MnDOT Extreme Flood Vulnerability Analysis

Chris Dorney, WSP

NAEP November Webinar
November 16, 2021

Presentation Overview

- Context & project goal
- Exposure analysis
- Risk calculations

Geographic Scale of the Analysis

Systems-level vulnerability assessment

An analysis to determine the degree to which a transportation <u>system</u> is susceptible to, or unable to cope with adverse effects of climate change and/or extreme weather events

Project-level adaptation assessment

An analysis of the vulnerability of a transportation asset/project to climate change and/or extreme weather events and, if found to be vulnerable, the development and evaluation of adaptation alternatives

Systems-Level Analysis Approaches

Stakeholder Input

Likelihood \ Impact	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med Hi	High	High
Likely	Low	Low Med	Medium	Med Hi	High
Possible	Low	Low Med	Medium	Med Hi	Med Hi
Unlikely	Low	Low Med	Low Med	Medium	Med Hi
Very Unlikely	Low	Low	Low Med	Medium	Medium

Indicators

Flash Flood Vulnerability and Adaptation Assessment Pilot Project (2014)

Quantitative Risk

Indicators-Based Systems-Level Analysis (2014)

Bridges

Large culverts

Pipes

Roads

Calculate the Vulnerability Ratings for Each Asset (0 = least vulnerable, 100 = most vulnerable)

Sensitivity

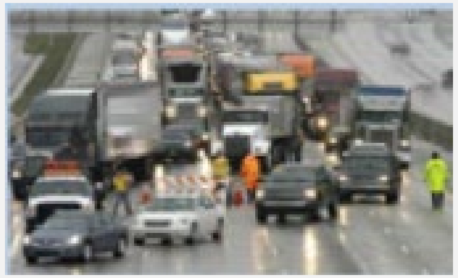
- Capacity to handle higher flows
  - Percent change in peak design flow required for overtopping (based on StreamStats)
- Asset condition
  - Pavement condition (roads)
  - Scour rating (bridges)
  - Substructure condition (bridges)
  - Channel condition (bridges and large culverts)
  - Culvert condition (large culverts)
  - Pipe condition (pipes)

Exposure

- Stream velocity
- Previous flooding issues
- Belt width to span length ratio (bridges, large culverts, pipes)
- Belt width to floodplain width ratio (roads)
- Percent of total roadway length parallel to the floodplain at risk of erosion from the stream channel (roads)
- Percent forest land cover in drainage area (bridges, large culverts, pipes)
- Percent drainage area not covered by lakes & wetlands (storage capacity)
- Percent urban land cover in drainage area

Adaptive Capacity

- Average annual daily traffic (AADT)
- Heavy commercial average daily traffic (HCADT)
- Detour length
- Flow control regime (bridges, large culverts, and pipes)



Rank Flood Vulnerabilities (pilot in Districts 1 & 6)

Systems-Level Analysis Approaches

Stakeholder Input

Likelihood ↑ / Impact →	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med Hi	High	High
Likely	Low	Low Med	Medium	Med Hi	High
Possible	Low	Low Med	Medium	Med Hi	Med Hi
Unlikely	Low	Low Med	Low Med	Medium	Med Hi
Very Unlikely	Low	Low	Low Med	Medium	Medium

