

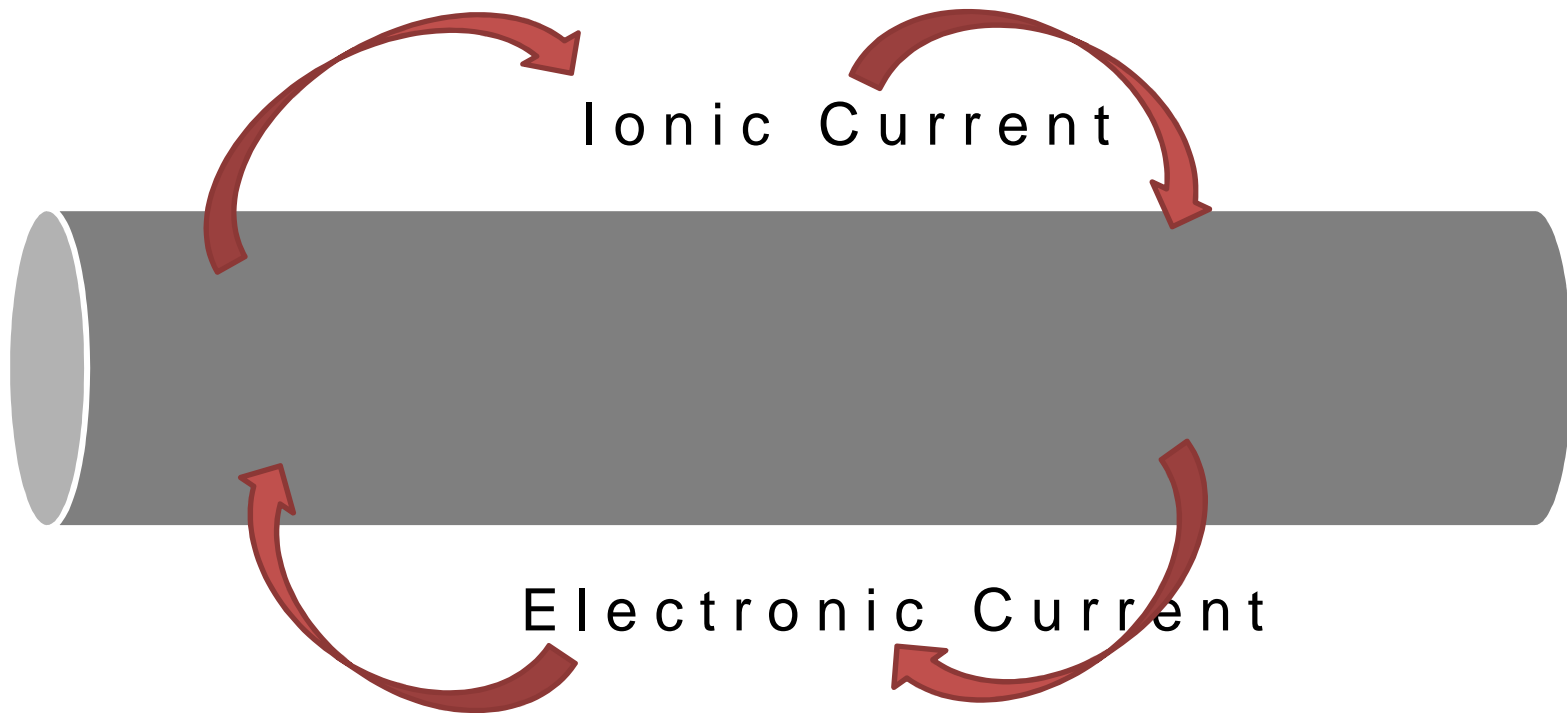


~~Cos~~ Effectively Extending
Lives of Severely Deteri
Concrete Substructure
Purdue Road School
March 8, 2011

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We will discuss:

- Quantifying corrosion in RC substructure
(answering how bad is bad?)
- Recommending and designing corrosion protection to extend service life cost
- Partnering with owners to solve problems



