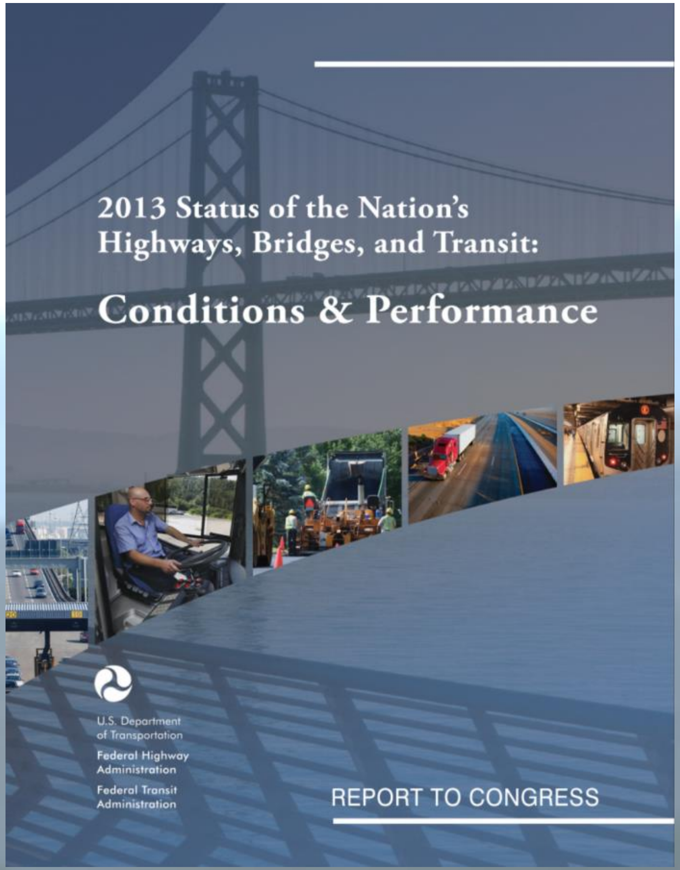
National-scale bridge deterioration model for NBIAS