Indicators

Quantitative Risk

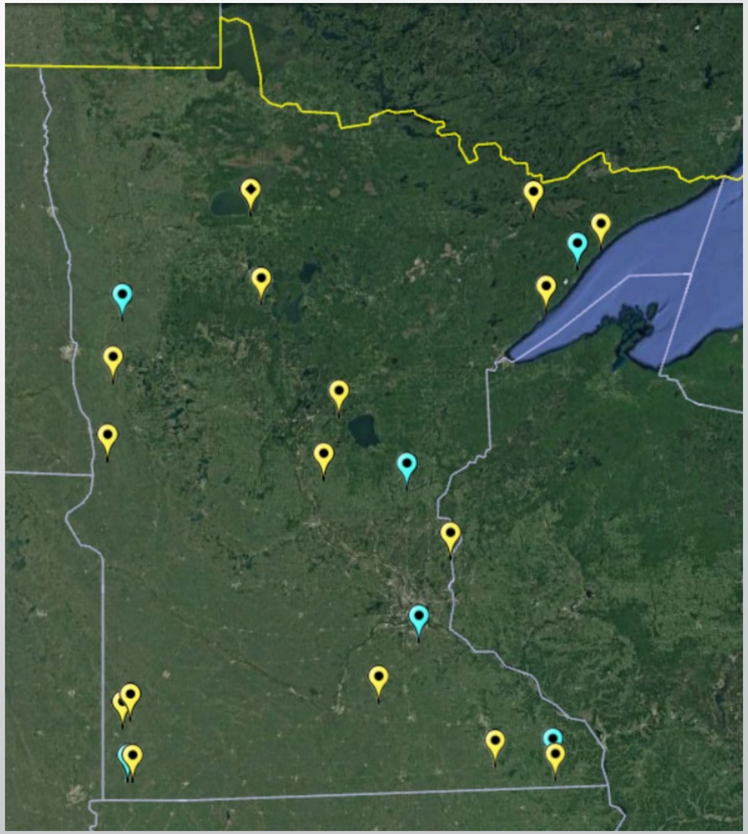
Extreme Flood Vulnerability Assessment (Ongoing)

Quantitative Risk Approach

- Calculates expected costs (risk) to assets from climate stressors if no adaptation actions are taken
- Costs estimates may include
  - Damage and repair costs
  - Costs to system users
- Advantages over the indicators approach
  - Links between hazard, impact, and consequences are explicit (less "fuzzy")
  - More relatable & actionable to DOT engineers (helps with internal buy-in)
  - $ based outputs are more relatable to policy-makers (speaks their language)

Project Goal & Sample Assets

- Goal: Develop and pilot test an approach capable of efficiently quantifying the future risk of riverine flooding to <u>all</u> 32,000+ MnDOT owned bridges and culverts
- Representative sample of 22 assets selected for pilot testing
  - 6 bridges
  - 16 culverts

