# HAMPTON ROADS BRIDGE TUNNEL APPROACH STRUCTURES

# DEVELOPING A CORROSION MITIGATION STRATEGY FOR SERVICE LIFE EXTENSION

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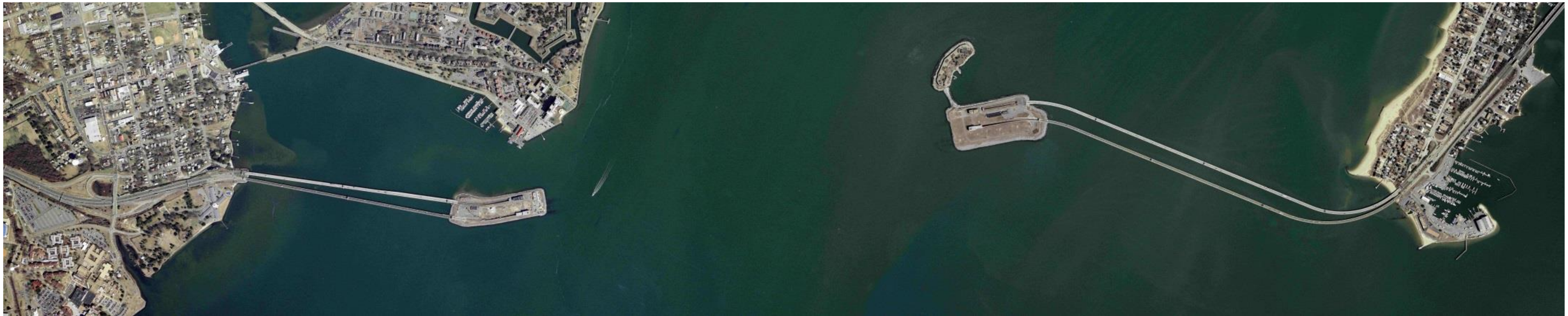
NATIONAL BRIDGE PRESERVATION PARTNERSHIP

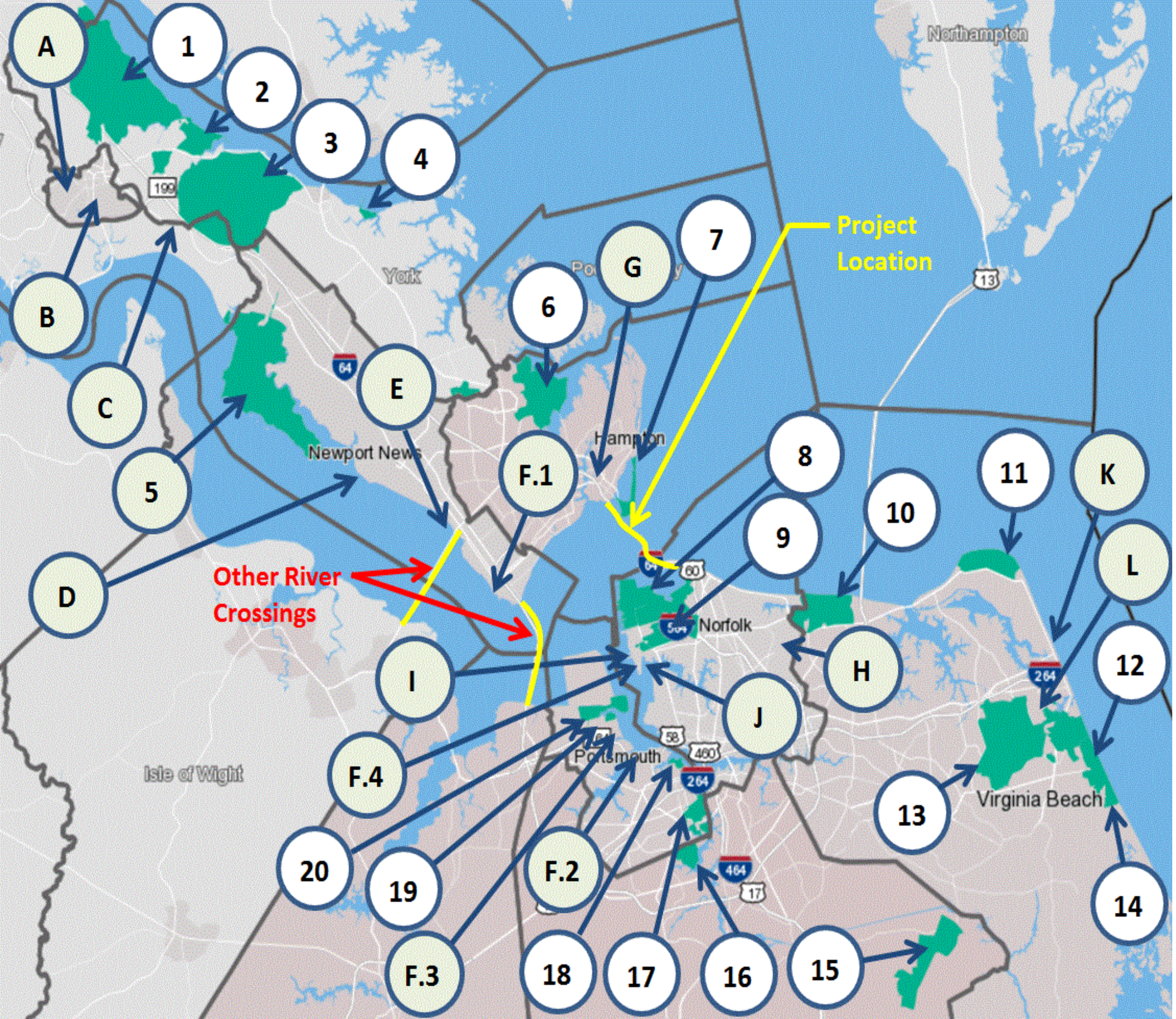
CONFERENCE, ORLANDO, 2018

# HAMPTON ROADS BRIDGE TUNNEL

- SERVES VITAL FACILITIES
- ONE OF ONLY TWO MEANS OF REACHING NORFOLK &VIRGINIA BEACH
- ADT = 90,000
- 35 MILE DETOUR

# Vital to the Nation: Access to Military Bases




Facilities Served by the HRBT

| Military Facilities | |
|---|---|
| 1. | Camp Peary (Army) |
| 2. | Naval Supply Center (Cheatham Annex) |
| 3. | Naval Weapons Center Yorktown |
| 4. | U.S. Coast Guard Training Center Yorktown |
| 5. | Fort Eustis (Army) |
| 6. | Langley Air Force Base |
| 7. | Fort Monroe (Army) |
| 8. | Naval Air Station Norfolk |
| 9. | Naval Support Activity Norfolk |
| 10. | Naval Amphibious Base Little Creek |
| 11. | Fort Story (Army) |
| 12. | Camp Pendleton (Marines) |
| 13. | Naval Air Station Oceana |
| 14. | Dam Neck |
| 15. | Naval Auxiliary Landing Field Fentress |
| 16. | Saint Juliet's Creek Annex |
| 17. | Naval Shipyard Norfolk |
| 18. | Naval Medical Center Portsmouth |
| 19. | Coast Guard Station Portsmouth |
| 20. | Craney Island Fuel Depot (Navy) |

