Being Resilient: Challenges and Opportunities for Public Works

Paul Moss, Minnesota Pollution Control Agency

May 7, 2015

Presentation overview

* What is resilience?
* Why is it important?
* Examples of resilience activities
* How to increase resilience?
* What is MN state government doing?

What is resilience? Two perspectives

- Resilience: Ability to bounce back from challenges, setbacks, and disasters

- Resilience: Implementing best practices that can offer benefits now while also helping to prepare for future stresses

Why is resilience important… challenges

* Frequency of disasters, extreme events, and crises
* Past is no longer a good guide to the future
* Anticipate future trends and be prepared to respond to them
* Ability to plan, prepare, continue operations, and bounce back
* Significant cost impacts to recover and rebuild

Why is resilience important… opportunities

* Resilience gives you options
  * Reducing damage from extreme events
  * Buying time during a disaster response
* Benefits today with normal operations
  * Cost savings, improved communications (internal and external), employee health, safety, and morale.
* Opens up future opportunities
  * "Resilience Dividend" by Judith Rodin (2014)

Examples of everyday benefits of resilience

- **Green infrastructure and low impact development** (permeable pavers, trees, rain gardens) can help to reduce impacts of spikes in rainfall and costly damage now, while also helping for longer term preparedness to projected extreme weather.
  - Narrower streets can also reduce traffic speeds, reduce the amount of snow to plow, and reduce salt/sand usage. Also can save money on irrigation but need to consider maintenance costs.
- **Light colored roofs** can reduce power bills now, while also making buildings more resilient to hotter temperatures. Also helps address urban heat island effect for community members.



Examples of everyday benefits of resilience

* **Back up power sources** can help with occasional outages now, while also making the community more prepared for larger future extreme events.
* **Reducing vulnerability of roads and structures on flood plains** lowers risks now, while also helping to be more resilient to projected extreme precipitation. Also helps with maintaining access for emergency response.
* **Added training for work crews about health risks** from extreme heat, vector-borne disease, or impacts of utility disruptions helps now, while also preparing for expected trends. Helps to keep key staff healthy for when they are needed most.

Examples of everyday benefits of resilience

* **Water conservation** now can help stretch existing capacity of water utility infrastructure, while also helping communities to be better prepared for droughts.
  * Water costs money. Leak testing of water mains not only reduces wasted water, but identifies maintenance needs and potential vulnerabilities.
* **Construction and maintenance of infrastructure** taking into account projected trends can be cost effective in meeting long term needs.
* **Redundancy in sources of water supplies** adds to resiliency, while also preparing for risks from drought, contamination (surface or underground), or accidents.

More examples?

Mitigation Ideas:

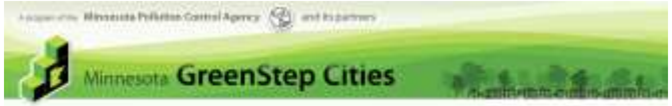
A Resource for Reducing Risk to Natural Hazards

http://tinyurl.com/lbud7k8

Mitigation ideas for drought, flood, extreme temps, storms, etc.)

Minnesota GreenStep Cities:

http://greenstep.pca.state.mn.us



28 best practices for community sustainability and quality of life (including resilience)

Steps to become more resilient: general principles

* Track current and emerging threats
  * http://tinyurl.com/p4p9mwp (State Hazard Mitigation Plan)
  * http://nca2014.globalchange.gov/report/regions/midwest
* Assess vulnerabilities to these threats
  * http://www.ready.gov/risk-assessment
  * http://www.fema.gov/media-library/assets/documents/26335 (THIRA)
* Consider a range of alternative responses to these threats, and **identify co-benefits when possible**
* Strategically implement prioritized resilience actions and **take advantage of many actions which offer a range of benefits now**
* Continue to refine as trends shift

State resilience/adaptation activties

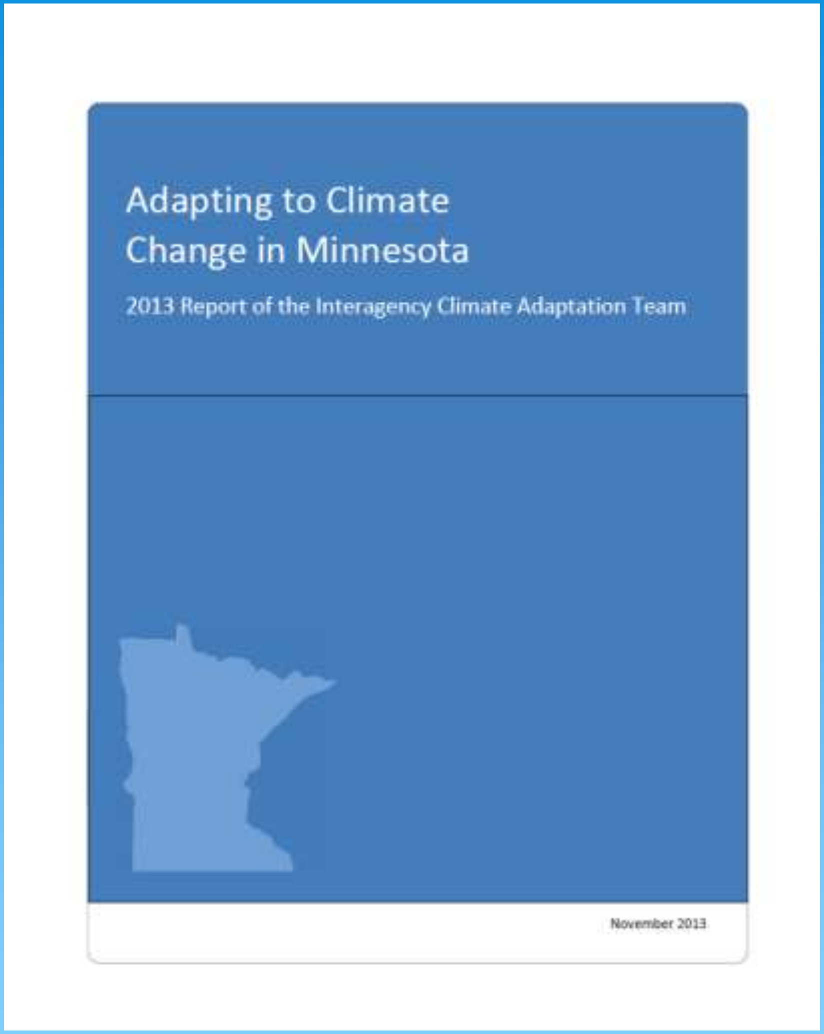
- Agency-based approach
- No mandate from Governor's Office or Legislature
- Interagency Climate Adaptation Team started in 2009
- Includes core group of 9 agencies (Agriculture, Commerce, Health, Natural Resources, Pollution Control, Public Safety, Transportation, Water & Soil Resources, Metropolitan Council) + others
- "Adapting to Climate Change in Minnesota" report identifies vulnerabilities and opportunities

Opportunities identified

* Building resilience to extreme precipitation
* Implementing best practices that achieve multiple benefits
* Protecting human health
* Strengthening existing ecosystems by addressing ongoing challenges and risks

Opportunities identified

* Building partnerships with local governments
* Quantifying climate impacts
* Conducting public and community outreach, education, and training



Report can be downloaded from www.pca.state.mn.us

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Public Health Implications of a Changing Climate

Kristin Raab, MPH, MLA, Director
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APWA Minnesota Chapter 2015 Spring Conference

May 7, 2015

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MN Climate & Health Program
Environmental Impacts Analysis Unit
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MN Climate & Health Program

Overview of Presentation

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- **What are the trends?**
- **What are the health implications of the trends?**
- **Protection/adaptation measures**

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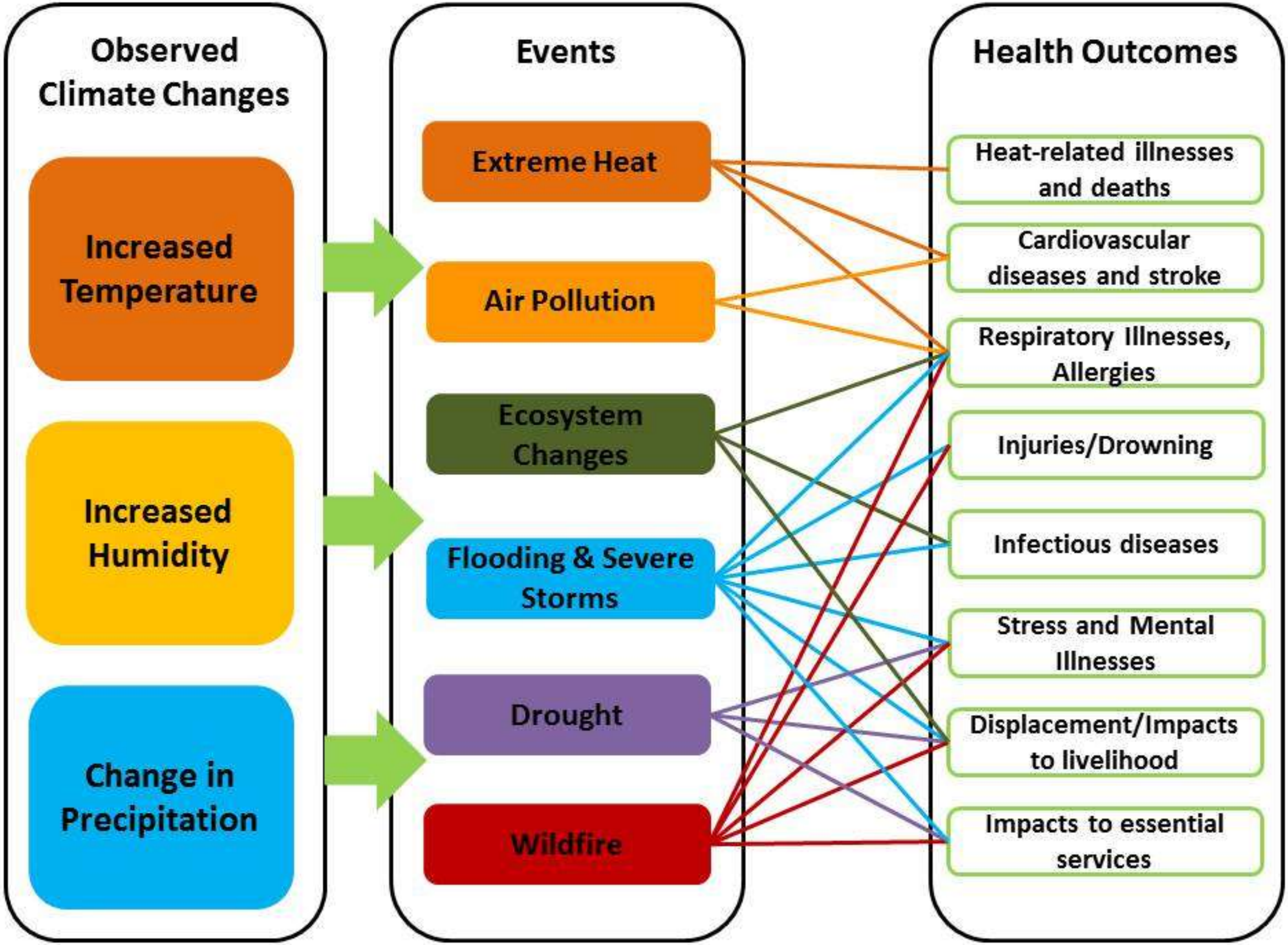
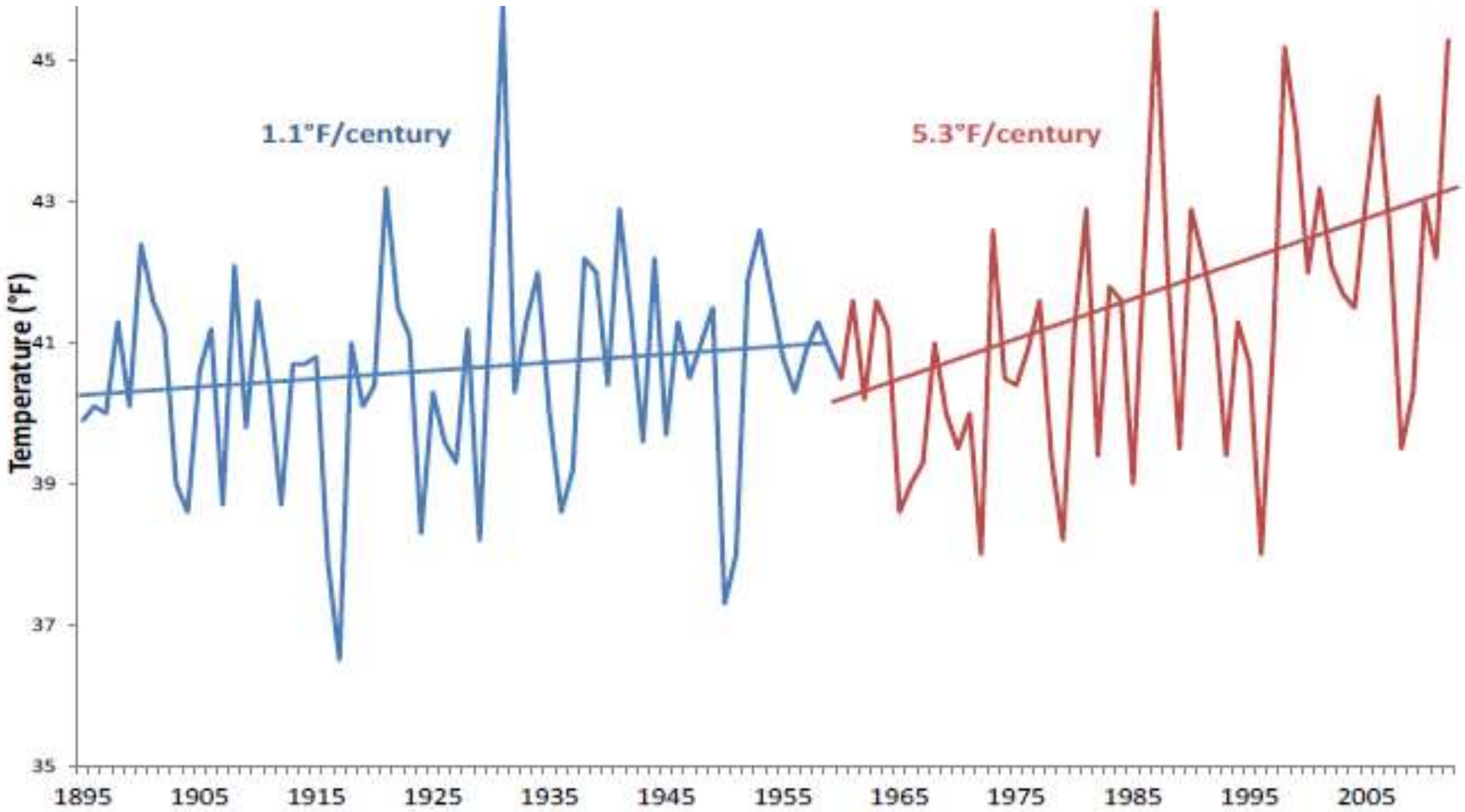


Observed Climate Changes
Increased Temperature
Increased Humidity
Change in Precipitation
Events
Extreme Heat
Air Pollution
Ecosystem Changes
Flooding & Severe Storms
Drought
Wildfire
Health Outcomes
Heat-related illnesses and deaths
Cardiovascular diseases and stroke
Respiratory Illnesses, Allergies
Injuries/Drowning
Infectious diseases
Stress and Mental Illnesses
Displacement/Impacts to livelihood
Impacts to essential services

Temperature Changes in Minnesota

MN Climate & Health Program



Minnesota Average Annual Temperatures

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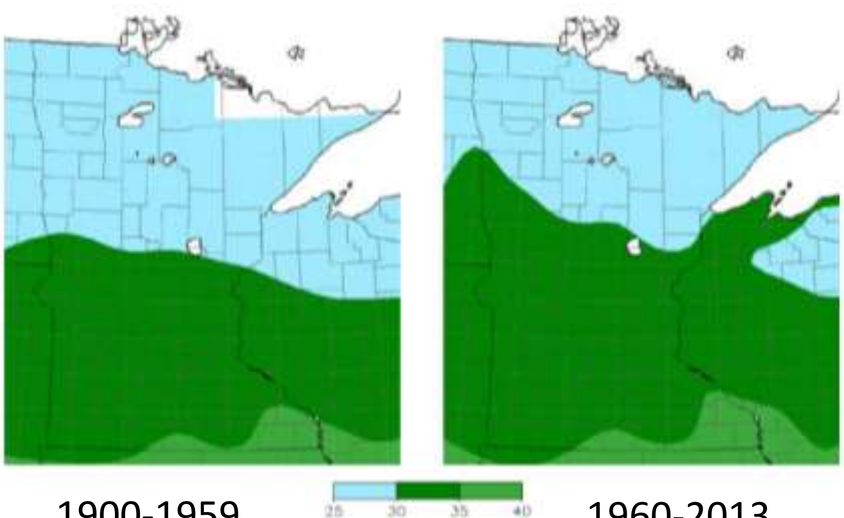
Temperature Changes in Minnesota

MN Climate & Health Program

Significant observations in warming pattern:



1900-1959 1960-2013

Minnesota Average Minimum Temperatures

- Winter temps have been rising about twice as fast as annual average temps
- Minimum or ‘overnight low’ temps have been rising faster than maximum or ‘daytime high’ temps
- Temp has risen faster in northern MN than southern MN

