Bringing Flood Resiliency into MassDOT Asset Management

Presented by
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CAFM Annual Conference & Meeting | October 30, 2019

MILONE & MACBROOM

ACKNOWLEDGEMENTS

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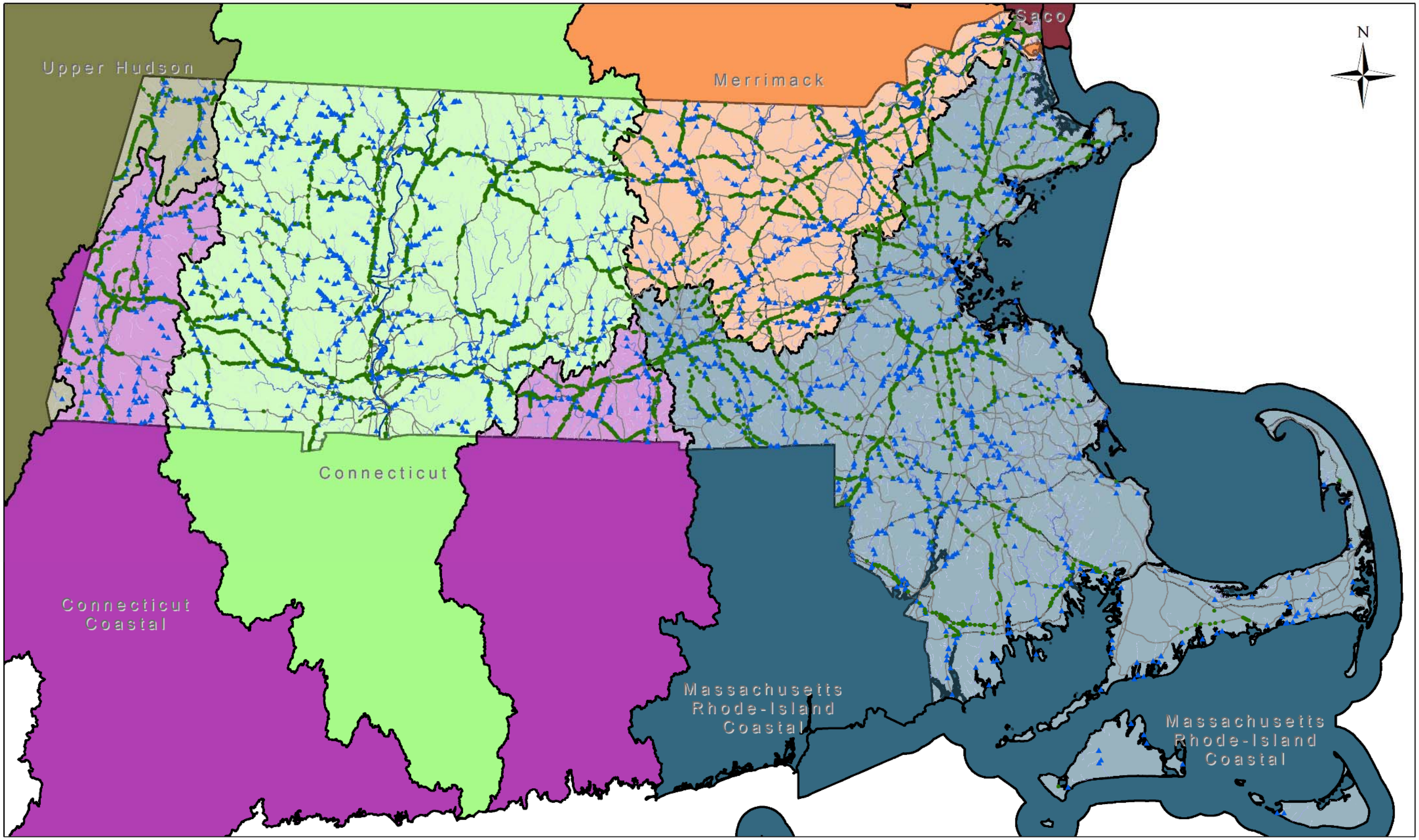
FHWA Asset Management, Extreme Weather, and Proxy Indicators Pilot Project

PROBLEM STATEMENT

- **Where** is infrastructure vulnerable?
- **Why** are those assets vulnerable?
- **How** do we reduce risk?

PROJECT SCOPE



PROJECT SCOPE

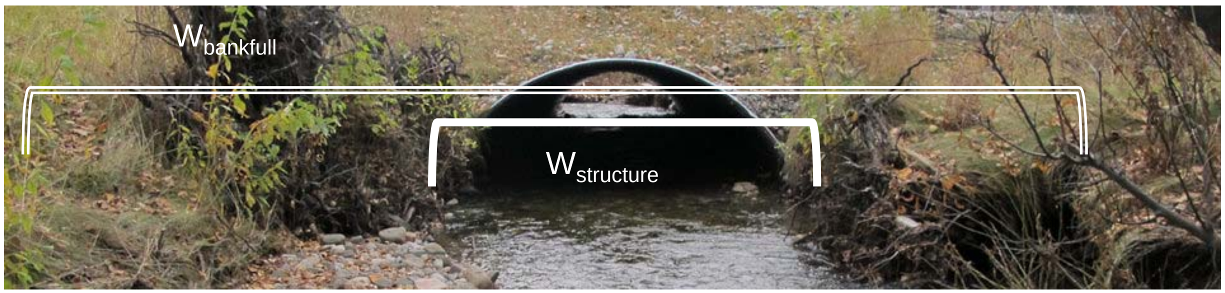
Item	Amount	Notes
Major basins	8	From NHDPlus HR, USGS Hydrologic Unit Code 4 (HUC-4)
Watersheds	20	From NHDPlus HR, HUC-8
Stream channels	16,704 miles	From the NHDPlus-HR. Excludes intermittent streams. Includes stream orders 1 through 8.
State Roads	4,443 miles	Approximated from GIS.
State Culverts	1,171	State-owned structures from the MassDOT Culvert Database. Excludes culverts not on a mapped stream channel or that do not have a known width.
State Bridges	2,787	NBI and short-span bridges in the MassDOT Bridges Database owned by the state or a municipality. Excludes coastal bridges.

- MassDOT Road Inventory (MassDOT, 2018b): 55,977 miles of roads. The average road segment length is 0.1 miles.
- National Hydrography Dataset High-Resolution (NHDPlus HR) (USGS, 2018): 16,704 miles of GIS stream centerline segments. The average channel segment length is 0.2 miles.
- The MassDOT Culvert Database: 5,582 culverts. Focus on 1,171 culverts on perennial streams.
- The MassDOT Bridge Database: 3,120 structures. Focus on 2,787 bridges on perennial streams.

