Building Resiliency to Extreme Precipitation in Minnesota

ICAT Workgroup #1 White Paper 7-24-18

Contents:

1) Introduction and History of the Workgroup

This white paper was developed by a workgroup consisting of members of the Minnesota Interagency Climate Adaptation Team (ICAT). The workgroup was formed in 2017 to advance Recommendation #1 from the ICAT report "Adapting to Climate Change in Minnesota" - https://www.pca.state.mn.us/sites/default/files/p-gen4-07c.pdf (p. 62): *Build greater resilience to extreme precipitation*. The objective of this white paper is to advance this recommendation by

- *Identifying priority risks from current and projected extreme precipitation that threaten state and local infrastructure, environmental quality, health, ecosystems, public safety, and economic development.*
- *Developing recommendations, including specific steps to increase resiliency to these impacts.*

The goal of this white paper is to increase resilience to extreme precipitation that can impact Minnesota's human and ecological health, infrastructure, property, and economy. The content of the white paper is intended to inform and guide those planning implementation actions to address these challenges.

The intended audience for this white paper includes: state, federal and local governmental agencies, professionals working in non-governmental organizations, consultants, land and water managers, emergency managers, engineers, water operators, architects, landscape architects, and those making decisions about land use and the built environment.

2) Workgroup Participants:

Kenny Blumenfeld (MN Department of Natural Resources), Anne Gelbmann (MN Pollution Control Agency), Karen Jensen (Metropolitan Council), Pat Lynch (MN Department of Natural Resources), Paul Moss (MN Pollution Control Agency), Kristin Mroz-Risse (MN Environmental Quality Board), Jennifer Nelson (MN Division of Homeland Security and Emergency Management), Bob Patton (MN Department of Agriculture), Katie Retka (MN Department of Military Affairs), Pam Rodewald (MN Pollution Control Agency), Lori Ruff (MN Department of Military Affairs), Dan Shaw (MN Board of Water and Soil Resources), Emmy Waldhart (MN Department of Health)

3) Definitions

Climate Adaptation: Developing and implementing strategies, initiatives, and measures to help human and natural systems prepare for and address climate change impacts.

Extreme Precipitation: A weather event that is rare within its statistical distribution at a particular geographic location.

Extreme Precipitation Resilience: The capacity of human constructed or natural systems to maintain integrity and function in the face of stresses that result from extreme precipitation.

4) Why ICAT Agencies are Engaged in this Topic:

1) Metropolitan Council – The Council manages infrastructure that needs to be resilient to extreme weather events such as eight water treatment plants, flood protection structures, lift and pump stations and transit operations.

2) Minnesota Board of Water and Soil Resources (BWSR) – The BWSR mission is to improve and protect Minnesota's water and soil resources by working in partnership with local organizations and private landowners. Large storms threaten both soil and water resources by causing erosion and nutrient loss in agricultural, urban and natural landscapes. Fluctuating water levels in wetlands, streams and lakes also cause erosion and stress to aquatic ecosystems. BWSR's Landscape Resiliency Toolbox, One Watershed One Plan guidance and Climate Change Trends and Action Report provide information and guidance related to extreme precipitation.

3) Minnesota Department of Agriculture – Large storms impact agricultural productivity through flooding and crop damage and lead to pollution of waterbodies.

4) Minnesota Department of Health – Flooding from extreme precipitation can lead to increases in food and water-borne illnesses, pollute water used for drinking or recreation, promote mold growth in homes, and impact mental health. Agency efforts to reduce public health risks from flooding include:
• Water: help public water suppliers to develop plans to protect drinking water sources, enforce the well code to ensure wells are constructed properly, coordinate certain beach monitoring efforts, educate private well owners on well testing and provide testing after a flood, and explore water reuse in Minnesota
• Air: help building owners and renters to understand health risks of mold exposure and provide information to building owners on how to clean up mold
• Mental health: educate local public health partners and the public on the connections between natural disasters, such as flooding, and mental health risks

5) Minnesota Department of Public Safety – The Department of Public Safety Division of Homeland Security and Emergency Management (HSEM) is focused on prevention, preparedness, response, and recovery from natural and other disasters. There is a need to prepare ahead of time for larger storms rather than to repair damage later. HSEM is currently working to update the State Hazard Mitigation Plan. This plan looks at hazard prone areas and addresses 14 types of natural hazards. This white paper and its recommendations can inform the statewide plan.

6) Minnesota Department of Military Affairs – The Department of Military Affairs is the state agency that supports the Minnesota National Guard in carrying out its federal, state and community missions. The National Guard operates facilities in 58 communities throughout Minnesota; in addition, the Guard manages more than 55,000 acres of training lands. Camp Ripley is a State Game Refuge and a regional training center for 13,300 military personnel. It is also used by civilian agencies including the Department of Corrections, Homeland Security and Emergency Management, Department of Natural Resources, State Patrol and Department of Transportation. Increasingly intense rainfall, heavy snowfall and extreme wind have the potential to damage the Guard's built infrastructure and to hinder readiness training.

7) Minnesota Department of Natural Resources, Floodplains – The state invests a significant amount of funding for flood preparation, response and recovery through the floodplain management program. The Department of Natural Resources is also focused on maintaining the integrity of infrastructure that provides recreational opportunities and protection for fish and wildlife populations.

8) Minnesota Department of Natural Resources, State Climatology Office – Extreme rainfall influences infrastructure as well as natural resources. There have been significant increases in the large storm events. Larger storms are having a statewide impact and can cause significant local damage. The State Climatology Office exists to gather, archive, manage, and disseminate historical climate data in order to address questions involving the impact of climate on Minnesota and its citizens.

9) Minnesota Department of Transportation – Extreme precipitation will potentially affect the way the Department designs, builds and maintains the state's multi-modal transportation infrastructure. It will also lead to the need to inventory all transportation assets, assess which ones are most vulnerable to the impacts of climate change and determine a cost-effective method to mitigate and minimize those impacts. Emergency preparedness plans will need to be updated to reflect lessons learned as a result of recent flash flooding events.

10) Minnesota Environmental Quality Board – The agency has an interagency coordinating role for the topics of climate change and adaptation to extreme precipitation.

