Adapting to Climate Change in Minnesota

2017 Report of the Interagency Climate Adaptation Team

May 2017

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Summary

Climate change is already occurring in Minnesota and its impacts are affecting our state's environment, economy, and communities. Minnesota state government is concerned about the impacts of a changing climate on our natural resources, economy, health, and quality of life, and is taking action to address these emerging challenges.

Work on climate change can be categorized into two areas: adaptation and mitigation. Climate *adaptation*, the focus of this report, is defined as developing and implementing strategies, initiatives, and measures to help human and natural systems prepare for and address climate change impacts. State agencies are working to adapt to a changing climate and manage its risks by building a more resilient state. Climate change *mitigation* emphasizes reducing greenhouse gas emissions with the goal of limiting the magnitude or progression of climate change. Minnesota state government has a number of policies and laws in place that have helped us make significant progress toward our greenhouse gas reduction goals, including the 2007 Next Generation Energy Act. The section of this report, *Climate Adaptation and Mitigation,* outlines how these two approaches are complementary to each other.

This 2017 Interagency Climate Adaptation Team (ICAT) report updates previous reports from this team, and represents a continuing and evolving step in a planning process by Minnesota state government. This revised report highlights steps taken by state agencies since the previous ICAT report in 2013 to adapt to a changing climate, reduce risks and impacts, and increase the resilience of our communities.

Since July 2009, Minnesota state agencies have been collaborating on climate adaptation efforts through ICAT. ICAT currently includes representatives from the following Minnesota state departments and agencies: Administration, Agriculture, Commerce (Division of Energy Resources), Corrections, Employment and Economic Development, Environmental Quality Board, Health, Military Affairs, Natural Resources (including the State Climatology Office), Pollution Control, Public Safety (Division of Homeland Security and Emergency Management), Transportation, Water and Soil Resources, as well as the Metropolitan Council and Minnesota State Colleges and Universities.

ICAT prepared a preliminary report in August 2010, *Adapting to Climate Change in Minnesota*, which was followed up with a 2013 report of the same title. This 2017 report updates and expands on the 2013 document. The purpose of this updated report is to:

- Further describe observed and projected climate impacts in Minnesota.
- Outline Minnesota state agency activities that are helping to adapt to climate change.
- Provide recommendations for future state action and interagency collaboration.

Complementary to this interagency effort within state government, 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. MCAP serves as a valuable networking and educational resource to connect and educate professionals working in the climate adaptation field and sponsors a statewide climate adaptation conference. This year, instead of a standalone conference, the Minnesota conference has been integrated into the National Adaptation Forum in Saint Paul on May 9-11, 2017.

Minnesota is one of a growing number of state governments working to address climate adaptation. A wide range of adaptation planning activities in other states are described on the Georgetown Climate Center's website at http://www.georgetownclimate.org/adaptation/plans.html and the Center for Climate and Energy Solutions' website at https://www.c2es.org/us-states-regions/policy-maps/adaptation.

Minnesota's climate background

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

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

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

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

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

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

Figure 1

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

Confidence Scale

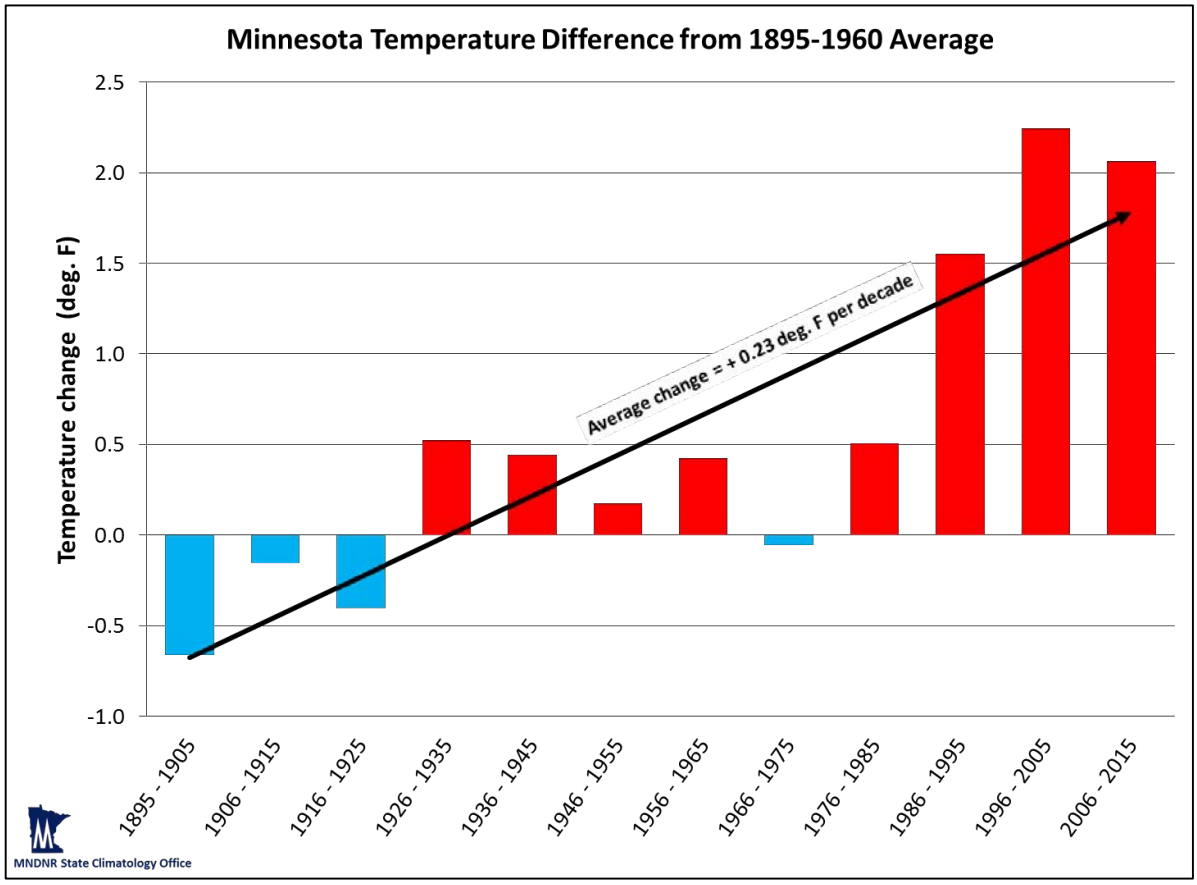
Lowest	Low	Moderately Low	Moderately High	High	Highest

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

Observed warming in Minnesota

Minnesota's warming is well underway, with annual temperatures increasing at an average rate of nearly a quarter degree Fahrenheit (F) per decade since 1895. Much of the total warming, however, has been concentrated in the most recent several decades, with warming rates averaging nearly a half a degree per decade since 1970. The three most recent 10-year periods (through 2015) have been by far the warmest on record. Both the long-term and recent rates of warming in Minnesota are faster than national and global trends.

Figure 2



Minnesota annual temperature comparisons between consecutive 10-year periods and the 1895-1960 average (black line). Courtesy of Minnesota State Climatology Office. Data from National Centers for Environmental Information (http://www.ncdc.noaa.gov/cag/time-series).

Cold weather warming

Many people are surprised to learn that much of the observed temperature increase in Minnesota has not resulted from more warm weather, but instead from major reductions in cool and cold weather. The majority of Minnesota's warming has taken place where and when it's usually the coldest — namely during winter, at night, and especially in the northern parts of the state.

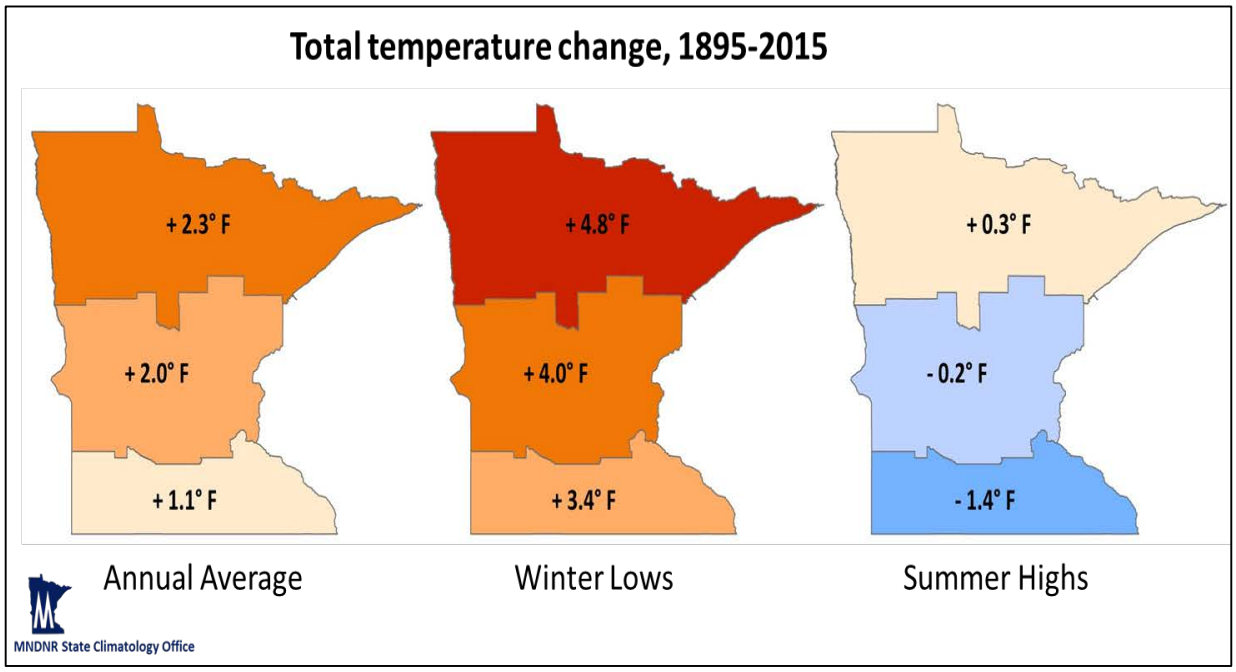
Our state is renowned for its severe winters, but these in particular have been less common in recent decades, as cold weather extremes have become rare. Simply put, we don't get as cold as we used to, and it is now increasingly common for Minnesota communities to fail to reach formerly common "cold weather benchmarks."

For example, of the 50 winters from 1944-45 through 1993-94, only six failed to produce a reading of -40° F at an official weather observing site in Minnesota. By contrast, nine of the last 22 winters have failed to do so, meaning that it is now over three times more likely that Minnesota will not see a -40° reading than it was historically. Although some Minnesotans view any warming during winter as a major improvement, the reality is that we have already begun to see detrimental impacts on our natural resources and availability of popular winter recreational activities such as ice fishing and skiing.

Although it's most noticeable in winter, this "cold weather warming" is affecting the lowest temperatures of each of our seasons, and accounts for the majority of our observed annual warming. Summer has indeed gotten warmer, especially in the past few decades, but this warming has been observed almost entirely during the night, when daily minimum temperatures are recorded. Summer

high temperatures are actually falling slightly in the southern parts of Minnesota. Winter low temperatures, on the other hand, have been warming dramatically across the entire state, and especially in the north (see Figure 3). The geographic and seasonal patterns of observed warming are consistent with changes expected from increased atmospheric greenhouse gases, because those gases trap heat escaping from the earth, and the majority of heat escapes when there is little or no incoming sunlight — during winter and at night.

Figure 3



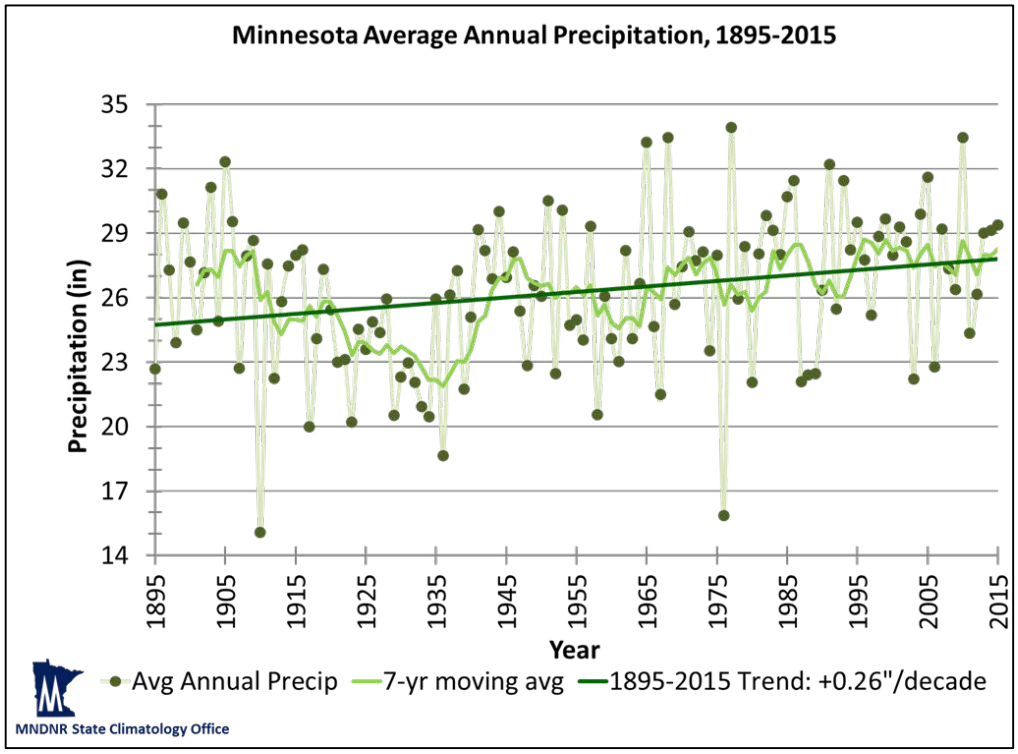
Comparisons of total change between 1895 and 2015 using 30-year averaging periods, for annual average temperature, winter low temperature, and summer high temperatures over the northern, central, and southern portions of the state. Values were obtained by subtracting the average of the first 30 years of record (1895-1924) from the average of the last 30 years of record (1986-2015). Each region is a blend of three climatic divisions, as defined by the National Centers for Environmental Information (https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php), which is also the source for the divisional climate data used (http://www.ncdc.noaa.gov/cag/time-series). Maps prepared by Minnesota State Climatology Office.

Increased precipitation

Higher temperatures globally have evaporated more surface and ocean water into the atmosphere, which in turn has provided more potential moisture for precipitating weather systems. 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 4).

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 4



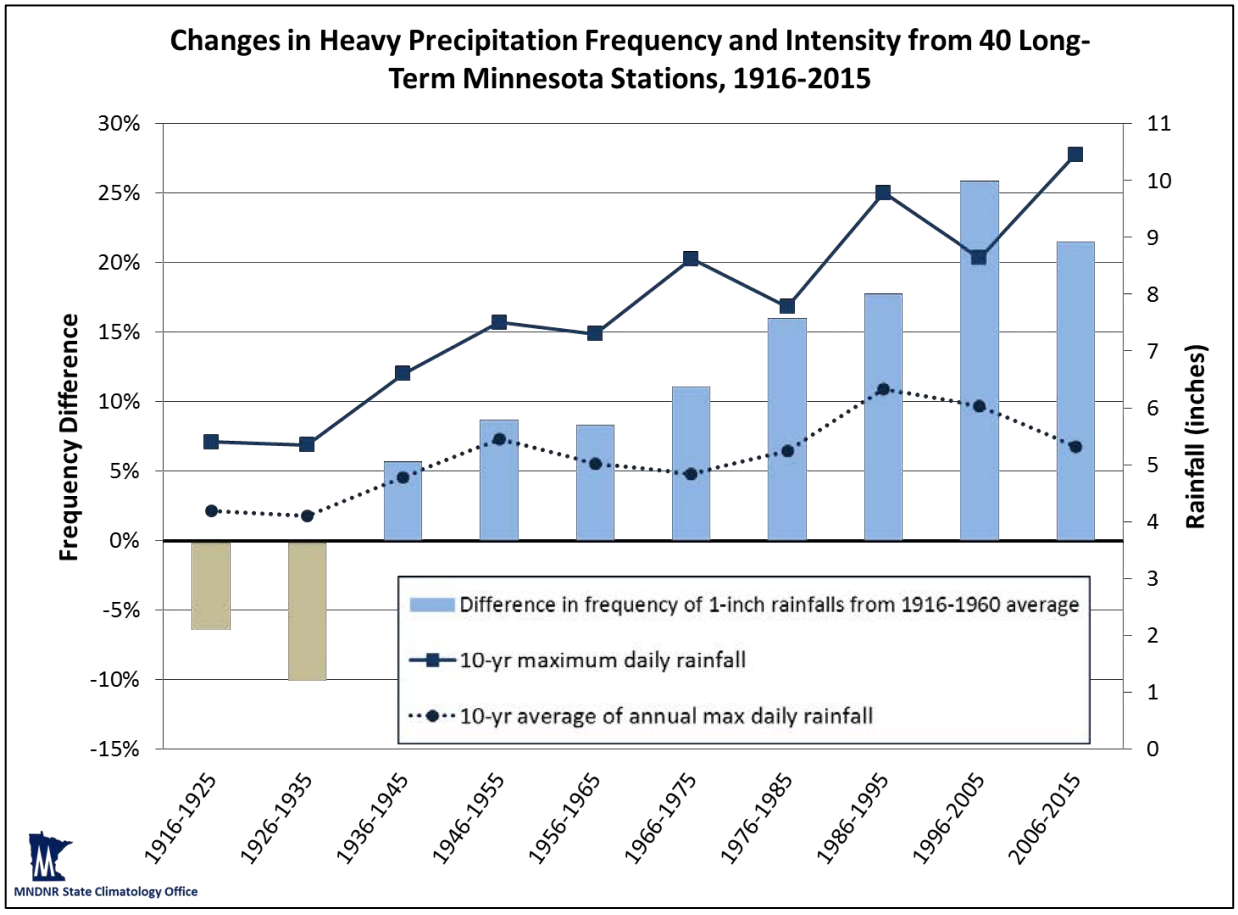
Statewide average annual precipitation, 1895-2015. The 1895-2015 trend (solid dark green line) is based on linear statistical techniques and does not imply an exact decade-by-decade precipitation increase. Source: National Oceanic and Atmospheric Administration (NOAA) Climate at a Glance (http://www.ncdc.noaa.gov/cag/)

Heavy rainfall and unprecedented extremes

Heavy rainfall events in Minnesota are already becoming larger and more common, and have been contributing to an increasing share of annual precipitation in Minnesota. For instance, the state has 40 daily weather observing sites whose records stretch back 100 years. One-inch rainfalls at these sites have been up to 26% more frequent during the past 40 years than the 1916-1960 average. The single heaviest rainfall amount recorded among those 40 sites each year has increased by nearly an inch since 1916, and the single heaviest rainfall amount recorded per 10-year interval has roughly doubled (from just over five inches to just over 10 inches) during that same period (see Figure 5).