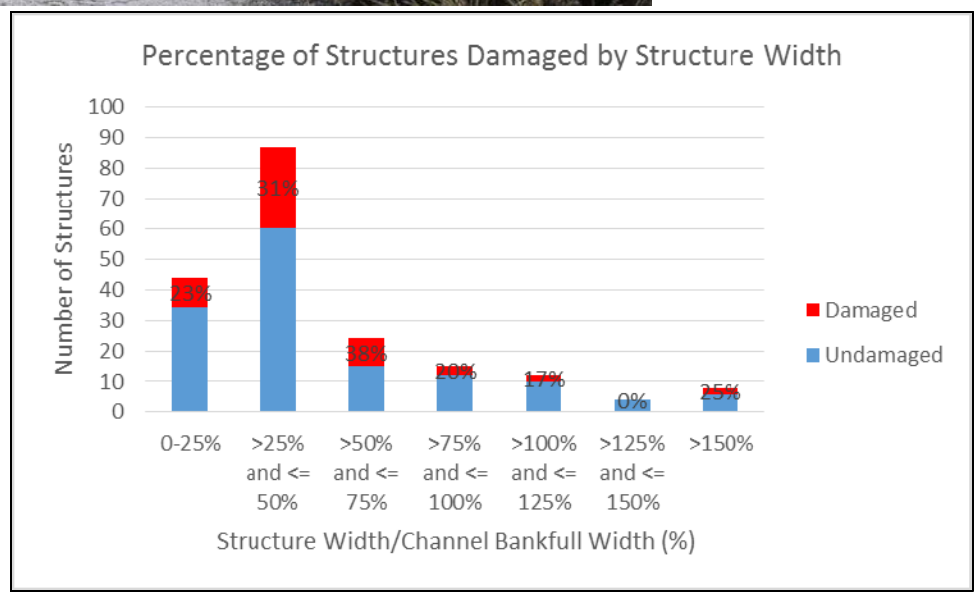
METHODS

GEOMORPHIC COMPATIBILITY

$$\text{Percent-Bankfull Channel Width} = \frac{\text{Structure Width } (W_{structure})}{\text{Bankfull Channel Width } (W_{bankfull})}$$



- **Percent Bankfull** as a proxy indicator for **Geomorphic Compatibility**
- Damages tend to occur structures that do not span the bankfull width



(MMI, UMass, MassDOT, 2017)

METHODS

GEOMORPHIC COMPATIBILITY

$$\text{Percent-Bankfull Channel Width} = \frac{\text{Structure Width } (W_{structure})}{\text{Bankfull Channel Width } (W_{bankfull})}$$

$$W_{bankfull} = 15.0418 \times \text{Drainage area}^{0.4038}$$

(Bent and Waite, 2013)

METHODS

GEOMORPHIC COMPATIBILITY

Percent Bankfull Width	Estimated Geomorphic Compatibility
0 – 49%	Low
50 – 100%	Moderate
> 100%	High

Mitchel Brook, Conway Road, Whately, MA

(AR and MADER, 2016)

METHODS

POTENTIAL CHANNEL BED EROSION

Green River
Colrain, MA
Hinesburg Road near the Deer Park Bridge
(J. MacBroom, 2011)

Specific Stream Power X Predicted Bed Resistance

Proxy indicators for potential channel bed erosion

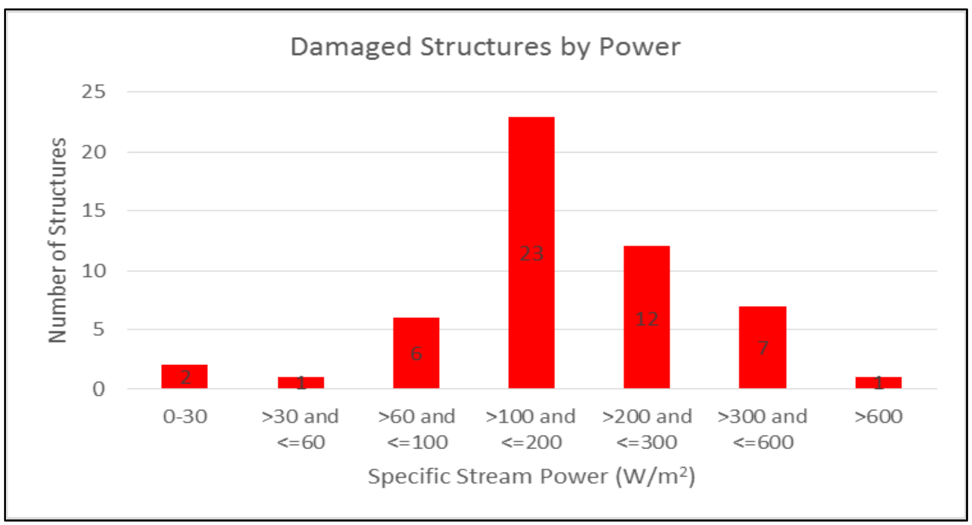
Damage more common in mid-range power (100 – 300 W/m^2) with low resistance bed material

METHODS

POTENTIAL CHANNEL BED EROSION

Specific Stream Power (SSP) = Weight of Water X Flow X Channel Slope (Bagnold, 1966)

Potential geomorphic work to a unit area of the channel bed.



(MMI, UMass, MassDOT, 2017)

