



Middle Aged Deck Preservation

When to overlay or replace?

By Bruce Thill

Washington State DOT (WSDOT)

Bridge Asset Manager

May 2013

WBPP

Mission Statement



- Provide a platform ... to exchange, promote, and advance best practices, new technologies, and innovation ...

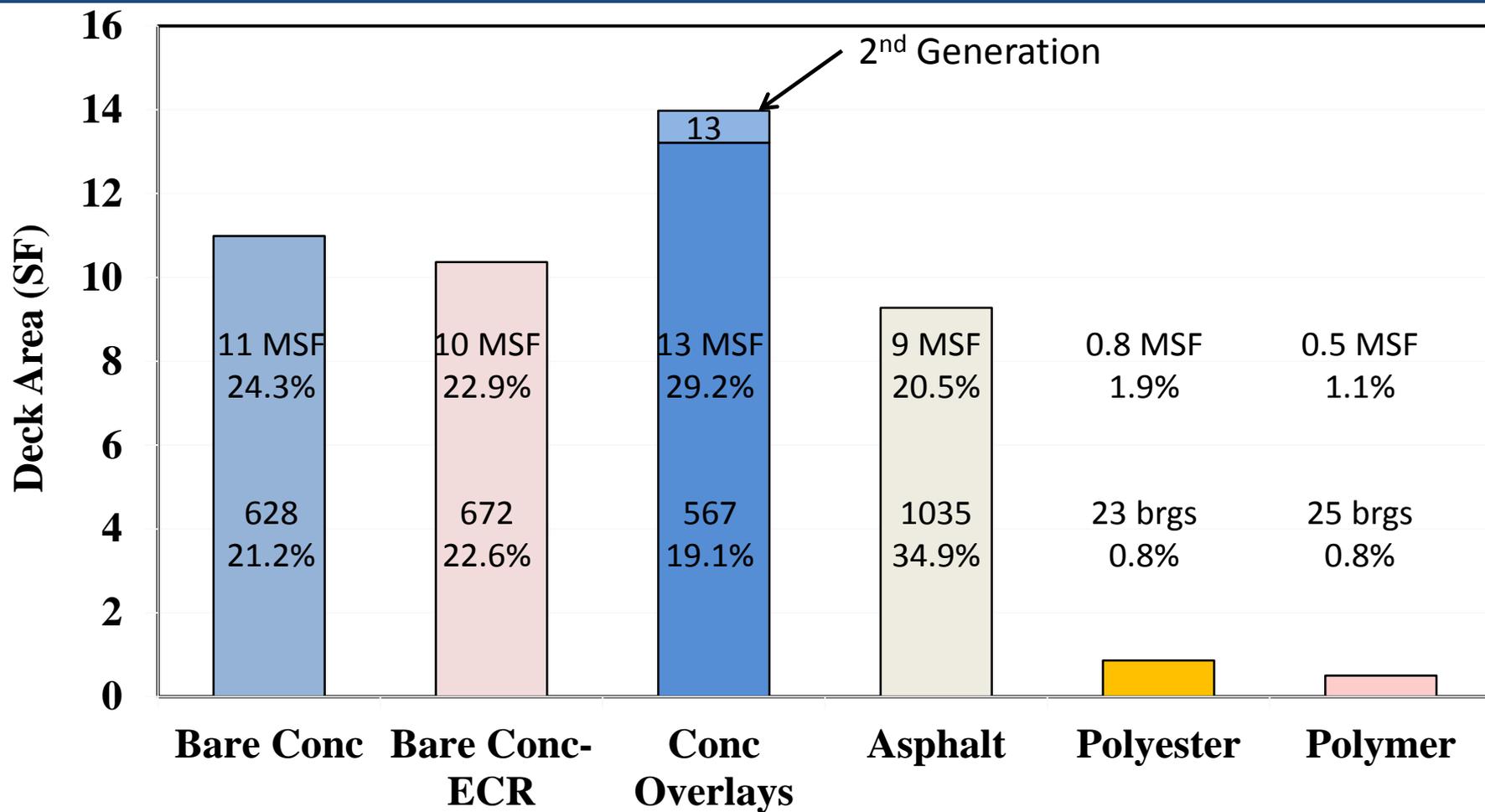
Deck Preservation Agenda

- WSDOT Deck History and Data
- Deck Theory & Management
 - Concrete Overlays vs. Deck Replacement
 - WSDOT Data triggers for optimum timing.
- Calibration Examples and Field conditions
- Forecasting /Managing the Deck Inventory



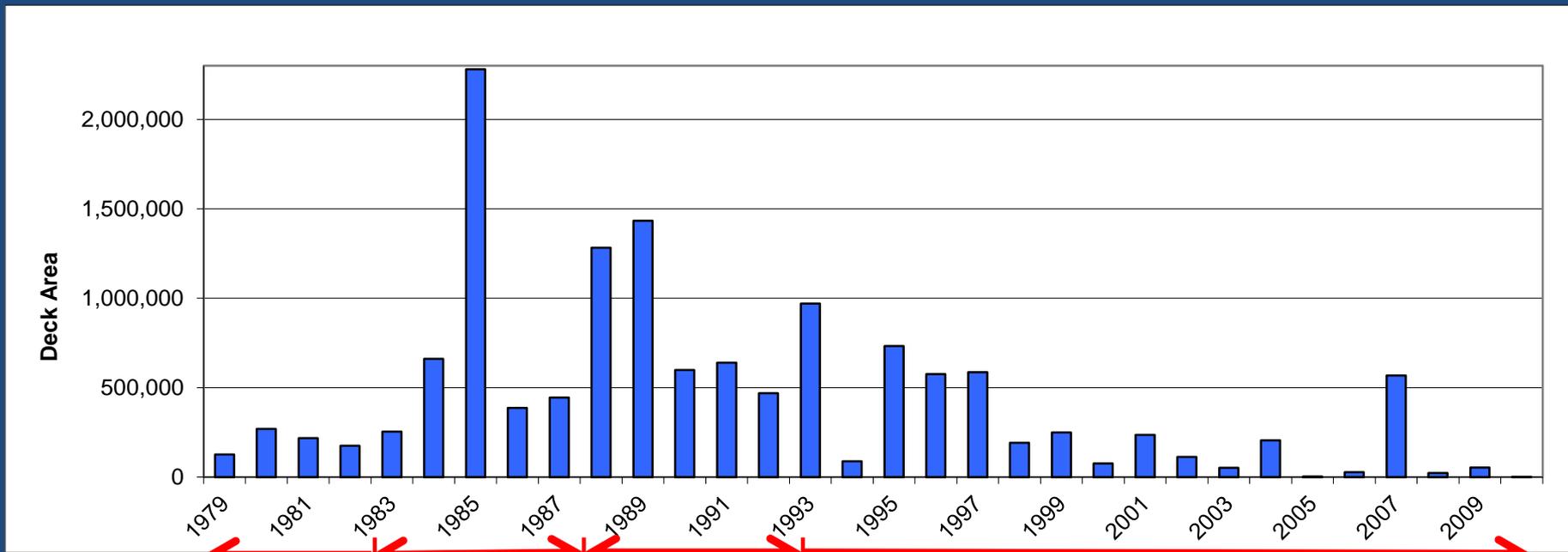
Washington State's Concrete Bridge Deck Program

2,962 Bridges with Concrete Decks



WSDOT Concrete Overlay History

Expected Life = 25-30 years



> 30 yrs

25-30 yrs

20 - 25 yrs

< 20 yrs

25 brgs

140 brgs

189 brgs

226 brgs

Total Overlays = 580

\$0.6M

\$375M

\$440M

\$440M

Overlay Area = 14.1 MSF

4.3%

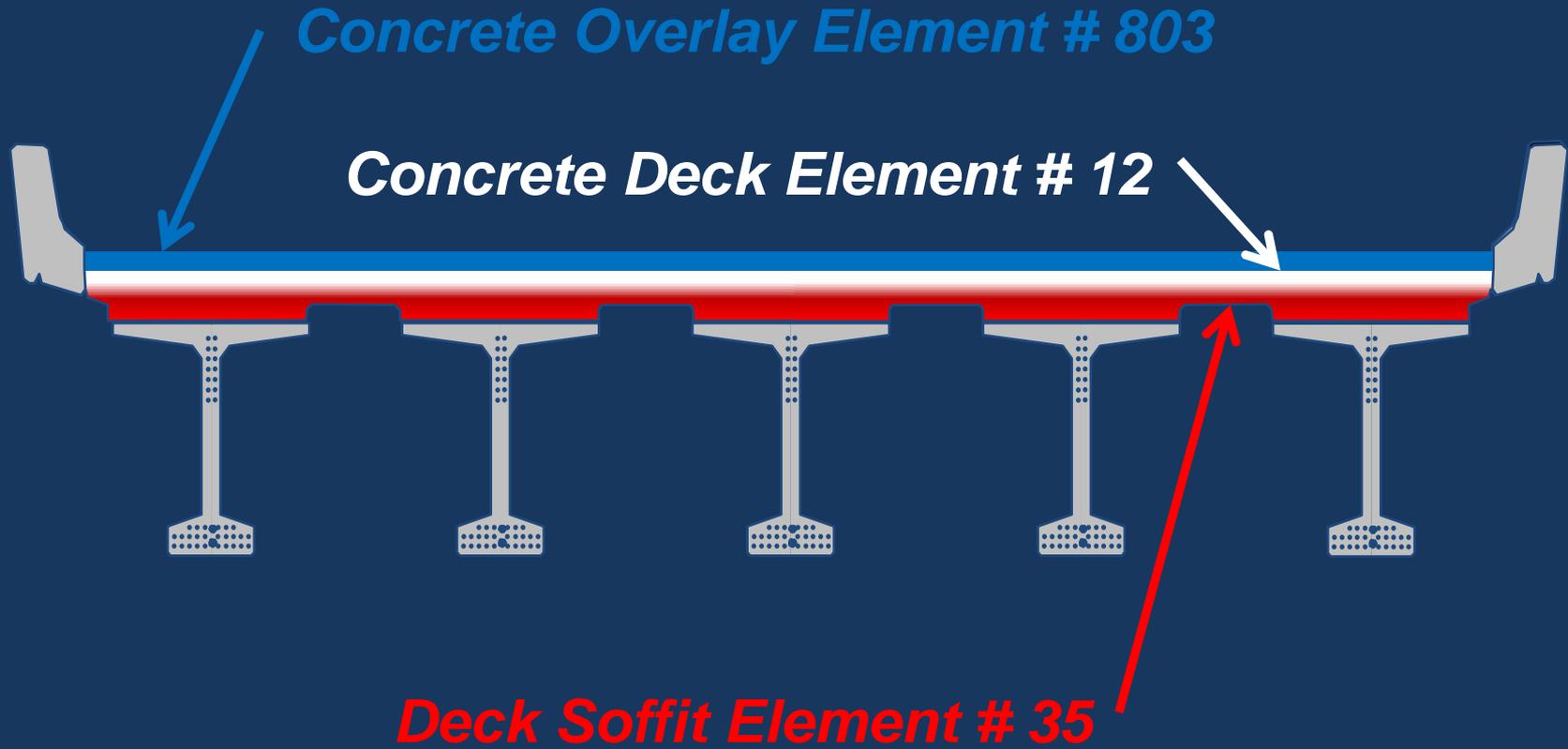
24.1%

32.5%

38.9%

2nd Gen. Overlays = 13 or 2%

WSDOT Deck & Overlay Elements



WSDOT Deck Data Definitions

Deck & Overlay

Condition State 1
Good



Condition State 2
Patches



Condition State 3
Spalling



Soffit

Condition State 1
Good



Condition State 2
Patches



Condition State 3
Structural

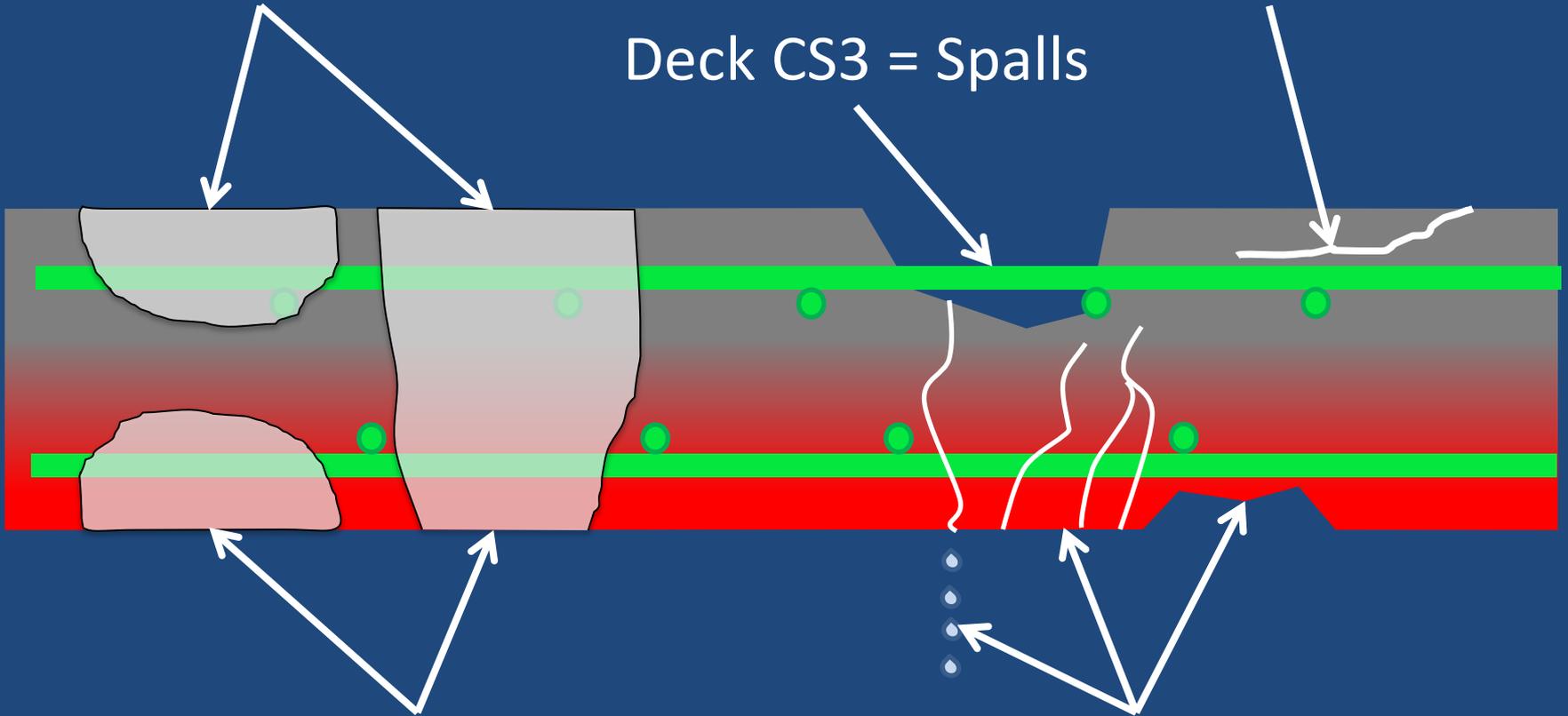


WSDOT Deck Element - Top Mat

Deck CS2 = Patches

Deck CS4 = Delams

Deck CS3 = Spalls



Soffit CS2 = Patches

Soffit CS3 = Any sign of Capacity loss

Raw Data: Sorted on % Patching (CS2)