Paul D. Thompson

Background

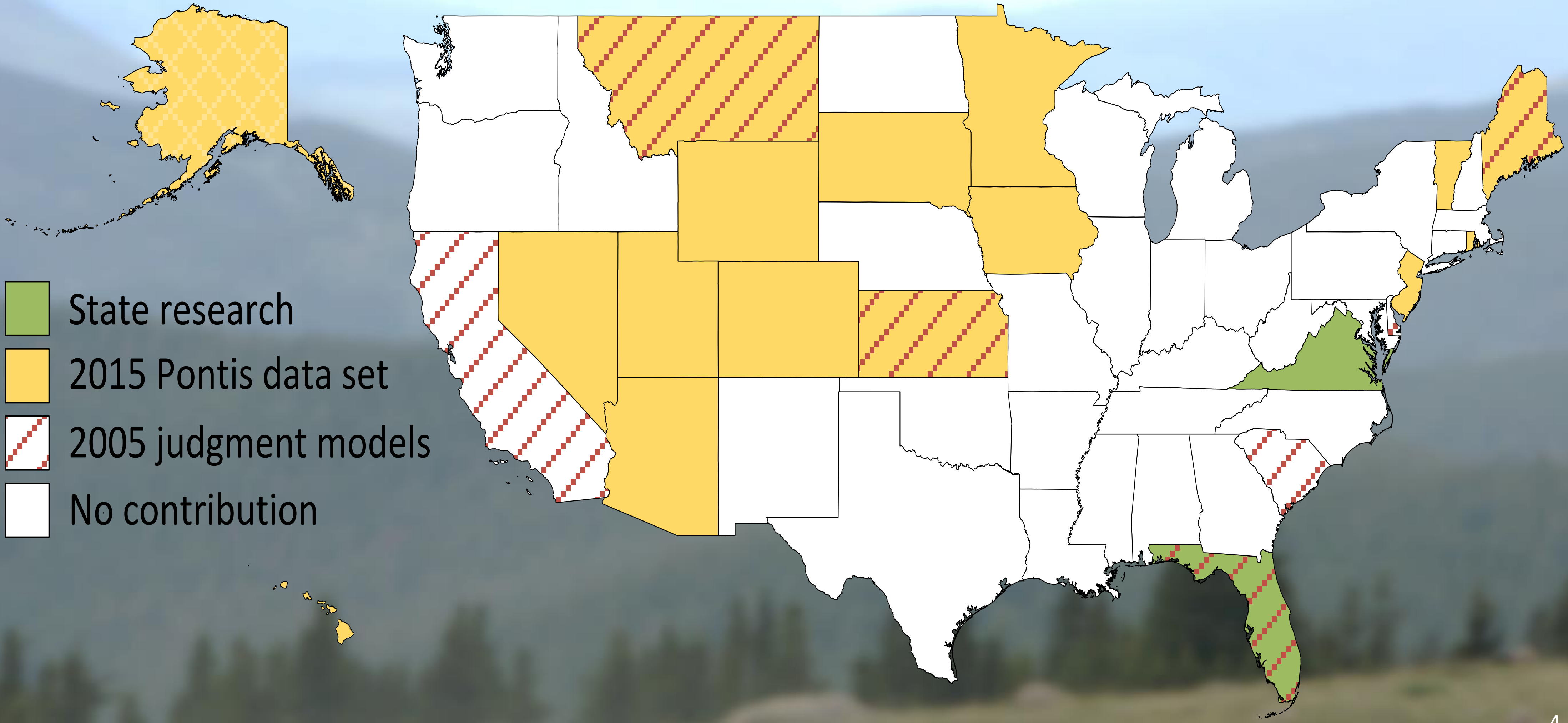


- Project team
  - Spy Pond Partners – Bill Robert, Project Manager
  - Paul D. Thompson, Subcontractor
- National Bridge Investment Analysis System (NBIAS)
  - Project began in 1995
  - Used in preparation of the Report to the Congress on the Conditions and Performance of the Nation's Highways, Bridges, and Transit (every 2-3 years)
  - A state version is also available

NBIAS life cycle cost analysis

- Similar to Pontis 4.x
  - Strictly network level
  - Markov models of deterioration and action effectiveness
  - Linear programming optimization
- Changes in 2016
  - Uses the 100 new NBI elements
  - Condition states conform to 2013 AASHTO Manual on Bridge Element Inspection
  - *New deterioration model based on statistical analysis of element inspection data*