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Dew Point Changes

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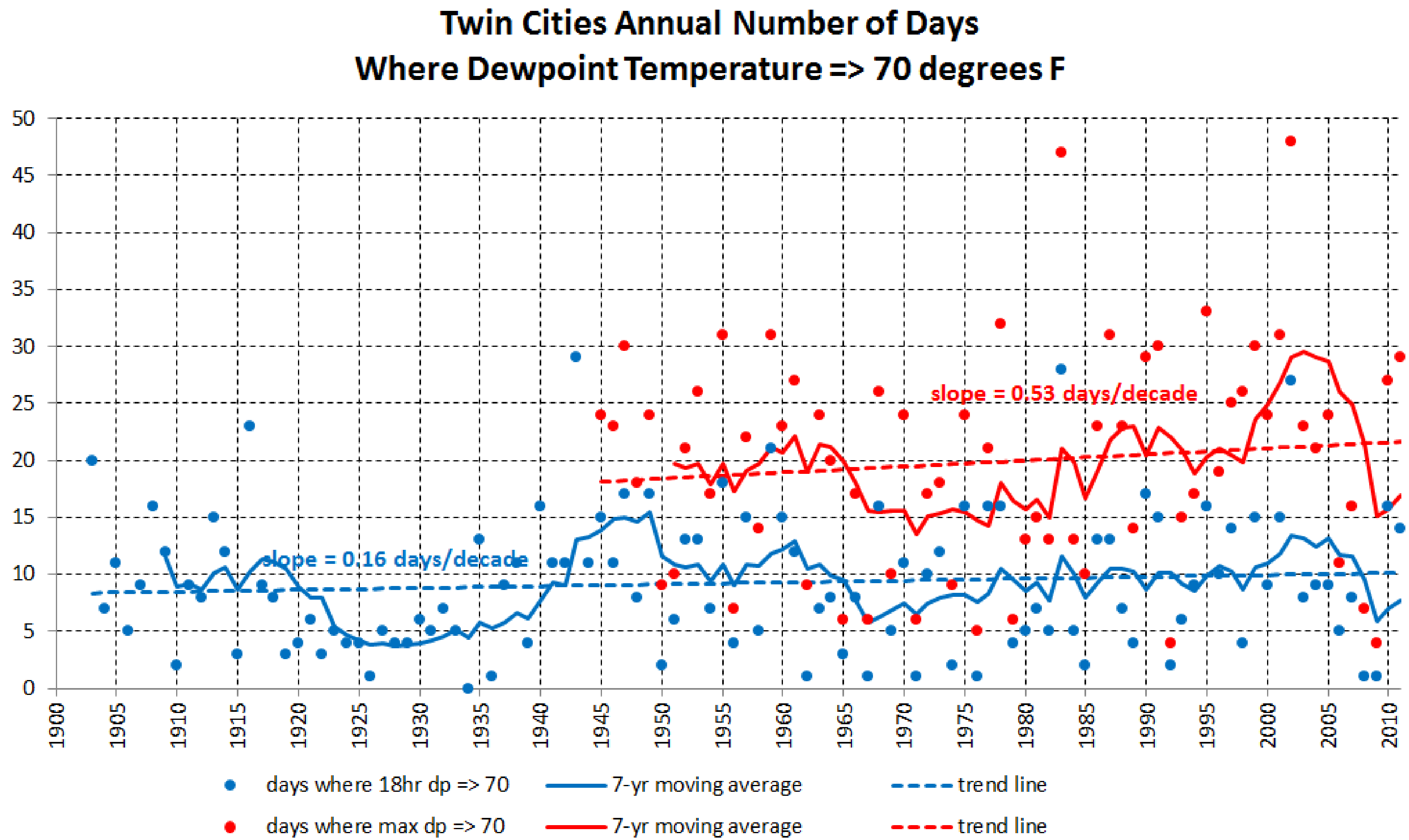

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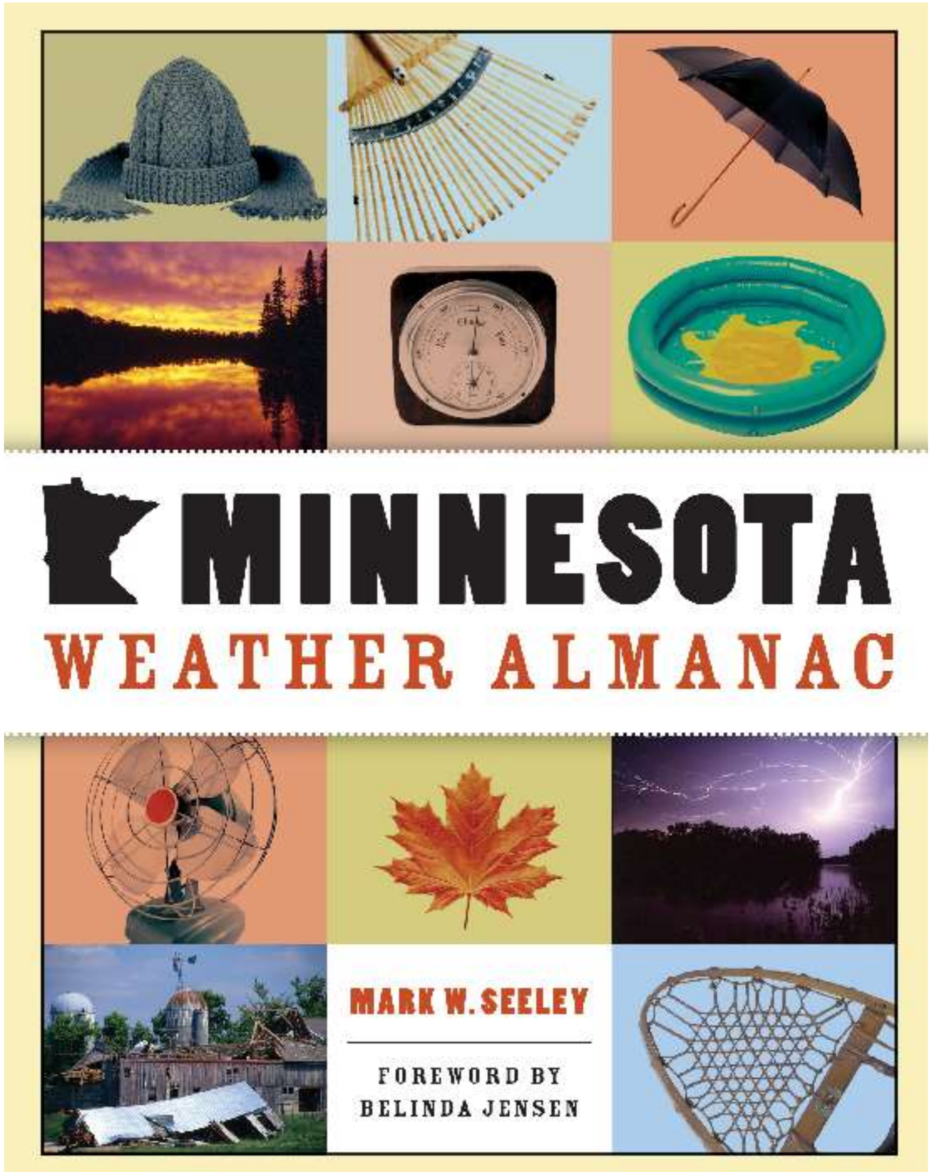
Extreme Heat Events: 1960-2011

MN Climate & Health Program



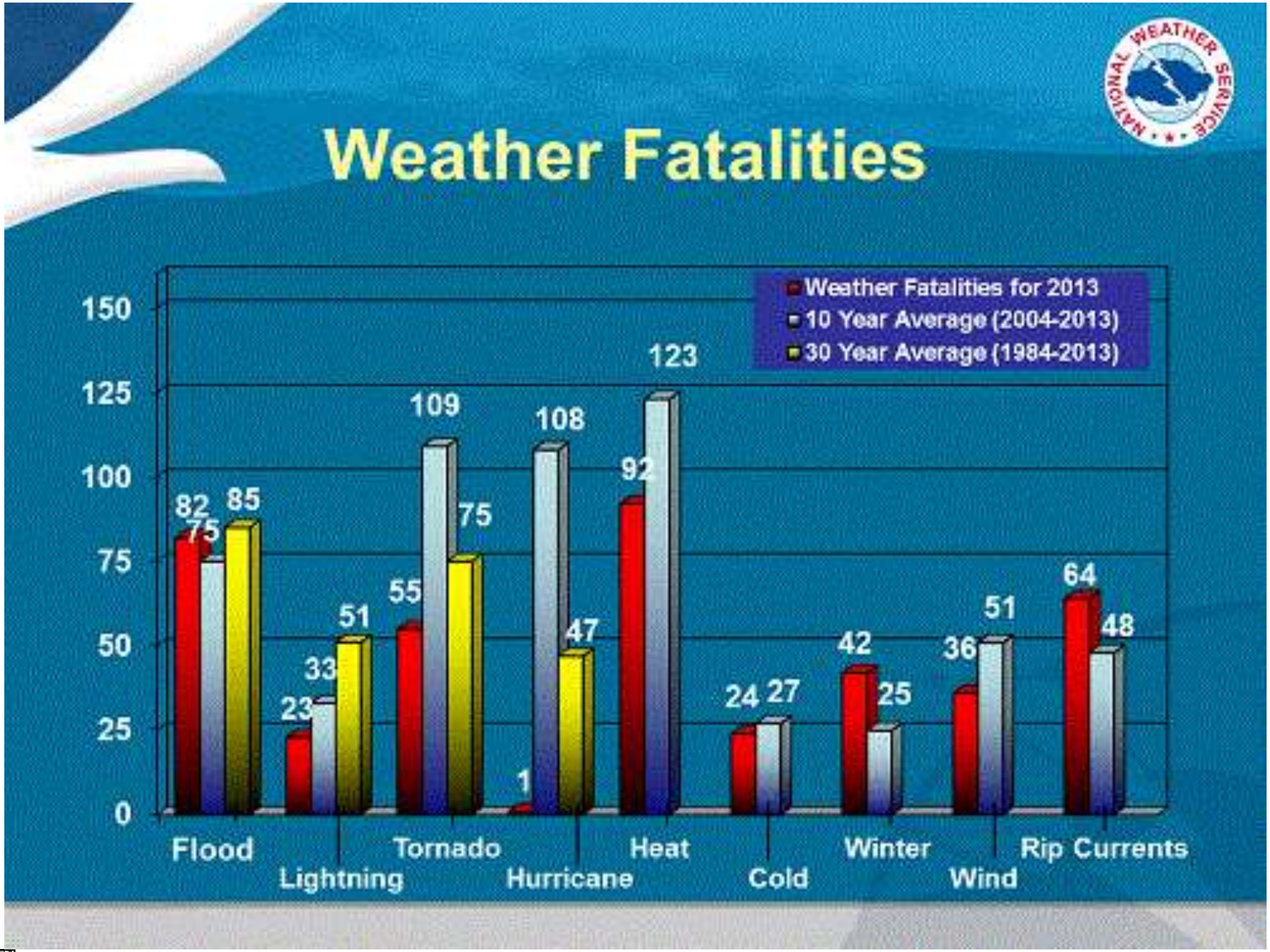
Out of 13 extreme heat events (from 1960-2011), 10 of them were driven by the dew point temperature.

Red denotes dew point driven

1964, 1976, 1977,
1983, 1988, 1995,
1999, 2001, 2005,
2006, 2007, 2010, 2011

Source: Dr. Mark Seeley, Climatologist, University of Minnesota

2013 NWS Death Data



http://www.nws.noaa.gov/os/hazstats.shtml

Extreme Heat Effects

Moorhead MN: 7/19/11: **HI record ≈ 134°**

With a record breaking 88°F dew point temp

Direct Effects	**Heat illnesses, worsening pre-existing conditions, deaths**
Indirect Effects	**Infrastructure failures, Strain on essential services, Disruption to economic and social activities**

Extreme Heat Events

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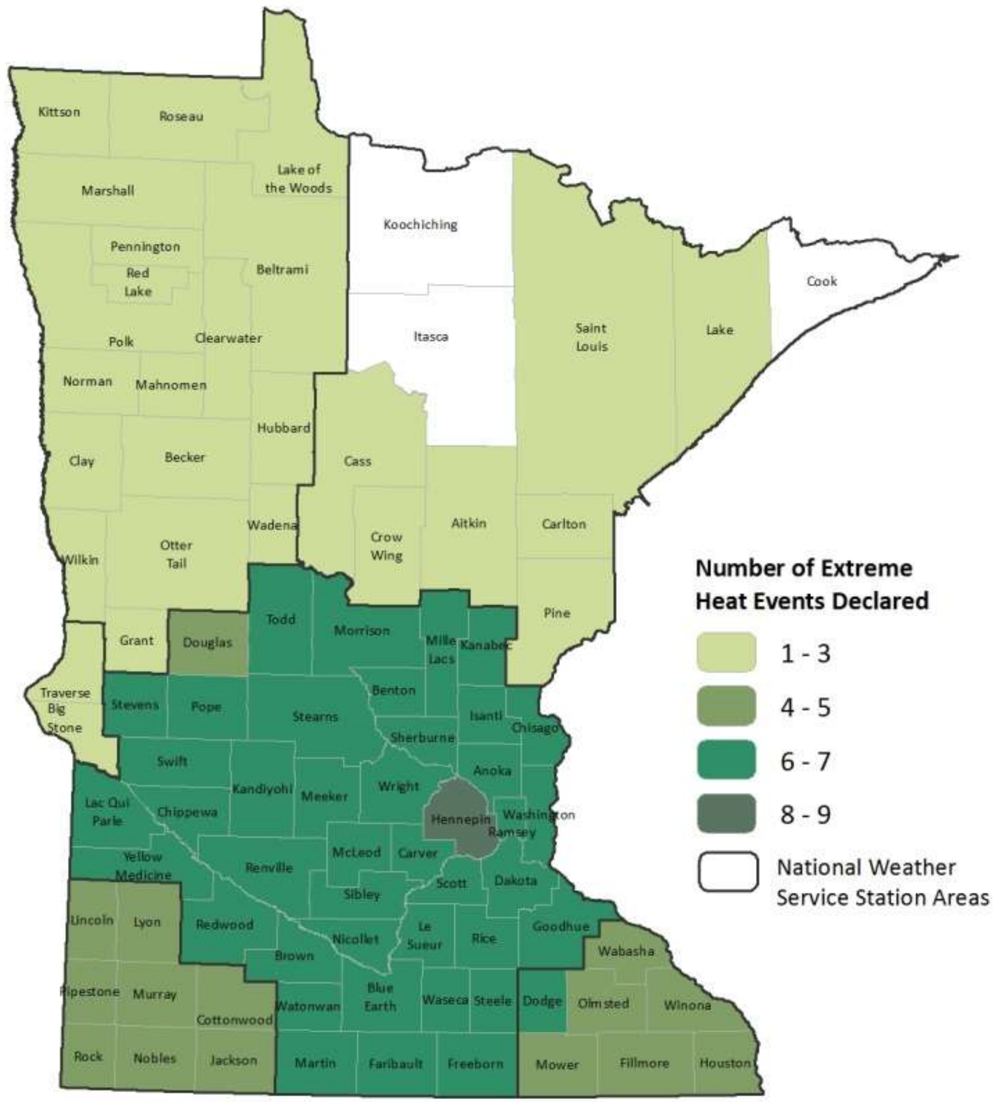
Number of Extreme Heat Events by County 1995 - 2012



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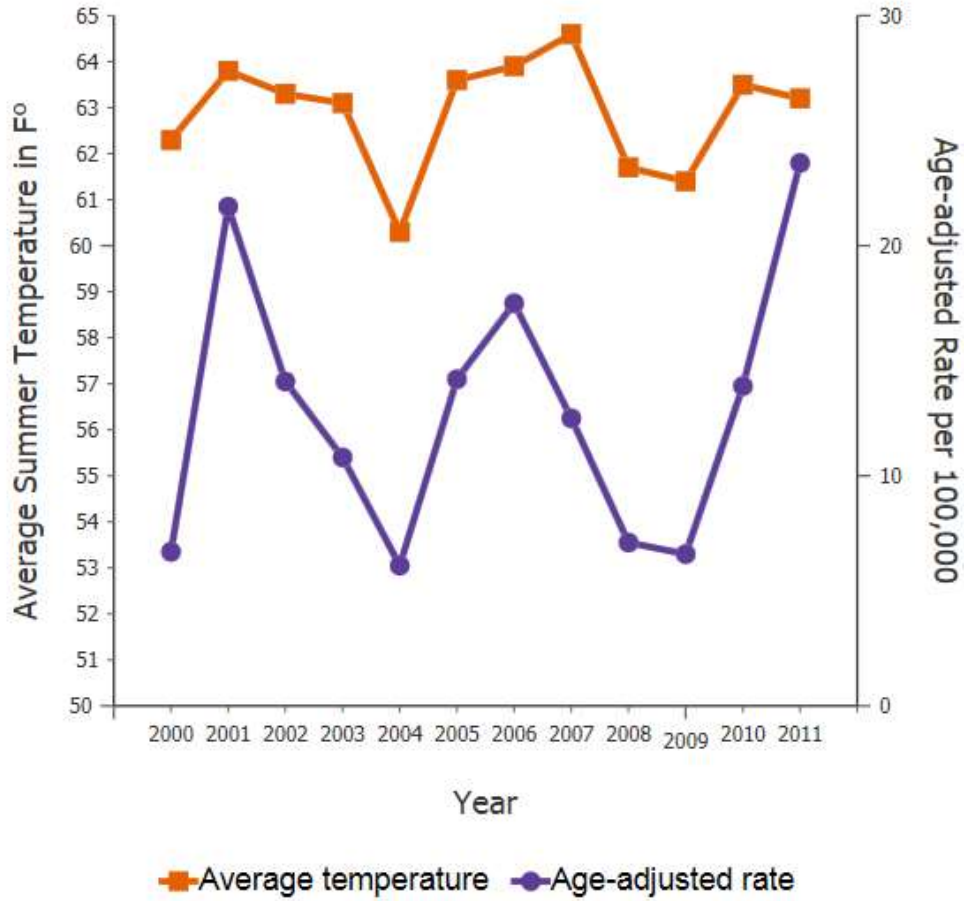
Heat-related illness ED visits* and temperatures by year in Minnesota

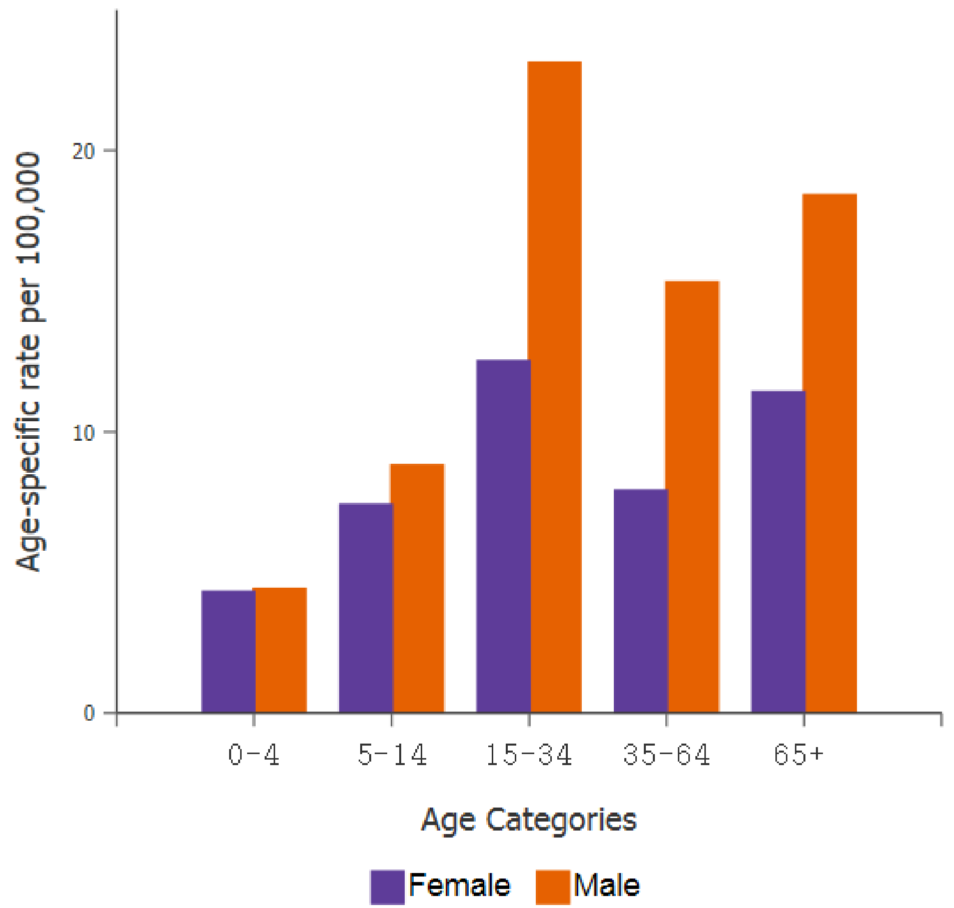


*Emergency department (ED) visits are directly heat-related and per 100,000 people.