# Vital to the Nation – Access to Military Bases

Norfolk Naval Base (Atlantic Fleet)

Oceana Naval Air Base

Newport News Shipbuilding

# Vital to the Nation – Port of Virginia

# HAMPTON ROADS BRIDGE TUNNEL APPROACH BRIDGE DATA

| Bridge | Year Built | Year Widened | Current General Condition Ratings | | |
|---|---|---|---|---|---|
| | | | Deck | Super | Sub |
| **64 Eastbound North Approach** | 1974 | - | 5 | 5 | 5 |
| **64 Eastbound South Approach** | 1974 | - | 5 | 5 | 5 |
| **64 Westbound North Approach** | 1957 | 1999 | 6 | 5 | 5 |
| **64 Westbound South Approach** | 1957 | 1999 | 5 | 4 | 4 |

# HAMPTON ROADS BRIDGE TUNNEL APPROACH BRIDGE DATA

| Bridge | Bridge Number | Year Constructed | Deck Surface Area (sq. ft.) | Wearing Surface Area (sq. ft.) | Length (ft.) | Width (ft.) | Number of Lanes |
|---|---|---|---|---|---|---|---|
| EBL North Approach (NW) | 2827 | 1974 | 142,688 | 129,788 | 3,225 | 44 | 2 |
| EBL South Approach (SW) | 2866 | 1974 | 260,700 | 237,000 | 5,925 | 44 | 2 |
| WBL North Approach (NE) | 2900 | 1957 | 283,561 | 148,800 | 6,250 | 44 | 2 |
| WBL South Approach (SE) | 2902 | 1957 | 158,225 | 265,436 | 3,250 | 44 | 2 |
| Totals | | | **845,174** | **781,024** | **18,650** | | |

| Bridge | Bridge Number | Numberof Spans | Number of Beams | Number of Bents | Number of Caps | Number of Piles | Number of Abutments |
|---|---|---|---|---|---|---|---|
| EBL North Approach (NW) | 2827 | 43 | 303 | 42 | 42 | 338 | 2 |
| EBL South Approach (SW) | 2866 | 80 | 560 | 79 | 79 | 449 | 2 |
| WBL North Approach (NE) | 2900 | 123 | 1,111 | 122 | 122 | 601 | 2 |
| WBL South Approach (SE) | 2902 | 65 | 629 | 64 | 64 | 472 | 2 |
| Totals | | **311** | **2,603** | **307** | **307** | **1,860** | **8** |

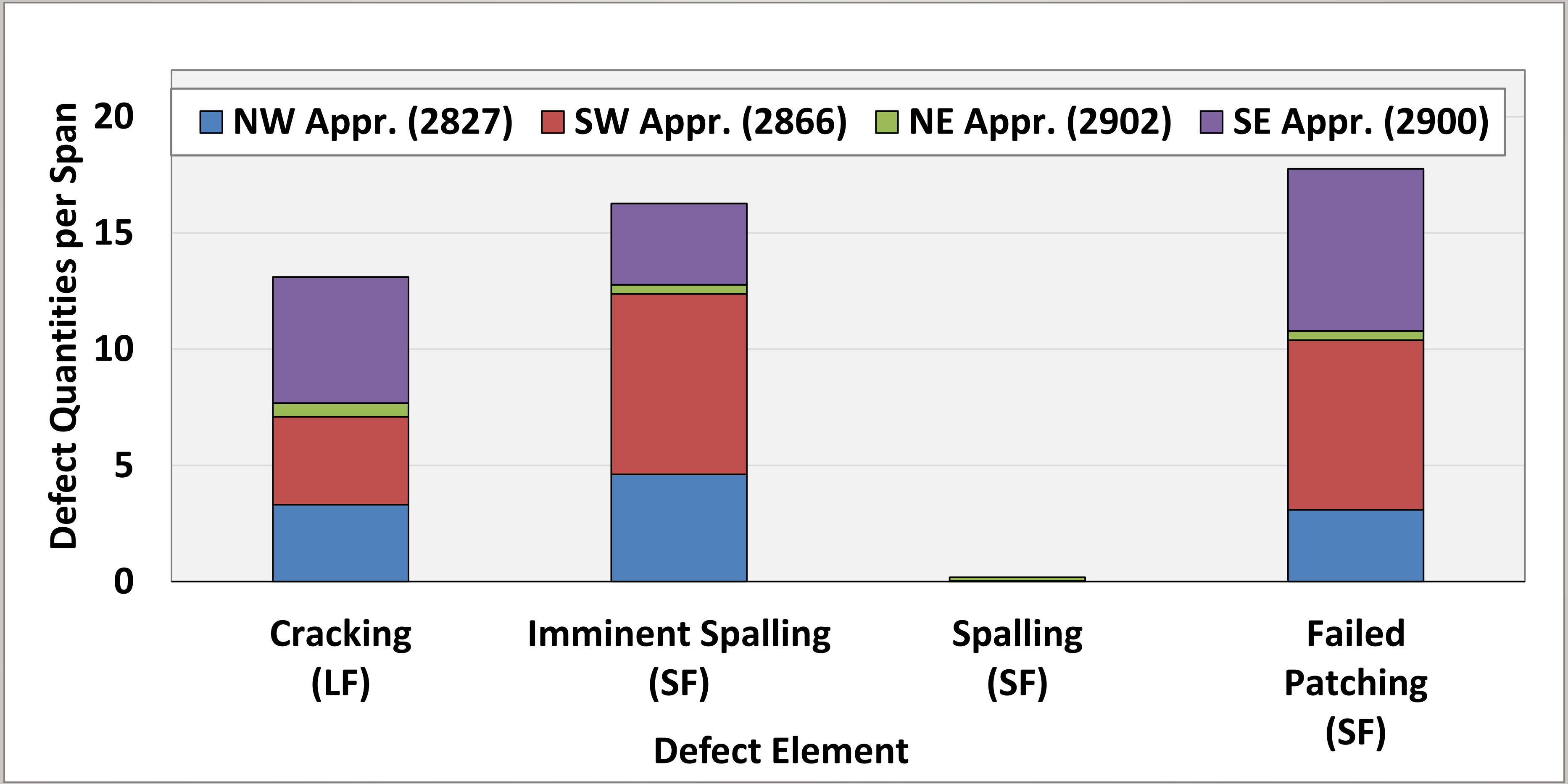
Westbound Structures Were Widened in 1999

