Embankment & Slope Monitoring

Andrew Eller, P.E. | Asst. Geomechanics/LRFD Engineer

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DEPARTMENT OF TRANSPORTATION

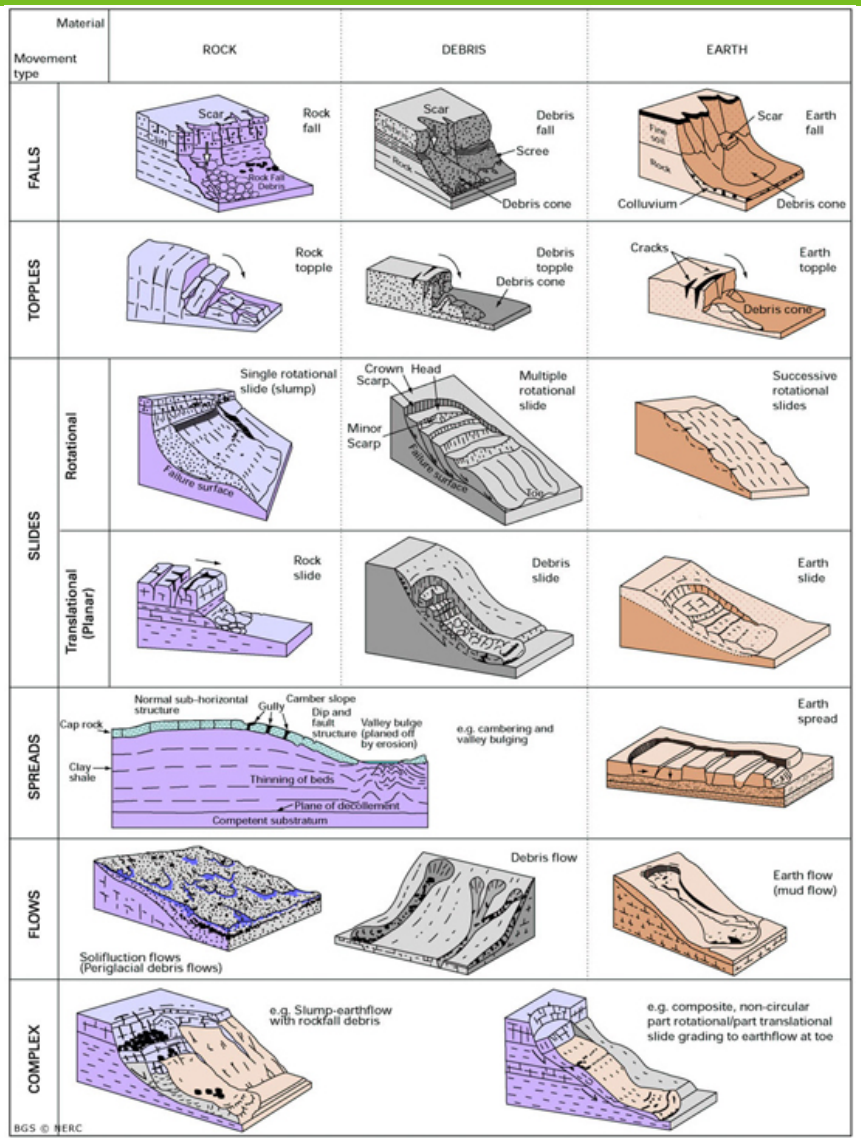
mndot.gov

In-Situ Monitoring: Agenda

1. General Concepts/Purpose
2. The Instruments
3. Project/Site Examples

In-Situ Monitoring: The Purpose

- Design issues for embankments/slopes on soft soils
  - Overall bearing capacity & edge bearing
  - Slope Stability
  - Embankment Spreading
  - Lateral Squeeze
  - Tolerable ("Service Limit") deformation



In-Situ Monitoring: The Purpose

- Why?? Assess Risk.
  - DEFINE THE PROBLEM (severity and extent)
  - What is the ADT?
    - Visual assessment
    - Periodic Maintenance OK?
  - Impacts to property?
  - Risk of injury to traveling public?
  - What is the risk & cost of doing “X” versus “Y”?

In-Situ Monitoring: The Purpose

- Monitor "Time Domain" Geotechnical Behavior
  - Observe Response
  - Characterize Behavior
    - Forensics & "Troubleshooting" slope failures
    - Does soil behavior match the model?
- Recommend Actions
    - Revised Designs to address concerns (Design Phase**)
    - Adjust Scope/Scale (Design & Construction)
    - Adjust Project Timeline (Construction)
- Correct or Mitigate Site Problems

**less expensive here!

The Instruments

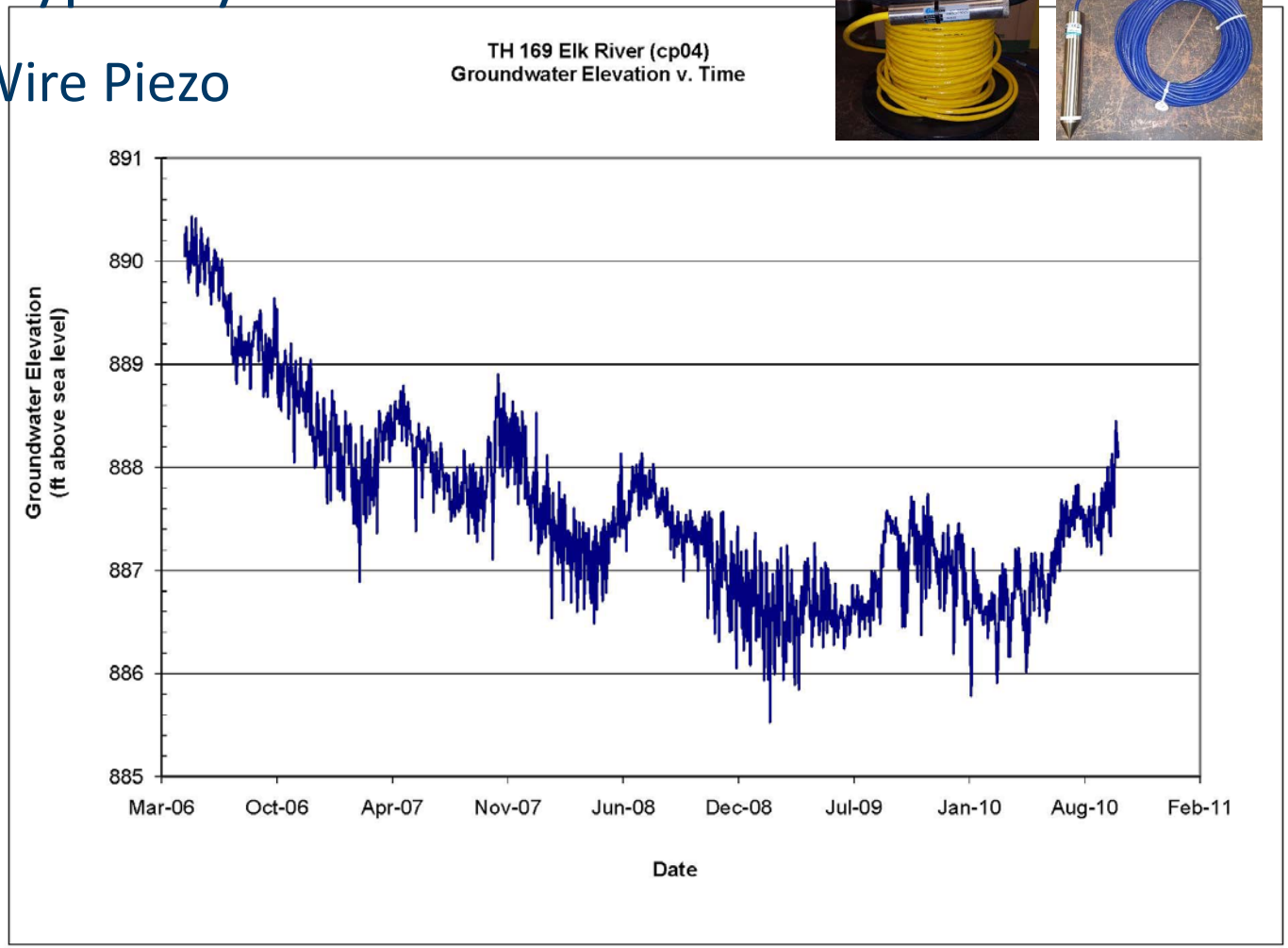
In-Situ Monitoring: The Instruments

- What do we typically monitor?
  - Groundwater levels
    - Open stand pipe
    - VWP (piezo)
    - WL data from SPT boring log

