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Repair Procedures: Pros & Cons of Repair Alternatives

Southeast Bridge Preservation Partnership
Thursday, April 14, 2011

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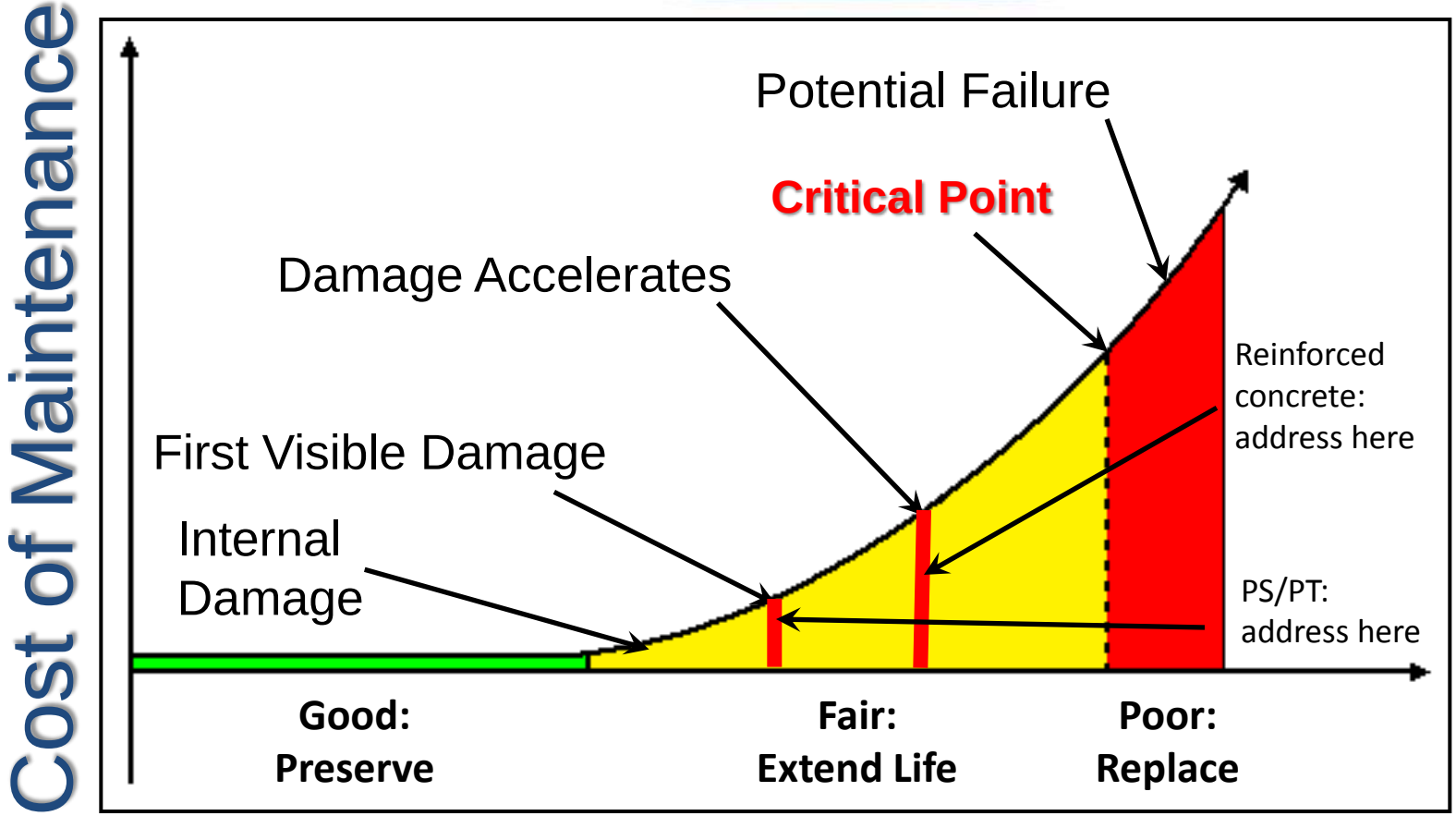
Corrosion Cost Progression



In This Presentation

In an era of aging bridge structures…

- Proactive repair approaches are increasingly available and cost-effective
- Repair solutions are only as good as the tools that bring engineers to their point of decision
- Selecting the best tools for quantifying problems is pivotal to long-term repair success

Areas to be Addressed

- ***Post-Tensioned Box Girder Bridges:*** *what we have learned after 40 evaluations.*

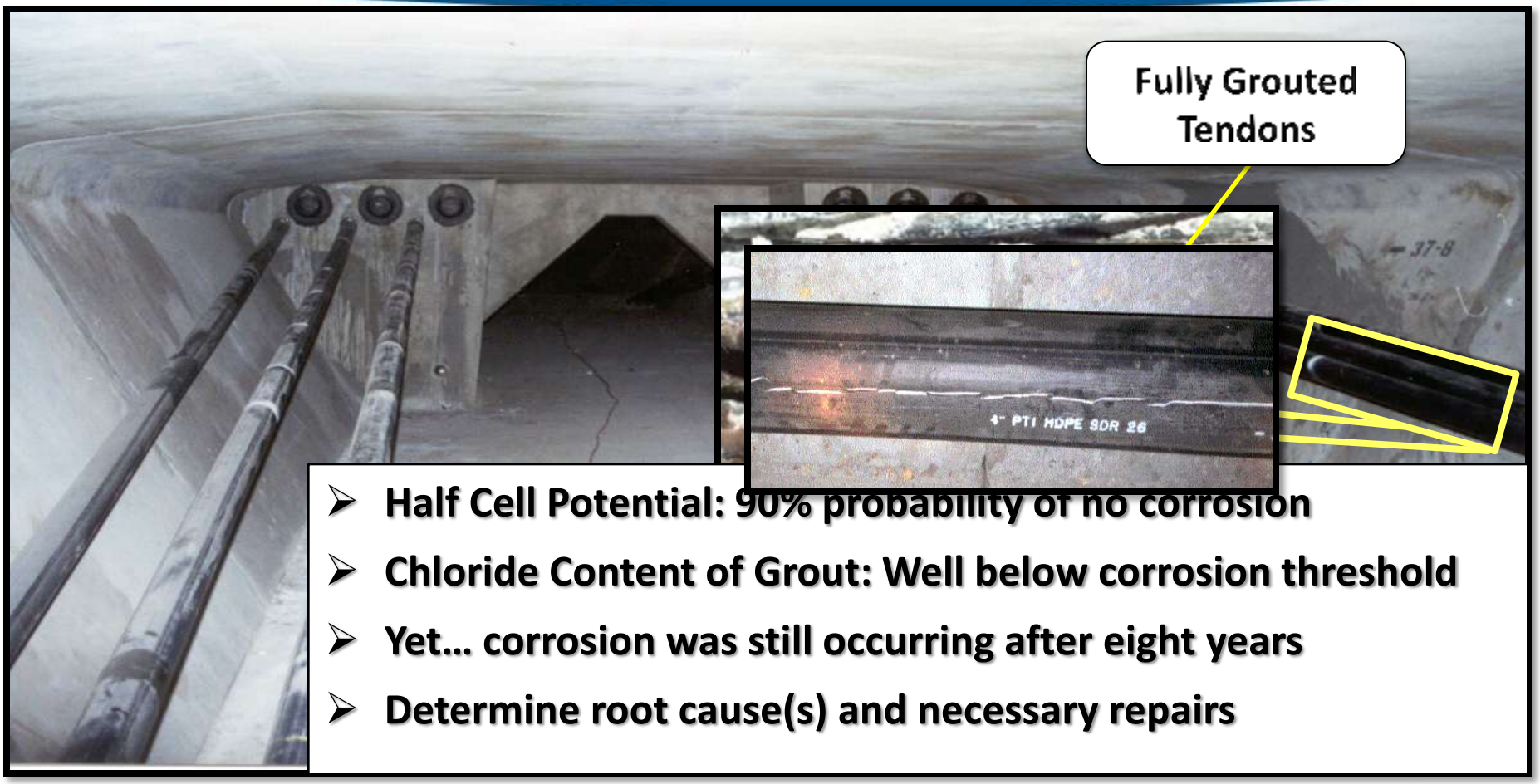
- ***Pre-Stressed Structures:*** *can beams be saved?*

- ***Aging RC Substructures:*** *what do we do with all of them?*

Problems in PT

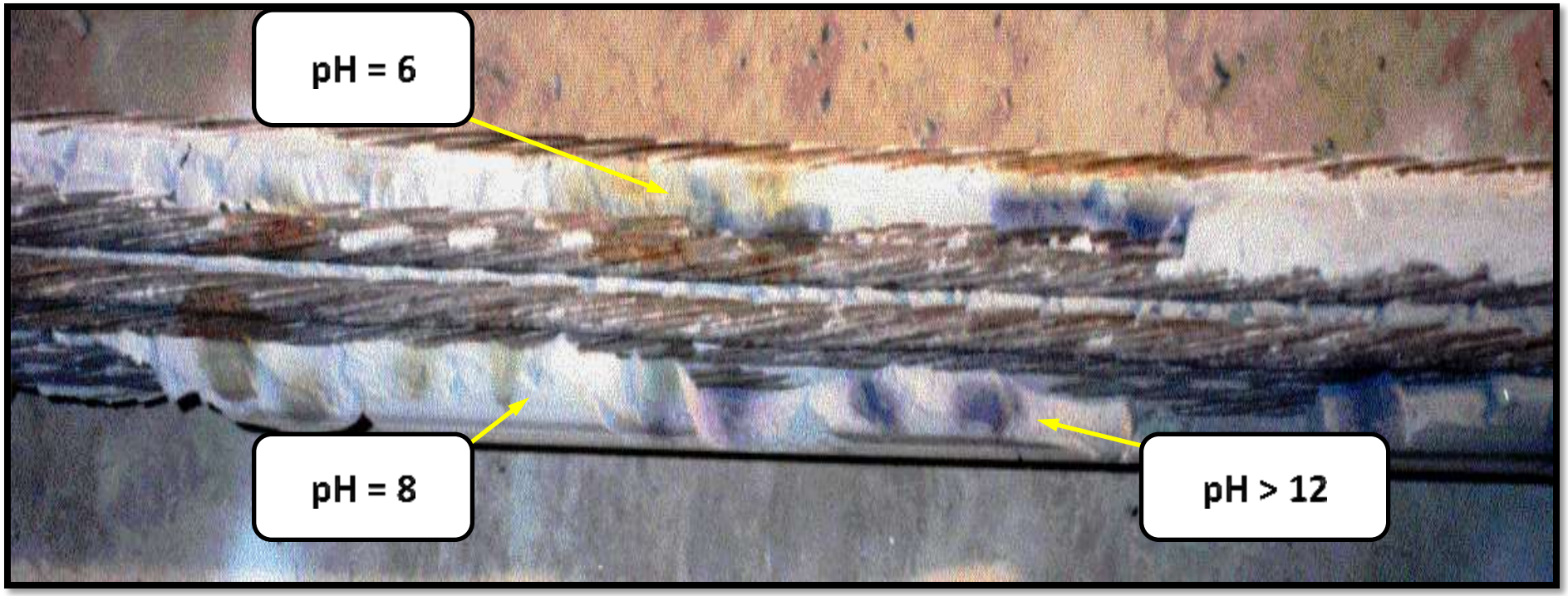
- Visual evaluation cannot quantify problems
- Low pH grout and high chloride content can increase the rate of corrosion of tendons
- Problematic voids need to be identified
- Cancerous corrosion can cause sudden failures as more wires/strands break

