Michigan Bridge Conference

Use of NDT Tools in Preserving Pre-stressed and Reinforced Concrete Substructures

by

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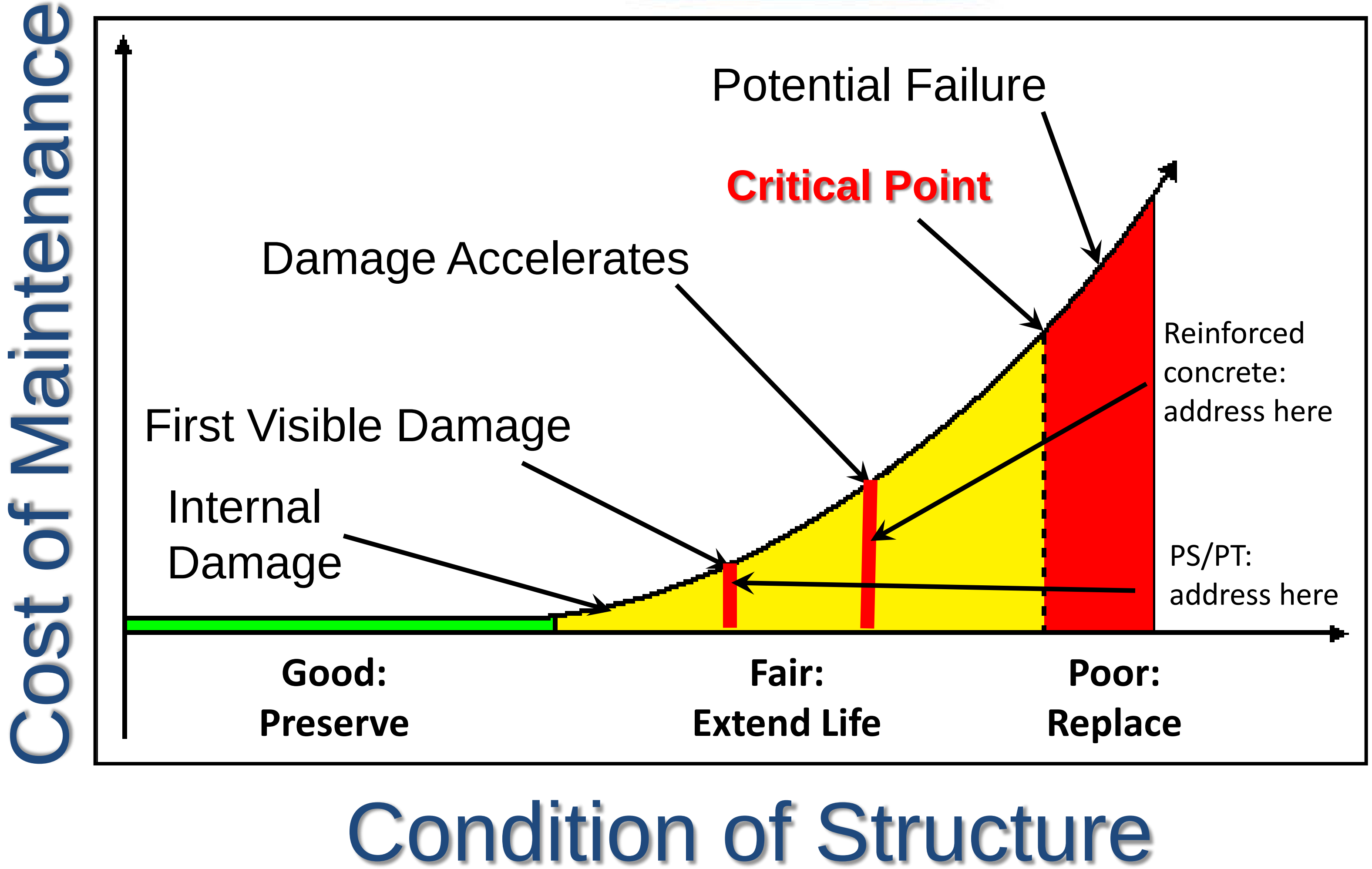
In This Presentation

- Impact Echo (IE) – New Jersey Pier Apron
- IR – Indiana I-65 Bridge Substructure
- GPR & IR – Illinois Cable-Stay Bridge
- GPR – New Jersey Deck Survey
- STAT Test – Wisconsin Post-Tensioned Box Girder Bridge
- PT Tendon & PT Bars – Virginia Varina-Enon Bridge
- Service Life Estimate – Virginia King Street Bridge

Corrosion Cost Progression



Impact-Echo (IE): NJ Pier Apron

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Challenge:

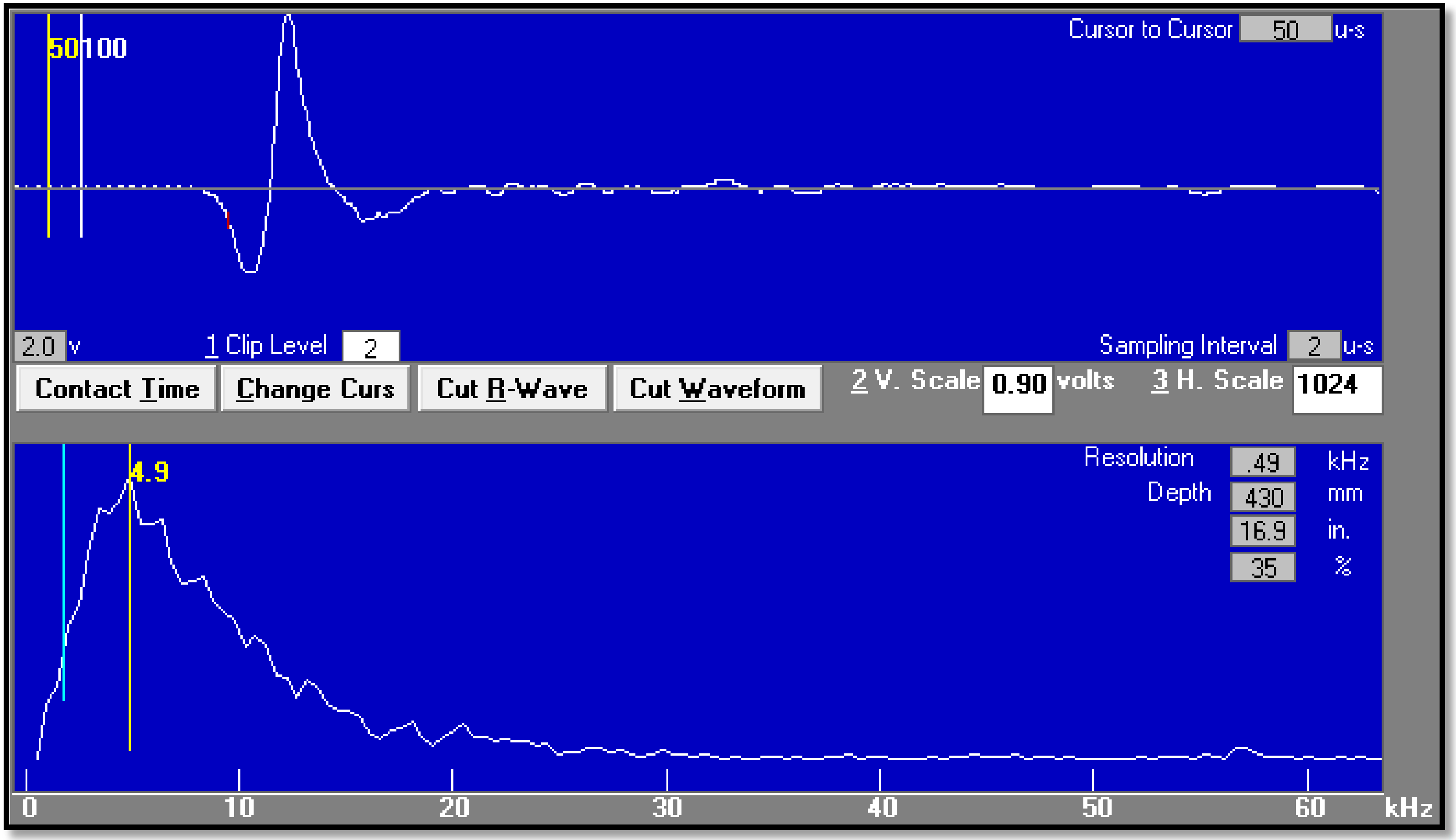
- Concrete apron was cast-in-place around pier to protect against scour
- During pouring, the form was breached and cementitious material leaked out
- Owner was concerned that excessive voids may lead to lack of scour protection

Impact-Echo (IE): NJ Pier Apron

Solution:

- Utilized Impact-Echo (IE) acoustic technique to identify large voids within the apron
  - Ultrasonic waves are introduced into the concrete via impacts with steel ball bearings
  - Sound waves reflect off of discontinuities (i.e. voids, cracks, honeycombing), thus locating voids
- Tests were performed in a 2’x 13’ grid along the apron

Impact-Echo (IE): NJ Pier Apron



InfraRed Survey: IN I-65 Bridge

IR: IN I-65 Bridge

Challenge:

- Highway I-65 in Indianapolis, Indiana passes over seven city streets and was constructed in 1972 of reinforced concrete
- The substructure of its 45 spans showed significant corrosion-related damage
- SCS evaluated the deck and substructure components to determine whether corrosion mitigation methods may be used to extend the structure's life

- IR quickly and effectively identifies areas of delamination

IR: IN I-65 Bridge

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IR: IN I-65 Bridge

Solution:

- IR quickly and effectively identified areas of delamination
- Delamination was used in conjunction with other data (cover, chloride profiles, etc.) to estimate remaining service life & life cycle cost of various repair options
- Recommended installation of an ICCP system at expansion joint piers to extend the life of the substructure

GPR & IR: IL Cable Stay Bridge

GPR & IR: IL Cable Stay Bridge

Challenge:

- During past inspections, cracks and voids were observed in the HDPE stay pipes
- Water was observed inside the tendon anchorages and neoprene boots
- Water or voids within grouted stay cables could lead to corrosion of the strands

GPR & IR: IL Cable Stay Bridge

Solution:

- As part of the overall inspection, one of the goals was to **non-destructively identify voids within the stay cables**
- After brief field trials, SCS identified infrared thermography (IR) and ground penetrating radar (GPR) to be the most effective tools
- Impact Echo was used as well, but cable wrapping significantly dampened the acoustic waves

GPR & IR: IL Cable Stay Bridge

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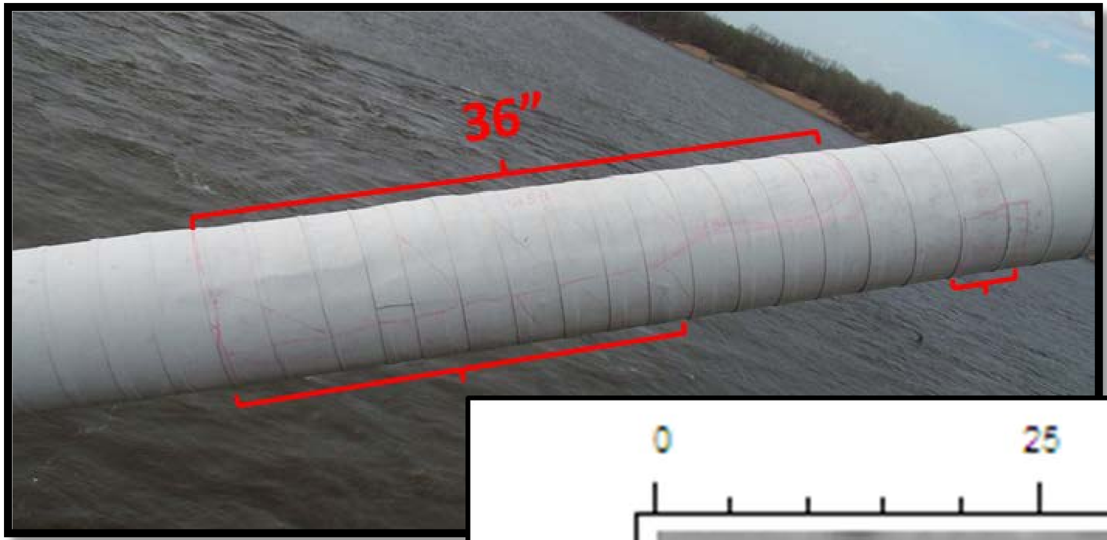
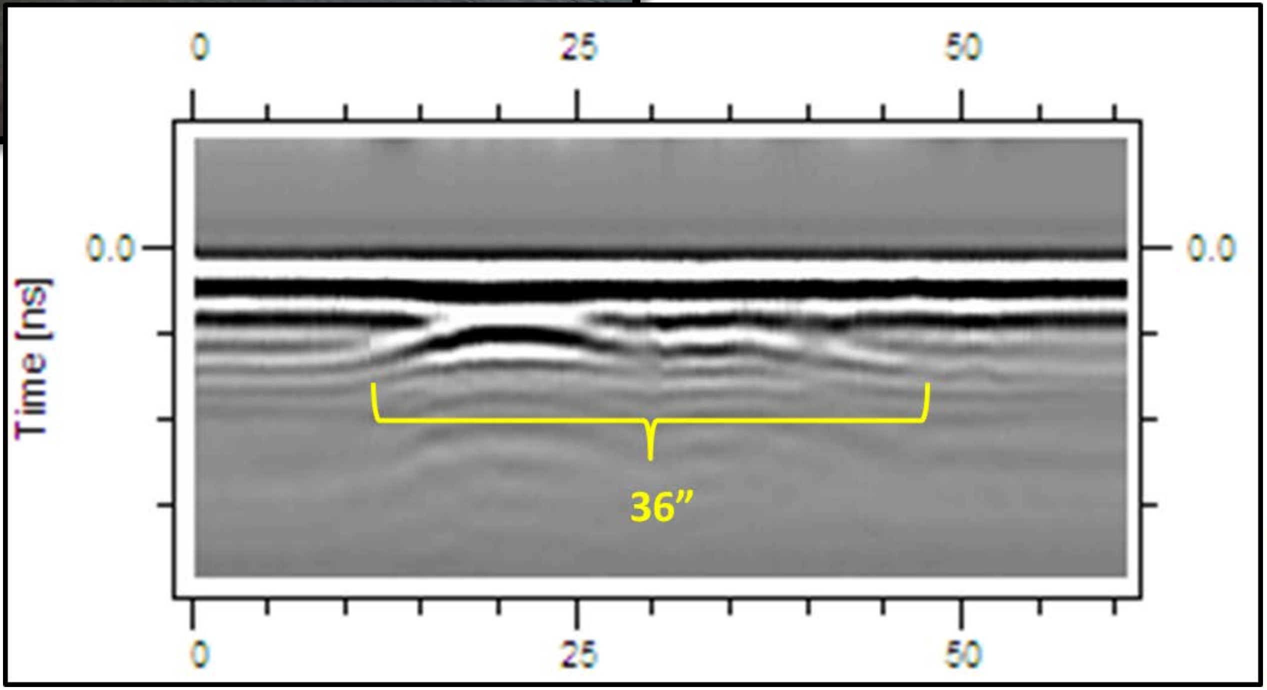
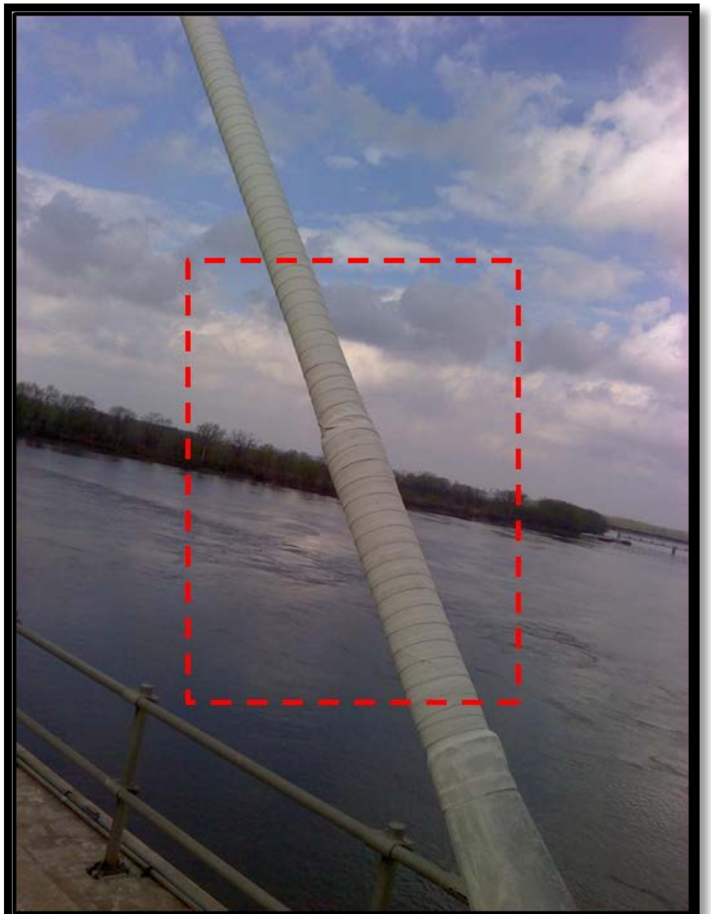
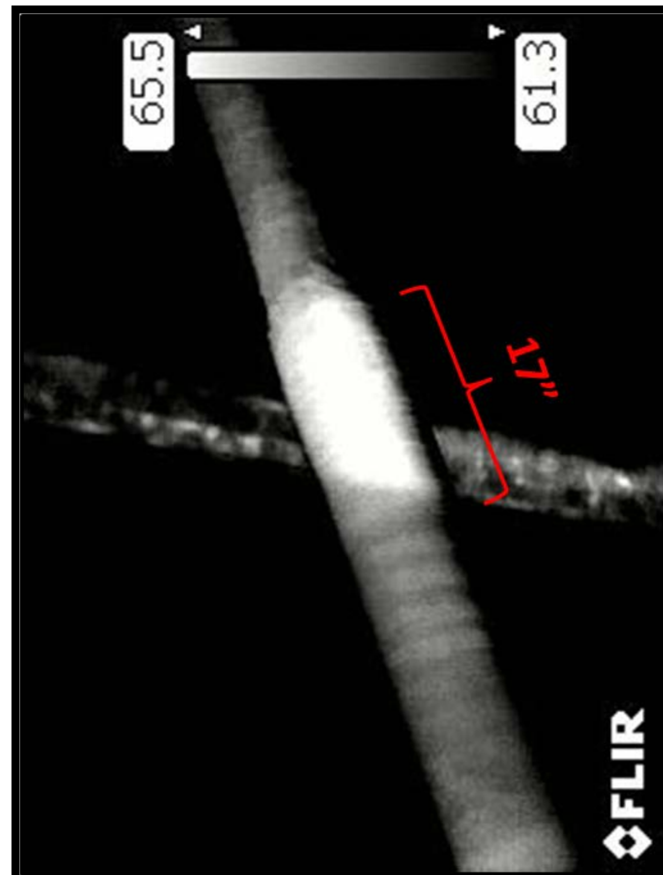




GPR & IR: IL Cable Stay Bridge





GPR & IR: IL Cable Stay Bridge

- Identified over 100 voided locations using IR/GPR
- All voids were confirmed with IR, GPR, or Sounding
- Invasive testing (borescoping) was performed to determine if voids are problematic
- Additional cable openings at voids locations is planned to quantify the extent of damage