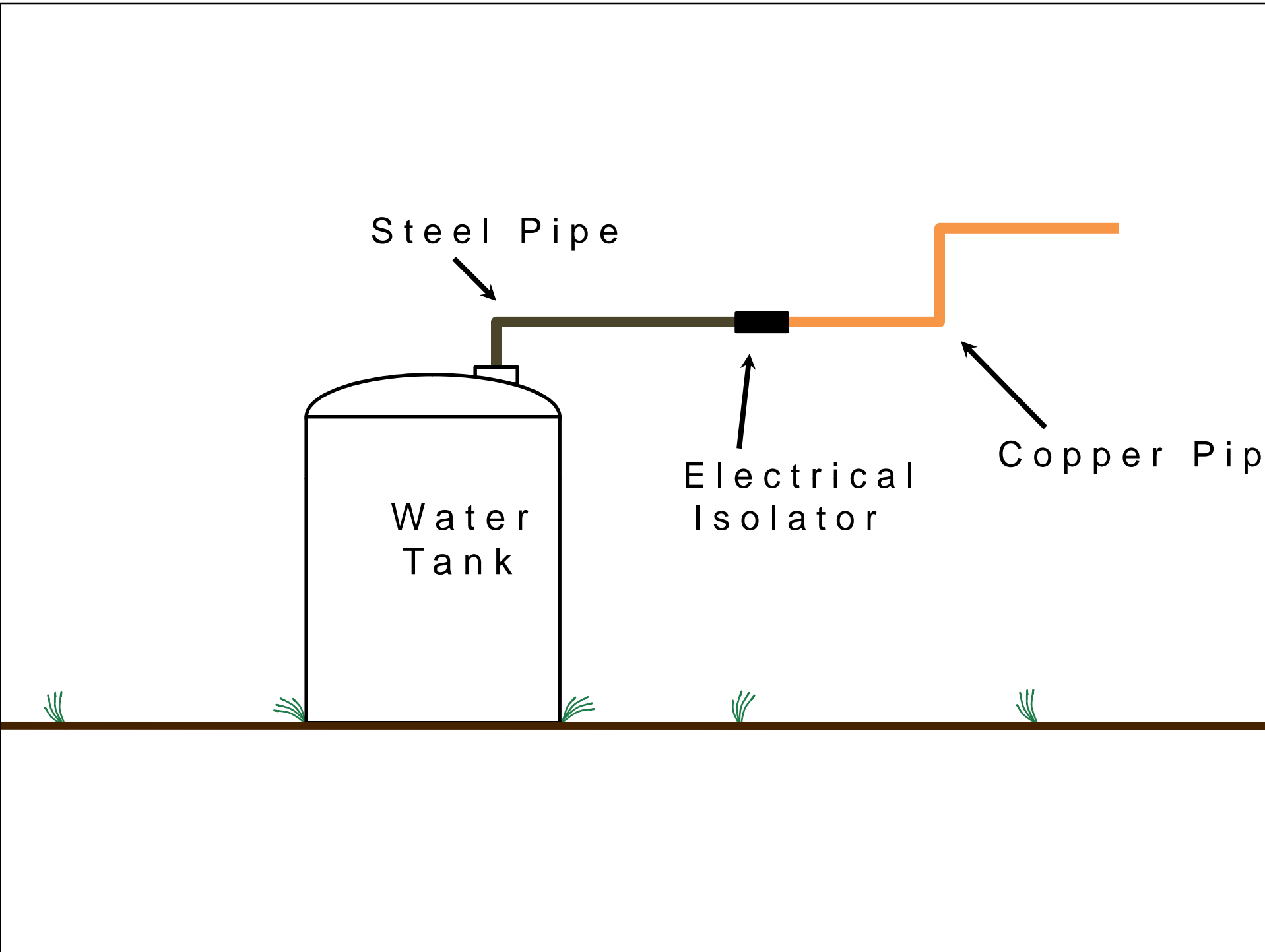
Ionic Current

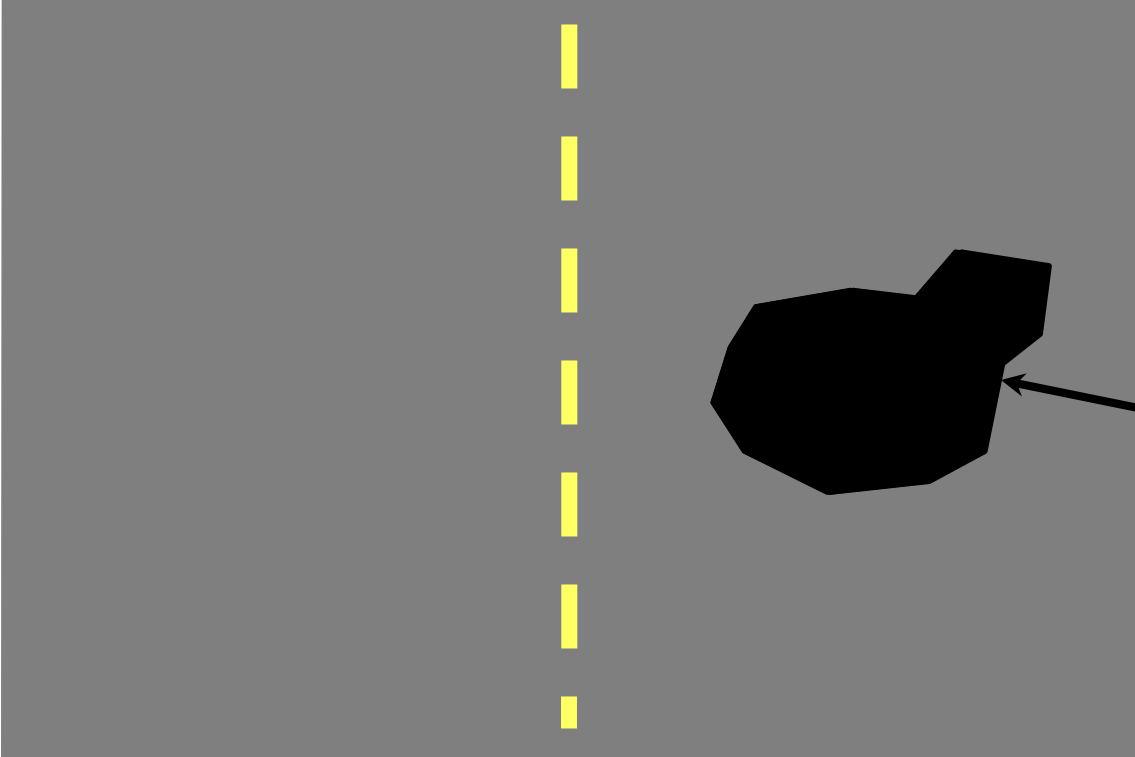
Electronic Current

The Anode

The Cathode

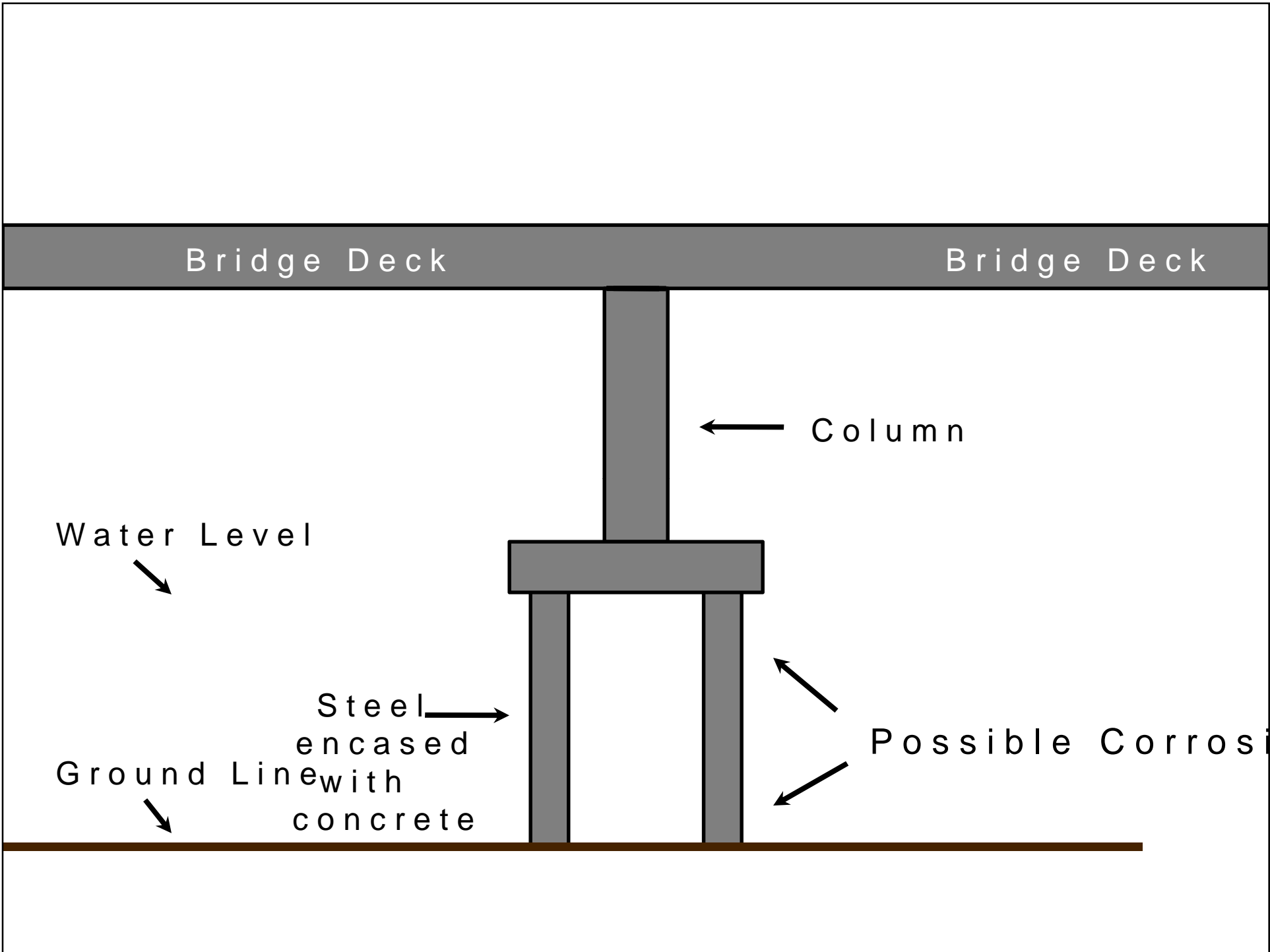
- Dissimilar metals (galvanic corrosion)
- Dissimilar electrolytes
- Anode/cathode area ratio
- Oxygen concentration
- Stray current corrosion





