VDOT
Virginia Department of Transportation

Deterioration Modeling
Bridge Management System Analysis
2017 Bridge Management User Group Meeting

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Presentation Outline
Deterioration Modeling

- Why do we perform bridge management system analysis?
- Examples of ranges of deterioration / What affects deterioration?
- Why is deterioration modeling so important in BMS analysis?
- How to model deterioration rates for all these effects?
- Protective Elements (Protective Factors / Child Elements)
- Environments (Global/Local, Environmental Factor/ Formula Factor)
- Baseline – necessary for calibration
- VDOT Tools

WHY?

Why do complete bridge management System anaysis?

One Reason

<u>It is required to satisfy federal and state laws</u>

to satisfy

asset management requirements.

23 U.S. Code § 144 National Bridge and Tunnel Inventory and Inspection Standards (1/3/2016)

- **(a)(2)Declarations.—Congress declares that it is in the vital interest of the United States—**
  - (B) to use a data-driven, risk-based approach and cost-effective strategy for systematic preventative maintenance, replacement, and rehabilitation of highway bridges and tunnels to ensure safety and extended service life
  - (C) to use performance-based bridge management systems to assist States in making timely investments;
  - (D) to ensure accountability and link performance outcomes to investment decisions; and

- **(d)(2)Inspection report - Not later than 2 years after the date of enactment of the MAP–21, each State and appropriate Federal agency shall report element level data to the Secretary, as each bridge is inspected pursuant to this section, for all highway bridges on the National Highway System.**

23 U.S. Code § 515
General Authorities and Requirements
4/1/2017

- **515.17 Minimum standards for developing and operating bridge & pavement management systems**
  - **(a) Collecting, processing, storing, and updating inventory and condition data for bridge assets.**
  - **(b) Forecasting deterioration for bridge assets;**
  - **(c) Determining the benefit-cost over the life cycle of assets to evaluate alternative actions (including no action decisions), for managing the condition of bridge assets;**
  - **(d) Identifying short-term and long-term budget needs for managing the condition of bridge assets;**
  - **(e) Determining the strategies for identifying potential bridge projects that maximize overall program benefits within the financial constraints.; and**
  - **(f) Recommending programs and implementation schedules to manage the condition of bridge assets within policy and budget constraints.**

Code of Virginia

- § 33.2-100 Definitions: As used in this title, unless the context requires a different meaning:
  - "Asset management" means a systematic process of operating and maintaining the systems of state highways by combining engineering practices and analysis with sound business practices and economic theory to achieve cost-effective outcomes.

- Code of Virginia - § 33.2-352. - Asset management practices report.
  - A. The Department shall develop asset management practices in the operation and maintenance of the systems of state highways. Such practices shall include a transparent methodology for the allocation of funds from the Highway Maintenance and Operating Fund established pursuant to § 33.2-1530 to highway systems maintenance and operations programs, including the allocations among the highway construction districts and among the Interstate System and primary and secondary state highway systems.

Code of Virginia

- **§ 33.2-352. - Asset management practices report.**
  - **B. The Commissioner of Highways shall advise the Board on or before June 30 of even-numbered years of performance targets and outcomes that are expected to be achieved, based on the funding identified for maintenance, over the biennium beginning July 1 of that year. In addition, not later than September 30 of even-numbered years, the Commissioner of Highways shall advise the Board on the Department's accomplishments relative to the expected outcomes and budget expenditures for the biennium ending June 30 of that year and <u>also advise the Board as to the methodology used to determine maintenance needs and the justification as to the maintenance funding by source.</u>**

RANGE

Range of Deterioration

What Affects Deteriorations Rates Design, Details and Materials & Details Local Environments

- Similar Vintage/Age ~1970’s (~ 47 years old)

- Similar Construction Materials
  - Normal Concrete
  - Black/Uncoated Rebar

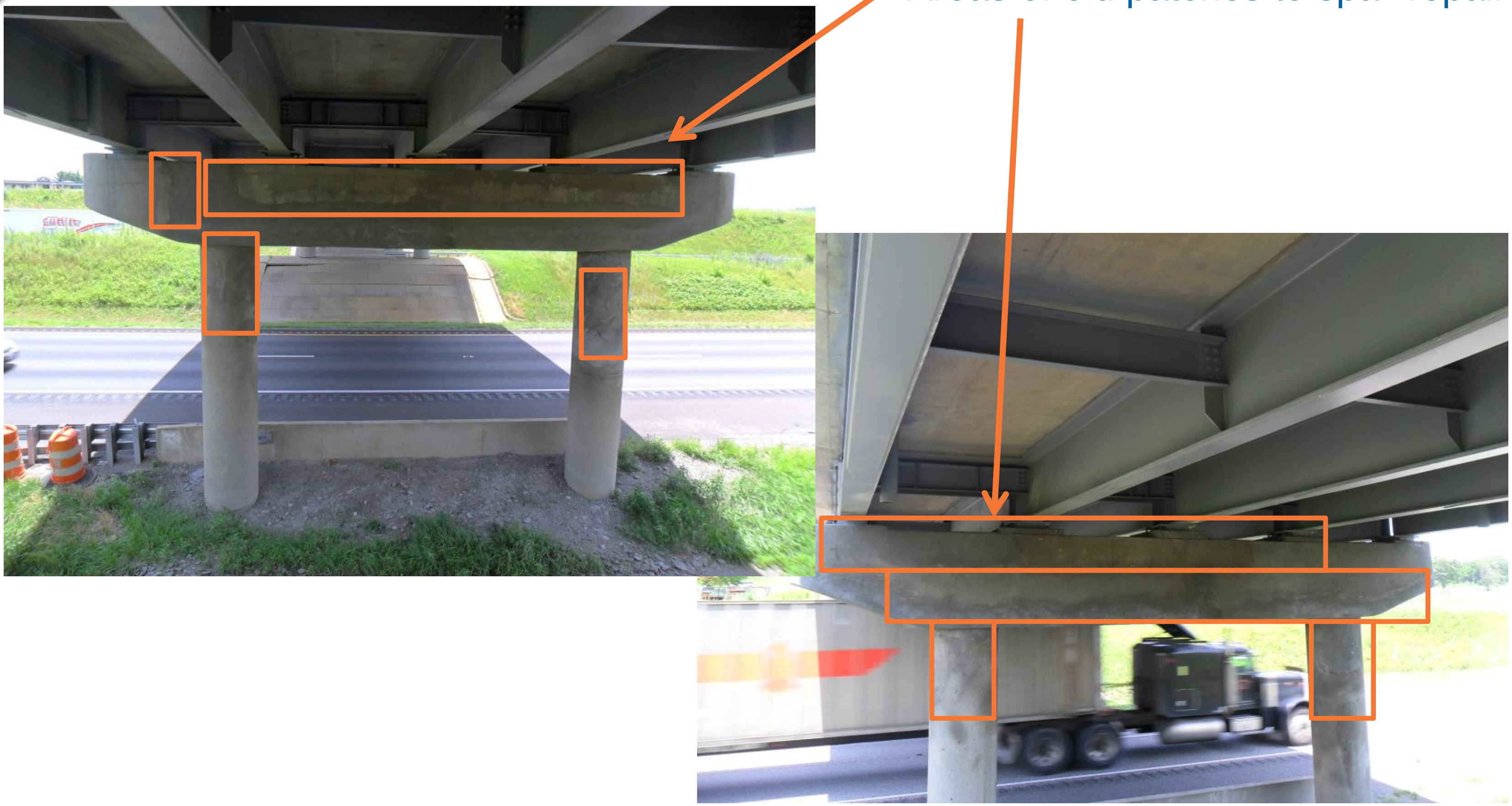
- Similar Details (Except for Presence of Joints)

- Different Local Environments
  - Joints Above
  - Splash Zones
  - Marine Environment

Pier 2 (Central in Distance)
No Joint Above / Away from Intestate

- No indication of leaking or leaching from deck above
- No indication of spalling or previous repairs.

Piers 1 &3
Link Slab Above/Adjacent to Interstate



- Pictures above representative of both piers
- Spalls on columns concentrated on traffic-facing sides indicative of road salt spray

Dual Interstate Bridges (Staunton District) Joints (left) vs Link Slab (right)

Joints Remain

Link Slab

Marine Environment

Photo #40

Looking at Bay 7 side of Beam 8 in Span 31 at Bent 31.

Spall in web, 12" long x 18" high x 4" deep, with 100% loss of section to exposed reinforcing.

Delamination and spalling in bottom flange, 14' long x 14" high x 10" under x 3" deep, with five (5) exposed prestressing strands; 100% loss of section to three (3) exposed prestressing strands (L1); 25% loss of section to two (2) exposed prestressing strands (1-L2, 1-L3); with hairline x up to 60" long longitudinal cracks in bottom of web on both sides of beam.

Photo #51

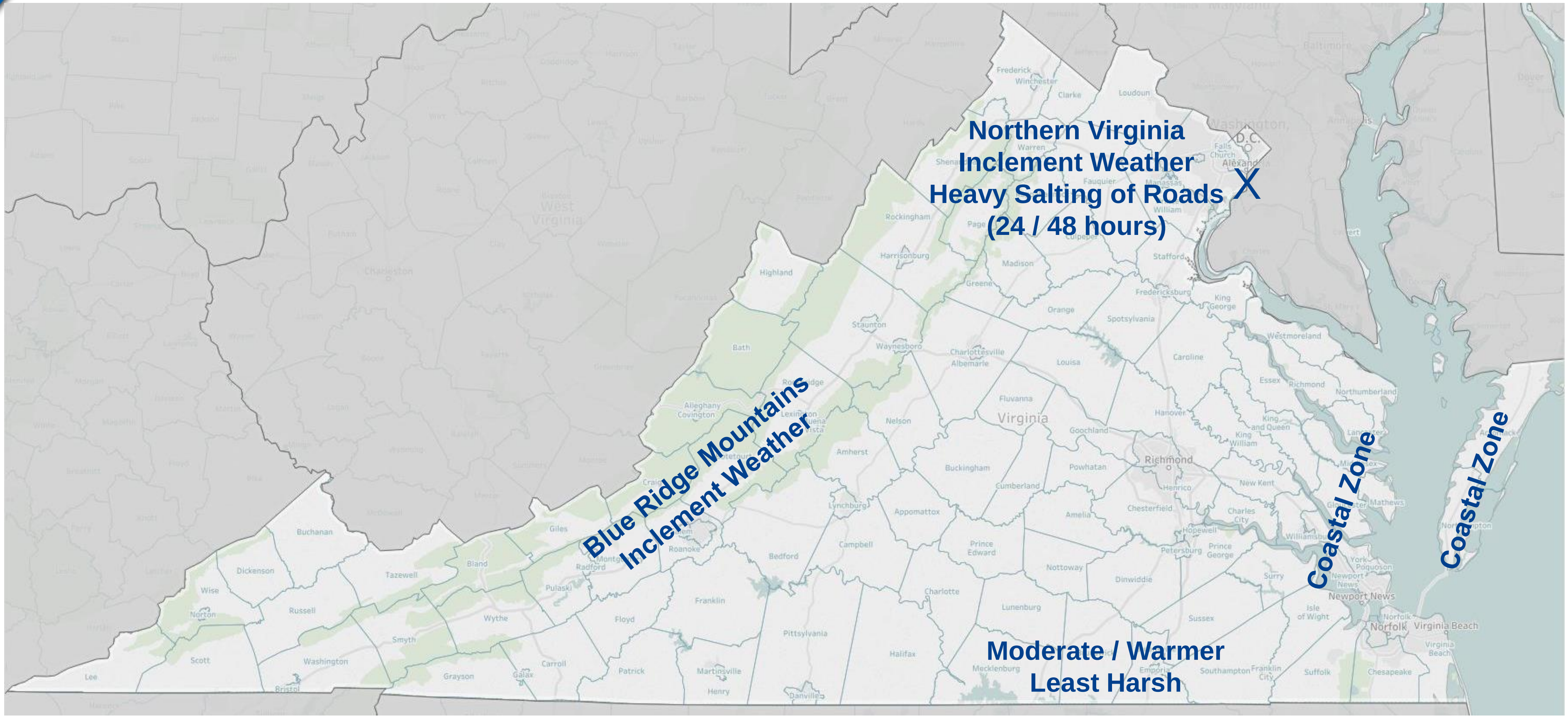
Looking at underside of Beam 9 bottom flange in Span 25 near Bent 26.

Spall on bottom flange, 12' long x 16" high x 7" deep on east face x up to 5" deep x full width under, with 100% loss of section to fifteen (15) exposed prestressing strands (7-L1, 3-L2, 3-L3, 2-L4) and delamination on bottom flange, 8' long x 17" high in front of bearing on west face.