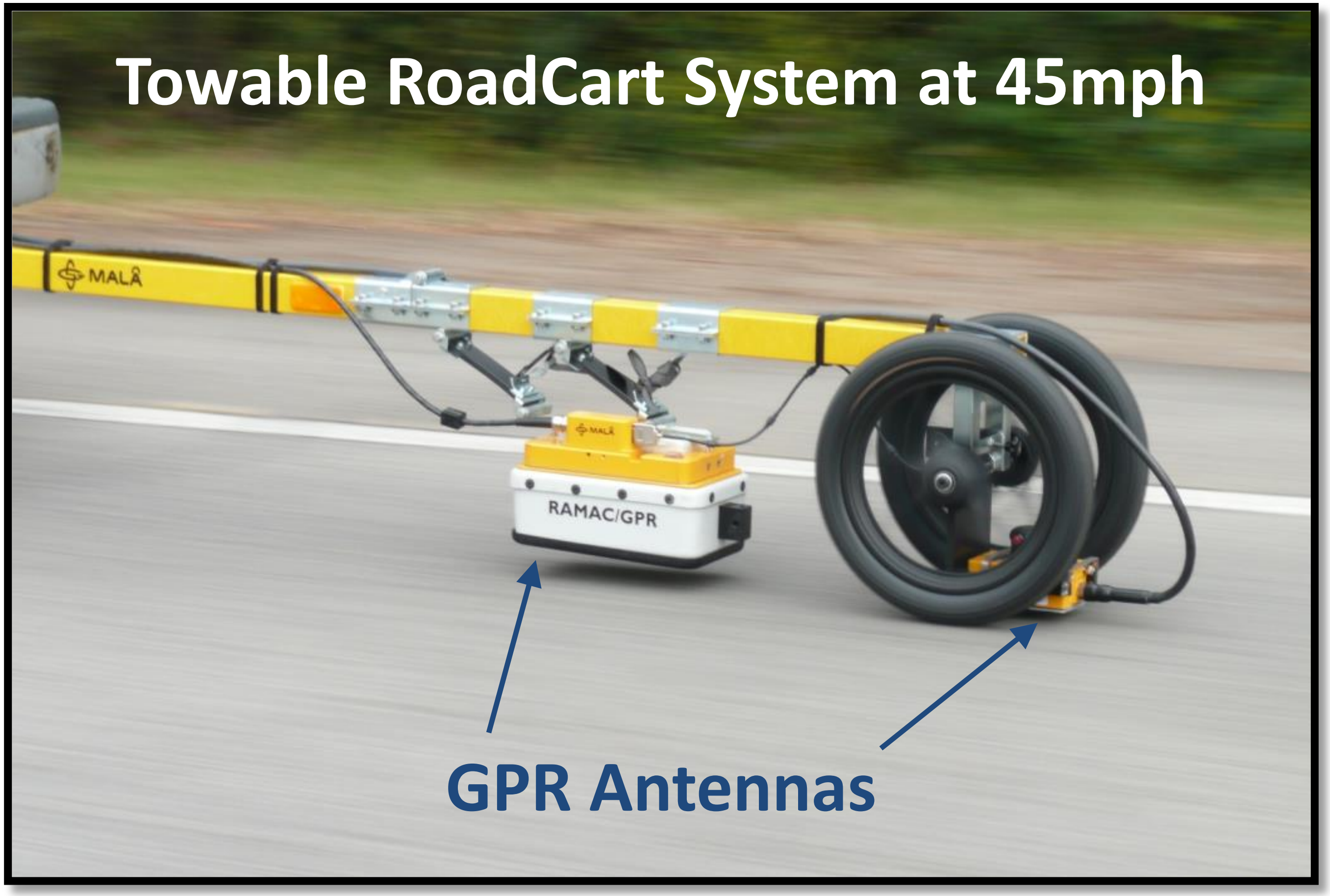
GPR: NJ Deck Survey

GPR: NJ Deck Survey

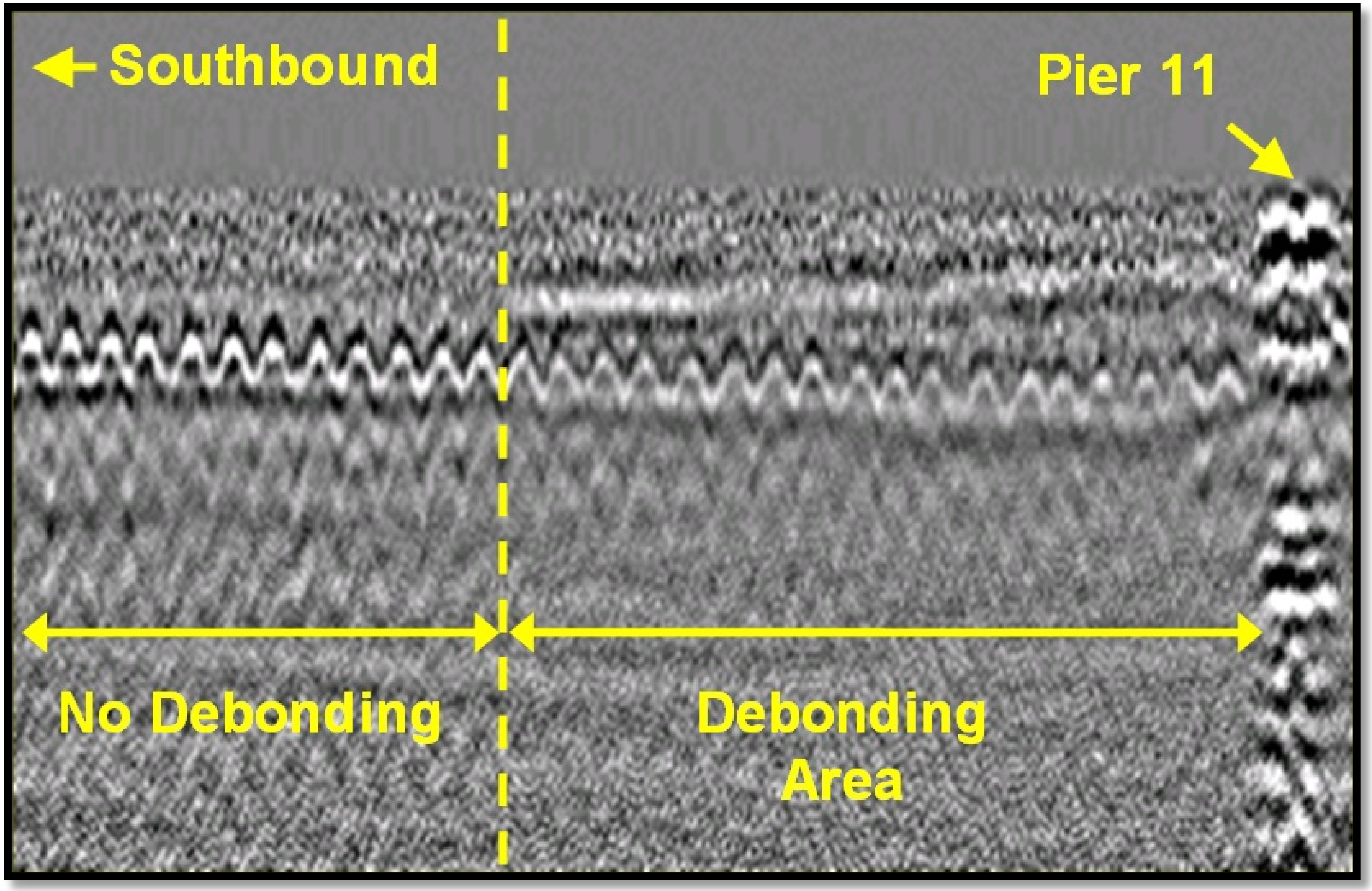
Challenge:

- The NJTA deck was over 100,000 sq. ft.
- The overlay placed in 1994 had current significant delamination and spall, cracks, and growth of spall
- Requested to determine the cause of delamination and quantify the extent of damage on the riding surface
- Use Ground Penetrating Radar (GPR) to identify deck delamination and confirm results via sounding and coring at select locations.
- Perform petrographic analysis and chloride content testing on cores