METHODS

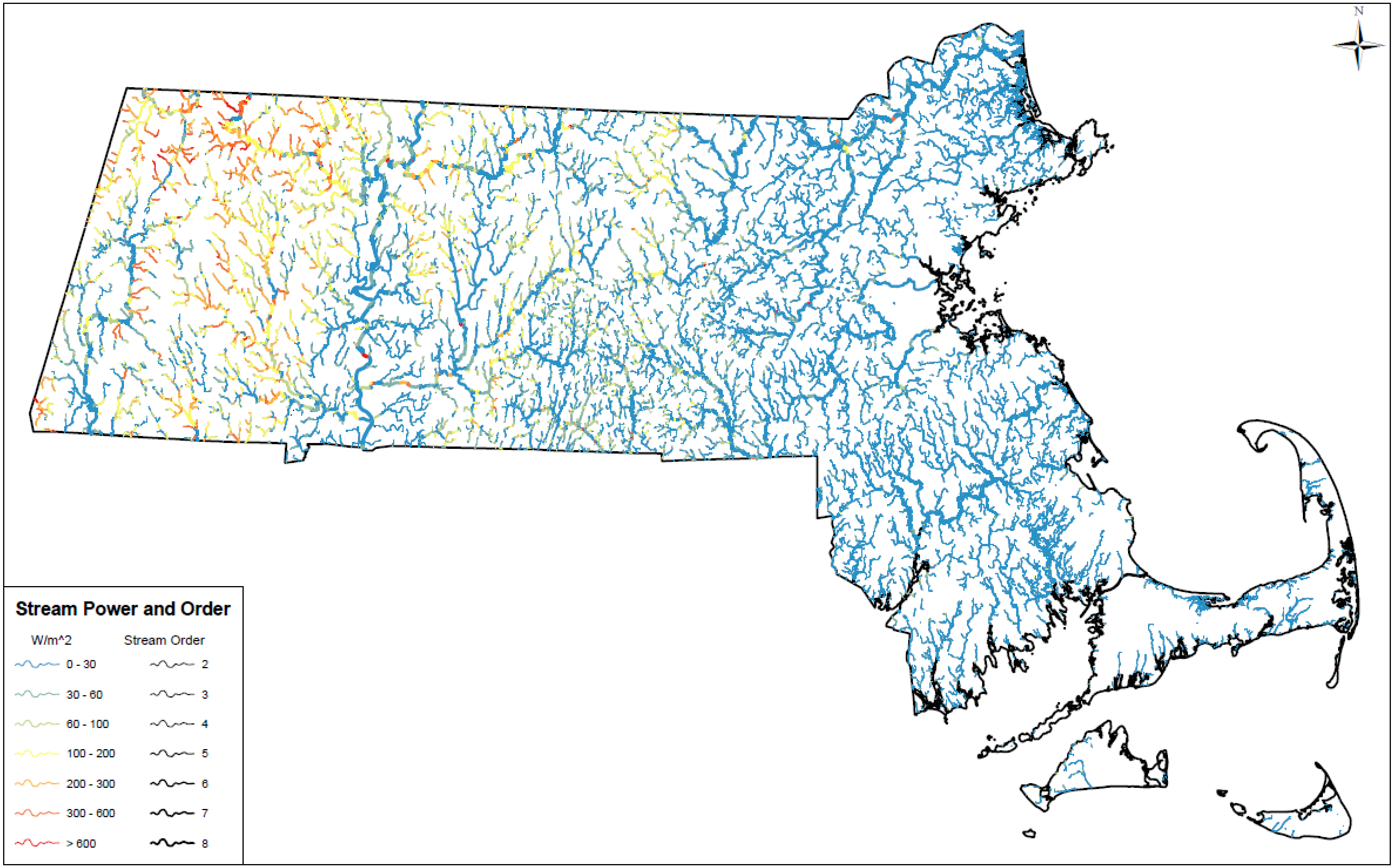
POTENTIAL CHANNEL BED EROSION

$$Q_2(ft^3/s) = 10^{\left\{ 1.631 + 0.801 \times \log_{10}(\textbf{Area}\ [mi^2]) + 0.00589 \times (\textbf{Elev}\ [m]) - 0.01137 \times (\textbf{Storage}\ [\%]) \right\}}$$

Zarriello, 2017

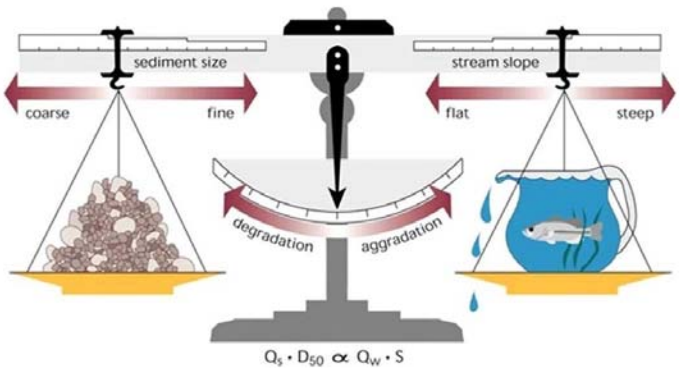
METHODS

POTENTIAL CHANNEL BED EROSION

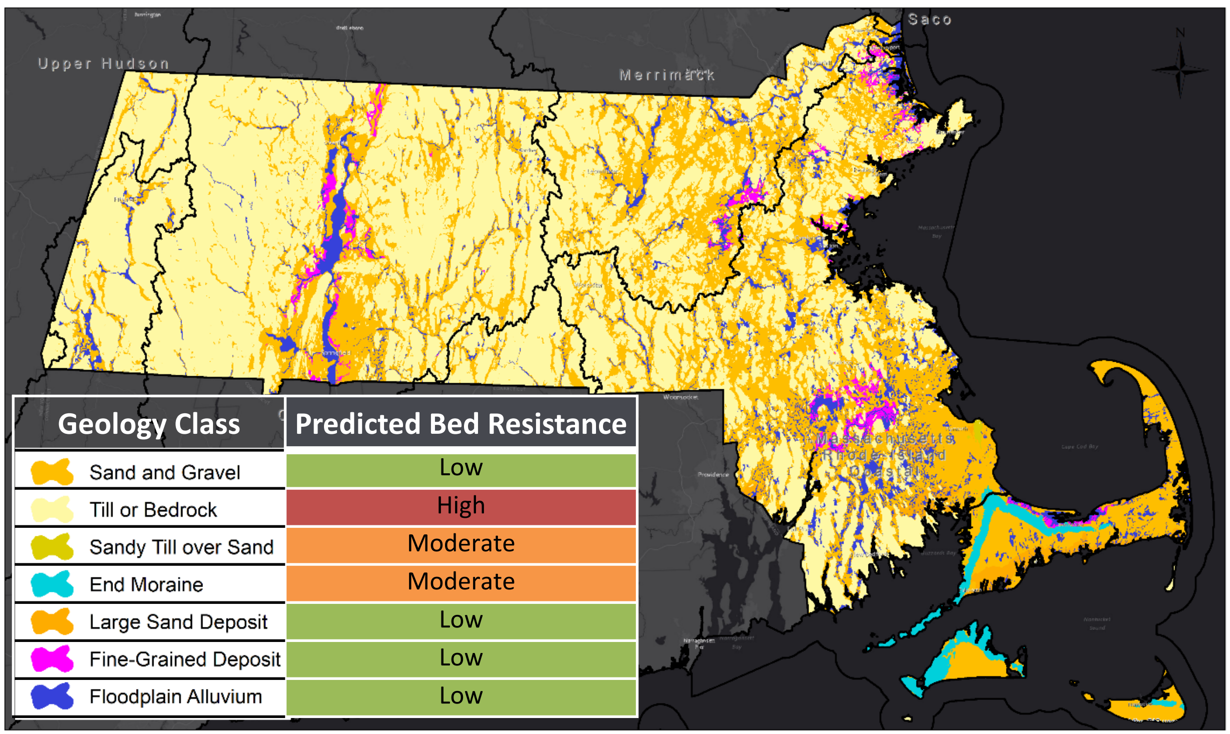


METHODS

POTENTIAL CHANNEL BED EROSION



"…balance between stream power and the bed resistance created by the sediment load and size"
- Lane, 1955; Rosgen and Silvey, 1996; FISRWG, 1998