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

Figure 5



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

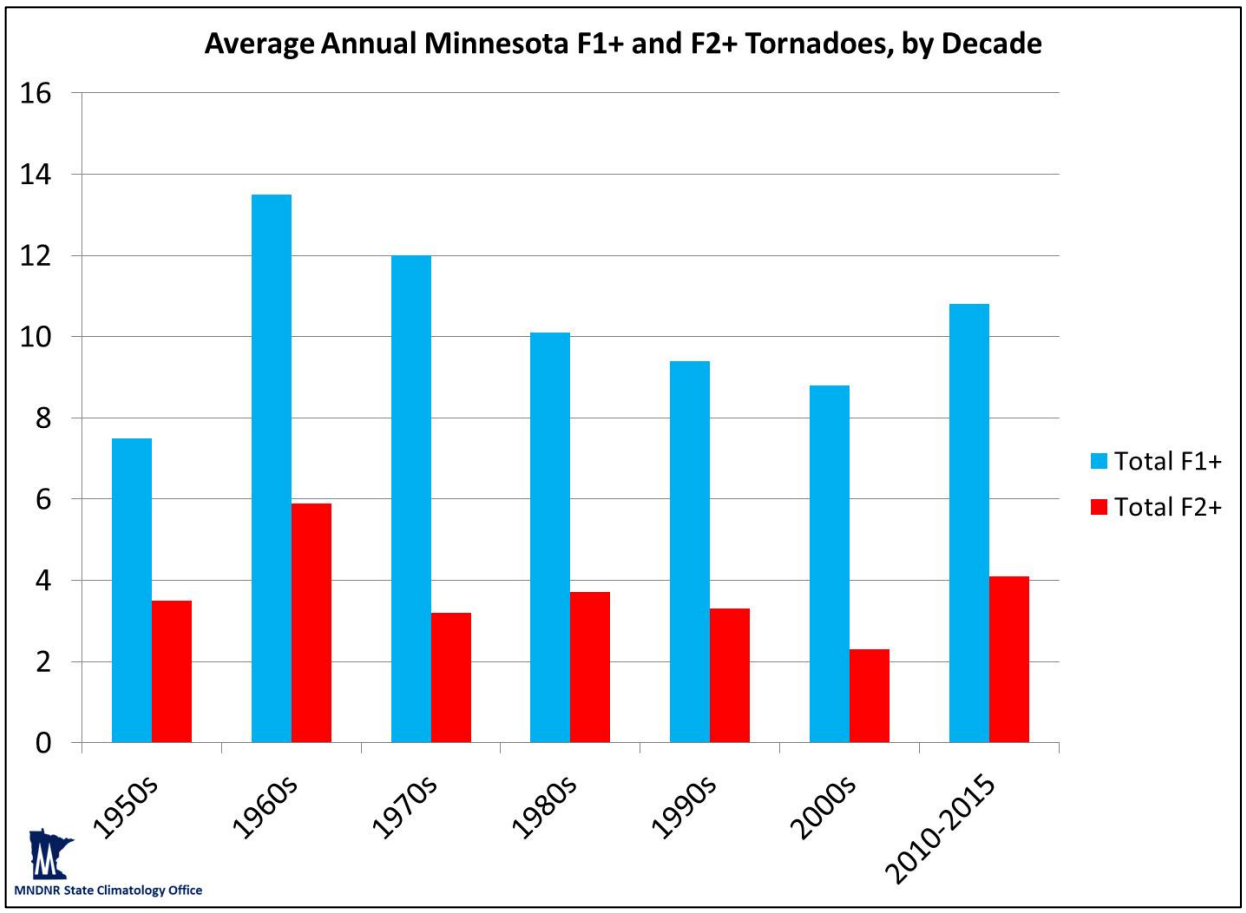
In addition to increases in the frequency and magnitude of heavy rain, Minnesota has also seen a dramatic increase in large-coverage flash floods events in recent years. Since the year 2000, the state has had seven catastrophic "mega-rain events" — when at least six inches of rain falls on an area greater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

No known change in tornadoes and severe convective storms

Tornadoes, straight-line winds, and large hail are a regular part of Minnesota's warm-season climate, and do not appear to be worsening in response to climate change. Unfortunately, serious study of trends among these hazards is limited by inconsistent tracking and measurement over time.

Since the 1990s, personal electronics, social media, improved forecasting, and spotter training programs have all led to increased reporting of small and generally weak tornadoes. Minnesota has not, however, seen an increase in damaging tornadoes rated F1 or greater (EF-1 or greater beginning in 2007; see Figure 6). The number of days with damaging tornadoes has not increased either, and these observations are consistent with those reported around the U.S. in the 2014 National Climate Assessment. Thus, at present, there is no indication that climate change is affecting the character of Minnesota's severe weather.

Figure 6



Annual counts averaged by decade, for damaging tornadoes in Minnesota rated at least F1 and F2 on the damage scale. The graph shows that even with improved detection technologies and spotter training, the number of these tornadoes has been relatively stable over time, indicating that these severe weather hazards are not currently responding to climate change. Source, NOAA Storm Prediction Center, and National Centers for Environmental Information.

Projected climate changes in Minnesota

Continued rapid loss of cold weather extremes and enhancement of extreme precipitation

In the years and decades ahead, winter warming and increased extreme rainfall will continue to be Minnesota's two leading symptoms of climate change (see Figure 7).

Figure 7

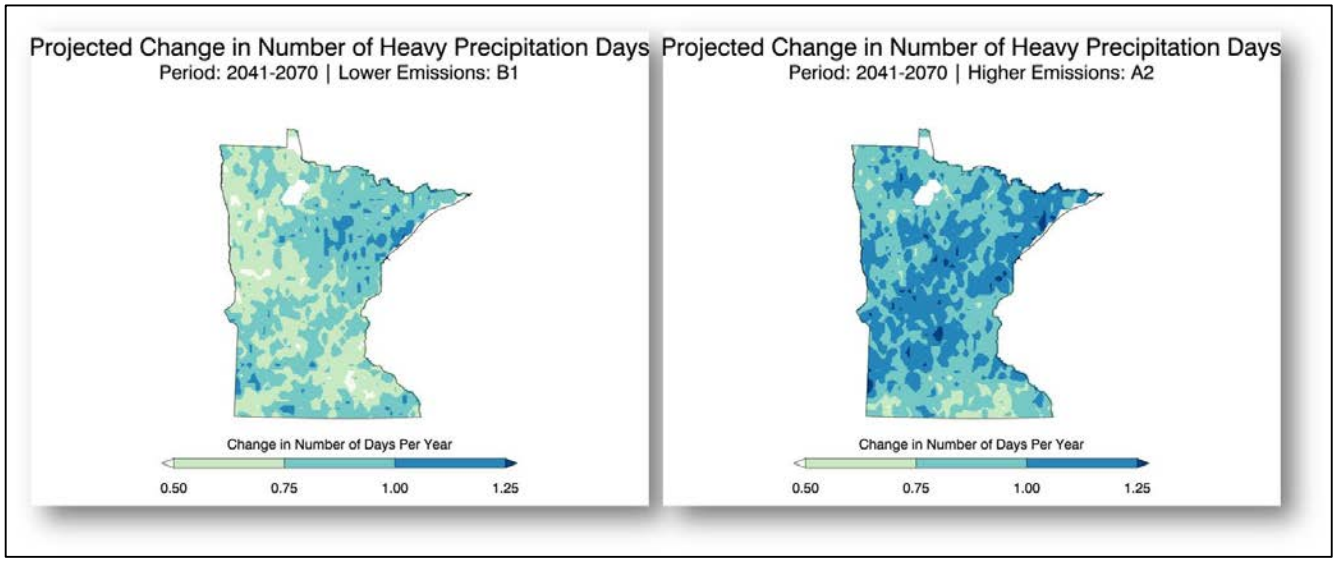
Hazard	Projections through century	Confidence in projected changes
Extreme cold	Continued loss of cold extremes and dramatic warming of coldest conditions	**Highest**
Extreme rainfall	Continued increase in frequency and magnitude; unprecedented flash-floods	
Heat waves	More hot days with increases in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

Confidence Scale

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

Greenhouse gas concentrations will continue rising through the century, and the air's ability to trap heat from the earth's surface will increase accordingly. As a result, winters, and cold conditions in particular, will continue warming well beyond historical bounds. Continued warming of the atmosphere will evaporate even more water into the air, further limiting the amount of cooling Minnesota will be able to achieve at night and during the winter. This increased water vapor will also enhance precipitating weather systems, continuing the trend toward more — and larger — heavy rainfall events (see Figure 8). Minnesota can expect unprecedented rainfall events during the remainder of the 21st century.

Figure 8



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

More hot days likely and more drought possible

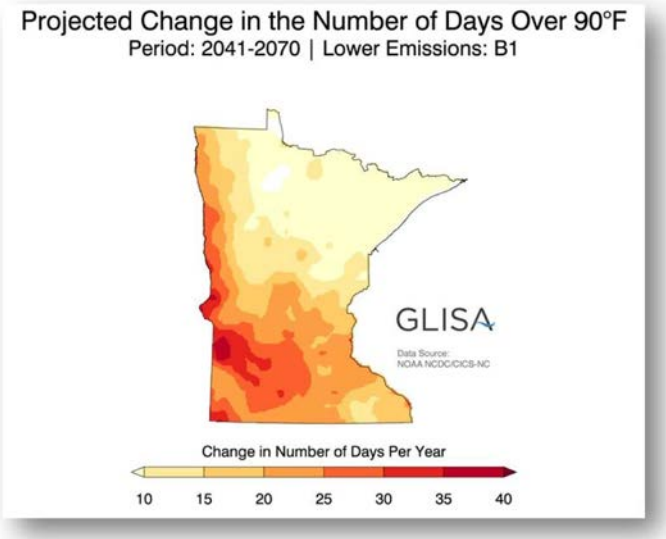
Climate models used in the 2014 National Climate Assessment project that Minnesota will have a greater tendency toward extreme heat, especially by the middle of the 21st century. Even the lower-emissions scenarios lead to significantly more hot days than Minnesota experiences presently (see Figure 9).

This projected increase is a likely outgrowth of the warmer winters, which will provide warmer baseline conditions during transition into summer, making it much easier to attain extremes of heat.

The future drought situation in Minnesota is less clear and appears to depend on how much greenhouse gas concentrations increase by mid-century (see Figure 10).

The majority of models used for the 2014 National Climate Assessment indicate that although drought will remain a part of Minnesota's climate, the state will continue growing wetter through the century. In lower-emissions scenarios, these models project no significant change statewide in the number of consecutively dry days between precipitation events — indicating that climate change will not significantly increase drought likelihood in a given year.

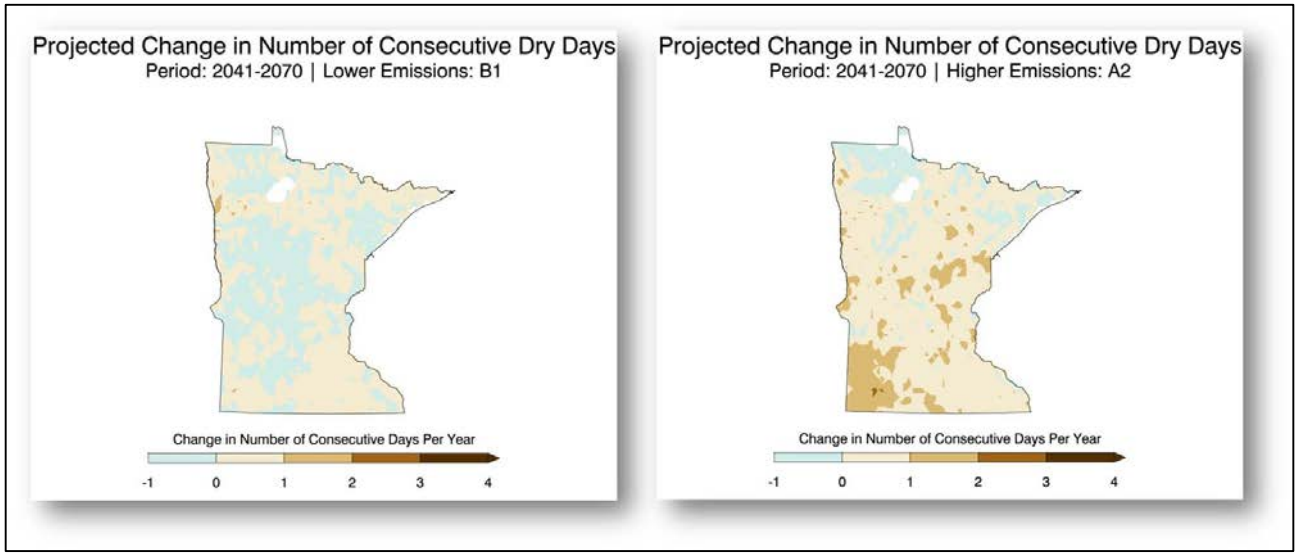
Figure 9



Projected changes by mid-century in number of days annually with high temperatures above 90°F, relative to the 1971-2000 climate period. Projection uses the "ensemble" or model average for a lower emissions scenario. Image derived from output used for the 2014 National Climate Assessment, courtesy of GLISA (Great Lakes Integrated Science + Assessments).

When these same models are run with higher emissions scenarios, however, they depict Minnesota becoming more prone to dry periods. Combined with dramatic increases in hot days, these dry periods would increase Minnesota's short-term, and possibly even long-term drought risk, suggesting that drought indeed could become worse as a result of climate change.

Figure 10



Projected changes by mid-century in annual average number of dry days between precipitation events. More consecutive dry days would suggest greater potential for at least short-term drought. Note that lower emissions scenario (left) yields no net change statewide, while higher emissions result in a nearly statewide increase. Both images show the "ensemble" or model averages given emissions scenarios. Images derived from output used for the 2014 National Climate Assessment, courtesy of GLISA (Great Lakes Integrated Science + Assessments).

Other hazards

The science is unclear about what will happen to the frequency and severity of tornadoes, damaging thunderstorms, and ice storms in Minnesota. It is clear that Minnesota will continue to experience all of these throughout the century, though research suggests their frequencies may decrease. Tornadoes and damaging thunderstorm hazards may become more concentrated on fewer days, indicating the potential for more "outbreaks," even major ones, in the years and decades ahead. However, the body of research into these hazards remains quite limited, and projections of future trends will change as more research is completed.

Impacts of climate change in Minnesota

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

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

The following descriptions summarize some currently observed and anticipated impacts of climate change by ICAT member agencies.

Increasing temperature and extreme heat

Climate data for the Midwest show observed increases in average temperatures. Projected temperatures are expected to rise significantly by mid-century, including an increase in particularly hot days. Extreme heat affects human and animal health, agriculture, and natural and constructed infrastructure.

Extreme heat events are linked to a range of illnesses, even death, and can exacerbate pre-existing chronic conditions such as cardiovascular, respiratory, liver, and neurological diseases, endocrine disorders, and renal disease or failure. Populations who are most vulnerable to extreme heat include persons over 65 or under five years old; living alone; living in a building or institution without air-conditioning, or residing on the topmost floor of a building; and with an income at or below the poverty line. People who are exposed to heat because of recreational activities or job-related activities also are more vulnerable, including athletes, construction workers, and landscape/agricultural workers.

Increasing temperatures also 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 unless new climate-adapted varieties are developed and utilized.

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 lead to a challenge in disposal of animal carcasses. There is limited rendering capacity 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.

Increasing air temperatures are causing water temperatures to rise, which impacts aquatic species as well as human health. Increased water temperature results in decreased dissolved oxygen and greater vulnerability of aquatic organisms to water pollution. Shifts of population of fish species from coldwater to warmwater species are expected to occur and are already being observed.

Increased water temperatures also may contribute to the occurrence of harmful algal blooms, including potentially toxic algae, in lakes and waterways where people swim, fish, or engage in other recreational activities. Harmful algal blooms can cause painful skin irritation and upper respiratory health problems as well as death of pets and other animals.

Permitted wastewater treatment ponds experiencing earlier ice-off face greater problems meeting effluent limits as warmer temperatures increase algal growth, which affects total suspended solids, pH, and carbonaceous biochemical oxygen demand. In addition, warmer temperatures in summer impact the biological processes in wastewater treatment plants, as higher temperatures increase bacterial reaction rates and the density of settled sludge.

Additionally, extreme heat can cause roads to buckle and damage other transportation infrastructure such as rail lines. This may increase expenditures for repairs, dangerous conditions for drivers, and potential for travel disruption.

Air quality

Extreme heat is often associated with degradation of air quality. Climate change may affect air quality directly through changes in seasonal climate and weather, and indirectly through drivers of energy use and resulting emissions. Climate change is expected to have a substantial effect on ambient particulate matter and ozone.

Increased temperatures can:

- Increase pollution from fossil fuel combustion.
- Increase the emission of volatile organic compounds from plants and vegetation that contribute to the formation of ozone.
- Increase formation of ground-level ozone.

Higher temperatures contribute to increased pollution from fossil fuel combustion as a result of electricity generated to run air conditioning. Extreme heat may result in deployment of stationary generators to reduce peak power loads, which further increases air pollution. Also, extreme heat and drought can lead to more wildfires, which create more particulate matter.

Increased ground-level ozone pollution and particulate matter associated with warmer temperatures raises the risk of potential nonattainment of air quality standards and increased air quality alerts in Minnesota. The urban heat island effect can also contribute to decreases in air quality through increased ozone formation and greater use of air conditioning. (This effect occurs because urban areas have less cooling vegetation, more heat-absorbing buildings and concrete surfaces, and greater combustion of fuels than surrounding rural areas, thereby typically leading to higher temperatures in cities.)

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.

Air pollution disproportionately impacts certain vulnerable populations. For example, higher ozone levels may cause asthma in children. People with respiratory and cardiovascular diseases and the elderly are particularly susceptible to increases in particulate matter and ozone pollution.

Drought

Although it is not yet clear how climate change will impact the occurrence of drought in Minnesota, drought and dry periods will continue to occur regularly in the state. Drought impacts availability of water for community and industrial purposes, as well as for natural ecosystems. Lack of water has significant economic and ecological effects.

Drought impacts the quality of soil, including the need to manage clay soils that shrink when dry and can create cracks that are a possible conduit for groundwater contamination. Drought also has impacts on the quality of crop yields, and leads to increased demand for irrigation, putting additional pressure on already strained aquifers and contributing to groundwater depletion. Drought adversely affects crop moisture and growth, and therefore may threaten Minnesota's local food production and access (including availability and potential price increases), as well as feed and pasture supplies for livestock.

Drought has significant impacts on water quality. For example, stream flow lowered by drought reduces dilution of water pollutants, negatively affecting fish and other aquatic organisms.

Discharge periods for stabilization pond type wastewater treatment systems may need to be modified to minimize impacts on receiving waters at lower flows. Low stream flow data for waters receiving continuous discharges from mechanical facilities may need to be modified to ensure that the receiving surface water quality is maintained for the local designated uses. Drought periods increase the value of exploring opportunities for treated wastewater reuse.

Drought has implications for air quality and human health. Drier soil/field conditions may cause more airborne particulate matter or increased frequency of low air quality in rural areas. Prolonged drought increases risk of wildfires that increase particulate matter and reduce air quality, impacting children, the elderly, and those with a range of chronic health conditions. Wildfires also can directly cause injuries or deaths from smoke inhalation and burns. Rural populations dependent on local food sources (such as fish, wildlife, and wild plants) also experience health impacts from drought when these sources are threatened.

Drought impacts certain contaminated site remediation practices, such as phytoremediation (using plants to remediate or stabilize hazardous wastes). Irrigation may be necessary if drought-tolerant plants are not used.

Extreme weather events

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

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

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

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

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

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

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

- Persistent mold problems in homes and businesses.
- Injury (particularly due to unsafe structures and clean-up efforts).
- Damaged health care and medical facilities.
- Stress and mental illness due to trauma, relocation, and loss.
- Death from drowning.

Flooding contaminates freshwater sources with untreated or partially treated sewage and can contaminate food crops with waste from nearby livestock or wild animals, threatening food safety. Increased water flow from a flood may disrupt municipal water supplies and sewage treatment facilities, as well as private wells and on-site septic systems. Flooding of private wells is a particularly serious public health concern, given that, in general, well owners do not test or treat their water according to health-protective guidelines.

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

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

There is increased need to properly clean up and manage solid waste, hazardous materials, and debris after floods, storms, and other natural disasters. More frequent occurrences of natural disasters increase the demand for disaster remediation and coordination efforts, as well as for trained staff to meet these specific needs. Design standards for permitted waste management facilities are linked by rule to certain magnitudes of storm events (i.e., 25- or 100-year storms), and as storm severity increases, this impacts facility needs. There is accelerated use of existing waste management capacity due to more waste and debris resulting from extreme weather.

Increasing numbers of floods and storms raise the need for state support and response. A greater demand for response from limited staff reduces time available for internal and external preparedness,

including partnering and preparing with local units of government, state agencies, and industry. Infrastructure damage due to flooding and storms, such as flooded roads and power and communication technology outages, can disrupt emergency response in affected areas, which also has health impacts.

Populations particularly vulnerable to flooding and extreme weather events include the elderly and those without the ability to evacuate when necessary. Those living in floodplains or other areas subject to flooding are at particular risk.

Changing seasonality and longer term ecological changes

Climate data indicate significant increases in the growing season, a trend that is anticipated to continue in coming decades. This impacts our state's health, economy, and ecosystems.

Climate change has an impact on vector-borne/zoonotic diseases. Temperature and precipitation are key factors that influence the abundance of vector mosquitoes and ticks. For example, the survival of blacklegged ticks (vector of Lyme disease and several other diseases) is enhanced during winters with heavy snowfall, which provides insulation from cold temperatures. Warmer and wetter spring and summer seasons provide ticks with sufficient heat and moisture to allow for increased survivability and feeding activity. Additionally, warmer climates facilitate introduction of invasive species of insects and animals that carry diseases not normally observed in Minnesota.

