massDOT Innovation Series

Bring Your A-GaME

Advanced Tools to Characterize Geotechnical Site Conditions

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MEET THE TEAM

Mary C. Nodine, P.E.

- Geotechnical Engineer with GEI since 2003
- Chair of the Subsurface Characterization Committee for the Deep Foundations Institute (DFI)
- Member of the A-GaME Federal implementation team
- Member of the Massachusetts State DOT implementation team

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- Geotechnical Engineer, MassDOT

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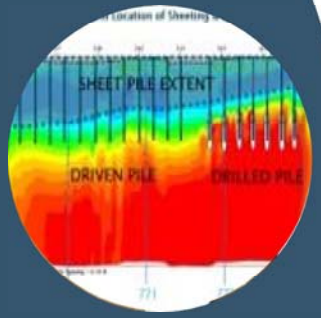
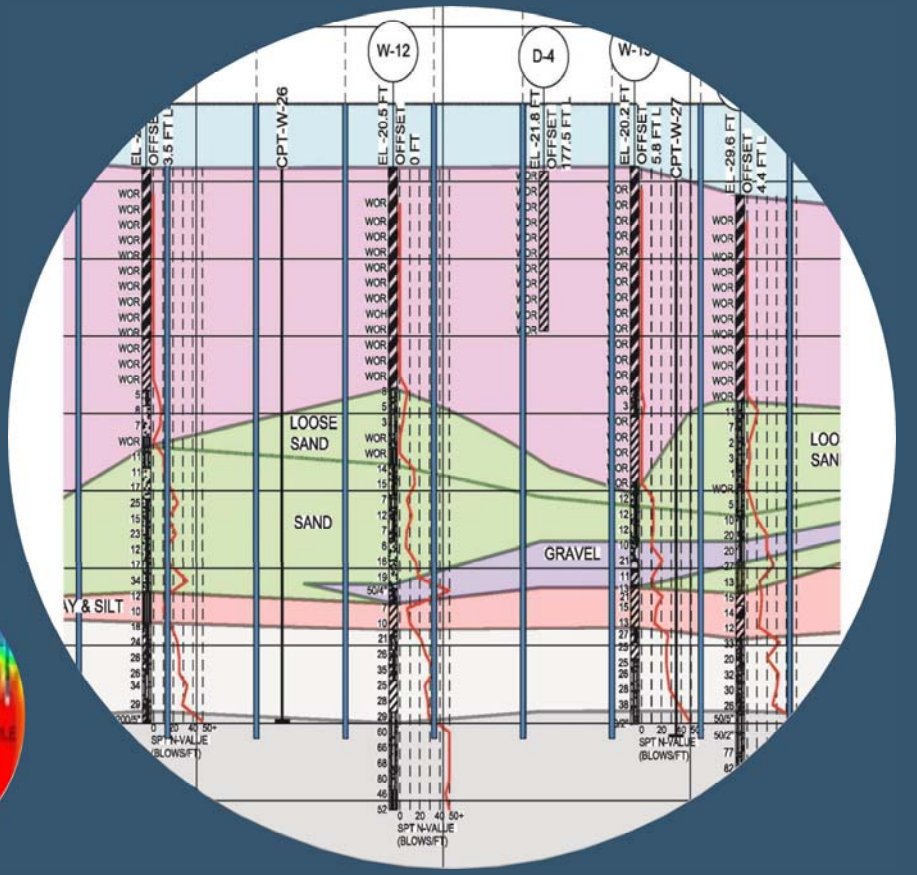
- Assistant Geotechnical Engineer

Overview

- A-GaME Background
- Geotechnical Risks
- Benefits of Enhanced Subsurface Investigation
- Current vs Enhanced Practice
- Featured Exploration Methods and Case Studies
- MassDOT Implementation

Background


SHEET PILE EXTENT
DRIVEN PILE
DRILLED PILE


W-12
D-4
CPT-W-26
CPT-W-27
LOOSE SAND
SAND
GRAVEL
SPT N-VALUE (BLOWS/FT)

Every Day Counts

- FHWA program that aims to "…deploy proven, yet underutilized innovations to shorten the project delivery process, enhance roadway safety, reduce traffic congestion and integrate automation."
- Goal: Save Time, Money and Resources
- Innovations adopted in two-year cycles

U.S. Department of Transportation
Federal Highway Administration

What is the A-GaME?

Advanced Geotechnical Methods in Exploration

- The A-GaME is a toolbox of underutilized subsurface exploration tools that will assist with:
  - *Assessing subsurface variability*
  - *Streamlining and optimizing subsurface exploration*
  - *Maximizing return on investment in project delivery*
- Selected innovation for EDC-5 (2019-2020)

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!!
  - *"Changed conditions" claims, cost overruns, change orders*
  - *Most are related to scope and quality subsurface exploration and site characterization*

Benefits of Bringing Your A-G$_a$ME

- **Reduced Risk.**
  - *Reduce subsurface uncertainties → Mitigate design and construction risk*
- **Improved Quality.**
  - *Improve confidence in site characterization → Reduce unnecessary conservatism and increase reliability*
- **Accelerated Project Delivery.**
  - *Fewer subsurface surprises → Improved decision making and constructability*

A-GaME Mission

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

Geotechnical Risk

Source: FHWA

Geotechnical Risk

Source: Florida DOT

Source: Florida DOT

Financial Benefits of the A-GaME

- Less contingency in bid
- Fewer change orders
- Fewer claims
- Faster construction

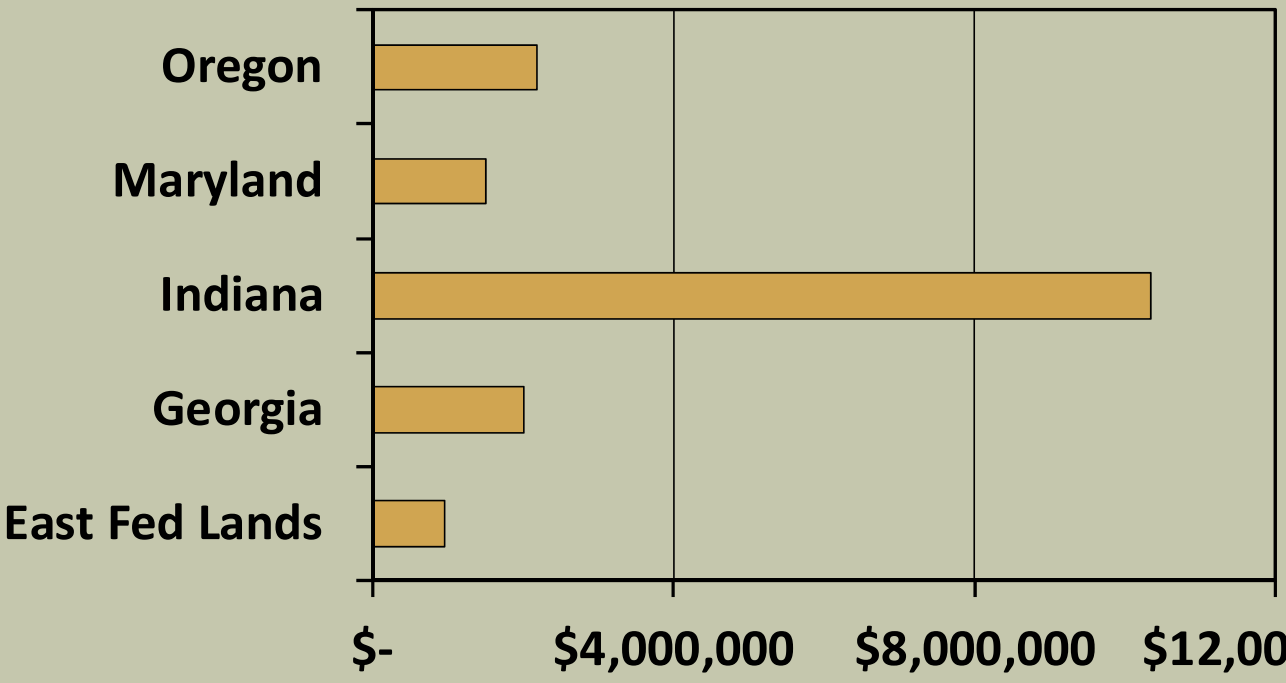
Sources of Delays and Cost Escalations:

- Pile overruns
- Higher than expected groundwater and seepage problems resulting in dewatering
- Mischaracterized subgrade → Earthwork and foundation quantity revisions
- Unanticipated rock during foundation construction
- Mischaracterized rock for drilled shaft construction

Findings from Synthesis 484

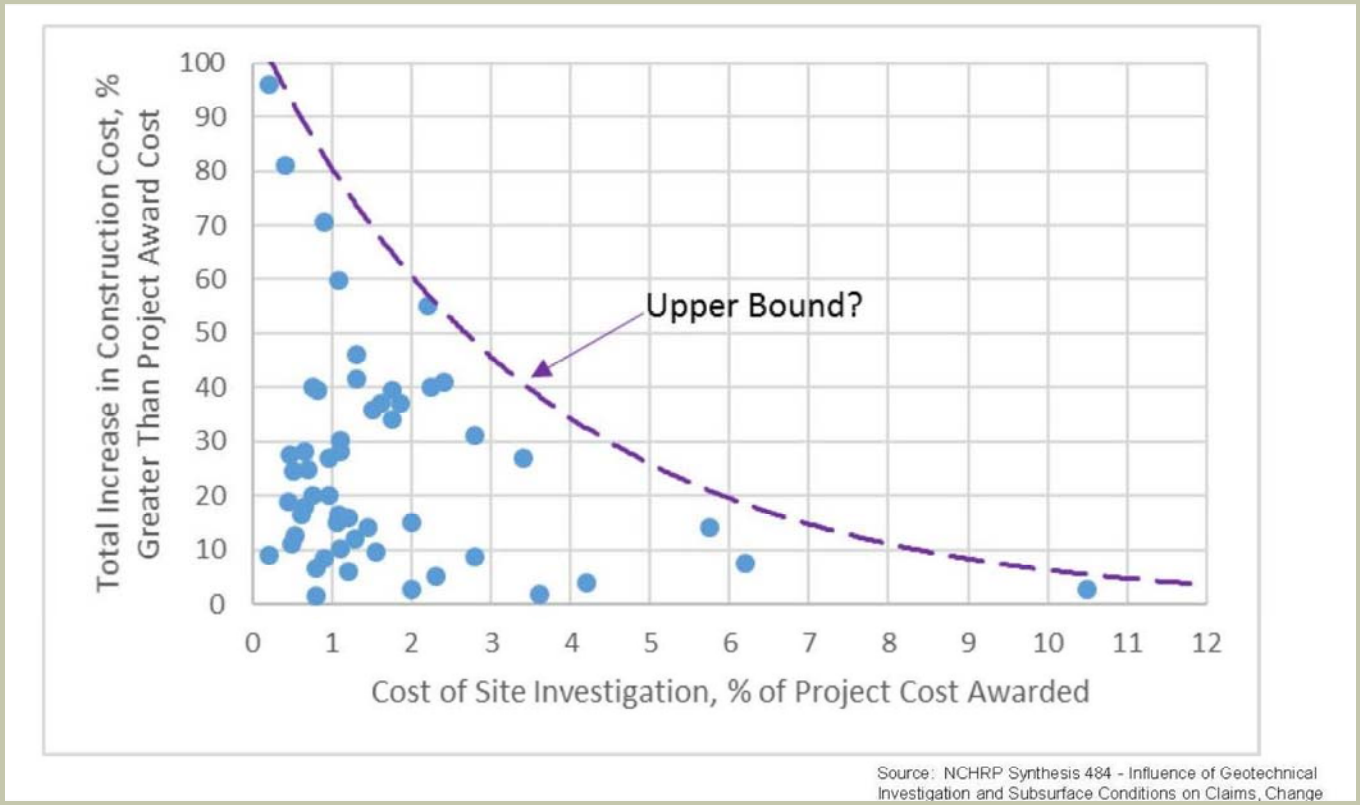
- Modest changes to subsurface investigation practices can produce significant reductions, particularly when the changes are tailored to a specific, recurring claim, change order, or cost overrun.
- Development of minimum standards for subsurface investigation and site characterization can result in more accurate plan quantities and better prepared contractors.
- In-house, centralized drilling and laboratory services provide a consistent standard of care, potentially associated with reduced claims, change orders, and cost overruns, especially when accompanied by robust training of agency personnel.
- Intra-agency training and communication to improve the implementation of subsurface information can be effective in reducing claims, change orders, and cost overruns attributed to subsurface conditions.
- The accuracy of boring locations can effectively reduce the occurrence of claims, change orders, and cost overruns, especially in locations with significant spatial variability.
- Implementation of minimum standards for subsurface investigation and site characterization can also produce design efficiencies.
- Drilling equipment capable of accessing difficult-to-reach locations is valuable, particularly for states with considerable areas of difficult terrain.
- Specification language that is incompatible with subsurface investigation and site characterization results or the lack thereof can result in claims, change orders, and cost overruns.

Annual Magnitude of Subsurface Change Orders



- From NCHRP Synthesis Report 484 survey of U.S. states
- Does not include cost overruns or claims
- Represent up to 17% of all agency change orders
- Qualitatively, a “priority concern” for most agencies