Pot Ho
and Pa





Bridge Deck

Bridge Deck

← Column

Water Level



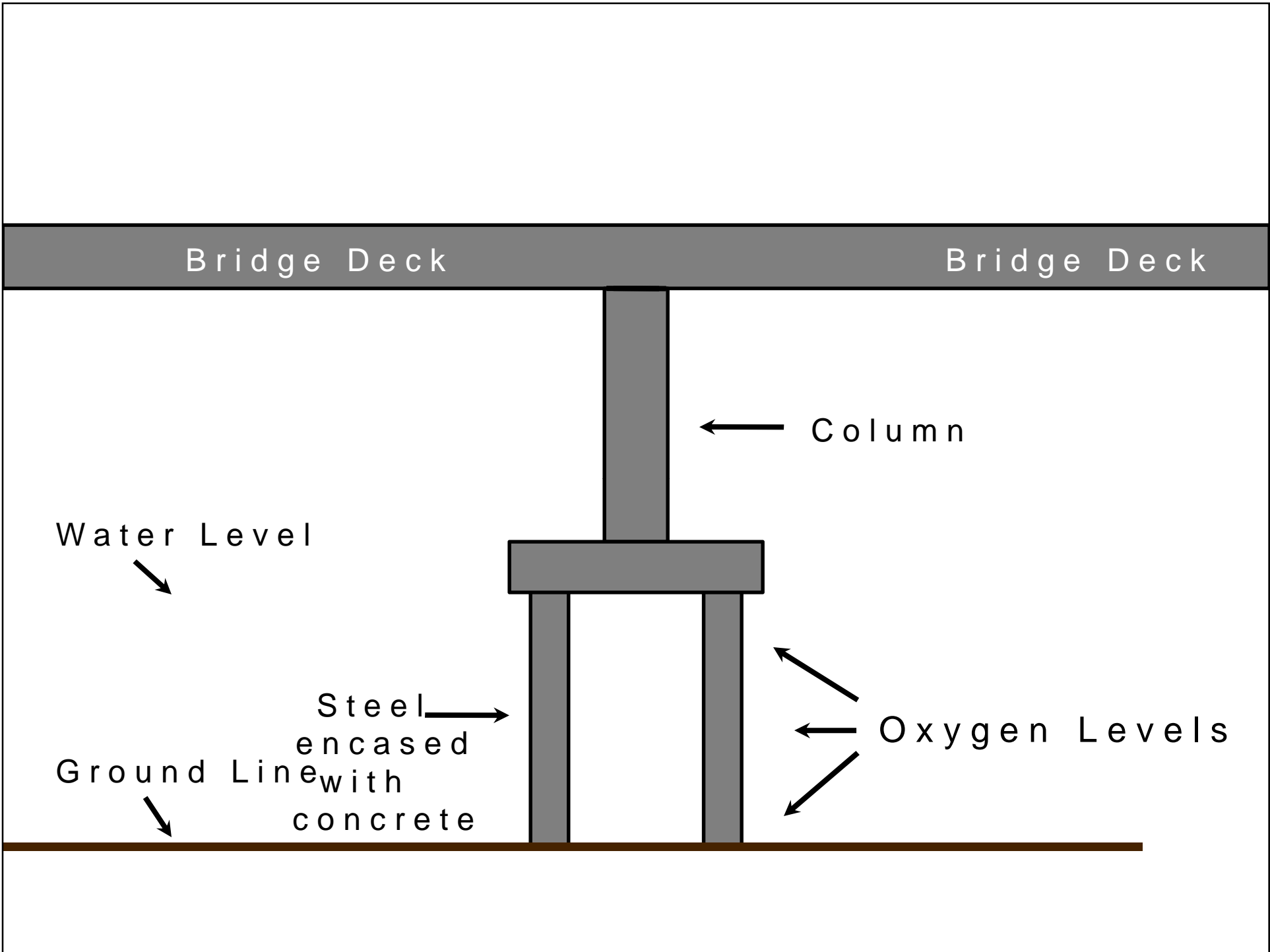
Steel →
encased
with
concrete

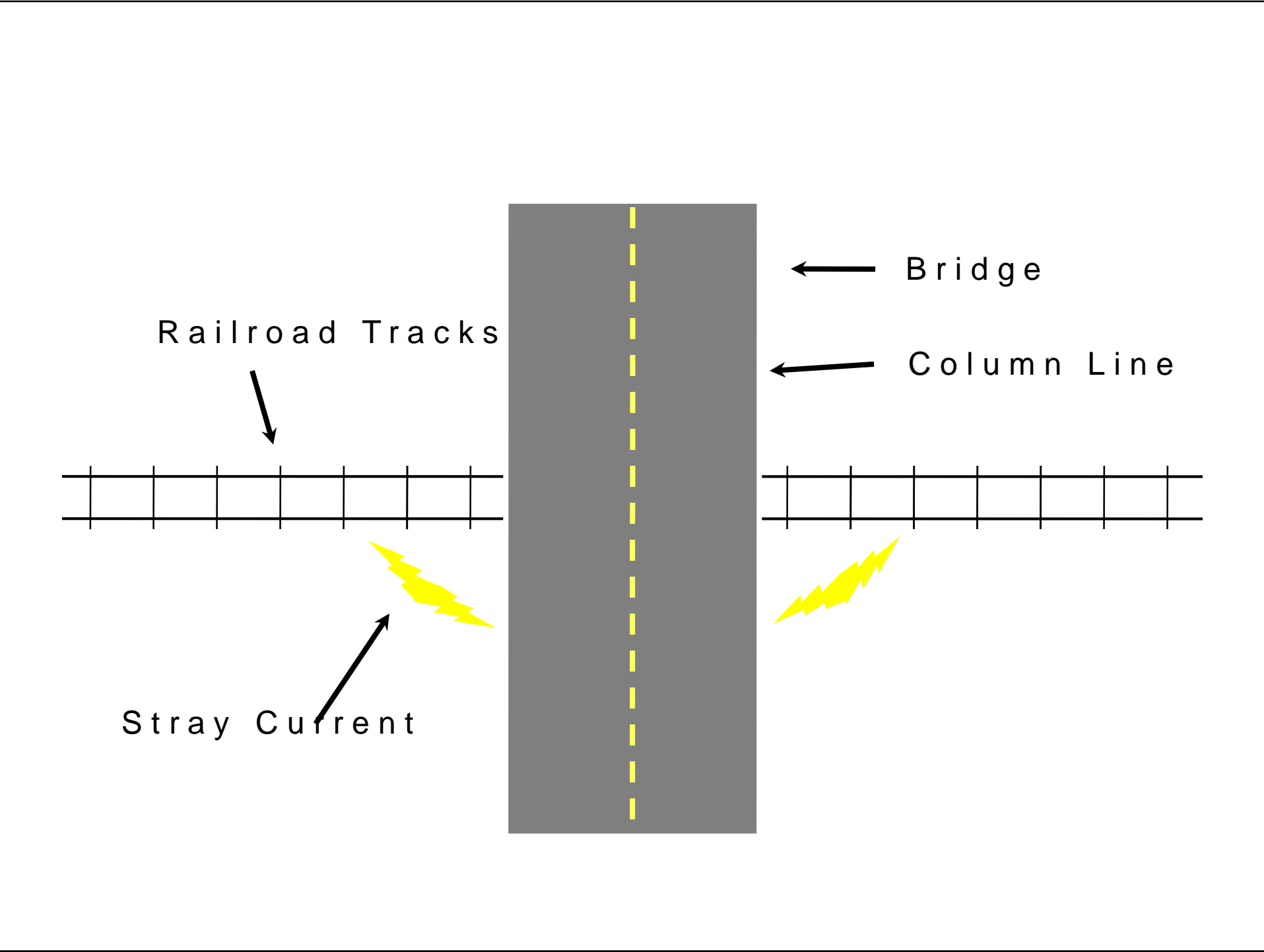
Ground Line



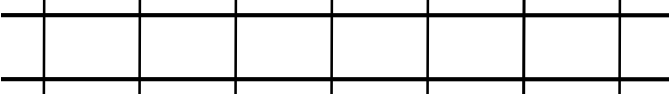
← Possible Corrosion



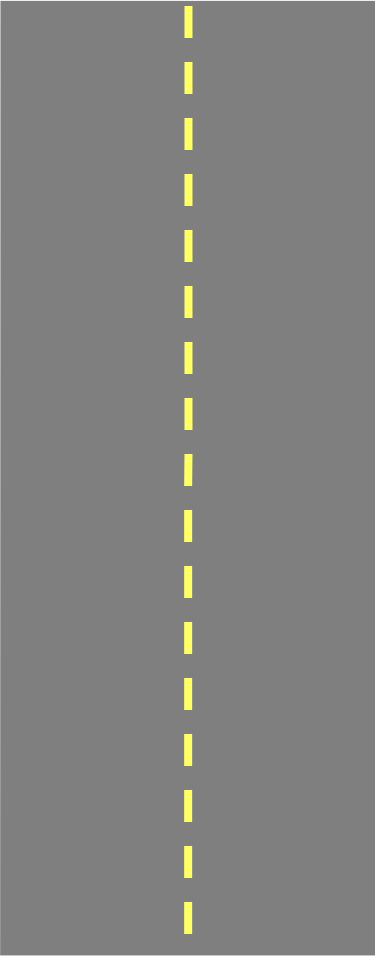
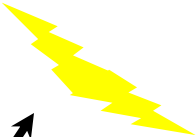
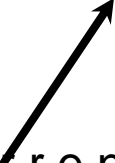




Railroad Tracks



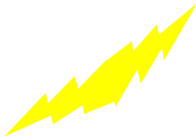
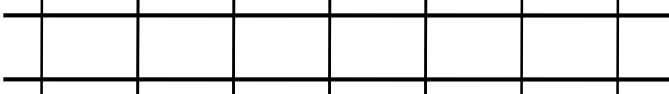
Stray Current



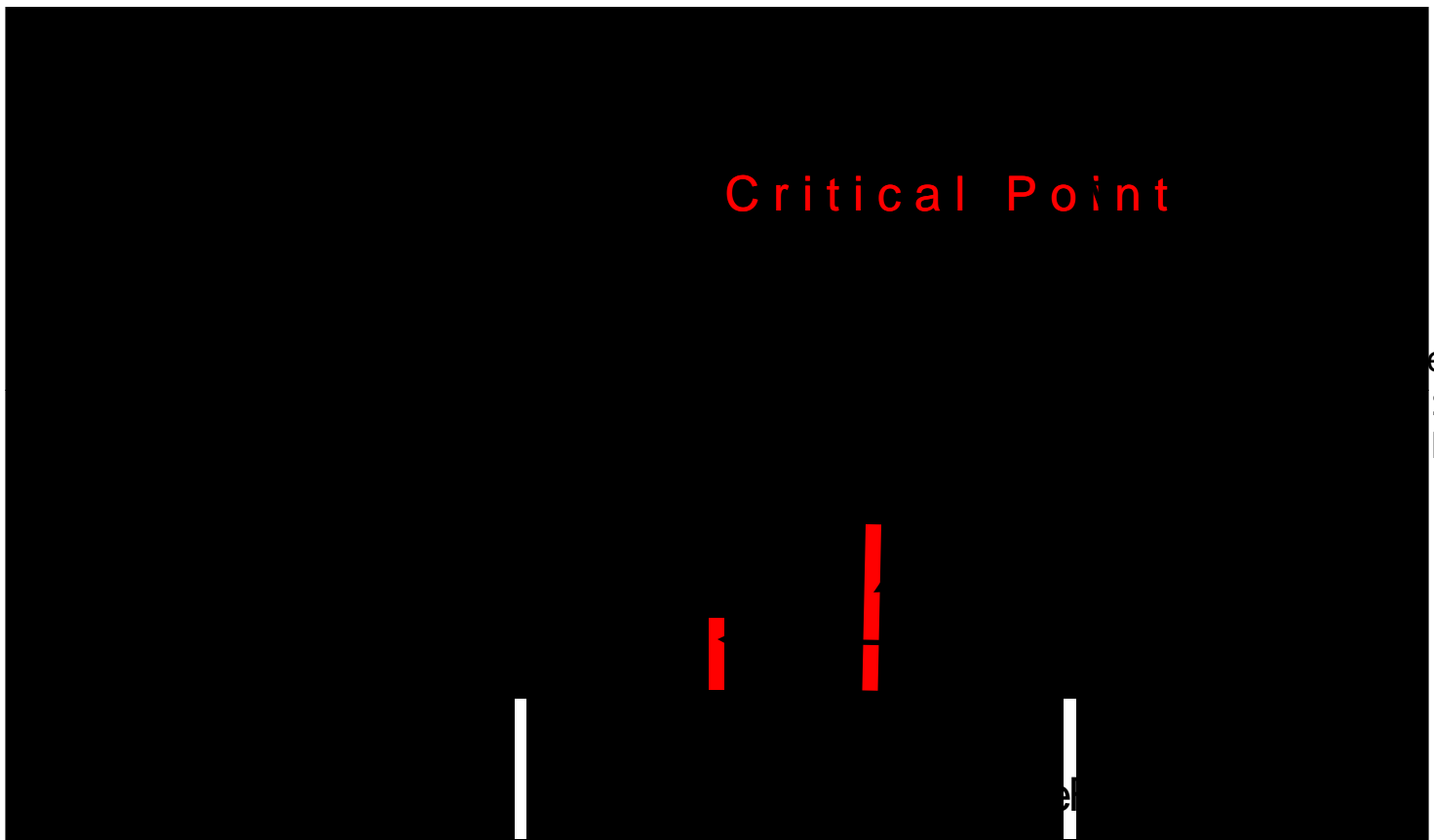
Bridge



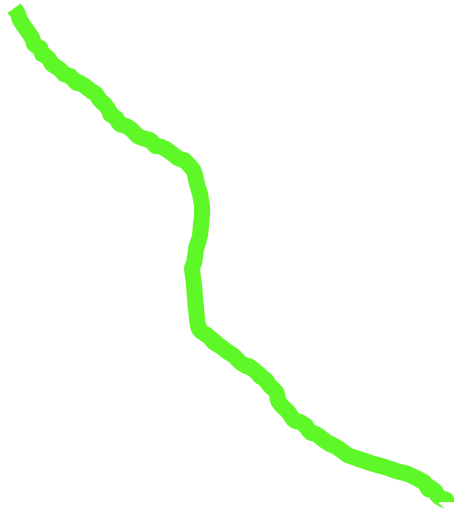
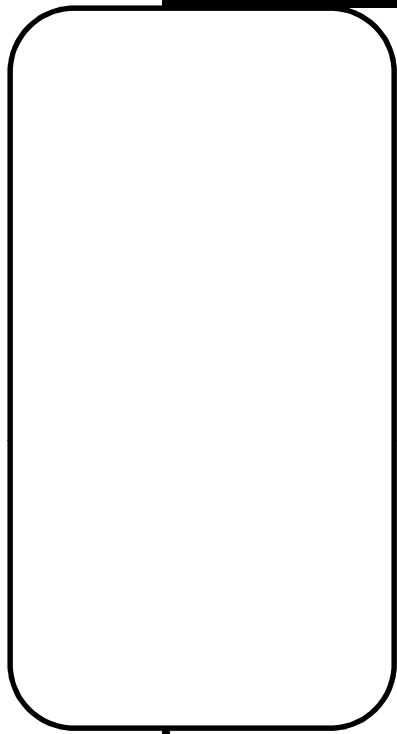
Column Line



