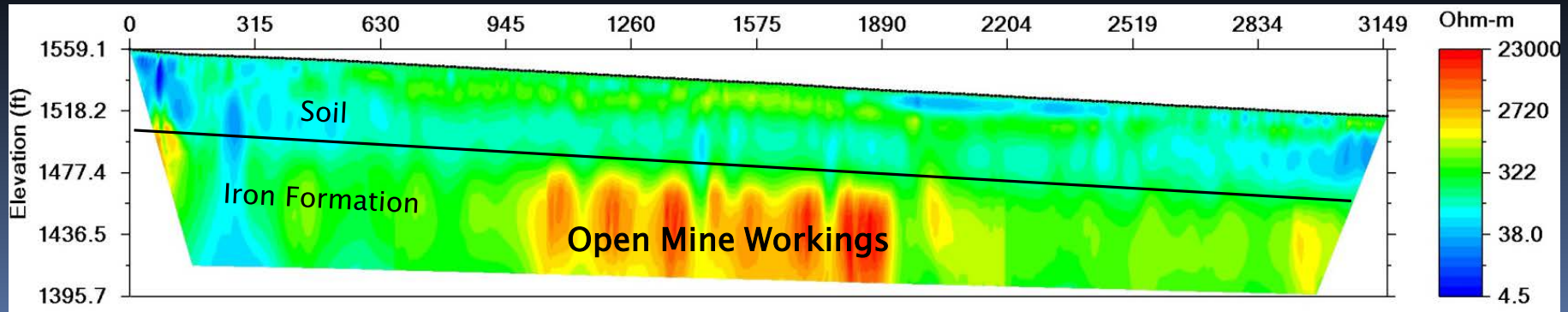




# Geophysics for risk assessment

- Valuable screening technique

- Systems can be selected and configured for optimum resolution with depth
- Excellent for linear features such as roadways



# Cone Penetration Testing (CPT)

Provides direct, electronic, in-situ geotechnical measurements for design  
Measurements can be used directly or to compliment borings and lab testing





# CPT (Cone Penetration Testing)

## Benefits

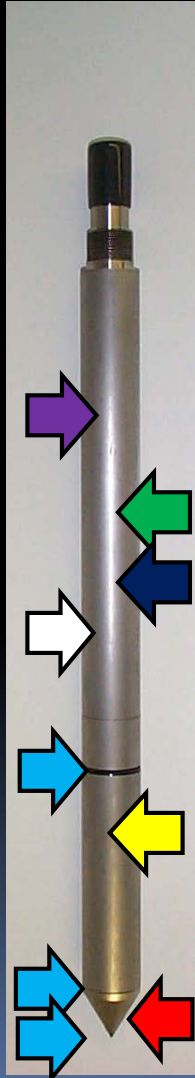
- Speed
  - Footage (150-500 ft. day); 3-10x faster than hollow-stem borings
- Provides a near-continuous soil profile
- Quality: Very repeatable results
- Direct measurements\*
- Many correlated parameters\*
- Native electronic data [direct design]
- Reduced fleet size / smaller crew
- Increased safety