Temperature data source: National Climatic Data Center, National Oceanic and Atmospheric Administration

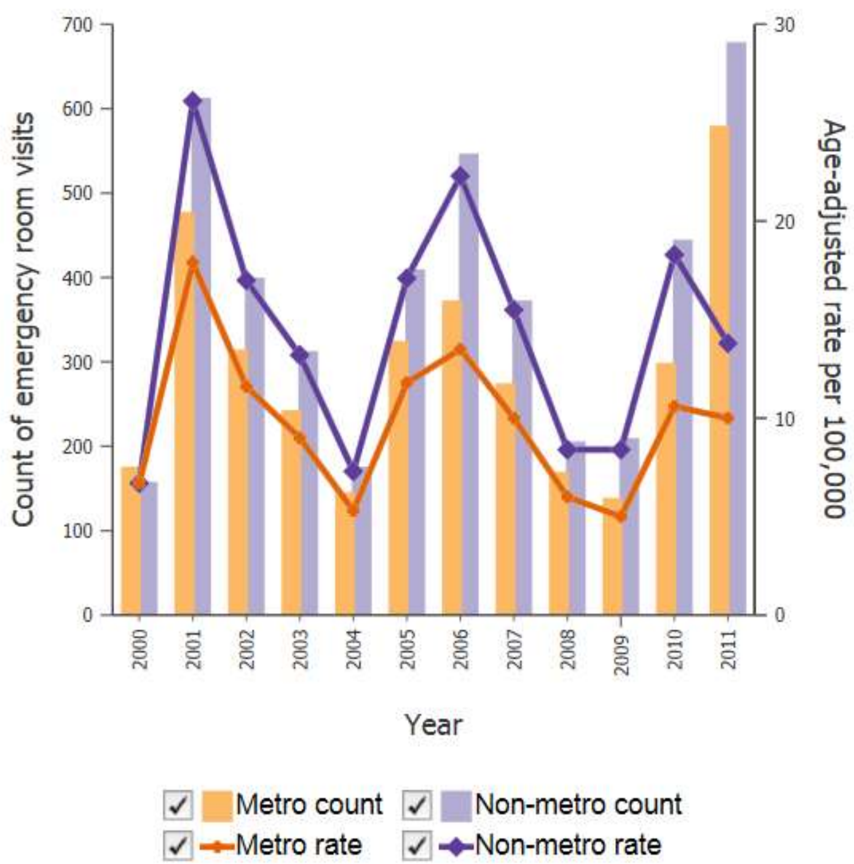
https://apps.health.state.mn.us/mndata/heat_ed

Heat-related illness ED visits* by age and sex in Minnesota



*Emergency Department (ED) visits are directly heat-related and per 100,000 people for the combined years of 2007-2011.

Heat-related illness ER visits* in Minnesota
Metro. vs. Non-metro



*Emergency Department (ED) visits are directly heat-related and per 100,000 people.

Metropolitan (Metro) is defined as the metro area of the Twin Cities (i.e., Minneapolis and St. Paul) and surrounding counties, which includes: Anoka, Hennepin, Ramsey, Washington, Carver, Scott, and Dakota. Non-metro is defined as all other counties in Minnesota.

Prevent Heat Stress!

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- [Prevent Heat Illness with Acclimatization]
- Drink from two to four cups of water every hour while working. Don't wait until you are thirsty to drink.
- Avoid alcohol or liquids containing large amounts of sugar.
- Wear and reapply sunscreen.
- Ask if tasks can be scheduled for earlier or later in the day to avoid midday heat.
- Wear a brimmed hat and loose, lightweight, light-colored clothing.
- Spend time in air-conditioned buildings during breaks and after work.
- Encourage co-workers to take breaks to cool off and drink water.
- Seek medical care immediately if you or a co-worker has symptoms of heat-related illness.
- http://www.cdc.gov/niosh/topics/heatstress

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Changes to Vector-borne Diseases (tick/mosquito-borne diseases)

Climate changes such as warmer temperatures, increased rainfall, longer warm season and less severe winters can impact the range and incidence of vector-borne disease.

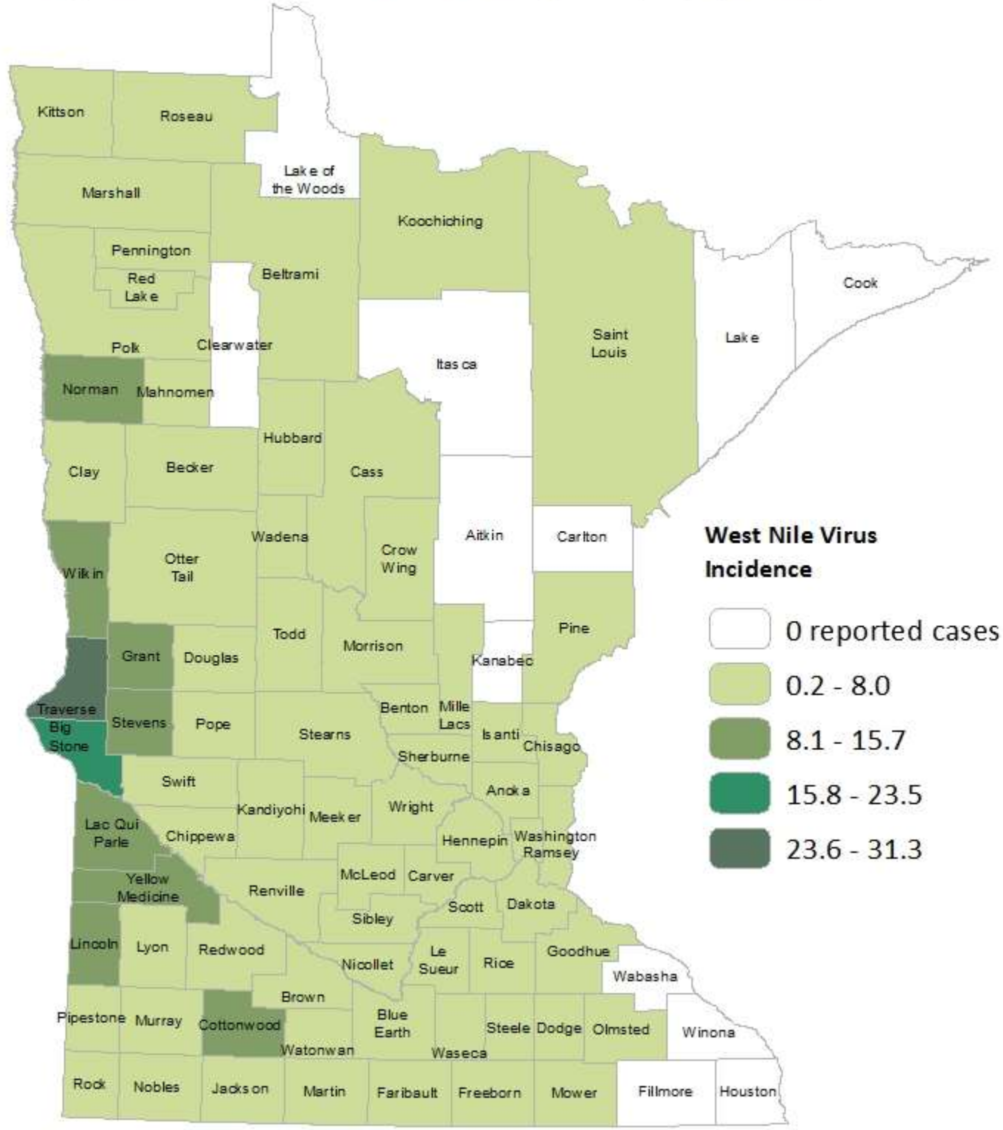
Risk is also impacted by land use, population density, and human behavior.

http://www.sjahs.org/ticks.html

For more information on climate and vectorborne disease, visit: http://www.health.state.mn.us/divs/idepc/dtopics/vectorborne/climate.html

West Nile Virus Incidence 2002 - 2012

Average Annual Human Rates of West Nile Virus per 100,000 population, 2002 - 2012



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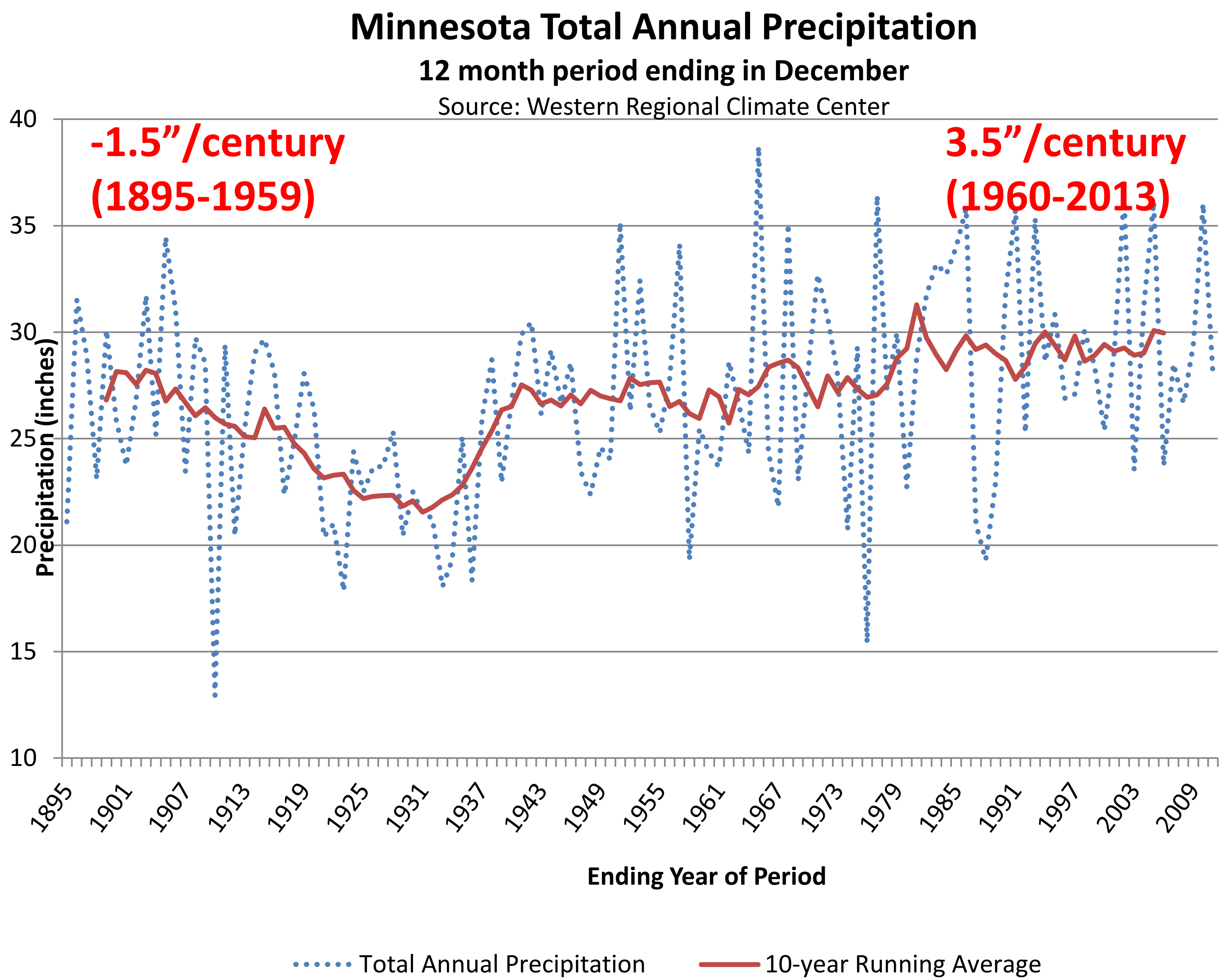
Preventing tick/mosquito-borne diseases

- **Tick-borne diseases:** wooded areas known to have blacklegged ticks
- Wear clothes that help shield you from ticks
- Use a good tick repellent (permethrin & DEET)
- Check for ticks & remove promptly
- **WNV:** western and central MN
- Wear mosquito repellent containing up to 30% DEET (10% for children).
- Wear long sleeve shirts and pants
- Avoid outdoor activity at peak mosquito feeding times (dawn and dusk).
- Eliminate water-holding containers (buckets, tires, etc.)
- http://www.health.state.mn.us/divs/idepc/dtopics/tickborne/prevention.html
- http://www.health.state.mn.us/divs/idepc/dtopics/mosquitoborne/prevention.html

Changes in Precipitation



Erratic Precipitation: 2012

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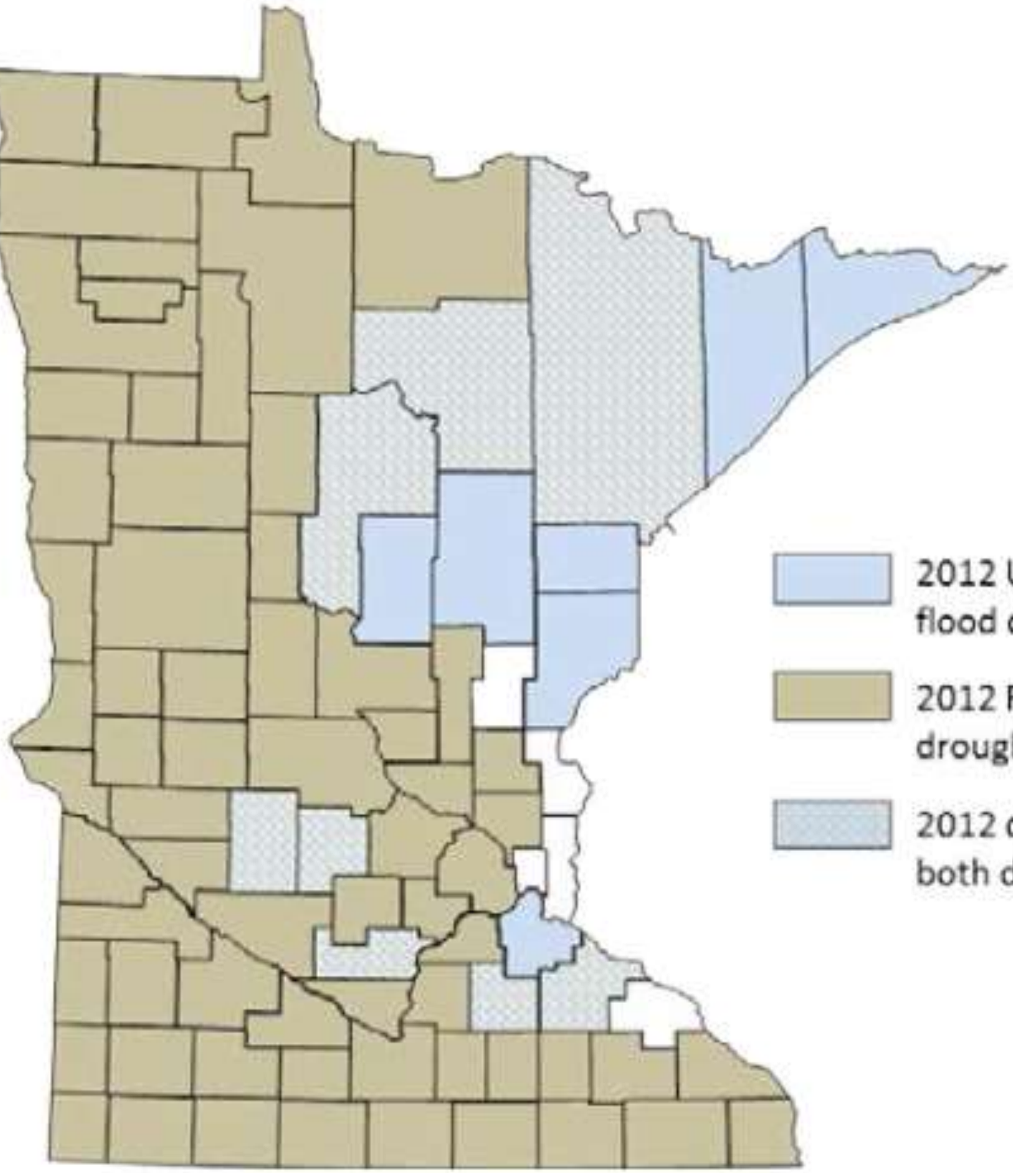

2012 USDA primary or contiguous flood disaster counties

2012 FEMA primary or contiguous drought disaster counties

2012 counties declared for both disasters

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Flooding

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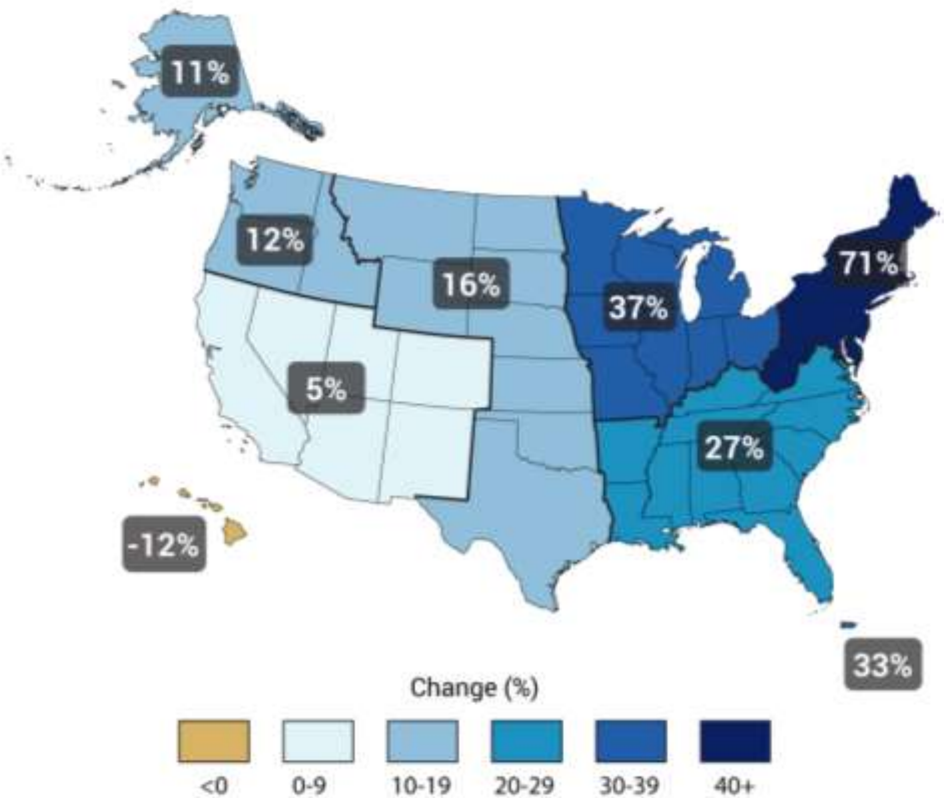
Storms with 3+" of rainfall has increased 104% in last 50 years



Heaviest 1% of all daily events : 1958-2012

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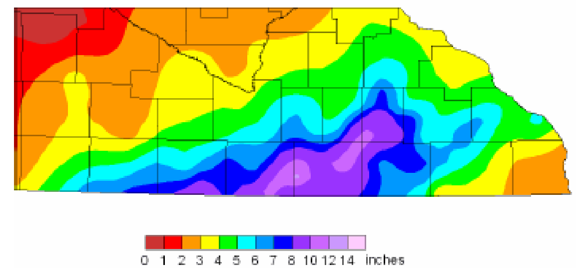
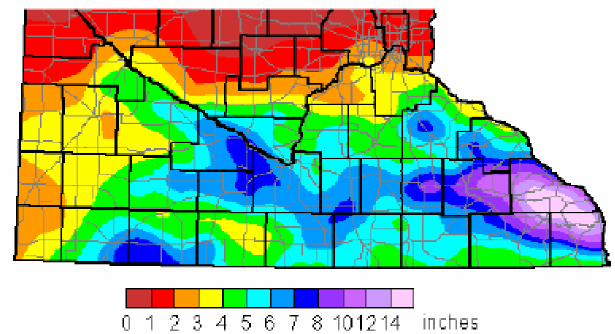
'1000-yr (approx.) events' in Southern Minnesota in the last decade.