Bridge Nu	Bridge Name	€	Total	qty_1	Patch SF	Spall SF	Delam SF	qty_4	%CS1	Patch	Spall	Delam
										%	%	%
142/9	KLICKITAT R	12	1568	581	985	2	0	37.05%	62.82%	0.13%	0.00%	
2/215	WENATCHEE R	12	6312	1649	2240	0	2423	26.12%	35.49%	0.00%	38.39%	
90/316N	I-90 OVER PAHA PACKARD	12	3990	2762	1053	12	163	69.22%	26.39%	0.30%	4.09%	
261/120	TUCANNON R	12	5486	4204	1222	27	33	76.63%	22.27%	0.49%	0.60%	
90/316S	I-90 OVER N PAHA PACKARD	12	3990	3040	864	3	83	76.19%	21.65%	0.08%	2.08%	
2/212	CHIWAUKUM CR	12	3384	2798	586	0	0	82.68%	17.32%	0.00%	0.00%	
90/156S	DRY CR	12	11700	6811	1900	485	2504	58.21%	16.24%	4.15%	21.40%	
290/2W-W	W-W RAMP OVER 2ND AVE	12	6600	3501	1036	0	2063	53.05%	15.70%	0.00%	31.26%	
101/44	BONE R	12	7128	6428	650	50	0	90.18%	9.12%	0.70%	0.00%	
90/150S	TANEUM CR	12	3942	2880	355	10	697	73.06%	9.01%	0.25%	17.68%	
195/52	US 195 OVR JOHN WAYNE TR	12	5680	5207	473	0	0	91.67%	8.33%	0.00%	0.00%	
90/120N	YAKIMA R	12	12458	11341	1006	0	111	91.03%	8.08%	0.00%	0.89%	
90/156N	DRY CR	12	11700	9064	893	0	1743	77.47%	7.63%	0.00%	14.90%	
900/30	SR 900 OVER I-90	12	17424	16126	1298	0	0	92.55%	7.45%	0.00%	0.00%	
97/534	OKANOGAN R	12	11704	10881	819	4	0	92.97%	7.00%	0.03%	0.00%	

- Rank by SF patching for highest maintenance investment
- Rank by % patching for prioritization
- Rank bridges by spalling to indicate need and budget
 - WSDOT Maintenance Performance Grading (ABCDF)

Deck Condition Summary

No Defects

Patches

Spalls

Delams

Num = 950 brgs

Area = 26.2 MSF

% SF = (99.57%)

Cost =

387 brgs

52,368 SF

(0.20%)

\$5.2 M

289 brgs

9,332 SF

(0.04%)

\$0.9 M

254 brgs

50,310 SF

(0.19%)

Totals
1703 brgs

26.3 MSF

State 1

State 2

State 3

State 4

Patch Distribution

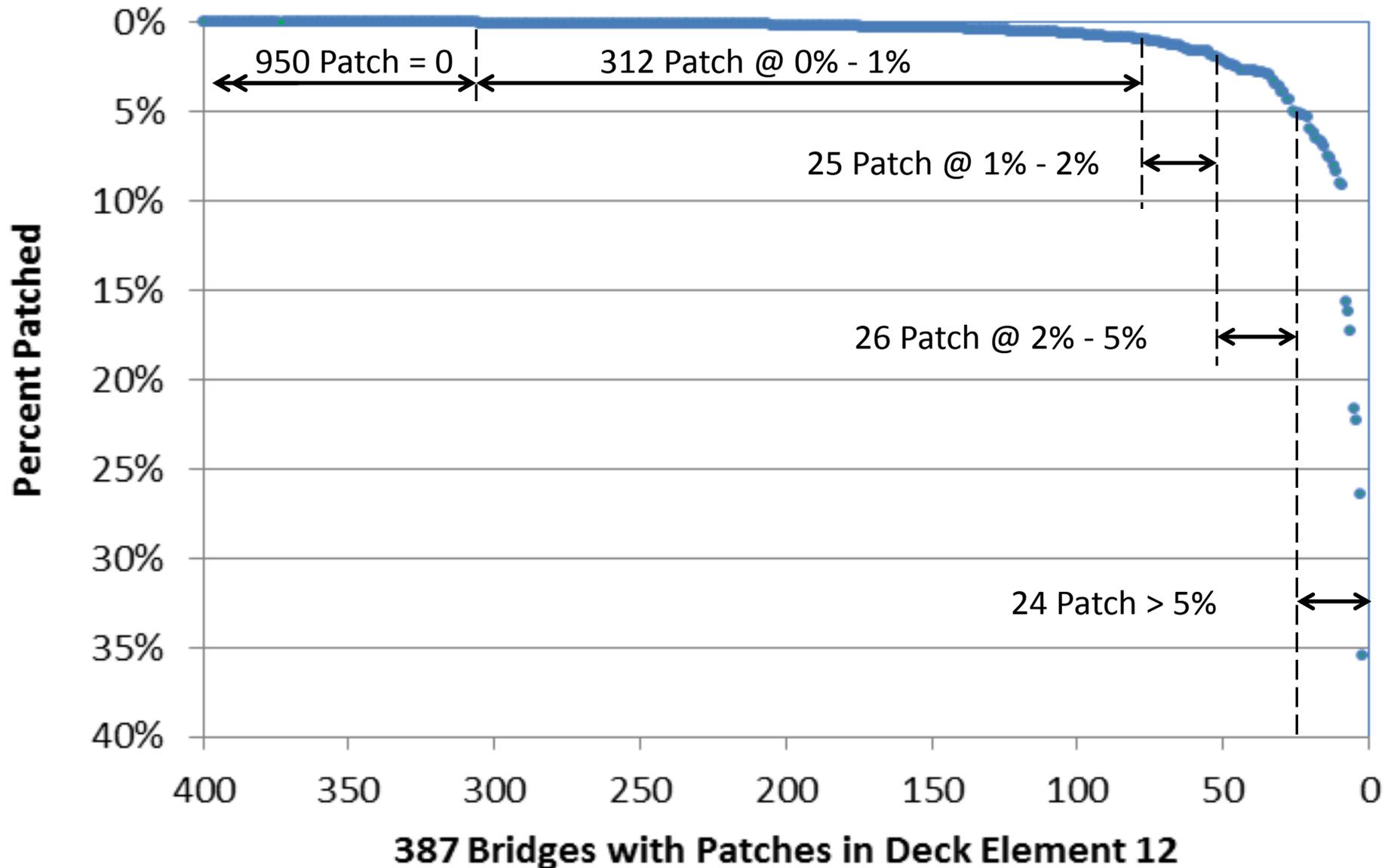
312 brgs @ 0% - 1%

25 brgs @ 1% - 2%

26 brgs @ 2% - 5%

24 brgs > 5%

Distribution of CS2 -Top 400

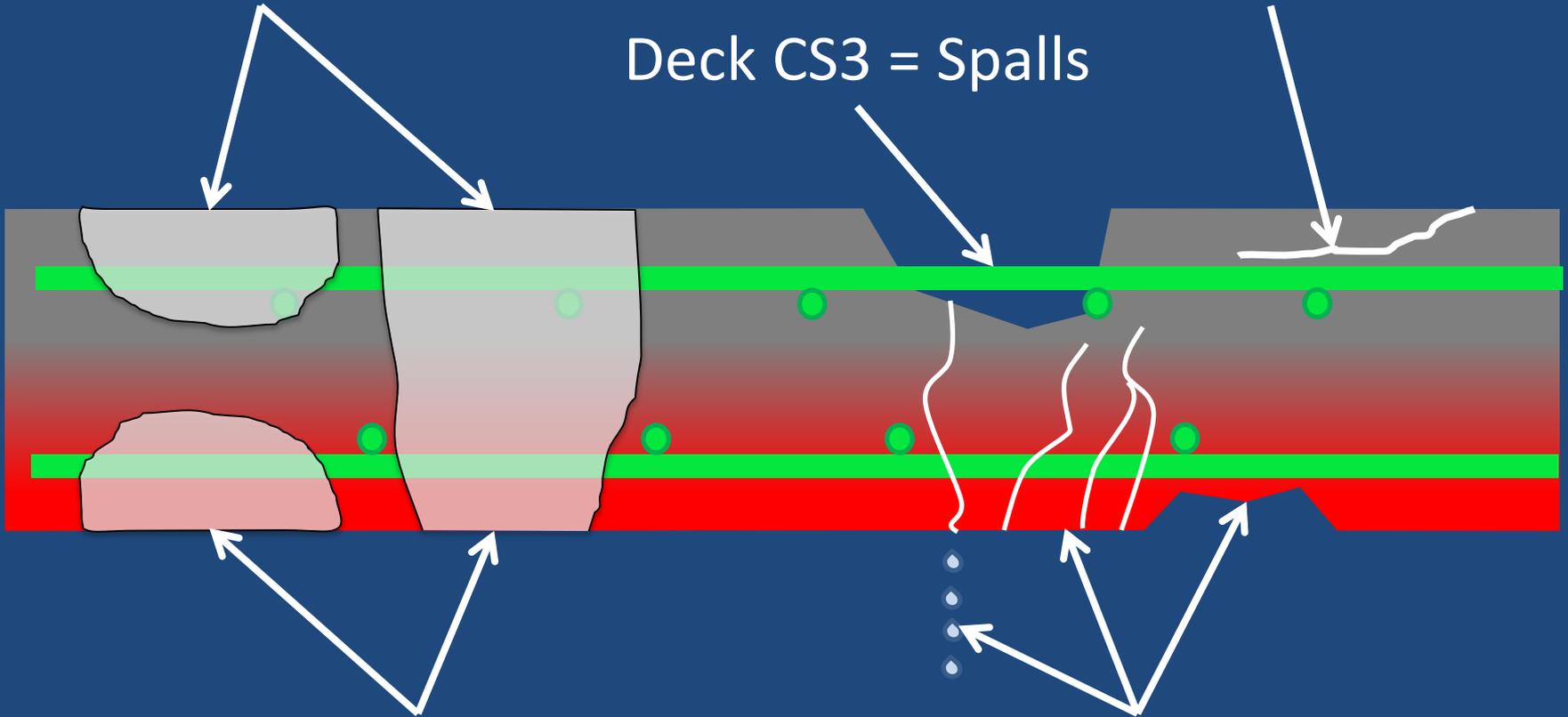


WSDOT Soffit Elem(SF)

Deck CS2 = Patches

Deck CS4 = Delams

Deck CS3 = Spalls



Soffit CS2 = Patches

Soffit CS3 = Any sign of Capacity loss

WSDOT Soffit Element Summaries

No Defects

Patches

Structural

39.9 MSF
(99.94%)
1705 brgs
73%

10,362 SF
(0.03%)
16 brgs > 2%

12,464 SF
(0.03%)
13 brgs >2%

311 brgs

516 brgs

State 1

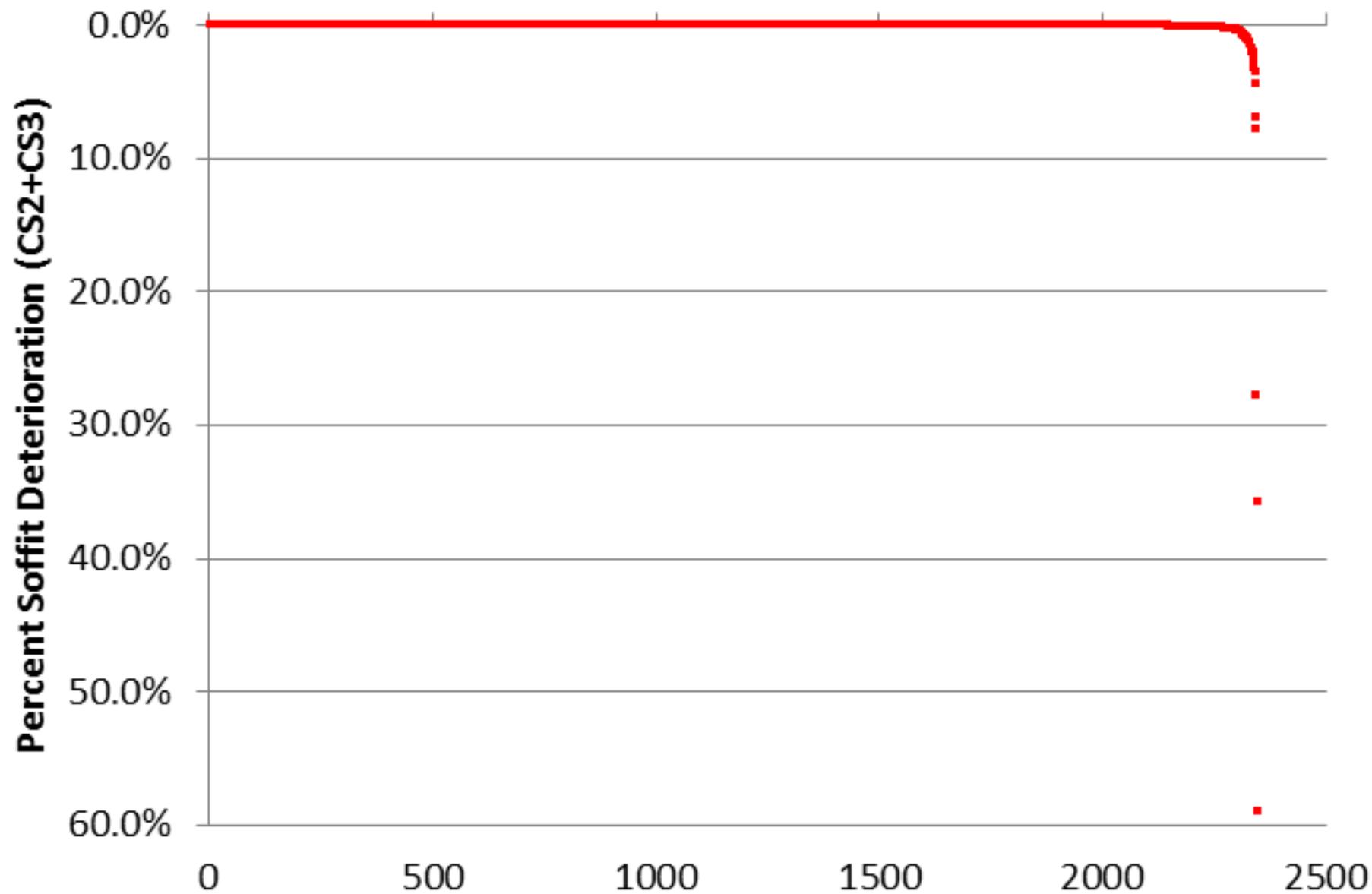
State 2

State 3

State 4

2349 Bridges @ 40.0 mil SF

Distribution of Soffit - 2349 brgs



12/309 Deck Repair – 5 SF?