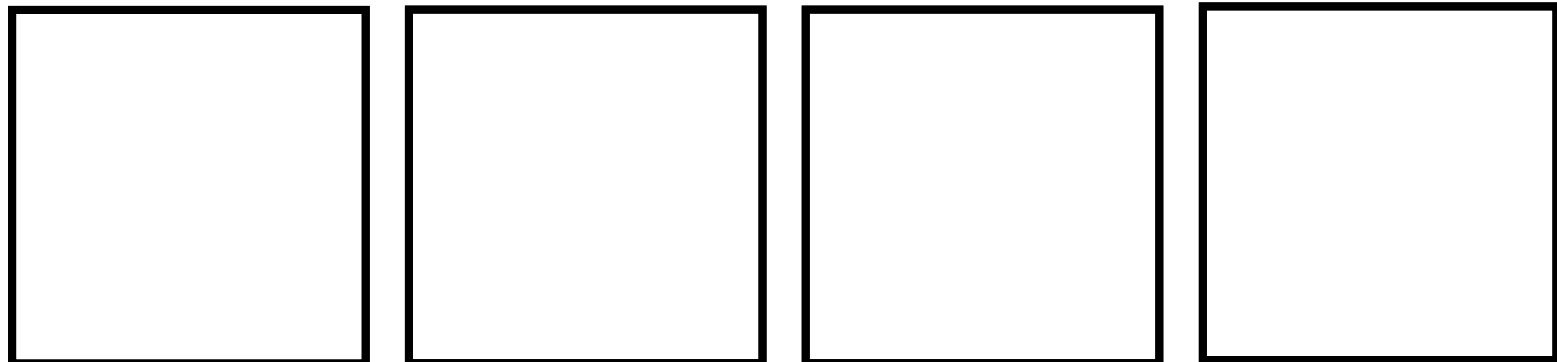
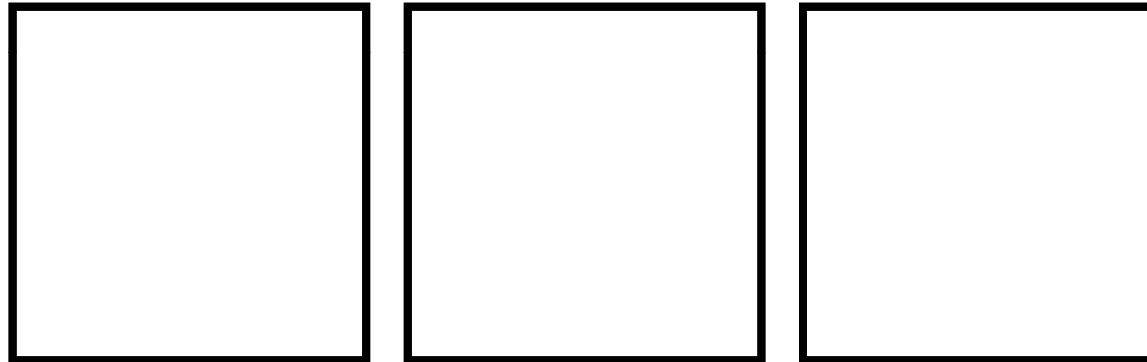
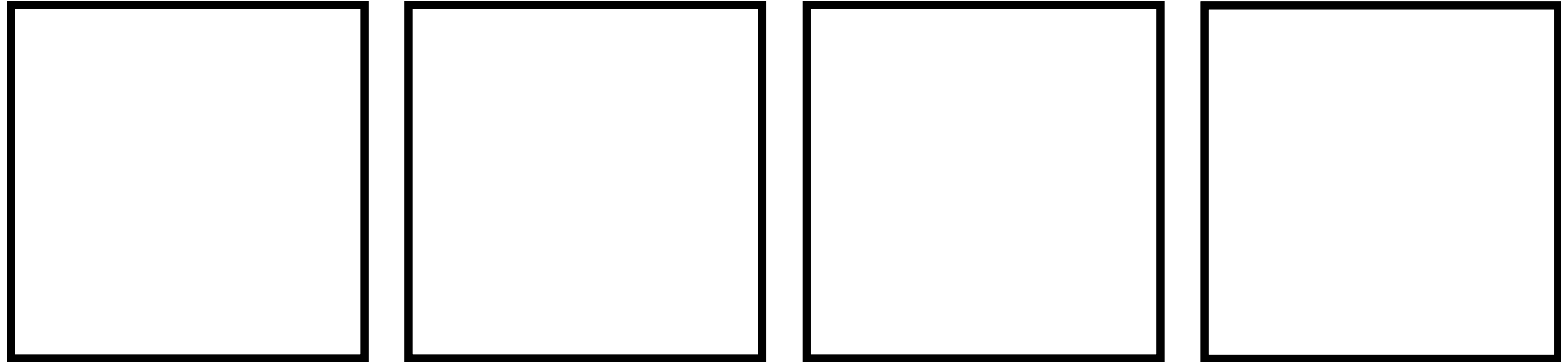
Cost of Maintenance

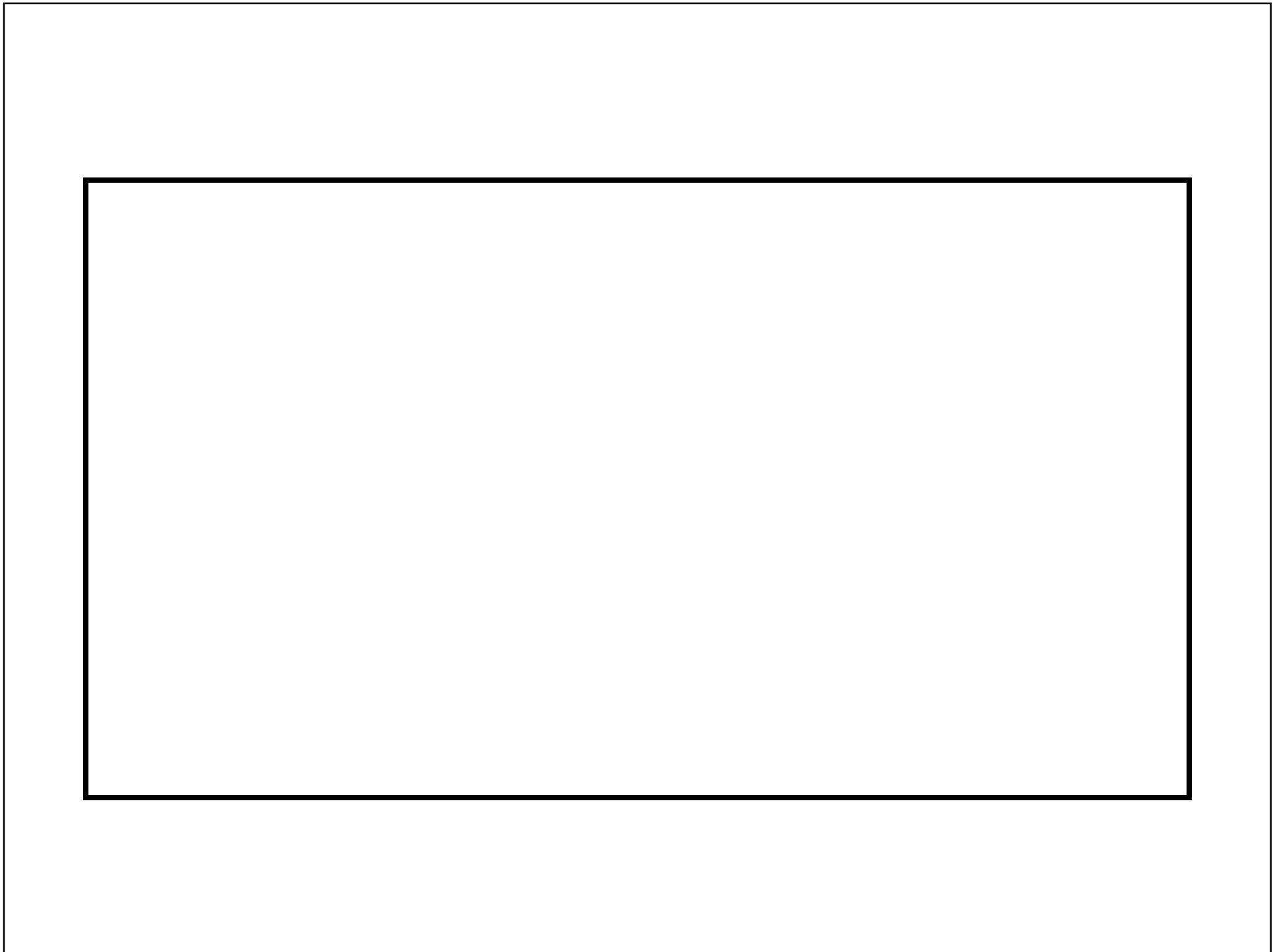


Condition of Structure



11 Bridges in Richmond, VA





• How much chloride is present at present?

• Chlorides at various depths?

• Future penetration and effects of chloride

• Active corrosion occurring? How quickly?

• How much future damage?