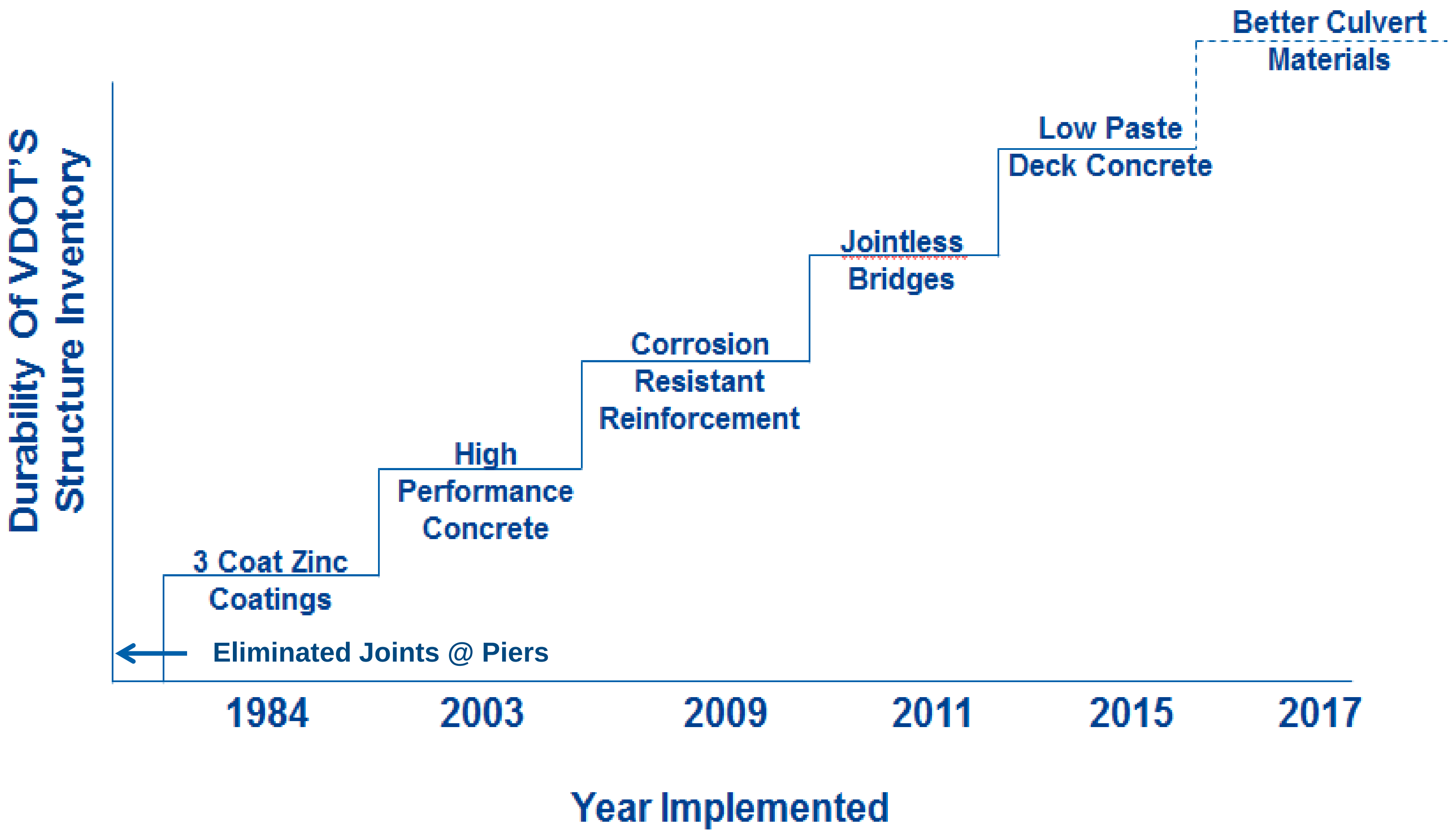
WHAT?

What affects deterioration rates?

What Affects Deteriorations Rates Regional Factors (Marco/Global) Non-Homogenous



VDOT's Bridge Technology Changes Details, Design & Materials



VDOT's Bridge Technology Changes Details (Design) / Materials

List of Changes to Materials and Technology

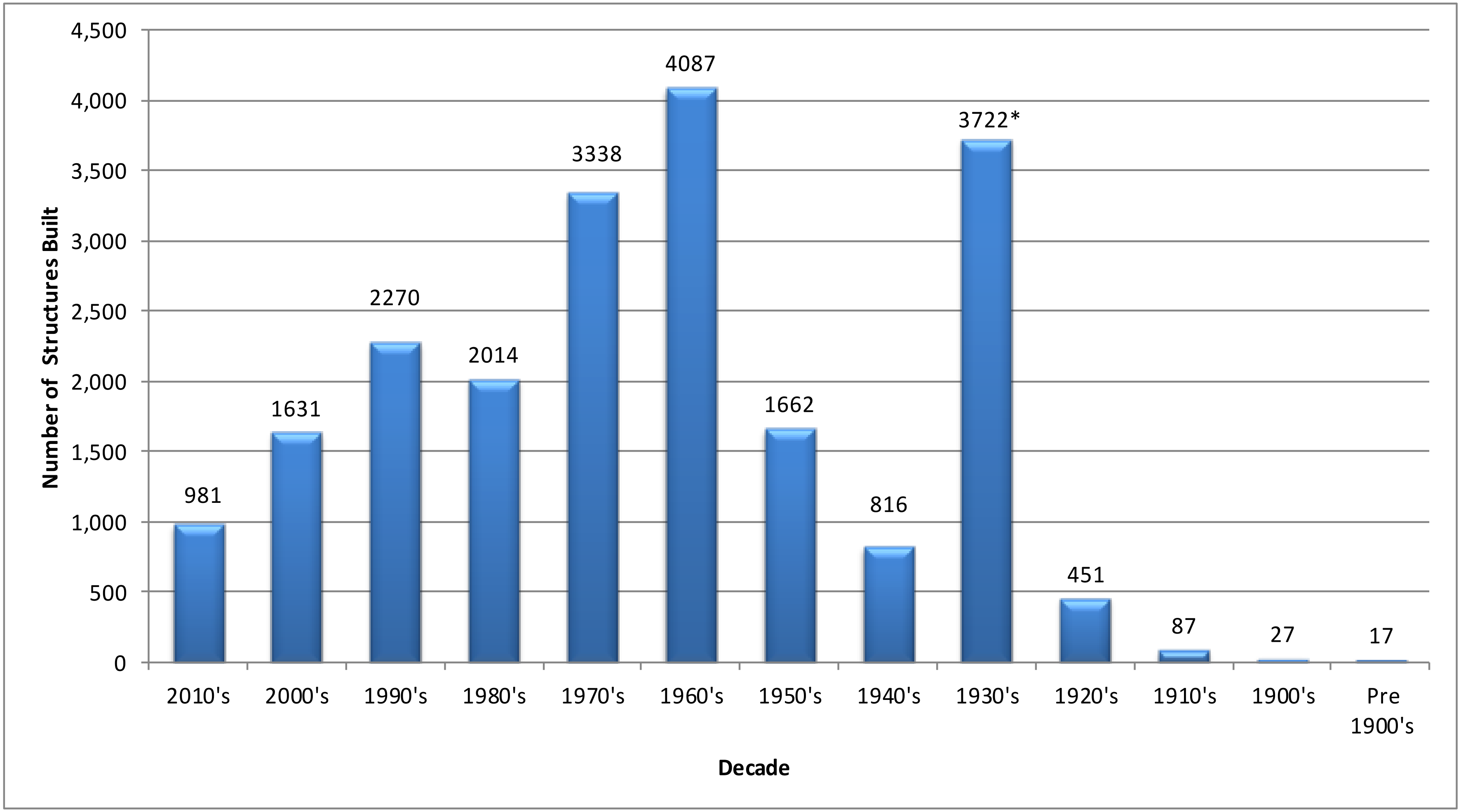
- Low-shrinkage, low-cracking, concrete in decks in 2015
- Latex modified concrete overlays with the addition of hydrodemolition to milling in 2015
- Complete Jointless bridge for new bridges technology in 2011*
- Corrosion resistant reinforcement for new bridges in 2009*
- High Performance Concrete in all bridge deck elements in new bridges in 2003*
- Three coat zinc-based paint in 1982 *
- Continuous spans over piers for new bridges starting in the 1970's
- Self-consolidating concrete for drilled shafts
- Latex modified concrete deck overlays (milling only) starting in the 1970s
- Epoxy deck overlays starting in the 1970s
- * Year of full implementation

VDOT's Bridge Technology Changes
Future Details (Design) / Material

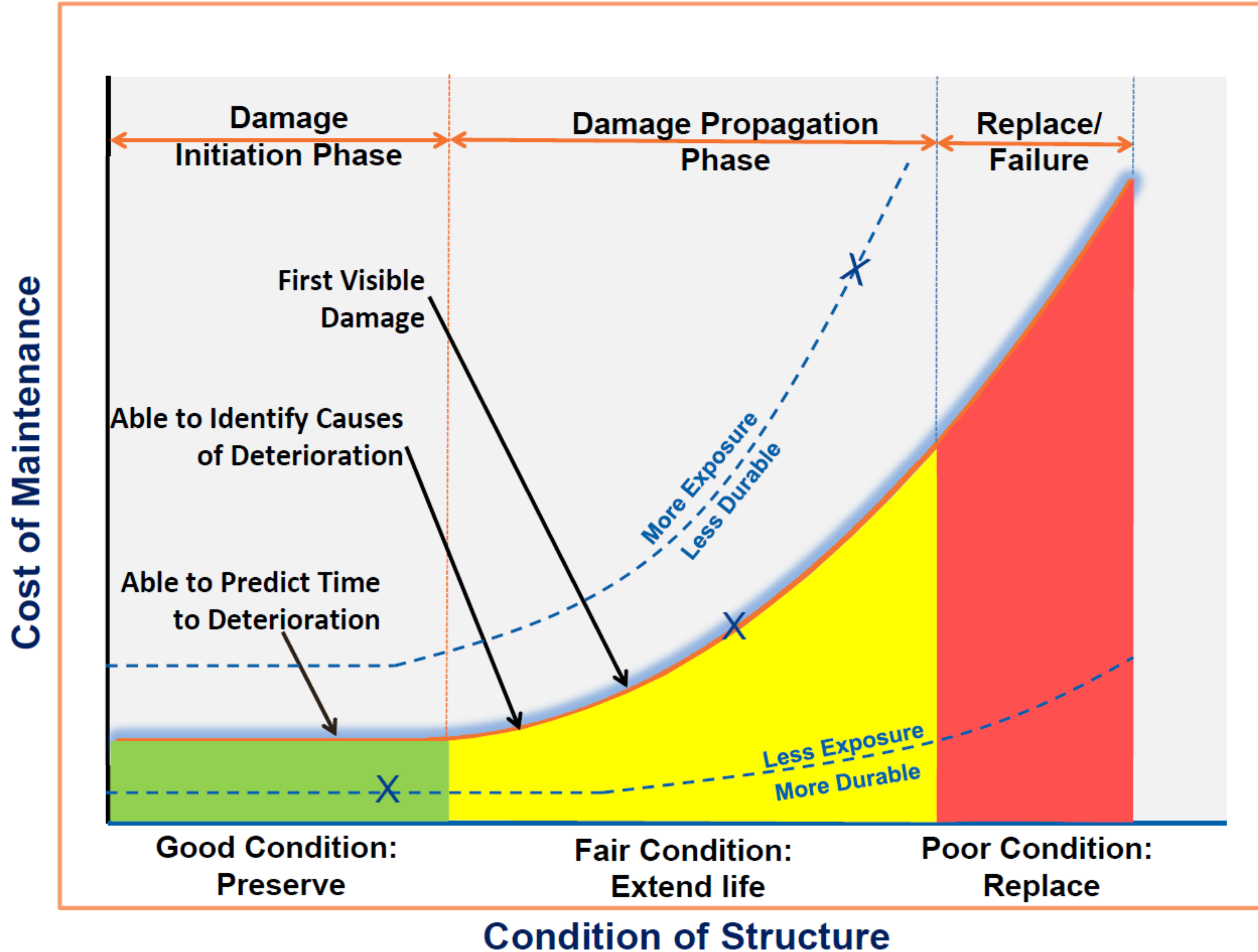
List of Near Term Changes:

- **Hydrodemolition for patches and refacing of substructures**
- **Increased use of joint elimination of existing bridges when repairing and rehabilitating bridges**
- **Implementation of partial depth link slabs for short span bridges**
- **Use of materials for large culverts that have shown good past performance**
- **Carbon fiber prestressing strands in prestressed concrete piles**
- **Lightweight concrete**
- **Elastomeric Concrete Plug Joints (Implementation project under way)**
- **Self-consolidating concrete for substructure surface repairs**