01/29/2013 17:40

Soffit – CS2=10 SF, CS3=70 SF



Localized or Systemic



01/29/2013 18:19

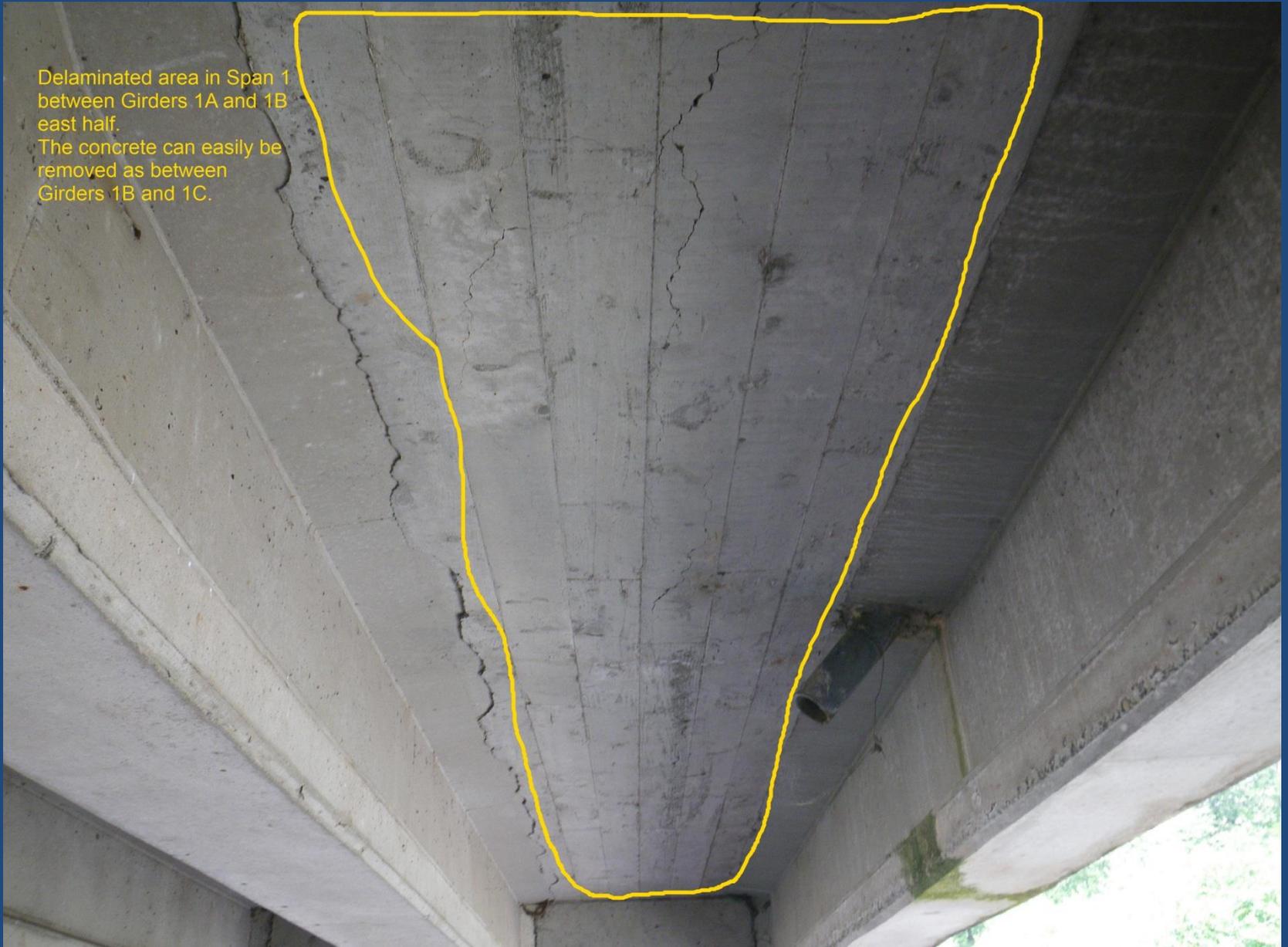
Soffit Stalactites & Rebar



- White stalactites are salts from the top.
- Not calcium from the concrete matrix.
- Brown = rust, asphalt or dirt.

Structural Problem in Soffit?

Delaminated area in Span 1
between Girders 1A and 1B
east half.
The concrete can easily be
removed as between
Girders 1B and 1C.

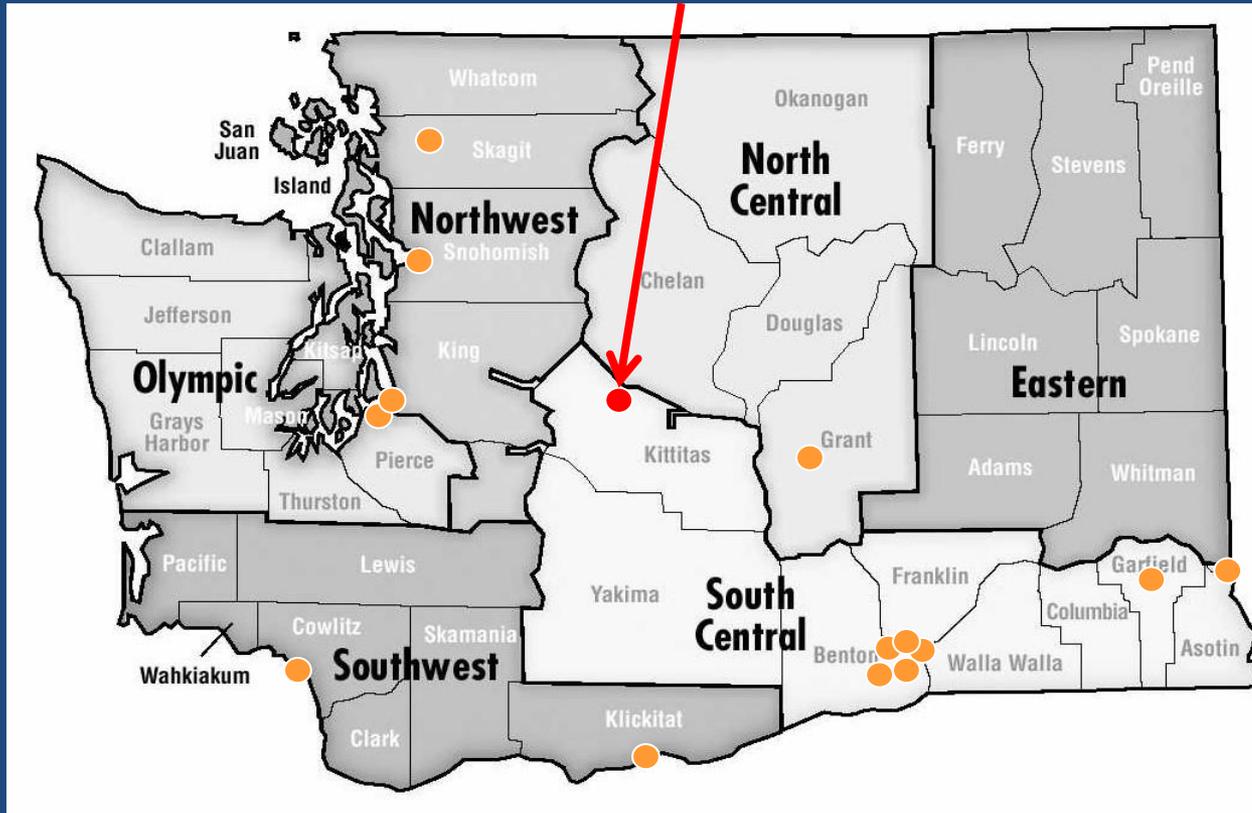


Exposed with little effort



Historical Deck Replacements = 13

10/143 Bristol Fill
Completed Nov 2012



Br Num	Yr	Length
9/130	1991	344
12/512N	1987	1,270
82/280S	1988	1,471
97/1	2009	2,567
240/32W	1989	244
281/1	1990	196
395/16	1988	72
395/40	1986	2,451
397/10	1995	261
433/1	2004	5,478
509/101	1995	562
509/103	1995	264
529/10E	1994	1,544

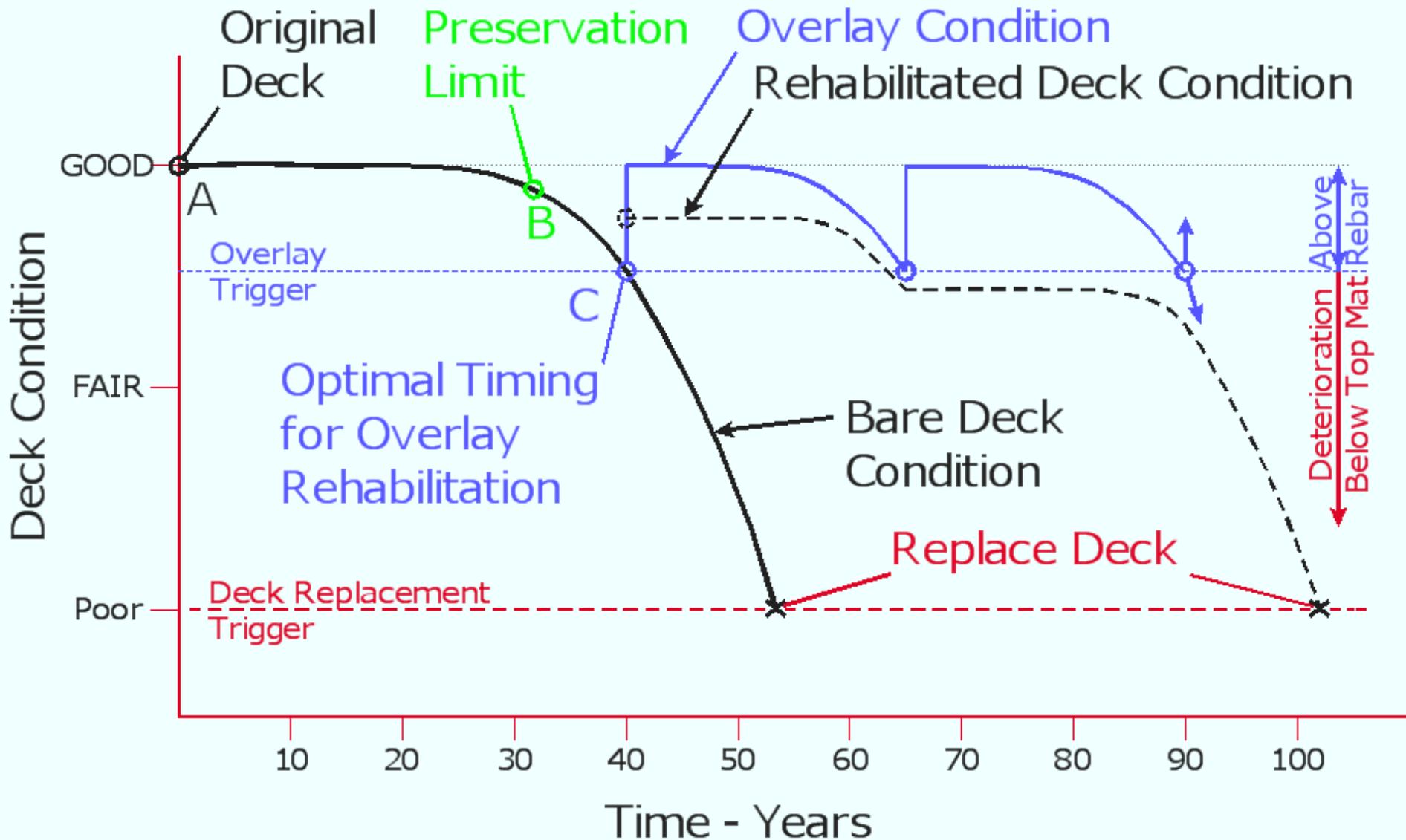
14 bridges (588,536 sq ft) or 1.3% of total Statewide Deck Area



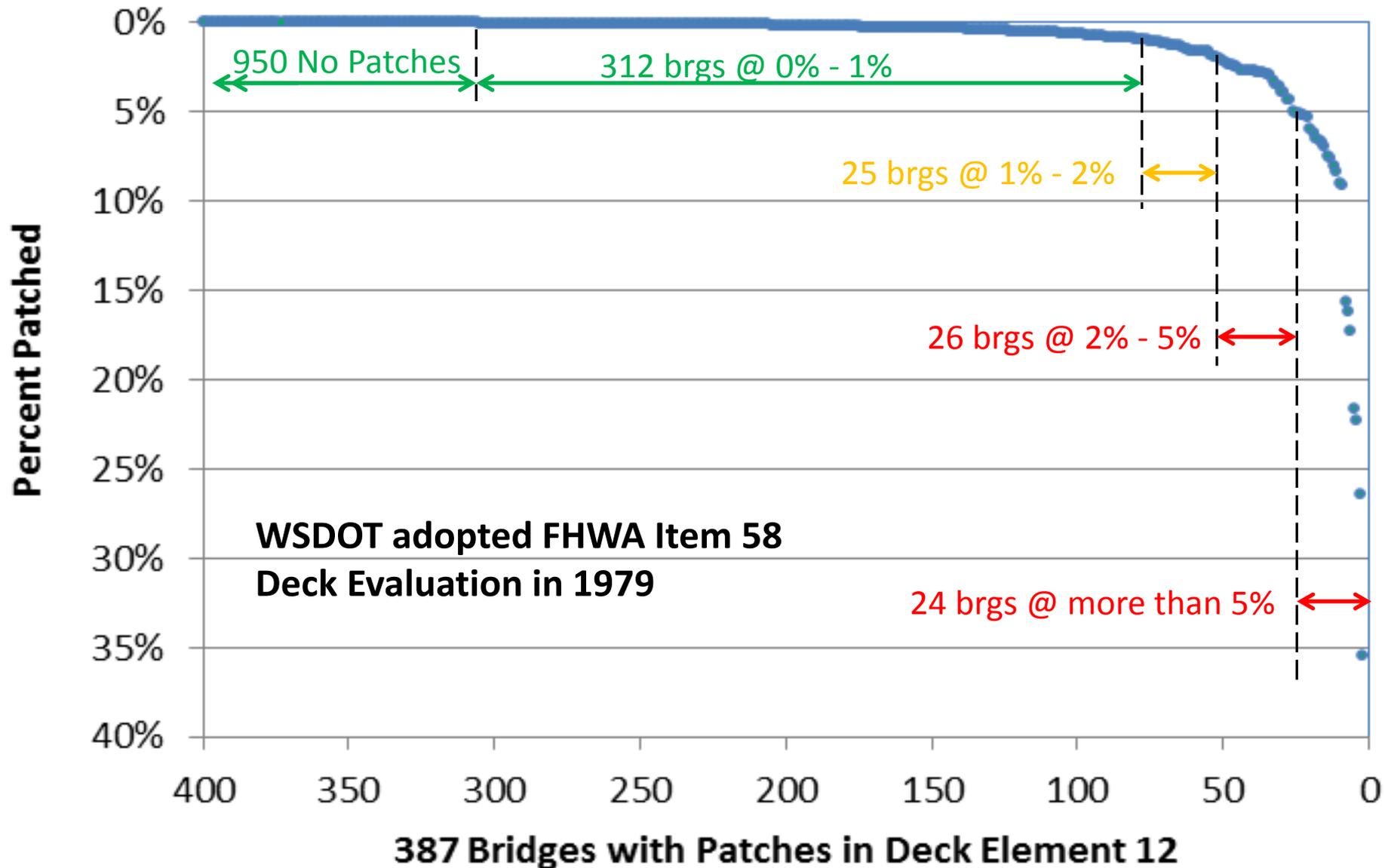
Deck Management Theory Based on Data

- Historically concrete overlays last 25-30 years?
- When to do a concrete overlay?
- When to Replace the Deck?