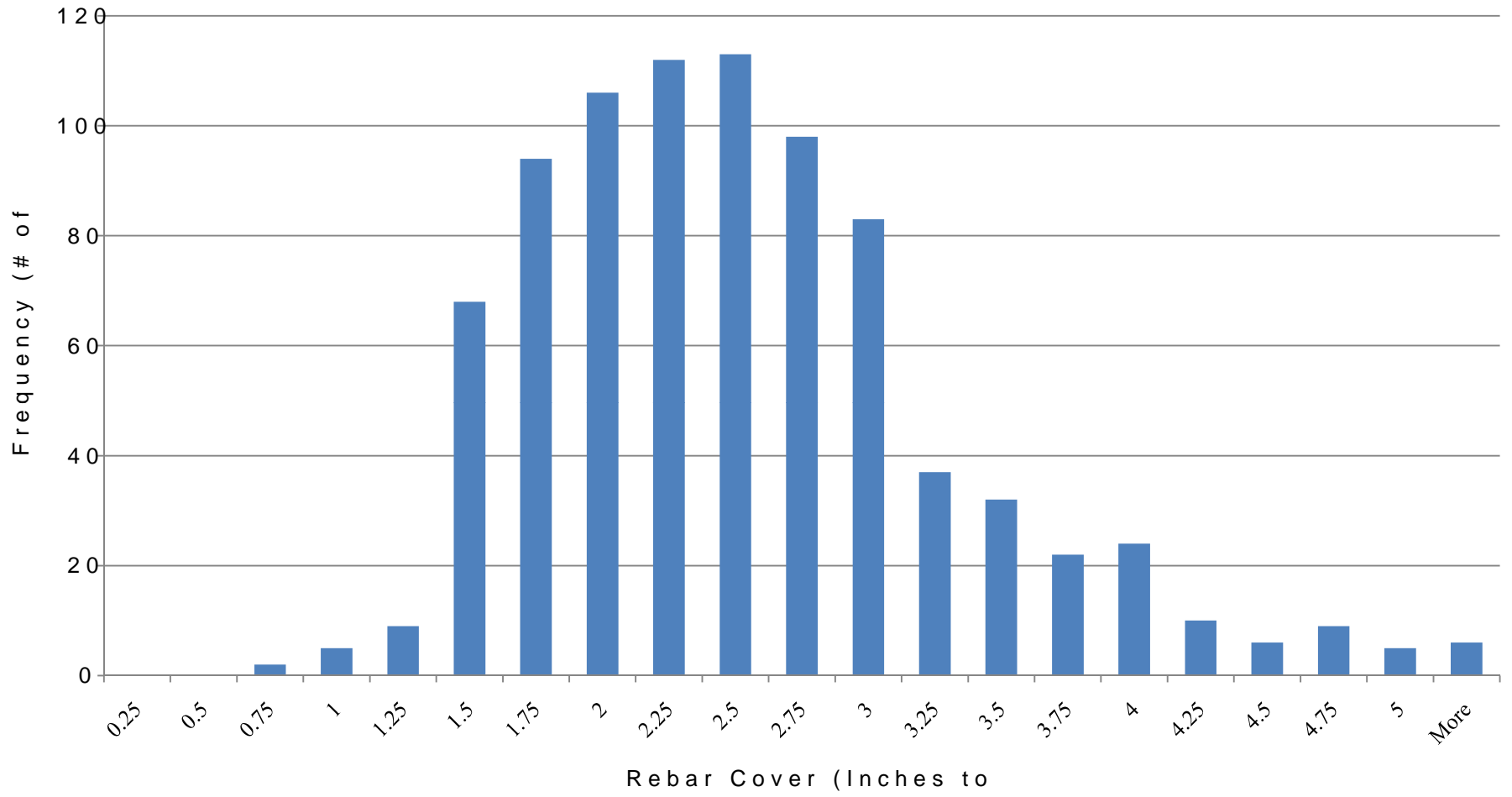
• Presence and progression of ASR?