# The Challenge

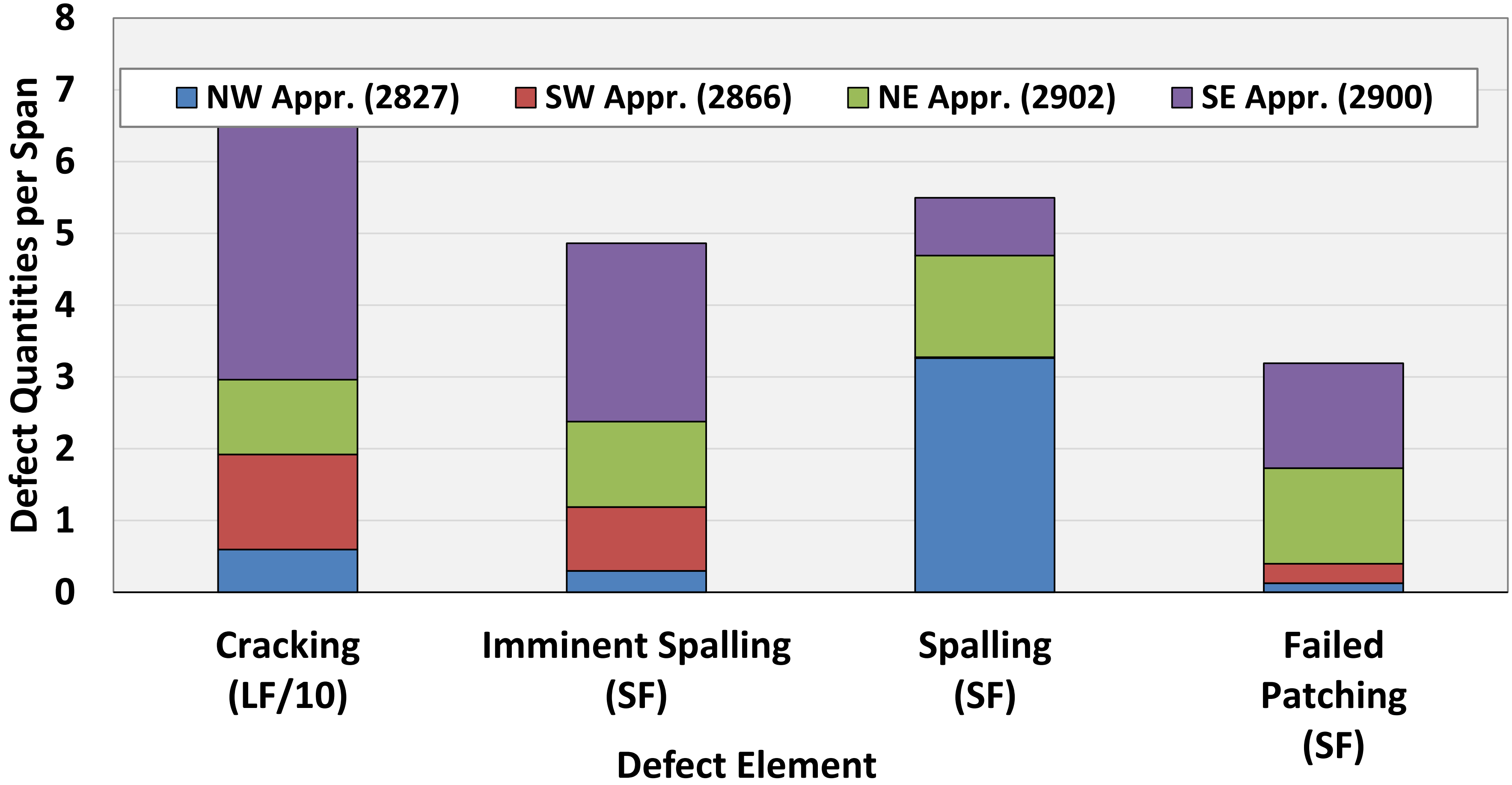
- $700M Needed to Replace 4 HRBT Structures
- Virginia has over 21,000 Highway Structures
- Annual Bridge Maintenance Funds: $160M
- Annual Bridge Capital Improvement Funds: $220M
- 25 "Special Structures" Annual Needs = $80M
- Replacement Needs = $400M per year

| | STRUCTURE | | ROUTE | YEAR BUILT (AGE) | 2018-2027 | 2028-2037 | 2038-2047 | TOTAL |
|---|---|---|---|---|---|---|---|---|
| TUNNELS | BRISTOL | Big Walker Mountain | I-77 | 1972 | $12 M | $2 M | $5 M | $20 M |
| | BRISTOL | East River Mountain | I-77 | 1974 | $13 M | $3 M | $6 M | $21 M |
| | HAMPTON ROADS | Hampton Roads Bridge Tunnel | I-64 | WBL - 1958<br>EBL - 1974 | $86 M | $51 M | $113 M | $250 M |
| | HAMPTON ROADS | Monitor Merrimac Memorial Bridge Tunnel | I-664 | 1992 | $142 M | $46 M | $110 M | $298 M |
| | HAMPTON ROADS | Elizabeth River Downtown Tunnel | | | *Maintained by Elizabeth River Crossings* | | | $0 M |
| | HAMPTON ROADS | Elizabeth River Midtown Tunnel | | | *Maintained by Elizabeth River Crossings* | | | $0 M |
| | NORTHERN VIRGINIA | Rosslyn Tunnel | I-66 | 1983 | $4 M | $2 M | $2 M | $8 M |
| | | | | Subtotal | **$257 M** | **$103 M** | **$236 M** | **$597 M** |
| MOVABLE BRIDGES | RICHMOND | Benjamin Harrison | Rte 156 | 1967 | $56 M | $3 M | $4 M | $63 M |
| | HAMPTON ROADS | Chincoteague | Rte 175 | 2010 | $1 M | $2 M | $18 M | $21 M |
| | HAMPTON ROADS | High Rise | I-64 | 1969 | $5 M | $2 M | $0 M | $7 M |
| | HAMPTON ROADS | Berkley | I-264 | WBL - 1952<br>EBL - 1990 | $78 M | $20 M | $18 M | $116 M |
| | HAMPTON ROADS | Coleman | Rte 175 | 1996 | $9 M | $11 M | $14 M | $33 M |
| | HAMPTON ROADS | James River | Rte 17 | 1980 | $55 M | $6 M | $25 M | $86 M |
| | FREDERICKSBURG | Eltham | Rte 30/33 | 2007 | $12 M | $1 M | $9 M | $22 M |
| | FREDERICKSBURG | Gwynn's Island | Rte 223 | 1938 | $18 M | $1 M | $40 M | $59 M |
| | | | | Subtotal | **$234 M** | **$45 M** | **$127 M** | **$406 M** |
| COMPLEX FIXED SPAN STRUCTURES | BRISTOL | 460 Connector | 460 | 2017 | $1 M | $0 M | $3 M | $4 M |
| | SALEM | Smart Road Bridge | | 2001 | $1 M | $1 M | $2 M | $4 M |
| | RICHMOND | Varina Enon | I-295 | 1990 | $69 M | $20 M | $11 M | $99 M |
| | RICHMOND | 895/Pocahontas Parkway | 895 | | *Maintained by Globalvia* | | | $0 M |
| | HAMPTON ROADS | HRBT Approaches | I-64 | WBL 1957<br>EBL 1974 | $79 M | $490 M | $15 M | $584 M |
| | HAMPTON ROADS | Willoughby Bay | I-64 | 1972 | $33 M | $2 M | $0 M | $35 M |
| | HAMPTON ROADS | MMMBT approaches | I-664 | 1992 | $36 M | $48 M | $20 M | $104 M |
| | HAMPTON ROADS | James River bridge approaches | Rte 17 | 1980 | $61 M | $38 M | $23 M | $122 M |
| | HAMPTON ROADS | I-64 High Rise bridge approaches | I-64 | 1969 | $22 M | $13 M | $0 M | $35 M |
| | FREDERICKSBURG | Norris bridge | Rte 3 | 1957 | $27 M | $258 M | $12 M | $297 M |
| | | | | Subtotal | **$329 M** | **$869 M** | **$85 M** | **$1,283 M** |
| | | | | Total (rounded to $100M) | **$0.8 B** | **$1.0 B** | **$0.5 B** | **$2.3 B** |