11) Minnesota Pollution Control Agency, Stormwater – The MPCA Stormwater program regulates stormwater runoff from Industrial facilities, regulated municipal separate storm sewer systems, and construction sites via National Pollutant Discharge Elimination System/State Disposal System (NPDES/SDS) stormwater permits. Stormwater runoff is a leading source of water pollution. Larger storm events will likely increase pollutant loads to receiving waters. Stormwater infrastructure and the Best Management Practices (BMPs) installed to control and treat stormwater runoff will need to increase their resiliency and effectiveness in response to greater and more frequent storm events to prevent failure. The Stormwater Program provides technical assistance and outreach to consultants and stormwater managers through its Minnesota Stormwater Manual. The manual promotes Minimal Impact Design Standards and Green Infrastructure to reduce stormwater runoff from new development and retrofits to existing development. There is a need to increase communication and information about resiliency to larger and more frequent storms and their effects on stormwater infrastructure in the manual, and update the manual to incorporate BMP design factors that consider resiliency.

12) Minnesota Pollution Control Agency, Wastewater Treatment – Wastewater treatment can be impacted by extreme precipitation, leading to water quality issues in receiving waters. Resiliency planning can help prevent future problems.

13) Minnesota Pollution Control Agency, Community & Business Assistance – There is a need to provide additional best practice assistance to local governments and NGOs on adaptation and resiliency for extreme precipitation events. GreenStep Cities and Minnesota GreenCorps encourage use of Minimal Impact Design Standards (MIDS) for appropriate design and installation of stormwater infrastructure, and other best practice actions that help strengthen resilience to extreme precipitation.

5) Priority Risks from Current and Projected Extreme Precipitation

The following passages are modified excerpts from pages 2 – 16 of the 2017 Interagency Climate Adaptation Team report "Adapting to Climate Change in Minnesota".

Minnesota's climate background

Minnesota's position near the center of North America, halfway between the Equator and the North Pole, subjects us to an exceptional variety of weather. During the course of a single year, most Minnesotans will experience blinding snow, bitter wind chills, howling winds, pounding thunderstorms, torrential rains, and heat waves, as well as dozens of bright and sunny days. Given the high variability that we expect from Minnesota's climate, it can be difficult to discern where, when, and how climatic conditions have changed in our state.

The conditions, however, have changed rapidly, and an overwhelming base of scientific evidence projects that Minnesota's climate will see additional significant changes through the end of the 21st century. Over the last several decades, the state has experienced substantial warming during winter and at night, with increased precipitation throughout the year, often from larger and more frequent heavy rainfall events. These changes alone have damaged buildings and infrastructure, limited recreational opportunities, altered our growing seasons, impacted natural resources, and affected the conditions of lakes, rivers, wetlands, and our groundwater aquifers that provide water for drinking and irrigation. The years and decades ahead in Minnesota will bring even warmer winters and nights, and even larger rainfalls, in addition to other climatic changes not yet experienced in the state.

Climate observations and trends in Minnesota: What has changed and what has not?

In 2014, the U.S. Global Change Research Program completed its third National Climate Assessment. This comprehensive scientific review of the state of climate change science demonstrated that the U.S. is already seeing increasing temperatures, larger rainfalls with increased flash-flooding, heavier snowstorms, more severe heatwaves, and worsening drought conditions in some areas. Within particular regions of the U.S., some of these observed changes are more intense, some are less intense, and some are negligible or not yet occurring.

Both the science summarized in the National Climate Assessment and high-quality climatic data show that in Minnesota and the Midwest, rising temperatures have been driven by a dramatic warming of winter and also nights, with both the frequency and the severity of extreme cold conditions declining rapidly. Annual precipitation increases have been punctuated by more frequent and more intense heavy rainfall events. The heaviest snowstorms have also become larger, even as winter has warmed (see Figure 1).

Several other changes noted elsewhere in the U.S. and world have not yet been observed in Minnesota. For instance, summer high temperatures have not increased in several decades, and heat waves have not worsened when compared to historical patterns. Droughts in Minnesota also have shown no long-term increase in magnitude, duration, or geographic coverage. Tornadoes, large hail, and damaging thunderstorm winds are difficult to compare historically but show a complex tendency toward more "outbreaks" consisting of multiple events at a time, though no increases in overall numbers or severity.

Figure 1

Hazard	Observed Trend	Confidence Change is Occurring
Extreme cold	Rapid decline in severity & frequency	**Highest**
Extreme rainfall	Becoming larger and more frequent	
Heavy snowfall	Large events more frequent	**High**
Severe thunderstorms & tornadoes	Overall numbers not changing but tendency toward more "outbreaks"	**Moderately Low**
Heat waves	No recent increases or worsening	**Lowest**
Drought		