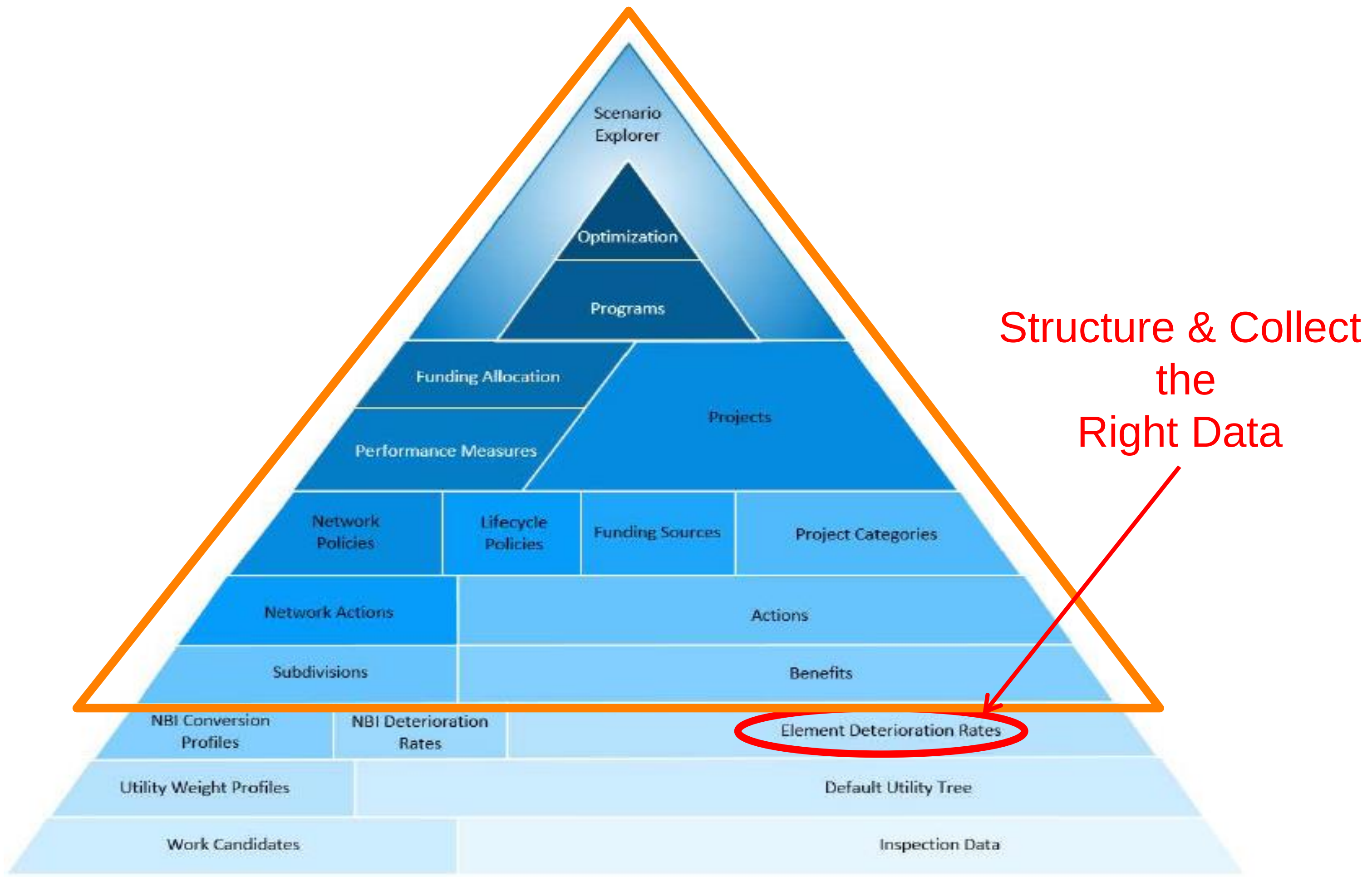
Virginia
No. Bridges Built by Decade
(47.5% are at-least 50-years old)



Deterioration Concept



Why is Deterioration Modeling Important? in Bridge Management System Analysis



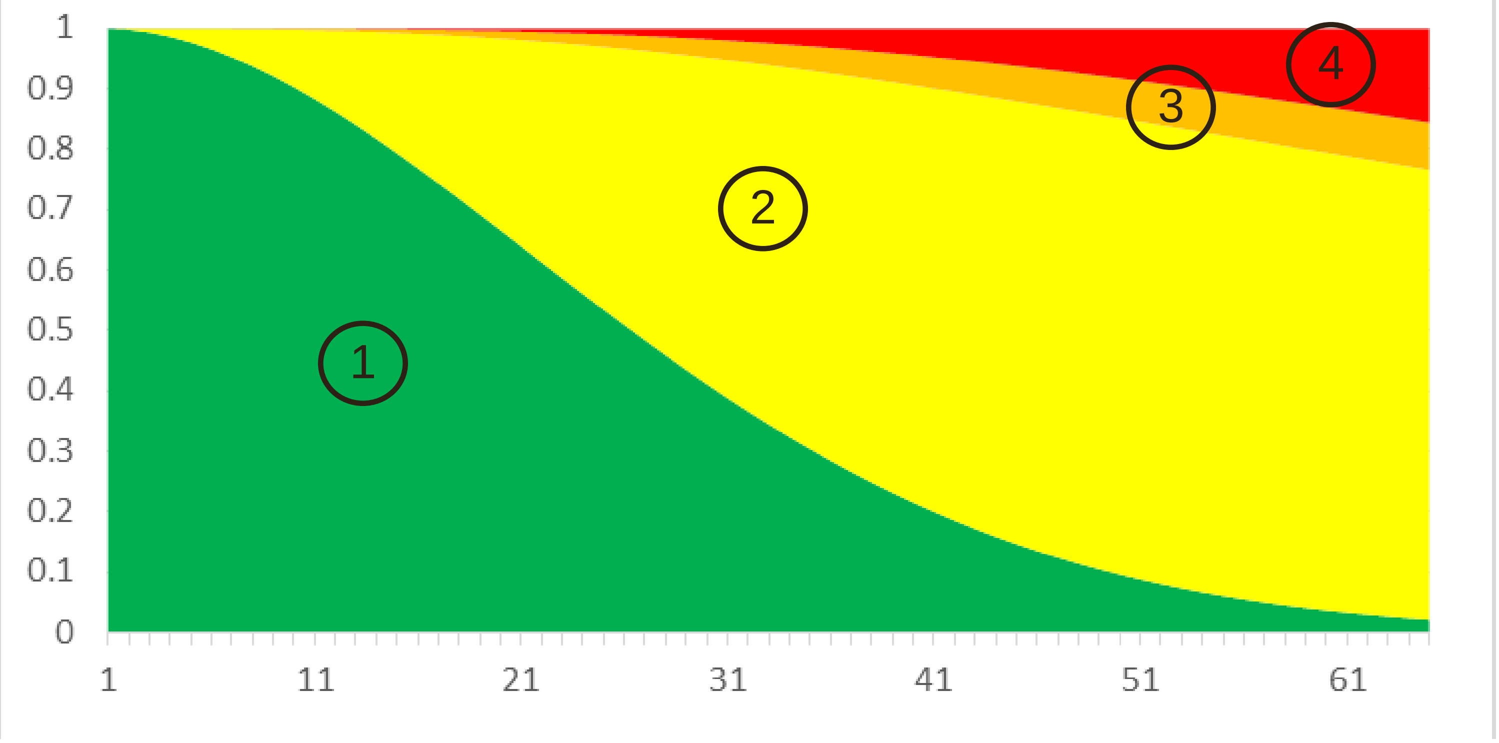
HOW?

How do we collect the right data and structure it

to

model deterioration rates for all these effects?

AASHTOWare BrM 5.2.3
Deterioration Curve
Element 311



AASHTOWare BrM 5.2.3 Deterioration Modeling

- **Element Deterioration Curves**
  - **with adjustments**
    - no longer has individual deterioration curves for environments
    - Promotes use of Protective Elements

- **Adjustments to Element Median Transition Times**

$$f = f^E * f^F * f^M_{combined}$$

  - **f = Adjustment Factor**
  - **f^E = Environmental Factor**
  - **f^F = Formula Factor estimated from a user-customized formula**
  - **$f^M_{combined}$ = combined modifier factor for all Protective Systems**

Protection Elements

- **Adjustments to Element Median Transition Times**

$$f = f^{E} * f^{F} * f^{M}_{combined}$$

- **Protective Elements**
  - 510 Wearing Surface
  - 515 Steel Protective Coatings
  - 520 Concrete Reinforcing Steel Protective Systems
  - 521 Concrete Protective Coating

- **Child Protective Elements**
  - Determined and created by agencies

- **Child Elements for Decks NBE Elements**
  - Low Permeability Concrete
  - Corrosion Resistance Reinforcement

Proposed Child Protective Elements

Proposed List of New Child Elements to the Protection Elements in BrM 5.2.3				Unit of Measure
Protection System		**Protection System Children**		
No.	**Name**	**No.**	**Name**	
510	**Wearing Surface**	510	Wearing Surface	SF
		901	AC W/O Waterproofing	SF
		902	AC W/ Waterproofing	SF
		903	Thin Epoxy Overlay	SF
		904	Rigid Overlay	SF
		919	Other Wearing Surface Coatings	SF
515	**Steel Protective Coating**	515	Steel Protective Coating	SF
		920	Paint (Aluminum, Color & Mastic) over Lead Primer	SF
		923	Paint (Various coatings & uncoated)over Zinc Primer	SF
		925	Galvanized	SF
		926	Metalized	SF
		928	Weathering Steel	SF
		929	Weathering Steel - Partially Painted	SF
		930	Weathering Steel - Totally Painted	SF
		934	A1010 Protection	SF
		936	CRR - Protection	SF
		939	Other Steel Protective Coating	SF
520	**Conc. Reinforcing Steel Protective System**	520	Conc. Reinf. Steel Protective Systems	SF
		940	Deck - Epoxy & Galvanized Coated Reinforcing	SF
		942	Deck - CRR-Class I	SF
		943	Deck - CRR-Class II	SF
		944	Deck - CRR-Class III	SF
		945	Deck - Cathodic Protection	SF
		958	Deck - Other Reinf. Steel Protection	SF
		950	Non-Deck - Epoxy & Galvanized Coated Reinforcing	SF
		951	Non-Deck - CRR-Class I	SF
		952	Non-Deck - CRR-Class II	SF
		953	Non-Deck - CRR-Class III	SF
		954	Non-Deck - Cathodic Protection	SF
		959	Non-Deck - Other Reinf. Steel Protection	SF
521	**Concrete Protective Coating**	521	Concrete Protective Coating	SF
		960	Waterproofing	SF
		961	Crack Sealer	SF
		962	Top Coat	SF
		963	Metalizing	SF
		979	Other Conc. Coating Protection	SF
890	**High Performance Deck Concret** (New VDOT Protection System)	890	High Performance Deck Concrete	SF
		980	Low Permeability Concrete	SF
		982	Low Permeability/Low Shrinkage/Low Cracking	SF

Proposed Child NBE Elements for Deck

Main Example

- **12 Concrete Reinforced Deck**

  Child Elements
  - ### Regular Concrete with Uncoated or Epoxy Coated Reinforcement
  - ### Low Permeability Concrete with Corrosion Resistant Reinforcement I
  - ### Low Permeability Concrete with Corrosion Resistant Reinforcement II
  - ### Low Permeability Concrete with Corrosion Resistant Reinforcement III

  Next – VDOT Starting to use Low Shrinkage-Cracking-Permeability Concrete

Proposed Environments

- **Local Environments (by Inspection Staff)**
  - **Expansion Joints (bearings, beam ends, piers, abutments) ****
    - Joints Present
      - Type of Joint
    - Joint Elimination
    - No Joints
  - **Marine Environment ****
  - **Splash Zones ****
  - **Bridges in Very Humid Environment (ex. FHWA memo for weathering steel)**

- **Global Environments (by CO Staff)**
  - **Climates ****
  - **Coastal Environment (air born chlorides) ***
  - **District Practices (ex. de-icing salts, other) ****
  - **High ADT/ADTT/Posted Speed Limit ***

Proposed Local Environments Environmental Factor (MAINLY SUBSTRUCTURE ELEMENTS)

