Minnesota State Hazard Mitigation Plan

Including Recommended Actions for Climate Change Adaptation

2019

Department of Public Safety

Division of Homeland Security and Emergency Management

Approved: March 11, 2019
Adopted: March 18, 2019

U.S. Department of Homeland Security
Region V
536 South Clark Street, Floor 6
Chicago, IL 60605

MAR 1 8 2019

FEMA

Mr. Joe Kelly, Director
Homeland Security and Emergency Management
445 Minnesota St., Suite 223
St. Paul, MN, 55101

Dear Director Kelly:

I am pleased to inform you that the Federal Emergency Management Agency (FEMA), within the Department of Homeland Security (DHS), formally approves the 2019 State of Minnesota Hazard Mitigation Plan, officially adopted by the State of Minnesota. The plan is now in compliance with the Disaster Mitigation Act of 2000 requirements for an updated Standard State Mitigation Plan. The updated state mitigation plan is effective March 20, 2019 through March 19, 2024.

The approval of this plan ensures the continued availability of non-emergency Stafford Act funding for the next 5 years within the State of Minnesota. This includes the Pre-Disaster Mitigation Program, Flood Mitigation Assistance Program, Hazard Mitigation Grant Program, Fire Management Assistance Grant Program, and Public Assistance Grants (Categories C-G). In addition the approval of this plan allows the State of Minnesota to be eligible for the reduced cost share (90/10) for grants awarded under the Flood Mitigation Assistance Program. All requests for funding however, will be evaluated individually according to the specific eligibility and other requirements of the particular program under which the application is submitted.

If you have any questions regarding this planning process, please contact Mary Beth Caruso, Mitigation Division Director, at 312-408-5455 or marybeth.caruso@fema.dhs.gov.

Sincerely,

James K. Joseph
Regional Administrator

MINNESOTA DEPARTMENT OF PUBLIC SAFETY

Homeland Security and Emergency Management

445 Minnesota Street • Suite 223 • Saint Paul, Minnesota 55101-6223
Phone: 651-201-7400 • Fax: 651-296-0459 • TTY: 651-282-6555
http://hsem.dps.mn.gov

Alcohol and Gambling Enforcement

Bureau of Criminal Apprehension

Driver and Vehicle Services

Emergency Communication Networks

Homeland Security and Emergency Management

Minnesota State Patrol

Office of Communications

Office of Justice Programs

Office of Pipeline Safety

Office of Traffic Safety

State Fire Marshal

15 March 2019

MEMORANDUM FOR RECORD

SUBJECT: Adoption of State Hazard Mitigation Plan

Minnesota adopts the 2019 State of Minnesota All-Hazard Mitigation Plan Update, Including Recommended Actions for Climate Change Adaptation.

The purpose of this Plan is to identify the State's major hazards, assess the vulnerability, and to reduce risk using the technical and program resources to implement mitigation projects. The Plan identifies goals and recommended actions and initiatives for state government agencies to reduce and/or prevent injury and damage from hazardous events. The intent of the Plan is to provide unified guidance for ensuring coordination of recovery-related hazard mitigation efforts following a major emergency/disaster, and to implement an on-going comprehensive state hazard mitigation strategy intended to reduce the impact of loss of life and property due to effects of natural hazards. This Plan update includes an integration of climate change considerations, risk analysis of state owned critical facilities, and an updated flood hazard analysis.

The State Hazard Mitigation Team will continue to coordinate with state agencies (Natural Resources, Transportation, Health, Commerce, Labor and Industry, Administration) and other partners, including the Interagency Climate Adaptation Team to implement mitigation measures. The Recovery Mitigation Branch in coordination with other branches in HSEM will continue to cross train and work together in preparation, response, recovery and long term recovery to integrate mitigation strategies and actions. Through continued collaboration, providing technical resources through state agency staff expertise and support, and training and education, the State of Minnesota will continue to increase its resiliency to the effects of natural hazards.

Joe Kelly
State Emergency Management Director

CONTENTS

FIGURES

TABLES

Section 1: Introduction

1.1 Introduction

The authority for this document is the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended by Public Law 106-390, October 30, 2000, and the Disaster Mitigation Act of 2000. This All-Hazard Mitigation Plan (hereinafter referred to as the plan) conforms to the 44 Code of Federal Regulations (CFR) Parts 201 and 206: Mitigation Planning and the Hazard Mitigation Grant Program Requirements. The state will continue to comply with all applicable federal statutes and regulations during the periods for which it receives grant funding, in compliance with 44 CFR 13.11(c), and will amend its plan whenever necessary to reflect changes in state or federal laws and statutes as required in 44 CFR 13.11(d).

The State of Minnesota is vulnerable to a variety of potential hazards. These hazards, both natural and human-caused, threaten loss of life and property. Events such as riverine and flash flooding, wildfires, blizzards, tornados and straight-line winds, extreme temperatures (both heat and cold), bluff erosion, coastal erosion, hailstorms, earthquakes, ice and severe storms, drought, and many human-caused incidents have the potential for inflicting devastating economic loss and personal hardship. Natural disasters cost the state and its taxpayer's money, both directly and indirectly. Many severe weather events in the state do not warrant federal disaster designation, which often result in the state, local governments, businesses and citizens bearing the costs of recovery. Risk and vulnerability to natural and human-caused hazards may continue to increase as Minnesota's population grows and the climate changes.

The Minnesota Department of Public Safety, Division of Homeland Security and Emergency Management (HSEM) is responsible for ensuring the state has a FEMA approved All-Hazard Mitigation Plan to address the many hazards that impact the state. State All-Hazard Mitigation Plans are required to be updated every five years, and Minnesota's last plan was approved March 18, 2014. The 2019 update of the state plan was funded through a planning grant from the 2016 Pre-Disaster Mitigation (PDM) program. HSEM contracted with the University of Minnesota Duluth Geospatial Analysis Center (GAC) to update the state profile, natural hazard risk assessment, vulnerability assessments and other sections of the plan, including mapping. HSEM and the GAC have worked together on previous updates of the state plan. In addition, the GAC updates many of the state's county multi-jurisdictional hazard mitigation plans.

HSEM led the planning process, coordinating the review of mitigation goals, strategies and actions, as well as updating the state's capability assessment. To gather additional input and review, HSEM and the GAC convened a climate change workgroup, utilized the federal/state interagency group (the Silver Jackets), and met with the state Interagency Climate Adaptation Team (ICAT).

The plan's guiding principles include fostering cooperative relationships, following the planning process, focusing on reducing risks and improving mitigation capabilities. State hazard mitigation planning aims to foster partnerships for natural hazard mitigation, promoting more resilient and sustainable states and communities and reducing the costs associated with disaster response and recovery.

FEMA is committed to promoting resilience as expressed in Presidential Policy Directive 8 (PPD-8): *National Preparedness*; the President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience; the Administrator's 2011 *FEMA Climate Change Adaptation Policy Statement* (Administrator Policy 2011-OPPA-01); and the *2014–2018 FEMA Strategic Plan*. FEMA recognizes challenges posed by climate change, including more intense storms, frequent heavy precipitation, heat waves, drought, extreme flooding, and higher sea levels. These phenomena may have impacts on mitigation, preparedness, response and recovery operations as well as the resiliency of critical infrastructure and various emergency assets. FEMA encourages recipients and sub-recipients of hazard mitigation grants to consider climate change adaptation and resiliency in their planning efforts. Minnesota is including a focus on climate adaptation and resiliency in this plan, as well as in local hazard mitigation plants and other related plans and efforts.

The fact that mitigation represents a sound financial investment is backed up. According to the updated Natural Hazard Mitigation Saves: 2017 Interim Report that examined two sets of mitigation strategies and found that society saves $6 for every $1 spent through mitigation grants funded through select federal agencies and a corresponding benefit-cost ratio (BCR) of 4:1 for investments to exceed select provisions of the 2015 model building codes.

Given the rising frequency of disaster events and the increasing cost of disaster recovery across the nation, mitigation actions are crucial for saving money, property, and, most importantly, lives. Activities designed to reduce disaster losses also may spur job growth and other forms of economic development.

Just implementing these two sets of mitigation strategies would prevent 600 deaths, 1 million nonfatal injuries, and 4,000 cases of post-traumatic stress disorder (PTSD) in the long term. In addition, designing new buildings to exceed the 2015 International Building Code (IBC) and International Residential Code (IRC), the model building codes developed by the International Code Council (also known as the I-Codes) would result in 87,000 new, long-term jobs, and an approximate 1% increase in utilization of domestically produced construction material. Natural Hazard Mitigation Saves: 2017 Interim Report.

Historical data records show that climate change is increasing the severity, extent and impact of some hazards. The Minnesota Department of Natural Resources (DNR) State Climatology Office, housed at the University of Minnesota, has provided expertise and guidance about the scientific confidence that recently observed and projected future changes to common weather hazards are attributable to climate change, beyond Minnesota's typical and historical climate variations. Hazard mitigation planning is a proven and effective means by which to reduce losses by identifying ways to lessen or avoid the impact of disasters upon people and property. Although mitigation efforts cannot completely eliminate impacts of disastrous events, the state shall endeavor to reduce the impacts of hazardous events to the greatest extent possible. The engagement of the state Interagency Climate Adaptation Team (ICAT) in the planning process to update this plan has resulted in the addition of climate change adaptation recommendations. Incorporation of these recommendations will help the state to be more resilient and adapt to climate change through mitigation and cooperation with state agencies.

This plan represents the efforts of the State of Minnesota in fulfilling the responsibility for hazard mitigation planning. The purpose of this plan is to identify the state's major hazards, assess the vulnerability to those hazards, and take steps to reduce vulnerability using the technical and program resources of Minnesota agencies. The process has included consideration of current and expected future impacts from Minnesota's already changing climate, as relevant to hazard mitigation planning. The plan identifies goals and recommends actions and initiatives for the state government to adapt to, reduce, and/or prevent injury and damage from hazardous events. The intent of the plan is to provide unified guidance for ensuring coordination of recovery-related hazard mitigation efforts following a major emergency/disaster, and to implement an ongoing comprehensive state hazard mitigation strategy intended to reduce the impact of loss of life and property due to disasters. In addition to post-disaster hazard mitigation, pre-disaster mitigation and climate change adaptation can reduce the impacts to Minnesotans' lives and property.

1.1.1 Scope

The State of Minnesota aims to focus on natural hazards, and on projects that make the state and its people and property more resilient to the effects of natural hazards. The plan evaluates and ranks the major natural and human-caused hazards affecting the State of Minnesota as determined by frequency of event, economic impact, deaths and injuries. The plan assesses hazard risk, reviews current state and local hazard mitigation and climate adaptation capabilities, develops mitigation and climate adaptation strategies and identifies state agency and other interagency working groups' actions to address mitigation and climate adaptation needs. The plan does not attempt to develop local plans or projects. Recommendations are based on input from federal, state and local agencies and national best practices. The plan identifies existing resources that may be used as a tool to assist communities to succeed in their mitigation and climate adaptation efforts. This is accomplished by establishing statewide mitigation recommendations, providing technical resources for mitigation and climate adaptation through federal, state and local agency staff expertise and support, providing financial assistance through various programs, offering training and education, and other agency initiatives.

1.1.2 Hazard Mitigation Definition

Hazard mitigation may be defined as any action taken to eliminate or reduce the future risk to human life and property from natural and human caused hazards. Potential types of hazard mitigation measures include the following:

- Structural hazard control or protection projects
- Retrofitting of at-risk facilities
- Acquisition and relocation of at-risk structures
- Development of mitigation standards, regulations, policies, and programs
- Public awareness and education programs
- Development or improvement of warning systems

1.1.3 Climate Change Adaptation Definition

Climate change adaptation may be defined as developing and implementing strategies, initiatives, and measures to help human and natural systems prepare for and address climate change impacts (hereafter referred to as climate adaptation).

1.1.4 Resilience Definition

Resilience may be defined as the ability of a system or community to survive disruption and to anticipate, adapt, and flourish with change.

1.1.5 Benefits

The benefits of hazard mitigation, climate adaptation, and resilience include the following:

- Saving lives, protecting the health of the public, and reducing injuries
- Preventing or reducing property damage
- Reducing economic losses
- Minimizing social dislocation and stress, especially for vulnerable populations
- Reducing agricultural losses and protecting soil health
- Maintaining critical facilities in functioning order
- Protecting infrastructure from damage
- Protecting mental health to increase individual resilience, especially for vulnerable populations
- Reducing legal liability of government and public officials
- Maintaining critical ecosystem services
- Reducing greenhouse gas emissions as a co-benefit of adaption and resilience actions
- Providing awareness and education for governments, businesses, non-governmental organizations (NGO's) and individuals to make better-informed decisions and take action to reduce risk and improve quality of life.

1.2 Authorities

Hazard mitigation planning for the state aligns with Minnesota HSEM's mission: Helping Minnesota prepare for, respond to, and recover from emergencies and disasters. Minnesota HSEM's vision is: A resilient Minnesota – prepared to respond and recover. For the 2019 plan update, the state's Interagency Climate Adaptation Team's (ICAT) reports, updates, recommendations, and proposed follow-up actions developed during stakeholder meetings are included to meet the goal of adapting to the changing climate, reducing risks and impacts, and increasing the resiliency of our communities.

1.2.1 Governor's Executive Order 15-13

Each department, independent division, bureau, board, commission and independent institution of the state government, hereinafter referred to as "agency" or "agencies," shall carry out the necessary planning for emergency preparedness, response, recovery, hazard mitigation, continuity of operations and service continuation responsibilities described in Minnesota Governor's Executive Order 15-13: *Assigning Emergency Responsibilities to State Agencies (July 13, 2015)*, the specific emergency assignments contained in the Minnesota Emergency Operations Plan, the State All-Hazard Mitigation Plan and such other duties as may be requested by the Division of Homeland Security and Emergency Management. The head of each agency shall be accountable for the execution of the responsibilities described in this Executive Order.

Section 2000 of the Executive Order directs that "The Division of Homeland Security and Emergency Management shall facilitate hazard mitigation efforts statewide by coordinating maintenance of the Minnesota All-Hazard Mitigation Plan and working with local jurisdictions to develop and update mitigation plans and projects."

1.2.2 Minnesota Statute, Chapter 12, Emergency Management

Minnesota State Statute, Chapter 12, Emergency Management directs that all emergency management functions of the state be coordinated to the maximum extent with the comparable functions of the federal government, including its various departments and agencies, of other states and localities, and of private agencies of every type, to the end that the most effective preparations and use may be made of the nation's labor supply, resources, and facilities for dealing with any disaster that may occur.

1.2.3 Hazard Mitigation Assistance Administrative Plan and Procedures

The State of Minnesota Hazard Mitigation Assistance Administrative Plan and Procedures is required by Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), Public Law 93-288 as amended, and the Disaster Mitigation Act of 2000, Public Law 106-390. These requirements direct the state to administer cost-sharing Hazard Mitigation Assistance (HMA) grant programs to be used to fund state and local hazard mitigation projects. Section 404 of the Stafford Act is closely tied to the post-disaster hazard mitigation plans defined and required in Section 409 of the Stafford Act and the Disaster Mitigation Act of 2000. Sections 322 and 404 of the Stafford Act, in combination with several other state and federal programs and activities, help to form an overall pre- and post-disaster hazard mitigation strategy for the State of Minnesota and affected local governments in the state. The purpose of the administrative plan is to describe the organization, staffing, and procedures the State of Minnesota will use when implementing the Section 404 Hazard Mitigation Grant Program in both the post- and pre-disaster mitigation environment. This manual is updated to reflect changes in policy, lessons learned administering the plan and procedures, post-disaster after action reports, and input from the Minnesota Recovers Task Force. This document is updated following each Presidential Disaster Declaration.

1.2.4 Hazard Mitigation Assistance Sub-grantee Handbook

As part of FEMA's Hazard Mitigation Assistance (HMA) grant programs, a sub-grantee handbook was developed that provides general HMA information and summarizes the specific sub-grantee responsibilities relative to the program. Under Section 404 of the Stafford Act, Federal Emergency Management Agency (FEMA) hazard mitigation monies are provided to the state. In Minnesota, these monies are awarded to the Minnesota Division of Homeland Security and Emergency Management (HSEM) which serves as the grantee. Potentially eligible sub-grantees (applicants) include: state and local governments, certain private non-profit organizations or institutions, and Indian tribes or authorized tribal organizations. HSEM ensures the policies outlined in the Sub-grantee Handbook are followed in the award of HMA grant funding for projects in the state. The Sub-grantee Handbook, along with the state's Hazard Mitigation Grant Program Administrative Plan, provide direction to sub-grantees regarding management of their grants.

1.3 Hazard Mitigation Programs

Under the FEMA HMA program there are three distinct hazard mitigation assistance programs available: the Hazard Mitigation Grant Program, the Pre-Disaster Mitigation grant program and the Flood Mitigation

Assistance grant program. Although all three programs have unique statutory authorities, program requirements and triggers for funding, all of the programs also have the common goal of providing funds to states and local communities to reduce the loss of life and property from future natural hazard events. Each of the three HMA grant programs provide funding opportunities for pre- and post-disaster mitigation. Brief descriptions of the HMA grant programs are listed below.

- **Hazard Mitigation Grant Program** (HMGP) HMGP assists in implementing long-term hazard mitigation measures following Presidential disaster declarations. Funding is available to implement projects in accordance with state, tribal, and local priorities.
- **Pre-Disaster Mitigation** (PDM) PDM provides funds on an annual basis for hazard mitigation planning and the implementation of mitigation projects prior to a disaster. The goal of the PDM program is to reduce overall risk to the population and structures, while at the same time reducing reliance on federal funding from actual disaster declarations.
- **Flood Mitigation Assistance** (FMA) FMA provides funds on an annual basis so that measures can be taken to reduce or eliminate risk of flood damage to buildings insured under the National Flood Insurance Program (NFIP).

1.4 Plan Organization

Each section in the plan has been revised and updated by state hazard mitigation staff and the Minnesota Silver Jackets. Changes to the previous plan include the incorporation of the Hazard Identification and Risk Assessment into one section, and the incorporation of climate change adaptation throughout the plan as well as specific climate change implications for each hazard. The population vulnerability and climate sections in the state profile have also been expanded.

The contents of this plan are outlined below:

- **Section One: Introduction:** Purpose, scope and a description of changes included in the plan update.
- **Section Two: The Planning Process:** Includes a description of how the plan was updated utilizing subject matter experts, the Interagency Climate Adaptation Team, and a federal collaborative risk management group, the Silver Jackets. Other trainings, outreach and educational opportunities HSEM mitigation staff utilized to promote mitigation, resilience, climate change and adaptation are further summarized in this section.
- **Section Three: State Profile:** Includes geographic, demographic, and economic characteristics; how mitigation relates to development; and economic trends as well as climate change adaptation. Population vulnerability is also discussed in general and additional mentions are found in individual hazard sections as applicable.
- **Section Four: Hazard Identification and Risk Assessment:** This section provides information on the nature of each hazard that the State of Minnesota is susceptible to, a history of the hazard in the state and the probability of its occurrence in the future. All maps in this document have been updated as of August 2018 with the most recent data available, unless otherwise noted. Climate change considerations are included for each hazard as well as the probability of future events. The natural hazards included in this plan are: flooding, wildfire, windstorms, tornadoes, hail, lightning, coastal erosion, winter storms, land subsidence, drought, extreme cold, extreme heat, earthquakes, dam/levee failure, erosion/landslides/mudslides, and ground and surface water supply. Coastal erosion and flooding has been pulled out as a separate section for the first time in

this plan. The human-caused hazards included in this plan are hazardous materials, infectious disease, terrorism, transportation incidents and nuclear power plant incidents.

- **Section Five: Goals, Objectives, Strategies and Actions**: This section was updated to include climate change adaptation into two broad goals and objectives. Strategy types from FEMA's *"Mitigation Ideas"* handbook have been utilized locally since 2016. The updated strategy types are: Local Planning and Regulations, Structure and Infrastructure Projects, Natural Systems Protection and Education and Awareness Programs. A fifth type, Mitigation Preparedness and Response Support for local emergency management professionals has been utilized since 2016, and a sixth strategy type has been included for this state plan update: Data for climate adaptation. The mitigation actions listed for each natural hazard are broad enough for any jurisdiction to utilize them in the development of local mitigation plans. An assessment of state and local mitigation capabilities, pre- and post-disaster funding programs and the severe and repetitive loss strategy requirement are addressed.

The *Inventory of Hazard Mitigation Programs, Policies, and Funding Resources* section provides information on resources available to assist with hazard mitigation planning and project implementation. Many organizations have capabilities that may assist local jurisdictions or the state to increase resiliency to hazards. A comprehensive list of federal and state agencies and other organizations that may assist in mitigation, resilience and climate adaptation projects is included. The 2017 ICAT Report contains state agency programs, policies and funding resources. In addition, the ICAT Report includes six recommendations that were developed for Climate Change Adaptation. The recommendations address resources such as habitat and the built environment and are summarized with links to the full report.

The *Mitigation Strategy* states the goals, objectives, actions, and projected funding sources to guide the mitigation program, including resilience and climate adaptation. The State Capability Assessment lists the programs and the funding sources in place that are used in statewide mitigation efforts and addresses where gaps exist. Additional information on climate adaptation and resilience are included.

- **Section Six: Coordination of Local Planning:** A description of how the state prioritizes local jurisdictional funding and technical assistance is explained. FEMA climate change adaptation and resilient project types are included in the state's updated priority. This section describes how local mitigation planning and projects are prioritized, coordinated and funded. Local funding and technical assistance is available from the local, state and federal levels. Local planning capabilities differ, but a lack of capability does not exclude a community from any of the grant programs.

Local plan integration portrays the importance of having a FEMA-approved and locally-adopted mitigation plan at the time of a disaster. Jurisdictions must address the hazard and mitigation project type in their plan to be eligible for FEMA pre- and post-disaster funding. The state supports and is actively working to integrate climate change and resilience into local planning efforts.

Table 1 summarizes the 2019 plan update.

Table 1. 2019 Plan Update Summary

Section	Update
Section 1	• Climate change adaptation and resilience. Scope of Plan has been updated to include adaptation actions.
Section 2	• Coordination with Interagency Climate (change) Adaptation Team. Planning process included subject matter experts, interagency reports and sectors that have not previously been include in plan (agriculture, vulnerable populations). • Coordination with Minnesota Department of Health Climate Change and Health program. Process to develop meaningful link between emergency management, climate change and public health resulted in six regional reports that included webinars and presentations. • Collaboration to integrate GIS communities and hazard mitigation data needs. • Participation in federal flood public policy and funding roundtables.
Section 3	• New data included for land cover and demographics (age and race added), and development trends. • Updated content for projected population change. • Populations' vulnerability section added with social vulnerability index (SVI) and other measures. • Economic characteristic section included addressing agriculture and tourism. • The climate change risks and vulnerabilities section was expanded to address the six NCA4 Key Messages for the Midwest: agriculture, invasive species, ecosystems, human health, infrastructure, and populations. • The importance of climate change adaptation is discussed for increasing the resilience of communities and the environment
Section 4	**Hazards addressed in the plan** • A new coastal erosion and flooding hazard section was added. • Each hazard now has vulnerability and climate change sections. • All hazards and maps are updated with most current data. • Vulnerability addresses populations, jurisdictions, state infrastructure and critical facilities as possible for each hazard. **Vulnerability of State Assets (Section 4.6)** • Statewide Essential Facilities and critical facilities were compiled from public databases. All locations were mapped and assessed with flooding analysis. • Current data for transportation and water and sewer infrastructure were discussed. • Several databases were consulted for state-owned and leased properties. MDA managed ARCHIBUS contains state-owned facilities and exposure, MDA managed occupancy databases contain more comprehensive exposure totals, but does not contain accurate locational information. Another MDA database reports on state-leased buildings. UMN and MNSCU systems maintain their own property databases. All available locational data were used in the flood risk analysis. **County- and city-owned structures** • County- and city-owned structure database continues to be updated at the city/county hazard mitigation plan level.
Section 5	**New mitigation actions and projects** • New strategy categories based on FEMA Mitigation Ideas Handbook, Emergency Management and data gaps and needs. • New climate change adaptation actions. Updated ICAT report and work towards resiliency goals information included. • New state and interagency programs. • Based on evaluation of hazards, new mitigation actions and projects have been included. Interagency workgroups continue to work to identify problems and resolutions based on the inter-agency nature of the work; Silver Jackets, ICAT, and GIS collaborations.
Section 6	**Problem identification and resolution** • Resource lists were updated and now include climate adaptation resources. • New success stories for hazard mitigation, resilience and climate change adaptation included.

Section 2: Planning Process

2.1 Plan Update Process

S1. Does the plan describe the planning process used to develop the plan? [44 CFR §§201.4(b) and (c)(1)]

HSEM serves as the lead agency for preparation of the State Hazard Mitigation Plan and serves as lead agency for monitoring, evaluating, and updating the plan. The State Hazard Mitigation Officer (SHMO) is responsible for coordinating plan updates and maintenance. Significant input into all phases of the plan are derived from the state agencies subject matter experts, the Silver Jackets and the ICAT. HSEM applied to FEMA's 2016 Pre-Disaster Mitigation grant for funds to update this Plan. The grant was awarded in January of 2017 and HSEM contract was executed in July of 2017 with UMD to update state profile, risk and vulnerability assessment for all natural hazards. Both UMD and the state coordinated to lead the subject matter review for natural hazards and climate change. The federal/state/local hazard risk management team the, Minnesota Silver Jackets have been the State Hazard Mitigation Team (SHMT) that continually meet to identify, assess and brainstorm interagency solutions to current and new natural hazards in the state. Each month the Silver Jackets meet is an effort towards increasing the resilience of the state through cross programmatic education and data sharing. Special topical information sharing from subject matter experts is a monthly occurrence. The implementation of interagency (previously referred to as pilot) projects and ongoing application for new interagency projects has resulted in studies, workshops and a more risk aware Minnesota. The tracking of Silver Jackets efforts is done monthly and all activities are listed below.

Based on the 2014 schedule of maintenance, evaluation and update, this Plan did require HSEM to reassess its goals and objectives. The SHMO coordinated the revision and review for the Silver Jackets, ICAT and state agency representatives to add and review proposed changes. Climate change adaptation, vulnerable populations, and impacts to agriculture and natural resources were included in this revision to address current, changing and expected conditions. The evaluation criteria for this revision resulted in the inclusion of a separate coastal erosion and flooding hazard, and a unique goal, strategy and action section for dams and levee failure.

No new changes in federal or state laws required revisions, so no consultation for advice on how to conform to new legislation was needed. The SHMO attended multiple roundtables with Congressional representatives and state Representative's staff, State NFIP Coordinator, MNAFPM Legislative Liaison and others to discuss Pew Charitable Trust Federal Flood Policy; Federal Flood Risk Management Standards, Flood-Prepared Communities, Disclosure Policy for new homebuyers/renters, and State Revolving loan fund for Flood Mitigation.

An assessment of resource availability for implementing the plan would indicate that all state agencies are meeting their programs goals, and that interagency work continues to improve the overall efficacy of hazard mitigation. There were no opportunities for largescale cooperation from the Minnesota Recovers Task Force, as no disaster event rose to the level of a special state legislative session. No specific implementation problems occurred on the state hazard mitigation side other than shortage of qualified personnel to handle the workload. There are currently only two state staff assigned to handle all the hazard mitigation assistance grants for the state of Minnesota. Some implementation issues did occur during the federal government shutdown, however the positive working relationship between state and FEMA staff ensure continued successful outcomes, even if some work may have been delayed. Section six indicated the process utilized during each presidential disaster. Each disaster is an opportunity for state hazard mitigation staff and FEMA staff to improve, streamline and increase knowledge through training and experience. Outcomes from the 2014 plan goals meet with expectations. Continued improvement is a path hazard mitigation and other state staff will persevere. The assessment of agencies participate as originally proposed?

One major challenge was the timeline for the process of incorporating climate adaptation into the state plan. The SHMO was a member of the ICAT and the team was made aware at each meeting of the status of the State Plan. Data in the 2014 state plan was used to inform the ICAT reports, and data from the ICAT reports was to be included in the updated 2019 Plan. Only towards the end of the 2019 State plan update process was the integration of the actions to be included. This document is not an integrated hazard mitigation and climate adaptation plan. Climate change was included in the 2014 Plan and is updated with the most recent scientific data and projections. Climate adaptation recommended actions from the ICAT workgroup teams is included in this state plan as a way to reach a larger audience and promote the work of state agency experts and stakeholder input. The future of integrating climate adaptation actions is currently unknown as the state has a new Governor and new state agency heads.

Continued review of implementation issues, stakeholder participation, and capability assessment will assist Minnesota in keeping its mitigation planning on track and ensure measures and capacity are in-line with needs. Reviews of the hazards, risk assessment and associated mitigation actions and projects will also keep Minnesota’s efforts on track. Addressing the above items in a regular and consistent manner will allow for enhanced adaptability to new federal and state guidance and plan adoption.

For the next update, the process will be further refined and simplified to allow for a more efficient process for the collection and update of hazard specific information, local data integration, and agency-specific capabilities and mitigation measures including climate change adaptation and resilience.

Each section of the plan was reviewed and revised by state hazard mitigation staff and multiple state and federal agency staff. Membership on the Silver Jackets team includes staff from federal and state agencies. An opportunity for the public, businesses and other organizations to review and comment will be provided during the posting of the plan on the MN HSEM website. Additionally, the State of Minnesota Interagency Climate Adaptation Team reviewed sections and incorporated climate adaptation into this updated plan.

The state will submit the plan to the FEMA Region V office for review and approval before a formal adoption process is pursued. Once approved, the plan will be adopted by the Governor. The option exists for state agency heads or groups to adopt as a measure of support. Once the plan has been approved, an official notice announcing the approval will be posted in the State Register and on the HSEM website.

Activities pertinent to the collaborations, results, outreach activities and plan review and update are included in the following agency coordination section.

2.2 Agency Coordination

S2. Does the plan describe how the state coordinated with other agencies and stakeholders? [44 CFR §§201.4(b) and (c)(1)]

Mitigation plans, policies and programs are directed by federal legislation (CFR 44 Emergency Management and Assistance), and Executive Orders (19988 and 19900). The state takes its role very seriously regarding emergency management. HSEM and other state agencies that participate in preparedness, recovery, response and mitigation abide by the following policies and executive orders. The Governor's Executive Order 15-13 assigns Emergency Responsibilities to state agencies and Recovery/Hazard Mitigation requirements. This policy indicates the importance of coordination with federal agencies, other state agencies and locals in emergency management.

The following interagency groups exemplify how planning goals can be achieved and how mitigation planning and project implementation can be integrated into existing efforts. Hazard mitigation staff have developed and continue to strengthen relationships with state and federal agency partners. Links with the emergency management sector are strong.

FEMA requires coordination with agencies and stakeholders responsible for: Emergency Management, Economic Development, Land Use Development, Housing, Health and Social Services, Infrastructure and Natural and Cultural Resources. The Plan has sufficient coordination with all sectors of emergency management, from federal to local representatives, though tribal representation is lacking. Collaboration with the Silver Jackets and ICAT aim to include personnel from other sectors.

Milestones for the state and the state plan include:

- **July 21, 2014:** Minnesota Presidential Declaration for Severe Storms, Straight-line Winds, Flooding, Landslides, and Mudslides (DR-4182). Incident Period: June 11, 2014 - July 11, 2014.
- **November 2, 2016:** Presidential Disaster Declaration for Minnesota Severe Storms and Flooding (DR-4290). Incident Period: September 21, 2016 - September 24, 2016.
- **September 29, 2017:** State Plan update meeting kick-off meeting. Discussed roles, timeline and potential subcommittees.
- **September 29, 2017:** State Plan Climate Change meeting. Discussed integrating climate change into state plan update. Staff from UMD, HSEM, DNR climatology and MPCA attended.
- **June 3, 2018:** Governor Dayton signs "MN is Still In" Proclamation in response to White House withdrawal from Paris Climate Agreement.
- **June 26, 2018:** FEMA/HSEM State Consultation meeting. Annual meeting to discuss Risk MAP process, mapping and data needs. Strategized local and state planning update and new programmatic tools.
- **August 31, 2018:** Participated in Lake Superior North Watershed Coastal Erosion Hazard Map project meeting. Presented on hazard mitigation opportunities for integrating risk, vulnerability assessments and strategies into state plan and for FEMA project implementation.
- **September 5, 2018:** Presidential Disaster Declaration for Severe Storms, Tornadoes, Straight-line Winds, and Flooding (DR-4390). Incident Period: June 15, 2018 - July 12, 2018.

- **October 23, 2018:** HSEM, UMD, FEMA and ICAT representatives discussed how to integrate climate adaptation into the state plan.
- **January 18, 2019:** Submitted draft State Hazard Mitigation Plan to FEMA.
- **March 8, 2019:** Submit final State Hazard Mitigation Plan to FEMA
- After approval, send to Governor for adoption.

See Silver Jackets, MDH and ICAT timeline for additional planning process activities.

The Minnesota Silver Jackets

The Minnesota Silver Jackets are a natural hazards risk management team. This group is the leading committee to review the plan and provide input. Membership on the Silver Jackets includes members of federal and state agencies. The name Silver Jackets comes from the different colored jackets which various agencies wear when responding to disasters, such as, USACE personnel wear red and FEMA personnel wear blue. The "Silver" Jackets represents a unified interagency team. While Silver Jackets typically provide information on flooding, the Minnesota group is all-hazard oriented. The Silver Jackets hold monthly meeting to share information. Silver Jackets aka State Hazard Mitigation Plan Review team are required to review and provide subject matter input.

The Minnesota Silver Jackets team (Table 2) conducts monthly meetings to discuss agency updates, interagency projects, current disaster declarations and response efforts, and other pertinent topics. Most meetings include educational special presentations by subject matter experts regarding topics that directly relate to team activities or impact those activities in some way. Many of the topics will be included in the next update of the Minnesota all-hazard mitigation plan for FEMA. Presenters have been team members and other professional affiliates of the team. Topics have included wildfire briefing and impacts on flood risk management, NOAA Atlas 14, Minnesota drainage and culvert calculation updates based on Atlas 14, recent increase of catastrophic slope failures, climate adaptation, climate change in Minnesota and the region and implications for emergency preparedness, mitigation, and health risks. The presentations are usually related to recent disasters, publication of benchmark reference reports, or conference proceedings. This activity allows the agency representatives on the team to have direct access to leading edge technology and the experts who created it. It improves awareness across agency boundaries, promotes innovation that leads to improving processes, and additional interagency project ideas. From the March 2014 approval of the plan, the Silver Jackets met monthly to share federal/state and local emergency management and other disciplines information.

Table 2. Silver Jackets Membership

Agency	Name	Title
FEMA - Region V	Christine Meissner	Planner
FEMA - Region V	John Devine	NFIP Coordinator
FEMA - Region V	Nicolas Bruscato	Emergency Management Specialist
FEMA - Region V	Valeria Nieves	Hazard Mitigation Officer
Hennepin Co.	Eric Waage	Director, Emergency Management

Agency	Name	Title
Metropolitan Council	Eric Wojchik	Senior Planner
Metropolitan Council	Lisa Barajas	Director of Community Development
MN Department of Natural Resources	Ceil Strauss	NFIP State Coordinator
MN Department of Natural Resources	Pat Lynch	Flood Hazard Mitigation (FHM) Grants Administrator
MN Department of Natural Resources	Jason Boyle	Dam Safety Engineer
MN Department of Natural Resources	Suzanne Jiwani	RiskMAP - Hydrologist
MN Department of Natural Resources	Mary Presnail	Hydrologist
MN Board of Water and Soil Resources	Al Kean	Chief Engineer Manager
MN Department of Commerce	Doug Renier	Office of Energy Security
MN Department of Transportation	Petra DeWall	Waterway Engineer (Retired)
MN HSEM	Wayne Lamoreaux	Public Assistance Engineer
MN HSEM	Jim McClosky	Hazard Mitigation Planner
MN HSEM	Jennifer Nelson	State Hazard Mitigation Officer
MN HSEM	John Moore	Recovery Branch Director
MN HSEM	Angela Brown	Disaster Recovery Coordinator
MN Pollution Control Agency	Jim Chiles	Agency Rules
National Weather Service	John Wetenkamp	La Crosse Office
National Weather Service	David Lawrence	La Crosse Office
National Weather Service	Craig Schmidt	River Forecast Center- Chan/Twin Cities
Natural Resources Conservation Services	Amanda Deans	State Hydraulic Engineer
Natural Resources Conservation Services	Lea Holter	Ag Engineer
St. Paul, City of	Lucy Angelis	Acting Emergency Management Director
United States Army Corps of Engineers	Mary Weidel	Detroit District
United States Army Corps of Engineers	Terry Zien	Silver Jackets Coordinator
United States Geological Services	Julia Prokopec	Hydrologist
United States Geological Services	James Fallon	Data Chief

- **May 23, 2014:** Silver Jackets pilot project publication released Development of Flood-Inundation Maps for the Mississippi River in Saint Paul, Minnesota. U.S. Geological Survey Scientific Investigations Report 2014–5079.
- **January 13, 2015:** Silver Jackets pilot project publication released: An Assessment of Two Methods for Identifying Undocumented Levees Using Remotely Sensed Data U.S. Geological Survey Scientific Investigations Report 2015–5009.
- **January 21, 2015:** Flash Flood Vulnerability and Adaptation Assessment Pilot Project Presentation to Silver Jackets by Phillip Schaffner, MnDOT.
- **March 24, 2015:** $1 Billion for HUD - National Disaster Resilience Competition application for Duluth. Presentation by Jodi Slick of Ecolibrium3 to Silver Jackets.

- **May 19, 2015:** Climate Adaptation in MN State Government: Interagency Climate Adaptation Team, presentation by Paul Moss, MPCA to Silver Jackets. Collaboration between Minnesota Pollution Control Agency ICAT and the Silver Jackets began at this meeting and continues.
- **July 16, 2015:** Climate and Health in Minnesota presentation by Kristin Raab, MDH to Silver Jackets. Coordination with MDH Climate and Health started here and continues.
- **September 2015:** Silver Jackets produce Interagency Project: Blue Earth Bluff Erosion Final Report.
- **October 2015:** Minnesota Silver Jackets became a NOAA Weather-Ready Nation Ambassador
- **October 7, 2015:** Stream Gage Radio Frequencies presentation by James Fallon, USGS to Silver Jackets.
- **December 2, 2015:** SHMO panelist on Interagency Flood Risk Management Workshop Silver Jackets–Federal Perspectives Panel. SHMO discussion focused on state perspective.
- **March 21, 2016:** SHMO presentation on FEMA Climate Resilient Mitigation Activities (CRMA) to Silver Jackets. State and local agencies that participate on the team are eligible for FEMA grants. Local units of government that all agencies work with may also be eligible.
- **May 18, 2016:** Kenny Blumenfeld, Ph. D., DNR/State Climatology Office presents Climate Change in MN to Silver Jackets
- **Spring 2016:** Silver Jackets Charter updated.
- **September 27-30, 2016:** Silver Jackets led Red River Valley of the North Flood Emergency Action Plan Workshops (Two in ND two in MN)
- **November 29, 2016:** Silver Jackets pilot project completed; placement of soil moisture and temperature instrument packages throughout the Red River basin.
- **January 20, 2017:** Silver Jackets Pilot/interagency project Lake of the Woods Wind-Wave Modeling Report released.
- **February 14-16, 2017:** Silver Jackets led Minnesota River Valley Flood Emergency Action Plan Workshops (3).
- **June 1, 2017:** Interagency Climate Adaptation Team Update presentation by Paul Moss to Silver Jackets.
- **August 24, 2017:** Carrie Jennings MNDNR/Freshwater Society presented "The Cost of Landslides in Minnesota" to Silver Jackets. Funded by *Legislative-Citizen Commission on Minnesota Resources* (LCCMR) statewide Landslide Inventory. The 2014 plan included erosion and landslide as a separate and new hazard due to the increased occurrence of landslides in the state. The scientific study of this phenomenon has led to many reports. This hazard continues to be studied as many residents and infrastructure are at risk.
- **December 7, 2017:** Brenda Hoppe, MDH presents Draft Climate Change data Profiles for HSEM Regions to Silver Jackets. As part of the integration of emergency management, climate change and health, the draft reports were presented to the Silver Jackets members for input and recommendations from their sectors.
- **February 28 – March 3, 2017:** Participated in USACE Silver Jackets Interagency Flood Risk Management Workshop. Objectives of the workshop were to unify the interagency flood risk management team, share repeatable and achievable interagency successes in flood risk

management and enhance interagency capacity to deliver integrated and adaptive approaches to flood risk management.

- **January 9, 2018:** Silver Jackets Pilot/interagency project Red River of the North Gage Datum Conversion Phase 1 Report released.
- **April 26, 2018:** Silver Jackets meeting: St. Paul High water Mark Public Outreach Campaign discussion with City of St. Paul Public Works, Science Museum of Minnesota and National Park Service.
- **May 1-4, 2018:** Participated in USACE Silver Jackets Interagency Flood Risk Management Community of Practice Training Seminars.
- **May 23, 2018:** Silver Jackets led Itasca County Flood Emergency Action Plan Workshop.
- **June 13, 2018:** Reviewed and provided comments on USACE St. Paul District Hazard Mitigation Plan.
- **September 20, 2018:** State of Minnesota Hazard Mitigation Plan Update – presentation by Jen Nelson, HSEM and Stacey Stark, UMD to Silver Jackets. Present progress to date, timetable for review and completion.
- **November 1, 2018:** Silver Jackets discussion regarding to USGS /DNR /NWS Stream Gages and existing FEMA/USGS/USACE/HSEM High Water Mark Memorandum of Understanding. Mobilizing data collection efforts immediately after water recedes is important in order to gather high water marks post flood event. Having an up-to-date MOU can speed up the data collection. Previous efforts by the Silver Jackets to document high water marks has resulted in scientific studies. A recent event (DR-4290-MN) high water mark collection did not occur due to many factors, including the event was as flash flood, not a riverine event. Future discussions will include documentation of flash floods and criteria to mobilize agencies.
- **January 10, 2019:** State of Minnesota Hazard Mitigation Plan Update – presentation by Jen Nelson, HSEM and Stacey Stark, UMD to Silver Jackets. Discussion regarding inclusion of new hazard based on recent events, both state and presidential disaster declarations in city of Duluth on Lake Superior coastal erosion and flooding. Recall Silver Jackets Lake of the Woods wave run-up study as source of information for hazard background. Discuss new strategy type (Data) as revision to previous plan mitigation strategy types had been previously presented to group. Request members input potential projects and resources into strategy section. Request subject matter review of draft sections of plan.
- **February 28, 2019:** State of Minnesota Hazard Mitigation Plan Update – presentation by Jen Nelson, HSEM and Stacey Stark, UMD to Silver Jackets. Discuss final draft plan. Review current and update plan monitoring and evaluation section.

Minnesota Interagency Climate Adaptation Team (ICAT)

The state agency collaborative effort began meeting in 2009 and has produced several reports. Its goal is to have state agencies work toward adapting to the changing climate, reducing risks and impacts, and increasing the resilience of our communities. Various HSEM staff have been members of the ICAT since its inception (Table 3. The SHMO and a Public Assistance Engineer provided data and input into the revised 2013 report, *Adapting to Climate Change in Minnesota* and have continued to participate. The updated document shares a summary of observed and projected climate impacts, outlines state agency activities and responses, and identifies opportunities for future action and interagency collaboration. Crossover between ICAT and Silver Jackets happened as each group has information to share to benefit others. Each interagency group updates the other on pertinent activities and opportunities. HSEM staff continue to work with this group to incorporate mitigation ideas and planning for a more disaster resilient future.

Table 3. Current ICAT Membership

Agency	Name	Title
MN Department of Administration	Larry Herke	Office of Enterprise Sustainability
MN Board of Water and Soil Resources	Dan Shaw	Senior Ecologist
MN Board of Water and Soil Resources	Marcey Westrick	Clean Water Coordinator
MN Department of Commerce	Doug Renier	Office of Energy Security
MN Department of Commerce	Bill Grant	Deputy Commissioner of Energy and Telecommunications
MN Department of Employment and Economic Development	Kari Howe	Business and Community Development
MN Department of Labor and Industry	Timothy Manz	Construction Code Representative
MN Department of Labor and Industry	Scott McLellan	Director, State Building Official
MN Department of Natural Resources	Pat Lynch	Flood Hazard Mitigation (FHM) Grants Administrator
MN Department of Natural Resources	Kenneth Blumenfeld	Senior Climatologist
MN Department of Natural Resources	Valerie McClannahan	Forestry Program Coordinator
MN Department of Natural Resources	Amanda Kueper	Forestry Planner
MN Department of Natural Resources	Ken Holman	Community Forestry Program Coordinator
MN Department of Natural Resources	Mark Lindquist	Buildings Maintenance and Sustainability Manager
MN Department of Corrections	Alice Remillard	State Program Administrator Principal
Environmental Quality Bureau	Katie Pratt	Director of Communications and Public Engagement
Environmental Quality Bureau	Kristin Mroz-Risse	Local Government Coordinator
Environmental Quality Bureau	Will Seuffert	Executive Director
MN Governor’s Office	Lorinda Getman	
MN Governor’s Office	Stephanie Zawistowski	Senior Policy Advisor
MN Homeland Security and Emergency Management	Wayne Lamoreaux	Public Assistance Engineer
MN Homeland Security and Emergency Management	Jennifer Nelson	State Hazard Mitigation Officer
Metropolitan Airport Council	Chad Leqve	Vice President Management and Operations
MN Department of Agriculture	Bob Patton	Energy and Environment
MN Department of Health	Kristin Raab	MN Climate & Health Program Director
MN Department of Health	David Bell	Environmental Research Scientist
Metropolitan Council	Karen Jensen	Environmental Analyst
Metropolitan Council	Eric Wojchik	Senior Planner
Metropolitan Council	Lisa Barajas	Director of Community Development

Agency	Name	Title
MN Housing Finance Authority	Katherine Teiken	Energy Efficiency Fellow
MN Housing Finance Authority	Margret Kaplan	Policy Director at Housing Justice Center
MN Department of Military affairs	Katherine Retka	Senior Planner
MN Department of Military affairs	Lori Ruff	Environmental sustainability program manager
Minnesota State (Colleges and Universities)	Emily Ziring	Sustainable Facilities Program Manager
Metropolitan Mosquito Control District	Nancy Read	Technical Services Coordinator
MN Department of Transportation	Philip Schaffner	Transportation Program Director
MN Department of Transportation	Timothy Sexton	Chief Sustainability Officer
MN Pollution Control Agency	David Thorton	Assistant Commissioner
MN Pollution Control Agency	Peter Ciborowski	Environmental Research Scientist
MN Pollution Control Agency	Brian Timerson	Community and Business Sustainability
MN Pollution Control Agency	David Benke	Director Resource Management & Assistance
MN Pollution Control Agency	Roberta Getman	Pollution Control Specialist
MN Pollution Control Agency	Rick Patraw	Pollution Control Program Administrator
MN Pollution Control Agency	Stephanie Zawistowski	Environmental Consultant
MN Pollution Control Agency	Laura Millberg	MPCA Climate Adaptation Coordinator

Additional activities from ICAT include presentations and reports to the Environmental Quality Bureau. A separate but related endeavor, the Minnesota Climate Adaptation Conference (MCAP) is based in the University of Minnesota Extension College of Food, Agricultural and Natural Resource Sciences Water Resources Center. The MCAP is a relatively new initiative to bring together climate adaptation professionals. The SHMO attended the following conferences and is often on the conference committee in an effort to ensure the emergency management sector is included, promote hazard mitigation and continue to learn ways to apply adaptation. Looking forward, the SHMO is on the 2019/2020 conference committee and will be attending the National Adaptation Forum in 2019.

ICAT has made presentations to the Environmental Quality Board (EQB). The EQB consists of the Commissioners of the following 10 Minnesota state agencies: Agriculture, Health, BWSR, DEED, MPCA, Commerce, MnDOT, DNR, Metropolitan Council, and Administration as well as 5 citizen members. Presenting to the EQB is a valuable vehicle for communicating with key executive branch agency leaders. Bullets below point out some applicable adaptation areas of focus, not all topics covered at meetings are included.

- **November 6, 2014:** Attended MN Climate Adaptation Conference (MCAP): Building Minnesota's Capacity for Climate Adaptation.
- **March 24, 2015:** ICAT Quarterly Meeting: Presentation and discussion: 2015 MDH Minnesota Climate and Health Profile Report, and 2014 Minnesota Climate Change Vulnerability Assessment.

Presentation from DNR 2014 Operational Order on "Climate Adaptation and Mitigation in Natural Resource Management". Directs all staff to consider climate change in DNR planning, operations, communications, and staff training, and to enhance ecosystems' abilities to respond and adapt to climate change.

- **June 2, 2015:** ICAT quarterly meeting. Discussion on developing metrics to measure climate adaptation in Minnesota. Identify membership for measures of adaptation in Minnesota subcommittees, includes HSEM staff.
- **August 20, 2015:** ICAT quarterly meeting. Discuss path to formal connection with EQB.
- **September 8, 2015:** Special ICAT Results Based Accountability workshop for developing indicators to measure statewide climate adaptation progress. Work from vision of "ICAT's vision is of a resilient, economically thriving, and healthy Minnesota that is prepared for both short- and long-term climate changes and weather extremes."
- **September 14, 2015:** Presentation to Minnesota Environmental Quality Board (EQB) on contents of Goal 4: Ensuring Resilience to Extreme Rainfall. EQB Water Policy Report.
- **January 20, 2016:** ICAT provided updated information from each of the member agencies on developments in climate adaptation (and needs and gaps) since November 2013. HSEM presented data on Increased Frequency and Intensity of Severe Weather.
- **January 28, 2016:** Climate Adaptation Conference (MCAP): Transforming Awareness into Action. SHMO on conference committee and panel presentation **"**Building Connections between Emergency Management and Climate Adaptation".
- **February 27, 2016:** Governor's Water Summit. SHMO attend summit and co-lead "Resilience to Extreme Events" workshop break-out sessions.
- **December 21, 2016:** SHMO presentation to EQB on "Inflation Adjusted Damages from Extreme Weather" part of ICAT Presentation on Statewide Climate Adaptation Indicators
- **May 9-11, 2017:** National Adaptation Forum / Minnesota Climate Adaptation Partnership (MCAP) Joint Conference Saint Paul, MN. Panelist "Building Climate Resilience along 2,500 miles of Mississippi River Corridor".
- **May 2017:** The revised *Adapting to Climate Change in Minnesota* report was completed in May 2017 for distribution at the National Adaptation Forum. This report includes discussions of MPCA climate adaptation indicators as well as high priority recommendations for action that were developed and accepted by ICAT by consensus. After the report was completed, ICAT divided into six working groups to advance the recommendations. These working groups have become the focus of ICAT efforts. ICAT working groups continue to develop priorities for advancing recommendations in the 2017 ICAT report.
- **June 14, 2017:** Attended and presented at Minnesota Environmental Quality Board meeting in Waseca, MN regarding flood disaster and mitigation strategies. DR-4290 resulted in PA and IA declaration for Waseca County.
- **November 8, 2017:** ICAT Workgroup for Recommendation #1: Building Resilience to Extreme Precipitation. This effort focused on identifying priority risks from current and projected extreme precipitation and developing recommendations/action steps to increase Minnesota's resiliency to these impacts. The workgroup continued throughout 2018 to:

- *Identify priority risks from current and projected extreme precipitation that threatens state and local infrastructure, environmental quality, health, ecosystems, public safety, and economic development.*
- *Develop state agency action plans including specific steps to increase resiliency to these impacts and implement priority projects to address key vulnerabilities, and as appropriate, integrate flood and flash flood resilience into existing plans and planning mechanisms.*

Key agencies for implementation: Minnesota Board of Water and Soil Resources, Minnesota Pollution Control Agency, Minnesota Division of Homeland Security and Emergency Management, Minnesota Department of Natural Resources, Minnesota Department of Agriculture, Minnesota Department of Transportation, Minnesota Department of Employment and Economic Development, Minnesota Environmental Quality Board, Metropolitan Council, Minnesota Department of Military Affairs. The group was led by Dan Shaw, BWSR and Paul Moss, MPCA.

The group utilized data and goals/strategies/actions section for hazards related to extreme precipitation: flash and riverine flooding, lake and wetland flooding, winter storms, hail, dam/levee failure and erosion from the 2014 state plan as a template. The workgroup revised and reworked the actions for additional stakeholder input.

- **May 14, 2018:** Stakeholder Resilience Workshop. A half-day workshop focused on discussing and prioritizing a range of resiliency actions that can be implemented in Minnesota. Key stakeholders (50) provided input and feedback on draft resiliency actions. Participants were divided into five discussion groups/five categories of resiliency actions (State Policy, Local Planning & Regulations, Structure & Infrastructure Projects, Natural Systems Protection, and Education & Awareness Programs). SHMO co-facilitated Structures and Infrastructure Projects resiliency actions. This process resulted in the climate adaptation goals/strategies/actions that are now included in this plan. Participants (13) in the structures and infrastructure projects category were from MnDOT, USACE, DNR, MNAFPM, MHFA, cities of Edina and Minneapolis and flood engineering consultants. Additional information on workgroup process and participants is included in the final White Paper.
- **November 19, 2018:** Special ICAT Meeting – Combining Climate Adaptation Actions w/ State Hazard Mitigation Plan. Present proposal to integrate adaptation into State Hazard Mitigation Plan strategy sections. Each ICAT meeting SHMO had updated group on status of state plan. The workgroup #1 strategies and activities were to be included in plan and it made sense to include all of ICATs work into the plan to elevate the progress the group had made, and to include adaptation into state hazard mitigation strategies. Some workgroup activities were easily integrated whereas others were not as easy to integrate. Different groups had different processes and outcomes for their goals. Discussion of the title was a concern, as this is **not** the state of Minnesota Climate Adaptation Plan. It is what is says, the state of Minnesota Hazard Mitigation Plan with ***recommended actions for climate adaptation***. Inclusion of ICAT was primarily from workgroup #1, with inputs from other workgroups (#3 Habitat and #5 Built Environment) #4 Agriculture also provided strategies. Resources from all workgroups is included in section 6.
- **December 18, 2018:** ICAT Meeting – Update to ICAT on including Climate Adaptation Actions w/ State Hazard Mitigation Plan. Plan draft sent to group and reviewed. Presentation on FEMA Funding Available to State Agencies.

- **February 2019:** MPCA fielded the 2019 Climate Adaptation Planning Survey again to update the indicator and present the new data at the 2019 National Adaptation Forum. This is an update to the 2016 survey to assess progress by Minnesota's governmental entities in planning and preparing for the impacts of our changing climate.

Minnesota Department of Health: Climate and Health Program

Emergency management addresses manmade disasters and natural hazards events, such as flooding, wildfires, and extreme heat, which are predicted to occur more often and worsen with climate change. In 2015 and 2016, the Minnesota Department of Health (MDH) performed a literature review to identify climate change adaptation strategies that could be used by local emergency managers in Minnesota to address climate change impacts through all hazard mitigation planning.

The literature review found that strategies used to prevent property damage and loss of life from natural hazard mitigation efforts are similar to adaptation strategies identified throughout the climate change literature. The primary difference is hazard planning focuses on historical conditions, response, and short-term planning, while climate change adaptation focuses on future conditions, mitigation, and long-term planning.

In 2017, emergency management and public health professionals (referred to as EMP) met with MDH's Minnesota Climate & Health Program staff to discuss the literature review and explore ways to incorporate climate change strategies into emergency management. The working group found that many, but not all of the identified existing emergency management mitigation strategies are also recommended climate change adaptation strategies. In theory, professionals in this field may already be implementing some climate change adaptation best practices; however, the working group found that a lack of knowledge and understanding of climate projection data and how to use it for planning purposes was a major obstacle. To overcome this obstacle, the Minnesota Climate & Health Program, partnering with EMP and state climatologists, drafted climate data profiles for the state's six Homeland Security and Emergency Management (HSEM) regions.

Each regional profile includes a description of climate change trends along with a summary of climate and population projection data. Climate projection data came from publically available data sources administered by the National Oceanic and Atmospheric Administration and the United States Geological Survey.

Additionally, each regional profile provides a local case study to illustrate the links between extreme weather and natural disasters. Recent climate-related disasters were used as 'focusing events' and included drought, wildfire, heat waves, flooding, and winter storms. For each event, associated weather drivers were characterized and compared to similar estimates for the future based on best available climate projection data. EMP project advisors suggested that without context, future temperature and precipitation estimates lack meaning and fail to articulate potential impact and urgency. They suggested using a recent disaster meaningful to each region as a case study for comparing past weather and future climate data, alongside details of cost and impacts from the disaster to emphasize scale of threat. Other content includes an interpretation of the climate data, general next steps, and resources.

A communications expert translated the information into a product that project advisors considered effective and easy to comprehend. The profiles provide a framework for discussing projected local risks related to climate change and support the development of climate adaptation strategies that protect community health and safety.

The profiles cover all of Minnesota and will be used in the State Hazard Mitigation Plan. Ideally, the information will also be used in regional and county-level planning documents.

The Minnesota Climate & Health Program rolled out the profiles for the first time via a webinar on August 22, 2018. The webinar was promoted to Minnesota counties, cities, and townships member organizations; Department of Public Safety emergency communication networks; MDH avenues (Climate & Health Govdelivery, Intranet, and Community Health Services weekly email for local public health); and Minnesota Greenstep Cities social media outlets. The webinar was scheduled for an hour (40 minutes presenting, 20 minutes of question and answer). The webinar had 109 attendees.

Dr. Brenda Hoppe, Senior Research Scientist with the MN Climate and Health Program, presented the webinar "Climate Data Profiles for Minnesota's Emergency Management & Preparedness Professionals: Tools for Better Resiliency Planning." The aim of this webinar was to provide EMP with comprehensive information on the regional climate data profiles that were developed for each of the six HSEM jurisdictions in Minnesota. The webinar included an explanation of climate projection data, the importance of these data for effective disaster resiliency planning, the role for EMP in advancing resiliency, and a step-by-step description of the profile contents. Special emphasis was placed on the use of a case study disaster incident, or "focusing event", in each profile to put climate projection estimates in a context meaningful to the EMP audience. Attendees were provided with suggestions on how the profiles could be used to inform disaster response planning.

MDH did a short term evaluation of the project using survey results of the nearly 100 webinar attendees. Data from the survey, recommendations and next steps from the MDH evaluation can help HSEM and others in the continued outreach to EMP on this topic.

- **January 14, 2018:** "Getting the Best Tools in Their Toolbox: Assisting Emergency Management with Confronting Climate Change Through Better Products." Dr. Kenny Blumenfeld, DNR and Dr. Brenda Hoppe, MDH presentation at 2018 HSEM Governor's Conference.
- **August 22, 2018:** Minnesota Climate & Health Program presents [Planning for Climate & Health Impacts: Emergency Management Considerations]() webinar and releases six HSEM regional profile reports: http://www.health.state.mn.us/divs/climatechange/data.html
- **February 13, 2019:** HSEM Governor's Conference. Presentation: Minnesota Climate Change Projection Profiles for Hazard Mitigation. Bonnie K. Hundrieser, Emergency Management Planning Consultant, Hundrieser Consulting, Dr. Brenda Hoppe, MDH and Stacey Stark, Director Geospatial Analysis Center, University of Minnesota Duluth.

Geospatial Advisory Council Emergency Preparedness Committee

The Minnesota Geospatial Information Office (MnGeo) and the Geospatial Advisory Council - Emergency Preparedness Committee have been engaged to help facilitate a workflow for local jurisdictions to update the critical infrastructure/facilities database for inclusion in a future, more comprehensive and accurate analysis.

The state has continually provided guidance and technical support to the local mitigation plans and has encouraged the sharing of information both between local planning projects and with the state. The state has brought this information directly to the local planning efforts via statewide workshops and planning forums. Contractors and local governments facilitating county, city and tribal hazard mitigation efforts are encouraged to mirror state mitigation strategies and utilize data developed for this plan in their projects including GIS maps, tables and text necessary to assess risks, statewide datasets of essential facilities, and county Hazus reports for flooding risk assessment.

Continued collaboration between state agency partners will continue after the plan is approved. This new collaboration with the Geospatial Advisory Council will assist local jurisdictions become more aware of their hazards and assist the state in the next update of this plan. Participation in state and national conferences provides HSEM an opportunity to promote emergency management and hazard mitigation. It is also an opportunity for state staff to gain insight to best practices for implementation at home.

Minnesota Association of Floodplain Managers

The Minnesota Association of Floodplain Managers (MnAFPM) was formed in 2002. The goal of the organization was to form a network of associates who could bring their ideas and experiences to a forum for people to share and learn from. The result of the association is a network of floodplain managers who can improve the effectiveness and efficiency of all aspects of floodplain management in the State of Minnesota. The board now conducts meetings periodically to discuss the status of the association and to discuss any upcoming floodplain management issues. HSEM staff have been members of the state floodplain manager association and often participate on the annual conference committee and the board. The SHMO is the co-chair for the annual state conference for 2018 and 2019, has filled roles on the board and is the 2019 board chair. Continued collaboration with the national association and national conference attendance will ensure state of Minnesota floodplain managers are aware of cutting edge developments in the field and able to provide information to local units of government at home. Opportunity exists to pursue national flood policy based on state interests through the national association.

Pew Charitable Trusts

The Pew Charitable Trusts are an independent, nonprofit, global research and public policy organization. They are non-partisan, non-governmental organization dedicated to serving the public. The focus of our interaction is the Flood-Prepared Communities and other NFIP and flood related projects. The SHMO attended multiple roundtables with Congressional representatives and state Representative’s staff, with the State NFIP Coordinator, MNAFPM Legislative Liaison and others to discuss Pew Charitable Trusts Federal Flood Policy; Federal Flood Risk Management Standards, Flood-Prepared Communities, Disclosure Policy for new homebuyers/renters, and State Revolving loan fund for Flood Mitigation. The round table meetings are an opportunity to educate elected officials and thank them for continued support of smart flood policy.

2.3 Monitoring, Evaluating, and Updating the Plan

S17. Is there a description of the method and schedule for keeping the plan current? [44 CFR §§201.4(c)(5)(i) and 201.4(d)]

Provisions for monitoring, evaluating, and updating the plan are located in the Code of Federal Regulations (44 CFR). The 44 CFR regulations require that the state "must review and revise its plan to reflect changes in development, progress in statewide mitigation efforts, and changes in priorities, and resubmit it for approval to the appropriate Regional Director every five years."

HSEM serves as the lead agency for preparation of the State Plan and serves as lead agency for monitoring, evaluating, and updating the plan. The State Hazard Mitigation Officer (SHMO) is responsible for coordinating plan updates and maintenance. This position is located within HSEM and also serves as the lead coordinator of the State Hazard Mitigation Team (SHMT). Significant input into all phases of the planning process is derived from the SHMT, state stakeholders, and the Silver Jackets Team.

The SHMT will be regularly involved in monitoring, evaluating, and updating of information and projects for inclusion in the future plan over the next five years.

Triggers for Plan updates include, but are not limited to:

- If a disaster requires HSEM to reassess its goals and objectives.
- If a reassessment indicates that some adjustments are needed on goals and objectives, the SHMT will coordinate that process.
- If changes in federal or state laws require revisions, the SHMT and appropriate State Stakeholder Agencies will be consulted for advice on how to conform to new legislation.

Table 4. Plan Monitoring, Evaluating and Updating Matrix

Monitoring, Evaluating, and Updating Activity	Responsibility	Schedule
Review and update the Hazard Analysis and Risk Assessment	HSEM, SHMT, Silver Jackets, Subject matter experts	**5-Years**
Provide updates, evaluate progress of mitigation and adaptation actions and projects	SHMT, Silver Jackets, ICAT	**Ongoing, Annual**
Identification of implementation issues	HSEM, SHMT, Silver Jackets, ICAT	**Annual**
State Capability Assessment Updates	SHMT, Silver Jackets	**Ongoing, 5-years**
Plan review, evaluate and provide input	SHMT, State Agencies, Silver Jackets,	**5-Years**
Plan Adoption by State of Minnesota	Governor	**5-Years**
Plan Approval by FEMA	FEMA	**5-Years**
Review and update the Hazard Analysis and Risk Assessment	HSEM, SHMT, Silver Jackets, Subject matter experts	**5-Years**

As part of the monitoring, evaluating and updating component, the update evaluation will use the following criteria:

- Do the goals and objectives still address current and expected conditions?
- What were the nature and the magnitude of problems encountered and changes that have occurred?

- Were the current resources appropriate for implementing the plan?
- What implementation problems occurred, as technical, political, legal, or coordination issues?
- Were the outcomes as expected?
- Did the agencies participate as originally proposed?

This process will require the SHMT to participate in updating all parts of the Plan. Approval of the updated Plan will be required by all State Agency Administrators and the Governor.

Multiple activities will be addressed differently for future monitoring, evaluating, and updating efforts for the state mitigation Plan. More frequent (quarterly) review of implementation issues, stakeholder participation, and the capability assessment will assist Minnesota in keeping its mitigation planning on track and ensure measures and capabilities are in-line with needs. Reviews of the hazards, Risk Assessment and associated mitigation and adaptation actions and projects will also keep Minnesota's efforts on track. Addressing the above items in a regular and consistent manner will allow for enhanced adaptability to new federal and state guidance and Plan adoption.

The Silver Jackets will meet annually in January of each year to track and record all natural hazard mitigation, adaptation and risk awareness education projects. Each participating agency will be requested to provide end of year summaries of mitigation, adaptation and resilience programs, projects, success stories and barriers to implementation. This yearly assessment will better enable the state plan five year review tracking. The SHMO is the state lead of the Silver Jackets and will collect this information. A MPCA member of Silver Jackets will track yearly ICAT efforts for collection in the yearly evaluation.

The next update process will be further refined and simplified to allow for a more efficient process for the collection and update of hazard specific information, local data integration, and agency specific capabilities and mitigation measures.

2.4 Monitoring Progress of Mitigation Activities

S18. Does the plan describe the systems for monitoring implementation and reviewing progress? [44 CFR §§201.4(c)(5)(ii) and 201.4(c)(5)(iii)]

The plan is a document that requires regular monitoring, review, and evaluation. Also, the Federal Hazard Mitigation Planning regulations require the plan to be updated and submitted for approval to the Regional Director of FEMA every five years. The plan will be reviewed post-disaster or as needed. Mitigation staff will initiate planning to update the plan at least 24 months before FEMA approval is required to integrate input from federal, state, local agencies and the public.

The Silver Jackets and the ICAT teams meet on a regular basis and will conduct a review of the plan as necessary. The SHMO will lead the Silver Jackets and update the ICAT to:

- Review the goals and action items to determine their relevance to changing situations in the state.
- Review the risk assessment as necessary to incorporate current information, including updated hazard profiles and any new data on vulnerable state facilities.
- Consider recommendations by the Silver Jackets members to increase hazard mitigation involvement by federal agency representatives, state agencies and local jurisdictions.

- Discuss changes in policies, priorities, programs and funding that alter the plan's goals and objectives, projects and timelines.

Specifically, the SHMO will continue to present funding opportunities for both disasters and non-disasters to all emergency management directors in the state, Silver Jackets and the ICAT. HSEM works directly with the DNR flood hazard mitigation staff in times of flood disasters to gage matching funds availability. Each meeting with the Silver Jackets, ICAT, MDH and other state agencies is an opportunity to promote the state plan, funding opportunities and coordination. Each disaster is an opportunity to review existing hazards and do additional research and gather more information for inclusion in next state plan.

The State of Minnesota will update its plan as necessary to reflect:

- **Hazards addressed in the plan** – All of the natural and human-caused hazards that have been identified as posing a threat to the state of Minnesota have been included in the plan. As situations change or new information becomes available 1) the hazards currently included in the plan will be updated and 2) new hazards identified as a threat will be added to the plan.
- **State-owned structures** – A state-owned and other critical facilities database is still a priority, though funding is lacking. This database inventories all state-owned structures and will be maintained, as necessary.
- **County- and city-owned structures** – Funding for geocoding county and city critical facilities will continue to be pursued.
- **New mitigation actions and projects** – Additional actions and projects may be identified during the plan evaluation.
- **Problem identification and resolution** – Recommendations developed to overcome problems (technical, political, legal and financial) may affect the mitigation strategy.

Review and update will involve all of the original participants in the planning process and others identified as important for the plan update. This process will occur, as needed, or at a minimum every five years. The plan will be resubmitted to FEMA for their review as required by the federal DMA 2000 planning guidelines.

The State Hazard Mitigation Officer (SHMO) has the overall authority and responsibility for maintenance of the plan. The updated plan will be submitted to FEMA for review. Once FEMA has determined the plan is "Approved - Pending Adoption," the updated plan must be submitted for approval by the Governor.

Disasters provide an opportunity to evaluate the effects of the disaster, to improve resistance to the hazard, review the accuracy of hazard-specific sections and to determine if the planning efforts affected damage reduction. In the case of a disaster declaration in the state, the plan can be updated if HSEM believes this necessary.

Plan Distribution

The plan, and any changes to it, will be available in an electronic format on the HSEM website. Revised portions of the plan will be annotated with the date of the revision. Digital and/or hard copies of the plan will be distributed to state and federal agencies as requested.

2.5 Acknowledgements

The State Hazard Mitigation Team would like to acknowledge and thank those individuals, agencies, and organizations that provided guidance, input and support in the development of the 2019 State Hazard

Mitigation Plan update (Table 5). The intent of the plan is to provide unified guidance for ensuring coordination of both pre- and post-disaster focused hazard mitigation and adaptation efforts. To implement an ongoing, comprehensive State Hazard Mitigation and Adaptation Strategy, the Silver Jackets and the Interagency Climate Adaptation Team are the primary forces behind the review and coordination of the plan update. Subject matter experts were consulted on specific natural hazards and other information needed to comprehensively update the plan. Staff from Board of Soil and Water resources provided grant information and success stories, in addition to many goals/strategies/actions for flooding and other hazards. DNR Climatology Office staff reviewed all natural hazard sections (Section 4.7) and the State Profile (Section 3) and provided content throughout the plan about Climate Change that is consistent with their office messaging. DNR Water and Ecological Resources staff provided up-to-date information on flood mapping, NFIP participation and state flood hazard mitigation grants and success stories. DNR Dam Safety and USACE provided current dam information for the dam hazard profile and goals/strategies/actions. DNR Forestry provided information on wildfire hazards. MDH provided helpful resources and review of the population vulnerability content throughout. The Minnesota Housing Finance Agency offered guidance on the Development Trends (Section 3.5). The Department of Agriculture added new information regarding impacts to that sector not previously included, including new strategies and actions gleaned from the ICAT process for adaptation. The state climatology office has been working with HSEM, ICAT and MDH on many ongoing projects. Their updates to all natural hazards, specifically drought and flooding are comprehensive. The Coastal Erosion Hazard Mapping workgroup, whose activities spawned from the BWSR One Watershed, One Plan initiative, as well as resources from the Great Lakes Coastal Flood Study (FEMA, 2018) greatly contributed to the content and currency of the coastal erosion and flooding section.

Table 5. Subject Matter Experts

Agency	Name	Title
MN Board of Water and Soil Resources	Al Kean	Chief Engineer Manager
MN Board of Water and Soil Resources	Nicole Clapp	Grants Coordinator
MN Board of Water and Soil Resources	Melissa Lewis	Land and Water Program and Policy Supervisor
MN DNR (Ecological and Water Resources)	Ceil Strauss	National Flood Insurance Program (NFIP) State Coordinator
MN DNR (Ecological and Water Resources)	Pat Lynch	Flood Hazard Mitigation (FHM) Grants Administrator
MN DNR (Dam Safety)	Jason Boyle	Dam Safety Engineer
MN DNR (Ecological and Water Resources)	Suzanne Jiwani	RiskMAP - Hydrologist
MN DNR (State Climatology Office)	Kenneth Blumenfeld	Senior Climatologist
MN DNR (Ecological and Water Resources)	Mary Presnail	Hydrologist
MN DNR (State Climatology Office)	Luigi Romolo	State Climatologist - Drought
MN DNR (Lake Superior Coastal Program)	Clinton Little	Coastal Program Specialist
MN DNR (Forestry)	Amanda Kueper	Applied Science Coordinator
MN Department of Agriculture	Bob Patton	Energy and Environment

Agency	Name	Title
MN Department of Health (Climate & Health)	Kristin Raab	Program Director
MN Department of Health (Climate & Health)	Brenda Hoppe	Senior Research Scientist
MN DNR (Forestry)	William Glesener	Predictive Services Coordinator
MN DNR (Forestry)	Brian Schwingle	Tree & Insect Disease Specialist
MN Department of Transportation	Philip Schaffner	Program Director
MPCA (Climate Adaptation)	Laura Millberg	MPCA Climate Adaptation Coordinator
United States Army Corps of Engineers	Terry Zien	Silver Jackets Coordinator

We thank those with a passion for mitigation and adaptation for making Minnesota more resilient to future events.

Section 3: State Profile

3.1 Geographic Characteristics

Minnesota is located in the north central United States (Figure 1). Near the geographic center of North America, it is bordered on the north by the Canadian provinces of Manitoba and Ontario, on the west by North Dakota and South Dakota, on the south by Iowa, and on the east by Wisconsin and Lake Superior. Minnesota entered the Union on May 11, 1858, as the 32nd state.

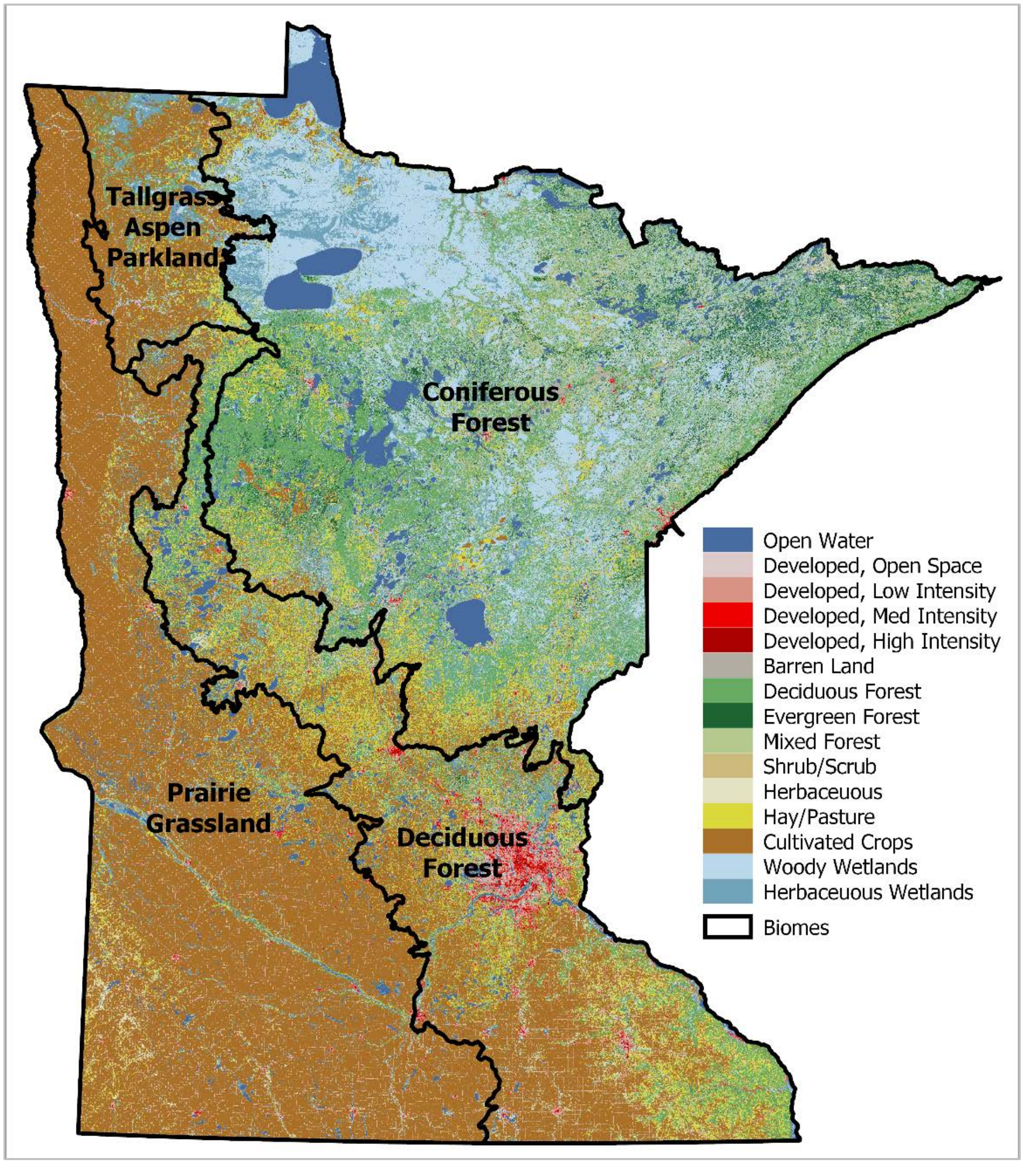
Figure 1. Minnesota Location Map

Minnesota covers 86,943 square miles, of which 4,780 square miles are inland waters and 2,546 square miles consist of a portion of Lake Superior under the state's jurisdiction. Of the 50 states, Minnesota ranks 12th in total land area. From north to south the state measures 406 miles, and from east to west it measures 358 miles at its maximum extent and about 180 miles at its narrowest point.

The mean elevation is approximately 1,200 feet. Three areas in the state reach higher than 1,600 feet: the Iron Range (paralleling the north shore of Lake Superior), the Coteau Des Prairies (also known as Buffalo Ridge), and a small area in the Lake Itasca region. The highest point in the state is Eagle Mountain in the extreme northeast, at 2,031 feet. The lowest elevation is 602 feet along the shores of Lake Superior.

The natural environment of the state is broken into four ecological regions. A small region in the far northwest and north central part of the state is in the tallgrass aspen parkland biome. The coniferous forest in Minnesota is found in the northeastern half of the state and extends diagonally into the deciduous forest and then prairie grassland in the western and southwestern part of the state. Most of these forests were cleared and converted to farmland during Minnesota's first 50 years of statehood. The state once had 18 million acres of prairie that stretched across the southern portion of the state and northward along the western border. Like the deciduous forest, the vast majority of the prairie grassland biome has been converted to agricultural land (Figure 2).

Figure 2. Land Cover and Ecological Regions in Minnesota



SOURCE: MN DNR, NOAA

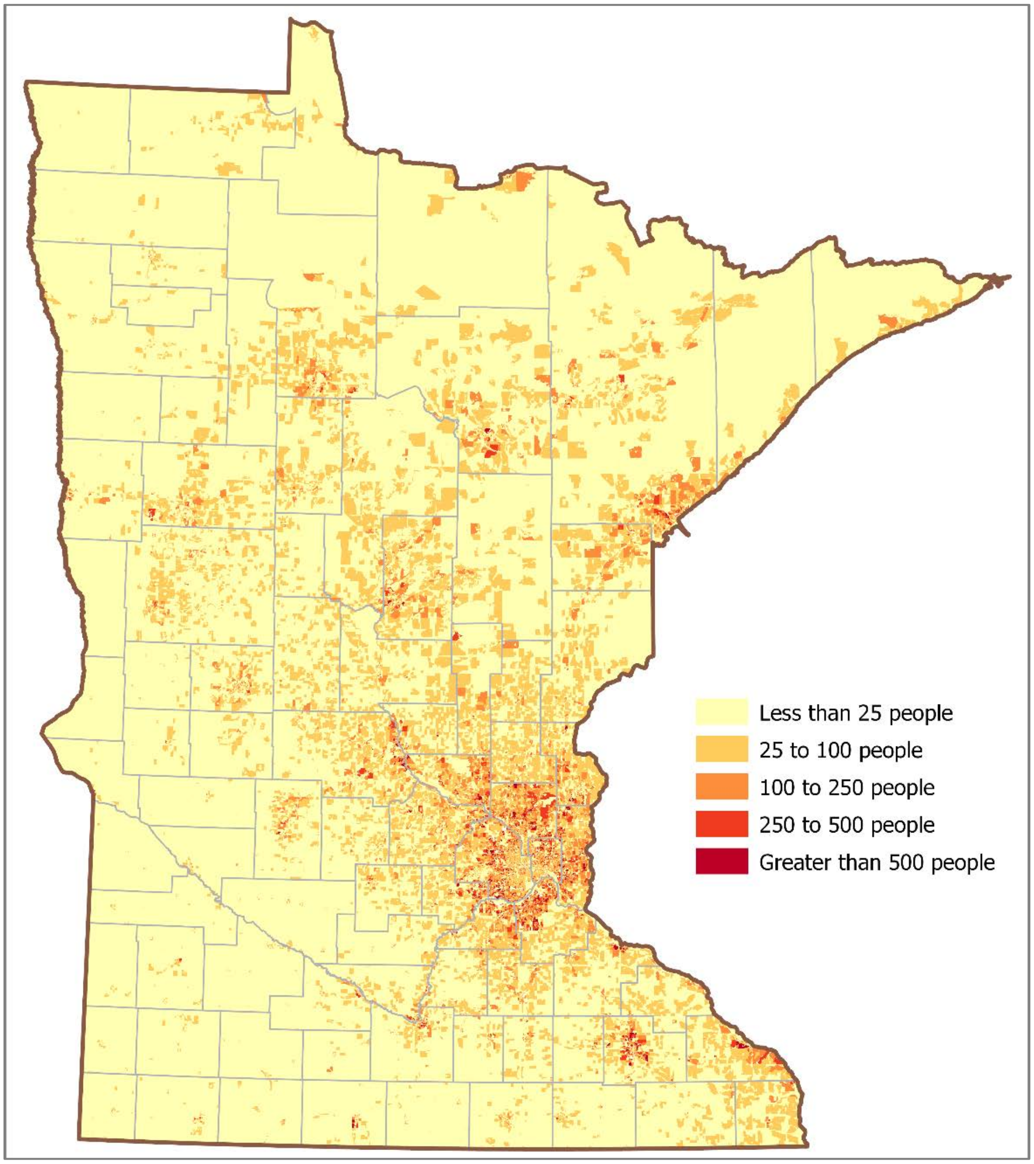
3.2 Demographic Characteristics

Minnesota is home to 5.6 million residents, 55% of which live in the Twin Cities 7-county region. Through 2030, 36 counties in the state are expected to see population declines of at least 2%. Strong population growth is expected to be in the Twin Cities, with Carver, Hennepin, Ramsey, Scott, and Washington Counties expecting growth values of at least 10% through 2030 (Minnesota Compass, 2018).

According to the 2010 U.S. Census Bureau data, Minnesota's total population on April 1, 2010 was 5,303,925. The Minnesota State Demographic Center estimates the state's population in 2016 was

5,528,630. This is a 4.2% increase from 2010 to 2016. Population by census block based on 2010 U.S. Census is illustrated in Figure 3.

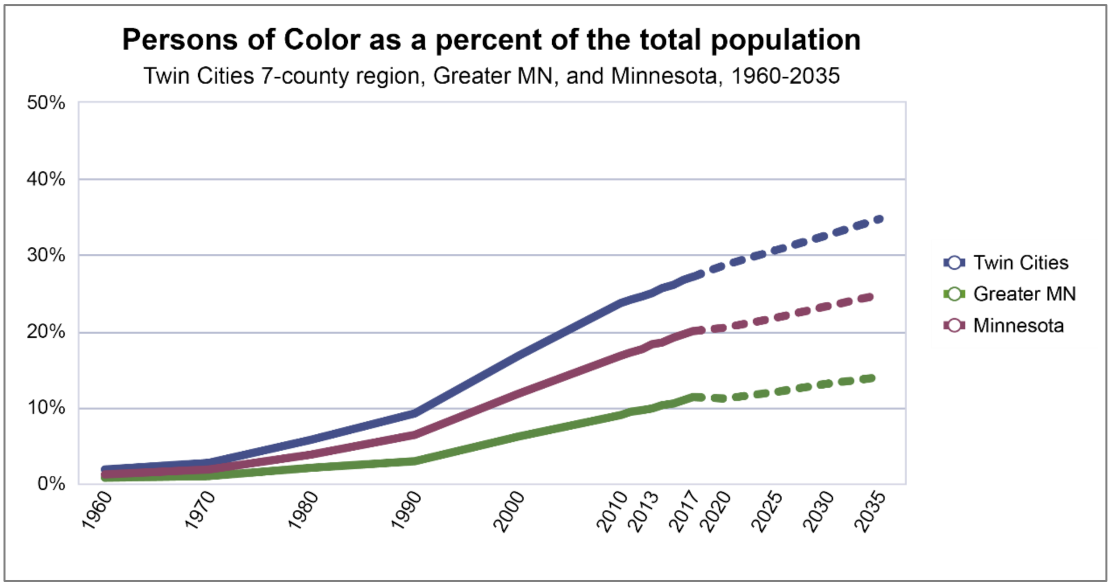
Figure 3. Population by Census Block, 2010



SOURCE: US CENSUS BUREAU

In the last 50 years, Minnesota's population has become much more diverse. In 2017, residents of color composed 20% of the state's population (Minnesota Compass, 2018). 75% of this population was living in the seven-county metro area and the non-white population will continue to grow faster in the Twin Cities compared to the rest of Minnesota (Figure 4). The "Population of Color" or "Non-White" includes people who are American Indian, Asian, Black, Two or more races, and people who are Hispanic of any race.

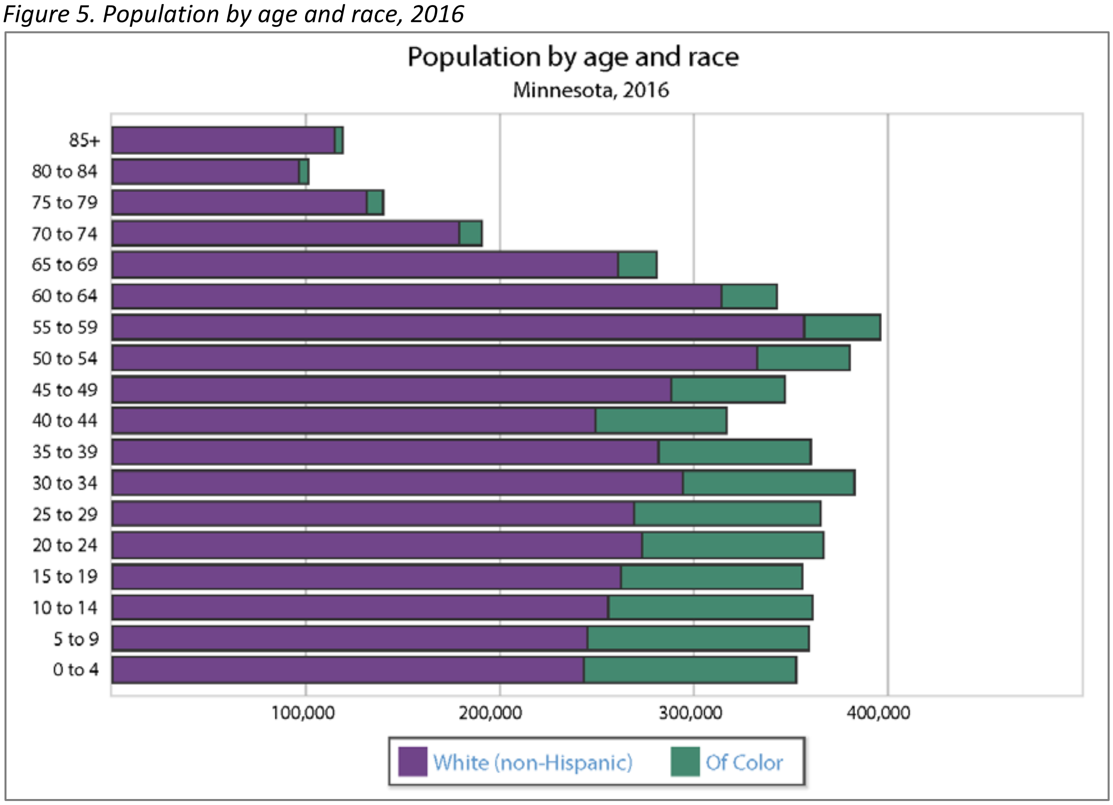
Figure 4. Population of Color as a percent of the total population



SOURCE: US CENSUS BUREAU, MN STATE DEMOGRAPHIC CENTER, MNCOMPASS.ORG

Age trends are also transforming the Minnesota population. The number of Minnesotans age 65 years and older is projected to increase to about a fifth of the state population by 2030. Figure 5 shows Minnesota's population by age group and race according to 2016 estimates (Minnesota Compass, 2018).

Figure 5. Population by age and race, 2016



SOURCE: US CENSUS BUREAU, MN STATE DEMOGRAPHIC CENTER, MNCOMPASS.ORG

Since the 2010 Census, Minnesota has grown by 224,705 people, ranking 23rd among states in the percent of growth. Minnesota remains one of the fastest-growing states in the Midwest (MN State Demographic Center, 2018).

Population growth is occurring throughout the Twin Cities Metro Area. Population projections indicate that the strongest areas of growth will remain the outer ring suburbs within the seven-county metropolitan area surrounding the Twin Cities of Minneapolis and St. Paul. Strong increases are also projected for the Rochester and St. Cloud areas (Figure 6). By 2025, 65% of Minnesota's population will live in one of these three metropolitan areas, including their suburban and exurban areas. Counties located in western and southwestern Minnesota are projected to lose population in the coming decades. These projections indicate that 35 of the state's 87 counties will experience population increases. A majority of the counties with projected population declines are spread throughout the southwestern region of the state, with a few counties in the northeastern region and a few in the northwestern region.

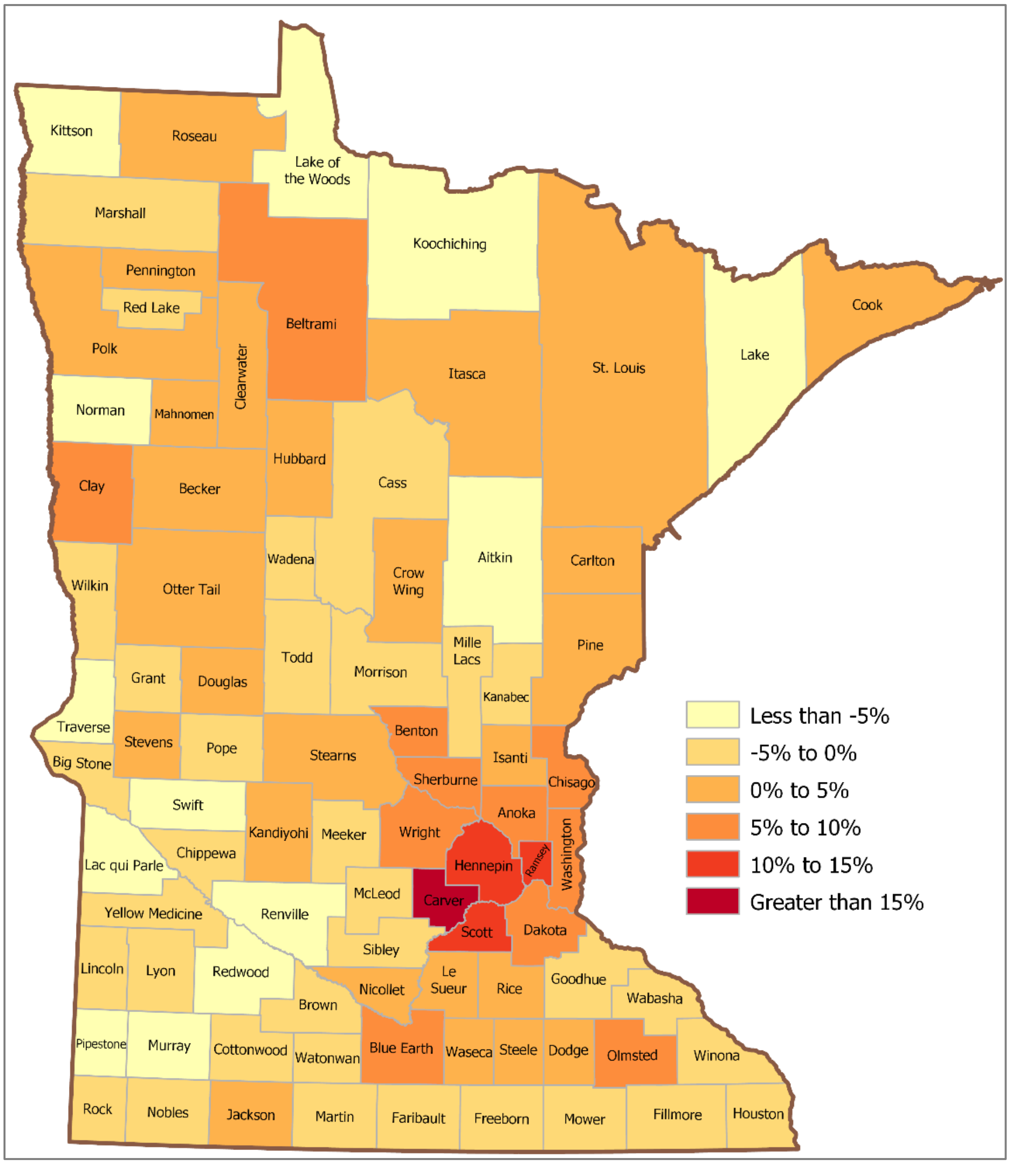
Minnesota's most rural counties have experienced population declines since the 1940s. The population of these counties peaked at 162,439 and declined 41% to a 2016 estimate of 94,916. Currently only 2% of Minnesota's population live in these counties. With increases of younger people migrating to urban areas and increases of older people to rural counties, the median age of most rural areas is increasing faster than in urban ones (Asche, 2018). Minnesota's changing climate with its increasing impact on the agricultural and tourism sectors may also start to affect population growth and decline in the state.

Minnesota ranks among the top five states in the country in several important factors, such as home ownership, labor force participation and high school completion. According to the U.S. Census, Minnesota's rankings include:

- 2nd in home ownership (74.5% owner-occupied)
- 4th in labor force participation (69.9% for ages 16 and over)
- 2nd in high school completion (92.6% for ages 25 and over)
- 5th lowest poverty rate (10.8% of all people)
- 11th highest per capita income ($33,225)

The Minnesota State Demographic Center has published a report on the economic outcomes for the state's 17 largest cultural groups, as well as descriptive social characteristics (birthplace, age, educational attainment, etc.) that may influence economic outcomes. In Minnesota, as is true across the nation, race is associated with the likelihood of living in poverty (MDA, 2018).

Figure 6. Projected Population Change, 2015-2025



SOURCE: MN STATE DEMOGRAPHIC CENTER

3.3 Population Vulnerability

The degree to which a person is vulnerable to the impacts of a hazard depends on how well he/she is able to react before, during and after a hazardous event. The Centers for Disease Control and Prevention: Agency for Toxic Substances & Disease Registry (ATSDR) defines social vulnerability as the resilience of communities when confronted by external stresses on human health, stresses such as natural or human-caused disasters, or disease outbreaks. These stressors now increasingly include the more extreme weather events and longer-term impacts of Minnesota's changing climate.

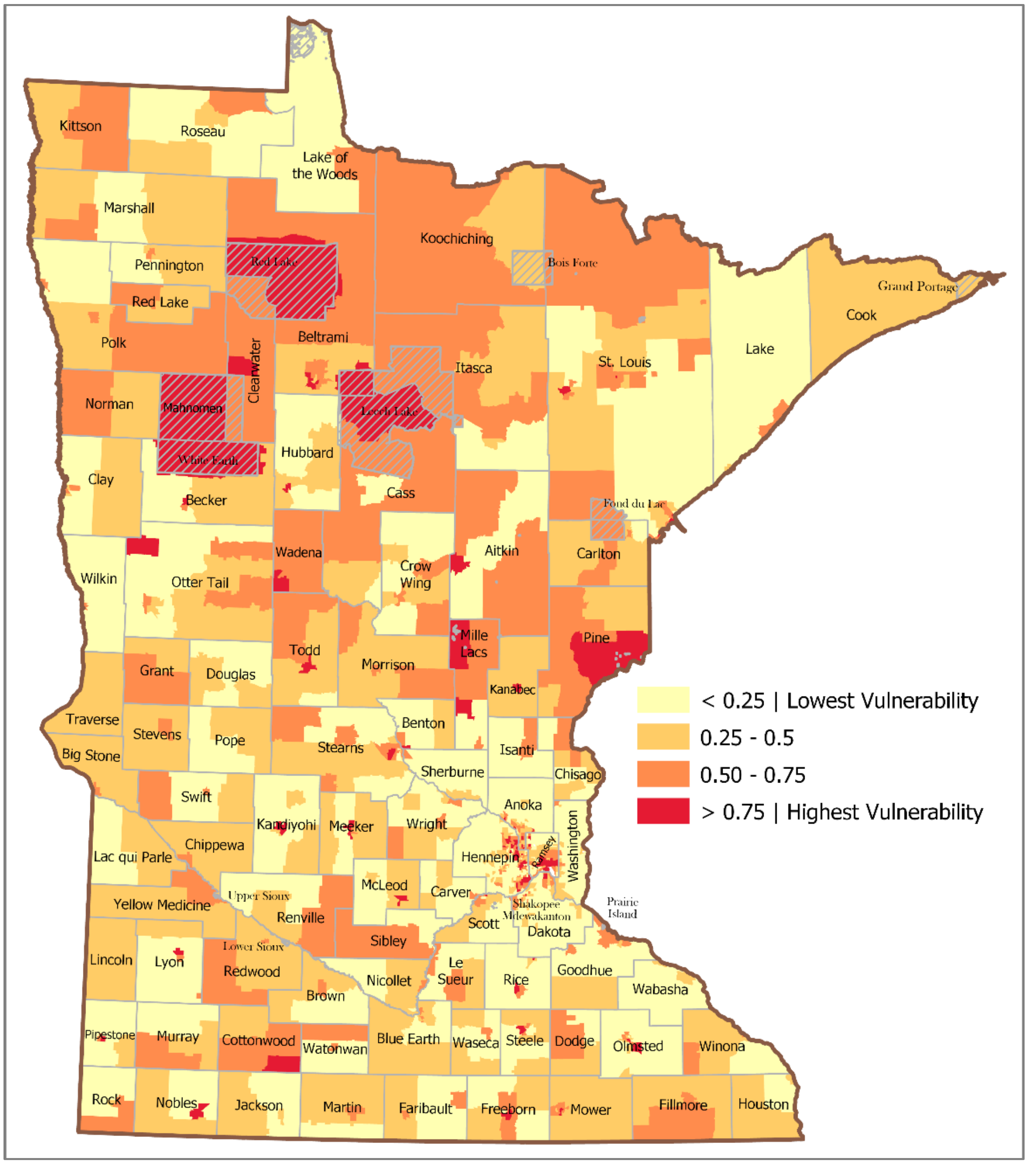
Reducing social vulnerability can decrease both human suffering and economic loss. ATSDR's Social Vulnerability Index (SVI) uses U.S. census variables at the tract level to help local officials identify communities that may need support in preparing for hazards or recovering from disaster. Certain social conditions, such as high poverty, low percentage of vehicle access, or crowded households can increase a community's social vulnerability (ATSDR, 2018).

The ATSDR SVI aggregates U.S. Census data to determine the social vulnerability of every census tract. The ATSDR SVI ranks each census tract on 15 social factors compiled in the census and groups them into four related themes:

• Socioeconomic:	Proportion individuals below poverty level Proportion civilian unemployed 16+yrs Per capita income in 1999 Proportion persons with no high school diploma 25+yrs
• Housing Composition and Disability:	Proportion persons 65 years or older Proportion persons 17 years or younger Proportion persons with disability 5+yrs Proportion single-parent HH with children under 18 yrs
• Minority Status and Language:	Proportion minority Proportion persons 5+yrs who speak English less than 'well'
• Housing and Transportation:	Proportion housing with 10+units Proportion mobile home Proportion HH with more people than rooms Proportion HH with no vehicle access Proportion of persons who are in institutional & non-institutional group quarters

Census tracts within Minnesota were ranked and given a percentile value from 0 to 1, with higher values indicating greater vulnerability. For more information and full SVI documentation, visit https://svi.cdc.gov/. Figure 7 below maps overall social vulnerability at the census tract level in 2016 based on the Social Vulnerability Index (Flanagan et al., 2011).

Figure 7. Social Vulnerability by Census Tract in Minnesota (2016)

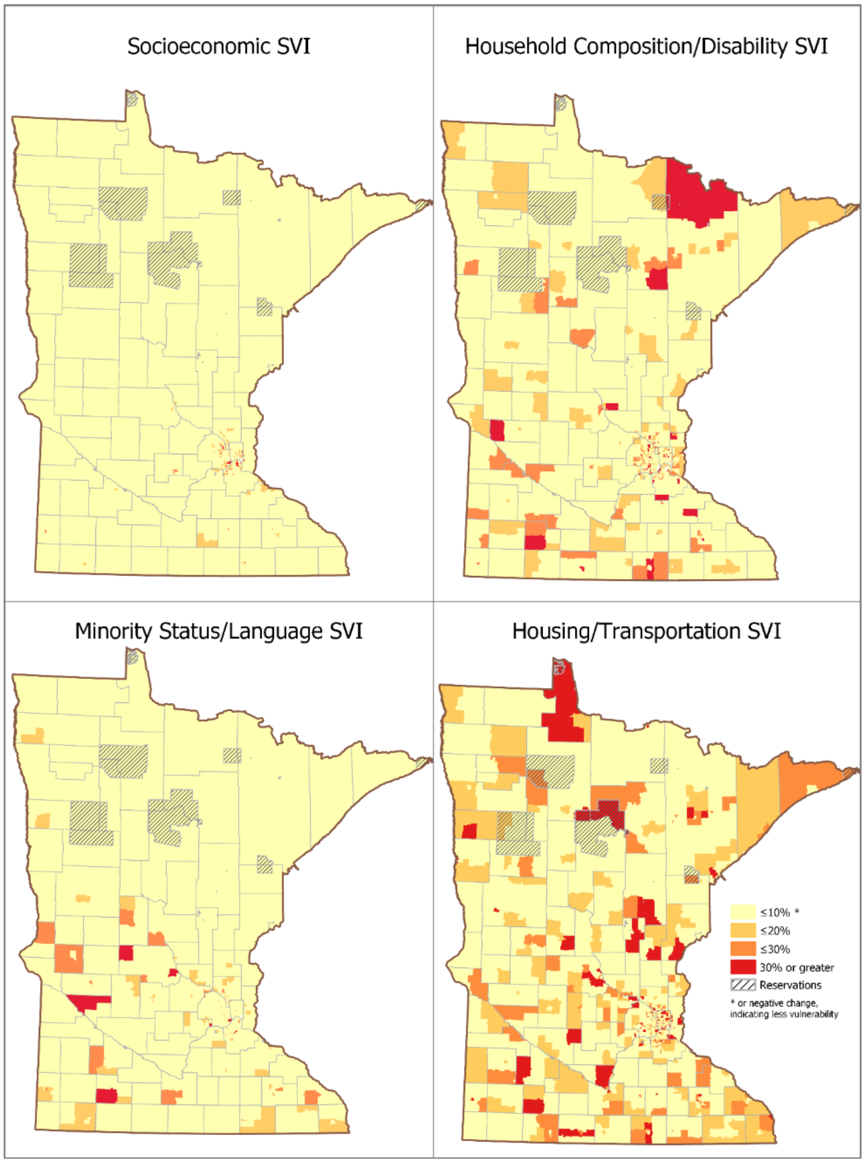


SOURCE: MN DNR, AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY, CDC

Population vulnerability is dynamic. As population demographics and economic and housing characteristics change, so will a population's vulnerability to hazards and climate changes.