PT Box Girder – External Tendons

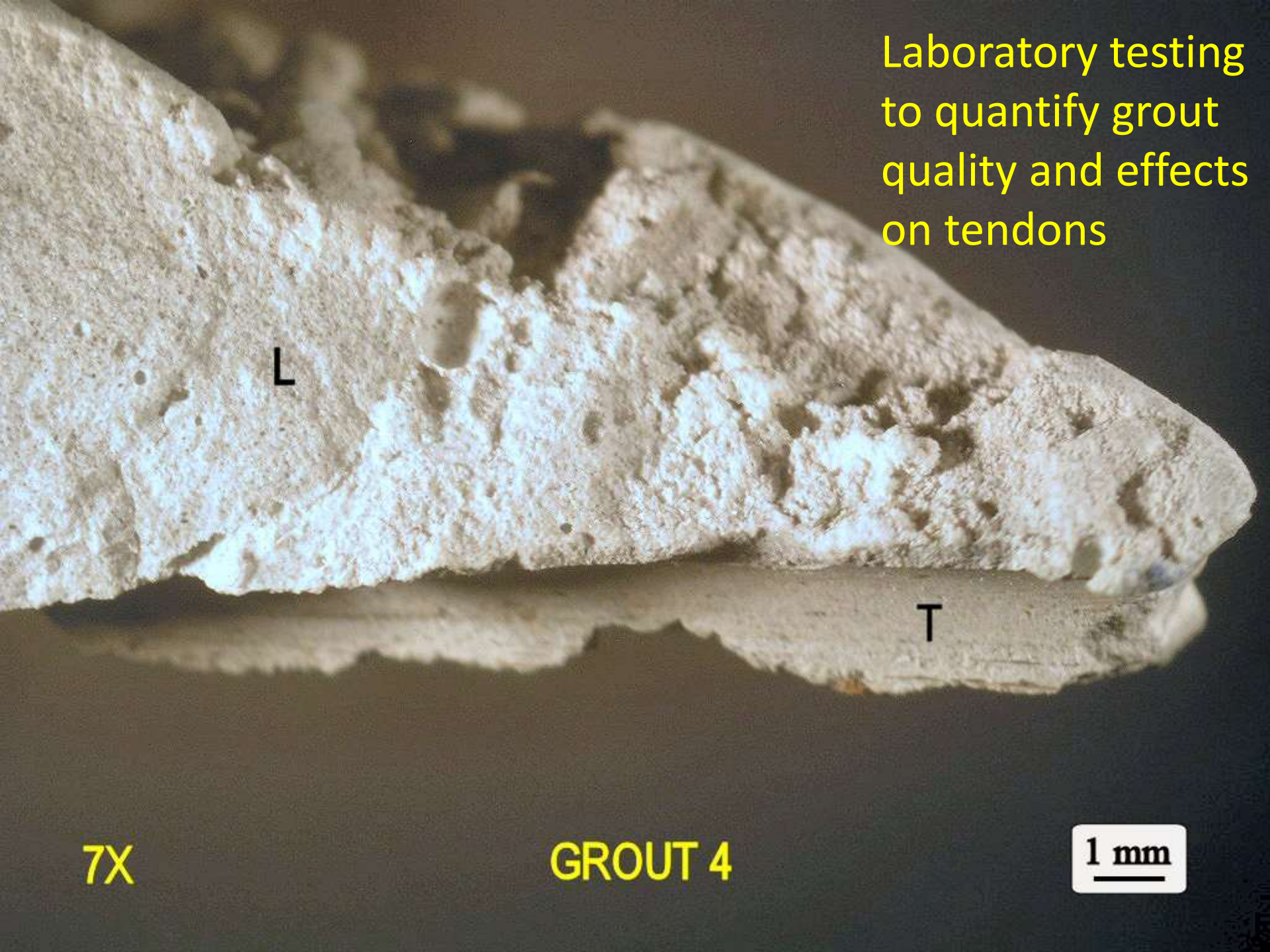


- Half Cell Potential: 90% probability of no corrosion
- Chloride Content of Grout: Well below corrosion threshold
- Yet… corrosion was still occurring after eight years
- Determine root cause(s) and necessary repairs

Grout pH Variation



PT Box Girder – Internal Tendons


Laboratory testing to quantify grout quality and effects on tendons
L
T
7X
GROUT 4
1 mm

Quantifying “Hidden” Corrosion

- Evaluation:
  - GPR to locate tendons
  - IR camera to quantify subsurface concrete damage
  - Computer-driven testing for corrosion rate, present/future section losses, effects of grout, and time-to-criticality
  - Laboratory testing for material quality
  - Remaining strength (collaborate with structural firm)

Quantify problems early

Cost Effective Solutions for PT

- Solutions:
  - Quantify existing and future degradation
  - Address ongoing corrosion
  - Corrosion protection (where applicable)
  - Targeted rehabilitation - structural strengthening
  - Exceed service life goals