- **Adjustments to Element Median Transition Times**

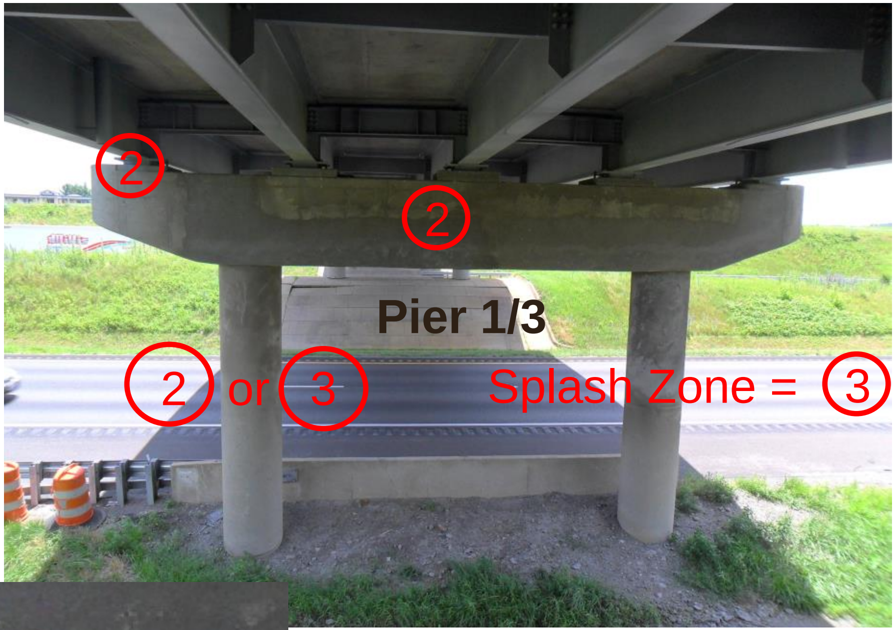
$$f = f^E * f^F * f^M_{combined}$$

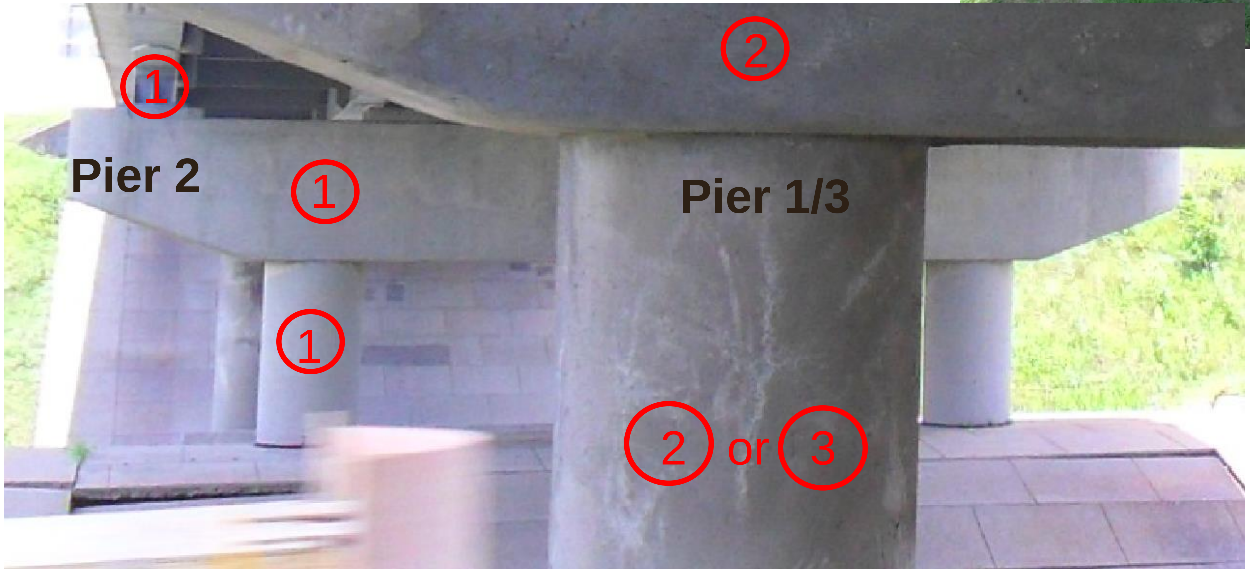
Needs Tweak

- **Environment 1**
  - **Continuous Superstructure Above**
- **Environment 2**
  - **Link Slab Above / Deck Extension Above (midlife)**
- **Environment 3**
  - **Joint Above**
  - **Splash Zone**
  - **Directly Located in Brackish Environment**
- **Environment 4**
  - **Directly Located in Marine Environment**
    - Can be used for superstructure, parapets and deck Elements as well
- **Environment 5 & 6**
  - **Ideally - Add two or three more**

Proposed "Local Environment"
Pier 2 – Continuous / Piers 1 & 3 – Link Slab

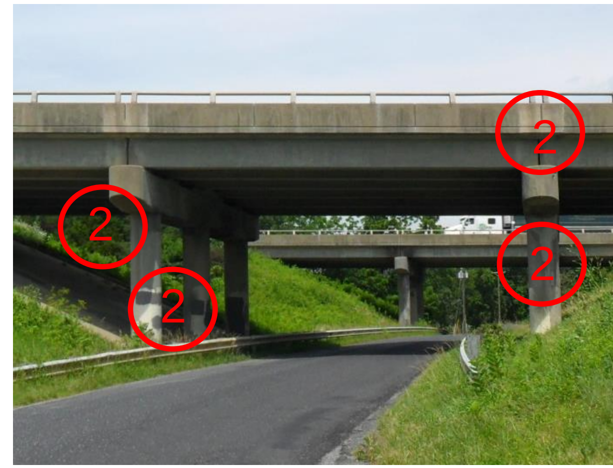
(#) # - Environment Factor





Proposed "Local Environment" Joint (left) vs Link Slab (right)

(#) # - Environment Factor



Joints Remain

Link Slab

Proposed “Local Environment”
VA Marine Environment
(Separate from Global Coastal Zone)

Photo #40

Looking at Bay 7 side of Beam 8 in Span 31 at Bent 31.

Spall in web, 12" long x 18" high x 4" deep, with 100% loss of section to exposed reinforcing.

Delamination and spalling in bottom flange, 14' long x 14" high x 10" under x 3" deep, with five (5) exposed prestressing strands; 100% loss of section to three (3) exposed prestressing strands (L1); 25% loss of section to two (2) exposed prestressing strands (1-L2, 1-L3); with hairline x up to 60" long longitudinal cracks in bottom of web on both sides of beam.

Photo #51

Looking at underside of Beam 9 bottom flange in Span 25 near Bent 26.

Spall on bottom flange, 12' long x 16" high x 7" deep on east face x up to 5" deep x full width under, with 100% loss of section to fifteen (15) exposed prestressing strands (7-L1, 3-L2, 3-L3, 2-L4) and delamination on bottom flange, 8' long x 17" high in front of bearing on west face.

BrM 5.2.3 Environmental Factor Tweak

- **Environments - PONTIS**
  - **Four Environments / A Different Deterioration Curve per Environment**
  - **Too complicated**

- **Environmental Factor - BrM 5.2.3**
  - **Tried to Simplify (??too far??)**

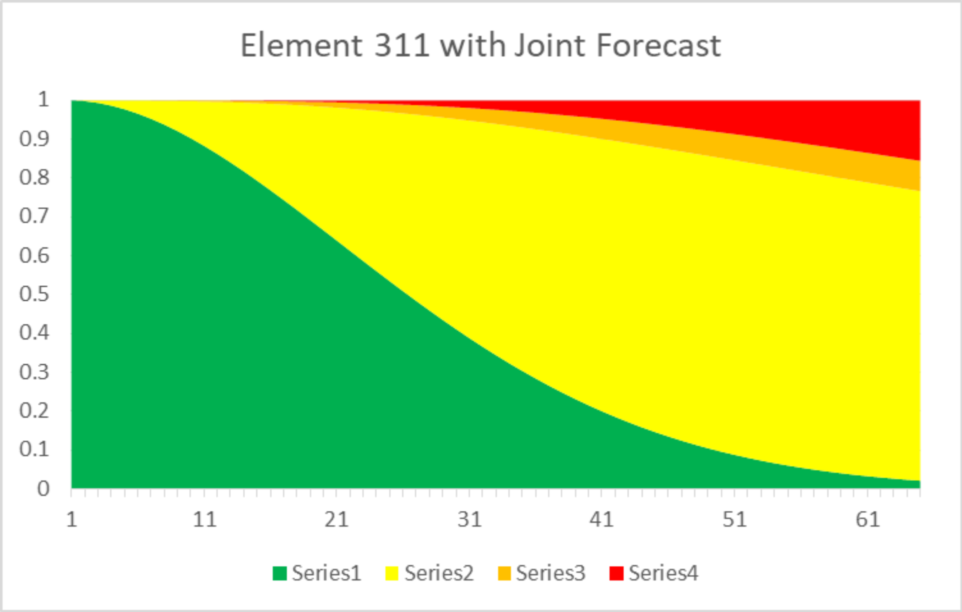
CURRENT

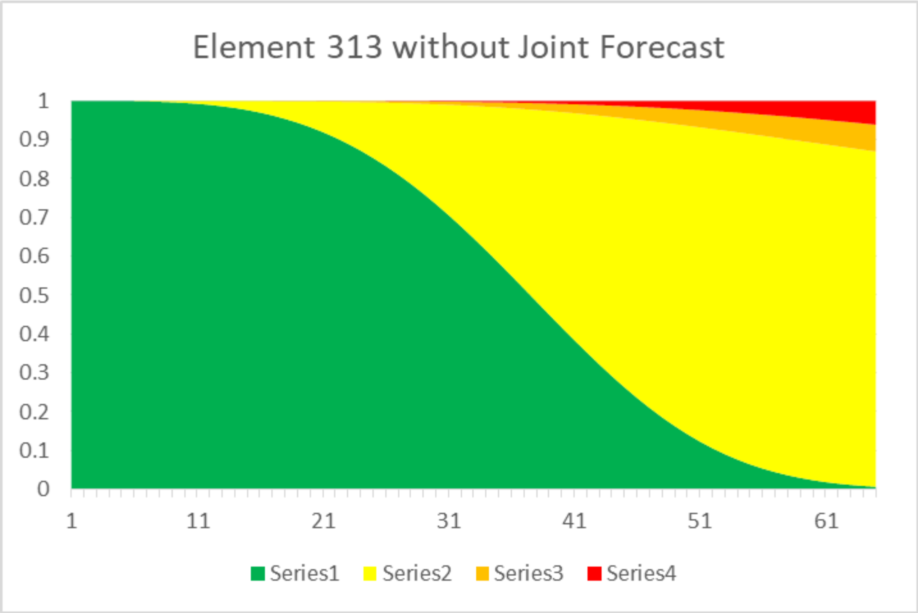
Element		Environmental Factor			
No.	Decription	1	2	3	4
801	Sidewalk	1.20	1.00	0.85	0.65
802	Deck Drains	1.20	1.00	0.85	0.65
310	Concrete Bridge Railing	1.20	1.00	0.85	0.65
12	Concrete Reinforced Deck	1.20	1.00	0.85	0.65
###	Rigid Overlay	1.20	1.00	0.85	0.65
300	Strip Seal Expansion Joints	1.20	1.00	0.85	0.65
107	Steel Open Girder	1.20	1.00	0.85	0.65
811	Beam/Girder Ends	1.20	1.00	0.85	0.65
###	Three Coat Painting System	1.20	1.00	0.85	0.65
310	Elastomeric Bearing	1.20	1.00	0.85	0.65
234	Reinforced Concrete Pier Cap	1.20	1.00	0.85	0.65
215	Reinforced Concrete Abutment	1.20	1.00	0.85	0.65
205	Reinforced Concrete Column	1.20	1.00	0.85	0.65

PROPOSED

Element		Environmental Factor			
No.	Decription	1	2	3	4
801	Sidewalk	1.00	1.00	1.00	0.85
802	Deck Drains	1.00	1.00	1.00	0.85
310	Concrete Bridge Railing	1.00	1.00	1.00	0.85
12	Concrete Reinforced Deck	1.00	1.00	1.00	0.85
###	Rigid Overlay	1.00	1.00	1.00	0.85
300	Strip Seal Expansion Joints	1.00	1.00	1.00	0.85
107	Steel Open Girder	1.00	1.00	1.00	0.85
811	Beam/Girder Ends	1.20	1.10	**1.00**	0.80
###	Three Coat Painting System	1.05	1.03	**1.00**	0.90
310	Elastomeric Bearing	1.05	1.03	**1.00**	0.95
234	Reinforced Concrete Pier Cap	1.30	1.15	**1.00**	0.65
215	Reinforced Concrete Abutment	1.25	1.13	**1.00**	0.75
205	Reinforced Concrete Column	1.35	1.18	**1.00**	0.65

“Local Environment” Bearing Deterioration as a Function of Joint





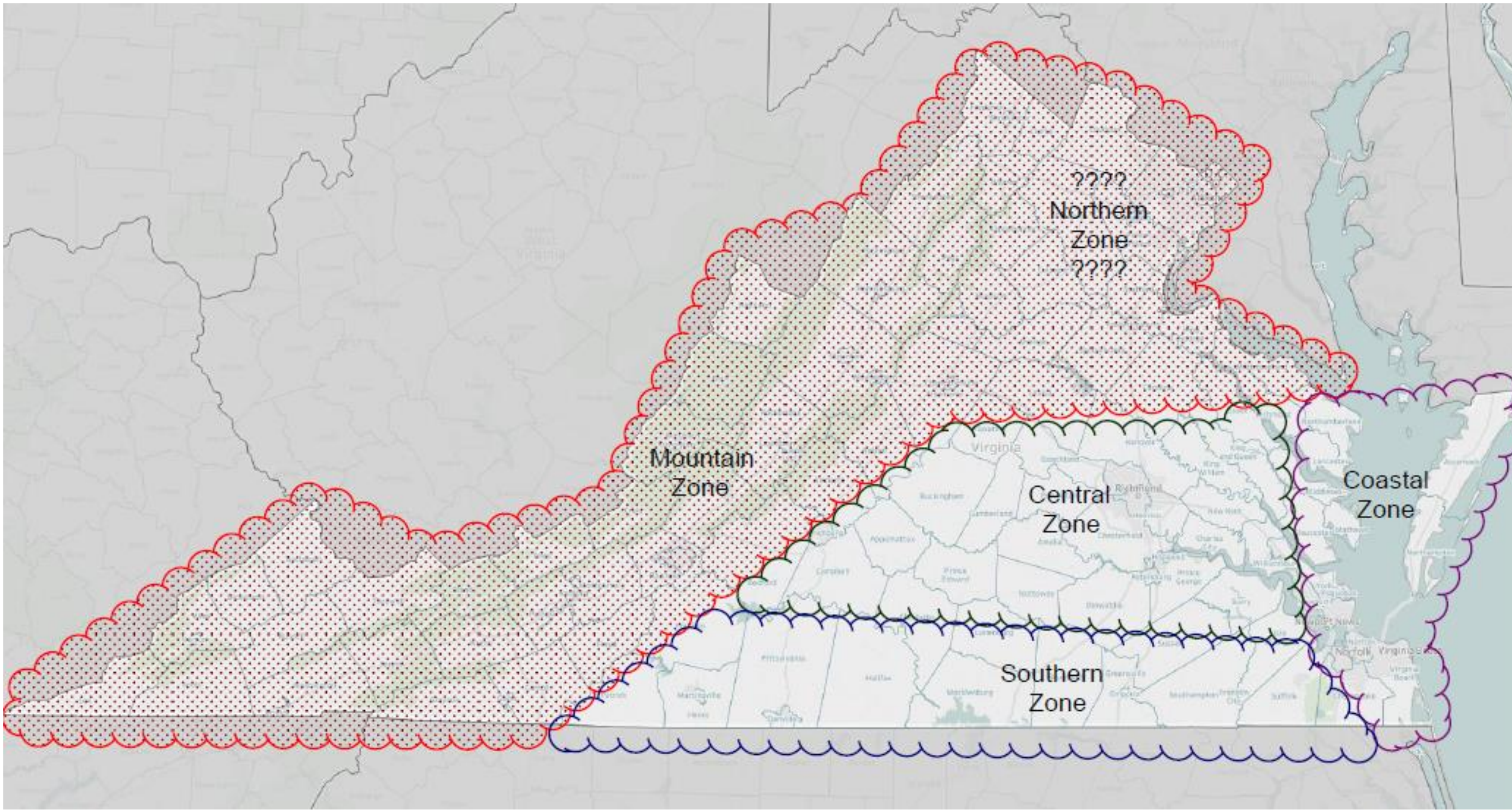
Global Environments Formula Factor

- **Adjustments to Element Median Transition Times**

$$f = f^E * f^F * f^M_{combined}$$

- **Factors**
  - **Zones (GIS)**
    - Climates
    - Coastal Environment (air born chlorides)
    - District Practices (ex. de-icing salts, other)
  - **Data Fields**
    - High ADT/ADTT/Posted Speed Limit
    - Functional Class
- **Currently looking at indicator elements**
- **Formula Factor**
  - **General form**
  - **New tables**