Warmer temperatures can lengthen the allergy season, increase potency of allergens, and introduce plants with more allergenic pollen. Pollen and mold cause mild to severe allergic reactions in many Minnesotans, especially those already burdened with asthma or other respiratory ailments. Allergens can interact with air pollution to amplify their individual effects.

Changing climate also impacts endemic and exotic pests, weeds, and diseases that affect crops and livestock. Many weeds, pests, and fungi thrive under warmer temperatures, wetter climates, and increased carbon dioxide levels. Specifically, there are threats from invasive species such as emerald ash borer and gypsy moth. Some pests from other areas that travel by wind are moving closer to Minnesota — cutworms, aphids, soybean rust, wheat rust, corn earworm, and leafhoppers. Certain pests are able to produce more generations per year due to longer summers, such as European corn borer and brown marmorated stinkbug.

Climate change will lead to changes in agricultural seasons and planting dates. This may present an opportunity in Minnesota, in that longer growing seasons could potentially increase productivity in some regions; however, heavier precipitation can delay planting dates or even drown crops. Changing seasons may also lead to the potential opportunity or need for developing or using different plant varieties. Climate change amplifies the effects of existing disturbances, such as invasive species, insect pests and diseases, and land-use change in agriculture.

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.

Climate change also is altering Minnesota's natural lands and waters and the uses they sustain. Examples include:

- **Lakes, rivers, and streams:** Likely climate-induced impacts include earlier ice-out dates; less seasonal ice cover; increases in warmwater fish species and decreases in coldwater fish species, such as ciscoes; increased growth of algae and diatom blooms; warmer surface water temperatures in lakes; and increased variability in the seasonal and annual flow volume in Minnesota watersheds. Climate change also reduces the effectiveness of fish and macroinvertebrate indicators currently used as biomonitors to evaluate the ecological health of water bodies.

- **Wetlands:** Climate change threatens to alter physical, chemical, and biological processes. Under projected warming scenarios, prairie pothole wetlands could shrink and shift optimal waterfowl breeding conditions into western Minnesota. Without major restoration efforts to replace drained wetlands in Minnesota, the prairie pothole "duck factory" could largely disappear by the end of the century. Peatlands, which are currently important carbon sinks, may begin to dry out, causing them to add carbon emissions into the atmosphere.
- **Forests:** Projected climate changes will shift tree ranges, and some common northern tree species such as spruce and fir may become rare in Minnesota. Depending on whether precipitation rates increase or decrease, Minnesota's forests could either transition to communities dominated by central hardwood trees such as oaks and hickories, or forests could shrink and be replaced by grasslands. In both scenarios, climate change will likely exacerbate and intensify the effects of invasive plant species, insect pests, and tree diseases.
- **Prairies:** The less than 1% of remaining native prairie will likely become drier, causing declines in mesic and wet prairie plant and wildlife species. Proliferation of invasive species will make it difficult for Minnesota's prairies to expand and take advantage of potential new habitat conditions created by a warming climate. Intensive human management, such as prescribed burns and seeding, will be necessary to facilitate new native prairie establishment.

Connection between climate adaptation and mitigation

While this report focuses on climate adaptation and not climate mitigation, it is important to acknowledge and summarize some of the connections between these two complementary approaches. Without serious climate mitigation, humans and natural systems will find it increasingly difficult, if not impossible, to adapt.

More often than one might think, there is an overlap between climate adaptation and mitigation, meaning that the same action can achieve both goals.

Figure 11 helps to illustrate that climate adaptation and mitigation can overlap in some cases.

The chart below (see Figure 12) provides several examples of those overlapping climate adaptation responses that also can reduce emissions of greenhouse gases.

Figure 11

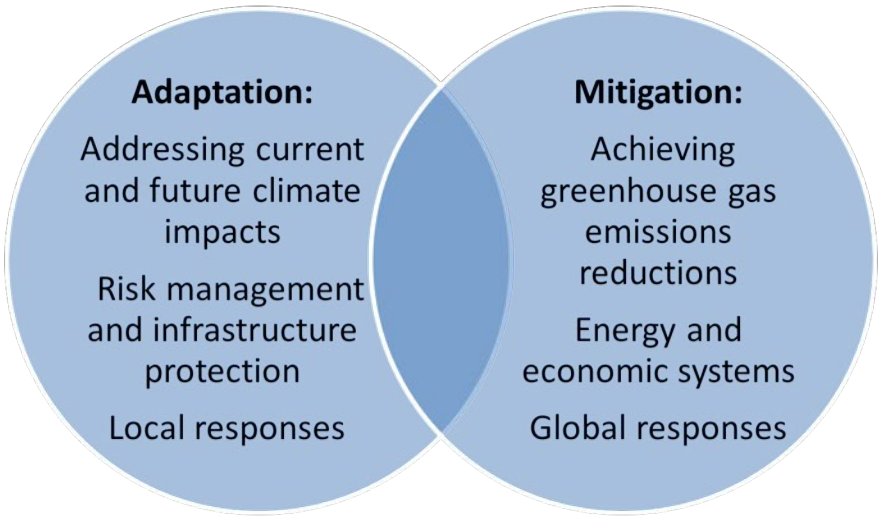


Figure 12

Climate adaptation practice	Climate adaptation benefits	Climate mitigation benefits
Urban and community trees	• Provides cooling that increases resilience to extreme heat and the urban heat island effect • Increases resilience to heavy rainfall by interception of raindrops by leaves and absorption of water by roots	• Shade from trees can reduce energy use for air conditioning in the summer • Acts as a windbreak that can block cold winter winds, reducing energy needed for heating
Water conservation	• Increases resilience to drought by reducing need for and use of groundwater and surface water	• Reduces need for energy used to purify and transport water
White roofs and green roofs	• Increases resilience to extreme heat	• Reduces need for air conditioning in the summer
Home insulation	• Increases resilience to extreme heat and cold	• Reduces energy needed for cooling and heating

In addition to those climate adaptation actions that contribute to climate mitigation, many other adaptation actions result in a range of other benefits, which can include increased water and air quality, habitat for wildlife, public safety, and economic benefits. Some examples of climate adaptation activities that can lead to multiple benefits include wetland restoration, soil conservation/erosion prevention, preserving or restoring natural open space on floodplains, wastewater recycling and reuse, sustainable agriculture, and stormwater management best practices.

Minnesota state agency responses to climate impacts

Based on state agency understanding of climate trends, agencies participating in ICAT are implementing programs to address climate impacts as described below.

Minnesota Department of Agriculture

Agriculture is highly dependent on specific climate conditions and, consequently, is sensitive to the effects of climate change. As the climate continues to change, agricultural producers will need to continually adapt. They will need to respond to and rebuild from disasters when they occur. More generally, they will need to adapt their pest, nutrient, and water management, conservation practices, crop rotations and areas of crop production, and crop/livestock management.

The Minnesota Department of Agriculture (MDA) has many resources to help producers respond and adapt to climate change impacts, which are outlined below. They include disaster assistance for catastrophic events, pest and disease management, conservation and water management, and research and demonstration for developing production systems that are more resilient to climate change.

Providing assistance related to extreme weather events

MDA offers assistance to producers who are experiencing damage and losses to crops, livestock, and structures; potential water, soil, food, or other contamination, and other catastrophic events that can result from climate change. The MDA webpage, Food and Ag Emergency Response (www.mda.state.mn.us/about/aer) provides comprehensive information on MDA's and other agencies' resources. There are three types of assistance: financial, emergency response/cleanup, and advisory.

Financial assistance for losses of crops, livestock, or buildings includes:

- **Disaster Recovery Loan Program**: These funds are available at 0% interest to farmers for expenses not covered by insurance, including clean up, repair, or replacement of farm structures and septic and water systems, as well as replacement of seed, other crop inputs, feed, and livestock, when damaged by high winds, hail, tornado, floods, or excessive rainfall. www.mda.state.mn.us/grants/disaster/disasterloan
- **Agricultural Improvement Loan Program**: This loan program can provide 3.25% financing for buildings that have been lost to flooding and are being replaced with new buildings. www.mda.state.mn.us/grants/loans/improvement
- **Restructure II Loan Program**: Farmers can use this loan program to refinance their debt at 3.50%, providing them with funds to help repair flood damage of an agricultural nature. www.mda.state.mn.us/grants/loans/restructure2
- **Livestock Investment Grant Program**: Producers who suffer a loss due to adverse conditions may apply for these funds to help cover up to 10% of the cost for the purchase, construction, or improvement of buildings or facilities for the production of livestock, and the purchase of fencing as well as feeding and waste management equipment. www.mda.state.mn.us/grants/grants/livestockinvestment

Emergency response and cleanup assistance includes:

- **24 hour Agricultural Chemical Emergency Response**: All new reports of incidents are directed to the MDA emergency response (spills) team, which is responsible for directing and assisting with the response and cleanup of emergency incidents. www.mda.state.mn.us/chemicals/spills/emergresponse.aspx
- **Agricultural Chemical Response and Reimbursement Account (ACRRA)**: ACRRA reimburses costs incurred in cleaning up agricultural chemical (pesticide and fertilizer) incidents. www.mda.state.mn.us/grants/disaster/acrra
- **Emergency Response to Ammonia Spills website**: This site is designed as an educational aid for those who respond to, prepare for, or who will be in charge when a spill of anhydrous ammonia occurs. www.mda.state.mn.us/chemicals/spills/ammoniaspills
- **Food Safety Rapid Response Team**: Consisting of technical experts in food manufacturing, food inspection, microbiology and epidemiology, this team can verify the safety of stored food products after a disaster. www.mda.state.mn.us/about/aer/foodsafety

Advisory assistance includes:

- **Flood Prevention and Recovery Information for Farmers and Ranchers**: Before and after a flood, MDA provides recommendations and guidance for moving livestock, stored grain, food items, agricultural inputs, seed, and other materials out of harm's way. Our field personnel also work with agricultural chemical facilities to strengthen safeguards around equipment and storage tanks to prevent accidental release of product. www.mda.state.mn.us/about/aer/flooding

- **Minnesota Farmer Assistance Network (MFAN)**: MFAN provides business and financial guidance at no cost to Minnesota farmers and farm families facing economic hardship. www.mda.state.mn.us/about/mfan
- **Minnesota Farm Advocates**: Farm Advocates provide one-on-one assistance for Minnesota farmers who face crisis caused by either a natural disaster or financial problems. www.mda.state.mn.us/about/commissionersoffice/farmadvocates

Preventing and managing pests and disease

As weeds, insects, diseases, and other pests increase, MDA has resources focused on managing pests, and preventing, detecting, and responding to invasive insects, diseases, and weeds. Programs include:

- **Integrated Pest Management (IPM) Program**: The IPM Program develops and implements statewide strategies for the increased use of IPM to manage established pests on private and state managed lands. www.mda.state.mn.us/plants/pestmanagement/ipm
- **Pest Detection and Response Unit**: The Pest Detection and Response Unit focuses on invasive insects and plant diseases that threaten Minnesota's forests and crops. This includes:
    - Prevention — pest risk assessments to evaluate the chances that a pest will become established in Minnesota, and educating the public on how to identify and report invasive pests.
    - Early detection — field surveys and inspection, and innovative detection efforts such as the "Arrest the Pest" hotline.
    - Rapid response — If an invasive pest is detected in Minnesota, MDA has response plans to quickly determine the extent of the infestation and containing it to limit the spread. www.mda.state.mn.us/plants/pestmanagement/invasivesunit
- **Noxious and Invasive Weeds Program**: The Noxious and Invasive Weed Team works with local governments and landowners to protect the environment, public health, public roads, crops, livestock, or other property in Minnesota from the injurious impacts of noxious and invasive weeds. www.mda.state.mn.us/plants/pestmanagement/weedcontrol

Helping develop more resilient production systems and practices

The MDA provides technical assistance, conducts and supports research and demonstration projects, and encourages best management practices to help farmers and others protect and preserve Minnesota's water resources. Improved understanding and innovation in water-related issues can also help agriculture deal with new and fluctuating conditions of climate change. MDA programs include:

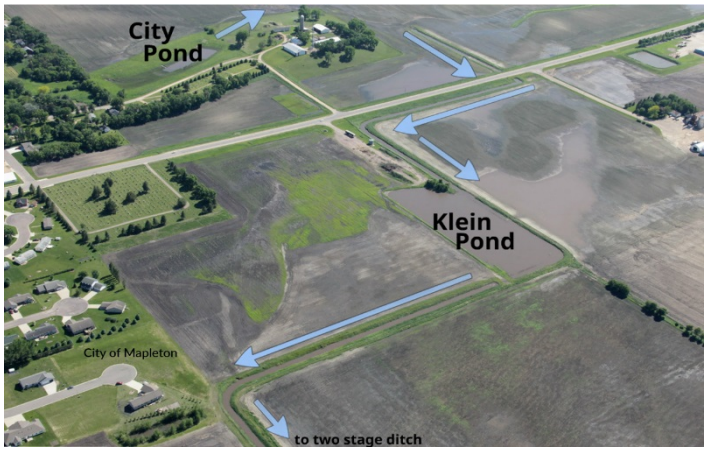
- **Clean Water Research Program** identifies underlying processes that affect water quality, evaluates the effectiveness of agricultural best management practices (BMPs), and develops technologies to target BMPs to critical areas of the landscape. www.mda.state.mn.us/protecting/cleanwaterfund/research
- **On-Farm Projects** monitor trends over time, and demonstrate and evaluate management practices under conditions that are typical in an area. These include Discovery Farms Minnesota. www.mda.state.mn.us/protecting/cleanwaterfund/onfarmprojects
- **Minnesota Agricultural Water Quality Certification Program** (MAWQCP) is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect our water. Those who implement and maintain approved farm management practices will be certified and in turn obtain regulatory certainty for a period of 10 years. www.mda.state.mn.us/protecting/waterprotection/awqcprogram
- **Drainage Water Management**: The MDA collaborates with other agencies, local governments, academic institutions, and industry organizations to foster innovation in designing and managing agricultural drainage (removal of excess water from fields through the use of ditches and

subsurface pipe), including temporary storage, to maximize benefits and protect the environment.

- **Sustainable Agriculture Demonstration Grants**: Grants are awarded to individuals or groups for on-farm sustainable agriculture research or demonstration of practices that promote environmental stewardship and conservation of resources as well as improve profitability and quality of life on farms and in rural areas. www.mda.state.mn.us/grants/grants/demogrant

Features (see photos below) to store water and allow infiltration are among agricultural water management practices that help reduce impacts of extreme weather events to farmers, downstream landowners, and the environment.

Constructed wetland in foreground provides additional water storage capacity to reduce field flooding, visible in background. Photo: Dustin Benes, Martin County SWCD.



A drainage improvement project on Blue Earth County Ditch No. 57 (CD 57) helps control flows and improve water quality of drainage water from agriculture and stormwater from the City of Mapleton. Photo: ISG Architecture, Engineering, Environmental, and Planning.

Minnesota Department of Commerce

The Minnesota Department of Commerce plays a significant role in making Minnesota more resilient to the threats posed by our changing climate. In the area of climate adaptation, Commerce maintains the state's energy emergency plan, coordinates with Minnesota's utilities on restoration of service during or after emergencies, including weather-induced outages, and deploys a Consumer Response Team to assist with disaster recovery situations through its Insurance Division. Commerce has been actively collaborating with the National Association of Insurance Commissioners to survey Minnesota insurance companies on their preparation for climate change.

Commerce serves as the lead entity to coordinate resources and information among state agencies that have responsibilities for matters related to energy. Climate adaptation-related activities of the department include:

Energy reliability

- Model long-term energy needs under changing economic and environmental conditions, including changes in climate.
- Monitor utilities' generation, transmission and distribution plans to assure that energy reliability is maintained.
- Coordinate activities with regional and federal agencies responsible for assuring reliability in the electricity sector, such as the Midwest Independent System Operator (MISO), the Midwest Reliability Organization, and the North American Electric Reliability Organization.
- Monitor supplies of liquid fuels (petroleum, biofuels) to assure that adequate supplies are maintained.

Energy emergency planning

- Create in-house expertise at the state level on energy assurance planning and resiliency, focusing on critical infrastructure interdependencies, cyber security, energy supply systems, energy data analysis, and communications. Commerce has staff working in energy assurance planning and Certified Emergency Management.
- Coordinate Minnesota's utilities on restoration of utility service during or after a weather-related emergency.
- Refine the existing Energy Assurance Plan to incorporate response actions to new energy portfolios.
- Smart Grid technologies, cyber security, and emerging energy issues, gather data on delivered fuels and update contact lists.
- Revise appropriate state policies, procedures, and practices to reflect the Energy Assurance Plan.
- Develop and initiate processes or mechanisms for tracking the duration, response, restoration, and recovery time of energy supply disruption events.
- Train appropriate personnel on energy infrastructure and supply systems and the content and execution of the Energy Assurance Plan.
- Conduct and/or participate in energy emergency exercises (intra- and interstate) to evaluate the effectiveness of the Energy Assurance Plan.

Consumer response team

- Distribute information, answer questions, work with insurance companies on claims.
- Help individuals make informed decisions after a storm damages a home, vehicle, or property.

Planning and data analysis

- Coordinate with the Minnesota Pollution Control Agency to produce a report on greenhouse gas emission trends every two years.
- Evaluate impacts of climate change on insurance investments through participation on the National Association of Insurance Commissioners' Climate Change and Global Warming Working Group.

- Signatory to "Under 2 MOU" — Subnational Global Climate Leadership Memorandum of Understanding: The parties agree to share information and experience on redesign of the power supply and grid, technical solutions and advances in promoting large-scale switch to renewable energy and the integration of renewable energy sources, actions needed to ensure security of supply, and strategies to promote energy efficiency.

Energy efficiency and renewable energy

- Administer the federal Weatherization Assistance Program to help low-income families make their homes energy efficient, which can increase adaptation to extreme temperatures.
- Assure that electric and natural gas utilities offer cost-effective energy efficiency programs for their customers with a goal of reducing electric usage by 1.5% annually, which can help to address peak electric loads in periods of extreme heat.
- New state initiatives such as the Commerce-administered Made in Minnesota Solar Energy Incentive Program and Xcel Energy's community solar garden program are expanding solar businesses in Minnesota and creating local jobs.
- Participate in Department of Labor and Industry's Advisory committee that adopted new energy codes for Minnesota in 2015.

Case study: Weatherization Assistance Program

The Weatherization Assistance Program (WAP) provides free home energy upgrades to income-eligible homeowners and renters to help save energy and ensure their homes are healthy and safe. WAP upgrades help low-income Minnesotans permanently reduce their energy bills. Eligibility is for households at or below 200% of the federal poverty income guidelines. Funded by the U.S. Department of Energy, WAP is administered by the Minnesota Department of Commerce in cooperation with a network of 25 local service providers.

Benefit to Minnesotans: Minnesota weatherized about 2,200 homes during the program year July 1, 2014-June 30, 2015. An annual 30% reduction in energy bills can be achieved when furnace upgrades are combined with insulation, air leak sealing, and new energy-efficient appliances.