  - Pore Water Pressure (PWP)
    - Vibrating Wire Piezometers
      - Install by SPT or CPT

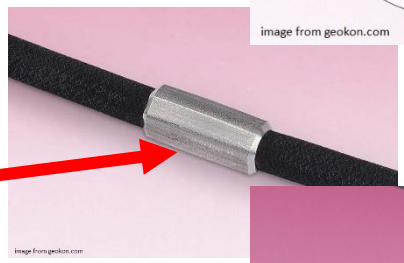
In-Situ Monitoring: The Instruments

- What do we typically monitor?
  - Vibrating Wire Piezo



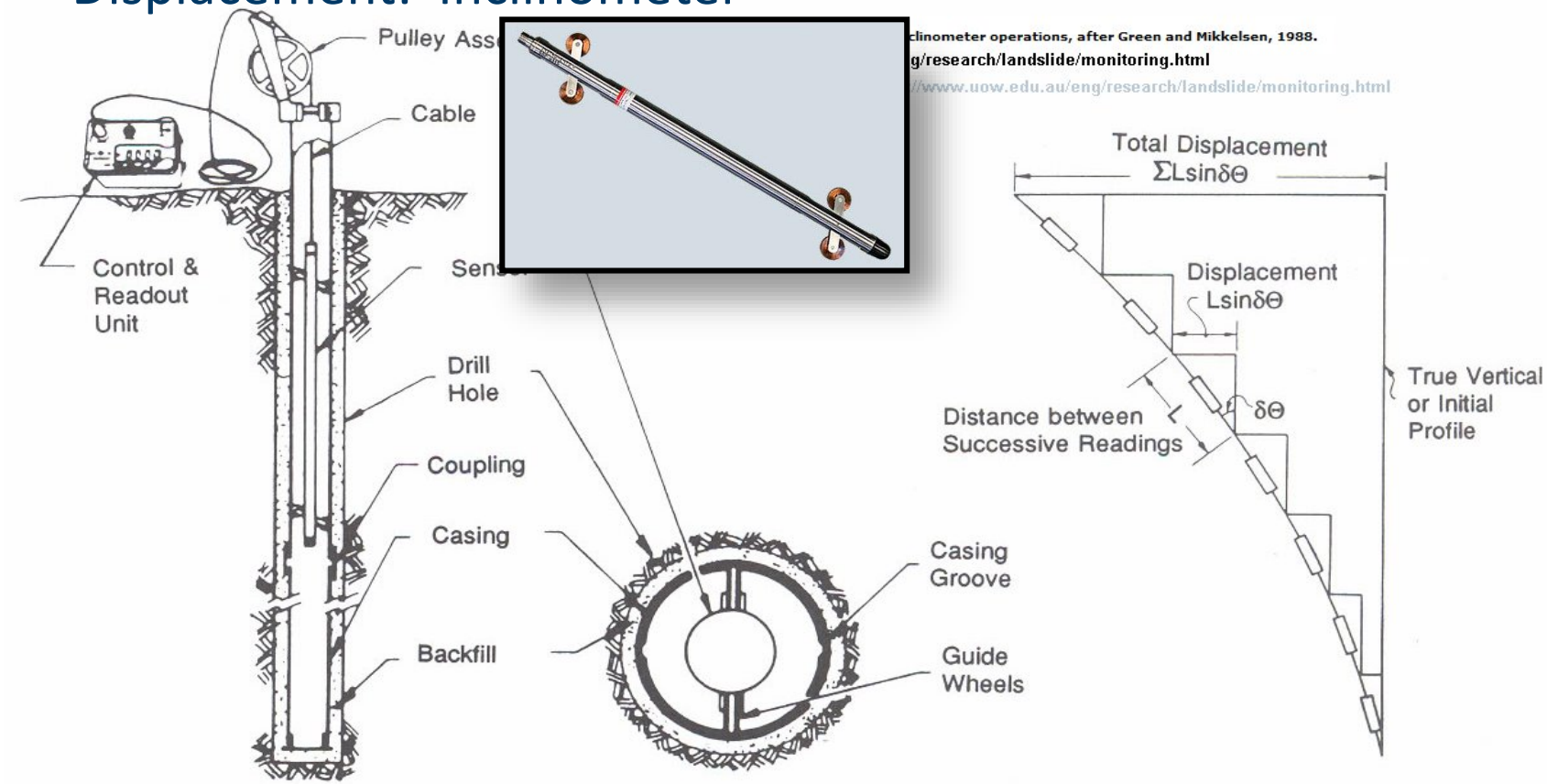
In-Situ Monitoring: The Instruments

- What do we typically monitor?
  - Displacement
    - Traversing Probe Inclinometer (manually read)
      - MEMS accelerometer