Confidence Scale

Lowest	Low	Moderately Low	Moderately High	High	Highest

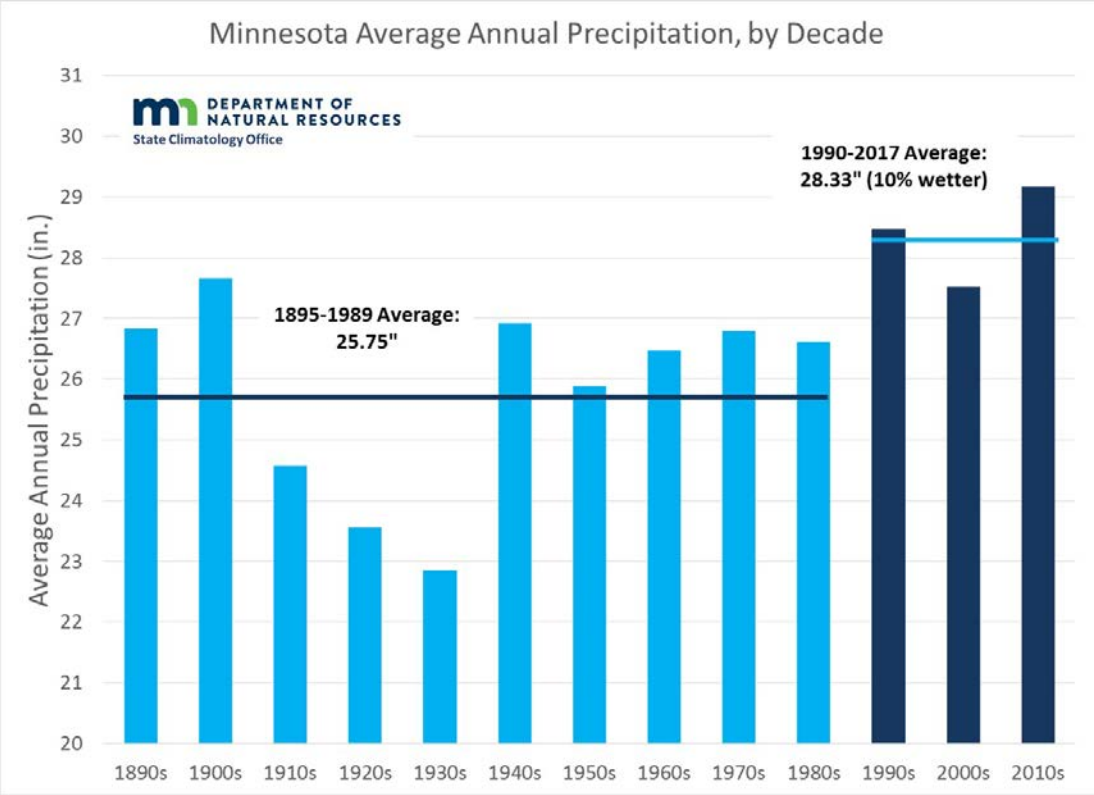
Snapshot of observed trends among common weather hazards in Minnesota, and confidence that those hazards are changing in response to climate change. Graphic based on information from 2014 National Climate Assessment and data analyzed by the Minnesota DNR State Climatology Office.

Increased precipitation

Higher temperatures globally have evaporated more surface and ocean water into the atmosphere, which in turn has provided more potential moisture for precipitating weather systems. This has resulted in more precipitation for Minnesota, which now finds itself in its wettest period in over 125 years of record. Since 1990, Minnesota has been 10% wetter on average than period 1895 to 1989 (see Figure 2).

This precipitation increase is found in all seasons, but spring and summer are becoming wetter at faster rates than fall and winter. Whereas temperature increases have been greatest in the northern parts of the state, precipitation increases have been well distributed geographically, and have somewhat favored southern Minnesota, which has better access to moisture from the Gulf of Mexico, and is more frequently near the "low-level jet" airflow (a relatively fast-moving zone of winds in the lower atmosphere) that influences precipitation production.

Figure 2



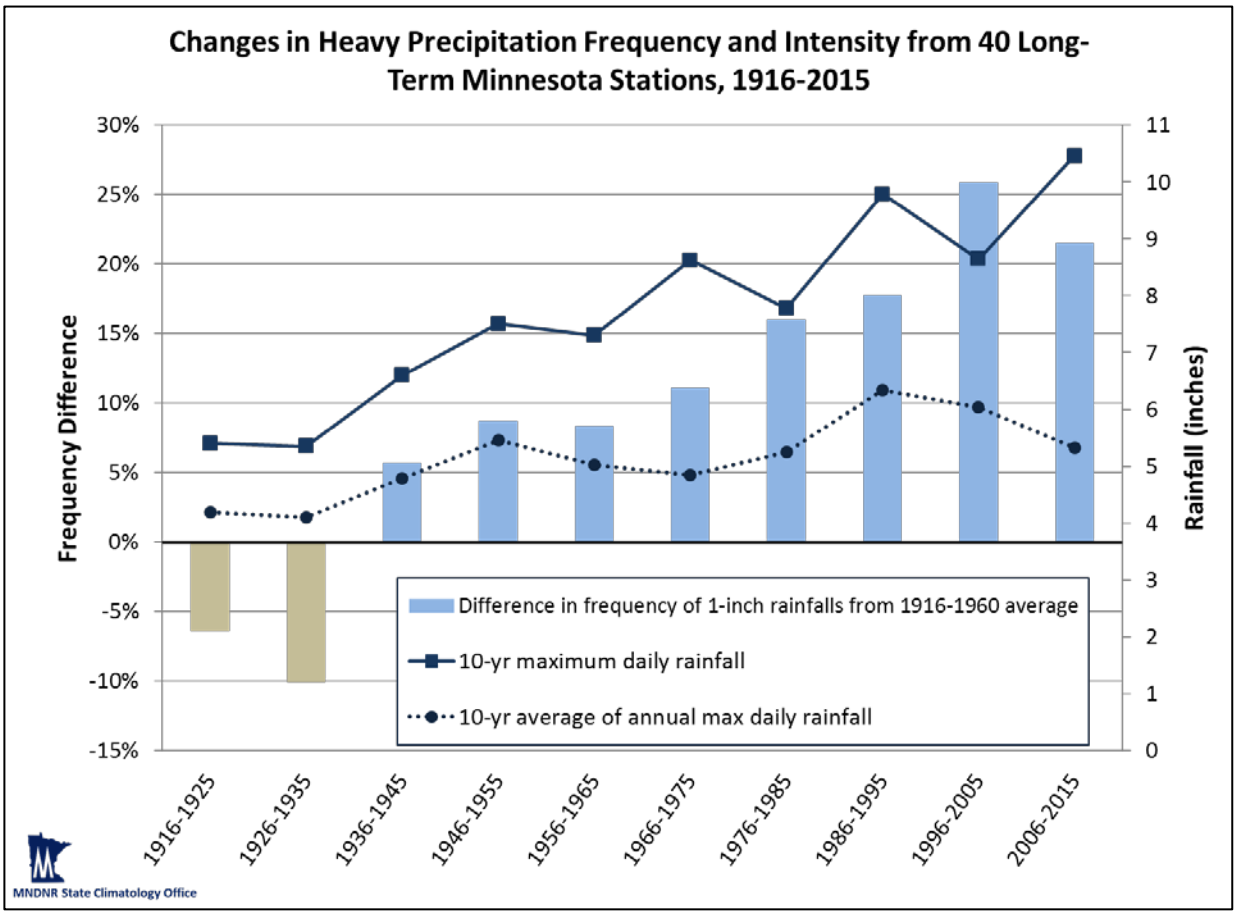
Statewide average annual precipitation, by decade, for the period 1895-2017. Please note that the 1890s and 2010s have fewer than 10 years of record. Source: Minnesota DNR State Climatology Office and National Oceanic and Atmospheric Administration (NOAA) Climate at a Glance (http://www.ncdc.noaa.gov/cag/)