Sleep well at night

18 Bridges in Oklahoma








9 Bridges in Indiana

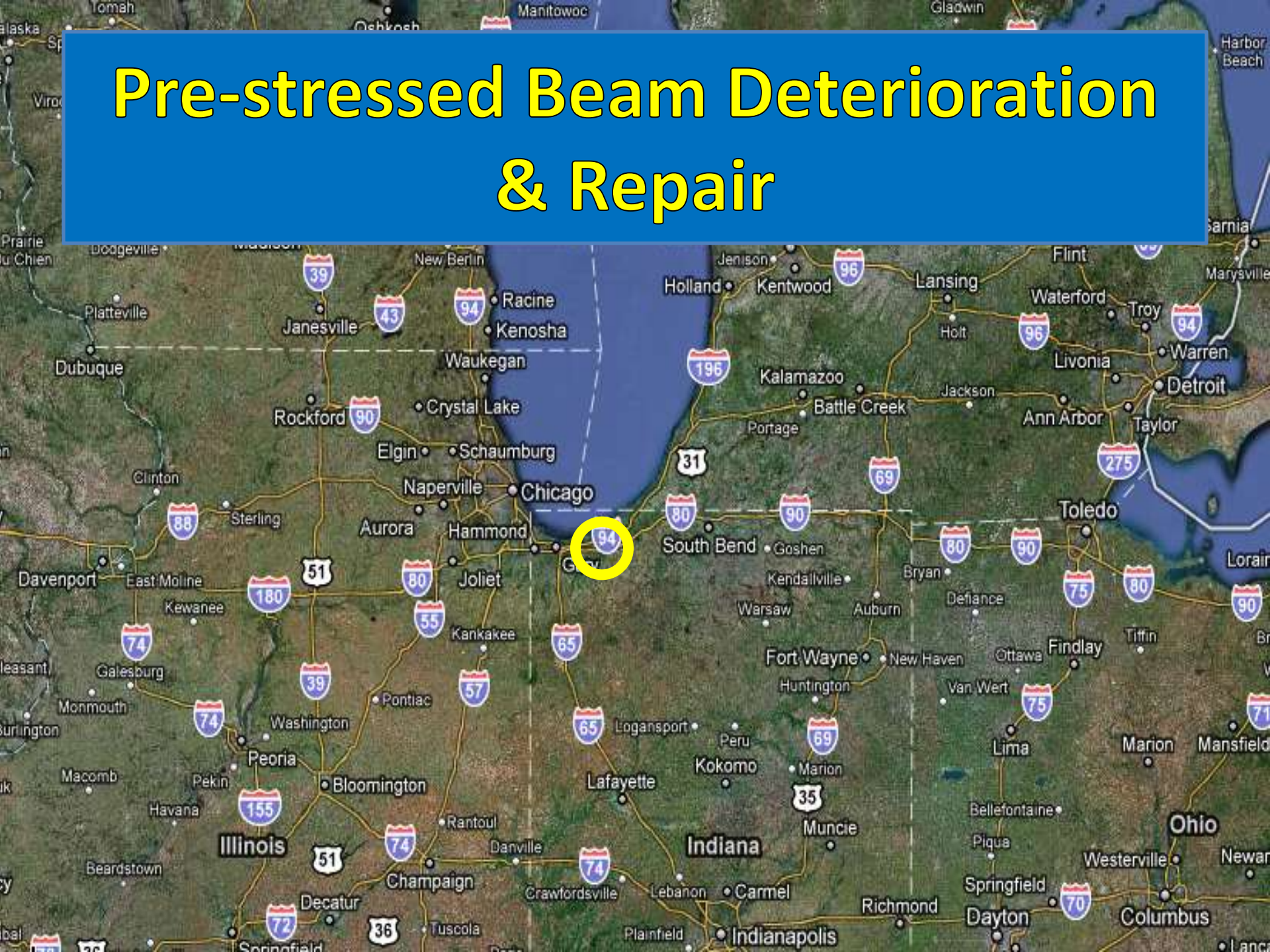


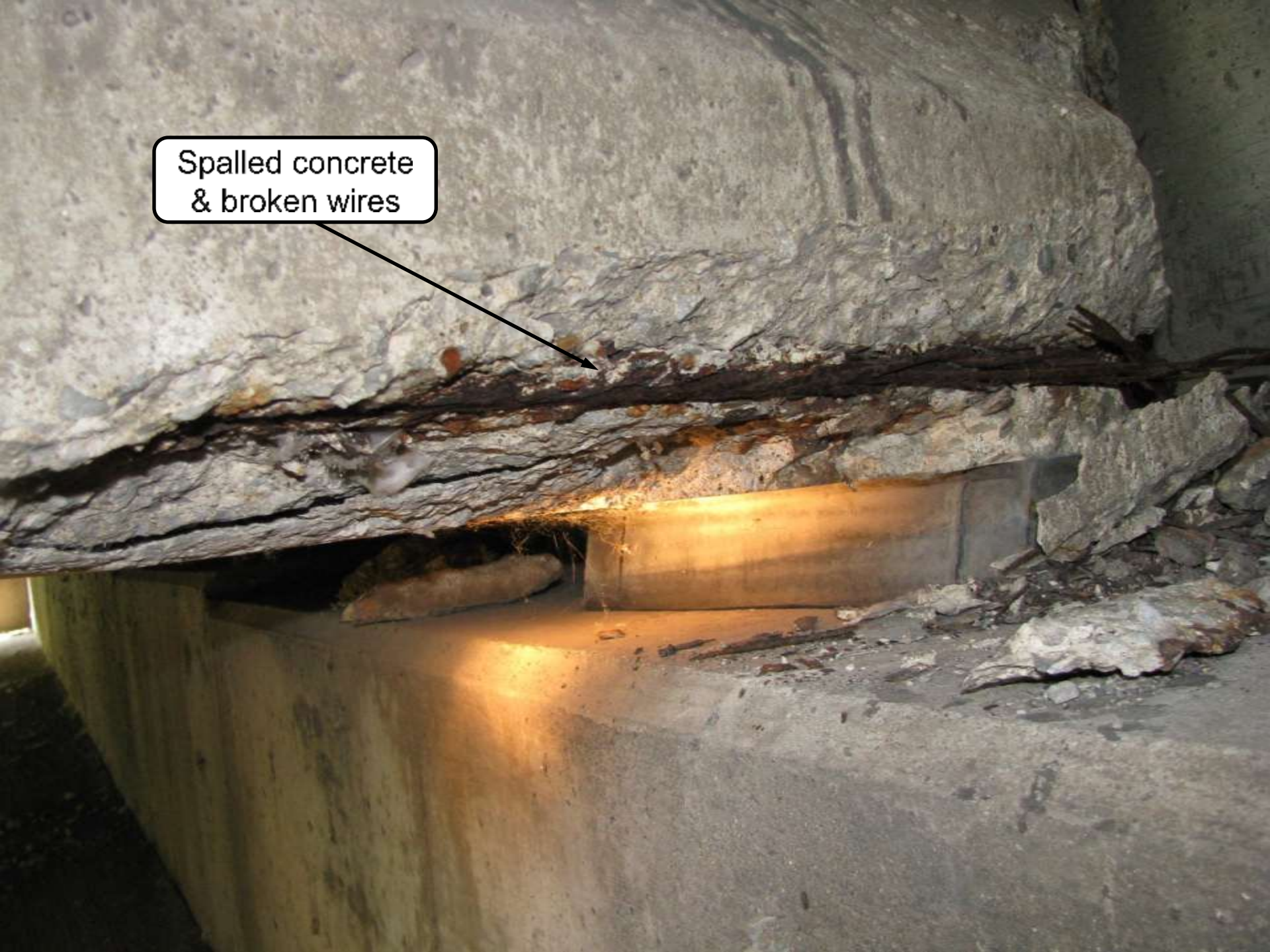






Pre-stressed Beam Deterioration & Repair



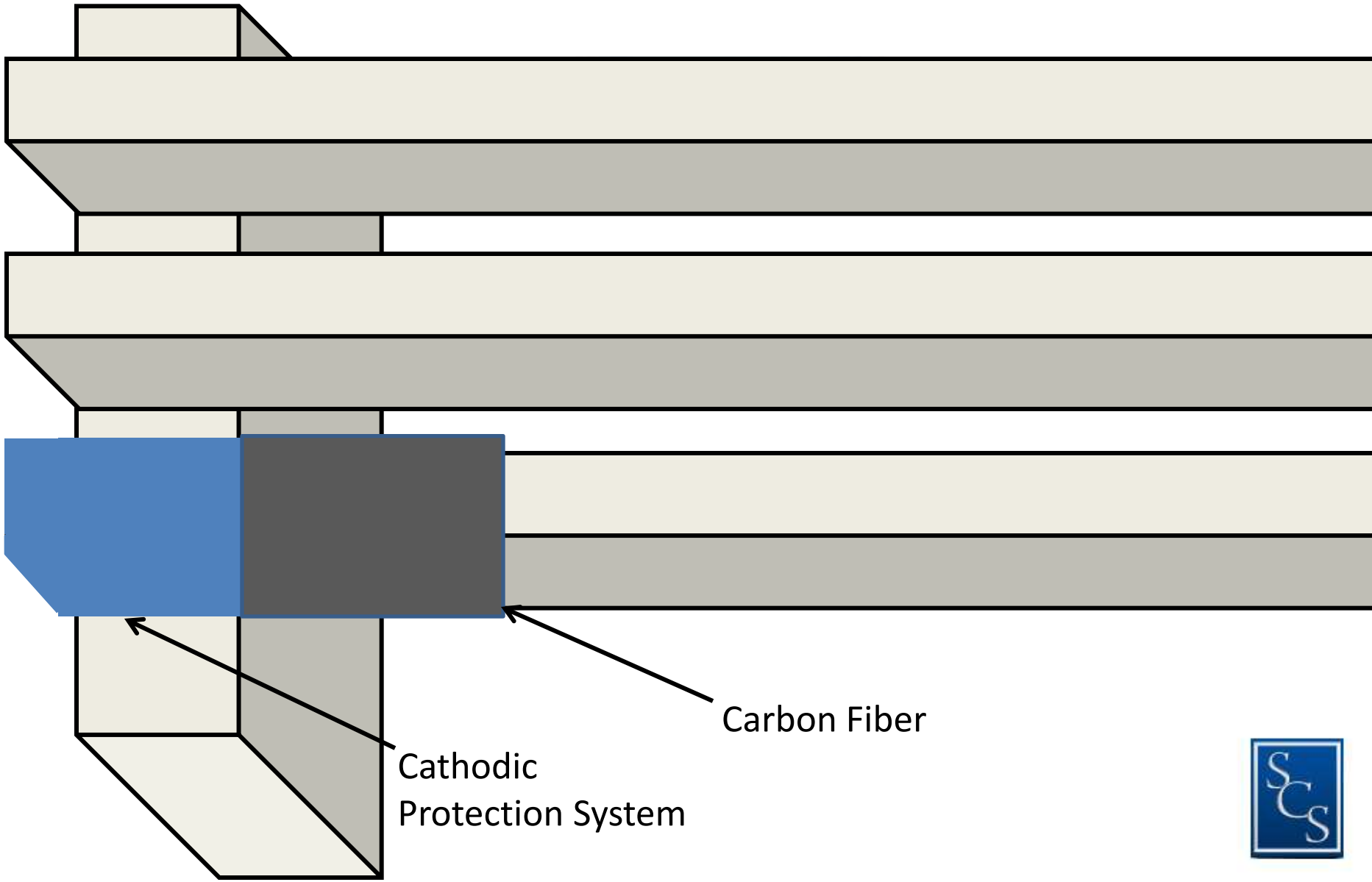

Spalled concrete
& broken wires


Suspected Stray Current problem from nearby railroad tracks
1/3 section loss of undrwater steel piles

Solution

- SCS quantified the extent of deterioration at beam ends and steel piles
- We designed a corrosion mitigation system and developed plans to extend the service lives of pre-stressed beams and steel piles