\*Discussed shortly



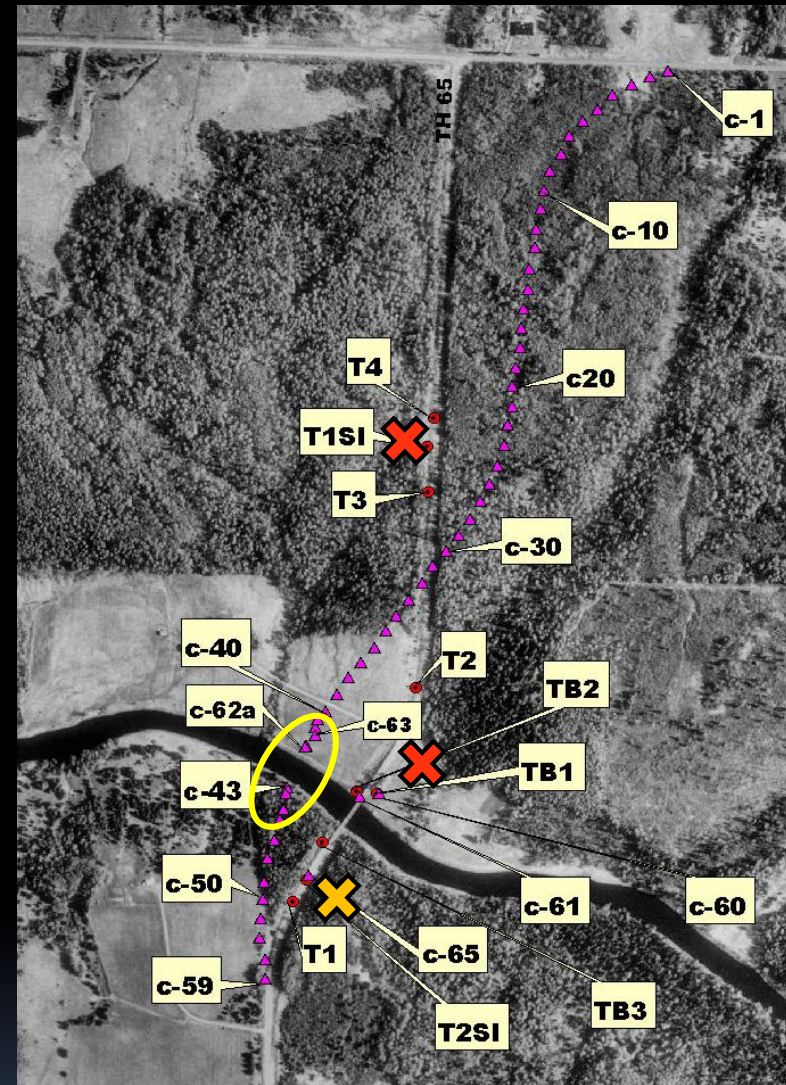
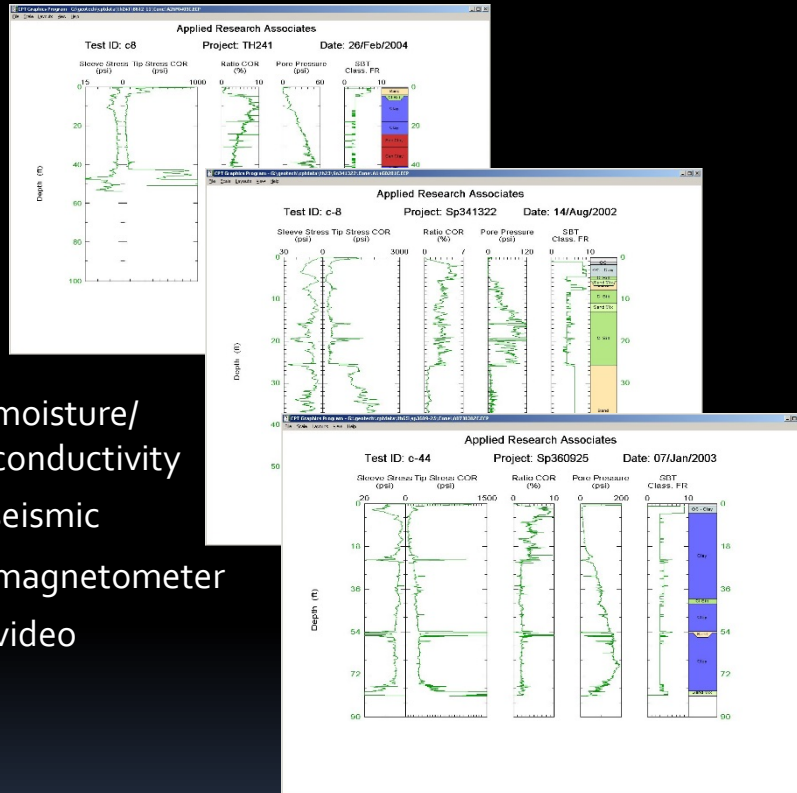
# CPT (Cone Penetration Testing)