Heavy rainfall and unprecedented extremes

Heavy rainfall events in Minnesota are already becoming larger and more common, and have been contributing to an increasing share of annual precipitation in Minnesota. For instance, the state has 40 daily weather observing sites whose records stretch back more than 100 years. These long-term stations have shown a 20% increase in the annual number of 1-inch daily rainfalls, a 65% increase in the number of 3-inch rainfalls, and a 13% increase in the size of the heaviest rainfall of the year. Additionally, the single heaviest rainfall amount recorded per 10-year interval at those 40 sites has roughly doubled (from just over five inches to just over 10 inches) during that same period (see Figure 3).

Research specific to the Upper Midwest indicates that the physical mechanisms supporting heavy rainfall events in Minnesota are likely to have begun intensifying in response to climate change. This research also shows that these major events may be taking place earlier during the growing season than the historical average. Thus, in addition to increases in the frequency and intensity of heavy rainfall, its seasonal timing may be expanding across the calendar.

Figure 3



Changes in the frequency of one-inch rainfalls relative to the 1916-1960 average (vertical bars), from 40 long-term stations in Minnesota. Also shown are the 10-year average (lower dotted line, right axis) and 10-year maximum values (upper solid line, right axis) of the heaviest single rainfall amount recorded each year at any of the 40 stations. Note that the 10-year maximum value has doubled from just over five inches at the beginning of the record, to just over 10 inches at the end of the record. Courtesy of Minnesota State Climatology Office.

In addition to increases in the frequency and magnitude of heavy rain, Minnesota has also seen a dramatic increase in large-coverage flash floods events in recent years. Since the year 2000, the state has had eight catastrophic "mega-rain events" — when at least six inches of rain falls on an area greater than 1,000 square miles. The years 2002 and 2016 both had two of these damaging rainstorms. By contrast, the 30 years from 1970 through 1999 saw only four. Incidentally, the mega-rains since 2000 have included the largest, earliest, and latest on record, suggesting that we are seeing not just an intensification, but also a lengthening of our heavy and extreme rainfall season.

Projected continued enhancement of extreme precipitation

In the years and decades ahead, winter warming and increased extreme rainfall will continue to be Minnesota's two leading symptoms of climate change (see Figure 4).

Figure 4

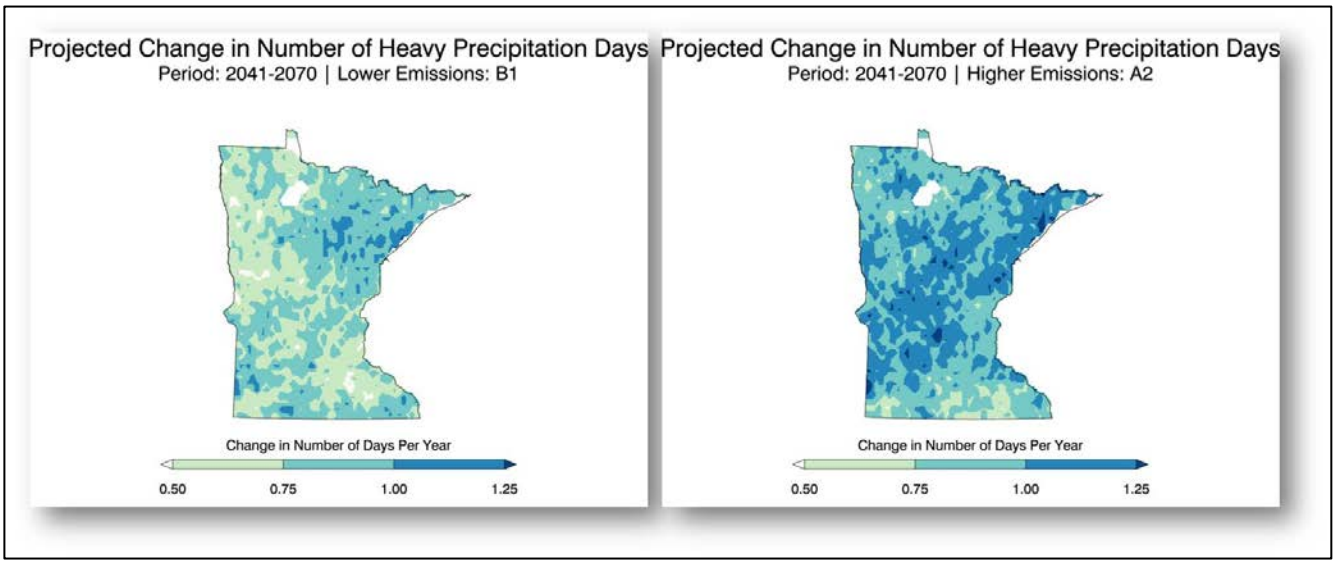
Hazard	Projections through century	Confidence in projected changes
Extreme cold	Continued loss of cold extremes and dramatic warming of coldest conditions	**Highest**
Extreme rainfall	Continued increase in frequency and magnitude; unprecedented flash-floods	
Heat waves	More hot days with increases in severity, coverage, and duration of heat waves	**High**
Drought	More days between precipitation events, leading to increased drought severity, coverage, and duration	**Moderately High**
Heavy snowfall	Large events less frequent as winter warms, but occasional very large snowfalls	**Moderately low**
Severe thunderstorms & tornadoes	More "super events" possible, even if frequency decreases	

Confidence Scale

Snapshot of projected and expected trends among common weather hazards in Minnesota, and confidence that those hazards will change (further) through the year 2099 in response to climate change. Graphic based on information from 2014 National Climate Assessment, and data analyzed by the Minnesota DNR State Climatology Office.