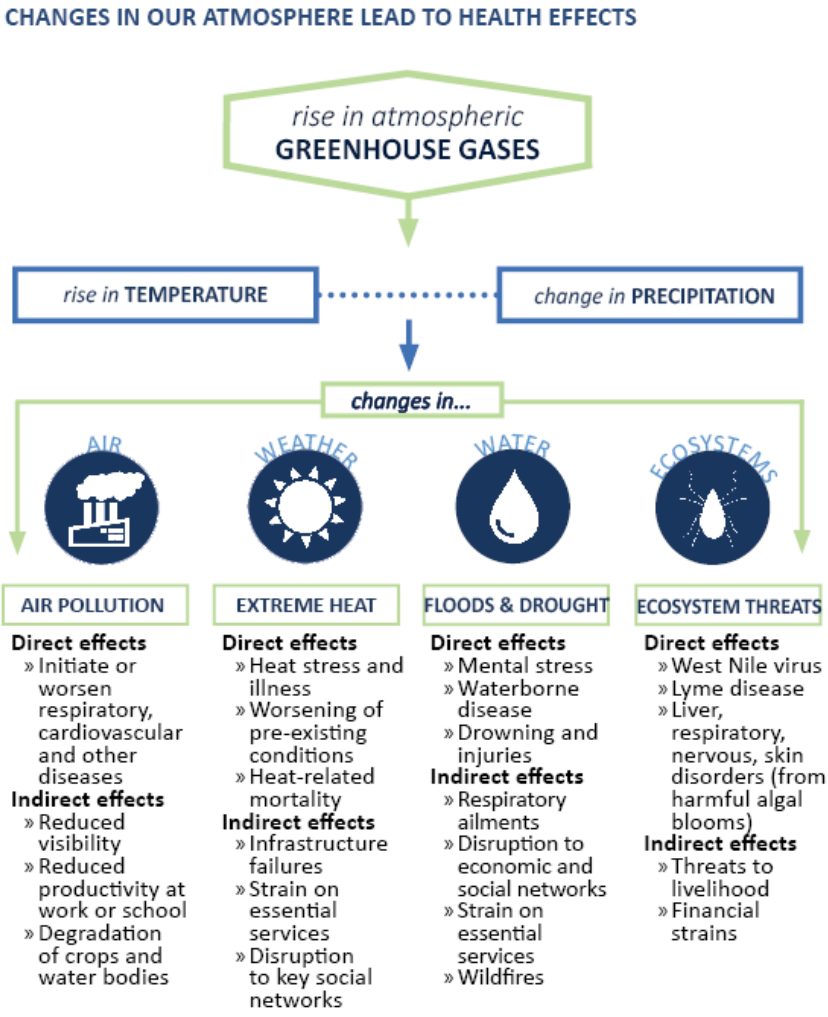
Adding batt insulation in the attic reduces heat loss and increases energy efficiency. Photo from the Minnesota Department of Commerce

Minnesota Department of Health

Minnesota is already seeing impacts to public health from climate change. While there are known, effective public health responses to many of these impacts, the scope, timeline, and complexity of climate change challenges are unprecedented. Critical gaps remain in the resources, programs, and

expertise in Minnesota's public health system to address the consequences of climate change on public health.

Figure 13



Source: Minnesota Department of Health

The Minnesota Department of Health (MDH) is responding to these challenges by planning and providing information and resources to the public. The MDH Strategic Plan to Adapt to Climate Change outlines goals and objectives for MDH to adapt and respond to the impacts of climate change: http://www.health.state.mn.us/divs/climatechange/data.html. Descriptions of the programs below highlight some of MDH's work to protect the public from climate change impacts.

Minnesota Climate & Health Program

The Minnesota Climate & Health Program provides information, tools, trainings, and education to public health professionals and the public on the health impacts of climate change. Below is a summary of information and tools available to the public.

- The Minnesota Climate & Health Program's website contains information on topics that are influenced by climate change: http://www.health.state.mn.us/divs/climatechange/. The website serves as a communication vehicle with the public and also provides access to resources and

tools. The program also maintains a listserv of about 1,800 subscribers and routinely distributes timely and topical information. Join the listserv by visiting the link above.

- The Minnesota Climate and Health Profile Report 2015 provides a comprehensive assessment of climate change impacts and potential health issues specific to Minnesota: http://www.health.state.mn.us/divs/climatechange/climate101.html.
- The Minnesota Extreme Heat Toolkit contains materials that a public health planner or emergency manager can use to plan for extreme heat, including a draft response plan: http://www.health.state.mn.us/divs/climatechange/extremeheat.html#toolkit. It also contains a tip sheet on how to stay cool on a hot day: http://www.health.state.mn.us/divs/climatechange/docs/appendix_e.pdf.
- Climate and health training modules provide information on the effects of climate change on several topic areas: Climate Change and Public Health 101; Extreme Heat Events; Water Quality and Quantity; Air Quality; Mental Health; and Agriculture and Food Security: http://www.health.state.mn.us/divs/climatechange/communication.html.
- The Health and Climate film, created through a partnership between the Twin Cities Public Television and MDH, examines climate change impacts on the health of Minnesotans. The film highlights the impact of climate change on people's day-to-day lives, especially through the lenses of sports, recreation, and farming: http://www.health.state.mn.us/divs/climatechange/climatevideo.html.
- The Minnesota Climate Change Vulnerability Assessment 2014 reviews the geographic occurrence of several "climate hazards:" extreme heat, air pollution, vector-borne disease, flooding, and drought. The vulnerability assessment mapped the location of past climate hazards and populations vulnerable to the climate hazards: http://www.health.state.mn.us/divs/climatechange/data.html.
- The Minnesota Healthy Planning Training and the Minnesota Healthy Planning How-To Guide describe comprehensive planning strategies for creating healthy and climate resilient communities: http://www.health.state.mn.us/topics/places/plans.html.
- The Incorporating Health and Climate Change into the Minnesota Environmental Assessment Worksheet (EAW) report provides information on how we can better address health and climate change issues during Minnesota's environmental review process: http://www.health.state.mn.us/topics/places/review.html.

Minnesota Environmental Public Health Tracking Program

The Minnesota Environmental Public Health Tracking Program provides environmental health surveillance data on a variety of topics related to climate change such as air quality, asthma, chronic obstructive pulmonary disease, drinking water quality, heart attacks, and heat-related illness. Heat-related illness data, for example, are being used to inform efforts to protect vulnerable populations from extreme heat events. Learn more about available data at MDH's data portal: https://apps.health.state.mn.us/mndata/.

Vector-borne disease program

MDH's extensive vector-borne disease program performs the following activities that may relate to climate change:

- Monitors the number of cases of each vector-borne disease (e.g., mosquito and tick-transmitted disease) over time and space within the state.
- Collects field surveillance data (e.g., tick infection prevalence with various disease agents) to determine how vector distribution and infection prevalence changes over time and space.

- Disseminates disease prevention information to the public, medical providers, high-risk groups, and other health agencies.
- Conducts vector-borne disease research. In particular, the program has efforts to describe new or emerging disease agents, changes in endemic disease patterns, and the burden of vector-borne diseases on society.

Asthma Program

The MDH Asthma Program has been involved in a number of activities related to climate change and respiratory/allergic disease.

- Program staff participated in the Council of State and Territorial Epidemiologists (CSTE) Climate Change work group that developed a suite of indicators related to climate change http://www.cste.org/?page=EHIndicatorsClimate, including a pollen indicator that states can use to track changes in the length of pollen seasons, pollen levels, and pollen types over time. Staff currently serve on the CSTE Asthma and Allergy work group that is working to develop a national aeroallergen (pollen and outdoor mold) monitoring network: http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/2016PS/16_EH_01.pdf.
- The program provides technical reviews of materials, including those related to climate change, that reference allergies and asthma.

Emergency Preparedness and Response section

The MDH Emergency Preparedness and Response section helps prepare public health and healthcare for all types of hazards, including natural disasters and weather-related incidents. The section supports local readiness by:

- Providing tools, resources, and trainings to local public health departments, health care, and other key partners to develop emergency preparedness and response plans.
- Designing, implementing, and evaluating emergency preparedness exercises with partners using weather-related scenarios.
- Sharing information, creating situational awareness, coordinating resources, and providing risk communications in times of an emergency.

MDH Drinking Water Protection and Well Management sections

MDH Drinking Water Protection and Well Management staff are actively engaged with their regulated communities, agency partners, and local resource staff in helping to address potential future changes in a manner that protects human health and safeguards our drinking water sources. Specifically, staff provide technical assistance to public water suppliers in planning for source water protection; evaluating and developing a contingency strategy and local response in the event of a water supply disruption; conducting assessment and monitoring of water quality; and supporting implementation of source water and wellhead protection plans. These activities will result in better preparation, adaptation, and resiliency to the impacts of climate change on drinking water supplies.

About 80% of Minnesotans are provided with drinking water in their homes by a public water supply. MDH partners with public water suppliers to ensure safe and sufficient drinking water through a series of strategic safeguards. Water treatment challenges arising from climate change include water quality changes (algal-related taste and odor issues) that require increased use of granular/power activated carbon and increased levels of total organic carbon due to extreme flows, drought, and runoff. MDH provides technical assistance to public water suppliers in order to increase their technical, financial, and administrative capacity to manage change. MDH strengthened the resilience of public water systems by hosting a workshop on the Minnesota Water/Wastewater Agency Response Network and by providing training on emergency preparedness and incident response. MDH also encourages the development of

green water infrastructure by awarding grant money through the State Drinking Water Revolving Fund Loan program.

In 2016, MDH developed an agency-wide Strategic Plan to Adapt to Climate Change to increase statewide resilience and public health preparedness that can be accessed at http://www.health.state.mn.us/divs/climatechange/data.html. A number of important drinking water strategies were identified to help public water suppliers and private well owners evaluate and prepare for potential impacts of climate change based on potential regional and local conditions. MDH Drinking Water Protection staff have formed and developed a Climate Change Adaptation Team and charter to help carry out and implement specific strategies to protect public sources of drinking water from potential impacts of climate change.

Minnesota Department of Military Affairs

The Department of Military Affairs (DMA) serves under the umbrella of the Minnesota National Guard (MNNG) and can be used by the governor to assist the state during disasters and other state emergencies. The impacts of climate change present major transformations in the mission of the MNNG. Diverse response actions, such as assisting in wildland fire fighting and providing logistical support in stemming the outbreak of avian influenza, compel the MNNG to foster a more resource-informed culture that supports decisions and behaviors across all levels, locations, and domains.

To provide these trained and ready forces, the MNNG has incorporated the sustainable use of resources and facilities as a vital part of mission readiness. MNNG is responding to climate change impacts in the following areas.

Vigilant Guard exercise

In 2015, more than 1,400 service members from the Minnesota, Iowa, and Wisconsin National Guard joined approximately 500 participants from various state, federal, and emergency response agencies to carry out the Vigilant Guard exercise at three training sites across the state: Duluth, Camp Ripley, and Saint Paul. The exercise, which simulated multiple weather-related disaster events, tested the MNNG's ability to respond to large-scale incidents that could affect Minnesotans. The Vigilant Guard exercise also provided an opportunity for the organization to build valuable interagency relationships and coordinate resources with civilian authorities, responders, and other military units that might be a part of a future response effort.

Climate change vulnerability assessments

In 2015, the DMA completed a vulnerability assessment of all owned facilities and installations to determine susceptibility to the impacts of climate change. These assessments identified installations at risk or potentially at risk in the future and began the process of integrating climate change considerations into installation and organizational level plans.

Net Zero initiative

The MNNG uses a Net Zero initiative as a holistic planning strategy founded upon long-standing and emerging best practices to manage energy, water, and waste at all facilities and installations. This strategy recognizes that better resource management contributes to mission effectiveness and more resilient installations.

Energy resiliency

In 2016, The MNNG partnered with its electric utility, Minnesota Power, to construct a utility-scale 10-megawatt solar photovoltaic power plant at Camp Ripley Training Center. This solar array is owned and

operated by Minnesota Power and is connected to the utility grid. The MNNG will purchase the electricity produced from the array and is investing in infrastructure that will use the distributed energy systems in a microgrid technology that enables the use of the onsite energy systems to sustain critical services during potential utility outages. This system will also assist in meeting both organizations' renewable energy and greenhouse gas reduction goals.

A biomass-fueled district heating system is being designed that will provide Camp Ripley Training Center with a sustainable and redundant heating system. Camp Ripley consists of more than 53,000 acres and possesses the forest resource capacity to use onsite biomass for district heating and to decrease dependence on non-renewable gas.

Water conservation

The MNNG maintains an aggressive approach in conserving potable water and reducing surface water and wastewater discharges. Areas that have been addressed in the past year include studying the implementation of a leak detection system for water main valves that will enable quick repair. Other activities include researching and implementing measures that reduce stormwater runoff and increase the amount of water reclamation projects for irrigation and vehicle washing activities.

Case Study: Energy resiliency at Camp Ripley Training Center

The Minnesota National Guard is pursuing Net Zero energy at Camp Ripley Training Center by producing as much energy on site as it consumes over the course of a year. This effort includes developing interconnected loads and distributed energy resources that can connect and disconnect from the primary grid, enabling continuous operations while also providing resilient and dependable energy infrastructure, and significantly reducing the MNNG's carbon footprint.

First Solar thin film modules were selected for the 10-megawatt solar photovoltaic power plant. These advanced thin film modules have a demonstrated performance advantage over conventional crystalline silicon of up to 10% more energy production each year. Source: MN National Guard Public Affairs Office

Construction of the 10-megawatt solar photovoltaic power plant spans 62 acres on a former gravel mining pit at Camp Ripley Training Center.
Source: MN National Guard Public Affairs Office

Planned implementation of the Net Zero energy strategy includes three phases:

- Phase One consists of a public-private partnership with Camp Ripley's electric utility provider, Minnesota Power, for the construction of an onsite 10-megawatt solar photovoltaic power plant

with the capacity to generate more electricity than is consumed at Camp Ripley in a years' time. Minnesota Power will own and operate the solar photovoltaic power plant and all electric energy generated will feed the primary grid. In the event of a grid outage, control switches will redirect the flow of electricity to Camp Ripley's electrical distribution system, providing the capability to function in island mode, independent from the primary grid.

- Phase Two began in 2016 with upgrades to electrical substations and infrastructure that include sophisticated communication controls to detect and communicate with distributed energy loads, essentially serving as a microgrid.
- Phase Three includes the acquisition of natural gas- or duel-fueled generators to work in conjunction with the microgrid and solar photovoltaic power plant. Opportunities for energy storage are being considered and closely monitored as new technology becomes available.

Minnesota Department of Natural Resources

The Department of Natural Resources took a big step on the issue of Minnesota's climate change by issuing Operational Order 131 (Climate Adaptation and Mitigation in Natural Resources Management) in November 2014. This high-level Commissioner's directive requires all DNR divisions to develop climate guidance and performance measures to assess internal progress on the integration of climate data and information into projects, programs, plans, communications, and training. The guidance documents direct all DNR staff to adapt their work with climate change in mind.

As of August 2016, three of six DNR divisions have completed their guidance and have begun implementation activities. Progress has already been made as a result of this operational order and is reflected in some of the department-wide adaptation actions between 2013-2016 highlighted below.

Operations Support Division (OSD)

Planning and decision support:

- OSD represented the agency on the Interagency Climate Adaptation Team until 2015.
- OSD provides ongoing planning, logistical, and administrative support and leadership to the DNR's interdivisional Climate and Renewable Energy Steering Team (CREST).

Management activities:

- OSD collaborated with Minnesota Homeland Security to complete a map-based risk assessment for DNR facilities.
- All DNR facilities undergoing significant improvements were informed by hydraulic and hydrologic models using updated Atlas 14 data to design water control structures (dams, culverts, etc.). Native tree and shrub specifications and details also were modified to increase the probability of long-term survival on DNR facilities.

Division of Ecological and Water Resources (EWR)

Assessments:

- EWR completed a coarse vulnerability assessment of its 32 management programs; six programs were found to be "high risk." More in-depth interviews revealed key needs to be met for these vulnerable programs to adapt as climate change impacts program resources.

Planning and decision support:

- Climate adaptation guidance for all EWR staff, Division leadership, and staff working in eight functional areas was developed in 2015 under DNR's Operational Order #131 and disseminated to staff in 2016.
- An EWR Climate Adaptation Implementation team has been assigned to carry out high priority climate adaptation actions on behalf of the Division.
- Minnesota's Wildlife Action Plan 2015-2025 focuses on prioritizing conservation for Species in Greatest Conservation Need within a mapped Wildlife Action Network of terrestrial and aquatic habitats throughout the state. The Wildlife Action Network facilitates adaptation to climate change and other stressors by identifying core areas large enough to contain a diversity of habitats and connections to allow for species movements and the flow of energy and materials.
- The Division participates on the DNR's CREST to implement climate change adaptation strategies across the department.

Management activities:

- EWR's Land Use Unit has incorporated climate change into its shoreland protection courses to local governments.
- Climate change has been incorporated into EWR's annual floodplain trainings for local governments, which are offered an average of 10 times per year.
- Adaptive Management Plans for specific Scientific and Natural Areas (SNA's) now include discussion of anticipated climate change impacts on the site's native plant communities and other resources (about 10-15 new or revised plans are prepared per year to guide all site management work).
- An in-depth Climate Change Review was developed as part of staff participation in the U.S. Fish and Wildlife Service's National Conservation Training Center's (NCTC) Climate Academy to be part of the plan for the new Badoura Jack Pine Woodland SNA; this may serve as a model for future SNA plans.

Monitoring:

- The Water Monitoring and Surveys Unit has expanded its groundwater level observation well network by 200 wells for a total of 1,030 wells that track groundwater-surface water interaction and will enable better management of the hydrologic system.
- The Water Monitoring and Surveys Unit added 11 "real time" weather stations to its network of 40. The unit also continues to enhance its stream and lake gages and a 1,500-citizen science observer network that provides precipitation data.
- A long-term wetland monitoring program is in progress to identify changes in the number of wetlands statewide and climate change impacts to wetlands.
- A long-term wetland hydrology monitoring program to further help identify climate change impacts is in the planning stage.
- Implementation of a Legislative-Citizen Commission on Minnesota Resources grant begins July 1, 2016, to design and test a statewide system of vegetation monitoring plots to detect changes in plant communities over time.

  Twenty permanent monitoring plots were established in the peatlands to track changes in that system due to climatic conditions and other stressors.
- The State Climatology Office has installed a weather monitoring station at Sedan Brook Scientific and Natural Area (four others are in progress) and a water monitoring well nest has been installed at Badoura Jack Pine Woodland SNA, in the heavily irrigated Pineland Sands area.

Training, outreach, and communication:

- Sixty-six EWR staff attended Minnesota DNR's 2016 Climate Change in-service, day-long training.
- Fifteen EWR staff participated in the six-month Climate Academy offered by the National Conservation Training Center and submitted climate adaptation projects to conclude the course.

Division of Fish and Wildlife (F&W)

Research and assessments:

- F&W continues to monitor epilimnetic temperatures in 24 sentinel lakes and associated fish community sampling as part of its Sustaining Lakes in a Changing Environment (SLICE) program.
- Moose research continues to investigate the causes of adult and calf mortality.
- Research continues on the expansion of warm water fishes in Minnesota lake systems.
- Preliminary long-term monitoring research has begun on the viability of spruce grouse, a boreal game bird that is vulnerable to climate change.
- Soil moisture and temperature monitoring stations were installed at Red Lake Wildlife Management Area to inform future habitat management as climate changes.
- Minnesota DNR is an active collaborator on a Northeast Climate Science Center-funded research project that is investigating the effects of climate on lake and stream temperatures in Minnesota, Wisconsin, and Michigan.

Planning and decision support:

- Climate adaptation guidance was developed under DNR's Operational Order #131 and disseminated to staff with detailed guidance on how to address climate change in management plans, technical consultations, infrastructure, land acquisition, and habitat management.
- A scenario planning process on North Shore Fisheries Management was completed.
- DNR Fisheries worked with the Coldwater Coalition, a multiple stakeholder group, to develop a priority of streams/rivers along the North Shore for restoration and protection. Resiliency to climate change was one of the criteria used to develop this list.
- DNR Fisheries began incorporating climate change into lake and stream management plans.

Management activities:

- Tullibee Lake Watershed Stewardship Project. Clean Water Funds were used by DNR Forestry to work with private forest landowners in the watersheds of tullibee fish refuge lakes.
- Tullibee Lakes grant program. DNR Fisheries is working with DNR Forestry and the Leech Lake Area Watershed Foundation to protect private forests in the watersheds of five important tullibee refuge lakes with conservation easements.
- Implementing action plan to manage North Shore stream systems and watersheds to increase long-term benefit and prepare for potential problems.
- Habitat management on Wildlife Management Areas is integrating changing seed mixes (e.g., more mesic species), increased water management, increased management to address woody encroachment, phenological monitoring, and an increased focus on habitat complexes in wetland systems.

Training, outreach, and communication:

- The *Climate Change Handbook* was developed and shared within DNR. It contains selected information on climate change effects on fish, wildlife and ecosystems; adaptation; mitigation; training opportunities; case studies; recommended, peer-reviewed resources; and contacts.

- F&W staff were given an overview and training on climate adaptation at two large training events (Wildlife School and Fish Academy).
- Staff supported and participated in two NCTC courses (Climate Academy and Climate Change Vulnerability Assessment).
- Staff participated in two Northern Institute of Applied Climate Science workshops: integrating climate change Section Forest Resource Management Plans and Forest Adaptation.
- F&W staff has access to a monthly newsletter on climate news, research, case studies, training opportunities, and resources.
- Staff has been notified of webinars on climate data, impacts to resources, and management opportunities.