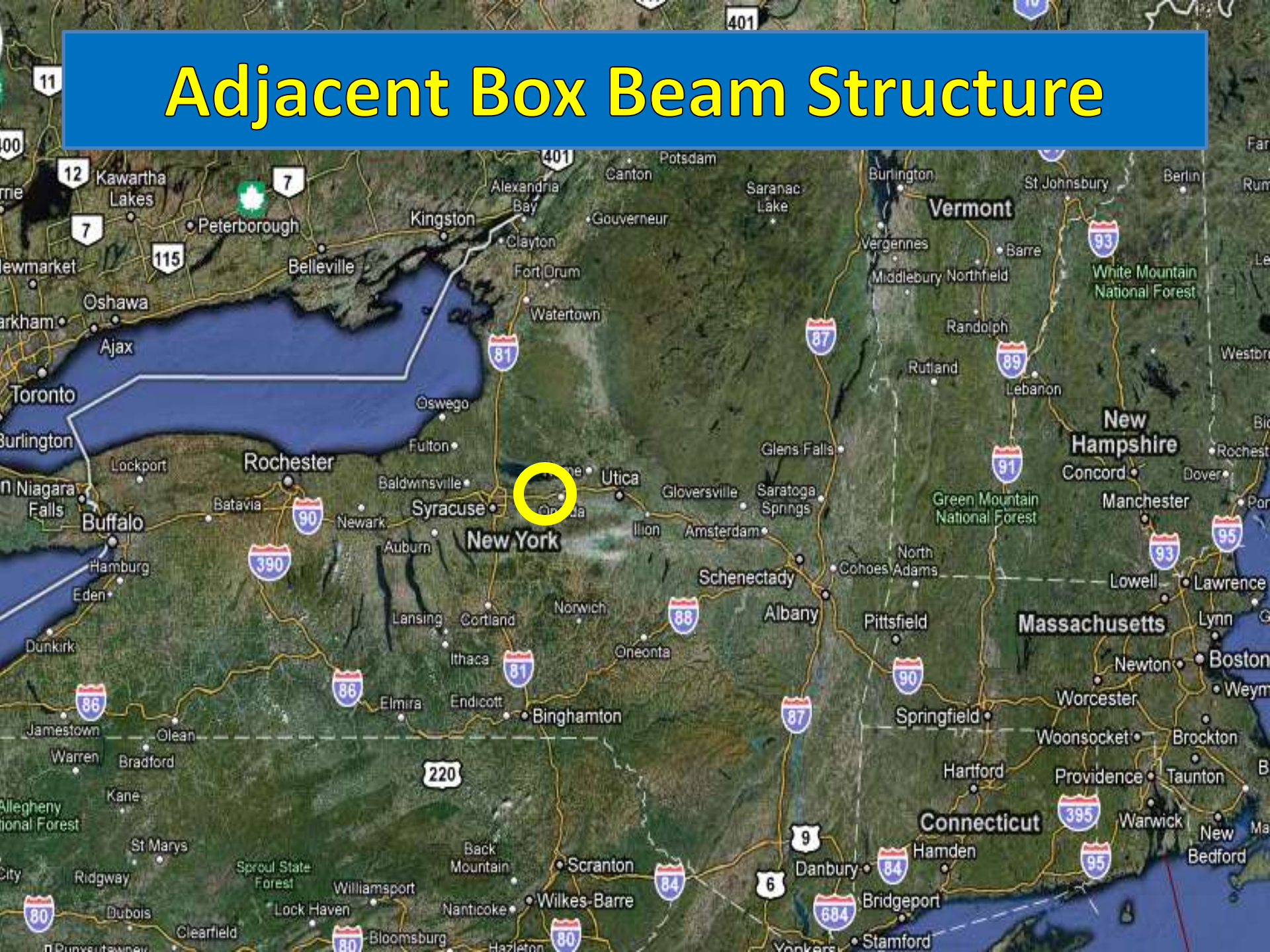
Design of Life Extension System

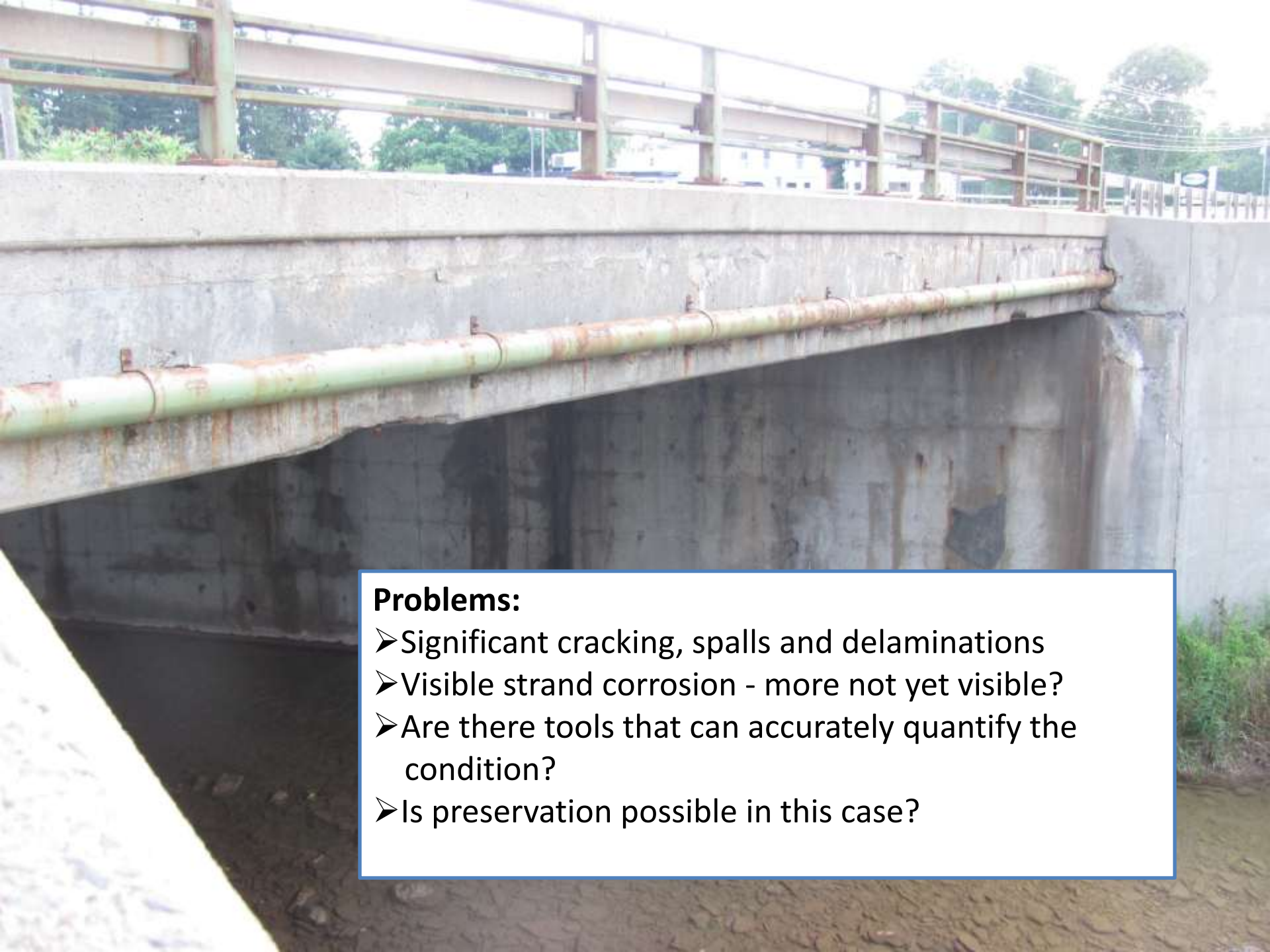


Benefit

- As an independent firm, SCS selected the most suitable corrosion protection system
- The Department was able to avoid the cost of mitigating the effects of stray current
- The Department was able to save 80% of the replacement cost

Adjacent Box Beam Structure





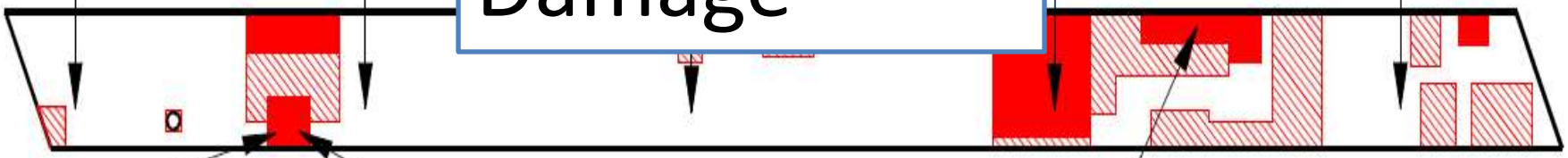
Problems:

- Significant cracking, spalls and delaminations
- Visible strand corrosion - more not yet visible?
- Are there tools that can accurately quantify the condition?
- Is preservation possible in this case?

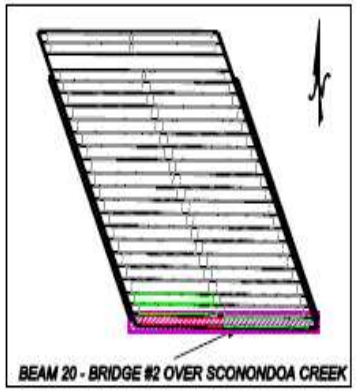
Water in Beam

- Half-inch hole was drilled
- Water drained for a few hours
- Chloride concentration of the water was very high
- Resistivity of the water was low

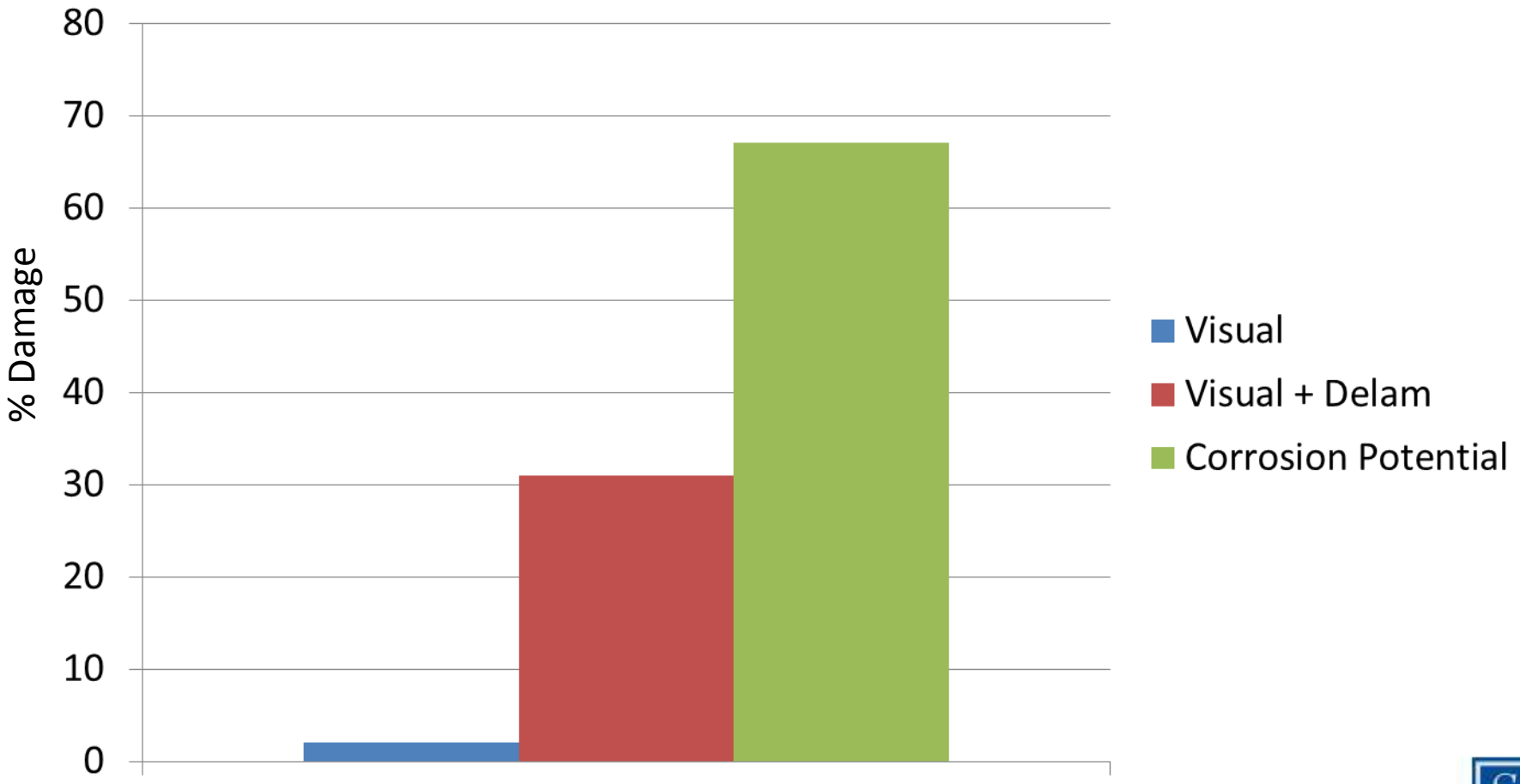
31% Concrete Damage



BEAM 20 - UNDERSIDE
BRIDGE #2 OVER SCONONDOA CREEK
N.T.S.