Greenhouse gas concentrations will continue rising through the century, and the air's ability to trap heat from the earth's surface will increase accordingly. As a result, winters, and cold conditions in particular, will continue warming well beyond historical bounds. Continued warming of the atmosphere will evaporate even more water into the air, further limiting the amount of cooling Minnesota will be able to achieve at night and during the winter. This increased water vapor will also enhance precipitating weather systems, continuing the trend toward more — and larger — heavy rainfall events (see Figure 5). Minnesota can expect unprecedented rainfall events during the remainder of the 21st century.

Figure 5



Projected changes by mid-century in number of days annually with heavy rainfall, defined as the upper 2% of daily precipitation for the 1971-2000 climate period. Left image is the "ensemble" or model average for a lower emissions scenario. The right image is the same, but for a higher emissions scenario. Images derived from output used for the 2014 National Climate Assessment, courtesy of GLISA (Great Lakes Integrated Science + Assessments).

Impacts of climate change in Minnesota

The observed measurements and future projections described by the National Climate Assessment and the Minnesota State Climatology Office provide insight into climate trends that are impacting Minnesota now as well as those anticipated in the future. Complicating the varied impacts of climate change is that these changes also interact with and reinforce each other. For example, drought and heat may both contribute to wildfires, which may in turn lead to changes in plant and animal populations as well as other ecological shifts. Extreme precipitation may increase flooding, along with the potential for runoff or combined-sewer overflow and contamination of recreational and drinking water sources, which may already be in short supply due to drought. In addition, climate change will amplify the effects of existing public health and environmental challenges, such as impaired air quality, loss of wildlife habitat, invasive species, and limitations to clean water supplies.

As informed by climate data and trends, Minnesota state agencies are identifying significant current and future climate change impacts. These impacts, including variable and considerable changes in temperature and precipitation, are expected to have substantial effects on public health, community infrastructure, ecosystem health, environmental quality, and natural resource-based economies.

The following description of the impacts of extreme weather events summarizes some currently observed and anticipated impacts of climate change by ICAT member agencies.

Extreme weather events

Both observed climate data as well as future projections indicate increases in very heavy precipitation in Minnesota. Heavy precipitation events, storms, and flooding have significant impacts on Minnesota's communities and ecosystems. These include effects on water and soil resources, agriculture, drainage infrastructure, human health, stormwater management, wastewater treatment, solid waste management, and emergency response.

More frequent, heavier, or longer-duration rainfall events will increase soil erosion and runoff, thereby increasing deposition of sediment and contaminants in water bodies. Climate change has the potential to impact the quality of water and soil resources throughout Minnesota.

More frequent extreme weather events will impact Minnesota agriculture, resulting in increased runoff of fertilizers, pesticides, and sediment particularly from agricultural fields that do not have best management practices in place such as buffers, grassed waterways, and crop residue left on the fields. Field flooding can result. There are also costs to the state for disaster assistance (e.g., the Minnesota Department of Agriculture's flood assistance programs) which will likely increase as a result of climate change.

Damage to feed crops from extreme weather also affects livestock. Greater precipitation increases challenges for applying manure in an environmentally safe manner to fields. Flooding can also cause overflow of manure storage basins which have inadequate storage capacity, leading to contamination of nearby water bodies and death of aquatic organisms.

Increased extreme weather events put additional pressure on the state's drainage infrastructure. There is a potential for more erosion within older drainage systems that do not have adequate outlets or erosion controls in place.

Flash flooding from extreme precipitation can damage the built environment, affecting commercial and residential buildings, roads, parks, and stormwater infrastructure. Water-saturated soils can destabilize bluffs, trees, and utility poles.

Flooding from increased average rainfall, rapid snowmelt, or localized, heavy rainfall can lead to human health impacts such as:

- Persistent mold problems in homes and businesses.
- Increases in food and water-borne illness
- Food insecurity
- Injury (particularly due to unsafe structures and clean-up efforts).
- Interruption of medical and emergency services. .
- Stress and mental health impacts due to trauma, displacement, and loss.
- Death from drowning.

Flooding contaminates freshwater sources with untreated or partially treated sewage and can contaminate food crops with waste from nearby livestock or wild animals, threatening food safety. Increased water flow from a flood may disrupt municipal water supplies and sewage treatment facilities, as well as private wells and on-site septic systems. Flooding of private wells is a particularly serious public health concern, given that, in general, well owners do not test or treat their water according to health-protective guidelines. Flooding is also connected to direct (anxiety, stress) and indirect (post-traumatic stress disorder, chronic stress, social cohesion) mental health impacts. Resources for recovery need to focus on immediate issues as well as be expanded to include full community recovery, which can take years.

Changes in amount, frequency, and intensity of precipitation impact stormwater management, potentially exceeding the design capacity of stormwater treatment structures or impacting future structure design. Extreme weather also adds to challenges in monitoring water quality.

Higher peak intensity rainfall events may result in bypass of wastewater treatment facilities or sanitary sewer overflows, leading to the release of minimally treated or untreated wastewater. Wastewater facility staff need to track changes in floodplain elevations as peak rainfall intensities increase so that treatment facility infrastructure can be protected during possible flood events.

There is increased need to properly clean up and manage solid waste, hazardous materials, and debris after floods, storms, and other natural disasters. More frequent occurrences of natural disasters increase the demand for disaster remediation and coordination efforts, as well as for trained staff to meet these specific needs. Design

standards for permitted waste management facilities are linked by rule to certain magnitudes of storm events (i.e., 25- or 100-year storms), and as storm severity increases, this impacts facility needs. There is accelerated use of existing waste management capacity due to more waste and debris resulting from extreme weather.

Increasing numbers of floods and storms raise the need for state support and response. A greater demand for response from limited staff reduces time available for internal and external preparedness, including partnering and preparing with local units of government, state agencies, and industry. Infrastructure damage due to flooding and storms, such as flooded roads and power and communication technology outages, can disrupt emergency response in affected areas, which also has health impacts.

Populations particularly vulnerable to flooding and extreme weather events include the elderly and those without the ability to evacuate when necessary. Long-term recovery from flooding and extreme weather events can be more difficult for low-income populations, especially in regards to housing and employment. Community infrastructure (cohesion, relationships, ability to respond as a whole) should be considered just as much as environmental and built infrastructure.