Financial Benefits of Enhanced Subsurface Characterization

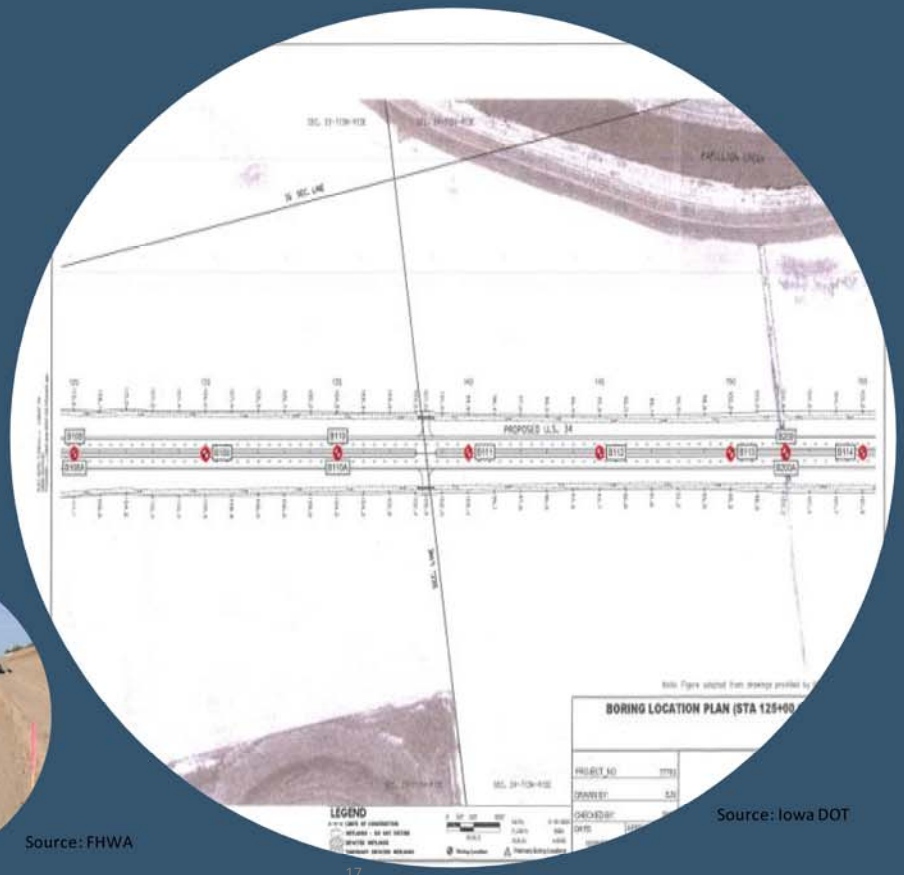


Spending more on site investigation reduces magnitude of cost overruns

Current vs Enhanced Practice

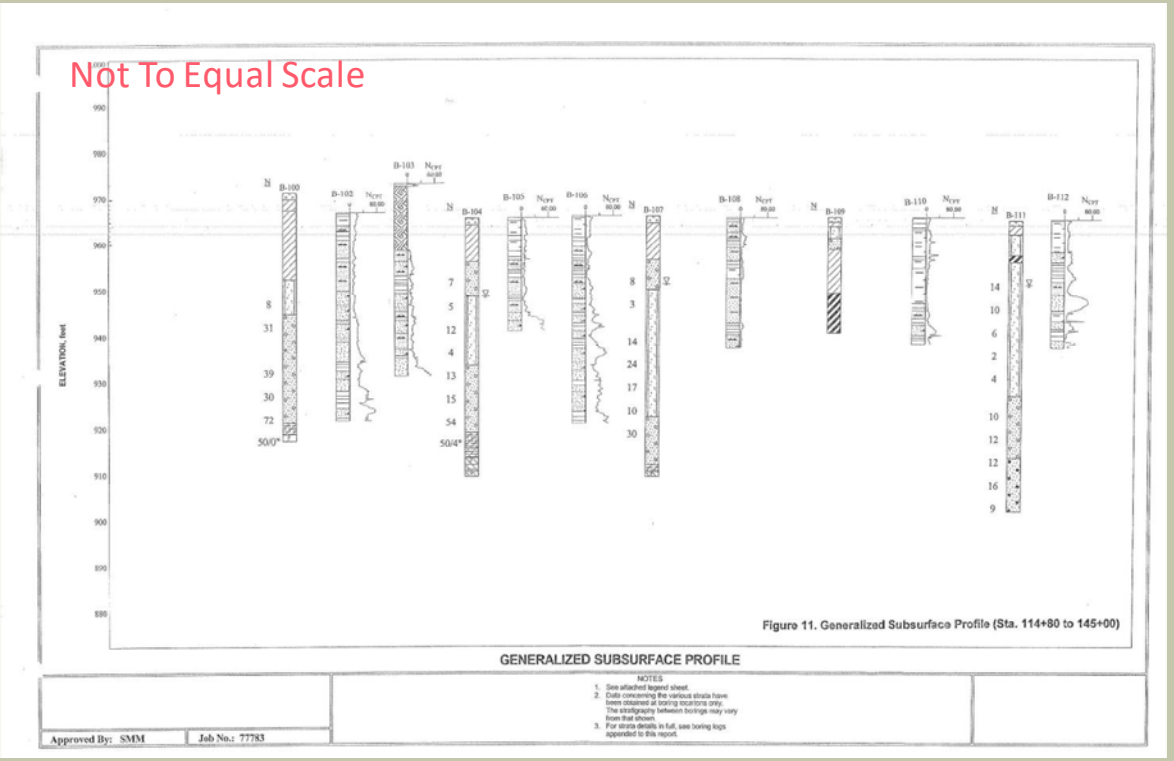
Prescribed minimum standards
→Standard of Practice

Source: FHWA



Source: Iowa DOT

Site Characterization – Current Practice

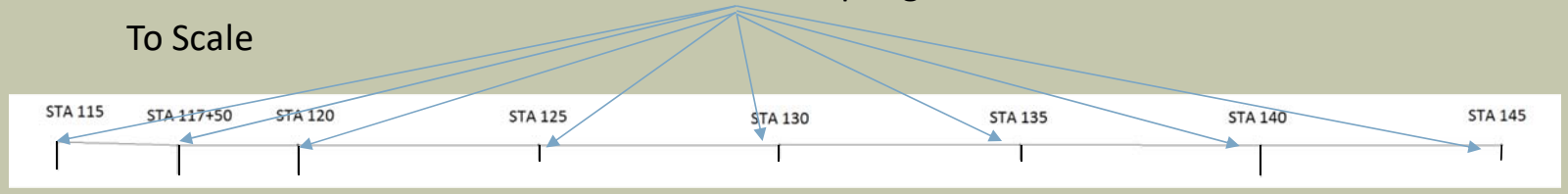


Source: Iowa DOT

Site Characterization – Current Practice

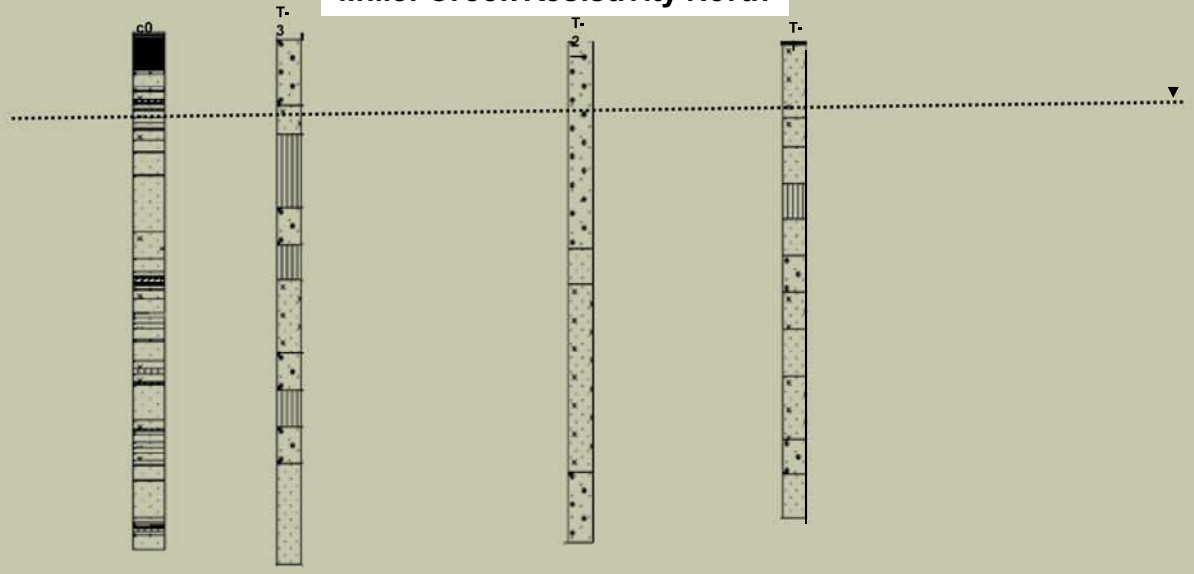
Boring/CPT Locations
Borings: Typ. SPT every 5 feet; 18 inch of Sampling