Visual/Delam/Potential Data



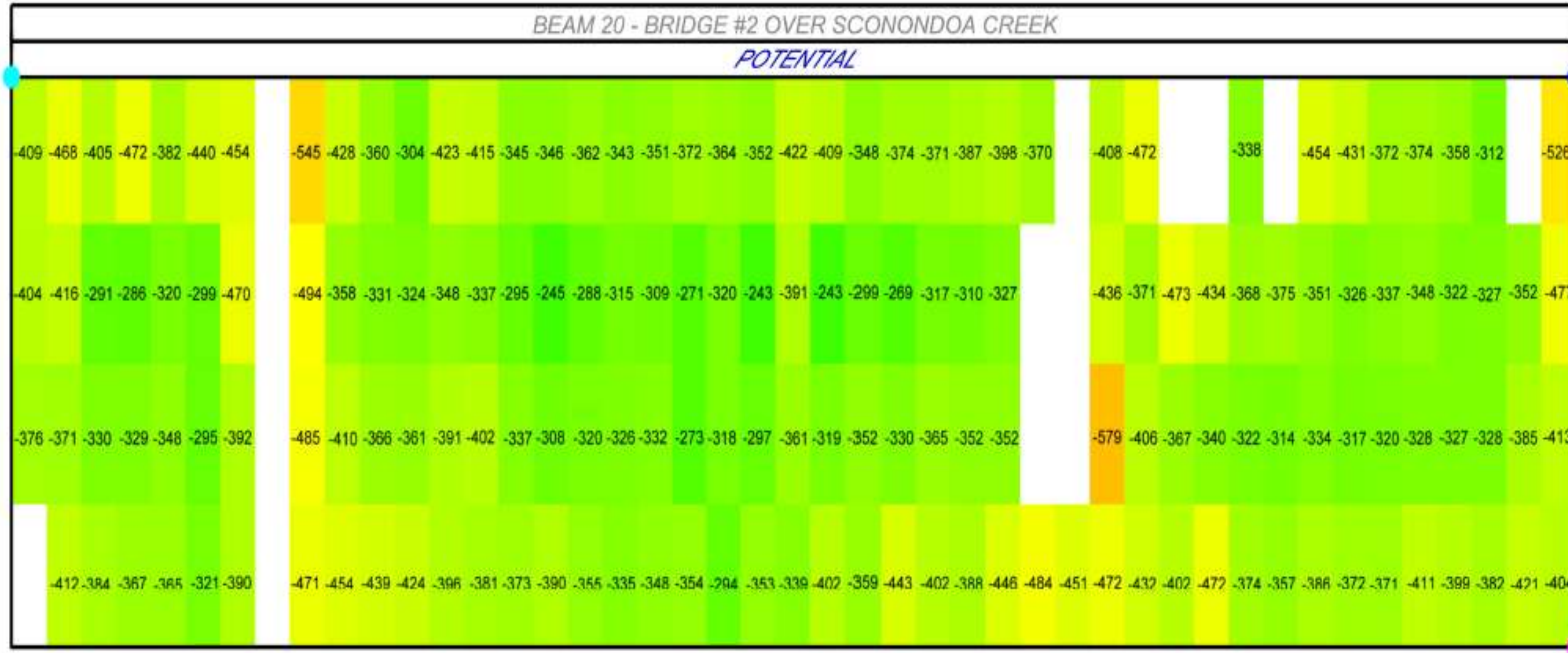
Strand Section Losses

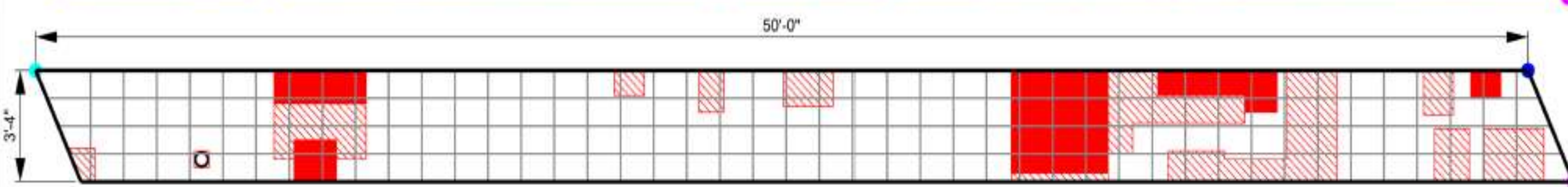
No.	Test Location	Strand Size (inch)	Measurement (inch)	Difference in Diameter	Section Loss (%)	Note
Beam 20						
1	Location 1 (Strand 1)	0.50	0.45	0.05	19	Spall
2	Location 1 (Strand 2)	0.50	0.43	0.07	26	Spall
3	Location 2 (Strand 13)	0.50	0.48	0.02	8	Chipout
4	Location 2 (Strand 14)	0.50	0.48	0.02	8	Chipout
5	Location 3 (Strand 7)	0.50	0.48	0.02	8	Spall
6	Location 3 (Strand 8)	0.50	0.42	0.08	29	Spall
7	Location 4 (Strand 1)	0.50	0.00	0.50	100	Spall
8	Location 4 (Strand 1)	0.50	0.00	0.50	100	Spall
9	Rebar (Near Strand 1)	0.50	0.33	0.17	56	Spall

LEGEND:

1) RED HATCHED AREA REPRESENTS DELAMINATION -

2) RED FILLED AREA REPRESENTS SPALLING -



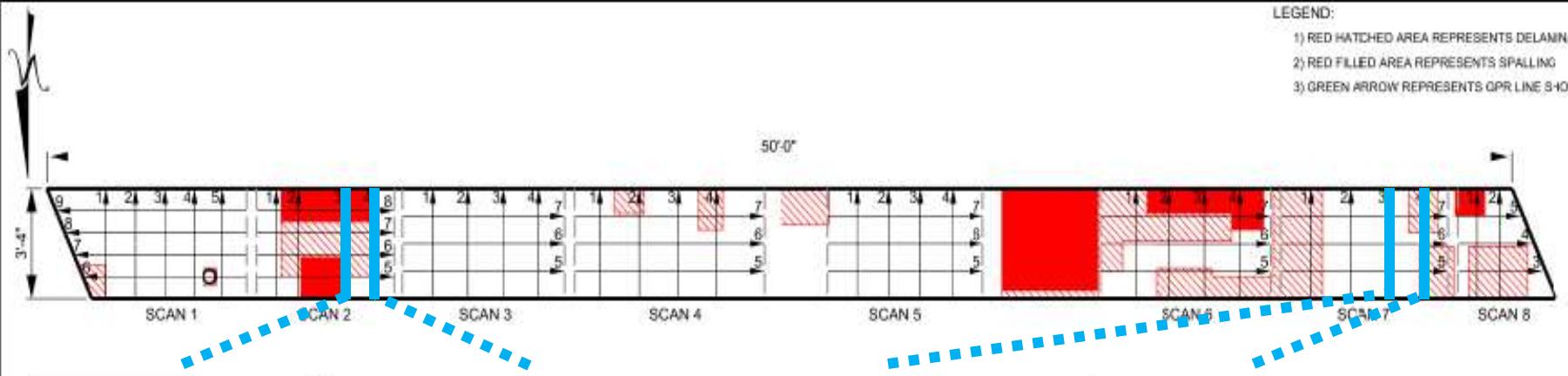


BEAM 20 - UNDERSIDE
BRIDGE #2 OVER SCONONDOA CREEK
N.T.S.

Siva Corrosion Services, Inc. Materials & NDT Specialists www.SivaCorrosion.com	POTENTIAL READING BEAM 20	NEW YORK STATE DEPARTMENT OF TRANSPORTATION	HORIZONTAL SCALE N.T.S. / VERTICAL SCALE N.T.S. — DRAWING NUMBER A-3
	DESIGNED: ___ DRAWN: BJ / CHECKED: ___ CHECKED: S.Y.	BRIDGE #2 OVER SCONONDOA CREEK	SURVEY BOOK N/A — SHEETS 1 OF 1 / DATE SEPTEMBER 2010 — PROJECT 1001

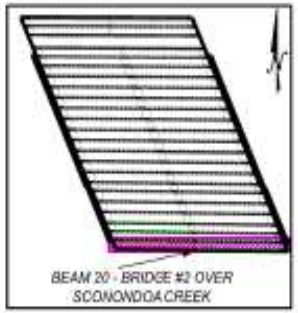
LEGEND:

1) RED HATCHED AREA REPRESENTS DELAMINATION
2) RED FILLED AREA REPRESENTS SPALLING
3) GREEN ARROW REPRESENTS GPR LINE SHOWN



BEAM 20 - UNDERSIDE
BRIDGE #2 OVER SCONONDOA CREEK
N.T.S.

NOTE: GPR LINE LOCATIONS ARE APPROXIMATE.