Sources of data



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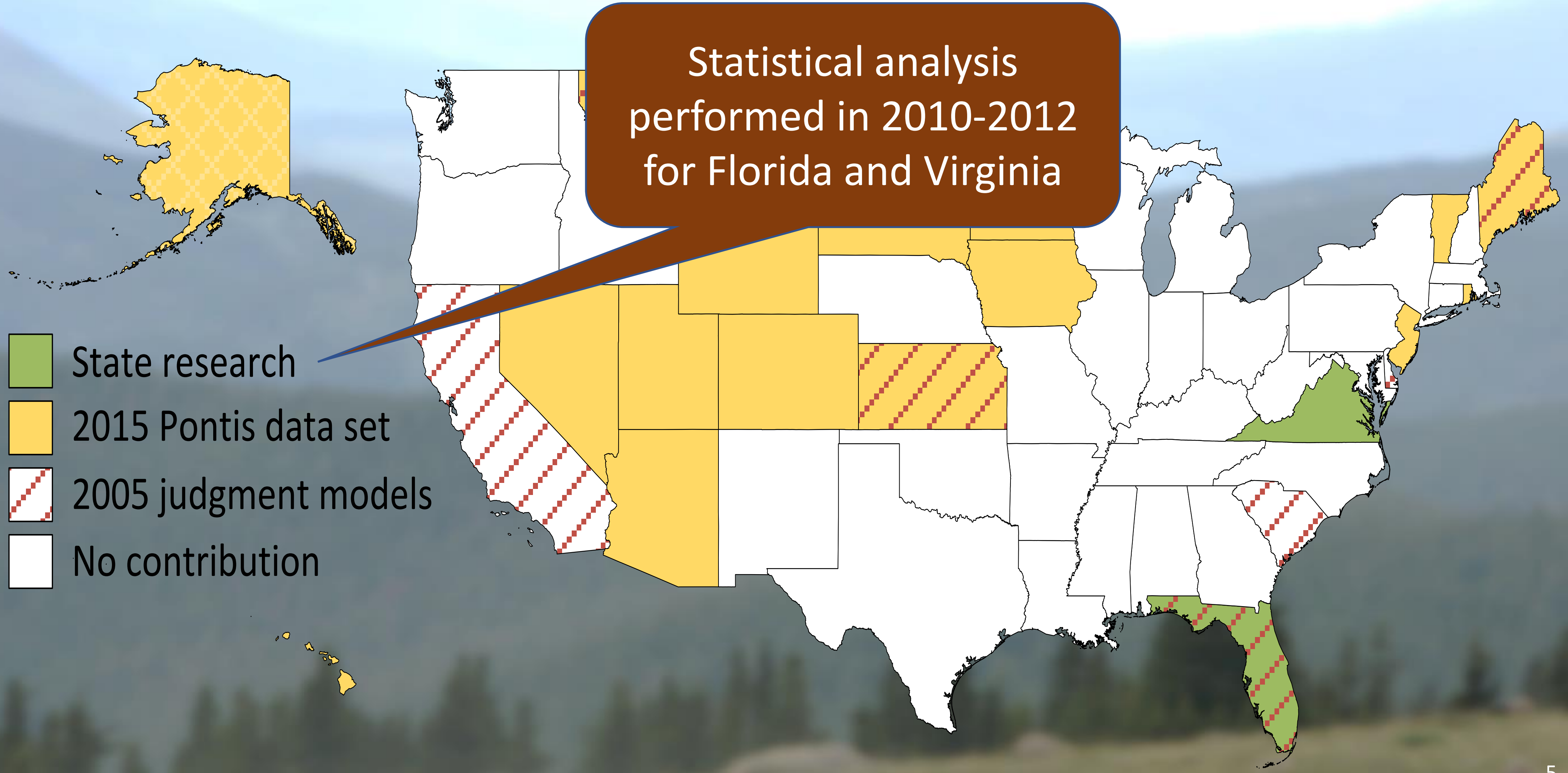