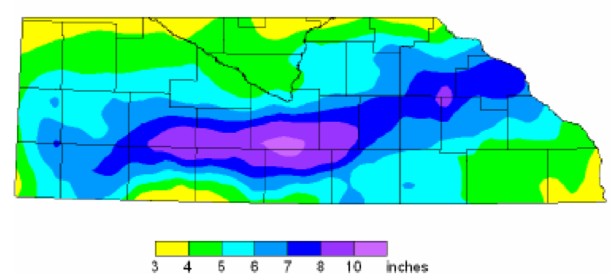
September 14-15, 2004



August 18 through August 20 (8:00 AM CDT), 2007



September 22-23, 2010



A 'by-eye' estimate of the total area covered by 10" of rain over the 7 years of 2004-2010 appears to be near 1400 s mi. or about 200 sq. mi per year. Given that the area of the southern 3 layers of counties looks to be approximately 20000 sq. mi. the areal fraction of the southern three counties covered by 10" per year appears to be approximately 1/100; i.e. at the rate of coverage for the last 7 years an area equal to the whole southern three county area could b covered in about 100 years.

Flooding

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Health Impacts

- physical injuries (including drowning)
- allergies (mold)
- food and water-borne illnesses
- interruption of emergency services
- displacement
- mental health issues

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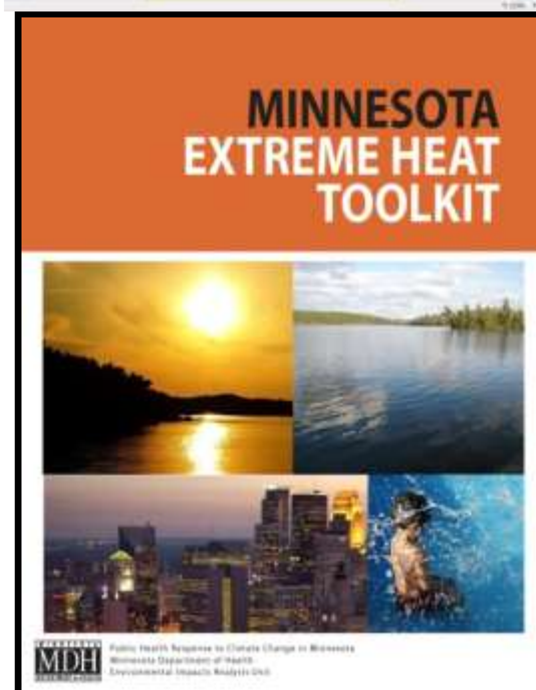
Learn More!

MN Climate & Health Program

Minnesota Climate and Health Program

www.health.state.mn.us/divs/climatechange/



- **MN Climate & Health Program**
- Kristin Raab, Director, kristin.raab@state.mn.us, 651-201-4893
- Brenda Hoppe, Senior Epidemiologist, brenda.hoppe@state.mn.us, 651-201-4908
- Dan Symonik, Supervisor

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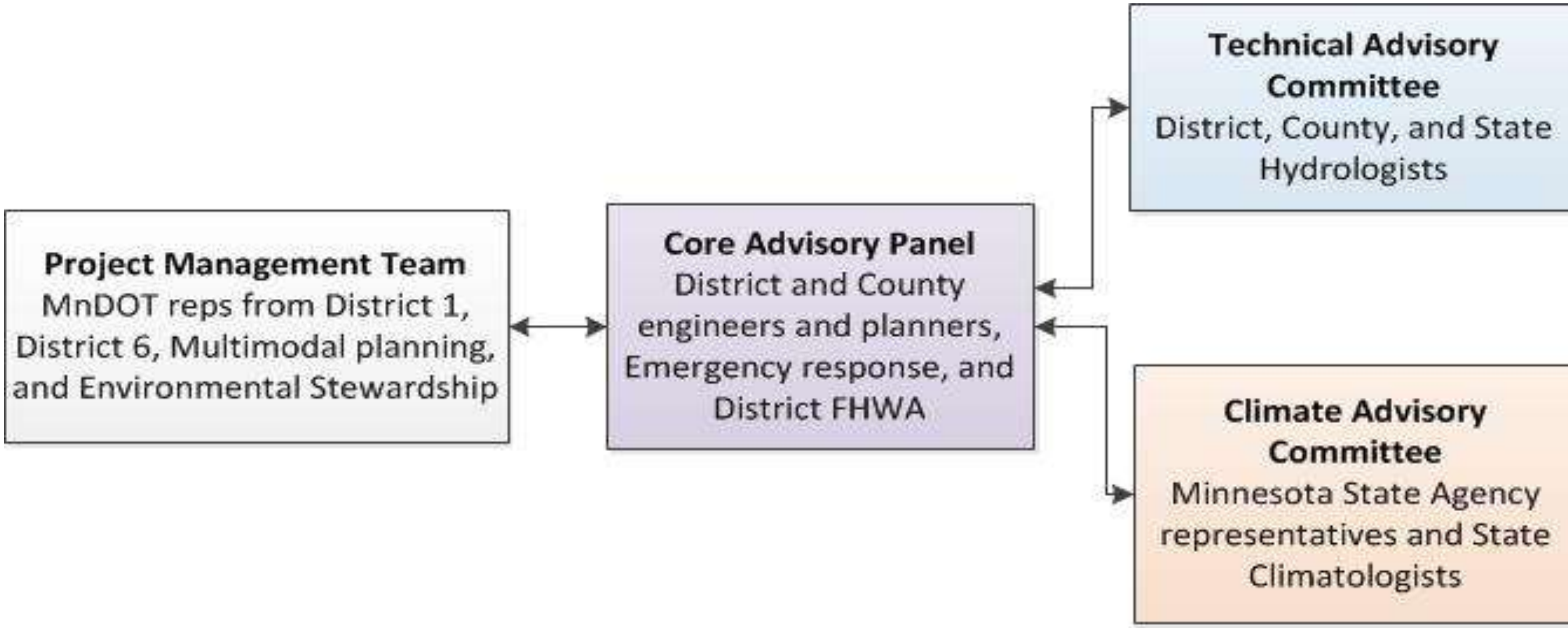
Flash Flood Vulnerability and Climate Adaptation Pilot Project

Philip Schaffner
Office of Transportation System Management
May 7, 2015

MnDOT's Pilot Project Objectives

- Better understand the trunk highway network's risk from flash flooding
- Identify cost-effective options to improve the network's resiliency
- Support MnDOT's asset management planning
- Provide feedback to FHWA on the Draft Framework

Project Roles and Responsibilities



Consultant: PARSONS BRINCKERHOFF, Catalysis

Pilot Project Overview

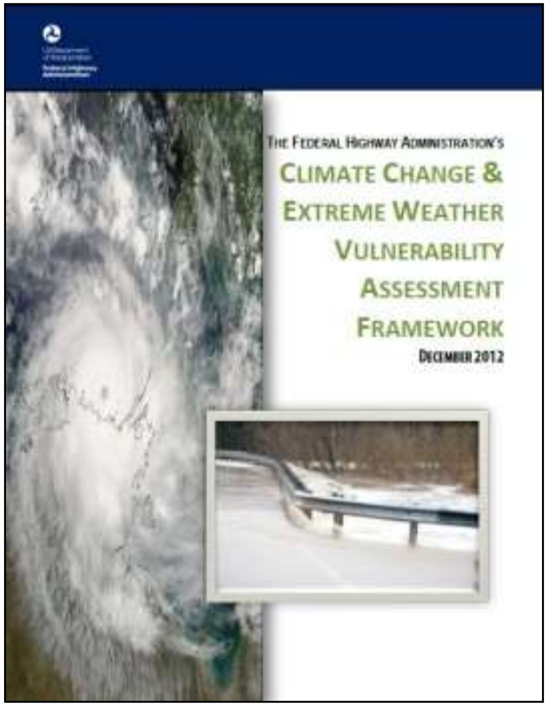
- Phase 1: System-wide vulnerability assessment
  – High-level screen of trunk highway network in Districts 1 & 6

- Phase 2: Facility-level adaptation analysis
  – Two high risk facilities (one in each district)

Defining Vulnerability

"Climate change ***vulnerability*** in the transportation context is a function of a transportation system's *exposure* to climate effects, *sensitivity* to climate effects, and *adaptive capacity*." (Vulnerability Framework)

- ***Exposure-*** whether the asset or system is located in an area experiencing direct impacts of climate change
- ***Sensitivity*** - how the asset or system fares when exposed to an impact
- ***Adaptive capacity*** - the systems' ability to adjust or cope with existing climate variability or future climate impacts



Systemwide Vulnerability Assessment Approach

Identify Assets of Interest


Bridges


Large culverts


Pipes


Roads paralleling floodplains

Calculate the Vulnerability Scores for Each Asset

Sensitivity

- Capacity to handle higher flows
  - % 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)
- % of total roadway length parallel to the floodplain at risk of erosion from the stream channel (roads)
- % forest land cover in drainage area (bridges, large culverts, pipes)
- % of drainage area not covered by lakes & wetlands (storage capacity)
- % urban land cover in drainage area

Adaptive Capacity

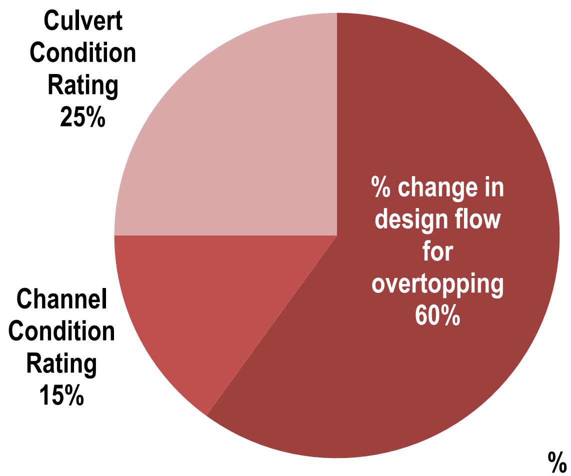
- Average annual daily traffic (AADT)
- Heavy commercial average daily traffic (HCADT)
- Detour length
- Flow control regime (bridges, large culverts, and pipes)