6) Collaboration with the State Hazard Mitigation Plan Development

This white paper seeks to support the development of Minnesota's State Hazard Mitigation Plan as is being updated by the MN Division of Homeland Security and Emergency Management. Hazard mitigation, as defined by the Disaster Mitigation Act of 2000, is any sustained action taken to reduce or eliminate the long-term risk to human life and property from hazards. A recent study on hazard mitigation shows that for each dollar spent on mitigation, society saves an average of six dollars in avoided future losses. (National Institute of Building Sciences, 2017) Mitigation can take many different forms from construction projects to public education.

The development of a mitigation strategy allows the State of Minnesota to create a vision for preventing future disasters, establish a common set of mitigation goals across state, tribal, and local agencies, prioritize actions, and evaluate the success of such actions. The Minnesota Mitigation Strategy is based on the results of the statewide risk assessment, local and tribal risk assessments and mitigation strategies, and additional recommendations by mitigation stakeholders. The goals are broad, forward-looking statements that outline in general terms what the state would like to accomplish in collaboration with its partners.

The simplified, straightforward and implementable goals and objectives for the state are provided below.

State of Minnesota Hazard Mitigation Goals and Objectives:

Goal 1. Enhance the State's capacity to make Minnesota more resilient to the effects of all hazards.

Goal 2. Build and support local capacity and commitment to increase resiliency to all hazards.

- Increase awareness and knowledge of hazard mitigation principles and practice among local public officials.
- Provide direct technical assistance to local public officials and help communities obtain funding for mitigation planning and project activities.
- Encourage communities to update and implement local hazard mitigation plans and incorporate with other land use planning mechanisms.
- Improve compliance with State floodplain regulations and encourage participation in the National Flood Insurance Program (NFIP), and Community Rating System (CRS).
- Provide training and assist jurisdictions in developing and implementing cost-beneficial mitigation projects.

- Maximize available post-disaster "windows of opportunity" to implement major mitigation outreach initiatives, including social media.

7) Resiliency Actions for Extreme Precipitation and Cross-cutting Themes

The tables below summarize resiliency actions to extreme precipitation for state policy, local planning and regulations, structure and infrastructure projects, natural systems protection, and education and awareness programs. The goal of the resiliency actions in the following tables is to reduce negative flooding-related health impacts, property loss, and economic disruption due to extreme precipitation.

The five categories of action in the table include:

State Policy: Recommended changes to state policies to increase protection of infrastructure, industries or natural systems from changes in extreme precipitation.

Local Planning and Regulations: Government, administrative, or regulatory actions or processes that influence the way land and buildings are developed and built. These actions also include public activities to reduce hazard losses.

Structure and Infrastructure Projects: Actions that involve the construction of structures to reduce the impact of a hazard, such as dams, levees, floodwalls, seawalls, retaining walls, and safe rooms; and actions that involve the modification of existing buildings or structures to protect them from a hazard or remove them from the hazard area.

Natural Systems Protection: Actions that, in addition to minimizing hazard losses, preserve or restore the functions of natural systems. These actions include sediment and erosion control, stream corridor restoration, watershed management, forest and vegetation management, and wetland restoration and preservation.

Education and Awareness Programs: Actions to inform and educate citizens, elected officials, and property owners about the hazards and potential ways to mitigate them. Such actions include outreach projects, real estate disclosure, hazard information centers, and school age and adult education programs.

These resiliency actions address the following hazards related to extreme precipitation:

- Flash flooding
- Riverine flooding
- Lake and wetland flooding
- Winter storms
- Erosion
- Landslides and mudslides
- Subsidence

The resiliency actions are ranked on the following metrics:

- Ease of action (high or low)
- Potential impact (high or low)

The charts below represent input from over 50 stakeholders attending a half-day workshop on Building Resiliency to Extreme Precipitation in Minnesota held in St. Paul on May 14, 2018. Attendees were invited based on their expertise in the five categories of action above, and divided into groups during the workshop. Each topic group was provided with a draft list of Resiliency Actions relevant to their topic and was tasked with making changes to the draft list (adding, editing or removing actions) and then prioritizing and ranking the actions in their category,

with the focus being on the top actions they would recommend. The edited actions and selected priorities are listed below in priority order with the top five recommendations numbered for each topic.

A primary outcome of this White Paper is to move toward implementation of priority resiliency actions. To progress toward this goal the top 25 priority actions identified in the White Paper (top 5 from each category) were reviewed to come up with five cross cutting themes. The themes below will be used to help identify the highest priorities for implementation.

- **Improve availability, accessibility, and quality of data relevant to preparing for current and projected extreme precipitation events** (including climate projections, historical data, ongoing monitoring, and characterization of natural flow regimes)

- **Implement policies that will increase resilience to extreme precipitation** (including development of model codes, setting standards for state bonding projects, providing flexibility in state building codes, and improved emergency response)

- **Better incorporate resilience into local and statewide planning and associated ordinances and funding** (including flood mitigation strategies, consideration of mental and behavioral health concerns, sensitivity to at risk populations, promotion of green infrastructure, and protection of natural areas)

- **Further integrate resilience considerations into design, siting, maintenance, and funding of built and natural infrastructure** (including a focus on critical facilities and infrastructure, removal of structures when needed from flood hazard areas, utilization of stable plant communities and soil health, and prioritization of best practices)

- **Advance resilience to extreme precipitation through outreach, education, demonstration projects, voluntary programs, and developing partnerships for collective action** (including local governments, at-risk populations, agricultural producers, private well users, and property owners)