Data is different from soil borings; it provides more, and higher quality, measurements



moisture/  
conductivity  
seismic  
magnetometer  
video

sleeve  
pore  
pressure  
tip

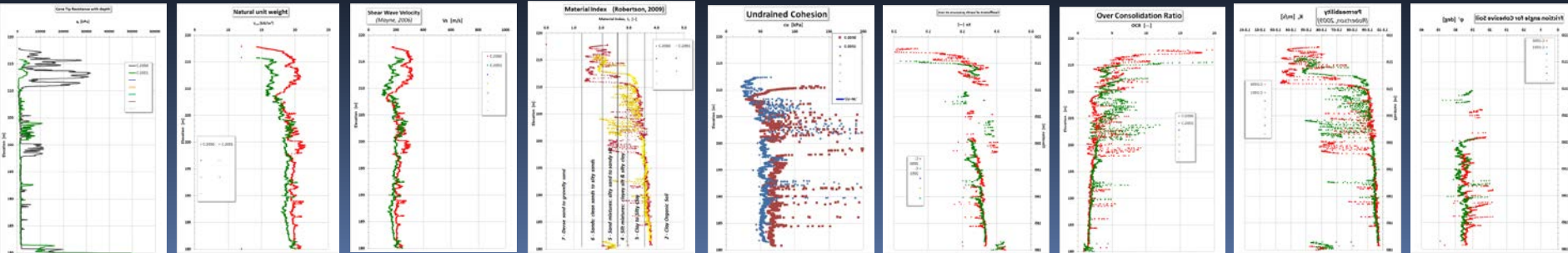




# CPT (Cone Penetration Testing)

## Electronic data for input for computational modeling

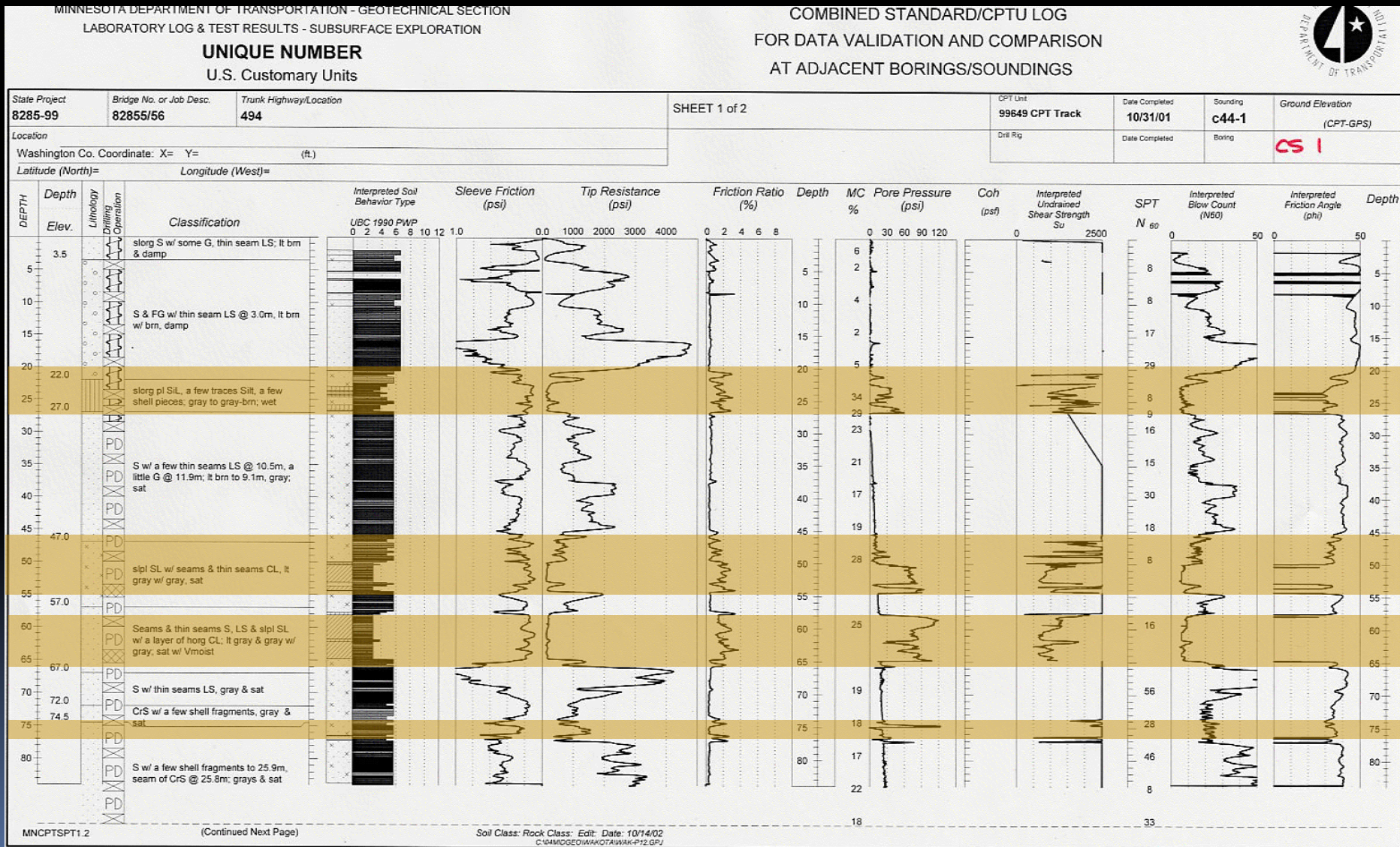
Frequent data acquisition provides a more continuous record of soil properties and stratigraphy. This is especially useful when directly importing into design software. Today there are numerous correlations allowing the estimation of soil parameters.