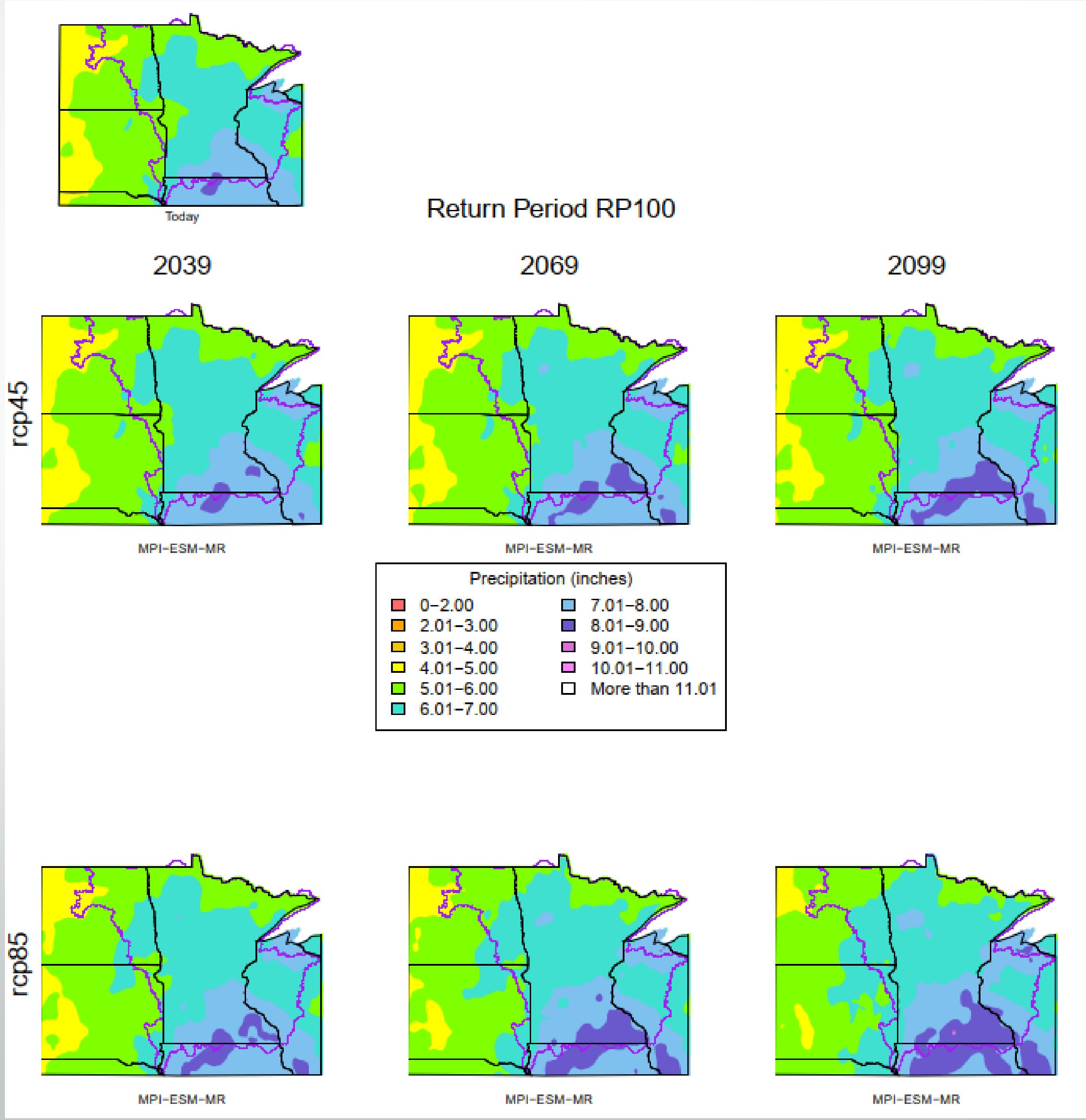


Source: Google Earth

Exposure Analysis

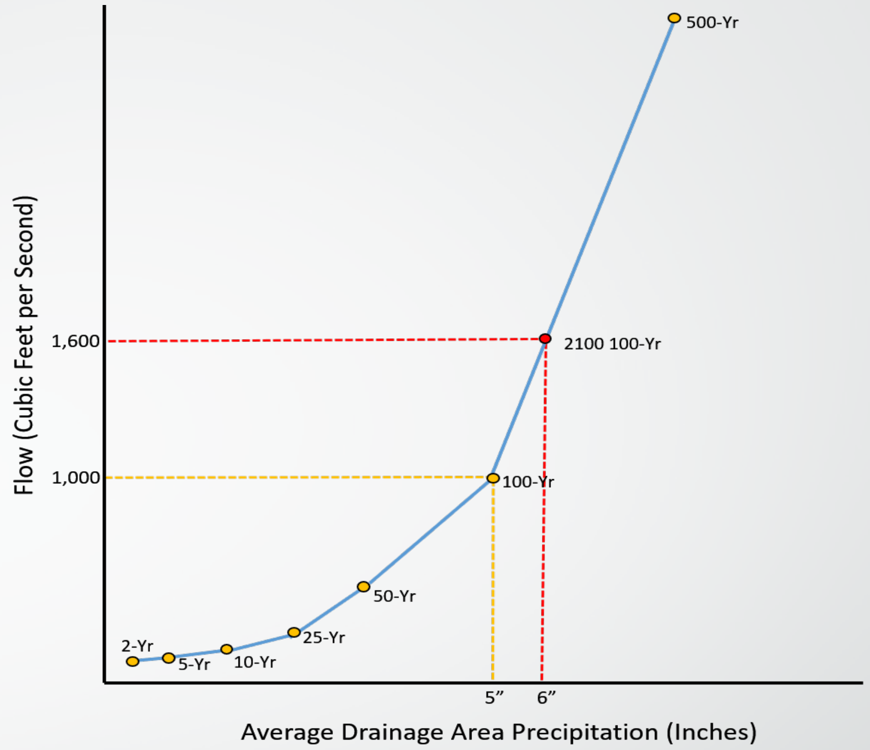
Precipitation Projections

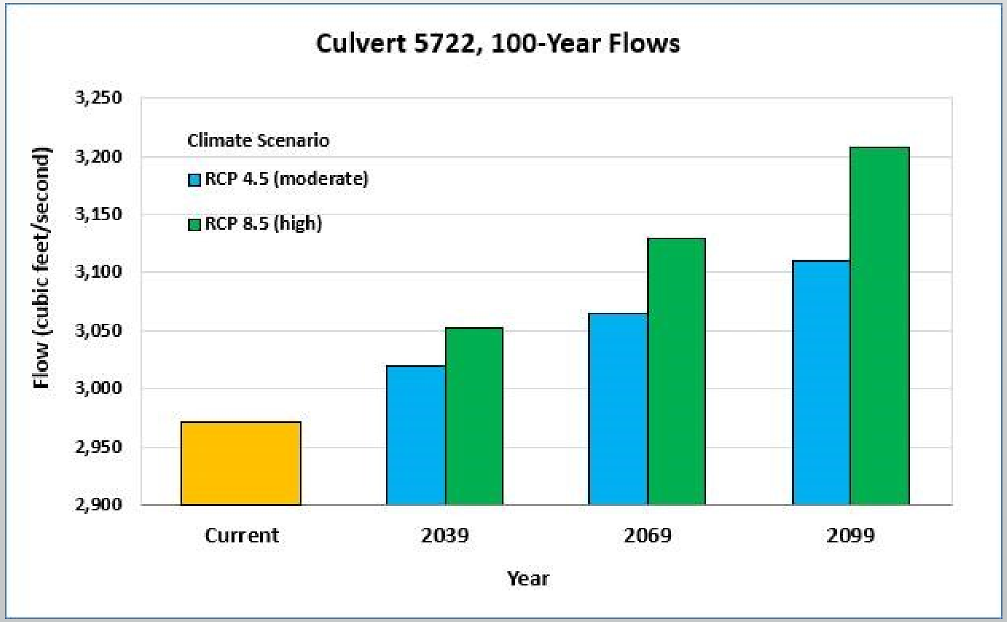
- Developed projections of 2, 5, 10, 25, 50, 100, 200, and 500-year 24-hour precipitation depths through end-of-century
  - Moderate climate change scenario (RCP 4.5)