Proposed "Global Environment" "Weather &/or Deicing Chemical" Zones & Coastal Zone



Establish a Baseline Deterioration Curve Early in Calibration

- Protective Elements
  - not present
- Local Environments
  - Expansion Joints above (substructure elements)
  - Not in a splash zone
  - Not in a marine environment
- Global Environments
  - Statewide average

VDOT's
Sample Model Validation

BASE ELEMENT — With Protective Elements

Transition Times (Half Life Period)

	TT Used	TT bserved	TT BrM	TT Expt	TP* Used
S1 to CS2	40	14.42	14.42	14.42	0.9828
S2 to CS3	20	42.00	42.00	42.00	0.9659
S3 to CS4	10	14.86	14.86	14.86	0.9330

TP* - updated for Environmental factor

Damage Index

	Weights
CS1-	0.00
CS2-	0.00
CS3-	0.65
CS4-	1.00
DI Threshold-	1.00
Service Life-	>400 years
BrM HI (@SL)-	
MHI (@SL)-	

BrM BE

Transition Probability Matrix

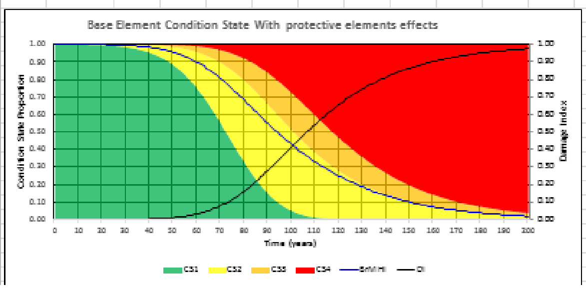
	CS1	CS2	CS3	CS4
CS1	0.9828	0.0172	0	0
CS2	0	0.9659	0.0341	0
CS3	0	0	0.9330	0.0670
CS4	0	0	0	1.0000

BrM Health Index Weights

	Used	bserve	BrM	Expt
y1-	1	1	1	1
y2-	2/3	2/3	2/3	2/3
y3-	1/3	1/3	1/3	1/3
y4-	0	0	0	0

Environmental Factor, fE_BE- 1.00

		Used	bserve	BrM	Expt
Weibull Shape Parameter	β-	2.50	1.30	1.30	1.30
Weibull Scale Parameter	α-	46.3159			



PROTECTIVE ELEMENT — Wearing+Surfaces

Transition Times (Half Life Period)

	TT Used	TT bserved	TT BrM	TT Expt	TP* Used
CS1 to CS2	20	8.00	8.00	8.00	0.9659
CS2 to CS3	10	6.00	6.00	6.00	0.9330
CS3 to CS4	5	4.00	4.00	4.00	0.8706

BrM Health Index Weights

	Used	bserve	BrM	Expt
y1-	1	1	1	1
y2-	2/3	2/3	2/3	2/3
y3-	1/3	1/3	1/3	1/3
y4-	0	0	0	0

Damage Index

	Weights
CS1-	0.00
CS2-	0.00
CS3-	0.65
CS4-	1.00
DI Threshold-	1.00
Service Life-	118 years
BrM HI (@SL)-	0.0077
MHI (@SL)-	0.0101

BrM PE1

Transition Probability Matrix

	CS1	CS2	CS3	CS4
CS1	0.9659	0.0341	0	0
CS2	0	0.9330	0.0670	0
CS3	0	0	0.8706	0.1294
CS4	0	0	0	1.0000

tive Element Efficiency Coeff

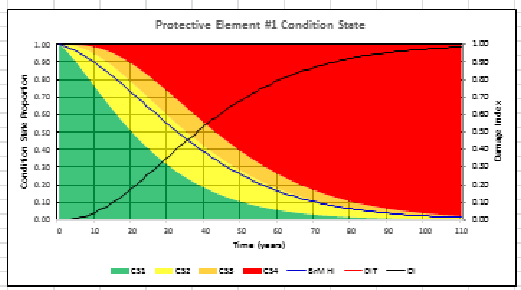
	Used	bserve	BrM	Expt
c1-	1	1	1	1
c2-	2/3	2/3	2/3	2/3
c3-	1/3	1/3	1/3	1/3
c4-	0	0	0	0

Environmental Factor, fE_PE1- 1.00

	Used	bserve	BrM	Expt
β-	1.30	1.00	1.00	1.00
α-	26.5138			

Protective Elements protection parameters

	Used	bserve	BrM	Expt	
ppe+-	3.00	1.41	1.41	1.41	Full Protection
ppe--	1.00	1.00	1.00	1.00	No Protection



PROTECTIVE ELEMENT — Concrete+Reinforcing+Steel+Protective+System

Transition Times (Half Life Period)

	TT Used	TT bserved	TT BrM	TT Expt	TP* Used
CS1 to CS2	40	8.00	8.00	8.00	0.9828
CS2 to CS3	20	6.00	6.00	6.00	0.9659
CS3 to CS4	10	4.00	4.00	4.00	0.9330

BrM Health Index Weights

	Used	bserve	BrM	Expt
y1-	1	1	1	1
y2-	2/3	2/3	2/3	2/3
y3-	1/3	1/3	1/3	1/3
y4-	0	0	0	0

Damage Index

	Weights
CS1-	0.00
CS2-	0.00
CS3-	0.65
CS4-	1.00
DI Threshold-	1.00
Service Life-	195 years
BrM HI (@SL)-	0.0076
MHI (@SL)-	0.0103

BrM PE2

HI T

Transition Probability Matrix

	CS1	CS2	CS3	CS4
CS1	0.9828	0.0172	0	0
CS2	0	0.9659	0.0341	0
CS3	0	0	0.9330	0.0670
CS4	0	0	0	1.0000

tive Element Efficiency Coeff

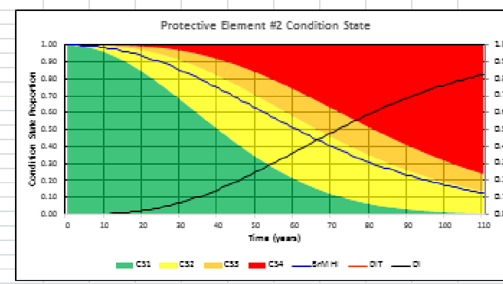
	Used	bserve	BrM	Expt
c1-	1	1	1	1
c2-	2/3	2/3	2/3	2/3
c3-	1/3	1/3	1/3	1/3
c4-	0	0	0	0

Environmental Factor, fE_PE2- 1.00

	Used	bserve	BrM	Expt
β-	2.00	1.00	1.00	1.00
α-	48.0449			

Protective Elements protection parameters

	Used	bserve	BrM	Expt	
ppe+-	1.50	1.39	1.39	1.39	Full Protection
ppe--	1.00	1.00	1.00	1.00	No Protection



VDOT's
Sample Model Validation

BASE ELEMENT — With Protective Elements

Transition Times (Half Life Period)

	TT Used	TT Observed	TT BrM	TT Expt	TP* Used
CS1 to CS2	40	14.42	14.42	14.42	0.9828
CS2 to CS3	20	42.00	42.00	42.00	0.9659
CS3 to CS4	10	14.86	14.86	14.86	0.9330

TP* - updated for Environmental factor

Damage Index

	Weights
CS1-	0.00
CS2-	0.00
CS3-	0.65
CS4-	1.00
DI Threshold-	1.00
Service Life-	>400 years
BrM HI (@SL)-	
MHI (@SL)-	

BrM BE

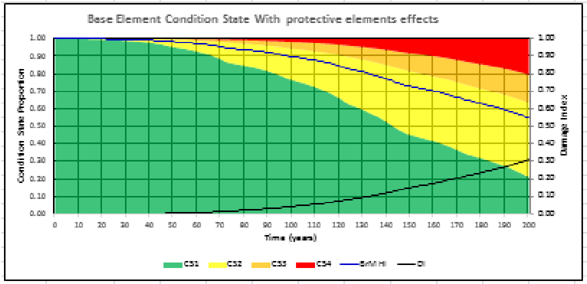
Transition Probability Matrix

	CS1	CS2	CS3	CS4
CS1	0.9828	0.0172	0	0
CS2	0	0.9659	0.0341	0
CS3	0	0	0.9330	0.0670
CS4	0	0	0	1.0000

BrM Health Index Weights

	Used	Observed	BrM	Expt
y1-	1	1	1	1
y2-	2/3	2/3	2/3	2/3
y3-	1/3	1/3	1/3	1/3
y4-	0	0	0	0

			Used	Observed	BrM	Expt
Environmental Factor, fE_BE-	1.00	Weibull Shape Parameter	β- 2.50	1.30	1.30	1.30
		Weibull Scale Parameter	α- 46.3159			



PROTECTIVE ELEMENT — Wearing+Surfaces

Transition Times (Half Life Period)

	TT Used	TT Observed	TT BrM	TT Expt	TP* Used
CS1 to CS2	20	8.00	8.00	8.00	0.9659
CS2 to CS3	10	6.00	6.00	6.00	0.9330
CS3 to CS4	5	4.00	4.00	4.00	0.8706

BrM Health Index Weights

	Used	Observed	BrM	Expt
y1-	1	1	1	1
y2-	2/3	2/3	2/3	2/3
y3-	1/3	1/3	1/3	1/3
y4-	0	0	0	0

Damage Index

	Weights
CS1-	0.00
CS2-	0.00
CS3-	0.65
CS4-	1.00
DI Threshold-	0.25
Service Life-	24 years
BrM HI (@SL)-	0.6693
MHI (@SL)-	0.0689

BrM PE1

Transition Probability Matrix

	CS1	CS2	CS3	CS4
CS1	0.9659	0.0341	0	0
CS2	0	0.9330	0.0670	0
CS3	0	0	0.8706	0.1294
CS4	0	0	0	1.0000

Protective Element Efficiency Coeff

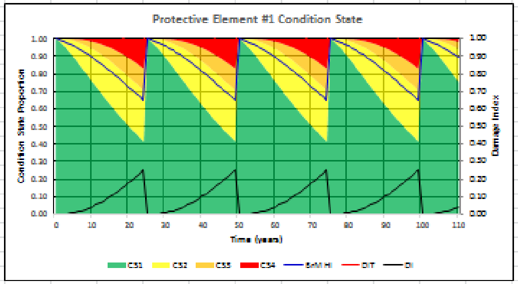
	Used	Observed	BrM	Expt
c1-	1	1	1	1
c2-	2/3	2/3	2/3	2/3
c3-	1/3	1/3	1/3	1/3
c4-	0	0	0	0

Environmental Factor, fE_PE1- 1.00

	Used	Observed	BrM	Expt
β-	1.30	1.00	1.00	1.00
α-	26.5138			

Protective Elements protection parameters

	Used	Observed	BrM	Expt	
ppe+-	3.00	1.41	1.41	1.41	Full Protection
ppe--	1.00	1.00	1.00	1.00	No Protection



PROTECTIVE ELEMENT — Concrete+Reinforcing+Steel+Protective+System

Transition Times (Half Life Period)

	TT Used	TT Observed	TT BrM	TT Expt	TP* Used
CS1 to CS2	40	8.00	8.00	8.00	0.9828
CS2 to CS3	20	6.00	6.00	6.00	0.9659
CS3 to CS4	10	4.00	4.00	4.00	0.9330

BrM Health Index Weights

	Used	Observed	BrM	Expt
y1-	1	1	1	1
y2-	2/3	2/3	2/3	2/3
y3-	1/3	1/3	1/3	1/3
y4-	0	0	0	0