To Scale

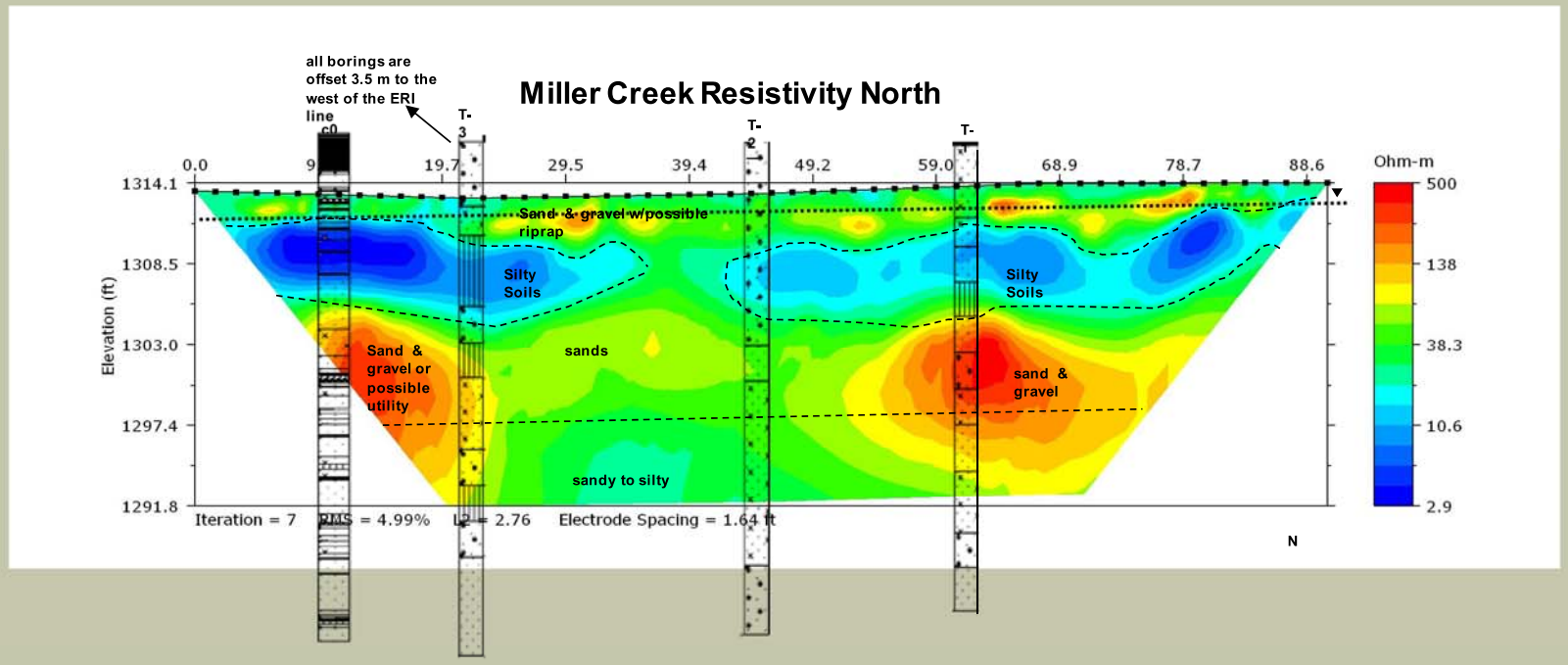


Total Volume Tested or Sampled < 0.01% (typically)

Miller Creek Resistivity North

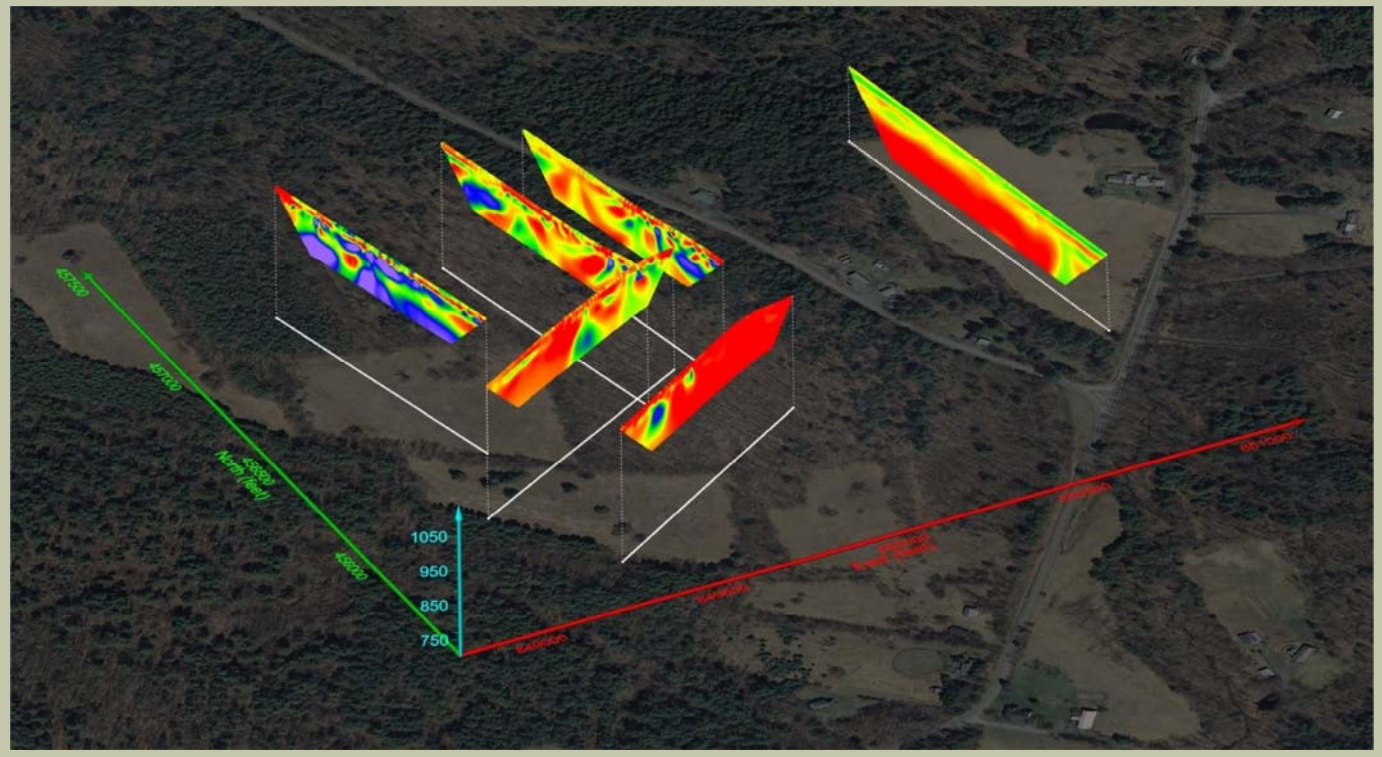


Source: Minnesota DOT



Source: Minnesota DOT

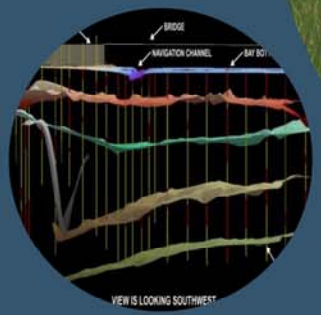
Site Characterization – Bringing your A-GaME



Courtesy of Jeff Reid,
Hager-Richter Assoc.

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)