Division of Parks and Trails

Assessments and monitoring:

- Parks and Trails coordinated with EWR to install more than a dozen weather stations on state park lands to monitor climate change.
- Parks and Trails is working in cooperation with other DNR divisions to implement a long-term native plant community monitoring project that will aid in understanding climate change effects and adaptation strategies.

Planning and decision support:

- Consideration of climate change impacts and adaptation is being incorporated into new park management plans and revised plans. A recent example is the St. Croix State Park Management Plan.
- Climate change impacts and adaptive approaches have been incorporated into unit resource management plans.
- The Division participates on the DNR's CREST to implement climate change adaptation and renewable energy strategies across the department.

Management activities:

- A stream restoration project at Whitewater State Park was designed and implemented to address more frequent/extreme rainfall events.
- The Whitewater State Park campground was relocated to address higher flood levels.
- Resource specialists are considering climate change effects when designing seed/plant species compositions for native plant community restorations in the parks.
- The Division continues to work with OSD to install a variety of renewable energy sources (solar panels, wind, wood heaters, etc.) at state park units to reduce energy use.
- Management of terrestrial invasive plant species has increased both due to extreme rainfall events re-infesting areas and range expansions of other invasive species into Minnesota.
- Parks served on an interdisciplinary DNR team that developed departmental plant material standards for native plant community restorations that incorporated climate change into restoration planning and sourcing of plant materials.

Training, outreach, and communication:

- Climate adaptation guidance was developed under DNR's Operational Order #131 to adapt to climate change on Parks & Trails-administered lands and facilities.
- Staff presented a case study as part of DNR's Climate Change in-service training on the response to the Whitewater State Park flood.
- Fifty-six Division staff attended the Climate Change in-service training conducted in winter 2016.
- Outreach staff incorporates key messages regarding climate change into communications with visitors and the public.
- Parks participated in the development of the Minnesota Climate and Health documentary by Twin Cities Public Television and the Minnesota Department of Health in 2013.
- Climate change webinars related to communications strategies were shared with interpretive naturalists to help them communicate about climate change to visitors and the public.

Division of Forestry

Assessments:

- Forestry continues to conduct assessments of forest management issues that involve many factors, including climate (e.g., tamarack) and make recommendations to share with other land managers.
- Forestry participates in departmental climate change vulnerability assessments.
- The Division is evaluating the possibility and potential benefits of developing resistant and resilient tree genotypes for use in Minnesota.
- The assessment of forest Native Plant Communities is being completed.
- Forestry is exploring opportunities to establish mitigation projects suitable for generating revenue via carbon markets.
- Forestry participates in activities of the Minnesota Invasive Terrestrial Plants and Pests Center to focus research on priority invasive species.

Planning and decision support:

- DNR Forestry participates in the Northwoods Climate Change Response Framework. The framework includes a detailed assessment of the vulnerability of tree species and forest plant communities as well as a decision approach and compilation of strategies that will help forestland owners determine appropriate management goals and work toward those goals in the face of climate change.
- DNR Forestry is participating in revision of the Minnesota Forest Resources Council's North Central Landscape Plan, which will incorporate information on climate change impacts as well as recommend management strategies that take those impacts into account.
- Forestry has adopted into DNR's Sustainable Forest Resources Management plans the incorporation of maintaining and increasing diversity as a primary adaptation strategy.
- The Division is revising its tree suitability tables to reflect anticipated vegetation shifts due to climate change. The goal is to provide foresters with additional information on which tree species would be favored in a warmer and/or drier climate.
- The Division is developing a plan to use the state's forest nurseries to help protect the fitness and resilience of native forest ecosystems from invasive species and climate change.
- Several different climate-related grant proposals have been submitted by interdisciplinary groups, including "Lowland conifer ecosystems: Holistic assessment for adaptive management," "Long live the (northern) conifers," and "Seed sourcing in an era of climate change."

- Northern Superior Uplands and Northern Minnesota and Ontario Peatlands Section Forest Resource Management Planning processes have both included consideration of a climate change-based cover type change scenario.

Management response:

- DNR's Adaptive Forest Management Projects are used as demonstration areas for enhancing forest resilience to climate change.
- Forestry uses the invasive species control program to maintain and enhance forest resilience to impacts of climate change.
- Forestry maintains the State Tree Nursery and its seed source control program to ensure adequate supply of needed tree species.
- Through the Division's Minnesota Tree Improvement Program, orchard seed is bred to be adapted to a variety of biotic and abiotic conditions.
- The Division invests in modeling the effects of state forest management on carbon stocks and assessing any tradeoffs with adaptation strategies.
- Division staff developed climate-informed forest stewardship plans for private landowners in Itasca (http://www.forestadaptation.org/node/392) and Pine (https://www.forestadaptation.org/node/391) counties.
- Forestry is adapting its fire prevention and suppression strategies to changes in the frequency, intensity, and distribution of wildfire.
- The Forest Health Unit conducts aerial surveys to detect defoliation and other damage on eight to 13 million acres annually to respond more quickly to forest insects, disease organisms, and abiotic agents facilitated by climate change.

Training, outreach, and communication:

- Employee education and training was offered that addressed Forestry's climate change efforts, anticipated changes in species composition, and silvicultural methods for sustaining forest ecosystems.
- Selected regional Forestry staff were designated climate change experts to answer questions from Forestry staff.
- An internal team was created to anticipate science-based, climate-related information needs and solutions to management problems.

Minnesota Environmental Quality Board

The Minnesota Environmental Quality Board (EQB) provides a public forum for discussion of state environmental policies (including climate change), encourages public engagement on cross-cutting environmental issues, and facilitates interagency collaboration. The board is made up of the Governor's Office, five citizens, and the heads of nine state agencies as well as the Metropolitan Council.

Minnesota Environment and Energy Report Card (2017)

The 2017 Environment and Energy Report Card is a status update on Minnesota's land, water, air, climate, and energy. The goal of the report card is to evaluate trends and to provide a framework that could inform agency agendas, policy initiatives, and citizen and stakeholder actions. EQB worked with member agencies to select metrics using Results-Based Accountability methodology. An interagency team of experts collaborated to develop text, graphics, and analysis that would clearly communicate to the public the state of Minnesota's environment.

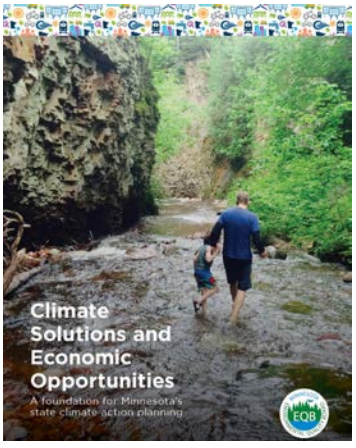
Source: MN Environmental Quality Board

Environmental Congress (2017)

Source: MN Environmental Quality Board

Working in tandem with the Environment and Energy Report Card, the Minnesota Environmental Congress happens every two years and is a cornerstone of citizen dialog and engagement on the environment. The goals are to inform citizens about the state of Minnesota's environment, engage the public on pressing policy issues, and to provide space for cross-sector dialogue. The 2017, Congress included a session on climate adaptation and resiliency, and sessions on climate mitigation and energy policy, transportation, and environmental justice.

Climate Solutions and Economic Opportunities (2016)



Source: MN Environmental Quality Board

Minnesota is committed by statute to do its part for the climate by meeting its Next Generation Energy Act goals. This 2007 law sets a goal for the state to cut its annual emissions of greenhouse gases by 80% between 2005 and 2050.

While much progress has been made, the 2050 goal will require policies well beyond what is already in place at the federal or state level. This report focuses on near-term emissions reductions between the present and 2030. It includes analysis and discussion of the options before us, providing a framework for decision-making that is based in part on the EQB and member agencies. Stakeholder engagement for this project occurred between 2014 and 2016, engaging 969 stakeholders and 130 different organizations on climate policy through nine public meetings and seven technical webinars.

Beyond the Status Quo: 2015 EQB Water Policy Report (2015)

Source: MN Environmental Quality Board

This report is organized as a menu of options to move beyond the status quo on water challenges Minnesota faces.

Water resources in Minnesota are impacted by climate change and are also a critical component of adaptation strategies. The report was developed and written by multiple state agencies with the intent of providing a framework to continue a broad conversation on water policy with local and state implementation partners.

Source: MN Environmental Quality Board

Minnesota and Climate Change: Our Tomorrow Starts Today (2014)

This report explains how climate change impacts the way we live, work, and play in Minnesota. It is designed to be modular with sections focused on different sectors of the state, including energy, buildings, health, transportation, agriculture, natural resources, and waste.

The report has been used for community climate discussions led by the University of Minnesota Extension School and by the Climate Generation organization. This report was used as the base document for the Governor's 2016 Water Summit and for a breakout discussion at the summit on adaptation.

Stakeholder engagement (ongoing)

EQB hosts monthly board meetings that are open to the public and where anyone from the public can make a comment to the board. The Interagency Climate Adaptation Team presented to the board in December 2016, January 2016, and November 2013. EQB also convenes other public meetings and forums as issues emerge that are of concern to agency representatives and citizens. Climate adaptation is frequently featured at these events. For example, EQB convened two public forums for Minnesota citizens who attended the international climate negotiations in Paris in 2015. These forums provided a way for Conference of the Parties (COP) 21 attendees to network and communicate with the administration.

Minnesota Pollution Control Agency

The Minnesota Pollution Control Agency (MPCA) is responding to climate change impacts, which affect environmental quality in a number of areas.

MPCA Climate Adaptation Strategy and Proposed Near-Term Actions

The MPCA created an internal MPCA Climate Adaptation Team (MCAT) in December 2013 for the purpose of advancing climate adaptation through collaboration between the agency's divisions and programs. MCAT was directed to recommend a strategy and near-term actions to MPCA senior management on climate adaptation by mid-2014. MCAT prepared the *MPCA Climate Adaptation Strategy and Proposed Near-Term Actions* in July 2014: https://www.pca.state.mn.us/sites/default/files/p-gen4-10.pdf This document recommends a climate adaptation strategy and near-term actions for the MPCA, and it was accepted by agency senior management. MCAT has been implementing these actions over the past three years.

Stormwater management

The MPCA's Stormwater Program has been addressing the issues related to climate change adaptation since 2005 with the first issuance of the Minnesota Stormwater Manual. It advanced the concept of treating water on site, using low impact design, and volume control best management practices (BMPs). Since then, stormwater permits have advanced these BMPs, and MPCA has worked to set goals and quantify credits for using these BMPs through the Minimal Impact Design Standards (MIDS) Project. Consistent with MIDS are BMPs that can increase infiltration and reduce runoff (including green infrastructure like rain gardens, urban forestry/trees, permeable pavement, swales, etc.).

The Minnesota Stormwater Manual https://stormwater.pca.state.mn.us/index.php?title=Main_Page now in a Wiki format, contains detailed information on green infrastructure practices that can assist in reducing climate change impacts. Best management practices such as rain gardens, permeable pavement, and other infiltration practices work to reduce the volume of stormwater, which can help to reduce flooding. Rainwater harvesting techniques such as rain barrels and cisterns reduce the volume of water by collecting and storing it for a later use such as irrigation or toilet flushing. Planting trees in tree boxes that capture stormwater and installing green roofs on buildings help to reduce urban heat island effect.

Local units of government have traditionally worked to get water off the landscape as quickly as possible. In the last couple of decades, the MPCA started addressing pollutant and rate control. Now volume control is being addressed. Volume control, and working to mimic natural hydrology, helps to result in less dramatic runoff events, which reduces stream erosion and scouring. Impervious surfaces are increasing faster than population growth. This increase in impervious surface coupled with larger storm events will have a significant impact on receiving waters. Stormwater capture and reuse is an opportunity to reduce runoff and reap benefits from heavier rainfalls while reducing demands on the potable water supply. To that end, stormwater staff have gathered information on water reuse projects around the state, participated on the Interagency Water Reuse Team, and helped plan a statewide water reuse workshop.

National Oceanic and Atmospheric Administration (NOAA) Atlas 14 updates are being used to more accurately reflect precipitation intensities and durations. NOAA Atlas 14 incorporates 50 additional years of data into the estimate of precipitation intensity and durations, and could account for changes that may be related to climate change. These estimates, used as an engineering standard, are vital to ensure proper design of culverts, storm sewers, and water quality devices.

In August 2013, the reissued Municipal Separate Storm Sewer System (MS4) General Permit became effective, which regulates stormwater discharge from counties, cities, townships, and other publicly owned entities in urbanized areas. The goal of the MS4 program is to prevent or reduce the discharge of pollutants to stormwater, and ultimately, surface waters. This permit's provisions will help to address problems of erosion and water pollution associated with heavy precipitation events.

Wastewater treatment

MPCA reviews climate-related issues on a regular basis either due to reissuance of National Pollutant Discharge Elimination System (NPDES) permits (approximately every five years), or at times when the municipality is looking to either upgrade/expand the wastewater collection or treatment facilities. While reviewing the permit reissuance (or modification) or the proposed modifications to the collection system or treatment facility, MPCA staff can ask that the municipal staff or their consultants review or consider climate-related concepts (changing peak flows, changing flood elevations, wastewater reuse opportunities).

MPCA encourages wastewater permittees to join the Minnesota Water/Wastewater Utilities Agency Response Network (MnWARN), an emergency response mutual assistance program for water utilities, in order to help them to address flood and other disaster response and recovery.

MPCA encourages wastewater permittees to explore reuse of wastewater, which can extend water supplies in drought conditions.

MPCA works with wastewater treatment plants in ways that can include infrastructure improvements to manage increasing rainfall intensities. The Clean Water Revolving Fund prioritizes financial assistance for infrastructure improvements that would fix problems such as bypassing.

Watershed approach

MPCA has adopted a watershed approach that includes water quality monitoring, modeling, identification of stressors affecting aquatic life, completing total maximum daily loads for pollutants impairing water quality, and developing strategies for restoring and protecting the water resources in major watersheds. Biological, physical, and chemical monitoring are integrated to develop relationships between environmental factors (including climate) and aquatic life. Monitoring activities include components that will allow long-term trend analysis at various geographic scales. The processes for biological stressor identification and development of implementation strategies include climate change considerations.

Subsurface Sewage Treatment Systems

The Subsurface Sewage Treatment System (SSTS) program provides a framework for the local regulation of decentralized wastewater treatment systems that effectively treat sewage and recharge groundwater. Minnesota rules that govern facility planning and infrastructure spending prioritization emphasize right-size solutions to address wastewater treatment needs. Replacing outdated and polluting onsite disposal systems with individual or clustered septic systems that meet current design standards can present the most cost-effective option from a life-cycle basis and may offer considerable resource consumption savings.

The regulatory framework itself may be adopted to respond to increasing demand for onsite water resource management or treatment practices that are increasingly being offered as effective responses to impacts from climate change. Climate change will increase the need to deploy quality control efforts to new industries and regions based on emerging climate adaptation strategies and practices that may include erosion control, landscape drainage modifications, rainwater harvesting, and water reuse. This state defined and locally implemented model for reviewing, permitting, inspecting and managing SSTS offers a reasonable and state/locally balanced regulatory path to other onsite efforts to adapt to climate change.

Climate change will introduce risks that could impact the effectiveness of some septic systems in some areas, and may make decentralized wastewater management a more attractive strategy in others. SSTS that meet current design standards are expected to be more resilient to climate change. Regions that experience a reduced treatment capacity of natural soils may need to consider advanced technologies to meet treatment needs. A reduced ability to beneficially land apply septage may require policy changes to reevaluate septage management practices.

Emergency response

MPCA's Emergency Management Unit (EMU) is the lead program at the agency to plan and prepare for emergency situations that may involve the MPCA. When local government seeks MPCA assistance, the EMU staff coordinates all agency programs to respond in a unified manner. A priority for the agency is to improve the agency's preparedness and our responses. Diligent after-action reviews are conducted and improvement plans are created to document and prioritize needs. Additionally, in-house training and exercises are a priority and increased participation is planned and occurring.

MPCA sustainable community assistance

Minnesota GreenStep Cities

Launched in 2010, Minnesota GreenStep Cities 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 (co-coordinated by MPCA), is based on 29 sustainability best practices. Cities implement a best practice by completing one or more actions at a 1-, 2- or 3-star level, from a list of four to eight possible actions. GreenStep Cities tailors actions to be relevant for all Minnesota cities, focuses on cost savings and energy use reduction, and encourages civic innovation. As of April 2017, 109 cities and three tribal nations had become members of Minnesota GreenStep Cities.

Source: MN Pollution Control Agency

In early 2016, Minnesota GreenStep Cities released a beta version of the first new best practice since the program's inception, focusing on actions cities can take to increase their resilience in acknowledgement of a changing climate. Subsequent revisions were incorporated in Best Practice 29: Climate Adaptation and Community Resilience, https://greenstep.pca.state.mn.us/bestPracticesDetail.cfm?bpid=31 , which calls on cities to plan and prepare for extreme weather, adapt to changing climatic conditions, and foster stronger community connectedness and social and economic vitality. This best practice organizes its actions according to the four essential dimensions of urban resilience from the City Resilience Framework http://www.100resilientcities.org/resilience#/: Leadership & Strategy, Health & Wellbeing, Economy & Society, and Infrastructure & Environment. Best Practice 29 complements the other 28 sustainability best practices, which contain actions that also contribute to climate change mitigation and resilience.

Best Practice 29 provides eight climate resilience best practice actions as follows, each specifying three potential levels of implementation for cities to explore:

- Prepare to maintain public health and safety during extreme weather and climate-change-related events while taking a preventive approach to reduce risk.
- Integrate climate resilience into planning, policy, operations, and budgeting.
- Increase social connectedness and provide opportunities for economically vulnerable residents to improve their prosperity.
- Encourage private sector action to invest in preventive approaches that reduce risk and minimize impacts of extreme weather and the changing climate.
- Protect public buildings and natural/constructed infrastructure to reduce physical damage and sustain function.
- Reduce the urban heat impacts of public buildings, sites, and infrastructure and provide resiliency co-benefits.
- Protect water supply and wastewater treatment facilities to reduce physical damage and sustain function.
- Improve local energy resilience by minimizing fuel poverty, installing distributed renewable energy systems, and developing microgrids.

MPCA awarded event sponsorships during Fiscal Year 2016 to incentivize and support implementation of Best Practice 29 community engagement efforts. Six Minnesota cities (Austin, Falcon Heights, Fridley, Hutchinson, LaPrairie, St. Anthony Park) held events to engage residents about some or all of the following: needs of immigrant populations, green infrastructure for extreme rainfall and urban heat,

community energy resilience, planning for climate resilience, and information sharing about city resilience efforts to date.

By April 2017, 22 cities had completed a total of 34 actions implementing Best Practice 29. These actions included reviewing the Hazard Mitigation Plan with their county; identifying city personnel responsible for extreme weather planning, preparation and recovery; adding resilience chapters to comprehensive plans; proactively engaging community members in resilience planning efforts; addressing the needs of vulnerable populations in the community; organizing residents to plant trees, and retrofitting low-income homes for flood resilience and renewable power.

Minnesota GreenCorps

Launched in 2009, Minnesota GreenCorps is a statewide program of the MPCA to help preserve and protect Minnesota's environment while training a new generation of environmental professionals. This program places AmeriCorps members with local governments, educational institutions, and nonprofit organizations around Minnesota, where they serve for 11 months on focused environmental projects.

2016 Minnesota GreenCorps energy conservation member leads a rooftop tour showing off installed Solatubes and solar thermal panels that add to Camp Ripley's resiliency while reducing greenhouse gas emissions. Source: MN Pollution Control Agency

The Minnesota GreenCorps program involves three types of activities in a comprehensive approach to tackling community-identified environmental stewardship projects.

Members:

- Assess the local circumstances and gather data.
- Engage community and organizational members.
- Implement locally appropriate solutions.

Member projects incorporate a variety of evidence-based best management practices in energy conservation, public land environmental stewardship, and recycling. The projects are carefully designed to have positive environmental impacts, be sustainable long-term at the community level, and build the capacity of communities to adapt and become more resilient to threats posed by a changing climate.