  - High climate change scenario (RCP 8.5)



Peak Flow Projections

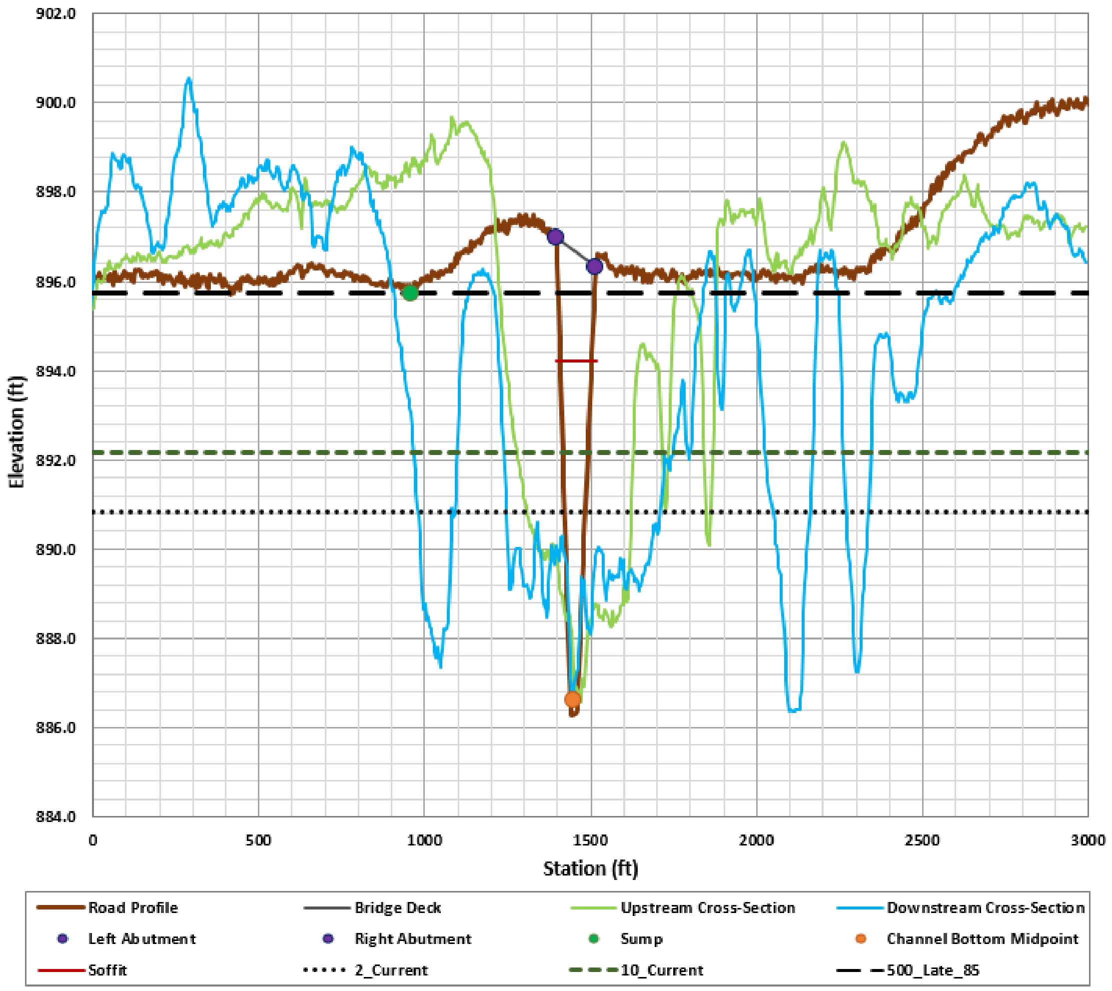
- Developed projections of the 2, 5, 10, 25, 50, 100, 200, and 500-year peak flows at each asset for each scenario through end-of-century
- Scaled up (or down) USGS StreamStats flow estimates based on projected precipitation change





