Virginia Department of Transportation

2015 Virginia Concrete Conference

VDOT's Experience with Reinforced Concrete and Metal Culverts

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Presentation Outline

- State Maintained Bridges and Culverts in Virginia
- Bridge/Culvert Safety Inspection Program - Overview
- VDOT Structure Inventory - Overview
- Bridge/Culvert Condition Measures
- Overview of the Condition of Virginia's Structures
- Current Condition of Existing Steel Culverts in Virginia
- Current Condition of Existing Concrete Culverts in Virginia
- Culvert Conditions - Historical Data
- Comparison of Current Culvert General Condition Ratings
- Proposed Culvert Material Type Selection Process

State Maintained Bridges and Culverts in Virginia

Number of Bridges	Number of Culverts	Total
11863	7563	19426

Number of Steel Culverts	Number of Concrete Culverts	Number of Misc. Culverts	Total
2057	5474	32	7563

Bridge/Culvert Safety Inspection Program

- **The bridge/culvert safety inspection program has two primary objectives:**
  - **Ensure the safety of the traveling public.**
  - **Obtain the information necessary to plan and implement a program for the maintenance and improvement of the bridges and culverts on the highway system.**

- **During the bridge construction boom of the 1950's and 1960's, little emphasis was placed on safety inspection and maintenance of bridges and culverts. This changed when the 2,235-foot Silver Bridge, at Point Pleasant, West Virginia, collapsed into the Ohio River on December 15, 1967, killing 46 people .**

SILVER BRIDGE TUMBLES,
TOLL, 7 DEAD, 41 MISSING
Point Pleasant Register
'I Couldn't Understand Why I Made It'
Five Survivors Give Accounts
Divers Begin Search For Untold Loss

Bridge/Culvert Safety Inspection Program

- The collapse of the Silver Bridge aroused national interest in the safety inspection and maintenance of bridges and culverts. The U.S. Congress was prompted to add a section to the Federal Highway Act of 1968 which required the Secretary of Transportation to establish a national bridge inspection standard.

- In 1971, the National Bridge Inspection Standards (NBIS) came into being. The NBIS established national policy regarding:
  - Inspection procedures
  - Frequency of inspections
  - Qualifications of personnel
  - Inspection reports
  - Maintenance of state bridge inventory
  - Applied to bridges on the Federal Aid highway systems

- The Surface Transportation Assistance Act of 1978 act provided federal bridge funding and required that all public bridges over 20 feet in length be inspected and inventoried in accordance with the NBIS.

Bridge/Culvert Safety Inspection Program

- **Virginia inspects highway structures in accordance with the requirements of the National Bridge Inspection Standards (NBIS).**

- **In addition to the federal requirements, Virginia also inspects all bridges shorter than 20 feet, and all culverts having an opening of 36 square feet or more.**

VDOT Structure Inventory - Overview

- The NBIS require an inventory of all bridges/culverts that are subject to the standards.
- The national bridge inventory, known as the NBI, is maintained in accordance with the requirements of the FHWA publication “Recording and Coding Guide for the Structure Inventory and Appraisal of the Nations Bridges” (NBI Coding Guide).
- Virginia collects all of the data fields required by the FHWA in the NBI Coding Guide.
- In addition to the required federal data, Virginia also collects data for state specific data fields.
- With the Federal fields and the State fields combined, we collect 209 items of data for each structure in the inventory.

Bridge/Culvert Condition Measures

- **There are a number of different measures that provide an indication of bridge and culvert condition. These measures include the following:**
  - **General Condition Rating**
  - **Element Condition State – VDOT is currently utilizing the AASHTO Commonly Recognized (CORE) Elements. VDOT is in the process of transitioning to the new AASHTO Elements as required by U.S. Code that was amended by the MAP-21 legislation.**

- **Both General Condition Ratings and Element Condition States are collected as a part of the VDOT safety inspection program – these ratings are assigned by the safety inspectors.**

Bridge/Culvert Condition Measures

- **We use General Condition Ratings as the primary measure for the overall condition of the structure inventory at the network level.**

- **What are "general condition ratings?"**

According to the National Bridge Inspection Standards (NBIS), condition ratings are used to describe an existing bridge or culvert compared with its condition if it were new. The ratings are based on the materials physical condition of the deck (riding surface), the superstructure (supports immediately beneath the driving surface) and the substructures (foundation and supporting posts and piers) or the culvert.

General condition ratings range from 0 (failed condition) to 9 (excellent).

Bridge/Culvert Condition Measures

- **General Condition Rating Scale**
  - 9 EXCELLENT CONDITION
  - 8 VERY GOOD CONDITION
  - 7 GOOD CONDITION
  - 6 SATISFACTORY CONDITION
  - 5 FAIR CONDITION
  - 4 POOR CONDITION
  - 3 SERIOUS CONDITION
  - 2 CRITICAL CONDITION
  - 1 "IMMINENT" FAILURE CONDITION
  - 0 FAILED CONDITION

- **General Condition Ratings Are Provided At Each Inspection For:**
  - DECK
  - SUPERSTRUCTURE
  - SUBSTRUCTURE
  - CULVERT

Bridge/Culvert Condition Measures

- **Elements Condition States**

For the AASHTO Commonly Recognized (CORE) Elements there are 4 condition states, for culverts.

The general description of the four culvert condition states follows:

- **Condition State 1 - Good**
- **Condition State 2 - Fair**
- **Condition State 3 - Poor**
- **Condition State 4 - Very Poor**

Overview of the Condition of Virginia's Structures

- The Structure and Bridge Division uses structure condition categories to determine the overall condition of the structure inventory at the network level.

- The structure condition categories of Good, Fair, and Poor are determined using NBI General Condition Ratings (GCR) as follows:
  - Good – lowest GCR greater than or equal to 6
  - Fair – lowest GCR equal to 5
  - Poor – lowest GCR less than or equal to 4

- The current overall condition for the VDOT maintained statewide inventory is shown below:

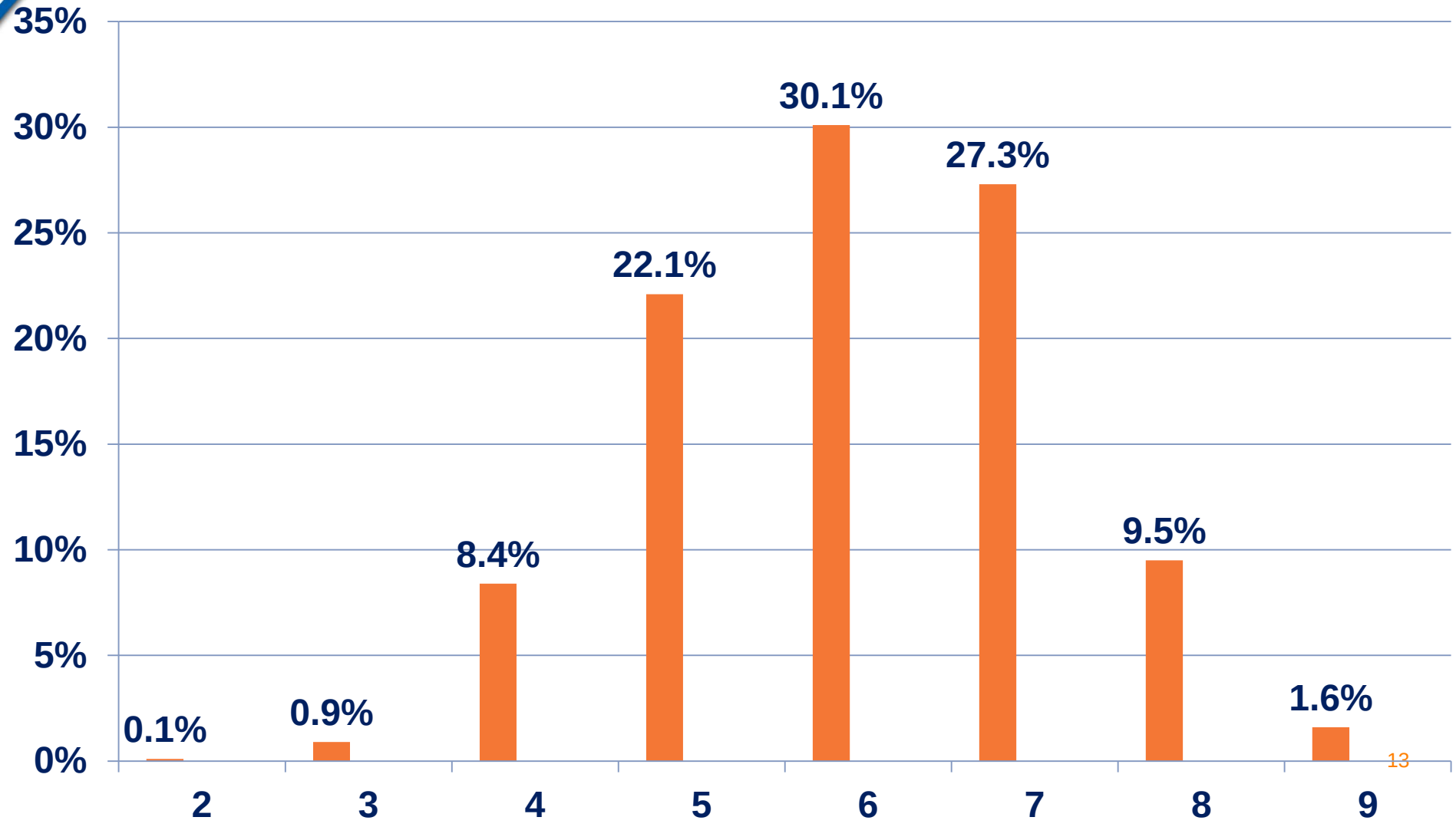
  69.9% of the structures are in Good condition