# SUPERSTRUCTURE DEFECTS



# SUBSTRUCTURE DEFECTS



# COMPLEXITY

| Element Tag | Ele-ment Family | Year Built | Age at Testing | Element Design | Notes |
|---|---|---|---|---|---|
| BM-50-III-74 | Beam | 1974 | 40 | AASHTO Type III - 50 foot | |
| BM-50-III-85 | Beam | 1985 | 29 | AASHTO Type III - 50 foot | |
| BM-50-III-86 | Beam | 1986 | 28 | AASHTO Type III - 50 foot | |
| BM-50-III-92 | Beam | 1992 | 22 | AASHTO Type III - 50 foot | |
| BM-50-III-96 | Beam | 1996 | 18 | AASHTO Type III - 50 foot | |
| BM-50-ORG-57 | Beam | 1957 | 57 | Pre-Stressed - 50 foot | |
| BM-75-III-74 | Beam | 1974 | 40 | AASHTO Type III - 75 foot | |
| DT-57 | Deck | 1957 | 57 | Concrete Deck Top | |
| DT-74 | Deck | 1974 | 40 | Concrete Deck Top | |
| DT-96 | Deck | 1996 | 18 | Concrete Deck Top | |
| DT-E-85 | Deck | 1985 | 29 | Concrete Deck Top | Epoxy coated rebars |
| DT-E-86 | Deck | 1986 | 28 | Concrete Deck Top | Epoxy coated rebars |
| DT-E-92 | Deck | 1992 | 22 | Concrete Deck Top | Epoxy coated rebars |
| PC-57 | Pile Cap | 1957 | 57 | Concrete Pile Cap | |
| PC-74 | Pile Cap | 1974 | 40 | Concrete Pile Cap | |
| PC-85 | Pile Cap | 1985 | 29 | Concrete Pile Cap | |
| PC-E-86 | Pile Cap | 1986 | 28 | Concrete Pile Cap | Epoxy coated rebars |
| PC-E-92 | Pile Cap | 1992 | 22 | Concrete Pile Cap | Epoxy coated rebars |
| PC-E-96 | Pile Cap | 1996 | 18 | Concrete Pile Cap | Epoxy coated rebars |
| PL-24-74 | Piles | 1974 | 40 | 24 Inch Square Pile | |
| PL-24-85 | Piles | 1985 | 29 | 24 Inch Square Pile | |
| PL-24E-86 | Piles | 1986 | 28 | 24 Inch Square Pile | Epoxy coated deformed bars and spiral |

# CORROSION CONDITION EVALUATION

1. **Chloride Profile Analysis**
2. **Carbonation Testing**
3. **Clear Concrete Cover Survey**
4. **Delamination Survey**
5. **Electrical Continuity**

# CHLORIDE CONTAMINATION & DIFFUSION

Fick's Second Law of Diffusion

$$C_{(x,t)} = C_0\left[1 - erf\left(\frac{x}{2\sqrt{Dt}}\right)\right]$$

Accumulation of Chlorides with time

$$C_{(x,T)} = \int_0^T m\left[1 - erf\left(\frac{x}{2\sqrt{Dt}}\right)\right]dt$$

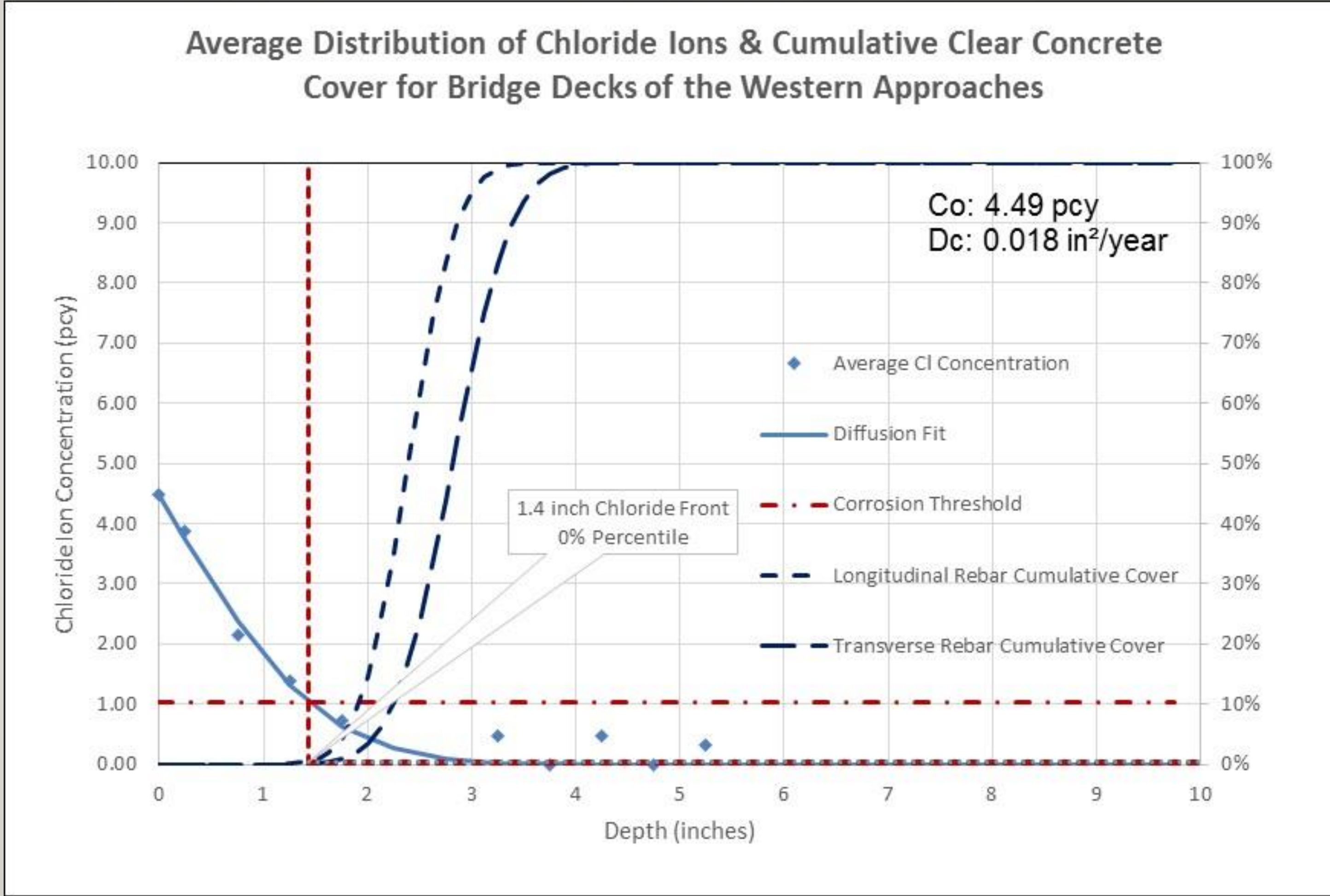
# DECK CONDITION

- **Eastern Approaches**
  - **Impressed current cathodic protection system**
  - **Not functional due to:**
    - **Lack of lightning protection**
    - **Insufficient and/or improper grounding**