Rank Flood Vulnerabilities by District

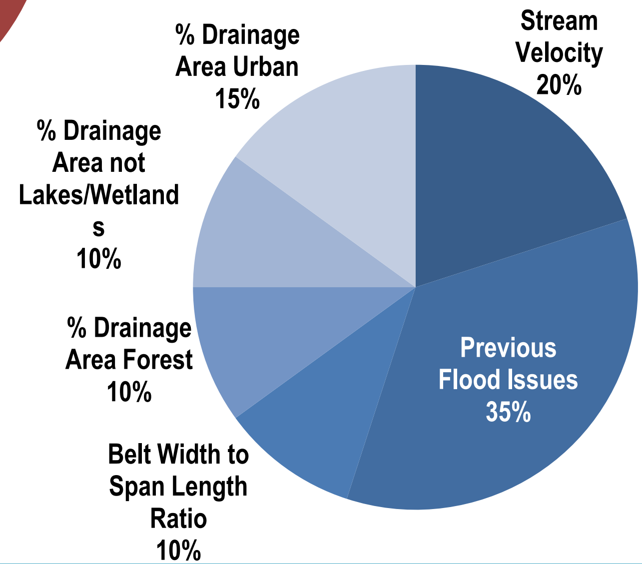
Criteria Weighting

Example: Culverts

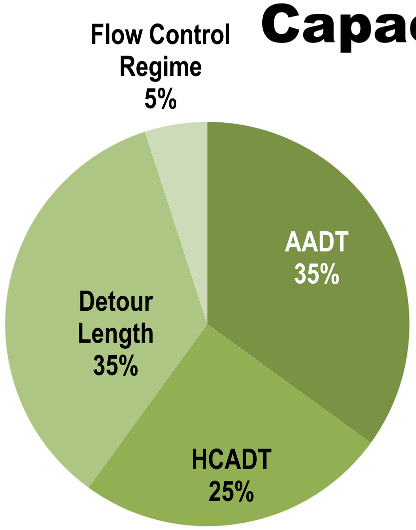
Sensitivity



Exposure



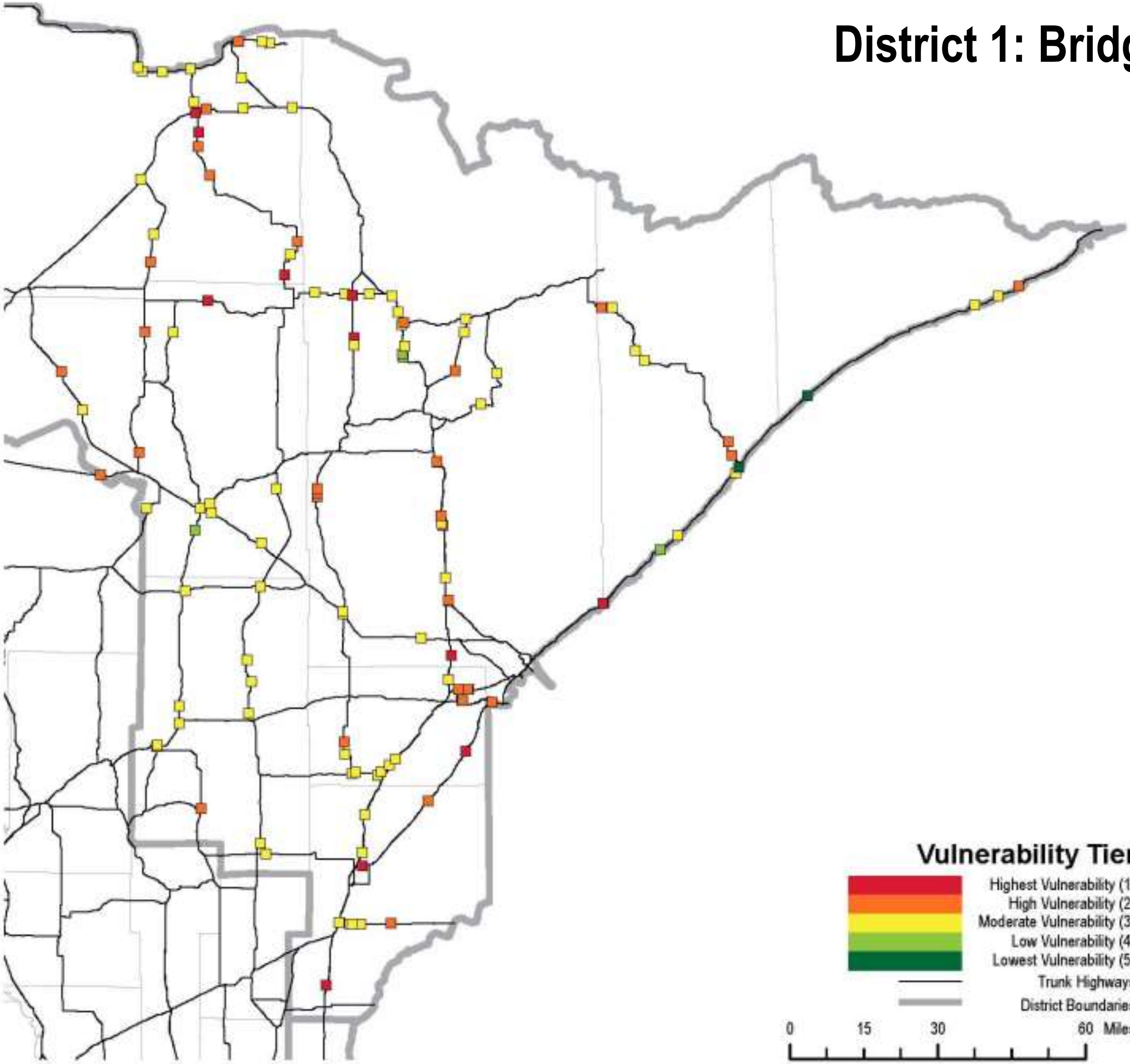
Adaptive Capacity



Number of Assets Scored

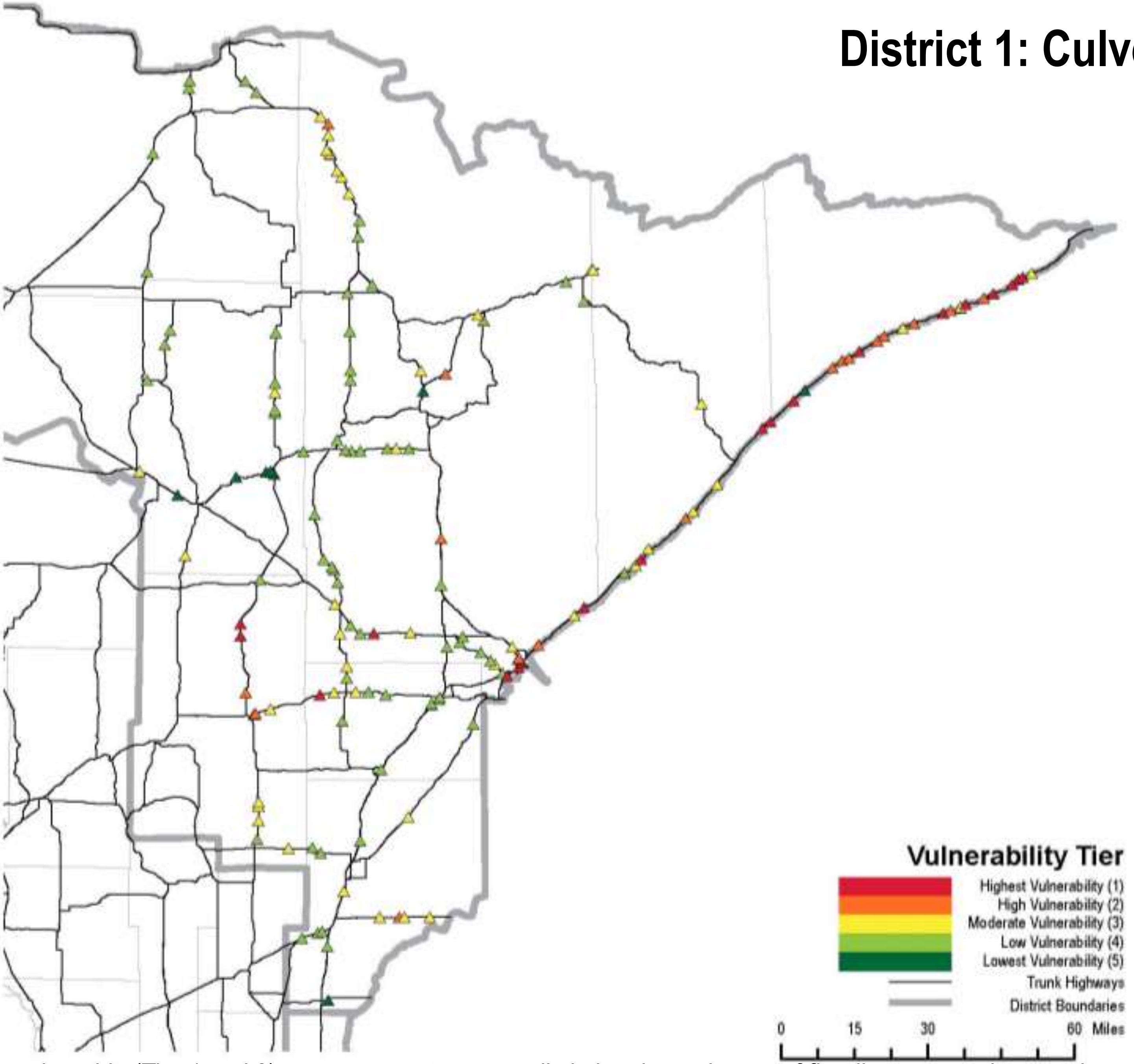
	Bridges	Large Culverts	Pipes	Roads Paralleling Streams (segments)	Total
District 1	140	160	543	18	**861**
District 6	176	361	377	44	**958**
Total	**316**	**521**	**920**	**62**	**1,819**

District 1: Bridges



Highly vulnerable (Tier 1 and 2) assets are not necessarily in imminent danger of flooding, nor are lower vulnerability assets immune from flooding. Values are indicators of relative vulnerability compared with other assets in the same district.

District 1: Culverts



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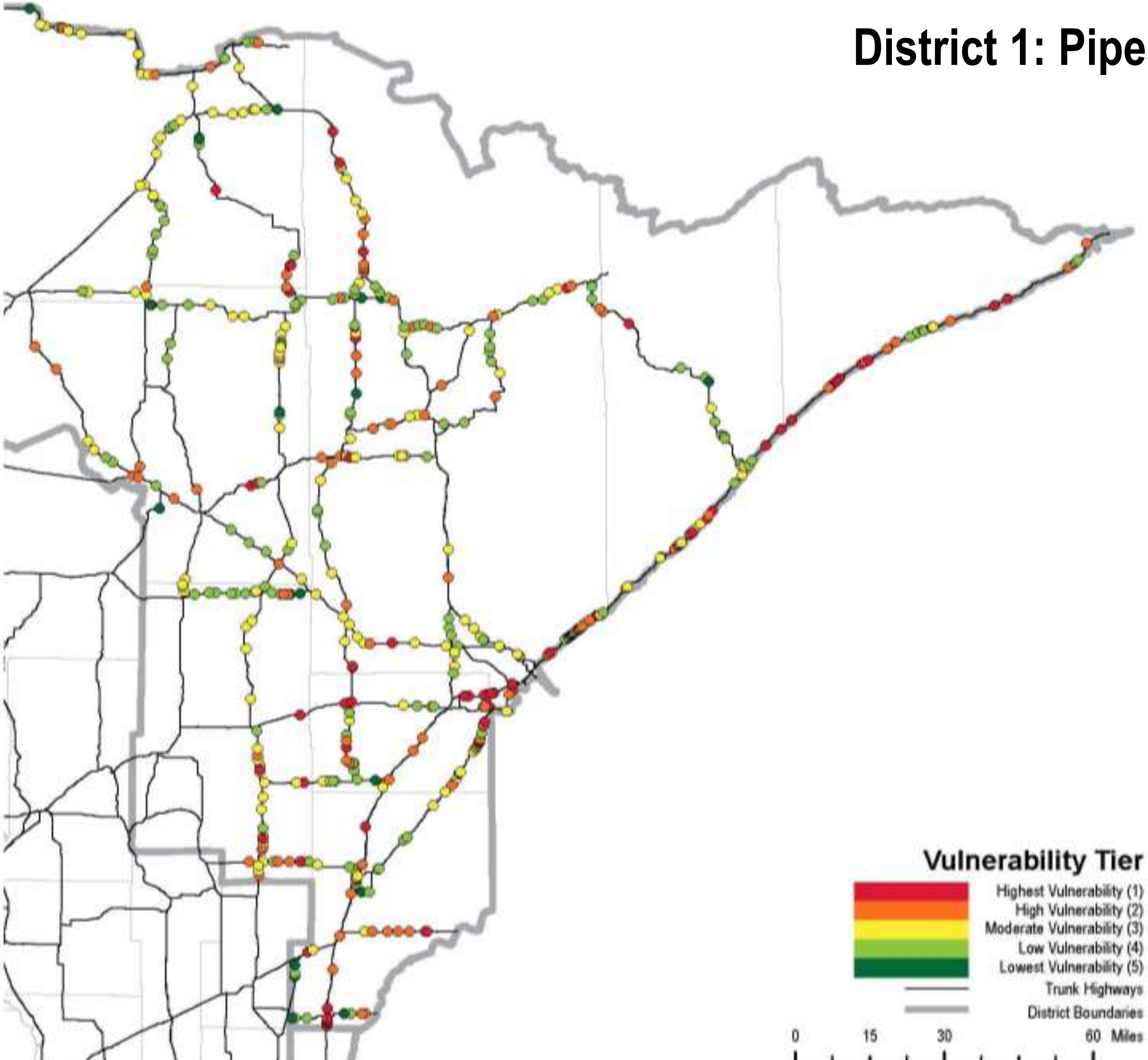
District 1: Pipes



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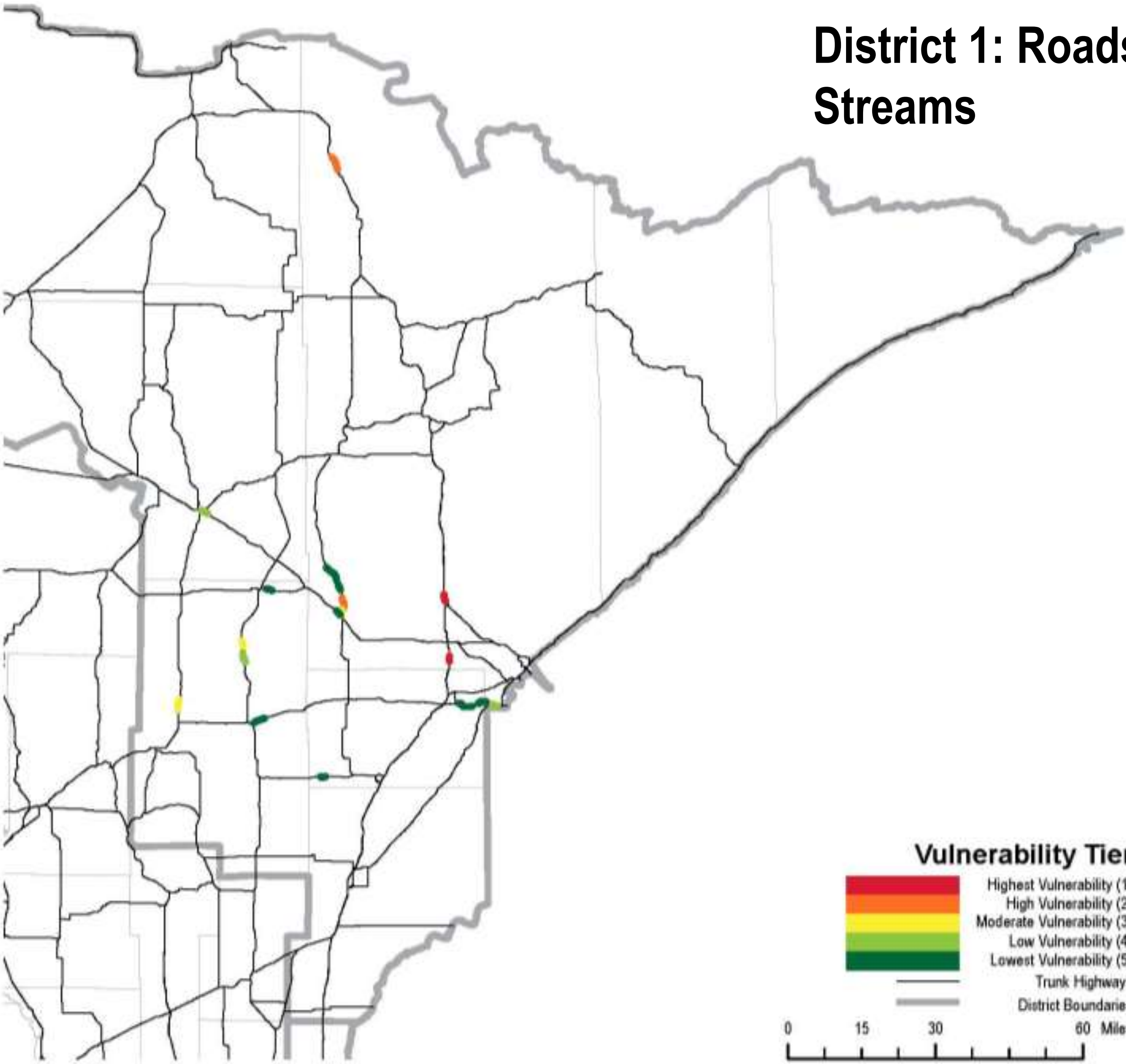
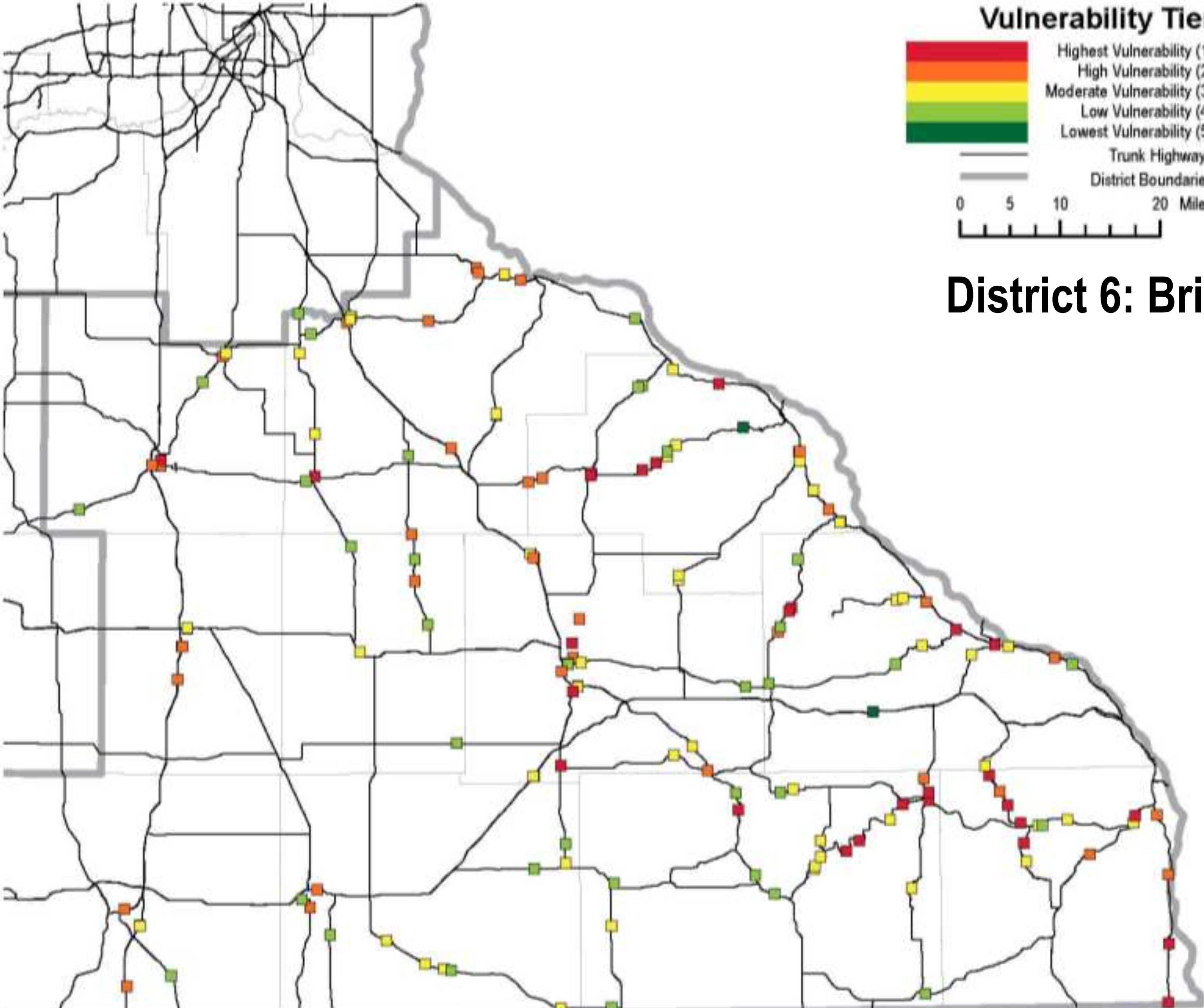
District 1: Roads Paralleling Streams



Highly vulnerable (Tier 1 and 2) assets are not necessarily in imminent danger of flooding, nor are lower vulnerability assets immune from flooding. Values are indicators of relative vulnerability compared with other assets in the same district.

District 6: Bridges



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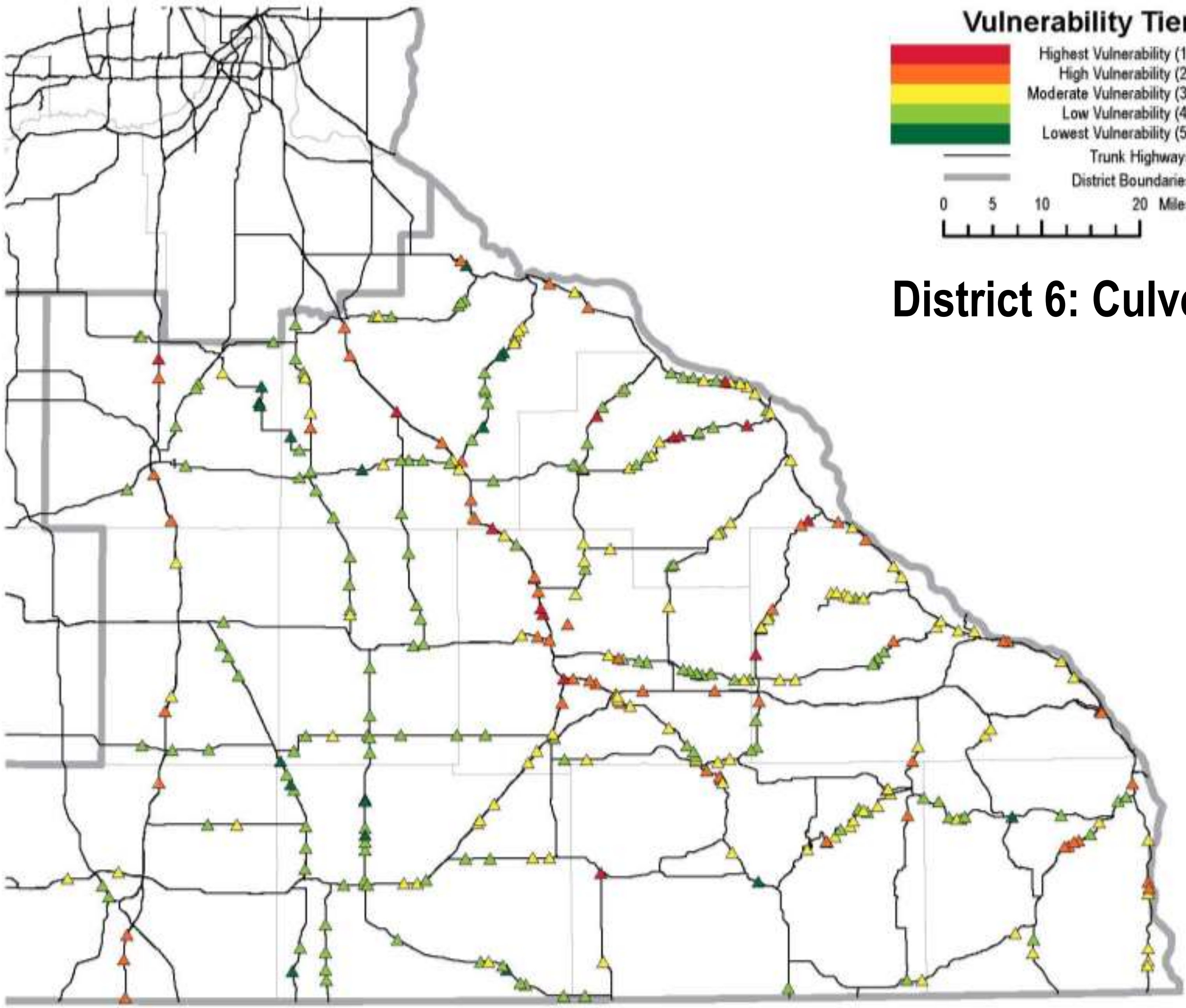
District 6: Culverts