General Deck & Overlay Theory



Distribution of CS2 -Top 400



WSDOT Deck Assessment

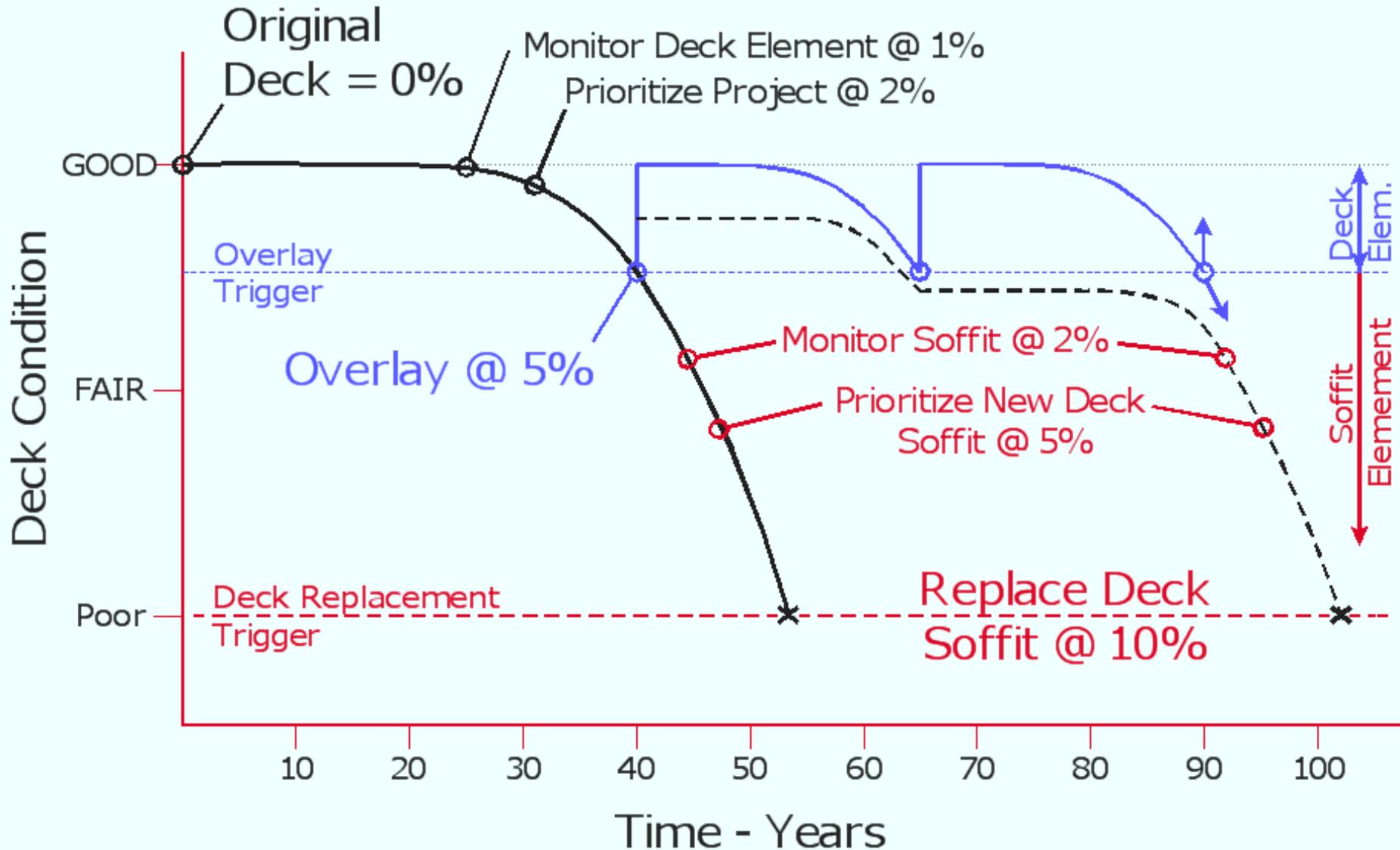
Deck – Top Surface

Deck Assessment For Concrete Overlay	Percent of Deck Patches & Spalls (CS2 + CS3)
Good Deck Condition	< 1%
Monitor for Overlay	1% - 2%
Prioritize for Overlay	2% - 5%
Prioritize for Replacement	> 10 %

Soffit – Bottom Surface

Deck Assessment For Replacement	Percent of Soffit in Distress (CS3)
Good Structural Condition	< 2%
Monitor for Replacement	2% - 5%
Prioritize for Replacement	5% - 10%

WSDOT Data Triggers for Management



Alternate Theories - NBI Data?

TRB 2013: Journal No.2313

- How to Prioritize or Forecast NBI Deck 3, 4, & 5?
- How to decipher overlay from replacements?

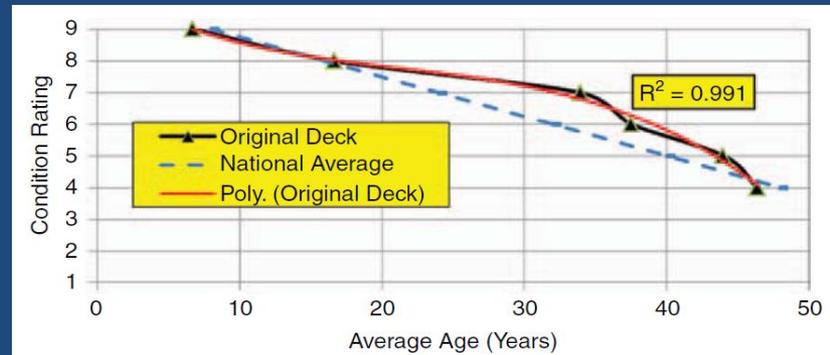
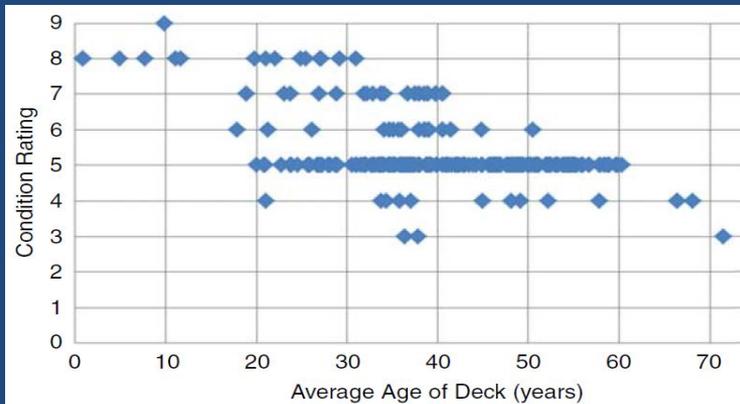


FIGURE 1 Original deck deterioration curve (Poly. = polynomial).

TABLE 4 Transition Probability Matrix for Decks in Severe Environment

Condition	Condition								
	9	8	7	6	5	4	3	2	1
9	0.66	0.34	0	0	0	0	0	0	0
8	0	0.90	0.10	0	0	0	0	0	0
7	0	0	0.68	0.32	0	0	0	0	0
6	0	0	0	0.77	0.23	0	0	0	0
5	0	0	0	0	0.73	0.27	0	0	0
4	0	0	0	0	0	0.70	0.30	0	0
3	0	0	0	0	0	0	0.90	0.10	0
2	0	0	0	0	0	0	0	0.99	0.01
1	0	0	0	0	0	0	0	0	1.00

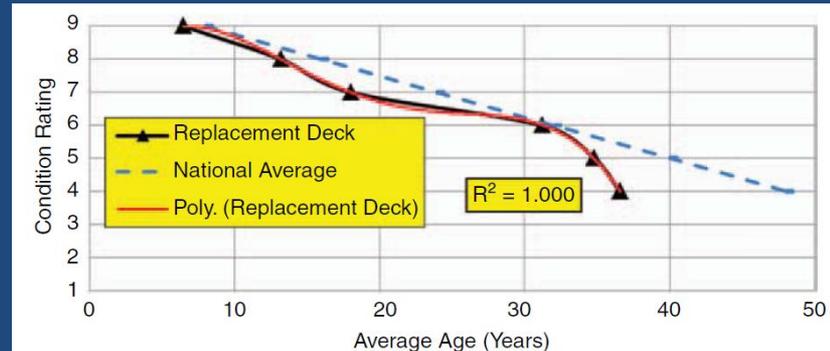


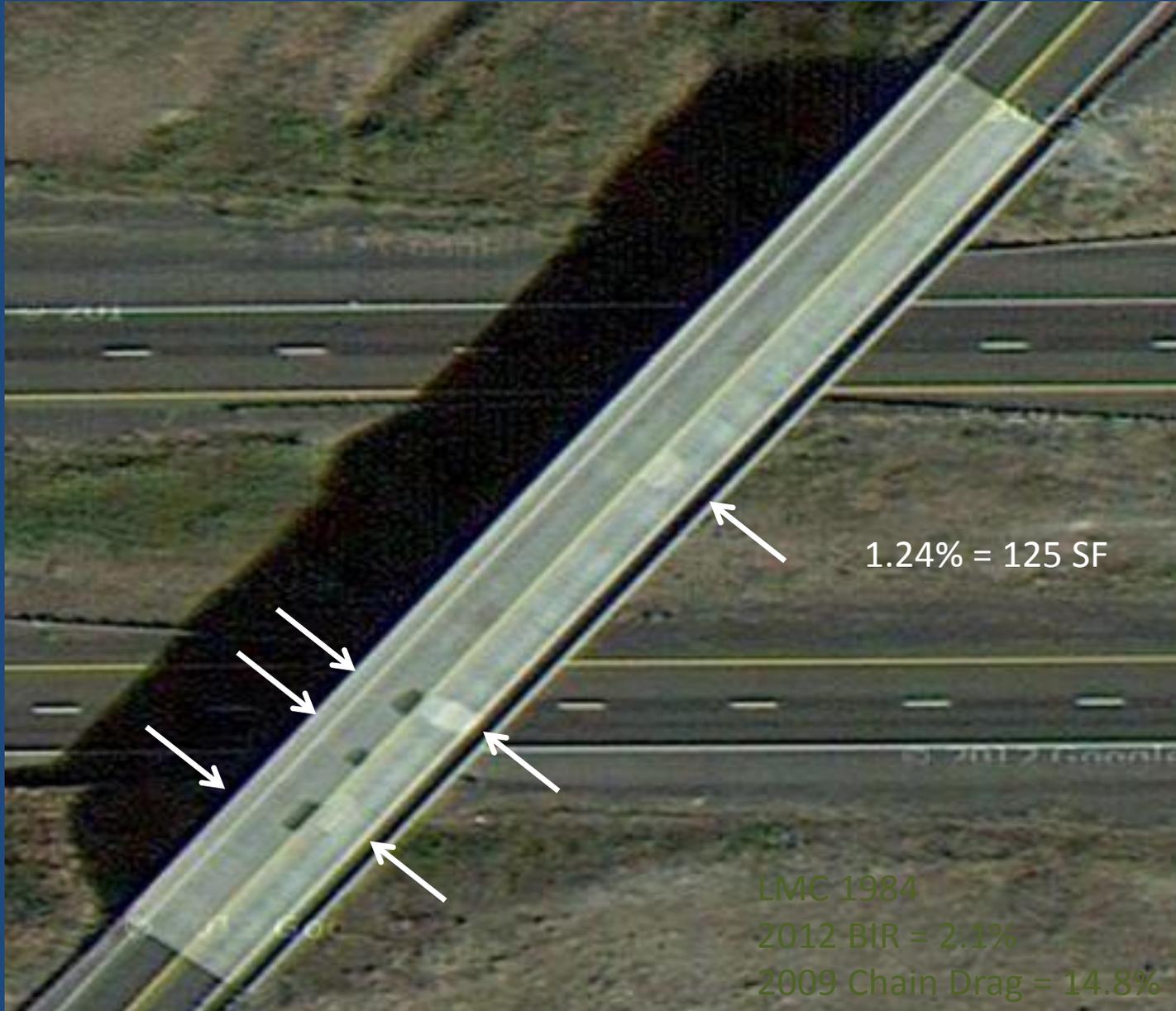
FIGURE 2 Replacement deck deterioration curve.



Field Calibration

- What does 1%, 2%, 5% Patching look like?

395/212N-W Monitor @ 1.24%



90/336S – Prioritize @ 2%

- 2008 = 1.1%
- 2009 Patches Shown = 3.0%



Raw Data – #31 Sorted on Patching

Bridge Nu	Bridge Name	Total	qty_1	qty_2	qty_3	qty_4	%CS1	%CS2	%CS3	%CS4	
142/9	CLICKITAT R	12	1568	581	985	2	0	37.05%	62.82%	0.13%	0.00%
2/215	WENATCHEE R	12	6312	1649	2240	0	2423	26.12%	35.49%	0.00%	38.39%
90/316N	I-90 OVER PAHA PACKARD	12	3990	2762	1053	12	163	69.22%	26.39%	0.30%	4.09%
261/120	TUCANNON R	12	5486	4204	1222	27	33	76.63%	22.27%	0.49%	0.60%
90/316S	I-90 OVER N PAHA PACKARD	12	3990	3040	864	3	83	76.19%	21.65%	0.08%	2.08%
2/212	CHIWAUKUM CR	12	3384	2798	586	0	0	82.68%	17.32%	0.00%	0.00%
90/156S	DRY CR	12	11700	6811	1900	485	2504	58.21%	16.24%	4.15%	21.40%
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900/30	SR 900 OVER I-90	12	17424	16126	1298	0	0	92.55%	7.45%	0.00%	0.00%
97/534	OKANOAGAN R	12	11704	10881	819	4	0	92.97%	7.00%	0.03%	0.00%
82/213S	CHANDLER CANAL BRIDGE	12	4294	3992	290	12	0	92.97%	6.75%	0.28%	0.00%
195/49	PINE CR #1	12	12000	11200	800	0	0	93.33%	6.67%	0.00%	0.00%
12/329	COWICHE CR	12	4452	4152	290	10	0	93.26%	6.51%	0.22%	0.00%
162/22	SPIKETON CREEK	12	4882	3582	300	0	1000	73.37%	6.15%	0.00%	20.48%
90/154N	YAKIMA R	12	17850	16760	1069	0	21	93.89%	5.99%	0.00%	0.12%
90/140N	YAKIMA R	12	11700	11076	624	0	0	94.67%	5.33%	0.00%	0.00%
90/512S	I-90 OVER RAILROAD	12	5475	4578	288	220	389	83.62%	5.26%	4.02%	7.11%
90/314S	I-90 OVER N WAHL RD	12	4826	4459	250	48	69	92.40%	5.18%	0.99%	1.43%
90/78N	I-90 OVER SR 18	12	11060	10336	564	160	0	93.45%	5.10%	1.45%	0.00%
110/15	BOGACHIEL RIVER	12	5018	4366	255	0	397	87.01%	5.08%	0.00%	7.91%
90/96.5N	I-90 OVER DENNY CREEK RD	12	12688	12022	630	36	0	94.75%	4.97%	0.28%	0.00%
90/512N	BN RR OC (NP)	12	5475	5072	240	70	93	92.64%	4.38%	1.28%	1.70%
18/17S	GREEN R (NEELEY BRIDGE)	12	10945	10468	475	2	0	95.64%	4.34%	0.02%	0.00%
5/707	BLACKBURN ST OVER I-5	12	5148	4948	200	0	0	96.11%	3.89%	0.00%	0.00%
82/217	SR 22 OVER I-82	12	17332	16572	670	48	42	95.62%	3.87%	0.28%	0.24%
18/31N	SR 18 OVER HOBART RD/CRK	12	12251	11776	435	40	0	96.12%	3.55%	0.33%	0.00%
5/534S-W	S-W RAMP OVER LUCILE ST	12	17050	16045	591	2	412	94.11%	3.47%	0.01%	2.42%
22/7	SLOUGH OF YAKIMA R	12	2760	2182	90	2	486	79.06%	3.26%	0.07%	17.61%
290/1W-W	W-W RAMP OVER SR 290 WB	12	19684	17806	582	0	1296	90.46%	2.96%	0.00%	6.58%
101/316	SOL DUC RIVER	12	5808	5637	171	0	0	97.06%	2.94%	0.00%	0.00%
82/280S	COLUMBIA R BR @ UMATILLA	12	52800	50520	1497	783	0	95.68%	2.84%	1.48%	0.00%
97/512	GRIGGS CANYON	12	3180	3090	90	0	0	97.17%	2.83%	0.00%	0.00%
97/103	SATUS CR 3RD CROSSING	12	8316	8055	235	15	11	96.86%	2.83%	0.18%	0.13%
90/136S	I-90 OVR CLE ELUM RD, RR	12	12750	12390	350	10	0	97.18%	2.75%	0.08%	0.00%
9/315	N FK NOOKSACK R U S	12	10660	10368	292	0	0	97.26%	2.74%	0.00%	0.00%
12/282	CLEAR FORK CREEK	12	18260	17725	500	35	0	97.07%	2.74%	0.19%	0.00%
5/537E-E	6TH AVE S TO NB I-5	12	1303	1265	35	0	3	97.08%	2.69%	0.00%	0.23%
128/10	SNAKE R - RED WOLF BR	12	46400	42737	1246	44	2373	92.11%	2.69%	0.09%	5.11%
90/579E	ARGONNE RD OVER I-90	12	6720	6401	180	119	20	95.25%	2.68%	1.77%	0.30%
90/154S	YAKIMA R	12	17850	17380	436	0	34	97.37%	2.44%	0.00%	0.19%
90/150N	TANEUM CR	12	3942	3102	96	0	744	78.69%	2.44%	0.00%	18.87%
90/97.8N	FRANKLIN FALLS BR	12	36400	35510	868	22	0	97.55%	2.38%	0.06%	0.00%