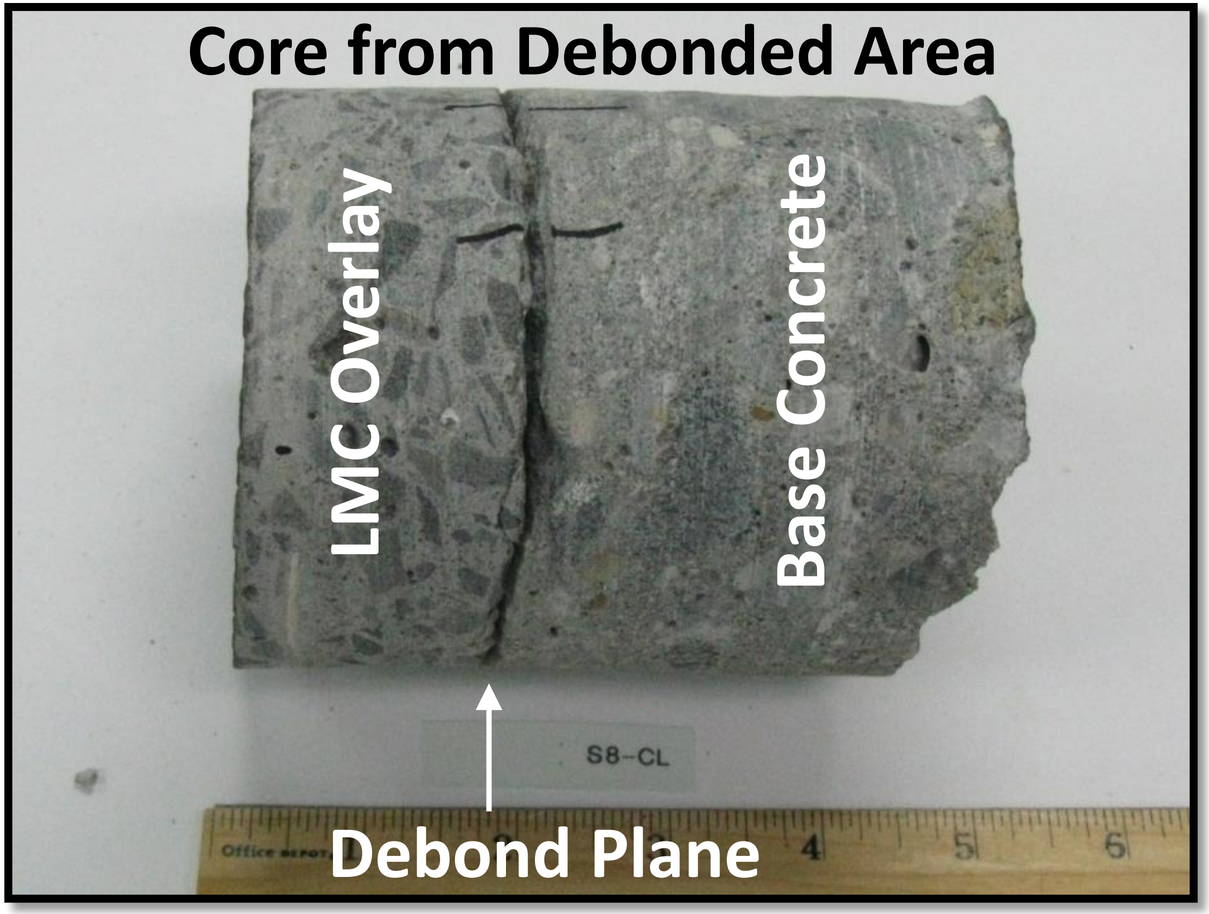
GPR: NJ Deck Survey



GPR: NJ Deck Survey



GPR: NJ Deck Survey

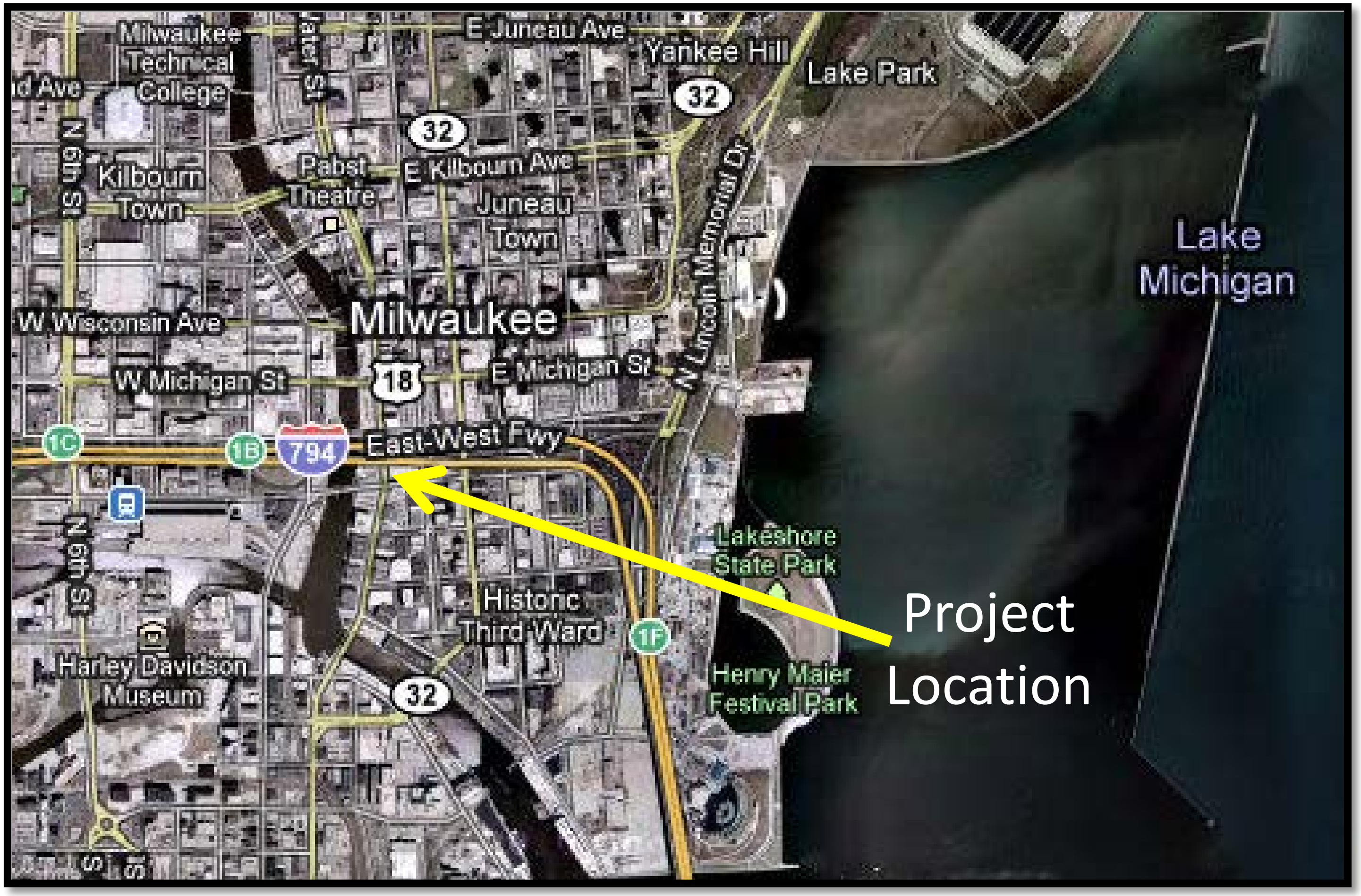


GPR: NJ Deck Survey

Solution:

- Extent of delamination quantified
- Petrographic analysis revealed:
  - Cause of delamination was improper finishing of the base concrete leading to a weakened layer at the overlay-base interface
  - High chlorides at the rebar due to escalating delamination
- Replacement of overlay recommended