(USGS, 1999)

METHODS

SCORING

Potential Channel Erosion Vulnerability

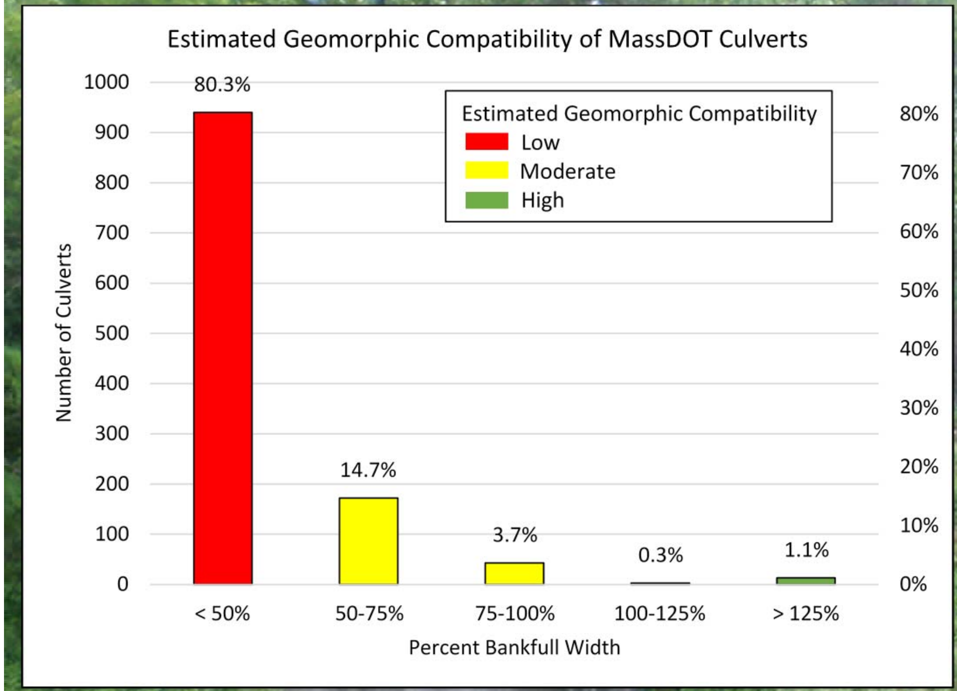
Estimated Specific Stream Power (W/m^2)				
	0-29	Low	Low	Low
	30-59	Moderate	Moderate	Low
	60-99	High	Moderate	Low
	100-199	High	High	Moderate
	200-299	High	High	Moderate
	300-599	High	High	Moderate
	600+	High	High	High
Predicted Bed Resistance		Low	Moderate	High

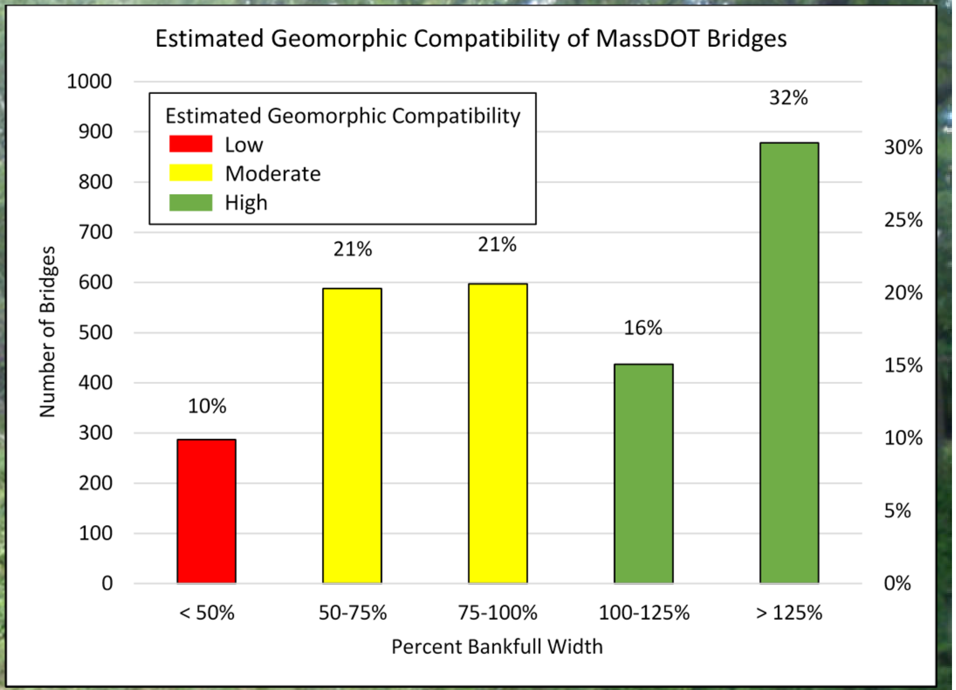
Estimated Structure Vulnerability

		Estimated Structure Geomorphic Compatibility		
		Low	Moderate	High
		($\%_{W_{bankfull}} < 50$)		($\%_{W_{bankfull}} \geq 100$)
Potential Channel Erosion Vulnerability (SSP and Bed Resistance)	High	H	H	M
	Moderate	H	M	L
	Low	M	L	L