  24.0% of the structure are in Fair condition

  6.1% of the structures are in Poor condition

Current Conditions of Existing Steel Culverts in Virginia

Distribution of Culvert General Condition Ratings (GCR) – All Culverts



Current Conditions of Existing Steel Culverts in Virginia

- **Distribution of Culvert General Condition Ratings (GCR)**

  GCR of 2 – 1 (0.1%)
  GCR of 3 – 19 (0.9%)
  GCR of 4 – 174 (8.4%)
  GCR of 5 – 455 (22.1%)
  GCR of 6 – 619 (30.1%)
  GCR of 7 – 561 (27.3%)
  GCR of 8 – 195 (9.5%)
  GCR of 9 – 33 (1.6%)

- **Average GCR – 6.09**

Current Conditions of Existing Steel Culverts in Virginia

- **Condition Categories**
  - Good – 1408 (68.4%)
  - Fair – 455 (22.1%)
  - Poor – 194 (9.4%)

- **Condition States**
  - State 1 – 48486 LF (58.5%)
  - State 2 – 22788 LF (27.5%)
  - State 3 – 7772 LF (9.4%)
  - State 4 – 3878 LF (4.7%)
  - Total – 82925 LF

- **Year Built Range: 1900 to 2014**

- **Average Year Built – 1977**

Survey Results of Residencies: Causes of Problems with Existing Metal Culverts in Virginia

Current Conditions of Existing Steel Culverts in Virginia

Built 1995 – Culvert GCR 4

Current Conditions of Existing Steel Culverts in Virginia

Current Condition of Existing Steel Culverts in Virginia

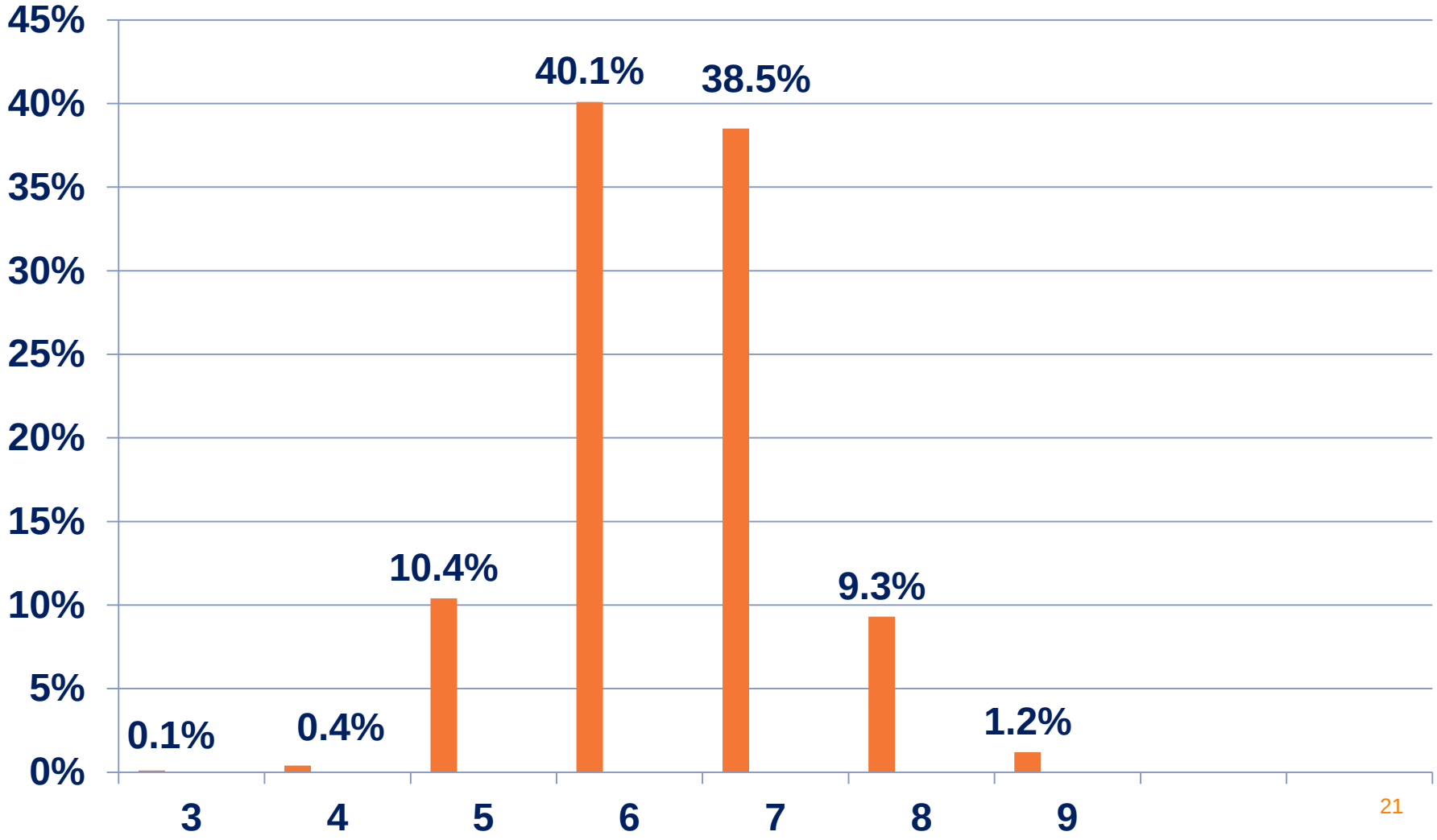
Built 1997 – Culvert GCR 4

Current Condition of Existing Steel Culverts in Virginia

Built 2006 – Culvert GCR – 4

Current Conditions of Existing Concrete Culverts in Virginia

Distribution of Culvert General Condition Ratings (GCR)



Current Condition of Existing Concrete Culverts in Virginia

- **Distribution of Culvert General Condition Ratings (GCR)**

  GCR of 3 – 2 (0.1%)
  GCR of 4 – 23 (0.4%)
  GCR of 5 – 571 (10.4%)
  GCR of 6 – 2194 (40.1%)
  GCR of 7 – 2109 (38.5%)
  GCR of 8 – 507 (9.3%)
  GCR of 9 – 68 (1.2%)