High risk of prescribing a
without proper diagnosis

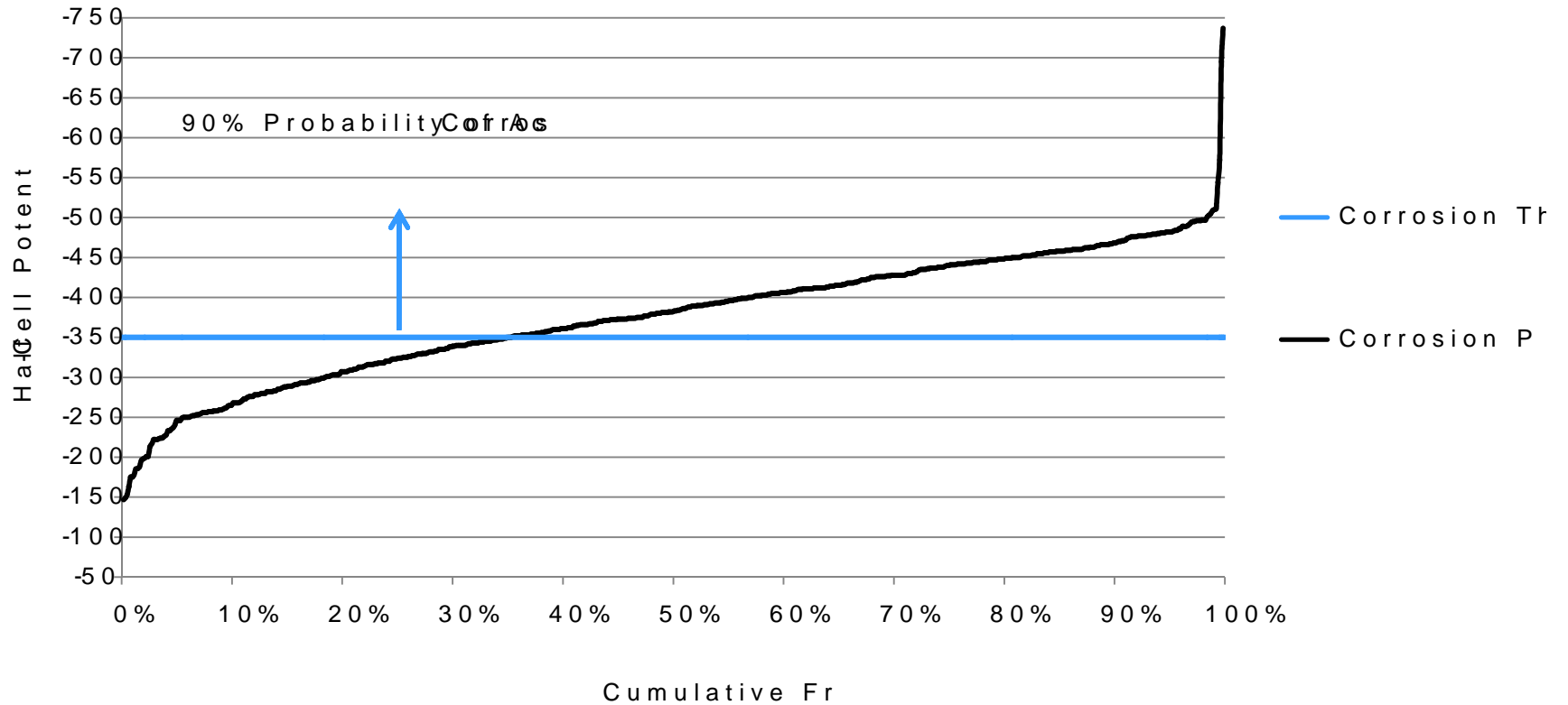




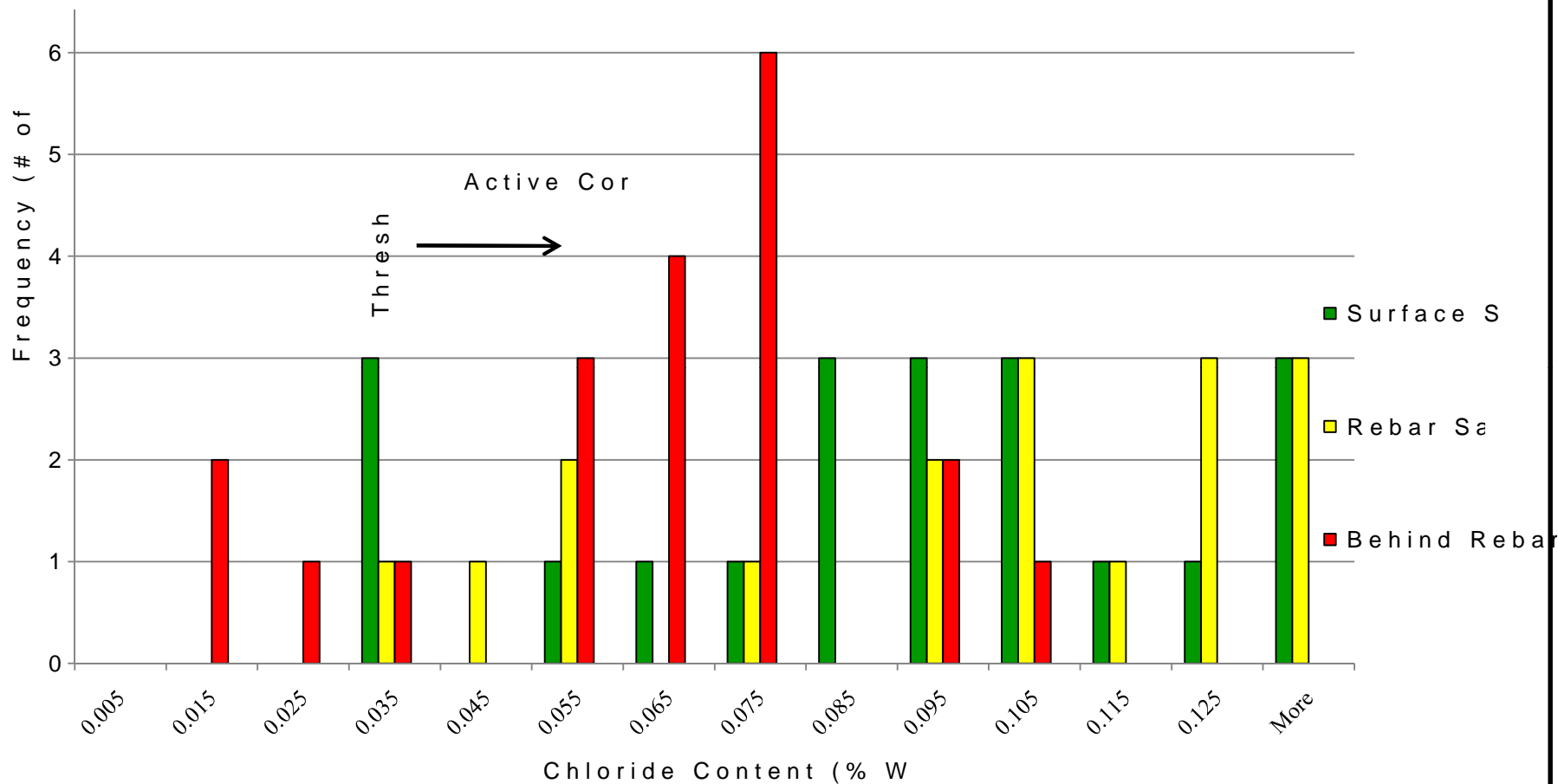
Boulevard Structure 1 Rebar Cover Hist

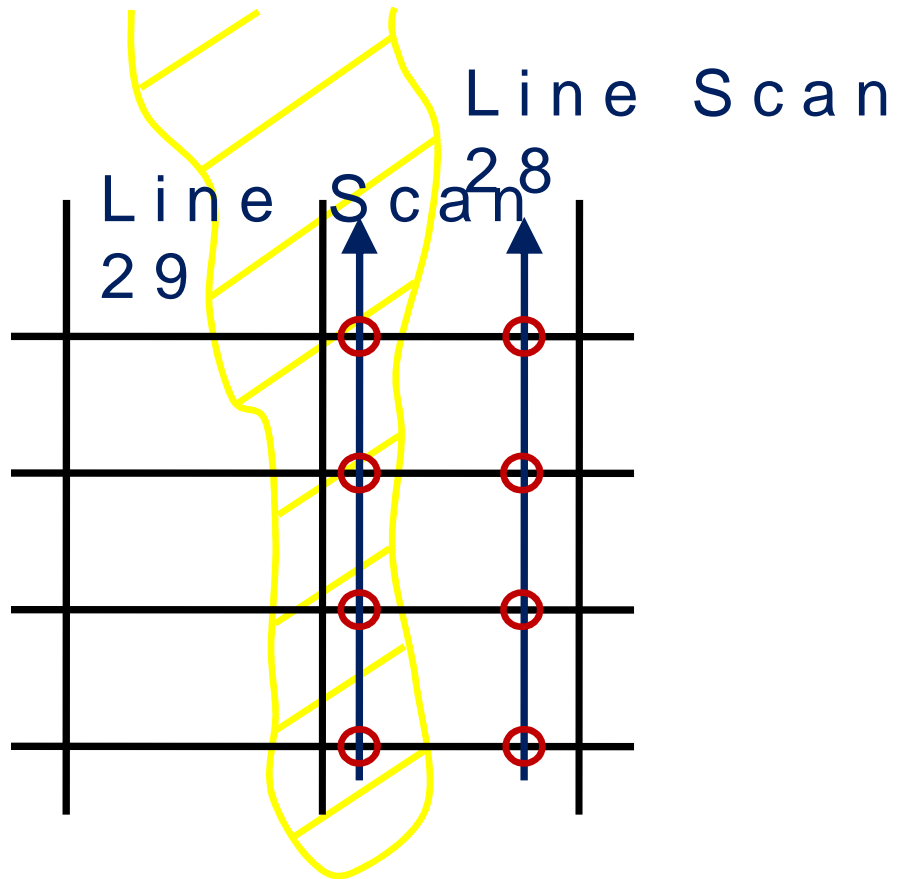


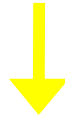
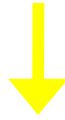
Boulevard Structure Total Corrosion Potential



Boulevard Structure Total Chloride Concentration Histogram













- Visible concrete damage significant increase
- Developed a concrete damage scale for each element
- Average recorded cover moderate to high
- Majority of potential test results corrosive
- High chloride readings in rebar
- Near future concrete damage result
- Significant weakening of the structure within five years

• Based on a unique methodology, we develop recommendations for repair / replacement / extension

• Concrete repairs on all bridges

• ECE to lower chloride level near rebar
re-polarize bars

• Sacrificial CP to maintain polarization

• 25-year additional life for structures

• Sprayed Zinc Al widely used, easy to apply

S. No.	Structure	Replacem cost	Repai cost	Cost Savings	Repair co Replaceme cost, %
1	Boulevard	\$1,931,20	\$402,30	\$1,528,9	21%
2	Hermitage F	\$3,240,31	\$619,72	\$2,620,5	19%
3	Laburnum Av	\$1,730,25	\$380,48	\$1,349,7	22%
4	Lombardy/C	\$5,821,42	\$2,019,	\$3,802,0	35%
5	Overbrook F	\$1,147,00	\$312,24	\$834,76	27%
6	Ram-A	\$926,000	\$146,44	\$779,56	16%
7	Robin Hood	\$1,877,81	\$568,50	\$1,309,2	30%
8	Sherwood Av	\$1,595,04	\$397,70	\$1,197,3	25%
9	Upham Brook	\$2,287,71	\$429,62	\$1,858,0	19%
10	Westwood Av	\$3,592,00	\$402,44	\$3,189,5	11%
	Total	\$24,148,7	\$5,678,	<u>\$18,469,</u>	24%

• Why testing?

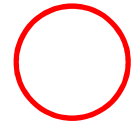
• To understand where and how big the
are

• To properly design the solution

• Department will save \$18,400,000

• 5-years additional life

• Peace of mind



Ø Built in 1962

Ø Bridge No. 160.2

Ø Four spans, three E
type piers (CIP
reinforced concrete)

Ø Four steel girders per
span

Ø Field inspection
July 2010



• Correlate NDT results with other tests / identify NDT accuracy

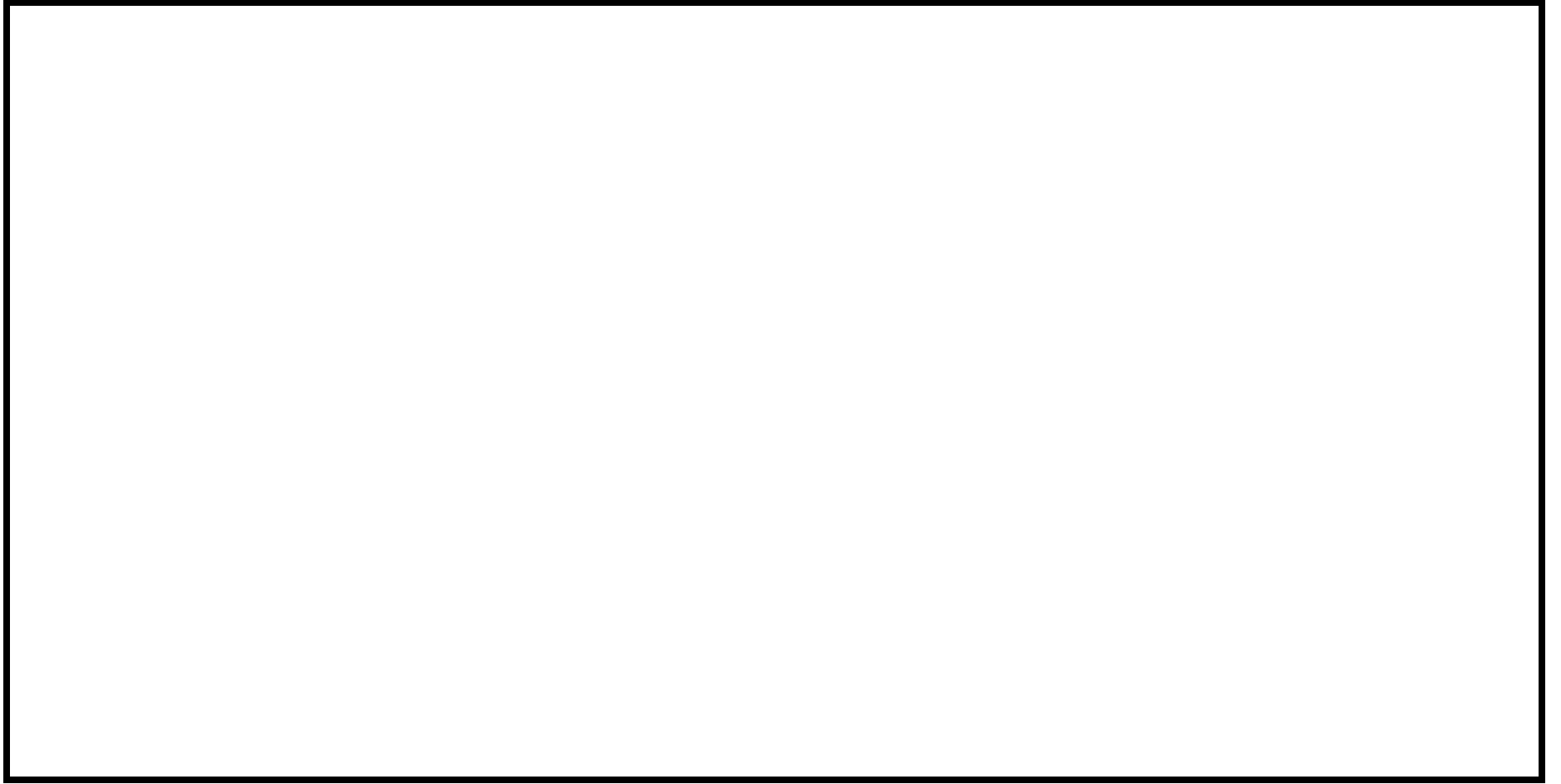
• Quantify the extent of corrosion

• Predict future corrosion activity

• Recommend effective corrosion solutions

Ø 18% of the cap was delaminated or
(western end)