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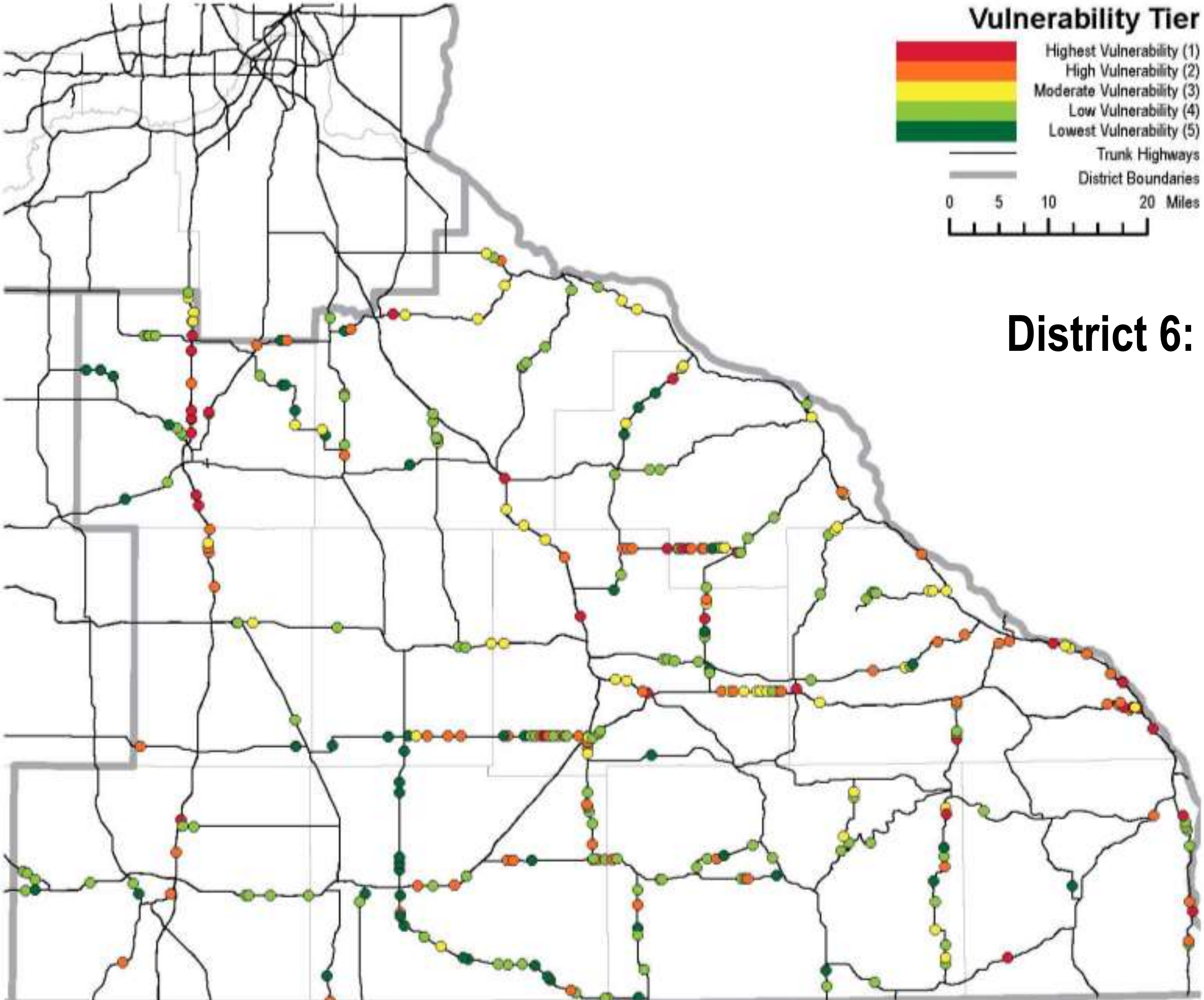

District 6: Pipes

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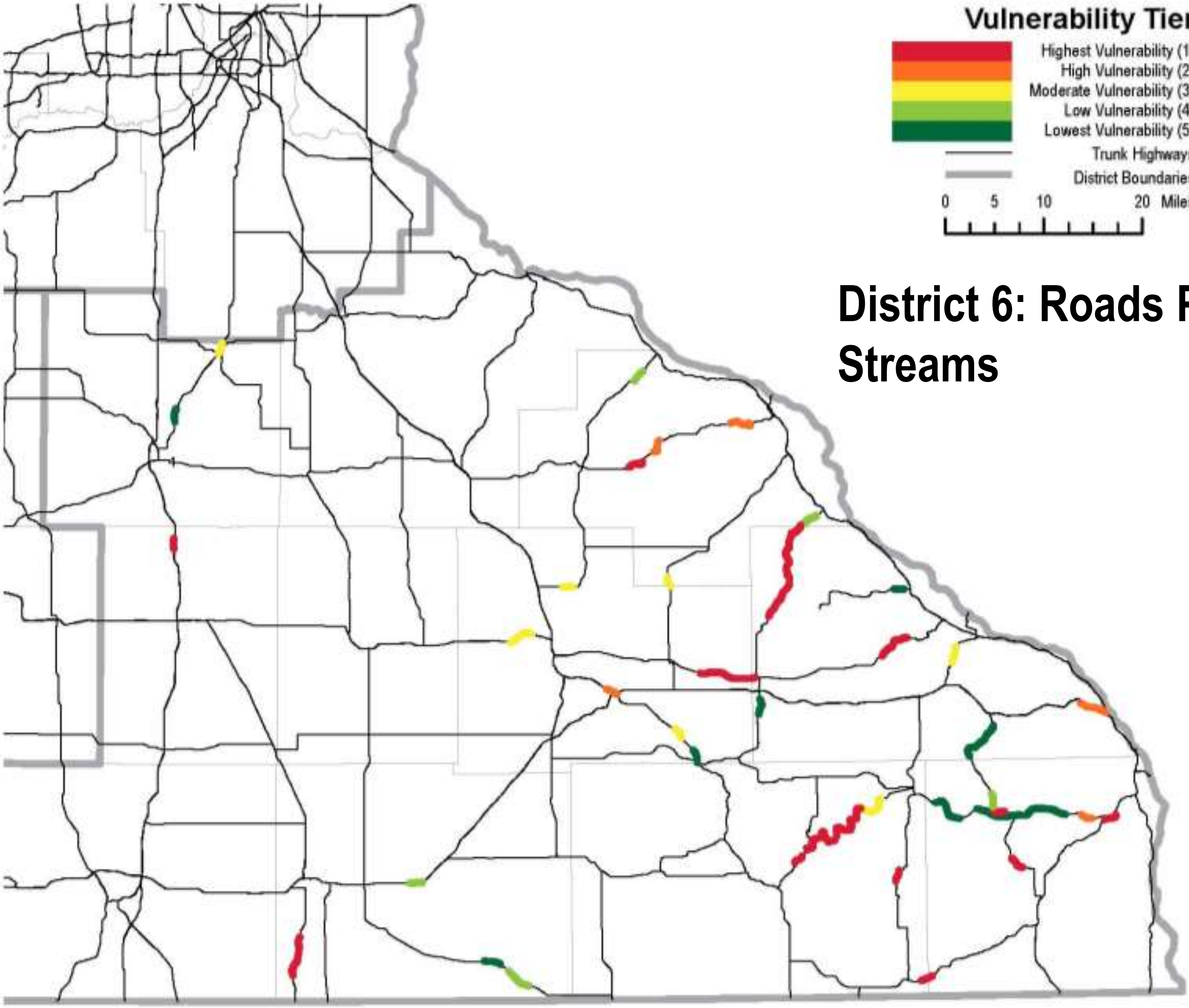
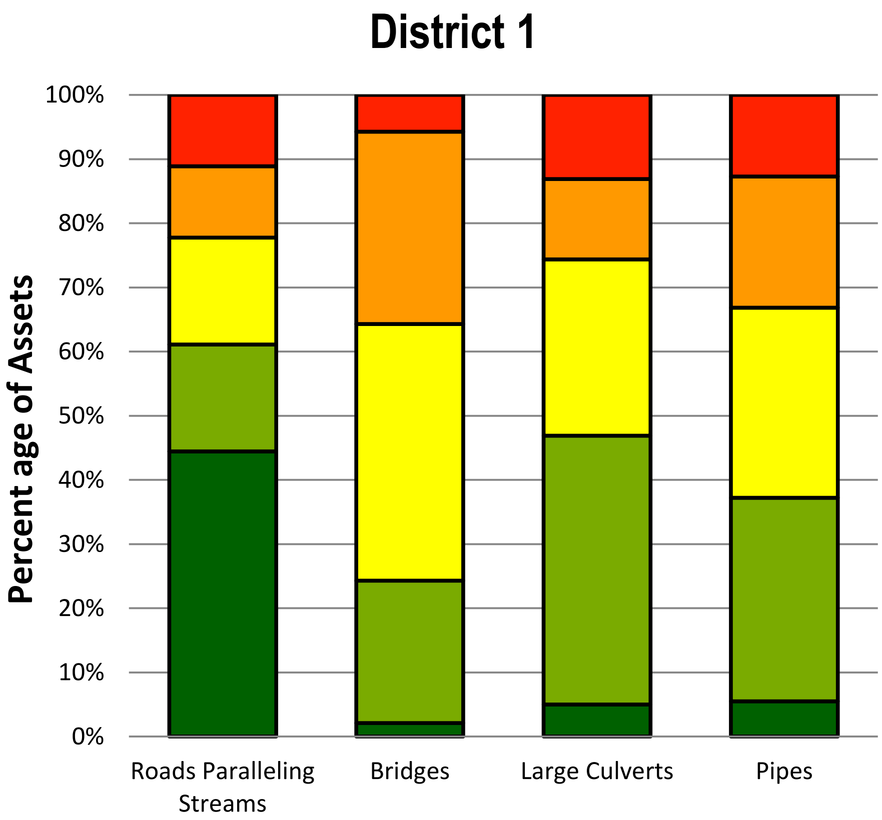
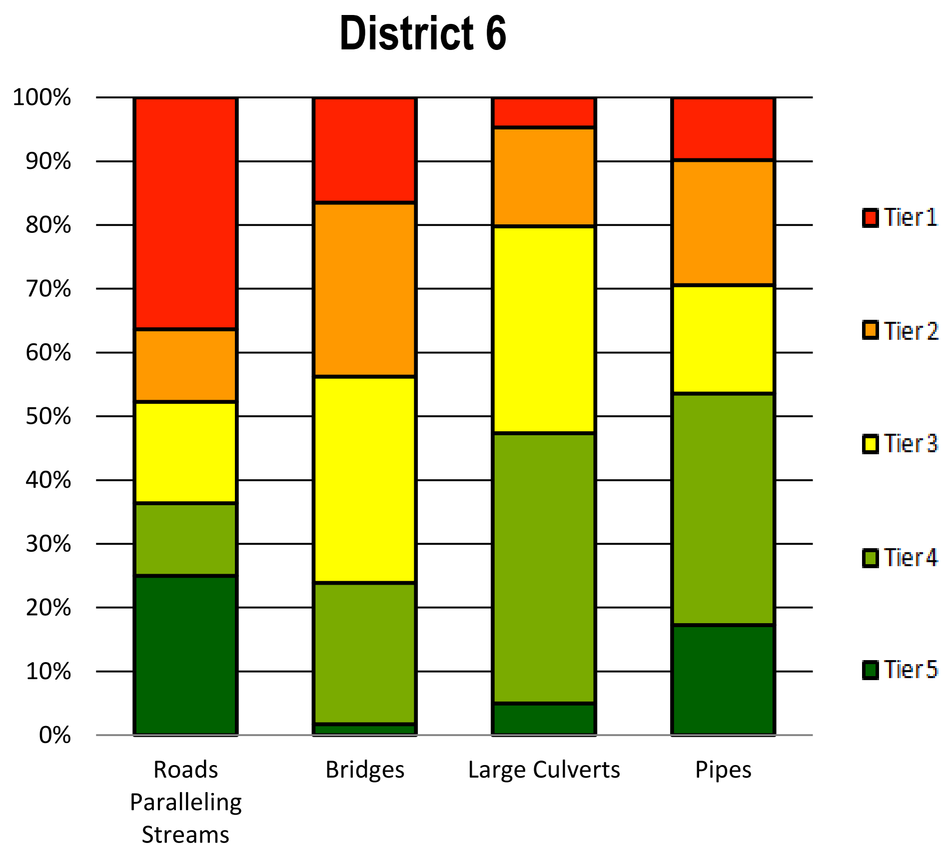


District 6: Roads Paralleling Streams

Highly vulnerable (Tier 1 and 2) assets are not necessarily in imminent danger of flooding, nor are lower vulnerability assets immune from flooding. Values are indicators of relative vulnerability compared with other assets in the same district.

Vulnerability By Asset Type





Facility Level Adaptation Assessments

Adaptation Assessment General Approach

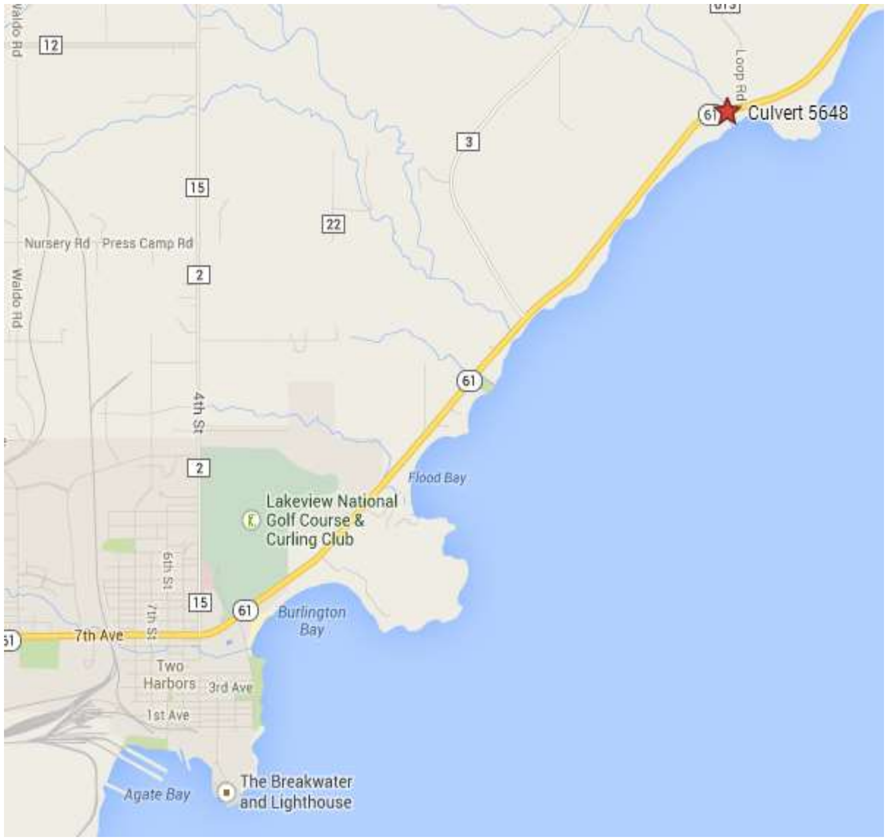
1. Describe the site context
2. Describe the facility
3. Identify climate stressors
   - Heavy precipitation
4. Develop climate scenarios (Low*, Medium, High)
5. Assess performance of the facility
6. Identify adaptation options
   - Meet MnDOT 50-year clearance guidance
   - Meet FEMA 100-yr floodplain impact regulations
7. Assess performance of the adaptation options
8. Conduct an economic analysis
9. Evaluate additional considerations
10. Select a course of action
11. Plan and conduct ongoing activities

**we used IPCC RCP4.5 for the low, which used to be called a medium scenario*

MN 61 Silver Creek Culvert

Adaptation Analysis Case Study 1

District 1 – Silver Creek



- Culvert 5648
- Crosses Silver Creek
- MN 61- Parallel to Lake Superior from Duluth up to Canadian Border
- AADT: 5,900
- Detour Length: 24 miles

Existing Facility

Existing Hydrology

- Drainage Area: 19.65 mi^2
- Precipitation and Discharge:

24-hour Storm Event Return Period						
2-yr storm	5-yr storm	10-yr storm	25-yr storm	50-yr storm	100-yr storm	500-yr storm
(in)	(in)	(in)	(in)	(in)	(in)	(in)
2.48	3.26	3.89	4.80	5.53	6.31	8.26

24-hour Storm Event Return Period						
2-yr storm	5-yr storm	10-yr storm	25-yr storm	50-yr storm	100-yr storm	500-yr storm
(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
769	1354	1879	2693	3373	4136	6085

Performance of Existing Facility

- Currently system is functioning well when compared to design storm conditions
  - Does not overtop at the current 50-year storm

- Performance decreases under future climate projections

Projected Climate Conditions

24-Hr Storm Return Period	Atlas 14 Precip. Depth (in)	Low Scenario Precipitation Depth (in)			Medium Scenario Precipitation Depth (in)			High Scenario Precipitation Depth (in)		
		2040	2070	2100	2040	2070	2100	2040	2070	2100
2-yr storm	2.48	2.56	2.60	2.62	2.59	2.67	2.75	2.69	2.91	3.12
5-yr storm	3.26	3.36	3.42	3.44	3.41	3.51	3.62	3.54	3.83	4.12
10-yr storm	3.89	4.02	4.08	4.11	4.08	4.20	4.33	4.24	4.60	4.95
25-yr storm	4.8	4.96	5.05	5.09	5.04	5.21	5.38	5.26	5.73	6.19
50-yr storm	5.53	5.73	5.84	5.89	5.83	6.02	6.23	6.08	6.66	7.22
100-yr storm	6.31	6.55	6.68	6.74	6.67	6.91	7.16	6.98	7.68	8.36
500-yr storm	8.26	8.63	8.83	8.92	8.81	9.17	9.56	9.28	10.35	11.39

Data from SimCLIM

Projected Hydrologic Conditions

24-Hr Storm Return Period	Existing Discharges (cfs)	Low Scenario Discharges (cfs) 2100	Medium Scenario Discharges (cfs) 2100	High Scenario Discharges (cfs) 2100
2-yr storm	770	1,120	1,230	1,550
5-yr storm	1,350	1,830	2,000	2,460
10-yr storm	1,880	2,450	2,660	3,250
25-yr storm	2,690	3,390	3,670	4,460
50-yr storm	3,370	4,170	4,500	5,480
100-yr storm	4,140	5,000	5,420	6,610
500-yr storm	6,090	7,150	7,800	9,630