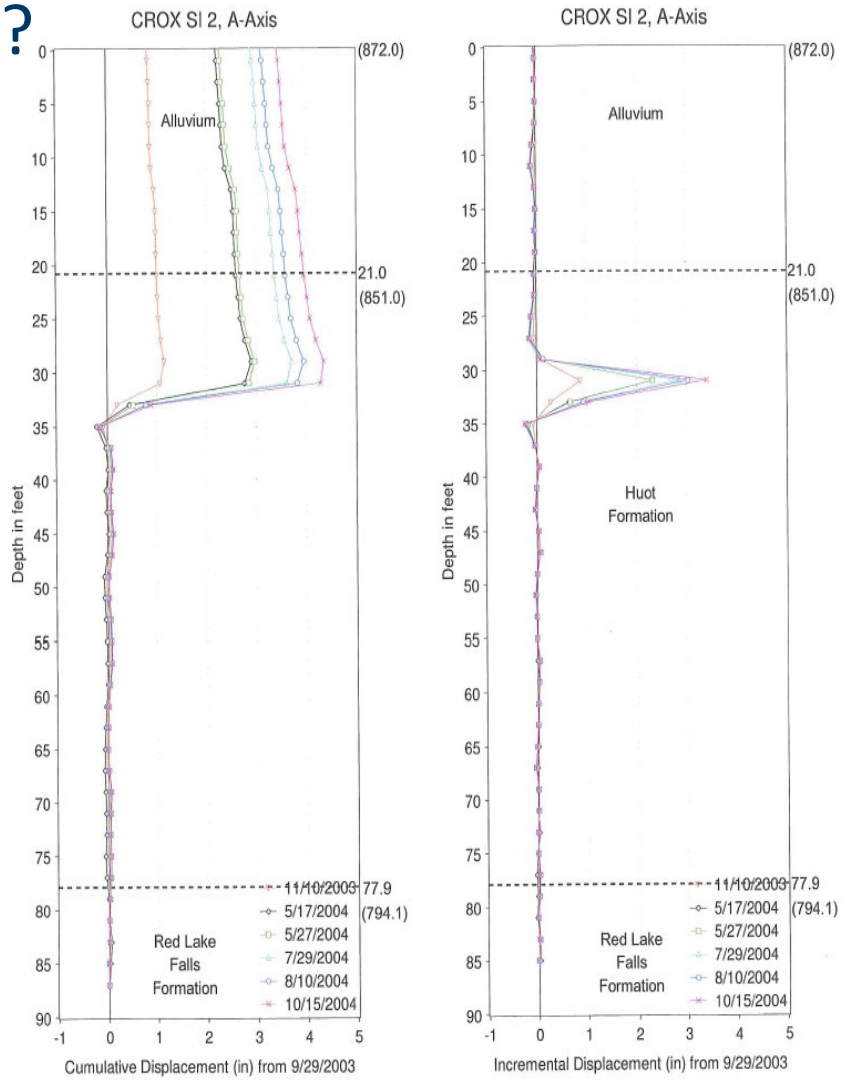
In-Situ Monitoring: The Instruments

- What do we typically monitor?
  - Displacement: Inclinometer



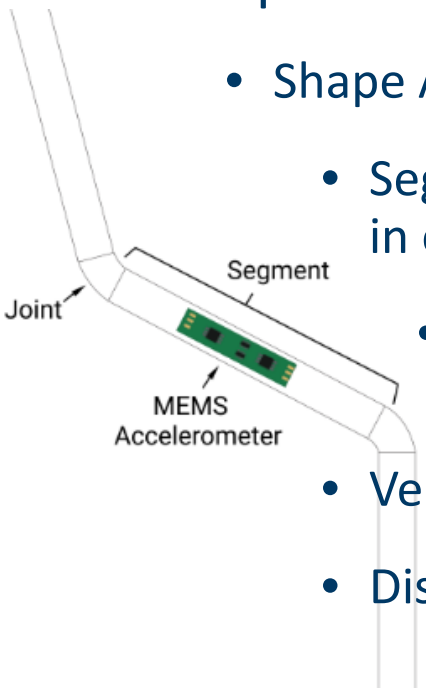
In-Situ Monitoring: The Instruments

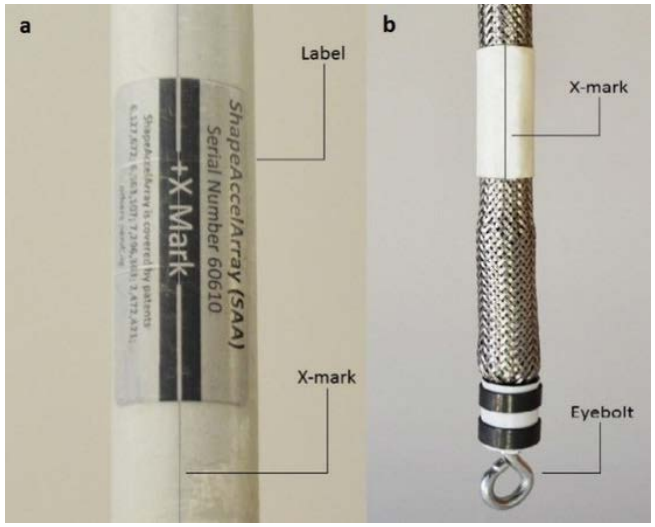
- What do we typically monitor?
  - Displacement
    - Inclinometer



In-Situ Monitoring: The Instruments

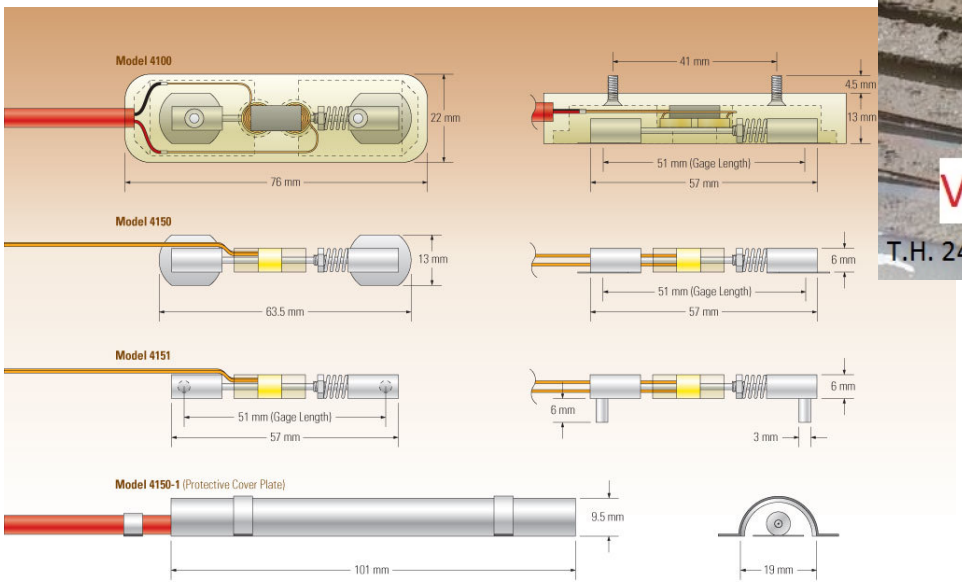
- What do we typically monitor?
  - Displacement
    - Shape Accel Array (SAA-F)
      - Segmented w. MEMS accelerometer in each segment
        - Segments: 8” 1’ 1’8”
          Lengths: up to 150m (~492’)
      - Vertical or Horizontal placement
      - Displacement Accuracy
        - ±0.005 foot (±1.5mm) for 105 ft. SAA