# DECK CONDITION

**Western Approaches**

- **In good condition**
- **Minimal damage (0.3%), mostly concentrated at joints**
- **Thin polyester overlay at the end of its service life**



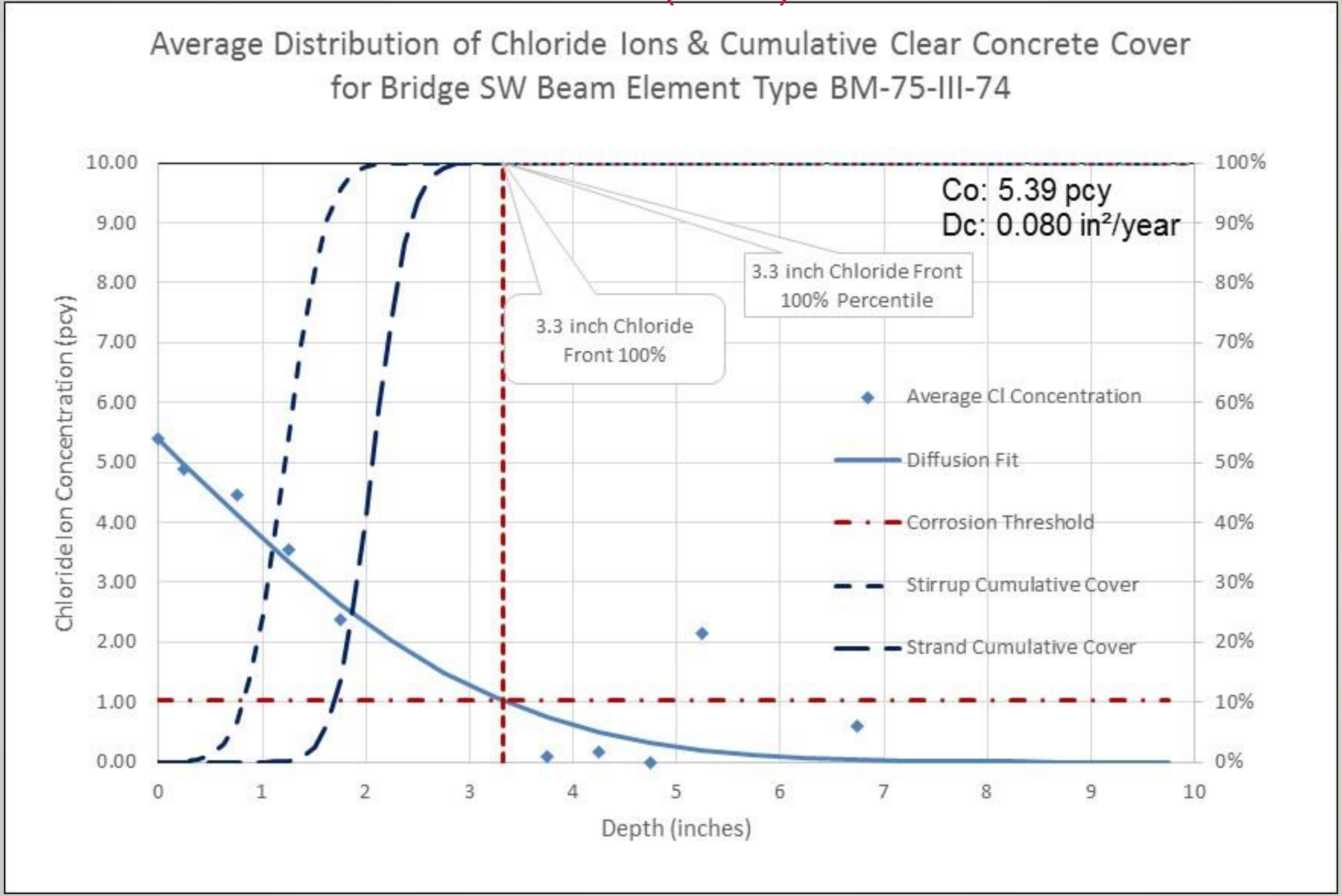
# BEAM CONDITION

- **Southern approaches exhibit higher damage than the Northern approaches. SW Approach exhibits damage an order of magnitude higher than the other 3 approaches.**
- **Significantly lower cover (2.78 vs 4.0) on the bottom surface is likely responsible.**
- **Beams experience wave action during big storms.**