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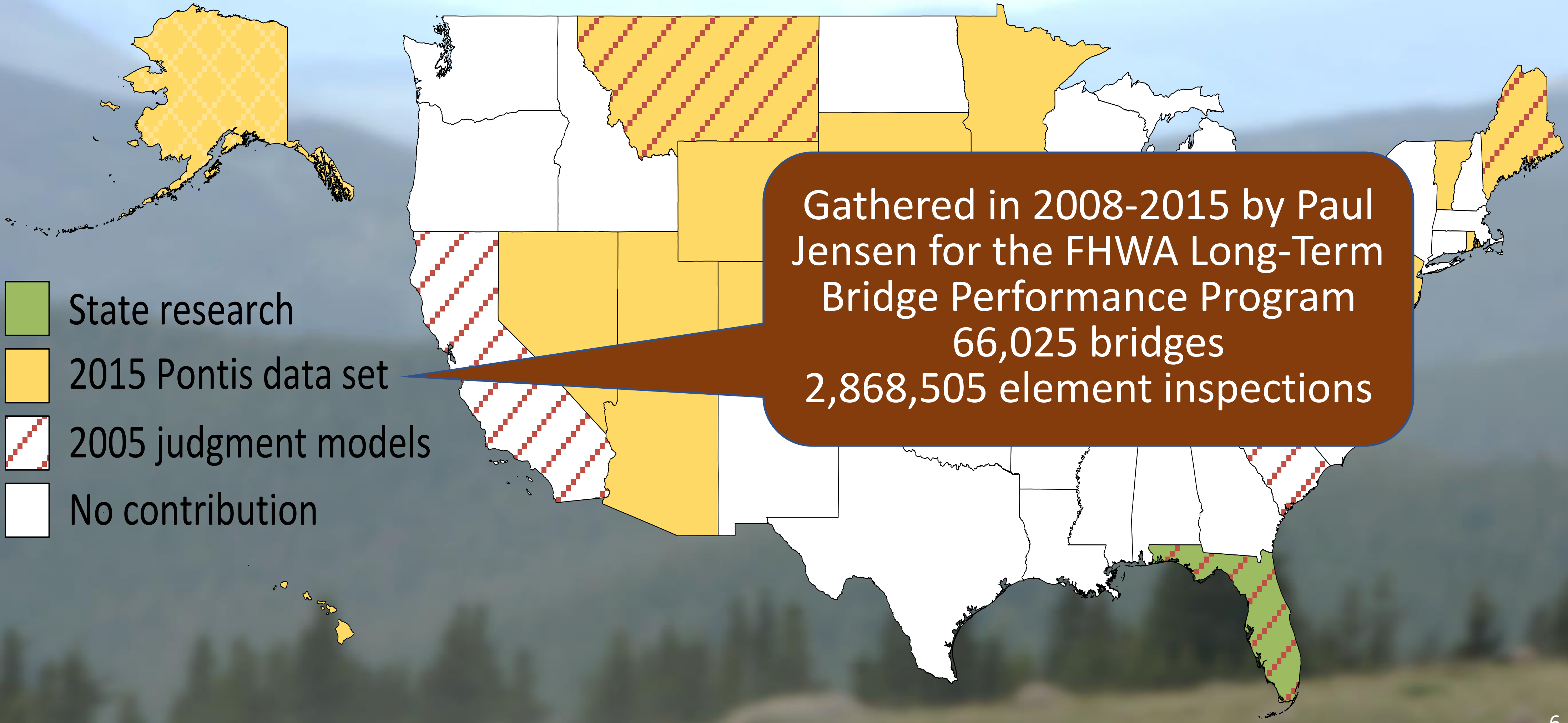