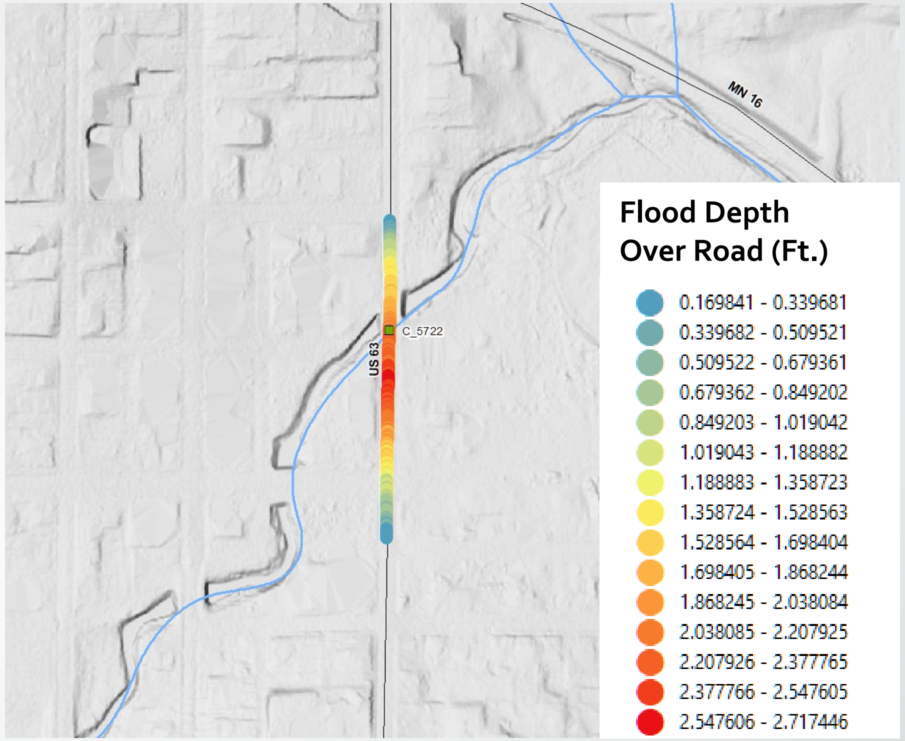
Hydraulic Analysis

- Used custom-built tools and GIS processes that run HEC-RAS hydraulic software in batch mode for thousands of assets at a time
- Example outputs
  - Upstream water elevations
  - Flow velocities
  - Channel vs. overbank flows