18/31N Prioritized @ 2%

Polyester Overlay 1989: 435 SF = 3.55%



18/31N Deck View @ 3.55%



90/78N Contract @ 5%

- 2011 @ 5.1%



90/140N Contract @ 5%



90/140N = 5.33%
Contract

90/140S = 2.2%
Prioritize

90/154N Contract @ 5%



90/154N = 5.99%
Contract

90/154S = 2.44%
Prioritize



290/2W-W @ 15.7%

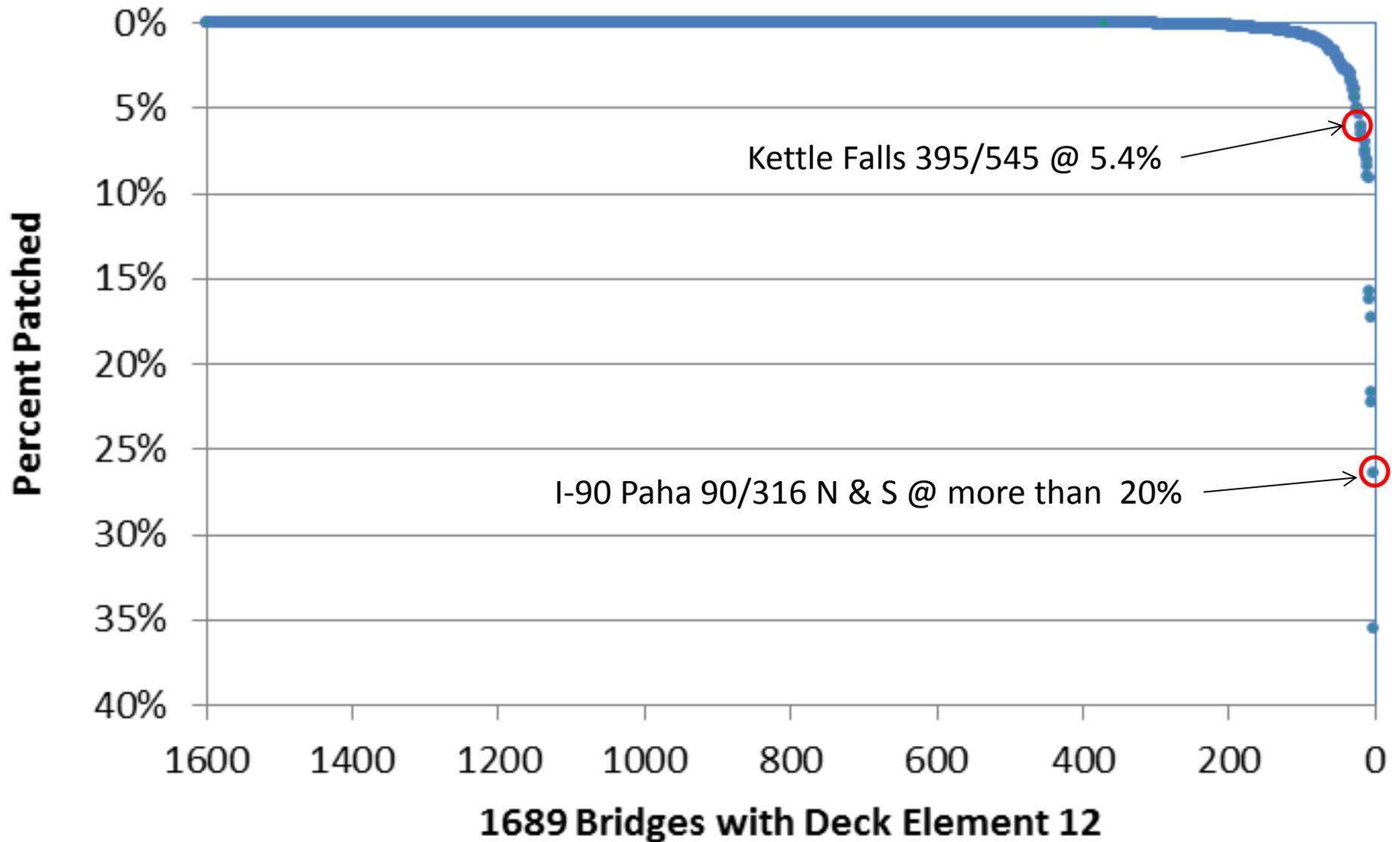




In Depth Examples

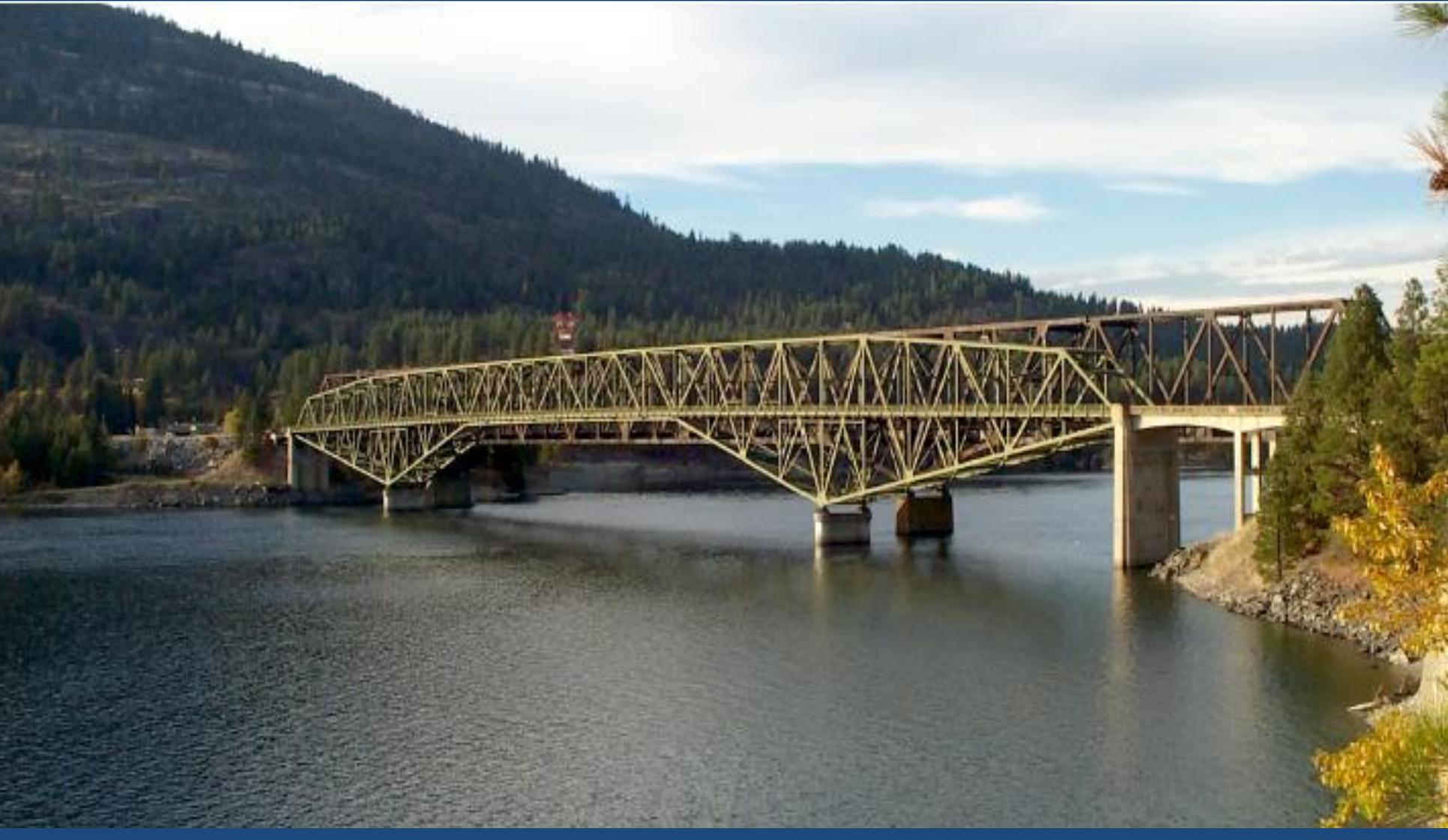
- Were these the right decisions?
- Kettle Falls 395/545: Overlay vs Replace Deck
- Paha 90/316N: No Action/Overlay/Replace

Distribution of Deck Patching (CS2)



Kettle Falls 398/545

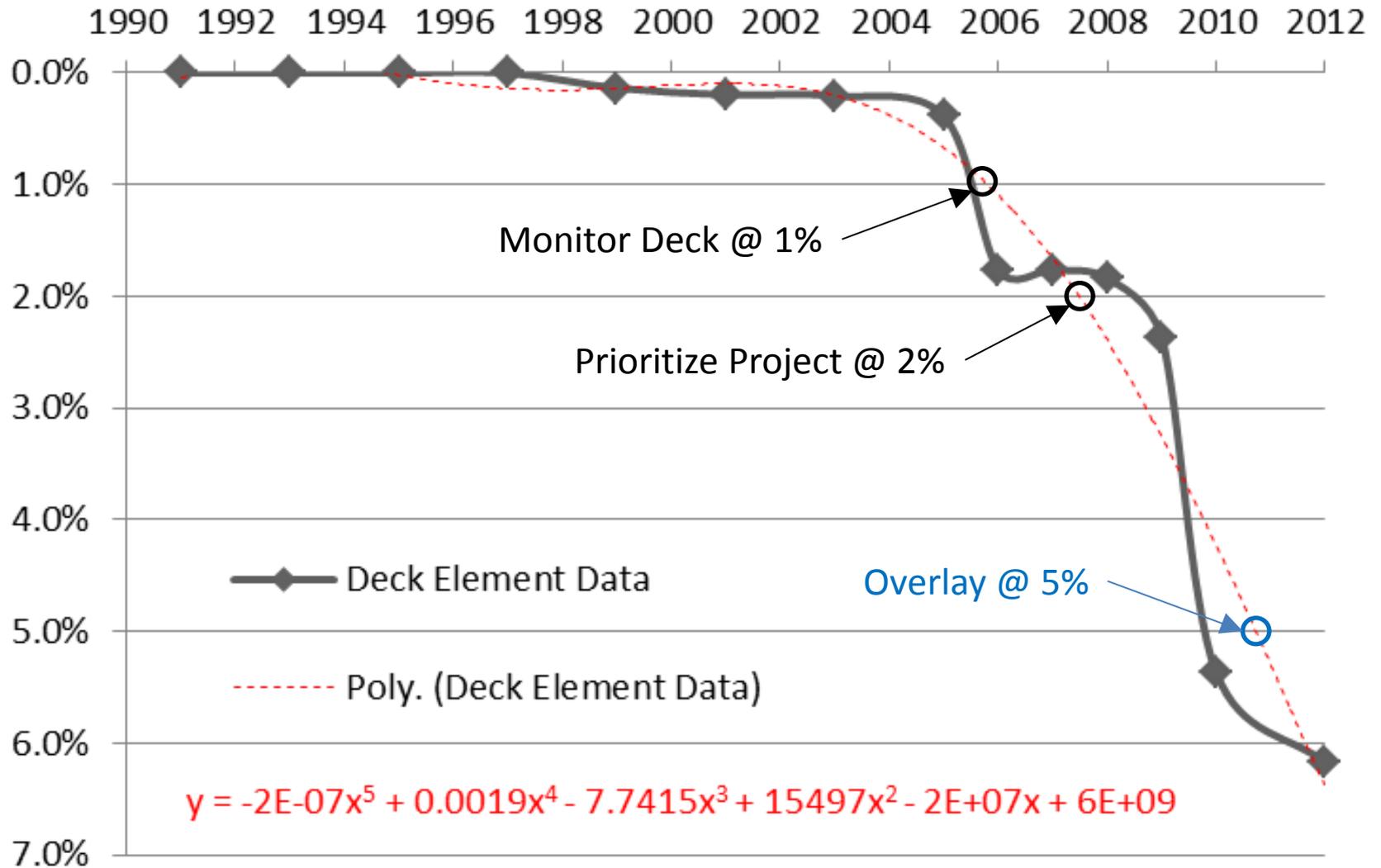
(Foreground)