STAT Test: WI PT Box Girder Bridge

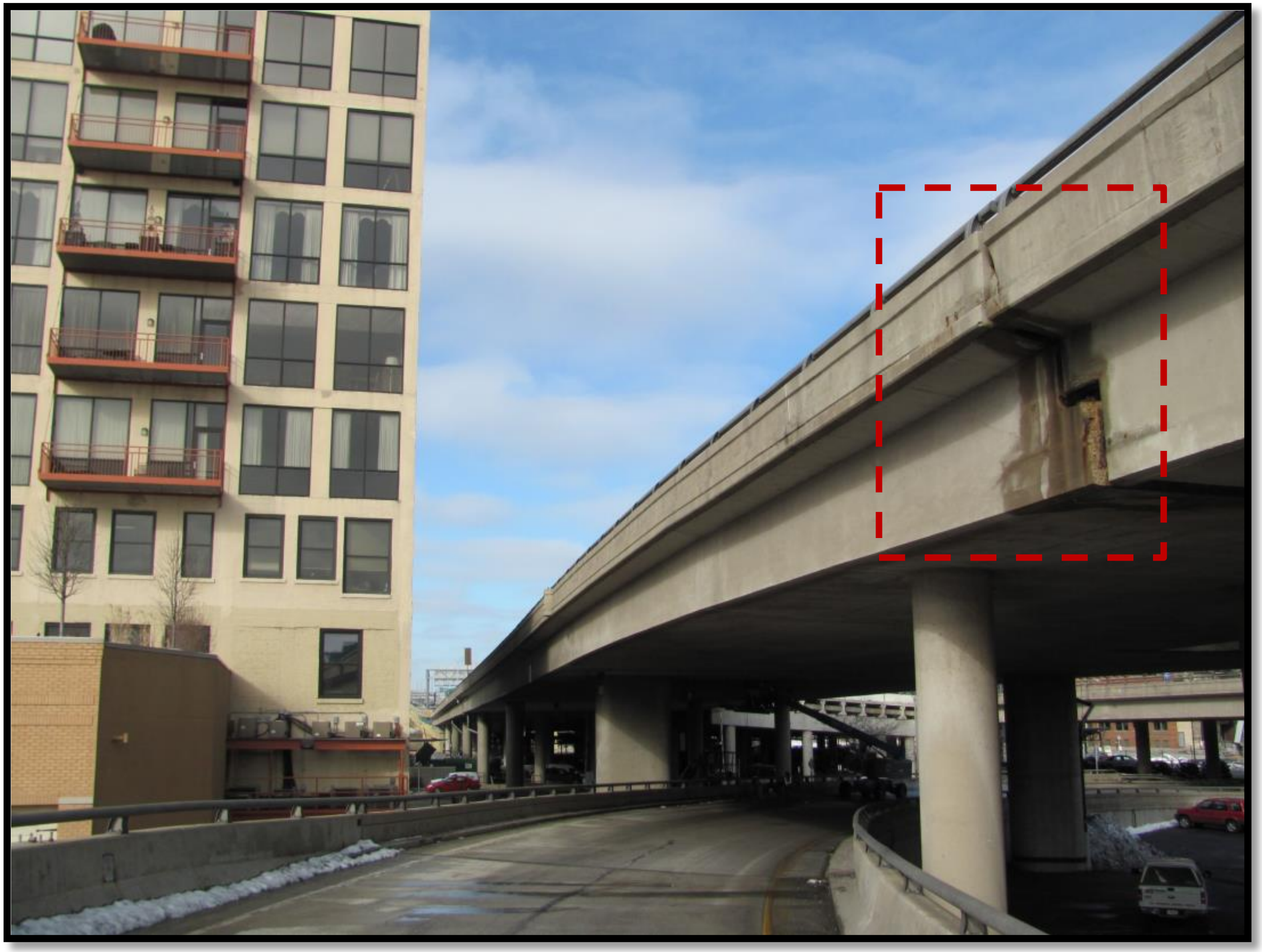


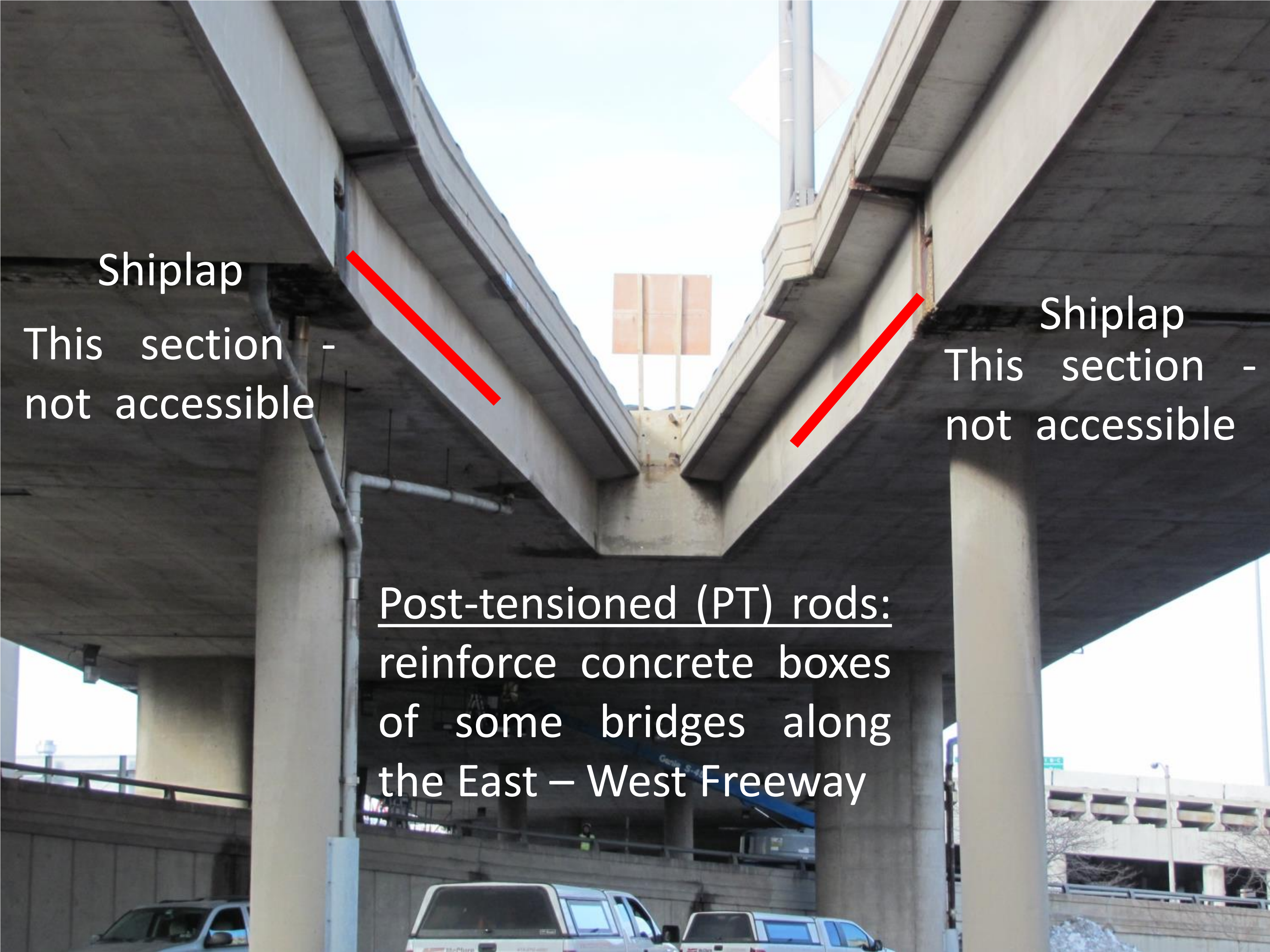
STAT Test: WI PT Box Girder Bridge

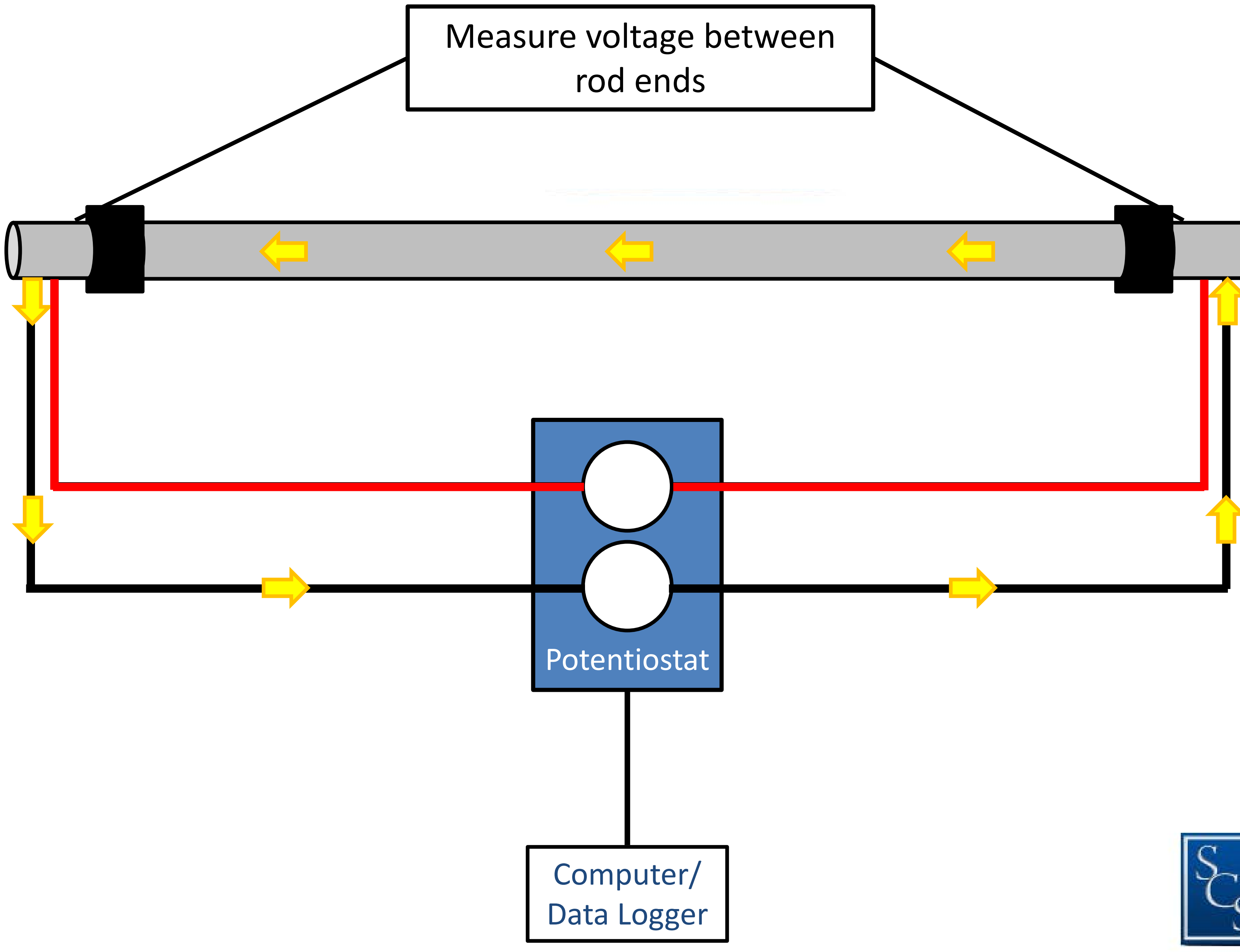
Challenge:

- Post-tensioned (PT) rods may be broken or deteriorated
- Remaining strength depends on the number of PT rods still in good condition
- Unlike regular reinforced concrete structures, any significant reduction in PT rod section can result in increased stress which then lead to sudden failure
- Test Wisconsin bridge PT rods in a unit that also had visible corrosion on the exterior of the boxes

STAT Test: WI PT Box Girder Bridge

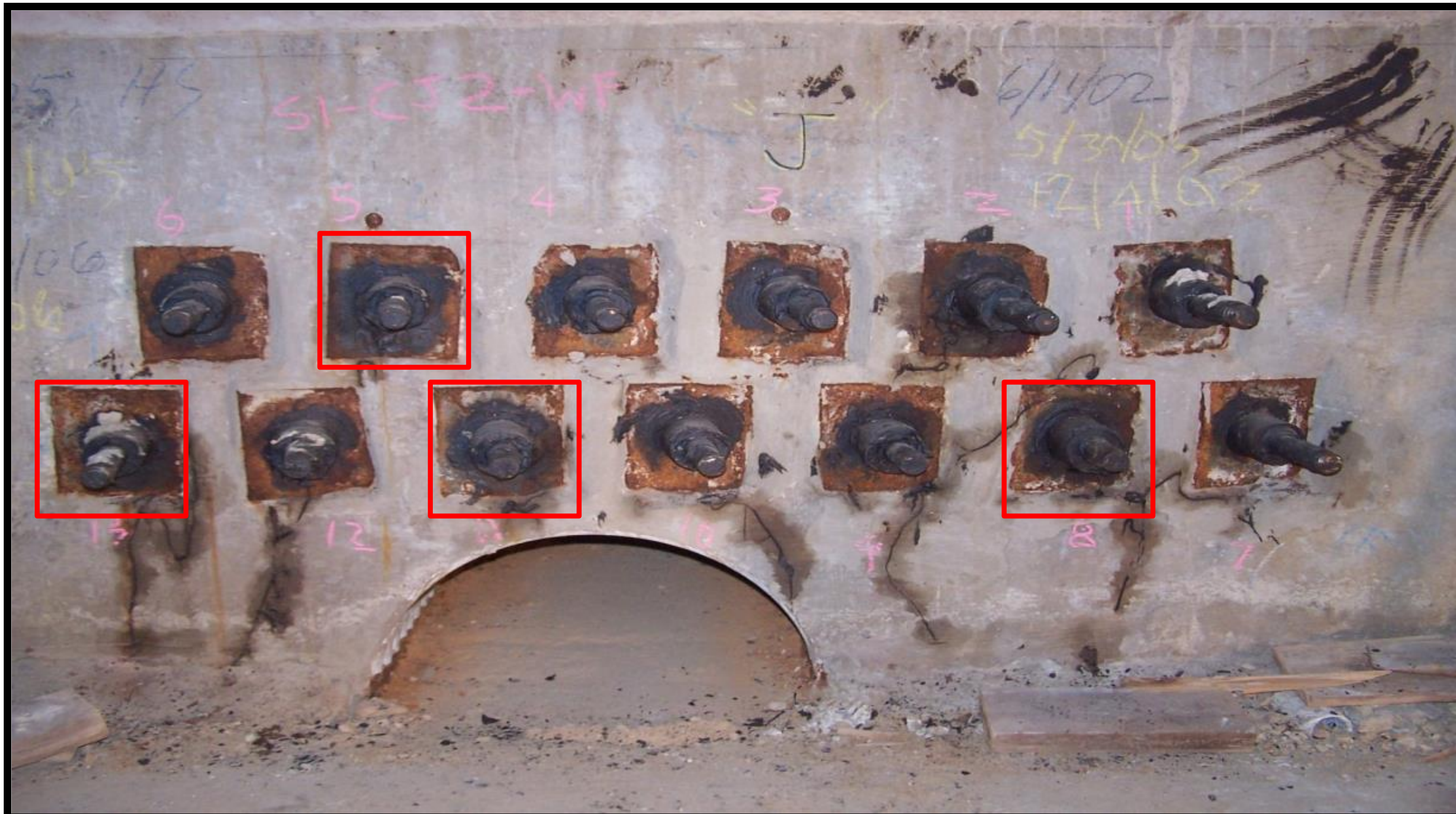



Shiplap
This section - not accessible
Shiplap
This section - not accessible
Post-tensioned (PT) rods:
reinforce concrete boxes of some bridges along the East – West Freeway