Exposure Reporting

- Exposure summary tables for each asset showing change in exposure over time under each scenario
- Accompanying GIS data showing flood depths over the road in the vicinity of each asset for each scenario and time period



C_5722

Road EL: 1271.258 | Crown EL: 1270.066 | Low Road EL: 1270.573

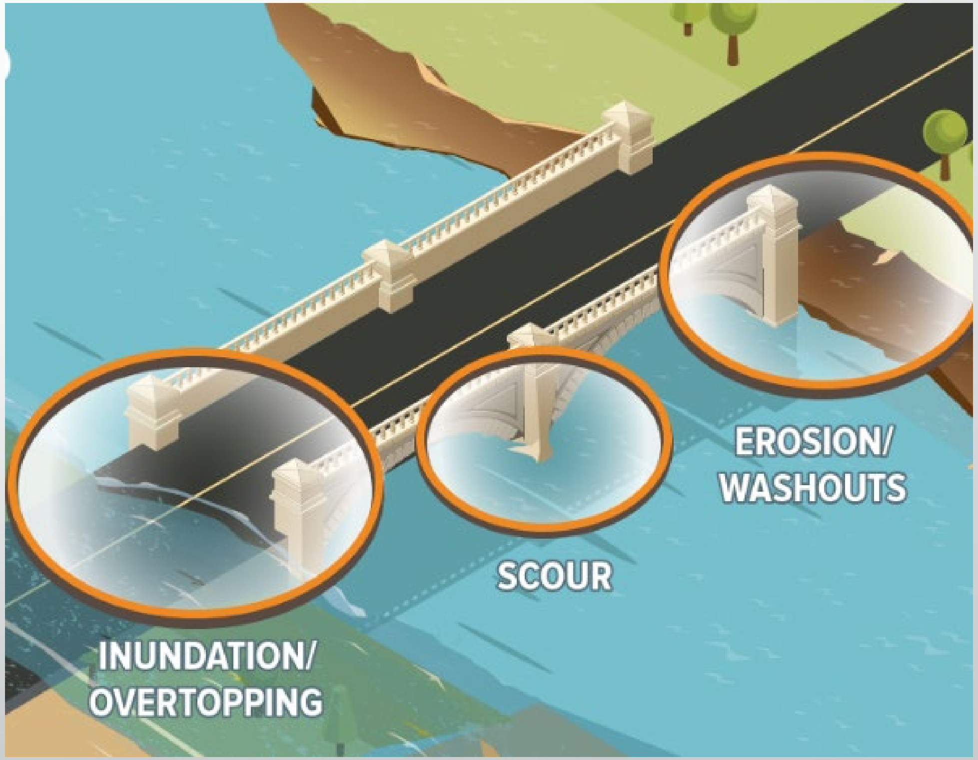
Return Period	Current	RCP 4.5 2039	RCP 4.5 2069	RCP 4.5 2099	RCP 8.5 2039	RCP 8.5 2069	RCP 8.5 2099
2	1268.93	1269.22	1269.49	1269.88	1269.45	1269.97	1270.32
5	1270.65	1270.76	1270.85	1270.94	1270.83	1270.98	1271.14
10	1271.35	1271.42	1271.48	1271.53	1271.46	1271.56	1271.65
25	1271.99	1272.04	1272.08	1272.12	1272.07	1272.15	1272.22
50	1272.40	1272.44	1272.48	1272.52	1272.47	1272.53	1272.59
100	1272.77	1272.80	1272.83	1272.87	1272.82	1272.88	1272.96
500	1273.25	1273.26	1273.27	1273.29	1273.28	1273.29	1273.29

Water Above Minimum Bridge Deck Elevation or Road Elevation Above Culvert	->	
Water Above Bridge Low Chord Elevation or Top of Culvert Elevation	->	
Water Above Roadway Sump Elevation	->	###
Glass-Walling Occuring	->	###