# BEAM DAMAGE ON SW APPROACH

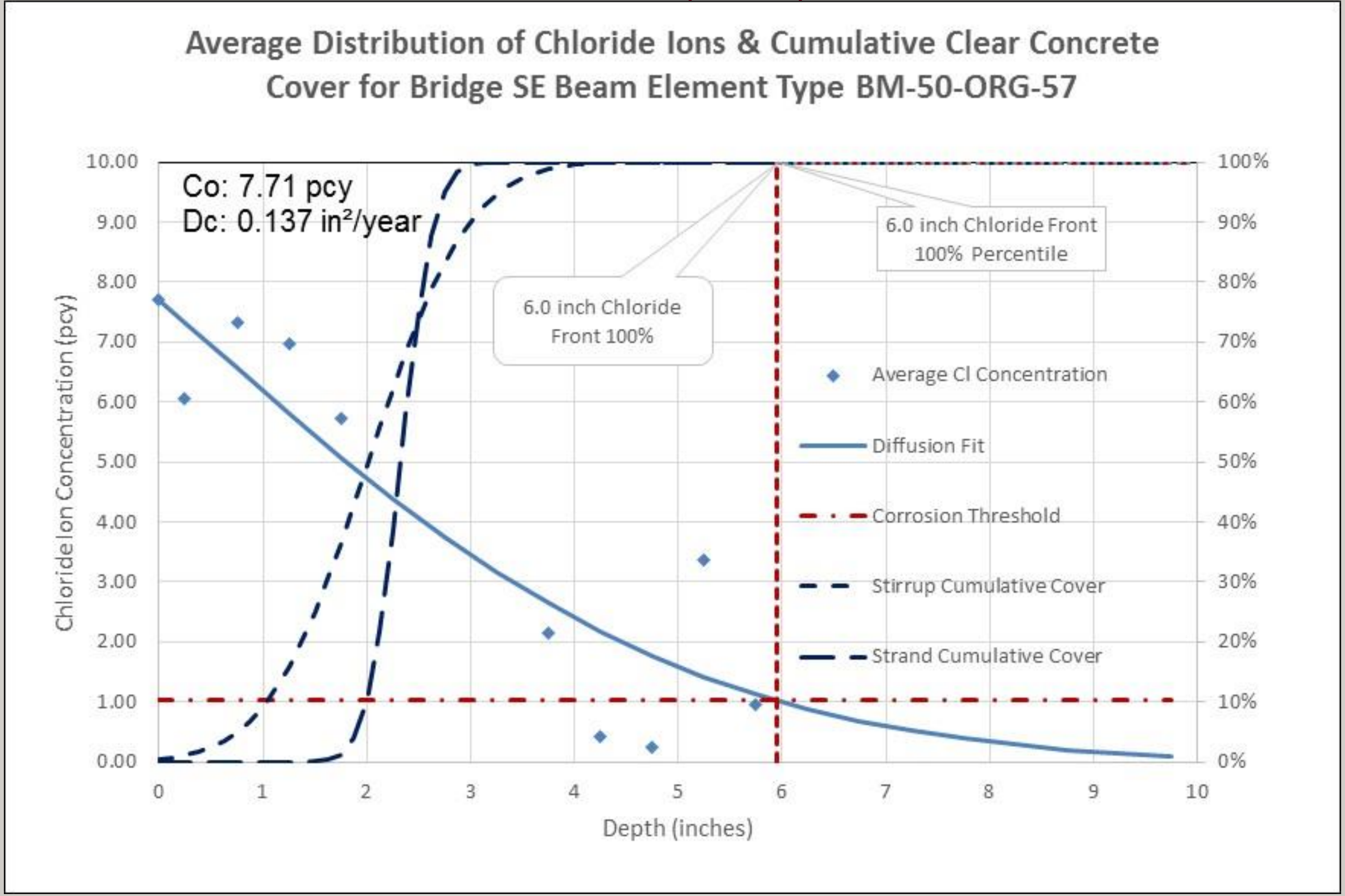
# BEAM CHLORIDE CONTAMINATION

## SW APPROACH (1974)



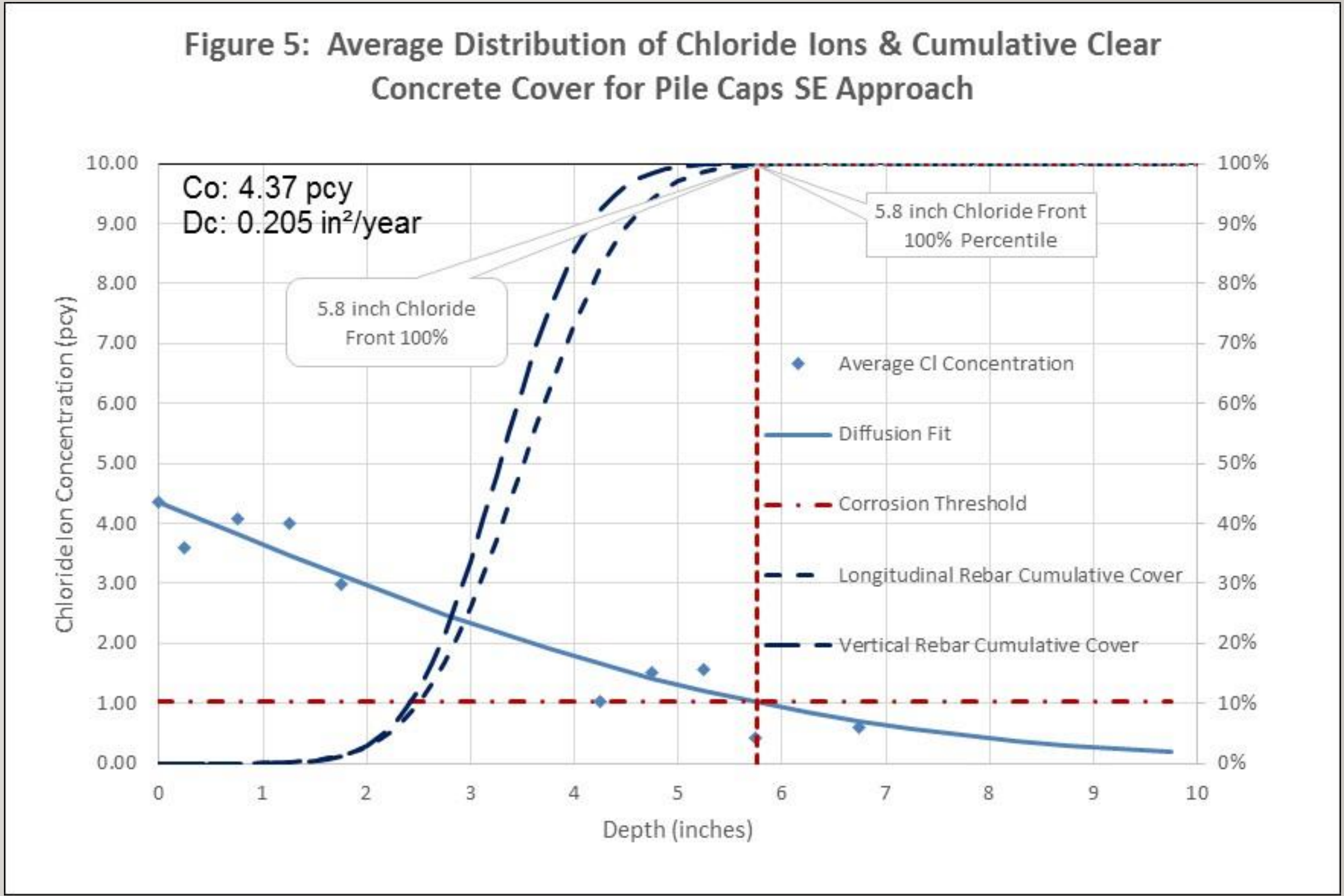
# BEAM CHLORIDE CONTAMINATION

## SE APPROACH (1957)



# PILE CAPS CONDITION & CHLORIDE CONTAMINATION

- Eastern and Western Approaches have suffered 3.4% and 0.5% damage, respectively.
- Chloride front on the Eastern and Western Approaches range from 4.1 to 5.8 inches and 1.3 to 2.8 inches, respectively.