Results: During the 2015-16 service year, Minnesota GreenCorps members completed activities to help increase the resilience of Minnesota communities. These included 101 energy saving retrofits or operational improvement projects; 275,000 gallons of new annual capacity to capture or infiltrate rainwater; 44 raingardens, 1,273 trees, and 31,588 square yards of backyard/school/community gardens installed; 116 acres of urban forests and stormwater green infrastructure treated or improved. Twenty-two tons of waste were prevented, recycled, composted, or diverted; plans, policies, and resources developed; trainings and presentations given at classes and workshops; booths hosted; volunteer events coordinated; and data sets collected and analyzed.

These efforts resulted in more than $65,927 in direct financial savings for Minnesota communities, and much larger anticipated annual savings from energy conservation projects that extend beyond the timeframe of the GreenCorps service year.

Youth Crews for Community Resilience Partnership

This partnership, started in 2016 between the MPCA and Conservation Corps Minnesota, represents a new way to implement community resilience projects and a new approach for the Summer Youth Corps and Youth Outdoors programs. Projects are located in underserved urban neighborhoods and cities throughout Minnesota instead of state parklands. The youth crews interact with local volunteers, community members, and/or city staff instead of working alone in the woods. The resilience projects involve installation of new green infrastructure — a new amenity for each community — rather than maintenance of existing parklands.

2016 Conservation Corps Summer Youth Corps crew plants sumac to improve roadside vegetation along the Mississippi River Regional Trail in Fridley. The sumac plants can reduce stormwater runoff while also providing co-benefits for improved air and water quality. Source: MN Pollution Control Agency

Each of the projects provides ongoing environmental and resilience benefits beyond what existed before, including some or all of the following: reducing stormwater runoff, helping improve local water quality, helping improve local air quality, enhancing greenspace available for community use, supporting local pollinators, diversifying the urban tree canopy, and increasing shaded areas. All four 2016 resilience projects were located in lower-income neighborhoods: three inner city and one first-ring suburban. Two abutted busy interstate roads with poor air quality. For 2017, 25 days of youth crew service are available to local communities throughout Minnesota.

The Community Resilience Partnership also developed five hours of educational content on climate change science, global and local impacts, and planning for resiliency. The crew leaders for the four resilience projects (and an occasional guest speaker) taught this educational content to the crewmembers, using an interactive format during lunch hours and evening discussions. In 2017, all youth crews in Conservation Corps' spring, summer, and fall programs will have access to these lessons on climate change and resilience.

Results: The 2016 partnership reported the following measurable outcomes: 101 trees, 293 shrubs, 2,900+ pollinator perennials, and 425+ non-pollinator perennials planted; 3,766 square yards (3/4+ acre) of parks, green space, gardens, and public land improved; 12 green stormwater infrastructure BMPs installed; and 3,587 gallons of rainwater captured and/or infiltrated during each one-inch rain event.

Environmental Assistance Grant Program (open round and time-sensitive awards)

For the 2014-15 Environmental Assistance Grant Program Open Round and again for the 2016-17 Open Round, MPCA included climate adaptation and community resilience as a priority funding area.

In the 2014-15 round, MPCA awarded six climate adaptation and resilience grants, including:

- Climate dialogues and action in Stevens County.
- A series of five climate adaptation convenings in Greater Minnesota.
- Development of a Strategic Resilience Framework for the City of Saint Paul.
- Vulnerability assessment and adaptation planning in South Central Minnesota led by the Region Nine Development Commission.
- Community outreach on potable water conservation in the City of Woodbury.

- Outreach and tool development to increase community emergency preparedness of historically underserved and vulnerable populations in the Twin Cities.

In the 2016-17 round, MPCA again awarded six climate adaptation and resilience grants, including:

- Riley Purgatory Bluff Creek Watershed partnership for public planning to address climate change impacts.
- Winona Engaged coordinated effort to build momentum and visibility for climate resilience.
- High visibility demonstration of a gravel bed nursery at the Science Museum of Minnesota, with adapted trees to be planted along the Mississippi River in Saint Paul.
- Coordinated effort to benchmark City of Duluth ordinances, policies, and plans against environmental/resilience metrics and provide community outreach.
- Research to identify effective climate-resilient design strategies for two common building types (mid-rise multi-family mixed-use, libraries) for use in updating the State of Minnesota Sustainable Building Guidelines.
- Exhibit on Climate, Energy, and Community: What We Can Do.

In addition, MPCA opened a time-sensitive grant opportunity in winter 2014-15 to fund next step implementation efforts for those Minnesota cities that had participated in the National League of Cities Midwest Regional Convening for Climate Resilience in Saint Paul. Three cities (St. Louis Park, Burnsville, and Falcon Heights) received mini-grant awards of $3,000 each for vulnerability assessment and community engagement efforts. These mini-grants helped spur ongoing climate resilience efforts in all three cities.

Another time-sensitive grant opportunity was opened by MPCA in spring 2017 to fund preparation of population vulnerability assessments for cities interested in incorporating climate resilience in their comprehensive plans.

Green Building Program

MPCA's Green Building Program facilitates partnerships to lessen the environmental impact of Minnesota's built environment. Increasingly, the architectural community views resiliency as an important component of green building practice, including adaptations to the changing climate.

In 2014, MPCA received an in-kind assistance grant for the Georgetown Climate Center (GCC) to research Minnesota options to increase climate resilience in buildings. The resulting January 2015 report, *Minnesota Options to Increase Climate Resilience in Buildings* (https://www.pca.state.mn.us/sites/default/files/tdr-fg15-01.pdf), posted on MPCA's website, addresses resilient building practices (building codes and municipal powers in Minnesota); statewide action to improve municipal ability to act (state agency authority and legislative solutions); and municipal solutions (best practices and incentives). These options have informed MPCA's work on legislative policy initiatives, best practices development, and grant funding.

As a result of outreach and partnerships developed with the design community over the years, major state and regional conferences of national associations, including the Association of Flood Plain Managers, American Institute of Architects, Society of American Military Engineers, U.S. Green Building Council, American Planning Association, and the National Adaptation Forum have invited MCPA to give presentations on climate resilience for the built environment.

Minnesota State Fair Eco Experience

Beginning in 2014 and ongoing, the MPCA's Eco Experience at the Minnesota State Fair began including exhibit pieces on climate adaptation and community resilience as part of the Climate Change Exhibit. MPCA refreshes the exhibit pieces every year. Past exhibits have included:

- Display about resilient urban trees and best practices for planting.
- Exhibit highlighting community assets that contribute to resilience, with supplementary information on the MPCA Community Resilience webpage https://www.pca.state.mn.us/quick-links/community-resilience.
- Flip panels about changing conditions and how to adapt; large banners describing how Minnesota's climate is already changing and expected future trends.
- Large walk-on scale to highlight the impact of people working together to take action.
- Climate connection bingo game.

MPCA redesigned the Resilient Communities exhibit in 2015 to make it portable. Now libraries and other public venues throughout the state are displaying it year-round.

The 2016 Eco Experience Climate Scale exhibit demonstrated how much can be accomplished to increase climate resilience by enlisting others in planting trees, biking and walking, saving energy, and more. Source: MN Pollution Control Agency

Air quality

In 2013, Minnesota completed a multi-stakeholder Clean Air Dialogue process with the goals of identifying new opportunities for emissions reductions, laying the groundwork for future collaboration to improve air quality in Minnesota, and preparing for potential nonattainment designations of air quality standards. Some of the options recommended through this process have potential for addressing and adapting to climate change challenges. MPCA also conducts monitoring for climate-influenced air pollutants.

Solid and hazardous waste management

MPCA works with communities to collect household hazardous wastes (HHW) after disaster events, which may be one of the most important steps a local community can take to prevent chemicals from entering local drinking water supplies. HHW coordination efforts require team collaboration with various MPCA programs, including solid waste, hazardous waste, and emergency response staff. Coordination with county, city, and other local units of government is also necessary and essential following a disaster event.

In terms of climate adaptation at permitted solid waste facilities, precipitation data is used for stormwater modeling. At this point, all permittees know they should be drawing on NOAA's Atlas 14 for data, not the old Technical Publication No. 40 from the National Weather Service dated 1961. For lined landfills, there is a rule requirement that stormwater management systems must cope with 24-hour storms at 25-year intervals. When permits come up for reissuance, some of these landfills are voluntarily designing for 24-hour storms at 100-year intervals.

For Class 1 demolition debris landfills, the rule requirement is that stormwater management systems should handle 24-hour storms at 10-year intervals. When permits come up for reissuance, some of these landfills are voluntarily designing for 24-hour storms at 25-year intervals.

Minnesota Department of Public Safety, Division of Homeland Security and Emergency Management

The Division of Homeland Security and Emergency Management (HSEM) helps Minnesotans prevent, prepare for, respond to, and recover from disaster. The HSEM Recovery and Hazard Mitigation branch is tasked with reducing the risk to people and property from the effects of natural hazards by developing and implementing long-term mitigation measures that will reduce or eliminate future impacts of extreme weather events.

In order to improve the disaster resilience of communities, HSEM incorporated climate change and adaptation into the 2014 State of Minnesota All-Hazard Mitigation Plan. Local multi-jurisdictional hazard mitigation plans are encouraged to analyze their hazards and implement hazard mitigation actions to reduce and avoid future damages using Climate Resilient Mitigation Actions as available through Federal Emergency Management Agency (FEMA) grants.

Minnesota's most common natural hazard threat is severe weather, including torrential rains and the resulting flash flooding. Post Presidential Disaster Declarations, HSEM implements the FEMA Hazard Mitigation Grant Program (HMGP). Acquisition and demolition of flood-damaged homes is a priority project for the state and many local governments. The land is deed restricted to open space in perpetuity, with the goal of returning the floodplain to fully function and remove the possibility of future damages.

Heavy rains in June 2012 resulted in many Pine County residents' homes being flooded. Using the Presidential Disaster Declaration HMGP funding, Pine County offered its residents' pre-event fair market value for their flood damaged homes. Voluntary participation in the acquisition project was offered to all 40 damaged property owners; 27 participated in the program. Buyouts occurred in 2014. The project cost was $5 million, with FEMA cost sharing 75% and the Minnesota Department of Natural Resources covering the remaining 25%.

Four years later, the intense rainfall in July of 2016 led to a state disaster declaration in this same area. Many of the homes that did not participate were damaged in this event.

Many jurisdictions in the state of Minnesota have used the HMGP and other federal, state, and local programs to remove homes in the floodplain. HSEM Recovery and Mitigation will continue to work with local communities to plan for and act to remove properties out of harm's way, whether it's from intense rainfall, wind, wildfire, or other extreme weather events.

Case study: Hazard Mitigation Grants

FEMA's Hazard Mitigation Grant Program, administered by the Division of Homeland Security and Emergency Management, allows for purchase of flood-damaged homes when risk of a repeat event is considered to be significant.

Source: MN Homeland Security and Emergency Management

For example, this home in Pine County was impacted by severe storms and heavy, intense rainfall in June 2012 and was considered to be at high risk for future flooding. The homeowners voluntarily accepted pre-flood fair market value for their property, which was then demolished after it was purchased by the county with support from federal and state funds. After homes like this are demolished, the land must remain open space, which eliminates repeated damage and allows the floodplain to function.

See this 2015 HSEM video to learn more: https://tinyurl.com/kue65co

Minnesota Department of Transportation

The impacts of climate change on the Department of Transportation (MnDOT) are projected to be significant. MnDOT is committed to addressing climate change adaptation in our statewide vision for a multimodal transportation system that "is flexible and nimble enough to adapt to changes in society, technology, the environment, and the economy." Climate issues will affect many functional groups within MnDOT, including Bridge, Hydraulics, Water Resources, Maintenance, Design, Construction, Materials, and Freight, Rail and Waterways. MnDOT has incorporated discussion of climate adaptation and its importance in its February 2017 Sustainability Report: http://www.dot.state.mn.us/climate/pdf/sustainability-report-2016.pdf

The predictions for increased frequency and intensity of rainfall events, warmer winters leading to more ice than snow, extreme heat events resulting in worsened air quality, and an increased number of freeze/thaw cycles will affect the way MnDOT designs, builds, operates, and maintains the state's multimodal transportation system. It will also compel MnDOT to inventory more statewide transportation assets to assess their vulnerability to the impacts of climate change, and determine cost-effective methods to minimize and mitigate those impacts.

The definitions of extreme weather events vary between climatologists and hydraulic engineers. To hydraulic engineers, an "extreme event" represents an event greater than the design event (based on annual probability of occurrence in a specific location), i.e., a 100-year storm may be considered a check storm by hydraulic engineers when considering flooding impacts. A more frequent storm might be considered "extreme weather" by climatologists.

MnDOT is responding to climate change impacts in a number of the following areas.

Climate vulnerability assessment pilot project

MnDOT conducted a system-wide assessment of trunk highway network vulnerability to increased heavy precipitation in MnDOT Districts 1 and 6. The assessment was one of 19 pilot studies across the

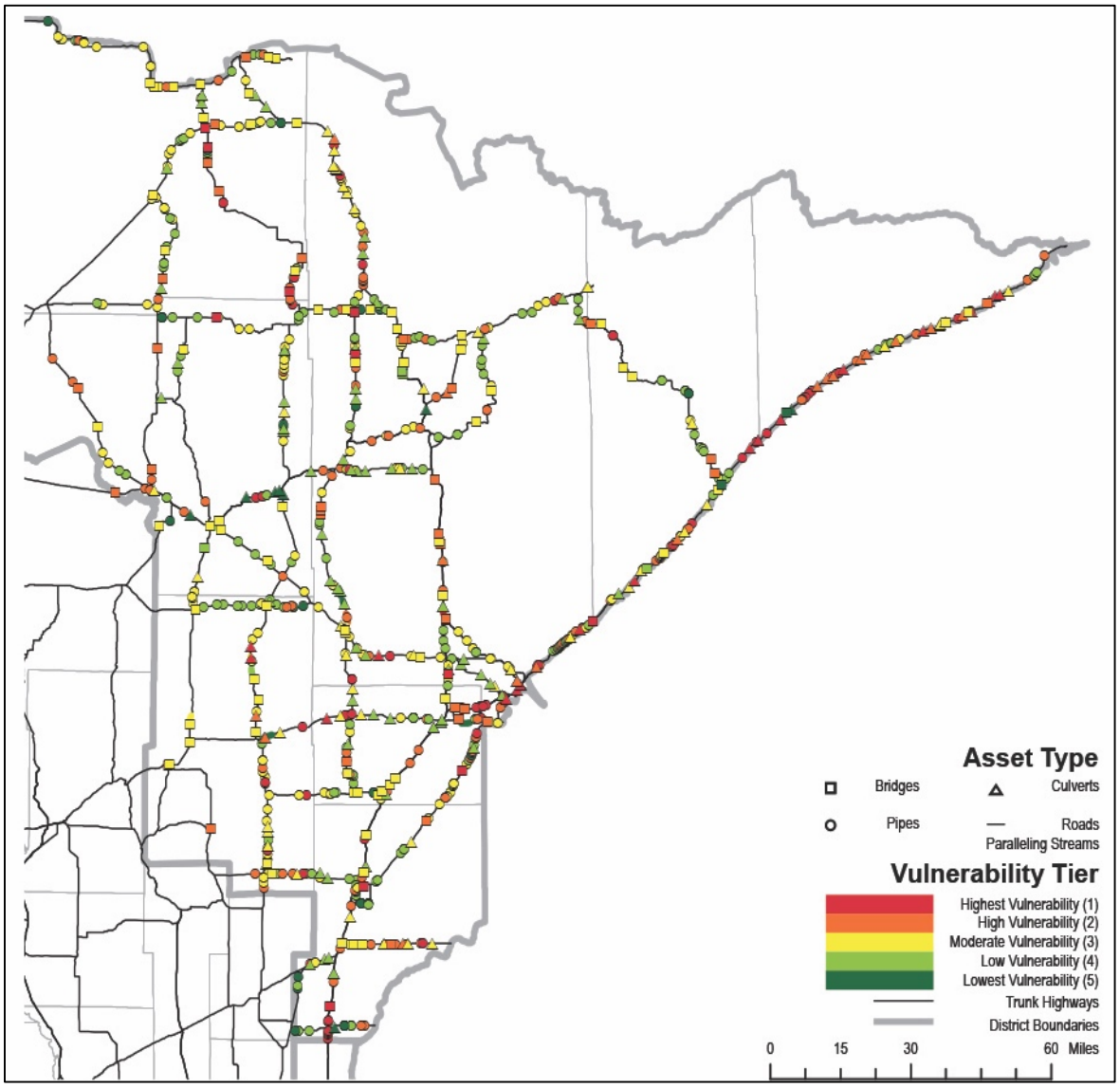
country sponsored by the Federal Highway Administration (FHWA) to examine the effects of climate hazards on transportation systems.

The project team scored and ranked 316 bridges, 521 large culverts, 920 pipes, and, approximately 45 miles of road segments paralleling streams based on the sensitivity and exposure to heavy precipitation and the system's adaptive capacity.

The project also included an adaptation analysis of two culverts: one on Minnesota 61 over Silver Creek in District 1 and one on U.S. 63 in the City of Spring Valley in District 6. The analysis evaluated the current culvert performance and three adaptation options. All options were assessed against three future climate scenarios and a preferred option was identified based on lowest lifecycle cost analysis that included cost for direct repair, replacement, detours, and safety.

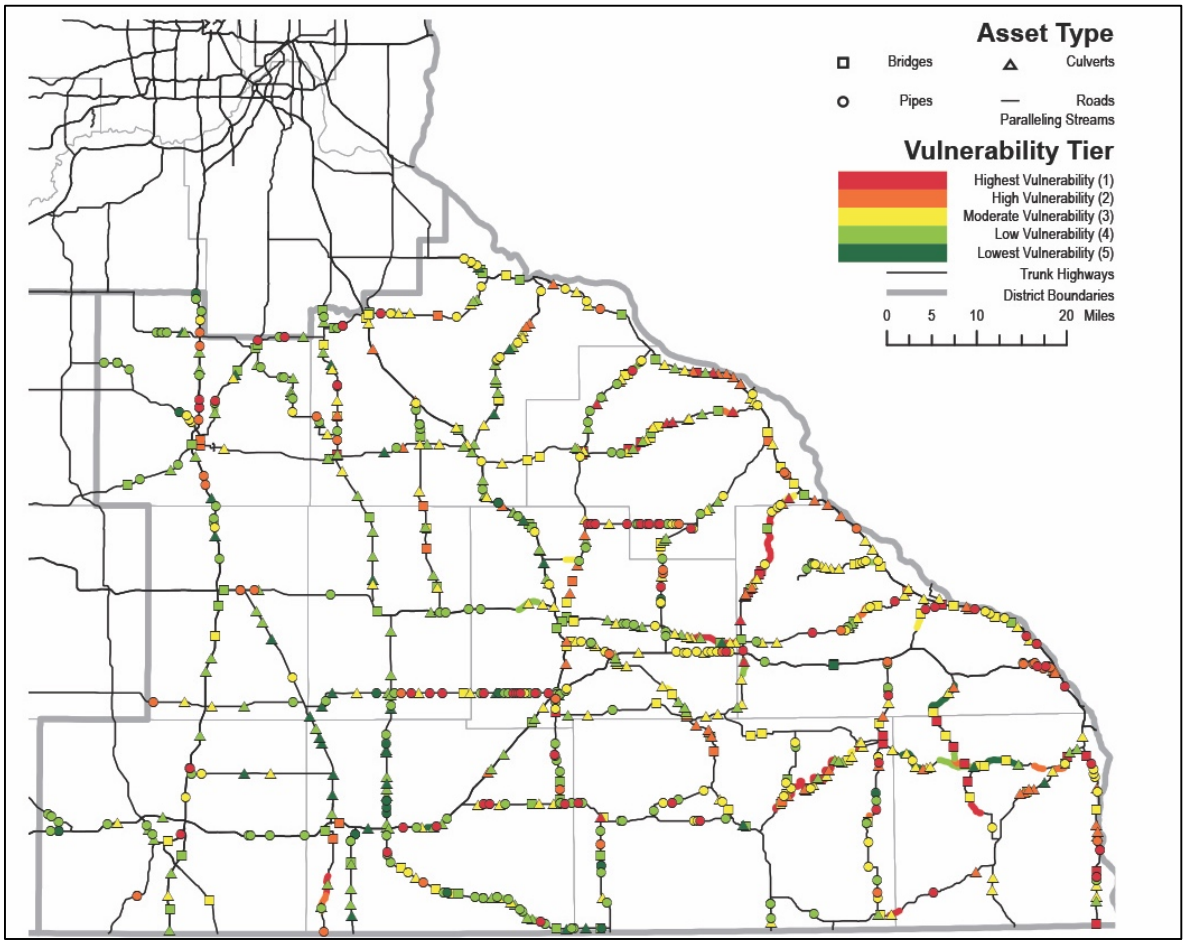
More information is available at: http://www.dot.state.mn.us/climate/pilotproject.html

Figure 14



Asset vulnerability to flash flood events in MnDOT District 1. Source: MnDOT

Figure 15



Asset vulnerability to flash flood events in MnDOT District 6. Source: MnDOT

Flood mitigation projects

In 2011, MnDOT dedicated $50 million of Chapter 152 bonds to fund projects that mitigate and ensure long-term sustainability for flood-prone highways. The program funded 34 projects all of which are now complete or under construction. Some of the projects included the following:

- Hwy 101 Flood mitigation project (Metro District). http://www.dot.state.mn.us/metro/projects/hwy101river/index.html
- Hwy 169 & Hwy 22 Flood mitigation projects (District 7). http://www.dot.state.mn.us/d7/projects/floodmitigation/
- Hwy 75 near Kent (District 4). http://www.dot.state.mn.us/d4/projects/hwy75kent/

More information about the program and a list of all the mitigation projects is available at http://www.dot.state.mn.us/floodmitigation/

Bridge scour-related efforts

Scour may leave bridges vulnerable to damage and failure during flooding by undermining bridge foundations or removing the protection from the abutment slopes.