Damage Index

	Weights
CS1-	0.00
CS2-	0.00
CS3-	0.65
CS4-	1.00
DI Threshold-	0.50
Service Life-	72 years
BrM HI (@SL)-	0.3907
MHI (@SL)-	0.0068

BrM PE2

HI TI

Transition Probability Matrix

	CS1	CS2	CS3	CS4
CS1	0.9828	0.0172	0	0
CS2	0	0.9659	0.0341	0
CS3	0	0	0.9330	0.0670
CS4	0	0	0	1.0000

Protective Element Efficiency Coeff

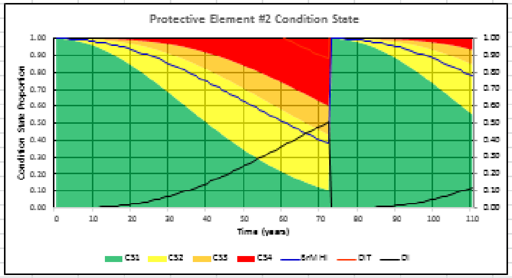
	Used	Observed	BrM	Expt
c1-	1	1	1	1
c2-	2/3	2/3	2/3	2/3
c3-	1/3	1/3	1/3	1/3
c4-	0	0	0	0

Environmental Factor, fE_PE2- 1.00

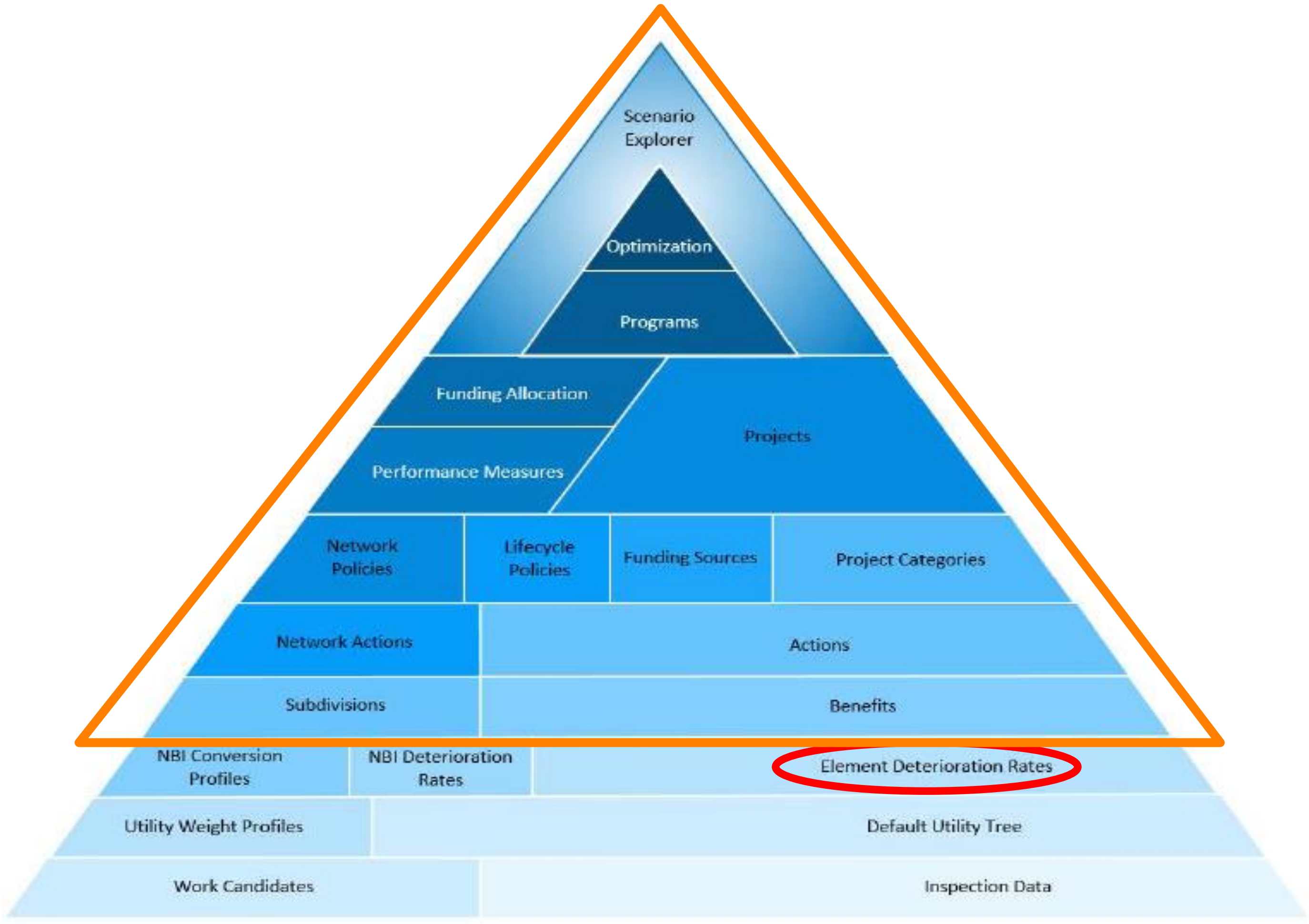
	Used	Observed	BrM	Expt
β-	2.00	1.00	1.00	1.00
α-	48.0449			

Protective Elements protection parameters

	Used	Observed	BrM	Expt	
ppe+-	1.50	1.39	1.39	1.39	Full Protection
ppe--	1.00	1.00	1.00	1.00	No Protection

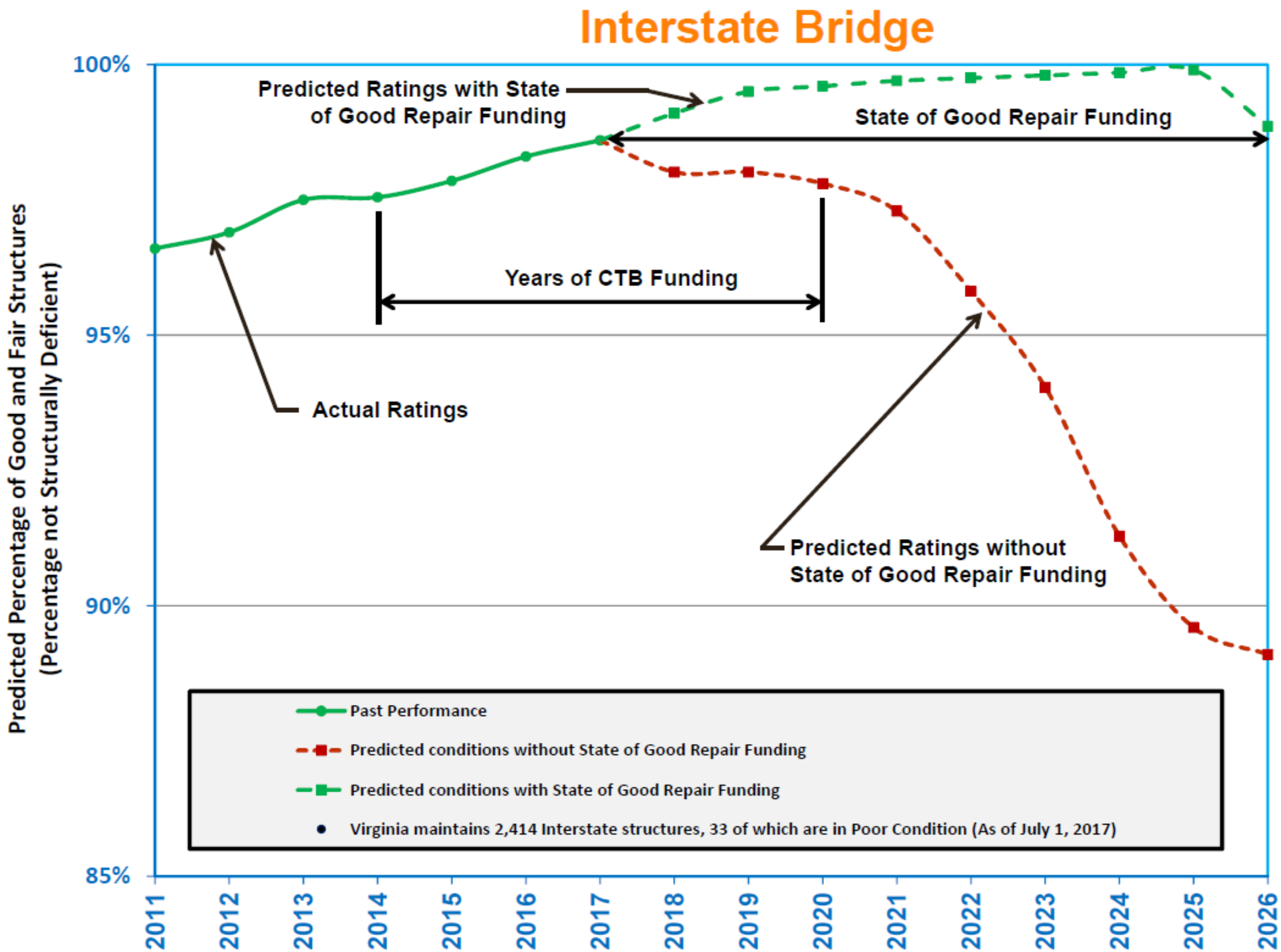


CONCLUSION
Effective Deterioration Modeling
Structure and Collect the Right Data
For Effective Bridge Management Analysis