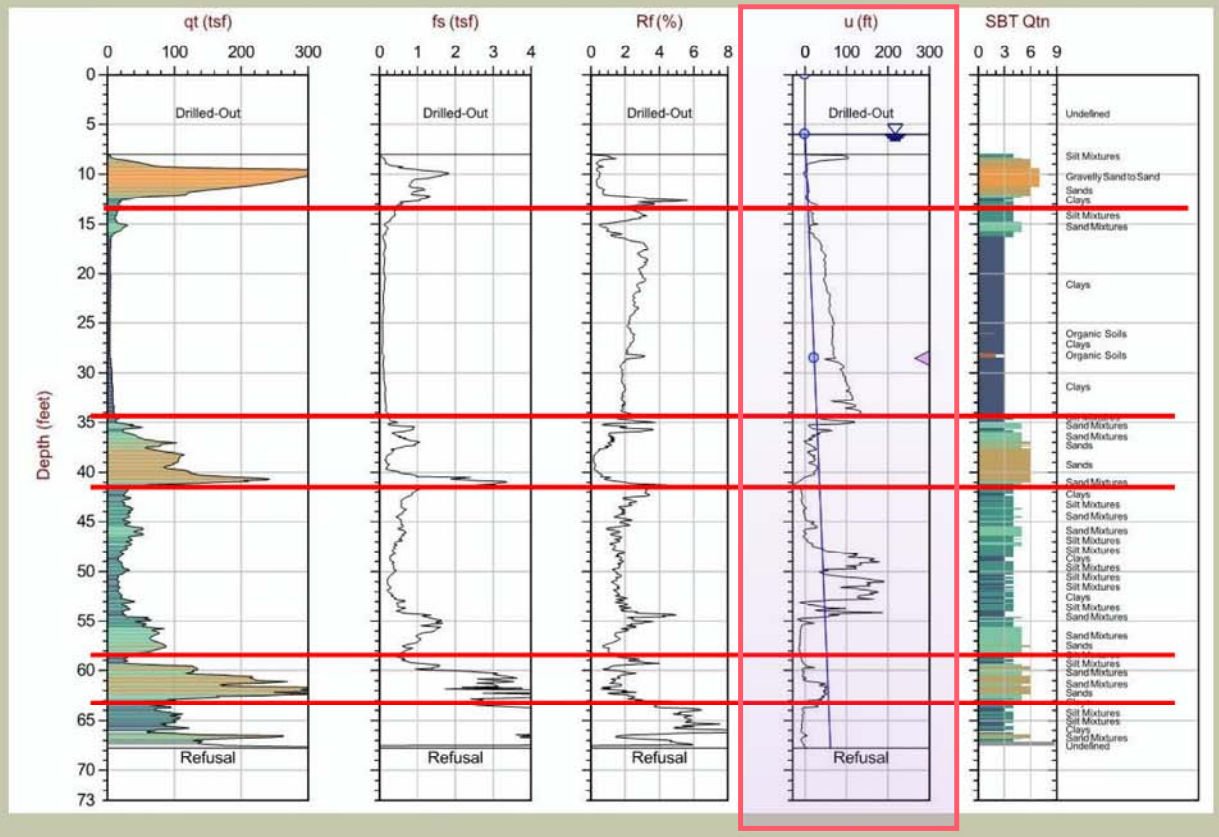
Source: Fugro

Source: Minnesota DOT

Cone Penetration Testing

CPTu/SCPTu

- More reliable measurements than from SPT
- Small strata changes easily discernable
- Pore-water pressure measurements
- Shear-wave measurements with SCPTu
- 3-10 times faster than conventional drilling
- Many correlations with measured parameters
- Direct design techniques from electronic data



MassDOT Case Study (CPT)

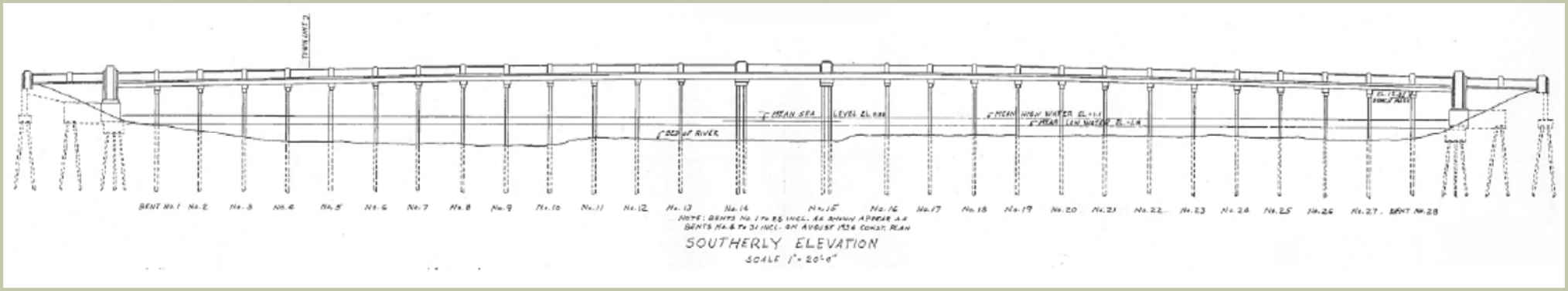
Photo Credits: Mass.gov

Bass River Bridge

- Yarmouth, Massachusetts on Cape Cod
- Current structure built in 1935

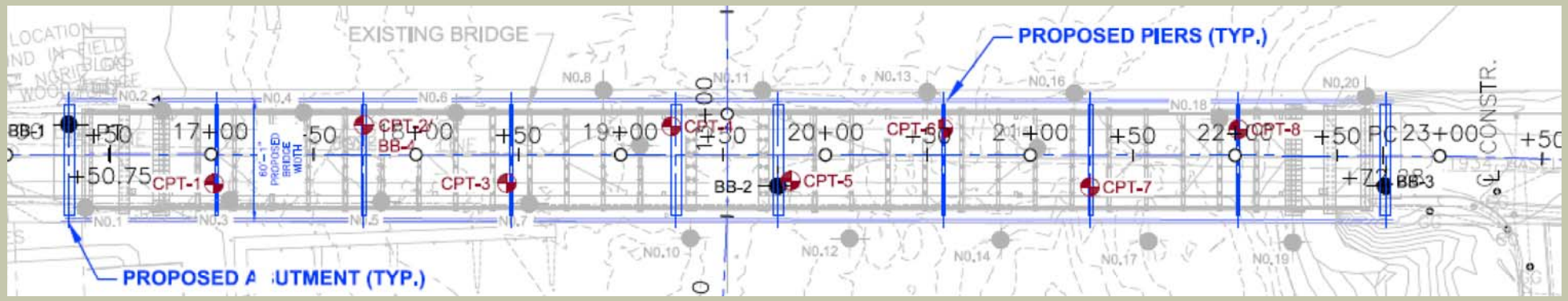
Bass River Bridge

- Replacing bridge in place due to structural deficiencies
- 640-ft-long integral abutment structure 60 feet wide
- Soils consist of medium dense to dense outwash sand
- Tapered steel piles recommended
- $17.5 million budget

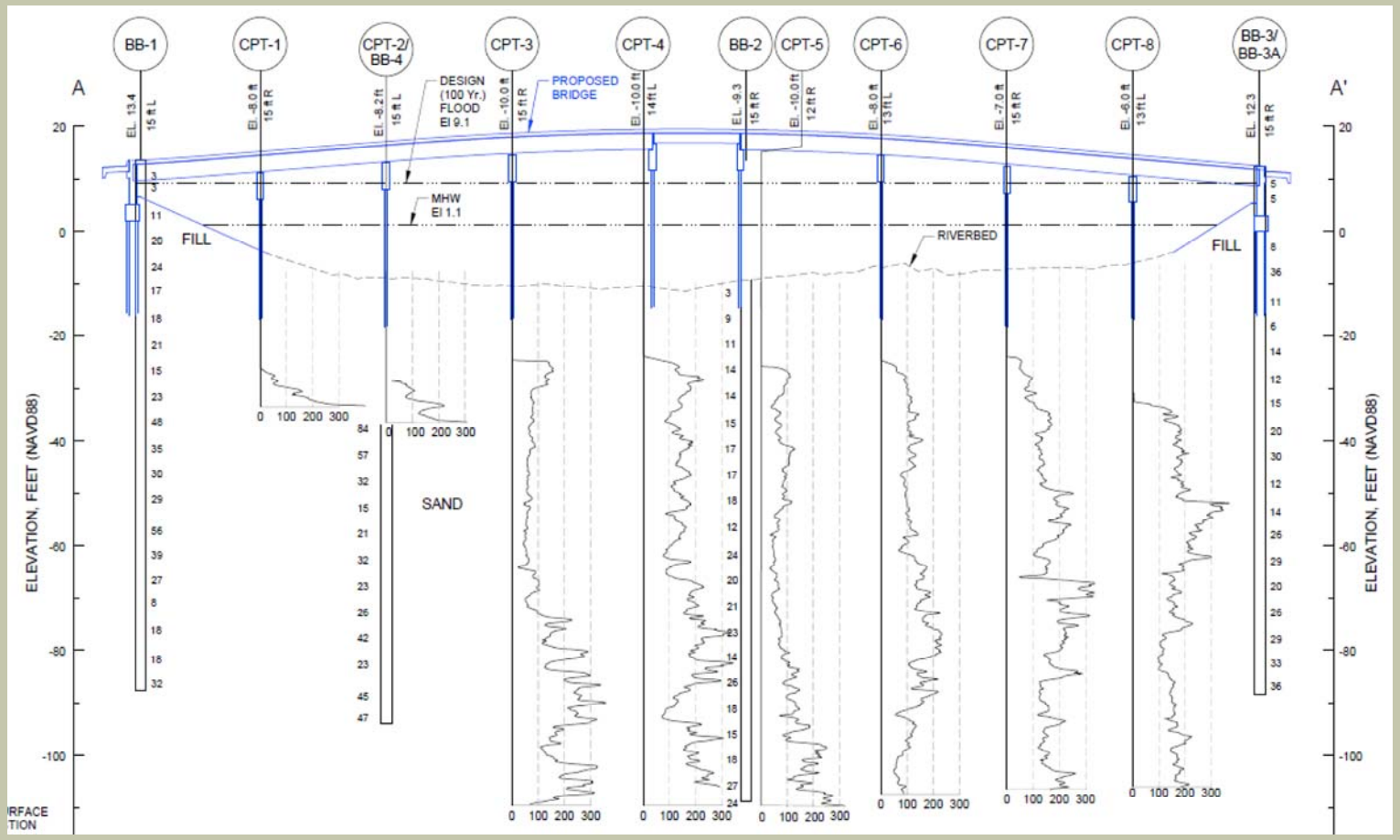


Bass River Bridge

- Exploration program consisted of 3 borings and 8 CPTs
- Drilled borings and CPTs from existing bridge deck