Deck Deterioration Curve- 395/545

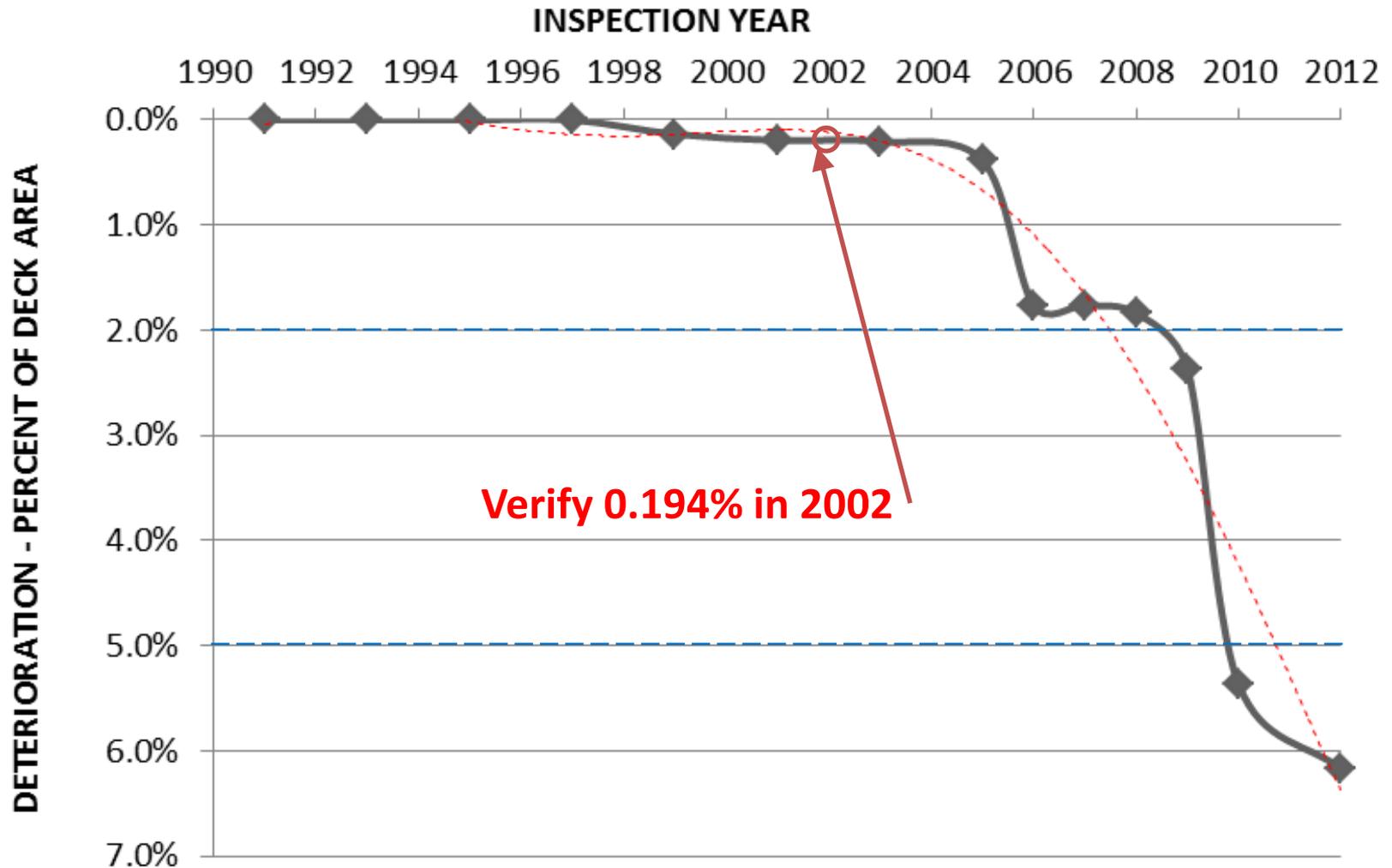
INSPECTION YEAR

DETERIORATION - PERCENT OF DECK AREA



Calibration of Deck Trigger - Monitor

Deck Deterioration Curve- 395/545



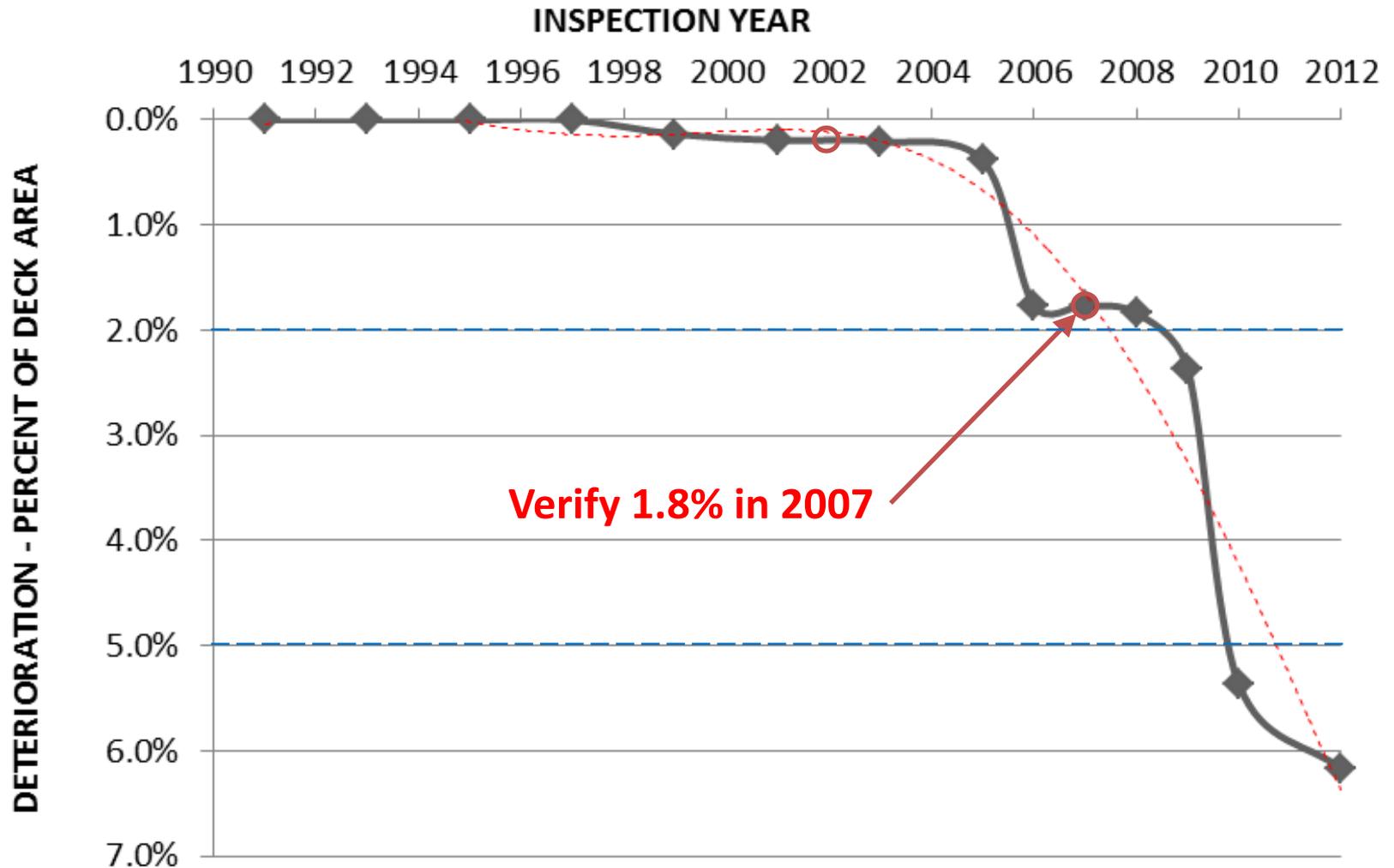
Kettle Falls 395/545 - 2002

- Two truss panels: 60 SF patching = 0.194%
- Not on the Radar
- Built 1941 Length = 1267 ft. Area = 30,408 SF



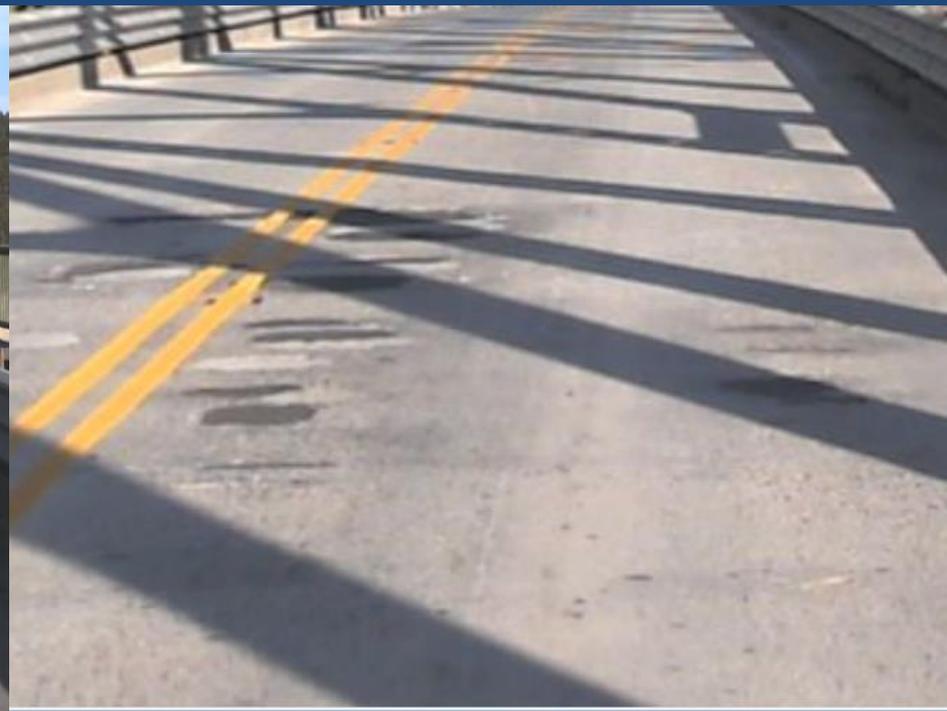
Calibration of Deck Trigger - Prioritize

Deck Deterioration Curve- 395/545



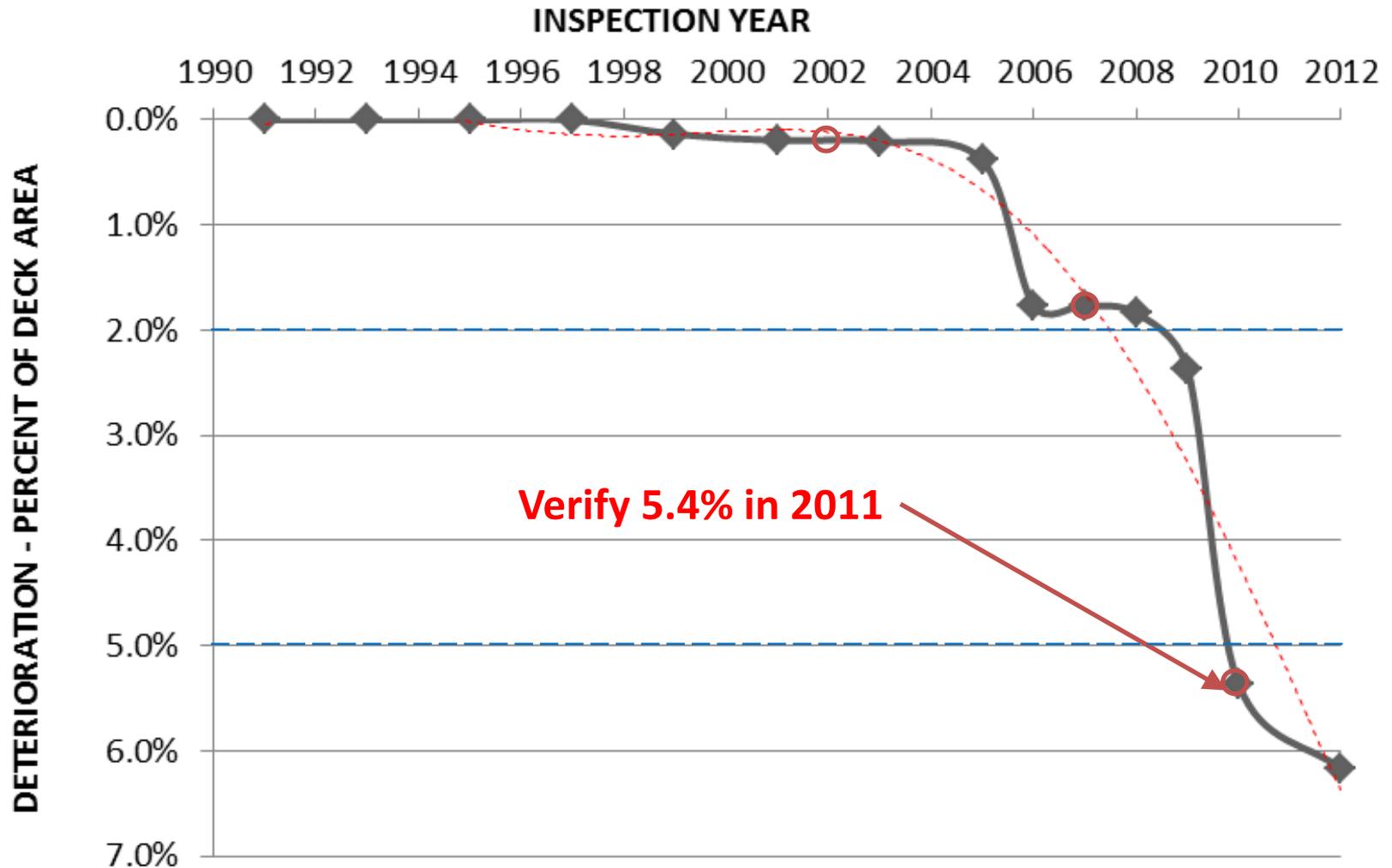
Kettle Falls 395/545 – 2007

- Same two truss panels: (2002 @ 60 SF)
- 2007: Five Panels & other patching, 536 SF = 1.8%
- On the Radar – Prioritized in 2008



Calibration of Deck Trigger - Prioritize

Deck Deterioration Curve- 395/545



Delams by Chain Drag Pattern in the Patches?



Kettle Falls 395/545 – 2010

- 2010 Chain Drag Results = 5.4% Deterioration
 - Patch = 1159 SF, Spall = 156 SF, Delam = 324 SF
- New deteriorated truss panels
- Raised the priority in 2010



395/545 - Soffit Element

- Deck Replacement or Overlay?



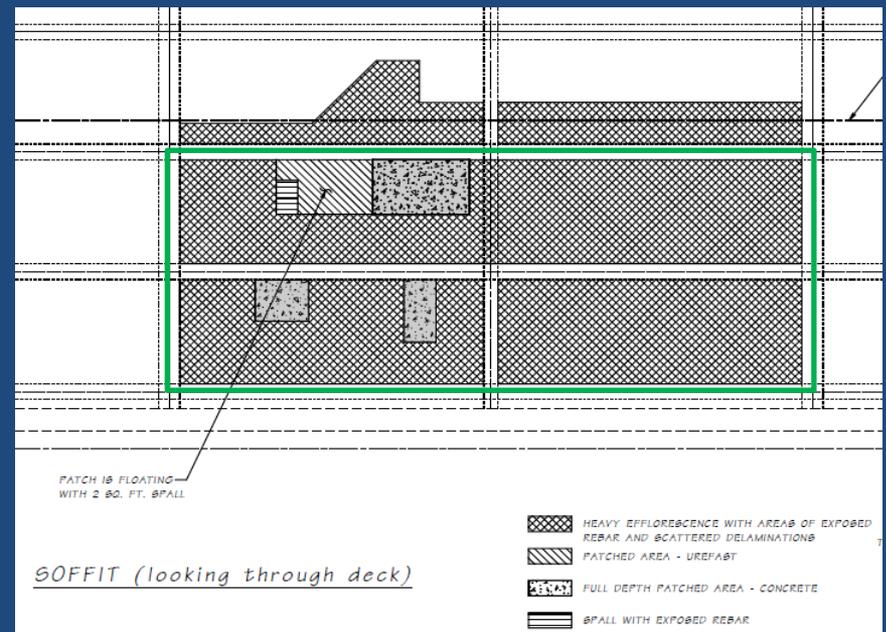
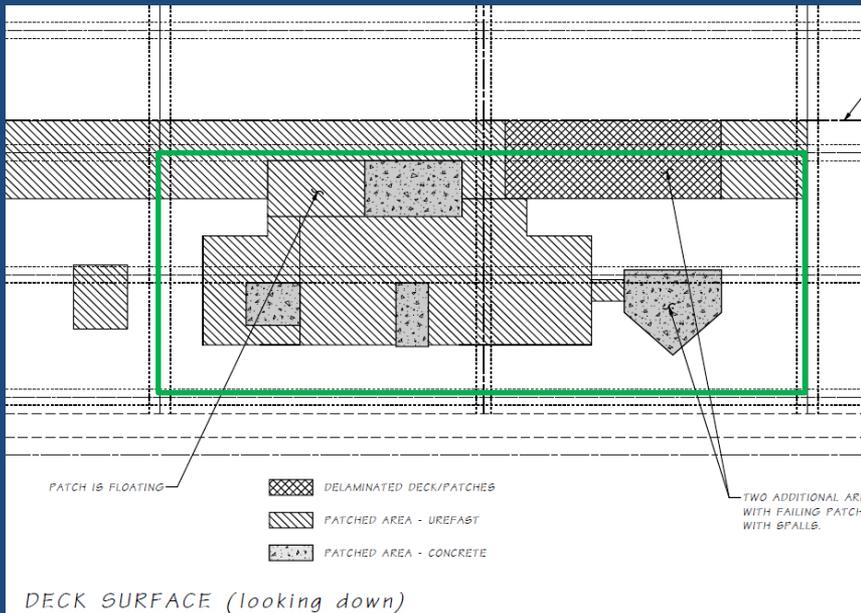
Soffit

- With patching this bad, can the deck be saved?
- Deck replacement ruled out based on soffit quantity @ 0.35% or 105 SF and cost.
- Additional \$20,000 provided for full depth deck repairs.