# CPT (Cone Penetration Testing)

Traditional boring information compared with the “squiggly lines” of CPT measurements





# CPT (Cone Penetration Testing)

Efficient, high quality, site investigation

Whitewater Park (MN 74): The project was reported by engineers based on electronic CPT data sent by cell modem before the field crew returned to the office.



Jay Cooke Park (MN 210): Timely and thorough investigations helped speed design.

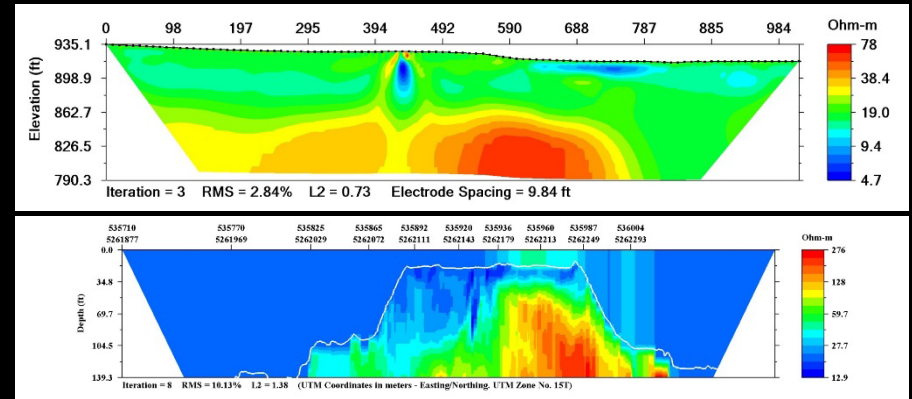


# Enhanced, Effective, Site Characterization

Using advanced geotechnical methods to better define site variability

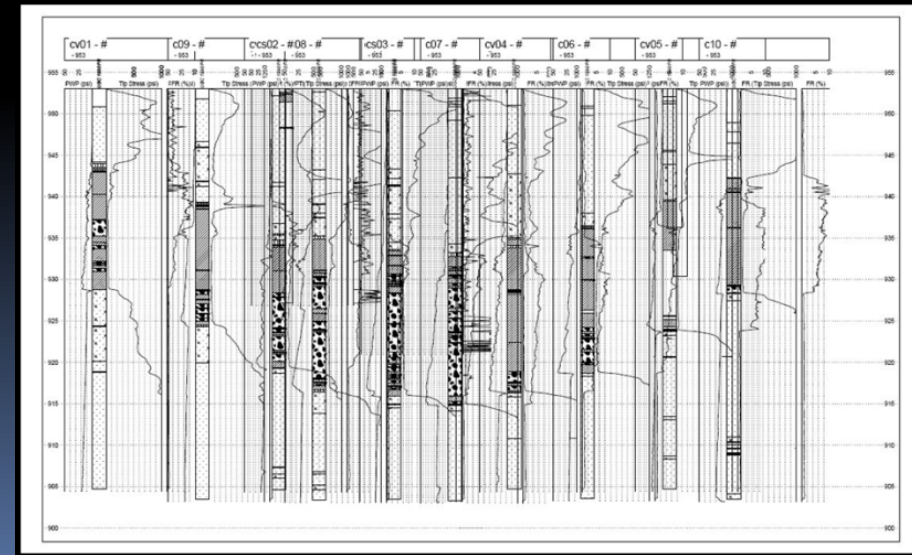
## ■ Geophysics

- Many methods available
- Minimally invasive
- Economical
- Excellent screening tool
- MnDOT has been using for 10+ years on routine projects