Ø Significant weakening in near future
action is taken)





~~Ø~~Average cover (columns) = 3.3

~~Ø~~Average cover (sides of the cap) = 3.4

~~Ø~~Average cover (underside of cap) = 2.2



Columns 95% passive, 5% active
Cap 18% passive, 29% active

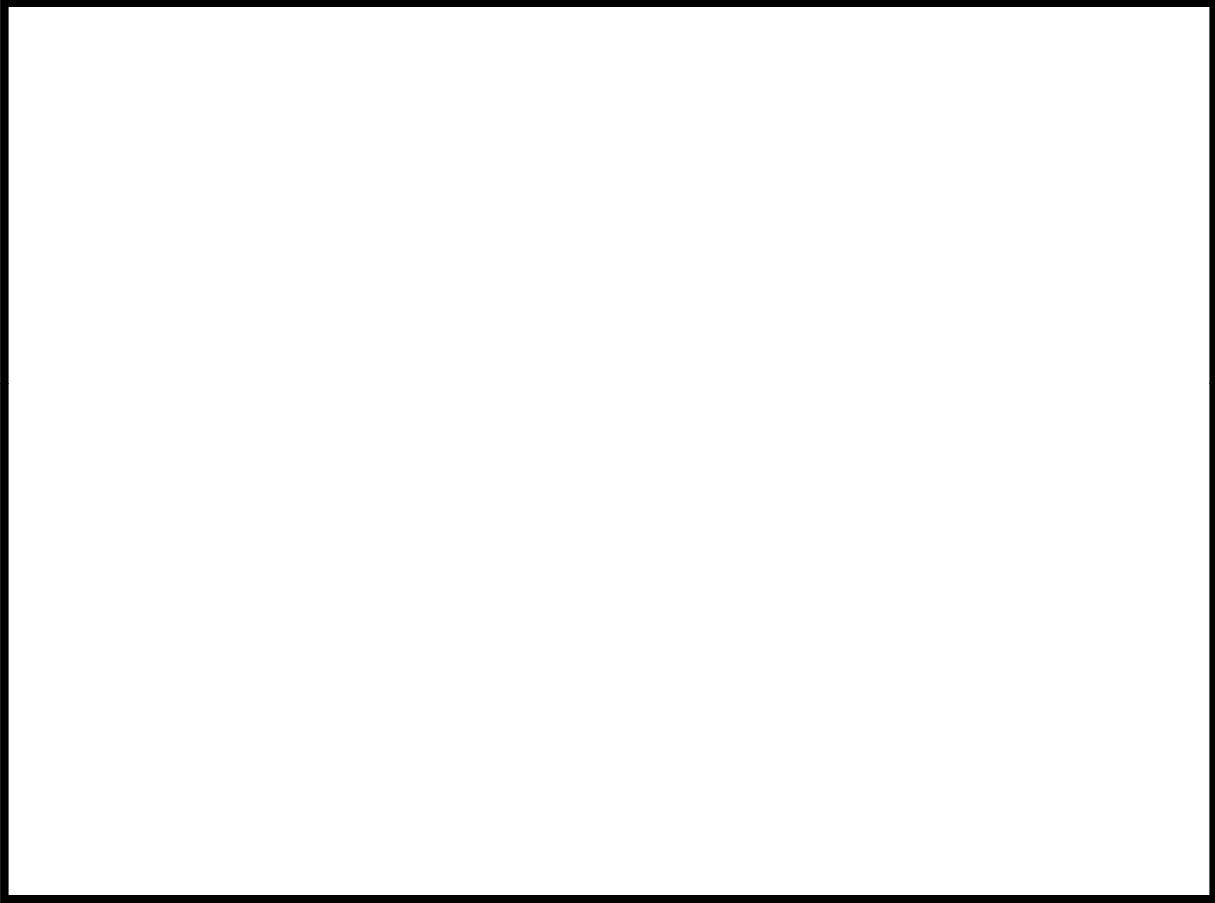


• High concentrations at the surface

• No concentrations at rebar level exceeded threshold for corrosion

• Undamaged areas will have 60 years before threshold for corrosion is reached

• Based on limited data





Ø Difficult to identify delamination by sounding

Ø GPR can rapidly identify delamination before they become visible

Ø GPR can identify reinforcement location/depth and member dimensions

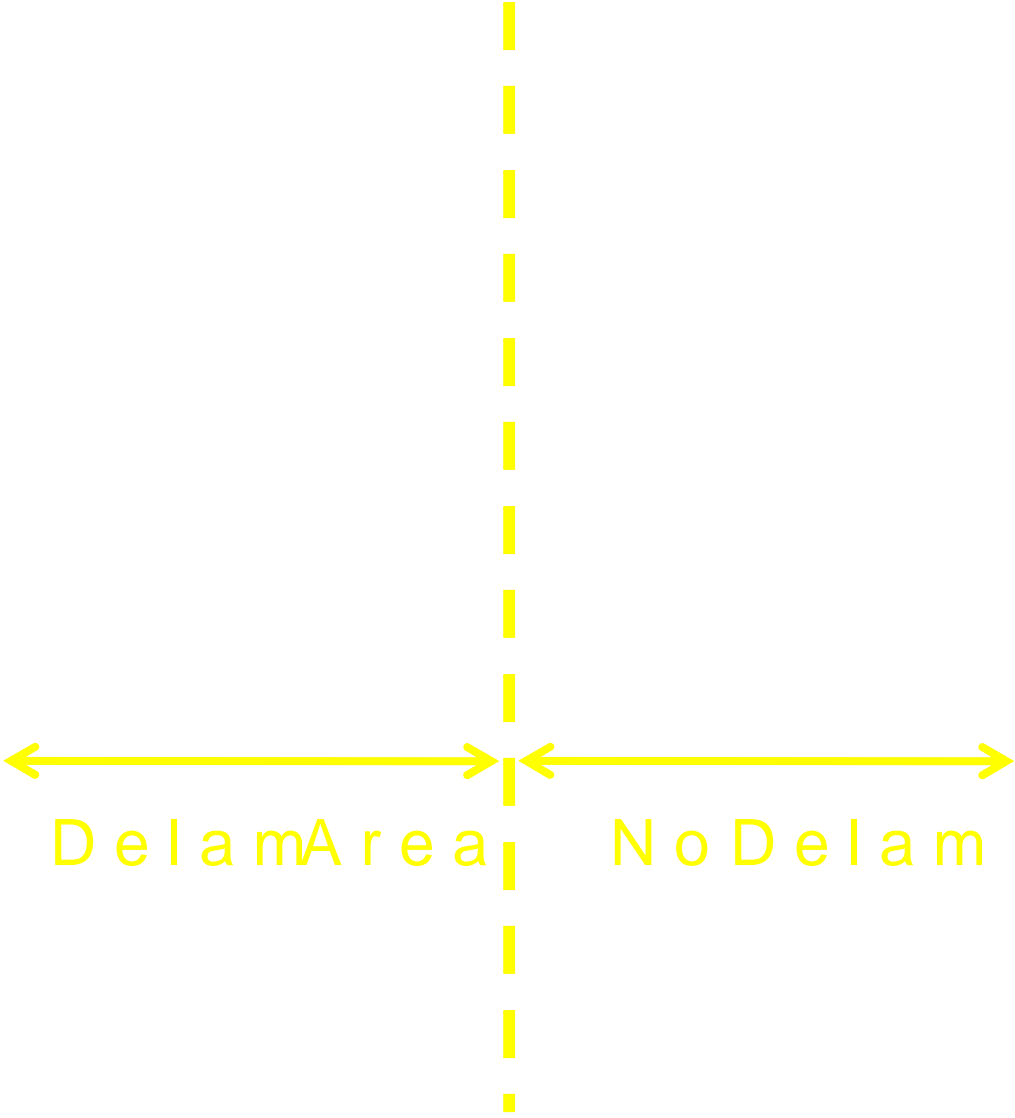
Surface Reflection

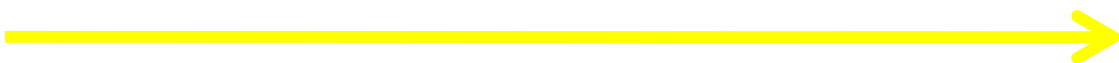
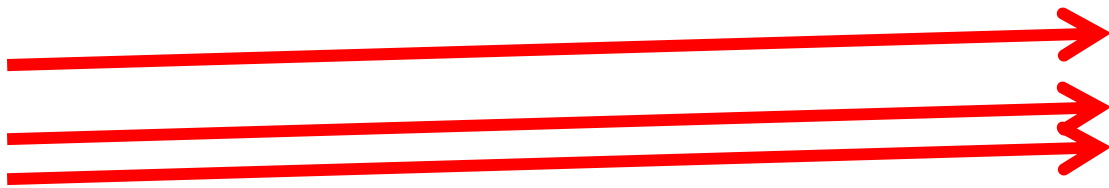




V Joints







∅ Can find flaws not detectable by GPR and provide more information about those flaws

∅ Well suited for flaw determination on structures with difficult access or multiple layers of materials (e.g. overlays)