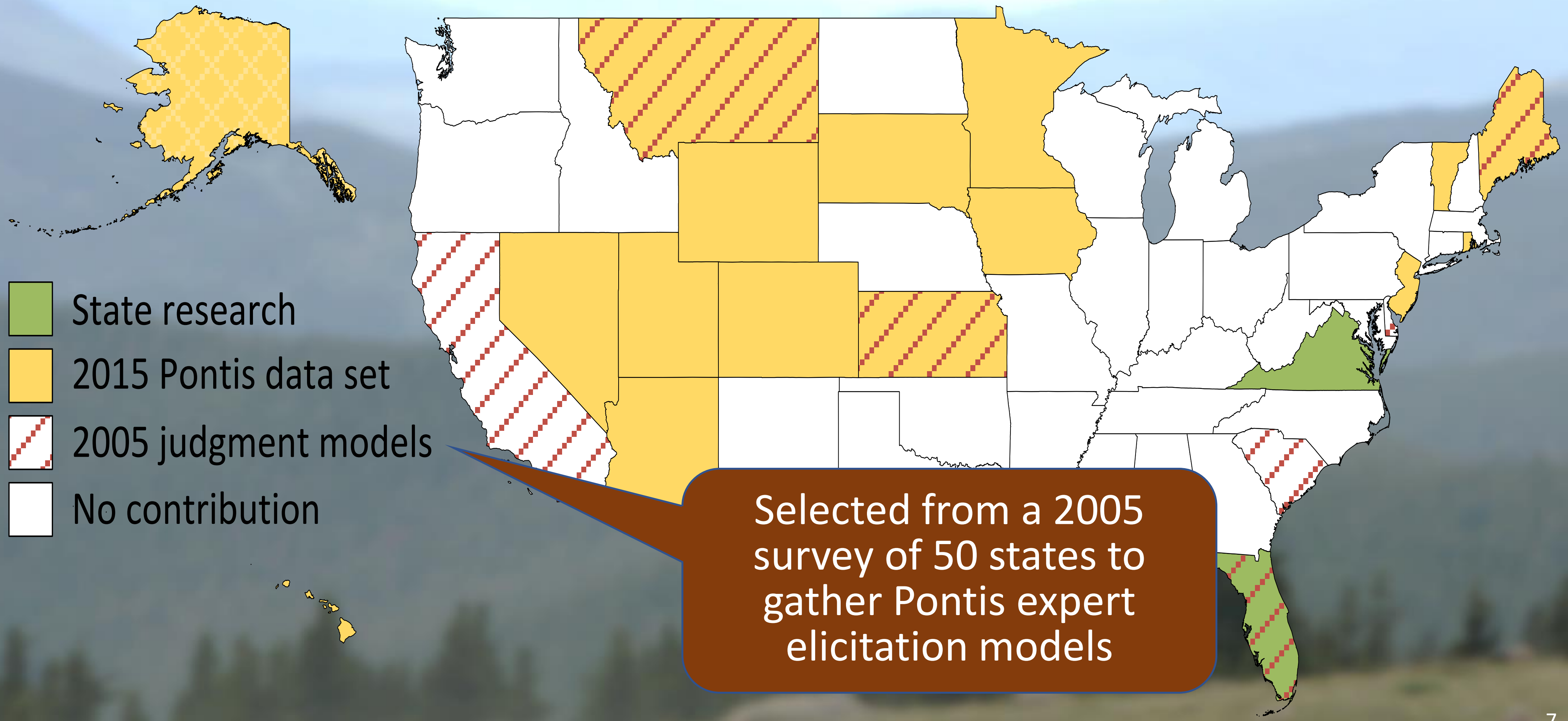
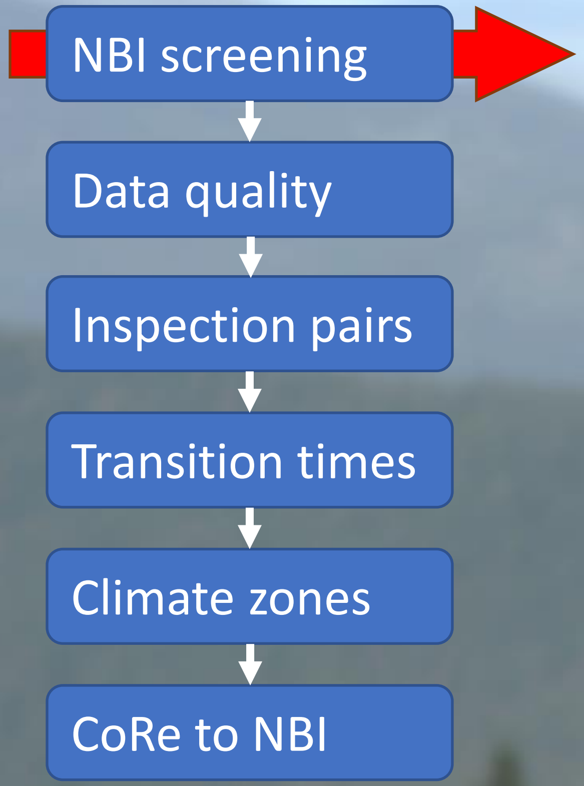