State Policy

Resiliency Action	Flash Flooding	Riverine Flooding	Lake and Wetland Flooding	Winter Storms	Erosion	Landslides and Mudslides	Subsidence	Ease of Action (high or low)	Potential Impact (high or low)
#1 Fund development and dissemination of dynamically downscaled climate projection data to enable local decision-making and education.	X	X	X	X	X	X	X	High	High
#2 Provide increased flexibility in state building codes to address extreme precipitation, including during the code adoption process, by reviewing and amending the model codes as needed to address extreme precipitation, and by statutorily authorizing any municipality with the approval of the state building official to adopt a more restrictive ordinance when climatic conditions warrant it.	X	X	X	X	X	X	X	Low	High
#3 Adopt new statewide policies and revise existing ones to reduce stormwater runoff.	X	X	X	X	X	X		Low	High
#4 Require incorporation of water-sensitive infrastructure – such as protection of natural areas, development of green infrastructure, and minimization of impervious areas to treat both water quality and quantity – in all comprehensive plans and watershed plans.	X	X	X	X	X	X		Low	High
#5 Establish resiliency standards for state bonding projects and increase capital investment in climate-adapted and resilient infrastructure throughout the state.	X	X	X	X	X	X	X	Low	High
Increase state funding to enhance resilience to extreme precipitation, including exploring potential mechanisms to accomplish this such as a state revolving fund or green bank.	X	X	X	X	X	X		Low	High
Improve flood risk assessment methods and mapping.	X	X	X	X	X	X	X	Low	High
Fund partnership efforts to gather, maintain and disseminate current information about populations vulnerable to climate change impacts to better serve their needs.	X	X	X	X	X	X	X	Low	Low
Integrate climate adaptation into watershed-based planning efforts through collaboration and agency support.									

	X	X	X	X	X	X	X	Low	Low
State government establishes a goal and tracking system to increase resiliency to extreme precipitation.	X	X	X	X	X	X	X	Low	High
Adopt new statewide policies that promote reuse of water.	X	X	X					Low	High

Local Planning, Regulations and Implementation

Resiliency Action	Flash Flooding	Riverine Flooding	Lake and Wetland Flooding	Winter Storms	Erosion	Landslides and Mudslides	Subsidence	Ease of Action (High or Low)	Potential Impact (High or Low)
#1 Incorporate specific flood mitigation strategies and associated funding mechanisms in local planning.	X	X	X	X				Low	High
#2 Incorporate mental and behavioral health strategies into local all-hazards plans by identifying lead and support agencies to provide mental and behavioral care and identifying support processes, critical facilities, and resources for first responders during post-disaster scenarios.	X	X	X	X		X	X	High	Low
#3 Include at-risk populations when designing post-disaster recovery plans to ensure that plans for rebuilding and resource allocation take into account at-risk populations' needs, including education and communication.	X	X	X	X		X	X	High	High
#4 Include specific requirements and recommendations for addressing extreme precipitation in community comprehensive plans and where appropriate adopted into ordinances.	X	X	X	X	X	X	X	High	High
#5 Implement urban and regional planning that considers protection of natural areas, development of green infrastructure, protection of floodplains, and minimization of impervious areas to treat both water quality and quantity though a variety of practices, including ecological restoration and green infrastructure.	X	X	X	X	X	X	X	Low	High
Strengthen local partnerships.	X	X	X	X	X	X	X	High	High
Restrict new development and remove current development in floodplain areas.	X	X	X	X	X	X	X	Low	High
Adopt and enforce Building Codes and Development Standards that increase resilience to extreme precipitation such as for snow load and flooding, or soil creating soil conditions that can infiltrate water on new developments.	X	X	X	X	X	X	X	Low	Low
Adopt other local ordinances and development standards that address extreme precipitation.	X	X	X	X	X	X	X	High	Low
Improve stormwater infrastructure management planning and implementation (including design, construction, and maintenance) through collaboration and use (by implementing a communications plan) of the Minnesota Stormwater Manual.	X	X	X	X	X	X	X	High	High
Adopt local policies (like ordinances and Minimal Impact Design Standards (MIDS)) and provide incentives.	X	X	X	X	X	X	X	High	High

Resiliency Action	Flash Flooding	Riverine Flooding	Lake and Wetland Flooding	Winter Storms	Erosion	Landslides and Mudslides	Subsidence	Ease of Action (High or Low)	Potential Impact (High or Low)
Improve flood risk assessment methods, models, and mapping and connect the resources to local officials and staff.	X	X	X	X	X	X	X	High	High
Support compliance with the National Flood Insurance Program (NFIP) including joining the NFIP community rating system (CRS).	X	X	X					High	High
Support education of local officials and local government staff on local flood risks and assessments.									

Structures and Infrastructure Projects

Resiliency Action	Flash Flooding	Riverine Flooding	Lake and Wetland Flooding	Winter Storms	Erosion	Landslides and Mudslides	Subsidence	Ease of Action (High or Low)	Potential Impact (High or Low)
#1 Design, site and protect critical facilities and infrastructure such as roads, bridges, water and energy utilities, buildings to be more resilient to extreme precipitation.	X	X	X	X	X	X	X	Low	High
#2 Support the further development and refinement of climate projections and modeling for planning projects.	X	X	X	X	X	X	X	Low	High
#3 Update Atlas 14 every ten years if possible. Use of NOAA Atlas 14 rainfall frequency data (designing beyond Atlas 14 for larger events when needed), best management practices, landscape planning and design practices to build resilience to storm events as appropriate.	X	X	X	X	X	X	X	High	High
#4 Remove existing built structures identified as high priority from flood hazard areas.	X	X	X					High	High
#5 Prioritize maintenance for existing flood control structures, and stormwater and drainage systems; including keeping floodplains, flow paths, and overflows unobstructed.	X	X	X	X	X	X	X	Low	High
Create infrastructure to hold back water for when it is needed such as in drain tiles with water controls in agricultural areas and retention systems that can be used for irrigation in urban areas.	X	X	X	X	X	X	X	Low	High
Develop public amenities such as athletic fields for water detention to provide more than one function.	X	X	X	X				High	High
Publish data on flood risks.	X	X	X	X	X	X	X	High	High
Incorporate equity analysis into how, when, and where infrastructure projects are built and rebuilt.	X	X	X	X	X	X	X	High	Low
Support emergency response and education.	X	X	X	X		X	X	High	Low
Elevate or retrofit structures and utilities that are located in floodplain.	X	X	X	X			X	Low	High
Flood proof existing residential and non-residential structures that are located in unmapped floodplain but are prone to flooding.	X	X	X	X			X	High	High
Focus on flood control structures.	X	X	X	X	X	X	X	Low	High