Average GCR – 6.49

Current Condition of Existing Concrete Culverts in Virginia

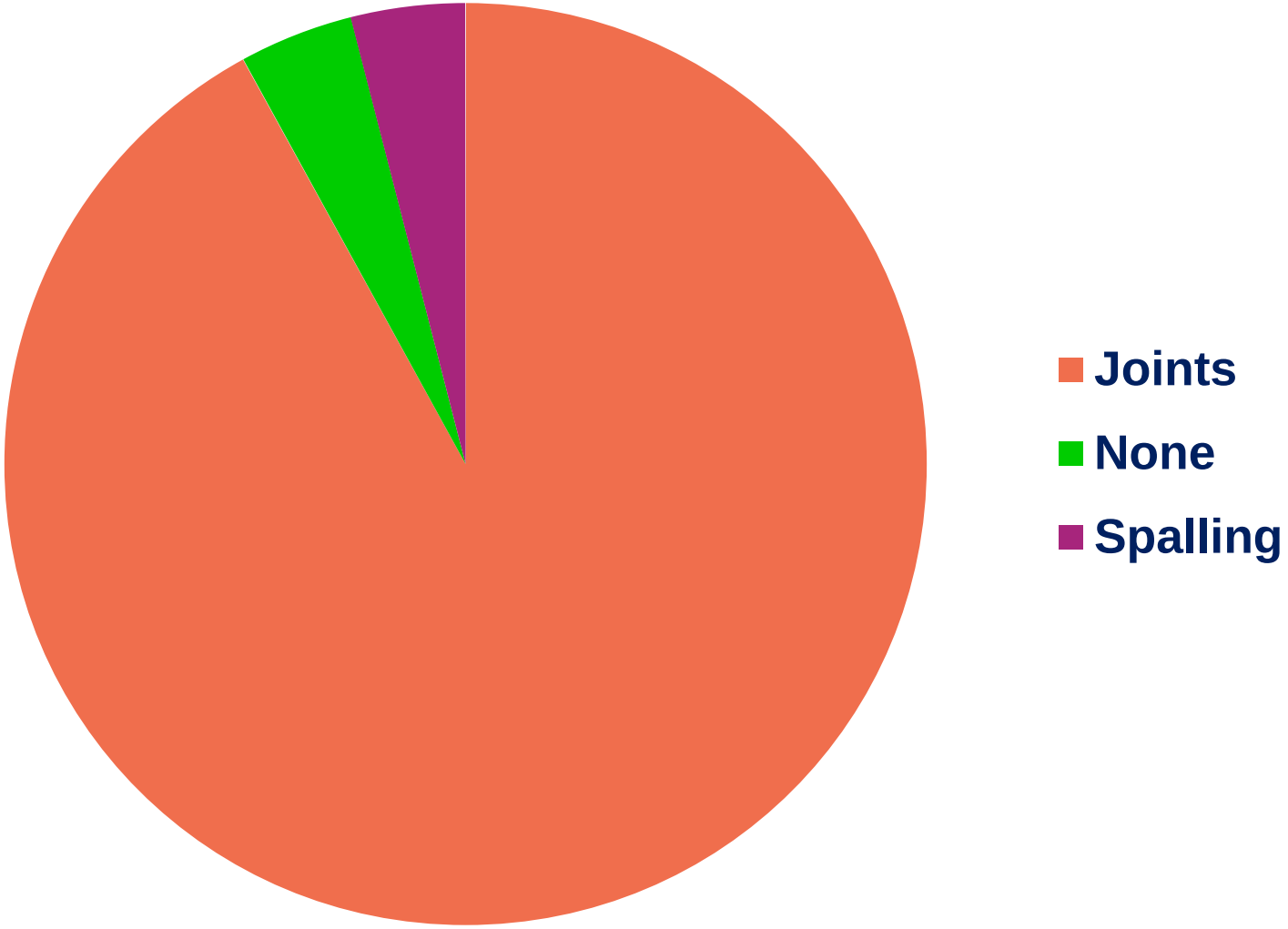
- **Condition Categories**
  - Good – 4878 (89.1%)
  - Fair – 571 (10.4%)
  - Poor – 25 (0.4%)

- **Condition States**
  - State 1 – 333495 (77.5%)
  - State 2 – 88713 (20.6%)
  - State 3 – 7582 (1.8%)
  - State 4 – 639 (0.2%)
  - Total – 430431

- **Year Built Range: 1903 to 2014**

- **Average Year Built – 1970.41**

Survey Results of Residencies: Causes of Problems with Existing Concrete Culverts in Virginia