Figure 8 below shows the ATSDR SVI percentile change for census tracts in Minnesota that have increased their vulnerability ranking within the state. The socioeconomic characteristics used to in the SVI have had little significant change within census blocks (or the population percentage in these groups has changed) except within the Twin Cities metro area. The percentage of the population changing in the minority status and language has increased significantly in agricultural counties such as Stearns, Chippewa, and Cottonwood, as well as some isolated census tracts in the metro area. Household composition/disability factors as well as transportation factors in populations have trended in the "more vulnerable" direction across the state.

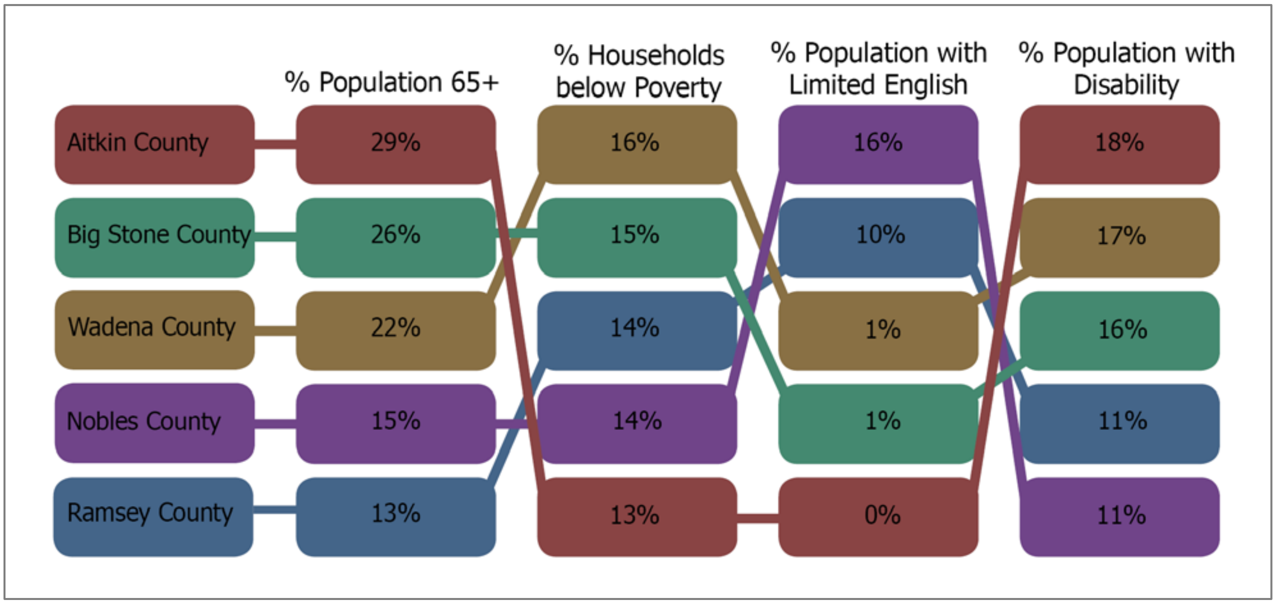
Figure 8. Percent change in SVI scores from 2000 to 2016



Source: MN DNR, Agency for Toxic Substances and Disease Registry, CDC

Another geographic analysis of population vulnerability was conducted using only four of the more significant factors in populations. This simplistic analysis, following the Indiana Department of Homeland Security methods, is valuable to highlight groups in the most socially vulnerable counties. Figure 9 reveals that counties where one factor is high, may or may not experience another high vulnerability factor. Four counties with the highest vulnerability in four categories, along with Ramsey County (second highest in population with limited English), were compared. The full results of this ranking, as well as the ATSDR Social Vulnerability Ranking by county, can be seen in *Appendix A - Social Vulnerability Ranking*.

Figure 9. Social Vulnerability Populations in 5 highly ranked counties overall



SOURCE: 2012-16 AMERICAN COMMUNITY CENSUS DATA, OBTAINED FROM IPUMS

3.4 Economic Characteristics

Minnesota currently ranks 9th in the nation with 18 Fortune 500 Companies (MSN, 2018). The top companies include UnitedHealth Group (ranking 5th with $201.2 billion in revenues and $10.5 billion in profit), Target, Best Buy, CHS, and 3M. The 18 companies represent sectors of health care, transportation, retail, food production, chemicals, utilities, insurance and finance (Fortune 500, 2018).

Minnesota ranks 3rd in the Midwest and 14th nationwide in real per capita GDP ($54,805), which is also 6% above the national average. Healthcare services and manufacturing are the largest sectors by employment. Minnesota's seasonally adjusted unemployment rate fell to 2.8% in September of 2018, the lowest state unemployment rate since May 1999 (MN DEED, 2018).

Minnesota is the sixth largest agricultural producer in the nation, with 75,000 farms covering 26 million acres, generating $19 billion in 2014 (USDA Census of Agriculture, 2018). Minnesota ranks first in the nation in production of sugar beets, turkeys, sweet corn for processing, and green peas for processing (MDA, 2018). Agriculture supports many other industries, such as manufacturing, transportation, wholesale and retail trade, services, construction, banking, insurance, and real estate. The economic contribution of Minnesota's agricultural industry reaches far beyond the agricultural sector due to the "multiplier effect." Minnesota's changing climate will increasingly present challenges for the agricultural sector with ripple effects for the state's economy.

Tourism is also a key sector of Minnesota's economy, comparable to agriculture in its contribution to the gross state product, and similarly one that is at risk due to Minnesota's changing climate. Leisure and hospitality in Minnesota generated $15 billion in gross annual sales and $969 million in state sales taxes in 2016, and the industry employed nearly 265,000 full- and part-time workers in 2016. In 2014, the annual number of travelers (in person-trips) in Minnesota was 67.5 million, over twelve times the total population of the state (Explore Minnesota, 2017).

3.5 Development Trends

S7. Was the risk assessment revised to reflect changes in development? [44 CFR §201.4(d)]

According to the 2018 *State of Rural Minnesota* report by the Center for Rural Policy and Development, the share of Minnesota's population is becoming increasingly urban, with signs indicating that this trend may be intensifying. The trend is exacerbated by three statewide trends: Minnesota's population growth is slowing; only the most urban counties are experiencing overall in-migration; and the number of immigrants coming to the state is decreasing and only occurring in very concentrated areas. While incomes remain highest in urban areas, rural areas are gradually closing the gap with per-capita income and median household incomes. Unemployment is at its lowest level since the early 2000s (Asche, 2018).

According to the Metropolitan Council, population growth is highest in communities with major transit investments. As of May 2018, this population growth was outpacing residential construction, which was leading to a decrease in the region's housing vacancy rate. Nearly 40% of the region's growth has occurred in communities containing existing transitways. Another 18% has occurred in communities with planned transitways. Estimates report that the region added 83,000 households between 2010 and 2017, but only 63,670 housing units. The remaining households occupied existing housing, which decreased vacancy rates. Within the metro area, Blaine had the highest percentage population increase from 2010-2017, increasing over 14%. Woodbury's population grew by 12%. The Council's estimates are based on latest local information on each community's housing stock, vacancy rate and group quarter's population (Metropolitan Council, 2018).

One ongoing challenge associated with population growth is maintaining a balance between development and natural resource protection. Each community is responsible for ensuring ordinances that protect residents from flooding, wildfire and other hazards are enforced. Communities with floodplain ordinances and communities that participate in Firewise are more resistant to associated hazards. Comprehensive plans, land-use plans, watershed management plans and all types of long-term community planning are a local responsibility. Hazard mitigation plans (HMP) requiring federal funding aim to give incentives to these communities to reduce vulnerability to all hazards for existing properties. The state does not dictate how communities grow; however, the current participation of Minnesota's counties (and some tribes and cities) in all-hazard mitigation planning is a positive step towards making the state and its residents disaster resilient.

Utilizing land use and comprehensive planning resources will ensure Minnesota remains safe for its residents, as well as environmentally and economically sound. It is up to local jurisdictions to enforce existing regulations, and work with communities to develop and grow sustainably, and out of harm's way, to the maximum extent possible.

Communities should explore local, state and regional climate change projections and vulnerability assessments (detailed below) for additional information to evaluate hazards, understand risks, and determine the highest potential for losses.

3.6 Climate

Minnesota has a highly variable, continental-type climate as described below. Despite its high degree of natural variability, climate scientists are finding clear evidence that recent temperature and precipitation increases are exceeding the historical variability of Minnesota's climate, and can be attributed to climate change.

Minnesota's position near the center of the continent, and halfway between the Equator and North Pole, subjects it to a wide variety of air mass types throughout the year. Frequent outbreaks of continental polar air occur in every season, with occasional bitterly cold Arctic outbreaks during the winter. Similarly, the state experiences occasional mild to warm conditions in all seasons, with extreme heat episodes common during the summer, particularly in the southern and western portions of Minnesota.

Minnesota's typical variability is such that during the course of a single year, most communities will experience heavy snow, frigid wind chills, howling winds, intense thunderstorms, torrential rains, and heat waves, as well as dozens of bright and sunny days. In a typical year, 30-40 tornadoes will strike isolated parts of Minnesota, as will lines and clusters of hail or damaging wind-producing thunderstorms. Drought is also a natural consequence of Minnesota's varying climate, and even though it does not affect the state every year, all areas have suffered from severe episodes of it at one point or another, with drought conditions being more frequent in the southwest than in the northeast.

Minnesota's climate exhibits geographic variations related to latitude, and also access both to moisture from the Gulf of Mexico and colder air masses from Canada. As a result, southern Minnesota is warmer than northern Minnesota, and eastern and southern Minnesota are wetter than western and northern parts of the state.

The mean annual temperature in Minnesota ranges from 45-48°F in the Twin Cities region and southernmost counties to 35-38°F in the northern counties. Temperatures in the state have been as high as 115°F and as low as -60°F, a range of 175 degrees, which is unrivaled over most parts of the world (Seeley, 2015).

Annual precipitation in the state generally ranges from over 36 inches in the southeast to under 20 inches in the far northwest, with a historical statewide average of just under 26 inches. Approximately 60-70% of annual precipitation falls during the growing season (May through September). Historical averages show that the driest month for most of the state is February, while the wettest is June. At a statewide scale, the two driest years on record were 1910 and 1976, with an average precipitation of less than 16 inches.

The wettest years on record are 1965, 1968, 1977 and 2010, with over 33 inches averaged statewide. The wettest growing seasons occurred in 1905, 1944, 1993 and 2010, all averaging more than 23 inches of rain across the state (Seeley, 2015). These wet years and growing seasons only tell part of the story, however, because very wet and very dry periods can also affect only *portions* of Minnesota, and some recent differences across the state illustrate this point. For instance, four of the five wettest years on record in southeastern Minnesota have occurred since the year 2000 (2004, 2007, 2010, and 2016), but only one of those years (2010) ranked in northwestern Minnesota's top five. The years 2006 and 2011 ranked as the ninth and tenth driest on record in northeastern Minnesota, but those same years were much closer to average in south-central Minnesota.

Mean seasonal snowfall ranges from more than 80 inches along Lake Superior's North Shore to less than 35 inches in southwestern Minnesota. On average, there are 110 days every year in which there is snow cover of 1 inch or more, ranging from 85 days in the south to 140 days in the north. Snow has fallen in every month except July. Heavy snowfalls of greater than four inches are common anytime from mid-November through early April, with earlier and later-season snowfall events most likely in northern parts of the state. Blizzards of heavy snow with gusty winds occur one to two times per year on average, while "ground blizzards" of severe blowing snow affecting areas near the Red River and the Minnesota River once every year or so. During extremely active winters, like those of 1996-97, and more recently in 2013-14, both types of blizzards have occurred with greater than five times their typical frequency (Seeley, 2015).

3.6.1 Minnesota's Climate Is Changing

Minnesota's climate is already changing—rapidly in some cases—with additional changes expected through the 21st century. The state is becoming both warmer and wetter, with milder winters, fewer cold extremes, and both more frequent and heavier downpours. These changes have altered growing seasons, destroyed forests, challenged natural resource management, limited recreational opportunities, damaged infrastructure, and affected the conditions of lakes, rivers, wetlands, and groundwater aquifers that provide water for drinking and agriculture. The changes observed already are expected to continue through the century, meaning that even though we will have cool and dry periods occasionally, we can expect to be even warmer and wetter than we are now, with even milder winters and even heavier downpours. Although heat extremes and drought have not increased in Minnesota as of yet, climate projections summarized in the 4th *National Climate Assessment (NCA4)* indicate that both will play more prominent roles in the state's future.

To help the public understand how the changing climate has affected and is expected to affect the behavior of common weather hazards in the Minnesota, the DNR State Climatology Office developed graphical summaries of the scientific confidence associated with each hazard's relationship to climate change (Table 6 and Table 7). Climate change in Minnesota has by far the strongest associations with 1) sharp declines in the frequency and severity of extreme cold outbreaks, tied to a persistent warming of winters, and 2) sharp increases in the frequency and intensity of extreme rainfall events. For instance, since 1970, Minnesota's winters are warming at a rate of over one degree F per decade, and approximately 10 times faster than summer. During that same period, the coldest night of the year has warmed almost twice as fast as winter as a whole—up to two degrees F per decade (or 20 degrees F per century). Additionally, across the state, comparing the 40 years, 1977-2016, to the sixty years prior reveals that 1, 2, 3, and 4-inch daily rainfall totals have become more frequent by 21%, 39%, 66%, and 84%, respectively, and the heaviest rain of the year is now 13% larger. Thus, losses in extremes of cold and gains in heavy precipitation mark Minnesota's two most prominent changes, and scientists have the highest levels of confidence that these trends are linked to climatic changes.

Despite major losses to cold extremes, the warming climate and increased abundance of atmospheric moisture has led to an uptick in many heavy snowfall metrics across Minnesota, leading to moderately high confidence that the changing climate is increasing heavy snowfall events—even as other winter characteristics decline. Tornadoes and severe convective storms are weakly connected at best to recent climate changes, and since the 1950s, despite superior detection and verification capabilities, the number of damaging tornadoes rated at least F-2 or EF-2 in Minnesota has shown no increases. Lastly, confidence is as low as possible that heat waves and drought in Minnesota have worsened in any way because of climatic changes, as neither shows recent increases in frequency or severity. In all locations across the state, the hottest days of the year and the number of days above 95 degrees are well within historical ranges, and drought is as infrequent and geographically sparse as any time on record.

The climatic picture is expected to change further beyond the year 2025, and in particular as Minnesota approaches the middle of the 21st century (Table 7). Dramatic losses in extreme cold and additional increases in heavy and extreme precipitation are expected to remain the state's leading climate change symptoms. Although Minnesota has not yet observed increases in the frequency, severity, or duration of heat waves or drought (through 2018), climate model projections summarized in NCA4 indicate that heat waves will nearly double in frequency by mid-century. A 2018 study conducted by NOAA scientists indicates that by the 2050s, heat waves in Minnesota will be more attributable to climate change than to natural variability (Lopez, et al., 2018). Drought, although somewhat less certain than extremes of heat, may become more frequent by mid-century as well, resulting from the combination of hotter conditions and the potential for slightly longer dry spells. Meanwhile, the warming of winter should shrink the window of opportunity for heavy snowfall, potentially reducing the frequency of those events. The science summarized in NCA4 suggests that conditions favorable for severe convective weather will become more common in the years and decades ahead, but it is unclear if that will translate to more severe weather events in general, or if it means some combination of more damaging tornadoes, stronger convective winds, and larger hail.

Table 6. Confidence that climate change has already impacted common Minnesota weather / climate hazards

Confidence	Hazard	Recent & Current Observations
Highest	**Extreme cold**	Rapid decline in severity, frequency
	Extreme rainfall	Becoming larger and more frequent
Moderately High	**Heavy snowfall**	Large events more frequent
Moderately Low	**Severe thunderstorms & tornadoes**	Historical comparisons difficult; Few major tornadoes in MN since late 2010
Lowest	**Heat waves**	No recent increases or worsening
	Drought	

SOURCE: DNR STATE CLIMATOLOGY OFFICE

Table 7. Confidence that climate change will impact common Minnesota weather/climate hazards beyond 2025

Confidence	Hazard	Expectations beyond 2025
Highest	**Extreme cold**	Continued rapid decline
	Extreme rainfall	Unprecedented events expected
High	**Heat waves**	Increases in severity, coverage, and duration expected
Moderately High	**Drought**	Increases in severity, coverage, and duration possible
Moderately Low	**Heavy snowfall**	Large events less frequent as winter warms
Moderately Low	**Severe thunderstorms & tornadoes**	More "super events" possible, even if frequency decreases

SOURCE: DNR STATE CLIMATOLOGY OFFICE

As computing resources have grown, multi-decadal simulations of global climate models are now being conducted at horizontal resolutions on the order of 15 miles (25 km) that provide more realistic characterization of intense weather systems (USGCRP, 2017). Advances in computing technology are beginning to enable regional climate modeling at higher resolutions (1–4 km), permitting the direct simulation of convective clouds systems (e.g., Ban, Schimidli, & Schar, 2014). Minnesota is seeking high resolution projections dynamically downscaled on this order to provide local jurisdictions with better information for assessing vulnerability to climate hazards and planning to address risks for communities and infrastructure.

3.6.2 Climate Change Risks and Vulnerability

Every four years, the United States Global Change Research Program publishes a National Climate Assessment Report (NCA) which includes Key Messages for each region of the U.S. Released in November 2018, NCA4 Vol 2 introduces two new Key Messages for the Midwest. One recognizes the important role that ecosystems play in providing important benefits such as flood control, crop pollination and outdoor recreation. The other addresses how at-risk communities are becoming more vulnerable to climate change impacts. The four remaining Key Messages address improvements in the understanding of risks from climate change since NCA3. Following are the six NCA4 Key Messages for the Midwest, followed by additional highlights of Minnesota-based concerns.

Agriculture

NCA4 Key Message: Increases in warm-season absolute humidity and precipitation have eroded soils, created favorable conditions for pests and pathogens, and degraded the quality of stored grain. Projected changes in precipitation, coupled with rising extreme temperatures before mid-century, will reduce Midwest agricultural productivity to levels of the 1980s without major technological advances.

Agriculture is highly dependent on specific climate conditions and increasing temperatures and precipitation events will impact Minnesota's agriculture industry. As a result of increasing temperature, crop production areas may shift to new regions of the state where the temperature range for growth and yield of those crops is optimal. And although the growing season is lengthening, other climate changes, such as increased crop losses and soil erosion from more frequent and intense storms, and increases in pests and invasive species, could outweigh this benefit (ICAT, 2017).

Invasive Species

NCA4 Key Message: Threats from a changing climate are interacting with existing stressors such as invasive species and pests to increase tree mortality and reduce forest productivity. Without adaptive actions, these interactions will result in the loss of economically and culturally important tree species such as paper birch and black ash and are expected to lead to the conversion of some forests to other forest types or even to non-forested ecosystems by the end of the century.

Climate change is having an impact on the pests that damage the health and composition of Minnesota forests. Shorter winters are allowing two reproductive cycles of the Eastern Larch Beetle (ELB), which has now killed off at least 143,000 acres (11%) of mature tamarack forest in Minnesota since 2001, and affected about 535,000 acres to some degree during that period. The decline in severity and frequency of extreme cold is contributing to the more rapid spread of Emerald Ash Borer (EAB) within areas it has already infested, and to latitudes further north than without climate change. Minnesota forests are home to an estimated one billion ash trees. Many of these trees are in nearly pure stands of black ash growing in wet areas. Once EAB has killed these trees, there is a concern that the wet forest habitat may change over to grass, cattails, and shrubs, threatening the plants and animals that rely on black ash and forest habitats. In northeastern Minnesota, Bur Oak Blight, caused by a native fungus not even known until the last 10 years, is starting to cause problems due to increased spring precipitation.

Ecosystems

NCA4 Key Message: The ecosystems of the Midwest support a diverse array of native species and provide people with essential services such as water purification, flood control, resource provision, crop pollination, and recreational opportunities. Species and ecosystems, including the important freshwater resources of the Great Lakes, are typically most at risk when climate stressors, like temperature increases, interact with land-use change, habitat loss, pollution, nutrient inputs, and nonnative invasive species.

As Minnesota's climate continues changing beyond 2025, weather fluctuations between extreme rain events and drought, along with increasing temperatures and more severe heat waves will lead to ongoing changes in forest composition or distribution. The northern boreal forest may give way to more deciduous forests or grassland, with a period of dying or diseased trees during the transition. Weather fluctuations can lead to dry conditions with increased fire risk in grassland, forest, and peatland environments.

Human Health

NCA4 Key Message: Climate change is expected to worsen existing health conditions and introduce new health threats by increasing the frequency and intensity of poor air quality days, extreme high temperature events, and heavy rainfalls; extending pollen seasons; and modifying the distribution of disease-carrying pests and insects. By mid-century, the region is projected to experience substantial, yet avoidable, loss of life, worsened health conditions, and economic impacts estimated in the billions of dollars as a result of these changes.

Climate change has an impact on vector-borne/zoonotic diseases (ICAT, 2017). There is evidence that the suitable habitat and survivability of blacklegged tick populations may increase with mild winters and forest changes (Leighton, Koffie, Pelcat, Lindsay, & Ogden, 2012; Johnson, Neitzel, Dorr, Schiffman, & Eisen, 2016). This could lead to more human Lyme disease cases in Minnesota. Additionally, warmer climates facilitate introduction of invasive species of insects and animals that carry diseases not normally observed in Minnesota (ICAT, 2017).

The Minnesota Department of Health's (MDH) Minnesota Climate & Health Program teamed up with state and local emergency management and preparedness professionals as well as state climatologists to develop a custom climate profile for each of the six Homeland Security and Emergency Management (HSEM) regions across the state. Each 12-page report includes a description of climate change trends along with a summary of climate projection data to illustrate these trends. Regional climate data are presented alongside population projection data, as it's important to consider both climate future and population future to minimize risk and build resilience against climate impacts (MDH, 2018).

Additionally, a local case study is used to illustrate the links between extreme weather and natural disasters and what climate projection data can (and can't) indicate for similar events in the future. This resource provides a framework for discussing projected local risks related to our changing climate and supports the development of climate adaptation strategies that protect community health and safety.

Infrastructure

NCA4 Key Message: Storm water management systems, transportation networks, and other critical infrastructure are already experiencing impacts from changing precipitation patterns and elevated flood risks.

An increase in extreme precipitation events will result in more damage to highways, rail infrastructure, hydraulics infrastructure, and airport runways. Flooding on roads will slow operations and performance and cause dangerous conditions for drivers. Recurring freeze/thaw cycles are becoming more common, and can result in dangerous driving conditions and damage to infrastructure. Extreme heat can cause roads to buckle and damage other transportation infrastructure such as rail lines. This may increase expenditures for repairs and potential for travel disruption (MNDOT, 2018).

Minnesota's water and sewer infrastructure protects public health and provides vital services to residents throughout the state. Many communities with aging infrastructure do not have a large enough population base to spread the costs of these large capital projects (OSA, 2017). Aging infrastructure will be at higher risk to flooding, landslides and other hazards where the land is moving, putting human health at risk.

Populations

NCA4 Key Message: Community Vulnerability and Adaptation: At-risk communities in the Midwest are becoming more vulnerable to climate change impacts such as flooding, drought, and increases in urban heat islands. Tribal nations are especially vulnerable because of their reliance on threatened natural resources for their cultural, subsistence, and economic needs.

Although the impacts from Minnesota's changing climate affect everyone, some groups of people are more at risk. Added climate risk exists for the very old and very young, people of color, and people with health issues, disabilities, economic vulnerability, outdoor occupations, exposure to environmental pollution, and cultural/language barriers. The most vulnerable have multiple sources of risk.

Tourism is being affected already with shorter, warmer winters, less predictable snowfall, earlier ice out, and extreme precipitation affecting water quality and shorelines. Higher winter temperatures can lead to reduced or unsafe ice cover on Minnesota's lakes, and increasing risk in winter recreational activities such as snowmobiling and ice fishing.

Changing conditions will affect everything from safety to management. The delayed seasonal mixing of lakes causes both depletion of oxygen and warmer surface water temperatures affecting some fish populations. For example, a recent study shows only 11% of Wisconsin lakes with successful walleye recruitment may experience the same walleye populations by mid-century, resulting in many management and sport fishing implications (Hansen, Read, Hansen, & Winslow, 2016).

If Minnesota companies invest in climate change adaptation and mitigation this could produce a significant boost to the state's economy. This is already being seen in some areas of the state that are investing is solar and wind power. EcoLab and Pentair are other companies investing in the water industry to address water quality and quantity issues that are related to climate change.

Climate change has broad, sweeping impacts on ecosystems that impact fish, game, and wild plant populations which are used for food. This may have a particularly negative impact on rural, American Indian, and other population groups relying more heavily on subsistence hunting and wild plants (ICAT, 2017).

3.6.3 Climate Change Adaptation

The Fourth National Climate Assessment identifies these climate adaptation responses to risks which provide ongoing opportunities in the Midwest for reducing the impacts of climate change (NCA4 Vol 2, CH 21):

- Restoration of natural systems, increases in the use of green infrastructure, and targeted conservation efforts, especially of wetland systems, can help protect people and nature from climate change impacts.
- Improved basic health services and increased public health measures—including surveillance and monitoring—can prevent or reduce the impacts of the anticipated increased frequency and intensity of poor air quality days, extreme high temperature events, and heavy rainfalls; extended pollen seasons; and modified distribution of disease-carrying pests and insects.
- Green infrastructure is reducing some of the negative impacts by using plants and open space to absorb storm water. The annual cost of adapting urban storm water systems to more frequent and severe storms is projected to exceed $500 million for the Midwest by the end of the century.
- Integrating climate adaptation into planning processes offers an opportunity to better manage climate risks now. Developing knowledge for decision-making in cooperation with vulnerable communities and tribal nations will help to build adaptive capacity and increase resilience.

Since July 2009, Minnesota state agencies have been collaborating on climate adaptation efforts through the Interagency Climate Adaptation Team (ICAT). In addition, the University of Minnesota Extension and the University of Minnesota's Water Resources Center coordinate the Minnesota Climate Adaptation Partnership (MCAP), which brings together federal and state agencies, organizations, and individuals statewide with an interest in climate adaptation. Various state agencies have also developed their own climate mitigation or adaptation projects, many of which are discussed throughout this document.

Climate change adaptation is important for increasing the resilience of communities and the environment. The shocks caused by more extreme weather events and the stressors of longer-term changes to the climate affect all natural systems. For human communities, these impacts challenge the surroundings in which they live, the critically important ecosystem services upon which they depend, public health, local facilities and infrastructure, the safety of their residences, and the viability of their livelihoods. Development trends can further exacerbate both climate impacts and population vulnerability. Communities are only as resilient as the most vulnerable within them.

The Minnesota Pollution Control Agency (MPCA) funded studies to identify climate-vulnerable populations, resilience indicators, and strategies to reduce risk in 23 cities throughout Minnesota (paleBLUEdot, 2018). A valuable section in these plans is the outlining of climate adaptation and resilience goals for environmental hazards of climate change including: heat stress and extreme weather, air quality impacts, flood vulnerability, vector-borne disease risks, water quality and quantity risks, and waterborne illness risks. In addition, goals are outlined to build capacity for preparing for and responding to population risks of climate change impacts and economic resilience in support of climate resilience.

HSEM is encouraging jurisdictions, through various modes of outreach, to integrate the MDH Regional Climate Profile information and the paleBLUEdot climate adaptation goals and strategies throughout their Hazard Mitigation Planning processes. Hazard mitigation can be used to reduce the risk of damaging climate change impacts on communities and the environment such as increased flash flooding. The impacts of climate change are discussed regionally and by natural hazard in each risk and vulnerability section of this report.

Section 4: Hazards Risk Assessment

4.1 Overview

S3. Does the risk assessment include an overview of the type and location of all natural hazards that can affect the state? [44 CFR §201.4(c)(2)(i)]

This section of the plan is a result of a risk and vulnerability assessment conducted for the State of Minnesota. The risk assessment is intended to support the state's long-term hazard mitigation planning efforts. It was prepared to satisfy the requirements of the Disaster Mitigation Act (DMA) of 2000 and to provide a statewide overview of natural hazards and their risks. This plan also includes an overview of seven human-caused hazards.

The framework of the risk assessment was developed to provide a basis for activities proposed during the state's mitigation planning effort and should be used by state and local officials to plan and prioritize resource allocations. The risk assessment results should be used to identify and prioritize appropriate mitigation actions to minimize potential losses from hazards identified in this study.

The hazards profiled in the Minnesota Risk Assessment were selected from the comprehensive list of natural hazards FEMA identified in the 1997 publication, *Multi-Hazard Identification and Risk Assessment: A Cornerstone of the National Mitigation Strategy (MHIRA)* (FEMA, 1997).

The following risk assessment was based on input from published sources such as the U.S. National Oceanographic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), the U.S. Department of Agriculture (USDA), the Minnesota Department of Natural Resources (MN DNR), and the Minnesota Division of Homeland Security and Emergency Management (HSEM), among others. All data and maps in this document have been updated as of August 2018 with the most recent data available, unless otherwise noted.

All 22 hazards that potentially affect the state are described, as is the nature of each hazard, history, location of occurrence, and probability of future occurrence.

4.2 Presidential Disaster Declaration History

The state of Minnesota has been granted Presidential Disaster Declarations 61 times between 1957 and 2018 (61 years). Of those declarations, 46 involved flooding in 33 different years. Those numbers translate into approximately a 55% chance of a major flood annually somewhere in the state. Disaster Declarations for the last five years are listed in Table 8.

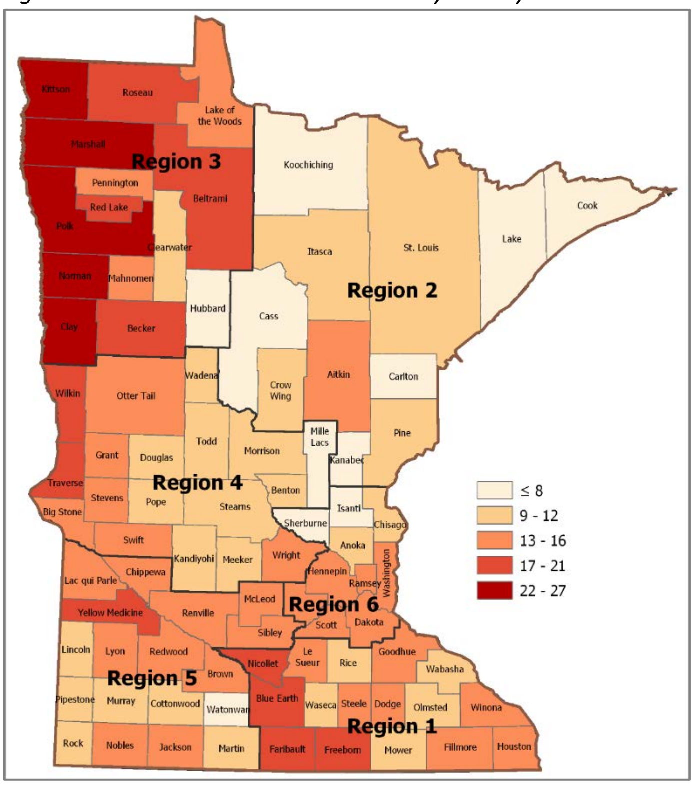
Table 8. FEMA Disaster Declarations, 2013-2018

Incident Period/ DR Date	DR Number	Designated Counties PA-Public Assistance IA-Individual Assistance	Incident Description	Total Public and Total Individual Assistance
June 15, 2018 -July 11, 2018 09/05/18	4390	Aitkin, Beltrami, Blue Earth, Brown, Carlton, Cass, Clearwater, Cottonwood, Faribault, Itasca, Jackson, Koochiching, Lake, Lyon, Martin, Murray, Nicollet, Nobles, Pine, Pipestone, Polk, Redwood, Renville, Rock, St. Louis, Sibley, and Watonwan Counties, as well as the Leech Lake Band of Ojibwe, Red Lake Nation, and White Earth Nation.	Severe Storms, Tornadoes, Straight-line Winds, and Flooding	Not Available See fema.gov
September 21, 2016 - September 24, 2016 11/02/2016	4290	PA - Blue Earth, Fillmore, Freeborn, Goodhue, Houston, Le Sueur, Rice, Steele, Waseca IA - Hennepin, Blue Earth, Freeborn, Le Sueur, Rice, Steele, and Waseca	Flood	$2,598,417 Individual & Households Program (IHP) $2,411,058 Housing Assistance (HA) $187,358 (ONA) Other Needs Assistance 661 Individual Assistance (IA) Applications **$6,785,409 (PA)**
June 11, 2014 - July 21, 2014	4182	Beltrami, Blue Earth, Brown, Carver, Chippewa, Dodge, Faribault, Freeborn, Hennepin, Jackson, Koochiching, Lac Qui Pale, Lake of the Woods, Le Sueur, Lyon, Marshall, Martin, McLeod, Murray, Nicollet, Nobles, Pipestone, Ramsey, Redwood, Renville, Rice, Rock, Roseau, Scott, Sibley, Steele, Todd, Wadena, Waseca, Watonwan, Wright, and Yellow Medicine	Severe Storms, straight-line winds, flooding, landslides, and mudslides	**$41,106,113 (PA)**
July 25, 2013	4131	Benton, Big Stone, Douglas, Faribault, Fillmore, Freeborn, Grant, Hennepin, Houston, McLeod, Morrison, Pope, Sibley, Stearns, Stevens, Swift, Traverse and Wilkin	Severe Storms, Straight-line Winds, Flooding	**$14,013,795 (PA)**
May 3, 2013	4113	Cottonwood, Jackson, Murray, Nobles and Rock	Severe Winter Storm	**$11,090,674 (PA)**

SOURCE: FEMA (12/14/2018)

Each of the 87 counties in the state has been included in a Presidential Disaster Declaration. FEMA maintains a chronological history of Minnesota disasters at www.fema.gov. Records contain information on the type of programs: Public Assistance, Individual Assistance, and number of applicants for Individuals and Household Program, Other Needs Assessment, Small Business Administration disaster loan program, state match, if any, and total dollar amounts where available. All jurisdictions in the state are vulnerable to natural hazards, especially flooding and severe storms. Figure 10 shows FEMA disaster declarations by county, through 2018.

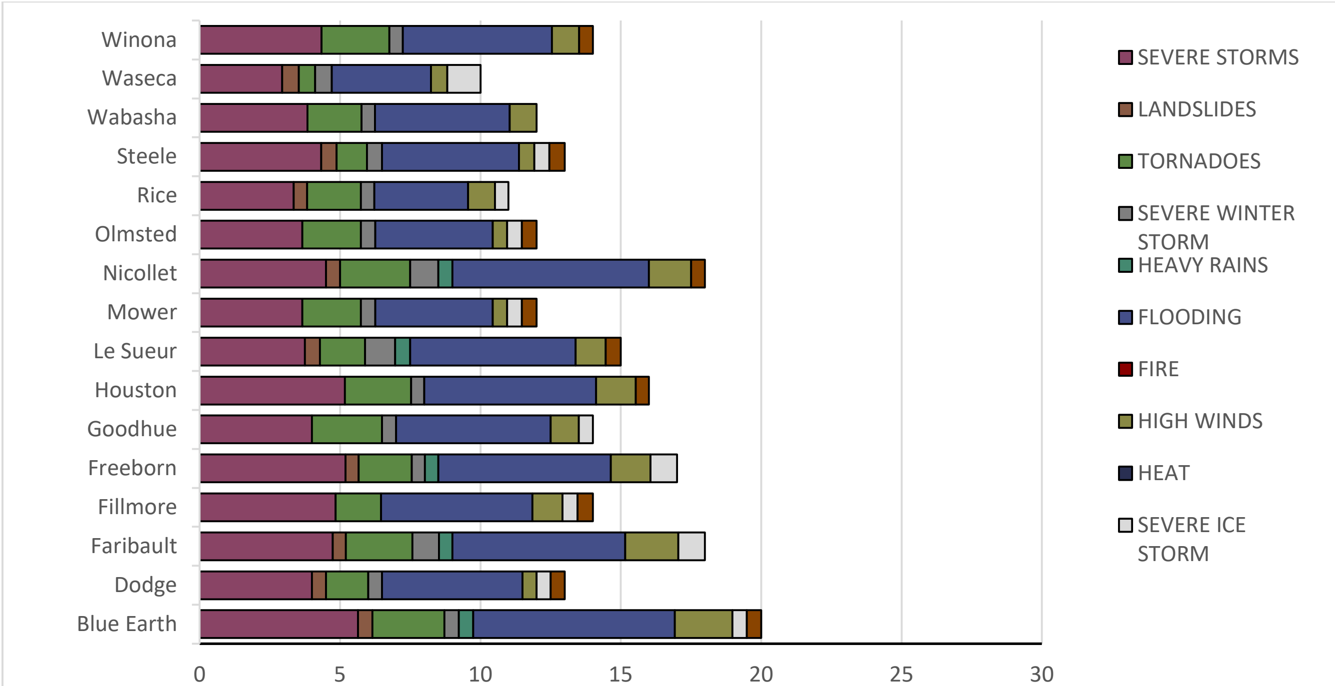
Figure 10. FEMA Disaster Declarations by County



Source: FEMA

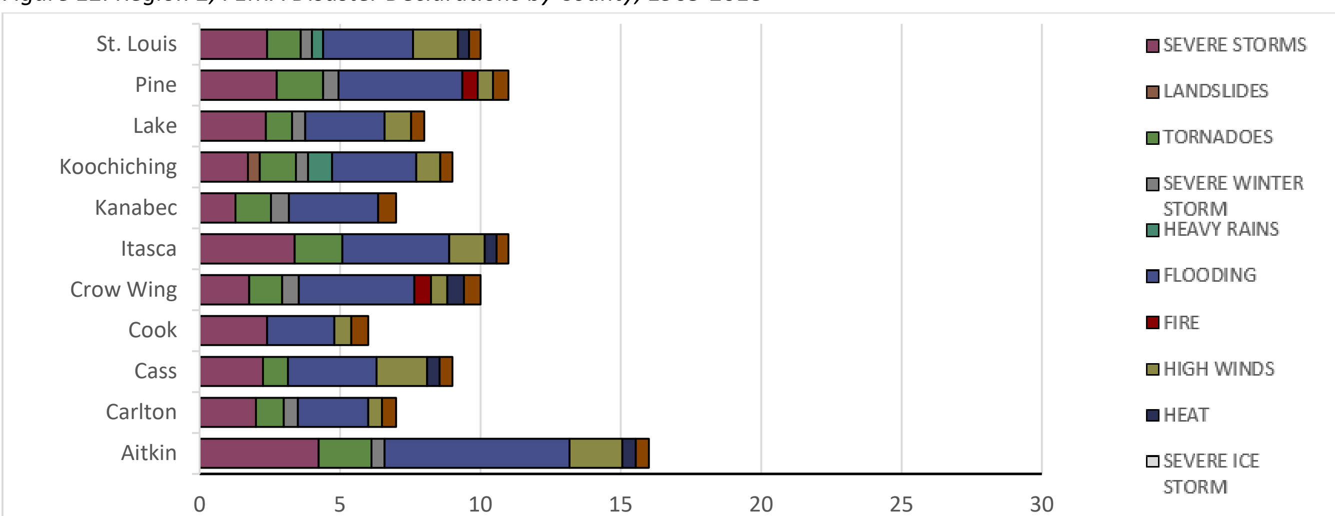
A summary of FEMA Disaster Declarations by county is shown in the following figures. The proportion of hazard type has been broken out from the FEMA title of the declaration into the 12 hazard types corresponding with the hazards identified in this plan. For example, DR-4390 is titled "Severe Storms, Tornadoes, Straight-line Winds, and Flooding." For each county or reservation included in this declaration, this declaration will be represented by .25 flooding, .25 severe storms, .25 high winds, and .25 tornadoes for the one declaration. Therefore the coloration represents proportional occurrence of hazard within declaration total.

Figure 11. Region 1, FEMA Disaster Declarations by County, 1965-2018



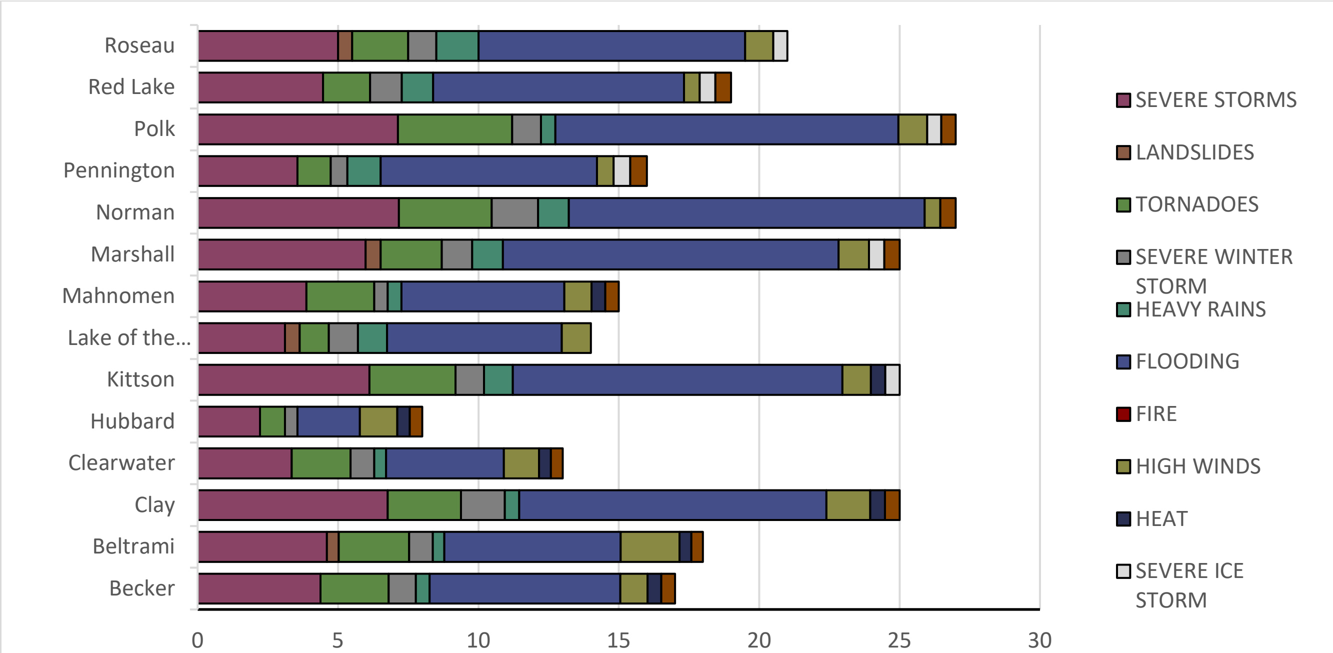
SOURCE: FEMA

Figure 12. Region 2, FEMA Disaster Declarations by County, 1965-2018



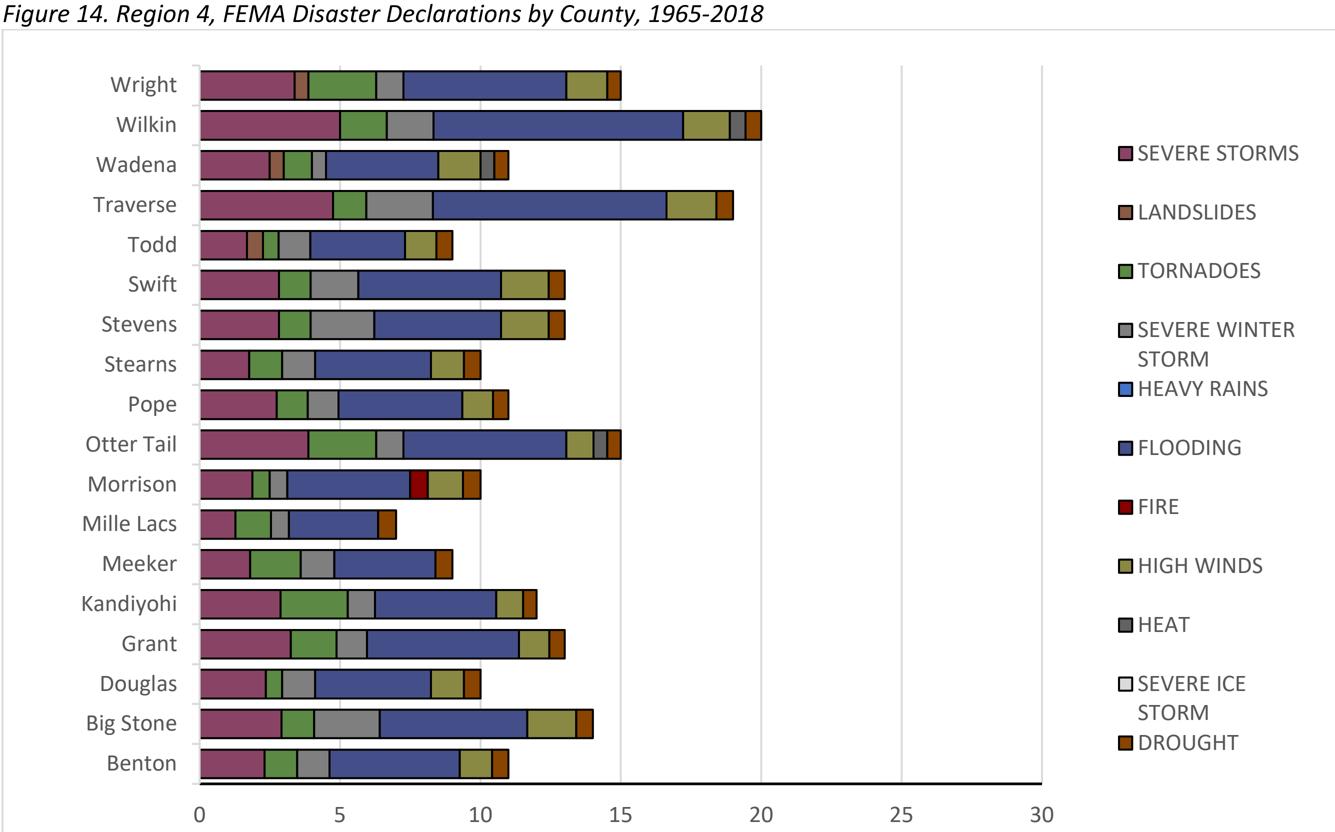
SOURCE: FEMA

Figure 13. Region 3, FEMA Disaster Declarations by County, 1965-2018



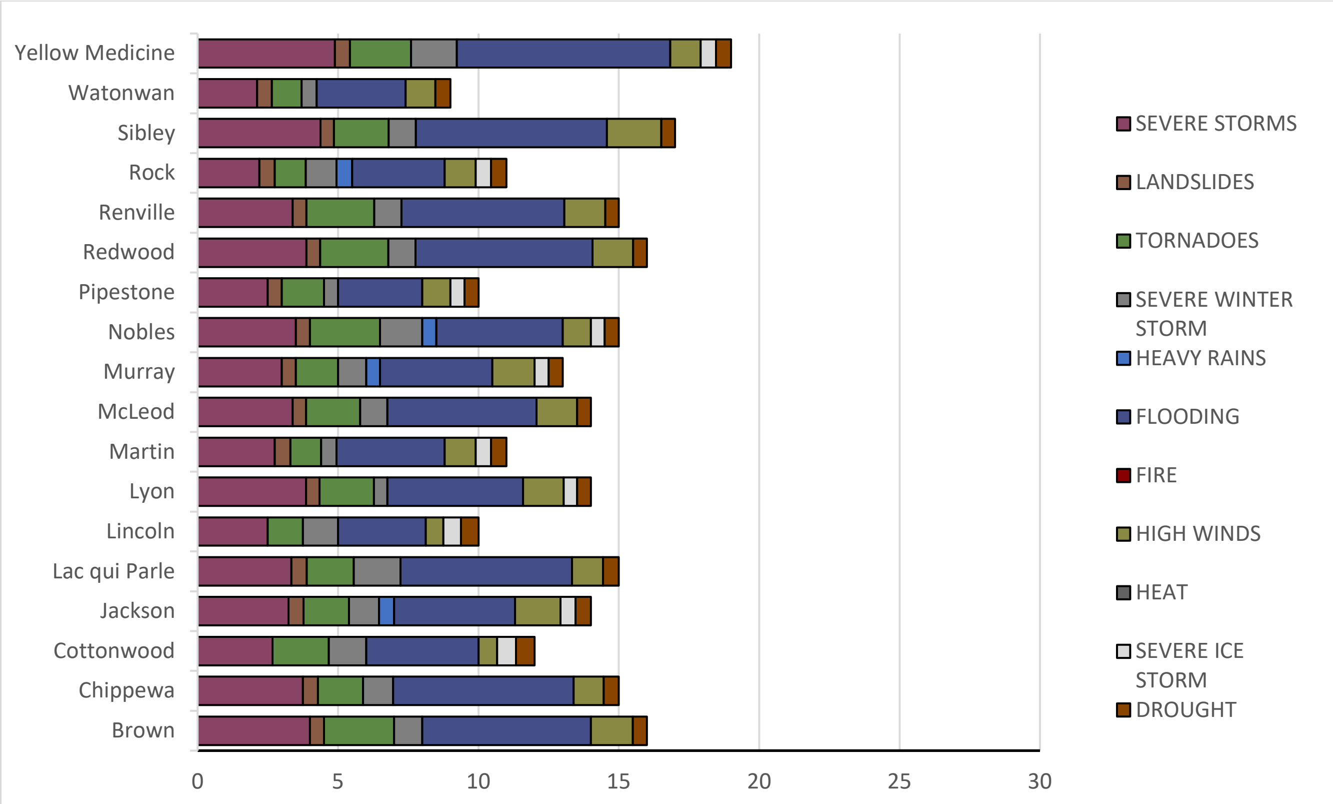
SOURCE: FEMA

Figure 14. Region 4, FEMA Disaster Declarations by County, 1965-2018



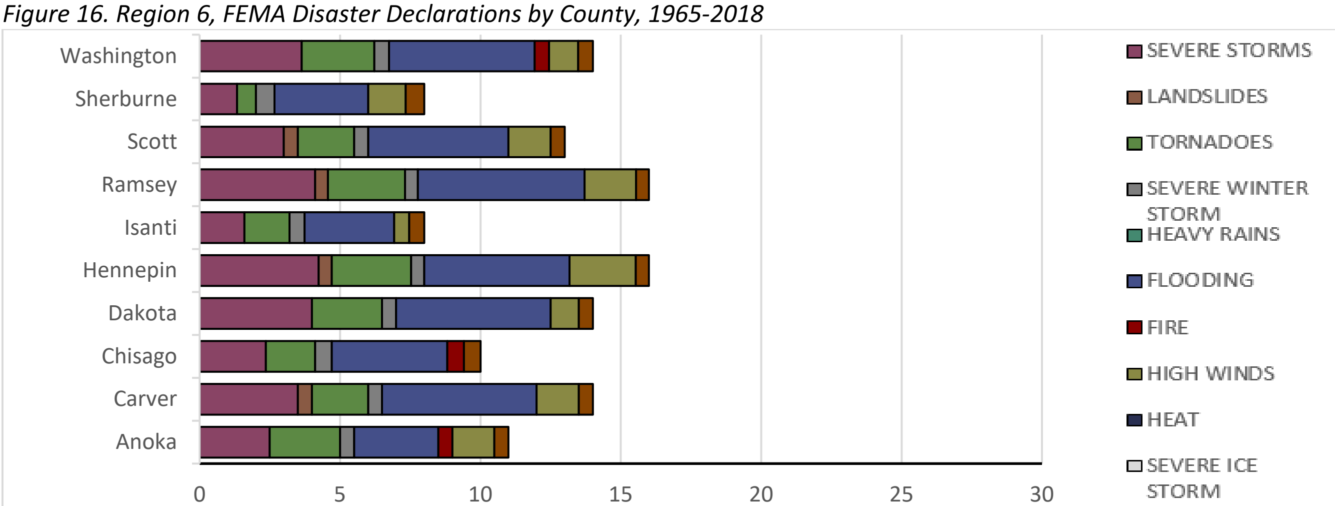
SOURCE: FEMA

Figure 15. Region 5, FEMA Disaster Declarations by County, 1965-2018



SOURCE: FEMA

Figure 16. Region 6, FEMA Disaster Declarations by County, 1965-2018



SOURCE: FEMA

4.3 State Disaster Declarations

The State Disaster Assistance program and eligibility is described in Section 5.7.8. Since the inception of the state recovery program there have been 32 state-declared disasters in 78 counties or reservations. The counties where more than $1 million in funds have been obligated, or the county has had more than one disaster declared, are shown in Table 9.

Table 9. Counties with More than One State Disaster Declaration or more than $1M Obligated.

County	# State Disasters	State Share Obligated	Type of disaster for most recent or open declarations
St. Louis	3	$7,036,351	Severe Winter Storm
Pine	1	$3,944,617	Severe Thunderstorms and High Winds
Rice	1	$2,787,754	Severe thunderstorms
Cass	4	$2,144,687	Severe Storms and Tornadoes
Crow Wing	5	$2,005,597	Severe Storms and Tornadoes
Dakota	1	$1,931,748	Heavy rains and flooding
Renville	4	$1,737,804	Severe Storms, Tornadoes, and Flooding
Aitkin	3	$1,074,068	Severe Thunderstorms and High Winds
Ramsey	1	$1,022,360	Slope Failure
Morrison	2	$661,012	Severe Thunderstorms and High Winds
Redwood	2	$469,110	Severe Storms, Tornadoes, and Flooding
Martin	2	$462,756	Severe thunderstorms
Clearwater	2	$443,079	(closed, so data not readily available)
Norman	2	$166,555	Severe Storms and Tornadoes

SOURCE: HSEM (02/06/2019)

Tables in *Appendix B – State Disaster Assistance Program Summary* indicate the county/tribe, number of applicants, actual project cost, and state share paid to date. Other documentation includes hazard type and date of incident and declaration. The table below shows the year, number of state disasters per year, and state expenditures to date.

Table 10. Financial Summary, State Public Assistance Program

Year	# State Disasters	State Share Paid To Date (75%)
2014	2	$2,168,574
2015	3	$1,916,938
2016	8	$9,158,203
2017	11	$2,183,208
2018	8	$1,103,943
Total	**29**	**$16,530,867**

SOURCE: HSEM (02/06/2019)

4.4 Identifying Hazards

S4. Does the risk assessment provide an overview of the probabilities of future hazard events? [44 CFR §201.4(c)(2)(i)]

This section of the state plan profiles the potential hazards that pose a threat to the state of Minnesota. As part of the 2019 revision, the current list of hazards was revised to specifically identify coastal flooding and erosion from the previous coastal erosion and landslides categories. The efforts of the Silver Jackets and the Lake Superior Coastal Hazard Task Force have dramatically increased the amount of data and reporting on these hazards. They have provided us with a substantial hazard assessment and mitigation strategies.

Based on previous plans, and state and federal disaster declarations, the following 15 natural hazards and seven other hazards were considered for inclusion in this plan (Table 11).

Table 11. Hazards Included in This Plan

Natural Hazards		
Flooding	Dam Failure	Coastal Erosion and Flooding
Wildfire	Extreme Heat	Erosion, Landslides, Mudslides
Wind Storms	Drought	Land Subsidence
Tornadoes	Lightning	Extreme Cold
Hail	Winter Storms	Earthquakes
Other Hazards		
Terrorism	Hazardous Materials Incidents	Infectious Disease Outbreaks
Fires (Structures and Vehicles)	Transportation Incidents	Nuclear Generating Plant Incidents
Ground and Surface Water Supply Contamination		

The DMA of 2000 and supporting requirements in the Interim Final Rule (IFR) requires states to first identify hazards that may affect them, and then perform a comprehensive multi-hazard assessment, which includes a review of detailed information concerning hazard characteristics, past occurrences and probability of future occurrences. The initial hazard identification cataloged potential hazards statewide and determined which have the most chance of significantly affecting the state and its citizens. The hazards include those that have occurred in the past, as well as those that may occur in the future. A variety of sources were used in the investigation, as noted earlier.

The qualitative ranking system rated each of the 22 hazards by its probability and potential for mitigation. This ranking is not intended to supplant detailed risk assessment, but rather to allow time and technical resources to be focused on the most significant hazards.

Defined in the tables below, each hazard was determined to have a high, medium or low ranking for probability and mitigation potential. Each of the ranking levels has several criteria. These criteria were used as general guidelines, so in some cases the rankings were weighted toward one or two of the criteria rather than all of them.

Table 12. Probability Ranking and Criteria for Hazard Identification

Ranking	Criteria
High	• The hazard has impacted the state annually, or more frequently • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations
Medium	• The hazard impacts the state occasionally, but not annually • The hazard is somewhat localized, affecting only relatively small or isolated areas when it occurs • The methodology for identifying events is not well-established, or is not applied across the entire state
Low	• The hazard occurs only very infrequently, generally less than every five years on a large scale, although localized events may be more frequent • The hazard is generally very localized and on a small scale (i.e. sub-county level)

	• A methodology for identifying event occurrences and/or severities is poorly established in the state, or is available only on a local basis.

Table 13. Mitigation Potential Ranking and Criteria for Hazard Identification and Disposition

Ranking	Criteria
High	• Methods for reducing risk from the hazard are technically reliable • The state or counties have experience in implementing mitigation measures • Mitigation measures are eligible under federal grant programs • There are multiple possible mitigation measures for the hazard • The mitigation measure(s) are known to be cost-effective • The mitigation measures protect lives and property for a long period of time, or are permanent risk reduction solutions
Medium	• Mitigation methods are established • The state or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard • Some mitigation measures are eligible for federal grants • There is a limited range of effective mitigation measures for the hazard • Mitigation measures are cost-effective only in limited circumstances • Mitigation measures are effective for a reasonable period of time
Low	• Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental • The state or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them • Mitigation measures are ineligible under federal grant programs • There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative • The mitigation measure(s) have not been proven cost effective and are likely to be very expensive compared to the magnitude of the hazard • The long-term effectiveness of the measure is not known, or is known to be relatively poor.

The hazard identification and disposition table below lists the name of the hazard, the relative rankings for probability and mitigation potential. Guidance provided by FEMA in the document served as the basis for selecting the natural hazards profiled in the report. The probability and mitigation potential have not changed since the 2014 plan.

Table 14. Hazard Identification and Disposition

Hazard	Section in Plan	Probability	Mitigation Potential
Flooding	4.7.1	High	High
Wildfire	4.7.2	High	High
Wind Storms	4.7.3	High	High
Tornadoes	4.7.4	High	High
Hail	4.7.5	High	Medium
Dam Failure	4.7.6	Medium	Medium
Extreme Heat	4.7.7	High	Low
Drought	4.7.8	High	Low
Lightning	4.7.9	High	Low
Winter Storms	4.7.10	High	Low

Hazard	Section in Plan	Probability	Mitigation Potential
Coastal Erosion and Flooding	4.7.11	Medium	Medium
Erosion, Landslides and Mudslides	4.7.12	Medium	Low
Land Subsidence	4.7.13	Medium	Low
Extreme Cold	4.7.14	High	Low
Earthquakes	4.7.15	Low	Low
Fire (Structure and Vehicle)	4.8.1	Medium	Low
Ground and Surface Water Supply	4.8.2	Medium	Medium
Hazardous Materials	4.8.3	Medium	Low
Nuclear Incidents	4.8.4	Low	Low
Infectious Disease Outbreak	4.8.5	Low	Low
Transportation	4.8.6	Low	Low
Terrorism	4.8.7	Low	Low

As expected, the classification process provided a clear stratification of the hazards based on these criteria. The state has identified floods, tornadoes, straight-line winds and wildfires as the hazards that present the highest risk to the state and the most potential for mitigation, based on this limited assessment. In the sections that follow, these hazards are afforded detailed risk assessments in order to identify the areas of the state that are most at risk, and this information is in turn used as the basis for determining appropriate actions to reduce the risks.

As discussed earlier, this ranking system is not intended to supersede more detailed and focused risk assessment procedures. As the state re-evaluates and updates this plan, it may be appropriate to revisit this ranking methodology and perform full risk assessments for additional hazards.

It is important to understand the meanings of several terms that appear in both the federal hazard mitigation planning rules and this plan. The terms *probability, vulnerability* and *risk* appear many times in both places, and those terms and others are defined below and given some context in terms of this plan.

Probability is the likelihood that events of particular severities will occur. The ability to calculate probability varies considerably depending on the hazard in question. In many areas of the country, flood studies of various kinds can provide reasonably accurate estimates of how often water will reach particular places and elevations. On the other hand, tornadoes are notoriously difficult to predict, although general areas of impact can be determined (it is also possible to predict the seasons of the year that are most likely to produce tornadoes). Probability is a key element of risk because it determines how often the events are likely to happen. Climate change may also affect these probabilities in unknown ways.

It is important to note that risk is cumulative. This means that although natural hazards may not affect a place in any particular year, the probability of one or more events (in some places multiple events) occurring “adds up” over time. Risk calculations incorporate all expected future events – usually with some limit on the time horizon that is considered – in order to account for both repetitive events and for the probabilities that accumulate over time. So, over time the possibility of the hazard event happening increases.

Vulnerability can be defined as to the extent to which people will experience harm and property will be damaged from a hazard. Vulnerability is the susceptibility of people to injury as the result of a hazardous event and the susceptibility of the things people value to damage as the result of a hazardous event. Some add the concept of resilience to the definition of vulnerability (Buckle, 1999). Buckle identifies potential social, economic, and environmental effects and introduces the notion that vulnerability is associated with an ability to recover.

Risk is often expressed in dollar costs of future expected losses. Although the concept may generate disagreement, it is possible to assign a value to many community "assets" including physical components such as buildings and infrastructure, functional ones such as government or business operations, and even injuries and casualties.

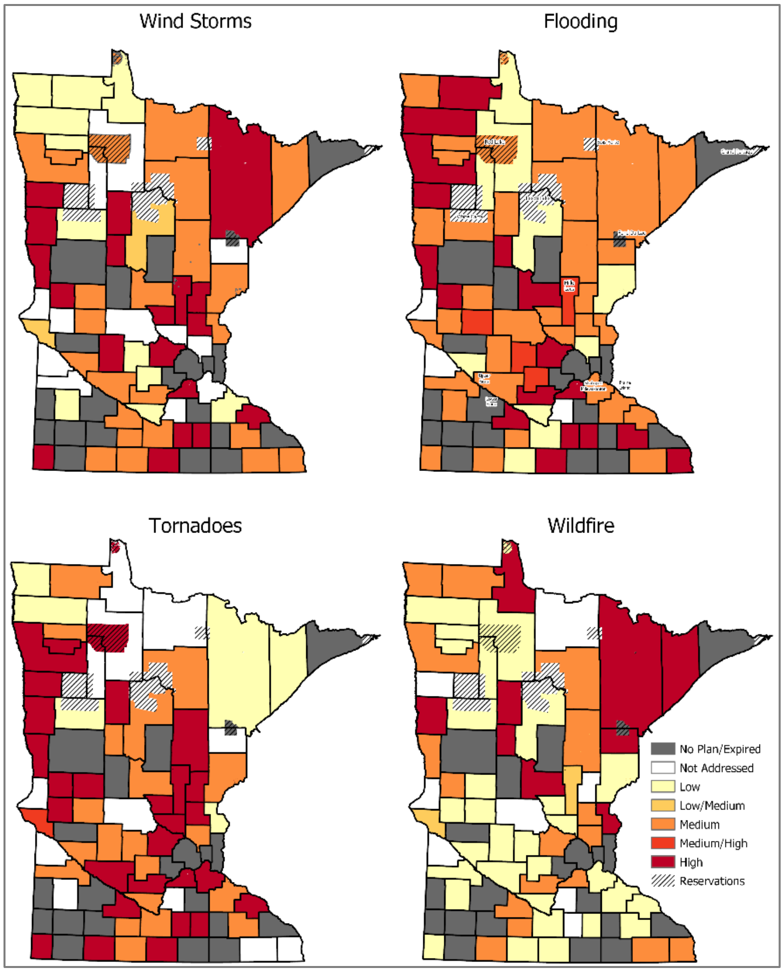
It is calculated in this way so that different kinds of losses can be adequately compared. For example, without a common basis for comparison, it would be virtually impossible to determine if the risk of injury from future tornadoes is greater than damage to vehicles in future floods. When the expected losses are converted to and expressed in dollars, the damages can be compared and prioritized. In combination with the concepts discussed above, almost any kind of hazard can be quantified and its risk expressed. The exceptions to this idea are infrequent or highly unpredictable events such as meteors impacting the earth, or manmade hazards such as terrorism. In these cases, the element of probability is virtually impossible to characterize, and the risk calculus cannot be accurate without it.

4.5 Risk Assessment by County

S6. Does the risk assessment include an overview and analysis of the vulnerability of jurisdictions to the identified hazards and the potential losses to vulnerable structures? [44 CFR §§201.4(c)(2)(ii) and 201.4(c)(2)(iii)]

A statewide capability and vulnerability analysis was conducted which compiled information in all jurisdictional Multi-Hazard Mitigation Plans. Only approved and active (not expired) plans were reviewed. The assessment sections from the 84 MHMP plans (67 counties, 7 tribal governments, and 1 city) considered during the update process included the hazard identification and ranking, potential economic losses due to flooding, and local planning, policy, and staff capabilities. Jurisdictional planning, policy and staff capabilities are discussed in Section 5.8.

Figure 17. Perceived Risk of Top Four Natural Hazards in Minnesota



All current jurisdictional Multi-Hazard Mitigation Plans (84) in Minnesota were reviewed for hazard ranking. Not every county ranked hazards. Seventy-four hazard mitigation plans included an indication of ranking (though did not necessarily specify a method) for the hazards. The jurisdictional ranking for the natural hazards included in this plan can be seen in *Appendix C – Jurisdictional Ranking of Natural Hazards in HMP*. Figure 17 shows the perceived risk of counties and tribal governments identifying risk rankings for the top four Minnesota hazards.

The statewide flood risk analysis included in this plan includes a "level 1" Hazus analysis for those jurisdictions where floodplain data is not available. Jurisdictions are encouraged to develop "level 2" Hazus analyses for inclusion in flood risk assessment. While it is challenging for many jurisdictions to produce the data necessary for this input, the fact that 30 of Minnesota's 87 counties now have "level 2" analyses complete may incentivize counties to advocate for floodplain data and/or develop a workflow to make tax and parcel data available for this analysis. The difference between these flood analyses is discussed further in Section 4.7.1.

4.6 Risk Exposure of State Assets

S5. Does the risk assessment address the vulnerability of state assets located in hazard areas and estimate the potential dollar losses to these assets? [44 CFR §§201.4(c)(2)(ii) and 201.4(c)(2)(iii)]

State-owned and operated facilities are important centers that link the government of the State of Minnesota to the public it serves. These facilities range from the State Capitol building in St. Paul to storage buildings for transportation centers throughout the state. These facilities are hubs for everything from administrative activities to public safety functions and every conceivable role in between. Should these facilities be rendered inoperable by an incident, the public would lose a vital link with their government and the services it provides.

4.6.1 Statewide Essential Facilities

Schools, hospitals, fire and police station facilities location data was compiled from public sources (Table 15). The databases containing these facilities do not include value or capacity of the facilities. Essential facilities locations were considered in the flood analysis Section 4.7.1, and an estimated value was assigned to facilities in affected areas. The valuation methodology is described in that section.

Table 15. Essential Facilities Data Sources, 2018

Facilities	Count	Source	Filter
Schools	2396	MN Department of Education	Schools with lunch programs. Does not include school level "district" or "library"
Police Stations	531	MN Geospatial Commons	All in Minnesota
Fire	987	Homeland Infrastructure Foundation Level Data (HIFLD)	All in Minnesota
Critical Care	498	MN Department of Health	Hospital, Nursing Homes, Boarding Care Home. Does not include Hospice, dialysis centers supervised living facilities

4.6.2 Statewide Critical Facilities and Infrastructure

In addition to the essential facilities, the availability of critical facilities locations was also assessed. Table 16 below outlines the available data by general category; however, availability is not comprehensive and some categories may be redundant. Emergency services data were discussed above as essential facilities. Many of the critical facilities are discussed in other sections of this plan as noted. These data did not all have accurate locational data associated with them, and were not all able to be assessed for vulnerability in terms of value or in a site-specific way. Vulnerability is described for the sectors that have a hazard assessment section noted.

Table 16. Critical Facilities Data Sources, 2018

Critical Facility & Infrastructure Sectors	Available State-Wide Data	Source of Data
Chemical Facilities	EPA Tier II Facilities MPCA potentially contaminated sites, permits, licenses, inspections, etc. MPCA Remediation Sites	MN Depart of Safety – HSEM MPCA
Government Buildings and State-Owned Buildings (see Section 4.7.1)	ARCHIBUS database COPE report (insured state-owned buildings)	Department of Administration (ADM) Department of Administration (ADM)
Communications	Applied Rapid Matrix for Emergency Response (ARMER) Communication & Radio Towers	Minnesota Department of Transportation (ARMER sites) Federal Communications Commission (antenna structure registration)
Correctional Facilities	Prisons	Minnesota Department of Corrections
Critical Manufacturing	No state-wide geospatial data available	No statewide source known
Dams and Levees (see Section 4.7.6)	Inventory of Dams in Minnesota National Levee Database	Minnesota Department of Natural Resources U.S Army Corp of Engineers
Energy	Electric Transmission Lines & Substations	Minnesota Geospatial Information Office
Food & Agriculture	Food manufacturing, processing Livestock feedlots	No statewide source known Minnesota Pollution Control (feedlots)

Critical Facility & Infrastructure Sectors	Available State-Wide Data	Source of Data
Transportation Systems (see Section 4.8.6)	Airports, heliports, sea plane bases Roads, Passenger Rail, bridges	Federal Aviation Administration (airports) MN DOT (roads, rail)
Water (see Section 4.8.1)	Wastewater Facilities Wells	MPCA (wastewater facilities) MN Geological Survey (active public & municipal wells)

Highways

The primary mode of transportation in Minnesota is highways. Minnesota has the fifth largest highway system in the United States. Minnesota has nearly 143,000 miles of streets, roads and highways and 19,600 bridges. MN DOT is directly responsible for the trunk highway system and its bridges.

Centerline miles are defined as the measure in length of roads and highways throughout the country. Trunk Highways (Interstate, U.S., and MN Hwy routes) contain only 9% of the centerline mileage in Minnesota, but they carry 58% of the annual miles of vehicle travel. By contrast, County State Aid and County Road routes contain 32% of the centerline mileage, but they carry only 24% of the annual miles of vehicle travel (Table 17) (MNDOT, 2019).

Table 17. Miles vs. Travel Comparison

Route Type	Center Line Miles	Vehicle Miles Traveled (VMT)	% Miles	% VMT
Interstate	914	252,986,737	0.7	31.6
U.S. Hwy	3,245	89,103,389	2.3	11.1
MN Hwy	7,697	119,613,283	5.6	14.9
County State Aid	30,584	124,015,111	22.1	15.5
County Road	14,326	5,587,155	10.3	0.7
Municipal State Aid	3,382	98,140,883	2.4	12.2
Municipal Street	18,816	104,032,316	13.6	13.0
Township	53,717	8,211,086	38.7	1.0
Other	6,019	271,577	4.3	0.03

Source: MN DOT Highway Data 2018

The Seven-County Metro Area contains only 12% of the centerline mileage in Minnesota, but it accounts for 48% of the annual miles of vehicle travel. The Greater Minnesota counties contain 88% of the centerline mileage in the state and account for 52% of the annual miles of vehicle travel (MNDOT, 2019).

Minnesota has nearly 20,000 bridges ranging from roads on culverts to massive spans across rivers and lakes. The Interstate-35W bridge collapse on August 1, 2007, was a catalyst in Minnesota that spurred increased bridge inspections and maintenance along with replacement of impaired bridges. MN DOT's Bridges and Structures program sets criteria for design, inspection, and maintenance. Inspection reports are retained, and the results are digested in annual bridge reports. The program also provides tools to determine the hydraulics for construction, replacement, or modification of bridges (MNDOT, 2019).

Railroads

The majority of railroads in Minnesota are owned and operated by companies dedicated to freight operations (Table 18). The Northstar Line is a commuter rail that operates on 40 miles of existing track and right-of-way between Big Lake and Minneapolis, and is owned by the BNSF Railway. Amtrak operates the only intercity passenger rail service in Minnesota on the Empire Builder route, which connects Seattle and Chicago.

Minnesota has two light rail lines. One runs between downtown Minneapolis and the Mall of America in Bloomington, and the other runs between downtown Minneapolis and downtown St. Paul. Both lines are operated by Metro Transit.

Table 18. Freight Railroads Operating in Minnesota

Type	Number of Operators	Miles of Track Operated in Minnesota	Percent of Total Miles Operated
Major Railroads	4	3,634	73.8
Regional and Short Line Railroads	12	1,016	20.6
Switching and Terminal Railroads	3	156	3.2
Captive Industry Railroads	2	119	2.4
Total	21	4,925	100%

SOURCE: MINNESOTA STATE RAIL PLAN 2015 UPDATE

Class I railroads are defined as the largest railroads with revenues exceeding $319.3 million (based on 2004 dollar values). There are seven such carriers operating in the United States, four of which operate in Minnesota: Burlington Northern Santa Fe (BNSF), Union Pacific, Canadian National, and Canadian Pacific. Class II railroads are defined as railroads operating 350 miles or more with operating revenues of at least $40 million but less than $319.3 million. Class II railroads are also known as regional railroads. In Minnesota there is one Class II railroad: Genesee & Wyoming, Inc. operates the former Dakota, Minnesota and Eastern railroad line west of Tracy, Minnesota. Class III railroads encompass all remaining railroads with revenues less than $40 million and that are engaged in line-haul movement (Minnesota State Rail Plan, 2015).

Commercial Waterways

The Mississippi River System stretches over 195 miles in Minnesota and supports four ports that have a combined 2016 tonnage of 14.7 million net tons. The river accounts for over 50% of the state's agricultural exports. The largest river commodities are agricultural products such as corn, soybeans, and wheat. In 2016, more than seven million tons of grain were shipped down the river in Minnesota. River ports also handle commodities such as fertilizer, cement, steel, scrap metal, petroleum, caustic soda, and anhydrous ammonia, among others (MNDOT, 2019).

The Mississippi River Navigation System is maintained by the U.S. Army Corps of Engineers (USACE), which dredges rivers to maintain channels for nine-foot deep barges and operates the 29 locks and dams on the Upper Mississippi. The locks are also used by recreational boaters at no cost. The commercial barge operators on the river pay a user fee of 20 cents per gallon of fuel purchased. These fees are used to pay for half of major federal lock structure improvements (MNDOT, 2019).

Minnesota contains three active ports on Lake Superior, in Silver Bay, Two Harbors, and Duluth/Superior. In 2016 the combined waterway tonnage for these ports was nearly 50 million tons. There is currently an increasing demand for taconite, and in 2016 the total amount of taconite shipped from Minnesota was over 33 million tons, accounting for 68% of Minnesota's Great Lakes tonnage for the year. Western coal is the second leading commodity shipped from Duluth/Superior, while other commodities include grain, cement, salt, steel, limestone, and wind generator components (MNDOT, 2019).

The Great Lakes/St. Lawrence Seaway has 16 locks. The U.S. Army Corps of Engineers operates three of the 16 locks and maintains a 29-foot deep channel throughout this system. The Canadian government operates and maintains the other 13 locks (MNDOT, 2019).

Aeronautics

Aviation is an important part of the transportation system in Minnesota (MNDOT, 2018). The aviation industry consists of three distinct parts.

- General aviation may be characterized as small aircraft used for private or small business purposes. The aircraft include business jets, single and multiple engine airplanes, balloons, and ultralight/experimental aircraft. Drones are a newer enterprise that fits under general aviation. Both private and public sectors operate aircraft in this category. General aviation is the largest part of the industry, consisting of 75%.
- Air carriers that charge for transporting people and cargo make up 20% of the industry.
- Military activity comprises 5% of the industry.

Minnesota airports are comprised of the following:

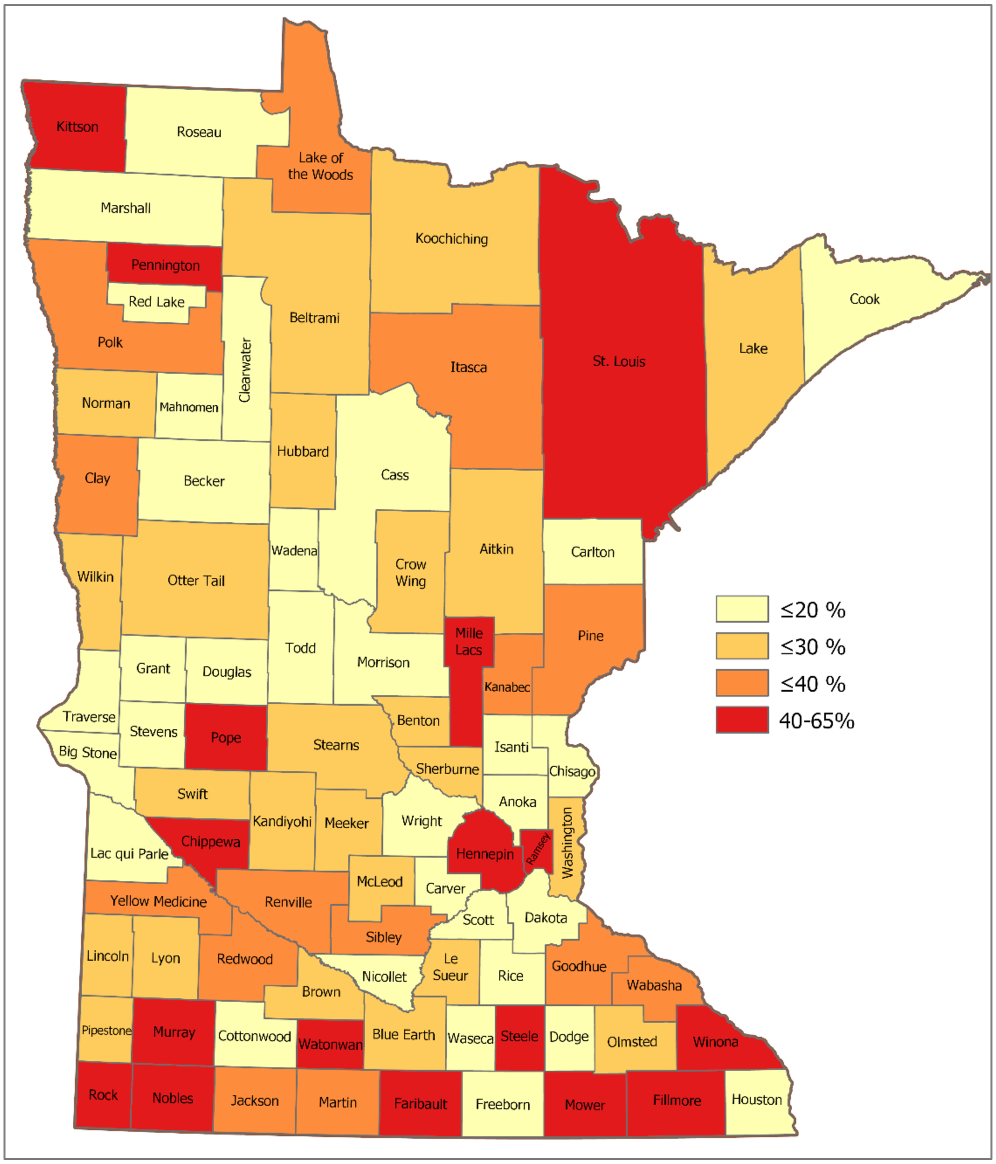
- Eight commercial airports with runway lengths capable of handling large airliners.
- One hundred paved runways designed for smaller private and business type aircraft.
- Five paved runways with seaplane bases for smaller private and business type aircraft.
- Twenty-two turf airstrips for light recreational and private aircraft.

Transportation hazard incidents are outlined in Section 4.8.6, and bridges are additionally discussed in Section 4.7.1 Flooding.

Water and Sewer Infrastructure

Minnesota has a vast amount of aging infrastructure. This infrastructure protects public health and provides vital services to residents throughout the State. Maintaining, rehabilitating and replacing this infrastructure over the next few decades will be challenging without proper planning. Many communities do not have a large enough population base to spread the costs across of these large capital projects. The percentage of each counties total sewer lines that are greater than 50 years old are shown in (Figure 18). The Minnesota Smart City Infrastructure Stress Transparency Tool is an online tool that provides public access to sewer financials, production, and ages by city and sanitary district. The goal of creating these maps and reports is to better inform the decision making process at all levels of government to improve the long term financial planning for our civil infrastructure needs.

Figure 18. Percentage of Sewer System Miles over 50 Years Old of Total System Mileage



4.6.3 State-Owned Properties

State-owned properties (active or inactive, and not buildings under construction or leased) were identified using the state integrated workplace management system (IWMS), ARCHIBUS, managed by the Minnesota Department of Administration (ADM) Enterprise Real Property Department (ERP). Only nineteen agencies use this IWMS, so it is not comprehensive. Furthermore, some agencies do not have all buildings assessed in order for a value to be calculated. ERP uses a standardized facility condition assessment (FCA) process to populate current replacement value (CRV) for each building. CRV is a calculated dollar amount representing the estimated cost to replace a building and is based on 2017 RS-Means construction costs for basic labor, materials and equipment. A system quantity is needed from the building being assessed and is applied as a multiplying factor to the system unit cost. The buildings reported in ARCHIBUS for this query totaled over $8.8 billion (Table 19).

Table 19. State-owned Facility Exposure Reported in ARCHIBUS

Agency Name	Number of Structures in database	CRV sum
Agriculture	1	$7,079,845
Amateur Sports Commission	24	$170,280,044
Department of Administration	56	$1,729,319,518
Department of Commerce	1	$793,588
Department of Corrections	331	$2,625,984,833
Department of Employment & Economic Development	2	$6,819,591
Department of Human Services	169	$831,325,918
Department of Natural Resources	2881	$623,882,633
Department of Transportation	896	$1,277,929,794
Historical Society	154	$318,226,310
Iron Range Resource	65	$48,509,696
Military Affairs	1324	$623,010,068
Minnesota State Academies (not assessed)	19	$0
Minnesota Veterans Affairs	63	$313,818,411
Minnesota Zoological Garden	124	$179,415,066
MN State Retirement Systems	2	$46,787,116
Perpich Center	5	$37,351,824
Pollution Control Agency	18	$10,523,744
Public Safety	6	$4,611,357
State Fair (not assessed)	77	$0

SOURCE: ARCHIBUS, MN ENTERPRISE REAL PROPERTY

Critical facilities are not easily identified in the state-owned building database. There is no differentiation between the functions performed within the facility, and the facility itself. In some cases the occupants of a facility are critical assets, but not the actual building or location. On the other hand, the building itself may be a critical facility because the functions performed at the facility are necessarily intertwined with the structure (e.g. a state prison). ARCHIBUS does track building criticality related to deferred maintenance and building replacement costs. For some agencies an assessment of building capacity, room type, and available internet options to identify buildings that can serve as a locational backup during a disaster. Additionally, MnDOT has initiated a project to assess how critical their infrastructure is in three categories. (Mussett, personal communication, ERP, ADM, 2019). None of these data were not available to access for this plan.

Essential facilities reported by state databases were evaluated for risk of exposure to flood, as were all state buildings. There may be redundancy within these datasets.

Minnesota Universities and Colleges

The University of Minnesota (UMN) and Minnesota State Colleges and Universities (MNSCU) track their capital building assets in separate IWMS systems. In 2014 the UMN listed gross capital building assets with improvements at $425 billion and MNSCU listed building assets $3.1 billion.

State-Leased Properties

The state maintains some liability for properties it leases from other owner as well as properties it rents out. The Department of Administration reports the state leases 664 properties from non-state entities with an annual rent expense of $130.7 million. The state also has at least 53 leases to non-state entities, for a total annual rent income of $1.3 million. These properties were geo-coded and their associated flood risk is noted in Section 4.7.1.

Properties in Minnesota's Risk Management Fund

The Department of Administration provided a Construction Occupancy Protection Exposure (COPE) report of all properties insured through the State of Minnesota's Risk Management Fund. These properties may be redundant with properties reported in as leased or in ARCHIBUS, however, the total exposure of state properties value is presumed to be more comprehensive. The structure only exposure totaled $25.3 billion as of January 31, 2018.

4.6.4 Federal Public Assistance Review of State Facilities and Infrastructure

ADM Risk Management carries comprehensive insurance on most state owned facilities that includes flood insurance. While this coverage is not a mitigation measure, it reduces the burden to the Public Assistance (PA) program when declarations are declared in Minnesota. The number of structures covered by the Risk Management comprehensive policy has increased since the last plan update due to more participation of agencies.

A review of Public Assistance data from the years of 1999 – 2018 in Table 20, reveals some relative risk among agencies. The complete list of requests can be found in *Appendix R – PA Grant Program (CDFA Number 97.036), Funded Projects.*

Table 20. Public Assistance by Agency, 1999 - 2018

PA Data for DR-1283 to DR-4390 (1999 to 2018)	Cost all categories or work
METROPOLITAN AIRPORTS COMMISSION	$394,709
METROPOLITAN COUNCIL	$1,530,218
MINNESOTA DEPT. OF MILITARY AFFAIRS	$3,958,277
MINNESOTA DEPARTMENT OF ADMINISTRATION	$41,871
MINNESOTA DEPARTMENT OF CORRECTIONS	$111,945
MINNESOTA DEPARTMENT OF EDUCATION	$951
MINNESOTA DEPARTMENT OF HEALTH	$63,326
MINNESOTA DEPARTMENT OF HUMAN SERVICES	$6,238

PA Data for DR-1283 to DR-4390 (1999 to 2018)	Cost all categories or work
MINNESOTA DEPARTMENT OF NATURAL RESOURCES	$12,579,805
MINNESOTA DEPT OF AGRICULTURE	$10,195
MINNESOTA DEPT. OF TRANSPORTATION	$1,944,601
MINNESOTA EMERGENCY MEDICAL REGULATORY BOARD	$14,017
MINNESOTA HISTORICAL SOCIETY	$3,128
MINNESOTA POLLUTION CONTROL AGENCY	$579,623
MINNESOTA STATE BUILDING CODES AND STANDARDS	$20,428
MINNESOTA STATE PATROL	$298,309
MINNESOTA ZOOLOGICAL GARDEN	$60,349
MN DEPT OF LABOR & INDUSTRY	$14,218
UNIVERSITY OF MINNESOTA	$1,923,596
Total	$23,555,804

Public Assistance by damage category is also available in *Appendix R – PA Grant Program (CDFA Number 97.036), Funded Projects*. The most numerous category used is Category B – Protective Measures. A comparison of the two agencies with the highest payments was performed to illustrate mitigation actions.

Table 21. Public Assistance Comparison by Damage Category for MnDOT and MnDNR

Damage Category	MnDOT	MnDNR
A - Debris Removal	$305,318	$528,412
B - Protective Measures	$375,496	$211,080
C - Roads and Bridges	$0	288,987
D - Water Control Facilities	$0	$1,482,733
E - Public Buildings	$375,496	$688,336
F - Utilities	$0	$0
G - Parks, Recreational Facilities	$0	$4,944,704
Total	$1,056,310	$8,144,252

Based on the previous plan, most recovery costs for MnDOT for roads and infrastructure come from the Federal Highway Administration. Category E damages are for state owned structures such as garages and visitor centers. MnDOT is currently insuring these structures in the Risk Management policy.

MnDNR operates facilities in flood hazard areas as part of their mission. One example is Fort Snelling State Park that is located in the flood zone. The park was designed to flood, as most recreational areas are designed. The nature interpretive center is located well above the Base Flood Elevation. Other minor structures are flood-proofed or protected when a flood is predicted. There are no campsites so damages are limited to infrastructure and beaches. MnDNR takes mitigation seriously and funds many of their own projects. Whitewater State Park moved their cabins and camping area to a higher elevation. Lac Qui Parle State Park discussed doing the same with state mitigation staff. The FEMA Public Assistance 406 Hazard Mitigation grant opportunities are discussed with applicants post-disaster. HSEM will continue to coordinates with state agency staff pre and post-disaster to ensure state parks and other state owned and operated facilities are more disaster resilient. For more information about flooding risks to state-owned structures, see Section 4.7.1 and *Appendix E – Statewide Flood Risk Assessment Results.*

4.7 Natural Hazards Assessment and Vulnerability

Each natural hazard is assessed below by addressing historical events, probability of occurrence, vulnerability of state assets, critical facilities and populations as available, and any known expected vulnerabilities due to climate change.

4.7.1 Flooding

A flood is the partial or complete inundation of normally dry land. Floods in Minnesota occur in low-lying areas near streams, rivers, lakes, ponds, and intersections; along roads and roadside ditches; and also in heavily-paved, human-occupied areas of many cities and towns. The various types of flooding include riverine flooding, flash flooding, ice jam floods, coastal flooding, and dam-break floods. Coastal flooding is considered in section 4.7.11 with coastal erosion. Section 4.7.6, Dam and Levee Failure, addresses flooding due to dam or levee failure. Flooding behavior and impacts can be similar in all types of floods. Common impacts of flooding include damage to personal property, buildings, and infrastructure; bridge and road closures; service disruptions; and injuries or even fatalities (FEMA, Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards, 2013).

Riverine Flooding, also known as overbank flooding, involves water rising out of the banks of streams and rivers. The size of the river and the number of other sources that feed it will determine the amount of time required for the rise to occur. In general, large rivers can take weeks for floods to work through them, whereas many smaller streams are considered “flashy” and may rise and fall within hours or a small number of days.

Riverine floods occur in floodplains that range from narrow, confined channels in the steep valleys of mountainous and hilly regions, to wide, flat areas in plains and coastal regions. The amount of water in the floodplain is a function of the size and topography of the contributing watershed, the regional and local climate, and land use characteristics. In steep valleys, flooding is usually rapid and deep, but of short duration, while flooding in flat areas is typically slow, relatively shallow, and may last for long periods.

In Minnesota, the primary historical cause of flooding in large rivers has been from the “spring freshet,” or, more simply, the melting and drainage of the winter snowpack into area streams and rivers. The larger the snowpack and the greater its water content, the more likely area streams and rivers will be to see flooding, and this annual event has typically marked the highest level a given river will reach that year. In recent years, however, many large rivers have experienced peak levels and flows from warm-season heavy rainfall events. For instance, seven of the ten highest crests on the Minnesota River at Jordan were from spring snowmelt (National Weather Service, 2019). However, the 2nd, 3rd, and 5th highest crests (in 1993, 2010, and 2014) all arose from heavy rainfall.

When large rivers flood from rainfall rather than snowmelt, it is usually attributable to either repeated episodes of heavy rainfall over a period of days or weeks, or from a massive singular extreme rainfall event. Continuing with the example of the Minnesota River at Jordan, the crest in June of 1993 resulted from a four-week period in which the entire basin received a half-dozen rainfall events with daily totals in the range of 1-2 inches, and maximum daily values of 3-4 inches. By contrast, the crest in September of

2010 resulted from a single mega-rain event with a 5,000 square-mile, 20-county footprint of six-inch rainfall totals including pockets of totals in excess of 10 inches. Either type of rainfall scenario saturates the ground and overloads the streams and basins that drain into larger rivers, and almost always entails flash-flooding in those smaller and streams and basins prior to the larger river flooding.

Flash Flooding refers to acute, significant, and sometimes catastrophic surges in water levels near streams, ponds, and even in low-lying areas, typically resulting from prolonged bouts of excessive rainfall. The storms that produce flash flooding may need only a few hours to produce excessive runoff, and as a result warning time in flash flood scenarios is usually minimal. Flash floods transport enormous volumes of water at high velocity, carrying large amounts of debris downstream, tearing out trees, undermining buildings and bridges, scouring new channels, and producing a wide array of significant damages.

The intensity of flash flooding is a function of the intensity and duration of rainfall, steepness of the watershed, stream gradients, watershed vegetation, soil moisture and storage capacity, natural and artificial flood storage areas, and configuration of the streambed and floodplain. Dam failure and ice jams may also lead to flash flooding. Urban areas are increasingly subject to flash flooding due to the removal of vegetation, covering of ground cover with impermeable surfaces, and construction of drainage systems. Local flash flooding can be very destructive along the steep bluffs of Lake Superior and the hilly terrain and narrow valleys of southeast Minnesota; however, flash flooding can occur anywhere in Minnesota. Typically, a flash flood occurs within six hours of a rain event, or after a dam or levee failure, or following a sudden release of water held by an ice or debris jam. Flash floods often catch people unprepared. The actual time threshold may vary in different parts of the country. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters.

The definition of a flash flood per the Minnesota State Climatology Office is "*the occurrence of 6 inches or more rainfall within a 24 hour period.*" The size of a flash flood is measured via area in square miles over which a 4-inch or more rainfall occurs. The rationale for using this criteria is that a rainfall of six inches in a 24-hour period will produce a river flow in equivalent to that in the 1%-annual-chance return period in Minnesota and that four-inch and greater rainfall generally leads to reports of increased erosion or other economic damages.

Ice jam floods usually occur in the spring and are most likely to occur where the channel slope naturally decreases, when culverts freeze solid, in reservoir headwaters, near natural channel constructions (e.g., bends and bridges), and along shallows. The resulting impacts are similar to a flash flood.

Flood History

Notable floods in Minnesota since March of 2013 are summarized in the table below.

Table 22. Major Minnesota Floods, 2013-2018

Year	Areas Affected	Remarks	Total Public Assistance	Per capita impact
2018 FEMA-4390-DR	Aitkin, Beltrami, Blue Earth, Brown, Carlton, Cass, Clearwater, Cottonwood, Faribault, Itasca, Jackson, Koochiching, Lake, Lyon, Martin, Murray, Nicollet, Nobles, Pine, Pipestone, Polk, Redwood, Renville, Rock, St. Louis, Sibley, and Watonwan Counties, as well as the Leech Lake Band of Ojibwe, Red Lake Nation, and White Earth Nation.	FEMA disaster declared on September 05, 2018, due to severe storms, tornadoes, straight-line winds, and flooding during the period of June 15 to July 12, 2018. A well-forecast heavy precipitation event drenched the already soggy southeast part of Minnesota with 4-6 inch rains. An automated rain gauge near Rochester measured 6.64 inches. At the University of Minnesota, saturated fields were an issue as well as street flooding in the hardest hit areas. Rivers that were at flood stage the week before were on the rise once again, and excessive water on the road closed I-90 for about a half-hour between Mapleview and Austin.	*unknown*	*unknown*
2016 FEMA-4290-DR	Blue Earth, Fillmore, Freeborn, Goodhue, Houston, Le Sueur, Rice, Steele, and Waseca.	FEMA disaster declared on November 02, 2016, due to severe storms and flooding during the period of September 21-24, 2016.	$8,128,123	$1.53
2016	Chippewa, Lac Qui Parle, McLeod, Meeker, Kandiyohi, Renville, Sibley, and Wabasha.	Severe thunderstorm event consisting of flash flooding and mudslides during the period of August 10-11, 2016. The highest total of 9.74 inches was recorded just east of Willmar. The arena and track at the Kandiyohi County Fairgrounds flooded. Residents in Willmar were being asked to limit water use due to the impact on the city's wastewater treatment plant.	*unknown*	*unknown*
2016 2016-SD-008	Aitkin, Benton, Carlton, Crow Wing, Kanabec, Meeker, Mille Lacs, Morrison, Pine, and Traverse.	The highest two-day total found was 9.34 inches at a DNR rain gauge site in eastern Pine County. Numerous roads were affected by water in the hardest hit counties. Southbound I-35 was closed for a time. The area covered by at least six inches of rainfall exceeded 2,000 square miles, easily qualifying this as a "mega" rainfall event. Pine County alone would have qualified for this unusual distinction.	*unknown*	*unknown*

Year	Areas Affected	Remarks	Total Public Assistance	Per capita impact
2014 FEMA-4182-DR	Chippewa, Freeborn, Jackson, Murray, Nobles, Pipestone, Renville, and Rock.	FEMA disaster declared on July 21, 2014, due to severe storms, straight-line winds, flooding, landslides, and mudslides during the period of June 11 to July 11, 2014.	$9,476,993	$1.79
2013 FEMA-4131-DR	Benton, Big Stone, Douglas, Faribault, Fillmore, Freeborn, Grant, Hennepin, Houston, McLeod, Morrison, Pope, Sibley, Stearns, Stevens, Swift, Traverse, and Wilkin.	FEMA disaster declared on July 25, 2013, due to severe storms, straight-line winds, and flooding during the period of June 20-26, 2013. A powerful complex of thunderstorms marched across the southern half of Minnesota, producing damaging winds, hail, and flooding rains. It was the second such event in less than 24 hours. The twin storms led to innumerable reports of flooded fields, streets, and basements; rivers and streams leaving their banks; and damage to trees and property. Damaged or downed power lines left over one-half million Xcel Energy customers without electricity at some point during or after the events. Xcel Energy declared it the largest power outage in company history.	$17,855,840	$3.37
2012 FEMA-4069-DR	Aitkin, Carlton, Cook, Crow Wing, Dakota, Goodhue, Kandiyohi, Lake, Meeker, Pine, Rice, Sibley, and St. Louis Counties and the Fond du Lac Band of Lake Superior Chippewa, Grand Portage Band of Lake Superior Chippewa, and the Mille Lacs Band of Ojibwe.	FEMA disaster declared on July 6, 2012, due to severe storms and flooding during the period of June 14-21, 2012. Duluth received 7.24 inches of rainfall in two days. The St. Louis River at Scanlon set a new record crest at 16.62 feet, rising 10 feet in 24 hours.	$26,058,290	$6.55

SOURCES: (MN DNR, 2018) (FEMA , 2018)

The events listed in Table 23 are characterized as historic mega rain events (which requires at least 1,000 square miles of six inches or more rain) by the Minnesota Climatology Office. In this case, record high amounts of rainfall are characterized to show unusually high amounts of damage to communities. In each of the cases a Presidential Disaster Declaration was made. Not all flash flood events require Public Assistance since county and/or statewide thresholds are not met. Not meeting these thresholds indicates that the rainfall event was localized and/or did not cause extensive damage to public infrastructure.

Table 23. Additional Minnesota Mega Rain Events, 1972-2010

Date	Description	Declaration Number
July 21-22, 1972	10.84 inches fell in 24 hours at Fort Ripley. This was the state record for a highest 24 hour total at a National Weather Service station until Hokah broke the record in 2007.	DR-347
June 28-29 and July 1-2, 1975	Geographically extensive and intense rains fell on eastern North Dakota and Northwest Minnesota in two separate events.	DR-473
July 23-24 2002	Greatest calendar day precipitation on record for Twin Cities International Airport with 9.15 inches.	DR-797
June 9-10, 2002	48 hour rainfall totals topped 12 inches in some areas of Roseau and Lake of the Woods counties.	DR-1419
September 14-15, 2004	More than ten inches of rain fell in a 36 hour period in Faribault and Freeborn Counties.	DR-1569
August 18-20, 2007	The 15.10 inches measured one mile south of Hokah still stands as the record 24 hour rainfall at a Minnesota National Weather Service Cooperative station. The three day total for this station was 16.27 inches.	DR-1717
September 22-23 2010	The National Weather Service site in Amboy measured 9.48 inches on September 23, with 10.68 inches for the event.	DR-1941

Source: (MN DNR, 2018)

Probability of Occurrence

Flooding is the number one natural hazard to impact Minnesota. As illustrated in Section 4.2, flooding accounts for the most federal disaster declarations of any hazard. NFIP mapping is an important tool in determining vulnerability to floods for mitigation planning and projects.

All portions of the State of Minnesota are subject to flooding. Some locations, however, are more susceptible to severe, repeated flooding than others. As noted by the Minnesota Department of Natural Resources (DNR), Division of Waters, one river that has flooded consistently nearly every other or every third year is the Red River of the North. Repeated flooding at this location is due primarily to two factors: (1) The river flows north, often into areas that have not yet thawed, hence the water backs up; (2) Flat terrain around the river allows flooding above the banks to go on for miles (much further than most rivers in Minnesota).

A Hazus 1%-annual-chance flood analysis was performed for each county using DFIRMs (digital flood insurance rate maps) or Q3 flood boundaries (FEMA surveyed older data) when available. As of December 2018, 55 counties have preliminary or approved DFIRMs (see

Appendix D – FEMA flood mapping products available or in progress for each county). (Find more information about the NFIP and the MN DNR's Floodplain Management Unit in Section 5.6).

Q3 Flood Data are derived from the Flood Insurance Rate Maps (FIRMS), published by FEMA, and follow standards required for mapping at a scale of 1:24000; however, these maps are often outdated. Fourteen counties have new DFIRMs or preliminary DFIRMS that had no FIRM in 2013. These counties include: Carver, Cottonwood, Lake of the Woods, Le Sueur, Mahnomen, McLeod, Morrison, Pennington, Pipestone, Polk, Red Lake, Rock, Sherburne, and Watonwan.

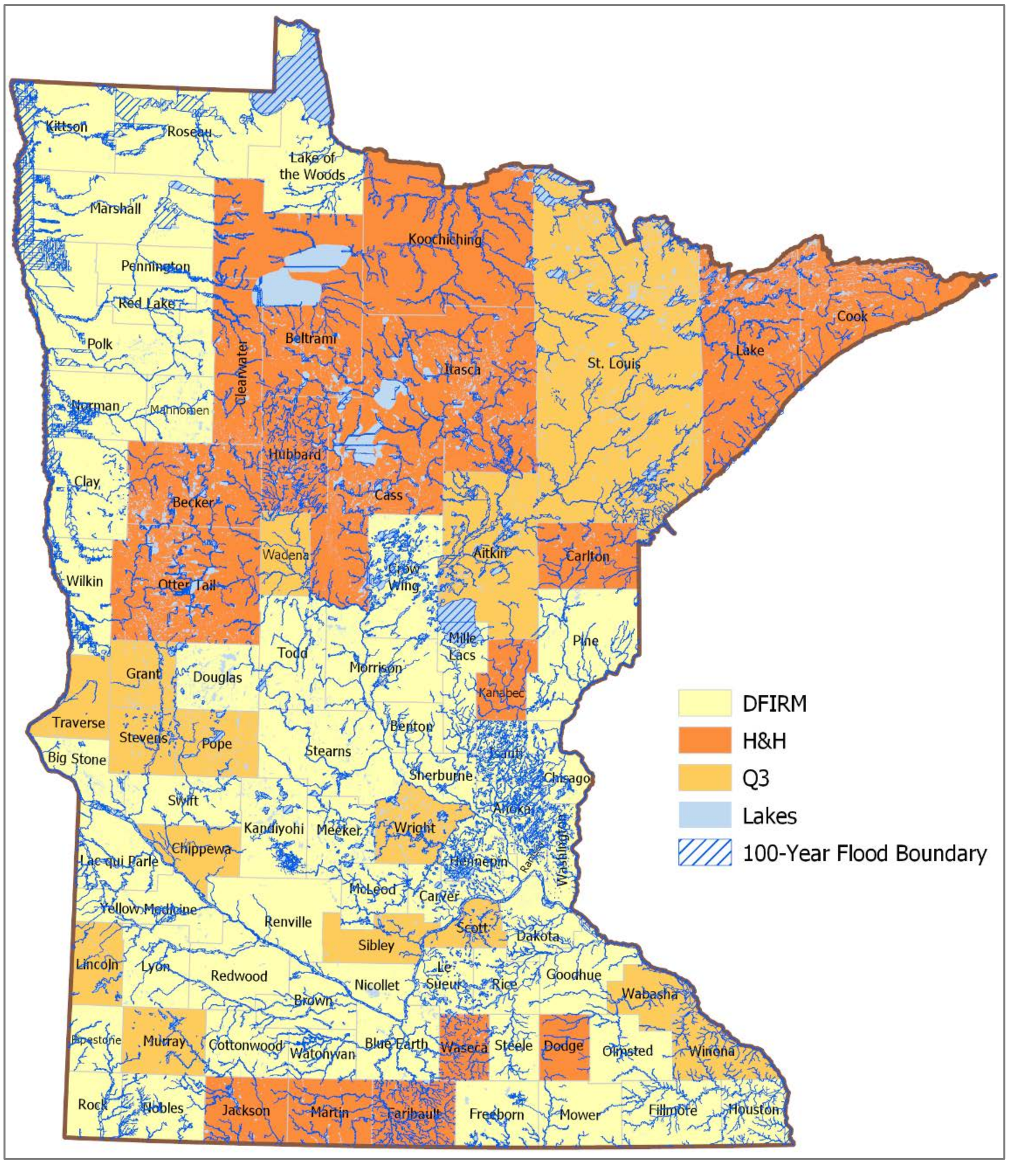
At the time of the flood analysis, 20% of Minnesota counties did not have FEMA flood insurance rate maps available county-wide (Table 24). For counties with no DFIRM or Q3, the Hydrology and Hydraulic method in Hazus (FEMA, 2018) was performed at ten square mile intervals on all reaches generated from USGS 10-meter DEMs. A 10-meter digital elevation model (DEM) was then used to create a flood depth grid for every county based on the flood boundary available or derived. Koochiching and Lake County were exceptions: a 30-meter DEM was used to generate the floodplain and depth grid in those counties. Figure 19 shows the analysis source used and the output of the flood boundaries.