Bass River Bridge



Bass River Bridge

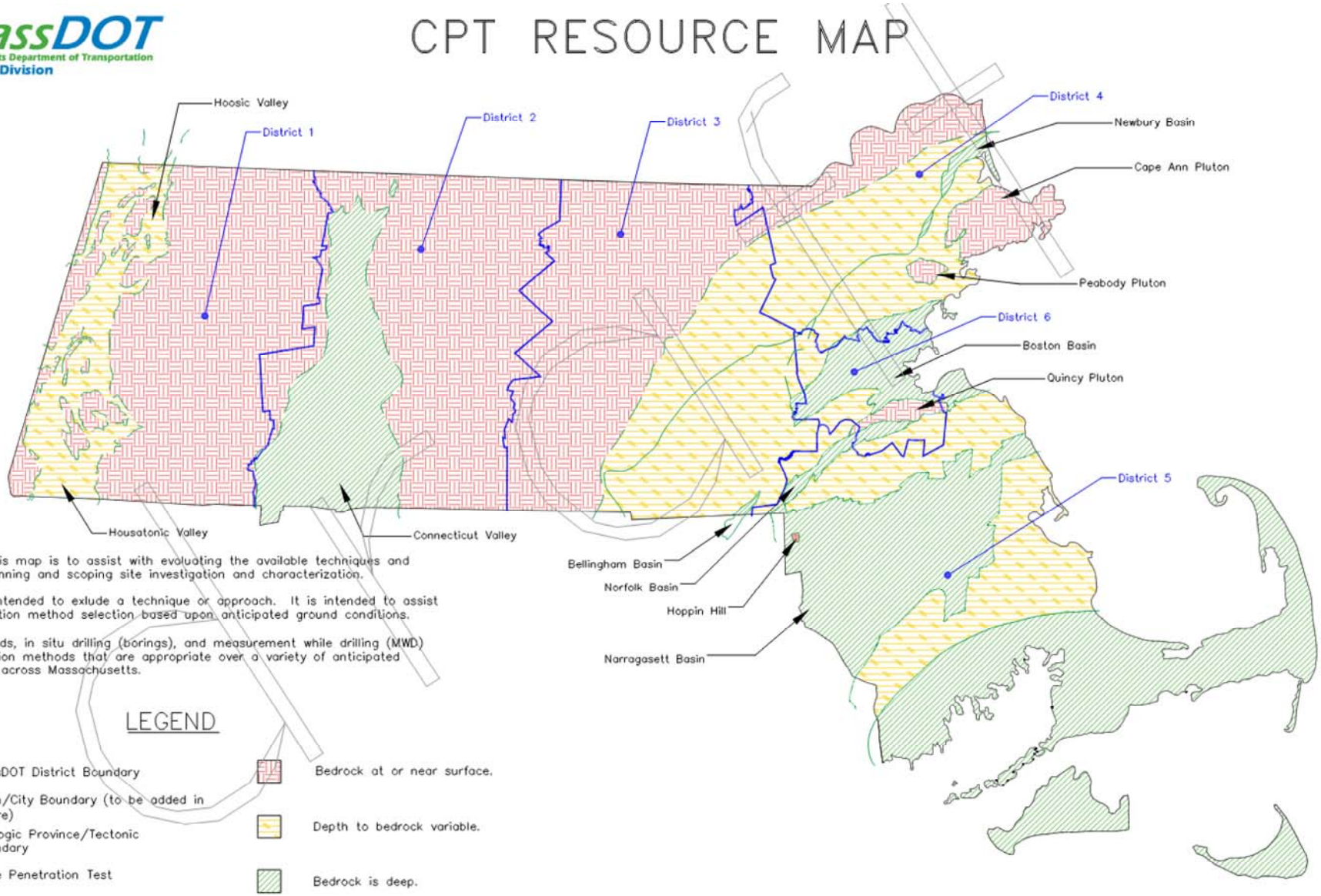
- Use of CPTs saved $25k in exploration costs, or about 25% of subconsultant fee
- Reduced need for laboratory tests
- Expedited exploration program
- Allowed for use of direct pile design methods using CPT data
  - *Preferable to empirical methods using SPT N-values*
  - *Calculate pile capacity using continuous profile*

MassDOT CPT Resource Map

- Indicates where CPT is recommended based on bedrock depth
- Draft map completed
- Will be issued as an Engineering Directive

massDOT
Massachusetts Department of Transportation
Highway Division

CPT RESOURCE MAP



The purpose of this map is to assist with evaluating the available techniques and approaches to planning and scoping site investigation and characterization.

This map is not intended to exlude a technique or approach. It is intended to assist with site investigation method selection based upon anticipated ground conditions.

Geophysical methods, in situ drilling (borings), and measurement while drilling (MWD) are site investigation methods that are appropriate over a variety of anticipated ground conditions across Massachusetts.

LEGEND

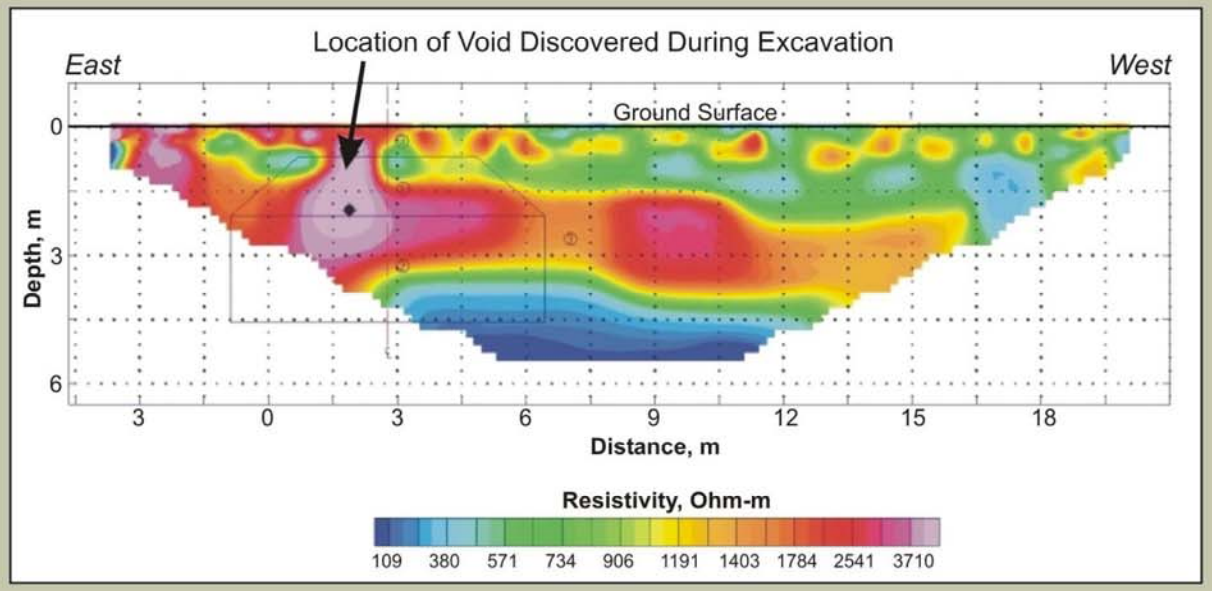
- MassDOT District Boundary
- Town/City Boundary (to be added in future)
- Geologic Province/Tectonic Boundary
- CPT — Cone Penetration Test
- Bedrock at or near surface.
- Depth to bedrock variable.
- Bedrock is deep.