Measure voltage between rod ends
Potentiostat
Computer/
Data Logger

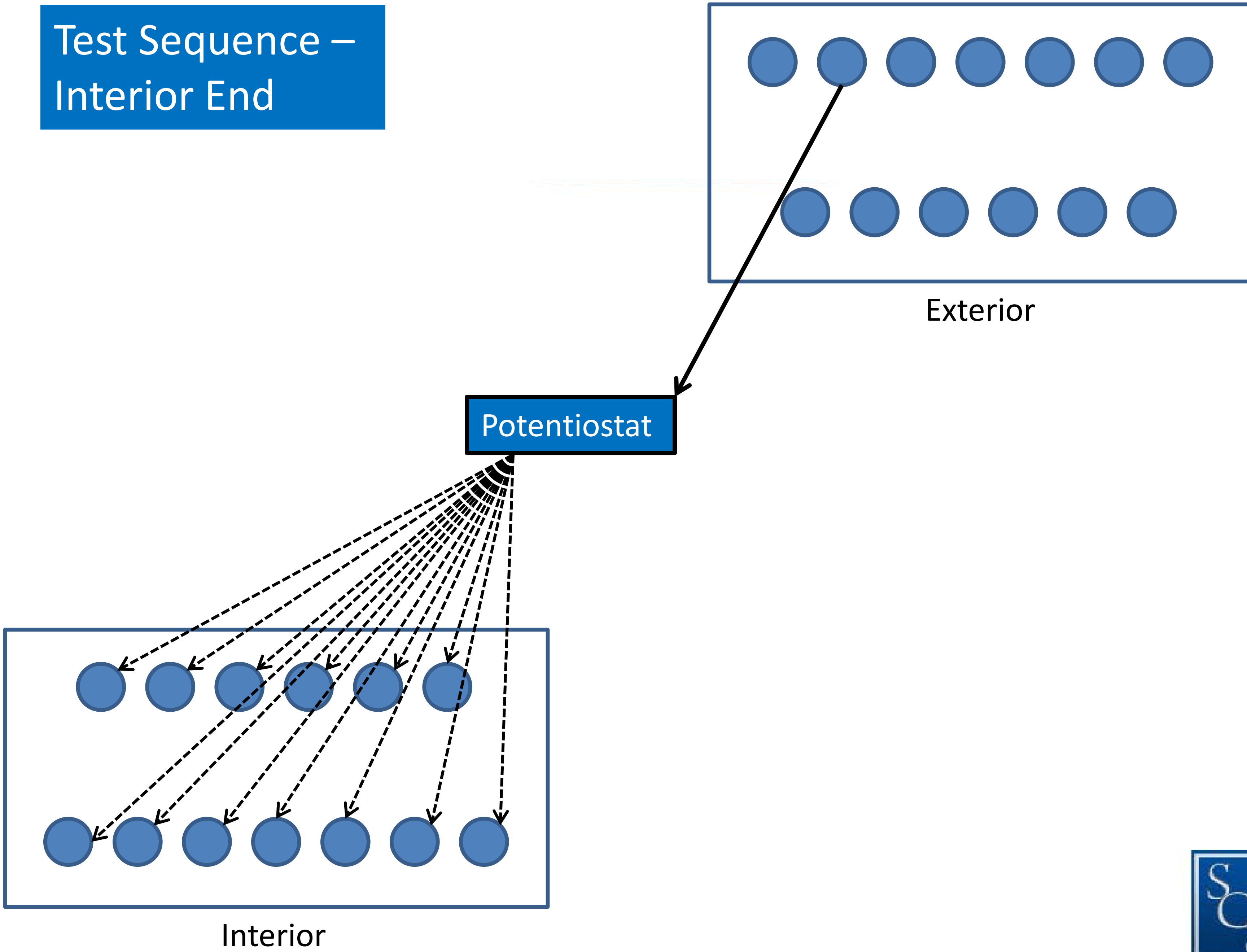
STAT Test: WI PT Box Girder Bridge

Problem Rods – Interior End

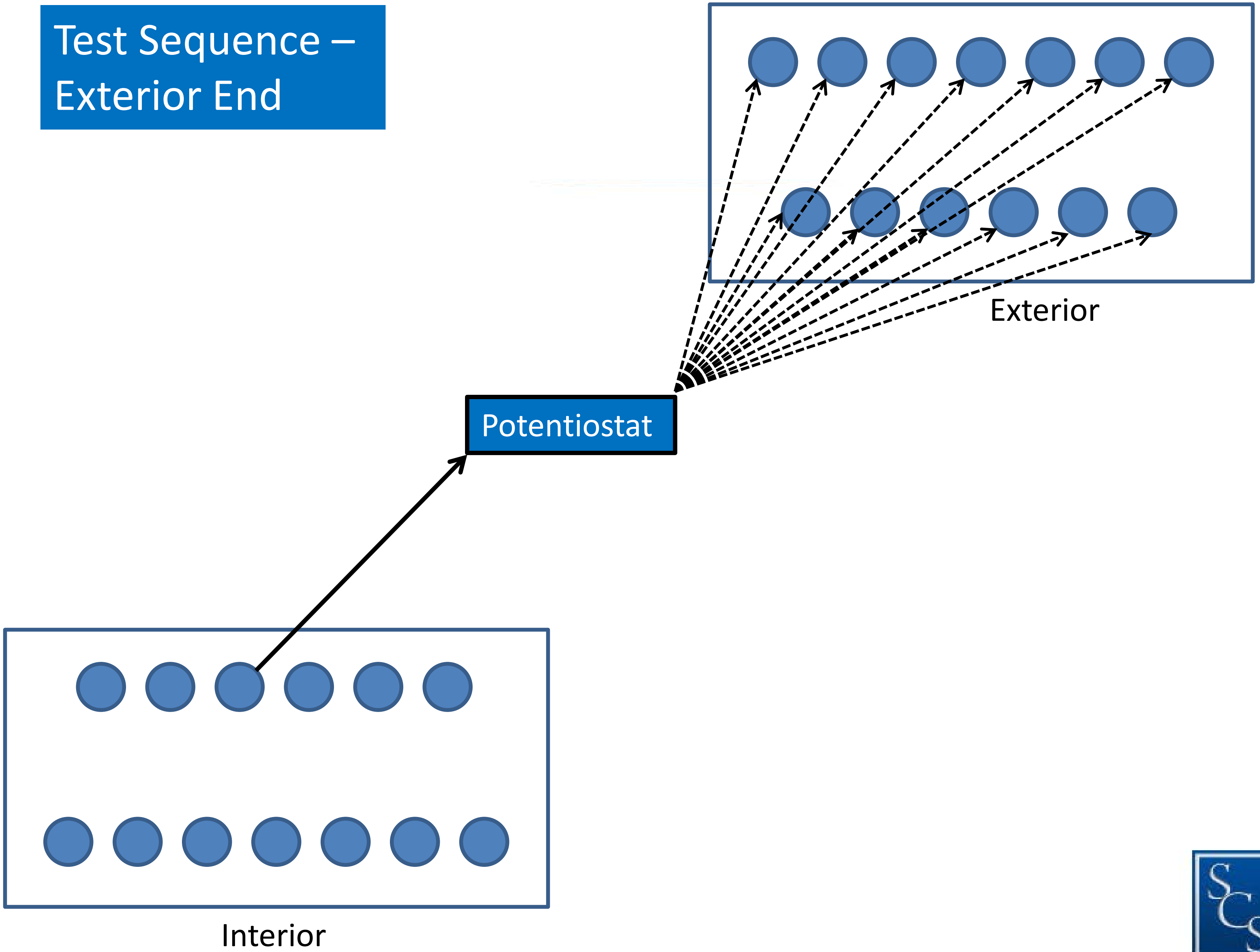


See Manual For
Replacement

Test Sequence – Interior End



Test Sequence – Exterior End



STAT Test: WI PT Box Girder Bridge

Solution:

- Remove and replace all rods identified as significantly corroded or already broken
- By identifying and replacing severely corroded PT rods, the Department can mitigate risks and extend the service life

PT Tendon & Bars Evaluation: VA Varina-Enon Bridge

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Challenge:

- During previous inspections, voids were identified in the tendons and PT bar ducts
- Some tendons had experienced significant corrosion (broken wires)

PT Tendon & Bars Evaluation: VA Varina-Enon Bridge

Solution:

- Inspect 18 vertical PT bar's condition
  - 9 Northbound / 9 Southbound
  - Using the borescope check for presence of
    - Voids
    - Water
    - Grout segregation
    - Tendon corrosion
  - Seal and mark drilled holes
  - Document process with pictures and video
- Future monitoring can be performed in the same locations to compare condition over time