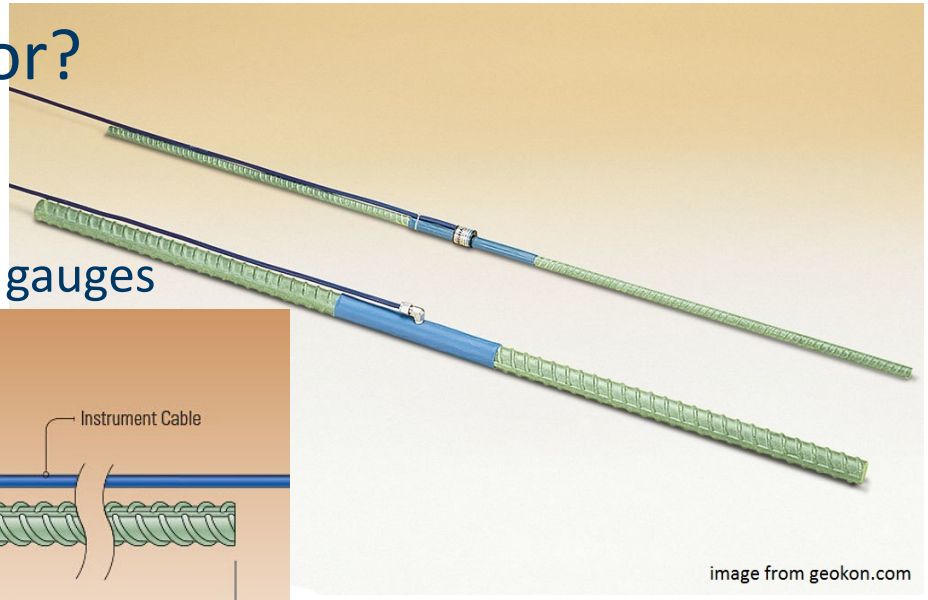
In-Situ Monitoring: The Instruments

- What do we typically monitor?
  - Strain
    - Vibrating wire strain gauges



In-Situ Monitoring: The Instruments

- What do we typically monitor?
  - Strain
    - Large Bar & “Sister Bar” strain gauges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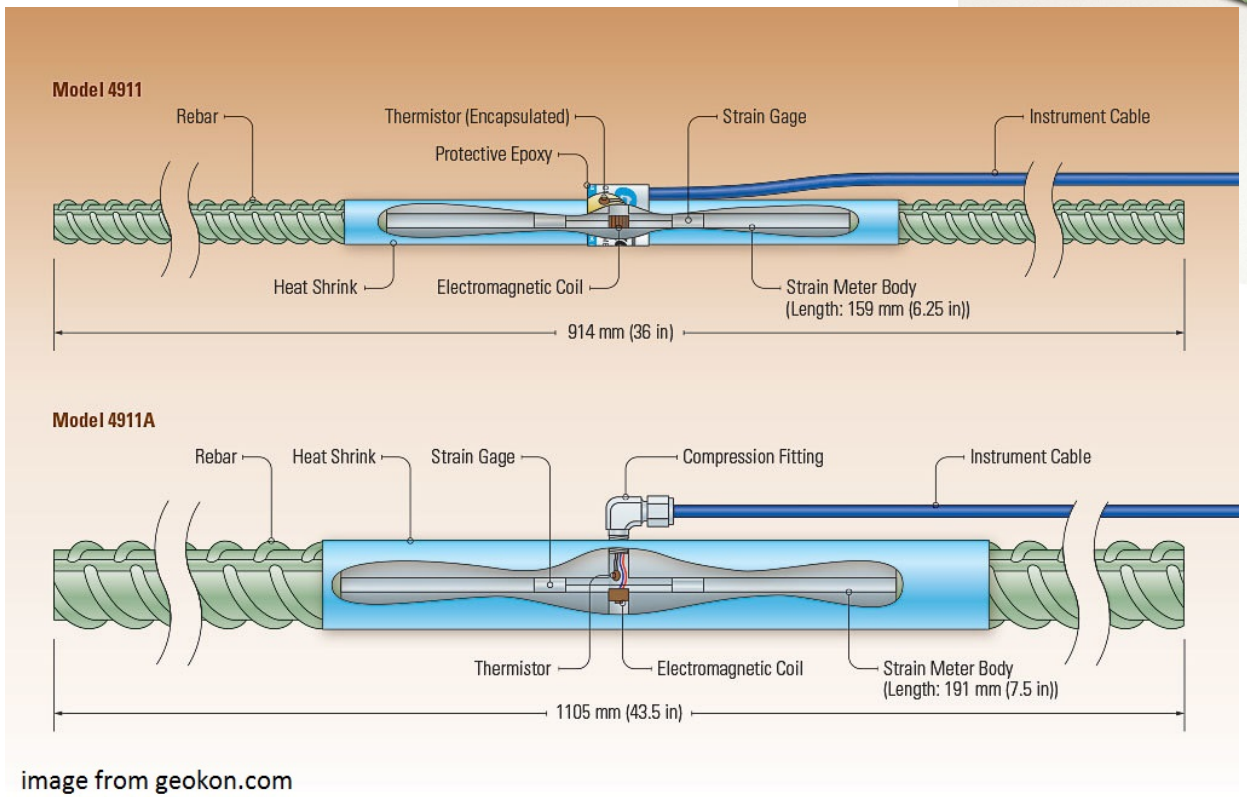

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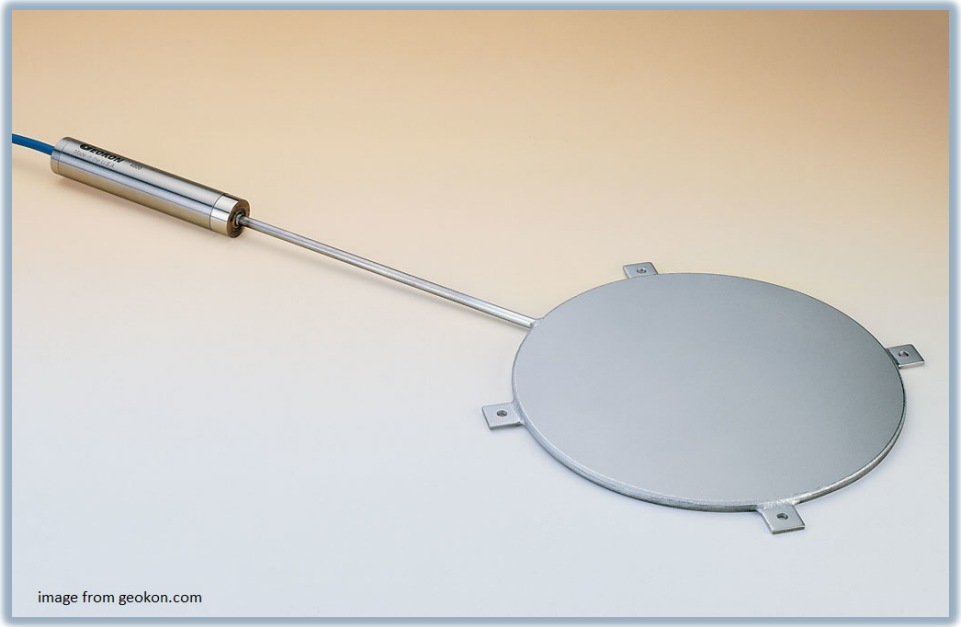
In-Situ Monitoring: The Instruments

- What do we typically monitor?
  - Load
    - Earth Pressure Cells (EPC)
      - Use fluid pressure and VW pressure transducer.
      - Readings are affected by temperature changes in the grade.



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In-Situ Monitoring: The Instruments

- What do we typically monitor?
  - Robotic Total Station survey monitoring
    - Trimble or Leika most common
      - S8 Trimble Total Station for in-house use.
        - 25mm prisms, most common.