Table 24. Floodplain Sources Used for Risk Calculation in 2018

Sources of Floodplain	Counties (2018)	Ratio (2018)
DFIRM / PreDFIRM	55	63%
Q3 (pre digital FIRM)	15	17%
Hazus Hydrology and Hydraulics model	17	20%
Total	**87**	

SOURCE: (MN DNR, 2018)

Figure 19. Statewide Flood Boundary and Analysis Source.



SOURCE: (FEMA, 2018) (MN DNR, 2018)

Vulnerability

A few different analyses were done to estimate economic loss potential to county structures and to state buildings. The potential loss estimation was performed using Hazus, a risk mitigation tool developed by FEMA (FEMA, 2018).

Hazus flood modeling was performed one county at a time. The Hazus flood model performs an area-weighted and occupancy type-weighted assessment of flood damage to each census block. The result is used to estimate damage at a flood depth determined by the generated flood grid for each occupancy class in each census block. Buildings are considered a total loss once they reach the 50% damage threshold. How the economic loss potential is estimated varies depending on the General Building Stock inventory inputs available for each county.

Estimating building losses for all counties is aggregated by occupancy class per census block (Table 25). Tables showing the statewide flood risk assessment results using updated flood boundary data in 2018 are found in *Appendix E – Statewide Flood Risk Assessment*. In summary, 20,096 structures were found to be a potentially damaged as a result of the analysis. This number is higher than the 2013 number, however the numbers are largely due to the use of different data and Hazus database differences, so a direct comparison cannot be made. The estimated total building loss is estimated to be $3.7 billion, and a total loss (including structure, building contents and economic losses) is estimated at $665 billion statewide. Potential Economic Loss by County is summarized by county in **Error! Reference source not found.**.

Table 25. Estimated Loss Reported by Hazus, 1%-Annual-Chance Flood

General Occupancy	Estimated Total Loss (Buildings, Contents, Economic)	Estimated Building Loss 2018	Total Damaged Buildings 2018
Residential	$5,357,750,000	$2,935,830,000	19,826
Commercial	$3,168,720,000	$397,670,000	178
Industrial	$864,620,000	$205,010,000	55
Other (Government, Education, Agricultural, and Religious)	$2,572,730,000	$180,130,000	37
Total	**$11,963,820,000**	**$3,718,640,000**	**20,096**

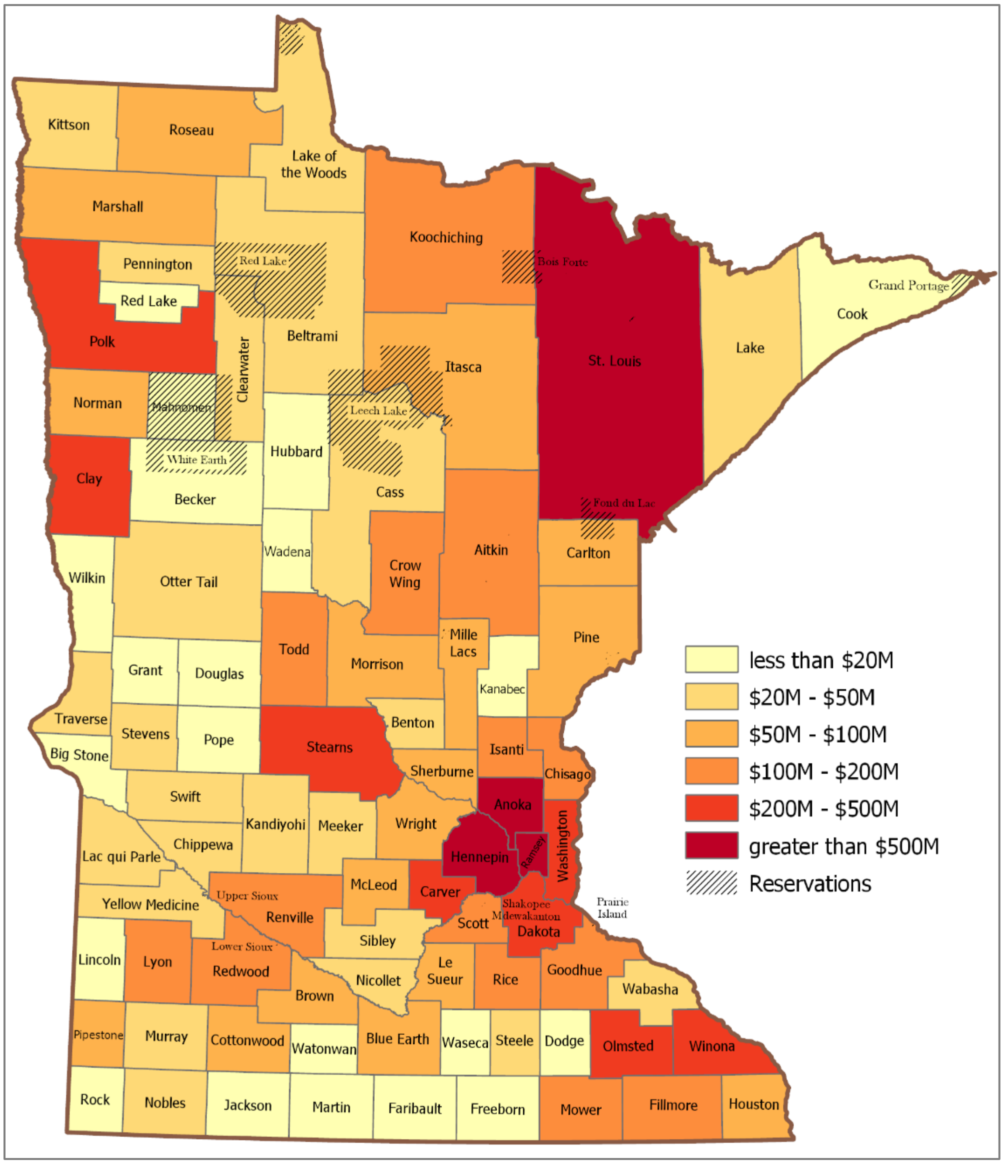
Source: (FEMA, 2018)

A level 1 analysis uses General Building Stock (GBS) databases packaged with Hazus. The level 2 analysis is done with county specific parcel data to estimate values and occupancy class losses. Because twenty-nine counties have had a level 2 Hazus analysis completed since 2014, the outputs of the level 2 analysis, presumably a more accurate estimate, were reported. Collecting data for individual counties for analysis was beyond the scope of the State Hazard Mitigation Plan so for the remainder of the counties, the level 1 model outputs provide a reasonable comparison between counties using the same methods.

The distinctions of the two levels are briefly summarized below.

- **Hazus level 1:** The General Building Stock (GBS) databases packaged with Hazus include residential structures values derived from Census 2010 and non-residential structures derived from Dun & Bradstreet (D&B). Three reports from the Department of Energy (DOE) were used to define regional variations in characteristics such as number and size of garages, type of foundation, and number of stories. Valuation sources are from R.S. Means. The economic loss outputs from these counties do not accurately reflect local replacement values and may have more errors in occupancy classifications, however they can be compared across Minnesota with other counties using the same method.
- **Hazus level 2:** The level 2 analysis is done with county specific tax and building data to estimate values and occupancy class losses. Of twenty-nine counties with a level 2 analysis complete, twenty-two of those had completed in the years 2015-2017, and 7 counties were completed in 2018 using the most current Hazus application an updated model 4.2 SP1. All level 2 analyses required specific building data was sourced from the parcel tax and spatial databases to include building valuations, occupancy class, square footage, year built and number of stories. Attributes were obtained from county assessor's offices and supplemented with regional averages where values were missing.

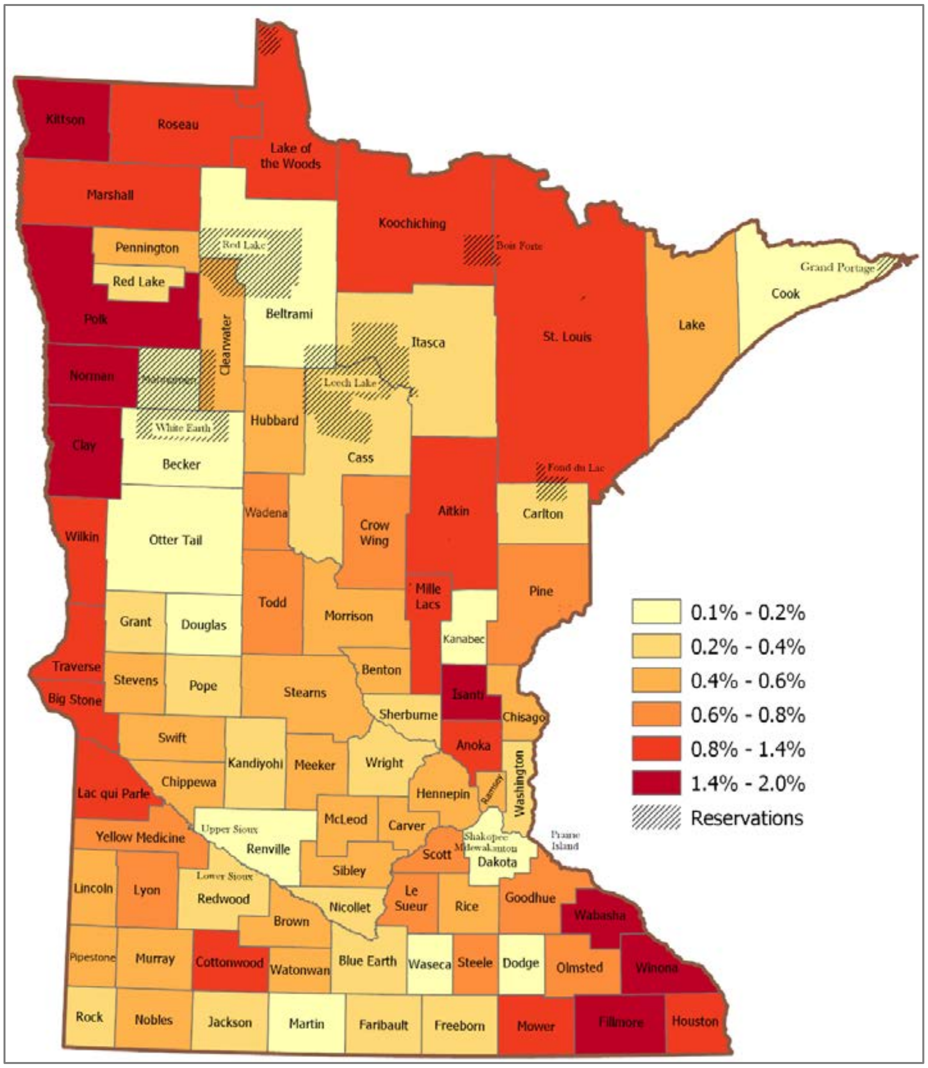
Figure 20.Potential Economic Loss by County, 1%-annual-chance flood



SOURCE: (FEMA, 2018)

The map below demonstrates potential building loss as a percent of total building exposure by county for a 1%-annual-chance flood as estimated by the Hazus model.

Figure 21. Potential Estimated Building Loss to Total Building Exposure by County, 1%-annual-chance flood



Source: (FEMA, 2018)

Damages to crops from floods may also reflect jurisdictional exposure. The total crop indemnity payments due to floods for the 2013-2016 (most recent available) was over $3.6 million with claims in 50 Minnesota counties (CEMHS, 2018). The Spatial Hazard Events and Losses Database for the United States (SHELDUS) (CEMHS, 2018) is a source of other monetary damage reporting. Table 26 shows the 10 counties in Minnesota with the greatest monetary damages from flooding, from 1960 to 2017. The monetary damage data FEMA's Willingness to Pay (WTP) values were used to multiply against the number of windstorm related deaths and injuries in each county; $90,000 for each injured person and $5,800,000 for each person killed. The $90,000 WTP injury value is based on the Treat & Release" injury severity level (FEMA, 2009) because SHELDUS data does not specify the extent of an injury. See *Appendix F - Monetary Damages from Flooding* for the full table of monetary damages from flooding.

Table 26. Top 10 Counties with Monetary Damages from Flooding 1960-2017

County	Injuries WTP	Fatalities WTP	Property Damage (ADJ 2016)	Crop Damage (ADJ 2016)	Total Damages
Polk	$236,700	$812,000	$924,412,915	$979,905	$926,441,520
Olmsted	$236,700	$29,812,000	$267,198,168	$34,363,261	$331,610,129
Roseau	$236,700	$812,000	$278,336,066	$16,639	$279,401,405
Houston	$3,116,700	$18,850,000	$92,427,781	$47,469,299	$161,863,780
Winona	$236,700	$42,050,000	$79,617,806	$36,459,147	$158,363,653
Marshall	$236,700	$812,000	$37,598,792	$114,091,968	$152,739,460
Kittson	$236,700	$812,000	$30,515,081	$115,880,222	$147,444,004
Clearwater	$236,700	$812,000	$19,902,694	$113,556,331	$134,507,726
Pennington	$236,700	$812,000	$19,470,493	$113,612,366	$134,131,558
Cass	$236,700	$812,000	$18,985,889	$113,573,370	$133,607,959

SOURCE: (CEMHS, 2018)

Repetitive Loss and Severe Repetitive Loss Properties

Federal, state, and local funding has resulted in the acquisition of a significant number of repetitive loss structures. The NFIP Repetitive Loss Mitigated data indicates 242 properties have been acquired. The total for these properties for building payments was over $8.9 million, contents payments were over $1.4 million for a total of $10.4 million in losses (FEMA, 2018).

The NFIP Repetitive Loss Non-Mitigated data indicates 463 properties. The total for these properties for building payments was over $18 million, contents payments were over $3.7 million for a total of $21.8 million in losses (FEMA, 2018).

Currently there are 56 repetitive loss properties in Minnesota per the Repetitive Loss Properties Eligible for HMA Funding in Table 27. Payments total 2.7 million for Repetitive Loss and over $5.1 million for Severe Repetitive Loss. Tracking repetitive loss properties that are either eligible or not eligible for HMA funding gives planners a broader insight to the risk found in communities.

Table 27. FEMA Severe Repetitive Loss and Repetitive Loss Properties by County

County Name	# RL properties	# SRL properties	Totals
Becker County	1	0	1
Brown County	1	0	1
Chippewa County	0	1	1
Clay County	3	3	6
Dakota County	1	2	3
Freeborn County	0	1	1
Goodhue County	1	2	3
Hennepin County	1	0	1
Houston County	2	0	2
Le Sueur County	0	1	1
Marshall County	0	3	3
Mower County	8	7	15
Polk County	1	2	3
Scott County	2	1	3
St. Louis County	1	0	1
Sibley County	0	1	1
Steele County	1	0	1
Traverse County	1	0	1
Wabasha County	1	1	2
Washington County	4	2	6
Totals	**29**	**27**	**56**

SOURCE: (FEMA, 2018)

Repetitive loss and Severe Repetitive Loss properties and the HSEM mitigation program to facilitate acquisition of them is covered in Section 5.7. *Appendix G – Repetitive Loss and Severe Repetitive Loss* Properties also list properties by jurisdiction.

The SRL/RL list includes counties from previous lists but adds several smaller counties. The City of Austin is at the confluence of five streams and has been installing flood controls and acquiring properties for green space over the past 15 years. The cities of Oslo and Warren in Marshall County are engaged in extensive flood control projects to reduce flood damage to their cities. Clay County and the City of Moorhead have been very active in flood control and acquisition. Chippewa County is developing flood controls for the City of Montevideo and has been active in acquisition. Goodhue County has acquired properties to mitigate flooding along the Cannon River and its tributaries. These and other jurisdictions with SRL/RL properties are working to mitigation flood losses in their communities.

Vulnerability of Essential Facilities

The most recent facilities databases for the State of Minnesota includes schools, hospitals, fire stations and police stations. The updated state data was used with the 2018 1%-annual-chance floodplain to identify structures potentially in the floodplain (Table 28).

Data per county is found in *Appendix H – Essential Facilities in 1 % Annual Chance Flood Boundary*. A total of 4,412 structures were in the database with 44 of these structures to be found in the in the 1%-annual-chance floodplain. The reduced number of structures in the floodplain likely has to do with precise floodplain data used compared with 2013.

Approximately 1% of the profiled structures were found to be in the floodplain. This may be an overestimation since the analysis did not take into account elevation and data errors. No verification of these structures occurred.

School structure value was calculated based on the 2017-2018 enrollment data from the Minnesota Department of Education. The total was based on the total students multiplied by an average per student cost from previous Hazus databases and adjusted to current value per previous best practice methods.

Care facility structure value was calculated based on the number of beds with a modifier based on a size class derived from the number of beds. Facilities with beds were obtained from the Minnesota Department of Health Care Directory Database.

Fire and Police structure values were based on the Homeland Infrastructure Foundation-Level Data with average values set per type of facility per previous best practice methods.

Table 28. Minnesota Schools, Hospitals, Fire Stations and Police Station Facilities Loss Estimates

County	City	Address	Facility Type	Facility Name	Est Cost of Replacement
Aitkin	Jacobson	68368 198Th Avenue	Fire Dept	Jacobson Fire Department	$840,000
Cass	Pillager	12763 County Rd 1	Education	Pillager Area Charter	$1,692,000
Chisago	Rush City	650 Bremer Avenue South	Healthcare	The Estates At Rush City Llc	$8,820,000
Hennepin	Minnetrista	7701 County Road 110 West	Law Enforcement	Minnetrista Public Safety Department	$1,960,000
Hennepin	Edina	4015 Inglewood Ave S	Education	Calvin Christian-Edina	$3,689,500
Hennepin	St Louis Park	7500 West 22Nd Street	Healthcare	The Villa At St Louis Park	$10,500,000
Isanti	Isanti	903 6Th Avenue Ct Ne Ste A	Education	Art & Science Academy	$16,826,000
Itasca	Bigfork	200 Main Avenue	Law Enforcement	Bigfork Police Department	$1,960,000
Itasca	Bigfork	101 State Highway 38	Fire Dept	Bigfork Fire Department	$840,000
Koochiching	Littlefork	301 Mcpherson Street	Fire Dept	Littlefork Fire Department	$840,000
Koochiching	Loman	State Highway 11 And Midway Lane	Fire Dept	Loman Rural Fire Department	$840,000
Koochiching	Littlefork	700 Main St	Education	L-Bf Elem	$8,883,000
Koochiching	Littlefork	912 Main Street	Healthcare	Littlefork Medical Center	$8,820,000
Marshall	Grygla	115 Valley Street	Fire Dept	Grygla Fire Department	$840,000
Nobles	Worthington	965 Mcmillan Street	Healthcare	Crossroads Care Center	$5,000,000
Norman	Perley	201 Main Street	Fire Dept	Perley-Lee Township Fire Department	$1,200,000
Olmsted	Rochester	305 28Th Street Southeast	Fire Dept	Rochester Fire Department Station 5	$1,200,000
Olmsted	Rochester	251 Wood Lake Drive Se	Healthcare	Comm Behav Hlth Hosp Rochester	$2,880,000
Pipestone	Pipestone	36 Reservation Avenue	Law Enforcement	National Park Service - Pipestone Nation	$250,000
Ramsey	Saint Paul	355 Randolph Avenue	Education	College Prep Elem	$15,933,000
Scott	Savage	12305 Quentin Avenue	Fire Dept	Savage Fire Department Station 1	$1,200,000

County	City	Address	Facility Type	Facility Name	Est Cost of Replacement
Scott	New Prague	1001 Columbus Avenue North	Healthcare	Mala Strana Care & Rehab Ctr	$9,000,000
Sibley	Henderson	210 Main St	Education	Minnesota New Country	$6,157,000
St. Louis	Kabetogama	9940 Cedar Lane	Law Enforcement	National Park Service - Voyageurs Nation	$250,000
St. Louis	Proctor	100 Pionk Drive	Law Enforcement	Proctor Police Department	$1,960,000
St. Louis	Duluth	2138 Minnesota Avenue	Fire Dept	Duluth Fire Department Station 5	$1,200,000
St. Louis	Cook	111 2Nd Street Southeast	Fire Dept	Cook Fire Department / Cook Ambulance Service	$1,200,000
St. Louis	Duluth	1601 St Louis Avenue	Healthcare	Bayshore Health Center Rule 80	$12,000,000
St. Louis	Duluth	3910 Minnesota Avenue	Healthcare	Franciscan Health Center	$8,460,000
St. Louis	Duluth	1601 St Louis Avenue	Healthcare	Bayshore Residence & Rehab Ctr	$13,900,000
Traverse	Tintah	105 3Rd Street	Fire Dept	Tintah Fire Department	$840,000
Traverse	Dumont	Main Street East	Fire Dept	Dumont Fire Department	$840,000
Wabasha	Wabasha	129 Hiawatha Drive West	Fire Dept	Wabasha Fire Department	$840,000
Wabasha	Zumbro Falls	342 State Highway 60	Fire Dept	Zumbro Falls Fire Department	$1,200,000
Watonwan	Madelia	221 6Th Street Sw	Healthcare	Luther Memorial Home	$5,100,000
Watonwan	St James	1101 Moulton & Parsons Drive	Healthcare	Mayo Clinic Health Sys St Jame	$5,580,000
Wilkin	Breckenridge	201 4Th Street South	Fire Dept	Breckenridge Fire Department Station 2	$840,000
Winona	Dakota	725 Frontage Road	Fire Dept	Dakota Fire And Rescue Department	$1,000,000
Winona	Winona	1570 Homer Rd	Education	Winona Middle	$43,569,000
Wright	Delano	433 County Road 30	Healthcare	The Estates At Delano Llc	$5,400,000
Yellow Medicine	Granite Falls	501 Prentice Street	Fire Dept	Granite Falls Fire Department	$1,200,000

SOURCE: *(FEMA, 2018)*

Vulnerability of Other State Assets

Minnesota Colleges and Universities

The University of Minnesota System conducted its own risk assessment in the 2016 UMN Hazard Mitigation Plan. This plan found the following:

There are three University of Minnesota Twin Cities (UMTC) Campus assets located within the 1% annual chance SFHA (also known 4419 as the 100 year floodplain) with an estimated potential loss of $75M. There is one UMTC 4420 Campus asset located within the .2% annual chance SFHA (also known as the 500 year 4421 floodplain) with an estimated potential loss at $69M.

There are two UMD Campus assets located within the SFHA with an estimated potential loss at $2M. The asset is fleet grounds maintenance, and is not located at the main campus area. A second asset – the St.

Louis Bay Aquatic Center – is also within the SFHA. It is possible that the campus could be impacted by other types of flooding, such as overland flooding during spring snow melts, or flash flooding from unusually heavy rain events.

It is highly unlikely that the Crookston campus would experience riverine flooding. However, the campus could be impacted by other types of flooding, such as overland flooding during spring snow melts, or flash flooding from unusually heavy rain events. The University of Minnesota Morris also determined that the risks to the campus from a flooding hazard were very low.

State-owned Structures

260 state-owned structures in the ARCHIBUS database were found to be in the 1% annual chance flood boundary. Of these agencies, the Department of Natural Resources has the majority of the building exposure in the floodplain, however over half of the 237 structures (123) have a CRV of less than $50k. Of the five most valuable DNR structures in the 1% annual chance flood boundary, three are fish hatchery related structures. The agencies, total buildings and current replacement values (CRV) recorded are found in Table 29. This table has been expanded to include all building names in *Appendix I – State-Owned Structures and Values*.

Table 29. State-owned structures in 1% Annual Chance Floodplain

Agency	Number of Structures	Sum of Current Replacement Values
Department of Human Services	1	$587,865
Iron Range Resource	2	N / A
Military Affairs	3	$23,014,302
MN DNR	237	$44,930,990
MN DOT	16	$5,782,338
Total	**259**	**$74,315,494**

Ramsey County stands out as the county with the greatest exposure to flood with one building owned by Military Affairs. Winona and Fillmore Counties both have high exposure for structures related to Lanesboro Fish Hatchery and Whitewater State Park respectively. The structures may be near a watercourse by design. Unfortunately the database containing state structures was somewhat unreliable for locational accuracy, so all records would need to be located with certainty with high resolution imagery or field visits in order to understand the risk to state-owned structures.

Table 30. State-owned structures in 1% Annual Chance Floodplain by County.

County	Buildings	Current Replacement Value
Ramsey	2	$23,014,302
Winona	32	$9,631,065
Fillmore	17	$6,300,327
Anoka	11	$4,391,849
Beltrami	19	$3,775,710
Koochiching	11	$3,612,240
Isanti	2	$3,434,564
Washington	16	$3,418,497
St. Louis	22	$2,877,828
Hennepin	8	$1,848,493
Swift	3	$1,575,890
Hubbard	4	$1,487,131
Wabasha	12	$1,448,142
Polk	9	$1,246,575
Chippewa	13	$1,116,294
Dakota	5	$981,556
Marshall	4	$551,634
Yellow Medicine	5	$491,620
Pipestone	2	$424,297
Blue Earth	1	$336,142
Goodhue	2	$302,435
Freeborn	2	$256,374
Lake	7	$192,480
Otter Tail	3	$174,564
Houston	3	$168,773
Itasca	2	$161,180
Cook	2	$122,703
Clay	4	$119,215
Roseau	2	$118,351
Crow Wing	2	$109,261
Nobles	1	$98,942
Scott	6	$85,318
Carlton	1	$76,858
Wright	1	$61,659
Chisago	4	$55,550
Pine	4	$49,429
Murray	2	$32,845
Clearwater	3	$30,600
Stearns	1	$27,280
Wilkin	1	$27,231
Kittson	2	$25,922
Le Sueur	1	$19,437
Lake Of The Woods	1	$16,517
Mower	1	$10,788
Kandiyohi	1	$7,626
Brown	1	$0
Morrison	1	$0
Grand Total	259	$74,315,494

State-leased Structures

The stated leased-buildings were geo-coded as possible. 78% of the properties could be geocoded from the database, and those locations were intersected with the 1% chance annual floodplain. The state leases 11 properties that appear to fall in this floodplain (Table 31):

Table 31. State-lease Properties in 1% Annual Chance Floodplain

County	Owner	Tenant
Carver	605 Lewis LLC	NR/Region 3
Cass	City of Pine City	Public Safety
Cottonwood	Windom Professional Offices Inc	Human Services
Mower	Nicol's Fast Lube and Car Wash	Public Safety/Driver & Vehicle S
Olmsted	A & A Mini Storage	Agriculture
Olmsted	Rochester Clinic Partners LLC	Human Services/DCT
Otter Tail	Rural Minnesota CEP Inc	Employment and Economic Development
Pine	Benjamin and Heather Ritger	Human Services/DCT/MSOP
Ramsey	River Bend Venture I LLC	Natural Resources
Ramsey	St Paul Flight Center	Transportation

County	Owner	Tenant
Winona	MnSCU; Winona Campus	Employment and Economic Development
Hubbard	NR/Region 1 Leased to:	Hosteling International-US

Vulnerability of state Infrastructure and agricultural areas are also a concern. Stormwater systems are often designed for a fraction of the conveyance needed in a mega rain event. The cost effectiveness of designing and installing systems to higher standards is not cost effective due to the lack of frequency of the events.

Erosion of bridge abutments is another issue associated with flooding. MN DOT maintains a classification system for bridges that identifies bridges susceptible to erosion of the streambed or the approach embankment during flood events (MNDOT, 2009). 1044 bridges are required to have a scour plan of action, which requires monitoring (and potential closure) during periods of high water, due to scour potential (Table 32).

Table 32. Bridges by Ownership with Scour Action Plans

Bridge Scour Code	MN DOT	County	City or Township	Federal	Other State	Other Local or Private	Railroad
TOTAL (1044)	85	470	417	2	54	12	4
O – stable, action required.	24	73	10	0	2	0	2
P – Stable due to protection.	27	24	12	0	0	0	
R – Critical, monitor.	33	174	63	1	2	0	1
U – Critical, protection required.		33	6	0	0	0	
K – Screened, limited risk.	1	134	247	0	22	9	1
G – No evaluation, foundations unknown		32	78	1	28	3	
D – Observed scour, immediate protection required.			1	0	0	0	

Population Vulnerability

River flooding in large rivers like the Mississippi, Minnesota and its tributaries can flood surface streets and low-lying areas, resulting in drinking water contamination, evacuations, and damage to buildings, injury, and death. Flooded buildings can experience mold growth that can trigger asthma attacks and allergies during cleanup efforts. Mental stress following flooding events can cause substantial health impacts, including sleeplessness, anxiety, depression, and post-traumatic stress disorder. Similarly, drought has been identified as a slow-moving stressor that contributes to acute and chronic mental health impacts such as anxiety and depression.

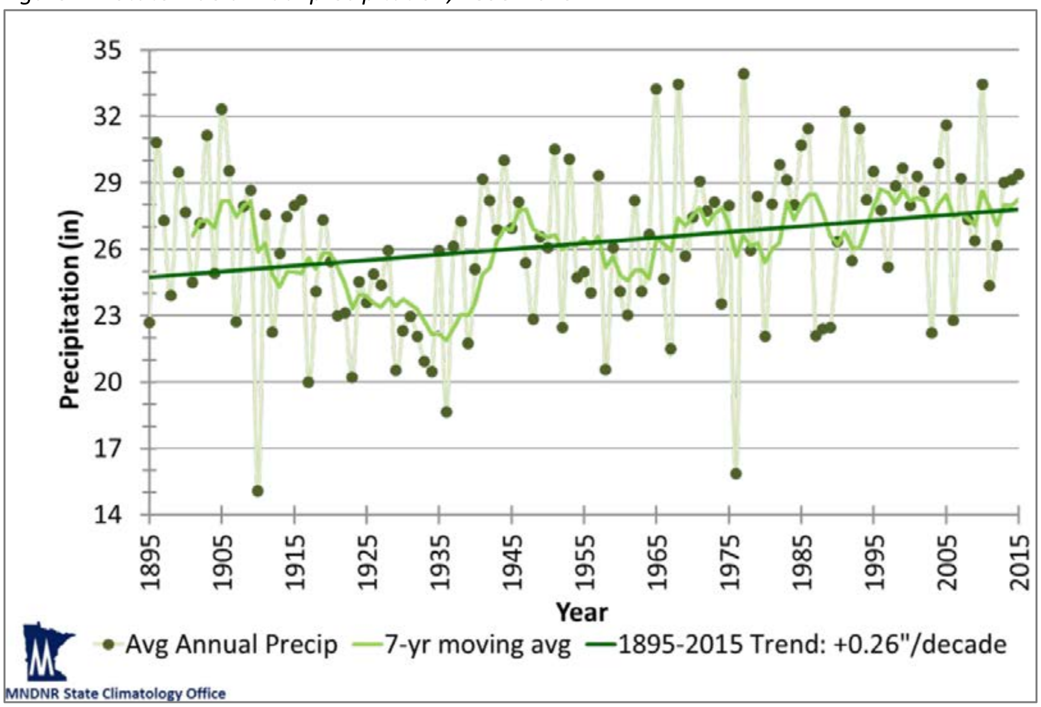
Precipitation events can transport pathogens that cause gastrointestinal illnesses, putting populations who rely on untreated groundwater (such as wells) at an increased risk of disease, particularly following large rainfall events. Many midwestern communities use wells as their drinking water sources. Adaptive measures, such as water treatment installations, may substantially reduce the risk of gastrointestinal illness, in spite of climate change (USGCRP, 2018).

Flooding and Climate Change

The fact that Minnesota will see more frequent extreme precipitation events is a primary concern for Minnesota. Heavy rains are now more common in Minnesota and more intense than at any time on record. Long-term observation sites have seen dramatic increases in 1-inch rains, 3-inch rains, and the size of the heaviest rainfall of the year. Since 2000, Minnesota has seen a significant uptick in devastating, large-area extreme rainstorms as well. Rains that historically would have been in the 98th percentile annually (the largest 2%) have become more common. Climate projections indicate these big rains will continue increasing into the future (MN DNR, 2018).

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. In Minnesota, the result has been increased precipitation, with annual totals increasing at an average rate of just over a quarter inch per decade statewide since 1895 (see Figure 22).

Figure 22. Statewide annual precipitation, 1895-2015

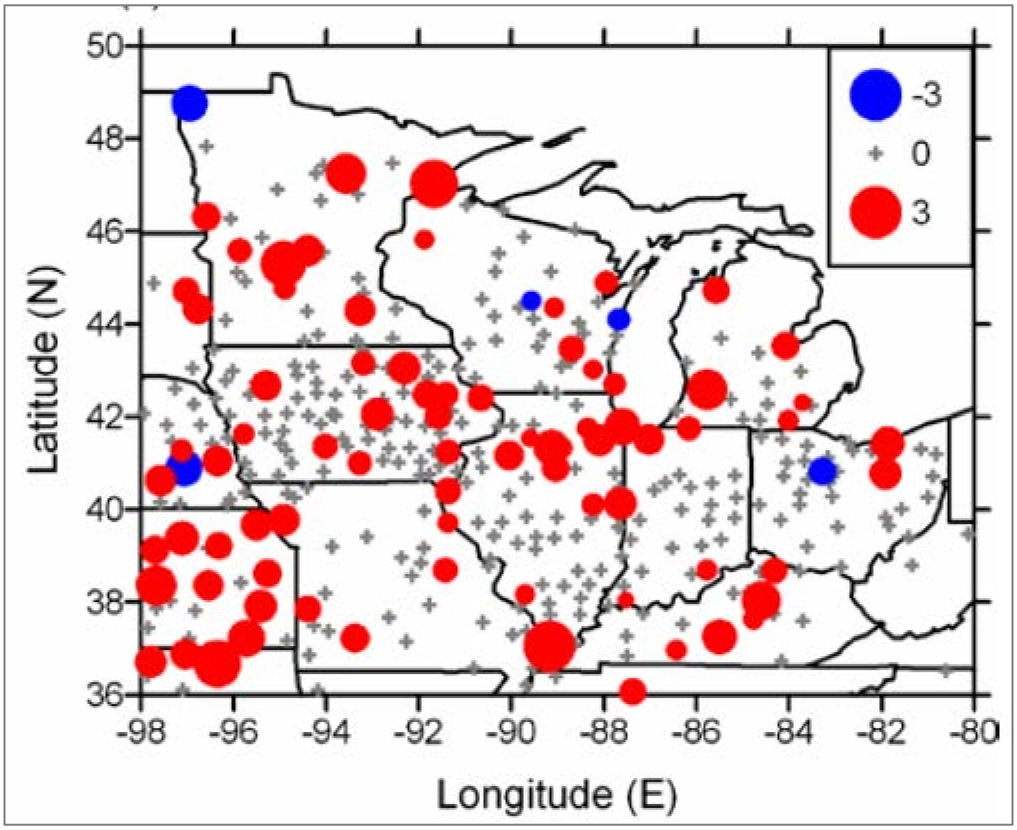


SOURCE: (ICAT, 2017)

This precipitation change has led to increased magnitude of flooding. Figure 23 shows a trend in the sum of the top 10 wettest days in a year for 1901- 2000, expressed in a percent per decade, for the Midwest region. A red circle indicates that the station showed a statistically significant increase through time; a blue circle indicates a statistically significant decrease. A plus symbol indicates that the trend was not significant (shown as 0 in the legend). The diameter of the circle scales linearly with the trend magnitude. Most stations with statistical significance show upward trends. Only stations with 80 years of precipitation data between 1895 and 2002 are shown (Pryor et al. 2009b).

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 23. Percent per decade trend in the sum of the top 10 wettest days in a year for 1901- 2000



SOURCE: NOAA TECHNICAL REPORT NESDIS 142-3: PART 3. CLIMATE OF THE MIDWEST U.S.

4.7.2 Wildfire

A wildfire is an uncontrolled fire spreading through vegetative fuels, exposing and possibly consuming structures. They often begin unnoticed, spread quickly, and are usually signaled by dense smoke that may fill the area for miles around. Wildfires can be human-caused through acts such as arson or campfires, or can be caused by natural events such as lightning. Wildfires can be categorized into four types by source and behavior:

- **Wildland fires** are fueled primarily by natural vegetation in grasslands, brush lands and forests.
- **Firestorms** occur during extreme weather (e.g., high temperatures, low humidity, and high winds) with such intensity that fire suppression is virtually impossible. These events typically burn until the conditions change or the fuel is exhausted.
- **Interface or intermix fires** occur in areas where both vegetation and structures provide fuel. These are also referred to as wildland/urban interface fires.
- **Prescribed fires** and prescribed natural fires are intentionally set or natural fires that are allowed to burn for beneficial purposes.

The following factors contribute significantly to wildfire behavior:

- **Topography**: As slope increases, the rate of wildfire spread increases. South facing slopes are also subject to greater solar radiation, making them drier and thereby intensifying wildfire behavior. However, ridge tops may mark the end of wildfire spread, since fire spreads more slowly or may even be unable to spread downhill.
- **Fuel**: Size class, moisture content and volume are the methods of classifying fuel, with volume also referred to as fuel loading (measured in tons of vegetative material per acre). As fuel loading increases, fire intensity (energy released) and flame length increase, making fire suppression more difficult. Fuels with low moisture content ignite easier than wet fuels. The fuel's continuity is also an important factor, both horizontally and vertically.
- **Weather**: The most variable factor affecting wildfire behavior is weather. Important weather variables are temperature, humidity, wind and lightning. Weather events ranging in scale from localized thunderstorms to large fronts can have major effects on wildfire occurrence and behavior. Extreme weather, such as high temperatures and low humidity, can lead to extreme wildfire activity. In contrast, cooling and higher humidity often signals reduced wildfire occurrence and easier containment.

If not promptly controlled, wildfires may grow into an emergency or disaster. Even small fires can threaten lives and resources, and destroy properties. It is also important to note that in addition to affecting people, wildfires may severely affect livestock and pets. Such events may require emergency watering/feeding, shelter, evacuation and even burying of animals.

The indirect effects of wildfires can also be catastrophic. In addition to stripping the land of vegetation and destroying forest resources, large, intense fires can harm the soil and waterways. Soil exposed to intense heat may lose its capability to absorb moisture and support life. Exposed soils erode quickly and enhance siltation of rivers and streams, thereby increasing flood potential, harming aquatic life and degrading water quality. Lands stripped of vegetation are also subject to increased landslide hazards.

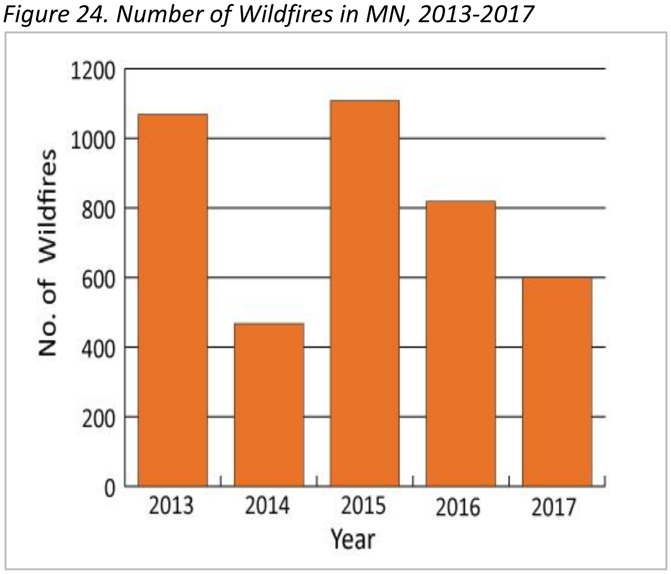
Wildland fires and Wildland fire history

Wildfires can occur at any time of day and during any month of the year; however, the greatest wildland fire activity usually occurs from snowmelt in March or April, through green-up in late May or early June. Careless fire use, arson, equipment use and weather conditions such as wind, low humidity, and lack of precipitation are the chief factors determining the number of fires and acreage burned. Generally, fires are more likely when vegetation is dormant or after extended drought periods.

Wildland fires are capable of causing significant injury, death, and damage to property. Much of the state is covered with forests. The potential for property damage from fire increases each year as more recreational properties are developed on wooded land and increased numbers of people use these areas. Fires can extensively impact the economy of an affected area, especially the logging, recreation and tourism industries, upon which many northern counties depend. There can be major direct costs associated with timber salvage and the restoration of the burned area. Burned woodlands and grasslands may need to be replanted quickly to prevent the possibility of widespread soil erosion, landslides, mudflows and floods which could compound the damage.

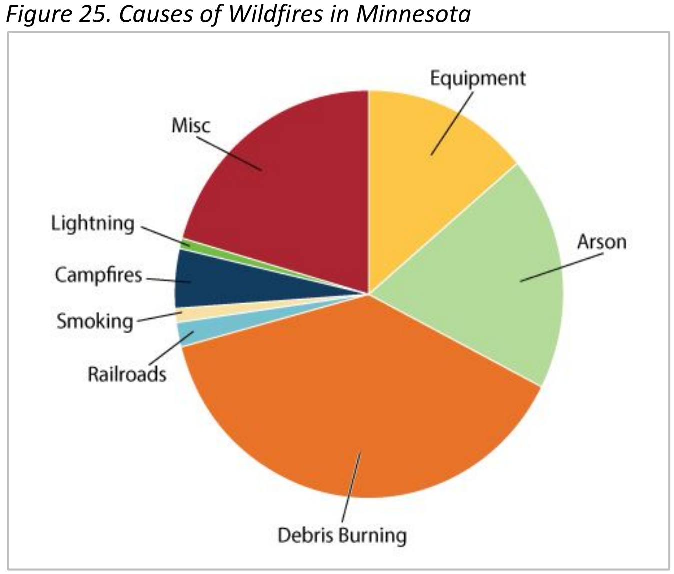
The years 2013 and 2015 recorded over 1,000 wildfires in the state (Figure 24).One in four wildfires are caused by yard debris fires burning out of control (Figure 25). Unattended debris thought to be extinguished continues to be the leading cause of wildfires. Since 2013, vehicles have caused almost half of all fires started by equipment. When parking off-highway, residents should avoid dry, fine vegetation such as grass, since hot exhaust can readily ignite it (MN DNR, 2018).

Figure 24. Number of Wildfires in MN, 2013-2017



SOURCE: MN DNR

Figure 25. Causes of Wildfires in Minnesota



SOURCE: MN DNR

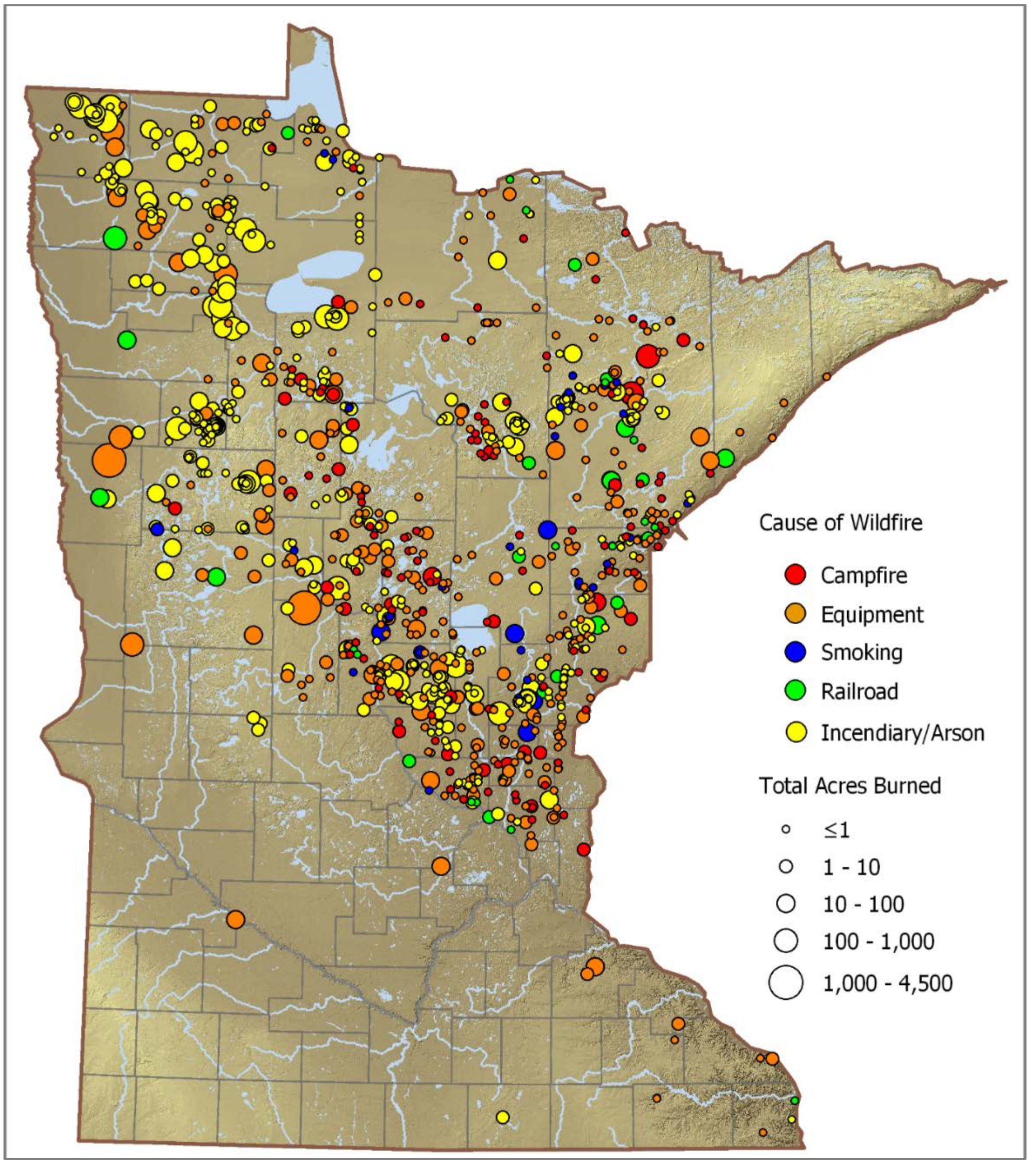
In 2013, the Green Valley Fire started on private land and burned a total of 7,100 acres in Becker, Hubbard and Wadena Counties, destroying 12 homes, 43 outbuildings and 3 commercial structures.

It must be noted that in the residential setting the leading causes of wildland fires are debris burning, arson, and equipment use. However, as the urban-rural interface in Minnesota increases, fire ignition sources become less clear. Urban fires can result from wildland fires in the wildland urban interface where wildland fires usually result from human rather than natural causes.

In May of 2007 the Ham Lake Fire started from a campfire. The fire produced so much smoke that Interstate 35 had to be closed for a period of time. 75,000 acres were consumed (Seeley, 2015).

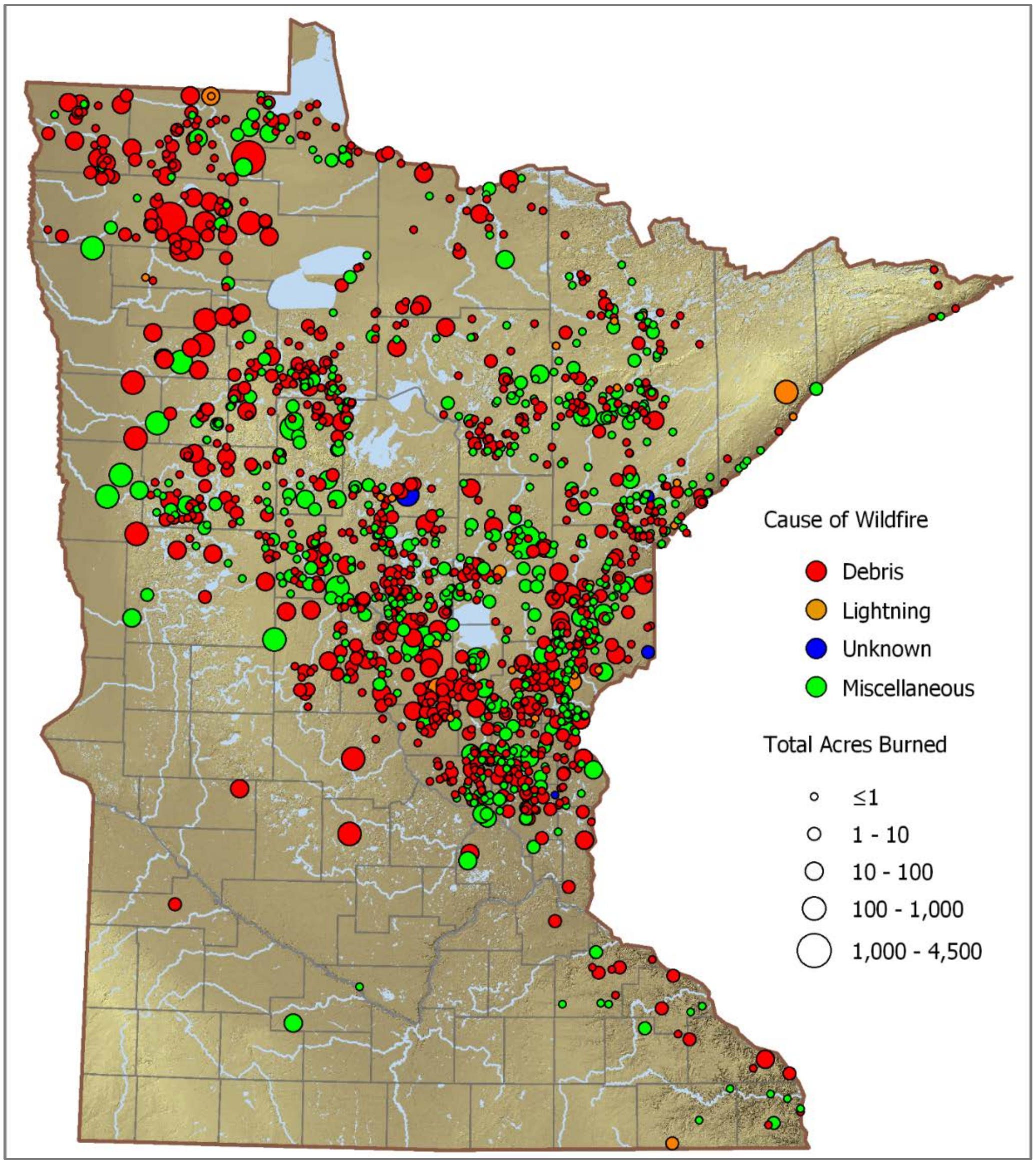
Figure 26 shows the size and cause (campfires, equipment, smoking, railroad and incendiary/arson) of wildfires in Minnesota between 2015 and 2017 as recorded by the MN DNR. Figure 27 shows wildfires caused by debris, lightning, power lines and miscellaneous causes.

Figure 26. Size and Cause of Wildfires from 2015-2017: Campfires, Equipment, Smoking, Railroads, and Incendiary/Arson



SOURCE: MN DNR

Figure 27. Size and Cause of Wildfires from 2015-2017: Debris, Lightning, Power Lines, and Miscellaneous



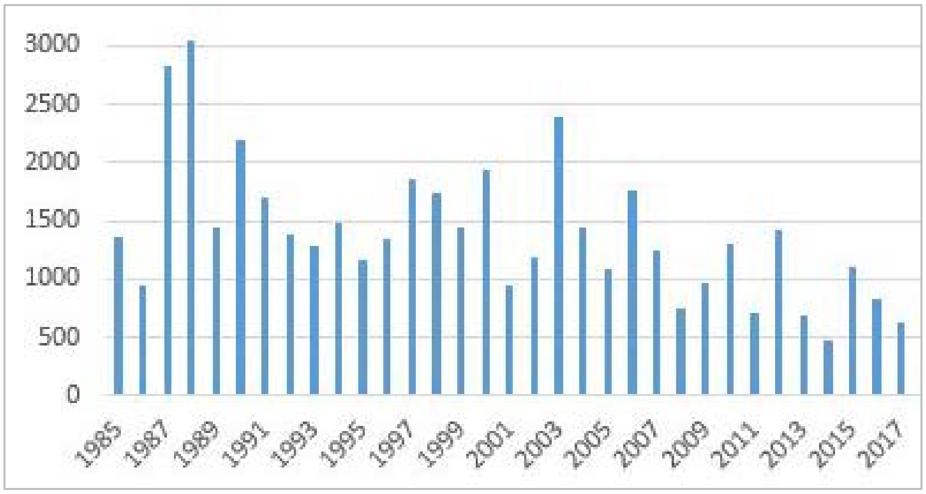
SOURCE: MN DNR

Wildfire frequency has varied throughout time in Minnesota. In the past four decades, the fewest reports occurred in 1973 (713). However, in some years the number of wildfires exceed 2,000. Short- or long-term droughts are generally the rule for those high-frequency years: 1929, 1930, 1931, 1932, 1933, 1934, 1936, 1976, 1980, 1987, 1988, 1990, 2003, 2004, 2006, and 2012. While 2010 was Minnesota's wettest year on record, there were also more than 2,000 wildfires in the state, particularly in the northeastern forested region where severe drought occurred (Seeley, 2015).

Severe drought conditions in July of 2006 coupled with a lightning strike caused the Cavity Lake Fire, which burned more than 31,000 acres (Seeley, 2015).

Figure 28 below depicts the number of wildfires by year in the state, through 2017. According to these statistics, the years of 1987, 1988 and 2003 had the highest incidences of wildfires.

Figure 28. Number of Wildfires in Minnesota by Year, 1985-2017



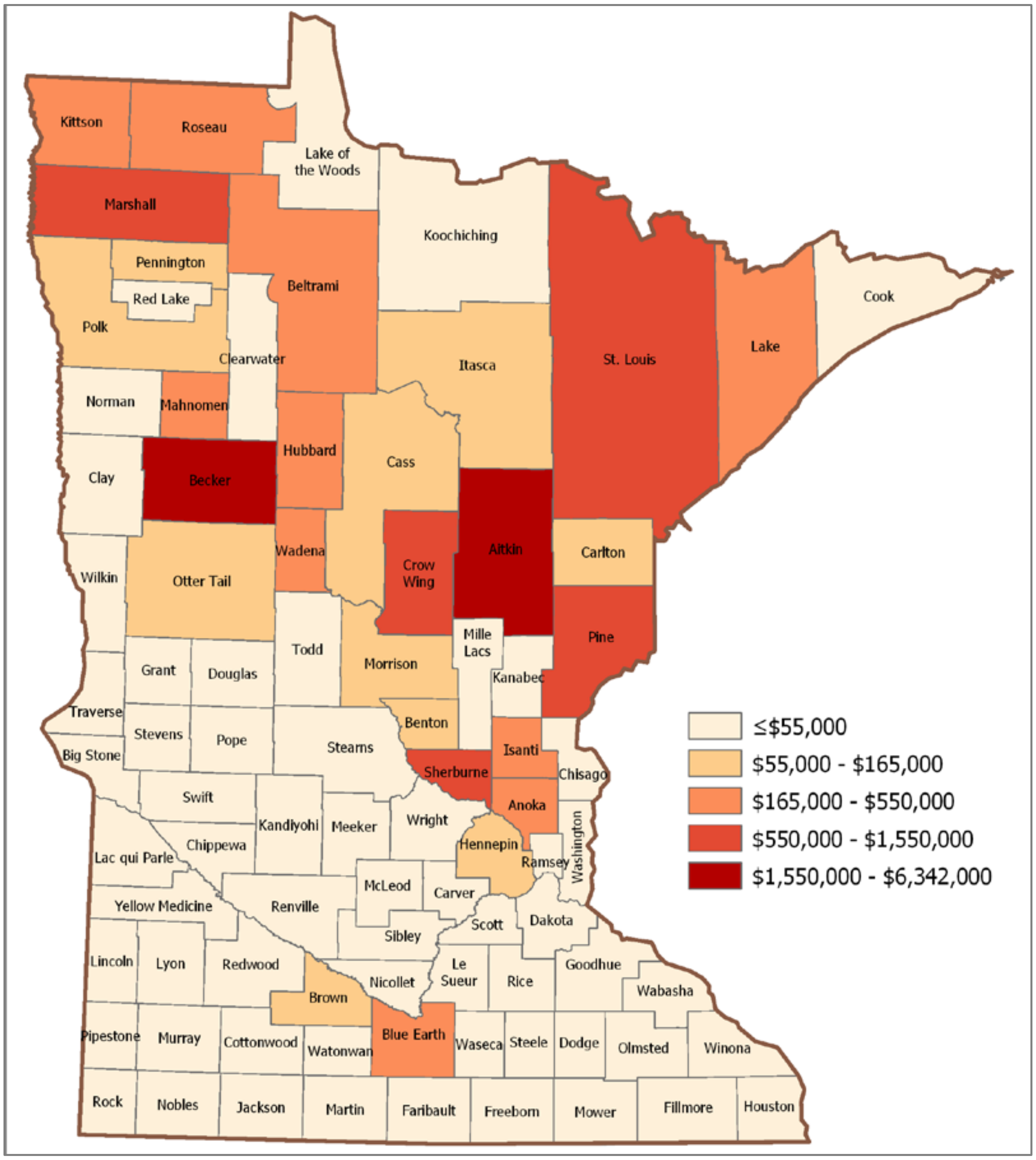
SOURCE: MN DNR

In August and September of 2011, the Pagami Creek Fire burned over 92,000 acres in northern Minnesota. The fire was started by lightning in August, but continued smoldering in a boggy landscape until late August, when low humidity and high winds resulted in the fire spreading through understory growth and jumping through forests as a crown fire. Smoke from the fire traveled as far away as Michigan, Illinois and Ontario (Seeley, 2015).

The extensive costs associated with wildfire are difficult to capture in a single estimate. Besides evacuations and structural damage, the Pagami Creek Fire resulted in substantial costs associated with mobilizing more than 960 firefighters and support personnel to suppress the fire and support affected communities. The Minnesota National Guard was called up to assist with response efforts. Some sources cite that the fire-fighting effort alone cost nearly 23 million dollars. Despite major investments in fighting the fire, essential resources were limited due to aircraft and personnel being dedicated to competing wildfires in the south and west regions of the U.S. In addition, months of battling the flames required a massive cleanup of more than 150 miles of fire hose, water pumps, watercraft, and other gear.

In 2017, the Minnesota Department of Natural Resources (DNR) costs of fighting wildfires topped $25 million with 98% of all wildfires resulting from people (MN DNR, 2018). The DNR is the lead state agency for wildland fire prevention and response. However, other agencies also respond to fires in designated protection areas including local fire departments and federal agencies such as the Bureau of Indian Affairs, Forest Service, Fish and Wildlife Service and the National Park Service. Figure 29 depicts total dollar losses by county due to wildfires from 2007-2017 as reported by the MN DNR.

Figure 29. Losses from Wildfire by County, 2007-2017



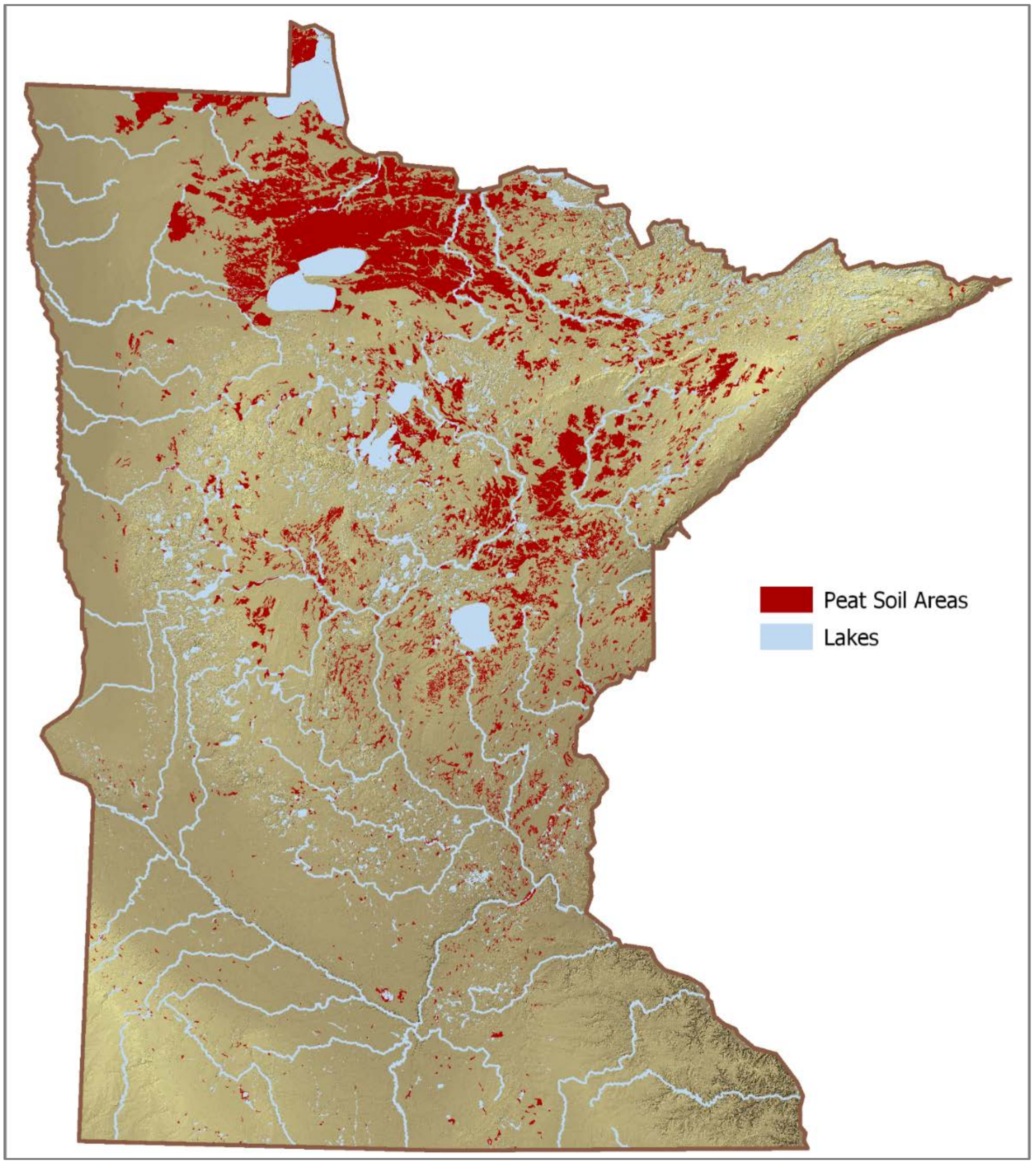
SOURCE: MN DNR

Peat Fires and Peat Fire History

Peat is partially decayed plant matter found in ancient bogs and swamps. Minnesota has approximately six million acres of peatland, the highest total acreage in the contiguous United States, concentrated primarily in northern Minnesota (Figure 30).

Peat fires are deep-rooted fires that burn underground, lasting for weeks, months, or even years. They can smolder during winter months beneath the snow, surfacing again in the spring to burn above ground. Peat ignites when its moisture content is low, and then it supports combustion rather than flame. Once started, combustion is persistent because peat contains oxygen and needs little or no outside oxygen to continue burning. Peat's insulating qualities mean the fire loses little heat. As the peat dries, it becomes water repellent. These factors result in long-lasting fires that require extensive operations to extinguish.

Figure 30. Peat Soil Areas in Minnesota



SOURCE: MN DNR

Peat fires can be extremely difficult to battle because the fire smolders beneath the ground as a glowing combustion rather than as an open flame. Pumping water on a peat fire is often ineffective. Heavy equipment may be needed to alternately work and pack the soil, exposing hot pockets and then sealing them off from surface oxygen. A peat fire can take weeks or months to extinguish, and costs to fight the fire can be substantial.

In 1988, peat fires burned 45,000 acres starting in the spring near Warroad and Baudette on the northern border of Minnesota, one of the largest peat fires. In December 2011, the MN DNR noted a high incidence of peat fires across the state, warning landowners to take caution in burning brush and grasses. Peat fires are normally rare in the middle of winter, but the lack of precipitation in the fall of 2011 made conditions just right.

In March of 2012, dry conditions and sparks from a train ignited a peat bog in a remote area near Brainerd. Over 20 firefighters were dispatched, but the location was too rugged to reach with their vehicles. Then in October of the same year, a series of 8 wildfires flared up and shifted through Northwestern Minnesota. Many of the fires ignited peat bogs making the event more dangerous and unpredictable. One of the eight fires to hit the area had been caused by the reigniting of a peat bog that had been smoldering since the summer of 2012. Since 2012, there have been no other recorded peat fires in Minnesota.

Prairie Fires and Prairie Fire History

Brushland or prairie fires are the primary type of wildland fire in the agricultural areas of southern Minnesota. It is the introduction of fire by prescription, sparks from machines, or lightning that ignite most prairie wildland fires. These fires are usually less of a risk to large populations, infrastructure or wildlife because of the nature of them being in an agricultural or other sparsely populated area. Additionally, many of these fires will occur on private lands and historical records related to their occurrence are difficult to find.

*Figure 31. Houses blaze in Marshall County***Invalid source specified.**

In 2012, a grass fire which started in Marshall County on September 30th became a wildfire 2 days later when south winds increased dramatically (Figure 31). The fire consumed over twelve square miles and led to the evacuation of over 400 people from Karlstad, Minnesota. The fire burned a total of seven homes, two garages, a warehouse, and numerous other outbuildings. One firefighter battling the blaze suffered from heat exhaustion. The fire was 95% contained by October 3rd.

In March 2015, a grass fire, aided by windy and dry conditions, quickly spread through Bartlett Township in Todd County destroying a house and an outbuilding along Highway 210. Fire departments in Wadena, Hewitt, Verndale and Sebeka and the DNR fought the fire with aircrafts and grass units. Fortunately, no one was injured in the event and the area consumed by the fire was estimated to be three miles long and one mile wide.

In April 2018, record size wildfires broke out in western Roseau County in far northern Minnesota. Known as the “County Road 7 Fire”, the wildfire burned about 4,000 acres of mostly grass and swampland habitat north of Roseau County Road 7 about 15 miles northwest of Greenbush. It is the largest fire of the year to date in Minnesota, and the largest since the 2015 Palsburg Fire, which burned 4,558 acres in Beltrami State Forest.

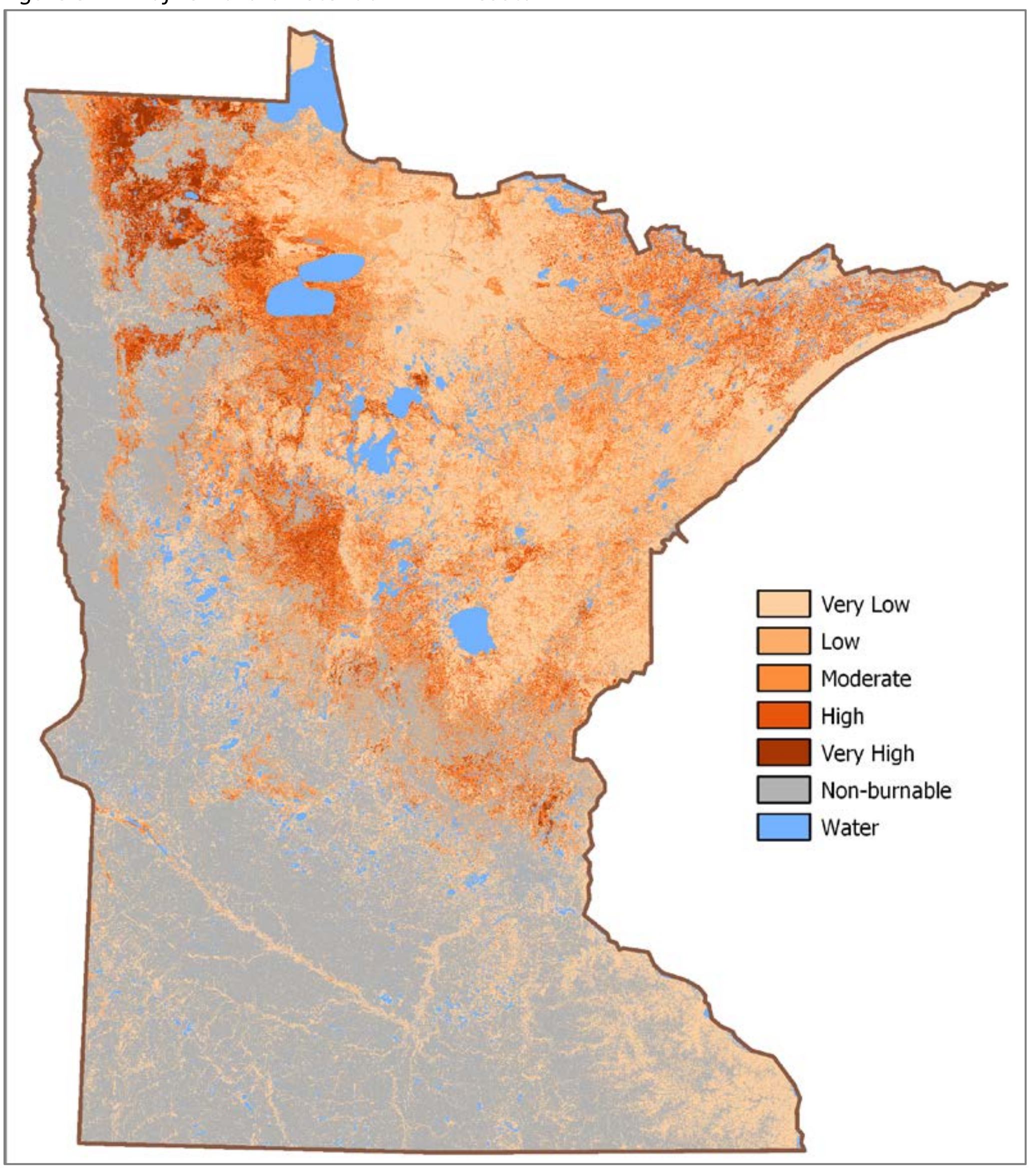
Probability of Occurrence

Like most weather-related phenomena, wildfire probability cannot be accurately predicted in the short-term. It is reasonable to assume that wildfire incidence will remain stable over the long-term, bearing in mind that weather patterns (in particular periods of drought and very low humidity); fuel load, insect infestations and human behavior can all greatly influence near-term probabilities. The qualitative probability is rated High for the state, although the rating is only intended for general comparison to other hazards that are being considered for this stage of the planning process. The MN DNR Wildfire Information

Center provides daily fire weather forecasts, current data on wildfire conditions and burning restrictions throughout the state.

Fires in Minnesota can be classified by their fuel source and setting: forest wildfires, prairie fires and peat fires occur in distinct regions throughout the state. A wildfire hazard potential (WHP) map for the conterminous United States was produced by www.firelab.org that can help inform evaluations of wildfire risk or prioritization of fuels management needs across very large areas (Figure 32). The specific objective with the WHP map is to depict the relative potential for wildfire that would be difficult for suppression resources to contain. The most recent version, from 2014, was built upon spatial estimates of wildfire likelihoods and intensity generated in 2014 with the Large Fire Simulator (FSim) for the Fire Program Analysis system (FPA), as well as spatial fuels and vegetation data from LANDFIRE 2010 and point locations of fire occurrence from FPA (ca. 1992 - 2012). With these datasets as inputs, a WHP index was produced for all of the conterminous United States at a 270-meter resolution.

Figure 32. Wildfire Hazard Potential in Minnesota



SOURCE: USDA FOREST SERVICE, FIRE MODELING INSTITUTE

Areas with higher WHP values represent fuels with a higher probability of experiencing torching, crowning and other forms of extreme fire behavior under conducive weather conditions, based primarily on 2010 landscape conditions.

On its own, WHP is not an explicit map of wildfire threat or risk, but when paired with spatial data depicting highly valued resources and assets such as communities, structures or power lines, it can approximate relative wildfire risk to those resources and assets. WHP is also not a forecast or wildfire outlook for any particular season, as it does not include any information on current or forecasted weather or fuel moisture conditions. Rather, it is intended for long-term strategic planning and fuels management.

Vulnerability

The immediate danger from wildfire is the destruction of timber, property, wildlife, and injury or loss of life to persons who live in the affected area or who are using recreational facilities in the area. Long-term effects include large amounts of scorched and barren land, which may not return to its pre-fire condition for many years. Major fires can completely destroy ground cover, which can in turn cause erosion. Flash floods, landslides and mudflows can occur if heavy rains follow a major fire. A large blowdown, such as the 1999 event in the BWCAW, make losses due to wildfire greater now than in the past.

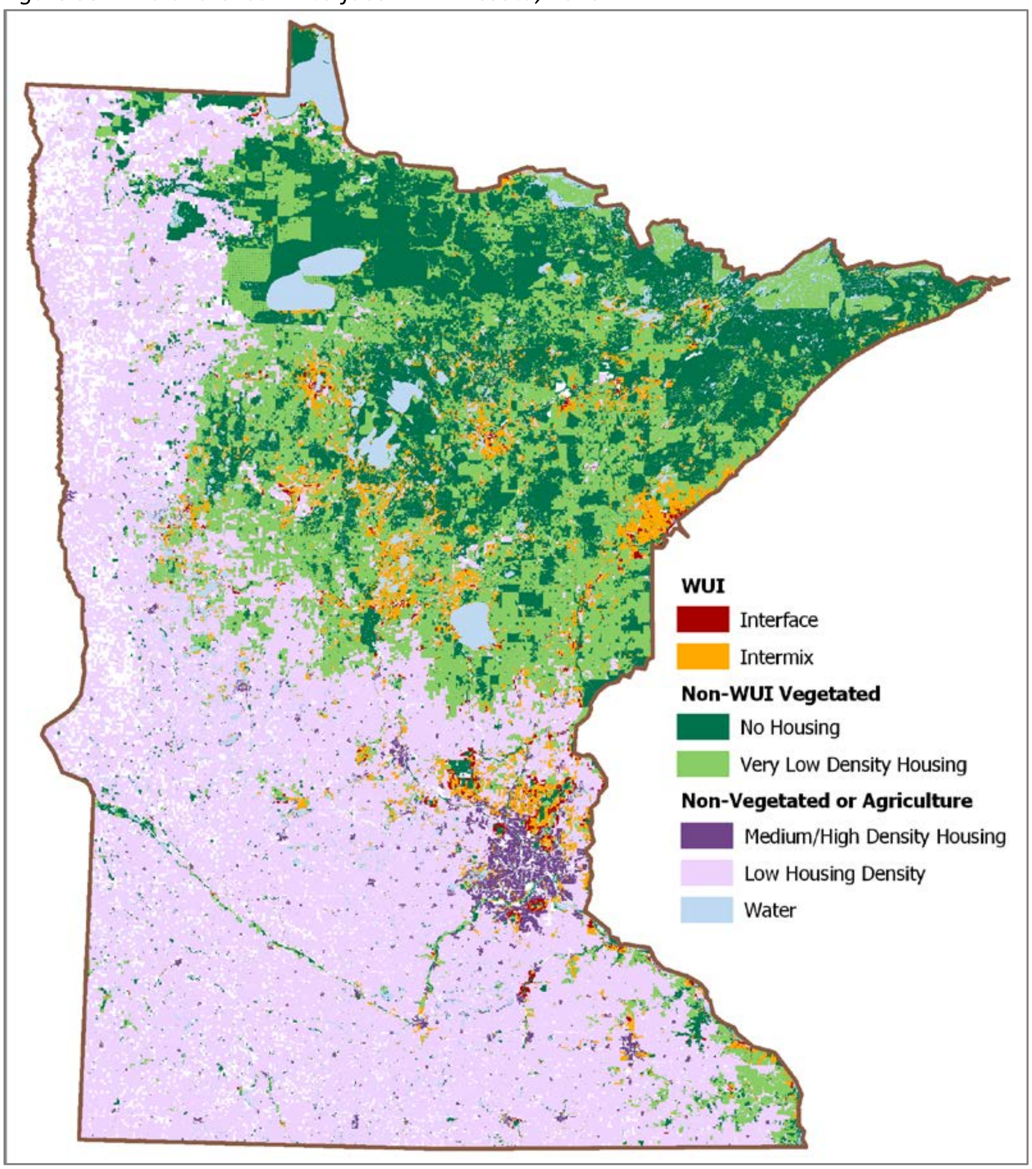
Structures in jurisdictions that interface or mix with forests, peat bogs and prairies are vulnerable to damages to wildfire statewide. Even counties with higher population densities are not completely “built out” and have large wildland or agriculture tracts. Structural damage due to wildfire also depends on the location of the structure in relation to the fuel source. Economic activity and the environment are also vulnerable to wildfire damages. Loss of jobs and revenue associated with the lumber industry and tourism may be depressed for years since timber stands take time to grow back. Peat is considered a non-renewable fossil fuel so permanent damage may take place due to wildfire.

For fires outside urban areas, vulnerabilities are dependent upon fuel sources and availability. One major example of property wildfire vulnerabilities is the area impacted by the July 4, 1999 massive windstorm. This windstorm raked northeastern Minnesota with straight-line winds exceeding 90 miles per hour. In less than 30 minutes, the storm cut an unbroken fuel pathway (10 - 12 miles long and 40 miles wide) through the Boundary Waters Canoe Area Wilderness (BWCAW) in the Superior National Forest, along the Gunflint Trail outside Grand Marais, with an estimated 80 - 120 tons of fuel per acre on over 477,000 acres. Much of this land cannot be legally, cost-effectively, or safely salvaged or cleared. Downed trees and outbreaks of insects and disease previous to the blowdown storm of July 4, 1999 have significantly increased the fire risk in the area. The task of mitigating fire risk and managing any fires that may occur is complicated by: the remoteness and inaccessibility of the area; the number of government entities that have responsibility for land within the area; the extent of the area affected; constraints on the type of activity that can take place within the BWCAW; and the large number of permanent and seasonal residents and tourists that may be affected by a fire in the area. The size and severity of the Ham Lake and Cavity Lake fires can be attributed to the unique fuel conditions in that part of the state. Following the 1999 blowdown, several mitigation projects occurred in the affected area, including: construction of helipads and safety zones, development of an evacuation plan for the Gunflint Trail, fuel reduction projects, development of the Northeastern Minnesota Wildfire Integrated Response Plan, Community Wildfire Protection Plans, Firewise programs, and defensible space and sprinkler projects around structures.

The SILVIS Lab at University of Wisconsin – Madison created a nationwide dataset documenting the 2010 Wildland Urban Interface. With the increase of development in metropolitan fringes and rural areas, the wildland-urban interface (WUI) is increasing. The WUI is defined as the area where structures and other human development meet or intermingle with undeveloped wildland. The expansion of the WUI in recent decades has significant implications for wildfire management and impact. The WUI creates an environment in which fire can readily move between structural and vegetation fuels. Its expansion has increased the likelihood that wildfires will threaten structures and people.

There are two types of WUI: intermix and interface. Intermix WUI are areas where housing and vegetation intermingle; interface WUI are areas with housing in the vicinity of contiguous wildland vegetation. Concentrations of interface and intermix values in Minnesota are located north of the Twin Cities metro area and around the Duluth area. There are also areas located throughout the north-central portion of the state (Figure 33). Table 33 lists the top 15 counties by area of Wildland-Urban Interface (WUI).

Figure 33. Wildland Urban Interface in Minnesota, 2010



SOURCE: (RADELOFF, 2005)

As wildfires affect more people, active public involvement becomes integral to the success of any wildfire management initiative. The Lake County Community Wildfire Protection Plan (CWPP) is an example of a community-based plan with two objectives. First, to identify and prioritize Wildland Urban Interface (WUI) areas within Lake County (including state, county, federal and nonfederal lands) for hazardous fuels reduction treatments and recommends methods for achieving hazardous fuels reductions. Second, the plan outlines measures for reducing fire danger to structures throughout Lake County in at-risk communities.

Table 33. Top 15 Counties in MN by Area of Wildland-Urban Interface (WUI)

County	Acres of WUI
St. Louis	388,012
Crow Wing	202,448
Cass	192,823
Itasca	182,599
Anoka	121,116
Beltrami	109,488
Hubbard	104,790
Carlton	90,314
Aitkin	90,038
Sherburne	75,374
Pine	75,093
Becker	63,673
Washington	58,332
Otter Tail	55,302
Chisago	49,730

SOURCE: (RADELOFF, 2005)

Minnesota has adopted the national Firewise program, which addresses the risks of homes in the wildland/urban interface to wildland fire. The goal of this program is making homes able to survive an approaching wildfire.

Table 34 lists the top 20 counties in Minnesota based on total loss due to wildfires from 2007-2017.

Table 34. Top 20 MN Counties based on total cost of wildfires from 2007-2017

County	Total (State) Cost	Total Number of Wildfires	Total Number of Acres Burned	Average Number of Wildfires per Year	Average Number of Acres Burned per Year	Average Cost per Wildfire
Becker	$6,341,990	381	12,076	38	1,208	$16,646
Aitkin	$5,278,417	358	6,779	36	678	$14,744
St. Louis	$1,533,692	1,293	4,171	129	417	$1,186
Marshall	$1,255,550	302	33,444	30	3,344	$4,157
Crow Wing	$831,772	476	1,138	48	114	$1,747
Sherburne	$802,193	315	368	32	37	$2,547
Pine	$550,465	639	2,363	64	236	$861

County	Total (State) Cost	Total Number of Wildfires	Total Number of Acres Burned	Average Number of Wildfires per Year	Average Number of Acres Burned per Year	Average Cost per Wildfire
Roseau	$339,550	338	71,140	34	7,114	$1,005
Lake	$318,250	106	NA	11	NA	$3,002
Isanti	$283,260	235	754	24	75	$1,205
Beltrami	$254,998	454	38,970	45	3,897	$562
Wadena	$233,397	183	2,477	18	248	$1,275
Blue Earth	$225,000	5	65	1	7	$45,000
Hubbard	$214,106	209	1,215	21	122	$1,024
Anoka	$209,100	224	4,280	22	428	$933
Kittson	$205,250	354	53,602	35	5,360	$580
Mahnomen	$166,400	325	7,503	33	750	$512
Carlton	$158,560	342	518	34	52	$464
Benton	$125,140	212	906	21	91	$590
Otter Tail	$123,920	117	1,522	12	152	$1,059

SOURCE: MN DNR

Vulnerability was also considered using normalized costs of wildfire over a ten-year period (the average total cost of the 1996-2006 and 2007-2017 time periods). The top six counties were the same in both lists. Ten-year normalized costs by county along with average costs per year can be found in *Appendix J – Wildfire Ten-year Normalized Costs by County*.

Damages to crops from wildfire are another dataset that can be important when considering jurisdictional vulnerability. The total indemnity claims due to wildfire for 1989-2017 was $332,372, with losses to counties listed below.

Table 35. Indemnity Claims for Wildfires on Crops, 1989-2017

County	Indemnity Claims (ADJ 2016)
Norman	$43,290
Sibley	$39,370
Lake of the Woods	$38,557
Fillmore	$37,712
Kittson	$32,528
Le Sueur	$18,257
Yellow Medicine	$18,213
Big Stone	$16,333
Rice	$15,302
Polk	$11,327
Roseau	$8,777
Jackson	$8,697
Blue Earth	$7,781
Murray	$7,415

County	Indemnity Claims (ADJ 2016)
Lac qui Parle	$4,571
Hennepin	$3,871
Clay	$3,524
Pipestone	$3,408
Koochiching	$3,340
Martin	$3,314
Mower	$2,069
Wabasha	$1,956
Renville	$791
Todd	$695
Crow Wing	$658
Stevens	$214
Redwood	$142
Faribault	$140
Swift	$119

Source: SHELDUS

Geography will make certain populations more disposed to wildfire risk, but certain demographic groups are also more vulnerable. Wildfires commonly result in more particulate matter and degradations in air quality which will impact children, the elderly, and those with a range of chronic health conditions. Exposure to particulate matter can aggravate illnesses, such as chronic obstructive pulmonary disease (COPD), cardiovascular disease, asthma, and development of chronic lung disease. It is also associated with cardiopulmonary mortality. Ozone exposure can exacerbate asthma and COPD (ICAT, 2017).

Wildfire and Climate Change

The changing climate poses a complex web of issues for wildfire in Minnesota. More frequent and severe smoke plumes from wildfires in Canada, mostly during the summer have already contributed to a near doubling in the number of smoke-related air quality alerts in Minnesota since 2015 compared to the previous seven years (MPCA, 2018). Climate change likely is affecting the frequency and intensity of Canadian wildfires, similar to its effect on wildfires in the western U.S. and Alaska (Wehner, 2017). Small particulate pollution from smoke plumes has numerous health impacts as described above, and if severe enough can result in spikes of demand for emergency services.

Changes in Minnesota's climate also may be influencing the frequency, severity, and areal coverage of wildfires. For example, warmer winters with inconsistent snow cover, the arrival of wet conditions prior to the growing season, plus early and more frequent thaws, all combine to prolong the exposure of susceptible vegetation to dry conditions, potentially extending the peak wildfire season.

Minnesota's changing climate also may affect fire-damaged areas. For instance, heavy rains in burned areas can lead to erosion and mudslides. Documented and projected increases in the frequency and intensity of heavy and extreme rainfall suggest that Minnesota is becoming and will become more prone to post-fire landscape hazards. Climate change also is having an impact on the pests that damage the health and composition of Minnesota forests, although the ultimate consequences for wildfire are complex and uncertain. Shorter winters are allowing two reproductive cycles of the Eastern Larch Beetle, which has now killed off at least 143,000 acres of mature tamarack forest in Minnesota since 2001, and affected about 535,000 acres to some degree during that period. The decline in severity and frequency of extreme cold may allow more rapid establishment of Emerald Ash Borer to latitudes further north than without climate change. Minnesota forests are home to an estimated 1 billion ash trees. Many of these trees are in nearly pure stands of black ash growing in wet areas. So while the deaths of these lowland species will increase fuel loading, their decreased transpiration will increase water on the ground. The ultimate contribution to wildfire will depend on the interplay between increased precipitation, warming temperatures, extreme heat, and periods of drought as our climate continues to change.

Temperatures are predicted to rise in the state, which could lead to more extreme heat events and associated wildfire risks. As Minnesota's climate changes, weather fluctuations between drought and extreme rain events and increasing temperatures will result in changes to forest composition and/or distribution. These fluctuations can lead to dry conditions that may cause increased fire risk in both grassland and forest environments.

The varied impacts of climate change are complicated by how these changes also interact with and reinforce one another. Drought and heat may both contribute to wildfires, which may in turn lead to changes in plant and animal populations and other ecological shifts. Increasing events of extreme heat and drought can increase the number of wildfires.

4.7.3 Windstorms

A windstorm hazard is a wind strong enough to cause light damage to trees and buildings. Wind speeds during a windstorm typically exceed 34 miles per hour (29.5 knots). Wind damage can be caused by gusts or sustained winds (Pielke, 2012). Windstorms encompass a large variety of damaging wind types, including straight-line wind (thunderstorm wind not associated with rotation), downdraft (a small-scale column of air that rapidly sinks toward the ground), downburst (a strong downdraft with an outrush of damaging winds on or near the earth's surface), gustnado (small whirlwind originating from the ground and not connected to any cloud-based rotation), and a derecho (widespread, long-lived wind storm associated with a band of rapidly moving showers or thunderstorms) (NOAA National Severe Storms Laboratory, n.d.). Tornadoes and hurricanes are categorized as separate hazards from windstorms.

NOAA's National Centers for Environmental Information Storm Events Database includes storm events classified using the following criteria to define each of three storm events:

- Strong windstorm events are "non-convective winds gusting less than 50 knots (58 mph), or sustained winds less than 35 knots (40 mph), resulting in a fatality, injury, or damage" (NWS, 2016).
- High wind storm event are "sustained non-convective winds of 35 knots (40 mph) or greater lasting for one hour or longer or gusts of 50 knots (58 mph) or greater for any duration" (NWS, 2016).
- Thunderstorm windstorm events are "winds arising from convection (occurring within 30 minutes of lightning being observed or detected), with speeds of at least 50 knots (58 mph) or winds of any speed producing a fatality, injury, or damage" (NWS, 2016). Downbursts and gustnadoes are classified as thunderstorm windstorm events.

When wind speeds are not able to be measured, they are estimated. Part of the process to determine wind speed is observing the damage. Table 36 lists the expected effects of increasing wind speeds.

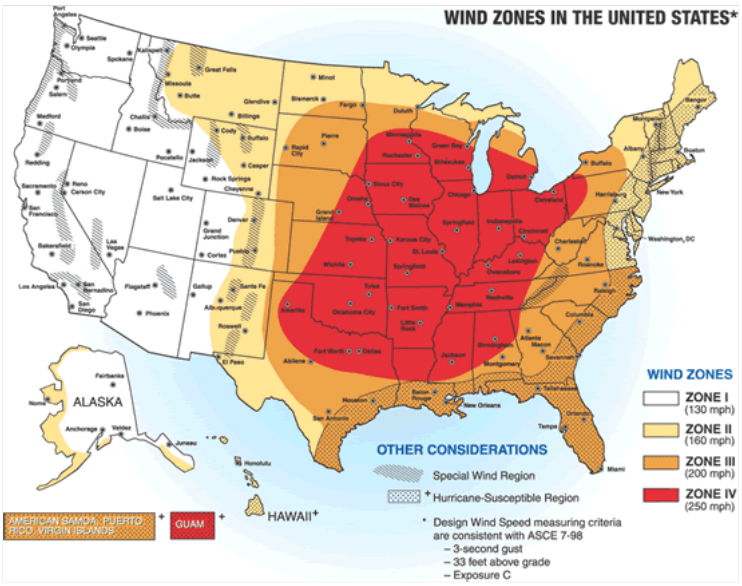
Table 36. Effects of Wind Speed

Wind Speed	Effects
26-38 knots (30-44 mph)	Trees in motion. Lightweight loose objects (e.g., lawn furniture) tossed or toppled.
39-49 knots (45-57 mph)	Large trees bend; twigs, small limbs break; and a few larger dead or weak branches may break. Old/weak structures (e.g., sheds, barns) may sustain minor damage (roof, doors). Buildings partially under construction may be damaged. A few loose shingles may be removed from houses. Carports may be uplifted; minor cosmetic damage may occur to mobile homes.
50-64 knots (58-74 mph)	Large limbs break; shallow-rooted trees may be pushed over. Semi-trucks may be overturned. More significant damage to old/weak structures occurs. Shingles, awnings may be removed from houses; mobile homes and carports incur minor structural damage.
65-77 knots (75-89 mph)	Widespread damage to trees with trees broken/uprooted. Mobile homes may incur more significant structural damage; Roofs may be partially peeled off industrial/commercial/ warehouse buildings. Some minor roof damage may occur to homes. Weak structures (e.g., farm buildings, airplane hangars) may be severely damaged.
78+ knots (90+ mph)	Many large trees broken and uprooted. Mobile homes may be severely damaged; moderate roof damage to homes may occur. Roofs may be partially peeled off homes and buildings. Moving automobiles may be pushed off dry roads. Barns and sheds may be demolished.

SOURCE: (NATIONAL WEATHER SERVICE, 2018)

Wind data is also used to determine areas within the U.S. that are at a greater risk of experiencing a windstorm. Based on 40 years of tornado history and over 100 years of hurricane history, the U.S. has been divided geographically into four zones reflective of the frequency and intensity of previous windstorms in areas (FEMA). Minnesota intersects three of the wind zones. The southern third of the state is in Zone IV, the middle third is in Zone III, and the northern third in Zone I (Figure 34).

Figure 34. Wind Zones in the United States



SOURCE: (NIST, 2017)

Windstorm History

According to the National Centers for Environmental Information, there have been 11,578 windstorm events in Minnesota between 1955 and June of 2018. Of these windstorm events, 70 are classified as strong wind, 1,024 as high wind, and 10,484 as thunderstorm wind. These windstorm events have been the cause of 168 injuries and 18 deaths (NOAA NCEI, 2018).

Notable wind events since 2014 are described briefly in Table 37.

Table 37. A Sample of Notable Windstorms, 2014-July 2018

Date	Location	Remarks
4/13/2018	Rock County	High winds toppled power poles along I-90 at the Magnolia exit. The NCEI reported $728,000 in property damage.
9/19/2017	Stearns County	Hundreds of trees were blown down from northeast of Elrosa to Melrose. Numerous cornfields and other crops were also damaged. The NCEI estimated $1 million in property damage.
7/11/2017	Becker County/Clay County	Thunderstorm winds in Becker and Clay Counties resulted in $1,550,000 in property damage and $1,000,000 in crop damage. Power lines were toppled, along with trees up to 18 inches in diameter.
6/13/2017	Otter Tail County, Grant County, Wilkin County	Almost $1 million in property damage was done to Otter Tail County, $250,000 was done in Grant County, and Wilkin County experienced $500,000 during this windstorm. Estimated wind gusts reached 80 knots. Several semi-trucks were blown off the Interstate near Ashby.

Date	Location	Remarks
7/21/2016	St. Louis County	Winds up to 100 mph resulted in over 75,000 customers without power for up to five days. The storm moved through the Boundary Waters Canoe Wilderness, killing two campers on Basswood Lake in Quetico, just across the Minnesota border in Ontario.
7/5/2016	Hennepin County	Winds of up to 70 knots destroyed six miles of transmission lines, in addition to sporadic tree damage. The worst of the damage was in the southern part of Crow-Hassan County Park. Hennepin County had approximately $2 million in property damage.
6/19/2016	Cook County	One man was killed and one injured when a tree fell on campers at Duncan Lake.
6/10/2016	Goodhue County	One fatality occurred when a tree fell on a detached garage, trapping an individual as the garage collapsed. Property damage of $500,000 due to falling trees and blowing debris was reported.
7/18/2015	Goodhue County	Severe downburst winds blew down trees, destroyed farm buildings and flattened cornfields. Property damage was estimated at $500,000. Survey damage indicated winds between 80-85 mph.
6/22/2015	Martin County	Winds of up to 61 knots near Ceylon ripped a large grain silo off its foundation and crushed it.
7/21/2014	St. Louis County	Two campers were injured when a tree fell on their campsite at Loon Lake. Winds were estimated at 70 knots.
6/16/2014	Blue Earth County	Blue Earth County had wind speeds up to 87 knots, which caused $500,000 in property damage. A metal building system north of Minnesota Lake was damaged, and nearby grain bins were tipped. Two homes also sustained wind damage to shingles.

SOURCE: (NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION, 2018)

A widespread derecho occurred in the Arrowhead Region in July of 1999, resulting in a severe blowdown. The blowdown impacted 180,000 acres and resulted in a Presidential Disaster Declaration for Cook County. Much of the blowdown was located within the Boundary Waters Canoe Area Wilderness (BWCAW) and the Superior National Forest. According to the NCEI, timber loss was approximately .5 to .75 million cords and valued at between $12 and $18 million, though salvage value was only around $5 million. Twenty people had to be airlifted to hospitals after suffering injuries from falling trees. The cost of damage and debris clearance for Lake and Cook counties was estimated at nearly $5 million (National Centers for Environmental Information, 2018). This storm contributed to fire risk in subsequent years.

Violent thunderstorms reached the Northland around 3:00 am on July 21st, 2016 with winds reaching up to 100 mph leaving more than 75,000 customers without power for up to five days. The storm moved through the Boundary Waters Canoe Wilderness, killing two campers on Basswood Lake in Quetico, just across the Minnesota border in Ontario (MN DNR, 2016).

Probability of Occurrence

Although windstorms occur year-round throughout the state of Minnesota, the majority of windstorms occur during the months of May through August (Table 38). This recurrence is expected to remain relatively stable, although there will be year-to-year fluctuations. Long-term changes in weather patterns may also influence the number of windstorms that occur.

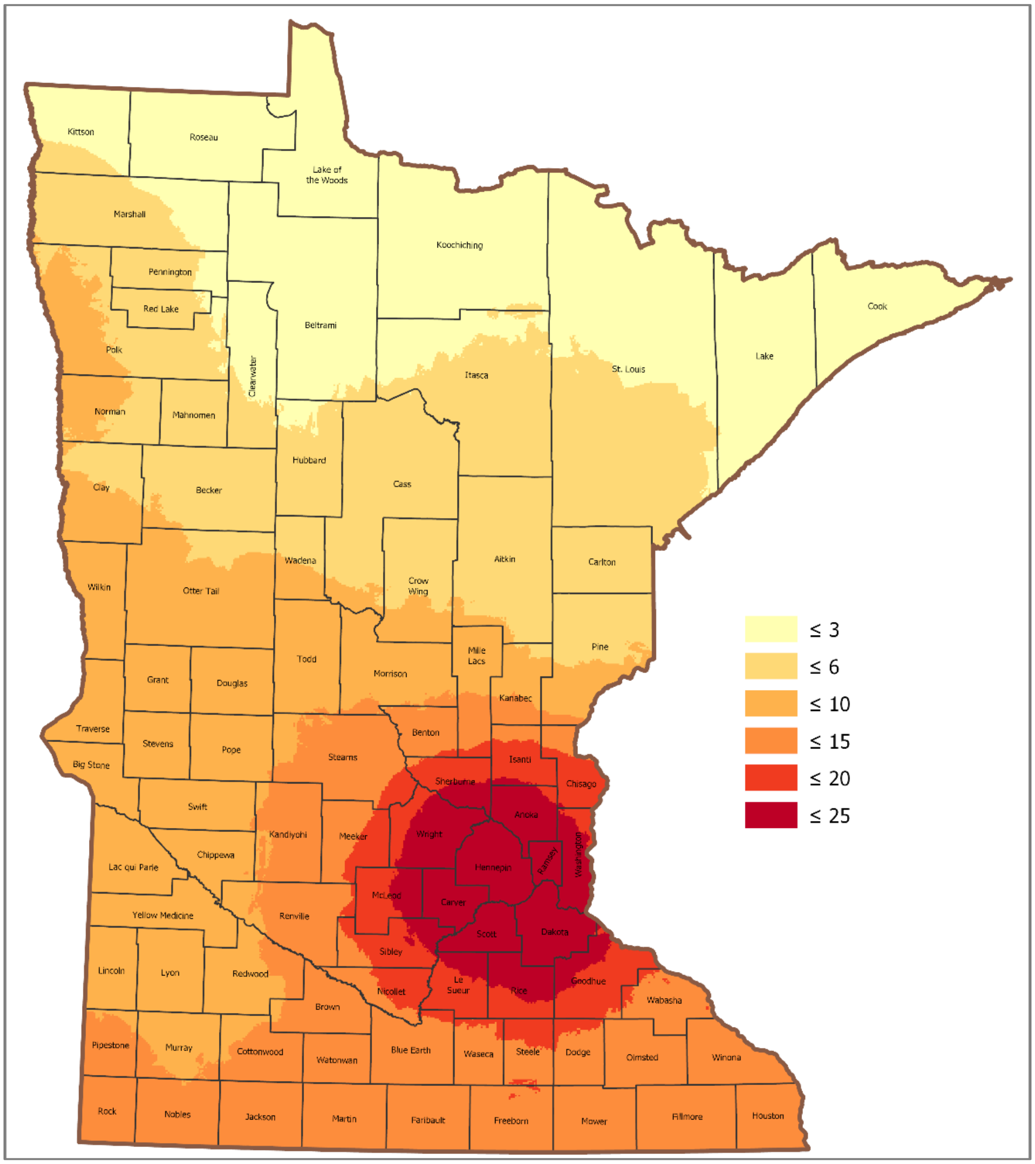
Table 38. Windstorm Occurrences by Month, 1955-June 2018

Month	Windstorm Count	Percentage of Total
January	24	0.21%
February	95	0.82%
March	132	1.14%
April	529	4.57%
May	1,116	9.64%
June	3,190	27.55%
July	3,508	30.30%
August	1,795	15.50%
September	634	5.48%
October	310	2.68%
November	148	1.28%
December	97	0.84%

Source: (NOAA National Centers for Environmental Information, 2018)

Figure 35 shows the annual frequency of thunderstorm wind events with wind speeds greater than or equal to 50 knots, which occurred within 50 miles (approximately an hour) of a given location in Minnesota from 1955 through June 2018. More wind events reported in the Twin Cities Metro region are somewhat due to the density in reporting of storms and damage.

Figure 35. Annual Frequency of Reported Thunderstorm Wind Events ≥ 50 Knots within a 50-mile radius, 1955-June 2018



SOURCE: (NCEI, 2018)

A value representing expected number of windstorms was developed for each county using the average frequency of windstorms events in a 50-mile radius, normalized by the county's area. All other factors being equal, the larger county will have more storms so this method adjusts for area and reporting bias in order to compare county to county. This value represents the expected number of windstorms in the county, based on local and regional trends in reported data as opposed to administrative boundaries. *Appendix K – Windstorm Vulnerability Ranking* shows the expected number of windstorms data by county. The county expected number of windstorms is used in a vulnerability index described below.

Vulnerability

Vulnerability to injury from all kinds of wind storm decreases with adequate warnings, warning time, and sheltering in a reinforced structure. Vulnerability to structures depends upon construction of the building and infrastructure. Higher damages occur when a windstorms strike a densely populated area.

Table 39 shows the ten counties in Minnesota with the greatest monetary damages from windstorms ≥ 50 knots, from 1960 to 2017. The monetary damage data is from the Spatial Hazard Events and Losses Database for the United States (SHELDUS) (CEMHS, 2018). FEMA's Willingness to Pay (WTP) values were used to value the number of windstorm related deaths and injuries in each county; $90,000 for each injured person and $5,800,000 for each person killed. The $90,000 WTP injury value is based on the Treat & Release" injury severity level (FEMA, 2009).

Table 39. Counties with Greatest Monetary Damages from Windstorms ≥ 50 knots, 1960-2017

County	Windstorms ≥ 50 knots	Injuries WTP	Fatalities WTP	Property Damage (ADJ 2016)	Crop Damage (ADJ 2016)	Total Damages
Dakota	111	$1,717,951	$3,799,000	$261,786,779	$5,270,297	$272,574,026
Scott	104	$372,001	$6,438,000	$170,845,687	$14,208,961	$191,864,649
Hennepin	247	$4,670,025	$32,122,314	$108,395,938	$995,231	$146,183,508
Blue Earth	65	$699,750	$9,106,000	$24,639,318	$67,752,895	$102,197,963
St. Louis	169	$890,550	$78,590,000	$2,581,267	$674,965	$82,736,782
Otter Tail	112	$531,600	$32,219,000	$16,101,518	$3,287,765	$52,139,884
Ramsey	89	$3,616,426	$16,665,372	$24,065,559	$879,396	$45,226,753
Clay	54	$273,001	$9,222,000	$5,143,080	$30,437,876	$45,075,957
Washington	103	$3,371,401	$8,448,686	$27,219,438	$6,029,624	$45,069,149
Kandiyohi	69	$477,900	$6,544,314	$24,954,751	$10,182,117	$42,159,082

SOURCE: (CEMHS, 2018)

In another attempt to assess how vulnerable a county is to windstorms, a vulnerability score was constructed. The vulnerability score uses the total replacement value of all the buildings in a county (building exposure) and the expected number of windstorms value together for this score. The expected storm values were scored as a percentage of the highest number of storms in a county. The building exposure values were scored using the percentage of the log the highest exposure (to moderate the extremely high value of Hennepin and other metro counties). Finally the two scaled scores were added to produce a vulnerability score. Table 40 displays the 10 counties with the highest vulnerability ranking.