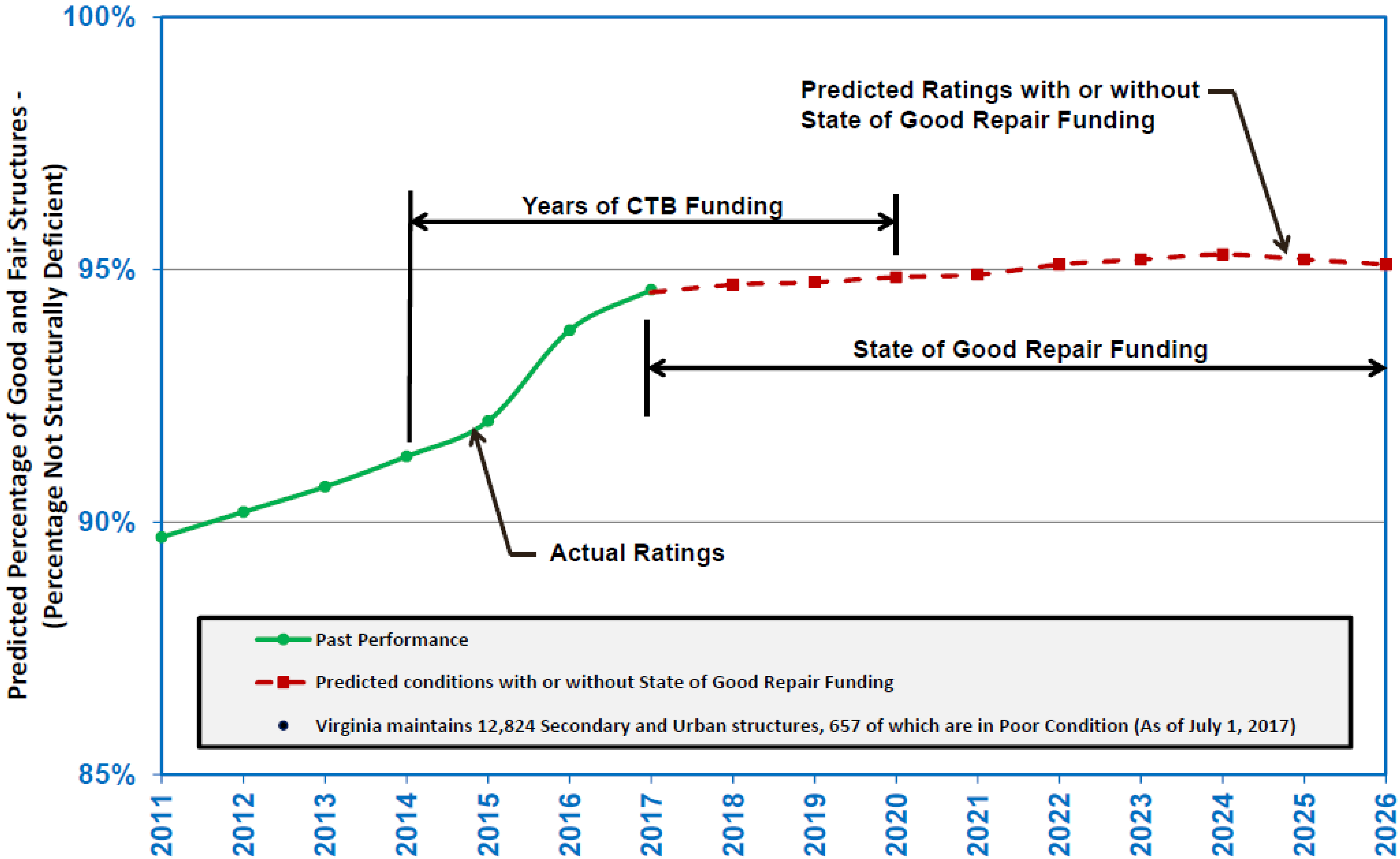
Questions

Bridge Charts
FY2017 Annual Report

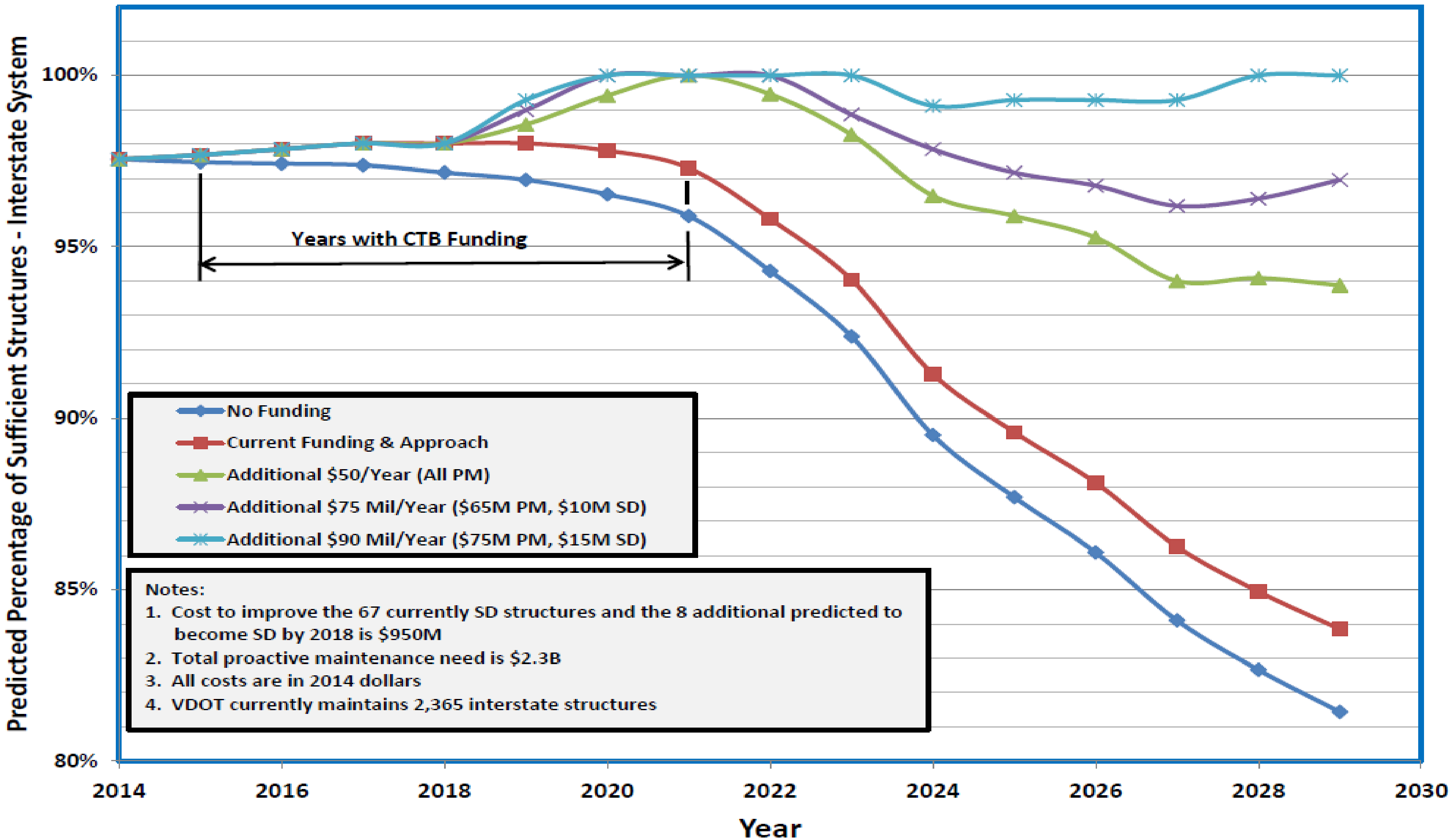


Bridge Charts
FY2017 Annual Report

Secondary and Urban Bridge



VDOT
Non-SD vs Time
(Funding Options)



VDOT's Proposed Modification to BrM "Global Environments"

- From:
  - Nil
- To:
  - "Weather &/or Deicing Chemical" Zones & Coastal Zone
  - System Factor
  - District Factor
  - Other Factor
- How
  - Table of Local Adjustment Factors for the "Global Environment" Adjustment Factor
  - New Tables
  - Use Formula Factor

VDOT "Local Environment" Splash Zones / Overspray

1. Bridges Subjected to Overspray of contaminated water
   1. contaminated with de-icing chemicals

2. NCHRP Report 782 defines overspray "the de-icing chemicals on a roadway that are being picked up and dispersed by traveling vehicles onto adjacent highway structures, including bridges."

3. VDOT enacted IIM S&B 81.7 to use corrosion resistant reinforcement in substructure elements that are subject to overspray water based on horizontal clearance of a bridge.

4. VTRC will study further: Speed, ADT, AADT, Functional Class, Horizontal Clearance, Vertical Clearance

Environmental Factor
“Local Environments”

- **From:**
  - **Four Environments**
  - **For a given environment, there is only one adjustment value for median transition time for all elements.**

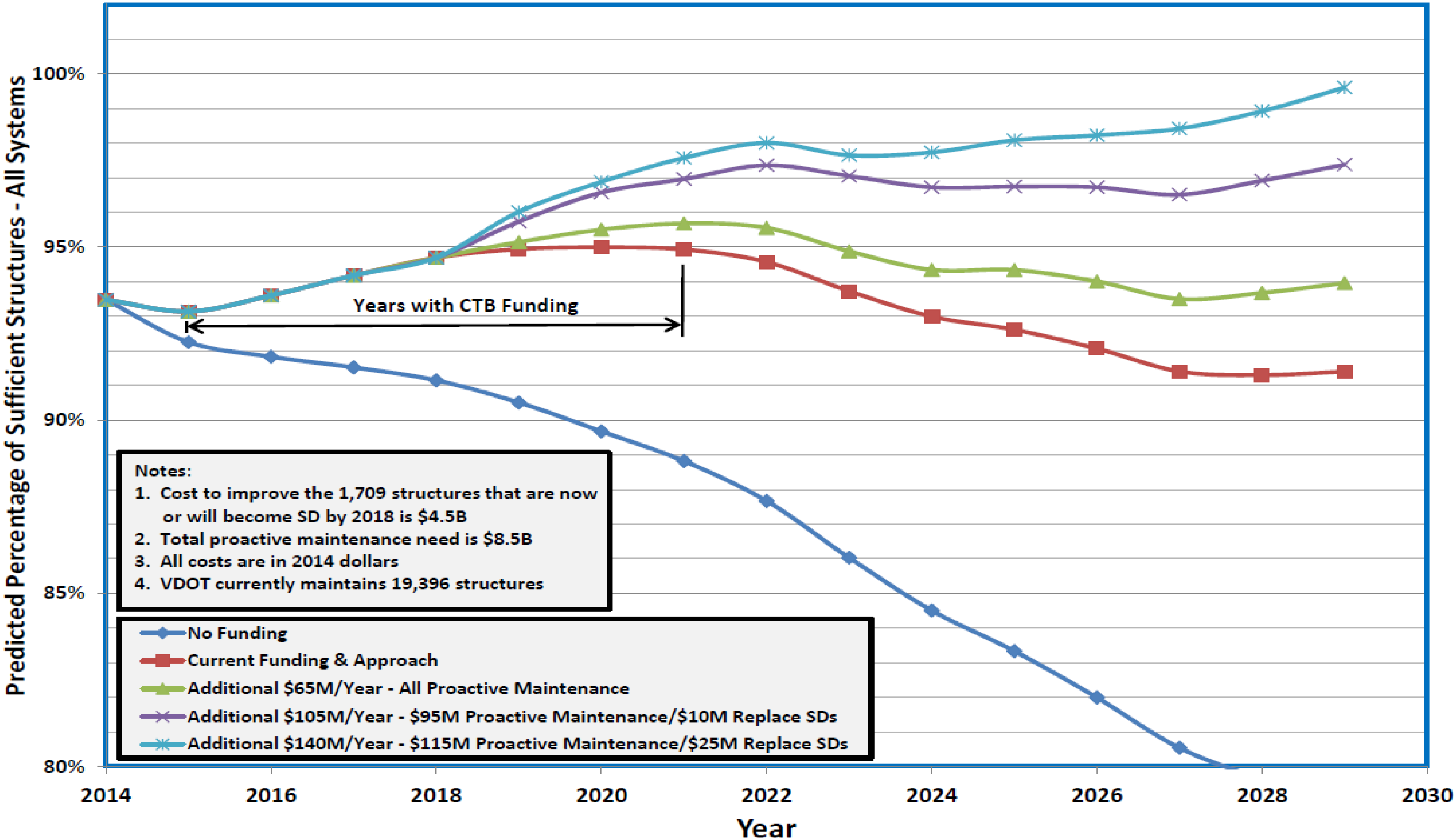
- **To**
  - **Have between 4 (to 10) Environments**
  - **For a given environment, there is one adjustment value for median transition time specific to each elements**

- **How**
  - **“PON_MOD_DETER: add adjustment values for four (to ten) Environments for each element**
  - **PON_ELEM_INSP: identifies Environment per normal practice for four (to ten) Environments for each element**

VDOT
Set a Baseline

No.	Title	Unit of Measure	Element Type	Component	Local Environment	Global Environment	Common Protection
12	Concrete Reinforced Deck	SF	NBE	Deck	N/A	VA Average	- No Overlay
13	Prestressed Concrete Deck	SF	NBE	Deck	N/A	VA Average	-No LPC
15	Prestressed/Reinforced Conc Top Flange	SF	NBE	Deck	N/A	VA Average	-No CRR
16	Reinforced Concrete Top Flange	SF	NBE	Deck	N/A	VA Average	
28	Open Grid Steel Deck	SF	NBE	Deck	N/A	VA Average	N/A
29	Concrete Filled Grid Steel Deck	SF	NBE	Deck	N/A	VA Average	- No Overlay
30	Corrugated/Orthotropic/Etc. Deck	SF	NBE	Deck	N/A	VA Average	
31	Timber Deck	SF	NBE	Deck	N/A	VA Average	- No Overlay
38	Concrete Reinforced Slab	SF	NBE	Deck	N/A	VA Average	- No Overlay
							-No LPC
							-No CRR
54	Timber Slab	SF	NBE	Deck	N/A	VA Average	N/A
60	Other Deck	SF	NBE	Deck	N/A	VA Average	N/A
801	Sidewalk	SF	ADE	Deck	N/A	VA Average	N/A
802	Deck Drains	EA	ADE	Deck	N/A	VA Average	N/A
102	Steel Closed Web/Box Girder	LF	NBE	Superstructure	Assume Joint Above	VA Average	-No Coatings
104	P/S Concrete Closed Web/Box Girder	LF	NBE	Superstructure	Assume Joint Above	VA Average	-No LPC
105	Reinf. Concrete Closed Web/Box Girder	LF	NBE	Superstructure	Assume Joint Above	VA Average	-No CRR
106	Other Closed Web/Box Girder	LF	NBE	Superstructure	Assume Joint Above	VA Average	N/A
107	Steel Open Girder	LF	NBE	Superstructure	Assume Joint Above	VA Average	-No Coatings
109	P/S Concrete Girder	LF	NBE	Superstructure	Assume Joint Above	VA Average	-No LPC
110	Reinf. Concrete Girder	LF	NBE		Assume Joint Above	VA Average	-No CRR
111	Timber Open Girder	LF	NBE	Superstructure	N/A	VA Average	N/A
112	Steel Open Girder Painted with Timber Deck	LF	NBE	Superstructure	N/A	VA Average	-No Coatings
811	Beam/Girder Ends	EA	ADE	Superstructure	Assume Joint Above	VA Average	
813	Steel diaphragms	EA	ADE	Superstructure	Assume Joint Above	VA Average	-No Coatings
113	Steel Stringer	LF	NBE	Superstructure	Assume Joint Above	VA Average	-No Coatings
115	P/S Concrete Stringer	LF	NBE	Superstructure	Assume Joint Above	VA Average	-No LPC
116	Reinf.\ Concrete Stringer	LF	NBE	Superstructure	Assume Joint Above	VA Average	-No CRR

VDOT
Non-SD vs Time
(Funding Options)



VDOT & BMS / Asset Management Current Activities

- $45B current valuation (replacement = $100B)
- PONTIS 4.4 - Extensive calibration via Paul Thompson
- Bridge Asset Management Plan / Needs Analysis
  - Combined with State Asset Management Plan
  - Distributes funds by District and Type of Work
  - Allocates $250M/year to State of Good Repair (SGR) Bridge Program
  - Allocates $200M/year of funds to State Bridge Maintenance Program
- Multi-Objective Prioritization (NCHRP 590)
  - Used for SGR Project Selection (SD Bridge Projects)
- Extensive use of Dashboards and Performance Measures
- BrM
  - BrM 5.2.1- Implemented in 2016
  - BrM 5.2.3- Implementing for Inspection Program in 7/31/2017
  - BrM 5.2.3- Assessing for BMS Analysis / Asset Management
- Implementing New Maintenance Management System

VDOT & BMS / Asset Management Near Term Activities

- **FHWA - Performance Measures / Asset Management Plan**
- **New State Performance Measures (to be implemented)**
- **New Dashboard**
- **BrM 5.2.3 – BMS Analysis / Asset Management Modules**
  - **Calibration of deterioration**
    - Team: (1) VDDOT CO (2) VTRC (UVA) (3) * Bentley / Paul Thompson
      - (ASAP) (AASHTO Service Units)
  - **Migration of Database for**
    - Protective Elements
    - Environmental Factor
  - **BMS Analysis Training (by Bentley in Fall 2017)**
  - **Calibration Other Modules of BrM 5.2.3 BMS Analysis**
  - **Action Effectiveness Cost Analysis – VDOT Extensive Analysis**
  - **VDOT BMS Analysis User and Technical Guide for VDOT Element Manual**
  - **District S&B Staff Training (by CO S&B in Winter 2017/2018)**

Engineering Answers
Uses of Element Data

- **Maintenance Management Systems**
  - **Determine immediate actions**
    - Painting / Patching / Overlays / etc.