Risk Calculations

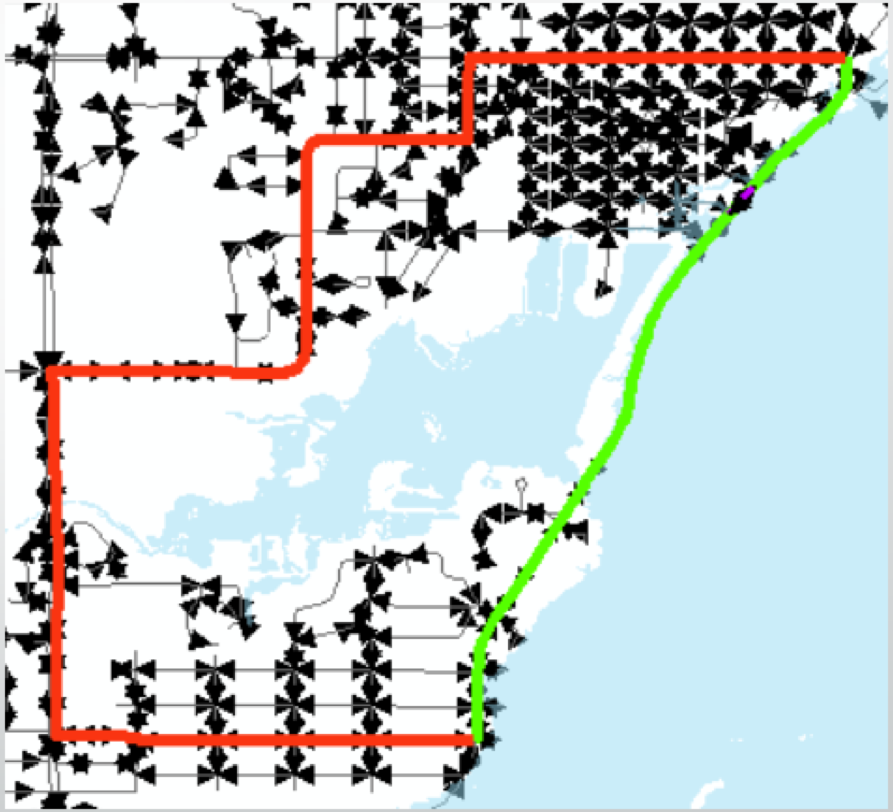
Physical Damage Assessment

- Will estimate damage costs at each asset from projected flood events
- Roadway damage model (approaches)
  - Pavement delamination
  - Shortening of pavement life
  - Embankment erosion
- Culvert damage model
  - Loss via embankment erosion
- Bridge damage model
  - Pavement delamination
  - Deck damage/displacement
  - Pier, abutment, & contraction scour



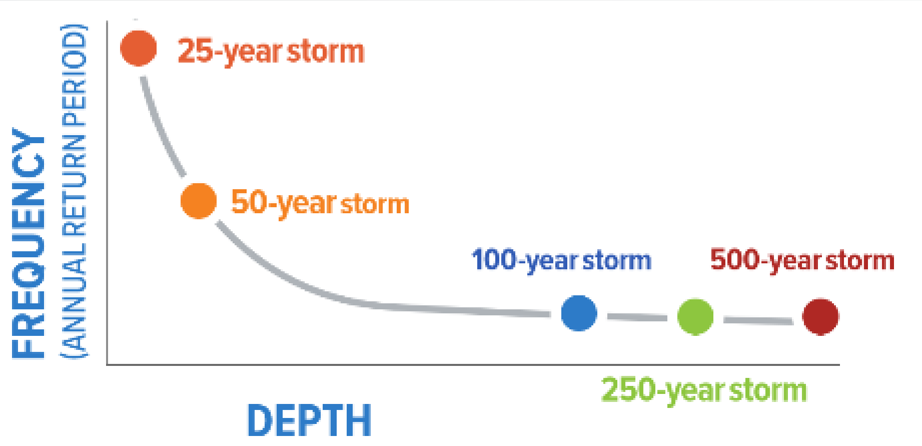
User Impacts Assessment

- Will estimate costs to the traveling public for detouring around a flood-impacted asset considerate of
  - Traffic volumes
  - Network redundancy
  - Estimated outage durations
  - Time, fuel, & operating costs
- To be implemented through a custom-designed detour routing algorithm run in GIS