Adaptation Options

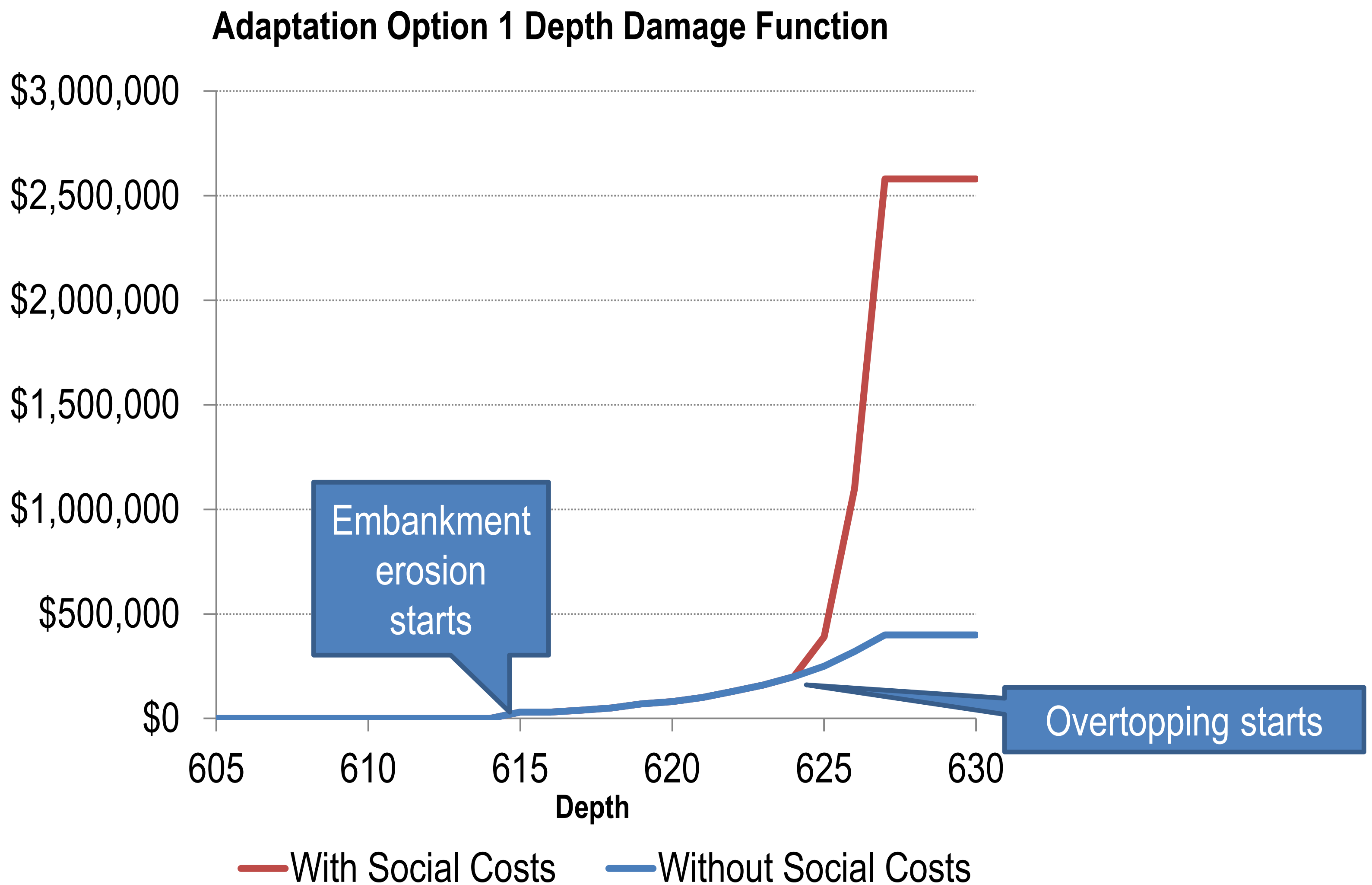
- Base: Replace in-kind
  - Construct cost: $710,000
- Option 1: Increase culvert to 16’ X 14’
  - Construction cost: $770,000
- Option 2: Replace Culvert with a 35’ span bridge
  - Construction cost: $1,130,000
- Option 3: Replace Culvert with a 40’ span bridge
  - Construction cost: $1,210,000

Benefit-Cost Assumptions

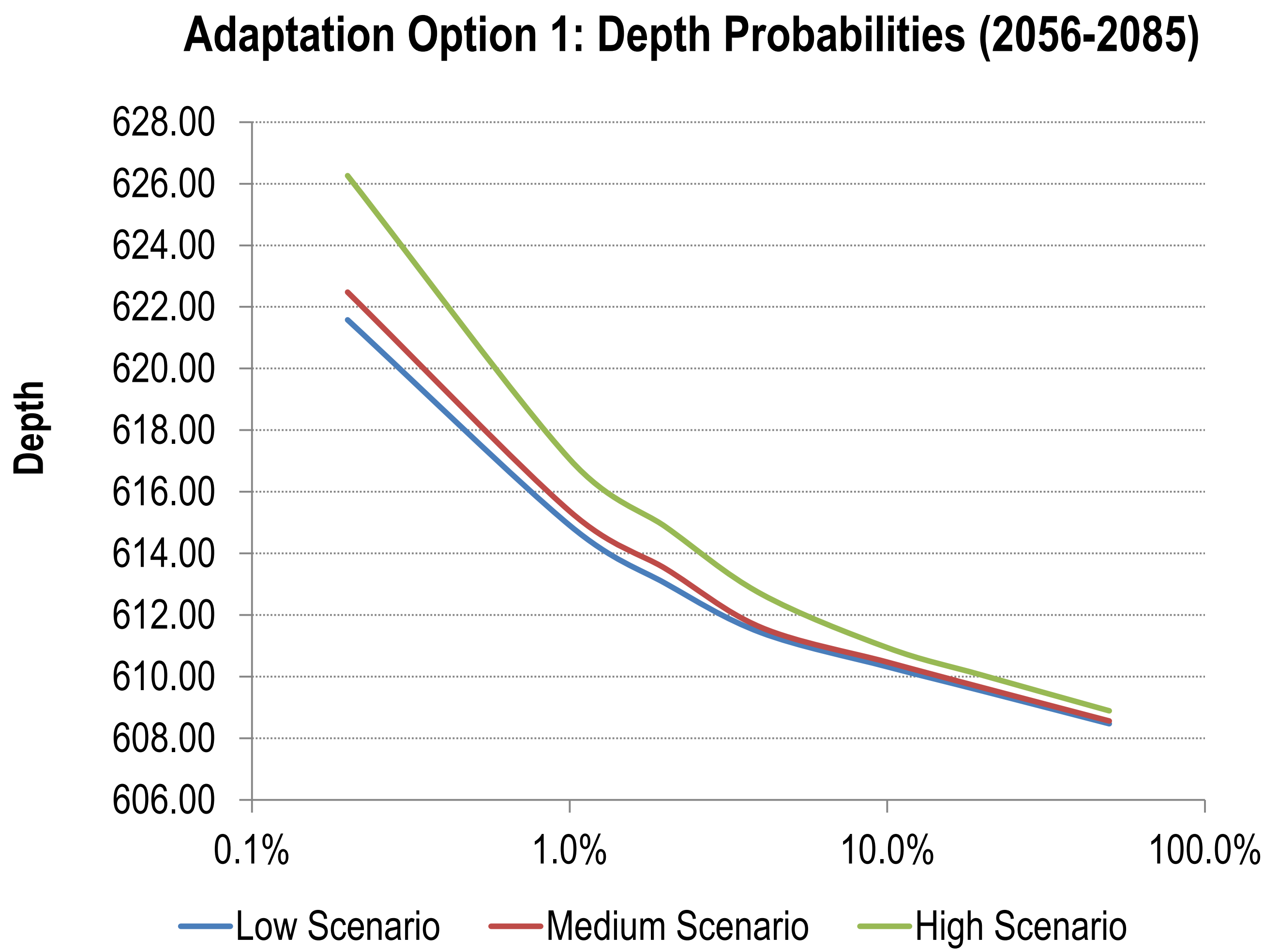
- Analysis period: 2020 - 2100
- Discount rate: 2.0%
- Safety Cost: $80,000
- Detour Cost Per Day:

	Car	Truck	Total
Operating Costs	$40,176	$11,520	$51,696
Travel Time	$78,624	$9,555	$88,179
Total	$118,800	$21,075	$139,875

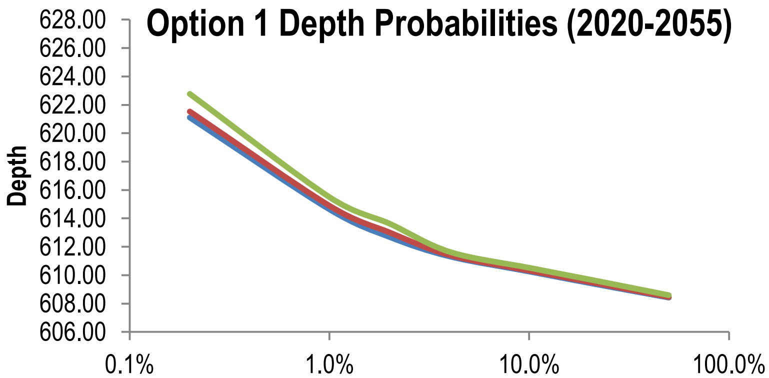
For Each Adaptation Option

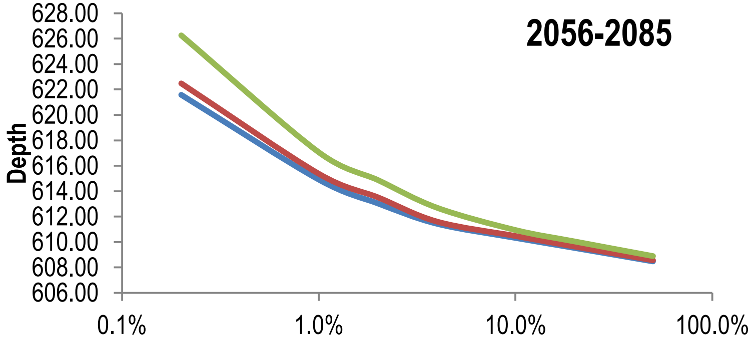


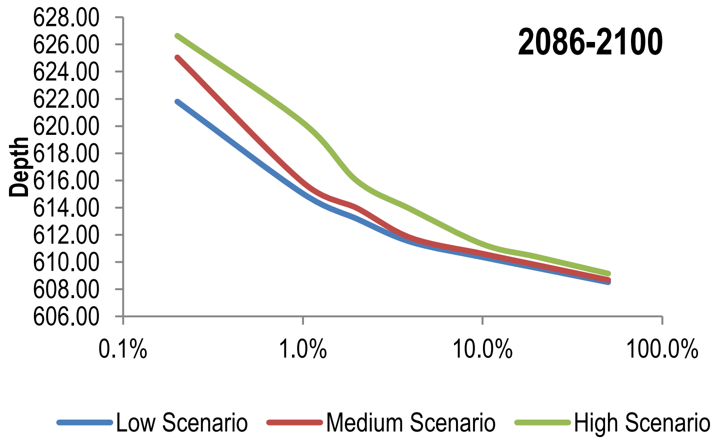
For Each Adaptation Option for 3 time periods

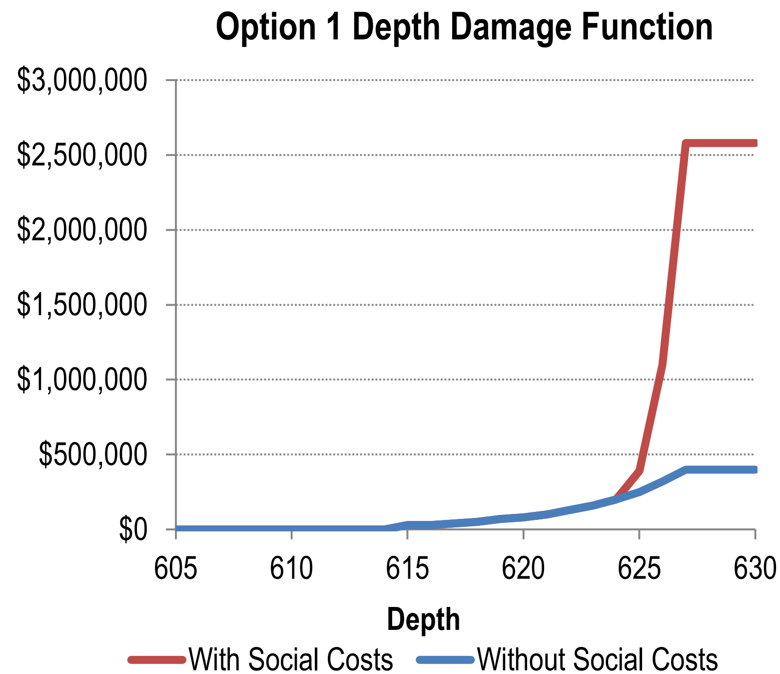


COAST Model



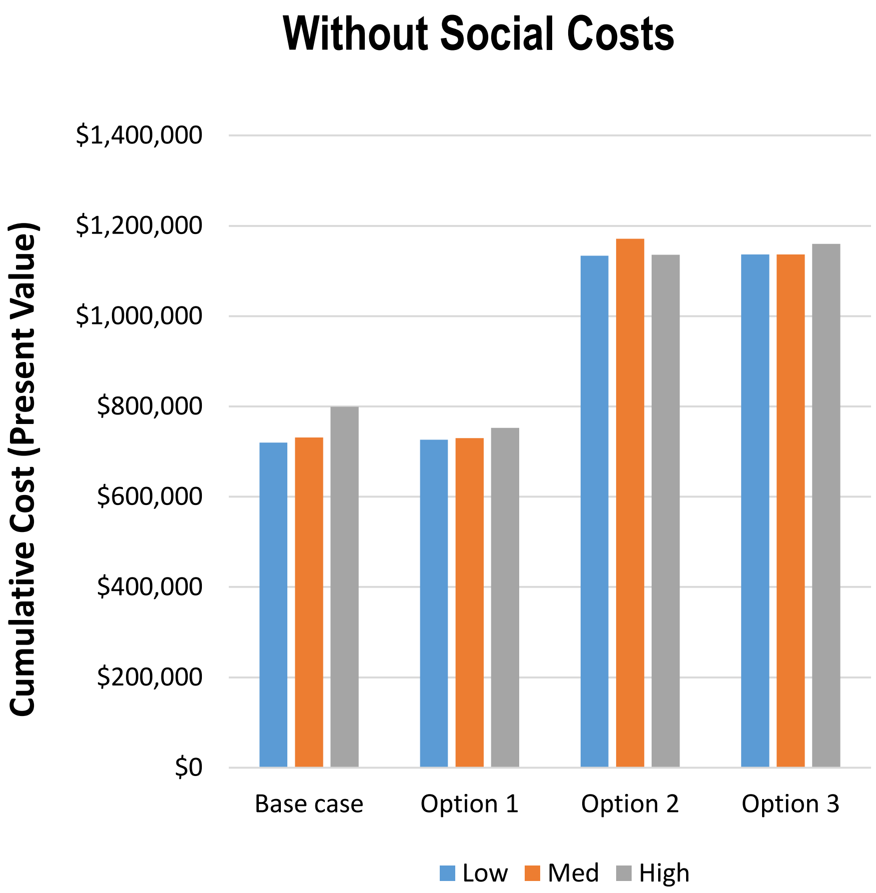


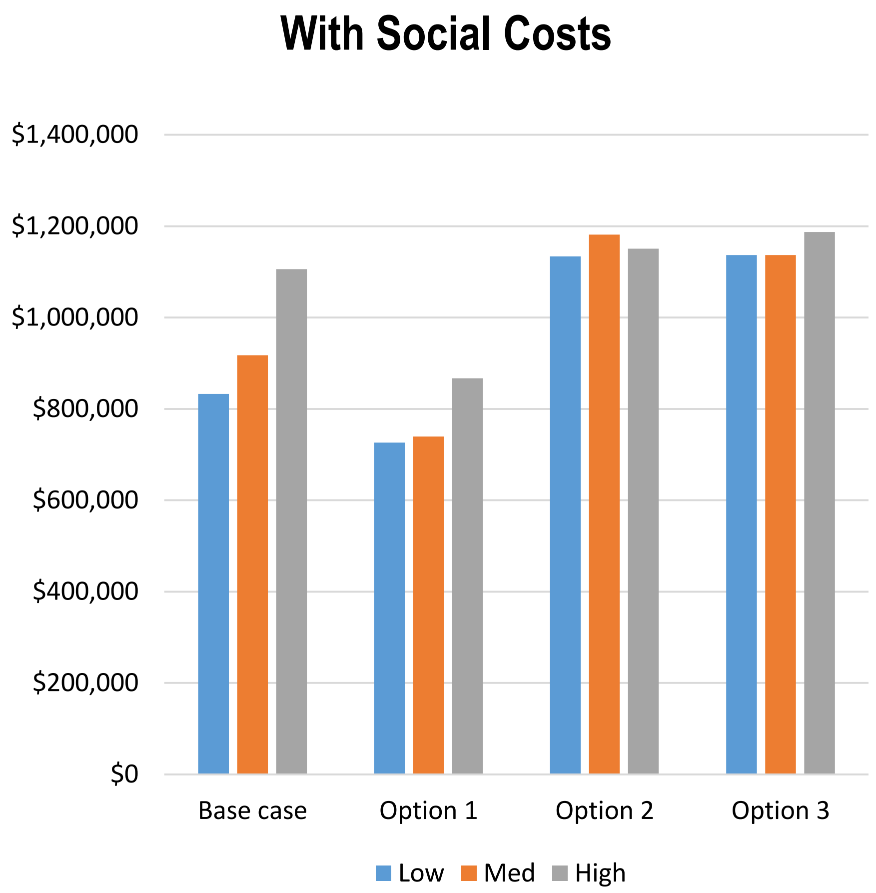




Construction Cost

Cost Effectiveness: Silver Creak





US 63 Spring Valley Culvert

Adaptation Analysis Case Study 2

District 6 – Spring Valley Creek

- Culvert 5722
- Crosses Spring Valley Creek
- US 63 – connects Rochester to Cedar Rapids
- AADT 5,700
- Detour: 0.6 miles

Existing Facility

Existing Hydrology

- Drainage Area: 13.94 mi^2
- Precipitation and Discharge:

24-hour Storm Event Return Period						
2-yr storm	5-yr storm	10-yr storm	25-yr storm	50-yr storm	100-yr storm	500-yr storm
(in)	(in)	(in)	(in)	(in)	(in)	(in)
2.79	3.7	4.49	5.69	6.7	7.81	10.8

24-hour Storm Event Return Period						
2-yr storm	5-yr storm	10-yr storm	25-yr storm	50-yr storm	100-yr storm	500-yr storm
(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
851.5	1383.8	1880.2	2665.3	3341.8	4100.2	6157.6

Performance of Existing Facility

- **Currently Overtopped by 10-year Storm**
- Prone to nuisance flooding due to
  - Undersized conveyance area of culverts
  - Low lying roadway profile
- Performance decreases under all future climate projections