Deck Replacement Considerations

- In depth inspection suggested.
- Accurate Deck and Soffit quantities
 - Quality assessment
 - Quality prioritization



Hydromill 1.5" & Overlay 1.5"



Hydromill 1.5" & Overlay 1.5"

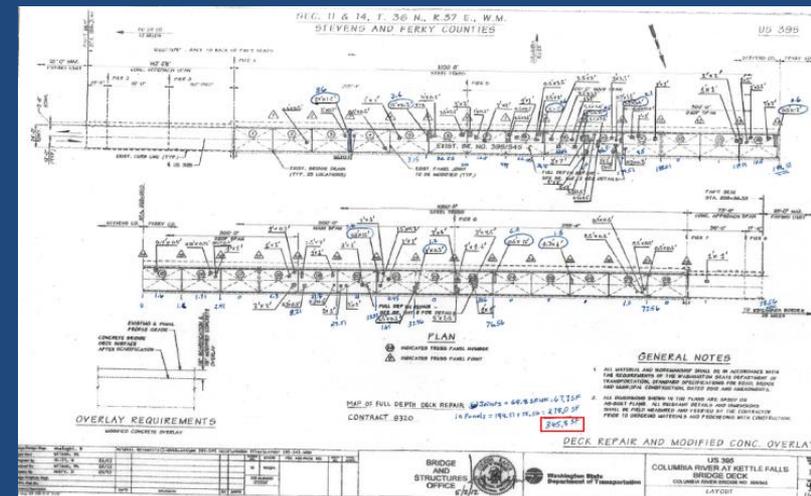


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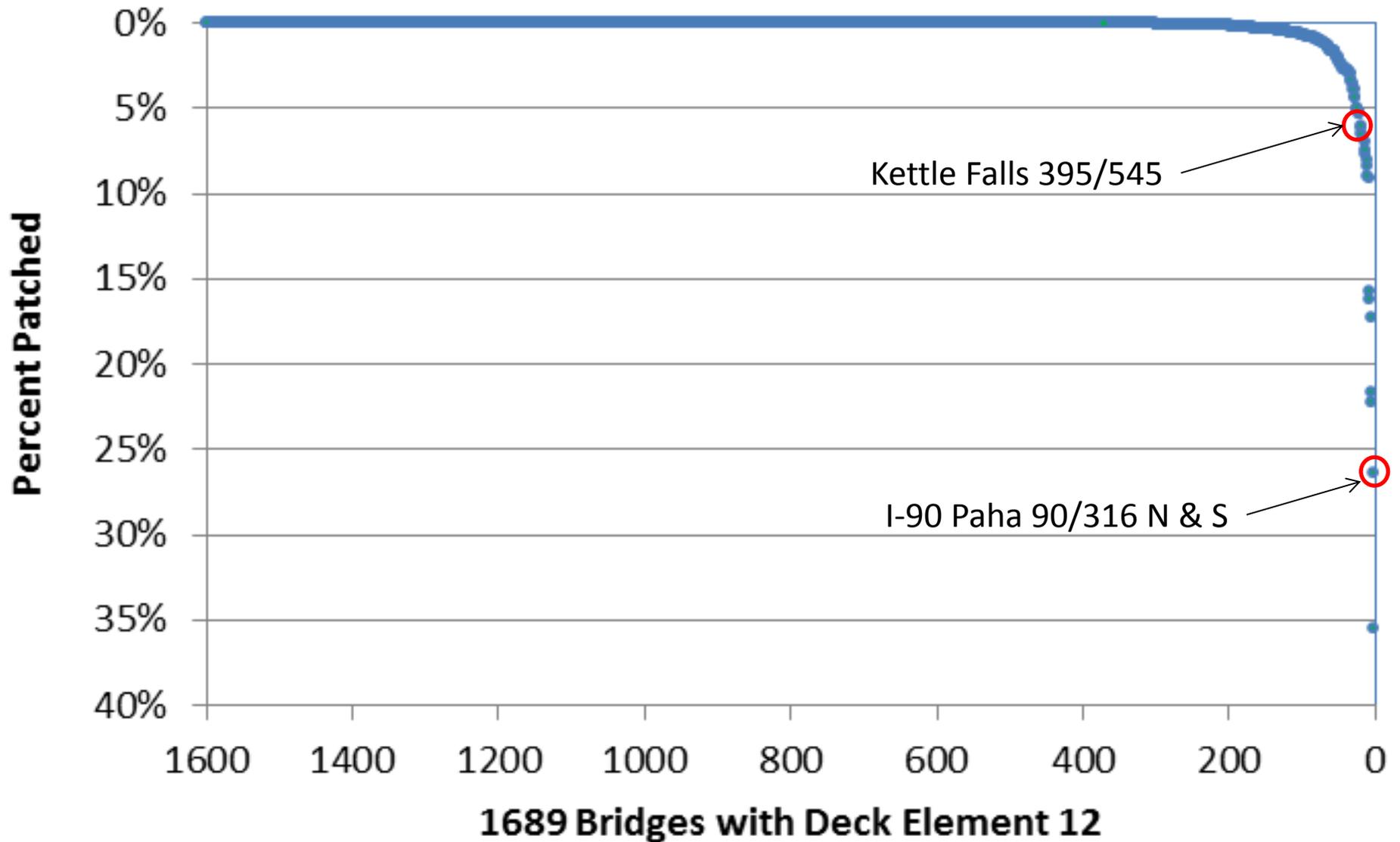
Element Quantities useful for Contract

- 2012 Bridge Inspection Patching was 337 SF and used for Contract.
 - Deep or Full depth Asphalt patching + Bad Deck
- 2012 Constructed quantity was 345 sf

BRIDGE INSPECTION REPORT							
WO	CC	WE	PD	Ver Date	Agency: Washington State		
BAM	0	1	0	7/25/2012	Status: Released		
				Printed on:	7/25/2012		
				Program Mgr: Harvey L. Coffman			
Bridge No.	395/545			Page 2 of 8	Structure Type ST CTB		
Bridge Name	COLUMBIA R KETTLE FALLS			Route	00395		
Structure ID	0002613A			MilePost	241.49		
				Location	2.5 N JCT SR 25		
				Intersecting	COLUMBIA R KETTLE FALLS		
BMS Elements							
Element	Element Description	Total	Units	State 1	State 2	State 3	State 4
12	Concrete Deck	30,408	SF	28,531	337	1,216	324
35	Concrete Deck Soffit	30,408	SF	30,303	94	11	0
0008	FORMS FOR FULL DEPTH DECK REPAIR	S.F.	98	\$50	\$4,910	\$16,850	337.00



Distribution of Deck Patching (CS2)

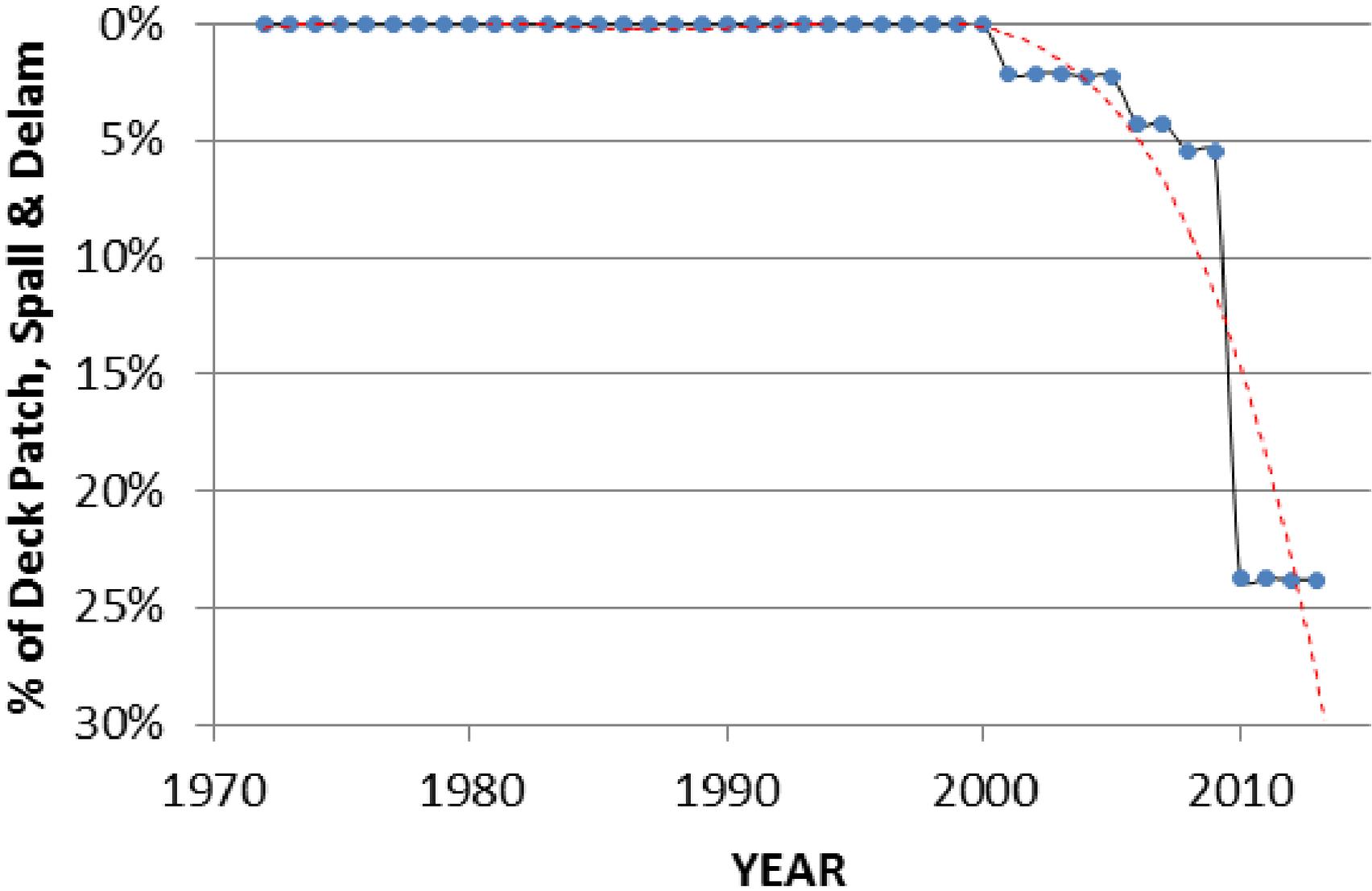


- Patch 1053 SF = 26.4%
- Spall 12 SF = 0.3 %
- Delam 163 SF = 4.0%
- Soffit @ 0%

- Patch 864 SF = 21.7%
- Spall 3 SF = 0.08 %
- Delam 83 SF = 2.1%
- Soffit = 1 SF



Paha 90/316S: Deteration History



Bridge Deck Preservation Options



06/23/2010 10:35

Maintain Only?

Bridge Deck Decisions for 90/316N

Maintain only \$

Deck Rehab and Concrete Overlay \$\$\$

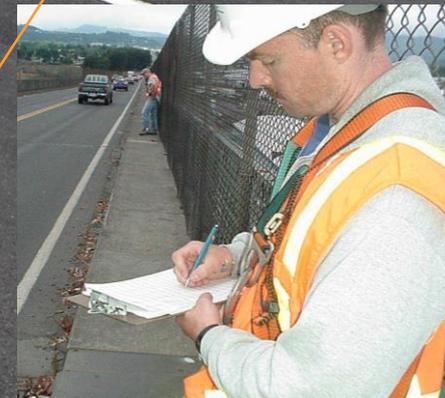
Deck Replacement \$\$\$\$\$

To overlay or Not to overlay. What to do?

Elem	Description	Total	Unit	State1	State2	State3	State4
12	Conc. Deck	3,990	SF	2,774	1,053	0	163
35	Soffit	3,990	SF	3,990	0	0	0
376	Delam Testing	3,990	SF	3,827	0	0	163

(26%)

(4%)



Delam Test - October 2001

Bridge Deck Preservation Economics

Bridge 90/316N

Length: 105ft

Width: 38ft

Deck Area: 3,990 sq. ft.

Year Built: 1972

Deck Thickness: 7"

Top Conc. Cover: 2"

Contract Overlay

Overlay Cost = \$80 per sq. ft.

Deck Area = 3,990 sq. ft.

Overlay life = 30 years

Annual cost of \$10,640 per year

Contract Deck Replacement

Deck Cost = \$250 per sq. ft.

Deck Area = 3,990 sq. ft.