*Table 40. Counties most Vulnerable to Windstorms, 1955-June 2018**

County	Rank	Building Exposure in Millions	Avg Annual Count	Expected Annual Count
Hennepin	1	$171,961	4.10	1.87
Saint Louis	2	$28,176	3.02	2.40
Dakota	3	$53,322	1.92	1.67
Stearns	4	$18,983	2.02	2.16
Wright	5	$15,132	2.29	1.96
Anoka	6	$39,560	1.71	1.26
Otter Tail	7	$8,543	1.98	1.97
Washington	8	$31,565	1.71	1.14
Goodhue	9	$6,112	1.50	1.88
Ramsey	10	$67,354	1.48	0.49

SOURCES: (NOAA NCEI, 2018) (FEMA, 2018)

**THE HISTORICAL AVERAGE ANNUAL WINDSTORM COUNT IS INCLUDED FOR REFERENCE, BUT ONLY THE EXPECTED ANNUAL TORNADO COUNT IS USED IN THE INDEX.*

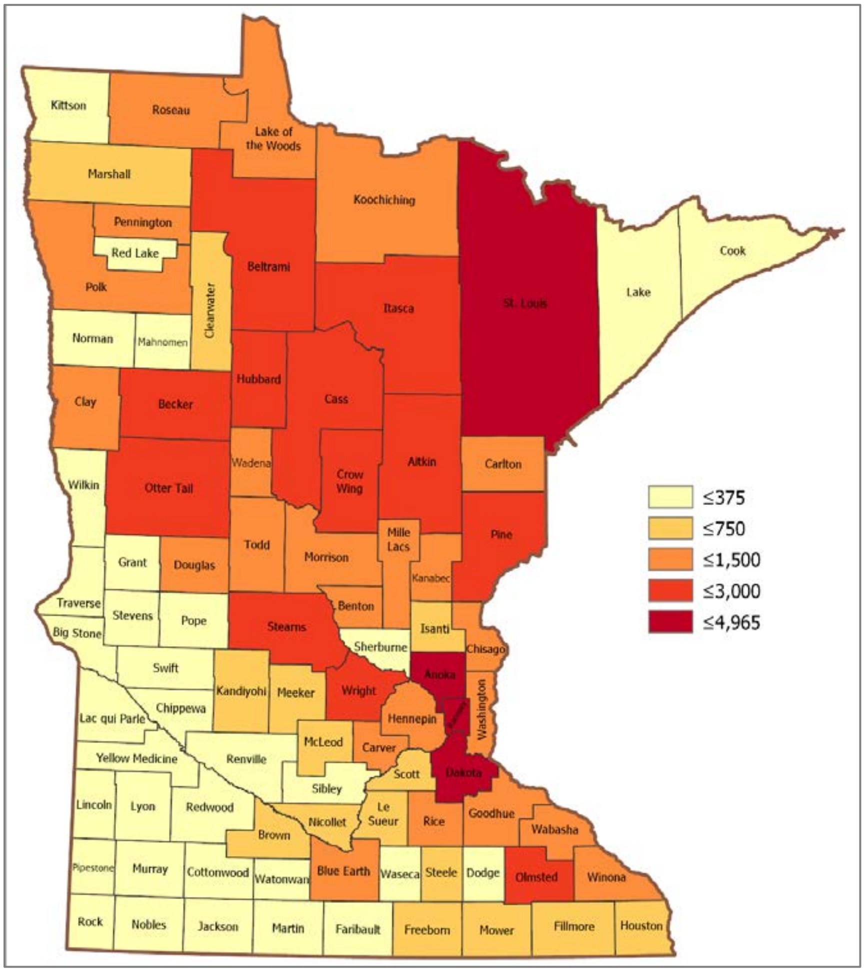
Residents of mobile homes are more vulnerable to fatality or injury from windstorms because mobile homes are not able to withstand high winds as well as other structural dwellings. Wind in excess of 50 mph (43.4 knots) is the lower limit of wind speeds capable of damaging mobile homes (American Meteorological Society, 2004). Steps to mitigate these vulnerabilities have been taken but have not proven sufficient. For example, mobile home parks with 10 or more homes that received their primary license after March 1, 1998, are required to provide storm shelters that meet standards specified by the commissioner of administration (MDH, 2018). However, mobile home parks often do not provide the required storm shelters. Building codes have also changed to improve the strength of new mobile home construction, but there are still many older mobile homes in use that do not meet these new standards. According to NOAA's Storm Prediction Center, from 1985-2002, 49% of tornado fatalities in the United States were people who remained within or attempted to flee from mobile homes (American Meteorological Society, 2004). Given the vulnerability of mobile home residents to windstorm events, it is important to have a general understanding of where mobile homes around the state are located. Figure 36 on the next page displays the number of mobile homes in each county.

Rural Electric cooperatives statewide are vulnerable to storms. In fact, some 9 Presidentially Declared Disasters probably would not have occurred had rural electric cooperatives and municipal cooperatives not been damaged (DR-4113, DR-4009, DR-1921, DR1283) – damage would have occurred during the storm however, the State might not have met its threshold for a disaster declaration without the cooperatives. Rural electric cooperatives are vulnerable and could very well be becoming more vulnerable without mitigating against future damages.

A long-term wind storm that exceeds 58 mph and extends for more than 240 miles is a windstorm that can be classified as a derecho storm. Because derecho storms are long lived and travel great distances, Minnesota rural electric cooperatives are highly vulnerable.

The most vulnerable electrical structures to wind events are overhead utility lines and the poles. Of the 46 distribution cooperatives in the state, only 5 cooperatives have more miles of underground lines than overhead lines, making them only slightly less vulnerable. State-wide there is an estimate 127,669 miles of distribution lines, of which only 35% (45,372) are underground and less vulnerable to windstorms. The resulting 64.5% (82,297) of the overhead distribution lines owned and maintained by the cooperatives are vulnerable to damage from windstorms (Minnesota All Hazard Mitigation Plan Rural Electric Annex, 2014).

Figure 36. 2016 Mobile Home Estimate per County in Minnesota



SOURCES: CDC AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY 2016 SOCIAL VULNERABILITY INDEX

Windstorms and Climate Change

Lack of high-quality long-term data sets makes assessment of changes in wind speeds very difficult (Kunkel, et al., 2013). In general, one analysis found no evidence of significant changes in wind speed distribution. Other trends in severe storms, including the number of hurricanes and the intensity and frequency of tornadoes, hail, and damaging thunderstorm winds, are uncertain. Since the impact of more frequent or intense storms can be larger than the impact of average temperature, climate scientists are actively researching the connections between climate change and severe storms (USGCRP, 2017).

4.7.4 Tornadoes

Tornadoes are defined as violently rotating columns of air extending from thunderstorms to the ground, with wind speeds between 65 and 235 mph. They have been observed in a wide variety of meteorological conditions but tend to develop under three main scenarios: (1) within supercells, which are large, often isolated, rotating thunderstorms that form near boundaries separating warm and humid air from cooler and/or drier air and when winds aloft are strong—these are the largest, most visible, and most damaging types of tornadoes, (2) in connection with thunderstorm squall lines—these tornadoes can be difficult to detect and observe, and (3) in the outer portion of a tropical cyclone. Funnel clouds are rotating columns of air not in contact with the ground; however, the column of air can reach the ground very quickly and become a tornado. Only the first two types of tornadoes have been observed in Minnesota, although tornadoes associated with the remnant circulations of decaying tropical weather systems have been observed in other Midwestern states.

Since 2007, tornado strength in the United States has been ranked on the Enhanced Fujita Scale (EF scale), replacing the Fujita Scale introduced in 1971. The EF Scale uses principles similar to the Fujita Scale, with six categories from 0-5, based on wind estimates and damage caused by the tornado. The EF Scale is used extensively by the National Weather Service in investigating tornadoes (all tornadoes are now assigned an EF Scale number) and by engineers to correlate building damage with approximate wind speeds. Table 41 below outlines the Fujita Scale, the Derived EF Scale, and the Operational EF Scale. Though the Enhanced Fujita Scale itself ranges up to EF28 for the damage indicators, the strongest tornadoes attain the EF5 range (262 to 317 mph).

Table 41. Fujita Scale, Derived EF Scale, and Operational EF Scale

Fujita Scale			Derived EF Scale		Operational EF Scale	
F Scale	Fastest ¼-mile (mph)	3-second Gust (mph)	EF Scale	3-second Gust (mph)	EF Scale	3-second Gust (mph)
0	40-72	45-78	0	65-85	0	65-85
1	73-112	79-117	1	86-109	1	86-110
2	113-157	118-161	2	110-137	2	111-135
3	158-207	162-209	3	138-167	3	136-165
4	208-260	210-261	4	168-199	4	166-200
5	261-318	262-317	5	200-234	5	>200

SOURCE: (NOAA SPC, 2018)

Tornado History

Minnesota lies along the northern edge of the region of maximum tornado occurrence in the United States. Tornado Alley, as this part of the central United States has come to be known, reaches across parts of Texas, Oklahoma, Kansas, Missouri, eastern Nebraska, and western Iowa. In Minnesota, tornadoes have occurred in every month from March through November. The earliest tornado occurrence, within a calendar year, happened on March 6, 2017, when four tornadoes were recorded near the towns of Bricelyn, Bancroft, Orrock, and Ellendale (NOAA, 2018). The latest tornado occurrence took place on November 16, 1931, east of Maple Plain (MN DNR, 2016).

In 2010, a historic year for tornadoes in Minnesota, 126 tornados were recorded (60 of those occurring on June 17, 2010). This year of devastation resulted in three deaths and 46 injuries (all occurring on June 17 and one injury on August 13). The year 2010 beat both previous state records of the most tornadoes in a year (79 tornadoes in 2001) and the most tornadoes in a day (27 tornadoes on June 16, 1992). In 2017, 70 tornadoes occurred in Minnesota (NOAA, 2018). Tornadoes of magnitude EF2 or greater since January 2013 are listed in Table 42.

Despite a higher number of tornadoes reported in recent years, the number of fatalities and injuries due to tornadoes has been decreasing. This is in part due to better National Weather Service tornado detection tools, namely the NEXRAD Doppler radar network installed in the mid-1990s. Also, the ability of alerting the public has improved with more National Weather Service radio transmitters and a close relationship with media outlets. An energetic spotter network has also been a key to alerting the public in Minnesota. The increasing number of tornadoes reported may be a direct result of improved communication networks, public awareness, warning systems, and training.

Table 42. Tornadoes in Minnesota, ≥ EF2, January 2013 – December 2017.

Location of Tornado Path	Date	Magnitude	Length (Miles)	Width (Yards)	Deaths	Injuries
Norman County	7/11/2017	EF2	11.64	600	0	0
Clay County Norman County	7/11/2017	EF2	12.81	500	0	0
Norman County Polk County	8/28/2016	EF2	9.57	400	0	0
Meeker County	7/11/2016	EF2	3.1	100	0	0
Meeker County Stearns County	7/11/2016	EF2	2.22	400	0	1
Crow Wing County	6/19/2016	EF2	3.52	730	0	0
Todd County Wadena County	7/12/2015	EF2	12.09	400	0	0
Kittson County	9/19/2014	EF2	10	500	0	0
Otter Tail County Wilkin County	9/4/2014	EF2	2.7	200	0	0
Polk County Red Lake County	7/21/2014	EF2	37.92	800	0	0
Clearwater County Mahnomen County	7/22/2013	EF2	21.09	400	0	0

SOURCE: (NCEI, 2018)

The five tornadoes in Minnesota that caused the highest property damage are listed in Table 43. None of them occurred in the past five years.

Table 43. Tornadoes with the Highest Property Damage in Period of Record

Date	Location of Tornado Path	Magnitude	Property Damage (Year of Report)
5/22/2011	Hennepin, Ramsey, Anoka	EF1	$166,620,000
5/15/1998	Ramsey	F1	$150,000,000
3/29/1998	Nicollet, Le Sueur	F3	$120,000,000
5/6/1965	Hennepin, Ramsey, Anoka	F4	$75,000,000
5/6/1965	Carver, Hennepin	F4	$50,000,000

SOURCE: (NCEI, 2018)

Probability of Occurrence

The NOAA Storm Prediction Center indicates Minnesota averaged 36 tornadoes per year from 1985 to 2014. According to the National Centers for Environmental Information's (NCEI) Storm Event Database, in Minnesota, tornadoes are most prevalent in the months of June (34%), July (25%), and May (16%); 63% of tornadoes occur between 2:30 PM - 7:00 PM. The majority of tornadoes are ≤ F1, have an average tornado path of three miles long, and a width slightly wider than 100 yards (NOAA, 2018).

The NCEI Storm Events Database shows that from 1950 through 2017, Minnesota tornadoes caused 100 deaths, 1,979 injuries, and over $1.9 billion dollars in property damage. This equates to a yearly average of 1.5 deaths, 29.5 injuries, and over $28 million in property damage. From the 67-year state total of 1,972 tornadoes, 44 (2.23%) were ranked at EF4, F4, or F5 (NOAA, 2018).

There are multiple ways to calculate the probability of tornadoes in a county. While tornado paths are recorded as distinct events with specific start and end points, the destruction from a tornado is often greater than the tornado's path and not confined to county boundaries. Therefore, when determining an area's risk, a fixed distance around tornado paths should be factored in.

One method of examining tornado frequency is counting the number of tornadoes that intersect (either touch down or travel through) each county.

Table 44 displays this data and compares it between three timeframes: 67 years, 30 years, and 10 years. While the annual number of tornados has not increased in every county, the data shows an increase in the total number of tornadoes per year between these timeframes (NOAA, 2018), an indicator that tornadoes in Minnesota may be occurring more frequently. The five counties with the greatest number of tornados in each time period are highlighted in gold.

Table 44. Tornado Counts ≥ F1, by County, for Three Time Periods (Gold indicates top 5 counties in each period)

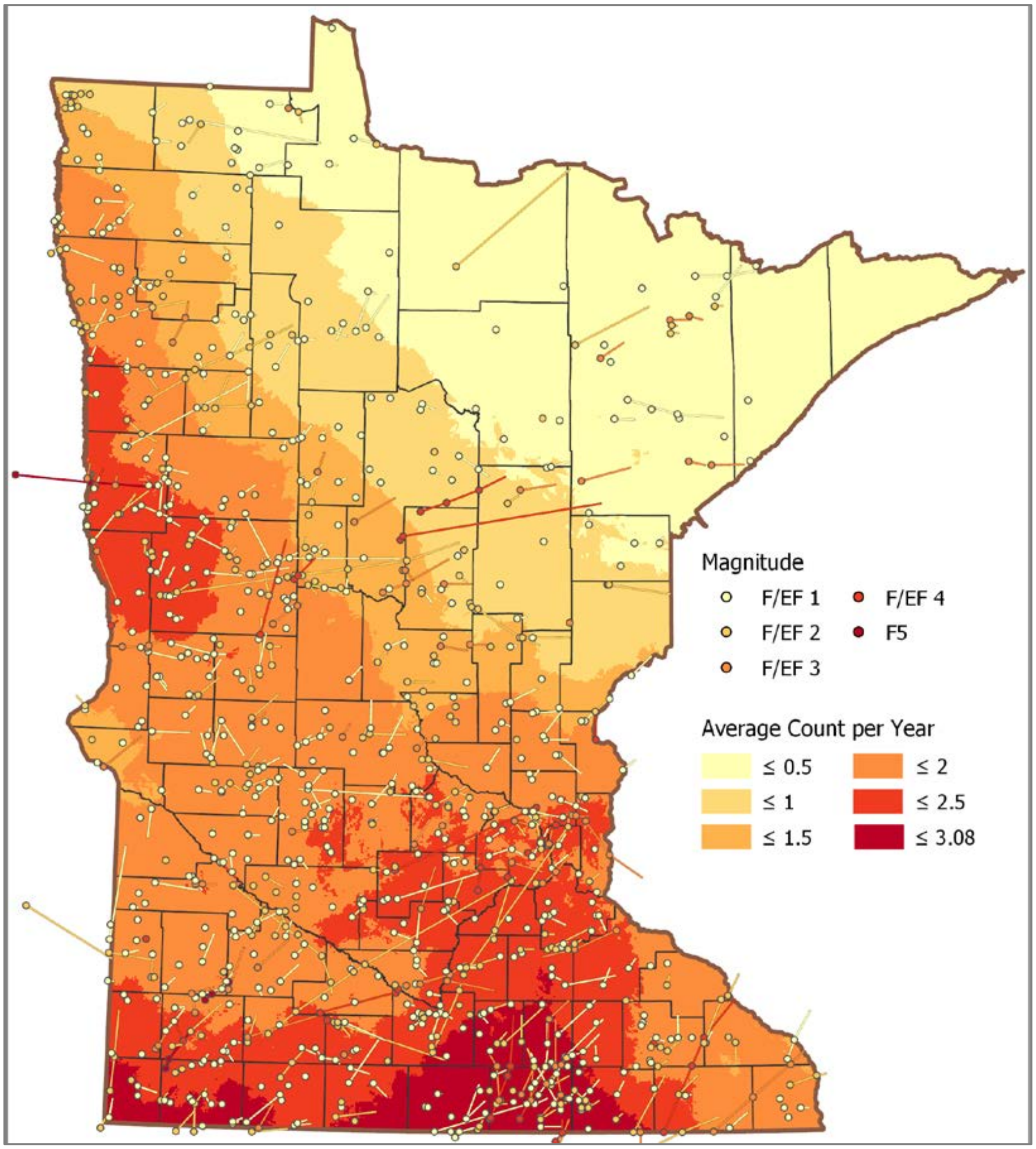
1950 - 2017			1987 - 2017			2007 - 2017		
County	Events	Tornadoes Per Year	County	Events	Tornadoes Per Year	County	Events	Tornadoes Per Year
Aitkin	11	0.16	Aitkin	2	0.07	Aitkin	2	0.20
Anoka	16	0.24	Anoka	7	0.23	Anoka	4	0.40
Becker	15	0.22	Becker	9	0.30	Becker	2	0.20
Beltrami	11	0.16	Beltrami	7	0.23	Beltrami	2	0.20
Benton	9	0.13	Benton	1	0.03	Benton	0	0.00
Big Stone	4	0.06	Big Stone	2	0.07	Big Stone	1	0.10
Blue Earth	23	0.34	Blue Earth	15	0.50	Blue Earth	4	0.40
Brown	9	0.13	Brown	5	0.17	Brown	3	0.30
Carlton	5	0.07	Carlton	0	0.00	Carlton	0	0.00
Carver	9	0.13	Carver	1	0.03	Carver	1	0.10
Cass	20	0.30	Cass	5	0.17	Cass	1	0.10
Chippewa	10	0.15	Chippewa	8	0.27	Chippewa	2	0.20
Chisago	8	0.12	Chisago	4	0.13	Chisago	1	0.10
Clay	27	0.40	Clay	12	0.40	Clay	2	0.20
Clearwater	11	0.16	Clearwater	6	0.20	Clearwater	5	0.50
Cook	0	0.00	Cook	0	0.00	Cook	0	0.00
Cottonwood	9	0.13	Cottonwood	4	0.13	Cottonwood	0	0.00
Crow Wing	14	0.21	Crow Wing	6	0.20	Crow Wing	1	0.10
Dakota	16	0.24	Dakota	8	0.27	Dakota	3	0.30
Dodge	7	0.10	Dodge	2	0.07	Dodge	2	0.20
Douglas	13	0.19	Douglas	8	0.27	Douglas	3	0.30
Faribault	14	0.21	Faribault	8	0.27	Faribault	4	0.40
Fillmore	7	0.10	Fillmore	2	0.07	Fillmore	2	0.20
Freeborn	34	0.51	Freeborn	15	0.50	Freeborn	8	0.80
Goodhue	8	0.12	Goodhue	4	0.13	Goodhue	0	0.00
Grant	14	0.21	Grant	7	0.23	Grant	3	0.30
Hennepin	25	0.37	Hennepin	7	0.23	Hennepin	2	0.20
Houston	6	0.09	Houston	2	0.07	Houston	1	0.10
Hubbard	11	0.16	Hubbard	10	0.33	Hubbard	9	0.90
Isanti	9	0.13	Isanti	6	0.20	Isanti	0	0.00
Itasca	6	0.09	Itasca	2	0.07	Itasca	1	0.10
Jackson	11	0.16	Jackson	3	0.10	Jackson	0	0.00
Kanabec	6	0.09	Kanabec	3	0.10	Kanabec	0	0.00
Kandiyohi	24	0.36	Kandiyohi	15	0.50	Kandiyohi	4	0.40
Kittson	16	0.24	Kittson	13	0.43	Kittson	2	0.20
Koochiching	3	0.04	Koochiching	0	0.00	Koochiching	0	0.00
Lac qui Parle	6	0.09	Lac qui Parle	1	0.03	Lac qui Parle	0	0.00
Lake	6	0.09	Lake	2	0.07	Lake	0	0.00
Lake of the Woods	6	0.09	Lake of the Woods	3	0.10	Lake of the Woods	2	0.20
Le Sueur	10	0.15	Le Sueur	5	0.17	Le Sueur	0	0.00
Lincoln	12	0.18	Lincoln	3	0.10	Lincoln	1	0.10
Lyon	9	0.13	Lyon	6	0.20	Lyon	0	0.00
Mahnomen	8	0.12	Mahnomen	4	0.13	Mahnomen	3	0.30
Marshall	15	0.22	Marshall	13	0.43	Marshall	7	0.70
Martin	7	0.10	Martin	0	0.00	Martin	0	0.00

1950 - 2017			1987 - 2017			2007 - 2017		
County	Events	Tornadoes Per Year	County	Events	Tornadoes Per Year	County	Events	Tornadoes Per Year
McLeod	10	0.15	McLeod	1	0.03	McLeod	0	0.00
Meeker	6	0.09	Meeker	4	0.13	Meeker	2	0.20
Mille Lacs	8	0.12	Mille Lacs	2	0.07	Mille Lacs	0	0.00
Morrison	13	0.19	Morrison	7	0.23	Morrison	1	0.10
Mower	17	0.25	Mower	6	0.20	Mower	1	0.10
Murray	17	0.25	Murray	11	0.37	Murray	2	0.20
Nicollet	11	0.16	Nicollet	6	0.20	Nicollet	2	0.20
Nobles	21	0.31	Nobles	12	0.40	Nobles	3	0.30
Norman	10	0.15	Norman	7	0.23	Norman	6	0.60
Olmsted	17	0.25	Olmsted	3	0.10	Olmsted	2	0.20
Otter Tail	52	0.78	Otter Tail	34	1.13	Otter Tail	17	1.70
Pennington	6	0.09	Pennington	3	0.10	Pennington	1	0.10
Pine	3	0.04	Pine	2	0.07	Pine	1	0.10
Pipestone	7	0.10	Pipestone	3	0.10	Pipestone	1	0.10
Polk	34	0.51	Polk	20	0.67	Polk	13	1.30
Pope	14	0.21	Pope	7	0.23	Pope	2	0.20
Ramsey	7	0.10	Ramsey	2	0.07	Ramsey	1	0.10
Red Lake	8	0.12	Red Lake	5	0.17	Red Lake	4	0.40
Redwood	19	0.28	Redwood	12	0.40	Redwood	3	0.30
Renville	17	0.25	Renville	12	0.40	Renville	2	0.20
Rice	10	0.15	Rice	5	0.17	Rice	1	0.10
Rock	6	0.09	Rock	3	0.10	Rock	0	0.00
Roseau	16	0.24	Roseau	11	0.37	Roseau	3	0.30
Scott	5	0.07	Scott	3	0.10	Scott	0	0.00
Sherburne	2	0.03	Sherburne	1	0.03	Sherburne	1	0.10
Sibley	12	0.18	Sibley	6	0.20	Sibley	1	0.10
St. Louis	23	0.34	St. Louis	2	0.07	St. Louis	2	0.20
Stearns	23	0.34	Stearns	9	0.30	Stearns	4	0.40
Steele	18	0.27	Steele	6	0.20	Steele	5	0.50
Stevens	7	0.10	Stevens	1	0.03	Stevens	1	0.10
Swift	15	0.22	Swift	11	0.37	Swift	4	0.40
Todd	7	0.10	Todd	5	0.17	Todd	2	0.20
Traverse	9	0.13	Traverse	6	0.20	Traverse	2	0.20
Wabasha	4	0.06	Wabasha	2	0.07	Wabasha	1	0.10
Wadena	14	0.21	Wadena	8	0.27	Wadena	5	0.50
Waseca	12	0.18	Waseca	1	0.03	Waseca	0	0.00
Washington	9	0.13	Washington	5	0.17	Washington	3	0.30
Watonwan	11	0.16	Watonwan	3	0.10	Watonwan	0	0.00
Wilkin	12	0.18	Wilkin	5	0.17	Wilkin	4	0.40
Winona	7	0.10	Winona	1	0.03	Winona	0	0.00
Wright	20	0.30	Wright	14	0.47	Wright	2	0.20
Yellow Medicine	14	0.21	Yellow Medicine	10	0.33	Yellow Medicine	2	0.20
Total	**1062**	**15.85**	**Total**	**523**	**17.43**	**Total**	**195**	**19.50**

Source: (NOAA, 2018)

Another method used to estimate tornado frequency without using administrative boundaries is shown in Figure 37, which displays ≥ F1 tornadoes' paths in Minnesota from 1950-2017, along with a frequency risk layer showing the annual average number of tornadoes occurring within 50 miles (approximately an hour) of any location within Minnesota. To create the risk layer, a raster consisting of 900-square-meter cells was created over the entire state, and from each cell, a 50-mile search radius was performed counting the number of tornado lines that intersected the search radius.

Figure 37. Tornadoes ≥ F1 in Minnesota, 1950-2017



SOURCE: *(NOAA, 2018)*

A value representing expected number of tornadoes was then developed for each county using the average frequency data in a 50-mile radius, normalized by the county's area. This method adjusts for area and reporting bias in order to compare county to county. This value represents the expected number of tornadoes in the county based on local and regional trends in reported data as opposed to administrative boundaries. *Appendix L – Tornado Vulnerability Ranking* shows the expected number of tornadoes by county. These values are also used in a vulnerability index in the Vulnerability section below.

Vulnerability

Tornadoes cause death, injury, destruction of property, damage to public spaces and infrastructure, and significant disruption to commerce and day-to-day activities in their aftermath. Injured victims of tornadoes may be unable to work for days or weeks, while other victims who do not suffer directly nevertheless cannot work because of damage to their business or place of employment. Others yet may suffer from a loss of goods and services in the tornado-affected area. Vulnerability to tornadoes is quite complex and is governed by a host of socioeconomic, cultural, and physical factors.

In general, tornado casualties decrease when people receive adequate warnings with sufficient time to seek shelter in a reinforced structure.

Many outdoor warning sirens in the US were built from the Federal Civil Defense Act of 1950 in response to a growing nuclear threat. These sirens started to be used as tornadoes warnings sirens around 1970 when the U.S. government began allowing civil defense funds to be used for natural disaster preparedness (Coleman, Knupp, Spann, Elliott, & Peters, 2011).

The NCEI tornado data was examined to see if there is a correlation between the use of tornado warning sirens in Minnesota and the number of tornado-related deaths and injuries. From 1950 to 1970, there were 332 tornado events resulting in 71 deaths and 1,292 injuries. There have been 1,650 tornado events reported from 1970 to 2018 with 28 deaths and 685 injuries (NOAA, 2018). There seems to be a correlation that warning sirens save lives and reduce injuries, but there may be other influencing factors, such as warnings via mass-media, expansion of the NOAA weather radio's broadcast and tone alerts, and more efficient dissemination of warnings, including the use of storm-based warnings and the Common Alerting Protocol (Coleman, Knupp, Spann, Elliott, & Peters, 2011).

The vulnerability to structures depends upon the strength and path of the tornado. The NCEI's tornado data reports no damages for 1,053 tornado events out of a total 1,973 tornadoes. The remaining records escalate damages from the low thousands of dollars up to just over $1.6 million (NOAA, 2018). The insight gained from this assessment is that densely developed jurisdictions will experience higher levels of damage than rural communities.

In the article "The Frequency of High-Impact Convective Weather Events in the Twin Cities Metropolitan Area, Minnesota," Kenneth Blumenfeld examines the frequencies and recurrence intervals of high end convective weather events in the Twin Cities Metropolitan Area (TCMA). According to Blumenfeld (2010):

> …thunderstorms capable of serious damage and disruption strike the TCMA *regularly*. Major damage from a convective weather episode is 'normal,' and tornadoes--including long-lasting and violent ones--are part of the area's history, and should be expected to be part of its future. (p. 630)

Blumenfeld (2010) states communicating to the public the risk of a serious tornado outbreak in the future is challenging because it has been decades since the last violent single or multiple-tornado event in the TCMA. Also, the significant population growth of the area since the 1965 tornado outbreak means many of the residents may not be aware of what to do during the next major tornado outbreak (Blumenfeld, 2010, p. 630). It is important for emergency preparedness officials, especially in urban areas facing similar challenges, to ask themselves, "Do all groups have equal access to warning information? Can the disabled and elderly be notified and moved to safety quickly? Are people responding to warnings based on their beliefs about the unlikelihood of tornadoes hitting urban areas?" (Blumenfeld, 2010)

Death, injury, crop, and property damage data from the Spatial Hazard Events and Losses Database for the United States (SHELDUS) was used to identify the 10 Minnesota counties that have suffered the greatest monetary loss due to tornadoes from 1960 to 2017, as shown in Table 45 (CEMHS, 2018). FEMA's Willingness to Pay (WTP) values were used to multiply against the number of deaths and injuries; $90,000 for each injured person and $5,800,000 for each person killed. The $90,000 WTP injury value is based on the Treat & Release injury severity level (FEMA, 2009) because SHELDUS data does not specify the extent of an injury.

Table 45. Monetary Damages from Tornadoes ≥ F1, by County, 1960 to 2017

County	Tornadoes ≥ F1	Injuries WTP	Fatalities WTP	Property Damage (ADJ 2016)	Crop Damage (ADJ 2016)	Total Damages
Hennepin	21	$12,716,100	$23,006,686	$246,481,550	$45,903	$282,250,239
Nicollet	10	$905,999	$5,800,000	$180,427,256	$136,368	$187,269,624
Murray	17	$3,510,000	$5,800,000	$48,114,625	$29,672,803	$87,097,428
Brown	7	$1,622,100	$5,800,000	$68,203,820	$74,996	$75,700,916
Freeborn	27	$3,600,000	$20,880,000	$51,199,967	$11,237	$75,691,203
Yellow Medicine	14	$2,610,000	$5,800,000	$61,140,877	$115,022	$69,665,899
Lyon	9	$12,330,000	$52,200,000	$3,794,314	$47,356	$68,371,669
Cass	19	$4,637,100	$40,600,000	$10,126,020	$354,411	$55,717,530
Washington	7	$3,669,000	$14,306,686	$35,521,010	$3,914	$53,500,611
Stearns	19	$5,222,100	$14,500,000	$27,252,867	$205,539	$47,180,506

Source: (NCEI, 2018), (CEMHS, 2018)

A vulnerability score was constructed to assess county vulnerability to tornadoes in a second way. The vulnerability score uses the total replacement value of all the buildings in a county (also known as the building exposure) and the expected number of tornadoes together for this score. The expected tornado values were scored as a percentage of the highest number of events in a county, and the building exposure values were scored as a percentage of the highest building exposure value. The log of the building exposure values was used to moderate the extremely high value of Hennepin and other metro counties. Finally, the two scaled scores were added to produce a vulnerability index.

Table 46 displays the ten counties in Minnesota with the highest vulnerability ranks. *Appendix L – Tornado Vulnerability Ranking* provides the vulnerability ranking using this index for all counties.

*Table 46. 10 Counties with Highest Vulnerability Rank**

County	Building Exposure in Millions	Historical Annual Storm Count	Expected Annual Storm Count	Vulnerability Rank
Otter Tail	$8,542.94	0.84	0.60	1
Hennepin	$171,960.81	0.40	0.17	2
Saint Louis	$28,175.81	0.37	0.31	3
Stearns	$18,983.40	0.37	0.33	4
Dakota	$53,322.27	0.26	0.17	5
Polk	$3,775.99	0.55	0.42	6
Anoka	$39,560.16	0.26	0.12	7
Ramsey	$67,353.65	0.10	0.05	8
Becker	$4,525.62	0.24	0.34	9
Clay	$6,285.45	0.44	0.30	10

Source: (CEMHS, 2018) (FEMA, 2018)

**The historical average annual tornado count is included for reference, but only the expected annual tornado count is used in the index.*

Damages to crops from tornadoes should also be considered when determining the vulnerability of a county, especially rural counties where crops may contribute to a large portion of the region's economy. Since 1989, the total crop indemnity claims due to tornadoes has been over $786,000. Indemnity claims with losses to the counties are shown in Table 47.

Table 47. Indemnity Claims for Tornadoes on Crops 1989-2017

County	Indemnity Claims (Adjusted 2016)
Le Sueur	$273,295
Pipestone	$110,659
Morrison	$61,137
Red Lake	$46,853
Meeker	$40,752
Otter Tail	$29,441
Rice	$27,516
Sibley	$23,173
Freeborn	$22,960
Renville	$20,546
Polk	$19,389
Steele	$16,894
Nicollet	$16,327
Olmsted	$14,806

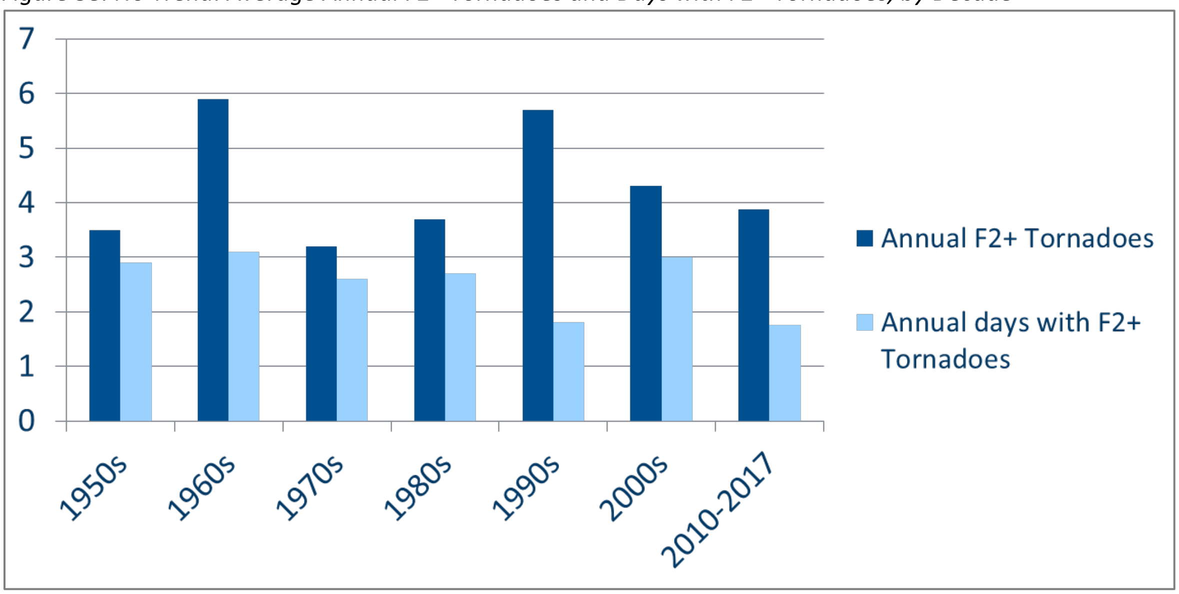
County	Indemnity Claims (Adjusted 2016)
Wilkin	$12,803
Carver	$12,481
Roseau	$9,263
Yellow Medicine	$5,873
Clearwater	$4,929
Nobles	$4,803
Norman	$3,433
Kandiyohi	$2,704
Faribault	$2,113
Jackson	$1,604
Redwood	$1,300
Marshall	$800
Lincoln	$629
Murray	$317

Source: (CEMHS, 2018)

Tornadoes and Climate Change

Minnesota's climate is undergoing distinct changes, but as reported by the Minnesota DNR State Climatology Office, these changes have not yet led to increases in tornadoes or severe convective storms. Minnesota, like all parts of the U.S., has seen increases in the weakest class of tornadoes (rated F-0 or EF-0), but these increases are known to be linked to improved spotting, detection, and verification procedures within the National Weather Service. When examining tornadoes that cause significant structural damage and are rated EF-2 or above, Minnesota has seen no recent trends towards increasing frequencies—whether measured as raw counts, or as days with one or more of these tornadoes (Figure 38).

Figure 38. No Trend: Average Annual F2+ Tornadoes and Days with F2+ Tornadoes, by Decade



SOURCE: (MN DNR STATE CLIMATOLOGY OFFICE, 2019)

The tornado trends in Minnesota match those found nationally, but climate scientists are unclear about whether the recent statistical behavior of these severe convective storm events has any relationship with the changing climate. This uncertainty results from the fact that tornadoes and their parent thunderstorms operate on smaller scales and more localized processes than the global climate. There has been some indication that, on a national basis, tornadoes are being clustered into fewer days, suggesting a greater tendency towards outbreaks. Scientific modelling studies summarized in Volume I of the *Fourth National Climate Assessment* indicate that meteorological conditions supportive of severe thunderstorms should increase in the future, but it is unclear whether the specific conditions required for the formation of tornadoes, and particularly significant tornadoes, will increase (Kossin, 2017). Until further studies are completed, the State Climatology Office recommends assuming that tornadoes will remain an important and dangerous part of Minnesota's climate, even if they do not increase in frequency or severity in response to changing climatic conditions.

4.7.5 Hail

A hailstorm forms in severe thunderstorms and develops within an unstable air mass. Warm moist air rises rapidly into the upper atmosphere and subsequently cools, leading to the formation of ice crystals. These are bounced about by high velocity updraft (or strong) winds and accumulate into frozen droplets, falling as precipitation after developing enough weight (FEMA, 1997).

Hailstorms cause millions of dollars in property, livestock, and crop damage each year. Severe hailstorms cause considerable damage to buildings, automobiles, and airplanes. Significant property damage does not occur until hailstone size reaches about 1.5 inches in diameter. This size will cause damage to cars, windows, and siding. When hailstones get larger and approach three inches in diameter, roofs start to experience major damage. According to the National Centers for Environmental Information (NCEI), combined property and crop damage annual totals for recent years in Minnesota were $4,030,000 (2017), $854,000 (2016), and $53,000 (2015).

The National Weather Service (NWS) defines severe thunderstorms as those with downdraft winds in excess of 58 miles per hour and/or hail one inch in diameter or greater. While only about 10% of thunderstorms are classified as severe, all thunderstorms are dangerous because they produce numerous dangerous conditions, including one or more of the following: hail, strong winds, lightning, tornadoes, and flash flooding. The land area affected by individual hail events, an average of 15 miles in diameter around the center of the storm, is similar to the area affected by the parent thunderstorm. Hail risk at a point or over an area is a function of the target at risk (property or crop) and the hail frequency, intensity, and size.

The size of hailstones varies and is a direct consequence of the severity of the thunderstorm. Hail quarter size (one inch in diameter) or larger is considered severe.

Hailstorms occur most frequently during the late spring and early summer, when the jet stream moves northward across the Great Plains. During this period, extreme temperature changes occur from the surface up to the jet stream, resulting in the strong updrafts required for hail formation.

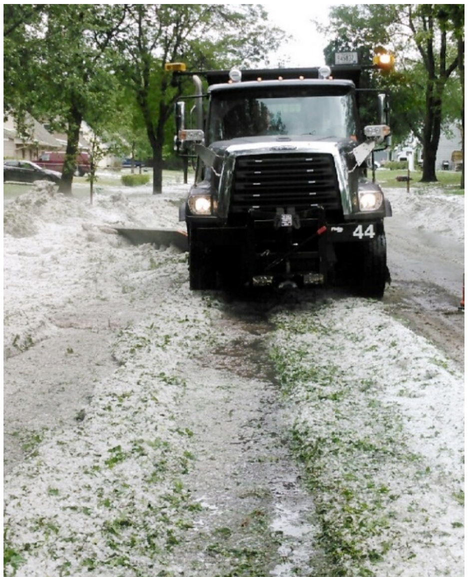
Hail History

The annual average number of hail days in Minnesota ranges from less than one in the north to three in the southwest. Reports have been made of hailstones with diameters greater than four inches. Every year hailstorms result in crop losses for farmers in the state, most of whom carry insurance. While hail has been recorded during every month, the hail season's peak is approximately June 1, with the most common time between 4:00 PM and 8:00 PM (Seeley, 2015).

The NCEI has maintained a list of weather and climate disasters in the United States since 1980, in which overall damages and costs reached or exceeded $1 billion. In June 2017, Minnesota experienced a hail and windstorm that caused considerable damage across the state and into Wisconsin (Figure 39). The metro area suffered particularly bad damage to buildings and vehicles. The total estimated cost was $2.4 billion. In August of 2013, large hail in Minnesota and Wisconsin resulted in another billion-dollar event. And in May 1998, severe thunderstorms with large hail fell over wide areas of Minnesota, resulting in over $1.5 billion in damages and one death (NOAA, 2018).

According to data from NOAA's Storm Prediction Center, Minnesota experienced an annual average of 19 hail events (hail sizes from 0.75 to 6.0 inches) during the five-year period between 2013 and 2017 (NOAA

Figure 39. A Snow Plow in Coon Rapids after a June 2017 Hail Storm (Covington, 2017)



Storm Prediction Center, 2018). The total amount of recorded property and crop damage due to hail during this time was $2.9 million dollars, or an annual average of $599,099 dollars.

Between 2013 and 2017, 83% of the hail occurred from May through July. June had 44% of the hail events, May had 21%, and July had 18%. During this five-year period, 44% of hail events had hail one inch or less; 3% of hail events had hail three inches or greater.

The table below summarizes a number of notable hail events occurring from 2013 to April 2018.

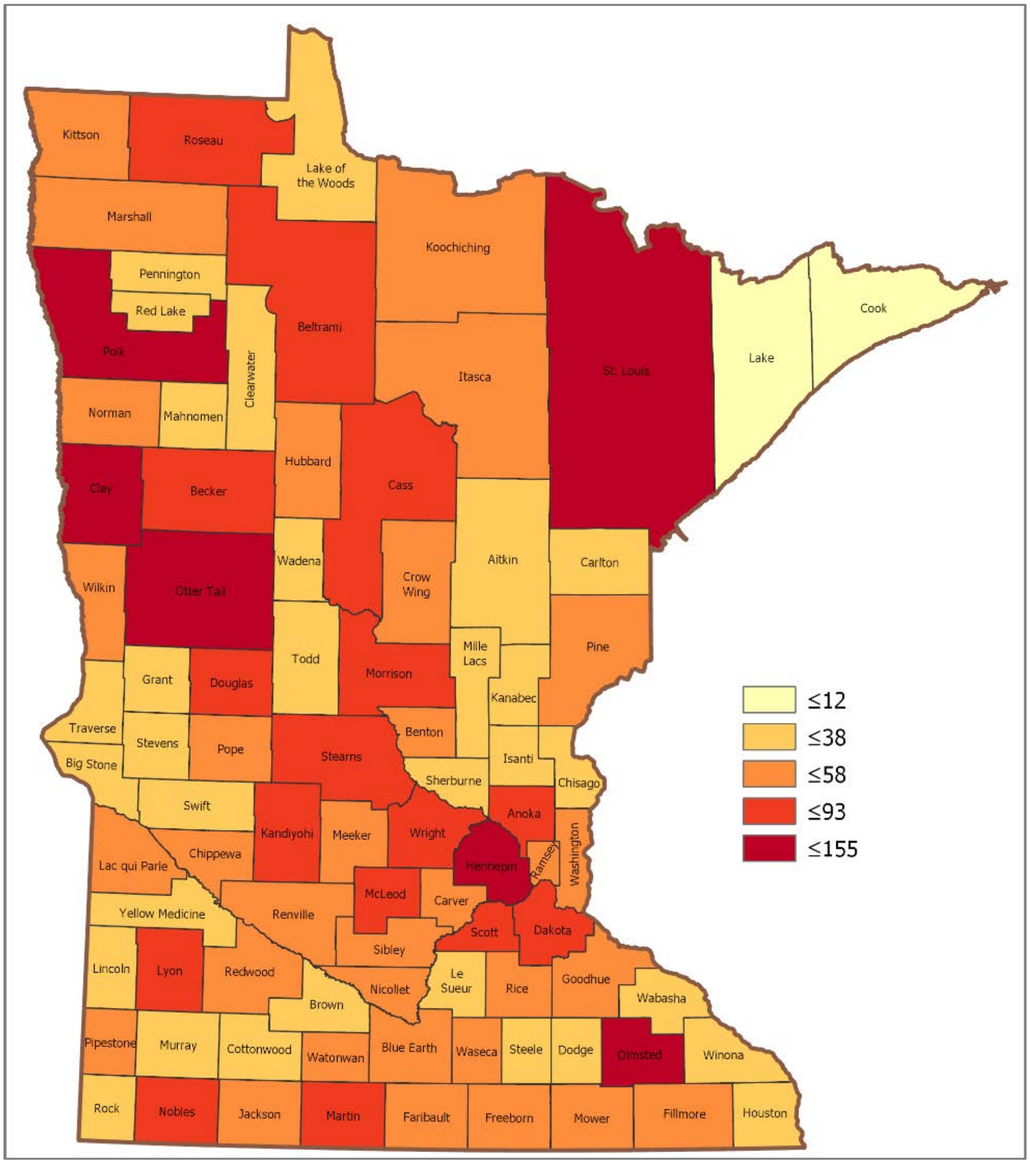
Table 48. Notable Hail Events in Minnesota, 2013-April 2018

Date	Location	Remarks
7/9/2017	South-Central MN	Many reports of very large hail were reported, along with two tornadoes. Softball-sized hail occurred in the Sibley County towns of Gibbon and Winthrop, causing $250,000 in property damage and $1 million in crop losses. Crops were also severely damaged in rural Nicollet County.
6/11/2017	Southern MN	The NCEI reported $650,000 in property damage to public property and infrastructure in Anoka County. Some areas of the county received up to two feet of hail, which caused several cities to use snowplows.
6/10/2017	Itasca State Park	Hail up to 1.75 inches fell, resulting in $500,000 in property damage.
5/16/2017	Southeastern and East-Central MN	Several reports of hail up to 2.5 inches in diameter were recorded from west of Dennison to near Canon Falls, resulting in damage to siding, cars, and roofs. The NCEI recorded $850,000 in property damage from the event.
11/28/2016	Central / Western Twin Cities	In a rare November hailstorm, pea to dime-sized hail was reported. The largest hail reported with in Blaine in southern Anoka County (MN DNR, 2016).
7/19-20/2016	Red River Valley	Flooding, high winds, and large hail were recorded in the Red River Valley, with gusts up to 70 mph. Crystal, North Dakota experienced baseball-sized hail for up to 35 minutes (MN DNR, 2016).
7/5/2016	Kandiyohi County	Hail the size of golf balls crushed crops across the southern half of Kandiyohi County, with crop losses estimated at $500,000.
5/24/2016	Central and Southern MN	Hail of up to 1.75 inches was reported in Morrison County, where high winds also caused tree damage. In Arlington in Sibley County there was enough hail to cover the ground like snow (MN DNR, 2016).
5/3/2015	Twin Cities	Multiple reports of hail up to quarter size occurred in the north metro area. The largest hail was golf ball-sized near Stillwater. There were reports of hail piling up like snow several inches deep, and some of the hail remained on the ground 12 hours later (MN DNR, 2015).

SOURCE: (NCEI, 2018) UNLESS OTHERWISE NOTED

Figure 40 summarizes the total number of hail events producing hail of an inch in diameter or greater that were recorded in each county from 1955-2017.

Figure 40. Number of Hail Events ≥ 1", by County, 1955-2017



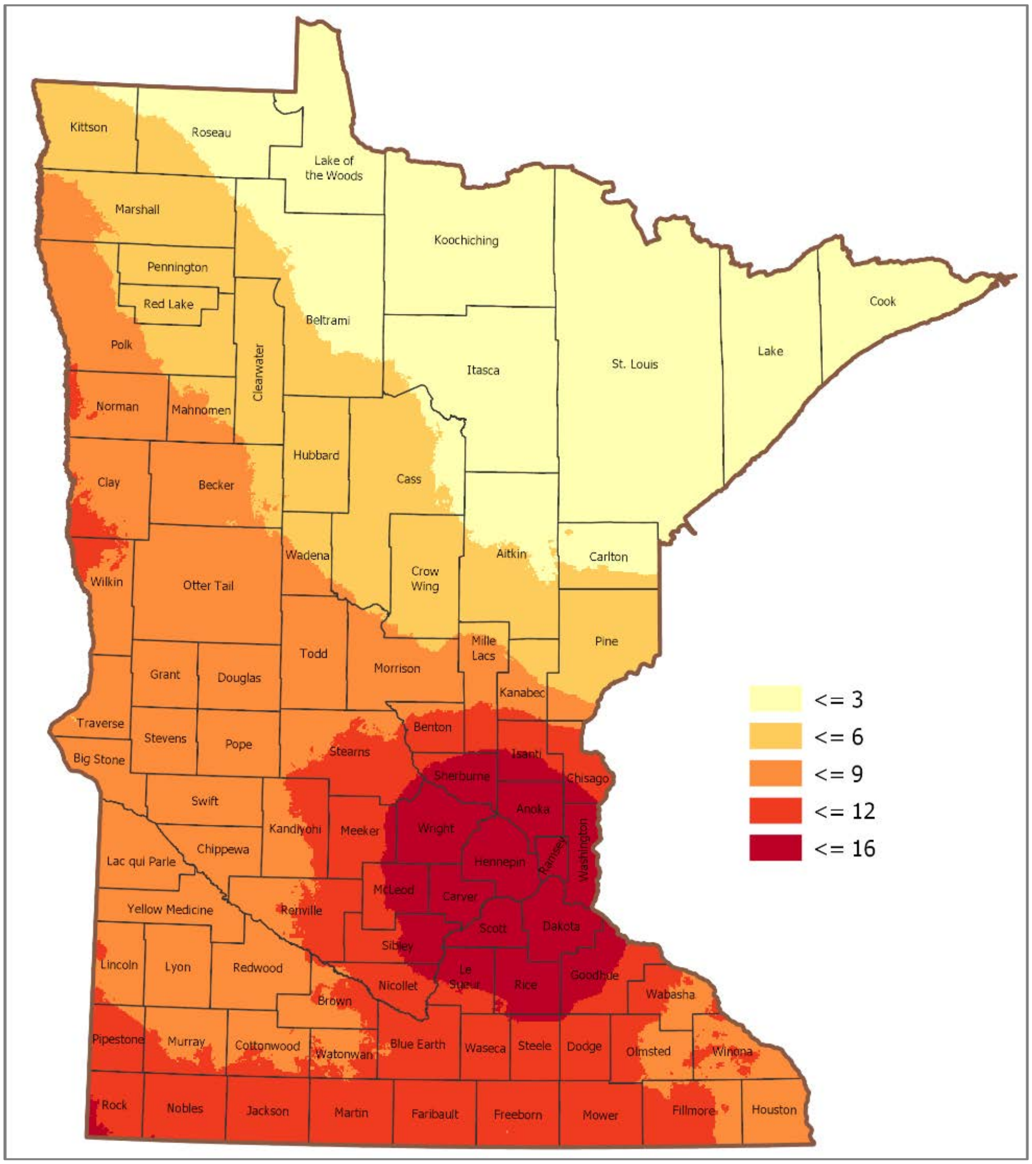
SOURCE: (NCEI, 2018)

Probability of Occurrence

The probability of hail occurring somewhere in the state during the late spring and early summer is clearly high. Every county receives hail annually.

Figure 41 shows the annual frequency of hailstorm events producing hail greater than or equal to one inch that occurred within 50 miles (approximately an hour) of a given location in Minnesota from 1955 through June 2018. More hail events reported in the Twin Cities Metro region are somewhat due to the density in reporting of storms and damage.

Figure 41. Annual Frequency of Hail Storms ≥ 1 inch, 1955-2017



SOURCE: (NOAA STORM PREDICTION CENTER, 2018)

A value representing expected number of hailstorms was developed for each county using the average frequency of hail events in a 50-mile radius with hail of one-inch in diameter, normalized by the county's area. All other factors being equal, the larger counties will have more storms, so this method adjusts for area and reporting bias in order to compare county to county. This expected number of hailstorms in the county is derived from local and regional trends in reported data as opposed to administrative boundaries. *Appendix M – Hailstorm Vulnerability Ranking* shows the expected number of hailstorms data by county. The county expected number of hailstorms is also used in a vulnerability index described below.

Vulnerability

Death, injury, crop, and property damage data from the Spatial Hazard Events and Losses Database for the United States (SHELDUS) was used to identify the ten counties in Minnesota that have suffered the greatest monetary loss due to hailstorms that produced hail ≥ 1 inch, from 1960 to 2017 (Table 49) (CEMHS, 2018). FEMA's Willingness to Pay (WTP) values were used to value the number of deaths and injuries; $90,000 for each injured person and $5,800,000 for each person killed. The $90,000 WTP injury value is based on the "Treat & Release" injury severity level (FEMA, 2009).

Table 49. Counties with the Greatest Monetary Damages from Hailstorms ≥ 1 inch, 1960 to 2017

County	Hailstorms ≥ 1"	Injuries WTP	Fatalities WTP	Property Damage (ADJ 2016)	Crop Damage (ADJ 2016)	Total Damages
Blue Earth	52	$480,600	$203,000	$7,797,049	$80,412,842	$88,893,491
St. Louis	128	$137,400	$5,800,000	$75,737,912	$50,774	$81,726,086
Hennepin	171	$3,144,975	$8,284,314	$62,577,348	$1,378,027	$75,384,664
Lincoln	34	$4,200	$203,000	$987,347	$36,950,611	$38,145,159
Traverse	26	$139,501	$261,000	$1,449,136	$34,084,007	$35,933,644
Carver	56	$2,246,476	$2,967,686	$26,803,519	$3,240,604	$35,258,284
Renville	43	$21,300	$0	$860,765	$31,182,782	$32,064,847
Ramsey	70	$3,087,676	$4,417,686	$17,763,844	$618,042	$25,887,248
Pipestone	36	$4,200	$203,000	$5,014,396	$19,589,019	$24,810,616
Nobles	55	$4,200	$203,000	$14,286,162	$9,869,243	$24,362,605

SOURCE: (CEMHS, 2018) (NOAA STORM PREDICTION CENTER, 2018)

In another attempt to assess how vulnerable a county is to hailstorms, a vulnerability score was constructed. The vulnerability score uses the total replacement value of all the buildings in a county (building exposure) and the expected number of hailstorms value together for this score. The expected storm values were scored as a percentage of the highest number of storms in a county, and the building exposure values were scored as a percentage of the highest building exposure value. This was done to moderate the extremely high value of Hennepin and other metro counties with the rest of the state. Finally, the two scaled scores were added to produce a vulnerability score. Table 50 displays the ten counties with the highest vulnerability ranking.

Table 50. Counties Most Vulnerable to Hailstorms, 1955 to 2017

County	Building Exposure in Millions	Avg Annual Count*	Expected Annual Count	Vulnerability Rank
Hennepin	$171,961	2.79	1.20	1
Otter Tail	$8,543	2.13	2.11	2
Saint Louis	$28,176	2.10	1.61	3
Stearns	$18,983	1.69	1.67	4
Dakota	$53,322	1.40	1.09	5
Wright	$15,132	1.55	1.38	6
Anoka	$39,560	1.27	0.81	7
Polk	$3,776	1.77	1.65	8
Washington	$31,565	0.74	0.73	9
Ramsey	$67,354	1.18	0.31	10

SOURCE: (NOAA NCEI, 2018) (FEMA, 2018)

*The historical average annual windstorm count is included for reference, but only the expected annual tornado count is used in the index.

Hail and Climate Change

According to the U.S. Global Change Research Program (USGCRP) National Climate Assessment (NCA), trends in severe storms, including the numbers of hurricanes and the intensity and frequency of tornadoes, hail, and damaging thunderstorm winds are uncertain. Since the impact of more frequent or intense storms can be larger than the impact of average temperature, climate scientists are actively researching the connections between climate change and severe storms (USGCRP, 2014). The NCA reports that in Minnesota's neighboring Great Plains region to the west, fewer hail days are expected, but more frequent occurrences of larger hail in spring months are possible (USGCRP, 2017).

The occurrence of very heavy precipitation has increased in Minnesota in recent decades, and future projections also indicate this will continue (ICAT, 2013). While it is unknown if this precipitation will occur during severe storms that produce hail, the possibility has not been ruled out.

4.7.6 Dam/Levee Failure

Dams and levees—artificial barriers that have the ability to impound water, wastewater, or any liquid material for the purpose of storage or control—are an important part of Minnesota's infrastructure. Dams maintain lake levels and impound water for flood control, power production, and water supply. Levees are used to increase cultivation in agriculture and to protect population and structures from floods. Severe flood damage may result from a failed structure or its overtopping. Overtopping is when floodwaters simply exceed the design capacity of the structure, thus the water flows over the lowest crest of the system. Such overtopping can lead to erosion on the landward side, which may then lead to failure. Many factors affect the impact of a failure, such as the volume of impounded liquid, location of structures and critical facilities, intended purpose of the dam or levee, and/or its construction type. Failure may occur from one or a combination of the following reasons:

- Prolonged periods of rainfall and flooding.
- Inadequate spillway capacity, resulting in overtopping flows.
- Internal erosion caused by embankment or foundation leakage or piping.
- Improper maintenance, including failure to remove trees, repair internal seepage problems, replace lost material from the cross section of the dam and abutments, or maintain gates, valves, and other operational components.
- Improper design, including the use of improper construction materials and construction practices.
- Improper operation, including the failure to remove or open gates or valves during high flow.
- Upstream dam failure on the same waterway that releases water to a downstream dam.
- Earthquake activity, which typically causes longitudinal cracks at the tops of the embankments resulting in weakened structures.

Dams are complicated structures, and it can be difficult to predict how a structure will respond to distress. The modes and causes of failure are varied, multiple, and often complex and interrelated. Often the triggering cause may not have resulted in failure had the dam not had a secondary weakness. Therefore, careful, critical review of all facets of a dam is needed (National Research Council, 1983).

A levee breach can be caused by surface erosion due to water velocities or subsurface actions. Subsurface actions usually involve sand boils whereby the upward pressure of water flowing through porous soil under the levee exceeds the static pressure of the soil weight above it (i.e., under seepage). These boils can indicate instability of the levee foundation given the liquefied substrate below it, leading to breaching. Additionally, as mentioned above, levees can be subjected to overtopping, thereby causing landward erosion. To prevent this type of landward erosion, many levees are reinforced with rocks or concrete. The concern with levees is that they may fail when exposed to floodwaters for an unusually long period. The prolonged hydraulic forces may weaken the structure to the point of failure. Monitoring and reinforcement measures may prevent that from happening.

Dam Failure History

According to the Minnesota Department of Natural Resources (MN DNR), there are over 1,250 dams in Minnesota: approximately 800 are public, and of those, over 430 are owned by the state. Most of the public dams are more than 50 years old and require ongoing or emergency repairs and reconstruction to maintain their structural integrity. Through state bonding, the MN DNR spends approximately $2 million annually on repairs and reconstruction. An estimated $114 million is needed over the next 20 years to assure public dams remain in a safe and usable condition (MN DNR, 2018).

Notable incidents relating to dams since 2013 are listed in Table 51. These events show how important design, operation, maintenance, and nature play a role in potential failures. Economic impacts were not available with the dam incident history provided below.

Table 51. Notable Dam Incidents in Minnesota, 2013-2018

Year	Location	MN Dam Safety Engineer Remarks
2018	Springdale 21, Redwood County	Overtopping but not complete failure.
2018	Ajax, St. Louis County	Not sure if this was a dam or not. Not sure if embankment is natural ground and the channel was cut too close to the pit, or if this is a partially constructed embankment.
2017	Ajax, St. Louis County	Not sure if this was a dam or not.
2017	Johnson Pond, Todd County	During 2017 inspection noted that dam had failed.
2017	Hibbing Taconite stockpile, St. Louis County	Apparent rotational failure of stockpile road embankment (over steepened slope) into a wetland. Bulldozer on site at time of failure but no injuries as they had indications it was failing.
2017	Brawner, Lyon County	Reservoir had refilled on its own after draining in 2015. This time the reservoir is completely drained and will stay that way until the dam is repaired.
2016	Willow River, Pine County	Large flood after very heavy rains overtopped entire embankment. Failure occurred on right abutment.
2015	Brawner, Lyon County	Reservoir slowly drained due to bad connection of riser and conduit.
2014	High Island Creek, Sibley County	Persistent high water, lots of trees in spillway. Dam removed.
2014	Blue Mounds State Park – South Mound Creek Pool, Rock County	Large flood after heavy rains overtopped spillway.
2014	Inland Steel Tailings Basin, St. Louis County	West embankment on northwest corner likely failed by piping. Piping likely due to high water flowing through coarse roadway material. High water was likely due to spring snowmelt and excessive ice in the western part of the reclamation pond, which prevented flow from the Upland II decant from flowing to the main reclamation pond.
2013	Korsness Pool, Mille Lacs County	Pipe separation caused downstream erosion, cut emergency breach in spillway.

SOURCE: (MN DNR, 2018)

Other notable events have occurred as well. In June of 2018, an earthen dam failed in rural northwestern Wisconsin, which resulted in bridges flooding on the Tamarack River, which flows into the St. Croix River on the Minnesota-Wisconsin border. A flash flood warning was issued for Markville, Minnesota, located downstream of the Radigan Flowage Dam, and portions of area highways were closed due to washouts (MPR, 2018).

A 2012 event showed the potential impacts due to high rainfall and river levels. Large portions of the state experienced heavy rainfall on June 20. Carlton County saw record rainfalls in a 24-hour period that fell on an already saturated ground. The St. Louis River at Scanlon rose 11 feet and hit a record crest of 16.62 feet, breaking the old record of 15.8 feet that was set on May 9, 1950. Some evacuation of homes was necessary. An earthen dike on Forebay Lake that feeds the Thomson Hydro-Power Dam was saturated with water and gave way during heavy rains. Figure 42 shows the flooded forebay had washed out a 100-foot deep gap in Highway 210 in Jay Cooke State Park (MPR, 2012). High water at Thomson Dam overtopped the Thomson Reservoir, but the reservoir did not fail. Operators of the dam activated the Emergency Action Plan thereby averting injuries. The alarm was sounded due to the channel collapse as opposed to concerns about catastrophic failure of the dam. Approximately $3 million in damages to public structures were recorded based on FEMA and MN DOT records. The recorded damages were impacted by three different dynamics: extreme rain with previously saturated ground, structural failure, and designed overtopping.

Figure 42. A section of Highway 210 was washed out after a dike was overtopped at Forebay Lake

SOURCE: DEREK MONTGOMERY FOR MPR NEWS

Dam Regulation

The agencies with regulatory authority of dams in Minnesota are:

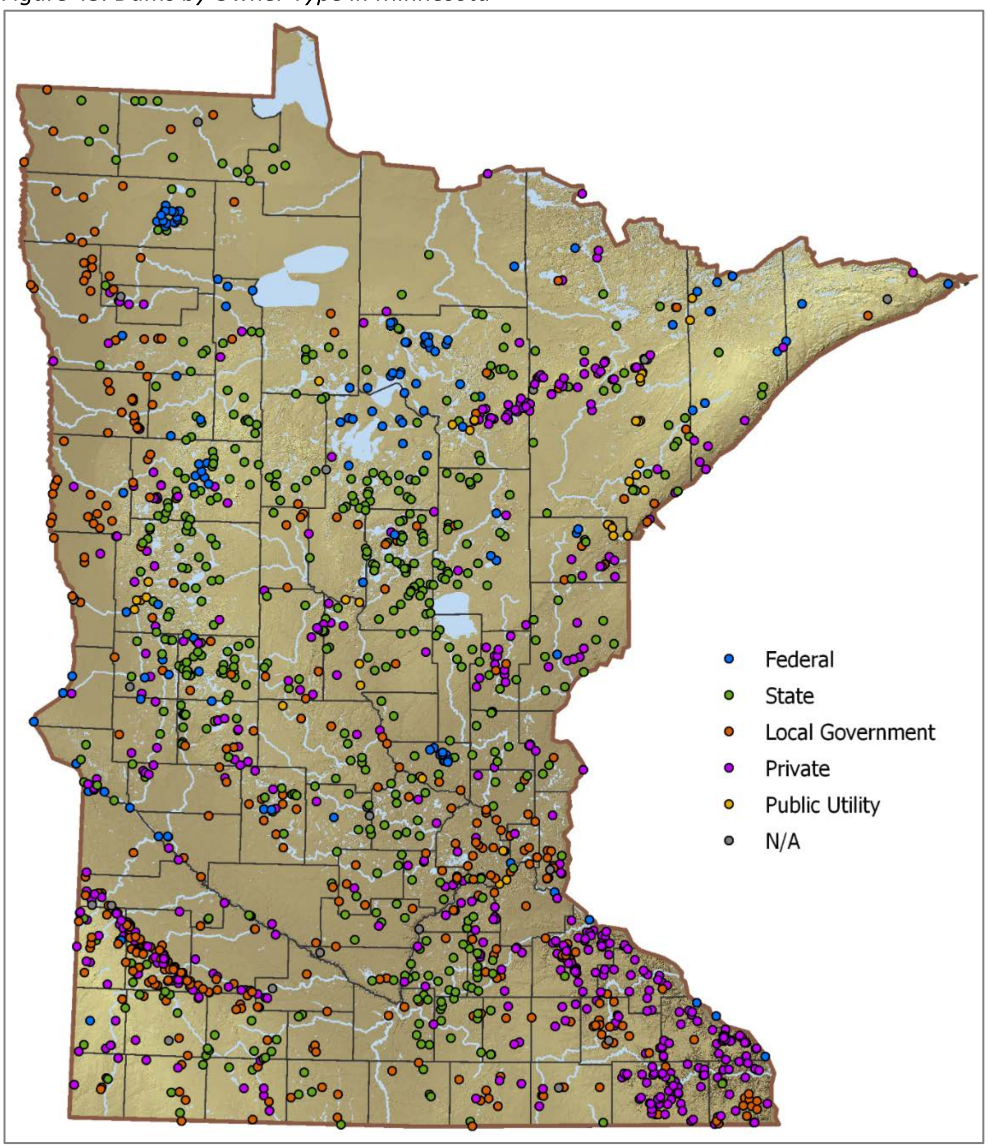
- The MN DNR Dam Safety Program has the mission of protecting the life and safety of people by ensuring that dams are safe. Minnesota's program sets minimum standards for dams and regulates the design, construction, operation, repair, and removal of dams. Both privately and publicly owned dams are regulated.
- The U.S. Army Corp of Engineers (USACE) maintains the lock and dam system on the Mississippi River and has regulatory authority over the flood control dams that it owns. USACE also participates with local communities in all phases of flood control that includes dams, levees, or other means.
- The Federal Power Act (FPA) authorizes the Federal Energy Regulatory Commission (FERC) to issue exemptions or licenses to construct, operate and maintain dams, water conduits, reservoirs, and transmission lines to improve navigation and to develop power from streams and other bodies of water over which it has jurisdiction. 16 U.S.C. § 797(e). Regulatory tools include the Federal Power Act, Public Utility Regulatory Policies Act, the Electric Consumers Act of 1986 and the Energy Policy Act of 1992.

The authorities vary between agencies but the overall design, construction, operation, and maintenance of dams come under their authority. They also classify dams for emergency response purposes. This classification system does not imply that the dam is unsafe. Regulatory agencies require Emergency Action Plans (EAP) for all high hazard dams. The hazard classifications for dams are as follows:

- **High (Class I)** - loss of life or potential serious hazards; damage to health, main highways, high-value industrial or commercial properties, or major public utilities; or serious direct or indirect economic loss to the public;
- **Significant (Class II)** - possible health hazard or probable loss of high-value property; damage to secondary highways, railroads or other public utilities; or limited direct or indirect economic loss to the public other than that described in Class III (Low); and
- **Low (Class III)** - property losses restricted mainly to rural buildings and local county and township roads that are an essential part of the rural transportation system serving the area involved.

Figure 43 below depicts dams by owner type.

Figure 43. Dams by Owner Type in Minnesota



SOURCE: (MN DNR, 2018)

The National Inventory of Dams (NID) count 1,097 dams in the state, 55 of which have a high hazard potential and 144 of which have a significant hazard potential. Of the 55 high hazard potential dams, 53 have EAPs reflected in the 2015 data available from the NID. Thirty of the 144 significant hazard potential dams have EAPs (National Inventory of Dams, 2018).

Levee Failure History

According to the National Levee Database, Minnesota has 145 levee systems and 218 miles of levees. There are 26,700 structures and 91,400 people living in areas protected by levees. 34% of the levees are accredited. The U.S. Army Corp of Engineers has management responsibility for 36% of the levees.

Levees garnered attention after the 2005 Hurricane Katrina devastation in New Orleans. There is no official historical source for failed levees in Minnesota. Failed levees for the protection of life and property have been reported as part of Presidential Disaster Declarations in Minnesota. The most notable event due to floodwaters overtopping a levee was the 1997 flood in East Grand Forks (DR-1175). Extensive damages were due to water cresting over earthen levees. The Red River crested at 54.32 feet. The earthen levees in place were designed to protect to level of a 100-year flood plus three feet of freeboard, or 52 feet. During the flood fight, there were 3.5 million sandbags used plus many cubic yards of clay and gravel. The one inch per hour (two feet per day) rise of the river overcame the reinforcement efforts (FEMA, 2019).

A significant amount of resources go into providing flood forecasts so that the appropriate flood fighting measures may be taken. NOAA provides flood forecasts based on extensive surveys of snow cover. Communities use the NOAA forecasts to activate the flood fight plans to ensure all levee components are in place. Engineers determine the height and width of sandbags to be added to a levee. Patrols walk the levees to determine leaks or degradation. All of these actions usually prevent losses; however, there are extreme conditions that may not be overcome. The East Grand Forks example shows how a heavy snowpack and a fast, late spring snowmelt overcame that city's defenses. Exposure to high levels of water and hydraulic pressure for an extended period of time is another extreme condition where levees may fail. Even though spring floods are an annual event, the probability of catastrophic failure is low due to the ongoing planning and response efforts by local, state, and federal agencies.

Levee Regulation

Levees for agricultural purposes are permitted by watershed districts or county soil and water conservation districts administered by the Board of Soil and Water Resources (BWSR). The number of levees for agriculture was not known at the time of this plan update. Agricultural levees funded by the U.S. Natural Resources Conservation Service are not regulated by the state and are handed over to the property owners after construction is complete. The Minnesota Silver Jackets team is taking on a project to identify levees at several communities in Minnesota to assess the location and impact of levees.

Using flood analysis and mapping projects, the National Flood Insurance Program (NFIP) is responsible for identifying flood risks behind levees within the FEMA Special Flood Hazard Area (SFHA). While the SFHA represents flooding that has only a 1% chance of an annual occurrence, FEMA has established criteria for those levees that may be affected should a flood occur. Levees on FEMA maps are shown as accredited levees, provisionally accredited levees, non-accredited, (including emergency levees) and levees under construction or restoration.

An *accredited levee* is certified if evidence has been presented showing the structure meets current design, construction, maintenance, and operation standards to provide protection from floods that fall into the 1% annual chance of inundation zone. Evidence is typically a statement by a licensed professional engineer or federal agency responsible for levee design. The levee owner is responsible for ensuring that the levee is being maintained and operated properly and for providing evidence of certification FEMA will accredit (formally recognize) levees that have evidence that they will provide adequate protection. Therefore, on flood hazard maps, the area behind the accredited levees will be shown as moderate risk zones. FEMA accredits levees that meet the criteria and maps areas behind those levees as having a certain risk level, but it does not perform the actual certifications. There are 49 accredited levees in Minnesota, which is five more since 2013 (Table 52).

Table 52. FEMA Accredited Levee Systems

Levee System Name	County	Waterway
Austin Flood Control Project 1	Mower	Cedar River
Austin Flood Control Project 2	Mower	Cedar River
Austin Flood Control Project 3	Mower	Cedar River
Bear Creek Levee	Olmsted	Bear Creek
Black Bear - Miller Lake	Crow Wing	
Blue Lake WWTP Levee	Scott	Minnesota River
Brentwood Rolyn Acres Levee	Clay	Oakport Coulee
Brookdale Levee	Clay	Red River of the North
Burnsville Sanitary Levee	Dakota	Minnesota River
City of Ada Judicial Ditch 51 Levee	Norman	Judicial Ditch 51
City of Ada Marsh River Flood Risk Reduction	Norman	Marsh River
City of Crookston Levee 1	Polk	Red Lake River
City of Crookston Levee 2	Polk	Red Lake River
City of Crookston Levee 3	Polk	Red Lake River
City of Crookston Levee 4	Polk	Red Lake River
City of Crookston Levee Ash Street Road Raise	Polk	Red Lake River
City of Crookston Levee Elm Street Levee	Polk	Red Lake River
City of Montevideo Levee	Chippewa	Chippewa River
Dawson	Lac qui Parle	
Gilmore Creek - Winona	Winona	
Hendrum Flood Control Levee Project	Norman	Red River
Horn Park Flood Mitigation Project 1	Clay	Red River of the North
Horn Park Flood Mitigation Project 2	Clay	Red River of the North
Metropolitan (Pigs Eye) Wastewater Treatment Plant Levee	Ramsey	Mississippi River
Middle River - Argyle	Marshall	
Minnesota River - Chaska	Carver	
Minnesota River - Granite Falls, Segment #2	Yellow Medicine	Minnesota River
Minnesota River - Henderson - North Levee	Sibley	
Minnesota River - Henderson - South Levee	Sibley	

Levee System Name	County	Waterway
Minnesota River - Lehillier	Blue Earth	
Minnesota River - Mankato - River Levee	Blue Earth	
Mississippi River - Winona City & Prairie Island	Winona	
Moorhead Country Club Mitigation Project 3	Clay	Red River of the North
Pig's Eye Wastewater Treatment Facility Levee	Ramsey	Mississippi River
Red River of the North - East Grand Forks	Polk	
Red River of the North - East Grand Forks Point	Polk	
Red River of the North - Fargo - Ridgewood Addition	Cass, Wright	
Red River of the North - Oslo	Marshall	
Redwood River - Marshall - Left Bank Downstream	Lyon	
Redwood River - Marshall - Right Bank Downstream	Lyon	
Redwood River - Marshall - Right Bank Upstream	Lyon	
Root River - Houston	Houston	
Root River-Houston	Houston	
Root River/ Rush Creek - Rushford - East Levee - Levees D, E, and F	Fillmore	
Root River/ Rush Creek - Rushford - North Levee - Levee C	Fillmore	
Root River/ Rush Creek - Rushford - West Levee - Levees A and B	Fillmore	
Snake River - Alvarado	Marshall	
Valleyfair Amusement Park Levee	Scott	Minnesota River
Vermillion River - Hastings	Dakota	

Source: National Levee Database, 2018

The inability to provide full and prompt documentation of a levee's status does not necessarily mean that the levee no longer provides the level of protection for which it was designed. It also does not mean that the flood hazard map should show the levee as providing protection against the flood that may occur in the 1% annual chance. FEMA has created the Provisionally Accredited Levee (PAL) designation to facilitate the certification process for communities whose levees are reasonable expected to continue to provide protection from those 1% floods. FEMA Provisionally Accredited Levees are listed in Table 53.

Table 53. FEMA Provisionally Accredited Levees

Levee System Name	Counties	Waterway
Mississippi River - South St. Paul	Dakota	
Mississippi River - St. Paul	Ramsey	
Red River of the North - Halstad	Norman	
Redwood River - Marshall - Left Bank Upstream 1963 level	Lyon	
Rochester Levee & Channel	Olmsted	Bear Creek
South Branch Yellow Medicine - Minneota	Lyon	
South St. Paul - Segment #2	Dakota	Mississippi River

Source: National Levee Database, 2018

Non-Certified and Emergency Levees

Non-accredited levees are not shown on the FEMA FIRM map as reducing the flood hazard during the 1% annual chance flood (Table 54). Emergency levees are a subset of non-accredited levees. They are built when floods are predicted without minimal engineering design. Usually emergency levees are removed after the flood event to receive Public Assistance funding under Category B. Some communities may have earthen works in place that were constructed before the flood event.

Table 54. Non-accredited Levees

Name	County	Name	County
Aitkin	Aitkin	St Peter	Nicollet
Fridley	Anoka	Norman County	Norman
New Ulm	Brown	Perley	Norman
Springfield	Brown	Fisher	Polk
Carver	Carver	Duxby	Roseau
Watertown	Carver	Elk River	Sherburne
Windom	Cottonwood	Lake City	Wabasha
Inver Grove Heights	Dakota	Wabasha	Wabasha
Blue Earth	Faribault	Wabasha county	Wabasha
Peterson	Fillmore	Afton	Washington
Preston	Fillmore	Lake St Croix Beach	Washington
Cannon Falls	Goodhue	Newport	Washington
Bradford Twp	Isanti	St Mary's Point	Washington
Jackson	Jackson	Stillwater	Washington
Hallock	Kittson	Elba	Winona
St Vincent	Kittson	Delano	Wright
Kasota	LeSueur	Otsego	Wright
Hutchinson	McLeod		

SOURCE: (MN DNR DIVISION OF WATERS, 2018)

Probability of Occurrence

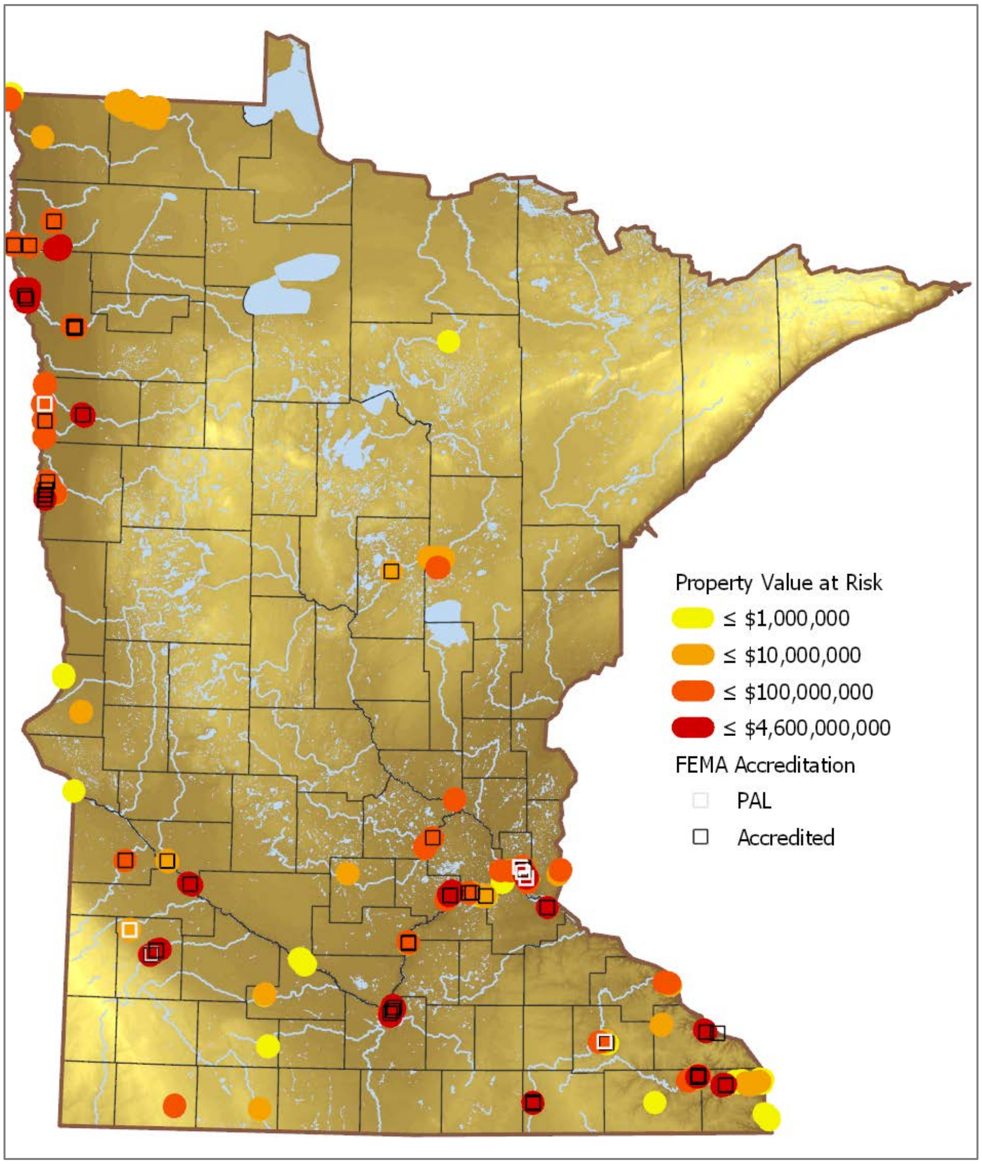
A general probability for dam or levee failure cannot be determined since each structure is unique in its engineering, construction, maintenance, and the intensity of the flooding that may cause damage.

Vulnerability

Communities downstream of high-risk dams and those which have needed protection by emergency levees are vulnerable to flooding due to dam or levee failure. An emergency levee is not maintained by the community and is not provisionally accredited. Therefore, communities with emergency levees are likely more vulnerable to flooding than provisionally accredited or accredited levees. High-risk dams are required to have Emergency Action Plans so this regulatory component can indicate a higher vulnerability to flooding.

Figure 44 below shows levees in Minnesota by property value at risk according to the National Levee Database. FEMA accreditation status is also shown.

Figure 44. Levees in Minnesota, property risk and accreditation status



SOURCE: NATIONAL LEVEE DATABASE

Dam/Levee Failure and Climate Change

Dams are designed based on assumptions about a river's annual flow behavior that will determine the volume of water behind the dam and flowing through the dam at any one time. Changes in weather patterns due to climate change may change the hydrograph, or expected flow pattern. Spillways are put in place on dams as a safety measure in the event of the reservoir filling too quickly. Spillway overflow events are mechanisms that also result in increased discharges downstream. It is conceivable that bigger rainfalls at earlier times in the year could threaten a dam's designed margin of safety, causing dam operators to release greater volumes of water earlier in a storm cycle in order to maintain the required margins of safety. Such early releases of increased volumes can increase flood potential downstream.

Climate change may increase the probability of design failures. Some spillways may not be large enough to convey the increased flow pattern. A spillway that is undersized could lead to dam overtopping and failure. The forebay canal in Carlton County had operated as designed for nearly 100 years before the failure from the June 2012 storm event. The intensity of the 2012 rain event caused a failure of the canal wall, which caused significant damage.

Climate change is adding a new level of uncertainty that needs to be considered with respect to assumptions made during the dam construction.

4.7.7 Extreme Heat

Extreme summer heat is the combination of very high temperatures and exceptionally humid conditions. If such conditions persist for an extended period of time, it is called a heat wave (FEMA, 1997). Heat stress can be indexed by combining the effects of temperature and humidity. The index estimates the relationship between dry bulb temperatures (at different humidity) and the skin's resistance to heat and moisture transfer—the higher the temperature or humidity, the higher the apparent temperature (NWS, 2018). The relationship between the apparent temperature and heat disorder risk is shown in Table 55.

Table 55. Heat Index and Disorders

Danger Category		Heat Disorders	Apparent Temperatures (°F)
IV	Extreme Danger	Heatstroke or sunstroke imminent.	>125
III	Danger	Sunstroke, heat cramps, or heat exhaustion likely; heat stroke possible with prolonged exposure and physical activity.	103-125
II	Extreme Caution	Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and physical activity.	90-103
I	Caution	Fatigue possible with prolonged exposure and physical activity.	80-90

Source: (NWS, 2018)

The major human risks associated with extreme heat are as follows:

Heatstroke: Considered a medical emergency, heatstroke is often fatal. It occurs when the body's responses to heat stress are insufficient to prevent a substantial rise in the body's core temperature. While no standard diagnosis exists, a medical heatstroke condition is usually diagnosed when the body's temperature exceeds 105°F due to environmental temperatures. Rapid cooling is necessary to prevent death, with an average fatality rate of 15%, even with treatment.

Heat Exhaustion: While much less serious than heatstroke, heat exhaustion victims may complain of dizziness, weakness, or fatigue. Body temperatures may be normal or slightly to moderately elevated. The prognosis is usually good with fluid treatment.

Heat Syncope: This refers to sudden loss of consciousness and is typically associated with people exercising who are not acclimated to warm temperatures. This causes little or no harm to the individual.

Heat Cramps: May occur in people unaccustomed to exercising in the heat and generally ceases to be a problem after acclimatization.

In addition to affecting people, severe heat places significant stress on plants and animals. The effects of severe heat on agricultural products may include reduced yields and even loss of crops.

Extreme Heat History

The hottest temperature ever recorded in Minnesota occurred in Beardsley in Big Stone County in July of 1917, with a record of 115°F (MN DNR, 2018). On July 19, 2011, Moorhead, Minnesota, set a new state record for the hottest heat index ever, at 134° F. That same day, Moorhead also recorded a new state record for the highest dew point at 88°F. It was the hottest, most humid spot on the planet that day (Douglas, 2011).

However, extreme heat in Minnesota is uncommon and usually short-lived. Since 1871, the Twin Cities has seen temperatures over 100°F in 30 summers, a frequency of approximately 21%. The occurrences of high heat are just one or two days. In more recent years, heat waves in the state have combined moderately high air temperatures with very high dew points (or humidity). The summers of 1983, 1995, 1999, 2001, 2005, 2010, and 2011 had heat index values from 110-120°F. These events can be a serious threat for both humans and animals (Seeley, 2015).

Extreme heat has been Minnesota's third deadliest weather factor since 1990. There were fifty-four heat-related deaths in Minnesota from 2000 – 2016 (MDH, 2018).

Southeastern Minnesota experienced excessive heat at the end of June, 2018. According to the NCEI, heat indices reached between 105°F and 115°F, and the highest heat index recorded was 118°F from a mesonet station in Plainview (Wabasha County).

On May 28, 2018, the temperature at the Minneapolis-Saint Paul International Airport reached 100°F, which was the earliest recording of this temperature since 1871. The previous record for May 28 was 98°F in 1934 (MN DNR , 2018).

Heat indices of 105°F occurred in August 2013 during the Minnesota State Fair. Treatment was required for 216 people due to heat-related illnesses. Ten people required transport to local hospitals. Minneapolis schools also cancelled outdoor athletic practices during this period of extreme heat. The NCEI reported that one person passed away from heat-related causes in Olmsted County. The individual is believed to have died due to working outside in the heat in combination with his prescription medications. The heat index was 95°F at the Rochester International Airport.

An extreme heat wave affected most of Minnesota in 2011. Minneapolis experienced its most humid day on record and tied the all-time record for a heat index in the city, with 119 degrees. Meteorologists labeled the event a "humidity storm." During heat waves, the urban heat island—a metropolitan area that is significantly warmer than surrounding rural areas due to human activities — effect can spike temperatures by as much as nine degrees. During the heat wave, ultraviolet monitoring showed dangerously high levels of radiation, which can cause acute and chronic effects on the skin, eyes, and immune system. During July of 2011, the average UV index was 9.7, the highest for any July since 1994. The level was above 10 on the days during peak intensity, a level which is associated with high risk levels for serious health effects (MDH, 2018).

During the July 2011 heat wave, nearly 800 people in the metro region were treated for heat-related illnesses, and fatalities were recorded. The Minnesota Department of Transportation (MN DOT) reported various locations where the road buckled due to heat, including on areas of I-94. In addition, utilities were strained while attempting to meet cooling demands. One utility in northeastern Minnesota used more power during a single day of the heat wave than any other day throughout the utility's records (MDH, 2018).

Probability of Occurrence

Extreme heat events are common in Minnesota; however, probability of occurrence of heat waves has not yet departed from the historical record. Average high summer temperatures have not increased in several decades, and heat waves have not worsened in recent years when compared to historical patterns (ICAT, 2017). However, according to the Minnesota Extreme Heat Toolkit by the Minnesota Department of Health, based on observed and predicted trends, there is a high probability of extreme heat events occurring more frequently in Minnesota in the future (see Extreme Heat and Climate Change below).

Vulnerability

In Minnesota, the impacts of increased extreme heat events and heat waves will impact both urban and rural regions. While the temperatures in metropolitan areas can be higher due to the heat island effect, the Minnesota Department of Health and other health departments across the United States have observed that there is typically more emergency department visits for heat-related illnesses in rural areas than in urban areas during a heat wave. This may be due to a number of factors, including a lack of air conditioning or healthcare resources in rural areas, as well as more people exposed to heat in rural areas due to job types, like farming and forestry.

The Minnesota Department of Health report *Planning for Climate & Health Impacts in Metro Minnesota* notes several adverse impacts on the metro region during the 2011 heat wave, with 800 people taken to emergency departments or hospitalized, infrastructure damage with roads buckling due to heat, and strains on essential services when utilities were struggling to meet cooling demands. The heat wave required an upsurge in activity for paramedics, emergency services personnel, and police officers who checked on people susceptible to heat, such as the elderly and the homeless.

Many cities have responded by creating Heat Wave Response Plans to ensure that those in marginal health without air conditioning can obtain the relief and care they need. Additionally, the Minnesota Department of Health developed the Extreme Heat Toolkit to help educate at-risk populations on how to reduce risks associated with heat waves (Seeley, 2015).

For the U.S., mortality increases 4% during heat waves compared with non-heat wave days (Anderson & Bell, 2011). During July 2011, 132 million people across the U.S. were under a heat alert—and on July 20 the majority of the Midwest experienced temperatures in excess of 100°F. Heat stress is projected to increase as a result of climbing summer temperatures and humidity (Schoof, 2012).

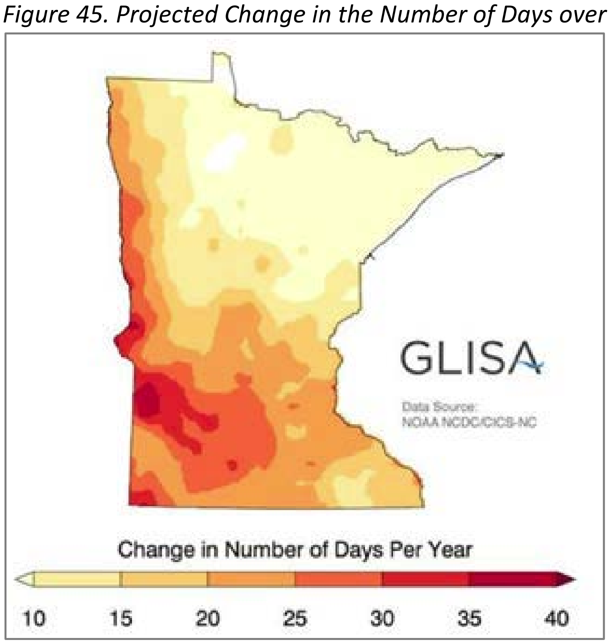
Increasing temperatures impact Minnesota's agricultural industry. Agriculture is highly dependent on specific climate conditions. As a result of increasing temperature, crop production areas may shift to new regions of the state where the temperature range for growth and yield of those crops is optimal. According to the National Climate Assessment, the Midwest growing season has lengthened by almost two weeks since 1950 due in large part to earlier timing of the last spring freeze. This trend is expected to continue. While a longer growing season may increase total crop production, other climate changes, such as increased crop losses and soil erosion from more frequent and intense storms and increases in pests and invasive species, could outweigh this benefit. There may also be higher livestock losses during periods of extreme heat and humidity. Losses of livestock from extreme heat pose a challenge in the disposal of animal carcasses. Currently there are only two rendering facilities in Minnesota available for livestock disposal. If a rendering facility is not available, lost livestock must be composted on an impervious surface. If losses are high, finding an impervious surface large enough is a challenge. In an attempt to adapt to increased temperatures, livestock areas in Minnesota may shift farther north. As a result of new livestock areas and the resulting manure production, farmers may transition to manure-based fertilizer applications in areas where traditionally only commercial fertilizers have been used, with accompanying environmental advantages and disadvantages (ICAT, 2017). In order to minimize the detrimental effects of heat stress on animal metabolism and weight gain, Minnesota farmers have also begun redesigning and retrofitting dairy, hog, and poultry barns with better watering, feeding, and ventilation systems (Seeley, 2015).

Extreme Heat and Climate Change

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. 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. As warmer winters and warmer baseline conditions transition into summer, it will be much easier to attain extreme heat (ICAT, 2017).

Minnesota's annual average temperature has increased more than 1.5°F since recordkeeping began in 1895, and the three most recent 10-year periods (through 2015) have been by far the warmest on record (ICAT, 2017). Annual temperatures in the Midwest have generally been well above the 1901-1960 average since the late 1990s, with the decade of the 2000s being the warmest on record (Kunkel, et al., 2013).

Figure 45. Projected Change in the Number of Days over 90ºF, 2041-2070



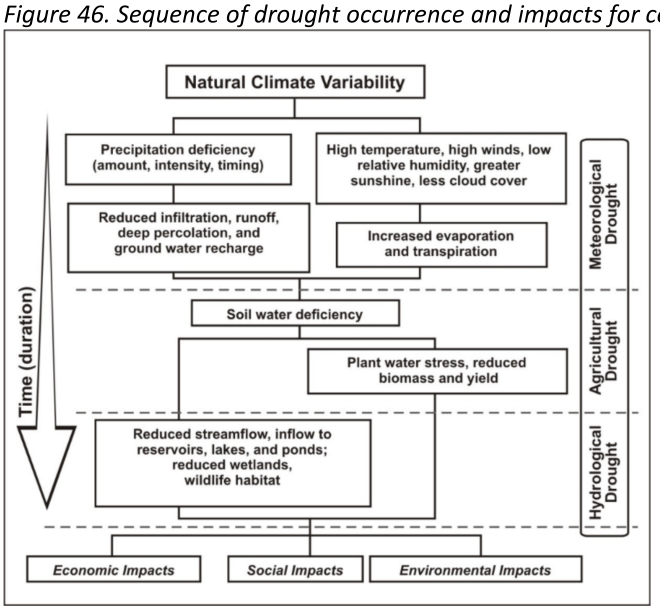
SOURCE: 2014 NATIONAL CLIMATE ASSESSMENT (GLISA, 2018)

An increased frequency of heat waves, while not necessarily observed yet, is expected to increase in severity, coverage, and duration beyond 2025, even with conservative models. Climate models used in the 2014 National Climate Assessment project that Minnesota will have a greater tendency toward extreme heat, especially by the middle of the twenty-first century. A lower-emissions scenario used in the *2014 National Climate Assessment* projects significantly more hot days than Minnesota experiences presently (U.S. Global Change Research Program, 2014). A Great Lakes Integrated Science + Assessments (GLISA) figure illustrating this change is shown (Figure 45).

4.7.8 Drought

Within the broad domain of natural hazards that comprise disaster science, drought is unequivocally the most difficult to define. This is primarily due to its insidious nature and because the parameters that typically control it vary both spatially and temporally. For instance, the hydro-meteorological conditions that constitute drought in one location may not necessarily qualify as drought in a contrasting climate. Even in regions that share a statistically similar climate, other factors such as soil type, antecedent moisture conditions, ground cover, and topography all play a vital role in dictating drought emergence. To further complicate matters, drought is associated with a diverse number of climatic and hydrological stressors, which come with a unique set of collective impacts that affect nearly every corner of our economy and environment. Subsequently, there are over 150 different definitions of drought, not just because it is difficult to define but because drought affects different regions in different ways (Fu *et al., 2013*). When one attempts to merge and understand these various definitions and impacts, it is evident that drought can be integrated into five principle categories. These are meteorological, hydrological, agricultural, ecological, and socio-economic drought (Figure 46).

Figure 46. Sequence of drought occurrence and impacts for commonly accepted drought types.



SOURCE: NATIONAL DROUGHT MITIGATION CENTER, UNIVERSITY OF NEBRASKA-LINCOLN.

Meteorological drought

In general, meteorological drought refers to a shortage of precipitation relative to normal climatic conditions over an unspecified period of time. Not only is this the prevailing interpretation of drought meteorological drought is also the most frequently occurring type because precipitation is the main driver of the hydrological cycle. Because the measure of normal climatic conditions varies by location, meteorological drought is often referred to as *region-specific*. It is also important to consider the distribution of annual precipitation. Shortfalls in precipitation occurring during naturally dry seasons will require a different assessment than when shortfalls are observed during months where precipitation is naturally higher. In Minnesota, a majority of the observed droughts fall into the category of meteorological drought, or at the very least, they start off that way. This is especially true when deficiencies in rainfall occur during the wettest and warmest months of summer.

Hydrological drought

Hydrological drought occurs when deficiencies in precipitation result in reduced streamflows, reduced lake and reservoir levels, and depleted groundwater supplies. Hydrological drought may be considered a consequence of meteorological drought in that it can often occur in the weeks or months following a sustained meteorological drought. The timing of this lag effect varies from location to location and is dependent upon several factors, such as the size of a given lake, reservoir or watershed. It is also dependent upon the time of the year since seasons dictate precipitation type, precipitation amount, and temperature regimes. Northern regions often depend on snowmelt to help replenish water supplies in a region. Warm winters associated with mid-winter melt conditions may deliver snowmelt runoff during months when snow would normally be stored for delivery in the spring. Another key factor to consider about hydrological drought is that it can very well occur in regions that are not deficient in precipitation at all. The basic premise of hydrology is that water flows to lower elevations, therefore, deficiencies in precipitation in the upper reaches of a basin may trigger hydrological drought in lower reaches that are currently observing normal climatic conditions. In Minnesota, the impacts of hydrological drought are numerous. For instance, streamflow deficiencies have, in part, led to significant reductions in thermoelectric power generation. In addition to the power sector, hydrological drought plays a major role in public water supply and water quality. During prolonged drought events, groundwater levels can be adversely affected to the point where wells can go dry.

Agricultural drought

Figure 47. Man Inspects Soil in Cottonwood County

SOURCE: MARK STEIL, MPR, 2012

Agricultural drought is observed during situations where moisture demands for crop and plant life are not met. Agricultural drought is, therefore, connected to both meteorological and hydrological drought in that it is measured as a deficiency in the collective water budget of the region over which it is considered. Water budget factors for agricultural drought include precipitation, evapotranspiration (the combination of evaporation and transpiration), soil moisture storage, and runoff. Although a given crop has fixed water supply requirements, many other variables that control the overall water budget for a region varies, and thus, agricultural drought can be triggered under varying meteorological conditions. These variables include temperature, which controls the surface water demand; precipitation, which controls the surface water supply; and more critically, soil type, which dictates soil porosity. Even changes in the slope and aspect of the landscape can alter the balance of water. In Minnesota, the impacts and potential devastation of agricultural drought largely depends on the geography, severity and duration of the drought event. Geography is significant because some crops are less vulnerable to immediate shortfalls in precipitation, while other crops can be impacted quickly. For example, sugar beets, which are grown in the northwest, are less vulnerable to early drought conditions than other arable crops because their deep root systems can grow deeper into the soil. Corn on the other hand, which is grown throughout much of the state, is more vulnerable to drought. Timing of drought is also a critical factor. For example, soybeans, which are grown in the western and southern counties, are most susceptible to drought stress during the stages of germination and seed reproduction (Figure 47). Regardless of which crops are impacted, the cost of drought to the agricultural industry are well documented (Figure 52). In 1988, drought cost the state over one billion dollars (MN DNR, 1988).

Ecological drought

Perhaps the most nascent drought type in the literature, ecological drought, occurs when the combined effects of meteorological and/or hydrological drought begin to impact the delicate balance of a given ecosystem. Because ecosystems are generally quite sensitive to small changes in environmental conditions, the impacts and feedback mechanisms associated with ecological drought are typically numerous and mutually inclusive. In Minnesota, sustained reductions in lake levels, for example, may result in sustained increases in water temperatures, which can impact aquatic plant life and fish populations. This can have a direct impact on the amphibious and terrestrial wildlife that rely on wetlands as a source of food. In extreme cases, prolonged drought conditions may result in severe reductions in wetlands, which then become more vulnerable to invasive species that can further alter the local ecology of a region. Moreover, drought conditions can cause a reduction in terrestrial vegetation, which in turn may lead to animal scarcity due to migration and/or starvation. Impacts of ecological drought in Minnesota are also observed in the state’s forestry resources. Tree damage from drought often lingers for several years after the event is over. In addition, drought-impacted trees are much more vulnerable to insect infestations and disease. During the drought of 1988, for example, many thousands of trees were lost due to prolonged moisture deficiencies.

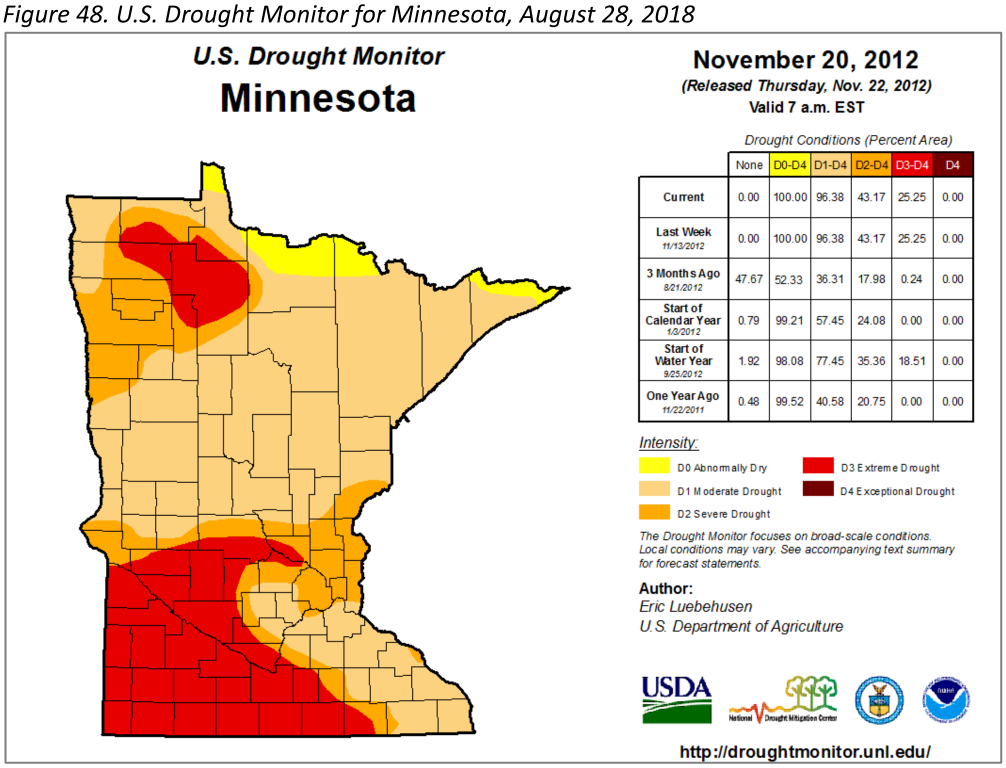
Socioeconomic drought

Socioeconomic drought occurs when the collective impacts of the preceding four drought types begin to affect the economy of a given region. Like hydrological drought, there is a lag effect associated with it. The timing of this lag effect is chiefly dependent upon each individual drought impact. Because this drought type is associated with the supply and demand of economic goods, economic impacts could be observed early into a drought onset, or they can linger on long after a given drought has ended. A few of the impacts of socioeconomic drought in Minnesota include reductions in crop yields or livestock holdings, reductions in hydroelectric power productions, and impacts to tourism and recreation. In the case of the latter, it is quite difficult to quantify the economic impact of drought to tourism. This is true because it is almost impossible to estimate indirect losses that may result from negative perceptions of drought-related actions or negative experiences, which in turn may prevent tourists from participating in future recreational activities (Thomas, Wilhelmi, Finnessey, & Deheza, 2013). In Minnesota, water and snow/ice related activities are responsible for a significant portion of tourism and recreation revenues. According to Explore Minnesota, travel and tourism generates more than $11 billion in gross sales each year and accounts for over 200,000 full- and part-times jobs.