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GPR SCANS
BEAM 20

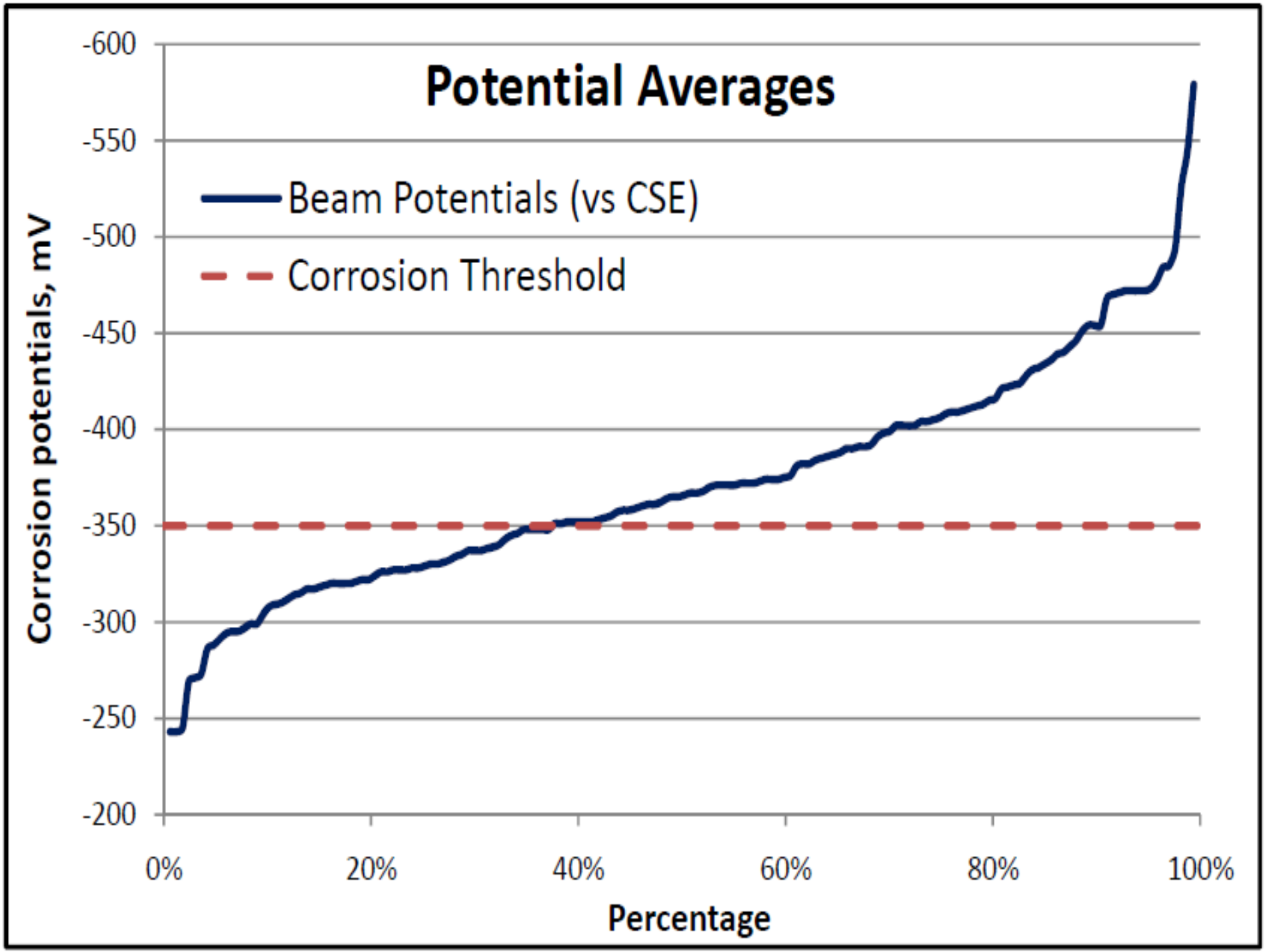
NEW YORK STATE
DEPARTMENT OF TRANSPORTATION

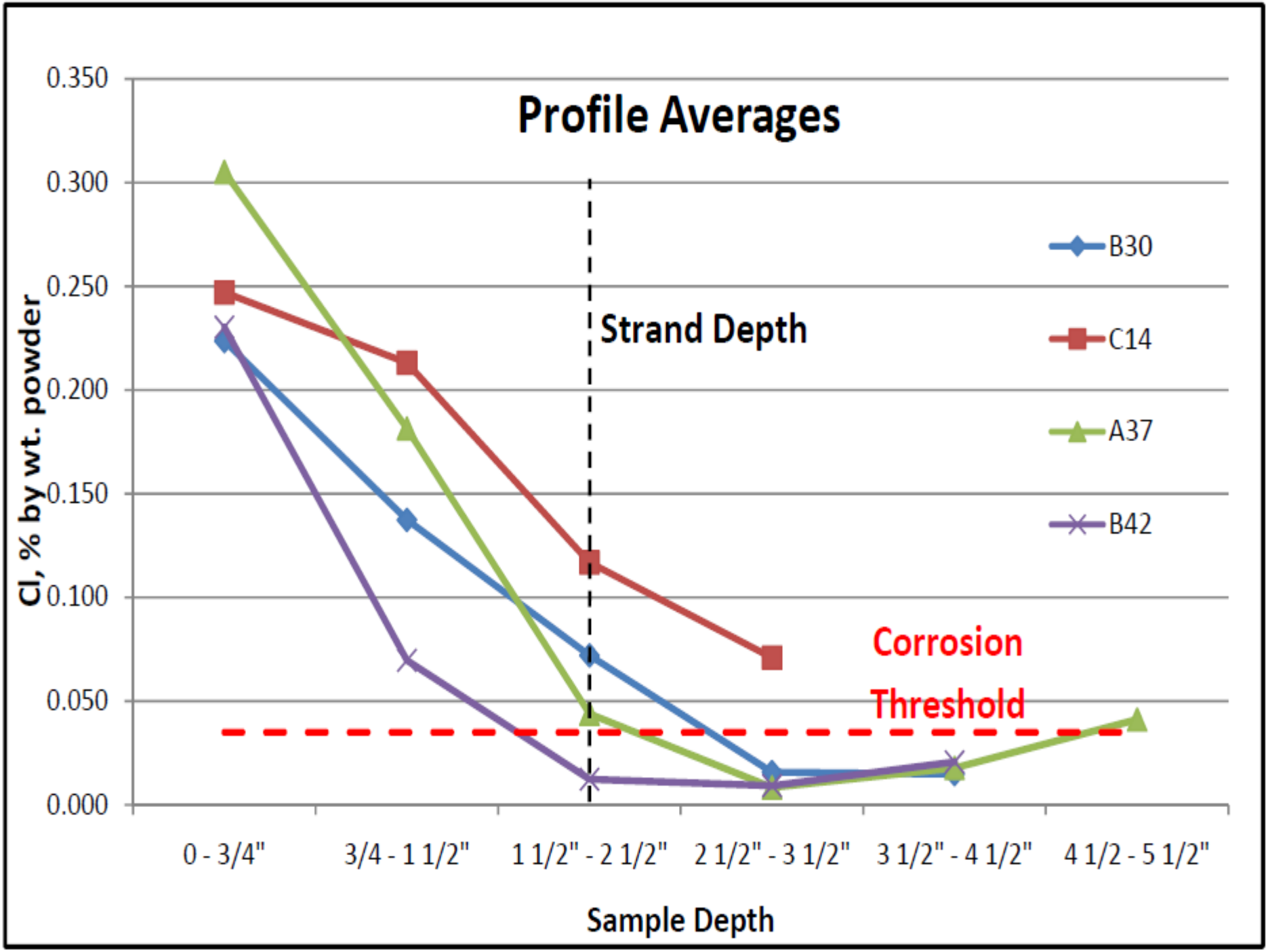
DESIGNED: DRAWN: SJ
CHECKED: CHECKED: S.J.

BRIDGE #2 OVER
SCONONDOA CREEK

HORIZONTAL SCALE	DRAWING NUMBER
N.T.S.	
VERTICAL SCALE	A-4
N.T.S.	

SURVEY BOOK	SHEETS
N/A	1 OF 1
DATE	PROJECT
SEPTEMBER 2010	1001


Potential Averages
Beam Potentials (vs CSE)
Corrosion Threshold
Corrosion potentials, mV
-600
-550
-500
-450
-400
-350
-300
-250
-200
0%
20%
40%
60%
80%
100%
Percentage


Profile Averages
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Cl, % by wt. powder
Strand Depth
B30
C14
A37
B42
Corrosion
Threshold
0 - 3/4"
3/4 - 1 1/2"
1 1/2" - 2 1/2"
2 1/2" - 3 1/2"
3 1/2" - 4 1/2"
4 1/2 - 5 1/2"
Sample Depth

Visual/Delam/Potential Data

- Visual data – only a small percentage of the beam corroding
- Visual & delam data – 31% of the beam corroding
- Corrosion potential data – 67% of the beam corroding
- Evaluate before visual signs of distress to achieve and exceed service life goals

Benefits

- The owner better understood proper combinations of NDT tools needed to:
  - Identify existing deterioration
  - Quantify the extent of deterioration
  - Predict future deterioration
- Plan proactive, cost effective preservation instead of expensive replacement
- Service life can be typically extended 10 to 25 years at 20-25% of the cost of replacement

11 Bridges in Richmond, VA

Evaluation

- How much delam/spall at present?
- Chlorides at various depths?
- Future penetration and effects of chlorides?
- Active corrosion occurring? How quickly?
- How much future damage?
- Presence and progression of ASR?