Transient Response

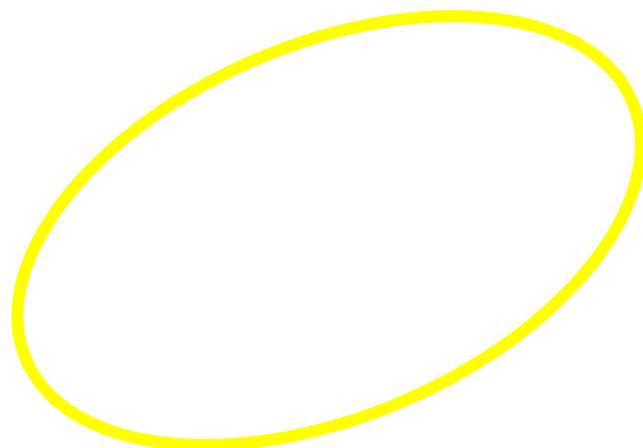
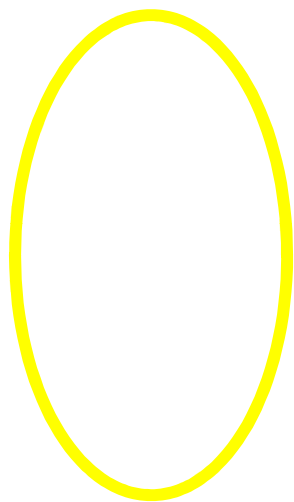
← Sound Response

↙ Delaminated Response









(Previous Inspection by Chas. H. Sells)

Ø Concrete damage 8% of the pier cap

Ø Damage and section losses concentrated in one area of the pier

Ø Runoff water leaks onto pier cap and structural steel below (leaky deck joint)

Ø No corrosion damage on columns

Ø Emergency repairs will be necessary unless corrosion mitigation applied soon

Ø Non-Destructive Testing identified the extent of corrosion

• GPR results clearly show the extent of concrete damage

• Identifies concrete damage before visible to naked eye

• GPR cannot determine the rate of future damage or identify effective life extension solutions

• Impact Echo identifies delamination when GPR cannot

• Divert runoff water away from the top of the pier

• Remove damaged concrete to a depth of one inch behind the rebar

• Install a corrosion mitigation system to prevent future deterioration

• Closely inspect concrete and deck joint repairs in the future

• Evaluate efficacy of repairs in six years

- Develop a ~~cost~~ effective repair methodology the entire structure corrosion evaluation
- NDT of deck, coupled with limited coring (validate results)
- Perform NDT of steel beams to measure section losses at critical points

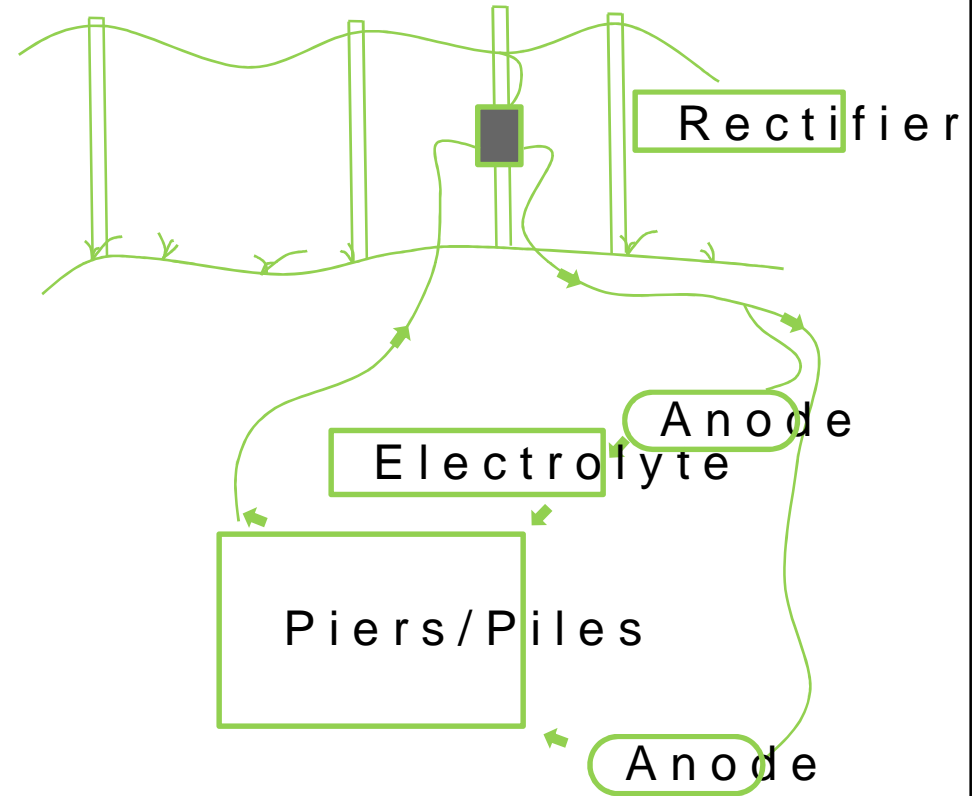
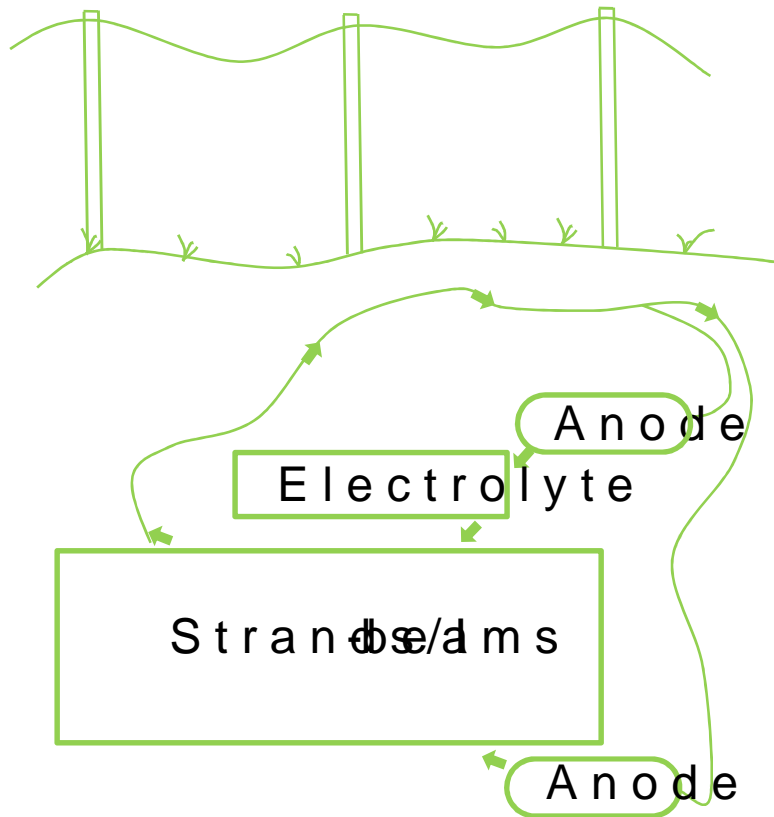
• Determined the current condition of the
• Quantified the extent of corrosion
• Predicted future corrosion activity in the
• Recommended-effective life extension
• Identified corrosion using both NDT and

Typical Solutions

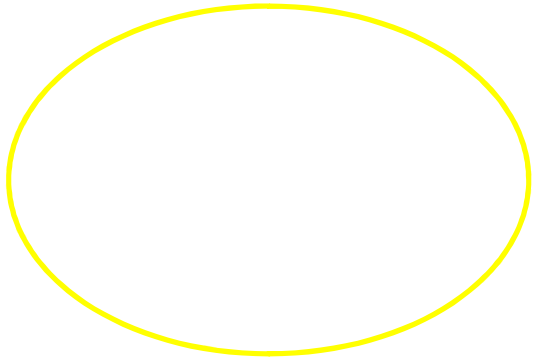
Galvanic CP Impressed Current

For strands/beams

For piers/piles



Rebar Mat



Area of Interest





- Liquid Penetrant Testing (LPT)
- Magnetic Particle Testing (MPT)
- Ultrasonic Testing (UT)

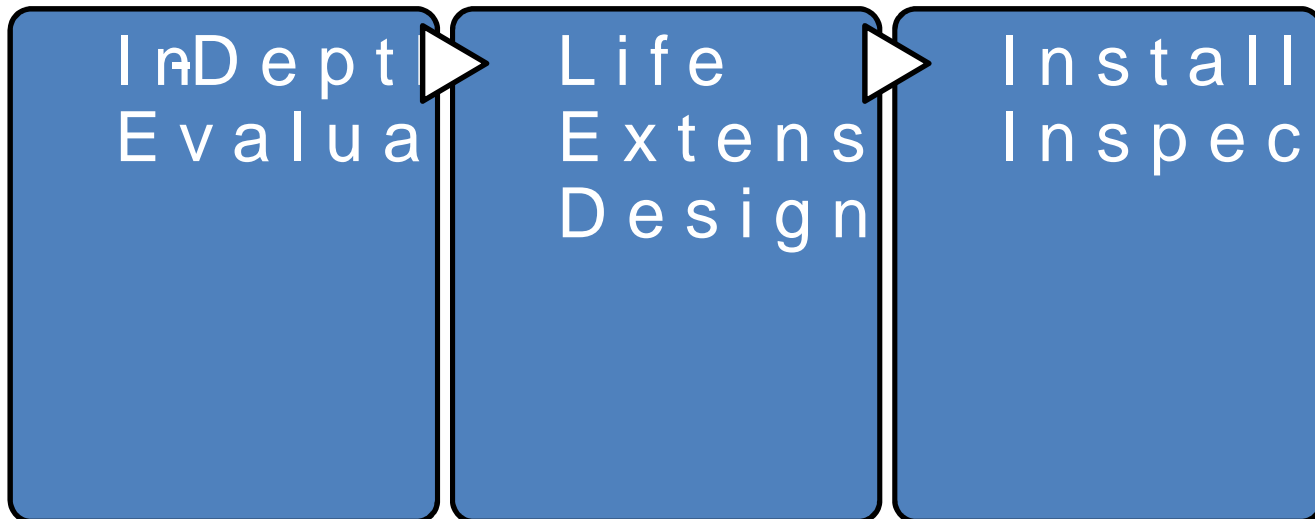
Closing: About SCS

Service Life Extension

• Typically only 2-5% of replacement cost

• Solutions for simple & complex steel & concrete structures

• Our Goal: Life Extension at the lowest overall cost



Thank You

Questions?

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