## ■ Cone Penetration Testing

- Fast, efficient
- Highly advantageous for providing multiple design parameters
- MnDOT has been using for 15+ years on routine projects





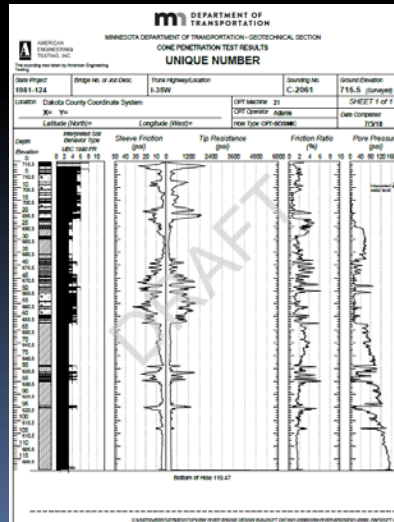
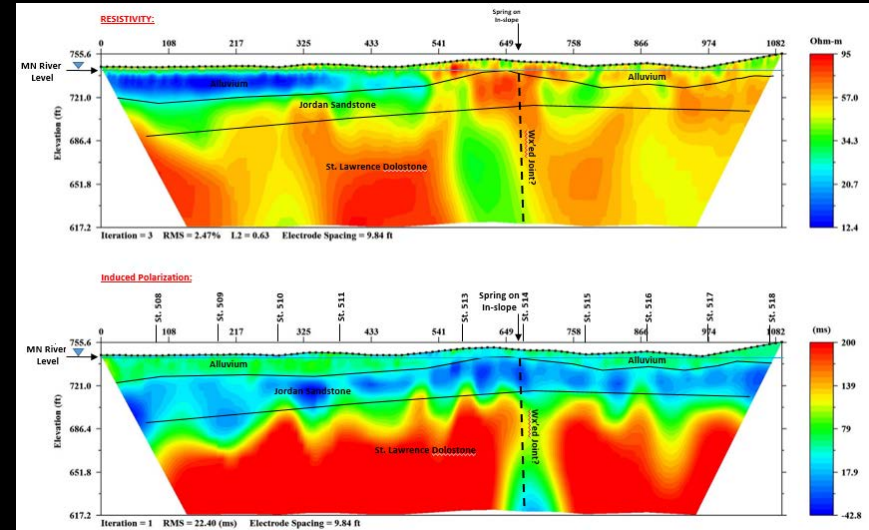
# Advanced Geotechnical Methods in Exploration: Enhanced, Effective, Site Characterization

## ■ Proven Results

- Performance
- Cost/Budget
- Time
- Safety
- Decision Making

## ■ Applicability + Availability

- Program/Project
- In-house/Consultant
- Fed/State/County/City



# Implementation Strategies

- Training on unfamiliar methods and application, demonstrations, and peer exchange
- Project level integration – assistance and peer exchange
  - Assessing and quantifying risk and variability
  - Scoping, phasing, contracting (or performing) work
  - Reducing, interpreting, applying, reporting/presenting results
- Program level integration – assistance and peer exchange
  - Establish program objectives and expectations
  - Procedures, requirements, contracting work
- User Groups – lessons-learned, knowledge-sharing, practice improvements, standardization



# Implementation

What do you want to see from improved geotechnical subsurface practice?

How can we help you best for project risks?

How can we help you best for improving design, construction and performance reliability?

# EDC-5 Funding Opportunities:

- ❑ ***State Transportation Innovation Council (STIC) Incentive***
  - ✓ Up to \$100,000 per STIC per year to standardize an innovation
  - ✓ <https://www.fhwa.dot.gov/innovation/stic/>
  
- ❑ ***Increased Federal-share for Project-level Innovation***
  - ✓ Up to 5% increase in federal share when new innovation is added to a project
  
- ❑ ***Accelerated Innovation Deployment (AID) Demonstration***
  - ✓ Up to \$1 million available per year to deploy an innovation not routinely used
  - ✓ <https://www.fhwa.dot.gov/innovation/grants/>

# Innovation Deployment News



Weekly newsletter



Bi-monthly magazine

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