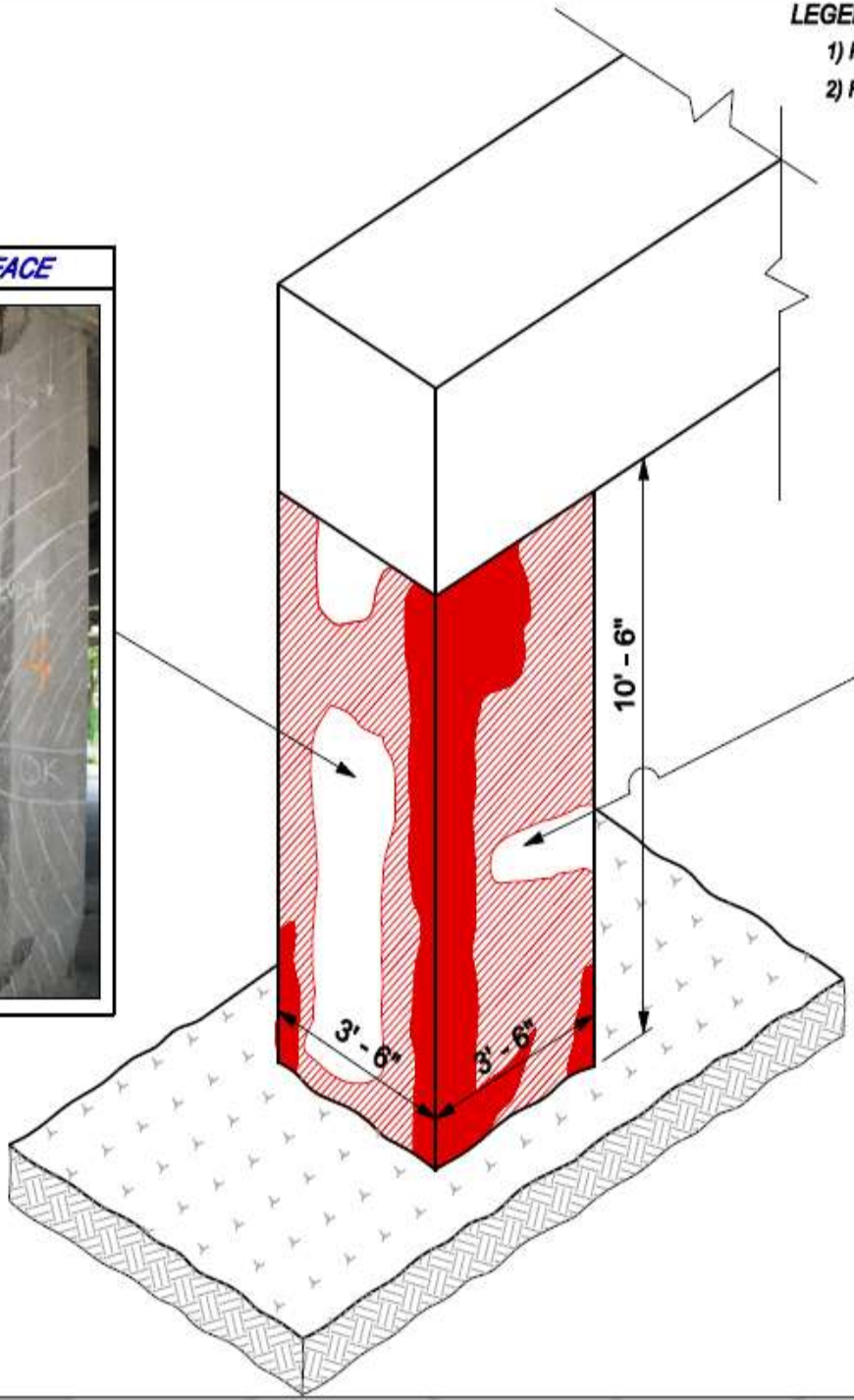
High risk of prescribing a poor solution without proper diagnosis…

LEGEND:

1) RED HATCHED AREA REPRESENTS DELAMINATION -

2) RED FILLED AREA REPRESENTS SPALLING -

PIER 1 COLUMN 4 EAST FACE

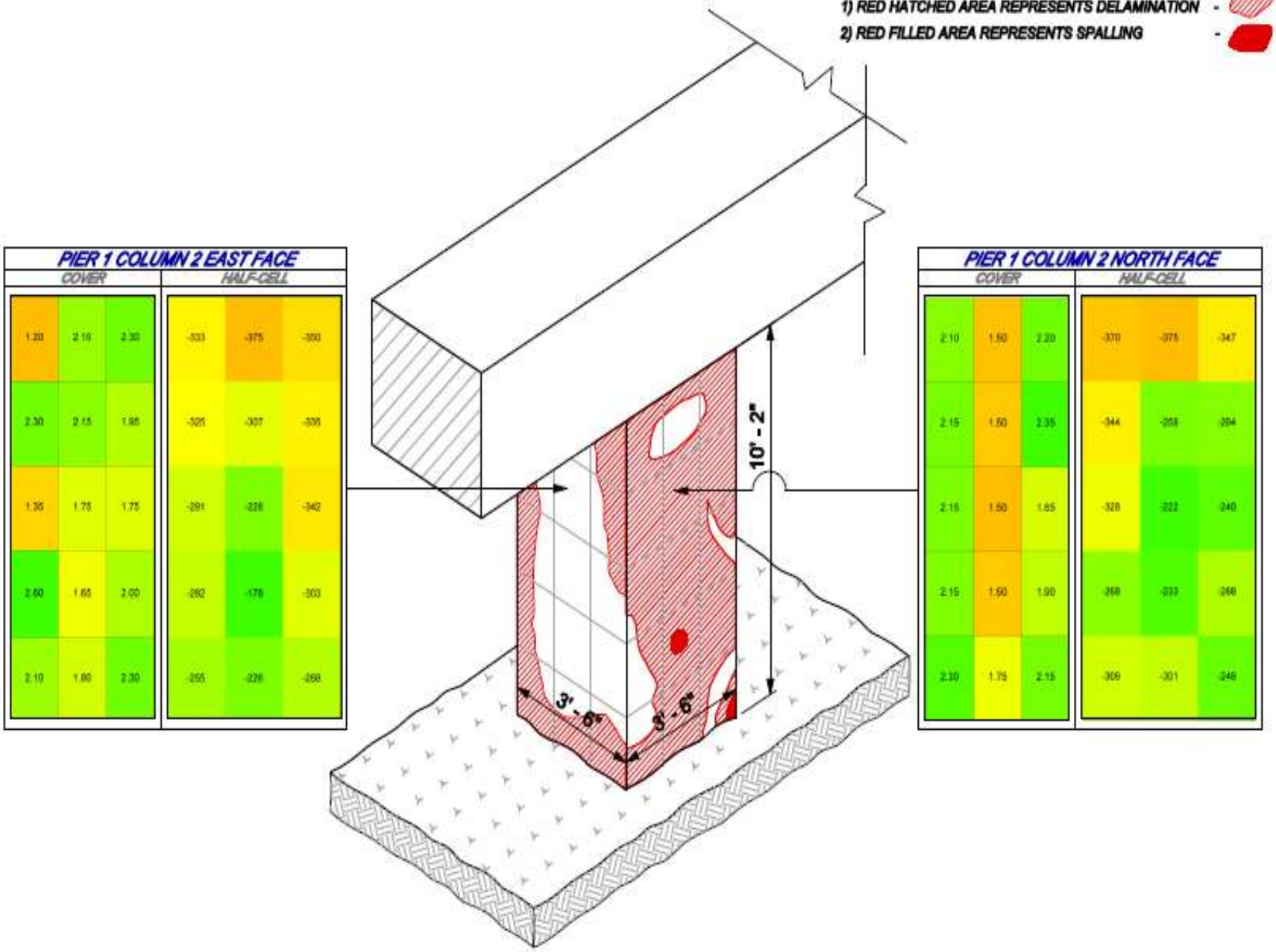


PIER 1 COLUMN 4 NORTH FACE

LEGEND:

1) RED HATCHED AREA REPRESENTS DELAMINATION -

2) RED FILLED AREA REPRESENTS SPALLING -



PIER 1 COLUMN 2 EAST FACE

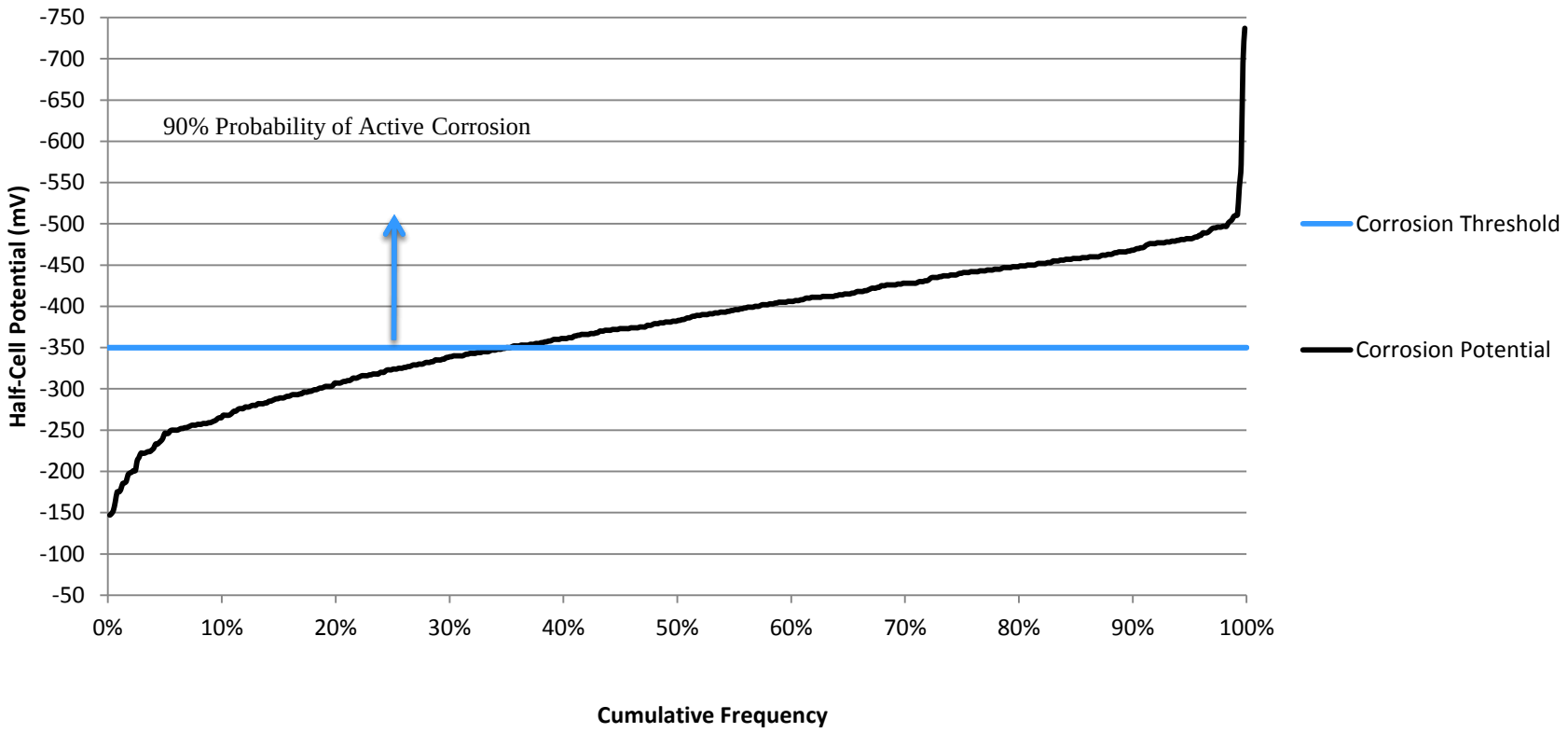
COVER			HALF-CELL		
1.20	2.10	2.30	-333	-375	-350
2.30	2.15	1.95	-325	-307	-336
1.35	1.75	1.75	-281	-228	-342
2.60	1.65	2.00	-262	-178	-303
2.10	1.80	2.30	-255	-226	-268