- **Bridge Management System Analysis**
  - **Recommending Actions**
  - **Performance Projections**
  - **Multi-Objective Prioritization**

- **Translate Element Conditions to GCRs (serve as a check)**

- **Performance Measures / Health Index**

VDOT
Corrosion Resistant Reinforcement
Higher Performance Concretes

Option # 1

- **Approach**
  - **Protective Elements**
    - Child Protective Elements
  - **Agency Defined Protective Elements**
    - Child Protective Elements
- **Examples**
  - **Previous Slide**

Option # 2

- **Approach**
  - **Child Elements to Concrete Deck**
- **Examples**
  - **Regular Concrete with Normal Reinforcing Steel (NRS)**
  - **Low Permeability Concrete with NRS**
  - **Low Permeability Concrete with Corrosion Resistant Reinforcement (CRR)**
  - **Low Shrinkage/Cracking/Permeability Concrete with CRR**

BrM 5.2.3
Exposure Environments for Bridges

- **Environmental Factor, f^E**
  - **Adjustment factor for median transition time**
  - **Each element is assigned an Environment Factor**
  - **Four adjustment values for the median transition time**
  - **Values correspond to four environments <u>for all elements</u>**

Thus, for a given environment, this provides for only one adjustment value for median transition time for <u>all elements</u>.

- **Formula Factor f^F**
  - **A general adjustment factor**
  - **Estimated from a user-customized formula**

VDOT "Local Environment" Quantities

Element					Environment	Quantity			
No.	Description	Unit	Element Type	Component		CS1	CS2	CS3	CS4
801	Sidewalk	SF	ADE	Deck	2				
802	Deck Drains	EA	ADE	Deck	2				
331	Concrete bridge railing	LF	NBE	Deck	2				
12	Concrete Reinforced Deck	SF	NBE	Deck	2				
904	Rigid Overlay	SF	ADE	Protective Element	2				
107	Steel Open Girder	LF	NBE	Superstructure	1				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	1				
811	Beam/Girder Ends	EA	ADE	Superstructure	1				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	1				
310	Elastomeric bearing	EA	NBE	Substructure	1				
234	Reinforced Concrete Cap	LF	NBE	Substructure	1				
202	Steel Column or Pile Extension	EA	NBE	Substructure	1				
107	Steel Open Girder	LF	NBE	Superstructure	2				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	2				
811	Beam/Girder Ends	EA	ADE	Superstructure	2				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	2				
310	Elastomeric bearing	EA	NBE	Substructure	2				
234	Reinforced Concrete Cap	LF	NBE	Substructure	2				
202	Steel Column or Pile Extension	EA	NBE	Substructure	2				
300	Strip Seal Expansion Joint	LF	BME	Deck	2				
107	Steel Open Girder	LF	NBE	Superstructure	3				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	3				
811	Beam/Girder Ends	EA	ADE	Superstructure	3				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	3				
215	Reinforced Concrete Abutment	LF	NBE	Substructure	3				
310	Elastomeric bearing	EA	NBE	Substructure	3				
234	Reinforced Concrete Cap	LF	NBE	Substructure	3				
202	Steel Column or Pile Extension	EA	NBE	Substructure	3				
853	Protected Slope - Rip Rap	EA	ADE	Substructure	2				

VDOT "Local Environment" Quantities

Element					Environment	Quantity			
No.	Description	Unit	Element Type	Component		CS1	CS2	CS3	CS4
801	Sidewalk	SF	ADE	Deck	2				
802	Deck Drains	EA	ADE	Deck	2				
331	Concrete bridge railing	LF	NBE	Deck	2				
12	Concrete Reinforced Deck	SF	NBE	Deck	2				
904	Rigid Overlay	SF	ADE	Protective Element	2				
300	Strip Seal Expansion Joint	LF	BME	Deck	2				
107	Steel Open Girder	LF	NBE	Superstructure	1				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	1				
107	Steel Open Girder	LF	NBE	Superstructure	2				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	2				
107	Steel Open Girder	LF	NBE	Superstructure	3				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	3				
811	Beam/Girder Ends	EA	ADE	Superstructure	1				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	1				
811	Beam/Girder Ends	EA	ADE	Superstructure	2				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	2				
811	Beam/Girder Ends	EA	ADE	Superstructure	3				
923	Paint (Various coatings & uncoated)over Zinc Primer	SF	ADE	Protective Element	3				
310	Elastomeric bearing	EA	NBE	Substructure	1				
310	Elastomeric bearing	EA	NBE	Substructure	2				
310	Elastomeric bearing	EA	NBE	Substructure	3				
234	Reinforced Concrete Cap	LF	NBE	Substructure	1				
234	Reinforced Concrete Cap	LF	NBE	Substructure	2				
234	Reinforced Concrete Cap	LF	NBE	Substructure	3				
202	Steel Column or Pile Extension	EA	NBE	Substructure	1				
202	Steel Column or Pile Extension	EA	NBE	Substructure	2				
202	Steel Column or Pile Extension	EA	NBE	Substructure	3				
215	Reinforced Concrete Abutment	LF	NBE	Substructure	3				
853	Protected Slope - Rip Rap	EA	ADE	Substructure	2				

VDOT "Local Environments"

"Local Environmental Factor" by Element

Component	Element		Unit of Measure	Joint				Overspray *			Tidal **	
	No.	Description		With Joint	Link Slab / Deck Ext.	W/O Joint	VA Pier / Abut	Horz > 22'	Horz <= 22' & > 10'	Horz <= 10'	Vert > 20'	Vert <= 20'
Deck	12	Reinforced Concrete Deck	SF									
	13	Prestressed Concrete Deck	SF									
	15	Prestressed Concrete Top Flange	SF									
	16	Reinforced Conc Top Flange	SF									
	28	Steel Deck - Open Grid	SF									
	29	Steel Deck - Conc Fill Grid	SF									
	30	Steel Deck - Orthotropic	SF	3	3	3	3	1	2	3	2	4
	31	Timber Deck	SF									
	38	Reinforced Concrete Slab	SF									
	39	*Prestressed Concrete Slab **	*SF*									
	54	Timber Slab	SF									
	60	Other Deck	SF									
	65	Other Slab	SF									
	801	Sidewalk	SF									
	802	Deck Drains	EA									
Railings	330	Metal Bridge Railing	LF									
	331	Reinforced Conc Bridge Railing	LF									
	332	Timber Bridge Railing	LF	3	3	3	3	1	2	3	2	4
	333	Other Bridge Railing	LF									
	334	Masonry Bridge Railing	LF									
Joints	300	Strip Seal Exp Joint	LF									
	301	Pourable Joint Seal	LF									
	302	Compressn Joint Seal	LF									
	303	Assembly Joint With Seal	LF									
	304	Open Expansion Joint	LF	3	3	3	3	1	2	3	2	4
	305	Assembly Joint Without Seal	LF									
	306	Other Joint	LF									
	843	Link Slab	EA									
	844	Slab Extension	EA									
	845	Joint Effectiveness	EA									
Superstructure	102	Steel Closed Box Gird	LF									
	104	Prestressed Closed Box Girder	LF									
	105	Reinforced Closed Box Girder	LF									
	107	Steel Opn Girder/Beam	LF									
	109	Prestressed Open Conc Girder/Beam	LF									
	110	Reinforced Conc Opn Girder/Beam	LF									
	111	Timber Open Girder	LF									
	113	Steel Stringer	LF									
	115	Prestressed Conc Stringer	LF									
	116	Reinforced Conc Stringer	LF									
	117	Timber Stringer	LF									
	120	Steel Truss	LF	1	1	1	1	1	2	3	3	4
	135	Timber Truss	LF									
	141	Stl Arch	LF									
	142	Other Arch	LF									
	143	Prestressed Conc Arch	LF									
	144	Reinforced Conc Arch	LF									
	145	Masonry Arch	LF									
	152	Steel Floor Beam	LF									
	155	Reinforced Conc Floor Beam	LF									
	156	Timber Floor Beam	LF									
	161	Steel Pin or Pin & Hanger	EA									
	162	Steel Gusset Plate	EA									
	813	Diaph/XFrame Curved Girder	LF									
	811	Beam/Girder Ends	EA	3	2	1	1					
Bearings	310	Elastomeric Bearing	EA									
	311	Moveable Bearing	EA									
	312	Enclosed Bearing	EA									
	313	Fixed Bearing	EA	3	2	1	1	1	2	3	3	4
	314	Pot Bearing	EA									
	315	Disk Bearing	EA									
	316	Other Bearing	EA									
Substructure	231	Steel Pier Cap	LF									
	233	Prestressed Conc Pier Cap	LF									
	234	Reinforced Conc Pier Cap	LF	3	2	1	2					
	235	Timber Pier Cap	LF									
	236	Other Pier Cap	LF									
	202	Steel Column	EA									
	204	Prestressed Conc Column	EA									
	205	Reinforced Conc Column	EA									
	206	Timber Column or Pile Extension	EA									
	207	Steel Tower	EA					2	2	3	4	4
	208	Timber Trestle	EA									
	210	Reinforced Conc Pier Wall	LF									
	211	Other Pier Wall	LF	3	2	1	3					
	213	Masonry Pier Wall	LF									
	215	Reinforced Conc Abutment	LF									
	216	Timber Abutment	LF									
	217	Masonry Abutment	LF									
	218	Other Abutments	LF									
	219	Steel Abutment	LF									
	822	Steel Wingwall	EA									
	824	Reinforced Conc Wingwall	EA									
	826	Timber Wingwall	EA	3	2	1	3	2	2	3	4	4
	828	Masonry Wingwall	EA									
	830	MSE Wall	LF									
Culvert	240	Steel Culvert	LF									
	241	Reinforced Conc Culvert	LF									
	243	Other Culvert	LF									
	244	Masonry Culvert	LF								4	4
	245	Prestressed Concrete Culvert	LF									
	831	Conc. Culvert End/Headwall	EA									
	833	Roadway Over Culvert	EA									
Slope / Channel	851	Unprotected Slope	EA									
	852	Protected Slope - Paved	EA	3	2	1	2	1	2	3	4	4
	853	Protected Slope - RipRap	EA									
	854	Channel	EA									

VDOT “Local Environments”

"Local Environmental Factor" by Element

Component	Element		Unit of Measure	Joint				Overspray *			Tidal **	
	No.	Description		With Joint	Link Slab / Deck Ext.	W/O Joint	VA Pier / Abut	Horz > 22'	Horz <= 22' & > 10'	Horz <= 10'	Vert > 20'	Vert <= 20'
Superstructure	102	Steel Closed Box Gird	LF									
	104	Prestressed Closed Box Girder	LF									
	105	Reinforced Closed Box Girder	LF									
	107	Steel Opn Girder/Beam	LF									
	109	Prestressed Open Conc Girder/Beam	LF									
	110	Reinforced Conc Opn Girder/Beam	LF									
	111	Timber Open Girder	LF									
	113	Steel Stringer	LF									
	115	Prestressed Conc Stringer	LF									
	116	Reinforced Conc Stringer	LF									
	117	Timber Stringer	LF									
	120	Steel Truss	LF	1	1	1	1	1	2	3	3	4
	135	Timber Truss	LF									
	141	Stl Arch	LF									
	142	Other Arch	LF									
	811	Beam/Girder Ends	EA	3	2	1	1					
Bearings	310	Elastomeric Bearing	EA									
	311	Moveable Bearing	EA									
	312	Enclosed Bearing	EA									
	313	Fixed Bearing	EA	3	2	1	1	1	2	3	3	4
	314	Pot Bearing	EA									
	315	Disk Bearing	EA									
	316	Other Bearing	EA									
Substructure	231	Steel Pier Cap	LF									
	233	Prestressed Conc Pier Cap	LF									
	234	Reinforced Conc Pier Cap	LF	3	2	1	2					
	236	Other Pier Cap	LF									
	202	Steel Column	EA									
	204	Prestressed Conc Column	EA									
	205	Reinforced Conc Column	EA									
	206	Timber Column or Pile Extension	EA									
	207	Steel Tower	EA					2	2	3	4	4
	215	Reinforced Conc Abutment	LF									
	219	Steel Abutment	LF									
	822	Steel Wingwall	EA									
	824	Reinforced Conc Wingwall	EA									
	826	Timber Wingwall	EA	3	2	1	3	2	2	3	4	4
	828	Masonry Wingwall	EA									
	830	MSE Wall	LF									