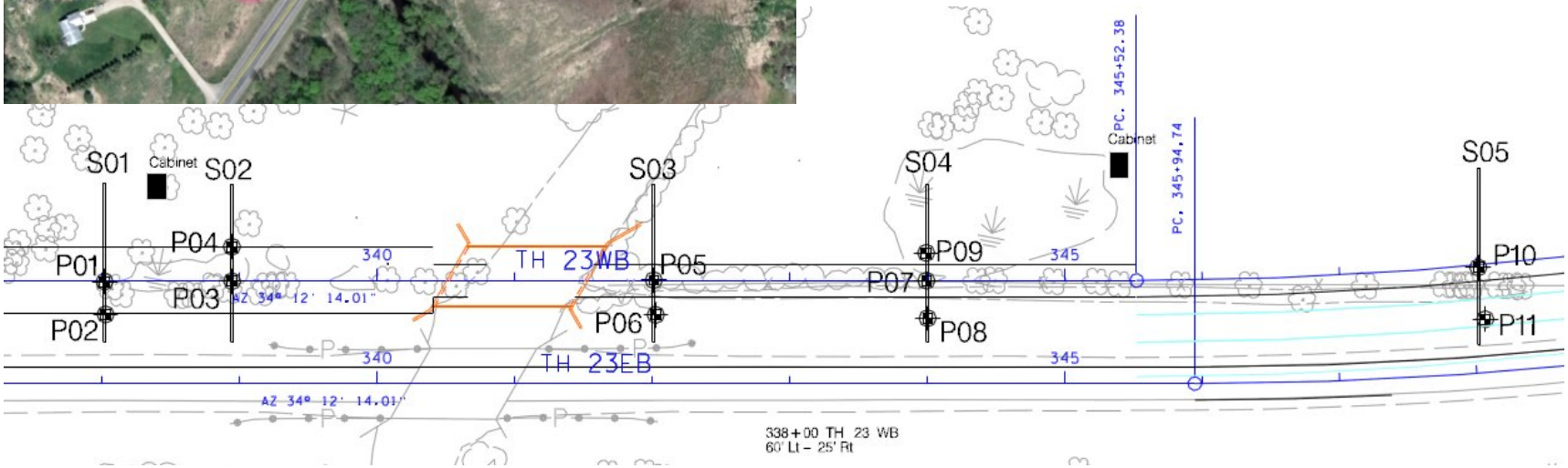
Project/Site Examples

In-Situ Monitoring: Examples – Foley, MN

- T.H. 23 - Foley, MN
  - Rural 2-lane hwy.
    - Widen to 4-lanes.
    - Add bridge.
    - Low lying area with soft, compressible clays and organics.
  - 2011, Destination Innovation Funds.
    - First MnDOT project using SAA.
    - Also used EPC and VWP.

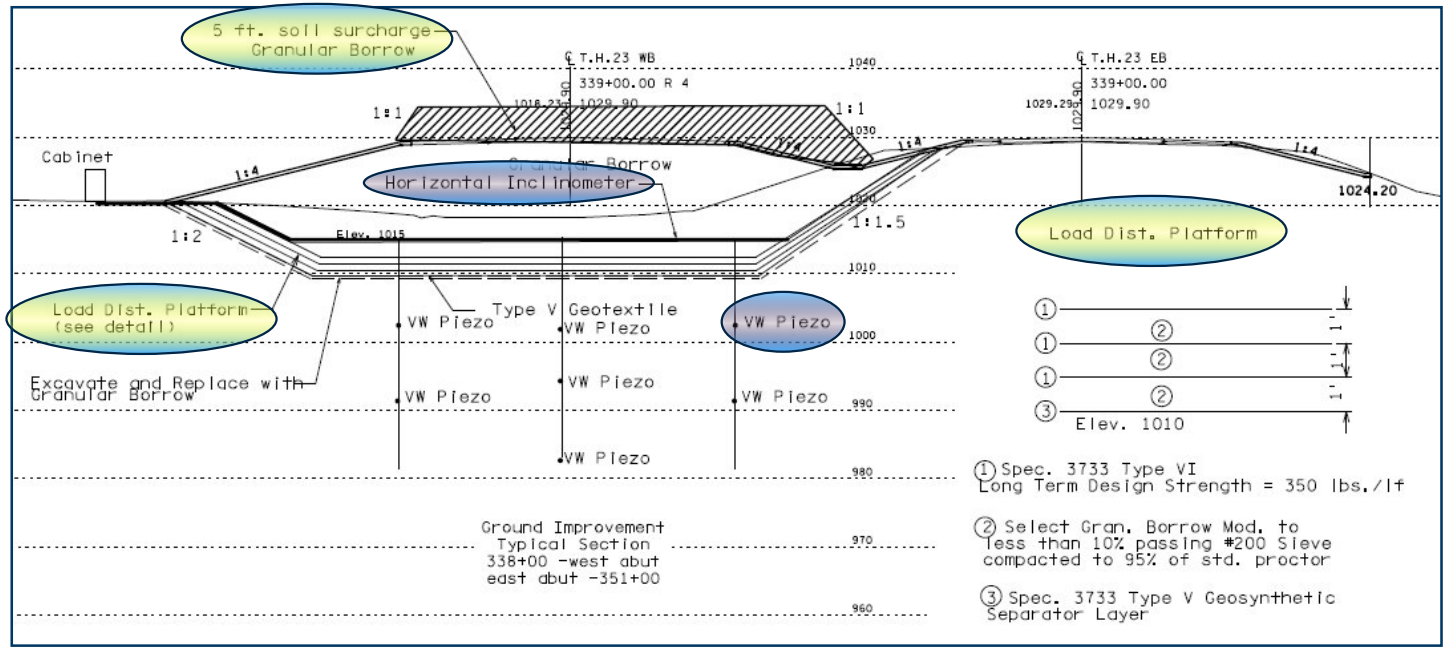
In-Situ Monitoring: Examples – Foley, MN

- T.H. 23 - Foley, MN



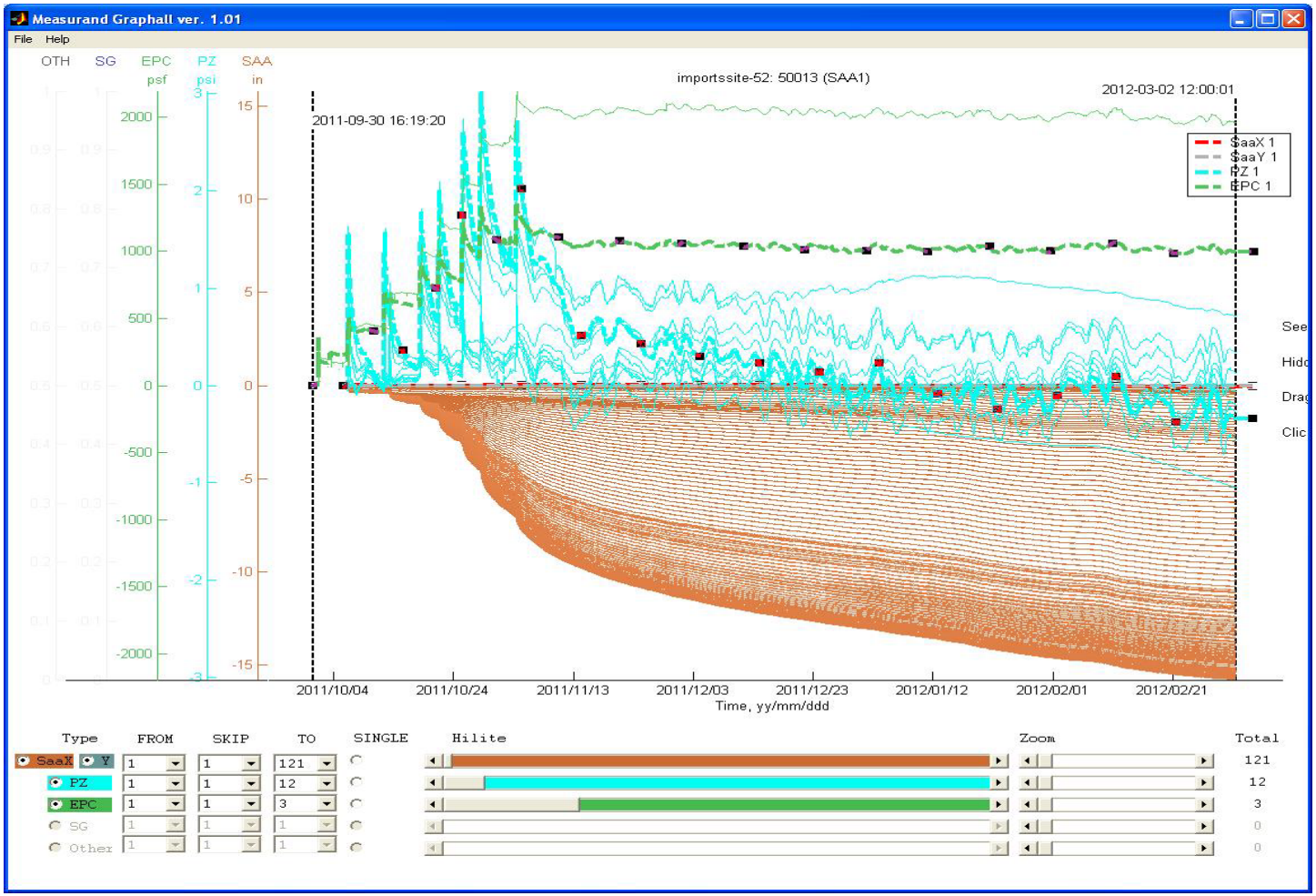
In-Situ Monitoring: Examples – Foley, MN

- T.H. 23 - Foley, MN
  - Remove 10 ft. of soil
  - Place reinforced Load Distribution Platform
  - EPC, SAA, PZ
  - Place embankment & 5 ft. surcharge
  - Wait.