# PILE CAP CONDITIONS

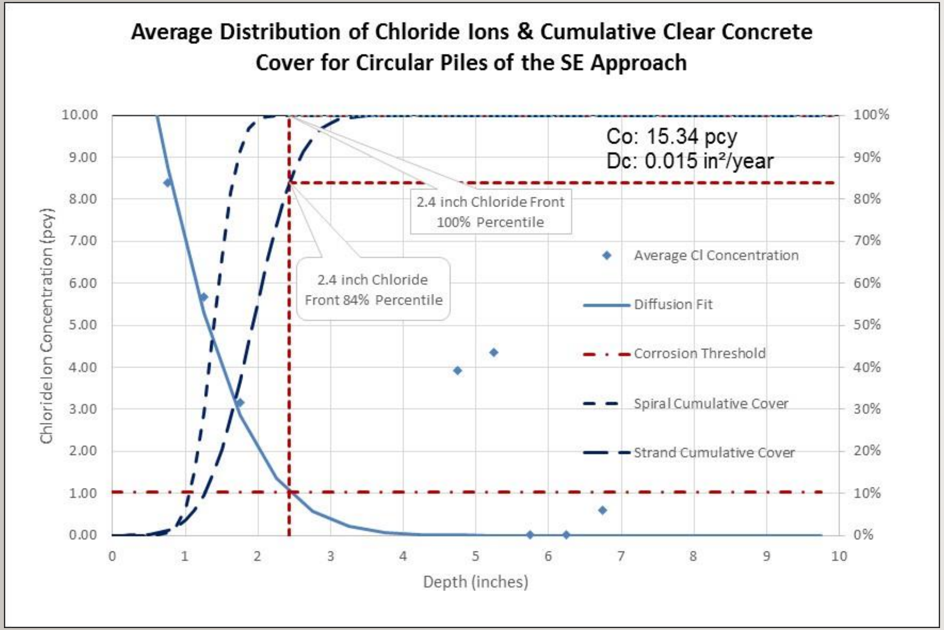


# PILE CONDITION

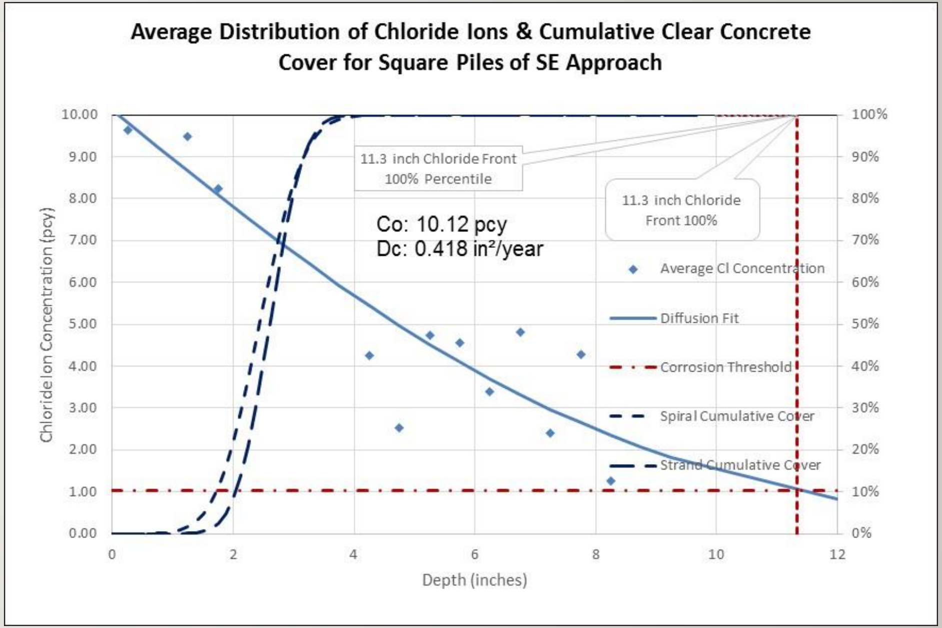
# PILE CONDITION

# PILE CHLORIDE CONTAMINATION

## CIRCULAR PILES SE APPROACH

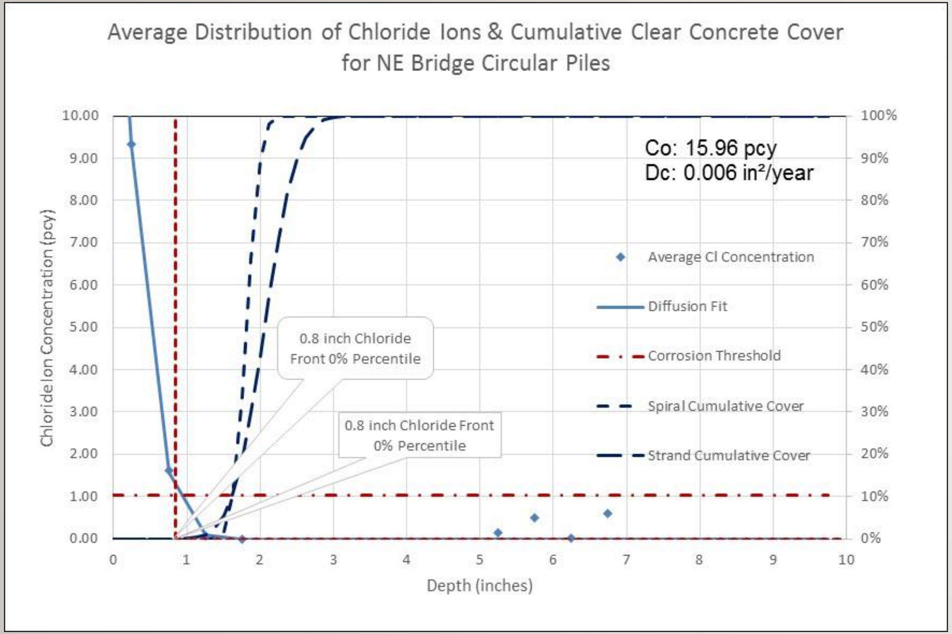



## SQUARE PILES SE APPROACH

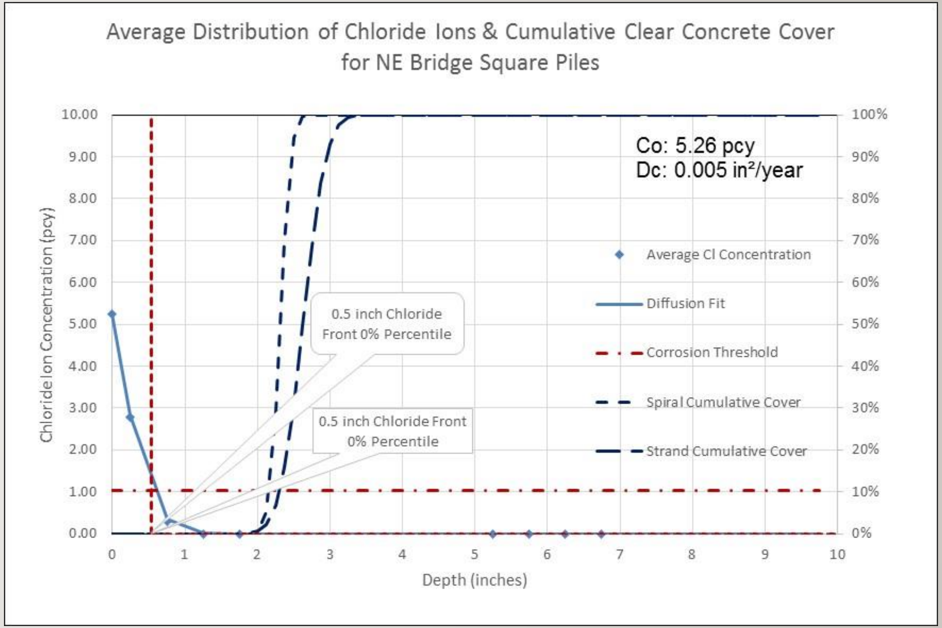


# NEWER PILE CHLORIDE CONTAMINATION

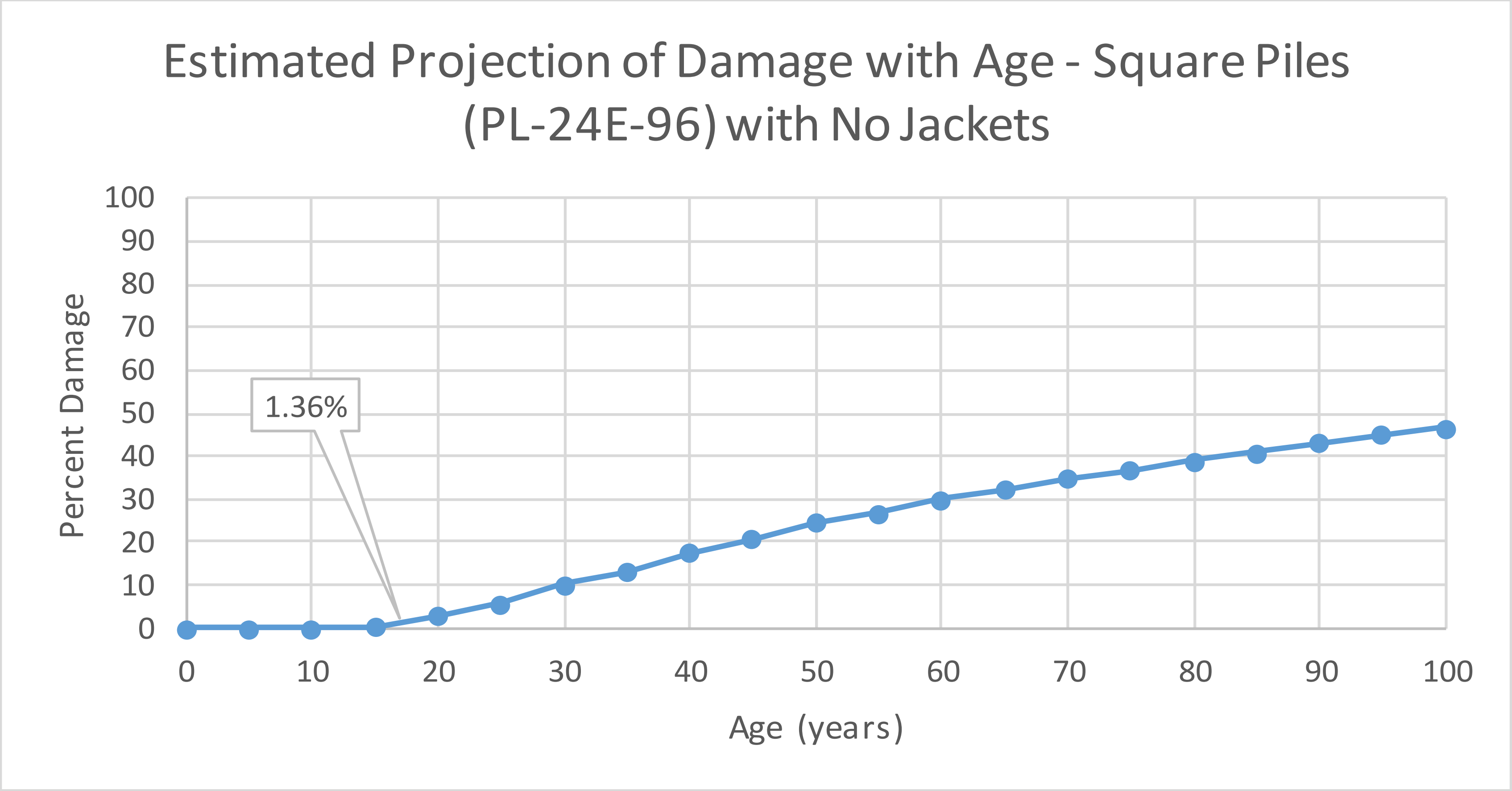
## CIRCULAR PILES NE APPROACH




## SQUARE PILES NE APPROACH



# NEWER PILES – SERVICE LIFE PROJECTION



# RECOMMENDATIONS - DECK

## 30 – 40 YEAR LIFE EXTENSION

1. **Install lightning protection system on all four bridge structures.**
2. **Repair and make operational the existing impressed current cathodic protection systems on the NE and SE approaches.**
3. **Perform Type B Patch repairs, mill off the top 1.25 inches of concrete, and install a rigid concrete (a latex modified concrete) overlay on decks of the NW and SW approaches.**

# RECOMMENDATIONS - BEAMS

## 30 – 40 YEAR EXTENSION

1. **Replace 51 beams which exhibit damage in excess of 15%.**
2. **Patch repair all damage on all beams including those that will not receive a cathodic protection system.**
3. **Install hybrid cathodic protection system on all beams except those replaced during immediate repairs, beams with damage in excess of 15% and beams constructed in 1996.**

# RECOMMENDATIONS – PILE CAPS

## 30 –YEAR EXTENSION

1. Patch repair all damage with discrete anodes on the pile caps of the NW and the SW Approaches.