PT Tendon & Bars Evaluation: VA Varina-Enon Bridge

PT Tendon & Bars Evaluation: VA Varina-Enon Bridge

Borescope: VA Varina-Enon Bridge

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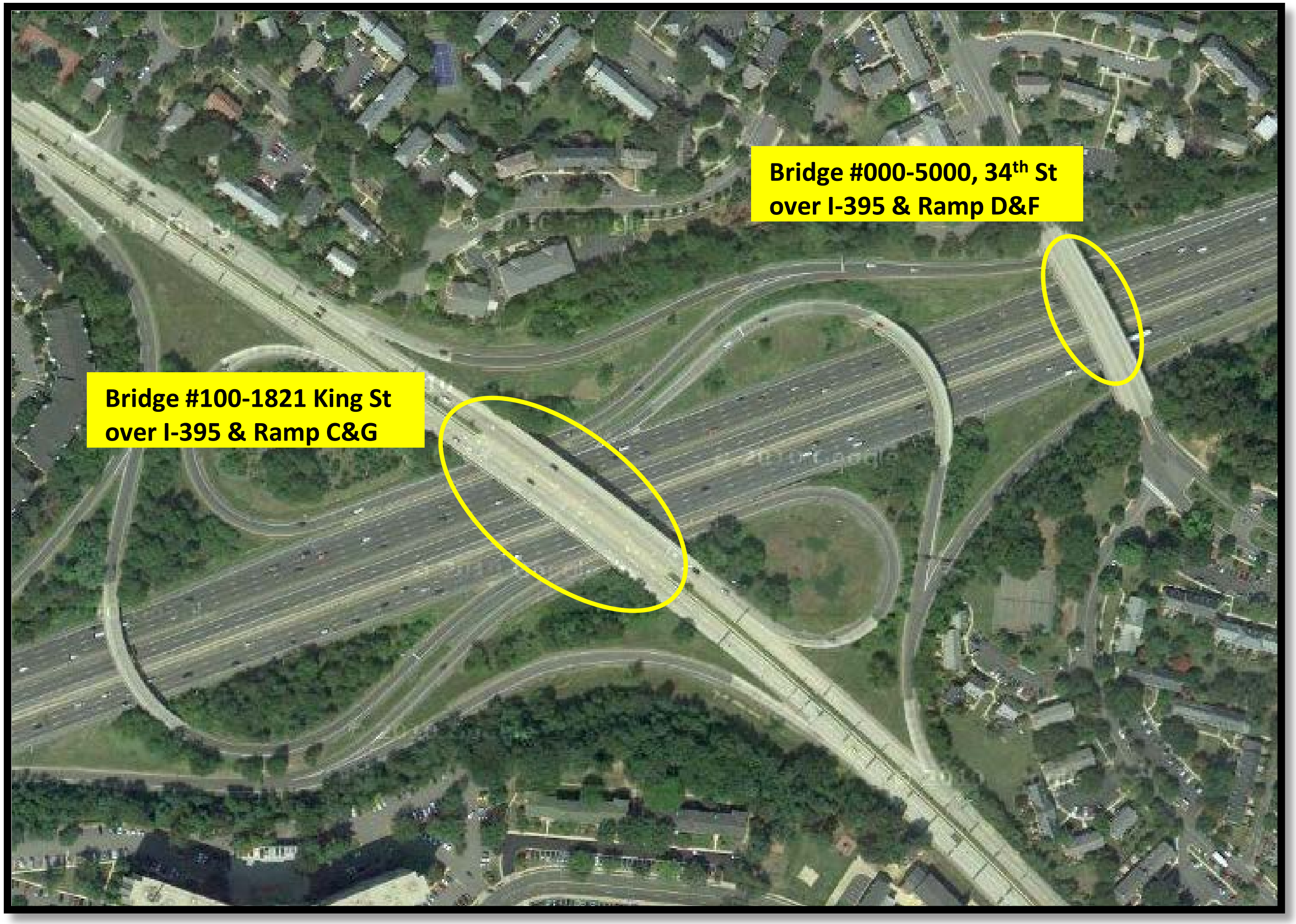
Service Life Estimate: VA Bridges

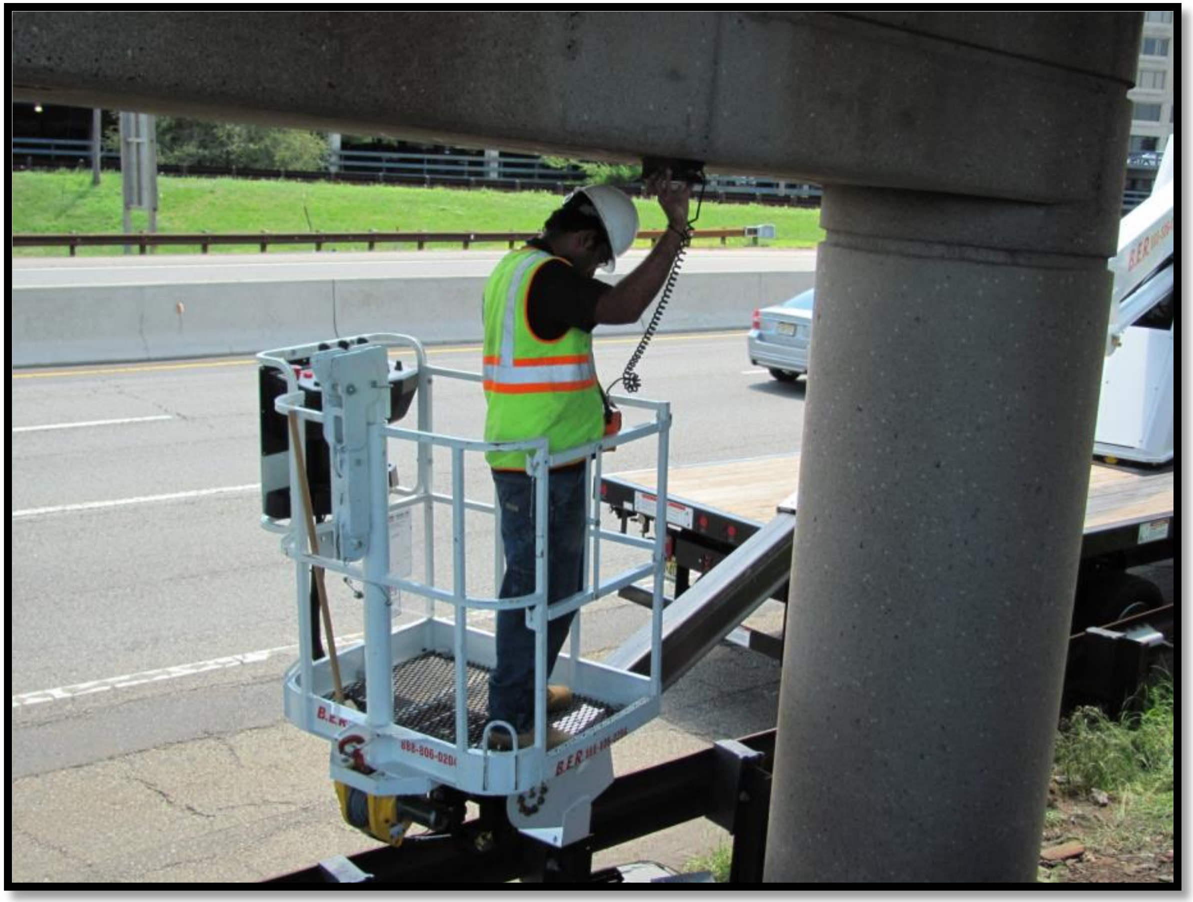


Service Life Estimate: VA Bridges

Challenge:

- Heavy traffic area bridges (over 180,000 VPD) along the I-395 and King Street Interchange in Alexandria, VA - exhibit evidence of: ongoing corrosion - concrete damage - reinforcement section losses
- VDOT desired an additional 50 year life and required rehabilitation alternatives to facilitate that goal
- Evaluated the deck and substructure of two bridges to determine whether corrosion mitigation methods can be used to extend service life