In-Situ Monitoring: Examples – Foley, MN

- T.H. 23 - Foley, MN
  - EPC
  - SAA
  - PZ

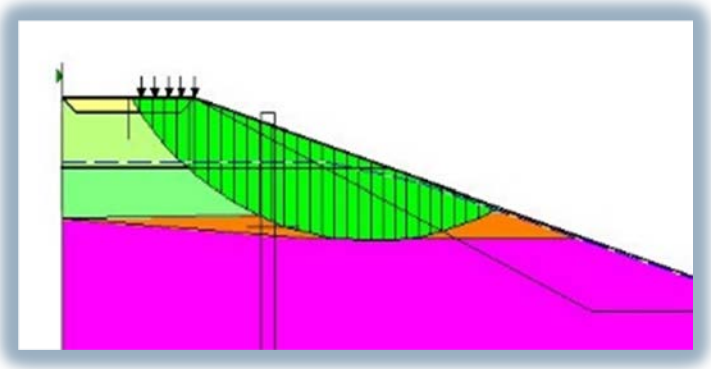


In-Situ Monitoring: Examples – Foley, MN

- T.H. 23 - Foley, MN **<u>*RESULTS*</u>**
- Shortened bridge length by 1 span
  - Saved
- Shorter surcharge duration
  - Saved 1 month on the expected “waiting period”
- Better long-term performance from precise settlement data.
- Demonstrated value of real time monitoring.
  - Adjust waiting periods during construction.
  - Monitor long-term performance.

In-Situ Monitoring: Examples – Kent, MN

- US 75 – Kent, MN
- Bridge Approach Failure during Construction



In-Situ Monitoring: Examples – Kent, MN

- US 75 – Kent, MN

In-Situ Monitoring: Examples – Kent, MN

- US 75 – Kent, MN
  - Observe/Document field cond.
  - Get a close look at the soil.
  - Several Site visits.
  - Take Soil Samples.
    - Look at density(?) and moisture content.

In-Situ Monitoring: Examples – Kent, MN

- US 75 – Kent, MN <u>*RESULTS*</u>
  - Actual Site Conditions
    - Clayey Soil type
    - Poor compaction of outer roadway core slopes
    - Very high moisture content
  - Solution:
    Material was dried, re-compacted and replaced.
  - <u>No sensors this time!</u>
    It's all about risk.

In-Situ Monitoring: Examples – 169/494 DB

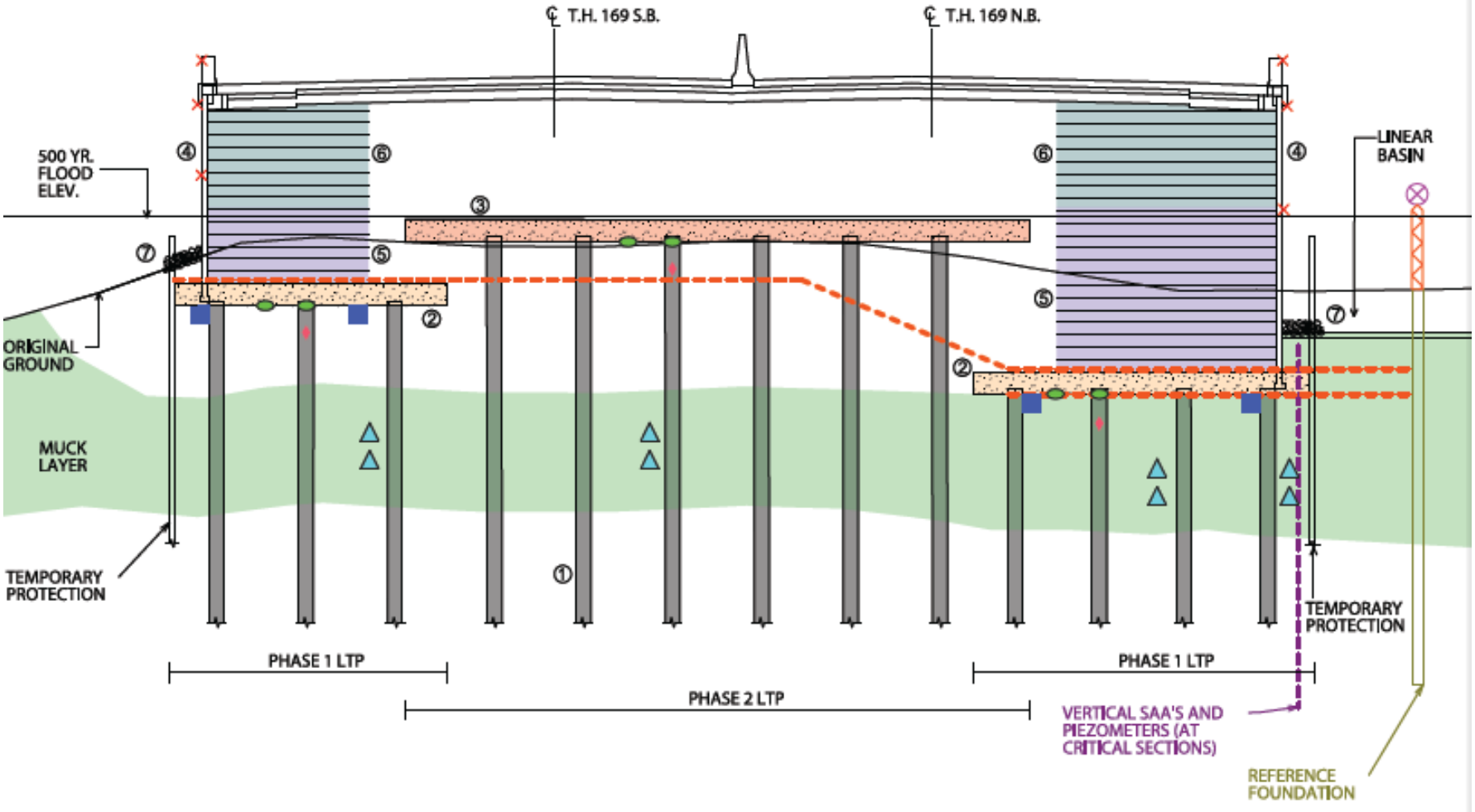
- T.H. 169/494 Interchange – DB (Metro area)
  - West 78th Street w. localized poor soils
    - ~100 ft. of road (small area)
  - Remove/Replace missed some organics
  - "Small" project issue, rediscovered after construction was nearly complete.
  - Solution – Surcharge & Monitor
    - MnDOT performed settlement monitoring
      - Trimble S8 and monitoring prisms. Custom cabinet and solar panels.
      - TSC-3 automates the data collection.