2. Patch repair all damage and install titanium ribbon anode in slots on the caps of the NE and SE Approaches.

## 50 –YEAR EXTENSION

1. Patch repair all damage.
2. Install titanium Ribbon anode in slots on all pile caps.

# RECOMMENDATIONS - PILES

## 30 – YEAR EXTENSION

1. **Remove all existing jackets.**
2. **Install hybrid jacket system.**

## 50 – YEAR EXTENSION

1. **Remove all existing jackets.**
2. **Install ICCP jacket system.**

# COST OF RECOMMENDED ACTION

## 30 – YEAR EXTENSION

1. Remove all existing jackets.
2. Install hybrid jacket system.

## 50 – YEAR EXTENSION

# COSTS

| Cost Estimate for 40 to 50 Year Life Rehabilitation | | |
|---|---|---|
| **Component or Element** | **Work Item** | **Estimate of Initial Cost*** |
| **Deck** | Rigid Concrete Overlay with Joint Elimination and Repair of Existing Deck CP System | $9M |
| **Beams** | Hybrid Cathodic Protection | $70M |
| **Pile Caps** | Titanium Ribbon in Slots (Patch + Ti Mesh Anode) | $5M |
| **Piles** | Hybrid Cathodic Protection Jacket | $12M |
| | **Total** | **$96M** |

* An estimated $5M will be required for maintenance over the life of this option

# SUMMARY OF OPTIONS

1. Rehabilitation $101M for 40 to 50 Year Service Life
2. Replace: $700M for 100 Year Service Life
   - Carbon fiber strands for piles and caps
   - Stainless bars in deck
   - Stainless strands in girders