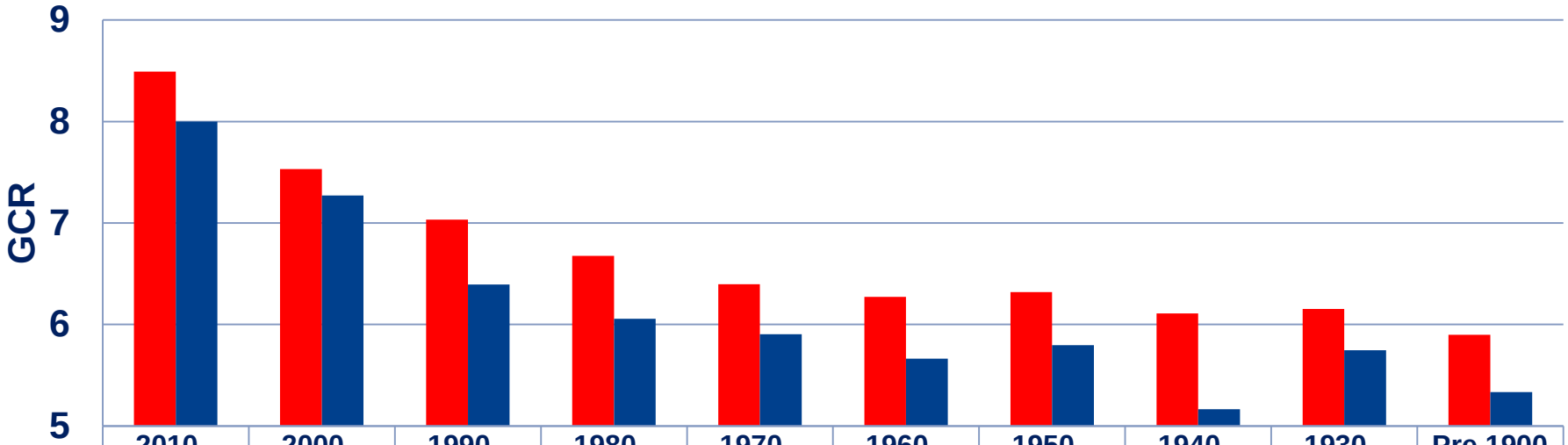


Current Conditions of Existing Concrete Culverts in Virginia

Built 1997 - Culvert GCR – 7

Culvert Conditions - Historical Data

Average Culvert GCR by Decade and Material

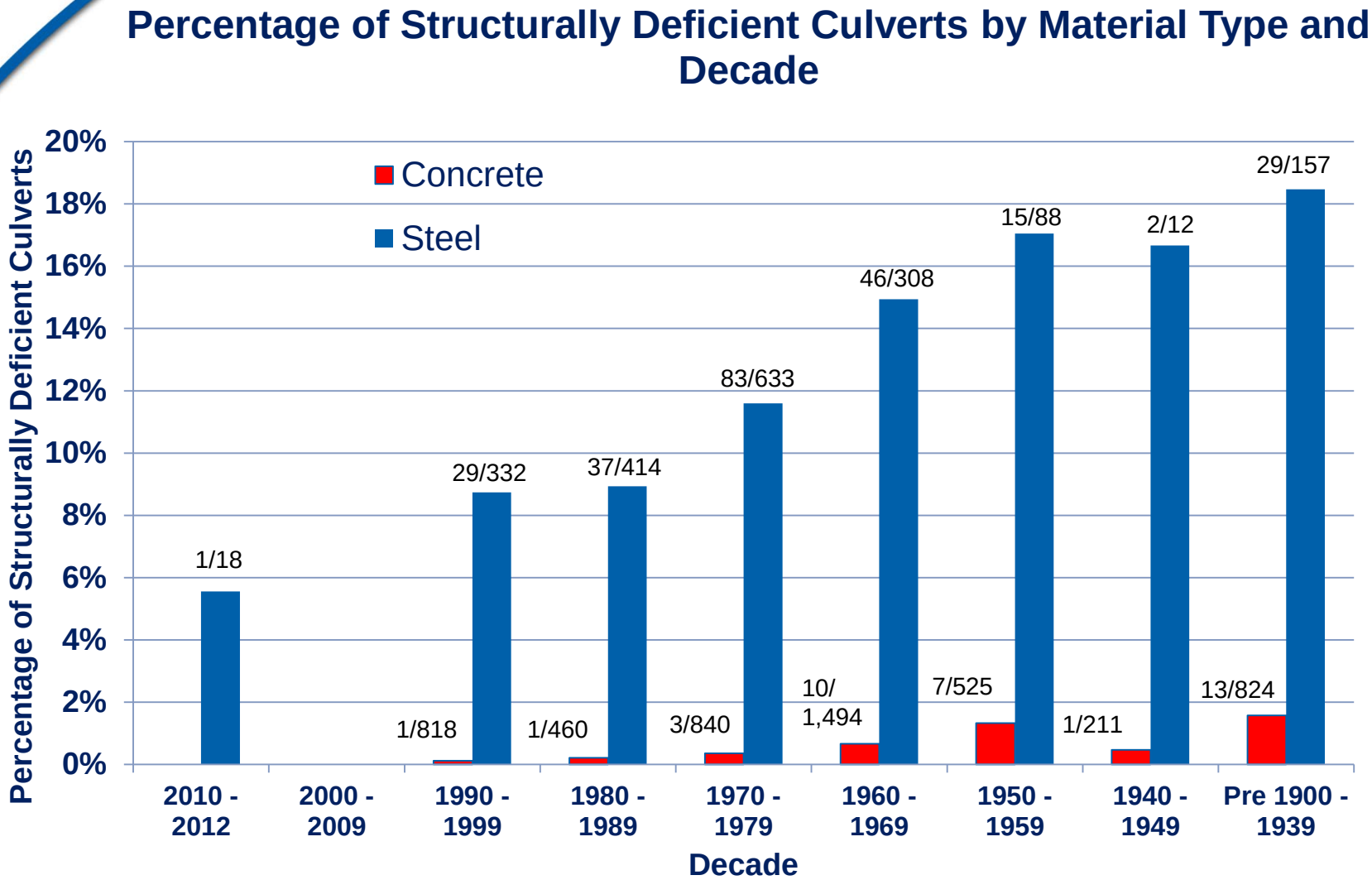


	2010 - 2012	2000 - 2009	1990 - 1999	1980 - 1989	1970 - 1979	1960 - 1969	1950 - 1959	1940 - 1949	1930 - 1939	Pre 1900 - 1929
Concrete	8.49	7.53	7.03	6.68	6.40	6.27	6.32	6.11	6.15	5.90
Steel	8.00	7.27	6.39	6.06	5.91	5.66	5.80	5.17	5.75	5.33

Decade

Culverts have outperformed bridges and concrete culverts have outperformed steel culverts

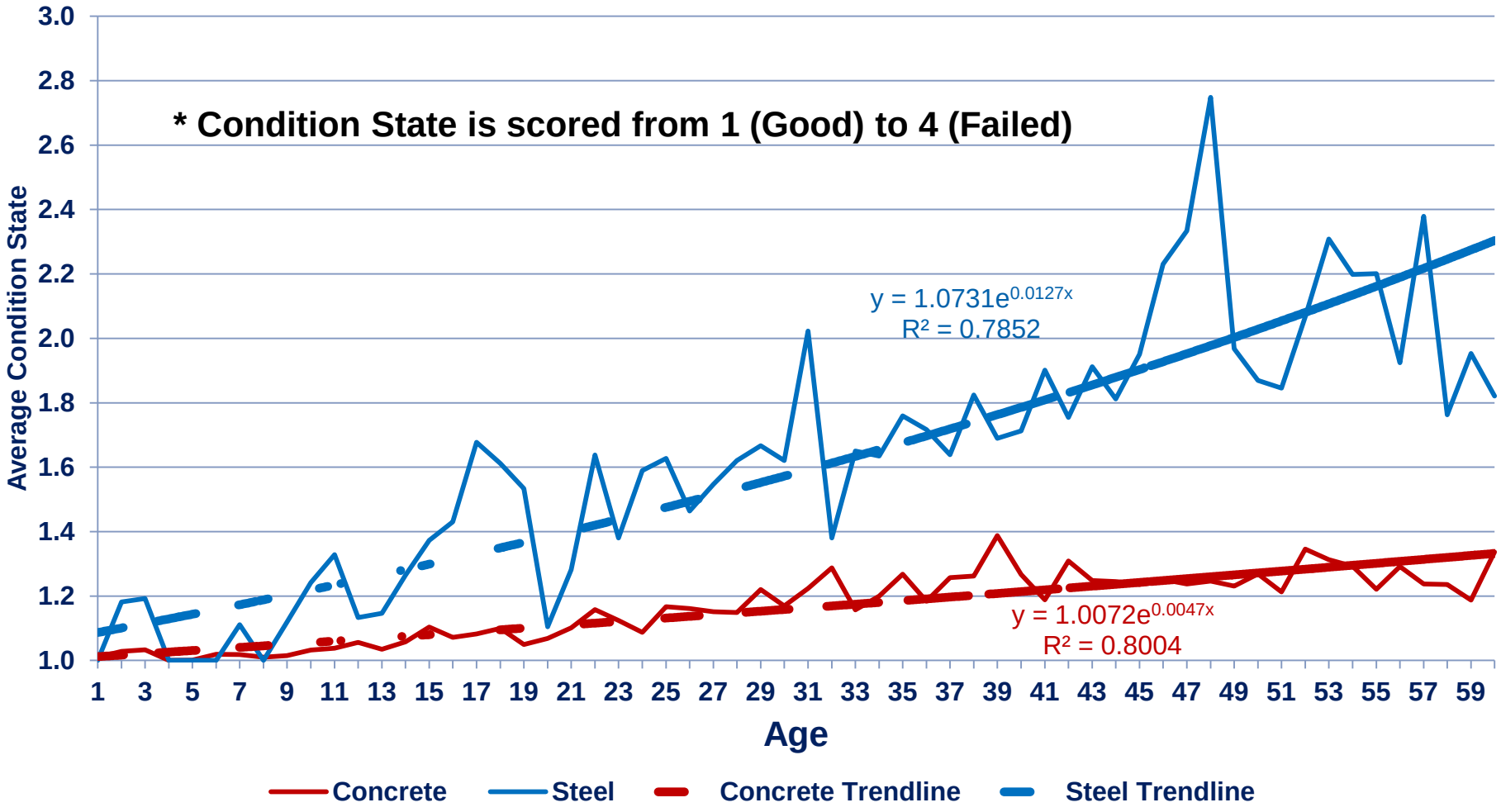
Culvert Conditions - Historical Data



Culverts have outperformed bridges and concrete culverts have outperformed steel culverts

Culvert Conditions - Historical Data

Comparison of Average Condition State* for Concrete and Steel Culverts



Comparison of Current Culvert General Condition Ratings

- **Current Condition Categories for Steel Culverts**
  - **Good – 1408 (68.4%)**
  - **Fair – 455 (22.1%)**
  - **Poor – 194 (9.4%)**
  - **Average GCR - 6.09**

- **Current Condition Categories for Concrete Culverts**
  - **Good – 4878 (89.1%)**
  - **Fair – 571 (10.4%)**
  - **Poor – 25 (0.5%)**
  - **Average GCR – 6.49**

- **A review of both the historical and current conditions indicate that concrete culverts have outperformed steel culverts**