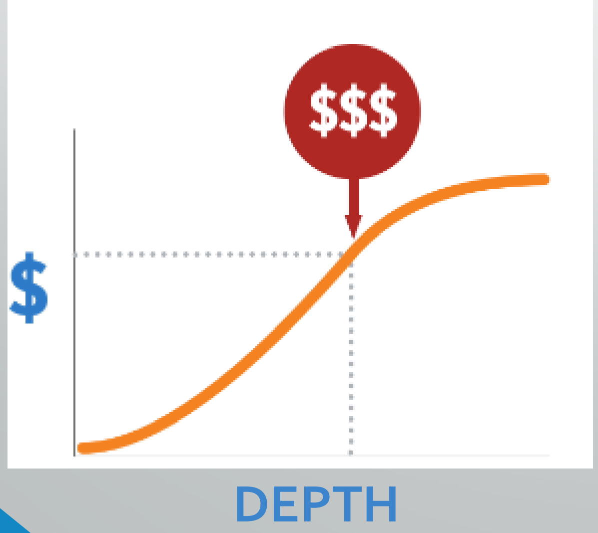


Estimation of Cumulative Costs

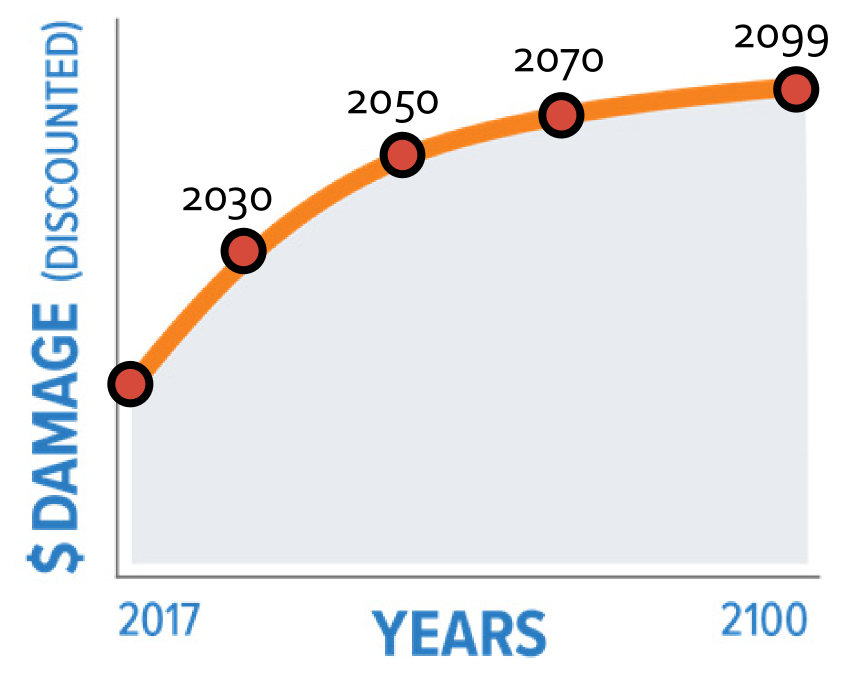
Exposure Likelihood



Physical Damage & User Costs



Total Expected Flooding Costs Through 2099



Anticipated Outputs

Asset	Moderate Climate Scenario (RCP 4.5)					High Climate Scenario (RCP 8.5)				
	Total Costs (Median)	Total Costs (Lower Conf. Int.	Total Costs (Upper Conf. Int.)	Agency Costs	User Costs	Total Costs (Median)	Total Costs (Lower Conf. Int.	Total Costs (Upper Conf. Int.)	Agency Costs	User Costs
1	$	$	$	$	$	$	$	$	$	$
2	$	$	$	$	$	$	$	$	$	$
…	$	$	$	$	$	$	$	$	$	$
N	$	$	$	$	$	$	$	$	$	$

- Costs can also be disaggregated by year
- To address timing of adaptation needs
  1. Select a risk tolerance threshold (acceptable $ per year)
  2. Determine year when each threshold crossed for each climate scenario

Contact Information

MnDOT

Jeff Meek

Sustainability Coordinator

651-366-4263

Jeffrey.Meek@state.mn.us

WSP

Chris Dorney

Director (Climate, Resilience, & Sustainability)

1 703-742-5866

Chris.Dorney@wsp.com