RESULTS

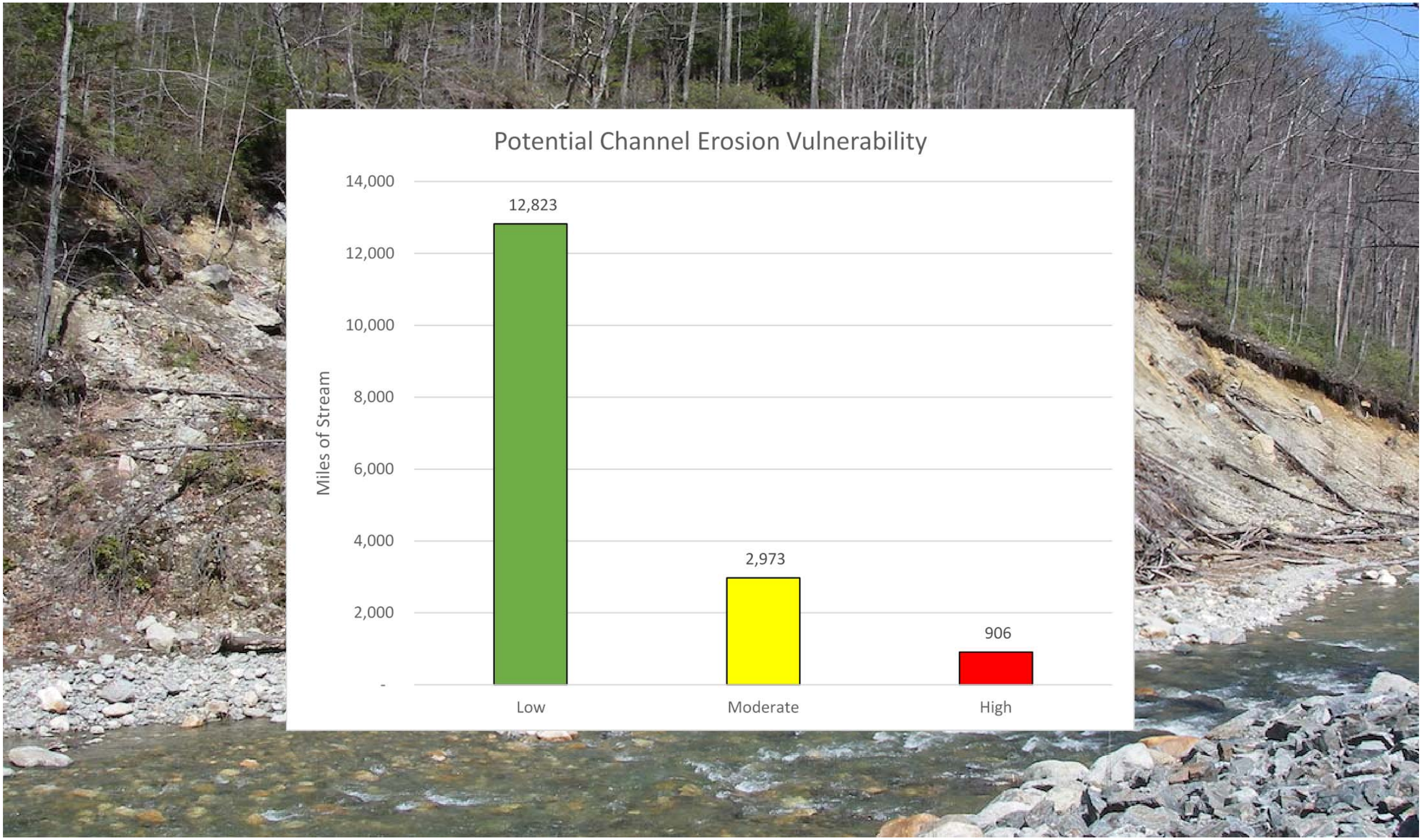
ESTIMATED STRUCTURE GEOMORPHIC COMPATIBILITY