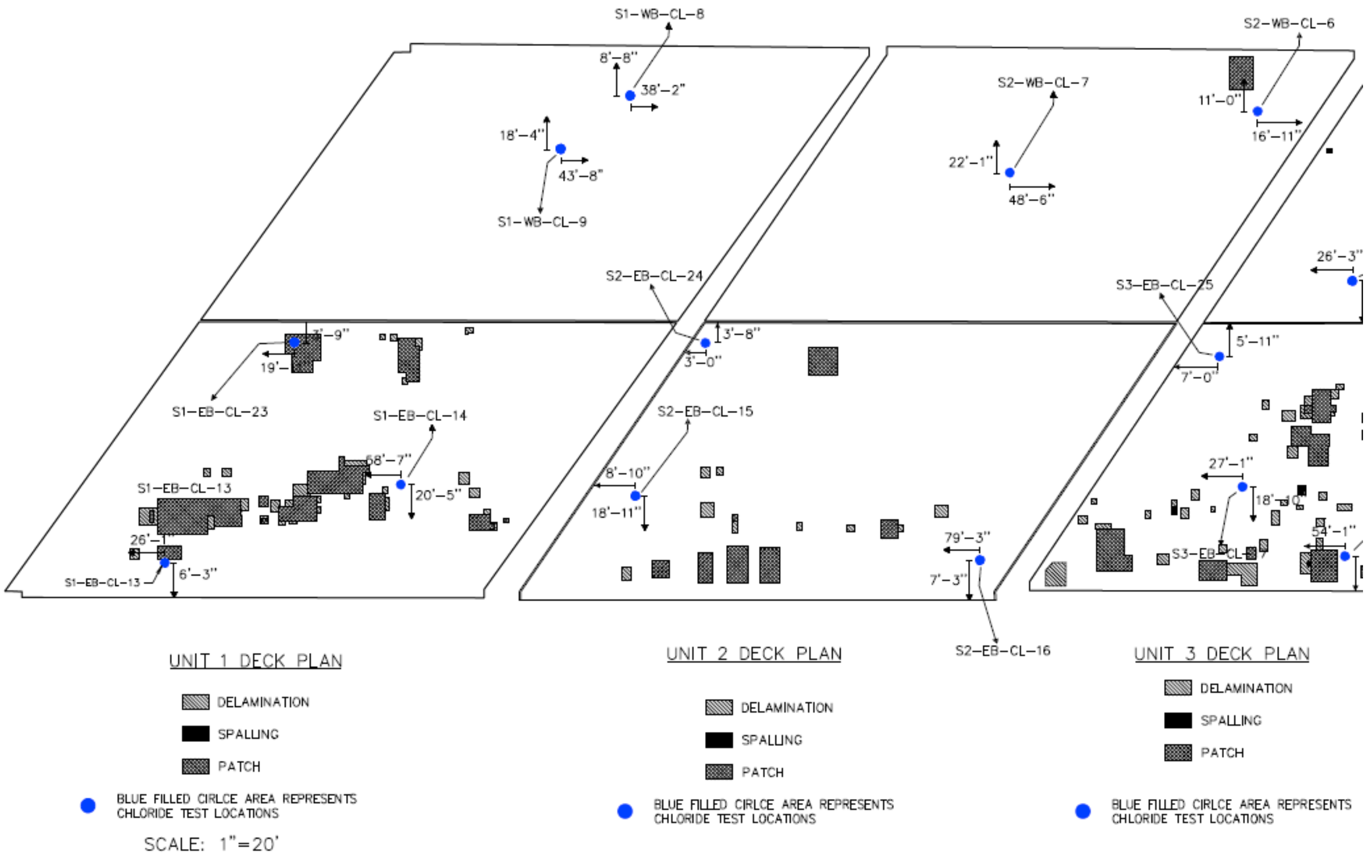
Service Life Estimate: VA Bridges



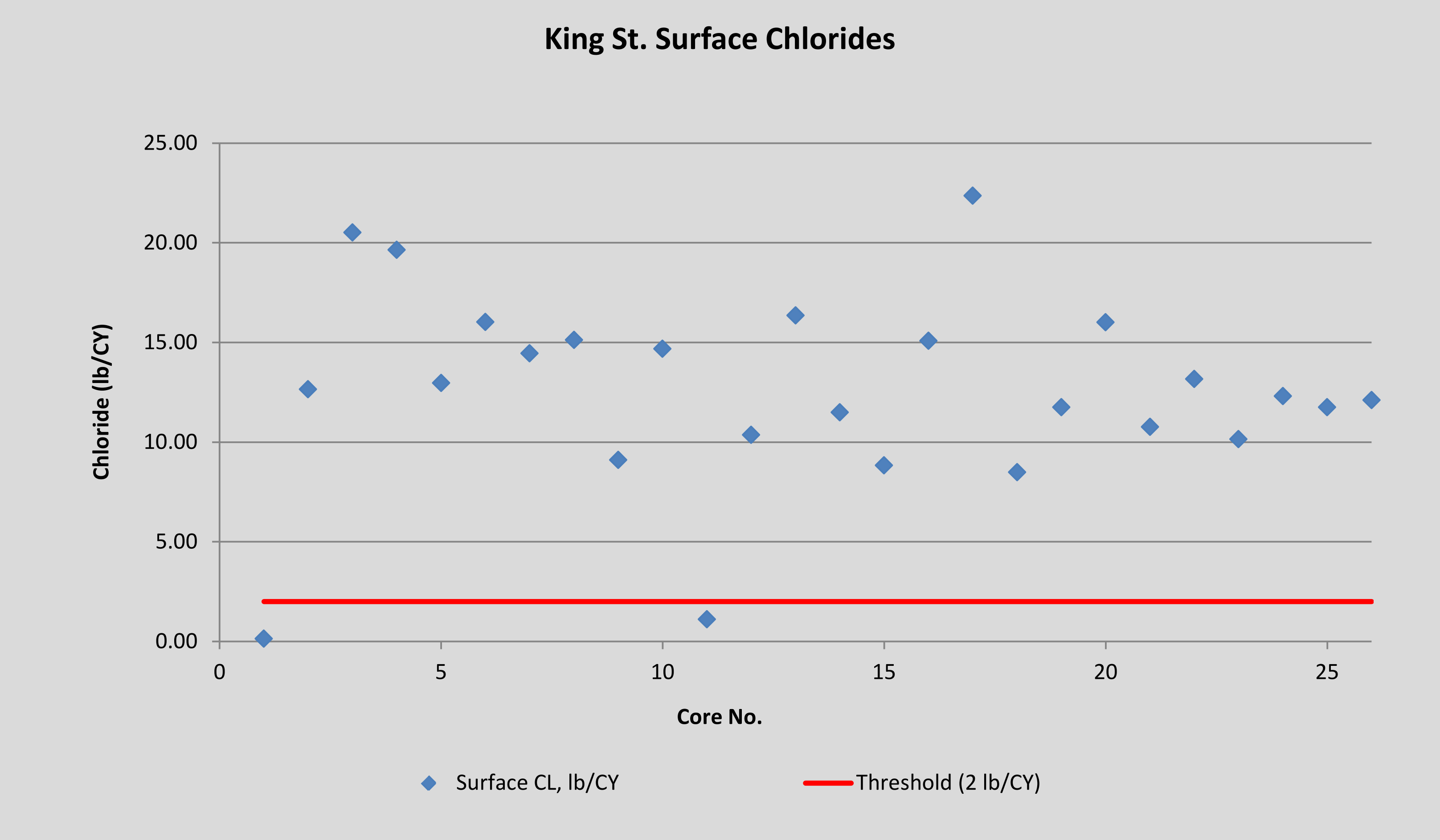
Rebar Cover Meter & Data Logger

Service Life Estimate: VA Bridges

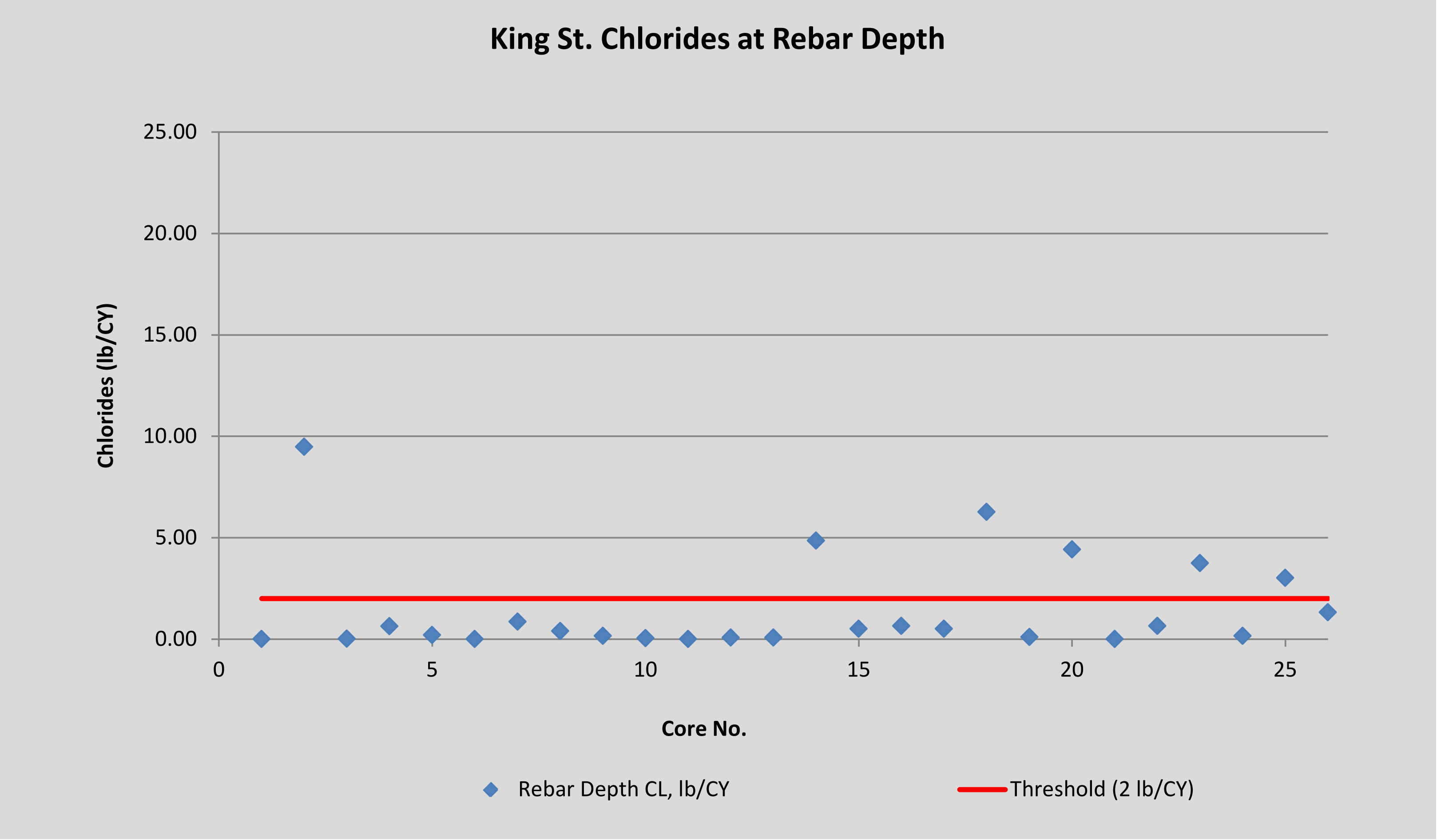
- Deck



Service Life Estimate: VA Bridges



Service Life Estimate: VA Bridges



Service Life Estimate: VA Bridges

Petrographic Testing Results -

- Water/cement ratio was normal for age of deck
- Total air void content was more than the minimum required for freeze thaw resistance; however, the structure did not exhibit freeze thaw damage yet
- The unit weight is 149 lb/ft^3
- Carbonation was less than 1mm and not a corrosion concern
- Small, observed amount of Alkali-Silica Reaction (ASR) produced no cracks

Service Life Estimate: VA Bridges

- Using NCHRP 558 service life modeling, the deck is projected to experience 39% of concrete damage in about 50 years if nothing is done
- The deck has a total compromised area of 28% (5.28% delam + 23% chloride above threshold)
- The SR for this structure is 56.1
- The deck would not last another 50 years if nothing other than patching is done

Service Life Estimate: VA Bridges

Deck Repair Option		Life Cycle Cost	MOT Cost	Total LCC
A	Patch + LPC	$ 1,581,643	$ 126,431	$ 1,708,074
B	Patch+LMC+ICCP	$ 1,145,818	$ 0	$ 1,145,818
C	Patch+ECE	$ 1,574,182	$ 345,231	$ 1,919,413
D	Replace	$ 2,451,083	$ 36,500	$ 2,487,583

Conclusions

- Deterioration is like cancer – typically hidden
- Necessary to quantify deterioration to determine remaining strength and time-to-failure
- If left unaddressed, deterioration is costly
- An appropriate combination of corrosion rate analysis and NDT testing helps to identify and quantify hidden corrosion problems
- Infrastructure preservation benefits the environment and future generations

Questions?

Thank you!