Deck life = 50 years

Annual cost of \$19,950 per year

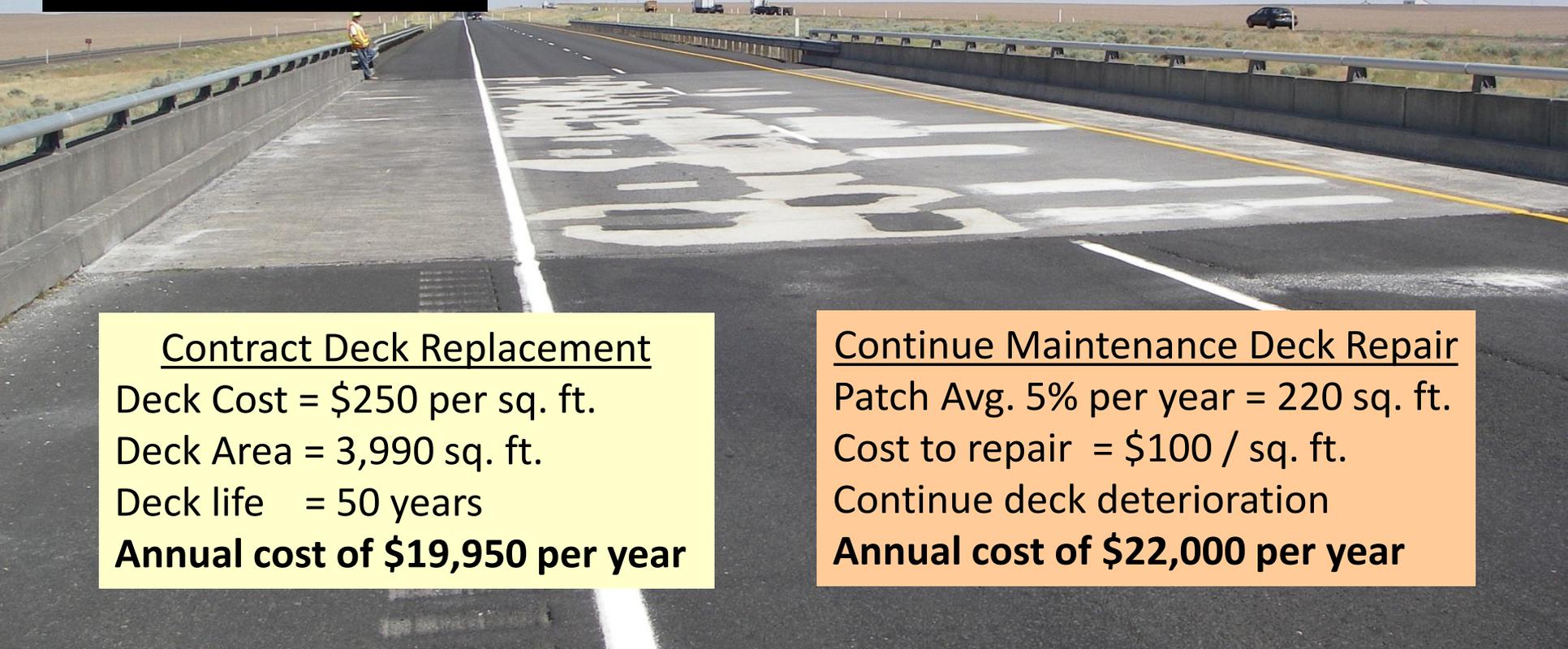
Continue Maintenance Deck Repair

Patch Avg. 5% per year = 220 sq. ft.

Cost to repair = \$100 / sq. ft.

Continue deck deterioration

Annual cost of \$22,000 per year





In Depth Examples

- Were these the right decisions?
- Kettle Falls 395/545: Overlay vs Replace Deck?
 - Contract confirmed assumptions.
- Paha 90/316N: No Action/Overlay/Replace
 - Overlay construction 2013



Managing the Deck Inventory

Forecasting for the Future

WSDOT Bridge Asset Management?

Identify Bridge Problem (Need)



Prioritize Need

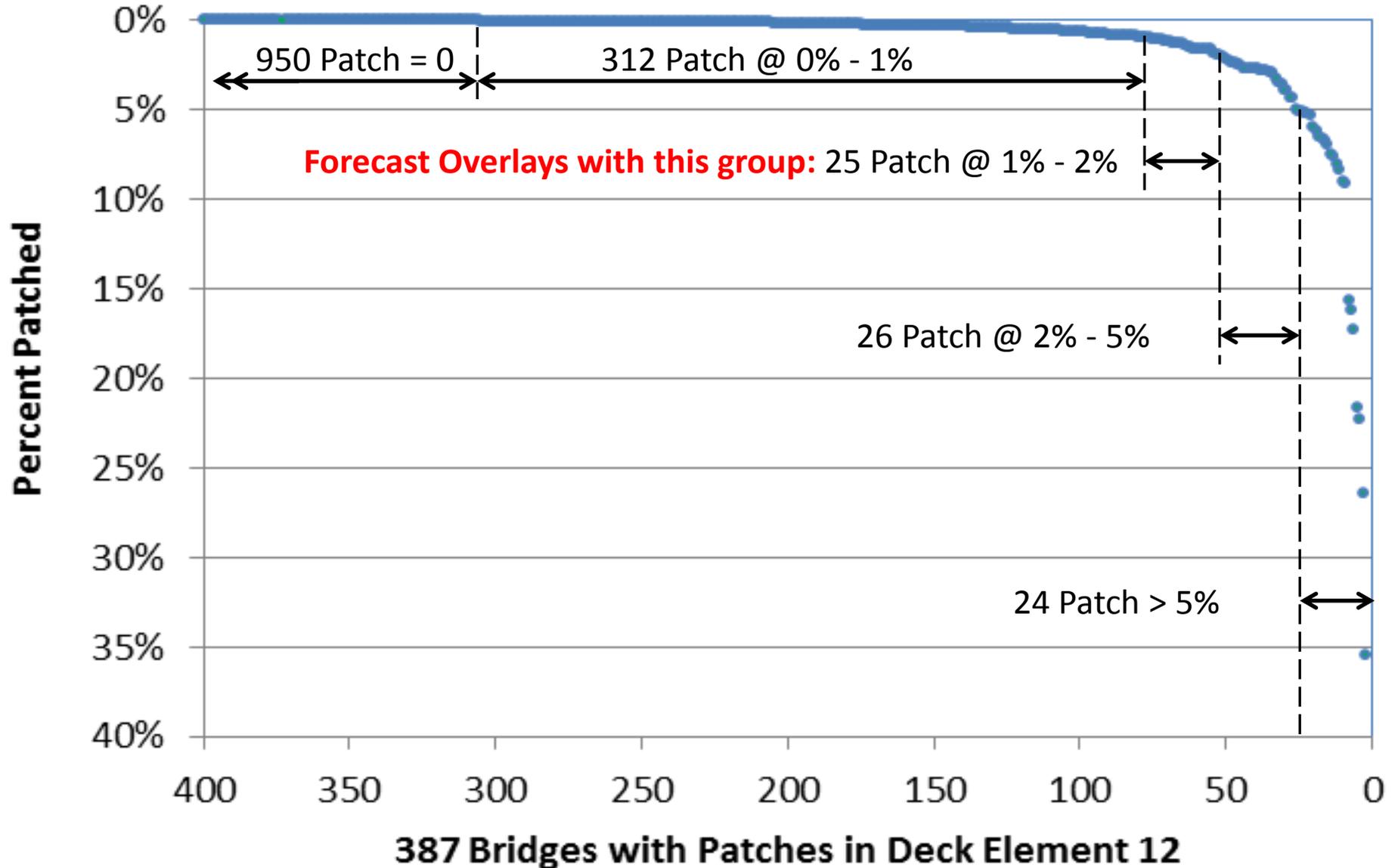


Budget and Secure Funding for Need



Fix the Problem

Distribution of CS2 -Top 400



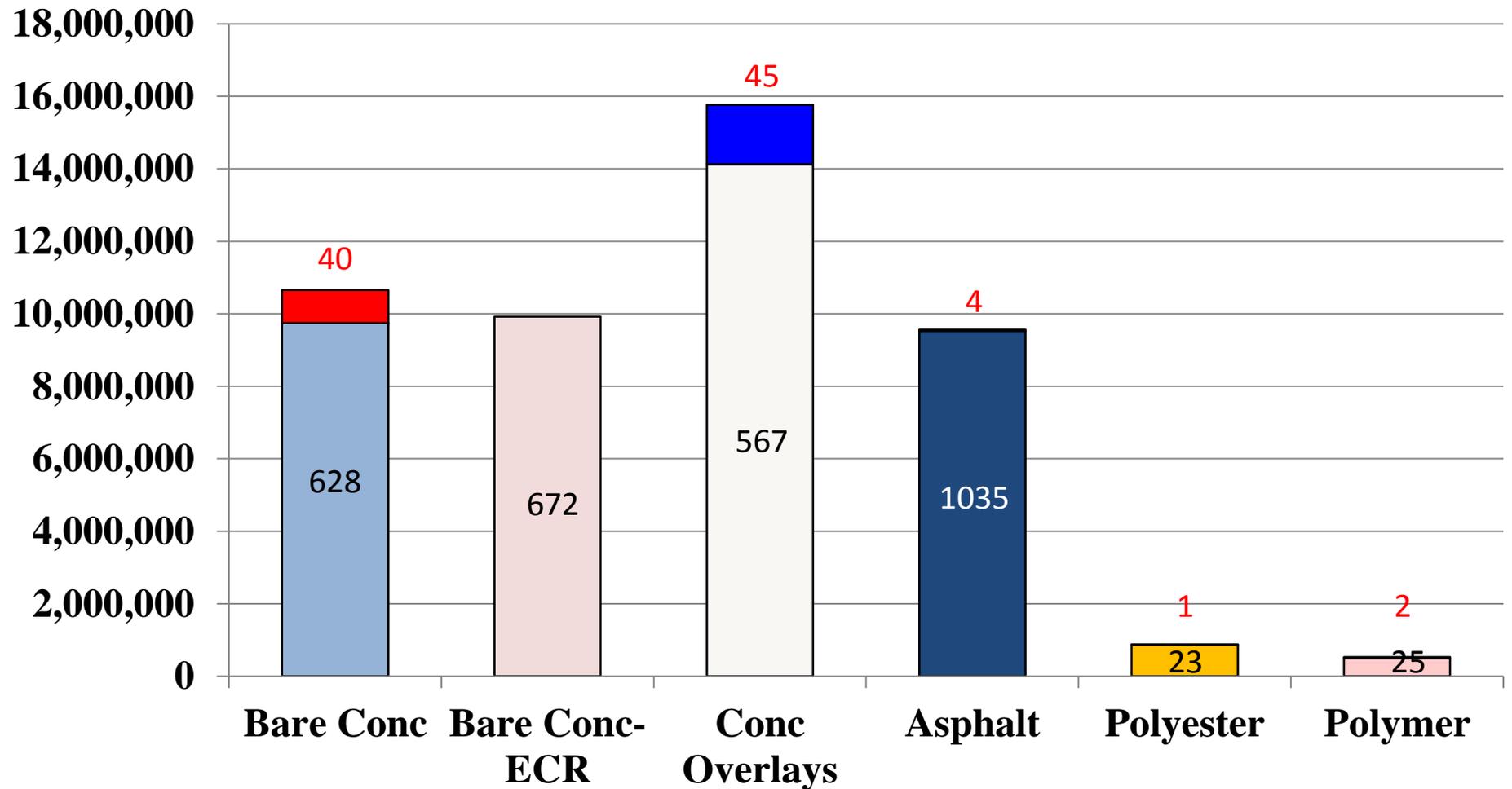
Washington State's Bridge Deck Preservation Needs

\$50.5M

\$104.6M

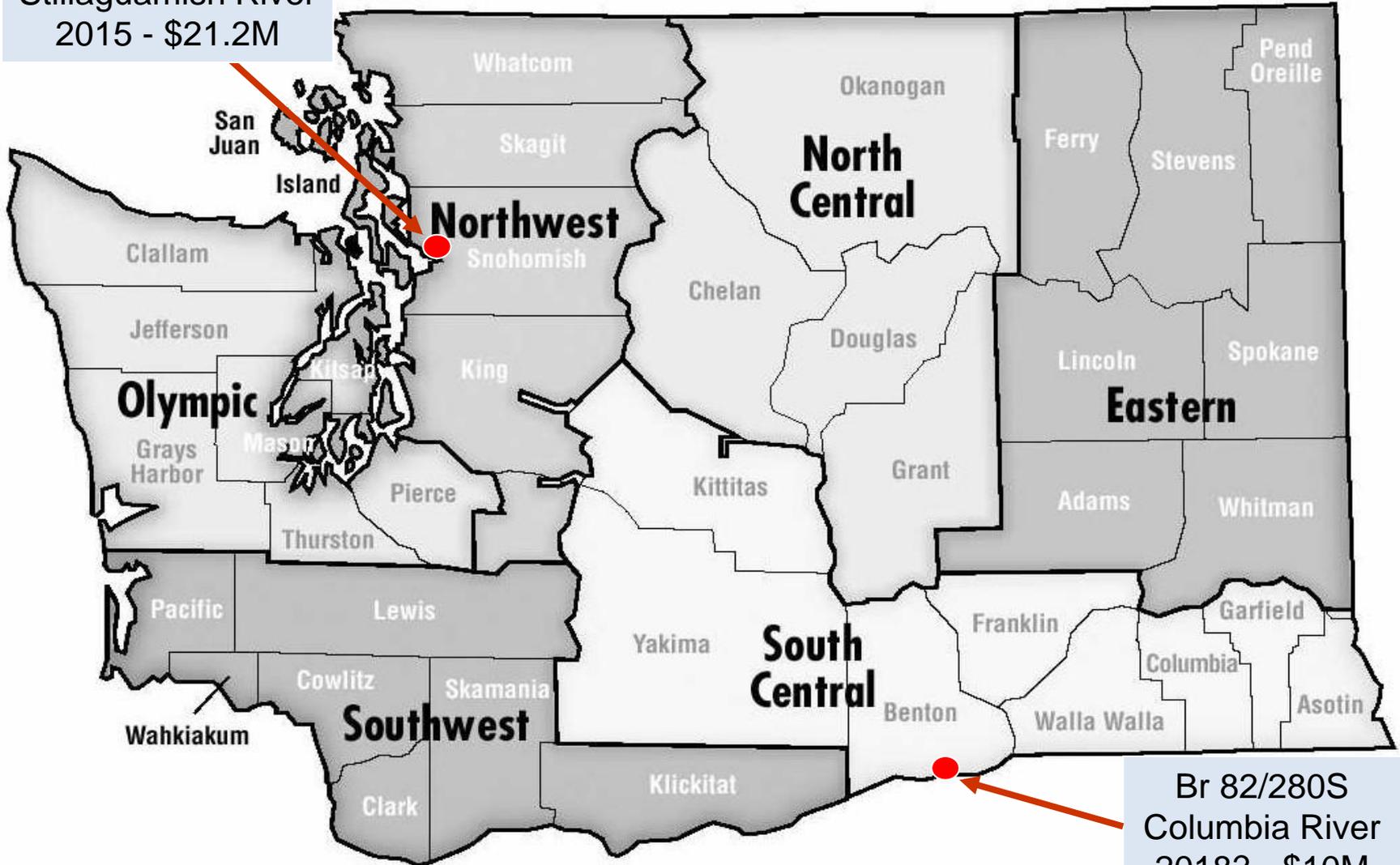
\$0.9M

\$156M



Future Bridge Deck Replacements

Br 5/670W
Stillaguamish River
2015 - \$21.2M



Br 82/280S
Columbia River
2018? - \$10M

Summary of 10-year WSDOT bridge funding needs

Dollars in millions

Category	Allocated for 2011 - 2013 biennium	Projected needs for fiscal years 2013 - 2023
Bridge replacement/rehabilitation	\$101.1	\$285
Bridge repairs, movable bridges	\$17.4	\$100
Steel bridge painting	\$39.1	\$566
Concrete deck rehabilitation	\$13.4	\$156
Seismic retrofit	\$22.4	\$152
Scour mitigation	\$3.2	\$15
Total	\$196.6	\$1,274

Data source: WSDOT Bridge and Structures Office.



Bridge Deck Decisions Summary

- History, Engineering Practice, & Useful Data
- Theory based in maintenance
- Theory supported by Data
- Calibrate data and triggers



Bridge Deck Decisions

When to overlay or replace?

By Bruce Thill

Washington State DOT (WSDOT)

Bridge Asset Manager

May 2013