In-Situ Monitoring: Examples – CSE

- Column Supported Embankments (CSE) & LTP
  - Historically: Closed Form Solution Design
  - Steel Pipe Pile w. circular caps
    - LTP designed using the "Beam" method with:
      3.5 foot thick LTP with 3 or more layers of geogrid
      Edge reinforcement confinement
  - Contemporary: FEM using PLAXIS 2-D/3-D software
  - Rigid Inclusion (grout columns)
    - Drilled Displacement Piles
      Grout Columns with no reinforcement
      LTP with no geogrid reinforcement

In-Situ Monitoring: Examples – CSE

- Column Supported Embankments (CSE)



In-Situ Monitoring: Examples – CSE

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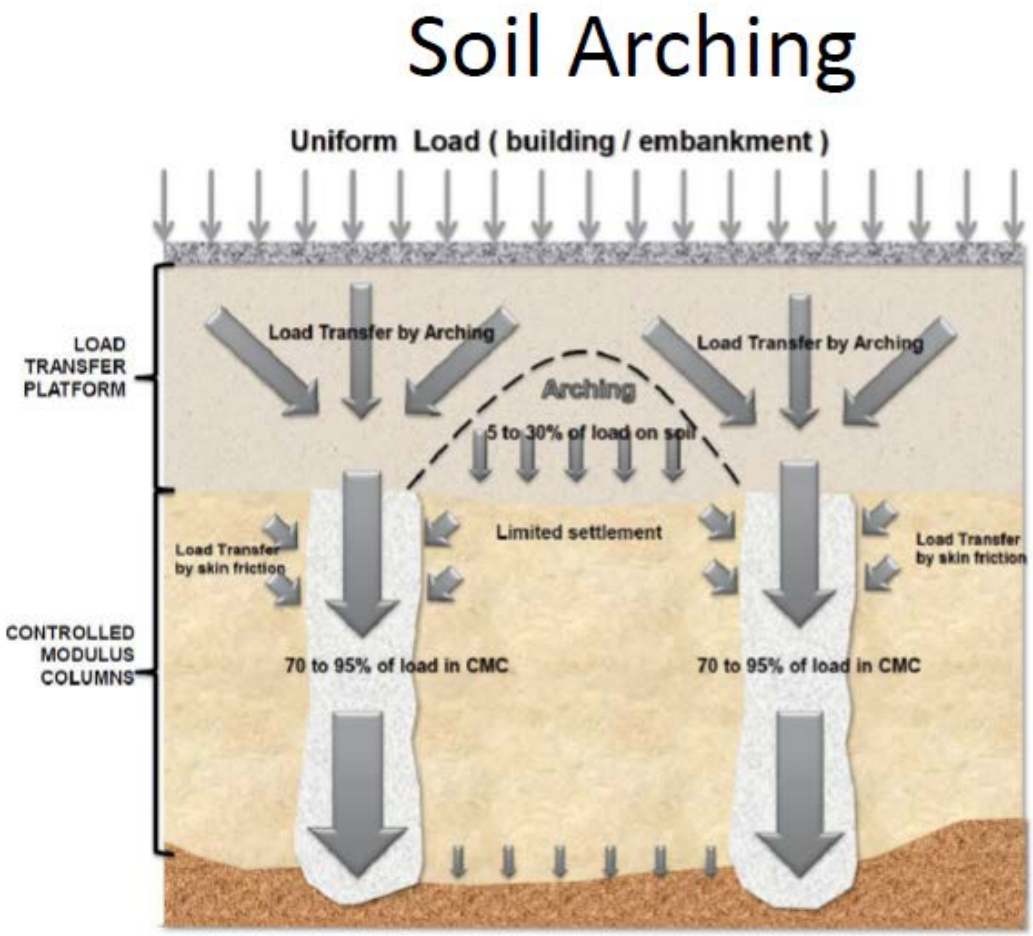
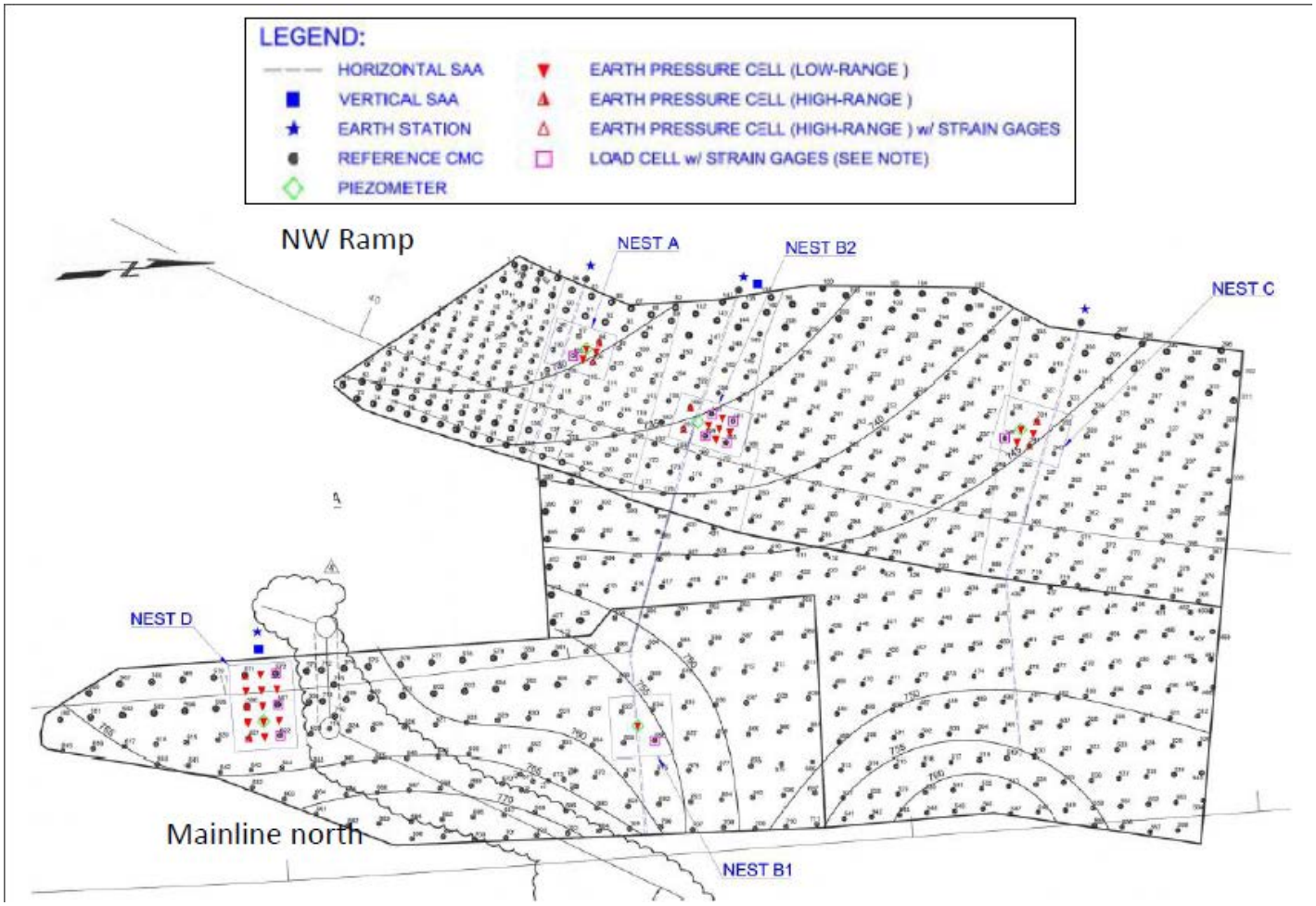