9 02/28/2020 11 x 17

Electrical Methods

Resistivity, Induced Polarization, Self-Potential

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



Source: FHWA-CFL

FLDOT Case Study (ER)

Photo Credits: Florida DOT

Site Characterization – Bringing your A-GaME

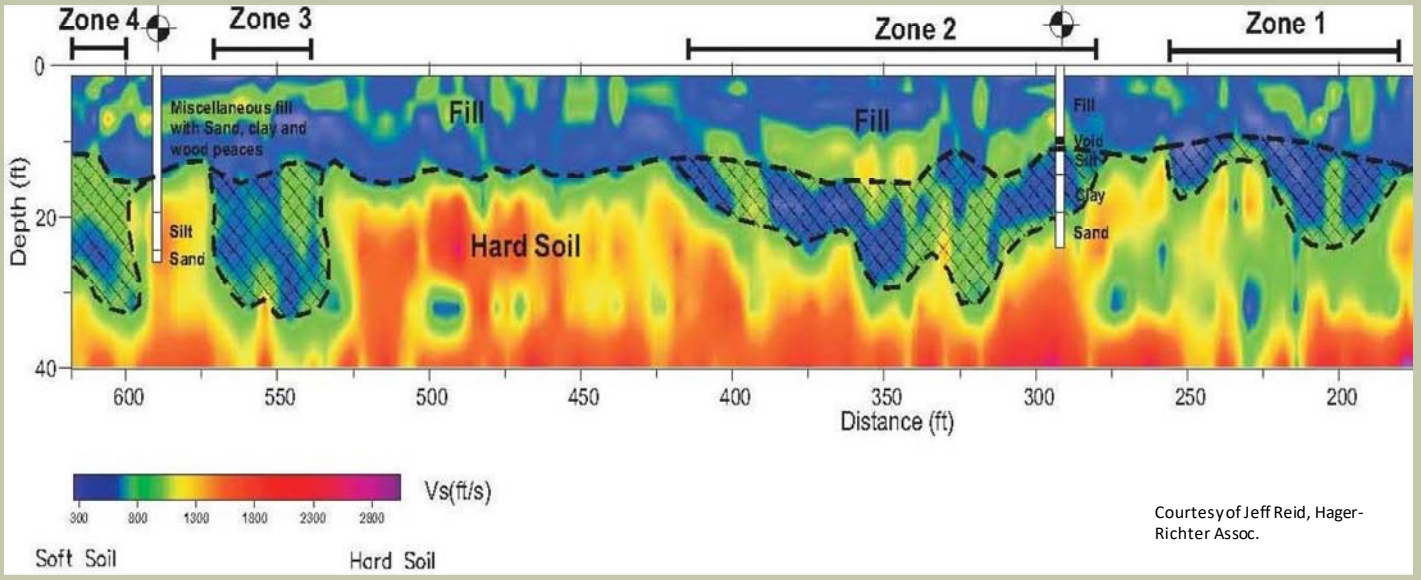
- 6-Mile Section
- 1-day Field Testing
- ½-day Processing

Confirm conditions

Concentrate additional investigation where most valuable

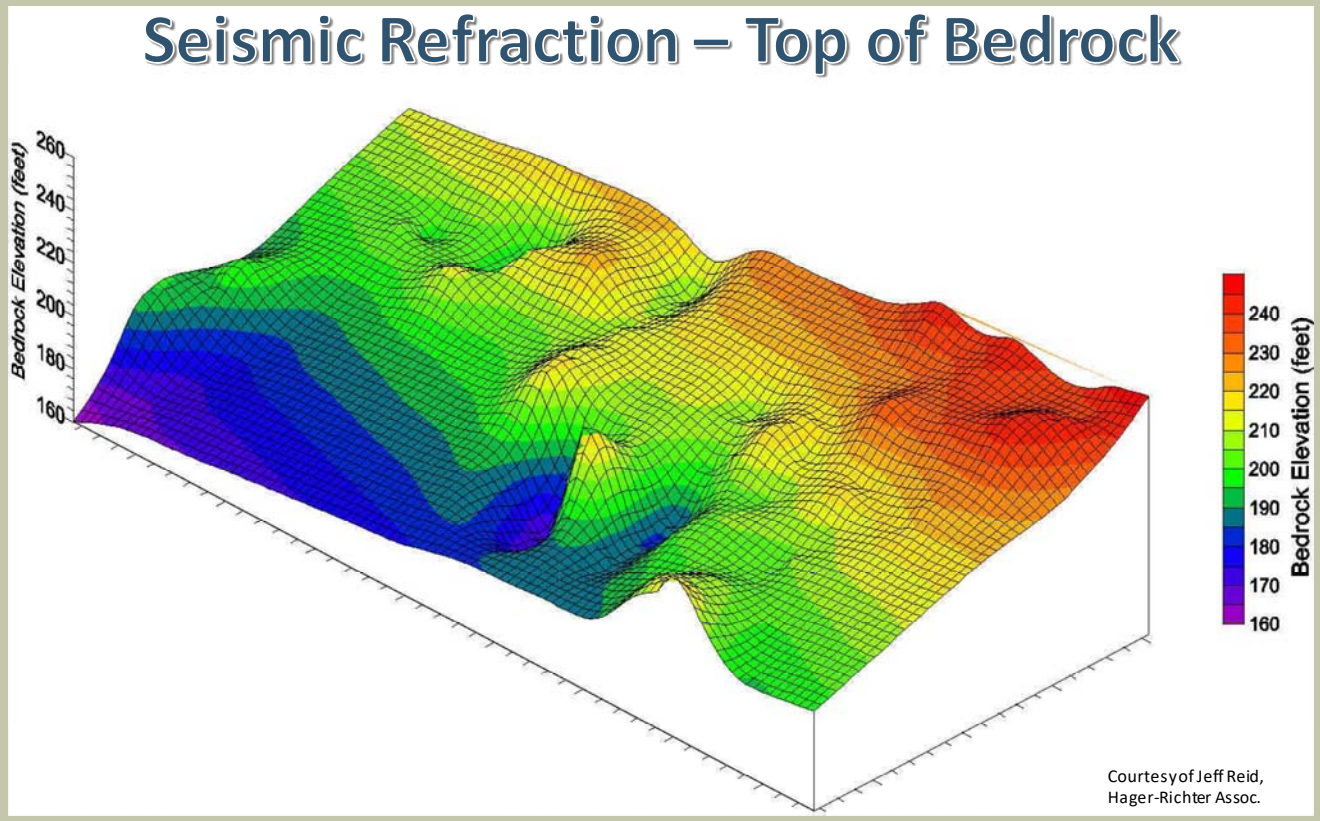
Seismic Methods

- **Surface Waves, Refraction, Downhole, Reflection, Full Waveform Inversion**
- Indicates stratigraphic changes and boundaries over large areas
- Load-displacement behavior
- Seismic hazard susceptibility



Courtesy of Jeff Reid, Hager-Richter Assoc.