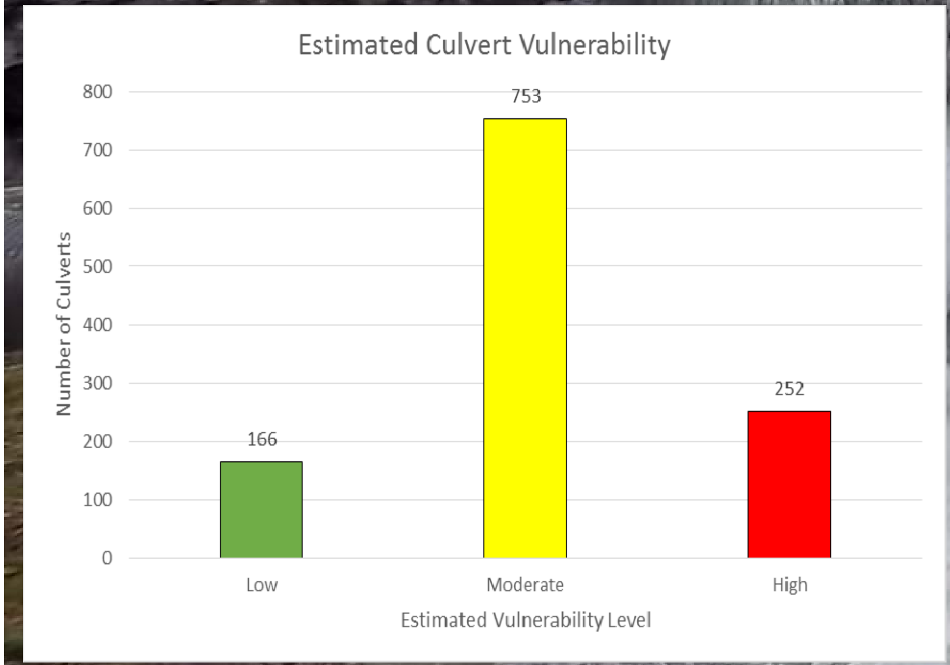
RESULTS

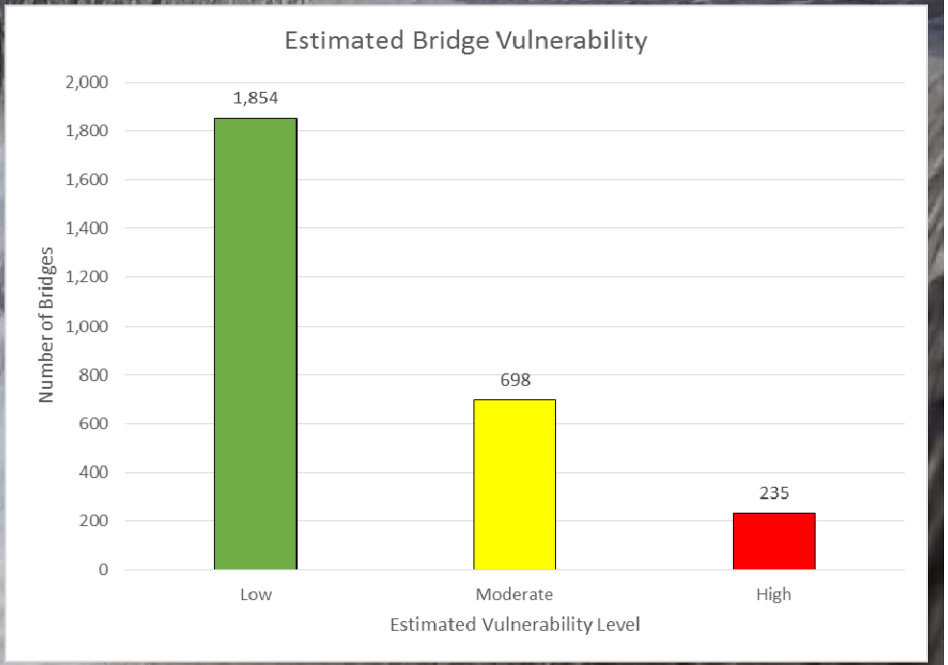
POTENTIAL CHANNEL EROSION VULNERABILITY



RESULTS

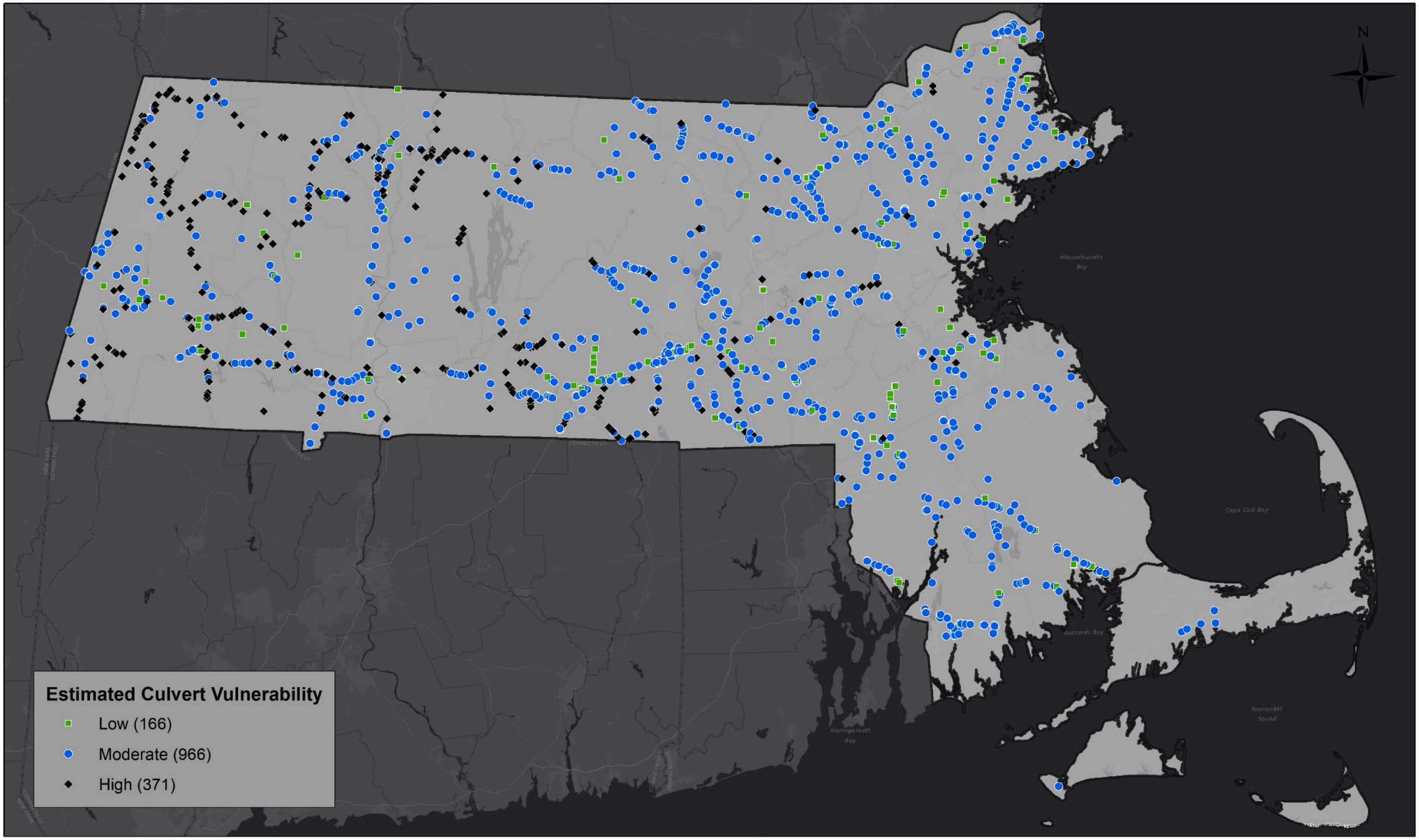
ESTIMATED CULVERT AND BRIDGE VULNERABILITY