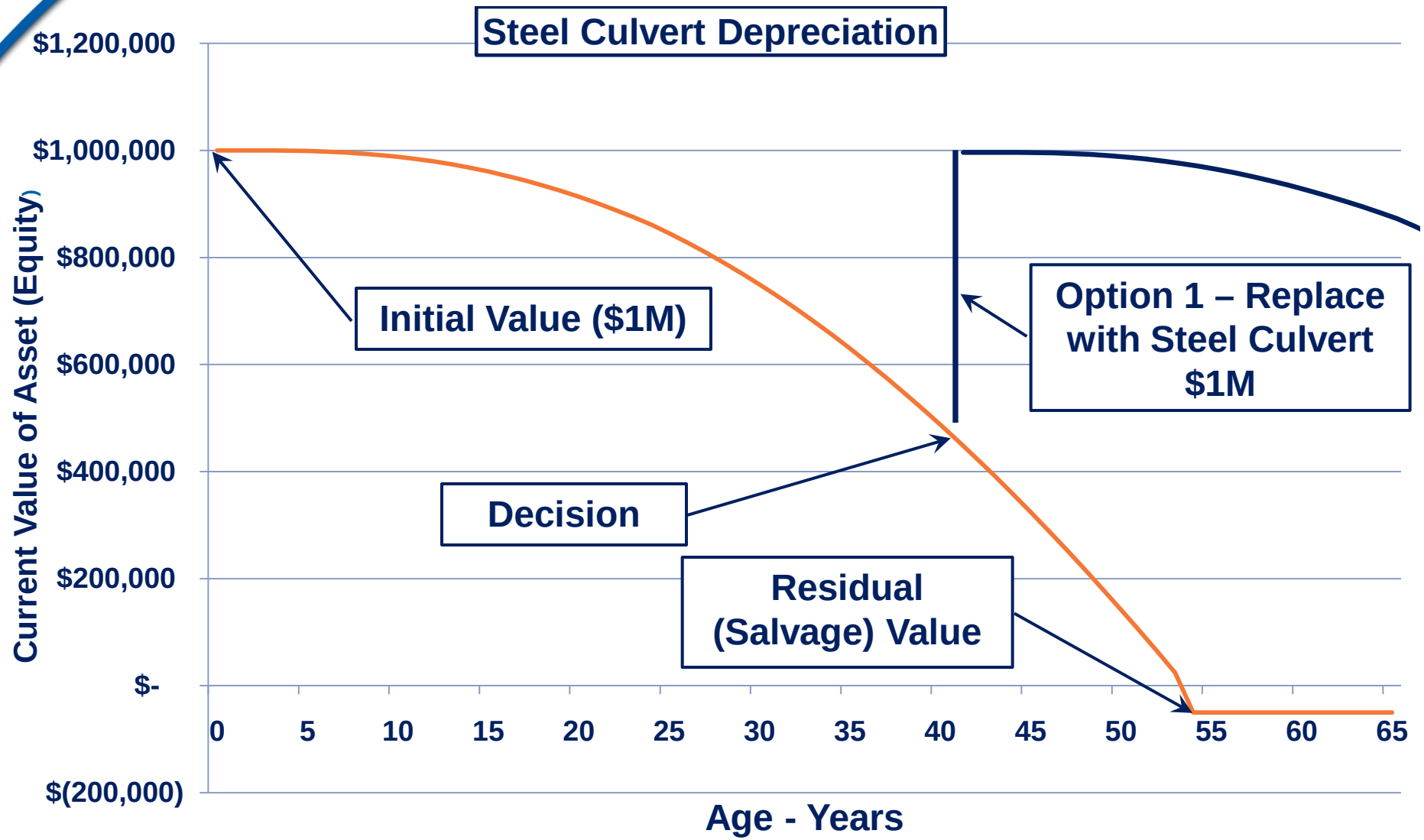
Culvert Selection Process

Bridge Class Culverts will be selected by the Engineer rather than the Contractor

S&B Division is providing guidance to Engineers for rational decision-making

- **Process will utilize current and predicted future equity as the primary basis for decisions**
- **Decisions should be based on best value**

The Benefits of Using Equity as the Basis for Engineering Decisions



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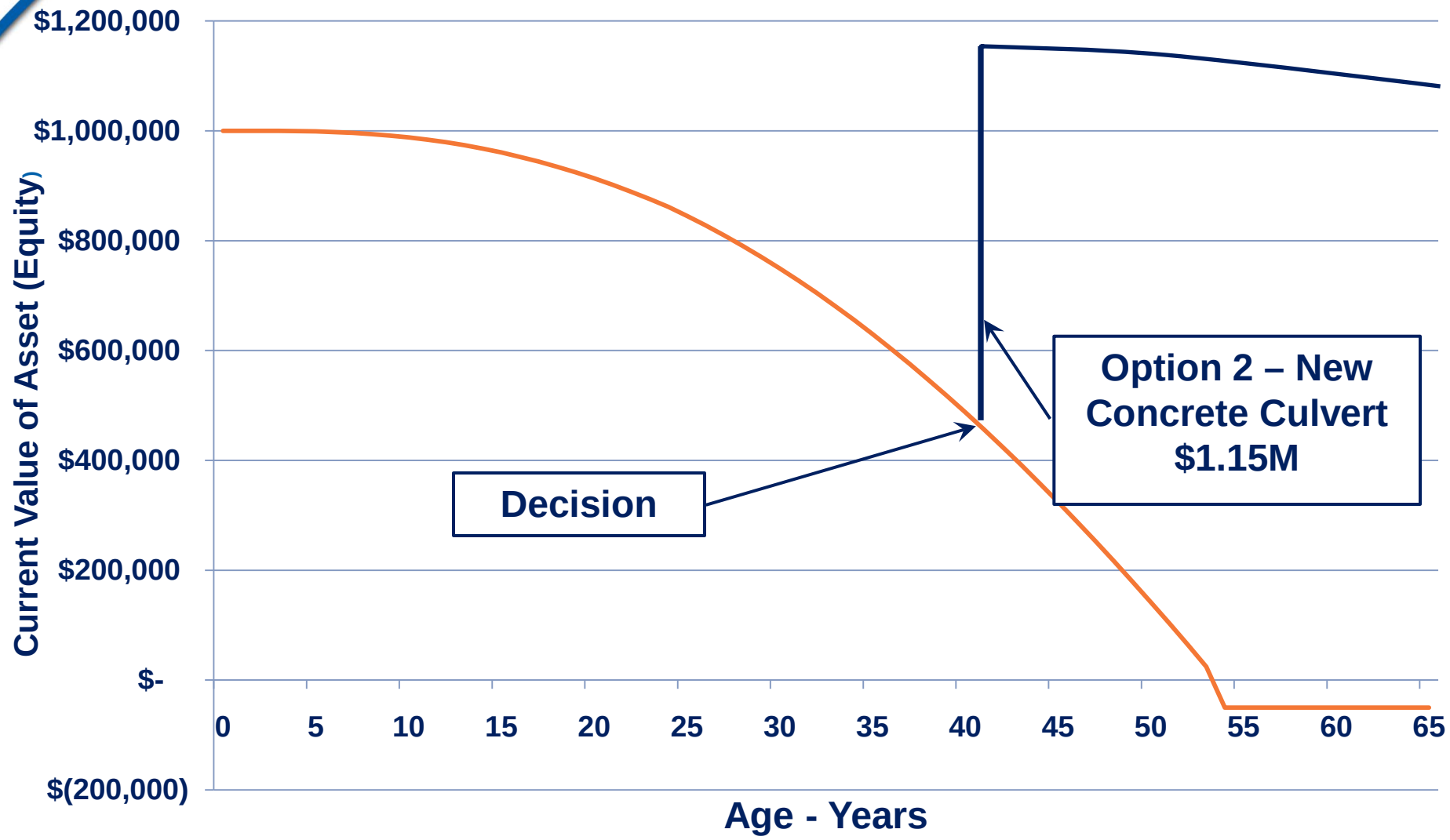