Quantifying Drought Conditions

There are numerous approaches to assessing drought conditions. The current gold standard for accurate drought conditions in the United States is the United States Drought Monitor (USDM) Map. Established by the National Drought Mitigation Center (NDMC) in 1999, the Drought Monitor is a weekly map that depicts drought conditions in all 50 states and Puerto Rico. Each weekly map is produced by an NDMC-assigned author. Though drought map authors utilize a broad domain of geospatial, climatic data, and drought indices that cover every aspect of drought, perhaps their most valuable resource is the input they receive each week from hundreds of drought experts throughout the country. The drought monitor map is, thus, a collective synthesis of the best quantitative and the most reliable qualitative information available (The National Drought Mitigation Center, 2018). Figure 48 displays an example map and statistics table prepared by the U.S. Drought Monitor for Minnesota on November 20, 2012. In total, there are four drought categories: moderate (D1), severe (D2), extreme (D3), and exceptional drought (D4). A fifth category, abnormally dry (D0) is used to depict areas that are abnormally dry but not yet in drought. Abnormally dry conditions are indicative of the meteorological circumstances that precede drought onset and those that are coming out of drought. D0 is often considered a bellwether of drought, but it is also an accurate warning sign that crop growth may be slowed and wildfire risk may be elevated. The decision to declare or alter a drought category in a given location is dependent upon a comprehensive set of climate products that are specifically manufactured to quantify drought. Many of these products are referred to as drought indices. These indices each serve a specific purpose. There are indices that are designed for measuring short-term drought, and there are indices that are built to reflect long-term drought. Similarly, other indices are useful for sector specific areas such as water resources or agriculture.

Figure 48. U.S. Drought Monitor for Minnesota, August 28, 2018



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	96.38	43.17	25.25	0.00
Last Week 11/13/2012	0.00	100.00	96.38	43.17	25.25	0.00
3 Months Ago 8/21/2012	47.67	52.33	36.31	17.98	0.24	0.00
Start of Calendar Year 1/3/2012	0.79	99.21	57.45	24.08	0.00	0.00
Start of Water Year 9/25/2012	1.92	98.08	77.45	35.36	18.51	0.00
One Year Ago 11/22/2011	0.48	99.52	40.58	20.75	0.00	0.00

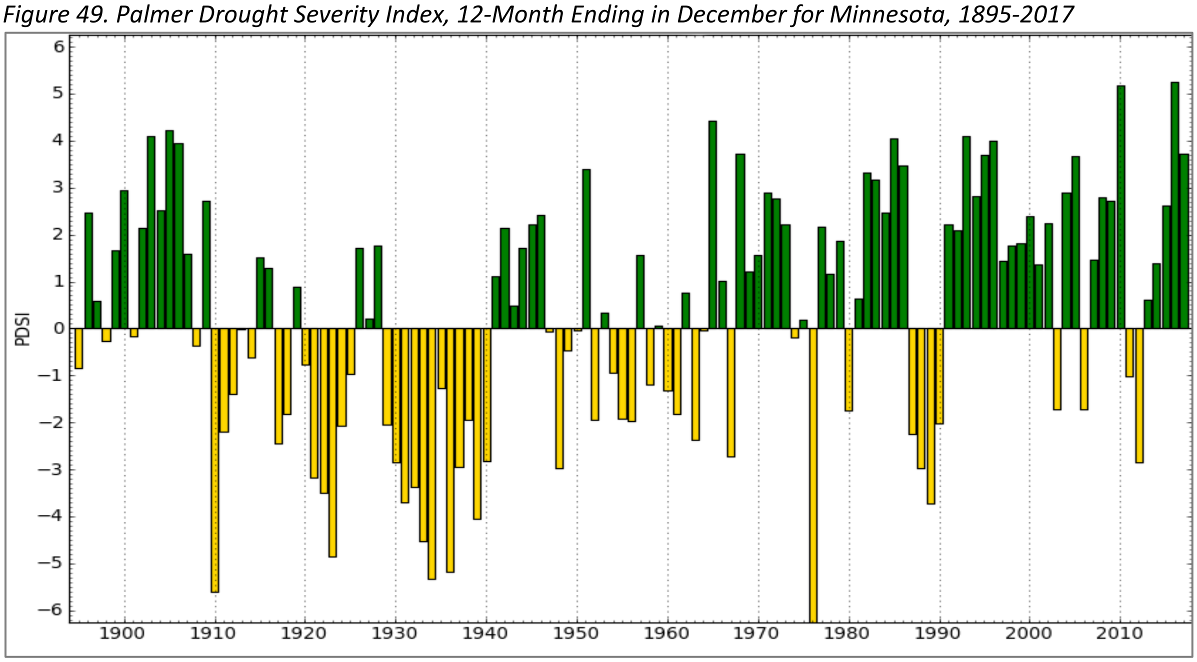
SOURCE: UNITED STATES DROUGHT MONITOR

Palmer Drought Indices

Developed in 1965 by W.C. Palmer, the Palmer Drought Severity Index (PDSI), published weekly, is a measure of long-term meteorological drought (Palmer, 1965). It measures the duration and intensity of drought events by measuring departure of the moisture supply based on a supply-and-demand concept of the water balance equation. It uses temperature and rainfall information to determine dryness in a given area, and accounts for all of the basics of the water balance equation, including: evapotranspiration, soil recharge, runoff, and moisture loss from the surface layer (Hayes, Alvord, & Lowrey, 2007).

An example of the Palmer Drought Severity Index (PDSI) by Climate Division map is shown in Figure 49). The primary strengths of the PDSI are that it is effective in measuring long-term meteorological and agricultural drought in the mid-latitudes, it takes antecedent moisture conditions into account, and it is used globally as a standard for drought quantification. The index, however, does have its weaknesses. For example, it does not take streamflow or delayed runoff (snow and ice conditions) situations into account (McKee, Doesken, & Kleist, 1995). A second weakness is that it does not provide a means for comparing dryness from one region to another, which is somewhat problematic given that drought definitions vary spatially. The index is also less effective in areas of varying topography. Despite its weaknesses, the PDSI has been regarded as a reliable index and has been used for over fifty years. There are three other indices that are derived from the PDSI or slightly altered versions of the PDSI. These include the Palmer Hydrological Drought Index (PHDI), the Palmer Z-Index, and the Crop Moisture Index (CMI).

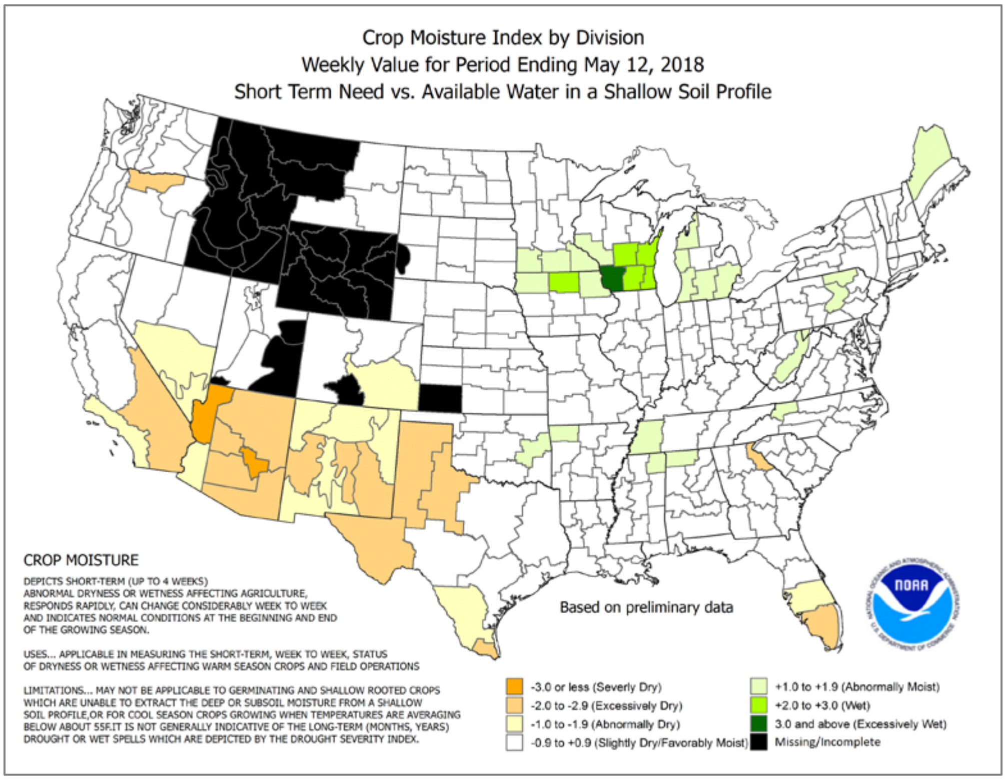
Figure 49. Palmer Drought Severity Index, 12-Month Ending in December for Minnesota, 1895-2017



SOURCE: WEST WIDE DROUGHT TRACKER, WESTERN REGIONAL CLIMATE CENTER

Based on the PDSI, the PDHI is derived from temperature, precipitation and evaporation, and it is used to quantify hydrological drought on longer time scales. Though similar to the PDSI, the PDHI better reflects groundwater storage and reservoir levels, and it is more useful for water resource applications. The Crop Moisture Index (CMI), monitors agricultural drought conditions in the short-term (up to 4 weeks) by measuring weekly precipitation and temperature levels (averaged over a climate division) in agricultural producing areas. It is a relatively good indicator of soil moisture and is most useful during the growing season. Thus, it is really intended as a summer drought index. An example of a CMI map is displayed in Figure 50. Like the CMI, the Palmer Z-index is useful for short time scales of a month or less and is intended as a drought measure based on soil moisture conditions.

Figure 50. Crop Moisture Index by Division, Week of May 12, 2018

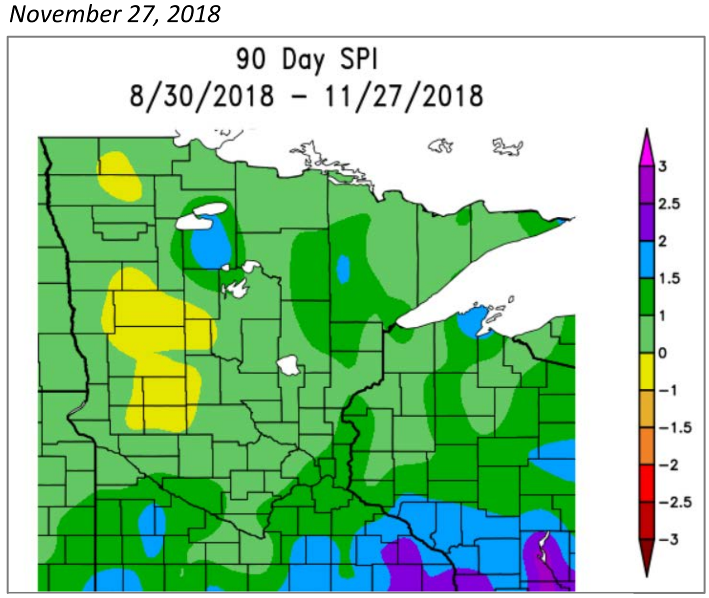


SOURCE: NATIONAL WEATHER SERVICE CLIMATE PREDICTION CENTER

Standardized Precipitation Index

The Standardized Precipitation Index (SPI) is a prolifically used drought index for quantifying meteorological drought on a variety of time scales (Figure 51). At long time scales, the SPI is effective for reflecting reservoir storage and groundwater. At short time intervals, the SPI is an excellent proxy of soil moisture. The prime advantage that the SPI has over other indices is that it is specifically designed to allow for comparing drought conditions in different climatic regions. Unlike other drought indices, the SPI is easy to interpret in that its value is essentially a normalized precipitation anomaly. For instance, an SPI value of -2.0 is basically a precipitation total that is two standard deviations below the long-term average. These two factors has made the SPI very

Figure 51. 90-Day Standardized Precipitation Index ending November 27, 2018



SOURCE: HIGH PLAINS REGIONAL CLIMATE CENTER.

popular among drought scientists. The primary disadvantage of the SPI is that it does not consider evapotranspiration. An alternative version of the SPI, the Standardized Precipitation-Evapotranspiration Index (SPEI), does incorporate.

Other Drought Indices

In addition to the above, the following list of indices are also frequently used to monitor drought conditions in Minnesota and throughout the United States.

1) Keetch-Byram Drought Index (KBDI): a useful index for measuring wildfire risk associated with extended periods of surface moisture deficiencies. The KBDI ranges from 0 to 800, with the latter indicating extreme dryness.
2) Vegetation Drought Response Index (VegDRI): is an indicator of vegetation stress. Maps are produced every two weeks. The VegDRI utilizes a combination of climate data and remote sensing producing an integrated representation of relative greenness at high spatial resolutions.
3) United States Geological Survey's (USGS) Average Streamflow Percentiles: Produced by the USGS, these maps indicate average streamflow over various time scales compared to historical streamflow for the day of the year. Streamflow values are displayed as percentile classes, providing a quick and useful approach to assessing hydrological drought.

Monitoring Drought

Each week hundreds of drought scientists collaborate with a NDMC assigned drought author to develop an accurate depiction of drought on the USDM weekly map. In Minnesota, scientists at the Minnesota Department of Natural Resources' Minnesota State Climate Office are tasked with providing vital information to the drought map authors. Meteorologists from various National Weather Service Offices also contribute. It is important to note that monitoring occurs with the same level of scrutiny regardless of drought conditions in the state. Understanding normal conditions throughout the state is crucial when assessing drought conditions. All contributors utilize the aforementioned drought indices and drought products to assist their drought assessments

In addition, the Minnesota Department of Natural Resources' Ecological and Water Resources Division uses actual precipitation, stream flow, lake level, and ground water level data to assess the status of hydrologic conditions in Minnesota. The Ecological and Water Resources Division produces maps of stream flow, precipitation, and seasonal departures from normal.

Because drought is often insidious in nature, data, value-added climate products and drought proxies do not always provide enough information to make an accurate judgement. In such cases, drought map contributors rely on local citizens to assist in providing critical information related to drought onset and drought-related impacts. One such resource that allows citizens to contribute is the NDMC's Drought Impact Reporter (DIR). Scientists at the Minnesota State Climate Office encourage citizens to visit the DIR website and report drought related impacts. The DIR is located at the following website: https://droughtreporter.unl.edu/map/. Citizens are also welcome to call or email the MN State Climatology Office.

Drought History

Minnesota has been collecting streamflow records as a way of monitoring droughts since the early 1900's. Since this time Minnesota has experienced a number of major state-wide droughts, including the periods of 1911-1914, 1921-1942, 1954-1961, 1976-1977, and 1987-1989 (Zandlo, Milles, & Sium, 1989). These are clearly evident in Figure 49 where the PDSI is consistently negative.

The drought of 1988

The 1988 drought (in the time period of 1987-1988) is considered one of the worst and most widespread droughts to hit the Midwest. Abnormally dry conditions started as early as late winter and conditions deteriorated through the spring. Dryness from April to June, compounded by soaring summer temperatures, placed significant stress on crops early in their growth cycle. By most measures, the summer of 1988 ranks as the one of the hottest summer on record with 44 days of 90°F or above temperatures. As corn plants stop growing in temperatures above 90°F, crop loss was substantial. Maximum temperatures for May through July, when the drought peaked, were on average 8.0°F hotter than historical baseline values. June is normally the wettest month in Minnesota; however, precipitation levels for June in 1988 were (and still are) the lowest ever recorded for most of the state. From April through July, the state as a whole averaged just 6.6 inches of precipitation (MDH, 2018).

Like most droughts, the drought of 1988 in Minnesota was quite unexpected. This was especially true because it was preceded by one of the wettest decades on record. Soil moisture in the fall of 1986 was fully charged at a surplus that equates to over two years of normal precipitation. In fact, throughout the mid-1980s it was flooding, not drought, that was the primary concern of water scientists. The winter of 1986-87 was both extremely warm, and exceptionally dry. Many regions throughout the state remained snow-free throughout most of the winter months. The following spring saw more persistent dryness across the state. By early to mid-summer, 1987, drought had started in portions of the state and agricultural areas were beginning to be stressed. High soil moisture levels allowed crop yields to remain high in most areas of the state. In July, heavy rainfall in the Twin Cities provided some relief in the metro area, but other areas of the state remained dry with precipitation deficits ranging from four to eight inches below normal. By fall, moderate to severe drought persisted in central and northwestern Minnesota. By the start of the spring in 1988, soil moisture across the state was low. Though some areas of the state did receive a fair amount of snow over the winter, it was not enough to recharge the soils. This was because most of the runoff does not infiltrate the soil profile since the ground surface is often still frozen when snow ablation is initiated. Instead, approximately 85% of the snowfall contributes to runoff in streams and lakes. Dryness persisted throughout the spring and summer of 1988. Combined with persistently high temperature extremes, severe drought had set in with no relief in sight. Impacts from the drought covered a broad domain of economic and ecological sectors, including agriculture, forestry, energy, public water safety, streamflow, and tourism. Impacts included:

- Crop yields for 1988 were extremely low compared to previous years. Corn, soybeans, wheat, oats, and barely were hit the hardest. Loss estimates to the state's economy exceeded the $1 billion mark.

- With respect to forestry, thousands of trees were lost or damaged due to a lack of moisture. Due to cooling problems related to low streamflows, power plants were greatly impacted by the drought.
- Dry river channels had an adverse effect on the ecology of Minnesota impacting fish populations and benthic organisms. Ground water levels, lake levels, and streamflows throughout the state reached record low values. Near St. Cloud, Minnesota, wells dried up at the Wayside Housing Addition in Haven Township. Emergency water was brought in by the National Guard to help alleviate water shortages. Water shortages were also experienced in Stephen. The city mitigated this by purchasing seven million gallons of water. In the Twin Cities, a sprinkling ban was implemented and lasted for seventeen days.

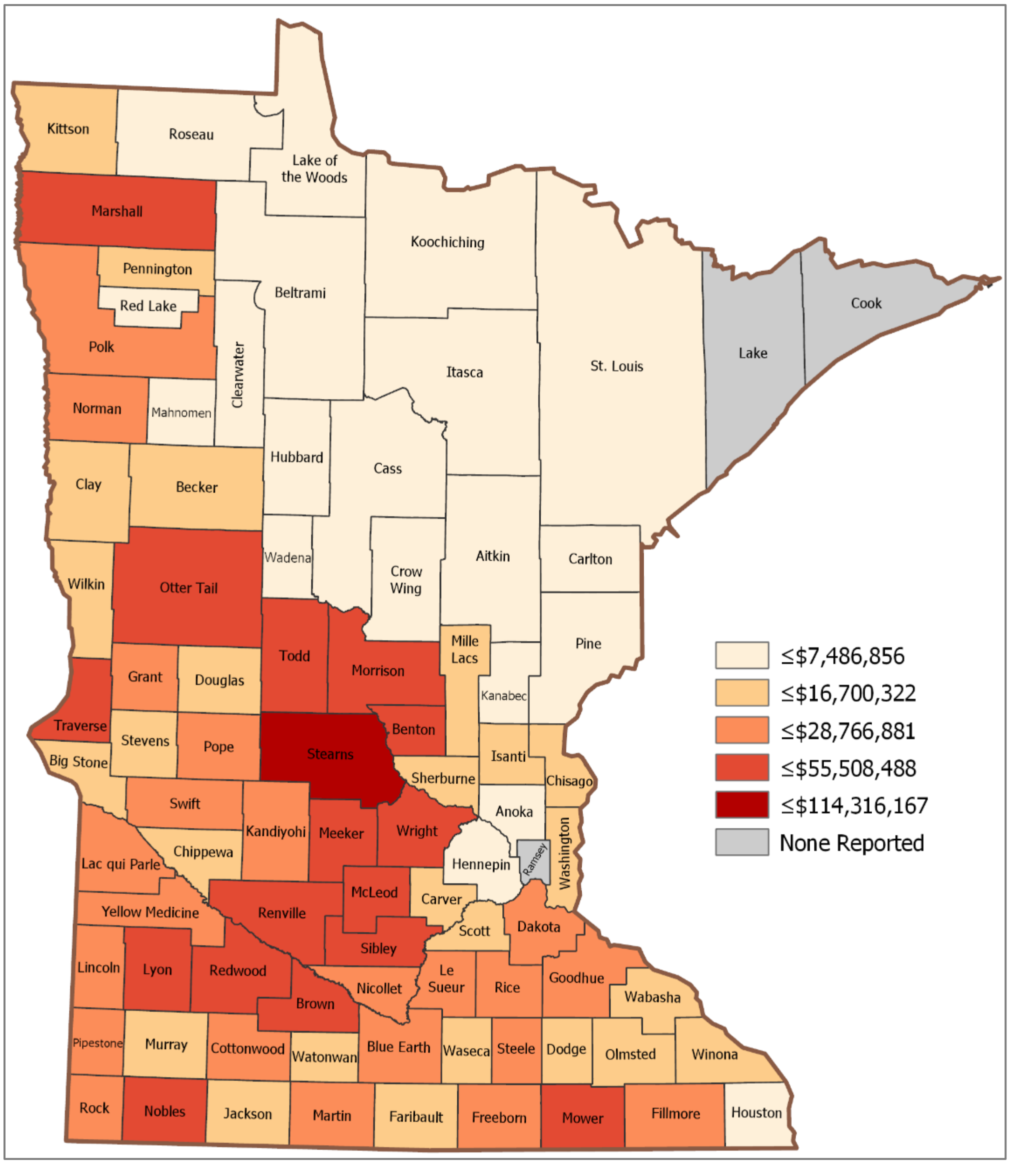
Because the drought was so severe, a State Drought Task Force was convened by the Minnesota Department of Natural Resources (DNR), Director of the Division of Waters. The State Drought Task Force brought together local, state, and federal officials to share information and coordinate drought response strategies. Many lessons were learned from this severe event and action was taken by the state to re-evaluate water allocation frameworks, expand data collection activities, expand water conservation measures and establish surface water allocation plans.

The drought of 2011-2012

The most recent widespread severe drought in Minnesota began in the fall of 2011, which ranks among the driest fall seasons on record. The drought continued into the 2012 growing season with July 2012 having the lowest precipitation levels on record. That year, the U.S. Department of Agriculture (USDA) declared 75 Minnesota counties disaster areas. The 2012 drought is considered to be the most extensive drought to impact the U.S. since the 1930s and estimated to have cost the U.S. approximately $33 billion (MDH, 2018). No droughts of significance were recorded since the April 2013, which was the end of the 2011-2012 drought.

Between 1989 and 2016, over $1.6 billion of indemnity payments had been paid to counties across Minnesota for crop loss caused by droughts. Figure 52 displays the range of amounts paid to each county.

Figure 52. Estimated Crop Indemnity Payments (2016 USD adjusted) due to Drought, 1989-2016



SOURCE: (CEMHS, 2018)

Probability of Occurrence

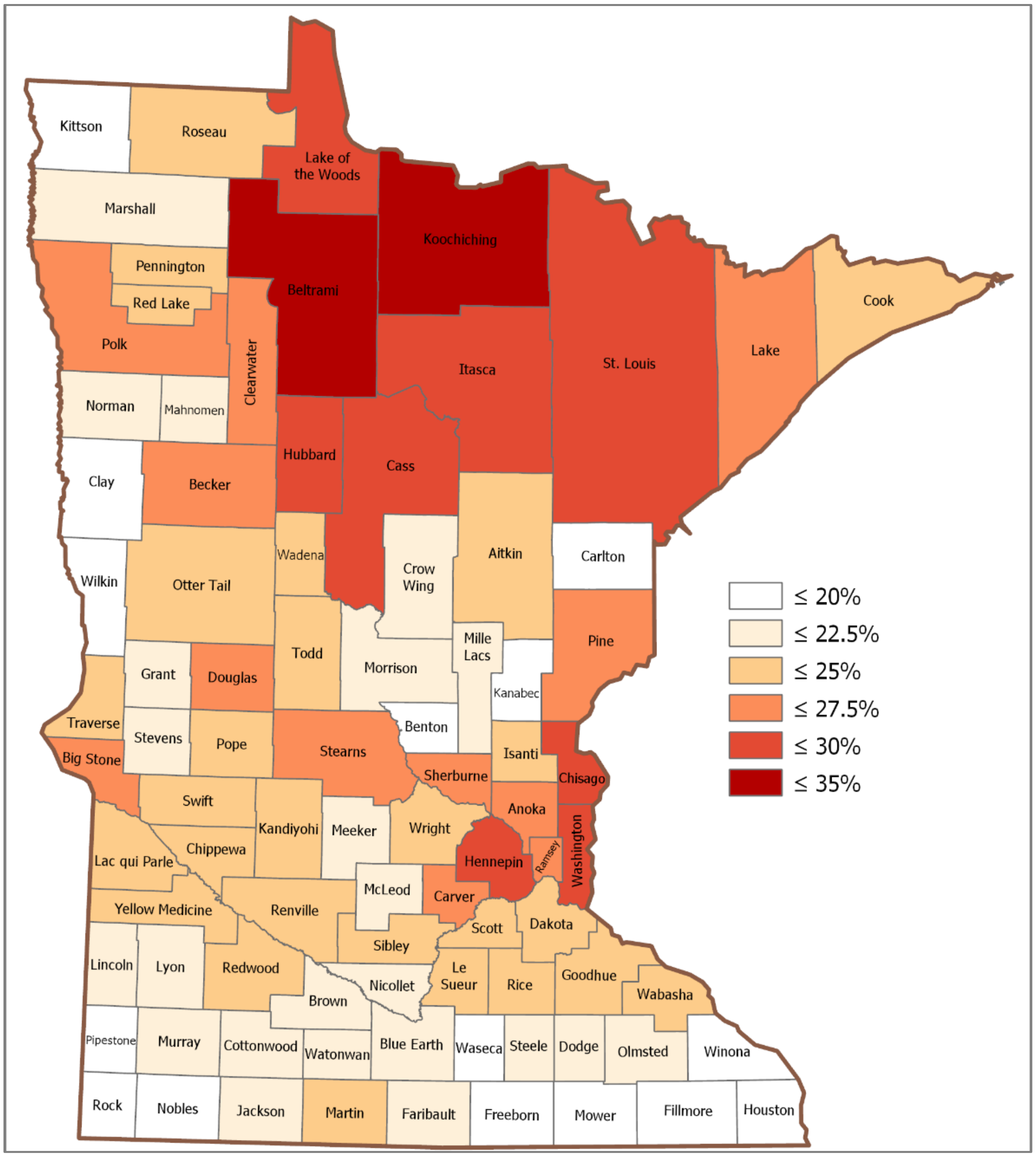
Drought is a naturally occurring aspect of Minnesota's climate. It usually occurs somewhere in the state almost every year in some form or another for at least a few weeks at a time. Typically, drought will occur within a given location in the state, but impacts are usually not observed until drought has developed over a sustained period of at least one month or longer. Because the geography of Minnesota is such that it lies in the path of two primary low-pressure system storm tracks that originate in Colorado and Alberta, Canada, droughts in the state are often of short duration. These storm tracks are responsible for a bulk of the precipitation in the state of Minnesota. On occasion, and for reasons that we do not fully understand, one or both of these storm tracks can sometimes get displaced. When these displacements are extended temporally, drought conditions in the state can become quite severe. In addition, blocking patterns are also responsible for drought conditions in Minnesota. A blocking pattern is any circulation pattern in our atmosphere that obstructs the normal west-to-east migration of high and low pressure systems. When blocking patterns develop, they can remain in place for a few days or, in severe cases, several weeks. If a sustained blocking pattern is associated with high pressure over Minnesota, drought conditions can develop quickly.

As is the case in many other locations, temperature plays a fundamental role in Minnesota drought severity. Higher than normal temperatures during periods of reduced precipitation can augment drought conditions by increasing the water demand of a given environment. Conversely, lower than normal temperatures decrease the water demand and can attenuate or even delay the effects of a given drought.

Drought is highly unpredictable and may also be localized, making it difficult to determine probability with any accuracy. Interpreting what is “too dry” or what is “too long” is difficult. What we do know is that when a serious hydrologic imbalance occurs in Minnesota, soil moisture reserves, groundwater supplies, lake levels, and stream flows are negatively influenced. Water-dependent industries including agriculture, public utilities, forestry, and tourism are profoundly affected. Because long-term (months/years) climate variations are unpredictable, drought is also largely unpredictable. Understanding the nature of drought in Minnesota is essential for building higher coping and adaptation capacities.

The first step to understanding drought risk and drought probability is to identify the geography of drought in Minnesota. Figure 53 illustrates the percentage of time each county of Minnesota was in at least moderate (D1) drought or worse. Data for this map spans the period from January, 2000 when the USDM Drought Monitor Map was established to November 6, 2018. Though the map does not provide detailed information related to specific drought event duration or intensity, it does provide a relatively accurate spatial representation of drought occurrence in Minnesota.

Figure 53. Percentage of Time In At least Moderate (D1) Drought from 2000 - 2018

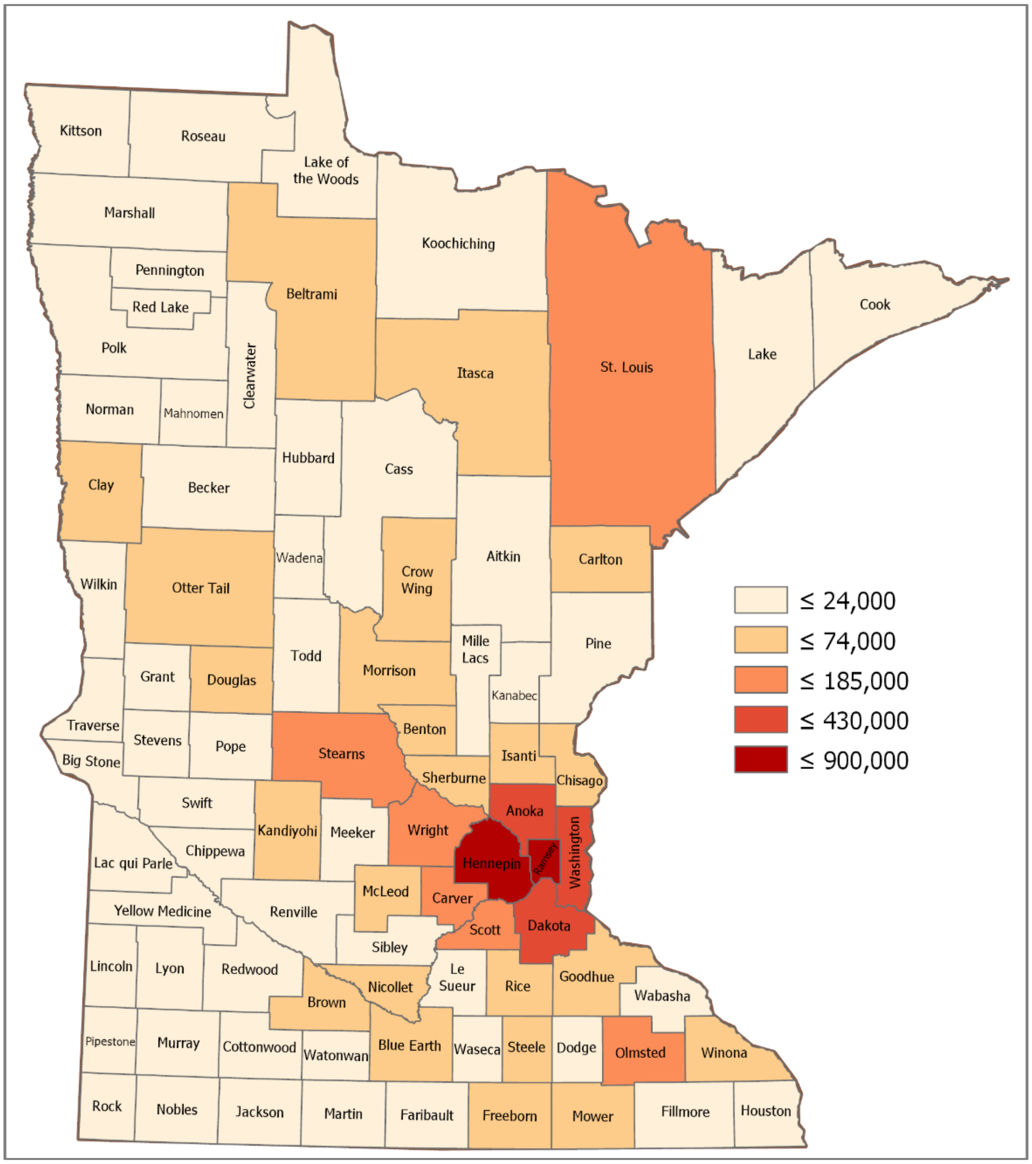


SOURCE: NATIONAL DROUGHT MITIGATION CENTER

Figure 53 also demonstrates that drought occurrence does not vary much across the state, with most counties experiencing at least some drought between 20% to 35% of the time. This is not surprising given that the spatial distribution of precipitation deficiencies is expected to be random over time. Some variations, however, are evident. Drought does appear to be slightly more frequent in the north central and east central counties, where drought occurrence is consistently above 30-35%. Conversely, southern counties clearly show a slightly lower percentage of occurrence, with values ranging from 20% to 25%.

Figure 54 illustrates the average population affected by moderate (D1) drought or worse by county in Minnesota from January, 2000 to November 6, 2018, and is based on a total of 984 weeks. When comparing Figure 53 and Figure 54 , it is interesting to note that though drought is slightly more frequent in north central counties, less people are affected by the impacts. By contrast, the average number of people affected by drought when it occurs in the Twin Cities seven-county metro area is much higher.

Figure 54. Average Population Affected by at Least Moderate (D1) Drought, 2000 - 2018



SOURCE: NATIONAL DROUGHT MITIGATION CENTER

Vulnerability

Regardless of the mechanisms that initiate drought emergence, all counties in Minnesota are vulnerable to this hazard and its potential impacts. As shown in Figure 53, drought is more common in the northern central and east central regions of the state. Though occurrence frequencies do not vary much across the state, drought is slightly less frequent in the southern third of Minnesota. Impacts of drought in the state cover a broad spectrum of vulnerability sectors. These include:

- Water Resources Sector
- Agriculture Sector
- Wildfire Sector
- Fisheries and Wildlife Sector

- Health Sector
- Energy Sector
- Tourism and Recreation Sector

The collective socioeconomic and ecological severity of a given drought depends on the number of sectors that are impacted. Impacts, in turn, depend on many factors. These include the total area of the drought, the total population affected by the drought, the duration of the drought, and the type of drought that is occurring, the latter of which depends on how drought is defined in a given location.

Droughts can contribute to poor air quality by increasing the risk of wildfires and creating a dustier than normal environment. Populations vulnerable to these conditions include children, older adults, and those with respiratory issues. The Minnesota Department of Health examined the history of droughts in the nine climate regions of Minnesota, compared these data to the counties where a higher than average number of these vulnerable populations live, and identified the counties susceptible to drought that have a high number of vulnerable residents. The following table shows the department's findings.

Table 56. Populations Vulnerable to Drought, Living in Drought-Prone Areas

Vulnerable Population	Locations	Drought Effects to the Area
Children 5 and younger	Twin Cities and surrounding counties	Higher frequency of extreme drought, longer periods of drought, dust storms from agricultural lands
	Northwest MN: Mahnomen Co. and surrounding counties	Forest fire emissions during drought conditions
Adults 65 and older	Western MN: Traverse, Big Stone, Laq Qui Parle, Grant, Lincoln, and Murray counties	Higher frequency of extreme drought; longer periods of drought
	Northwest MN: Kittson Co. Northeast MN: Aitkin and Lake counties	Forest fire emissions during drought conditions
Individuals with respiratory issues (asthma or COPD)	Mille Lacs, Benton, and Kanebec counties	Air pollution as a result of droughts from forest fire emissions

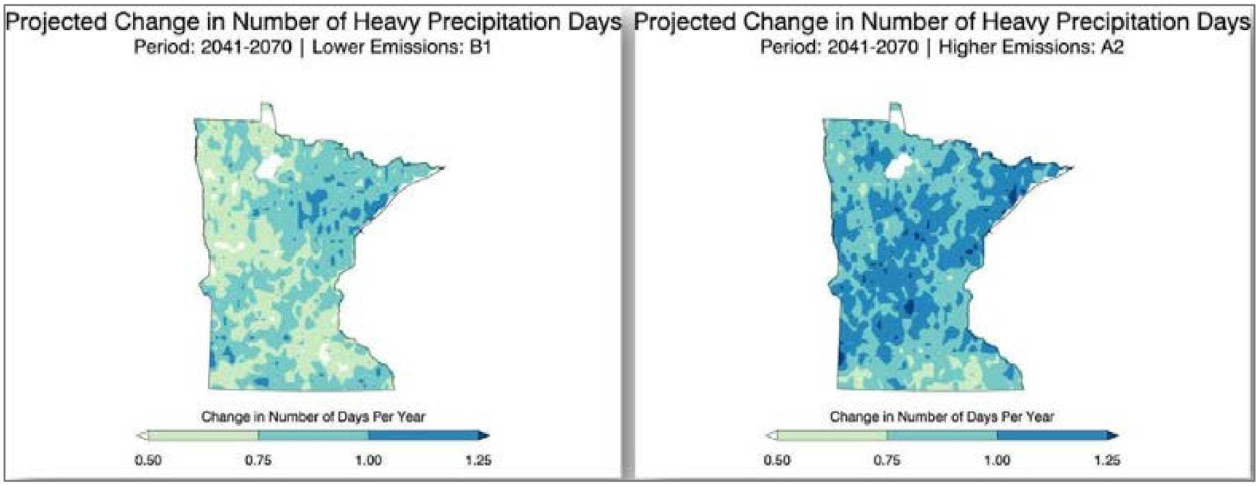
Source: Minnesota Climate Change Vulnerability Assessment, 2014

Drought and Climate Change

Droughts have been happening throughout Minnesota's history, and it is not yet clear the degree at which climate change may impact future droughts. In 2014, the most recent National Climate Assessment was completed by the U.S. Global Change Research Program. It provided a comprehensive scientific review of how climate change is impacting the U.S. as well as providing climate change projections.

The climate models used in the 2014 National Climate Assessment projects Minnesota to have an increase in days over 90°F by mid-century; however, the future drought situation is less clear. The climate model run with the lower emissions scenario projects no significant change in the number of consecutive days of no rain, while the higher emissions scenario shows an increase in dry periods, increasing Minnesota's drought risk (MPCA, 2017). These climate models are shown in Figure 55.

Figure 55. Projected Change in Number of Consecutive Dry Days in Low & High Emission Scenarios.



SOURCE: (ICAT, 2017)

Even in areas where precipitation does not decrease, projected higher air temperatures will cause increases in surface evaporation and loss of water from plants, leading to drier soils. As soil dries out, a larger proportion of the incoming heat from the sun goes into heating the soil and adjacent air rather than evaporating its moisture, resulting in hotter summers under drier climatic conditions (Mueller & Seneviratne, 2012).

4.7.9 Lightning

Lightning typically occurs as a by-product of a thunderstorm. In only a few millionths of a second, the air near a lightning strike is heated to 50,000°F, a temperature hotter than the surface of the sun. Initially air acts as an insulator between the positive and negative electric charges in the cloud and between the cloud and the ground; however, when the differences in charges becomes too great for the insulating capacity, there is a rapid discharge of electricity that we know as lightning (NWS, 2018).

The hazard posed by lightning is significant. High winds, rainfall, and a darkening cloud cover are the warning signs for possible cloud-to-ground lightning strikes. While many lightning casualties happen at the beginning of an approaching storm, more than half of lightning deaths occur after a thunderstorm has passed. Lightning has been known to strike more than 10 miles from the storm in an area with clear sky above.

Lightning strikes the ground approximately 25 million times each year in the U.S. According to the National Weather Service, the chance of an individual in the U.S. being killed or injured by lightning during a given year is 1 in 1,171,000 (NWS, 2018).

Lightning is a major weather hazard that most people in the United States experience annually. The lightning current from a tree, fence, pole, or other tall object can branch off to strike a person. In addition, an electrical current may be conducted through the ground to a person after lightning strikes a nearby tree, antenna, or other tall object. The current may also travel through power lines, telephone lines, or plumbing pipes to damage property or cause fires. There is little an individual can do to substantially reduce risk outdoors in a thunderstorm. The only completely safe action is to get inside a safe building or vehicle.

Lightning History

Based on an analysis of cloud-to-ground flash densities in the United States from 2008-2017, as measured by the National Lightning Detection Network (NLDN), Minnesota ranked #30, with an average of just over 400,000 flashes per year (4.8 flashes per square mile) (Vaisala Inc, 2017). According to the analysis, there were 498,032 flashes in Minnesota in 2017.

Between 1950 and 2017, the National Centers for Environmental Information (NCEI) recorded a total of nine deaths due to lightning in Minnesota, 67 injuries, and $22 million in property damage. The majority of injuries occurred between May and August. The event with the highest number of injuries occurred in July of 2001, when 25 people were injured at Camp Ripley; however, everyone survived.

According to NCEI records, between 2008 and 2017, lightning caused four fatalities and 18 injuries (Table 57) in Minnesota. The causes of those fatalities are described below. During this period, $10 million of property damage was also reported due to lightning.

In August of 2013, a man died near Sturgeon Lake, Minnesota, when he was standing in a large puddle of water near a tree that was struck by lightning.

A young child died and four were injured in August of 2012 near the Duluth Sky Harbor Airport on Park Point when lightning struck nearby water. The group had been sailing in the harbor when the storm approached. They beached the boat, but lightning struck when they were returning to the boat.

Table 57. Lightning Injuries Reported in Minnesota, 2008-2017

Location	Date	Injuries
Pontoria, Cass County	6/12/2016	3
Kirk, St. Louis County	6/28/2015	2
Duluth Heights, St. Louis County	6/28/2015	1
Ham Lake, Anoka County	5/31/2014	1
Duluth Sky Harbor Airport, St. Louis County	8/18/2012	4
Nopeming, St. Louis County	7/27/2010	1
Waite Park, Stearns County	5/6/2009	1
Monticello, Wright County	7/10/2008	1
Mora, Kanabec County	6/27/2008	1
Minneapolis/St. Paul, Hennepin County	4/22/2008	3
Total:		***18***

SOURCE: NCEI

The number of deaths due to lightning strikes in Minnesota from 2008 through 2017 is listed below.

Table 58. Lightning Deaths Reported in Minnesota, 2008-2017

Location	Date	Deaths
Sturgeon Lake, Pine County	8/26/2013	1
Duluth Sky Harbor Airport, St. Louis County	8/18/2012	1
Stillwater, Washington County	7/21/2009	1
Waite Park, Stearns County	5/6/2009	1
Total:		***4***

SOURCE: NCEI

Probability of Occurrence

The probability of lightning occurring in the state is high. However, the site-specific incidence of lightning is considered low because of the localized nature of the hazard. The annual incidence of lightning across the state is presumed to remain stable, although year-to-year fluctuations are expected.

Vulnerability

All humans and structures in the state are vulnerable to lightning. According to the State Climatology Office, lightning is a serious hazard in Minnesota, and the risks are greatest during the summer, when outdoor recreational activities are most common. Southern Minnesota typically sees 3-4 times more lightning strikes annually than northern Minnesota. However, the abundant lakes, boats, parks, and trails in northern Minnesota place clusters and concentrations of people at risk to afternoon and evening thunderstorms, especially on weekends and during the major summer holidays.

Lightning and Climate Change

The conditions associated with lightning are uncertain. These conditions—tornadoes, large hail, and damaging thunderstorms are difficult to compare historically but may become more concentrated on fewer days or multiple events may occur at one time. These events could happen without necessarily increasing overall numbers or severity (ICAT, 2017). Severe rain events are certain to be more common and may include an additional risk of lightning.

4.7.10 Winter Storms

Winter storms vary in size and strength and include heavy snowstorms, blizzards, freezing rain, sleet, ice storms, and blowing and drifting snow conditions. Extremely cold temperatures accompanied by strong winds can result in wind chills that cause bodily injury, such as frostbite and death.

Winter storms tend to be very disruptive to transportation and commerce. Some storms can coat trees, cars, roads, and other surfaces with ice. Even small accumulations of ice can be extremely hazardous to motorists, bicyclists, and pedestrians. The most prevalent impacts of heavy accumulations of ice are slippery roads and walkways that lead to vehicle and pedestrian accidents; collapsed roofs from fallen trees and limbs and heavy ice and snow loads; and felled trees, telephone poles and lines, electrical wires, and communication towers. As a result of severe ice storms, telecommunications and power can be disrupted for days. Heavy snow or accumulated ice can also isolate people from assistance or services.

The NWS issues a Wind Chill Advisory for Minnesota when widespread wind chills of -40°F or lower and winds of at least 10 miles per hour (mph) are expected. In some parts of southern Minnesota, the threshold may be -35°F. A Wind Chill Warning is issued when widespread wind chills of -40°F in northern Minnesota and -35°F in southern and winds greater than 10 mph are expected.

Winter Storm History

Mean seasonal snowfall ranges from more than 80 inches along Lake Superior's North Shore to less than 35 inches in southwestern Minnesota. Snow has fallen in every month except July. Heavy snowfalls of 4 or more inches typically occur between November and April (Seeley, 2015).

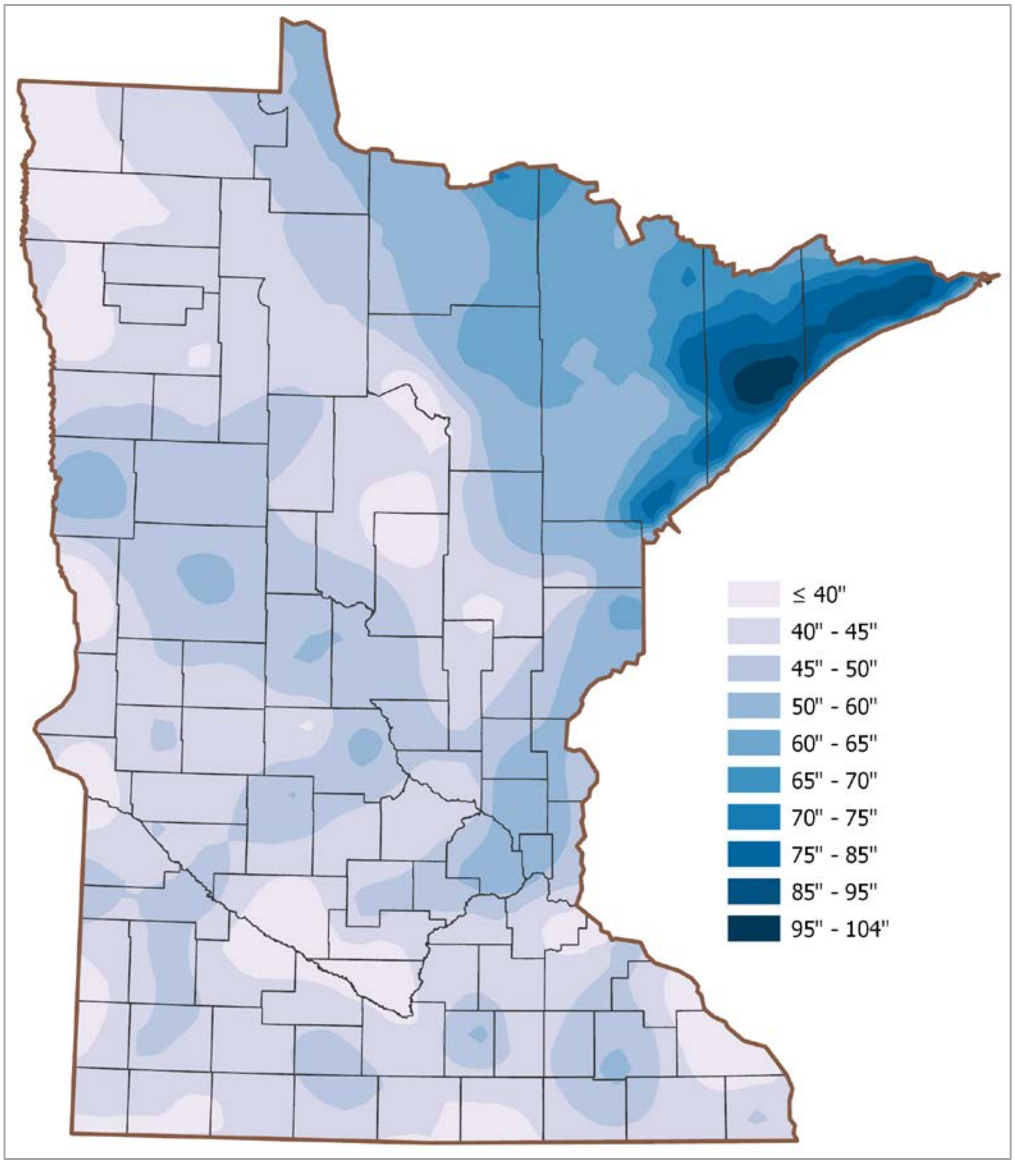
The earliest measureable snowfall occurred on September 14, 1964, when International Falls (Koochiching County) received 0.3 inches. The latest measureable snowfall occurred on June 4, 1935 when Mizpah (also in Koochiching County) received 1.5 inches (MN DNR, 2018).

The Minnesota record for 24-hour snowfall occurred in January of 1994, when Finland, Minnesota recorded 36 inches. That snowstorm also holds the record for maximum single-storm snowfall, with a total of 47 inches. The state record for maximum snowfall is 75 inches, reported near Grand Portage, Minnesota in March of 1950. Grand Portage also holds the record for maximum seasonal snowfall, with 171 inches in the winter of 1949-1950 (MN DNR, 2018).

In the winter of 2017-2018, the Minnesota Department of Transportation (MN DOT) spent $124 million on its snow and ice removal operations, the most spent since 2013-14. Average snowfall in each MN DOT district was higher than usual, and the average number of storm events (30) and average total snowfall (88.7 inches) increased from 2016-2017. In that winter, the average number of winter events was 33, with total costs of MN DOT snow and ice operations at $97 million. The average total snowfall was 54 inches. The average annual cost of snow and ice operations between 2013 and 2018 was $107 million (MNDOT, 2018). However, in extreme cases, the cost of snow removal can soar to over $200 million. Costs in the winter of 1996-1997 were $215 million due to anomalously high snowfall and exceedingly strong winds.

Figure 56 below maps the annual snowfall for 1981-2010 according to the most recent three-decade averages known as Climate Normals (NCEI)**.**

Figure 56. Normal Annual Snowfall, 1981-2010



SOURCE: STATE CLIMATOLOGY OFFICE - MN DNR

Blizzards

Blizzards are characterized by low and/or falling temperatures, winds of over 35 mph, and blowing snow that reduces visibility to 0.25 miles or less. Blizzards are particularly hazardous in the open prairie areas of the state where snow can blow without obstructions. On average, one to two blizzards occur each winter season; however, 11 blizzards were recorded in the winter of 1996-1997 (Seeley, 2015).

The most notable blizzards in Minnesota history are: the “Armistice Day Blizzard” in November 1940 in which there were 49 deaths; “The Storm of the Century” in January 1975 in which there were 14 deaths; the blizzard in February 1984 in which there were 16 deaths; the “Halloween Monster Storm” of 1991 which did not result in any deaths but set staggering snowfall records; and the unprecedented series of blizzards in November 1996 through January 1997, which resulted in a Presidential Disaster Declaration

(DR-1158-MN). In Fargo-Moorhead, the total seasonal snowfall of 1996-1997 was 117 inches, the impetus for the record-setting flood of 1997 in the Red River Valley.

There have been many recent large blizzards as well. In December of 2010, the state saw record snowfalls with the highest total accumulation found of 23 inches measured at Winona Dam. That snow event cause the roof of the 64,000-seat sports venue, the Metrodome, in Minneapolis to collapse under the snow's weight.

February 2012, saw heavy snow in northern Minnesota, with Duluth and Silver Bay accumulating up to 15 inches and Hinckley accumulating 20 inches. At the Duluth harbor, the winds heavily damaged the roof of a 157,000- square-foot building owned by the Seaway Port Authority, causing $1 million in damage. Gusts of 68 mph were recorded near downtown Duluth.

Ice and Sleet Storms

In January of 2017, an ice storm glazed roads and walkways in southeastern Minnesota with up to half an inch of freezing rain. Hundreds of accidents resulted, and MN DOT noted a rate of one incident every 2 to 3 minutes in the Twin Cities area during the storm's peak (MN DNR, 2017).

In April of 2013, a severe ice storm occurred in southwestern counties, where ice thickness ranged from 0.5 to 1.0 inches. Combined with strong winds, the ice resulted in intense tree damage (Figure 57) that activated the State Emergency Operations Center to help citizens find shelter. Around Worthington the cleanup took over two months. Estimated damages exceed $70 million (Seeley, 2015). In addition, a Presidential Disaster Declaration was declared (DR-4113). Public Assistance Grants exceeded $11 million. No ice storms approaching the severity of April 2013 have occurred since.

Figure 57. Fallen Trees from Ice Storm, April 2013

SOURCE: (MPR, 2013)

Table 59 below lists notable winter storms and blizzards from 2013-2018.

Table 59. Notable Winter Storms and Blizzards, 2013-2018

Date	Location	Remarks
April 2018	Statewide	A severe, late-season storm produced thunderstorm wind damage and prolonged blizzard whiteout conditions. Lightning, thunder, and wind gusts of 78 mph were reported in Nobles County. Over a foot of snow covered 20% of the state, though some areas reported over 26 inches. In the Twin Cities, the snowfall total of 15.8 inches was the largest to occur so late in the winter, breaking the storm total accumulation record for April and making it the snowiest April on record (MN DNR, 2018).
January 2018	Twin Cities	Over a foot of snow fell at the Twin Cities International Airport, resulting in the closure of all four runways. Over 600 flights were canceled, and a section of I-35 was closed between Owatonna and Faribault. Governor Mark Dayton issued an Emergency Executive Order for the National Guard to provide assistance to stranded people (MN DNR, 2018).
November 2017	Olmsted County & Winona County	Seven people were injured when a school bus rolled over near Rochester due to icy to roads after light freezing rain fell on untreated roads. Two more people were hospitalized from crashes along Interstate 90 in Winona County.
February 2014	Southeastern Minnesota	A storm system produced nearly a foot of heavy snow that was then blown around by wind gusts up to 50 mph. This resulted in whiteout conditions, road closures, and loss of power to thousands of customers. One person was killed in an accident on State Highway 42 near Plainview. The National Centers for Environmental Information recorded $50,000 in damage from the storm.
January 2014	Southern half of Minnesota	Blizzard conditions resulted in numerous highways, including I-90 and I-94 being closed due to whiteout conditions and wind gusts over 50 mph. The Olivia Armory sheltered 52 stranded travelers overnight, and 69 people were sheltered in Albert Lea. There was one fatality due to this storm.
April 2013	Southwestern Minnesota	Ice up to 1-inch thick produced damages exceeding $70 million and a FEMA Disaster Declaration (DR-4113). Public Assistance grants topped $11 million (see Figure 57).

SOURCE: NCEI

Probability of Occurrence

As shown in the section above, Minnesota experiences a variety of severe winter weather events annually. Although it is impossible to predict probabilities for this type of event over short periods of time, the state can presumably expect one ice and ice/snow storm every year on average and one major annual blizzard.

Vulnerability

Transportation systems, electrical distribution systems, and structures are vulnerable to winter storms throughout the entire state. Damage and disruption affects the state dramatically in numerous ways. However, while dollar amounts have been stated in the disaster history, total damages and vulnerability cannot be assessed since reporting on all of the relevant factors does not occur. According to HSEM, winter Storms will continue to be a hazard with high probability and low mitigation potential that effects the entire state.

Figure 58. Perceived Risk of Winter Storms from County HMPs.

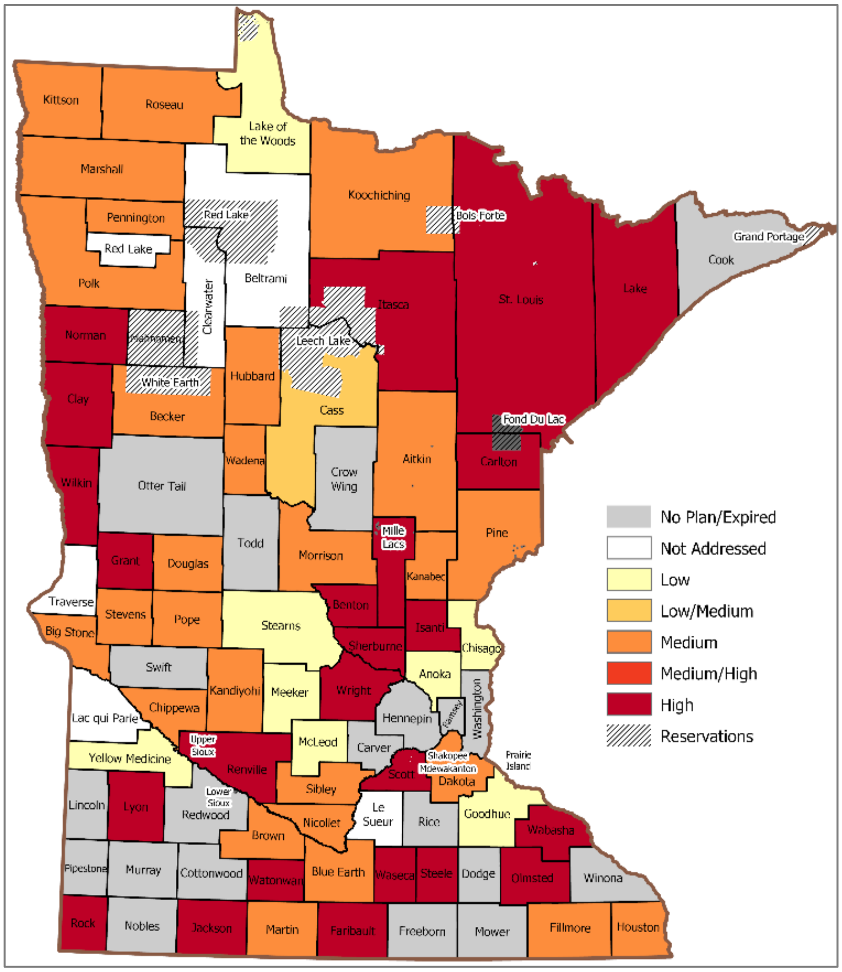


Figure 58 to the left is shows that counties rank Winter Storms as high, medium, or low based on all kinds of perceptions that don't appear to trend geographically. A county ranking the hazard high may be adjacent to a county that ranks the risk low. This could be due to very localized vulnerabilities such as demographics, access to services, resilience of energy infrastructure, and historical events that had a lasting impression on the community.

Winter Storms and Climate Change

Historically, winter storms have had a large impact on public safety in Minnesota. If the frequency of snowstorms and annual total snowfalls increase, as anticipated effects of Climate Change, the effects on public safety will also increase. Pressures on energy use, reduced reliability of services, potential outages, and potential rise in household energy costs are major climate change risks to public health that can occur from winter weather.

The number of heavy snowfall years for the Midwest has fluctuated between 1900 and 2006. The periods of 1900-1920 and 1960-1985 had numerous years with snowfall totals over the 90th percentile. In the past three decades, the number of heavy seasonal snowfall totals has been much lower. Despite these generally lower seasonal snowfall totals, some areas of the Midwest have still experienced significant snow totals in the most recent decade. The 100-year linear trends based on decadal values show that the upper Midwest had statistically significant (1% level) upward linear trends in snowstorm frequency from 1901 to 2000 (Kunkel, et al., 2013).

According to the 2015 Minnesota Weather Almanac, a recent study of seasonal snowfall records across the state from 1890-2000 showed that 41 of 46 climate stations recorded an increase in average annual snowfall, by as much as 10 inches. Higher snowfall levels can result in greater runoff potential during spring snowmelt, and many watersheds in Minnesota have shown more consistent measures of high-volume flows during spring, often at or above flood stage (Seeley, 2015).

4.7.11 Coastal Erosion and Flooding

This plan identifies coastal erosion and flooding as a hazard of moderate risk and separates it from other erosion and flooding as hazards. Coastal flooding is primarily caused by storm surge and waves, but many other factors have an influence. On the Lake Superior shoreline, flooding is dependent on anthropogenic activities as well as lake levels, which vary as a result of precipitation, evaporation, and other natural processes. Ice cover also impacts the risk of a flood hazard significantly. These phenomena distinguish the analysis of flood hazards on the Great Lakes from those for ocean coastal areas—as well as from riverine flooding or erosion (FEMA, Great Lakes Coastal Flood Study, 2018).

Northeast Minnesota has 189 miles of Lake Superior shoreline and a coastal population of 216,268 (NOAA OCM, 2018). Section 304(1) of the Coastal Zone Management Act identifies the coastal zone as the coastal waters (including lands therein and thereunder) and the adjacent shorelands (including the waters therein and thereunder), strongly influenced by each other and in proximity to the shorelines of the several coastal states, and includes islands, transitional and intertidal areas, salt marshes, wetlands, and beaches.

Coastal Erosion

Erosion along 36 miles of unstable, tall clay shoreline is a particular problem for the north shore of Lake Superior Typically, shorelines are quite high—often greater than 25 feet—and erosion and bluff instability can harm the aquatic zone near the shore.

Shoreline erosion of St Louis County's Minnesota Point (aka Park Point) in Duluth has been a studied concern since at least 1970 when the residential population of that area was at a peak. Dredging operations in the Duluth harbor of Lake Superior have benefitted the erosion-prone areas by making the beach slope flatter and slowing the erosion rate (USACE, 1974). Occasional dramatic losses of beach are of great concern to residents of the point, and dredging/beach nourishment projects continue today. In 2019, USACE has another planned dredging operation in the harbor that will provide clean sediment for Minnesota Point (City of Duluth, 2019).

The Lake of the Woods, located in the northern most part of the state and a southern portion of the Canadian provinces of Ontario and Manitoba, is the sixth largest freshwater lake that is partially located in the United States. The Lake of the Woods is large enough in size (300,000 acres) and has wind fetch lengths long and wide enough (ranging from 25 to 32 miles) to lead to substantial wave growth and wind setup conditions throughout the lake (USACE, 2017).

Coastal erosion is defined as the wearing away of land and the loss of beach, shoreline, or dune material over a period of time as a result of natural coastal processes or human influences. Characteristics such as supply of sand and processes such as sea level change, currents, tides, waves, and wind are natural factors that contribute to the rate of erosion. Human-caused contributors to erosion include dredging tidal entrances, jetty and groin construction, hardening shorelines with seawalls, beach nourishment, and construction of harbors and sediment-trapping dams.

A survey of St Louis County's Minnesota Point residents showed that 88% rated long-term lake level fluctuations as very important to extremely important in the cause of coastal flooding and erosion problems (Rasid, 1992). The results suggest residents perceive the hazards of coastal erosion from their own personal experience, in that Minnesota Point has experienced fluctuating water levels more than high wave impact.

Results from a 1998 survey questionnaire of Minnesota Point residents showed that 54% of the residents experienced either flooding of basements due to a rise in the water table or direct inundation of water to yards and buildings, such as garages and storage sheds, during the reported average of 18 years spent on Minnesota Point. Beach erosion, loss of land, and landscaping, destruction or damage of shore protection devices, and damage to buildings and related structures were the common types of reported erosion issues (Rasid, 1992).

Small lakes can experience shoreline erosion due to wind and wave action as well, particularly where native upland vegetation has been replaced with turf or aquatic vegetation has been removed. Excessive and/or chronic recreational activity too close to the shore can also make shorelines vulnerable to erosion (MN DNR, 2018).

Coastal Flooding

Severe flood events on the Lake Superior occur when high lake levels are combined with strong winds that drive water and waves onshore. When large waves are paired with elevated lake levels, the waves are able to reach farther onshore, eroding the backshore, and potentially reaching developed lakefront areas. Whether wave hazards reach development depends on local conditions—for instance, in many areas the bluffs are high enough to limit the wave effects to the bluff face. However, in other areas, the bluff or shore protection structures may be overtopped or waves may pass over inundated, low-lying areas. Waves can cause dramatic structural damage to buildings, including splintering walls and causing homes to float off foundations or even to collapse (Great Lakes Coastal Flood Study, 2018). In addition, periods of high water levels have plagued the city of Duluth's sanitary sewer collection system with flooding (Berg, 1985).

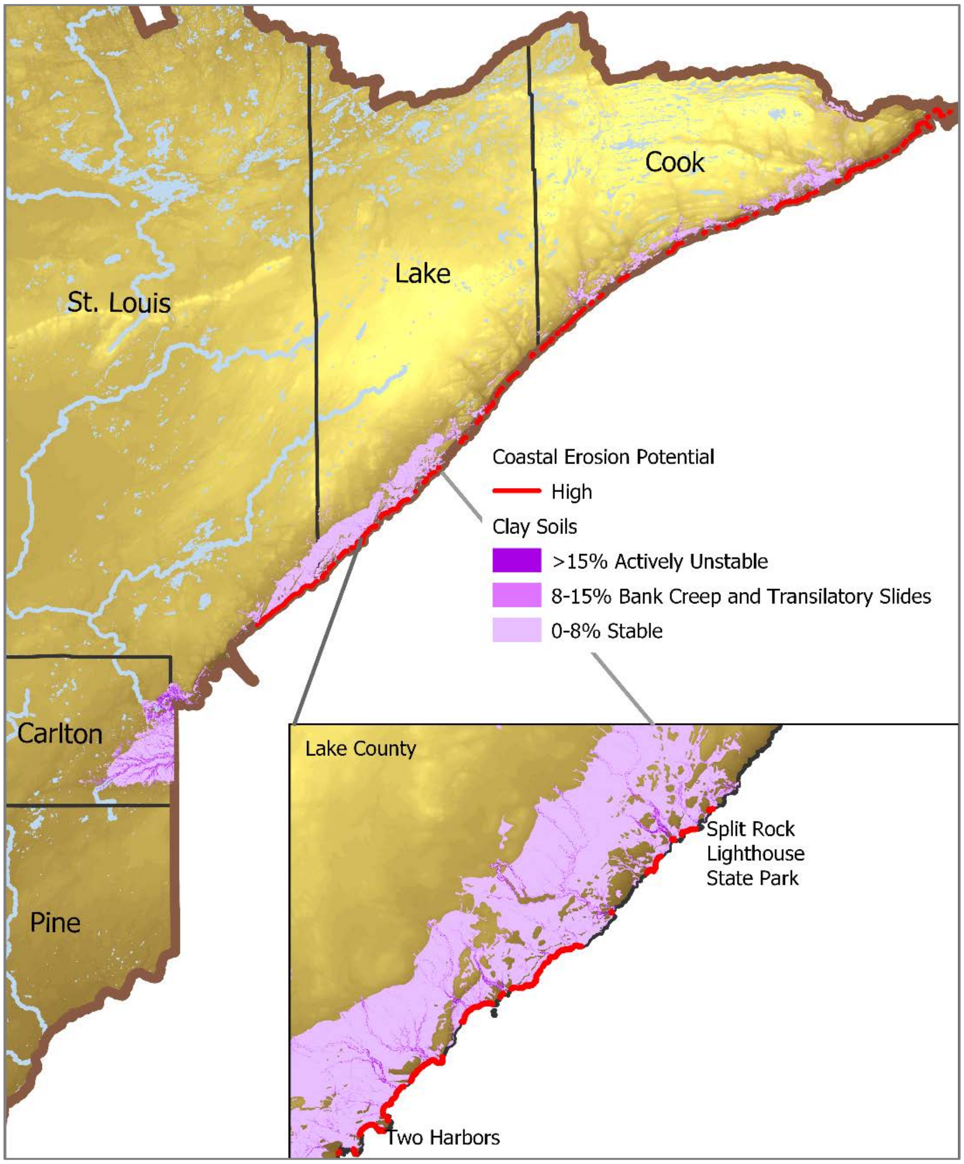
Coastal Erosion History

The most extensive study of coastal erosion on the North Shore of Lake Superior was conducted in 1988, using aerial photographs taken in the 1930s, 1975, and 1988/89 (Johnson B. L., 1995) (Johnston, Sales, Bonde, Aunan, & Raby, 1989). This research showed that the North Shore of Lake Superior is variable in its geology and geometry, and these variations result in varying rates of erosion. The study showed that non-bedrock areas at or near the shoreline receded at an average rate of .46 ft. /yr., and a maximum of 1.1 ft. /yr.

Major storm winds and waves come from the northeast, with a greater impact on the north and northeast-facing shores. (Johnson B. L., 1995). These differences in coastal aspects indicate areas of higher and lower susceptibility among Lake Superior coasts.

A corresponding mapping project and report were produced with the research, (Johnston, Sales, Bonde, Aunan, & Raby, 1989) that cited growing concerns for reducing the economic and environmental losses along the shores of Lake Superior that arose from increases in development pressures and water levels of the mid-1980s. Figure 59 below shows the resulting erosion risk dataset along with location and stability of clay soils, which were determined in another study (Jereczek & Little, 2016). Sixty-nine miles were deemed at high risk for coastal erosion.

Figure 59. High Erosion Zones and Clay Soils on the North Shore of Lake Superior.



SOURCES: (JOHNSTON, SALES, BONDE, AUNAN, & RABY, 1989; JERECZEK & LITTLE, 2016)

The Lake County Soil and Water Conservation District (SWCD) received 15 inquiries about coastal erosion cost-share and technical assistance in 2017. Many landowners inquire at SWCDs and County P&Zs and are surprised to find they've bought or built in an erosion hazard area. Coastal erosion is something cities are dealing with as well (particularly related to structures).

Coastal Flooding History

Coastal communities face flood risks from a combination of increased water levels and/or high-energy waves. When storms affect the coast, communities can face serious threats to human safety, extensive damage to infrastructure and the built environment, and negative economic impacts. To help protect against these impacts, more stringent building practices and flood insurance are required in the hazardous areas along the coast.

In October 2018, winds of 64 mph were reported at the Duluth harbor. Waves reached as high as 14 to 18 feet, causing the Canal Park business district near Lake Superior to close due to standing floodwater and the City's very popular lakewalk to be closed (Figure 60).

Figure 60. Wave Action and Flooding in Duluth's Canal Park, October 2018.

SOURCE: *(WDIO, 2018)*

Plans and Programs in Place

Lake Superior North One Watershed, One Plan partners have determined that mapped coastal erosion hazard data for the Lake Superior Coastal Shoreline is top priority. The age of the aforementioned erosion studies, combined with current research and technology has prompted the new initiative and work group of Coastal Erosion Hazard Mapping (CEHM Project).

Key outcomes of the CEHM project include common guidelines for landowners along the entire North Shore with accessibility to geospatial data. The data include a parcel level, specific database; an interactive, workable database with ground-truthed data and the capacity to update; and an outreach initiative (such as in the form of a property owner's resource guide). The SWCD's board conservationist is also pursuing additional training so that SWCDs are able to provide technical assistance to landowners.

The purpose of the North Shore Management Board (NSMB) is to direct the development of strategies for environmental protection and orderly growth along the North Shore of Lake Superior (NSMB, 2016). NSMB provides zoning standards for property lots located within the North Shore Management Zone that are adopted in the local ordinances.

The Lake Superior North Watershed Management plan (LSNWP) was created to maximize the ecosystem services delivered by Lake Superior, a globally significant body of water that provides economic, social and environmental well-being particularly in Cook and Lake County. This comprehensive plan is used for the management and health of these counties' water resources. This plan identifies problematic water and resource areas and maps a sustainable course of action to improve and protect.

Both Cook and Lake Counties have comprehensive plans that serve as the legal basis for their official controls, but the counties will ensure that the LSNWP is implemented by revising and adopting these policies. Both counties have developed incentive programs for the protection, restoration, and management of the LSNWP.

A Great Lakes Coastal Flood Study was initiated in 2014 for the purpose of updating the coastal flood hazard information and Flood Insurance Rate Maps (FIRM) for Great Lakes coastal communities using analysis of historic storm and high water events and an extensive storm surge study (FEMA, Great Lakes Coastal Flood Study, 2018).

Probability of Occurrence

Wind, waves, water levels, and human activities constantly affect the communities along the shores of the Great Lakes. Shoreline flooding and erosion are natural processes, occurring at high, average, and even low Great Lakes' water levels. However, during periods of high water, flooding and erosion are more obvious, causing serious damage to homes and businesses, roads, water and wastewater treatment facilities, and other structures in coastal communities. Long-term and seasonal variations in precipitation and evaporation rates primarily control the Great Lakes' water levels and their fluctuations.

As high lake levels increase, bluff recession rates also increase. Increasing assaults by wave action against the base of the bluff cause erosion and beach-building sediments. Navigational improvements and dredge-material disposal practices deplete both tributary and shore land sources of sediment; removing these sediments from the shore system contributes to erosion. Ice ridges that form and break up each winter along the shoreline cause erosion by trapping sand in floating fragments of ice that are carried offshore into deep water. This continual natural process is one of the principle mechanisms by which sand is lost from the near shore system.

Coastal erosion is usually a gradual process, and sudden incidents prompting emergency action are rare. Such rare events include strong storms with high winds or heavy wave action that can cause sudden failure of bluffs. Coastal property owners are acutely aware of hazards during periods of high water levels and especially right after a damaging storm or a bluff failure, but this awareness can fade over time if low lake levels slow the erosion rate.

Vulnerability

Continued shoreline development is inevitable, and it contributes to erosion problems. Erosion rates can accelerate with increases in impervious surfaces, changing and eliminating vegetation cover, and alterations to beach makeup. Serious situations are rare but massive/fast erosion can occur during one storm event leaving houses dangling from cliffs or beginning to slide down hillsides. The effective management of areas with high erosion potential is necessary to protect property owners and provide measures for reducing erosion.

Natural processes of deep-water waves and swells determine Lake Superior water fluctuation. These natural processes are further modified by International Joint Commission (IJC) navigation control structures. IJC strives to keep Lake Superior's monthly mean water level between 593.36 and 601.97 feet, but because meteorological conditions greatly affect lake levels, attempts to balance the system can be difficult (Rasid, 1992).

Low elevation beaches and sandspits, such as that of Park Point in St. Louis County, are vulnerable to even minor fluctuations in lake levels, which may induce significant coastal flooding and erosion problems.

Coastal Erosion and Flooding and Climate Change

Heavy, extreme precipitation is expected to be a primary symptom of climate change in northern Minnesota. Erosion is exacerbated during storm events. At an average increase of 2 degrees per decade, Lake Superior's rising water temperatures are leading to more storm events. Storm events which have also increased in recent years, further intensify with high water levels. Increased wave action due to high water levels are evidenced in the Great Lakes Coastal Flood Study 2018 draft for Lake Superior from the FEMA and partners.

4.7.12 Erosion, Landslides & Mudslides

Erosion and other forms of slope failure resulting in landslide and mudslide events are hazards caused by numerous diverse mechanisms. An erosion hazard area is defined by Section 577 of National Flood Insurance Reform Act (NIFRA): "Erosion hazard area means, based on erosion rate information and other historic data available, an area of erosion or avulsion is likely to result in damage or loss of property or infrastructure within a 60 year period." (FEMA, 1999).

The movement of a mass of rock, debris, or earth down a slope by the force of gravity is considered a landslide. They occur when the slope or soil stability changes from stable to unstable, which may be caused by earthquakes, storms, volcanic eruptions, erosion, fire, or additional human-induced activities. Slopes greater than 10 degrees are more likely to slide, as are slopes where the height from the top of the slope to its toe is greater than 40 feet. Slopes are also more likely to fail if vegetative cover is low and/or soil water content is high. Potential impacts include environmental disturbance, property and infrastructure damage, and injuries or fatalities (FEMA, Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards, 2013).

The USGS definition of landslides includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity acting on an over-steepened slope is the primary reason for a landslide, there are other contributing factors:

- Erosion by rivers create over steepened slopes
- Rock and soil slopes are weakened through saturation by snowmelt or heavy rains
- Excess weight from accumulation of rain or snow, or from man-made structures may stress weak slopes to failure and other structures

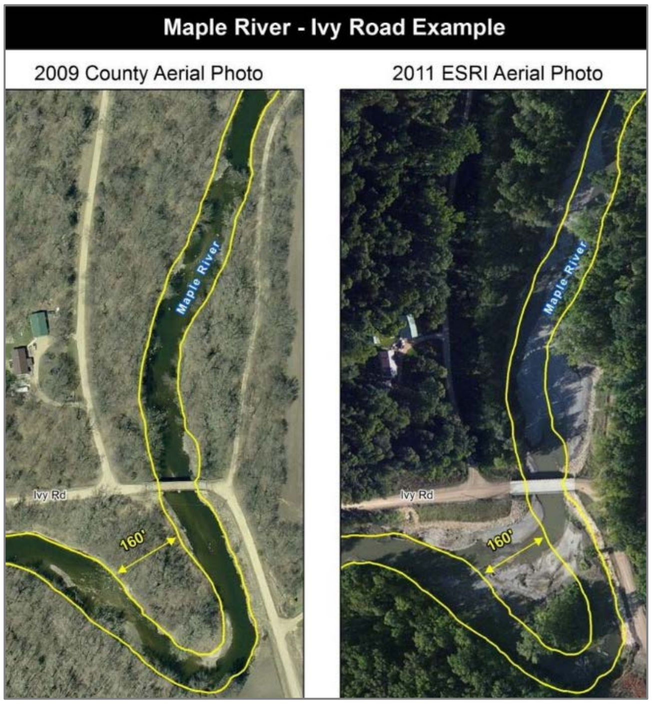
Slope materials that become saturated with water may develop a debris flow or mud flow. The resulting slurry of rock and mud may pick up trees, houses, and cars, thus blocking bridges and tributaries causing flooding along its path.

Landslides and mudslides often occur together with other major natural disasters, thereby exacerbating relief and reconstruction efforts. Wildfires may remove vegetation from hillsides, significantly increasing runoff and landslide potential. Earthquakes commonly trigger rock falls. Floods and landslides are closely related and both involve precipitation, runoff, and ground saturation that may be the result of severe thunderstorms. However, landslides also take place over time and often take place when no natural disaster is evident.

Streambank erosion

Streambank erosion is a natural process, but acceleration of this natural process leads to land loss, stream channel instability, increased sediment, habitat loss and other adverse effects. Bank erosion takes place by two processes, channel migration and channel widening. Widening of channels can be caused by natural processes of incision, bank erosion and direct modification by construction activities. The result is more erosion from stream bed and banks, increased sediment deposition, and loss of habitat. Increased flows due to watershed changes, stormwater runoff, reservoir releases and scour below culverts and bridges can all contribute to channel enlargement and therefore bank erosion (Day, 2013).

Figure 61. Example of Streambank erosion before event and after restoration.



SOURCE: BLUE EARTH COUNTY

Maple River in Blue Earth County bridge abutments shown in Figure 61 were washed out in 2010. The Maple River of 2009 is outlined in both a 2009 and 2011 photos, showing how the stream channel migrated due to erosion. The stream bank was fortified with rip-rap to mitigate future damages.

Bluff erosion

Bluff erosion occurs on features with greater than 10 feet of relief in 20 foot by 30 foot area. The vertical nature of bluffs makes them susceptible to sudden and catastrophic failure. During periods of moderate and high flow, bluffs are eroded by the river in deeply incised channels lacking a floodplain. Bluffs also fail due to landslides and mass wasting. The river removes the soils deposited by mass wasting and landslides. As a result the eroded, nearly vertical slope cannot stabilize and reestablish itself with vegetation (Day, 2013).

Figure 62.Example of Bluff Erosion in Blue Earth County.

SOURCE: BLUE EARTH COUNTY, PICTOMETRY 2009

The bluff erosion example in Figure 62 shows how structures become at risk due to the combination of long term processes and floods.

The river bluffs around the Twin Cities have a high risk of natural landslides in the spring, when ice thaws within the bluff and destabilizes rock (Stanley, 2018)

Bedrock exposure in the Mississippi River corridor in St. Paul follows a sequence of flat-lying to gently dipping marine sedimentary units. Bedrock failure occurs where the St. Peter Sandstone forms a reentrant in the bluff face, leaving an overhanging ledge of the PlatteVille Formation. Undercutting can be facilitated by springs, sapping and mechanical erosion. Vertical fractures allow water to move down at high rates and bedding- plane fractures and finer-grained beds allow water to move horizontally and exit the bluff face at predictable horizons (Jennings, 2016).

Landslides & Mudslides History

On April 28, 2018, an estimated 400,000 pounds of rock and soil came loose on the bluff to cover Wabasha Street in Ramsey County. After having an engineering firm study the slope, city officials decided to build a 12-foot-high retaining wall that will run about 250 feet along Wabasha Street. Ramsey County will receive $766,770 from the state's disaster-assistance fund to help with these repair costs (Stanley, 2018).

Figure 63. Landslide in Lilydale in 2013

On May 22nd, 2013, two children were killed in a landslide in Lilydale Regional Park along the Mississippi River. The incident was preceded by several weeks of heavy rain, which inundated the soils around the area (Figure 63). The children were part of a school group looking for fossils. A group of four children were walking on a path on the edge of a bluff when the path collapsed beneath them. Two students died and another two were injured. Two firefighters were also injured (Gottfried, 2013). Engineers investigating the landslide said that groundwater played a major role and that all bluff areas like Lilydale have similar risks.

Locally heavy rains in July of 2017 caused a mudslide to occur near Minneiska in Winona County that covered U.S. Highway 61. As the heavy rain continued overnight, another mudslide occurred on July 20th, covering U.S. Highway 61 near Homer.

The Blue Earth County HMP lists 23 events between 1960 and present day where structures and infrastructure were impacted.

For the past three years, researchers have been working on an inventory of landslides around Minnesota and have determined that nearly 500 landslides have occurred in the Mankato area alone. Eight colleges and universities received a $500,000 grant in 2016 to inventory the geological activity around Minnesota. They hope the landslide inventory will lead to predictive landslide regulations similar to the ones found in Washington and Oregon (Claims Journal, 2018). Landslide inventories from this project were not available for inclusion into this plan.

Probability of Occurrence

The sandy river bluffs along the Mississippi and Minnesota Rivers suffer erosion regularly, and intense or frequent rains exacerbate this issue. Red clay erosion is a natural process in the western Lake Superior basin that also occurs regularly.

Erosion associated with mass wasting processes is extremely difficult to predict due to the episodic nature of climatic events that initiate movement. Often landslides occur many years following vegetation and land use changes due to complex interactions of root mass decay and soil saturation from major storms.

Bank-failure problems are caused by gravity acting on earth materials resting on a slope. In the case of failure, gravitational forces exceed the forces holding the sediment together. Failures can take several forms depending on sediment type, sediment layering, and moisture content.

The geotechnical properties of a soil (shear strength, permeability etc.), are significant factors in determining landslide susceptibility. Soils with a high shear strength are less susceptible to landslides than soils with a lower shear strength. The hydraulic soil properties of the soil are also important because these properties affect what intensity and duration of rainfall event is required to initiate a landslide (Barr Engineering, 2017).

Vulnerability

Human life and safety, structures, and infrastructure are all vulnerable to landslides. Erosion is a statewide hazard but the drivers of landslide susceptibility vary within the state. All streams in Minnesota susceptible to erosion with damaging erosion occurring during a flash flood caused by a heavy rain event or up to sixty years of the hydraulic pressure exerted on its banks. However the Minnesota and Red River Valleys each have unique erosion concerns based on the geomorphology of the valleys. Agricultural practices can create conditions conducive to landslide occurrence just as urban land use does. Major regions of erosion concern discussed below are labeled in Figure 64.

Northwest Minnesota

Red River Valley bank failures are typically the result of slumping in which a block of earth moves downward along a curved failure plane, commonly with a backward rotation of the slump block. The fundamental reason why deposits in this area rupture and sag is because they consist of clay rather than sand, silt, or gravel.

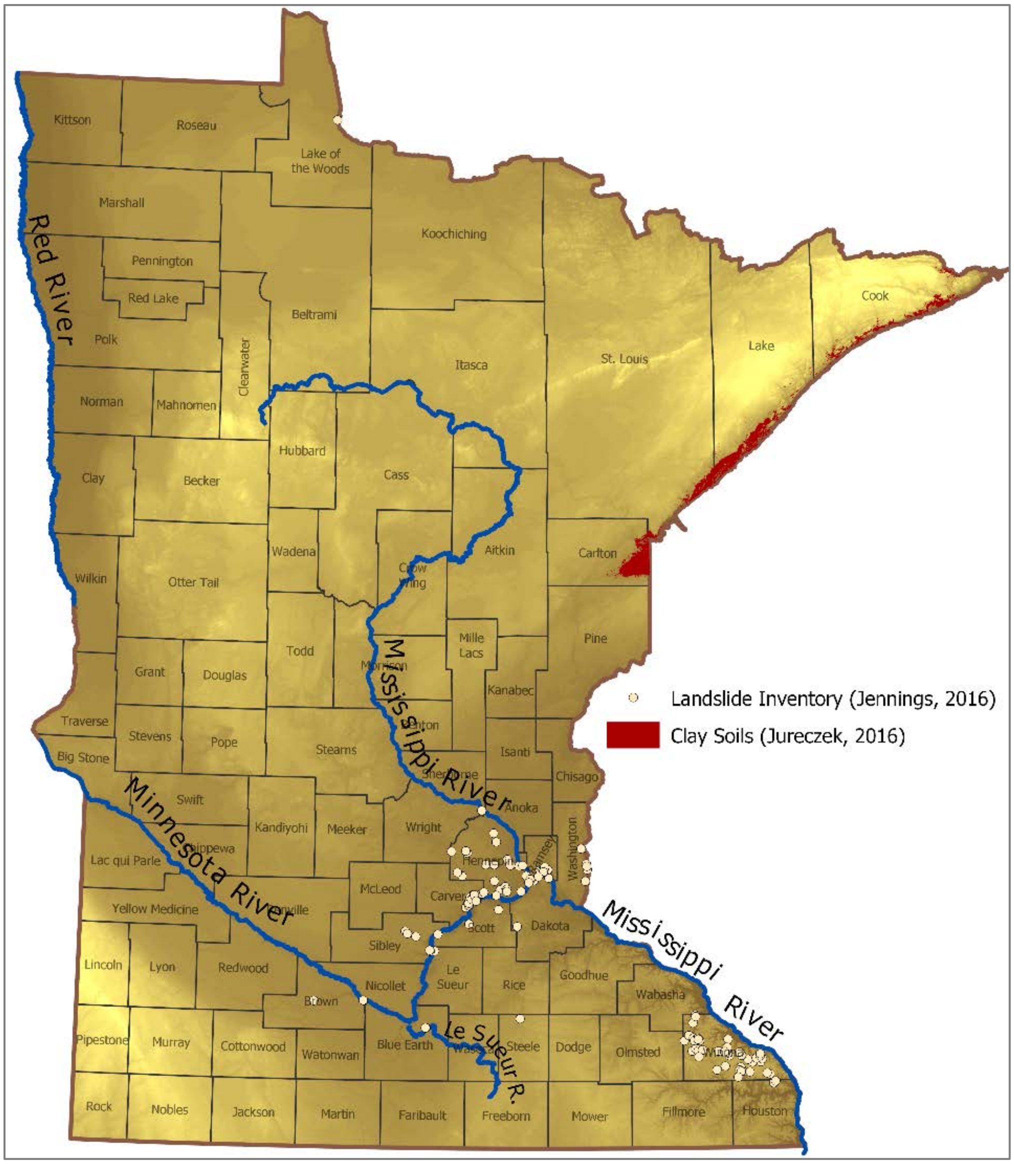
Clays are present in northwestern Minnesota because the Red River Valley is the floor of ancient glacial Lake Agassiz, a large lake that formed at the edge of a retreating ice-age glacier (Clayton and Moran, 1982; Fenton and others, 1983). Both glacial and lake sediments were deposited and these clays are exposed along the rivers of the Red River Valley. Riverbanks particularly vulnerable to slumping are those that consist of an upper, relatively competent layer of sediment called the Sherack Formation resting on more easily deformable clays of the Huot and Brenna Formations.

Mid Minnesota Watershed (Le Sueur and Minnesota rivers)

Deeply incised rivers in Blue Earth County create unique hazards not seen in other areas in Minnesota. The geologic history of this area paired with modern land use, creates rivers highly susceptible to significant bluff failures, bank erosion, and ravine growth (Day, 2013).

Dry sand and gravel lack cohesion and typically seek an angle of repose of approximately 30 to 45° depending on the average grain size and mixture. If storm water is focused and creates a ravine in dry sediment, newly formed steep slopes quickly fail to the angle of repose. This style of failure has occurred along the high terraces of the Minnesota River in Eden Prairie both recently and historically (Jennings, 2016).

Figure 64. Major Regions of Erosion Concern



Head-cutting of ravines that were formed entirely in glacial sediment occurred owing to the infiltration capacity of the soil and glacial sediment being overwhelmed resulting in overland flow or from storm water being focused by pipes. This resulted in newly created, over steepened reaches of the ravines that were susceptible to failure on the side slopes. Shallow storm flow also weakened saturated slopes or led to failure by sapping. Ravines may be preferentially located where springs emerge from sediment layers. Once a deepening occurs, groundwater will discharge laterally into ravines (Jennings, 2016).

The Blue Earth HMP identified eighty properties that are vulnerable in the county. The plan suggested that setbacks in local planning ordinance for streambank and bluff erosion is necessary based on development trends. The Blue Earth County Environmental Department developed a mitigation action to work on the technical basis for the setbacks.

Western Lake Superior Watersheds

Red clay erosion is significant in the western Lake Superior basin. The predominant red clays are interspersed with sands and silts that are geologically young and are undergoing a high rate of natural erosion. Surveys of land erosion have been compiled since the 1977 to address the pervasive erosion and associated damages and costs (EPA, 1980). Clay soils have been mapped in this region and are shown on the coastal erosion map in Section 4.5.8 (Jereczek & Little, 2016).

Agricultural Areas

Agricultural practices in highly erodible soil types can create conditions conducive to landslide occurrence. Natural and human caused changes in hydrology play a critical role in the failure of stream banks, bluffs and ravines, as more water is entering ravines and rivers. Land use changes have increased runoff to rivers from urban and agricultural land uses. Vegetation changes, such as conversion of native prairie, pastures and wetlands to row crops and removing trees and vegetated buffers, reduce soil stability, reduce evapotranspiration and increase runoff.

Agricultural areas are more susceptible than forests because they lack large, deep tree roots that can hold soil material together. Pastures on steep lands, typically have shallow-rooted grasses and may also experience slumping. With certain soil types, landslides may become liquefied and turn into mudslides (Sustainable Agriculture Research and Education, 2012).

Sediment from erosion and run-off from agriculture is a statewide impact. This section does not address sediment although it effects both environment and economy.

Erosion and Climate Change

The conditions that make certain lithologies more vulnerable to erosion, landslides and mudslides will be exacerbated by the expected increase in heavy rainfall events. Changing summer storm intensity also results in increased runoff and higher flows which worsening near channel erosion.

The increased magnitude and frequency of flooding events and storm activity that may result from climate change may in turn increase the risk of soil erosion and landslides. According to University of Washington geologist Dave Montgomery, “If the climate changes in a way that we get a lot more rainfall you would expect to see a lot more landslides” (Phillips, 2014).

In Minnesota, the wettest days are getting wetter. This can contribute to increased erosion in many locations due to flooding and saturation of soils. Reduced ice cover on lakes and shorelines (due to warmer temperatures) could potentially expose shorelines to increased erosion or damage during weather events when they previously may have been covered with ice (National Climate Assessment Development Advisory Committee, 2013).

According to the 2014 National Climate Assessment, “Increased precipitation intensity also increases erosion, damaging ecosystems and increasing delivery of sediment and subsequent loss of reservoir storage capacity” (Pryor, et al., 2014).

4.7.13 Land Subsidence (Sinkholes and Karst)

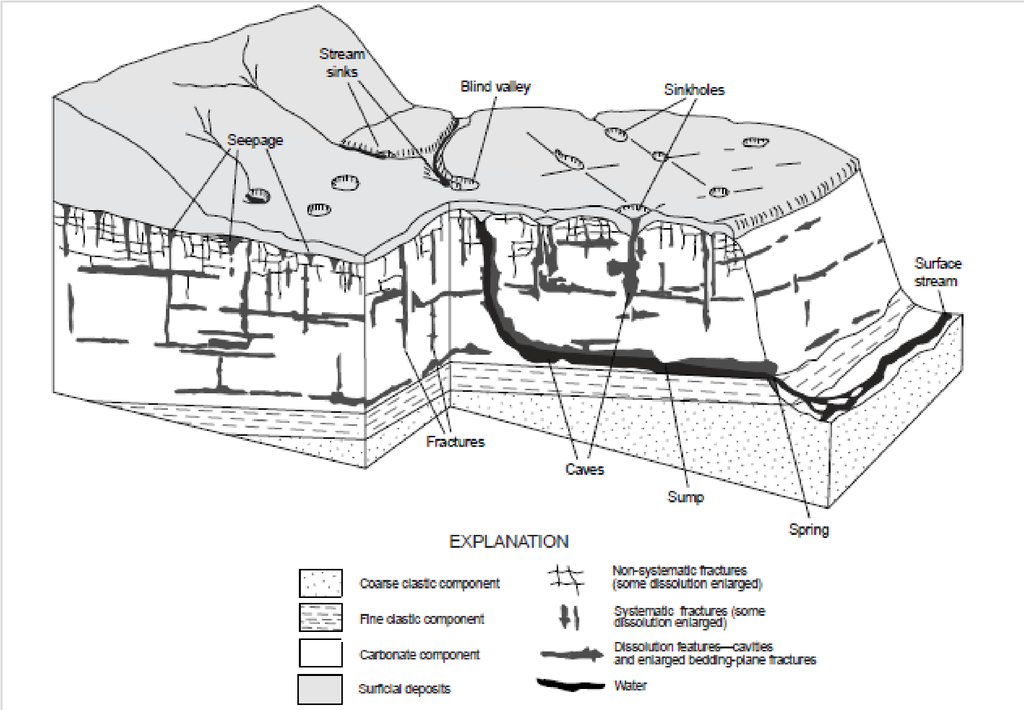
Subsidence is the gradual settling or sudden sinking of the earth's surface due to subsurface movement of earth materials. Subsidence commonly involves a gradual sinking, but it also refers to an instantaneous or catastrophic collapse. The level of subsidence ranges from a broad lowering to collapse of land surface. Many causes of subsidence are human-induced, such as groundwater pumpage, aquifer system compaction, drainage of organic soils, underground mining, and hydrocompaction. Natural compaction, and thawing permafrost can also have natural causes of subsidence. Areas located above or adjacent to karst topography have a greater risk of experiencing subsidence. Sudden collapses of surface areas can damage and destroy buildings and infrastructure (FEMA, Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards, 2013). Other problems associated with subsidence include the formation of sinkholes, flooding and pollution.

The change in the local environment affecting the soil mass causing subsidence and sinkholes collapse is called a triggering mechanism. Water is the main factor affecting the local environment that causes subsidence. The main triggering mechanisms for subsidence are water level decline, changes in groundwater flow, and increased loading and deterioration (abandoned coal mines) of the earth. Water level decline can happen naturally or be human induced. Factors in water decline are pumping water from wells, localized drainage from construction, dewatering, and drought. Changes in the groundwater flow include an increase in the velocity of groundwater movement, increase in the frequency of water table fluctuations, and increased or reduced recharge. Increased loading causes pressure in the soil leading to failure of underground cavities and spaces. Vibrations caused by an earthquake, heavy machinery, and blasting can cause structural collapse followed by surface settlement.

Sinkholes and subsidence are also common in those areas of the state underlain by old abandoned coal and iron mines. Pillows left for roof support in the mines generally deteriorate over time and eventually collapse, removing roof support. This is particularly a problem where mines underlie more recently developed residential areas and roads.

In Minnesota, the primary natural causes of land subsidence are karst landforms, which develop on or in limestone, dolomite, or gypsum by dissolution and are identified by the presence of features such as sinkholes, underground (or internal) drainage through solution-enlarged fractures (joints) and caves. Karst landforms can be hazardous because of the sinkholes that form there and for the ease with which pollutants can infiltrate into the water supply. Figure 65 on the next page illustrates a cross-section of karst drainage and related landforms, karst-prone areas, and karst lands in southeastern corner of the state.

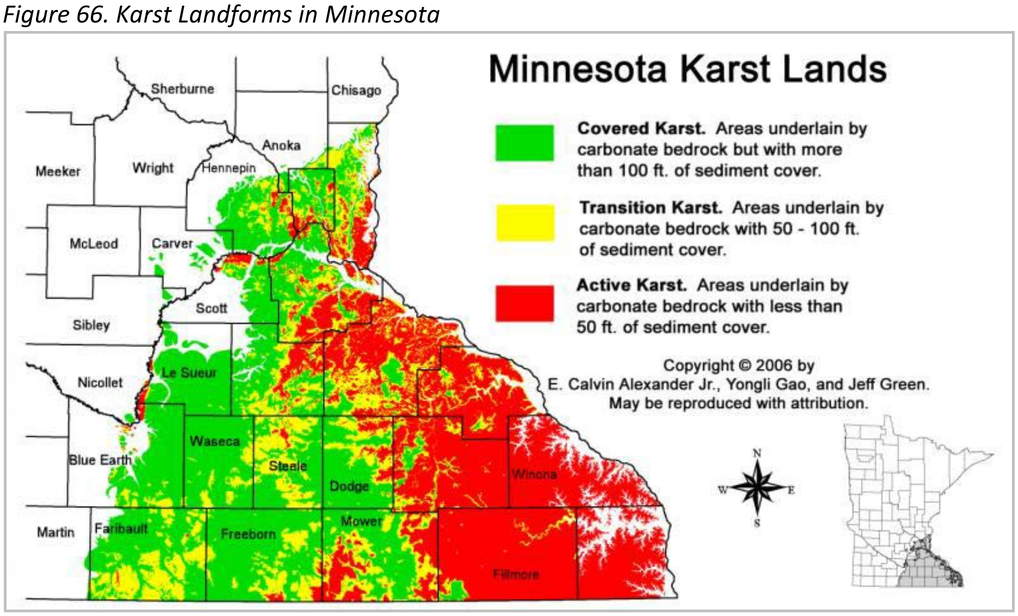
Figure 65. Karst Drainage and Related Landforms



SOURCE: ALEXANDER AND LIVELY (1995) IN MINNESOTA GEOLOGICAL SURVEY, CAVES IN MINNESOTA

Minnesota Karst Lands map developed by Alexander and others in 2006 depicts the extent of karst prone areas in Minnesota and defined active karst as places underlain by carbonate bedrock with less than 50 feet of sediment cover (Figure 66).

Figure 66. Karst Landforms in Minnesota



SOURCE: E. CALVIN ALEXANDER JR., YONGLI GAO, AND JEFF GREEN, 2006

An updated dataset showing a more extensive range of karst-prone areas (Figure 67 in the *Probability of Occurrence* section below) adds the Mesoproterozoic Hinckley Sandstone (Shade, 2002) and the St. Peter

Sandstone (Alexander, 1988, Alexander, 2011). The Hinckley and St. Peter sandstones are included because University of Minnesota and DNR karst geologists have found various karst features in these units (Pine County). The areas shown on the map are areas where karst features can form on the land surface and where karst conditions are present in the subsurface. Karst processes provide a direct, rapid exchange between surface and ground waters and significantly increase the risk of groundwater contamination from surface pollutants.

Land Subsidence History

In Minnesota, limestone and dolostone underlie the southeastern corner of the state, which includes the Minneapolis-St. Paul Metropolitan Area. Similar rocks are also found deep beneath the surface in northwestern Minnesota. In southeastern Minnesota, carbonate rocks from the Cedar Valley Group of geological formations down through the bottom of the Prairie du Chien Group contain caves and other karst features. Because most of Minnesota is buried beneath a thick cover of glacial sediments, the karst landscape may not be apparent. In parts of southeastern Minnesota, erosion has removed most of this glacial cover and exposed the carbonate bedrock. Counties known for karst features include parts of Dakota, Rice, Dodge, and Mower, and most of Goodhue, Olmstead, Winona, Wabasha, Houston, and Fillmore. Fillmore County has more caves, sinkholes, and disappearing streams than all other Minnesota counties combined.

According to data from the MN DNR, there 15,380 sinkholes, 274 stream sinks/sieves, 4,695 springs, and 88 tile drain outlets in Minnesota.

The limestone landscape in southeastern Minnesota makes the protection of water resources difficult. Petroleum and other chemicals released from underground storage can travel quickly into groundwater supplies. Manure from agricultural spills can result in fish kills miles from the release point. Chemicals used on the landscape can reappear at unexpected times and locations. As rainwater infiltrates limestone, hidden, rapid pathways can form between pollution release points and drinking water wells and surface water. This quick transportation of pollutants means that conventional hydrogeologic tools, such as monitoring wells, are limited in their usefulness (MPCA, 2018).

The collapse of carbonate bedrock beneath liquid storage basins has been reported in Minnesota. Since 1976, three communities in southeastern Minnesota (Altura, Bellechester, and Lewiston) have had municipal sewage lagoons collapse, resulting in millions of gallons of sewage being released into a nearby aquifer (MPCA, 2018).

In July of 2018, a sinkhole opened up in Redwood Falls after heavy rain. One person drove into the sinkhole but was not injured due to his seatbelt and airbag (ABC7 News, 2018).