Seismic Methods



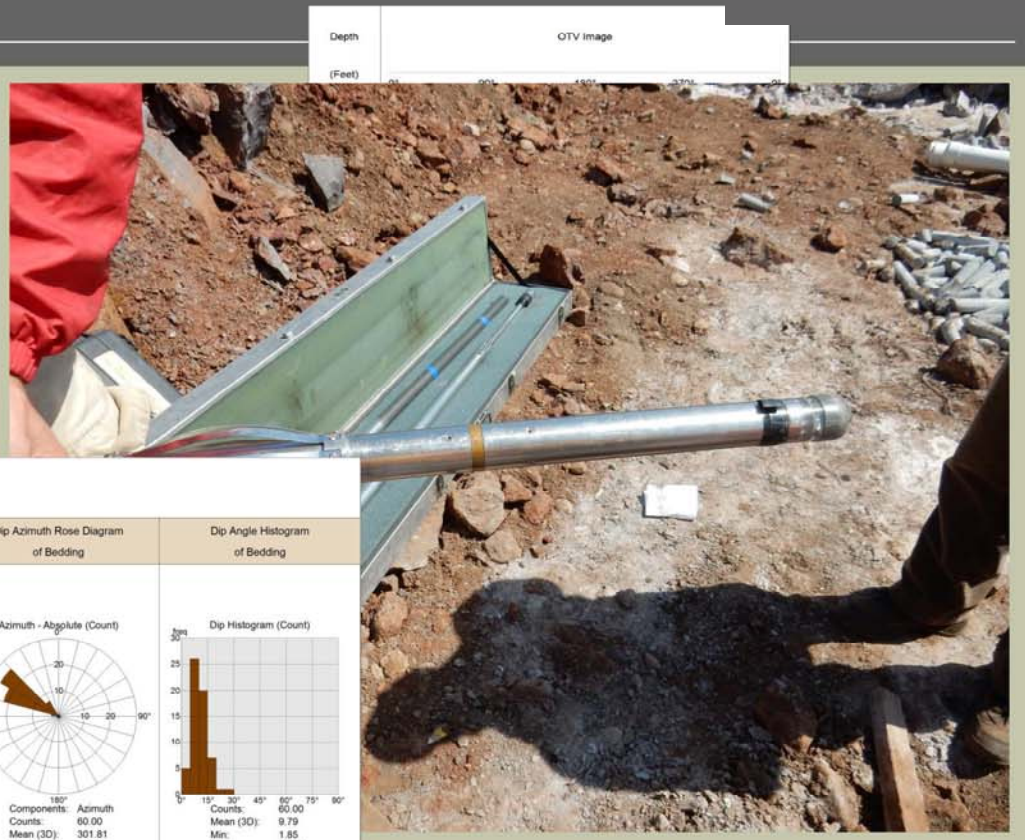
Measurement While Drilling

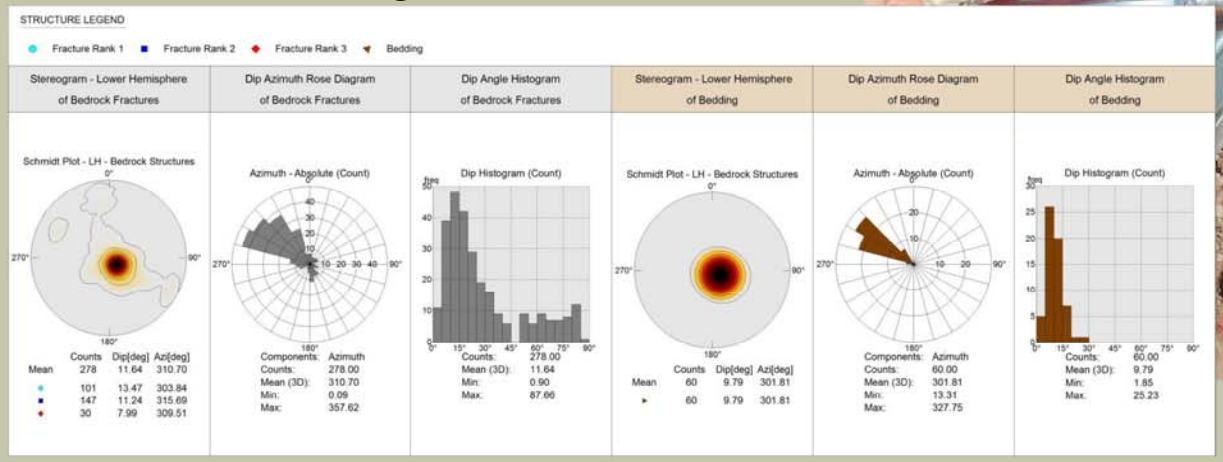
- **Measurement While Drilling (MWD)**
- Continuous profile (fluid pressure, torque, rotation speed, depth, downward thrust)
- Discernable stratigraphic and material changes
- Rock or Soil
- Standardized in Europe ISO 22476-15

Source: FHWA

Optical and Acoustic Televiewers

- **Televiewers – Optical and Acoustic** (OTV/ATV)
- High-resolution, 360°, GIS, spatially oriented rock drillhole images





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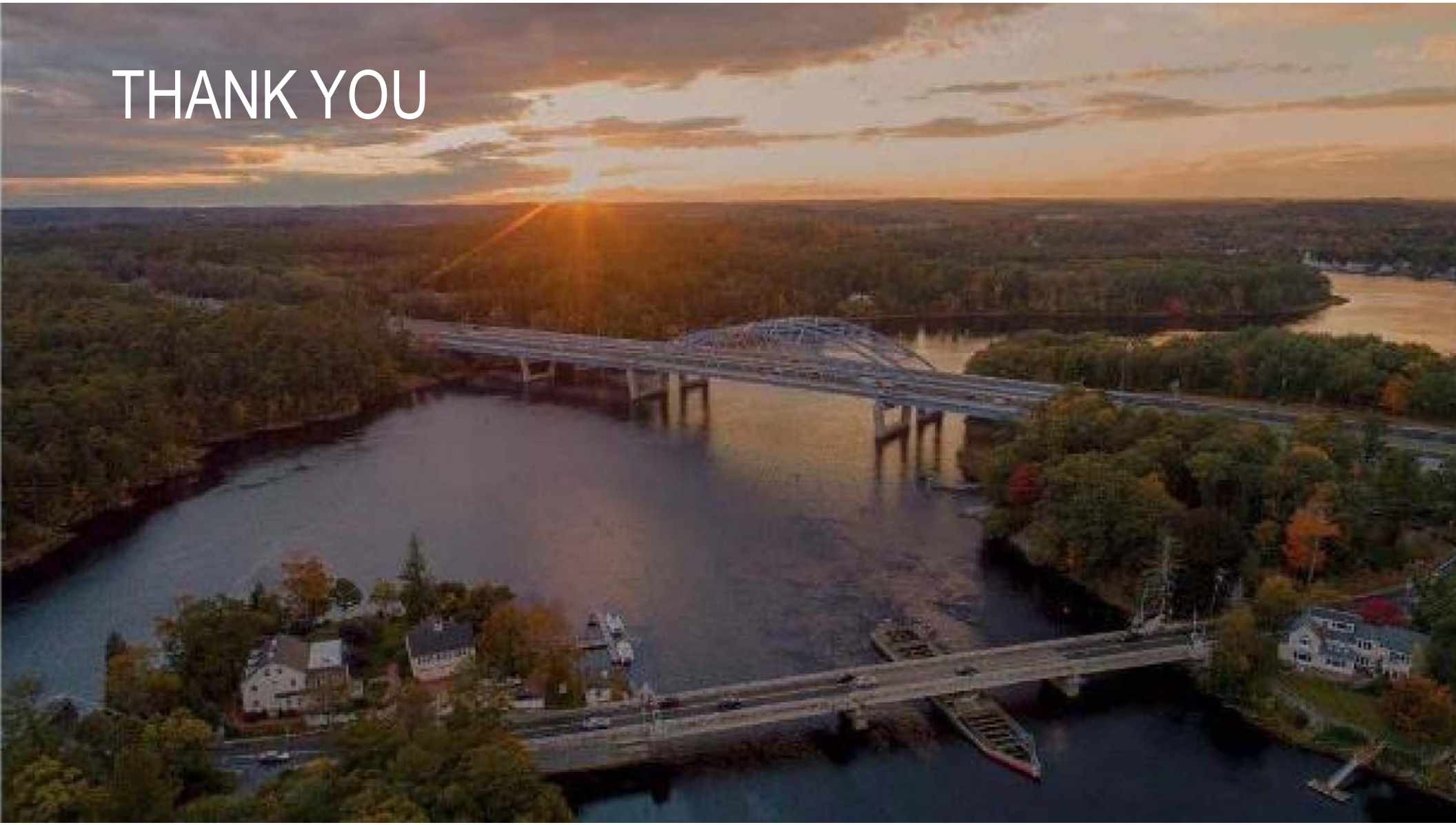
THANK YOU