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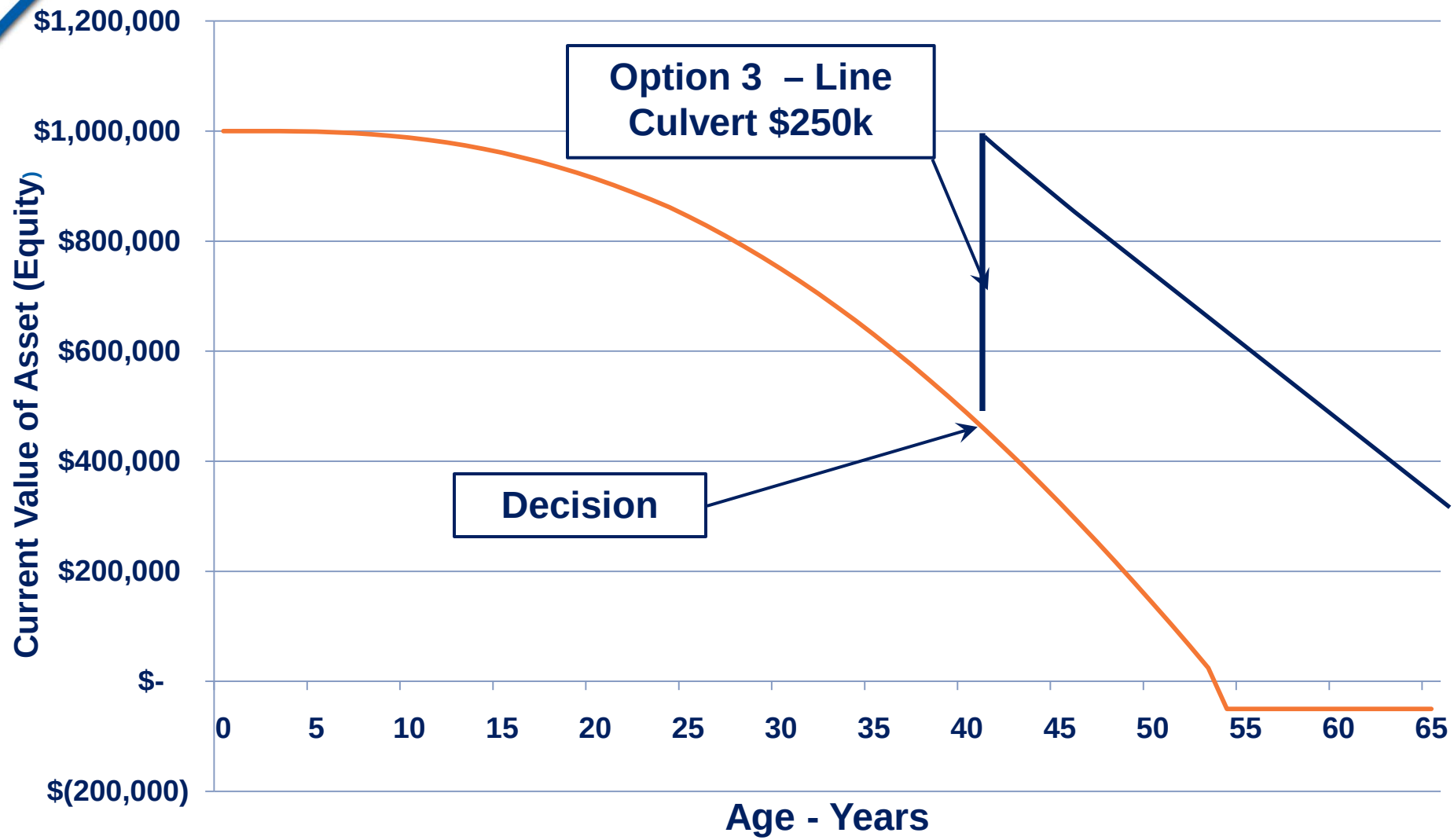


With Equity Curves Simple Life Cycle Analysis is Practical

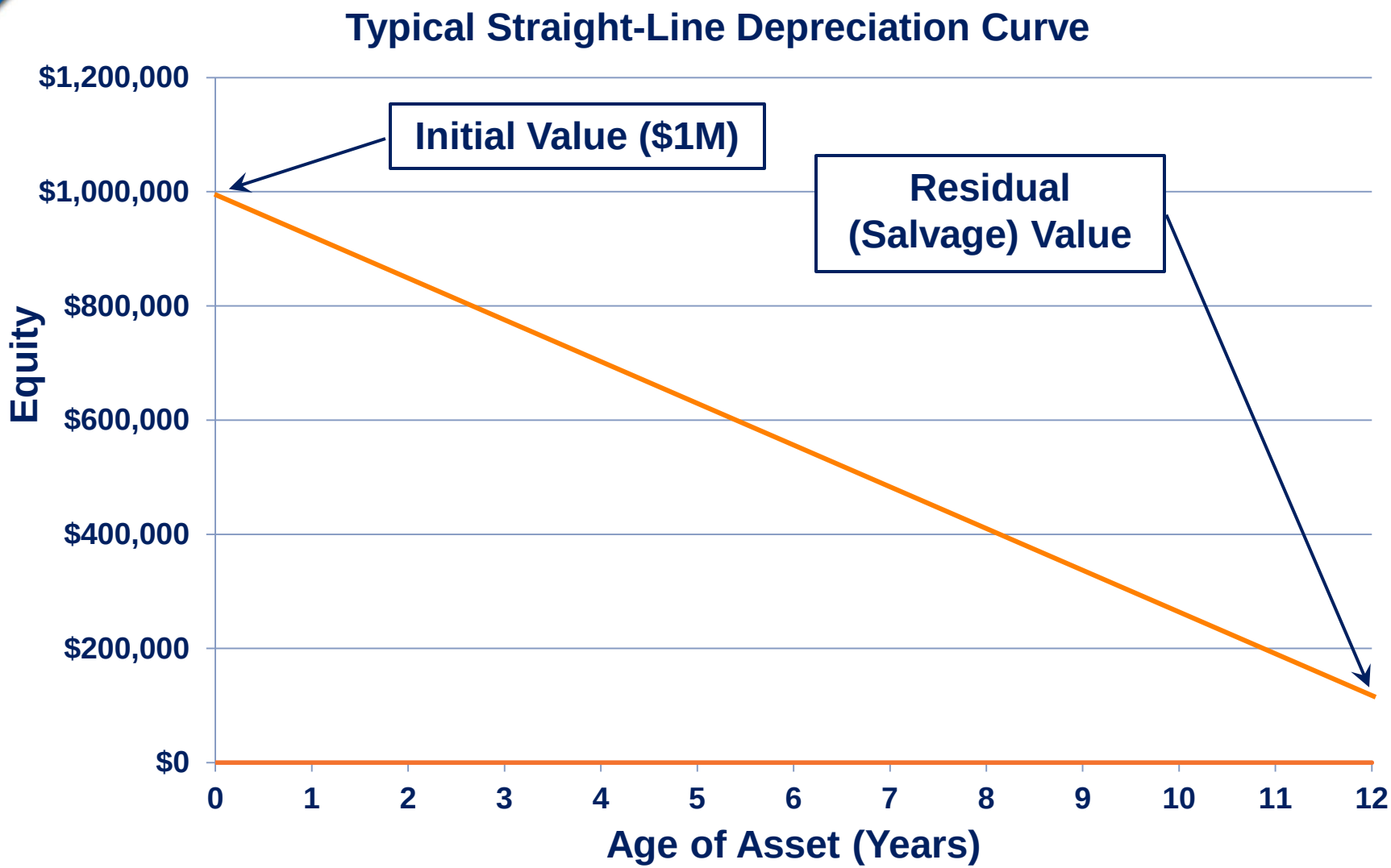
		Initial Costs						
	Name	Initial Construction	Traffic Control	Engineering, Inspection, R/W	Total Initial Cost	Estimated Maintenance Costs Per 10 Year Interval	Replacement Year	Present Value (calculated)
Option 1	Coated Steel	$748,400	$64,500	$187,100	$1,000,000	$4,000	53	-$1,131,192
Option 2	Precast Concrete	$850,240	$87,200	$212,560	$1,150,000	$6,000	110	-$893,554
Option 3	Steel Liner	$190,000	$12,500	$47,500	$250,000	$4,000	30	-$1,380,666

Discount Rate	1.50%

Suggested PE, CEI, R/W Factor	0.25

Steel Liner Option Assumes New Steel Culvert Required in 25 Years

Measuring Equity – Common Practice: Time Based Depreciation



Developing A Measurement of Equity Using Condition

VDOT has a good understanding of the condition of each element of every structure

Element Data Collected During Inspections

Component	Number	Title
Deck	801	Sidewalk
	802	Deck Drains
Superstructure	811	Beam/Girder End
	812	Reinforced Concrete Frame
Substructure	821	Steel Abutment
	822	Steel Wingwall
	823	Reinf.\ Concrete Abutment
	824	Reinf.\ Concrete Wingwall
	825	Timber Abutment
	826	Timber Wingwall
	827	Masonry Abutment
	828	Masonry Wingwall
	829	MSE Abutments
	830	MSE Wingwall
Culverts	831	Concrete Culvert Endwall/Headwall
	832	Concrete Cuvlert Wingwall
	833	Roadway Over Culvert
Joints	841	Asphalt Plug Joint
	842	Elastomeric Concrete Plug Joint
	843	Link Slab
	844	Slab Extension
	845	Joint Effectiveness
Slopes & Channels	851	Unprotected Slope
	852	Protected Slope - Paved
	853	Protected Slope - Riprap
	854	Channel
Protective	881	Wearing Surface - Unprotected Asphalt Wearing Surface
	882	Wearing Surface - Protected Asphalt Wearing Surface
	883	Wearing Surface - Thin Overlay
	884	Wearing surface - Rigid Overlay
	885	Wearing Surface - Other

Element Data Collected During Inspections

Table 1. Bridge Elements.