Gathered in 2008-2015 by Paul Jensen for the FHWA Long-Term Bridge Performance Program
66,025 bridges
2,868,505 element inspections

Sources of data

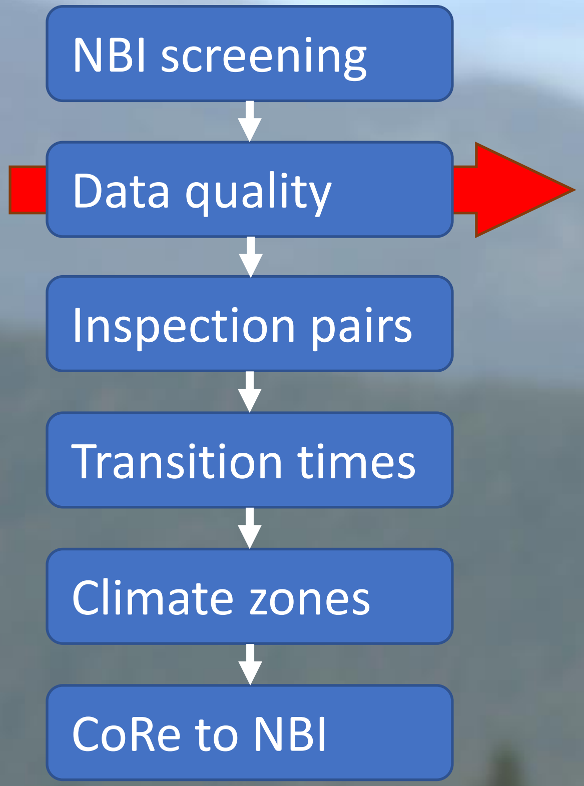


Model development process



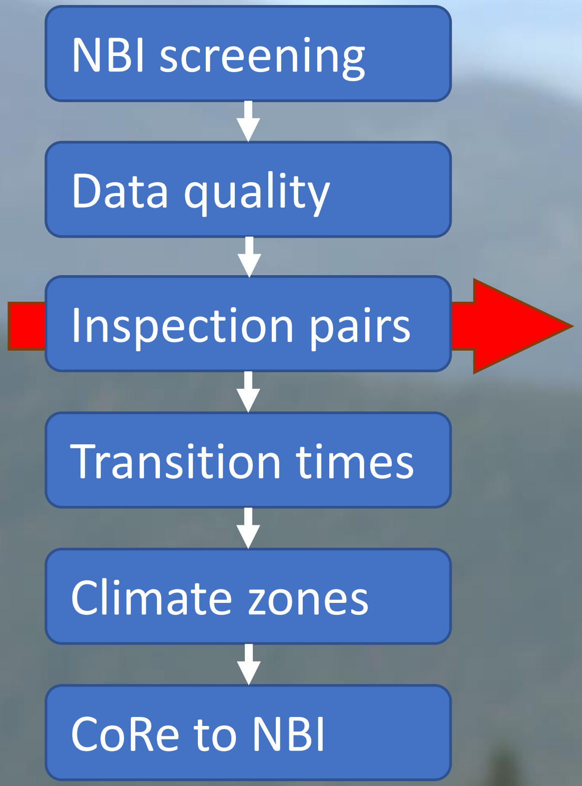
- No non-NBI structures
- No agency-defined or customized elements
- No approach slabs, slope protection, or other non-NBI elements
- No 2001 interim revisions to bridge decks

Model development process



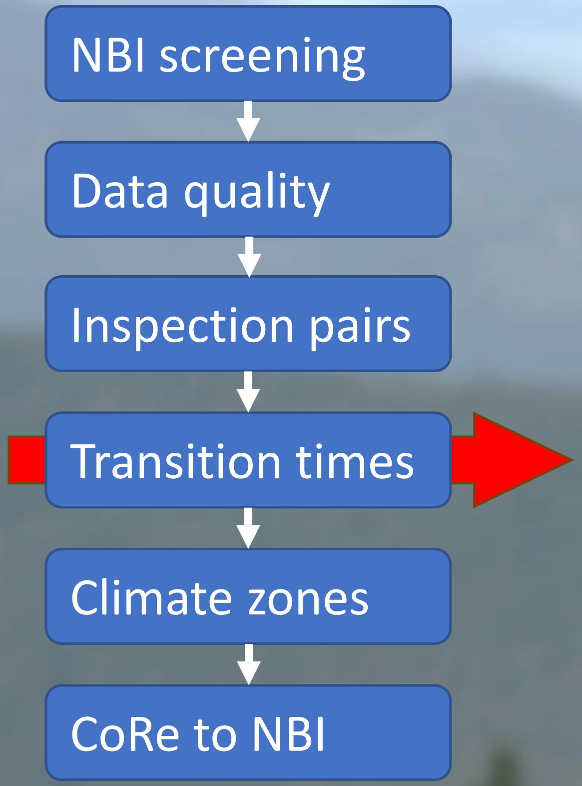
- Omit the first inspection cycle
- Omit incomplete inspection cycles
- Perform data quality checks
  - Quantities sum to total element quantity
  - No unpopulated condition states
  - Element inspections conform to AASHTO CoRe element definitions
- Estimate trial models and check their internal consistency