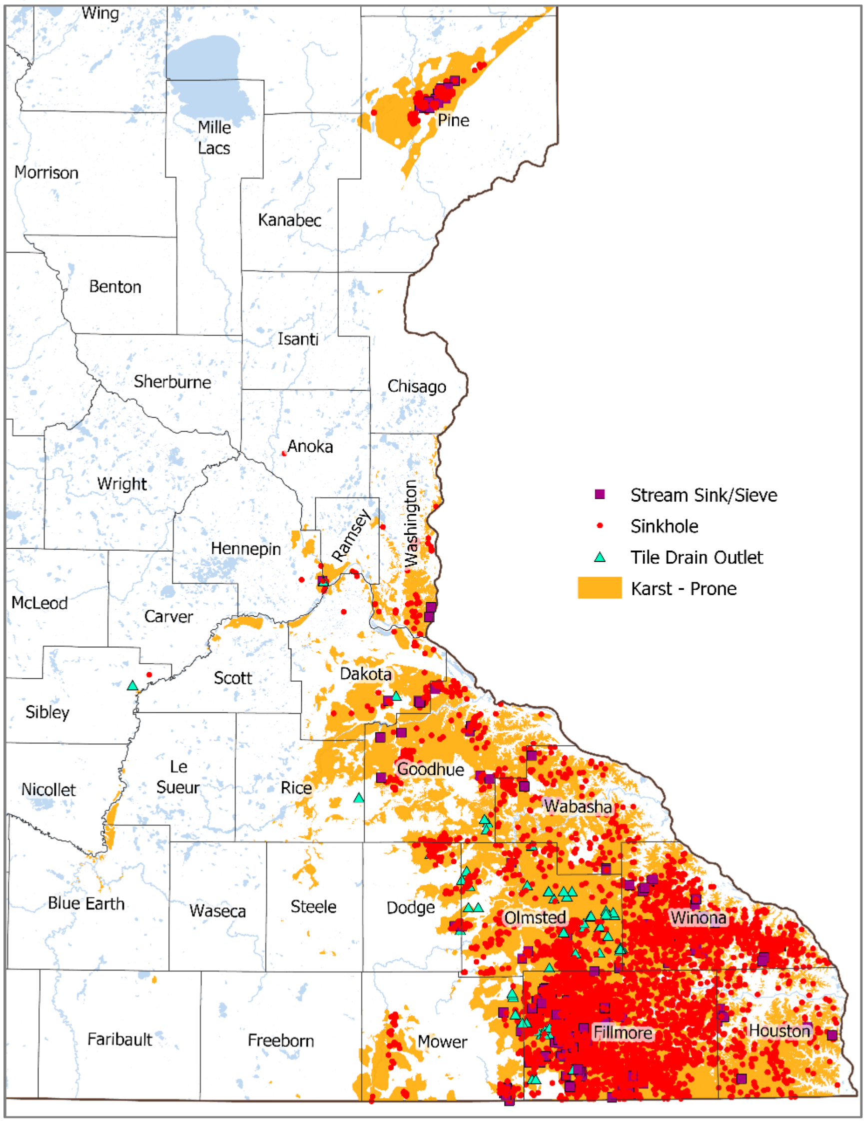
Another sinkhole appeared on Highway 61 on June 20, 2014 following heavy rains during the previous 24 hours. Ramsey County Parks noted the sinkhole in the median of Highway 61, just south of the intersection of County Road B and Highway 61, according to information in the 2018 Ramsey County MHMP.

In June of 2016, another Ramsey County resident reported that a sinkhole on city park property behind her residence had become quite large. Originally, she noticed it to be a foot wide and a foot deep. About a week later, it was three feet wide and much deeper.

Probability of Occurrence

The probability of sinkholes and land subsidence in Minnesota is directly related to local landscape conditions and triggers likely to produce these conditions. Sinkhole probability is highly site-specific and cannot be accurately characterized on a statewide basis, except in the most general sense. In Minnesota, karst features are most widespread in the southeast. Figure 67 shows the extent of karst-prone areas in the state and know features related to land subsidence on top of these areas.

Figure 67. Karst Features in Minnesota



SOURCE: (UNIVERSITY OF MINNESOTA, DEPARTMENT OF GEOLOGY AND GEOPHYSICS; MN DNR ECOLOGICAL AND WATER RESOURCES DIVISION)

Vulnerability

Table 60 on the next page shows the vulnerability of Minnesota counties to land subsidence from sinkholes, stream sinks/sieves and springs. The counties of Fillmore, Olmsted, and Winona have the highest number of sinkholes and springs. The counties of Fillmore, Winona, and Pine have the highest number of stream sinks/sieves. The counties of Fillmore, Olmsted, and Winona have the highest vulnerability based on the number of significant karst features.

Table 60. Top Ten Minnesota Counties with Significant Karst Features

County with Karst Features	Number of Sinkholes	Number of Stream Sinks/Sieves	Number of Springs	Approx. Percent of County that is Karst-Prone
Fillmore	10,243	161	980	89%
Olmsted	1,530	8	607	83%
Winona	1,478	31	404	71%
Pine	573	24	162	15%
Goodhue	455	9	166	60%
Mower	352	18	94	32%
Houston	303	8	145	62%
Wabasha	210	5	69	61%
Dodge	116	1	59	18%
Washington	58	2	345	25%

SOURCE: (UNIVERSITY OF MINNESOTA, DEPARTMENT OF GEOLOGY AND GEOPHYSICS; MN DNR ECOLOGICAL AND WATER RESOURCES DIVISION)

While Fillmore County has more sinkholes than all other Minnesota counties combined, the 2017 Fillmore County MHMP notes that the county has not recorded any significant sinkhole, cave collapse, or subsidence-related disasters.

According to the 2017 Wabasha County MHMP, issues relating to land subsidence since Wabasha County's previous plan in 2009 were minimal. The Wabasha Soil and Water Conservation District (SWCD) works with the Natural Resource Conservation Service (NRCS) on practices to address sinkholes and with other agencies to monitor and assess related affects. The SWCD also collaborates with NRCS to educate on the public on karst landforms and sinkholes.

The 2018 Winona County MHMP notes that the county maintains an ongoing, but limited, education and awareness program through the SWCD in relationship to karst features and the dangers associated with sinkholes. Winona County also maintains a specific ordinance for karst, which restricts new development in areas with karst features.

Olmsted County's Zoning Ordinance regulates development in areas prone to land subsidence.

While most of Minnesota's karst features are located in the southeastern corner of the state, Pine County in east-central Minnesota has a series of sinkholes, stream sinks, springs and caves. According to data from the University of Minnesota, Department of Geology and Geophysics and MN DNR – Ecological and Water Resources Division, as of August 2018, Pine County contained 573 sinkholes, 24 stream sinks/sieves, and 162 springs. Approximately 15% of the county is estimated as karst-prone.

Land Subsidence and Climate Change

The increased magnitude and frequency of flooding events resulting from climate change may in turn increase the risk of land subsidence in Minnesota if associated geological conditions exist.

4.7.14 Extreme Cold

Wintertime in Minnesota can be a brutal time and especially dangerous for disabled citizens and outdoor workers. Record temperature lows and arctic-like wind chill factors can cause cold-related illnesses such as frostbite and hypothermia, which can be deadly. The two major human risks associated with extreme cold are as follows:

> Frostbite occurs when skin tissue and blood vessels are damaged from exposure to temperatures below 32°F. The most susceptible parts of the body are fingers, toes, ear lobes, or the tip of the nose. Symptoms include a loss of feeling in the extremity and a white or pale appearance. The affected area should be slowly rewarmed.
>
> Hypothermia occurs when body temperature falls below 95°F. Young children under the age of two and the elderly (more than 60 years of age) are most susceptible to hypothermia. Anyone who is exposed to severe cold without enough protection can develop hypothermia. Hypothermia is the greatest and most life-threatening cold weather danger.

In Minnesota, cold winter weather can have severe or fatal impacts. Wind chill factors can increase the risk of frostbite or hypothermia. The wind chill factor describes what happens to a body when it is cold and windy outside. As wind increases, heat is carried away from the body at a faster rate, driving down both skin temperature (which can cause frostbite) and eventually the internal body temperature (which can cause hypothermia). The NWS issues "Extreme cold" warnings when apparent temperature (wind chill) is -30°F or colder across a wide area for several hours. Extreme cold watches are issued a day or two before the conditions are expected.

Extreme Cold History

Extreme cold temperatures affect the state nearly every year. A new record low temperature for Minnesota of -60°F was set in the town of Tower on February 2, 1996. Numerous record low temperatures were set during the same period at St. Cloud, Rochester and the Twin Cities. Minneapolis/St. Paul set three new record low temperatures as well as recording the second coldest day on record on February 2, 1996. A mean temperature of -25°F was measured that day with a high of -17°F and a low of -32°F in the Twin Cities. This was within two degrees of tying the all-time record low temperature set in the Twin Cities and the coldest temperature recorded this century. Many central and southern Minnesota locations set new record low temperatures the morning of the February 2. The Governor closed all schools that day.

On January 6, 2014, the Governor cancelled K-12 schools statewide due to extreme wind chills. The coldest wind chill reported in the state that day was -63° F at the Grand Marais Airport. The coldest wind chill in the Twin Cities was -48°F. Many schools cancelled operations again the following day. School closures also occurred at various locations on January 23, 27, and 28. Wind chills were in the negative thirties. However, on January 28 a wind chill of -52°F was recorded in Fosston (Minnesota State Climatology Office, 2014).

Extreme cold events caused 13 deaths and four injuries in Minnesota from 2014 to May 2018. Table 61 on the following page shows extreme cold events in Minnesota between 2014 and May 2018 in which deaths occurred.

Table 61. Deaths from Extreme Cold, 2014-May 2018

Date	Location	Comments
1/1/2018	St. Paul	An individual who apparently died from exposure after wind chills of -35°F occurred was found in St. Paul
1/12/2017	Eveleth	A young man was found dead in an Eveleth park. An autopsy revealed that he succumbed to hypothermia. Nearby temperature records were -28°F.
12/18/2016	Washington County	An individual froze to death while outside taking photographs when wind chills reached -50° F.
12/12/2016	St. Paul	An individual froze to death outside of the apartment building where he/she lived. Wind chills reached -19°F.
1/15/2016	Rochester	An elderly woman died of exposure after wandering away from a care facility. Wind chills were between 5° and 10°F.
1/14/2016	St. Louis County	A man died of hypothermia when low temperatures reached 5°F. His body was found in a park.
1/3/2015	St. Louis County	A woman was found dead on a trail, when temperatures were in the teens below zero. The official cause of death was hypothermia secondary to alcohol intoxication.
2/5/2014	St. Louis County	A man was found dead in a snowbank, having apparently fallen. The low temperature that morning was -16°F in Hibbing.
1/14/2014	Embarrass	A woman froze to death at the end of her driveway after slipping and falling. Law enforcement officials reported that she seemed to be impaired and was not dressed for subzero temperatures.
1/9/2014	Melrose	An 83-year-old woman died after her car got stuck in a snow bank, and she began walking for help. The coldest wind chill reported was 1°F.
1/5/2014	Lakeville	Wind chills reached -50°F or lower, and a 32-year-old woman was found frozen to death outside of her home on January 7.
1/2/2014	New Ulm & Virginia	A man fell outside his home in New Ulm, and when evening temperatures fell to -18°F, he died from exposure to the cold.,. The wind chill was -25° to -30°F. Also, a man in Virginia froze to death after leaving a nearby bar while he was intoxicated.

SOURCE: NCEI

Probability of Occurrence

Below zero temperatures occur every winter in Minnesota. January is the coldest month, with daytime highs averaging 20°F and nighttime lows averaging 2°F. However, these averages do not tell the whole story. Maximum temperatures in January have been as high as 61°F and minimums as low as -36°F. The amount of snow and ice, number of blizzard conditions, and days of sub-zero temperatures each year are unpredictable.

Vulnerability

Citizens living in climates such as these must always be prepared for situations that put their lives or property at risk. The youngest and more elderly citizens, homeless persons, and those who are working or recreating outdoors are most at risk for frostbite and hypothermia. It is not always the depth of the cold that poses a threat but rather unpreparedness for the cold; such as an individual with a vehicle breakdown who lacks a personal winter safety kit in the vehicle. The cost of propane can make rural citizens more vulnerable to issues with extreme cold. A propane shortage and resulting crisis, such as that which occurred in 2014, may increase the cost of heating homes and farms to a prohibitive amount. The Minnesota Department of Commerce presents options and suggestions for homeowners who use propane on their website (MCD, 2018).

The CDC publication “Extreme Cold: A Prevention Guide to Promote Your Personal Health and Safety” outlines preparation measures that individuals can take to reduce their vulnerability to extreme cold. Highlights in this document include advice about travel preparations, securing your home water supply, and safety during recreation (CDC, 2018).

Extreme Cold and Climate Change

Although climate research indicates that Minnesota’s average winter lows are rising rapidly, and our coldest days of winter are now warmer than we have ever recorded (NCEI, 2018), cold temperatures have always been a part of Minnesota’s climate, and extreme cold events will continue. As the climate changes, an increase in extreme precipitation or storm events, such as ice storms, could lead to a higher risk of residents being exposed to cold temperatures during power outages or other storm-related hazards.

4.7.15 Earthquakes

An earthquake is a sudden motion or trembling caused by an abrupt release of accumulated strain in the tectonic plates that comprise the earth's crust. These rigid plates are some 50 to 60 miles in thickness and move slowly and continuously over the earth's interior. The plates meet along their edges, where they move away, past or under each other at rates varying from less than a fraction of an inch up to five inches per year. While this movement sounds minimal, at a rate of two inches per year a distance of 30 miles would be covered in approximately one million years (FEMA, 1997).

The tectonic plates continually bump, slide, catch and hold as they move past each other which causes stress to accumulate along faults. When this stress exceeds the elastic limit of the rock, an earthquake occurs, immediately causing ground motion and seismic activity. Secondary hazards may also occur, such as surface faulting, sinkholes and landslides. While the majority of earthquakes occur near the edges of the tectonic plates, earthquakes may also occur at the interior of plates.

The vibration or shaking of the ground during an earthquake is described by ground motion. The severity of ground motion generally increases with the amount of energy released and decreases with distance from the fault or epicenter of the earthquake. Ground motion causes waves in the earth's interior, also known as seismic waves, and along the earth's surface, known as surface waves. The following are the two kinds of seismic waves:

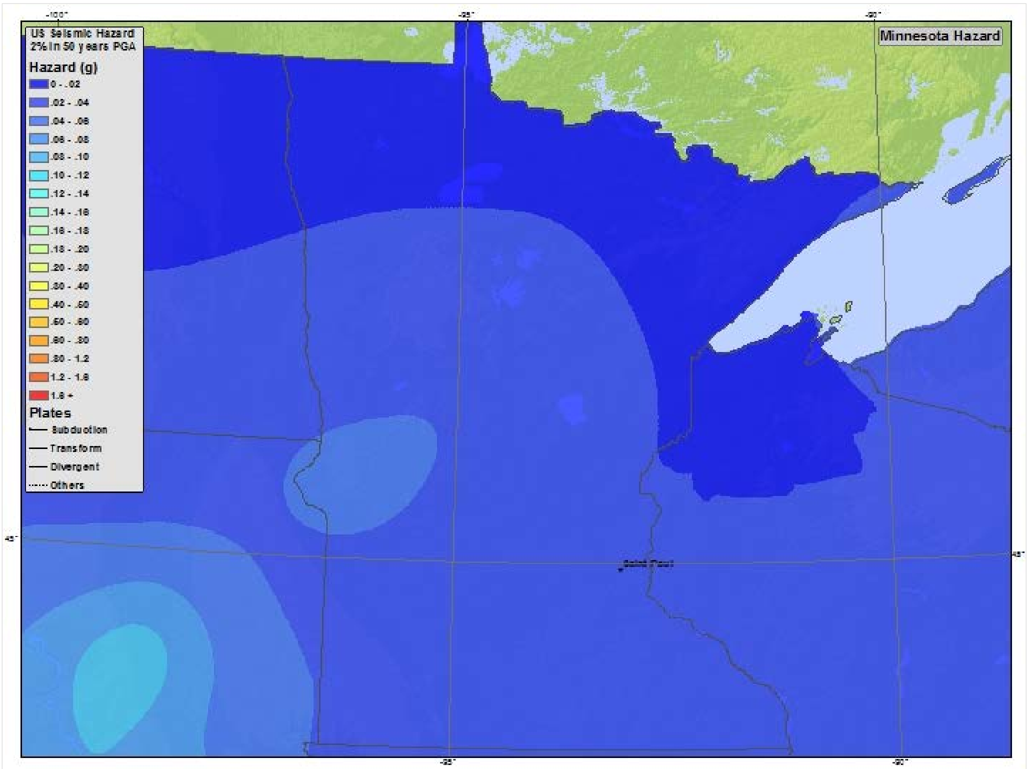
> **P (primary) waves** are longitudinal or compressional waves similar in character to sound waves that cause back-and-forth oscillation along the direction of travel (vertical motion), with particle motion in the same direction as wave travel. They move through the earth at approximately 15,000 mph.
>
> **S (secondary) waves**, also known as **shear waves**, are slower than P waves and cause structures to vibrate from side-to-side (horizontal motion) due to particle motion at right-angles to the direction of wave travel. Unreinforced buildings are more easily damaged by S waves.

There are also two kinds of surface waves, Raleigh waves and Love waves. These waves travel more slowly and typically are significantly less damaging than seismic waves.

Seismic activity is described in terms of magnitude and intensity. *Magnitude* (M) describes the total energy released by the seismic wave, commonly referred to using the Richter scale, and *Intensity* (I) subjectively describes the effects at a particular location. Although an earthquake has only one magnitude, its intensity varies by location. Magnitude is expressed on a logarithmic scale, meaning that an increase in value of one digit equates to a 10-fold increase that may in turn equate to approximately 30 times more energy. The largest known earthquakes have had magnitudes around 9.0, and the famous San Francisco earthquake of 1906 had a magnitude near 8.3. Although there have been notable exceptions, earthquakes with magnitudes less than 5.5 usually do not cause major damage or injuries. Intensity is a measure based on people's observations or felt reports at a particular location, and is expressed by the Modified Mercalli Intensity (MMI) scale.

Another way of expressing an earthquake's severity is to compare its acceleration to the normal acceleration due to gravity (Figure 68). If an object is dropped while standing on the surface of the earth (ignoring wind resistance), it will fall towards earth and accelerate faster and faster until reaching terminal velocity. The acceleration due to gravity is often called "g" and is equal to 9.8 meters per second squared (980 cm/sec/sec). This means that every second something falls towards earth, its velocity increases by 9.8 meters per second. Peak Ground Acceleration (PGA) measures the rate of change of motion relative to the rate of acceleration due to gravity. For example, acceleration of the ground surface of 244 cm/sec/sec equals a PGA of 25%.

Figure 68. Peak Ground Acceleration with 2% probability of exceedance in 50 years



Source: USGS

It is possible to approximate the relationship between PGA, the Richter scale and the MMI (Table 62). The relationships are, at best, approximate, and also depend upon such specifics as the distance from the epicenter and depth of the epicenter. An earthquake with 10% PGA would roughly correspond to an MMI intensity of V or VI, described as being felt by everyone, overturning unstable objects, or moving heavy furniture.

Table 62. Earthquake PGA, Magnitude and Intensity Comparison

PGA (%g)	Magnitude (Richter)	Intensity (MMI)	Description (MMI)
<0.17	1.0 - 3.0	I	*I.* Not felt except by a very few under especially favorable conditions.
0.17 - 1.4	3.0 - 3.9	II – III	*II.* Felt only by a few persons at rest, especially on upper floors of buildings. *III.* Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck.

PGA (%g)	Magnitude (Richter)	Intensity (MMI)	Description (MMI)
1.4 - 9.2	4.0 - 4.9	IV – V	*IV.* Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably. *V.* Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
9.2 - 34	5.0 - 5.9	VI – VII	*VI.* Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. *VII.* Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
34 - 124	6.0 - 6.9	VII – IX	*VIII*. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. *IX.* Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
>124	7.0 and higher	VIII or higher	*X*. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. *XI*. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. *XII*. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: Wald, Quitoriano, Heaton, and Kanamori, 1999.

Earthquake-related ground failure, due to liquefaction, is a common potential hazard from strong earthquakes in the central and eastern United States. Liquefaction occurs when seismic waves pass through saturated granular soil, distorting its granular structure and causing some of the empty spaces between granules to collapse. Pore-water pressure may also increase sufficiently to cause the soil to behave like a fluid for a brief period and cause deformations. Liquefaction causes lateral spreads (horizontal movement commonly 10-15 feet, but up to 100 feet), flow failures (massive flows of soil, typically hundreds of feet, but up to 12 miles), and loss of bearing strength (soil deformations causing structures to settle or tip). Sands blows were common following major New Madrid earthquakes in the central United States.

Earthquake History

The Midwest is far from any plate margin, but even here, earthquakes do occasionally happen. Although the earthquake-generating mechanism in the Midwest is not completely understood, it may be related to the westward drift of the North American plate away from its spreading center, the Mid-Atlantic ridge, toward the subduction and transform zones along the Pacific coast. This westward drift sets up a subtle but pervasive compression that is oriented roughly east-west for most of North America, and this stress can reactivate minor movement along some ancient faults. The great forces that originally formed these ancient faults have long since ceased, but the faults themselves remain as zones of weakness that, if oriented appropriately to the modern stress field, could be slightly reactivated.

Minnesota has one of the lowest occurrence levels of earthquakes in the United States, but a total of 20 small to moderate earthquakes have been documented since 1860 (Figure 69). Although the two earliest recorded earthquakes may have had magnitudes of 4.7 to 5.0, the 1917 Staples earthquake documented a 4.3 magnitude. The largest earthquake on record in Minnesota occurred in 1975, with a magnitude of 4.6 and intensity of VI Also felt in Iowa and the Dakotas, the earthquake damaged walls and basement foundations in the town of Morris, located in Stevens County. Although less dramatic than the Staples or Morris events, the 1993 Dumont earthquake and the 1994 Granite Falls earthquake are more typical of those that occur in Minnesota. The magnitude 4.1 Dumont earthquake was felt over 26,873 square miles and was associated with intensity V-VI near the epicenter. The shaking near the epicenter was accompanied by a loud, explosive noise that alarmed many people, but no injuries or serious damage occurred. In contrast to the Dumont event, the much weaker Granite Falls earthquake (magnitude 3.1) was felt over only 4,478 square miles, and although intensity V may have occurred locally near the epicenter, most reported intensities were III to IV.

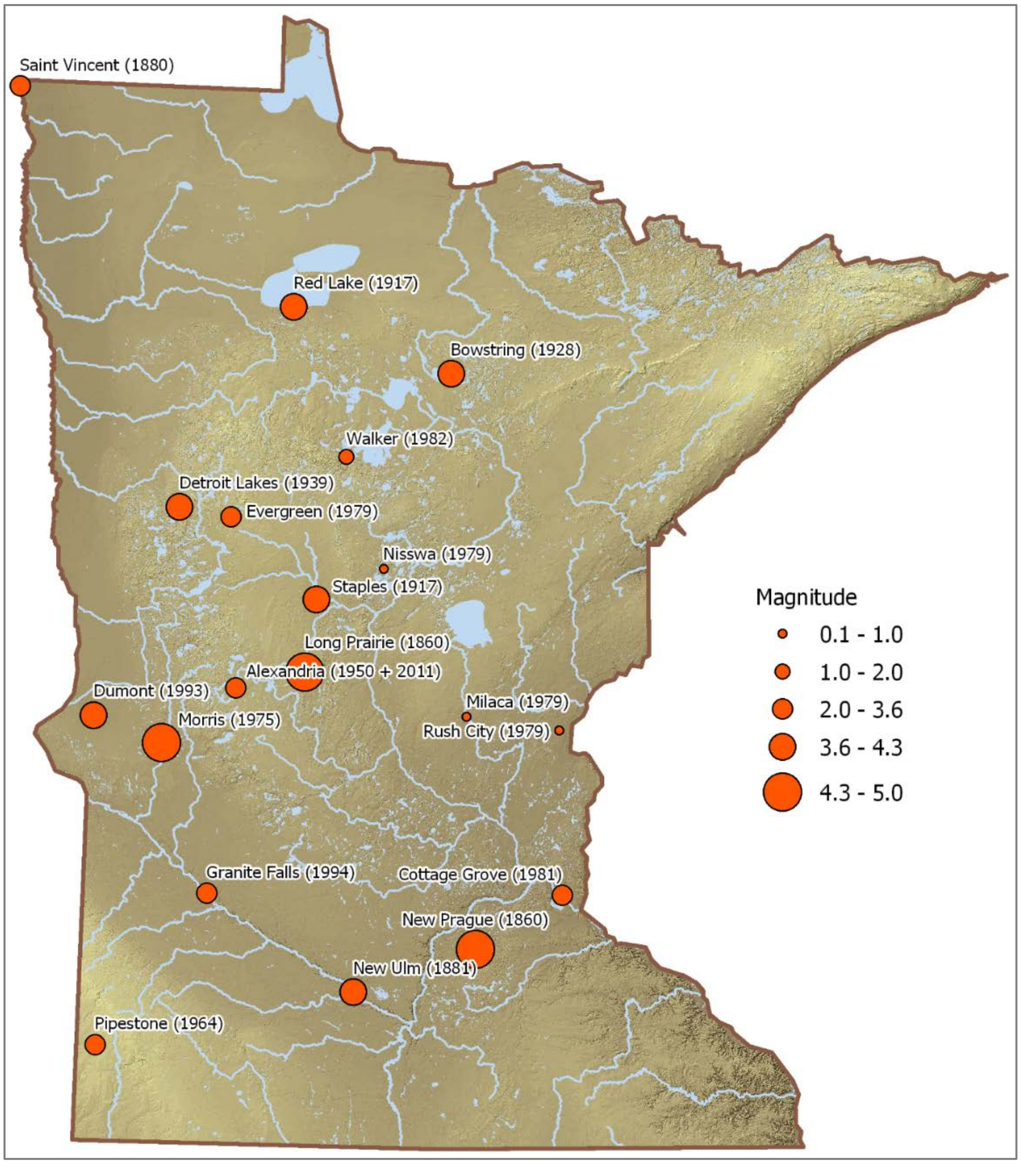
The most recent earthquake in Minnesota occurred in 2011 near Alexandria, with a magnitude of 2.5. However, there were no reports of damage or injury. Table 63 and Figure 69 below document Minnesota's earthquake history.

Table 63. Earthquakes in Minnesota, 1860-2017

Epicenter (Nearest Town)	Date	Maximum Intensity	Magnitude
Alexandria	04-29-2011	N/A	2.5
Granite Falls	02-09-1994	V	3.1
Dumont	06-04-1993	V-VI	4.1
Walker	09-27-1982	II	2.0
Cottage Grove	04-24-1981	III-IV	3.6
Nisswa	07-26-1979	III	1.0
Rush City	05-14-1979	N/A	0.1
Evergreen	04-16-1979	N/A	3.1
Milaca	03-05-1979	N/A	1.0
Morris	07-09-1975	VI	4.7
Pipestone	09-28-1964	N/A	3.4
Alexandria	02-15-1950	V	3.6
Detroit Lakes	01-28-1939	IV	3.9
Bowstring	12-23-1928	IV	3.8
Staples	09-03-1917	VI-VII	4.3
Red Lake	02-06-1917	V	3.8
New Ulm	02-12-1881	VI	3.0-4.0
St. Vincent	12-28-1880	II-IV	3.6
New Prague	12-16-1860	VI	4.7
Long Prairie	(Date unknown) 1860-61	VI-VII	5.0

SOURCE: USGS

Figure 69. Historical Earthquake Occurrences by Magnitude on the Richter Scale



SOURCE: USGS

Several earthquakes occurring outside of Minnesota have still been felt in the state. On November 15, 1877, two earthquakes 45 minutes apart occurred in eastern Nebraska. The shocks caused damage in North Platte and Columbus, Nebraska and in Sioux City, Iowa. Felt zones from these earthquakes encompassed an elliptical area roughly 600 by 300 miles, including the southwestern part of Minnesota.

A strong earthquake centered in Illinois occurred on May 26, 1909, affecting an area of approximately 500,000 square miles, including parts of Minnesota. Intensity VII effects were noted over a considerable area from Bloomington, Illinois to Platteville, Wisconsin. Many chimneys fell in Aurora, Illinois. Although details are lacking, this shock was probably felt at intensity IV or V in southeastern Minnesota. Note that earthquakes with magnitudes less than 5.5 usually do not cause major damage or injuries.

An earthquake on February 28, 1925, centered in the St. Lawrence River region near La Malbaie, Quebec, Canada, was felt widely in the Northeastern United States. The shock was lightly felt in Minneapolis.

Ten years later, on November 1, 1935, another strong earthquake occurred near Timiskaming, Canada, and was felt over an area of the United States estimated at one million square miles. This tremor was also lightly felt in Minneapolis.

In the autumn of 1968 an earthquake in Illinois was strong enough to be felt throughout the Twin Cities area and southern Minnesota, with a maximum intensity of I-IV.

Probability of Occurrence

Probabilistic ground motion maps are typically used to assess the magnitude and frequency of seismic events. These maps measure the probability of exceeding a certain ground motion, expressed as peak ground acceleration (PGA), over a specified period of years. The magnitudes of earthquakes are generally measured using the Richter scale. The severity of earthquakes is site specific and influenced by proximity to the epicenter and soil type, among other factors.

According to the Minnesota Geological Survey (MGS), Minnesota has one of the lowest occurrence levels of earthquakes in the United States; only 20 small to moderate earthquakes have been documented since 1860. MGS further notes that although weak to moderate earthquakes do occur occasionally in Minnesota, a severe earthquake is very unlikely. Average recurrence rates for Minnesota earthquakes have been estimated by the MGS (Mooney, 1979) as follows:

- Magnitude 4.0 - 10 years
- Magnitude 4.5 - 30 years
- Magnitude 5.0 - 89 years
- Magnitude 5.5 - 266 years

The absence of major earthquakes, together with the infrequency of earthquakes in general, implies a low risk level for Minnesota. (This statement, however, must be tempered in light of the brief span of historical record.) An earthquake history for the state has significant implications for public policy. For example, the location and design of nuclear power plants must be guided by an assessment of the probability of a damaging earthquake. Minnesota has two nuclear plants in operation, at Prairie Island (near Red Wing) and Monticello. The Monticello plant lies within the probable felt areas of three Minnesota earthquakes. The Prairie Island plant probably lies within the felt area of one Minnesota earthquake, as well as within the felt areas of several earthquakes with epicenters outside of Minnesota.

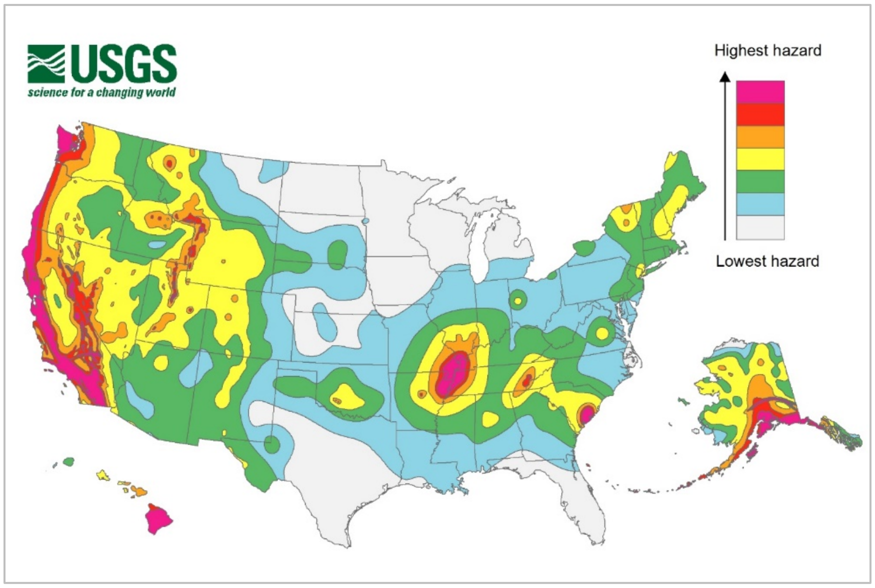
Building construction codes present another aspect of public policy dependent upon earthquake history. Certain standards of construction must be met depending upon earthquake zoning classification. The Uniform Building Code of the International Conference of Building Officials assigns every location in the United States to a five-grade Seismic Risk Zone (0 = least risk; 4 = greatest risk); Minnesota rates in Seismic Risk Zone 0. North Dakota and Wisconsin are also in Zone 0 in their entirety, in addition to most of Iowa and South Dakota.

Current data and knowledge indicates that, although weak to moderate earthquakes do occur occasionally in Minnesota, a severe earthquake is very unlikely. Although a zero probability of a damaging earthquake occurring in the time span of a human life cannot be assigned, the threat is very small compared to other natural hazards such as flooding and tornadoes.

Vulnerability

The entire state of Minnesota has a low vulnerability to earthquakes. According to the USGS earthquake hazard map of 2014 (Figure 70), all but a small portion of the state is ranked as the lowest hazard ranking.

Figure 70. Earthquake Hazard Map, 2014



SOURCE: USGS

Earthquakes and Climate Change

There is no evidence that climate change will increase the risk of earthquakes in Minnesota.

4.8 Other Hazards

This plan also includes an overview of 7 human-caused hazards: structure and vehicle fires, ground and surface water supply, hazardous materials, nuclear incidents, infectious disease outbreak, transportation incidents, and terrorism. The hazards included are believed to be of moderate to low probability and mitigation potential as compared with the natural hazards included in this plan. HSEM coordinates with other state agencies that are charged with monitoring risk and developing mitigation tools for these plans. Strategies and actions for these hazards are not included in this plan.

Human-caused hazards are assessed below by stating historical events, plans and programs in place, and any known expected vulnerabilities due to climate change.

4.8.1 Structure and Vehicle Fires

This section addresses fires to property that are not considered wildfires. The two types of property fires are classified as structure fires and vehicle fires.

- Structure fires are classified to occur to residential single-family dwellings, apartments, manufactured homes, hotels, and motels. Public and mercantile facilities vulnerable include stores, restaurants, grocery stores, institutions, churches, public facilities, education. Industrial, manufacturing. Other structure classifications include basic industry, manufacturing, storage, residential garages, and vacant buildings.
- Vehicle Fires include those occurring to mobile property such as aircraft, automobiles, trucks, trains, buses, and boats.

Fires have many causes: cooking, heating, open flame and arson are the typical leading causes each year. Other causes include careless smoking, misuse of materials, improper storage, equipment/appliance malfunctions, improper building wiring, industrial mishaps, and instances such as train derailments or transportation collisions.

Flood, tornado, and high winds may cause structural fires in their aftermath. Downed power lines, natural gas leaks, or other sources of ignition initiated by natural hazards may spark structure fires. Routes to structures for response vehicles may be restricted due to flooding or debris from storms. Blizzards and ice storms may also impair the movement of response vehicles. Operation of critical response facilities located in flood hazard zones may be impaired if they become inundated with floodwaters.

Extremely cold temperatures can also increase the risk of household fires. When homes are too cold due to power failures or inadequate heating systems, residents are more likely to use alternative heating methods such as space heaters, wood burning stoves and fireplaces, which increase the risk of fire (MDH, 2019). Most heating fires in Minnesota involve fireplaces or chimneys (National Weather Service, 2019). High heating costs can also prompt the use of alternative heating methods.

Fire History

According to the 2017 report Fire in Minnesota, by the State Fire Marshal, there has been 1,434 civilian deaths in Minnesota during the past 28 years. For 2017, 45% of the state population lived in greater Minnesota, where the per capita fire death rate was 1.65 deaths for every 100,000 people. In the Twin Cities Metro Region the per capita fire death rate was 0.89 per 100,000 people. This equates to a statewide rate of 1.23 deaths per 100,000, which is slightly above the national per capita fire death rate (1.12 per 100,000). In 2017 there were 68 civilian deaths in the state due to fires and over $224 million in property loss. There are three counties in Minnesota which have remained fatality free for the last 28 years: Traverse, Stevens, and Murray (Minnesota State Fire Marshal, 2017).

In 2016, one fire was reported every 40 minutes in Minnesota. One structure fire was reported every 1.27 hours. Rural structure fires occurred every 3.23 hours, and metro structure fires occurred every 2.33 hours. One arson fire was reported every 10.35 hours. Total dollar loss from structure fires exceeded $259 million; approximately $709,761 per day, $29,573 per hour, and $492 per minute.

Table 64 represents the total deaths, injuries, and property loss resulting from fires from 2011 to 2017.

Table 64. Civilian Deaths, Injuries, and Dollar Loss Due to Fire, 2011-2017

Year	Classification	Civilian Deaths	Civilian Injuries	Dollar Loss (in millions)
2017	Residential	57 (85%)	119 (97%)	$122.2
	Other	11 (15%)	4 (3%)	$101.8
	Total	**68**	**123**	**$224.0**
2016	Residential	31 (72%)	100 (90%)	$133.4
	Other	12 (28%)	11 (10%)	$125.7
	Total	**43**	**111**	**$259.1**
2015	Residential	48 (84%)	102 (86%)	$133.5
	Other	9 (16%)	16 (14%)	$90.1
	Total	**57**	**118**	**$223.6**
2014	Residential	34 (77%)	165 (95%)	$122.0
	Other	10 (23%)	8 (5%)	$103.7
	Total	**44**	**173**	**$225.7**
2013	Residential Structure	34 (77%)	134 (85%)	$122.9
	Other	10 (23%)	23 (15%)	$106.2
	Total	**44**	**157**	**$229.1**
2012	Residential Structure	29 (58%)	150 (87%)	$111.1
	Other	21 (42%)	22 (13%)	$181.1
	Total	**50**	**172**	**$292.2**
2011	Residential Structure	45 (80%)	153 (76%)	$94.4
	Other	11 (20%)	48 (24%)	$57.6
	Total	**56**	**201**	**$152.0**

SOURCE: (MINNESOTA FIRE BRIDGE, 2017)

Plans and Programs in Place

Funding for fire suppression and education is available through the Federal Assistance to Firefighters Grant (AFG), Staffing for Adequate Fire and Emergency Response (SAFER) Grants, Fire Prevention and Safety (FP&S) Grants, and the Assistance to Firefighters Station Construction (SCG) Grant programs. Firefighter training grants are available through the Minnesota Board of Firefighter Training and Education.

Building codes, smoke and CO2 detector education, and automatic sprinkler information are available through the State Fire Marshal Division.

4.8.2 Ground and Surface Water Supply

Clean water is a prized commodity. Increased population, climate changes, pollution, and unabated usage of water are leading to shortages of drinking water around the world. With more than 10,000 lakes, 100,000 river and stream miles, and extensive groundwater systems, water is a major part of Minnesota's culture, economy, and natural ecosystems. Minnesota is fortunate in its abundance of clean water, but potential misuses or mishaps may negatively impact the opportunities afforded by this important resource.

Ground water is an important resource for residents of Minnesota, providing drinking water for 75% of residents and irrigation for agriculture, which is a large contributor to Minnesota's economy. Monitoring ground water quality and availability is vital for preserving this natural resource. Ground water quality in Minnesota is generally good and is most concerned by naturally occurring amounts of arsenic and boron, and human sources of nitrate, pesticides, fuel oils, and industrial chemicals. Groundwater in parts of the central and southwestern regions of the state is contaminated with high nitrate concentrations from agriculture. Nitrate levels are higher in groundwater under agricultural land than water below urban areas (MPCA, 2019).

Availability of groundwater in Minnesota varies by region and is generally more difficult to access in the northeast and is scarce and/or nonexistent in areas of the southwest (MPCA, 2019). The availability of groundwater is most dependent upon geologic conditions that determine the type and properties of aquifers (MN DNR, 2019).

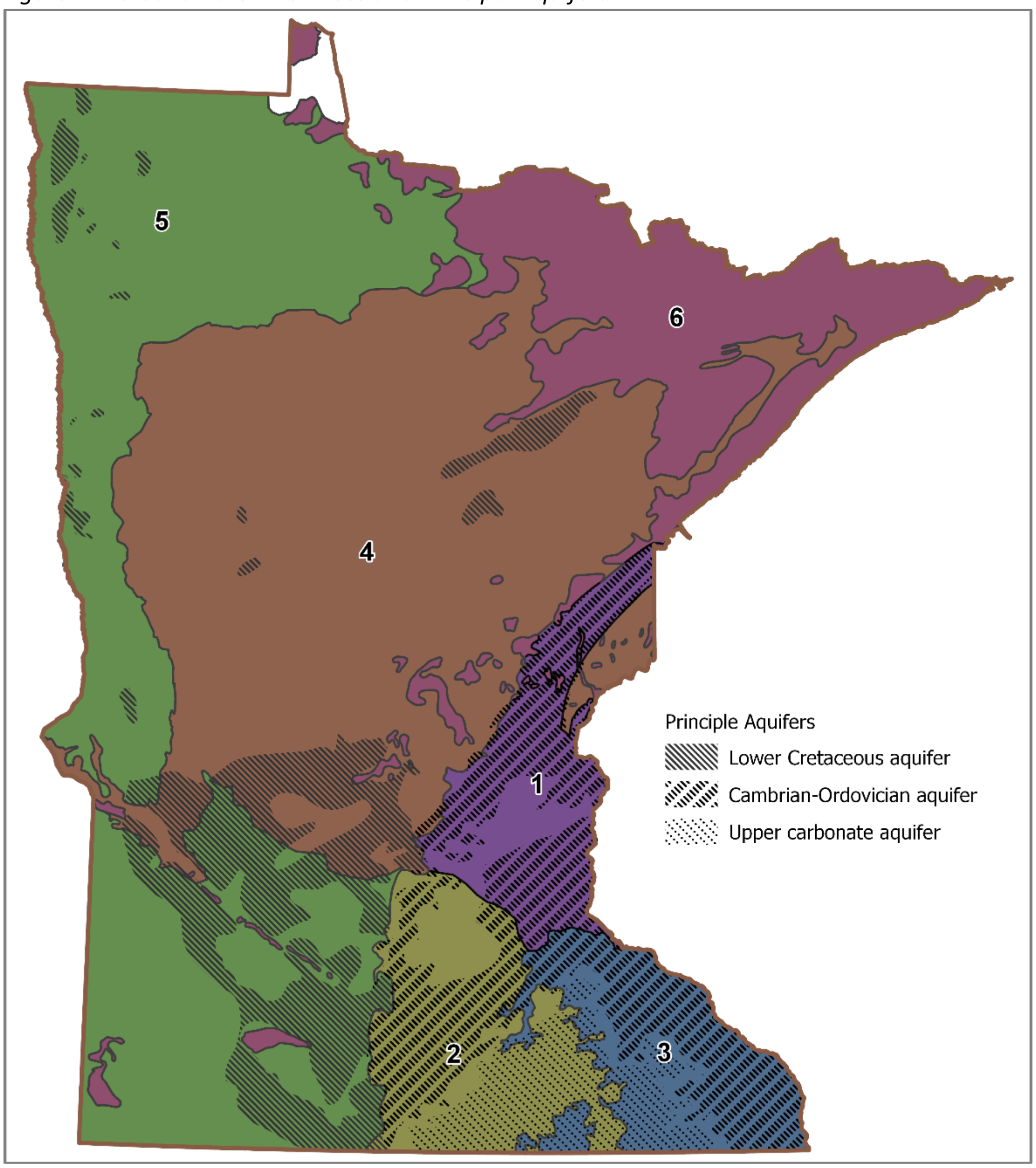
Minnesota's ground water systems are a function of the state's geology. There are three basic types of aquifers in Minnesota; Igneous and metamorphic rock aquifers, sedimentary rock aquifers, glacial sand and gravel aquifers. Areas where the characteristics of the ground water system are similar are summarized in six groundwater provinces described below.

- Province 1: Sand aquifers are usually greater than 100 feet thick and yield large quantities of water. Aquifers in agricultural areas often have high concentrations of nitrate and pesticides may be in low concentration. Low concentrations of fuel oils and industrial chemicals are often found in shallow aquifers from urban areas
- Province 2: Small isolated sand and gravel aquifers occur more than 100 feet below the land surface. Deeper sedimentary rock aquifers provide moderate to good quantities of water. Aquifers are generally safe from contamination but may have high concentrations of dissolved chemicals such as calcium.
- Province 3: Sedimentary rock aquifers provide large quantities of water. When these aquifers are close to the land surface they are vulnerable to contamination. In these aquifers, nitrate is often present at high concentrations and pesticides are detected. Sand aquifers generally occur only along rivers.
- Province 4: Sand aquifers are thick and yield large quantities of water. When these aquifers are near the land surface, they may be vulnerable to contamination. In agricultural areas, shallow ground water often has detectable concentrations of pesticides and high concentrations of nitrate. Bedrock aquifers yield low to moderate quantities of water in areas where sand aquifers do not occur.

- Province 5: Sand aquifers are isolated and occur more than 100 feet below the land surface. In areas where these are not present, bedrock aquifers provide low to moderate quantities of water. Aquifers are generally not vulnerable to contamination except sand aquifers located along rivers. Ground water often contains high concentration of dissolved chemicals, such as calcium and sulfate.
- Province 6: Igneous and metamorphic rocks occur at or near the land surface. Ground water occurs in fractures and faults in this rock. Quantities of available water are small. Water quality varies with this type of rock. Concentrations of dissolved solids are usually low but concentrations of iron, manganese and boron can be high.

The groundwater provinces are depicted in Figure 71. Minnesota's principle aquifers are overlaid on this map.

Figure 71. Groundwater Provinces and Principal Aquifers.



SOURCE: (MN DNR, 2019) (MPCA, 2019)

There are many ways water supplies, aquifers, and wells may become contaminated. Examples are:

- Sewage, Partially Treated Waste Water, Sludge
- Leakage from Underground Storage Tanks
- Stormwater Runoff
- Runoff from Construction Sites
- Mines, Tailings, and Spoils
- Landfills and Dumps
- Industrial Effluents and Dumps
- Pesticides
- Animal Production Wastes
- Agricultural Run-Off from Crops

Flooding is a primary hazard that leads to water contamination. Bacteria and nitrate from farms, septic systems, and other sources flow into wells and aquifers affecting drinking water supplies. Sewage bypass from treatment plants into streams is caused by damages to the plant or lack of treatment capacity. Levees containing tailing in ponds may rupture releasing the metals and minerals into streams and aquifers. Hazardous material storage at facilities like gas stations, chemical plants, and landfills may fail leading to a release of contents. Impacts to clean water from floods may be mitigated with proper design, maintenance, and monitoring of point sources for pollution.

Drought impacts the availability of clean water. Details about drought may be found in its hazard description in this plan. The Aquafer Storage and Recovery Project in Salina Puerto Rico by FEMA is an example of how to address drought in relation to clean water. In 2015, Puerto Rico suffered nearly a yearlong drought that drastically affected the water supply and farmlands throughout many communities on the island. FEMA funded a project in 2016 to recharge aquifers from streams that would eventually drain into the sea. Similarly in Minnesota, communities are installing retention basins and rain gardens to decrease stormwater discharge. A side benefit of these projects may be the charging of aquifers to ensure that there are ample water supplies for the future.

Runoff and erosion increase turbidity and contribute to algae in freshwater. Heavy rains and flooding accelerate this situation. Increased flow in streams accelerates erosion of streambanks where soils are loose and inadequately protected. Eroded soils mix with water and are transported downstream and increase sediment along the way to the mouth of the major river. Large areas not equipped to handle runoff, such as construction sites, have soils that find their way into stormwater systems unless protective measures are taken. Runoff from fields and lawns treated with phosphorus-rich fertilizer provides nutrition for algae blooms that negatively impact habitat. Measures taken by local jurisdictions and property owners could increase the health of streams and lakes.

Three-quarters of Minnesota’s residents get their water from aquifer-tapping wells, and today parts of the state seem to be on a path that is not sustainable. Some cities have to look harder for good municipal water or pay to treat it. In the Twin Cities, concern is growing over whether suburbs should shift from tapping wells to pulling water from the Mississippi River. Elsewhere, Park Rapids, Marshall, and other cities have had to spend millions of dollars to respond to dropping water levels or contamination. Research is also taking place regarding use of nitrates in agriculture and how to reduce water use to maintain lawns.

Solutions are being implemented to slow water from entering the sewage infrastructure, to reduce flooding, and to reduce demands on water supply. Some examples include the City of Mankato re-using wastewater to wash city-owned vehicles and to sell to landscapers, rain-harvesting for use in toilets and landscaping at the St Paul Saints Stadium, and use of stormwater to water many golf courses (MPR, 2014) (CHS Field, 2018).

Plans and Programs in Place

Clean Water, Land and Legacy Amendment

Minnesotans care deeply about the quality and availability of their water. In 2008, citizens chose to invest in water resources. Minnesotans voted to increase their sales tax by three-eighths of 1% and passed the Clean Water, Land, and Legacy Amendment. From July 1, 2009, through June 30, 2034, about $90 million will be invested annually from the Clean Water Fund to protect drinking water sources and to protect, enhance, and restore lakes, rivers, streams, and groundwater. With this significant investment comes a responsibility to ensure progress is being made and that funds are making a difference for the state's water resources and its citizens.

Seven state agencies are charged with specific responsibilities in managing Minnesota's water resources: Metropolitan Council, Minnesota Board of Water and Soil Resources, Minnesota Department of Agriculture, Minnesota Department of Health, Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, and the Minnesota Public Facilities Authority.

Following the initial passage of the Clean Water, Land and Legacy Amendment, decision makers and stakeholders alike have raised questions about the water resource outcomes Minnesotans can expect to achieve after 25 years of investment, as well as the pace of progress that will be required to achieve those outcomes over time.

The Clean Water Roadmap lays out a course for the future that includes long-term goals and interim benchmarks for statewide outcomes that can be achieved with Clean Water Fund investments. Ultimately, the Roadmap is a big picture guide for more detailed planning and policymaking and is not itself a specific plan or strategy (Clean Water Fund, 2014).

The Clean Water Roadmap will help the seven agencies with Clean Water Fund responsibilities:

- Define aspirational, yet achievable goals for outcomes associated with 25 years of Clean Water Fund expenditures,
- Establish interim benchmarks, to assess progress towards the 25-year goals,
- Adjust program or funding priorities based on progress made towards the benchmarks and the 25-year goals, and
- Create realistic expectations among interested stakeholders and citizens about the potential for progress with the addition of Clean Water Fund dollars.

Minnesota Buffer Law

Minnesota's buffer law establishes new perennial vegetation buffers of up to 50 feet along lakes, rivers, and streams and buffers of up to 16.5 feet along ditches. These buffers will help filter out phosphorous, nitrogen, and sediment. The Board of Water and Soil Resources (BWSR) reports that statewide 89% of the parcels adjacent to Minnesota waters meet preliminary compliance with the law. Soil Water Conservation

Districts (SWCDs) are reporting encouraging progress in their work with landowners around the state. BWSR also provides support for shore and streambank restoration to SWCDs (Mn.gov, 2018).

Drinking Water Protection Program

The Minnesota Department of Health (MDH) is the state authority for drinking water. Several programs at MDH work together to ensure safe and adequate drinking water. The Drinking Water Protection program focuses on public water supplies. Public water supplies serve 25 people or more in places where they live, work, gather, and play. Program functions include:

- Helping public water suppliers to protect the water supply (groundwater, river, or lake).
- Administering grants to protect water supplies and for infrastructure and activities.
- Coordinating training and certification for water operators.
- Reviewing plans for new infrastructure or changes in water treatment procedures.
- Enforcing federal safe drinking water standards through inspections and corrective action.
- Sampling water or assisting public water operators in sampling.
- Helping public water suppliers address contamination problems.
- Communicating important information about drinking water with the public and other stakeholders.

In addition, MDH provides pre- and post-disaster support regarding the safety of the drinking water supply with testing and technical advice on how to protect and restore safe water supplies. See: MDH MDH Drinking Water Protection

River Health and Restoration

One of the primary objectives of DNR's River Ecology Unit is to ensure that an adequate amount of water is flowing in rivers and streams throughout the year to protect fish and wildlife. This is done by studying rivers in each of the state's 39 major watersheds to determine how much water these ecosystems need to be healthy. In conjunction with natural flow regimes, healthy rivers have stable banks, high water quality, natural shapes, variation in depths, water velocities, streambed substrates, types of cover, connectivity to other water bodies, and healthy floodplains. The River Ecology Unit is also actively involved in restoring degraded stream channels. Restoration projects that the program has worked on include the removal or modification of dams on the Pomme de Terre River in Appleton and on the Red River of the North in Fargo/Moorhead. See: DNR River Ecology Unit

Soil and Water Conservation Districts (SWCDs)

SWCDs were formed in the early to mid-1940s in response to national concern over floods, erosion, and the dust storms of the 1930s. Today, SWCDs work in partnership with federal, state, and local governments to conserve and manage land and water resources in the county where they are located. The Dakota County SWCD provides a comprehensive catalog of resources to address diverse conservation challenges relating to clean water. These resources exemplify potential resources provided by SWCDs statewide.

4.8.3 Hazardous Material Incidents

Approximately 6,000 facilities in Minnesota report their storage of hazardous chemicals to the Minnesota Department of Public Safety's EPCRA Program and their local fire department. Facilities meeting the reporting criteria submit this information annually as required under Section 312 of the federal Emergency Planning and Community Right-to-Know Act (EPCRA). The information is used by emergency planners and responders to plan for and respond to hazardous materials emergencies.

Over 400 facilities in Minnesota report their routine chemical emissions and on- and off-site chemical management activities to the Minnesota Department of Public Safety's EPCRA Program and the U.S. Environmental Protection Agency (EPA). Facilities meeting the reporting criteria submit this information annually as required under Section 313 of the federal EPCRA and is known as the Toxic Release Inventory (TRI). TRI data can be used to prioritize environmental regulatory efforts and promote pollution prevention and waste reduction.

Nearly 400 facilities in Minnesota submit Risk Management Plans (RMPs) to the EPA, summarizing procedures they have implemented to prevent accidental releases of certain chemicals into the air. Facilities meeting the reporting criteria submit this information every five years as required under Section 112r of the Clean Air Act Amendments of 1990. The information is used by emergency planners and responders to plan for and respond to hazardous chemical emergencies.

Hazardous material releases may occur from any of the following:

- Fixed site facilities (e.g. refineries, chemical plants, storage facilities, manufacturing, warehouses, wastewater treatment plants, swimming pools, dry cleaners, automotive sales/repair, gas stations)
- Highway and rail transportation (e.g. tanker trucks, chemical trucks, railroad tankers and intermodal containers)
- Marine transportation (e.g. bulk liquefied gas carriers, oil tankers, tank barges)
- Air transportation (e.g. cargo packages)
- Pipeline transportation (liquid petroleum, natural gas, other chemicals)

The Office of Pipeline Safety oversees pipeline operations throughout the state since 1987. The main office is located in St. Paul, with field offices located in Grand Rapids, Detroit Lakes, and Mankato. The Office of Pipeline Safety is in the Minnesota Department of Public Safety. In Minnesota, there are 93 pipeline operators, Nearly 1.5 million gas meters, Over 65,000 miles of pipeline, and 900 to 1000 inspection days annually.

Natural hazards, such as wildfires, floods, high winds, and lightning may be the catalyst to a hazardous materials release. For example, people are often warned to shut off natural and propane gas when floods are imminent to prevent structural fires. More often, releases are related to human activity including terrorism.

The secondary events to a leak or spill may expose humans, animals, and food to toxins. Fires and explosions may expose large areas to contaminants. Populations may need to be evacuated, monitored, decontaminated and perhaps treated for exposures. Long-term remediation before normal activity resumes may impact the state's tourism if natural resources are involved. Impacts to commerce may occur due to transportation stoppage or embargo of food products.

Hazardous Materials Incident History

Table 65 shows significant events in Minnesota for all hazardous material modes including pipelines. Initiating calls appear under all appropriate categories. For example, a spill call requiring CAT/ERT response is listed under both "Spills" and "CAT/ERT Request." These numbers reflect only calls resulting in a Minnesota Duty Officer report.

Table 65. 2017 Annual Initiating Calls to Minnesota Duty Officer (MDO)

Initiating Call Category	Initiating calls to MDO*
Air Quality	314
Fire Marshal Investigation	567
Methamphetamine Lab	0
Spills	2,467
Waste Water Bypass	186
**Bomb Squad	103
**Chemical Assessment Team/Emergency Response Team Request (CAT/ERT)	29
**Pipeline Break/Leak	181
**Tank Pulls (Contaminated Soil)	362
**SARA Title III Release	50
**WMD Threat	2

*SOURCE: (MN DPS, 2017)**RELATED TO DISCHARGES OF OIL AND HAZARDOUS SUBSTANCES.*

The Minnesota Pollution Control Agency's Emergency Management Unit (EMU) fields over 2,000 spill calls annually in the state, including chemical fires, train derailments, pipeline breaks and tanker truck accidents, among others.

A train derailed on a bridge in St. Paul over the Mississippi River in August of 2018, resulting in 3,200 gallons of diesel spilling into the river. Absorbent booms were placed in the water in an attempt to collect the spilled diesel (Vezner, 2018).

In June of 2017 a chemical spill resulted in an evacuation at the University of Minnesota's Masonic Cancer Research Building. No injuries were reported.

In November of 2016, a train derailment in Ellendale, Minnesota released a cloud of liquefied petroleum gas. Seven hundred residents were evacuated from a two-mile area around the leaking tanker (Hudson, 2016).

Anhydrous ammonia was spilled near Brownton, Minnesota in November of 2016, resulting in a shelter in place order. The spill occurred when a tanker was being pulled by a tractor (Valley News, 2016).

Plans and Programs in Place

The links below profile the wide range of capabilities available in Minnesota regarding hazardous materials:

Gopher State One Call
Office of Pipeline Safety
Minnesota Duty Officer Program
Emergency Planning and Community Right-To-Know Act (EPCRA)
HSEM Emergency Response
MPCA Emergency Response

4.8.4 Nuclear Generating Plant Incidents

Nuclear generating plants use the heat from nuclear fission in a contained environment to convert water to steam. The steam then powers generators to produce electricity. The design, construction, and operation of nuclear generating plants are closely monitored by the U.S. Nuclear Regulatory Commission (NRC).

In 2006, the Minnesota Department of Health (MDH) assumed part of the NRC's regulatory authority over certain radioactive materials in the state. Since then, the MDH is responsible for licensing, rulemaking, inspection and enforcement activities for: (1) radioactive materials produced as a result of processes related to the production or utilization of special nuclear material; (2) uranium and thorium source materials; and (3) special nuclear material in quantities not sufficient to form a critical mass.

The potential danger from an accident at a nuclear generating plant is exposure to radiation. This exposure would most probably come from the release of radioactive material from the plant to the environment. The release may be characterized by a plume (cloud-like formation) of radioactive gasses and particles. The major hazards to the people in the vicinity of the plume are radiation exposure to the body from the cloud and particles deposited on the ground, inhalation of radioactive materials, and ingestion of radioactive materials.

The effects of radiation exposure depend on the intensity and length of time of exposure to radiation. Low exposure, comparable to chest x-rays, may slightly increase the risk of cancer. Much higher exposures can cause fatalities.

Nuclear generating plants do not explode like nuclear detonation devices since the fuel is of low enrichment. There is no risk of a nuclear explosion with the associated physical mass destruction.

Nuclear Generating Plant History

The Monticello Nuclear Generating Plant (MNGP), located in Monticello, Minnesota, is owned by Xcel Energy Inc. It is a one-unit, boiling water reactor, rated at 671 megawatt capacity. MNGP completed a nine-year process of virtually rebuilding the plant to increase its generation an additional 71 megawatts. Major equipment was installed during the refueling/power uprate outages in 2009, 2011, and 2013. The plant generates approximately 10% of the electricity used by Xcel's customers in the Upper Midwest.

MNGP began commercial operation in June 1971. In 2006, the NRC renewed MNGP's license for 20 years, which allows operations until 2030.

The Prairie Island Nuclear Generating Plant is located five miles north of Red Wing, Minnesota, and is also owned by Xcel Energy Inc. The plant has two pressurized water reactors, which generate approximately 20% of the energy used by Xcel's customers in the Upper Midwest. The two reactors combined produce 1,100 megawatts of electricity and began operation in 1973 (unit 1) and 1974 (unit 2). The NRC initially licensed the reactors for 40 years of operation, and then extended the licenses for 20 more years, until 2033 and 2034.

On December 7, 1979, following the March 1979 Three-Mile Island nuclear power plant accident in Pennsylvania, President Carter transferred the federal lead role in off-site radiological emergency planning and preparedness activities from the NRC to the Federal Emergency Management Agency (FEMA). FEMA established the Radiological Emergency Preparedness (REP) Program to (1) ensure that the public health and safety of citizens living around commercial nuclear power plants would be adequately protected in the event of a nuclear power station accident and (2) inform and educate the public about radiological emergency preparedness. FEMA's REP Program responsibilities encompass only off-site activities; that is state and local government emergency preparedness activities that take place beyond the nuclear power plant boundaries. Onsite activities continue to be the responsibility of the NRC.

Plans and Programs in Place

Annual exercises are held so the NRC and FEMA may evaluate utility, local, and state response organizations. In addition, FEMA evaluates the local and state plans and preparation activities annually and issues a letter of certification if the planning for a response to an incident provides reasonable assuredness of safety to the public.

Nuclear power plants are not immune to natural hazards, but the potential impacts are minimal. Sites are evaluated for vulnerabilities to natural hazards before a construction permit is issued. Plants are then designed to withstand the most violent forces of nature. Procedures are also developed to implement regimens to protect the plant. The aftermath of a natural hazard should have no impact to public health and safety based on the robust design of the facility and the vigilance of the plant staff.

4.8.5 Infectious Disease Outbreak

Infectious diseases have the potential to affect any form of life. Some infectious diseases that were thought to have been eradicated have re-emerged. New strains of some infectious diseases, such as the flu, present seasonal threats to the populace and require continuous monitoring. Widespread epidemics are almost non-existent in the United States. An "epidemic" is defined as a disease that occurs suddenly in numbers clearly in excess of normal expectancy, especially infectious diseases, but is applied also to any disease, injury, or other health-related event occurring in such outbreaks. If an epidemic event were to occur, deaths could be in the many hundreds of thousands across the nation. If the health of the general public is perceived to be threatened on a large scale, riots or states of lawlessness are a possibility. State agencies activities are directed in the Minnesota Emergency Operations Plan (MEOP).

Infectious Disease History

The Minnesota Department of Health's Health Alert Network (HAN) enables information exchange during disease outbreaks, environmental threats, natural disasters, and acts of terrorism. They also provide health advisories on an as-needed basis. Below is a brief overview of health advisories recorded in the last 3 years (Table 66).

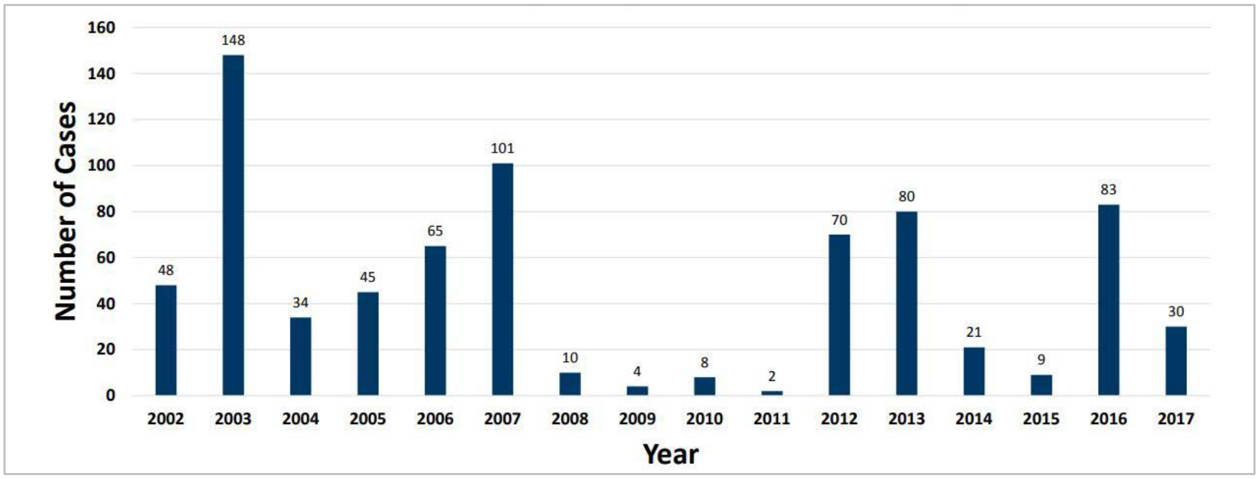
Table 66. HAN Health Advisories in Minnesota, 2016-2018

Date	Health Advisory
10/4/2018	Increase in Pediatric Acute Flaccid Myelitis cases
9/24/2018	Tuberculosis risk in adult day care centers
9/14/2018	Third Travel-Associated Measles case (targeted to Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties)
8/23/2018	Second Travel-Associated Measles case
8/7/2018	Travel-Associated Measles case in Hennepin County
6/15/2018	Increase in Cyclosporiasis cases
4/5/2018	Significant bleeding associated with Contaminated Synthetic Cannabinoids
7/31/2017	Tuberculosis outbreak continues
7/14/2017	Measles outbreak continues
6/21/2017	Tularemia case in Minnesota
5/23/2017	Mumps outbreak at U of MN – Twin Cities
4/12/2017	Measles cases in Hennepin County
4/4/2017	Varicella (Chickenpox) outbreak in North Metro
2/27/2017	Syphilis on the rise, outbreak in drug users
12/27/2016	NTM infections following hCG injections
12/22/2016	Pertussis increase in Minnesota
11/9/2016	Hepatitis A linked to frozen strawberries
10/4/2016	Nontuberculous Mycobacteria infections following surgery
9/14/2016	Measles exposure in Metro
9/9/2016	Legionellosis cases
8/9/2016	Cryptosporidiosis in waterpark
7/20/2016	Recall of Docusate Sodium
6/21/2016	Salmonella outbreak associated with live poultry contact
5/26/2016	Diarrheal illnesses outbreak associated with farm visits
5/2/2016	Travel-Associated Measles case in Hennepin County
4/1/2016	Lead exposure at shipyard in Wisconsin
3/17/2016	Peak Influenza activity

SOURCE: MDH HAN

West Nile Virus (WNV) was found in Minnesota in 2002 and remains a public health concern. The state's abundant bird and mosquito populations allowed for the rapid establishment of the virus. WNV can cause inflammation of the brain (encephalitis); however, most people who are bitten by infected mosquitoes will either experience mild illness or no symptoms at all (MDH, 2018). The highest risk areas for the virus in the state are in the western and central regions. Open areas, including farmland and prairie, are the prime habitats for *Culex tarsalis*, which is the main mosquito vector of WNV. Most cases occur in late summer. In 2017, 30 cases of WNV were reported in Minnesota, down from 83 cases in 2016 (Figure 72) (MDH, 2018).

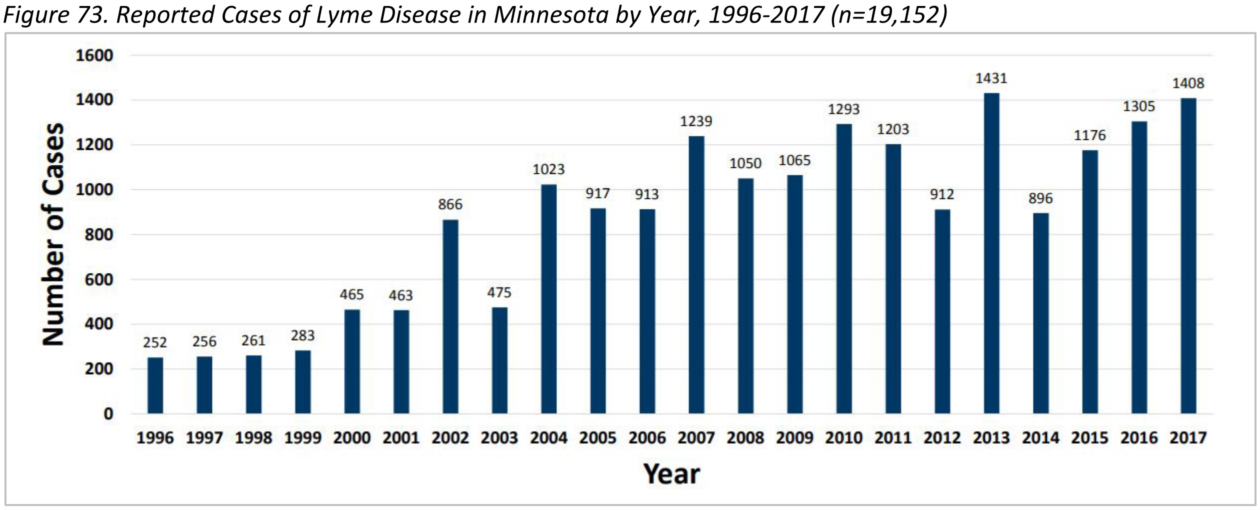
Figure 72. Reported Cases of West Nile Virus in Minnesota by Year, 2002-2017 (n=758)



SOURCE: MDH

Tickborne diseases, such as Lyme disease, are another potential public health concern in Minnesota. Both humans and animals can be affected when bitten by an infected blacklegged tick (also called a deer tick or bear tick). The Minnesota Department of Health began collecting information on diagnoses of Lyme disease in 1982. During the time period of 1996-2010, there were 10,821 confirmed cases of Lyme disease in Minnesota (MDH, 2018). Over 1400 cases were recorded in 2013 and 2017 (Figure 73). MDH reported cases are expected to underestimate total cases because many cases are not reported.

Figure 73. Reported Cases of Lyme Disease in Minnesota by Year, 1996-2017 (n=19,152)



SOURCE: MDH

Plans and Programs in Place

Minnesota Department of Health (MDH) has multiple divisions that deal with Emergency Preparedness and Response, Infectious Disease Prevention, and Public and Environmental Health. The Emergency Preparedness & Response section of the Health Partnerships Division coordinates preparedness activities and assists Minnesota Department of Health staff, local public health agencies, hospitals, health care organizations, tribes and public safety officials in their efforts to plan for, respond to and recover from public health emergencies. HSEM coordinates with MDH and other agencies as directed in the MEOP during emergencies and disasters. Agencies also train together to prepare for actual emergencies.

MDH leads the health aspect of emergencies in Minnesota. Various plans detail what MDH will do during emergencies. MDH has an All-Hazards Response and Recovery Base Plan. This plan describes actions the Minnesota Department of Health (MDH) will take in response to incidents that have public health and/or medical implications. They produced the specific *All-Hazards Response and Recovery Plan: Ebola Virus Disease*. This is a structure for how MDH and partners would operate if there was an Ebola outbreak, dated July, 2018.

Information systems help to ready responders for emergencies. Minnesota Response Systems address topics such as: learning about health alerts; how to volunteer during an emergency (Minnesota Responds); how hospital beds and supplies are tracked (MN*TRAC*); how to register and take online courses (MN.TRAIN); and how medicines and supplies are requested, received and distributed through the Strategic National Stockpile (SNS) program (MDH, 2018).

MDH has a history of collaborating, creating and sustaining Public Health and Health Care Emergency Preparedness, Response and Recovery Systems with local health departments and health care partners. There has been a new emphasis on response and recovery planning for terrorism and natural disasters among state, local, tribal and health care partners. This is documented in Public Health & Health Care Emergency Preparedness in Minnesota.

MDH and its local partners have responded to many local emergencies and presidential disaster declarations. MDH's Environmental Health System role is to provide services essential for protecting and ensuring the well-being of the people in affected areas, with an emphasis on prevention and control of disease and injury during a natural disaster or other emergency, such as a terrorist attack.

An outbreak of a highly contagious animal disease in Minnesota could have public health or economic ramifications for the state and potentially the whole nation. The Board of Animal Health (BAH) is the lead state agency in responding to domestic animal disease emergencies in Minnesota, emergency preparedness is a priority for the Board. They work with federal, state and local government agencies, industry organizations and livestock producers to ensure adequate preparation, to promote prevention and provide assistance in response to contagious animal diseases. Current response plans are exercised periodically to provide training for staff and partners.

The BAH website provides information on Foreign Animal Diseases, Foot and Mouth Disease and has many other resources regarding animal health and disease. Assets available to support an animal disease emergency include:

- A Minnesota agriculture incident management team

- State and federal animal health employees trained as responders in outbreak control
- Minnesota Veterinary Medical Reserve Corps – an organization of veterinary professionals with a subset of their membership trained in animal disease response
- USDA financial support, resources and national regulatory authority for disease response

Infectious disease is predicted to become increasingly significant as people and goods move more readily around the globe, organisms become resistant to our treatments and control methods, and livestock and people encroach on natural habitat. New diseases are discovered when they move from wildlife populations and impact people and livestock, and diseases are found in new places with the movement of people and goods around the world.

Climate Change and Infectious Diseases

Climate change has the potential to affect human health by increasing the occurrence of vector-borne diseases. Elements of climate change such as warmer temperatures, shorter/milder winters, and earlier spring seasons can result in an increasingly hospitable environment for carriers of vector-borne diseases. Climatic factors strongly influence the survival of ticks and the bacterium that causes Lyme disease, in particular temperature, precipitation and humidity. Warmer, milder winters can result in higher survival rates of disease-carrying ticks. West Nile Virus (WNV) can also become more prevalent due to climate change (Centers for Disease Control and Prevention, 2014).

4.8.6 Transportation Incidents

The areas of transportation discussed in this section are highways, railroads, commercial waterway, and aeronautics. Minnesota's transportation infrastructure is outlined in Section 4.6.2.

Transportation Incident History

The Minnesota Department of Public Safety maintains a database of crash events and trends (Table 67). Records are available from 1984 to present, and record highs reflect this time period. The fatality rate is the number of people who died in traffic crashes divided by the number of vehicle miles traveled. It is expressed as the number of people who died for every 100 million-vehicle miles traveled. Economic cost estimates are based on factors such and productivity losses, medical expenses, administrative expenses, motor vehicle damage, and employers' uninsured costs.

Table 67. Traffic Crash Trends, 2012-2016

	2012	2013	2014	2015	2016	Record High	
Crashes							
Fatal Crashes	349	357	324	375	357	878	1973
Injury Crashes	20,972	21,960	21,257	21,516	21,734	33,868	1978
Severe	1,044	981	862	932	1,702	5,109	1984
Moderate	5,423	5,563	5,302	5,721	8,642	12,326	1985
Minor	14,505	15,416	15,093	14,863	11,390	18,578	1996
Property Damage Only Crashes	47,915	55,390	56,815	52,978	56,978	94,810	1975
Total Crashes	69,236	77,707	78,936	74,772	79,069	123,106	1975
Injuries							
Severe	1,268	1,216	1,044	1,127	1,992	6,573	1984
Moderate	6,902	7,109	6,712	7,251	11,097	17,670	1985
Minor	21,144	22,328	21,683	21,603	16,736	28,631	1996
Total Injuries	29,314	30,653	24,439	29,981	29,825	50,332	1978
Fatalities							
Motor Vehicle Occupant	276	269	279	285	261	544	2002
Motorcycle	55	60	46	61	54	121	1980
Pedestrian	40	35	17	41	60	157	1971
Bicycle	7	6	5	10	7	24	1977
All-Terrain Vehicle	9	7	7	10	7	10	2008
Commercial Bus	1	2	4	1	0	9	1984
Farm Equipment	2	5	1	2	1	N/A	N/A
Other Type Vehicle	5	3	3	1	2	N/A	N/A
Minnesota Fatality Rate	0.69	0.68	0.63	0.70	0.67	23.6	1934
U.S. Fatality Rate	1.14	1.10	1.08	1.13	1.18	18.0	1925
Minnesota Economic Loss ($ millions)	$1,514	$1,588	$1,604	$1,773	$1,874	$1,874	$2016
Total Fatalities	**395**	**387**	**361**	**411**	**392**	**1,060**	**1968**

Source: MnDPS Office of Traffic Safety Crash Facts 2016

Minnesota has over 20,000 bridges ranging from roads on culverts to massive spans across rivers and lakes. The Interstate-35W bridge collapse on August 1, 2007, was a catalyst in Minnesota that spurred increased bridge inspections and maintenance along with replacement of impaired bridges. MN DOT's Bridges and Structures program sets criteria for design, inspection, and maintenance. Inspection reports are retained, and the results are digested in annual bridge reports. The program also provides tools to determine the hydraulics for construction, replacement, or modification of bridges (MNDOT, 2019).

MN DOT and MnDPS have highway safety components built into many of their programs. The following links show the in-depth capabilities available in the state:

Child Passenger Safety

Speed/Aggressive Driving

Move Over Law

Bike/Pedestrian Safety

State Aid for Local Transportation

Rail Grade Crossing Safety

Natural hazards impact highway safety. The most impactful hazards are:

- Winter storms/blizzards that shut down highways and make travel hazardous
- Floods that inundate roadways and wash away culverts, bridges, and roads
- Tornadoes/high winds that have potential for traffic accidents and debris

Railroads

A summary of major rail accidents in Minnesota is provided in Table 68 below.

Table 68. Major Rail Accidents in Minnesota

Date	Accident	Location	Fatalities	Injuries
5/25/2016	Employee fatality during maintenance	Minneapolis	1	0
9/30/2010	Collision of two freight trains	Two Harbors	0	5
12/29/2009	Derailment of freight train	Minneapolis	1	0
6/14/1984	Head-on collision of two freight trains	Motley	3	4

SOURCE: NTSB RAILROAD ACCIDENT REPORTS

Rail safety has many facets. Legislation was signed into law by Governor Mark Dayton in 2014 to help protect those who live and work near railways that carry crude oil and other hazardous materials (Homeland Security and Emergency Management, 2019). The new law includes:

- Increased oversight of railroad companies.
- Requirements for more railway inspections.
- Provisions for better emergency response training and preparedness in communities across the state.

The Minnesota Department of Public Safety is involved in the following ways:

- Working with railroad and pipeline companies in developing safety protocols and facilitating coordination between these companies and local public safety officials.
- Assisting local governments as they include emergency response information into their emergency operations plans.
- Collaborating with local emergency managers and responders to understand the dangers of oil and other hazardous substances traveling through Minnesota.
- Partnering with the Minnesota Department of Transportation, Minnesota Pollution Control Agency, and the railroads to carry out the rail safety legislation.

Rail crossing safety is a life safety issue for motorists, bicyclists, and pedestrians. Crude oil and hazmat transportation may be a secondary hazard if train cars become derailed due to a crash at a crossing.

Minnesota Operation Lifesaver is a private nonprofit educational organization dedicated to ending deaths and injuries at highway-rail crossings and on railroad property.

There are over 4,000 railroad grade crossings in Minnesota. In the early 1990s, over 100 automotive crashes per year occurred at rail crossings in the state. However, currently the state records around 45 crashes per year, of which five involve fatalities. MN DOT oversees crossings on all roadways (MNDOT, 2019).

Accidents due to natural hazards aren't frequently reported since operations are usually curtailed during hazard events. The most impactful hazards are:

- Winter storms/blizzards that slow down or stop rail transport.
- Floods that may inundate and/or wash away tracks adjacent to culverts and bridges.
- Tornadoes/high winds that have potential for accidents and interruptions due to debris.

Commercial Waterways

Water transportation incidents are investigated by the National Transportation Safety Board (NTSB). The NTSB is an independent federal agency that investigates every civil aviation accident in the United States as well as significant accidents in other modes of transportation, including marine transportation. The NTSB determines probable cause for each accident investigated and then issues recommendations aimed to prevent future accidents (National Transportation Safety Board, 2019).

The NTSB's marine accident report database includes reports for three accidents in Minnesota. The most recent incident occurred in October of 2017 when a towing vessel on the Mississippi River struck a fixed pier of the St. Paul Union Pacific Rail Bridge. No injuries or pollution were reported; however, damages to the bridge and barge were estimated at $800,000 and $153,000, respectively. In June of 2013 an uninspected towing vessel lost engine throttle control and was swept into a dam gate of Lock and Dam 7 on the Mississippi River, where the vessel capsized. One crewmember died. Approximate damage to the vessel was estimated at $500,000. In July of 1999, two recreational vessels collided on the St. Croix River near Bayport, Minnesota. One of the vessels had three occupants, and the other had two: all five died as a result of the accident (three from drowning, two from blunt force trauma) (National Transportation Safety Board, 2019).

Commercial waterways also allow recreational boating. Boating statistics from the U.S. Coast Guard (USCG) are included in the table below to give a better indication of the hazards that may be encountered.

Table 69. Recreational Boating Statistics for Minnesota, 2013-2017

	2013	2014	2015	2016	2017
Alcohol Use as a Contributing Factor					
Accidents	8	8	10	18	14
Deaths	3	4	7	8	4
Injuries	5	11	7	11	12
Accidents and Casualties					
Total Accidents	75	50	87	96	105
Fatal Accidents	10	14	16	17	13
Deaths	12	14	18	17	14

SOURCE: USCG 2017

Natural hazards impact commercial waterways. The most impactful hazards are:

- Icing of rivers and lakes. Shipping seasons are set to accommodate these occurrences.
- High winds due to sudden storms that make lake transport hazardous.
- High river levels after floods that hamper commercial transportation due to high flow velocities.

Aeronautics

Aviation accidents are the least frequent type of transportation accident. The National Transportation Safety Board, the federal agency responsible for aviation accident information, indicates that from 2014-2018, there were 98 air transportation accidents in Minnesota. Most of these accidents involved small aircraft, and many resulted in only minimal injuries. Of the total accidents, 15 were fatal, resulting in 24 deaths (National Transportation Safety Board, 2019).

MN DOT has an aeronautics office that ensures the safety of the state's aviation system. Just like the highway department works to keep the roads and highways safe, the aeronautics office works with the aviation community to make the aviation system safe. The office helps airports with the following:

- Paved runways and taxiways
- Painted markings
- Lights to identify the runways and taxiways
- Navigation equipment
- Weather information for flying
- Maintenance equipment to plow snow and mow grass around runways
- Promotion of aviation to continue having qualified employees who keep the state's aviation system successful and thriving

Airport facilities are vulnerable to all types of natural hazards such as flooding. Airports often close due to a variety of atmospheric-related natural hazards. Significant investments in de-icing commercial airliners and plowing runways are made during the winter months.

Floods are seldom reported, but an example of flood prevention is the removable floodwall installed in 2009 at St. Paul Holman Field and utilized several times since. In Figure 74 the system is seen withholding several feet of floodwaters from the Mississippi River in the summer of 2014. This flood protection system is the largest American-made removable flood wall in the world. The flood barriers span multiple runways for a total linear span of nearly a mile. This system also includes an architectural half-wall area. The removable floodwall takes about one week to erect after airport staff determine that flooding is probable based on a flood gauge located nearby. The system is cost beneficial compared to when the airport was completely inundated with floodwater. All operations were fully curtailed for weeks and full restoration took longer. Another benefit of the wall is that the beauty of the scenic Mississippi River valley is not marred by permanent structures when the river is running at normal levels.

Figure 74. Removable Floodwall at the St. Paul Holman Field

SOURCE: (FLOOD CONTROL AMERICA, 2014)

4.8.7 Terrorism

The Federal Bureau of Investigation (FBI) defines domestic terrorism as that perpetrated by individuals and/or groups inspired by or associated with primarily U.S.-based movements that espouse extremist ideologies of a political, religious, social, racial, or environmental nature. Domestic organizations fall into four (4) broad categories: special interest, rightwing, leftwing, and lone wolf/homegrown violent extremists (FBI, 2018).

U.S. Code 18 U.S.C. § 2331 defines Domestic Terrorism activities as acts that:

- Are dangerous to human life that violate federal or state law;
- Appear intended (i) to intimidate or coerce a civilian population; (ii) to influence the policy of a government by intimidation or coercion; or (iii) to affect the conduct of a government by mass destruction, assassination, or kidnapping; and
- Occur primarily within the territorial jurisdiction of the U.S.

International terrorism is that perpetrated by individuals and/or groups inspired by or associated with designated foreign terrorist organizations or nations (state-sponsored) (FBI, 2018).

The Director of National Intelligence Daniel R. Coats testified in February of 2018 that Sunni violent extremists—most notably ISIS and al-Qaida—pose continuing terrorist threats to U.S. interests and partners worldwide, while U.S.-based homegrown violent extremists (HVEs) will remain the most prevalent violent extremist threat in the United States.

U.S. Code 18 U.S.C. § 2331 defines International Terrorism activities as acts that:

- Are violent or dangerous to human life that violate federal or state law;
- Appear to be intended (i) to intimidate or coerce a civilian population; (ii) to influence the policy of a government by intimidation or coercion; or (iii) to affect the conduct of a government by mass destruction, assassination, or kidnapping; and
- Occur primarily outside the territorial jurisdiction of the U.S. or transcend national boundaries in terms of the means by which they are accomplished, the persons they appear intended to intimidate or coerce, or the locale in which their perpetrators operate or seek asylum

U.S. Code 18 U.S.C. § 2331 defines the Federal Crime of Terrorism as an offense that:

- Is calculated to influence or affect the conduct of government by intimidation or coercion or to retaliate against government conduct; and
- Is a violation of one of several listed statutes, including § 930(c) (relating to killing or attempted killing with a dangerous weapon during an attack on a federal facility); and § 1114 (relating to killing or attempted killing of officers and employees of the U.S.)

The FBI divides terrorist-related activity into three categories:

- A terrorist incident is a violent or dangerous act to human life, in violation of the criminal laws of the United States or of any state, to intimidate or coerce a government, the civilian population, or any segment thereof.
- A suspected terrorist incident is a potential act of terrorism to which responsibility cannot be attributed at the time to a known or suspected terrorist group or individual.

- Terrorism prevention is a documented instance in which a violent act by a known or suspected terrorist group or individual with the means and a proven propensity for violence is successfully interdicted through investigative activity.

In Minnesota, agencies such as the Minnesota Fusion Center, the Federal Bureau of Investigation's (FBI) Joint Terrorism Task Force, and regional law enforcement working groups work with the FBI in gathering evidence, making arrests, sharing intelligence, and working to prevent terrorist attacks. The FBI, as the lead agency in terrorism investigations, uses the U.S. Code of Federal Regulations 18 U.S.C. § 2331 definition of terrorism as either domestic or international, depending on the origin, base, and objectives of the terrorist organization.

History of Terrorism

On January 19, 2018, Tnuza Jamal Hassan of Minneapolis set nine fires in an attempt to kill people at St. Catherine's University. The self-radicalized Hassan told investigators that she tried to join al-Qaida and that she was willing to carry out a suicide bombing if asked. She traveled as far as Dubai on her way to Afghanistan in 2017 but was stopped due to the lack of a visa. Hassan also told investigators that they were "lucky" she didn't know how to build a bomb, according to the criminal complaint.

On August 5, 2017, the Dar al-Farooq Islamic Center (DAF) in Bloomington, Minnesota, was targeted by a militia group known as the "White Rabbits," which consisted of four Illinois residents. A PVC pipe bomb was thrown through a window causing extensive damage. The defendants targeted the Islamic center "with intent to damage the mosque because of its religious character and with intent to obstruct Muslims from worshipping there," the Justice Department said in a statement.

On September 17, 2017, twenty-year-old Dahir Adan, while wearing a security guard uniform and armed with two steak knives, went on a mass stabbing attack at the Crossroads Center shopping mall in St. Cloud, Minnesota. While the Islamic State claimed that Adan was a "soldier of the Islamic State," the FBI has been unable to confirm the relationship. There were ten people injured before the perpetrator was shot dead by an off-duty police officer.

June 2016, three Minnesota men were found guilty of attempting to join ISIS and were convicted of conspiracy to commit murder outside the United States. Their convictions were upheld in 2018.

A 2015 report from the House Homeland Security Committee titled "Combating Terrorist and Foreign Fighter Travel" highlights that since 2011 Minnesota had more cases (58) of people trying to travel to Syria to join ISIS than any other state in the country.

In April of 2015, six young men of Somali decent were charged with trying to join ISIS.

Since the late 1990s, more than 20 Somali youth have been recruited by al-Shabaab and left the Twin Cities to fight in Somali.

Created in the wake of 9/11, the Terrorist Screening Center (TSC) maintains the TSC Watchlist as a single nationwide database that identifies information about those known or reasonably suspected of being involved in terrorist activity who try to obtain visas, enter into the country, board aircraft, or engage in suspicious activities. While there are over 20,000 contacts with watch-listed people annually nationwide, Minnesota ranks second in the United States with Hennepin County having the most watch-listed encounters of any county in the country.

Vulnerability

In terms of national consequence to Homeland Security, Minnesota is home to 19 Fortune 500 companies and statewide revenues exceed $300 billion per year. Minnesota is at an increased risk from terrorism as a target of economic strategic value with financial centers, agri-business, and an international airport located within our borders. Two large public venues include the Mall of America, with over 40 million visitors annually and over 12,000 parking spaces for visitors, and the U.S. Bank Stadium which has 66,200 seats and is located in the heart of Minneapolis.

Section 5: Hazard Mitigation and Climate Adaptation Strategy

S8. Does the mitigation strategy include goals to reduce / avoid long-term vulnerabilities from the identified hazards? [44 CFR §201.4(c)(3)(i)]
S9. Does the plan prioritize mitigation actions to reduce vulnerabilities identified in the risk assessment? [44 CFR §§201.4(c)(3)(iii) and (iv)]
S10. Does the plan identify current and potential sources of funding to implement mitigation actions and activities? [44 CFR §201.4(c)(3)(iv)]
S11. Was the plan updated to reflect changes in development, progress in statewide mitigation efforts, and changes in priorities? [44 CFR §201.4(d)]

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. Researchers at the National Institute of Building Sciences looked at the results of 23 years of federally-funded mitigation grants provided by the Federal Emergency Management Agency (FEMA), U.S. Economic Development Administration (EDA) and U.S. Department of Housing and Urban Development (HUD) and found mitigation funding can save the nation $6 in future disaster costs, for every $1 spent on hazard mitigation (National Institute of Building Sciences, 2017).

Mitigation can take many different forms from construction projects to public education. Climate adaptation strategies that address the effects of current and future changing conditions are included. HSEM and the Minnesota Department of Health's (MDH) – Climate and Health Program collaborated to bring the climate change message to local emergency managers throughout the state. MDH developed six HSEM regional profile reports: *Planning for Climate and Health Impacts: Emergency Management Considerations*. MDH, with HSEM, released the reports on August 22, 2018 via a training webinar. Over 100 emergency managers and emergency preparedness professionals attended. MDH will visit all HSEM regions to share their regional specific reports and discuss ways to incorporate climate projection data into hazard mitigation planning.

The development of mitigation/adaptation actions allows the State of Minnesota to create a vision for preventing future disasters, establish a common set of mitigation/adaptation goals across state, tribal, and local agencies, prioritize actions, and evaluate the success of such actions. The previous Minnesota Hazard Mitigation Strategy was based on the results of the statewide risk assessment, local and tribal risk assessments and mitigation strategies, and additional recommendations by mitigation stakeholders. The new, updated Minnesota Hazard Mitigation and Climate Adaptation Strategy includes the previous input, plus information gathered during the development and revisions of ICAT Climate Change Adaptation reports, and continued workgroup efforts.

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 inclusion of climate change and adaptation strategies to revised mitigation strategies will increase the value, visibility and implementation possibilities to reduce risk statewide.

5.1 Update

The goals and objectives for the 2019 HMP have been revised and climate change adaptation integrated. FEMA has updated and released many new project types and guidance materials. The Interagency Climate Adaptation Team (ICAT) has been working a parallel path to develop goals, objectives and strategies. This plan aims to integrate traditional project types, new FEMA mitigation strategies and project types, and Climate Adaptation recommendations for action.

The 2017 ICAT report and recommendations workgroups identified data as a strategy needed to achieve goals. Additional actions to support climate adaptation and resilience were added to the standard hazard mitigation actions.

The Sandy Recovery and Improvement Act (SRIA) of 2013 gave FEMA the authority to provide states and tribes with funds for advance assistance on a pilot basis. Advance assistance is now available under HMGP, PDM and FMA. Additional new project types include community flood mitigation projects under FMA, and resilient infrastructure projects under PDM.

In 2015 FEMA released Climate Resilient Mitigation Actions (CRMA) which include the following project types: Aquifer Storage and Recovery (ASR), Floodwater Diversion and Storage (FDS), and Floodplain and Stream Restoration (FSR). These methods may be used to address drought in addition to flooding hazards. CRMA allows for green infrastructure (GI) and nature-based design to incorporate more ecosystem service benefits. The Benefit–Cost Analysis (BCA) required for mitigation projects had been updated to include the value of forest, green open space, marine and estuary areas, riparian areas and wetlands.

The FEMA publication *Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards* (2013) illustrated aligning strategies with specific natural hazards. Since the release of that document, HSEM has utilized the new, updated strategies of Local Planning and Regulations, Structure and Infrastructure Projects, Natural Systems Protection and Education and Awareness Programs versus the previous Prevention, Property Protection, Public Education and Awareness, Natural Resource Protection and Emergency Services.

The mitigation action strategy types used in this plan are:

- Data
- Local Planning and Regulations
- Structure and Infrastructure Projects
- Natural Systems Protection
- Education and Awareness Programs

A sixth type was determined by Minnesota HSEM for use in the state:

- Mitigation Preparedness and Response Support

These new strategy types have been promoted and used as a guide for local mitigation plans in the state. The Mitigation Preparedness and Response Support strategies are popular with county emergency managers, as their needs for these types of projects and programs are high.

Data collection, development, funding for, dissemination of as a strategy has been added. It was added as a result of the workgroups working on the six recommendations/goals of the 2017 ICAT report. Most of the groups identified data as an important need to implement any future adaptation. The need for data exists at the state level. The data strategy includes coordinating with other state agencies to address the accuracy of existing data and identify gaps. Good data is needed to inform better understanding of state asset vulnerability. Data collection also includes projected and actual changes in development as it is difficult to collect. Data as a strategy will be promoted for the update of local county hazard mitigation plans.

The update to the state's 2014 list of mitigation actions is included in *Appendix P – 2014-2019 Update on Goals and Strategies*.

5.2 State Plan Goals and Objectives

The natural hazard and climate adaptation goals, strategies and actions are listed to provide a path for local communities and state agencies to utilize grant programs based on project type. Based on state agency and local priorities, the grant programs can guide communities to develop an overall mitigation strategy and implement projects to make their communities more disaster resistant.

The 2019 goals and objectives for the Minnesota State Hazard Mitigation Plan are:

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

Objectives:

- Increase awareness and knowledge of hazard mitigation and climate adaptation principles and practice among state agency program administrators.
- Leverage state agency subject matter experts to empower local community applicants to apply to HMA and other resilience programs.
- Coordinate state programs and state capabilities to increase mitigation and adaptation project implementation.
- Increase awareness of grant funding to buyout properties on the Severe Repetitive Loss and Repetitive Loss lists.
- Gather data on state owned/operated infrastructure and critical facilities.
- Develop and/or improve hazard vulnerability assessments for state owned/operated, infrastructure and critical facilities.
- Improve state agency awareness of eligibility for hazard mitigation grant funds.
- Prioritize and fund high priority mitigation and adaptation projects to increase vulnerability of state-owned infrastructure and critical facilities.

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

Objectives:

- Increase awareness and knowledge of hazard mitigation and climate adaptation principles and practice among local public officials.

- Encourage the use of FEMA Advance Assistance and phased applications by local governments utilizing state agency experts.
- Provide direct technical assistance to local public officials and help communities obtain funding for mitigation and climate adaptation planning and project activities.
- Encourage communities to update and implement local hazard mitigation plans and incorporate climate adaptation 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 and climate adaptation projects.
- Maximize available post-disaster "windows of opportunity" to implement major mitigation and climate adaptation outreach initiatives, including social media.
- Promote use of available funds for buying out Severe Repetitive Loss and Repetitive Loss properties.
- Improve data on locally owned/operated infrastructure and critical facilities.
- Improve vulnerability assessments for locally owned/operated infrastructure and critical facilities.

5.3 Mitigation, Climate Adaptation and Resilience Strategies

Traditional hazard mitigation actions in this plan are categorized into the following strategy types, as described in the *FEMA publication Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards (2013)*. This includes FEMA Climate Resilient Mitigation Actions (CRMA) released in 2016. FEMA continues to add job aids, benefit/cost analysis tools and supplemental information to develop projects. See Mitigating Flood and Drought Conditions Under Hazard Mitigation Assistance for updated information.

Data: Collection, development, funding for, and dissemination of data of all types. State asset data is needed to better assess hazard vulnerability. Data collection on changes in development is necessary to address future hazards. Fund, develop, utilize and disseminate climate data; high-resolution dynamically-downscaled climate projection information; monitor and analyze existing best practices for effectiveness and scale; obtain updated NOAA-Atlas 14 data for use statewide, update hazard maps and other information; assess vulnerable populations, assess current/projected land use, and identify existing tools and address gaps.

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. Examples include planning and zoning, building codes, capital improvement programs, open space preservation, and stormwater management regulations. Inclusion of tribal nations, environmental justice communities, and vulnerable populations. Integration of emergency management and public health planning, exercises and training.

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. Examples include acquisition, elevation, structural retrofits, storm shutters, and shatter-resistant glass. CRMA project types include flood diversion and storage (FDS) and green infrastructure (GI).

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. CRMA project types include aquifer storage and recovery (ASR) and floodplain and stream restoration (FSR). Continue and expand partnerships among government and non-government organizations for conservation/adaptation.

Education and Awareness Programs: Actions to inform and educate citizens, practitioners, public officials, and property owners about the hazards and potential ways to mitigate them. Such actions include outreach projects, real estate disclosure, hazard information centers, continuing professional education, and school-age and adult education programs. Develop knowledge for decision-making in cooperation with vulnerable communities and tribal nations. Integration of emergency management and public health planning, exercises and training.

A sixth type was determined by Minnesota HSEM for use in local Hazard Mitigation Plans:

Mitigation Preparedness and Response Support: Actions that protect people and property prior to, during and immediately after a disaster or hazard event. Services include warning systems and emergency response services. These activities are typically not considered mitigation, but support reduction of the effects of damaging events.

Mitigation Preparedness and Response Support actions are the primary role of local emergency managers; they prepare, train for and respond to events. Preparedness, response and recovery are components of the emergency management cycle, however most requested project types (generators and sirens) are considered preparedness activities, not mitigation, and as such are not eligible under the FEMA Hazard Mitigation Assistance. Emergency Protective Measures, Response and Recovery Planning, Response and Recovery Training, and Warning Systems and Power Supply continue to be included in local hazard mitigation plans as they are local priorities. This project type includes integration of emergency management and public health planning, exercises and training.

5.4 Mitigation, Climate Adaptation and Resilience Actions

The actions outlined in this section are intended to further specify how the state can reduce deaths, injuries, property losses and other losses due to natural hazards using the strategies in Section 5.3.
Traditional hazard mitigation actions and potential resources are listed under each natural hazard. The timeline for actions depends on funding availability and staffing resources. The potential resources are included in the Section 5.6. State policy recommendations and strategies are provided in Table 70.

Based on the state mitigation program history and FEMA eligibility requirements, planning measures are a high priority. New hazard research on coastal erosion and bluff erosion going on in the State is included in the Plan. The research is based in science with climate change projections. The hazard update process includes the identification of goals, strategies and actions to increase resilience.

2017 ICAT recommendations

ICAT's vision is of a resilient, economically thriving, and healthy Minnesota that is prepared for both short- and long-term climate changes and weather extremes. ICAT's goal is to encourage state agencies to identify and implement measures to assist the state and its communities in adapting to climate change. The team recognizes that building a resilient Minnesota in the face of a changing climate is a complex challenge. While Minnesota state agencies are carrying out a wide range of activities related to adaptation as described in this report, additional opportunities also exist for agencies to increase their work together on this issue.

The 2017 ICAT report resulted in six recommendations for the state to address climate adaptation. Workgroups formed to continue the efforts surrounding each recommendation. Each workgroup furthered its work on the goal and recommendation. The results of the workgroups are included as appropriate in the goal, strategy and action sections of this plan. The recommendations are not in priority order.

ICAT continues to further flesh out priority actions and work plans related to these six recommendations. The team recognizes that implementation of these recommendations involves staff and financial resources and depends upon increased collaboration among state agencies.

1. Build greater resilience to extreme precipitation:
    - Identify priority risks from current and projected extreme precipitation that threatens state and local infrastructure, environmental quality, health, ecosystems, public safety, and economic development.
    - Develop state agency action plans including specific steps to increase resiliency to these impacts and implement priority projects to address key vulnerabilities.
    - Integrate flood and flash flood resilience into existing plans and planning mechanisms.
        - Key agencies for implementation: Minnesota Board of Water and Soil Resources, Minnesota Division of Homeland Security and Emergency Management, Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, Minnesota Department of Agriculture, Minnesota Department of Transportation, Minnesota Department of Employment and Economic Development, Minnesota Environmental Quality Board, Metropolitan Council, Department of Military Affairs
2. Identify opportunities to strengthen the climate resilience and health of vulnerable populations of Minnesotans across state agency programs and through cooperation with local governments:
    - Protect health of vulnerable populations from climate impacts, including flooding, heat, reduced air quality (ozone, pollen, wildfire, dust), vector-borne disease, and drought.
    - Develop tools that individual communities at the county or city level can use to better increase the resilience of their vulnerable populations.
        - Key agencies for implementation: Minnesota Department of Health, Minnesota Pollution Control Agency, Metropolitan Council, Minnesota Division of Homeland Security and Emergency Management, Minnesota Environmental Quality Board
3. Increase focus on preserving natural and restored terrestrial and aquatic ecosystems and habitat to increase resilience of wildlife and native plants:

- Develop contiguous migration corridors for wildlife and native plants that will increase resilience of Minnesota’s natural and restored terrestrial and aquatic communities to climate change impacts, with priority focus on previously identified populations most at risk.
    - Key agencies for implementation: Minnesota Department of Natural Resources, Minnesota Board of Water and Soil Resources, Minnesota Pollution Control Agency, Minnesota Department of Military Affairs, Minnesota Environmental Quality Board

4. Strengthen agricultural water management efforts to increase resilience to climate change impacts:

- Mitigate increased amount and intensity of precipitation and drought, including through agronomic, soil conservation, soil health, irrigation, and drainage water management practices.
- Reduce erosion, promote infiltration, manage water retention and runoff, and improve resilience to drought through crop selection and management, and soil and water management of cropland.
    - Key agencies for implementation: Minnesota Department of Agriculture, Minnesota Board of Water and Soil Resources, Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, Minnesota Environmental Quality Board

5. Increase focus on managing climate impacts in cities, towns, and other population centers:

    - Reduce urban heat island and other climate impacts through approaches that will preserve and expand tree canopy, incorporate trees and vegetation into complete street design, encourage use of pervious and cool paving materials, use cool colored and green roofs, reduce generation of waste heat from buildings and vehicles, and incorporate energy efficiency, renewable energy, infrastructure upgrades, and principles of resiliency and sustainability in building design to strengthen our built environment.
        - Key agencies for implementation: Minnesota Pollution Control Agency (lead agency), Minnesota Department of Commerce, Minnesota Department of Transportation, Metropolitan Council, Minnesota Department of Natural Resources, Minnesota Environmental Quality Board

6. Strengthen our climate information infrastructure to support climate adaptation practices:

    - Enhance the state’s capacity to collect, analyze, share and communicate both measured and projected climate data at all scales to help ensure that the people, communities, and organizations in all regions of Minnesota can better plan for, respond to, and withstand the impacts of ongoing and anticipated climatic trends through implementing climate adaptation practices.
        - Key agencies for implementation: Minnesota Department of Natural Resources, Metropolitan Council, Minnesota Department of Health, Minnesota Pollution Control Agency, Minnesota Environmental Quality Board

Climate adaptation and resilience goals, strategies and actions included in the flooding hazard are the result of ICAT Recommendation #1: Increasing Resilience to Extreme Precipitation. There is overlap between traditional mitigation actions and the work of the ICAT #1 Resiliency Actions for Flooding. The Climate Adaptation/Resilience text has not been integrated to ensure all input to the process and intent is maintained. Future revisions of the state plan will integrate actions. The terms Mitigation, Resilience and Climate Adaptation actions can be used interchangeably and referred to as flooding actions.

State Policy Recommendations stem from ICAT #5: “Increase focus on managing climate impacts in cities, towns, and other population centers”. Adding Actions for the Built Environment could have been included in the extreme temperatures (heat) hazard because there are many actions the built environment field can do to reduce the impacts of extreme heat. However, many of the actions can be applied to all natural hazards, as the built environment is adversely affected by extreme weather.

In addition to the specific recommendations above, ICAT also recommends that the Minnesota state government accelerate the incorporation of climate adaptation into all aspects of state agency operations. This can be accomplished through a variety of methods, such as a Governor’s Executive Order, Legislative directive, commissioner-led agency operational orders, agency strategic planning processes, program budgeting and development, and staff training.