Element	Units	Element Number					
		Steel	Prestressed Concrete	Reinforced Concrete	Timber	Masonry	Other
Deck/Slab							
Deck	SF		13	12	31		60
Open Grid Deck	SF	28					
Concrete Filled Grid Deck	SF	29					
Corrugated or Orthotropic Deck	SF	30					
Slab	SF			38	54		65
Top Flange	SF		15	16			
Superstructure							
Closed Web/Box Girder	LF	102	104	105			106
Girder/Beam	LF	107	109	110	111		112
Stringer	LF	113	115	116	117		118
Truss	LF	120			135		136
Arch	LF	141	143	144	146	145	142
Main Cable	LF	147					
Secondary Cable	EA	148					149
Floor Beam	LF	152	154	155	156		157
Pin, Pin and Hanger Assembly	EA	161					
Gusset Plate	EA	162					
Substructure							
Column	EA	202	204	205	206		203
Column Tower (Trestle)	LF	207			208		
Pier Wall	LF			210	212	213	211
Abutment	LF	219		215	216	217	218
Pile Cap/Footing	LF			220			
Pile	EA	225	226	227	228		229
Pier Cap	LF	231	233	234	235		236
Culvert							
Culvert	LF	240	245	241	242	244	243
Bridge Rail							
Bridge Rail	LF	330*		331	332	334	333
Joint							
Strip Seal	LF	300					
Pourable	LF	301					
Compression	LF	302					
Assembly with Seal (Modular)	LF	303					
Open	LF	304					
Assembly without Seal	LF	305					
Other	LF	306					
Bearing							
Elastomeric	EA	310					
Movable (roller, sliding, etc.)	EA	311					
Enclosed/Concealed	EA	312					
Fixed	EA	313					
Pot	EA	314					
Disk	EA	315					
Other	EA	316					

Virginia Health Index: Example Equation

If a structure has the following characteristics:

- **0 to 100 scale**
- **0 means no health left (failed)**
- **100 for a new (ideal) structure**
- **Example: If a structure has deteriorated 32%, the VAHI = 68 (68 = 100 - 32)**

$$VAHI = \frac{\Sigma\,(VAHI_{Element} * Replacement\ Value_{Element})}{\Sigma\ Replacement\ Value_{Elements}}$$

If Σ Superstructure Value = 0, then deck = 0

If Σ Substructure Value = 0, then deck and superstructure = 0

Equity Determination: Example Equation

Equity = VAHI * Structure Replacement Cost

Example Structure:

VAHI= 78

Replacement Value = $2,000,000

Equity = .78 * 2,000,000 = $1,560,000

Virginia Health Index: Example Calculation #1

Element Name	$VAHI_{Element}$	Element Replacement Value	VAHI * Replacement Value
Columns	63	$25,000	$15,750
Pier Caps	54	$30,000	$16,200
Abutments	75	$60,000	$45,000
Girders	83	$160,000	$132,800
Diahragms	86	$30,000	$25,800
Deck	92	$180,000	$165,600
Joints	65	$30,000	$19,500
Parapet	92	$40,000	$36,800
Sum	**-**	**$555,000**	**$457,450**

VAHI = $457,450 ÷ $555,000 = 82

Virginia Health Index: Example Calculation #2

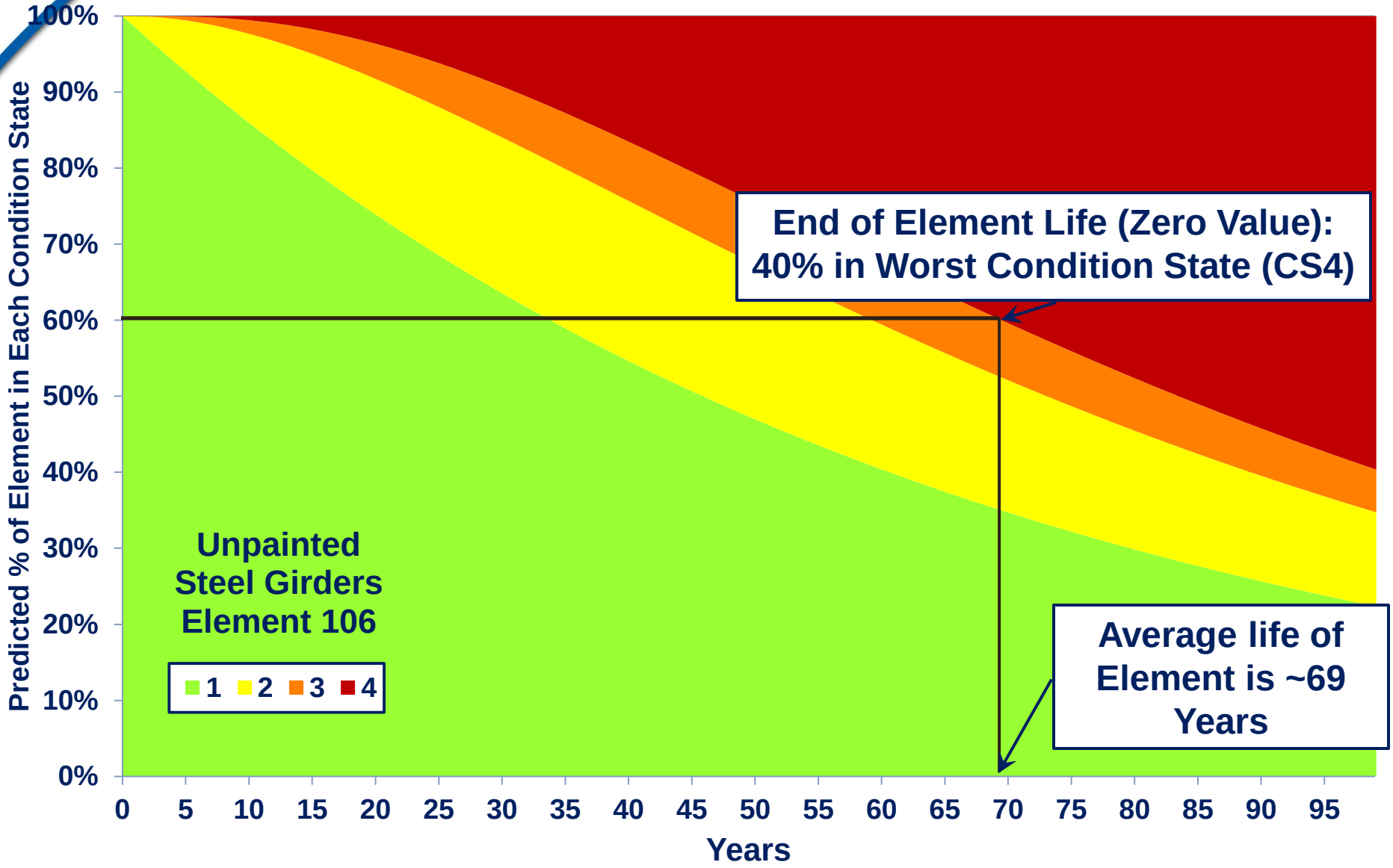
Element Name	$VAHI_{Element}$	Element Replacement Value	VAHI * Replacement Value
Columns	63	$25,000	$15,750
Pier Caps	54	$30,000	$16,200
Abutments	75	$60,000	$45,000
Girders	83	$160,000	$132,800
Diahragms	86	$30,000	$25,800
Deck	0	$180,000	$0
Joints	0	$30,000	$0
Parapet	0	$40,000	$0
Sum	**-**	**$555,000**	**$235,550**