Model development process



- Create element inspection pairs
  - Inspections 2 years (± 6 months) apart
  - Must match by element, environment, quantity
- Omit inspection pairs showing improvement
  - Unfortunately, we had no activity data
- Cluster elements into groups based on population and similarity
- Partitions for statistical tests and validation

Model development process

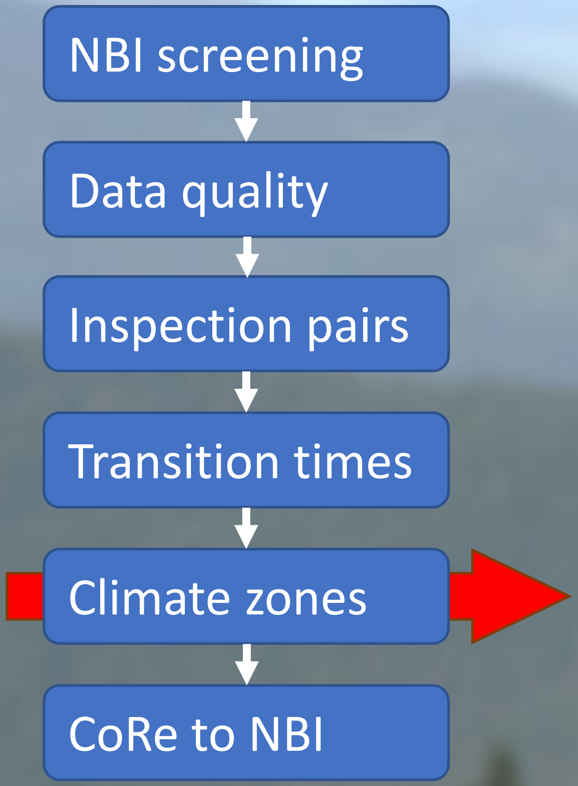


- Used the algebraic "one-step" method developed for Florida DOT
- Prediction equation

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} & 0 & 0 \\ & p_{22} & p_{23} & 0 \\ & & p_{33} & p_{34} \\ & & & p_{44} \end{bmatrix}^2 \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$$

Given [X] and [Y], solve for p_{xx} and then $p_{x(x+1)}$ and convert to transition times

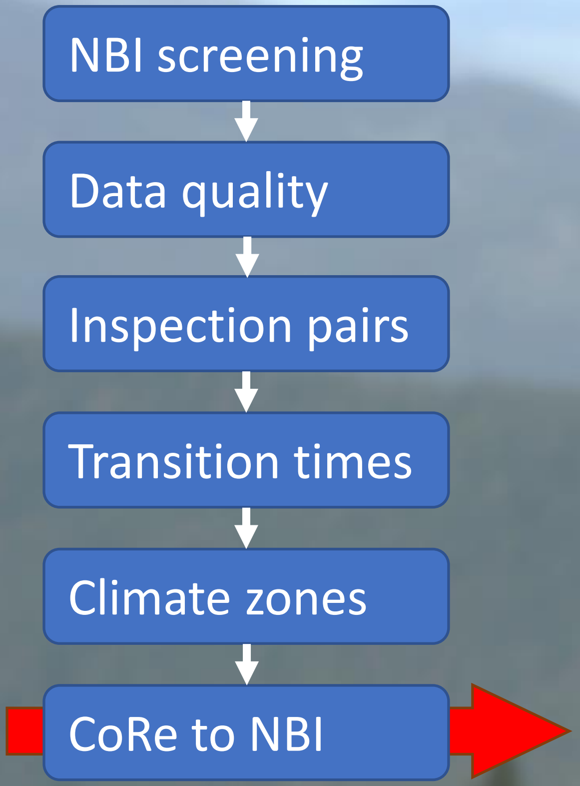
Model development process



- 9 HPMS climate zones by county
- Some were under-represented in the data
  - So we used the 2005 research and 2010-2012 FL and VA models to develop climate zone factors applied to transition times

Zone	Moist	Temp	ClFactor
1	1-Wet	1-Freeze	0.64
2	1-Wet	2-Thaw	0.58
3	1-Wet	3-Warm	0.92
4	2-Damp	1-Freeze	0.84
5	2-Damp	2-Thaw	0.75
6	2-Damp	3-Warm	1.20
7	3-Dry	1-Freeze	0.94
8	3-Dry	2-Thaw	0.84
9	3-Dry	3-Warm	1.34