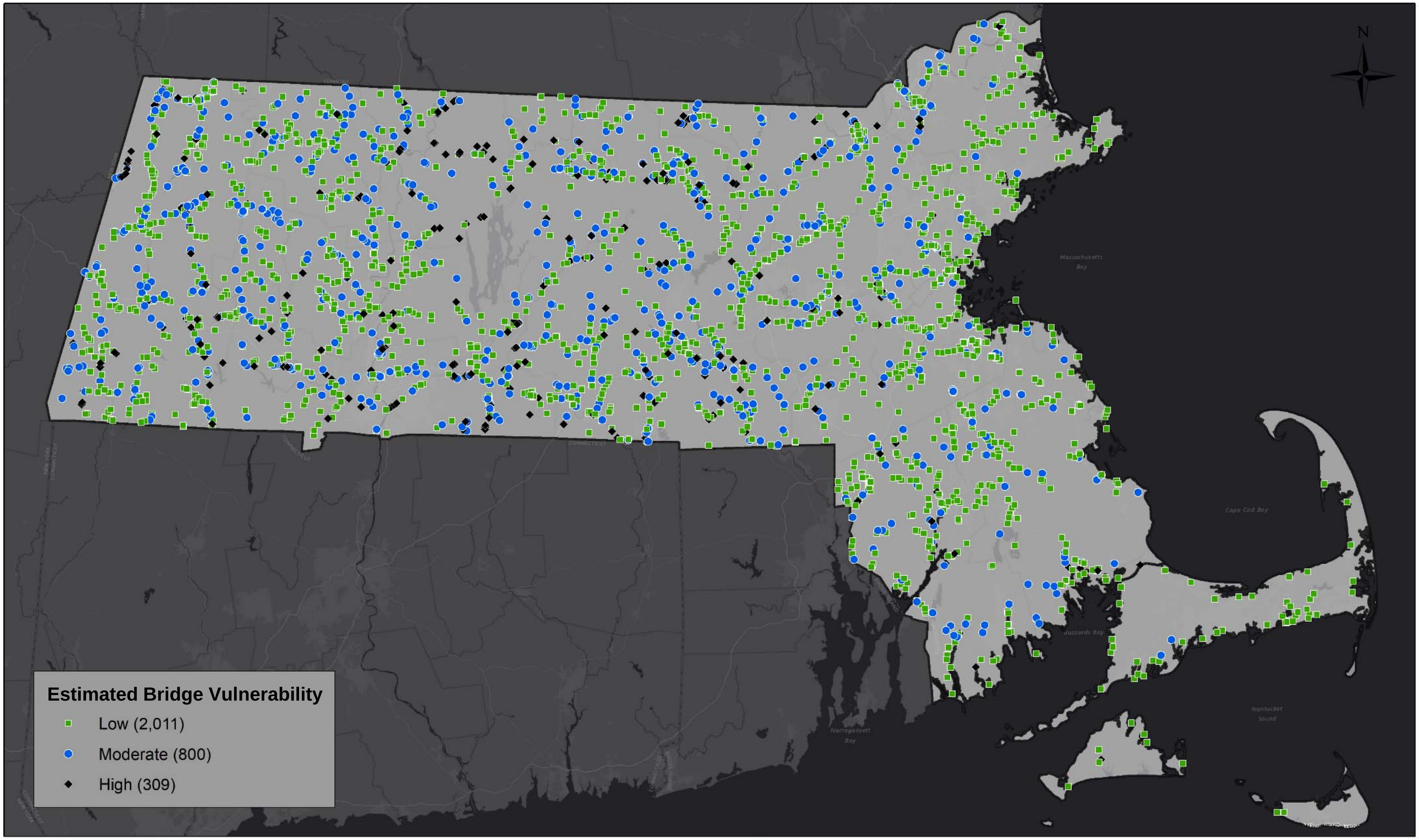
RESULTS

ESTIMATED CULVERT VULNERABILITY



RESULTS

ESTIMATED BRIDGE VULNERABILITY

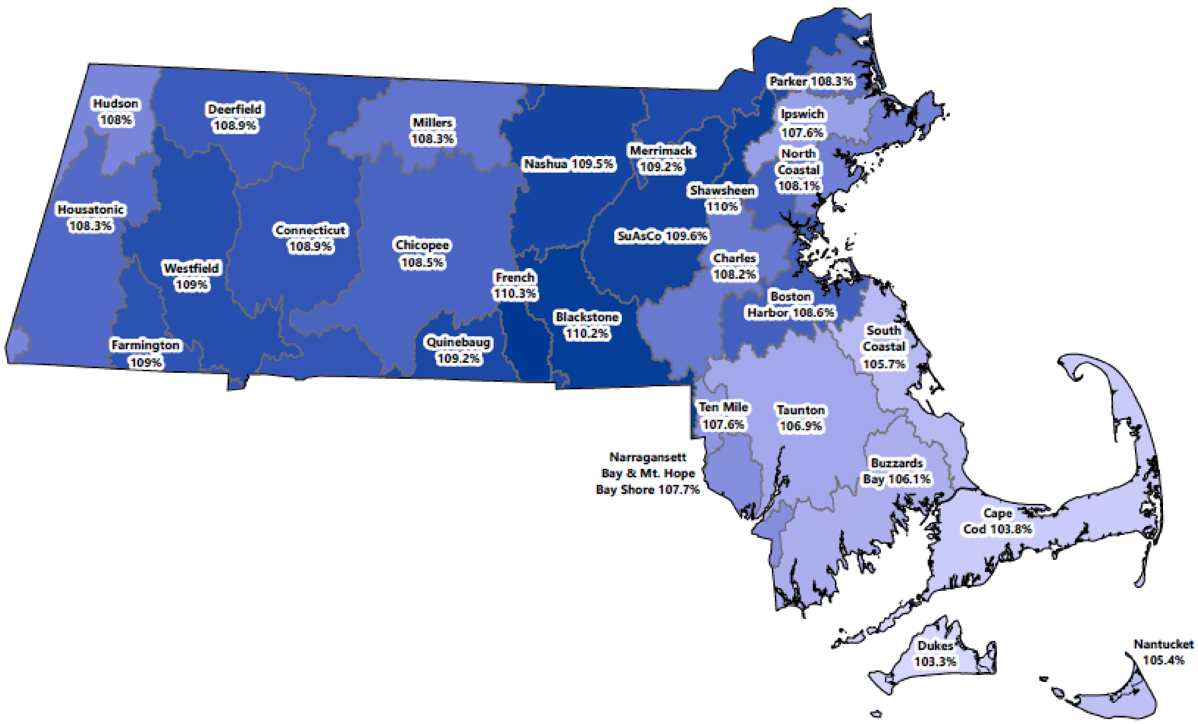


METHODS

CLIMATE CHANGE

Resilient MA Climate Change Data Clearing House

Downscaled Massachusetts Projections for Consistent Planning



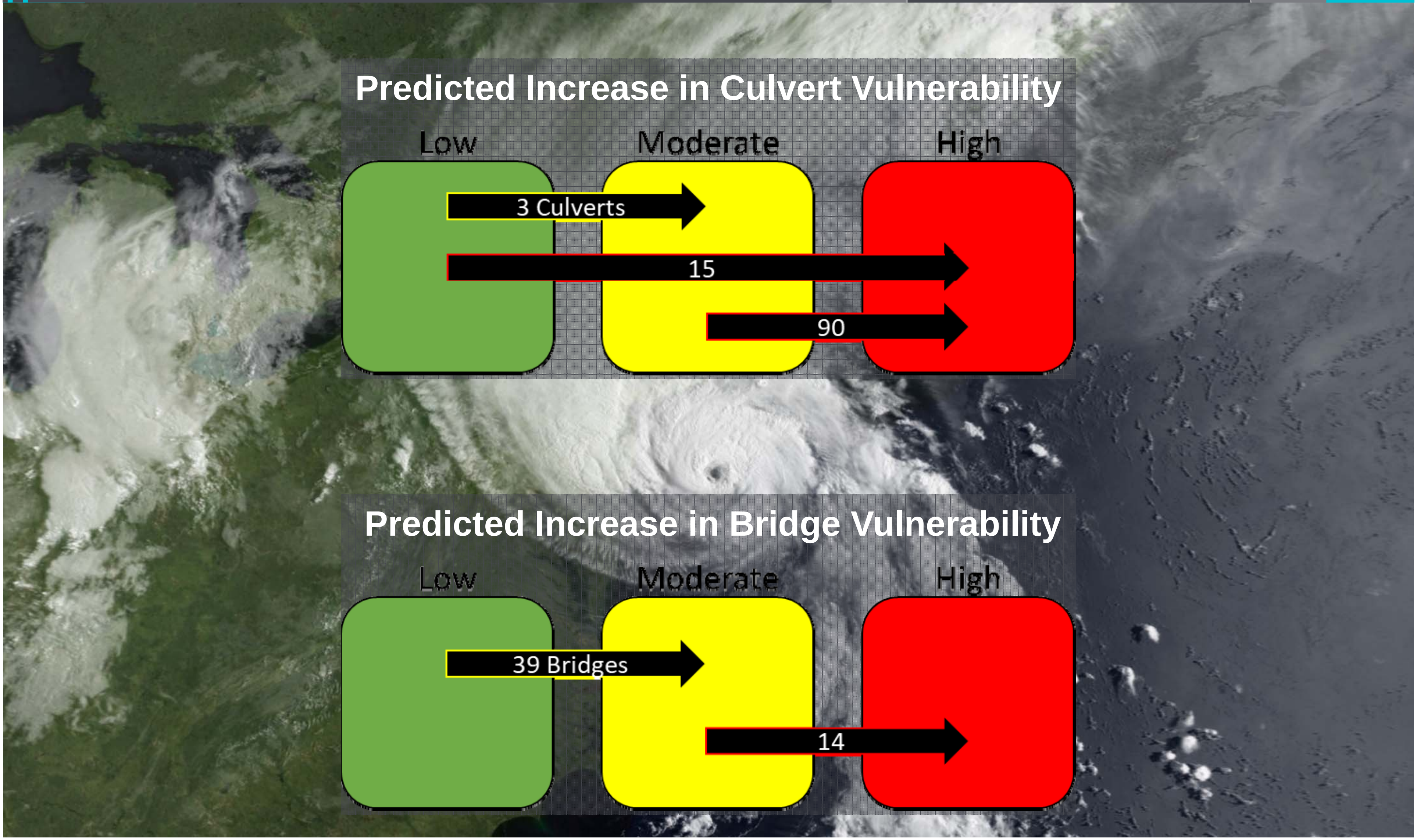
Mean annual precipitation increase 5 – 10% over next 50 years