Projected Climate Conditions

24-Hr Storm Return Period	Atlas 14 Precip. Depth (in)	Low Scenario Precipitation Depth (in)			Medium Scenario Precipitation Depth (in)			High Scenario Precipitation Depth (in)		
		2040	2070	2100	2040	2070	2100	2040	2070	2100
2-yr storm	2.79	2.80	2.81	2.81	2.94	3.04	3.15	3.01	3.21	3.46
5-yr storm	3.7	3.72	3.73	3.73	3.87	3.98	4.09	4.14	4.61	5.11
10-yr storm	4.49	4.52	4.53	4.54	4.68	4.81	4.95	5.30	6.16	7.07
25-yr storm	5.69	5.73	5.76	5.77	5.94	6.10	6.27	6.93	8.24	9.66
50-yr storm	6.7	6.76	6.79	6.81	7.00	7.20	7.41	8.22	9.83	11.61
100-yr storm	7.81	7.90	7.94	7.96	8.18	8.43	8.69	9.58	11.45	13.59
500-yr storm	10.8	10.97	11.05	11.10	11.40	11.80	12.23	12.96	15.33	18.25

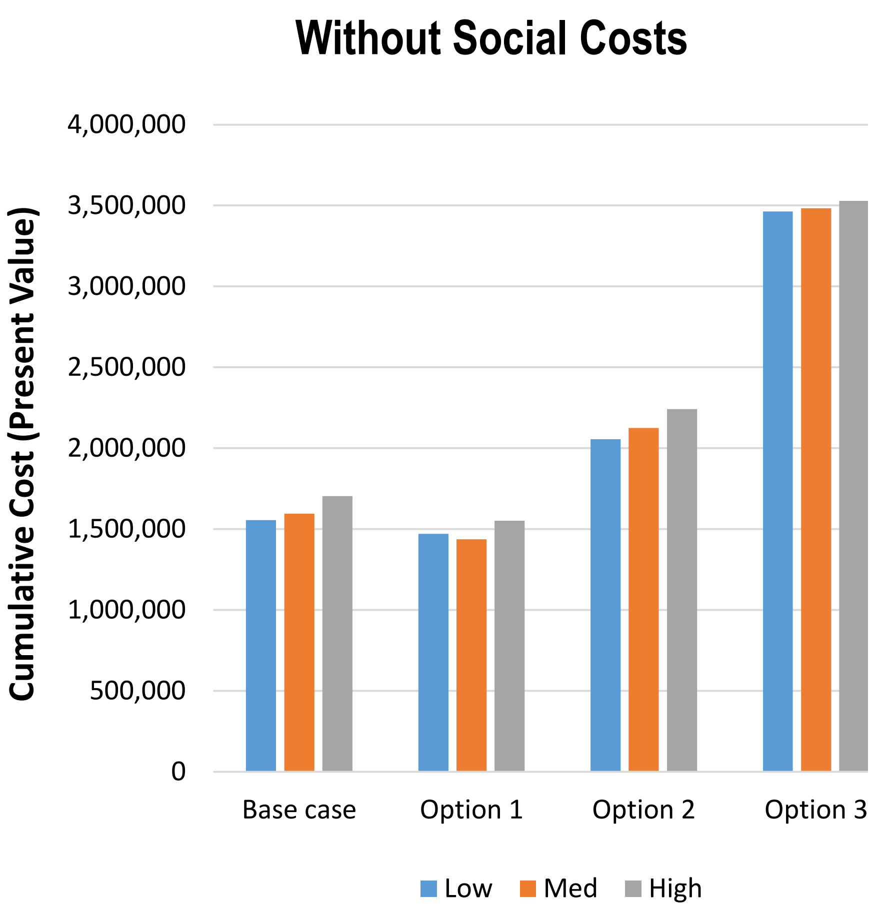
Projected Hydrologic Conditions

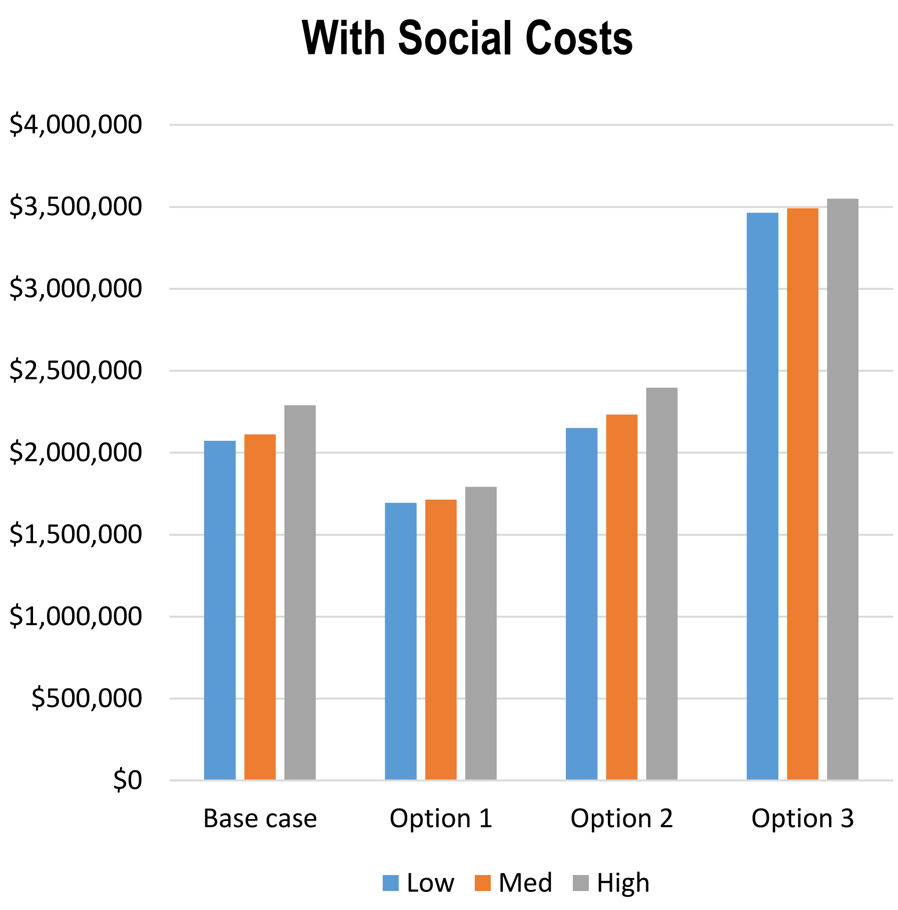
24-Hr Storm Return Period	Existing Discharge (cfs)	Low Scenario Discharges (cfs)			Medium Scenario Discharges (cfs)			High Scenario Discharges (cfs)		
		2040	2070	2100	2040	2070	2100	2040	2070	2100
2-yr storm	850	930	965	980	960	1020	1080	1040	1210	1380
5-yr storm	1390	1480	1520	1540	1520	1590	1660	1610	1810	2010
10-yr storm	1880	2000	2040	2060	2030	2120	2210	2150	2390	2630
25-yr storm	2670	2810	2860	2890	2860	2970	3090	3000	3330	3650
50-yr storm	3340	3520	3590	3630	3590	3720	3870	3760	4170	4550
100-yr storm	4100	4310	4400	4445	4390	4560	4740	4610	5100	5590
500-yr storm	6160	6490	6630	6700	6620	6900	7200	6980	7800	8600

Adaptation Options

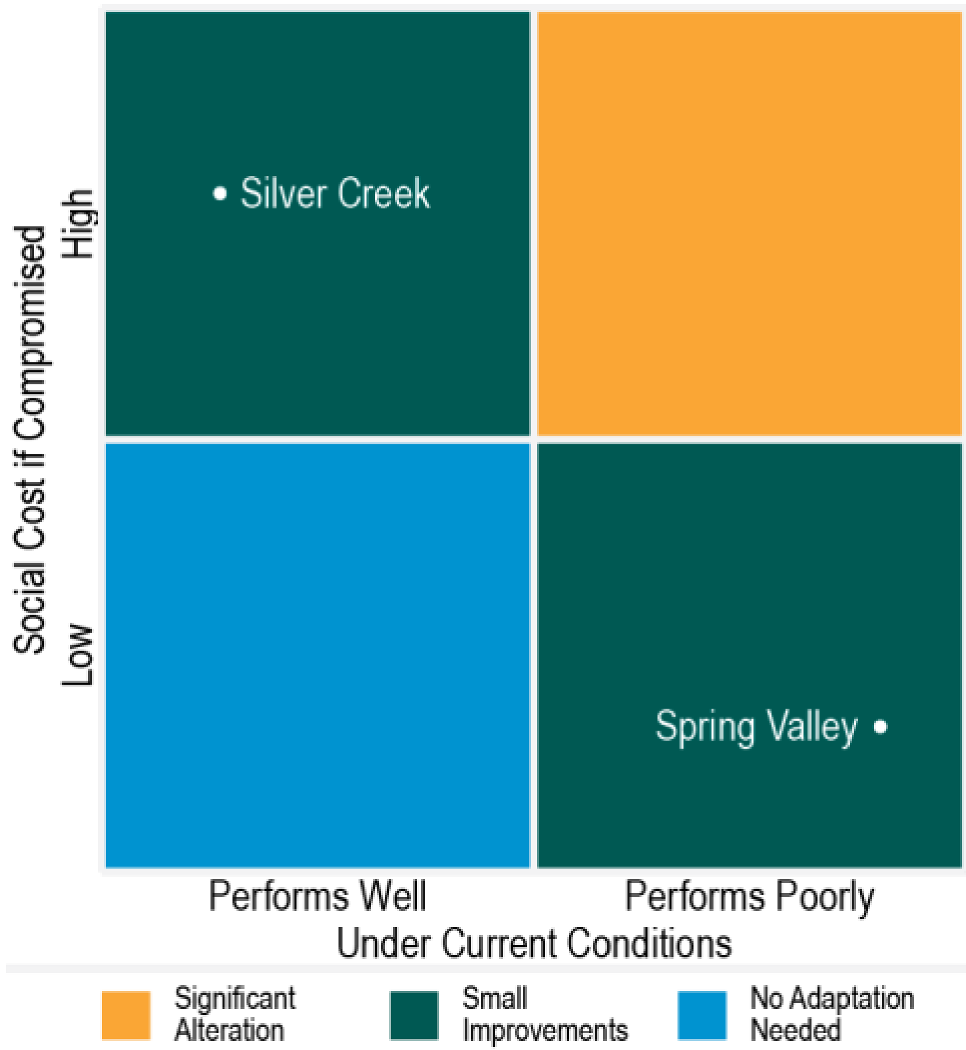
- Base: Replace in-kind
  - Construct cost: $460,000
- Option 1: Add 2 6'x10' culvert cells to existing design
  - Construction cost: $690,000
- Option 2: same as option 1 + floodplain enhancement
  - Construction cost: $1,130,000
- Option 3: Replace Culvert three span 84-foot long bridge
  - Construction cost: $4,210,000

Cost Effectiveness: Spring Valley

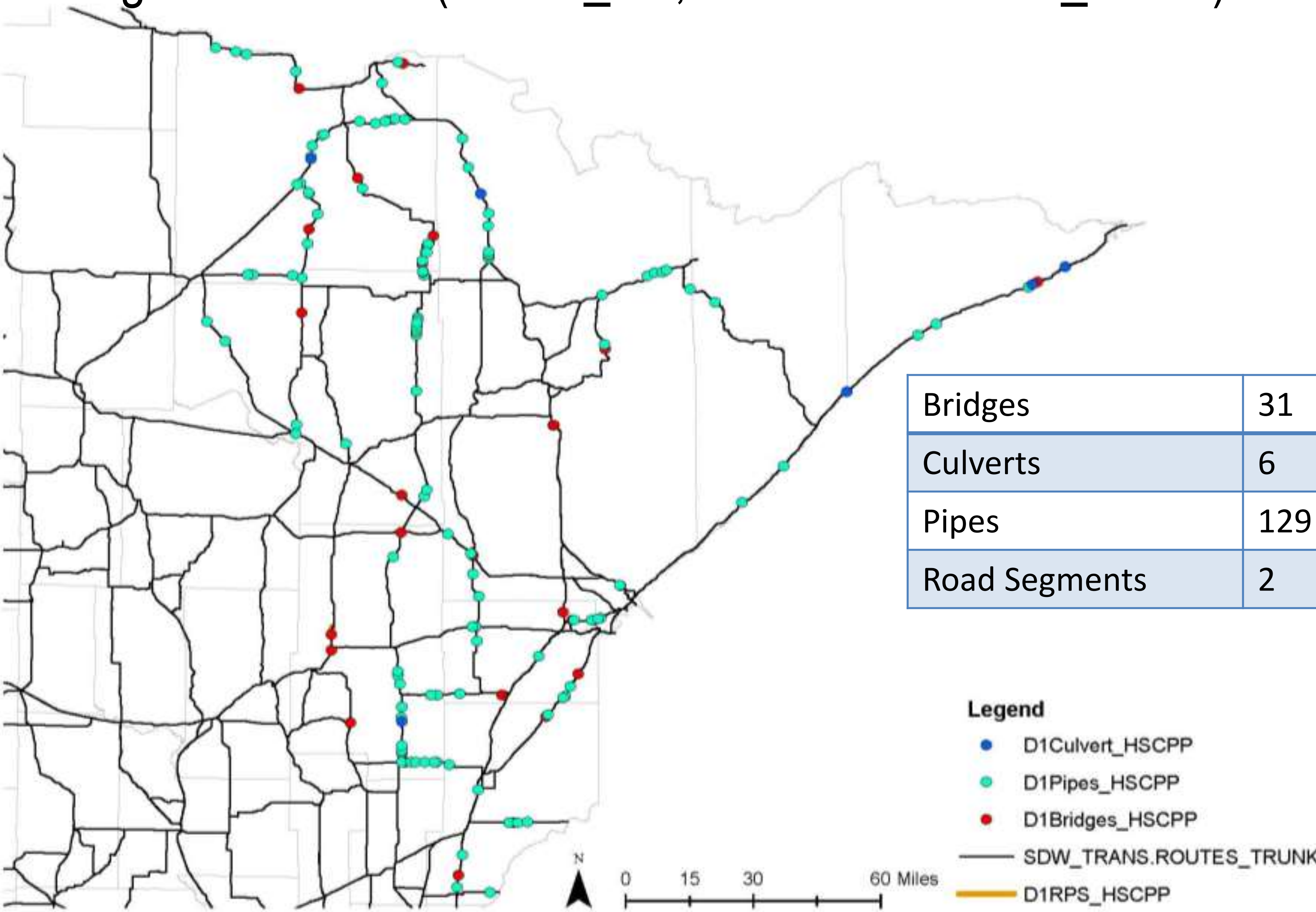




Conceptual Adaptation Screening Framework

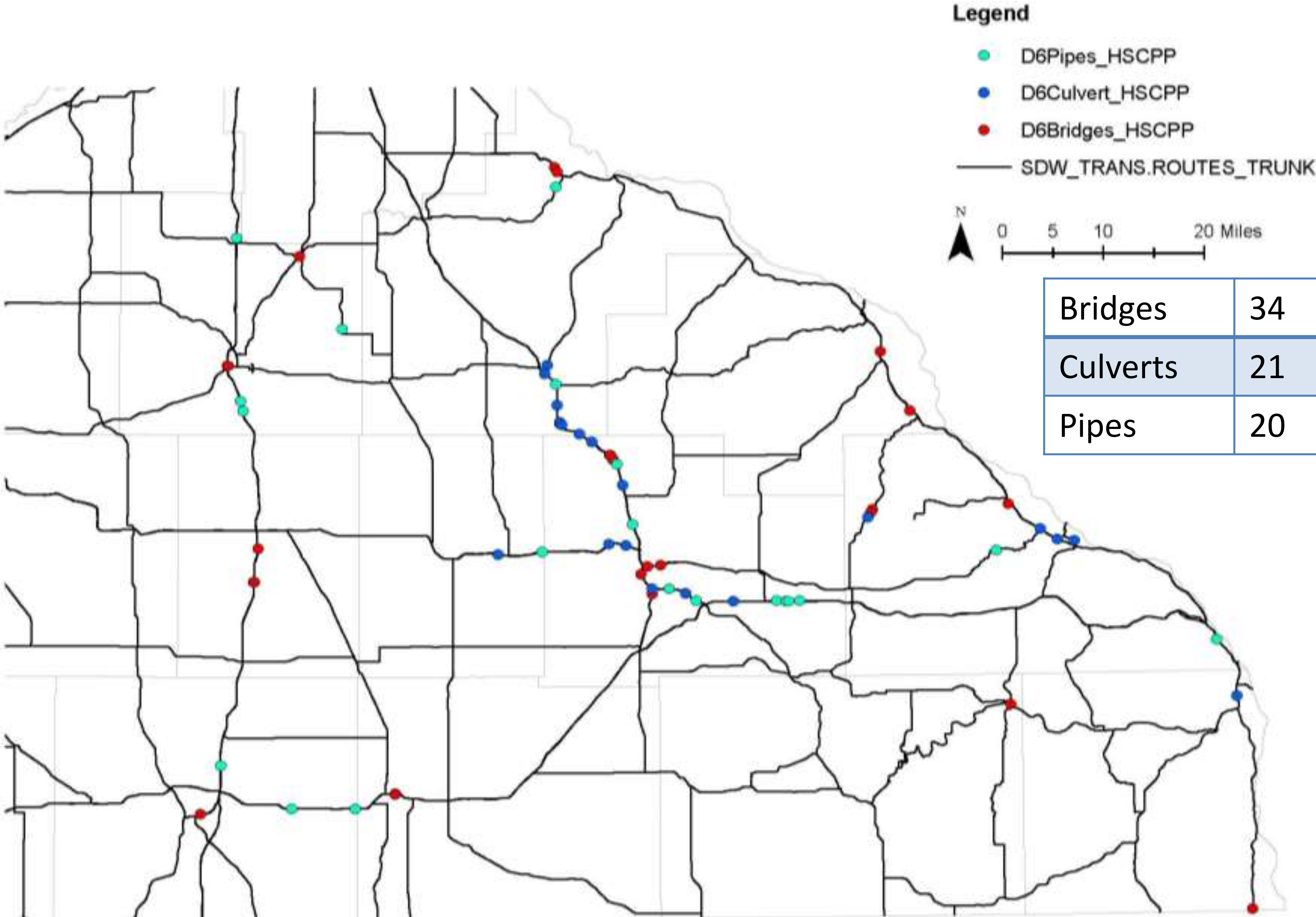


Assets currently performing poorly compared to design storm with high social costs (AADT ≥ 10,000 and/or detour ≥ 20 mi)



Bridges	31
Culverts	6
Pipes	129
Road Segments	2

Assets currently performing poorly compared to design storm with high social costs (AADT ≥ 10,000 and/or detour ≥ 20 mi)



Bridges	34
Culverts	21
Pipes	20

Next Steps

- Complete assessments in other districts and/or other types of “assets” (i.e. slopes)
- Support efforts to improve downscaling techniques and availability
- Incorporate considerations of risk into ongoing culvert and bridge improvement programs
- Incorporate scores into asset management databases and the asset management plan

QUESTIONS?

www.mndot.gov/climate/pilotproject.html

Project Contact:
Philip Schaffner
Policy Planning Director
MnDOT Office of Transportation System Management
philip.schaffner@state.mn.us
651-366-3743