Model development process



- Converted models based on CoRe Elements to NBI elements using migration probability matrix
  - Migration prob matrix developed using judgment, based on the changes in element/state definitions

	Migration probabilities																			
	Probability to state 1					Probability to state 2					Probability to state 3					Probability to state 4				
Element type name	From 1	From 2	From 3	From 4	From 5	From 1	From 2	From 3	From 4	From 5	From 1	From 2	From 3	From 4	From 5	From 1	From 2	From 3	From 4	From 5
Name	P11	P21	P31	P41	P51	P12	P22	P32	P42	P52	P13	P23	P33	P43	P53	P14	P24	P34	P44	P54
A1- Concrete deck	100%	0%	0%	0%	0%	0%	80%	30%	0%	0%	0%	20%	70%	70%	0%	0%	0%	0%	30%	100%
A2- Concrete slab	100%	0%	0%	0%	0%	0%	80%	60%	20%	0%	0%	20%	40%	70%	50%	0%	0%	0%	10%	50%
A3- Prestressed concrete slab	100%	0%	0%	0%	0%	0%	80%	60%	20%	0%	0%	20%	40%	70%	50%	0%	0%	0%	10%	50%
A4- Steel deck	100%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%
A5- Timber deck/slab	100%	0%	0%	0%	0%	0%	60%	0%	0%	0%	0%	40%	70%	0%	0%	0%	0%	30%	100%	100%
A6- Approach slabs	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	60%	0%	0%	0%	0%	40%	100%
B1- Strip Seal expansion joint	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B2- Pourable joint seal	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B3- Compression joint seal	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B4- Assembly joint/seal	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B5- Open expansion joint	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B6- Other expansion joint	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
C1- Uncoated metal rail	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
C2- Coated metal rail	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
C3- Reinforced concrete railing	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
C4- Timber railing	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	100%	100%

Final results

- Transition times by element group (national average)
- Multiply by climate zone factors and expand to the level of 100 NBI elements for NBIAS use

		From-To condition state (national average)			
		1-2	2-3	3-4	1-worst
Group	**Name**	**FinT1**	**FinT2**	**FinT3**	**FinTW**
A1	Concrete deck	12	24	24	79
A2	Concrete slab	9	30	17	72
A4	Steel deck	14	8	9	41
A5	Timber deck/slab	10	10	21	53
B1	Strip Seal expansion joint	28	10	10	59
B2	Pourable joint seal	12	6	6	32
B3	Compression joint seal	13	10	10	42
B4	Assembly joint/seal	24	15	15	70
B5	Open expansion joint	22	16	16	70
C1	Uncoated metal rail	18	27	56	127
C2	Coated metal rail	32	22	20	96
C3	Reinforced concrete railing	44	36	28	140
C4	Timber railing	31	9	9	62
C5	Other railing	36	13	13	77
D1	Unpainted steel super/substructure	23	40	40	132
D2	Painted steel superstructure	23	35	12	90
D6	Prestressed concrete superstr	68	40	15	152
D7	Reinforced concrete superstructure	24	40	24	113
D8	Timber superstructure	41	24	13	100
E1	Elastomeric bearings	94	18	18	152
E2	Metal bearings	28	34	34	123
F1	Painted steel substructure	19	30	11	77
F3	Concrete column/pile	38	34	36	140
F5	Concrete abutment	50	57	30	176
F6	Concrete cap	70	73	34	225
F8	Timber substructure	18	31	16	85
G1	Reinforced concrete culverts	37	42	53	170
G2	Metal and other culverts	12	18	31	78
P1	Deck wearing surface	11	32	19	79
P2	Protective coating	17	12	9	50

Conclusions

- Applicable to any NBI bridge or culvert in the USA for NBIAS
- Can be adapted for use in AASHTOWare Bridge Management
  - May be suitable as a default model for agencies lacking their own deterioration models
- Most significant limitations:
  - Lack of bridge activity history data
  - Under-representation of some of the climate zones

Long-term, not a substitute for agency-specific models