MnDOT addresses bridge scour through efforts including the following:

- Manage a webpage that provides bridge scour monitoring information: http://www.dot.state.mn.us/bridge/hydraulics/scour.html.
- Educate bridge inspectors during re-certification training about what bridge scour is, how to monitor scour, and how to use a Bridge Scour Plan of Action (POA).
- Develop POAs for all bridges that are scour critical or need to be monitored for scour.
- Assist districts with Flood Response Plans.
- Invest in new underwater sonar/inspection technology.
- Set up a cooperative agreement with the U.S. Geological Survey (USGS) that allows MnDOT to hire them to monitor bridges during floods.

Support updated hydrology

While not predictive of future changes, MnDOT continues working to keep precipitation frequency estimates and discharge regression equations up to date through an ongoing interagency agreement with the USGS. MnDOT and USGS match funding to maintain crest gages to collect data to develop stream regression equations, develop new regression equations (about every 10 years), develop and maintain *Streamstats*, and perform hydrologic studies. A regression equation study is underway and new regression equations should be published in 2018.

MnDOT provided funding to NOAA to develop updated precipitation frequency data: published as Atlas 14 (http://hdsc.nws.noaa.gov/hdsc/pfds/). Atlas 14 is an important new data source that fully documents the changing frequency of extreme precipitation in Minnesota, updating older precipitation frequencies which, in some cases, are decades old. MnDOT adopted Atlas 14 in December 2013 and it is required for all projects after June 2014.

Funding for research projects

MnDOT funds research projects to investigate slope vulnerability, ditch or swale infiltration to reduce runoff, roadway overtopping protection, scour monitoring implementation, new/improved scour countermeasure techniques, drought-tolerant sod, and using natural flocculants to reduce total suspended solids and phosphorous discharge from extreme weather events during project construction.

Other MnDOT climate adaptation activities include:

- Incorporating planning for flood events and any other weather-related incidents into MnDOT Incident Management Plans and applying lessons-learned from recent flood events.
- Developing more efficient ways to inventory our transportation assets that may be impacted by extreme climate events.
- Partnered with the DNR and BWSR to develop flood and drought tolerant seed mixtures that are being used on roadsides and in stormwater ponds.
- Created management-level Sustainable Transportation Steering Committee (STSC) to set agency direction on climate and sustainability efforts, including climate adaptation.
- Participating in statewide climate change, climate adaptation, and air quality groups to better understand how climate issues directly affect Minnesota and collaborate with other state agencies to minimize impacts and increase our climate resilience.

- Participate in national committees and research projects to stay informed on transportation climate strategies, including leadership roles in the following efforts:
  - National Cooperative Highway Research Program (NCHRP) research project: Applying Climate Change Information to Hydrologic and Hydraulics Design of Transportation Infrastructure.
  - National Academies Transportation Research Board Task Force on Climate Change.
  - American Association of State Highway and Transportation Officials (AASHTO) Resilient and Sustainable Transportation Systems Steering Committee.
  - FHWA Climate Change Resilience Pilots National Air Quality and Health Peer Exchanges, and international Symposium on Decarbonizing Transportation.

Figure 16

Climate Change Impact	Likelihood this will change in MN over next 20 years	Implications for the Transportation System
Heavy precipitation / flooding	Very High	• Damage to highway and rail infrastructure, airport runways • Flooded roads will slow operations and performance • Slope failures and erosion
Warmer winters	Very High	• More ice • Reduced pavement conditions and life cycles • Downed power lines with ice storms
New species ranges	High	• Changes in roadside vegetation mixes • Soil erosion • Increase in invasive species populations • Increased exposure of construction and maintenance crews to vector-borne diseases
Drought	Medium	• Reduced river navigability for barges • Roadside vegetation stress, reduces rainwater storages and increases soil erosion
High heat	Low	• Pavement and rail buckling • Vehicles overheating • Electrical system malfunctions • Limitations on construction hours
Wildfires	Unknown	• Road closures • Immediate and significant threat to human safety • Damage to roadside infrastructure

Potential effects of climate change in Minnesota from MnDOT's February 2017 Sustainability Report (source of chart: Minnesota State Climatology Office)

Minnesota Board of Water and Soil Resources

The Board of Water and Soil Resources' (BWSR) mission is to improve and protect Minnesota's water and soil resources by working in partnership with local organizations and private landowners.

BWSR is focused on using current climate change science and climate adaptation solutions to protect Minnesota's natural resources. The board recently updated its Climate Change Trends and Action Report: http://www.bwsr.state.mn.us/native_vegetation/BWSR_Climate_Change.pdf

Shallow lake in Anoka County. Source: BWSR

Local water management planning

BWSR supports and promotes integrated water resources management that uses a watershed approach to solve soil and water resource issues and considers the potential for more extreme weather events and their implications for the water and land resources. This includes the use of design standards for stormwater and conservation projects that address larger precipitation events.

Wetland protection and restoration

Wetland and upland buffer restoration and protection conducted through the Reinvest in Minnesota (RIM) Reserve Program and federal partnerships, Wetlands Conservation Act implementation, and Clean Water Fund projects, help to restore and maintain water retention, runoff reduction, wildlife habitat, and water quality in Minnesota. This, in turn, enhances adaptation to climate change.

The ecosystem services provided by wetlands also protect against intense storm events and periods of drought. Associated upland buffers protect wetland ecosystems, and provide landscape connectivity and other functions that promote landscape resiliency. Restoration projects also increase carbon sequestration that can increase infiltration rates and store water on the landscape.

Agricultural conservation practices

BWSR promotes a variety of conservation practices in agricultural areas that promote soil health and the ability of soils to capture and store rainfall, store carbon, and decrease heat absorption from tilled ground. Examples of conservation practices that minimize impacts from larger storms include cover crops, field terraces, no-till farming, buffer strips, retention areas, and constructed wetlands.

Multipurpose drainage management

BWSR promotes and supports implementation of traditional and new conservation practices for multiple purposes, including conservation drainage and drainage water management practices. These practices help reduce runoff and nutrient loss, avoid runoff concentration, protect areas where runoff concentrates, reduce peak flows to reduce erosion, maintain agricultural productivity, improve water quality and habitat, and reduce flooding. Multipurpose drainage practices help make working lands, as well as artificial and natural drainage systems, more resilient to high intensity rainfall.

Increasing landscape resiliency

A variety of restoration and land management strategies are promoted for conservation projects to increase resiliency to extreme storms and other landscape stressors. Examples include:

- Restoring healthy natural systems where they can have the greatest landscape benefits.
- Decreasing fragmentation of intact plant communities, and creating habitat corridors.
- Restoring plant communities and vegetation that fit current and expected project site conditions.
- Promoting individual species for projects that can handle expected conditions and provide ecological functions.
- Promoting species diversity to increase resiliency and promote habitat for a wide range of wildlife species including pollinators.
- Using deep-rooted plants to promote infiltration and groundwater recharge.
- Restoring high quality habitat for pollinators and other beneficial insects.
- Managing invasive species across geographic and ownership boundaries to minimize their competitive advantage.
- Adapting project design, implementation, and management approaches based on project experience.
- Taking a long-term view to the management of natural resources.

Adaptive landscape management

Disturbances associated with climate change can give invasive species a competitive advantage over native species. BWSR's Cooperative Weed Management Area (CWMA) program is focused on forming local organizations that share invasive species management expertise and resources across ownership boundaries.

CWMAs are also focusing on controlling emerging weed threats that benefit from warming climate such as woody invasive species that are invading northern forests. By promoting adaptive landscape management practices such as forest management and prescribed burning, BWSR is also working to increase the landscape's ability to sequester carbon and withstand large rain events.

Northern forest management

BWSR is working through partnerships to protect the integrity of northern forests. Recent efforts include:

- Protection of wild rice lakes and surrounding forests through the RIM Program.
- An effort to protect and restore white cedar wetlands that are becoming less common.
- Support of CWMAs in northern Minnesota to address emerging weed threats.

BWSR also promotes managing forests for high diversity to adapt to climate variation, large storms, diseases, and pathogens.

Disaster response

Flooding has caused significant damage to private lands and conservation practice infrastructure in Minnesota. Since 2000, BWSR has provided $53 million for flooding in southeast, northeast and northwest Minnesota with a focus on rebuilding infrastructure that will be resilient to future storms.

Case study: Ellefson Group Wetland Restoration

Restored wetlands and prairies provide an important approach in adapting to climate change by increasing the resiliency of watersheds. The Ellefson Group Wetland Restoration in Norman County was a combined effort by four landowners and state, federal, and local agencies.

The site was previously farmland that frequently had crop failure due to flooding. Through hydrology restoration and the planting of diverse seed mixes, the site was restored to 448 acres of restored prairie and wetland and contains eight wetland basins.

The wetland and prairie restoration now provides a refuge to a wide range of wildlife, including pollinators, amphibians, reptiles, shorebirds, and waterfowl.

Restored wetland in Norman County. Source: BWSR

Marsh milkweed. Source: BWSR

The site also decreases downstream flooding by detaining water from large storms. Surface runoff from the site is estimated to be reduced by 88%.

Metropolitan Council

Climate adaptation planning and implementation is occurring at all divisions of the Metropolitan Council (Council), including those providing organizational leadership and regional planning assistance — like Regional Administration and Community Development — as well as those providing operations and services, like Metro Transit, Metro Mobility, and Environmental Services (MCES). The sections below provide a select overview of adaptation activities at the Council, and is not exhaustive.

Regional administration

Based on outcomes from *Thrive MSP 2040* — the Council's 25-year regional vision — the Council established an Implementation Work Group on Climate Change and Environmental Sustainability (CCEST). CCEST's goals include coordinating across the Council; developing and improving environmentally sustainable plans, policies, and procedures (including resiliency and climate adaptation); leading by example in the Council's operations; and helping metropolitan area communities and others improve their environmental footprint and sustainability.

Senior executives from the Metropolitan Council divisions have been provided GETS (Government Emergency Telecommunications Service) to get priority access during a crisis.

Moreover, Metropolitan Council Information Services has focused on development and implementation of technology recovery strategies and plans to ensure recovery and resumption of disrupted information technology systems and services for many hazard situations, ranging from natural hazards (floods, fires, tornados, pandemic, etc.) to human-caused hazards (bombings, riots, etc.). Information Services' strategies for recovery of technology operations outages due to climate-related events, including off-site data backup strategies, are included in the business continuity plans.

Community development

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, (https://metrocouncil.org/Planning/Projects/Thrive-2040/Thrive-MSP-2040-Plan.aspx?source=child) encourages climate change adaptation to be part of comprehensive plan updates, which are required of all cities, counties, and townships within the seven-county metropolitan every 10 years. The next comprehensive plan updates are due by December 31, 2018.

Thrive MSP 2040, the Council's regional 25-year vision, provides climate adaptation strategies to metro communities. Source: Metropolitan Council

Communities are encouraged to identify and address vulnerabilities to strengthen their ability to prepare for and respond to climate impacts. Resiliency includes planning for more frequent and more intense severe weather (including prolonged heatwaves), for health of residents, and for economic strength and diversity. The Council's Local Planning Handbook (https://metrocouncil.org/Handbook.aspx) 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.

As part the Council's 2016-2017 *PlanIt* series (https://metrocouncil.org/Handbook/PlanIt.aspx), webinars on topics such as Comprehensive Planning for Solar Energy Systems are available to communities. A *PlanIt* December 2016 conference provided adaptation-related breakout sessions: *Adapting the Urban Forest in the Twin Cities Metro Area to Climate Change* and *Integrating Sustainability and Resilience Planning in the City Comprehensive Plan*. Additional training and workshops on community resiliency and climate change in the areas of solar, energy, open space, and urban forestry/climate vulnerability assessment are being planned for 2017.

Focus group meets on the Met Council's Climate Vulnerability Assessment during July 2016. Source: Metropolitan Council

The Community Development division is currently conducting a Climate Vulnerability Assessment, which considers the climate hazards of localized flooding and extreme heat on regional assets. The division has also collaborated with a University of Minnesota capstone class to complete a Social Climate Vulnerability Assessment for the same two climate hazards. Both of these assessments should be complete by the end of summer in 2017.

The Community Development division is also working closely with Freshwater Society in leading workshops for community resilience planning. The division has completed one cohort of community workshops across two watershed districts in the southwest metro, and the partnership plans to roll out more community resilience planning workshops across other watershed districts in 2017.

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 http://www.gosparc.org/ during the current comprehensive planning cycle.

Environmental Services

Metropolitan Council Environmental Services (MCES) provides wastewater services and integrated planning to ensure sustainable water quality and water supply for the metropolitan region. MCES operates seven wastewater treatment plants (WWTPs) and one water reclamation facility (WRF), which treat over 200 million gallons of sewage per day. 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.

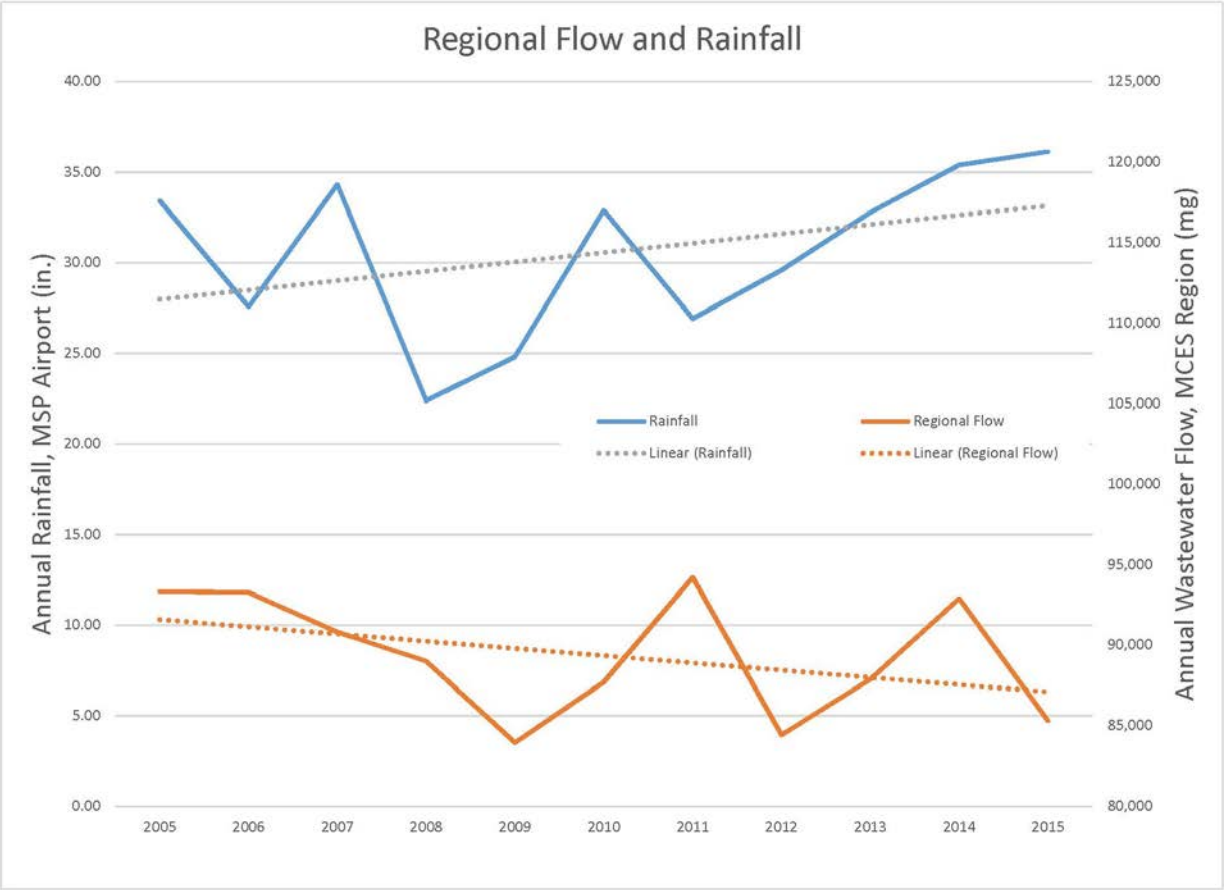
Previous studies of the MCES system indicate that up to 20% of the annual wastewater flow is from I/I. Reduction of the base flow from I/I preserves system capacity for growth and allows for surface water to recharge the region's aquifers. (https://metrocouncil.org/Wastewater-Water/Planning/Wastewater/Inflow-and-Infiltration.aspx)

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 metropolitan area. 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. The figure below shows the trends in rainfall and regional wastewater from 2005-2015. This flow reduction can be attributed to I/I mitigation and water conservation.

Figure 17



Trends in rainfall and regional wastewater annual flow, 2005 – 2015. Source: Metropolitan Council

From 2007-2015, MCES completed $205 million of improvements to the regional interceptors. MCES will continue to address I/I through long-range planning and investments, including $80 to $100 million of maintenance to the interceptor system annually through 2023. It is estimated that I/I source mitigation avoids billions of dollars in unnecessary capital spending for the region. Given the uncertainty in predicting rainfall intensities and frequencies for the next 20 to 50 years, a more precise estimate of the amount of spending to provide additional capacity for I/I in the regional system is not currently available.

An I/I Task Force met in 2016 to evaluate the ongoing I/I Program, and to discuss the technical and financial challenges associated with mitigating I/I from private property sources. The task force recommended that MCES develop a public outreach program; support communities through development of model ordinances and best practices for private property mitigation programs; and pursue consistent funding for I/I mitigation from state and potentially regional sources. MCES plans to complete these recommendations by 2019.

Flood response and mitigation

Wastewater treatment facilities are protected by dikes and floodwalls that exceed the level of extreme flooding that occurred in 1965, or greater. Other adaptations include auxiliary equipment and backup pumps (to pump flood waters over the flood wall and into the effluent channel) and stocking of reserve fuel during periods of imminent flooding.

In addition, the Council has stockpiled gravel to allow quick construction of temporary road access during floods, and has a helicopter company on contingency. Also, at some sites, dewatering pumps have been installed to lower the groundwater table and protect underground infrastructure.

Auxiliary equipment provides backup service at MCES wastewater treatment plants during floods, power outages, and other emergencies. Source: Metropolitan Council

Infrastructure rehabilitation

Despite Council programs to mitigate inflow and infiltration, periods of excess precipitation can tax the wastewater system. Ongoing maintenance ensures capacity exists to handle increased flows during wet weather. The Council has also implemented a Condition Assessment Program, resulting in inspection of most of the gravity interceptor system.

A 1-5 rating system, with "5" being the worst condition, is used to rate the condition of the Council's regional wastewater conveyance infrastructure. Necessary improvements are prioritized based on condition and addressed through an ongoing $100 million/year capital improvement program, which is focused primarily on rehabilitation.