ICAT recognizes that the state government will not be able to fully achieve the complex and evolving goal of climate adaptation on its own. It will be necessary and important to build and nurture partnerships on climate adaptation between state government and federal, tribal, and local governments, higher educational institutions, the private sector, nonprofit organizations, community members, and other collaborators. As a vehicle for focusing this collaboration, ICAT recommends that the Minnesota state government engage in a comprehensive effort along with public and private partners to develop a multi-stakeholder statewide climate adaptation plan by 2020.

Funding Resources

Funding is available post-disaster as HMGP funds, or annually with the release of the non-disaster grants, PDM and FMA. Mitigation and other strategic planning documents are typically due for review on a set schedule: state mitigation plans every five years, local hazard mitigation plans every five years. Other planning documents may be created or updated dependent upon funding availability. With the goal of integrating climate change and adaptation into local hazard mitigation plans and the State Hazard Mitigation Plan, local jurisdictions and state agencies can utilize the increasing variety of mitigation project types to increase resilience.

Since the last plan was approved in March 2014, the State of Minnesota has received two Presidentially Declared Disasters (DR-4920 and DR-4390). These disasters have emphasized the vulnerabilities and obstacles the state faces in relation to natural hazards such as flooding, severe storms, straight-line winds and ice storms. In the 2008-2014 time period, there were 10 disasters. The multitude of these disasters has offered opportunities for the state to strengthen its mitigation capabilities through the availability of HMA funding. Federally approved and funded mitigation projects are being administered by the state through post-disaster HMGP funding and annual congressionally appropriated pre-disaster PDM and FMA program funding. However, we have utilized both of these programs to implement projects that address the state’s hazard mitigation goals and objectives meeting the priorities and criteria outlined in the mitigation strategy.

In addition to federal programs, several programs at the state level support the state’s goals and objectives, and are utilized in advancing mitigation statewide. The State Capability Assessment provides some of the programs and initiatives currently supporting mitigation in Minnesota. Further, this assessment demonstrates the success of the state’s mitigation programs administered by both federal and state agencies. Interagency projects funded through the Silver Jackets in the past five years have been very successful, as has partnering with the MN DNR FHM program on flood buyouts. Continued collaboration with agencies in the ICAT will further increase the resiliency of Minnesotans. MDH addresses climate change from a public health stand point, specifically addressing vulnerable populations. The 2014 MDH Climate Change Vulnerability Assessment identifies extreme heat events, air pollution, vector-borne disease, flooding and flash flooding and drought in its plan. MDH and HSEM have developed materials to help locals understand and address these hazards at the regional level.

Flood mitigation projects remain the highest priority in the state due to the high occurrence and high mitigation potential. Tornadoes and severe storm mitigation measures are also higher risk as demonstrated by the hazard analysis and risk assessment process, and while lives can be saved and damages can be reduced, not all damages can be completely mitigated. Depending upon the funding source - disaster or non-disaster - project priority is subject to an evaluation process. HMGP, PDM and FMA priorities are dependent on many factors, including causes of disaster (flooding vs wind storm) and congressional priorities. Generally, public education and various types of hazard or risk reduction training and education measures are also a high priority.

With each project evaluation, the benefit-cost ratio, feasibility, and environmental review issues are analyzed. Only projects that meet the criteria of being cost-beneficial, feasible and able to pass NEPA review are selected for further review and implementation. Based on the state’s past mitigation successes, the following discussion of high priority actions considers and explains how each activity contributes to the overall mitigation strategy of the state. The state aims to geographically disperse funds and maximize the number of people protected to ensure available funding is used responsibly. By including environmental benefits in certain circumstances in a BCA, mitigation projects can further increase resilience to the effects of certain hazards.

Mitigation Strategy and Action Tables

State policy recommendations and strategies are provided in Table 70. State Mitigation and climate adaptation actions, funding and resources, and timeline are outlined in Table 71 through **Error! Reference source not found.**, with the goal for each natural hazard in the title of each table.

Table 70. State Policy Recommendations- All Hazard

Strategy	State Mitigation & Climate Adaptation Actions	Funding and Resources
Data	1a Fund development of high-resolution dynamically downscaled climate projections (that replicate atmospheric conditions) with a web portal that makes output available for use by planners, architects, designers, and engineers for building and infrastructure design including energy and stormwater modeling.	Legislature, state agencies, other partners
	1a Extend funding for and access to data portals that include climate projection data as well as state asset and population vulnerability data in order for planners to easily access these data and maps. A relevant pilot tool is here: https://maps.umn.edu/climatehealthtool/	MDH, other state agencies, other partners
	Engagement with MN Geospatial Advisory Council to support 2019 (and forward) priorities. Priorities that will benefit future Jurisdictional HMPs include: statewide address points data, street centerline data, and parcel data (all publicly available and including a data standard) and an emergency management damage assessment data standard for rapid, post event damage assessment GPS field collection (see: http://www.mngeo.state.mn.us/councils/statewide/index.html)	MN Geospatial Advisory Council, MnGeo, state agencies, other partners
	Engagement with MN Geospatial Data community to develop a sustainable workflow to acquire and maintain essential state facility data in the Minnesota Geospatial Commons	MN Geospatial Advisory Council, MnGeo, state agencies, other partners
	Engagement with MN Geospatial Data community to develop a sustainable workflow to acquire and maintain MN critical facility data, including Minnesota State Owned Buildings.	MN Geospatial Advisory Council, MnGeo, state agencies, other partners
Local Planning and Regulations	1b Provide flexibility within the Minnesota Building Code for municipalities to adopt measures needed to increase resiliency for local climate conditions.	Legislature and/or DLI, then cities
	1c Adopt a Minnesota Stretch Code that includes measures to increase climate resiliency. (A stretch code is a locally mandated code or alternative compliance path that is more aggressive than base code, resulting in buildings that achieve higher energy savings.)	Legislature and/or DLI
	1d Explore opportunities to piggyback off an existing energy/resiliency revolving loan fund or otherwise meet the goals of a Green Bank to finance resilient energy and stormwater infrastructure projects and reduce the perception of risk for private investment.	State agencies or Legislature or local governments
	1e Incorporate climate resilience requirements and recommendations into the B3 Sustainable Building Guidelines, SB2030, and city sustainable building policies/ordinances, including consideration of scenario planning based on climate projections.	State agencies maybe Leg. Authorization; cities
	2a Provide increased funding specifically for resilient public infrastructure projects through bonding and grants.	Legislature, state agencies and LGUs

Strategy	State Mitigation & Climate Adaptation Actions	Funding and Resources
Structure and Infrastructure Projects	2b Encourage utilities or other partners to provide – and local projects to use – design assistance throughout Minnesota for modeling building energy / resilience / health (such as Energy Design Assistance through the Conservation Improvement Program), and to explore the use of climate projections for modeling scenarios.	State agencies through utilities
	2c Implement pilot projects that utilize more resilient standards and/or materials to demonstrate efficacy for local projects, with state agencies leading by example.	DLI, HSEM
	2d Work with the insurance industry and HSEM to develop solutions to the economic/structural disincentives that currently limit design and construction of more resilient buildings and infrastructure.	State agencies
	2e Fund evaluation of cost/payback for incorporating climate resiliency into new and remodeled buildings, with an initial focus on high-risk facilities such as hospitals and schools.	State agencies
	2f Work with PUC on adoption of tariff(s) to improve economic feasibility of grid interconnections with on-site storage and islanding during grid failure.	PUC and state agencies
Natural Systems Protection	3a Coordinate guidance provided by state agencies to reduce conflicting language.	State agencies
	Mitigate and improve resilience to increased amount and intensity of precipitation, and drought, through practices including agronomic, crop selection and management, soil conservation, soil health, irrigation, and drainage water management.	LGUs, state agencies
	Promote collective action between state agencies to address the stability of natural systems in the built environment by providing sufficient water storage, reducing volume, slowing velocity, and promoting practices to stabilize soils and maintain the diversity of native plant communities	State agencies
Education and Awareness	4a Provide more technical assistance to local governments about climate resilience including but not limited to: (a) model actions developed by Climate Smart Communities Program; (b) the need to design public facilities such as community centers and libraries with the capability to function as places of refuge/resilience hubs; (c) how the "heat island effect," exacerbated by climate change increases the need for adaptive measures by many communities, not just the Minneapolis/Saint Paul urban core; and (d) resilience benefits of on-site solar + storage.	State agencies & partners
	4b Provide more technical assistance/training for project professionals and trades about climate adaptation / resilience and incorporate into licensure CE courses and requirements as possible.	State agencies MPCA
	4c Expand the GreenStep Cities program – including its climate adaptation and community resilience best practice – to counties, towns, and other communities.	State agencies & partners. MPCA
	Educate and inform farmers and rural landowners on impacts of changing weather patterns and ways to mitigate impacts and increase resilience.	LGUs, state agencies

Table 71. Flood Goal: Reduce deaths, injuries, property loss, and economic disruption due to all types of flooding (riverine, flash, coastal, and dam/levee failure). ICAT Recommendation #1 Actions for Flooding (Flash, Riverine, Lakeland and Wetland)

Strategy	Mitigation, Resilience & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeframe
Data	*#1 Fund development and dissemination of dynamically downscaled climate projection data to enable local decision-making and education.*	LCCMR for funding, DNR Climatology, University of Minnesota and/or MDH for modeling. DNR, MDH, DOT etc. for outreach. Include in county HMP and other Plans	ongoing
	Complete FIRM data for all of MN counties: Current Status: 8 unmapped (neither paper or digital), 9 paper with no digital data. MN DNR in the process of getting GIS delineations for the remaining 70 counties. The MN DNR plan is to obtain funding from FEMA to digitize the 9 paper counties and then 8 unmapped counties. The 8 unmapped are mostly lake development and the Shoreland rules already require minimum elevations for development.	FEMA, DNR www.DNR.state.mn.us/waters/watermgmt_section/floodplain/access-flood-maps.html	ongoing
	Improve state owned and operated facility database to indicate structures located in floodplains.	MnGeo-GAC, Admin, HMGP & PDM planning	ongoing
State Policy	*#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.*	DNR, LGUs. MN DNR is working with state building code staff to update the rules and to adopt ASCE 24, which requires higher minimum elevations for critical facilities. MN DNR model ordinance already has some higher standard language for critical facilities. MN DNR can work with communities that would like additional higher standards.	ongoing
	#3 Adopt new statewide policies and revise existing ones to reduce stormwater runoff.	MPCA	ongoing
	#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.	MPCA	ongoing

Strategy	Mitigation, Resilience & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeframe
	#5 Establish resiliency standards for state bonding projects and increase capital investment in climate-adapted and resilient infrastructure throughout the state.	Most of the MN DNR FHM projects are designed to 100 Year +1 foot. Encourage the governor and legislature to prioritize and fund projects.	ongoing
	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.	HSEM, MPCA	ongoing
	Improve flood risk assessment methods and mapping.	Incorporate FEMA's RISK Map standards into work being done.	ongoing
	Fund partnership efforts to gather, maintain and disseminate current information about populations vulnerable to climate change impacts to better serve their needs.	MDH, MPCA	ongoing
	Integrate climate adaptation into watershed-based planning efforts through collaboration and agency support.	FEMA, MN DNR, BWSR, MPCA	ongoing
	State government establishes a goal and tracking system to increase resiliency to extreme precipitation.	FEMA, MPCA	ongoing
	Adopt new statewide policies that promote reuse of water.	MDH, MPCA	ongoing
Local Planning and Regulations	Planning, technical studies, training, adoption of ordinances and legislation, acquisition and use of equipment, establishing shelters, and encouraging participation in NFIP and CRS will be used to prevent or reduce risks to lives and property from flooding.	HMGP-Planning, PDM-Planning, FMA, BWSR - One Watershed One Plan	Ongoing, as required
Structure and Infrastructure Projects	Acquire/demolish, elevate or retrofit RL, SRL, substantially damaged properties and other flood prone properties	HMGP, FMA, PDM, MN DNR	Pre- and post-disaster
	Identify vulnerable state owned structures and critical infrastructure	MnGeo-GAC, Admin, HMGP & PDM planning	Ongoing
Natural Systems Protection	Stream corridor protection projects and restoration and soil erosion control projects will be used to prevent or reduce risks and increase the protection of natural resources from flooding.	Local, HMGP, PDM, MN DNR, BWSR, PFA, USACE, NRCS, FSA, MPCA	Ongoing, pre- and post-disaster

Strategy	Mitigation, Resilience & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeframe
	Mitigate and improve resilience to increased amount and intensity of precipitation through practices including agronomic, crop selection and management, soil conservation, soil health, irrigation, and drainage water management.	MDA, BWSR, NRCS, FSA, MPCA	Post-disaster, ongoing
Education and Awareness Programs	Utilize existing and promote public education campaigns (ex. Turn Around Don't Drown and FloodSmart.gov) Access to information will be used to raise public awareness of risks from flooding in order to prevent or reduce those risks.	HMGP 5%, MN DNR NFIP, Risk MAP, NWS, USGS	ongoing
	Educate and inform farmers and rural landowners on impacts of changing weather patterns and ways to mitigate impacts and increase resilience.	MDA, BWSR, NRCS, FSA, MPCA	ongoing
Mitigation Preparedness and Response Support	Technological improvements, warning systems, responder training, emergency response services, acquisition and use of equipment, and planning will provide emergency services to prevent or reduce the risks to lives and property from flooding.	HMGP and HMGP 5%,	Post-disaster, ongoing

Table 72. Tornado Goal: Reduce deaths, injuries, property loss, and economic disruption due to tornadoes

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state.	Funding and Resources	Timeframe
Data	Improve state owned and operated facility database	MnGeo-GAC, Admin, HMGP & PDM planning	Ongoing
Local Planning and Regulations	Adoption of ordinances and legislation, acquisition and use of equipment, planning, conducting technical training, studies, and retrofit or construction of safe rooms will be used to prevent or reduce risks to lives, property, and economic activity from tornadoes.	HMGP, PDM	Pre- and post-disaster, ongoing
Structure and Infrastructure Projects	Constructing safe rooms and storm shelters, and retrofits will be used to prevent or reduce risks to property from tornadoes.	HMGP, PDM	Post-disaster, annually
Education and Awareness Programs	Warning systems, IPAWS, public education, and access to information will be used to raise public awareness of risks from tornadoes in order to prevent or reduce those risks.	HMGP-5%, NWS, USGS	Ongoing, Pre- and post-disaster
Mitigation Preparedness and Response Support	Warning systems, technological improvements, responder training, planning, emergency response services, and acquisition and use of equipment will provide emergency services to prevent or reduce risks from tornadoes.	SHSP	Annually

Table 73. Wildfire Goal: Reduce deaths, injuries, property loss, natural resource and economic disruption due to wildfires (forest, prairie, grass, and peat bogs)

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeframe
Data	Map and Assess Vulnerability to Wildfire	DNR Firewise, USFS, HMGP-Planning, PDM-Planning	ongoing
	Improve state owned and operated facility database		Ongoing
Local Planning and Regulations	Enforcement of regulations, adoption of ordinances, technical studies, and planning will be used to prevent or reduce wild land fires and the risks they pose to lives, property, and the natural environment.	DNR Firewise, USFS, HMGP-Planning, PDM-Planning	Ongoing, as required
Structure and Infrastructure Projects	Vegetation management, defensible space, water treatment measures (for example: sprinklers) will be used to prevent or reduce the risk of wild land fires.	HMGP, PDM	Pre- and post-disaster, ongoing
Natural Systems Protection	Vegetation management, defensible space	DNR Firewise, USFS	
Education and Awareness Programs	Public education and access to information will be used to raise public awareness of risks from wild land fires in order to prevent or reduce those risks, specifically the Firewise program.	DNR Firewise, USFS	HMGP 5%
Mitigation Preparedness and Response Support	Planning, responder training, acquisition and use of equipment, evacuations, warning systems, technological improvements, and emergency response services will provide emergency services to prevent or reduce risks to lives and property from wild land fires.	SHSP	ongoing

Table 74. Windstorms Goal: Reduce deaths, injuries, property loss, and economic disruption due to windstorms

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeframe
Data	Improve state owned and operated facility database	MnGeo-GAC, Admin, HMGP & PDM planning	ongoing
Local Planning and Regulations	Planning, training, technical studies, acquisition and use of equipment, adoption of ordinances and legislation, and construction new or retrofit safe rooms will be used to prevent or reduce risks from windstorms to lives, property, and economic activity.	HMGP-5%, NWS, USGS	Post-disaster, annually
Structure and Infrastructure Projects	Constructing safe rooms and storm shelters, retrofitting, and vegetation management will be used to prevent or reduce risks to the protection of property from windstorms.	HMGP, PDM	Post-disaster, annually
Education and Awareness Programs	Public education, warning systems, and access to information will be used to raise public awareness of risks from windstorms in order to prevent or reduce those risks.	HMGP-5%, NWS	Ongoing, pre- and post-disaster
Mitigation Preparedness and Response Support	Purchase and install generator hook-ups and encourage local generator purchases for identified critical facilities that require back-up power.	County, city, HMGP 5%	Annually

Table 75. Extreme Temperature (Heat/Cold) Goal: Reduce deaths, injuries, and economic disruption due to extreme temperatures.

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeline
Data	None identified	NA	NA
Local Planning and Awareness	Reduce Urban Heat Island Effect. Increase tree plantings around buildings to shade parking lots and along public rights-of-way. Encourage installation of green roofs and cool roofing products that reflect sunlight and heat away from a building.	HMGP, PDM, DNR Urban Forestry	ongoing
	Planning and the acquisition and use of equipment will be used to prevent or reduce risks from extreme heat/cold.	HMGP-Planning, PDM-Planning, EMPG	Ongoing, as required
Structure and Infrastructure Projects	Acquisition and use of equipment to prevent or reduce risks to property and economic disruption from extreme heat/cold.	EMPG	Ongoing, as required
Education and Awareness Programs	Public education and access to information will be used to raise public awareness of the risks from extreme heat/cold in order to prevent or reduce those risks.	HMGP-5%, NWS, USGS	Ongoing, pre- and post-disaster
	Assist vulnerable populations. Organize outreach to vulnerable populations, establish and promote accessible heating or cooling centers in the community. Create a database to track those individuals at high risk of death, such as the elderly, homeless, etc.	HMGP-5%	ongoing
Mitigation Preparedness and Response Support	Purchase and install generator hook-ups and encourage local generator purchases for identified critical facilities that require back-up power.	County, city, HMGP 5%	ongoing
	Planning, responder training, warning systems, establishing shelters, and technological improvements will provide emergency services to prevent or reduce risks from extreme heat/cold.	EMPG	Ongoing, as required

Table 76. Winter Storms Goal: Reduce deaths, injuries, property loss, and economic disruption due to winter storms (blizzard, ice, and ice storm)

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeline
Data	None identified	NA	NA
Local Planning and Regulations	Acquisition and use of equipment, adoption and enforcement of ordinances and legislation, <u>planning</u>, <u>training</u>, and technical studies will be used to prevent or reduce risk to the protection of lives, property, and economic activity from the risks from severe winter storms.	HMGP-Planning, PDM-Planning, EMPG	Ongoing, as required
Structure and Infrastructure Projects	Acquisition and use of equipment and vegetation management will be used to prevent or reduce risks to property from the risks from severe winter storms.	MN DNR, USFS, MN DOT	Pre- and post-disaster, ongoing
	<u>Structural projects for critical infrastructure will be implemented</u> and maintained to <u>prevent or reduce risks from severe winter storms.</u>	HMGP, PDM	Pre- and post-disaster, ongoing
Education and Awareness Programs	Public education, warning systems, access to information, and outreach projects will be used to raise public awareness of the risks from severe winter storms in order to reduce those risks.	HMGP-5%, NWS, USGS	Ongoing, pre- and post-disaster
Mitigation Preparedness and Response Support	Acquisition and use of equipment, emergency response services, warning systems, technological improvements, planning, and responder training will provide emergency services to prevent or reduce risks from severe winter storms.	SHSP	Annually

Table 77. Lightning Goal: Reduce deaths, injuries, property losses, loss of services, and economic disruption due to lightning

Strategy	**Mitigation & Climate Adaptation Actions** Underlined actions indicate priority for state	**Funding and Resources**	**Timeline**
Data	None identified	NA	NA
Local Planning and Regulations	Planning, technical studies, acquisition and use of equipment, adoption of ordinances and legislation, and establishing shelters will be utilized to prevent or reduce the risks from lightning.	HMGP-Planning, PDM-Planning, EMPG	Ongoing, as required
Structure and Infrastructure Projects	<u>Retrofits and construction of safe rooms and storm shelters will be used to prevent or reduce the risks to property from lightning.</u>	HMGP, PDM	Ongoing, pre- and post-disaster
Education and Awareness Programs	Public education, outreach projects, and access to information will be used to raise public awareness of risks from lightning in order to prevent or reduce those risks.	HMGP-5%, NWS	Ongoing, pre- and post-disaster

Table 78. Hail Goal: Reduce deaths, injuries, property damage, and economic disruption due to hailstorms

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Time frame
Data	None identified	NA	NA
Local Planning and Regulations	Planning, technical studies, and adoption of ordinances and legislation will be used to prevent or reduce risks to life, property, and economic activity from hailstorms.	HMGP-Planning, PDM-Planning, EMPG	Ongoing, as required
Structure and Infrastructure Projects	Retrofit critical facilities and maintenance of existing structures will be used to prevent or reduce the risks from hailstorms.	HMGP, PDM	Ongoing, pre- and post-disaster
Education and Awareness Programs	Public education and access to information will be used to raise awareness of the risks of hailstorms in order to prevent or reduce those risks.	HMGP-5%, NWS, USGS	Ongoing, pre- and post-disaster
Mitigation Preparedness and Response Support	Warning systems, responder training, technological improvements, and planning will be used to provide emergency services to prevent or reduce the risks from hailstorms.	SHSP	Annually

Table 79. Dam/Levee Failure Goal: Reduce deaths, injuries, property loss, natural resource and economic disruption due to dam/levee failure.

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeline
Data	Map and Assess Vulnerability of Dams, Levees, and Low Head Dams	USACE, DNR, Silver Jackets	On-going
Local Planning and Regulations	Inundation mapping and Emergency Action Plans	Silver Jackets	On-going
Structure and Infrastructure Projects	Remove obsolete structures	DNR, USACE, FERC	On-going
Natural Systems Protection	Remove obsolete structures	DNR, USACE, FERC	On-going
Education and Awareness Programs	Increase dam/levee risk awareness	DNR, USACE, FERC, Silver Jackets, HMGP and HMGP 5% Initiative. National Dam Safety awareness day is May 31 annually.	On-going
Mitigation Preparedness and Response Support	Support response to dam/levee failure.	SHSP	Annually

Table 80. Drought Goal: Reduce economic loss and environmental impacts due to drought

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeline
Data	Assess vulnerability to drought risk	HMGP - planning, PDM-planning	Ongoing
Local Planning and Regulations	Planning, acquisition and use of equipment, and technical studies will be used to prevent or reduce risks from drought.	HMGP-Planning, PDM-Planning, USGS, NWS	Ongoing
	Monitor Drought Conditions U.S. Drought Monitor https://droughtmonitor.unl.edu/	USGS, NWS	Ongoing
	Plan for Drought Plan for future drought events: developing a drought emergency plan, develop criteria or triggers for drought-related actions, develop a drought communication plan and early warning system.	USDA, County SWCD, County and Cities, MPCA	Ongoing
Natural Resource Protection:	Planning and implementing watershed plans will be used to prevent or reduce risks from drought.	MN DNR	As funding allows
Structure and Infrastructure Projects	Retrofit Water Supply Systems	HMGP, PDM	Pre and post-disaster
	Water treatment measures will be used to prevent or reduce risks to property from drought.	MN DNR	As funding allows
Natural Systems Protection	Enhance Landscaping and Design Measures. Incorporate drought tolerant or xeriscape practices into landscape ordinances to reduce dependence on irrigation. Encourage drought-tolerant landscape design through measures such as: provide incentives for xeriscaping, using permeable driveways and surfaces to reduce runoff and promote groundwater recharge.	BWSR, USDA, County SWCD County, Cities, MPCA	As funding allows
Education and Awareness	Mitigate and improve resilience to drought on agricultural land through practices including agronomic, crop selection and management, soil conservation, soil health, irrigation, and drainage water management.	MDA, BWSR, NRCS	Ongoing
	Educate and inform farmers and rural landowners on impacts of changing weather patterns and ways to mitigate impacts and increase resilience.	MDA, BWSR, NRCS, FSA	Ongoing

Table 81. Coastal Erosion and Flooding Goal: Reduce deaths, injuries, property loss, and economic disruption due to coastal erosion and flooding of shoreline: caused primarily by flowing water or wave and/or wind action

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeframe
Data	Map and Assess Vulnerability to Erosion	HMGP, PDM, MN DNR, BWSR, USDA, NRCS, FSA, SWCDs, Silver Jackets	Ongoing, pre- and post-disaster
	Inventory data and research related to Northshore Coastal Erosion.	HMGP, PDM, MN DNR, BWSR, USDA-NRCS-FSA, SWCDs, Silver Jackets	Ongoing, pre- and post-disaster
	Develop data based tools to aid local SWCDs and Cities develop common guidelines for landowners Lake Superior's North Shore	HMGP, PDM, MN DNR, BWSR, USDA-NRCS-FSA, SWCDs, Silver Jackets	Ongoing, pre- and post-disaster
	Develop data based tools to aid local SWCDs and Cities develop common guidelines for landowners Lake Superior's North Shore	HMGP, PDM, MN DNR, BWSR, USDA-NRCS-FSA, SWCDs	Ongoing, pre- and post-disaster
	Improve state owned and operated facility database	MnGeo-GAC, Admin, HMGP & PDM planning	Ongoing
Local Planning and Regulations	Encourage locals to manage development and/or ag land use	HMGP, PDM, MN DNR, BWSR, USDA-NRCS-FSA, SWCDs	Ongoing, pre- and post-disaster
	Planning, technical studies, land use plans, adoption of setback ordinances, and adoption of building code	HMGP, PDM, MN DNR, BWSR, USDA-NRCS-FSA, SWCDs	Ongoing, pre- and post-disaster
	Promote site and building design standards	ICAT, LGUs, GreenStep Cities	Ongoing, pre- and post-disaster
Structure and Infrastructure Projects	Remove Existing Buildings and Infrastructure from Erosion Hazard Areas. Acquire/demolish or relocate at-risk buildings and infrastructure and enforce permanent restrictions on development after land and structure acquisition.	HMGP, PDM, MN DNR, USDA-NRCS-FSA	Ongoing, pre- and post-disaster
Natural Systems Protection	Stabilize Erosion Hazard Areas using best management practices	HMGP, PDM, MN DNR, BWSR, USDA, NRCS, FSA	Ongoing, pre- and post-disaster
Education and Awareness Programs	Increase Awareness of Erosion Hazards.	HMGP-5%, NWS, USGS, Silver Jackets, BWSR	Ongoing, pre- and post-disaster

Strategy	**Mitigation & Climate Adaptation Actions** Underlined actions indicate priority for state	Funding and Resources	Timeframe
	Educate and inform farmers and rural landowners on impacts of changing weather patterns and ways to mitigate impacts and increase resilience.	MDA, BWSR, NRCS, FSA	Ongoing, pre- and post-disaster
Emergency Services:	Planning to implement emergency services will be used to prevent or reduce risks from coastal erosion and flooding.	SHSP	Annually

Table 82. Erosion/Landslide/Mudslide Goal: Reduce deaths, injuries, property loss, and economic disruption due to hillside, coastal, bluff: caused primarily by oversaturation of soil. (Also see Coastal Erosion and Flooding)

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeframe
Data	Map and Assess Vulnerability to Landslides. Ongoing multi-agency workgroups at universities to map and inventory landslide information. MNDNR has limited information on bluffs and landslides on website.	HMGP, PDM, MN DNR, USDA, NRCS, FSA, SWCDs, Silver Jackets	Ongoing, Pre and post-disaster
	Improve state owned and operated facility database	Admin	Ongoing
Local Planning and Regulations	Manage Development in Landslide Hazard Areas	LGU's	Ongoing, Pre and post-disaster
Structure and Infrastructure Projects	Prevent Impacts to Roadways	MnDOT, Counties, Cities and Townships, B3-MSBG	Ongoing, Pre and post-disaster
	Remove Existing Buildings and Infrastructure from Landslide Hazard Areas	HMGP, PDM, MN DNR, USDA, NRCS, FSA	Ongoing, Pre and post-disaster
Natural Systems Protection	Stabilize Erosion Hazard Areas	HMGP, PDM, MN DNR, BWSR, USDA, NRCS, FSA	Ongoing, Pre and post-disaster
	Mitigate and improve resilience to increased amount and intensity of precipitation on agricultural land through practices including agronomic, crop selection and management, soil conservation, soil health, and drainage water management.	MDA, BWSR, NRCS, FSA	Ongoing, Pre and post-disaster
Education and Awareness Programs	Increase Awareness of Erosion Hazards	HMGP-5%, NWS, USGS, MPCA	Ongoing, Pre and post-disaster
	Educate and inform farmers and rural landowners on impacts of changing weather patterns and ways to mitigate impacts and increase resilience.	MDA, BWSR, NRCS, FSA	Ongoing, Pre and post-disaster

Table 83. Subsidence Goals: Reduce the threat to public health, property loss, and damages to structures and infrastructure due to sinkholes and karst

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeframe
Data	Map and Assess Vulnerability to Subsidence	HMGP, PDM, MN DNR, BWSR, USDA-NRCS-FSA, SWCDs	Ongoing
	Improve state owned and operated facility database	Admin	Ongoing
Local Planning and Regulations	Planning, technical studies, and building/development regulations will be used to prevent or reduce risks from sinkholes and karst.	HMGP, PDM, MN DNR, BWSR, USDA-NRCS-FSA, SWCDs	Ongoing, as required
Structure and Infrastructure Projects	Measures to reduce the volume of water passing into a sinkhole will be used in order to reduce financial loss, property damage, and threats to the public health and safety.	MN DNR, HMGP-5%	Pre-and post-disaster, ongoing
Education and Awareness Programs	Outreach efforts, public education and access to information will be employed to raise public awareness in order to reduce financial loss and risks to lives and property from subsidence.	MN DNR, BWSR, USDA-NRCS-FSA, SWCDs, HMGP-5%, NWS, USGS	Pre- and post-disaster, ongoing
Mitigation Preparedness and Response Support	Planning to implement emergency services will be used to prevent or reduce risks from subsidence.	SHSP	Annually

Table 84. Earthquake Goal: Limit property damage, economic loss, and disruptions in commercial and industrial activities in Minnesota due to earthquake

Strategy	Mitigation & Climate Adaptation Actions Underlined actions indicate priority for state	Funding and Resources	Timeframe
Data	None identified	NA	NA
Local Planning and Regulations	Planning, building code adoptions and management programs will be used to prevent or reduce risks to property and economic activity from earthquakes.	HMGP-Planning, PDM-Planning, EMPG	Ongoing, as required
Structure and Infrastructure Projects	Repair and retrofitting of structures will be used to prevent or reduce risks from earthquakes.	HMGP, PDM, EMPG	Ongoing, as required
Education and Awareness Programs	Public education and access to information will be used to raise awareness of the risks from earthquakes in order to prevent or reduce those risks.	HMGP-5%, NWS, USGS	Ongoing, pre- and post-disaster
Mitigation Preparedness and Response Support	Planning, responder training, alert systems, establishing shelters, and technological improvements will provide emergency services to prevent or reduce risks from earthquakes.	SHSP	Annually

5.5 Funding and Project Implementation

RL4. Did Element S10 (funding sources) address RL and SRL properties? [44 CFR §§201.4(c)(3)(iv) and 201.4(c)(3)(v)]
RL5. Did Element S13 (local and tribal, as applicable, capabilities) address RL and SRL properties? [44 CFR §§201.4(c)(3)(ii) and 201.4(c)(3)(v)]
RL6. Did Element S15 (prioritizing funding) address RL and SRL properties? [44 CFR §§201.4(c)(4)(iii) and 201.4(c)(3)(v)]

The State of Minnesota continues to experience many long-term successes with mitigation. During the last five years, multiple mitigation projects continue to coincide with the objectives and goals in the State Hazard Mitigation Plan to prevent and reduce the risks to lives, property, and economic activity from the effects of all hazards. Minnesota communities continue to benefit from mitigation activities through the implementation of actions in their local hazard mitigation plans, such as acquiring flood-damaged properties, relocating buildings out of flood- and erosion-prone areas, and building tornado safe rooms. These mitigation measures are making communities across the state safer and more secure against the negative impacts of natural and human-caused hazards. The State of Minnesota continues to effectively implement mitigation programs towards achieving its goals as identified in this plan.

To date, the state has successfully administered HMA funding to assist local governments in implementing mitigation measures that include planning, property acquisitions, electrical utility system and infrastructure retrofit/hardening, wildfire sprinklers, defensible space and wildfire-resistant construction materials, and community tornado safe-rooms. Disaster-specific events and associated disaster response and recovery measures can result in the prioritization of specific mitigation measures that contribute to the disaster recovery process. In Minnesota, this holds true in particular for acquisition or relocation of erosion-prone structures, severe repetitive loss and repetitive loss residential and commercial structures, as well as flood retrofitting projects for critical facilities and infrastructure. Hazard mitigation planning, and the acquisition of hazard-prone (flood and erosion) structures and community tornado safe rooms remain a priority. Since the previous plan there have been no new electrical utility retrofit or wildfire protection projects applications developed.

State and local community mitigation plans review the potential hazards in their respective jurisdictions and consider how those hazards may affect residents, infrastructure, services, business and industry. The planning then identifies the priorities and techniques to mitigate the effects from a particular hazard. Some techniques may be low-cost and can be done at the local level while other measures may need the assistance of state and federal funding.

The difference between the Minnesota All-Hazard Mitigation Plan and local (multi-jurisdictional) plans is that the state plan contains strategies on how to support hazard mitigation and climate adaptation planning and programs statewide. The goals do not recommend specific mitigation/adaptation techniques for a specific location but outline support for local governments with technical assistance and grant funding from state and federal agencies in regards to mitigation/adaptation planning and projects. The state program goals also point to how mitigation/adaptation planning needs a broad base of input from state agencies, regional development commissions, universities, the private sector and communities.

5.5.1 Hazard Mitigation Funding

Post-disaster Hazard Mitigation Grant Program (HMGP) funding in the state from DR-824-MN (1989) through DR-4390-MN (2018) has resulted in the following federal HMGP expenditures and obligations for:

- Acquisition projects ~$53 million: 1,128 structures
- Electric distribution over $19.9 million
- Mitigation planning over $3.3 million
- Drainage projects over $11.8 million
- Wildfire projects over $2.8 million

From 2000 through 2018, the State of Minnesota received over $11.6 million through non-disaster programs: Pre-Disaster Mitigation (PDM), both through the annual competitive program and Congressional Earmarks for the following:

- Local mitigation planning over $2.3 million
- Tribal mitigation planning ~ $180,000
- Acquisition projects ~$ 1.5 million (18 structures)
- Wildfire projects over $2.8 million

Flood Mitigation Assistance (FMA) included the following:

- Acquisition projects $2,747,000 (47 properties)
- Flood Planning $66,160

FEMA data is available here https://www.fema.gov/media-library/assets/documents/85455.

Applications for DR-4390-MN and 2018 PDM and FMA are currently open.

5.5.2 Priority Mitigation Actions

Each disaster has its own priority based on the natural hazard that caused damage and each congressional appropriated non-disaster grant (PDM and FMA) has its own priority list. The priority mitigation actions in Minnesota include the following:

- **Hazard Mitigation Planning:** Planning mitigation measures address multiple objectives in the state plan that largely impact the state goals for the prevention and reduction of risks to lives, property, and economic activity from the effects of all hazards. Hazard mitigation planning is a high priority mitigation measure for implementation in the State of Minnesota. Development of local plans offer communities the opportunity to identify and evaluate hazards; assess risk, probability, vulnerability, and impact; and develop mitigation goals and actions for the prevention and preparation of future hazard events. At the time of this plan update, of the 87 counties in the state, 63 have approved plans and the remaining 24 have FEMA planning grants or are in the process of applying for a FEMA grant. Two cities have single-jurisdiction plans (Saint Paul and Rochester) and the University of Minnesota has a plan that covers all of its campuses. Of the 11 tribal communities, eight have an approved plan, and three have planning grants.

FEMA Region V, the MnDNR NFIP Coordinator and HSEM coordinate with local jurisdictions that have Repetitive Loss (RL) and Severe Repetitive Loss (SRL) properties. Local mitigation plans must contain RL/SRL information in order to be eligible for property acquisition projects. HSEM also coordinates potential acquisitions with the MnDNR Flood Hazard Mitigation (FHM) Grant program to determine if funding is available for the local share. Funding for RL and SRL properties is determined at the time of application (either under HMGP or FMA).

- **Acquire flood prone (repetitively and severely repetitively damaged) properties and convert to open space/green space:** Nearly 1,600 property acquisitions have been funded due to catastrophic flooding in the state. Hazard Mitigation grant programs provide funding for acquisition/demolition of properties. Additional properties are being acquired through FHM funding by the Minnesota Department of Natural Resources.

Application of property acquisitions as a mitigation measure directly address objectives for river and flash flooding and infrastructure failure hazards. Acquisitions are an important way to reduce the risk of future disasters. Property acquisition is one of many forms of hazard mitigation and it is the most permanent form. It removes people from harm's way indefinitely, and reduces risks to property from riverine and flash flooding. It is a terrific opportunity for people who live on or near hazard areas to get to safer ground.

Flooding is the highest ranked hazard in this plan. Acquisition/demolition of RL or SRL properties and conversion to open-space is ranked as a high priority for mitigation measures in this plan. Property acquisitions of homes in special flood hazard areas will directly reduce deaths, injuries, property loss and economic disruption from future flooding events. Loss Avoidance Studies for the cities of Austin, Moorhead and Montevideo demonstrate that flood mitigation through property acquisition has had positive community impacts.

In the cities of Lake St. Croix Beach and Lakeland, several homes were relocated to higher elevations on their property. The properties were subdivided and the flood-prone sections were deeded to the local jurisdiction to be kept as open space.

- **Structures Elevation:** Structure elevation activities involve physically raising an existing structure to an elevation no lower than the Base Flood Elevation (BFE) plus one foot to reduce damages due to flooding. The structure is raised or moved so that a higher foundation can be installed. Continuous foundation walls or elevating on fill are common methods used in Minnesota. All utilities are raised above the regulatory flood protection elevation (RFPE) so they are not damaged by water. Any space below the elevated first floor must remain unoccupied. The foundation must be in compliance with American Society of Civil Engineers publication 24-14 and all FEMA criteria must be met. The net result is that the owner is required to carry a National Flood Insurance Program policy to protect against damage to the foundation only. This policy is a huge savings over having the entire structure insured.

Five homes have been elevated in Lake St. Croix Beach and two homes in Waterville.

- **Acquire hazard-prone (imminent threat) properties:** Acquisition/demolition and relocation of erosion prone properties are a newer project type in Minnesota. Due to changing intensity and duration of rainfall events, geologically young river systems are eroding. A home with a view is now a home with an encroaching riverbank threatening destruction. The criteria for FEMA erosion-prone buyouts is documenting a 20% rate of erosion per year, with 5-year danger of imminent threat.

Examples of acquiring and demolishing hazard-prone properties occur in Blue Earth County along the Le Sueur River. Extreme and sustained stream flows due to heavy rains undercut the toe of a river bluff and caused extreme rates of erosion, threatening four homes. In Red Lake Falls, the conditions resulted in the acquisition for two residential properties. In these cases, the homes were appraised at pre-disaster values so the owners are reimbursed at a higher value than the current state of their property.

In 2016 Lac Qui Parle County, a home on a farm started in the 1880s was relocated to a plot outside of the hazard area on the same property. The county took ownership of the land where the home had been located and maintains it as open space.

- **Construct or retrofit community tornado safe rooms:** Constructing safe rooms or retrofitting existing structures help prevent and reduce risks to life from tornadoes, thunderstorms and lightning, hailstorms, and windstorms. Community tornado safe rooms are for two-hour life safety protection from severe storms. Priority projects address areas with unprotected populations, such as campgrounds, parks, recreational areas, areas with insufficient protection, manufactured home parks, and places with vulnerable populations, such as schools, eldercare and day care centers, government facilities, and critical facilities.
- **Electrical utility retrofit/hardening:** Historically, Minnesota has experienced a great number of ice storms, windstorms, and severe weather events that cut off power for rural electric cooperative customers. HSEM has worked in partnership with rural electric cooperatives to fund projects to limit the loss of electrical services to Minnesotans. The state continues to fund projects that reduce the future risk of life safety and health, property loss and economic disruption effected by hazards from severe winter storms, wind storms, power failure, tornadoes, and lightning.
- **Wildfire mitigation:** The forested northeastern counties of Cook, Lake and St. Louis are the most wildfire-prone in the state. The state has funded many homeowners in the Arrowhead Region to implement wildfire mitigation projects. Counties assisted homeowners with defensible space activities, vegetation management, use of ignition-resistant building materials and installation of external wildfire sprinkler systems. DR-4131-MN funded a project in Lake County to replace standard roofing with wildfire resistant roofing. 55 structures were fitted with metal roofs.
- **Drainage and flood control mitigation:** The state and eligible communities throughout the state have worked in partnership to develop infrastructure mitigation projects. These mitigation projects are broadly defined as drainage and flood control type mitigation. Mitigation projects in development are intended to retrofit existing drainage systems to more effectively handle riverine and overland flooding, protect commercial, residential, and governmental facilities critical to the health, safety and welfare of the populations they serve, and reduce and/or eliminate the long-term risk to people and property from natural hazards. These projects involve storm sewer systems, sanitary sewer systems, potable water treatment facilities, wastewater

treatment, buildings, equipment and life safety. Proposed projects from local jurisdictions are the result of local mitigation plan updates, Risk MAP meetings and Public Assistance/Hazard Mitigation outreach. State agencies recognize potential projects through the vulnerability review process and review of capital improvement plans.

An example of a successful flood mitigation project is from the city of Worthington in Nobles County. Nobles County Ditch No. 12 (CD 12), also known as Okabena Creek, runs through many residential neighborhoods and by commercial facilities in the city of Worthington. CD-12 was originally built over 100 years ago and would flood during winter snowmelt and moderate to heavy rainfall events. In addition, the culvert that crosses under Interstate 90 was restricting flow due to its limited size and was causing flooding upstream in the city. The best option for the city was to construct a regional flood storage basin that would cover approximately ten acres and upsize several culverts on the creek. The implementation of these efforts reduced the impact of flooding to hundreds of homes and businesses.

An additional example of localized flood mitigation is from the city of Chanhassen. A home in the city was in immediate danger of damage due to erosion in a ravine. Stormwater from roads and a golf course drained down the ravine to a creek at its foot. The force of the water caused by extreme rainfalls was essentially causing a flash flood in the ravine. The pressure of the excess water eroded soils and uprooted established trees which accelerated the failure of the soils. The solution was to install a storm drain to capture water at the top of the ravine and direct it through a piping system to the creek below. The ravine was restored to its natural contours and vegetation installed to stabilize the soil for any residual rain that may come down the ravine. Through these mitigation measures risk to the home was eliminated.

The 5 Percent Initiative allows grantees under HMGP to use up to 5% of total HMGP grant funds for projects that are difficult to evaluate using FEMA-approved cost-effectiveness methodologies, but which otherwise meet HMGP eligibility requirements. To demonstrate cost-effectiveness under the 5 Percent Initiative, applicants and subapplicants must provide a narrative description of the project's cost-effectiveness in lieu of a standard FEMA benefit-cost analysis (BCA). Applicants cannot use the 5 Percent Initiative to fund mitigation activities that do not meet the required BCA threshold using a FEMA approved methodology.

- **Installation of early warning and communication systems:** Currently, the use of the 5% Initiative Program is being directed toward implementation of lightning prediction and warning systems. Coaches and referees of outdoor youth sports are trained to stop games and take shelter when lightning is in the area. The problem is that this method is a subjective call based on observation and interpretation of area-wide weather notifications. Systems have been developed to measure atmospheric conditions on site and send a uniform warning. This type of system was installed at the Bielenberg Sports Center and Eagle Valley Golf Course in Woodbury. The sports center may host up to several thousand players and spectators during various summer tournaments. The National Sports Center in Blaine is funded to install a lightning prediction and warning system in 2019. The center hosts the Schwan's Cup each July when more than 20,000 people may be on site at any one time.

5.5.3 Interagency Programs

River Gauges: River gauges are vitally important for the people of Minnesota, and are used in many ways, including flood warnings, river forecasts for flooding, navigation, water supply, and recreation, water quality monitoring, flood mitigation efforts, and more. Agencies at every level cooperate to install gauges, collect and disseminate data, and share information among all interested parties in order to provide valuable information to the public. This cooperation has resulted in a network of over 350 gauges across the state. The U.S. Geological Survey (USGS) and MN DNR both maintain over 100 gages each, while the Minnesota Pollution Control Agency (MPCA) and U.S. Army Corps of Engineers (USACE) have many gauges as well. Local watershed districts, cities and counties have also added gauges to the mix, and in many cases provide local funding to keep gauges maintained in their areas. Most of these gauges are equipped with NOAA satellite telemetry to provide real-time information to the National Weather Service (NWS), local officials, HSEM, DNR, USGS, and the USACE. The data is provided to the public on websites from all the entities, and utilized by the private sector for web-based and mobile applications.

The NWS utilizes these real-time reports as input to river models which provide forecasts of river levels and flow, which are used to issue flood warnings for the protection of life and property. The data is also used to calibrate and validate the river model. The USGS and MN DNR take manual measurements of river flow to calibrate the river height/flow relationships, which is vitally important to assure the accuracy of both the gauge readings and river forecasts. All of the agencies involved use gauge resources cooperatively in the mitigation, preparation, response, and recovery phases of emergency management. The river data is also vitally important to dam operators who use it to make decisions on power generation, navigation, flood control and recreational use.

Future development of the National Water Model by the NWS will require continued real-time river information for calibration and validation of the model information. The model is being designed to provide forecast information for any stream in the country, and thus methods to obtain "ground truth" for currently un-gaged streams will need to be pursued.

Minnesota Silver Jackets: The vision of the Minnesota Silver Jackets is to "Create, maintain, and integrate comprehensive partnerships to reduce risk associated with natural hazards in Minnesota." Their mission is "To establish an inter-agency working group with State and Federal Agencies to: 1) Enable the effective and efficient sharing of information, 2) Identify and promote the sharing and coordination of available agency resources, and 3) Promote natural hazard risk education and information dissemination throughout the state of Minnesota.

The Silver Jackets worked on and continues to implement a variety of mitigation projects and collaborate across agencies. The team has implemented/supported or is in the process of implementing/supporting a number of interagency projects, including:

- Participation in State Hazard Mitigation Planning update
- Catastrophic bluff erosion and collapse issue - science-based method to assist zoning officials with reducing risk.
- Emergency Action Plan Guide Book Workshops

- Flood Inundation Mapping projects
- River gauge system enhancement
- FEMA Risk MAP process support
- High Water Mark sign and outreach project
- Enhanced hydrologic data instrumentation in the Red River basin

The Silver Jackets signed-on as a NOAA Weather-Ready Nation Ambassador in October of 2015. The Weather-Ready Nation Ambassador initiative is an effort to formally recognize NOAA partners who are improving the nation's readiness against extreme weather, water, and climate events. As a Weather-Ready Nation Ambassador, the organization is committing to work with NOAA and other ambassadors to strengthen national resilience against extreme weather. The group receives and disseminates newsletters and other risk awareness publications.

MDH Climate and Health Program: HSEM and MDH collaborations have been ongoing since 2015. HSEM was invited to work with MDH on the Climate & Health Strategic Plan Objective *'Develop mechanisms to broaden engagement of, and increase coordination among, all stakeholders with the shared problem solving joint management of health and safety needs both prior and to and during incidents.'* The activity proposed under this objective was for the MDH Climate and Health Program to work in collaboration with key partners to evaluate best practices for incorporating climate change strategies into emergency preparedness plans and processes. After a thorough review of strategies, it was determined that the most useful strategy would be to develop resources for emergency managers and emergency preparedness professionals to help them better understand and utilize climate projection data for planning.

Emergency management professionals are on the front-lines of responding, but often lack access to and understanding of climate trend data to help plan for and minimize the risks of impacts from extreme weather events. As a way to help planners and decision-makers in emergency management and related fields understand regional climate trends, the Minnesota Climate & Health Program developed climate and health data profiles tailored to each of the six HSEM regions across the state. Work on this initiative began in 2017 and a release of the final regional profile reports occurred in August, 2018.

Each regional profile includes a description of climate change trends along with a summary of climate and population projection data. Additionally, each regional profile provides a local case study to illustrate the links between extreme weather and natural disasters and what climate projection data can (and can't) indicate for similar events in the future. This resource provides a framework for discussing projected local risks related to the changing climate and supports the development of climate adaptation strategies that protect community health and safety. All of the profile reports can be found at: http://www.health.state.mn.us/divs/climatechange/data.html.

Summary

Funding for mitigation planning and projects primarily comes from federal grants. However, the state continues to pursue additional funding sources to assist locals. Interagency collaboration for funding climate adaptation projects will have to continue to come from each agency as its mission dictates. There currently is no distinct funding for ICAT-specific projects. The newly-elected state government and its administration's direction will shape the future activities of the ICAT.

The following sections contain the Inventory of Programs, Policies, and Funding, which provides information on the funding source, description of the type of funding and monetary capabilities. Mitigation measures identified in local hazard mitigation plans reflect the reliance on federal and state resources to assist with these measures.

5.6 Inventory of Programs, Policies, and Funding

Requirement §201.4(c)(3)(iv): [The State mitigation strategy shall include an] identification of current and potential sources of Federal, State, local, or private funding to implement mitigation activities.

In addition to FEMA disaster and non-disaster hazard mitigation grants programs, there are funding sources available to the state and local jurisdictions for mitigation projects. A listing of federal, state and other agency resources is contained in this section. The site summary and agencies have all-hazard mitigation information and potential funding capabilities.

5.6.1 Federal Agencies and Programs

The Federal Agency Programs Reference document was updated for the 2018 Interagency Flood Risk Management Community of Practice Training Seminars (Silver Jackets) in 2018. The updated, consolidated information may be used as a catalyst to increase interagency coordination and collaboration among state and federal agencies and improve the combined efficiency and effectiveness of agencies. It lists federal agencies and their activities at times in the emergency management cycle: Preparation, Response, Mitigation and Recovery (Table 85). The entire document is in *Appendix Q – Federal Agency Programs Reference.*

Table 85. Available Assistance from Federal Agencies

Agency	Preparation	Response	Mitigation	Recovery
DOT	X	X	X	X
EPA	X	X	X	X
FEMA	X	X	X	X
HUD	X		X	X
NASA	X	X	X	X
NOAA NWS	X	X	X	X
NOAA OCM	X		X	X
NRCS			X	X
USACE	X	X	X	X
USFWS	X		X	X
USGS	X	X	X	X

Another valuable resource is Assistance Listings (previously known as the Catalog of Federal Domestic Assistance (CFDA)). It provides a full listing of all federal programs available to state and local governments; federally recognized Indian tribal governments; domestic public, quasi-public, and private profit and nonprofit organizations and institutions; specialized groups; and individuals.

The Mitigation Funding Sources document outlines the numerous federal hazard mitigation funding sources that are available to assist with state and local mitigation projects, ranging from planning and technical assistance to housing and infrastructure. A list of grant programs is provided in the summary table, beginning on the following page. Each program is denoted by the corresponding recovery support functions established under the National Disaster Recovery Framework (NDRF). The support functions are aimed at restoration and revitalization. Detailed descriptions of each grant program are also provided, including information about the program, eligibility requirements, cost sharing, and application timeframe.

The six support functions are:

Community Planning and Capacity Building support increases community recovery capacity and builds community planning resources needed to effectively plan for, manage, and implement disaster recovery activities.

Economic Recovery support focuses on sustaining and/or rebuilding businesses, employment, and tourism along with the development of economic opportunities that result in sustainable and economically resilient communities.

Health and Social Services support assists in the restoration of public health, health care, and social services networks to promote the resilience, health, and well-being of affected individuals and communities.

Housing support addresses post-disaster housing issues and coordinates the delivery of assistance resources activities to rehabilitate and reconstruct destroyed and damaged housing, when feasible, as well as the development of accessible temporary and permanent housing.

Infrastructure Systems support facilitates efforts by infrastructure owners to achieve recovery goals relating to public engineering of infrastructure systems. Infrastructure systems and services should be restored to support a viable, sustainable community and improve resilience to and protection from future hazards.

Natural and Cultural Resources support addresses long-term environmental and cultural resource recovery needs. This includes the protection of natural and cultural resources and historic properties through response and recovery actions to preserve, conserve, rehabilitate, and restore them in a way consistent with community priorities and in compliance with applicable laws (FEMA, 2012).

Program Name	Recovery Support Area(s)					
	Community Planning and Capacity Building	Economic Recovery	Health and Social Services	Housing	Infrastructure Systems	Natural and Cultural Resources
Flood Mitigation Assistance (FMA) Program[1]	●			●	●	●
Pre-Disaster Mitigation (PDM) Program[1]	●			●	●	●
Hazard Mitigation Grant Program (HMGP)[2]	●			●	●	●
National Flood Insurance Program (NFIP)[1]	●			●		
Public Assistance (PA) Program[2]			●		●	
Emergency Management Performance Grants (EMPG)[1]	●					

Program Name	Recovery Support Area(s)					
Community Assistance Program – State Support Service Element (CAP—SSSE) [1]	●					
Individuals and Households Program (IHP) [2]				●		
Environmental Planning and Historic Preservation (EHP) Program[2]						●
Flood Plain Management Services (FPMS) Program[1]	●				●	
Continuing Authorities Program[1]	●				●	●
Inspection of Completed Works Program[1]	●				●	
Rehabilitation and Inspection Program[1]					●	
Community Development Block Grant (CDBG) Program[3]	●	●	●	●	●	●
Department of Homeland Security Grant Program (HSGP) [1]	●					
Small Business Administration (SBA) Disaster Loan Program[2]		●		●		
National Earthquake Hazards Reduction Program (NEHRP) [1]	●					
Drought Assistance Programs[2]		●				●
FEMA Firefighter Assistance Grants[1]	●		●			
Forest Legacy Program (FLP) [1]	●					●
Federal Excess Personal Property Program[1]	●					●
Forest Stewardship Program[1]	●					●
Rural Housing Programs[3]			●	●		
Reimbursement for Firefighting on Federal Property[2]	●		●			
Fire Management Assistance Grant Program (FMAGP) [2]	●		●			●
USDA Farm Service Agency (FSA) Emergency Conservation Program (ECP) [2]		●				●
The Conservation Reserve Program (CRP) [1]						●
USDA Farm Service Agency (FSA) Tree Assistance Program (TAP) [2]		●				
USDA Water and Waste Disposal Programs[1]					●	
Internal Revenue Service (IRS) Disaster Assistance and Emergency Relief for Individuals and Businesses[2]		●		●		
National Oceanic and Atmospheric Administration Restoration Center Grants[2]						●
U.S. Department of Housing and Urban Development Programs[3]	●			●		
Department of Transportation/Federal Highway Administration Emergency Relief Program[2]					●	

Program Name	Recovery Support Area(s)					
Department of Commerce/Economic Development Authority (EDA) [1]	●	●			●	

[1] Pre-Declaration, [2] Post-Declaration, [3] Pre and Post

FEMA has developed a Hazard Mitigation & Resiliency Toolkit for FEMA Region V. It contains a collection of strategies and tools to assist local governments in promoting hazard mitigation through existing policies and programs, or to consider new opportunities to integrate resiliency within the community.

5.6.2 State Agencies and Programs

Examples of state agencies and programs include:

Minnesota Environmental Quality Bureau (EQB) - The Environmental Quality Board is made up of 9 agency heads and 8 citizen members. They provide leadership and coordination across agencies on priority environmental issues that are multi-jurisdictional, and multi-dimensional, as well as provide for opportunities for public access and engagement.

Climate Solutions and Economic Opportunities – An interagency and partner-collaboration report outlining a foundation for Minnesota's state climate action planning with identified co-benefits for climate change adaptation.

Minnesota Department of Administration – Provides services to government agencies: information technology, facilities and property management, graphic and geographic information systems data and software.

Minnesota Department of Agriculture (MDA) – Responsible for the regulation of pesticides, fertilizers, food safety and feed including emergency response, state Superfund authority and financial assistance for agricultural entities.

Agriculture Best Management Practices (AgBMP) Loan Program – The AgBMP Loan Program is a water quality program that provides low-interest loans to farmers, rural landowners, and agriculture supply businesses.

Minnesota Agricultural Water Quality Certification Program (MAWQCP) – Interagency effort by MDA, PCA, BWSR and DNR to promote water quality Best Management Practices on agricultural lands that promote resilient resources, reduce emissions and sequester carbon such as cover crops, no till, biomass plantings, riparian buffers and conservation cover. *Funding:* Supplemental grants of $5,000 or 75% Cost Share to install BMPs.

Minnesota Board of Water and Soil Resources (BWSR) – Assists local governments to manage and conserve water and soil resources.

Conservation Easements – Minnesota's premier conservation easement program on privately-owned lands. Administered by the USDA Natural Resources Conservation Service (NRCS). RIM-WRP combines the Reinvest In Minnesota (RIM) Reserve program, administered by the Minnesota Board of Water and Soil

Resources, with the Wetlands Reserve Program (WRP), administered by the USDA Natural Resources Conservation Service (NRCS). The RIM-WRP partnership is implemented by local Soil and Water Conservation Districts. Conservation easements on frequently flooded lands. *Funding:* The RIM-WRP Partnership restores wetlands and grasslands through permanent conservation easements on privately owned lands.

RIM Wetlands Conservation Easements – *Funding:* The RIM Wetlands program restores wetlands and grasslands through permanent conservation easements on privately-owned lands. BWSR has received this funding through the Outdoor Heritage Fund (from the Clean Water, Land and Legacy Amendment).

One Watershed, One Plan – BWSR's vision for One Watershed, One Plan is to align local water planning on major watershed boundaries with state strategies towards prioritized, targeted and measurable implementation plans – the next logical step in the evolution of water planning in Minnesota.

Minnesota Department of Commerce (COMM) – The Market Assurance Division in the Department of Commerce regulates insurance companies & agents, banks, and real estate. The Office of Energy Security within the Department of Commerce manages energy assistance funds and provides information and assistance to consumers and businesses on home improvements, financial assistance, renewable technologies, and utility regulations.

Energy Assistance Program – The Energy Assistance Program (EAP) helps pay home heating costs. Households with the lowest incomes and highest energy costs receive the greatest benefit. Households who are at or below 50% of the state median income are eligible. Size of grant is based on household size, income, fuel type and energy usage. Funds are available for renters or homeowners. *Funding:* Federally funded through U.S. Department of Human Services.

Local Energy Efficiency Program (LEEP) – Program providing local government's investment grade audits for energy projects.

Energy Audit & Renewable Feasibility Study Loan Program – *Funding:* 2- or 3-year low interest loan for local governments to complete energy or renewable studies.

Energy Savings Partnership (ESP) – *Funding:* Lease-purchase financing for energy projects at local governments through St Paul Port Authority; low interest rates and low minimum project cost.

Sustainability and Energy Efficiency Resources – Compendium of agency initiatives and sustainability resources for single and multifamily housing.

B3 Design Guidelines – Design guidelines for new buildings or renovations to meet sustainability goals for site, water, energy (SB2030), indoor environment, materials and waste that required for buildings that receive general obligation bond funds.

B3 / SB 2030 Energy Efficient Operations Manual – Web-based public building operations manual. B3 Sustainable Building SB 2030 – Progressive energy standard designed to significantly reduce the energy and carbon in Minnesota commercial, institutional and industrial buildings.

Zero Net Energy (ZNE) Schools Accelerator – MN ZNE School Roadmap to be used by schools to attain ZNE facility.

Minnesota Emergency Medical Services Regulatory Board – Provides leadership for emergency medical care for the people of Minnesota.

Minnesota Department of Employment and Economic Development (DEED) – Advances the economic vitality of Minnesota through trade and economic development, including the provision of employer and labor market information.

Public Facilities Authority (PFA) – Administers and oversees the financial management of three revolving loan funds and other programs that help local units of government construct facilities for clean water (including wastewater, stormwater and drinking water) and other kinds of essential public infrastructure projects. *Funding:* Provides municipal financing programs and expertise to help communities build public infrastructure that preserves the environment, protects public health, and promotes economic growth.

Small Cities Development Program – The purpose of this program is to provide decent housing, a suitable living environment and expanding economic opportunities, principally for persons of low-and-moderate income to cities and townships with populations under 50,000 and counties with populations under 200,000. *Funding:* Provides federal grants from the U.S. Department of Housing and Urban Development (HUD) to local units of government. State program rules subdivide grant funds into three general categories: Housing Grants, Project Facility Grants, and Comprehensive Grants. Public Facility Grants could include projects involving storm sewer projects and flood control projects.

Greater Minnesota Public Infrastructure Grant Program – Their purpose is to stimulate new economic development, and create or retain jobs in Greater Minnesota through public infrastructure investments. *Funding:* Provides grants to cities of up to 50% of the capital costs of the necessary public infrastructure, which expand or retain jobs in the area, increase the tax base, or which expand or create new economic development. Eligible projects include, but not limited to wastewater collection and treatment, drinking water, storm sewers, utility extensions, and streets.

Redevelopment Grant Program – The purpose of this program is to provide grants to assist development authorities with costs related to redeveloping blighted industrial, residential or commercial properties. *Funding:* Grants pay up to 50% of eligible redevelopment costs for a qualifying site, with a 50% local match. Grants can pay for land acquisition, demolition, infrastructure improvements, stabilizing unstable soils, ponding, environmental infrastructure, building construction, design and engineering and adaptive reuse of buildings.

Minnesota Environmental Quality Bureau (EQB) – The Environmental Quality Board is made up of 9 agency heads and 8 citizen members. They provide leadership and coordination across agencies on priority environmental issues that are multi-jurisdictional and multi-dimensional, and provide opportunities for public access and engagement.

Climate Solutions and Economic Opportunities – An interagency and partner-collaboration report outlining a foundation for Minnesota's state climate action planning.

Minnesota and Climate Change: Our Tomorrow Starts Today Report – 2014 interagency report that provides an overview of climate change impacts in Minnesota and how Minnesotans are responding.

Minnesota Management & Budget (MMB) – Expedites fiscal management during a state disaster and assists with funding issues when federal assistance is not provided.

Minnesota Department of Health (MDH) – Provides data on the past and current health status of the citizens of Minnesota and other information on protecting the public's health from numerous natural and human-caused disasters, including infectious diseases, extreme weather events, and chemical/radiological contamination.

MDH Climate and Health Program – The program provides webinars, trainings and communication materials to the public and stakeholders on the health impacts of climate change. The program publishes a monthly newsletter on climate and health with the latest research, events, and tools related to climate adaptation.

MN Climate and Health Profile Report – Summary of MN historic climate trends, future projections, and likely impacts of climate change on health of Minnesotans.

Extreme Heat Toolkit – Provides information to local governments and public health professionals about preparing for and responding to extreme heat events.

MN Climate Change Vulnerability Assessment – Provides communities with information about risks of climate change across MN counties and identifies how to prepare for climate hazards and how to protect vulnerable populations.

Planning for Climate & Health Impacts in Minnesota – The MDH Climate and Health Program developed Climate and health data profiles for each of the six Homeland Security and Emergency Management (HSEM) regions across the state. Each regional profile includes a description of climate change trends along with a summary of climate and population projection data. Additionally, each regional profile provides a local case study to illustrate the links between extreme weather and natural disasters and what climate projection data can (and can't) indicate for similar events in the future. This resource provides a framework for discussing projected local risks related to our changing climate and supports the development of climate adaptation strategies that protect community health and safety.

Health and Climate Change Training Module Series – Developed training modules on a wide range of MN climate change and health topics along with supporting materials available as a "train the trainer" resource.

MDH has a climate and health strategic plan that coordinates climate-related work across multiple programs and areas of disciplines within the department to protect the public's health from climate change impacts.

Minnesota's State Historic Preservation Office (SHPO) – Review and Compliance: The SHPO consults with federal and state government agencies to identify historic properties in government project areas and advise on ways to avoid or reduce adverse effects on those properties.

Minnesota Housing Finance Agency (MHFA) – Provides low- and moderate-incoming housing and resources.

Sustainability and Energy Efficiency Resources – Compendium of agency initiatives and sustainability resources for single and multifamily housing.

Minnesota Department of Human Services (DHS) – Provides health care, economic assistance, and other services for those in need.

Minnesota Department of Labor & Industry (DLI) – Assists with investigations when workers are injured, detects air contaminants caused by chemical or geological agents and assesses hazards. Statewide building codes and construction planning and inspection.

Metropolitan Council – Provides information on economic development and planning for anticipated growth in the seven county metro areas –Anoka, Carver, Dakota, Ramsey, Scott and Washington Counties.

Livable Communities Grant Program – The Metropolitan Council awards grants to participating communities in the seven-county metro area to help them, among other things, create development or redevelopment that demonstrates efficient and cost-effective use of land and infrastructure, a range of housing types and costs, commercial and community uses, walkable neighborhoods and easy access to transit and open space. *Funding:* Four different accounts to enable communities through the region to carry out their development plans, and leverage millions of dollars in private and public investment while providing jobs and business growth.

Regional Climate Vulnerability Assessment – This resource provides tools for communities, including an interactive Localized Flood Map Screening Tool and an Extreme Heat Map Tool. The webpage also includes story maps and other resources to assist metropolitan communities.

Resilience Plan Element – Web-based portion of the Local Planning Handbook that provides resources for resilience and climate-action planning to local communities, specifically tailored around comprehensive plans.

Minnesota Department of Natural Resources (MN DNR) – The Financial Assistance Directory provides summary level information on all of the Department of Natural Resources' financial assistance programs. The department offers a wide variety of financial assistance programs to cities, counties, townships, non-profits, schools, private individuals and others. Categories include:

- Aquatic Invasive Species
- Enforcement (snowmobile & OHV safety)
- Fire Protection Programs
- Forest management
- Gifts and donations
- Habitat improvement
- Recreation (general, trails, and water)
- Road Improvements
- Water

MN DNR Division of Ecological and Water Resources – Addresses the conservation of natural systems and the maintenance of biodiversity. Water education information is available on and discusses floodplain management, flood mitigation, drought/water supply, dam safety, flood warning, climatology, and lake and stream gaging.

Flood Hazard Mitigation Grant Assistance (FMA) – The FMA program is under the FEMA Hazard Mitigation Assistance grant programs. The program provides technical and financial assistance to local governmental units for conducting flood risk reduction studies and for planning and implementing flood risk reduction measures. *Funding:* A maximum of 50% of total eligible project costs up to $150,000 with grants more than $150,000 requiring approval by the Legislature.

Dam Safety Grants – Improves the safety and condition of publicly owned dams and water level control structures. *Funding:* Reimbursement of costs, up to 50% for repairs, up to 100% for removals. Grants ranged from $25,000 to $1,000,000.

Wetland Tax Exemption Program – Provides a financial incentive to maintain wetlands in their natural state and to promote an awareness of wetland values. *Funding:* Qualifying areas are exempt from property taxes that remain in effect as long as wetland meets the requirements set forth in the statutes.

Firewise in Minnesota **–** The Minnesota Firewise Program is administered by the MN DNR. Under this program the MN DNR helps to support community wildfire mitigation efforts by passing federal Fire Plan funds through to local communities as grants for various "on-the-ground" activities including homeowner, mitigation education, home site assessment, access improvement, and dry hydrants. It involves community groups including fire and emergency services, local schools, city staff (i.e. foresters, planners), and local interest groups. *Funding:* Grant request for 50:50 cost-share funding for assessment & planning, education & mitigation activities. Initial grant request may be for a small amount ($15,000) until Firewise Action Plan is developed. Second grants are available to implement additional actions.

Forest Stewardship – Provides technical advice and long-range forest management planning to interested landowners. All aspects of the program are voluntary. Plans are designed to meet landowner goals while maintaining the sustainability of the land. *Funding:* For the state's cost share program to help defer the costs of implementation of forest management activities. Must enroll forested lands into the Sustainable Forestry Incentive Act or 2c Managed Forest Land to be eligible for property tax relief programs.

Shade Tree Short Course – Provides information to communities on adapting forests to climate change.

Great Lakes Restoration Initiative *Funding:* Grants to help communities engage citizens in tree planting and maintenance in boulevards to help North Shore communities begin to adapt to climate change and stormwater management. Grants to 3 communities from $30,000-$35,000 and to the city of Duluth $175,000.

MN DNR State Climatology Office – The State Climatology Office exists to study and describe the climate of Minnesota. Each of its members concentrates its efforts on specific topical areas in which climate plays a significant role. As Minnesota’s climate information authority, the Climatology Office collects, manages, analyzes, and disseminates climate information in service to the citizens of Minnesota. It is funded by the State of Minnesota Department of Natural Resources, Division of Ecological and Water Resources.

Minnesota Pollution Control Agency (MPCA) – Provides pollution prevention and management information and regulation for Minnesota.

Clean Water Fund – This fund is established under the Federal Clean Water Act and state law to make loans for both point source (wastewater and stormwater) and nonpoint source water pollution control projects. The Public Finance Authority prepares an annual Intended Use Plan (IUP) based on a Project Priority List developed by the MPCA. The IUP describes the projects and activities eligible for funding during the state fiscal year. MPCA dollars mainly go to monitoring and watershed strategies and TMDLs. Strategies and reduction goals are developed to address water pollution problems including restoration and protection.

MN Clean Water Roadmap – Includes information on changing climate patterns (p.8): "It is essential to consider Minnesota's changing temperature and precipitation patterns as protection and restoration strategies are developed and as projects are implemented across the state."

Stormwater Program – Minnesota Pollution Control Agency (MPCA) is the delegated permitting authority for Minnesota of the U.S. Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES). Permits are required for most construction activities designed to limit polluted discharges and implement best management practices, including volume retention, and erosion and sediment control.

Stormwater Financial Assistance is available for public entities to expand or improve stormwater infrastructure. The Industrial Stormwater Best Management Practices Guidebook v1.1 contains best management practices and considerations for extreme weather events in Chapter 8. The Minnesota Stormwater Manual provides a wealth of information in a wiki format. The Manual contains Minimal Impact Design Standards with performance goals, credit calculations, design specification, and an ordinance guidance package. The Manual also contains Stormwater Infiltration Best Management Practices. Climate Benefits of Green Stormwater Infrastructure are explored. Rainwater/stormwater harvesting and reuse is encouraged and can be used for pollution and volume credits towards meeting permit requirements.

Surface Water Ambient (monitoring) – Provides data and information about the potential impacts of climate change on streamflow and water quality. That information, in turn, is ultimately used to inform planning, plans, practices, and projects which have hazard mitigation dimensions.

Watershed Program – MPCA staff work with local units of government in identifying water quality problems, developing restoration and protection strategies, managing funds for development of watershed restoration and protection strategies and total maximum daily loads (TMDL). Watershed project funding includes:

> Clean Water Partnership Loans – provides funds for implementing best management practices related to nonpoint source pollution to improve water quality in watersheds.
>
> Section 319 Grant Program – provides funds for nonpoint source BMP implementation, focusing on a small number of specific small watersheds.

Wastewater Program – This MPCA website contains information on permitting and regulations, engineering and technical information.

Wastewater Financial Assistance – This MPCA website offers multiple types of financial assistance and includes a factsheet on Flood guidance for wastewater treatment facilities

Interagency Climate Adaptation Team (ICAT) – The MPCA initiated and coordinates this collaboration of state agencies with the purpose of addressing climate change adaptation issues in the state. ICAT issued the 2017 Report: *Adapting to Climate Change in Minnesota* which includes five Statewide Climate Adaptation Indicators and six Recommendations for Action. Subsequently, ICAT formed six workgroups to obtain stakeholder input and identify ways to implement the recommendations. Other MPCA information related to mitigation: Preparing for homes and businesses for floods

Community Resilience – Compendium of resources and menu of strategies to help communities reduce risks from climate impacts, including for climate-vulnerable populations.

Minnesota GreenCorps – An AmeriCorps program that pairs members in host sites to preserve and protect Minnesota's environment, including solid waste, greenhouse gases (GHG), energy use and water reduction; increase community resilience, educate community members, etc.

Minnesota GreenStep Cities – A voluntary challenge, assistance and recognition program to help cities achieve their sustainability and quality-of-life goals. This free, continuous improvement program, managed by a public-private partnership, is based upon 29 best practices including the most recent one for Climate Adaptation and Community Resilience.

Minnesota Department of Public Safety (DPS) – Includes State Fire Marshal, Office of Communications, Office of Pipeline Safety Team, State Patrol, Office of Justice Programs, Bureau of Criminal Apprehension, Alcohol and Gambling, Enforcement and Office of Traffic Safety.

MN DPS Homeland Security and Emergency Management (HSEM) – MN HSEM is also housed under DPS. This site contains information and resources for emergency management in Minnesota.

Minnesota Recovers Task Force – Minnesota Recovers is the state's clearinghouse for all information about floods, tornadoes and other natural disasters that strike Minnesota communities. Information about federal, state and local government disaster-assistance efforts is available on this website. *Funding:* Application for community financial assistance is available. Depending upon disaster, different types of funding become available. Flood-Control Grants, Small Cities Development Program and Public Facilities Authority funding information is available here.

Minnesota Office of the State Archaeologist – Conducts research into the prehistoric and historic archaeology of Minnesota.

Minnesota State Colleges and Universities – Provides information about Minnesota State universities and colleges.

Minnesota Department of Transportation – Works on comprehensive transportation issues in Minnesota. Their Sustainability webpage includes links to greenhouse gas reduction, climate resilience, solar, electric vehicles and other initiatives.

Climate resilience

Statewide Extreme Flood Vulnerability Analysis: MN DOT is currently developing a process for evaluating flood risk to MN DOT bridges, large culverts, and pipes. Studying the performance of infrastructure under predicted extreme events will help MN DOT assess the impacts of climate changes to plan, design, build, and maintain assets for resilience. This project is estimated to be complete in 2020.

Climate Vulnerability Pilot: In 2014, as part of a FHWA pilot program in 19 states, MN DOT completed a climate vulnerability pilot study examining the effects of climate hazards on MN DOT assets in District 1 and District 6. The project developed a decision-making process to determine the vulnerability of a corridor of trunk highway based on a weighted score of three subsets of metrics (exposure, sensitivity, and adaptive capacity). The results of the pilot study established a framework for assessing vulnerability of statewide MN DOT assets and adaptation measures.

University of Minnesota – The University of Minnesota's mission of education, research, and public engagement; its academic scope; and its statewide presence are marks of distinction and position UMN well to address the critical problems of this new century.

5.6.3 Climate Adaptation Resources

Climate adaptation resources in Minnesota include:

Climate Resilience Toolkit: https://toolkit.climate.gov/ The U.S. Climate Resilience Toolkit is a website designed to help people find and use tools, information, and subject matter expertise to build climate resilience. The Toolkit offers information from all across the U.S. federal government in one easy-to-use location. The goal is to improve people's ability to understand and manage their climate-related risks and opportunities, and to help them make their communities and businesses more resilient to extreme events. This inter-agency initiative operates under the auspices of the United States Global Change Research Program. The site is managed by NOAA's Climate Program Office and is hosted by NOAA's National Centers for Environmental Information.

Adaptation Clearinghouse: http://www.adaptationclearinghouse.org/ The Adaptation Clearinghouse seeks to assist policymakers, resource managers, academics, and others who are working to help communities adapt to climate change. Content in the Adaptation Clearinghouse is focused on the resources that help policymakers at all levels of governments reduce or avoid the impacts of climate change to communities in the United States. The Adaptation Clearinghouse tends to focus on climate change impacts that adversely affect people and the built environment. Content focal areas include the water, coastal, transportation, infrastructure and public health sectors, and adaptation planning, policies, laws, and governance. Resources that fall within these areas receive priority and are the most likely to be published in the Adaptation Clearinghouse.

Climate Change Resource Center: https://www.fs.usda.gov/ccrc/ The Climate Change Resource Center (CCRC) is a web-based, national platform that connects land managers and decision makers with useable science to address climate change in natural resources planning and management.

The CCRC provides information about climate change impacts on forests and other ecosystems, and approaches to adaptation and mitigation in forests and grasslands. The website compiles and creates educational resources, climate change and carbon tools, video presentations, literature, and briefings on management-relevant topics, ranging from basic climate change information to details on specific management responses. The CCRC is supported by the US Forest Service.

The main components of the CCRC are:

- Educational modules and other educational resources for managers
- Climate change topic pages
- Climate change adaptation and mitigation tools
- Adaptation examples
- Research library

Climate Adaptation Knowledge Exchange (CAKE): https://www.cakex.org/ The Climate Adaptation Knowledge Exchange (CAKE) is managed by EcoAdapt. It aims to build a shared knowledge base for managing natural and built systems in the face of rapid climate change. It is intended to help build an innovative community of practice. It consists principally of four interlinked components: case studies, virtual library, directory and tools. It also houses community forums for the discussion of current issues in climate adaptation.

Interagency Climate Adaptation Team (ICAT): Select ICAT workgroups developed resource documents based on their work.

- The *Built Environment Workgroup* aims to increase focus on managing climate impacts in cities, towns, and other population centers, and developed Minnesota Agency Resources for Local Governments Related to Climate Adaptation. Reduce urban heat island and other climate impacts through approaches that will preserve and expand tree canopy, incorporate trees and vegetation into complete street design, encourage use of pervious and cool paving materials, use cool colored and green roofs, reduce generation of waste heat from buildings and vehicles, and incorporate energy efficiency, renewable energy, infrastructure upgrades, and principles of resiliency and sustainability in building design to strengthen our built environment.
- The *Habitat Resiliency Workgroup* developed an Inventory of Existing Habitat Resilience Tools, a summary of tools from state, federal, NGOs and international agencies. The tools include a combination of website resources intended to guide resiliency planning, program planning for specific conservation programs that include the topic of resiliency, agency climate adaptation and mitigation directives, resilient landscape plans and related resources. The also group developed an Inventory of Existing Habitat Management Networks. Planning and implementing habitat resilience often requires interdisciplinary collaboration. Here they provide an inventory of habitat management networks operating within Minnesota. If ICAT were to convene a habitat resilience network, it could look to these networks as potential partners. Furthermore, this inventory of networks also demonstrates various models of functioning habitat groups within the state.

5.6.4 Other Organizations

Other organizations that are available to assist the state include:

American Red Cross – Provides relief to victims of disasters and help people prevent, prepare for, and respond to emergencies.

American Water Works Association – Provides information on safe water resources.

League of Minnesota Cities – A membership organization dedicated to promoting excellence in local government. The League serves its more than 800 member cities through advocacy, education and training, policy development, risk management, and other services.

Association of Minnesota Counties – A broad range of services to its members, including education, communications, and intergovernmental relations. AMC works closely with the legislative and administrative branches of government in seeing that legislation and policies favorable to counties are enacted.

Association of State Dam Safety Officials – General Information about dams and dam safety in the US.

Mid-America Earthquake Center (MAE) – One of three national earthquake engineering research centers established by the National Science Foundation.

Minnesota Geological Survey (MGS) – The University outreach center for the science and technology of earth resources in Minnesota.

Minnesota Association of Watershed Districts (MAWD) – Provides educational opportunities, information and training for watershed district managers and staff through yearly tours, meetings and quarterly newsletters.

Minnesota Association of Soil and Water Conservation Districts (MASWCD) – Provides voluntary, incentive driven approaches to landowners for better soil and cleaner water. Provides private landowners with technical assistance to implement a wide variety of conservation practices.

National Association of Counties (NACo) – NACo is the only nation-wide organization representing county governments.

Minnesota Natural Resource Conservation Service – Locally based NRCS staff work directly with farmers, ranchers, and others, to provide technical and financial conservation assistance.

National Drought Mitigation Center – Information on drought preparation and risk management.

National Emergency Management Association (NEMA) – NEMA is the professional association of state, pacific, and Caribbean insular state emergency management directors.

Natural Hazard Mitigation Association – NHMA is an association for those in the hazard mitigation profession by offering workshop and brining expertise and experience to organizations, communities or regions with mitigation planning, training, outreach and implementation.

Association of Minnesota Emergency Managers (AMEM) – AMEM is the professional association of emergency managers in Minnesota.

National Energy Foundation – This is a site for kids, parents and teachers, with a focus on water conservation in the home.

National Fire Protection Association (NFPA) – Provides scientifically-based fire codes and standards, research, training, and education.

National Lightning Safety Institute – Independent, non-profit consulting, education and research organization focusing on lightning safety.

Natural Hazards Center at UC Boulder – Clearinghouse for natural hazards information. Publishes the Natural Hazards Observer.

Societal Aspects of Weather-Injury and Damage Statistics – Contains societal impact data for weather related disasters.

The Disaster Center – Provides news and information on current disasters, and the emergency management field.

The Disaster Research Center (University of Delaware) – Research center for the preparation and mitigation of natural and technological disaster for groups, organizations and communities.

The Tornado Project – Offers tornado books, posters, and videos.

United Nations International Strategy for Disaster Reduction – Increase public awareness of hazard and risk issues for the reduction of disasters in modern societies, motivate public administration policies and measures to reduce risks, and improve access of science and technology for risk reduction in local communities.

University of Wisconsin Disaster Management Center – The center's goal is to help improve the emergency management performance of non-governmental organizations, local and national governments, and international organizations, through a comprehensive professional development program in disaster management.

5.7 State Capability Assessment

S12. Does the plan discuss the evaluation of the state's hazard management policies, programs, capabilities, and funding sources to mitigate the hazards identified in the risk assessment? [44 CFR §201.4(c)(3)(ii)]

The state of Minnesota has the legal authority to engage in pre- and post-disaster mitigation activities via federal programs. MN HSEM is continually pursuing ways to improve programs, plans and policies for hazard mitigation to become incorporated into other types of planning, programs and policies. The Minnesota Recovers Task Force (MRTF) is a group of federal, state and local agencies working together to prioritize and coordinate the disaster recovery efforts by its member agencies. The State Hazard Mitigation Officer (SHMO) coordinates mitigation outreach and prioritizes funding for mitigation projects with this task force, with the goal of building long-term disaster resilience into communities. Continued coordination and integration of planning and hazard mitigation make the state of Minnesota more disaster resistant. The Minnesota Silver Jackets brings state and federal agencies together to advise the SHMO on natural hazards, collaborate on resource coordination, and to participate in joint projects aimed towards making Minnesota more disaster-resilient on the local level.

An evaluation of federal and state programs indicates the successes of mitigation efforts. However, much more can be done to integrate mitigation into existing planning efforts. The following is an assessment of existing programs, projects and policies that should be pursued to further increase mitigation efforts and results. Contribution to and participation in existing initiatives and coordinated efforts will strengthen mitigation planning at the state and local level and will continue to integrate hazard mitigation planning at all levels.

5.7.1 National Flood Insurance Program (NFIP)

The Floodplain Management Unit with the MN DNR, Division of Ecological and Water Resources oversees the administration of the state Floodplain Management Program by promoting and ensuring sound land use development in floodplain areas in order to promote the health and safety of the public, minimize loss of life, and reduce economic losses caused by flood damages. This unit also exists to oversee and administer the National Flood Insurance Program (NFIP) for the state of Minnesota. See the NFIP Community Status Book at https://www.fema.gov/cis/MN.html for current list of communities that participate in the program.

The goals of the Community Rating System (CRS) are to reduce flood losses, to facilitate accurate insurance rating, and to promote the awareness of flood insurance. The CRS was developed to provide incentives for communities to go beyond the minimum floodplain management requirements to develop extra measures to provide protection from flooding. Participation in CRS is voluntary and the incentives are in the form of premium discounts. Since the previous plan in March of 2014, three communities joined the CRS. Table 86 includes the CRS participants in Minnesota.

Table 86. Minnesota Participants in the Community Rating System (CRS)

Community Name	CRS Entry Date	Current Effective Date	Current Class	% Discount For SFHA	% Discount For Non-SFHA
Austin, City of	10/1/91	5/1/08	5	25	10
Carver, City of	05/1/16	05/1/16	7	15	5
Granite Falls, City of	5/1/13	5/1/13	5	25	10
Golden Valley, City of	10/1/14	10/1/14	7	15	5
Lake St. Croix Beach, City of	10/1/95	10/1/11	6	20	10
Montevideo, City of	5/1/10	5/1/10	5	25	10
Moorhead, City of	5/1/10	5/1/10	7	15	5
Mower County	10/1/95	4/1/00	8	10	5
Rochester, City of	10/1/91	10/1/96	10	0	0
West St. Paul, City of	10/1/91	10/1/96	10	0	0
Wilkin County	05/1/17	05/1/17	9	0	0

Source: Community Rating System, April 2018

State mitigation planners will continue to encourage local communities to update their mitigation plans, and prioritize mitigation actions according to jurisdictional risks. HSEM will continue to promote participation in the NFIP, CRS and identify funding for the local share for acquisitions of repetitively damaged homes.

NFIP mapping is an important tool in determining vulnerability to floods for mitigation planning and projects. An important advancement is digital NFIP rate maps. Converting the maps from paper copies affords for greater degrees of accuracy and convenience. Community participation in the mapping processes results in digital maps with a higher degree of accuracy. MN DNR's Floodplain Management Unit coordinates the map revision process between FEMA and local jurisdictions. As of December 2018, 55 counties have preliminary or approved Digital Flood Insurance Rate Maps (DFIRMs). The MN DNR Floodplain Management website includes all of the FEMA flood mapping products available or in progress for each county.

5.7.2 FEMA Risk MAP

The vision for FEMA Risk MAP (*Risk Mapping, Assessment and Planning*) is to deliver quality data that increases public awareness and leads to action that reduces risk to life and property. Risk MAP builds on flood hazard data and maps produced during the Flood Map Modernization program. Risk MAP goes beyond providing the regulatory rate maps required for the NFIP program. Communities are asked to review areas of high flood risk during Risk MAP meetings then develop potential mitigation projects.

The meetings are coordinated by the MN DNR's Floodplain Management Unit with input on hazard mitigation from HSEM mitigation staff. Representatives from the U. S. Army Corp of Engineers and National Weather Service participate as part of the MN Silver Jackets local outreach. County Emergency Management directors are invited to attend these meeting since the potential projects and participants should be integrated into the local multi-jurisdictional mitigation plan processes. The estimated FEMA Map Modernization status in Minnesota current schedule is available here.

The purpose of Risk MAP is to collaborate with tribal, state, and local entities to deliver quality flood data that increases public awareness and leads to action that reduces risk to life and property from flood hazards. The previous map updating process was called Map Modernization. It was a five-year effort from 2003-2008 to modernize Flood Insurance Rate Maps and make them digital for the majority of the population in Minnesota. This was done on a countywide basis without much up-front coordination and scoping with local stakeholders.

Risk MAP is the newer method, and uses a collaborative approach at a watershed scale to improve public awareness of flood risk and provide quality data. "Discovery" is the first phase in FEMA's Risk MAP Program, and creates an opportunity to take a holistic view of the watershed. Discovery has an important emphasis on developing partnerships, combining resources, and sharing flood risk information to develop a vision for the watershed. The process allows local communities to determine the need for FEMA flood risk products that can potentially be scoped through Risk MAP. Some of the flood risk products can be regulatory, such as Flood Insurance Rate Maps and Flood Insurances Studies, or non-regulatory, such as depth grids, water surface elevation grids, and Hazus risk analysis.

Another important aspect of the Discovery process is discussing the importance of mitigating flood risk. HSEM has participated in Discovery meetings by educating local officials about hazard mitigation programs with the goal of building solutions to their flood hazard risks. Silver Jackets members often attend these meetings to offer their subject matter expertise, historical project knowledge of area and additional programmatic availability.

5.7.3 Flood Hazard Mitigation (FHM)

The Flood Hazard Mitigation Grant Assistance Program was created by the Minnesota Legislature in 1987 to provide technical and financial assistance to local government units for reducing the damaging effects of floods. Under this program the state can make cost-share grants to local units of government for up to 50% of the total cost of a project. The goal of existing regulations and programs for flood damage reduction is to minimize the threat to life and property from flooding. The efforts of local governments to enforce their zoning ordinances, to sponsor flood mitigation public improvement projects, and to acquire or relocate flood-prone buildings have significantly helped to reduce risk to lives and flood damages across the state. See Success Story in Section 6 for more information on the state Flood Hazard Mitigation Grant program.

5.7.4 Firewise

The Minnesota Firewise program, administered by MnDNR, works with local communities by passing federal Fire Plan funds through to local communities as grants for various on-the-ground activities including local Firewise plans, mitigation education, home site assessment, access improvement, and dry hydrants. Firewise does not provide funds to make structures fire resistant.

Community Wildfire Protection Plans (CWPP) are the foundation to make structures in Wildland Urban Interface (WUIs) areas more resilient to wildfires. Regional Firewise coordinators work with county emergency management directors, fire departments, local elected officials, federal agencies and community members to develop a CWPP. The plans cover the development and enforcement of building codes, establishing defensible space around structures, and other measures. CWPPs are used to determine funding for Firewise eligible projects.

Pre-Disaster Mitigation (PDM) and Hazard Mitigation Grant Program (HMGP) funds have been used to install wildfire sprinkler systems to protect structures from wildfires. Several hundred sprinkler systems have been installed in Cook, Lake, and St. Louis counties. Wildfire sprinkler systems combined with defensible space have proven to be effective mitigation techniques. Water is sprayed over structures and surrounding property to increase the moisture content. Wildfires burn around treated areas and the sprinklers extinguish any embers that may fly into the treated area. The net effect is that structures sustain only minimal damage at worst and the workload for fire crews can be focused on controlling the fire instead of trying to save structures. Wildfire sprinklers systems may even inhibit the spread of fire over larger areas. The technology has been changing to accommodate a variety of water source conditions. County emergency managers in wildfire-prone areas are aware of the Firewise program depending on the county's vulnerability to wildfire.

5.7.5 MDH Climate and Health Program

Climate and health data profiles were developed specifically for each of the six Homeland Security and Emergency Management (HSEM) regions across the state. Each regional profile includes a description of climate change trends along with a summary of climate and population projection data. Additionally, each regional profile provides a local case study to illustrate the links between extreme weather and natural disasters and what climate projection data can (and can't) indicate for similar events in the future. This resource provides a framework for discussing projected local risks related to our changing climate and supports the development of climate adaptation strategies that protect community health and safety. Evaluations survey have been developed to assess each of the presentations.

Additional information about the program follows. HSEM will continue to work with MDH on climate and health, mitigation, resilience and education.

The Minnesota Climate & Health Program at the Minnesota Department of Health (MDH) improves our state's and partners' ability to protect the public's health and prevent further harms from climate change through implementing the following strategies to further climate change adaptation and mitigation:

- **Educate:** Resonate with the hearts and minds of the public and decision-makers to build a culture of health and climate action. The Program provides webinars, trainings and communication materials to the public and stakeholders on the health impacts of climate change. The program publishes a monthly newsletter on climate and health with the latest research, events, and tools related to climate adaptation.
- **Research:** Conduct credible, rigorous and innovative research to facilitate implementation of evidence-based adaptation strategies. The program has researched the most likely health impacts of climate change now and into the future, sharing this information publicly through the MN Climate and Health Profile Report. The program developed a methodology to determine risk of contamination to drinking water due to possible future increased precipitation. Additionally, the program has been a leader in promoting the use of climate projection data to better understand the risks and vulnerabilities to climate change.
- **Build Capacity:** Provide technical assistance, tools and products to expand and accelerate health and climate solutions. The program has developed a significant number of tools to help planners and emergency management and preparedness professionals adapt to and mitigate climate change, including the Minnesota Extreme Heat Toolkit, the MN Climate Change Vulnerability Assessment, and a series of six HSEM profile reports for Planning for Climate & Health Impacts in Minnesota.

MDH has a climate and health strategic plan that coordinates climate-related work across multiple programs and areas of disciplines within the department to protect the public's health from climate change impacts.

5.7.6 Minnesota Recovers Task Force

The Minnesota Recovers Task Force (MRTF) formed in response to the Great Flood of 1993, when the Mississippi and Missouri Rivers and their tributaries overflowed, causing one of the most costly and devastating floods in the history of the United States. The task force's purpose is to combine and coordinate government resources toward long-term recovery efforts and hazard mitigation activities. The MRTF helps get funds and assistance directly to those areas most affected by a recent disaster. This approach is an example of how efficiently funds, ideas and resources can cross agency and political boundaries to accomplish mitigation actions. Based on type, severity and extent of disaster, different subcommittees are formed to assist individuals and communities in need.

Following a major disaster, state disaster relief funds may be allocated to assist local units of government in their disaster recovery. These funds may be appropriated to address those needs, which are not met by other disaster assistance programs. In a presidentially declared disaster, this is typically grant assistance from the FEMA Public Assistance and Individual Assistance Programs, and loan assistance from the Small Business Administration.

Funds are typically allocated to different state agencies and their programs, to acquire and to better publicly-owned land and buildings and for other public improvements of a capital nature. In some instances, funds may become available to assist local homeowners, businesses, and non-profit organizations. In these cases, the impact on the community will be weighed when funding decisions are made. The local unit of government should apply on behalf of these groups when a significant impact exists.

While the MRTF is mainly recovery focused, mitigation actions are often funded, including acquisitions and drainage and infrastructure improvements. Funding the local match for mitigation projects has been a priority for the subcommittee as the local share has been identified as an unmet need for many communities post-disaster. A summary of the most recent legislative activities follow:

January 27, 2015 Disaster Assistance Contingency Account (DACA):

- Appropriates $9,635,000 to the DPS in FY 2015 for DACA
    - Non-federal share of federal assistance,
    - 75% of state public assistance
- Appropriates $3,000,000 to Mn/DOT in FY 2015 for the 20% non-federal match of the FWHA Emergency Relief assistance
    - Appropriates $2,476,000 to BWSR in FY 2015 for erosion and sediment control, water quality and watershed protection projects resulting from the disaster.

May 1, 2015

- Appropriates $514,000 to MDA in FY 2015 for the costs associated with the HPAI response,
- Appropriates $379,000 to BAH in FY 2015 for the costs associated with the HPAI response.

May 19, 2015 Agriculture Policy and Technical Changes

- Increases funding amounts in the disaster recovery loan programs to help farmers,
- Adds language to assist farmers; Replace flocks, make building improvements, or obtain an operating line of credit if losses or damages are a result of the confirmed presence of HPAI in a commercial poultry flock in Minnesota.

May 22, 2015 Chapter 12/12B Revisions

- Transfers $1,000,000 from the General Fund to the DACA,
- Provides language for further funding of the DACA,

- Authorizes the use of the DACA for the HPAI emergency response activities,
- Authorizes DPS to provide the non-federal matches for the FWHA ER program and the NRCS EWP program from the DACA,
- Changes eligibility requirements for state disaster assistance to require the state or COUNTY to declare a disaster or emergency during the incident period,
- Adds state government to state disaster assistance eligibility,
- Places state disaster assistance application responsibility on the impacted county

June 13, 2015 Electric Co-op Non-Federal Share

- Authorizes state appropriations to be used to pay the non-federal share for federal assistance to eligible utility cooperatives,
- Authorizes additional unemployment benefits to commercial poultry workers as a result of confirmed HPAI.

As a result of the impacts from DR-4182 the state legislature provided funds to the 2015 Disaster Relief Bill on June 13, 2015.

- Appropriates **$800,000** to Mn/DOT for local road and bridge reconstruction and replacement in the area identified in FEMA-DR-4182,
- Appropriates **$100,000** for a grant to the city of Jordan through the Historical Society for damages and repair of historical structures,
- Appropriates **$2,140,000** to the DNR for facility and natural resource damages,
- Appropriates **$3,015,000** to the DNR for flood hazard mitigation grants, including the non-federal share for flood mitigation projects,
- Appropriates **$4,700,00** to BWSR for the Reinvest in Minnesota Conservation Easements for damages caused by the flooding,
- Appropriates **$10,600,000** to BWSR for erosion, sediment, and water quality projects caused by the flooding in the area included in DR-4182,
- Appropriates **$100,000** to DEED for flood damages to the Children's Museum of Southern Minnesota,
- Appropriates **$4,000,000** to DEED for the Steele County public works project in Owatonna.

In response to Presidential Disaster Declarations DR-4290-MN and DR-4390-MN the task force met. The State legislature did not allot any additional funds for the task force to address unmet needs**.**

5.7.7 Homeland Security and Emergency Management (HSEM): Recovery

Coordination of mitigation during long-term recovery is essential for communities to become resilient to future disasters. HSEM has developed the Minnesota Disaster Recovery Assistance Framework to assist local units of government recover from disasters. The Recovery Function Index is a comprehensive guide of 18 functions for funding, programs and policies from insurance assistance, damage assessments, debris management, and housing assistance to public infrastructure recovery.

HSEM has expanded disaster recovery roles to include staff, including a Disaster Recovery Coordinator, Community Recovery Coordinator and Volunteer Resource Coordinator. The Disaster Recovery Coordinator provides coordination between local, state and federal agencies during the recovery phase of the numerous disasters declared in Minnesota, as well as coordinates long-term recovery efforts from state, county and local levels. The state offers multiple Disaster Recovery Workshops to local emergency managers and other interested parties. The role of the Community Recovery Coordinator is to provide technical assistance to local jurisdictions, counties, tribal governments, regional consortiums and non-profit organizations in coordinating long-term recovery activities following a major disaster or emergency. This position also assists in the coordination of voluntary resources in long-term recovery efforts. The role of the Volunteer Resource Coordinator is to coordinate on an ongoing basis with state government, local government and voluntary agencies on response issues, to ensure that the public and private sectors work together to address these issues in a coordinated manner, and that volunteer resources are incorporated into local disaster response and recovery plans to the greatest extent possible.

5.7.8 State Public Assistance Program

Minnesota Statutes Chapter 12 lays out emergency management responsibilities of HSEM and other state agencies. Minnesota Statutes Chapter 12A established a framework for state agencies to help communities recover from disaster. In 2014 Governor Mark Dayton signed legislation establishing the state's Disaster Assistance Contingency Account to assist local communities after a natural disaster when federal aid is not available. The legislation also requires the state to cover the full FEMA match in federally declared disasters. The state and/or county must meet a certain damage threshold in order to qualify for state or federal disaster assistance. The state must have at least half the federal disaster threshold in damage; and counties must meet individual county threshold (County population x $3.61). Since the inception of the state PA program in 2014 there have been 32 state disaster declarations.

Facts about the State Public Assistance Program include:

Eligibility Criteria

- The state or applicable county government declares a disaster or emergency during the incident period;
- Damages suffered and eligible costs incurred are the direct result of the disaster;
- Federal disaster assistance is not available to the applicant;
- The applicant incurred eligible damages that equal or exceed 50% of the countywide per capita indicator under FEMA's Public Assistance Program;
- The applicant assumes responsibility for 25% of the applicant's total eligible costs;
- The applicant satisfies all requirements in chapter 12B.
- Costs eligible for payment are those eligible for federal financial assistance under FEMA's Public Assistance Program.

The process for a county to request state or federal assistance is found on HSEM's website. HSEM does not currently have a state mitigation program.

5.7.9 Disaster Assistance Contingency Account (DACA)

The state Disaster Assistance Contingency Account (DACA) funds 75% of state disaster reimbursement to local units of government and eligible non-profits. This account also supports LGU and eligible non-profits with the 25% match for federal disaster declarations. Since DACA was established in May 2014 more than $51 million have been transferred to provide the state share of state and federal disaster assistance to tribes, counties, cities, townships, and state agencies.

5.7.10 Minnesota Geospatial Advisory Council Emergency Preparedness Committee

There is a need for downscaled climate data tools and resources to better assess Minnesota's changing climate and to better prepare for temperature increases and precipitation extremes. UMD and MDH presented to the committee on "Hazard Mitigation and Climate Adaption Planning: Geospatial Data Uses and Gaps" to highlight the need and gaps.

These changes are impacting valuable resources, such as swimmable, fishable lakes and rivers; productive forests that sustain iconic species, like moose and birch; fertile farmland cultivated for local food systems and commodity export; and many aspects of the built environment that support our daily lives, such as roads and bridges, stormwater/sewer infrastructure, potable water supply, and power utilities. High-quality projections at the local level of changes in temperature, precipitation and other weather-related variables are urgently needed by researchers, planners, emergency managers, engineers, farmers and businesses to ensure sound planning and implementation of appropriate adaptation and mitigation strategies for maintaining and protecting our natural environment, built infrastructure, property, economy and health. The MN Pollution Control Agency (MPCA) and the MN Department of Health (MDH), along with other state agencies, are attempting to find funding for Dr. Peter Snyder at the University of Minnesota to 1) produce high-resolution (areas equivalent to a quarter size of a township – small enough for the model to replicate atmospheric conditions) climate model projections for the entire state of Minnesota; 2) develop a publicly-accessible web-based portal for obtaining the projections; and 3) develop educational resources and train professionals on using and interpreting the projections for planning and adaptation purposes.

In 2016, MDH helped shepherd a Legislative-Citizen Commission on Minnesota Resources (LCCMR) proposal for climate projection data funding, which was denied at the last minute; however, work continues to develop high-quality projection data, create a user-friendly GIS data portal and tool for climate adaptation & mitigation, and educate climate data users.

MDH worked with U-Spatial to develop a pilot climate and health vulnerability pilot tool: https://maps.umn.edu/climatehealthtool/.

MDH used existing projection data to develop profile reports of current and future climate hazards for Minnesota's six Homeland Security and Emergency Management (HSEM) regions: http://www.health.state.mn.us/divs/climatechange/data.html (which are being incorporated into the Minnesota State All Hazards Plan), and MDH is facilitating a Climate Data Community of Practice: http://www.health.state.mn.us/divs/climatechange/cop.html.

The Minnesota GreenStep Cities and Tribal Nations Program is a voluntary challenge, assistance and recognition program to help cities achieve their sustainability and quality-of-life goals. This free continuous improvement program, managed by a public-private partnership, is based upon 29 best practices. Each of the best practice actions are environmental and sustainability efforts. Each best practice can be implemented by completing one or more actions at a 1, 2 or 3-star level, from a list of four to eight actions. These actions are tailored to all Minnesota cities, focus on cost savings and energy use reduction, and encourage civic innovation. Partners include MPCA, EQB, DNR, Commerce, and MN DOT.

A recent update includes FEMA HMA programs. The current resource listed in Best Practice 29.2 under the Implementation Tools tab reads as follows: Funding for Climate Resilient Mitigation Activities is available from FEMA Hazard Mitigation Assistance programs. Eligible activities are: Aquifer Storage and Recovery, Floodplain and Stream Restoration, Flood Diversion and Storage, and Green Infrastructure Methods focused on mitigating the impacts of flood and drought conditions. (Applicable to 3 Star implementation.)

5.8 Repetitive and Severe Repetitive Loss

Requirement §201.4(c)(3)(v): *A State may request the reduced cost share authorized under §79.4(c)(2) of this chapter for the FMA and SRL programs, if it has an approved State Mitigation Plan … that also identifies specific actions the State has taken to reduce the number of repetitive loss properties (which must include severe repetitive loss properties), and specifies how the State intends to reduce the number of such repetitive loss properties.*

It is a priority for the state to ensure property owners in flood risk areas are aware of programs to insure, buyout and/or flood-proof their structures. The National Flood Insurance Program is available to property owners whose communities participate in the program. The DNR NFIP state coordinator continually provides education to local units of governments, insurance brokers and others on the benefits of NFIP, the process and benefits. Individual property owners with NFIP protection are eligible for FEMA and state mitigation programs, however participation is voluntary. The state and local jurisdictions make it a priority to educate home and business owners of their options to avoid future flood damages to their properties. The state will continue to promote and elevate the importance of grant funding opportunities to jurisdictions with flood properties.