Note: Replacement Cost of Bridge < ΣElement Replacement Values

VAHI = $235,550 ÷ $555,000 = 42

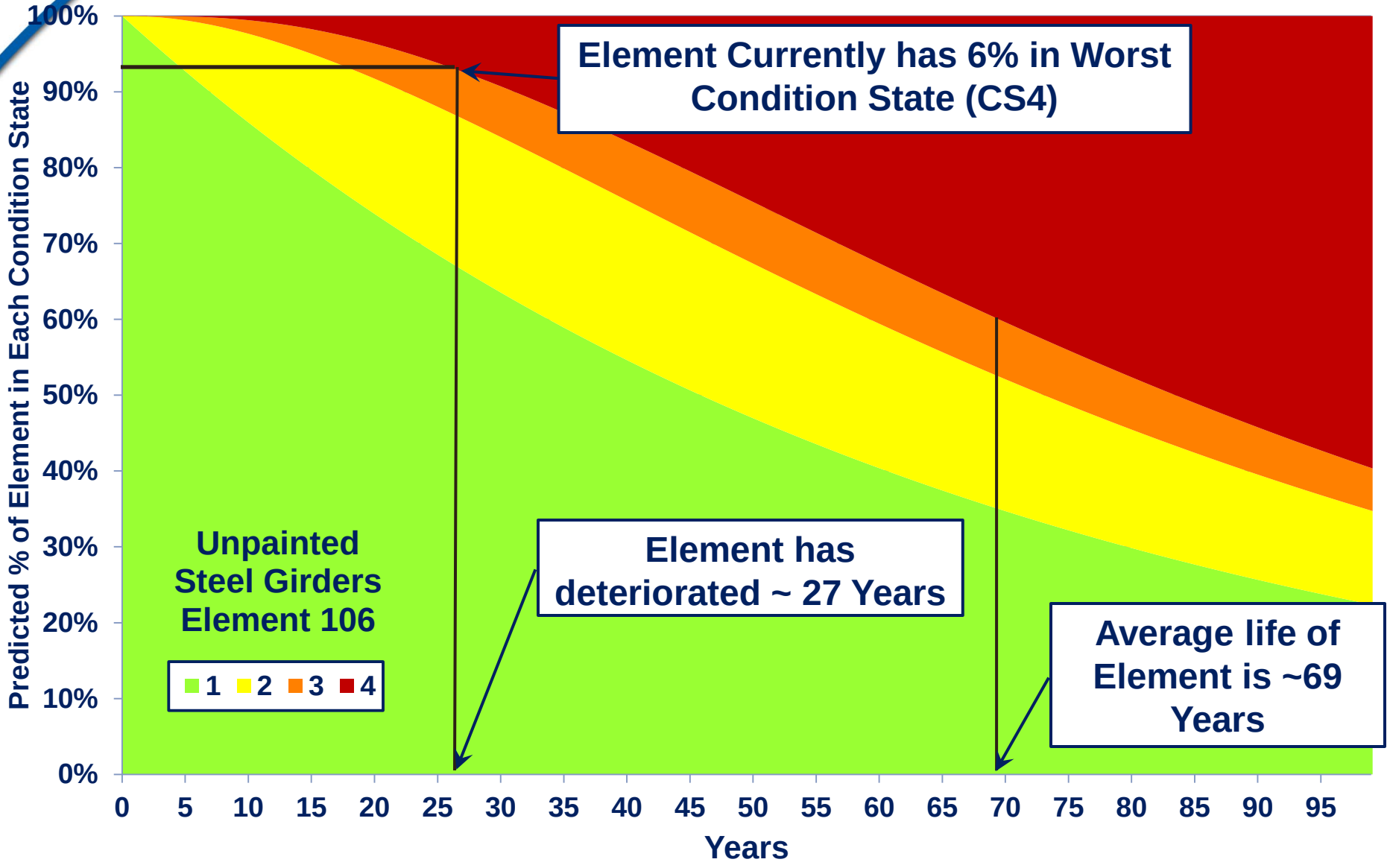
Using Deterioration Models to Determine Current Value:

Step 1: Define End of Life of Elements in Terms of Condition States



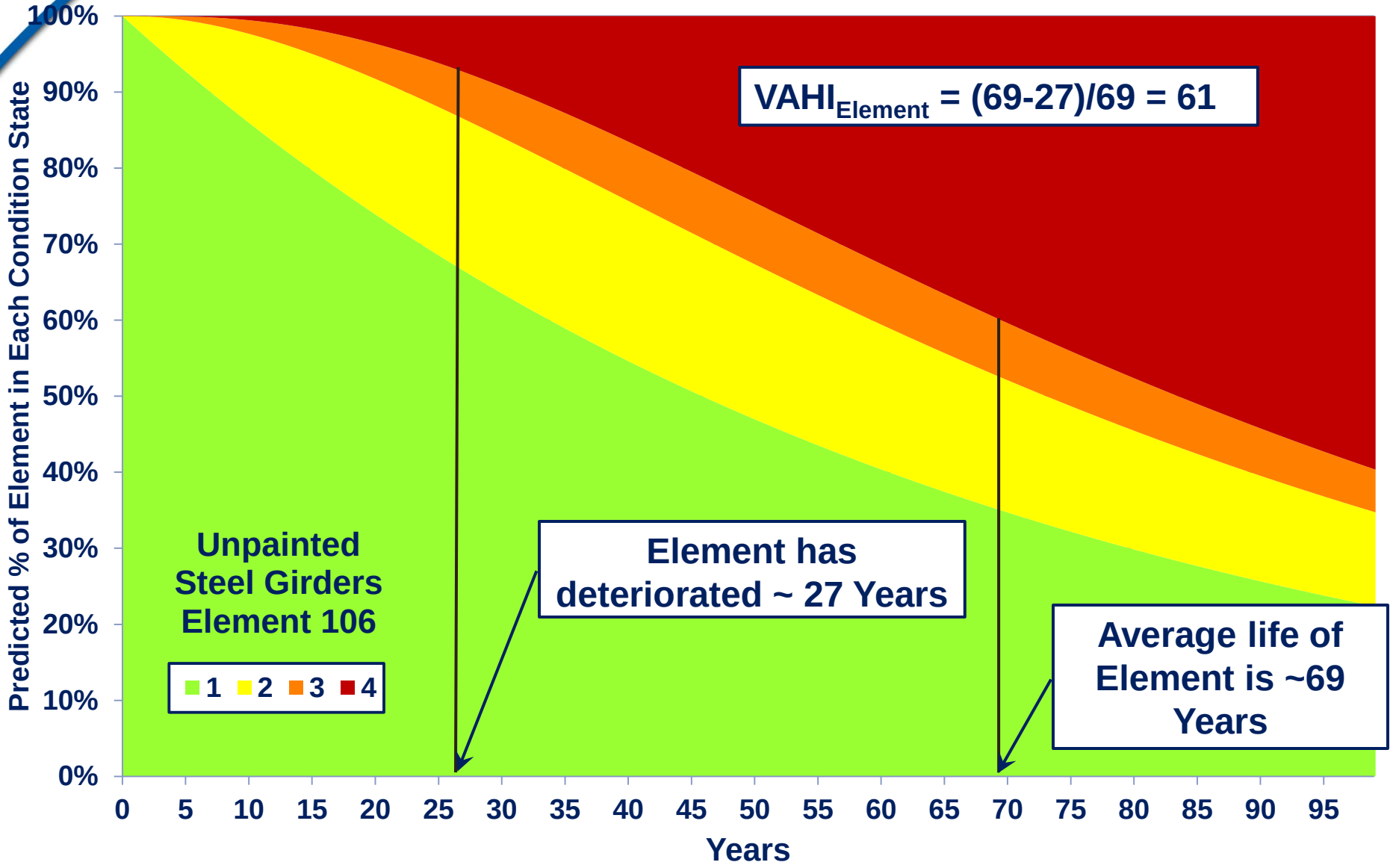
Using Deterioration Models to Determine Current Value:

Step 2: Determine Current Value in Terms of Current Condition



Using Deterioration Models to Determine Current Value:

Step 3: Determine VAHI for Each Element



Equity – Multiple Uses

Equity can be a powerful tool in guiding bridge management

- **Can determine the most cost-effective actions on a given structure**
- **Helpful in selecting which structures should be worked on**
- **Can be used to measure effectiveness of various work programs**
- **Helpful as a measurement of progress**

Virginia Department of Transportation

Thank you for your time and attention

Questions??

2015 Virginia Concrete Conference

VDOT's Experience with Reinforced Concrete and Metal Culverts

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