Maintenance and rehabilitation of regional wastewater conveyance infrastructure reduces excess flows caused by unusual periods of extended wet weather and intense storms. Source: Metropolitan Council

Stormwater Planning and Green Infrastructure Pilot Grant Programs

Research and monitoring have shown that nonpoint source pollution is having a detrimental effect on the water quality of lakes, streams, and rivers in the Minneapolis–St. Paul metropolitan area. Nonpoint source pollution is stormwater runoff from agricultural and urban land that enters wetlands, lakes, streams, and rivers without treatment. Changes in temperature and precipitation patterns — particularly those trending toward excessive heat and precipitation — and more intense storms likely exacerbate declines in surface water quality.

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 seven-county metropolitan area. These grants will help fund and document innovative, high visibility demonstration projects that could be replicated throughout the metro region. Projects approved for funding in 2016 include activities like stormwater capture and reuse, raingarden construction, and groundwater conservation. $1 million is again available for stormwater grant funding in 2017. Eligible entities include water management organizations and soil and water conservation districts. Projects will be selected from the applicant pool by early June 2017.

Also in 2017, the Council is offering up to $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. More frequent and intense rain events associated with climate change often tax the region's aging stormwater and wastewater infrastructure. 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 provides an integrated network of buses, light rail, and commuter trains, as well as resources for those who carpool, vanpool, walk, or bike in the metropolitan area. In 2016, Metro Transit provided more than 80 million rides.

Metro Transit has not developed specific climate adaptation strategies, but instead 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.

Statewide climate adaptation indicators

With the goal of better tracking and monitoring Minnesota's climate adaptation progress, ICAT developed five statewide indicators in late 2015 using the Results-Based Accountability process. Working with consultant support from Minnesota Management and Budget, ICAT members participated in a half-day workshop in September 2015, which was followed up by additional meetings and discussion through which indicators were agreed upon by consensus. ICAT established baselines and data sources for each of these indicators in fall 2016.

These indicators and accompanying baseline and/or trend data are described below.

Climate adaptation planning by state agencies, local units of government and tribal governments

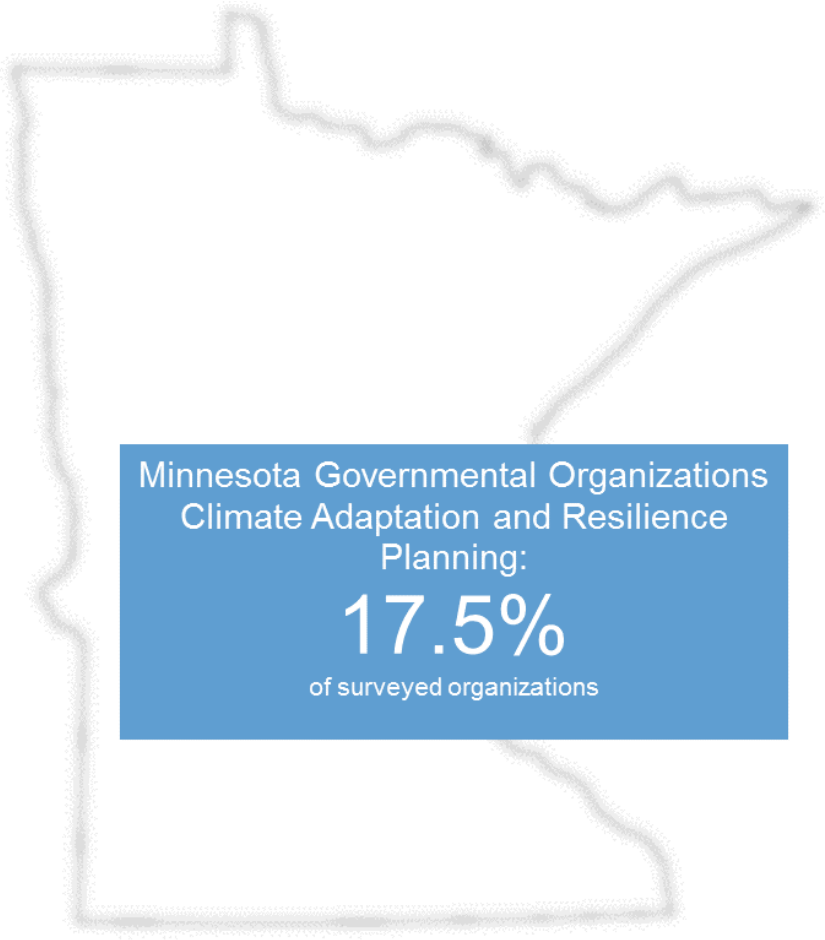
Purpose of indicator

- Measure degree to which stand-alone adaptation plans are being prepared by agencies, local units of government and tribes.
- Also measure degree to which adaptation is being incorporated into ongoing plans and planning.

Data collection strategy: Online survey.

Lead agency: Minnesota Pollution Control Agency

Baseline/ongoing data source: 17.5% of surveyed organizations in a 2016 online survey indicate that they have at least one type of plan or planning effort that specifically addresses climate adaptation and resilience. This online survey will be repeated periodically (every three to five years).



Source: MN Pollution Control Agency

Disruptions to the power grid

Purpose of indicator

- Proxy measure of preparedness/resilience for extreme weather and other potential climate impacts.

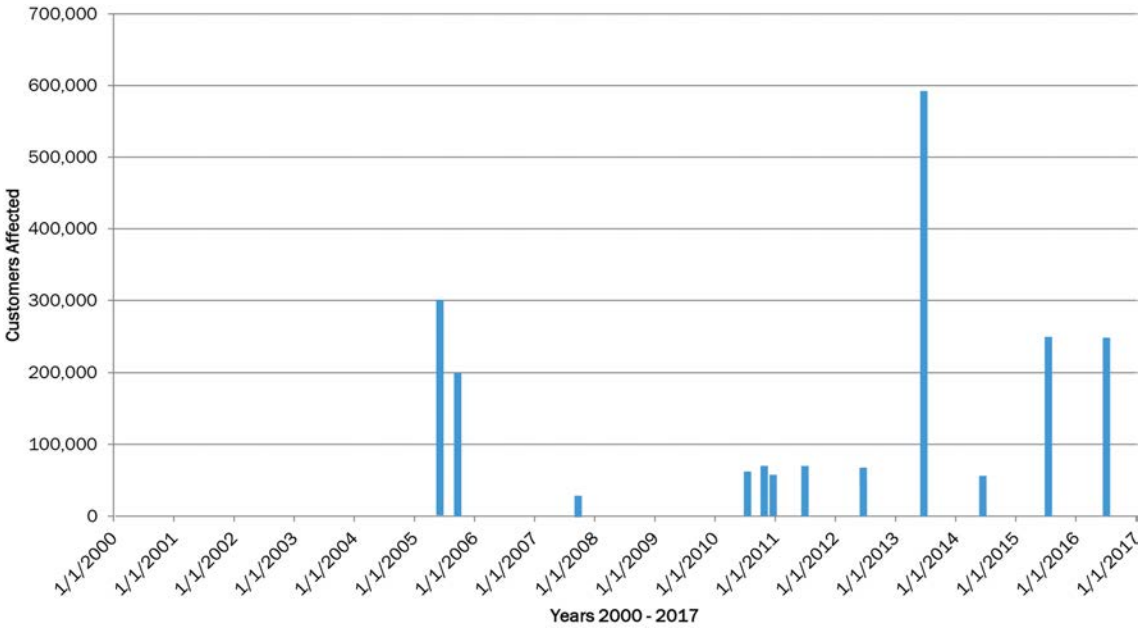
Data collection strategy: Use existing data sources from the U.S. Department of Energy.

Lead agency: Minnesota Department of Commerce

Baseline/ongoing data source: Data are available for the years 2000-2016 for Minnesota Severe Weather Electric Disturbance Events from reporting from the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability (Report OE-417) https://www.oe.netl.doe.gov/oe417.aspx.

Data indicate the number of customers affected and provide insight into trends of severe weather occurrences and time to achieve total power restoration.

Figure 18



Minnesota Severe Weather Electric Disturbance Events (OE-417) – Available data from Energy.gov, Office of Electricity Delivery and Energy Reliability (https://www.oe.netl.doe.gov/oe417.aspx) archives from the year 2000 through 7/5/2016 is illustrated in the graph (Figure provided by the Minnesota Department of Commerce) of reportable severe weather related electric grid disturbances for Minnesota.

Emergency department data for heat-related health impacts

Purpose of indicator

- Proxy measure of preparedness/resilience for extreme heat on human health.

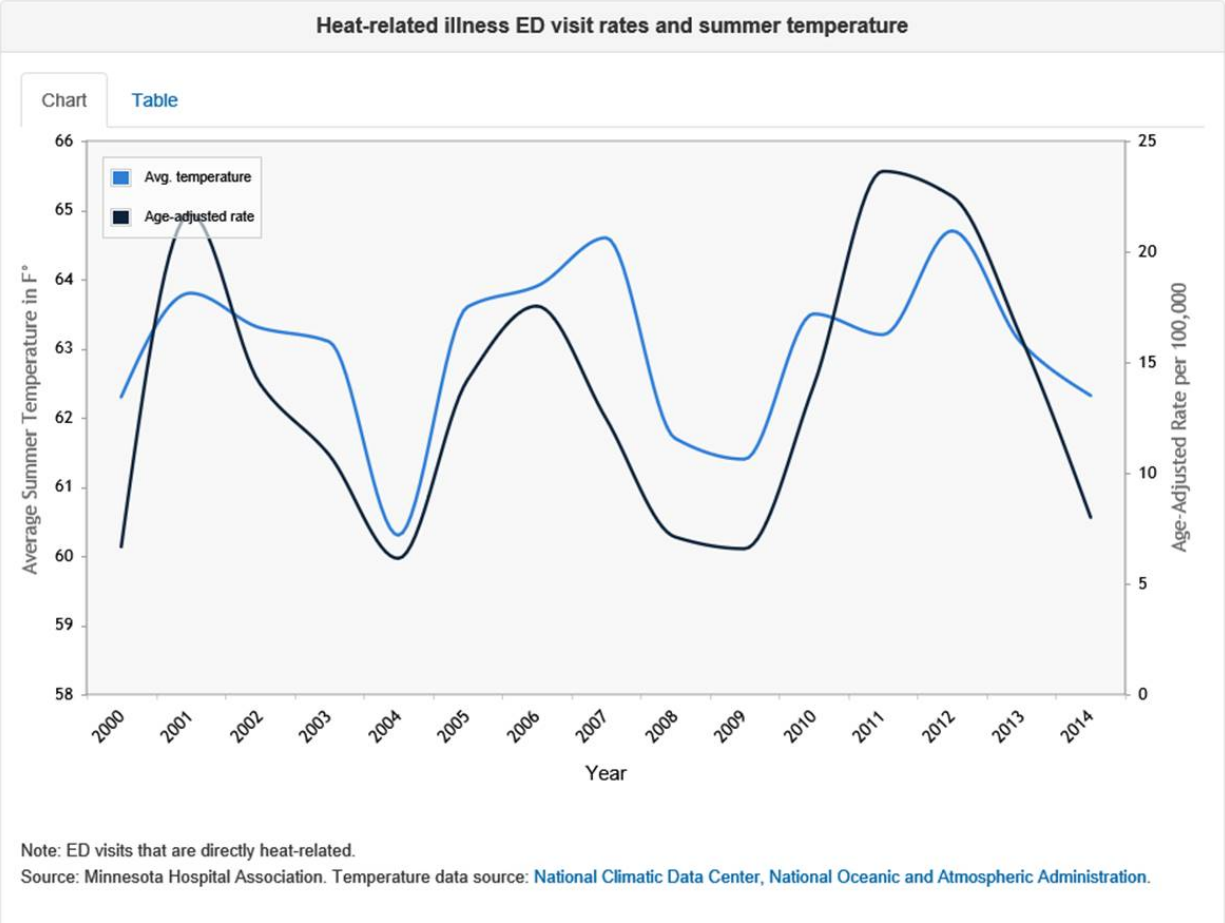
Data collection strategy: Use existing data sources.

Lead agency: Minnesota Department of Health

Baseline/data source: Data are available for the years 2000-2014 from the MDH's Minnesota Public Health Data Access Portal at https://apps.health.state.mn.us/mndata/heat_ed

The graph shows emergency department (ED) visit rates for heat-related illnesses with average summer temperatures per year.

Figure 19



Inflation adjusted damages from extreme weather

Purpose of indicator

- Proxy measure of preparedness/resilience for climate impacts.

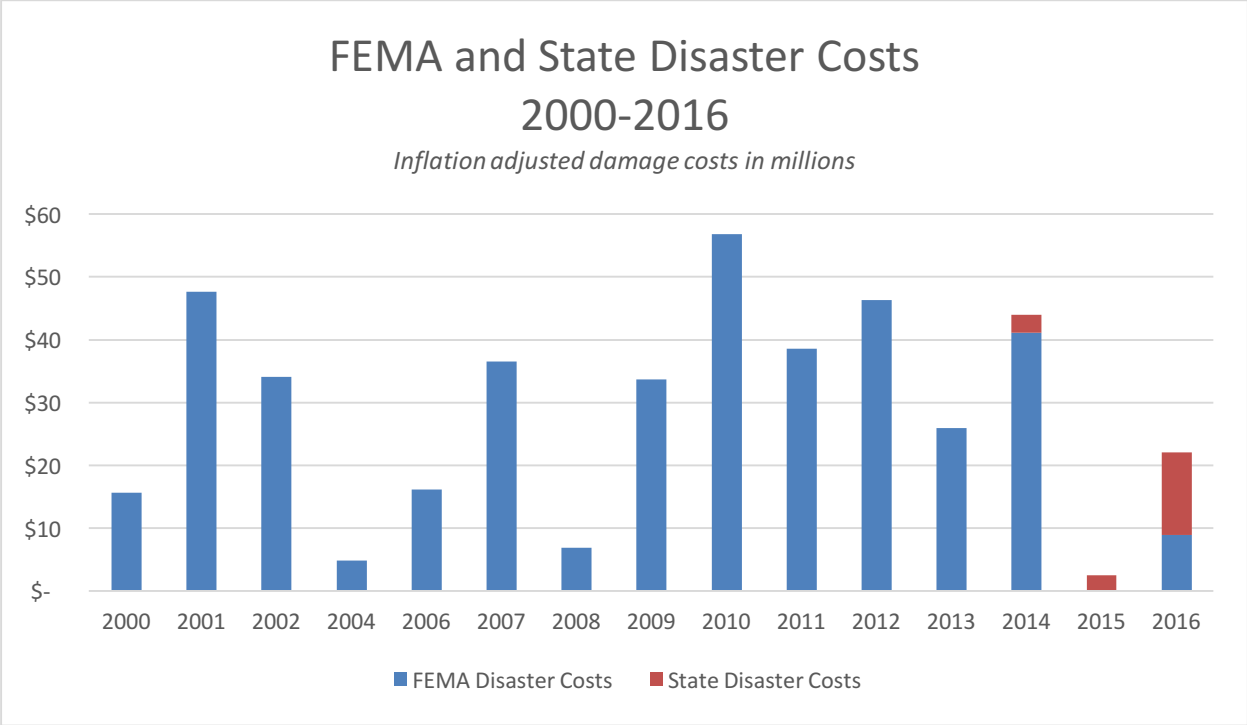
Data collection strategy

- Use existing data sources.

Lead agency: Minnesota Division of Homeland Security and Emergency Management

Baseline/data source: Annual cost for eligible damages from federal and state declared disasters 2000-2016. The Minnesota HSEM Public Assistance Program is designated to restore public infrastructure and promotes recovery for local, county and state governments, tribal governments, and certain private nonprofits. Each eligible applicant within the Public Assistance Program will have project worksheets created to represent estimated costs to restore their facilities back to a pre-disaster condition. The Public Assistance Program is based on the Stafford Act, 44 (CFR) Code of Federal Regulations and FEMA's policies and guidance as outlined for each presidential disaster. Each disaster varies due to its intensity, duration and type of storm (e.g., flooding, rainfall, wind) and therefore the extent of the damages will be subject to various conditions of the event. Minnesota's State Disaster fund was created in 2014 to assist local units of government recover in cases when damages do not meet the federal threshold.

Figure 20



Sources: https://www.fema.gov/states/minnesota and HSEM

Canopy cover of urban and community forests

Purpose of indicator

- Proxy measure of implementation of green infrastructure practices for climate adaptation and degree of vulnerability to climate change.

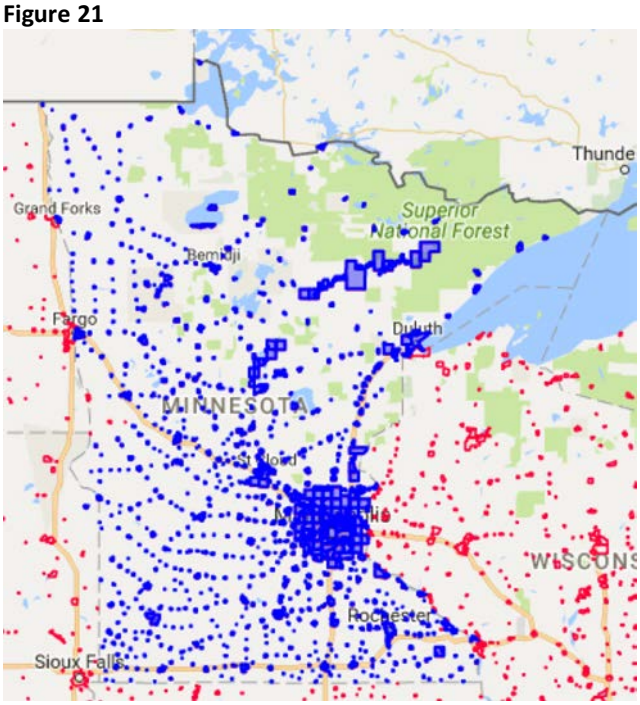
Data collection strategy

- Use existing data sources from DNR.

Lead agency: Minnesota Department of Natural Resources

Baseline/data source: The USDA Forest Service software, i-Tree Landscape, was used to overlay the 2011 U.S. Geological Survey National Land Cover Database with U.S. Census Bureau data of U.S. Census Places to define urban and community forestry canopy cover. U.S. Census Places is boundary data developed in 2010 and is designated by high concentrations of population of 2,500 inhabitants or more. Based on the method provided above, urban and community forestry canopy cover was measured at 15.1% in 2011.

Figure 21



Map of U.S. Census Places. Areas in blue are considered urban and community areas in Minnesota due to population levels and are being measured for urban and community forest tree canopy cover through US Forest Service i-Tree software. Source: Minnesota Department of Natural Resources

Recommendations for action

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. ICAT has identified the following priority recommendations for needed action in climate adaptation by state government.

These six recommendations were presented in draft form for discussion to participants in the "*Adaptation and Resiliency: How Do We Meet the Challenges of Minnesota's Changing Climate?*" breakout session at the EQB Environmental Congress on February 3, 2017, and the wording below reflects feedback received in that session. The recommendations are not in priority order.

ICAT will work in 2017 to further flesh out priority actions and work plans related to these 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, 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 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, Minnesota 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, 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*

In addition to the specific recommendations above, ICAT also recommends that 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 Governor's Executive Order, Legislative directive, commissioner-led agency operational orders, agency strategic planning processes, program budgeting and development, and staff training.

ICAT also recognizes that 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 among 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 Minnesota state government engage in a comprehensive effort along with public and private partners to develop a multistakeholder statewide climate adaptation plan by 2020.

Resources

Harding, K. J., and P. K. Snyder (2014), Examining future changes in the character of Central U.S. warm-season precipitation using dynamical downscaling, J. Geophys. Res. Atmos., 119, doi:10.1002/2014JD022575.

Harding, K. J., and P. K. Snyder (2015), Using dynamical downscaling to examine mechanisms contributing to the intensification of Central U.S. heavy rainfall events, J. Geophys. Res. Atmos., 120, doi:10.1002/2014JD022819.

Melillo J., Richmond, T., and Yohe, G., 2014. An assessment from the U.S. Global Change Research Program to inform the public with scientific information and methods regarding climate change.

Pryor, S. C., D. Scavia, C. Downer, M. Gaden, L. Iverson, R. Nordstrom, J. Patz, and G. P. Robertson, 2014: Ch. 18: Midwest. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 418-440. doi:10.7930/J0J1012N.