Acquisition of Severe Repetitive Loss (SRL) Properties: Acquisition of property where the structures are demolished or relocated out of the floodplain works hand in hand with enforcement of NFIP regulations. Acquisition of repetitively damaged properties breaks the cycle of construction, destruction, and reconstruction. SRL properties are the most costly to the NFIP fund due the number and magnitude of sustained damages. The Biggert-Waters Act of 2012 revised the definition of SRL properties:

(a) Is covered under a contract for flood insurance made available under the NFIP; and

(b) Has incurred flood-related damage –

(i) For which 4 or more separate claims payments have been made under flood insurance coverage with the amount of each such claim exceeding $5,000, and with the cumulative amount of such claims payments exceeding $20,000; or

(ii) For which at least 2 separate claims payments have been made under such coverage, with the cumulative amount of such claims exceeding the market value of the insured structure.

The procedure is that HSEM's mitigation program contacts the local jurisdiction to start the process of acquiring the property. Severe Repetitive Loss Properties Eligible for HMA Funding in *Appendix G – Repetitive Loss and Severe Repetitive Loss Properties* shows details by jurisdiction.

Acquisition of Repetitive Loss (RL) Properties: Federal, state, and local funding has resulted in the acquisition of a significant number of repetitive loss structures. The NFIP Repetitive Loss Mitigated (in *Appendix G – Repetitive Loss and Severe Repetitive Loss Properties*) indicates 224 properties have been acquired. The total for these properties for building payments was over $7.2 million, contents payments were over $1.2 million for a total of $8.7 million in losses. The top five counties in number of Repetitive Loss Properties acquired are listed in the table below:

Table 87. Top Counties for Acquisition of Repetitive Loss Properties

County	# of RP Loss Properties Acquired
Mower	86
Clay	34
Marshall	18
Chippewa	15
Hennepin	13

The definition of a repetitive loss property for Flood Mitigation Assistance (FMA) structures covered by a contract for flood insurance made available under the NFIP that:

- Has incurred flood-related damage on 2 occasions, in which the cost of the repair, on the average, equaled or exceeded 25% of the market value of the structure at the time of each such flood event; and
- At the time of the second incidence of flood-related damage, the contract for flood insurance contains increased cost of compliance coverage.

5.8.1 Flood Mitigation Assistance: Severe Repetitive Loss and Repetitive Loss Properties

There are 27 properties defined as FMA SRL. A detailed spreadsheet is included as of 7/31/2018 in *Appendix G – Repetitive Loss and Severe Repetitive Loss Properties* for RL and SRL for FMA. The 133 claims total $4,059,291 in building payments and $1,100,456 in contents for a total of $5,159,747.

There are 29 properties defined as FMA RL. A detailed spreadsheet is included as of 7/31/2018 in *Appendix G – Repetitive Loss and Severe Repetitive Loss Properties* for RL and SRL for FMA. The 64 claims total $2,449,086 in building payments and $249,194 in contents for a total of $2,698,281.

SRL and RL properties by county are listed in Table 88.

Table 88. FEMA Severe Repetitive Loss (SRL) and Repetitive Loss (RL) Properties by County

County Name	# RL Properties	# SRL Properties	Totals
Becker County	1	0	1
Brown County	1	0	1

County Name	# RL Properties	# SRL Properties	Totals
Chippewa County	0	1	1
Clay County	3	3	6
Dakota County	1	2	3
Freeborn County	0	1	1
Goodhue County	1	2	3
Hennepin County	1	0	1
Houston County	2	0	2
Le Sueur County	0	1	1
Marshall County	0	3	3
Mower County	8	7	15
Polk County	1	2	3
Scott County	2	1	3
St. Louis County	1	0	1
Sibley County	0	1	1
Steele County	1	0	1
Traverse County	1	0	1
Wabasha County	1	1	2
Washington County	4	2	6
Total	**29**	**27**	**56**

5.8.2 NFIP Severe Repetitive Loss (SRL) and Repetitive Loss (RL) Properties

The NFIP Repetitive Loss List indicates there are 463 properties with 26 meeting the Severe Repetitive Loss definition that have not been mitigated as of 7/31/18. The full list is provided in *Appendix G – Repetitive Loss and Severe Repetitive Loss Properties*. The top 10 counties with non-mitigated NFIP properties are listed in Table 89.

Table 89. Top 10 Counties with NFIP Non-Mitigated Properties

County Name	RL	SRL	Total
Marshall	87	3	90
Washington	59	2	61
Clay	27	3	30
Mower	20	7	27
Hennepin	23	0	23
Chippewa	17	1	18
Goodhue	14	2	16
Dakota	12	2	14
Norman	13	0	13
Polk	11	1	12

Totals paid out of the NFIP for the State of Minnesota include over $18,029,142 in building payments and $3,750,238 in contents payments, for a total of $21,779,380 over 1,190 loss events.

HSEM and the MN DNR will continue to offer funds to acquire properties. Additionally, state staff have a relationship with a representative of the Pew Charitable Trusts Flood-Prepared Communities. The Pew representative coordinates roundtable meetings with congressional staff, State NFIP Coordinator, MN Association of Floodplain Managers legislative liaison, SHMO and others to review flood-related legislation.

Section 6: Coordination of Local Mitigation Planning

6.1. Local Funding and Technical Assistance for Plan Development

S14. Does the plan describe the process to support the development of approvable local and tribal, as applicable, mitigation plans? [44 CFR §§201.3(c)(5) and 201.4(c)(4)(i)]

Local mitigation plans in the state of Minnesota include those developed by counties (multi-jurisdictional); Indian Tribes; and single-jurisdictions (i.e. Cities of the First Class). Funding for local hazard mitigation programs and technical assistance is available through federal, state, government and other agencies, as listed in this Plan. The PDM and HMGP are two grant programs available to assist locals in their hazard mitigation plan (HMP) development. PDM grant funding provides funds to states, territories, Indian Tribal governments, and communities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event. Funding these plans and projects reduces overall risks to the population and structures, while also reducing reliance on funding from actual disaster declarations. The PDM is a competitive grant program that is ranked via a national ranking process. Under the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 it is the responsibility of the state to identify and select hazard mitigation projects to be recommended to the Federal Emergency Management Agency for final approval and funding of the Hazard Mitigation Grant Program.

Local all-hazard mitigation plans are consistent with and incorporate information from the state Plan. Local hazard mitigation plans are encouraged to incorporate other local planning mechanisms, thus providing a unified mitigation strategy throughout all levels and aspects of government within Minnesota. The state has continually provided guidance and technical support to the development of local mitigation plans and has encouraged the sharing of information between both local planning projects and with the state. MDH is providing Regional Climate Change Data Profiles at HSEM Regional meetings in an effort to provide information to emergency managers for incorporation into local hazard mitigation and other planning efforts.

FEMA grant funding for planning is available through HMGP and PDM (FMA for flood-only portions of a plan) for local multi-jurisdictional planning efforts. Up to 7% of the HMGP funds may be used for planning for local, multi-jurisdictional hazard mitigation plans.

Facilitation of Plan Updates

Historically, HSEM funded plans and updates through HMGP or PDM on a single county basis. Counties would apply to HSEM/FEMA for plan funding, and hire a contractor. In an effort to reduce grant responsibilities and improve risk and vulnerability assessments, HSEM applies on behalf of counties for funding and hires the University of Minnesota Duluth (UMD) to update plans. As funds are available through PDM or HMGP, county emergency managers are surveyed to gage interest in participating in the UMD update process. Some counties in the state are covered by Regional Development Commissions (RDC) that have capability and capacity to update plans. Counties in other regions do not have the capacity or are not served by a RDC. The majority of counties opt to participate in the UMD plan update process.

The multi-county plan update process does not result in a multi-county plan; each county has its own county and multi-jurisdictional plan.

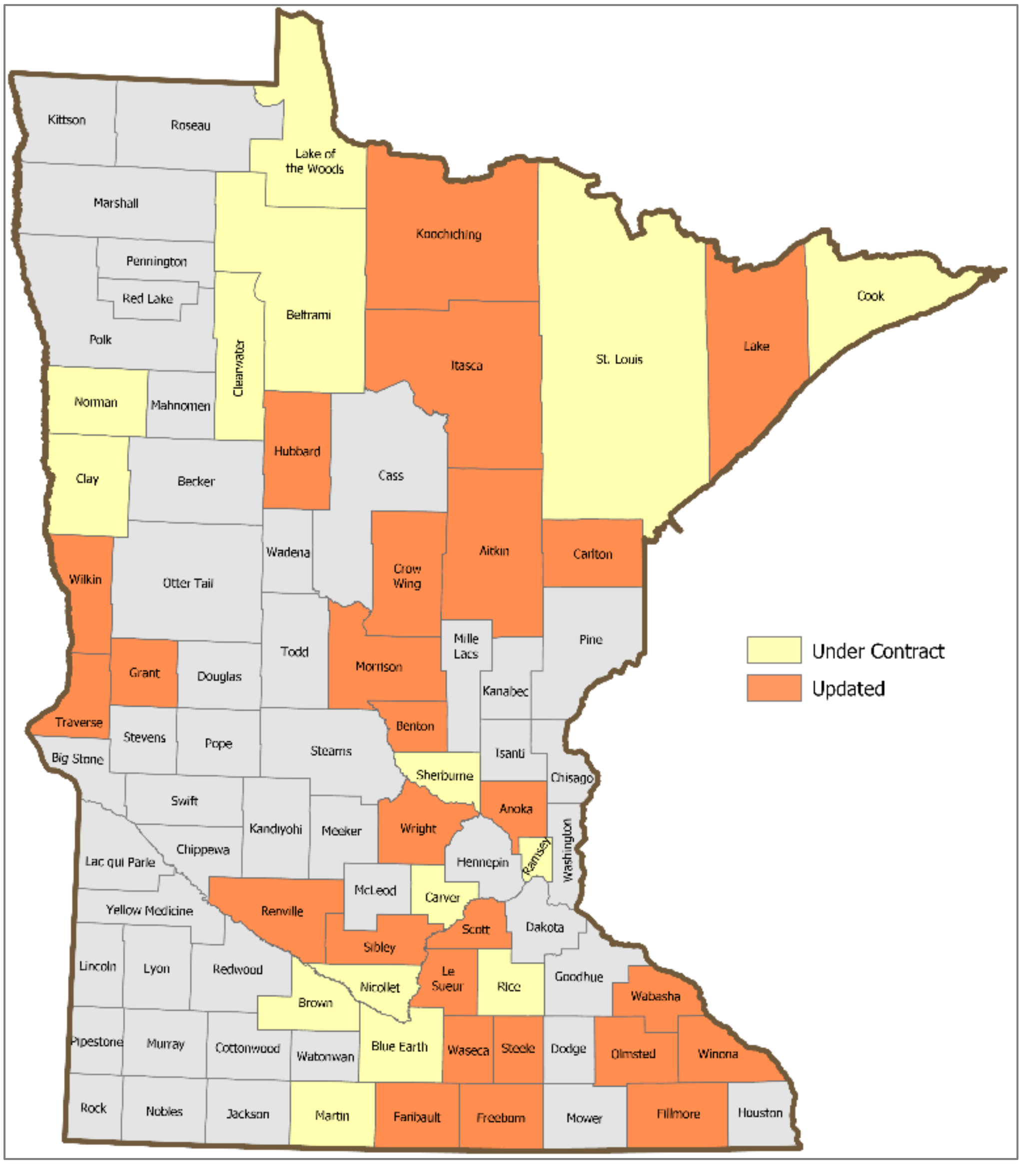
UMD subcontracts part of the process to a planner who has a specialization in emergency management and hazard mitigation planning, and therefore relationships with many Emergency Management Directors (EM), to conduct outreach and mitigation action development in jurisdictions. Through this collaboration, UMD is able to stay closely connected to EMs who are typically coordinators for their own HMP. Additionally UMD has developed and shared best practices for jurisdictional HMPs. UMD conducts a lot of outreach related to the planning process and best practices. Since the 2014, UMD has presented at the HAZUS Annual Conference, Esri International Users Conference, the MN Governor's Emergency Management Conference and many other GIS and/or emergency manager meetings about jurisdictional HMP updates.

The UMD team coordinates and guides each EM throughout the plan update process. Key elements of the plan update that require EM engagement include:

- Webinar orientation with UMD
- *Public Outreach*: Media Release #1 *(plan kickoff)* [templates provided]
- Conduct Capabilities Assessment (Plans & programs in place / program gaps or deficiencies), [worksheet provided]
- Conduct Past Mitigation Action Review [worksheet provided]
- Conduct Local Mitigation Survey [worksheet provided]
- Planning Team Meeting #1
- Develop draft Mitigation Action Charts
- Planning Team Meeting #2
- Complete full draft MHMP
- *Public Outreach*: Media Release #2 *(public review period)*
- Coordinate local level review of plan & promote public engagement
- Public meetings and outreach

The economy of scale in the process and updates of plans makes the match and in-kind tracking the only financial burden on the local county staff. Other benefits include a comparable structure to the plans that make risk, vulnerability and capability assessments as well as mitigation tracking much easier to accomplish. The figure below shows the extent of HMPs that UMD has completed.

Figure 75. UMD Geospatial Analysis Center Plan Updates



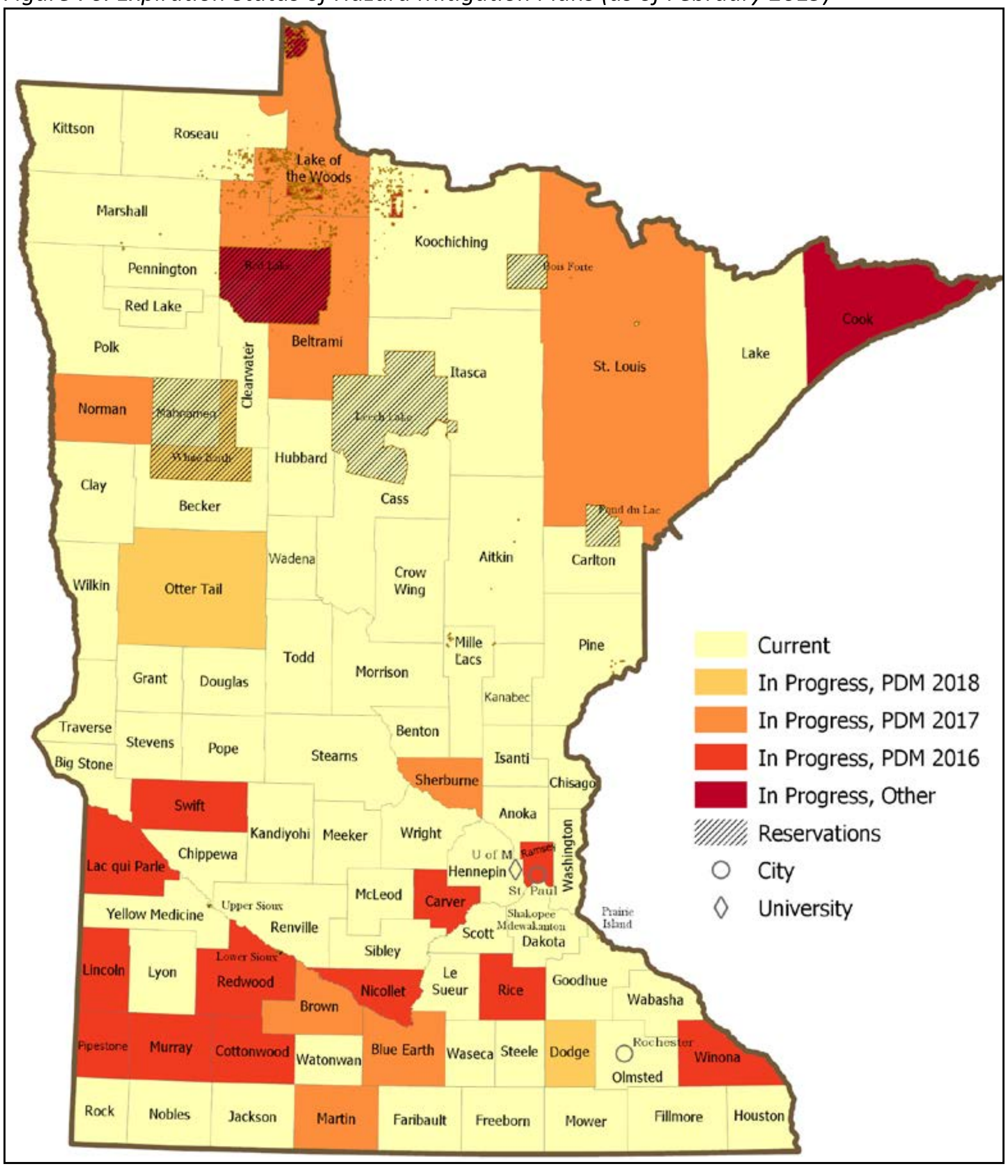
Local plans offer communities the opportunity to identify and evaluate hazards, assess risk, probability, vulnerability, impact, and develop mitigation goals and actions for the prevention and preparation of future hazard events. Of the 87 counties in the state, 63 have approved plans, the remaining have FEMA planning grants or are in the process of applying for a FEMA grant. Two cities have single jurisdiction plans (Saint Paul and Rochester) and the University of Minnesota has a plan that covers all of its campuses. Of the 11 tribal communities, eight have an approved plan, and three have planning grants.

HMP Plan Status

The state maintains a spreadsheet to track state and federal review, local adoption, and plan approval date. The five-year lapse date is tracked to ensure the state provides opportunity to apply for financial assistance in developing an application for funding an updated mitigation plan. HSEM and FEMA crosscheck approval and adoptions status on a regular basis.

The Planning Grant Status in *Appendix O – Plan Status* lists all jurisdictions' (counties, cities and tribes) plan status. The document is revised as plans are funded, submitted for review, approved pending adoption or are formally approved. County emergency management directors are aware that it is the responsibility of the jurisdiction to complete plans prior to their expiration date in order to be eligible for HMA funding.

Figure 76. Expiration Status of Hazard Mitigation Plans (as of February 2019)



Source: MN HSEM, 2019

6.2 Mitigation Success Stories in Minnesota

Success stories illustrate how mitigation projects have worked to reduce damages to people and property, and keep Minnesota and its population safe. By utilizing existing programs, funding mitigation programs and coordinating with other planning efforts, losses can be even further reduced. Promoting how mitigation is successful in our local communities is important to the state mitigation program. Publicizing success stories via press releases in the local media, posting on the FEMA website and other methods of transmitting the message of how mitigation helps locals is a priority for the state.

This section highlights the successes of several state agency funding programs that support effective local mitigation projects. The examples listed here provide information and documentation of the value of comprehensive hazard mitigation and climate adaptation programs and initiatives.

Minnesota DNR's Flood Hazard Mitigation Grant Assistance Program

The DNR Flood Hazard Mitigation program has awarded local governments over $73 million for flood projects during the past five years and many of the grants have served as match to the FEMA mitigation grants.

Since Minnesota's Flood Hazard Mitigation (FHM) Grant Assistance Program was established by the State Legislature in 1987, communities and citizens across the state have more readily mitigated flood risk and damage. Because of the large number of flood-prone rivers and lakes in Minnesota, there are dozens of additional flood mitigation proposals awaiting funding. Few communities can fund large, costly flood mitigation projects on their own. The partnership of federal, state and local dollars makes it possible. Our weather history suggests that floods will continue to occur, and that larger, catastrophic storm events are trending upward. Working in partnership with local, state and federal resources, incidents of repetitive loss to structures and communities have been significantly reduced due to planning and implementation of flood mitigation measures funded in whole or in part with State FHM grant funding. Statewide, to date, over 3,700 flood prone structures have been removed from the floodplain with assistance from the FHM program.

Many communities around Minnesota have taken action to protect homes and businesses from flood damage. They administer floodplain ordinances, and some home and business owners have wisely purchased flood insurance. But many communities can reflect upon their own flooding histories and anticipate a catastrophic event will occur unless further preventive measures are taken. One frequently used measure is the acquisition and removal of at-risk structures from the floodplain.

The allocation of DNR FHM state flood hazard mitigation funding during calendar years 2014 -2018 are listed below (Table 90). These include projects funded by both bonding and state general funds, including state disaster funds. In total, over $73 million in state funds were awarded over that five-year period. Projects the DNR covered 25% match for FEMA hazard mitigation project are indicated. FEMA match dollars for this time period (2014-2018) total nearly $1 million.

Table 90. State of DNR Flood Hazard Mitigation Grant Assistance Funding, 2014-2018

Year	Award	Grantee	Project Description
2014	$500,000	City of Granite Falls	comprehensive community flood risk reduction
2014	$300,000	Wild Rice Watershed District	City of Halstad levee
2014	$4,026,000	City of Roseau	diversion
2014	$650,000	City of Delano	community flood risk reduction
2014	$365,000	Lake County	buyouts (Lake Superior bank erosion)
2014	$480,000	City of Duluth	buyouts (HMGP match for 9 properties)
2014	$100,000	City of Alvarado	levee

Year	Award	Grantee	Project Description
2014	$50,000	Bridgewater Township	flood study
2014	$190,000	Buffalo-Red River Watershed District	City of Georgetown levee
2014	$810,000	City of Oslo	levee
2014	$14,000	City of Montevideo	buyout
2014	$7,200,000	City of Moorhead	levee, buyouts, and pumping stations
2014	$2,700,000	City of Montevideo	levee
2014	$9,200	Yellow Medicine County	buyout
2014	$100,000	City of Melrose	WWTP levee
2014	$150,000	Roseau River Watershed District	impoundment
2014	$700,000	City of Austin	North Main downtown flood protection
2014	$53,900	City of Minneota	levee improvements
2014	$60,000	City of Argyle	levee improvements
2015	$3,000,000	City of Ada	levee and diversion
2015	$2,300,000	Sand Hill River Watershed District	City of Climax levee
2015	$1,372,000	City of Melrose	WWTP levee
2015	$560,000	Bridgewater Township	Flood storage
2015	$264,000	Red River Watershed Management Board	assorted flood risk reduction efforts in the Red River Valley
2015	$65,265	City of Rushford	levee
2015	$100,000	City of Inver Grove Heights	buyouts
2015	$400,000	Red River Watershed Management Board	farmstead and rural ring levees
2015	$85,000	City of Newport	Buyouts (HMGP match)
2015	$260,000	Brown County	buyouts (slope failure) (HMGP match)
2015	$560,000	City of Oslo	levee
2015	$128,700	Scott County	buyout (slope failure) (HMGP match)
2015	$118,750	Blue Earth County	buyout (slope failure) (HMGP match)
2015	$177,613	City of Redwood Falls	Buyouts (HMGP match)
2015	$5,530,000	Buffalo-Red River Watershed District	Oakport Township levee
2015	$10,000,000	Otter Tail County	Little McDonald and Devils Lake pumped outlets
2015	$36,360	Lac qui Parle County	buyout/relocation (HMGP match)
2015	$2,050,000	Roseau River Watershed District	impoundment
2015	$93,000	Bassett Creek Watershed Mgmt Commission	flood study/modeling
2015	$98,000	Bois de Sioux Watershed District	impoundment
2015	$110,980	City of Waterville	buyout and elevation (HMGP match)
2015	$405,000	City of Delano	community flood risk reduction
2015	$91,040	Buffalo-Red River Watershed District	City of Georgetown levee
2015	$125,000	Wild Rice Watershed District	City of Halstad levee
2015	$264,000	Red River Watershed Management Board	assorted flood risk reduction efforts in the Red River Valley

Year	Award	Grantee	Project Description
2016	$560,000	City of Owatonna	buyouts
2016	$4,500	Brown County	Buyout (HMGP match)
2016	$112,500	City of St. Michael	Beebe Lake outlet
2016	$8,235	City of Houston	levee
2016	$60,000	Roseau River Watershed District	wetland mitigation for impoundment project
2016	$110,000	City of Bloomington	residential flood-proofing
2016	$550,000	Bridgewater Township	flood storage
2016	$69,500	City of Mankato	flood study
2016	$181,000	City of Delano	community flood risk reduction
2016	$150,000	City of Inver Grove Heights	buyouts
2016	$300,000	City of Golden Valley	buyouts
2016	$53,500	City of Luverne	flood berm
2016	$187,000	Middle-Snake-Tamarac River Watershed District	Oslo flood study
2016	$161,031	City of Breckenridge	levee
2016	$88,604	City of South St. Paul	levee
2016	$14,874	City of Afton	levee
2017	$10,400	City of Montevideo	buyout
2017	$45,000	City of St. Michael	Beebe Lake outlet
2017	$24,350	City of Faribault	flood study
2017	$264,000	Red River Watershed Management Board	assorted flood risk reduction efforts in the Red River Valley
2017	$14,600	City of Oslo	wetland mitigation for levee project
2017	$150,000	City of Rushford	levee
2017	$65,000	Mower County	buyout
2017	$200,000	City of Golden Valley	buyouts
2017	$3,485	Bridgewater Township	flood storage
2017	$5,300	Brown County	buyout (slope failure) (HMGP match)
2017	$2,000,000	Wild Rice Watershed District	City of Halstad levee
2017	$200,000	Roseau River Watershed District	flood storage
2017	$1,200,000	Cedar River Watershed District	impoundments
2017	$264,000	Red River Watershed Management Board	assorted flood risk reduction efforts in the Red River Valley
2017	$85,033	Blue Earth County	buyout (slope failure) (HMGP match)
2017	$450,000	City of Montevideo	levee
2017	$1,850,000	City of Afton	levee
2018	$98,000	Mower County	buyout
2018	$750,000	City of Browns Valley	community flood risk reduction
2018	$125,000	City of Golden Valley	buyouts
2018	$8,904	Blue Earth County	buyout (slope failure) (HMGP match)
2018	$771,000	City of Breckenridge	levee

Year	Award	Grantee	Project Description
2018	$383,000	City of Moorhead	levee, buyouts, and pumping stations
2018	$1,125,000	City of Austin	North Main downtown flood protection - final phase
2018	$57,840	City of Jordan	flood study
2018	$89,250	Steele County	buyout
2018	$7,194	Brown County	buyout (slope failure) (HMGP match)
2018	$13,500	City of Montevideo	buyout
2018	$180,000	City of Chanhassen	buyout
2018	$2,000,000	Wild Rice Watershed District	City of Halstad levee
2018	$2,300,000	City of Golden Valley	community flood risk reduction
2018	$1,500,000	Red Lake Watershed District	City of Thief River Falls CD 70 Diversion
2018	$500,000	City of Afton	levee
2018	$1,200,000	City of Austin	Turtle Creek flood mitigation
2018	$355,000	City of St. Anthony Village	community flood risk reduction
2018	$202,756	City of Owatonna	buyouts
2018	$4,000,000	City of Moorhead	levee, buyouts, and pumping stations
2018	$264,000	Red River Watershed Management Board	assorted flood risk reduction efforts in the Red River Valley
2018	$1,000,000	Roseau River Watershed District	Flood storage
2018	$34,352	Sand Hill River Watershed District	City of Climax levee
TOTAL	**$73,059,516**		

The DNR FHM program has partnered with HSEM to fund the local share of FEMA flood buyouts over the years and will continue to collaborate. The state and federal programs are utilized, in addition to local programs.

Minnesota Board of Water and Soil Resources: Disaster Recovery Assistance Program (DRAP)

Disasters and emergency legislative funding occur frequently and usually unpredictably. These characteristics require a standard operating procedure for Minnesota Board of Water and Soil Resources (BWSR) staff and LGUs to follow to optimize efficiencies, responsiveness, and legislative appropriations. In the event of a disaster, the BWSR's DRAP program policy provides BWSR staff and LGUs the needed implementation information and related processes of BWSR and other state and federal assistance providers. Following are mitigation highlights supported by BWSR funding programs:

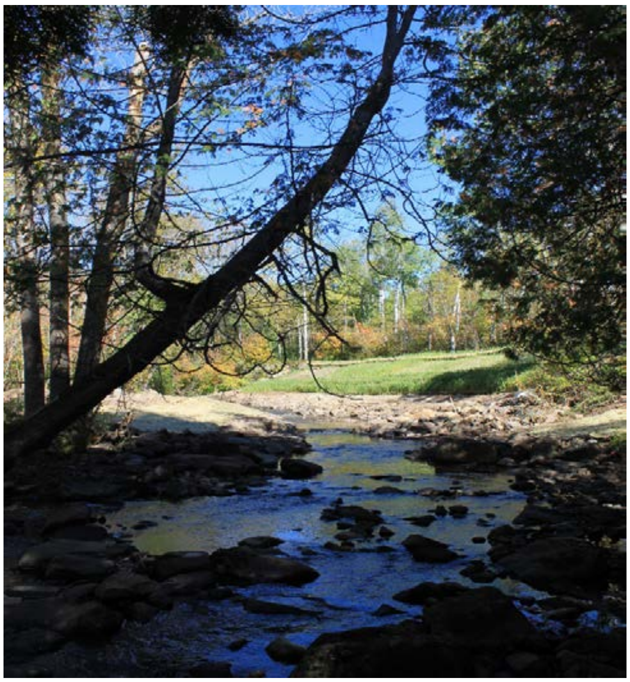
Post-2012 Duluth Flood: Chester Creek Restoration

June 20, 2017 marked five years since the Duluth Flood of 2012. It was an event that forever changed Duluth. The area received a total of 7.25 inches of rain and some of the surrounding areas received 8-10 inches. This event triggered a Presidential Major Disaster on July 6, 2012 and on Friday, Aug. 24, 2012 Governor Mark Dayton signed a $167 million disaster relief bill.

This flood caused damage all over the northland, much of it located in the riparian areas. Streambanks eroded, causing threats to private and public infrastructure, while also, degrading the riparian and in stream habitat and biota.

Many of Duluth's 16 cold water trout streams had significant damage. One of the most recreated streams affected was Chester Creek. Chester Creek has a 7.1 mile watershed and is home to some of the oldest volcanic rock on earth. Because of the watersheds unique topography, lush forests and cold water it has a rich history of providing recreational opportunities for the community. Chester Park was established in 1889 and is home to hiking, skiing, student adventure camps, festivals, fishing, field sports and mountain biking. At one point it was home to training for Olympic ski jumpers.

Figure 77. Chester Creek, Natural Channel Design



Extensive damage to Chester Creek was a high priority for the City of Duluth, the South St. Louis County Soil and Water District, Trout Unlimited, MN Department of Natural Resource and other partners to focus restoration efforts.

In 2016 the City of Duluth completed three major restoration projects for Chester Creek totaling $487,000. Two of the projects used toe-wood methodology to create a floodplain bench from all-natural materials: tree trunks, root wads, brush, soil and willow. This bench was installed to reduce erosion from the stream bank, to create fish habitat and to provide native vegetation along the river corridor. Figure 77 to the left shows Chester Creek, which was restored using natural channel design principles.

In the fall of 2017 the South St. Louis SWCD removed two dams, one that failed during the flood, re-aligned and stabilized the stream, and provided trout habitat and increase resilience to future flooding with $516,000.

2014 Rock County Storm Damage and Recovery

When the waters receded from Rock County farmlands in June 2014, they left in their wake nearly 600 flood-damaged or heavily eroded conservation practices. Three years later, Rock County Soil & Water Conservation District staff reflected on some of the unforeseen challenges and resulting improvements.

Figure 78. June 2014 flooding in Rock County brought erosion

PHOTO CREDITS: ROCK COUNTY SWCD

"There were some places that recorded 22 inches of rain in eight days in the June '14 event," said Doug Bos, Rock County Soil & Water Conservation District assistant director.

Nearly 14 inches of rain fell in Luverne that June – nearly 10 inches more than the longtime monthly average, according to Midwestern Regional Climate Center data. Unofficial reports from other areas of Rock County showed higher rainfall totals. The federal disaster declaration named eight counties, including Rock.

Constructed water and sediment control basin, top left, will capture surface flow and dissipate energy to prevent gullies.

In Rock County alone, more than 30 bridges and culverts washed out, as did numerous roads. Responding to disaster declarations, the Minnesota Legislature in 2015 appropriated funds implemented through the Minnesota Board of Water & Soil Resources' Disaster Recovery Assistance Program. DRAP aided 31 SWCDs, including Rock County. Rock County staff from the Natural Resources Conservation Service, SWCD and Rock County Land Management Office surveyed the damage in June 2014. Besides the nearly 600 flood-damaged or heavily eroded conservation practices, they documented new areas requiring protective measures from gully erosion. The estimated cost to implement all of those projects topped $4.2 million.

Through four rounds of DRAP requests, which listed projects and partner-fund contributions, Rock County SWCD garnered nearly $1.5 million. The money would provide cost sharing to private landowners who implemented or repaired conservation projects, or implemented new erosion or sediment management practices.

As of May 2017, the ongoing DRAP framework has spent and/or contracted $945,000 on private lands in Rock County. Those projects have included installing and/or engineered 45 waterways, 100 terraces/water and sediment control basins and two streambank and shoreland protections. The results came in spite of a few challenges. Coordinating grant opportunities to address heavy erosion and damage has tested the limits of the Rock County SWCD technical and administrative staff, its partners and the Area 5 Technical Service Area, who already were administering programs and overseeing buffer activities.

The volume of large-scale engineered projects in Rock and surrounding counties made it difficult to secure construction contractors and technicians for design and onsite work. Weather conditions further delayed projects. Saturation continued after the June 2014 floods. A wetter-than-average August 2015 and September 2016 followed, with single-day deluges exacerbating matters. Wet conditions delayed implementation in a couple of different ways. They delayed harvest, which pushed construction back. They kept water-table levels high, which meant sites were too wet for construction.

Prolonged wet conditions did bring a strange opportunity. The June 2014 flood not only affected the "weakest" erosion areas on the landscape, but also exposed vulnerable areas in need of some protection. Most years' tillage would erase signs of that need.

The flood also brought in landowners who usually declined to participate in cost-sharing for erosion control conservation strategies. At first, these folks had sought help when rains opened gullies in fields. As time passed, some landowners waited – or backed out of cost-share contracts – as fall 2014 and spring 2015 brought drier conditions. Everything seemed OK after fall tillage. Wet falls in 2015 and 2016 punctuated by storms that brought washouts inspired many of these folks to re-sign conservation contracts using the DRAP funding to conserve soil.

It's only two-thirds of the way through the first round of funding. But, Rock County SWCD staff are starting to see the effects of the 2014 DRAP process and how it affects district dynamics and on-the-ground conservation. Bos summarized the experience to date:

> *"The funding to install these greatly needed conservation practices has been very welcome, but we just never anticipated the huge demand this would place on our staff. We were in the process of training new engineering technical staff and – other than NRCS on Environmental Quality Incentives Program-funded projects – we had to rely totally on our Southwest Prairie (Area 5) TSA.*
>
> *"Given that the TSA was stretched thin with their other 10 counties, some of which had damages from heavy rainfall events also, we tried hiring private engineering to keep ahead of the demand. What we found out was that most engineering firms are not familiar with conservation practice design and installation and can be very expensive. In some cases, the engineering was more than the cost of the conservation practice.*
>
> *"Fast forward to today, we have projects getting done with a combination of our engineering technicians, Southwest Prairie TSA and some private engineering. We definitely have had a large learning curve, but it is finally coming together."*

FEMA Story Maps Featuring Minnesota Cities

FEMA Region V prepared multiple story maps that discuss past flood damage and how various Minnesota cities have recovered from floods and reduced their future flood damage potential. One story map, A Journey to Resilience: How Granite Falls, MN Implemented Two Decades of Flood Mitigation reviews historical flood damage in Granite Falls as well as the various mitigation efforts undertaken by the city. Another story map, The Great Floods of 1993 – 25 Mitigated Years Later, looks at several cities, including Austin, Minnesota. The story map includes a flood history and discussion of flood risk reduction tools used by the city. A third story map created by FEMA is Red River Flood 1997 and FEMA Region 5 Mitigation

Efforts. The story looks at acquisitions from three Minnesota communities following the 1997 flood: East Grand Forks, Moorhead, and Breckenridge.

Metropolitan Council

The Metropolitan Council (Council) is the regional policy-making body, planning agency, and provider of essential services for the Twin Cities metropolitan region. The Council's focus on climate adaptation is wide-ranging and two-pronged – the Council leads by example and collaborates with communities and stakeholders.

Institution Award – MN State Climate Adaptation Conference 2018

In 2018, the Met Council received an Institution Award for the work Council has conducted to integrate climate adaptation activities into its divisions and programs, including: Regional Administration, Community Development, Environmental Services, Stormwater Planning and Green Infrastructure Pilot Grant Programs, and Metro Transit.

The Council's mission is to foster efficient and economic growth for a prosperous region. The Council efficiently moves 260,000 people every day via its transit system; the Council provides cost-effective and sustainable treatment of more than 250 million gallons of wastewater per day across 8 wastewater treatment plants; and the Council works with partners to plan the regional parks and trails system, a system that received more visitors in 2017 than the Mall of America. The Council provides award-winning and innovative technical assistance to 188 metropolitan jurisdictions for comprehensive planning, including training, workshops, and resources related specifically to planning for community resilience and adaptation to climate change.

Climate adaptation planning and implementation is occurring across all divisions of the Metropolitan Council, including those providing organizational leadership and regional planning assistance as well as those providing operations and services. This integrated approach to climate adaptation planning, across operations, maintenance, and planning is unique in the nation and worthy of consideration for this MN Climate Adaptation Award – Institution.

While the Council works to create internal goals, objectives, and implementation strategies related to climate adaptation planning, it also works closely with agency partners, external stakeholder groups, and communities to create a vibrant, sustainable, and resilient Twin Cities region. Following is a description of the successful work by Council divisions and associated programs to integrate climate adaptation planning:

Community Development Division

Metropolitan Council's Community Development division provides resources for communities working to integrate climate adaptation strategies into local comprehensive plans. Thrive MSP 2040, the Council's 25-year regional vision, encourages communities to integrate climate change adaptation into their comprehensive plan updates, which are required of all cities, counties, and townships within the seven-county metropolitan every 10 years. The current comprehensive plan updates are due by December 31, 2018, and many communities are including climate adaptation objectives, policies, and implementation strategies.

The Council's award-winning Local Planning Handbook provides guidance and resources on all elements of a comprehensive plan update, including a Resilience Plan Element that addresses four areas: Infrastructure and Environment, Energy Infrastructure and Resources, Healthy Communities and Economy and Society.

The Community Development division is currently conducting a Climate Vulnerability Assessment (CVA), which considers the climate hazards of localized flooding and extreme heat on regional assets. The CVA includes tools that communities can use to identify potential climate vulnerabilities and engage in adaptation and resilience planning.

The Community Development division has also worked closely with Freshwater Society, communities, and other stakeholders in hosting workshops for community resilience planning. The division has completed several cohorts of community workshops at the watershed district scale in the metro.

Community Development division staff work closely with academic institutions, like St. Thomas' Sustainability Communities Partnership, to facilitate climate adaptation projects and research that serves the region.

The division has worked with the Solar Foundation and the McKnight Foundation to fund a new Solar Advisor position to provide technical assistance to metropolitan communities in planning for solar and obtaining SolSmart Certifications during the current comprehensive planning cycle.

Environmental Services Division

Metropolitan Council Environmental Services (MCES) provides wastewater services and integrated planning to ensure sustainable water quality and water supply for the metropolitan region. Multiple climate adaptation strategies are being implemented throughout MCES, including the Inflow and Infiltration Reduction Program, Flood Response and Mitigation, and Infrastructure Rehabilitation.

Inflow and Infiltration Reduction Program

Inflow and Infiltration (I/I) are separate and related challenges that allow clear water from stormwater and groundwater to enter the wastewater system, increasing base flow and peak flow delivered to WWTPs and resulting in costly and unnecessary expansion of pipes and WWTP capacity. I/I volumes are affected by increased precipitation and storm intensities. I/I can cause excessive flows, leading to untreated sewage discharges to basements or waterways that endanger public and environmental health.

Previous studies of the MCES system indicate that up to 20% of the annual wastewater flow is from I/I. Reduction of the base flow from I/I preserves system capacity for growth and allows for surface water to recharge the region's aquifers. MCES owns and maintains more than 600 miles of regional interceptor sewers that collect wastewater flow from roughly 5,000 miles of sewer mains owned and operated by 109 communities within the region. Upstream of the regional and local systems are over a million connections to private properties, including an estimated 7,500 miles of private sewer laterals. Service lateral pipes to over 400,000 homes were constructed prior to 1970 from brittle materials that are past design life and contribute an estimated 20% to 80% of I/I in the region.

The MCES I/I program began in 2004 to address sources of I/I in the local wastewater systems. Through 2016, over 50 communities have participated in I/I mitigation work plans and have reported over $160 million of investments into local and private infrastructure. After completion of the work plan, many communities chose to continue investing in I/I source identification and mitigation projects as part of system maintenance and asset management. Since the beginning of the I/I program, regional wastewater volumes have reduced by roughly eight billion gallons per year. The flow decrease has occurred even as precipitation volumes, rainfall intensities, and populations have increased. This flow reduction can be attributed to I/I mitigation, adaptation efforts, and water conservation. It is estimated that I/I source mitigation avoids billions of dollars in unnecessary capital spending for the region.

Stormwater Planning and Green Infrastructure Pilot Grant Programs

The goal of Metropolitan Council's stormwater grant program is to demonstrate innovative practices that treat and manage stormwater with the intent of reducing runoff volume and pollutants discharging to receiving waters in the region. These grants will help fund and document innovative, high visibility demonstration projects that could be replicated throughout the metro region.

In 2017, the Council offered $1 million for one-water green infrastructure projects, available to metropolitan area communities, to support approaches to solving water-related problems that acknowledge the connection between wastewater, stormwater, groundwater, and surface water. The "One Water Grant Program" is geared toward implementing solutions for community water problems that will provide multiple benefits for regional water quality quantity and quality.

Metro Transit

Metro Transit has focused on creation and implementation of route- and facility-specific business continuity plans to ensure recovery and resumption of disrupted transit operations for many hazard situations, ranging from natural hazards (floods, fires, tornados, etc.) to human-caused hazards (bombings, riots, etc.). Many adaptations of operations to climate-related events, like establishing alternative routes during periods of localized flooding or establishing alternative operations headquarters due to tornado or storm damage, are included in the business continuity plans.

The Metropolitan Council recognizes that climate mitigation and adaptation work serve the same end – creating a more resilient region and state. The information above highlights the work and collaborations related specifically to climate adaptation. The Council recognizes that it can achieve much by leading by example through its operations and maintenance function, but it can achieve even more across the region through its ability to convene partnerships and invaluable collaborations, whether it be with communities, watershed districts, agencies, or other stakeholder groups.

Conclusion

There are many more hazard mitigation success stories in Minnesota as a result of FEMA grants, State programs, local initiatives and individual efforts. Hazard mitigation is effective when there are no (or reduced) damages or impacts from severe weather. Climate adaptation considerations must be included in our efforts to continue to protect people, our natural and built environments. The State will continue to monitor and compile successful mitigation stories for the next update of the state plan.

6.3 Local Mitigation Project Update

Each disaster and non-disaster funding availability has its own priorities associate with it. The following indicate how the past three disasters since the 2014 plan have been prioritized and funded, to date.

FEMA-4182-DR-MN Mitigation Strategy

The Hazard Mitigation Strategy developed for FEMA-4182-DR-MN declared July 21, 2014 for Public Assistance and Hazard Mitigation identifies action items and provides information on how they will be accomplished. FEMA-4182-DR-MN, 2014 addresses Severe Storms, Straight-line Winds, Flooding, Landslides, and Mudslides. It provides the steps for implementing short and long-term cost-effective solutions to reduce statewide disaster damage for future events and provides guidance to the Joint Field Office (JFO), MN Homeland Security Emergency Management (MN HSEM) mitigation staff and MN Department of Natural Resources (MN DNR) floodplain management staff. The priorities identified for FEMA-4182-DR-MN that are listed here are consistent with the State of Minnesota's Hazard Mitigation Plan and are as follows:

GOAL 1: Assist the State, Tribes and Communities in the development of Hazard Mitigation Grant applications.

- Provide technical assistance to the State in the administration and implementation of the Hazard Mitigation Grant Program (HMGP).
- Provide assistance to the State in promoting the HMGP.

GOAL 2: Assist the State, Tribes and Communities in Hazard Mitigation Planning.

- Provide technical assistance to the State in the development and review of State, Local and Tribal Hazard Mitigation Plans.

GOAL 3: Promote effective floodplain management through outreach and data analysis, and the provision of technical assistance to the State.

- Provide NFIP outreach to non-participating communities, including Tribal Nations.
- Provide technical assistance on floodplain regulations, including substantial damage.
- Provide Minnesota specific floodplain management and NFIP training for JFO staff.

GOAL 4: Support the Public Assistance Program through technical assistance in the engineering and building science-related aspects of this disaster.

- Provide assistance in the recovery, reconstruction, and hazard mitigation of flood-damaged areas through technical assistance available from the §406 Public Assistance Mitigation and other opportunities, as appropriate.
- Provide technical assistance for mitigating the slope failures that caused damage in this disaster

HSEM and FEMA staff held two planning workshops, two benefit cost analysis and three application workshops. The classes were held throughout the state to bring the classes to disaster-affected areas. Over 50 people attended the plan update workshop, 25 attended the BCA classes and 36 attended the application development workshop. Of the $6,232,862 available, 94% of the funds were applied for and listed below in Table 91.

Table 91. FEMA-4182-DR-MN Project Funding

Project Type	Sub-grantee	County	Project Cost 100%	Federal Share 75%	Local Match 25%
Acquisition of 4 erosion-prone structures	Brown County	Brown	$879,895	$659,921	$219,974
Acquisition of 3 flood-prone structures	City of Newport	Washington	$764,656	$573,492	$191,164

Project Type	Sub-grantee	County	Project Cost 100%	Federal Share 75%	Local Match 25%
Acquisition of 1 flood-prone structure and elevation of 4 flood-prone structures	City of Waterville	Le Sueur	$443,911	$332,933	$110,978
Acquisition and relocation of 1 structure	Lac Qui Parle	Lac Qui Parle	$139,789	$104,842	$34,947
Acquisition of 1 erosion-prone structure	Brown County	Brown	$174,551	$130,913	$43,638
Flood Reduction Phase 1	City of Worthington	Nobles	$ 455,449	$341,587	$113,862
Flood Reduction Phase 2	City of Worthington	Nobles	2,807,772	$2,105,829	$701,943
Soil Stabilization / Drainage	City of Chanhassen	Carver	$ 288,000	$216,000	$ 72,000
2 Community Tornado Safe Rooms	Boy Scouts Camp Wilderness/Hubbard	Hubbard	$1,428,791	$1,071,593	$357,198
Plan Update	HSEM - UMD 10 counties	Statewide	$350,000	$262,500	$87,500
Plan Update	Goodhue County	Goodhue	$15,769	$ 11,827	$3,942
Plan Update	Fillmore Co Plan	Fillmore	$8,440	$28,830	$9,610

FEMA-4290-DR-MN Mitigation Strategy

The Hazard Mitigation Strategy was developed for FEMA-4290-DR-MN, which was declared November 2, 2016, for Public Assistance and statewide Hazard Mitigation with an amendment dated November 29, 2016 for Individual Assistance. The purpose of the Hazard Mitigation Strategy identifies action items and provides information on how they will be accomplished. It provides the steps for implementing short and long-term, cost-effective solutions to reduce statewide disaster damage and provides guidance to the Joint Field Office (JFO) and State Mitigation Staff. Hazard Mitigation goals and objectives have been established for this disaster and are based on the current State of Minnesota Hazard Mitigation Plan, the conditions of the State, and the priorities of the Federal Coordinating Officer (FCO), and are as follows:

GOAL 1: Assist the State and Communities in the development of Hazard Mitigation Grant Applications.

- Provide technical assistance to the State in the administration and implementation of the Hazard Mitigation Grant Program (HMGP).
- Provide assistance to the State in promoting the Climate Resilient Mitigation Activities (CRMA) now funded under HMGP.

GOAL 2: Assist the State, Tribes, and Communities in Hazard Mitigation Planning.

- Provide technical assistance to the State in the development, review, and implementation of State, Tribal, and Local Hazard Mitigation Plans.

GOAL 3: Promote effective floodplain management through outreach and data analysis, and the provision of technical assistance to the State.

- Provide NFIP and Substantial Damage outreach to non-participating communities, including Tribal Nations.

GOAL 4: Coordinate with and support Public Assistance efforts with engineering technical assistance as necessary and by providing the best available flood risk data.

- Provide support in the recovery, reconstruction, and hazard mitigation of flood-damaged areas through providing best available flood risk data for decision making and technical assistance as necessary to the Section 406 Public Assistance Mitigation Program.

GOAL 5: Promote effective hazard mitigation through community education and outreach in conjunction with Disaster Recovery Center teams.

HSEM Mitigation staff participated in Preliminary Damage Assessments for Individual Assistance and staffed the Disaster Recovery Centers. Staff used this opportunity to discuss hazard mitigation methods homeowners and affected individuals can take and promote programs with community leaders.

The Notice of Availability of Funds for this disaster resulted in over $20 million in requests. Application development trainings were held on the requested project types: acquisition, flood damage reduction/flood control, road/culvert/bridge and soil stabilization. The two one-day trainings had 29 attendees. Two benefit cost analysis training webinars were also held to educate attendees on how to utilize the software and what inputs are required. The webinar had sixteen attendees.

Priority projects for this disaster were:

1. Projects in Disaster Declared jurisdictions;
2. Acquisition and demolition of flood prone properties;
3. Flood damage reduction and small flood control projects;
4. Acquisition and demolition, or relocation of structures in landslide hazard areas where risk of catastrophic failure of the slope is imminent (defined as five-years);
5. New community tornado safe room construction or retrofit projects; currently unprotected populations at mobile home parks, schools, parks and camping facilities, neighborhoods, and apartments with slab-on-grade construction;
6. Any project incorporating Climate Resilient Mitigation Actions (CRMA), including Green Infrastructure;
7. Retrofitting of facilities, including burying or retrofitting of power lines;
8. Wildfire resistant construction materials, defensible space and sprinklers;
9. Soil stabilization to protect critical facilities and/or infrastructure; and
10. Elevation or relocation or flood prone facilities.

Of the total available funds $1,412,188 for DR-4290, $1,193,023 or 84% has been applied for. Applications approved for this disaster are shown in Table 92:

Table 92. FEMA-4290-DR-MN Project Funding

Project Type	Sub-grantee	County	Project Cost 100%	Federal Share 75%	Local Match 25%
1 Erosion-Prone Acquisition	Blue Earth County	Blue Earth	$ 395,250	$ 296,437	$ 98,812
1 Flood-Prone Acquisition	Waseca County	Waseca	$ 119,313	$89,485	$ 29,828
2 Flood-Prone Acquisitions	City of Red Lake Falls	Red Lake	$ 518,259	$ 388,694	$129,565
1 Flood-Prone acquisition	Sibley County	Sibley	$ 100,000	$ 75,000	$ 25,000
Plan update	Cook County	Cook	$ 27,000	$20,250	$ 6,750
Community Tornado Safe Room	City of Staples	Todd	$ 339,100	$254,325	$ 84,775
5% Lightning Detection & Warning System	Minnesota Amateur Sports Commission	Anoka	$ 91,775	$ 68,831	$ 22,944

FEMA-4390-DR-MN Mitigation Strategy

The Hazard Mitigation Strategy for FEMA-4390-DR-MN declared September 6, 2018, for Public Assistance and statewide Hazard Mitigation outlines the tasks and targets to be accomplished for the declared event.

Hazard Mitigation goals and objectives have been established for this disaster and are based on the current state hazard mitigation plan, the conditions of the State, and the priorities of both the State Coordinating Officer (SCO) and the Federal Coordinating Officer (FCO), and are as follows:

GOAL 1: Assist the State and communities in the development of Hazard Mitigation Grant Applications.

- Provide technical assistance to the State in the administration and implementation of the HMGP.

GOAL 2: Assist the State, Tribes, and Communities in Hazard Mitigation Planning.

- Provide technical assistance to the State in the development, review, and implementation of State, Tribal, and Local Hazard Mitigation Plans.

GOAL 3: Assist the State of Minnesota in increasing awareness and knowledge of the NFIP and supporting floodplain management compliance and flood insurance.

- Encourage individuals and communities to evaluate their risk and protect their investments through a targeted Flood Insurance Outreach Strategy.
- Encourage participation in the NFIP through outreach to non-participating communities throughout the state.
- Provide appropriate technical assistance to communities on the requirements of the NFIP and opportunities to promote resilience and sustainability.

GOAL 4: Coordinate with and provide support to PA and HMA in the recovery, reconstruction, and hazard mitigation of flood-damaged areas through the delivery of best available data and technical assistance opportunities as appropriate.

The dates for application development and benefit cost analysis are scheduled for February 2019. Priorities will be given to complete applications that address:

1. Projects in Disaster Declared jurisdictions;
2. Acquisition and demolition of hazard prone properties;
3. Flood damage reduction and small flood control projects;
4. Community tornado-safe rooms;
5. Climate Resilient Mitigation Activities; and
6. Retrofitting of critical facilities, including burying electrical lines.

Advance assistance funds are available to develop data needed for mitigation applications; developing project alternatives, and gathering and calculating benefit cost data. Examples include; engineering and design, technical assistance to determine project feasibility, including hydrologic and hydraulic modeling. The 30-day estimate for HMGP funds are $2,475,000.

6.4 Local Plan Integration

S16. Does the plan describe the process and timeframe to review, coordinate and link local and tribal, as applicable, mitigation plans with the state mitigation plan? [44 CFR §§201.3(c)(6), 201.4(c)(2)(ii), 201.4(c)(3)(iii), and 201.4(c)(4)(ii)]

HSEM has developed a process that enables local mitigation plan integration into the state plan and the identification of potential projects. The process is completed during the update of the state plan and periodically throughout the 5-year update period. At time of plan update application, the plans previous crosswalk is reviewed and any recommendations for improvement are addressed. The plan update process includes utilizing the state plan goals, (new) strategies and actions as a starting point. UMD and regional planning commissions have their own update process. Once the plan has been reviewed by the local units of government, HSEM reviews within 45 days. If all requirements are met, HSEM forwards the plan to FEMA for review. Once all requirements are met, FEMA will send HSEM, who in turns notifies jurisdictions and consultants of approval pending adoption. HSEM sends adoption templates to jurisdictions. As the county adopts the plan by resolution, they send to HSEM who sends to FEMA. FEMA produces an approved letter and that date starts the five-year eligibility. Participating jurisdictions are encouraged to submit adoption within three months of plan approval, and must submit adoptions within one year of county adoption. Most if not all plans are updated well within the three-year Period of Performance dictated by FEMA regulations. Many tribal nations have opted to update their plans directly through FEMA non-disaster grant funds. Tribal governments are eligible to apply directly to FEMA for projects with the FEMA approved plan. The state will assist as requested on plan or project applications. Tribal nations may also apply as a sub-grantee through the state. As sovereign nations, the decision is up to each tribal government how to prioritize projects.

During the State's update of its hazard mitigation plan, staff and/or a consultant reviews all the counties plans for perceived risk and county capabilities (*Appendix C – Jurisdictional Ranking of Natural Hazards in HMP* and *Appendix N – Local Planning Capabilities*). The top four state risks (wind storms, flooding, tornado, and wildfire) are mapped for visual representation and project identification (see Section 4.5 Risk Assessment by County). County plan rankings for all hazards are reported in *Appendix C – Jurisdictional Ranking of Natural Hazards in HMP*.

Prior to sending local plans to FEMA for review of compliance with the Federal Regulations, project officers review local plans. The project officer reviews are completed not only to ensure Federal Regulations are met, but to identify potential projects, identify potential new risks and to integrate into the State Mitigation Plan. When project officers identify a potential mitigation project that could be funded through either disaster or non-disaster grant programs, the officer discusses the options with the local emergency manager or appropriate county staff person. Natural hazards are reviewed and if deviation from previous hazards occurs the project officer discusses the deviation with the county to get a better sense of the new or outdated hazard.

The state tracks all hazard mitigation project applications, from Notice of Interest, through application, benefit cost analysis, historical and environmental review, implementation and closeout. The projects each entity applies for is tracked at least quarterly. It is really the projects that applicants apply for to address natural hazards that is tracked and integrated into the state plan. Locals are affected by disasters, and the natural hazard type drives the mitigation project type. The acquisition of flood prone homes is a high priority for the state as it often floods and homes are damaged. Wildfire retrofit projects have been popular in the past, however the state has not experienced a blowdown or wind event to make timber vulnerable to wildfire. With climate change, changing ecosystems and invasive species, interest in wildfire projects may increase in the future. Recent slope failure/bluff erosion projects have been popular for the past five years due to extreme rainfall. The number of imminent threat buyouts/relocation has increased in the past five years also. Most recently the coastal erosion and flooding hazard has become a priority for the state as a declaration (DR-4414) was just declared due to this (new) hazard in St Louis County for damages to the city of Duluth from Lake Superior. As the climate continues to change, the hazards and impacts Minnesotans face will also change. The state plan will reflect local hazards and local priority project types.

6.5 Local Capability Assessment

S13. Does the plan generally describe and analyze the effectiveness of local and tribal, as applicable, mitigation policies, programs, and capabilities? [44 CFR §201.4(c)(3)(ii)]

A statewide capability and vulnerability analysis was conducted was completed to better understand the capabilities that support mitigation by all jurisdictions in the Minnesota. Only approved and active (not expired) plans were reviewed, which included 84 MHMP plans (67 counties, 7 tribal and 1 city). If the MHMP mentioned a specific plan, policy or staff member as a capability it was recorded as a capability. The results of this examination are included in *Appendix N – Local Planning Capabilities*.

The following table summarizes the highest percentage of specific plans that counties identified as a capability in their hazard mitigation plan. Please note, not all capabilities were easily recognized from the MHMP, depending on the content of the plan, so capabilities are expected to be underestimated. The same data was collected in 2013 for the 2014 State MHMP, and is included in the tables below. Water/Watershed Management Plans and NFIP Programs were among the highest planning capability in the state by jurisdiction.

Table 93. Local Plan Capabilities

Capabilities (plans) Cited in Jurisdictional MHMP	Percent of Counties (67) with Capability in 2013	Percent of Counties with Capability in 2018	Percent of all Jurisdictions (75) with Capability in 2018
Emergency Response/Management Plan	80%	88%	88%
Water/Watershed Management Plan	76%	94%	91%
Comprehensive Plan	49%	76%	73%
Land-use Plan	46%	55%	56%
Pandemic or Public Health Incident Response Plan	32%	42%	44%
National Flood Insurance Program (NFIP)	31%	93%	89%
Wellhead Protection Plan	27%	48%	48%
Capital Improvement Plan	20%	54%	51%
Contingency Plan	12%	25%	25%
Fire Plan	N/A	36%	40%
Forest Management Plan	N/A	6%	8%

Jurisdictional hazard mitigation plans were also reviewed for county policy capabilities (Table 94). The majority (93%) of plans identified Land Use, Planning, & Zoning Ordinances as a capability available to the county. This was closely followed by Floodplain & Soil Erosion Ordinances and Building Code ordinances.

Table 94. Local Policy Capabilities

Capabilities (policies) Cited in Jurisdictional MHMP	Percent of Counties (67) with Capability in 2013	Percent of Counties with Capability in 2018	Percent of all Jurisdictions (75) with Capability in 2018
Land Use, Planning & Zoning Ordinance	65%	97%	93%
Floodplain & Soil Erosion Ordinance	60%	84%	80%
Building Code	42%	69%	68%
Subdivision Ordinance	28%	52%	47%
Methamphetamine Lab Ordinance	20%	25%	25%
Fire Code	11%	28%	29%

The engagement of County Staff in the hazard mitigation planning process was the third measure of local capabilities (Table 95). The Hazard Mitigation Planning is almost always coordinated by an Emergency Management Coordinator or Director in Minnesota. However, jurisdictions have varying levels of full-time equivalent (FTE) staff dedicated to Emergency Management Coordination.

Table 95. Local Staff Capabilities

Capabilities (staff) Cited in Jurisdictional MHMP	Percent of Counties with Capability in 2013	Percent of Counties with Capability in 2018	Percent of Jurisdictions with Capability
Emergency Management Director	80%	100%	100%
Mapping Specialist (GIS)	56%	36%	36%
Public Health Coordinator/Department	55%	84%	80%
Sheriff/Police Department	54%	82%	79%
MN Department of Natural Resources	46%	27%	25%
Soil and Water Conservation District	N/A	51%	47%
Public Works/Utility	N/A	66%	63%
Schools	44%	64%	60%

6.6 Prioritizing Local Assistance

S15. Does the plan describe the criteria for prioritizing funding? [44 CFR §201.4(c)(4)(iii)]

The application process, project review, ranking and selection criteria for Hazard Mitigation Grant Program planning and projects are described below. All other HMA grant program funds are evaluated first by state mitigation staff and then forwarded to regional FEMA staff for review. All projects must meet eligibility and feasibility requirements described in Hazard Mitigation Assistance Guidance and Addendum. The natural hazard cause of each disaster declaration has specific hazard mitigation projects associated with reducing future damages. As such, the priority project types for each disaster will differ. Additionally the non-disaster grants also have priorities set by Congress. The state also has its own priorities that depend on available disaster funding. Jurisdictions in declared areas will have priority at disaster funding. Jurisdictions not declared will have priority in non-disaster funding. Additional criteria are included in each disaster or non-disaster strategy.

As part of a Presidential Disaster Declaration, the State is required to submit an Administrative Plan. This document details how the State will administer the Hazard Mitigation Grant Program funds made available by the disaster declaration. The state's FEMA-approved HMGP Administrative Plan describes the organization, staffing, and procedures to be used when implementing the Section 404 Hazard Mitigation Grant Program in both the post and pre-disaster mitigation environment. The following is excerpted from the FEMA approved Administrative Plan for DR-4390-MN.

Eligibility

A. Applicants

Applicant eligibility criteria will be in accord with federal statutes and regulations. Specifically, potentially eligible applicants will include: state agencies, local governments, private non-profit organizations (or institutions that own or operate a private non-profit facility as defined in 44 CFR 206.2211(e), and Indian tribes. Any questions regarding the eligibility of an applicant will be resolved by the SHMO, or, if necessary, by the Governor's Authorized Representative or his/her designee.

B. Planning

Up to 7% of the HMGP funds may be used for planning for the State All-Hazard Mitigation Plan or local, multi-jurisdictional mitigation plans. HSEM tracks plan expiration dates and makes funds available for update in a timely manner.

C. Projects

Projects may be of any nature that will result in the reduction or elimination of potential natural hazards and the protection of life and property. Specific types of eligible projects include, but are not limited to:

1. Projects in Disaster Declared jurisdictions;
2. Acquisition and demolition of hazard prone properties;
3. Flood damage reduction and small flood control projects;

4. New community tornado safe room construction or retrofit projects; currently unprotected populations at mobile home parks, schools, parks and camping facilities, neighborhoods, and apartments with slab-on-grade construction;
5. Any project incorporating Climate Resilient Mitigation Actions (CRMA), including Green Infrastructure;
6. Retrofitting of facilities, including burying or retrofitting of power lines;
7. Wildfire resistant construction materials, defensible space and sprinklers;
8. Soil stabilization to protect critical facilities and/or infrastructure; and
9. Elevation or relocation or hazard prone facilities.

D. 5% Initiative

These projects, which are only available pursuant to an HMGP disaster, provide an opportunity to fund mitigation actions that are consistent with the goals and objectives of the State, Tribal (Standard or Enhanced), and local/or mitigation plans and meet all HMGP program requirements, but for which it may be difficult to conduct a standard Benefit-Cost Analysis (BCA) to prove cost-effectiveness. For additional information, see Part VII A.14 of the 2015 Hazard Mitigation Assistance Guidance. Activities that might be funded under the 5 Percent Initiative include:

1. The use, evaluation, and application of new, unproven mitigation techniques, technologies, methods, procedures, or products;
2. Equipment and systems for the purpose of warning citizens of impending hazards;
3. Purchase of generators or related equipment, such as generator hook-ups;
4. Hazard identification or mapping and related equipment for the implementation of mitigation activities;
5. GIS software, hardware, and data acquisition whose primary aim is mitigation;
6. Public awareness or education campaigns about mitigation; and
7. Evaluation of model building codes in support of future adoption and/or implementation.

E. Advance Assistance (AA)

The state will assist jurisdictions utilize AA funds that are available to develop mitigation strategies and obtain data to prioritize, select and develop complete HMGP applications in a timely manner. For additional information, see Part VIII A.12 of the 2015 Hazard Mitigation Assistance Guidance and Job Aid.

F. Non-Duplication of Programs

HMGP funds cannot be used as a substitute or replacement to fund projects or programs that are available under other federal authorities, except under limited circumstances in which there are extraordinary threat to life, public health, safety or improved property. Other federal program authorities that should be looked into before requesting use of HMGP monies are, for example:

Section 406 of the Stafford Act, Federal Insurance Administration Programs, the U.S. Army Corps of Engineers, the Small Business Administration, and the Natural Resources Conservation Service.

Project criteria: Projects must be in conformance with the State Hazard Mitigation Plan developed as a requirement of Section 409 of the Stafford Act and Section 322 of the Disaster Mitigation Act of 2000. Projects must have a beneficial impact upon the designated disaster area. Projects do not have to be located in the designated disaster area, funding is made available statewide. Projects must be in conformance with 44 CFR Part 9, Floodplain Management and Protection of Wetlands, and 44 CFR Part 10, Environmental Considerations. Projects must solve a problem independently or constitute a functional portion of a solution where there is assurance that the project as a whole will be completed. Projects that merely identify or analyze hazards or problems are not eligible.

Projects must be cost-effective and substantially reduce the risk of future damage, hardship, loss, or suffering resulting from a major disaster. The sub-grantee must demonstrate this by documenting that the project:

- Addresses a problem that has been repetitive or a problem that poses a significant risk if left unsolved.
- Will not cost more than the anticipated value of the reduction in both direct damages and subsequent negative impacts to the area if future disasters were to occur. Both costs and benefits will be computed on a net present value basis.
- Has been determined to be the most practical, effective, and environmentally sound alternative after consideration of a range of options.
- Contributes, to the extent practicable, to a long-term solution to the problem it is intended to address.
- Considers long-term changes to the areas and entities it protects and has manageable future maintenance and modification requirements.
- Environmental Considerations: Projects funded under the HMGP must comply with all appropriate environmental requirements. These include the National Environmental Policy Act (NEPA), P.L. 91-190, as amended; Executive Order 11988, Floodplain Management; Executive Order 12898, Environmental Justice in Minority and Low-Income Populations, and Executive Order 11990, Protection of Wetlands. (Minnesota is a NEPA - compliant state.). The SHMO will ensure through coordination that all required environmental review is performed. The extent of such review will depend upon (1) the nature of a project, (2) environmental contractor assistance, if any, made available by FEMA or funded by the state, and/or (3) the environmental requirements imposed by other agencies participating in a project (if any). Approval to initiate a project will not be granted, nor will any HMGP monies be expended prior to the completion and satisfactory outcome of a required environmental review.

Pre-Identification and Notification of Potential Applicants

Information acquired during the Preliminary Damage Assessment (PDA) process may be used in identifying potential projects if mitigation was included as part of the PDA process. In the event of an expedited presidential declaration request, mitigation may not be included in the PDA. The SHMO will review the existing State Mitigation Plan for identification of potential statewide projects for HMGP funding. Projects that include the acquisition of properties that have severe repetitive (SRL) and repetitive flood insurance claims (RL) will be of high priority.

Information acquired during the Preliminary Damage Assessment (PDA) process may be used if completed by Mitigation in identifying potential projects. In the event of an expedited presidential declaration request, mitigation may not be included in the PDA. The SHMO will review the existing State Mitigation Plan for identification of potential statewide projects for HMGP funding. Following a presidential disaster declaration but prior to the establishment of a JFO, the SHMO will confer with the federal HMO on a number of issues. Among these will be early indications of potential HMGP applicants. Public Assistance staff may also discover potential hazard mitigation projects. Projects that include the acquisition of properties that have repetitive flood-insurance claims will be of high priority**.**

During Applicant Briefings and individual meetings, potential applicants will be given directions as to how pre-applications for potential hazard mitigation projects can be submitted to the SHMO. At the discretion of the SHMO and in coordination with the federal HMO, press release(s) describing the program may be developed and issued. Such press release(s) would include a point of contact for obtaining additional program information. The release could also include an announcement of HMGP briefings or meetings to be held in the area, should the SHMO decide to hold such briefings. At the discretion of the SHMO and in coordination with the federal HMO, mitigation information describing the program may be disseminated to communities and the public through Disaster Recovery Centers (DRC's) and/or public meetings held by local officials of the disaster-impacted area.

Shortly after the presidential declaration of disaster, the SHMO determines if a separate HMGP briefing (in addition to that given at the Applicant Briefing) would be beneficial, and if so, could be scheduled. Depending on the scope of a disaster, the Minnesota Recovers Task Force (MRTF) may hold a consolidated, multi-agency applicant briefing. Such briefing(s) would include the following: general program overview; eligibility; application process; and technical assistance.

In Minnesota, applicants for HMGP funds will be required to submit a completed application form within a time frame established by the SHMO. The deadline to submit applications to FEMA is 12 months from the date of declaration with a possibility for two-to-three month time extensions totaling up to an additional six months.

Once an application or Notice of Interest is received by HSEM, it is brought to the attention of the MRTF (if activated). At this time, a consensus is obtained as to which agency represented on the MRTF, if any, can/should fund the project.

Ranking

Review of the application forms by the SHMO may reveal that several eligible projects are competing for insufficient hazard mitigation funding. Should this be the case, projects will be prioritized or ranked in accord with FEMA and state criteria. These criteria are as follows:

1. Measures that best fit within an overall plan for development and/or hazard mitigation in the community, disaster area, or state.

2. Measures that, if not taken, will have a severe detrimental impact on the applicant such as potential loss of life, loss of essential services, damage to critical facilities, or economic hardship on the community.

3. Measures that have the greatest potential impact on reducing future disaster losses.

4. Measures that are designed to accomplish multiple objectives, including damage reduction, environmental enhancement, and economic recovery.

5. Measures that are in accordance with any overall hazard mitigation project priorities established by the State Mitigation Plan.

6. Additional state criteria that may be considered

- Geographic distribution of projects
- Projected cost of proposed project
- Relative cost-effectiveness of projects
- Conformity of project with existing local hazard mitigation plans and land use/building regulations in the communities.
- Sub-grantees who have an expired plan will be required to update and adopt an all-hazard mitigation plan.
- Applicant's level of interest and demonstrated degree of commitment to hazard mitigation actions and programs.
- Communities with most intense development pressures.

Process for Integrating State and Local Mitigation Measures

Identification of proposed mitigation measures within each local jurisdiction are the responsibility of the local community. The process of identification should take place during the local hazard mitigation planning process, but it may take place post disaster. The transition between identifying potential mitigation projects and submitting applications for funding of those projects is accomplished through the following process:

1. The State notifies potential applicants of Hazard Mitigation Assistance (HMA) program funding availability, program requirements and disaster specific priority.
2. Applicants submit a Notice of Interest (NOI) declaring their intent to apply to HSEM by the established deadline. The NOI will include the name of the applicant, a brief description of the proposed project, date of FEMA plan approval, mitigation measure from the approved plan that corresponds with the proposed project, approximate cost, and the location.
3. NOI's are reviewed to determine initial eligibility and whether the sub-applicant will be invited to complete a full HMA application. The review will consider the level of funding available under the grant; how the proposed project fits within an overall plan for development and/or hazard

mitigation in the community and how the project addresses the State's priorities. All NOI's are tracked and are utilized for current and future funding opportunities.

4. If all eligibility requirements are met and funding is available, then a formal invitation to apply for FEMA funding will be sent to the sub-applicant. Project specific application development trainings and technical assistance/benefit cost analysis webinars and workshops will be held based on community need as planned in the disaster strategy document.

5. Upon application completion, the sub-applicant will submit the application to the State for review, approval, and submittal to FEMA. Additional information regarding HSEMs internal process are included in the Administrative Plan, and sub-recipient's instructions are included in the Sub-Grantee Handbook.

Current Status

The State has several Hazard Mitigation funding opportunities currently available. The DR-4390 application period is currently open, as is the 2018 Federal Fiscal Year PDM cycle. HSEM will continue to promote grant opportunities to state agency partners and local units of government. As federal grant opportunities continue to include funds for new project types, including Advance Assistance, Resilient Infrastructure (PDM) and Community Flood Mitigation Projects (FMA) HSEM will continue to support planning and project implementation to make Minnesota more resilient.

Acronyms & Abbreviations

ADM	Minnesota Department of Administration
ATSDR	Agency for Toxic Substances and Disease Registry (Centers for Disease Control)
BAH	(Minnesota) Board of Animal Health
BCA	Benefit Cost Analysis
BWCAW	Boundary Waters Canoe Area Wilderness
BWSR	Board of Water and Soil Resources
CDC	Centers for Disease Control
CDMS	Comprehensive Data Management System
CEMHS	Center for Emergency Management and Homeland Security, Arizona State University
CFM	Certified Flood Manager
CFR	Code of Federal Regulations
CI	Critical Infrastructure
COMM	Minnesota Department of Commerce
CRS	Community Rating System
CRV	Current Replacement Value
DEED	Department of Employment and Economic Development
DEM	Digital Elevation Model
DFIRM	Digital Flood Insurance Rate Map
DHS	Department of Human Services
DLI	(Minnesota) Department of Labor and Industry
DMA	Disaster Mitigation Act
DOT	(Minnesota) Department of Transportation
DNR	(Minnesota) Department of Natural Resources
DPS	Department of Public Safety
EAS	Emergency Alert System
EM	Emergency Manager (usually Emergency Management Director)
EMPG	Emergency Management Grant Program
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act

FDR	Flood Damage Reduction
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMA	Flood Mitigation Act
FSA	Farm Services Administration
GAC	Geospatial Analysis Center (at UMD)
GIS	Geographic Information System
GLISA	Great Lakes Integrated Sciences + Assessments (Center)
HAZUS	HAZards US (FEMA software tool)
HMA	Hazard Mitigation Assistance
HMGP	Hazard Mitigation Grant Program
HMP	Hazard Mitigation Plan
HSEM	(Minnesota) Homeland Security and Emergency Management
ICAT	Interagency Climate Adaptation Team
IFR	Interim Final Rule
IWMS	Integrated Workplace Management System
JFO	Joint Field Office
LCCMR	Legislative-Citizen Commission on Minnesota Resources
LIDAR	LIght Detection And Ranging
MAC	Metropolitan Airport Commission
MCD	Minnesota Department of Commerce
MDA	Minnesota Department of Agriculture
MDE	Minnesota Department of Education
MDH	Minnesota Department of Health
MEOP	Minnesota Emergency Operations Plan
MGS	Minnesota Geological Survey
MIFC	Minnesota Inter-Agency Fire Coordination Center
MHIRA	Multi-Hazard Identification and Risk Assessment
MMI	Modern Mercalli Intensity Scale

MN DOT	Minnesota Department of Transportation
MN DNR	Minnesota Department of Natural Resources
MnGEO	Minnesota Geospatial Information Office
MNHS	Minnesota Historical Society
MNAFPM	Minnesota Association of Floodplain Managers
MNOPS	Minnesota Office of Pipeline Safety
MNSCU	Minnesota State Colleges and Universities
MPCA	Minnesota Pollution Control Agency
MPR	Minnesota Public Radio
MRTF	Minnesota Recovers Task Force
NCEI	National Centers for Environmental Information
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Interest
NRCS	Natural Resource Conservation Service
NSMB	North Shore Management Board
NWS	National Weather Service
OSA	(Minnesota) Office of the State Auditor
PDA	Preliminary Damage Assessment
PDM	Pre-Disaster Mitigation
PGA	Peak Ground Acceleration
RL	Repetitive Loss
SCO	State Coordinating Officer
SHELDUS	Spatial Hazard Events and Losses Database for the United States
SFHA	Special Flood Hazard Area
SHMO	State Hazard Mitigation Officer
SHMT	State Hazard Mitigation Team
SRL	Severe Repetitive Loss

SWCD	Soil and Water Conservation District
TRI	Toxic Release Inventory
UMD	University of Minnesota Duluth
UMTC	University of Minnesota Twin Cities
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDOT	United States Department of Transportation
USFS	United States Forest Service
USGS	United States Geological Survey
WMA	Wildlife Management Area

References

ABC7 News. (2018, July 4). *Sinkhole swallows car after heavy rain in Minnesota*. Retrieved from https://abc7news.com/sinkhole-swallows-car-in-minnesota/3705372/

American Meteorological Society. (2004, October 8). *Mobile Homes and Severe Windstorms*. Retrieved December 28, 2018, from American Meteorological Society: https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/archive-statements-of-the-ams/mobile-homes-and-severe-windstorms/

Anderson, G., & Bell, M. (2011). Heat Waves in the United States: Mortality Risk during Heat Waves and Effect Modification by Heat Wave Characteristics in 43 U.S. Communities. *Environmental Health Perspectives*, 210-218.

Asche, K. (2018, March). *State of Rural Minnesota, 2018*. Retrieved from Center for Rural Policy and Development: https://www.ruralmn.org/state-of-rural-minnesota-2018/

ATSDR. (2018). *CDC's Social Vulnerability Index (SVI)*.

Barr Engineering. (2017). *Slope Failure Risk Analysis Mapping.* Minneapolis.

Berg, H. (1985, October). Preliminary Investigation and Recommendations for Solving the Problem of Heavy Lakewater Inflow into the Homes and the Sanitary Sewer Collection System on Park Point, Duluth, Minnesota. *High Lake Level Impact on Park Point*. City of Duluth.

Blumenfeld, K. A. (2010, April). The Frequency of High-Impact Convective Weather Events in the Twin Cities Metropolitan Area, Minnesota. *Journal of Applied Meteorology and Climatology, 49*, 619-631. Retrieved January 25, 2019, from https://journals.ametsoc.org/doi/pdf/10.1175/2009JAMC2223.1

CDC. (2018). *Extreme Cold: A Prevention Guide to Promote Your Personal Health and Safety.* Retrieved from https://www.cdc.gov/disasters/winter/pdf/extreme-cold-guide.pdf

CEMHS. (2018). Spatial Hazard Events and Losses Database for the United States, Version 17.0. [Online Database]. *SHELDUS*. Phoenix, AZ: Center for Emergency Management and Homeland Security, Arizona State University.

Centers for Disease Control and Prevention. (2014). *Climate Effects on Health* . Retrieved from https://www.cdc.gov/climateandhealth/effects/default.htm

CHS Field. (2018). *Rainwater-harvesting*. Retrieved from CHS Field: The Greenest Ballpark in America: http://sustainability.chsfield.com/rainwater-harvesting/

City of Duluth. (2019, January 16). Public Information Meeting on Harbor Dredging and Proposed Beach Nourishment Project, Press Release.

Claims Journal. (2018, November 26). *Study Examines Minnesota Landslides*. Retrieved from https://www.claimsjournal.com/news/midwest/2018/11/26/287989.htm

Clean Water Fund. (2014). *Minnesota's Clean Water Roadmap.* Retrieved from https://www.pca.state.mn.us/sites/default/files/wq-gov1-07.pdf

Coleman, T. A., Knupp, K. R., Spann, J., Elliott, J. B., & Peters, B. E. (2011, May). The History (and Future) of Tornado Warning Dissemination in the United States. *American Meteorological Society*, 567-582. Retrieved June 28, 2018, from https://journals.ametsoc.org/doi/pdf/10.1175/2010BAMS3062.1

Day, S. (2013). *Special Hazard Mitigation Risk Assessment of Near Channel Riverine Erosion Hazards in Blue Earth County - Streambanks, bluffs, and ravines .* Blue Earth County.

Douglas, P. (2011, July 20). *"Heat Storm" (record-setting dew point of 82 at MSP, heat index tied all-time record at 119!).* Retrieved from StarTribune: http://www.startribune.com/blogs/125847178.html

EPA. (1980). *Red Clay Project, Final Part II.* Retrieved from http://www.lrcd.org/uploads/1/6/4/0/16405852/redclay2ndpartbioandveg_.pdf

Explore Minnesota. (2017). *Minnesota Traveler Profile - 2014*. Retrieved from http://www.exploreminnesota.com/industry-minnesota/research-reports/researchdetails/?nid=1499

FBI. (2018). *Terrorism*. Retrieved from FBI: What We Investigate: https://www.fbi.gov/investigate/terrorism#Terrorism-Definitions

FEMA. (n.d.). Retrieved December 6, 2018, from https://www.fema.gov: https://www.fema.gov/pdf/library/ism2_s1.pdf

FEMA . (2018). *Disasters*. Retrieved from https://www.fema.gov/disasters

FEMA. (1997). *Multi-Hazard Identification and Risk Assessment: A Cornerstone of the National Mitigation Strategy.* United States. Federal Emergency Management Agency.

FEMA. (1999). *Riverine Erosion Hazard Areas.* Retrieved from https://www.fema.gov/media-library-data/20130726-1545-20490-8123/ft_rivex.pdf

FEMA. (2009, June). *BCA Reference Guide.* Retrieved June 25, 2018, from https://www.fema.gov/media-library-data/1396550224865-548160e5f22dabb793d8a045fa89f5fe/bca_reference_guide_508_final.pdf

FEMA. (2013, January). *Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards.* Retrieved from http://www.fema.gov/media-library-data/20130726-1904-25045-0186/fema_mitigation_ideas_final508.pdf

FEMA. (2018). Retrieved from Great Lakes Coastal Flood Study: http://www.greatlakescoast.org/

FEMA. (2018). *BureauNet Reporting*. Retrieved from National Flood Insurance Program, Bureau and Statistical Agent (BSA) : https://nfipservices.floodsmart.gov/home/reports

FEMA. (2018). Hazus Software 4.2 (SP 1).

FEMA. (2019). *1997 Grand Forks Flood By The Numbers*. Retrieved from https://www.fema.gov/1997-grand-forks-flood-numbers

FEMA HAZUS. (2018). HAZUS Software 4.2 (SP 1).

Flanagan et al. (2011). A Social Vulnerability Index for Disaster Management. *Journal of Homeland Security and Emergency Management*, Vol. 8: Iss. 1, Article 3.

Flood Control America. (2014). *Removable Flood Wall Project - St. Paul Downtown Airport*. Retrieved from http://floodcontrolam.com/projects/flood-wall-st-paul

Fortune 500. (2018). *Visualize the Fortune 500*. Retrieved from http://fortune.com/fortune500/visualizations/

GLISA. (2018). *Great Lakes Regional Climate Change Maps*. Retrieved from http://glisa.umich.edu/resources/great-lakes-regional-climate-change-maps

Gottfried, M. (2013, May 22). *Landslide at St. Paul's Lilydale Park kills one; injures two; one missing*. Retrieved from Pioneer Press: https://www.twincities.com/2013/05/22/landslide-at-st-pauls-lilydale-park-kills-one-injures-two-one-missing/

Great Lakes Coastal Flood Study. (2018). *Fact Sheets*. Retrieved from http://www.greatlakescoast.org/great-lakes-coastal-analysis-and-mapping/outreach/fact-sheets/

Hansen, G. J., Read, J. S., Hansen, J. F., & Winslow, L. (2016). Projected shifts in fish species dominance in Wisconsin. *Global Change Biology*.

Hayes, M. J., Alvord, C., & Lowrey, J. (2007, July). Retrieved from Western Water Assessment: http://wwa.colorado.edu/climate/iwcs/archive/IWCS_2007_July_feature.pdf

Homeland Security and Emergency Management. (2019). *Minnesota Rail Safety*. Retrieved from https://dps.mn.gov/divisions/hsem/planning-preparedness/Pages/minnesota-rail-safety-regulations.aspx

Hudson, B. (2016, November 11). *Evacuation Lifted, Ellendale Residents Return Following Train Derailment*. Retrieved from CBS Minnesota: https://minnesota.cbslocal.com/2016/11/11/train-derailment-ellendale/

ICAT. (2013). *Adapting to Climate Change in Minnesota.* St Paul: Minnesota Pollution Control Agency.

ICAT. (2017). *Adapting to Climate Change in Minnesota.* St Paul: Minnesota Pollution Control Agency.

Jennings, C. M. (2016). *Historical Landslide Inventory for the Twin Cities Metropolitan Area.* St. Paul: State of Minnesota Department of Natural Resources and the Regents of the University of Minnesota.

Jereczek, J., & Little, C. (2016). *Enhancing the Lake Superior North and South Watershed Assessments.* Minnesota Department of Natural Resource.

Johnson, B. L. (1995). Relationship of Lithology and Geomorphology to Erosion of the Western Lake Superior Coast. *Journal of Great Lakes Research*, 3-16.

Johnson, T. L., Neitzel, D. F., Dorr, F. M., Schiffman, E. K., & Eisen, R. J. (2016). Habitat Suitability Model for the Distribution of Ixodes scapularis (Acari: Ixodidae) in Minnesota. *Journal of Medical Entomology*.

Johnston, C., Sales, J., Bonde, J., Aunan, T., & Raby, R. (1989). *Erosion Hazard of Minnesota's Lake Superior Shoreline.* Natural Resources Research Institute.

Kossin, J. T. (2017). *Extreme storms*. Retrieved from In: Climate Science Special Report: Fourth National Climate Assessment, Volume I: https://science2017.globalchange.gov/chapter/9/

Kunkel, K., Stevens, L., Stevens, S., Sun, L., Janssen, E., Wuebbles, D., & … Dobson, J. (2013). Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. *NOAA Technical Report NESDIS*, 142-3, 95.

Leighton, P. A., Koffie, J. K., Pelcat, Y., Lindsay, L. R., & Ogden, N. H. (2012). Predicting the speed of tick invasion: an empirical model of range expansion for the Lyme disease vector Ixodes scapularis in Canada. *Journal of Applied Ecology*.

Lopez, H., West, R., Dong, S., Gon, G., B. K., Lee, S.-K., & Atlas, R. (2018). Early emergence of anthropogenically forced heat waves in the western United States and Great Lakes. *Nature Climate Change*.

MCD. (2018). *Be prepared for propane season* . Retrieved from Minnesota Commerce Department: https://mn.gov/commerce/consumers/tips-tools/propane/

McKee, T., Doesken, N., & Kleist, J. (1995). Drought monitoring with multiple time scales. *Proceedings of the Ninth Conference on Applied Climatology.* Boston: American Meteorological Society.

MDA. (2018). Retrieved from Minnesota Department of Agriculture: https://www.mda.state.mn.us/~/media/Files/agprofile.ashx

MDA. (2018). *The Economic Status of Minnesotans 2018.* Retrieved from Minnesota State Demographic Center, Minnesota Department of Administration: http://mn.gov/admin-stat/documents/MNSDC_EconStatus_2018Report.pdf

MDH. (2018). *About Lyme Disease*. Retrieved from http://www.health.state.mn.us/divs/idepc/diseases/lyme/basics.html

MDH. (2018). *Extreme Heat Events.* Retrieved from MDH Environmental Health Division : http://www.health.state.mn.us/divs/climatechange/docs/extremeheatsummary.pdf

MDH. (2018). *Planning for Climate & Health Impacts in Metro Minnesota.* Minnesota Department of Health.

MDH. (2018). *Planning for Climate & Health Impacts in Northwest Minnesota.* Minnesota Department of Natural Resources. Minnesota Department of Health. Retrieved from http://www.health.state.mn.us/divs/climatechange/docs/hsem_region3.pdf

MDH. (2018). *Planning for Climate & Health Impacts in West Central Minnesota.* Minnesota Department of Health. Minnesota Department of Health. Retrieved September 11, 2018, from http://www.health.state.mn.us/divs/climatechange/docs/hsem_region4.pdf

MDH. (2018). *Planning Tools & Data*. Retrieved from Minnesota Department of Health: http://www.health.state.mn.us/divs/climatechange/data.html

MDH. (2018). *Response Systems*. Retrieved from http://www.health.state.mn.us/oep/responsesystems/index.html

MDH. (2018). *Summary of General Requirements for Manufactured Home Parks*. Retrieved from http://www.health.state.mn.us/divs/eh/mhprca/mhpgenreq.html

MDH. (2018). *West Nile Virus (WNV)*. Retrieved from http://www.health.state.mn.us/divs/idepc/diseases/westnile/

MDH. (2018). *West Nile Virus Maps and Statistics*. Retrieved from http://www.health.state.mn.us/divs/idepc/diseases/westnile/statistics.html

MDH. (2019). *Extreme Cold (Hypothermia)*. Retrieved from http://www.health.state.mn.us/divs/eh/emergency/natural/cold/extremecold.html

Metropolitan Council. (2018, May 16). *Metro Area Grows 8% between 2010-2017*. Retrieved from https://metrocouncil.org/News-Events/Communities/Newsletters/Metro-area-continues-to-grow,-with-8-growth-rate.aspx

(2014). *Minnesota All Hazard Mitigation Plan Rural Electric Annex.*

Minnesota Compass. (2018). *Overview*. Retrieved from https://www.mncompass.org/demographics/overview

Minnesota Fire Bridge. (2017). Retrieved from http://www.mnfirereport.net/

Minnesota State Climatology Office. (2014, January 29). *Historic Wind Chill Temperatures in Minnesota*. Retrieved from http://climateapps.dnr.state.mn.us/doc/journal/historic_windchills.htm

Minnesota State Fire Marshal. (2017). *Fire in Minnesota .*

(2015). *Minnesota State Rail Plan.*

MN DEED. (2018). Retrieved from https://mn.gov/deed/

MN DNR . (2018). *100 degrees on Memorial Day: 2018*. Retrieved from https://www.dnr.state.mn.us/climate/journal/100-degrees-memorial-day-2018.html

MN DNR. (1988). *Drought of 1988.*

MN DNR. (2015). *Hail in the Twin Cities: May 3, 2015*. Retrieved from https://www.dnr.state.mn.us/climate/journal/150503_hail.html

MN DNR. (2016). *Hail and Severe Storms: May 24, 2016*. Retrieved from https://www.dnr.state.mn.us/climate/journal/160524_hail.html

MN DNR. (2016). *November Storms and Hail: November 28, 2016*. Retrieved from https://www.dnr.state.mn.us/climate/journal/161128_hail.html

MN DNR. (2016, August 25). *November Tornadoes in Minnesota*. Retrieved June 8, 2018, from MN Department of Natural Resources: https://www.dnr.state.mn.us/climate/journal/121110_tornado.html

MN DNR. (2016). *Severe Storms hit Northwest Minnesota: July 19-20 2016*. Retrieved from https://www.dnr.state.mn.us/climate/journal/160719_20_severe.html

MN DNR. (2016). *Severe Storms Strike Northland Again: July 20-21 2016.* Minnesota Department of Natural Resources.

MN DNR. (2017). *2017 M.L.K. Day Ice Storm*. Retrieved from https://www.dnr.state.mn.us/climate/journal/170116_ice.html

MN DNR. (2018). *Climate Journal*. Retrieved from https://www.dnr.state.mn.us/climate/journal/index.html

MN DNR. (2018). *Climate trends*. Retrieved from MN Department of Natural Resources, Climate Change and Minnesota: https://www.dnr.state.mn.us/climate/climate_change_info/climate-trends.html

MN DNR. (2018, June 25). *Dams and Dam Safety*. Retrieved from https://www.dnr.state.mn.us/waters/surfacewater_section/damsafety/index.html

MN DNR. (2018). *Erosion*. Retrieved from https://www.dnr.state.mn.us/rys/sl/shoreline.html

MN DNR. (2018). *Floodplain Management*. Retrieved from https://www.dnr.state.mn.us/waters/watermgmt_section/floodplain/access-flood-maps.html

MN DNR. (2018). *Minnesota Climate Extremes*. Retrieved from https://www.dnr.state.mn.us/climate/summaries_and_publications/extremes.html

MN DNR. (2018, June 25). *Wildfires in Minnesota*. Retrieved from https://www.dnr.state.mn.us/wildfire/prevention/causes.html

MN DNR Division of Waters. (2018). State Floodplain Manager.

MN DNR State Climatology Office. (2019, January). Average Annual Minnesota F2+ Tornadoes and Days with F2+ Tornadoes, by Decade. St. Paul, Minneosta.

MN DPS. (2017). *2017 Report to the Legislature: The readiness of state government to respond to discharges of hazardous substances.* Retrieved from https://www.leg.state.mn.us/docs/2018/mandated/180006.pdf

MN State Demographic Center. (2018). *Our Estimates*. Retrieved from https://mn.gov/admin/demography/data-by-topic/population-data/our-estimates/

Mn.gov. (2018). *Minnesota Buffer Law.* Retrieved from Mn.gov: https://mn.gov/portal/buffer-law/

MN DOT. (2009). *Bridge Scour Evaluation Procedure for Minnesota Bridges, Minnesota Department of Transportation.*

MN DOT. (2018). *Aviation in Minnesota, Minnesota Department of Transportation*. Retrieved from http://www.dot.state.mn.us/aero/documents/aviationinminnesotabrochure.pdf

MN DOT. (2018). *Climate Change Adaptation*. Retrieved from Minnesota Department of Transportation: http://www.dot.state.mn.us/climate/adaptation.html

MN DOT. (2018). *Winter Maintenance Report 2017-2018*. Retrieved from https://www.dot.state.mn.us/maintenance/pdf/AtaGlance2018.pdf

MN DOT. (2019). *Bridges and Structures*. Retrieved from http://www.dot.state.mn.us/bridge/index.html

MN DOT. (2019). *Commercial waterways, Minnesota Department of Transportation*. Retrieved from http://www.dot.state.mn.us/ofrw/waterways/commercial.html

MN DOT. (2019). *Rail Safety and Education*. Retrieved from http://www.dot.state.mn.us/ofrw/railroad/safety.html

MN DOT. (2019). *Roadway Data, Minnesota Department of Transportation*. Retrieved from http://www.dot.state.mn.us/roadway/data/fun-facts.html

MPCA. (2017). *Adapting to Climate Change in Minnesota.* St. Paul: Minnesota Pollution Control Agency. Retrieved September 13, 2018, from https://www.pca.state.mn.us/sites/default/files/p-gen4-07c.pdf

MPCA. (2018). *Karst in Minnesota*. Retrieved from https://www.pca.state.mn.us/karst-minnesota

MPCA. (2018). *Smoky summers the new normal?* Retrieved from MPCA: https://www.pca.state.mn.us/featured/smoky-summers-new-normal-0

MPR. (2013, April 10). *Photos: Ice storm knocks out power in SW Minn.* Retrieved from https://www.mprnews.org/story/2013/04/10/regional/winter-storm-photos

MPR. (2014). *Beneath the Surface: Minnesota's Pending Groundwater Challenge*. Retrieved from Minnesota Public Radio: http://minnesota.publicradio.org/projects/2014/01/ground-level-beneath-the-surface/

MPR. (2018, June 18). *NW Wisconsin dam failure near MN border triggers flooding*. Retrieved from https://www.mprnews.org/story/2018/06/18/possible-dam-break-near-duluth

MSN. (2018). *States home to the most Fortune 500 companies*. Retrieved from https://www.msn.com/en-us/money/companies/states-home-to-the-most-fortune-500-companies/ss-AAvX7gT#image=30

Mueller, B., & Seneviratne, S. I. (2012). Hot days induced by precipitation deficits at the global scale. *PNAS*, 12398-12403. Retrieved from http://www.pnas.org/content/109/31/12398

National Centers for Environmental Information. (2018). *Storm Events Database*. Retrieved from https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=5713146

National Climate Assessment Development Advisory Committee. (2013). Retrieved from http://ncadac.globalchange.gov/

National Institute of Building Sciences. (2017). *Natural Hazard Mitigation Saves: 2017 Interim Report.*

National Inventory of Dams. (2018). Retrieved from http://nid.usace.army.mil/cm_apex/f?p=838:3:0::NO::P3_STATES:MN

National Transportation Safety Board. (2019). *About the National Transportatin Safety Board*. Retrieved from https://www.ntsb.gov/about/Pages/default.aspx

National Transportation Safety Board. (2019). *Aviation Accident Database & Synopsis*. Retrieved from https://www.ntsb.gov/_layouts/ntsb.aviation/index.aspx

National Transportation Safety Board. (2019). *Marine Accident Reports*. Retrieved from https://www.ntsb.gov/investigations/AccidentReports/Pages/marine.aspx

National Weather Service. (2018). *National Weather Service Storm Data Preparation.* National Weather Service.

National Weather Service. (2019). *Winter Hazard Awareness Week in Minnesota*. Retrieved from https://www.weather.gov/mpx/winterpns3

NCEI. (2018, June). *Climate at a Glance: Statewide Mapping*. Retrieved from NOAA National Centers for Environmental information: https://www.ncdc.noaa.gov/cag/

NIST. (2017). *National Institute of Standards and Technology*. Retrieved from https://www.nist.gov/sites/default/files/images/2017/02/07/wind_zone_map.jpg

NOAA. (2018, June 4). *Storm Events Database: NOAA National Centers For Environmental Information*. Retrieved June 4, 2018, from NOAA National Centers For Environmental Information: https://www.ncdc.noaa.gov/stormevents/

NOAA. (2018). *U.S. Billion-Dollar Weather & Climate Disasters 1980-2018*. Retrieved from https://www.ncdc.noaa.gov/billions/events.pdf

NOAA National Centers for Environmental Information. (2018, June). Storm Events Database. Retrieved from https://www.ncdc.noaa.gov/stormevents/

NOAA National Severe Storms Laboratory. (n.d.). *NSSL Severe Weather 101 - Damagine WInds*. Retrieved July 19, 2018, from National Severe Storms Laboratory: https://www.nssl.noaa.gov/education/svrwx101/wind/types/

NOAA NCEI. (2018, June). National Centers for Environmental Information Storm Events Database. Retrieved from https://www.ncdc.noaa.gov/stormevents/

NOAA OCM. (2018). *Office for Coastal Management: Minnesota*. Retrieved from NOAA Office for Coastal Management : https://maps.coast.noaa.gov/states/minnesota.html

NOAA SPC. (2018). *Storm Prediction Center*. Retrieved from NOAA / National Weather Service: https://www.spc.noaa.gov/

NOAA Storm Prediction Center. (2018). *SVRGIS*. Retrieved from https://www.spc.noaa.gov/gis/svrgis/

NSMB. (2016). *North Shore Management Plan Update.* North Shore Management Board.

NWS. (2016, March 23). *NOAA National Centers for Environmental Information Storm Events Database.* Retrieved 12 3, 2018, from NOAA National Centers for Environmental Information: https://www.ncdc.noaa.gov/stormevents/pd01016005curr.pdf

NWS. (2018). *https://www.weather.gov/safety/lightning-science*. Retrieved from NAtional Weather Service : https://www.weather.gov/safety/lightning-science

NWS. (2018). *What is the heat index?*

OSA. (2017). *Office of the State Auditor*. Retrieved from Infrastructure Stress Transparency Tool Version 2.0: https://www.auditor.state.mn.us/maps/

paleBLUEdot. (2018, 09 21). *Vulnerable Populations and Climate Adaptation Framework*. Retrieved from http://www.bluedotregister.org/mpca-vulnerable-population-assessments

Palmer, W. C. (1965). *Meteorological drought.* U.S. Weather Bureau.

Phillips, A. (2014, March 24). *Landslide Kills 8 People In Washington As Climate Change Makes Them More Likely In The Future.* Retrieved from Climate Progress: http://thinkprogress.org/climate/2014/03/24/3418117/climate-change-landslides-washington/

Pielke, R. A. (2012, February 2). *Windstorm*. Retrieved December 3, 2018, from Encyclopedia Britannica: https://www.britannica.com/science/windstorm

Pryor, S., Scavia, D., Downer, C., Gaden, M., Iverson, L., Nordstrom, R., . . . Robertson, G. (2014). *Climate Change Impacts in the United States: The Third National Climate Assessment, Ch. 18: Midwest.* Washington, D.C.: U.S. Global Change Research Program.

Radeloff, V. R. (2005). The Wildland Urban Interface in the United States. *Ecological Applications*, 15: 799-805.

Rasid, H. B. (1992). Coping with Great Lakes Flood and Erosion Hazards: Long Point, Lake Erie, vs. Minnesota Point, Lake Superior. *Great Lakes Journal of Research*, 29-42.

Schoof, J. (2012). Scale Issues in the Development of Future Precipitation Scenarios. *Journal of Contemporary Water Research and Education*, 8-16.

Seeley, M. (2015). *Minnesota Weather Almanac.* St. Paul: Minnesota Historical Society.

Stanley, G. (2018, July 11). *State disaster dollars to help Ramsey County clean up St. Paul landslide*. Retrieved from Star Tribune: http://www.startribune.com/state-disaster-dollars-to-help-clean-up-st-paul-landslide/487938161/

Sustainable Agriculture Research and Education. (2012). *Erosion.* College Park: Sustainable Agriculture Research and Education.

The National Drought Mitigation Center. (2018). *Background*. Retrieved from United States Drought Monitor: https://droughtmonitor.unl.edu/AboutUSDM/Background.aspx

Thomas, D., Wilhelmi, O., Finnessey, T., & Deheza, V. (2013). A comprehensive framework for tourism and recreation drought vulnerability reduction. *Environmental Research Letters*, 1-8.

U.S. Global Change Research Program. (2014). *Midwest*. Retrieved from National Climate Assessment: http://nca2014.globalchange.gov/report/regions/midwest

University of Minnesota, Department of Geology and Geophysics; MN DNR Ecological and Water Resources Division. (n.d.). Springs, Karst Features database. MN DNR.

USACE. (1974). *Minnesota Point at Duluth Minnesota.* St. Paul: U.S. Army Corp of Engineers.

USACE. (2017). *Lake of the Woods Wind-Wave Modeling Report.* U.S. Army Corps of Engineers, St. Paul District.

USDA Census of Agriculture. (2018). Retrieved from https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_US_State_Level/

USGCRP. (2014). *Midwest*. Retrieved from National Climate Assessment: http://nca2014.globalchange.gov/report/regions/midwest

USGCRP. (2017). *Climate Science Special Report: Fourth National Climate Assessment, Volume I.* Washington, DC, USA: U.S. Global Change .

USGCRP. (2018). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II.* Washington, DC, USA: U.S. Global Change Research Program. doi:10.7930/NCA4.2018

Vaisala Inc. (2017). *Number of Cloud-To-Ground Flashes by State from 2008-2017*. Retrieved from https://www.weather.gov/media/safety/08-17Flash_Density_State.pdf

Valley News. (2016, November 15). *Chemical Spill in MN*. Retrieved from https://www.valleynewslive.com/content/news/Chemical-spill-in-MN-401265706.html

Vezner, T. (2018, August 8). *Locomotives derail, sending 3,200 gallons of diesel into Mississippi River*. Retrieved from Twin Cities Pioneer Press: https://www.twincities.com/2018/08/08/st-paul-train-derailment-sends-3200-gallons-of-diesel-fuel-into-mississippi-river/

WDIO. (2018). *WDIO.com*. Retrieved from ABC Eyewitness News: https://www.wdio.com/news/duluth-canal-park-october-10-flooding/5103273/

Wehner, M. J. (2017). *Droughts, floods, and wildfires.* Retrieved from Climate Science Special Report: Fourth National Climate Assessment, Volume I : https://science2017.globalchange.gov/chapter/8/

Zandlo, J. A., Milles, D. B., & Sium, O. (1989). *Minnesota Floods and Drought.* Minnesota Department of Natural Resources, St. Paul. Retrieved September 11, 2018, from https://files.dnr.state.mn.us/natural_resources/climate/summaries_and_publications/minnesota_floods_and_drought.pdf