In-Situ Monitoring: Examples – CSE

- 35E Cayuga – Just north of downtown St. Paul



In-Situ Monitoring: Examples – CSE

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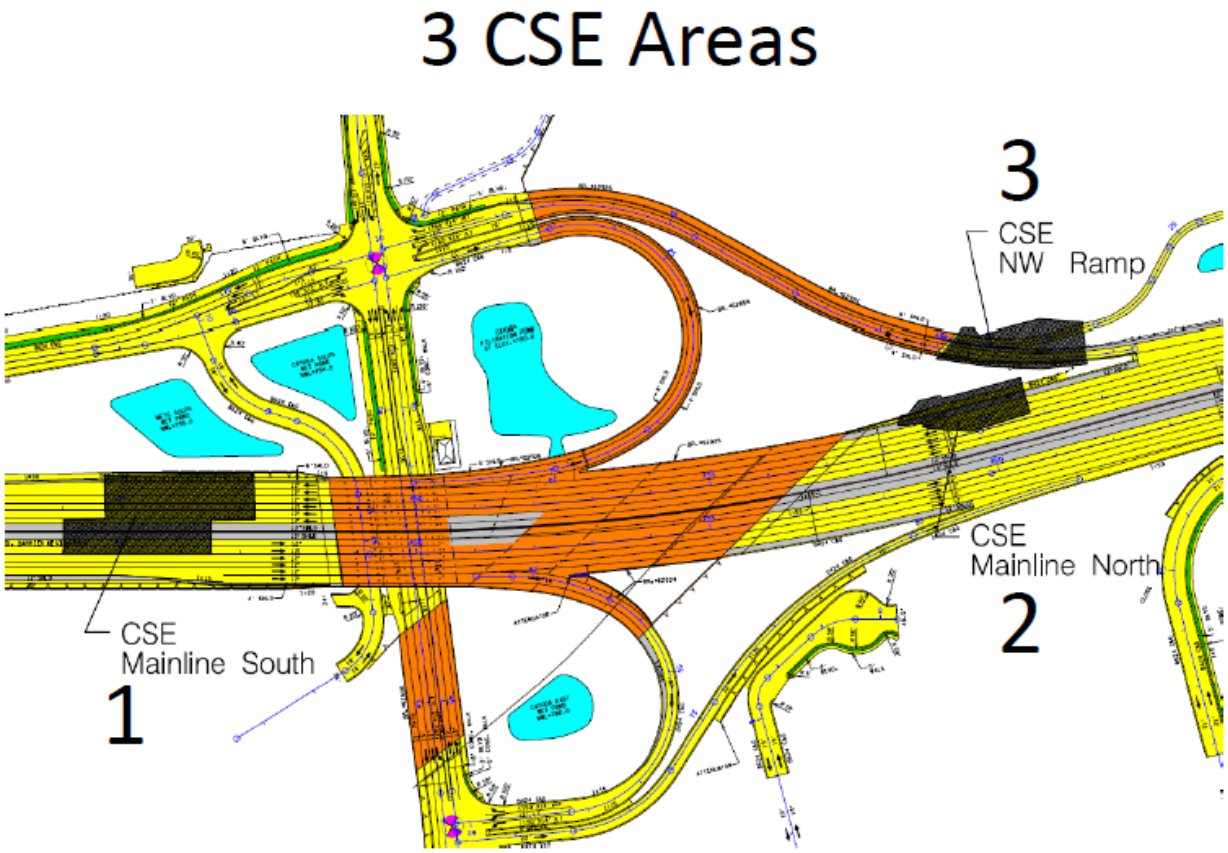

In-Situ Monitoring: Examples – CSE

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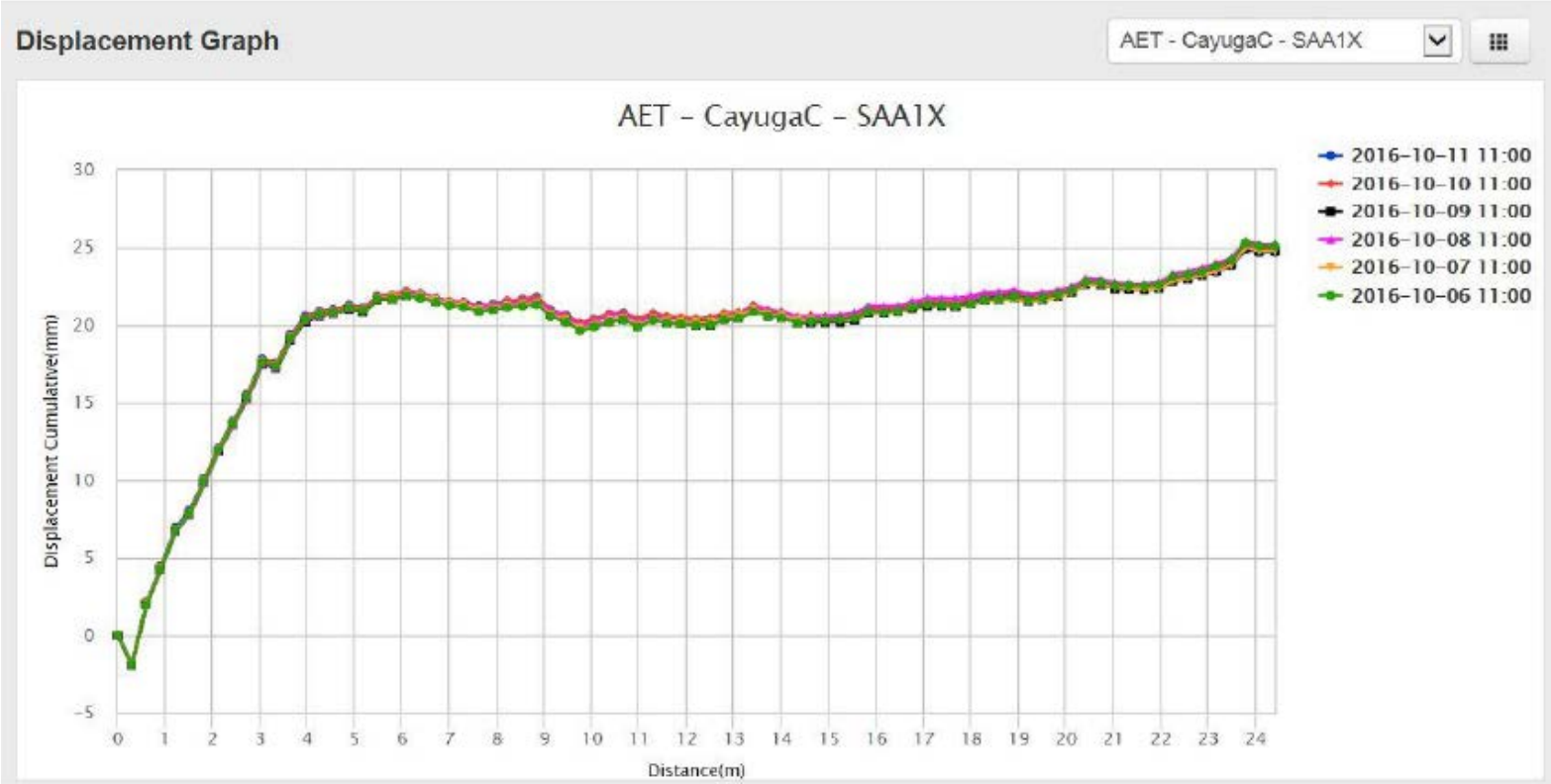
Settlement



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Thank You !

Andrew Eller, P.E.
MnDOT Geotechnical Section

Andrew.Eller@state.mn.us