PIER 1 COLUMN 2 NORTH FACE

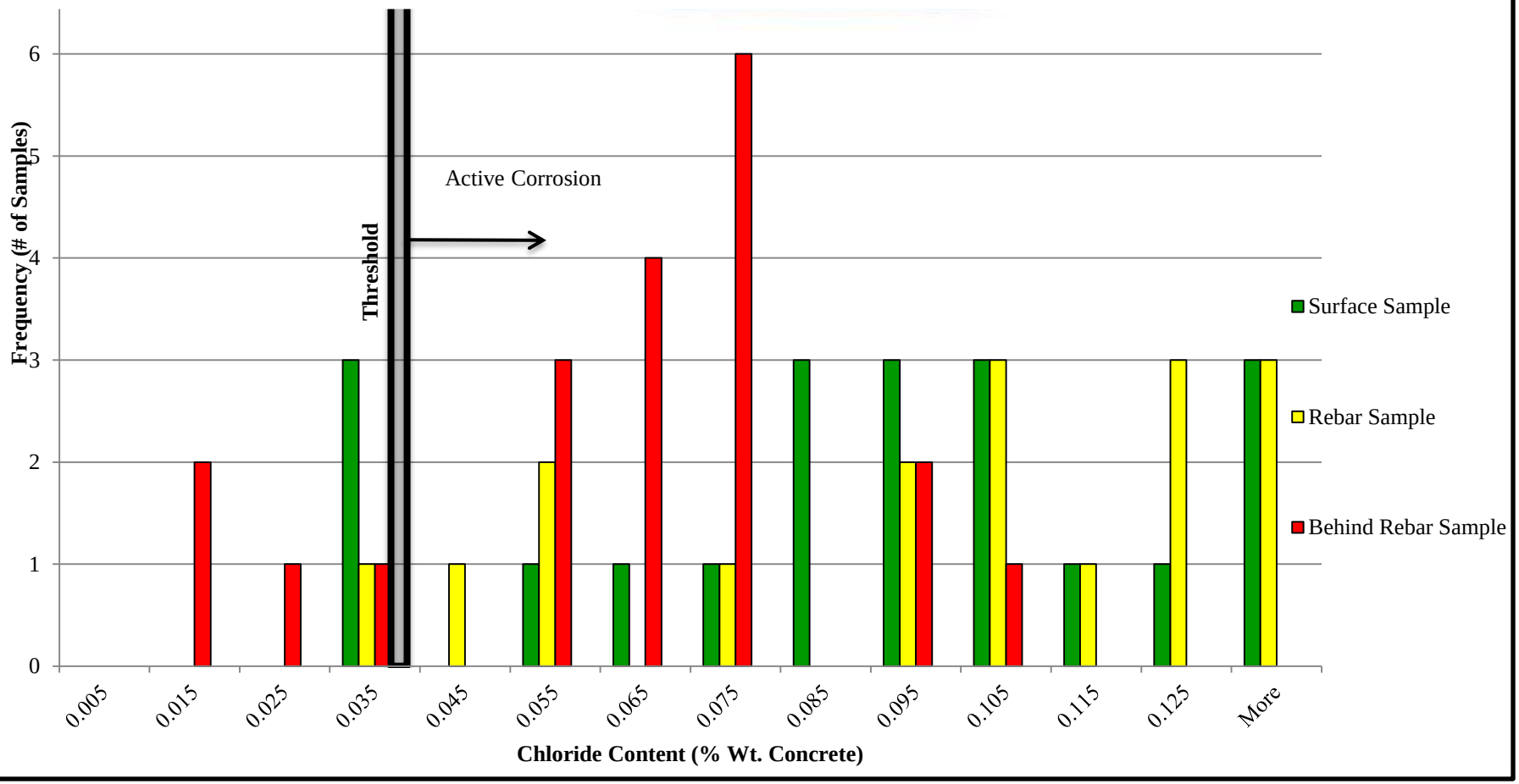
COVER			HALF-CELL		
2.10	1.50	2.20	-370	-375	-347
2.15	1.50	2.35	-344	-258	-294
2.15	1.50	1.85	-328	-222	-240
2.15	1.50	1.90	-268	-233	-268
2.30	1.75	2.15	-309	-301	-248

PIER 1 COLUMN 2
EAST/NORTH ELEVATION
N.T.S.

Boulevard – Structure
Total Corrosion Potential



Boulevard – Structure Total Chloride Concentration Histogram



Conclusions

- Visible concrete damage – significant increase
- High chloride readings behind rebars
- Near future concrete damage will result
- Significant weakening of the structure within five years if the rate of corrosion is not reduced

Recommendations

- Based on a unique methodology, we developed recommendations for repair / replace / life extension
- Concrete repairs on all bridges
- ECE to lower chloride level near rebars and repolarize rebars
- Sacrificial CP to maintain polarization of rebars

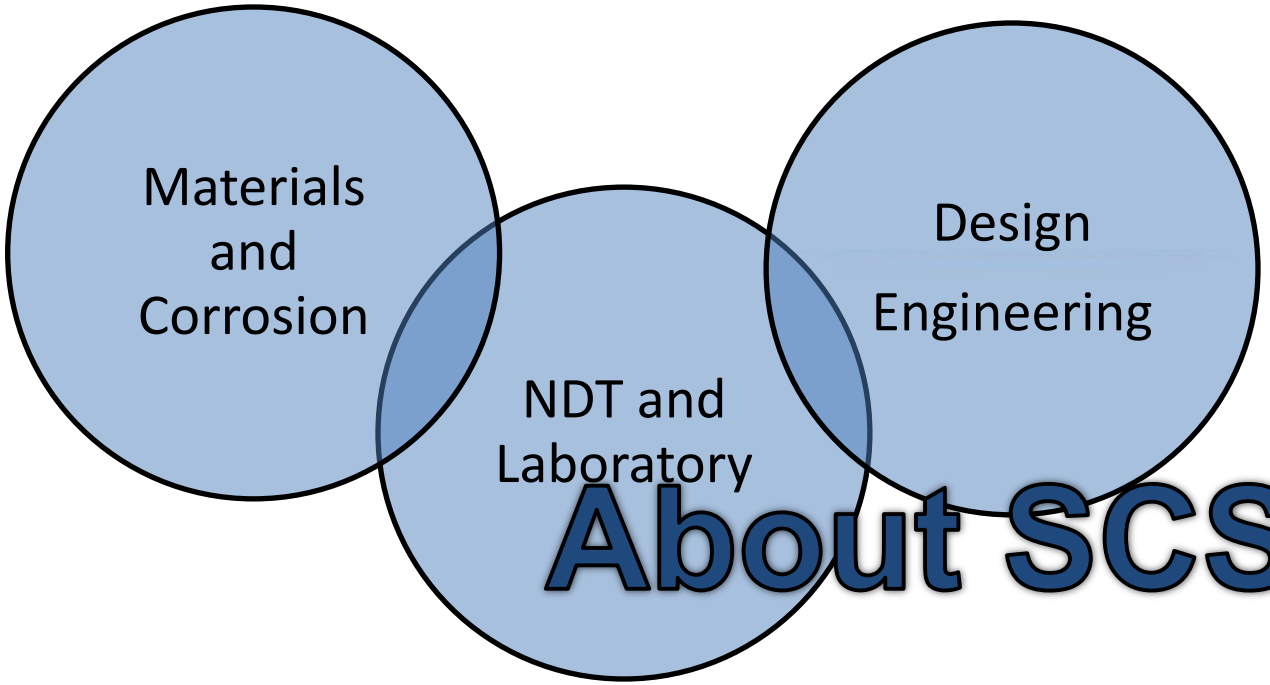
S. No.	Structure	Replacement cost	Repair cost	Cost Savings	Repair cost/ Replacement cost, %
1	Boulevard	$1,931,202	$402,300	**$1,528,902**	21%
2	Hermitage Road	$3,240,312	$619,720	**$2,620,592**	19%
3	Laburnum Avenue	$1,730,258	$380,480	**$1,349,778**	22%
4	Lombardy/CSX	$5,821,420	$2,019,420	**$3,802,000**	35%
5	Overbrook Road	$1,147,005	$312,240	**$834,765**	27%
6	Ramp-A	$926,000	$146,440	**$779,560**	16%
7	Robin Hood Road	$1,877,817	$568,560	**$1,309,257**	30%
8	Sherwood Avenue	$1,595,045	$397,700	**$1,197,345**	25%
9	Upham Brook Run	$2,287,719	$429,620	**$1,858,099**	19%
10	Westwood Avenue	$3,592,000	$402,440	**$3,189,560**	11%
	Total	$24,148,778	$5,678,920	**$18,469,858**	24%

Preservation is Possible

- SCS develops preservation methodology based on the understanding of materials/corrosion/NDT data
- NDT is increasingly cost effective
- Use appropriate combination of tools to evaluate and preserve

An Independent Consultant

- Materials, NDT, and Corrosion Specialist
- Partner with owners to solve problems
- Do not sell or install materials or products
- Address corrosion without bias towards a proprietary product or method



In-Depth Evaluation

Life Extension System Design

Installation Inspection

Structure Types:

- Reinforced Concrete
- Steel
- Pre-Stressed
- Post-Tensioned
- Cable Stayed

Thank You

Questions?

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