The projected increase applied to estimates of bankfull discharge.

(Resilient MA Climate Change Data Clearinghouse, http://resilientma.org)

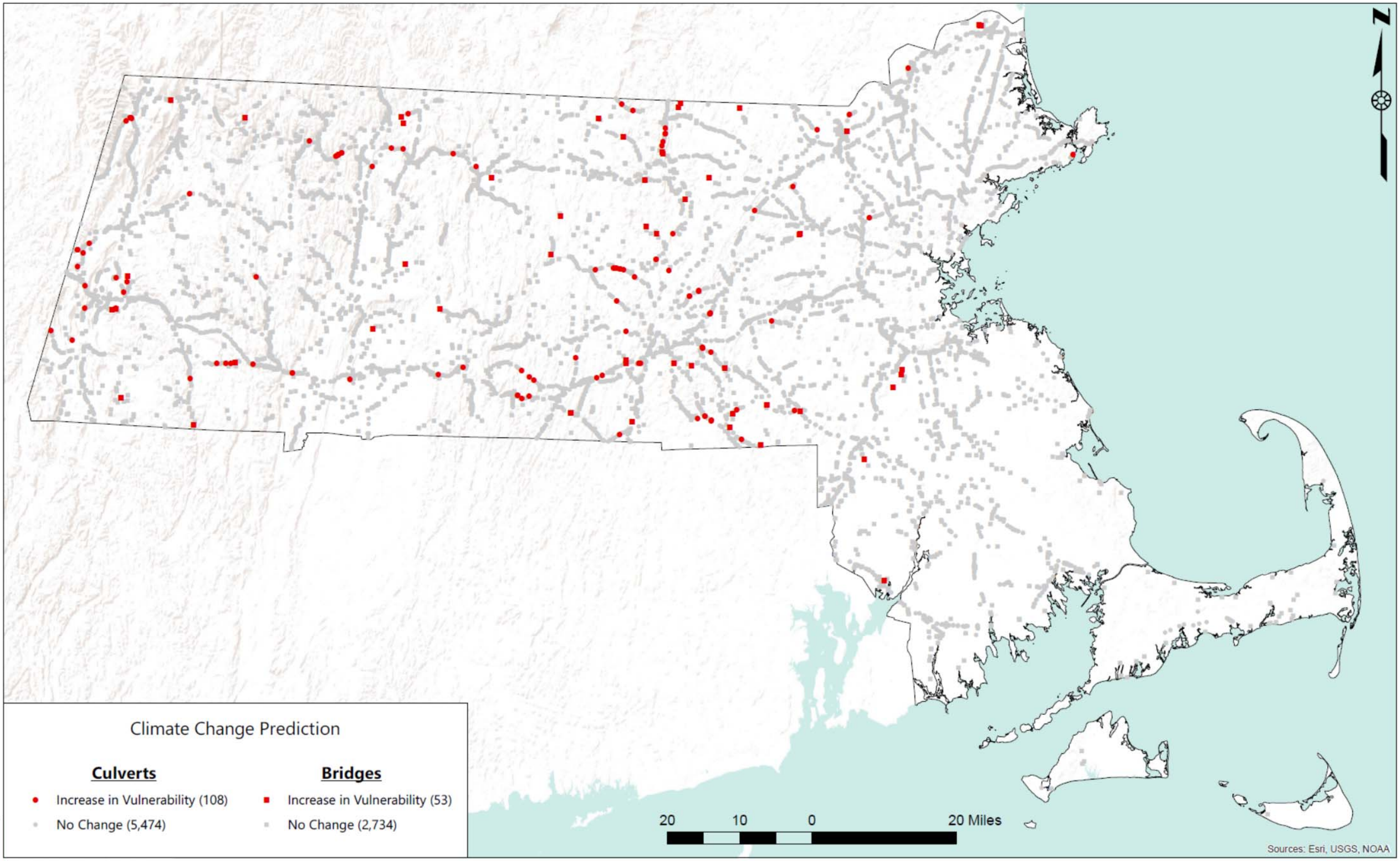
RESULTS

CLIMATE CHANGE IMPACTS



RESULTS

CLIMATE CHANGE IMPACTS



CONCLUSIONS

- Most MassDOT culverts have low geomorphic compatibility
- ¼ of channels have mod – high channel erosion vulnerability
- Most culverts have mod – high estimated vulnerability
- Most bridges have low – mod estimated vulnerability
- Vulnerable structures are spread across the state
- Estimated vulnerability will increase across state with climate change
- Culverts are of particular concern since less is known about location, size, condition, and geomorphic compatibility as compared to bridges.

NEXT STEPS

1. Validate results of vulnerability screen with data from districts
2. Validate results of screen with field inspections at high-vulnerability crossings
3. Import results into GeoDOT to create online GIS maps
4. Add results of screen to MaPIT to improve project development and design
5. Complete development of the MassDOT Culvert Database
6. Coordinate with FHWA on culvert replacement and improvement program
7. Apply screen to culverts added to MassDOT Culvert Database in the future