Natural Systems Protection

Resiliency Action	Flash Flooding	Riverine Flooding	Lake and Wetland	Winter Storms	Erosion	Landslides and Mudslides	Subsidence	Ease of Action (High or Low)	Potential Impact (High or Low)
#1 Protect and restore diverse natural habitats that provide multiple benefits including water quality protection for groundwater and surface water, and stable plant communities that can resist invasive species, protect pollinator populations, preserve and improve wildlife habitat, and provide resiliency to weather extremes.	X	X	X	X	X	X		Low	High
#2 Promote collective action.	X	X	X	X	X	X	X	High	High
#3 In agricultural landscapes, implement and maintain combinations of best practices including continuous living cover practices that promote soil health and the ability of soils to capture and store rainfall, and store carbon. Also promote the Minnesota Agricultural Ag Water Quality Certification Program or similar programs.	X	X	X	X	X	X		High	High
#4 Characterize/determine natural flow regimes and manage landscapes to mimic natural hydrology in wetland and floodplain systems.	X	X	X	X	X	X		Low	High
#5 Support and fund applied research and demonstration, monitoring and adaptation.	X	X	X	X	X	X	X	High	High
Strategize and prioritize high-risk mapping of natural and resilient landscapes and communities through an equitable lens.	X	X	X	X	X	X	X	Low	High
Preserve and restore floodplains as open space to ensue water storage to mimic natural hydrology.	X	X	X	X	X			Low	High
In urban areas, implement and maintain combinations of practices to reduce volume, slow velocity and improve water quality. Practices in urban areas that are commonly combined include raingardens, infiltration trenches, treatment swales, stormwater wetlands, and detention basins.	X	X	X	X	X	X	X	Low	High
Capture and retain precipitation as close to where it falls as possible prior to it flowing into streams, lakes, and rivers, contributing to erosion, and flooding.	X	X	X	X	X	X	X	Low	High
Conduct wetland restoration and protection in watersheds prone to flooding to provide benefits for peak flow reduction. Water plans should support the continued implementation and maintenance of the Wetland Conservation Act and look for opportunities to improve coordination across jurisdictional boundaries. (See Restorable Wetland Prioritization Tool and the Minnesota Wetland Restoration Guide or similar resources.)	X	X	X	X	X	X	X	High	High
Plan for financing and resources for long-term management of installed practices.	X	X	X	X	X	X	X	Low	High

Resiliency Action	Flash Flooding	Riverine Flooding	Lake and Wetland	Winter Storms	Erosion	Landslides and Mudslides	Subsidence	Ease of Action (High or Low)	Potential Impact (High or Low)
Implement and maintain soil stabilization practices to prevent further erosion within ravines, shorelines and streambanks.	X	X	X	X	X	X	X	High	High
Use conservation practices to retain water at the head of ravines, bluffs and other sensitive landscape features.	X	X	X	X	X	X	X	High	High
Use natural systems and best practices, such as conservation easements and buffers, to protect wellheads and public water supplies as natural systems.	X	X	X	X			X	High	High
Ensure that stormwater permits for construction are written and implemented to anticipate and react to extreme precipitation.	X	X	X	X	X	X	X	High	High

Education and Awareness Programs

Note: "Providing information" can encompass hosting or supporting online or in-person educational events and trainings; conducting outreach (e.g., via email/mail, phone, social media, presentations, marketing campaigns, press releases); and developing educational resources (e.g., tools, exhibits, demonstration sites). Education and awareness efforts should always be informed by stakeholder analysis and evaluation.

Resiliency Action	Flash Flooding	Riverine Flooding	Lake and Wetland Flooding	Winter Storms	Erosion	Landslides and Mudslides	Subsidence	Ease of Action (High or Low)	Potential Impact (High or Low)
#1 Provide information to **local government staff and decision-makers** about the risks of extreme precipitation and opportunities to reduce the risks. Programs and resources: Nonpoint Education for Municipal Officials (NEMO); GreenStep Cities; CREAT Risk Assessment Application for Water Utilities; Restorable Wetland Prioritization Tool; conferences; state web-portal for climate adaptation	X	X	X	X	X	X	X	High	High
#2 Provide information to **at-risk populations**[1] about preparing for and responding to extreme precipitation.	X	X	X	X		X	X	High	High
#3 Provide information to **private well users and local government staff** about how to prevent and respond to drinking water contamination from extreme precipitation. Programs and resources: Minnesota State Fair Eco-experience program; state web-portal for climate adaptation (future)	X	X	X					High	High
#4 Provide information to **property owners** about practices to reduce the impact of extreme precipitation. Programs and resources: Eco Experience at the Minnesota State Fair; BWSR Landscape Resiliency Toolbox	X	X	X	X	X	X		Low	Low
#5 Provide information to **agricultural producers** about practices, programs, and resources to reduce the impact of extreme precipitation. *Programs and resources: Minnesota Agricultural Water Quality Certification Program; BWSR Landscape Resiliency Toolbox; NRCS Funding Opportunities; citizen action programs*	X	X	X	X	X	X	X	Low	Low
Provide information to **people living in Minnesota** about local government efforts to reduce the impact of and respond to extreme precipitation.	X	X	X	X	X	X	X	Low	High

Resiliency Action	Flash Flooding	Riverine Flooding	Lake and Wetland Flooding	Winter Storms	Erosion	Landslides and Mudslides	Subsidence	Ease of Action (High or Low)	Potential Impact (High or Low)
Provide information to **developers and stormwater managers** about stormwater management regulations, programs, and resources. Programs and Resources: Minnesota's Stormwater Manual; state web-portal for climate adaptation (future)	X	X	X	X	X	X	X	Low	High

[1] Who Might be Considered "At Risk" Populations During Disaster and Crisis according to the Minnesota Department of Health: children, senior citizens, pregnant women; people who have disabilities, live in institutionalized settings, are from diverse cultures, have limited English proficiency or are non-English speaking, are transportation disadvantaged, have chronic medical disorders, or have pharmacological dependency; and people with an economic disadvantage or absence of a support network

[1] Soil and Water Conservation Districts are likely the most relevant implementer.